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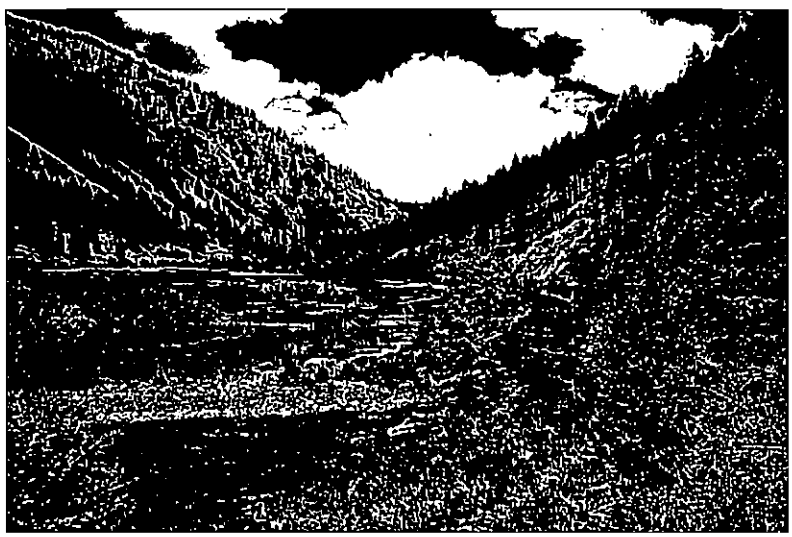
Prepared for:

Blackbird Mine Site Group

Final

Focused Feasibility Study for the Blackbird Mine Site

Lemhi County, Idaho



Submitted by:

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Golder Associates

June 21, 2002
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Golder Associates Inc.

18300 NE Union Hill Road, Suite 200
Redmond, WA 98052-3333
Telephone (425) 883-0777
Fax (425) 882-5498

FINAL

FOCUSED FEASIBILITY STUDY FOR THE BLACKBIRD MINE SITE LEMHI COUNTY, IDAHO

Prepared for:

BLACKBIRD MINE SITE GROUP

Submitted by:

Golder Associates Inc.
Redmond, Washington

June 21, 2002

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Final Report Ch-1.doc

EXECUTIVE SUMMARY

This report presents the final focused feasibility study (FS) for the Blackbird Mine Site. The FS was prepared by Golder Associates Inc. (Golder) on behalf of the Blackbird Mine Site Group (BMSG), under oversight from the Environmental Protection Agency (EPA) in consultation with the Natural Resource Trustees (Trustees). The Trustees include the Idaho Department of Environmental Quality (IDEQ), the US Forest Service (USFS), the National Marine Fisheries Service (NMFS), and the National Oceanic and Atmospheric Administration (NOAA).

The detailed analysis of alternatives contained in Chapter 7 and the summaries of the comparison of alternatives provided in Section ES-4 of this Executive Summary was prepared by EPA, not by the BMSG or Golder. Changes to the description of alternatives (Chapter 6) and other sections of the FS Report were also required by EPA. In significant respects, the BMSG and Golder do not agree with EPA's changes to the FS Report and the resulting conclusions. The BMSG reserves the right to comment on the FS Report including the analysis and conclusions in Chapter 7 and to submit its own analysis of alternatives.

The BMSG has worked cooperatively with EPA and the Trustees to implement effective removal actions, which have cost nearly $60 million. These extensive removal actions are detailed in Section 2.2.

As a result of these Early Actions, between 1995 and 2001 the BMSG has reduced metals loadings from Meadow Creek, Blackbird Creek, and Bucktail Creek, which have resulted in significant improvements in water quality in Panther Creek and Big Deer Creek. Copper meets water quality standards in Panther Creek during low flow periods, which occur during a large part (about 9 months) of the year. Cobalt does not have a water quality standard and current concentrations in Panther Creek only exceed EPA's proposed preliminary remediation goal (PRG) by a factor of less than 2 during low flow periods of the year. However, the PRG for cobalt was met during the low flow synoptic sampling event in September 2001. The BMSG has provided EPA with extensive comments (BMSG 2001a and 2001b) and does not agree with many aspects of the aquatic risk assessment that resulted in PRGs for sediment and water quality. Even though the BMSG does not agree with EPA's PRGs, they were used as guides in the development and evaluation of alternatives for site cleanup presented in this FS.

A summary of improvements in water quality observed between 1995 and 2000/2001 achieved through Early Actions is as follows (reductions are based on comparisons of peak concentrations in 1995 and peak concentrations during 2000/2001):

- Reduced peak metals concentrations in Panther Creek (at PASW-09 downstream of Blackbird Creek) by over 94% for both spring and fall for dissolved copper and 71% in the spring and 61% in the fall for dissolved cobalt, as shown in Figure ES-1.
- Reduced peak metals concentrations in Panther Creek (at PASW-04 downstream of both Blackbird and Big Deer Creeks) by 78% in the spring and 92% in the fall for dissolved copper and by over 89% in the spring and 79% in the fall for dissolved cobalt, as shown in Figure ES-2.

- Reduced peak metals concentrations in Big Deer Creek (at BDSW-03) by over 97% in the spring and 85% in the fall for dissolved copper and by over 90% spring and fall for dissolved cobalt, as shown in Figure ES-3.
- Reduced risk to human health through implementation of removal actions of soils containing elevated concentrations of arsenic and other metals.
- Reduced risk to terrestrial and aquatic ecological receptors through removal of soils containing elevated concentrations of metals and improvements to water quality.

The additional incremental improvement to completely achieve PRGs in Big Deer Creek and Panther Creek is small relative to actions already taken.

The purpose of the focussed FS is to evaluate alternatives for a final remedy for the site to achieve remedial action objectives at the site. The alternatives presented in this FS were agreed to with EPA based on the comments to and subsequent discussions on the *Draft Assembly and Screening of Alternatives for the Blackbird Mine Site* (Golder 2001f).

ES-1 SITE DATA

A remedial investigation (RI) was performed to evaluate the nature and extent of residual and/or remaining metals releases from historic mining activities at the Blackbird Mine Site and their impacts to soils, water quality and environmental receptors following implementation of the Early Actions (Golder 2001a). Baseline human health and environmental risk assessments have been completed to evaluate the potential risk to human, aquatic, and terrestrial receptors (CH2M Hill 2002 and 2001a and Golder 2001b). Chapter 2 of this FS provides a summary of:

- Background information for the site (Section 2.1)
- Early Actions that have been implemented (Section 2.2)
- Conclusions of a report on the stability of the West Fork Tailings Impoundment Dam (Section 2.3)
- Environmental sampling results from the RI report (Section 2.4)
- Additional data collected during 2001 (Section 2.6).
- Human health, aquatic, and terrestrial risk assessments (Section 2.7).

ES-2 ARARS AND EPA'S RAOS AND PRGS

Potential applicable or relevant and appropriate requirements (ARARs) are discussed in Chapter 3. Compliance with ARARS is a threshold criterion that remediation alternatives must meet per the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The EPA has developed proposed remedial action objectives (RAOs) and has proposed preliminary remediation goals (PRGs) for the site (See Tables 3-2 and 3-3). PRGs are numeric expressions of the remedial action objectives. The PRGs developed by EPA for water quality and sediments are based primarily on protection of aquatic biota. PRGs for soils along Blackbird Creek and Panther Creek have been developed based on protection of human health. A PRG based on protection of human health has also been established for in-stream sediments in lower Blackbird Creek adjacent to the Panther Creek Inn.

ES-3 DEVELOPMENT OF REMEDIATION ALTERNATIVES

Remediation alternatives were developed using the following steps:

- Identification and screening of potentially applicable technologies for each contaminated medium to obtain a set of technologies feasible for use in achieving RAOs and PRGs (see Chapter 4).
- Assembly of retained technologies into remediation alternatives that cover the full range of possible response actions. The alternatives were then screened based on effectiveness, implementability, and cost to eliminate alternatives that are impractical, infeasible or have higher costs relative to the other alternatives without being more effective (Chapter 5).
- Further development (conceptual design) of retained alternatives (Chapter 6) to support detailed evaluation.

In order to address the different remediation needs of different areas, the Blackbird Mine Site has been divided into three (3) areas. A separate set of alternatives was developed for each area.

The following alternatives were retained for remediation of Blackbird Creek (including Meadow Creek and the Tailings Impoundment):

- Alternative BB-1 – No Further Action
- Alternative BB-4 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments
- Alternative BB-5 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments
- Alternative BB-6 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments
- Alternative BB-7 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with

Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments

- Alternative BB-8 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments.

The following alternatives were retained for remediation of Bucktail, S. Fork Big Deer, and Big Deer Creeks:

- Alternative BT-1 – No Further Action
- Alternative BT-3 – Seep Collection and Treatment; Natural Recovery of Sediments
- Alternative BT-4 – Seep Collection and Treatment; So. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments
- Alternative BT-5 – Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments
- Alternative BT-6 – Seep Collection; Complete Sediment Removal

The following alternatives were retained for remediation of Panther Creek:

- Alternative P-1 – No Further Action
- Alternative P-2 – Natural Recovery with Institutional Controls and Monitoring
- Alternative P-3 – Selective Overbank Deposit Removal; Natural Recovery of Remaining Sediments.

Water quality improvements for Panther Creek will be determined by the alternatives selected for Blackbird Creek and Bucktail Creek.

ES-4 EVALUATION OF ALTERNATIVES

The remediation alternatives were evaluated using criteria established in the NCP (40 CFR 300.430):

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction in toxicity, mobility, and volume through treatment;
- Short-term effectiveness;
- Implementability; and
- Cost.

The evaluation of the remediation alternatives against these criteria is summarized in Tables ES-1 for the Blackbird Creek alternatives, ES-2 for the Bucktail Creek alternatives, and ES-3 for the Panther Creek alternatives.

ES-4.1 Comparison of Blackbird Creek Alternatives

Figure ES-4 compares the relative reductions in metals concentrations (at PASW-09) to the costs for the Blackbird Creek alternatives. In this figure, the benefit of the alternative is measured relative to the concentrations observed in 1995 before remediation (including Early Actions). The percent decrease of each alternative is calculated by dividing the expected decrease for the alternative (1995 value minus the estimated post-remediation concentration) by the decrease needed to meet EPA's proposed PRG (1995 value minus the PRG). Thus, 100% represents meeting the PRG. The estimated post-remediation concentrations are the average of the estimates for spring and fall 2000 and 2001 (four values). The error bars on Figure ES-4 are based on the estimated post-remediation concentrations using the maximum and minimum observed values at BBSW-01A and PASW-09 during 2000 and 2001. Table ES-4 provides the predicted post-remediation concentrations at PASW-09 based on results of the 2000 and 2001 synoptic sampling events. Table ES-5 presents the sensitivity analysis of the predicted post-remediation concentrations at PASW-09 used to develop the error bars.

ES-4.1.1 Overall Protection of Human Health and the Environment

Alternative BB-1 (the No-Further Action alternative) would not prevent direct contact with Blackbird Creek overbank deposits containing arsenic concentrations above the human health PRG and would therefore not be protective of human health. The other action alternatives (BB-4 through BB-8) would all prevent direct contact with the Blackbird Creek overbank deposits and the in-stream sediments near the PCI through removal and/or armoring. In addition, the action alternatives would, through combinations of removal and stabilization (armoring), control remobilization of overbank materials along Blackbird Creek to prevent deposition downstream along Panther Creek at concentrations exceeding the arsenic PRGs. Thus, EPA has determined that all of the action alternatives (BB-4 through BB-8) would be protective of human health.

The water quality PRGs in Blackbird Creek would not be consistently met under any of the alternatives. Sediment PRGs in Blackbird Creek could not be met by any of the alternatives except BB-8 (complete removal). However, Alternative BB-8 would result in extensive disruption of the stream channel and habitat along Blackbird Creek that would require years to a decade or more for full recovery. The Panther Creek sediments would eventually meet PRGs through natural recovery. Alternatives BB-4 and BB-5 would not consistently meet the copper and cobalt water quality PRGs in Panther Creek. Alternative BB-6 could consistently meet the copper water quality PRG in Panther Creek. However, there is considerable uncertainty concerning whether Alternative BB-6 can meet the cobalt PRG in Panther Creek, or (if it can be met) whether it can be met in a timely manner. The copper and cobalt water quality PRGs would be consistently met in Panther Creek in a timely manner only under Alternatives BB-7 and BB-8. EPA has

therefore determined that Alternative BB-7 and BB-8 would be protective of the environment in Panther Creek.

ES-4.1.2 Compliance with ARARs

The copper water quality ARAR for Panther Creek would not be consistently met by Alternatives BB-1, BB-4, and BB-5, especially during spring runoff. Alternatives BB-6, BB-7, and BB-8 are predicted to consistently meet the copper water quality ARAR in Panther Creek throughout the year. Other ARARs would be met by all alternatives

Alternatives BB-6, BB-7, and BB-8 would have smaller mixing zone requirements than Alternatives BB-4 and BB-5. The mixing zone requirements for Alternatives BB-6, BB-7 and BB-8 would vary from approximately 30% to 62% of the width of Panther Creek, depending on conditions. The minimum mixing zone requirement for Alternatives BB-4 and BB-5 would be a approximately 30% of the width of Panther Creek; however, under worse case conditions, the copper water quality standard would not be met even using 100% of the width of Panther Creek.

ES-4.1.3 Long-term Effectiveness and Permanence

None of the alternatives would be effective in the long term at consistently meeting the copper PRG in Blackbird Creek as measured at BBSW-01A (near the confluence with Panther Creek). Alternatives BB-4 and BB-5 are predicted to come close to meeting the copper PRG at this location during low flow periods, but would exceed the PRG consistently during spring runoff. Alternative BB-6 is predicted to meet the copper PRG in Blackbird Creek during low flow periods, but would exceed the copper PRG during spring runoff. Alternatives BB-7 and BB-8 are predicted to meet the copper PRG at BBSW-01A during low flow periods, but would not consistently meet the copper PRG during spring runoff.

Currently, the cobalt water quality PRG is exceeded at all times in Blackbird Creek. All of the action alternatives would achieve significant reductions in cobalt concentrations in Blackbird Creek; however none of the alternatives would be effective at meeting the cobalt water quality PRG in Blackbird Creek on a consistent basis.

Alternative BB-1 (No Further Action) would not make any improvements to water quality, and is therefore ranked lowest for long-term effectiveness. The alternatives that primarily utilize stabilization to address Blackbird Creek overbank deposits (Alternatives BB-4 and BB-5) are predicted to meet the copper water quality PRG in Panther Creek most of the year, but would not likely be effective at meeting the PRG at times during spring runoff. Therefore, Alternatives BB-4 and BB-5 are rated next lowest for long term effectiveness. The alternatives that primarily utilize removal to address Blackbird Creek overbank deposits (Alternatives BB-6, BB-7, and BB-8) are rated higher for effectiveness because they have greater certainty of achieving the copper water quality PRG in Panther Creek on a consistent basis. Alternatives BB-6, BB-7, and BB-8 are essentially comparable in terms of copper water quality predictions in Panther Creek; the extensive

sediment removals under Alternative BB-8 would provide no discernable benefit to copper water quality in Panther Creek.

All of the alternatives except Alternative BB-1 (No Further Action) would achieve significant reductions in cobalt concentrations in Panther Creek. Therefore Alternative BB-1 is rated lowest for long-term effectiveness at reducing cobalt concentrations. The alternatives that rely upon the West Fork Tailings Impoundment cover/cap (Alternatives BB-4 and BB-6) are predicted to achieve the cobalt water quality PRG in Panther Creek consistently during spring runoff periods, and would likely meet the PRG at some other times of the year also. However, during the periods of highest cobalt concentrations (winter and early spring), Alternatives BB-4 and BB-6 are not predicted to be effective at consistently meet the cobalt PRG in Panther Creek. The alternatives that rely upon treatment at the Tailings Impoundment (Alternatives BB-5, BB-7, and BB-8) are rated higher for effectiveness because they are predicted to have greater certainty of achieving the cobalt PRG in Panther Creek. However, during the periods of highest cobalt concentrations, Alternative BB-5 may not consistently achieve the cobalt PRG. Alternatives BB-7 and BB-8 are the most effective because they are the only alternatives that are predicted to consistently achieve the cobalt PRG in Panther Creek. Alternatives BB-7 and BB-8 are essentially comparable in terms of cobalt water quality predictions; the extensive sediment removals under Alternative BB-8 would provide no discernable benefit to cobalt water quality in Panther Creek.

Sediments are expected to improve through natural recovery under all of the alternatives such that PRGs would eventually be achieved in Panther Creek. Only Alternative BB-8 is predicted to meet sediment PRGs in Blackbird Creek.

The long-term residual risks for all of the alternatives are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits (and in-stream sediments near the PCI) along Blackbird Creek. All of the alternatives would reliably address the releases of metals and arsenic from the mine area through continued operation and maintenance of the Early Actions. In terms of reliability of addressing the other residual risks, Alternative BB-8 is rated highest because it primarily utilizes treatment to address the cobalt releases (which has greater certainty of effectiveness) and would eliminate the risks to downstream overbank deposits and in-stream sediments through complete removal. Alternative BB-7 is rated next highest since it utilizes treatment to address the cobalt releases and would address the risks to downstream overbank deposits and in-stream sediments primarily through removal (which is more reliable and permanent than armoring). Alternatives BB-5 and BB-6 are rated comparable in terms of residual risks: Alternative BB-5 includes treatment for the cobalt releases but would utilize primarily armoring to address the risks to downstream overbank deposits and in-stream sediments; Alternative BB-6 would utilize primarily removal to address the risks to downstream overbank deposits and in-stream sediments, but would utilize the cover/cap to address the cobalt releases (which is judged less reliable than treatment). Alternative BB-4 is rated lowest in terms of residual risks because it would utilize the cap/cover to address arsenic releases and primarily armoring to address the risks to downstream overbank deposits and in-stream sediments.

All of the alternatives are judged to be comparable in terms of permanence. All of the alternatives depend on proper operation and maintenance of the facilities that would be constructed plus proper operation and maintenance of the already completed Early Actions. As long as the operation and maintenance is properly performed in the future, all of the facilities are considered permanent.

ES-4.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment

All of the alternatives include treatment via the existing Water Treatment Plant. Alternative BB-1 involves continued operation of the existing WTP at existing flow rates. Alternatives BB-4 and BB-6 add treatment of additional seepage to be collected from Meadow Creek. Alternatives BB-5, BB-7, and BB-8 provide treatment of both Meadow Creek seepage and Tailings Impoundment seepage.

ES-4.1.5 Short-term Effectiveness

Alternative BB-1 is rated highest for short-term effectiveness because it would not result in risks to workers or the community, would have no short-term environmental impacts associated with remedial actions, and would be implemented on signing of a Consent Decree. Alternatives BB-4, BB-5, BB-6, and BB-7 are essentially comparable in terms of risks to the community and workers during construction and short-term environmental risks. The construction activities for both removal and stabilization of the Blackbird Creek overbank deposits are similar in terms or risks to the community and workers. In addition, the short-term disruption of the environment is similar for both removal and stabilization. Each of these four alternatives could be completed within 1 to 2 years. Of these four alternatives, those that involve treatment to address cobalt (BB-5 and BB-7) would improve water quality much more rapidly than the alternatives that rely upon the cover/cap for cobalt reductions (BB-4 and BB-6). Alternatives BB-5 and BB-7 would see the cobalt water quality improvements within a year after completing construction; whereas Alternatives BB-4 and BB-6 may require years to a decade or more before the full cobalt water quality effects would be seen. Alternative BB-8 is rated lowest in terms of short-term effectiveness. This alternative would involve extensive disturbance of ecological habitat over a construction period of several years. The re-establishment of a stable stream channel and riparian vegetation following construction may require a decade of more. Alternative BB-8 would require excavating, hauling, and disposing of a very large quantity of sediments. The removal and construction activities would create more short-term risk to the community, site workers and the environment than the other alternatives. Alternative BB-8 would also take the longest time to implement (likely 3 years or more).

ES-4.1.6 Implementability

Alternative BB-1 is rated highest for technical implementability since no further actions would be required. Alternative BB-6 is rated next highest for technical implementability, since this alternative would utilize standard construction techniques for the overbank removals and would not involve design and construction of collection and treatment

facilities. Alternative BB-4 is rated next highest: it would not involve collection and treatment at the West Fork Impoundment; however there may be difficulties locating sufficiently sized armoring materials to handle the 500-year design storm. Alternative BB-7 is rated next highest for technical implementability because this alternative would utilize standard construction techniques for the overbank removals. However, collecting and treating seepage from the Tailings Impoundment would be more difficult than implementing the cover/cap. Alternative BB-5 is next highest because it would have the difficulties associated with seepage collection and treatment at the Impoundment, and would require locating sufficiently sized armoring materials to protect the Blackbird Creek overbank materials. Alternative BB-8 is rated lowest for technical implementability. It would experience the difficulties associated with collection and treatment at the West Fork Impoundment. During removal, Blackbird Creek would require diversion to allow access to the in-stream sediments. In addition, as excavation would extend below the water table, dewatering of excavation areas would be required. Under Alternative BB-8, extensive controls would have to be put in place to control sediment, which would be complicated by the fact that work would have to be conducted over several construction seasons. Alternative BB-8 would require sitting, constructing, and long-term maintenance and monitoring of a new large disposal cell.

There is not expected to be any difference among the alternatives in terms of administrative implementability of institutional controls on property managed by the USFS along Blackbird Creek.

ES-4.1.7 Cost

Figure ES-4 compares the cost-effectiveness of the Blackbird alternatives relative to meeting water quality PRGs in Panther Creek at PASW-09. Error bars on this figure are based on the minimum and maximum values from the uncertainty/variability analysis (see Section 7.2.1.3). Of the alternatives that can consistently meet the copper water quality PRG in Panther Creek, the best incremental cost-effectiveness is provided by Alternative BB-6. However, there is considerable uncertainty concerning whether Alternative BB-6 can meet the cobalt PRG in Panther Creek in a timely manner. Of the alternatives that can meet both the copper and cobalt water quality PRGs in Panther Creek with certainty and in a timely manner, Alternative BB-7 has the best incremental cost-effectiveness. Alternative BB-8 could meet the copper and cobalt water quality PRGs in Panther Creek with certainty and in a timely manner. In addition, it could meet the sediment PRGs in Blackbird Creek. However, Alternative BB-8 would not be able to consistently meet the water quality PRGs in Blackbird Creek, and would therefore not be protective of the environment in Blackbird Creek. Alternative BB-8 would not provide any substantial improvements to water quality in Panther Creek compared to Alternative BB-7. Therefore, the substantial difference in costs associated with Alternative BB-8 would not be justified, especially considering the extensive short-term environmental impacts and the considerable implementability issues associated with Alternative BB-8.

ES-4.2 Comparison of Bucktail Creek Alternatives

Figure ES-5 compares the relative reductions in copper concentrations (at BDSW-03) to the costs for the Bucktail Creek alternatives. In this figure, the benefit of the alternative is measured relative to the concentrations observed in 1995 before remediation (including Early Actions). The percent decrease of each alternative is calculated by dividing the expected decrease for the alternative (1995 value minus the estimated post-remediation concentration) by the decrease needed to meet EPA's proposed PRG (1995 value minus the PRG). Thus, 100% represents meeting the PRG. The estimated post-remediation concentrations are the average of the estimates for spring and fall 2000 and 2001 (four values). The error bars on Figure ES-5 are based on the estimated post-remediation concentrations using the maximum and minimum observed values at BDSW-03. Table ES-6 provides the predicted post-remediation concentrations in Big Deer Creek based on results of the 2000 and 2001 synoptic sampling events. Table ES-7 presents the sensitivity analysis of the predicted post-remediation concentrations in Big Deer Creek used to develop the error bars.

ES-4.2.1 Overall Protection of Human Health and the Environment

There would be no difference among the alternatives in terms of human health. EPA has determined that all of the alternatives (including BT-1, No Further Action) would be protective of human health.

EPA has determined that Alternative BT-5 is the only alternative that would be protective of the environment for both South Fork Big Deer and Big Deer Creeks. It is the only alternative that is predicted to meet water quality and sediment PRGs in South Fork Big Deer and Big Deer Creeks within a reasonable time frame. Alternative BT-3 would be protective of the environment in Big Deer Creek, since the water quality and sediment PRGs would be met in a reasonable time frame. However, Alternative BT-3 would not be protective of the environment in South Fork Big Deer Creek because water quality PRGs would not be achieved within a reasonable time frame (likely not for centuries). Alternative BT-4 and BT-6 would be protective of the environment in Big Deer Creek, since the water quality and sediment PRGs would be met in a reasonable time frame. The sediment removals for these alternatives would reduce the time to achieve sediment PRGs, however they would cause considerable short-term disruption of the stream channels and riparian habitat. Neither Alternative BT-4 nor BT-6 would be protective of the environment in South Fork Big Deer Creek since water quality PRGs would not be achieved within a reasonable time frame. Alternative BT-1 would not be protective of the environment since water quality PRGs would not be achieved for centuries.

ES-4.2.2 Compliance with ARARs

Alternative BT-5 is the only alternative that can meet all ARARs, including the copper ARAR in South Fork Big Deer Creek. All of the other action alternatives (BT-3, BT-4, and BT-6) could meet all ARARs except for the copper ARAR in South Fork Big Deer Creek.

The No-Further Action alternative would not meet the copper ARAR in either South Fork Big Deer or Big Deer Creeks.

ES-4.2.3 Long-term Effectiveness and Permanence

Alternative BT-5 is judged to have the best long-term effectiveness because it can meet the water quality and sediment PRGs in South Fork Big Deer and Big Deer Creeks. All of the other action alternatives (BT-3, BT-4, and BT-6) would be essentially equivalent in terms of long-term effectiveness. They would all achieve water quality and sediment PRGs, except for South Fork Big Deer Creek water quality PRGs (which would not be met for centuries). The primary difference among the other action alternatives is in terms of time to achieve the PRGs. Alternative BT-6 would achieve water quality PRGs in Big Deer Creek and sediment PRGs in South Fork Big Deer and Big Deer Creeks within 1 to 2 years after completion of remedial activities. Alternative BT-4 would require years to a decade or more to achieve water quality and sediment PRGs in Big Deer Creek. Alternative BT-4 would meet sediment PRGs in South Fork Big Deer Creek upon completion of remedial actions. Alternative BT-3 would require years to a decade or more to achieve water quality and sediment PRGs in Big Deer Creek and sediment PRGs in South Fork Big Deer Creek.

All of the action alternatives are essentially comparable in terms of mixing zone requirements in Big Deer Creek. Under worse case conditions, all of the alternatives require 100% of the width of Big Deer Creek for mixing, and may not even achieve the copper water quality standard at times even with 100% width for mixing. Under average conditions, the mixing zone requirements vary from 70% to 100% of the width of Big Deer Creek.

Most of the residual risks at the site were controlled through the Early Actions, which minimize risks of releases for storm events up to the 500-year design storm. Alternative BT-6 is judged to have the lowest level of residual risks because the sediments would be removed, eliminating the risk of re-mobilization and downstream deposition during large storm events. The other alternatives would have essentially the same risk of re-mobilization of Bucktail Creek sediments with downstream deposition during large storm events. These risks would be minimized as long as the lower Bucktail sediment dam remains in place.

All of the action alternatives would be essentially equivalent in terms of reliability of controls and permanence. The permanence of these alternatives would rely upon long-term maintenance of the facilities that would be included under each alternative, monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of these facilities is properly performed, any of the Bucktail action alternatives (BT-3, BT-4, BT-5, and BT-6) would provide a permanent remedy.

ES-4.2.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternatives BT-3, BT-4, BT-5, and BT-6 would provide the same reduction in toxicity, mobility, and volume through treatment of the collected groundwater. Alternative BT-1 would provide treatment of lesser volumes of groundwater than the action alternatives (continued treatment of groundwater collected at the existing Bucktail pump station).

ES-4.2.5 Short-term Effectiveness

Alternative BT-1 is rated highest for short-term effectiveness because it would not result in risks to workers or the community, would have no short-term environmental impacts associated with remedial actions, and would be implemented on signing of a Consent Decree. Alternatives BT-3 and BT-5 are rated next highest for short-term effectiveness and are essentially comparable with BT-3 having a slight edge because it involves less construction. Both alternatives would have minimal risks to the community, acceptable construction risks, minimal unavoidable short-term environmental risks, and could be implemented within 2 years. Alternative BT-4 is rated lower than Alternatives BT-1, BT-3 and BT-5 because the sediment removal in South Fork Big Deer Creek would result in greater construction risks and considerable disruption of the stream channel and riparian habitat. Alternative BT-6 is rated lowest because the extensive sediment removal would result in greater construction risks, extensive disruption of stream channels and riparian habitat, and a construction period that would last several years beyond the other alternatives.

ES-4.2.6 Implementability

Alternative BT-1 is rated highest for technical implementability since no further actions would be required. Alternatives BT-3 and BT-5 are rated next highest, and are essentially comparable since both alternatives would utilize standard construction techniques. Alternative BT-4 is rated lower due to the need for stream diversion, dewatering and sediment control during the sediment removal. Alternative BT-6 is rated lowest because of the need for stream diversion, dewatering and sediment control during the sediment removal, the need to site, design, and maintain an on-site repository, and the uncertainty of approval for construction of an access road along Big Deer Creek. All of the alternatives are rated comparable in terms implementing institutional controls on lands controlled by the Forest Service.

ES-4.2.7 Cost

Figure ES-5 compares the cost-effectiveness of the Bucktail alternatives relative to meeting water quality PRGs in Big Deer Creek at BDSW-03. Error bars on this figure are based on the minimum and maximum values from the uncertainty/variability analysis (see Section 7.3.1). Alternative BT-3 has the best cost-effectiveness of the alternatives for achieving ARARs in Big Deer Creek. Alternative BT-5 would also meet water quality PRGs in South Fork Big Deer Creek at a cost approximately $300,000 greater than Alternative BT-3. The other action alternatives (BT-4 and BT-6) would be considerably more costly, with minimal differences in long-term benefits to the environment.

ES-4.3 Comparison of Panther Creek Alternatives

Alternative P-1, because it does not monitor future land use, is not protective of human health. Alternatives P-2 and P-3 are comparable in terms of overall protection of human health and long-term effectiveness, as long as enforceable institutional controls are maintained. Alternative P-3 has greater reliability and permanence because it does not rely on institutional controls. The estimated cost for Alternative P-2 is lower than for Alternative P-3, although there is some uncertainty in the costs of implementing and monitoring institutional controls. Alternative P-3 would have greater short-term impacts than Alternative P-2.

TABLE ES-1
Evaluation Summary for Blackbird Creek Alternatives

Alternative / Criteria	BB-1 No Further Action	BB-4 Meadow Creek Seep Collection; Cap West Fork Tailings Impoundment; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments	BB-5 Meadow Creek Seep Collection; Cap West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments	BB-6 Meadow Creek Seep Collection; Cap West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments	BB-7 Meadow Creek Seep Collection; Cap West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments	BB-8 Meadow Creek Seep Collection; Cap Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments
Overall Protection	Not protective of human health or the environment	Protective of human health. Does not meet PRGs in Blackbird Creek. May periodically exceed water quality PRGs in Panther Creek. Stabilization of overbank deposits may not provide as good overall protection as alternatives that include more removal.	Protective of human health. Does not meet PRGs in Blackbird Creek. May periodically exceed copper and cobalt PRGs in Panther Creek. Stabilization of overbank deposits may not provide as good overall protection as alternatives that include more removal.	Protective of human health. Does not meet PRGs in Blackbird Creek. Meets copper PRGs in Panther Creek. Uncertainty in terms of meeting cobalt PRGs in Panther Creek, and would require years to decades. Removal of overbank deposits likely to provide better overall protection than alternatives that rely primarily on stabilization.	Protective of human health and the environment. Does not meet PRGs in Blackbird Creek. Meets copper and cobalt PRGs in Panther Creek. Removal of overbank deposits likely to provide better overall protection than alternatives that rely primarily on stabilization.	Protective of human health and the environment in long-term. Does not meet PRGs in Blackbird Creek. Meets copper and cobalt PRGs in Panther Creek. This alternative would result in signficant short-term impacts to the environment with no significant improvements to water quality.
Compliance with ARARs	Currently does not consistently meet copper water quality standard in Panther Creek. Meets all other ARARs.	Periodic exceedance of copper water quality standard in Panther Creek likely. Meets all other ARARs (a)	Occasional springtime exceedance of copper water quality standard in Panther Creek likely. Meets all other ARARs. (a)	Expected to consistently achieve copper water quality standard in Panther Creek. Meets all other ARARs (a)	Expected to consistently achieve copper water quality standard in Panther Creek Meets all other ARARs (a)	Expected to consistently achieve copper water quality standard in Panther Creek. Meets all other ARARs (a)
Long-Term Effectiveness	Does not consistently meet water quality PRGs. Existing controls inadequate to protect against residual risks. Not effective in long-term	Not expected to consistently achieve water quality objectives. Capping at West Fork Impoundment not as reliable and certain as treatment. Physical stabilization not as reliable as removal for overbank deposits.	Not expected to consistently achieve water quality objectives. Treatment at West Fork Impoundment more reliable and certain than capping. Physical stabilization not as reliable as removal for overbank deposits.	Not expected to consistently achieve water quality objectives. Expected to meet copper PRG in Panther Creek; capping at West Fork Impoundment not as reliable and certain as treatment for meeting cobalt PRG. Removal of overbank deposits more effective and reliable than physical stabilization.	Expected to consistently achieve water quality objectives. Treatment at West Fork Impoundment more reliable and certain than capping. Removal of overbank deposits more effective and reliable than physical stabilization.	Expected to consistently achieve water quality objectives. Treatment at West Fork Impoundment more reliable and certain than capping. Removal of all in-stream and overbank deposits most reliable in long-term.
Reduction in Toxicity, Mobility, Volume Through Treatment	No additional treatment provided	Treatment of Meadow Creek seepage	Treatment of Meadow Creek seepage and Tailings Impoundment seepage	Treatment of Meadow Creek seepage	Treatment of Meadow Creek seepage and Tailings Impoundment seepage	Treatment of Meadow Creek seepage and Tailings Impoundment seepage
Short-Term Effectiveness	Does not create the short-term construction risks	Short-term construction risks similar for Alternatives BB-4 through BB-7.	Short-term construction risks similar for Alternatives BB-4 through BB-7.	Short-term construction risks similar for Alternatives BB-4 through BB-7. May require years to a decade or more to achieve cobalt PRGs in Panther Creek.	Short-term construction risks similar for Alternatives BB-4 through BB-7. Would meet all PRGs within 1 to 2 years after implementation.	Extensive short-term environmental impacts for up to a decade until riparian vegetation recovers. Would require greatest time to implement (3 or more years).
Implementability	No implementation required	Readily implemented. Physical stabilization more difficult than removal because large riprap difficult to locate. Capping at West Fork less difficult than treatment.	Readily implemented. Physical stabilization more difficult than removal because large riprap difficult to locate. Treatment at West Fork more difficult than capping.	Readily implemented; less difficult than all other alternatives except No Further Action	Readily implemented. Treatment at West Fork more difficult than capping.	Very difficult to implement. Would require extensive sediment controls and excavation below the water table. Would require siting of new disposal facility.
Cost (millions, net present value)	$1.3	$4.2	$6.5 to $9.9 (b)	$4.6	$6.8 to $10 (b)	$53 to $56 (b)

(a) Final determination regarding NPDES mixing zone requirements in Panther Creek is pending
(b) Costs depend on treatment option for groundwater at the West Fork Tailings Impoundment (see Table 7-14 and Appendix E for details)

TABLE ES-2
Evaluation Summary for Bucktail Creek Alternatives

Alternative / Criteria	BT-1 No Further Action	BT-3 Seep Collection and Treatment; Natural Recovery of Sediments	BT-4 Seep Collection and Treatment; S. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments	BT-5 Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments	BT-6 Seep Collection and Treatment; Complete Sediment Removal
Overall Protection	Protective of human health. Would not meet water quality PRGs in South Fork or Big Deer Creeks.	Protective of human health. Would meet PRGs in Big Deer Creek. Would not meet PRGs in So. Fork Big Deer Creek.	Protective of human health. Would meet PRGs Big Deer Creek, but not in South Fork. Removal of sediments in So. Fork would not significantly improve time to meet PRGs in So. Fork Big Deer Creek.	Protective of human health. Would meet PRGs in Big Deer Creek. Diversion of Bucktail Creek would allow PRGs to be met in So. Fork Big Deer Creek.	Protective of human health. Would meet PRGs Big Deer Creek, but not in South Fork. Removal of all sediments would result in significant short-term impacts to the environment.
Compliance with ARARs *	Would not meet copper ARAR in South Fork or Big Deer Creeks. Meets all other ARARs	Would meet copper water quality ARAR in Big Deer Creek, but not in South Fork Creek. Meets all other ARARs	Would meet copper water quality ARAR in Big Deer Creek, but not in South Fork Creek. Meets all other ARARs	Would meet copper ARAR in both South Fork and Big Deer Creeks. Meets all other ARARs	Would meet copper water quality ARAR in Big Deer Creek, but not in South Fork Creek. Meets all other ARARs
Long-Term Effectiveness	Not effective or reliable in long term.	Would be effective and reliable in long-term for meeting PRGs in Big Deer Creek. Would not meet PRGs in South Fork.	Would be effective and reliable in long-term for meeting PRGs in Big Deer Creek. Would not meet PRGs in South Fork.	Would be effective and reliable in long-term for meeting PRGs in both South Fork and Big Deer Creeks.	Would be effective and reliable in long-term for meeting PRGs in Big Deer Creek. Would not meet PRGs in South Fork.
Reduction in Toxicity, Mobility, Volume Through Treatment	No additional treatment provided	Treatment of Bucktail seepage	Treatment of Bucktail seepage	Treatment of Bucktail seepage	Treatment of Bucktail seepage
Short-Term Effectiveness	Does not create the short-term construction risks	Flushing of Bucktail Creek sediments may result in exceedances of PRGs in Big Deer Creek until the sediments are flushed (a). There would be some short term construction risks for seepage collection system.	Flushing of Bucktail Creek sediments may result in exceedances of PRGs in Big Deer Creek until the sediments are flushed (a). Short term construction risks would be increased to remove sediments from So. Fork Big Deer Creek.	Flushing of Bucktail Creek sediments may result in exceedances of PRGs in Big Deer Creek until the sediments are flushed (a). PRGs should be met in South Fork within 2-5 years. There would be some short term construction risks for seepage collection system.	Would meet PRGs in Big Deer within 1-2 years of completion. Would not meet PRGs in South Fork. Would require 3 to 5 years for construction. Extensive short-term construction impacts to stream channels and riparian vegetation would require decade or more for recovery.
Implementability	No implementation required	There will be some technical challenges intercepting sufficient seepage to meet PRGs.	Difficult to implement. Would require extensive sediment controls and excavation below the water table in South Fork.	There will be some technical challenges intercepting sufficient seepage to meet PRGs.	Very difficult to implement. Would require extensive sediment controls and excavation below the water table. Would require siting of new disposal facility.
Cost (millions, net present value)	$1.3	$4.5	$5.1	$4.8	$11

(a) The timing for Bucktail Creek sediment flushing is uncertain, but may be years to a decade or more. If water quality PRGs are not consistently met in Big Deer Creek in an acceptable time frame, alternatives for contingencies to address water quality will be evaluated.

TABLE ES-3
Evaluation Summary for Panther Creek Alternatives

Alternative / Criteria	P-1 No Further Action	P-2 Natural Recovery with Institutional Controls and Monitoring	P-3 Selective Overbank Deposit Removal
Overall Protection	Not guaranteed	Overall protection relies on effectiveness of institutional controls and monitoring	Removal of deposits exceeding human health PRGs ensures overall protectiveness
Compliance with ARARs	Yes	Yes	Yes
Long-Term Effectiveness	Potential unacceptable risk under future residential land use scenario.	Effective and reliable for current and future land uses if institutional controls are maintained.	Effective and reliable for current and future land uses.
Reduction in Toxicity, Mobility, Volume Through Treatment	None	None	None
Short-Term Effectiveness	Does not create the short-term risks of Alternative P-3.	Does not create the short-term risks of Alternative P-3.	Removal creates potential short-term risks to the community, site workers, and the environment during implementation.
Implementability	No implementation required	Implementable as long as an appropriate entity is willing to serve as grantee of the land restriction instrument(s) and private property owners are willing to accept ICs.	Readily implemented
Cost (millions, net present value)	$0.0	$0.2	$1.4

NOTE: Water quality improvements in Panther Creek determined by alternatives selected for Blackbird Creek and for Bucktail Creek.

TABLE ES-4
Comparison of Estimated Post-Remediation Concentrations at PASW-09

	WTP Discharge (gpm)					
	Fall				Spring	
	0		600		800	
	2000	2001	2000	2001	2000	2001
COPPER (concentration in ug/L)						
Measured Hardness (mg/L)	49	42	49	42	41	43
PRG	6	6	6	6	5	6
Current (measured, synoptic)	3	3	---	---	7	13
Alternative BB-4	1	< 1	1	< 1	3	7
Alternative BB-5	< 1	< 1	1	< 1	2	6
Alternative BB-6	< 1	< 1	< 1	< 1	2	3
Alternative BB-7	< 1	< 1	< 1	< 1	1	3
Alternative BB-8	< 1	< 1	< 1	< 1	1	3
COBALT (concentration in ug/L)						
PRG	38	38	38	38	38	38
Current (measured, synoptic)	54	35	---	---	53	37
Alternative BB-4	39	23	45	29	16	29
Alternative BB-5	30	16	36	22	11	26
Alternative BB-6	34	21	40	26	16	16
Alternative BB-7	25	13	31	19	11	13
Alternative BB-8	24	13	30	19	10	11

Notes:

a. CAUTION - The concentrations and loads shown in this table are estimates based on synoptic water quality sampling data collected during 2000 and 2001. The synoptic data do not represent the highest cobalt concentrations. However, the removal efficiencies of the alternative may be understated. Therefore, post-remediation concentrations shown may be under-estimated or over-estimated during hydrologic conditions other than those at the time of sampling. The calculations included in these tables were prepared to provide a relative comparison of the effects on water quality of the alternatives under consideration in this feasibility study, and do not take into account a number of factors that could cause significant variability in the results.

b. All values shown are for dissolved copper and cobalt and total iron.

c. Estimated post-remediation concentrations are based reducing current load at PASW-09.

d. This analysis does not take credit for future decreases due to downward data trends.

TABLE ES-5
Uncertainty and Variability Analysis for Post-Remediation Concentrations at PASW-09

	Maximum Removal	Best Estimate Removal			Minimum Removal
	Min.Min.	Var.Min.	Average	Var.Max.	Max.Max.
COPPER (concentration in ug/L)					
Current (measured)	3	3	7	13	13
Alternative BB-4	< 1	1	2	5	7
Alternative BB-5	< 1	< 1	2	4	6
Alternative BB-6	< 1	< 1	2	3	4
Alternative BB-7	< 1	< 1	1	3	4
Alternative BB-8	< 1	< 1	1	3	4
COBALT (concentration in ug/L)					
Current (measured)	5	5	45	75	75
Alternative BB-4	3	3	30	51	61
Alternative BB-5	2	3	24	40	52
Alternative BB-6	2	3	25	43	55
Alternative BB-7	1	2	19	31	46
Alternative BB-8	1	2	18	30	44

NOTES:

a. Current values for "best estimate" low, average, and high based on synoptic data for PASW-09. Current value "min." and "max." based on all 2000 and 2001 data for PASW-09.

b. To estimate "min.var." and "max.var." for the alternatives, the current "min" and "max" values were multiplied by the ratio of the predicted "average" to the current "average".

TABLE ES-6
Comparison of Estimated Post-Remediation Concentrations at BDSW-03

	Fall		Spring	
	2000	2001	2000	2001
COPPER (ug/L)				
Hardness (measured, mg/L)	39	41	11	16
PRG	5	5	4	4
Measured Concentration	21	22	6	11
Alternative BT-3, BT-4, BT-5 & BT-6	4	5	2	4
COBALT (ug/L)				
PRG	38	38	38	38
Measured Concentration	11	22	6	10
Alternative BT-3, BT-4, BT-5 & BT-6	9	9	3	4

Notes:

a. CAUTION - The concentrations and loads shown in this table are estimates based on synoptic water quality sampling data collected during 2000 and 2001. The synoptic data do not represent the highest cobalt concentrations. However, the removal efficiencies of the alternative may be understated. Therefore, post-remediation concentrations shown may be under-estimated or over-estimated during hydrologic conditions other than those at the time of sampling. The calculations included in these tables were prepared to provide a relative comparison of the effectson water quality of the alternatives under consideration in this feasibility study, and do not take into account a number of factors that could cause significant variability in the results.

b. Estimated post-remediation concentrations are based reducing current load at BDSW-03.

c. This analysis does not take credit for future decreases due to downward data trends.

d. Iron concentrations not expected to be significantly impacted by Bucktail remediation.

TABLE ES-7
Uncertainty and Variability Analysis for Post-Remediation Concentrations as BDSW-03

	Maximum Removal		Best Estimate Removal					Minimum Removal	
	Min.Min.	Min.Avg	Var.Min.	Var.Low	Average	Var.High	Var.Max.	Max.Avg	Max.Max.
COPPER (concentration in ug/L)									
Current (measured, synoptic)	6	15	3	6	15	22	22	15	22
Alternatives BT-3, BT-4, BT-5, & BT-6	1	1	1	2	4	5	5	4	5

NOTES:

a. Current values for "best estimate" low, average, and high based on synoptic data for BDSW-03. Current value "min." and "max." based on all 2000 and 2001 data for BDSW-03

b. To estimate "min.var." and "max.var." for the alternatives, the current "min" and "max" values were multiplied by the ratio of the predicted "average" to the current "average".

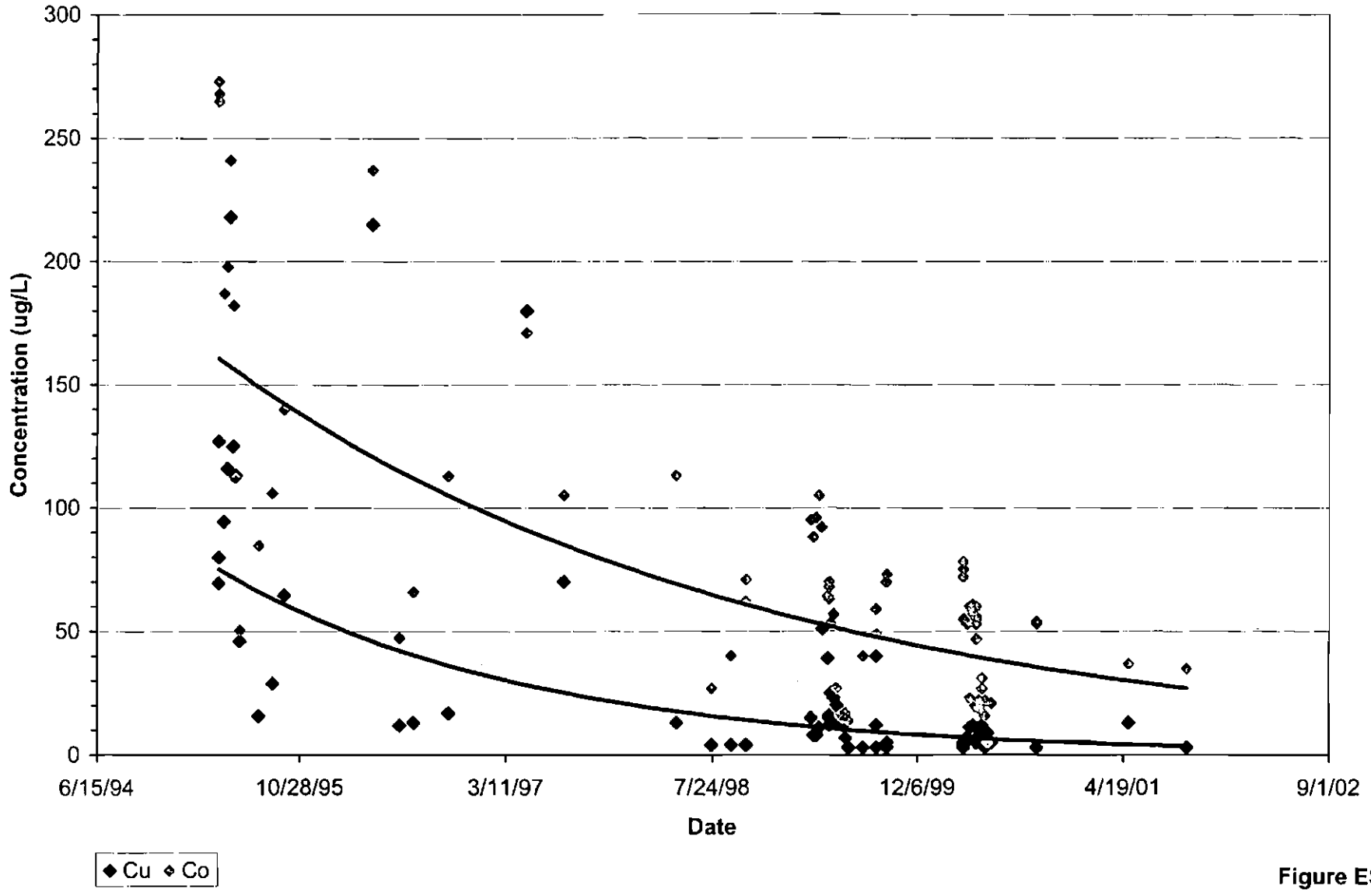


Figure ES-1

Decrease in Copper and Cobalt in Panther Creek Below Blackbird Creek (PASW-09)

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

Golder Associates

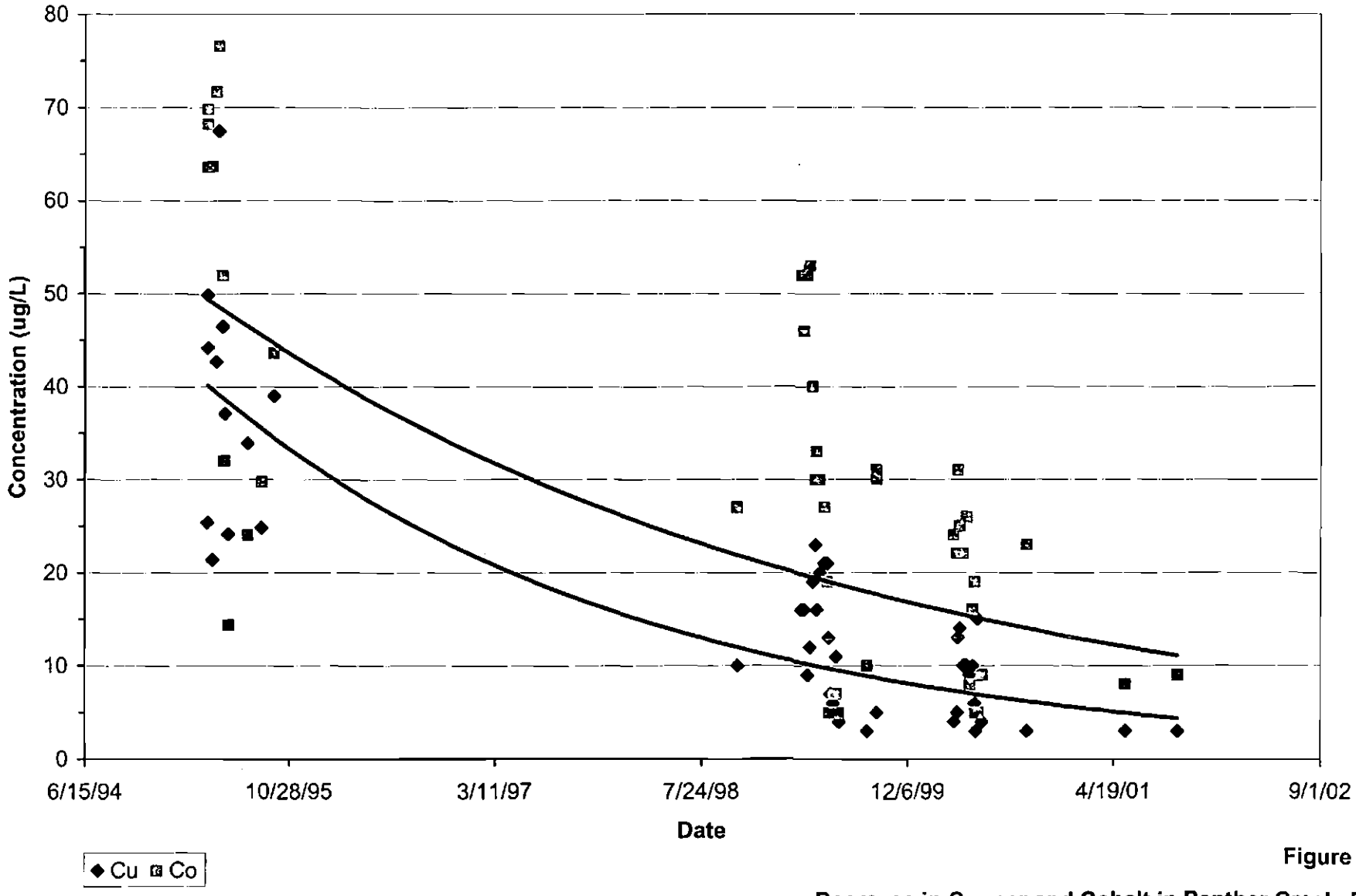


Figure ES-2

Decrease in Copper and Cobalt in Panther Creek Below Blackbird Creek and Big Deer Creek (PASW-04)

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

Golder Associates

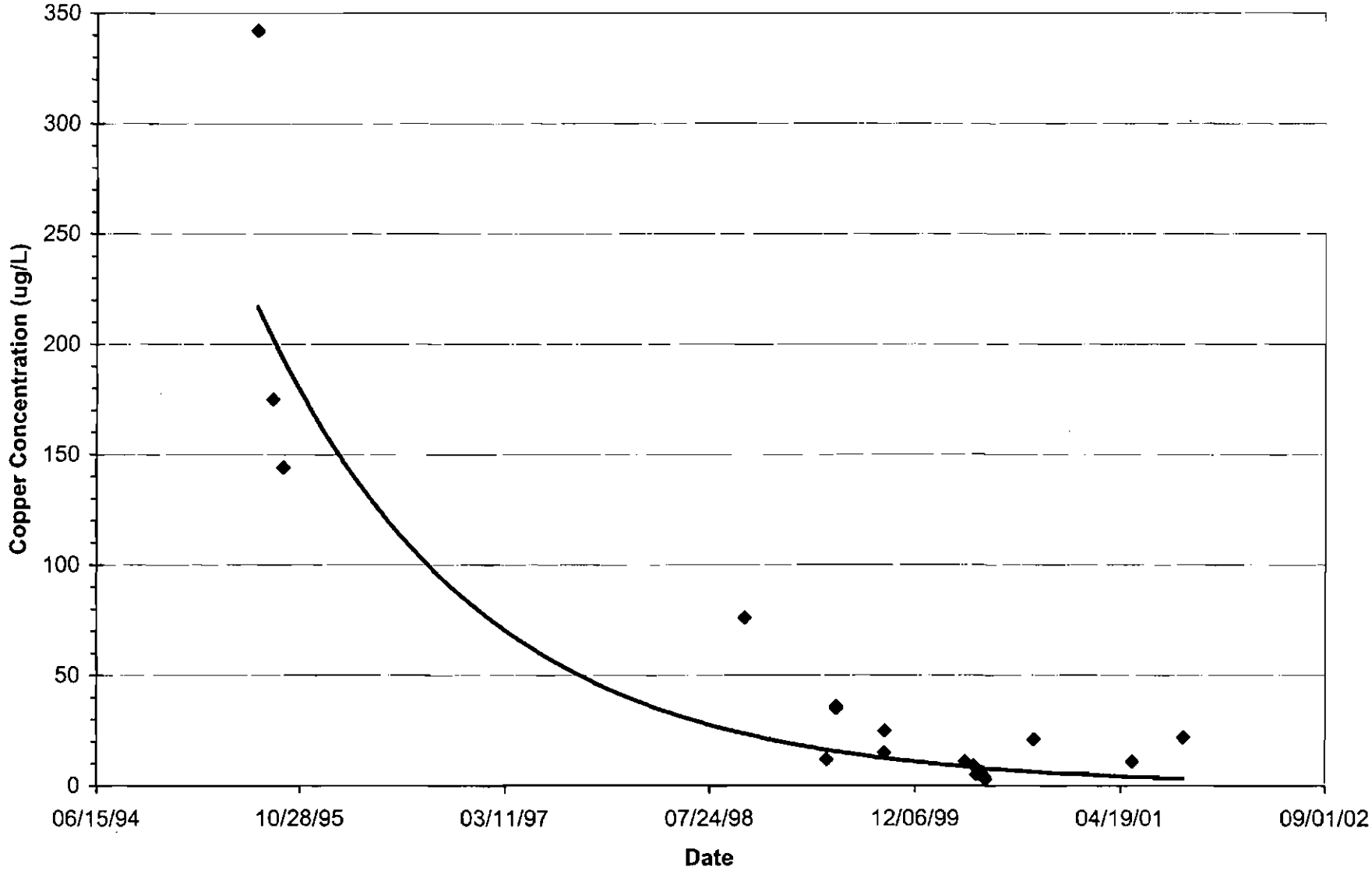
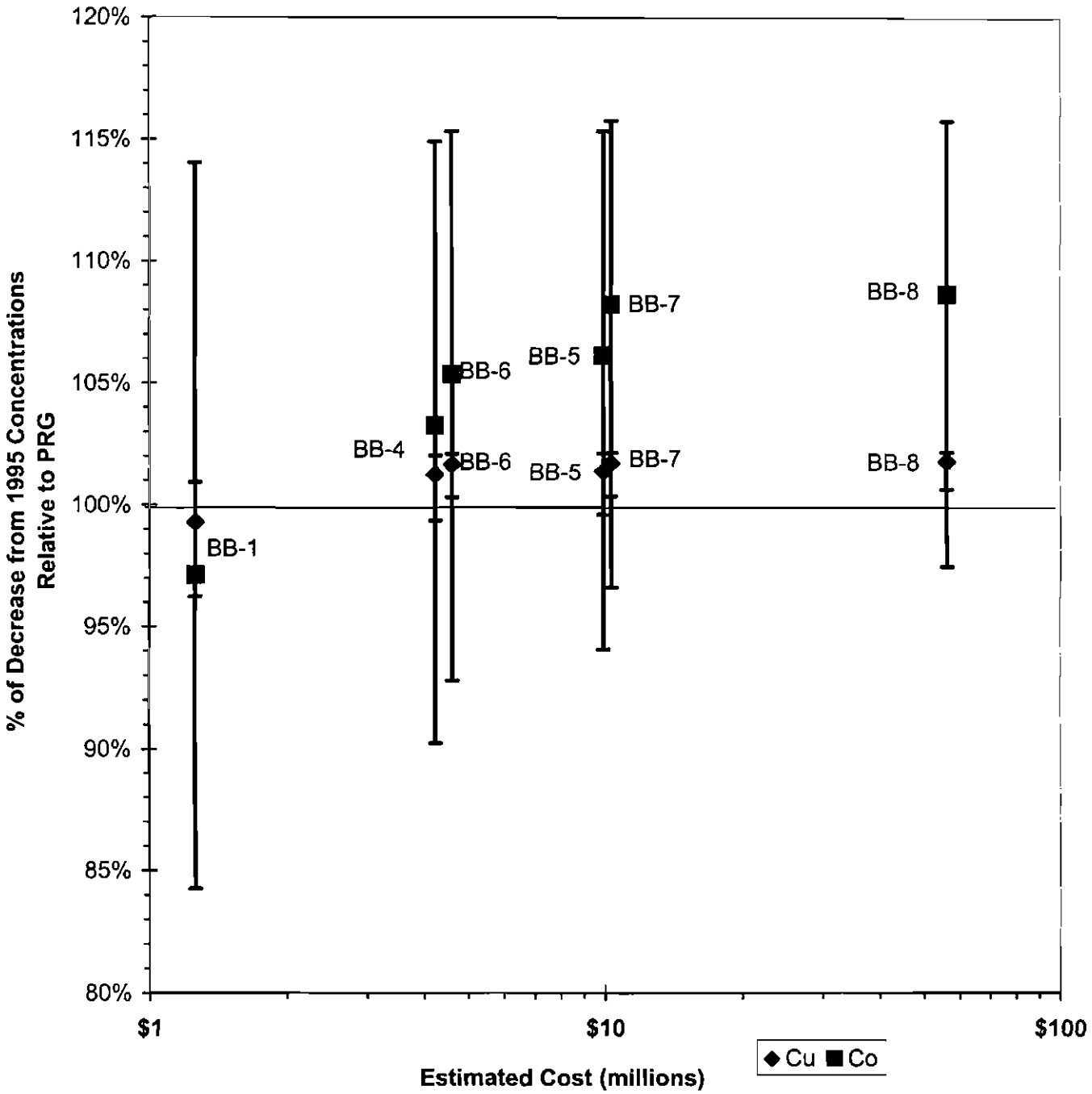


Figure ES-3

Decrease in Copper in Big Deer Creek

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

Golder Associates

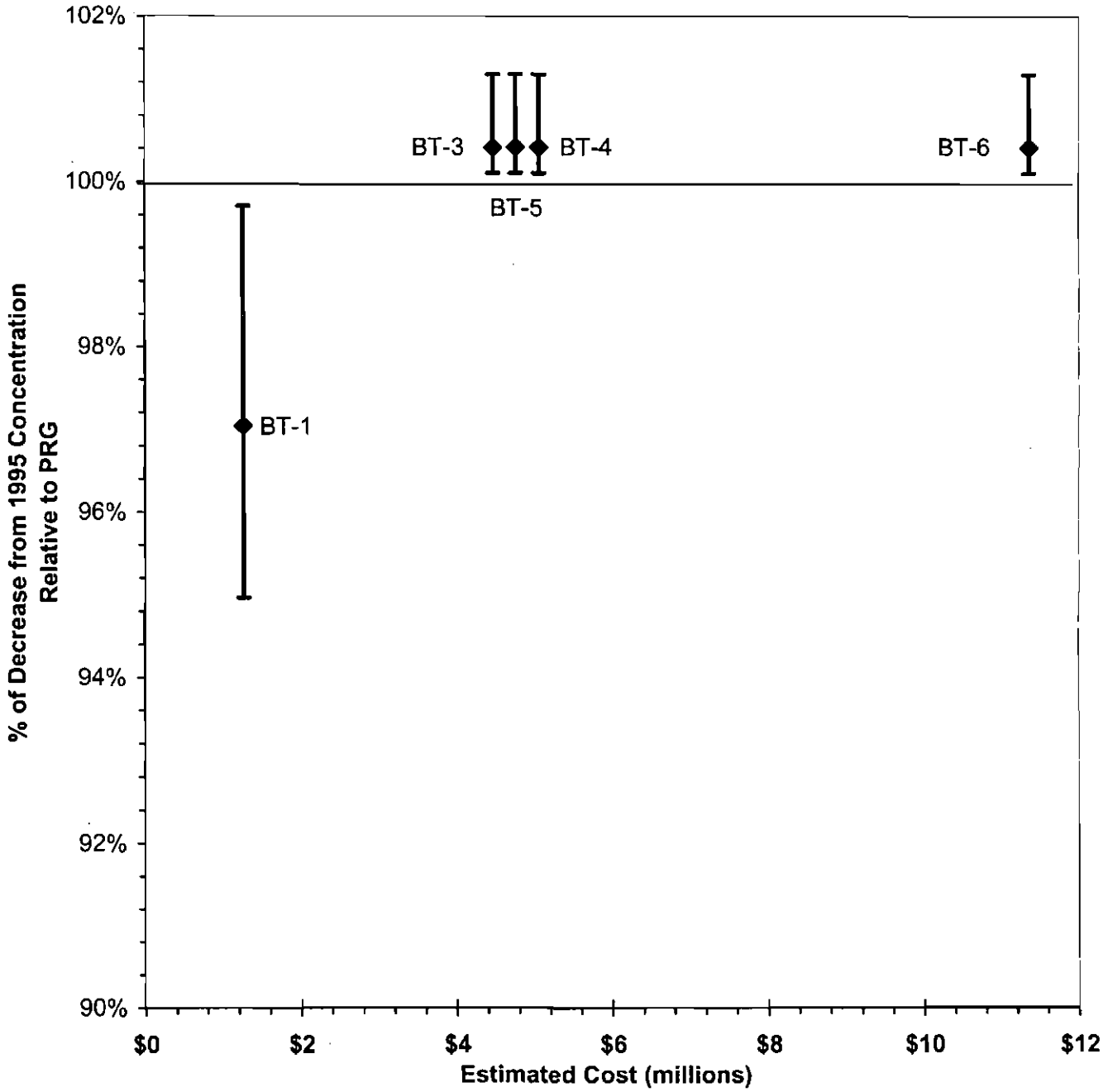


NOTE: Percent reductions calculated by dividing the difference between the highest 1995 concentrations and the average post-remediation concentration estimates by the difference between the highest 1995 concentrations and the PRGs. Estimates based on 2000 and 2001 synoptic data (spring & fall). Error bars based on estimated maximum and minimum removal efficiencies.

Figure ES-4

Cost-Effectiveness of Blackbird Creek Alternatives (based on PASW-09)

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID



NOTE: Percent reductions calculated by dividing the difference between the highest 1995 concentrations and the average post-remediation concentration estimates by the difference between the highest 1995 concentrations and the PRGs. Estimates based on 2000 and 2001 synoptic data (spring & fall). Error bars based on estimated maximum and minimum removal efficiencies.

Figure ES-5

Cost-Effectiveness of Bucktail Creek Alternatives (based on BDSW-03)

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

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ACRONYMS

AERA	Aquatic Ecological Risk Assessment
AOC	Administrative Order on Consent
ARAR	applicable or relevant and appropriate requirements
ARD	Acid Rock Drainage
BMSG	Blackbird Mine Site Group
BRCP	Biological Restoration and Compensation Plan
COC	Chemical of Concern
COPEC	Chemicals of Potential Ecological Concern
EPA	U.S. Environmental Protection Agency
FS	Feasibility Study
Golder	Golder Associates Inc.
HHRA	Human Health Risk Assessment
IDEQ	Idaho Department of Environmental Quality
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goals
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWQC	national water quality criteria
PRG	Preliminary Remediation Goal
RAO	Remedial Action Objective
ROC	Receptor of Concern
ROD	Record of Decision
TERA	Terrestrial Ecological Risk Assessment
Trustees	Natural Resource Trustees
UAA	Use Attainability Analysis
USFS	U.S. Forest Service

1. INTRODUCTION

1.1 Purpose and Scope

This report presents the final focused feasibility study (FS) for the Blackbird Mine Site. The FS has been prepared by Golder Associates Inc. (Golder) on behalf of the Blackbird Mine Site Group (BMSG), under oversight from the Environmental Protection Agency (EPA) in consultation with the Natural Resource Trustees (Trustees). The Trustees include the Idaho Department of Environmental Quality (IDEQ), the US Forest Service (USFS), the National Marine Fisheries Service (NMFS), and the National Oceanic and Atmospheric Administration (NOAA).

The focused FS was conducted pursuant to the *Administrative Order on Consent (AOC) for Remedial Investigation/Feasibility Study and Other Removal Action* issued by the EPA to the BMSG in November 1994 (U.S. EPA Docket No. 10-94-0222). In addition to the focused remedial investigation (RI) and FS, the AOC required that Early Actions be implemented. The Early Actions involved extensive removal actions, which have resulted in significant improvement in water quality and reduced risk to human health and the environment. Improvements to water quality, as a result of these actions, are described in more detail in Section 2.4 and summaries of the human health and ecological risk assessments are provided in Section 2.7. The purpose of the focused RI was to evaluate the nature and extent of metals releases from historic mining activities at the Blackbird Mine Site and to evaluate their impacts to soils, water quality, and environmental receptors following implementation of the Early Actions (Golder 2001a). The results of the RI, the Baseline Human Health Risk Assessment (CH2M Hill 2002), the Aquatic Ecological Risk Assessment (CH2M Hill 2001a), and the Terrestrial Ecological Risk Assessment (Golder 2000b) have been used to assess the potential remaining risk to human health and environmental receptors following implementation of Early Actions. The purpose of this FS is to evaluate alternatives for a final remedy for the site.

The detailed analysis of alternatives contained in Chapter 7 and the summaries of the comparison of alternatives provided in Section ES-4 of this Executive Summary was prepared by EPA, not by the BMSG or Golder. Changes to the description of alternatives (Chapter 6) and other sections of the FS Report were also required by EPA. In significant respects, the BMSG and Golder do not agree with EPA's changes to the FS Report and the resulting conclusions. The BMSG reserves the right to comment on the FS Report including the analysis and conclusions in Chapter 7 and to submit its own analysis of alternatives.

1.2 Overview of the Feasibility Study Process

In accordance with EPA guidance (EPA 1988a), an FS is generally conducted in the following steps:

1. Establish remedial action objectives (RAOs) and preliminary remediation goals (PRGs) for contaminants and media of concern. These objectives are developed based on the findings of the baseline risk assessment and chemical-specific applicable or relevant and appropriate requirements (ARARs).
2. Identify the applicable general response actions (e.g., containment, removal, and treatment).

3. Estimate the areas and volumes of contaminated media that exceed PRGs based on information developed during the RI.
4. Identification and screening of potentially applicable technologies for each contaminated medium to obtain a set of retained technologies, which are feasible for use in achieving RAOs and PRGs.
5. Assembly of retained technologies into remediation alternatives that cover the full range of possible response actions. The alternatives are then screened based on effectiveness, implementability, and cost to eliminate alternatives that are impractical, infeasible or have higher costs relative to the other alternatives without being more effective.
6. Further development and detailed evaluation of the alternatives to support selection of a final remedy.

The alternatives are evaluated using criteria established in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300.430):

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction in toxicity, mobility, and volume through treatment;
- Short-term effectiveness;
- Implementability, and
- Cost.

The first two criteria are considered "threshold" criteria that an alternative must meet to be acceptable. The remaining five criteria are considered the primary criteria used in the comparative evaluation of alternatives. EPA uses the results of the evaluation of alternatives to select a preferred remedy. The preferred remedy is then presented, along with the basis for its selection, in a Proposed Plan, which is provided for public comment. Two additional selection criteria, state acceptance and community acceptance, are determined based on comments received on the Proposed Plan. EPA then modifies the remedy as needed based on state and community acceptance and issues a Record of Decision (ROD).

1.3 Report Organization

This Feasibility Study is organized into the following sections:

Chapter 1, Introduction – This chapter.

Chapter 2, Site Background and Summary Of Early Actions, Remedial Investigation, and Baseline Risk Assessments – This chapter summarizes the RI and other site investigation activities relevant to remedy development. It also summarizes the Human Health, Terrestrial, and Aquatic Baseline Risk Assessments. Early actions that have been completed to improve water quality

and reduce risk to human health and the environment, and expedite site remediation are also summarized.

Chapter 3, Identification Of Remedial Action Objectives And Preliminary Remediation Goals – This chapter identifies potentially applicable or relevant and appropriate requirements (ARARs). These ARARs are combined with risk considerations to develop remedial action objectives. Preliminary remediation goals (PRGs), which are numeric expressions of the remedial action objectives, are then developed. Based on the PRGs, areas and volumes of affected media are estimated.

Chapter 4, Identification and Screening of Remediation Technologies – This chapter identifies technologies potentially applicable to remediation of the Site. These technologies are screened using the criteria effectiveness, implementability, and cost to produce a final list of technologies to consider for use at the Site.

Chapter 5, Assembly and Screening of Remediation Alternatives – In this chapter, retained technologies are assembled into a range of alternatives to address remediation of the site. In order to address the different remediation needs of different areas, the Blackbird Site has been divided into three (3) areas. A separate set of alternatives is assembled for each area.

Chapter 6, Development of Alternatives – This chapter presents conceptual designs of the remediation alternatives, which were developed in sufficient detail to allow evaluation of the alternatives. The alternatives share many common elements in their formulation. In order to avoid repetition, this section presents the descriptions of remedy components. These common elements are then referenced in the descriptions of the alternatives.

Chapter 7, Evaluation of Alternatives – In this chapter, the remediation alternatives are evaluated against the following CERCLA evaluation criteria: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction in toxicity, mobility and volume through treatment; short-term effectiveness; implementability; cost; state acceptance; and community acceptance. The alternatives are compared to each other based on the criteria evaluations to provide a basis for selecting a site remedy.

2. SITE BACKGROUND AND SUMMARY OF EARLY ACTIONS, REMEDIAL INVESTIGATION AND BASELINE RISK ASSESSMENTS

2.1 Site Background

The Blackbird Site consists of approximately 830 acres of private patented mining claims and 10,000 acres of unpatented claims previously held by the Blackbird Mining Company, all within the Salmon-Challis National Forest. The Blackbird Mine is approximately 13 miles south of the Salmon River and approximately 25 miles west of the town of Salmon in Lemhi County, Idaho (Figure 2-1a-e). The River of No Return Wilderness Area is located approximately 5 miles north of the mine site. Cobalt, the location of a former town used during mining activities, is located approximately 8 miles from the mine site along Panther Creek.

The mining activity associated with the site resulted in construction of approximately 14 miles of underground workings (12 levels with more than 15 adits and portals) and a 12-acre open pit mine (Figure 2-2a.) Additionally, the mine site included graded roads, numerous piles of waste rock, a tailings impoundment, sedimentation ponds, a water treatment plant, a wastewater sludge pond, an office, a maintenance shop and warehouse structures. A mill formerly located at the site has been demolished, as have the office and several other structures.

A small reservoir located on upper Blackbird Creek provides potable water. The water supply dam and reservoir on upper Blackbird Creek is located approximately 650 feet upstream of the confluence with Meadow Creek. The dam consists of a 30-foot high embankment with a drop structure leading to a discharge conduit.

A water treatment plant was placed in service in 1980 to treat mine seepage from the 6850 adit. The treatment plant originally had a design capacity of 450 gpm. During 1983, the 6850 adit was plugged and a valved outlet was installed in the bulkhead. Discharges to Blackbird Creek associated with the treatment plant are permitted under a National Pollutant Discharge Elimination System, Permit # ID-002525-9 (see Section 3.1.1.3.1 for further discussion of the NPDES Permit. The treatment plant was upgraded as part of the Early Actions to 800-gpm capacity to treat additional surface water collected from upper Meadow Creek, groundwater flows beneath the clean Meadow Creek soil cover, and upper Bucktail Creek water.

The West Fork Tailings Impoundment was constructed in 1950 across the West Fork of Blackbird Creek near the confluence with Blackbird Creek (Figure 2-2b). Prior to construction of the tailings impoundment, waste from milling operations (tailings) were disposed directly to Blackbird Creek downstream from the processing operations. The impoundment dam is approximately 150 feet high and 600 feet long. The tailings impoundment surface covers an area of about 9 acres and is 1,250 feet long. Construction of the tailings facility resulted in impoundment of 2 million tons of tailings over the West Fork Blackbird Creek, which was routed through a culvert underneath the tailings impoundment (Reiser 1986). In 1993, the Blackbird Mining Company constructed a groundwater cutoff wall at the upstream end of the tailings impoundment

and a surface water diversion channel and spillway for the West Fork of Blackbird Creek. These structures were constructed to bypass a concrete culvert running beneath the surface of the impoundment. The culvert formerly conveyed West Fork water to Blackbird Creek. Upon construction of the surface water diversion channel and spillway, the culvert was filled with pea gravel to prevent it from collapsing. The construction of the cutoff wall and surface water diversion channel was done as a time-critical early removal action under an Administrative Order with EPA.

2.1.1 Site History

The Blackbird Mine is located at one of North America's largest cobalt deposits. The Blackbird area was discovered in 1893, when the Blackbird Copper-Gold Mining Company consolidated several small prospects and conducted the first significant mining activities from 1893 until 1907. During this period, however, no economic returns were realized (Baldwin et al. 1978, USFS 1991).

From about 1917 until 1920, the Haynes-Stellite Company mined and milled approximately 4,000 tons of ore from a site located along the east side of Blackbird Creek approximately 1.2 miles downstream of the present Blackbird mine. The Stevenson Company owned the mine in the 1930s, but there was no production record (Baldwin et al. 1978, USFS 1991).

Mining activity slowed until 1938 when the Uncle Sam Mining Company reopened two old adits and built a 75-ton flotation mill at the present Blackbird Mine Site. During the period from 1938 to 1941, 461 ounces of gold, 332 ounces of silver, and 163,000 pounds of copper were produced in the area (Baldwin et al. 1978, USFS 1991).

The U.S. government conducted exploration activities in the area during the early 1940s for a domestic cobalt source and encouraged the development of the mine. The Calera Mining Company purchased the Blackbird Mine property in 1943. Full-scale mining activity was initiated in 1949 and at the request of the U.S. government, was expanded during the 1950s. In 1954, Calera initiated open pit activities in the Blacktail Pit. Calera also constructed the original tailings reservoir at the present location on the West Fork Blackbird Creek and the waste rock benches in the upper drainages of Bucktail and Meadow Creeks. Production peaked in 1958; however, demand for cobalt decreased after termination of the U.S. government contract for cobalt. Calera suspended operations in 1959 (USFS 1991). Production of metals from the Blackbird Mine included approximately 14 million pounds of cobalt in the period from 1951 to 1959, and about 63 million pounds of copper to 1952 (Baldwin et al. 1978).

Excavation of the open pit during this period resulted in the deposition of approximately 3.8 million tons of waste rock in the headwaters of Blackbird and Bucktail Creeks (Reiser 1986). The resulting waste rock piles are depicted on Figure 2-2a. Prior to full-scale mining, tailings from the mining operation were deposited directly in Blackbird Creek. After 1950, tailings were deposited behind the West Fork Tailings Impoundment, but some tailings "spills" are known to have occurred. It is estimated that 20,000 yd^3 of tailings were deposited or spilled along Blackbird Creek, and an estimated 2,000,000 yd^3

of tailings are impounded behind the West Fork Tailings Impoundment (Reiser 1986). Additional materials have been added to the tailings impoundment from Early Action overbank deposit removals. Underground mining operations during this period also resulted in the formation of a number of waste piles outside mine adits (e.g., the 7265 and 7117 Waste Rock Piles). Golder (1995a) presents estimates for the volume of waste rock contained in each of these piles. Subsequent to mining operations, debris flows, erosion, and acid rock drainage (ARD) has resulted in the spreading of metals from the original mining waste disposal areas to downstream locations.

The Calera Mining Company sold its interest in the Blackbird Mine to Machinery Center Company in 1963. Between 1963 and 1967, Machinery Center produced copper from the mine primarily through leasing operations. Machinery Center sold controlling interest to the Idaho Mining Company, a subsidiary of the Hanna Mining Company, in 1967. For the next few years, the Idaho Mining Company engaged in an exploration program on the property and initiated meetings with state and federal agencies to obtain authorizations to re-open the mine (USFS 1991).

In 1977, Noranda Exploration entered into an option agreement with the Idaho Mining Company, allowing Noranda to explore and acquire interest in the mine property. In December 1979, Noranda Mining Inc. and Hanna Services Company created the Blackbird Mining Company, a limited partnership, wherein Noranda Mining became the general partner responsible for reopening the mine. During this same time period, Idaho Mining Company sold all its real and personal property to Hanna Services Company. Noranda Exploration and then The Blackbird Mining Company conducted exploration activities from 1978 to 1982. Exploratory drilling activity included minor increases to the main Haynes-Stellite Adit openings in order to allow exploration equipment to access the interior of the adit. Exploration drill pads used by the Blackbird Mining Company were graded and revegetated and drill holes were plugged at the conclusion of exploratory activities (Lund, S., Memo to T. Buchta, 1985). The Blackbird Mining Company conducted limited pilot activities at the mine from 1980 to 1982. During this period, approximately 2,500 tons of ore was removed from the mine as part of a pilot project to determine the feasibility of full-scale operation of the mine. Approximately 250 tons of cobalt concentrate and 50 tons of copper concentrate were produced as part of the pilot program (Lund, S., Memo to T. Buchta, 1985).

Noranda Exploration and The Blackbird Mining Company conducted all activities in accordance with a Compliance Schedule Order issued by the Division of Environment of the Idaho Board of Health and Welfare in 1980, and a National Pollutant Discharge Elimination System permit issued by the EPA. The U.S. Forest Service approved the Blackbird Mining Company's Plan of Operation for the pilot program after determining that the pilot program would have no significant impact on the environment (Lund, S., Memo to T. Buchta, 1985; USFS 1991). In accordance with the compliance schedule and National Pollutant Discharge Elimination System (NPDES) permit, a wastewater treatment plant was constructed in 1981 to treat mine drainage from the 6850 level of the mine. The Blackbird Mining Company also diverted mine drainage from the 7400, 7200, and 7100-foot levels to the 6850-foot level for treatment by the wastewater treatment

plant (Lund, S., Memo to T. Buchta, 1985). The treatment plant continues to be in operation and was upgraded in 1997/1998 as part of the Early Action activities.

The Blackbird Mining Company also implemented other conditions of the 1980 compliance schedule including: installation of culverts for Blackbird Creek and under waste piles at the Hawkeye and 7100 Waste Pile deltas, construction of sewage treatment facilities, removal of trash and debris from Blackbird and Meadow Creeks, and performance of ambient water quality and biological monitoring in Blackbird and Panther Creeks. The Blackbird Mining Company also extended the culvert located at the old tailings reservoir (Lund, S., Memo to T. Buchta, 1985).

The Blackbird Mining Company proposed full-scale operation of the mine and an environmental impact statement (EIS) was prepared in 1982 to evaluate options for operating the mine site (ERT 1982). The Salmon Forest Supervisor (USFS 1991) selected a preferred alternative for full-scale operation of the mine at 1200 tons per day in 1982. However, in 1981, The Blackbird Mining Company suspended all pilot operations at the Blackbird Mine and in 1982 ceased all underground activities upon completion of the pilot program. Poor market conditions was identified as the reason that full-scale operation of the mine, approved in the environmental impact statement, was never initiated.

In 1992, the State of Idaho initiated a Natural Resource Damage Assessment (NRDA) for the Blackbird Mine, filing a natural resource damage claim pursuant to CERCLA. Subsequently, the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Forest Service joined the suit. The NRDA claim was settled in 1995 by a Consent Decree (Consent Decree No. 83-4179 State of Idaho, et al. v. The M.S. Hanna Company et al.), committing the Defendants (BMSG) to implementing a restoration plan, meeting water quality standards by a specified date, and implementing the final remedy and other response actions selected by EPA through separate consent decrees or administrative orders.

As noted in Section 1.1, this RI/FS and the Early Actions have been conducted pursuant to an AOC issued by EPA to the BMSG in November 1994 (U.S. EPA Docket No. 10-94-0222).

2.1.2 Environmental Setting

The Blackbird Mine is located within the Northern Rocky Mountain physiographic province and exhibits topography characterized by deep stream cut canyons having steep and rocky slopes. Regional elevations range from 3,000 feet at the confluence of Panther Creek and the Salmon River, to approximately 9,000 feet near the mine (Reiser 1986).

The mine site lies within two primary drainages: Bucktail Creek, and Meadow/Blackbird Creek. Figure 2-2a shows topographic features of the drainage areas. The Blacktail Open Pit was part of the Bucktail Creek drainage basin but has been partially filled with

waste rock removed as part of Early Actions described in Section 2.2 and drains to the underground mine workings.

Prior to Early Actions, Bucktail Creek drained an area of approximately 1.7 square miles, which included the northern portion of the mine area and several sub-basins. The headwaters of Bucktail Creek originated just below the Blacktail Pit. Following completion of the Early Actions described in Section 2.2, the flow from the upper section of Bucktail Creek below the waste rock dumps is now collected at the 7000 dam and downstream pump back station and diverted to the underground mine, from where it is withdrawn for treatment and discharge to Blackbird Creek. Downstream of the 7000 dam, Bucktail Creek flows north to its confluence with the S. Fork Big Deer Creek. Downstream of the 7000 dam the high gradient creek drops approximately 1500 ft. to an elevation of about 5500 ft. at the confluence with the S. Fork Big Deer Creek.

Meadow Creek is the southern drainage of the mine site. This basin formerly contained the surface mine facilities. Waste rock from the Blacktail Pit was disposed at the 7800 dump at the headwaters of Meadow Creek and waste rock from underground adits was disposed along the valley sides and bottom. Meadow Creek extends from the basin boundary near an approximate elevation of 7500 feet for 1.5 miles to its confluence with Blackbird Creek near the wastewater treatment plant at 6800 feet. The basin area is very steep, as is the Meadow Creek channel, which exhibits an 11 percent grade.

The Blackbird Creek basin is separated into two portions by the clean water reservoir. The upper section of the basin located west of Meadow Creek and upstream of the dam consisted of undisturbed forest prior to the Clear Creek Fire complex, which burned portions of the area during the summer of 2000. Flows from the upper Blackbird Creek basin flow through the conduit from the dam and discharge to the Blackbird Creek channel at a point upstream of the water treatment plant. From this point and prior to implementation of Early Actions, Blackbird Creek was in contact with waste rock for a limited section until it entered a pipeline and joined with Meadow Creek. Currently Blackbird Creek (below the clean water reservoir to just downstream of the water treatment plant) and Meadow Creek are conveyed in a concrete channel constructed as part of Early Actions. The channel runs from below the 7100 dam to just downstream of the water treatment plant, and was constructed on top of a clean soil cover, which was installed as part of the Early Actions to cover waste rock in the valley bottom. Blackbird Creek discharges to its normal channel at a culvert located immediately downstream of the treatment plant. From the mine site, Blackbird Creek flows for approximately 3 miles where it is joined by the West Fork Blackbird Creek. Blackbird Creek then flows approximately 2 miles downstream of West Fork Blackbird Creek to its confluence with Panther Creek. The Blackbird Creek drainage basin covers approximately 23 square miles, which includes the Meadow Creek and West Fork Blackbird Creek drainage basins.

2.1.3 Impacts to Panther Creek and Tributary Streams

The fisheries and aquatic resources downstream of the influence of the Blackbird Mine have undergone alteration since large-scale operation of the mine began in the 1940s

(Mebane 1994). Prior to the implementation of Early Actions, dissolved copper concentrations in Panther Creek and Big Deer Creek frequently exceeded the federal ambient water quality criteria by a factor of 10 or more. Historically, the Panther Creek drainage is reported to have supported runs of anadromous chinook salmon and steelhead trout. Water quality impacts from the mine in combination with factors such as the construction of dams in the Columbia River basin contributed to the significant declines in chinook salmon and steelhead runs in Panther Creek. The Snake River spring/summer chinook salmon (*Onchorynchus tshawytscha*), known to have historically used this basin, has been designated as threatened under the Endangered Species Act. Snake River steelhead *(Onchorynchus mykiss)* and Columbia Basin bull trout *(Salvelinus confluentus)* are also listed as threatened. Following implementation of the Early Actions, water quality in Panther Creek has improved to the point that the ambient chronic criterion for copper is met during low flow conditions and is only exceed during portions of spring runoff. During these periods, the criterion is exceeded by a factor of about 2 to 3.

Physical habitat available in both Blackbird and Big Deer creeks are considered to have the potential to support resident and anadromous fish species. However, this analysis is based on the ability of similar streams in the area to provide habitat for these types of fish, rather than on data collected prior to mine operations (Mebane 1994). Features that have been described as blockages to fish passage are located about 0.5 miles upstream of the mouth of Big Deer Creek and a few miles upstream of the mouth of Blackbird Creek at the West Fork Blackbird Creek Tailings impoundment spillway, which may affect the potential of these streams to support anadromous fish.

Resident fish populations are not present in Blackbird, So. Fork Big Deer, or Big Deer creeks downstream of the mine influence. Blackbird Creek is currently considered to be uninhabitable by most aquatic life in the zone of influence of the mine, but resident trout (species unknown) are present above the influence of the mine and in the freshwater reservoir (Mebane 1994). In Big Deer Creek one salmonid species (resident rainbow trout) is known to occur upstream of the mine discharges, with other species potentially present. Above the mine inflow into South Fork Big Deer Creek, rainbow trout are present at population levels approximately equal in density to similar streams in the drainage basin (Mebane 1994). Bucktail Creek likely never supported significant fish populations due to the high gradient and low flow. This creek is currently considered uninhabitable by aquatic life due to metals concentrations present. However, as indicated in the Aquatic Ecological Risk Assessment (CH2M Hill 2001a), Bucktail Creek is not considered to contribute significantly to the overall ecological management goals for the Site.

The structure of the benthic macroinvertebrate community in Panther Creek and the tributary streams was also impacted by the mine (Mebane 1994, Beltman et al. 1994a). Benthic invertebrates are a main food supply for salmonids and are important indicators of stream impairment. Overall populations of benthic macroinvertebrates, with the exception of pollution tolerant chironomids, had been reduced in aquatic habitats downstream of the mine. Prior to implementing Early Actions, sensitive species of mayflies, caddis flies, and stoneflies, which are principal components of the diet of

salmonids, were mostly absent within the zone of influence of water quality impacts from the mine.

Benthic macroinvertebrate sampling was conducted in 1998, 1999 and 2000 as part of the RI to evaluate their recovery following completion of Early Actions. The Early Actions have resulted in improved water quality and the benthic macroinvertebrate community has shown signs of recovery and is beginning to resemble reference conditions, especially in Panther Creek.

2.2 Summary of Emergency Response Actions and Early Actions

This section provides a summary of the Emergency Response Actions and Early Actions conducted at the Blackbird Mine Site.

Emergency Response Actions were conducted in 1993 at the West Fork Tailings Impoundment (Figure 2-2b) to minimize the potential for release of tailings into Blackbird and Panther Creeks. Prior to these actions, the West Fork Blackbird Creek flow was through a pre-existing buried concrete culvert and there was concern that mass failure of the tailings storage facility was possible if the culvert became plugged. The Emergency Response Actions as described in Knight Piesold (1998) included:

- Construction of a spillway excavated through bedrock and designed and constructed with steps to effectively dissipate kinetic energy and to pass the 500-year flood peak;
- Construction of a new channel for the West Fork over the top of the impoundment to the spill, which consists of: a flood-flow channel, designed to pass the 500-year flood peak, lined with machine-placed riprap; a low-flow channel of reinforced, prefabricated, half-round concrete sections; a 2-ft thick compacted clay liner installed beneath the low-flow and riprap-lined flood-flow channel to minimize infiltration into the tailings;
- Installation of a slurry cutoff trench into bedrock to minimize alluvial groundwater discharge into the tailings; and
- Filling of the existing concrete drainage culvert beneath the tailings with pea gravel to provide drainage of water entering the tailings and result in unsaturated tailings in the impoundment.

Early Actions were initiated during the summer construction season of 1995 and were continued in phases each year through 2001. From 1995 through 1998, the Phase I, II, and III Early Actions were focused on controlling sources of acid rock drainage that were impacting water quality. Generally, Phase I facilities were built during the 1995 construction season, Phase II facilities were built during the 1996 and 1997 construction seasons, and Phase III structures were initiated during the 1997 construction season and completed during the summer of 1998.

Phase IV and V Early Actions consisted of overbank deposit removal actions, which were conducted along Panther Creek and Blackbird Creek to mitigate potential risk to human

health associated with elevated levels of arsenic present in mine related deposits. These actions have also reduced potential risk to terrestrial and aquatic ecological receptors. Phase IV activities were initiated in 1998 and completed in 1999. Phase V activities were initiated in 1999; however, the forest fire during 2000 caused delays and Phase V was completed during 2001. Figure2-2a depicts the Early Action facilities at the mine site.

The Early Actions were evaluated, selected, and designed based on the following reports:

Analyses of Alternatives Reports

Golder Associates Inc., 1995b. *Final Report, Analysis of Early Action Alternatives, Blackbird Site, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, April 19.

Golder Associates Inc., 1995c. *Revised Final Report, Supplemental-1 Analysis of Early Action Alternatives, Waste Rock Removal versus Capping in the Meadow Creek and Blackbird Creek Channels, Blackbird Site, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, September 1.

Golder Associates Inc., 1996b. *Supplemental-2 Analysis of Alternatives, Waste Rock Removal, Bucktail Creek Basin, Blackbird Mine Site, Early Removal Action, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, August 14.

Golder Associates Inc., 1998a. *Analysis of Early Action Alternatives for the Panther Creek Inn Area, Blackbird Mine Remediation, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, September 3.

Golder Associates Inc., 1999b. *Analysis of Early Action Alternatives for the Panther Creek Overbank Deposits for Removal Action, Lemhi County, Idaho.* Prepared for the Blackbird Mine Site Group, August 20.

Design and Removal Reports

Golder Associates Inc., 1995d. *Volume I, Final Design Report, Phase I – Early Action Facilities, Blackbird Site, Cobalt Idaho.* Prepared for the Blackbird Mine Site Group, June 12.

Golder Associates Inc., 1996c. *Volume I, Phase IIA, Waste Rock Capping in the Meadow Creek and Blackbird Creek Channels, Design Report, Final Submittal, Blackbird Mine Site Reclamation, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, June 1.

Golder Associates Inc., 1996d. *Final Design Report, Phase IIB-Early Action Facilities, Meadow Creek Water Storage Conveyance Facilities.* Prepared for the Blackbird Mine Site Group, September 13.

Golder Associates Inc., 1997a. *Final Design Report, Phase IIIA-Early Action Facilities, Bucktail Creek Water Storage, and Conveyance Facilities.* Prepared for the Blackbird Mine Site Group, March 21.

Golder Associates Inc., 1998b. *Phase IV-A, Blackbird Creek Overbank Material Removal, Final Design Report, Blackbird Mine Site Remediation, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, October 22.

Golder Associates Inc., 1998c. *Revised Final Design, Panther Creek Inn Removal Actions, Blackbird Mine Site Early Removal Actions, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, December 1.

Golder Associates Inc., 1999c. *Revised Final Design Report, Phase 5A, Panther Creek Overbank Removal Actions, Blackbird Mine Site Early Actions, Cobalt, Idaho.* Prepared for the Blackbird Mine Site Group, November 10.

Golder Associates Inc., 2000c. *Technical Memorandum - 1999 Panther Creek Overbank Removal, Blackbird Mine, Idaho.* Prepared for the Blackbird Mine Site Group, October 13.

Golder Associates Inc., 2001b. *Technical Memorandum – 2000 Panther Creek Overbank Removal, Blackbird Mine Site, Lemhi County, Idaho.* Prepared for the Blackbird Mine Site Group. March 27, 2001.

Early Actions were conducted in both the Meadow/Blackbird Creek basin and in the Bucktail basin from 1995 to 1998. These actions focused on improving water quality.

Early Actions in Meadow/Blackbird Creek included:

- Construction of the 7100 earthen clay-core dam to collect and store water draining from the waste rock dumps in the Meadow Creek drainage basin before treatment. The 7100 dam is approximately 88 feet high, and impounds a reservoir with a maximum surface area of 2.56 acres and a maximum storage capacity of 49 acre-feet (Phase IIB, 1997 and 1998);
- Installation of pipelines from the 7100 dam to the water treatment plant and replacement of piping and instrumentation between the bulkhead at the 6850 adit and the water treatment plant. The bulkhead allows for storage of water in the mine workings (Phase IIB, 1998);
- Upgrade to and expansion of the existing water treatment plant, which is located approximately 1,200 feet downstream from the confluence of Meadow Creek and Blackbird Creek. The upgraded treatment plant has a normal maximum treatment capacity of 800 gallons per minute (gpm) and discharges treated water to Blackbird Creek (1997 and 1998);
- Installation of a sludge pipeline from the water treatment plant to the Hawkeye Ramp, which is an area of the underground mine isolated from the rest of the mine, to dispose of sludge generated by the water treatment plant (1998);
- Construction of a contaminated water collection system below the 7800 waste rock pile. The collection system is composed of ditches and pipelines that are used to collect and transport contaminated water to the 7100 dam reservoir (Phase IIB, 1997);

- Installation of a series of clean water ditches and pipelines, which are used to divert clean water around the contaminated areas and the 7100 dam reservoir, and transport clean water downstream of the 7100 dam. The clean water ditches and pipelines include the 7800 ditch, the 7410 ditch, the 7100 East ditch, and the 7100 West diversion system (Phase IIB – 1997 and 1998);
- Relocation of waste rock from the canyon walls of Meadow Creek and Blackbird Creek extending from the 7100 dam area to just upstream of the water treatment plant and from Hawkeye Gulch, which discharges to Blackbird Creek near the treatment plant. The relocated waste rock was used in the construction of the 7100 dam, deposited upstream of the 7100 dam in the 7400 waste rock dump, or placed in the Meadow Creek and Blackbird Creek bottom (Phases IIA and IIB, 1998);
- The waste rock in the Meadow Creek and Blackbird Creek bottoms was covered with a clean earth cover. Drains were installed beneath the cover to collect contaminated groundwater and transport it to the water treatment plant (Phase IIA, 1998);
- Concrete channels were constructed across the top of the capped waste rock to convey Meadow Creek and Blackbird Creek. This serves to isolate clean water from these creeks by preventing contact with waste rock prior discharge at a point in Blackbird Creek downstream of the water treatment plant (Phase IIA, 1998);
- Construction of a groundwater cutoff wall in upper Blackbird Creek about 300 feet upstream of the water treatment plant to intercept contaminated groundwater flowing through the waste rock beneath the cover. The water is piped to the water treatment plant (Phase I, 1995);
- Construction of a temporary sediment control basin used to settle out sediment generated during construction activities, and for a time after completion of the Early Actions. The sediment control basin is located at the downstream end of the Blackbird Creek concrete channel. This sediment control basin will be removed from service when EPA, in consultation with the State and Trustees, determines it is no longer necessary (Phase IIA, 1997);
- Removal of visually obvious, erodeable tailings from overbank deposits at several locations along Blackbird Creek between the confluence of Blackbird Creek and Panther Creek (Phase IVA, 1999), and
- Construction of three sediment basins along Blackbird Creek. One of these basins is located near the West Fork Tailings Impoundment, and the other two basins are located upstream of the confluence of Blackbird Creek and Panther Creek, just upstream of the Panther Creek Road (Phase IV-A, Fall of 1998).

Early Actions within the Bucktail drainage included:

- Construction of an earth fill clay-core dam (Bucktail 7000 dam) and pipeline and open-channel spillway to collect, store and divert contaminated water to the water treatment plant via the 6930 adit to the underground mine workings. The

7000 dam is approximately 70 feet high and impounds a reservoir with a maximum surface area of 0.52 acres and a maximum storage capacity of 5.85 acre-feet (Phase IIIA, 1997 to 1998);

- Construction of a new adit at elevation 6930 to connect to the 6850 level of the old mine workings. The 6930 adit extends approximately 1,300 feet into the mountain, and is used to transport the contaminated water from the Bucktail Creek basin into the mine, where it can be conveyed to the water treatment plant (Phase III, 1997 to 1998);
- Construction of a pump station and pipelines located downstream of the 7000 dam. The pump station and pipeline are used to collect and convey springs and dam seepage and pump it to the 6930 adit for transport through the mine to the water treatment plant (Phase IIIA, 1998);
- Relocation of waste rock piles. The rock piles were primarily disposal in the Blacktail Pit, and some was used in the construction of the 7000 dam. The waste rock piles that were relocated include the West Lobe, the southern portion of the 7117 pile, the 7600 pile, and the identified waste rock in the 7500 pile (Phase IIIA, 1998);
- Construction of a waste rock repository (Blacktail Pit), including a foundation drainage system, to drain water entering the former pit into the old mine workings and to the water treatment plant (Phase I, 1995);
- Installation of a series of clean water ditches and pipelines to divert clean water around the waste rock dumps and the 7000 dam reservoir, and to transport the clean water to Bucktail Creek downstream of the 7000 dam. The clean water ditches include the Sunshine Ditch, the 7900 Ditch, the 7600 Ditch, and the 7000 Ditch (Phase I and Phase IIIA, 1998);
- Construction of the 7200 Collection Ditch to collect contaminated water from the remainder of the West Lobe waste rock dump and to direct the contaminated water toward upper Bucktail Creek upstream of the 7000 dam (Phase IIIA, 1998);
- Construction of a series of sediment control ditches to reduce the slope length of the waste rock to remain in place. These include the 7117, 7550, 7265, and 7680 sediment control ditches (Phase IIIA, 1997);
- Construction of debris traps in the Bucktail Creek channel to reduce the risk of debris flows. These include the 7117 and 7265 debris traps (Phase IIIA, 1998);
- Two temporary sediment control dams were constructed to settle out sediment generated during construction activities and sediments from residual debris flow materials along Bucktail Creek. The upper sediment control dam is located just upstream of the upper access road crossing of Bucktail Creek and downstream of the Pump back station. The lower sediment control dam is located just upstream from the lower access road crossing of Bucktail Creek. These sediment control dams will be removed when EPA, in consultation with the State and Trustees, determines that they are no longer necessary (Phase I, 1995), and

- Relocation of a portion of the debris flow material along Bucktail Creek between the upper and lower sediment dams. This debris flow material was disposed of in the Blacktail Pit (Phase I, 1995).

Beginning in late 1998 and continuing during 1999 through 2001, overbank deposit removal actions were conducted along portions of Panther Creek. These actions were primarily focused on removal of mine-related materials that contained elevated concentrations of arsenic concluded by EPA to pose an unacceptable risk to human health (CH2M Hill 1999). The removal actions have also reduced any risk that these materials may have posed to terrestrial and aquatic ecological receptors. The Clear Creek fire delayed completing these actions during 2000. The removal actions were completed during the 2001 construction season. The removal actions included:

- Removal of the contaminated materials until analytical testing results indicated that the underlying soils were below the Preliminary Removal Goals (PRGs), or until the water table was reached. The PRGs varied from 100-mg/kg arsenic for a residential exposure scenario, 280-mg/kg arsenic for a camping scenario, and 590 mg/kg arsenic for a day use recreational exposure scenario;
- Excavated materials were hauled to the West Fork Tailings Impoundment for disposal;
- Following removal, clean soils were used to backfill the excavated areas. The depth of clean soils depended on site conditions and the amount of material removed. The soils were generally replaced to the original lines and grades. The soils were replaced to a minimum depth of 6 inches. If materials exceeded the PRG at the water table, the minimum depth of soil replacement was 12 inches, and
- The top 6 inches of replacement soils were composed of topsoil to act as a growth medium. The topsoils were then revegetated with either native species or pasture grasses to match the pre-removal vegetation.

Removal Actions completed at other areas as of the end of the 2000 construction season included:

- Panther Creek Inn (PCI) and the PCI campground area for ¼ mile downstream along Panther Creek. Removal of overbank deposits was performed to the water table or one foot, whichever was reached first. Visually identifiable tailings were removed to the water table regardless of depth (Phase IV-B, 1998);
- The Riprap Bar area approximately 1 mile downstream from the Cobalt Townsite. Overbank removals occurred at six separate areas on both sides of Panther Creek (Phase 5A, 1999);
- Portions of the Sillings/Fernandez area located approximately 2 miles downstream from the Cobalt Townsite. Removals occurred on both sides of Panther Creek (Phase 5A, 2000);

- Deep Creek Campground located just upstream of the confluence of Deep Creek and Panther Creek. Removals occurred on both sides of Panther Creek (Phase 5A, 2000), and
- The Bevan property located about 5.5 miles upstream from the confluence of Panther Creek and the Salmon River. Removals occurred at two areas along the west side of Panther Creek (Phase 5A, 1999 and 2000).

Removal actions that were delayed by the Clear Creek Fire and were conducted during 2001 include:

- The remainder of the Sillings/Fernandez area not completed during 2000 (Phase 5A);
- The Cobalt Townsite and the adjacent pasture area immediately downstream of the Cobalt Townsite. These removals occurred on both sides of the creek. Additional work to improve juvenile rearing habitat for salmonids was also conducted as part of the Biological Restoration and Compensation Plan (BRCP) (Phase 5B), and
- At the Napias Creek area just upstream from the confluence of Napias and Panther Creek. Most of the removals were on the west side of Panther Creek (Phase 5B).

2.3 West Fork Dam Stability

A stability analysis was conducted of the West Fork Tailings Impoundment dam (Golder 2001c). The report concluded that when considering both static and seismic conditions, adequate factors of safety and tolerable embankment displacements were calculated for the overall global stability of the tailings embankment, provided the water table remains near or below its present level. However, the analysis indicated that the localized stability of the relatively steep upper slope of the original tailings embankment and the lower section of the down stream berm have factors of safety less than the minimum criteria set by Idaho Dam Safety. For the localized stability of the steeper slopes, a static factor of safety lower than the 1.5 criteria set forth in the Idaho Mine Tailings Impoundment Structure Rules (IDAPA 36.03.05) was calculated. The analysis also indicated that when subjected to a large seismic event the steeper portions of the upper original tailings embankment and lower slope at the toe of the downstream berm may fail in the form of a shallow slump failure. However, the overall integrity of the embankment would not be compromised, as the failure surface is relatively shallow and this type of failure would not result in the release of any tailings. This shallow type of slope failure could also be repaired (maximum displacement is estimated to be only about 3 inches horizontal). A displacement of this magnitude would not jeopardize the integrity of the dam.

The report also concluded that it is unlikely that the groundwater table would rise within the tailings impoundment provided the under drain culvert remains functional. Even if the culvert were to clog, it is unlikely that the groundwater would rise to a level that would cause the dam to be unstable because of the permeability contrast between

the tailings and the underlying colluvium and talus deposits. As the groundwater flow out of the under drain culvert is limited, any rise of the groundwater table will occur slowly, allowing ample time for remedial action, if necessary. The report recommends that the water table within the tailings impoundment continue to be monitored, and each year the measured water levels be compared to historic levels. Based on this recommendation, the BMSG has modified the O&M Plan for the facility to require quarterly monitoring of the water table. The annual review should be performed by a qualified engineer.

In regards to the integrity of the existing culvert (which is acting as an underdrain to keep the water table depressed in the tailings), it is reported that the discharge water does not contain sediment, and flows are fairly constant year round. Therefore, the report concluded that the discharge from the pipe is groundwater flow. The culvert appears to be functioning as planned; however, to evaluate long-term performance, the report recommended that the flow rate and turbidity monitoring continue at the rate of at least twice a year.

In summary, continued monitoring and maintenance of the dam embankment will be performed to ensure stability is not compromised.

2.4 Summary of Remedial Investigation

Remedial Investigations conducted from 1995 through 2000 are described in detail in the *Final Blackbird Mine Site Remedial Investigation Report* (Golder 2001a). These investigations were conducted to meet the objectives stated in the *Focused Remedial Investigation and Feasibility Study Workplan* (Golder 1995a) and subsequent addenda (Golder 1996a, 1999a and 2000a). Remedial investigations included studies to determine the nature and extent of contamination in soils, tailings deposits, waste rock deposits, adit discharges and seeps, surface waters/sediments, and groundwater at the Blackbird Site and surrounding area. These investigations included an evaluation of the quantity and concentrations of metals (mass loading) released from known or potential sources during various hydrologic conditions. The Early Actions have resulted in a significant reduction in dissolved metals transported in surface water from the mine area. A major focus of the investigations was to determine the mass loading of metals from residual and remaining sources following implementation of the Early Actions. In addition, investigations were conducted to evaluate potential impacts to human health and to ecological receptors.

The RI investigations conducted during 1995 included comprehensive investigations to evaluate the nature and extent of contamination prior to implementing Early Actions. While Early Actions aimed at addressing water quality impacts were being implemented from 1995 through 1998, ongoing investigations were focused on specific objectives to address identified data needs. Work plans were prepared describing each phase of investigations and data summary reports were prepared to provide results of each year's investigations. Post Early Action investigations to evaluate improvements to water quality began in the Spring of 1998 for the portion of the site that includes Meadow and Blackbird Creeks, and in the Fall of 1998 for the portion of the site that includes Bucktail, S. Fork Big Deer, and Big Deer Creeks.

Information developed during the RI was used to complete both human health and ecological risk assessments. CH2M Hill prepared the Human Health and Aquatic Ecological Risk Assessments on behalf of EPA (CH2M Hill 2002 and 2001a). Human health risk assessments were also prepared to support overbank deposit removal actions (CH2M Hill 1998 and 1999). The Terrestrial Ecological Risk Assessment was conducted by Golder, which included additional field investigations to gather data specifically required for that assessment (Golder 2000b).

Sampling locations mentioned in the following sections are shown on Plate 1 and descriptions of the locations are provided in Table 1.

2.4.1 Water Quality and Remaining Sources of Metals Loading

The Early Actions have significantly improved water quality at the Blackbird Mine Site by controlling ARD emanating from mine workings and the waste rock deposits in Meadow Creek, upper Blackbird Creek, and Bucktail Creek. Other Early Actions conducted to remove selected overbank deposits that contained elevated concentrations of arsenic have mitigated potential human health risks posed by mine waste, and reduced the risks posed to terrestrial ecological receptors. Potential risks to human health, terrestrial receptors, and aquatic receptors were evaluated and are summarized in Section 2.7.

The following sections discuss the site water quality. The focus of the discussion is on the post-Early Action data with summaries of the changes to water quality as a result of the Early Actions.

2.4.1.1 Water Quality

In the following sections all discussions of copper and cobalt concentrations and loading refer to dissolved metals.

2.4.1.1.1 Panther Creek

Figures 2-3a and 2-4a illustrate the reduction in copper concentrations as a result of the Early Actions at Panther Creek stations PASW-09/10 and PASW-04. Figures 2-3b and 2-4b illustrate reductions in cobalt loading. During 2000, station PASW-09 was installed to replace station PASW-10. The cross section at station PASW-10 was not suitable to obtain accurate flow measurements, and accurate flow weighted composite samples were needed during high flow conditions. In the following discussion, station PASW-10 was used for data collected prior to 2000 and PASW-09 was used for 2000 data.

As seen on Figure 2-3a, the peak spring dissolved copper concentration in Panther Creek downstream of Blackbird Creek (stations PASW-09 and PASW-10) has been reduced from 0.218 mg/L measured in 1995 to 0.012 mg/L in 2000, a reduction of 94%. The peak cobalt concentration was reduced from 0.273 mg/L to 0.078 mg/L, a reduction of 71% (Figure 2-3b). At Station PASW-04 downstream of influence from Bucktail and Big Deer

Creek, the Early Actions have reduced the maximum dissolved copper concentration from 0.067 mg/L to 0.015 mg/L (78%) as shown in Figure 2-4a. The maximum cobalt concentration was reduced from 0.076 mg/L to 0.031 mg/L (59%) (Figure 2-4b).

During Fall low flow conditions the Early Actions resulted in reduction of the dissolved copper concentration from 0.064 mg/L at PASW-10 and 0.039 mg/L at PASW-04 to less than the detection limit (0.003 mg/L) at both stations (Figures 2-3a and 2-4a). This represents a reduction of 95% at PASW-10 and 92% at PASW-04. The dissolved cobalt concentration was reduced from 0.140 mg/L at PASW-10 to 0.054 mg/L at PASW-09 (which replaced PASW-10), a reduction of 61% (Figure 2-3b). At PASW-04 the cobalt concentration was reduced from 0.044 mg/L to 0.023 mg/L, a reduction of 48% (Figure 2-4b).

Under low flow conditions in both Spring (prior to runoff) and Fall 2000, dissolved copper concentrations were lower than the chronic water quality criterion in all Panther Creek stations downstream of Blackbird Creek. During portions of the rising limb of the snowmelt hydrograph during spring runoff, copper concentrations exceeded the chronic criterion at Stations PASW-09 and PASW-10 by about two times the criterion, and at PASW-04 by about 4 times the criterion. Cobalt concentrations were highest during low flow conditions (about 0.050 to 0.075 mg/L) and were lower during spring runoff with concentrations typically about half the concentrations observed during low flow.

As indicated by the data, within Blackbird Creek and Panther Creek, copper concentrations are highest during the rising limb of the snowmelt hydrograph, whereas cobalt concentrations are highest during low flow conditions. The maximum cobalt concentrations were observed in the spring prior to the onset of significant spring runoff.

2.4.1.1.2 Big Deer Creek

Figure 2-5a illustrates the reduction in dissolved copper concentrations in Big Deer Creek at station BDSW-03 as a result of the Early Action. Figure 2-5b illustrates the reduction in dissolved cobalt concentrations at this location. Comparable Pre-Early Action Spring runoff data were not available for Big Deer Creek. In July 1995, prior to Early Actions, concentrations of dissolved copper were as high as 0.342 mg/L at BDSW-03. In September 1995, concentrations were 0.144 mg/L compared to 0.021 mg/L in September 2000, representing an 85% reduction. Cobalt concentrations were reduced from 0.110 mg/L in 1995 to 0.011 mg/L in 2000 and 0.022 mg/L in 2001, representing a 90% reduction.

The concentrations of dissolved copper in Big Deer Creek exceed the chronic water quality criterion for most of the year (Figure 2-5a). However, unlike Panther Creek, concentrations are highest in Big Deer Creek during low flow conditions and either meet or are close to meeting the criterion during high flow conditions. One limitation on meeting the criterion during high flow is that hardness is typically lowest in Big Deer Creek during Spring runoff and is often 25 mg/L or less, resulting in the minimum copper criterion of 0.0035 mg/L. Concentrations measured during spring runoff of 2000 ranged from less than the detection limit (0.003 mg/L) to 0.009 mg/L or a maximum of about 2.5 times the chronic criterion. During low flow conditions, the dissolved copper

concentration was 0.021 mg/L, which exceeded the chronic criterion of 5.1 µg/L (at a hardness of 39.3) by a factor of about 4. Cobalt concentrations in Big Deer Creek are relatively low throughout the year ranging from the detection limit (0.005 mg/L) to 0.011 mg/L (Figure 2-5b). Diel variability in both copper and cobalt was not noticeable during the sampling conducted in S. Fork Big Deer Creek and Big Deer Creek on May 23 and 24, 2000.

2.4.1.1.3 S. Fork Big Deer Creek

In August 1995, prior to Early Actions, concentrations of dissolved copper were as high as 1.34 mg/L at SFSW-01. During September 1995, concentrations were 0.230 mg/L compared to 0.104 mg/L during September 2000, representing a 55% reduction. Cobalt concentrations were reduced from 0.533 mg/L to 0.056 mg/L, representing an 89% reduction.

Dissolved copper concentrations measured during spring runoff of 2000 ranged from 0.111 mg/L to 0.155 mg/L. During low flow conditions, the dissolved copper concentration was 0.104 mg/L. The base flow copper concentrations are believed to be influenced in part by releases from sediments in S. Fork Big Deer Creek. Cobalt concentrations in S. Fork Big Deer Creek throughout 2000 ranged from 0.056 mg/L to 0.089 mg/L. Diel variability in both copper and cobalt was not noticeable during the sampling conducted in S. Fork Big Deer Creek on May 23 and 24, 2000.

2.4.1.1.4 Blackbird Creek

Early Actions have resulted in significant reduction in copper and cobalt concentrations and loading to Blackbird Creek (See Tables 5-1a through 5-1c and Figures 5-1a through 5-1g in the RI Report (Golder 2001a)). Station BBSW-07 is the first station downstream of the Early Actions, which were implemented to improve water quality. Under similar flow conditions during the rising limb of the snowmelt hydrograph in 1995 and 2000, dissolved copper concentrations at this location have been reduced from a peak of 13.2 mg/L on May 10, 1995 to 0.26 mg/L on April 26, 2000, representing a reduction of 98%. Dissolved copper loading has been reduced from a peak load of 175 kg/day on May 18, 1995 to 2.4 kg/day in the spring of 2000, a 98% reduction. Dissolved cobalt concentrations were reduced from 5.4 mg/L on May 10, 1995 to 0.782 mg/L on April 26, 2000, a reduction of 85%. Peak cobalt loading decreased from 235 kg/day on June 2, 1995 to 7.3 kg/day in the spring of 2000, representing a reduction of 97%.

During low flow conditions in the fall, concentrations of both dissolved copper and cobalt were virtually the same at BBSW-07. Dissolved copper and cobalt concentrations at BBSW-07 were reduced from about 1 mg/L in 1995 with a load of about 2 kg/day to < 0.2 mg/L and a load of about 0.25 kg/day in 2000, representing reductions in concentration of 82% and loading of 88%.

Station BBSW-01A is the station near the mouth of Blackbird Creek prior to the confluence with Panther Creek. Similar to station BBSW-07, peak copper and cobalt concentration and loading were highest at BBSW-01A in 1995, prior to Early Actions.

Data from May 3, 1995 were used for the following comparison as flows on this date (9.4 cfs) were closest to 2000 flows (13.3 cfs) during the rising limb of the snowmelt hydrograph. During 2000, the dissolved copper concentration and loading were 0.044 mg/L and 1.4 kg/day, as compared to 1995 concentrations of 0.82 mg/L and loading of 18.8 kg/day. Even with the lower 1995 flows, this represents a reduction in concentration of about 95% and a reduction in loading of about 92%. The dissolved cobalt concentration was 0.387 mg/L and loading was 12.6 kg/day in 2000, compared to the 1995 concentration of 1.27 mg/L with loading of 29.2 kg/day. This represents a reduction in dissolved cobalt concentrations of 70% and loading of 57%.

2.4.1.1.5 Bucktail Creek

Station BTSW-02 is the surface water sampling station in Bucktail Creek located downstream of Early Actions that was used to evaluate reductions in metals loading. Table 5-3 and Figures 5-4a through 5-4g in the RI Report (Golder 2001a) summarize water quality results from pre-Early Action and post Early Action sampling at this station. Sampling was not conducted during 1995 at this location, thus data collected during 1994 by RMC (1994) were used to represent pre-Early Action conditions. During Spring runoff, dissolved copper concentrations were reduced from 181 mg/L on April 27, 1994 to 23.4 mg/L on May 16, 2000, and loading was reduced from 24.8 kg/day to 0.92 kg/day, representing reductions in concentration of 87% and loading of 96%. Dissolved cobalt was reduced from 31.3 mg/L and a load of 4.29 kg/day to a concentration of 6.42 mg/L and a load of 0.25 kg/day, representing reductions in concentration of 79% and loading of 94%.

During low flow conditions, copper concentrations were reduced from 185 mg/L and a load of 9.96 kg/day on September 8, 1994 to 20.6 mg/L and a load of 0.35 kg/day on September 19, 2000, representing reductions in concentration of 89% and loading of 96%. Cobalt concentrations were reduced from 36.1 mg/L and a load of 1.94 kg/day to 5.73 mg/L and a load of 0.1 kg/day, representing reductions in concentration of 84% and loading of 95%.

The major remaining source of metals loading in Bucktail Creek downstream of the Early Actions are seeps and groundwater discharges in the vicinity of BTSP-01, which is located between BTSW-02 and BTSW-01.6. Prior to Early Actions, dissolved copper loading measured at this station was 22.7 kg/day in April 1994 and 40 kg/day in June 1996, compared to 2.7 kg/day in May 2000, a reduction of 88% to 93%. Dissolved cobalt loading was reduced from 4.4 kg/day in April 1994 and 8.7 kg/day in June 1996 to 0.96 kg/day in 2000, a reduction of 78% to 89%. During low flow periods in September, the dissolved copper loading was reduced from 11.7 kg/day in 1994 and 21.2 kg/day in 1996 to 1.87 kg/day in 2000, a reduction of 84% to 91%. Dissolved cobalt loading during September was reduced from 2.45 kg/day in 1994 and 5.4 kg/day in 1996 to 0.66 kg/day in 2000, a reduction of 73% to 88%.

The overall improvements to water quality in Bucktail Creek where it discharges to So. Fork Big Deer Creek are best evaluated by comparing pre-Early Action data with post-Early Action data at the sampling station near the mouth of Bucktail Creek (BTSW-01).

Data collected by RMC in 1994 (station BT04 in the RMC (1994) data summary report) were used for this comparison because this station was not sampled in the spring of 1995.

In the spring of 1994, the dissolved copper concentration was 13.1 mg/L with loading of 5.45 kg/day, and dissolved cobalt was 5.53 mg/L with a load of 2.3 kg/day at stations BTSW-01. During spring of 2000 the dissolved copper concentration was 1.16 mg/L with loading of 0.68 kg/day, representing a reduction in concentration of 91% and loading of 88%. Dissolved cobalt concentration in the Spring of 2000 was 1.54 mg/L with a loading of 0.9 kg/day, representing a reduction in concentration of 72% and loading of 61%.

During the fall of 1994 the dissolved copper concentration was 8.21 mg/L with loading of 2.8 kg/day, and the dissolved cobalt concentration was 5.48 mg/L with loading of 1.88 kg/day at BTSW-01. During the fall of 2000 the dissolved copper concentration was 0.492 mg/L with loading of 0.176 kg/day, representing a 94% reduction in concentration and loading. The Fall 2000 cobalt concentration was 1.2 mg/L with loading of 0.43 kg/day, representing a 78% to 77% reduction in concentration and loading, respectively.

2.4.2 Synoptic Sampling Results – Remaining Sources of Metals Loading

Synoptic sampling was conducted during the rising limb of the snowmelt runoff hydrograph and during base flow conditions to determine the remaining sources of metals loading. In synoptic sampling, an attempt is made to sample the same parcel of water as it moves downstream. Synoptic sampling is conducted by collecting the first sample at the most upstream point of interest on the stream and then sampling the downstream stations sequentially while taking into account the travel time of the water based on flow velocity. Sampling in this manner allowed comparison between specific reaches of the stream to determine whether the stream between the stations is a gaining or losing reach in terms of both flow and metals loading. Synoptic sampling was conducted to identify sources of metals loading. This was especially important during the spring when the hydrograph changes throughout the day as runoff increases with increasing temperature and snowmelt. It was less critical in the fall during base flow conditions; however, the fall sampling was also conducted synoptically.

Figures 2-6a through 2-6c illustrate the current conceptual model for the remaining sources of metals loading within Meadow Creek, Blackbird Creek and Bucktail Creek. In addition, tables 2-2a through 2-3f and tables 2-6a through 2-7f compare metals loading to downstream locations. Remaining sources that are problematic need to be addressed in the FS. The remaining sources to Meadow Creek, Blackbird Creek and Panther Creek downstream of Blackbird Creek include:

- **Meadow Creek Waste Rock** – Seepage from below the 7800 waste rock dump and debris flow materials, which is bypassing the collection system and is not being collected for treatment, is a source of residual copper loading during Spring runoff. During the Blackbird Spring synoptic sampling event, this area (measured at the 7100 bypass) contributed 2.85 kg/day of copper. Areas where waste rock was removed from the east side of Meadow Creek contributed 0.25 kg/day of copper during the Blackbird Spring synoptic sampling event. The

dissolved copper load measured at the 7100 Bypass was greater than the load at BBSW-07 (although total copper load was higher at BBSW-07), and was about twice the load measured at BBSW-01A, which is an indication that copper attenuation is occurring. Waste rock in Meadow Creek does not contribute a significant amount of cobalt loading (< 1 kg/day), nor does it contribute significant copper loading (0.04 kg/day) during low flow conditions;

- **Wastewater Treatment Plant Discharge** – The water treatment plant discharge is an insignificant source of dissolved copper loading (<0.08 kg/day during Spring 2000 sampling). The wastewater treatment plant contributed 4.2 kg/day of cobalt to Blackbird Creek during the 2000 spring synoptic sampling event, which was 30% of the cobalt loading in Blackbird Creek at BBSW-01. The wastewater treatment plant effluent quality is discussed in more detail in section 3.4.1.3 and Appendix B in relation to Clean Water Act Requirements and effect of the discharge on PRGs in receiving waters established for this site;
- **Hawkeye Gulch** – Hawkeye Gulch surface water runoff contributes an insignificant percentage of the dissolved copper (4%) and dissolved cobalt load (1%) measured at BBSW-07 during spring runoff. Hawkeye gulch is dry during low flow conditions;
- **Groundwater discharge in upper Blackbird Creek downstream of the cutoff wall** – It appears that groundwater discharges to upper Blackbird Creek may have contributed a small amount of copper and cobalt, as evidenced by the unaccounted increase in loading between BBSW-07A and BBSW-07 during 2000 sampling. During the 2000 Spring synoptic sampling event there was an unaccounted load increase of about 0.6 kg/day of dissolved copper and 1.54 kg/day of cobalt, representing 25% of the dissolved copper load and 21% of the dissolved cobalt load at BBSW-07. During the fall of 2000, the unaccounted load increase was about 0.2 kg/day for both copper and cobalt, representing 88% of the dissolved copper load and 93% of the dissolved cobalt load at BBSW-07. The seeps and other loading sources in upper Blackbird Creek and Meadow Creek that contribute load during the spring are mainly dry at low flow. During 2001, a blockage of the pipeline that collects groundwater upstream of the cutoff wall was discovered. This blockage caused head to build up behind the wall and seepage to occur around a pipe, which had not been sealed properly where it exited the manhole upstream of the cutoff wall. It is likely that this blockage contributed to loading that was observed at BBSW-07 during 2000. The blockage was removed and a seal was installed around the pipe prior to conducting the 2001 spring synoptic sampling. During the 2001 spring synoptic sampling event, the unaccounted dissolved copper load at BBSW-07 was 0.37 kg/day (15% of the load at BBSW-07) and the dissolved cobalt load was 0.2 kg/day (10% of the load at BBSW-07). During low flow conditions in 2001, the unaccounted load increase between BBSW-07A and BBSW-07 was 0.19 kg/day for dissolved copper (83% of the load measured at BBSW-07) and the unaccounted dissolved cobalt load was 0.2 kg/day (80% of the load at BBSW-07). The higher percentage of load at BBSW-07 was due to the low flows and loading from upper Meadow Creek during the fall. The small load increase measured at BBSW-07 in the fall of 2001 was not

significant, as both the dissolved copper and cobalt concentrations at PASW-09 during the fall 2001 sampling were less than their respective PRGs;

- **Seeps BBSP-03, 09, and 45 discharging to Blackbird Creek between BBSW-04 and BBSW-03** – These seeps contributed a combined 0.63 kg/day of dissolved copper and 1.43 kg/day of cobalt during the Spring 2000 synoptic round of sampling. However, copper precipitation is also occurring in this reach as concentrations decrease and there was a net loss of copper between stations BBSW-04 and BBSW-03 when all measured sources are counted. Discharges from these seeps were minimal (less than 0.1 kg/day for both copper and cobalt) during the Fall 2000 round of sampling. There was a decrease in dissolved copper concentration and a reduction in load of 29% between stations BBSW-04 and BBSW-03. Cobalt concentrations increased from 0.166 mg/L to 0.298 mg/L in this reach and load increased from 0.4 kg/day to 0.66 kg/day (67%) during the Fall 2000 sampling. Seeps were not sampled in 2001;
- **West Fork Tailings Impoundment** – Loading from the West Fork Tailings Impoundment vary seasonally and from year to year. During low flow conditions (when concentrations are highest in Panther Creek), the West Fork Tailings Impoundment contributes about 70% (3 kg/day) of the cobalt loading from Blackbird Creek to Panther Creek as measured at BBSW-01A. Approximately 50% (7 kg/day) of the cobalt loading was due to the West Fork Tailings Impoundment during the Spring 2000 synoptic sampling event. The West Fork Tailings Impoundment contributes only small loading of copper, which is more than offset by the influence of the iron discharges from the impoundment. Copper sorbs to the iron hydroxides which causes a reduction in dissolved copper concentrations downstream of the impoundment; and
- **Overbank Deposits along Blackbird Creek** – With the possible exception of contributions from seeps discussed previously, tailings and overbank deposits between Station BBSW-07 and the West Fork Tailings Impoundment do not appear to contribute dissolved copper load to Blackbird Creek, but may contribute a small cobalt load. There was a small increase of dissolved cobalt loading between Stations BBSW-07 to BBSW-06 (0.59 kg/day) during the Spring 2000 synoptic sampling event. During the Fall 2000 sampling event, small increases in cobalt loading were observed at each station from BBSW-07 to BBSW-03A, with a cumulative load increase of about 0.4 kg/day. Metals concentrations may also be in part a result of natural mineralization through this reach. From the West Fork Tailings Impoundment to the mouth of Blackbird Creek (Stations BBSW-02 to BBSW-01A), there was a net loss of dissolved copper load during both spring and fall sampling. Cobalt loading also declined between these stations during the Spring 2000 sampling, but cobalt loading increased by 0.85 kg/day between these stations during the Fall 2000 sampling. Stability of the overbank deposits and in-stream sediments and their potential for erosion was evaluated as part of the RI. This assessment also meets requirements of Appendix C of the Consolidated Case No. 83-4179 (R) Consent Decree entered in U.S. District Court for Idaho on September 1, 1995. The evaluation concluded that some areas of overbank deposits and in-stream sediments in Blackbird Creek upstream of the West Fork Tailings Impoundment have the potential for erosion.

Some of the mine-related materials that were dredged by the USFS and piled on the bank can be accessed during peak flows. In some locations, surface water accumulates on the upslope of materials causing surficial erosion where it overtops the material. A 500-year design storm would likely result in mobilization of materials that contain elevated concentrations of metals. These materials would have the potential to be deposited in downstream areas at concentrations greater than the PRGs established for those areas.

The remaining sources of metals loading to Bucktail Creek, S. Fork Big Deer Creek, and Big Deer Creek and Panther Creek downstream of Big Deer Creek include:

- **Bucktail Creek Seeps** – Groundwater discharge to Bucktail Creek downstream of the 7000 dam and the upper sediment pond and upstream of BTSW-01.6 is the primary source of remaining copper loading to Bucktail Creek. Synoptic sampling indicated that the debris flow materials and in-stream sediments downstream from BTSW-01.6 do not appear to contribute significant metals loading under current conditions. However, if the groundwater sources upstream from BTSW-01.6 were to be remediated, there is a possibility that the debris flow materials and/or in-stream sediments downstream from BTSW-01.6 could begin to release metals through dissolution/desorption processes and therefore become sources, and
- **Sediments in South Fork Big Deer Creek** – During both the spring and fall synoptic sampling events there was an observed increase in dissolved copper concentrations between station SFSW-02 (downstream of Bucktail Creek) and SFSW-01 (upstream of confluence with Big Deer Creek). Sulfate concentrations also increased between these stations; however, there was no observed increase in cobalt. During the Spring 2000 synoptic sampling event dissolved copper concentrations increased from 0.088 to 0.129 mg/L. During the fall event, the concentrations increased from 0.058 to 0.104 mg/L. These increases are likely due to either dissolution/desorption of precipitates from sediments or discharges from groundwater. Geochemical modeling indicates that dissolution of copper carbonates is likely occurring along this reach. While groundwater discharge is another possible source of these metals, there was no observed increase in flow between SFSW-02 and SFSW-01. However, accurate flow measurements are difficult to obtain in South Fork Big Deer Creek. The dissolved copper loads from the South Fork Big Deer Creek sediments were sufficient during some of these sampling events to cause exceedances of water quality PRGs in the South Fork Big Deer Creek and Big Deer Creek, even if there were no dissolved copper loads from Bucktail Creek. However, this is expected to be a short-term condition (less than 5 years), if additional remediation is successful at reducing metals loading from Bucktail Creek.

2.4.3 Diel Sampling Results

2.4.3.1 Blackbird Creek

Diel sampling was conducted at station BBSW-01A during spring runoff on April 30 and May 1, 1998. Results are presented in Table 5-14 and Figures 5-17a through 5-17b which are available in the RI Report (Golder 2001a). These figures illustrate how concentrations and loading of copper and cobalt varied in relation to flow throughout the sampling period. There was almost no variation in total or dissolved cobalt and dissolved copper concentrations. There was a brief spike in total copper that quickly returned to concentrations comparable to the beginning of the sampling period even though flows were significantly higher. However, peak dissolved copper concentrations did not correspond to this peak total concentration. The highest total copper concentrations were apparently associated with an increase in turbidity and total suspended solids that corresponded with the increasing flows for the samples collected at 6:00 p.m., 8:00 p.m., and 10:00 p.m.

2.4.3.2 Bucktail/Big Deer Creek

A round of diel sampling was conducted in the Big Deer Creek drainage at stations SFSW-04, SFSW-01, BDSW-04, and BDSW-03 on May 23 to May 24, 2000. The May 23/24 diel sampling was conducted during peak seasonal flow on Big Deer Creek (as measured at BDSW-03) and just prior to peak flows on South Fork Big Deer Creek (measured at SFSW-01). Though slight variations in metals concentrations and loading were observed during the event, no conclusive diel variation was observed. The observed runoff during this sampling event did not follow an "ideal" diel pattern, of flow increases that correspond to melt during the day followed by flow decreases that result from cooler night temperature. For example, measured flows at BDSW-03 varied between about 129 cfs and 159 cfs during the sampling event. The highest flows on May 23 occurred at 16:40, after which flows declined prior to increasing again. Peak flows during the sampling event occurred at 4:10 in the morning of May 24. Additional details of the diel sampling results are provided in Section 5.1.2.2 of the RI Report (Golder 2001a).

2.4.4 Periodic Sampling Results

Water quality sampling was conducted periodically at selected stations during spring runoff to evaluate variability and to identify periods of maximum concentrations and loading. This section summarizes results from selected stations. Additional details are provided in Section 5.1.1 of the RI Report (Golder 2001a).

In Blackbird Creek, weekly sampling was conducted at BBSW-01A, which is located near the mouth of Blackbird Creek, between March 27 and June 2, 2000. Between April and late May, flow in Blackbird Creek generally increased as the result of snowmelt runoff. From late May to early June, flow generally decreased. Cobalt concentrations generally declined as flow increased. This is an indication that base flow discharges from the West Fork Tailings Impoundment are the likely source of much of the cobalt loading observed. These discharges are diluted by snowmelt runoff resulting in higher flows. Copper

behavior was observed to be different than that of cobalt. Copper concentrations generally increased as flow increased between late March and mid-May. Copper concentrations then declined as flow declined.

Samples were also collected weekly at Panther Creek stations PASW-10, PASW-11, PASW-09, PASW-04 and PASW-05 (March 27 to June 2, 2000). In general, cobalt and copper concentrations followed the same trends as those observed at BBSW-01A.

Sampling was conducted intermittently from April 6 through May 24, 2000 at the following stations in the Big Deer Creek drainage basin: SFSW-04, SFSW-01, BDSW-04, and BDSW-03. Panther Creek stations PASW-05 and PASW-04 were also sampled in conjunction with periodic sampling on Big Deer and South Fork Big Deer creeks. Stations SFSW-04 and BDSW-04 are the background stations for South Fork Big Deer and Big Deer Creeks respectively. Stations SFSW-01, BDSW-04 and PASW-04 exhibited similar trends over this period. At all three stations, increases in copper and cobalt loading, were observed with increases in flow.

2.4.5 Storm Sampling Results

Storm event sampling was conducted during the RI to evaluate metal loading following storm events. In 1998, two storm events in the Blackbird drainage (June and September) were sampled. Samples for these storm events were collected manually at BBSW-07, BBSW-03A and BBSW-01A. In 1999, flow-actuated automated samplers were installed at BBSW-01A and SFSW-01 to capture storm events in the Blackbird and Bucktail drainages, respectively. On August 28, 1999, a storm event in the Blackbird drainage triggered the automatic sampler at BBSW-01A. There were no storm events in the Bucktail drainage in 1999.

A detailed summary of the results of these storm events is discussed in Section 5.1.5 of the RI Report (Golder 2001a). The August 28, 1999 storm was likely typical of a small summer storm. Sampling began during the initial peak in streamflow. Analytical results indicated an increase in dissolved copper, cobalt and manganese concentrations of between 70% and 260% in comparison to the most recent sampling event prior to the storm. Maximum total metals loading rates (calculated as daily load) were 13.4-kg/day cobalt, 6.97 kg/day copper and 6.56 kg/day manganese. It is important to note that tailings removal was occurring along Blackbird Creek immediately prior to this storm event. Observed loading during this storm are likely partially attributable to flushing of sediments disturbed during tailings removal. Loading rates for both total and dissolved metals as a result of the storm event were considerably less than the loading during spring 1999 runoff.

2.4.6 Sediment Sampling and Geochemical Modeling

To evaluate the potential for trace metal releases from streambed sediments at the Blackbird Site, historic sediment and water quality data were reviewed. Analytical data for total metal concentrations in Blackbird sediments are available for pre-mining, post-

mining, and post Early Action conditions. Sediment and water quality data compiled by Mebane (1994), indicate that elevated metal concentrations (copper, cobalt and arsenic) in the sediments are found in areas of high cobalt-copper mineralization in the Blackbird mining district in comparison to sediment concentrations in areas without reported cobalt-copper mineralization. Water quality data indicate that at near-neutral pH, background concentrations of cobalt, copper, and arsenic on the order of 0.010 mg/L are possible in the presence of exposed sulfide mineralization.

Mining activities have increased the concentrations of metals in the streambed sediments at the Blackbird Site. However, a comparison of post-mining sediment concentrations (1995) to post Early Action concentrations (2000) indicates that an overall decline in total metal concentrations has occurred in both Panther and Big Deer Creeks.

Sequential Extraction Analyses. The phase in which trace metals are present in sediments at the Blackbird Site will dictate the extent to which metals will be released into water. Copper, arsenic, and cobalt, present in the sediments as secondary mineral phases or adsorbed to sediments, are expected to be released to the water column as sediments are flushed with stream water of improved quality. Sequential extraction analyses, conducted on samples collected in Fall 2000, provide information with respect to the percentage of each metal present in the "labile" or "leachable" fraction.

Sequential extraction and x-ray diffraction (XRD) analysis on Fall 2000 samples indicated the presence of sulfides in only the Blackbird and S. Fork sediment samples. At these sites, a combination of arsenic, cobalt, and copper sulfides are likely present at low concentrations. Because primary sulfide contents are low, and exposure to oxygen is limited, metal release from primary sulfides in the stream sediments into the water column is expected to be insignificant.

Geochemical Modeling

Geochemical modeling of sediment/water interaction at the Blackbird Site simulated metal release due to dissolution and desorption. For all creeks, dissolved metal concentrations are predicted to decline as cleaner water is transported over metal-bearing sediments. Results specific to each creek are summarized below.

In South Fork Big Deer, trace metal release from sediments is believed to be responsible for the observed increases in copper and sulfate concentrations between SFSW-02 and SFSW-01 observed during the fall 1999 and both spring and Fall 2000 sampling events. Copper carbonate dissolution is believed to be the primary mechanism responsible for copper loading. Sulfate loading is likely the result of desorption or sulfate mineral dissolution. Sequential extraction results for South Fork Big Deer indicate that half of the total sulfur is present as primary sulfides. Labile sulfur is therefore present in the sediments in this creek.

While groundwater discharge is another possible source of these metals, there was no observed increase in flow between SFSW-02 and SFSW-01. However, accurate flow measurements are difficult to obtain along S. Fork Big Deer Creek. Sampling during Spring 2001 did not indicate loading in this reach, which is consistent with the theory

that the cause of loading in 2000 was due to dissolution and/or desorption from sediments. Sampling results from 2001 are discussed in Section 2.6.

Desorption from iron and manganese (oxy) hydroxides in Big Deer and Panther Creeks may result in some trace metal loading. Desorption profiles are however generally smooth indicating a gradual release of metals as a new equilibrium is reached between the aqueous and adsorbed phases. The observed decrease in total sediment metal concentrations between 1995 and 2000 may be attributable to physical sediment transport, that is to say the scouring and mobilization of fine-grained sediments downstream combined with reduced loading to the sediments as a result of improvements in water quality.

Trace metal release due to desorption is also predicted to occur from Blackbird Creek sediments. The portion of total metals present as primary sulfides in this Creek, likely from a tailings source, is not expected to be a significant source of trace metal loading.

2.4.7 Remaining Sources of Potential Human and Ecological Exposure

The remaining sources of potential human and terrestrial and aquatic ecological exposure which were evaluated in the risk assessments are as follows:

2.4.7.1 Human Health

A conceptual exposure pathway model for human health is provided in the *Site-Wide Baseline Human Health Risk Assessment for the Blackbird Mine Site* (CH2M Hill 2002). Remaining sources of potential human exposure include the waste rock, tailings, and overbank deposits that contain elevated concentrations of metals (primarily arsenic) at the mine site and along Blackbird Creek, Bucktail Creek, South Fork Big Deer Creek, Big Deer Creek, and Panther Creek. These materials can be entrained in the air by wind, heavy equipment operation, and vehicle traffic. Exposure could potentially occur through incidental ingestion, dermal contact, or inhalation. In addition, the materials can erode and enter the area creeks and be deposited as sediments in the creeks, where humans could be exposed through dermal contact or incidental ingestion. Impacts resulting from infiltration and seepage to subsurface soils and groundwater are not considered to be complete routes of potential human exposure.

2.4.7.2 Terrestrial Ecological Receptors

The primary remaining sources of exposure evaluated in the terrestrial ecological risk assessment (Golder 2000b) include waste rock, overbank deposits, and soils containing elevated concentrations of chemicals of potential ecological concern (COPECs), which included arsenic, cobalt, and copper. The primary areas evaluated included the riparian areas along Blackbird Creek, Panther Creek, Bucktail Creek, S. Fork Big Deer Creek, and Big Deer Creek, where overbank deposits of mine waste occur, although the waste rock dumps were also evaluated.

2.4.7.3 Aquatic Ecological Receptors

The primary remaining sources of exposure evaluated in the aquatic ecological risk assessment (CH2M Hill 2001a) include water and sediment quality in Blackbird Creek, Panther Creek, South Fork Big Deer Creek and Big Deer Creek, as discussed in the previous sections. The primary COPECs include arsenic (sediments only), copper, cobalt, and iron.

2.5 Ecological Investigations

2.5.1 Benthic Invertebrate Populations

Benthic invertebrate populations are showing significant signs of recovery, especially in Panther Creek. Some indications of recovery are also occurring in S. Fork Big Deer Creek and Big Deer Creek. This section provides a summary of the changes in benthic invertebrate populations. A more complete analysis of improvements to the benthic invertebrate populations is provided in Section 5.7.3 of the RI Report (Golder 2001a) and is discussed in the Aquatic Ecological Risk Assessment Report (CH2M Hill 2001a).

Evidence for recovery of the benthic invertebrate community is provided in a number of metrics that were evaluated, including the presence of metals sensitive species in areas downstream of the mine discharges. The metrics evaluated include a variety of measurements that are indicators of environmental impairment of benthic communities. During 2000, some individual metric scores were higher at downstream stations in Panther Creek than they were at the upstream reference station. Significant recovery was observed at all stations between 1998 and 1999 and in comparison to 1993 pre-Early Action data. However, in 2000, the downstream stations, with the exception of station PABI-01, had lower numbers of insects and lower densities than the reference station.

Although there were dramatic increases in some species populations during 2000 (i.e. *Hydroptila sp.*), there were reductions in overall populations in most Panther Creek stations including the reference station in 2000 as compared to 1999. Ephemeroptera populations especially, declined during 2000. This year to year variation may be attributed to a number of factors including: antecedent environmental and hydrological conditions (i.e. algal blooms, drought, flooding, water temperature etc.); fluctuations in the life cycles of various invertebrate populations; and, the effects of the Clear Creek fire, which burned through the watershed shortly prior to the 2000 sampling round. Since metals concentrations were similar or lower during 2000 than during 1999, and declines in populations were also observed at the Panther Creek reference station, it is unlikely that metals contributed to the decline in total numbers of invertebrates. This is also supported by the fact that the metals tolerance index (MTI) scores at the downstream stations in Panther Creek were similar to the reference station score.

There is concern that ongoing recovery of invertebrates over the next several years may be affected by impacts from the Clear Creek fire on hydrology and water quality. Numerous studies on the effects of fire on benthic macroinvertebrate populations have

been conducted, which indicate that there can be detrimental effects lasting several years due primarily to increased sedimentation. The 2000 sampling round may only have been affected by very short-term effects related to the Clear Creek Fire and it is likely that additional impacts will occur over the next several years. The effects of the fire on invertebrate populations may complicate the evaluation of recovery from the metals impacts at the site.

2.5.2 Toxicity Testing

Hydroqual (1996a) conducted a 60-day flow-through cobalt toxicity test using rainbow trout starting at the swim-up stage, which is considered the most sensitive stage in the life cycle of salmonids. Testing was conducted using Panther Creek water and cobalt concentrations ranging from 6 to 213 μg/L. The highest concentration of cobalt in Panther Creek during 2000 was 75 μg/L at PASW-09. There was very little mortality over the entire 60-day exposure (<10%), some of which was due to predation in the first thirty days, mostly on swim-ups that did not take to feed. There was <1% mortality over the thirty to sixty day period.

Growth and overall condition of the fish was evaluated using a body condition factor (relationship between length and weight). Cobalt exhibited no significant dose dependent effect on growth over the range of the concentrations examined. There were also no differences amongst growth or body condition factors in any of the cobalt treatments as compared to the Panther Creek and laboratory controls.

A series of acute tests were conducted during the course of the 60-day test to evaluate whether there were any effects on toxicity due to water storage. Although no effects of storage were noted, the results of the acute testing indicated an apparent difference in the sensitivity to cobalt of test fish from two different hatchery stocks that were used for the test. Due to this variability, the EPA and Trustees have indicated that the chronic test results are not conclusive. The results of the test will be used along with a review of the literature in the *Aquatic Ecological Risk Assessment* (CH2M 2001a) to evaluate potential toxicity of cobalt.

Hydroqual (1996b and 1996c) also conducted a series of preliminary water-effects ratio (WER) tests on copper. These tests were not conducted under an EPA approved workplan and were intended to provide preliminary indications of potential for a site-specific WER. During these tests, acute lethality on rainbow trout fry was evaluated using laboratory water and Panther Creek water in side-by-side tests. If there is a difference between stream water and laboratory water, the ratio of the difference can be used to develop a WER, which is used to determine a site-specific criteria. Results of these preliminary tests indicated a ratio would likely be greater than 2. Discussions were held between EPA, the Trustees, and BMSG on whether to proceed with full scale WER testing, but it was decided that such testing would not be conducted, pending completion of Early Actions and evaluation of water quality data.

2.6 Additional Data Needs and 2001 Sampling Results

2.6.1 Additional Data Needs

Where it has been determined that data gaps exist through 2000, additional sampling was conducted during 2001 to fill these gaps. Details of sampling that were conducted in 2001 are included in the *Sampling and Analysis Plan for 2001, Blackbird Mine Site* (Golder, 2001g). Sampling conducted during 2001 included the following:

- One round of sampling at BBSW-01A, PASW-01, PASW-02, and PASW-09 prior to spring runoff;
- Weekly sampling at BBSW-07, BBSW-03A, and BBSW-01A during spring runoff;
- Additional rounds of Synoptic Sampling were conducted during the spring and fall of 2001. In particular, a round of sampling was conducted along the South Fork of Big Deer Creek. Additional locations were sampled to obtain data to evaluate the potential source of increases in metals concentrations observed during previous sampling between stations SFSW-02 and SFSW-01. No groundwater sampling was conducted during these sampling events;
- Sampling was conducted during one storm event on the Bucktail Creek/S. Fork Big Deer Creek drainages;
- An additional round of Benthic Macroinvertebrate sampling was conducted in fall of 2001;
- EPA also requested that additional overbank sampling be conducted along Blackbird Creek including areas where potential tailings were exposed following the fire;
- Sediments were sampled at the same locations that were sampled in 2000 and at two locations in Bucktail Creek (downstream of the upper road crossing and upstream of the lower sediment pond), and
- The surface of the West Fork Tailings Impoundment was sampled once removal actions were completed.

2.6.2 Summary of 2001 Sampling Results

Sample results from 2001 were obtained following completion of the RI report (Golder 2001a) and are presented in this section. Complete results are provided in the RI Addendum (Golder 2001d).

2.6.2.1 Weekly Sampling

Weekly sampling was conducted during spring runoff at stations BBSW-01A, BBSW-03A, and BBSW-07. In addition, a sample was collected prior to spring runoff at stations BBSW-01A and PASW-09. Results are presented in Table 2-1a and 2-1b. Trends were similar to those observed during previous years sampling, with the exception of the samples collected at station BBSW-03A on the May 2 synoptic sampling, which showed

an anomalously high increase in metals loading between station BBSW-07 and BBSW-03A as shown in Table 2-1b. This loading increase is not consistent with trends shown in weekly samples taken on dates prior to and after this date and the data are therefore suspect and will hereinafter be considered anomalous. This aside, as seen in previous years, concentrations of dissolved cobalt were highest early in the spring when flows were low and they decreased as flows increased. Dissolved copper concentrations were lowest during the early spring sample (4/17/01 at BBSW-01A), highest during the early stages of spring runoff, and then declined during higher flows.

2.6.2.2 Spring 2001 Synoptic Sampling

2.6.2.2.1 Blackbird Creek

Spring synoptic sampling on Blackbird Creek was conducted on May 2, 2001. A reduced list of stations was sampled including: 7100 Bypass, BBSW-08, BBSW-07A, BBSW-07, BBSW-03A, BBSW-01A, PASW-11, and PASW-09. Results of this sampling event are presented in Tables 2-2 a through 2-2f and Figures 2-7a through 2-7f.

Flows in Blackbird Creek were quite high during this sampling event. The flow at BBSW-03A (located upstream of the Impoundment) was 16 cfs, and the flow at BBSW-01A was 31 cfs, compared to 5 cfs at BBSW-03A and 13 cfs at BBSW-01A during the 2000 spring synoptic sampling.

The cumulative dissolved copper loading from Meadow Creek measured at BBSW-07 was 1.05 kg/day (28% of the load at BBSW-01A), and dissolved cobalt was 1.9 kg/day (17% of the load at BBSW-01A). Downstream along Blackbird Creek between stations BBSW-07 and BBSW-03A there was an apparent load increase in dissolved copper. As mentioned previously in this document, these data appear to be anomalous when compared to weekly samples collected prior to and after the synoptic event. Between stations BBSW-07 and BBSW-01A, there was an increase in dissolved copper load of 1.3 kg/day (35% of the load at BBSW-01A) and an increase in dissolved cobalt load of 9.7 kg/day. The majority of the load (71% of load at BBSW-01A) was contributed below the confluence of the West Fork Blackbird Creek.

Station BBSW-02 was not sampled during the Spring synoptic sampling, thus the loading from the West Fork Tailings Impoundment or overbank deposits and in-stream sediments cannot be distinguished in the reach between BBSW-03A and BBSW-01A. Based on previous sampling, the primary source of metals loading in this reach is due to groundwater discharges from the West Fork Tailings Impoundment.

The concentration of dissolved copper in Panther Creek at station PASW-09 during the spring synoptic sampling event was 0.013 mg/L. The concentration of dissolved cobalt at PASW-09 was 0.037 mg/L as shown in Table 2-1a.

2.6.2.2.2 Bucktail Creek

The Bucktail Creek Spring synoptic sampling was conducted on May 17, 2001. The spring synoptic 2001 sampling stations included: SFSW-04, BTSW-01, SFSW-02.5, SFSW-02.3, SFSW-02, SFSW-01.5, SFSW-01, BDSW-04, BDSW-03, PASW-05, and PASW-04. Results for the Bucktail Creek Spring synoptic event are presented in Tables 2-3a through 2-3f and figures 2-8a through 2-8f.

In addition to the spring synoptic samples noted above, IDEQ collected samples at the following locations in upper Bucktail Creek on the same date:

- BTSW-03A - all surface springs and seeps in the right ditch above the pump back station;
- BTSW-03B – all surface springs and seeps in the left ditch just below the pump back station;
- BTWFSW-01 – mouth of West Fork Bucktail Creek, and
- BTEFSW-01 – mouth of East Fork Bucktail Creek.

Results of the IDEQ samples are provided in Table 2-3g. Metals loading from upper Bucktail Creek stations sampled by IDEQ were: 0.40 kg/day dissolved copper and 0.24 kg/day dissolved cobalt at station BTSW-03A; 1kg/day dissolved copper and 0.44 kg/day dissolved cobalt at BTSW-3B; 0.33 kg/day dissolved copper and 0.21 kg/day dissolved cobalt at BTWFSW-01 (mouth of West Fork Bucktail Creek).

Flows in Bucktail Creek and South Fork Big Deer Creek during 2001 were much higher than flows during the Spring 2000 synoptic event. This may be due to impacts of the Clear Creek Forest Fire of 2000 including the destruction of vegetation and resulting reduction in plant transpiration over much of the drainage area. Hydrophobic soils that have been observed in the Bucktail drainage following the fire may also be a contributing factor. Flows from the West Fork of Bucktail Creek were measured at 0.24 cfs in 2001, whereas there was no surface flow during the spring 2000 synoptic sampling event. The flows at BTSW-01, SFSW-04, SFSW-02, and SFSW-01 during 2001 were 0.91 cfs, 6.96 cfs, 8.08 cfs, and 7.82 cfs, respectively. During 2000, the flows at these stations were 0.24 cfs, 2.05 cfs, 2.43 cfs and 1.98 cfs, respectively. Flows in Big Deer Creek were higher in 2001 than they were during the 2000 spring sampling event. The flow at BDSW-04 was 40.69 cfs in 2000 and 79 cfs in 2001. The flow at BDSW-03 was 42.31 cfs in 2000 and 89 cfs in 2001.

At the mouth of Bucktail Creek the dissolved copper concentration was 1.1 mg/L with loading of 2.45 kg/day. The dissolved cobalt concentration was 1.17 mg/L with loading of 2.6 kg/day. The cumulative dissolved copper load observed in South Fork Big Deer Creek below the confluence of Bucktail Creek, measured at station SFSW-02.5, was 1.81 kg/day and the dissolved cobalt load was 2.18 kg/day. Slight declines in dissolved phase copper and cobalt concentrations and loads were exhibited between SFSW-02.5 and the furthest downstream South Fork Big Deer station, SFSW-01. Dissolved copper concentration and load changed from 0.094 mg/L and 1.81 kg/day at SFSW-02.5 to 0.08

mg/L and 1.53 kg/day at SFSW-01. Dissolved cobalt concentration and load decreased from 0.113 mg/L and 2.18 kg/day at SFSW-02.5 to 0.098 mg/L and 1.87 kg/day at SFSW-01. As observed in past years, copper precipitation is probably the mechanism for continued declines from upstream stations.

The dissolved copper concentration at BDSW-03 was measured at 0.011 mg/L while loading was 2.4 kg/day. The dissolved cobalt concentration at BDSW-03 was 0.01 mg/L, and loading was 2.18 kg/day.

2.6.2.3 Panther Creek Sample Results - May 17, 2001

Several stations from the mouth of Panther Creek (PASW-01) to station PASW-05 above the confluence with Big Deer Creek were sampled on May 17, 2001. This sampling was not conducted synoptically and flows were not obtained at locations downstream of PASW-04. Results are presented in Table 2-4. Dissolved cobalt concentrations ranged from 0.006 mg/L at PASW-01 to 0.008 mg/L at PASW-04. Dissolved copper concentrations ranged from 0.003 mg/L at PASW-04 to 0.006 mg/L at PASW-02 and PASW-03.

Potential sources of dissolved copper detected at stations PASW-02 and PASW-03 are not known, but could be due to tributary streams containing elevated copper, effects of the Clear Creek Fire Complex, or analytical error. It is unlikely that overbank deposits or in-stream sediments associated with the mine could have been the source, since copper concentrations in these materials are lower in this area of Panther Creek than in areas upstream of PASW-04 and PASW-09.

2.6.2.4 Storm Event Sampling – Bucktail Creek

Storm sampling was conducted during a storm event that occurred on July 30-31 at three stations: BTSW-01.1, BTSW-02, and SFSW-01. Results for the Bucktail Creek storm event sampling are presented in Table 2-5 and Figures 2-9 a-c. The storm event sampling began at approximately 15:00 on July 30 and continued until 13:00 on July 31. Samples were collected approximately every two hours. Precipitation during this storm event was 0.6 inches over a 24-hour period. At station BTSW-01.1, a large increase in total copper concentration was observed between 17:00 and 19:00 on July 30. At 17:00 total copper concentration was1.25 mg/L, and at 19:00 it was 7.03 mg/L. Following this peak, the total copper concentration dropped to 5.88 mg/L at 21:00 and continued along a decreasing trend until the conclusion of the storm sampling, when the final total copper concentration was 1.03 mg/L. The dissolved copper concentration increased very slightly between 17:00 and 19:00 from 0.459 mg/L to 0.518 mg/L. Overall, dissolved copper concentrations, total cobalt concentrations and dissolved cobalt concentrations remained relatively stable throughout the storm event as shown in Figure 2-9a.

At station BTSW-02, total copper and cobalt concentrations were not reported from the laboratory. Both dissolved copper and cobalt at BTSW-02 remained relatively stable throughout the storm-sampling event as shown in Figure 2-9b.

Storm event data for SFSW-01 is only available from 15:00 on July 30 through 5:00 on July 31. Both dissolved and total copper and cobalt concentrations at SFSW-01 remained fairly stable throughout the storm event as shown on Figure 2-9c. A gradual increase in total copper was observed from the beginning of the storm event, when it measured 0.098 mg/L, through the 21:00 sample, when it measured 0.153 mg/L. Dissolved copper increased slightly form 0.086 mg/L to 0.093 mg/L. Dissolved cobalt also exhibited a slight increase in concentration from the beginning of the storm event, when it measured 0.104 mg/L, until 19:00, when it measured 0.124 mg/L. By 23:00 cobalt and copper concentrations were stable at SFSW-01.

2.6.2.5 Fall 2001 Synoptic Sampling

2.6.2.5.1 Blackbird Creek

A round of synoptic sampling was conducted on the Blackbird drainage basin on September 19, 2001. The sampling was conducted without the water treatment plant running as it has been in previous years. This synoptic sampling event consisted of two sampling teams "leap-frogging" from the 7100 Bypass down to the mouth of Blackbird Creek. Each sampling team measured flow, field parameters and collected water samples to be analyzed by the lab. The stations sampled include: 7100 Bypass, BBSW-08 BBSW-07A, BBSW-07, BBSW-03A, BBSW-02.1, BBSW-02, BBSW-01.7, BBSW-01A, PASW-11, and PASW-09. Springs and seeps were not sampled during this synoptic sampling event.

Flows in Blackbird Creek were higher during the 2001 sampling event than flows observed during the 2000 fall synoptic sampling event. The flow at BBSW-07 was 0.810 cfs as compared to 0.52 cfs in 2000. The flow at BBSW-03A was 1.48 cfs, and the flow at BBSW-01A was 2.93 cfs, compared to 0.91 cfs at BBSW-03A and 2.39 cfs at BBSW-01A during the 2000 fall synoptic sampling.

Blackbird Creek fall synoptic sampling results are presented in Tables 2-6a through 2-6f and Figures 2-10a through 2-10f. Loading results from the 7100 Bypass represent all loading from the Meadow Creek drainage. Dissolved copper loading at this station was 0.045 kg/day and dissolved cobalt loading was 0.049 kg/day. Total copper loading was 0.057 kg/day and the corresponding total copper concentration was 0.464 mg/L. Dissolved copper loading decreased slightly between the 7100 Bypass and BBSW-07A, while total copper loading increased slightly between these two stations. Both dissolved and total cobalt remained relatively unchanged between the 7100 Bypass and BBSW-07A. This suggests that there is no additional source of metals loading downstream of the upper Meadow Creek basin during low flow periods and that copper may be precipitating/sorbing in the concrete channel.

The dissolved and total copper and cobalt concentrations from Blackbird Creek at BBSW-08 were below detectable limits. This station is considered representative of background concentrations in Blackbird Creek.

The dissolved copper concentration between BBSW-07A and BBSW-07 increased from 0.018 mg/L with a corresponding load of 0.04 kg/day to 0.113 mg/L with loading of 0.2 kg/day. Dissolved cobalt concentration increased from 0.023 mg/L to 0.124 mg/L and loading increased from 0.05 kg/day to 0.2 kg/day. Flow decreased from 0.85 cfs to 0.81 cfs between stations BBSW-07A and BBSW-07. The increase in metals concentrations and loading downstream of BBSW-07A may be due to residuals from leakage of the tight line for the underdrain system through the cutoff wall, contaminated materials downstream of the cutoff wall, or groundwater discharges from Hawkeye Gulch. These small load increases are insignificant since both dissolved copper and cobalt concentrations at PASW-09 were less than their respective PRGs during the fall 2001 round of sampling.

Prior to implementation of the Early Actions in 1995, the dissolved copper concentration at BBSW-07 was 0.997 mg/L and cobalt was 1.03 mg/L with loads of 2.4 kg/day and 2.5 kg/day respectively, at flow rates of about 1 cfs. This represents a reduction of about 88% in dissolved copper concentrations and 91% reduction in copper loading. The reduction in cobalt concentrations is about 88% and loading is about 91%.

Dissolved copper concentrations and loading decreased between stations BBSW-07 (0.113 mg/L and loading of 0.224 kg/day) and BBSW-03A (0.038 mg/L and 0.14 kg/day). Copper loading between BBSW-03A and BBSW-02, which includes any contributions attributable to the tailings impoundment did not change. However, the copper concentration decreased slightly from 0.038 mg/L to 0.025 mg/L. Loading at BBSW-02.1, near the outlet of the West Fork Sediment Pond was 0.089 kg/day and concentration was 0.016 mg/L.

Additional sampling was conducted downstream of BBSW-02 to determine whether there are any additional sources of loading. The dissolved copper concentration and loading at station BBSW-01.7 remain basically unchanged from BBSW-02, increasing slightly from 0.025 mg/L to 0.027 mg/L and from 0.14 kg/day to 0.15 kg/day. Slight increases in total copper concentration from 0.078 mg/L to 0.089 mg/L and loading from 0.43 kg/day to 0.49 kg/day between these two stations were also observed.

Downstream of BBSW-01.7, as noted in previous years, dissolved copper was converted to total copper and co-precipitated with iron oxides, resulting in a decrease in copper concentrations downstream of the West Fork Tailings Impoundment. Overall, between stations BBSW-07 and BBSW-01A, upstream of the mouth of Blackbird Creek, dissolved copper concentration and loading declined, with dissolved copper concentration at BBSW-01A of 0.003 mg/L and loading of 0.022 kg/day.

Dissolved cobalt concentrations downstream of BBSW-07 increased from 0.124 mg/L to 0.178 mg/L at BBSW-03A. Sampling in previous years identified discharges from several seeps between these stations that contributed to this loading. Between stations BBSW-03A and BBSW-02.1, which is located near the outlet of the West Fork Sediment Pond, increased concentrations and loading were observed for cobalt, sulfate, iron and manganese as a result of discharges from the West Fork Tailings Impoundment. Dissolved cobalt concentrations increased to 0.615 mg/L and load increased to 3.42 kg/day from BBSW-03A to BBSW-02.1. Dissolved cobalt concentration then increased

again to 0.667 mg/L and loading increased to 3.704 kg/day at BBSW-02. Comparisons of dissolved cobalt concentrations and loading values between stations BBSW-03A and BBSW-02 show a concentration increase of 0.489 mg/L and a loading increase of 3.06 kg/day. Further dissolved cobalt increases are observed downstream of BBSW-02 at station BBSW-01.7, which had concentration and loading values of 0.672 mg/L and 3.732 kg/day. Cobalt concentration and loading near the mouth of Blackbird Creek, measured at station BBSW-01A were 0.484 mg/L and 3.47 kg/day. Similar increases in total cobalt concentration and loading was observed at all of these stations.

2.6.2.5.2 Bucktail Creek

The low-flow synoptic sampling in the Bucktail/Big Deer Creek basin was conducted on September 20, 2001. Springs and seeps were not sampled during this synoptic sampling event. The fall synoptic 2001 sampling stations included: SFSW-04, BTSW-01, SFSW-02.5, SFSW-02.3, SFSW-02, SFSW-01.5, BDSW-04, SFSW-01, BDSW-03, PASW-04, and PASW-05. Water quality results from the Bucktail synoptic sampling event are presented in Tables 2-7a through 2-7f and Figures 2-11a through 2-11f.

Flows in Bucktail Creek and South Fork Big Deer Creek during 2001 were comparable, but slightly higher than flows during fall of 2000. Flow at BDSW-04 was slightly lower than the fall 2000 flow.

At the mouth of Bucktail Creek, the dissolved copper concentration was 0.525 mg/L with loading of 0.244 kg/day. The dissolved cobalt concentration was 1.02 mg/L with loading of 0.474 kg/day. The dissolved copper load observed in South Fork Big Deer Creek below the confluence of Bucktail Creek, measured at station SFSW-02.5, was 0.23 kg/day and the dissolved cobalt load was 0.519 kg/day. Slight declines in dissolved cobalt concentrations and loads were exhibited between SFSW-02.5 (0.124 mg/L, 0.519 kg/day) and the furthest downstream South Fork Big Deer station, SFSW-01 (0.108 mg/L, 0.420 kg/day). Dissolved copper concentration and load increased slightly from 0.055 mg/L and 0.23 kg/day at SFSW-02.5 to 0.09 mg/L and 0.35 kg/day at SFSW-01, though this apparent load increase is probably attributable to flow measurement difficulties along this reach. This increase in copper loading is thought to be attributable to dissolution or desorption from sediments as described in the RI Report (Golder 2001a).

Dissolved copper concentration at BDSW-03 measured 0.022 mg/L while loading was 0.40 kg/day. Dissolved cobalt concentration at BDSW-03 was 0.022 mg/L and loading was 0.40 kg/day.

2.6.2.6 Sediment Sampling

In-stream sediments were sampled in 2001 at the same locations sampled during 2000, within Blackbird Creek, South Fork Big Deer Creek, Big Deer Creek, and Panther Creek to determine whether there were changes in sediment concentrations over time. In addition, two samples were collected from Bucktail Creek. At each location, three sediment samples were collected from the streambed surface (0-10 cm depth) with either a McNeil sediment sampler or a shovel. Samples were collected in depositional

environments in areas where the streambed consists of well-sorted gravels. The three samples from each location were composited, dried, and sieved, and the < 2 mm fraction was submitted to SVL for total metals analysis for arsenic, cobalt, copper, manganese, and iron. Results from these samples and comparison to PRGs are shown in Table 3-6.

Between 2000 and 2001, sediment metals concentrations increased at background locations, which may be due to fire related impacts. The concentrations for arsenic and cobalt at Blackbird Creek background location BBSW-08 increased 54% and 112% respectively, causing an exceedance in 2001 of the arsenic PRG for Blackbird Creek at this location. Arsenic and cobalt concentrations at stations along Blackbird Creek in 2001 remained relatively similar to 2000 concentrations, showing a slight decrease in arsenic at station BBSW-03 and a slight increase in cobalt at station BBSW-01. Copper concentrations remained similar or decreased from concentrations observed in 2000.

Similar to Blackbird Creek, increases in arsenic and cobalt concentrations at Big Deer Creek background location BDSW-04 and Panther Creek background location PASW-11 were observed. Panther Creek stations PASW-08, PASW-07, and PASW-05 showed increases greater than 100% in copper concentrations, while concentrations observed at stations PASW-10, PASW-04, and PASW-01 remained similar to 2000.

South Fork Big Deer Creek background station SFSW-04 showed increases in cobalt and copper concentrations while concentrations near the mouth of South Fork at station SFSW-01 remained similar to concentrations observed in 2000.

2.6.2.7 Benthic MacroInvertebrate Sampling

Complete results and a discussion of the 2001 benthic macroinvertebrate sampling are provided in the 2001 RI Addendum (Golder 2001d). Ongoing recovery of invertebrates over the next several years may be affected by impacts from the Clear Creek Fire on hydrology and water quality. The 2001 sampling round may have been affected by very short-term effects related to the Clear Creek Fire and it is likely that additional impacts will occur over the next several years. Minshall et al. (1997) report that declines in periphyton biomass, and macroinvertebrate abundance, species richness and diversity were observed in the first year following the 1988 Yellowstone fires. Richards and Minshall (1992) noted greater annual variation in diversity and increased species richness in drainages affected by fire events. Trophic generalists with the ability to switch between multiple food sources and populations having a wide variety of habitat preferences have a higher likelihood of survival in post fire conditions. Jones et al. (1989) note that a shift in functional feeding groups, from shredder and collector dominated communities to scraper and filter feeder communities, often occur in larger order streams as a result of large fires. In any case, the effects of the fire on invertebrate populations may complicate the evaluation of recovery from the metals impacts at the site.

A summary of the results is provided in the following sections.

2.6.2.7.1 Total Numbers

Comparisons of yearly benthic macroinvertebrate sampling results at Panther Creek stations are summarized in tables presented in the 2001 RI Addendum (Golder 2001d). Panther Creek stations were sampled during 1998, 1999, 2000, and 2001. Discussions and comparisons of 1998, 1999 and 2000 benthic macroinvertebrate sampling data are provided in the Blackbird RI Report (Golder 2001a). The 2001 RI Addendum compares the 2000 and 2001 results. As in 2000, all nine Panther Creek stations were sampled, including: PASW-01, PASW-02, PASW-04, PASW-05, PASW-07, PASW-08.5, PASW-09, PASW-10, and PASW-11. At all stations sampled, total numbers of insects were less in the downstream stations than in the reference stations.

Comparing results from 2000 with the 2001 results for stations in Panther Creek provides evidence that recovery of benthic invertebrate populations appeared to be continuing during this time period. Comparisons of 2000 to 2001 results show that total benthic invertebrate numbers increased at all Panther Creek stations except at PABI-01, where a decline in total numbers from 1808 to 1503 occurred.

Greater numbers of Ephemeroptera were seen at all Panther Creek stations except PABI-07, when comparing 2001 results to 2000 results. Comparisons of 2000 to 2001 results show that greater numbers of Plecoptera were found at all Panther Creek stations, except for PABI-01 and PABI-07. Coleptera totals show that all Panther Creek stations had greater numbers in 2001 than 2000. Total numbers of Trichoptera increased between 2000 and 2001 at all Panther Creek stations except at PABI-01 and PABI-04. Total numbers of Diptera increased at all Panther Creek stations except for PABI-04 and PABI-05.

Comparisons of 2001 to 2000 results for Blackbird Creek, West Fork Blackbird Creek, Big Deer Creek and South Fork Big Deer Creek results show increases in total numbers at all stations sampled. For each Order of insects, there were greater numbers found at many of these stations. Increases in Ephemeroptera were seen between 2000 and 2001 at all stations except BDBI-01, SFBI-01, and SFBI-04, where decreases were seen. Increases in Plecoptera between 2000 and 2001 were observed at all stations sampled except BDBI-01 and SFBI-01. Total Coleoptera numbers increased at all stations between 2000 and 2001, with the exception of BDBI-03 and BDBI-04. Trichoptera numbers increased at all stations between 2000 and 2001, except at BBBI-01, BDBI-01, and SFBI-04. Total Diptera numbers increased at all stations between 2000 and 2001.

2.6.2.7.2 Modified Biotic Indicator (MBI)

Modified Biotic Indicator scores are presented in Table 2-8 and in the 2001 RI Addendum and represent an assemblage of several of the biotic indices used in the evaluation of the benthic macroinvertebrate data. The various biotic index scores used to obtain the MBI values and comparisons of these scores with their respective reference sites are also summarized in the RI Addendum. It should be noted that the MBI was initially developed for assessment of physical and chemical habitat characteristics, such as temperature and sediment, and was not designed specifically for the assessment of the

effects of metals pollution on the health of aquatic ecosystems. According to IDEQ (Clark 2000), an MBI score of 2.5 or less is an indication of impairment for benthic invertebrates, a score of 3.5 or greater is an indication of no impairment, and scores between 2.5 and 3.5 are considered too close to determine impairment based on this measure. However, since the MBI was not developed to specifically assess effects of metals, the use of MBI scores in this report is limited to comparison of reference locations with areas potentially impacted by runoff from the mine site and to evaluate changes from year to year.

Total MBI scores in 2001 for sites downstream of mine discharges are generally lower than their respective reference sites at all of the Panther Creek stations sampled. However, some individual metrics at downstream stations were higher than the reference station. Total MBI scores increased at all of the Panther Creek locations between 2000 and 2001 except for PABI-01 and PABI-07.

Total MBI scores in 2001 for sites downstream of mine discharges are also generally lower than their respective reference sites on Big Deer Creek, South Fork Big Deer Creek, and Blackbird Creek. However, some individual metrics at downstream stations are higher than the reference station. An MBI score could not be calculated at BBBI-01, because the total number of invertebrates collected was fewer than 100. Between 2000 and 2001 total MBI scores increased at BDBI-01 and BDBI-03, but decreased at BDBI-04, the reference station. Total MBI scores decreased at SFBI-01 and the reference stations, SFBI-04 and WFBI-03, between 2000 and 2001.

2.6.2.8 Blackbird Creek Overbank Deposits

Sampling was conducted along Blackbird Creek in 2001 to further delineate overbank deposits that have been sampled in previous years. Results from these samples are included on Figures 6-13a through 6-13x. In addition, overbank materials were classified and grouped into five distinct material types for Lower Blackbird Creek below the confluence of West Fork, (Type A through Type E) and Upper Blackbird Creek above the confluence of West Fork (Type G through Type K). These categories are described in Table 2-9a. Samples collected in 2001 were analyzed by XRF in the field by Golder personnel and are presented in Table 2-9b. In addition, Tables 2-9c through 2-9l show summaries of the sample results organized by material type.

As shown on Tables 2-9a through 2-9l, material Type A had highest average and maximum concentrations for arsenic in lower Blackbird Creek. In upper Blackbird Creek, material Type J displays similar concentrations to Type A material, though, as shown on Figures 6-13a through 6-13m, there is far less of Type J material present in upper Blackbird Creek. Material Type K, materials from the tailings pipe breaks along upper Blackbird Creek, displayed the highest average and maximum arsenic concentrations observed on site, as shown on Table 2-9l.

In upper Blackbird Creek, the majority of materials sampled contained arsenic concentrations below the Preliminary Remediation Goal (PRG) for of 8500 mg/kg arsenic, with the exception of a few isolated areas as shown on Figures 6-13a through 6-13m. In

lower Blackbird Creek, the majority of materials sampled were also below the PRG of 4300 mg/kg, with the exception of a few isolated areas shown on Figures 6-13n through 6-13x.

2.6.2.9 West Fork Tailings Impoundment Surface Soils

Soil sampling was conducted of the surface of the West Fork Tailings Impoundment following completion of removal activities in 2001. Sampling was conducted along five transects equally spaced across the tailings impoundment with four samples collected along each transect as shown on Figure 2-12. The samples were composited by transect and analyzed using the XRF by Golder personnel in the field. Results from these samples are shown in Table 2-10.

Analytical results for all samples collected were below PRGs for arsenic for both upper and lower Blackbird Creek. The West Fork Transect 1 composite sample had the highest arsenic concentration (554 mg/kg) of all of the composite samples. The West Fork Transect 5 composite sample had a similar concentration of 533 mg/kg. The Transect 5 sample had the highest copper concentration of 650 mg/kg and the Transect 1 sample had a similar concentration of 640 mg/kg. The maximum iron concentration, 39,900 mg/kg, was detected in the Transect 1 sample.

2.7 Summary of Baseline Risk Assessments

Three risk assessments were conducted at the Blackbird Site to analyze the baseline risk, defined as the risk if no cleanup actions are taken at the site, and to assess the need for cleanup actions. Risk assessments provide a basis for determining the levels of chemicals that can remain at a site and still be protective to humans, and the aquatic and terrestrial ecosystems.

Summaries of the human health, aquatic and terrestrial risk assessments are provided below. Each risk assessment process involved the following steps:

- Data Evaluation – Data sets were compiled and chemicals of concern (COCs) were selected for further evaluation;
- Exposure Assessment – Exposure pathways and exposure scenarios were identified. Potential exposure to COCs was quantitatively evaluated;
- Toxicity Assessment – Potential adverse effects associated with exposure to COCs were evaluated; and
- Risk Characterization – The risk of adverse effects due to exposure was evaluated (e.g. cancer risk).

2.7.1 Human Health Risk Assessment

A site-wide baseline Human Health Risk Assessment (HHRA) was prepared for EPA by CH2M HILL (2002) to address potential risks to receptors that were not addressed in the two previously published reports for the Blackbird Mine Site (CH2M HILL 1998, 1999).

This site-wide baseline HHRA evaluated the potential for adverse health effects for persons who may contact contaminated surface soil, waste rock, tailings, sediment, or surface water at seven exposure areas:

1. Blackbird Mine;
2. Upper Blackbird Creek;
3. Lower Blackbird Creek;
4. West Fork Blackbird Creek;
5. Bucktail Creek;
6. South Fork Big Deer Creek/Big Deer Creek; and
7. Panther Creek (sediment and surface water exposures only).

For each exposure area and media, up to five COCs (arsenic, cobalt, copper, iron and manganese) were evaluated. Persons expected to contact contaminated media included workers, trespassers and/or recreational users.

The site-wide HHRA (CH2M HILL 2002) also included updated risk estimates for several of the properties along Panther Creek. These properties were evaluated in one of the previously published reports described above (CH2M HILL 1999). The updated risk estimates were based on samples collected during 2000. Conclusions of the HHRA are summarized below:

- Potential risks associated with exposure to contaminated surface soil/mine wastes, surface water and sediments do not exceed EPA's acceptable risk range for carcinogenic effects or for noncarcinogenic effects in any of the seven exposure areas;
- Although the risks from exposure to contaminated media in the exposure areas do not exceed the acceptable risk range, localized areas of elevated arsenic concentrations may present unacceptable acute or chronic risks based on assumed exposure conditions, and
- Overbank deposits at four private properties (Rogers 2, Rogers 3, Strawn and Rufe Pasture) exceed EPA's acceptable risk range for potential future residential exposure scenarios. Preliminary risk estimates for current and future exposure scenarios for the Hade property exceed EPA's acceptable risk range. Access for further sampling on the Hade property was denied by the property owner. Therefore, the EPA is unable to fully evaluate potential risks for this property.

2.7.2 Terrestrial Ecological Risk Assessment

A summary of the risk characterization prepared by Golder Associates Ltd. (Golder 2000b) is as follows.

2.7.2.1 Risk Characterization Results for Panther Creek Post Removal

The results of the post-removal residual risk characterization indicate that potential risks to individual deer mice, shrews and robins predicted in the pre-removal risk characterization have been reduced, especially within specific deposits in the Cobalt Townsite to Rip Rap Bar area of Panther Creek. A potential risk to receptors of concern (ROC) individuals or populations is not predicted based on post-removal chemicals of potential ecological concern (COPEC) concentrations at Rip Rap Bar.

2.7.2.2 Risk Characterization Results for Blackbird Creek

2.7.2.2.1 Pre-Removal

Individual

- Risks to individual deer mice, shrews and robins because of Tier 2 or Tier 3 hazard quotients greater than 1, and because of potential risks to individual deer mice, shrews, and robins because of changes in habitat suitability in 36 of 39 deer mice home ranges, 47 of 50.5 shrew home ranges and 5.8 of 6.2 robin home ranges, and
- Negligible risks to individual weasels, mule deer, elk, red-tailed hawk or northern goshawk because all Tier 2 and Tier 3 hazard quotients were less than 1 and changes in habitat suitability were all equivalent to less than one home range.

Sub-Populations

- Risks to sub-populations of deer mice and shrews if the "operational definition" of sub-population is used (limited to animals living solely within the narrow riparian zone). These risks would be lower if the boundary for the sub-population were extended beyond the riparian zone (see Section 6.6 of the TERA report (Golder 2000b) for additional discussion of the uncertainty associated with sub-population level risks);
- Negligible potential risks to sub-populations of robin because the total number of individuals potentially affected is very small (6) and highly unlikely to represent a sub-population, and
- No potential risks to sub-populations of all other ROC because less than one home range was predicted to have habitat suitability changes for any of these ROC, and because no Tier 3 hazard quotients were greater than 1.

Populations

- Negligible risks for populations of deer mice and shrews because it is unlikely that the number of individuals potentially affected by conditions in the riparian zone would affect birth rate or death rate sufficiently to pose a significant risk to the persistence of the overall valley populations;

- No population level risks were predicted for robins, weasels, ground squirrels, mule deer, elk, red-tailed hawk, or northern goshawk because no sub-population level risks were identified;
- There is some model uncertainty associated with analysis of habitat suitability and hazard quotients. However, the weight of evidence produced by the habitat suitability analysis, combined with the hazard quotients, the analysis of the association of ecological land classification (ELC) units with COPEC exposure categories, and the spatial extent of those exposure categories is sufficiently strong;
- The weight of evidence is sufficiently strong for plant community structure and small mammal population analyses. A large number of measures were employed and results were evaluated rigorously using epidemiological criteria. There was also coherence between univariate and multivariate statistical results. Furthermore, despite the presence of high natural variability and the influence of natural environmental gradients, responses along COPEC concentration gradients were detected;
- The weight of evidence for Blackbird Creek indicates that the overall habitat suitability and food resource quality of the Blackbird Creek riparian zone may not be adequate to support healthy sub-populations of deer mice and shrews (if the definition of sub-population is limited to animals living solely within the narrow riparian zone), but that population-level effects are not expected, and
- The prediction of negligible risks to populations of deer mice and shrews along Blackbird Creek is supported by the fact that deer mice and shrews were still present in the riparian zone during the sampling program in 1999, despite the exposure of deer mice and shrew populations in the area to mine-related deposits over several decades. However, this characterization is based in part on professional judgment because there are no demographic data to support the hypothesized boundaries for sub-populations and populations of deer mice and shrews.

2.7.2.2.2 Post-Removal

Removal actions at Blackbird Creek have reduced COPEC concentrations in some areas. However, potential risks to deer mouse, shrew and robin individuals and possible sub-populations of deer mice and shrews that feed exclusively within the riparian zone of Blackbird Creek may not have been significantly reduced as a result of the removal actions.

2.7.2.3 Risk Characterization Results for Bucktail, South Fork Big Deer and Big Deer Creeks

2.7.2.3.1 Pre-Removal

Individuals

- Risks to individual deer mice, shrews and ground squirrels from changes in habitat suitability and food resource quality along Bucktail and South Fork Big Deer creeks in 7, 9 and 2 home ranges, respectively;
- Risk to individual robins from changes in habitat suitability and food resource quality in an area equivalent to one home range along Bucktail Creek and South Fork Big Deer Creek. However, it is not realistic to assume that an individual robin would exclusively use the narrow riparian corridor as its home range;
- Potential risk to individual deer mice and shrews from changes in food resource quality in 36 deer mouse home ranges and 47 shrew home ranges along Big Deer Creek;
- Potential risks to 6 individual robin home ranges from changes in food resource quality in the section of the Big Deer riparian zone immediately downstream of the confluence with South Fork Big Deer Creek, although all Tier 3 HQs round to 1 or less, and
- No risks to individual weasels, mule deer, elk, red-tailed hawks or northern goshawks in Bucktail, S. Fork Big Deer or Big Deer creek riparian zones.

Sub-Populations and Populations

- Risks to sub-populations of deer mice and shrews along Big Deer Creek from changes in food resource quality if the "operational definition" of sub-population is used. The risk would be lower if it is assumed that the sub-population boundary would extend into adjacent habitat (see Section 6.6 of the TERA (Golder 2000b) for a discussion of the uncertainty associated with sub-population level risks). Furthermore, Tier 3 hazard quotients rounded to 1, and there were no significant changes in habitat quality;
- Negligible risks to populations of deer mice and shrews along Big Deer Creek because risks to sub-populations are likely to be very low;
- Negligible potential risks to sub-populations and populations of robins along Big Deer Creek because the number of home ranges affected by changes in food resource was too small to represent a sub-population and because there were no significant changes in habitat quality;
- No risks to sub-populations and populations of ground squirrels along Big Deer Creek because no risks to individuals were identified, and
- No risks to sub-populations and populations of weasels, mule deer, elk, red-tailed hawk and northern goshawk along Bucktail, S. Fork Big Deer or Big Deer creeks because no risks to individuals were identified.

2.7.2.3.2 Post-Removal

Removal actions at Bucktail Creek have reduced copper and arsenic concentrations in the section that was removed. However, benefits of the reduction in exposure will not significantly reduce the already negligible potential risk to ROC individuals and sub-

populations. Removal actions are not planned for South Fork Big Deer or Big Deer creeks.

2.7.2.4 Risk Characterization Results for Waste Rock Piles and the Tailings Impoundment Area

The qualitative analysis of information on the waste rock piles and tailings impoundment area indicated that:

- Although the waste rock piles may provide suitable breeding and hibernation sites for picas and ground squirrels, they contain no vegetation. Thus, the suitability of these areas with respect to food resources is low for all ROC evaluated in this study, which suggests that individuals would minimize the use of waste rock piles. Overall, the duration of exposure, the severity of effects from the exposure and the spatial extent of exposure relative to the home range size would be very low for all ROC;
- The surface layer of the tailings impoundment area has been used as a repository for mine-related deposit material that was removed from Panther and Blackbird Creeks. Thus, surface soils contain arsenic and copper concentrations within the moderate range (i.e., measured concentrations in 2001 ranged from 273 mg/kg to 554 mg/kg arsenic and 171 mg/kg to 650 mg/kg copper). Surface soils would contain lower concentrations than the underlying tailings. The area occupied by the tailings impoundment is greater than the home ranges of deer mice, shrews, robins, and ground squirrels. Thus, individuals could be exposed to COPECs in soil within the tailings impoundment area. However, these individuals are not likely to spend considerable amounts of time within the tailings impoundment due to a lack of suitable foraging habitat. Therefore, the duration of exposure and the severity of effects from exposure would be low. In addition, the spatial extent of possible exposure is low relative to the probable population size, especially in the West Fork Blackbird Creek area;
- The tailings impoundment area represents a small change in habitat quality (relative to total home range size), for weasels, ungulates and hawks, but does not represent a significant risk to populations of these ROC, and
- Based on the above lines of evidence, risks to ROC populations from the waste rock piles or tailings impoundment area are negligible.

2.7.3 Aquatic Ecological Risk Assessment

CH2M Hill prepared the Aquatic Ecological Risk Assessment (AERA) for the Blackbird Mine Site for EPA. The AERA focused on identifying and evaluating risks to the aquatic ecosystems of Blackbird Creek, Panther Creek, Bucktail Creek, South Fork of Big Deer Creek, and Big Deer Creek, in support of risk management decisions (CH2M Hill 2001a).

The potential risks to ecological receptors were predicted with a hazard quotient (HQ). The HQ is the ratio of the exposure point concentration (EPC) to the toxicity reference value (TRV) for water or sediment exposure, or the ration of the daily dose or intake for a

receptor to the appropriate dietary TRV. A HQ of 1 indicates a potential for risk, whereas a HQ below 1 indicates little potential for adverse effects. The following risk characterizations are summarized from the AERA (CH2M Hill 2001a) for each creek.

2.7.3.1 Blackbird Creek

According to the AERA (CH2M Hill 2001a), all the lines of evidence indicated that Blackbird Creek is potentially adversely affecting the aquatic ecosystem. Surface water HQs for the protection of aquatic life and salmonids are consistently greater than 10 for copper and cobalt during high flow. During low flow, HQs are occasionally less than 10, but are generally also greater than 10 for both copper and cobalt. The sediment HQs were greater than 50 to 100 for arsenic and copper, and 7 to 10 for cobalt. Copper sediment concentrations are two to five times higher than background in Blackbird Creek and cobalt sediment concentrations are about two times background. The sediment HQs, accounting for background conditions, are greater than 10 for arsenic and for copper and cobalt the sediment HQs based on background are only slightly greater than 1. The dietary HQs for copper and arsenic, based on sediment uptake, ranged from 7 to 12 for copper and 4 to 8 for arsenic. The benthic community data also indicate that there is the potential for adverse effects to the aquatic system since the downstream station does not resemble the reference stations. However, there has been an improvement in the water quality and the benthic community with the implementation of Early Actions.

2.7.3.2 Panther Creek

Panther Creek has shown significant improvements in water quality with the implementation of the Early Actions. The lines of evidence reflect this improvement; however, there is still potential for adverse effects to the aquatic ecosystem. Chronic and acute surface water HQs for copper during high flow range from 2 to 6. During low flow, surface water HQs are less than 1 for copper, indicating low potential for adverse effects during this period. Surface water HQs for cobalt range from 1 to 3 during both high and low flow periods for the protection of aquatic life. Based on protection of the salmonids, HQs range from less than 1 to 2. Sediment HQs for all metals ranged between 1 and 21, and metal concentrations were less than 1 to 6 times background. Background HQs exceeded 1. The highest HQs in sediments are found at station PASW-08A. The dietary HQs based on the uptake of sediments for copper were less than 1 and less than 1 to 4 for arsenic. The benthic data along Panther Creek are beginning to resemble the Panther Creek reference station. Panther Creek stations appear to have the healthiest communities compared to the other creeks that were sampled.

The comparison to background, the surface water sediment HQs, and the benthic community data suggest continuing effects on the aquatic ecosystem, although improvement had been observed due to implementation of Early Actions.

2.7.3.3 Bucktail Creek

Bucktail Creek continues to have poor water quality. HQs for surface water are the highest along this creek and range to over 2000 for copper. The ecological management goal for Bucktail Creek was to provide food for fish in downgradient areas if they drift downstream. However, based on the limited habitat conditions, and the low contribution of benthic invertebrates to the overall food supply in the drainage, it has been determined that Bucktail Creek does not contribute significantly to the overall achievement of the ecological management goals.

2.7.3.4 South Fork Big Deer Creek

The lines of evidence for the South Fork Big Deer Creek indicate there is continued potential for adverse effects. Surface water HQs were lower in 2000 than 1999; this may reflect continued improvements due to implementation of Early Actions. These improvements may also be partially attributable to the natural year-to-year variability in the system. Surface water HQs for copper range from 4 to 66 during high flow and up to 13 during low flow. Surface water HQs protective of aquatic life range from 2 to 9 during high flow and from 2 to 4 during low flow. Surface water HQs for the protection of salmonids are low, with a maximum HQ of 2 in 2000. Sediment HQs in the sample ranged from less than 1 to 203. Arsenic concentrations were 5 times higher than background conditions, and copper concentrations were 10 times higher than background conditions. The dietary HQs based on sediment uptake range from less than 1 to 9 for copper and are 3 or less for arsenic. The benthic community along South Fork Big Deer Creek continues to be impacted, with most of the indices evaluated at the downstream stations not resembling the reference station.

2.7.3.5 Big Deer Creek

The lines of evidence for Big Deer Creek indicate improvements in water quality. Surface water HQs for copper improved between 1999 and 2000 and ranged from 2 to 4. The improvement in surface water HQs between 1999 and 2000 may reflect the implementation of Early Actions. Surface water HQs for cobalt are below 1 for all the sampling events, indicating low potential for adverse effects due to cobalt. Sediment HQs ranged from less than 1 at the reference station to 12 at BDSW-01 for copper; HQs for arsenic, iron, and cobalt were less than 1 at the reference location and downgradient areas. Cobalt sediment concentrations were two times higher than background, and copper sediment concentrations were four times higher than background. The dietary HQs based on sediment uptake are 1 or less. The benthic community is beginning to resemble the upstream reference station for several indices. Based on the low dietary HQs and the uncertainty associated with establishing background upper tolerance limits (UTLs) for Big Deer Creek, it is unlikely that sediments are causing potential adverse effects to the aquatic system. The surface water HQs for copper, where there is less uncertainty, indicates the potential for continued adverse effects.

3. IDENTIFICATION OF REMEDIAL ACTION OBJECTIVES AND PRELIMINARY REMEDIATION GOALS

This section provides a description of potential applicable or relevant and appropriate requirements (Section 3.1), remedial action objectives (Section 3.2), preliminary remediation goals (Section 3.3), and a summary of the areas and volumes of impacted media exceeding preliminary remediation goals (Section 3.4).

3.1 Potential Applicable or Relevant and Appropriate Requirements

This section identifies and evaluates federal and state requirements that may be potentially applicable or relevant and appropriate requirements (ARARs) for response activities at the Blackbird site. Final ARARs for the Blackbird site will be determined by the EPA in the ROD.

In accordance with §121(d) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial actions must attain ARARs under federal or state environmental or siting laws, unless a waiver is granted pursuant to the requirements of 40 CFR 300.430 (f)(1)(ii)(C) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). A requirement is applicable if the specific terms of the law or regulations directly address the circumstances at a site. If not applicable, a requirement may nevertheless be relevant and appropriate if circumstances at the site are, based on best professional judgment, sufficiently similar to the problems or situations regulated by the requirements, and its use is well suited to the site. To be considered (TBC) information consists of non-promulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of potential ARARs; however, in some circumstances, TBCs will be considered by EPA along with ARARs in determining the remedial action necessary for protection of human health and the environment.

On-site remedial actions need to comply with the substantive requirements of ARARs, unless a waiver is invoked as discussed below. Section 121(e) of CERCLA states that administrative requirements such as federal, state or local permits (e.g., permit for direct discharge to surface waters) are not required for the portion of any response action conducted entirely on site. Off-site response actions must comply with administrative and substantive requirements that are applicable. With the possible exception of off-site activities to obtain construction materials, only on-site remedial activities are considered at the Blackbird site. The Blackbird site includes portions of Blackbird, West Fork Blackbird, Meadow, Bucktail, Big Deer, South Fork Big Deer, and Panther Creeks and other areas potentially requiring response actions. Response actions will utilize, to the extent practical, active existing facilities for construction materials.

Substantive requirements are requirements that pertain directly to actions or conditions in the environment. Examples of substantive requirements include quantitative health- or risk-based restrictions on exposure, activity restrictions, or technology based requirements. Administrative requirements are mechanisms used to facilitate implementation of the substantive requirements of a statute or regulation. Examples

include documentation requirements, permits, reporting, and recordkeeping requirements.

The EPA developed a two-volume guidance document for preparing ARARs titled *CERCLA Compliance with Other Laws Manual, Interim Final* (EPA 1988b, EPA 1989). This guidance document defines the three categories of ARARs, as follows:

> Chemical-specific requirements are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a contaminant that may be found in, or discharged to, the ambient environment.
>
> Action-specific requirements are usually technology- or activity-based requirements or limitations triggered by the response actions performed at the site.
>
> Location-specific requirements are restrictions placed on the concentration of hazardous substances or the conducting of activities solely because they occur in special geographic areas.

The EPA may waive ARARs and select a response action that does not attain the same level of cleanup as identified by ARARs. Section 121 of CERCLA as amended by the Superfund Amendments and Reauthorization Act (SARA) identifies six circumstances in which EPA may waive ARARs for on-site response actions. These six circumstances are:

- The response action selected is only a part of a total response action (such as an interim action), and the final remedy will attain the ARAR upon its completion. The Early Actions conducted at the Blackbird Site meet this condition;
- Compliance with the ARAR will result in a greater risk to human health and the environment than alternative options;
- Compliance with the ARAR is technically impracticable from an engineering perspective;
- An alternative response action will attain an equivalent standard of performance through the use of another method or approach;
- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances, and
- In the case of Section 104, Superfund-financed response actions, compliance with the ARAR will not provide a balance between protecting human health and the environment with the availability of Superfund money for response at other facilities.

Potential chemical-, location-, and action-specific ARARs are identified and discussed in this section. A summary of potential ARARs is presented in Table 3-1a. Detailed evaluation of potential ARARs typically occurs during the FS phase of the RI/FS process.

3.1.1 Chemical-Specific Requirements

A chemical-specific requirement sets concentration limits in various environmental media for specific constituents. Potential chemical-specific ARARs for the Blackbird site are provided in Table 3-1b. Chemical-specific requirements address exposure pathways that may include ingestion of soils, water, and biota; inhalation of particulates; and dermal contact with soils and water.

3.1.1.1 Federal Chemical-Specific Requirements

3.1.1.1.1 National Primary Drinking Water Standards (40 CFR 141)

These regulations, promulgated pursuant to the Safe Drinking Water Act [42 U.S.C. 300(f)] address contamination in community drinking water systems. The NCP identifies maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) established under the Safe Drinking Water Act as cleanup goals for groundwater and surface waters that are current or potential future sources of drinking water. These regulations are not applicable to the Blackbird site because surface and groundwater are not used for drinking water. However, the regulation may be considered relevant and appropriate because the Panther Creek Inn, located downstream of the Blackbird site, relies on groundwater from the shallow floodplain alluvial aquifer, which is in communication with surface waters.

On October 31, 2001, EPA announced that the arsenic standard for drinking water would be 0.010 mg/l, and that the new standard would be promulgated on February 22, 2002. However, the new standard will not go into effect for public drinking water systems until January 2006. The new standard of 0.010 mg/l will therefore be treated by EPA as a To Be Considered (TBC) standard. Table 3-1b presents the current MCLs and MCLGs for contaminants associated with the Blackbird site.

3.1.1.1.2 Federal Water Pollution Control Act (Clean Water Act)

The requirements of the Clean Water Act (CWS) establish chemical specific criteria and standards that may be relevant and appropriate for surface water cleanup. These CWA ARARs include the following:

- Water Quality Standards (40 CFR 131) (National Toxics Rule (NTR) – Pursuant to Section 303(c)(2)(C) of the Clean Water Act, EPA established numeric water quality criteria for protection of human health and aquatic organisms for 12 states, including Idaho. EPA withdrew the NTR for Idaho on April 12, 2000, because the state promulgated water quality criteria for specific pollutants (IDAPA 58.01.02) by adopting the NTR criteria by reference (65 FR 19659-19662). The NTR is not applicable but may be relevant and appropriate, and
- Ambient Water Quality Criteria: Pursuant to Section 304 of the Federal Clean Water Act (CWA), EPA has developed Ambient Water Quality Criteria (AWQC). These water quality criteria are updated periodically to reflect the latest scientific knowledge. These standards are used in implementing a number of environmental programs, including setting discharge limits in National Pollution

Discharge Elimination System (NPDES) permits. These criteria provide guidance for states in adopting water quality criteria. The State of Idaho has adopted the federal water quality criteria, but has not updated these criteria to include the most recent criteria for copper. Since these water quality criteria are utilized only as guidance, they are not applicable but may be relevant and appropriate for actions that involve surface water. However, as discussed in Appendix C, the AWQC for iron may not be relevant and appropriate for Panther Creek.

3.1.1.1.3 National Pollutant Discharge Elimination System Permit (NPDES), (40 CFR 122 through 125, 40 CFR 440)

These regulations establish a national permit program for discharges to waters of the United States. The regulations identify specific effluent limitation guidelines for discharges within specific industrial categories. The NPDES regulations also require, where a discharge causes or has the reasonable potential to cause or contribute to an excursion of water quality standards, that effluent limitations be established to meet water quality standards. Such water quality-based effluent limits are calculated based on achieving water quality criteria in the receiving water.

NPDES discharges are required to meet best practical control technology currently achievable (BPT) or best available technology economically available (BAT). Effluent guidelines and standards for ore mining and milling point source categories are promulgated under 40 CFR 440. Subpart J of this section presents effluent guidelines for mines that produce copper, lead, zinc, gold, silver, or molybdenum bearing ores. The Blackbird site NPDES effluent limits are consistent with these guidelines.

All point source discharges, including those associated with the water treatment plant and the West Fork underdrain culvert, must meet the substantive requirements of the NPDES regulations. Under CERCLA, an NPDES permit is not required for on-site actions that are necessary for implementation of the response action where the discharge receiving water is in the area of contamination or other areas that are in close proximity. Current discharges from the Blackbird site water treatment plant are regulated under an NPDES permit, #ID-002525-9 which expired on October 30, 1989. A new permit application was submitted to EPA; however, EPA deferred action on the new permit application until the RI/FS and ROD process. The NPDES permit will not be renewed for treatment of water covered under these CERCLA actions. Instead, the substantive NPDES requirements will be applied to the point source discharges. Both technology and water quality-based requirements in federal and state regulations must be evaluated in the process of establishing these discharge limits. National technology-based limits may be applicable if they are more stringent than the water quality-based requirements. The relevant technology-based limits are provided in Table 3-1b.

To meet the water quality-based requirements, the point source discharges from the water treatment plant and the West Fork underdrain culvert must be limited so as to avoid causing or contributing to exceedances of the water quality criteria established for the designated beneficial use for Blackbird Creek of secondary contact recreation (not cold water biota) and for the designated beneficial use for Panther Creek of cold water

biota. In accordance with the NPDES program, the water quality based requirements are established by calculating the amount of pollutant loading from Blackbird Creek that can mix with Panther Creek in a manner that is protective of cold water biota. The State of Idaho guidelines provide for a maximum mixing zone of 25% of the width of the receiving stream; however this can be expanded through site-specific mixing zone analysis. Appendix B provides the details of the mixing zone analysis in Panther Creek. A final determination regarding the acceptability of the mixing zones in Panther Creek is pending.

EPA stormwater requirements may be applicable to the Blackbird site. Regulations in 40 CFR Section 122.26 establish NPDES permit requirements for stormwater discharges associated with industrial activities.

3.1.1.2 State Chemical-Specific ARARs

The drinking water standards and the water quality standards are the only State of Idaho contaminant-specific ARARs identified for the Blackbird site.

3.1.1.2.1 State of Idaho Drinking Water Standards, Idaho Department of Health and Welfare, Title 1, Chapter 8

The purpose of these regulations is to control and regulate the design, construction, operation, maintenance, and quality of public drinking water systems in order to protect public health. These regulations are essentially equivalent to the federal primary and secondary drinking water regulations of 40 CFR 141 and 40 CFR 143, respectively. Idaho State MCLs for constituents at the Blackbird site are presented in Table 3-1b. These regulations are not applicable but may be relevant and appropriate to the Blackbird site. Refer to Section 3.1.1.1.1, federal drinking water regulations, for additional discussion.

3.1.1.2.2 Surface Water Quality Standards and Wastewater Treatment Requirements, Idaho Department of Health and Welfare, Rules and Regulations, Division of Environment, Title 1, Chapter 2

This chapter designates uses and water quality standards, which are protective of those uses. Idaho has promulgated surface water quality criteria, which are listed in IDAPA 58.01.02.210. These regulations are applicable to the Blackbird site to the extent the site impacts water quality. These regulations authorize restrictions on discharge of wastewaters that may adversely affect water quality and include an antidegradation policy. The Idaho water quality criteria for constituents present at the Blackbird site are presented in Table 3-1b.

It should be noted that the water quality criteria adopted by the State of Idaho are based on the Federal Ambient Water Quality Criteria (AWQC) as of 1992, and have not been updated to reflect changes made to the AWQC since 1992. The state water quality standard for arsenic for secondary contact recreation use (IDAPA 58.01.02.210.01) was based on the federal drinking water MCL of 50 ppb. As discussed in Section 3.1.1.1.1, EPA announced on October 31, 2001 that the federal MCL will be changed to 10 ppb.

The new standard will go into effect for public drinking water systems in 2006. However, the State of Idaho has not changed the state water quality standard to date and it is not known if and when the standard may be revised. Therefore, the State water quality standard may not be applicable or relevant and appropriate. However, the human health risk assessment (CH2M Hill 2002) did not show a risk from arsenic in surface water for recreational use. Where there are differences between the Idaho criteria and the Federal criteria, the Federal criteria may be considered relevant and appropriate.

Water classifications (i.e. beneficial use designations) are based on the uses that the water body is presently suited for or intended to become. Potential use categories identified for Panther Creek from Blackbird Creek to the mouth and Blackbird, Bucktail, South Fork Big Deer, and Big Deer Creeks are presented in Table 3-1c. According to Idaho Code (IDAPA 58.01.02.03.114), all named and unnamed tributaries to a water body are considered a single unit unless otherwise designated. Therefore, Meadow Creek, as a tributary of Blackbird Creek, is subject to the same use designations as Blackbird Creek. Blackbird Creek (downstream of the clean water reservoir) has been designated for secondary contact recreational use only, and Bucktail Creek has no use designations.

The use designation for Blackbird Creek was based on a use attainability analysis (UAA) prepared by the IDEQ (Mebane 1997) that was approved by EPA. Under the Clean Water Act, states are required to conduct a UAA whenever they designate a use for a water body that does not include the "fishable-swimmable" goals of the Act. The UAA concluded that salmonid spawning and coldwater biota are not existing uses for lower Blackbird Creek (downstream of the clean water reservoir). The UAA further concluded that with the current state of the civil engineering practice, Blackbird Creek could not in the foreseeable future be restored to meet or even approach meeting water quality standards for copper.

A UAA was also prepared for Bucktail Creek (Mebane 2002). As noted in the UAA, Bucktail Creek is too small to have any real likelihood of contact recreation such as wading, fishing, and swimming. Physical conditions related to the natural features of Bucktail Creek, such as steep gradient and small size and flow, likely precluded its pre-mining use by fish. In addition, limited habitat conditions result in minimum potential for significant contribution of benthic invertebrates to the overall food supply in the Big Deer Creek drainage. The UAA concluded it is unlikely that copper concentrations will decline to the point of meeting aquatic life criteria in the foreseeable future, and that sources of metals that preclude the attainment of use cannot be feasibly remedied.

40 CFR 131.20 requires states to review updated information on waters without aquatic life use designations at least every three years to determine if aquatic life uses are attainable. After a final remedy is selected and after CERCLA remedial actions that affect Blackbird Creek are implemented over the next few years, new information will be become available and the UAA may need to be re-examined. Should aquatic life uses ultimately be attainable for at least parts of the stream, future use designations may need to be changed to reflect this.

3.1.2 Action-Specific Requirements

Action-specific ARARs are requirements triggered by specific response actions at the site. This section identifies potential action-specific ARARs for response activities at the Blackbird site. Additional discussion of the potential ARARs specific to the alternatives identified may be found in Chapter 7.

3.1.2.1 Federal Action-Specific ARARs

3.1.2.1.1 National Pollutant Discharge Elimination System (NPDES) Permit Regulations (40 CFR 122 to 125)

These requirements are applicable because discharges to surface waters occur and are anticipated to continue. Under Part 301(b) of the Clean Water Act, all direct discharges to waters of the U.S. shall meet technology-based requirements. Best practical control technology currently achievable (BPT) will be used for toxic pollutants. Best management practices (BMPs) are required for any stormwater discharge containing pollutants listed as toxic or hazardous. BMPs for sediment control during construction activities will be implemented. BMPs for construction may include some of the following but are not limited to: limiting the extent of disturbed areas, diversion of runoff from undisturbed areas away from disturbed areas, disturbing the minimum area possible, and where feasible, incorporating concurrent reclamation, and collection and treatment of runoff from disturbed areas.

3.1.2.1.2 Occupational Safety and Health Act General Industry Standards (29 CFR 1910) and OSHA Construction Industry Standards (29 CFR 1926)

EPA does not consider the Occupational Safety and Health Act of 1970 (OSH Act)(20 USC 333 as amended) and occupational health and safety regulations promulgated pursuant to it, as "environmental protection" standards subject to consideration as ARARs. However, 40 CFR 300.150 specifies that all response activities are to comply with the provisions of response action worker safety and health standards in 29 CFR 1910.120. The preamble to the NCP (at 55 FR 8669-80) states Occupational Safety and Health Administration (OSHA) regulations are non-ARAR because they are specifically "designed to cover occupational exposures." This preamble requirement to comply with OSHA [which cannot be waived as allowed under CERCLA 121 (d) for ARARs] is one of the reasons it is considered non-ARAR. Therefore, response actions must also meet the requirements, standards, and regulations of the Occupational Safety and Health (OSH) Act of 1970 (29 U.S.C. 651 et seq.) and of state laws with plans approved under Section 18 of the OSH Act (state OSH laws) where applicable. Among the federal OSH requirements specifically identified in 40 CFR 300.150 are the general industry standards under 29 CFR 1910, and construction standards under 29 CFR 1926. A site specific Health and Safety Plan that incorporates OSHA requirements has been implemented for the Blackbird site. The plan defines protocols to be followed during investigation, remediation and reclamation activities at the Blackbird site.

The preamble to the NCP also notes "that there are some standards in OSHA that set contaminant levels in the work place... that may also be relevant - although not

applicable - to determination of a cleanup level at a CERCLA site (due to the absence of other standards). In such a case, those standards may be included among the requirements "To be considered" (TBCs). An OSHA action level of 05 $\mu g/m^3$ (time weighted average) has been established for airborne inorganic arsenic concentrations.

3.1.2.1.3 Federal Mine Safety and Health Act of 1977, Title 30 USC Chap. 22

The purpose of this law is the protection of all workers in the mining industry, to improve working conditions and practices in order to prevent injury, occupational disease, and death originating from working in the industry. Pursuant to this Act, federal safety and health regulations for metal and non-metal mines were promulgated under 30 CFR 56 for surface mining and under 30 CFR 57 for underground mining. These standards are non-ARAR because they are worker protection standards (See Section 3.1.2.1.2).

3.1.2.1.4 Guidelines for Land Disposal of Solid Wastes, (40 CFR 241)

The standards in this regulation delineate the minimum levels of performance required for land disposal of solid waste. The guidelines represent environmentally acceptable operational practices for disposal of sanitary and municipal wastes. The regulation specifically exempts mining wastes. The EPA guidelines established under 40 CFR 241 are not applicable nor relevant and appropriate to the Blackbird site because no municipal or sanitary wastes of the type covered by the guidelines will be disposed at the site and mining waste is exempted.

3.1.2.1.5 Resource Conservation and Recovery Act (RCRA), Subtitle C Regulations, (40 CFR 260-268)

The Resource Conservation and Recovery Act (RCRA) regulations promulgated pursuant to Subtitle C provide requirements for the safe management of hazardous waste. These regulations address the generation, transport, storage, treatment, and disposal of hazardous waste. Idaho State has adopted, by reference, the federal RCRA regulations. The EPA has approved the state program and has delegated the majority of RCRA regulatory authority to the State.

RCRA identifies solid wastes regulated as hazardous wastes in 40 CFR 261.3. Site soils, waste rock, and all wastewater treatment plant sludge are not listed wastes under RCRA. Solid wastes generated from the extraction, benefaction, and processing of ores (restricted to selected activities) are excluded from this listing (40 CFR 261.4). All testing of these materials to date indicates that these materials also do not designate as characteristic waste using the toxicity characteristic leaching procedure (TCLP). Therefore, RCRA Subtitle C regulations are not applicable nor relevant and appropriate to response activities at the site.

3.1.2.1.6 RCRA Subtitle D Regulations, (40 CFR 257 - 258)

The RCRA regulations under 40 CFR 257, Criteria for Classification of Solid Waste Disposal Facilities and Practices define criteria for waste disposal facilities and practices so that adverse affects to the environment and human health are minimized. This regulation is not applicable nor relevant and appropriate because the regulation exempts mining overburden at the mine site and response actions at the Blackbird site will not require construction or operation of sanitary landfills or open solid waste dumps.
The RCRA regulations in 40 CFR 258, Criteria for Municipal Solid Waste Landfills establish the national criteria for the location, design, operation, cleanup, and closure of municipal landfills. These regulations are not applicable nor relevant and appropriate to the Blackbird site because there are no municipal landfills at the Blackbird mine site.

3.1.2.1.7 New Source Performance Standards, (40 CFR 60)

The New Source Performance Standards (NSPS) are federal emission standards established for criteria and designated pollutants for specific source categories defined in the regulation. The Clean Air Act, as amended (CAA) specifies that states are to develop and submit for EPA approval, procedures for implementing NSPS requirements. EPA has approved the State of Idaho's NSPS program. Listed source categories are required to comply with NSPS for new, modified or reconstructed sources. Source categories specified in the federal program represent a wide variety of industrial and manufacturing processes. Response actions at the Blackbird Site will not include any of the regulated source categories and therefore, this regulation is not applicable nor relevant and appropriate.

3.1.2.1.8 National Emission Standards for Hazardous Air Pollutants (NESHAPs), (40 CFR 61)

The national emission standards for hazardous air pollutants are described in National Emission Standards for Hazardous Air Pollutants (40 CFR 61). These regulations list substances designated as hazardous air pollutants (HAPs) and consider the possible serious health affects with ambient air exposure. Title III of the 1990 amendments to the CAA directed EPA to identify emission standards for 189 toxic air pollutants based on current technology used in industry. This new list of substances replaces the previous Section 112 hazardous air pollutants for which NESHAPs were developed. The NESHAPs control emission of HAPs from specific source categories identified in the regulation. None of the constituents of concern at the Blackbird site are on the list of 189 HAPs. The NESHAPs regulations are not applicable nor relevant and appropriate to response activities at the Blackbird Site because response actions will not emit any of the hazardous air pollutants or include any source categories where NESHAPs have been developed.

EPA proposed in 59 FR 51913 (October 13, 1994) NESHAPs for the source category of off-site waste and recovery operations. The proposed rules will only apply to "major sources" (emit greater than 10 tons/yr. of a single HAP or 25 ton/yr. of any combination of

HAPs) and specifically exempt equipment used exclusively to manage waste generated at the affected site.

3.1.2.1.9 USFS Regulations for Public Land Closures (36CFR261.50)

Paragraph (a) of this regulation authorizes the Regional Forester to issue orders which close or restrict use of described areas within the area over which he or she has jurisdiction. An order may close an area to entry or may restrict the use of an area by applying any or all of the prohibitions authorized in the Subpart.
Paragraph (b) of this regulation authorizes the Regional Forester to issue orders which close or restrict the use of any National Forest System road or trail within the area over which he or she has jurisdiction.

This regulation is applicable for any alternative that requires closures or use restrictions of areas, roads, or trails on National Forest System lands.

3.1.2.1.10 USFS Regulations for Special Use Authorization (36CFR251.53)

This regulation provides authority to the Chief of the Forest Service, or other Agency official to whom such authority is delegated to issue special use authorizations for National Forest System land. Such special use authorizations may include permits, leases, and easements for; road rights-of-way; for reservoirs, canals, ditches, pipes, and pipelines, for the impoundment, storage, and transportation of water; and for system and related facilities for generation, transmission, and distribution of electricity. This regulation is applicable for remedial actions that require any of these facilities on National Forest System land.

3.1.2.2 State Action-Specific ARARs

3.1.2.2.1 Safety of Dams, State of Idaho Rules and Regulations, Chapter 17, Section 42-1714, Idaho Code and provisions of Section 42-1709 through 42-1721, Idaho Code

These requirements are intended to provide a guide for the establishment of acceptable standards for the construction of and safety evaluation of new or existing dams. These rules are considered applicable to response activities at the Blackbird site that include the use of dams for surface water impoundment because these rules apply to all new dams, to existing dams being altered or repaired and maintenance activities to existing dams as provided in the rules. As such, these rules are applicable to the 7000 dam and 7100 dam, which were constructed in compliance with these regulations as part of the Early Action activities.

3.1.2.2.2 Idaho Mine Tailings Impoundment Structure Rules and Regulations, Chapter 17, Section 42-1714, Idaho State Code

These rules and regulations apply to structures constructed, enlarged, or altered after July 1, 1978, used for the purpose of storing mine tailings slurry, and are more than 30 ft. in height from toe to the maximum crest. These regulations are not applicable to the Blackbird site because no mineral processing will be conducted during response activities

that meet the definition of mine tailings slurry. The regulation may be relevant and appropriate to response actions that include disposal of additional materials and alteration of the West Fork Tailings Impoundment.

3.1.2.2.3 State of Idaho Stream Channel Alteration – IDAPA 37, Title 03, Chapter07

The objectives of regulations under IDAPA 37, Title 03, Chapter 07 are to protect stream channels and their associated environments against alteration so that fish and wildlife habitat, aquatic life, recreation, aesthetics and water quality are also protected. Substantive portions of these requirements are applicable to response actions at the Blackbird site that involve alteration of stream channels.

3.1.2.2.4 Idaho Air Pollution Control Regulations, Title 1, Chapter 1, Idaho Code

These rules and regulations were developed to comply with the requirements of the federal Clean Air Act and are intended to control or abate air pollution. A Notice of Proposed Rules, Docket 16-0101-9303 announced proposed repeal, amendment, adoption, and renumbering of the air pollution control regulations. Response activities at the Blackbird site may have the potential to generate dust and particulate emissions and are not anticipated to emit any other air pollutants. These requirements are not applicable or relevant and appropriate to response activities at the Blackbird site because response activities do not meet the definition of significant emissions requiring regulation. The significant quantity threshold for particulates is defined as 25 tons per year and the significant threshold for PM-10 (particulates less than 10 microns in diameter), is set at 15 tons per year.

3.1.2.2.5 Solid Waste Management Regulations and Standards, Idaho Department of Health and Welfare Rules and Regulations, Title 1, Chapter 6

The state solid waste management and waste tire disposal regulations are presented in IDHW, Title 1, Chapter 6, Sections 01.6001 et. seq. These regulations specify general solid waste management site operations requirements for landfills, incinerators, compost plants, transfer stations, and recycling operations. These regulations are not applicable, nor relevant and appropriate to the Blackbird site because response actions will not require operation of any solid waste facility covered by the standard.

3.1.2.2.6 Rules, Regulations and Standards for Hazardous Waste, Idaho Department of Health and Welfare Rules, Title 1, Chapter 5

The Idaho Department of Health and Welfare, Division of Environmental Quality has adopted and incorporated by reference, the federal rules, and regulations for the management of hazardous wastes. The EPA has delegated the majority of RCRA enforcement authority to the state. Site soils, waste rock, and wastewater treatment plant sludge are not listed wastes under RCRA and all analytical testing of these materials to date indicates that they also do not designate as characteristic waste using the toxicity characteristic leaching procedure (TCLP). Because of the "Bevill" exclusion, mining wastes are generally exempt from RCRA Subtitle C requirements. Therefore, the

State of Idaho Rules, Regulations, and Standards for hazardous waste are not applicable nor relevant and appropriate to response actions at the Blackbird site.

3.1.3 Location-Specific Requirements

Location-specific ARARs identify requirements that are dependent on the location of the site such as the presence of wetlands or other sensitive habitats, historical and archeological resources or recreational resources.

3.1.3.1 Federal Location-Specific ARARs

3.1.3.1.1 National Historic Preservation Act (16 USC 470)

This law requires that historically significant properties be protected. The Act requires that agencies undertaking projects evaluate impacts to properties listed on or eligible for listing on the National Register of Historic Places. The National Register of Historic Places is a list of sites, buildings, or other resources identified as significant to United States history. Cultural resource surveys were performed for the Blackbird site as part of the environmental impact statement prepared by the U.S. Forest Service in 1982; in 1993 during surveys for borrow sites on Blackbird Creek, and in 1998 for the Analysis of Early Action Alternatives for the Panther Creek Inn Area. No sites listed on the National Register were identified. No other historic properties were discovered at the Blackbird site during the surveys (ERT 1982, Golder 1998a).

3.1.3.1.2 Endangered Species Act of 1973 (16 USC 1531 et seq.)

This law and implementing regulations identify threatened and endangered species and establishes requirements necessary for their protection. Substantive compliance with the Endangered Species Act means that a determination must be made as to whether a threatened or endangered species, or its critical habitat, will be affected by a proposed response action. If so, the action must be avoided or appropriate mitigation measures taken so that the action does not affect the species or its critical habitat. One of the primary purposes of the Early Actions, which have been implemented, and the actions being evaluated in this FS is to improve water quality for aquatic biota and to allow reintroduction of the threatened species discussed in the following paragraph.

The Snake River spring/summer and Snake River fall chinook salmon (*Onchorhynchus tshawytscha)* and the Snake River summer steelhead (*Onchorhynchus mykiss)* are presently listed as a threatened species and proposed for classification as endangered by the National Marine Fisheries Service (NMFS). In addition, the US Fish and Wildlife Service (USFWS) has designated the Snake River bull trout (*Salvelinus confluentus)* as threatened. Each of these species is known to occur within the Panther Creek drainage basin (Mebane 1994). The Middle Fork Salmon River-Panther Creek hydrologic unit has been designated as critical habitat for the Snake River Spring/summer chinook salmon.

The gray wolf (*Canis lupus*), an endangered species, has been reintroduced to Idaho and has been reportedly observed in the area. This species was not identified as an ecological receptor of concern in the Terrestrial Ecological Risk Assessment (Golder 2000b).

Federal and state review of threatened and endangered species will be conducted as part of the Section 7 consultation process, and EPA will prepare a Biological Assessment as part of the ROD process.

3.1.3.1.3 Migratory Bird Treaty Act of 1972 (Title 16, USC 703-712)

The Migratory Bird Treaty Act makes it unlawful to pursue, hunt, take, capture, kill, possess, sell, barter, purchase, export, import, transport or receive any migratory bird or any part of a migratory bird. EPA has indicated that this act may be relevant and appropriate at this site.

3.1.3.1.4 Section 404 of the Clean Water Act (40 CFR 230, 33 CFR 320-330)

Sections of the Clean Water Act and associated regulations prohibit discharge of dredge or fill material to wetlands. Protection of wetlands is one of the primary goals of the U.S. Army Corps of Engineers Section 404 permit program. The Army Corps of Engineers Section 404 permit program provides guidelines for the identification of wetlands and implements protective requirements for actions involving wetlands. Field surveys will be performed as necessary to identify wetlands and degradation or destruction of wetlands will be avoided to the extent practicable. Section 404 is applicable if jurisdictional wetlands are impacted and appropriate mitigation would be developed, in consultation with the Army Corps of Engineers.

Under CERCLA, onsite response actions do not need to meet administrative requirements such as permit acquisition; however, substantive requirements for wetlands protection are applicable for actions involving wetlands. The Army Corps of Engineers will be involved in determining if mitigation of potential impacts is required.

3.1.3.1.5 Executive Order 11990, Protection of Wetlands

This Executive Order requires the protection of wetlands from destruction and specifies that construction activity in the area of wetlands be minimized. The Executive Order directs federal agencies to implement these considerations through existing federal regulations when carrying out agency programs. EPA policy for implementing this Executive Order is promulgated in 40 CFR 6 and are applicable to the government agencies. Wetlands as defined in the Corps of Engineers *Wetlands Delineation Manual* (U.S. Corp. of Engineers 1987) may be present in the riparian zone of area creeks and streams. Federal lands compose a portion of the site and therefore this Executive Order may be applicable to response actions at the Blackbird site.

3.1.3.1.6 Executive Order 11988, Floodplain Management

Executive Order 11988 requires federal agencies conducting activities to reduce the risk of flood loss, impacts of floods on human health and safety, and to restore/preserve the natural and beneficial values served by floodplains. EPA policy for carrying out the provisions of this Executive Order is promulgated in 40 CFR 6. The requirements of this Executive Order are applicable to response actions at the Blackbird site because portions of the site are federal lands and involve floodplains along area creeks and streams.

3.1.3.1.7 The Wilderness Act, 16 USC Section 1131 et seq.

The Wilderness Act created the national wilderness preservation system to preserve the character of natural areas for future use. The Frank Church River of No Return Wilderness is the nearest national wilderness and it is greater than 5 miles from the Blackbird site. This statute is not applicable nor relevant and appropriate to response actions at the Blackbird site because no national wilderness areas are impacted.

3.1.3.1.8 Fish and Wildlife Coordination Act of 1934, 16 USC Section 661 et seq.

This statute requires federal agencies to consider the effect projects may have on fish and wildlife and to mitigate loss or damage to these resources. One of the primary purposes of the Early Actions, which have been implemented, and the actions being evaluated in this FS is to improve water quality for aquatic biota and to allow reintroduction of the threatened species. Evaluation of risks to terrestrial wildlife has also been conducted as discussed in Section 2.7.2. This statute is applicable to the Blackbird site and state and federal fish and wildlife agencies will be consulted.

3.1.3.2 State Location-Specific ARARs

3.1.3.2.1 State Historical Society, Chapter 41, Section 67-4127, Idaho State Code

Pursuant to Section 106 of the National Historic Preservation Act (NHPA) and implementing regulations, 40 CFR 800, the Director of the State Historical Society is designated as the Historic Preservation Officer for the State of Idaho. Upon notification, the Historic Preservation Officer will determine if significant cultural resources are located in the area of the Blackbird site. If significant cultural resources are identified, response actions will comply with the substantive portions of the NHPA. Cultural resource surveys were performed for the Blackbird site as part of the environmental impact statement prepared by the U.S. Forest Service in 1982; in 1993 during surveys for borrow sites on Blackbird Creek, and in 1998 for the Analysis of Early Action Alternatives for the Panther Creek Inn Area. No sites listed on the National Register were identified. No other historic properties were discovered at the Blackbird site during the surveys (ERT 1982, Golder 1998a).

3.1.4 Other Criteria and Guidance

In addition to the listed ARARs, there are other federal and state criteria, advisories, and guidance that can be considered in determining the appropriate degree of remediation for Blackbird site.

3.1.4.1 Forest Service Policies

The US Forest Service has developed requirements, which apply to activities conducted on National Forest lands. Because these policies are not promulgated regulations but are invoked by Executive Order they are not ARAR under CERCLA but have the status of a TBC. Policies which potentially need to be considered for response actions at the Blackbird site if these actions are conducted on National Forest lands include:

FSM 7400 - Public Health and Pollution Control Facilities
FSM 7500 - Water Storage and Transmission

FSM 7400 addresses requirements to comply with requirements of the federal clean water act and NPDES requirements for wastewater treatment facilities. FSM 7500 addresses requirements for design, review, and approval of dams and transmission facilities to ensure safety. As a general policy the Forest Service will not duplicate reviews performed by the State or other agencies if those reviews meet Forest Service objectives and standards.

3.2 Remedial Action Objectives

The process for determining remedial action objectives (RAO) was presented in *Remedial Action Objectives and Preliminary Remediation Goals for the Blackbird Mine Site* (CH2M HILL 2001b). RAOs provide a general description of what clean-up will accomplish. Blackbird Site RAOs developed by EPA are presented in Table 3-2. The Blackbird Mine Site Group (BMSG) provided extensive comments to EPA on the human health and aquatic ecological risk assessments. Many important comments and issues remain unresolved in EPA's final risk assessments, the RAO/PRG memorandum, and the cobalt position paper. Examples of these issues include EPA's establishment of unrealistic ecological management goals and RAOs for Blackbird Creek and South Fork Big Deer Creek and EPA's selection of PRGs for arsenic, cobalt, and copper in sediments and cobalt in surface water without adequate evidence that the PRGs need to be met for protection of aquatic life. The BMSG preserves these objections. However, the BMSG has proceeded with this FS in hopes that it will be possible to reach agreement on a final action even if agreement on the specific objectives is not obtained.

RAOs are considered to be a starting point in the remedial process. It is therefore not always necessary to identify remedial actions to address all of the RAOs. For instance, the human health risk assessment might determine that there is no risk to human receptors from ingestion of surface waters. This would mean that a PRG for surface waters from a human health standpoint would be unnecessary. Thus, EPA's RAO (listed under the Surface Water media in Table 3-2) to "prevent human receptors from direct

contact with surface water containing contaminants of concern in excess of the PRGs" would in essence already be met. Remedial actions would therefore not need to be developed to address surface water ingestion by humans.

3.3 Preliminary Remediation Goals

EPA's Preliminary Remediation Goals (PRGs) for the Blackbird Site for each drainage, media, and chemical of concern (COC) are presented in Table 3-3. The process for determining these PRG values, which are based on the site RAOs, was presented in the Remedial Action Objectives and Preliminary Remediation Goals for the Blackbird Mine Site (CH2M HILL 2001b). EPA's PRGs presented in Table 3-3 address potential risks within the site drainages based on the exposure assumptions as presented in the Site-Wide Human Health Risk Assessment, the Aquatics Ecological Risk Assessment and the Terrestrial Risk Assessment (CH2M HILL 2002, 2001a; Golder 2000b). For each PRG, the risk (human health or aquatic) governing the set PRG value is noted.

The BMSG has provided EPA with extensive comments (BMSG 2001a and 2001b) and does not agree with many aspects of the aquatic risk assessment that resulted in PRGs for sediment and water quality. Even though the BMSG does not agree with EPA's PRGs, they were used as guides in the development and evaluation of alternatives for site cleanup presented in this FS. The RAO/PRG memorandum stated that the selection of numerical PRGs involved both risk assessment and risk management for each medium and for all potential receptors. Risk assessment is the scientific process for evaluating the nature and magnitude of potential threats to human health and the environment. Risk management is the decision-making process that incorporates the results of risk assessment, technological feasibility, economic considerations, statutory requirements, public concern, site-specific conditions, and other factors to arrive at a decision on an acceptable cleanup level. At the completion of this FS, additional risk management decisions will be incorporated to establish the final remediation goals that will be included in the Record of Decision (ROD) for the site. EPA's PRGs presented in Table 3-3 are therefore subject to change following the FS process.

Although risks for some terrestrial sub-populations do exist, actions or alternatives based on calculated terrestrial PRGs have not been recommended (CH2M HILL 2001b). Habitat in the Blackbird Creek riparian area is steeply incised and makes up a small portion of total terrestrial habitat within the greater Blackbird Mine area. There are no threatened or endangered terrestrial species within the drainages and impacts are not seen on species at higher levels in the food chain. The EPA RAO/PRG memorandum states that PRGs based on human health will aid in the reduction of overall exposure and risks for terrestrial ecological receptors and ultimately reduce their exposure to site contaminants. Consequently, if actions or alternatives are implemented based on PRGs for human health or on contaminant remobilization potential, the resulting risks to small mammals are likely to be acceptable, and no remedial actions to address risks to these terrestrial receptors would be required.

A PRG for the Blackbird Creek instream and overbank materials that may become mobilized during high flow events has not been established. Currently, there is no

known method to predict the concentrations of the COCs in the mobilized materials that might be deposited downstream. Determination of those Blackbird Creek materials that will require action will use a qualitative approach outlined in the PRG report (CH2M Hill 2001b). If this evaluation results in a determination by EPA that there is a reasonable risk of mobilization of specific instream sediments or specific overbank deposits during the 500-year design event, and that there is a reasonable risk that those materials pose a risk of being deposited in downstream areas at concentrations that exceed the PRGs established for the downstream areas, action will be required.

3.4 Description of Impacted Media Exceeding PRGs

This section describes the impacted media (surface water, sediments, and soils), which exceed PRGs. Information on sources of metals loading and their relative contribution to the overall loading at the site are presented in Figures 2-6a through 2-6c.

3.4.1 Mine Site (Areas of Early Actions)

3.4.1.1 Springs and Seeps in Upper Meadow Creek

RAOs and PRGs have not been established for Meadow Creek. However, metals loading from Meadow Creek remains that contributes to exceedances of PRGs downstream in Blackbird and Panther Creeks. The area of seepage downstream of the 7800 waste rock dump that is entering the 7100 Bypass is a source area of remaining metals loading, with greatest measured loads occurring during spring runoff.

3.4.1.2 Alluvial Groundwater in Vicinity of Waste Water Treatment Plant

During spring runoff in 1999 and 2000 and the Fall 2000 synoptic sampling event some of the groundwater upstream of the cutoff wall near the water treatment plant, which was supposed to be collected for treatment, was discharging to Blackbird Creek. Maintenance was conducted, which included installation of a new drain line in 1999, and unclogging a blockage in a pipe and installation of a seal in a tight line during 2001 to correct these problems. This area will continue to be monitored and corrective maintenance will be implemented, as necessary. However, alternatives do not need to be considered in the FS for this portion of the site.

3.4.1.3 Water Treatment Plant Discharge

Effluent limitations under the current NPDES permit for discharges from the water treatment plant are currently based on total metals only. The monthly average limitation for total copper is 0.15 mg/L. There is no limitation in the permit for total cobalt. The average total cobalt and copper concentrations from treatment plant discharges from 1999 through August of 2001 were 0.246 mg/L (cobalt) and 0.107 mg/L (copper).

There is limited existing data on the dissolved metals concentrations in treatment plant discharges due to the fact that there are no limitations in the permit for dissolved metals. Dissolved and total metals were analyzed in treatment plant discharges during spring

runoff synoptic sampling in 1998, 1999, and 2000. The results from the Spring 2000 sampling for cobalt are considered atypical due to the startup problems discussed in the RI report (Golder 2001a). For the other sampling events, the dissolved cobalt concentrations were 0.046 mg/L (4/28/98) and 0.055 mg/L (5/6/99). These concentrations were 35% and 29% of the total cobalt concentrations measured on those dates. The dissolved copper concentrations were 0.004 mg/L (4/28/98), 0.013 mg/L (5/6/99), and 0.017 mg/L (4/26/00), which represent 3% to 5% of the total copper concentrations measured on those dates.

Assuming that the average dissolved cobalt is 35% of the total and copper is 5% of the total, the average dissolved concentrations for these metals from 1999 to August 2001 would be 0.086 mg/L for cobalt and 0.005 mg/L for copper in the treatment plant discharge. At these concentrations the discharge (prior to dilution in receiving waters) would exceed the PRG for cobalt but meets the PRG for copper. The discharge from the water treatment plant at design capacity (800 gpm or about 1.8 cfs) is about 30% to 60% of the flow at BBSW-07, and about 5% to 50% of the flow at BBSW-01A depending on the time of year and volume of flow in Blackbird Creek.

3.4.2 Blackbird Creek

3.4.2.1 Water Quality

The dissolved cobalt PRG for the protection of aquatic life is 0.038 mg/L. The dissolved copper PRG is the chronic Idaho water quality criteria (IWQC). This criterion is a function of hardness (equation 1).

$$PRG(Cu) = \left\lfloor e^{(0.8545[\ln\_hardness]-1.465)} x0.96 \right\rfloor / 1000 \qquad (1)$$

At the minimum hardness of 25 mg/L allowed in the formula (see IDAPA 58.01.02.210, which incorporates 40 CFR 131.36.c.4 by reference) the copper PRG is 3.5 µg/L.

Tables 3-4 and 3-5 compare cobalt and copper concentrations for Blackbird Creek samples collected in 2000 and 2001 to the appropriate PRGs. Values exceeding PRGs are shaded. These data indicate that water quality in Blackbird Creek does not meet the proposed PRGs, except occasionally for copper.

3.4.2.2 Overbank Deposits

Overbank deposits along Blackbird Creek exceed human health PRGs for arsenic in some locations and these materials may contribute as a source of metals loading (primarily cobalt) which may affect the ability to meet water quality PRGs. In addition, there is potential for erosion from these deposits during design storm events that could result in deposition in downstream areas that could exceed human health PRGs for arsenic along Panther Creek. Results are presented in Tables 2-8a through 2-8l. Figures 6-13a through 6-13x illustrate the locations of overbank deposits and include the arsenic and copper concentrations of samples collected. Most of the analysis of overbank deposits was conducted using an XRF, which has a high detection limit for cobalt.

Therefore, cobalt concentrations are provided only for samples where results are available from laboratory analysis.

Assessment of the geomorphologic stability of the overbank deposits is discussed in Appendix A.

3.4.2.2.1 Water Quality Impacts Potentially Associated with Deposits Upstream of West Fork Blackbird Creek

Tailings and overbank deposits between Station BBSW-07 and the West Fork Tailings Impoundment do not appear to contribute dissolved copper load to Blackbird Creek, but may contribute a small cobalt load. There was a net loss of copper loading from station BBSW-07 to BBSW-03A during both spring and fall sampling in 2000 and Fall 2001. However, there was a gain in copper loading in this reach during spring of 2001.

During the Spring 2000 sampling, there was a small (1 kg/day) decrease in cobalt loading between BBSW-07 and BBSW-03A. However, there was a small increase of dissolved cobalt loading between Stations BBSW-07 to BBSW-06 (0.59 kg/day) during Spring 2000. During Spring 2001, there were small (0.4 kg/day to 2 kg/day) dissolved cobalt load increases between stations BBSW-07 and BBSW-03A during three of the weekly sampling events and a large (6 kg/day) apparently anomalous load increase during the synoptic sampling event on May 2. During the Fall 2000 sampling, small increases in cobalt loading were observed at each station from BBSW-07 to BBSW-03A, with a cumulative load increase of about 0.4 kg/day. This was the same load increase measured in this reach during Fall 2001.

3.4.2.2.2 Water Quality Impacts Potentially Associated with Deposits Downstream of West Fork Blackbird Creek

From the area downstream of the West Fork Tailings Impoundment to the mouth of Blackbird Creek (Stations BBSW-02 to BBSW-01A), there is a net loss of dissolved copper load during both spring and fall sampling. Cobalt loading also declined between these stations during Spring 2000 sampling, but cobalt loading increased by 0.85 kg/day between these stations during Fall 2000 sampling and decreased slightly (0.2 kg/day) during Fall 2001 sampling. Some of this loading could be due to groundwater discharge in this reach, which is observed during the fall. During Spring 2001, no sampling was conducted at stations immediately downstream of the West Fork Tailings Impoundment, which are needed to distinguish cobalt-loading contributions from the impoundment versus from overbank deposits.

3.4.2.3 Water Quality Impacts From Storm Events

Water quality can also be affected as a result of storms events and resulting runoff from mine related deposits. Storm sampling was conducted during 1998 and 1999 with the 1999 data more useful in evaluating water quality during a storm (see table 5-28b in the RI Report (Golder 2001a). Sampling results indicated an increase in metals concentrations and loading as a result of the storm event. The peak loading rate

measured during the storm was comparable to loading measured during the spring synoptic sampling event for cobalt, but was less for copper.

3.4.2.4 Seeps and Springs

Metals present in seeps and springs could be the result of water discharging from areas of natural mineralization, due to contact with Blackbird mine related overbank materials and sediments, from other areas of mining such as Haynes Stellite, or from water discharging back to the creek that originated from a losing reach upstream. The measured seeps, as discussed below, do not account for a significant percentage of the metals loading to Blackbird Creek. Results from the seep and spring sampling are summarized below:

- BBSP-11/11A originates near the former Haynes-Stellite Mine gully and discharges to Blackbird Creek between BBSW-05 and BBSW-04. Metals in this seep may be associated with the former Haynes-Stellite, may be natural, or may represent a discharging reach of water originating upstream. During Spring 2000 synoptic sampling a flow rate of 0.076 cfs was recorded at this seep, contributing 0.029 kg/day of dissolved copper (0.156 mg/L) and 0.08 kg/day of dissolved cobalt (0.438 mg/L) to Blackbird Creek. This accounts for 2% of the dissolved copper load and 1% of the cobalt load at BBSW-04. A similar percentage was contributed to Blackbird Creek in 1999. In 1998, BBSP-11 had a slightly lower flow rate, 0.13 cfs, and accounted for 4% of the total dissolved copper load at BBSW-04. In the fall of 2000, loading percentages at BBSW-04 due to this seep increased to 14% for dissolved copper and 15% for dissolved cobalt. Dissolved copper and cobalt concentrations were considerably lower in Spring 2000 than they were in June 1995, prior to Early Actions, when BBSP-11 had dissolved copper and cobalt concentrations of 0.634 mg/L and 0.946, respectively;
- Between BBSW-04 and BBSW-03A, Seeps BBSP-03, BBSP-09, BBSP-45, BBSP-46, and BBSP-27 contribute some loading to Blackbird Creek. Some of these seeps may be associated with overbank materials. In Spring 2000, BBSP-03 contributed 24% of dissolved copper (0.106 mg/L) loading at BBSW-03A. BBSP-45 contributed 18% of dissolved copper ((0.223 mg/L). A 4% change in dissolved copper between BBSW-04 and BBSW-03A is noted, though these two seeps alone would contribute a 42% increase. It is likely that errors in flow measurements are accountable for this discrepancy. In 1999, Seep BBSP-03 contributed 3% and 8% of the dissolved copper and cobalt loads measured at BBSW-03A. In 1998, this seep accounted for 6% and 7% of the dissolved copper and cobalt loads at BBSW-03. The location of this seep is not associated with exposed tailings deposits at the surface. BBSP-09 is located below the lower mine gate. This seep contributed 14% of the dissolved copper load (0.217 mg/L) and 5% of the dissolved cobalt load (0.434 mg/L) at BBSW-03A. In 1999, this seep contributed 2% of the dissolved copper and cobalt load at BBSW-03A. In 1998, the contribution of this seep to the total load at BBSW-03 was higher, accounting for 7% and 4% of the dissolved copper and dissolved cobalt loads, respectively. BBSP-46 and BBSP-27 combined account for less than 2% of dissolved copper and less than 1% of dissolved cobalt loading at BBSW-03A. In fall of 2000, BBSP-03 accounted for 10% of dissolved

copper loading and 4% of dissolved cobalt loading at BBSW-03A, while BBSP-09 and BBSP-27 accounted for less than 1% of loading at BBSW-03A. Seeps BBSP-45 and BBSP-46 were dry in the fall. Concentrations were lower in all the seeps following Early Actions than they were in June 1995 prior to Early Actions. In June 1995 dissolved copper concentrations in BBSP-03 were 0.263 mg/L and cobalt was 0.509 mg/L. Concentrations in 1995 at BBSP-09 were 0.669 mg/L dissolved copper and 0.862 mg/L dissolved cobalt;

- BBSP-26 surfaces on the east side of Blackbird Creek near the West Fork Tailings Impoundment. This spring contributed significant loading in 1998. The source of metals in this seep is unknown and could be naturally occurring or due to discharging water that originated upstream. In 1999, the flow rate of this seep was 0.028 cfs. Dissolved copper and cobalt concentrations decreased by greater than 30% resulting in loading of 0.02 kg/day dissolved copper and 0.03 kg/day dissolved cobalt. In Spring 2000, these numbers increased slightly showing 0.028 kg/day dissolved copper (0.156 mg/L) and 0.049 kg/day dissolved cobalt (0.272 mg/L). In the fall of 2000, this seep accounted for 21% of dissolved copper loading (0.473 mg/L) and 1% of dissolved cobalt loading (0.685 mg/L) at BBSW-02. These concentrations are less than concentrations in June 1995, which were collected prior to Early Actions, when copper concentrations were 0.653 mg/L and cobalt concentrations were 0.894 mg/L, and
- BBSP-43, which discharges below the West Fork Tailings impoundment, was modified in 1998 as a result of tailings removal and sediment pond construction in this area. Discharge from this seep was 0.007 cfs. This seep combined with the adjacent WFSW-01, account for less than 1% of dissolved copper and cobalt loading at BBSW-02. The remainder of the loading from tailings impoundment seepage is either picked up at the West Fork Interceptor Ditch surface water sampling station, or is unaccounted for (i.e. discharges to the creek within the stream channel). In Fall 2000, BBSP-43 accounted for 2% dissolved copper and less than 1% dissolved cobalt loading at BBSW-02. This seep was not sampled (and may not have been present) during 1995 sampling.

3.4.2.5 West Fork Tailings Impoundment

3.4.2.5.1 Impoundment Surface

The surface of the tailings impoundment was sampled following completion of overbank removal actions in 2001 to determine metals concentrations for comparison with human health PRGs. Results of the sampling are presented in Table 2-10. The surface of the impoundment has been covered and sloped to promote runoff with temporary sediment control facilities (straw bales) and eventually will be vegetated to prevent erosion.

3.4.2.5.2 Groundwater Discharge

Several surface water-monitoring stations have been sampled in and adjacent to the West Fork Tailings Impoundment to determine metals loading from the impoundment. Cumulative metals loading between Stations BBSW-03/03A and BBSW-02 were 0.5

kg/day dissolved copper in the spring of 2000 and 0.05 kg/day in the fall of 2000. Total copper loading was 1.5 kg/day during the spring and 0.2 kg/day during the fall. The West Fork Tailings Impoundment is the primary residual source of cobalt loading, with loading during the Spring of 2000 of about 7 kg/day, and during the Fall of both 2000 and 2001 about 3 kg/day (dissolved and total cobalt are about the same). During the spring of 2001, station BBSW-02 was not sampled thus it was not possible to differentiate between metals loading coming from the impoundment versus seeps and overbank deposits. However, most of the loading observed during previous sampling events downstream of station BBSW-03A was attributed to discharges from the impoundment.

3.4.2.6 In-Stream Sediments

EPA's arsenic, cobalt, and copper sediment PRGs for Blackbird Creek are 35 mg/kg (As), 436 mg/kg (Co) and 637 mg/kg (Cu), respectively. Total metal concentrations (determined with a HCl/HNO_3 digestion on the < 2-mm fraction) for four samples collected in Blackbird Creek in Fall 2000 and 2001 are provided in Table 3-6. Concentrations that exceed the EPA PRGs are in bold type. With the exception of the background station (BBSW-08), arsenic and copper concentrations exceed the EPA PRGs in all samples in Fall 2000. Arsenic concentrations exceed the EPA PRG by a factor of 16 to 38 and copper concentrations are between 2 and 5 times the EPA PRG. Cobalt in the sample from BBSW-07 also exceeds EPA's cobalt PRG by a factor of 1.6. Results for 2001 were comparable.

The three sediment samples, which exceed EPA's PRG values, were collected at BBSW-07, BBSW-03, and BBSW-01. Provided the results from these samples are representative of sediment concentrations in Blackbird Creek between its mouth and the Water Treatment Plant, these data indicate that sediments along the entire length of Blackbird Creek would be expected to exceed EPA's PRGs.

3.4.3 Bucktail Creek

EPA has not established PRGs for Bucktail Creek. However, sources of metals loading in Bucktail Creek have to be evaluated as they relate to the PRGs in South Fork Big Deer Creek, Big Deer Creek, and Panther Creek.

3.4.3.1 Seeps and Springs

The locations of all seeps and springs that have been sampled previously for the RI on Bucktail Creek are shown in Plate 1 and a description of sampling locations is provided in Table 1. Synoptic sampling data collected during the RI indicated that subsequent to implementation of the Early Actions, metals loading to Bucktail Creek occurred from groundwater discharges to seeps and springs below the 7000 dam and between stations BTSW-02 and station BTSW-1.6. Following completion of Early Actions, the highest increase in dissolved copper loading measured in this reach was 6.14 kg/day, and cobalt loading was 1.76 kg/day on May 28, 1999. In samples collected during the fall of 1999 and spring and fall of 2000, the loading increase for dissolved copper has ranged from 1

kg/day to 1.8 kg/day, and the corresponding dissolved cobalt load increases measured in this area ranged from 0.5 kg/day to 0.7 kg/day.

A source of this loading downstream of BTSW-02, which was sampled during the RI, is groundwater discharging as seeps in the area of BTSP-01. During the 2000 synoptic sampling events on Bucktail Creek, BTSP-01 was the only seep that was flowing in both the spring and fall. Flow at this seep was measured at 0.009 cfs in both the spring and fall. This is the same flow rate that was recorded in the fall of 1999. This seep was not sampled during 2001. The flow at this location is difficult to measure due to the disperse nature of the seep. Flow estimations used to calculate loading are probably low.

In the spring of 2000, BTSP-01 accounted for 16% of the dissolved copper loading 0.43 kg/day (19.6 mg/L) and 13% of the cobalt loading 0.13 kg/day (5.71 mg/L) measured at BTSW-01.6. In the fall that number increased to 20% for copper and 18% for cobalt. This was attributed to the consistent flow of BTSP-01 and the reduced flow in Bucktail Creek. In fall of 1999, this seep contributed 30% of dissolved copper loading and 19% of dissolved cobalt loading at BTSW-01.6. The additional unaccounted metals loading observed at BTSW-01.6 was likely due to groundwater discharges directly into the creek channel that were not observed or sampled as discrete seeps. This seep was not sampled in 1995, but was sampled in June 1996, prior to Early Actions. Copper concentrations in 2000 were considerably lower than the concentrations in 1996, which were 58.4 mg/L for dissolved copper and 14 mg/L for dissolved cobalt.

3.4.3.2 Debris Flow Materials

Debris flow materials exist along portions of the Bucktail Creek channel that were not removed during Early Actions and in a debris fan downstream of the lower sediment dam extending to the South Fork of Big Deer Creek. The existing data indicate that debris flow materials are not resulting in dissolved metals loading sufficient to cause impacts on downstream water quality. During synoptic sampling events, the reach containing debris deposits was an area where metals have continued to precipitate and thus this area was a net metals losing area and was not acting as a source.

As discussed in Section 2.6.2.4, a storm event was sampled on July 30, 2001, which provides information on water quality potentially affected by debris deposits. As seen in Table 2-5, and Figure 2-9a, changes in water quality during the storm were most noticeable at station BTSW-1.1 located upstream of the lower sediment pond, especially for total metals. Although there were slight increases in dissolved copper and cobalt in South Fork Big Deer Creek at station SFSW-01 during the early part of the storm event, the debris flow is not considered a significant source of dissolved metals to downstream waters.

3.4.3.3 In-Stream Sediments

Metal precipitates have been observed on sediments in Bucktail Creek. Sediment samples were not collected during 2000 but were collected during the fall of 2001. Results are presented in Section 2.6.2.6 and in Table 3-6. As noted previously, Bucktail

Creek downstream of station BTSW-01.6 is a net losing reach in terms of metals loading. Metals are precipitated and/or adsorbed to the creek sediments and organic matter in the creek channel. Thus, sediment metals concentrations are predictably high. These sediments may be a future source of metals loading, once water quality has improved sufficiently to cause dissolution and/or desorption of the metals from the sediments.

3.4.4 South Fork Big Deer Creek

3.4.4.1 Water Quality

Table 3-7 compares cobalt and copper concentrations for South Fork Big Deer Creek samples collected in 2000 to EPA's PRGs. Tables 3-8 and 3-9 provide the comparisons for 2000 and 2001, respectively. Values exceeding PRGs are shaded. These data indicate that copper concentrations in South Fork Big Deer Creek consistently exceed the PRG. Water quality occasionally met the EPA cobalt PRG during spring runoff, but exceedances are common.

3.4.4.2 In-Stream Sediments

EPA's sediment PRGs for S. Fork Big Deer Creek are equivalent to those for Blackbird Creek. The arsenic, cobalt, and copper sediment PRGs are 35 mg/kg (As), 436 mg/kg (Co) and 637 mg/kg (Cu), respectively. Metal data for sediment samples collected at SFSW-04 and SFSW-01 in Fall 2000 and 2001 are provided in Table 3-6. Concentrations exceeding the PRGs are in bold type.

Metal concentrations in the background station sample (SFSW-04) were all below the PRGs. During the 2000 sampling event, arsenic (176 mg/kg) and copper (6400 mg/kg) at SFSW-01 exceeded the PRGs by factors of 5 and 10, respectively. Total metal concentrations for the Fall 2000 sample collected at SFSW-02 were determined using a HF/HNO_3 digestion as part of sequential extraction analysis. The hydrofluoric acid digestion is a more rigorous digestion than the hydrochloric acid digestion and therefore would be expected to yield higher total metal concentrations. Arsenic, cobalt, and copper concentrations for this sample were 183 mg/kg, 360 mg/kg, and 10300 mg/kg, respectively. These data indicate exceedances of the PRG for both arsenic and copper. Sequential extraction analysis indicated that the majority of arsenic (92%) was present as a residual (mineral) phase, and therefore would not likely be bioavailable as it would if it were present in other phases.

During 2001 metal concentrations in the background station sample (SFSW-04) were all below the PRGs. As seen in 2000, arsenic and copper concentrations again exceeded PRGs. These results are shown in Table 3-6.

Provided total metal concentrations for SFSW-02 and SFSW-01 are representative of metal concentrations for the entire reach of South Fork Big Deer Creek between its confluence with Bucktail Creek and its mouth, these data indicate that sediments along this reach are expected to consistently exceed PRGs for arsenic and copper. Exceedances of the Cobalt PRG for sediments in this reach are not expected. However, as water

quality improves, resulting in continued dissolution and/or desorption of metals from sediments, the copper and arsenic concentrations will decline over time as a result of the dissolution/desorption and physical sediment transport.

3.4.5 Big Deer Creek

3.4.5.1 Water Quality

Table 3-8 compares cobalt and copper concentrations for Big Deer Creek samples collected in 2000 to EPA's PRGs and 2001 comparisons are provided in Table 3-9. Values exceeding PRGs are shaded. BDSW-04 is the reference station and water quality at that location is below the PRGs. These data indicate that cobalt concentrations in Big Deer Creek downstream of South Fork Big Deer Creek are consistently less than EPA's PRG. Copper concentrations at BDSW-03 generally exceeded PRGs. Dissolved copper concentrations generally exceeded the PRG at BDSW-03. However, during a period of high flows on May 23 and 24, 2000 copper concentrations were non-detect at this station (<0.003 mg/L) and therefore in compliance with the PRG.

3.4.5.2 In-Stream Sediments

EPA's arsenic, cobalt, and copper sediment PRGs for Big Deer Creek are 35 mg/kg (As), 83 mg/kg (Co) and 151 mg/kg (Cu), respectively. Total metal concentrations for three sediment samples collected in Fall 2000 and 2001 are provided in Table 3-6. Concentrations exceeding the PRGs are in bold type.

As expected, total metal concentrations were all below the PRGs in the background sample (BDSW-04). Copper exceedances were recorded in samples collected at BDSW-01 and BDSW-02 during 2000 and at BDSW-03 during 2001. Copper in these samples ranged from 2.1 to 2.5 times the PRG. Cobalt slightly exceeded the PRG during 2001 at BDSW-03. Total copper analysis with a HF/HNO_3 digestion on the BDSW-03 sample yielded a total copper concentration of 960 mg/kg (average of original sample and duplicate). Sequential extraction analysis results indicated most copper (75%) was present in the carbonate and residual phases.

Copper results from BDSW-03, BDSW-02, and BDSW-01 indicate that copper likely exceeds the PRG of 151 mg/kg along the entire reach of Big Deer Creek between its confluence with S. Fork and Panther Creek. However, copper exceedances along Big Deer Creek may not solely be the result of mine impacts. Mebane (1994) who compiled sediment data for Indian Creek from a number of investigators, reported sediment copper concentrations ranging from 15 to 500 mg/kg (n=11). These data suggest that sediment contributions from other mineralized areas in the Big Deer Creek drainage may be contributing to copper exceedances above sediment PRGs.

3.4.6 Panther Creek

3.4.6.1 Water Quality

There has been substantial improvement in water quality in Panther Creek as a result of the Early Actions, which have been implemented. The peak Spring dissolved copper concentration in Panther Creek downstream of Blackbird Creek (stations PASW-09 and PASW-10) has been reduced from 0.218 mg/L measured in 1995 to 0.012 mg/L during 2000 and 0.013 mg/L during 2001, a reduction of 94%. The peak cobalt concentration has been reduced from 0.273 mg/L to 0.078 mg/L during the 2000 and 2001 sampling periods, a reduction of 71%. At Station PASW-04 downstream of influence from Bucktail and Big Deer Creek, the Early Actions have resulted in reduction in peak dissolved copper concentration from 0.067 mg/L to 0.015 mg/L (78%). The peak cobalt concentration has been reduced from 0.076 mg/L to 0.031 mg/L (59%).

During fall low-flow conditions the Early Actions have resulted in reduction in the dissolved copper concentration from 0.064 mg/L at PASW-10 and 0.039 mg/L at PASW-04 to less than the detection limit (0.003 mg/L) at both stations. This represents a reduction of 95% at PASW-10 and 92% at PASW-04. The dissolved cobalt concentration was reduced from 0.140 mg/L at PASW-10 to 0.054 mg/L at PASW-09 (which has replaced PASW-10), a reduction of 61%. At PASW-04 the cobalt concentration was reduced from 0.044 mg/L to 0.023 mg/L, a reduction of 48%.

Under low-flow conditions in both Spring (prior to runoff) and Fall 2000, dissolved copper concentrations were lower than the chronic water quality criterion in all Panther Creek stations downstream of Blackbird Creek. During portions of the rising limb of the snowmelt hydrograph during spring runoff, copper concentrations exceeded the chronic criterion at Stations PASW-09 and PASW-10 by at most about two times the criterion, and at PASW-04 by at most about 4 times the criterion. Cobalt concentrations are highest during low-flow conditions (0.050 to 0.075 mg/L) and are lower during spring runoff with concentrations typically about half the concentrations observed during low-flow.

Table 3-10 compares cobalt and copper concentrations for Panther Creek samples collected in 2000 to EPA's PRGs. Values exceeding PRGs are shaded. At the lower Panther Creek Stations (PASW-04 and PASW-05), cobalt concentrations are consistently below the PRG but copper PRG exceedances are common during the spring. Along the upper reaches of Panther Creek (PASW-10 to PASW-08) both copper and cobalt PRG exceedances were recorded in 2000. However, copper concentrations have consistently been less than the PRG during low-flow conditions and cobalt concentrations are frequently less than the PRG during periods of spring runoff.

During 2001 additional locations in lower Panther Creek, including PASW-01, PASW-02, and PASW-03 (spring sampling only), were sampled. Comparison of 2001 data to the PRGs is provided in Table 3-11. During 2001 the only exceedance of the cobalt PRG was the sample collected on April 17 at station PASW-09, prior to spring runoff. Concentrations were less than the cobalt PRG in all samples collected during the synoptic sampling events in May and September. Copper concentrations were near or

exceeded the PRG by a factor ranging from 1.3 to 2.6 at all stations during spring runoff, but was less than the PRG during fall low-flow periods.

3.4.6.2 Overbank Deposits

Removal actions have been conducted at most of the overbank deposits along Panther Creek that exceed human health PRGs. Some overbank deposits slightly exceeding EPA's arsenic PRG of 100 mg/kg for the potential future residential use scenario remain at the K. Rogers property, former Strawn property, and Rufe property. Access for sampling on the Hade property was denied by the property owner. Therefore, the EPA is unable to fully evaluate potential risks for this property. The results from these samples are provided in Table 5-36 and Figures 4-5 through 4-11 of the RI Report (Golder 2001a) and are summarized as follows:

- K. Rogers Property – The area sampled was along the creek bank on both sides of the creek adjacent to the Roger's property and in a pasture area on the west side of Panther Creek. Arsenic concentrations ranged from 5.2 mg/kg to 651 mg/kg in 28 surface soil samples collected. Eleven of the samples exceeded EPA's PRG for the future residential use scenario;
- Former Strawn Property – A pasture, an orchard area, and bank of the creek along the former Strawn property were sampled. Seventeen samples were collected along transects and composited into five samples. The arsenic concentrations in the composite samples ranged from <5mg/kg to 71 mg/kg, which are all less than EPA's PRG for the future residential scenario. Five discrete samples were collected in the orchard area with concentrations ranging from 2.9 mg/kg to 6.3 mg/kg. Five biased discrete samples were collected in areas near the head of a former irrigation ditch where apparent tailings materials were observed. Concentrations in these samples ranged from 7.5 mg/kg to 308 mg/kg, with two of the samples exceeding the PRG for the future residential scenario, and
- Rufe Property – A low bank terrace between Panther Creek and a pasture were sampled at the Rufe property. During 1998 two composite surface (0"-4") samples were collected. Each sample was composed of three individual samples. In addition, a test pit to 18 inches was sampled at a location where tailings were observed. Arsenic concentrations in these composite samples were 170 mg/kg and 230 mg/kg. Arsenic concentrations in the test pit ranged were 600 mg/kg at 0"-4", 900 mg/kg at 4"-12", and 110 mg/kg at 12"18". During 2000, ten additional discrete samples were collected to better define the area exceeding EPA's residential PRG. Arsenic concentrations in these samples ranged from 35.6mg/kg to 317 mg/kg. Only two of the samples exceeded the PRG.

3.4.6.3 In-Stream Sediments

EPA's arsenic, cobalt, and copper sediment PRGs for Panther Creek are equivalent to those for Big Deer Creek: 35 mg/kg (As), 83 mg/kg (Co) and 151 mg/kg (Cu). Total metal concentrations for seven sediment samples collected in Panther Creek in the Fall of 2000 and 2001 are provided in Tables 3-6. Concentrations exceeding the PRGs are in bold

type. Both the fall 2000 and 2001 sediment data indicated a number of PRG exceedances (usually less than a factor of 2 for copper, less than a factor of 3 for cobalt, and less than a factor of 6 for arsenic). Changes in concentrations from 2000 to 2001 were variable, with copper concentrations slightly higher in 2001, cobalt was relatively unchanged, and arsenic concentrations declined. The Aquatic Ecological Risk Assessment (CH2M Hill, 2001a) states, "Based on the low dietary HQs and the uncertainty associated with establishing background UTLs for Panther Creek, it is unlikely that the sediments are causing potential adverse effects to the aquatics system."

Although the five Panther Creek Stations between PASW-10 and PASW-04 all report metal concentrations exceeding PRGs, these samples are not likely representative of conditions along the entire reach of Panther Creek (between Blackbird and Big Deer Creeks). Panther Creek sediment sampling was conducted at water quality sampling locations and in areas where overbank deposits from mining activities were located. For the latter sites, sediment samples are likely biased toward higher metal concentrations. Results for each Panther Creek station are therefore considered representative of the area surrounding each station. Sediment concentrations along reaches between stations (for example between PASW-07 and PASW-05) cannot be inferred from upstream and downstream data.

3.4.7 Private Water Supply Wells

One round of sampling was conducted at five residential water supplies in the vicinity of the site during 1995. The Panther Creek Inn well was sampled in June and the other water supplies in late September. The residential water supply source location and well construction details, where applicable and available, are presented in the 1995 RI Data Summary Report (Golder 1996d). Residential wells and water supplied by springs to private residences in the vicinity of the Blackbird Mine Site are illustrated in Plate 1.

At the time of sampling (1995), the Safe Drinking Water Act (SWDA) maximum contaminant level (MCL) for arsenic was 0.050 mg/L. In October 2001, the EPA announced a reduction in the arsenic standard in drinking water to 0.010 mg/L.

Results of the private water supply well analyses are presented in Table 3-12. Copper was detected in the PCI well at 0.018 mg/L, which was less than the drinking water MCL for copper (1.3 mg/L). Cobalt was detected at 0.244 mg/L in the PCI well. There is no drinking water standard for cobalt. Copper was not detected (IDL = 0.0006 mg/L) in the water supplies at the G. Fernandez residence and the Sillings cabin. Cobalt was not detected (IDL = 0.0049 mg/L) at the Sillings cabin and house, and the Warbarton residence. In these cases, the values for the respective detection limits are shown with a "U" designation.

Arsenic in the G. Fernandez water supply exceeded the revised Safe Drinking Water Act (SDWA) maximum contaminant limit at the time of sampling (0.050 mg/L). However, the low levels of copper and cobalt detected in this water supply indicated they were not impacted by the mine site. The G. Fernandez water supply is a spring located several hundred feet above the elevation of Panther Creek and is not hydraulically connected to

the mine site. The arsenic concentration in this spring results from natural mineralization in the area and is not a result of the Blackbird mine site. Arsenic in the Warbarton well was 0.023 mg/L, which was below the MCL in 1995, but exceeded the revised MCL of 0.010 mg/L. Because the Warbarton's well is not hydraulically connected to the mine site, the occurrence of arsenic in this well is not related to mining activities. Arsenic was below the current MCL in the Sillings Cabin and House samples (<0.0015 mg/L) and the sample collected from the Panther Creek Inn (0.003 mg/L). The low arsenic concentration in the Panther Creek Inn well is important since this well has its source in the alluvial groundwater system, and therefore would be potentially influenced by water quality in Blackbird and/or Panther Creeks. The low arsenic concentrations in this well indicated that the mine has not impacted this well.

In conclusion, the mine site has not caused exceedances of the arsenic MCL in drinking water wells. Therefore, it is not necessary to develop alternatives to address arsenic for drinking water wells in this Feasibility Study.

4. IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

This chapter identifies and screens technologies that may be included in remediation alternatives for various portions of the Blackbird Site. A comprehensive list of technologies and process options to address the affected media and COCs was developed to include all the applicable general response actions. The list of technologies was then screened to develop a refined list of potentially feasible technologies that were used to develop remediation alternatives. The remediation technologies were screened using the following criteria:

- **Effectiveness** - The potential effectiveness of the technology to (1) address site-specific conditions, including applicability to the media and COCs for this site, (2) meet remedial action objectives, (3) minimize human health and environmental impacts during implementation, and (4) provide proven and reliable remediation under site conditions;
- **Implementability** - The technical and administrative feasibility of implementing a technology. Technical considerations cover site-specific factors that could prevent successful use of a technology, such as physical interferences or constraints, practical limitations of a technology, and the soil, surface water and groundwater properties. Administrative considerations include the ability to obtain permits and the availability of qualified contractors, equipment, and disposal services, and
- **Cost** - The capital and operation and maintenance costs associated with the technology. Costs that are excessive compared to the overall effectiveness of the technology may be considered as one of several factors used to eliminate technologies. Technologies that provide effectiveness and implementability similar to that of another technology by employing a similar method of treatment or engineering control, but at greater cost, may be eliminated. At the screening level, the cost evaluation is based on engineering judgment of relative costs.

The technologies and process options were screened against the criteria in the priority order listed above using the "fatal flaw" approach. This approach ranks the criteria in order of importance, as listed above. Once a technology is rejected based on effectiveness, it is not evaluated further (i.e., based on implementability or cost). Similarly, if a technology is effective, but not implementable, the technology is rejected and evaluation of cost is not undertaken. This approach streamlines the evaluation of technologies while maintaining the EPA screening methodology.

The technologies are discussed and screened below. Table 4-1 summarizes the identification and screening of technologies. Technologies retained through this screening process were then incorporated into remediation alternatives in Chapter 5.

4.1 General Response Actions

General response actions are broad categories of remedial actions that can be combined to meet remedial actions at a site. The following general response actions are generally applicable to most sites, including the Blackbird Site.

- No action,
- Institutional controls and physical restrictions,
- Monitoring,
- Natural Recovery,
- Containment,
- Removal,
- Treatment (*ex situ* and *in situ*), and
- Disposal.

Except for "no action," each of these response actions represents a category of technologies. Applicable technologies vary depending on the media and COCs.

4.2 Institutional Controls and Physical Restrictions

Institutional controls are legal restrictions that are typically used to prevent exposure to COCs or to prevent activities that might interfere with the remedy at a site. Risk is managed by institutional controls to the extent that they prevent exposure to the affected media. However, institutional controls generally do not prevent off-site transport of constituents. Institutional controls typically include monitoring required for ongoing effectiveness. Institutional controls can be effective for their intended purpose, are easily implemented, and are usually low in cost. Types of institutional controls that may be considered at a site include proprietary controls (e.g. easements), governmental controls (e.g. zoning restrictions), enforcement controls (e.g. administrative orders), and informational devices (advisories).

Physical restrictions are also measures designed to minimize risk by preventing exposure to affected media. Unlike containment, physical restrictions generally do not prevent off-site transport of constituents. Physical restrictions include monitoring and maintenance required for ongoing effectiveness. Physical restrictions are effective within their limitations, are easily implemented, and are usually low in cost.

4.2.1.1 Institutional Controls

Proprietary controls are legal instruments, such as easements or covenants, placed in the chain of title of a site or property. At the Blackbird site, proprietary controls may be considered to prevent certain activities on private property, such as the prevention of residential development. Conservation easements, which are specifically addressed

under Idaho law, may be the most likely proprietary control mechanism to be implemented at the Blackbird site.

Governmental controls are implemented and enforced by a governmental entity to restrict land or resource use at a site. Most of the land adjacent to the Blackbird mine is federal land administered by the USDA Forest Service. Governmental controls, such as road closures, land use restrictions, or overnight camping restrictions, could be implemented by the Forest Service to prevent uses that would interfere with the remedy or that could result in human health or environmental risks. The State could similarly restrict uses of surface water or groundwater at the site to prevent uses that are not compatible with the remedy selected.

Enforcement tools can be issued or negotiated by federal or state entities to compel a landowner or potentially responsible party to take action. For example, after selection of a remedy, an administrative order on consent (AOC) could be negotiated that would include institutional control provisions. At the Blackbird site, this could involve requirements to establish proprietary controls, perform monitoring for changes in land uses on private lands, implement physical restrictions, perform operation and maintenance, or to prevent activities on land controlled by the signatories that would be inconsistent with the remedy.

At some of the private properties where overbank soils were cleaned up as part of the Early Actions, soils with elevated arsenic concentrations were left at the water table. Even though a minimum of 12 inches of cover or more was generally provided at these areas, there is a potential that future activities (trenching, post hole digging, stream erosion, etc.) could bring these materials to the surface. Institutional controls to address these circumstances may be needed. These institutional controls would at a minimum be part of ongoing monitoring and operation and maintenance conducted by the BMSG and would consist of provisions for testing of soil materials brought to the surface, appropriate disposal of contaminated soil materials, and replacement with clean soil materials (if necessary).

Informational devices, such as public advisories or notices to downstream property owners, could be considered for the Blackbird site. These informational devices would typically be implemented by a governmental entity and "layered" with other controls such as enforcement tools or government controls.

Institutional controls are retained for further consideration.

4.2.1.2 Physical Restrictions

Physical restrictions typically include measures to prevent access by unauthorized persons. Access could be prevented, for instance, for areas containing materials that exceed human health PRGs. Fencing, combined with warning signs, is the most common means of restricting access. Security patrols are sometimes included for high-risk areas, but would not be warranted for this site. Fencing provides a physical barrier to site access. Warning signs discourage trespass by warning potential intruders of the hazards of entering the area. Physical restrictions are retained for further consideration.

4.3 Monitoring

Site monitoring is usually a required component of a site remedy (including "no action"). Short-term monitoring is conducted to ensure that potential risks to human health and the environment are controlled while a site remedy is being implemented. Long-term monitoring is conducted to measure the effectiveness of the remedy and thereby ensure that

the remedy continues to be protective of human health and the environment. Long-term monitoring would include periodic inspection, as necessary to determine maintenance needs (e.g., for armoring, fencing, or surface water controls). A monitoring plan will be developed for the selected remedial action. The type of monitoring performed will depend on the nature of the remedy. Monitoring could include periodic sampling and analysis of soils, sediments, surface water, groundwater, and biota, as appropriate.

4.4 Natural Recovery

Natural recovery refers to use of natural attenuation processes for site cleanup. These natural processes include a variety of physical, chemical, and biological processes that act without human intervention, and can include: precipitation, sorption, and dispersion. Natural attenuation processes result in reduction of toxicity, mobility, and/or volume of COCs.

Natural attenuation processes typically occur at all sites. The degree of effectiveness varies depending on the types and concentrations of COCs present, the physical, chemical, and biological characteristics of the soil and groundwater, and the proximity of potential receptors. Where conditions are favorable, natural attenuation processes can reduce COC concentrations at sufficiently rapid rates to be integrated into a site's remedy. In some cases, natural attenuation can be sufficiently effective without the aid of other (active) remedial measures.

Natural recovery is not a "walk-away" or "no action" alternative. It is an appropriate remedial approach where it is capable of achieving cleanup within a timeframe that is reasonable compared to that offered by other methods. It is often appropriate as a follow-up remedy to earlier source control measures, such as the "Early Action" remediation measures at the Blackbird Site. For example, at this site it is an approach that may be appropriate for consideration for in-stream sediments, which exceed PRGs. Natural recovery is retained for further consideration.

Cobalt, arsenic, and copper are present as both primary and secondary mineral phases in streambed sediments at the Blackbird Site (Camp Dresser and McKee, 1995). Whereas chemical processes are expected to reduce metal concentrations in secondary phases, these processes are not expected to significantly reduce primary mineral metal concentrations. The fact that chemical processes will not significantly reduce primary mineral metal concentrations is an indication that the metals have very low bioavailability in these forms. Physical processes affect metals associated with both primary and secondary mineral phases.

Historically, creek streambeds have acted as a sink for metals along certain reaches at the Blackbird Site. The precipitation of secondary minerals (copper carbonates, iron hydroxides, manganese hydroxides) and adsorption onto iron (oxy) hydroxides as well as other adsorbents (clays and manganese (oxy) hydroxides) have resulted in the transfer of metals from the aqueous to the solid phase. As surface water quality improves, trace metals may be liberated back to the water column. Secondary mineral dissolution and desorption are expected to result in a decline in sediment metal concentrations. Geochemical modeling, conducted as part of the RI, evaluated the effect of these reactions on Blackbird Site water quality. Because the focus of the modeling effort was to

predict impacts to water quality, only results for the water phase were presented (Golder, 2001). These model results are also applicable to sediment quality. Loadings to the water phase result in an equivalent loss in the solid phase.

Cobalt, copper, and arsenic are also present as primary mineral sulfides in stream sediments at the Blackbird Site, albeit at much lower concentrations than secondary minerals. The metals associated with primary sulfide minerals are of lesser concern in the stream sediments because they are generally less bioavailable than secondary sulfides. Chemical processes will likely result in minimal reductions in primary sulfide metal concentrations because the oxidation of primary sulfides is expected to be a slow process in the stream sediments at the Blackbird Site (Golder, 2001a).

Physical sediment transport, that is to say the scouring and mobilization of fine-grained sediments downstream, results in a decline in sediment metal concentrations with distance from the contaminant source. Loading of uncontaminated sediments from non-mineralized drainages, also serve to reduce total sediment metal concentrations through mixing of contaminated and clean sediments.

The Clear Creek Fire of 2000 may also have a positive impact on sediment quality. In some cases, natural recovery processes are enhanced by the addition of a thin layer of uncontaminated sediment to speed up natural depositional processes. Increased erosion resulting in stream deposition in fire-impacted areas may result in natural capping of contaminated sediments, thereby reducing their bioavailability.

4.5 Containment

Containment is a general response action used to prevent exposure to material affected by COCs that are left in place, and to control migration of constituents. Containment technologies are identified and screened in this section.

4.5.1 Armoring

Armoring is designed to minimize surface water transport of soils or sediments. Armoring of overbank sediments would be accomplished by installing angular rock riprap in such a way as to minimize the potential for flood flows to mobilize the affected sediments and transport them downstream. Armoring could also include vegetative armoring, spur dikes, and other less common armoring measures. The armor riprap would be installed along exposed banks of affected sediments from the bottom anticipated scour depth to a point above the water surface elevation for the design flood event. Armor rock would be designed to resist mobilization by the design flood event.

In addition, armoring also serves as a physical barrier to prevent humans, other animals, and vegetation from coming in contact with the affected sediments. Armoring is retained for further consideration.

4.5.2 Capping

In general, capping is a proven and effective technology for providing reliable long-term containment and preventing or minimizing off-site migration of constituents. Caps may be constructed of a variety of natural materials and synthetic materials. Caps may consist of a single layer or be a composite of several layers including a synthetic flexible membrane layer as well as clay and other soil layers. Capping provides containment in three primary ways:

- As a physical barrier to prevent humans, other animals, and vegetation from coming in contact with materials affected by COCs;
- To prevent erosion of soil by surface water and wind, thereby preventing off-site transport of COCs, and
- A low-permeability cap or vegetated soil cover reduces infiltration through waste there-by decreasing the potential for migration of COCs from waste into groundwater.

Capping may be an appropriate technology for overbank materials that exceed either water quality or human health PRGs along Blackbird Creek or for the final cover on the West Fork Surface Impoundment. For the overbank materials, a cap would consist of a soil or rock cover to prevent exposure to materials exceeding PRGs that do not require armoring. For any impoundment cover, the tailings would be graded for stormwater drainage before placing the cover. The cover would incorporate surface water control features to minimize surface water ponding and erosion of the cover.

At the West Fork Tailings Impoundment, a low-permeability cap may not be needed. A vegetated soil cover would greatly increase evapotranspiration of precipitation, thereby reducing infiltration. Grading and other surface water controls installed to promote stormwater runoff would further reduce infiltration. Reduced infiltration would result in a reduction of COC migration into Blackbird Creek. In addition, a vegetated soil cover would reduce the exposure of tailings to the atmosphere and limit oxidation. This may already be taking place to some extent due to the large amounts of overbank soils from removal actions on Panther Creek that have been placed on the tailings impoundment. The details of final cover design for the West Fork Tailings Impoundment will be determined based on the final water quality PRGs and the need for infiltration reduction, considering the effectiveness of other components of the selected remedy.

However, a low permeability cover would have a higher moisture content which may reduce the amount of oxygen available to cause oxidation of tailings. The effects of a low permeability cover in reducing oxidation are evaluated in Appendix D. For this FS, a low permeability cover is considered for the northern portion of the tailings impoundment and a soil cover for the southern portion of the impoundment is used as the representative process option in this FS.

4.5.3 Surface Water Controls

Surface water management involves controlling surface water run-on and run-off at the site. The purpose of these controls is to minimize erosion that can entrain exposed soil

affected by COCs, and expose underlying affected materials. These controls may be used as short-term measures (e.g., during excavation), or as long-term measures (e.g., in conjunction with armoring). Surface water controls can include:

- Grading,
- Swales and ditches for surface water diversion,
- Surface water deflector structures,
- Dams to create sedimentation ponds, and
- Dams for surface water flow control (flood control).

Surface water controls are proven technology and are effective. Many surface water controls are easily implemented and relatively inexpensive, although large dams can be difficult and expensive to construct.

Large flood control dams would be used on Blackbird Creek and West Fork to retain flood flows and minimize downstream transport of sediments. The dams would need to be large enough to contain or control the design storm event (500 yr./24 hr. flood). The dams would be intended to slow surface water flow sufficiently to minimize flood scouring of overbank deposits and in-stream sediments. These dams would be very expensive and no more effective than other retained technologies (e.g., armoring and removal). In addition, dams would not address water quality impacts from solubilization of metals in sediment and overbank deposits. Therefore, flood control dams are not retained.

Other surface water controls grading, swales and ditches; deflector structures and small sedimentation dams are retained for further consideration.

4.5.4 Vertical Barriers

Vertical barriers are intended to minimize lateral flow of groundwater or as barriers to direct or contain groundwater flow to locations for collection and treatment, thereby preventing or minimizing migration and discharge of COCs to surface water. For reliable containment, vertical barriers should be keyed into a continuous low-permeability stratum or an artificial horizontal barrier to prevent migration underneath the vertical barrier. Slurry walls, sheet pile walls, and grout walls are established technologies for constructing vertical barriers under appropriate site conditions.

Slurry Walls. Slurry walls are constructed by excavation of a vertical trench and adding admix to soil in a slurry to construct a low-permeability vertical wall. The slurry mixture is used to shore the trench to prevent collapse during construction and serves as part of the low-permeability backfill. Bentonite and cement/bentonite are common admixes. Cement admixes are used where structural strength is required in addition to low permeability. Slurry walls are retained for further consideration.

Grout Wall. A vertical barrier can be constructed with grout, using grout injection, "deep soil mixing," or a combination of these methods. As with slurry walls, a grout wall must be keyed into a horizontal confining layer to provide complete containment. Grout injection involves drilling boreholes and pressure-injection of grout into the boreholes and outward into the surrounding soil. The boreholes are spaced closely enough to obtain overlapping grout zones, forming a continuous wall. Grout walls are retained for further consideration.

Sheet Pile Wall. Sheet pilings are interlocking steel sheets that are driven into the soil to form a wall. Sheet piling is primarily used for providing structural containment in excavations. Leaking can occur between individual sheets unless special measures are taken (such as grouting) to seal the seams. Steel piles eventually deteriorate via corrosion. At the Blackbird Site, a slurry wall or grout wall would be easier to construct and less expensive. Therefore, sheet piling is not retained.

4.5.5 Horizontal Barriers

Horizontal barriers are intended to minimize the vertical migration of COCs in groundwater in an aquifer, into deeper aquifers, or under vertical barriers. Grout injection is a representative horizontal barrier technology that could be used to construct horizontal barriers under appropriate site conditions. However, at this site, there is no demonstrated need for a horizontal barrier for groundwater control. Therefore, no horizontal barrier technologies are retained.

4.6 Removal

Removal is a general response action for media affected by COCs prior to discharge, *ex situ* treatment, or disposal.

Removal can be complete (i.e., all portions of soil or groundwater with constituents above remediation goals), or partial (i.e., the highest concentrations of COCs). Removal by itself is not a complete remedial action, but must be combined with subsequent disposal or discharge of the removed media. Removal is retained for further consideration.

4.6.1 Removal of Soil/Sediment/Tailings

Removal of solid material outside of surface water (e.g., overbank deposits and other affected soils) would involve excavation using standard earthmoving equipment. Excavation is feasible and implementable, generally at reasonable unit cost. Excavation of overbank deposits and other tailings or affected soil is retained for further consideration.

Removal of in-stream sediments would involve dredging. For this site, dredging would generally be performed using excavation equipment operating from just outside the creek. For extensive dredging (e.g., complete removal options), other forms of dredging

equipment would be considered. Dredges sediments could be hauled wet to the destination (where free water would then drain out), or by being allowed to drain near the dredging location before loading. Sediment controls would be necessary during dredging to minimize negative effects on the stream. Dredging is retained for further consideration.

As an alternative to dredging, removal of in-stream sediments could be performed in some areas by temporarily diverting the stream channel around the excavation area. The removal could then be performed using standard earthmoving equipment. Excavation with stream diversion is retained for further consideration.

4.6.2 Removal of Groundwater and Seeps

Groundwater removal would consist of extracting groundwater below the ground surface, and/or by intercepting groundwater surfacing in seeps. Groundwater extraction could be performed with extraction wells and/or extraction trenches. Seeps would be collected using surface water control measures (see Section 4.5.3). The affected groundwater would be transferred to a treatment facility, either by pumping or by gravity flow. Groundwater extraction and seep interception are retained for further consideration.

4.7 Treatment (*Ex Situ* and *In Situ*)

Treatment is intended to reduce the toxicity, mobility, or volume of material affected by COCs. Metals cannot be destroyed by treatment. Metal toxicity can be reduced via chemical conversion to a less toxic compound of the metal, and metals can be immobilized by fixation (stabilization). Treatment of groundwater can remove metals from the water, resulting in a solid waste for disposal.

The same classes of treatment are generally available for both *ex situ* and *in situ* treatment. *Ex situ* processes are generally more reliable and easier to control, but for this site will generally require more operation and maintenance effort than passive *in situ* treatment. For an isolated location such as some portions of this site, therefore, passive treatment is generally preferred. Both *ex situ* and *in situ* treatment options are retained.

4.7.1 Treatment of Affected Soil and Sediments

Where metals are the COCs, the options for treatment are greatly reduced compared to organic COCs. Unlike organic compounds, metals are elements and cannot be destroyed. The best that can be done is to transform the metals into less mobile forms (e.g., chemical stabilization) or less toxic compounds. Because of this, and considering the specific conditions of the Blackbird Site, removal and disposal of affected soil or sediment accomplishes the same objectives in a manner more feasible, more implementable, and for less cost.

Biological treatment technologies do not destroy metals, nor due they reduce the toxicity, mobility, or volume of metals in affected soils/sediments. Therefore, biological treatment technologies are not retained.

Most thermal treatment technologies are designed for destruction of organic compounds, and are not applicable to metals. One thermal treatment technology, vitrification, was developed for encapsulation/stabilization of radionuclide wastes. However, this technology is extremely expensive and has many operational difficulties. It has not been proven for use with mine wastes. Therefore, thermal treatment technologies are not retained.

The most common metal treatment technology is fixation, also called chemical stabilization. Fixation processes involve mixing affected soil of sediments with reagents that reduce constituent mobility (leachability). Reagents include pozzolans that form a solid matrix that immobilizes the COCs, chemicals that raise pH (e.g., lime) to reduce the solubility of metals, and reagents (e.g., apatite) that sorb metals. Fixation can be performed after excavation (*ex situ*) or in place (*in situ*). Fixation is a common, established technology for immobilization of heavy metals. However, the common fixation processes do not work well on copper and similar COCs. In addition, fixation is more difficult to implement and more costly than other retained technologies that are effective and implementable (e.g., armoring and removal). Therefore, fixation is not retained.

4.7.2 Treatment of Surface Water and Groundwater

4.7.2.1 Settling

Affected sediments transported in surface water, and precipitates generated by chemical addition, would be removed by settling. The settling could be performed in a tank, or in a sedimentation pond. Settling is a proven technology for removing settleable solids from water, and is retained for further consideration.

4.7.2.2 Lime Precipitation

Precipitation using lime is a common means of removing metals from wastewater, and is used at the existing wastewater treatment plant. Lime precipitation could be performed in process vessels, as in traditional treatment plants. Lime addition could also be performed semi-passively, with a water wheel using the hydraulic energy of the stream to add the lime. Precipitates (metal hydroxides and carbonates) would settle in a downstream sedimentation basin. The settling basin would require periodic dredging to remove the precipitates, followed by on-site disposal of the sludge. Lime precipitation is feasible and implementable, and is retained for further consideration.

4.7.2.3 Limestone Precipitation

Precipitation using limestone is similar to lime precipitation, but is less efficient. However, in some situations limestone achieves the same level of treatment at less cost.

As with lime precipitation, the dissolved metals are removed from the water as hydroxide and carbonate precipitates. Limestone precipitation is feasible and implementable, and is retained for further consideration.

4.7.2.4 Sulfide Precipitation

Sulfide precipitation is also a proven technology for the removal of metals from wastewater. Because metal sulfides are less soluble than the corresponding hydroxides and carbonates, lower effluent metal concentrations can be achieved. In addition, less sludge is generated. However, sulfide precipitation requires closer process control (to avoid generation of toxic hydrogen sulfide), and is therefore more difficult than lime precipitation and would require construction of a complete new treatment plant to replace the existing treatment plant. Therefore, sulfide precipitation is not retained.

4.7.2.5 *In Situ* Treatment using Sulfate-Reducing Bacteria (SRB)

Sulfate-reducing bacteria could achieve removal of copper, cobalt, and other metals via precipitation as metal sulfides. A passive treatment cell could be constructed using organic media mixed with gravel for structural strength. The bacteria reduce sulfate to sulfide, which precipitates the metals. Reaction byproducts buffer acid pHs to between 6 and 7, which increases metals precipitation.

The bacterial reduction process is slow, requiring a long retention time (contact time). Thus, it is generally more suitable for slow-moving groundwater than for surface water. An SRB cell would most likely be constructed with a grout wall for groundwater control. Soil cover over the active SRB material would be needed to maintain anaerobic conditions.

SRB walls have been operated for over 5 years without replacement, but the ultimate life of SRB treatment walls is unknown. In addition, iron concentrations of the West Fork groundwater could potentially result in iron precipitation hindering groundwater flow through the treatment cell. If indefinite operation were required, periodic replacement of the SRB material would eventually be necessary. *In situ* SRB treatment is retained for further consideration.

4.7.2.6 Ion Exchange

Ion exchange is a proven technology for targeted removal of metals. However, ion exchange is generally more expensive than precipitation. Spent ion exchange resin is regenerated; however, it generates a concentrated wastewater requiring treatment or disposal. The high maintenance and cost of ion exchange, coupled with the requirement to further treat the wastewater from regeneration, is not desirable for an isolated site. Ion exchange is therefore not retained.

4.7.2.7 Reverse Osmosis

Reverse osmosis is proven technology for targeted removal of metals. However, reverse osmosis generates a concentrated wastewater that requires further treatment. Reverse

osmosis is generally more expensive than precipitation. The high maintenance and cost of reverse osmosis, coupled with the requirement to further treat the wastewater from regeneration, is not desirable for an isolated site. Reverse osmosis is therefore not retained.

4.7.2.8 Sorption

Apatite or other suitable sorption material could be used to remove metals from groundwater. Apatite sorption has been demonstrated for copper, zinc, and similar metals; however, it would need to be proven effective for cobalt. Due to the relatively non-specific sorption behavior of apatite, the method is expected to be suitable for the removal of cobalt.

Sorption could be performed in aboveground vessels or passively in a sorption wall. In a passive sorption wall, the apatite (or other sorption material) would be constructed for groundwater to pass through. A grout wall could be used to direct groundwater to the sorption wall. The spent apatite would be periodically removed for on-site disposal. *Ex situ* and *in situ* sorption processes are retained for further consideration.

4.7.2.9 Use of Existing Wastewater Treatment Plant

The Blackbird site has an existing wastewater treatment plant. Although not a separate technology, this treatment plant offers another option for treatment of affected surface water and groundwater. The quantity of affected water that could be treated depends on the excess capacity (considering available storage) of the existing plant, or the existing plant after any upgrades, which may be performed. This option is retained.

4.8 Disposal

Disposal is a general response action for final disposition of excavated waste and affected soil, or waste generated by treatment processes. For the Blackbird Site, several locations are already in use for permanent placement of waste rock and other mine wastes. These include the West Fork Tailing Impoundment, Blacktail Pit, waste rock dumps, and underground mine workings. The remaining capacity of the West Fork Impoundment following completion of the Panther Creek removal actions is limited. Only existing waste rock dumps or new dumps located within areas where runoff is collected for treatment would be considered for disposal locations. The underground mine workings (Hawkeye Ramp) are currently used for disposal of sludges generated from the wastewater treatment plant. On-site disposal in existing mine waste locations, including expansion of these areas when necessary, is retained for further consideration.

Because of the remoteness of the Site, it would be difficult and expensive to haul wastes off-site. In addition, hauling waste off-site would create the potential for off-site exposure via trucking accidents that would not occur with on-site disposal. Therefore, off-site disposal is not retained.

5. ASSEMBLY AND SCREENING OF REMEDIATION ALTERNATIVES

In this chapter, remediation technologies retained after screening in Chapter 4 are assembled into remediation alternatives. The technologies are combined to create a range of alternatives that represent various approaches to reducing potential risks to human health and the environment. The assembly of alternatives is introduced in Section 5.1. The key elements of each alternative are described in Section 5.2 in sufficient detail to allow a screening evaluation. The alternatives are screened in Section 5.3 based on effectiveness, implementability, and cost. The purpose of the screening evaluation is to reduce the number of alternatives for subsequent detailed development and evaluation. A summary of the retained alternatives is provided in Section 5.3.

5.1 Assembly of Alternatives

Following CERCLA guidance, remediation alternatives have been developed to satisfy the following key requirements for the selection of a remedy:

- Protect human health and the environment;
- Comply with ARARs, or justify a waiver;
- Be cost-effective, and
- Utilize permanent solutions and treatment to the maximum extent practicable.

Because of the differences between different Site areas, the Blackbird Site has been divided into the following potential remediation areas:

- Blackbird Creek (including Meadow Creek and the West Fork Tailings Impoundment);
- Bucktail, South Fork Big Deer, and Big Deer Creeks, and
- Panther Creek.

A separate set of alternatives has been developed for each of these areas.

5.1.1 Blackbird Creek (including Meadow Creek and the Tailings Impoundment)

The following initial list of alternatives have been developed for Blackbird Creek:

- Alternative BB-1 – No Further Action;
- Alternative BB-2 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Natural Recovery for Overbank Deposits and In-Stream Sediments;
- Alternative BB-3 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Natural Recovery for Overbank Deposits and In-Stream Sediments;

- Alternative BB-4 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-5 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-6 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-7 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-8 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments, and
- Alternative BB-9 – Treatment of All Blackbird Creek Flow.

5.1.2 Bucktail, South Fork Big Deer, and Big Deer Creeks

The following initial list of alternatives have been developed for Bucktail, South Fork Big Deer, and Big Deer Creeks:

- Alternative BT-1 – No Further Action;
- Alternative BT-2 – Natural Recovery with Monitoring;
- Alternative BT-3 – Seep Collection and Treatment; Natural Recovery of Sediments;
- Alternative BT-4 – Seep Collection and Treatment; S. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments;
- Alternative BT-5 – Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments;
- Alternative BT-6 – Seep Collection and Treatment; Complete Sediment Removal;
- Alternative BT-7 – Bucktail Creek Interception and Treatment; Natural Recovery of Sediments, and
- Alternative BT8 – Bucktail Creek Interception and Treatment; Complete Sediment Removal.

5.1.3 Panther Creek

The following initial list of alternatives have been developed for Panther Creek:

- Alternative P-1 – No Further Action;
- Alternative P-2 – Institutional Controls with Natural Recovery of Panther Creek Sediments;
- Alternative P-3 – Selective Overbank Deposit Removal; Natural Recovery of In-stream Sediments, and
- Alternative P-4 – Selective Overbank Deposit Removal; Complete Removal of In-stream Sediments.

5.2 Description of Alternatives

5.2.1 Common Elements

There are several components of a Site remedy that would be incorporated into most of the alternatives (except "no further action").

5.2.1.1 Institutional Controls

Institutional controls would be included in all alternatives. An enforcement tool, such as a Consent Decree, is anticipated that would require operation, maintenance, and monitoring of the remedy and would preclude activities at the mine site that would interfere with the remedy. Proprietary controls such as conservation easements could be needed on private properties to restrict future uses that could lead to unacceptable exposures to COCs. Proprietary controls would require that an independent third party (preferably a government entity) be willing to serve as grantee of the easements. Controls may be needed at some of the private properties cleaned up under the Early Actions to preclude re-contamination of clean backfill soils if underlying soils with elevated arsenic concentrations are brought to the surface (as a result of erosion or construction activities). Governmental controls could be imposed on the federal lands adjacent to the site to prevent land uses and activities that may interfere with the remedy or that could lead to unacceptable exposures to COCs. These limitations could include camping restrictions along Blackbird Creek or limitations on activities on national forest land that would degrade water quality. Additional institutional controls are included for specific alternatives.

5.2.1.2 Physical Restrictions

Physical restrictions include gates to restrict vehicle traffic and fencing. There is currently a gate located on the Blackbird Creek road a short distance upstream of the Ludwig Gulch Road, which restricts vehicular access to most of the site area.

5.2.1.3 Monitoring

Monitoring of surface waters, sediments, and biota (benthic macroinvertebrates and fish) is included as part of all alternatives, including the "no further action" alternatives.

Monitoring has been conducted since 1998 to evaluate improvements following Early Actions in surface water quality and benthic macroinvertebrate populations, and since 2000 for sediments. This monitoring has shown dramatic improvements in water quality.

Panther Creek meets the dissolved copper water quality criteria during low flow, and copper concentrations are about 2 to 3 times the criteria during the early part of spring runoff. Dissolved cobalt concentrations, which are highest during low flow periods, have been reduced to about 2 times EPA's proposed PRG when peak concentrations have been observed during the Fall and prior to Spring runoff, and typically meet the PRG in Panther Creek during Spring runoff. Benthic macroinvertebrate populations are exhibiting signs of recovery and more closely resemble reference stations, especially in Panther Creek, as compared to pre-Early Action conditions. Ongoing monitoring may show continued improvement in water quality and benthic macroinvertebrate populations as residual metals are flushed from the system.

Separate monitoring programs will be used for the short term (during remedial action) and the long term (following completion of remediation). Monitoring needs will be developed further in the development of alternatives (Chapter 6 of the full FS). Detailed monitoring plans will be developed for the selected remedy during final design.

5.2.1.4 Continued Operation of the Existing Wastewater Treatment Plant

Operation, maintenance, and monitoring of the existing wastewater treatment plant will continue as long as needed to achieve PRGs. This is expected to be a long-term activity continuing indefinitely.

The usable storage capacity of the 7000 and 7100 dams and the underground mine workings has a key effect on the overall capacity of the existing wastewater treatment plant. For those alternatives that entail collection and treatment of additional surface water and/or groundwater, the adequacy of the existing capacity and the potential need for additional storage and/or treatment capacity will be evaluated.

5.2.1.5 Blackbird Creek Channel Near the Panther Creek Inn

EPA has determined that, due to the proximity to the Panther Creek Inn (PCI), the residential human health PRG of 100 mg/kg for arsenic will be applied to the Blackbird Creek overbank deposits from the Panther Creek road bridge to the Blackbird/Panther Creek confluence. EPA has determined that the PRG for in-stream sediments in this reach is 490 mg/kg arsenic. Remedial actions need to be evaluated to address existing overbank areas and in-stream sediments that exceed these PRGs. The remedial actions also need to address the potential for recontamination of this reach.

Overbank deposits containing arsenic above the residential human health PRG for arsenic would be removed in this reach of Blackbird Creek under all the Blackbird Creek alternatives, except under Alternative BB-1. In addition, in-stream sediments would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments.

The actions under the various alternatives to stabilize or remove overbank deposits in upstream Blackbird Creek would reduce the potential for recontaminating the area where removal is conducted. In addition, the existing sediment ponds in Blackbird Creek upstream of the PCI area would be maintained and would provide additional protection. The sediment ponds were designed to store the volume of sediments that would be generated from 10 year/24-hour storm events, although not all the sediment would settle out in the ponds. To further lessen the potential for recontamination, the channel between the road and the mouth of Blackbird Creek would be deepened so that normal spring run-off would not overflow onto the overbank deposits adjacent to Blackbird Creek.

Following removal, the area would be periodically monitored to determine if the area has become recontaminated; additional removals would be conducted if future monitoring determines that the arsenic PRGs for overbank and/or in-stream sediments are exceeded. If redeposition of in-stream sediments causes PRGs to be exceeded on a frequent basis, other options may need to be considered.

An option of constructing a concrete channel (or box culvert) for this reach of Blackbird Creek was also considered. This channel would have to be several feet high and about 45 ft wide to contain flows from large run-off events. The channel area may have to be fenced as a safety measure. A concrete channel would make future removals (due to recontamination from upstream) slightly easier. However, the concrete channel would provide essentially the same level of protection of human health and the environment as the removal option (assuming periodic future removals as needed). Constructing a concrete channel with periodic maintenance would be much more costly than the removal option. There is also uncertainty in terms of implementability of the concrete channel option. A large fenced concrete channel would be visually obtrusive and unnatural; it may be difficult to obtain approval of the property owners at the PCI for construction of a concrete channel.

In summary, the concrete channel and removal options are approximately equal in terms of long-term effectiveness and protection of human health and the environment. The concrete channel would be considerably more expensive, and may have implementability difficulties. Therefore, the concrete channel option is screened out.

5.2.2 Blackbird Creek

The headwaters of Meadow Creek include the area where water is diverted around the 7100 dam. As noted in Section 2.4.2, residual loading from the 7800 waste rock dump is currently bypassing the 7100 dam and not being collected for treatment. With this exception, results of the RI (Golder 2001a) indicate that the Early Actions have been effective at controlling runoff from waste rock dumps in Meadow Creek. No additional actions are needed to address water quality impacts from waste rock dumps in Meadow Creek, except for the residual seepage from the 7800 waste rock dump.

Downstream of the water treatment plant, Blackbird Creek can be divided into upper and lower stream reaches, with the confluence of the West Fork as the dividing line.

These reaches have transport and depositional type sub-reaches. Transport areas are generally found in the upper reach; depositional areas are generally in the lower reach. However, isolated segments of transport and depositional areas can be found in both the upper and lower reaches.

Different human health PRGs have been established for the upper and lower reaches of Blackbird Creek: The arsenic PRG for the upper reach is 8,500 mg/kg, and 4,300 mg/kg for the lower reach. PRGs for water and in-stream sediments are provided in Table 3-3.

Upper Blackbird Creek has been characterized as a transport stream type. The channel has larger particles that comprise the streambed armor layer, consisting primarily of large cobbles, small boulders, and talus rock materials resulting from a higher transport competence associated with steeper gradient. Low-elevation overbank areas are limited, and relatively inactive or poorly developed, and there is generally no significant floodplain. Mid-channel gravel bars, point bars, and islands are commonly interspersed throughout these reaches, generally occurring immediately upstream of constrictions in the channel. These isolated areas can be depositional zones, for even sand-sized particles. The deposition does not often reflect long-term net accumulation. These gravel bars and islands tend to provide only temporary or short-term sediment storage. Sediment supply is minimal in these reaches.

Upper Blackbird Creek has accumulations of mine-related sediments, typically in piles of material excavated by the USFS from the channel, or accumulations from historical breaks in tailings pipelines. In some locations, the historical placement of mine-related sediments in overbank areas has caused blockages or diversion of overland run-off from upland watershed areas. This has been exacerbated in the recent past by changes to the watershed by fire. In these areas, natural overland drainage accumulates behind these sediments, causing isolated pooling of water. As this pooled water overtops, it causes erosion of the affected sediment piles. In these cases, grading of these affected sediments and/or the surrounding area would eliminate these blockages.

The West Fork Tailings Impoundment is located on the West Fork of Blackbird Creek near the confluence with Blackbird Creek. The West Fork is conveyed over the impoundment in a constructed channel (underlain by a clay liner), over a spillway, and thence into Blackbird Creek. The channel and spillway were designed to pass the 500-yr 24-hr storm event. The impoundment dam is approximately 130 feet high. The total impoundment area is approximately 20 acres. Groundwater in the West Fork area, which includes seepage from the impoundment, surfaces in springs that discharge into Blackbird Creek.

Lower Blackbird Creek has been characterized as a depositional stream type. The channel has more broad, flat valley floors with developed floodplains. The stream gradient in these reaches is relatively shallow; the channel tends to exhibit classic pool-riffle structures. These reaches experience lateral channel movement, occasional occurrences of minor braiding, and often large well-developed point bars and establishment of overbank areas. Lateral migration is limited to areas between the road and the valley wall. The shallow slope of the water surface promotes a depositional

environment as high flows access overbank areas. It is these areas that are most likely to collect sediments over time, as the basis of their morphological development is long-term deposition.

Lower Blackbird Creek has characteristic depositional accumulations of mine-related sediments. These sediment locations are typically characteristic of fluvially deposited sediments in gravel bars, point bars, and braided channel reaches. Target sediments are typically distributed within stream gravels and talus material in variable concentrations. In most cases, mine-related sediments are estimated (based on professional judgment) to represent less than 20% to 30% of the total stream sediment volume (i.e. that fraction of a given sample of stream sediments less than approximately the #200 sieve size).

5.2.2.1 Alternative BB-1 – No Further Action

A "no action" alternative is normally included in an FS as a baseline for comparison to the alternatives. However, for this Site, a number of "early action" measures have been completed to expedite remediation of the Site. Under this alternative, remediation measures that have already been performed ("early action" items) would be considered sufficient for this potential remediation area. This alternative would leave this area in its current state, assuming no restrictions on future site use. However, institutional controls and monitoring of this area would be performed in accordance with CERCLA requirements. In addition, the remediation alternatives selected for the other potential remediation areas would be implemented. Continued improvements in water quality, biota, and sediments are expected even with no further action as residual metals are flushed from the system.

5.2.2.2 Alternative BB-2 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Natural Recovery for Overbank Deposits and In-Stream Sediments

Several seeps have been identified in Upper Meadow Creek below the 7800 waste rock dump that are contributing COCs to Blackbird Creek. In this alternative, these seeps would be collected, and the water collected from the seeps would be diverted to the 7100 dam and/or underground mine workings for storage and to the existing wastewater treatment plant for treatment and discharge. Collection and treatment of the Meadow Creek seeps would improve the quality of water in Blackbird Creek and Panther Creek.

A soil cover would be used to close the Tailings Impoundment. This cover would prevent direct contact with the tailings and eliminate exposure if concentrations exceed human health PRGs and prevent surface water transport of the tailings. The cover would also reduce infiltration, thereby reducing COC migration into Blackbird Creek. A soil cover is being used as the representative process option in this FS. A low-permeability layer may not be needed in the cover. A vegetated soil cover would greatly increase evapotranspiration of precipitation, thereby reducing infiltration. Grading and other surface water controls to promote stormwater runoff would further reduce infiltration. Reduced infiltration would reduce the volume of seepage discharging into Blackbird Creek.

Overbank deposits and in-stream sediments would be addressed by natural recovery in this alternative. Over time, the contribution of COCs to Blackbird Creek from sediments would be expected to decline. However, some downstream migration of overbank deposits could occur during storm events.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.3 Alternative BB-3 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Natural Recovery for Overbank Deposits and In-Stream Sediments

In this alternative, Meadow Creek seep collection and a soil cover over the West Fork Tailing Impoundment would be used as described under Alternative BB-2.

In addition, groundwater affected by COCs from the Tailings Impoundment would be intercepted and treated. The treatment would result in a decrease in downstream cobalt concentrations in Blackbird Creek, and a lesser reduction in copper concentrations. Treatment could be accomplished either by collecting and pumping back to the existing Wastewater Treatment System, or *in situ* using a passive treatment system (e.g., sorption wall or SRB wall). Both *ex situ* pump-back and *in situ* treatment will be considered as process options for alternatives that include treatment of Tailings Impoundment seepage.

Overbank deposits and in-stream sediments would be addressed by natural recovery in this alternative. Over time, the contribution of COCs to Blackbird Creek from sediments would be expected to decline. However, some downstream migration of overbank deposits could occur during storm events.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.4 Alternative BB-4 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments

In this alternative, Meadow Creek seep collection and a soil cover over the West Fork Tailing Impoundment would be used as described under Alternative BB-2.

Overbank deposits would be addressed primarily by physical stabilization in key areas. Armoring would minimize the potential for downstream transport of these overbank deposits. Armoring would be designed to resist transport during the design flood event

(500-year/24 hour). Surface water controls would divert surface water away from the physically stabilized deposits.

In addition, a lesser quantity of overbank deposits would be removed where armoring is not considered practical or where concentrations exceed the human health PRGs. Removed sediments could no longer be transported downstream. Removed material would be placed on the West Fork Tailings Impoundment, 7400 waste rock dump, or the Blacktail Pit for disposal. Some minor grading around removal areas could be necessary to provide transitional slopes between removal areas and natural ground.

Excavations would not extend below the groundwater level at the time of excavation. Where overbank deposits are removed to the water table and the remaining sediments (below the water table) exceed human health PRGs, clean soil (with appropriate revegetation) or rock cover would be placed over the material to prevent direct contact and minimize the potential for erosion of the affected sediments.

In-stream sediments would be addressed by natural recovery. Over time, the contribution of COCs to Blackbird Creek from in-stream sediments would be expected to decline. Any COC contributions from in-stream sediments are not expected to prevent achieving PRGs in Panther Creek.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.5 Alternative BB-5 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments

In this alternative, Meadow Creek seep collection and a soil cover over the West Fork Tailing Impoundment would be used as described under Alternative BB-2.

In addition, groundwater affected by COCs from the Tailings Impoundment would be intercepted and treated as described under Alternative BB-3. The treatment would result in a decrease in downstream cobalt concentrations in Blackbird Creek, and a lesser reduction in copper concentrations.

In this alternative, overbank deposits would be addressed primarily by physical stabilization (i.e., armoring and soil cover) in key areas. In addition, a lesser quantity of overbank deposits would be removed where armoring is not considered practical or to remove materials that exceed the human health PRGs. Physical stabilization and selective removal would be performed as described for Alternative BB-4.

In-stream sediments would be addressed by natural recovery. Over time, the contribution of COCs to Blackbird Creek from in-stream sediments would be expected to

decline. Any COC contributions from in-stream sediments are not expected to prevent achieving PRGs in Panther Creek.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.6 Alternative BB-6 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments

In this alternative, Meadow Creek seep collection and a soil cover over the West Fork Tailing Impoundment would be used as described under Alternative BB-2.

Overbank deposits would be addressed primarily by removal from key areas. Excavation and disposal of removed materials would be performed in the same manner as described for Alternative BB-4.

In addition, a lesser quantity of overbank deposits would be physically stabilized by armoring (with surface water controls) where removal is not considered practical. Armoring would be designed installed in the same manner as described under Alternative BB-4.

In-stream sediments would be addressed by natural recovery. Over time, the contribution of COCs to Blackbird Creek from in-stream sediments would be expected to decline. Any COC contributions from in-stream sediments are not expected to prevent achieving PRGs in Panther Creek.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.7 Alternative BB-7 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments

In this alternative, Meadow Creek seep collection and a soil cover over the West Fork Tailing Impoundment would be used as described under Alternative BB-2.

In addition, groundwater affected by COCs from the Tailings Impoundment would be intercepted and treated as described under Alternative BB-3. The treatment would result in a decrease in downstream cobalt concentrations in Blackbird Creek, and a lesser reduction in copper concentrations.

Overbank deposits would be addressed primarily by removal from key areas. In addition, a lesser quantity of overbank deposits would be physically stabilized by armoring (with surface water controls) where removal is not considered practical. Removal and selective physical stabilization would be performed as described for Alternative BB-6.

In-stream sediments would be addressed by natural recovery. Over time, the contribution of COCs to Blackbird Creek from in-stream sediments would be expected to decline. Any COC contributions from in-stream sediments are not expected to prevent achieving PRGs in Panther Creek.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.8 Alternative BB-8 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments

In this alternative, Meadow Creek seep collection and a soil cover over the West Fork Tailing Impoundment would be used as described under Alternative BB-2.

In addition, groundwater affected by COCs from the Tailings Impoundment would be intercepted and treated as described under Alternative BB-3. The treatment would result in a decrease in downstream cobalt concentrations in Blackbird Creek, and a lesser reduction in copper concentrations.

In this alternative, all materials in and around Blackbird Creek containing COCs above the human health and aquatic PRGs would be excavated or dredged, including in-stream sediments and overbank deposits both above and below groundwater. The removal of all materials above the sediment PRGs would eliminate the risk of remobilization and downstream transport of these materials. This would require extensive excavation on either side of the creek and dredging of the entire creek bed.

The extent of removal would include sediments within the channel corridor (i.e., from valley wall on the west to the road on the east). Typically, the bottom extent of the target sediments would be the boundary with existing bedrock features. Provisions for stream diversions, dewatering, and temporary shoring of excavation areas during construction would be required. Affected sediments that are removed would most likely require some replacement of clean fill to maintain the natural dynamics of the stream system, and to preserve the existing road.

A very large quantity of material would be generated for disposal. A new on-site disposal area would be required.

Institutional controls (Section 5.2.1.1) would not be needed for overbank deposits and in-stream sediments because they would all be removed. However, they would be used to prevent activities or development that would compromise the integrity of the remedy (e.g., the Tailings Impoundment cover). Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.2.9 Alternative BB-9 – Treatment of All Blackbird Creek Flow

In this alternative, all flow from Blackbird Creek (up to a design 100-year storm event) would be collected near its confluence with Panther Creek. The Blackbird Creek water would be treated in a new water treatment plant. Because all of the Blackbird Creek flow would be treated, none of the remedial actions in the other alternatives would be provided in this alternative.

A series of large dams would be constructed at several stations along Blackbird Creek to create a series of water storage reservoirs. These reservoirs would provide more even flow and lessen peak treatment flows. Each reservoir would periodically flood the area upstream of the dam. These reservoirs would require relocation and reconstruction of the existing road along Blackbird Creek.

The design capacity of the treatment system could be between 1,000 and 10,000 gpm (2 and 20 cfs), depending on the size of the dams. This is a large treatment plant. Construction would be difficult, and would most likely take two or more construction seasons. The water treatment plant would be located along Blackbird Creek near the Panther Creek Inn. Due to space limitations, the treatment plant would need to be designed with a long, linear layout.

Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media, and to prevent activities or development that would compromise the integrity of the remedy. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3 Bucktail, S. Fork Big Deer, and Deer Creeks

5.2.3.1 Alternative BT-1 – No Further Action

A "no action" alternative is normally included in an FS as a baseline for comparison to the alternatives. However, for this Site, a number of "early action" measures have been completed to expedite remediation of the Site. Under this alternative, remediation measures that have already been performed ("early action" items) would be considered sufficient for this potential remediation area. This alternative would leave this area in its current state, assuming no restrictions on future site use. Continued improvements in water quality, biota, and sediments are expected even with no further action as residual metals are flushed from the system. However, monitoring of this area would be performed in accordance with CERCLA requirements.

5.2.3.2 Alternative BT-2 – Natural Recovery with Monitoring

In this alternative, natural recovery processes would be the key cleanup component. Continued improvements in water quality, biota, and sediments are expected as residual metals are flushed from the system. Institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3.3 Alternative BT-3 – Seep Collection and Treatment; Natural Recovery of Sediments

In this alternative, groundwater seeping into Bucktail Creek would be intercepted and treated at the existing treatment plant. The adequacy of the existing capacity and the potential need for additional storage and/or treatment capacity will be evaluated. The treatment would result in a decrease in downstream copper and cobalt concentrations in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek.

Phasing of the seepage collection would be required because it would not be feasible to collect design information, prepare designs, and complete construction of the entire seepage collection system within a single construction season. Seepage collection would be performed initially below the 7000 dam but above the existing Bucktail pump-back station. Affected groundwater would be intercepted in a french drain and routed to the pump-back station, whence it would be sent to the existing Wastewater Treatment Plant for treatment and discharge. Along with construction of the initial seep collection system, additional design information would be collected to allow design of additional seep collection systems. However, construction of the entire seepage collection could occur in one construction season if design information were collected the previous year and designs completed in the winter before the summer construction season.

After construction of the initial seepage collection with the french drain, additional seepage collection would be implemented downstream (unless it is determined unnecessary after the french drain system is constructed). Gravel would be placed in the creek bed to create a gravel drain, and a surface water channel constructed above the gravel. The intent would be to provide a clean water flow channel for stormwater, and to separately collect and treat the underlying seepage. A subsurface barrier would be constructed across Bucktail Creek as part of the seepage collection system. Depending on the seepage flow and copper loading, the seepage treatment could either be via pump-back to the existing Wastewater Treatment Plants, or *in situ* (e.g., apatite adsorption bed).

Stream sediments would be addressed by natural recovery. Loading from sediments in Bucktail Creek could continue to affect water quality. Ultimately, COC contributions from in-stream sediments in Bucktail Creek are expected to decline to the point where water quality PRGs in Big Deer Creek would be achieved. However, it is not possible to accurately estimate the time required to achieve these water quality PRGs.

The Upper Sediment Pond on Bucktail Creek would be removed during implementation of seep collection. The Lower Sediment Pond near the mouth of Bucktail Creek would

be retained to minimize the potential for Bucktail sediments to be carried into South Fork Big Deer Creek. After natural recovery of the Bucktail sediments, the Lower Sediment Pond would no longer be necessary and could either be removed, if required, or left in place. The emergency spillways for the sediment ponds in Bucktail Creek were originally designed for a hydraulic capacity equal to the 500-year thunderstorm (Golder 1995e). Since the structures were considered temporary, the spillway channels were not fully lined with riprap. Erosion within the spillway would not affect the integrity of the dam. The spillway channel would be repaired if soils were scoured from the channels during a large storm event. In 1999, minor modifications were made to the lower sediment dam spillway to facilitate sediment removal. Following sediment removal, a small earthen and rock berm was installed in the spillway. With this modification, the capacity of the spillway is approximately that of the 100-year thunderstorm. If a large storm occurs, the berm will act like a fuse plug and erode. Once the berm has eroded, the capacity of the spillway will be around that of the 500-year event. Sediments would not be retained within the sediment pond during large thunderstorm events.

Alternative-specific institutional controls would not be required. Access to the Bucktail Creek area is limited, and the gate on Blackbird Creek would continue to provide control of vehicular traffic. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3.4 Alternative BT-4 – Seep Collection and Treatment; S. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments

In this alternative, groundwater seeping into Bucktail Creek would be intercepted and treated as discussed under Alternative BT-3. The treatment would result in a decrease in downstream copper and cobalt concentrations in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek.

In-stream sediments in South Fork Big Deer Creek would be removed for on-site disposal. The intent of the sediment removal would be to speed the natural recovery process and thereby achieve water quality and sediment PRGs in South Fork Big Deer Creek and water quality PRGs in Big Deer Creek more quickly.

Remaining sediments in Bucktail and Big Deer Creeks would be addressed by natural recovery. Sediments in Bucktail Creek would be a potential source of metals and could cause recontamination of South Fork Big Deer Creek sediments. Loading from sediments in Bucktail Creek could continue to affect water quality. Ultimately, COC contributions from in-stream sediments in Bucktail Creek are expected to decline to the point where water quality PRGs in Big Deer Creek would be achieved. However, it is not possible to accurately estimate the time required to achieve these water quality PRGs.

Alternative-specific institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3.5 Alternative BT-5 – Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments

In this alternative, groundwater seeping into Bucktail Creek would be intercepted and treated as discussed under Alternative BT-3. The treatment would result in a decrease in downstream copper and cobalt concentrations in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek.

Stream sediments would be addressed by natural recovery. Loading from sediments in Bucktail Creek could continue to affect water quality. Ultimately, COC contributions from in-stream sediments in Bucktail Creek are expected to decline to the point where water quality PRGs in Big Deer Creek would be achieved. However, it is not possible to accurately estimate the time required to achieve these water quality PRGs.

In addition to natural recovery, Bucktail Creek would be diverted in a pipeline or ditch to bypass South Fork Big Deer Creek and discharge directly into Big Deer Creek. If a diversion pipeline is used it could be equipped with a diffuser where it discharges to Big Deer Creek, if needed. The intent of this diversion would be to divert the dissolved metals loading from Bucktail Creek around the short segment of South Fork Big Deer Creek downstream of Bucktail Creek. The diversion would also reduce the potential for recontamination of the South Fork Big Deer Creek sediments directly from Bucktail Creek sediments.

Alternative-specific institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3.6 Alternative BT-6 – Seep Collection and Treatment; Complete Sediment Removal

In this alternative, groundwater seeping into Bucktail Creek would be intercepted and treated as discussed under Alternative BT-3. The treatment would result in a decrease in downstream copper and cobalt concentrations in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek.

Sediments with COCs above aquatic PRGs in South Fork Big Deer Creek and Big Deer Creek would be removed for on-site disposal. The existing sediment ponds would be retained during construction and then removed.

Alternative-specific institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3.7 Alternative BT-7 – Bucktail Creek Interception and Treatment; Natural Recovery of Sediments

In this alternative, all of the flow in Bucktail Creek would be collected and treated in a new treatment plant constructed at the bottom of the Creek. A dam would be constructed across the creek both to help collect the water and also to create a storage pond. The existing sediment ponds would not be retained under this alternative.

Natural recovery would be used for remediation of affected sediments in South Fork Big Deer Creek and Big Deer Creek.

Alternative-specific institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.3.8 Alternative BT-8 – Bucktail Creek Interception and Treatment; Complete Sediment Removal

In this alternative, all of the flow in Bucktail Creek would be collected and treated in a new treatment plant constructed at the bottom of the Creek. A dam would be constructed across the creek both to help collect the water and also to create a storage pond.

Sediments with COCs above PRGs in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek would be removed for on-site disposal. The existing sediment ponds would be retained during construction and then removed.

Alternative-specific institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.4 Panther Creek

5.2.4.1 Alternative P-1 – No Further Action

A "no action" alternative is normally included in an FS as a baseline for comparison to the alternatives. However, for this Site, a number of "early action" measures have been completed to expedite remediation of the Site. Under this alternative, remediation measures that have already been performed ("early action" items) would be considered sufficient for this potential remediation area. This alternative would leave this area in its current state, assuming no restrictions on future site use. However, monitoring of this area would be performed in accordance with CERCLA requirements.

In addition, the remediation alternatives selected for the other potential remediation areas would be implemented. Evaluation of the effectiveness of alternatives for Blackbird Creek and the West Fork Tailings Impoundment are key to evaluating Panther Creek alternatives because they primarily determine water quality in Panther Creek.

5.2.4.2 Alternative P-2 – Institutional Controls with Natural Recovery of Panther Creek Sediments

In this alternative, water quality improvement would be achieved by upstream alternatives. Overbank deposit removal has already been performed to meet human health PRGs on USFS land and on several of the private properties along Panther Creek. Institutional controls (Section 5.2.1.1) would be used to minimize potential exposure to affected media. Institutional controls would be implemented for private property along Panther Creek with soils exceeding potential future residential PRGs.

The human health risk assessment identified the Strawn, Rufe, and Rogers properties as posing a potential future residential risk in excess of 10^{-4}. EPA might also consider the Hade property if access for sampling is granted in the future and it is found that there is a need for remediation to address human health risks.

Land use monitoring would be performed concurrent with the other monitoring and O&M requirements for the remedy that are anticipated to be required for the foreseeable future at the site. If land use changes at a property result in identification of an unacceptable risk, a contingent action of proprietary controls or removal would be performed. The enforcement institutional control would be layered with informational institutional controls performed by EPA to notify the landowners of the arsenic concentrations at the properties and the monitoring being performed by the BMSG.

Proprietary controls such as conservation easements that would exclude residential development in the vicinity of the overbank deposits on the three properties would be implemented. An enforcement tool (Consent Decree) would establish the requirement for the proprietary controls. The proprietary controls would be layered with informational devices implemented by EPA. The grantee of the easement would be an independent third party, preferably a government entity.
Natural recovery processes continue to improve sediment quality in Panther Creek. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.4.3 Alternative P-3 – Selective Overbank Deposits Removal

In this alternative, water quality improvement would be achieved by upstream alternatives. In addition, selected overbank deposits would be removed (based on human health PRGs for potential future residential use) at some or all of the three private Panther Creek properties evaluated by EPA to pose a potential future residential risk. This would eliminate the need for institutional controls on some or all of the private properties along Panther Creek. The human health risk assessment identified the Strawn, Rufe, Rogers properties as posing a potential future residential risk in excess of 10^{-4}. EPA might also consider the Hade property if access for sampling is granted in the future and it is found that there is a need for remediation to address human health risks.

Natural recovery processes continue to improve sediment quality in Panther Creek. Institutional controls (Section 5.2.1.1) could be used to minimize potential exposure to affected media. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.2.4.4 Alternative P-4 – Complete Sediment Removal

In this alternative, water quality improvement would be achieved by upstream alternatives. In addition, both overbank deposits and in-stream sediments above PRGs would be removed.

Because all affected sediments would be removed, institutional controls would not be required. Monitoring (see Section 5.2.1.3) would determine the effectiveness of the alternative.

5.3 Screening of Alternatives

In this section, the remediation alternatives are screened to produce a refined list for subsequent detailed development and evaluation. The criteria for screening alternatives, as for technologies, are effectiveness, implementability, and cost (see Chapter 4 for definitions). An alternative can be rejected because it is not sufficiently effective relative to another alternative or is not feasible to implement. An alternative can also be rejected by comparison to another alternative that is at least as effective for less cost, or is easier to implement for equivalent cost. An alternative can also be rejected in the case where the additional increase in effectiveness or implementability is not justified by the increased cost, provided the retained alternative is sufficiently protective of human health and the environment.

5.3.1 Blackbird Creek

Alternative BB-1 (No Further Action) is retained as a baseline for comparison to the other alternatives.

Both Alternative BB-2 (Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Natural Recovery for Overbank Deposits and In-Stream Sediments) and Alternative BB-3 (Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Natural Recovery for Overbank Deposits and In-Stream Sediments) use only natural recovery to address remediation of overbank deposits. However, neither of these alternatives provides remedial measures other than institutional controls to prevent direct contact with overbank deposits. In addition, neither of these alternatives includes measures to minimize downstream migration of overbank deposits. On this basis, the EPA has determined that these two alternatives do not meet the threshold requirement for protection of human health. Therefore, Alternative BB-2 and Alternative BB-3 are not retained.

Alternative BB-9 would require construction, operation and maintenance of a very large water treatment plant. It would also require construction and maintenance of several large dams for water storage. Finally, this alternative would require reconstruction of the existing road along Blackbird Creek. The dams would take the place of existing riparian and upland habitat; periodic flooding of the reservoirs created by these dams would destroy much more riparian and upland habitat. The water treatment plant for this alternative would be difficult to construct and maintain, and very expensive. This alternative would cost many millions of dollars more than any other alternative, and yet would provide only marginal improvement in the water quality at the mouth of Blackbird Creek. In addition, unlike the other alternatives, this alternative would not improve water quality in Blackbird Creek itself. Alternative BB-9 would have about the

same effectiveness as other alternatives with much poorer implementability and cost. Therefore, Alternative BB-9 is not retained.

All of the remaining alternatives (BB-4 through BB-8) would, using different approaches:

- Protect human health and the environment;
- Improve in-stream water quality, and
- Mitigate the potential for migration of affected sediments (by removal and/or physical stabilization).

Therefore, the remaining alternatives (BB-4 through BB-8) are retained for further development.

In summary, the following alternatives have been retained for remediation of Meadow and Blackbird Creeks:

- Alternative BB-1 – No Further Action;
- Alternative BB-4 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-5 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-6 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments;
- Alternative BB-7 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments, and
- Alternative BB-8 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments.

5.3.2 Bucktail, S. Fork Big Deer, and Big Deer Creeks

Alternative BT-1 (No Further Action) is retained as a baseline for comparison to the other alternatives.

Alternative BT-2 (Natural Recovery with Institutional Controls and Monitoring) would not be a reliable remedy, in that water quality is not likely to significantly improve without action being taken on seeps in upper Bucktail Creek. In addition, it is unlikely

that this alternative would meet PRGs in the foreseeable future. Therefore this alternative is not retained.

Alternative BT-3 (Seep Collection and Treatment; Natural Recovery of Sediments) would improve in-stream water quality by treating affected groundwater discharging into Bucktail Creek. Natural recovery is expected to improve sediment quality in a reasonable timeframe. This alternative is expected to be effective and implementable. It is therefore retained for further development.

Alternative BT-4 (Seep Collection and Treatment; South Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments) would improve in-stream water quality by treating affected groundwater discharging into Bucktail Creek (the same as Alternative BT-3). This alternative would add removal of South Fork Big Deer Creek sediments to the BT-3 actions and is retained at the direction of EPA.

Alternative BT-5 (Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments) would improve in-stream water quality by treating affected groundwater discharging into Bucktail Creek (the same as Alternative BT-3). Natural recovery is expected to improve sediment quality in a reasonable timeframe. Diversion of Bucktail Creek to avoid contact with South Fork Big Deer Creek sediments might have a short-term benefit for downstream water quality and would improve water quality in South Fork Big Deer Creek. This alternative is expected to be effective and implementable. It is therefore retained for further development.

Alternative BT-6 (Seep Collection and Treatment; Complete Sediment Removal) involves removal of sediments in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek. EPA has not established sediment PRGs in Bucktail Creek, but removal would eliminate potential downstream transport and eliminate them as a potential future source of metals loading. Sediments in South Fork Big Deer Creek and Big Deer Creek would be removed to PRGs. Sediment removal would require massive disruption of these creeks. The ecological damage of this alternative would offset potential benefits. It would also generate a large quantity of material requiring disposal. If existing disposal facilities do not have sufficient capacity, a new, large disposal area would require construction, operation, and maintenance. Sediment removal would be very difficult to implement and very costly. However, to examine the potential effects of sediment removal on water and sediment quality, this alternative is retained for further development and evaluation.

Alternative BT-7 (Bucktail Creek Interception and Treatment; Natural Recovery of Sediments) involves interception and treatment of all of Bucktail Creek. This would require a large new treatment plant. However, in-stream water quality could be improved more easily and at less cost by collection and treatment of water closer to the source areas (as in Alternative BT-3). Thus, Alternative BT-7 would have poorer implementability and be more costly than Alternative BT-3, BT-4, and BT-5, and yet would not be more effective. Therefore, Alternative BT-7 is not retained.

Alternative BT-8 (Bucktail Creek Interception and Treatment; Complete Sediment Removal) involves removal of sediments as described with Alternative BT-6. It also involves interception and treatment of all of Bucktail Creek (the same as with Alternative BT-7). Sediment removal would require massive disruption of these creeks. The ecological damage of this alternative would offset potential benefits. It would also generate a large quantity of material requiring disposal. If existing disposal facilities do not have sufficient capacity, a new, large disposal area would require construction, operation, and maintenance. Sediment removal would be very difficult to implement and very costly. In addition, interception and treatment of all of Bucktail Creek would require a large new treatment plant. In-stream water quality could be improved more easily and at less cost with selective water treatment (as in Alternative BT-3). Other retained alternatives would be effective, less ecologically disruptive, more implementable, and less costly. Therefore, Alternative BT-8 is not retained.

In summary, the following alternatives have been retained for remediation of Bucktail, South Fork Big Deer, and Big Deer Creeks:

- Alternative BT-1 – No Further Action;
- Alternative BT-3 – Seep Collection and Treatment; Natural Recovery of Sediments;
- Alternative BT-4 – Seep Collection and Treatment; S. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments;
- Alternative BT-5 – Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments, and
- Alternative BT-6 – Seep Collection and Treatment; Complete Sediment Removal.

5.3.3 Panther Creek

Alternative P-1 (No Further Action) is retained as a baseline for comparison to the other alternatives. Continued improvements in water quality, biota, and sediments are expected even with no further action as residual metals are flushed from the system.

Alternative P-2 (Institutional Controls with Natural Recovery of Panther Creek Sediments) would result in improved water and sediment quality over time. This alternative is retained for further development.

Alternative P-3 (Selective Overbank Deposit Removal) would result in improved water and sediment quality over time. In addition, selective overbank deposit removal would minimize the need for institutional controls. This alternative is retained for further development.

Alternative P-4 (Complete Sediment Removal) would require extensive removal of both overbank deposits and in-stream sediments in Panther Creek, resulting in massive disruption of the habitat. The ecological damage of the alternative would offset potential benefits. It would also generate a large quantity of material requiring disposal. If

existing disposal facilities do not have sufficient capacity, a new, large disposal area would require construction, operation, and maintenance. This alternative would be very difficult to implement and very costly. Sediment removal is not needed to achieve water quality PRGs in Panther Creek, and metals concentrations in sediments will continue to improve as upstream actions are taken and natural recovery processes take place. Therefore, Alternative P-4 is not retained.

In summary, the following alternatives have been retained for remediation of the Panther Creek Area:

- Alternative P-1 – No Further Action;
- Alternative P-2 – Institutional Controls with Natural Recovery of Panther Creek Sediments, and
- Alternative P-3 – Selective Overbank Deposit Removal; Natural Recovery of In-Stream Sediments.

6. DEVELOPMENT OF ALTERNATIVES

In this chapter, remediation alternatives retained after screening (Chapter 5) are further developed to allow detailed evaluation (Chapter 7). It is necessary to make a number of design assumptions to fully develop and evaluate each alternative. These design assumptions are representative of the technologies used in the alternatives. However, the design assumptions used here are not necessarily the same as the design basis that would be used for the final, detailed design. Additional investigations will be necessary for final design.

6.1 Remediation Components

The alternatives share many common elements in their formulation. In order to avoid repetition, this section presents the descriptions of remedy components. These common elements are then referenced in the descriptions of the alternatives.

6.1.1 Institutional Controls

Institutional controls would be included in all alternatives, except "no further action" alternatives. An enforcement tool, such as a Consent Decree, is anticipated that would require operation, maintenance, and monitoring of the remedy and would preclude activities at the mine site that would interfere with the remedy. Proprietary controls such as conservation easements could be needed on private properties to restrict future uses that could lead to unacceptable exposures to COCs. Proprietary controls would require that an independent third party (preferably a government entity) be willing to serve as grantee of the easements. Controls may be needed at some of the private properties cleaned up under the Early Actions to preclude re-contamination of clean backfill soils if underlying soils with elevated arsenic concentrations are brought to the surface (as a result of erosion or construction activities). Governmental controls could be imposed on the federal lands adjacent to the mine area to prevent land uses and activities that may interfere with the remedy or that could lead to unacceptable exposures to COCs (e.g. camping restrictions along Blackbird Creek). Additional institutional controls are included for Panther Creek alternatives.

6.1.2 Physical Restrictions

Physical restrictions on Blackbird Creek would include continued maintenance of the existing gate on the Blackbird Creek road upstream of the Ludwig Gulch Road and the fencing and gate that controls access from Ludwig Gulch Road to the West Fork Tailings Impoundment. The BMSG maintains control of the locked gate and road that accesses the West Fork Tailings Impoundment. The gate on the main road is also locked; however, the United States government holds a 2950-foot long, 33-foot wide easement on the main road and had keyed access though this locked gate to access National Forest System lands between the gate and the mine itself. The mine itself is located on private land and the BMSG maintains a sign-in and sign-out policy at the mine site. Foot and horse access is not precluded. However, the frequency and duration of such activities is expected to be very limited. The gate on the Blackbird Creek road controls access to the

only road to Bucktail Creek and will also limit access to the northern portion of the Blackbird Mine Site.

6.1.3 Monitoring

Monitoring will be required to maintain facilities, evaluate effectiveness of actions at meeting water quality and to document recovery of benthic invertebrate and fish populations. Water quality monitoring will be conducted of the water treatment plant discharge and at points of compliance. In addition, monitoring will be conducted of various components of the remediation system to ensure effectiveness. This monitoring will include selected overbank areas along Panther Creek (including near the Panther Creek Inn) following significant run-off events to ensure that these areas do not exceed human health PRGs due to remobilization of Blackbird Creek sediments. Monitoring will also be conducted to evaluate whether run-off from the Tailings Impoundment has any impact on water quality. Monitoring will be conducted to meet requirements of the NRD Consent Decree as well as requirements specified in the ROD for the selected remedy.

6.1.4 Water Balance and Storage Capacity Considerations

Alternatives included in this FS will involve collecting, storing and treating additional water containing metals. Storage capacity is currently provided by the underground mine workings above the 6850 bulkhead, the 7100 dam in Meadow Creek, and to a lesser extent the 7000 dam in Bucktail Creek.

An overall site water balance study (Golder 2001e) is being conducted over the next few years to evaluate assumptions used in the original modeling, which was conducted to determine storage and treatment capacity needs during design of Early Actions. This water balance study would include any additional water collected for the final remedy selected for the site.

If additional storage were determined to be needed based on the outcome of the water balance modeling and evaluation of the magnitude and effects of a projected shortage of storage during a design event, additional storage (and modification of the treatment plant operating schedule or increased water treatment plant capacity) would be provided as part of the Blackbird alternatives. The design of the 7100 dam allows it to be expanded if additional storage capacity is needed. In addition, the WTP operating schedule can be readily adjusted from year to year as needed, such as starting treatment of stored water sooner.

The existing components of the water balance model and the potential additional water inputs, depending on the alternatives selected, are illustrated in Figure 6-1. Specifically, the water balance model considers the storage requirements of the possible combinations of added water for treatment from Bucktail Creek, Meadow Creek, and/or the West Fork Tailings Impoundment. Estimates for volumes of water to be collected for storage and treatment for the various alternatives are provided in Table 6-1, with additional discussions for each basin area provided in the following sections. Results of the water balance model are provided in Appendix F.

6.1.5 Continued Operation of the Existing Wastewater Treatment Plant (WTP)

The continued operation of the existing Water Treatment Plant (WTP) would be necessary for treatment of waters collected by the Early Actions and for any remediation alternative involving additional collection of contaminated water for treatment.

The WTP is a lime precipitation plant that currently treats water from the 7100 dam, the underdrain flows below the Meadow Creek cover, and the 6850 portal (mine storage). The WTP is located in the upper part of Blackbird Creek near sampling stations BBSW-07A and BBSW-07. A process flow diagram for the WTP is presented in Figure 6-2. The WTP currently treats a yearly average of about 300 gpm with a maximum monthly average of about 650 gpm. The design capacity is 800 gpm with maximum hydraulic capacity of 1,000 gpm. The WTP normally operates between April and November, and is shut down in the winter.

The WTP currently operates under an expired NPDES permit, which was extended pending completion of the RI/FS and ROD. It includes effluent limitations for pH, copper (total metals) and total suspended solids (TSS). In addition to these parameters, monitoring is conducted (though not required under the permit) for total arsenic, cobalt, and iron. Analysis for dissolved metals is not required under the permit. Under CERCLA, a NPDES permit is not required for this site (see Section 3.1.1.1.3) and a new permit will not be issued. However, the substantive requirements of the Clean Water Act are ARAR for the site. As such, effluent limitations for the WTP will be determined in the ROD.

Appendix B provides the evaluation of total and dissolved metals concentrations that are expected in receiving waters as a result of discharges from the WTP. Panther Creek, as a receiving water, must meet criteria for chronic and acute affects on aquatic life as well as human health criteria. Based on a Use Attainability Analysis, the State of Idaho determined that the beneficial use for Blackbird Creek was only secondary contact, and that water quality criteria for cold-water biota do not apply. The Appendix B evaluation was conducted to be consistent with the evaluation required for an NPDES permit.

The WTP generates an alkaline sludge. TCLP testing of the WTP sludge has been performed and demonstrated that it is non-hazardous under RCRA. This sludge is currently disposed in the Hawkeye Ramp of the underground mine workings. At such time as this mine capacity is exhausted, estimated to be in approximately 7 years, a non-hazardous on-site disposal cell will be constructed for disposal of the WTP sludge. Before going to the disposal site, the sludge will need to be dried. Two drying beds will be constructed. While the sludge in one bed is drying, the other bed will be filling with sludge from the WTP. After the sludge has dried, it will be transported to the on-site disposal cell located in Blacktail Pit or other suitable location.

The continued operation of the Water Treatment Plant is necessary for any alternative that involves the collection of contaminated water for treatment. WTP operations will be continued as long as needed (indefinitely) under any remediation alternative.

6.1.6 Continued Maintenance and Monitoring of Early Actions

Several response measures conducted as Early Actions required ongoing monitoring and maintenance. These include:

- Seepage collection and control of groundwater head on the Upper Blackbird Creek cutoff wall.
- Meadow Creek channel and underdrain system.
- Diversion ditches and drop structures.
- 7000 Dam, 7100 Dam, and the West Fork Tailings Impoundment Dam.
- Pump-back station in Bucktail Creek.
- Underground mine workings for conveyance and storage of water for treatment.
- Sediment Ponds.
- Debris Traps.
- Water Treatment Plant.

For the Upper Blackbird Creek cutoff wall, it is anticipated that monitoring and maintenance of the associated groundwater control measures will reduce copper loading observed between monitoring stations BBSW-07 and BBSW-07A.

6.1.7 Meadow Creek Seep Collection / Surface Water Diversion

In the upper reaches of Meadow Creek, a number of seeps have been observed between the toe of the 7800 waste rock dump and the 7350 detention basin. Water analyses have shown metals loading in this area that contributes to elevated concentrations observed in Blackbird and Panther Creeks during spring run-off. A seep collection system was constructed in this area during the Early Actions; however, the data indicate that additional remediation in this area may be needed to achieve ARARs.

One of the following options would be used to decrease metals loading from Meadow Creek:

- Basin collection – collection of Upper Meadow Creek and northern basin flows in the 7100 reservoir, with a diversion of non-contact water around the existing collection system.
- Seep collection – collection of seeps and shallow groundwater from the drainage area below the toe of the 7800 waste rock dump.

For cost estimating, the remediation alternatives assume the "basin collection" option.

6.1.7.1 Basin Collection and Clean Water Diversion

This option would involve revising the drainage systems below the 7800 waste rock dump to collect contaminated water via the Meadow Creek channel, as shown in Figure 6-3. The intent is to separate clean water in the upper creek from lower creek water affected by seepage containing elevated metals. Currently, this portion of upper Meadow Creek discharges into the existing 7350-detention basin. The existing 7350-diversion structure would be regraded so that seeps and Meadow Creek would discharge into the 7100 reservoir for treatment in the WTP. This would provide collection for storage and treatment of seeps containing high levels of metals from the area below the toe of the 7800 waste rock dump and debris flow deposits.

Clean water from the upper creek would be intercepted and piped to the existing pipeline exiting the 7350 Detention Dam. A clean water diversion ditch would also be constructed to intercept water from the hillside to the south, which would be diverted into this line. An intake at the end of this ditch would channel this clean water into the existing 7100 West diversion system.

This option would provide more assurance of collecting seepage containing elevated metals compared to the option of collecting specific seeps. However, this option would result in collection of more water, and thus has greater operating costs than the seep collection option. The estimated annual average flow and 100-year snowpack runoff volumes, which would be collected for storage and treatment, are provided in Table 6-1. Treatment costs are based on annual average flows and storage requirements are based on the 100-year snowpack runoff. Estimates were developed based on measured flows and evaluation of overall basin hydrology and apportioning between portions of the basing that would be collected for treatment or diverted as clean water.

6.1.7.2 Seep Collection

This option would involve construction of a collection trench below the toe of the existing waste rock dump. Figure 6-4 shows a plan view and cross-section of the collection trench. The collection trench would be constructed below the existing collection ditch, which was built at the toe of the dump. It would be constructed to a depth of about 15 feet, which is about 5 feet above the start of fractured rock. The construction depth is limited to 15 feet due to the steep cross slope of this area, and the goal of utilizing conventional excavation equipment. Constructing the collection system to this depth should capture the majority of the existing seepage and shallow groundwater.

The collection system would include a perforated collection pipe that would be connected to the existing 7800 collection system tight line drain. This existing waste drain conveys contact water down to the 7100 reservoir. Estimates of the volume of water collected for storage and treatment are provided in Table 6-1, as described in the previous section.

Subsurface information important to the design of these elements includes the character of the overburden, and the depth to rock. Although the design of the collection trench is not dependent on the depth to rock, it is important to confirm the overall feasibility of this approach by confirming the depth to rock.

6.1.8 Soil Cover for the West Fork Tailings Impoundment

Upon completion of placement of all overbank deposits removed from Blackbird Creek, a soil cover would be placed over the Tailings Impoundment. The cover material would consist of existing overbank deposits removed from Panther Creek and any additional overbank materials that would be removed from Blackbird Creek, provided that these overbank deposits show acceptable risk to human health for the worker and trespasser scenarios. The thickness of cover over the tailings would be at least ten (10) feet over the portion of the impoundment south of the West Fork Blackbird Creek Channel, and at least six (6) feet over the impoundment north of the channel.

As discussed in Appendix D, use of compacted clay on the portion of the Tailings Impoundment north of the creek channel would add to the effectiveness of the cover in improving seepage water quality by decreasing tailings oxidation. For Alternatives BB-4 and BB-6, which do not include treatment of Tailings Impoundment seepage, a compacted clay layer one (1) foot thick is assumed. The clay layer would be protected by one to two feet of soil or other appropriate cover. Another cover that may be considered would be to place the overbank materials removed from along Blackbird Creek on the tailings impoundment, followed by any soils removed from the Panther Creek overbank deposits. This would provide approximately 6 feet of cover materials on the northern portion of the tailings impoundment. Alternatives BB-7 and BB-8 handle Tailings Impoundment seepage by collection and treatment, and therefore would not include the clay layer in the cover.

The cover would be graded to drain to the creek channel, and would be seeded to establish vegetation. Run-on controls could be provided if required. The soil cover plan view and cross-section is shown in Figure 6-5.

6.1.9 Treatment of West Fork Tailings Impoundment Seepage

Three representative process options are presented to evaluate treatment of tailings impoundment seepage:

- Pump-back to the WTP.
- Ex-situ treatment at the West Fork.
- In-situ treatment.

In-situ treatment is estimated to be less expensive (see estimates in Appendix E); however, in-situ treatment is unproven in this application. Therefore, pump-back to the WTP and ex-situ treatment has also been included to provide proven process options.

There is considerable uncertainty in the flow rate of seepage from the Tailings Impoundment. An analysis was conducted to determine the seepage flow from the Tailings Impoundment that may require collection, storage, and treatment, based on the cobalt loading observed between BBSW-03A and BBSW-02. The load difference between these two stations consists primarily of the seepage from the Tailings Impoundment. Using varying flow rates (1 to 200 gpm), the observed load difference was converted to average concentrations of cobalt in the seepage corresponding to each flow rate. The calculated concentrations were then compared with the average concentration of the Tailings Impoundment seepage (11.5 mg/L cobalt) to determine the flow of the seepage. These results were compared to measured flows from the West Fork Interceptor Ditch as a crosscheck. According to this analysis, the flow rate of the Tailings Impoundment seepage is estimated to be between 100 and 200 gpm. As discussed in Chapter 7, only about 50% of the load would need to be collected to achieve treatment objectives. For cost estimating purposes, collection and treatment of 100 gpm (50% of the high estimate) was assumed.

All three process options include installation of groundwater interception systems. The available data is adequate to define the top of rock below the tailings dam, and provides a basic indication of the character of the materials that overlie the rock. This information could be sufficient as the minimum required for design of a slurry wall and groundwater collection system. However, the bedrock intersections in the valley bottom are not definitive in some cases (i.e., they are defined on the basis of "refusal", or by projecting a surface eastward from borehole intersections in the area of the tailings dam). Available borehole data does not include information in the vicinity of the north end of the trench or slurry wall. Thus, additional investigation would be needed for this alternative. Effects of construction of a groundwater interception system on stability of the tailings dam would have to be evaluated if a seepage collection system is included as part of the selected alternative. For example, the potential for causing water to backup behind an interceptor wall, causing water levels in the tailings impoundment to rise, would be evaluated.

6.1.9.1 Pump-Back for Treatment in the WTP

Figure 6-6 illustrates a collection trench and pump station to transfer Tailings Impoundment seepage to the WTP. The collection trench would be constructed with conventional excavation equipment to a depth of approximately 15 feet. The depth to bedrock in this area is approximately 20 feet. A collection trench 15 feet deep should collect the majority of seepage. The existing culvert underdrain will be extended to connect to the collection trench. A clay trench cap would be used to minimize surface water infiltration. The collection trench would drain to a vault and pump station containing two pumps. The pumps would alternate to minimize wear on the pumps. Three booster pump stations would be used to pump the collected water to the 7100 dam for storage via an HDPE pipeline. Storage vaults would be installed to buffer flows between the pump stations and to provide storage to allow draining the pipeline. Each pump station would be provided with a backup generator, control equipment, and telemetry. The telemetry would provide the WTP with pump station status.

6.1.9.2 Ex-Situ Treatment at the West Fork

In this treatment process option, Tailings Impoundment seepage would be collected as described in the preceding section. Instead of pumping to the existing WTP, however, a pre-designed ("package") treatment plant would be installed near the Tailings Impoundment. The treatment plant would provide lime treatment and air oxidation the same as the existing WTP. Treated water would be discharged to Blackbird Creek immediately downstream of the West Fork.

6.1.9.3 In-Situ Treatment

In-situ treatment could be accomplished in a variety of ways, including a sorption cell, an anaerobic sulfate-reducing bacterial (SRB) cell, or some form of anaerobic wetlands. For the purposes of this FS, in-situ treatment was evaluated using the process option of in-situ sorption cells. As shown in Figure 6-7, in-situ sorption could be implemented in the following manner:

- A slurry wall would be constructed below the dam to intercept seepage into Blackbird Creek.
- A collection drain system would direct the seepage into subsurface treatment vaults.
- Two vaults would be constructed in the wall. Each vault would contain sorption material capable of sorbing cobalt under site conditions. For this FS, the sorption material was assumed to be apatite. Apatite has been used for sorption of copper, zinc, and other metals discharging from mine tailings (Calabretta et al. 2001). It is believed it would work for cobalt as well, but this would need to be established via a treatability study before use.

If in-situ treatment were to be used, a treatability study would be needed to select and design the most cost-effective in-situ process.

6.1.10 Physical Stabilization of Blackbird Creek Overbank Deposits

Two alternatives focus on physical stabilization (armoring) of overbank deposits. Typical cross-sections of overbank deposits under current conditions are shown in Figure 6-8. Figure 6-9 presents typical sections for physical stabilization. Grading and stormwater diversion features associated with physical stabilization are shown on Figure 6-10. Physical stabilization areas are shown on Figures 6-13a though 6-13x. The areas identified in these figures include a description of the proposed action at that area. In these figures, "Option A" refers to alternatives where stabilization is the primary component, and "Option B" refers to alternatives where removal is the primary component.

Overbank deposits that have the potential for mobilization by the design 500-year flood would be armored against mobilization. Armoring of overbank deposits would be accomplished by placing angular riprap armor rock. The armor riprap would be installed along exposed banks of mine related sediments from the bottom anticipated

scour depth to above the water surface elevation predicted for the design flood. The armor rock would be sized to resist mobilization during the design flood. A preliminary evaluation of the potential for materials to be mobilized and armor rock sizing is addressed in Appendix A. Additional design would be necessary to finalize the armor rock size, dimensions, and placement.

In a few selected areas (e.g. where the creek flows around a rock outcrop), armoring would be difficult and less reliable than removal. For these selected areas, overbank deposits would be removed rather than armored (see Figures 6-13a through 6-13x). Removal would be performed as described in Section 6.1.11.

In addition to armoring, overbank deposits with arsenic concentrations above human health PRGs will be removed. No further action would be taken for overbank deposits in talus slopes. The talus rock already provides armoring, and removal would be difficult. Removal in the talus slopes would also destabilize the hillside, increasing erosion of overbank deposits into the creek.

Where possible, armoring would be performed from the roadside (i.e., without crossing the creek). However, equipment would need to cross the creek in some locations. In these locations, direct creek crossing may be performed, or a temporary bridge constructed. Temporary bridges would be removed on completion of the work.

In some locations, overbank deposits are blocking overland run-off from upland watershed areas. In these areas, stormwater run-off accumulates behind the overbank deposits. In some locations, where the run-off has been unable to get around or over the deposits, the accumulated water has broken through the overbank deposits and washed out some of the deposits. To address this, where necessary, one or both of the following would be performed:

- Drainage pathways would be excavated through the piles to provide natural drainage of accumulated water, or the piles would be re-graded to minimize the potential for accumulation.
- Diversion ditches would be used to route surface water run-off around the overbank deposits.

6.1.11 Removal of Blackbird Creek Overbank Deposits

Two alternatives focus on removal of overbank deposits. Typical cross-sections of overbank deposits under current conditions are shown in Figure 6-8. Figure 6-11 presents typical sections for removal. Removal areas are shown on Figures 6-13a through 6-13x. The areas identified in these figures include a description of the proposed action at that area. In these figures, "Option A" refers to alternatives where stabilization is emphasized, and "Option B" refers to alternatives where removal is emphasized.

Designated overbank deposits would be excavated and hauled to the Tailings Impoundment or the Blacktail Pit for disposal. Excavation will be conducted to the

former slope or angle of repose, to natural ground surface, or to the water table as indicated for the individual deposits. Following excavation, the removal area would be graded as necessary for good stormwater drainage.

Where possible, excavation and loading would be performed from the roadside (i.e., without crossing the creek). However, equipment would need to cross the creek in some locations. In these locations, direct creek crossing may be performed, or a temporary bridge constructed. Temporary bridges would be removed on completion of the work.

In a few selected areas, armoring would be used instead of removal (see Figures 6-13a though 6-13x). In addition, armoring would be added in removal areas where residual concentrations exceed the human health PRG, or where EPA in consultation with BMSG determines based on best professional judgment that armoring is required to prevent significant remobilization of affected sediments. Armoring would be performed as described in Section 6.1.10.

No further action would be taken for overbank deposits in talus slopes. The talus rock already provides armoring, and removal would be difficult. Removal in the talus slopes would also destabilize the hillside, increasing erosion of overbank deposits into the creek.

6.1.12 Blackbird Creek Channel Near the Panther Creek Inn

EPA has determined that, due to the proximity to the Panther Creek Inn, the residential human health PRG of 100 mg/kg for arsenic for Panther Creek overbank deposits will be applied to the Blackbird Creek overbank deposits from the Panther Creek road bridge to the Blackbird/Panther Creek confluence. EPA has determined that the PRG for in-stream sediments in this reach is 490 mg/kg for arsenic. Remedial actions are required to address existing overbank areas and in-stream sediments that exceed these PRGs. The remedial actions also need to address the potential for recontamination of this reach.

Overbank deposits containing arsenic above the residential human health PRG for arsenic would be removed in this reach of Blackbird Creek under all the Blackbird Creek alternatives, except under Alternative BB-1. In addition, in-stream sediments would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments.

The actions under the various alternatives to stabilize or remove overbank deposits in upstream Blackbird Creek would reduce the potential for recontaminating the area where removal is conducted. In addition, the existing sediment ponds in Blackbird Creek upstream of the PCI area would be maintained and would provide additional protection. The sediment ponds were designed to store the volume of sediments that would be generated from 10 year/24-hour storm events, although not all the sediment would settle out in the ponds. To further lessen the potential for recontamination, the channel between the road and the mouth of Blackbird Creek would be deepened so that normal spring run-off would not overflow onto the overbank deposits.

Following removal, the area would be periodically monitored as discussed in Section 6.1.3 to determine if the area has become recontaminated, and removal of sediments conducted if future monitoring determines that overbank and/or in-stream sediment PRGs are exceeded. If redeposition of in-stream sediments causes the PRG to be exceeded on a frequent basis, other options may need to be considered.

6.1.13 Natural Recovery for In-Stream Sediments

Natural recovery would be used in most alternatives to address remediation of in-stream sediments. Natural recovery refers to a variety of natural physical, chemical, and biological processes that act without human intervention (e.g., precipitation, sorption, and dispersion. Natural recovery results in reduction in concentrations, toxicity, mobility, and/or volume of COCs.

Cobalt, arsenic, and copper are present as both primary and secondary mineral phases in streambed sediments at the Blackbird Site. Whereas chemical processes are expected to reduce metal concentrations in secondary phases, these processes are not expected to significantly reduce primary mineral metal concentrations. However, physical processes affect metals associated with both primary and secondary mineral phases.

Historically, creek streambeds have acted as a sink of trace metals along certain reaches at the Blackbird Site (e.g., Blackbird Creek below the West Fork, or Bucktail Creek). The precipitation of secondary minerals (copper carbonates, iron hydroxides, manganese hydroxides) and adsorption onto iron (oxy) hydroxides as well as other adsorbents (clays and manganese (oxy) hydroxides) have resulted in the transfer of metals from the aqueous to the solid phase. As surface water quality improves, trace metals may be liberated back to the water column. Secondary mineral dissolution and desorption are expected to result in a decline in sediment metal concentrations. Geochemical modeling, conducted as part of the RI, evaluated the effect of these reactions on Blackbird Site water quality. Because the focus of the modeling effort was to predict impacts to water quality, only results for the water phase were presented (Golder, 2001a). These model results are however also applicable to sediment quality. Loadings to the water phase result in an equivalent loss in the solid phase.

Cobalt, copper, and arsenic are also present as primary mineral sulfides in stream sediments at the Blackbird Site, albeit at much lower concentrations than secondary minerals. The metals associated with primary sulfide minerals are of lesser concern in the stream sediments because they are generally less bioavailable than secondary sulfides. Chemical processes are likely to result in minimal reductions in primary sulfide metal concentrations because the oxidation of primary sulfides is expected to be a slow process in the stream sediments at the Blackbird Site (Golder, 2001a).

Physical sediment transport from the scouring and mobilization of fine-grained sediments downstream will result in a decline in sediment metal concentrations with distance from the contaminant source. Loading of uncontaminated sediments from non-mineralized drainages, also serve to reduce total sediment metal concentrations through mixing of contaminated and clean sediments.

6.1.14 Contingent Remedial Actions

There is uncertainty about the effectiveness of many of the proposed remedial actions. If the selected remedy does not meet the remediation goals in an acceptable timeframe, additional actions will be evaluated. These actions could include, but would not necessarily be limited to:

- Actions to reduce the hydraulic head upstream of the cutoff wall on upper Blackbird Creek to reduce seepage through the wall and metals loading from groundwater discharging to Blackbird Creek, or extraction of groundwater for treatment.
- Increases to the water storage and/or treatment capacity, and/or revisions to the treatment schedule, if there is insufficient capacity to meet water storage and treatment needs.
- Additional removal of overbank deposits along Blackbird Creek.
- Run-on/run-off controls for the cover on the West Fork Tailings Impoundment, if monitoring indicates excessive erosion or water quality impacts from runoff.
- Measures to reduce the water table in the West Fork area, if the water table begins to rise to a level that threatens the stability of the dam at the West Fork Tailings Impoundment.
- Removal of Bucktail Creek sediments, if they result in unacceptable metals loading to Big Deer Creek.
- Additional collection and treatment of Bucktail Creek seeps, if they result in unacceptable metals loading to Big Deer Creek.
- Installation of a passive (or semi-passive) treatment system in lower Bucktail Creek (Alternatives BT-2, BT-3 and BT-4) or near the confluence of the South Fork Big Deer Creek and Big Deer Creek (BT-5), if water quality criteria in Big Deer Creek are not achieved through other actions.
- Additional removals along Panther Creek if monitoring following storm events result in deposition of overbank deposits that exceed remediation goals.

The schedule for evaluating effectiveness and considering contingencies will be determined in the ROD.

6.2 Description of Alternatives for Blackbird Creek (including Meadow Creek and the Tailings Impoundment)

This section contains details of the alternatives that were retained after screening in Chapter 5 for Blackbird Creek. Table 6-2 summarizes the components of each of these alternatives.

6.2.1 Alternative BB-1 – No Further Action

This alternative would leave the Blackbird Creek area in its current state, assuming no restrictions on future site use. There have been removal actions ("early actions") performed on the Site, and these would be considered sufficient. Continued improvement in water quality, biota, and sediments are expected even with no further action as residual metals are flushed out of the system. However, observed improvements to water quality, biota and sediments could be partially due to natural yearly variability and the timing of data collection.

"Early actions" which have proved beneficial to Blackbird Creek and Panther Creek include:

- Construction of the 7100 earthen clay-core dam to collect and store water draining from the waste rock dumps in the Meadow Creek drainage basin before treatment.
- Pipelines from the 7100 dam to the water treatment plant and replacement of piping and instrumentation between the bulkhead at the 6850 adit and the water treatment plant.
- Upgrade to and expansion of the existing water treatment plant. The upgraded treatment plant has a normal maximum treatment capacity of 800 gallons per minute (gpm) and discharges treated water to Blackbird Creek.
- Installation of a sludge pipeline from the water treatment plant to the Hawkeye Ramp.
- Construction of a contaminated water collection system below the 7800 waste rock pile.
- A series of clean water ditches and pipelines to divert clean water around the contaminated areas and the 7100 dam reservoir, and transport clean water downstream of the 7100 dam.
- Relocation of waste rock from the canyon walls of Meadow Creek and Blackbird Creek extending from the 7100 dam area to just upstream of the water treatment plant and from Hawkeye Gulch, which discharges to Blackbird Creek near the treatment plant.
- The waste rock in the Meadow Creek and Blackbird Creek bottoms was covered with a clean earth cover. Drains were installed beneath the cover to collect contaminated groundwater and transport it to the water treatment plant.
- Concrete channels were constructed across the top of the capped waste rock to convey Meadow Creek and Blackbird Creek.
- Construction of a groundwater cutoff wall in upper Blackbird Creek about 300 feet upstream of the water treatment plant to intercept contaminated groundwater flowing through the waste rock beneath the cover. The water is piped to the water treatment plant.

- Construction of a temporary sediment control basin to settle out sediment generated during construction activities, and for a time after completion of the Early Actions.
- Removal of visually obvious, erodeable tailings from overbank deposits at several locations along Blackbird Creek.
- Construction of three sediment basins along Blackbird Creek.

Monitoring of the site, in accordance with CERCLA, would continue as described in Section 6.1.3.

6.2.2 Alternative BB-4 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments

The major components in this alternative are:

1. Collection and treatment of Meadow Creek seeps as described in Section 6.1.7.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Construction of a soil cover over the Tailings Impoundment as described in Section 6.1.8.
4. Physical stabilization (with limited removal) for overbank deposits as described in Section 6.1.10.
5. Removal of overbank deposits along the Blackbird Creek channel near the PCI as described in Section 6.1.12.
6. Natural recovery for in-stream sediments as described in Section 6.1.13.
7. Establishing institutional controls and physical restrictions appropriate for this alternative as described in Sections 6.1.1 and 6.1.2.
8. Use of health and safety plans to mitigate worker risk.
9. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Tailings Impoundment soil cover – The soil cover will need to be checked periodically to ensure that the slopes and vegetation are intact.
- Inspection and maintenance of armoring.
- Institutional controls – Use restrictions by the USFS Regional Supervisor to prevent camping on National Forest System lands along Blackbird Creek, and any institutional controls on private property.

- Fencing and warning signs – Long-term maintenance of the signs will include making sure they are visible and legible. The fencing will need to be inspected periodically and repaired when necessary.
- Other monitoring as described in Section 6.1.3.

6.2.3 Alternative BB-5 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments

The major components of this alternative are:

1. Collection and treatment of Meadow Creek seeps as described in Section 6.1.7.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Construction of a soil cover over the Tailings Impoundment as described in Section 6.1.8.
4. Collection and treatment of seepage from the Tailings Impoundment as described in Section 6.1.9.
5. Physical stabilization (with limited removal) for overbank deposits as described in Section 6.1.10.
6. Removal of overbank deposits along the Blackbird Creek channel near the PCI as described in Section 6.1.12.
7. Natural recovery for in-stream sediments as described in Section 6.1.13.
8. Establishing institutional controls and physical restrictions appropriate for this alternative as described in Sections 6.1.1 and 6.1.2.
9. Use of health and safety plans to mitigate worker risk.
10. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Tailings Impoundment soil cover – The soil cover will need to be checked periodically to ensure that the slopes and vegetation are intact.
- Tailings Impoundment treatment system – Depending on the treatment option chosen, long term maintenance will vary from replacing sorption material to inspecting pipes and soil covers.
- Inspection and maintenance of armoring along Blackbird Creek.
- Institutional controls – Use restrictions by the USFS Regional Supervisor to prevent camping on National Forest System lands along Blackbird Creek, and any institutional controls on private property.

- Fencing and warning signs – Long-term maintenance of the signs will include making sure they are visible and legible. The fencing will need to be inspected periodically and repaired when necessary.
- Other monitoring as described in Section 6.1.3.

6.2.4 Alternative BB-6 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments

The major components of this alternative are:

1. Collection and treatment of Meadow Creek seeps as described in Section 6.1.7.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Construction of a soil cover over the Tailings Impoundment as described in Section 6.1.8.
4. Removal of overbank deposits (with limited armoring) as described in Section 6.1.11.
5. Removal of overbank deposits along the Blackbird Creek channel near the PCI as described in Section 6.1.12.
6. Natural recovery for in-stream sediments as described in Section 6.1.13.
7. Establishing institutional controls and physical restrictions appropriate for this alternative as described in Sections 6.1.1 and 6.1.2.
8. Use of health and safety plans to mitigate worker risk.
9. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Tailings Impoundment soil cover – The soil cover will need to be checked periodically to ensure that the slopes and vegetation are intact.
- Inspection and maintenance of armoring along Blackbird Creek.
- Institutional controls - Use restrictions by the USFS Regional Supervisor to prevent camping on National Forest System lands along Blackbird Creek, and any institutional controls on private property.
- Fencing and warning signs – Long-term maintenance of the signs will include making sure they are visible and legible. The fencing will need to be inspected periodically and repaired when necessary.
- Other monitoring as described in Section 6.1.3.

6.2.5 Alternative BB-7 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments

The major components of this alternative are:

1. Collection and treatment of Meadow Creek seeps as described in Section 6.1.7.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Construction of a soil cover over the Tailings Impoundment as described in Section 6.1.8.
4. Collection and treatment of seepage from the Tailings Impoundment as described in Section 6.1.9.
5. Removal of overbank deposits (with limited armoring) as described in Section 6.1.11.
6. Removal of overbank deposits along the Blackbird Creek channel near the PCI as described in Section 6.1.12.
7. Natural recovery for in-stream sediments as described in Section 6.1.13.
8. Establishing institutional controls and physical restrictions appropriate for this alternative as described in Sections 6.1.1 and 6.1.2.
9. Use of health and safety plans to mitigate worker risk.
10. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Tailings Impoundment soil cover – The soil cover will need to be checked periodically to ensure that the slopes and vegetation are intact.
- Tailings Impoundment treatment system – Depending on the treatment option chosen, long term maintenance will vary from replacing sorption material to inspecting pipes and soil covers.
- Inspection and maintenance of armoring along Blackbird Creek.
- Institutional controls – Use restrictions by the USFS Regional Supervisor to prevent camping on National Forest System lands along Blackbird Creek, and any institutional controls on private property.
- Fencing and warning signs – Long-term maintenance of the signs will include making sure they are visible and legible. The fencing will need to be inspected periodically and repaired when necessary.
- Other monitoring as described in Section 6.1.3.

6.2.6 Alternative BB-8 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments

This alternative differs from the other Blackbird Creek alternatives in that it includes complete removal of both overbank deposits and in-stream sediments. Removal would extend from the existing road to the valley wall across from the road (see Figure 6-12). Because separation of natural and mine-related in-stream sediments is not practical, all sediments in the stream channel would be removed to bedrock (including sediments below the water table). Following excavation, sufficient backfill would be placed in and around the stream channels to provide riparian habitat, and the backfill would be revegetated.

Such extensive excavation would take several construction seasons. The existing riparian habitat and sediments in Blackbird Creek would be removed in the process leaving exposed bedrock. Stream diversion, excavation dewatering, and temporary shoring of excavation areas would be required. The collected water from dewatering could require treatment before discharge. The existing access road would require reconstruction following completion of excavation.

The large volume of sediments would require construction of a new on-site disposal cell. A suitable location has not been identified at this time. For costing, the disposal cell was sized to hold 650,000 cy. The cell would be about 500 feet by 500 feet, with a total depth of about 53 feet.

The major components of this alternative are:

1. Collection and treatment of Meadow Creek seeps as described in Section 6.1.7.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Construction of a soil cover over the Tailings Impoundment as described in Section 6.1.8.
4. Collection and treatment of seepage from the Tailings Impoundment as described in Section 6.1.9.
5. Construction of large new on-site sediment disposal area.
6. Complete removal of overbank deposits and in-stream sediments (including the Blackbird Creek channel near the PCI).
7. Backfill and restoration of riparian habitat.
8. Establishing institutional controls and physical restrictions appropriate for this alternative as described in Sections 6.1.1 and 6.1.2.
9. Use of health and safety plans to mitigate worker risk.
10. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Tailings Impoundment soil cover – The soil cover will need to be checked periodically to ensure that the slopes and vegetation are intact.
- Tailings Impoundment treatment system – Depending on the treatment option chosen, long term maintenance will vary from replacing sorption material to inspecting pipes and soil covers.
- Other monitoring as described in Section 6.1.3.

6.3 Description of Alternatives for Bucktail, S. Fork Big Deer, and Big Deer Creeks

This section contains details of the alternatives that were retained after screening in Chapter 5 for Bucktail, South Fork Big Deer, and Big Deer Creeks. Table 6-2 summarizes the components of each of these alternatives.

6.3.1 Alternative BT-1 – No Further Action

This alternative would leave the Bucktail, South Fork Big Deer, and Big Deer creeks area in its current state, assuming no restrictions on future site use. There have been removal actions ("early actions") performed on the Site, and these would be considered sufficient. Continued improvement in water quality, biota, and sediments are expected even with no further action as residual metals are flushed out of the system. However, observed improvements to water quality, biota and sediments could be partially due to natural yearly variability and the timing of data collection.

"Early actions" which have proved beneficial to Bucktail, South Fork Big Deer, Big Deer, and Panther Creeks include:

- Construction of an earth fill clay-core dam (Bucktail 7000 dam) and pipeline and open-channel spillway to collect, store and divert contaminated water to the water treatment plant via the 6930 adit to the underground mine workings.
- Construction of a new adit at elevation 6930 to connect to the 6850 level of the old mine workings.
- Construction of a pump station and pipelines located downstream of the 7000 dam. The pump station and pipeline is used to collect and convey springs and dam seepage and pump it to the 6930 adit for transport through the mine to the water treatment plant.
- Relocation of waste rock piles, with primary disposal in the Blacktail Pit, and the use of some of the waste rock in the construction of the 7000 dam.

- A waste rock repository (Blacktail Pit), including a foundation drainage system to drain water entering the former pit into the old mine workings and to the water treatment plant.
- A series of clean water ditches and pipelines to divert clean water around the waste rock dumps and the 7000 dam reservoir, and transport the clean water to Bucktail Creek downstream of the 7000 dam.
- The 7200 Collection Ditch to collect contaminated water from the remainder of the West Lobe waste rock dump and direct the contaminated water toward upper Bucktail Creek upstream of the 7000 dam.
- A series of sediment control ditches to reduce the slope length of the waste rock to remain in place.
- Debris traps located in the Bucktail Creek channel to reduce the risk of debris flows.
- Two temporary sediment control dams to settle out sediment generated during construction activities and sediments from residual debris flow materials along Bucktail Creek.
- Relocation of debris flow material along Bucktail Creek between the upper and lower sediment dams.

Monitoring of the site, in accordance with CERCLA, would continue as described in Section 6.1.3.

6.3.2 Alternative BT-3 – Seep Collection and Treatment; Natural Recovery of Sediments

The major components of this alternative are:

1. Collection and treatment of Bucktail Creek seeps.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Natural recovery for in-stream sediments as described in Section 6.1.13.
4. Use of health and safety plans to mitigate worker risk.
5. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.

- Bucktail Creek seep collection system – Long-term maintenance would vary based on the extent of the collection system and whether a sorption wall is included. Phase 1 would require maintenance of piping, pumps and the collection trench. Phase 2 would require maintenance of pipeline and pumps or of the sorption wall.
- Other monitoring as described in Section 6.1.3.

Alternative BT-3 involves the collection and treatment of seeps in the upper Bucktail Creek. Seeps have been observed entering the creek upstream of the upper sediment pond and in an area upstream of BTSW-01.6. The primary source of seepage is believed to be immediately below the 7000 dam and an area around BTSP-01. There may be other, yet unidentified, sources of seepage containing metals. This alternative would involve installation of one or more interception trenches to collect affected groundwater.

Phasing of the seepage collection would be required because it would not be feasible to collect design information, prepare designs, and complete construction of the entire seepage collection system within a single construction season. Initially, one installation trench would be installed below the 7000 dam (see Figures 6-14 and 6-15). Collected water would flow by gravity to the existing pump-back station. If this action were sufficient to achieve PRGs in Big Deer Creek, then no further seep collection would be performed. Along with construction of the initial seep collection system, additional design information would be collected for increasing the capacity of the existing pump-back station and to allow design of additional seep collection systems. However, construction of the entire seepage collection could occur in one construction season if design information were collected the previous year and designs completed in the winter before the summer construction season.

After construction of the initial seepage collection with the french drain, additional seepage collection would be implemented downstream (unless it is determined unnecessary after the french drain system is constructed). Gravel would be placed in the creek bed to create a gravel drain, and a surface water channel constructed above the gravel. The intent would be to provide a clean water flow channel for stormwater, and to separately collect and treat the underlying seepage. A subsurface barrier would be constructed across Bucktail Creek as part of the seepage collection system.

If the metal loads in the groundwater were relatively low, then passive in-situ treatment (i.e., a sorption wall) would be considered. If the metals load were too high for cost-effective in-situ treatment, and an interception trench would be installed to collect the groundwater from the lower layer. A pump station next to this collection trench would pump water to the existing pump station for pumping to the 6930 adit. The estimated flows for initial and potential subsequent seep collection are provided in Table 6-1.

An interceptor trench would also be installed at the base of the West Fork of Bucktail Creek (Figure 6-14) to collect groundwater and to divert surface water onto the surface channel. Depending on the relative loading contribution from groundwater and an evaluation of loading reduction needed to achieve PRGs in Big Deer Creek, the

groundwater would either be diverted to the pump-back station or to the surface water channel. The quality of this water is uncertain. If it were clean, then the intercepted water would be routed to clean surface flow. Alternatively, if this water required treatment, then the water would flow by gravity to the existing pump-back station.

The Upper Sediment Pond on Bucktail Creek would be removed during implementation of seep collection. The Lower Sediment Pond near the mouth of Bucktail Creek would be retained to minimize the potential for Bucktail sediments to be carried into South Fork Big Deer Creek. After natural recovery of the Bucktail sediments, the Lower Sediment Pond would no longer be necessary and could either be removed, if required, or left in place. The emergency spillways for the sediment ponds in Bucktail Creek were originally designed for a hydraulic capacity equal to the 500-year thunderstorm (Golder 1995e). Since the structures were considered temporary, the spillway channels were not fully lined with riprap. Erosion of the spillway channel would not affect the integrity of the dams. The spillway channel would be repaired if soils were scoured from the channels during a large storm event. In 1999, minor modifications were made to the lower sediment dam spillway to facilitate sediment removal. Following sediment removal, a small earthen and rock berm was installed in the spillway. With this modification, the capacity of the spillway is approximately that of the 100-year thunderstorm. If a large storm occurs, the berm will act like a fuse plug and erode. Once the berm has eroded, the capacity of the spillway will be around that of the 500-year event. Sediments would not be retained within the sediment pond during large thunderstorm events.

6.3.3 Alternative BT-4 - Seep Collection and Treatment; S. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments

The major components of this alternative are:

1. Collection and treatment of Bucktail Creek seeps as discussed in Section 6.3.2.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. In-stream sediment removal in South Fork Big Deer Creek, with backfill and restoration of riparian habitat.
4. Natural recovery for remaining in-stream sediments as described in Section 6.1.13.
5. Use of health and safety plans to mitigate worker risk.
6. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Bucktail Creek seep collection system – Long-term maintenance will vary based on the extent of the collection system and whether a sorption wall is included.

Phase 1 will require maintenance of piping, pumps, and the collection trench. Phase 2 will require maintenance of pipeline and pumps or of the sorption wall.

- Other monitoring as described in Section 6.1.3.

Alternative BT-4 involves the collection and treatment of seeps in the upper Bucktail Creek, the same as for Alternative BT-3 (see Section 6.3.3 for details). In-stream sediments in South Fork Big Deer Creek (Figure 6-16) would be removed for on-site disposal at the Blacktail Pit or other suitable location. The intent of the sediment removal would be speed recovery of the sediments in the South Fork Big Deer Creek and to remove a source of metals affecting water quality in Big Deer Creek. Remaining sediments in Bucktail and Creek and Big Deer Creek would be addressed by natural recovery. Loading from sediments in Bucktail Creek may continue to affect ability to meet water quality. Ultimately, COC contributions from in-stream sediments in Bucktail Creek are expected to decline to the point where water quality PRGs in Big Deer Creek would be achieved. However, it is not possible to predict the time frame until these PRGs can be achieved. COC contributions from in-stream sediments are not expected to be sufficient to prevent achieving PRGs.

The existing sediment dams would be handled the same as described under Alternative BT-3.

6.3.4 Alternative BT-5 – Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments

The major components of this alternative are:

1. Collection and treatment of Bucktail Creek seeps as discussed in Section 6.3.2.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Diversion of Bucktail Creek, discharging into Big Deer Creek (potentially via a diffuser).
4. Natural recovery for in-stream sediments as described in Section 6.1.13.
5. Use of health and safety plans to mitigate worker risk.
6. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Bucktail Creek seep collection system – Long-term maintenance will vary based on the extent of the collection system and whether a sorption wall is included. Phase 1 will require maintenance of piping, pumps and the collection trench. Phase 2 will require maintenance of pipeline and pumps or of the sorption wall.

- Bucktail Creek diversion piping – The diversion collection and piping system would have to be maintained to ensure it remains functional.
- Other monitoring as described in Section 6.1.3.

Alternative BT-5 involves the collection and treatment of seeps in the upper Bucktail Creek, the same as for Alternative BT-3 (see Section 6.3.3 for details).

This alternative differs from Alternative BT-3 in that it also involves the diversion of Bucktail Creek around South Fork Big Deer Creek to discharge directly into Big Deer Creek (Figure 6-16). Although bypassing base flow should be sufficient, to be conservative the bypass pipeline or ditch would be sized for flows up to a 10-year, 24-hour design storm (based on restored conditions rather than immediate post-fire conditions). On this basis, a 24-inch pipeline would be sufficient. Flows in excess of the pipe or ditch carrying capacity would be allowed to discharge into South Fork Big Deer Creek. However, in such high-flow conditions, the copper in Bucktail Creek would be diluted by water with low concentrations of metals in South Fork Big Deer Creek, which would likely be under high flow conditions as well. Flows in South Fork Big Deer Creek are typically about an order of magnitude larger than flows in Bucktail Creek. The diversion pipeline would potentially be equipped with a diffuser where it discharges into Big Deer Creek.

The intent of this diversion would be to divert the dissolved metals loading in Bucktail Creek around the short segment of South Fork Big Deer Creek downstream of Bucktail Creek. The diversion would also reduce the risk of recontamination of the South Fork Big Deer Creek sediments directly from Bucktail Creek sediments and from copper released from Bucktail Creek sediments.

The existing sediment dams would be handled the same as described under Alternative BT-3.

6.3.5 Alternative BT-6 - Seep Collection and Treatment; Complete Sediment Removal

The major components of this alternative are:

1. Collection and treatment of Bucktail Creek seeps as discussed in Section 6.3.2.
2. Continued operation of the WTP as discussed in Section 6.1.5.
3. Removal of sediments in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek.
4. Backfill and restoration of riparian habitat.
5. Use of health and safety plans to mitigate worker risk.
6. Monitoring as discussed in Section 6.1.3.

This alternative would involve long-term maintenance and monitoring of the following:

- Wastewater Treatment Plant – The piping, monitoring equipment, tanks, and pumps will need long-term maintenance to ensure that they remain functional.
- Bucktail Creek seep collection system – Long-term maintenance would vary based on the extent of the collection system and whether a sorption wall is included. Phase 1 would require maintenance of piping, pumps and the collection trench. Phase 2 would require maintenance of pipeline and pumps or of the sorption wall.
- Other monitoring as described in Section 6.1.3.

Alternative BT-6 involves the collection and treatment of seeps in the upper Bucktail Creek, the same as for Alternative BT-3 (see Section 6.3.3 for details).

Removal of sediments with COCs above the PRGs in Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek would serve to improve the water quality of those creeks as well as Panther Creek. This would involve massive excavation of in-stream sediments. For volume and cost estimating purposes, this alternative assumes that within Bucktail Creek sediments would be removed to bedrock. Within South Fork Big Deer Creek and Big Deer Creek two feet depth of sediment removal is assumed. Following excavation, sufficient backfill would be placed in and around the stream channels to provide riparian habitat, and the backfill would be revegetated.

Such extensive excavation would take several construction seasons. Stream diversion, excavation dewatering, and temporary shoring of excavation areas would be required. The collected water from dewatering could require treatment before discharge. The existing access road would require reconstruction following completion of excavation.

No location has been identified for disposal of the large volume of sediments. However, locations such as the existing waste rock dumps, where runoff is collected for treatment would be considered. For costing, a new on-site disposal cell was assumed. The disposal cell was sized to hold 36,000 cy. The cell would be about 150 feet by 100 feet, with a total depth of 35 feet.

6.4 Description of Alternatives for Panther Creek

This section contains details of the alternatives that were retained after screening in Chapter 5 for Panther Creek. Table 6-2 summarizes the components of each of these alternatives. In considering these alternatives, it should be kept in mind that the alternatives selected for Blackbird Creek and Bucktail Creek will determine water quality improvements in Panther Creek. The Panther Creek alternatives focus on sediments along Panther Creek (overbank deposits and in-stream sediments), and are considered source control alternatives for human health.

6.4.1 Alternative P-1 – No Further Action

This alternative would leave the Panther Creek area in its current state, assuming no restrictions on future site use. There have been removal actions ("early actions") performed on the Site, and these would be considered sufficient. Continued improvement in water quality, biota, and sediments are expected even with no further action as residual metals are flushed out of the system. However, observed improvements to water quality, biota and sediments could be partially due to natural yearly variability and the timing of data collection.

The Early Action which were implemented along Panther Creek have proved beneficial; contaminated materials were removed until testing indicated that the underlying soils were below the PRGs, or until the water table was reached. Removed areas were backfilled with clean soil and the top six inches were replaced with topsoil and revegetated. No samples exceeding PRGs were left above the water table at removal areas along Panther Creek. At areas where elevated arsenic concentrations remain at the water table, there is a risk that these materials could be brought to the surface as a result of erosion or construction activities. The No-Further Action alternative would not address this risk. Monitoring would be conducted following significant storms to ensure that downstream properties were not recontaminated as a result of remobilization of sediments from Blackbird Creek.

The Early Actions performed in the Blackbird and Bucktail Creek watersheds have resulted in major improvements to the water quality in Panther Creek (see discussions in Sections 6.2.1 and 6.3.1). Final water quality after remediation will be determined by the alternatives selected for Blackbird Creek and Bucktail Creek.

No action would be taken for those properties where EPA predicts a future potential risk due to soil ingestion under a future residential use scenario.

6.4.2 Alternative P-2 – Institutional Controls with Natural Recovery of Panther Creek Sediments

The major components of this alternative are:

1. Remediation alternatives from Blackbird and/or Bucktail Creeks.
2. Natural recovery for in-stream sediments as described in Section 6.1.11.3.
3. Establishing institutional controls appropriate for this alternative.
4. Monitoring as discussed in Section 6.1.3.

The human health risk assessment identified the Strawn, Rufe, and Rogers' properties as posing a potential future residential risk in excess of 10^{-4}. EPA might also consider the Hade property if access for sampling is granted in the future and it is found that there is a need for remediation to address human health risks.

Proprietary controls such as conservation easements that would exclude residential development in the vicinity of the overbank deposits on the three properties would be implemented. An enforcement tool (Consent Decree) would establish the requirement for the proprietary controls. The proprietary controls would be layered with informational devices implemented by EPA and the BMSG. The grantee of the easement would be an independent third party, preferably a government entity. Controls may also be needed at some of the private properties cleaned up under the Early Actions to preclude unacceptable future exposure if underlying soils with elevated arsenic concentrations are brought to the surface (as a result of erosion or construction activities).

Monitoring would be conducted following significant storm events to ensure that downstream properties were not recontaminated due to remobilization of sediments from Blackbird Creek. This monitoring would be performed concurrent with the other monitoring and O&M requirements for the remedy that are anticipated to be required for the foreseeable future at the site. If land use changes at a property result in identification of an unacceptable risk, a contingent action of proprietary controls or removal would be performed. The enforcement institutional control would be layered with informational institutional controls performed by EPA to notify the landowners of the arsenic concentrations at the properties and the monitoring being performed by the BMSG.

6.4.3 Alternative P-3 – Selective Overbank Deposit Removal; Natural Recovery of In-Stream Sediments

The major components of this alternative are:

1. Remediation alternatives from Blackbird and/or Bucktail Creeks.
2. Selective removal of overbank deposits.
3. Use of health and safety plans to mitigate worker risk.
4. Establishing institutional controls appropriate for this alternative.

Selected overbank deposits would be removed at the Rogers, Rufe, and former Strawn properties. Soils would be removed to meet human health PRGs for potential future residential use (100 mg/kg arsenic). Removal of soils would avoid the need for institutional controls along Panther Creek. As discussed in Section 6.4.1, monitoring would also be conducted following significant storm events to ensure that downstream properties were not recontaminated due to remobilization of sediments from Blackbird Creek.

Institutional controls may also be needed at some of the private properties cleaned up under the Early Actions to preclude unacceptable future exposure if underlying soils with elevated arsenic concentrations are brought to the surface (as a result of erosion or construction activities).

Figures showing locations of the selective removals are shown in Figure 6-17 through 6-19.

7. EVALUATION OF ALTERNATIVES

The remediation alternatives developed in the previous chapter are evaluated in this chapter. The detailed analysis of alternatives contained in Chapter 7 was prepared by EPA, not by the BMSG or Golder. In significant respects, the BMSG and Golder do not agree with EPA's analysis and the resulting conclusions. The BMSG reserves the right to comment on the analysis and conclusions in Chapter 7 and to submit its own analysis of alternatives.

7.1 Evaluation Criteria

CERCLA and the NCP require evaluation of remediation alternatives in terms of nine criteria (40 CFR 300.430(e)(9)):

- Overall protection of human health and the environment;
- Compliance with ARARs;
- Long-term effectiveness and permanence;
- Reduction in toxicity, mobility and volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost;
- State Acceptance, and
- Community acceptance.

The first two criteria are termed "threshold" criteria. Threshold criteria are minimum requirements that must be satisfied by an alternative. These criteria are applied to individual alternatives, but not used in the comparative evaluation of alternatives.

The next five are the "balancing" criteria. Comparative evaluation is based on the balancing criteria that are used to weigh tradeoffs between alternatives.

The FS evaluates the alternatives using the two threshold and five balancing criteria. The remaining two "modifying" criteria, state and community acceptance, are not evaluated in the FS. After the FS is finalized, an alternative is selected as the proposed remedial action. The proposed remedial action is described along with the basis for its selection in the Proposed Plan. The evaluation of the modifying criteria is based on state and public comments on the FS and the Proposed Plan. The proposed remedial actions may be modified based on state and public comments. State and community concerns, and any resulting changes in the selected remedial actions, are documented in the Record of Decision (ROD) for the site. Therefore, the two modifying criteria are not included in the FS evaluation.

The seven FS criteria are discussed below. The criteria definitions used herein are consistent with those in CERCLA and the NCP, and have been developed to minimize overlap of considerations. This allows a more independent evaluation of each criterion, and avoids double counting in the evaluation (i.e., considering the same technical factor more than once).

7.1.1 Overall Protection of Human Health and the Environment

This criterion addresses the degree to which each alternative is protective of human health and the environment, considering both long-term and short-term risks. Overall protectiveness is a "threshold" criterion, in that alternatives that do not achieve adequate protection of human health or the environment are eliminated from further consideration. The ability of the alternatives to achieve remedial action objectives is part of the evaluation of this criterion (as well as part of long-term effectiveness). This FS presents an objective comparison of the ability of the alternatives to meet PRGs (both water quality and sediments). As part of selecting an alternative for the proposed remedy, EPA has made determinations on the "protectiveness" of each alternative.

This criterion is derived from the evaluation of other criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. It is not an independent criterion, but more a summary of the overall evaluation of these other criteria.

7.1.2 Compliance with ARARs

This criterion addresses whether or not the alternative meets applicable or relevant and appropriate requirements (ARARs), as defined in Chapter 3. As with overall protectiveness, compliance with ARARs is a threshold criterion that must be met for an alternative to be selected, unless a waiver is obtained.

A complete discussion of ARARs is provided in Chapter 3. The primary ARARs addressed in evaluation of remediation alternatives in this section are the copper water quality criterion and NPDES requirements. The copper water quality criterion is an ARAR for Panther Creek, South Fork Big Deer Creek, and Big Deer Creek. The copper criterion is not an ARAR for Blackbird Creek or Bucktail Creek, since the IDEQ has determined that neither of these creeks is suitable for cold-water biota (see Table 3-1c).

A water quality criterion has not been promulgated for cobalt and therefore the cobalt PRG is not an ARAR. As discussed in Section 3.1.1.3 and Appendix C, the water quality criterion for iron may not be relevant and appropriate. Therefore, it is not addressed as an ARAR in the detailed analysis of alternatives.

Appendix B provides an assessment of NPDES requirements including evaluation of mixing zones in Panther Creek and Big Deer Creek. As indicated in Appendix B, when Blackbird Creek enters Panther Creek, the plume immediately occupies over 50% of the width of the stream under worse case conditions. Thus, 50% is the minimum mixing

zone required by any of the alternatives under worse case conditions Under average conditions the minimum width of the mixing zone is 30%. The mixing zone and assessment of the remaining zone of passage for fish is provided in Appendix B and summarized for each alternative in the individual ARAR sections of the detailed analysis. NPDES requirements are not ARAR for the Bucktail Creek alternatives evaluated in this FS.

7.1.3 Long-term Effectiveness and Permanence

This criterion addresses the results of an alternative after RAOs have been met:

- The magnitude of residual risks remaining at the site after implementation of the remediation alternative has been completed, and
- The adequacy and reliability of the controls (if any) provided to control residual risks (e.g., treatment residuals) after completion of the alternative.

In other words, this criterion addresses the effectiveness of the alternatives at reducing risks over an extended period of time. Long-term effectiveness can be measured by the degree to which remedial action objectives are met. Permanence involves estimating the longevity of the remedy (i.e., life span of institutional controls or containment) and the reliability of the remedy (i.e., the chances of remedy failure).

Risks during the implementation period are addressed under short-term effectiveness. For containment alternatives, risks during operation, maintenance, and monitoring (after completion of construction) are considered under long-term effectiveness because of the indefinite, long time period involved. For other alternatives, where the time to achieve RAOs is finite and relatively short, risks during operation, maintenance and monitoring of the remedy are considered under short-term effectiveness.

The benefits of treatment in improving the effectiveness of an alternative are considered under this criterion. The preference for treatment, above and beyond improved effectiveness, is addressed under the treatment criterion.

7.1.4 Reduction of Toxicity, Mobility and Volume through Treatment

This criterion addresses the degree to which a remediation alternative employs treatment technologies to reduce "principal threats at a site" permanently and significantly by:

- Destruction or detoxification of the toxic contaminants;
- Permanently reducing the ability of contaminants to migrate in the environment, and/or
- Reducing the quantity of remaining contaminated material.

This criterion expresses the preference for treatment under CERCLA. To avoid double counting in the comparative evaluation, the effectiveness and reliability of the treatment

should be addressed under the long-term effectiveness and permanence criterion, rather than under this criterion.

7.1.5 Short-term Effectiveness

This criterion addresses short-term effects on human health and the environment during construction and implementation until RAOs are met. The evaluation includes consideration of the following factors:

- Risk to the surrounding community from implementing the remedial action, such as dust from excavation or transportation of hazardous materials;
- Risks to site workers and effectiveness and reliability of protective measures that would be taken;
- Risk to the environment (short-term ecological risk) that may result from construction and implementation of an alternative and reliability of the available mitigation measures in preventing or reducing the potential impacts; and
- The time required before remedial action objectives are achieved.

7.1.6 Implementability

This criterion addresses the degree of difficulty in implementing each alternative. Implementability can be sub-divided into technical feasibility, administrative feasibility, and availability of services and materials. Implementability issues become more significant as the complexity of the alternative increases and as the reliance on innovative technology increases. Implementability issues are important because they address the potential for delays, cost overruns, and failure.

The implementability criterion focuses on poorly quantifiable known and potential difficulties in completing the remedial action. It is evaluated considering the following:

- **Technical Feasibility**. Technical feasibility addresses the potential for problems during implementation of the alternative and related uncertainties. The evaluation includes the likelihood of delays due to technical problems and the ease of modifying the alternative, if required;
- **Administrative Feasibility**. The degree of difficulty anticipated due to regulatory constraints and the degree of coordination required between various agencies, and
- **Availability of Services and Materials**. The availability of experienced contractors and personnel, equipment and materials needed to implement the alternative, and disposal capacity.

7.1.7 Cost

This criterion is used to consider the costs of performing each alternative, including capital, operation, and maintenance, and monitoring costs. Alternative costs are

compared on a net present value basis. Known implementation difficulties with quantifiable cost impacts are included in the cost estimates. The interest rate of 7% (net of inflation) used for present value calculations is the rate recommended by the EPA for feasibility study cost estimates, and is in the range of typical historical net interest rates.

The cost estimates in this FS are based on the description of the alternatives and associated design assumptions in Chapter 6. The design assumptions used here are representative and sufficient for the purposes of comparative evaluation of the alternatives, but are not necessarily the same as the design basis that would be used for the final, detailed design. Pre-design investigations would be included in the final design phase for any of these remedial actions, and the results of these investigations could result in changes from the preliminary designs presented in this FS.

EPA guidance suggests a target accuracy of +50%/-30%. The cost estimates in the FS were developed to meet this target to the extent practical. The design basis is subject to change during final, detailed design of the selected alternative, and these changes would affect the cost of the remedy. Changes in design assumptions could result in costs outside the target precision range.

The uncertainties in the FS designs and associated cost estimates are such that actual costs could vary significantly from these estimates. However, the uncertainty in the *relative* cost of the alternatives is much less than the uncertainty in the magnitude of the costs, and these cost estimates are suitable for comparative evaluation of the alternatives.

7.2 Individual Evaluation of Blackbird Creek Alternatives

This section presents the evaluation of individual Blackbird Creek alternatives using the CERCLA criteria. These alternatives are compared in Section 7.5.1.

7.2.1 Common Evaluation Elements

A number of evaluation considerations common to the Blackbird Creek alternatives are discussed in this section.

7.2.1.1 Effectiveness of a Soil Cover on the West Fork Tailings Impoundment

A soil cover on the West Fork Tailings Impoundment is included in all alternatives except BB-1. To avoid repetition, the long-term and short-term effectiveness of this component is discussed in this section. This discussion is a summary of the conclusions of the analysis presented in Appendix D.

A soil cover over the Tailings Impoundment (described in Section 6.1.7) would have two key benefits:

- Reduce infiltration of water through the tailings, and

- Decrease the oxygen flux into the tailings, thereby reducing production of soluble cobalt and copper via oxidation.

Based on the conceptual model of the Tailings Impoundment presented in Appendix D, about 17% of the water coming from the Tailings Impoundment originates as precipitation on the surface of the impoundment. The remainder of the water comes down the hill slopes, along the sides of the impoundment, and mixes with the tailings infiltration. The soil cover (including diversion of runoff from the hillsides) would produce an estimated 69% reduction in infiltration through the tailings. The net effect would be to produce an estimated 12% overall reduction in infiltrating water. Assuming that the cobalt and copper concentration in the pore water are uniform throughout the unconsolidated deposits, this reduction in infiltrating water would produce a corresponding 12% reduction in metals loading. This benefit would be realized shortly after the cover is placed. This benefit would remain approximately the same until the tailings pore water from the top oxidative zone has migrated through the tailings and shows up in seepage.

The long-term benefits of a soil cover depend on reducing the oxidative process that produces soluble cobalt and copper. Based on currently available information, the proposed soil cover would reduce the flux of oxygen into the tailings, and thus the production of soluble cobalt and copper. Thus, the effectiveness of the proposed soil cover in reducing metals loading would eventually increase, once drainage of the residual pore water resulting from historic oxidation of tailings has occurred. The time for pore water to infiltrate from the top to the bottom of the tailings is estimated to range from almost immediate in certain areas of the impoundment to between a few years and several decades in other areas. This would depend on thickness of tailings and extent of the oxidized zone within various locations of the impoundment.

Estimated reductions in metals loading as a result of reduced oxidation are included in the estimates for load reduction of the Blackbird Creek alternatives (see Section 7.2.1.2). Based on the modeling discussed in Appendix D, cobalt and iron reductions in comparison to no cover would be a maximum of approximately 50%. This is based on: 1) a 40% reduction of the southern portion of the impoundment (>3 ft cover over 49% of the area); 2) a 55% reduction on the northern portion of the impoundment (1 ft clay over 30% of the area); and a 55% reduction under the clay liner for the West Fork Blackbird Creek channel (21% of the area). For copper, which is not expected to show the same degree of reduction due to its non-conservative behavior (see Appendix D for discussion), 15% reduction was assumed based on infiltration reduction as discussed above. It should be noted that the input parameters for the modeling included in Appendix D were based on very limited field data. In addition, as with most models, a number of simplifying assumptions were made that do not take into account the complexity and heterogeneity of actual conditions within the tailings impoundment. Thus, there is considerable uncertainty in terms of the predictions made by the model, especially in terms of the reductions of cobalt loads as a result of changes in oxidation caused by the soil cover/cap. It is uncertain whether the cover/cap will be effective at reducing cobalt loads at all. If the cover/cap does indeed prove effective, there is

considerable uncertainty in terms of the amount of cobalt load reductions that would occur and the time required to achieve those reductions.

The Response Actions conducted between 1993 and 2001 are expected to provide continued long-term benefits to water quality. These actions included constructing an upstream cutoff wall and the clay cap and channel for diversion of West Fork of Blackbird Creek over the surface of the tailings, filling the culvert underdrain with gravel, and installing p-traps in the pipe to prevent oxygen from entering the pipe. These actions may have already resulted in reducing oxidation of tailings in portions of the impoundment and could be producing benefits in reducing metals loading that have not been fully realized yet.

7.2.1.2 Evaluation of Improvements to Water Quality

Early Actions have resulted in vast improvements in water quality in Panther Creek. Water quality is expected to continue to slowly improve even without further action. However, water quality and sediment PRGs would not be met in the foreseeable future (i.e. decades to centuries) without further actions. Therefore, the various remediation alternatives have been developed to improve water and sediment quality and need to be evaluated for meeting PRGs in Blackbird Creek and Panther Creek. Additional improvements in concentrations of dissolved copper and cobalt resulting from each of the Blackbird Creek alternatives were estimated for Blackbird Creek and Panther Creek. These predictions are provided in Tables 7-1a&b through 7-5a&b, 7-6, and 7-7. Mixing zone considerations (for discharge of Blackbird Creek into Panther Creek) are addressed in Appendix B.

The estimated improvements in water quality shown in these tables are based on synoptic sampling data collected during 2000 and 2001. The synoptic data represent a "snapshot" of water quality because the data are collected for a 1 or 2 day period, once in the spring and once in the fall. Therefore, the data in these tables do not represent the highest observed concentrations, especially for cobalt (highest cobalt concentrations typically occur in the winter and in spring prior to runoff). The measured metals loads at PASW-09 were allocated between the following Blackbird Creek components: load measured at BBSW-07, the WTP load, load in upper Blackbird Creek from the Water Treatment Plant to the West Fork of Blackbird Creek (between stations BBSW-07 and BBSW-03A), the West Fork Tailings Impoundment, and lower Blackbird Creek downstream of the Tailings Impoundment (between stations BBSW-02 and BBSW-01A). The BBSW-07 load is primarily due to drainage from waste rock in upper Meadow Creek that has not been completely controlled by Early Actions. The WTP load used in these estimates was based on average concentrations with variable rate of discharge. Allocating the load at PASW-09 (instead of BBSW-01A) was necessary to minimize the effects of differing flow measurement errors in estimating concentrations at PASW-09. However, this approach does not account for background concentrations in Panther Creek. Nevertheless, this approach is suitable for comparative evaluation of the effectiveness of the alternatives within the accuracy of the estimates.

The estimates also do not take into account data trends indicating potential for additional water quality improvements even with no further action. For example, it is unlikely that the full effects of the Early Actions have been observed yet. In addition, these estimates do not account for the reduction in iron and resultant potential impacts on dissolved copper concentrations. Treatment of the West Fork Tailings Impoundment seepage would result in iron removal. This iron is currently contributing to copper removal through sorption and precipitation. As discussed in Appendix D, under some modeled conditions (pH of about 7, such as was observed during the fall of 2000), copper concentrations in Blackbird Creek were predicted to be higher as a result of iron removal compared to conditions with no iron removal. Therefore, removal of this iron may have the potential to result in small increases in concentrations of dissolved copper in Blackbird and Panther Creek downstream of the tailings impoundment compared to alternatives that remove less iron from the system.

For stream segments where there are currently load increases, a percent load reduction was estimated for each alternative. The percent load reductions are based on the estimated effectiveness for the remedial action components of each alternative.

For stream segments where there are currently load losses ("losing reaches"), the amount of load loss following implementation of remedial actions is expected to decrease due to decreasing load entering the reach. If the future load losses are assumed to be the same as losses measured over the past several years, then negative total loads result, which is impossible. Therefore, future losses in losing reaches were estimated as follows: where no remedial action is conducted in a reach, the decrease in load losses was assumed to be proportional to the decrease in the load entering the reach. The additional load decrease in a losing reach as a result of remedial actions within the reach was estimated assuming a percentage removal.

"Best estimate" removal efficiencies, shown in Table 7-9, were derived using professional judgment (removal uncertainty is addressed in Section 7.2.1.3). The removal efficiency for alternatives with treatment of Tailings Impoundment seepage (Alternatives BB-5, BB-7, and BB-8) was calculated from two removal components: the percentage of the seepage collected, and the removal due to the soil cover (see Section 7.2.1.1). The combined removal was calculated using the assumed treatment efficiency for the seepage collected, added to the removal efficiency for the uncollected seepage.

The complex interaction of hydrology, hydrogeology, water chemistry, and other factors makes it impossible to estimate the load decrease more precisely without considerably more data collection and analysis. In addition, the load calculations could only be made using synoptic data, which does not exhibit the full variability in metals concentrations. However, even with additional data collection, the estimates would have considerable uncertainties. Because of these uncertainties, the estimated post-remediation concentrations are approximate rather than precise indications of potential post-remediation concentrations. Many of these uncertainties "cancel out" when comparing alternatives, meaning that the differences among estimated post-remediation concentrations have less uncertainty. The estimated concentrations presented in this FS are sufficient for comparative evaluation and selection of alternatives.

7.2.1.3 Uncertainty and Variability in Post-Remediation Water Quality Estimates

Approximate variability and uncertainty in the water quality estimates for the Blackbird Creek alternatives were developed to provide the potential range of post-remediation concentrations that might be expected. The potential range of post-remediation concentrations for Blackbird Creek near the mouth (Station BBSW-01A) are presented in Table 7-10a and Figure 7-1 (for copper), and Figure 7-2 (for cobalt). The potential range of post-remediation concentrations for Panther Creek downstream from Blackbird Creek (Station PASW-09) are presented in Table 7-10b, and Figure 7-3 (for copper), and Figure 7-4 (for cobalt). The potential range of post-remediation concentrations for Big Deer Creek downstream from South Fork Big Deer Creek (Station BDSW-03) is presented in Table 7-13. The meaning of the abbreviations used in these tables and these figures are as follows:

Abbreviation	Explanation
Min. Min.	Minimum potential concentrations based on maximum removal percentages
Var. Min.	Minimum concentrations based on best estimate removal percentages and the entire post-Early Action data set
Average	Average concentrations based on best estimate removal percentages for the synoptic sampling events
Var. Max.	Maximum concentrations based best estimate removal percentages and the entire post-Early Action data set
Max. Max.	Maximum potential concentrations based on minimum removal percentages.

To understand how the values shown in Tables 7-10a and 7-10b were developed, it is best to start at the middle of the tables. The "average" value, used as the mid-point for the uncertainty/variability analysis, is the average of the fall and spring estimates using the 2000 and 2001 synoptic sampling data. (Tables 7-1a&b through 7-5 a&b). The "average" values were also calculated using the "best estimate" removal percentages shown in Table 7-9. For example, the "average" copper value in Blackbird Creek shown on Table 7-10a for Alternative BB-4 is 16 µg/L. This is the average of the six values shown on Table 7-1b for the row labeled "BBSW-01A post-remediation". Similarly, the "average" cobalt value in Panther Creek shown on Table 7-10b for Alternative BB-6 is 25 µg/L. This is the average of the six values shown on Table 7-3b for the row labeled "PASW-09 post-remediation".

Since the synoptic data do not represent the full variability of concentrations that could be expected in the area creeks (especially for cobalt), it was necessary to calculate the potential post-remediation concentrations for each alternative utilizing the full data set.

These calculations are represented by the "Var.Min." and "Var.Max." columns in Tables 7-10a and 7-10b, and were based on the full data set for all sampling conducted since 1999 at BBSW-01A and PASW-09. The "Var.Min." and "Var.Max." values for each alternative were calculated by multiplying these minimum and maximum data values (respectively) by the removal ratio developed in the "average" column. For example, the removal ratio in the "average" column of Table 7-10a between current (measured) conditions for copper in Blackbird Creek and post-remediation conditions under Alternative BB-4 is 16 µg/L divided by 27 µg/L or a removal ratio of about 0.59. In other words, the post-remediation value for copper in Blackbird Creek under Alternative BB-4 is predicted to be about 0.59 times the pre-remediation value for copper. This ratio was then applied to the highest measured value for copper from the full data set to estimate the highest post-remediation value for copper (in the "Var. Max" column, 63 µg/L X 0.59 = 38 µg/L). Similarly, the ratio was also applied to the lowest measured value for copper from the full data set to estimate the lowest post-remediation value for copper (in the "Var. Min" column, 3 µg/L X 0.59 = 2 µg/L). Similar post-remediation ratios and values were estimated to develop the Var. Max and Var. Min values for each of the alternatives.

Uncertainties in the predicted post-remediation concentrations due to uncertainties in removal efficiencies are represented by the "Min. Min." and "Max. Max." columns in Tables 7-10a and 7-10b. These columns were estimated by performing the post-remediation calculations used in Tables 7-1a&b through 7-5a&b, but using estimated maximum removal effectiveness and estimated minimum removal effectiveness for each of the primary components of the alternatives. The maximum and minimum removal effectiveness estimates are shown in Table 7-9. The potential range of removal effectiveness was estimated based on professional judgment. The "Min. Min." values for each of the alternatives thus represent the absolute minimum concentrations that could be expected using optimistic (highest) assumptions for removal effectiveness. Similarly, the "Max. Max." values for each of the alternatives thus represent the absolute maximum concentrations that could be expected using pessimistic (lowest) assumptions for removal effectiveness.

7.2.1.4 Hypothetical Maximum Removal Estimate

Table 7-8a&b presents hypothetical maximum removal, estimated in the same manner as the alternatives. The removal effectiveness values used in this estimate are the maximum removals used in the uncertainty analysis (see preceding section). However, these removal effectiveness values are not based on any specific remedial actions and are probably not achievable.

Table 7-8b suggests that it might be possible to achieve the copper water quality PRG at the mouth of Blackbird Creek using hypothetical maximum removals. However, the estimated hypothetical cobalt concentrations at the mouth of Blackbird Creek are several times the cobalt water quality PRG. Concentrations of both copper and cobalt would increase going upstream in Blackbird Creek. For example, Table 7-8b shows estimated copper concentrations at least 2 times the copper water quality PRG at BBSW-03A. This table also indicates that the cobalt water quality PRG would be exceeded at BBSW-03A.

Thus, it can be seen that the water quality PRGs for both copper and cobalt cannot be consistently met in Blackbird Creek by any feasible remediation alternative.

7.2.1.5 Natural Recovery for Sediments

Natural recovery for the in-stream sediments in Panther Creek is included as part of all of the alternatives. Natural recovery for in-stream sediment is included as part of all of the Bucktail Creek alternatives except Alternative BT-6 (complete removal). The sediment data collected to date and the evaluations conducted in the Aquatic Ecological Risk Assessment (CH2M Hill, 2001) indicate:

For Panther Creek

- arsenic concentrations range from 6 to 203 mg/kg. These measured concentrations exceed a probable effects concentration for benthic invertebrates (PEC) of 33 mg/kg at 4 out of 6 locations;
- copper concentrations range from 40 to 231 mg/kg. Measured concentrations exceed a PEC of 149 mg/kg at only 1 out of 6 locations;
- cobalt concentrations range from 3 to 198mg/kg. Measured concentrations exceed an estimated PEC of 80 mg/kg at 3 out of 6 locations;
- iron concentrations range from 5,890-16,900 mg/kg. The background UTL concentration is 51,900 mg/kg (CH2M Hill, 2001), which is not exceeded.

For Big Deer Creek

- arsenic concentrations range from 6 to 7 mg/kg. These measured concentrations are below the PEC of 33 mg/kg at both impacted sampling locations;
- copper concentrations range from 30 to 385 mg/kg. Measured concentrations exceed a PEC of 149 mg/kg at 2 out of 2 impacted locations;
- cobalt concentrations range from 1 to 70 mg/kg. Measured concentrations are below the estimated PEC of 80 mg/kg at all impacted locations;
- iron concentrations range from 4,490-9,460 mg/kg. The background UTL concentration is 51,900 mg/kg (CH2M Hill, 2001) which is not exceeded.

The threshold effects concentration (TEC) is a sediment concentration below which effects rarely occur, and the PEC is a concentration above which effects frequently occur in benthic communities. Concentrations within the range of the TEC-PEC produce adverse effects about 50% of the time, with the probability of adverse effects increasing as the concentrations approach the PEC (MacDonald et al., 2000).

Sediment concentrations exceed the copper PEC infrequently in Panther Creek, and exceed the arsenic PEC fairly frequently but at factors predominantly less than 2. Cobalt only exceeds its proposed PEC at 3 out of 6 locations, also at factors predominantly less than 2. This suggests that, although the sediment PRGs are exceeded, adverse effects on benthic communities due to copper are not expected at most locations. While adverse

effects due to arsenic or cobalt are expected more frequently, there is little concentration attenuation that must take place before sediment arsenic and cobalt levels fall within the TEC-PEC range.

Sediment concentrations exceed the copper PEC in Big Deer Creek by about a factor of 2 Measured concentrations do not exceed the arsenic or cobalt PEC. This suggests that, although the sediment copper PRGs are exceeded, adverse effects on benthic communities are not expected at most locations. There is little concentration attenuation that must take place before sediment copper levels fall within the TEC-PEC range.

Removal of sediments requires extensive environmental disruption. Heavy equipment must be mobilized along banks in riparian habitat. Substrate removal essentially removes all benthic habitat and disrupts benthic communities for an undetermined period of time. Removal of sediments was previously considered as Alternative P-4 (see Section 5.2.4.4) and would require extensive removal of both overbank deposits and in-stream sediments in Panther Creek, resulting in extensive disruption of the habitat. The ecological damage of sediment removal in Panther Creek would offset any immediate potential benefits. It would also generate a large quantity of material requiring disposal. Existing disposal facilities do not have sufficient capacity; therefore a new, large, disposal area would require construction, operation, and maintenance. Sediment removal is not needed to achieve water quality PRGs in Panther Creek, and metals concentrations in sediments will continue to improve as upstream actions are taken and natural recovery processes take place.

As indicated above, adverse effects are expected at relatively few locations given the 2000 data and existing toxicological literature. Furthermore the probability of adverse effects will decrease as sediment concentrations fall below the PEC. Therefore, natural recovery is adequate for sediments and Panther Creek and Big Deer Creek given the magnitude of environmental disruption that would occur were sediments to be removed.

7.2.2 Alternative BB-1 - No Further Action

7.2.2.1 Overall Protection of Human Health and the Environment

As discussed in Section 6.2.1, this alternative includes the extensive Early Actions, which have resulted in significant improvement in water quality (see Figures 2-3 and 2-4). However, water quality PRGs for copper and cobalt would not be met in Blackbird Creek throughout the year. Water quality currently meets the copper PRG in Panther Creek during low-flow conditions, which can be 9 or more months out of the year, but exceeds the PRG periodically especially during early stages of spring runoff. Exceedances of the water quality PRG for copper have been by less than a factor of 2.5 during the spring runoff of 2000 and 2001.

For the foreseeable future, Alternative BB-1 would be expected to exceed the water quality PRG in Panther Creek for cobalt during most of the year. There have been some periods of high runoff in Panther Creek and even during some periods of lower flows

when the cobalt PRG has been meet. For example, the cobalt water quality PRG was met during the spring and fall 2001 synoptic sampling events and has typically been met during high flow periods. However, the PRG was exceeded during previous low-flow sampling events and during sampling conducted during the winter of 2001/2002. Exceedances have been by a factor of about 3 or less, with the highest concentrations detected in the early spring prior to significant runoff.

Arsenic concentrations in some of the exposed overbank deposits along Blackbird Creek exceed the human health PRG established by the EPA. In addition, some of the overbank materials along Blackbird Creek could become mobilized during large runoff events and be re-deposited along Panther Creek at concentrations that exceed the human health PRGs for Panther Creek.

No actions would be taken to address the Blackbird Creek channel and overbank areas in the vicinity of the Panther Creek Inn (PCI). The residents and guests at the PCI would thus be exposed to arsenic concentrations that exceed the PRGs established by EPA for this area.

Water quality is expected to improve slowly even without further actions. However, aquatic and sediment PRGs would not be met for the foreseeable future (likely not for centuries) without further action. Sediment PRGs would not likely be met in Blackbird Creek, but are nevertheless expected to improve through natural recovery. Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek.

Because overbank sediments would continue to pose an unacceptable risk without further action, EPA has determined that Alternative BB-1 is not protective of human health. In addition, since water quality and sediment PRGs would not be met in the foreseeable future, EPA has determined that Alternative BB-1 is not protective of the environment.

7.2.2.2 Compliance with ARARs

The copper water quality PRG in Panther Creek is an ARAR and is not met currently during portions of spring runoff (lasting from a few weeks to 2 or 3 months) immediately downstream of Blackbird Creek. NPDES requirements are also an ARAR, as discussed in Section 3.1.1.3.1. This alternative would not comply with NPDES requirements for water-quality-based effluent limits (see Appendix B). On this basis, Alternative BB-1 would not meet all ARARs.

As noted in Section 3.1.1.2.2, the copper water quality PRG for Blackbird Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis for Blackbird Creek that concluded that the copper water quality standard was not currently being met, and that engineering controls would not be capable of reductions in copper loadings such that the standard could be met in Blackbird Creek within the foreseeable future.

7.2.2.3 Long-Term Effectiveness and Permanence

The Early Actions taken in the Blackbird Creek watershed have resulted in reductions in copper and cobalt loads to Blackbird Creek and Panther Creek. These improvements have been demonstrated in water quality data collected prior and subsequent to implementation of Early Actions as described in Chapter 2. Dissolved copper and cobalt concentrations in Panther Creek have decreased dramatically since 1995 (see Figures 2-3, 2-4).

The copper and cobalt water quality PRGs are currently exceeded in Blackbird Creek throughout the year (see Table 7-10a). The copper concentrations near the mouth of Blackbird Creek (BBSW-01A) range from 3 to 63 µg/L (below the PRG to about 7 times the PRG). Under current conditions, the cobalt concentrations near the mouth of Blackbird Creek range from 82 to 800 µg/L (about 2 times to 21 times the PRG).

Currently, the copper concentration in Panther Creek (e.g., PASW-09/10) is below the water quality PRG for most of the year (9 months or more), only exceeding this PRG for several weeks to 2 or 3 months during the rising limb of the spring hydrograph. The cobalt concentration in Panther Creek is below the water quality PRG during periods of high spring runoff, but typically exceeds this PRG during the rest of the year. Data collected since 1998 indicate that the cobalt concentration at PASW-09 and PASW-10 has ranged from 5 µg/L to 75 µg/L, with the maximum concentration less than a factor of two times the water quality PRG.

It is expected that there would continue to be additional improvement to water quality due to actions implemented to date even with no further action. Due to a number of variables that affect metals concentrations, it is not possible to quantitatively predict future concentrations. However, it is likely that water quality PRGs would not be consistently achieved in Panther Creek under this alternative, probably for decades to a century or more. Copper concentrations would likely still exceed the water quality PRG during early stages of spring runoff, and cobalt concentrations would likely exceed the water quality PRG during low-flow conditions and early stages of spring runoff.

Sediment PRGs would not likely be met in Blackbird Creek, but the sediments are nevertheless expected to improve through natural recovery. Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek.

Under this alternative, some overbank deposits with arsenic concentrations above the human health PRG would remain exposed along Blackbird Creek. These and other overbank materials along Blackbird Creek could become mobilized during large runoff events and be re-deposited along Panther Creek at concentrations that exceed the human health PRGs for Panther Creek. The arsenic in the Blackbird Creek channel and overbank areas near the PCI would continue to pose unacceptable risks to residents and guests.

Since no additional actions would be taken to control the contaminants of concern, Alternative BB-1 would not provide a reliable or permanent remedy.

7.2.2.4 Reduction in Toxicity, Mobility and Volume through Treatment

The "No Further Action" alternative includes treatment through the continued operation of the WTP. No additional treatment would be included.

7.2.2.5 Short-Term Effectiveness

Any further action would create potential short-term risks that would not exist with no further action. The short-term risks *avoided* in Alternative BB-1 include:

- Risk for the surrounding community from increased traffic of heavy trucks and construction equipment;
- Normal construction-related risks for site workers, and
- Risk to the environment resulting from disturbing habitat during construction.

The "No Further Action" alternative, being current conditions, would be implemented immediately upon signing an AOC.

7.2.2.6 Implementability

There would be no implementation difficulties associated with no further action.

7.2.2.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-1 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.2.3 Alternative BB-4 – Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment, Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments

7.2.3.1 Overall Protection of Human Health and the Environment

As discussed below under long-term effectiveness and presented in Table 7-1b, this alternative would not be expected to meet copper or cobalt water quality PRGs in Blackbird Creek on a consistent basis. The copper PRG may be met at times during low flow periods, however the cobalt PRG would be exceeded at all times in Blackbird Creek.

Alternative BB-4 is predicted to result in copper concentrations in Panther Creek below the copper water quality PRG during most of the year. There may be periods during the spring runoff when the copper water quality PRG would be exceeded slightly.

The predicted post-remediation cobalt concentrations in Panther Creek would be below the water quality PRG during certain periods of the year (generally higher flow periods) and above the water quality PRG at other times (generally during low flow periods during fall, winter, and early spring).

Selective removal of overbank deposits would achieve the arsenic human health PRG along Blackbird Creek and would minimize potential risks to downstream areas along Panther Creek. Stabilization (armoring) of most of the overbank deposits would be provided to minimize the potential for erosion and recontamination of areas along Panther Creek where the arsenic human health PRG is lower. With stabilization, this alternative should reduce the amount of materials that could be remobilized, and any remobilized material would be mixed with clean sediments, such that this alternative would minimize potential downstream threats to human health along Panther Creek. This stabilization would also minimize the potential for direct contact with these materials in Blackbird Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn (PCI) containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments.

Sediment PRGs would not likely be met in Blackbird Creek, but sediments are nevertheless expected to improve through natural recovery. Sediment quality in Panther Creek would also be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Meeting sediment PRGs in Panther Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Because most of the current measured concentrations are below known probable toxic levels (see Section 7.2.1.5), benthic communities in Panther Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Panther Creek despite the current exceedances of the sediment PRGs.

EPA has determined that the stabilization and selective removal of overbank materials (and in-stream sediments adjacent to the PCI) along Blackbird Creek associated with Alternative BB-4 would provide protection of human health. The water quality and sediment PRGs in Blackbird Creek would not likely be met under Alternative BB-4. Water quality PRGs in Panther Creek would not be consistently met under Alternative BB-4, while sediment PRGs in Panther Creek would eventually be met through natural recovery. EPA has determined that this alternative would not be protective of the environment.

7.2.3.2 Compliance with ARARs

Improvement in water quality in Panther Creek downstream of Blackbird Creek is predicted to meet the copper criterion of the Clean Water Act most of the time. However, there is potential for periodic exceedance (a few days to weeks) during spring runoff. BMPs required under the Clean Water Act for sediment control during construction activities would be implemented in the same manner as conducted during implementation of Early Actions. The actions along Blackbird Creek to address overbank deposits would be conducted in accordance with requirements of State of Idaho Stream Channel Alteration rules in IDAPA 37, Title 03, Chapter 7.

As noted in Section 3.1.1.2.2, the copper water quality PRG for Blackbird Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis for Blackbird Creek that concluded that the copper water quality standard was not currently being met, and that engineering controls would not be capable of reductions in copper loadings such that the standard could be met in Blackbird Creek within the foreseeable future.

The point source discharges from the water treatment plant and the West Fork underdrain culvert are subject to the substantive requirements of the National Pollutant Discharge Elimination System (NPDES). These discharges must be limited so as to avoid causing or contributing to exceedances of the water quality criteria established for the designated beneficial use for Blackbird Creek of secondary contact recreation (not cold water biota) and for the designated beneficial use for Panther Creek of cold water biota. In accordance with the NPDES program, the water quality-based requirements are established by calculating the amount of pollutant loading from Blackbird Creek that can mix with Panther Creek waters in a manner that is protective of cold water biota. The State of Idaho guidelines provide for a maximum mixing zone of 25%, however this can be expanded through a site-specific mixing zone analysis. Appendix B provides the details of the mixing zone analysis in Panther Creek. For Alternative BB-4 the analysis indicated that, under worse case conditions, the copper water quality standard would not be met in Panther Creek even with 100% mixing in the spring; in the fall a mixing zone requiring approximately 53% of the width of Panther Creek would be required. For Alternative BB-4 under average case conditions, the mixing zone requirement would vary from approximately 30% of the width of Panther Creek in the fall to 48% of the width of Panther Creek in the spring. It should be noted that, due to physical constraints in Panther Creek in the vicinity of the Blackbird Creek confluence, the minimum mixing zone that could be achieved (regardless of alternative) under worse case is 50% of the width of Panther Creek. Under average conditions the minimum width of the mixing zone is 30%. The final determination regarding the acceptability of the mixing zones is pending.

7.2.3.3 Long-Term Effectiveness and Permanence

Table 7-1b shows estimated post-remediation concentrations for this alternative. Copper concentrations in Blackbird Creek are predicted to exceed the PRG most of the time. There may be periods during low flow when the copper concentrations in Blackbird Creek could meet the water quality PRG. The average post-remediation copper

concentration is predicted to be about 16 µg/L, which is about twice the PRG. An evaluation of variability based on the full range of effectiveness estimates and a full range of copper concentrations observed at BBSW-01A during 2000 and 2001 predicts a range of post-remediation copper concentrations from 1 to 53 µg/L for this alternative (see Table 7-10a).

Cobalt concentrations in Blackbird Creek are anticipated to exceed the water quality PRG all of the time. The average predicted post-remediation cobalt concentration at BBSW=01A is about 303 µg/L, which is about 8 times the cobalt PRG. The evaluation of variability indicates that cobalt could range from about 44 to 637 µg/L (see Table 7-10a).

Copper concentrations in Panther Creek are predicted to meet the water quality PRG during periods of low flow (9 months or more). Predictions based on spring data for 2000 also show this alternative meeting the water quality PRG during a period of high flow in Panther Creek. The estimate based on the spring 2001 data, exceeds this PRG by about 1 µg/L. This sample was taken during the rising limb of the Blackbird Creek spring runoff hydrograph, which typically lasts for several weeks. The average predicted post-remediation copper concentration is 2 µg/L (see Table 7-10b). An evaluation of variability based on the full range of effectiveness estimates and a full range of copper concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation copper concentrations from 1 to 7 µg/L for this alternative (see Table 7-10b). At 7 µg/L, the concentration would exceed the copper PRG by about 1 µg/L.

The estimated post-remediation cobalt concentrations are below the water quality PRG during both spring and fall synoptic sampling events, except for the estimate based on low-flow 2000 results with the treatment plant discharging at 600 gpm. However, the spring and fall synoptic sampling events do not represent the highest cobalt concentrations. The highest cobalt concentrations have been observed during the low flow prior to spring runoff. The average predicted post-remediation cobalt concentration is 30 µg/L (see Table 7-10b). An evaluation of variability based on the full range of effectiveness estimates and a full range of cobalt concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation cobalt concentrations from 3 to 61 µg/L for this alternative (see Table 7-10). It should be noted that there is considerable uncertainty associated with the predicted cobalt values since the reductions in loads depend primarily on the effectiveness of the West Fork Impoundment cover/cap. As noted in Section 7.2.2.1, the predictions are based upon a geochemical model with a large degree of uncertainty concerning the magnitude and timing of cobalt load reductions. Therefore, it is uncertain whether Alternative BB-4 could consistently meet the cobalt PRG in Panther Creek.

Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Sediment PRGs would not likely be met in Blackbird Creek, but are nevertheless expected to improve through natural recovery.

With respect to human health, overbank deposits containing arsenic above the human health PRGs would be selectively removed or covered with armoring. The vast majority

of the mass of the remaining arsenic-containing overbank deposits (those with elevated concentrations of arsenic but not at concentrations above the human health PRGs) would also be protected against downstream transport by armoring. This armoring would reduce the potential for re-deposition of materials above the human health PRGs along Blackbird Creek adjacent to the PCI and along Panther Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn (PCI) containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments. The overbank and in-stream materials would be monitored to determine if they become re-contaminated from materials upstream along Blackbird Creek. If these materials become re-contaminated in the future, additional removals to the respective PRGs would be conducted.

The long-term residual risks under Alternative BB-4 are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits along Blackbird Creek. The main concern associated with the West Fork Impoundment is that the cover/cap will not be as effective as predicted at reducing cobalt loads, or that the reductions will not occur within a reasonable time frame. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. The risks associated with the overbank deposits along Blackbird Creek would be addressed through armoring and selective removal of the overbank deposits, which would protect these deposits from significant re-mobilization during storm events up to the 500-year design storm.

The reliability and permanence of this alternative depends on long-term operation of the treatment plant, and monitoring and maintenance of the Early Actions previously implemented, as well as the additional Meadow Creek seep collection system, the Tailings Impoundment soil cover, armoring of overbank deposits, monitoring of overbank and in-stream deposits near the PCI, and monitoring of overbank deposits along Panther Creek after significant storm events. This alternative depends primarily on the soil cover to achieve cobalt reductions, which may not be as reliable as treatment. With proper long-term operation, monitoring, and maintenance, this alternative may provide a reliable and permanent remedy, with the reliability depending on the ultimate effectiveness of the soil cover.

7.2.3.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BB-4 includes continued operation of the WTP. Meadow Creek seep collection would increase the volume treated in the WTP. Continued mixing of iron-rich Tailings Impoundment seepage into lower Blackbird Creek would provide some natural in-situ removal to lower dissolved copper concentrations.

Armoring of overbank deposits would reduce the mobility of these deposits, albeit without treatment.

7.2.3.5 Short-Term Effectiveness

As discussed in Section 7.2.1.1, decreases in cobalt and copper concentrations due to reduced infiltration and oxidation in the Tailings Impoundment (resulting from the soil cover) would be expected to occur over time. The timing of these reductions is uncertain, and full effect could occur over a period of years or a decade or more. The other remedial action components of this alternative are predicted to reduce copper and cobalt concentrations in Blackbird Creek and Panther Creek relatively quickly following completion of construction.

The physical stabilization and selective removal of overbank deposits included in this alternative would create potential risks to the community and site workers typical of construction activities. These activities would also result in unavoidable short-term disturbance of ecological habitat.

7.2.3.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. The most difficult aspect of this alternative would be obtaining and placing armoring materials appropriately sized to protect the overbank deposits along Blackbird Creek. Design and agency review of the armoring for overbank deposits would be more difficult than for removal.

The administrative implementability of instituting institutional controls on property managed by the USFS along Blackbird Creek is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders, which close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.2.3.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-2 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.2.4 Alternative BB-5 - Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Stabilization with Selective Removal of Overbank Deposits; Natural Recovery for In-Stream Sediments

7.2.4.1 Overall Protection of Human Health and the Environment

As discussed below under long-term effectiveness and presented in Table 7-2b, this alternative would not be expected to meet copper or cobalt water quality PRGs in

Blackbird Creek on a consistent basis. The copper PRG may be met at times during low flow periods, however the cobalt PRG would be exceeded virtually all of the time in Blackbird Creek.

Alternative BB-5 is predicted to result in copper concentrations in Panther Creek at or below the copper water quality PRG during most of the year. There may be short periods during the spring runoff when the copper water quality PRG would be exceeded slightly for a few days to a week or more.

Cobalt concentrations in Panther Creek are predicted to meet the cobalt water quality PRG under most circumstances. There may be periods during low flows and during the winter when the cobalt PRG would be exceeded slightly in Panther Creek. The uncertainty and variability analysis, which includes consideration of higher cobalt concentrations than were present during the synoptic events, is discussed below under long-term effectiveness.

Sediment PRGs would not likely be met in Blackbird Creek, but sediments are nevertheless expected to improve through natural recovery. Sediment quality in Panther Creek would also be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Meeting sediment PRGs in Panther Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Because most of the current measured concentrations are below known probable toxic levels (see Section 7.2.1.5), benthic communities in Panther Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Panther Creek despite the current exceedances of the sediment PRGs.

Selective removal of overbank deposits would achieve the arsenic human health PRG along Blackbird Creek and would minimize potential risks to downstream areas along Panther Creek. Stabilization (armoring) of most of the overbank deposits would be provided to minimize the potential for erosion and recontamination of areas along Panther Creek where the arsenic human health PRG is lower. With stabilization, this alternative should reduce the amount of materials that could be remobilized, and any remobilized material would be mixed with clean sediments, such that this alternative would minimize potential downstream threats to human health along Panther Creek. This stabilization would also minimize the potential for direct contact with these materials in Blackbird Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments.

EPA has determined that the stabilization and selective removal of overbank materials (and in-stream sediments adjacent to the PCI) along Blackbird Creek associated with

Alternative BB-5 would provide protection of human health. The water quality and sediment PRGs in Blackbird Creek would not be met under Alternative BB-5. Water quality PRGs in Panther Creek would not be consistently met under Alternative BB-5, while sediment PRGs in Panther Creek would eventually be met through natural recovery. EPA has determined that this alternative would not be protective of the environment.

7.2.4.2 Compliance with ARARs

This alternative is predicted to generally meet ARARs in Panther Creek. However, based on the uncertainty and variability analysis, there is a potential that the copper PRG could be exceeded in Panther Creek for a few days to a week or more under worst-case assumptions (see Table 7-10b). Other ARARs would be met as described in Section 7.2.3.2 for Alternative BB-4.

As noted in Section 3.1.1.2.2, the copper water quality PRG for Blackbird Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis for Blackbird Creek that concluded that the copper water quality standard was not currently being met, and that engineering controls would not be capable of reductions in copper loadings such that the standard could be met in Blackbird Creek within the foreseeable future.

The NPDES issues associated with Alternative BB-5 are similar to those noted for Alternative BB-4 in Section 7.2.3.2. Appendix B provides the details of the mixing zone analysis in Panther Creek. For Alternative BB-5, the analysis indicated that, under worse case conditions, the copper water quality standard would not be met even with 100% mixing in the spring; in the fall a mixing zone requiring approximately 53% of the width of Panther Creek would be required. For Alternative BB-5 under average case conditions, the mixing zone requirement would vary from approximately 30% of the width of Panther Creek in the fall to 48% of the width of Panther Creek in the spring. It should be noted that, due to physical constraints in Panther Creek in the vicinity of the Blackbird Creek confluence, the minimum mixing zone that could be achieved (regardless of alternative) under worse case is 50% of the width of Panther Creek. Under average conditions the minimum width of the mixing zone is 30%. A final determination regarding the acceptability of the mixing zones is pending.

7.2.4.3 Long-Term Effectiveness and Permanence

Table 7-2b shows estimated post-remediation concentrations for this alternative. Copper concentrations in Blackbird Creek are predicted to exceed the PRG most of the time. There may be periods during low flow when the copper concentrations in Blackbird Creek could meet the water quality PRG. The average post-remediation copper concentration is predicted to be about 13 µg/L, which is about 1 ½ times the PRG. An evaluation of variability based on the full range of effectiveness estimates and a full range of copper concentrations observed at BBSW-01A during 2000 and 2001 predicts a range of post-remediation copper concentrations from 1 to 48 µg/L for this alternative (see Table 7-10a).

Cobalt concentrations in Blackbird Creek are anticipated to exceed the water quality PRG virtually all of the time. The average predicted post-remediation cobalt concentration at BBSW-01A is about 233 µg/L, which is about 6 times the cobalt PRG. The evaluation of variability indicates that cobalt could range from about 25 to 537 µg/L (see Table 7-10a).

Copper concentrations in Panther Creek are predicted to meet the water quality PRG based on the analysis of the synoptic data. The average predicted post-remediation copper concentration is about 2 µg/L (see Table 7-10b). An evaluation of variability based on the full range of copper concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation copper concentrations from 1 to 6 µg/L for this alternative (see Table 7-10b). At 6 µg/L, the concentration would be about at the copper PRG (depending upon hardness). The post-remediation concentration estimates do not account for potential effects on copper due to iron removal, however these effects are expected to be minor (see Section 7.2.1.2).

Cobalt concentrations are also predicted to meet the water quality PRG in Panther Creek based on the analysis of the synoptic data. The average predicted post-remediation cobalt concentration is 30 µg/L (see Table 7-10b). An evaluation of variability based on the full range of effectiveness estimates and a full range of cobalt concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation cobalt concentrations from 2 to 52 µg/L for this alternative (see Table 7-10b). Most of the cobalt load reductions are due to removal of cobalt from the West Fork groundwater utilizing treatment, and there is a high degree of certainty associated with removal of cobalt loads utilizing treatment processes. Once the collection and treatment facilities are constructed, treatment should provide reasonably certain cobalt removals within a short time period (within 1 year after startup).

Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Sediment PRGs would not likely be met in Blackbird Creek, but are nevertheless expected to improve through natural recovery.

With respect to human health, overbank deposits containing arsenic above the human health PRG would be selectively removed. The vast majority of the mass of the arsenic-containing overbank deposits would also be protected against downstream transport by armoring, thereby minimizing the potential for re-deposition of materials above the human health PRGs along Blackbird Creek adjacent to the PCI and along Panther Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments. The overbank and in-stream materials would be monitored to determine if they become re-contaminated from materials upstream along Blackbird Creek. If these materials become re-contaminated in the future, additional removals to the respective PRGs would be conducted.

The long-term residual risks under Alternative BB-5 are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits along Blackbird Creek. The risk of continued cobalt releases from the West Fork Impoundment would be minimized primarily through collection and treatment of the groundwater from the impoundment. Treatment of cobalt has been proven to be effective at this site, and the treatment would reduce the cobalt loads within a reasonable and assured time frame (within 1 year of construction). The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. The risks associated with the overbank deposits along Blackbird Creek would be addressed through armoring and selective removal of overbank deposits, which would protect these deposits from significant re-mobilization during storm events up to the 500-year design storm.

The reliability and permanence of this alternative depends on long-term operation of the treatment plant, monitoring and maintenance of the Early Actions previously implemented, as well as the additional Meadow Creek seep collection system, the Tailings Impoundment soil cover and seep collection system, armoring of overbank deposits, monitoring of overbank and in-stream deposits near the PCI, and monitoring of Panther Creek overbank areas after significant storm events. With proper long-term operation, monitoring, and maintenance, Alternative BB-5 would provide a reliable and permanent remedy.

7.2.4.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BB-5 includes continued operation of the WTP. Meadow Creek seep collection would increase the volume treated in the WTP. Additional treatment would be provided for Tailings Impoundment seepage (either in the WTP or in-situ).

Armoring of overbank deposits would reduce the mobility of these deposits, albeit without treatment.

7.2.4.5 Short-Term Effectiveness

Most of the benefits of remedial action, including water quality improvements due to treatment of Tailings Impoundment seepage, would be realized relatively quickly following completion of construction (within 1 to 2 years). The physical stabilization and selective removal of overbank deposits included in this alternative would create potential risks to the community and site workers typical of construction activities. These activities would also result in unavoidable short-term disturbance of ecological habitat.

7.2.4.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. The most difficult aspect of this alternative would be designing, installing, and operating a collection system for

Tailings Impoundment seepage, and either pumping the collected water back to the treatment plant or treating the water in-situ. Schedule delays could be encountered during implementation of the seepage collection and treatment system: a treatability study would be necessary, and construction may take more than one season. Another difficult aspect of this alternative would be obtaining and placing the armoring materials appropriately sized to protect the overbank deposits along Blackbird Creek. Design and agency review of the armoring for overbank deposits would be more difficult than for removal.

The administrative implementability of instituting institutional controls on property managed by the USFS along Blackbird Creek is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.2.4.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Tables E-3, E-4, and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.2.5 Alternative BB-6 - Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments

7.2.5.1 Overall Protection of Human Health and the Environment

As discussed below under long-term effectiveness and presented in Table 7-3b, this alternative would not be expected to meet copper or cobalt water quality PRGs in Blackbird Creek at all times. The copper PRG could be met at times during low flow periods, but it would be exceeded consistently during the spring runoff. The cobalt PRG would be exceeded at virtually all times in Blackbird Creek.

Alternative BB-6 is predicted to result in copper concentrations in Panther Creek below the copper water quality PRG all times of the year. Cobalt concentrations in Panther Creek are predicted to meet the cobalt water quality PRG during some of the year. However, the cobalt PRG would likely be exceeded during low flow periods in the winter and spring prior to runoff. The uncertainty and variability analysis, which includes consideration of higher cobalt concentrations than were present during the synoptic events, is discussed below under long-term effectiveness.

Removal of large volumes of overbank deposits would achieve the arsenic human health PRG along Blackbird Creek and would minimize potential risks to downstream areas along Panther Creek. Stabilization of small areas of remaining deposits would be provided to minimize potential for erosion and recontamination of areas along Panther

Creek where the arsenic human health PRG is lower. In addition, this stabilization would minimize the potential for direct contact with these materials in Blackbird Creek. The large volume of removal combined with stabilization of remaining materials would minimize the amount of materials that could be remobilized, and any remobilized material would be mixed with clean sediments, such that this alternative would minimize potential downstream threats to human health along Panther Creek. The removal of overbank sediments would also result in reduction in the copper and cobalt loads to Blackbird and Panther Creeks.

Sediment PRGs would not likely be met in Blackbird Creek, but sediments are nevertheless expected to improve through natural recovery. Sediment quality in Panther Creek would also be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Meeting sediment PRGs in Panther Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Because most of the current measured concentrations are below known probable toxic levels (see Section 7.2.1.5), benthic communities in Panther Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Panther Creek despite the current exceedances of the sediment PRGs.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments.

EPA has determined that the removal with selective stabilization of overbank materials (and in-stream sediments adjacent to the PCI) along Blackbird Creek associated with Alternative BB-6 would provide protection of human health. The water quality and sediment PRGs in Blackbird Creek would not likely be consistently met under Alternative BB-6. The Panther Creek sediments would eventually meet PRGs through natural recovery. The copper water quality PRG would likely be consistently met in Panther Creek; however, the cobalt water quality PRG would likely be exceeded at times during winter and early spring. EPA has therefore determined that Alternative BB-6 would not be protective of the environment at all times.

7.2.5.2 Compliance with ARARs

This alternative is predicted to meet all ARARs. The copper ARAR is predicted to be achieved throughout the year. Other ARARs would be complied with as described in Section 7.2.3.2.

As noted in Section 3.1.1.2.2, the copper water quality PRG for Blackbird Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis for Blackbird Creek that concluded that the copper water quality standard was not currently being met, and that

engineering controls would not be capable of reductions in copper loadings such that the standard could be met in Blackbird Creek within the foreseeable future.

The NPDES issues associated with Alternative BB-6 are similar to those noted for Alternative BB-4 in Section 7.2.3.2. Appendix B provides the details of the mixing zone analysis in Panther Creek. For Alternative BB-6, the analysis indicated that, under worse case conditions, a mixing zone of 62% of the width of Panther Creek would be required in the spring; in the fall a mixing zone requiring approximately 50% of the width of Panther Creek would be required. For Alternative BB-6 under average case conditions, the mixing zone requirement would be approximately 30% of the width of Panther Creek in the fall and in the spring. It should be noted that, due to physical constraints in Panther Creek in the vicinity of the Blackbird Creek confluence, the minimum mixing zone that could be achieved (regardless of alternative) under worse case is 50% of the width of Panther Creek. Under average conditions the minimum width of the mixing zone is 30%. A final determination regarding the acceptability of the mixing zones is pending.

7.2.5.3 Long-Term Effectiveness and Permanence

Table 7-3b shows estimated post-remediation concentrations for this alternative. Copper concentrations in Blackbird Creek are predicted to exceed the PRG much of the time. There may be periods during low flow when the copper concentrations in Blackbird Creek could meet the water quality PRG. The average post-remediation copper concentration is predicted to be about 7 µg/L, which is below the PRG (depending on hardness). An evaluation of variability based on the full range of effectiveness estimates and a full range of copper concentrations observed at BBSW-01A during 2000 and 2001 predicts a range of post-remediation copper concentrations from 1 to 33 µg/L for this alternative (see Table 7-10a).

Cobalt concentrations in Blackbird Creek are anticipated to exceed the water quality PRG virtually all of the time. The average predicted post-remediation cobalt concentration at BBSW-01A is about 264 µg/L, which is about 7 times the cobalt PRG. The evaluation of variability indicates that cobalt could range from about 37 to 588 µg/L (see Table 7-10a).

Copper concentrations in Panther Creek are predicted to meet the water quality PRG at all times of the year. The average predicted post-remediation copper concentration is 2 µg/L (see Table 7-10b). An evaluation of variability based on the full range of copper concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation copper concentrations from <1 to 4 µg/L for this alternative (see Table 7-10b).

Cobalt concentrations in Panther Creek are predicted to meet the water quality PRG most of the time based on the analysis of the synoptic data. The average predicted post-remediation cobalt concentration is 25 µg/L (see Table 7-10). An evaluation of variability based on the full range of effectiveness estimates and the full range of cobalt concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation cobalt concentrations from 2 to 55 µg/L for this alternative (see Table 7-10b).

It should be noted that there is considerable uncertainty associated with the predicted cobalt values since the reductions in loads depend primarily on the effectiveness of the West Fork Impoundment cover/cap. As noted in Section 7.2.2.1, the predictions are based upon a geochemical model with a large degree of uncertainty concerning the magnitude and timing of cobalt load reductions.

Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Sediment PRGs would not likely be met in Blackbird Creek, but are nevertheless expected to improve through natural recovery.

With respect to human health, overbank deposits containing arsenic above the human health PRG would be removed and thus minimize the potential for direct contact. In addition, the remaining mobilizable overbank deposits containing the significant arsenic concentrations would be removed, thereby reducing the potential for downstream transport and redeposition of sediments with metal concentrations above human health PRGs along Blackbird Creek adjacent to the PCI and along Panther Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments. The overbank and in-stream materials would be monitored to determine if they become re-contaminated from materials upstream along Blackbird Creek. If these materials become re-contaminated in the future, additional removals to the respective PRGs would be conducted.

The long-term residual risks under Alternative BB-6 are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits along Blackbird Creek. The main concern associated with the West Fork Impoundment is that the cover/cap will not be as effective as predicted at reducing cobalt loads, or that the reductions will not occur within a reasonable time frame. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. The risks associated with the overbank deposits along Blackbird Creek would be addressed through removal with selective armoring of overbank deposits, which would protect these deposits from significant re-mobilization during storm events up to the 500-year design storm.

The reliability and permanence of this alternative depends on long-term operation of the treatment plant, and monitoring and maintenance of the Early Actions previously implemented, as well as the additional Meadow Creek seep collection system, the Tailings Impoundment soil cover/cap, monitoring of overbank and in-stream deposits near the PCI, and monitoring of Panther Creek overbank areas after significant storm events. Alternative BB-6 relies more on removal than armoring for overbank deposits, and removal is considered more permanent. This alternative depends primarily on the soil cover to achieve cobalt reductions, which may not be as reliable as treatment. With

proper long-term operation, monitoring, and maintenance of the Early Actions, Meadow Creek Seep Collection, and the Tailings Impoundment cover, and monitoring of overbank materials along Panther Creek following significant flood events this alternative may provide a reliable and permanent remedy, with the reliability depending on the ultimate effectiveness of the soil cover.

7.2.5.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BB-6 includes continued operation of the WTP. Meadow Creek seep collection would increase the volume treated in the WTP. Continued mixing of iron-rich Tailings Impoundment seepage into lower Blackbird Creek would provide some natural in-situ removal to lower dissolved copper concentrations.

Removal of overbank deposits would reduce the mobility of these deposits, albeit without treatment.

7.2.5.5 Short-Term Effectiveness

As discussed in Section 7.2.1.1, decreases in cobalt and copper concentrations due to reduced infiltration and oxidation in the Tailings Impoundment (resulting from the soil cover) would be expected to occur over time. The timing of these reductions is uncertain, and full effect could occur over a period of years or a decade or more. The other remedial action components of this alternative are predicted to reduce copper and cobalt concentrations in Blackbird Creek and Panther Creek relatively quickly (within 1 to 2 years) following completion of construction.

The removal and selective physical stabilization of overbank deposits included in this alternative would create potential risks to the community and site workers typical of construction activities. These activities would also result in unavoidable short-term disturbance of ecological habitat.

7.2.5.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. There would be some difficulties associated with removal of overbank deposits, but they would be less than for armoring the deposits.

The administrative implementability of instituting institutional controls on property managed by the USFS along Blackbird Creek is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.2.5.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this

alternative are presented in Table E-5 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.2.6 Alternative BB-7 - Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Removal with Selective Stabilization of Overbank Deposits; Natural Recovery for In-Stream Sediments.

7.2.6.1 Overall Protection of Human Health and the Environment

As discussed below under long-term effectiveness and presented in Table 7-4b, this alternative would not be expected to meet copper or cobalt water quality PRGs in Blackbird Creek at all times. The copper PRG could be met at times during low flow periods, but it would often be exceeded during the spring runoff. The cobalt PRG would be exceeded at virtually all times in Blackbird Creek.

Alternative BB-7 is predicted to result in copper concentrations in Panther Creek below the copper water quality PRG all times of the year. Cobalt concentrations in Panther Creek are also predicted to meet the cobalt water quality PRG, even during low flow periods when cobalt concentrations are highest. The uncertainty and variability analysis is discussed below under long-term effectiveness.

Removal of large volumes of overbank deposits would achieve the arsenic human health PRG along Blackbird Creek and would minimize potential risks to downstream areas along Panther Creek. Stabilization of small areas of remaining deposits would be provided to minimize potential for erosion and recontamination of areas along Panther Creek where the arsenic PRG is lower. This stabilization would also minimize the potential for direct contact with these materials in Blackbird Creek. The large volume of removal combined with stabilization of remaining materials would minimize the amount of materials that could be remobilized, and any remobilized material would be mixed with clean sediments, such that this alternative would minimize potential downstream threats to human health along Panther Creek. The removal of overbank sediments would also result in reduction in the copper and cobalt loads to Blackbird and Panther Creeks.

Sediment PRGs would not likely be met in Blackbird Creek, but sediments are nevertheless expected to improve through natural recovery. Sediment quality in Panther Creek would also be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Meeting sediment PRGs in Panther Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Because most of the current measured concentrations are below known probable toxic levels (see Section 7.2.1.5), benthic communities in Panther Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Panther Creek despite the current exceedances of the sediment PRGs.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments.

EPA has determined that the removal with selective stabilization of overbank materials (and in-stream sediments adjacent to the PCI) along Blackbird Creek associated with Alternative BB-7 would provide protection of human health. The water quality and sediment PRGs in Blackbird Creek would not likely be consistently met under Alternative BB-7. The Panther Creek sediments would eventually meet PRGs through natural recovery. The copper and cobalt water quality PRGs would be consistently met in Panther Creek. Therefore, EPA has determined that Alternative BB-7 would be protective of the environment for Panther Creek.

7.2.6.2 Compliance with ARARs

This alternative is predicted to meet all ARARs both for water quality for copper in Panther Creek and the other ARARs as described in Section 7.2.3.2.

As noted in Section 3.1.1.2.2, the copper water quality PRG for Blackbird Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis for Blackbird Creek that concluded that the copper water quality standard was not currently being met, and that engineering controls would not be capable of reductions in copper loadings such that the standard could be met in Blackbird Creek within the foreseeable future.

The NPDES issues associated with Alternative BB-7 are similar to those noted for Alternative BB-4 in Section 7.2.3.2. Appendix B provides the details of the mixing zone analysis in Panther Creek. For Alternative BB-7, the analysis indicated that, under worse case conditions, a mixing zone of 62% of the width of Panther Creek would be required in the spring; in the fall a mixing zone requiring approximately 50% of the width of Panther Creek would be required. For Alternative BB-7 under average case conditions, the mixing zone requirement would be approximately 30% of the width of Panther Creek in the fall and in the spring. It should be noted that, due to physical constraints in Panther Creek in the vicinity of the Blackbird Creek confluence, the minimum mixing zone that could be achieved (regardless of alternative) under worse case is 50% of the width of Panther Creek. Under average conditions the minimum width of the mixing zone is 30%. A final determination regarding the acceptability of the mixing zones is pending.

7.2.6.3 Long-Term Effectiveness and Permanence

Table 7-4b shows estimated post-remediation concentrations for this alternative. Copper concentrations in Blackbird Creek could meet the PRG some of the time. However, there would likely be extended periods (weeks to months) during spring runoff when the copper concentrations in Blackbird Creek would not meet the water quality PRG. The average post-remediation copper concentration is predicted to be about 5 µg/L, which is lower than the PRG (depending on hardness). An evaluation of variability based on the

full range of effectiveness estimates and a full range of copper concentrations observed at BBSW-01A during 2000 and 2001 predicts a range of post-remediation copper concentrations from <1 to 28 μg/L for this alternative (see Table 7-10a).

Cobalt concentrations in Blackbird Creek are anticipated to exceed the water quality PRG virtually all of the time. The average predicted post-remediation cobalt concentration at BBSW-01A is about 194 µg/L, which is about 5 times the cobalt PRG. The evaluation of variability indicates that cobalt could range from about 19 to 488 µg/L (see Table 7-10a).

Copper concentrations in Panther Creek are predicted to meet the water quality PRG at all times of the year. The average predicted post-remediation copper concentration is 1 μg/L (see Table 7-10b). An evaluation of variability based on the full range of copper concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation copper concentrations from <1 to 4 μg/L for this alternative (see Table 7-10b). The post-remediation concentration estimates do not account for potential effects on copper due to iron removal, however these effects are expected to be minor (see Section 7.2.1.2).

Cobalt concentrations in Panther Creek are also predicted to meet the water quality PRG under virtually all circumstances. The average predicted post-remediation cobalt concentration is 19 μg/L (see Table 7-10b). An evaluation of variability based on the full range of effectiveness estimates and a full range of cobalt concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation cobalt concentrations from 1 to 46 μg/L for this alternative (see Table 7-10b). It should be noted that the predicted maximum cobalt concentration in Table 7-10b assumes a worse case scenario of cobalt loading conditions and minimal removal efficiencies (i.e. each of the elements of the remedy is not functioning as well as anticipated). It is anticipated that these worse case conditions, if they were to occur at all, would occur only temporarily. Most of the cobalt load reductions are due to removal of cobalt from the West Fork groundwater utilizing treatment, and there is a high degree of certainty associated with removal of cobalt loads utilizing treatment processes. Once the collection and treatment facilities are constructed, treatment should provide reasonably certain cobalt removals within a short time period (within 1 year from startup).

With respect to human health, overbank deposits containing arsenic above the human health PRG would be removed and thus minimize the potential for direct contact. In addition, the remaining mobilizable overbank deposits containing the significant arsenic concentrations would be removed, thereby reducing the potential for downstream transport and redeposition of sediments with arsenic concentrations above human health PRGs along Blackbird Creek adjacent to the PCI and along Panther Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed as necessary to meet the reach-specific arsenic human health PRG for in-stream sediments. The overbank and in-stream materials would be monitored to determine if they become re-contaminated from materials upstream along Blackbird Creek. If these materials become

re-contaminated in the future, additional removals to the respective PRGs would be conducted.

Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Sediment PRGs would not likely be met in Blackbird Creek, but are nevertheless expected to improve through natural recovery.

The long-term residual risks under Alternative BB-7 are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits along Blackbird Creek. The risk of continued cobalt releases from the West Fork Impoundment would be minimized primarily through collection and treatment of the groundwater from the impoundment. Treatment of cobalt has been proven to be effective at this site, and the treatment would reduce the cobalt loads within a reasonable and assured time frame (within 1 year of construction). The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. The risks associated with the overbank deposits along Blackbird Creek would be addressed through removal and selective armoring of overbank deposits, which would protect these deposits from significant re-mobilization during storm events up to the 500-year design storm.

The reliability and permanence of this alternative depends on long-term operation of the treatment plant, and monitoring and maintenance of the Early Actions previously implemented, as well as the additional Meadow Creek seep collection system, the Tailings Impoundment soil cover and seep collection system, monitoring of overbank and in-stream deposits near the PCI, and monitoring of Panther Creek overbank areas after significant storm events. Alternative BB-7 relies more on removal than armoring for overbank deposits, and removal is considered more permanent. With proper long-term operation, monitoring, and maintenance of the Early Actions, Meadow Creek Seep Collection, and the Tailings Impoundment cover and seep collection system, and monitoring of overbank materials along Panther Creek following significant flood events, this alternative would provide a reliable and permanent remedy.

7.2.6.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BB-7 includes continued operation of the WTP. Meadow Creek seep collection would increase the volume treated in the WTP. Additional treatment would be provided for Tailings Impoundment seepage (either in the WTP or in-situ).

Removal of overbank deposits would reduce the mobility of these deposits, albeit without treatment.

7.2.6.5 Short-Term Effectiveness

Most of the benefits of remedial action, including water quality improvements due to treatment of Tailings Impoundment seepage, would be realized relatively quickly

following completion of construction (within 1 to 2 years). The removal and selective physical stabilization of overbank deposits included in this alternative would create potential risks to the community and site workers typical of construction activities. These activities would also result in unavoidable short-term disturbance of ecological habitat.

7.2.6.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. The most difficult aspect of this alternative would be designing, installing, and operating collection and treatment system for Tailings Impoundment seepage. Schedule delays could be encountered during implementation of the seepage collection and treatment system: a treatability study would be necessary, and construction could take more than one season. There would also be some difficulties associated with removal of overbank deposits, but they would be less than for armoring the deposits.

The administrative implementability of instituting institutional controls on property managed by the USFS along Blackbird Creek is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.2.6.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Tables E-6, E-7, and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.2.7 Alternative BB-8 - Meadow Creek Seep Collection; Cover West Fork Tailings Impoundment and Treat Tailings Impoundment Seepage; Complete Removal of Overbank Deposits and In-Stream Sediments

7.2.7.1 Overall Protection of Human Health and the Environment

As discussed below under long-term effectiveness and presented in Table 7-5b, this alternative would not be expected to meet copper or cobalt water quality PRGs in Blackbird Creek at all times. The copper PRG could be met at times during low flow periods, but it would often be exceeded during the spring runoff. The cobalt PRG would be exceeded at virtually all times in Blackbird Creek.

Alternative BB-8 is predicted to result in copper concentrations in Panther Creek below the copper water quality PRG at all times of the year. Cobalt concentrations in Panther Creek are also predicted to meet the cobalt water quality PRG, even during low flow periods when cobalt concentrations are highest. The uncertainty and variability analysis is discussed below under long-term effectiveness.

By design, removal of all sediments would achieve sediment PRGs in Blackbird Creek, at least initially. The removal of sediments would also result in reduction in the copper and cobalt loads to Blackbird and Panther Creeks. There is a minor risk of recontamination due to processes such as secondary precipitation from source areas. Removal of all sediments would be expected to prevent remobilization of arsenic-containing sediments affecting in-stream sediments in Panther Creek and potential for re-deposition at concentrations that exceed human health PRGs along Panther Creek. However, the extensive sediment removal required to implement this alternative would destroy existing wildlife habitat that could take years to reestablish. In addition, there would be greater risk of injury to workers due to the longer duration of construction activities.

Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek. Meeting sediment PRGs in Panther Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Because most of the current measured concentrations are below known probable toxic levels (see Section 7.2.1.5), benthic communities in Panther Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Panther Creek despite the current exceedances of the sediment PRGs.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed.

EPA has determined that the removal of all in-stream and overbank deposits along Blackbird Creek would provide protection of human health. The water quality PRGs in Blackbird Creek would not be consistently met under Alternative BB-8. Sediment PRGs in Blackbird Creek would be met through complete sediment removal. The Panther Creek sediments would eventually meet PRGs through natural recovery. The copper and cobalt water quality PRGs would likely be consistently met in Panther Creek. EPA has therefore determined that Alternative BB-8 would be protective of the environment for Panther Creek in the long-term. However, this alternative would result in extensive short-term disruption of the stream channel and habitat along Blackbird Creek that would require years to a decade or more for full recovery.

7.2.7.2 Compliance with ARARs

This alternative is predicted to meet all ARARs.

As noted in Section 3.1.1.2.2, the copper water quality PRG for Blackbird Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis for Blackbird Creek that concluded that the copper water quality standard was not currently being met, and that engineering controls would not be capable of reductions in copper loadings such that the standard could be met in Blackbird Creek within the foreseeable future.

The NPDES issues associated with Alternative BB-8 are similar to those noted for Alternative BB-4 in Section 7.2.3.2. Appendix B provides the details of the mixing zone analysis in Panther Creek. For Alternative BB-8, the analysis indicated that, under worse case conditions, a mixing zone of 62% of the width of Panther Creek would be required in the spring; in the fall a mixing zone requiring approximately 50% of the width of Panther Creek would be required. For Alternative BB-8 under average case conditions, the mixing zone requirement would be approximately 30% of the width of Panther Creek in the fall and in the spring. It should be noted that, due to physical constraints in Panther Creek in the vicinity of the Blackbird Creek confluence, the minimum mixing zone that could be achieved (regardless of alternative) under worse case is 50% of the width of Panther Creek. Under average conditions the minimum width of the mixing zone is 30%. A final determination regarding the acceptability of the mixing zones is pending.

7.2.7.3 Long-Term Effectiveness and Permanence

Table 7-5b shows estimated post-remediation concentrations for this alternative. Copper concentrations in Blackbird Creek could meet the PRG some of the time. However, there would likely be extended periods (weeks to months) during spring runoff when the copper concentrations in Blackbird Creek would not meet the water quality PRG. The average post-remediation copper concentration is predicted to be about 4 µg/L, which is lower than the PRG (depending on hardness). An evaluation of variability based on the full range of effectiveness estimates and a full range of copper concentrations observed at BBSW-01A during 2000 and 2001 predicts a range of post-remediation copper concentrations from <1 to 21 µg/L for this alternative (see Table 7-10a).

Cobalt concentrations in Blackbird Creek are anticipated to exceed the water quality PRG virtually all of the time. The average predicted post-remediation cobalt concentration at BBSW-01A is about 185 µg/L, which is about 5 times the cobalt PRG. The evaluation of variability indicates that cobalt could range from about 17 to 471 µg/L (see Table 7-10a).

Copper concentrations in Panther Creek are predicted to meet the water quality PRG at all times of the year. The average predicted post-remediation copper concentration is 1 µg/L (see Table 7-10b). An evaluation of variability based on the full range of copper concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation copper concentrations from <1 to 4 µg/L for this alternative (see Table 7-10b). The post-remediation concentration estimates do not account for potential effects on copper due to iron removal, however these effects are expected to be minor (see Section 7.2.1.2).

Cobalt concentrations in Panther Creek are predicted to meet the water quality PRG virtually all of the time. The average predicted post-remediation cobalt concentration is 18 µg/L (see Table 7-10b). An evaluation of variability based on the full range of effectiveness estimates and a full range of cobalt concentrations observed at PASW-09 during 2000 and 2001 predicts a range of post-remediation cobalt concentrations from 1 to 44 µg/L for this alternative (see Table 7-10b). It should be noted that the predicted maximum cobalt concentration in Table 7-10b assumes a worse case scenario of cobalt

loading conditions and minimal removal efficiencies (i.e. each of the elements of the remedy is not functioning as well as anticipated). It is anticipated that these worse case conditions, if they were to occur at all, would occur only temporarily. Most of the cobalt load reductions are due to removal of cobalt from the West Fork groundwater utilizing treatment, and there is a high degree of certainty associated with removal of cobalt loads utilizing treatment processes. Once the collection and treatment facilities are constructed, treatment should provide reasonably certain cobalt removals within a short time period (within 1 year from startup).

With respect to human health, overbank deposits containing arsenic above the human health PRG would be removed, thereby minimizing the potential for direct contact. By design, removal of all sediments would achieve sediment PRGs in Blackbird Creek, at least initially. There is a possibility of recontamination due to processes such as secondary precipitation from source areas. Removal of all sediments would be expected to prevent remobilization of arsenic-containing sediments affecting in-stream sediments in Panther Creek and eliminate the potential for re-deposition at concentrations that exceed human health PRGs along Blackbird Creek adjacent to the PCI and along Panther Creek. Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek.

Overbank deposits along Blackbird Creek adjacent to the Panther Creek Inn containing arsenic above the residential human health PRG would be removed. In addition, in-stream sediments in Blackbird Creek adjacent to the PCI would be removed.

The long-term residual risks under Alternative BB-8 are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits along Blackbird Creek. The risk of continued cobalt releases from the West Fork Impoundment would be minimized primarily through collection and treatment of the groundwater from the impoundment. Treatment of cobalt has been proven to be effective at this site, and the treatment would reduce the cobalt loads within a reasonable and assured time frame (within 1 year of construction). The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. The risks associated with the overbank deposits along Blackbird Creek would be addressed through removal of all sediments.

The reliability and permanence of this alternative depends on long-term operation of the treatment plant, and monitoring and maintenance of the Early Actions previously implemented, as well as the additional Meadow Creek seep collection system, and the Tailings Impoundment soil cover and seep collection system. Alternative BB-8 relies on extensive removal along Blackbird Creek, which is considered more permanent. With proper long-term operation, monitoring, and maintenance of the Early Actions, Meadow Creek Seep Collection, and the Tailings Impoundment cover and seep collection system, this alternative would provide a reliable and permanent remedy.

7.2.7.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BB-8 includes continued operation of the WTP. Meadow Creek seep collection would increase the volume treated in the WTP. Additional treatment would be provided for Tailings Impoundment seepage (either in the WTP or in-situ).

Removal of overbank deposits and in-stream sediments would reduce the mobility of these deposits, albeit without treatment.

7.2.7.5 Short-Term Effectiveness

The benefits of remedial action would be realized quickly following completion of construction (within 1 to 2 years). However, it would require several construction seasons to implement Alternative BB-8.

Although the channel would be backfilled with clean materials and replanted, the short-term risks posed by this alternative would be much greater than in any of the other Blackbird Creek alternatives. Complete removal of in-stream sediments would destroy existing wildlife habitat, which would take years to reestablish. In addition, this alternative would require much more extensive construction activities and truck traffic that the other alternatives, resulting in greater risks to the community and site workers.

Due to the extensive amount of sediment excavation required to implement this alternative, and the limited amount of time following spring runoff when construction can take place, this alternative would require several construction seasons to complete.

7.2.7.6 Implementability

This alternative would be extremely difficult to implement. During removal, Blackbird Creek would require diversion to allow access to the in-stream sediments. In addition, as excavation would extend below the water table, dewatering of excavation areas would be required. Extensive controls would have to be put in place to control sediment, which would be complicated by the fact that work would have to be conducted over several construction seasons.

This alternative would also require siting, design, construction, and long-term maintenance of a large on-site disposal cell. A suitable site has not been identified, and it is not certain that an acceptable site is available.

7.2.7.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Tables E-8, E-9, and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.3 Individual Evaluation of Bucktail Creek Alternatives

This section presents the evaluation of individual Bucktail Creek alternatives using the CERCLA criteria. These alternatives are compared in Section 7.5.2.

7.3.1 Common Evaluation Elements

A number of evaluation considerations common to the Bucktail Creek alternatives are discussed in this section.

7.3.1.1 Evaluation of Improvements to Water Quality

The key element in evaluating the long-term effectiveness of the Bucktail Creek alternatives is their ability to meet the water quality PRGs for copper and cobalt. Early Actions have resulted in vast improvements in water quality in Big Deer and Panther Creeks, with trends indicating there would be continued improvements even without further action (See Figures 2-3 and 2-4). However, water quality PRGs would likely not be met for decades to centuries.

As can be seen from the evaluations of long-term effectiveness for the Bucktail Creek alternatives, it is not technically practical to meet the copper water quality PRG in Bucktail Creek. The various remediation alternatives have been developed to improve water and sediment quality in Bucktail Creek, and need to be evaluated for meeting PRGs within South Fork Big Deer, Big Deer, and Panther Creeks. Additional improvements in concentrations of dissolved copper and cobalt resulting from each of the Bucktail Creek alternatives were estimated for South Fork Big Deer Creek and Big Deer Creek. Predicted copper and cobalt concentrations are provided in Tables 7-11a&b and 7-12. Predictions of copper and cobalt concentrations were not performed for impacts of the Bucktail Creek Alternatives on Panther Creek. This is because the goal of the Bucktail Creek Alternatives is to meet water quality PRGs in Big Deer Creek. Assuming that water quality PRGs are met in Big Deer Creek, there would be no negative impacts on Panther Creek waters. These estimates of post-remediation water quality were calculated in a manner similar to that described for the Blackbird Creek alternatives (see Section 7.2.1). Any loading gains or losses attributed to sediments in South Fork Big Deer Creek were taken to be zero after remedial action, because these sediments will not be a long-term source of loading factor due to either natural recovery or removal. Loading losses to these sediments were also taken as zero. In any case, they do not significantly affect the evaluation. The estimates do not include any improvements due to natural recovery.

7.3.1.2 Uncertainty and Variability in Post-Remediation Water Quality Estimates

Approximate variability and uncertainty in the post-remediation water quality estimates for the Bucktail Creek alternatives are presented in Table 7-13. The methodology and the meaning of the table column headings are the same as for the Blackbird Creek alternatives (see Section 7.2.1.3).

7.3.2 Alternative BT-1 - No Further Action.

7.3.2.1 Overall Protection of Human Health and the Environment

Significant improvement to water quality in Big Deer Creek and Panther Creek has resulted from the Early Actions implemented in the Bucktail drainage. However, the copper water quality PRG is exceeded in Big Deer Creek under most flow conditions. During fall low-flow conditions in 2000 and 2001 the copper PRG was exceeded by a factor of about 10 in South Fork Big Deer Creek and by a factor of about 4 in Big Deer Creek. During some periods of high flow in 2000, dilution in Big Deer Creek was sufficient to meet the copper water quality PRG. The PRG was exceeded by factors of about 1.5 to 3 in Big Deer Creek during other periods of spring runoff.

The cobalt PRG is met in Big Deer Creek throughout the year. This PRG is exceeded throughout the year in South Fork Big Deer Creek.

No human health PRG (for surface water quality, in-stream sediments or overbank deposits) is exceeded in Bucktail, South Fork Big Deer, or Big Deer Creeks.

There are no sediment PRGs for Bucktail Creek. Sediment quality might improve through natural recovery such that sediment PRGs might eventually be achieved in South Fork Big Deer, Big Deer, and Panther Creeks.

EPA has determined that Alternative BT-1 would be protective of human health. However, since the water quality and sediment PRGs would continue to be consistently exceeded in South Fork Big Deer Creek and in Big Deer Creek, EPA has determined that Alternative BT-1 is not protective of the environment.

7.3.2.2 Compliance with ARARs

The copper water quality PRG in South Fork Big Deer Creek and Big Deer Creek is an ARAR. This ARAR is exceeded throughout the year in South Fork Big Deer Creek, and is exceeded in Big Deer Creek except under some high-flow conditions. On this basis, Alternative BT-1 would not meet ARARs. As noted in Section 7.1.2, NPDES requirements are not ARARs for the Bucktail Creek alternatives.

As noted in Section 3.1.1.2.2, the copper water quality standard for Bucktail Creek is not an ARAR. The State of Idaho prepared a Use Attainability Analysis (UAA) for Bucktail Creek. As noted in the UAA, Bucktail Creek is too small to have any real likelihood of contact recreation such as wading, fishing, and swimming. Physical conditions related to the natural features of Bucktail Creek, such as steep gradient and small size and flow, likely precluded its use by fish. The UAA concluded it is unlikely that copper concentrations will decline to the point of meeting aquatic life criteria in the foreseeable future, and that sources of pollution that preclude the attainment of use cannot be remedied.

7.3.2.3 Long-Term Effectiveness and Permanence

Significant improvement to water quality in Big Deer Creek and Panther Creek has resulted from the Early Actions implemented in the Bucktail drainage. However, the copper water quality PRG in Big Deer Creek is exceeded except when high flow in Big Deer Creek provides sufficient dilution. The copper water quality PRG is exceeded throughout the year in South Fork Big Deer Creek. It is likely that natural recovery would not be effective at meeting the copper water quality PRG for centuries.

The cobalt PRG is met in Big Deer Creek throughout the year. This PRG is exceeded throughout the year in South Fork Big Deer Creek. It is likely that natural recovery would not be effective at meeting the cobalt water quality PRG in South Fork Big Deer Creek for centuries.

The sediments in South Fork Big Deer Creek and Big Deer Creek would eventually meet the PRGs through natural recovery. The time to meet the sediment PRGs cannot be accurately predicted, but is likely to be decades to a century or more.

Human health PRGs are not an issue for the Bucktail Creek alternatives.

Alternative BT-1 would not be effective in terms of magnitude of residual risks. This is because the groundwater downgradient from the 7000 dam would continue to be released over the long term. There would be minimal risks of release of contaminants from the mine area because the Early Actions would preclude releases of contaminants for storm events up to the 500-year design storm. There would be a slight risk that sediments in Bucktail Creek could be re-mobilized during a large storm event and deposited in downstream areas. However, this risk would be minimized as long as the lower Bucktail sediment dam remains in place.

Alternative BT-1 would not meet the water quality or sediment PRGs within a reasonable time frame. Therefore, this alternative is not reliable or permanent.

7.3.2.4 Reduction in Toxicity, Mobility and Volume through Treatment

No further action would include continued treatment of water collected at the 7000 dam and existing pump-back station.

7.3.2.5 Short-Term Effectiveness

Any further action would create potential short-term risks that would not exist with no further action. The short-term risks *avoided* in Alternative BT-1 include:

- Risk for the surrounding community from increased traffic of heavy trucks and construction equipment;
- Normal construction-related risks for site workers, and
- Risk to the environment resulting from disturbing habitat during construction.

The "No Further Action" alternative, being current conditions, would be implemented immediately upon signing a Consent Decree.

7.3.2.6 Implementability

There would be no implementation difficulties associated with no further action. There is not expected to be a need for institutional controls to address human health risks on National Forest System Lands in Bucktail, South Fork Big Deer Creek or Big Deer Creek. Should they be needed, the administrative implementability of instituting institutional controls on property managed by the USFS is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.3.2.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-10 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.3.3 Alternative BT-3 - Seep Collection and Treatment; Natural Recovery of Sediments.

7.3.3.1 Overall Protection of Human Health and the Environment

As presented in Table 7-11a&b and discussed below under long-term effectiveness, this alternative is predicted to result in meeting the water quality PRGs for both copper and cobalt in Big Deer Creek. The copper and cobalt water quality PRGs are not predicted to be met consistently in South Fork Big Deer Creek.

There are no sediment PRGs for Bucktail Creek. Sediment quality may improve through natural recovery such that sediment PRGs might be achieved eventually in South Fork Big Deer. Sediment quality in Big Deer Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Big Deer Creek. Meeting sediment PRGs in Big Deer Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Benthic communities in Big Deer Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Big Deer Creek despite the current exceedances of the sediment PRGs.

No human health PRG (for surface water quality, in-stream sediments, or overbank deposits) is exceeded in Bucktail, South Fork Big Deer, or Big Deer Creeks.

EPA has determined that Alternative BT-3 would be protective of human health. Water quality PRGs would be met in the long-term for Big Deer Creek, and the sediment PRGs in Big Deer Creek would be met through natural recovery. Therefore, EPA has determined that Alternative BT-3 would be protective of the environment in Big Deer Creek. The sediment PRGs would be met in South Fork Big Deer Creek through natural recovery. However, the water quality PRGs would not be met in South Fork Big Deer Creek for centuries. Therefore, EPA has determined that Alternative BT-3 would not be protective of the environment in South Fork Big Deer Creek within a reasonable time frame.

7.3.3.2 Compliance with ARARs

This alternative is predicted to meet all ARARs in Big Deer Creek, but is not predicted to meet the copper water quality ARAR for South Fork Big Deer Creek. As noted in Section 7.1.2, NPDES requirements are not ARARs for the Bucktail Creek alternatives.

As noted in Section 3.1.1.2.2, there is no copper water quality standard for Bucktail Creek. The State of Idaho prepared a Use Attainability Analysis (UAA) for Bucktail Creek. As noted in the UAA, Bucktail Creek is too small to have any real likelihood of contact recreation such as wading, fishing, and swimming. Physical conditions related to the natural features of Bucktail Creek, such as steep gradient and small size and flow, likely precluded its use by fish. The UAA concluded it is unlikely that copper concentrations will decline to the point of meeting aquatic life criteria in the foreseeable future, and that sources of pollution that preclude the attainment of use cannot be remedied.

7.3.3.3 Long-Term Effectiveness and Permanence

By definition of the alternative, sufficient seepage into Bucktail Creek would be collected to meet the copper water quality PRG in Big Deer Creek (i.e., BDSW-03) under average conditions. Table 7-11b presents estimated post-remediation copper concentrations. As this table shows, the copper water quality PRG is predicted to be achievable by collecting and treating at least 65% of the affected groundwater currently discharging into Bucktail Creek. The uncertainty and variability analysis suggests that copper concentrations in Big Deer Creek could range from 1 to 5 μg/L, which is below the copper PRG. This analysis also indicates that cobalt concentrations in Big Deer Creek could range from 3 to 9 µg/L, which is well below the cobalt PRG (see Table 7-13). The copper and cobalt water quality PRGs are not predicted to be met consistently in South Fork Big Deer Creek.

To evaluate the water quality impacts in Big Deer Creek in the mixing zone immediately downstream from the South Fork Big Deer Creek, a mixing zone analysis was prepared. Appendix B provides the details of the mixing zone analysis in Big Deer Creek. For Alternative BT-3, the analysis indicated that, under worse case conditions, the copper water quality standard would not be met even with 100% mixing in both the spring and fall. Under average case conditions, the entire width (100%) of Big Deer Creek would be required for mixing. As noted above, the copper water quality predictions were based on the assumption that 65% of the copper loads discharging to Bucktail Creek would be

collected and treated. This is a conservative assumption, since greater than 65% removal could be achieved using the groundwater collection technologies under consideration. Therefore, the mixing zone analysis in Appendix B was also performed assuming that more than 65% of the copper loads in Bucktail Creek could be collected. If 80% copper load removal is assumed, the mixing zone requirement would be 100% of the width of Big Deer Creek under worse case conditions for both spring and fall. Under the average case conditions, 70% of the width of Big Deer Creek would be required for mixing in both spring and fall. It should be noted that 70% of the width of Big Deer Creek is the minimum mixing zone that could be achieved, regardless of upstream copper load reductions. This is due to physical constraints in the vicinity of the confluence of South Fork and Big Deer Creeks. Post-remediation water quality monitoring will be conducted to evaluate mixing zones in Big Deer Creek. If necessary, alternatives for contingencies to address the mixing zone issues would be evaluated.

Depending on percentage of seepage collected, copper precipitation could continue to occur in Bucktail Creek. However, dissolved copper concentrations could be reduced such that copper would be released from sediments in Bucktail Creek. Sediments in South Fork Big Deer Creek would release dissolved copper until no more copper can be solubilized. However, this would be a short-term effect and does not affect the long-term effectiveness of this alternative. It is not possible to accurately predict the time required until the Bucktail Creek sediments would no longer impact downstream water quality, but it is likely to be years to a decade or more. If post-remediation monitoring indicates that the sediments will continue to impact downstream water quality for an unacceptable period, alternatives for contingencies to address water quality would be evaluated.

Human health PRGs are not an issue for the Bucktail Creek alternatives.

The long-term magnitude of residual risks under Alternative BT-3 would be minimal. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. There would be a slight risk that sediments in Bucktail Creek could be re-mobilized during a large storm event and deposited in downstream areas. However, this risk would be minimized as long as the lower Bucktail sediment dam remains in place.

The reliability of Alternative BT-3 would depend upon long-term maintenance of the collection and pumping systems, monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of the collection and treatment facilities is properly performed, this alternative would provide a reliable and permanent remedy.

7.3.3.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BT-3 uses treatment of collected groundwater as the primary remediation component.

7.3.3.5 Short-Term Effectiveness

Because the sediments in Bucktail Creek are currently acting as a sink for metals, it could be some time before the full effects of seep removal would be seen. With improvement to water quality, the sediments could become a source of metals loading, which could persist for years to a decade or more. Sediments in South Fork Big Deer Creek could also release dissolved copper until no more copper can be solubilized. The metals release from South Fork Big Deer Creek sediments would be a comparatively small release, would mostly likely be complete in a short period of time, and would not have a major effect on water quality. The time required is uncertain and cannot be precisely estimated, but could be five years or less.

There would be short-term unavoidable impacts to portions of the Bucktail Creek channel during construction of the groundwater collection system. There would also be short-term risks to workers during the construction period. Because access to the site is controlled, there would be minimal risks to the local community during the construction.

7.3.3.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. Pre-design investigations would be required for final design of the seepage collection system.

There is not expected to be a need for institutional controls to address human health risks on National Forest System Lands in Bucktail, South Fork Big Deer Creek or Big Deer Creek. Institutional controls should not be necessary to protect remediation facilities, because of the remote location and because road access to this area is controlled by the gate on Blackbird Creek. Should they be needed, the administrative implementability of instituting institutional controls on property managed by the USFS is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.3.3.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-11 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.3.4 Alternative BT-4 - Seep Collection and Treatment; S. Fork Big Deer Creek Sediment Removal; Natural Recovery of Remaining Sediments.

7.3.4.1 Overall Protection of Human Health and the Environment

As presented in Table 7-11a&b and discussed below under long-term effectiveness, this alternative is predicted to result in meeting the water quality PRGs for both copper and cobalt in Big Deer Creek. The copper and cobalt water quality PRGs are not predicted to be met consistently in South Fork Big Deer Creek. There are no sediment PRGs for Bucktail Creek. Sediment PRGs would be met in South Fork Big Deer Creek through removal. Removal of sediments from South Fork Big Deer Creek might speed recovery of water quality in South Fork Big Deer and Big Deer Creeks; however, given the small quantity of South Fork sediments relative to Bucktail Creek, it is likely that any long-term benefits would be minor. There would be short-term risks associated with sediment removal as discussed in section 7.3.5.5. In addition there would be potential for South Fork Big Deer Creek sediments to become recontaminated from Bucktail Creek sediments if the Bucktail Creek sediments were to be mobilized (e.g. during a large storm event) prior to the metals being flushed from Bucktail Creek. However, the sediment dam at the mouth of Bucktail Creek would reduce the potential for sediment recontamination from Bucktail Creek.

Sediment quality in Big Deer Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Big Deer Creek. Meeting sediment PRGs in Big Deer Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Benthic communities in Big Deer Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Big Deer Creek despite the current exceedances of the sediment PRGs.

No human health PRG (surface water quality, in-stream sediments or overbank deposits) is exceeded in Bucktail, South Fork Big Deer, or Big Deer Creeks.

EPA has determined that Alternative BT-4 would be protective of human health. Water quality PRGs would be met in the long-term for Big Deer Creek, and the sediment PRGs in Big Deer Creek would be met through natural recovery. Therefore, EPA has determined that Alternative BT-4 would be protective of the environment in Big Deer Creek. The sediment PRGs would be met in South Fork Big Deer Creek through removal. However, the water quality PRGs would not be met in South Fork Big Deer Creek for centuries. Therefore, EPA has determined that Alternative BT-4 would not be protective of the environment in South Fork Big Deer Creek within a reasonable time frame.

7.3.4.2 Compliance with ARARs

This alternative is predicted to meet all ARARs in Big Deer Creek, but is not predicted to meet the copper water quality ARAR for South Fork Big Deer Creek. As noted in Section

7.1.2, NPDES requirements are not ARARs for the Bucktail Creek alternatives. Also, as noted in Section 3.1.1.2.2, the State of Idaho has determined through a Use Attainability Analysis that there is no copper water quality ARAR for Bucktail Creek.

7.3.4.3 Long-Term Effectiveness and Permanence

With respect to water quality, the long-term effectiveness of this alternative is expected to be the same as Alternative BT-3 (see Section 7.3.3.3). The uncertainty and variability analysis suggests that copper concentrations in Big Deer Creek could range from 1 to 5 µg/L, which is below the copper PRG. This analysis also indicates that cobalt concentrations in Big Deer Creek could range from 3 to 9 µg/L, which is well below the cobalt PRG. (see Table 7-13). The copper and cobalt water quality PRGs are not predicted to be met consistently in South Fork Big Deer Creek.

To evaluate the water quality impacts in Big Deer Creek in the mixing zone immediately downstream from the South Fork Big Deer Creek, a mixing zone analysis was prepared. Appendix B provides the details of the mixing zone analysis in Big Deer Creek. As noted in Appendix B, there is no significant difference in the mixing zone conditions in Big Deer Creek under any of the action alternatives (BT-3 through BT-6). Therefore, the mixing zone analysis results are similar to those noted in Section 7.3.3.3 for Alternative BT-3. Under worse case conditions, the copper water quality standard would not be met under Alternative BT-4 even with 100% mixing in both the spring and fall. Under average case conditions, the entire width (100%) of Big Deer Creek would be required for mixing. As also noted in Section 7.3.3.3, the copper water quality predictions were based on the assumption that 65% of the copper loads discharging to Bucktail Creek would be collected and treated. This is a conservative assumption, since greater than 65% removal could be achieved using the groundwater collection technologies under consideration. Therefore, the mixing zone analysis in Appendix B was also performed assuming that more than 65% of the copper loads in Bucktail Creek could be collected. If 80% copper load removal is assumed, the mixing zone requirement under Alternative BT-4 would be 100% of the width of Big Deer Creek under worse case conditions for both spring and fall. Under the average case conditions, 70% of the width of Big Deer Creek would be required for mixing in both spring and fall. It should be noted that 70% of the width of Big Deer Creek is the minimum mixing zone that could be achieved, regardless of upstream copper load reductions. This is due to physical constraints in the vicinity of the confluence of South Fork and Big Deer Creeks. Post-remediation water quality monitoring will be conducted to evaluate mixing zones in Big Deer Creek. If necessary, alternatives for contingencies to address the mixing zone issues would be evaluated.

Depending on percentage of seepage collected, copper precipitation could continue to occur in Bucktail Creek. However, dissolved copper concentrations could be reduced such that copper would be released from sediments in Bucktail Creek. It is not possible to accurately predict the time required until the Bucktail Creek sediments would no longer impact downstream water quality, but it is likely to be years to a decade or more. If post-remediation monitoring indicates that the sediments will continue to impact downstream water quality for an unacceptable period, alternatives for contingencies to address water quality would be evaluated. Removal of sediments from South Fork Big

Deer Creek would not affect long-term effectiveness (see discussion of short-term effectiveness in Section 7.3.4.5).

Human health PRGs are not an issue for the Bucktail Creek alternatives.
The long-term magnitude of residual risks under Alternative BT-4 would be minimal. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. There would be a slight risk that sediments in Bucktail Creek could be re-mobilized during a large storm event and deposited in downstream areas. However, this risk would be minimized as long as the lower Bucktail sediment dam remains in place.

The reliability of Alternative BT-4 would depend upon long-term maintenance of the collection and pumping systems, monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of the collection and treatment facilities is properly performed, this alternative would provide a reliable and permanent remedy.

7.3.4.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BT-4 uses treatment of collected groundwater as the primary remediation component.

7.3.4.5 Short-Term Effectiveness

Because the sediments in Bucktail Creek are currently acting as a sink for metals, it could be some time before the full effects of seep removal would be seen. With improvement to water quality, the sediments could become a source of metals loading, which could persist for years to a decade or more. Removal of sediments in South Fork Big Deer Creek would meet the sediment PRGs immediately upon completion of construction. In addition, removal of sediments from South Fork Big Deer Creek might speed recovery of water quality in South Fork and Big Deer Creeks; however, given the small quantity of South Fork sediments relative to Bucktail Creek, it is likely that any benefits would be minor. It is also possible that removing these sediments would not result in a measurable difference in copper concentrations in South Fork Big Deer Creek waters. In addition, erosion of Bucktail Creek sediments could cause recontamination of South Fork Big Deer Creek sediments.

There would be short-term ecological impacts from the disruption of riparian habitat and the existing stream channel required to excavate the South Fork Big Deer Creek sediments. There would be short-term risks to workers due to construction of the groundwater collection system and during excavation and transportation of removed sediments.

7.3.4.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. Pre-design investigations

would be required for final design of the seepage collection system. This alternative would have implementation issues associated with sediment removal. During removal, South Fork Big Deer Creek would require diversion to allow access to the in-stream sediments. In addition, as excavation would extend below the water table, dewatering of excavation areas would be required. Extensive temporary controls would be required to control sediment generation during the removal.

There is not expected to be a need for institutional controls to address human health risks on National Forest System Lands in Bucktail, South Fork Big Deer Creek or Big Deer Creek. Institutional controls should not be necessary to protect remediation facilities, because of the remote location and because road access to this area is controlled by the gate on Blackbird Creek. Should they be needed, the administrative implementability of instituting institutional controls on property managed by the USFS is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.3.4.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-12 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.3.5 Alternative BT-5 - Seep Collection and Treatment; Diversion of Bucktail Creek; Natural Recovery of Sediments.

7.3.5.1 Overall Protection of Human Health and the Environment

As presented in Table 7-11a&b and discussed below under long-term effectiveness, this alternative is predicted to result in meeting the water quality PRGs for both copper and cobalt in Big Deer Creek. By constructing a diversion pipeline to remove the Bucktail Creek surface water discharge from South Fork Big Deer Creek, the water quality PRGs would also be expected to be met in South Fork Big Deer Creek (after natural recovery of sediments). Bucktail Creek flows in excess of the capacity of the diversion pipeline (10-year storm event) would overflow into South Fork Big Deer Creek. However, this overflow would occur during times of increased flow is South Fork Big Deer Creek as well as Bucktail Creek. The increased flows would provide additional dilution in both creeks, such that the effects of overflow on water quality and sediments would be expected to be minimized and of short duration.

There are no sediment PRGs for Bucktail Creek. The construction of the diversion pipeline would mean that the sediments in South Fork Big Deer Creek would no longer be consistently subjected to the metals in the Bucktail Creek flows. This should speed the natural recovery process for the sediments, such that the sediment PRGs would be met in South Fork Big Deer Creek more rapidly.

Sediment quality in Big Deer Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Big Deer Creek. Meeting sediment PRGs in Big Deer Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Benthic communities in Big Deer Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Big Deer Creek despite the current exceedances of the sediment PRGs.

No human health PRG (for surface water quality, in-stream sediments, or overbank deposits) is exceeded in Bucktail, South Fork Big Deer, or Big Deer Creeks.

EPA has determined that Alternative BT-5 would be protective of human health. This alternative is expected to meet all water quality PRGs in South Fork Big Deer Creek and Big Deer Creek. Sediment PRGs in South Fork Big Deer and Big Deer Creeks would be met through natural recovery. Therefore, EPA has determined that Alternative BT-5 would be protective of the environment for South Fork Big Deer and Big Deer Creeks.

7.3.5.2 Compliance with ARARs

This alternative is predicted to meet all ARARs in Big Deer Creek, and would be expected to achieve ARARs is South Fork Big Deer Creek as well. As noted in Section 7.1.2, NPDES requirements are not ARARs for the Bucktail Creek alternatives. Also, as noted in Section 3.1.1.2.2, the State of Idaho has determined through a Use Attainability Analysis that there is no copper water quality ARAR for Bucktail Creek.

7.3.5.3 Long-Term Effectiveness and Permanence

By definition of the alternative, sufficient seepage into Bucktail Creek would be collected to meet the copper and cobalt water quality PRGs in Big Deer Creek (i.e., BDSW-03). If the Phase I groundwater interception were to prove insufficient, then the Phase II interception system would be implemented. Table 7-11b presents estimated post-remediation copper and cobalt concentrations. As this table shows, the copper water quality PRG is predicted to be achievable by collecting and treating at least 65% of the affected groundwater currently discharging into Bucktail Creek. The uncertainty and variability analysis suggests that post-remediation copper concentrations in Big Deer Creek could range from 1 to 5 µg/L. This analysis also indicates that cobalt concentrations in Big Deer Creek could range from 3 to 9 µg/L, which is well below the cobalt PRG (see Table 7-13).

The mixing zone analysis in Appendix B was also performed to evaluate mixing zone issues for Alternative BT-5. The analysis indicated that, because of physical constraints in Big Deer Creek near its confluence with the South Fork, there would be no essential difference between Alternative BT-5 and the other alternatives in terms of the mixing zone in Big Deer Creek. In other words, the diffuser of Alternative BT-5 would not result in any substantial difference in the mixing zone in Big Deer Creek. Therefore the mixing

zone analysis for Alternative BT-5 indicated results similar to those noted for Alternative BT-3 in Section 7.3.3.3. Under worse case conditions, the copper water quality standard would not be met even with 100% mixing in both the spring and fall. Under average case conditions, the entire width (100%) of Big Deer Creek would be required for mixing. The copper water quality predictions were based on the assumption that 65% of the copper loads discharging to Bucktail Creek would be collected and treated. This is a conservative assumption, since greater than 65% removal could be achieved using the groundwater collection technologies under consideration. Therefore, the mixing zone analysis in Appendix B was also performed assuming that more than 65% of the copper loads in Bucktail Creek could be collected. If 80% copper load removal is assumed, the mixing zone requirement would be 100% of the width of Big Deer Creek under worse case conditions for both spring and fall. Under the average case conditions, 70% of the width of Big Deer Creek would be required for mixing in both spring and fall. It should be noted that 70% of the width of Big Deer Creek is the minimum mixing zone that could be achieved, regardless of upstream copper load reductions. This is due to physical constraints in the vicinity of the confluence of South Fork and Big Deer Creeks. Post-remediation water quality monitoring will be conducted to evaluate mixing zones in Big Deer Creek. If necessary, alternatives for contingencies to address the mixing zone issues would be evaluated.

By constructing a diversion pipeline to remove the Bucktail Creek surface water discharge from South Fork Big Deer Creek, the water quality PRGs for copper and cobalt are expected to be met in South Fork Big Deer Creek (after natural recovery of sediments). However, it is possible that groundwater discharges into South Fork Big Deer Creek associated with the Bucktail Creek drainage could prevent consistently meeting water quality PRGs even with the Bucktail Creek bypass. If this is the case, a contingency for a groundwater collection system would be evaluated for intercepting the groundwater discharges to South Fork Big Deer Creek.

Depending on percentage of seepage collected, copper precipitation could continue to occur in Bucktail Creek. However, dissolved copper concentrations could be reduced such that copper could be released from sediments in Bucktail Creek. It is not possible to accurately predict the time required until the Bucktail Creek sediments would no longer impact downstream water quality, but it is likely to be years to a decade or more. If post-remediation monitoring indicates that the sediments will continue to impact downstream water quality for an unacceptable period, alternatives for contingencies to address water quality would be evaluated. Sediments in South Fork Big Deer Creek would release dissolved copper until no more copper can be solubilized. However, this would be a short-term effect (likely less than 5 years) and does not affect the long-term effectiveness of this alternative.

Bucktail Creek flows in excess of the capacity of the diversion pipeline (10-year storm event) would overflow into South Fork Big Deer Creek. However, this overflow would occur during times of increased flow is South Fork Big Deer Creek as well as Bucktail Creek. The increased flows would provide additional dilution in both creeks, such that the effects of overflow on water quality and sediments would be expected to be minimized and of short duration.

Human health PRGs are not an issue for the Bucktail Creek alternatives.

The long-term magnitude of residual risks under Alternative BT-5 would be minimal. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. There would be a slight risk that sediments in Bucktail Creek could be re-mobilized during a large storm event and deposited in downstream areas. However, this risk would be minimized as long as the lower Bucktail sediment dam remains in place.

The reliability of Alternative BT-5 would depend upon long-term maintenance of the collection and pumping systems and of the diversion pipeline, monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of the collection, treatment, and diversion facilities is properly performed, this alternative would provide a reliable and permanent remedy.

7.3.5.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BT-5 uses treatment of collected groundwater as the primary remediation component.

7.3.5.5 Short-Term Effectiveness

Because the sediments in Bucktail Creek are currently acting as a sink for metals, it could be some time before the full effects of seep removal would be seen. With improvement to water quality, the sediments could become a source of metals loading, which could persist for years to a decade or more. Sediments in South Fork Big Deer Creek could also release dissolved copper until no more copper can be solubilized. The metals release from South Fork Big Deer Creek sediments would be a comparatively small release, would mostly likely be complete in a short period of time, and would not have a major effect on downstream water quality in Big Deer Creek. The time required is uncertain and cannot be precisely estimated, but could be five years or less.

Diversion of Bucktail Creek would have an immediate post-construction improvement to water quality in South Fork Big Deer Creek. However, this diversion would not result in water quality improvements in Big Deer Creek.

There would be short-term unavoidable impacts to portions of the Bucktail Creek channel during construction of the groundwater collection system. There would also be short-term risks to workers during the construction period. Because access to the site is controlled, there would be minimal risks to the local community during the construction.

7.3.5.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. Pre-design investigations

would be required for final design of the seepage collection system and diversion of Bucktail Creek.

There is not expected to be a need for institutional controls to address human health risks on National Forest System Lands in Bucktail, South Fork Big Deer Creek or Big Deer Creek. Institutional controls should not be necessary to protect remediation facilities, because of the remote location and because road access to this area is controlled by the gate on Blackbird Creek. Should they be needed, the administrative implementability of instituting institutional controls on property managed by the USFS is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.3.5.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-13 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.3.6 Alternative BT-6 - Seep Collection and Treatment; Complete Sediment Removal

7.3.6.1 Overall Protection of Human Health and the Environment

As presented in Table 7-11a&b and discussed below under long-term effectiveness, this alternative would result in meeting the water quality PRGs for both copper and cobalt in Big Deer Creek. The copper and cobalt water quality PRGs are not predicted to be met consistently in South Fork Big Deer Creek. Sediment PRGs in South Fork Big Deer Creek and Big Deer Creek would be met through removal. Although there are no sediment PRGs in Bucktail Creek, these sediments would also be removed for greater assurance that water quality and sediment PRGs for copper in Big Deer and Panther Creeks would be met. There would be significant short-term impacts to the stream environments until the channels stabilized and riparian vegetation is re-established.

No human health PRG (for surface water quality, in-stream sediments or overbank deposits) is exceeded in Bucktail, South Fork Big Deer, or Big Deer Creeks.

EPA has determined that Alternative BT-6 would be protective of human health. The water quality and sediment PRGs in Big Deer Creek would be met shortly after implementation. Although the removals would result in significant impacts to the stream environments, these impacts would not last more than a few years to a decade. Therefore, the EPA has determined that Alternative BT-6 would be protective of the environment in Big Deer Creek. The sediment PRGs would be met in South Fork Big Deer Creek on completion of the removals. However, the water quality PRGs would not be met in South Fork Big Deer Creek for centuries; therefore EPA has determined that

Alternative BT-6 would not be protective of the environment in South Fork Big Deer Creek within a reasonable time frame.

7.3.6.2 Compliance with ARARs

This alternative is predicted to meet all ARARs in Big Deer Creek, but is not predicted to meet the copper water quality ARAR for South Fork Big Deer Creek. As noted in Section 7.1.2, NPDES requirements are not ARARs for the Bucktail Creek alternatives. Also, as noted in Section 3.1.1.2.2, the State of Idaho has determined through a Use Attainability Analysis that there is no copper water quality ARAR for Bucktail Creek.

7.3.6.3 Long-Term Effectiveness and Permanence

With respect to water quality, the long-term effectiveness of this alternative is expected to be similar to Alternative BT-3, including the mixing zone in Big Deer Creek (see Section 7.3.3.3). Removal of sediments in South Fork Big Deer Creek and Big Deer Creek would have no substantial long-term benefits over natural recovery of these sediments. A road would have to be constructed along Big Deer Creek to provide access for equipment to remove sediments. Following completion of the removal activities, the road would be removed and revegetated to mitigate the long-term impacts.

The long-term magnitude of residual risks under Alternative BT-6 would be minimal. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. The removal of sediments in all of the creeks would eliminate the risk of re-mobilization of sediments with deposition in downstream areas.

The reliability of Alternative BT-6 would depend upon long-term maintenance of the collection and pumping systems, monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of the collection and treatment facilities is properly performed, this alternative would provide a reliable and permanent remedy.

7.3.6.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BT-6 uses treatment of collected groundwater as a primary remediation component.

7.3.6.5 Short-Term Effectiveness

The water quality and sediment PRGs in Big Deer Creek would be met shortly following completion of construction. The sediment PRGs would also be met in South Fork Big Deer Creek shortly after construction. The water quality goals in South Fork Big Deer Creek would not be met, likely for centuries.

Although the channels would be backfilled with clean materials and replanted, the short-term environmental impacts posed by this alternative would be much greater than in

any of the other Bucktail Creek alternatives. Complete removal of in-stream sediments would destroy existing wildlife riparian habitat, which would take years to a decade or more to re-establish. In addition, this alternative would require much more extensive construction activities and truck traffic than the other alternatives, resulting in greater risks to the community and site workers. Construction of a road along Big Deer Creek would result in unavoidable short-term impacts to vegetation and wildlife habitat along the road alignment. The road would be removed and re-vegetated following construction.

Due to the extensive amount of sediment excavation required to implement this alternative, and the limited amount of time following spring runoff when construction can take place, this alternative would require likely require several construction seasons to complete.

7.3.6.6 Implementability

This alternative would be extremely difficult to implement. During removal, Bucktail, South Fork Big Deer, and Big Deer Creeks would require diversion to allow access to the in-stream sediments. In addition, for excavation to extend below the water table, dewatering of excavation areas would be required. Extensive controls would be required to control sediment, which would be complicated by the fact that work would have to be conducted over several construction seasons.

This alternative would also require siting, design, construction, and long-term maintenance of a large on-site disposal cell. A suitable site has not been identified. It may be difficult to obtain approvals to construct the access road along Big Deer Creek. This is because the main Big Deer Creek valley is currently road less.

There is not expected to be a need for institutional controls to address human health risks on National Forest System Lands in Bucktail, South Fork Big Deer Creek or Big Deer Creek. Institutional controls should not be necessary to protect remediation facilities, because of the remote location and because road access to this area is controlled by the gate on Blackbird Creek. Should they be needed, the administrative implementability of instituting institutional controls on property managed by the USFS is not expected to be difficult. Pursuant to 36 CFR 251.50, the Regional Forester is authorized to issue orders that close or restrict use of areas on National Forest System Lands over which he or she has jurisdiction.

7.3.6.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-14 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables. Volume estimates for sediment removal could be low, which would result in underestimating the cost of this alternative.

7.4 Individual Evaluation of Panther Creek Alternatives

This section presents the evaluation of individual Panther Creek alternatives using the CERCLA criteria. These alternatives are compared in Section 7.5.3.

7.4.1 Alternative P-1 – No Further Action

7.4.1.1 Overall Protection of Human Health and the Environment

Arsenic concentrations exceed EPA's future residential human health PRG in some overbank areas along Panther Creek. Residential use frequency of exposure does not occur currently for the portions of the Rogers, Rufe, and former Strawn properties being evaluated in this FS. However, there is a potential for future changes in land use that could increase frequency of exposure. In addition, there is a risk that contamination remaining at the water table in areas cleaned up under the Early Actions could be brought to the surface as a result of erosion or construction activities. Without land use monitoring and institutional controls, future protection of human health is not assured.

Sediments are expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek.

Water quality in Panther Creek is dependent on the alternatives selected for Blackbird and Bucktail Creeks.

Residential development could occur in the future at the private properties where concentrations of arsenic in overbank deposits exceed the residential arsenic PRG of 100 mg/kg. If this were to occur, the exposures would be greater than EPA's acceptable risk range. Therefore, EPA has determined that Alternative P-1 is not protective of human health. The risks to the environment are acceptable under current and future scenarios, therefore EPA has determined that Alternative P-1 is protective of the environment.

7.4.1.2 Compliance with ARARs

This alternative would meet all ARARs.

7.4.1.3 Long-Term Effectiveness and Permanence

Since water quality standards in Panther Creek will be addressed by selection of suitable alternatives for Blackbird and Bucktail Creeks, evaluation of long-term effectiveness and permanence for the Panther Creek alternatives is focused on human health.

The magnitude of residual human health risks under current land use is within EPA's acceptable risk range. However, Alternative P-1 does not include land use monitoring and institutional controls to prevent potential future human health risks. Therefore, this alternative is not reliable or permanent.

7.4.1.4 Reduction in Toxicity, Mobility and Volume through Treatment

None of the Panther Creek alternatives involve treatment.

7.4.1.5 Short-Term Effectiveness

Any further action would create potential short-term risks that would not exist with no further action. The short-term risks *avoided* in Alternative P-1 include:

- Risk for the surrounding community from increased traffic of heavy trucks and construction equipment;
- Normal construction-related risks for site workers, and
- Risk to the environment resulting from disturbing habitat during construction.

The "No Further Action" alternative, being current conditions, would be implemented immediately upon signing a Consent Decree.

7.4.1.6 Implementability

There would be no implementation difficulties associated with no further action.

7.4.1.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-15 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.4.2 Alternative P-2 - Institutional Controls with Natural Recovery of Panther Creek Sediments

7.4.2.1 Overall Protection of Human Health and the Environment

Alternative P-2 includes implementation of institutional controls at the Rogers, Strawn and Rufe properties where arsenic concentrations in overbank areas exceeds 100 mg/kg. Institutional controls may also be needed at some of the private properties cleaned up under the Early Actions to preclude unacceptable future exposure if underlying soils with elevated arsenic concentrations are brought to the surface (as a result of erosion or construction activities). With institutional controls, human health would be protected by preventing future human exposure to arsenic concentrations above the human health PRG.

Water quality in Panther Creek is dependent on the alternatives selected for Blackbird and Bucktail Creeks.

Sediments are expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek.

Institutional controls can provide protection of human health if properly maintained and enforced. EPA or another government entity would assure maintenance and enforcement of the institutional controls; therefore EPA has determined that Alternative P-2 is protective of human health. The risks to the environment are acceptable under current and future scenarios; therefore EPA has determined that Alternative P-2 is protective of the environment.

7.4.2.2 Compliance with ARARs

This alternative would meet all ARARs.

7.4.2.3 Long-Term Effectiveness and Permanence

Since water quality standards in Panther Creek will be achieved by selection of suitable alternatives for Blackbird and Bucktail Creeks, evaluation of long-term effectiveness and permanence for the Panther Creek alternatives is focused on human health.

EPA has determined that the potential human health risks under current land use are acceptable, but that risks under a future residential scenario would be above the acceptable range. Alternative P-2 includes implementation of proprietary controls, such as conservation easements that would exclude residential development in the vicinity of the overbank deposits on the three properties. An enforcement tool (Consent Decree) would establish the requirements for the proprietary controls. The proprietary controls would be layered with informational devices implemented by EPA. The grantee of the easements would be an independent third party, preferably a government entity.

Institutional controls are effective and reliable if they are maintained and enforced. With proper maintenance and enforcement, Alternative P-2 can be considered a reliable and permanent remedy.

7.4.2.4 Reduction in Toxicity, Mobility and Volume through Treatment

None of the Panther Creek alternatives involve treatment.

7.4.2.5 Short-Term Effectiveness

This alternative would become effective as soon as institutional controls were put in place. Natural recovery of in-stream sediments would take an uncertain amount of time, but would not hinder the ability of the selected Blackbird Creek and Bucktail Creek alternatives in meeting water quality and sediment PRGs in Panther Creek.

The short-term risks *avoided* in Alternative P-2 include:

- Risk for the surrounding community from increased traffic of heavy trucks and construction equipment;

- Normal construction-related risks for site workers, and
- Risk to the environment resulting from disturbing habitat during construction.

7.4.2.6 Implementability

Implementation would consist of designing and obtaining approval of a monitoring plan and implementing institutional controls. Obtaining acceptance by property owners and the Grantee are the primary implementation difficulties associated with this alternative. The willingness of the private property owners to grant the easements is uncertain. In addition, an independent third party that is willing to accept the grants of easement has not been identified.

7.4.2.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-16 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.4.3 Alternative P-3 - Selective Overbank Deposit Removal; Natural Recovery of In-Stream Sediments.

7.4.3.1 Overall Protection of Human Health and the Environment

Human health would be protected by preventing human exposure to arsenic concentrations above the human health PRG for future residential use via selective removal of overbank deposits.

Institutional controls may also be needed at some of the private properties cleaned up under the Early Actions to preclude unacceptable future exposure if underlying soils with elevated arsenic concentrations are brought to the surface (as a result of erosion or construction activities).

Water quality in Panther Creek is dependent on the alternatives selected for Blackbird and Bucktail Creeks.

Sediments are expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek.

The removal of overbank deposits above the residential arsenic PRG of 100 mg/kg would eliminate the future risks associated with those deposits. Therefore, EPA has determined that Alternative P-3 is protective of human health. The risks to the environment are acceptable under current and future scenarios, therefore EPA has determined that Alternative P-3 is protective of the environment.

7.4.3.2 Compliance with ARARs

This alternative would meet all ARARs.

7.4.3.3 Long-Term Effectiveness and Permanence

As water quality standards in Panther Creek will be achieved by selection of suitable alternatives for Blackbird and Bucktail Creeks, evaluation of long-term effectiveness and permanence for the Panther Creek alternatives is focused on human health.
The magnitude of residual human health risk under current land uses is not above EPA's acceptable risk range. Alternative P-3 provides for removal of all soils above the residential arsenic PRG, such that, if land uses change to residential in the future, this alternative would prevent potential human health risks. Monitoring would be conducted following significant runoff events that might mobilize sediments from Blackbird Creek. Alternative P-3 provides a reliable and permanent remedy.

7.4.3.4 Reduction in Toxicity, Mobility and Volume through Treatment

None of the Panther Creek alternatives involve treatment.

7.4.3.5 Short-Term Effectiveness

Removal would take no more than one construction season, except at the Rogers property, where removal could take more than one season. Natural recovery of in-stream sediments would take an uncertain amount of time, but would not hinder the ability of the selected Blackbird Creek and Bucktail Creek alternatives in meeting water quality and sediment PRGs in Panther Creek.

The short-term risks posed by Alternative P-3 include:

- Risk for the surrounding community from increased traffic of heavy trucks and construction equipment;
- Normal construction-related risks for site workers, and
- Risk to the environment resulting from disturbing habitat during construction.

This alternative could be implemented in one to two construction seasons following completion of the Consent Decree.

7.4.3.6 Implementability

This alternative is feasible both technically and administratively. This alternative could be implemented using standard construction techniques. There could be difficulties associated with obtaining permission to perform overbank deposit removal. In some locations, stream crossing would be required to excavate overbank deposits.

7.4.3.7 Cost

Table 7-14 presents the estimated capital, O&M (net present value), and total (net present value) costs for this alternative. The details of the cost estimates for this alternative are presented in Table E-17 and associated detail tables in Appendix E. The cost estimate for this alternative is based on the description and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.5 Comparative Evaluation of Alternatives

Selection of a remediation alternative (that meets the threshold criteria) is based on comparative evaluation of the alternatives using the five balancing criteria: 1) long-term effectiveness and permanence, 2) reduction in toxicity, mobility, and volume through treatment, 3) short-term effectiveness, 4) implementability, and 5) cost.

7.5.1 Blackbird Creek Alternatives

This section compares the remediation alternatives for Blackbird Creek, the West Fork Tailings Impoundment, and Meadow Creek. A summary of the comparative evaluation of the alternatives is included in Table 7-15.

7.5.1.1 Overall Protection of Human Health and the Environment

This criterion addresses the degree to which each alternative is protective of human health and the environment, considering both long-term and short-term risks. The ability of the alternatives to achieve remedial action objectives is part of the evaluation of this criterion (as well as part of long-term effectiveness). It is important to note that there is uncertainty in the effectiveness of the various alternatives in improving water quality.

Currently, the copper water quality PRG is exceeded most of the time in Blackbird Creek (as measured at BBSW-01A). As shown in Table 7-7, all of the action alternatives (BB-4 through BB-8) would achieve significant reductions in copper concentrations in Blackbird Creek. Alternatives BB-4 and BB-5 are predicted to come close to meeting the copper water quality PRG during low flow periods, but would exceed the PRG consistently during spring runoff. Alternative BB-6 is predicted to meet the copper water quality PRG in Blackbird Creek at BBSW-01A during low flow periods, but would exceed the PRG during spring runoff. Alternatives BB-7 and BB-8 are predicted to meet the copper water quality PRG at BBSW-01A during low flow periods, and could meet the PRG at times during spring runoff.

Currently, the cobalt water quality PRG is exceeded at all times in Blackbird Creek. As shown in Table 7-7, all of the action alternatives would achieve significant reductions in cobalt concentrations in Blackbird Creek. Alternatives BB-7 and BB-8 might be able to occasionally meet the cobalt PRG at BBSW-01A during spring runoff. However, none of the Blackbird Creek action alternatives are predicted to meet the cobalt water quality PRG in Blackbird Creek on a consistent basis.

Currently, the copper water quality PRG is met in Panther Creek during low-flow conditions and is exceeded only during the initial spring flush (i.e., the rising limb of the spring hydrograph). As shown in Table 7-6, all of the alternatives except Alternative BB-1 (No Further Action) would achieve major reductions in copper concentrations in Panther Creek. Alternative BB-4 is predicted to generally meet this PRG, but (considering the spring 2001 data) might not consistently meet this PRG. Alternative BB-5 would meet the copper water quality PRG under most circumstances, but might exceed the PRG at times during spring runoff. The remaining alternatives (BB-6, BB-7 and BB-8) are predicted to consistently meet this PRG based on synoptic data. The uncertainty and variability analysis ("minimum removal columns" of Table 7-10b) suggests that, under the worst-case scenario, Alternatives BB-6, BB-7, and BB-8 have greater certainty of achieving the copper water quality PRG than Alternatives BB-4 and BB-5. Due to the similar copper concentrations predicted in Panther Creek for Alternatives BB-6, BB-7, and BB-8, and because some factors that may affect copper concentrations could not be accounted for in the loading analysis (such as the effect of iron concentrations on copper removals), it is not possible to distinguish among these alternatives within the accuracy of the post-remediation concentration estimates.

Under current "No Further Action" conditions, the water quality PRG for cobalt is already met in Panther Creek during some periods of spring runoff and during the 2001 fall synoptic sampling event. Cobalt concentrations during low-flow conditions historically have exceeded the cobalt water quality PRG, with highest concentrations typically occurring in the early spring prior to significant snowmelt runoff. Improvements in water quality may continue even without additional actions, based on the trends in water quality data. These apparent improvements could be due to continued reductions from various sources (such as the Tailings Impoundment) as a result of the Emergency Actions and the soil cover placed over the tailings. However, these trends could also be the result of variability from year to year, the effects of the Clear Creek Fire, and other factors. All of the alternatives except Alternative BB-1 ("No Further Action") would achieve additional significant reductions in cobalt concentrations in Panther Creek.

Based on the synoptic sampling events (see Table 7-6), the alternatives that rely upon the West Fork Tailings Impoundment cover/cap (Alternatives BB-4 and BB-6) are predicted to achieve the cobalt water quality PRG in Panther Creek consistently during spring runoff periods, and would likely meet the PRG at other times of the year also. During the periods of highest cobalt concentrations (winter and early spring), Alternatives BB-4 and BB-6 are not predicted to consistently meet the cobalt PRG in Panther Creek (see the "Variable Maximum" column on Table 7-10b). The alternatives that rely upon treatment at the Tailings Impoundment (Alternatives BB-5, BB-7, and BB-8) are predicted to achieve the cobalt PRG in Panther Creek based upon the synoptic data (Table 7-6). However, during the periods of highest cobalt concentrations, Alternatives BB-7 and BB-8 are the only alternatives that are predicted to consistently achieve the cobalt PRG in Panther Creek (see the "Variable Maximum" column on Table 7-10b). It should be noted that Alternatives BB-7 and BB-8 are essentially comparable in terms of cobalt water quality predictions; the extensive sediment removals under Alternative BB-8 would provide no discernable benefit to cobalt water quality in Panther Creek.

Sediment quality in Panther Creek would be expected to improve through natural recovery such that sediment PRGs would eventually be achieved in Panther Creek for all of the action alternatives (BB-4 through BB-8). Meeting sediment PRGs in Panther Creek is not as time-critical for improvement of aquatic habitat quality as meeting surface water PRGs. Because most of the current measured concentrations are below known probable toxic levels (see Section 7.2.1.5), benthic communities in Panther Creek should not exhibit high levels of impact due to sediment exposure. Salmonids are not expected to be directly impacted by sediment concentrations, and the food supply for salmonids provided by the benthic community should improve with improving water quality in Panther Creek despite the current exceedances of the sediment PRGs.

None of the alternatives would achieve sediment PRGs within Blackbird Creek, with the exception of Alternative BB-8. However, BB-8 would require extensive sediment removal.

Alternative BB-1 would not prevent direct contact with Blackbird Creek overbank deposits containing arsenic concentrations above the human health PRG. The other alternatives would all prevent direct contact and, by varying means also prevent or minimize sediment transport. Therefore, all of the alternatives except Alternative BB-1 would provide approximately the same protection of human health. The difference among these alternatives is the degree of reliability and permanence they provide. Removal of most of the Blackbird Creek overbank deposits (Alternatives BB-6and BB-7) provides greater reliability and permanence than physical stabilization (Alternatives BB-4 and BB-5). The greatest reliability and permanence would be provided by Alternative BB-8 since all of the Blackbird Creek overbank and in-stream materials would be removed.

Alternative BB-1 would not prevent contact with the contaminated Blackbird Creek overbank deposits and in-stream sediments in the vicinity of the Panther Creek Inn. Alternatives BB-4 through BB-7 would provide for removal of these materials and future monitoring and removals if they become re-contaminated; Alternative BB-8 would provide removal of the overbank and in-stream materials but would not require long-term monitoring or future removals. As long as monitoring is properly conducted and future removals performed as needed, all of the alternatives except BB-1 would provide approximately the same protection of human health in the vicinity of the PCI.

Alternative BB-8 would involve extensive disturbance of ecological habitat over a period of several years. Alternative BB-8 would require excavating, hauling, and disposing of a very large quantity of sediments. A new, large disposal cell would need to be sited, designed, and constructed to receive the excavated materials. The removal and construction activities would create much more risks to the community, site workers and the environment than the other alternatives.

EPA has determined that the combinations of removal and stabilization of overbank materials along Blackbird Creek (and removal of in-stream sediments near the PCI) under all of the action alternatives (BB-4 through BB-8) would provide protection of

human health. The water quality PRGs in Blackbird Creek would not be consistently met under any of the alternatives. Sediment PRGs in Blackbird Creek could not be met by any of the alternatives except BB-8 (complete removal). The Panther Creek sediments would eventually meet PRGs through natural recovery. The copper and cobalt water quality PRGs would be consistently met in Panther Creek only under Alternatives BB-7 and BB-8. EPA has determined that Alternative BB-7 would be protective of the environment for Panther Creek. EPA has also determined that Alternative BB-8 would be protective of the environment for Panther Creek in the long-term. However, this alternative would result in extensive short-term disruption of the stream channel and habitat along Blackbird Creek that would require years to a decade or more for full recovery.

7.5.1.2 Compliance with ARARs

The water quality PRG for copper in Panther Creek, which is based on an ARAR, is not predicted to be consistently met by Alternatives BB-1, BB-4, and BB-5. The copper ARAR could be met during much of the year under these alternatives; however, the ARAR would not be met consistently during spring runoff for a few weeks to a month or more. Alternatives BB-6, BB-7, and BB-8 have essentially the same predicted post-remediation copper concentrations in Panther Creek (within the accuracy of the analysis), both in terms of average and range (see Table 7-10b); all of these alternatives are predicted to consistently meet the copper water quality ARAR in Panther Creek throughout the year.

The mixing zone analysis detailed in Appendix B indicates that Alternatives BB-4 and BB-5 would be similar in terms of mixing zone requirements in Panther Creek. The analysis also indicated that Alternatives BB-6, BB-7, and BB-8 would be similar to each other in terms of mixing zone requirements in Panther Creek, and that they would have smaller mixing zone requirements than Alternatives BB-4 and BB-5. For Alternatives BB-4 and BB-5, the analysis indicated that, under worse case conditions, the copper water quality standard would not be met even with 100% mixing in the spring; in the fall a mixing zone requiring approximately 53% of the width of Panther Creek would be required. For Alternatives BB-4 and BB-5 under average case conditions, the mixing zone requirement would vary from approximately 48% of the width of Panther Creek in the spring to approximately 30% of the width of Panther Creek in the fall. For Alternatives BB-6, BB-7 and BB-8, the analysis indicated that, under worse case conditions, a mixing zone of 62% of the width of Panther Creek would be required in the spring; in the fall a mixing zone requiring approximately 50% of the width of Panther Creek would be required. For Alternatives BB-6, BB-7, and BB-8 under average case conditions, the mixing zone requirement would be approximately 30% of the width of Panther Creek in the spring and in the fall. It should be noted that, due to physical constraints in Panther Creek in the vicinity of the Blackbird Creek confluence, the minimum mixing zone that could be achieved (regardless of alternative) under worse case is 50% of the width of Panther Creek. Under average conditions the minimum width of the mixing zone is 30%.

7.5.1.3 Long-Term Effectiveness and Permanence

Currently, the copper water quality PRG is exceeded most of the time in Blackbird Creek as measured at BBSW-01A. As shown in Table 7-7, all of the action alternatives would achieve significant reductions in copper concentrations in Blackbird Creek. Alternatives BB-4 and BB-5 are predicted to come close to meeting the copper PRG during low flow periods, but would exceed the PRG consistently during spring runoff. Alternatives BB-6 is predicted to meet the copper PRG at BBSW=01A during low flow periods, but would exceed the copper PRG during spring runoff. Alternatives BB-7 and BB-8 are predicted to meet the copper PRG at BBSW-01A during low flow periods, and could meet the copper PRG at times during spring runoff.

Currently, the cobalt water quality PRG is exceeded at all times in Blackbird Creek. As shown in Table 7-7, all of the action alternatives would achieve significant reductions in cobalt concentrations in Blackbird Creek. Alternatives BB-7 and BB-8 might be able to occasionally meet the cobalt PRG at BBSW-01A during spring runoff. However, none of the Blackbird Creek action alternatives are predicted to meet the cobalt water quality PRG in Blackbird Creek on a consistent basis.

Currently, the copper water quality PRG is met in Panther Creek during low-flow conditions and is exceeded only during the initial spring flush (i.e., the rising limb of the spring hydrograph). As shown in Table 7-6, all of the alternatives except Alternative BB-1 ("No Further Action") would achieve major reductions in copper concentrations in Panther Creek. Alternatives BB-4 and BB-5 are predicted to generally meet this PRG, with an average predicted post-remediation concentration of 2 μg/L (Table 7-10). However, considering the spring 2001 data, Alternative BB-4 might not consistently meet this PRG. The variability and uncertainty analysis (Table 7-10) suggest that post-remediation copper concentrations could range from <1 to 7 μg/L for Alternative BB-4, and from <1 to 6 μg/L for Alternative BB-5.

The remaining alternatives (BB-6, BB-7 and BB-8) are predicted to consistently meet the copper water quality PRG based on synoptic data, with an average predicted post-remediation concentration of 2 μg/L for Alternative BB-6 and 1 μg/L for Alternatives BB-7 and BB-8. The variability and uncertainty analysis (Table 7-10) suggest that post-remediation copper concentrations could range from <1 to 4 μg/L for all three alternatives. In other words, the predicted post-remediation concentrations are essentially the same for these three alternatives.

Under current "No Further Action" conditions, the water quality PRG for cobalt is already met in Panther Creek during some periods of spring runoff and during the 2001 fall synoptic sampling event. Cobalt concentrations during low-flow conditions historically have exceeded the cobalt water quality PRG, with highest concentrations typically occurring in the early spring prior to significant snowmelt runoff. Improvements in water quality may continue even without additional actions, based on the trends in water quality data. These apparent improvements could be due to continued reductions from various sources (such as the Tailings Impoundment) as a result of the Emergency Actions and the soil cover placed over the tailings. However,

these trends could also be the result of variability from year to year, the effects of the Clear Creek Fire, and other factors. All of the alternatives except Alternative BB-1 ("No Further Action") would achieve additional significant reductions in cobalt concentrations in Panther Creek.

All of the alternatives except BB-1 are predicted to reduce cobalt concentrations due to the effects of a soil cover over the Tailings Impoundment and collection and treatment of seeps in Meadow Creek. However, there is considerable uncertainty associated with the predicted cobalt values since the reductions in loads depend primarily on the effectiveness of the West Fork Impoundment cover/cap. As noted in Section 7.2.2.1, the predictions are based upon a geochemical model with a large degree of uncertainty concerning the magnitude and timing of cobalt load reductions. Treatment of seepage from the Tailings Impoundment (Alternatives BB-5, BB-7, and BB-8) would provide additional cobalt reduction. There is greater certainty of cobalt reductions through treatment, and the timing of reductions is more assured (within 1 year following construction). Some additional cobalt reduction would be provided by removal of overbank deposits (Alternatives BB-6, BB-7, and BB-8); lesser removal would be expected from physical stabilization (Alternatives BB-4 and BB-5).

Alternative BB-4 has an average predicted post-remediation cobalt concentration of 30 μg/L (Table 7-10b). The uncertainty and variability analysis (Table 7-10b), which considers the full range of effectiveness estimates and a full range of cobalt concentrations detected during 2000 and 2001, predicts a range of post-remediation cobalt concentrations from 3 to 61 μg/L for Alternative BB-4.

Alternative BB-5 has an average predicted post-remediation cobalt concentration of 24 μg/L (Table 7-10b). The uncertainty and variability analysis (Table 7-10b), which considers the full range of effectiveness estimates and a full range of cobalt concentrations detected during 2000 and 2001, predicts a range of post-remediation cobalt concentrations from 2 to 52 μg/L for Alternative BB-5. Alternative BB-6 has an average predicted post-remediation cobalt concentration of 25 μg/L (Table 7-10b). The uncertainty and variability analysis (Table 7-10b), which considers the full range of effectiveness estimates and a full range of cobalt concentrations detected during 2000 and 2001, predicts a range of post-remediation cobalt concentrations from 2 to 55 μg/L for Alternative BB-6.

Alternative BB-7 has an average predicted post-remediation cobalt concentration of 19 μg/L (Table 7-10b). The uncertainty and variability analysis (Table 7-10b), which considers the full range of effectiveness estimates and a full range of cobalt concentrations detected during 2000 and 2001, predicts a range of post-remediation cobalt concentrations from 1 to 46 μg/L for Alternative BB-7.

Alternative BB-8 has an average predicted post-remediation cobalt concentration of 18 μg/L (Table 7-10b). The uncertainty and variability analysis (Table 7-10b), which considers the full range of effectiveness estimates and a full range of cobalt concentrations detected during 2000 and 2001, predicts a range of post-remediation cobalt concentrations from 1 to 44 μg/L for Alternative BB-8.

Alternative BB-1 would not prevent direct contact with overbank deposits containing arsenic concentrations above the human health PRG. The other alternatives all prevent direct contact and, by varying means also prevent or minimize sediment transport. Therefore, all of the alternatives except Alternative BB-1 would provide approximately the same protection of human health.

Alternative BB-1 would not prevent contact with the contaminated Blackbird Creek overbank deposits and in-stream sediments in the vicinity of the Panther Creek Inn. Alternatives BB-4 through BB-7 would provide for removal of these materials and would therefore be essentially comparable in terms of long-term effectiveness, as long as monitoring was properly performed and future removals were conducted if the overbank materials or in-stream sediments became re-contaminated at arsenic concentrations above the PRGs. Alternative BB-8 would provide the greatest reliability and permanence because it would not require long-term monitoring or future removals of the materials in the vicinity of the PCI.

The long-term residual risks for all of the alternatives are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and arsenic from the mine area, and human health risks of the overbank deposits along Blackbird Creek (and in-stream sediments in the vicinity of the PCI). Alternative BB-1 would address the risks of releases from the mine area through continued operation and maintenance of the Early Action facilities; however, Alternative BB-1 would not address the other identified risks. The cobalt releases from the West Fork Impoundment would rely upon the cover/cap under Alternatives BB-4 and BB-6. The cover/cap may not be as effective as anticipated at reducing cobalt loads, and the timing of the cobalt reductions (if they occur) is uncertain and may require years to a decade or more to be fully realized. The cobalt releases from the West Fork Impoundment would be addressed primarily through collection and treatment under Alternatives BB-5, BB-7, and BB-8. Treatment of cobalt has been proven to be reliable and effective at this site, and the treatment would reduce the cobalt loads within a reasonable and assured time frame (within 1 year of construction). The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm; continued operation and maintenance of the Early Action facilities would address the risk of releases from the mine area. The risks associated with the overbank deposits along Blackbird Creek would be addressed through a combination of removal and armoring of overbank deposits, which would protect these deposits from significant re-mobilization during storm events up to the 500-year design storm. In-stream sediments near the PCI would be addressed through removal. The difference among these alternatives is the degree of reliability and permanence they provide. Removal with selective stabilization (Alternatives BB-6 and BB-7) provides greater reliability and permanence than physical stabilization (Alternatives BB-4 and BB-5). Complete removal (Alternative BB-8) would provide the greatest reliability and permanence.

With proper long-term operation, monitoring, and maintenance of the Early Actions, Meadow Creek Seep Collection, Blackbird Creek armoring, PCI removals, and assuming long-term effectiveness of the Tailings Impoundment cover/cap, Alternatives BB-4 and

BB-6 could provide a reliable and permanent remedy; however the reliability of the cover/cap at reducing cobalt loads is uncertain. With proper long-term operation, monitoring, and maintenance of the Early Actions, Meadow Creek Seep Collection, Blackbird Creek armoring, PCI removals, and Tailings Impoundment seep collection/treatment system, Alternatives BB-5 and BB-7 would provide a reliable and permanent remedy. Alternative BB-8 would provide the most reliable and permanent remedy because of the complete removal of the Blackbird Creek sediments.

7.5.1.4 Reduction in Toxicity, Mobility and Volume through Treatment

All of the alternatives include treatment via the existing WTP. Alternative BB-1 involves continued operation of the existing WTP at existing flow rates. Alternatives BB-4 and BB-6 add treatment of additional seepage to be collected from Meadow Creek. Alternatives BB-5, BB-7, and BB-8 provide treatment of both Meadow Creek seepage and Tailings Impoundment seepage.

For overbank deposits, physical stabilization (Alternatives BB-4 and BB-5) and removal (Alternatives BB-6, BB-7, and BB-8) would reduce the mobility of overbank deposits, albeit not using treatment. Removal would likely provide more reduction in metals loading from overbank deposits than physical stabilization.

7.5.1.5 Short-Term Effectiveness

Alternative BB-1, requiring no further action, would be the quickest to implement and would not create short-term risks.

Physical stabilization (Alternatives BB-4 and BB-5) and removal (Alternatives BB-6 and BB-7) of overbank deposits would have similar short-term effectiveness. These four alternatives involve similar short-term risks to the community and site workers due to construction activities. These four alternatives would also involve approximately the same degree of short-term disturbance of ecological habitat. All of these alternatives could be constructed within 1 to 2 construction seasons.

For all of the alternatives except Alternative BB-1, the water quality improvements for most of the remedial action components would be realized quickly following completion of construction. For Alternatives BB-4 and BB-6, decreases in cobalt and copper concentrations due to reduced infiltration and oxidation in the Tailings Impoundment (resulting from the soil cover) would be expected to occur over time. The magnitude and timing of these reductions is uncertain, and full effect could occur over a period of years or a decade or more. For Alternatives, BB-5, BB-7, BB-8, most of the benefits of remedial action, including water quality improvements due to treatment of Tailings Impoundment seepage, would be realized relatively quickly following completion of construction (within a year).

Alternative BB-8 has very poor short-term effectiveness. Although backfilling and revegetation would be included, it would involve extensive disturbance of ecological habitat over a construction period of several years. The re-establishment of a stable

stream channel and riparian vegetation following construction may require a decade of more. Alternative BB-8 would require excavating, hauling, and disposing of a very large quantity of sediments. A new, large disposal cell would need to be created for disposal of the excavated materials. The removal and construction activities would create much more short-term risk to the community, site workers and the environment than the other alternatives. Alternative BB-8 would take the longest time to implement (likely 3 years or more).

7.5.1.6 Implementability

Alternative BB-1, requiring no further action, would be the easiest to implement.

Physical stabilization of Blackbird Creek overbank deposits (Alternatives BB-4 and BB-5) would be somewhat more difficult to design and construct than removal of these deposits (Alternatives BB-6 and BB-7). This is due to the need to locate suitably sized armoring materials to handle the 500-year design storm.

Collecting and treating seepage from the Tailings Impoundment (Alternatives BB-5, BB-7, and BB-8) would be more difficult than implementing the soil cover (Alternatives BB-4 and BB-7). There is not expected to be any difference between the alternatives in the administrative implementability of instituting institutional controls on property managed by the USFS along Blackbird Creek.

Alternative BB-8 has very poor implementability relative to the other alternatives. During removal, Blackbird Creek would require diversion to allow access to the in-stream sediments. In addition, as excavation would extend below the water table, dewatering of excavation areas would be required. Extensive controls would have to be put in place to control sediment, which would be complicated by the fact that work would have to be conducted over several construction seasons. Siting, constructing, and long-term maintenance and monitoring of a new large disposal cell would be required.

7.5.1.7 Cost

The estimated costs for the alternatives are summarized in Table 7-14. Detailed cost estimates are presented in Appendix E. These estimates include capital, O&M (net present value), and total (net present value) costs. The cost estimates for the alternatives are based on the descriptions and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.5.1.8 Summary

7.5.1.8.1 Overall Protection of Human Health and the Environment

Alternative BB-1 (the No-Further Action alternative) would not prevent direct contact with Blackbird Creek overbank deposits containing arsenic concentrations above the human health PRG and would therefore not be protective of human health. The other action alternatives (BB-4 through BB-8) would all prevent direct contact with the

Blackbird Creek overbank deposits and the in-stream sediments near the PCI through removal and/or armoring. In addition, the action alternatives would, through combinations of removal and stabilization (armoring), control remobilization of overbank materials along Blackbird Creek to prevent deposition downstream along Panther Creek at concentrations exceeding the arsenic PRGs. Thus, EPA has determined that all of the action alternatives (BB-4 through BB-8) would be protective of human health.

The water quality PRGs in Blackbird Creek would not be consistently met under any of the alternatives. Sediment PRGs in Blackbird Creek could not be met by any of the alternatives except BB-8 (complete removal). However, Alternative BB-8 would result in extensive disruption of the stream channel and habitat along Blackbird Creek that would require years to a decade or more for full recovery. The Panther Creek sediments would eventually meet PRGs through natural recovery. Alternatives BB-4 and BB-5 would not consistently meet the copper and cobalt water quality PRGs in Panther Creek. Alternative BB-6 could consistently meet the copper water quality PRG in Panther Creek. However, there is considerable uncertainty concerning whether Alternative BB-6 can meet the cobalt PRG in Panther Creek, or (if it can be met) whether it can be met in a timely manner. The copper and cobalt water quality PRGs would be consistently met in Panther Creek in a timely manner only under Alternatives BB-7 and BB-8. EPA has therefore determined that Alternative BB-7 and BB-8 would be protective of the environment in Panther Creek.

7.5.1.8.2 Compliance with ARARs

The copper water quality ARAR for Panther Creek would not be consistently met by Alternatives BB-1, BB-4, and BB-5, especially during spring runoff. Alternatives BB-6, BB-7, and BB-8 are predicted to consistently meet the copper water quality ARAR in Panther Creek throughout the year. Other ARARs would be met by all alternatives

Alternatives BB-6, BB-7, and BB-8 would have smaller mixing zone requirements than Alternatives BB-4 and BB-5. The mixing zone requirements for Alternatives BB-6, BB-7 and BB-8 would vary from approximately 30% to 62% of the width of Panther Creek, depending on conditions. The minimum mixing zone requirement for Alternatives BB-4 and BB-5 would be a approximately 30% of the width of Panther Creek; however, under worse case conditions, the copper water quality standard would not be met even using 100% of the width of Panther Creek.

7.5.1.8.3 Long-term Effectiveness and Permanence

None of the alternatives would be effective in the long term at consistently meeting the copper PRG in Blackbird Creek as measured at BBSW-01A (near the confluence with Panther Creek). Alternatives BB-4 and BB-5 are predicted to come close to meeting the copper PRG at this location during low flow periods, but would exceed the PRG consistently during spring runoff. Alternative BB-6 is predicted to meet the copper PRG in Blackbird Creek during low flow periods, but would exceed the copper PRG during spring runoff. Alternatives BB-7 and BB-8 are predicted to meet the copper PRG at

BBSW-01A during low flow periods, but would not consistently meet the copper PRG during spring runoff.

Currently, the cobalt water quality PRG is exceeded at all times in Blackbird Creek. All of the action alternatives would achieve significant reductions in cobalt concentrations in Blackbird Creek; however none of the alternatives would be effective at meeting the cobalt water quality PRG in Blackbird Creek on a consistent basis.

Alternative BB-1 (No Further Action) would not make any improvements to water quality, and is therefore ranked lowest for long-term effectiveness. The alternatives that primarily utilize stabilization to address Blackbird Creek overbank deposits (Alternatives BB-4 and BB-5) are predicted to meet the copper water quality PRG in Panther Creek most of the year, but would not likely be effective at meeting the PRG at times during spring runoff. Therefore, Alternatives BB-4 and BB-5 are rated next lowest for long term effectiveness. The alternatives that primarily utilize removal to address Blackbird Creek overbank deposits (Alternatives BB-6, BB-7, and BB-8) are rated higher for effectiveness because they have greater certainty of achieving the copper water quality PRG in Panther Creek on a consistent basis. Alternatives BB-6, BB-7, and BB-8 are essentially comparable in terms of copper water quality predictions in Panther Creek; the extensive sediment removals under Alternative BB-8 would provide no discernable benefit to copper water quality in Panther Creek.

All of the alternatives except Alternative BB-1 (No Further Action) would achieve significant reductions in cobalt concentrations in Panther Creek. Therefore Alternative BB-1 is rated lowest for long-term effectiveness at reducing cobalt concentrations. The alternatives that rely upon the West Fork Tailings Impoundment cover/cap (Alternatives BB-4 and BB-6) are predicted to achieve the cobalt water quality PRG in Panther Creek consistently during spring runoff periods, and would likely meet the PRG at some other times of the year also. However, during the periods of highest cobalt concentrations (winter and early spring), Alternatives BB-4 and BB-6 are not predicted to be effective at consistently meet the cobalt PRG in Panther Creek. The alternatives that rely upon treatment at the Tailings Impoundment (Alternatives BB-5, BB-7, and BB-8) are rated higher for effectiveness because they are predicted to have greater certainty of achieving the cobalt PRG in Panther Creek. However, during the periods of highest cobalt concentrations, Alternative BB-5 may not consistently achieve the cobalt PRG. Alternatives BB-7 and BB-8 are the most effective because they are the only alternatives that are predicted to consistently achieve the cobalt PRG in Panther Creek. Alternatives BB-7 and BB-8 are essentially comparable in terms of cobalt water quality predictions; the extensive sediment removals under Alternative BB-8 would provide no discernable benefit to cobalt water quality in Panther Creek.

Sediments are expected to improve through natural recovery under all of the alternatives such that PRGs would eventually be achieved in Panther Creek. Only Alternative BB-8 is predicted to meet sediment PRGs in Blackbird Creek.

The long-term residual risks for all of the alternatives are associated primarily with continued cobalt releases from the West Fork Impoundment, releases of metals and

arsenic from the mine area, and human health risks of the overbank deposits (and in-stream sediments near the PCI) along Blackbird Creek. All of the alternatives would reliably address the releases of metals and arsenic from the mine area through continued operation and maintenance of the Early Actions. In terms of reliability of addressing the other residual risks, Alternative BB-8 is rated highest because it primarily utilizes treatment to address the cobalt releases (which has greater certainty of effectiveness) and would eliminate the risks to downstream overbank deposits and in-stream sediments through complete removal. Alternative BB-7 is rated next highest since it utilizes treatment to address the cobalt releases and would address the risks to downstream overbank deposits and in-stream sediments primarily through removal (which is more reliable and permanent than armoring). Alternatives BB-5 and BB-6 are rated comparable in terms of residual risks: Alternative BB-5 includes treatment for the cobalt releases but would utilize primarily armoring to address the risks to downstream overbank deposits and in-stream sediments; Alternative BB-6 would utilize primarily removal to address the risks to downstream overbank deposits and in-stream sediments, but would utilize the cover/cap to address the cobalt releases (which is judged less reliable than treatment). Alternative BB-4 is rated lowest in terms of residual risks because it would utilize the cap/cover to address arsenic releases and primarily armoring to address the risks to downstream overbank deposits and in-stream sediments.

All of the alternatives are judged to be comparable in terms of permanence. All of the alternatives depend on proper operation and maintenance of the facilities that would be constructed plus proper operation and maintenance of the already completed Early Actions. As long as the operation and maintenance is properly performed in the future, all of the facilities are considered permanent.

7.5.1.8.4 Reduction of Toxicity, Mobility, and Volume through Treatment

All of the alternatives include treatment via the existing Water Treatment Plant. Alternative BB-1 involves continued operation of the existing WTP at existing flow rates. Alternatives BB-4 and BB-6 add treatment of additional seepage to be collected from Meadow Creek. Alternatives BB-5, BB-7, and BB-8 provide treatment of both Meadow Creek seepage and Tailings Impoundment seepage.

7.5.1.8.5 Short-term Effectiveness

Alternative BB-1 is rated highest for short-term effectiveness because it would not result in risks to workers or the community, would have no short-term environmental impacts associated with remedial actions, and would be implemented on signing of a Consent Decree. Alternatives BB-4, BB-5, BB-6, and BB-7 are essentially comparable in terms of risks to the community and workers during construction and short-term environmental risks. The construction activities for both removal and stabilization of the Blackbird Creek overbank deposits are similar in terms or risks to the community and workers. In addition, the short-term disruption of the environment is similar for both removal and stabilization. Each of these four alternatives could be completed within 1 to 2 years. Of these four alternatives, those that involve treatment to address cobalt (BB-5 and BB-7) would improve water quality much more rapidly than the alternatives that rely upon the

cover/cap for cobalt reductions (BB-4 and BB-6). Alternatives BB-5 and BB-7 would see the cobalt water quality improvements within a year after completing construction; whereas Alternatives BB-4 and BB-6 may require years to a decade or more before the full cobalt water quality effects would be seen. Alternative BB-8 is rated lowest in terms of short-term effectiveness. This alternative would involve extensive disturbance of ecological habitat over a construction period of several years. The re-establishment of a stable stream channel and riparian vegetation following construction may require a decade of more. Alternative BB-8 would require excavating, hauling, and disposing of a very large quantity of sediments. The removal and construction activities would create more short-term risk to the community, site workers and the environment than the other alternatives. Alternative BB-8 would also take the longest time to implement (likely 3 years or more).

7.5.1.8.6 Implementability

Alternative BB-1 is rated highest for technical implementability since no further actions would be required. Alternative BB-6 is rated next highest for technical implementability, since this alternative would utilize standard construction techniques for the overbank removals and would not involve design and construction of collection and treatment facilities. Alternative BB-4 is rated next highest: it would not involve collection and treatment at the West Fork Impoundment; however there may be difficulties locating sufficiently sized armoring materials to handle the 500-year design storm. Alternative BB-7 is rated next highest for technical implementability because this alternative would utilize standard construction techniques for the overbank removals. However, collecting and treating seepage from the Tailings Impoundment would be more difficult than implementing the cover/cap. Alternative BB-5 is next highest because it would have the difficulties associated with seepage collection and treatment at the Impoundment, and would require locating sufficiently sized armoring materials to protect the Blackbird Creek overbank materials. Alternative BB-8 is rated lowest for technical implementability. It would experience the difficulties associated with collection and treatment at the West Fork Impoundment. During removal, Blackbird Creek would require diversion to allow access to the in-stream sediments. In addition, as excavation would extend below the water table, dewatering of excavation areas would be required. Under Alternative BB-8, extensive controls would have to be put in place to control sediment, which would be complicated by the fact that work would have to be conducted over several construction seasons. Alternative BB-8 would require siting, constructing, and long-term maintenance and monitoring of a new large disposal cell.

There is not expected to be any difference among the alternatives in terms of administrative implementability of institutional controls on property managed by the USFS along Blackbird Creek.

7.5.1.8.7 Cost

Figure 7-5 compares the cost-effectiveness of the Blackbird alternatives relative to meeting water quality PRGs in Panther Creek at PASW-09. Error bars on this figure are based on the minimum and maximum values from the uncertainty/variability analysis

(see Section 7.2.1.3). Of the alternatives that can consistently meet the copper water quality PRG in Panther Creek, the best incremental cost-effectiveness is provided by Alternative BB-6. However, there is considerable uncertainty concerning whether Alternative BB-6 can meet the cobalt PRG in Panther Creek in a timely manner. Of the alternatives that can meet both the copper and cobalt water quality PRGs in Panther Creek with certainty and in a timely manner, Alternative BB-7 has the best incremental cost-effectiveness. Alternative BB-8 could meet the copper and cobalt water quality PRGs in Panther Creek with certainty and in a timely manner. In addition, it could meet the sediment PRGs in Blackbird Creek. However, Alternative BB-8 would not be able to consistently meet the water quality PRGs in Blackbird Creek, and would therefore not be protective of the environment in Blackbird Creek. Alternative BB-8 would not provide any substantial improvements to water quality in Panther Creek compared to Alternative BB-7. Therefore, the substantial difference in costs associated with Alternative BB-8 would not be justified, especially considering the extensive short-term environmental impacts and the considerable implementability issues associated with Alternative BB-8.

7.5.2 Bucktail Creek Alternatives

This section compares the remediation alternatives for Bucktail Creek, South Fork Big Deer Creek, and Big Deer Creek. The comparative evaluation of the Bucktail Creek alternatives is summarized in Table 7-16.

7.5.2.1 Overall Protection of Human Health and the Environment

There are no unacceptable risks to human health as a result of the mine-generated materials in the Bucktail Creek drainage under existing and anticipated future conditions. Thus EPA has determined that all of the Bucktail alternatives are protective of human health.

Water quality in Bucktail, South Fork Big Deer, and Big Deer Creeks has been improving steadily since completion of Early Actions. Additional improvements are possible without further actions; however, it is unlikely that these improvements would result in achieving water quality PRGs within the foreseeable future. Existing groundwater seeps into Bucktail Creek downgradient from the 7000 dam would prevent achieving water quality PRGs, likely for centuries. As shown in Tables 7-11b and 7-12, all of the Bucktail alternatives except BT-1 (No Further Action) are predicted to achieve water quality PRGs in Big Deer Creek. Thus, there would be no difference among the Bucktail action alternatives (BT-3 through BT-6) in long-term water quality in Big Deer Creek and Panther Creek. The sediments in Bucktail Creek are currently acting as a sink for metals. With improvement to water quality, the sediments could become a source of metals loading, which could persist for years to a decade or more. However, the amount and duration of any potential metals release in the future is not possible to predict with accuracy. If post-remediation monitoring indicates that the sediments will continue to impact downstream water quality for an unacceptable period, alternatives for contingencies to address water quality would be evaluated.

The removal of the groundwater loads from Bucktail Creek would not be sufficient to achieve copper or cobalt water quality PRGs in South Fork Big Deer Creek under Alternatives BT-1, BT-3, BT-4, or BT-6.

By removing the Bucktail Creek surface water discharge from South Fork Big Deer Creek, Alternative BT-5 would likely achieve the copper and cobalt water quality PRGs in South Fork Big Deer Creek. However, it is possible that groundwater discharges into South Fork Big Deer Creek associated with the Bucktail Creek drainage could prevent consistently meeting water quality PRGs even with the Bucktail Creek bypass. If this is the case, a contingency for a groundwater collection system would be evaluated for intercepting the groundwater discharges to South Fork Big Deer Creek.

It is not possible to accurately predict when the water quality PRGs would be met in the South Fork Big Deer Creek because sediments would release dissolved copper until no more copper can be solubilized. However, this would be a short-term effect, likely less than 5 years.

There are no sediment PRGs for Bucktail Creek. Under Alternatives BT-3 and BT-5, sediment quality would improve through natural recovery such that sediment PRGs would eventually be achieved in South Fork Big Deer and Panther Creeks. Because the Bucktail Creek waters would be removed from the South Fork Big Deer Creek under Alternative BT-5, it is anticipated that the sediment PRGs in South Fork Big Deer Creek would be achieved more rapidly than under Alternative BT-3.

Removal of sediments from South Fork Big Deer Creek (Alternative BT-4) might speed recovery of water quality in South Fork and Big Deer Creeks; however, given the small quantity of South Fork sediments relative to Bucktail Creek, it is likely that any benefits would be minor. It is also possible that removing these sediments would not result in a measurable difference in copper concentrations in South Fork Big Deer Creek. In addition, there would be the potential for recontamination if Bucktail Creek sediments were remobilized during high flows.

Complete sediment removal (Alternative BT-6) would result in achieving sediment PRGs in South Fork Big Deer and Big Deer Creeks upon completion of removal. However, this alternative would cause significant disturbance of riparian habitat and the existing stream channels. This disturbance would have a negative short-term effect that would last for years to a decade or more. In addition, removal would result in greater short-term risks to workers during the excavation and transportation of removed sediments. Sediment removal only in South Fork Big Deer Creek (Alternative BT-4) would have the same negative effects, but the degree would be less because of the smaller extent of sediment removal.

EPA has determined that Alternatives BT-3, BT-4, and BT-6 would be protective of the environment for Big Deer Creek. However, since water quality PRGs would continue to be exceeded in South Fork Big Deer Creek, these alternatives would not be protective of the environment for South Fork Big Deer Creek. Alternative BT-5 is the only alternative

that would be protective of the environment for South Fork Big Deer Creek and for Big Deer Creek.

7.5.2.2 Compliance with ARARS

All of the Bucktail alternatives except BT-1 (No Further Action) are predicted to achieve the water quality PRG for copper, which is based on an ARAR, in Big Deer Creek and in Panther Creek (when combined with an appropriate Blackbird alternative). There would be no difference among the Bucktail action alternatives in long-term water quality in Big Deer Creek. Alternative BT-5 is the only alternative that could achieve ARARs in South Fork Big Deer Creek. Other ARARs described in Section 3.1 and Table 3-1a and 3-1b would be met by all alternatives.

7.5.2.3 Long-Term Effectiveness and Permanence

Water quality in Bucktail, South Fork Big Deer, and Big Deer Creeks has been improving steadily since completion of Early Actions. Additional improvements are possible without further actions; however, it is unlikely that these improvements would result in achieving water quality PRGs within the foreseeable future. Groundwater seeps into Bucktail Creek are likely to prevent achieving water quality PRGs for an extended period of time, likely for centuries. As shown in Tables 7-11b and 7-12, all of the Bucktail alternatives except BT-1 (No Further Action) are predicted to achieve water quality PRGs in Big Deer Creek. Thus, there would be no difference among the Bucktail action alternatives in long-term water quality in Big Deer Creek.

By removing the Bucktail Creek surface water discharge from South Fork Big Deer Creek, Alternative BT-5 also would likely achieve the copper and cobalt water quality PRGs in South Fork Big Deer Creek. However, it is possible that groundwater discharges into South Fork Big Deer Creek could prevent consistently meeting water quality PRGs even with the Bucktail Creek bypass. If this is the case, a contingency for a groundwater collection system would be evaluated for intercepting the groundwater discharges to South Fork Big Deer Creek.

The mixing zone analysis (see Appendix B) indicated that all of the action alternatives (BT-3 through BT-6) would be essentially comparable in terms of mixing zone requirements in Big Deer Creek. The analysis indicated that, under worse case conditions, the copper water quality standard would not be met in Big Deer Creek for any of the action alternatives, even with 100% mixing in both the spring and fall. Under average case conditions, the entire width (100%) of Big Deer Creek would be required for mixing. However, the copper water quality predictions were based on the conservative assumption that 65% of the copper loads discharging to Bucktail Creek would be collected and treated. If 80% copper load removal is assumed, the mixing zone requirement for all of the action alternatives would be 100% of the width of Big Deer Creek under worse case conditions for both spring and fall. Under the average case conditions, 70% of the width of Big Deer Creek would be required for mixing in both spring and fall. It should be noted that 70% of the width of Big Deer Creek is the minimum mixing zone that could be achieved, regardless of alternative and upstream

copper load reductions. This is due to physical constraints in the vicinity of the confluence of South Fork and Big Deer Creeks.

There are no sediment PRGs for Bucktail Creek. For all of the Bucktail alternatives except BT-6, sediment quality would improve through natural recovery such that sediment PRGs would eventually be achieved in South Fork Big Deer and Big Deer Creeks. Except for Alternative BT-6, Bucktail Creek sediments, which are currently a sink, could release metals in the future. However, sediment releases would be a short-term effect (see discussion of short-term effectiveness).

Alternative BT-6 would be more reliable in removing sediments as a source of water quality problems, but would require extensive sediment removal relative to potential benefit. Therefore, Alternative BT-6 does not have any better long-term effectiveness than the Alternatives BT-3, BT-4, or BT-5. Similarly, Alternative BT-4 does not have any better long-term effectiveness than Alternatives BT-3 or BT-5.

In the long term, Alternatives BT-1, BT-3, BT-4, and BT-5 would be essentially comparable in terms of magnitude of residual risks. The risks of release of contaminants from the mine area were controlled by the Early Actions for storm events up to the 500-year design storm. There would be a slight risk that sediments in Bucktail Creek could be re-mobilized during a large storm event and deposited in downstream areas. However, this risk would be minimized as long as the lower Bucktail sediment dam remains in place. Alternative BT-6 ranks slightly higher than the other alternatives in terms of magnitude of residual risks since the Bucktail sediments would be removed under this alternative.

All of the action alternatives would require long-term operation and maintenance to assure permanence. The reliability of these alternatives would depend upon long-term maintenance of the facilities that would be included under each alternative, monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of these facilities is properly performed, any of the Bucktail action alternatives (BT-3, BT-4, BT-5, and BT-6) would provide a reliable and permanent remedy.

7.5.2.4 Reduction in Toxicity, Mobility and Volume through Treatment

Alternative BT-1 would not provide reduction in toxicity, mobility, and volume through treatment. The remaining alternatives (BT-3, BT-4, BT-5, and BT-6) all include treatment of affected seepage, and rank the same under this criterion. BT-4 and BT-6 include sediment removal, but the sediments would not be treated.

7.5.2.5 Short-Term Effectiveness

The time for Alternative BT-1 to become effective would depend on the time required for natural recovery of water quality, which is unknown (but is likely to be centuries). This alternative would not create short-term risk to the community or site workers. The remaining Bucktail alternatives are predicted to achieve water quality PRGs in Big Deer

Creek through the collection of Bucktail Creek groundwater. The sediments in Bucktail Creek are currently acting as a sink for metals. With improvement to water quality, the sediments could become a source of metals loading, which could persist for years to a decade or more. However, the amount and duration of any potential metals release in the future is not possible to predict with accuracy. If post-remediation monitoring indicates that the sediments will continue to impact downstream water quality for an unacceptable period, alternatives for contingencies to address water quality would be evaluated.

Alternative BT-5 would likely achieve water quality PRGs in South Fork Big Deer Creek quickly (within 1 to 2 years following the diversion of Bucktail Creek to discharge directly into Big Deer Creek).

Removal of sediments from South Fork Big Deer Creek (Alternative BT-4) might speed recovery of water quality in South Fork and Big Deer Creeks; however, given the small quantity of South Fork sediments relative to Bucktail Creek, it is likely that any benefits would be minor. In addition, erosion of Bucktail Creek sediments could cause recontamination of South Fork Big Deer Creek. Based on the apparent downward trend in copper loading from South Fork Big Deer Creek, there might be no reduction in dissolved copper concentrations by removing these sediments.

Complete sediment removal (Alternative BT-6) would cause major disturbance of riparian habitat and the existing stream channels. This disturbance would have a large negative short-term effect. In addition, removal would result in short-term risks to workers due to normal construction risks during the excavation and transportation of removed sediments. Sediment removal only in South Fork Big Deer Creek (Alternative BT-4) would have the same negative effects, but the degree would be less because of the smaller extent of sediment removal.

Seepage collection on Bucktail Creek (all alternatives except BT-1) would create short-term risks for site workers typical of construction activity. Alternative BT-5 would have greater short-term worker risk than Alternative BT-3 because it includes installing a diversion pipeline along South Fork Big Deer Creek. Alternative BT-4 would have greater short-term worker risk than Alternative BT-5 because sediment removal would involve more construction activities.

Alternative BT-6 involves greater worker risk because of the additional sediment removal activity. Based on ecological effects and short-term worker risks, Alternative BT-3 has the greater short-term effectiveness than Alternative BT-6. Alternative BT-6 has significant negative short-term impacts, and therefore ranks much lower than the other alternatives for this criterion.

7.5.2.6 Implementability

Alternative BT-1 would be the easiest to implement since it requires no further action except monitoring. Seep collection construction and operation would make the remaining alternatives more difficult to implement than Alternative BT-1.

Alternative BT-5 would be more difficult to implement than Alternative BT-3 because it includes installation of a diversion pipeline along South Fork Big Deer Creek. Alternative BT-4 would be more difficult to implement than Alternative BT-5 because South Fork sediment removal would be more difficult than installing a diversion pipeline. Alternative BT-6 would be much more difficult to implement then the other Bucktail alternatives because of the extensive sediment removal that would be required. In addition, Alternative BT-6 would require siting, design, construction, and maintenance of a large on-site repository. It may also be difficult to obtain approvals to construct an access road along Big Deer Creek through an area that is currently road less.

There is not expected to be any difference among the alternatives in the administrative implementability of instituting institutional controls on property managed by the USFS along Bucktail, South Fork Big Deer, or Big Deer Creeks.

7.5.2.7 Cost

The estimated costs for the alternatives are summarized in Table 7-14. Detailed cost estimates are presented in Appendix E. These estimates include capital, O&M (net present value), and total (net present value) costs. The cost estimates for the alternatives are based on the descriptions and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.5.2.8 Summary

7.5.2.8.1 Overall Protection of Human Health and the Environment

There would be no difference among the alternatives in terms of human health. EPA has determined that all of the alternatives (including BT-1, No Further Action) would be protective of human health.

EPA has determined that Alternative BT-5 is the only alternative that would be protective of the environment for both South Fork Big Deer and Big Deer Creeks. It is the only alternative that is predicted to meet water quality and sediment PRGs in South Fork Big Deer and Big Deer Creeks within a reasonable time frame. Alternative BT-3 would be protective of the environment in Big Deer Creek, since the water quality and sediment PRGs would be met in a reasonable time frame. However, Alternative BT-3 would not be protective of the environment in South Fork Big Deer Creek because water quality PRGs would not be achieved within a reasonable time frame (likely not for centuries). Alternative BT-4 and BT-6 would be protective of the environment in Big Deer Creek, since the water quality and sediment PRGs would be met in a reasonable time frame. The sediment removals for these alternatives would reduce the time to achieve sediment PRGs, however they would cause considerable short-term disruption of the stream channels and riparian habitat. Neither Alternative BT-4 nor BT-6 would be protective of the environment in South Fork Big Deer Creek since water quality PRGs would not be achieved within a reasonable time frame. Alternative BT-1 would not be

protective of the environment since water quality PRGs would not be achieved for centuries.

7.5.2.8.2 Compliance with ARARs

Alternative BT-5 is the only alternative that can meet all ARARs, including the copper ARAR in South Fork Big Deer Creek. All of the other action alternatives (BT-3, BT-4, and BT-6) could meet all ARARs except for the copper ARAR in South Fork Big Deer Creek. The No-Further Action alternative would not meet the copper ARAR in either South Fork Big Deer or Big Deer Creeks.

7.5.2.8.3 Long-term Effectiveness and Permanence

Alternative BT-5 is judged to have the best long-term effectiveness because it can meet the water quality and sediment PRGs in South Fork Big Deer and Big Deer Creeks. All of the other action alternatives (BT-3, BT-4, and BT-6) would be essentially equivalent in terms of long-term effectiveness. They would all achieve water quality and sediment PRGs, except for South Fork Big Deer Creek water quality PRGs (which would not be met for centuries). The primary difference among the other action alternatives is in terms of time to achieve the PRGs. Alternative BT-6 would achieve water quality PRGs in Big Deer Creek and sediment PRGs in South Fork Big Deer and Big Deer Creeks within 1 to 2 years after completion of remedial activities. Alternative BT-4 would require years to a decade or more to achieve water quality and sediment PRGs in Big Deer Creek. Alternative BT-4 would meet sediment PRGs in South Fork Big Deer Creek upon completion of remedial actions. Alternative BT-3 would require years to a decade or more to achieve water quality and sediment PRGs in Big Deer Creek and sediment PRGs in South Fork Big Deer Creek.

All of the action alternatives are essentially comparable in terms of mixing zone requirements in Big Deer Creek. Under worse case conditions, all of the alternatives require 100% of the width of Big Deer Creek for mixing, and may not even achieve the copper water quality standard at times even with 100% width for mixing. Under average conditions, the mixing zone requirements vary from 70% to 100% of the width of Big Deer Creek.

Most of the residual risks at the site were controlled through the Early Actions, which minimize risks of releases for storm events up to the 500-year design storm. Alternative BT-6 is judged to have the lowest level of residual risks because the sediments would be removed, eliminating the risk of re-mobilization and downstream deposition during large storm events. The other alternatives would have essentially the same risk of re-mobilization of Bucktail Creek sediments with downstream deposition during large storm events. These risks would be minimized as long as the lower Bucktail sediment dam remains in place.

All of the action alternatives would be essentially equivalent in terms of reliability of controls and permanence. The permanence of these alternatives would rely upon long-term maintenance of the facilities that would be included under each alternative,

monitoring and maintenance of the Early Actions previously implemented, and upon continued treatment of the collected groundwater. As long as the operation and maintenance of these facilities is properly performed, any of the Bucktail action alternatives (BT-3, BT-4, BT-5, and BT-6) would provide a permanent remedy.

7.5.2.8.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Alternatives BT-3, BT-4, BT-5, and BT-6 would provide the same reduction in toxicity, mobility, and volume through treatment of the collected groundwater. Alternative BT-1 would provide treatment of lesser volumes of groundwater than the action alternatives (continued treatment of groundwater collected at the existing Bucktail pump station).

7.5.2.8.5 Short-term Effectiveness

Alternative BT-1 is rated highest for short-term effectiveness because it would not result in risks to workers or the community, would have no short-term environmental impacts associated with remedial actions, and would be implemented on signing of a Consent Decree. Alternatives BT-3 and BT-5 are rated next highest for short-term effectiveness and are essentially comparable with BT-3 having a slight edge because it involves less construction. Both alternatives would have minimal risks to the community, acceptable construction risks, minimal unavoidable short-term environmental risks, and could be implemented within 2 years. Alternative BT-4 is rated lower than Alternatives BT-1, BT-3 and BT-5 because the sediment removal in South Fork Big Deer Creek would result in greater construction risks and considerable disruption of the stream channel and riparian habitat. Alternative BT-6 is rated lowest because the extensive sediment removal would result in greater construction risks, extensive disruption of stream channels and riparian habitat, and a construction period that would last several years beyond the other alternatives.

7.5.2.8.6 Implementability

Alternative BT-1 is rated highest for technical implementability since no further actions would be required. Alternatives BT-3 and BT-5 are rated next highest, and are essentially comparable since both alternatives would utilize standard construction techniques. Alternative BT-4 is rated lower due to the need for stream diversion, dewatering and sediment control during the sediment removal. Alternative BT-6 is rated lowest because of the need for stream diversion, dewatering and sediment control during the sediment removal, the need to site, design, and maintain an on-site repository, and the uncertainty of approval for construction of an access road along Big Deer Creek. All of the alternatives are rated comparable in terms implementing institutional controls on lands controlled by the Forest Service.

7.5.2.8.7 Cost

Figure 7-6 compares the cost-effectiveness of the Bucktail alternatives relative to meeting water quality PRGs in Big Deer Creek at BDSW-03. Error bars on this figure are based on the minimum and maximum values from the uncertainty/variability analysis (see Section

7.3.1). Alternative BT-3 has the best cost-effectiveness of the alternatives for achieving ARARs in Big Deer Creek. Alternative BT-5 would also meet water quality PRGs in South Fork Big Deer Creek at a cost approximately $300,000 greater than Alternative BT-3. The other action alternatives (BT-4 and BT-6) would be considerably more costly, with minimal differences in long-term benefits to the environment.

7.5.3 Panther Creek Alternatives

This section compares the remediation alternatives for Panther Creek. The comparative analysis of the Panther Creek alternatives is summarized in Table 7-17.

7.5.3.1 Overall Protection of Human Health and the Environment

Water quality standards in Panther Creek will be achieved by selection of suitable alternatives for Blackbird and Bucktail Creeks; therefore evaluation of overall protectiveness for the Panther Creek alternatives is focused on human health. Under current land use, overbank deposits do not pose an unacceptable risk to human health. Therefore, evaluation of human health depends on consideration of future land use.

Alternative P-1 does not provide monitoring or institutional controls of any future changes in land use. Therefore, under Alternative P-1, changes in future land use could result in unacceptable human health risks due to exposure to arsenic. Alternatives P-2 and P-3 both address potential future land use. Removal (P-3) is generally considered more reliable and permanent than monitoring and institutional controls, which, if not properly enforced, could lead to human exposure to contaminants.

Alternatives P-2 and P-3 would address the risk of exposure of the contaminants remaining at depth at the private properties cleaned up under the Early Actions through institutional controls.

Neither Alternative P-1 nor Alternative P-2 would create any short-term risks. Sediment removal in Alternative P-3 would create short-term risks not present in the other two alternatives: risk to the community and site workers due to truck traffic and excavation equipment, and short-term disruption of ecological habitat.

EPA has determined that Alternative P-1 is not protective of human health. Alternative P-2 would be protective of human health as long as enforceable institutional controls can be implemented and properly maintained. Alternative P-3 would be protective of human health. The risks to the environment are acceptable under current and future scenarios, therefore EPA has determined that all of the Panther Creek alternatives are protective of the environment.

7.5.3.2 Compliance with ARARs

All of the alternatives for Panther Creek would comply with ARARs as described in Section 3.1 and Table 3-1a and 3-1b.

7.5.3.3 Long-Term Effectiveness and Permanence

As water quality standards in Panther Creek will be achieved by selection of suitable alternatives for Blackbird and Bucktail Creeks, evaluation of long-term effectiveness and permanence for the Panther Creek alternatives is focused on human health. Under current land use, overbank deposits are not considered to pose an unacceptable risk to human health. Therefore, evaluation of human health depends on consideration of future land use.

Alternative P-1 does not provide monitoring or institutional controls of any future changes in land use. Therefore, under Alternative P-1, changes in future land use could result in unacceptable human health risks due to exposure to arsenic.

Alternatives P-2 and P-3 both address potential future land use. Removal (P-3) is generally considered more reliable and permanent than institutional controls, which, if not properly enforced, could lead to unacceptable human health risks due to exposure to contaminants. Both alternatives would require monitoring to assure reliability and permanence: Alternative P-2 would require monitoring of future changes in land use; Alternative P-3 would require monitoring following significant flood events to assure that recontamination from upstream has not occurred. Alternative P-3 is more reliable and requires less monitoring than Alternative P-2; therefore Alternative P-3 ranks higher than Alternative P-2 for this criterion.

7.5.3.4 Reduction in Toxicity, Mobility and Volume through Treatment

Since none of the Panther Creek alternatives involve treatment, there is no difference among these alternatives for this criterion.

7.5.3.5 Short-Term Effectiveness

Alternative P-1, since it requires no further action, would be the quickest to implement and would not create any short-term risks. Alternative P-2 would not create any short-term risks, but would take longer to implement than Alternative P-1 because of the need to implement enforceable institutional controls. One to two years (or more) may be required before all institutional controls are in place.

Alternative P-3 may take longer to implement than Alternative P-2, depending on the time to implement enforceable institutional controls. Removal would create short-term risks not present in the other two alternatives: risk to the community and site workers due to truck traffic and excavation equipment, and short-term disruption of ecological habitat. Alternative P-3 would require 1 to 2 years to implement.

7.5.3.6 Implementability

Alternative P-1, as it requires no further action, would be the easiest to implement. Alternative P-2 requires a long-term monitoring program and/or institutional controls. Administratively this alternative would be the most difficult of the Panther Creek

Alternatives because it depends upon the acceptance of land use restrictions by the property owners, and acceptance by an independent third party as grantee of the land restriction easements. Alternative P-3 would be more difficult to physically implement than Alternative P-2 or Alternative P-1 because of the effort involved in removing overbank deposits.

7.5.3.7 Cost

The estimated costs for the alternatives are summarized in Table 7-14. Detailed cost estimates are presented in Appendix E. These estimates include capital, O&M (net present value), and total (net present value) costs. The cost estimates for the alternatives are based on the descriptions and design assumptions presented in Chapter 6. Additional documentation is presented in the cost tables.

7.5.3.8 Summary

Alternative P-1, because it does not monitor future land use, is not protective of human health. Alternatives P-2 and P-3 are comparable in terms of overall protection of human health and long-term effectiveness, as long as enforceable institutional controls are maintained. Alternative P-3 has greater reliability and permanence because it does not rely on institutional controls. The estimated cost for Alternative P-2 is lower than for Alternative P-3, although there is some uncertainty in the costs of implementing and monitoring institutional controls. Alternative P-3 would have greater short-term impacts than Alternative P-2.

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Figures

FIGURES

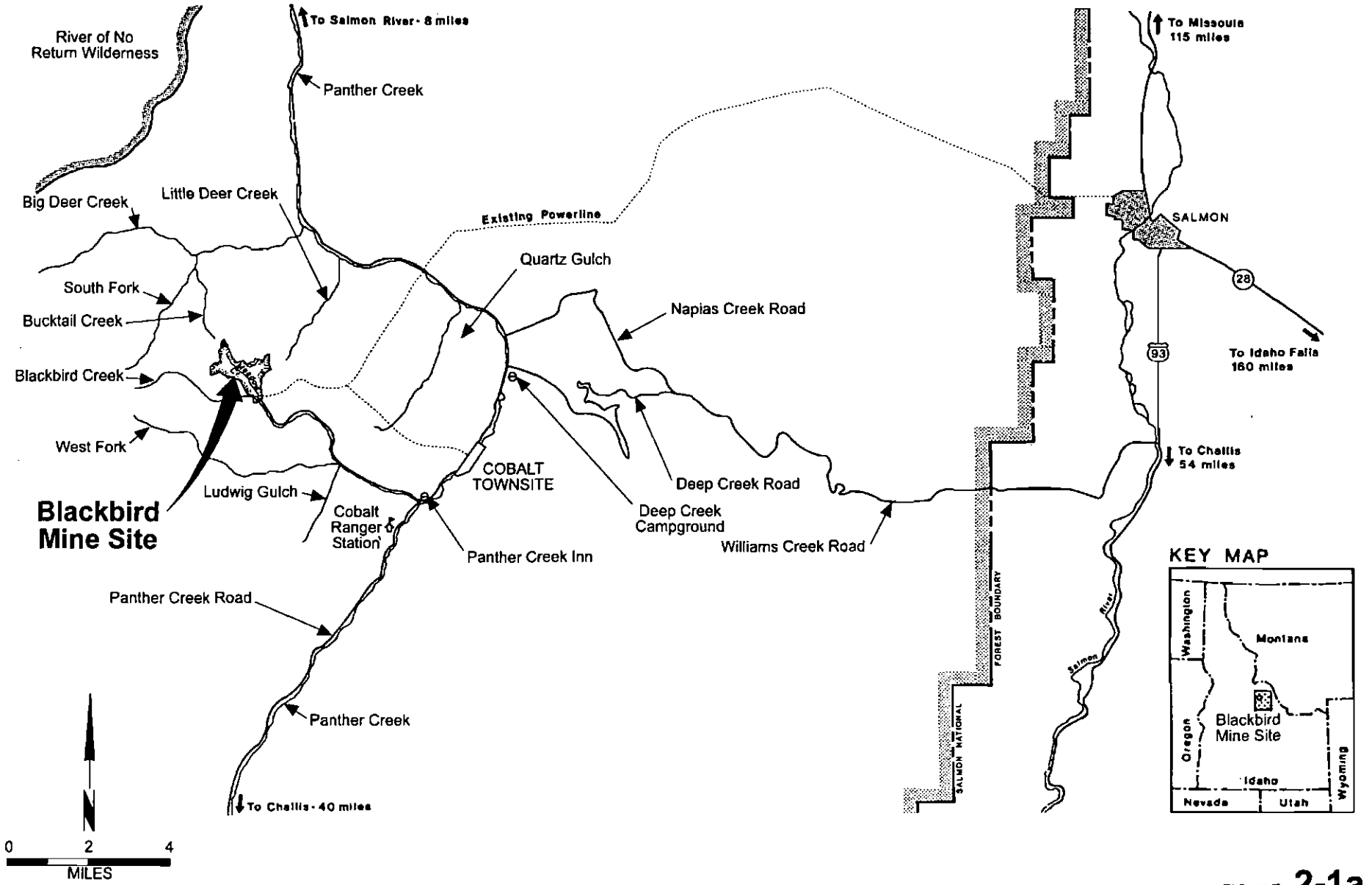

FIGURE **2-1a**
REGIONAL OVERVIEW MAP

SOURCE: ERT 1982

PROJECT NO. 943 1595x003_9000 DRAWING NO. 92866 DATE 2/25/02 DRAWN BY EL

Golder Associates

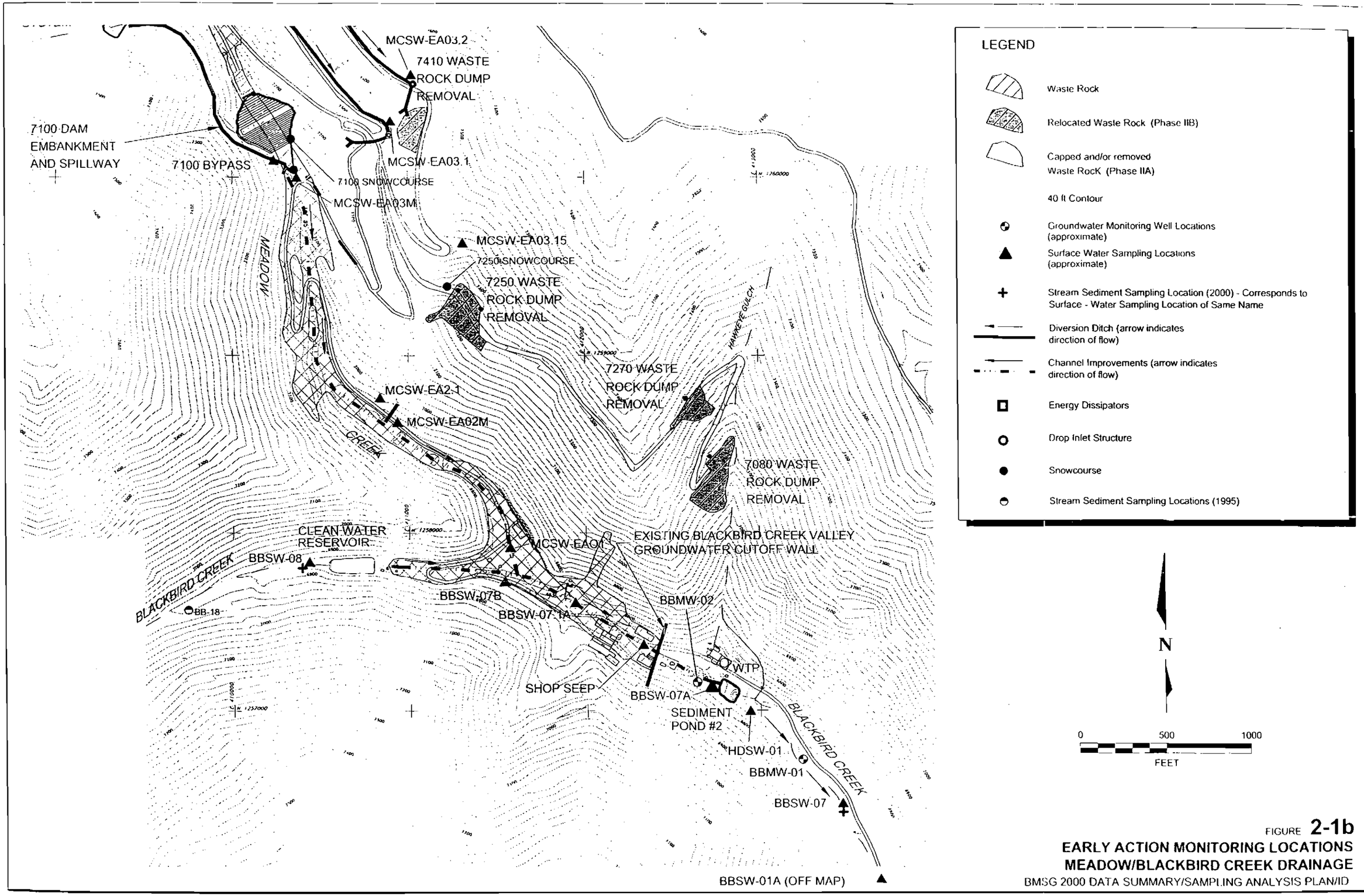

FIGURE **2-1b**

EARLY ACTION MONITORING LOCATIONS
MEADOW/BLACKBIRD CREEK DRAINAGE

BMSG 2000 DATA SUMMARY/SAMPLING ANALYSIS PLAN/ID

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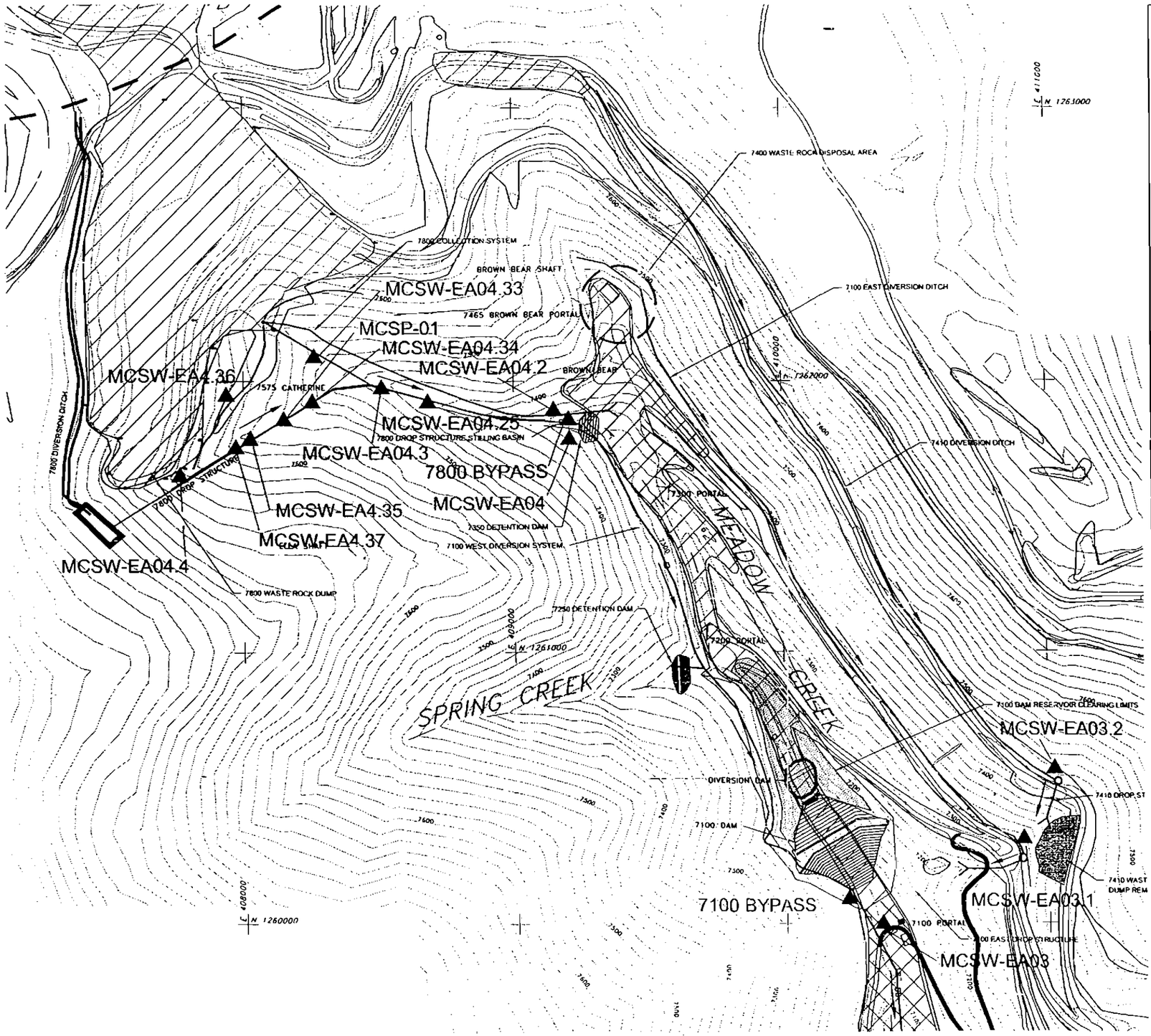
Golder Associates



LEGEND

- Waste Rock
- Relocated Waste Rock (Phase IIB)
- Capped and/or removed Waste Rock (Phase IIA)
- 40 ft Contour
- Groundwater Monitoring Well Locations (approximate)
- Surface Water Sampling Locations (approximate)
- Diversion Ditch or Channel(arrow indicates direction of flow)
- Drainage Divide
- Channel Improvements
- Energy Dissipators
- Drop Inlet Structure

N

0 400 800

FEET

FIGURE **2-1c**

EARLY ACTION MONITORING LOCATIONS

MEADOW CREEK DRAINAGE

BMSG 2000 DATA SUMMARY/SAMPLING ANALYSIS PLAN/ID

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Golder Associates

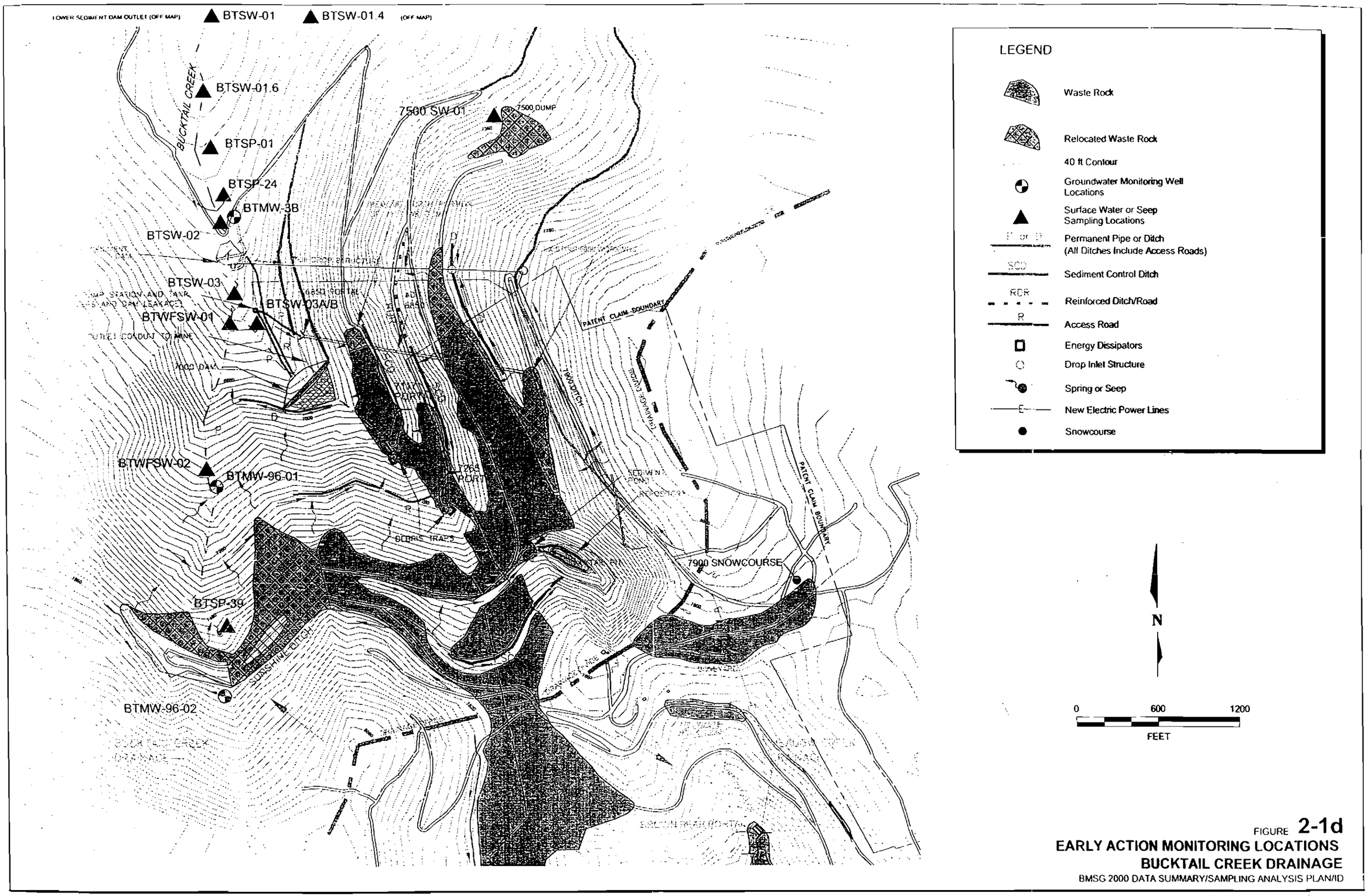

FIGURE **2-1d**

EARLY ACTION MONITORING LOCATIONS
BUCKTAIL CREEK DRAINAGE

BMSG 2000 DATA SUMMARY/SAMPLING ANALYSIS PLAN/ID

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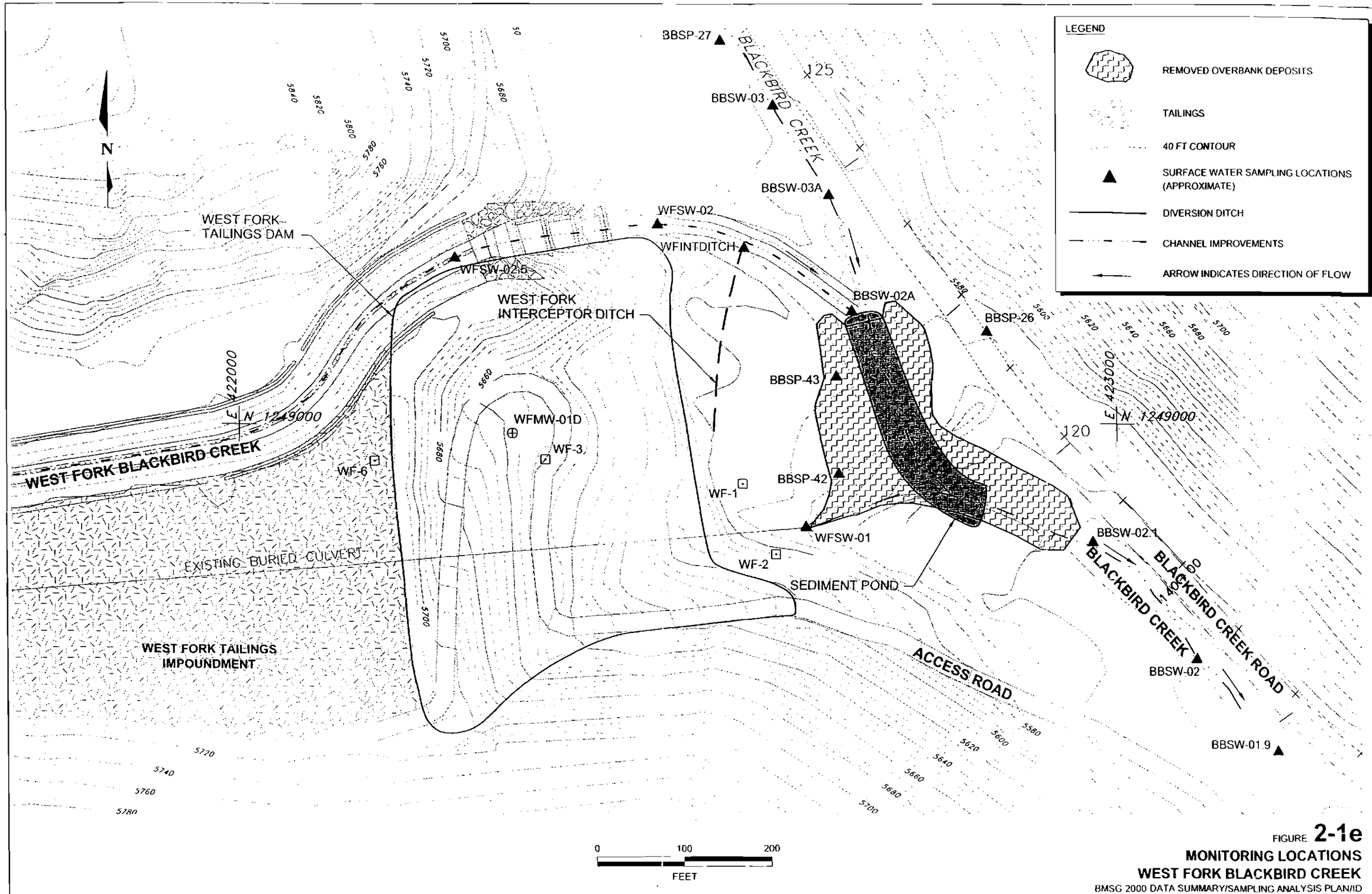

FIGURE **2-1e**

MONITORING LOCATIONS

WEST FORK BLACKBIRD CREEK

BMSG 2000 DATA SUMMARY/SAMPLING ANALYSIS PLAN/ID

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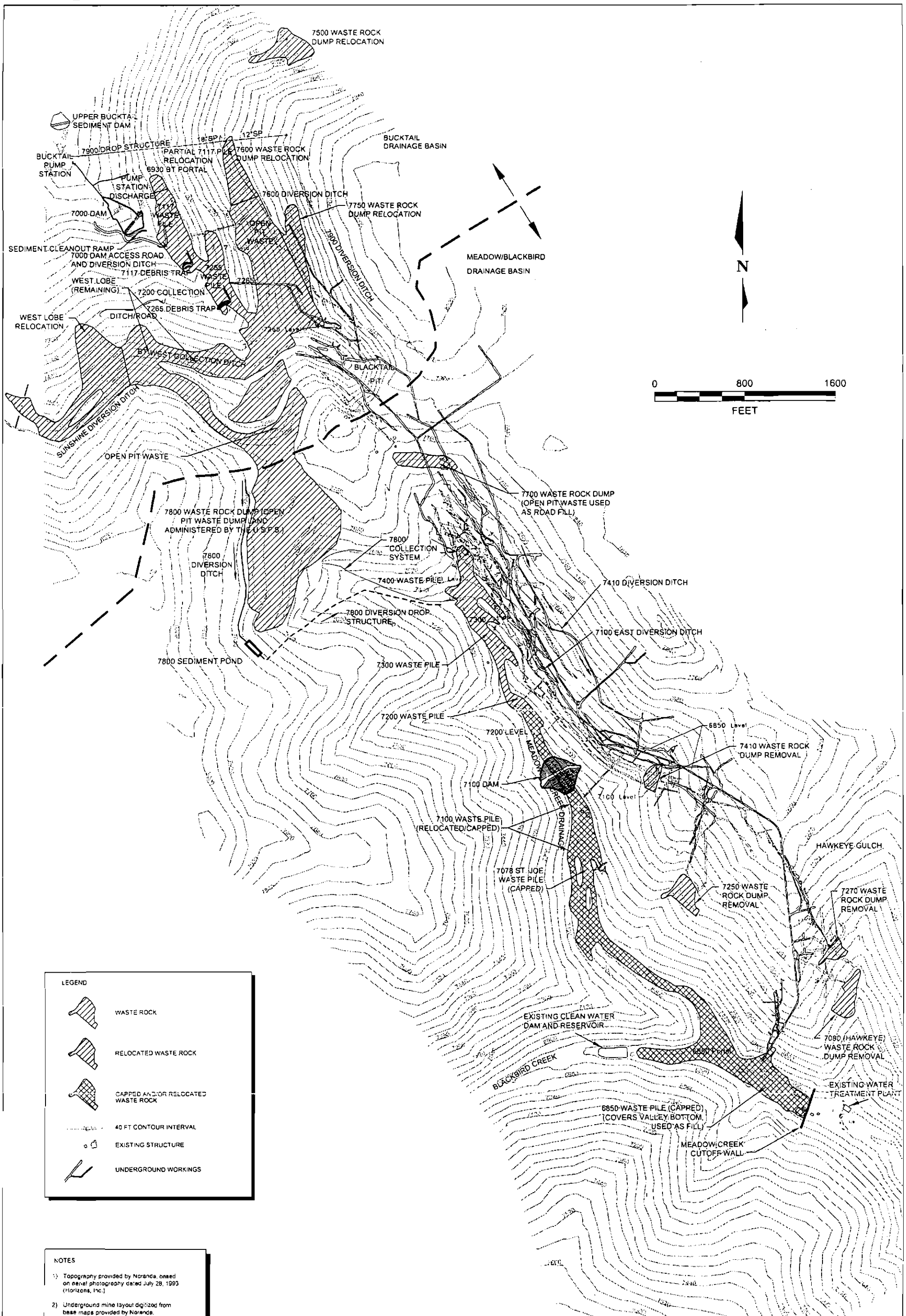

NOTES

1) Topography provided by Noranda, based on aerial photography dated July 28, 1993 (Horizons, Inc.)

2) Underground mine layout digitized from base maps provided by Noranda.

3) Waste piles as identified by Reiser 1986.

4) Haynes-Stellite waste rock pile is southeast of the area depicted on this figure and is not shown.

FIGURE **2-2a**

MINE SITE WITH EARLY ACTIONS

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

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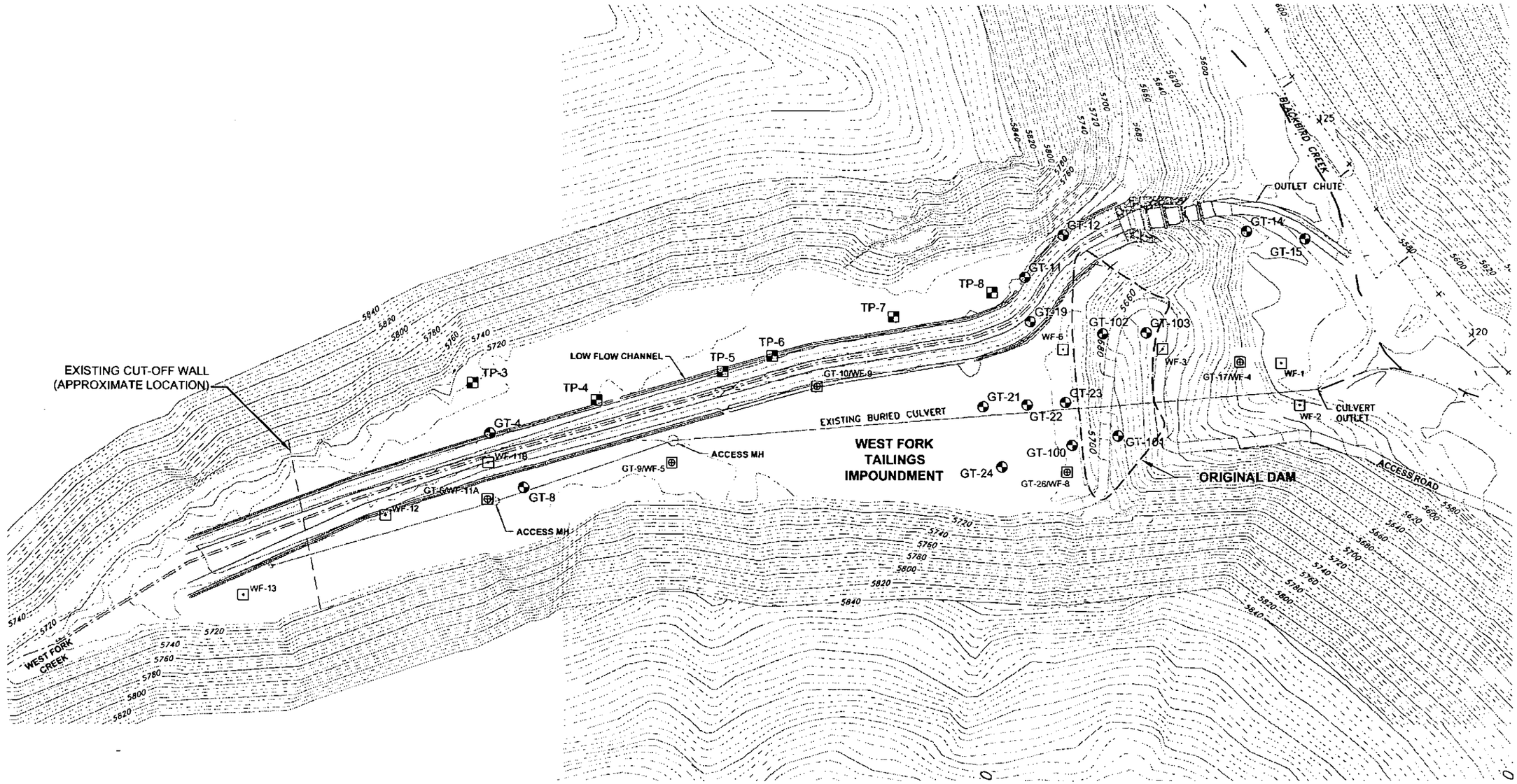
Golder Associates



LEGEND

GT-101	GEOTECHNICAL BORING
WF-12	GROUNDWATER MONITORING WELL
GT-9/WF-5	GEOTECHNICAL BORING CONVERTED TO MONITORING WELL
TP-3	APPROXIMATE KNIGHT-PIESOLD TEST PIT LOCATIONS, 1994

FIGURE **2-2b**

WEST FORK TAILINGS IMPOUNDMENT-EXISTING SITE PLAN

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

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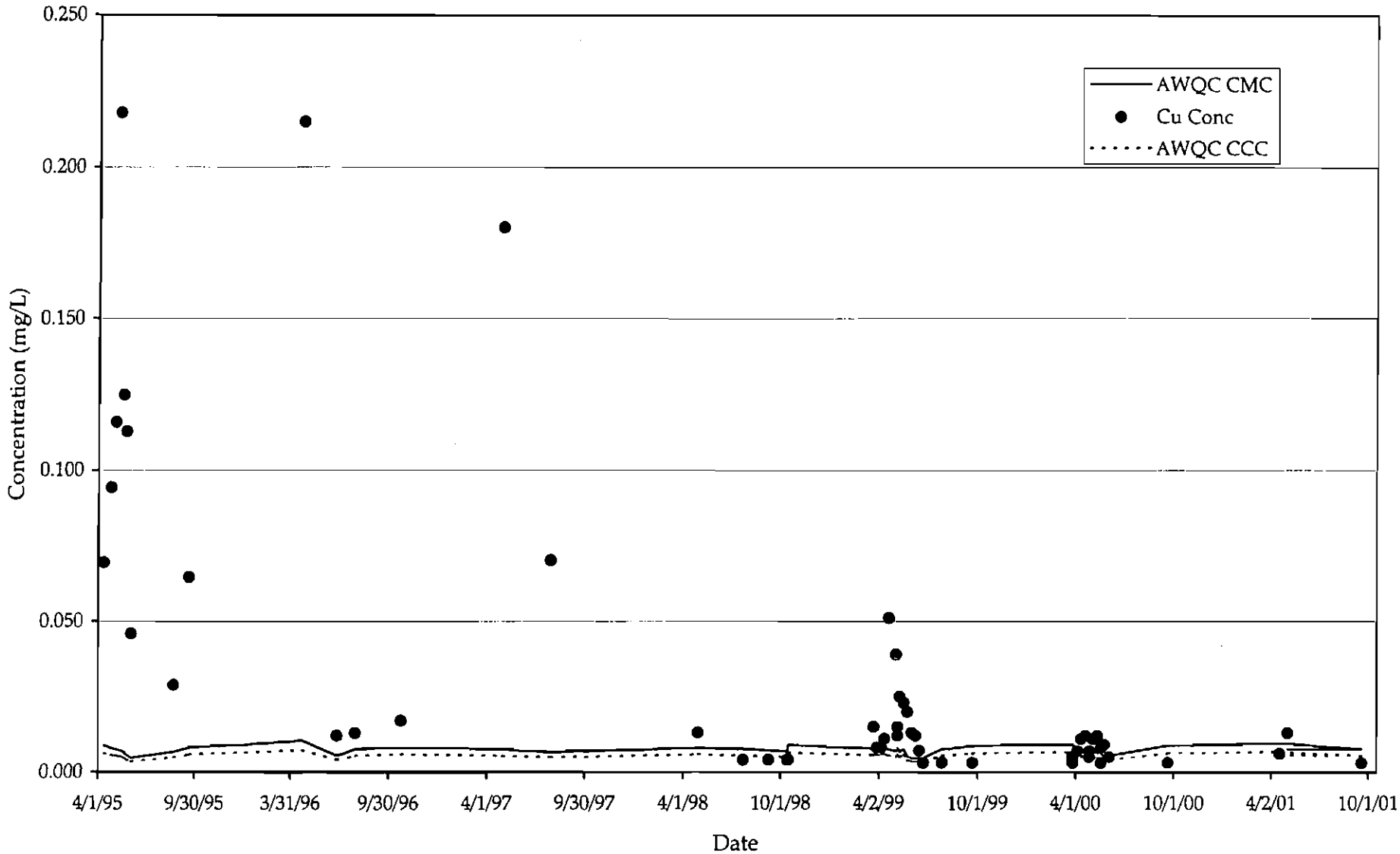
Golder Associates

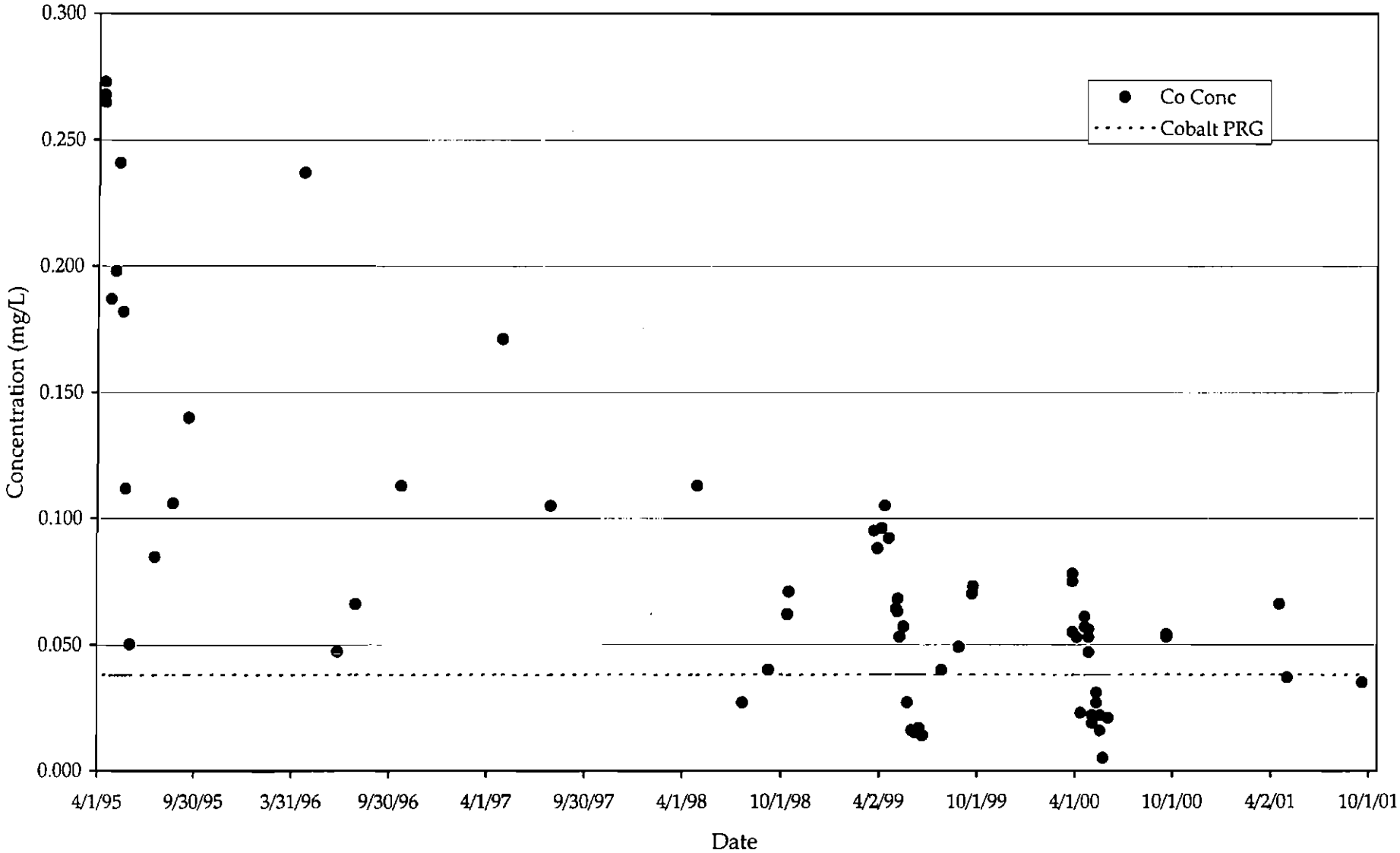


AWQC - Aquatic Water Quality Criteria
CCC - Criteria Continuous Concentration (chronic criteria)
CMC - Criteria Maximum Concentration (acute criteria)

Figure 2-3a
DISSOLVED COPPER CONCENTRATIONS VS. AWQC AT PASW-09 & PASW-10 -- 1995 THROUGH 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
PASW-10_AWQC_ch8.xls

Golder Associates



Cobalt PRG - Dissolved Cobalt Preliminary Remediation Goal

Figure 2-3b

DISSOLVED COBALT CONCENTRATIONS VS. PRG AT PASW-09 & PASW-10 -- 1995 THROUGH 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

PASW-10_AWQC_ch8.xls

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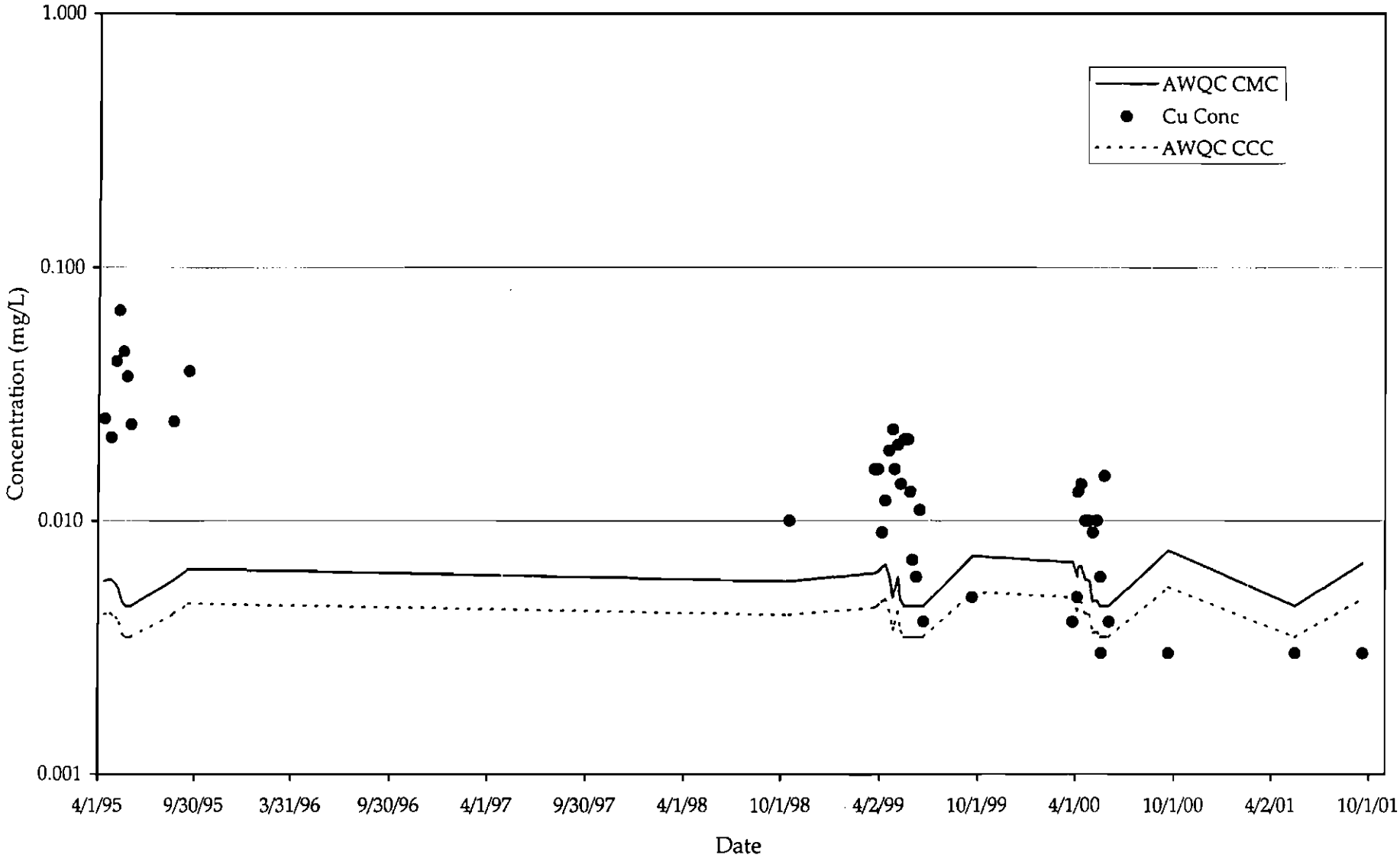
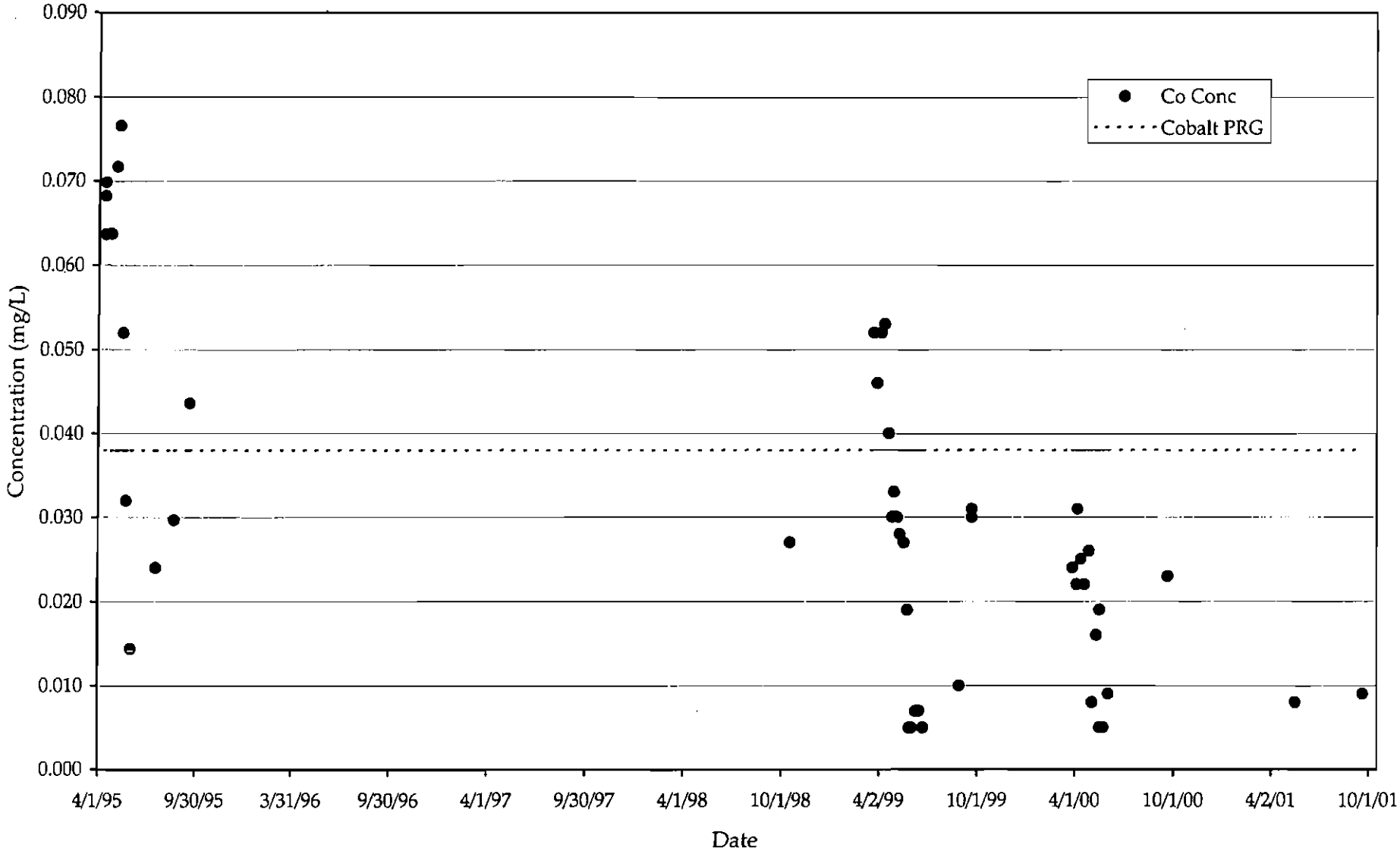


AWQC - Aquatic Water Quality Criteria
CCC - Criteria Continuous Concentration (chronic criteria)
CMC - Criteria Maximum Concentration (acute criteria)

Figure 2-4a
DISSOLVED COPPER CONCENTRATIONS VS. AWQC AT PASW-04 -- 1995 THROUGH 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
PASW-04_AWQC-ch8.xls

Golder Associates

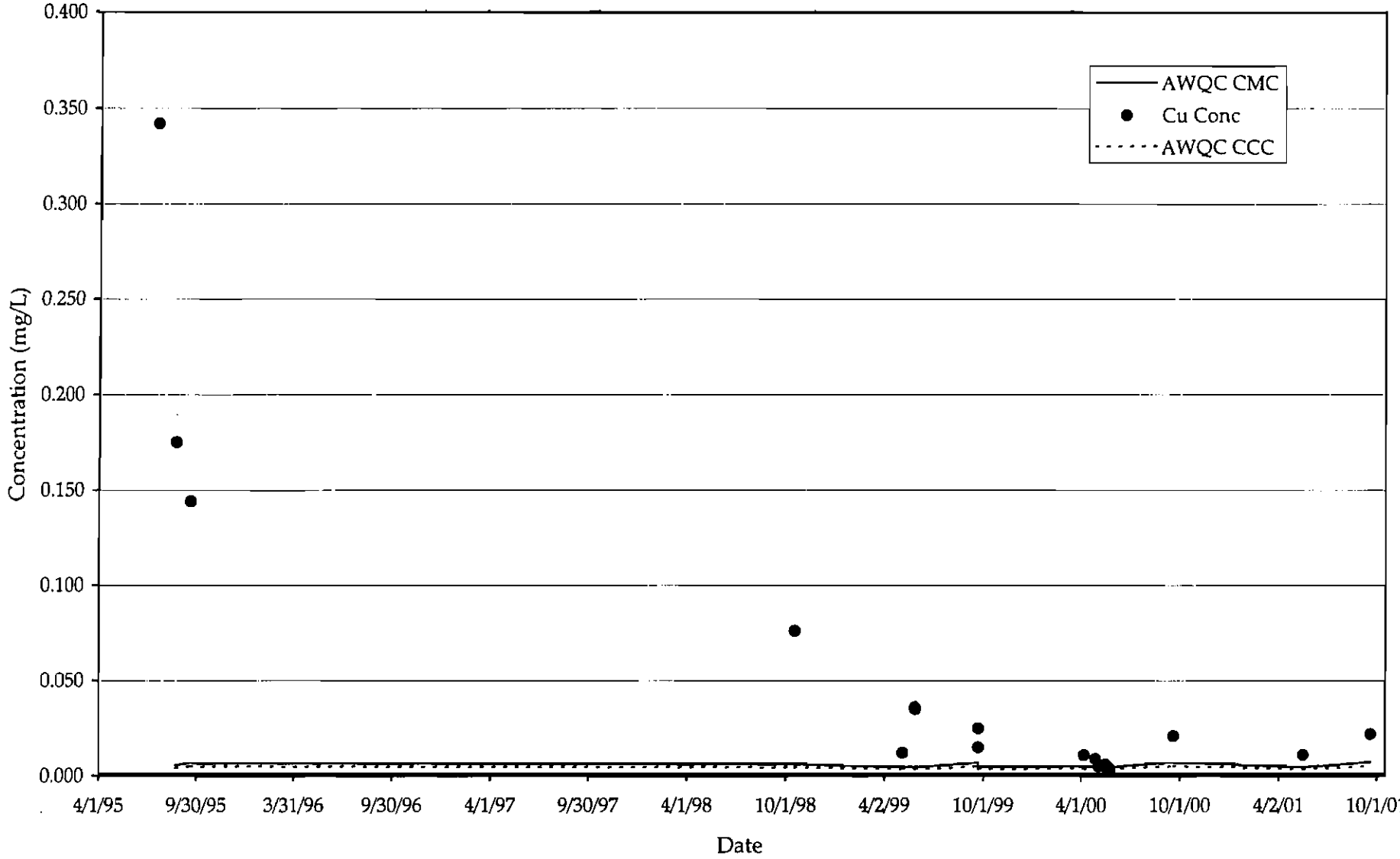


Cobalt PRG - Dissolved Cobalt Preliminary Remediation Goal

Figure 2-4b
DISSOLVED COBALT CONCENTRATIONS VS. PRG AT PASW-04 -- 1995 THROUGH 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
PASW-04_Cobalt.xls

Golder Associates



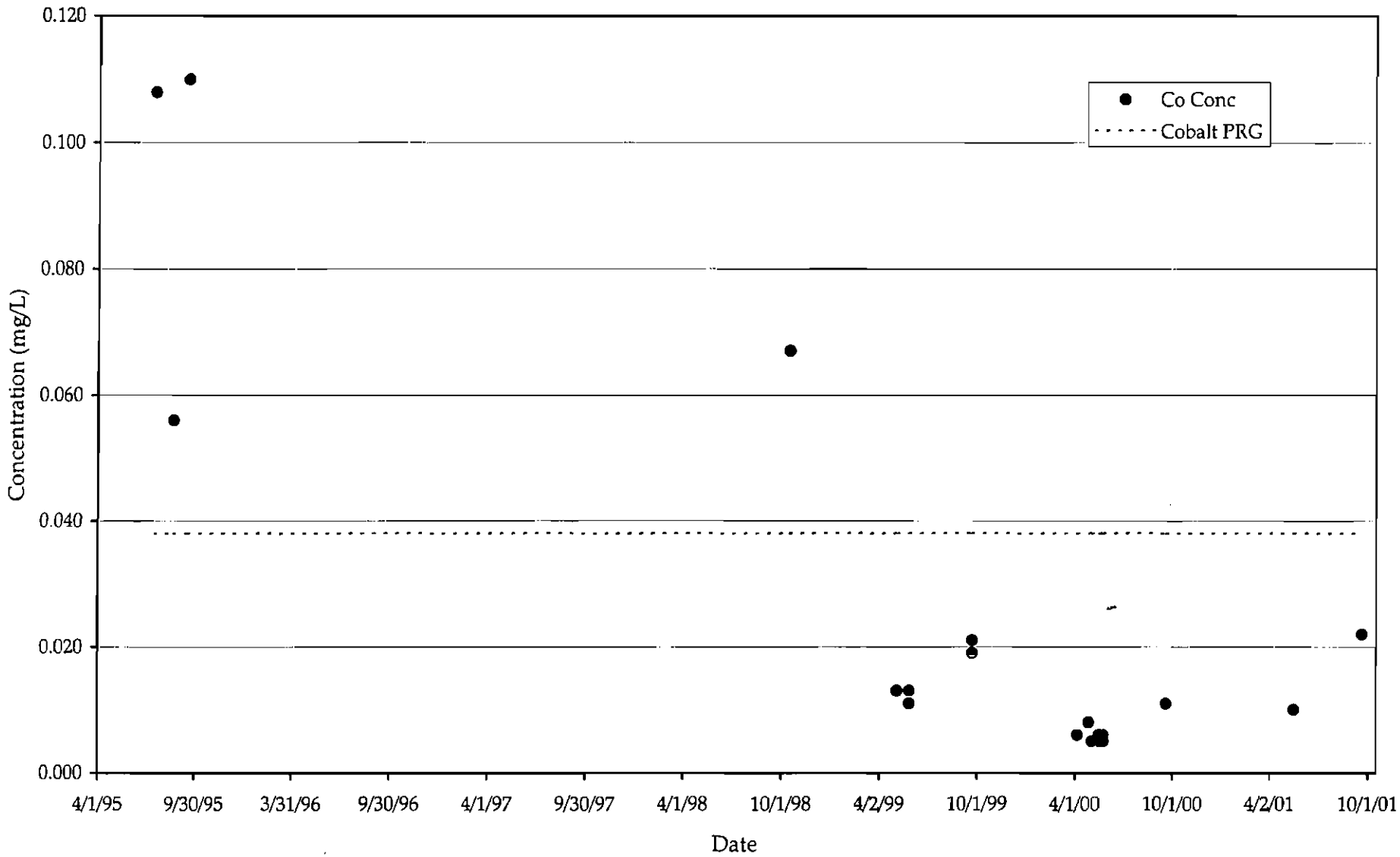
AWQC - Aquatic Water Quality Criteria
CCC - Criteria Continuous Concentration (chronic criteria)
CMC - Criteria Maximum Concentration (acute criteria)

Figure 2-5a
DISSOLVED COPPER CONCENTRATIONS VS. AWQC AT BDSW-03 -- 1995 THROUGH 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

BDSW-03_AWQC.xls

Golder Associates



Cobalt PRG - Dissolved Cobalt Preliminary Remediation Goal

Figure 2-5b
DISSOLVED COBALT CONCENTRATIONS VS. PRG AT BDSW-03 -- 1995 THROUGH 2001
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
BDSW-03_Cobalt.xls

Golder Associates

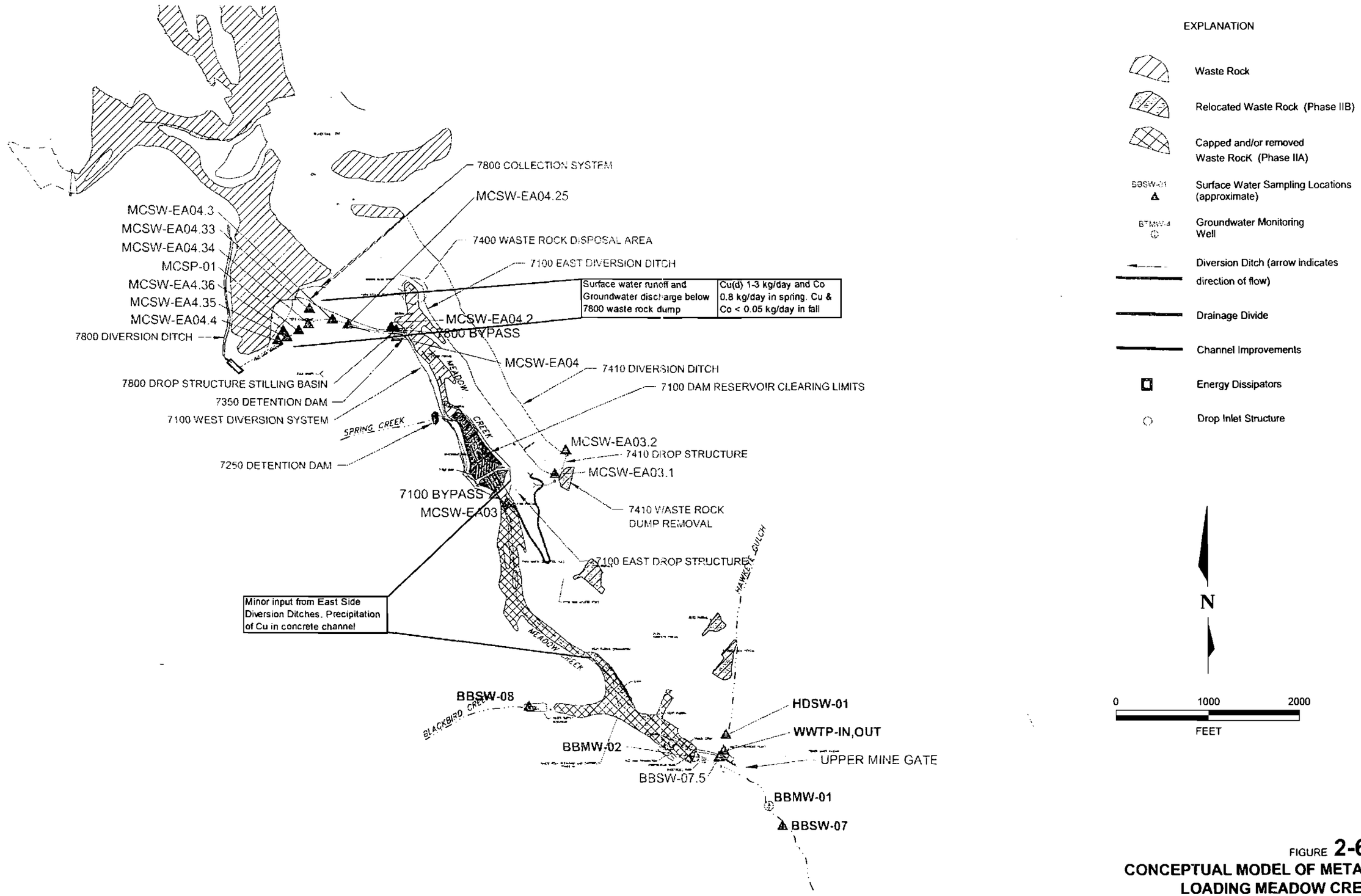


FIGURE **2-6A**

CONCEPTUAL MODEL OF METALS LOADING MEADOW CREEK

BMSG/BLACKBIRD MINE/ID

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Golder Associates

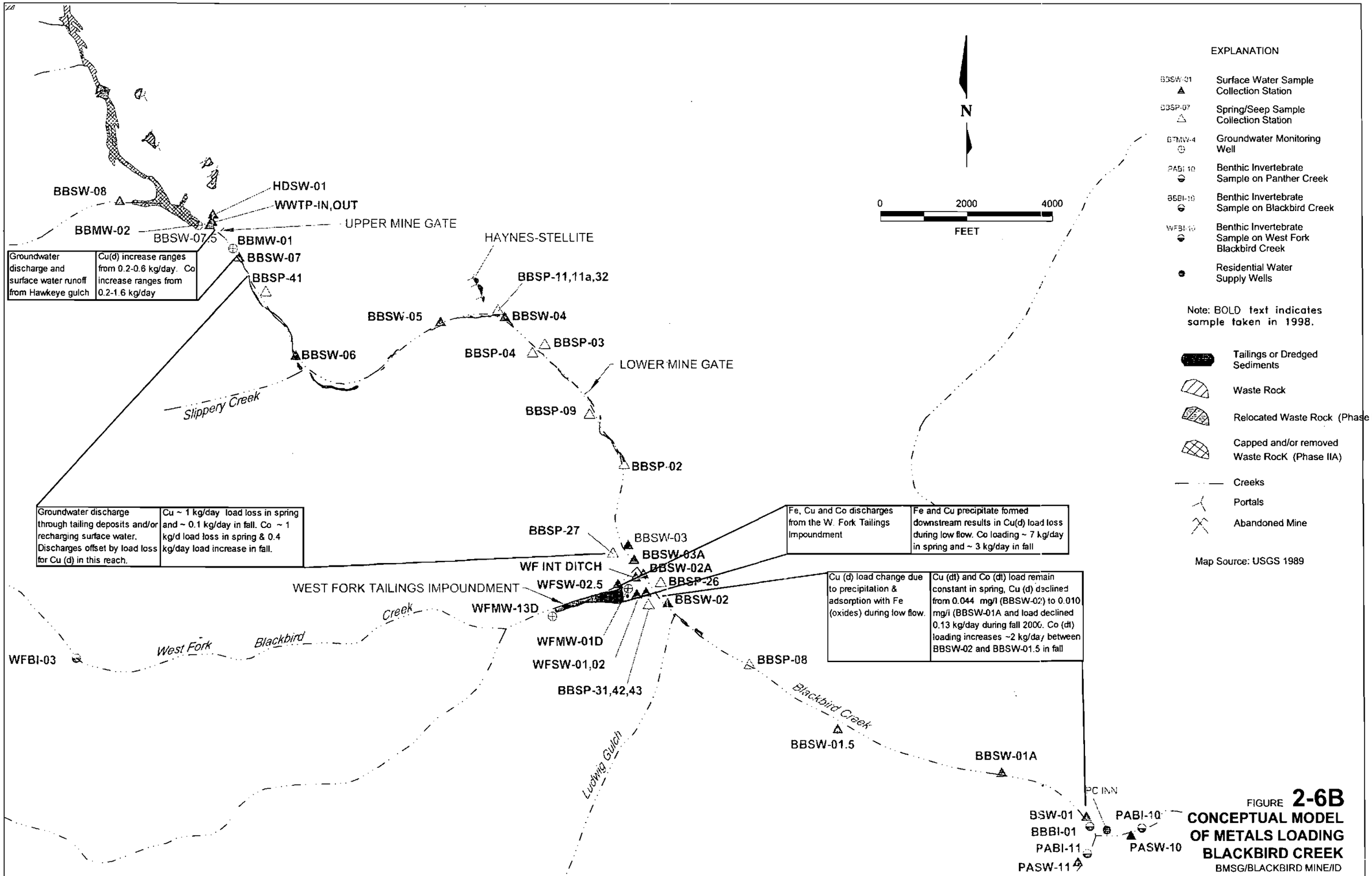

FIGURE **2-6B**

CONCEPTUAL MODEL OF METALS LOADING BLACKBIRD CREEK

BMSG/BLACKBIRD MINE/ID

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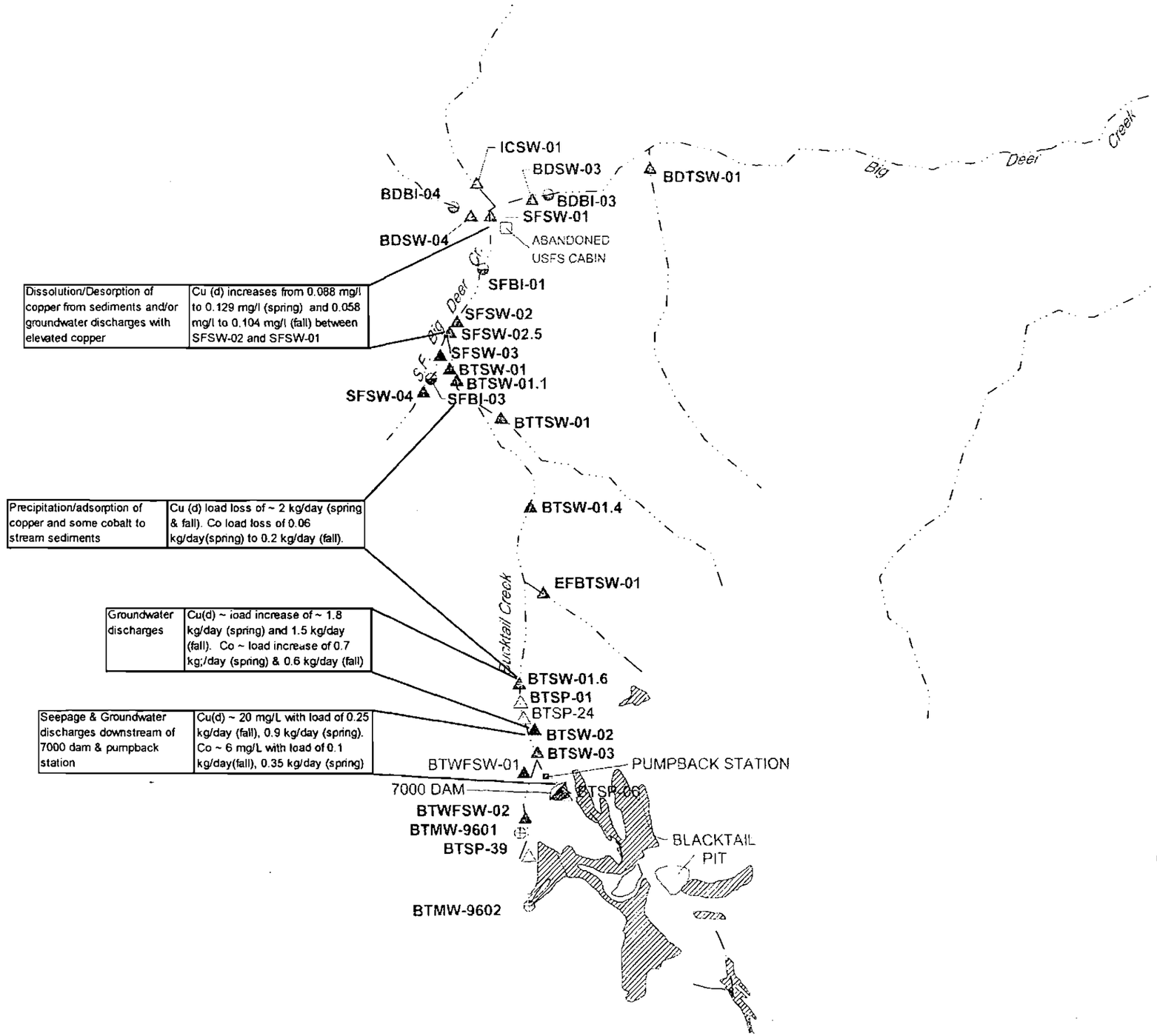
Golder Associates



EXPLANATION

BBSW-01 ▲	Surface Water Sample Collection Station
BBSP-07 △	Spring/Seep Sample Collection Station
BTMW-4	Groundwater Monitoring Well
PAB-10	Benthic Invertebrate Sample on Panther Creek
BDBI-10	Benthic Invertebrate Sample on Big Deer Creek
BBBI-10	Benthic Invertebrate Sample on Blackbird Creek
WFBI-10	Benthic Invertebrate Sample on West Fork Blackbird Creek
○	Residential Water Supply Wells

Note: BOLD text indicates sample taken in 1998.

Tailings or Dredged Sediments

Waste Rock

Relocated Waste Rock (Phase IIB)

Capped and/or removed Waste RocK (Phase IIA)

Creeks

Portals

Abandoned Mine

Map Source: USGS 1989

N

0 2000 4000
FEET

FIGURE **2-6C**
CONCEPTUAL MODEL OF METALS LOADING BUCKTAIL CREEK
BMSG/BLACKBIRD MINE/ID

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Golder Associates

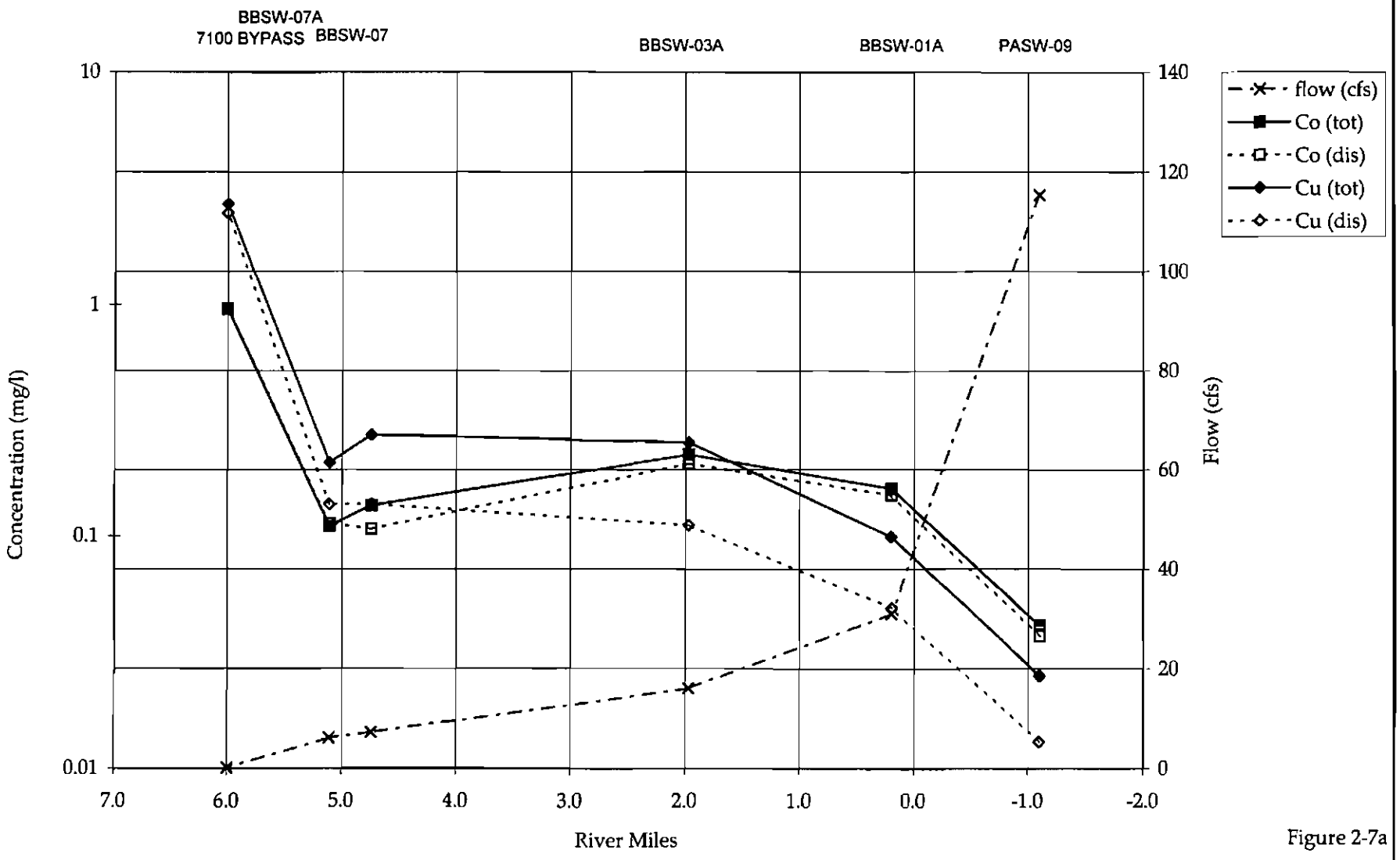

Figure 2-7a

BLACKBIRD CREEK SYNOPTIC COBALT AND COPPER CONCENTRATION SPRING 2001

BMSG/2001 DATA SUMMARY/ID

943-1595.003, 11/27/00, SPRING_BBSYN_01.xls

Note: BBSW-03A data appear to be anomalous

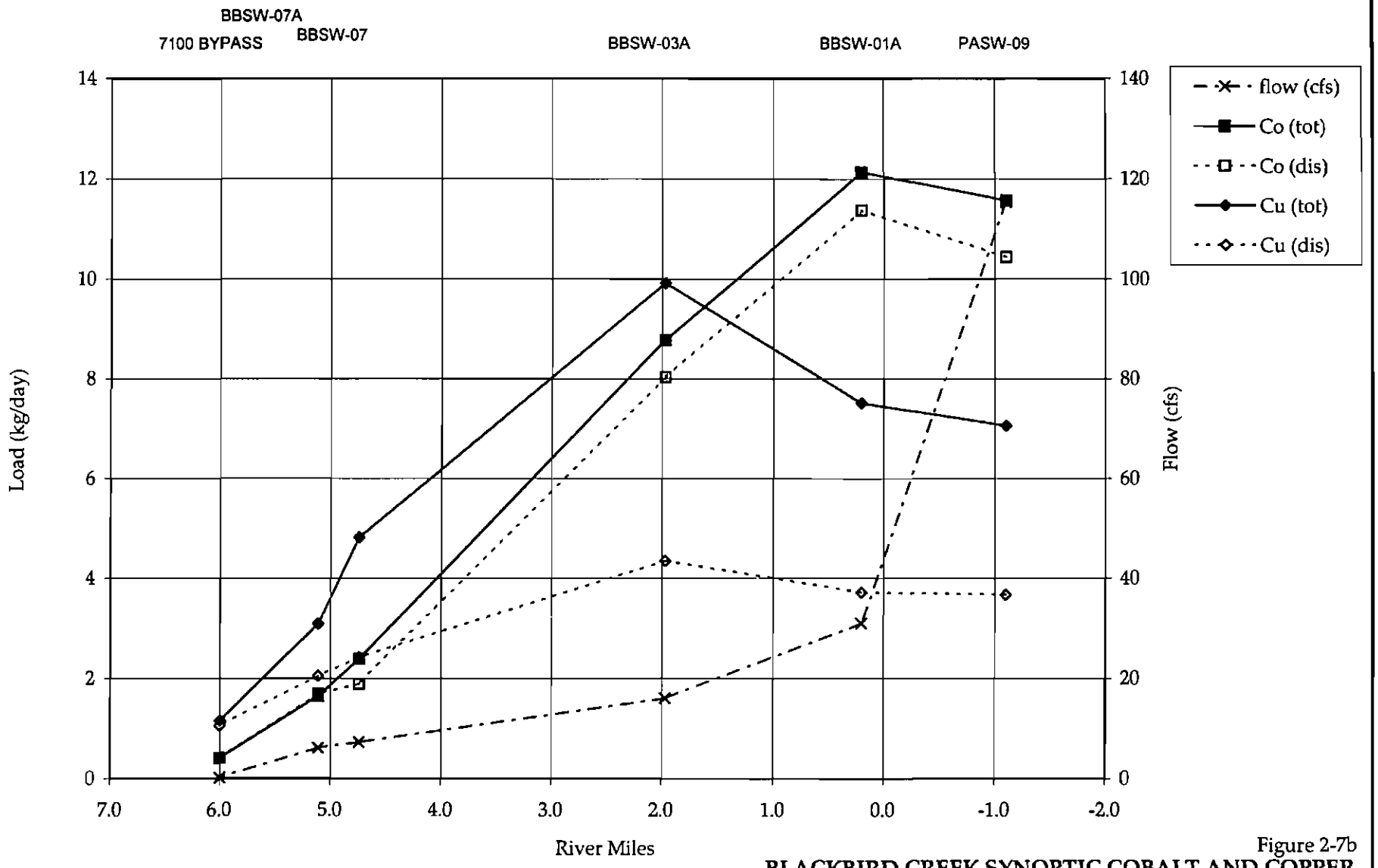

Figure 2-7b
BLACKBIRD CREEK SYNOPTIC COBALT AND COPPER LOADING SPRING 2001

Note: BBSW-03A data appear to be anomalous

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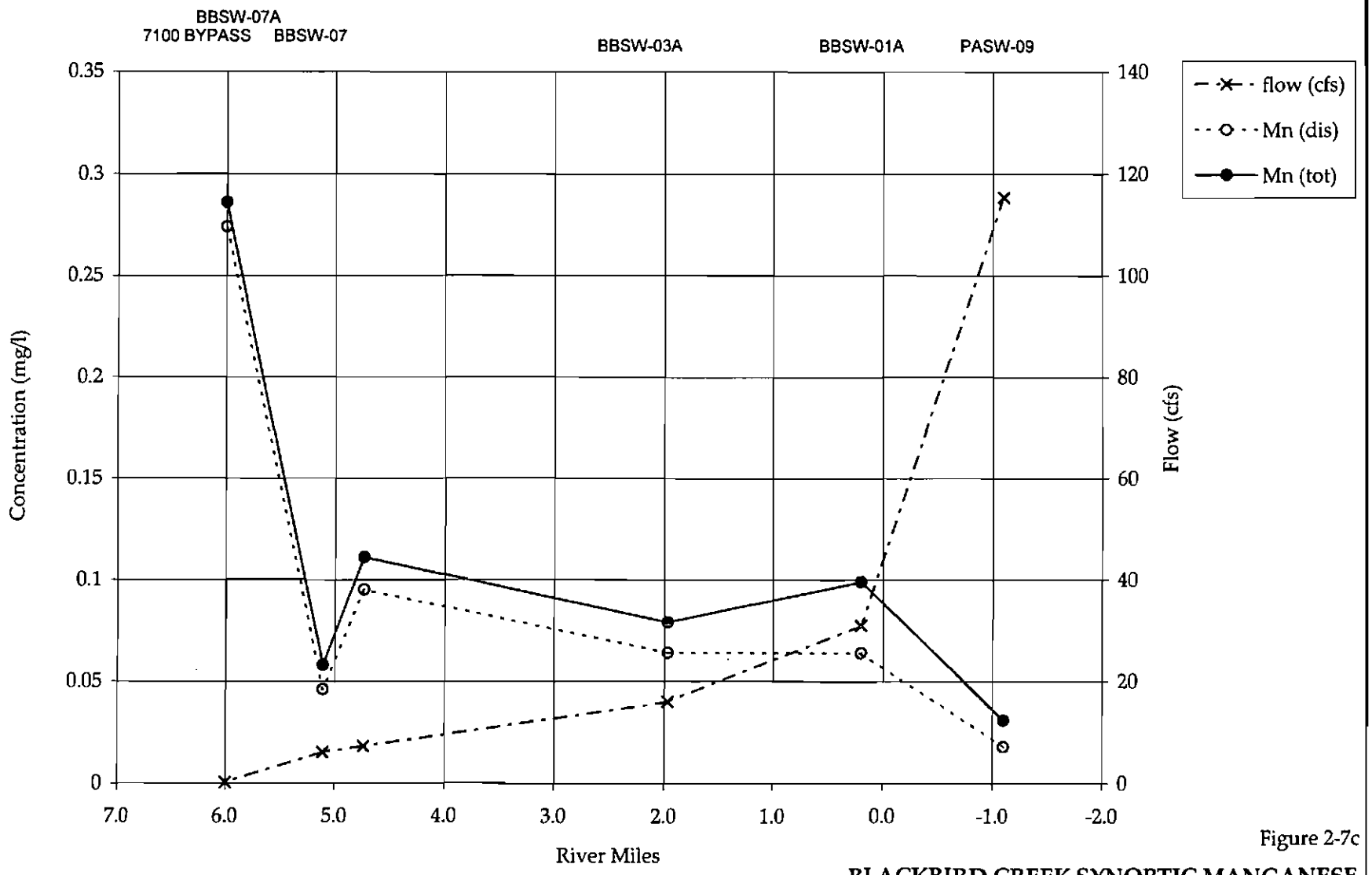

Figure 2-7c

BLACKBIRD CREEK SYNOPTIC MANGANESE CONCENTRATION, SPRING 2001

Note: BBSW-03A data appear to be anomalous

BMSG/2001 DATA SUMMARY/ID

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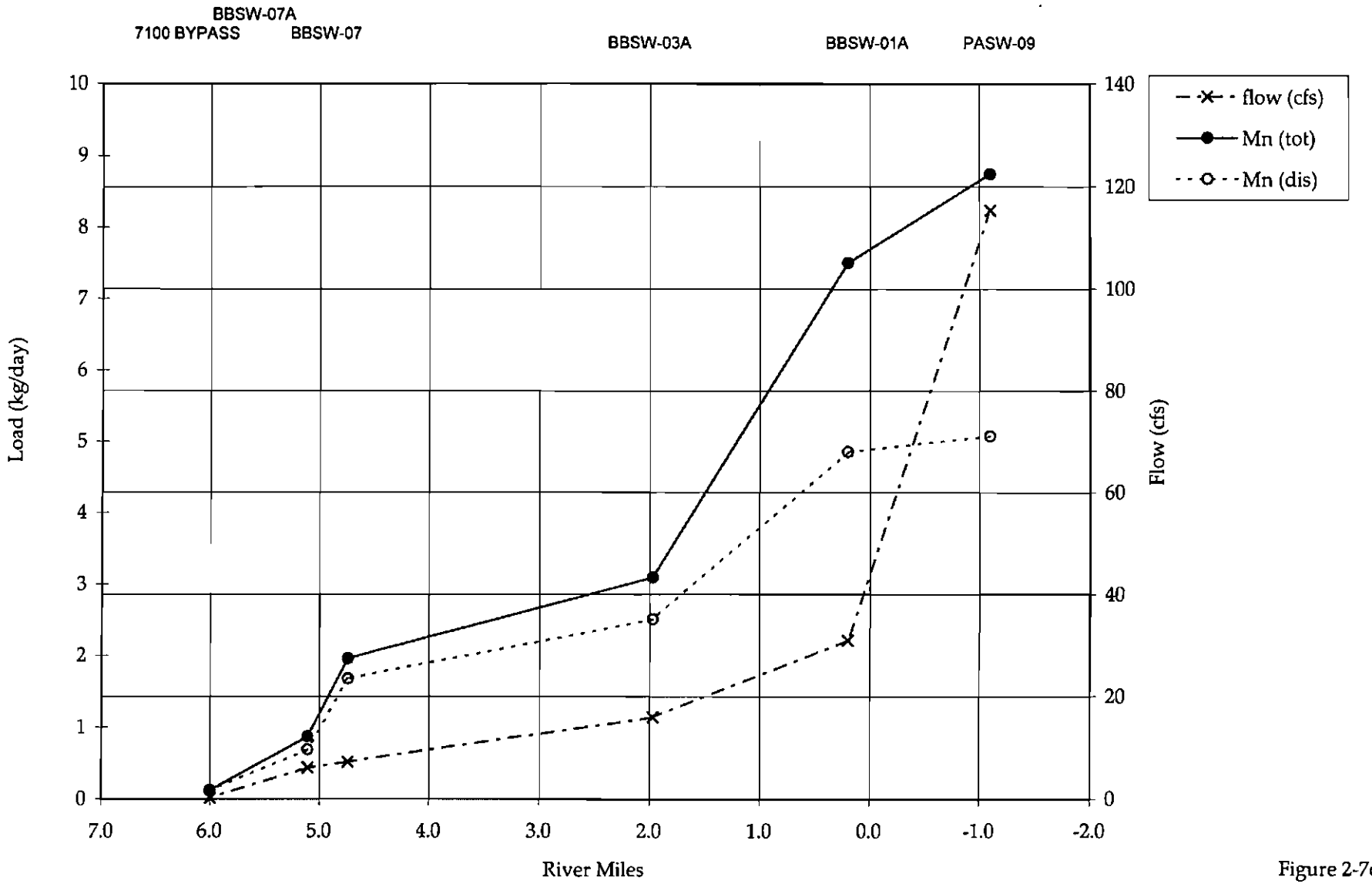

Figure 2-7d

BLACKBIRD CREEK SYNOPTIC MANGANESE LOAD, SPRING 2001

Note: BBSW-03A data appear to be anomalous

BMSG/2001 DATA SUMMARY/ID

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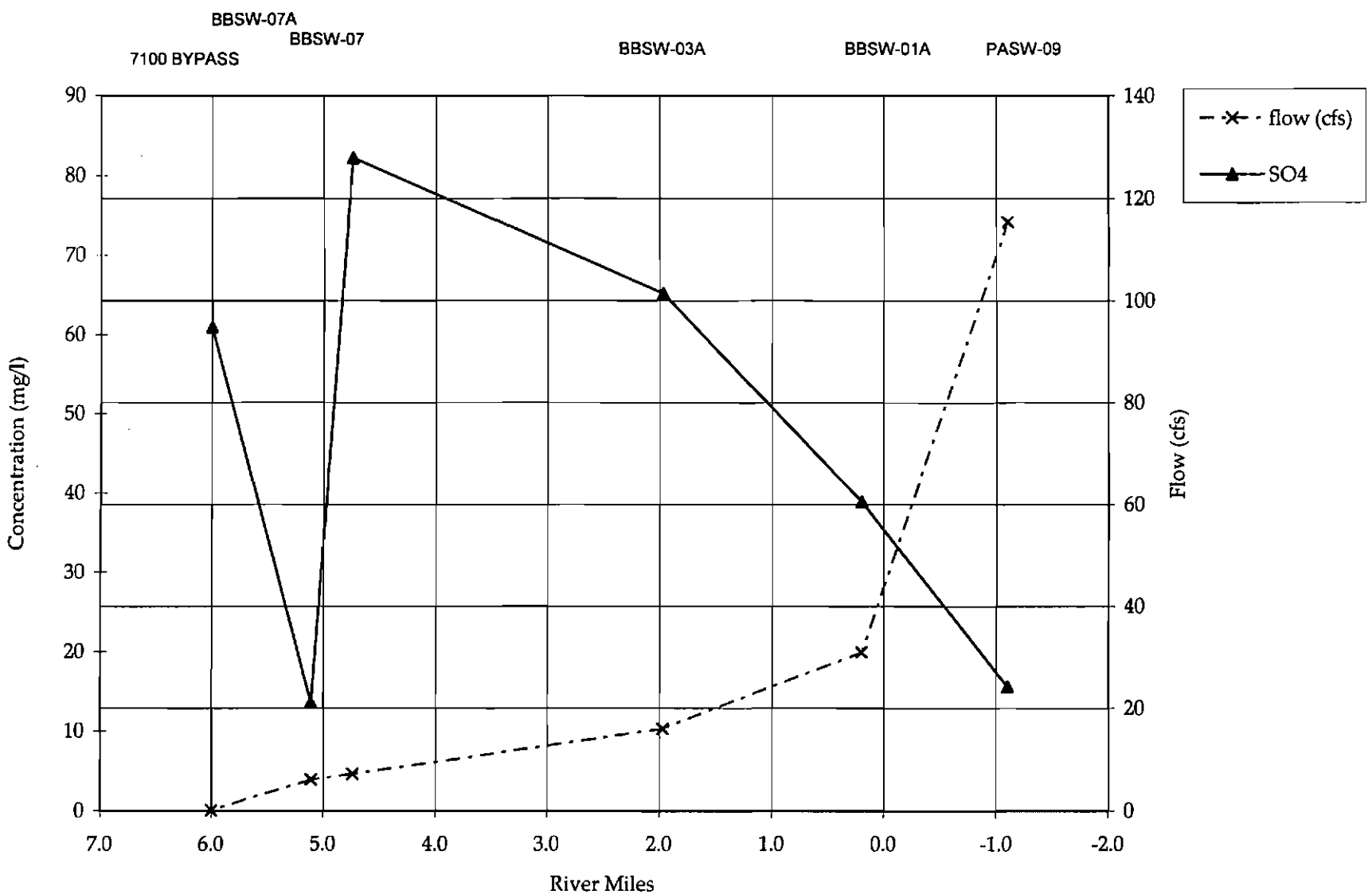

Figure 2-7e

BLACKBIRD CREEK SYNOPTIC SULFATE CONCENTRATION, SPRING 2001

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Note: BBSW-03A data appear to be anomalous

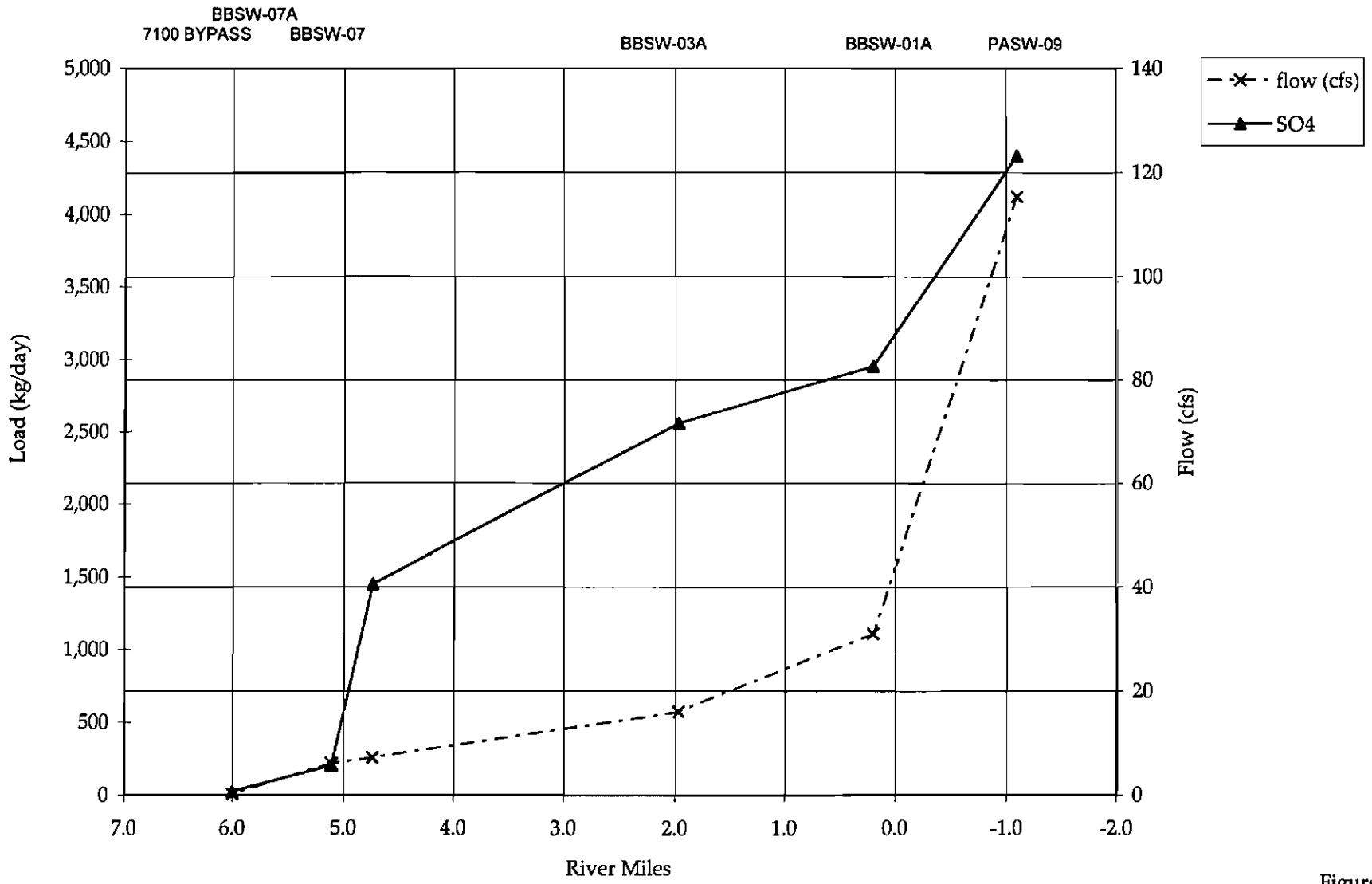

Figure 2-7f
BLACKBIRD CREEK SYNOPTIC SULFATE LOAD, SPRING 2001
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Note: BBSW-03A data appear to be anomalous

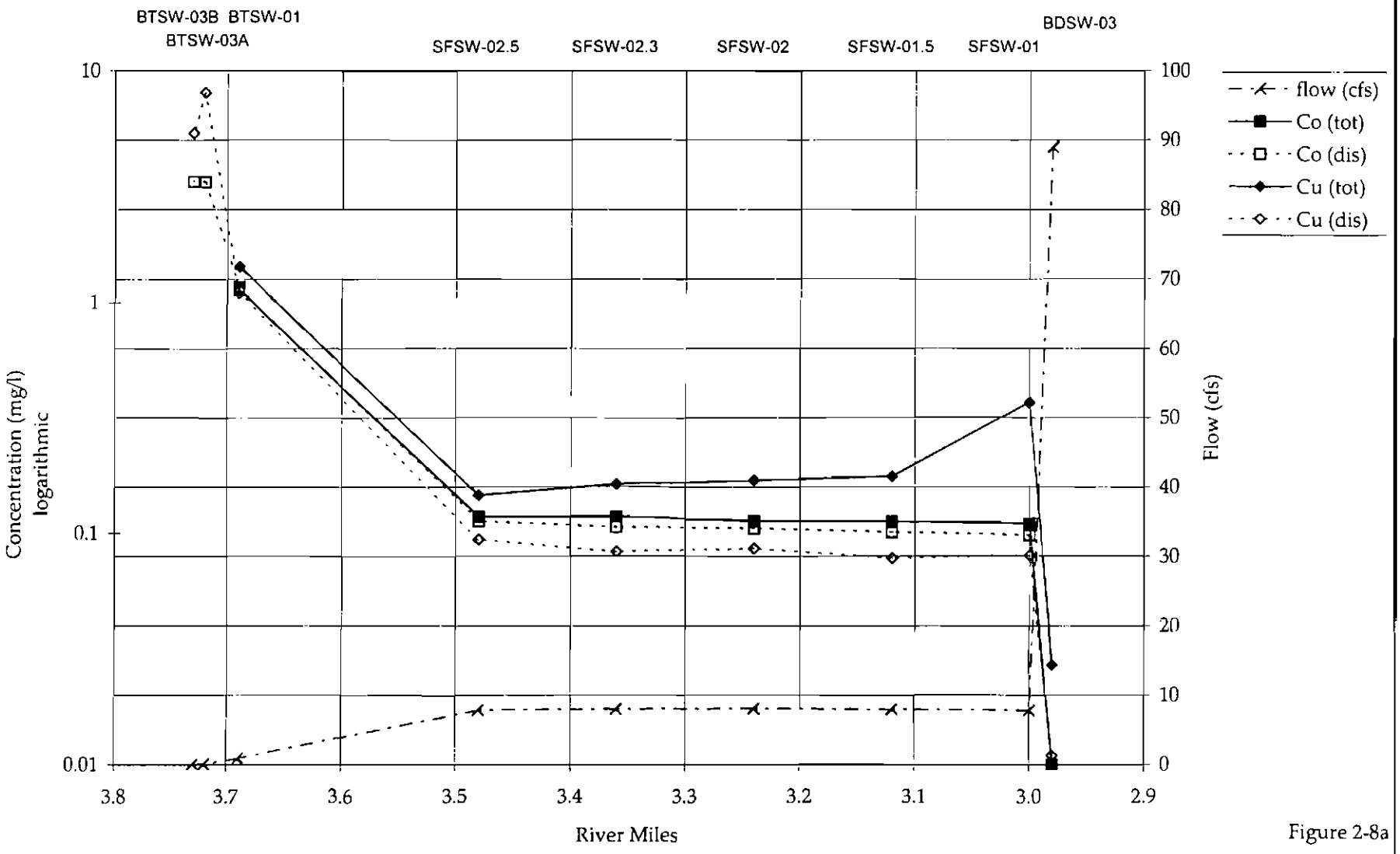


Figure 2-8a

BUCKTAIL CREEK SYNOPTIC COBALT AND COPPER CONCENTRATION SPRING 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

SPRING_BTSYN_01.xls

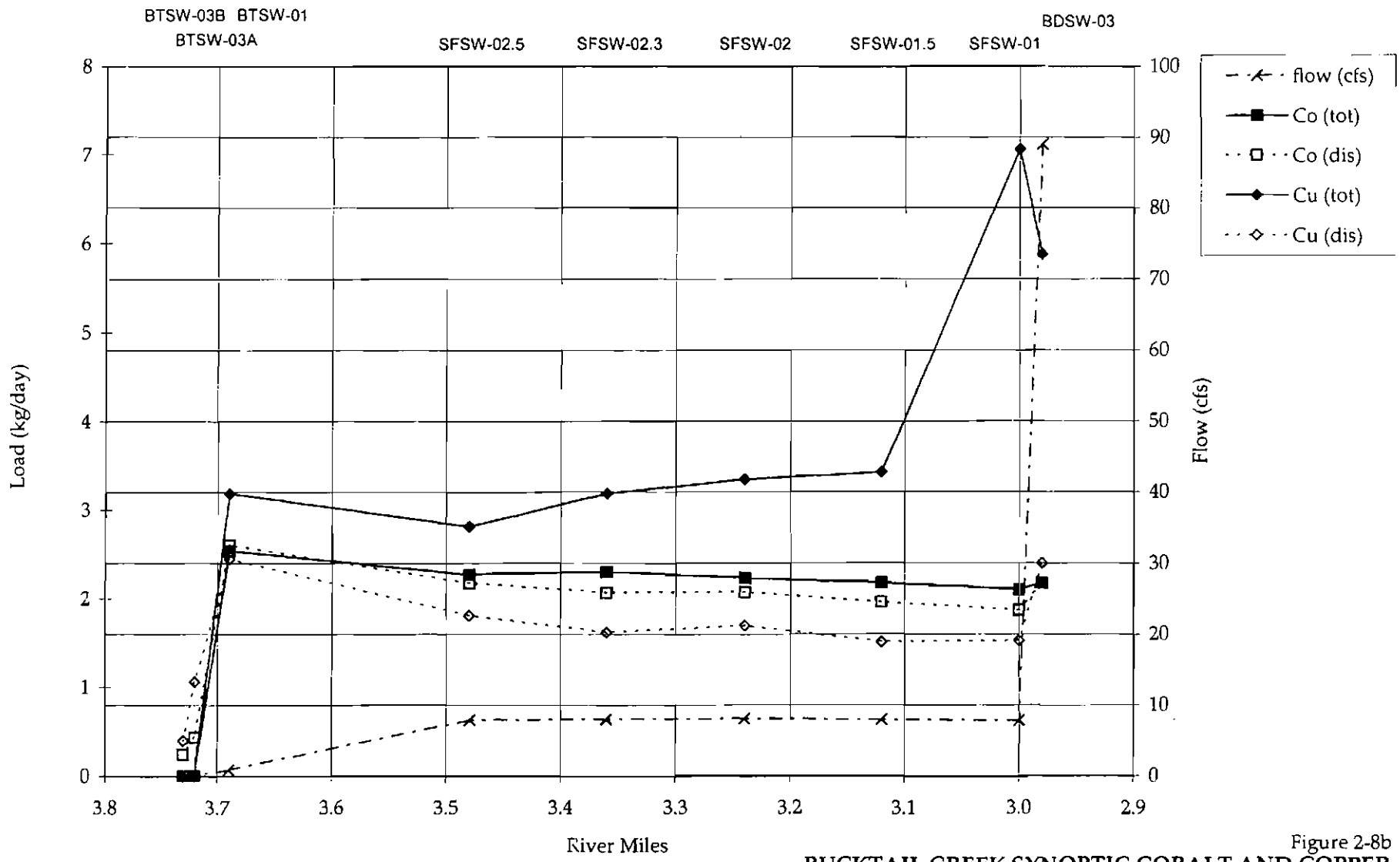


Figure 2-8b

BUCKTAIL CREEK SYNOPTIC COBALT AND COPPER LOADING SPRING 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

SPRING_BTSYN_01.xls

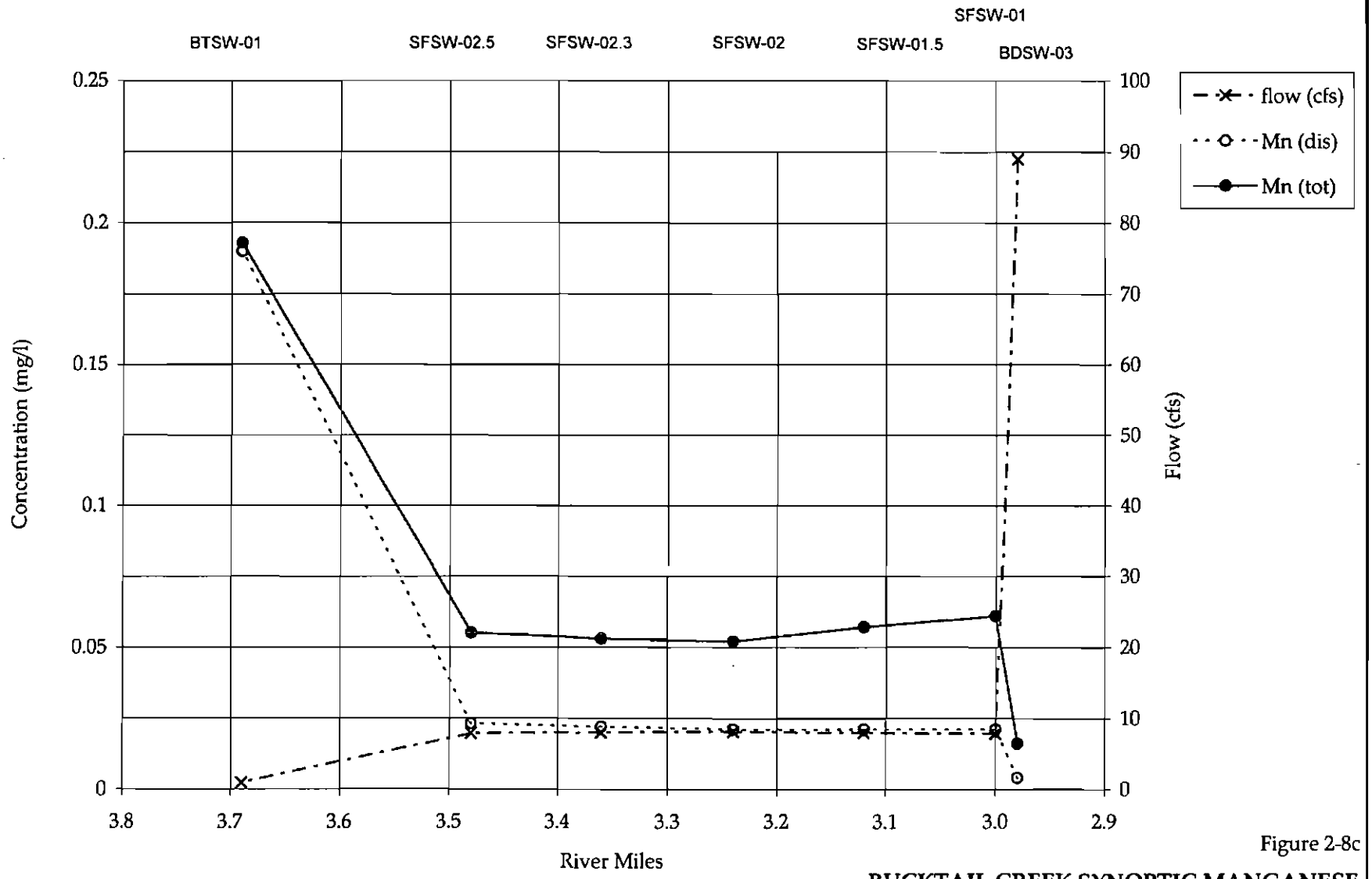


Figure 2-8c

BUCKTAIL CREEK SYNOPTIC MANGANESE CONCENTRATION, SPRING 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

SPRING_BTSYN_01.xls

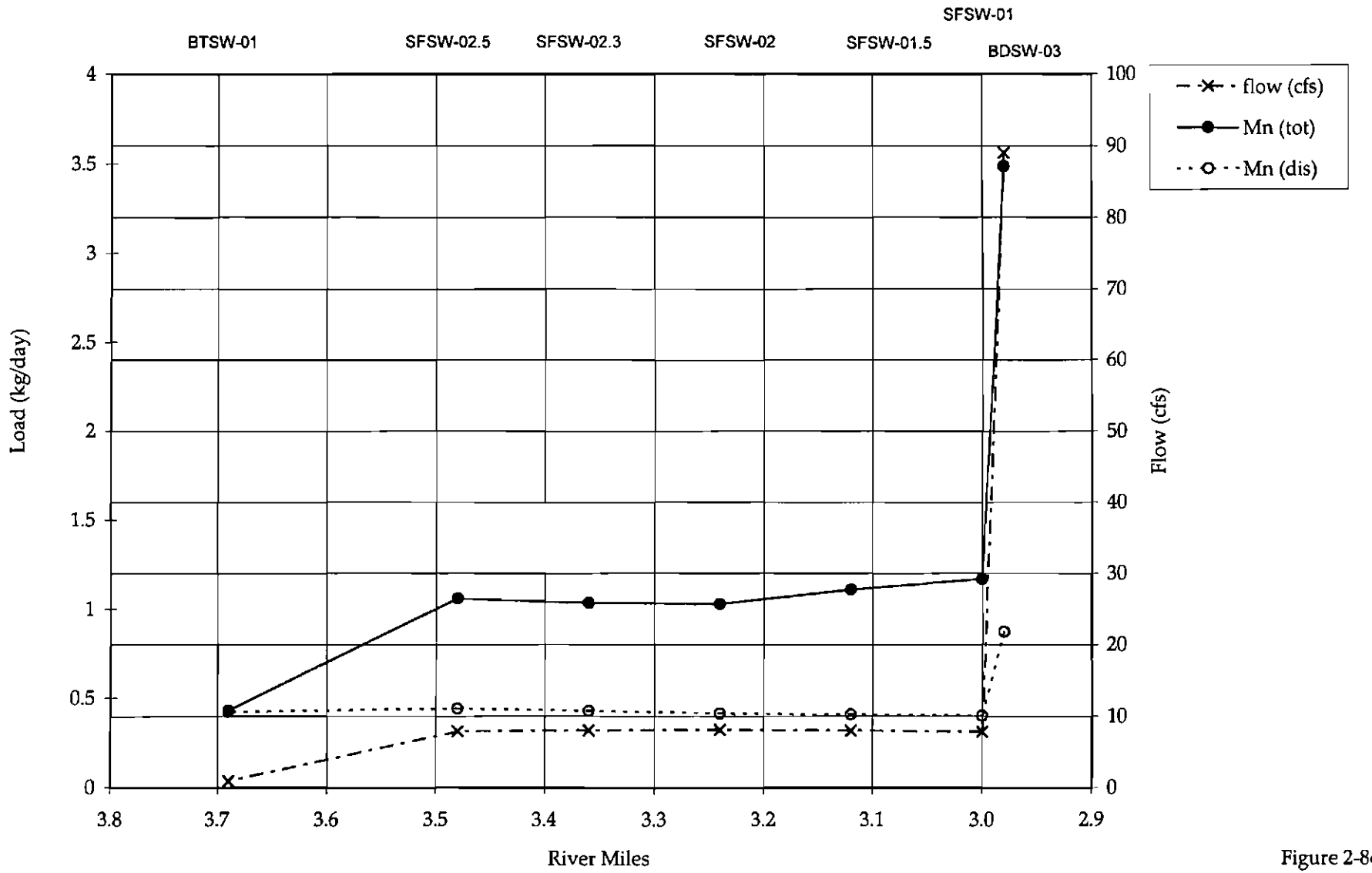


Figure 2-8d

BUCKTAIL CREEK SYNOPTIC MANGANESE LOAD, SPRING 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

SPRING_BTSYN_01.xls

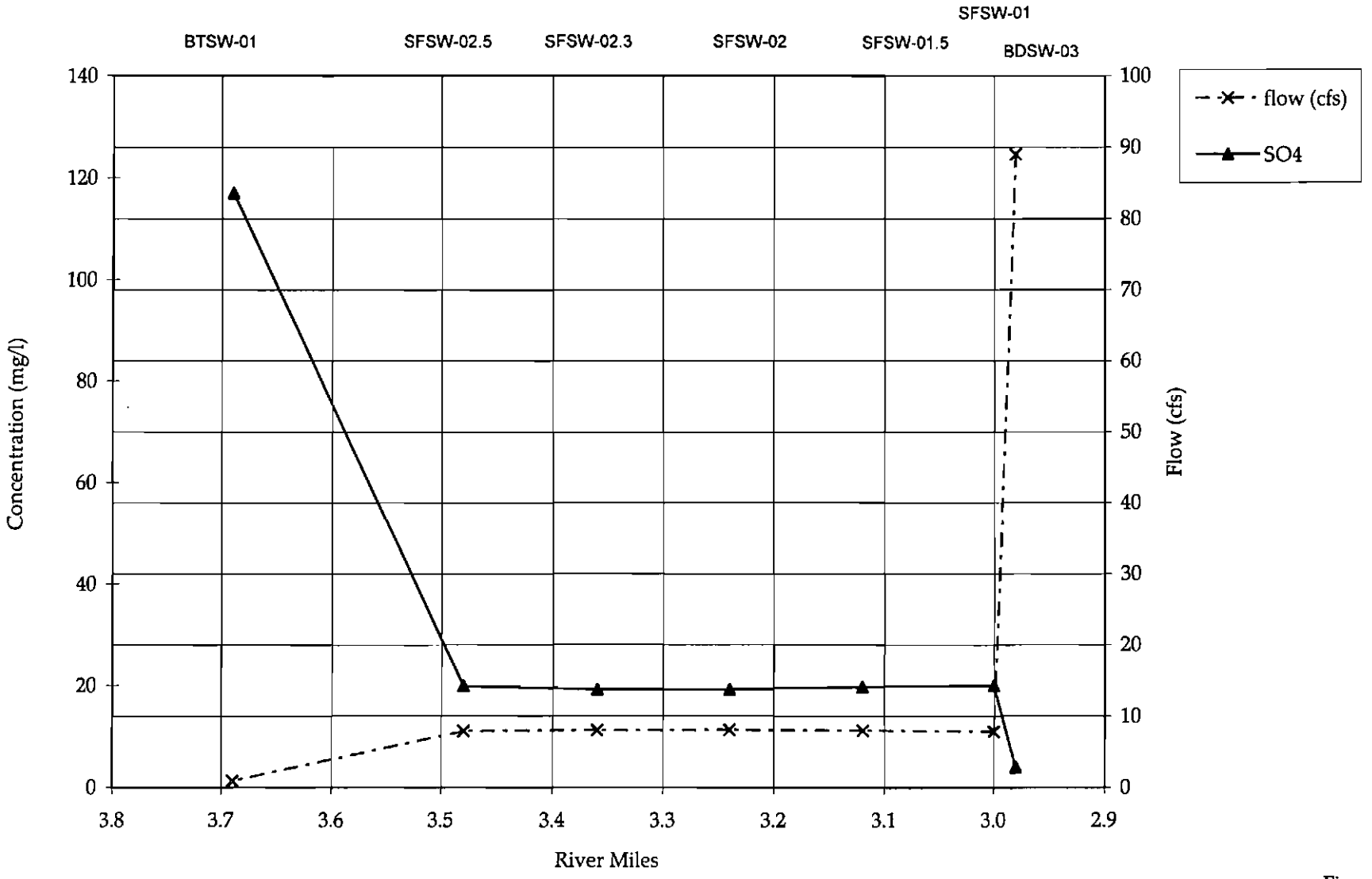


Figure 2-8e

BUCKTAIL CREEK SYNOPTIC SULFATE CONCENTRATION, SPRING 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

SPRING_BTSYN_01.xls

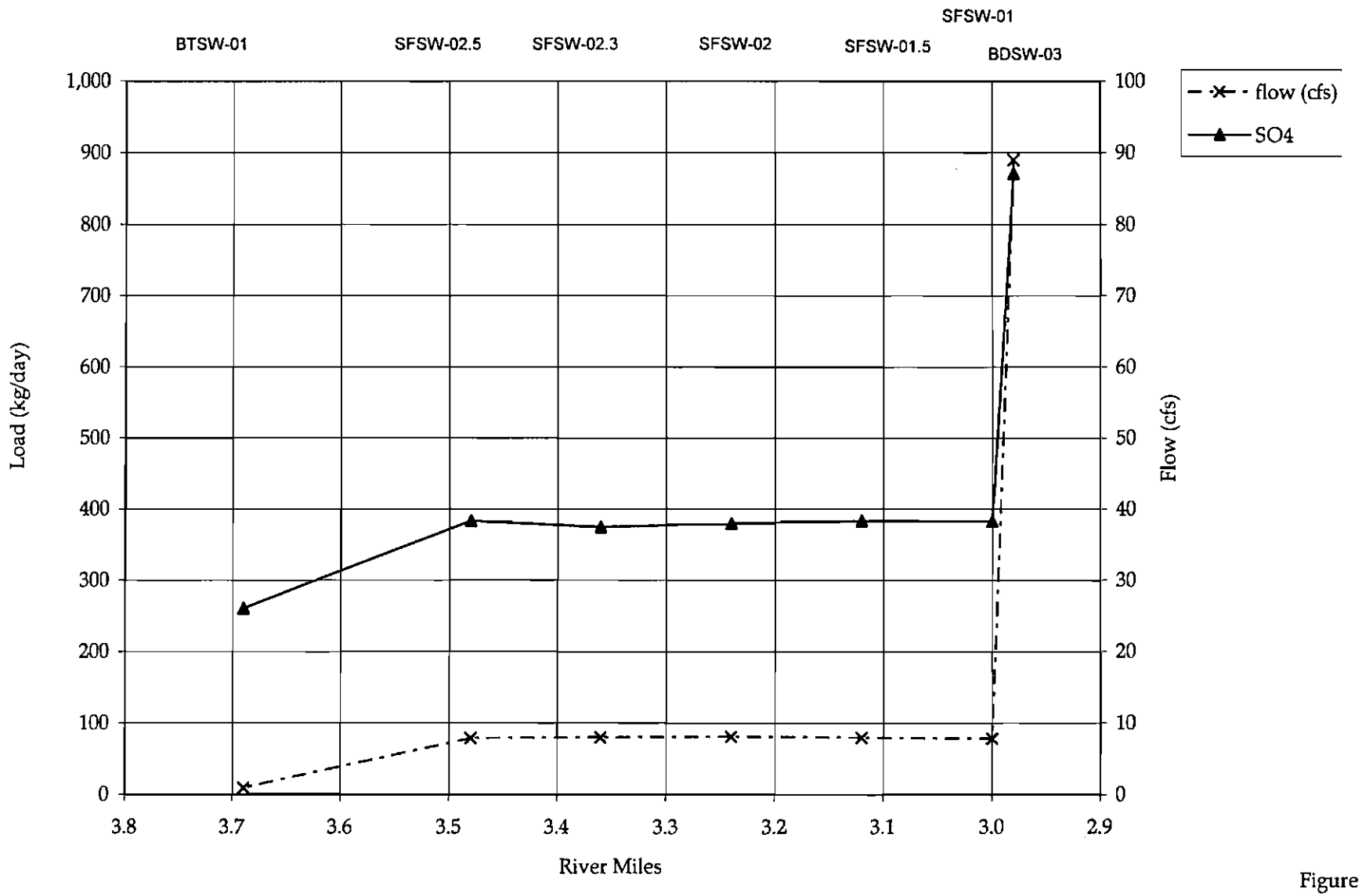


Figure 2-8f

BUCKTAIL CREEK SYNOPTIC SULFATE LOAD, SPRING 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

SPRING_BTSYN_01.xls

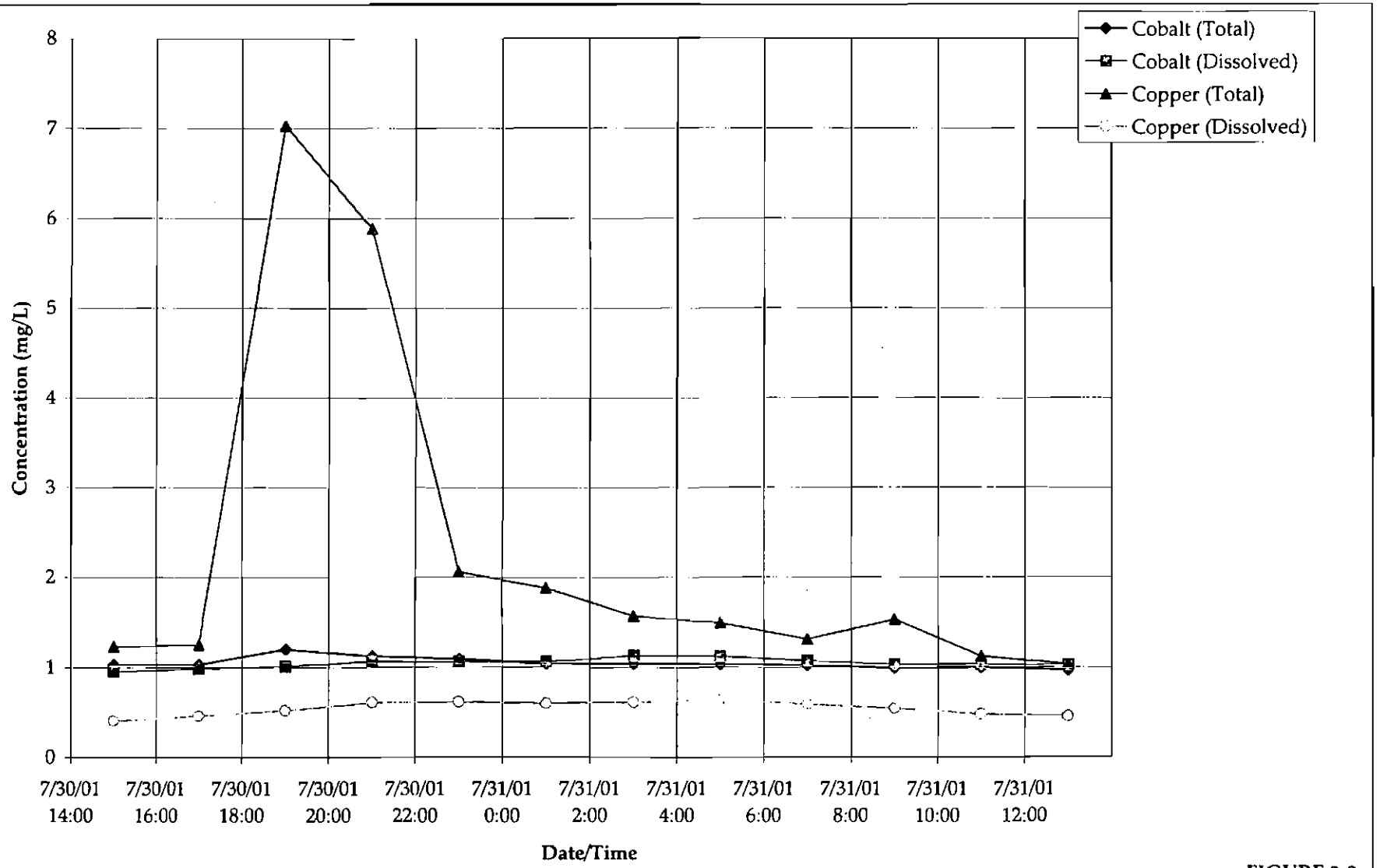


FIGURE 2-9a
STORM EVENT SAMPLING AT BTSW-01.1. IULY 30-31
COBALT AND COPPER CONCENTRATIONS
BMSG/FEASIBILITY STUDY/ID
943-1595-003.9000, 9/28/01, storm_panther creek_weekly summary

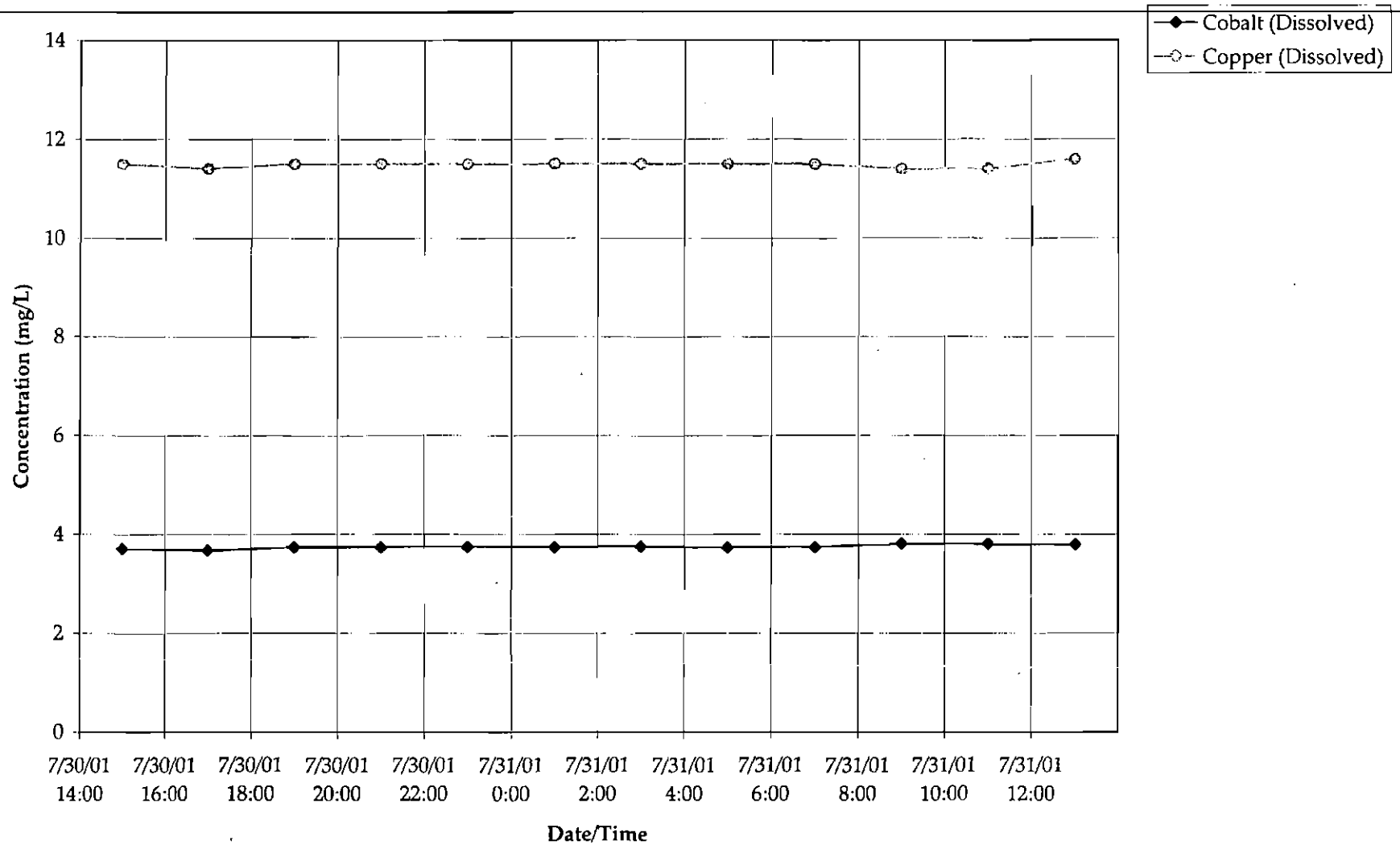


FIGURE 2-9b

STORM EVENT SAMPLING AT BTSW-02, JULY 30-31

COBALT AND COPPER CONCENTRATIONS

BMSG/FEASIBILITY STUDY/ID

943-1595-003.9000, 9/28/01, storm panther

Golder Associates

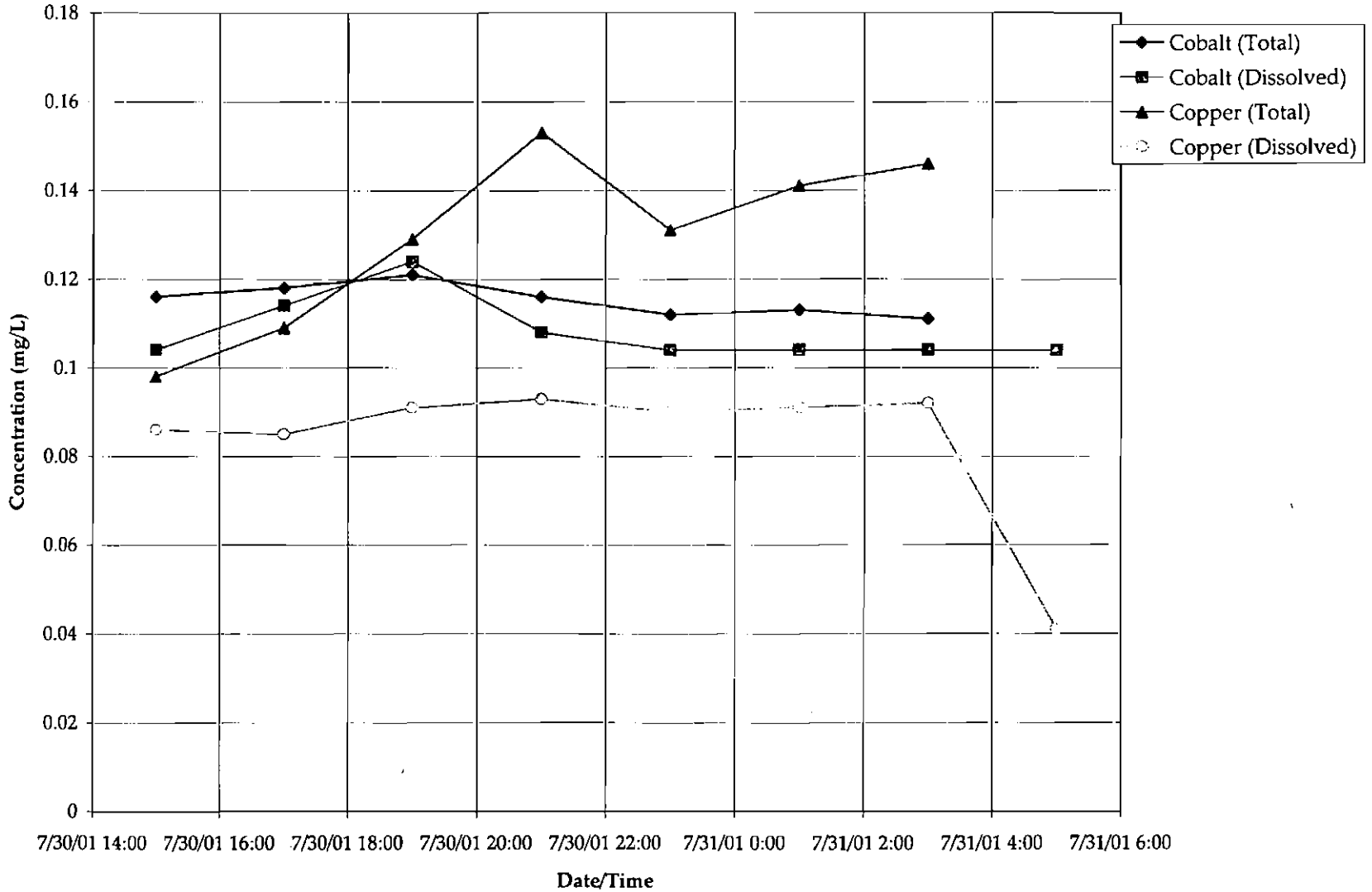


FIGURE 2-9c
STORM EVENT SAMPLING AT SFSW-01, JULY 30-31
COBALT AND COPPER CONCENTRATIONS
BMSG/FEASIBILITY STUDY/ID
943-1595-003.9000, 9/28/01, storm_pantther creek_weekly summary

Golder Associates

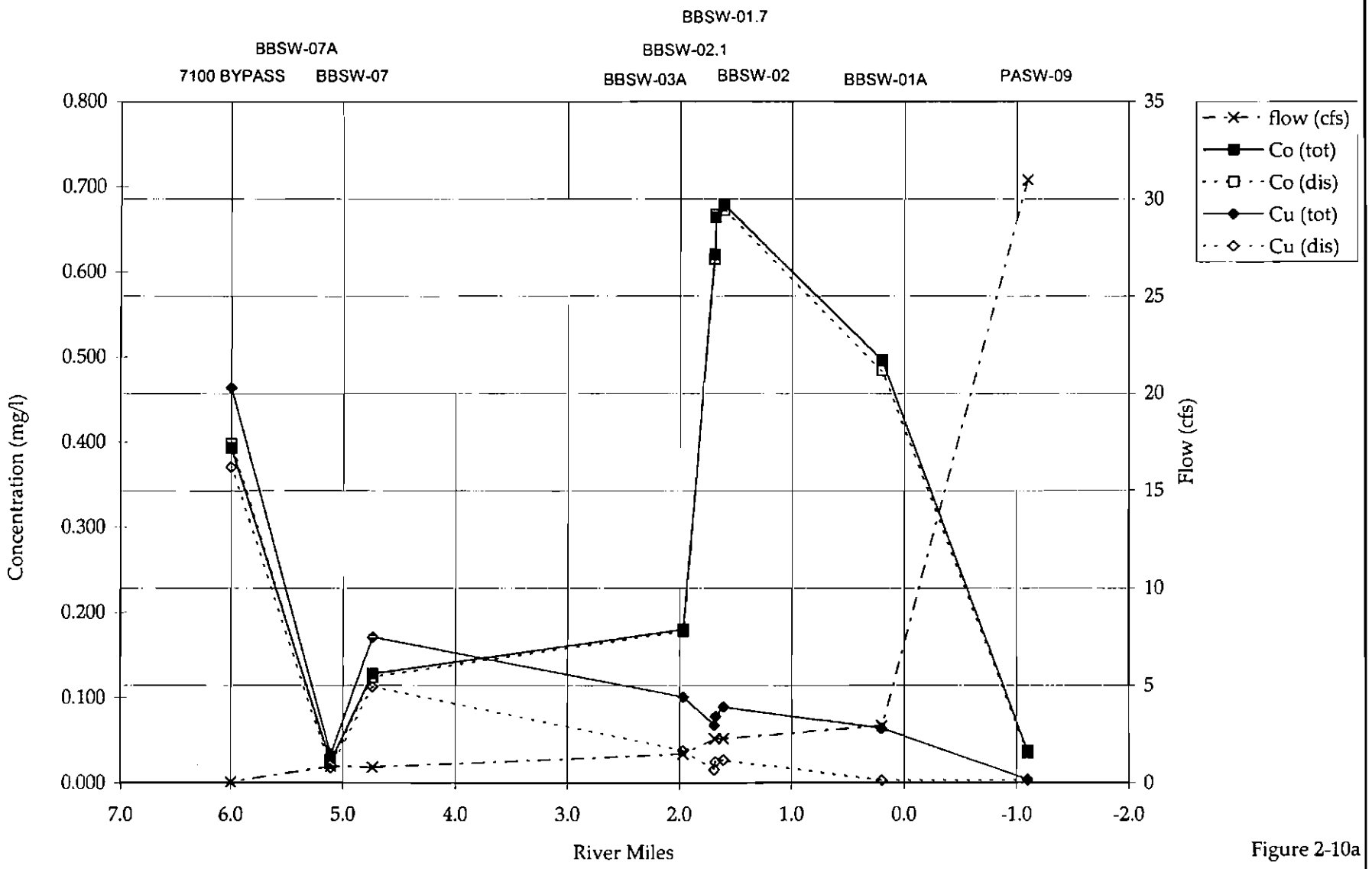


Figure 2-10a

BLACKBIRD CREEK SYNOPTIC COBALT AND COPPER CONCENTRATION FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE

FALL_BBSYN_01.xls

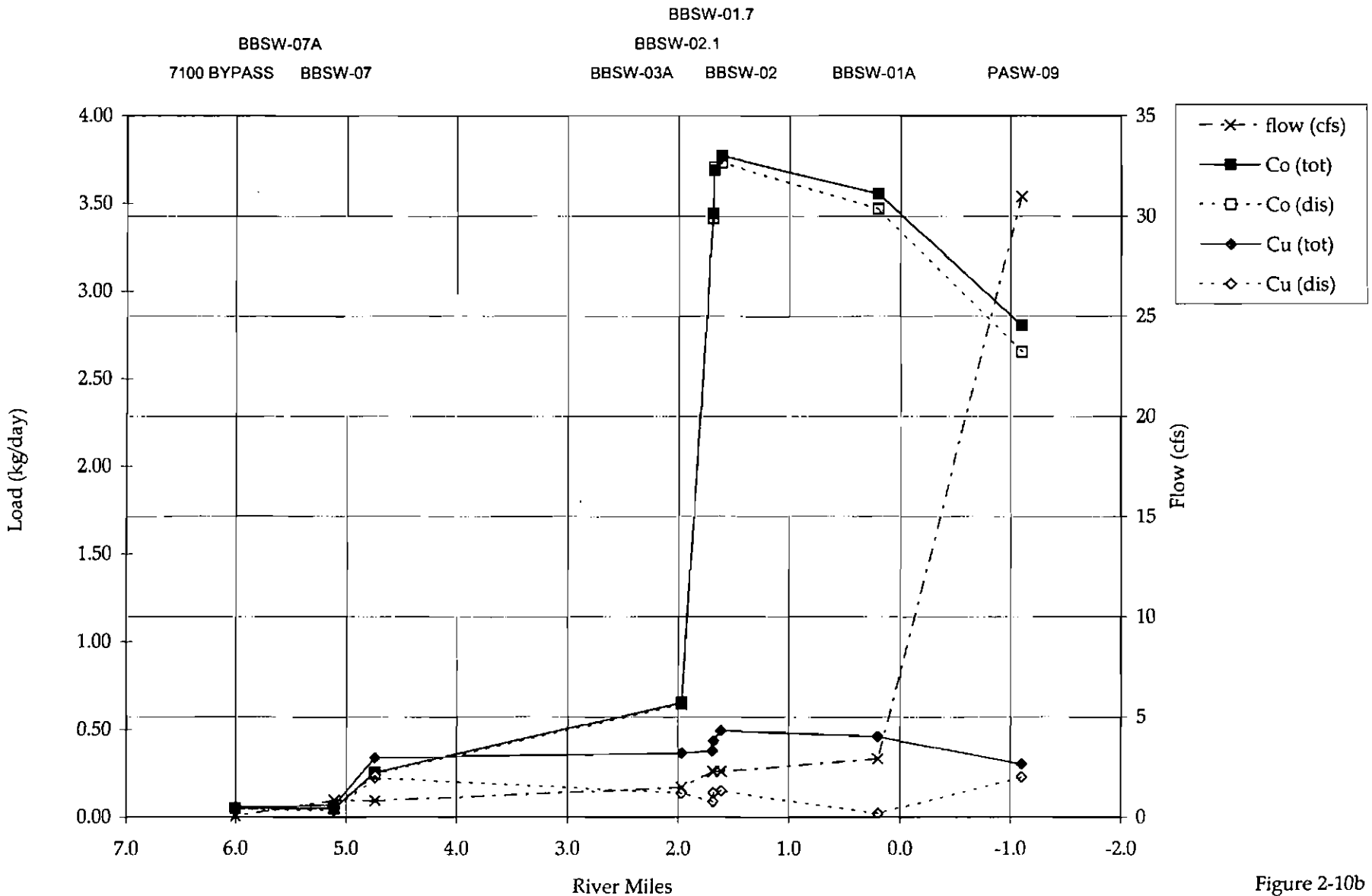


Figure 2-10b

BLACKBIRD CREEK SYNOPTIC COBALT AND COPPER LOADING FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE

FALL_BBSYN_01.xls

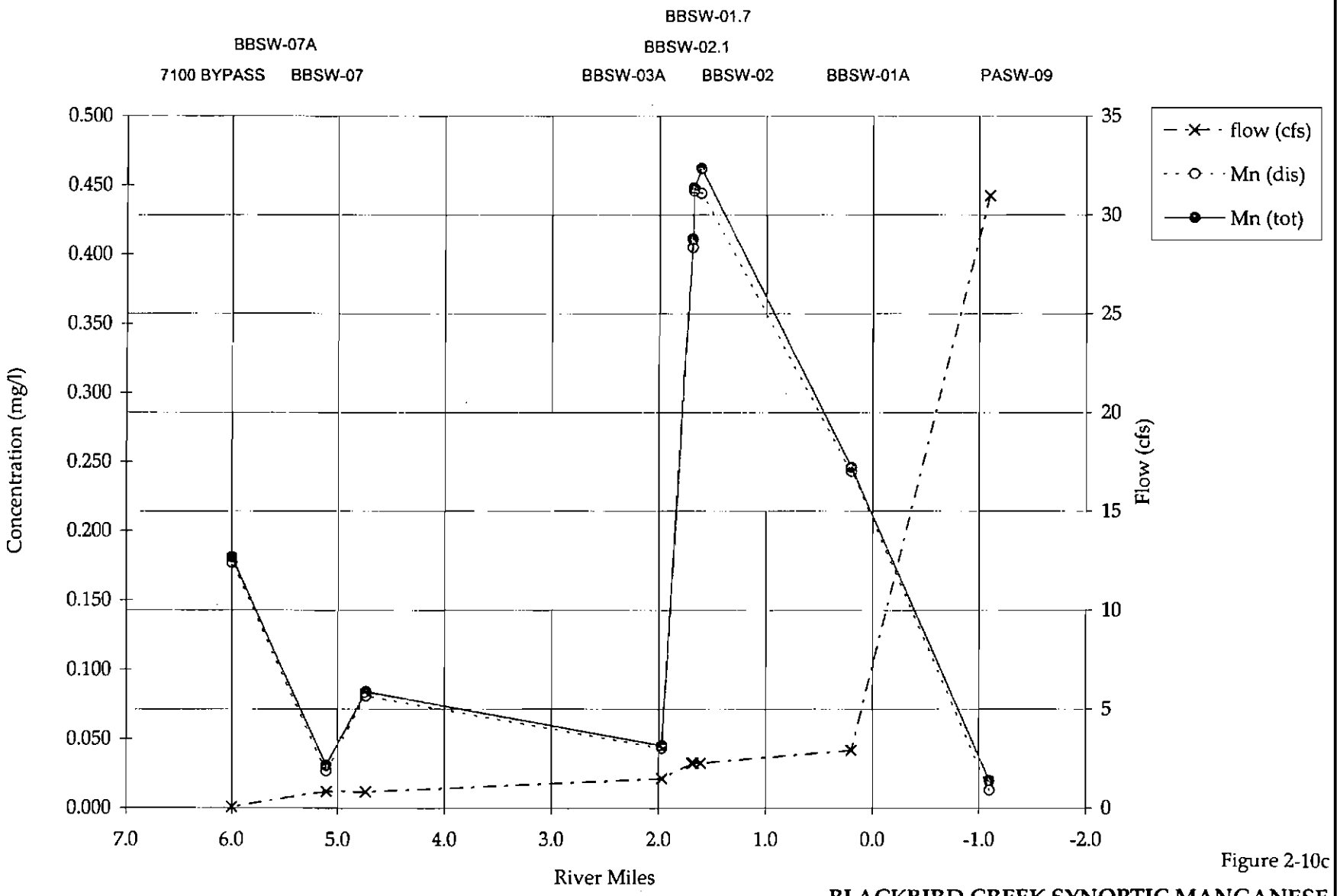


Figure 2-10c

BLACKBIRD CREEK SYNOPTIC MANGANESE CONCENTRATION, FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE

FALL_BBSYN_01.xls

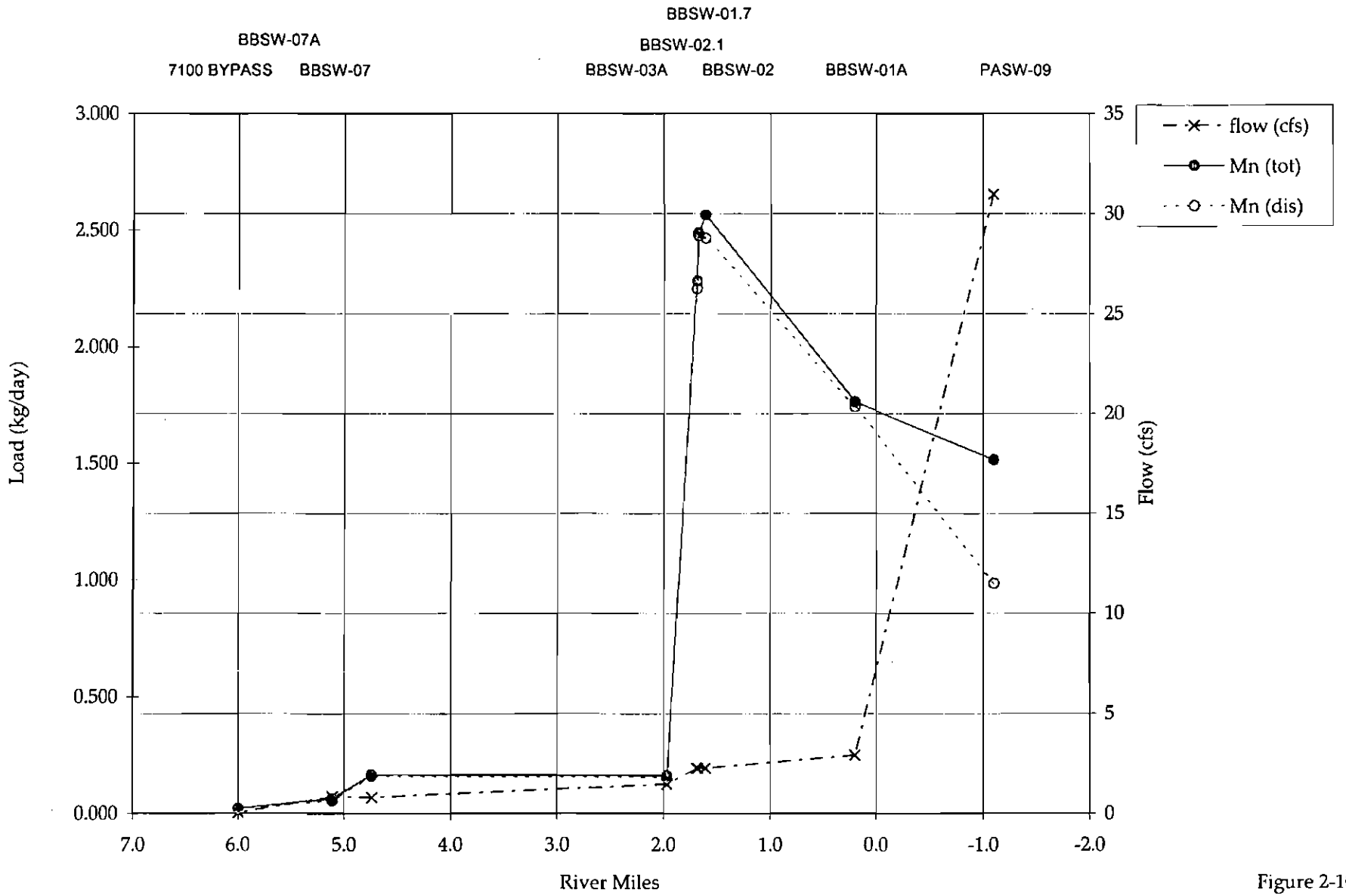


Figure 2-10d

BLACKBIRD CREEK SYNOPTIC MANGANESE LOAD, FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE

FALL_BBSYN_01.xls

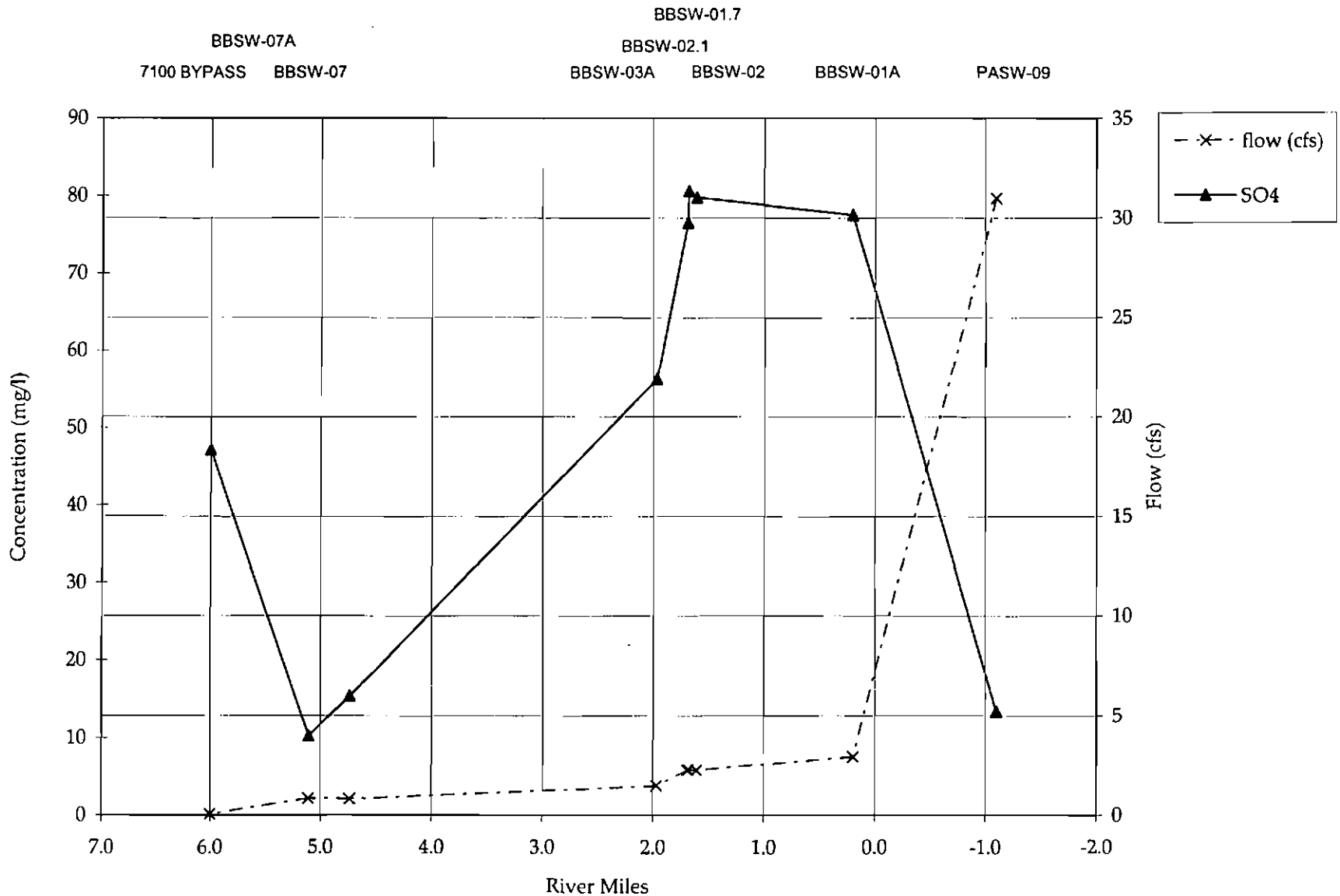


Figure 2-10e

BLACKBIRD CREEK SYNOPTIC SULFATE CONCENTRATION, FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE

FALL_BBSYN_01.xls

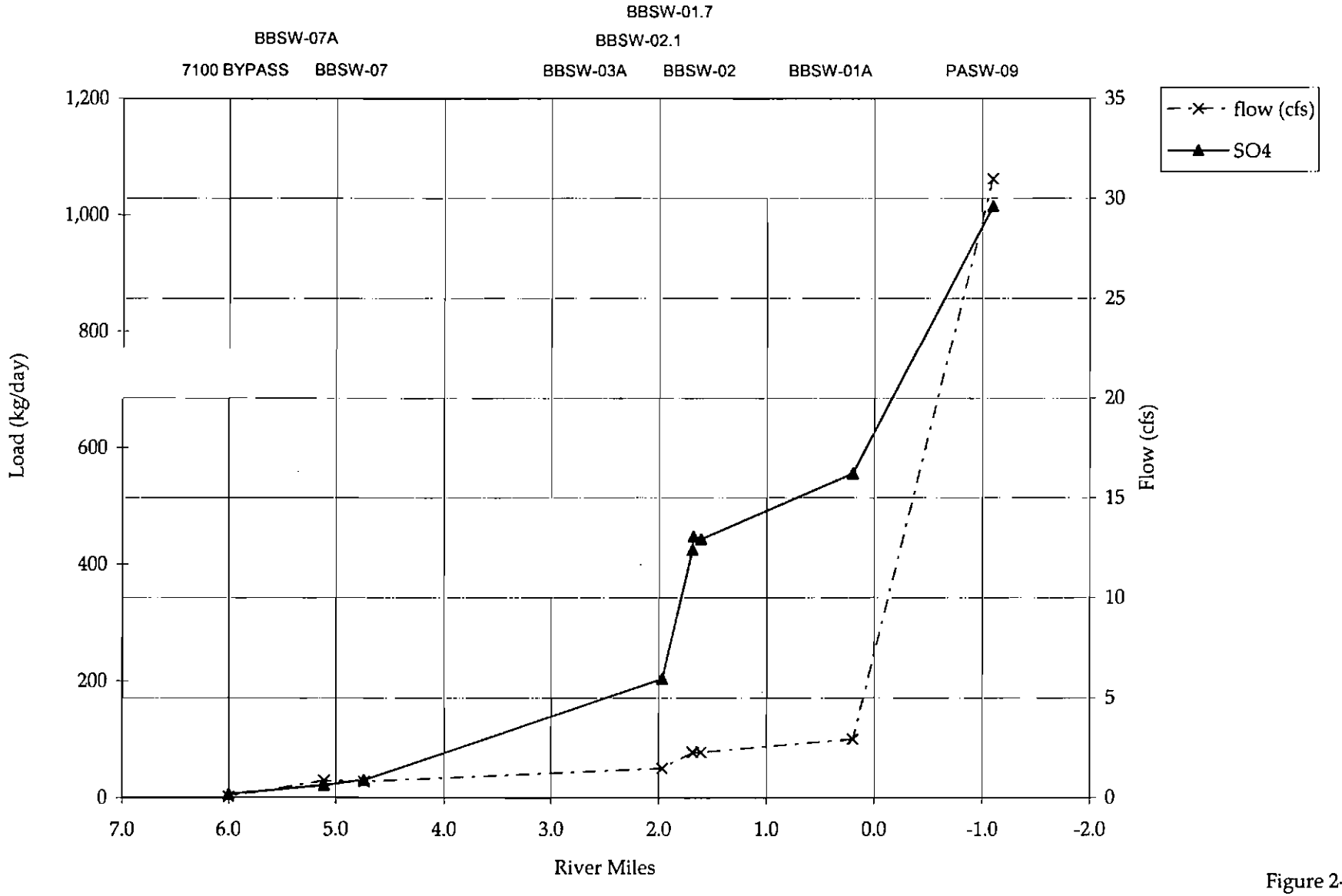


Figure 2-10f
BLACKBIRD CREEK SYNOPTIC SULFATE LOAD, FALL 2001
FEASIBILITY STUDY/BLACKBIRD MINE
FALL_BBSYN_01.xls

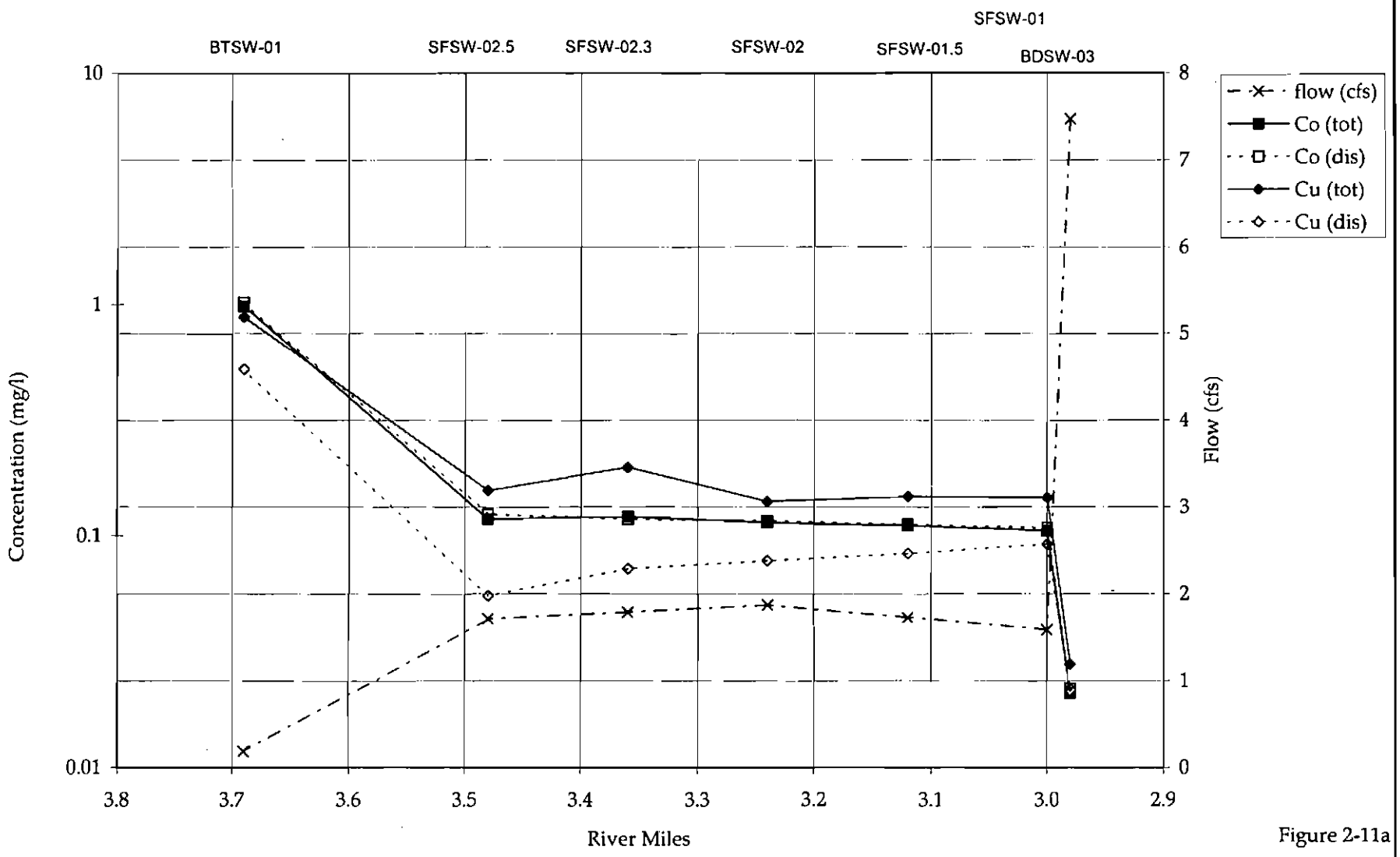


Figure 2-11a

BUCKTAIL CREEK SYNOPTIC COBALT AND COPPER CONCENTRATION FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

FALL_BTSYN_01.xls

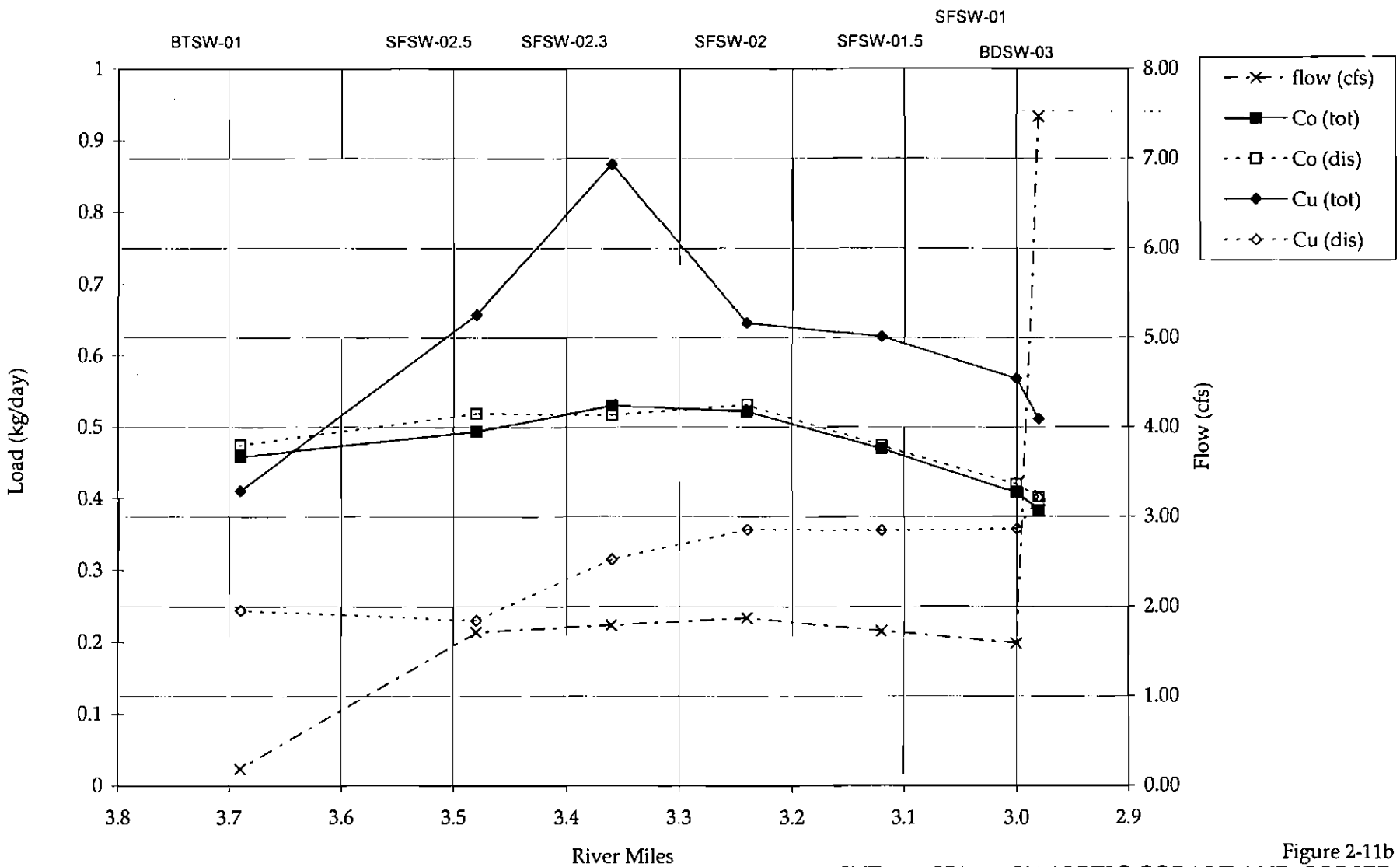


Figure 2-11b

BUCKTAIL CREEK SYNOPTIC COBALT AND COPPER LOADING FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

FALL_BTSYN_01.xls

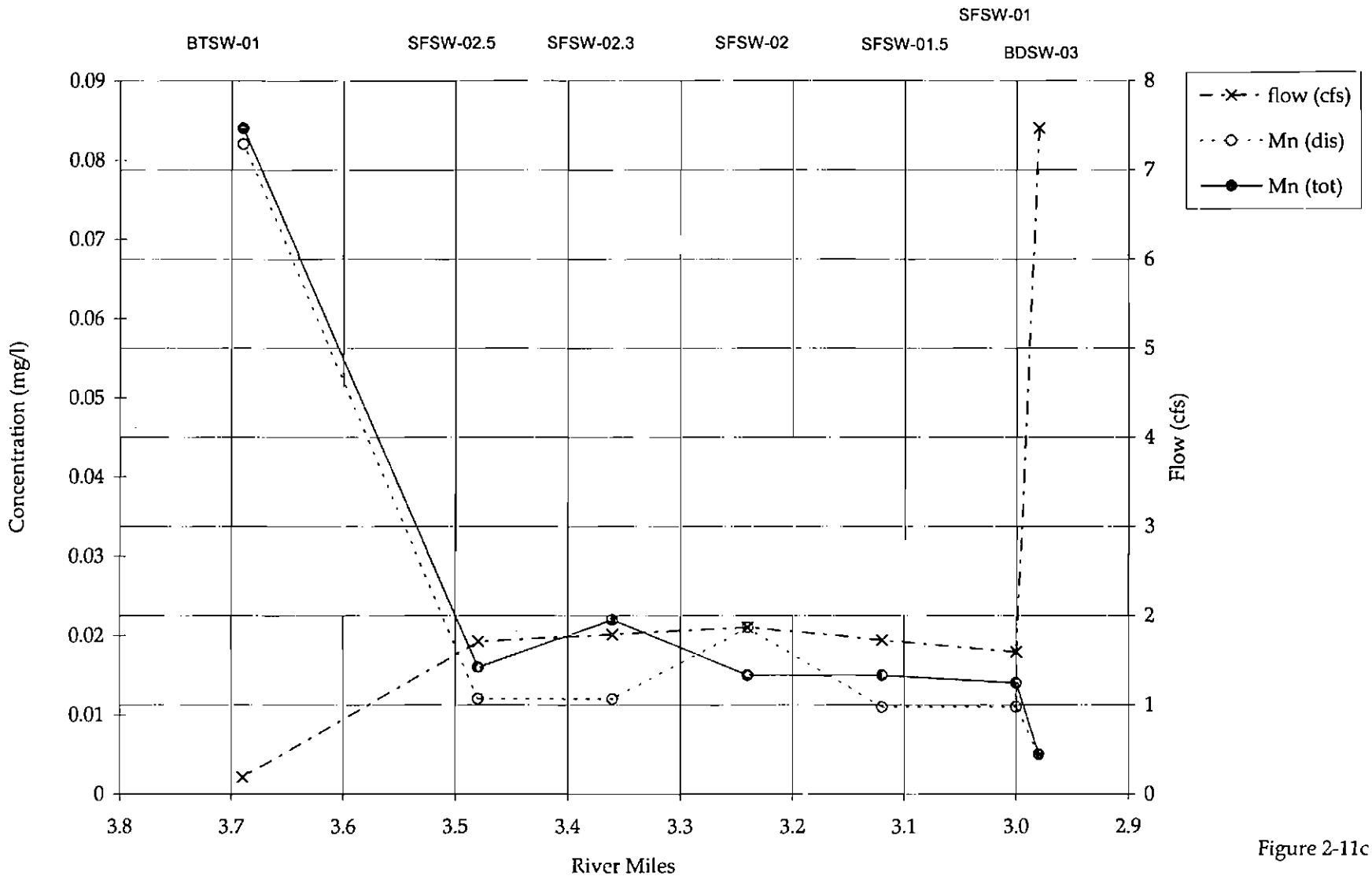


Figure 2-11c

BUCKTAIL CREEK SYNOPTIC MANGANESE CONCENTRATION, FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

FALL_BTSYN_01.xls

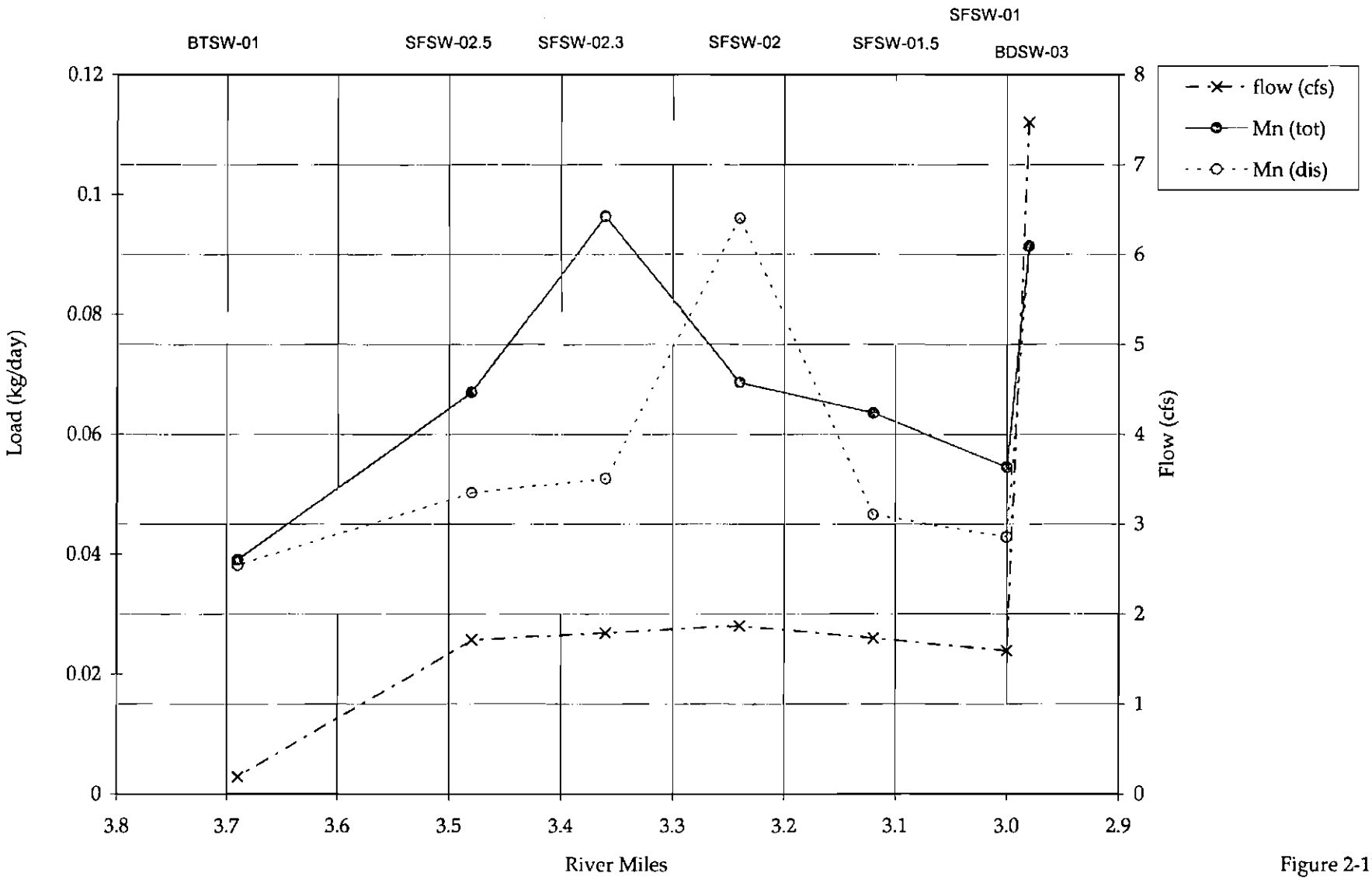


Figure 2-11d

BUCKTAIL CREEK SYNOPTIC MANGANESE LOAD, FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

FALL_BTSYN_01.xls

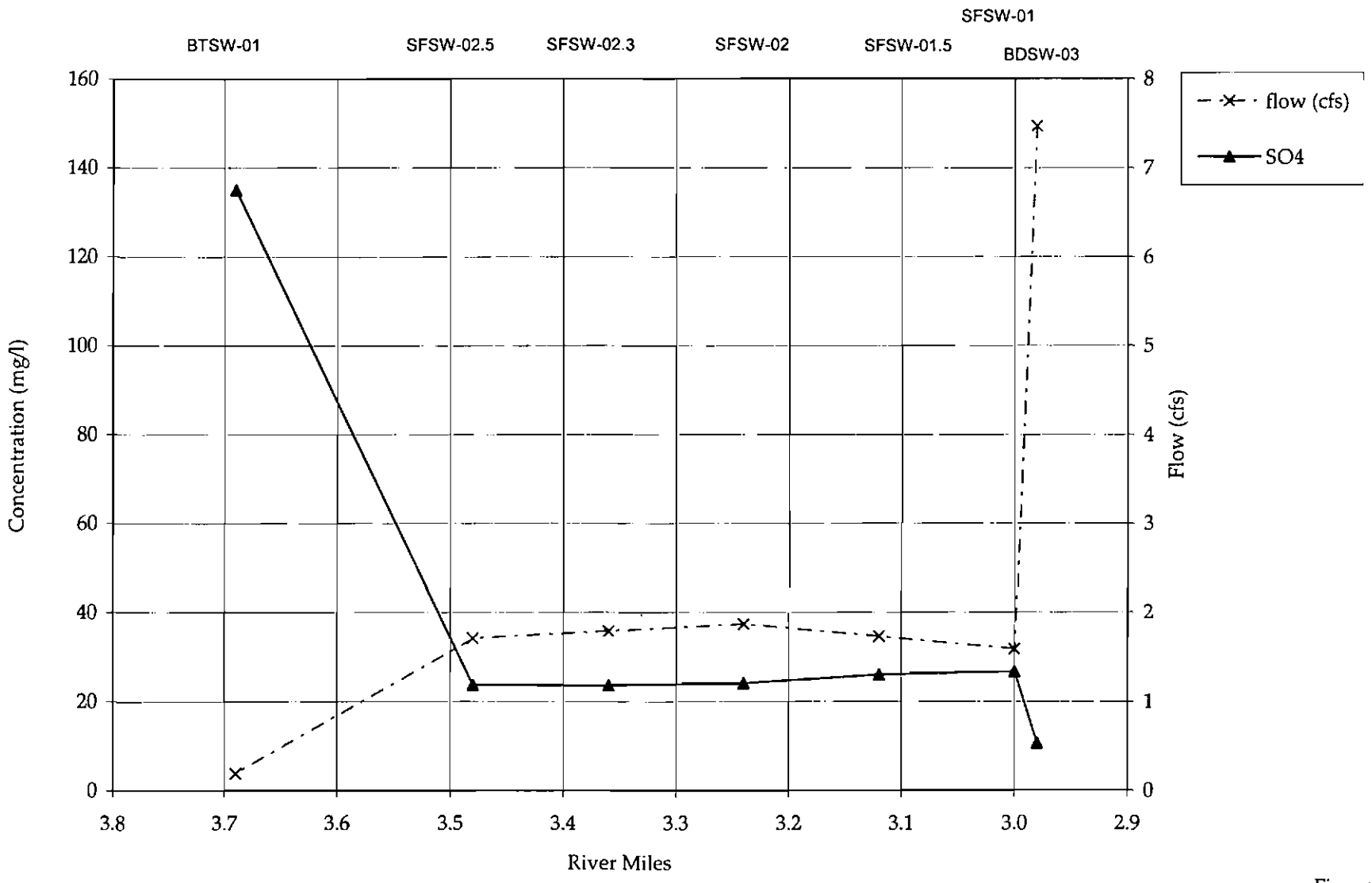


Figure 2-11e

BUCKTAIL CREEK SYNOPTIC SULFATE CONCENTRATION, FALL 2001

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

FALL_BTSYN_01.xls

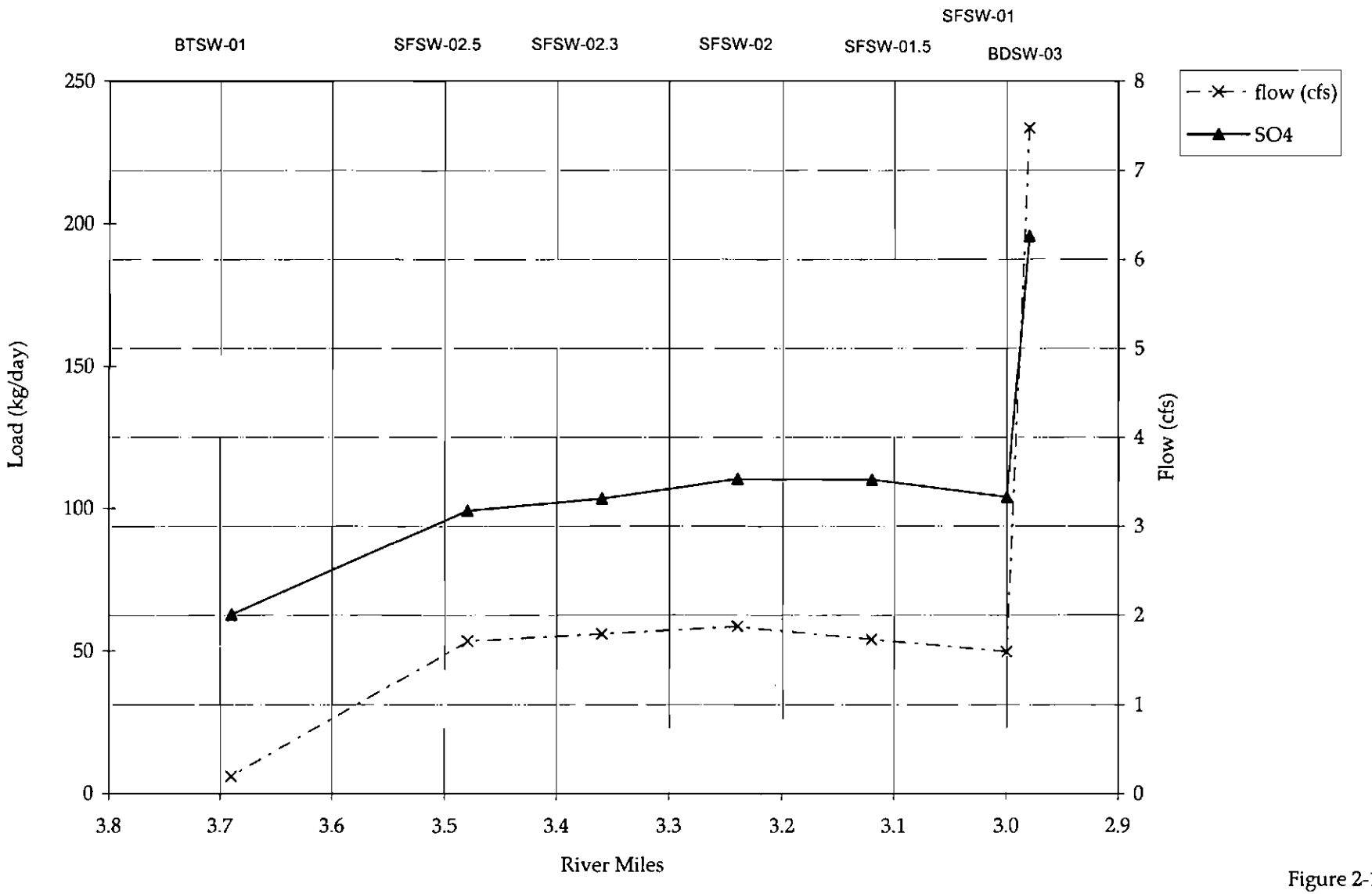
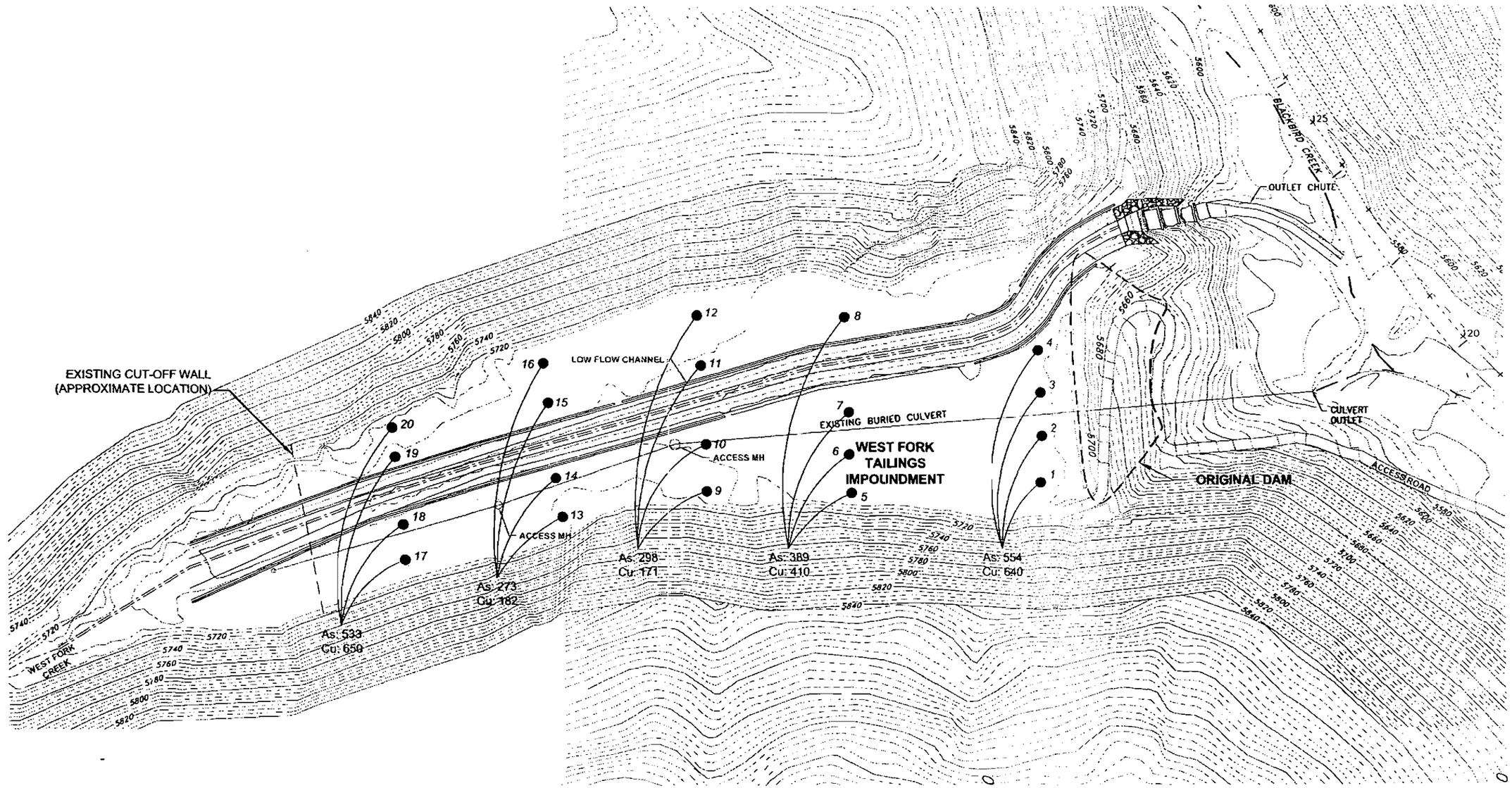


Figure 2-11f
BUCKTAIL CREEK SYNOPTIC SULFATE LOAD, FALL 2001
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
FALL_BTSYN_01.xls



LEGEND

● 12 — DISCRETE SOIL SAMPLE LOCATION
DISCRETE SAMPLE ID

COMPOSITED SAMPLE RESULT

As: 533 — ARSENIC CONCENTRATION (mg/kg)
Cu: 650 — COPPER CONCENTRATION (mg/kg)

N

0 200 400
FEET

FIGURE 2-12
WEST FORK TAILINGS IMPOUNDMENT-SURFACE SOIL SAMPLING LOCATIONS
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

DCabe|K:\Projects\1994\9431595\x003\8100\94315950038100F01b.dwg|4-24-2 12:05|x:Xr-Base-West_Fork|i.-

Golder Associates

Figure 3-1
Panther Creek Sediment Metal Concentrations
(1995 and 2000)

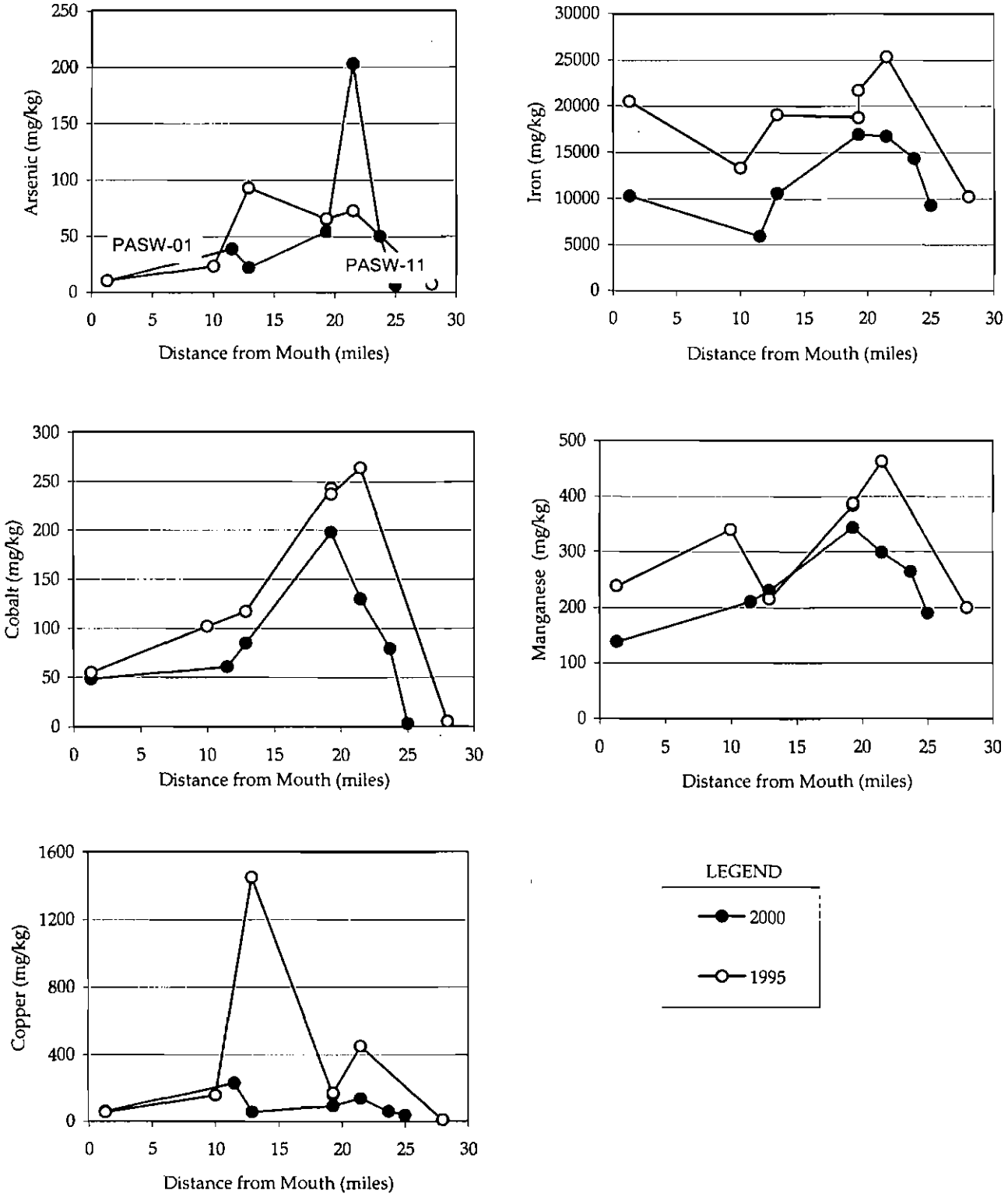
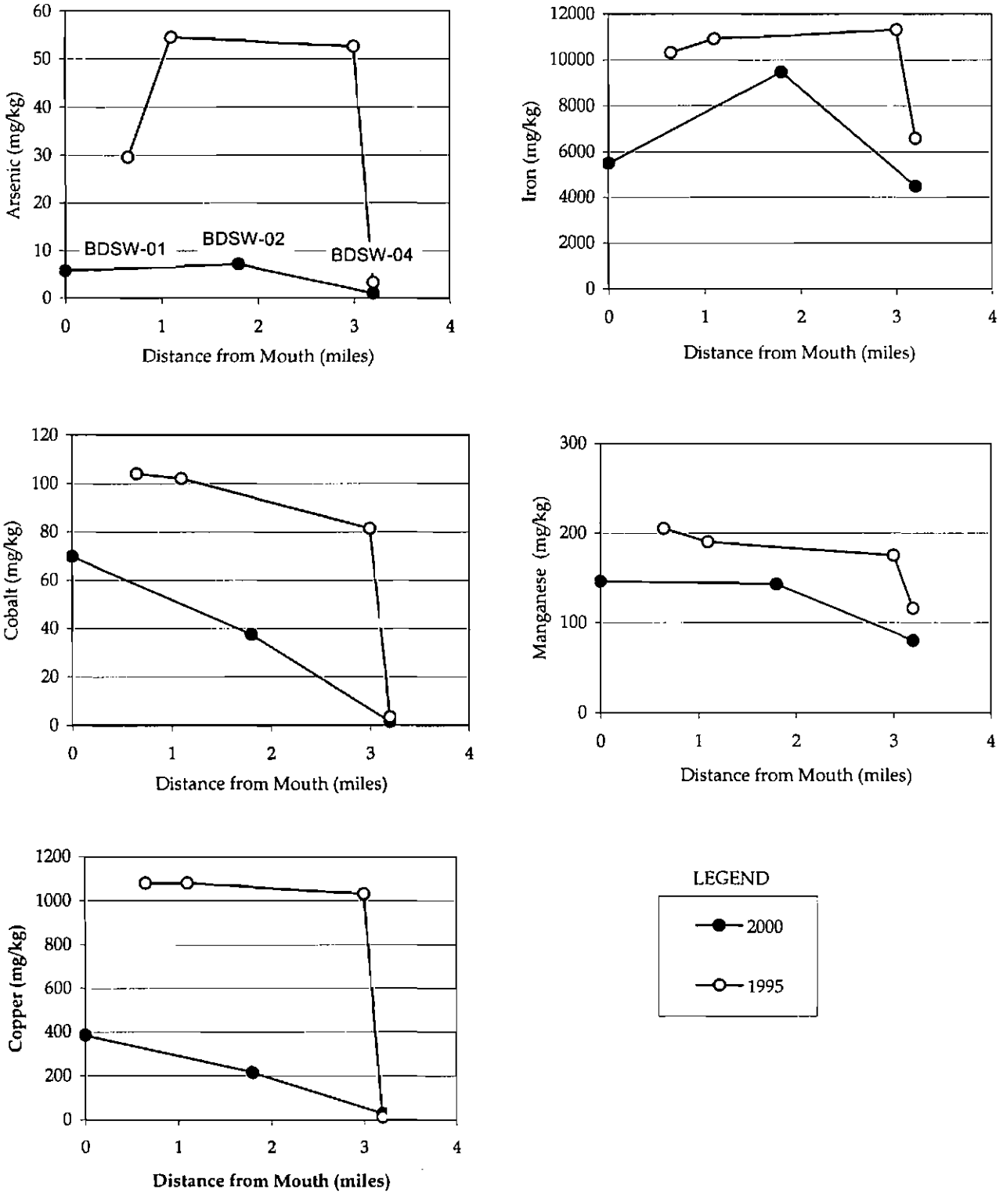


Figure 3-2
Big Deer Creek Sediment Metal Concentrations
(1995 and 2000)



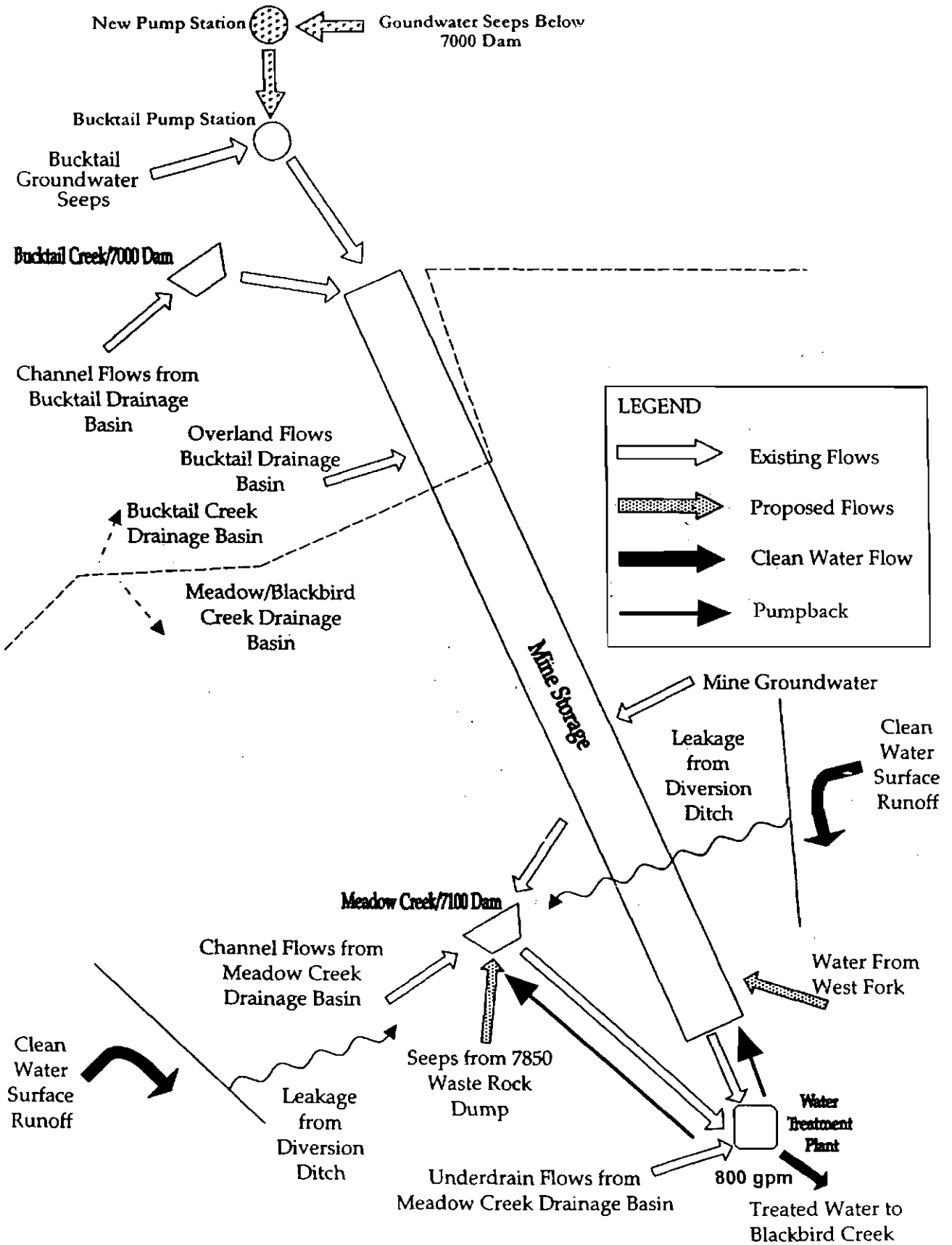


FIGURE **6-1**

FLOW DIAGRAM FOR WASTEWATER TREATMENT STORAGE

FEASIBILITY STUDY/BLACKBIRD MINE/ID

PROJECT NO.943 1595x003_9000 DRAWING NO. 96923 DATE 12/26/01 DRAWN BY JSR

Golder Associates

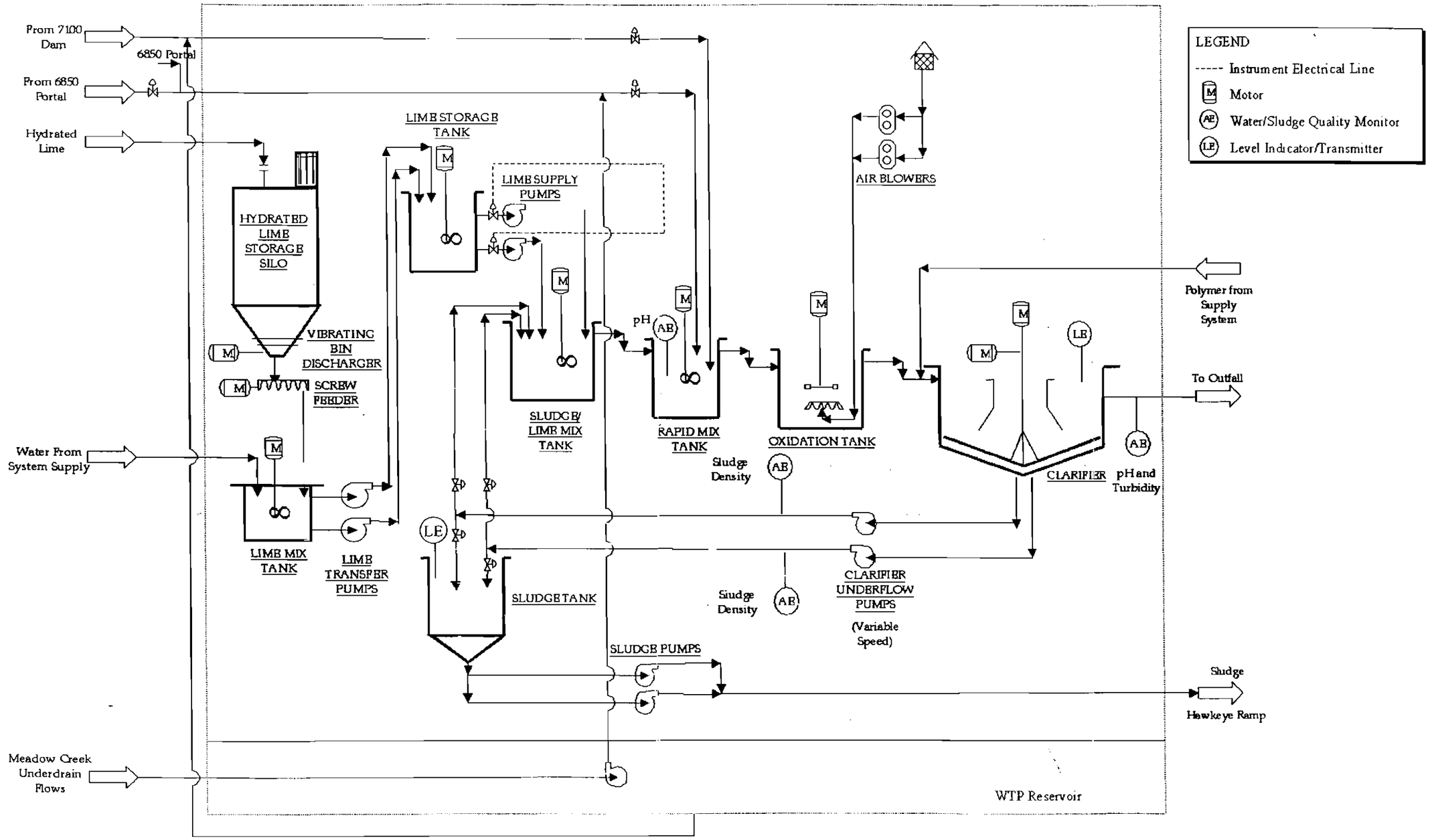


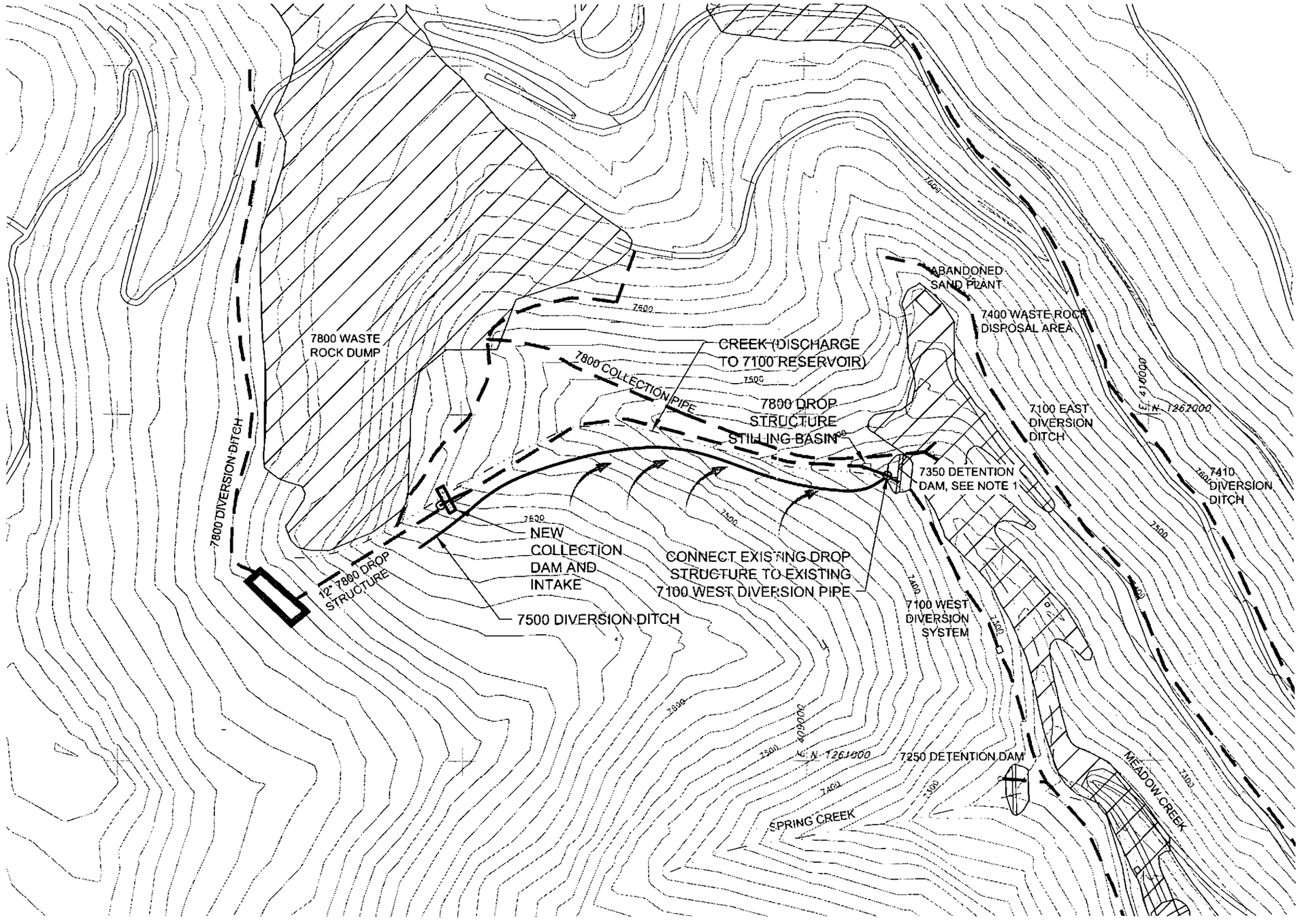
FIGURE **6-2**

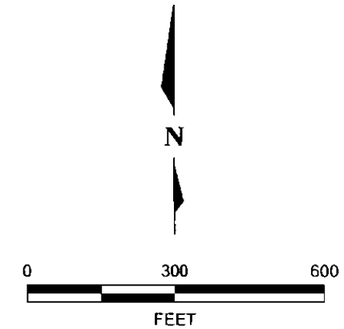
PROCESS FLOW DIAGRAM FOR EXISTING WASTEWATER TREATMENT PLANT

FEASIBILITY STUDY/BLACKBIRD MINE/ID

PROJECT NO. 943 1595 x003_9200 DRAWING NO 96911a DATE 2/22/02 DRAWN BY JSR

Golder Associates





LEGEND

- WASTE ROCK
- 40 FT CONTOUR
- DIVERSION DITCH (ARROW INDICATES DIRECTION OF FLOW)
- DROP STRUCTURE (PIPE)
- DROP INLET STRUCTURE

NOTES:

1. REMOVE EXISTING 7350 DAM TO ALLOW THE LOWER SEGMENT OF THE CREEK TO DISCHARGE TO THE 7100 RESERVOIR BASIN.

FIGURE **6-3**

MEADOW CREEK SEEP COLLECTION-CLEANWATER DIVERSION OPTION

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\94315950039200F04.dwg|5-20-2 11:49|x:Xr-Base-Mdw_crk|i:-

Golder Associates

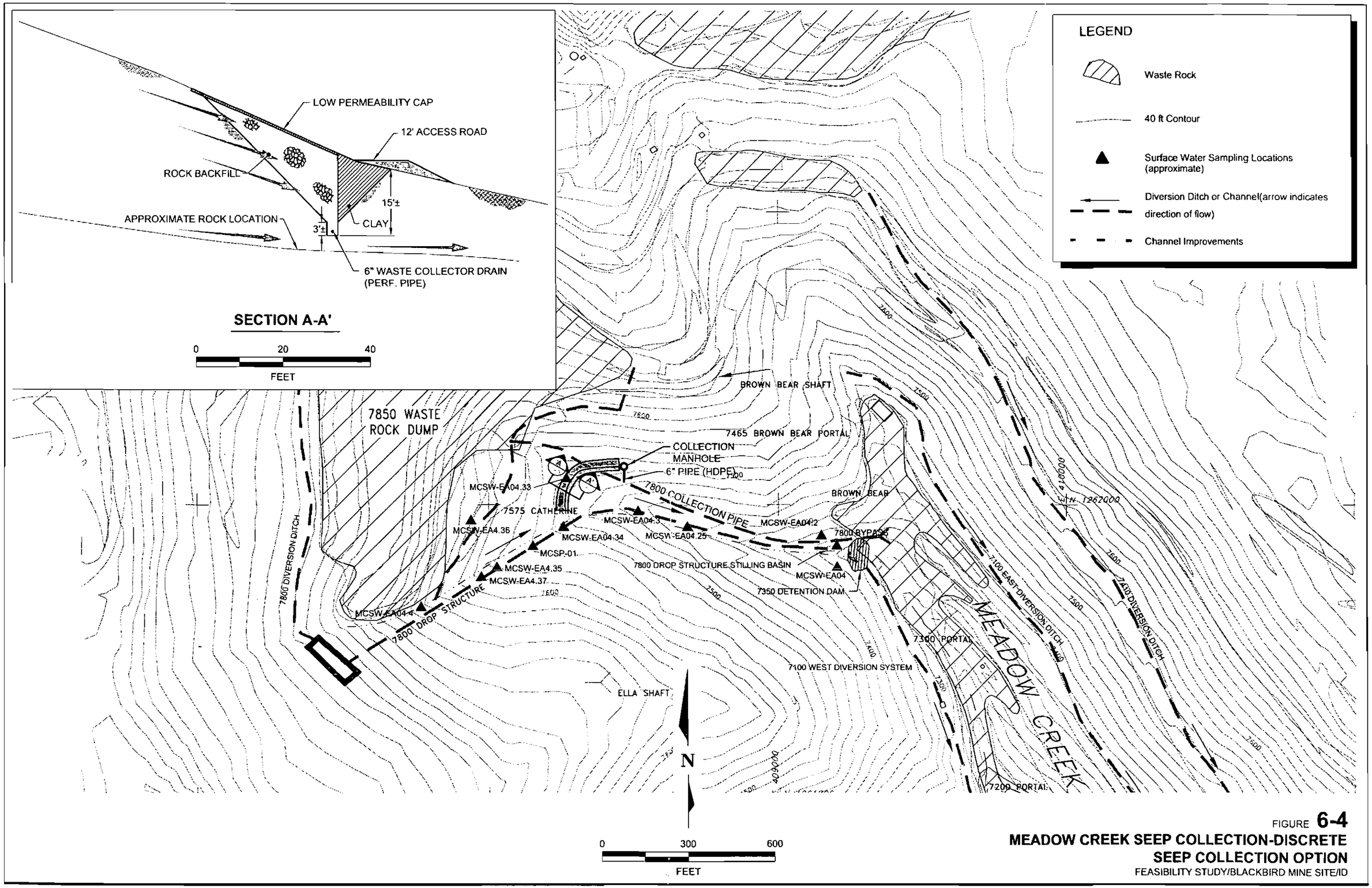


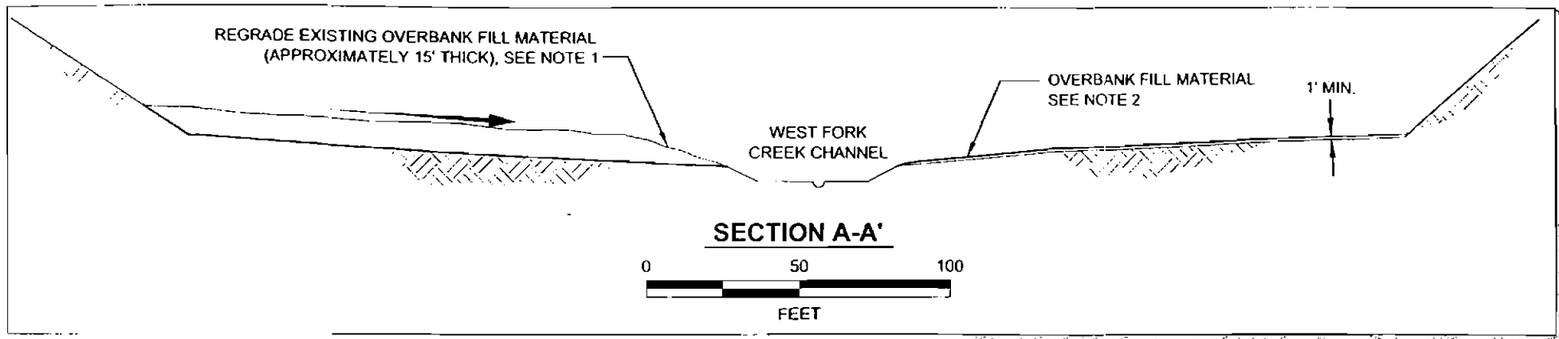
FIGURE **6-4**

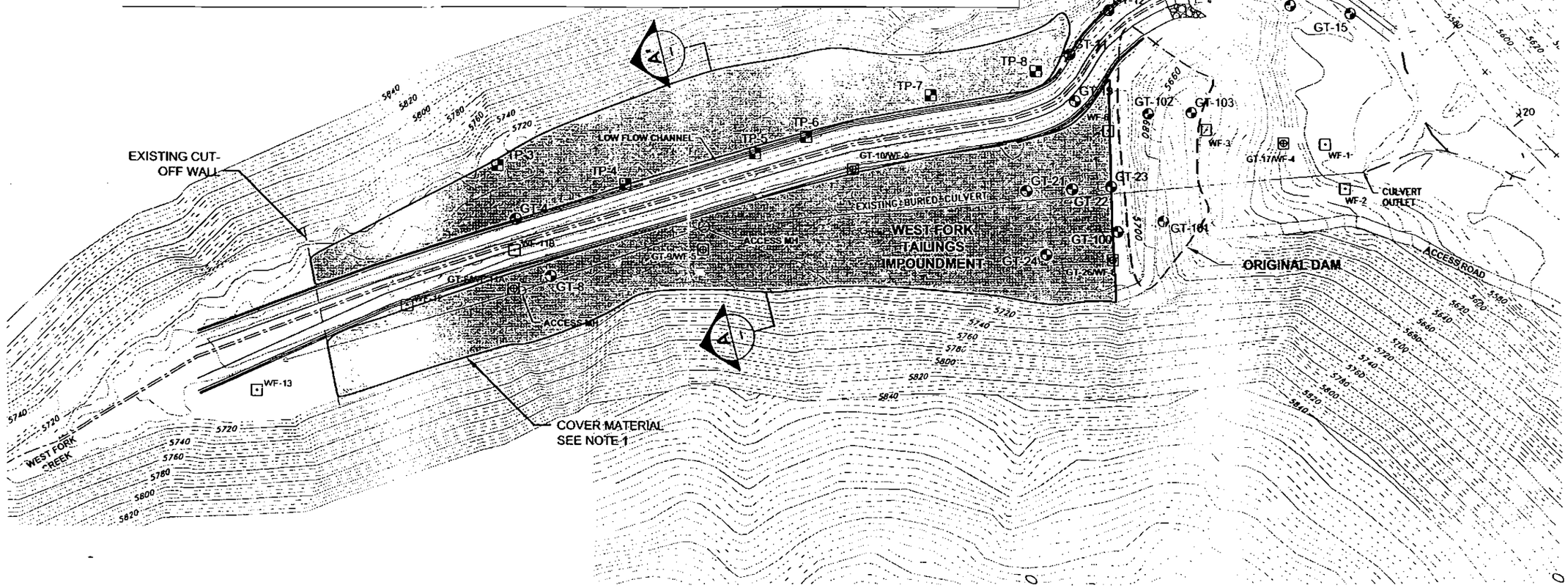
MEADOW CREEK SEEP COLLECTION-DISCRETE SEEP COLLECTION OPTION

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\94315950039200F05.dwg|5-20-2 12:53|x:Xr-Base-Mdw_crk|i -

Golder Associates





LEGEND

GT-101	GEOTECHNICAL BORING
WF-12	GROUNDWATER MONITORING WELL
GT 9/WF-5	GEOTECHNICAL BORING CONVERTED TO MONITORING WELL
TP-3	APPROXIMATE KNIGHT-PIESOLD TEST PIT LOCATIONS, 1994

NOTES:

1. REGRADED EXISTING OVERBANK MATERIAL TO DRAIN TO CREEK. HYDROSEED COVER.
2. PROVIDE 1.0 FOOT MINIMUM COVER OVER EXISTING TAILINGS. GRADE COVER TO DRAIN TO CHANNEL. HYDROSEED COVER

N

0 200 400
FEET

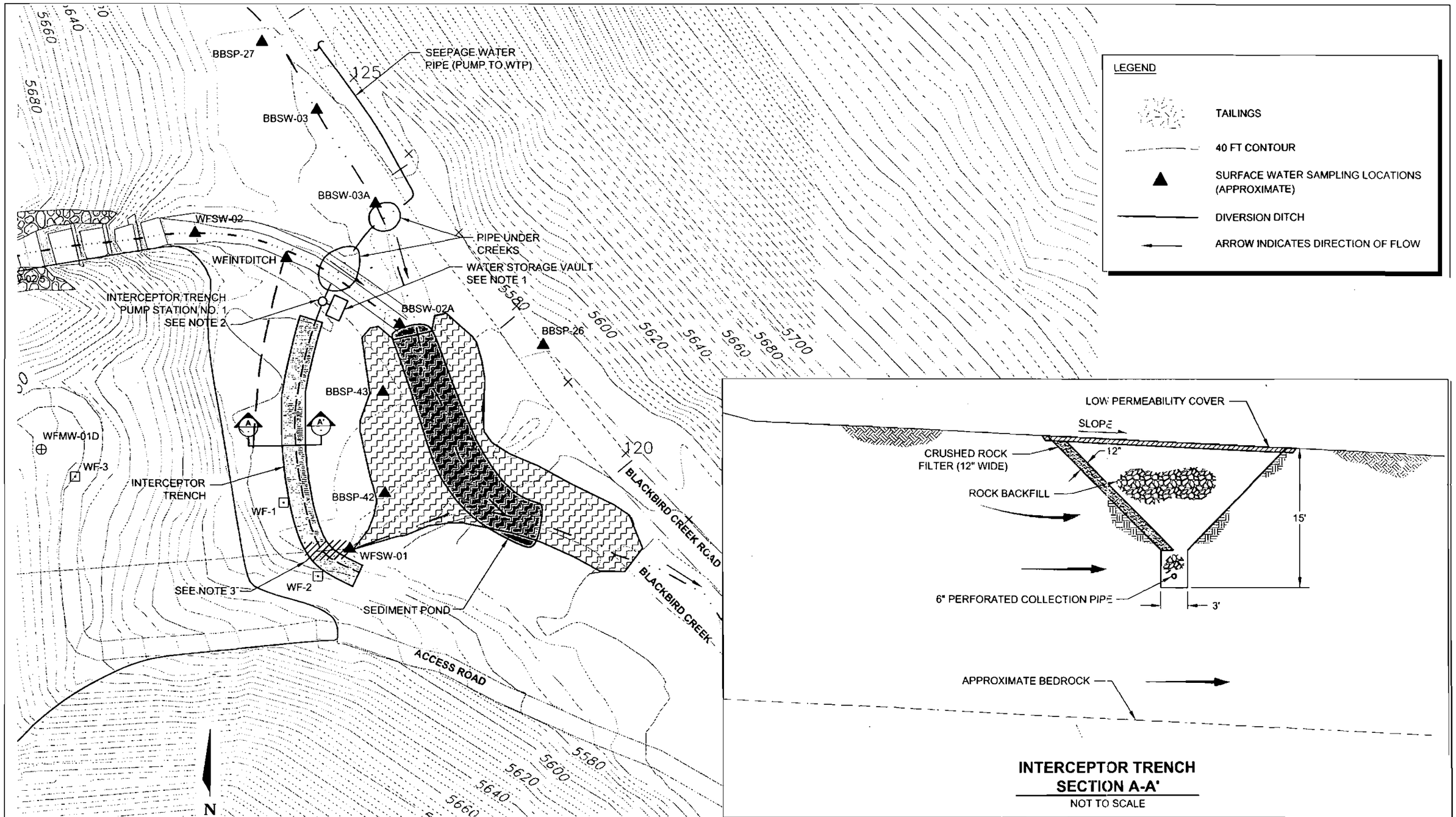
FIGURE **6-5**

TAILINGS IMPOUNDMENT SOIL COVER

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\100111.dwg|2-23-2 10:44|x.Xr-Base-West_Fork|i:wfork_image.tif

Golder Associates



NOTES:

1. 5000 GALLON STORAGE VAULT. NORMALLY EMPTY. VAULT AVAILABLE FOR DRAIN DOWN OF PUMP LINE IF NECESSARY.
2. A TOTAL OF 4 PUMP STATIONS WILL BE UTILIZED TO PUMP SEEPAGE WATER TO THE 7100 DAM, OR 3 IF PUMPING DIRECTLY TO THE WTP.
3. REMOVE CULVERT DOWNSTREAM OF INTERCEPTOR TRENCH.

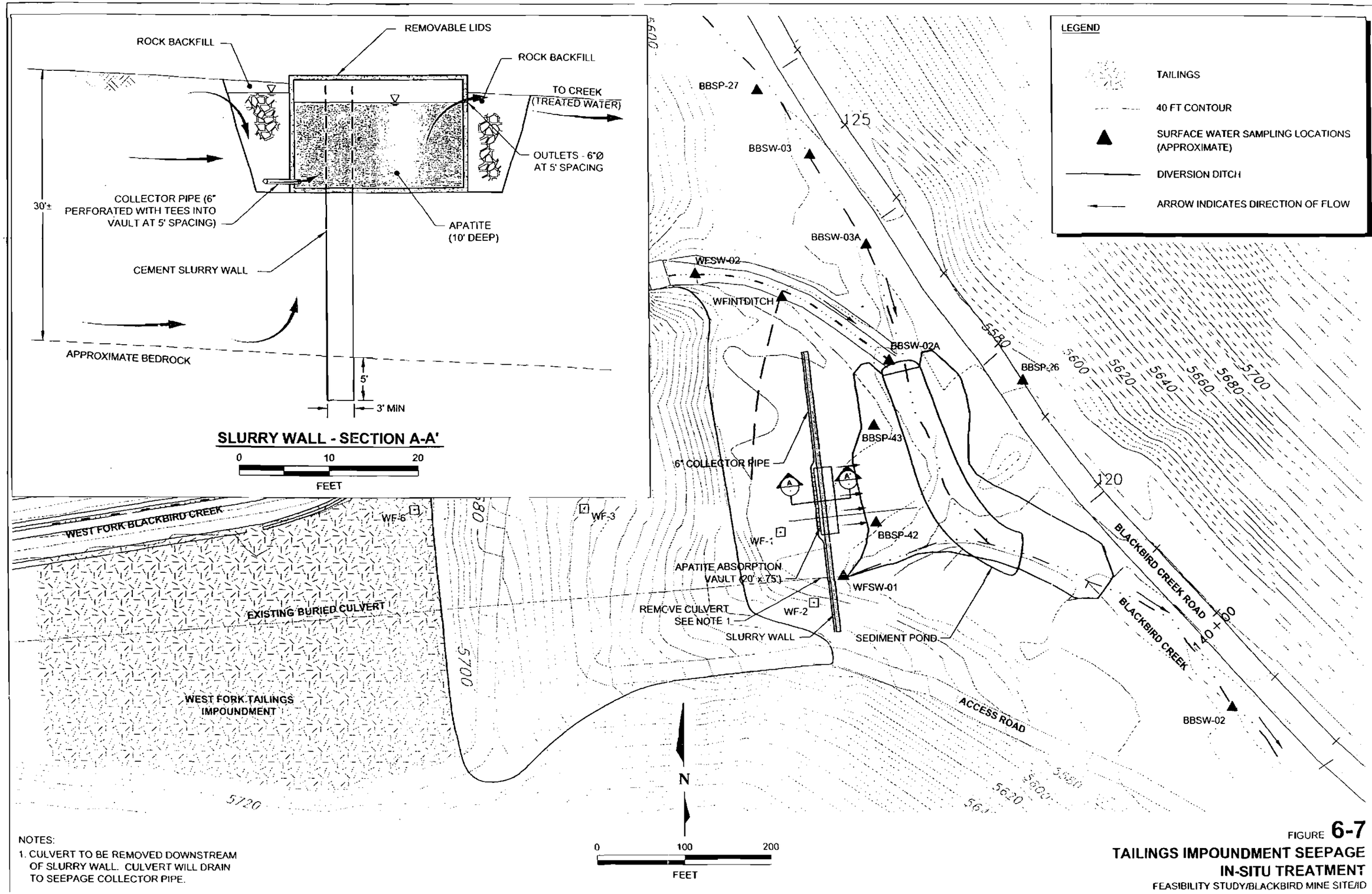
FIGURE **6-6**

TAILINGS IMPOUNDMENT SEEPAGE COLLECTION-PUMP BACK

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\94315950039200F06.dwg|5-20-2 12:57|x:Xr-Base-West_Fork|i -

Golder Associates



NOTES:

1. CULVERT TO BE REMOVED DOWNSTREAM OF SLURRY WALL. CULVERT WILL DRAIN TO SEEPAGE COLLECTOR PIPE.

FIGURE **6-7**

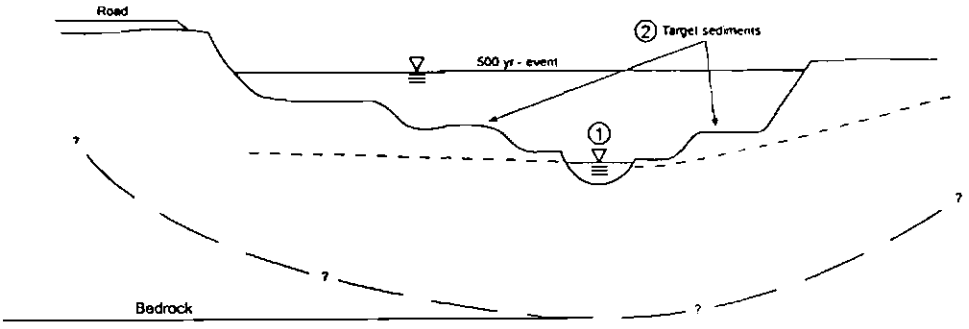
TAILINGS IMPOUNDMENT SEEPAGE
IN-SITU TREATMENT

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

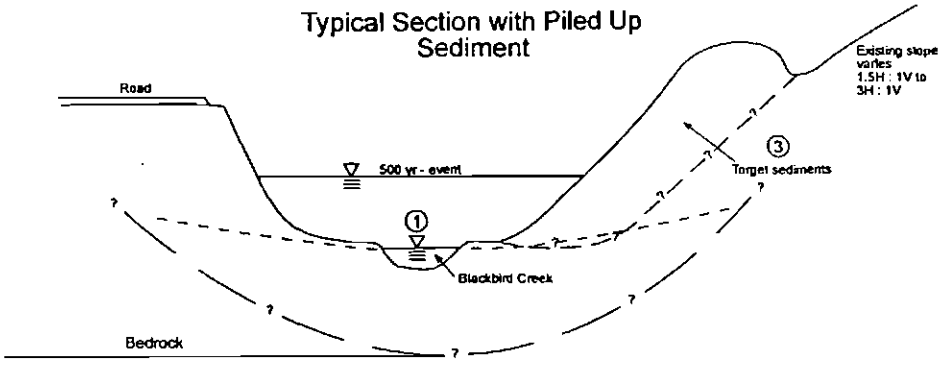
bclark|K:\Projects\1994\9431595\x003\9200\100113.dwg|2-23-2 10:43|x:Xr-Base-West_Forkj:-

Golder Associates

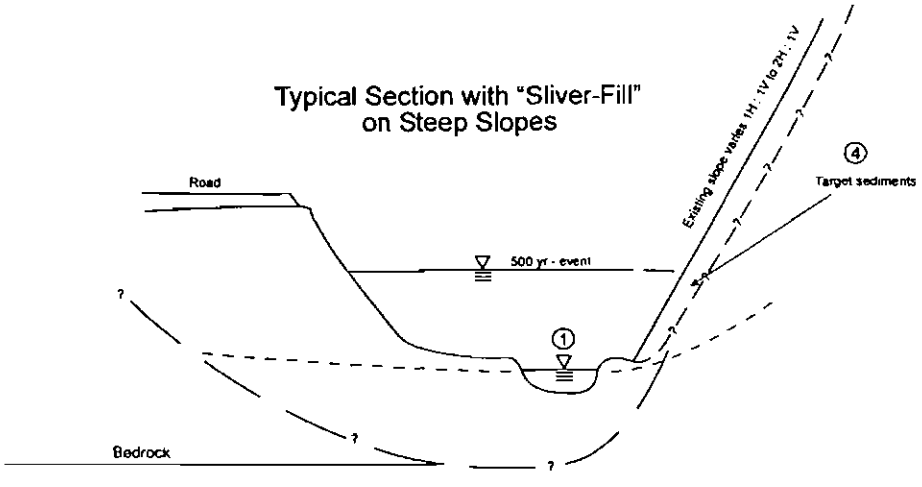
Typical Depositional Section



Typical Section with Piled Up Sediment



Typical Section with "Sliver-Fill" on Steep Slopes



① Normal low-flow water level.

② Target sediments located in terraced layers.

③ Target sediments located in piles excavated historically from channel.

④ Target sediments located in "sliver-fills" along steep slopes.

Note: View Looking Downstream, Figures Not To Scale

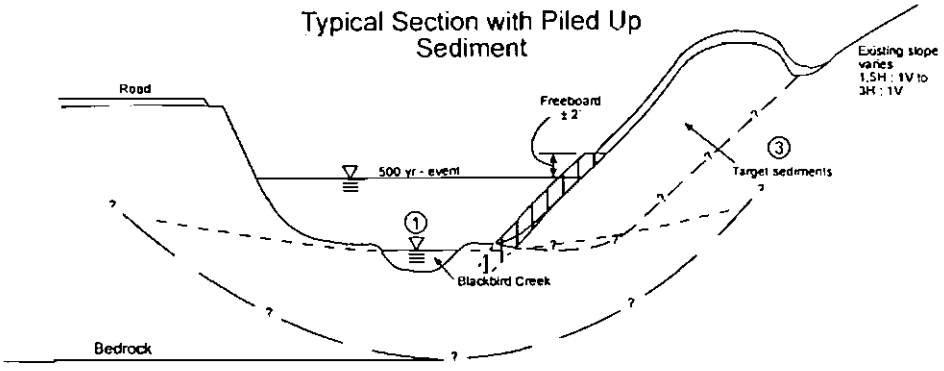
FIGURE **6-8**

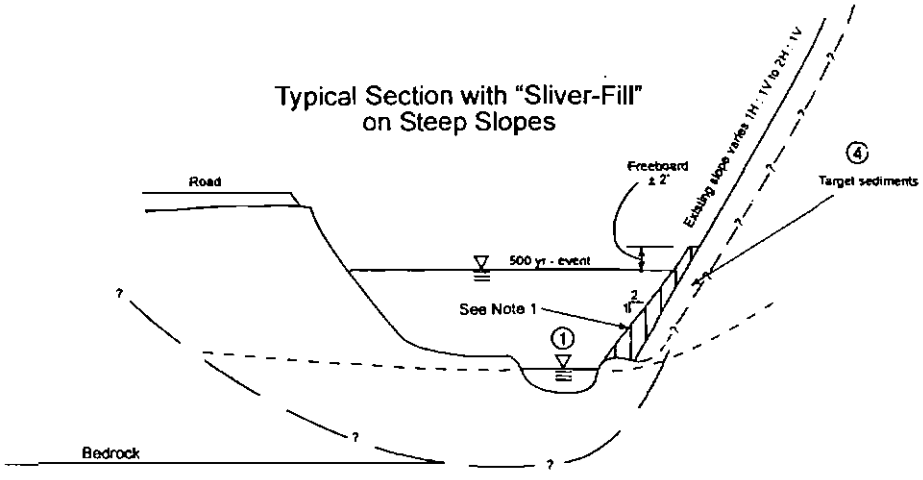
BASE CROSS-SECTIONS IN BLACKBIRD CREEK

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 94920 DATE 12/28/01 DRAWN BY DC

Golder Associates





LEGEND

Armoring

① Normal low-flow water level.

② Target sediments located in terraced layers.

③ Target sediments located in piles excavated historically from channel.

④ Target sediments located in "sliver-fills" along steep slopes.

Note: View Looking Downstream, Figures Not To Scale

NOTE

1. Rock armor placed to a 2:1 slope to stabilize areas below sliver-fills.

FIGURE **6-9**

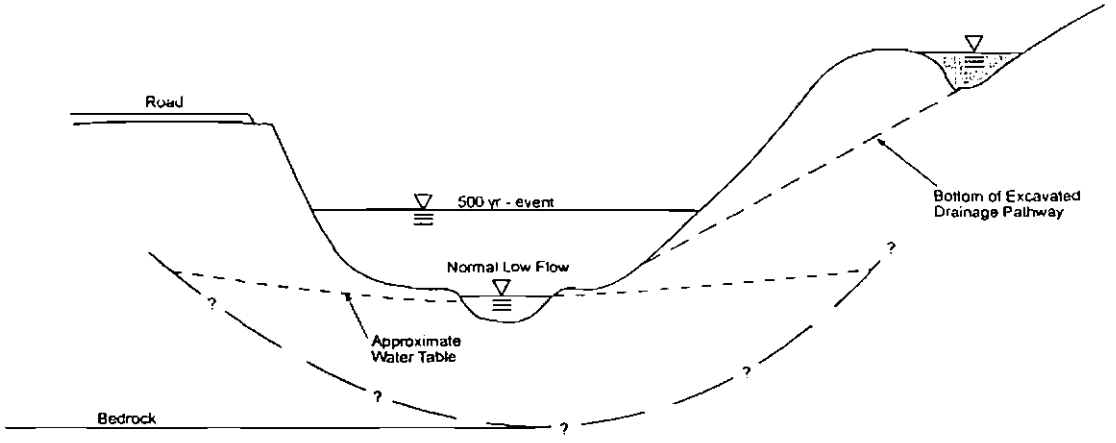
CROSS-SECTIONS FOR PHYSICAL STABILIZATION IN BLACKBIRD CREEK

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

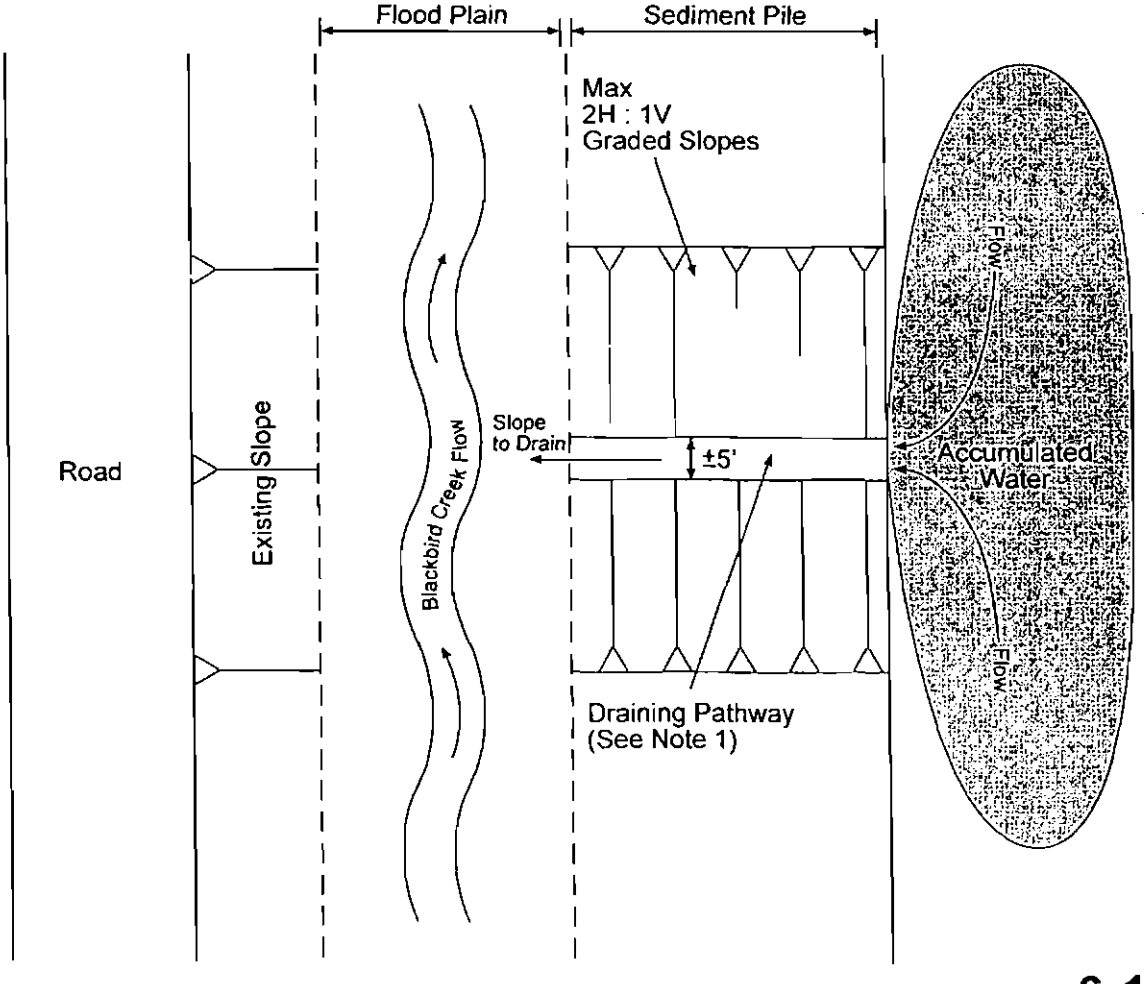
PROJECT NO. 943 1595x003_9000 DRAWING NO. 94921 DATE 02/23/02 DRAWN BY DC

Golder Associates

Typical Cross-Section
Not To Scale



Typical Plan View
Not To Scale



Notes:

1. Excavate to original grade and armor channel.

FIGURE **6-10**

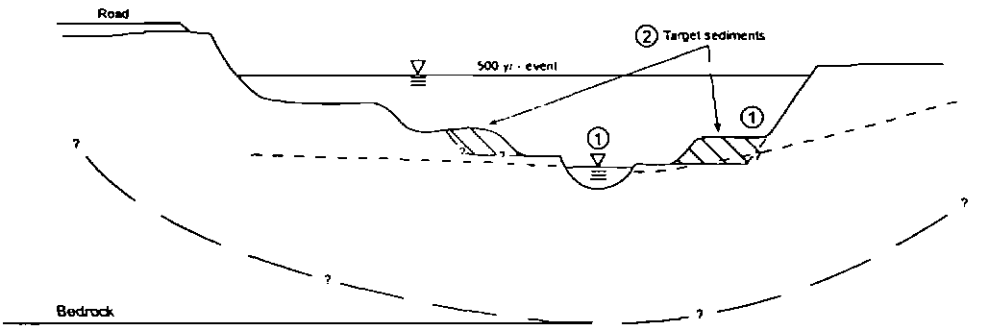
SURFACE DRAINAGE MODIFICATIONS

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

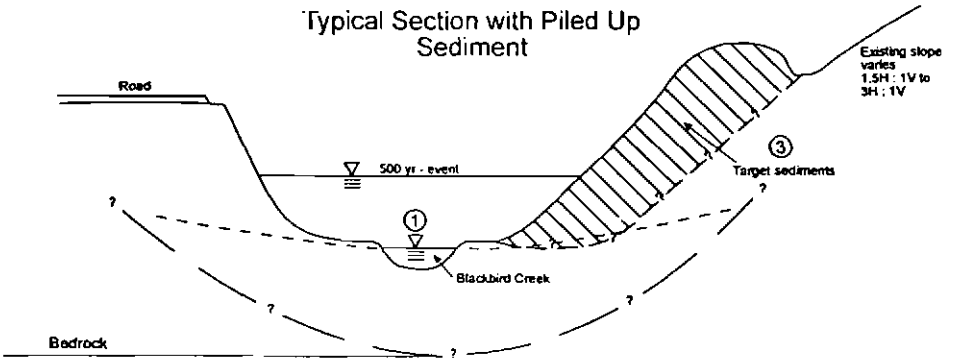
PROJECT NO. 943 1595x003_9200 DRAWING NO. 100420 DATE 02/25/02 DRAWN BY EL

Golder Associates

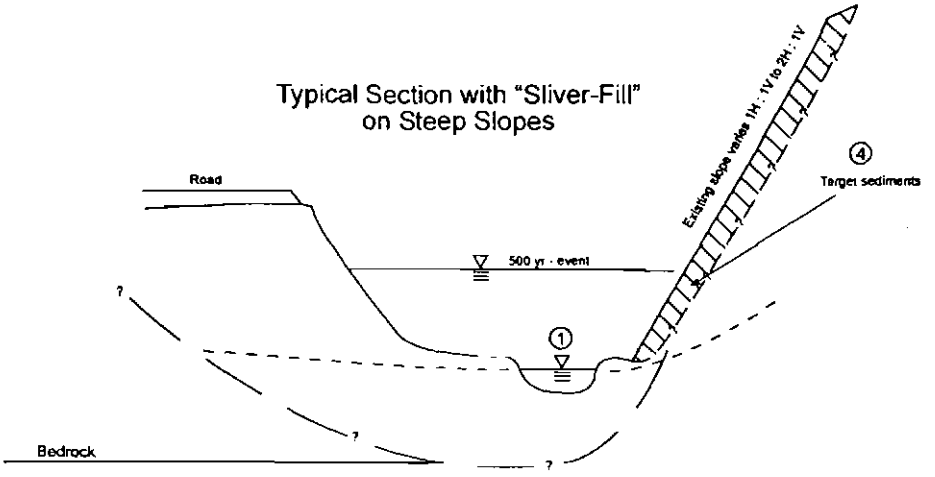
Typical Depositional Section



Typical Section with Piled Up Sediment



Typical Section with "Sliver-Fill" on Steep Slopes



LEGEND

Overbank Deposits For Removal

① Normal low-flow water level.

② Target sediments located in terraced layers.

③ Target sediments located in piles excavated historically from channel.

④ Target sediments located in "sliver-fills" along steep slopes.

Note: View Looking Downstream, Figures Not To Scale

FIGURE **6-11**

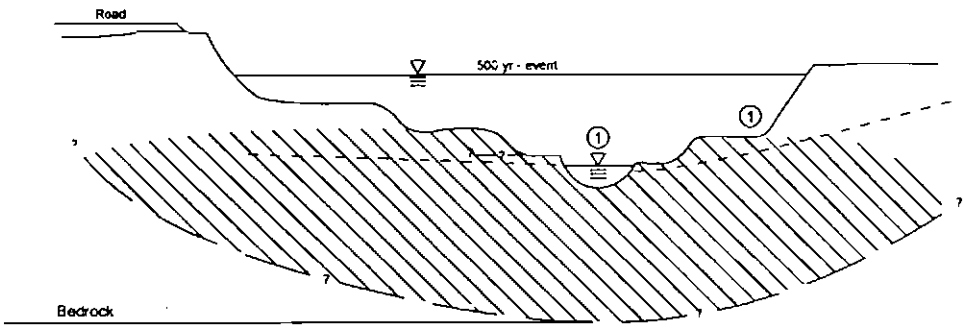
CROSS-SECTIONS FOR OVERBANK DEPOSIT REMOVAL IN BLACKBIRD CREEK

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

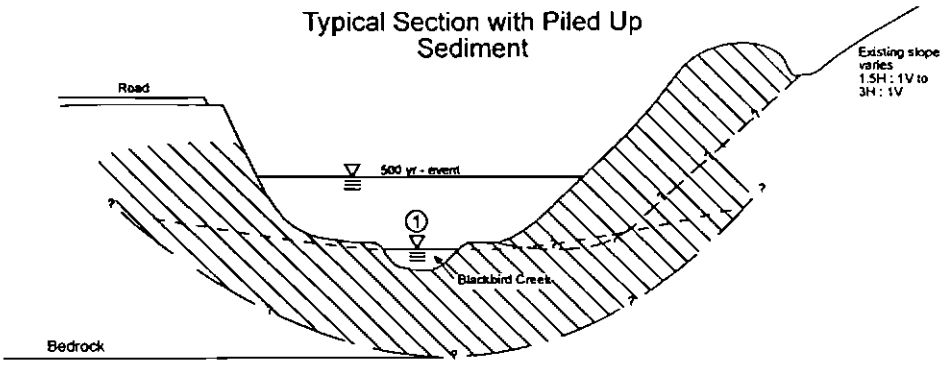
PROJECT NO. 943 1595x003_9000 DRAWING NO. 94922 DATE 12/28/01 DRAWN BY DC

Golder Associates

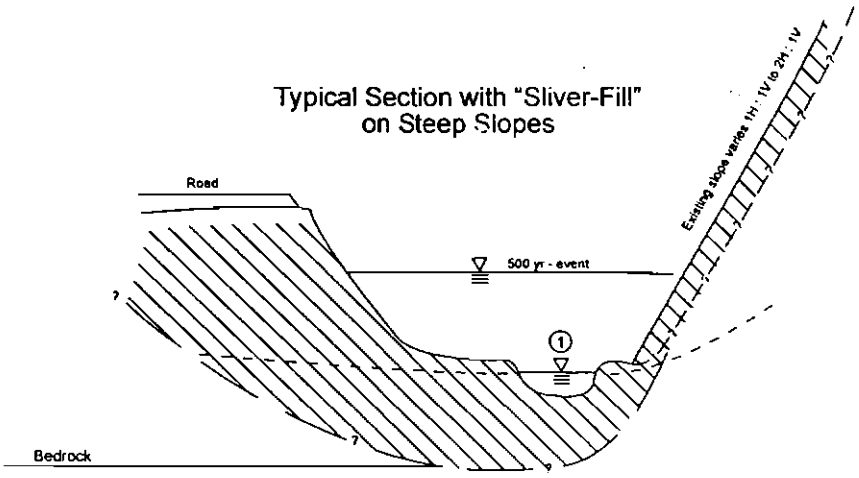
Typical Depositional Section



Typical Section with Piled Up Sediment



Typical Section with "Sliver-Fill" on Steep Slopes



LEGEND

Overbank Deposits and In-Stream Sediments For Removal

① Normal low-flow water level.

Note: View Looking Downstream, Figures Not To Scale

FIGURE **6-12**

CROSS-SECTIONS FOR COMPLETE SEDIMENT REMOVAL IN BLACKBIRD CREEK

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

PROJECT NO 943 1595x003_9000 DRAWING NO 94923 DATE 12/28/01 DRAWN BY DC

Golder Associates

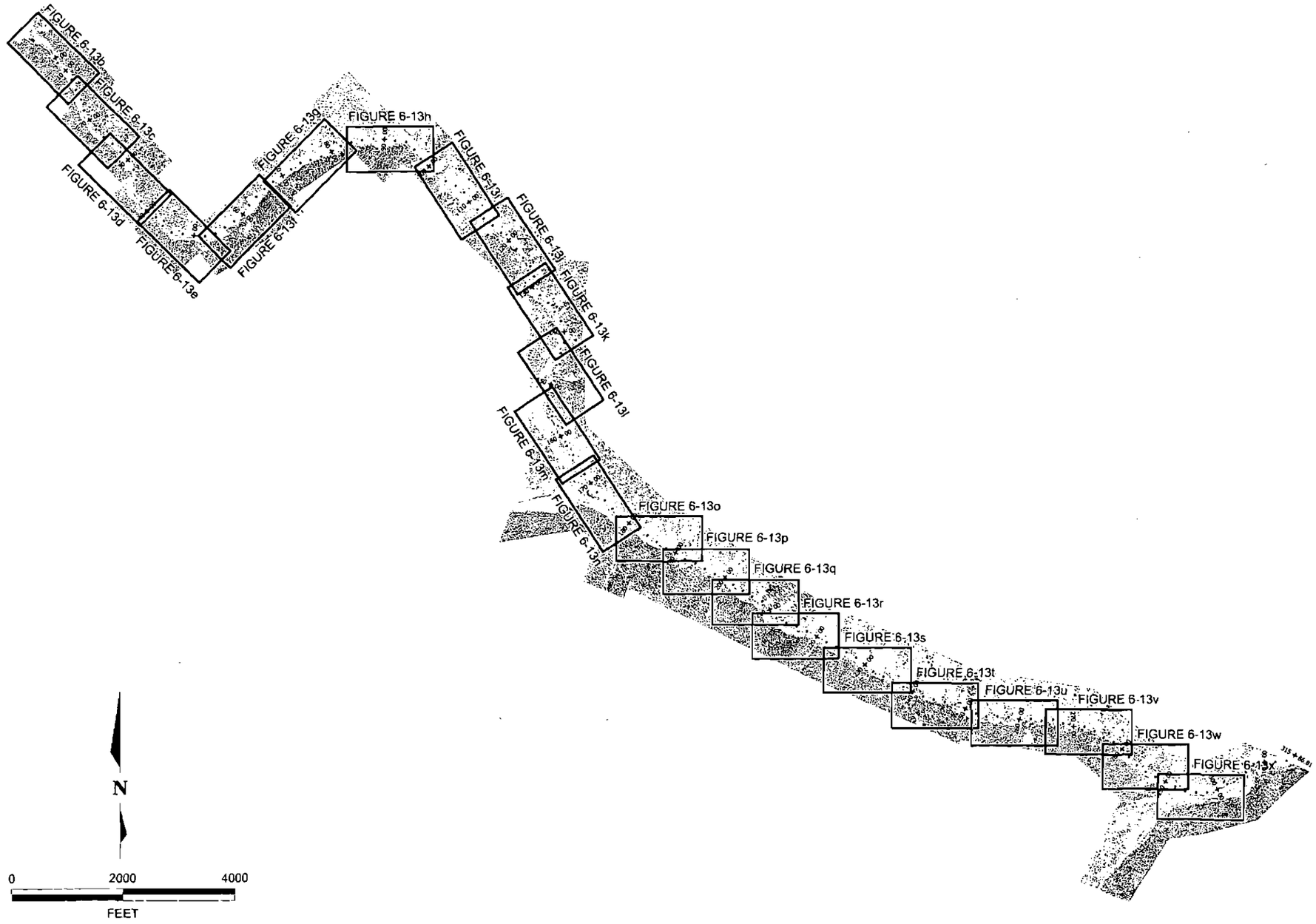


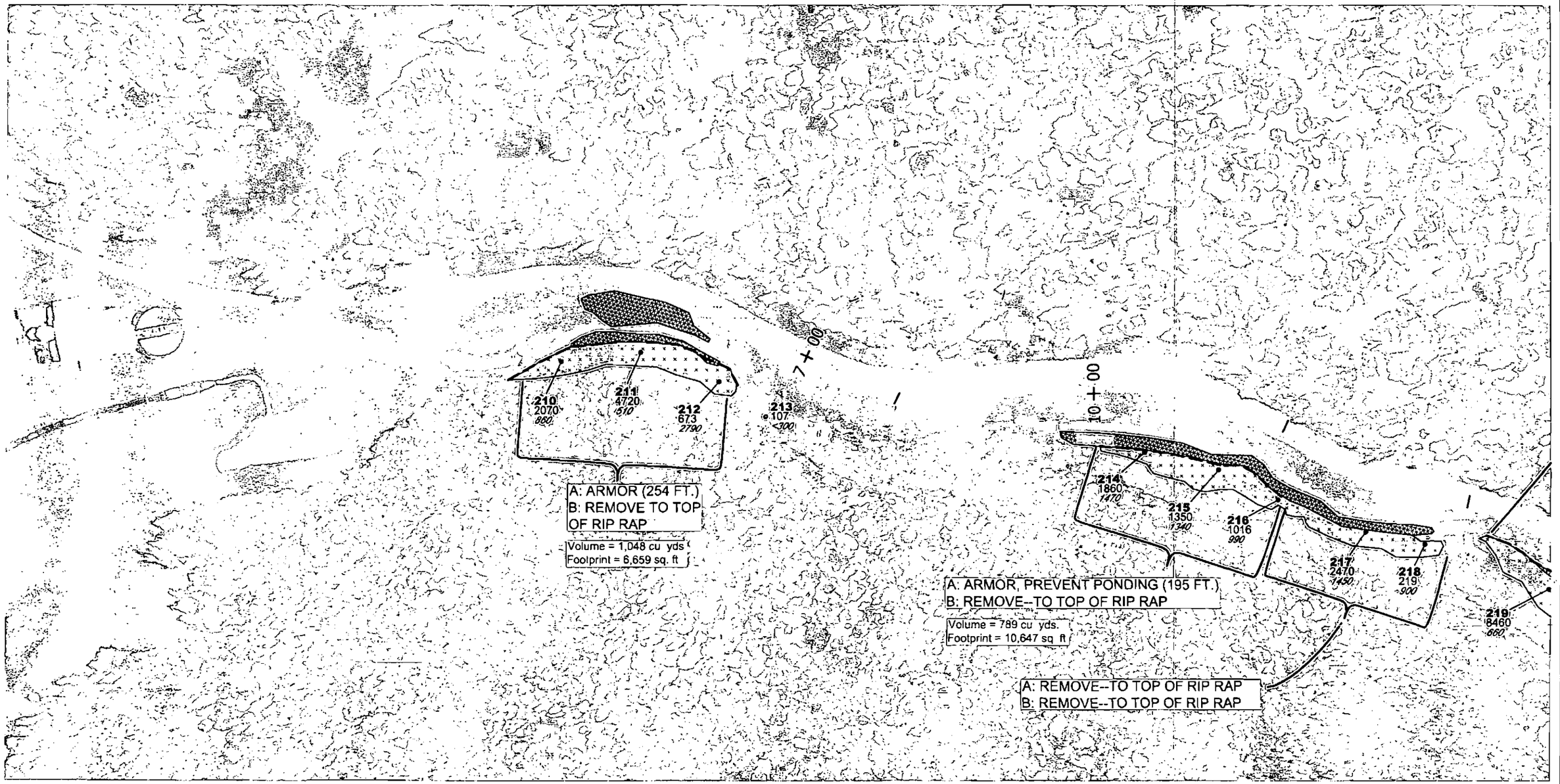
FIGURE **6-13a**

BLACKBIRD CREEK OVERBANK DEPOSITS OVERVIEW

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|i:-

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)
- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

293 — Sample ID
• 996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 — STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT.)

REFER TO FEASABILITY STUDY } A ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE **6-13b**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K \Projects\1994\9431595\x003\9000\100102 dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|i -

Golder Associates

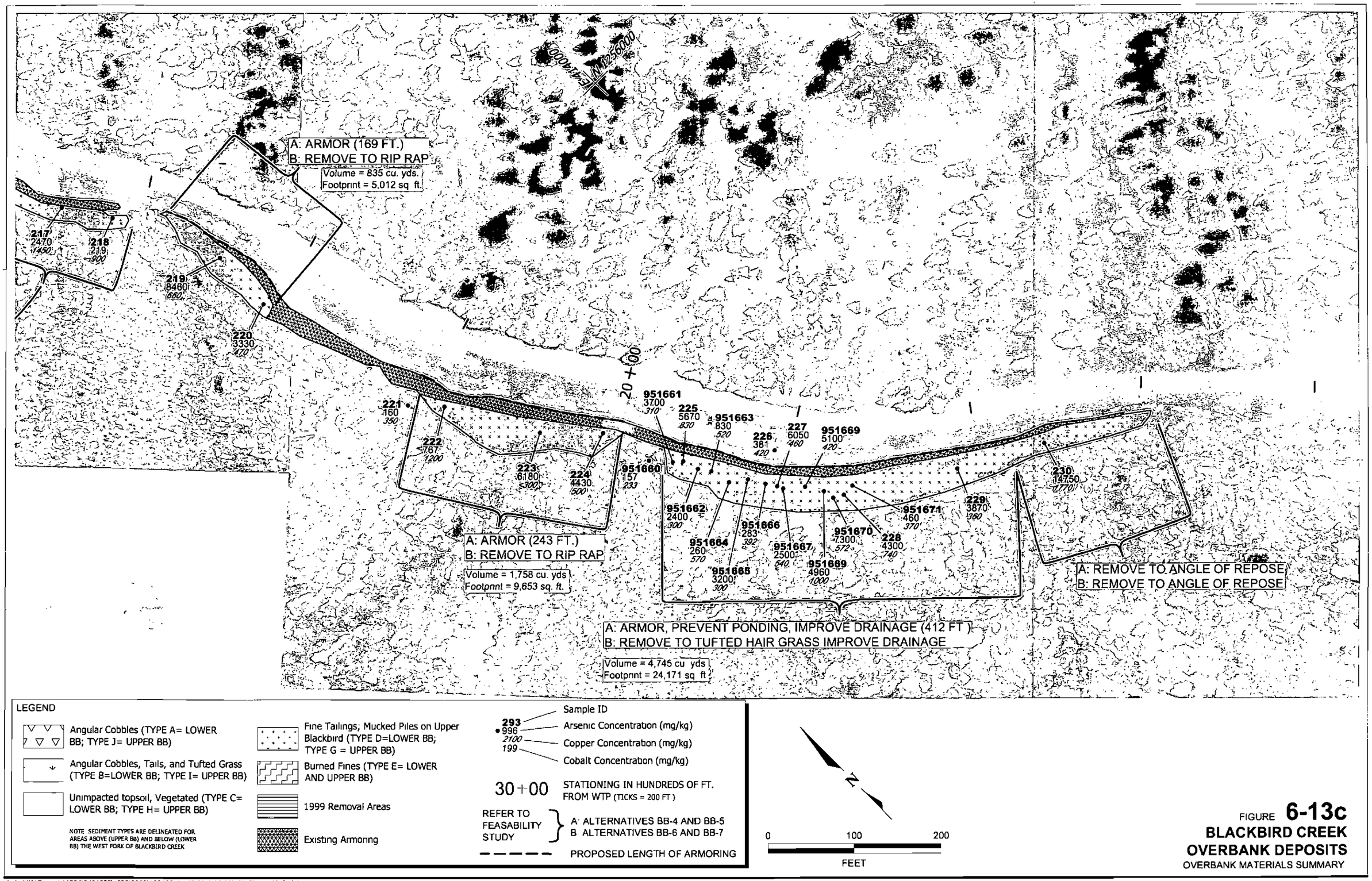


FIGURE **6-13c**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x Xr-Photos,Xr-Soils|

Golder Associates

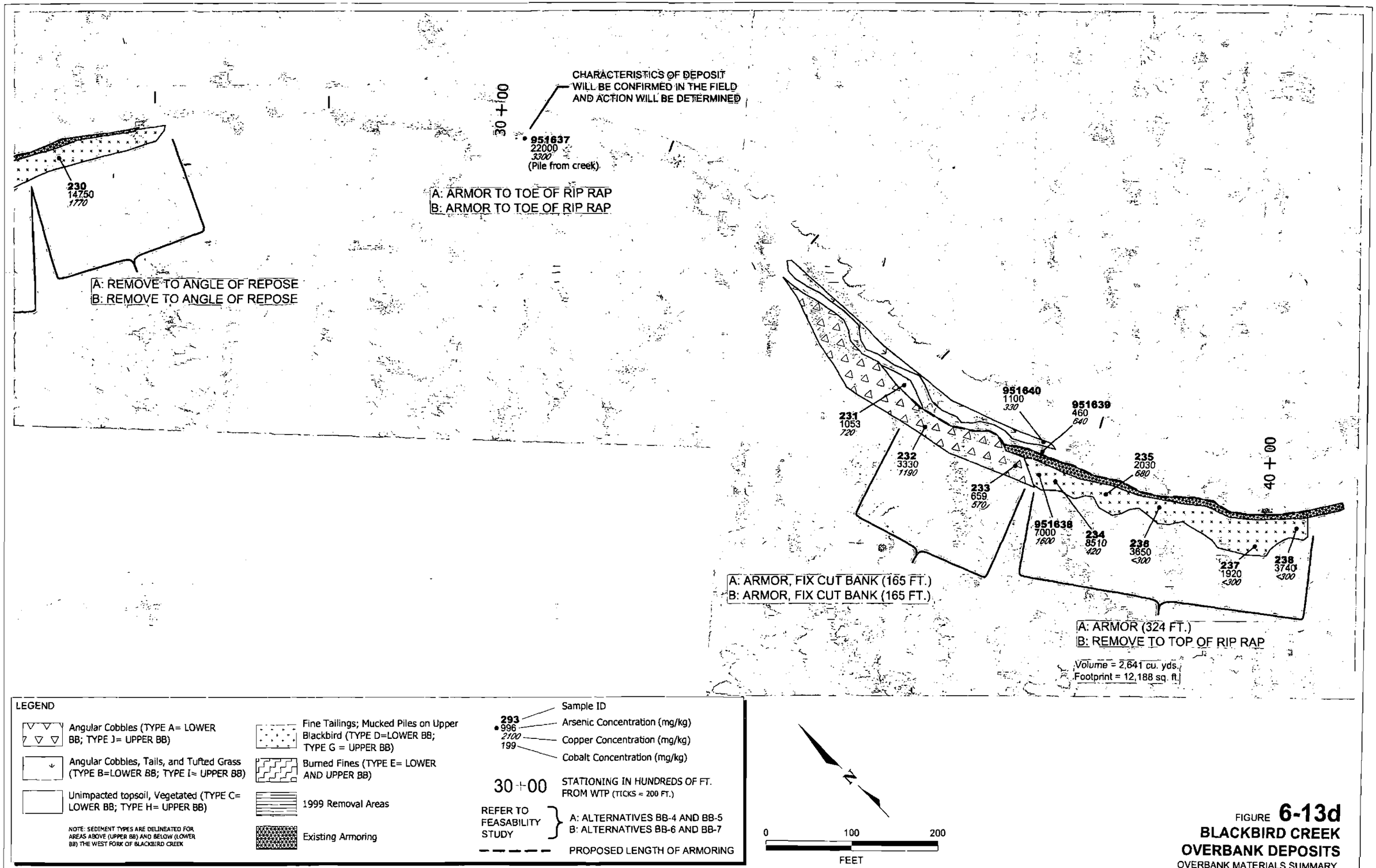


FIGURE **6-13d**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|:-

Golder Associates

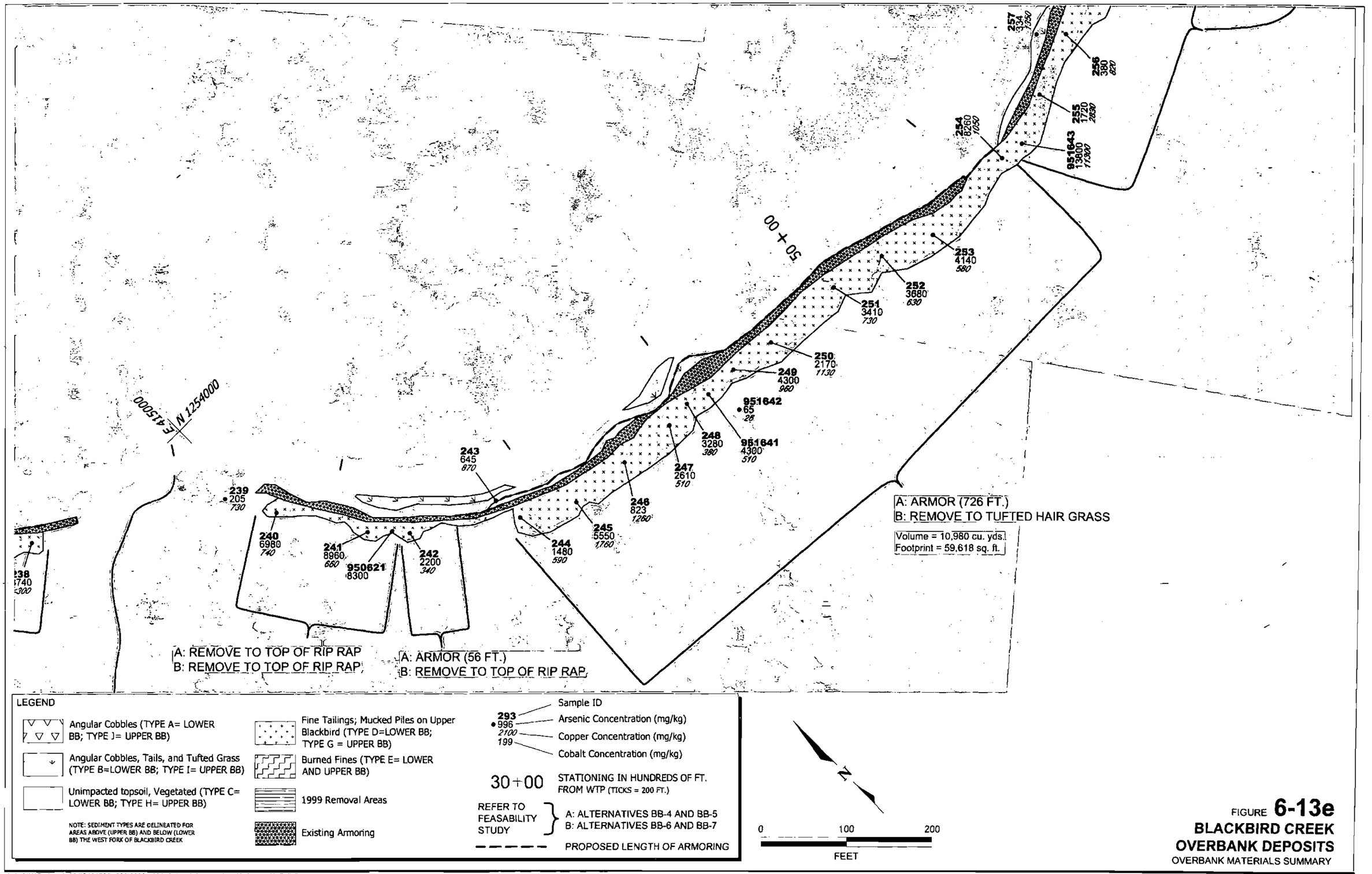
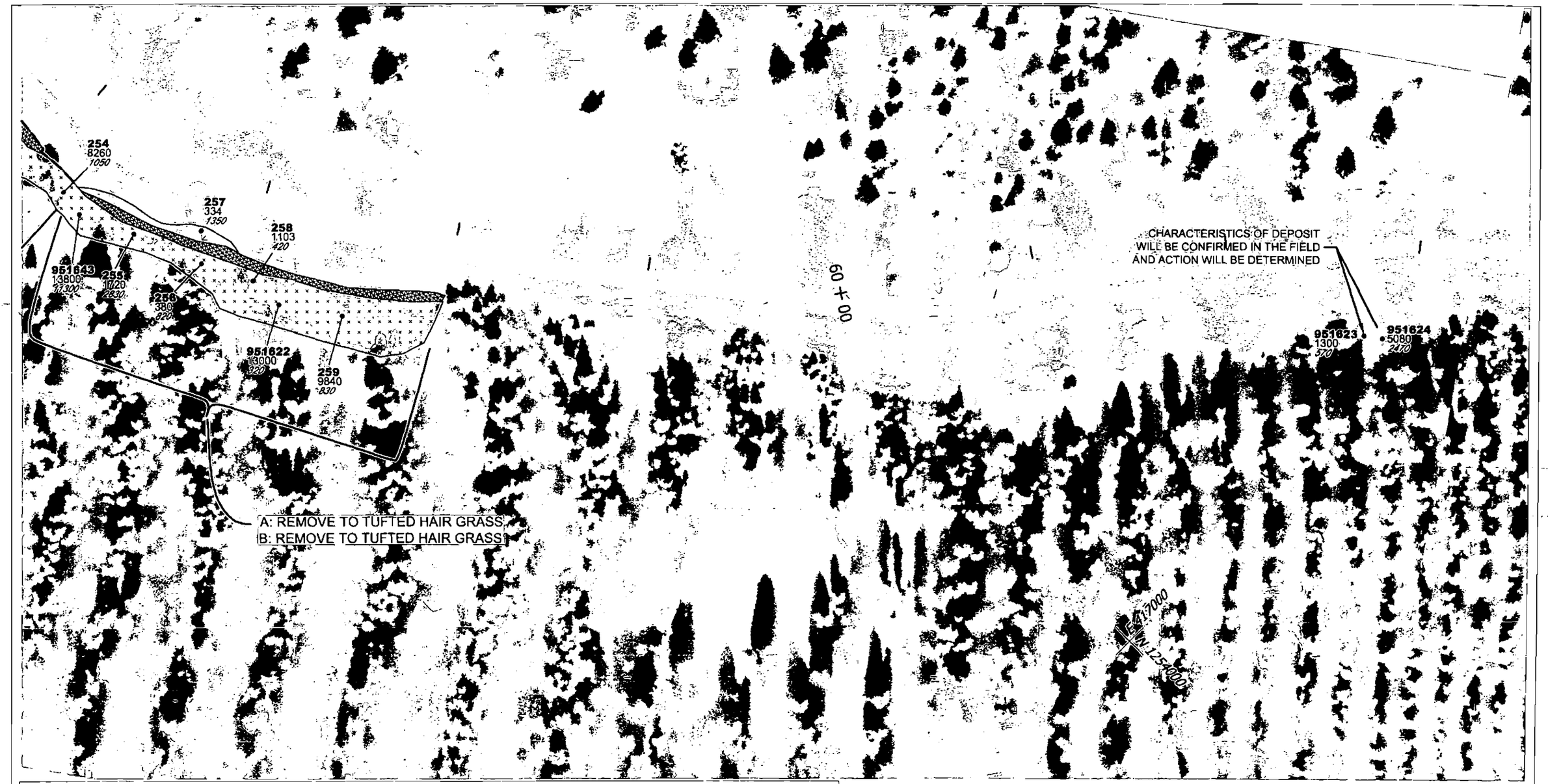


FIGURE **6-13e**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|i:-

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE: SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 — STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT.)

REFER TO FEASABILITY STUDY — A: ALTERNATIVES BB-4 AND BB-5; B: ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE **6-13f**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|i:-

Golder Associates

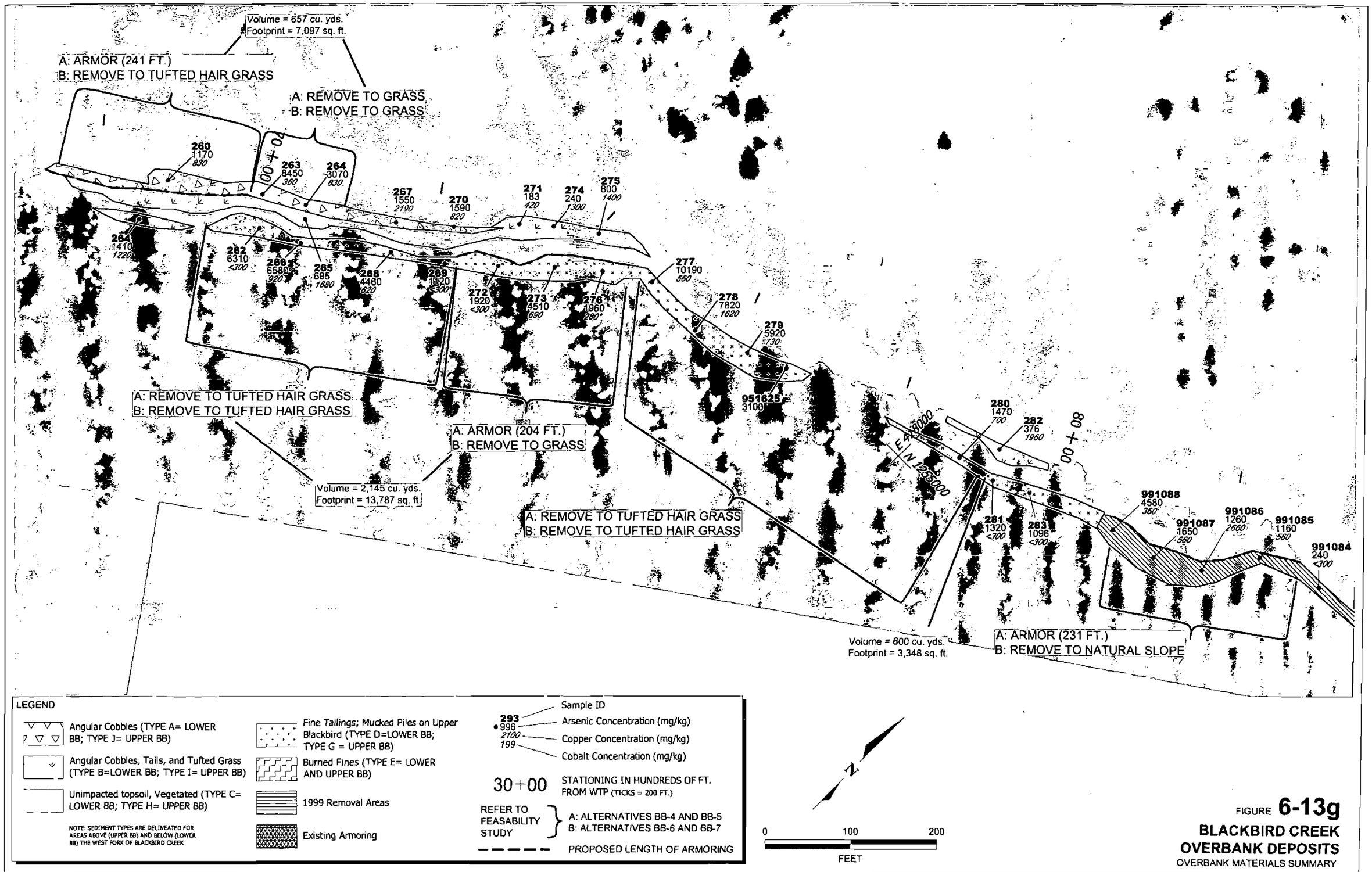


FIGURE **6-13g**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark[K:\Projects\1994\9431595\x003\9000\100102.dwg]2-28-1 15:29]x:Xr-Photos,Xr-Soils]:-

Golder Associates

991084
240
2300

991083
390
1270

285
3290
3570

286
1050
3440

284
5580
360*

951626
12000
300

A: REMOVE TO TUFTED HAIR GRASS
B: REMOVE TO TUFTED HAIR GRASS

Volume = 300 cu. yds.
Footprint = 1,145 sq. ft.

287
960
1110

288
331
1280

289
254
1220

90 + 00

290
296
1220

291
4190
1270

A: ARMOR (104 FT.)
B: REMOVE TO TUFTED HAIR GRASS

Volume = 524 cu. yds.
Footprint = 1,664 sq. ft.

E 419000

N 1255000

292
425
690

293
996
2100

991082
2470
360

295
6030
430

991081
600
900

991080
1610
830

951627
1500
440

A: ARMOR (54 FT.)
B: REMOVE TO TUFTED HAIR GRASS

Volume = 224 cu. yds.
Footprint = 1,545 sq. ft.

100 + 00

296
1420
1390

297
1980
1880

LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE: SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT.)

REFER TO FEASABILITY STUDY } A: ALTERNATIVES BB-4 AND BB-5
B: ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE **6-13h**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|i:-

Golder Associates

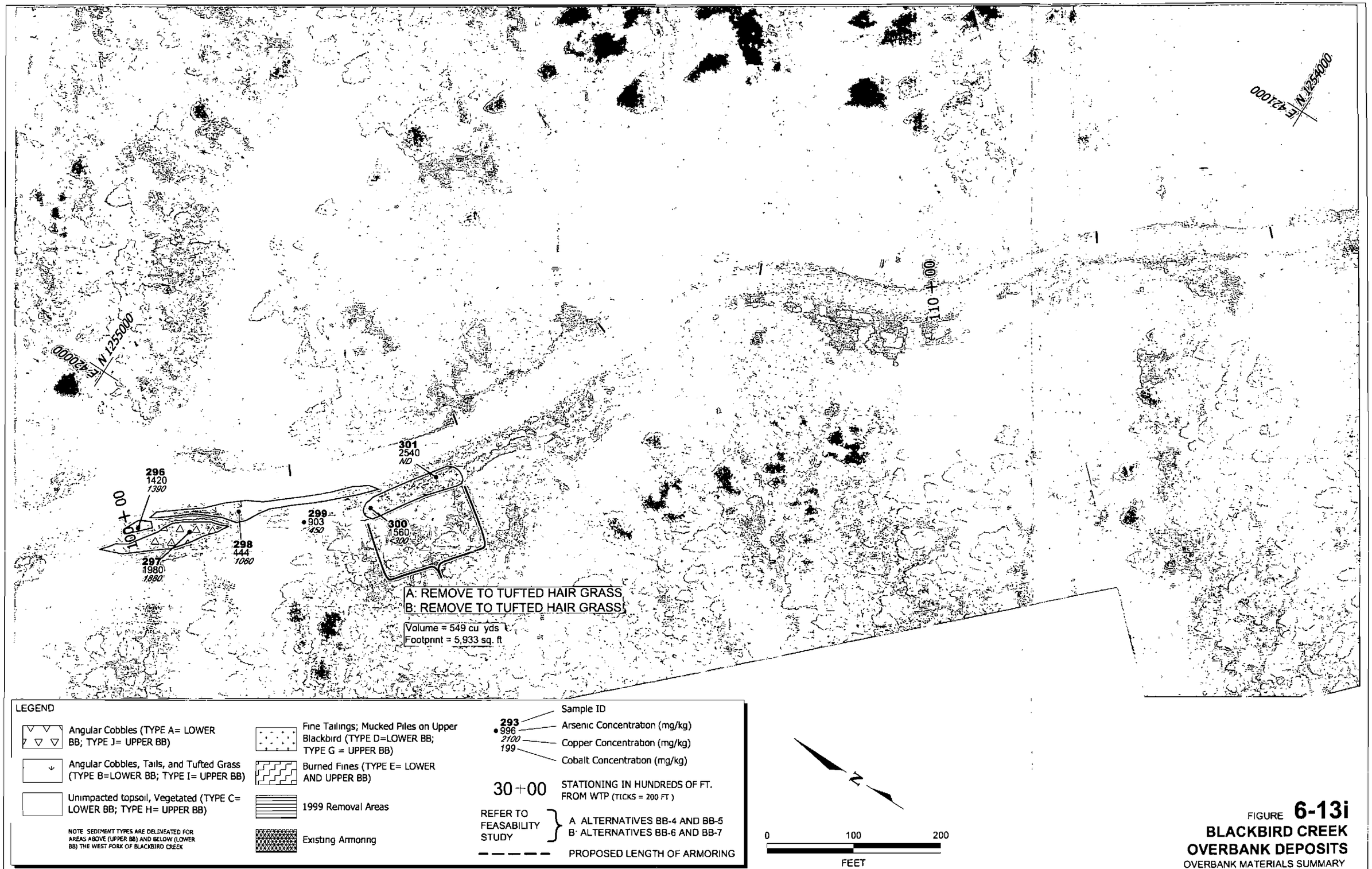


FIGURE **6-13i**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|-

Golder Associates

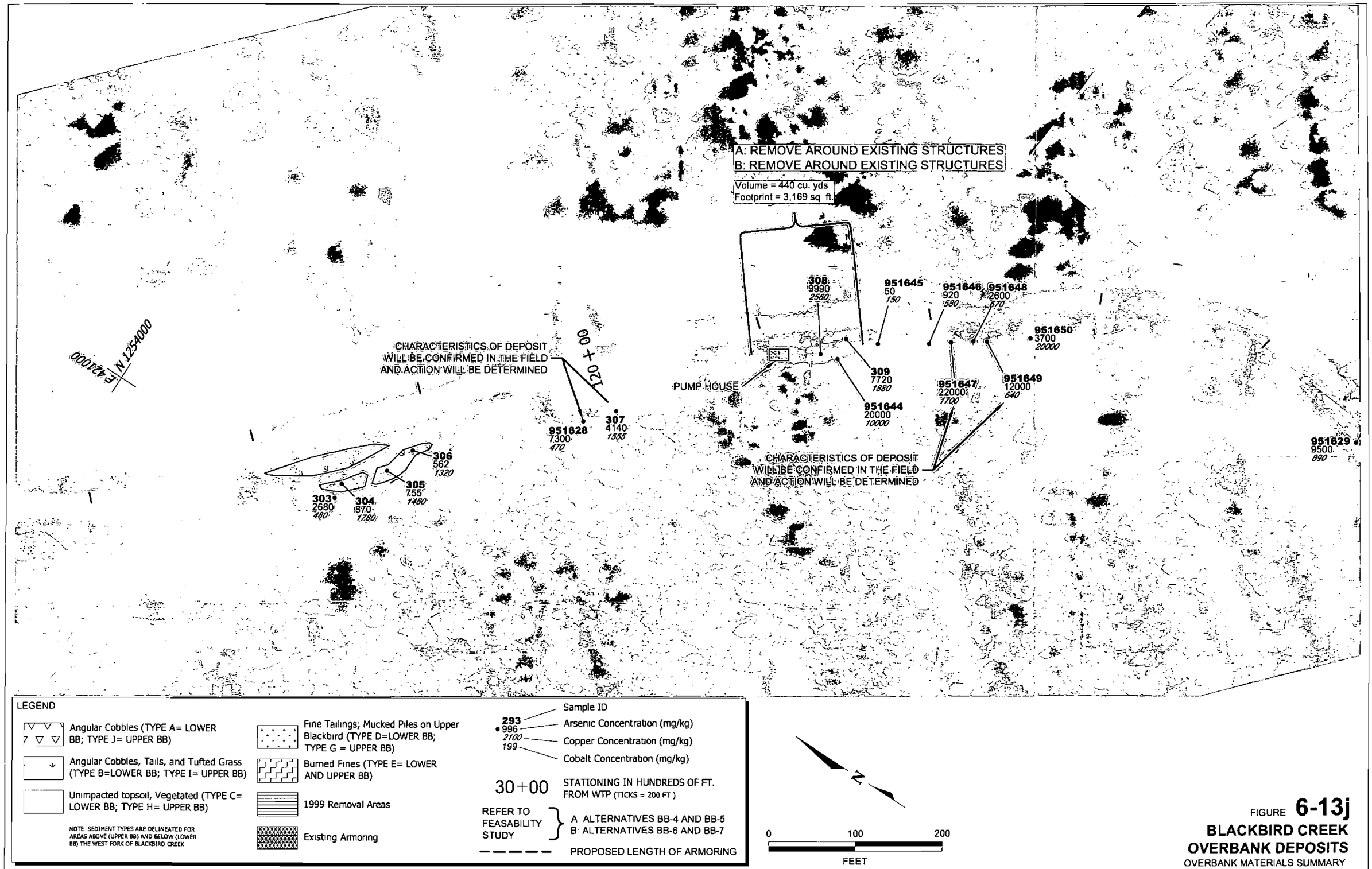


FIGURE **6-13j**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K \Projects\1994\9431595\x003\9000\100102 dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|i -

Golder Associates

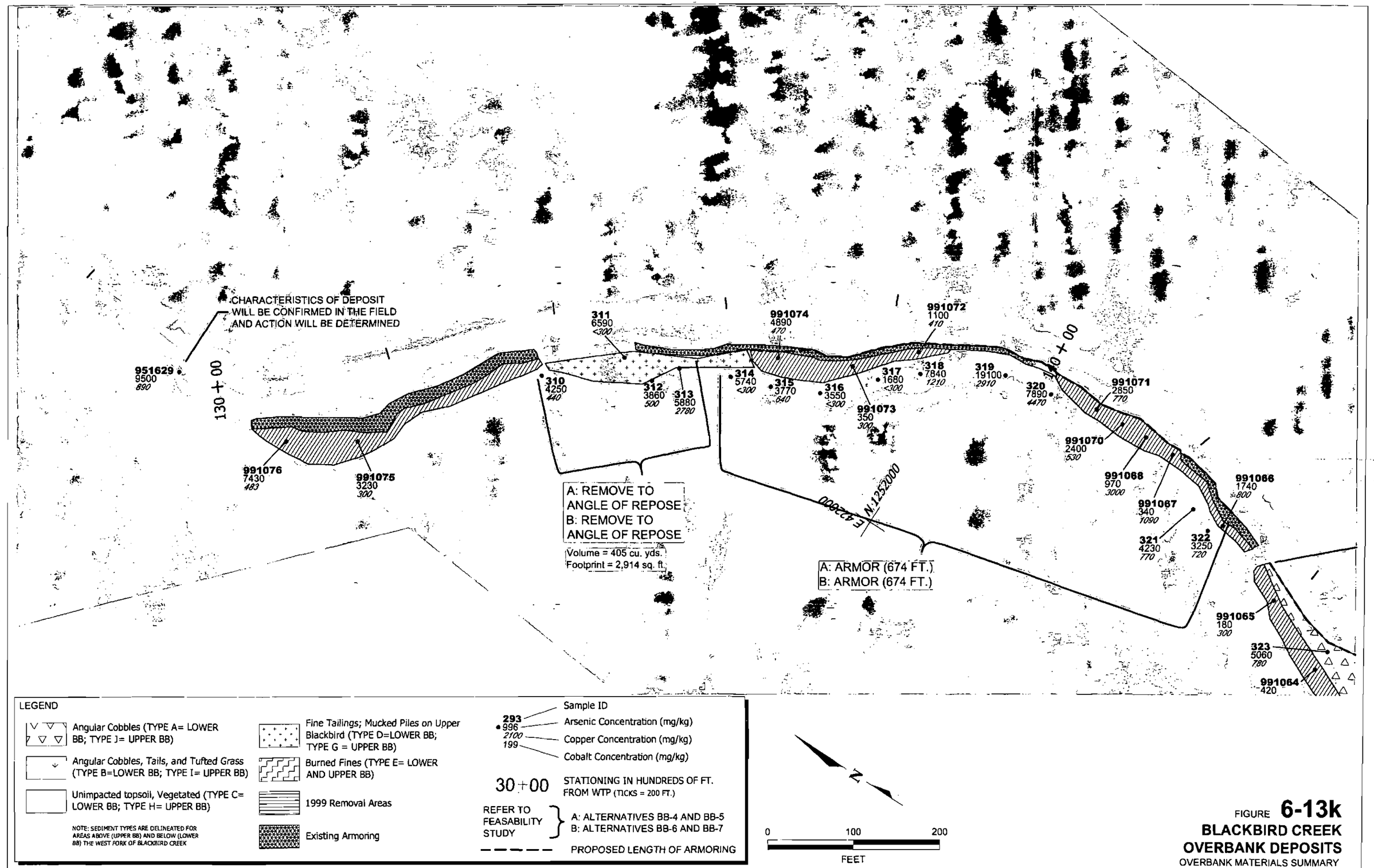


FIGURE **6-13k**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|;-

Golder Associates

991070
2400
1530

991068
970
3000

991067
340
1090

991066
1740
1800

321
4230
1770

322
3250
1720

A: AUGMENT ARMOR (193 FT.)
B: AUGMENT ARMOR (193 FT.)

991065
180
300

323
5060
780

991064
420
340

324
3530
1300

325
120
250

A: ARMOR (317 FT.)
B: REMOVE TO TUFTED HAIR GRASS

Volume = 2,850 cu yds
Footprint = 13,268 sq ft

991063
300
310

326
9240
630

991062
1290
490

991061
1620
490

327
912
160

991060
1480
610

991056
1030
2280

991055
1460
1460

991059
1090
590

991058
1980
770

991057
1930
640

991054
1050
668

951536
104
138

LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT.)

REFER TO FEASABILITY STUDY: A· ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE 6-13I
BLACKBIRD CREEK
OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K \Projects\1994\9431595\x003\9000\100102 dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|r -

Golder Associates

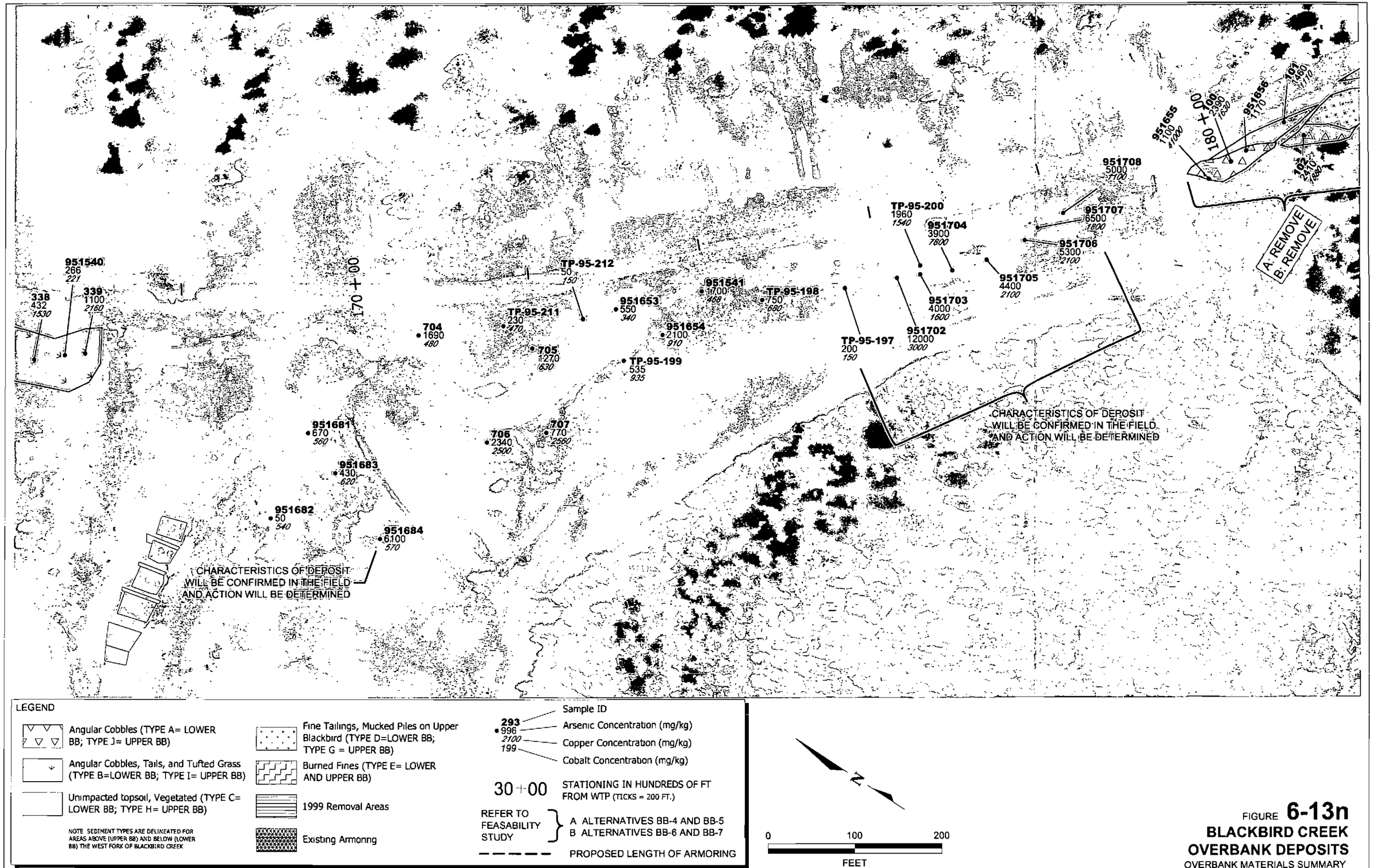


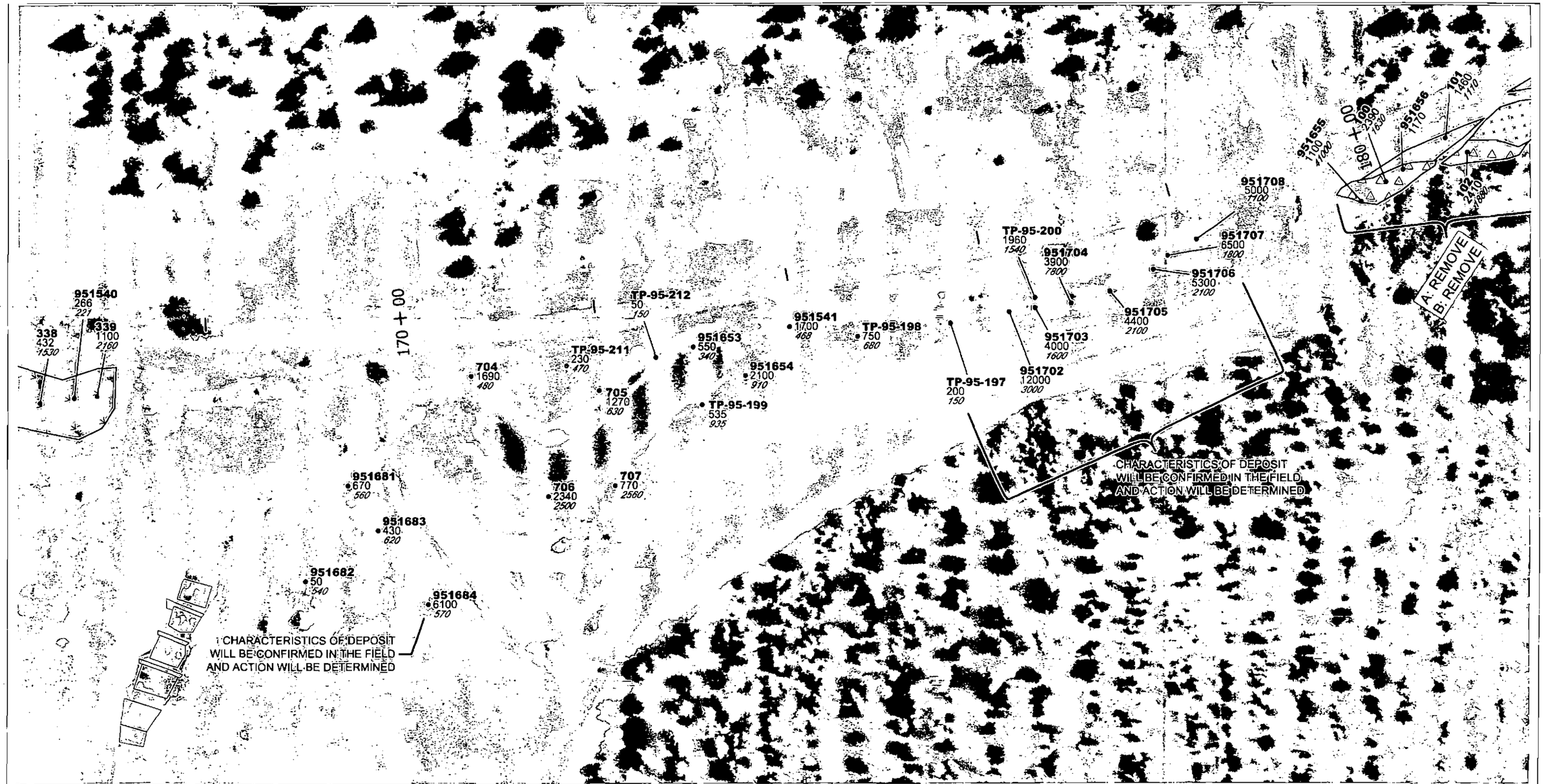
FIGURE **6-13n**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark[K:\Projects\1994\9431595\x003\9000\100102.dwg]2-28-1 15:29]x Xr-Photos,Xr-Soils|i -

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE: SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT.)

REFER TO FEASABILITY STUDY } A: ALTERNATIVES BB-4 AND BB-5; B: ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE **6-13n**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils||:-

Golder Associates

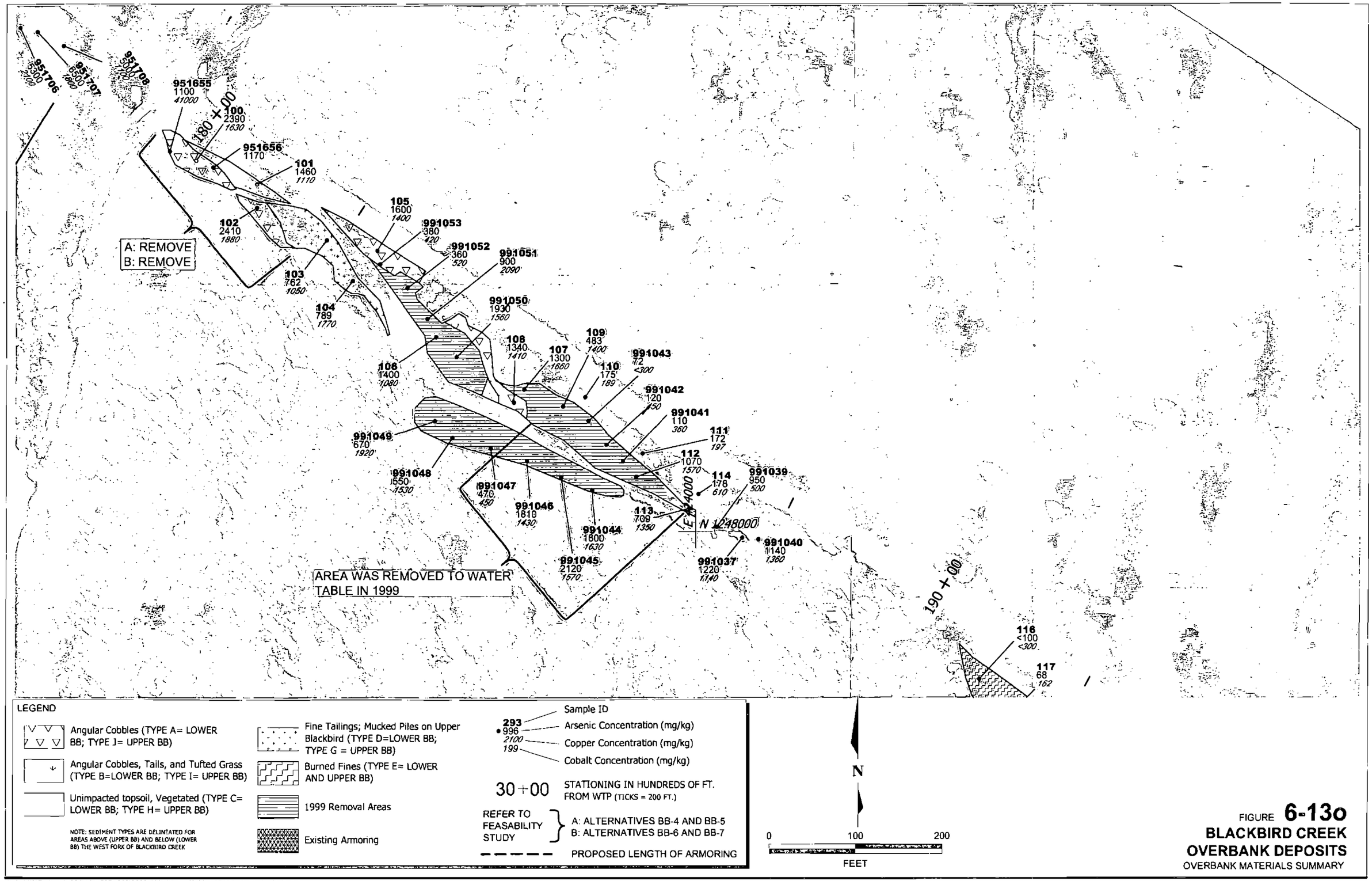


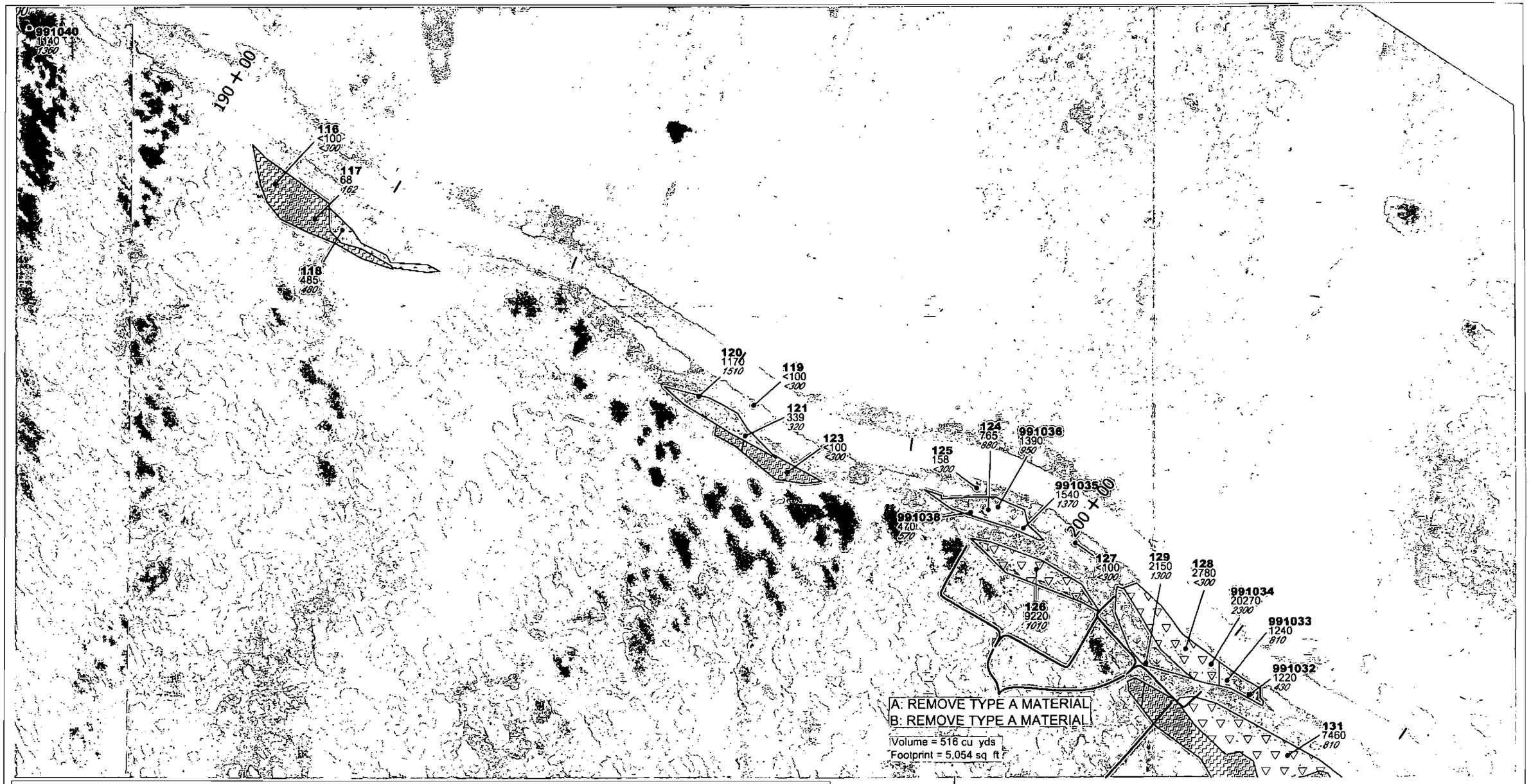
FIGURE **6-13o**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x:Xr-Photos,Xr-Soils|i.-

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT)

REFER TO FEASABILITY STUDY } A ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

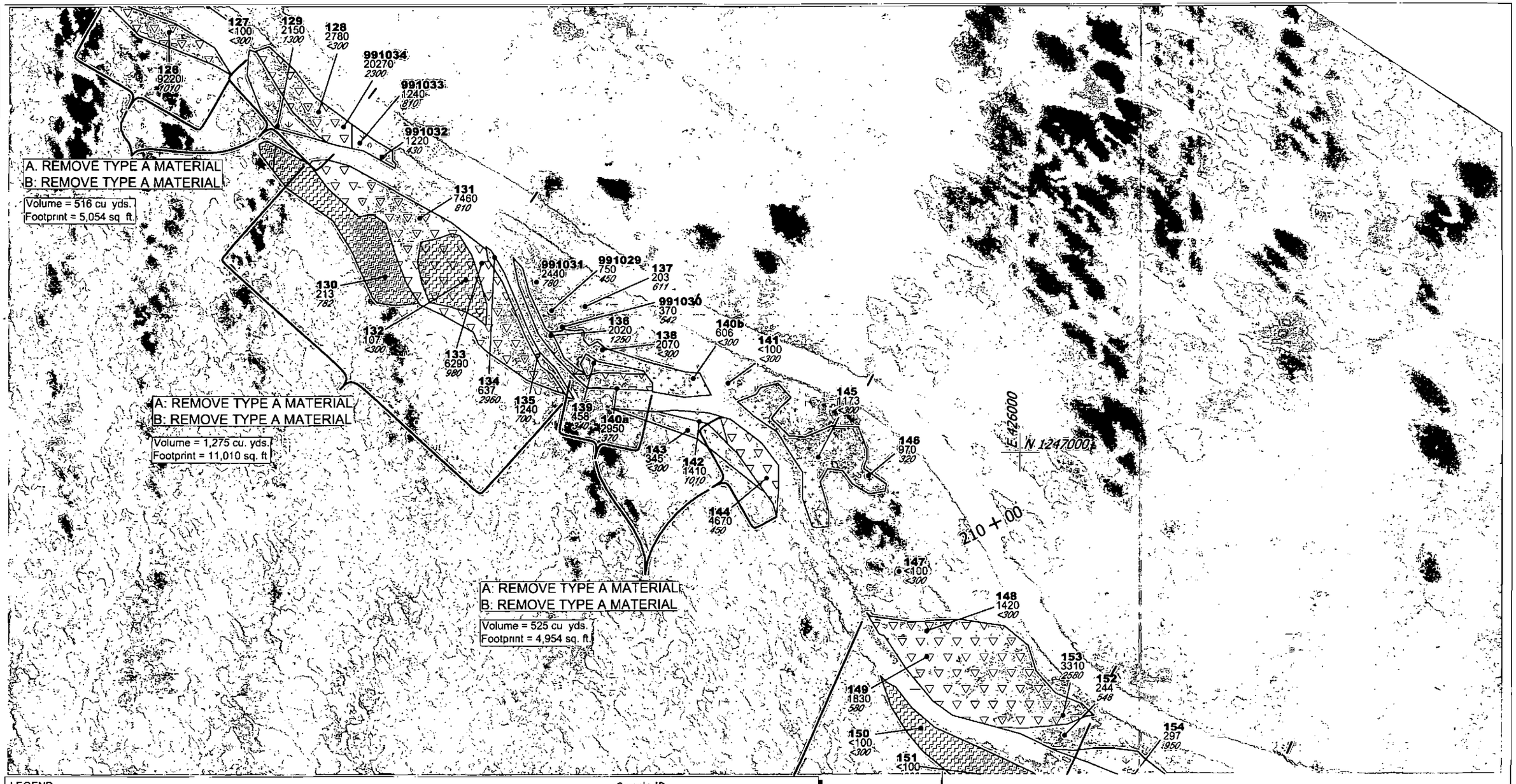
FIGURE **6-13p**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|j -

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)
- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT)

REFER TO FEASABILITY STUDY: A ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

FIGURE **6-13q**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x Xr-Photos,Xr-Soils|

Golder Associates

A: REMOVE TYPE A MATERIAL
B: REMOVE TYPE A MATERIAL

Volume = 1,292 cu. yds.
Footprint = 13,947 sq. ft.

A: REMOVE TYPE A MATERIAL
(LEAVE TUFTED HAIR GRASS)
B: REMOVE TYPE A MATERIAL
(LEAVE TUFTED HAIR GRASS)

Volume = 153 cu. yds
Footprint = 2,059 sq. ft

A ARMOR REMOVAL AREA
B ARMOR REMOVAL AREA

148 1420 <300
149 1830 590
150 <100 <300
151 <100 <300
152 244 548
153 3310 2580
154 297 950
155 1080 950
156 <100 <300
157 777 970
158 <100 <300
159 881 <300
951635 2700 320
991028 830 430
160 944 920
991027 594 1124
161 3540 <300
991026 330 1210
162 1035 1210
163 4620 4990
164 1350 1280
165 775 1700
166 2850 1580
991025 460 <300
991024 210 <300
167 153 <300
991023 370 937
991022 3180 3220
991021 1060 1360
991020 260 <300
951659 400 780
991019 410 410
991018 150 <300
991017 7420 1170
991016 3040 830
991015 15200 940
168 4340 460
991014 350 610

220+00

LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)
- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT)

REFER TO FEASABILITY STUDY: A ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

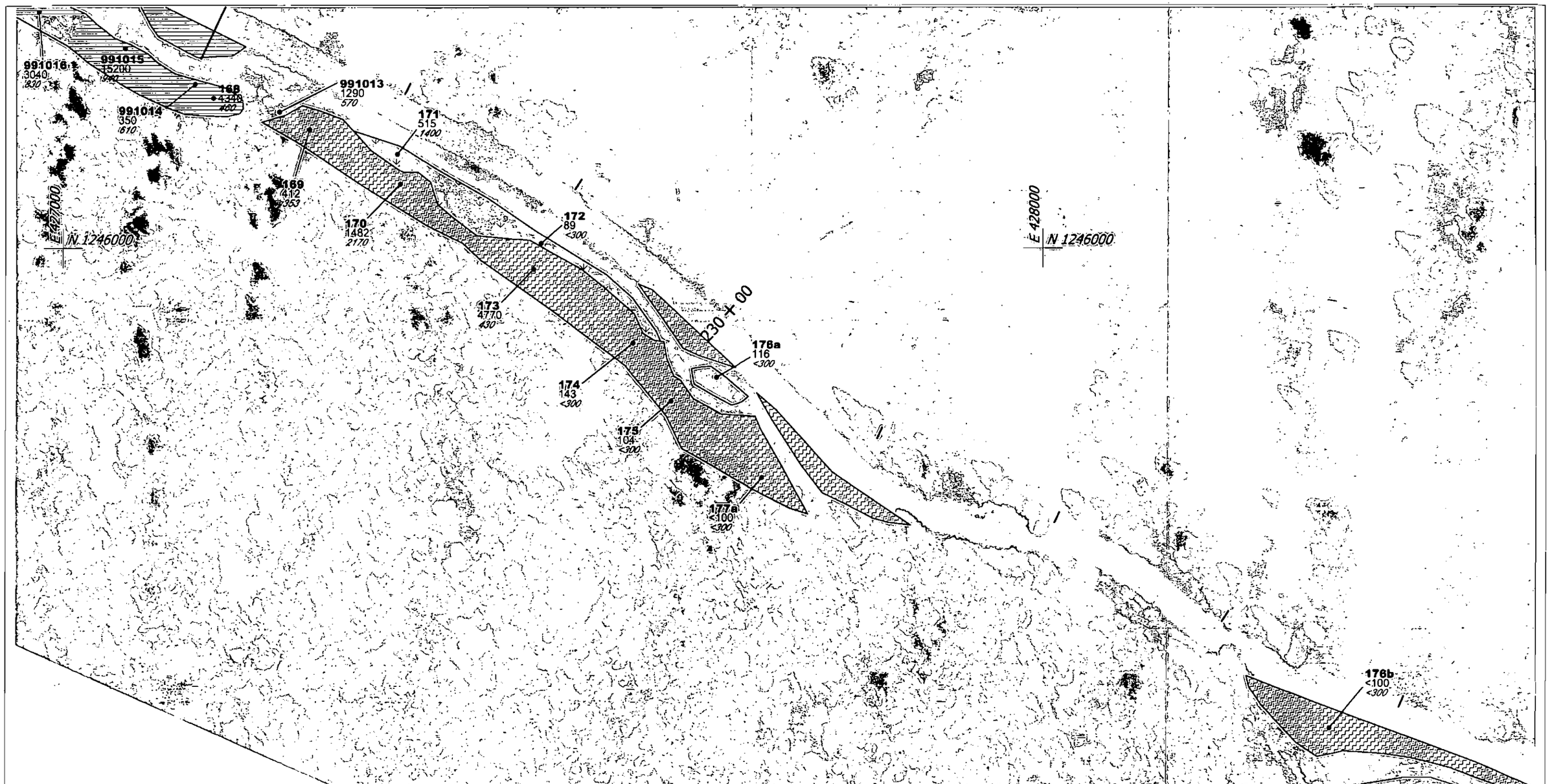
N

0 100 200
FEET

FIGURE 6-13r
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x Xr-Photos,Xr-Soils|-

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)
- Fine Tailings, Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- 293 — Sample ID
- 996 — Arsenic Concentration (mg/kg)
- 2100 — Copper Concentration (mg/kg)
- 199 — Cobalt Concentration (mg/kg)
- 30+00 — STATIONING IN HUNDREDS OF FT FROM WTP (TICKS = 200 FT.)
- REFER TO FEASABILITY STUDY: A ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7
- PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE **6-13s**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K \Projects\1994\9431595\x003\9000\100102 dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|-

Golder Associates

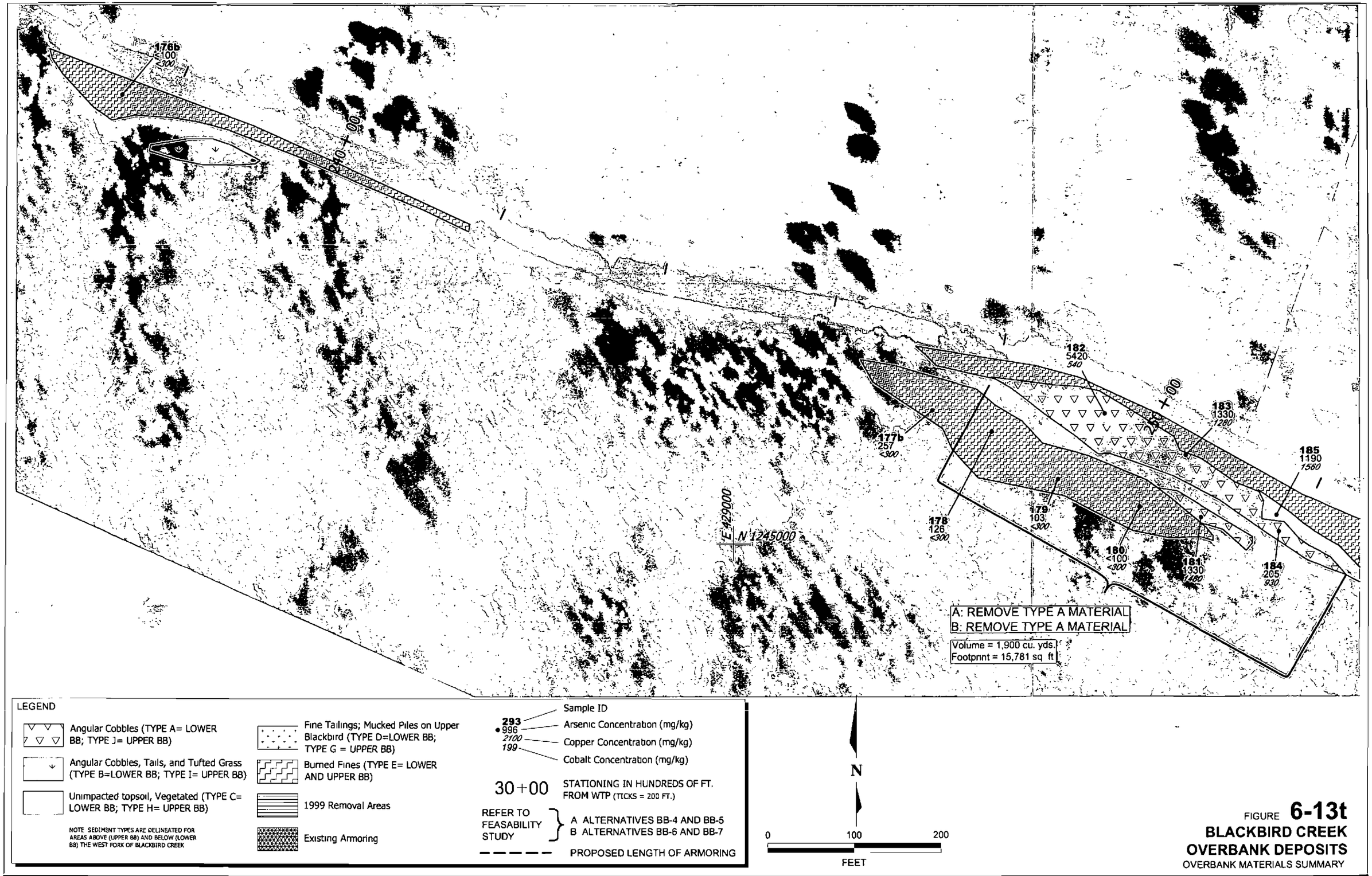


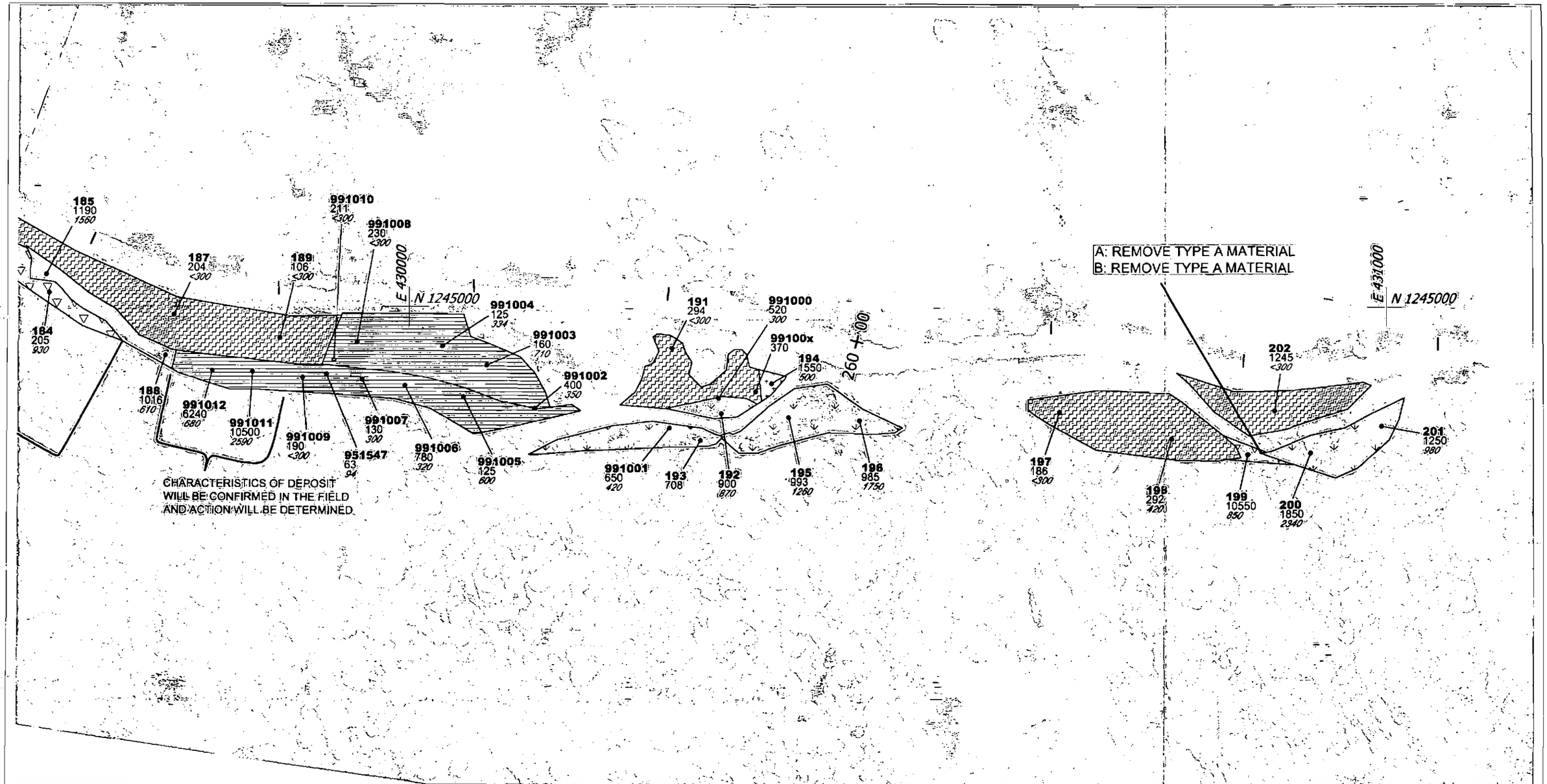
FIGURE **6-13t**

BLACKBIRD CREEK OVERBANK DEPOSITS

OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|i -

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE: SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 — STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT.)

REFER TO FEASABILITY STUDY } A: ALTERNATIVES BB-4 AND BB-5; B: ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

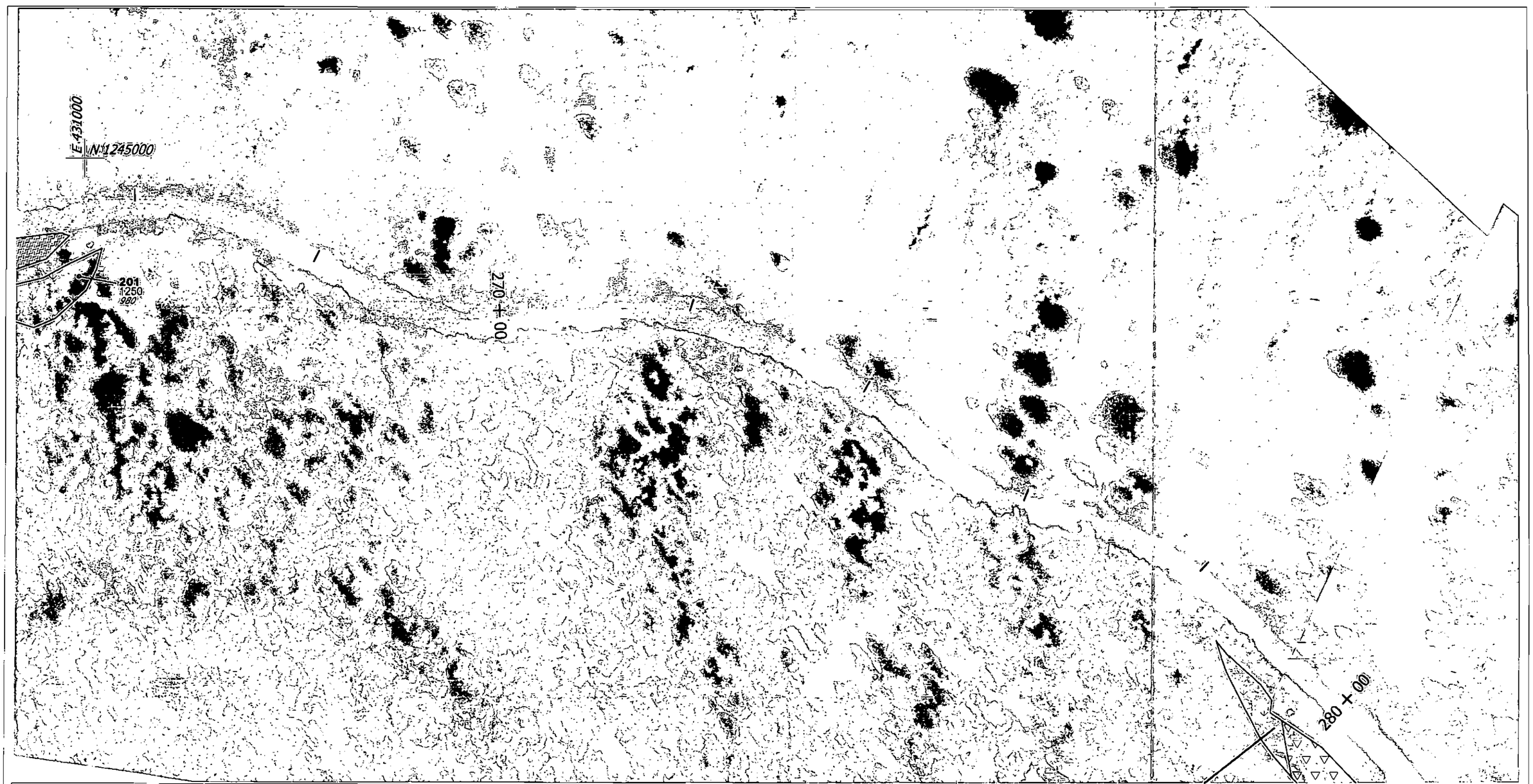
N

0 100 200
FEET

FIGURE **6-13u**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x.Xr-Photos,Xr-Soils|i-

Golder Associates



LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
•996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT)

REFER TO FEASABILITY STUDY } A· ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE **6-13v**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bdark|K:\Projects\1994\9431595\x003\9000\100102.dwg|2-28-1 15:29|x Xr-Photos,Xr-Soils|

Golder Associates

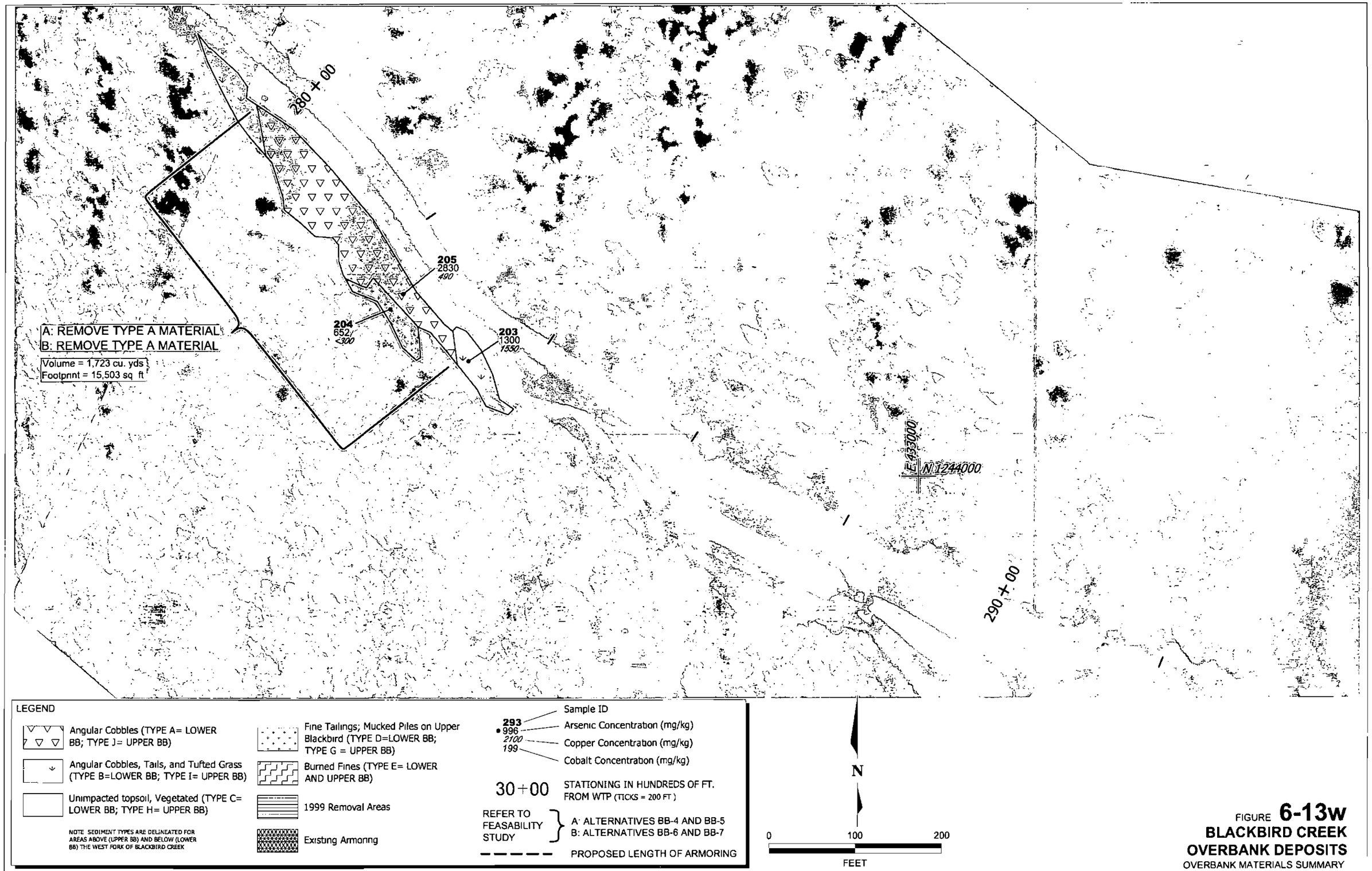


FIGURE **6-13w**
BLACKBIRD CREEK OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K \Projects\1994\9431595\x003\9000\100102 dwg|2-28-1 15 29|x Xr-Photos,Xr-Soils|-

Golder Associates

REMOVE TYPE A SEDIMENTS, SEE TYP. SECTION DRAWING 400A

NOTES:

1. REMOVALS WILL BE TO THE PRG OF 100 MG/KG ARSENIC FOR OVERBANK AREAS AND TO THE PRG OF 490 MG/KG ARSENIC FOR IN-STREAM SEDIMENTS.

2. BACKFILL MATERIAL (I.E. TYPE A RIPRAP AND/OR TYPE B RIPRAP) MAY BE REQUIRED AS DIRECTED BY THE ENGINEER.

3. CONSTRUCTION IMPLEMENTATION OF REMOVAL ACTIONS, INCLUDING TEMPORARY DIVERSIONS AND/OR CONSTRUCTION ACCESS, WILL BE AS DIRECTED BY THE ENGINEER AT THE TIME OF CONSTRUCTION.

290+00

300+00

LEGEND

- Angular Cobbles (TYPE A= LOWER BB; TYPE J= UPPER BB)
- Angular Cobbles, Tails, and Tufted Grass (TYPE B=LOWER BB; TYPE I= UPPER BB)
- Unimpacted topsoil, Vegetated (TYPE C= LOWER BB; TYPE H= UPPER BB)

NOTE SEDIMENT TYPES ARE DELINEATED FOR AREAS ABOVE (UPPER BB) AND BELOW (LOWER BB) THE WEST FORK OF BLACKBIRD CREEK

- Fine Tailings; Mucked Piles on Upper Blackbird (TYPE D=LOWER BB; TYPE G = UPPER BB)
- Burned Fines (TYPE E= LOWER AND UPPER BB)
- 1999 Removal Areas
- Existing Armoring

293 — Sample ID
996 — Arsenic Concentration (mg/kg)
2100 — Copper Concentration (mg/kg)
199 — Cobalt Concentration (mg/kg)

30+00 STATIONING IN HUNDREDS OF FT. FROM WTP (TICKS = 200 FT)

REFER TO FEASABILITY STUDY } A ALTERNATIVES BB-4 AND BB-5; B ALTERNATIVES BB-6 AND BB-7

PROPOSED LENGTH OF ARMORING

N

0 100 200
FEET

FIGURE 6-13x
BLACKBIRD CREEK
OVERBANK DEPOSITS
OVERBANK MATERIALS SUMMARY

bclark|K \Projects\1994\9431595\x003\9000\100102 dwg|2-28-1 15 29|x.Xr-Photos,Xr-Soils|i -

Golder Associates

N

0 200 400
FEET

LEGEND

PROPOSED CAP

NOTES:

1. LOWER BUCKTAIL PUMP STATION PUMPS TO A SECOND UPPER BUCKTAIL PUMP STATION VIA 4" PUMPED WASTE PIPELINE (PD) (PHASE 2).
2. ENLARGE EXISTING BUCKTAIL PUMPS TO PROVIDE CAPACITY FOR ADDITIONAL FLOW FROM PHASE 1 INTERCEPTOR TRENCH.

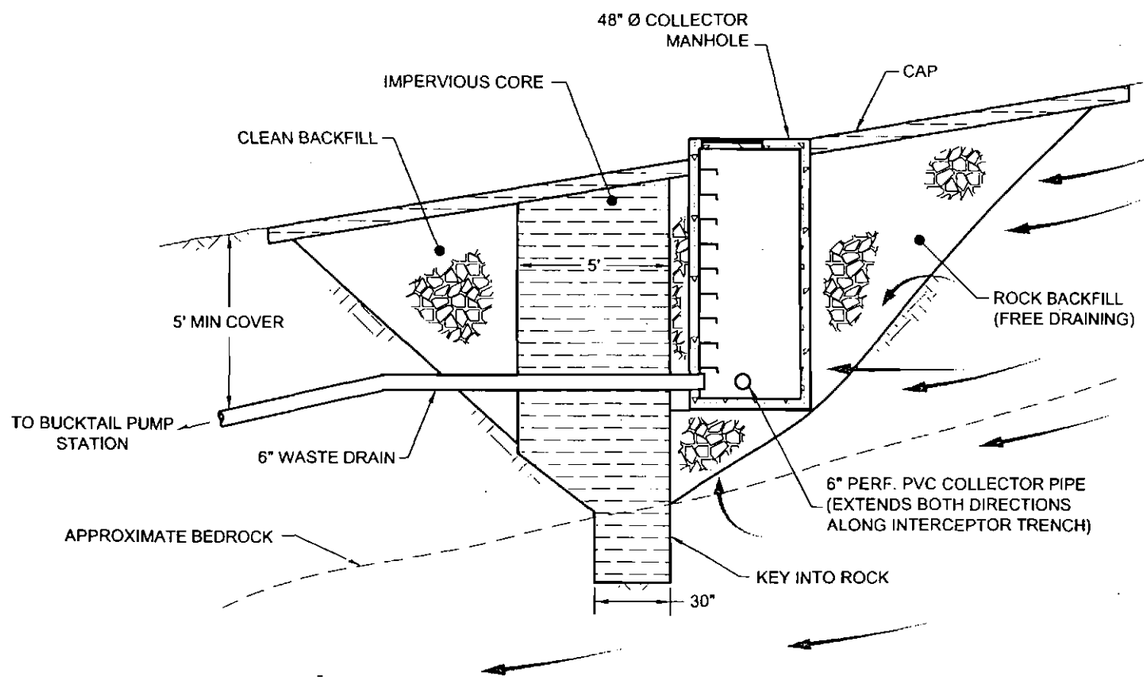
FIGURE **6-14**

BUCKTAIL CREEK SEEPAGE COLLECTION PLAN VIEW

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\94315950039200F07.dwg|5-22-2 11:54|x:-|i:Bucktail 28-2.tif

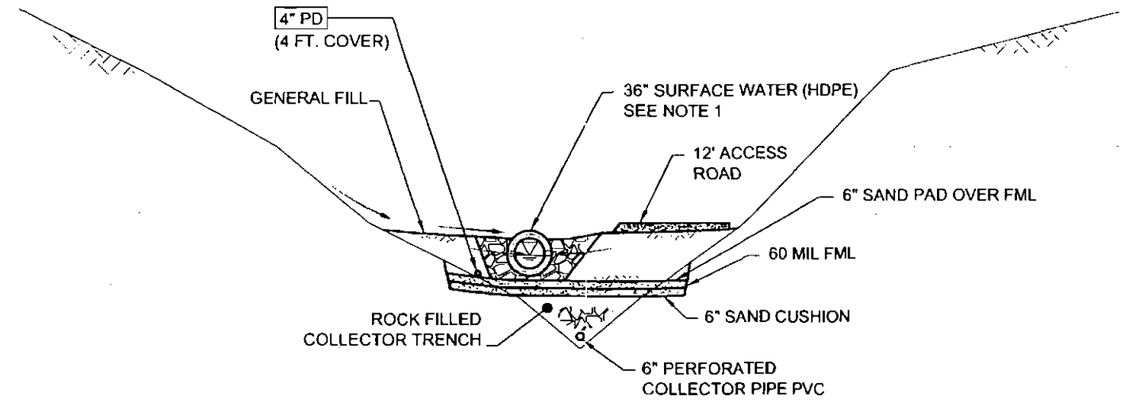
Golder Associates



A 6-14

CUT OFF TRENCH NO. 1 SECTION

NOT TO SCALE



B 6-14

LOWER CAP AND COLLECTION TRENCH

NOT TO SCALE

NOTE:
1. PERFORATE 36" SURFACE WATER PIPE WITH 1" DIAMETER HOLES EVERY 2 FEET.

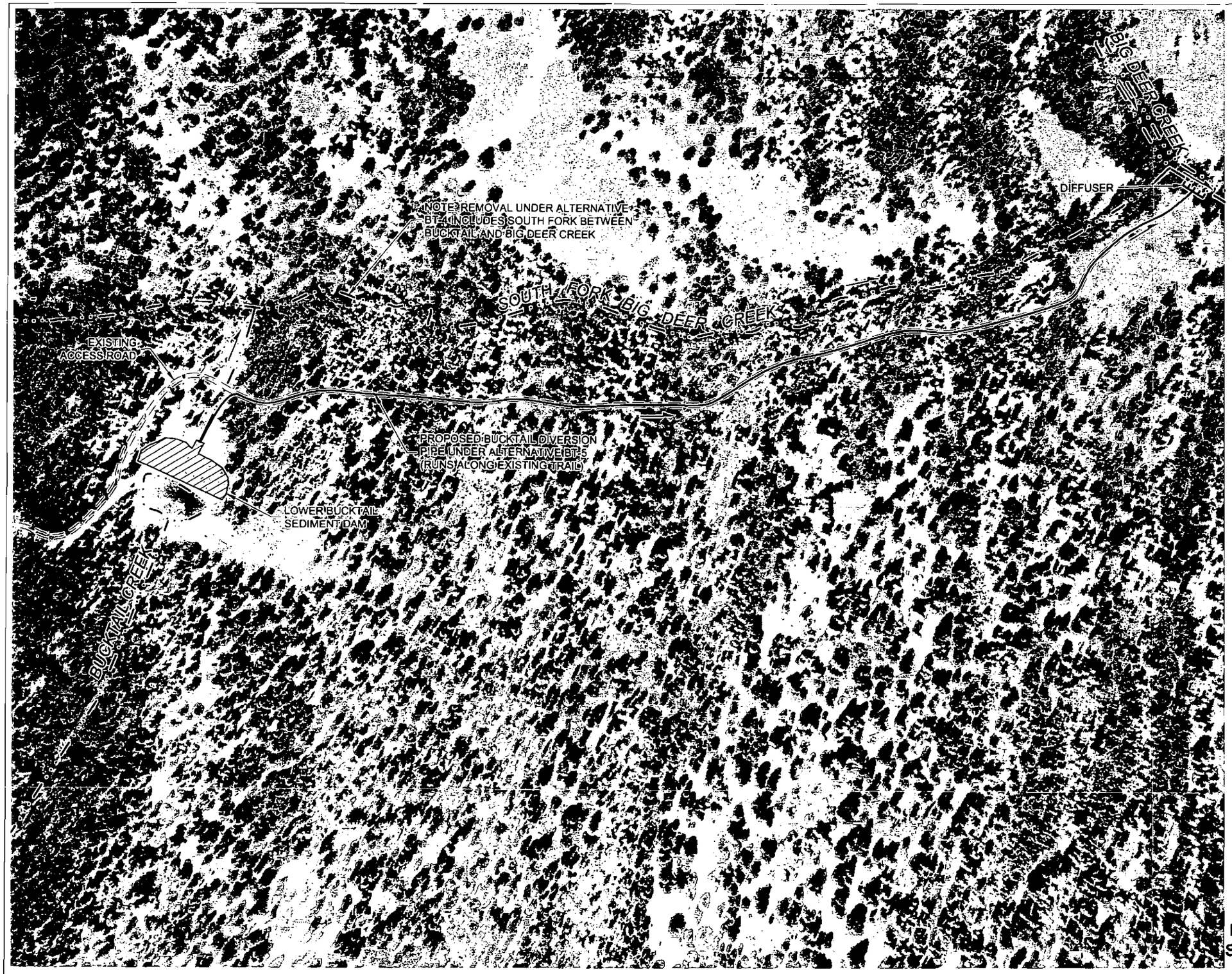
FIGURE **6-15**

BUCKTAIL CREEK SEEPAGE COLLECTION CROSS-SECTIONS

FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\94315950039200F08.dwg|5-22-2 11.02|x:-|i:-

Golder Associates



LEGEND

- CREEK
- SEDIMENT DAM
- PROPOSED DIVERSION
- ACCESS TRAIL

N

0 300 600

FEET

FIGURE **6-16**

BUCKTAIL CREEK DIVERSION AND SOUTH FORK SEDIMENT REMOVAL

FEASABILITY STUDY/BLACKBIRD MINE SITE/ID

bclark|K:\Projects\1994\9431595\x003\9200\94315950039200F09.dwg|5-22-2 11:09|x:-|i:South_Fork.tif

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990046 99-1 COMPOSITE
457 0-4"

990045/44/43
597 0-4"
<5 4-12"
<5 12-18"

981461/62/63
620 0-4"
940 0-4"
810 4-12"

981464
<100 0-4"

981465
660 0-4"

K. ROGERS 3

K. ROGERS 1

Panther Creek

Panther Creek Road

K-29
651 0-6"

K-28
33.2 0-6"

K-21
213 0-6"

K-22
73.3 0-6"

K-23
108 0-6"

981457
360 0-4"

981458
<100 0-4"

K-30
56.6 0-6"

K-26
6.2 0-6"

K-27
597 0-6"

K-25
26.4 0-6"

K-24
37.4 0-6"

981458A/59/60
<100 0-4"
<100 4-12"
<100 12-18"

990047 99-2 COMPOSITE
286 0-4"

LEGEND

991407 — 1999 SAMPLE LOCATION AND DESIGNATION

990051 — COMBINED 1999 SURFACE SAMPLE AND TESTPIT LOCATION AND DESIGNATION

ST-5 0-6" — 2000 SAMPLING LOCATION

ESTIMATED EXTENT OF AREA EXCEEDING PRG

ARROW INDICATES DIRECTION OF FLOW

NOTE: ACTUAL SAMPLE DEPTHS PRESENTED ON FIGURE

ARSENIC CONCENTRATIONS (mg/kg): <5 0-4", 450 4-8", 1000 8-12" — SAMPLE INTERVALS (in)

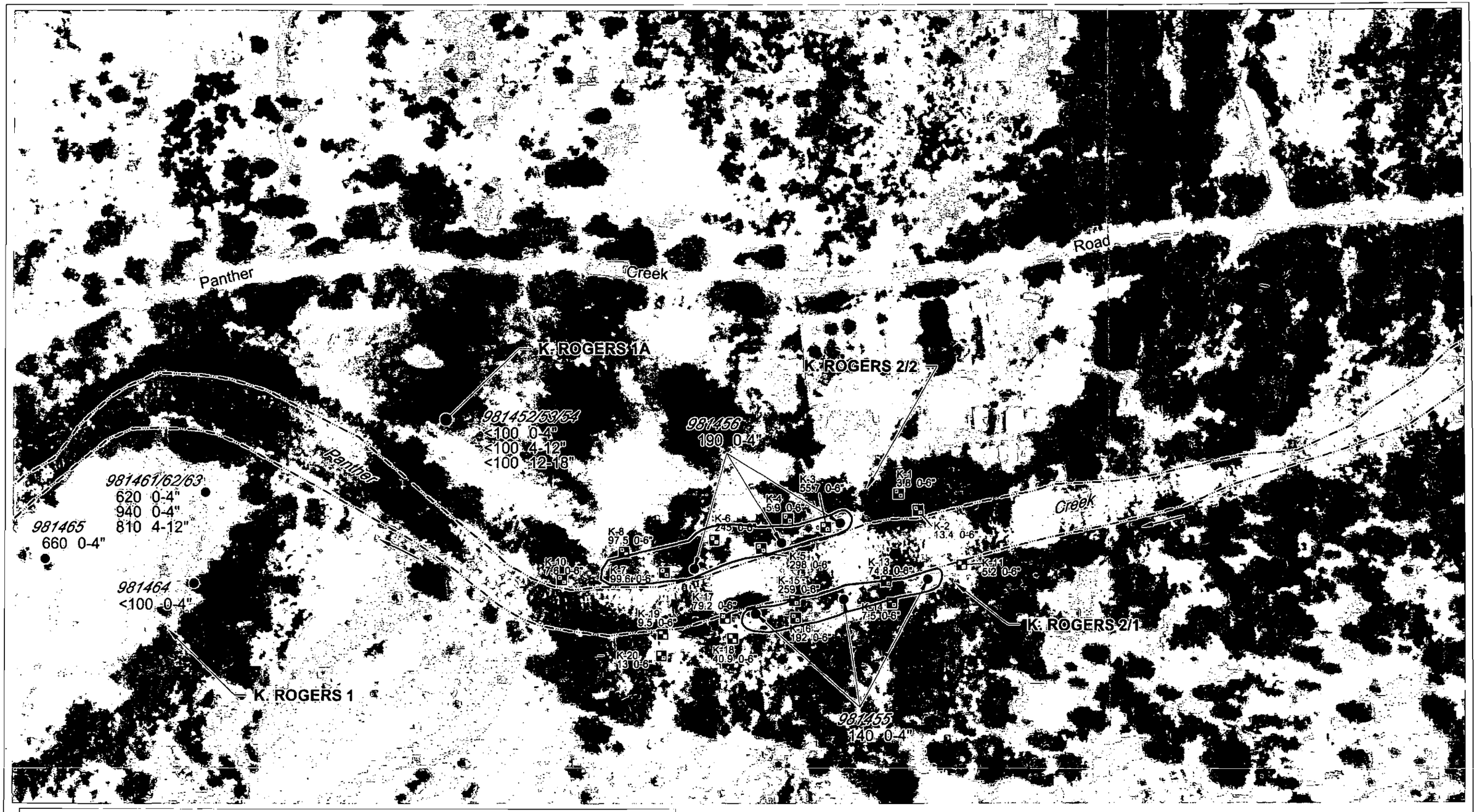
APPROXIMATE SCALE
1":100'
0 100 200
FEET

N

FIGURE **6-17b**
OVERBANK DEPOSIT SAMPLING LOCATIONS - K. ROGERS PROPERTY - AREA 3
BMSG/BLACKBIRD MINE/ID

bclark|K:\Projects\1994\9431595\x003\9000\94315950039000F02.dwg|5-7-2 7:59|x.-|i:GA-5-3.jpg

Golder Associates



LEGEND

- 991407 — 1999 SAMPLE LOCATION AND DESIGNATION
- 990051 — COMBINED 1999 SURFACE SAMPLE AND TESTPIT LOCATION AND DESIGNATION
- ST-5 0-6" — 2000 SAMPLING LOCATION
- ESTIMATED EXTENT OF AREA EXCEEDING PRG

ARROW INDICATES DIRECTION OF FLOW

NOTE: ACTUAL SAMPLE DEPTHS PRESENTED ON FIGURE

ARSENIC CONCENTRATIONS (mg/kg): <5 0-4", 450 4-8", 1000 8-12" — SAMPLE INTERVALS (in)

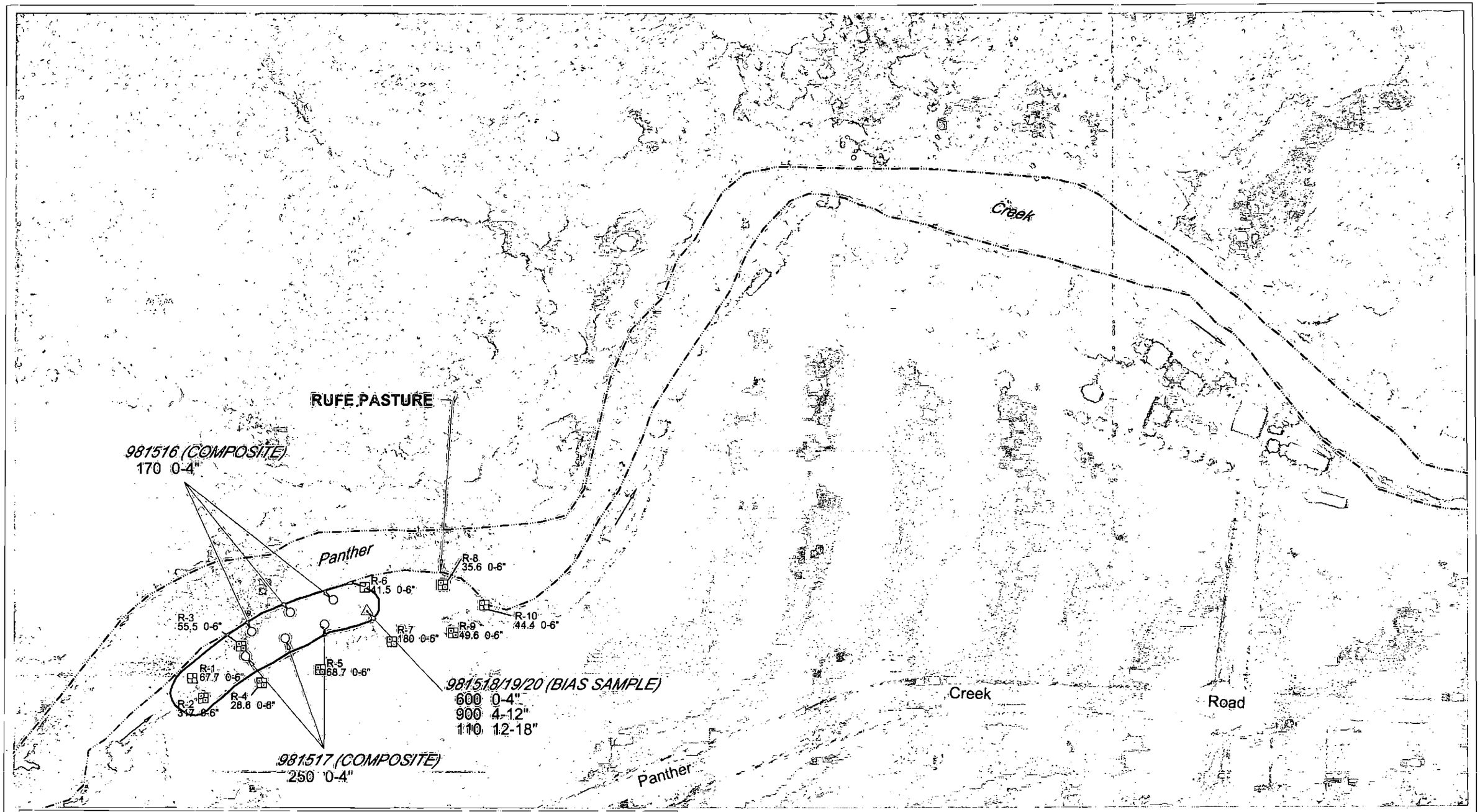
APPROXIMATE SCALE
1":100'
0 100 200
FEET

N

FIGURE **6-17a**
OVERBANK DEPOSIT SAMPLING LOCATIONS - K. ROGERS PROPERTY AREA 2/1 & 2/2
BMSG/BLACKBIRD MINE/ID

bclark|K:\Projects\1994\9431595\x003\9000\94315950039000F01.dwg|5-7-2 7:58|x:-|i:GA-5-3.jpg

Golder Associates



LEGEND

991407	1999 SAMPLE LOCATION AND DESIGNATION
990051	COMBINED 1999 SURFACE SAMPLE AND TESTPIT LOCATION AND DESIGNATION
ST-5 0-6"	2000 SAMPLING LOCATION
	ESTIMATED EXTENT OF AREA EXCEEDING PRG

ARROW INDICATES DIRECTION OF FLOW

NOTE: ACTUAL SAMPLE DEPTHS PRESENTED ON FIGURE

ARSENIC CONCENTRATIONS (mg/kg): <5 0-4", 450 4-8", 1000 8-12" — SAMPLE INTERVALS (in)

APPROXIMATE SCALE
1":100'
0 100 200
FEET

N

FIGURE 6-18
OVERBANK DEPOSIT SAMPLING LOCATIONS - RUFE PROPERTY
BMSG/BLACKBIRD MINE/ID

bclark|K:\Projects\1994\9431595\x003\9000\94315950039000F03.dwg|5-7-2 7:01|x:-|i:GA-4-2.jpg

Golder Associates

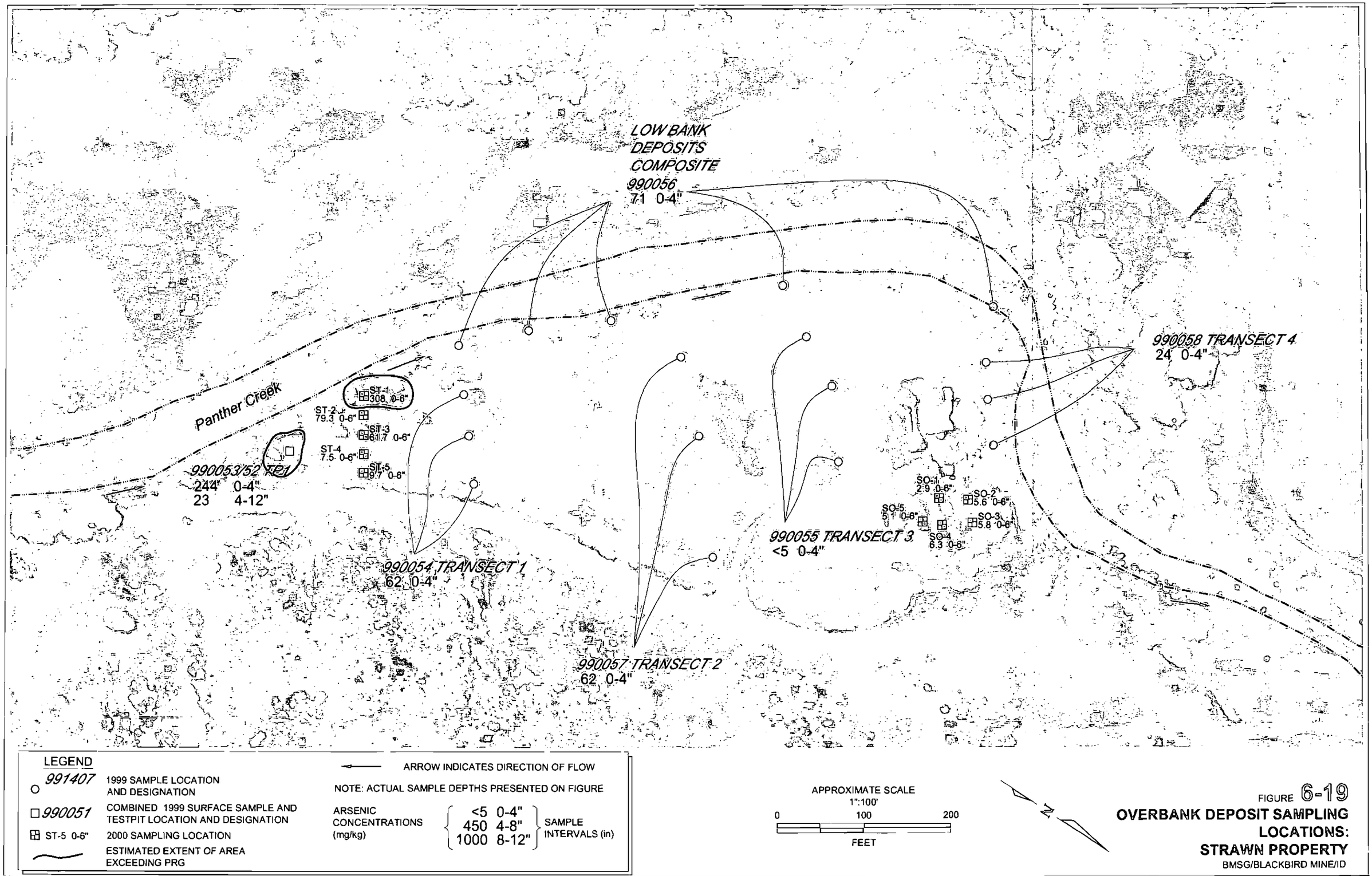


FIGURE 6-19

OVERBANK DEPOSIT SAMPLING LOCATIONS: STRAWN PROPERTY

BMSG/BLACKBIRD MINE/ID

bclark[K:\Projects\1994\9431595\x003\9000\94315950039000F04.dwg]5-7-2 7:56|x:-|i:GA-4-6.jpg

Golder Associates

Figure 7-1
Uncertainty and Variability in Post-Remediation Copper Concentrations (PASW-09)

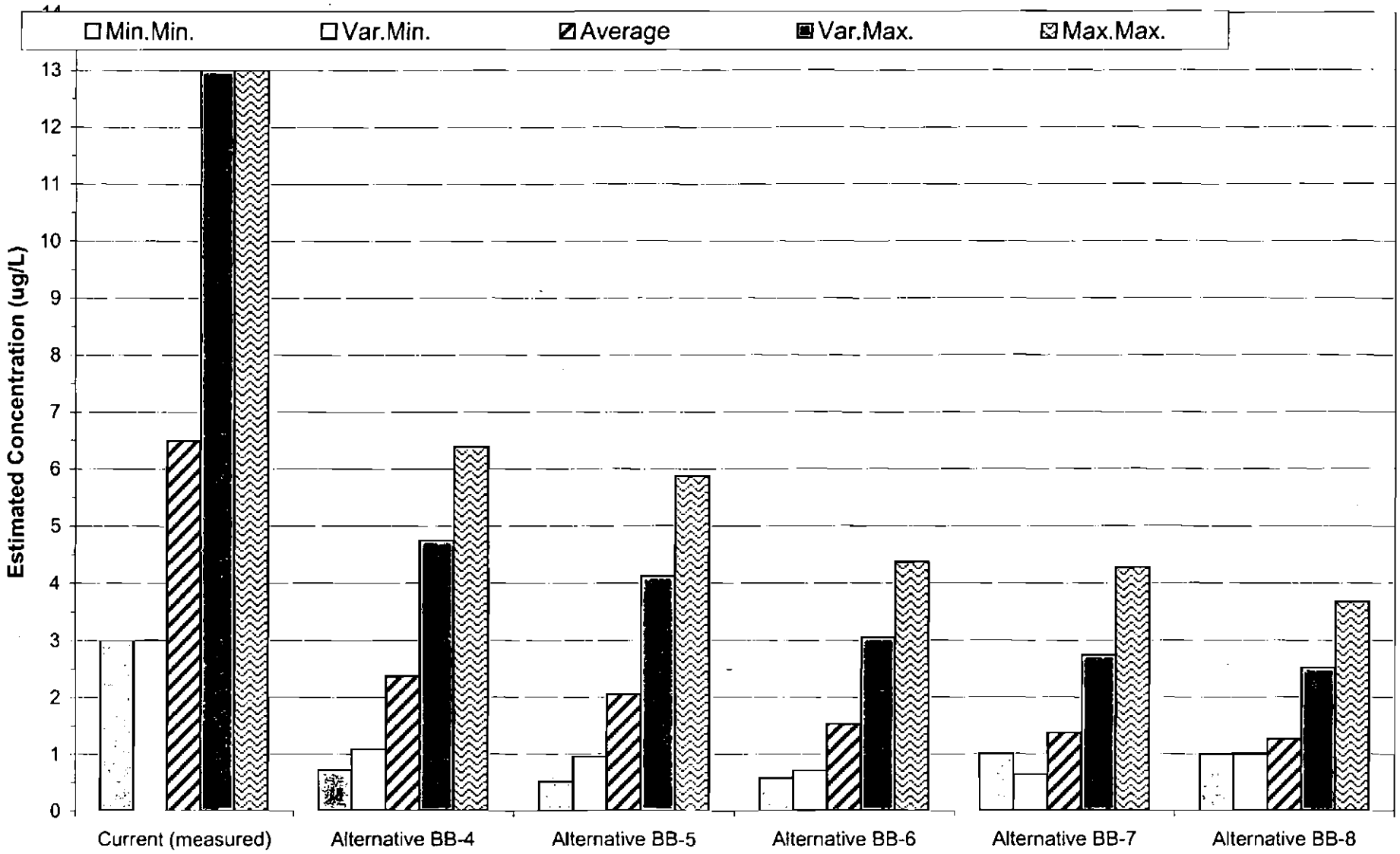


Figure 7-2
Uncertainty and Variability in Post-Remediation Cobalt Concentrations (PASW-09)

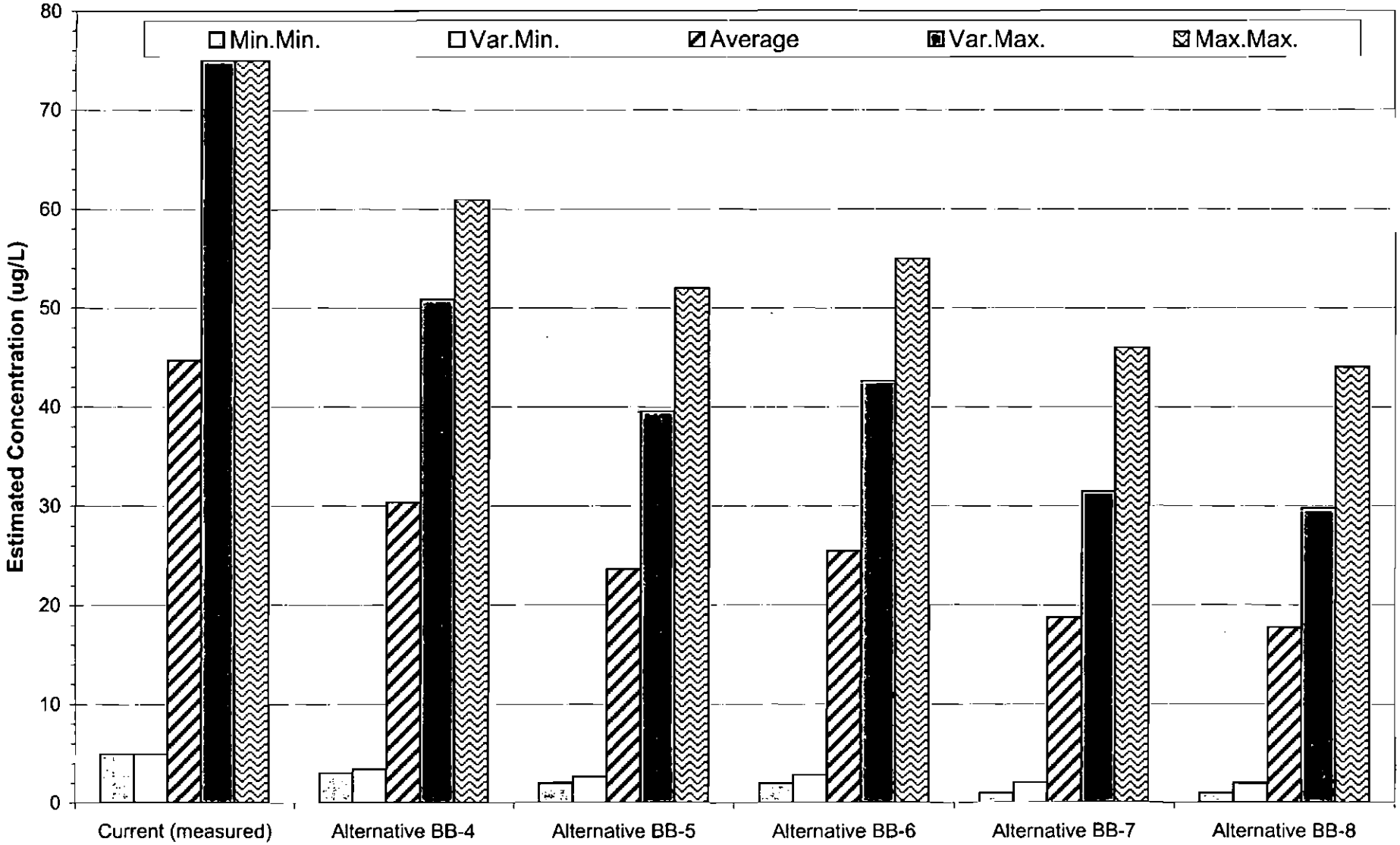


Figure 7-3
Uncertainty and Variability in Post-Remediation Copper Concentrations (BBSW-01A)

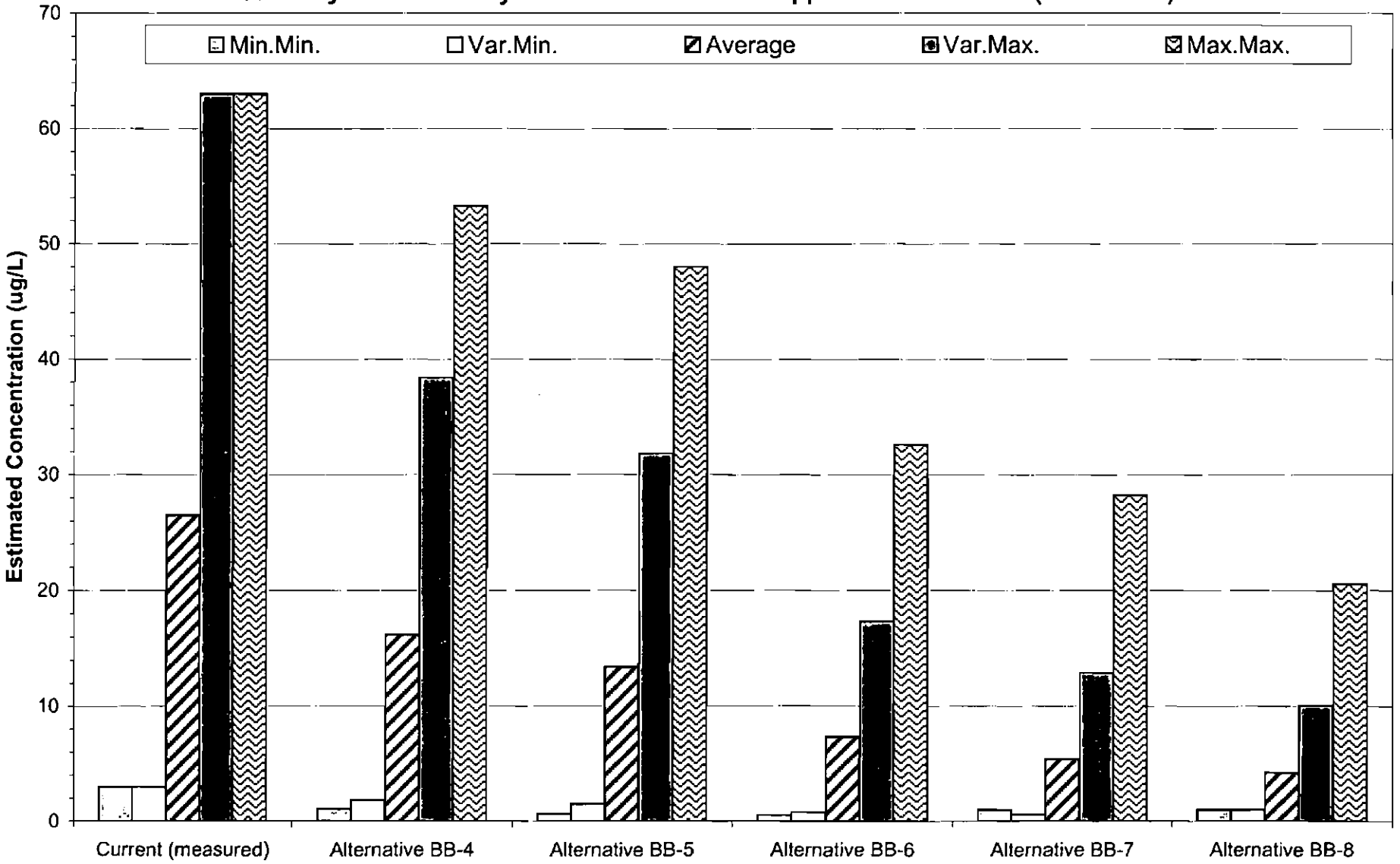
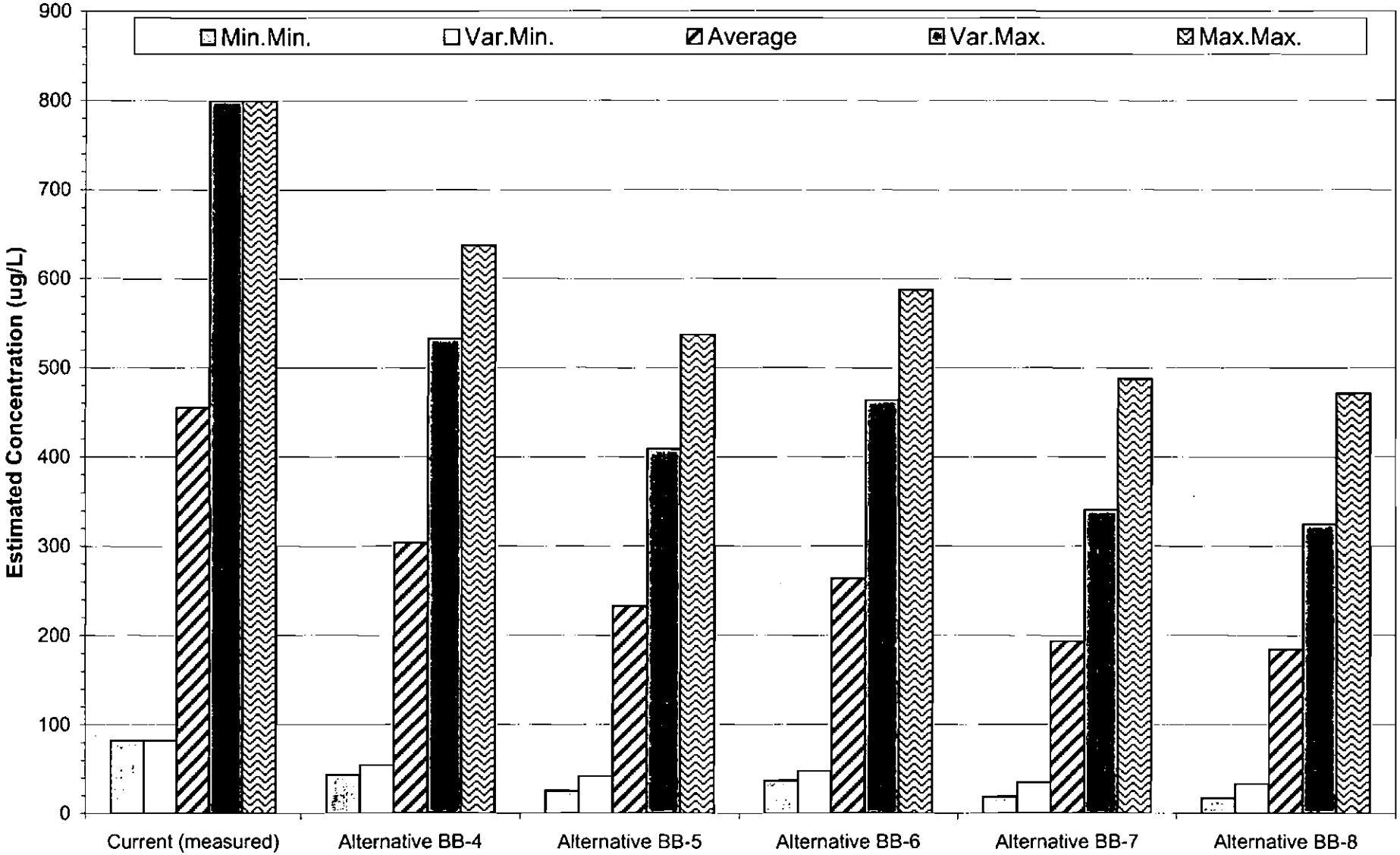
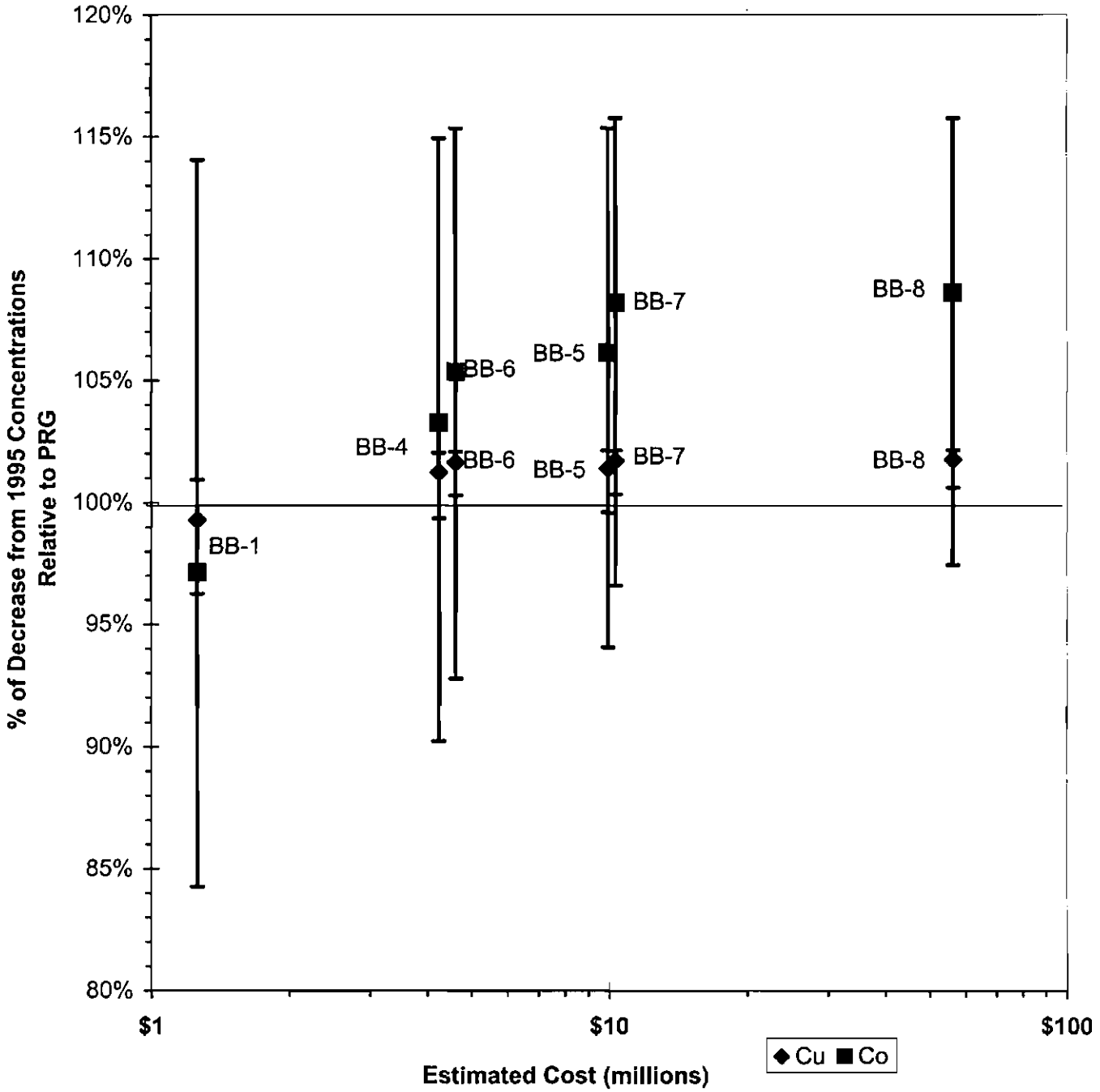


Figure 7-4
Uncertainty and Variability in Post-Remediation Cobalt Concentrations (BBSW-01A)



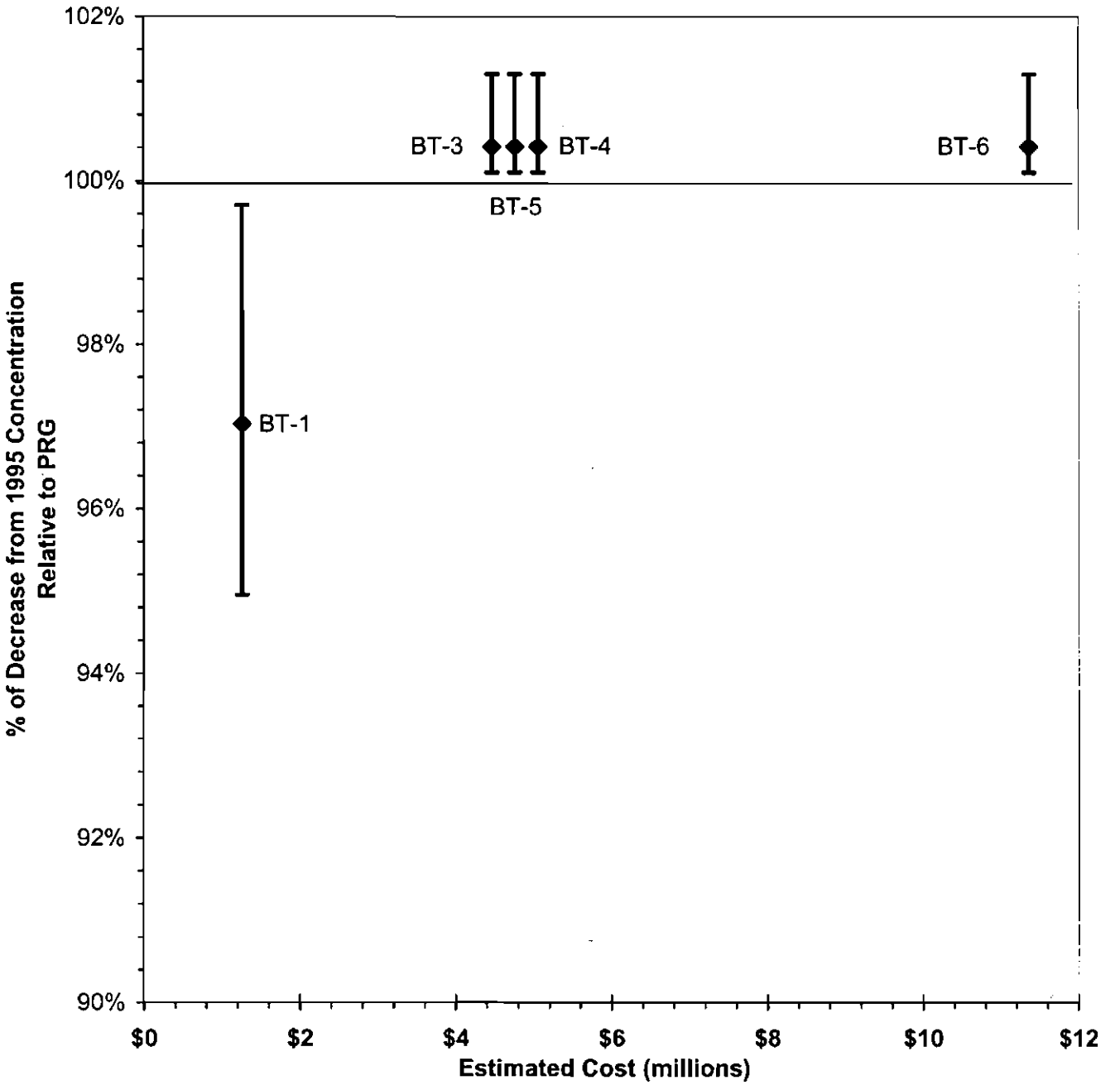


NOTE: Percent reductions calculated by dividing the difference between the highest 1995 concentrations and the average post-remediation concentration estimates by the difference between the highest 1995 concentrations and the PRGs. Estimates based on 2000 and 2001 synoptic data (spring & fall). Error bars based on estimated maximum and minimum removal efficiencies.

Figure 7-5

Cost-Effectiveness of Blackbird Creek Alternatives (based on PASW-09)

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID



NOTE: Percent reductions calculated by dividing the difference between the highest 1995 concentrations and the average post-remediation concentration estimates by the difference between the highest 1995 concentrations and the PRGs. Estimates based on 2000 and 2001 synoptic data (spring & fall). Error bars based on estimated maximum and minimum removal efficiencies.

Figure 7-6

Cost-Effectiveness of Bucktail Creek Alternatives (based on BDSW-03)

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

Plate

PLATE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
SEATTLE, WA 98101

TARGET SHEET

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Site Name:	Blackbird Mine (BBMSF)

Blackbird Mine Site Sampling Locations

Appendix A

APPENDIX A

EXISTING CONDITION GEOMORPHIC EVALUATION OF OVERBANK DEPOSITS IN BLACKBIRD CREEK

APPENDIX A

EXISTING CONDITION GEOMORPHIC EVALUATION OF OVERBANK DEPOSITS IN BLACKBIRD CREEK

BLACKBIRD MINE SITE
LEMHI COUNTY, IDAHO

Prepared for:

Blackbird Mine Site Group

Submitted by:

Golder Associates Inc.
Redmond, Washington

February 25, 2002

943-1595-003.9200
1227App A

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A-1. INTRODUCTION

A-1.1 Overview

The goal of this investigation is to develop a baseline understanding of channel conditions on upper and lower Blackbird Creek. This baseline evaluation will develop a qualitative understanding of the hydraulic and geomorphic characteristics corresponding to a design flood event for Blackbird Creek. The design flood event has been designated by regulatory representatives as the 500-year, 24-hour event. Data used to complete the evaluation was obtained from reference sections corresponding to upper and lower Blackbird Creek reaches. The reference sections were selected based on a site reconnaissance. For the purpose of this evaluation, the reference sections are assumed to provide a representation of wider reaches of upper and lower Blackbird Creek. This information will be used to develop mitigation strategies and assess the feasibility of varying alternatives for addressing mine-related sediments in Blackbird Creek.

A site reconnaissance was completed in October 2000 to observe and evaluate channel conditions in relation to presence of in-stream and over-bank mine related sediments. The reconnaissance included collection of geomorphic data, as well as a detailed photographic record of site conditions. Subsequent site visits and meetings with EPA to the site in July 2001 were also incorporated into the evaluation.

The report is organized as follows:

- Stream Reference Locations/Geomorphic Classification of System - Where stream reference sites were established, this section discusses the location and provides a general discussion of the morphologic condition of the stream system;
- Hydraulic Engineering Analysis – Hydraulic analysis of reference sections in upper and lower Blackbird Creek to determine basic flow parameters corresponding to the design flood event, and
- Discussion of Channel Stability/Existing Condition - This section discusses the existing stability of channel areas that were investigated.

A-1.2 Methods and Procedures

The methods and procedures related to the evaluation of channel morphology and channel hydraulics are as follows:

- Topographic maps and aerial photographs were used to determine the overall watershed and channel characteristics corresponding to the reference sites;
- Standard survey equipment (rod and level, hip chain, tape measure, inclinometer) were used to measure detailed channel geometry at selected reference locations;
- Morphologic assessment incorporated Rosgen methods (1996);
- Pebble counts were conducted to assess the bed material composition at the selected sites;

- Standard of practice hydraulic engineering calculation methods for irregular channel sections were used to evaluate hydraulic parameters corresponding to the design flood event.

A-2. BLACKBIRD CREEK

A-2.1 Geomorphic Classification

The primary reaches of Blackbird Creek addressed during the site reconnaissance extend from immediately below the treatment plant to the confluence with Panther Creek. This reach is generally characterized by either *transport* or *depositional* type stream sub-reaches. *Transport* areas are generally found above the confluence with the West Fork Blackbird Creek, and *depositional* areas are generally found below the confluence with West Fork Blackbird Creek, but it is not un-common for isolated segments of *transport* or *depositional* areas to be located throughout the Blackbird Creek system. Channel reference locations were established for each type of stream segment.

A summary table characterizing upper Blackbird Creek is provided in Table A-1. In the upper reaches of Blackbird Creek, the channel has larger particles that comprise the stream bed armor layer, consisting primarily of large cobbles, small boulders, and talus rock materials resulting from a higher transport competence associated with steeper gradient. Overbank areas are limited, and relatively inactive or poorly developed, and there is generally no significant floodplain. Mid-channel gravel bars, point bars, and islands are commonly interspersed throughout these reaches, generally occurring immediately upstream of constrictions in the channel. These isolated areas can be depositional zones, for even sand-sized particles. The deposition does not often reflect long-term net accumulation. These gravel bars and islands tend to provide only temporary or short-term sediment storage. Sediment supply is minimal in these reaches.

TABLE A-1

Blackbird Creek Typical Transport Reach

Geomorphology and Hydrology	
Stream name/Drainage Basin:	Blackbird Creek, Refer to Figure X (Figure to be completed) for location of Typical Transport Reach Reference Site location, Refer to Figure A-1 and A-2 for typical cross-sections.
Gradient:	~4-6%
Channel Form:	Single Thread in the upper reaches, channel is confined between the mine access road and valley wall.
Sinuosity:	Undetermined
Substrate:	Silts, sands, gravels, and some boulders. Native talus rock material prevalent throughout substrate. Extensive bank stabilization throughout the stream reach with angular riprap material mixing with substrate. Mine related sediments in overbank areas.
Pebble Counts:	No counts taken
Width/Depth Ratio:	3-5
Bankfull Width:	15-25 ft in upper reaches

Geomorphology and Hydrology	
Floodprone Width:	25-35 ft in upper reaches
Entrenchment:	1.4-1.6 in upper reaches
Rosgen Channel Type:	A2 in the transport reaches
Flow at time of survey:	1-3 cfs (est)
Flow depth at time of Survey:	0.2-0.5 feet
Tributaries:	Upper Blackbird
Bank erosion:	Generally, no erosion is evident on in channel materials, stream banks, and along the boundaries of the channel confinement area. Some erosion of historically excavated tailings materials evident. Channel confinement area is defined as between leftbank edge along road and rightbank edge along hillside.
Dominant Vegetation:	Grasses along stream banks and in depositional areas, sparse pine forest along edges of stream

A summary table characterizing lower Blackbird Creek is provided in Table A-2. In the lower reaches of Blackbird Creek, the channel has more broad, flat valley floors with developed floodplains. The stream gradient in these reaches is relatively shallow; the channel tends to exhibit classic pool-riffle structures. These reaches are usually meandering with lateral migration, occasional occurrences of minor braiding, and often large well-developed point bars and overbank areas. Lateral migration is limited to areas between the road and the valley wall. Although multiple channels and overbank areas will provide flood energy relief at higher flows, lateral migration of the active flow channel should be anticipated during larger magnitude flow events. The shallow slope of the water surface promotes a depositional environment as high flows access overbank areas. It is these areas that are most likely to collect sediments over time, as the basis of their morphological development is long-term deposition.

TABLE A-2

Blackbird Creek Typical Depositional Reach

Geomorphology and Hydrology	
Stream name/Drainage Basin:	Blackbird Creek, Refer to Figure X (Figure to be completed) for location of Typical Transport Reach Reference Site, Refer to Figures A-3 and A-4 for typical cross-sections.
Gradient:	~2-3%
Channel Form:	Braided, depositional areas, multiple channel threads, islands, overbank areas, active floodplain connection, channel is confined between the mine access road and valley wall.
Sinuosity:	Undetermined
Substrate:	Silts, sands, gravels, and some boulders. Mine sediments related in overbank areas.
Pebble Counts:	No counts taken
Width/Depth:	23
Bankfull Width:	80-95 ft, with multiple channels, lower reaches
Floodprone Width:	20-140 ft in lower reaches
Entrenchment:	N/A
Rosgen Channel Type:	D3 in the depositional reaches
Flow at time of survey:	2-8 cfs (est)
Flow depth at time of Survey:	0.2-0.5 feet
Tributaries:	Upper Blackbird, West Fork, Ludwig Gulch
Bank erosion:	Generally, depositional areas have characteristic multiple channel areas, and flow accessed overbank floodplains. Floodplain areas are vegetated with grasses and shrubs, and as such resist surface erosion during inundation events. Sorting of gravels in active channel areas is evident, but active lateral bank erosion is mitigated by multiple channels and overbank areas. Although multiple channels and overbank areas will provide flood energy relief at higher flows, lateral migration of the active flow channel should be anticipated during larger magnitude flow events.
Dominant Vegetation:	Grasses, shrubs, bushes, willows along stream banks and in braided areas, sparse pine, conifer forest along edges of stream

A-2.2 Hydraulic Calculations

As discussed previously, two reference sections were established corresponding to both upper and lower Blackbird Creek. The reference sections are summarized in Table A-3 below:

TABLE A-3

Blackbird Creek Reference Sections

X-Section Figure #	Reach/Stream Type	Location
A-1	Upper/Transport	Between Sample 228 and 229*
A-2	Upper/Transport	At Sample 249*
A-3	Lower/Depositional	At Sample 132*
A-4	Lower/Depositional	Between Sample 170 and 172*

Note: Reference cross-section locations indicated on Figure 6-13a through 6-13x.

Each reference section location was surveyed using a stadia rod and level. Key channel characteristics were identified and included in the section surveys. Refer to Figures A-1 through A-4 for the reference cross-sections. Standard of practice hydraulic calculations were performed on each of the irregular channel cross-sections to develop a baseline understanding of flow parameters corresponding to the design event for Blackbird Creek.

The design event is summarized in Table A-4 below. The 500-year flow peak magnitude for Lower Blackbird Creek was developed by completing a hydrologic model of the Blackbird Creek drainage basin. Specific analysis methods and assumptions are addressed in the cited references. The 500-year peak flow magnitude for upper Blackbird Creek was developed by scaling the corresponding drainage basin areas relative to flows developed for lower Blackbird Creek. Flow magnitudes are outlined below.

TABLE A-4

Blackbird Creek Design Event Summary

Stream Reach	Design Event	Peak Flow* (cfs)	Comments
Upper Blackbird Creek	500 year	481*	Reach extends from Treatment Plant to West Fork Creek
Lower Blackbird Creek	500 year	1726*	Reach extends from West Fork Creek to confluence with Panther Creek

*References:

1. Knight Piesold, "Hydrology Report for the West Fork of Blackbird Creek in Lemhi County, Idaho," February 4, 1994.
2. Golder Associates, Volume 1, "Final Design Report Phase 1-Early Action Facilities, Blackbird Mine Site, Cobalt, Idaho," Appendix B – Hydrological Technical Memorandum, June 1995.
3. Golder Associates, "Analysis of Early Action Alternatives for the Panther Creek Inn Area, Blackbird Mine Reclamation, Cobalt, Idaho," Appendix B-2, Rainfall Runoff Calculation, September 1998.

The reference section cross-sectional data and design flow values were used to build a hydraulic model representative of flood flow parameters at each reference section. For the purpose of this model, each modeled reach assumed a continuous stream segment using the reference survey sections. It is understood that this is not a full representation of all the channel characteristics along Blackbird Creek. This modeling exercise is only intended to gain a preliminary understanding of the magnitude for basic flow parameters corresponding to the design flood event. A more detailed analysis would require additional survey sections through the extent of upper and lower Blackbird Creek. The results from the analysis can be used to plan further investigations, if necessary.

Typical channel reaches were constructed using the surveyed reference cross-sections, and entered in HEC-RAS Version 2.2 to develop basic hydraulic parameters. HEC-RAS is a hydraulic model developed by the U.S. Army Corps of Engineers to analyze river and stream systems. The results from the model were used to perform an incipient motion analysis, and predict approximate stream sediment grain sizes that may be mobilized during the design flood event. The results of the model are presented in Table A-5 below:

TABLE A-5

Hydraulic Parameters 500-Year Design Event Summary

Reach/ Ref. Section #		Flow (cfs)	Maning Coeff. (n-value) LOB, CH, ROB			Depth of Flow in Channel (ft)	Velocity (ft/s) LOB, CH, ROB			Vel. Ave. (ft/s)	Shear (lbs/SF) LOB, CH, ROB		
Upper	1	481	0.05	0.035	0.05	3.4	4.1	9.9	4.4	5.9	1.0	2.3	1.1
	2					3.0	4.8	10.0	4.7	7.7	1.4	2.4	1.3
Lower	3	1726	0.05	0.035	0.05	5.2	5.6	12.8	5.4	7.2	1.6	3.3	1.5
	4					5.4	5.8	13.0	5.6	7.4	1.7	3.4	1.6

Note: 1) "LOB" refers to Left Overbank, "CH" refers to Channel, and "ROB" refers to Right Overbank, organized and presented in corresponding columns.

A sensitivity analysis was performed to evaluate a range of Manning Coefficients (n-values) used for overbank floodplain areas channel areas at the reference section locations. The Manning's Coefficient was varied for both the Left Overbank (LOB) and Right Overbank (ROB) floodplains, and within the channel (CH). The sensitivity analysis develops an understanding for the range of baseline hydraulic parameters at the reference sections. Results from the sensitivity analysis are presented in Figure A-5 through A-10. A listing of these figures is provided in Table A-6 below.

TABLE A-6

Summary of Sensitivity Analysis Results Figures

Figure	Data Reporting
A-5	XS 1 and 2, Sensitivity Analysis Results: Depth
A-6	XS 3 and 4, Sensitivity Analysis Results: Depth
A-7	XS 1 and 2, Sensitivity Analysis Results: Velocity
A-8	XS 3 and 4, Sensitivity Analysis Results: Velocity
A-9	XS 1 and 2, Sensitivity Analysis Results: Shear
A-10	XS 3 and 4, Sensitivity Analysis Results: Shear

The Manning's roughness coefficient for overbank (OB) and channel (CH) areas was varied between n=0.03 to 0.07 and n=0.03 to 0.05, respectively. The "baseline" condition for each cross-section (XS) represents a Manning's roughness coefficient of n=0.05 in overbank areas, and 0.035 in the channel. These Manning's coefficients represent the assumed characteristic stream system modeling condition. The sensitivity analysis therefore addresses variation in roughness relative to this "baseline" condition.

In the model, the definition of CH zones results in a very small static area relative to larger OB areas, and does not reflect dynamic changes in CH or OB location during design flow events. Because the CH zone represents such a small portion of the overall conveyance area, it is anticipated that OB zones will govern during the large magnitude 500-year design event. The sensitivity analysis showed that increases in Manning's roughness for OB areas resulted in corresponding increases in flow depth and shear stress, and decreases in velocity, as would be expected. Increases in Manning's coefficients for CH areas resulted in slight decreases in flow depth. This is attributed to the limited ability of the model to define CH areas relative to larger OB areas. The model shows the CH areas approaching supercritical flows (i.e. a more turbulent flow condition) during the 500-year design event, resulting in the slight decrease in flow depth. The results of the sensitivity analysis are consistent with the anticipated conditions during the 500-year design flow event considering the available cross-section data and limitations of the model, and therefore are used for continued conceptual evaluations.

The maximum and minimum values of the hydraulic parameters developed in the sensitivity analysis were used to evaluate the potential for mobilization of sediments within the channel corridor. The results provide a range of inputs for the mobilization evaluation.

It should be noted, that these results are approximate and primarily intended to offer a conceptual understanding for the order magnitude, not the exact dimension of hydraulic parameters or mobilized sediments. Additionally, this level of analysis does not develop a relationship for how target sediment particles interact relative to development of armor layers and sub-surface sediment layers. Reported values should therefore be used as a starting point for evaluation of sediment mobilization.

A mobilization analysis was completed for round stone sediment grain sizes that may be mobilized by the design flood event using Shield's Incipient Motion approach as outlined by the Bureau of Reclamation (BOR), and an Army Corps of Engineers (ACOE) approach. An analysis using Soil Conservation Service (SCS), Federal Highways Works Administration (FHWA), and ACOE methods was also completed for determination of the approximate minimum D50 riprap size that would resist mobilization by the design flood event. The input data used for the calculations are presented in Table A-7 below. The range of inputs represent the approximate maximum and minimum values developed in the sensitivity analysis for each of the primary design parameters. The results from the calculations are preliminary. Additional analysis using a wider range of baseline data may be necessary to finalize results. The results from this analysis are presented in Table A-8 below.

TABLE A-7

Sediment Mobilization Inputs for 500-Year Design Flood Event

Blackbird Creek Reach	Depth (ft) OB, CH		Vel. (ft/s) OB, CH		Shear (lbs/SF) OB, CH		Slope (ft/ft)
Upper	1.3-2.0	2.8-3.7	2.75-9.0	7.5-10.5	0.6-2.8	1.4-4.9	4.5%
Lower	2.2-3.4	4.6-5.7	4.0-8.7	9.0-13.9	1.0-3.5	2.0-6.9	2.3%

Note: 1) "OB" refers to Overbank, "CH" refers to Channel, organized and presented in corresponding columns.

TABLE A-8

Sediment Mobilization Summary for 500-Year Design Flood Event

Blackbird Creek Reach	Round Stone Dia. Mobilization Results				Riprap Size Results			
	Incipient Motion (1) (ft) OB, CH		COE (2) Round Stone (ft) OB, CH		SCS (3) Max Dia. Riprap (ft) OB, CH		COE (4) Min. D50 Riprap (ft) OB, CH	
Upper	0.59-0.87	1.3-1.6	0.1-1.0	0.7-1.25	0.1-1.0	0.7-1.3	0.2-0.7	0.4-1.3
Lower	0.50-0.77	1.1-1.3	0.2-0.8	1.0-2.1	0.3-1.0	1.0-2.3	0.3-0.8	0.5-1.7

References:
1) "Computing Degradation and Local scour," Technical Guideline for Bureau of Reclamation, 1984.
2) "Engineering and Design, Hydraulic Design of Flood Control Channels," Department of the Army, D.C., 1975.
3) United States Department of Agriculture, Soil Conservation Service, Engineering Field Manual, 1993.
4) "Engineering and Design, Hydraulic Design of Flood Control Channels," Department of the Army, D.C., 1975.
Note: 1) "OB" refers to Overbank, "CH" refers to Channel, organized and presented in corresponding columns.

A-2.3 Discussion of Channel Stability/Existing Condition

In general, there are no significant impacts or changes in channel morphology resulting from the recent fire on the mobilization of mine-related sediments. However, some areas were identified in the upper portion of Blackbird Creek where changes in the drainage characteristics as a result of the fire have resulted in increases in run-off, and corresponding drainage issues.

Further discussion related to stability will reference either *transport* or *depositional* reaches. For each reach stream type, a relative magnitude of stability is established as defined below:

High Stability – Minimal potential for changes in targeted channel dynamic characteristics correlating to minimal anticipated changes in channel configurations and minimal in-channel or over-bank of sediment mobilization. Stability consistent during all but extreme peak flow events.

Moderate Stability – Some potential for changes in targeted channel dynamic characteristics during extreme peak flood events but not during lower to medium frequency over-bank events correlating to minimal changes in channel configuration or slow changes in channel alignment. Some mobilization of sediments short distances downstream from the point of mobilization initiation. Higher flow events dissipate flood flow energy by accessing over-bank floodplain areas reducing erosive power of the event and minimizing lateral or vertical erosion. Existing native vegetation resistant to surficial over-bank flows resulting in stable over-bank areas.

Low Stability – Anticipate changes in targeted channel dynamic characteristics during low to medium frequency over-bank events resulting in frequent changes in channel alignment and lateral migration as well as the potential for localized down-cutting of the channel profile elevation. Anticipate mobilization of stream sediments resulting in changes in lateral channel location and/or vertical changes in channel profile depending on magnitude and duration of events. Due to constant mobilization of sediments, native vegetation is slow to establish and not considered resistant to over-bank flows or inundation of floodplain areas.

A-2.3.1 Transport Reach Stability

Transport reach areas can be considered to have High Stability. Stability is defined as outlined above. Channel sediments in this case can either be stored in laterally located over-bank areas, or vertically in deeper channel depositional zones. Correspondingly, the two primary modes of channel dynamics that may impact sediments are lateral erosion/channel migration and downcutting of the channel profile elevation.

In the case of potential lateral channel erosion or channel migration, it can be expected that the increases in erosive energy resulting from increases in flow magnitude will be resisted by the heavy, large, angular nature of the native talus hill slopes and in-channel material, the installed rip-rap armor rock along either side of the stream channel or roadway, or existing native bedrock outcroppings.

In some areas, mine related sediments have been excavated from the channel and placed in overbank areas. This was completed by the United States Forest Service (USFS) following historical peak flood events in the 1970's. These material placements are very distinctive, and easily defined in location and size. Where peak flows can access these areas, erosion of the fine grain sized material should be expected. These areas may be accessed by increases in water surface elevations, but should not be expected to be accessed by lateral erosion of stream channel banks or downcutting of the channel profile.

Limited locations of these mine related sediment deposits are subject to accumulation of drainage water behind and up-slope of the placement material. Some of this accumulation of drainage water appears to be the result of changes in drainage characteristics resulting from the recent fire. In limited instances, the accumulated drainage water flows over the top of the mine related sediment placements, causing surficial erosion of the fine-grained material. These areas can be easily mitigated by modifying and/or grading out flowpaths to allow for natural drainage of accumulated water.

A-2.3.2 Depositional Reach Stability

Depositional reach areas can be considered to have Moderate Stability. Stability is defined as outlined above. Channel sediments in this case can either be stored in laterally located overbank areas, or vertically in deeper channel depositional zones. Correspondingly, the two primary modes of channel dynamics, which may impact sediments, are lateral erosion/channel migration and downcutting of the channel profile elevation.

Although changes in channel bank configuration can be expected, these changes will most likely correlate to modification by the stream of new depositional material, and not longer term stream bank or deeper subsurface sediment materials. During low to medium events, it can be expected that these reaches will continue to aggrade (accumulate sediments) both in channel areas as well as over-bank floodplain areas. Larger magnitude flow events may cause lateral changes in channel alignment. But, the relative infrequent occurrence of extreme peak flow events (i.e. the 500-year design event) reduces the risk of substantial lateral changes in channel location.

By definition, depositional areas are not prone to significant downcutting changes in channel profile elevations, except during extreme peak events. It should be anticipated that depositional reaches will continue to exhibit braided channel alignments, and access the available floodplain areas to dissipate low to medium flood flow event energy.

A-3. REFERENCES

"Computing Degradation and Local Scour," Technical Guideline for Bureau of Reclamation (BOR), 1984.

"Engineering and Design, Hydraulic Design of Flood Control Channels," Department of the Army (ACOE), D.C., 1975.

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Knight Piesold, "Hydrology Report for the West Fork of Blackbird Creek in Lemhi County, Idaho," February 4, 1994.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

United States Department of Agriculture, Soil Conservation Service (SCS), Engineering Field Manual, 1993.

FIGURES

Figure A-1	Upper Blackbird Creek Reference Section 1
Figure A-2	Upper Blackbird Creek Reference Section 2
Figure A-3	Lower Blackbird Creek Reference Section 3
Figure A-4	Lower Blackbird Creek Reference Section 4
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Figure A-8	XS 3 and 4 Sensitivity Analysis results: Velocity
Figure A-9	XS 1 and 2 Sensitivity Analysis results: Shear
Figure A-10	XS 3 and 4 Sensitivity Analysis results: Shear

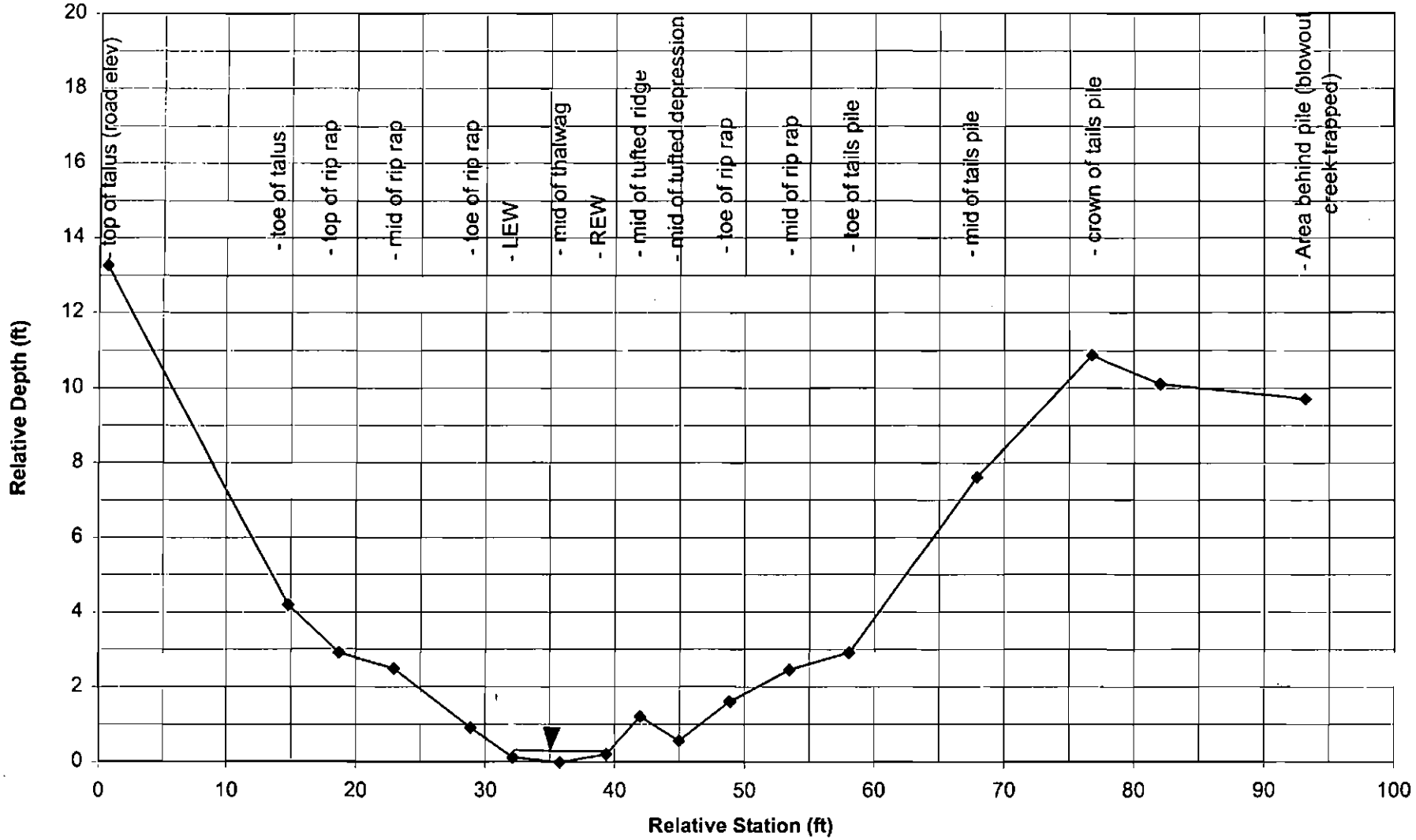

FIGURE **A-1**
UPPER BLACKBIRD CREEK
REFERENCE CROSS-SECTION 1
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96908 DATE 12/28/01 DRAWN BY EL

Golder Associates

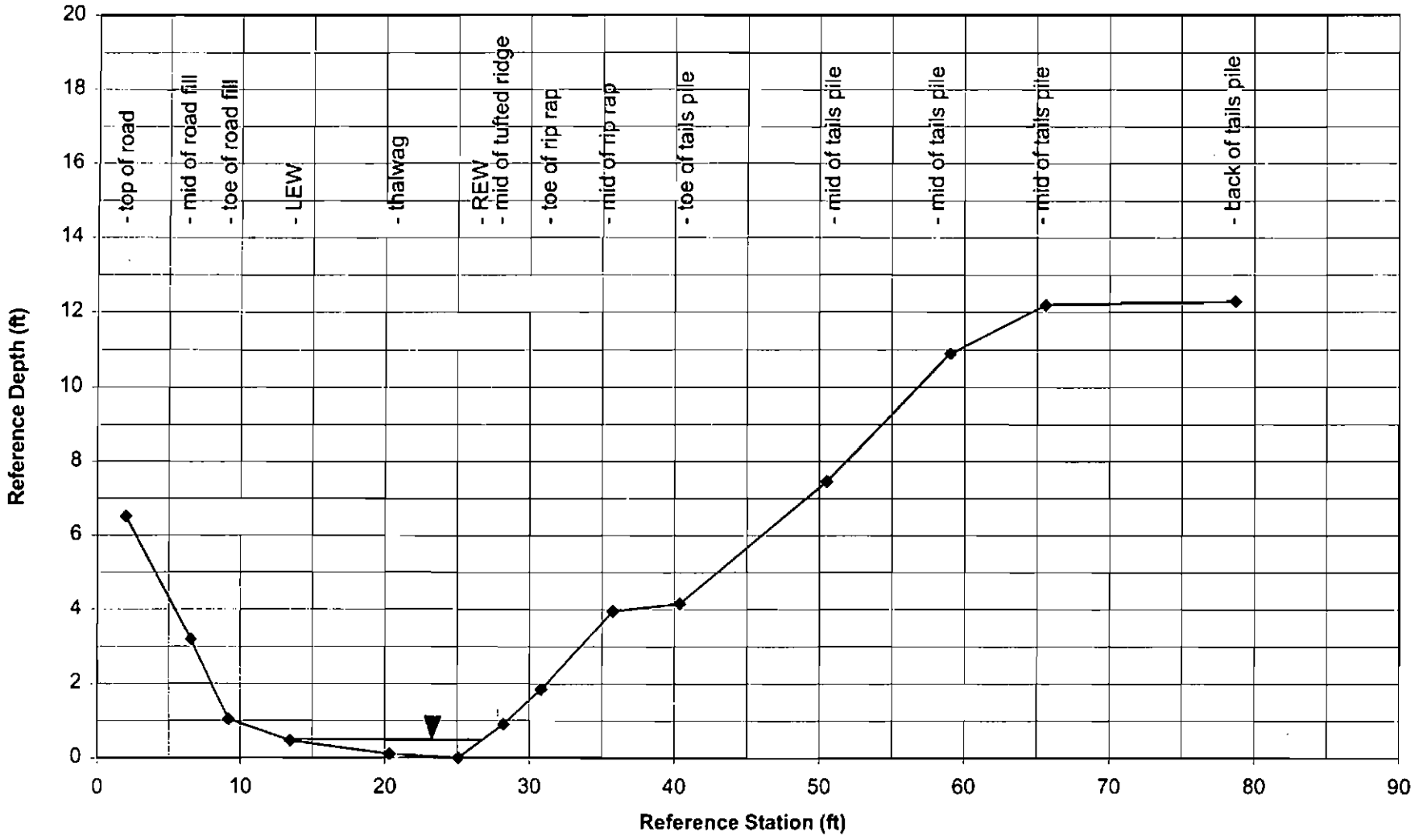

FIGURE **A-2**
UPPER BLACKBIRD CREEK
REFERENCE CROSS-SECTION 2
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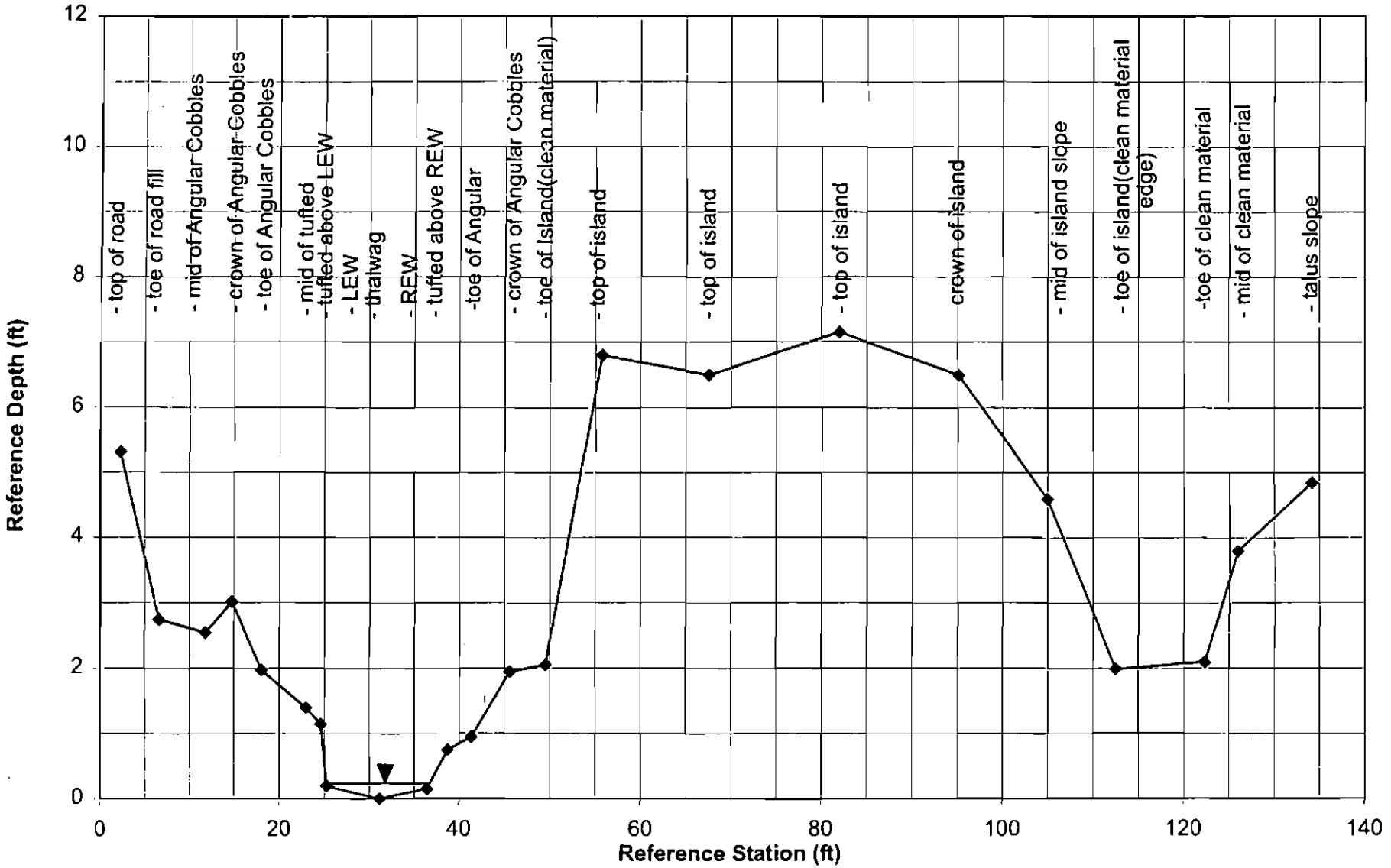

FIGURE **A-3**
LOWER BLACKBIRD CREEK
REFERENCE CROSS-SECTION 3
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96907 DATE 12/28/01 DRAWN BY EL

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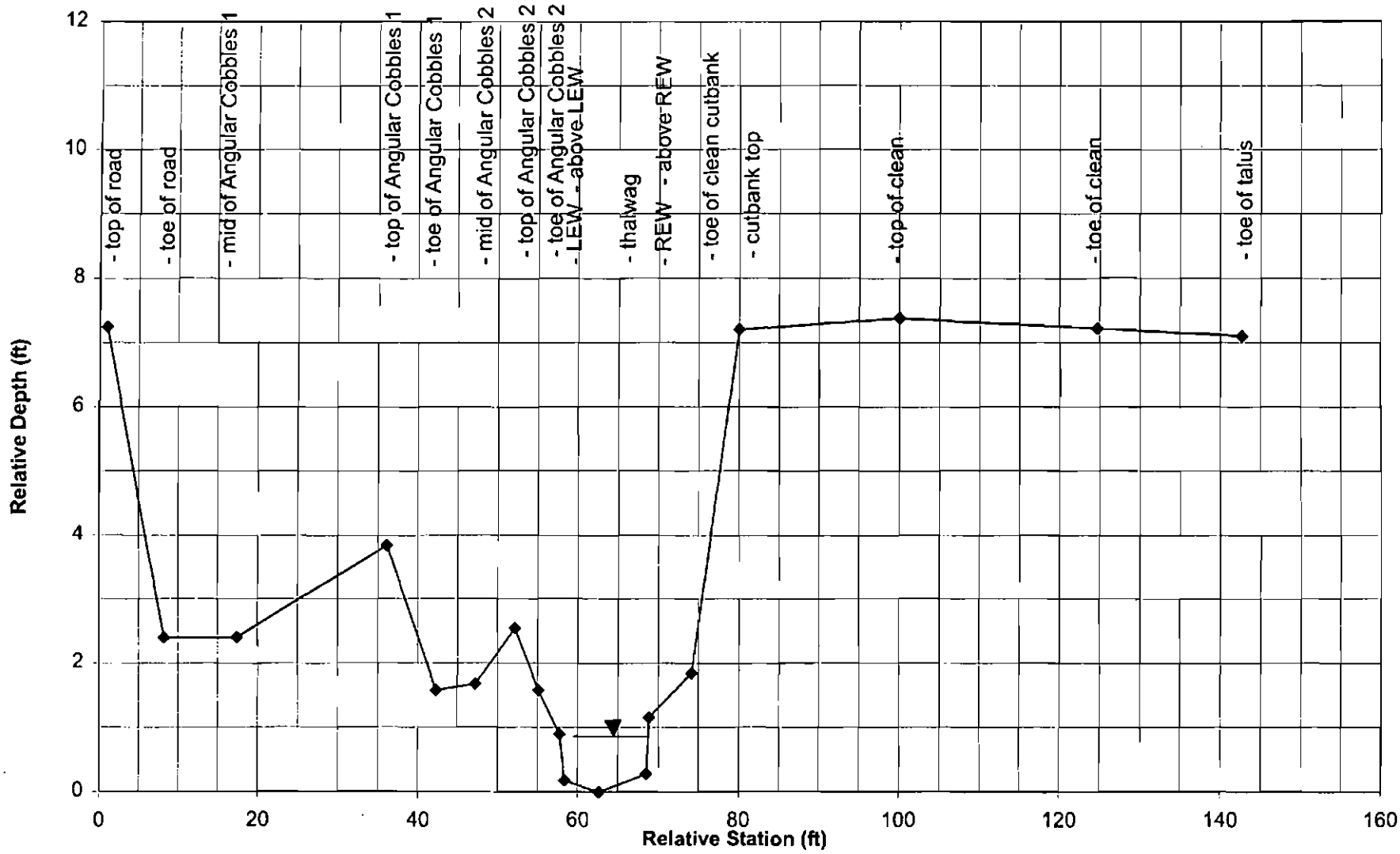

FIGURE **A-4**

LOWERR BLACKBIRD CREEK
REFERENCE CROSS-SECTION 4

BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96910 DATE 12/28/01 DRAWN BY EL

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XS-1and 2, Sensitivity Analysis Results: Depth
Overbank Areas varied between n=0.03 and 0.07
Channel varied between n=0.03 and 0.05

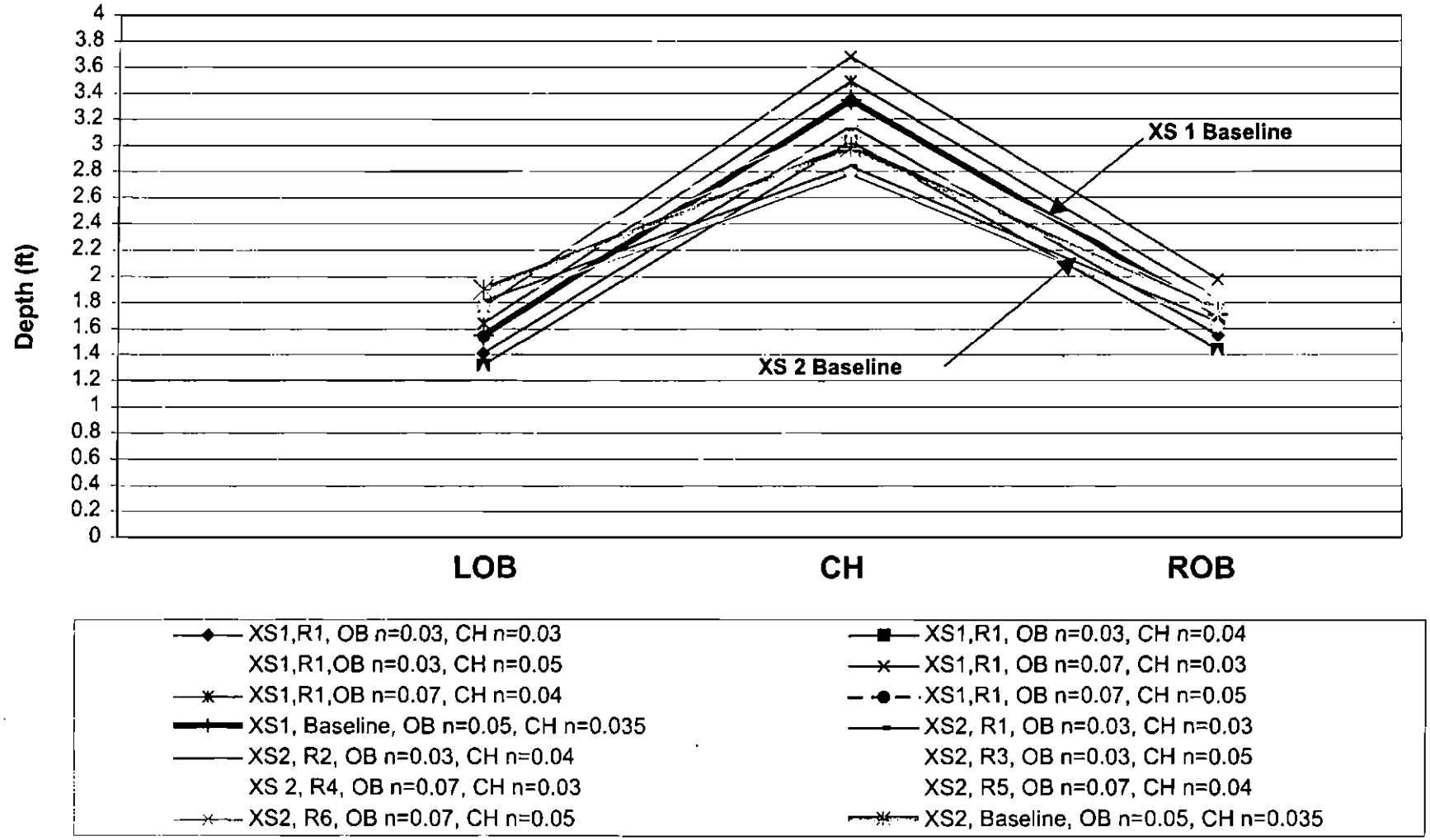

FIGURE **A-5**
SENSITIVITY ANALYSIS
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96886 DATE 12/28/01 DRAWN BY EL

Golder Associates

XS-1and 2, Sensitivity Analysis Results: Velocity
Overbank Areas varied between n=0.03 and 0.07
Channel varied between n=0.03 and 0.05

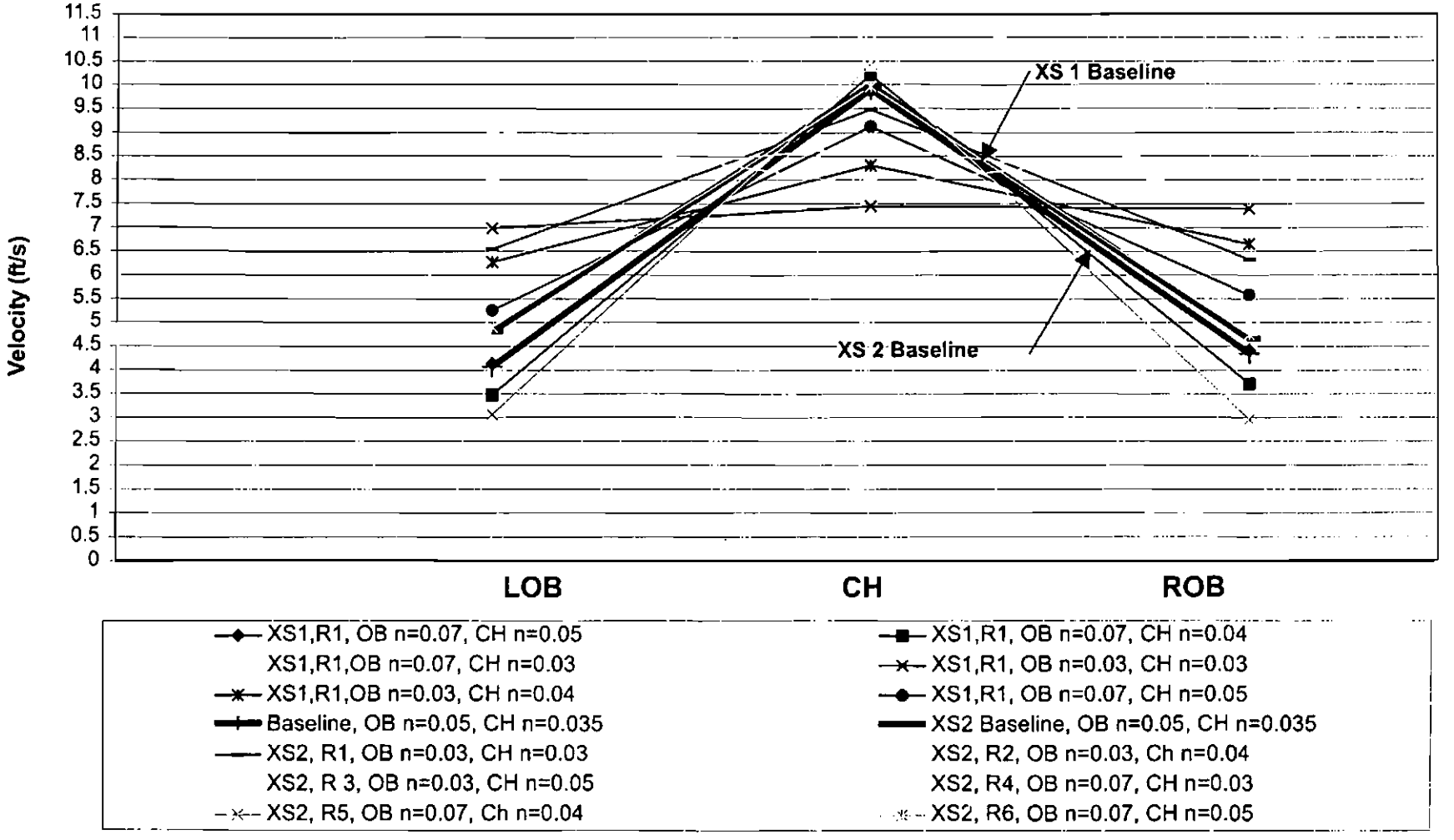

FIGURE **A-6**
SENSITIVITY ANALYSIS
BMSG/BLACKBIRD/ID

XS-1and 2, Sensitivity Analysis Results: Shear Stresses
Overbank Areas varied between n=0.03 and 0.07
Channel varied between n=0.03 and 0.05

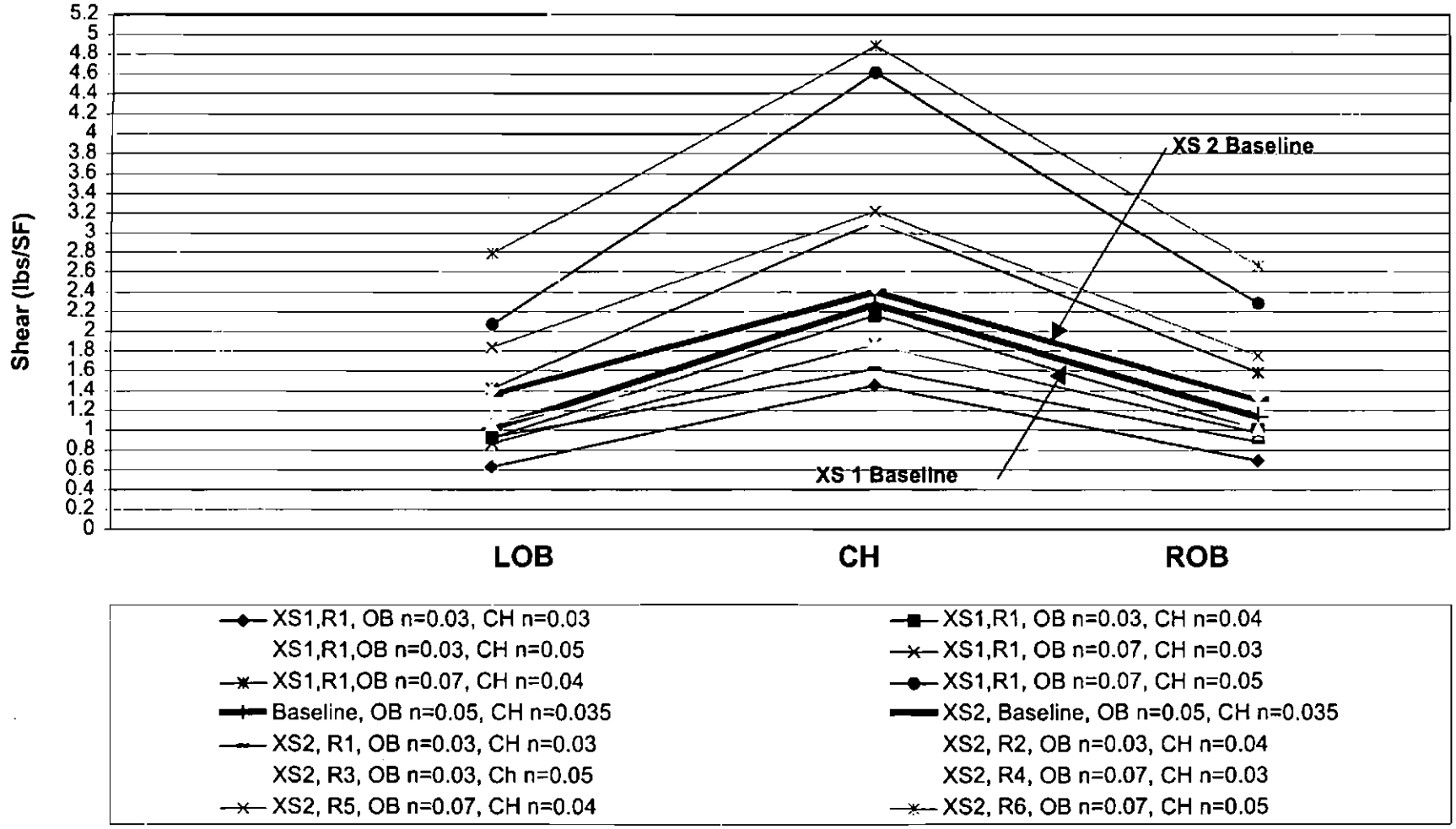

FIGURE **A-7**
SENSITIVITY ANALYSIS
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96888 DATE 12/28/01 DRAWN BY EL

Golder Associates

XS-3and 4, Sensitivity Analysis Results: Depth
Overbank Areas varied between n=0.03 and 0.07
Channel varied between n=0.03 and 0.05

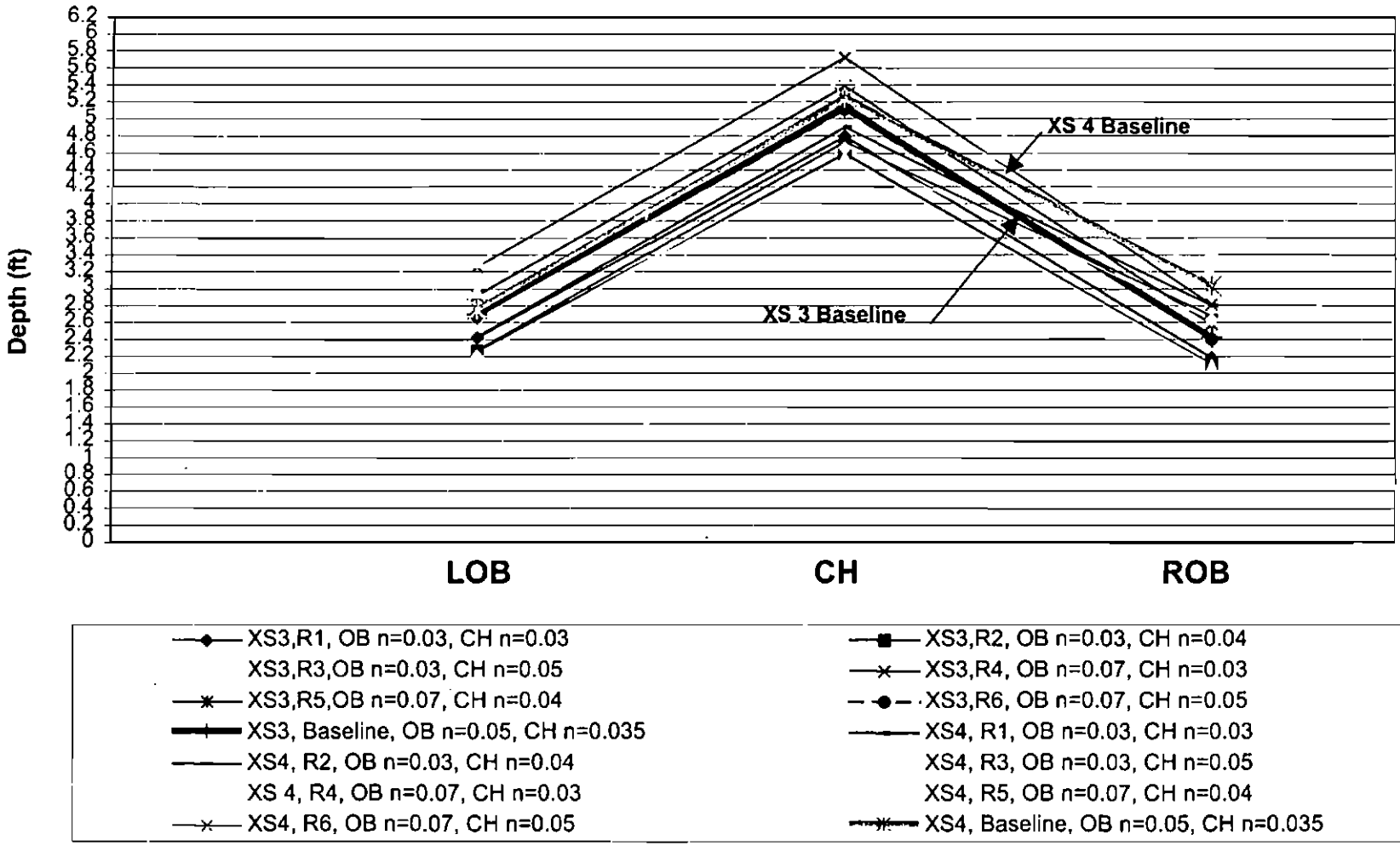

FIGURE **A-8**
SENSITIVITY ANALYSIS
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96889 DATE 12/28/01 DRAWN BY EL

Golder Associates

XS-3and 4, Sensitivity Analysis Results: Velocity
Overbank Areas varied between n=0.03 and 0.07
Channel varied between n=0.03 and 0.05

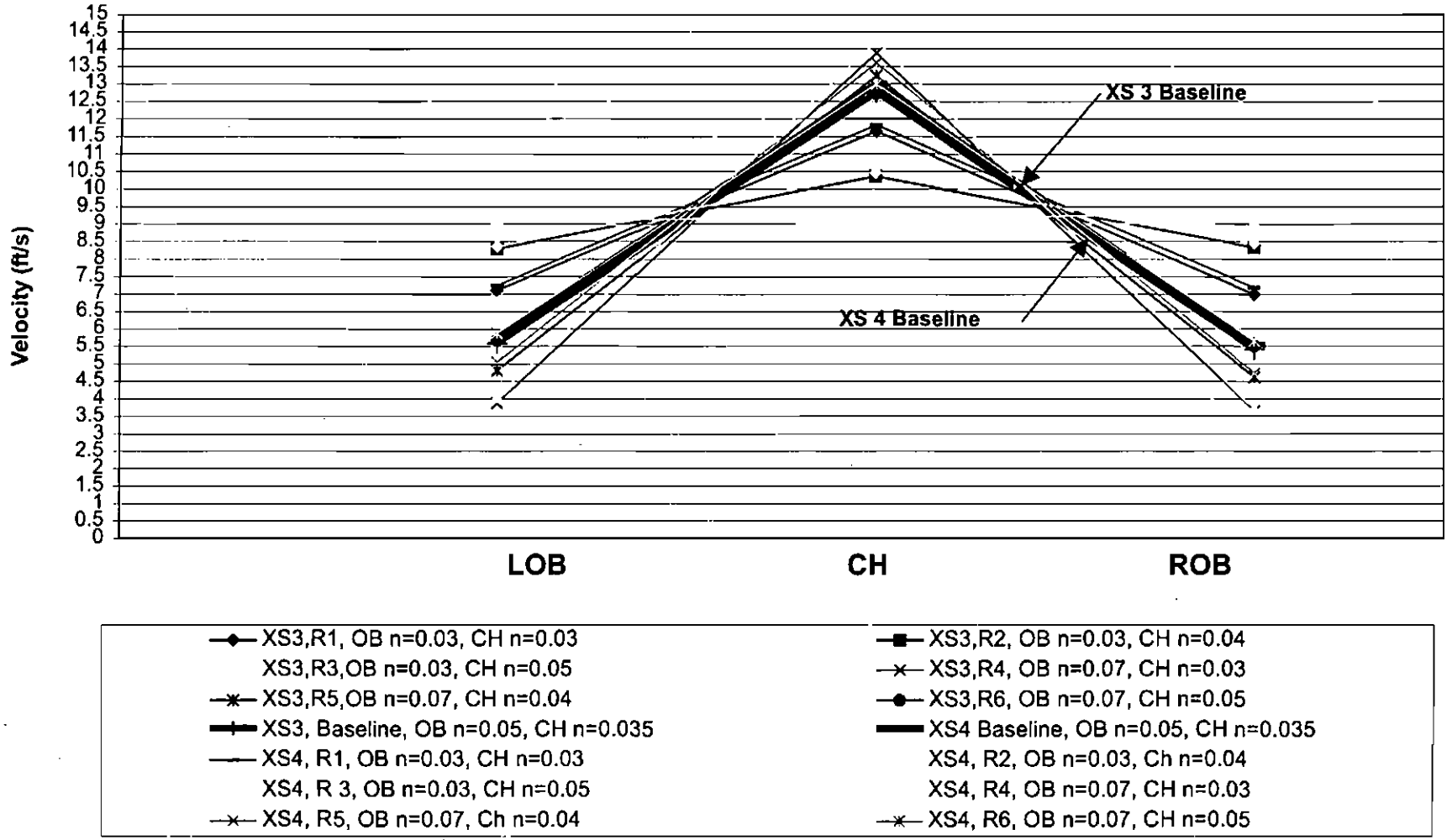

FIGURE **A-9**
SENSITIVITY ANALYSIS
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 96890 DATE 12/28/01 DRAWN BY EL

Golder Associates

XS-3and 4, Sensitivity Analysis Results: Shear Stresses
Overbank Areas varied between n=0.03 and 0.07
Channel varied between n=0.03 and 0.05

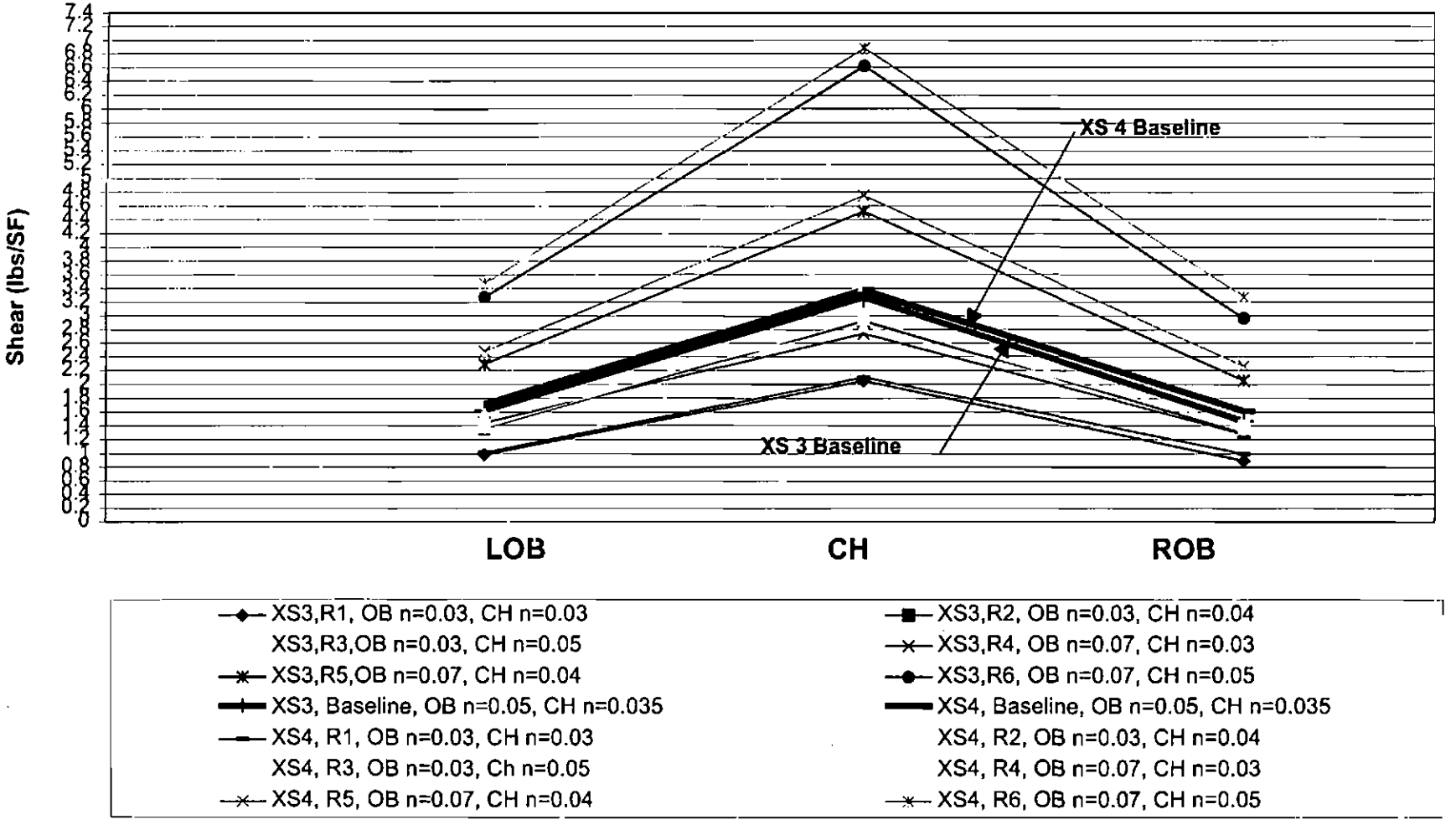

FIGURE **A-10**
SENSITIVITY ANALYSIS
BMSG/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO 96891 DATE 12/28/01 DRAWN BY EL

Golder Associates

Appendix B

APPENDIX B

NPDES CALCULATIONS

Golder Associates Inc.

18300 NE Union Hill Road, Suite 200
Redmond, WA 98052-3333
Telephone (425) 883-0777
Fax (425) 882-5498

APPENDIX B

NPDES AND MIXING ZONE EVALUATIONS

BLACKBIRD MINE SITE
LEMHI COUNTY, IDAHO

Prepared for:

Blackbird Mine Site Group

Submitted by:

Golder Associates Inc.
Redmond, Washington

June 21, 2002

943-1595-003.9200
0621dd1.doc

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B-1 INTRODUCTION

The applicability, relevance, and appropriateness of NPDES regulations and guidelines to the Blackbird Mine Site are discussed in Section 3.1.1.1.3 of this Feasibility Study (FS). The NPDES regulations identify specific effluent limitation guidelines for discharges within specific industrial categories. All point-source discharges, such as the Water Treatment Plant (WTP) on Blackbird Creek, must meet the substantive requirements of the NPDES regulations. Under CERCLA, an NPDES permit is not required for on-site actions that are necessary for implementation of the response action where the discharge receiving water is in the area of contamination or other areas that are in close proximity. While a NPDES permit is not required, under CERCLA, the substantive requirements of the NPDES program may need to be met. The effluent is analyzed for reasonable potential to cause excursions above the state water quality standard (WQS). If reasonable potential exists, water quality based effluent limits may be developed for the point source.

The WTP is located in the upper part of Blackbird Creek between stations BBSW-07A and BBSW-07. There is an existing NPDES permit (#ID-002525-9) for the treatment plant discharge, which expired on October 30, 1989. A new permit application was submitted to EPA; however, EPA deferred action on the new permit application until the RI/FS and ROD process. EPA intends to address the WTP under "substantive compliance" requirements; at this time EPA does not anticipate renewal of the NPDES permit.

Normally, limits for the WTP would be set as the lower of the technology-based limits and the allowable loading to meet WQS in the receiving water (Blackbird Creek). The State of Idaho's use designation for Blackbird Creek is for non-contact recreation. Therefore, WQS based on protection of cold water biota are not required for Blackbird Creek. In addition, as discussed in Section 7.2.1.4 and elsewhere in Chapter 7, no remediation alternative could consistently achieve the copper WQS for protection of cold water biota within Blackbird Creek.

Blackbird Creek flows into Panther Creek, which is protected for cold water biota. Although Blackbird Creek itself is not a "point source discharge" to Panther Creek for the purposes of the NPDES regulations, an NPDES mixing zone analysis has been developed to compare the various alternatives in terms of impacts of the mixing zones in Panther Creek downstream from Blackbird Creek. Chapter 7 provides evaluations of the effectiveness of the alternatives.

B-2 ANALYSIS OF BLACKBIRD CREEK DISCHARGE TO PANTHER CREEK

B-2.1 Technology-Based Limits

Section 301(b) of the Clean Water Act (CWA) requires technology-based controls on effluents. As of March 31, 1989, all permits must contain limits that control toxic pollutants and non-conventional pollutants using "best available technology economically achievable" (BAT), and conventional pollutants using "best conventional pollutant control technology" (BCT). Neither the BAT nor BCT can be less stringent than

the minimum level of control required by section 301(b)(1)(A) of the CWA, the "best practical control technology currently achievable" (BPT).

EPA has promulgated technology-based limits for the mining industry. Limits for point-source discharges from mining "Copper, Lead, Zinc, Gold, Silver, and Molybdenum Ores" are found at 40 CFR 440 Subpart J. The limits for the applicable criteria are presented in Table 3-1B of the FS.

B-2.2 State Water Quality Standards

The dissolved copper WQS in Idaho is found at IDAPA 58.01.02.210.07. Because PRGs for cold water biota cannot be met in Blackbird Creek, WQS are being applied in Panther Creek downstream of Blackbird Creek. The copper criterion is a function of hardness. In this analysis, the minimum copper WQS was calculated using the minimum observed hardness downstream of the confluence of Blackbird and Panther Creeks (at PASW-09). In the fall, a hardness of 42.5 mg/L results in a copper criterion of 6 μg/L. In the spring, a copper criterion of 4 μg/L was calculated using the minimum hardness of 26.6 mg/L.

The average hardness during the fall based on all sampling conducted since 1998 was about 46 mg/L, resulting in a copper criterion of 6 μg/L. In the spring, the average hardness based on all data collected since 1998 was about 39 μg/L, resulting in a copper criterion of about 5 μg/L.

B-2.3 Effluent Characterization

Copper is the only water quality parameter discussed in this NPDES evaluation. Section 2.6.5.3 of the RI discusses the site water quality, and copper and cobalt are identified as the contaminants of concern. There are no water quality standards or technology based standards for cobalt, so there are no applicable criteria for comparison in the reasonable potential calculation. The only remaining contaminant of concern for this NPDES evaluation is copper.

The NPDES program requires effluent characterization to determine whether the effluent "causes, has the reasonable potential to cause, or contributes to an excursion of the numeric or narrative water quality criteria." This is normally done through a reasonable potential analysis outlined in *Technical Support Document for Water Quality-Based Toxics Control* (TSD). However, when a more site-specific evaluation is available that considers the elements listed in 40 CFR 122.44(d)(1)(ii) (existing controls on point and non-point sources, the variability of the pollutant in the effluent, the sensitivity of the species to toxicity testing (when evaluating whole effluent toxicity) and, where appropriate, the dilution of the effluent in the receiving waters), the site-specific evaluation may be used to evaluate the potential to cause excursions above the water quality criteria. The evaluation in Section 7.2.1.3 of the FS provides a site-specific analysis of the variability of the predicted concentrations in Panther Creek. A summary of this analysis is provided below.

Section 7.2.1.3 and Table 7-10b of the FS provide the analysis of the variability of the predicted copper concentrations in Panther Creek due to variability in the observed data in Blackbird and Panther Creeks and the predicted removal efficiencies. This evaluation uses predicted controls on all point and non-point sources and the variability of contaminant concentrations in the effluent to predict a range of post-remediation concentrations in Panther Creek. Thus, this analysis shows the "potential to exceed" the copper WQS.

In Table 7-10b, the columns headed with "Best Estimate Removal" show the variability associated with the observed data and predicted post-remediation concentrations. To be consistent with using a "worst-case" scenario, the concentrations in the column labeled "Var.High", which contains the highest predicted copper concentrations at PASW-09, is used to determine if there is reasonable potential to exceed copper WQS.

The predicted post-remediation copper concentrations in Panther Creek for Alternative BB-4 are 7 μg/l and 6 μg/L for BB-5. Alternatives BB-6, BB-7 and BB-8 all result in predicted post-remediation concentrations of 3 μg/L. The mixing zone study showed that BB-4 and BB-5 under worst-case conditions and 100% mixing would still not meet WQS.

The post-remediation concentrations used in this appendix are slightly higher than those in EPA's final version of Chapter 7, due to changes made in the post-remediation estimates after this appendix was prepared. However, the differences are within the accuracy of the calculations and do not affect the conclusions of the site-specific variability analysis. The calculations in the site-specific variability analysis should be considered conservative; predicted post-remediation concentrations would likely be smaller.

According to this analysis, only Alternatives BB-4 and BB-5 have reasonable potential to exceed copper WQS in Panther Creek. Although the excursion would be only 2 or 3 μg/L above the WQS, additional evaluation of the effectiveness of the alternatives would be needed, if these alternatives were selected. If Alternative BB-4 or BB-5 were selected, a more detailed analysis, including sampling at BBSW-01A and PASW-09, would be performed after implementation. The new sampling data would be used in the reasonable potential analysis.

B-3 MIXING ZONE STUDY FOR PANTHER CREEK

Idaho Department of Environmental Quality (IDEQ) defines a mixing zone as "the area or volume of the receiving water surrounding or adjacent to a wastewater discharge where the receiving water, as a result of the discharge, may not meet all applicable water quality criteria or standards."

IDEQ has several guidelines it considers when determining the applicability of a mixing zone. The mixing zone should:

- Avoid interference with existing beneficial uses.
- Meet applicable chronic water quality standards and criterion at the edge of the mixing zone.
- Meet applicable acute water quality standards in a zone of initial dilution inside the mixing zone.
- Not be acutely toxic to biota significant to the receiving water's aquatic community.
- Be no more than 25% of the width and volume of the stream to allow a zone of passage for aquatic life.

These principles are not stand-alone regulatory requirements, and exceptions are made. IDEQ has approved mixing zones larger than 25% of the width and volume based on the results of a mixing zone study. A mixing zone study was performed for the discharge of Blackbird Creek in to Panther Creek to provide a basis for IDEQ to approve mixing zones in Panther Creek greater than 25%.

Included in this mixing zone study are:

- A summary of background chemical concentrations.
- Biological conditions of the receiving waters.
- Demonstration that the mixing zone will not interfere with the designated or existing uses of the receiving waters.
- Demonstration that there is adequate fish passage.
- The relative flows of the effluents and receiving waters.
- The physical boundaries where acute and chronic criteria are met.
- Demonstration that the mixing zone would not jeopardize the continued existence of any threatened or endangered species, or result in the adverse modification of critical habitat.

B-3.1 Water Chemistry

The concentrations presented in this section are the average from the 2000 and 2001 sampling events. After the selected remedy is implemented, the concentrations are expected to decrease. At the mouth of Blackbird Creek, the average concentration of copper is 7 μg/L in the fall and 57 μg/L in the spring. The hardness averaged 95 mg/L in the fall and 51 mg/L in the spring.

In Panther Creek, upstream of Blackbird Creek, the copper was not detected in the water (detection limit 3 μg/L). Copper has consistently been non-detect since July 1996, except for two outliers. In July 1997, a concentration of 6 μg/L was recorded, and in July 1999 a concentration of 8 μg/L was measured. The two outliers are believed to be anomalies. The hardness, on average was 40 mg/L in the fall and 32 mg/L in the spring.

Downstream of Blackbird Creek, the average fall copper concentration was 3 μg/L and the average spring copper concentration was 9 μg/L. On average, the hardness was 47 mg/L in the fall and 35 mg/L in the spring.

The expected post-remediation concentrations of copper in both Blackbird Creek and Panther Creek are presented in Table B-1. Further discussion of these results can be found in sections 7.2.3.1 and 7.2.5.1 of the FS.

B-3.2 Biological Conditions

Idaho Fish and Game (IDFG) has been conducting snorkel surveys in Panther Creek and tributaries for a number of years. Data for the early 1980's to 2000 were recently obtained. Results show the presence of rainbow trout/juvenile steelhead throughout the river between the mouth and upstream of Blackbird Creek. Other species present include brook trout, cutthroat, mountain whitefish and bull trout. Unpublished electrofishing studies conducted in support of the EIS being developed by Formation Capital confirmed these species as well as three species of cyprinids and sculpins. Chinook salmon were historically present in Panther Creek.

Rainbow/steelhead trout are spring spawners. Chinook salmon are fall spawners. Channel conditions relevant to passage for spawning fish outside the mixing zone are discussed in the following section. In the spring, juvenile chinook swim downstream in Panther Creek.

B-3.3 Physical Conditions

Figures B-1 and B-2 show the depth and velocity profiles for the station on Panther Creek downstream of Blackbird Creek. Blackbird Creek enters on the left side of Panther Creek (looking downstream). The profiles show that the left bank of Panther Creek is the shallowest part of the creek, and the right bank is much deeper. The majority of the stream volume (between 50% and 70%) is located along the right side of the creek.

The velocities along the left bank range between 0 and 2 feet per second (fps). The deepest part of Panther Creek (about 2.5 feet deep) is along the right bank. In this area, the velocities range from 0 to 3 fps. In the middle of the stream (middle 25%), the velocities range from 1.5 fps to 2.5 fps. Note that these velocities vary with flow, and the velocities presented here are some of the higher velocities seen in Panther Creek.

The slope along the right bank of Panther Creek is steep and covered with trees and bushes. This should provide adequate cover and protect any fish swimming along the right bank from predators.

The flows of Blackbird Creek and Panther Creek are correlated; both creeks have highest flows in the spring and the lowest flows in the fall. Upstream of Blackbird Creek, the flows average about 220 cfs in the spring and 45 cfs in the fall. Blackbird Creek flows average about 25 cfs in the spring and about 4 cfs in the fall.

B-3.4 CORMIX Modeling

CORMIX 3 was used to model the discharge of Blackbird Creek into Panther Creek. Using CORMIX to predict the mixing zone in Panther Creek may not accurately model the flow conditions in Panther Creek. CORMIX assumes laminar flow, but the flow in Panther Creek is generally turbulent. The CORMIX model cannot readily account for stream features such as boulders, logs, etc. that cause increased turbulence and mixing. Mebane (2000) compared modeled and measured mixing of a natural tributary "effluent" into a turbulent mountain stream and indicated that the mode produced very similar patterns and magnitude of mixing. However, measured dilutions showed that beyond initial near-field zones, mixing occurred more rapidly than predicted by CORMIX modeling (Mebane 2000).

CORMIX 3 has other limitations as a model for Blackbird and Panther Creeks. The model requires that the channel for both the discharge and the receiving waters be treated as a box, whereas stream channels are generally irregularly shaped. Treating the profiles of the creeks as boxes can result in a plume that is not as wide as actual conditions. The model also requires that the depth-to-width ratio of the discharge be no less than 0.05. For Blackbird Creek, this makes the channel wider than it really is. Because the Blackbird Creek is wider in the model than measured in the field, the plume may occupy a larger amount of Panther Creek than actually occurs. Finally, the discharge must be at least as warm as the receiving waters. In reality, Blackbird Creek has a lower average temperature than Panther Creek.

B-3.4.1 Input parameters

A summary of the input parameters for the CORMIX modeling of Blackbird Creek discharging into Panther Creek is provided in Tables B-2throughB-4. The study was limited to 3300 feet downstream of the discharge. Within 3300 feet, it is believed that Panther Creek would become fully mixed due to the rapids downstream of the Panther Creek Inn. The analysis was done for each alternative and split between fall and spring.

For flow, both the fifth (5th) percentile and average seasonal flow were used. For Panther Creek, these flows were taken directly from the data. For Blackbird Creek, ratios of Blackbird Creek to Panther Creek flows were determined for the full range of data. The fifth percentile ratio for fall and spring was used to determine Blackbird Creek flows for the worst-case scenario. The average spring and fall ratios were used for the average case. The flows and ratios used are presented in Table B-3.

The concentrations used for this analysis were taken from Table 7-7 of the FS. For the fall, worst-case scenario, the maximum of the four predicted concentrations for each alternative was used in this analysis. For the average case, the average of the four predicted post-remediation concentrations was used. For the spring, the analysis was performed with predicted concentrations for both 2000 and 2001. Both years were used because there are large differences between the two years of data and it is not possible to predict which is more representative. The concentrations used in the modeling are shown in Table B-4.

The post-remediation concentrations used in this appendix are slightly higher than those in EPA's final version of Chapter 7, due to changes made in the post-remediation estimates after this appendix was prepared. However, the differences are within the accuracy of the model and do not affect the conclusions of the mixing zone analysis. The calculations in the mixing zone analysis should be considered conservative; mixing zones would be slightly smaller and zones of passage would be slightly larger than predicted by the CORMIX model.

To determine where the chronic criteria is met under worst-case conditions, 6 μg/L is used in the fall and 4 μg/L is used in the spring as the WQS. These values are based on the minimum observed hardness in Panther Creek. For average conditions, the WQS of 6 μg/L in the fall and 5 μg/L in the spring are used, and are based on the average hardness in Panther Creek (see Section B-2.2).

The worst and average cases are included in this mixing zone analysis to provide both the maximum and average mixing zones that would be required in Panther Creek.. By definition, the worst-case scenario flows would occur less than 5% of the time. In addition, these are natural streams, and the highest copper concentrations do not occur during the lowest flows, as modeled in the worst-case scenario. The combination of these two unlikely events implies that the worst-case scenario would occur much less than 5% of the time. The average case is more representative of the system because it matches average copper concentrations with average flows.

B-3.4.2 Results

The CORMIX model predicts a plume that hugs the left bank of Panther Creek. Tables B-5 through B-7 summarize the resulting plume for each alternative and Figures B-3 through B-10 provide a graphical representation of the plume. As soon as the Blackbird Creek discharge hits Panther Creek, the plume would occupy about half of the width of Panther Creek under worst-case conditions. Under average conditions, the plume would occupy about 30% of the stream width. Thus, the minimum mixing zone required is 50% under worst-case conditions and 30% under average conditions. The 50% mixing zone would occupy about 30% of the volume of Panther Creek, and the 30% mixing zone would only occupy about 15% of the volume.

As the plume immediately spreads to 30% or 50% of the width of Panther Creek, the predicted copper concentrations would be between the WQS and 2 times the chronic copper criteria depending on the alternative and average or worst-case conditions. Since the plume expands to either 30% or 50% of the width in the first prediction interval, no concentration estimates at 25% of the stream width could be made. These estimated concentrations are shown in Table B-6.

The size of the initial mixing zone can be determined by both the physical conditions of the streams and the concentration of copper. In Panther Creek, it is believed that the flows primarily determine the size of the initial mixing zone. Concentration is not the controlling factor because, for both BB-4 and BB-5, the predicted minimum mixing zone is the same regardless of the concentration used in the model. When comparing the

spring average case and spring worst-case scenarios, everything in the modeling is constant except the flows. The difference in the minimum mixing zone indicates that the flow is controlling the size of the mixing zone. The angle of intersection of the creeks may also play an important part in the size of the initial mixing zone. Because the streams intersect at almost a 90º angle, the discharge from Blackbird Creek occupies more of the stream than if the angle of intersection were smaller.

Alternative BB-4 (which is also representative of Alternative BB-5) would require between a 30% and 100% mixing zone depending on the conditions. During the fall minimum flows, 53% would be required, but under average flow conditions, only 30% would be required. During spring minimum flows in 2001, 100% would be required and WQS would not be met before the plume is fully mixed. In Spring 200, a 90% mixing zone would be required. During spring average flows, the required mixing zone would be between 35% and 48%.

Alternative BB-6 (which is also representative of Alternatives BB-7 and BB-8) would require between a 30% and 62% mixing zone. Under average flow conditions, the WQS would be met with a 30% mixing zone. Under worst-case conditions, a 50% mixing zone would be required in the fall and between a 50% and 62% mixing zone would be required in the spring.

The distance to the WQS is the distance along the centerline of the plume where the chronic criterion is met. For Alternative BB-4, the WQS would be achieved within 30 feet of the discharge point under fall worst-case conditions and in the zone of initial dilution (less than 3 feet) under average conditions. For the spring worst-case conditions, the WQS would not be met in 2001 and would be met at 1700 feet in 2000. For Alternative BB-6, under spring average conditions, the model shows that the WQS would be achieved between 200 and 800 feet from the discharge. Under all other conditions, the WQS would be met within the zone of initial dilution.

CORMIX predicts that the plume would hug the left bank of Panther Creek. This leaves the deeper right bank available for fish passage. Table B-8 shows the width of stream below WQS, and the vertical lines on Figure B-1 indicate the possible locations for the edge of the mixing zones. Under spring worst-case conditions, Alternative BB-4 would provide between 0 and 5 feet of the stream width would be below WQS. Under average conditions, between 24 and 30 feet of the stream width would be below WQS. In the fall, under worst-case conditions, 22 feet of stream width would be below the WQS, and under average conditions, 32 feet of width would be below the WQS. For Alternative BB-6, between 17 and 22 feet of width would be below the WQS under spring worst-case conditions, and 32 feet of width would be below the WQS under average conditions. The fall worst-case conditions would allow 23 feet of width with Alternative BB-6; fall average conditions would allow 32 feet of width.

Table B-9 summarizes the maximum velocities that may be limiting for fish movement and the velocities seen in areas of Panther Creek occupied and unoccupied by the plume. Juvenile salmonid use would be limited to the areas near the banks, where the

flows range from 0 to 1 fps. Adult use would not be limited by the velocities in the stream (preferring velocities between 2 and 4 fps).

B-4 MIXING ZONE STUDY FOR BIG DEER CREEK

Even though NPDES regulations are not ARAR for the Bucktail Creek alternatives, a mixing zone analysis for the discharge of South Fork Big Deer Creek into Big Deer Creek was requested by the EPA. This section presents the mixing zone analysis for Big Deer Creek. Because NPDES is not ARAR, no reasonable potential analysis is needed.

B-4.1 Water Chemistry

One remedial action objective for the Bucktail Creek alternatives is to reduce copper concentrations to meet WQS in Big Deer Creek. An evaluation similar to the analysis conducted for Panther Creek was conducted based on estimated effectiveness of remedial alternatives for reducing metals loading from Bucktail Creek. The evaluations presented in this section are based on the average from the 2000 and 2001 sampling events.

At the mouth of South Fork Big Deer Creek, the average concentration of copper was 98 μg/L in the fall and 99 μg/L in the spring. The hardness averaged 89 mg/L in the fall and 71 mg/L in the spring.

In Big Deer Creek, upstream of South Fork Big Deer Creek, copper was below the detection limits (3 μg/L) in the water. The hardness, on average was 27 mg/L in the fall and 10 mg/L in the spring. Downstream of South Fork Big Deer Creek, the average fall copper concentration was 22 μg/L and the average spring copper concentration was 5 μg/L. On average, the hardness was 40 mg/L in the fall and 13 mg/L in the spring.

The expected post-remediation concentrations of copper in both South Fork Big Deer Creek and Big Deer Creek are presented in Table B-10. Further discussion of these results can be found in Section 7.3.1.1 of the FS.

B-4.2 Biological Conditions

An unpublished electrofishing study was conducted in Big Deer Creek in conjunction with the EIS being prepared for Formation Capital's cobalt project. Rainbow trout were found to be present in the reach downstream of South Fork Big Deer Creek. Cutthroat and cutthroat-rainbow crosses were reported in the upper reach above the South Fork Big Deer Creek. The falls at the lower end of Big Deer Creek prevent passage of Chinook salmon and steelhead trout and they are not known to have occurred historically in Big Deer Creek.

B-4.3 Physical Conditions

Figures B-11 and B-12 show the depth and velocity profiles for Big Deer Creek downstream of South Fork Big Deer Creek. South Fork Big Deer Creek enters on the right side of Big Deer Creek (looking downstream). These profiles show that the deepest portion of the river is in the middle of the channel. The velocities are highest in the deeper part of the channel. The majority of the stream volume is located in the middle of the creek.

The velocities along the left bank range between 0 and 1 fps. Along the right bank, the velocities range from 0 to 2.5 fps. In the deeper area of the creek, which is also the middle 25% of the width, the velocities range from 1.5 to 7 fps.

Below the confluence with South Fork Big Deer Creek, both sides of Big Deer Creek are steep and heavily vegetated. About a quarter of a mile downstream of the confluence, the banks become less steep and the vegetation starts to thin. There is adequate cover to protect any fish swimming along banks from predators within the first quarter mile.

The flows of South Fork Big Deer Creek and Big Deer Creek are correlated; both creeks have highest flows in the spring and the lowest flows in the fall. Upstream of South Fork Big Deer Creek, the flows average about 100 cfs in the spring and 8 cfs in the fall. South Fork Big Deer Creek flows average about 4 cfs in the spring and about 2 cfs in the fall.

B-4.4 CORMIX Modeling

CORMIX 3 was used to model the discharge of South Fork Big Deer Creek into Big Deer Creek. Using CORMIX to predict the mixing zone in Big Deer Creek may not accurately model the flow conditions in Big Deer Creek for the same reasons as discussed for Panther Creek in Section B-3.4.

B-4.4.1 Input Parameters

A summary of the input parameters for the CORMIX modeling of South Fork Big Deer Creek discharging into Big Deer Creek is provided in Tables B-11 throughB-13. The analysis was split between fall and spring. The analysis was done for two different removal efficiencies in Bucktail Creek, 65% and 80%. The removal of 65% is assumed in the FS, but the actions might result is removals as high as 80%.

For flow, both the fifth percentile and average seasonal flow was used. For Big Deer Creek, these flows were taken directly from the data. For South Fork Big Deer Creek, ratios of South Fork Big Deer Creek to Big Deer Creek flows were determined for the full range of data. The fifth percentile ratio for fall and spring was used to determine South Fork Big Deer Creek flows for the worst-case scenario and the average ratio for fall and spring was used for the average case. The flows and ratios used are presented in Table B-12.

The concentrations used for this analysis were either taken from Table 7-11b of the FS or calculated in a manner similar to Table 7-11b. The concentrations in Table 7-11b were calculated assuming 65% removal in Bucktail Creek. To obtain concentrations for 80% removal in Bucktail Creek, the same calculation as done for Table 7-11b was done, only changing 65% to 80%. For the fall, the maximum and average of the predicted concentrations for each alternative was used in this analysis. In this case, the average and maximum predicted post-remediation concentrations are the same. For the spring, the analysis was performed with predicted concentrations for both 2000 and 2001. The concentrations used in the modeling are shown in Table B-13.

The concentrations used are a slight over-prediction of post-remediation concentrations (due to iterations of the analysis in Chapter 7), but are within the accuracy of the model. The calculations in the mixing zone analysis should be considered conservative; mixing zones would be slightly smaller and zones of passage would be slightly larger than predicted by the CORMIX model.

Even though BT-5 involves diverting Bucktail Creek around South Fork Big Deer Creek, the concentrations and flows used for other alternatives apply to BT-5. Under Alternative BT-5, Bucktail and South Fork Big Deer Creeks would discharge into Big Deer Creek at nearly the same point, resulting in the same loading and flows if Bucktail Creek discharged in the South Fork Big Deer Creek.

To determine where the chronic criteria is met under worst-case and average conditions, 5 μg/L is used in the fall and 4 μg/L is used in the spring as the WQS. These values are based on the minimum and average observed hardness in Big Deer Creek.

The worst and average cases are included in this mixing zone analysis to provide both the maximum and average mixing zones that would be required in Big Deer Creek. By definition, the worst-case scenario flows would occur less than 5% of the time. In addition, these are natural streams, and the highest copper concentrations do not occur during the lowest flows, as modeled in the worst-case scenario. The combination of these two unlikely events implies that the worst-case scenario would occur much less than 5% of the time. The average case is more representative of the system because it matches average copper concentrations with average flows.

B-4.4.2 Results

CORMIX modeling indicates that the South Fork Big Deer Creek plume hugs the right bank of Big Deer Creek. Tables B-14 through B-16 summarize the resulting plume for each alternative and Figures B-13 through B-20 provide a graphical representation of the plume. As soon as the South Fork Big Deer Creek discharge hits Big Deer Creek, the plume occupies 70% of the width of Big Deer Creek. Thus, the minimum mixing zone required would be 70%. The 70% mixing zone occupies about 70% of the volume of Big Deer Creek.

As the plume immediately spreads to 70% of the width of Big Deer Creek, the predicted copper concentrations would be between the WQS and 6.5 times the chronic copper

criteria depending on the removal in Bucktail Creek and average or worst-case conditions. Since the plume expands to 70% of the width in the first prediction interval, no concentration estimates at 25% and 50% of the stream width could be made. These estimated concentrations are shown in Table B-15.

The size of the initial mixing zone can be determined by both the physical conditions of the streams and the concentration of copper. In Big Deer Creek, it is believed that the angle of intersection between the two streams primarily determines the size of the initial mixing zone. Concentration and flow are not controlling factors because, regardless of the concentration or flow used in the modeling, the minimum predicted mixing zone is 70%. Because the streams intersect at almost a 90º angle, the discharge from South Fork Big Deer Creek occupies more of the stream than if the angle of intersection were smaller.

With 65% removal in Bucktail Creek, WQS would not be met even with a 100% mixing zone under worst-case conditions year round and under average conditions in the spring. Average fall conditions would require a 95% mixing zone.

With 80% removal in Bucktail Creek, WQS would not be met even with a 100% mixing zone under worst-case conditions in the spring. Worst-case fall conditions would require a 91% mixing zone. The average case year round would require a 70% mixing zone.

The distance to the WQS is the distance along the centerline of the plume where the chronic criterion would be met. For 65% removal in Bucktail Creek, the WQS would not be achieved after the plume is fully mixed under worst-case conditions. Under average conditions in the fall, the WQS would be met 600 feet downstream of the discharge point. In the spring, under average conditions, the WQS would be met at 80 feet, but this would also be the point where the plume becomes fully mixed. For 80% removal, in the fall worst-case scenario, the WQS would be met at 600 feet. The WQS would not be met under the spring worst-case scenario. Under average conditions, the WQS would be met within the zone of initial dilution in the fall and at some point less than 80 feet in the spring. (For the spring average model run, the output of the model does not provide any information on plume concentrations between the zone of initial dilution and 80 feet.)

CORMIX predicts that the plume would hug the right bank of Big Deer Creek. Table B-17 shows the width of stream available for fish passage, and the vertical line on Figure B-11 indicates the possible location for the edge of the mixing zones. Under worst-case conditions, 65% removal would result in the full width of the stream above the WQS. Under average conditions, between 0 and 2 feet are below the WQS. For 80% removal, between 0 (spring) and 4 feet (fall) would be below the WQS under worst-case conditions, and 14 feet would be below the WQS under average conditions.

In Big Deer Creek, there is less width for passage than IDEQ generally considers sufficient for mixing zones for point source effluents (IDAPA 58.01.02.060). However, increased zone of passage in Big Deer Creek could only be obtained by additional, substantial reductions in copper loading in Bucktail Creek. Reductions to the point that

water quality criteria would be met over a significantly larger portion (e.g. 50% of width) of Big Deer Creek at the confluence of the South Fork Big Deer Creek are infeasible. Therefore, some potential limitations on full zone of passage of fish around the confluence of the South Fork Big Deer Creek may be inevitable for the near future. Post-remediation effectiveness monitoring may provide information whether this potential limitation appears to be significant.

Table B-18 summarizes the maximum velocities that may be limiting for fish movement and the velocities seen in areas of Big Deer Creek occupied and unoccupied by the plume. Juvenile salmonid use would be limited to the areas near the banks, where the velocities range from 0 to 1 fps. Adult use would be limited during times of high flows, which can result in velocities greater than 4 fps (Adults prefer velocities between 2 and 4 fps). Note that these velocities vary with flow, and the velocities presented here are some of the higher velocities seen in Big Deer Creek.

Adequate cover would be provided along the left bank of Big Deer Creek in the vicinity of the mixing zone.

B-5 SUMMARY

B-5.1 Blackbird Creek NPDES and Mixing Zone Study

CORMIX modeling results in a plume that hugs the left bank of Panther Creek. It immediately occupies 50% of the stream width (30% of the volume) under worst-case conditions, and 30% of the width (15% of the volume) under average conditions. Only the area of the stream along the right bank is below WQS. The depth along the right bank ranges from 0 to 1.5 feet; the velocities range from 0 to 2 fps.

B-5.1.1 Alternatives BB-4 and BB-5

During the fall, the WQS (6 μg/L) would be met, and the required mixing zone would be 53%. The uncertainty analysis done in Chapter 7 shows that the worst-case predicted post-remediation concentrations in Panther Creek would be 2 or 3μg/L above the WQS. Even with 100% mixing zone, the spring copper WQS (4 μg/L) would not be met in Panther Creek under worst-case conditions.

According to the CORMIX modeling, the alternatives, under average conditions, would meet the WQS in Panther Creek year round. The mixing zone required varies between 30% in the fall and a maximum of 48% in the spring.

The plume would not reach WQS after being fully mixed under worst-case conditions. Under average conditions, between 24 feet and 32 feet of stream width along the right bank would be below WQS. Adequate depth and cover for fish passage would be provided along this bank.

B-5.1.2 Alternatives BB-6, BB-7, and BB-8

In the fall, a 50% mixing zone would be required to meet the copper WQS under worst-case conditions. In the spring, between a 53% and 62% mixing zone would be required. Under average conditions, the WQS in Panther Creek would be met and the required mixing zones would be 30% year round.

At least 17 feet of stream width would be below WQS along the right bank of Panther Creek under worst-case conditions. Under average conditions, the width below WQS would be 32 feet. Adequate depth and cover for fish passage would be provided along this bank.

B-5.2 Big Deer Creek Mixing Zone Study

CORMIX modeling results in a plume that hugs the right bank of Big Deer Creek. It immediately occupies 70% of the stream width and volume. Only the area of the stream along the left bank is below WQS. The depth along the left bank ranges from 0 to 1.8 feet; the velocities range from 0 to 3 fps.

If 65% removal were achieved in Bucktail Creek, the WQS would not likely be met in Big Deer Creek, even with 100% mixing, under worst-case conditions. Under average conditions, the WQS would be met with 100% mixing in the spring and 95% mixing in the fall. If 80% removal is achieved, the WQS would be met with a 91% mixing zone in the fall under worst-case conditions. The spring WQS would not likely be met. Under average conditions, the WQS would be met year round with a 70% mixing zone.

Adequate cover for fish passage would be provided along the left bank of Big Deer Creek in the vicinity of the mixing zone. With 65% removal under worst-case conditions, the entire stream width would be above WQS. This would also be true for the spring average case. In the fall average case, 2 feet of stream width would be below WQS. With 80% removal, there would be between 0 (spring) and 4 feet (fall) of stream width below WQS under worst-case conditions and 14 feet under average conditions.

B-6 REFERENCES

Bjornn, T.C. and D. W. Riser. 1991. Habitat requirements of salmonids in streams. American Fisheries Society Special Publication 19:83-138.

Mebane, C.A. 2000. Evaluation of Proposed New Point Source Discharges to a Special Resources Water and Mixing Zone Determination: Thompson Creek Mine, Upper Salon River Subbasin, Idaho. Idaho Department of Environmental Quality, Boise. 126pp.

TABLE B-1

Comparison of Estimated Post-remediation Copper Concentrations at BBSW-01A and PASW-09

	WTP Discharge (gpm)					
	Fall				Spring	
	0		600		800	
	2000	2001	2000	2001	2000	2001
BBSW-01A						
Alternative BB-4 (ug/L)	16	8	18	9	20	26
Alternative BB-6 (ug/L)	7	< 1	9	1	14	12
PASW-09						
Alternative BB-4 (ug/L)	1	< 1	1	< 1	3	7
Alternative BB-6 (ug/L)	< 1	< 1	< 1	< 1	2	3

TABLE B-2
CORMIX 3 Inputs - Panther Creek Mixing Zone Study

	VALUE	UNITS	COMMENT
AMBIENT PARAMETERS			
CROSS SECTION	BOUNDED		
AVERAGE WIDTH	14	METERS	Average cross-section width at PASW-11, 10
CHANNEL REGULARITY	3		Channel is meandering and irregular
AMBIENT FLOW RATE	VARIABLE	M3/SEC	See Table B-2 for flows used
AVERAGE DEPTH	0.27	METERS	Average depth at PASW-11, 10
DEPTH AT DISCHARGE	0.27	METERS	Average depth at PASW-11, 10
MANNINGS	0.36	N	
WIND	2	M/S	Recommended Value
TEMPERATURE	9.11	C	Average tempterature at PASW-11
DISCHARGE PARAMETERS			
DISCHARGE TYPE	NEUTRALLY BOUYANT		
CONFIGURATION	FLUSH DISCHARGE		Discharge located on left bank
ENTRANCE ANGLE	50	DEG	Determined from Field Measurements
DEPTH NEAR OUTLET	0.228	METERS	Average Depth at BBSW-01
AVERAGE DEPTH	0.228	METERS	Average Depth at BBSW-01
AVERAGE WIDTH	4.56	METERS	Calculated by depth/width, limiting value of 0.05
DISCHARGE FLOW RATE	VARIABLE	M3/SEC	See Table B-2 for flows used
DISCHARGE TEMPERATURE	9.11	C	Limited to >= ambient Temp
DISCHARGE CONCENTRATION	VARIABLE	PPB	See Table B-3 for concentrations used

TABLE B-3
Flows Used for Panther Creek Mixing Zone Study

		PANTHER FLOW (CFS)	MIXING RATIO	BLACKBIRD FLOW (CFS)
Worst-case				
FALL		20	4.85	4.12
		47		9.69
SPRING	2000	88	4.67	18.84
		232		49.68
	2001	88		18.84
		232		49.68
Average Case				
FALL		20	10.95	1.83
		47		4.29
SPRING	2000	88	9.88	8.91
		232		23.48
	2001	88		8.91
		232		23.48

TABLE B-4
Copper Concentrations used in
Panther Creek Mixing Zone Study

Copper Concentrations (ug/L)			
Worst-case		BB-4	BB-6
FALL [a]		18	9
SPRING	2000	20	14
	2001	26	12
Average Case		BB-4	BB-6
FALL [b]		13	4
SPRING	2000	20	14
	2001	26	12

Notes: a. Fall is the maximum of the predicted concentrations in Table 7-7 of the FS.
b. Fall is the average of the predicted concentrations in Table 7-7 of the FS.
c. The concentrations in this table are at BBSW-01A

TABLE B-5
Required Mixing Zones to Meet Copper WQS in Panther Creek

Alternative	Fall Min. Flow	Fall Avg. Flow
BB-4	53%	30%
BB-6	50%	30%
	2000	
Alternative	Spring Min. Flow	Spring Avg. Flow
BB-4	90%	35%
BB-6	62%	30%
	2001	
Alternative	Spring Min. Flow	Spring Avg. Flow
BB-4	100%	48%
BB-6	53%	30%

Notes: a. Minimum mixing zone is 50% (worst case conditions/min. flow) or 30% (average conditions/avg. flow) due to the orientation and velocity of flows entering Panther Creek

b. 100% mixing Zone indicates that the WQS is not be met before Panther Creek becomes fully mixed (at PCI rapids)

TABLE B-6
CORMIX Predicted Copper Concentrations at Various Widths Across Panther Creek

Scenario	Blackbird flow (cfs)	Cu at mouth of Blackbird	Cu when plume reaches 25% width	Cu when plume reaches 50% width	Cu when plume reaches 100% width (fully mixed)
BB-4					
Fall - Worst-case	4.1	18	NA	6	4
Fall - Average Case	4.3	9	NA	2	1
Spring 2000 - Worst-case	18.8	20	NA	7	4
Spring 2000 - Average Case	23.5	14	NA	4	2
Spring 2001 - Worst-case	18.8	26	NA	9	5
Spring 2001 - Average Case	23.5	12	NA	5	3
BB-6					
Fall - Worst-case	4.1	13	NA	3	2
Fall - Average Case	4.3	4	NA	0.7	0.4
Spring 2000 - Worst-case	18.8	20	NA	5	3
Spring 2000 - Average Case	23.5	14	NA	2	2
Spring 2001 - Worst-case	18.8	26	NA	4	2
Spring 2001 - Average Case	23.5	12	NA	2	1

Notes: a. All concentrations are in µg/L
b. Values for the concentration at 25% width are not available because the plume immediately occupies between 30% and 50% of the stream width.

TABLE B-7
Distance in Feet Along the Centerline of the
Plume to Chronic Copper WQS in Panther Creek

Alternative	Fall Min. Flow	Fall Avg. Flow
BB-4	30	NA
BB-6	NA	NA
	2000	
Alternative	**Spring Min. Flow**	**Spring Avg. Flow**
BB-4	1700	200
BB-6	800	NA
	2001	
Alternative	**Spring Min. Flow**	**Spring Avg. Flow**
BB-4	>3300	800
BB-6	200	NA

Notes: a. If the distance is labeled as NA, then the WQS is met within the zone of initial dilution
b. These are approximate distances.

TABLE B-8
Panther Creek Minimum Stream Width Below WQS

Alternative	Fall Min. Flow		Fall Avg. Flow	
	Distance	% of Width	Distance	% of Width
BB-4	22	47%	32	70%
BB-6	23	50%	32	70%
	2000			
Alternative	Spring Min. Flow		Spring Avg. Flow	
	Distance	% of Width	Distance	% of Width
BB-4	5	10%	30	65%
BB-6	17	38%	32	70%
	2001			
Alternative	Spring Min. Flow		Spring Avg. Flow	
	Distance	% of Width	Distance	% of Width
BB-4	0	0%	24	52%
BB-6	22	47%	32	70%

TABLE B-9

Approximate Water Velocities (fps) Limiting Salmonid Movements and Mixing Zone Velocities in Panther Creek

Species	Adult migrating cruising speeds	Adult sustained speeds	Juvenile use
Chinook salmon	<3.4	3.4 - 10.8	0.3 - 0.8
Steelhead trout	<3.4	3.4 - 10.6	0.1 - 1.3
Bull trout	<2.0	2 - 6.4	0.3 - 0.4
Cutthroat trout	<2.0	2 - 6.4	0.3 - 0.7
Stream	**Velocities within the portion of the channel free from the plume**	**Velocities within plume (portion of the plume exceeding chronic WQS)**	
Panther Creek	0 to 3	0 to 3	

Source: Bjornn and Reiser (1991)

TABLE B-10
Estimated Reduced Copper Concentrations for Bucktail Creek Alternatives

Sampling Station	Fall		Spring	
	2000	2001	2000	2001
SFSW-01	22	22	49	45
BDSW-03	4	5	2	4

TABLE B-11

CORMIX 3 Inputs - Big Deer Creek Mixing Zone Study

Plume to Chronic Copper WQS in Big Deer Creek

	VALUE	UNITS	COMMENT
AMBIENT PARAMETERS			
CROSS SECTION	BOUNDED		
AVERAGE WIDTH	7.74	METERS	Average cross-section width at BDSW-03
CHANNEL REGULARITY	3		Channel is meandering and irregular
AMBIENT FLOW RATE	VARIABLE	M3/SEC	See Table B-8 for flows used
AVERAGE DEPTH	0.4	METERS	Average depth at BDSW-03
DEPTH AT DISCHARGE	0.4	METERS	Average depth at BDSW-04
MANNINGS	0.36	N	
WIND	2	M/S	Recommended Value
TEMPERATURE	6.95	C	Average tempterature at BDSW-03
DISCHARGE PARAMETERS			
DISCHARGE TYPE	NEUTRALLY BOUYANT		
CONFIGURATION	FLUSH DISCHARGE		Discharge located on left bank
ENTRANCE ANGLE	85	DEG	Determined from Field Measurements
DEPTH NEAR OUTLET	0.19	METERS	Average Depth at SFSW-01
AVERAGE DEPTH	0.19	METERS	Average Depth at SFSW-01
AVERAGE WIDTH	2.44	METERS	Calculated by depth/width, limiting value of 0.05
DISCHARGE FLOW RATE	VARIABLE	M3/SEC	See Table B-8 for flows used
DISCHARGE TEMPERATURE	6.95	C	Limited to >= ambient Temp
DISCHARGE CONCENTRATION	VARIABLE	PPB	See Table B-9 for concentrations used

TABLE B-12
Flows Used for Big Deer Creek Mixing Zone Study

		BIG DEER (CFS)	MIXING RATIO	SO. FORK BIG DEER FLOW (CFS)
Worst-case				
FALL		4	2.04	1.96
		7.7		3.77
SPRING	2000	10.4	2.84	3.66
		57		20.07
	2001	10.4		3.66
		57		20.07
Average Case				
FALL		4	3.63	1.10
		7.7		2.12
SPRING	2000	10.4	6.5	1.60
		57		8.77
	2001	10.4		1.60
		57		8.77

TABLE B-13
Copper Concentrations used in
Big Deer Creek Mixing Zone Study

Copper Concentrations (ug/L)			
Worst-case		65% Removal	80% Removal
FALL [a]		22	13
SPRING	2000	49	28
	2001	45	26
Average Case		65% Removal	80% Removal
FALL [b]		22	13
SPRING	2000	49	28
	2001	45	26

Notes: a. Fall is the maximum of the predicted concentrations in Table 7-11b of the FS.
b. Fall is the average of the predicted concentrations in Table 7-11b of the FS.

TABLE B-14
Required Mixing Zones to Meet Copper WQS
in Big Deer Creek

Removal in Bucktail Creek	Fall Min. Flow	Fall Ave. Flow
65%	100%	95%
80%	91%	70%
	2000	
Removal in Bucktail Creek	**Spring Min. Flow**	**Spring Ave. Flow**
65%	100%	100%
80%	100%	70%
	2001	
Removal in Bucktail Creek	**Spring Min. Flow**	**Spring Ave. Flow**
65%	100%	100%
80%	100%	70%

Notes: a. Minimum mixing zone is 70% due to the orientation and velocity of flows entering Big Deer Creek.
b. 100% mixing Zone indicates that the WQS is not be met before Big Deer Creek becomes fully mixed.

TABLE B-15

CORMIX Predicted Copper Concentrations at Various Widths Across Big Deer Creek

Scenario	South Fork Big Deer flow (cfs)	Cu at mouth of South Fork Big Deer	Cu when plume reaches 25% width	Cu when plume reaches 50% width	Cu when plume reaches 100% width (fully mixed)
65% Removal					
Fall - Worst-case	2.0	22	NA	NA	8
Fall - Average Case	2.1	22	NA	NA	5
Spring 2000 - Worst-case	3.7	49	NA	NA	13
Spring 2000 - Average Case	8.8	49	NA	NA	4
Spring 2001 - Worst-case	3.7	45	NA	NA	12
Spring 2001 - Average Case	8.8	45	NA	NA	4
80% Removal					
Fall - Worst-case	2.0	13	NA	NA	5
Fall - Average Case	2.1	13	NA	NA	3
Spring 2000 - Worst-case	3.7	28	NA	NA	7
Spring 2000 - Average Case	8.8	28	NA	NA	2
Spring 2001 - Worst-case	3.7	26	NA	NA	7
Spring 2001 - Average Case	8.8	26	NA	NA	2

Notes: a. All concentrations are in μg/L

b. Values for the concentration at 25% and 50% width are not available because the plume immediately occupies about 70% of the stream width.

TABLE B-16
Distance in Feet Along the Centerline of the
Plume to Chronic Copper WQS in Big Deer Creek

Removal in Bucktail Creek	Fall Min. Flow	Fall Avg. Flow
65%	>1600	600
80%	600	NA
	2000	
Removal in Bucktail Creek	**Spring Min. Flow**	**Spring Avg. Flow**
65%	>1600	80[b]
80%	>1600	<80
	2001	
Removal in Bucktail Creek	**Spring Min. Flow**	**Spring Avg. Flow**
65%	>1600	80[b]
80%	>1600	<80

Notes: a. If the distance is labeled as NA, then the WQS is met within the zone of initial dilution.
b. 80 feet is where the plume is fully mixed
c. These are approximate distances.

TABLE B-17
Big Deer Creek Minimum Stream Width Below WQS

Removal in Bucktail Creek	Fall Min. Flow		Fall Avg. Flow	
	Distance	% of Width	Distance	% of Width
65%	0	0%	2	5%
80%	4	9%	14	30%
	2000			
Removal in Bucktail Creek	Spring Min. Flow		Spring Avg. Flow	
	Distance	% of Width	Distance	% of Width
65%	0	0%	0	0%
80%	0	0%	14	30%
	2001			
Removal in Bucktail Creek	Spring Min. Flow		Spring Avg. Flow	
	Distance	% of Width	Distance	% of Width
65%	0	0%	0	0%
80%	0	0%	14	30%

TABLE B-18
Approximate Water Velocities (fps) Limiting Salmonid Movements and Mixing Zone Velocities in Big Deer Creek

Species	Adult migrating cruising speeds	Adult sustained speeds	Juvenile use
Chinook salmon	<3.4	3.4 - 10.8	0.3 - 0.8
Steelhead trout	<3.4	3.4 - 10.6	0.1 - 1.3
Bull trout	<2.0	2 - 6.4	0.3 - 0.4
Cutthroat trout	<2.0	2 - 6.4	0.3 - 0.7
Stream	**Velocities within the portion of the channel free from the plume**	**Velocities within plume (portion of the plume exceeding chronic WQS)**	
Panther Creek	0 to 3	0 to 7	

Source: Bjornn and Reiser (1991)

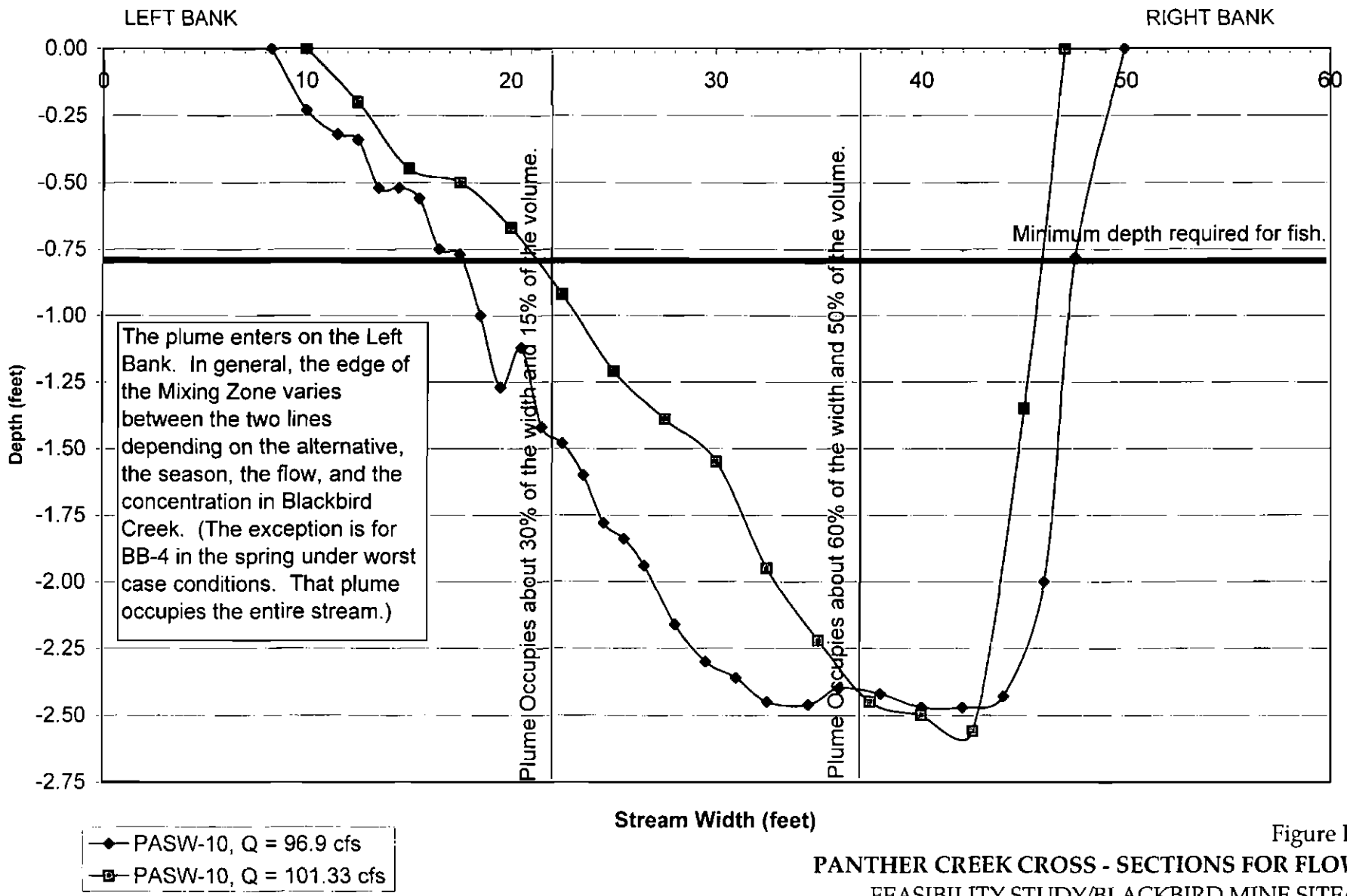


Figure B-1
PANTHER CREEK CROSS - SECTIONS FOR FLOWS
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Figs B-1 and B-2.xls
Golder Associates

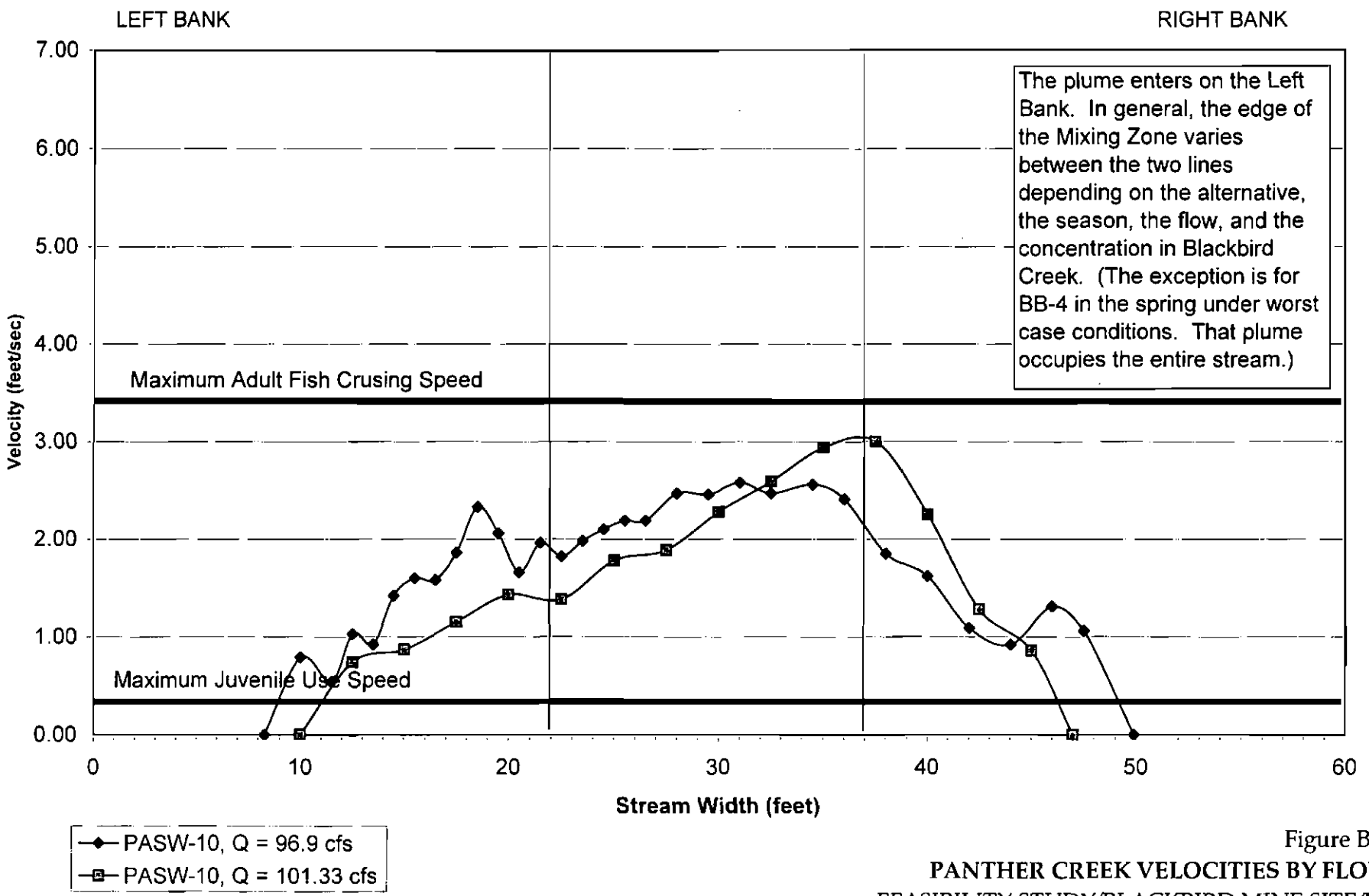
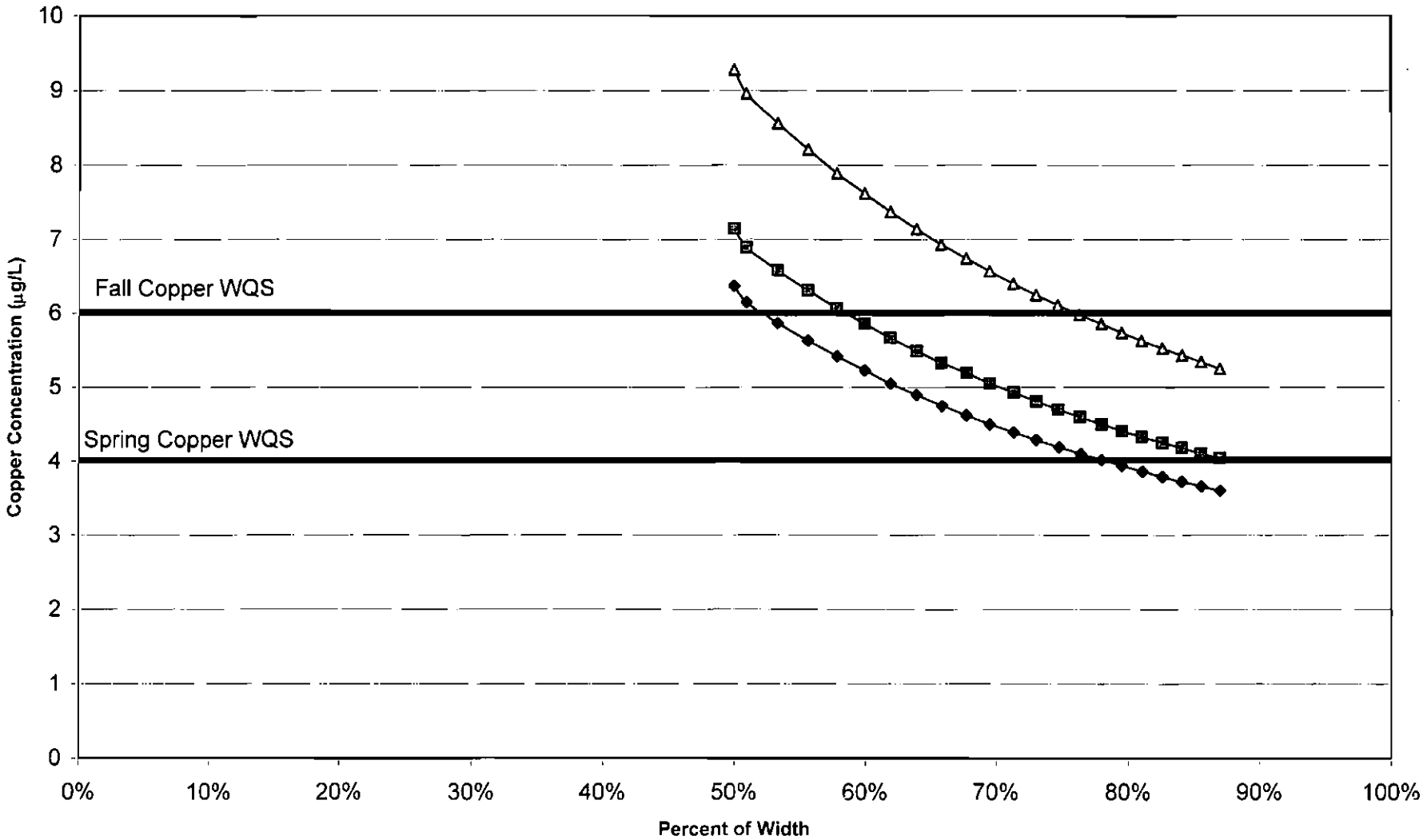


Figure B-2
PANTHER CREEK VELOCITIES BY FLOW
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Figs B-1 and B-2.xls
Golder Associates

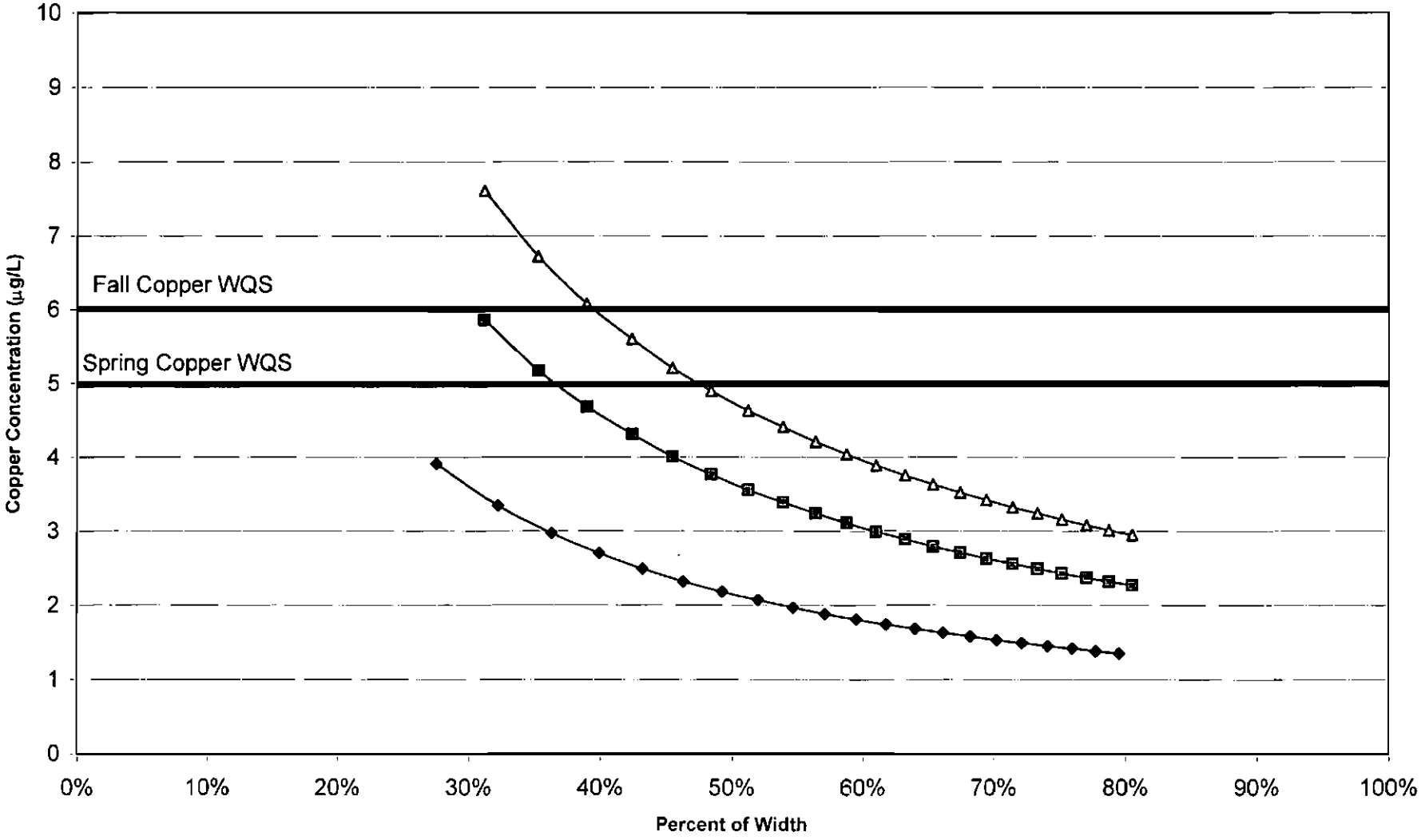
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-3

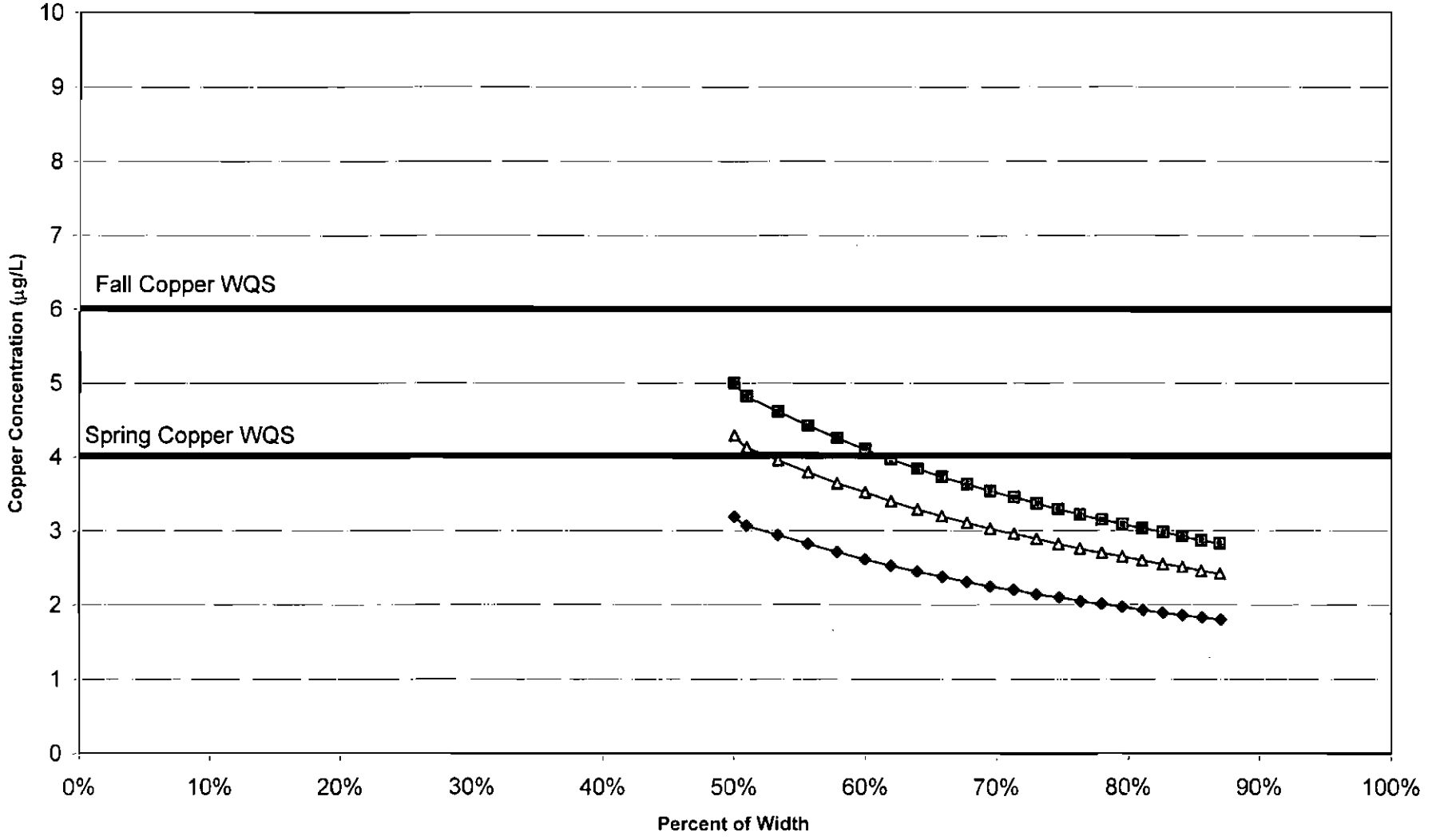
Figure B-3
BB-4 WORST CASE COPPER CONCENTRATIONS V. PERCENT WIDTH
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Average Case - Fall
Average Case - Spring 2000
Average Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-4

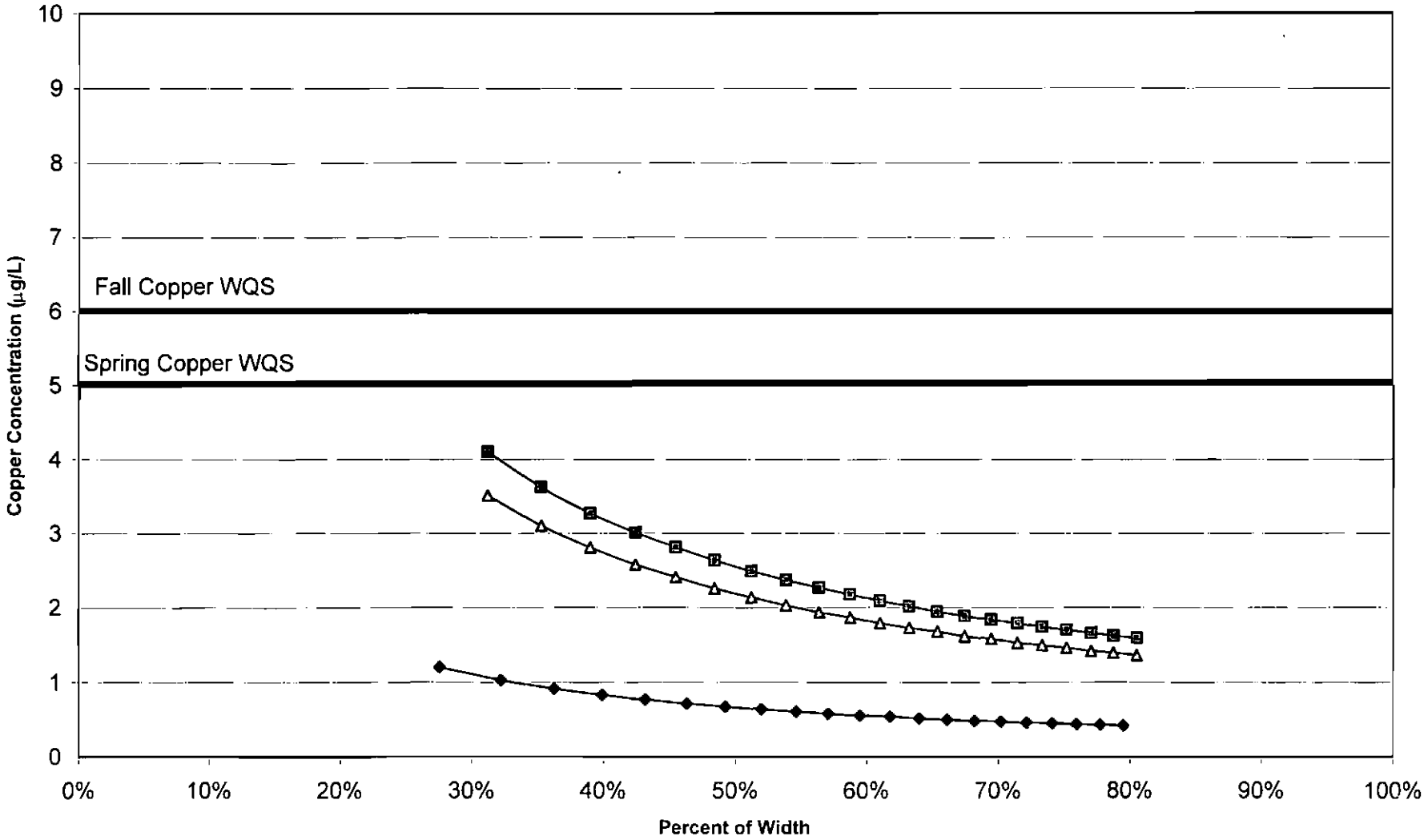
Figure B-4
BB-4 AVERAGE CASE COPPER CONCENTRATIONS V. PERCENT WIDTH
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-5

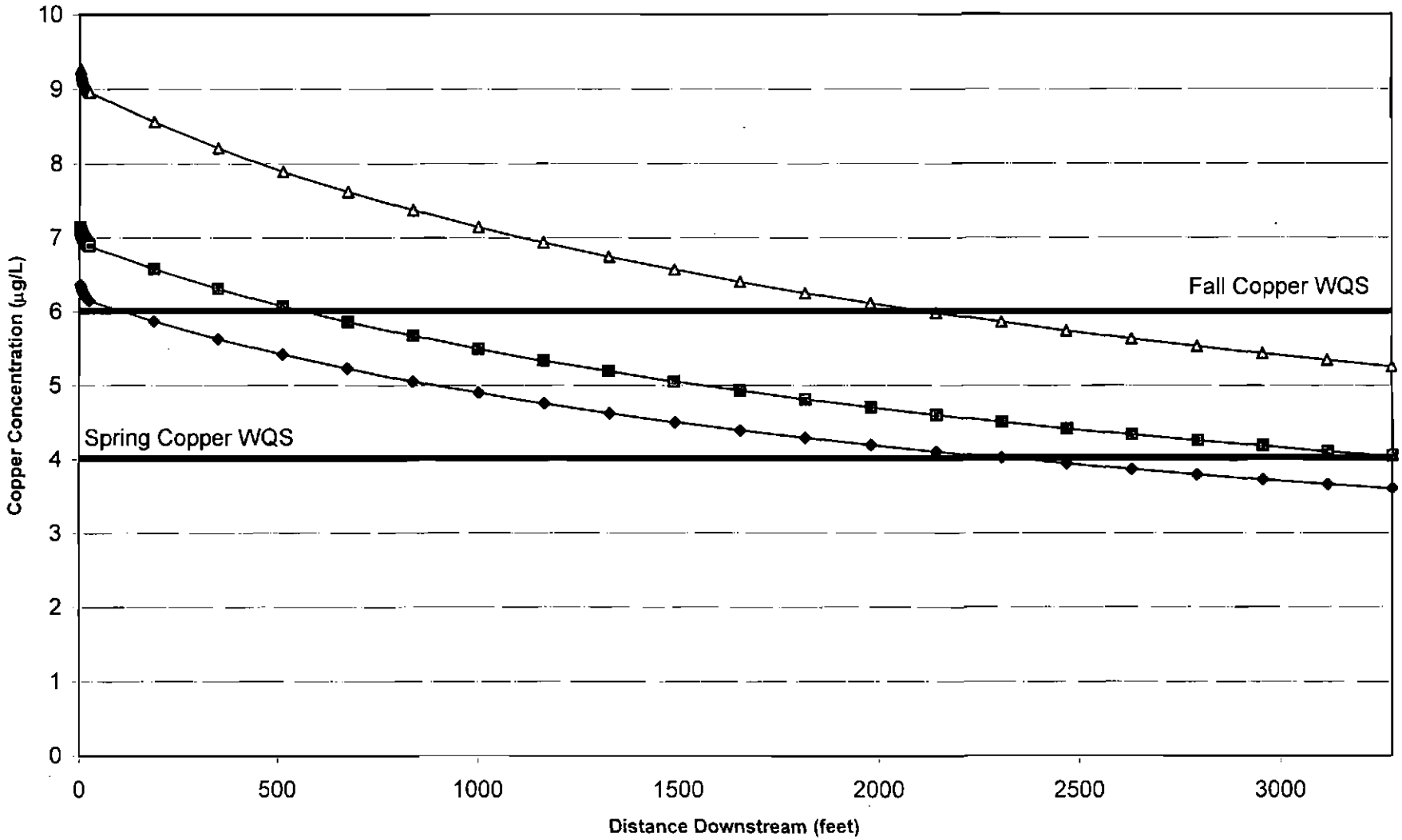
Figure B-5
BB-6 WORST CASE COPPER CONCENTRATIONS V. PERCENT WIDTH
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Average Case - Fall
Average Case - Spring 2000
Average Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-6

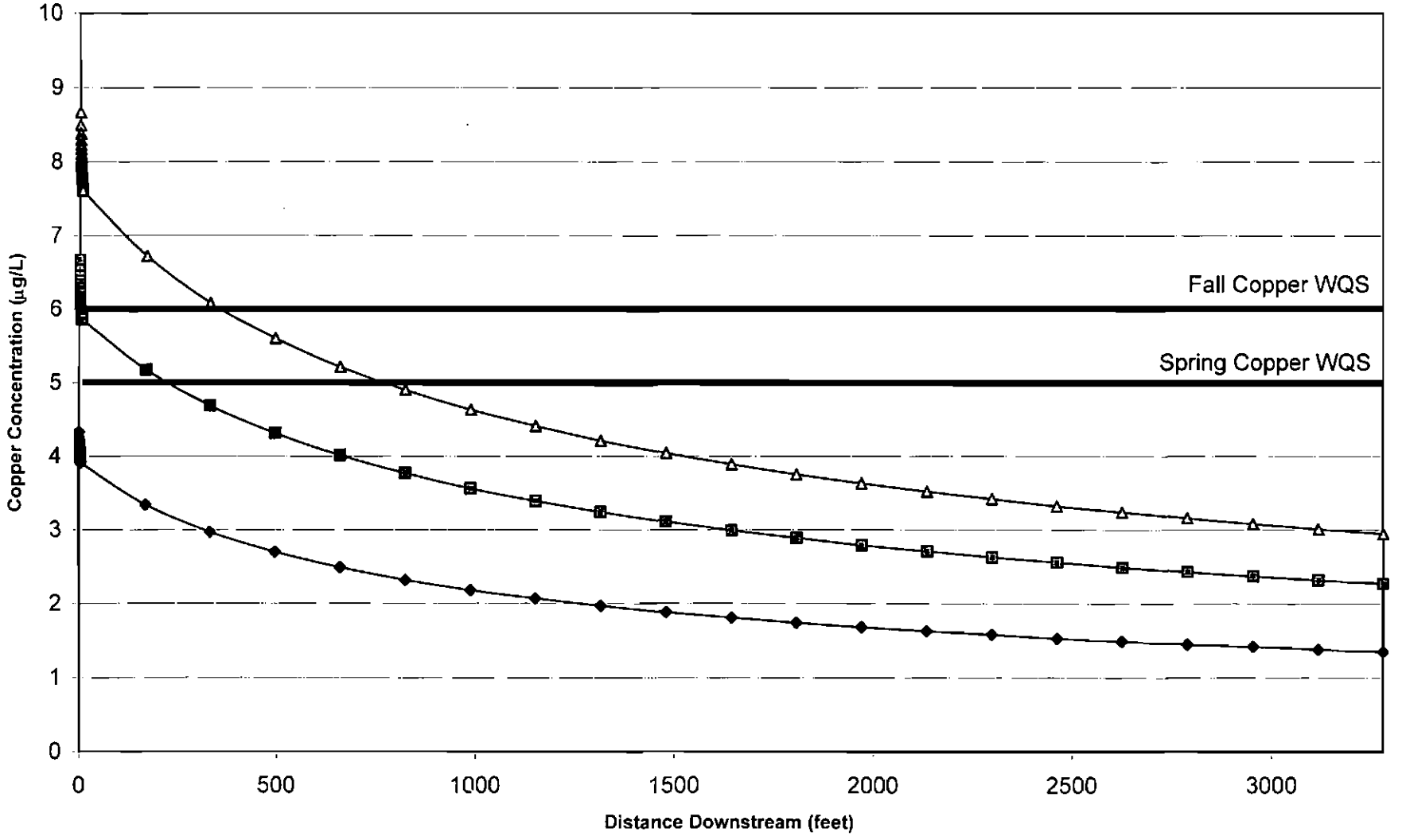
Figure B-6
BB-6 AVERAGE CASE COPPER CONCENTRATIONS V. PERCENT WIDTH
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

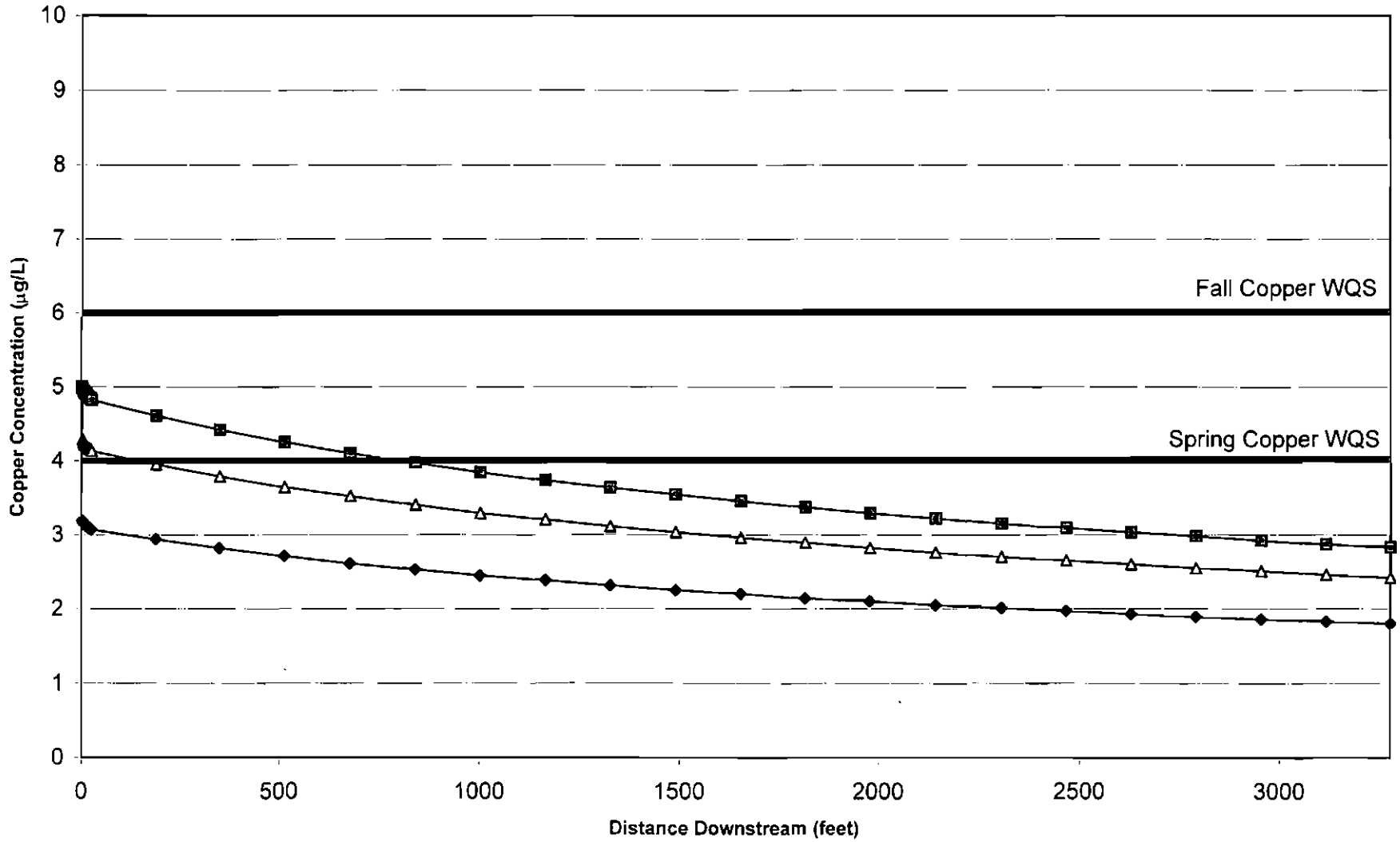
Figs B-7 thru B-10 and B-17 thru B-20, Fig B-7

Figure B-7
BB-4 WORST CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Figs B-7 thru B-10 and B-17 thru B-20, Fig B-8

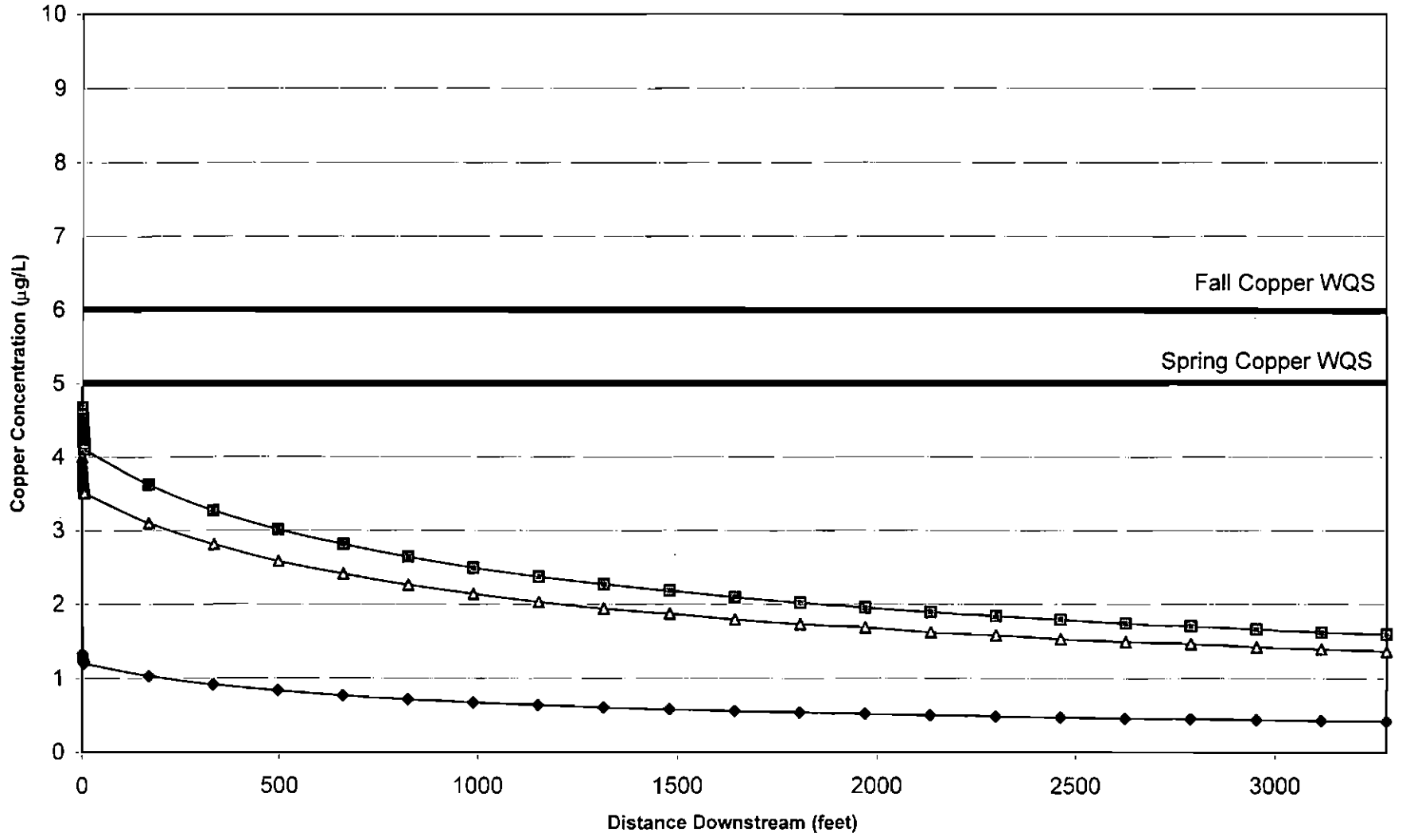
Figure B-8
BB-4 AVERAGE CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

Figs B-7 thru B-10 and B-17 thru B-20, Fig B-9

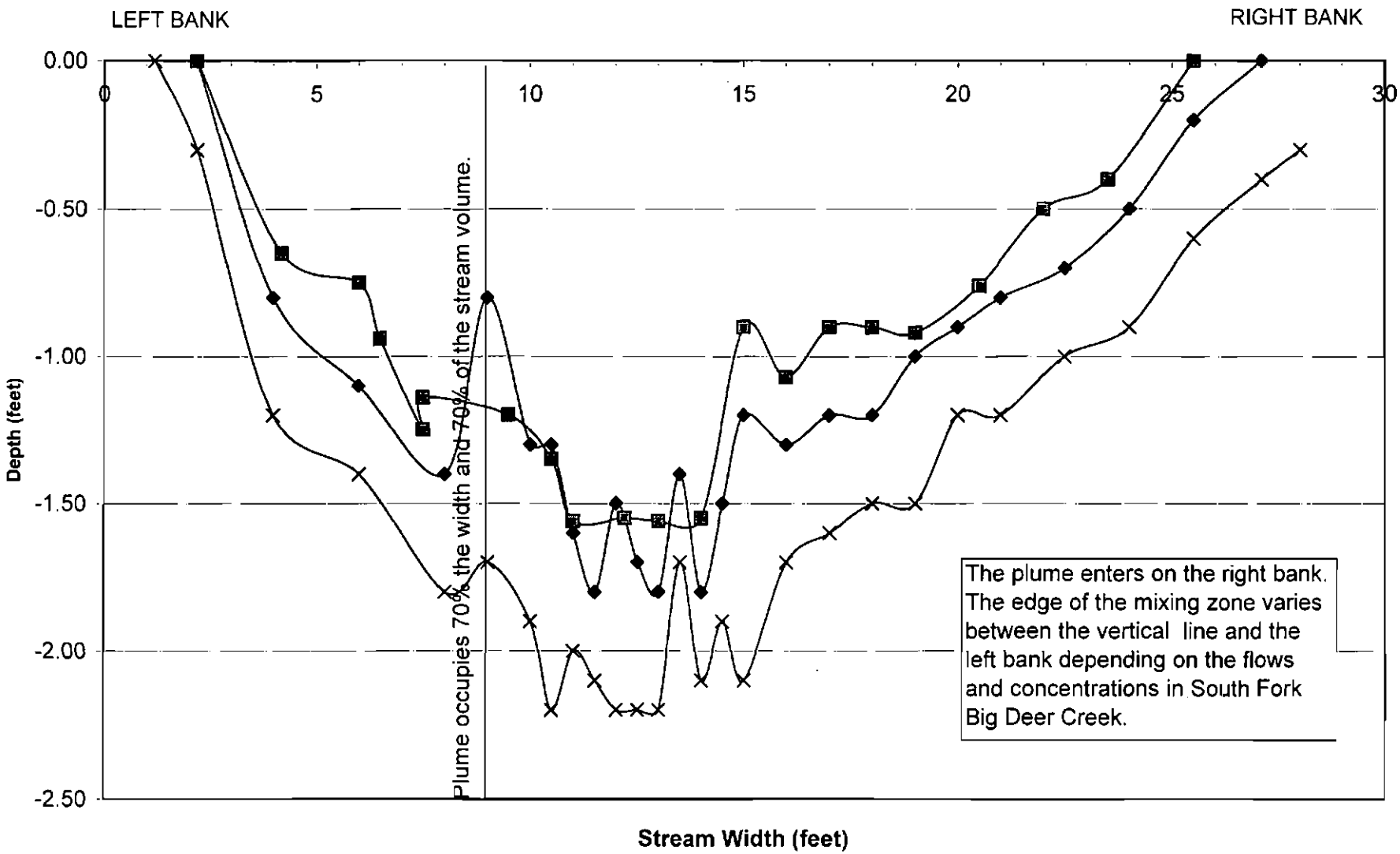
Figure B-9
BB-6 WORST CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Average Case - Fall
Average Case - Spring 2000
Average Case - Spring 2001

Figs B-7 thru B-10 and B-17 thru B-20, Fig B-10

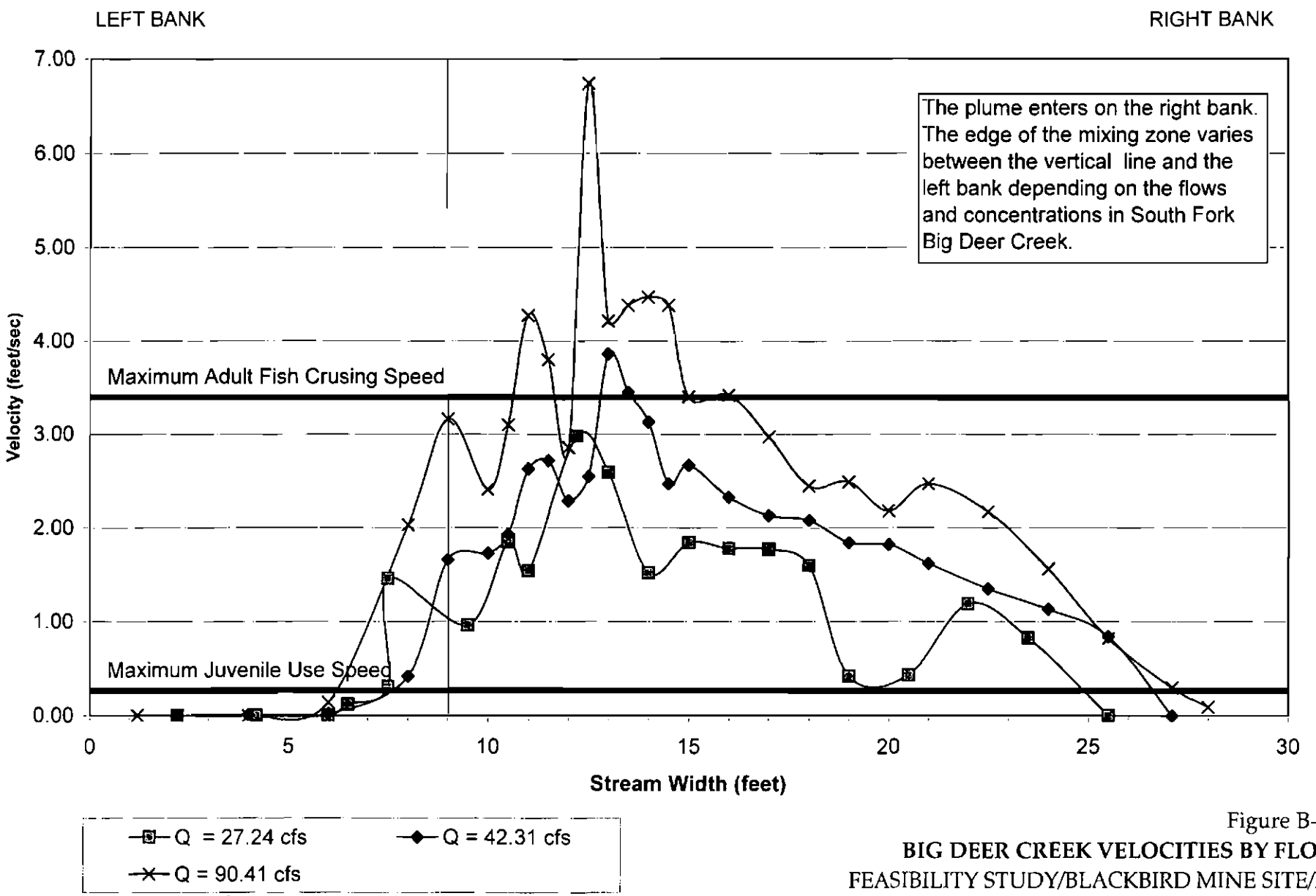
Figure B-10
BB-6 AVERAGE CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Notes: Q = 6.99 cfs was manually adjusted

Figs B-11 and B-12, Fig B-11

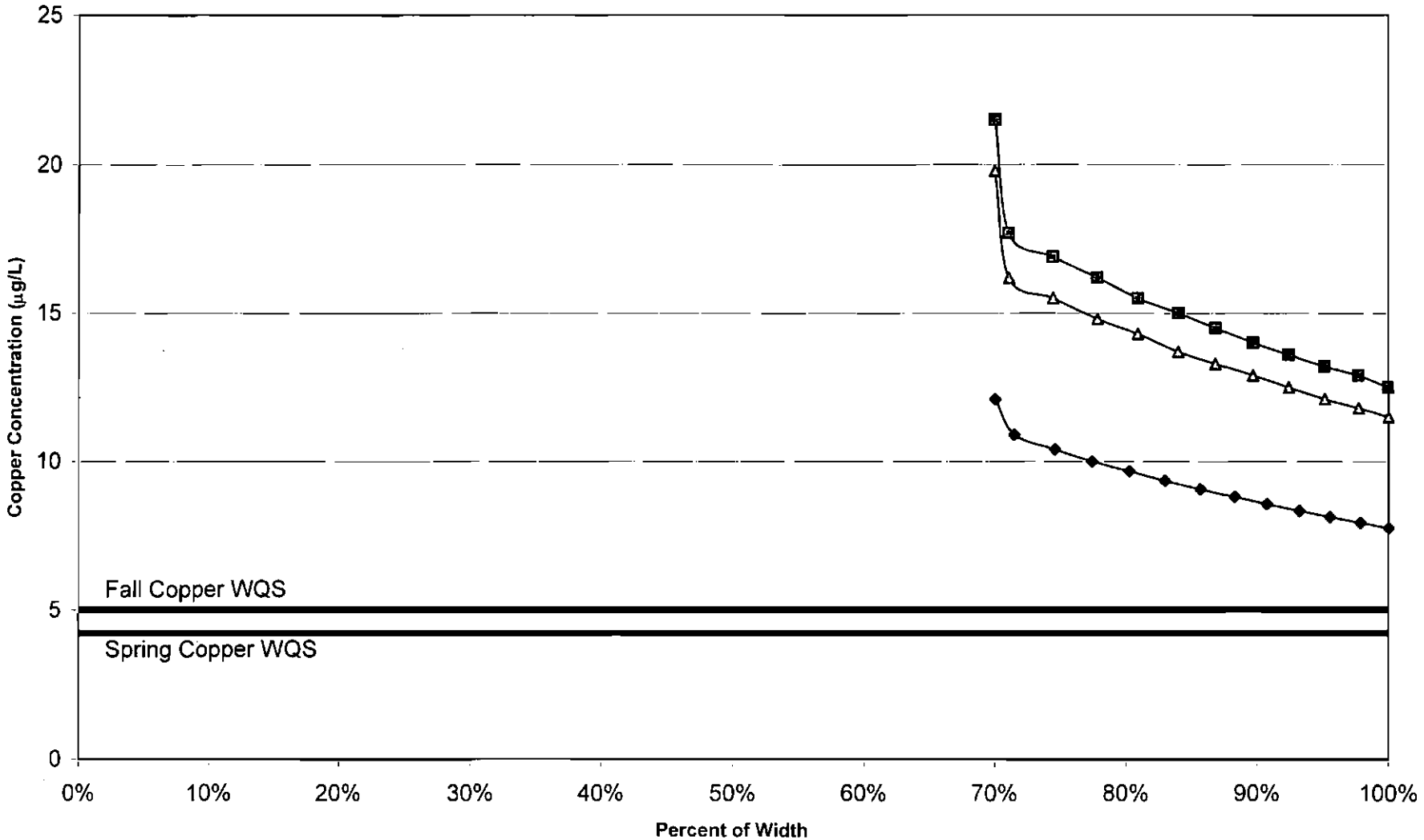
Figure B-11
BIG DEER CREEK CROSS-SECTIONS FOR FLOW
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Notes: Q = 6.99 cfs was manually adjusted

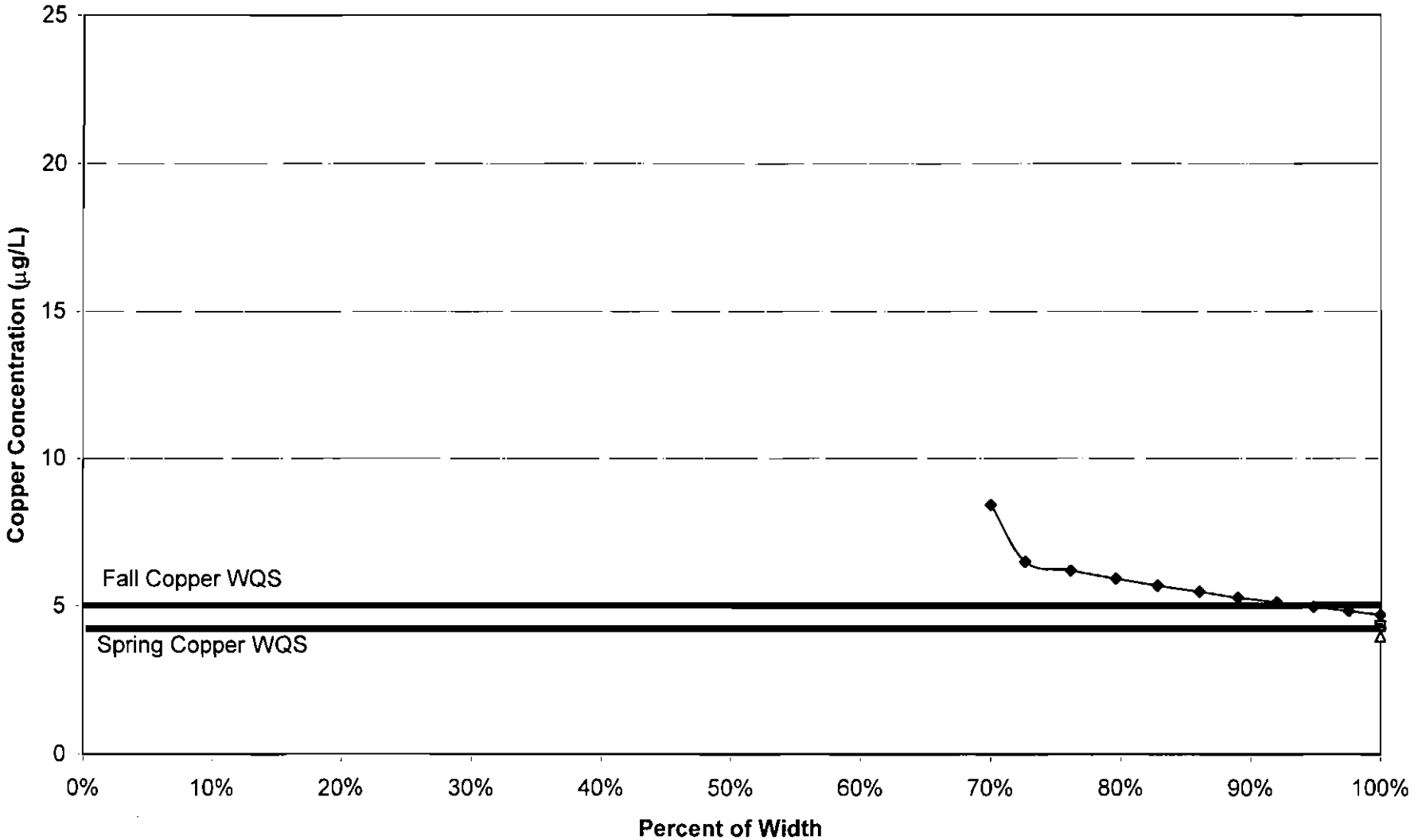
Figs B-11 and B-12, Fig B-12

Figure B-12
BIG DEER CREEK VELOCITIES BY FLOW
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

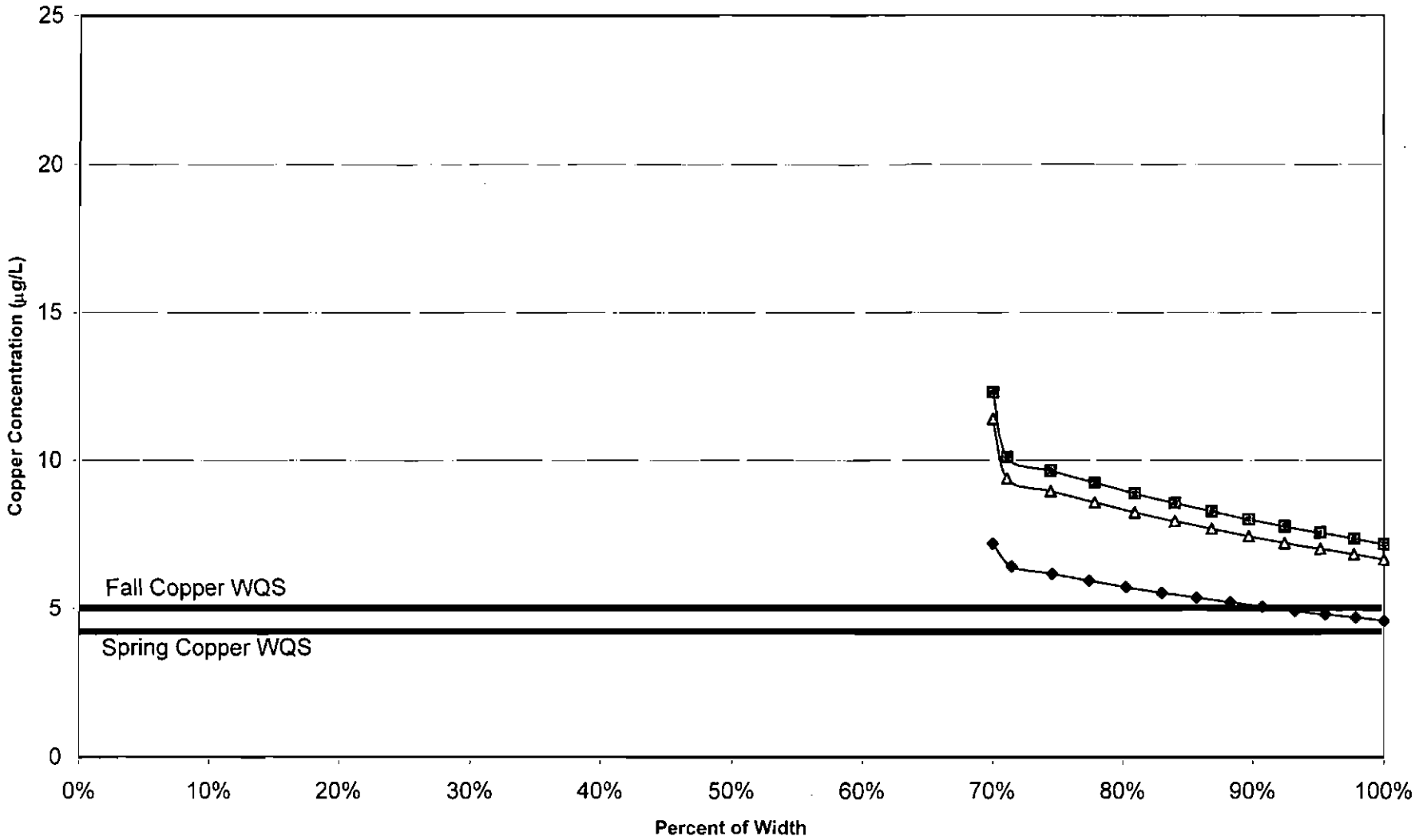
Figure B-13
BUCKTAIL CREEK REMOVAL AT 65%
WORST CASE COPPER CONCENTRATIONS V. PERCENT WIDTH
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Average Case - Fall
Average Case - Spring 2000
Average Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-14

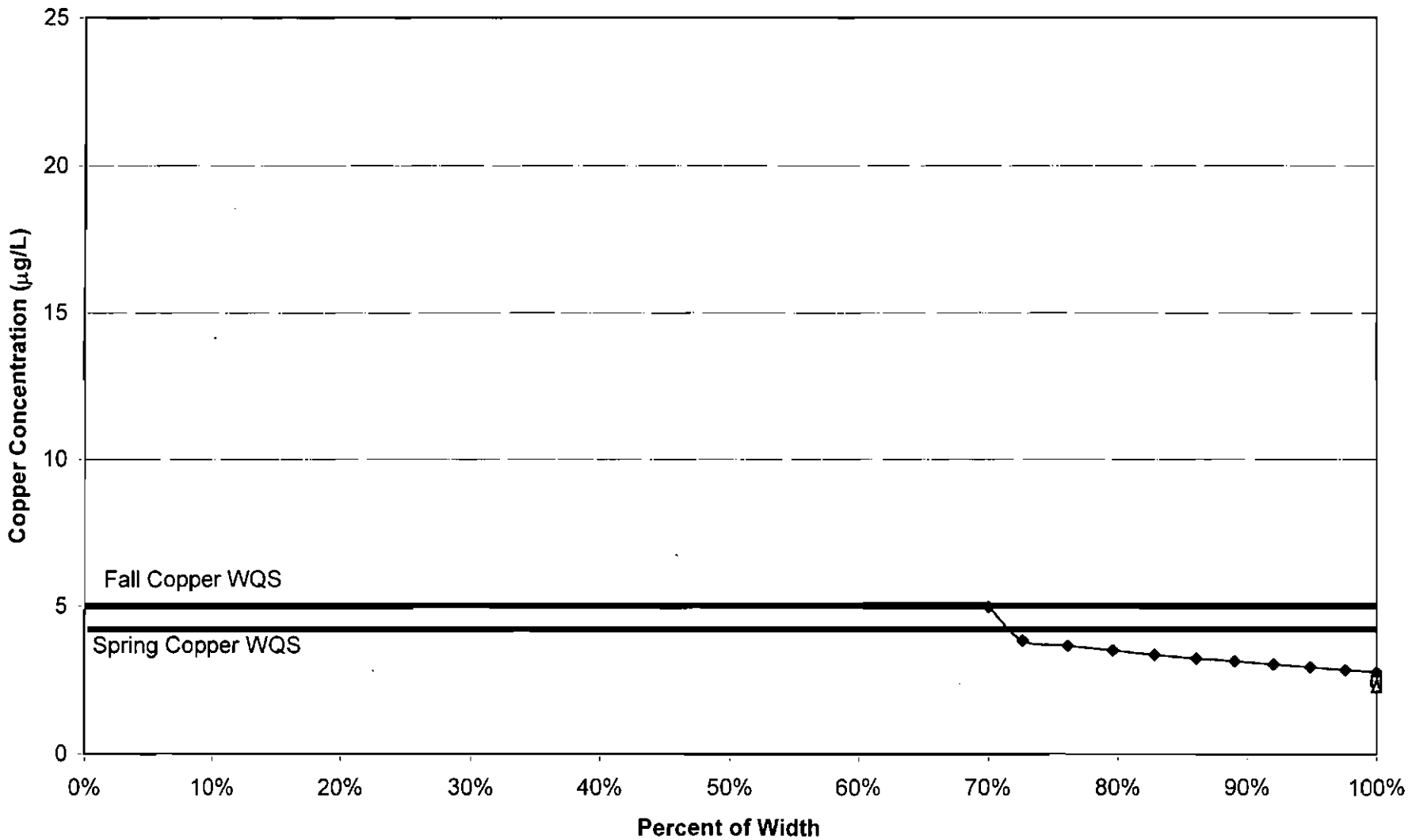
Figure B-14
BUCKTAIL CREEK REMOVAL AT 65%
AVERAGE CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-15

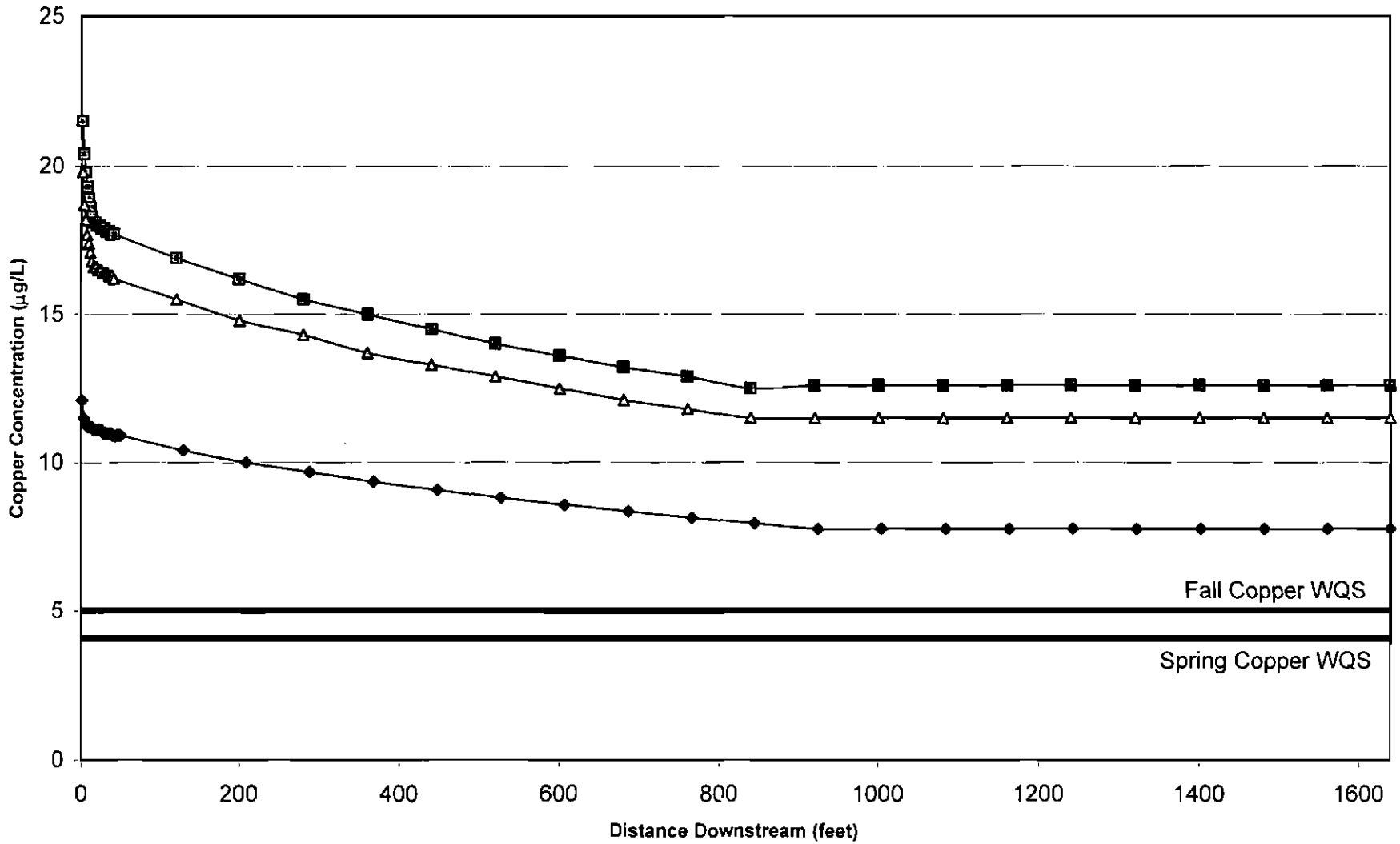
Figure B-15
BUCKTAIL CREEK REMOVAL AT 80%
WORST CASE COPPER CONCENTRATIONS V. PERCENT WIDTH
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Average Case - Fall
Average Case - Spring 2000
Average Case - Spring 2001

Figs B-4 thru B-6 and B-13 thru B-16, Fig B-16

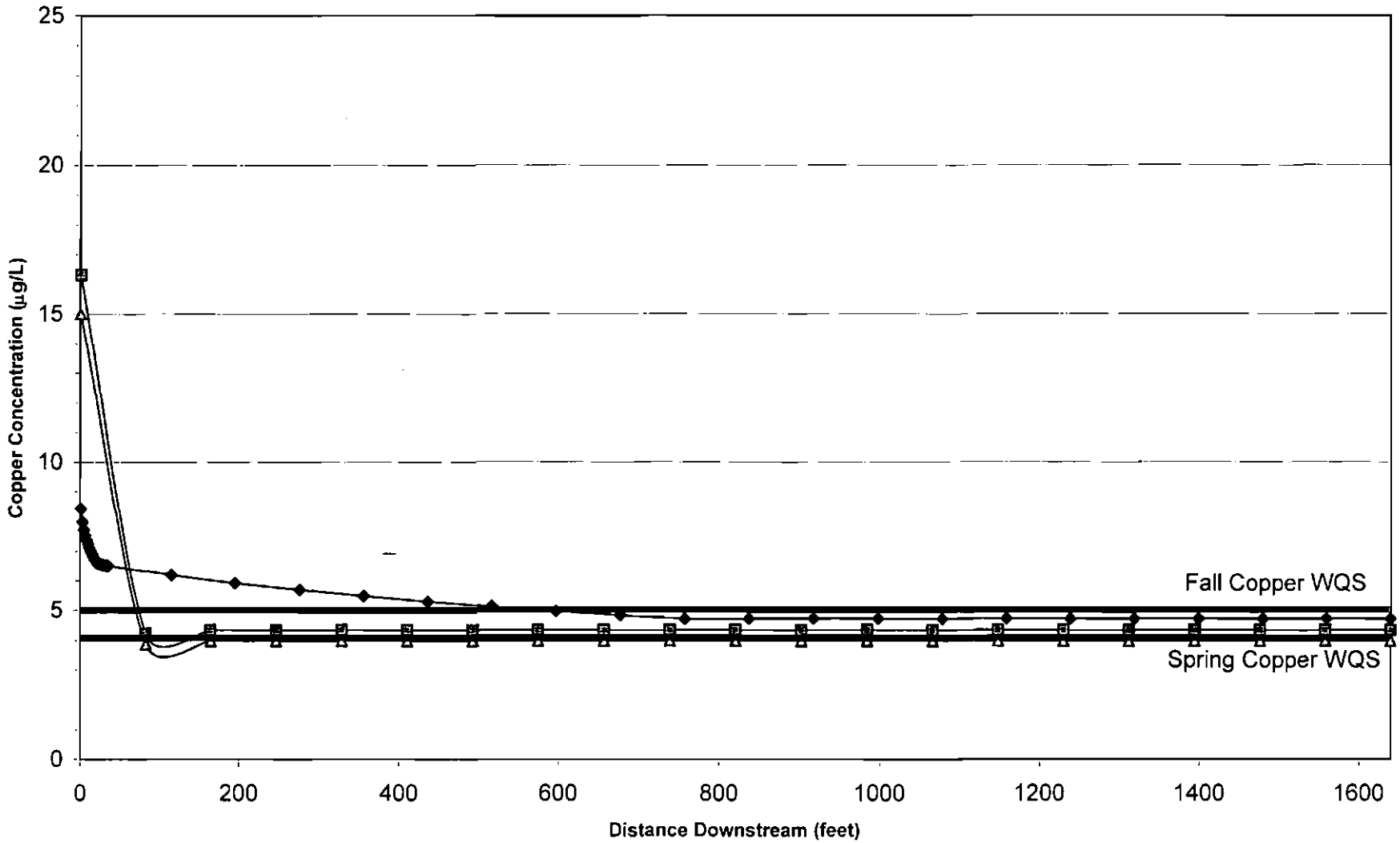
Figure B-16
BUCKTAIL CREEK REMOVAL AT 80%
AVERAGE CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

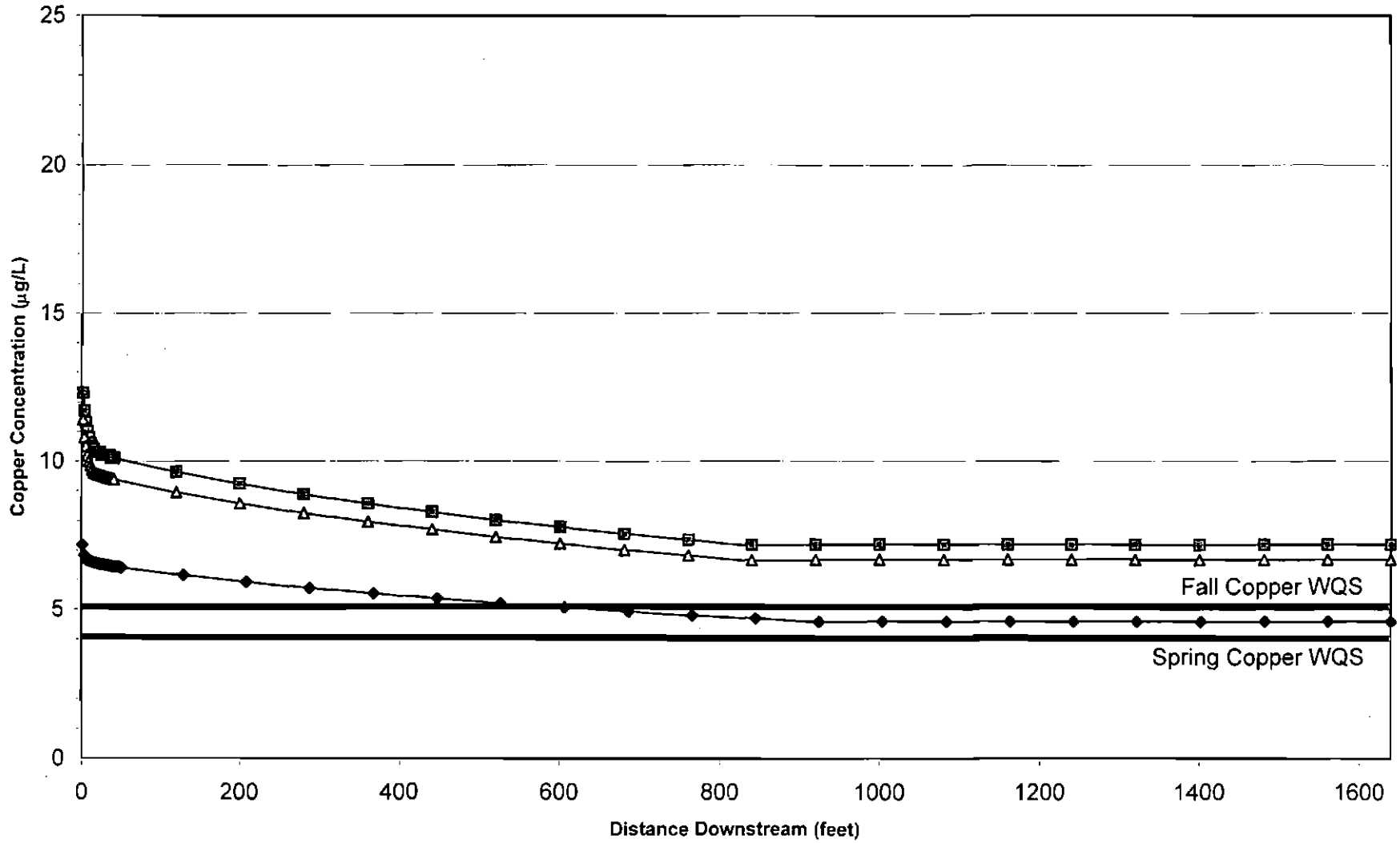
Figs B-7 thru B-10 and B-17 thru B-20, Fig B-17

Figure B-17
BUCKTAIL CREEK REMOVAL AT 65%
WORST CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Figs B-7 thru B-10 and B-17 thru B-20, Fig B-18

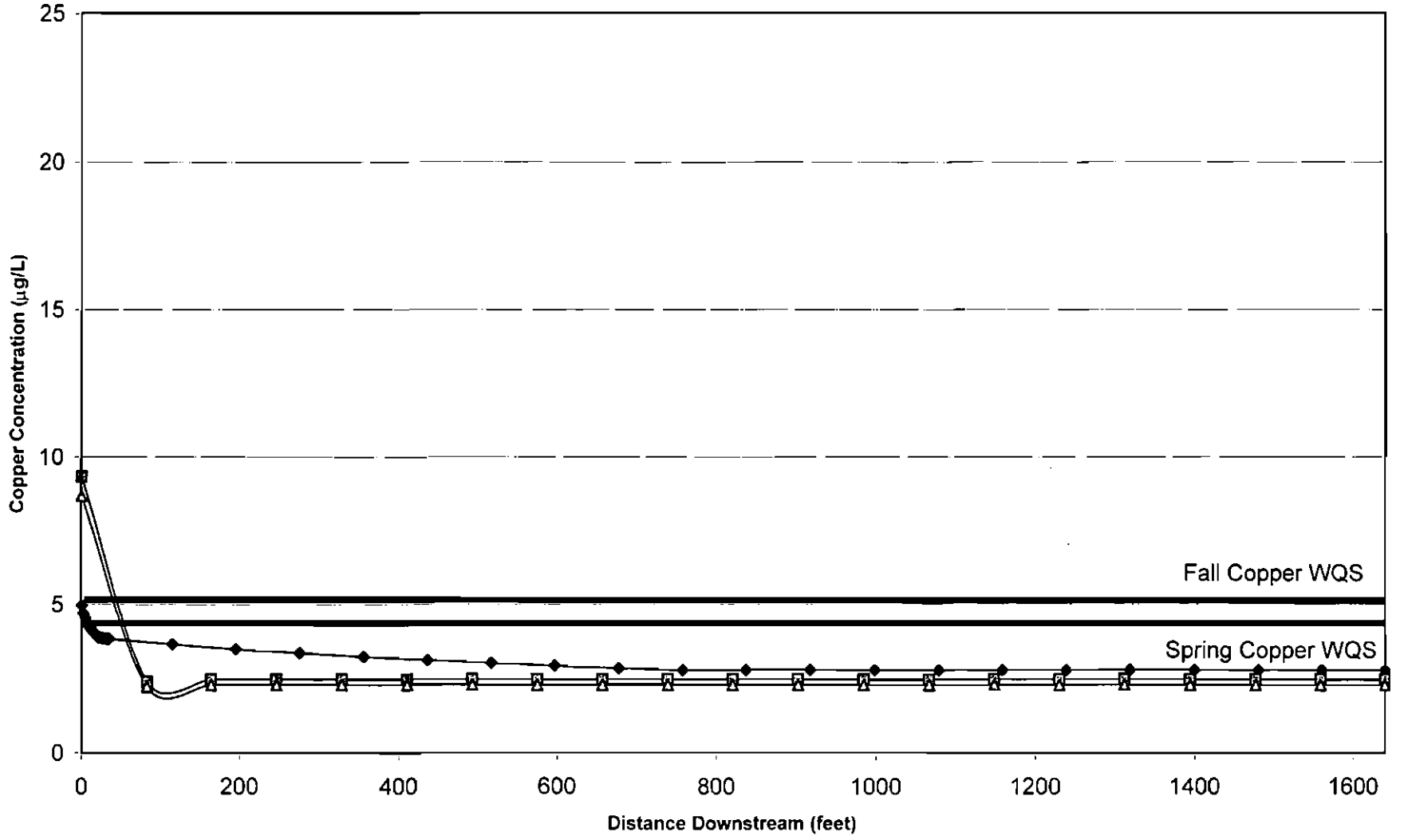
Figure B-18
BUCKTAIL CREEK REMOVAL AT 65%
AVERAGE CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Worst Case - Fall
Worst Case - Spring 2000
Worst Case - Spring 2001

Figs B-7 thru B-10 and B-17 thru B-20, Fig B-19

Figure B-19
BUCKTAIL CREEK REMOVAL AT 80%
WORST CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates



Average Case - Fall
Average Case - Spring 2000
Average Case - Spring 2001

Figs B-7 thru B-10 and B-17 thru B-20, Fig B-20

Figure B-20
BUCKTAIL CREEK REMOVAL AT 80%
AVERAGE CASE COPPER CONCENTRATIONS V. DISTANCE
FEASIBILITY STUDY/BLACKBIRD MINE SITE/ID
Golder Associates

Appendix C

APPENDIX C

EVALUATION OF THE USEPA AMBIENT WATER QUALITY CRITERION FOR IRON TO DETERMINE WHETHER IT IS RELEVANT AND APPROPRIATE TO THE BLACKBIRD MINE SITE

APPENDIX C

Evaluation of the USEPA Ambient Water Quality Criterion for Iron to Determine Whether it is Relevant and Appropriate to the Blackbird Mine Site

Prepared by
Stephen R. Hansen, Ph.D.
S.R. Hansen & Associates
P.O. Box 539
Occidental, California 95465

Evaluation of the USEPA Ambient Water Quality Criterion for Iron to Determine Whether it is Relevant and Appropriate to the Blackbird Mine Site

Prepared by
Stephen R. Hansen, Ph.D.
S.R. Hansen & Associates
P.O. Box 539
Occidental, California 95465

Comments from the EPA on the draft Feasibility Study for the Blackbird Mine Site indicated that the NAWQC for iron needed to be evaluated to determine whether it is potentially relevant and appropriate. The NAWQC for irons is 1 mg/L (ppm) total iron. However, a review of this criterion (which was promulgated in 1976) and of more recent scientific publications on the ecotoxicity of iron indicates that application of the NAWQC would not be relevant and appropriate to the conditions at the Blackbird Mine Site.

A review of the scientific literature since 1976 indicates that the toxicity of iron to aquatic organisms has not been a major area of investigation. However, the studies that have been performed demonstrate that the toxicity of iron to both fish and invertebrates in natural stream waters (such as those found in Panther Creek) is governed by the effects of the iron floc produced rather than by dissolved iron (which is a very small percentage of the total iron due to the very low solubility of iron under aerobic and neutral pH conditions). In addition, after the initial formation of the iron floc, it rapidly becomes less toxic because of changes in its physical structure (i.e, precipitated particles get larger and are less able to bind to gills and cell membranes of aquatic organisms).

For salmonids in Panther Creek, the scientific literature suggests that the safe concentration of iron from prolonged exposure (i.e., 30 days to 2 years) is between 3 and 6 ppm. In 35-week and 2-year studies on brook trout exposed to iron floc (Sykora et al. 1972 and Sykora et al. 1975, respectively), it was demonstrated that brook trout do not suffer reduced survival, growth, or egg hatchability at concentrations less than 12 ppm. Rainbow trout appear to have a similar level of sensitivity. In fish farms in Germany, it was reported that rainbow trout exhibited good survival and growth when the total iron content in the water was between 5 and 10 ppm as long as the pH was circumneutral or slightly alkaline and the dissolved oxygen remained higher than 5 mg/l (Steffins et al. 1993). Fertilized eggs of coho salmon and brook trout, exposed for approximately 45 days, exhibited no reduction in hatchability at 12 ppm iron floc, which was the highest concentration tested (Smith & Sykora 1976). In the same study, when exposed for 30, 60 and 90 days, coho salmon juveniles suffered reduced survival and growth in 6 ppm iron floc, but were not adversely affected in a 3 ppm solution (Smith & Sykora 1976). Smith et al. (1973) suggest that fish species that "live in cool, fast-flowing, spring-fed streams, where iron is more common and remains in suspension for longer periods" are more resistant to the toxicological effects of iron floc than are other species of fish.

For invertebrates likely to be found in Panther Creek, the scientific literature suggests a wide range of sensitivities to iron, with a safe level of approximately 5 ppm for the most sensitive species and a much higher level for the majority of species. Daphnids, which are not residents of fast-flowing streams such as Panther Creek, are apparently the most sensitive aquatic invertebrates to iron. However, even for daphnids, under conditions found in Panther Creek, a 3-

week exposure resulted in a LOEC for reproduction of 4.38 ppm and a LC50 for survival of 5.9 ppm (Biesinger and Christensen 1972, Dave 1984). Other stream invertebrate species have been shown to be considerably less sensitive, with the mayfly, *Leptophlebia marginata*, exhibiting no reduction in survival when exposed for 30 days at 40 ppm (Gerhardt 1995). Warnick & Bell (1969) reported 7-day and 9-day LC50s of 16 ppm for a caddisfly, *Hydropsyche betteni*, and a stonefly, *Acroneuria lycorias*, respectively. In the same study, they reported that a mayfly, *Ephemerella subvaria*, had a 96-hr LC50 of 0.32 ppm. However, as pointed out in the Canadian Water Quality Guidelines for Iron (1987), this value is in question because of the unusual sensitivity exhibited by this species to almost every metal tested in the Warnick & Bell study.

Based on available monitoring data in Panther Creek, concentrations of total iron (primarily resuspended iron floc) are likely to be the highest during high flow storm events and will exceed 1 ppm (with a maximum of 2.5 ppm, except for one observation of 4 ppm reported in 1999) for, at most, a few days to a week. The available toxicological data indicates that this exposure scenario will not adversely impact salmonid eggs or juveniles or the prey items upon which they feed.

It should be noted that several studies have been reported in the toxicological literature which indicate that some aquatic species can be adversely impacted by iron at concentrations less than 1.0 mg/l. For example, Dave (1984) reports a 21-day chronic value of 0.158 mg/l for *Daphnia magna* and Amelung (1982) reports acute mortality to freshly hatched rainbow trout at 0.47 mg/l. However, a review of these studies indicates that the results are based on a different form of iron than would be found in Panther Creek and, therefore, are not relevant to Panther Creek. In some of these studies, the test organisms were exposed to the reduced, ferrous form of iron; whereas in Panther Creek iron is in the oxidized, ferric form. In other of these studies, the oxidation and precipitation of iron occurred in the exposure chamber and, consequently, the test organisms were exposed to both ferrous iron and the very fine ferric hydroxide precipitates which may bind to gills and cause suffocation. In Panther Creek, on the other hand, the salmonids and their prey items would be exposed to much larger ferric hydroxide precipitates because the iron has been oxidized and precipitated much further upstream. These larger particles are less harmful to aquatic life.

The NAWQC for iron is not based on current scientific literature and it does not consider the differences in the toxicological effects of the different forms of iron described above. The NAWQC was promulgated in 1976 at 1.0 mg/l (total iron) and has not been modified since. As stated in the criterion document, it is "based on field observations principally". Reliance on field observations greatly reduces the accuracy of a criterion because it is not possible to discriminate between the effects of co-occurring multiple toxicants (e.g., low pH, iron, and other heavy metals). In fact, a review of the actual documents cited in the 1976 NAWQC for iron shows that, in those cases in which an attempt was made to measure other contaminants, adverse impacts to fish were primarily observed when pH was depressed (Brandt 1948, Doudoroff & Katz 1953). In its database on Toxicological Benchmarks for Screening Potential Contaminants of Potential Concern for Effects on Aquatic Biota, the Oakridge National Laboratory acknowledges this concern and states that "the NAWQC for iron is based on a field study at a site receiving acid mine drainage and is not consistent with current methods for deriving criteria". It should be noted that, in the early to mid 1980s, USEPA developed NAWQCs for almost all heavy metals of concern, using a procedure which requires a robust set of toxicological data generated under controlled laboratory conditions. No such effort has been undertaken for iron; apparently

because iron was not considered to be of sufficient environmental concern to warrant such an action.

In summary, the above review of the latest available information regarding the toxicity of iron as it applies to the conditions at the Blackbird Mine site demonstrates that the NAWQC for iron may not be relevant and appropriate for this site.

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Appendix D

APPENDIX D

EFFECTIVENESS OF A SOIL COVER ON THE TAILINGS IMPOUNDMENT

MEMORANDUM

APPENDIX D

TO:	Doug Dunster	April 19, 2002
FR:	Tony Burgess, Travis McGrath, Rens Verburg, Cheryl Ross	
RE:	Evaluation of the Effectiveness of a Soil Cover on Seepage from the West Fork Tailings Impoundment	943-1595.003.9000

D-1. INTRODUCTION

This technical memorandum presents analyses undertaken to evaluate the effectiveness of a soil cover on the West Fork Tailings Impoundment. Tailings were placed in the West Fork until the mill ceased operations. Subsequent remedial measures that have been undertaken include (year of completion provided in parentheses):

- Channelizing West Fork Creek across tailings to reduce erosion and infiltration (1993).
- Lining of the West Fork channel with clay, effectively providing a low permeability cap (1993).
- Placing buttress on downstream slope of dam for improved stability and erosion protection (1993).
- Installation of soil-cement-bentonite cutoff wall upstream of Tailings Impoundment to reduce groundwater flow and groundwater levels beneath the tailings (1993).
- Placing of lower metals content material as cover over portions of the tailings to reduce infiltration, soil and wind erosion (1998 to 2001).
- Addition of P-traps to discharge pipes through culvert plug to limit ingress of oxygen (2001).

In this memorandum, existing data are briefly reviewed, a conceptual model for the hydrogeology and geochemistry is developed, and the reductions in metals loading to Blackbird Creek and Panther Creek are estimated.

D-2. EXISTING DATA

D-2.1 Physical Data

Grain size analyses of the tailings were performed by Golder (2001a) in connection with the stability analyses of the tailings dam. These data are summarized below.

TABLE D-1

Tailings Grain Size Analyses

Sample ID		Depth		Percent		
		from	to	gravel	sand	silt+clay
GT-100	4	12	13.5	0	51.15	48.85
	9	25	26.5	0	22.39	77.61
	13	35	36.5	0	74.77	25.23
	21	57.5	59	6.19	33.44	60.37
	25	67.5	69	2.27	27.24	70.49
	31	87.5	89	0	58.3	41.7
GT-102	10	60	61.5	0.06	39.81	60.13
	11	65	66.5	0.02	45.09	54.89
	14	80	81.5	0.13	24.96	74.91
	18	47.5	49	0	18.86	81.14
	21	55	56.5	0	58.15	41.85
	26	67.5	69	0	65.11	34.89
	30	77.5	79	1.94	14.83	83.23
Average				0.82	41.08	58.10

The tailings gradations for West Fork are consistent with typical tailings gradations for other mines (see Mittal and Morgenstern, 1975, 1976). The order of magnitude of hydraulic conductivity is typically 10^{-4} to 10^{-5} cm/s. Slug testing by Knight Piésold (1994a) of the alluvium underlying the tailings showed hydraulic conductivities ranging from 1 x 10^{-4} to 3.5 x 10^{-5} cm/s. However, the presence of the buried West Fork Creek channel and the concrete culvert may act as a much more permeable drain within the alluvium in some areas.

D-2.2 Geology

The hill slopes above the tailings are mantled with colluvium and talus, overlying fractured phyllite bedrock. The base of the valley is infilled with unconsolidated deposits of colluvium and alluvium. Based on borehole data, the unconsolidated deposits are up to 37.5 feet thick (WFMW-3).

D-2.3 Hydrology

D-2.3.1 Surface Water

Surface water from the West Fork drainage area upstream of the Tailings Impoundment flows across the tailings surface in a rock-armored channel with concrete pipe half-round for low flows. The hillslopes to the north and south produce only limited runoff, because of the permeable talus and colluvium that mantles the slopes. Depending upon the volume and intensity of the run-on, this water ponds on the surface of the tailings and infiltrates, and/or runs off into the West Fork diversion channel. Downstream of the tailings dam, seeps and discharge from the culvert beneath the tailings are collected by ditches and discharge to Blackbird Creek.

D-2.3.2 Groundwater

Boreholes and monitoring wells into and through the tailings indicate that, throughout most of the Tailings Impoundment, the groundwater level is within the natural unconsolidated deposits. Water level elevations taken shortly after the 1993 series of monitoring wells were installed show that groundwater elevations approximate the adjacent invert elevations of the culvert, except upstream of WFMW-11 where the groundwater elevation drops below the culvert. However, since the mid-1990s, observations in the downstream area show that the water level has locally risen into the tailings. For example, at WFMW-6 the water level rose into the tailings in late 1996. The largest groundwater elevation increases have taken place in the most downstream monitoring wells. In WFMW-3, the groundwater level rose from elevation 5584.00 in June 1993 to 5605.79 in August 2000, an increase of over 21 feet. The cause of this increase has not been determined, although plugging of the gravel backfill within the culvert is the most likely explanation.

Downstream of the tailings dam, groundwater levels are at or near ground surface. There are a number of seeps from the toe of the dam and into shallow ditches in the alluvial sediments bordering West Fork and Blackbird Creek

D-2.4 Chemistry

Tailings Impoundment seepage contributes copper, cobalt, and iron loading to Blackbird Creek. Each of these metals exhibits unique behavior in Blackbird Creek. Spring and fall synoptic sampling results from 1998, 1999 and 2000, plotted in Figures D-1 through D-3, illustrate these differences. These figures include stations BBSW-03A, BBSW-02, BBSW-01.5, BBSW-01A, and BBSW-01. Station BBSW-03A is located immediately upstream of the Tailings Impoundment. The four remaining stations are located downstream of the impoundment.

Cobalt is transported relatively conservatively in Blackbird Creek. Although cobalt will adsorb to manganese and iron (oxy)hydroxide phases, the pH of Blackbird Creek (generally 6 to 7) is below the range for optimal cobalt adsorption. This is illustrated in Figure D-4, a plot of adsorption edges for copper, cobalt, arsenic, and sulfate, which

shows the effectiveness of adsorption as a function of pH. Olsen (Camp Dresser and McKee, 1995) noted cobalt in association with a manganese/iron oxyhydroxide phase in a sediment sample collected downstream of the Tailings Impoundment, indicating some cobalt attenuation is possible.

Cobalt concentrations between BBSW-02 and BBSW-01 are higher in the fall (Figure D-1). Dissolved cobalt concentrations in the fall typically increase from approximately 0.3 mg/L to 0.8 mg/L between BBSW-03A and BBSW-02. Cobalt concentrations in Blackbird Creek remain relatively stable between BBSW-02 and BBSW-01. In the spring, a small decrease in cobalt concentrations between BBSW-03A and BBSW-02 is consistently observed. This decline is attributed to dilution by inflow from the clean water diversion. In 1999 and 2000, dissolved cobalt concentrations showed a slight decreasing trend downstream of the Tailings Impoundment (between BBSW-02 and BBSW-01). This decline may be attributable to dilution from groundwater recharge or cobalt attenuation in association with (oxy)hydroxide phases. Dissolved cobalt concentrations in Panther Creek at PASW-08A in the spring and fall of 2000 were essentially equal at 0.053 and 0.055 mg/L, respectively.

Dissolved iron concentrations in Blackbird Creek are plotted in Figure D-2. Seepage from the Tailings Impoundment is a year-round significant source of iron to Blackbird Creek. Between BBSW-03A and BBSW-02, dissolved iron concentrations consistently increase in both the spring and fall. In the spring, iron concentrations between these stations typically increase from less than 0.2 mg/L to greater than 1 mg/L. In the fall, iron concentrations typically increase from less than 0.2 mg/L to greater than 5 mg/L. Downstream of BBSW-02, dissolved iron concentrations generally decline sharply due to the precipitation of iron (oxy)hydroxides.

Dissolved copper concentrations in Blackbird Creek are plotted in Figure D-3. In the spring, dissolved copper concentrations between BBSW-03A and BBSW-02 consistently decline. This decline in dissolved copper is attributed to both dilution from the clean water diversion and adsorption of copper onto iron (oxy)hydroxides. In the spring of 1998 and 1999, copper concentrations continued to decline between BBSW-02 and the mouth of Blackbird Creek. This decline is attributed to copper adsorption onto iron (oxy)hydroxides. The adsorption edge for copper (Figure D-4) illustrates that pH conditions in Blackbird Creek are within the range to promote maximum copper adsorption.

In spring 2000, copper concentrations were relatively stable downstream of BBSW-02 (0.044 mg/L to 0.054 mg/L). Converse to iron and cobalt, dissolved copper concentrations in Blackbird Creek are lower in the fall (<0.06 mg/L) than in the spring. Between 1998 and 2000, dissolved copper concentrations between BBSW-03A and BBSW-02 were relatively stable, showing less than 0.02 mg/L variability. Downstream of BBSW-02, dissolved copper concentrations consistently decline. This decline is attributed to the adsorption of copper onto iron (oxy)hydroxides, and can be reasonably simulated using the geochemical model PHREEQC (Parkhurst and Appelo, 1999). Olsen (Camp Dresser and McKee, 1995) confirmed the association of copper with an iron oxyhydroxide phase in sediment collected downstream of the Tailings Impoundment. Dissolved copper

concentrations in Panther Creek at PASW-08A in the spring and fall of 2000 were 0.010 mg/L and less than 0.003 mg/L, respectively.

Copper and cobalt concentrations in Tailings Impoundment seepage are generally at least an order of magnitude higher than those in Blackbird Creek. Water quality data from WFMW-1S, WFMW-1D and BBSP-42 are shown in Figure D-5. Well nest WFMW-1 is located downgradient of the impoundment between the dam and Blackbird Creek. The shallow (WFMW-1S) and deep (WFMW-1D) completions are screened within the alluvium and fractured bedrock, respectively. BBSP-42 is a seep located downgradient of WFMW-1 between the toe of the dam and Blackbird Creek.

Dissolved cobalt concentrations in WFMW-1 are higher than copper concentrations. For the period of record, dissolved cobalt concentrations are higher in the shallow alluvial well (12 to 16 mg/L) than the deep bedrock well (5 to 9 mg/L). Dissolved copper concentrations are below 1 mg/L in the shallow well and 0.1 mg/L in the deep well. Groundwater in the alluvium is more acidic (pH ~3.5) than the bedrock aquifer (pH ~5.5).

Golder (1997) presented water quality profiles for the alluvial and bedrock aquifers below the Tailings Impoundment. The West Fork monitoring wells were sampled three times between June 1995 and October 1996. Of the 8 wells sampled, only two (WFMW-13D and WFMW-1D) are completed within the bedrock. The remaining 6 wells are completed in the alluvium.

Based on the 1995 through 1996 sampling results, alluvial groundwater pH upstream of the Tailings Impoundment is near neutral (Figure D-6). Groundwater pH decreases in the direction of groundwater flow reaching a minimum at WFMW-1S (<3.6). Iron concentrations increase with decreasing pH between WFMW-13D and WFMW-06, and remain elevated (> 100 mg/L) in wells downstream of the toe of the impoundment (Figure D-7). This pH /iron relationship is consistent with expected geochemical trends.

Copper concentrations (in μg/L) are plotted in Figure D-8. With the exception of two samples, copper concentrations were less than 10 μg/L in wells upgradient of the toe of the impoundment. Dissolved copper concentrations increase downgradient of the dam to a peak of 0.9 mg/L in WFMW-01S (6/19/95). Unlike copper, dissolved cobalt concentrations (Figure D-9) are elevated (>10 mg/L) in groundwater beneath the impoundment (WFMW-6 and WFMW-4). Dissolved cobalt concentrations do not increase significantly in wells downgradient of the impoundment. The peak dissolved cobalt concentrations are recorded in well WFMW-02 (15.7 mg/L to 21.1 mg/L). Differences in copper and cobalt concentration profiles below the Tailings Impoundment likely reflect non-conservative versus conservative behavior of copper and cobalt, respectively.

As discussed previously, the mechanism for copper attenuation in Blackbird Creek is adsorption onto iron (oxy)hydroxides. Due to the acidic conditions within the tailings, as indicated by the pH of WFMW-01S groundwater (pH ~3.5), adsorption onto iron (oxy)hydroxides is an unlikely attenuation mechanism. Therefore, in the absence of

attenuation, copper concentrations in West Fork seepage would be expected to be similar to those measured in the water treatment plant inflow (i.e. mine water). This is indeed the case for cobalt, whose concentrations in tailings seepage (~5 to 20 mg/L) and water treatment plant inflow (13 to 22 mg/L) are similar due to an absence of attenuating mechanisms in both the tailings seepage and mine water.

Although dissolved copper concentrations from the water treatment plant range from 7 mg/L to 20 mg/L, dissolved copper concentrations in tailings seepage are typically less than 1 mg/L. This may be due to precipitation of a copper sulfide in the tailings (covellite (CuS) or possibly chalcocite (Cu_2S)), which acts as a control on copper levels due to its low solubility. Covellite precipitation near the oxygen reaction front has been identified by mineralogical analysis in tailings facilities at a number of mine sites (McGregor *et al.*, 1997; Blowes and Jambor, 1990). Table D-2 provides details of the geochemical conditions at two of these sites. Speciation modeling conducted on water quality data from WFMW-01S supports that, provided the pe of tailings pore water is below approximately 3 (180 mV), covellite has the potential to precipitate. Due to the much more oxidizing conditions in the mine water, covellite formation in mine water is very unlikely, and this control on copper concentrations is therefore not present in water treatment plant inflow.

Table D-2

Documented Covellite Occurrence in Tailings

Mine Site (Reference in Parentheses)	Location of Covellite (CuS) Occurrence	pH	Pore Water Cu Concentration (mg/L)	Redox Potential (mV)
Waite Amulet, Quebec (Blowes and Jambor, 1990)	Near the depth of active oxidation within the tailings.	3.5 to 5	Decline from > 50 mg/L to < 1 mg/L	400 to 600
Copper Cliff (McGregor et al., 1998)	At base of the oxidized zone within the tailings.	4 to 5	Decline from 0.2 mg/L to <0.05 mg/L	250

Covellite occurrence has not been documented during any of the West Fork Tailings field investigations. However, this is not unexpected since field identification is considered unlikely. At the sites referenced above, covellite was identified by mineralogical analysis, not field identification. At the Blackbird site, assuming all copper from the first five feet of tailings was released and precipitated in a 1-foot zone, the resultant covellite concentration would be less than 1%. At these concentrations, it would be difficult for even a skilled mineralogist to identify this mineral phase. Dr. John Jambor, a recognized leading authority on mine waste characterization and accomplished mineralogist, notes that "even at a 1% concentration, covellite could appear simply as blackish, sooty coatings on the tailings particles" (personal communication, 2002). Dr. Jambor has found covellite, or related minerals, in all or nearly all of the Cu-bearing oxidized impoundments he has examined. Even if covellite

was visible in the field, sampling during drilling at typical intervals (5 feet) means the narrow zone of covellite precipitation would likely be missed. Therefore, although covellite has not been observed at the Blackbird Site, its possible occurrence should not be discounted, and covellite is considered a potential control on aqueous copper concentrations.

D-3. CONCEPTUAL MODEL

D-3.1 Conceptual Geochemical Model

The copper and cobalt bearing phases in the ore and tailings at the Blackbird Site are chalcopyrite ($CuFeS_2$) and cobaltite (CoAsS). Pyrite (FeS_2) is also known to be present in Blackbird ores and tailings. Oxidation of these minerals is the principal mechanism for cobalt, copper, iron, and sulfate release from the Tailings Impoundment. Sulfide minerals are unstable under atmospheric conditions (i.e. in the presence of atmospheric oxygen or oxygenated waters). Diffusion of oxygen into the Tailings Impoundment therefore results in the weathering of chalcopyrite and cobaltite.

Oxygen diffusion into the Tailings Impoundment takes place through its surface and sides and may also occur through the culvert present at the base of the tailings. Because oxidation would have occurred continuously during placement of the tailings, lenses/layers of variably oxidized tailings likely occur throughout the tailings.

Sulfide oxidation rates are a function of a number of factors, including (Plumlee, 1999):

- Sulfide grain size (surface area);
- Texture;
- Trace element content;
- Temperature;
- Oxidant (oxygen or aqueous ferric iron); and,
- Presence/absence of microbial populations.

Oxidation rates for pyrite and chalcopyrite are available in the literature; however, Golder was unable to find published rates for cobaltite oxidation. Based on literature data, it is assumed that the rate of chalcopyrite oxidation in the Tailings Impoundment is slower than that of pyrite. Using arsenopyrite as an analogue, cobaltite oxidation is expected to be faster than that of chalcopyrite. A more detailed discussion of sulfide oxidation rate data is provided in Attachment A (Golder Associates, 2002a).

Cobalt and copper released by sulfide oxidation are transported through the Tailings Impoundment by infiltrating water. Water quality data from wells screened in the alluvium at the base of the tailings suggest that cobalt is transported conservatively through the tailings, that is to say secondary mineral precipitation reactions are not limiting dissolved cobalt concentrations. In addition, attenuation through adsorption is considered unlikely given the low pH of the pore water. Copper attenuation by precipitation of covellite (CuS) or chalcocite (Cu_2S) under reducing conditions at the base of the tailings is assumed to be a feasible mechanism. Geochemical speciation modeling conducted on data from WFMW-01S (9/23/95 and 10/25/96) indicates undersaturation with respect to credible cobalt and copper hydroxides and sulfates as well as ferrihydrite ($FeOH_3$). The absence of the latter mineral phases effectively eliminates adsorption as an attenuation mechanism. The pH of the water at WFMW-01S was 3.3 (9/23/95) and 3.6

(10/25/96). Provided the pe of this water is less than three, supersaturation with respect to covellite (CuS) is predicted (Figure D-10), as indicated by saturation index (SI) values > 0.

D-3.2 Conceptual Hydrological Model

D-3.2.1 Water Balance

The conceptual hydrological model is shown in Figure D-11. Precipitation and snowmelt in the West Fork basin above the Tailings Impoundment produces surface water flow in the creek and groundwater flow in the unconsolidated valley bottom sediments. A soil bentonite cutoff wall was constructed at the upstream end of the Tailings Impoundment. The objective was to force upgradient groundwater to the surface and into West Fork Creek, thus reducing groundwater flow and groundwater levels beneath the tailings. Based on groundwater levels in WFMW-12 and WFMW-13 by Knight-Piésold prior to the construction of the cutoff wall, the groundwater inflow from upgradient is estimated to be less than one gpm. Although the cutoff wall will not be completely effective in eliminating groundwater inflow from upgradient, the flow contributed is likely to be small in comparison to other potential sources. From the upstream limit of the Tailings Impoundment West Fork Creek flows across the tailings surface in a rock-armored channel with concrete pipe half-round for low flows. Some exfiltration from the channel may occur although it has not been quantified.

The tailings receive surface water from direct precipitation and run-on from the adjacent hillslopes. Surface water infiltrates into the tailings, runs off into the West Fork channel, or evaporates. Vegetation on the tailings surface is sparse and thus transpiration is negligible. The surface area of the tailings (including West Fork channel) is about 14.4 acres. Using the mean annual precipitation of 21.2 inches, the upper bound for infiltration from direct precipitation (no runoff or evaporation) is 15.8 gpm. The adjacent hillslopes are generally mantled with colluvium and talus. Visual observations indicate that runoff is low to negligible, except during extreme storm events. Most of the precipitation on the hillslopes will be evapotranspired or enter the interflow system. For the hillslopes north and south of the Tailings Impoundment, the drainage areas above the tailings are 25.3 and 41.4 acres respectively. These areas have maximum annual infiltrations of 27.7 and 45.3 gpm, respectively. This will recharge the groundwater system in the unconsolidated colluvial and alluvial sediments beneath the tailings. Thus the annual average maximum available infiltration is about 90 gpm, with about 17% infiltrating through the tailings and the remainder infiltrating through the hillslopes.

During operation of the Tailings Impoundment, West Fork Creek was diverted through a concrete culvert. The culvert was 48-inch diameter in the upstream section, and 42-inch diameter elsewhere. After the creek was channelized across the tailings, the culvert was backfilled with gravel and a concrete plug with drain pipes placed through the plug at the downstream end. Observations of the culvert immediately prior to backfilling showed that the culvert had open joints and cracking in places. Thus the culvert may function as a higher permeability drain for all or portions of its length.

Downstream of the tailings dam, approximately 2 to 5 gpm discharges from the relief pipes through the culvert plug (Golder, 2001a). At the toe of the dam, seeps have been identified where groundwater discharges to surface water in the valley bottom. Flow and water chemistry measurements in Blackbird Creek upstream and downstream of the West Fork confluence allow estimates to be made of the flow from the West Fork drainage. The groundwater base flow from the West Fork drainage is estimated to be between 100 and 150 gpm.

The annual average water balance for groundwater for the West Fork tailings can thus be summarized as shown in Table D-3.

TABLE D-3

West Fork Tailings Water Balance

Inflow source	Flow (gpm)	Discharge	Flow (gpm)
West Fork groundwater from upstream basin	<1	Culvert	2 – 5 gpm
Hillslope interflow	<73	Seeps	90 – 125 gpm
Infiltration through tailings	<16	Groundwater underflow directly to Blackbird Creek	estimated at <10 gpm
TOTAL	<90	TOTAL (estimated from comparison of Co concentrations upstream and downstream of West Fork)	100 – 150 gpm

These calculations indicate that it is likely that a significant proportion of the precipitation over the tailings and tributary hillslopes infiltrates into the groundwater system.

D-3.2.2 Infiltration through the Tailings

In order to understand the processes controlling the infiltration of water into and through the tailings, two public domain software codes, Hydraulic Evaluation Landfill Performance (HELP) and VS2DT, were considered. The HELP model was developed to predict hydrological processes in landfills. It requires input data on weather, soil parameters and the soil profile (natural or engineered). It includes built-in databases for meteorological conditions and soil properties. It computes the infiltration into the soil profile, and soil moisture conditions at the end of each year of simulation. The second software code considered was VS2DT, developed by the U.S. Geological Survey (USGS). This model uses a finite difference method to solve Richard's Equation for cross-

sectional, variably saturated flow and transport in porous media. Widely accepted empirical equations (Brooks and Corey, van Genuchten) are used to express the relationships between moisture content, degree of saturation and hydraulic conductivity. Default parameter values are included for soils based on the U.S. Department of Agriculture (USDA) classification. It has less inbuilt properties than HELP, but allows for the determination of the saturation profile at any time step in the simulation. Because of this latter capability it was selected for the initial evaluation. The implementation of VS2DT in the WHI UnSat software package (Waterloo Hydrogeologic, Inc.) was used.

The tailings grain size distribution (see Section D-2.1) indicates that the tailings are a "silt loam". The default parameters in VS2DT for a silt loam are as shown in Table D-4.

TABLE D-4

Default VS2DT Model Parameter Values

Parameter	Value
Saturated hydraulic conductivity	0.000347222 cm/s
Porosity	0.47 vol/vol
Specific storage	0.0000001 1/cm
Residual moisture content	10 %
van Genuchten alpha	-200 cm
van Genuchten beta	6

Since the underlying unconsolidated deposits have a similar hydraulic conductivity to the tailings, they were simulated using the same soil type (i.e. silt loam). The Tailings Impoundment was modeled as a vertical column 84 feet deep, underlain by unconsolidated sediments. The groundwater level was fixed in the unconsolidated sediments at a depth of 94 feet. Boundary conditions were applied to allow the model to reach an underdrained equilibrium profile. The upper boundary was then set to represent one inch of ponded water for a period of five days. The model was run to compute the saturation profile for a period of up to 200 days following the start of ponding. The start of ponding occurs at 400 days. Therefore, saturation profiles are shown for day 400 and onwards (up to day 600) in Figure D-12. The following observations can be made:

- The initial underdrained saturation profile increases from 24% saturation at ground surface to about 43% saturation near the base of the tailings.
- After ponding water for five days (day 405), the wetting front has moved downwards to a depth of 25 feet, and shows a steep saturation gradient. The tailings are fully saturated to a depth of 17 feet.
- Ten days after the start of ponding (day 410), the wetting front has progressed to a depth of 40 feet. None of the tailings are fully saturated. Near the tailings surface, the saturation has dropped to 40% as the water drains downwards.

- Forty days after the start of ponding (day 440), the wetting front has reached the base of the tailings.
- Two hundred days after the start of ponding (day 600), the tailings have returned to the underdrained equilibrium saturation profile.

The implication of this simulation is that infiltration at the surface of the tailings would result in drainage of pore water from the base of the tailings within a period of several weeks. For tailings depths less than the depth modeled, the time period would be shorter, and the converse for greater tailings thicknesses. Since the pore water throughout the tailings contains dissolved metals, infiltration of clean water at the surface expels water with metals concentrations from the base of the tailings into the underlying unconsolidated sediments. It is important to note that this process does not require the physical movement of a water particle from the surface to the base of the tailings.

While the above analyses are based on vertical flow, the same process would take place in the horizontal dimension. Thus, interflow from the hillslope would increase the degree of saturation in the colluvium and talus adjacent to the tailings. This would cause a wetting front to propagate into and downwards through the tailings, again resulting in the expulsion of pore water containing metals into the underlying unconsolidated sediments.

Currently, the saturated zone is located within the underlying unconsolidated sediments and to a limited extent in the downstream portion of the tailings. An increase in the recharge to the saturated zone will propagate and increase the discharge to surface water. If all of the pore water in the unconsolidated sediments has a similar chemistry, then an increase in discharge will result in an increase in loading. Thus, some seasonal variability in loading may be observed, depending upon the uniformity of the pore water chemistry, the magnitude of the changes in recharge, and the characteristics of the saturated zone (transmissivity, storativity, specific yield) that control the lateral propagation of piezometric changes.

D-3.3 Hydrogeochemical Model

In summary, oxidation of sulfide minerals in the tailings occurs as oxygen diffuses into the tailings, producing an oxidation front that advances downward with time. Infiltration of precipitation into the tailings, either directly or laterally from the hillslope talus, leaches the soluble oxidation products (Cu, Co, Fe and SO_4). Geochemical modeling indicates that, for estimates of existing of infiltration rates, there are no secondary mineral solubility controls on cobalt concentrations. Copper attenuation by precipitation of covellite (CuS) at the base of the tailings appears to be a feasible attenuation mechanism provided the pe is less than 3. Copper may also precipitate as chalcocite (Cu_2S). Soluble oxidation products that are produced dissolve in the pore water. The mass of soluble metals produced and dissolved in the pore water per unit time is controlled by the availability of oxygen and not by the infiltration rate. Thus, concentration will change in inverse proportion to infiltration, but the mass of soluble

oxidation products is independent of the infiltration rate. Unless the production rate of sulfide oxidation products is changed by limiting available oxygen, in the long term, the loading will not be altered.

Reducing infiltration, however, will have the immediate effect of reducing the flux draining from tailings. Using a reasonable assumption that pore water concentrations are constant throughout tailings, reducing flux will reduce loading from the tailings into the underlying unconsolidated sediments. A constant concentration profile through the tailings is a simplifying assumption, which is required to infer changes in loading due solely to a reduction in flux. As noted previously, infiltration at the surface of the tailings results in the propagation of a wetting front downwards through the tailings, leading to the expulsion of pore water containing metal-laden water. If infiltration at the surface is reduced, less metal-laden water will be expelled from the base of the tailings. In a similar manner, assuming that the pore water concentrations in the unconsolidated sediments are constant, reducing the flux from the unconsolidated sediments into the groundwater and surface water downstream of the Tailings Impoundment will reduce the loading to Blackbird Creek.

D-4. EFFECTIVENESS OF A SOIL COVER

Overbank deposits removed from along Panther Creek have been placed over portions of the Tailings Impoundment. The proposed soil cover would use these materials to create a cover over the Tailings Impoundment (except the West Fork channel). Over half of the Impoundment, the proposed cover would be at least 10 feet (3 meters) thick. The northern portion of the impoundment (approximately 30% of the total tailings area) will be covered by a 1-foot clay cover and a minimum of 2-feet of overbank materials. Beneath the West Fork channel there is currently a 2-foot clay cap. This cap was installed in 1993.

D-4.1 Reduction in Infiltration

The HELP model was used to determine the infiltration rates before and after placement of a 10-foot cover. For bare tailings with no surface slope (existing conditions), the annual infiltration is about 7.8 inches. A 10-foot thick cover of overbank deposits, vegetated with a 2% surface slope, reduces the infiltration to an estimated 2.2 inches per year (72% reduction).

HELP predicts significantly less infiltration through the tailings than the maximum annual precipitation (7.2 inches compared to 21 inches). Infiltration through the talus and colluvium on the hillslopes would also be less than the average annual precipitation, as there would be some evapotranspiration and runoff. However, these areas are not amenable to analysis using HELP due to the high slope angle and variable soil conditions. No reduction in infiltration through the talus and colluvium on the hillsides was assumed in this analysis.

About 17% of the infiltration originates on the tailings (see Section D-3.2.1). The 72% reduction in the tailings infiltration produced by covering results in a 12% overall reduction in infiltration, as cover placement would not affect the hillslope infiltration. As noted in Section D-3.3, reducing the infiltration would reduce the discharge flux. Assuming that the concentrations of soluble oxidation products in the pore water are uniform throughout the unconsolidated deposits, reduction in flux would produce a corresponding reduction in metals loading. Thus, covering of the entire tailings area with 10 feet of overbank deposits would result in an estimated initial 12% reduction in the metals loading from the Tailings Impoundment

D-4.2 Reduction in Sulfide Oxidation

To assess the benefits of the proposed soil cover on water quality of seepage from the Tailings Impoundment, geochemical modeling was conducted using the PYROX model (Wunderly, 1994). The assumed cover thickness for the initial model simulations was 3 meters (10 feet). The model assessed the relative changes to tailings seepage under a no cover versus cover scenario. A brief description of the model methodology and results are provided below. A more detailed description of model assumptions, limitations and source data is provided in Attachment A (Golder Associates, 2002a).

PYROX simulates the diffusion of oxygen into a mine Tailings Impoundment and subsequent pyrite oxidation as a two-stage process. In the first stage, oxygen diffuses from the atmosphere into the tailings pore space. The rate of oxygen diffusion is a function of the moisture content, temperature and porosity of the tailings. In the second stage of the model, pyrite oxidation is simulated according to the shrinking core theory. As pyrite oxidation progresses, an oxidized coating will form around each unoxidized pyrite core. With time, the thickness of the oxidized coating increases, further inhibiting oxygen from reaching the unreacted core and thus slowing the rate of oxidation. PYROX considers oxygen diffusion through this oxidized shell to the unreacted core. Since PYROX is only capable of modeling pyrite oxidation, in this study, the oxidation of pyrite was used as an analogue for chalcopyrite and cobaltite oxidation. Because the goal of this study was to evaluate relative changes to metals release under a cover versus no cover scenario, this approach is considered reasonable.

PYROX determines the mass of sulfate, iron and acidity produced due to pyrite oxidation for a defined vadose zone. Parameters required for vadose zone definition include: moisture content, temperature, porosity, pyrite grain size, bulk density and sulfide content of the tailings. The results of the HELP infiltration modeling were used to define the initial moisture content and porosity of the tailings. Solid phase definition of the tailings and cover material (sulfide fraction, pyrite grain size and bulk density) was based on data from Olsen (Camp Dresser and McKee, 1995), Beltman and others (RGG/ Hagler, Bailly, 1993), Knight Piésold (1994b) and the results of overbank and cover material sampling conducted by Golder Associates and the Blackbird Mine Site Group (BMSG) in 2001. The tailings and cover material were modeled assuming sulfide contents of 3% and 0.02%, respectively. A second simulation was conducted in which the sulfide content of the cover material was increased to 0.5%.

To establish current conditions in the tailings, sulfide oxidation was simulated for a period of 34 years (1967 – 2001). The results of this simulation were then compared to current water quality data for West Fork seepage. To evaluate future conditions, this simulation was extended in time for 20 years after assuming placement of the proposed soil cover.

Results of the PYROX modeling predict that the placement of a 10-foot (3-meter) soil cover on the Tailings Impoundment in the long-term would result in a decline in sulfide oxidation rates, relative to the no cover alternative. This is shown in Figure D-13, where sulfate production for the cover scenario is expressed as a ratio relative to the no-cover scenario. Placement of a cover containing sulfides may result in an initial increase in the loading of sulfide oxidation products. This is observed for the 0.5% sulfide cover. The magnitude and duration of this increase is dependent on the sulfide content of the cover material. Once sulfides in the cover material are depleted, sulfide oxidation rates are expected to stabilize at a lower level than in the uncovered scenario. This is caused by the addition of three meters of material, which depresses the oxygen concentration gradient and hence reduces the "driving force" for oxygen diffusion into the tailings. A reduction in loading of approximately 40% in comparison to the no cover simulation is predicted by the model. For cobalt, this should result in an equivalent decline in loading. Due to secondary controls on copper concentrations (i.e. covellite precipitation), a 40%

decline in copper loading is not expected. Instead, copper concentrations are likely to remain approximately constant.

The above discussion focuses on a 3-meter thick cover; however, only a portion (~50%) of the West Fork tailings will be covered with 3 meters of material. The proposed cover for the tailings area north of the West Fork channel (~30% of the total tailings area), will be comprised of 1 foot of clay overlain by a minimum of 2 feet of overbank materials. The remaining tailings area (~20% of the total area) is overlain by the West Fork channel, which is lined with two feet of clay (Knight Piésold, 1994c).

Attachment A presents the results of a sensitivity analysis conducted to evaluate the effect of cover thickness as a function of moisture content on sulfide oxidation reduction. For both a 3-meter cover and a composite 1-foot clay/2-foot soil cover, reduction in sulfide oxidation versus moisture content curves were developed (Figures D-14 and D-15). These curves were then used to estimate a reduction in sulfide oxidation for the entire tailings impoundment. Predicted sulfide oxidation reduction rates were apportioned on the basis of relative surface area coverage. As mentioned previously, the 3-meter soil (10-foot), composite 1-foot clay/2-foot soil and 2-foot clay cap provide coverage for 50%, 30% and 20%, respectively, of the tailings area. By assuming a range of moisture contents for each type of cover, a range of predicted reduction in sulfide oxidation was determined.

The expected range in moisture content for the 3-meter cover was determined by extracting the highest and lowest year-end moisture contents predicted by the HELP model for a 3-meter soil layer over a 50-year simulation. This resulted in a range in moisture content from 0.14 to 0.20 with an average of 0.18. This is predicted to result in a range of sulfide reduction from 37% to 46% (Figure D-14).

Because complete saturation for a clay layer is an inherent assumption in HELP, the HELP model could not be applied to predict a range of clay moisture contents. For the clay, a minimum saturation of 70% was assumed. This is equivalent to the minimum degree of saturation generally required to place a clay cover (personal communication with Frank Shuri, Golder). Average and high saturations of 80% and 90% were assumed based on typical design specifications for clay covers. Based on these degrees of saturation, for the 1-foot clay cover, reduction in sulfide generation was predicted to range from 30% to 90%. The 2-foot clay cover was assumed to provide an equivalent benefit. Additional PYROX modeling was performed to confirm the validity of this assumption.

Table D-5 presents the cumulative predicted effectiveness of the proposed cover for the West Fork Tailings Impoundment. The effectiveness of existing covers on part of the impoundment (2-foot clay and 3-meter soil) can also be identified from the table. For the proposed cover, the cumulative percent reduction in sulfide oxidation is predicted to range from approximately 30% to 70% relative to an uncovered scenario.

TABLE D-5

Cumulative Benefits of Tailings Cover

Cover Type	% Coverage	Moisture Content			% Reduction in Sulfide Oxidation		
		Low	Average	High	Low	Intermediate	High
2-ft clay	20%	0.30	0.34	0.37	30%	55%	92%
1-ft clay + 2-ft soil	30%	0.30	0.34	0.37	30%	55%	92%
3-m soil	50%	0.14	0.18	0.20	37%	41%	46%
Cumulative Predicted Reduction					**34%**	**48%**	**69%**

It is important to realize that the predicted reduction refers to the reduction in sulfide oxidation relative to a no-cover (bare tailings) simulation. Because the clay cap below the West Fork Tailings channel was constructed in the early 1990s, some of the benefits afforded from this cap may be reflected in the current water quality monitoring. This reduction should therefore not be interpreted as a reduction in comparison to current conditions. Figures D-16 and D-17 show fall and spring cobalt loading to Blackbird Creek from the West Fork Tailings Impoundment over time as determined by the difference in load between BBSW-03A and BBSW-02. Between September 1995 and October 1998, a decline in fall loading was observed (Figure D-16). Although this decline in loading may in part be attributed to a reduction in sulfide oxidation due to the clay cap below the West Fork Channel, it is more likely attributed to the installation of the cutoff wall upstream of the tailings impoundment in 1993. Between 1998 and 2001, fall cobalt loading from the West Fork Tailings Impoundment was relatively constant. Spring loading trends are different from those in the fall. Although a decline was observed between Spring 1995 and 1998, cobalt loading subsequently increased in 1999. Because travel times through the tailings are predicted to be on the order of years to tens of years, reductions in sulfide loading due to cover placement may not be observable for a number of years following placement of the cover.

It should also be noted that certain areas of the tailings will not benefit from any cover placement. For example, at this time no cover is planned for the tailings slope facing Blackbird Creek. This area has not been accounted for in the above calculations. This slope accounts for approximately 25% of the total tailings impoundment area (based on the plan view); however, the volume of tailings represented by this area is considerably less than 25%. Due to the uncertainties associated with the oxidation modeling, omission of this area was not considered significant.

D-4.3 Pyrox Model Assumptions and Limitations

The PYROX modeling outlined in this memo was conducted to evaluate potential benefits to West Fork seepage quality from the placement of overbank materials as a cover on the West Fork Tailings Impoundment. This modeling began as a comparative evaluation of a no cover versus cover scenario. As the feasibility study progressed, it became necessary to also evaluate the benefits of a clay cover. The goal of the modeling

effort therefore changed from a sensitivity analysis of the factors affecting sulfide oxidation (e.g. moisture content, length of oxygen diffusion path, sulfide content, grain size) and an evaluation of the impacts of changes in these factors due to the placement of 3-meter cover, to a performance assessment for an engineered clay cover. The reader should be cognizant that the authors of this memorandum are not engineers with experience in the design of clay caps. Although this modeling effort is valid with respect to how oxygen may diffuse through a clay cap of a specific thickness and specific moisture content, this memorandum does not address the integrity of the clay cap. For example, the effect of freezing and thawing on cap performance was not evaluated as part of this study. It should also be noted that the HELP model, which provided input parameters necessary for the sulfide oxidation modeling with PYROX, may not be the ideal tool for rigorous performance evaluation of a clay cover.

As with any modeling effort that aims to predict future behavior using a representation of current conditions, there are a number of assumptions and limitations inherent in this analysis. These assumptions and limitations were discussed in detail in Attachment A (Golder Associates, 2002a). It should be noted that despite these limitations, this modeling is a valid tool in evaluating the potential relative benefits of a cover. Based on the basic principals of sulfide oxidation, a cover should result in an improvement in water quality. The magnitude of this improvement is difficult to quantify with a high degree of certainty without extensive characterization due to the complexity of the modeled system. Because estimates of travel times through the tailings vary from years to tens of years, the benefits of cover placement may not be observed for years. Finally, without knowledge of whether the current water quality reflects any benefits of the existing cover, a baseline from which to apply predicted reductions is difficult to establish. Although it is likely that the effects of the clay cap beneath the West Fork channel and the 3-meter overbank cover have not yet been realized, this statement cannot be proven.

D-4.4 Arsenic Release from Overbank Cover Material

The EPA has proposed that the use of overbank tailings as a cover material could result in an increase in arsenic loading from the West Fork tailings impoundment due to arsenic desorption under less oxidizing conditions (EPA, 2002). Arsenic release by this mechanism is, however, unlikely, as supported by site monitoring results to date. Dissolved arsenic concentrations in Panther Creek have remained below 0.005 mg/L for the period of record (1995 to 2002). If overbank deposits along Panther Creek were releasing arsenic by any mechanism, elevated arsenic concentrations would have been recorded in Panther Creek. The overbank deposits that have been placed on top of the West Fork tailings are considered to be in a similar redox environment as those along the shores of Panther Creek. Therefore, arsenic behavior is expected to be similar.

If arsenic is released from the tailings it will be attenuated by adsorption in Blackbird Creek. Water quality monitoring has indicated that arsenic release does occur from the West Fork tailings. Low dissolved arsenic concentrations have been measured in the West Fork wells (non-detect to 0.060 mg/L). The highest dissolved arsenic concentration on record was measured in WFMW-06 at 0.144 mg/L in 1995. Low dissolved arsenic

concentrations have also been measured in the West Fork interceptor ditch (up to 0.022 mg/L). However, monitoring in Blackbird Creek below the tailings impoundment (BBSW-01 and BBSW-02) has indicated that arsenic concentrations remain below 0.006 mg/L.

D-4.5 Reduction in Iron Loading due to Cover Placement

Placement of a cover on the West Fork Tailings Impoundment is predicted to result in a decline in iron loading to Blackbird Creek. Iron loading from the West Fork Tailings Impoundment currently contributes to a net decline in copper concentrations in lower Blackbird Creek by acting as an adsorbent. Therefore, it was suggested by EPA (2002) that placement of a cover on the West Fork tailings, which would reduce iron loading to the creek, could conceivably result in an increase in Blackbird Creek copper concentrations. This hypothesis was evaluated through geochemical modeling. This modeling is described in the Technical Memorandum *West Fork Iron Geochemical Evaluation,* provided as Attachment B (Golder Associates, 2002b).

A geochemical evaluation was conducted to simulate the effect of reductions in iron loading of 12% and 50%. These percentages represent the anticipated reductions in iron loading related to the decrease in infiltration (12%) and the approximate decrease in infiltration + sulfide oxidation (50%) resulting from emplacement of a 3-meter thick cover. These simulations used synoptic water quality data from the Spring and Fall of 2000. Model results predict that at certain times during the year, an increase in Blackbird dissolved copper concentrations may occur following a reduction in iron load. For the Fall 2000 case, an increase in dissolved copper from 0.009 mg/L to 0.017 mg/L was predicted following a 50% reduction in iron load. Different copper behavior was predicted using the Spring 2000 water quality data. In these simulations, a 50% reduction in iron load resulted in no significant increase in dissolved copper. The difference in predicted copper behavior for the Spring and Fall 2000 cases is likely related to the fact that pH values in Fall 2000 are higher than in the Spring, which appears to have a pronounced effect of ferrihydrite formation and adsorption of dissolved copper. At circumneutral values for pH (6 to 8), copper adsorption increases with increasing pH. In the Fall, higher iron concentrations in Blackbird Creek also result in greater ferrihydrite precipitation (more adsorbent).

D-4.6 Reduction in Iron Loading due to Treatment

The collection and treatment option for West Fork will also result in a decline in iron loading to Blackbird Creek. In addition to iron, an equivalent reduction in copper and cobalt loading will occur. To evaluate the behavior of iron and copper under a treatment scenario, additional geochemical modeling was conducted. This modeling followed a methodology similar to that applied for the simulation of reduction in iron loading alone. This modeling is described in Attachment C (Golder Associates, 2002c).

Model results indicate significant reductions in cobalt loading to Blackbird Creek following collection and treatment. It is expected that treatment will result in greater declines in Blackbird Creek cobalt concentrations downstream of the impoundment in

the fall than in the spring. Treatment, however, is expected to result in only minor changes to dissolved copper concentrations in Blackbird Creek due to the low copper concentrations to begin with.

D-4.7 Conclusions

Based on the assumptions outlined above, covering the tailings with 10 feet of overbank deposits would result in a calculated 12% reduction in the metals loading from the Tailings Impoundment. This benefit will be realized shortly after the cover is placed, as it results from the reduction in flux from the tailings.

Reduction in the rate of production of oxidation products can only be achieved by reducing the available oxygen. Placing the proposed cover would result in an increase in the effective depth of the oxidation front, which would reduce the oxygen diffusion rate, and thus the production rate of oxidation products. It is estimated that in the long term, the oxidation rate would be reduced between 30% and 70% in comparison to a no cover (bare tailings) scenario. For cobalt, this should result in an equivalent decline in loading. Due to secondary controls on copper concentrations (i.e. covellite precipitation), a 30% to 70% decline in copper loading is not expected. Instead, copper concentrations are likely to remain approximately constant. The time at which this reduction begins to influence the discharge from the tailings depends upon the travel time from the oxidation front to the point of discharge. Using values for hydraulic conductivity, porosity, hydraulic gradient and infiltration rate consistent with those used for the infiltration analyses, travel times in the order of a few years to tens of years are estimated.

D-5. REFERENCES

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FIGURE D-1
Blackbird Dissolved Cobalt Concentrations

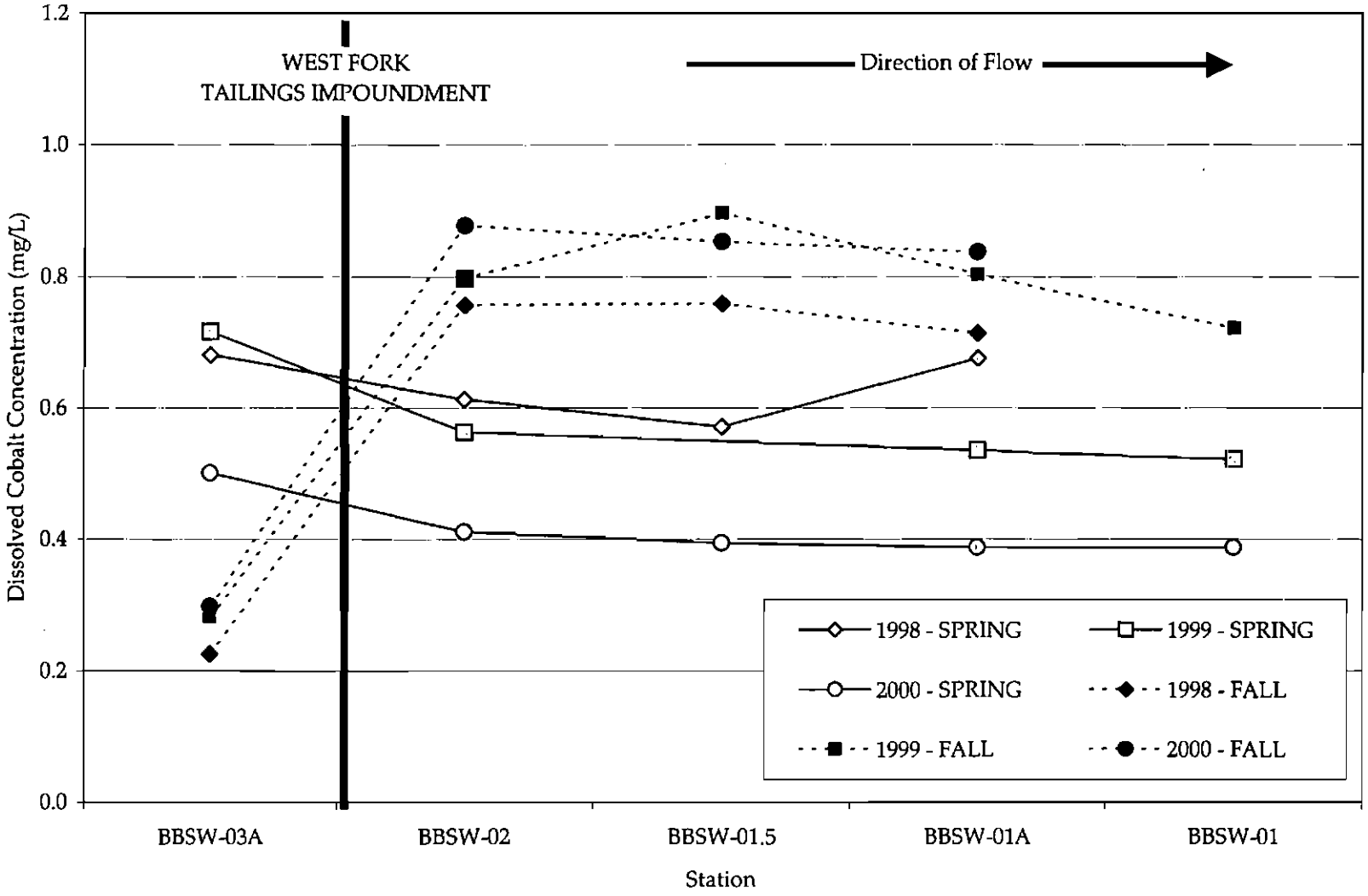


FIGURE D-2
Blackbird Dissolved Iron Concentrations

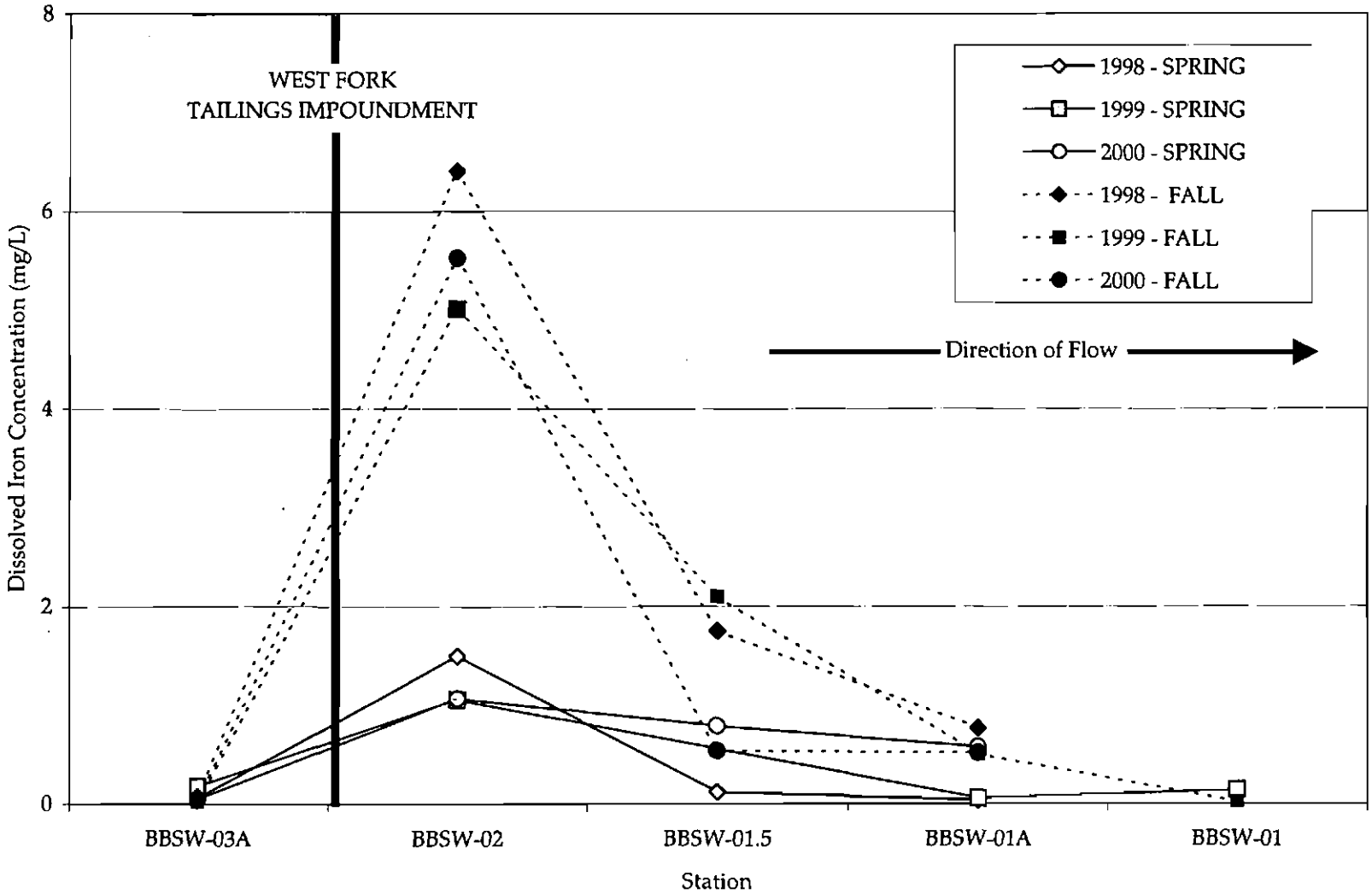


FIGURE D-3
Blackbird Dissolved Copper Concentrations

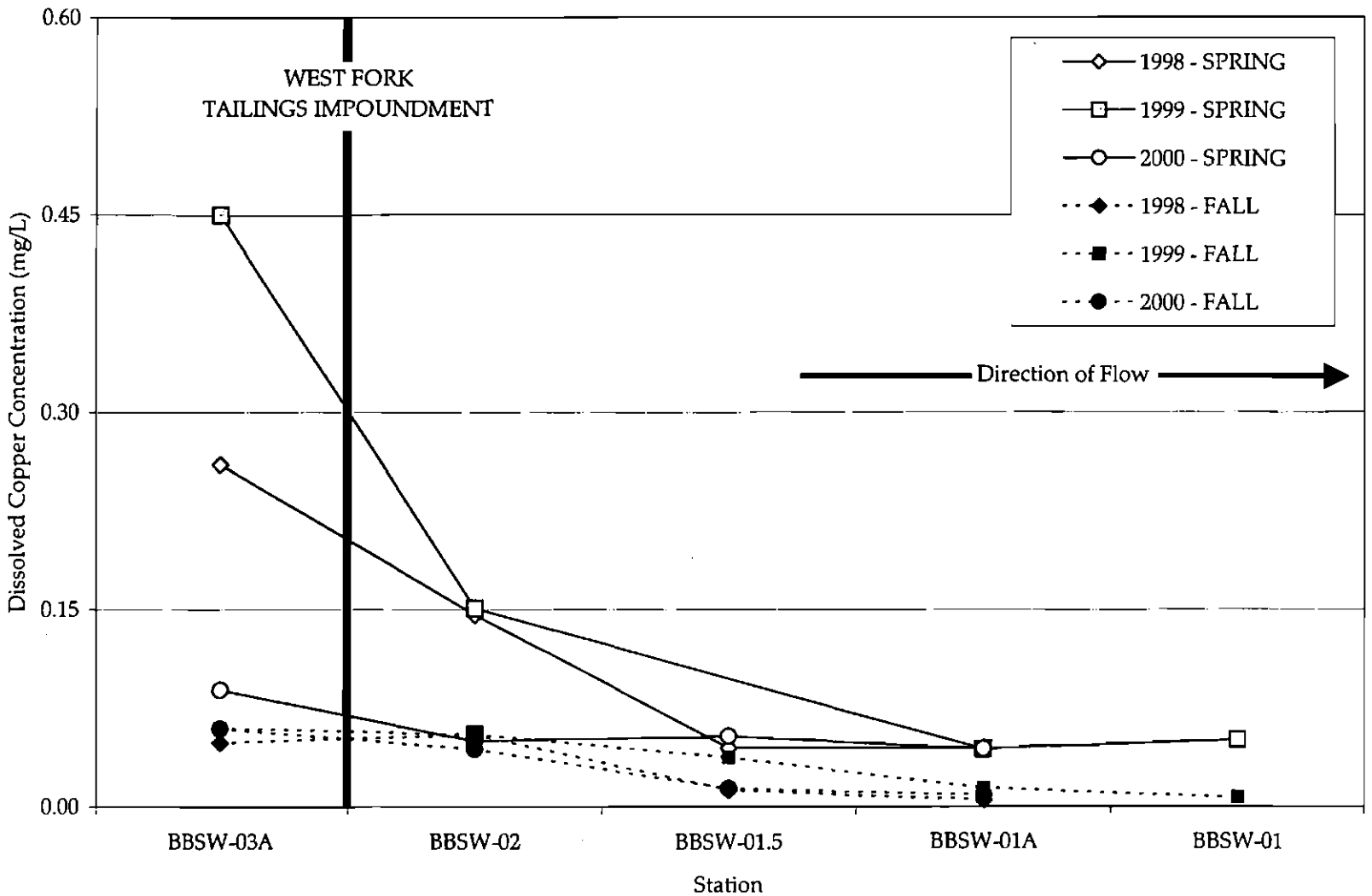
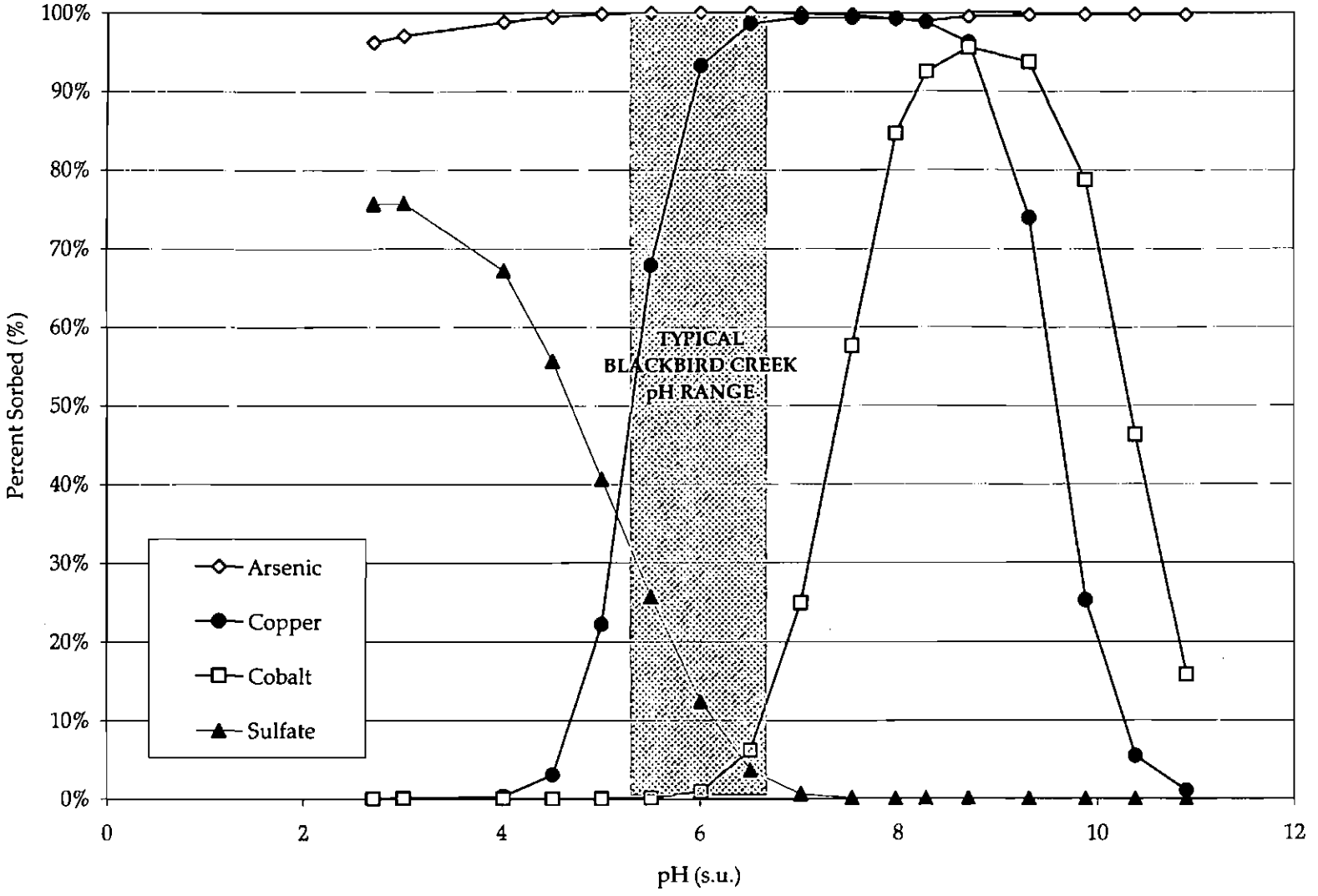
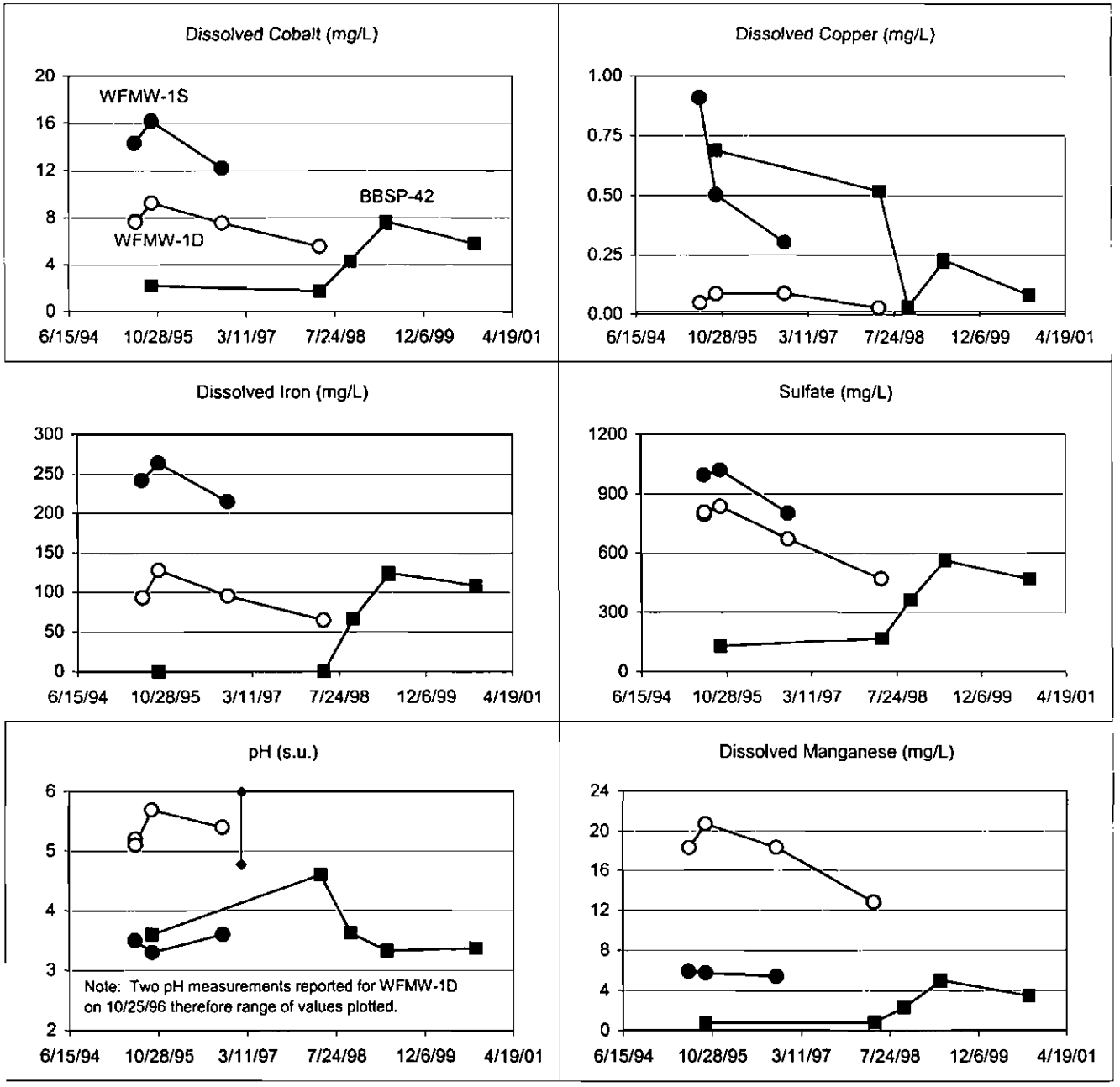


FIGURE D-4
Adsorption Edges



Note: Adsorption edges presented in this figure were created using PHREEQC for a specific water quality and adsorbent concentration.

FIGURE D-5
West Fork Water Quality



LEGEND

- ○ WFMW-1D
- ● WFMW-1S
- ■ BBSP-42

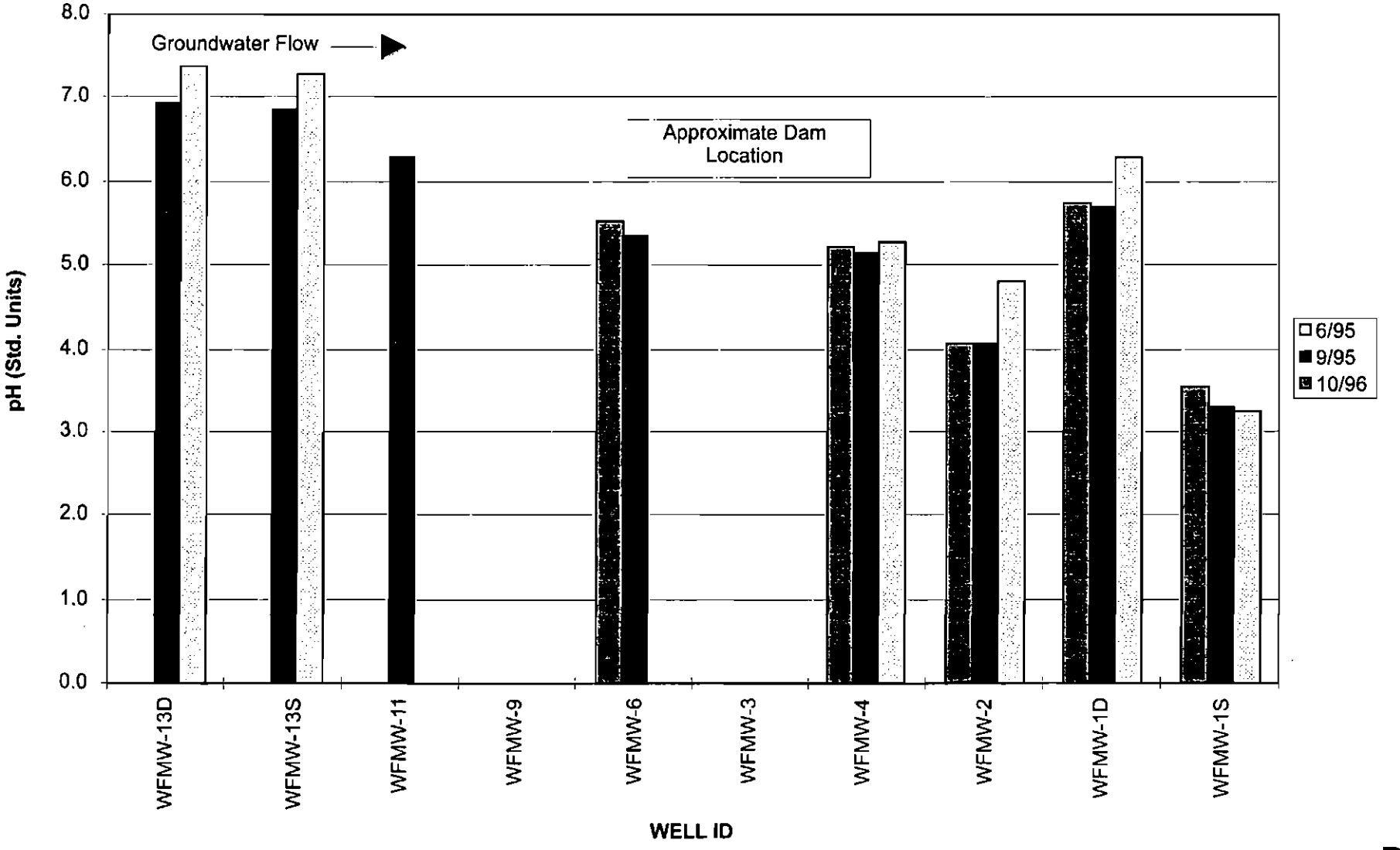


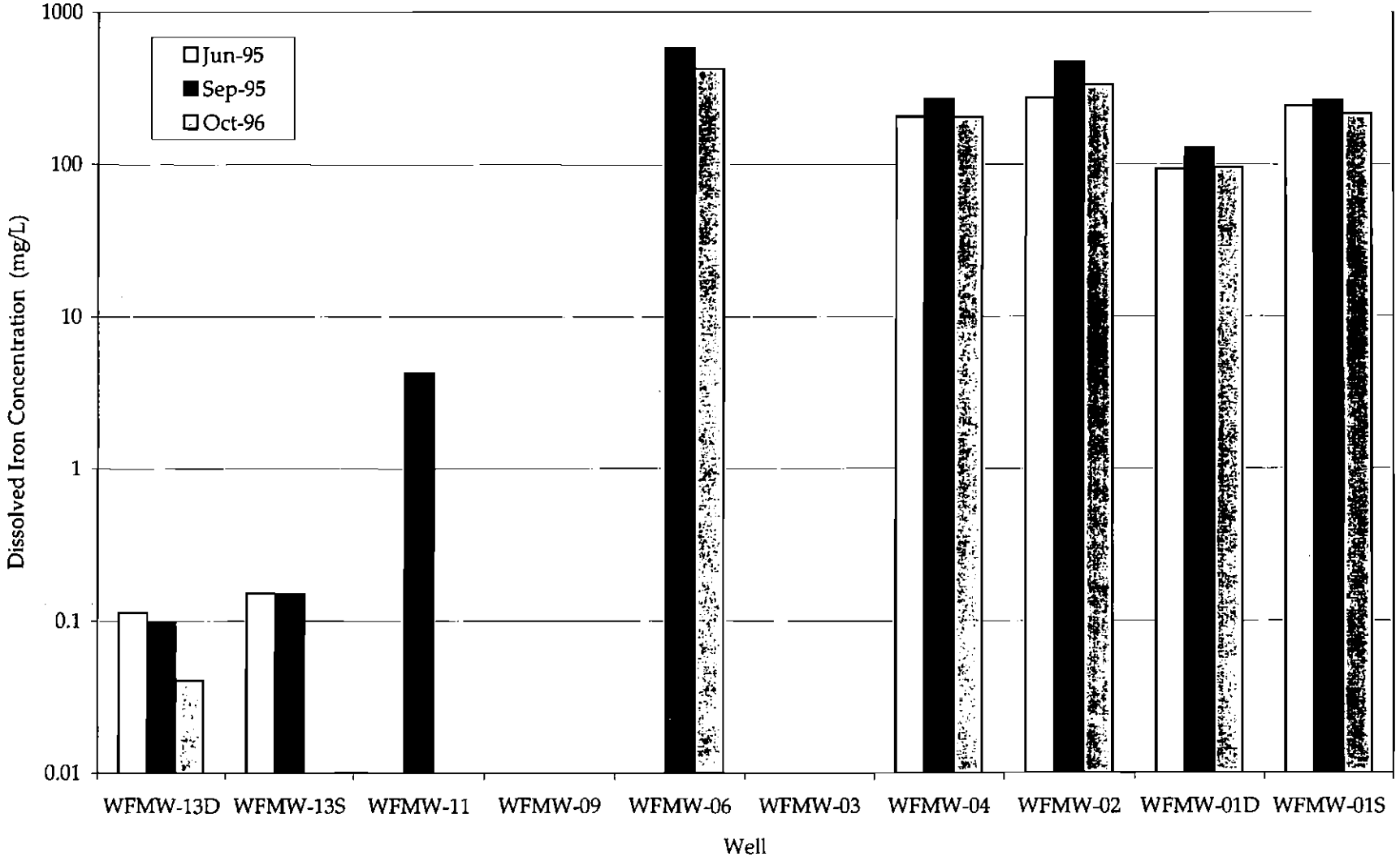
FIGURE **D-6**
GROUNDWATER pH
WEST FORK TAILINGS IMPOUNDMENT
NORANDA/BLACKBIRD/ID

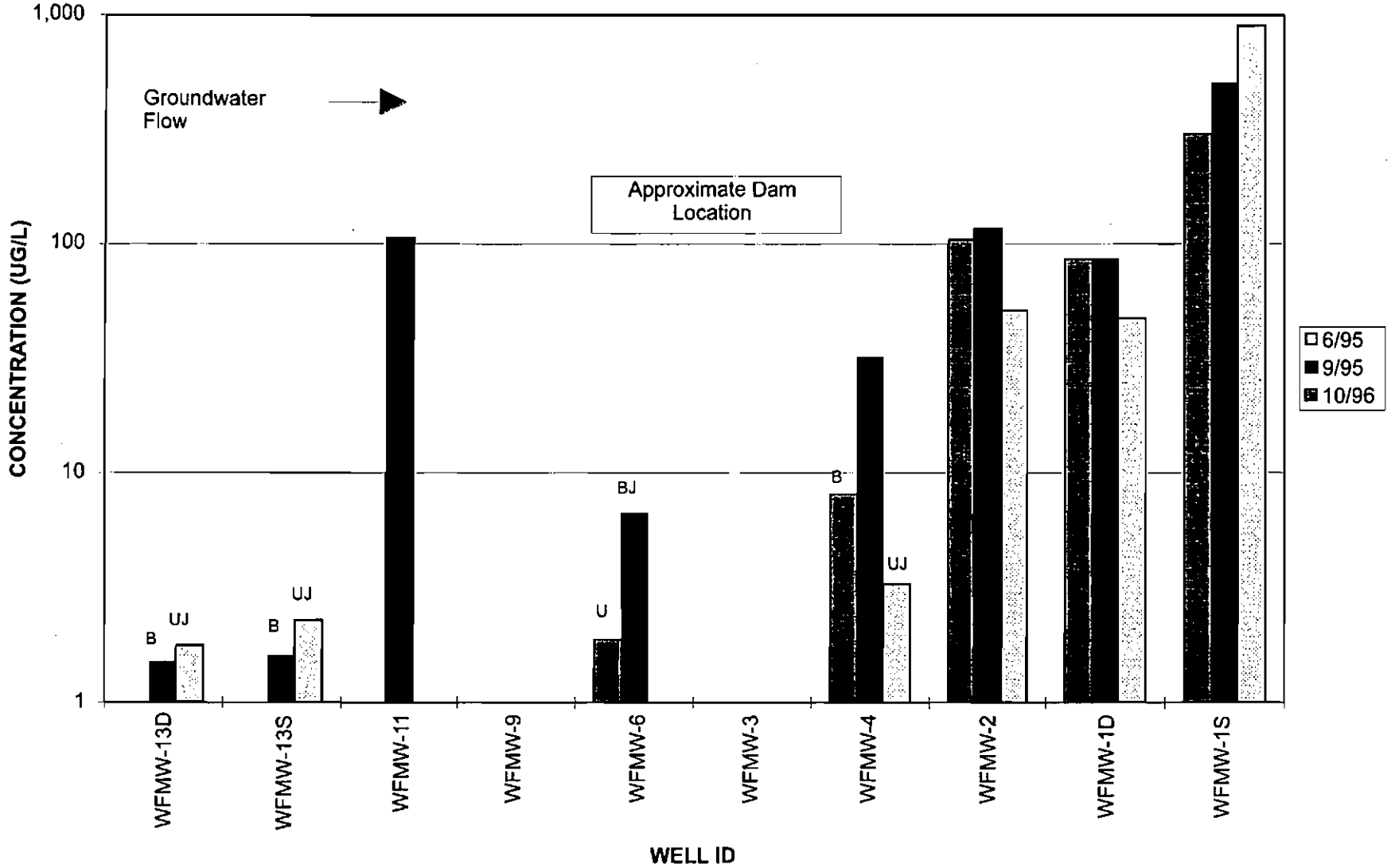
PROJECT NO. 943 1595x003_9000 DRAWING NO. 67832 DATE 04/29/02 DRAWN BY EL

Golder Associates

FIGURE D-7

West Fork Groundwater Dissolved Iron Concentrations





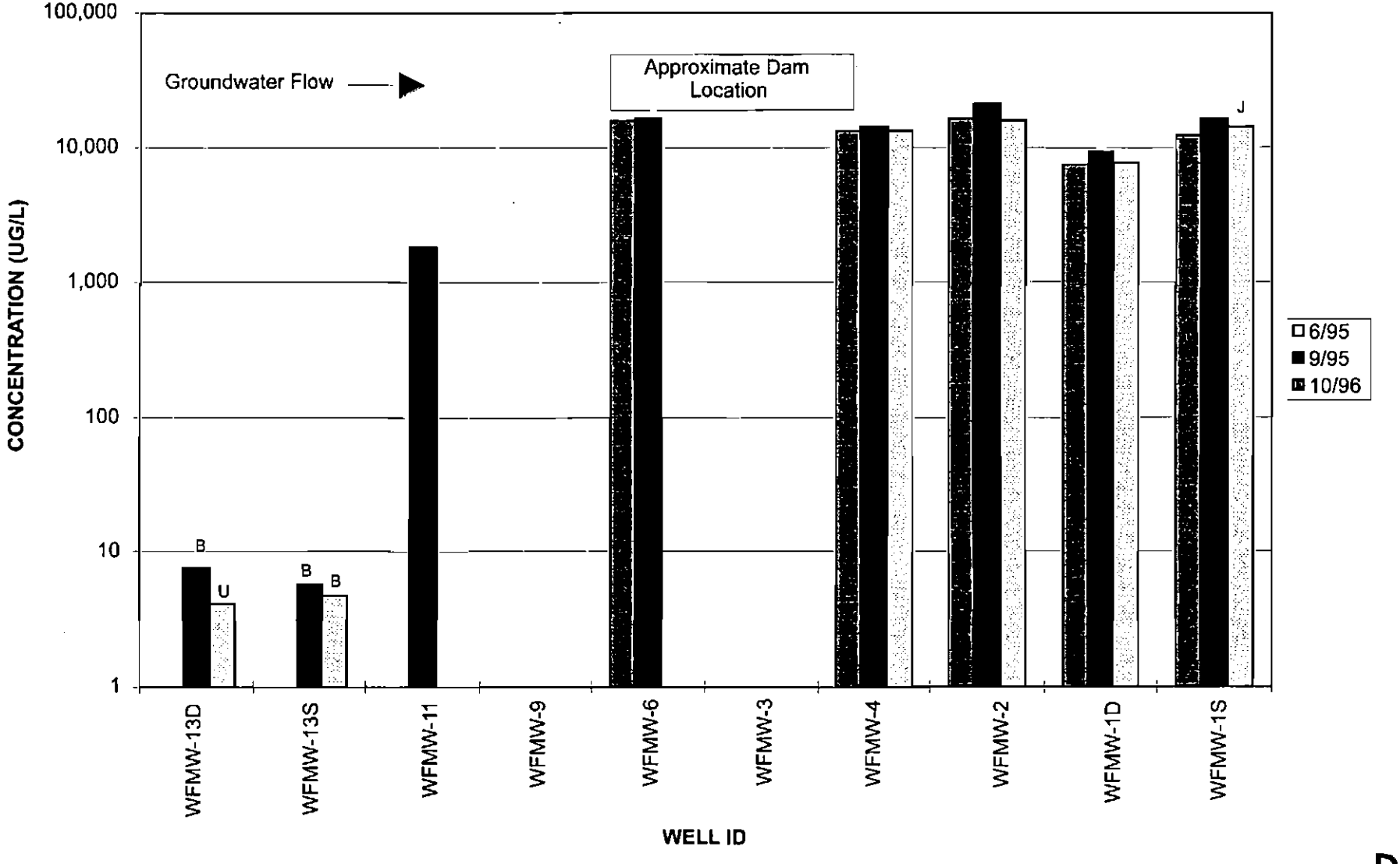
Note: See Table 8 for description of inorganic data qualifiers

FIGURE **D-8**

GROUNDWATER DISSOLVED COPPER CONCENTRATION
WEST FORK TAILINGS IMPOUNDMENT
NORANDA/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 67833 DATE 04/29/02 DRAWN BY EL

Golder Associates



Note: See Table 8 for description of inorganic data qualifiers

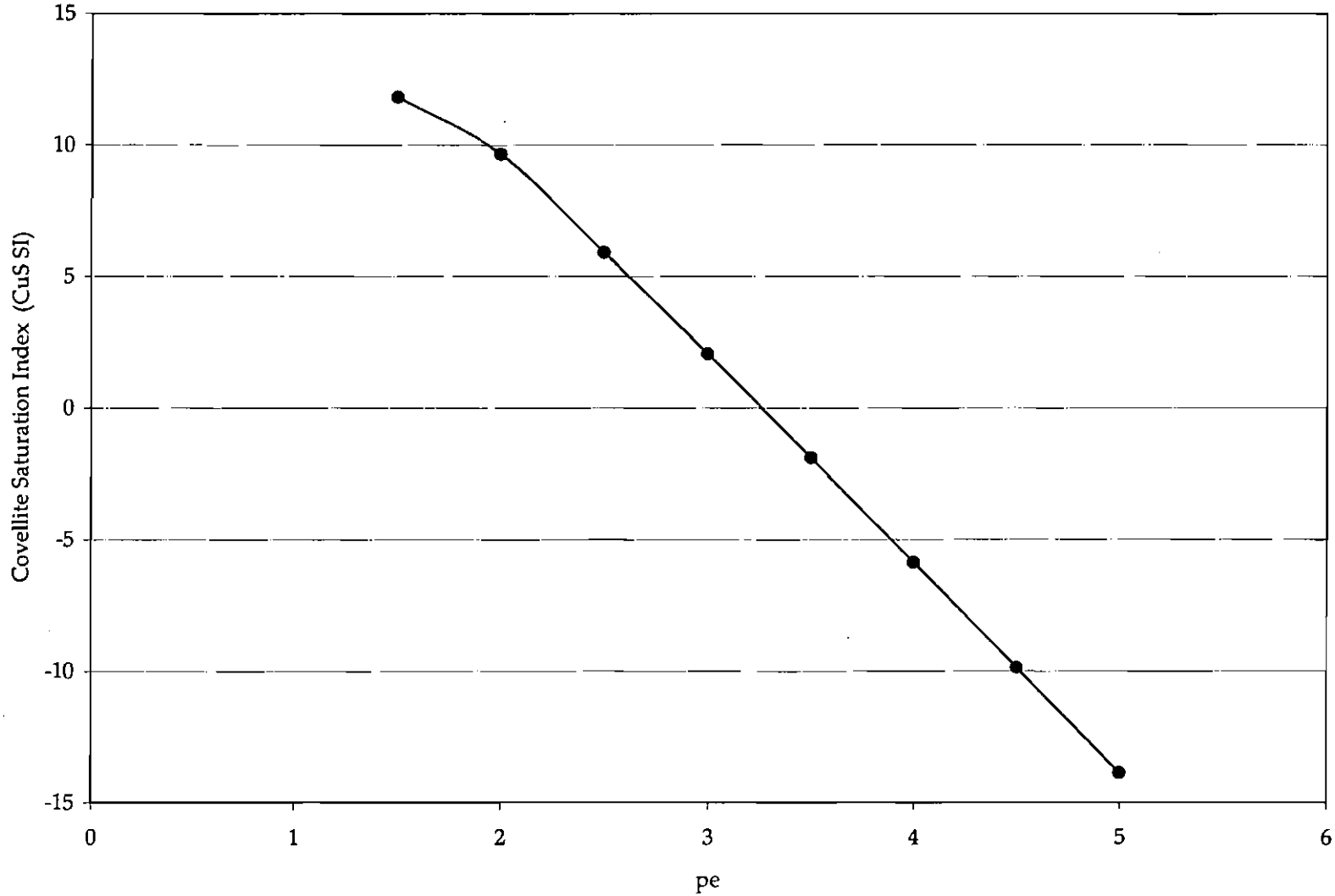
FIGURE **D-9**

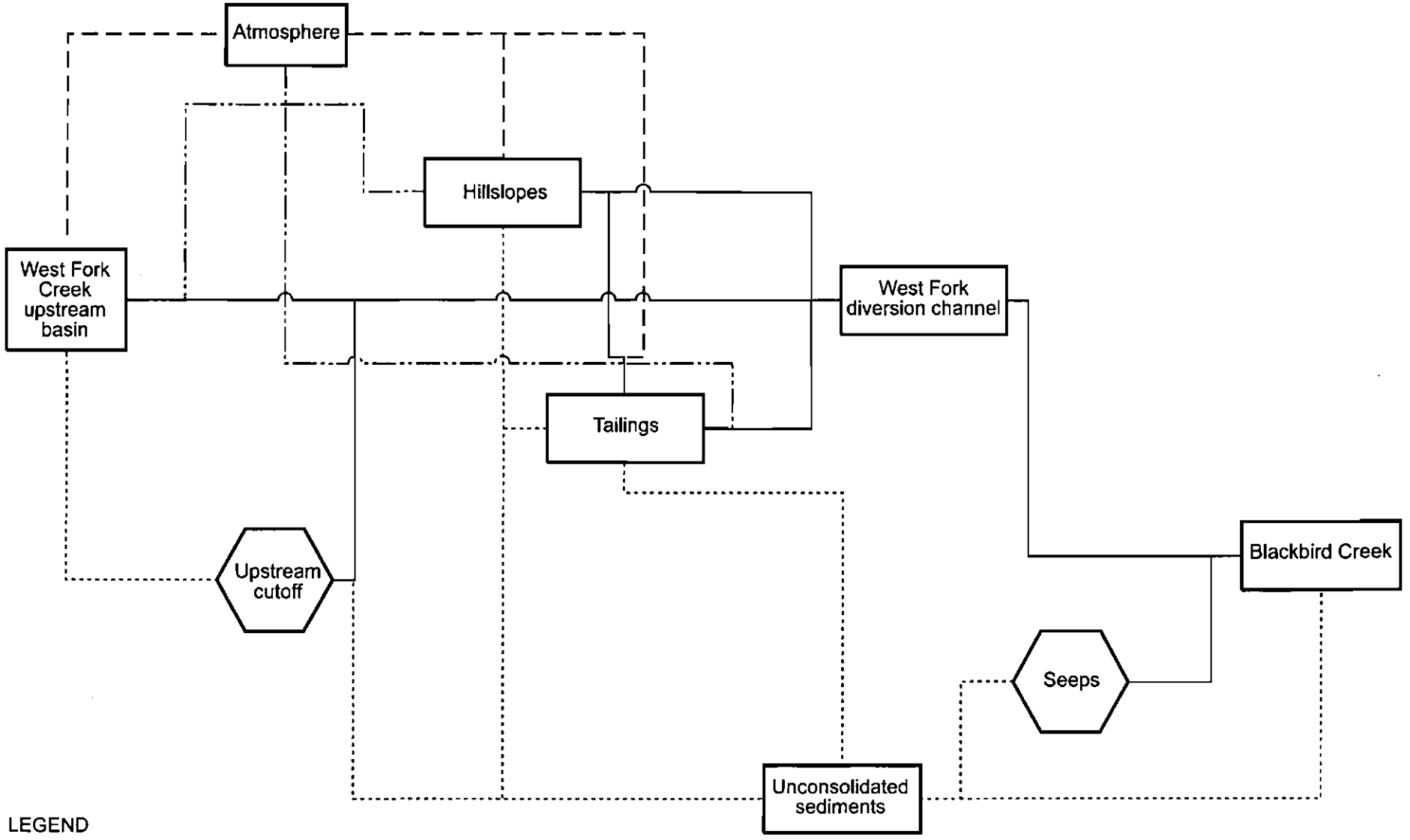
GROUNDWATER DISSOLVED COBALT CONCENTRATION
WEST FORK TAILINGS IMPOUNDMENT
NORANDA/BLACKBIRD/ID

PROJECT NO. 943 1595x003_9000 DRAWING NO. 67834 DATE 04/29/02 DRAWN BY EL

Golder Associates

FIGURE D-10
Covellite SI for WFMW-01S Versus pe





LEGEND

- Surface water
- Groundwater
- Evapotranspiration
- Precipitation and snowmelt

FIGURE **D-11**

WEST FORK CONCEPTUAL HYDROLOGICAL MODEL

BLACKBIRD MINE/ FEASIBILITY STUDY/ID

PROJECT NO. 943 1595X003_9000 DRAWING NO. 96936 DATE 04/29/02 DRAWN BY EL

Golder Associates

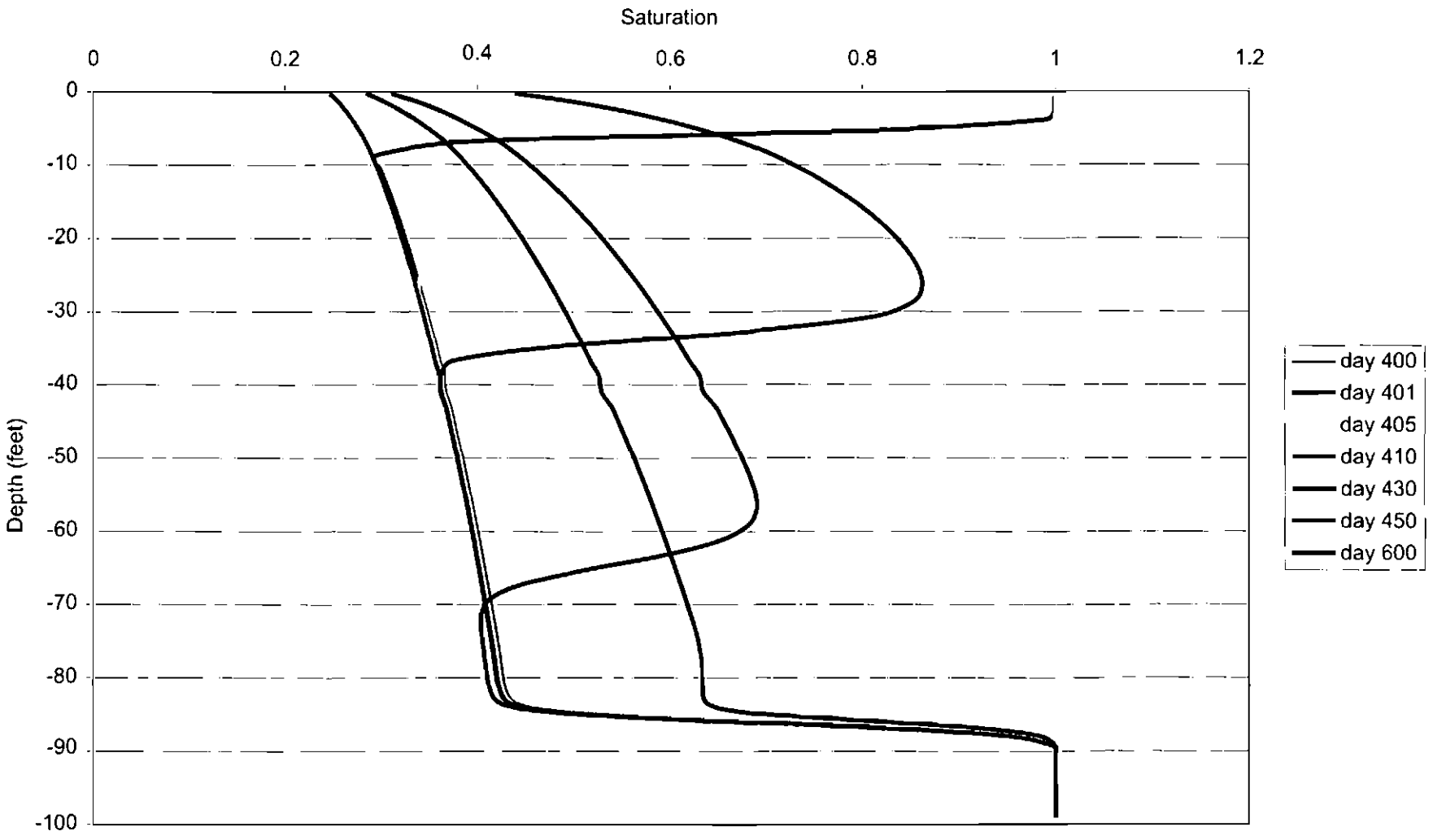


FIGURE **D-12**

SATURATION PROFILES FOR 1 INCH PONDING DAY 400 TO DAY 405

BLACKBIRDMINE/ FEASIBILITY STUDY/ID

PROJECT NO 943 1595X003_9000 DRAWING NO. 96935 DATE 04/29/02 DRAWN BY EL

Golder Associates

FIGURE D-13
Sulfate Generation Relative to No Cover Simulation

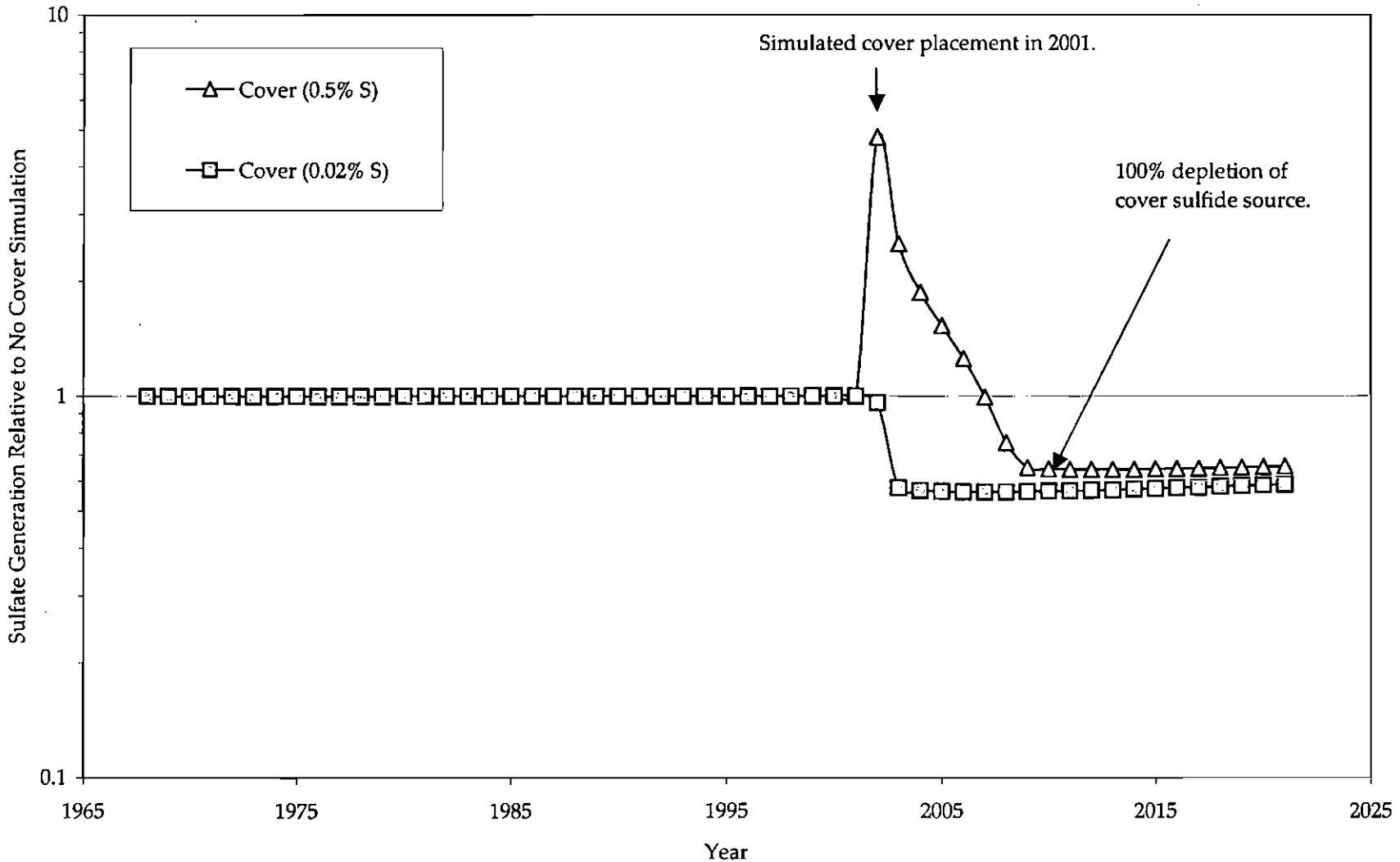


FIGURE D-14

Sulfide Oxidation Reduction Versus Moisture Content for a Soil Cover

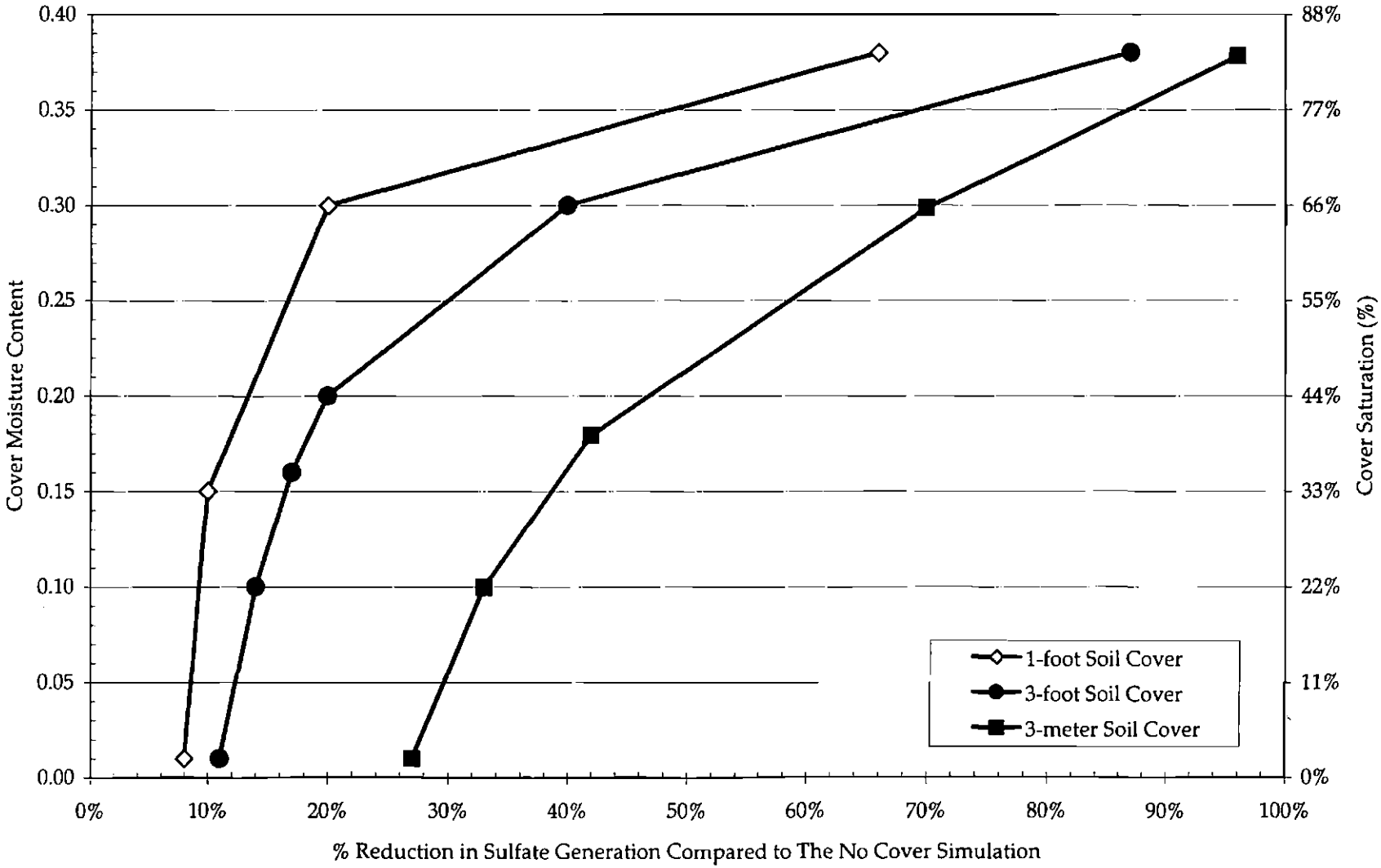


FIGURE D-15

Sulfide Oxidation Reduction Versus Moisture Content for a Composite Clay/Soil Cover

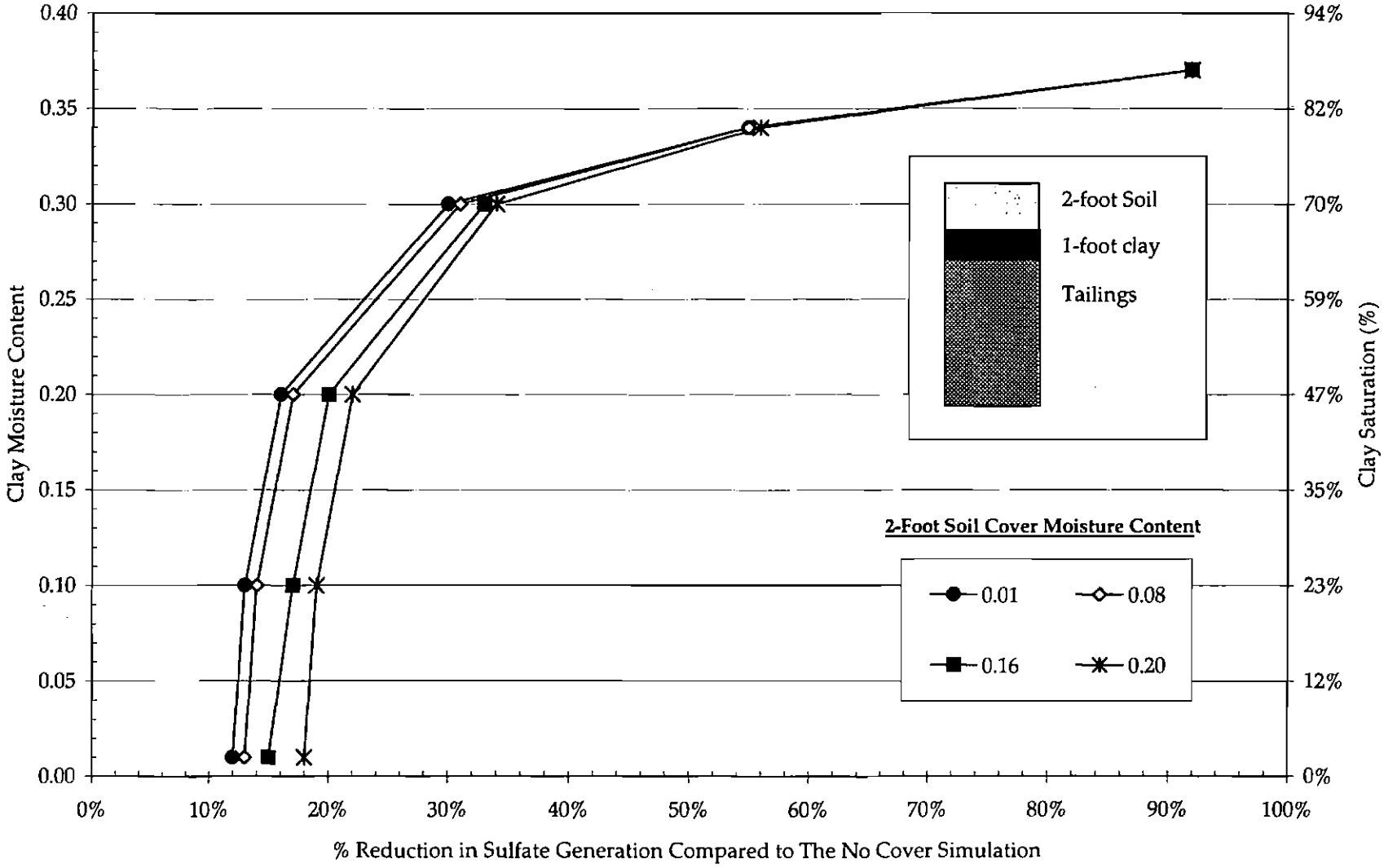


FIGURE D-16
Fall West Fork Impoundment Cobalt Loading to Blackbird Creek
Between BBSW-03A and BBSW-02

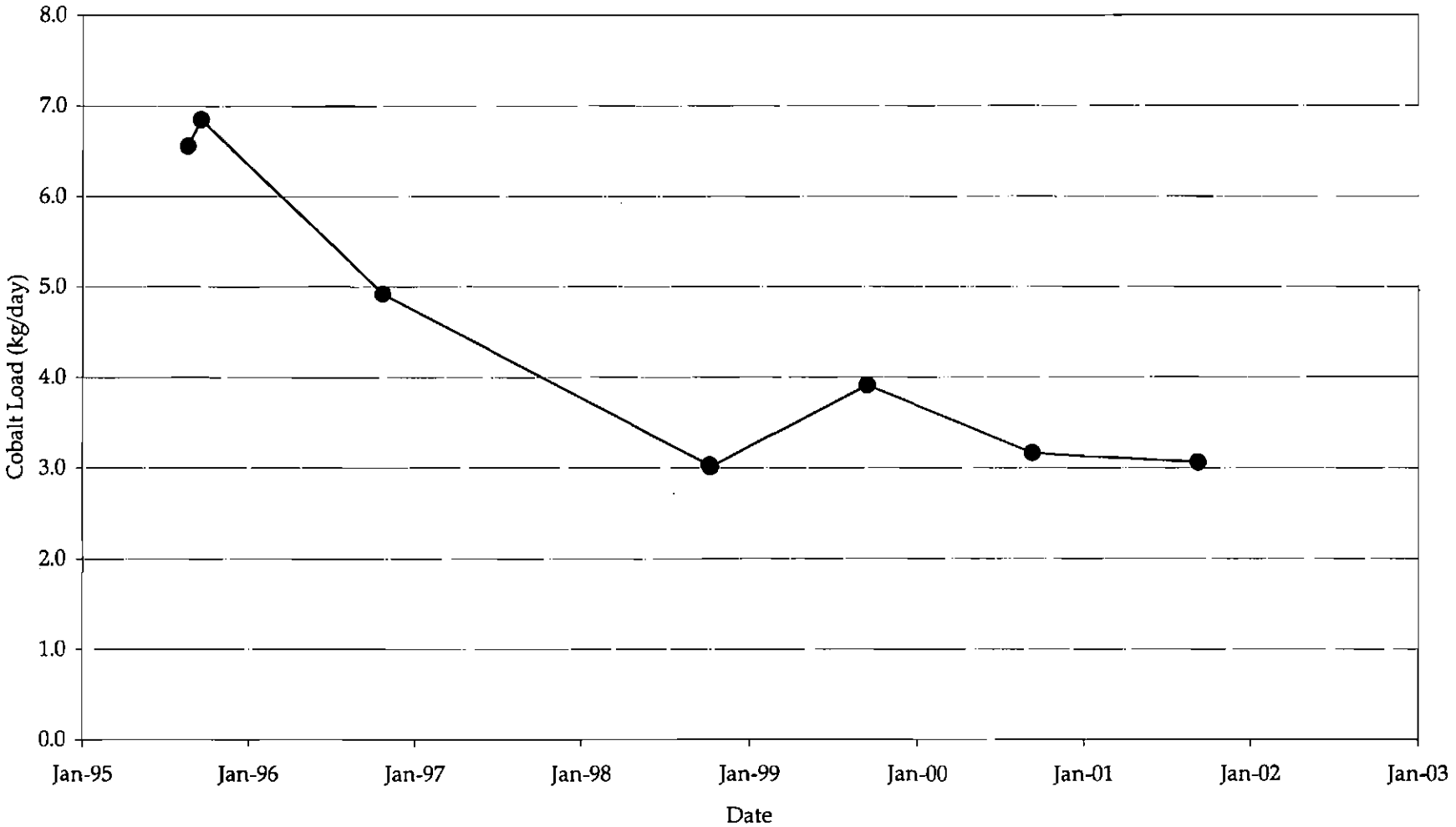
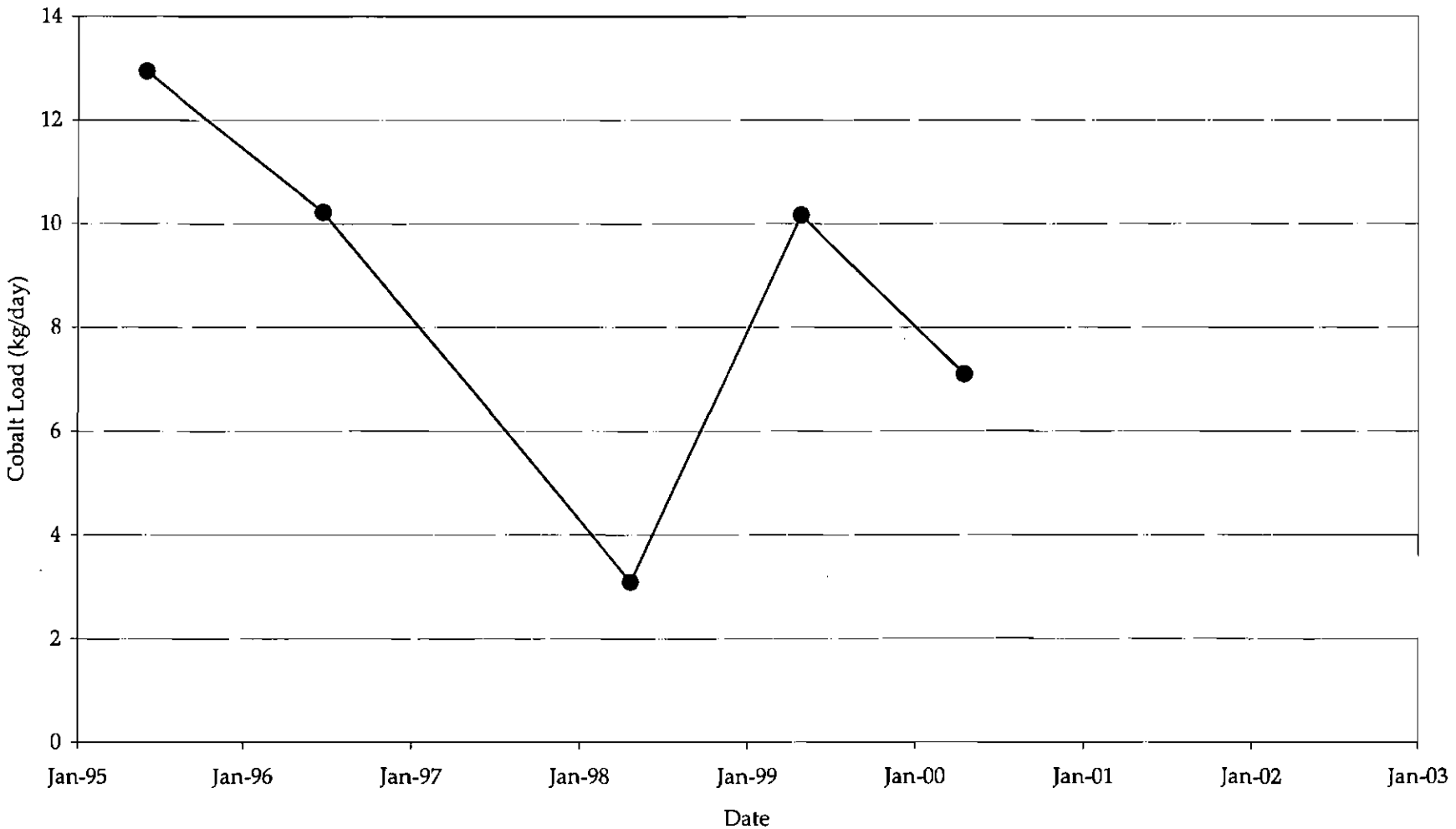


FIGURE D-17
Spring West Fork Impoundment Cobalt Loading to Blackbird Creek
Between BBSW-03A and BBSW-02



MEMORANDUM

ATTACHMENT A

TO:	Doug Dunster	April 19, 2002
FR:	Cheryl Ross, Rens Verburg	
RE:	WEST FORK TAILINGS IMPOUNDMENT – FEASIBILITY STUDY GEOCHEMICAL EVALUATION	943-1595.003 9000

D-A.1 WEST FORK WATER QUALITY

West Fork Tailings Impoundment seepage contributes copper, cobalt and iron loading to Blackbird Creek. Each of these metals exhibits unique behavior in Blackbird Creek. Spring and fall synoptic sampling results from 1998, 1999 and 2000, plotted in Figures D-A-1 through D-A-3, illustrate these differences. These figures include stations BBSW-03A, BBSW-02, BBSW-01.5, BBSW-01A and BBSW-01. Station BBSW-03A is located immediately upstream of the West Fork Tailings Impoundment. The four remaining stations are located downstream of the impoundment.

Cobalt is transported relatively conservatively in Blackbird Creek. Although cobalt will adsorb to manganese and iron (oxy)hydroxide phases, the pH of Blackbird Creek (generally 6 to 7) is below the range for optimal cobalt adsorption. This is illustrated in Figure D-A-4, a plot of adsorption edges for copper, cobalt, arsenic and sulfate, which shows the effectiveness of adsorption as a function of pH. Olsen (Camp Dresser and McKee, 1995) noted cobalt in association with a manganese/iron oxyhydroxide phase in a sediment sample collected downstream of the tailings impoundment, indicating some cobalt attenuation is possible.

Cobalt concentrations between BBSW-02 and BBSW-01 are higher in the fall (Figure D-A-1). Dissolved cobalt concentrations in the fall typically increase from approximately 0.3 mg/L to 0.8 mg/L between BBSW-03A and BBSW-02. Cobalt concentrations in Blackbird Creek remain relatively stable between BBSW-02 and BBSW-01. In the spring, a small decrease in cobalt concentrations between BBSW-03A and BBSW-02 is consistently observed. This decline is attributed to dilution by inflow from the clean water diversion. In 1999 and 2000, dissolved cobalt concentrations showed a slight decreasing trend downstream of the tailings impoundment (between BBSW-02 and BBSW-01). This decline may be attributable to dilution from groundwater recharge or cobalt attenuation in association with (oxy)hydroxide phases. Dissolved cobalt concentrations in Panther Creek at PASW-09 during synoptic sampling events in the spring and fall of 2000 were essentially equal at 0.053 and 0.054 mg/L, respectively.

Golder (1997) presented water quality profiles for the alluvial and bedrock aquifers below the West Fork Tailings Impoundment. The West Fork monitoring wells were sampled three times between June 1995 and October 1996. Of the 8 wells sampled, only two (WFMW-13D and WFMW-1D) are completed within the bedrock. The remaining 6 wells are completed in the alluvium.

Based on the 1995 through 1996 sampling results, alluvial groundwater pH upstream of the tailings impoundment is near neutral (Figure D-A-6). Groundwater pH decreases in the direction of groundwater flow reaching a minimum at WFMW-1S (<3.6). Copper concentrations (in μg/L) are plotted in Figure D-A-7. With the exception of two samples, copper concentrations were less than 10 μg/L in wells upgradient of the toe of the impoundment. Dissolved copper concentrations increase downgradient of the dam to a peak of 0.9 mg/L in WFMW-01S (6/19/95). Unlike copper, dissolved cobalt concentrations (Figure D-A-8) are elevated (>10 mg/L) in groundwater beneath the impoundment (WFMW-6 and WFMW-4). Dissolved cobalt concentrations do not increase significantly in wells downgradient of the impoundment. The peak dissolved cobalt concentrations are recorded in well WFMW-02 (15.7 mg/L to 21.1 mg/L). Differences in copper and cobalt concentration profiles below the tailings impoundment likely reflect non-conservative versus conservative behavior of copper and cobalt, respectively.

As discussed previously, the mechanism for copper attenuation in Blackbird Creek is adsorption onto iron (oxy)hydroxides. Due to the acidic conditions within the tailings, as indicated by the pH of WFMW-01S groundwater (pH ~3.5), adsorption onto iron (oxy)hydroxides is an unlikely attenuation mechanism. Therefore, in the absence of attenuation, copper concentrations in West Fork seepage would be expected to be similar to those measured in the water treatment plant inflow (i.e. mine water). This is indeed the case for cobalt, whose concentrations in tailings seepage (~5 to 20 mg/L) and water treatment plant inflow (13 to 22 mg/L) are similar due to an absence of attenuating mechanisms in both the tailings seepage and mine water.

Although dissolved copper concentrations in the water treatment plant inflow range from 7 mg/L to 20 mg/L, dissolved copper concentrations in tailings seepage are typically less than 1 mg/L. This may be due to precipitation of a copper sulfide in the tailings (covellite (CuS) or possibly chalcocite (Cu_2S)), which acts as a control on copper levels due to its low solubility. Covellite precipitation near the oxygen reaction front has been identified by mineralogical analysis in tailings facilities at a number of mine sites (McGregor *et al.*, 1997; Blowes and Jambor, 1990). Table D-A-1 provides details of the geochemical conditions at two of these sites. Speciation modeling conducted on water quality data from WFMW-01S supports that, provided the pe of tailings pore water is below approximately 3 (180 mV), covellite has the potential to precipitate (Figure D-A-9). Due to the much more oxidizing conditions in the mine water, covellite formation in mine water is very unlikely, and this control on copper concentrations is therefore not present in water treatment plant inflow.

TABLE D-A-1
Documented Covellite Occurrence in Tailings

Mine Site (Reference in Parentheses)	Location of Covellite (CuS) Occurrence	pH	Pore Water Cu Concentration (mg/L)	Redox Potential (mV)
Waite Amulet, Quebec (Blowes and Jambor, 1990)	Near the depth of active oxidation within the tailings.	3.5 to 5	Decline from > 50 mg/L to < 1 mg/L	400 to 600
Copper Cliff (McGregor et al., 1998)	At base of the oxidized zone within the tailings.	4 to 5	Decline from 0.2 mg/L to <0.05 mg/L	250

Covellite occurrence has not been documented during any of the West Fork Tailings field investigations. However, this is not unexpected since field identification is considered unlikely. At the sites referenced above, covellite was identified by mineralogical analysis, not field identification. At the Blackbird site, assuming all copper from the first five feet of tailings was released and precipitated in a 1-foot zone, the resultant covellite concentration would be less than 1%. At these concentrations, it would be difficult for even a skilled mineralogist to identify this mineral phase. Dr. John Jambor, a recognized leading authority on mine waste characterization and accomplished mineralogist, notes that "even at a 1% concentration, covellite could appear simply as blackish, sooty coatings on the tailings particles" (personal communication, 2002). Dr. Jambor has found covellite, or related minerals, in all or nearly all of the Cu-bearing oxidized impoundments he has examined. Even if covellite was visible in the field, sampling during drilling at typical intervals (5 feet) means the narrow zone of covellite precipitation would likely be missed. Therefore, although covellite has not been observed at the Blackbird Site, its possible occurrence should not be discounted, and covellite is considered a potential control on aqueous copper concentrations.

D-A.2 CONCEPTUAL MODEL – Co AND Cu RELEASE FROM THE WEST FORK TAILINGS IMPOUNDMENT

The copper and cobalt bearing phases in the ore and tailings at the Blackbird Site are chalcopyrite ($CuFeS_2$) and cobaltite (CoAsS). Pyrite (FeS_2) is also known to be present in Blackbird ores and tailings. Oxidation of these minerals is the principal mechanism for cobalt, copper, iron, and sulfate release from the West Fork Tailings Impoundment. Sulfide minerals are unstable under atmospheric conditions (i.e. in the presence of atmospheric oxygen or oxygenated waters). Diffusion of oxygen into the West Fork Tailings Impoundment therefore results in the weathering of chalcopyrite and cobaltite, as described by Equations 1 and 2. Two reactions for chalcopyrite oxidation are presented (Equations 1a and 1b). The first reaction (Equation 1a), which does not result in the production of acidity, is considered more likely. This is because sulfides with

metal to sulfur ratios of 1 (e.g. ZnS, PbS, $CuFeS_2$) tend not to produce acid when oxygen is the oxidant (Plumlee, 1999). Two reactions for cobaltite are presented as well. In Equation 2a, the overall reaction for cobaltite oxidation is assumed to be analogous to that of arsenopyrite (Equation 3). It should be noted that, despite extensive research of available resources, no information on overall cobaltite oxidation reactions could be found. Equation 2b is a mechanistic equation presented by Buckley (1987) developed in an attempt to enhance recovery of cobalt from sulfide ores. According to this reaction sequence, the initial products of cobaltite oxidation under ambient conditions are cobalt and arsenic oxides, which form an oxidized layer at the surface of the cobaltite particles. In this reaction, sulfur is not involved in the initial oxidation reaction, but the residual cobalt-sulfide phase presumably undergoes oxidation as ambient conditions persist.

$$CuFeS_2 + 4O_2 \rightarrow Cu^{2+} + Fe^{2+} + 2SO_4^{2-} \qquad \text{(Equation 1a)}$$

$$CuFeS_2 + 3.5O_2 + H_2O \rightarrow Cu^{2+} + Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad \text{(Equation 1b)}$$

$$CoAsS + 3.25O_2 + 1.5H_2O \rightarrow Co^{2+} + HAsO_4^{2-} + SO_4^{2-} + 2H^+ \qquad \text{(Equation 2a)}$$

$$2CoAsS + 2O_2 \rightarrow CoO + As_2O_3 + CoS_2 \qquad \text{(Equation 2b)}$$

$$FeAsS + 3.25O_2 + 1.5H_2O \rightarrow Fe^{2+} + HAsO_4^{2-} + SO_4^{2-} + 2H^+ \qquad \text{(Equation 3a)}$$

$$FeAsS + 3.25O_2 + 1.5H_2O \rightarrow Fe^{2+} + H_3AsO_4 + SO_4^{2-} \qquad \text{(Equation 3b)}$$

Oxygen diffusion into the tailings impoundment takes place through its surface and sides and may also occur through the culvert present at the tailings base. Because oxidation would have occurred continuously during placement of the tailings, lenses/layers of variably oxidized tailings likely occur throughout the entire tailings deposit.

The most likely reaction sequence for the oxidation of chalcopyrite by oxygen (Equation 1a) does not generate acidity; however, as shown in Equation 2a, each mole of cobaltite oxidized produces two moles of hydrogen ions. Acid mine drainage from the West Fork Tailings Impoundment results from not only the oxidation of cobaltite, but also pyrite (FeS_2) (Equation 4).

$$FeS_2 + 3.5O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \qquad \text{(Equation 4)}$$

Iron can also be an important oxidant in sulfide oxidation. Ferrous iron (Fe^{2+}), released by the oxidation of pyrite or chalcopyrite, once oxidized to ferric iron (Fe^{3+}) will oxidize sulfide minerals at rates that can be 2 to 3 orders of magnitude faster than by oxygen (Nordstrom and Alpers, 1999). The relative importance of oxidation by ferric iron increases as conditions become more acidic. The oxidation of chalcopyrite and cobaltite by ferric iron is described by Equations 5 and 6, respectively. Once again, the reaction

for cobaltite oxidation is assumed to be analogous to that of arsenopyrite (Equation 7). In addition to proceeding at a greater rate, acid generation is greatly enhanced due to the fact that significantly more moles of hydrogen ion are produced per mole of sulfide relative to oxidation by oxygen.

$$CuFeS_2 + 16Fe^{3+} + 8H_2O \rightarrow Cu^{2+} + 17Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad \text{(Equation 5)}$$

$$CoAsS + 13Fe^{3+} + 8H_2O \rightarrow 13Fe^{2+} + Co^{2+} + H_3AsO_4 + 13H^+ + SO_4^{2-} \quad \text{(Equation 6)}$$

$$FeAsS + 13Fe^{3+} + 8H_2O \rightarrow 14Fe^{2+} + HAsO_4^{2-} + SO4^{2-} + 15H^+ \quad \text{(Equation 7a)}$$

$$FeAsS + 13Fe^{3+} + 8H_2O \rightarrow 14Fe^{2+} + H_3AsO_4 + SO4^{2-} + 13H^+ \quad \text{(Equation 7b)}$$

Sulfide oxidation rates are a function of a number of factors, including (Plumlee, 1999):

- sulfide grain size (surface area);
- texture;
- trace element content;
- temperature;
- oxidant (oxygen or aqueous ferric iron); and,
- the presence/absence of microbial populations.

Oxidation rates for pyrite and chalcopyrite are available in the literature; however, Golder was unable to find published rates for cobaltite oxidation. Nordstrom and Alpers (1999) summarize the results of a number of sulfide oxidation studies. Abiotic reaction rates for pyrite and chalcopyrite oxidation by ferric iron are presented in Table D-A-2 for comparison. Rates for arsenopyrite, the analogue for cobaltite used in this study, are also presented.

TABLE D-A-2
Abiotic Sulfide Oxidation Rates (by Fe^{3+})

Mineral	Formula	Oxidation Rate (mol m^{-2} s^{-2})	Oxidation Rate Relative to Pyrite
Pyrite	FeS_2	1.9×10^{-8}	1
Chalcopyrite	$CuFeS_2$	9.6×10^{-9}	0.5
Arsenopyrite	FeAsS	1.7×10^{-6}	89

Source: Rimstidt *et al.* (1994)

These data indicate that the oxidation of chalcopyrite by ferric iron is somewhat slower than that of pyrite. If arsenopyrite oxidation is indeed analogous to that of cobaltite, cobaltite oxidation by ferric iron is significantly faster than that of chalcopyrite.

Plumlee (1999) presents relative mineral resistance to weathering for a number of sulfides. Plumlee incorporates data from Brock (1979), Jambor (1994) as well as his own

field observations. Plumlee defines pyrite resistance to oxidation as "medium" and chalcopyrite resistance to oxidation as intermediate between "medium" and "high". Arsenopyrite resistance to oxidation is slightly lower than that of pyrite. His qualitative listing is therefore in general agreement with the numeric values presented by Nordstrom and Alpers (1999).

Based on these data, it is assumed that the rate of chalcopyrite oxidation in the West Fork Tailings Impoundment is slower than that of pyrite. Using arsenopyrite as an analogue, cobaltite oxidation is expected to be faster than that of chalcopyrite. Cobalt and copper released by sulfide oxidation are transported through the tailings impoundment by infiltrating water. Water quality data from wells screened in the alluvium at the base of the tailings suggest that cobalt is transported conservatively through the tailings, that is to say secondary mineral precipitation reactions are not limiting dissolved cobalt concentrations. In addition, attenuation through adsorption is considered unlikely given the low pH of the pore water. Copper attenuation by precipitation of covellite (CuS) or chalcocite (Cu_2S) under reducing conditions at the base of the tailings is assumed to be a feasible mechanism. Geochemical speciation modeling conducted on data from WFMW-01S (9/23/95 and 10/25/96) indicates undersaturation with respect to credible cobalt and copper hydroxides and sulfates as well as ferrihydrite ($FeOH_3$). The absence of the latter mineral phases effectively eliminates adsorption as an attenuation mechanism. The pH of the water at WFMW-01S was 3.3 (9/23/95) and 3.6 (10/25/96). Provided the pe of this water is less than 3, supersaturation with respect to covellite (CuS) is predicted (Figure D-A-9), as indicated by saturation index (SI) values > 0.

D-A.3 PYROX MODEL INTRODUCTION

Materials excavated during overbank removal activities at the Blackbird Site have been placed on the West Fork Tailings Impoundment. These removals targeted soils with elevated arsenic concentrations, resulting from historic tailings deposition along Blackbird and Panther Creeks. Overbank materials placed on the southern portion of the impoundment between 1995 and 2001 have resulted in a three-meter (10-foot) cover. Although this cover will contain some sulfides, the sulfide content of this material is expected to be lower than that of the tailings.

To assess the benefits of the three-meter overbank material cover on the West Fork Tailings Impoundment with respect to the quality of tailings seepage, geochemical modeling was conducted using the PYROX model. This modeling made use of the results of the Hydraulic Evaluation Landfill Performance (HELP) infiltration modeling to define the initial moisture conditions for the tailings. The model assessed the relative changes to tailings seepage under a no cover versus cover scenario.

The West Fork Tailings Impoundment, which was constructed in the 1950s, contains over two million tons of material (Reiser, 1986). Tailings were deposited in this impoundment until 1967. In 1993, Noranda added old mill tailings and contaminated sediments from alongside the Blackbird Creek channel to the impoundment. As

mentioned above, additional overbank materials were placed by Noranda between 1995 and 2001.

To establish current conditions in the tailings, sulfide oxidation was simulated for a period of 34 years (2001 – 1967). The results of this simulation were then compared to current water quality data for West Fork seepage. To evaluate future conditions, this simulation was extended in time for 20 years assuming placement of a three-meter low sulfide cover.

D-A.4 THE PYROX MODEL

Sulfide oxidation of the West Fork Tailings was modeled using PYROX (Wunderly, 1994). PYROX simulates the diffusion of oxygen into a mine tailings impoundment and subsequent pyrite oxidation as a two-stage process. In the first stage, oxygen diffuses from the atmosphere into the tailings pore space. The rate of oxygen diffusion is a function of the moisture content, temperature and porosity of the tailings. In the second stage of the model, pyrite oxidation is simulated according to the shrinking core theory. As pyrite oxidation progresses, an oxidized coating will form around each unoxidized pyrite core. With time, the thickness of the oxidized coating increases, further inhibiting oxygen from reaching the unreacted core and thus slowing the rate of oxidation. PYROX considers oxygen diffusion through this oxidized shell to the unreacted core.

PYROX determines the mass of sulfate, iron and acidity produced due to pyrite oxidation for a defined vadose zone. Parameters required for vadose zone definition include: moisture content, temperature, porosity, pyrite grain size, bulk density and sulfide content of the tailings.

The primary sulfide minerals present in the West Fork Tailings impoundment are pyrite (FeS_2) chalcopyrite ($CuFeS_2$) and cobaltite (CoAsS). The oxidation of these minerals is responsible for copper, iron, cobalt, and sulfate releases from the tailings. Since PYROX is only capable of modeling pyrite oxidation, in this study, the oxidation of pyrite was used as an analogue for chalcopyrite and cobaltite oxidation. Because the goal of this study was to evaluate relative changes to metals release under a cover versus no cover scenario, this approach is considered reasonable. As discussed previously, it is expected that chalcopyrite oxidation will be slower than that of pyrite. Cobaltite oxidation may be slightly faster.

D-A.5 WEST FORK TAILINGS AND COVER MATERIAL CHARACTERIZATION

The PYROX model requires definition of the sulfide fraction of the tailings and cover material and pyrite grain size. Olsen (Camp Dresser and McKee, 1995), Beltman and others (RGG/ Hagler, Bailly, 1993) and Knight Piésold and Co. (1994a) conducted solid phase chemical analysis on West Fork Tailings samples. Data from these studies were used to determine the input sulfide concentration and pyrite grain size for the tailings in

the PYROX model. Results of overbank sampling, conducted during the 2001 removal activities, and cover sampling, conducted by Blackbird Mine Site Group (BMSG) in December 2001, were evaluated to define the sulfide content of the cover.

D-A.5.1 Tailings Characterization Data

Olsen (Camp Dresser and McKee, 1995) collected six samples from the West Fork Tailings Impoundment in the winter of 1995. Results of total metals analysis by X-ray fluorescence (XRF) on each of three size fractions are presented in Table D-A-3. Concentrations are presented in mg/kg (ppm). Total metals concentrations are generally highest in the smallest fraction (<74 μm). Average cobalt and copper concentrations range from 43 mg/kg to 350 mg/kg (Co) and 1277 mg/kg to 4690 mg/kg (Cu). Tailings copper concentrations are consistently higher than cobalt concentrations.

TABLE D-A-3
Olsen (CDM, 1995) XRF Total Metals Results

		less than 74 μm			74 to 250 μm			250 μm to 2 mm		
Station	**Description**	**Cu**	**Co**	**As**	**Cu**	**Co**	**As**	**Cu**	**Co**	**As**
300-001	Tailings 100 ft SSW of 104-001	1248	33.8	6118	1063	37.7	4692	1682	45.9	3985
301-001	Tailings below tailings pond dam 50 ft below confluence of Blackbird Creek and dam spillway, 20 feet west side of Blackbird Creek	969	ND	7489	787	2.5	5752	2058	35.0	6638
302-001	Tailings below tailings dam on bench between and upgradient of spillway and Blackbird Creek	281	26.3	698	266	18.5	728	264	31.9	512
303-001	Tailings pond surface @ 200 ft below upstream end/gauging station, 70 ft south of berm forming creek bypass	101	28.0	387	80	44.2	349	53	24.3	230
305-001	Tailings pond surface @ 400 ft upgradient of dam, centered between bypass and south side	1310	117	15437	1415	113	11930	2019	149	13000
306-001	Tailings pond surface 150 ft upstream of dam, 30 ft south of bypass	2878 2154	1147 1095	13858 15981	-	-	-	1636	289	2605
AVERAGE (mg/kg)		1277	350	8567	722	43	4690	1285	96	4495
AVERAGE (mmol/kg)		20	5.9	114	11	0.73	63	20	1.6	60

Olsen (Camp Dresser and McKee, 1995) noted that all cobalt and arsenic in the West Fork tailings samples were present as the primary mineral cobaltite and that all of the copper

was present as chalcopyrite. Cobaltite grains ranged in size from 4 to 100 microns and chalcopyrite ranged in size from 6 to 200 microns. Only 15% of the particles had a weathering rim or coating of iron oxides. Olsen described these rims as small and containing low concentrations of arsenic, cobalt and copper. Olsen concluded that secondary phases therefore do not contribute significantly to the total mass of arsenic, cobalt and copper in tailings.

Beltman and others (RCG/Hagler, Bailly, 1993) conducted water and solids sampling at the Blackbird Site in October 1992. Tailings samples were collected from both Blackbird Creek and the West Fork Tailings Impoundment. At each location, four sub-samples were collected along a transect and composited. At the time of sampling, mine personnel were in the process of removing debris from the area of the former mill on Blackbird Creek and depositing it near the West Fork tailings dam. Two samples were collected from waste piles recently placed by dump trucks. Total metals analysis results for these samples are summarized in Table D-A-4. TCLP results from a select number of samples are provided in Table D-A-5.

The two samples collected from the recently placed mill debris (WFSS-02 and WFSS-03) recorded the highest metals concentrations. Cobalt concentrations in these samples were greater than 5,000 mg/kg. Cobalt concentrations in the tailings samples ranged from 30 to 1,100 mg/kg. Copper concentrations in the mill debris samples were greater than 7,000 mg/kg, whereas the maximum copper concentration of the tailings samples was 2,000 mg/kg. These data suggest that the mill debris may represent a significant source of cobalt and copper, and that materials other than tailings were likely included. However, because the mill debris constitutes only a small fraction of the estimated 2 million tons of waste in the impoundment, this source was not evaluated independently.

TABLE D-A-4
RCG/Hagler, Bailly (1993) Total Metals Results

Sample No.	Location/ Description	As (mg/kg)	Co (mg/kg)	Cu (mg/kg)	Fe (mg/kg)
BBSS-03	Blackbird Creek near tailings dam – bare tailings	766	1,060 JQ	1,930 J	149,000
BBSS-05	Blackbird Creek – bare tailings	2,370	77.4 JQ	617 JQ	125,000
BBSS-08	Blackbird Creek – bare tailings	1,880	26.5 JQ	171 JQ	137,000
WFSS-02	West Fork above tailings dam – bare tailings	2,470	556 JQ	680 JQ	100,000
WFSS-03	West Fork above tailings dam – recently dumped Mill debris	12,100	5,060 JQ	17,200 JQ	234,000
WFSS-04	West Fork tailings dam – recently dumped Mill debris	16,900	7,410 JQ	7,640 JQ	146,000

Sample No.	Location/ Description	As (mg/kg)	Co (mg/kg)	Cu (mg/kg)	Fe (mg/kg)
WFSS-05	West Fork tailings dam – tailings beneath talus	4,470	125 JQ	813 JQ	125,000
Average (mg/kg)		5851	2045	4150	145143
Average (mmol/kg)		78	34	65	2599

J – Estimated concentration. JQ – Estimated concentration is a minimum value.

TABLE D-A-5
RCG/Hagler, Bailly (1994) TCLP Results

Sample No.	Location/ Description	As (mg/L)	Co (mg/L)	Cu (mg/L)	Fe (mg/L)
BBSS-03	Blackbird Creek near tailings dam – bare tailings (pinkish crust)	0.0246	26.2 JQ	14.2	1.46 JQ
BBSS-05	Blackbird Creek – bare tailings	0.016 UJ	0.621 JQ	2.36	5.07 JQ
WFSS-03	West Fork above tailings dam – recently dumped Mill debris	0.0242	19.4 JQ	59.4	1.35 JQ

U – Analyte not detected at concentration shown.
J – Estimated concentration.
JQ – Estimated concentration is a minimum value.

TCLP testing indicates that both copper and cobalt are readily leached from the tailings samples under the conditions of the TCLP test. The peak cobalt concentration recorded during leach testing (26 mg/L) is consistent with peak dissolved cobalt groundwater concentrations recorded in well WFMW-02 (21 mg/L). TCLP test copper concentrations ranging from 2.4 mg/L to 59 mg/L are, however, elevated in comparison to groundwater copper concentrations below the West Fork Tailings Impoundment. As shown in Figure D-A-7, groundwater dissolved copper concentrations remained below 1 mg/L in the West Fork wells between 1995 and 1996. Leach test copper results however are consistent with the range of dissolved copper concentrations measured in the water treatment plant inflow (7 mg/L to 34 mg/L). As explained previously, copper concentrations in West Fork seepage are believed to be controlled by the solubility of covellite (CuS). Lower copper concentrations in West Fork seepage may also be attributed to a slower rate for chalcopyrite oxidation. In both cases, future copper concentrations would not be expected to exceed current concentrations.

A comparison of Olsen and Beltman's tailings metal concentrations is provided in Table D-A-6. These data sets present similar ranges for tailings cobalt and copper concentrations. This comparison highlights the magnitude of cobalt and copper concentrations in mill debris relative to the tailings.

TABLE D-A-6
Comparison of Olsen and Beltman West Fork Tailings Impoundment Solids Data

Source	Arsenic (mg/kg)		Cobalt (mg/kg)		Copper (mg/kg)	
	Min.	Max.	Min.	Max.	Min.	Max.
Olsen - Tailings	230	15,981	2.5	1,147	53	2,878
Beltman - Tailings	766	4,470	26.5	1,060	171	1,930
Beltman – Mill Debris	12,100	16,900	5,060	7,410	7,640	17,200

Knight Piésold Co. (1994a) drilled a number of groundwater monitoring wells in the West Fork Tailings Impoundment in 1993. Wells WF-6, WF-9 and WF-11 are located within the main impoundment. Geologic descriptions from the field well logs indicate the depth of tailings oxidation. At WF-11 and WF-9, the oxidation front was 1 foot and 3 feet below the surface of the tailings, respectively. At these depths the tailings were described as changing in color from "pale yellow" and "light yellowish brown" to "dark grey". The borehole log for WF-6 does not indicate any degree of oxidation of the tailings. Tailings at this location are described as "dark grey, micaceous" over their entire depth.

Knight Piésold Co. (1994a) conducted acid base accounting (ABA) analysis on 14 samples collected from 4 geotechnical borings in the West Fork Tailings Impoundment. Sulfur results are presented in Table D-A-7. The average sulfide content of these samples is 2.8%. With the exception of the surface sample at GT-22 (0.5 to 1.5 foot depth), sulfate sulfur accounts for less than 0.1% of total sulfur. This is consistent with oxidation occurring near the surface of the tailings deposit, resulting in enrichment in sulfate.

TABLE D-A-7
Knight Piésold Co. (1994) Acid Base Accounting Results

	Depth			Sulfur (as S)				
Site	Top	Bottom	Mid (Graphing)	Total S	Pyrite S	Unidentified	Sulfate	Pyrite + Unidentified
GT-22	feet	feet	Feet	%	%	%	%	%
	0.5	1.5	1.0	1.38	0.06	0.24	1.08	0.3
	29.5	31.5	30.5	1.36	1.25	0.11	<0.01	1.36
	39.5	41.5	40.5	3.38	1.02	2.36	<0.01	3.38
	59.5	61.5	60.5	5.21	1.86	3.34	0.01	5.2
	74.5	76.5	75.5	6.65	6.29	0.26	0.1	6.55
	99.5	101.5	100.5	5.48	5.46	<0.01	0.04	5.46
GT-9	14.5	16.5	15.5	1.9	0.72	1.15	0.03	1.87
	34.5	36.5	35.5	1.17	1.1	0.07	<0.01	1.17
GT-5	17.5	19.5	18.5	0.46	0.39	0.07	<0.01	0.46

	Depth			Sulfur (as S)				
Site	Top	Bottom	Mid (Graphing)	Total S	Pyrite S	Unidentified	Sulfate	Pyrite + Unidentified
GT-22	feet	feet	Feet	%	%	%	%	%
	25	27	26.0	0.37	0.33	0.04	<0.01	0.37
	37.5	39.5	38.5	4	3.67	0.27	0.06	3.94
GT-10	19.5	21.5	20.5	1.1	0.91	0.15	0.04	1.06
	39.5	41.5	40.5	3.3	3.19	0.11	<0.01	3.3
	64.5	65.5	65.0	3.34	1.3	2.04	<0.01	3.34

Boring locations shown in Figure 2-2b of the Feasibility Study.

Sulfur content profiles for the four Knight Piésold sites are shown in Figure D-A-10. The most complete profile (GT-22) indicates increasing sulfide content with depth. GT-22 is located at the western end of the tailings impoundment between WFMW-6 and WFMW-8. Because cobalt was not recovered during the later stages of mining at the Blackbird site, it was hypothesized that the sulfide content of surface samples could be elevated relative to at depth. These data do not indicate this. The sulfide trend is also not considered reflective of decreasing oxidation with depth, as the PYROX modeling indicates only limited (i.e. several feet) penetration of oxygen.

D-A.5.2 Cover Characterization Data

The cover of the West Fork Tailings Impoundment consists of overbank materials removed from Blackbird and Panther Creeks. These overbank deposits were removed due to the presence of tailings with elevated arsenic. The West Fork cover will therefore contain sulfides, however because these materials also contain clean soils, the sulfide content is expected to be lower than that of pure tailings. The sulfur content of the cover material was estimated from the results of the 2001 overbank removal sampling and the December 2001 cover material sampling.

Prior to removal, overbank materials were analyzed for total arsenic, copper, iron and sulfur with a portable field XRF. Sulfur and copper results for overbank materials removed in 2001 are shown in Figures D-A-11 and D-A-12. The lower confidence limits (i.e. "practical quantitation limit") for sulfur and copper analysis using the field XRF are 5,000 mg/kg and 300 mg/kg, respectively. XRF results below these limits are presented as measured in Figures D-A-11 and D-A-12; however, these values are qualified as estimates. Concentrations reported as zero by the XRF are shown as non-detect.

Overbank sulfur analysis results indicate that the sulfur content of these materials is low. Only six percent of the samples tested recorded sulfur contents of greater than 1%. The maximum and average sulfide contents of the 390 samples tested were 2.6% and 0.1%, respectively. This average concentration was calculated assuming zero concentration for non-detect samples and concentrations as measured for values below the lower confidence limit (5,000 mg/kg). It should be noted that the calculated average value falls below the lower confidence limit for sulfur analysis. Based on these results however, it is

considered likely that the average sulfur content of the overbank materials placed on the West Fork Tailings Impoundment is less than 5,000 mg/kg (0.5%), the lower confidence limit for sulfur analysis.

The copper concentrations of the overbank materials provides an independent check of estimated sulfide contents. It is proposed that copper/sulfur ratios measured in West Fork Tailings Impoundment samples would be consistent with copper/sulfur ratios measured in the overbank deposits. A histogram of copper concentrations in West Fork tailings samples is shown in Figure D-A-13. This plot includes the data from Olsen (Camp Dresser and McKee, 1995) and Beltman (RCG/Hagler, Bailly, 1993) presented in the preceding section. The average copper concentration of the tailings samples is 1,015 mg/kg. The average sulfide content of the tailings, based on data presented in Knight Piésold (1994a), is 3%. Overbank copper concentrations are presented in Figure D-A-12. The average overbank copper concentration is 374 mg/kg. Therefore, assuming a constant tailings copper to sulfur ratio, the estimated sulfide content of the overbank materials is approximately 1%.

BMSG collected six samples from the West Fork Tailings Impoundment cover in December 2001. These samples were submitted to SVL analytical in Kellogg, Idaho for total metals (Cu, Co, As and Fe), total organic matter and acid base accounting analyses (ABA) (Tables D-A-8 and D-A-9).

TABLE D-A-8
Cover Material Total Metal and Total Organic Matter Concentrations – December 2001

Sample ID	As (mg/kg)	Co (mg/kg)	Cu (mg/kg)	Fe (mg/kg)	Total Organic Matter (TOM %)
WF-001	69.7	46.1	75.4	16,100	1.40
WF-002	268	94.3	196	18,000	0.7
WF-003	172	61.0	111	14,400	1.9
WF-004	254	62.6	147	13,500	0.2
WF-005	218	72.4	139	15,500	1.5
WF-006	324	86.4	222	18,600	2.1
AVERAGE	218	70.5	148	16,017	1.3

TABLE D-A-9
Cover Material Acid Base Accounting (ABA) Results – December 2001

Sample ID	AGP t CaCO3/ 1000 tons	ANP t CaCO3/ 1000 tons	NNP t CaCO3/ 1000 tons	NPR	S-Non-Extractable (%)	S-Pyritic (%)	S-Sulfate (%)	S-Total (%)
WF-001	<0.3	3.1	3.1	10.3	<0.01	<0.01	0.02	0.02
WF-002	0.5	10.1	9.6	20.2	<0.01	0.02	0.04	0.06

Sample ID	AGP t CaCO3/ 1000 tons	ANP t CaCO3/ 1000 tons	NNP t CaCO3/ 1000 tons	NPR	S-Non-Extractable (%)	S-Pyritic (%)	S-Sulfate (%)	S-Total (%)
WF-003	0.5	5.8	5.3	11.6	<0.01	0.01	0.02	0.03
WF-004	0.3	4.8	4.5	16.0	<0.01	0.01	0.03	0.04
WF-005	1.9	4.3	2.4	2.3	<0.01	0.06	0.06	0.12
WF-006	0.4	1.4	1.0	3.5	0.01	0.01	0.07	0.10
AVERAGE	0.65	4.9	4.3	10.7	0.01	0.02	0.04	0.06

AGP = acid generation potential
ANP = acid neutralization potential
NNP = net neutralization potential (ANP-AGP)
NPR = neutralization potential ratio (ANP/AGP)

Samples collected from the West Fork cover yield a lower average sulfide (S-pyritic) fraction than the 2001 overbank removal samples (Figure D-A-11). These data indicate an average sulfide sulfur content for the cover material of 0.02%. The sulfate fraction of these samples generally exceeds the sulfide fraction, suggesting partial oxidation has already occurred. On the basis of the net potential ratio (NPR) results for these samples, the cover material is classified as having a low potential to generate acidity (Price, 1997).

The average copper concentration of the cover material samples (148 mg/kg) (Table D-A-8) is 50% lower than that of the overbank removal samples (374 mg/kg). This result is consistent with the lower sulfide content of the cover material samples compared to that of the overbank samples. The measured total organic matter fraction of the cover material ranges from 0.02 to 2.1%, with an average value of 1.3%. The Environmental Protection Agency (EPA) recommends a default organic carbon fraction of 2% in the evaluation of attenuation mechanisms for the establishment of soil screening levels (EPA, 1993). Maximum total organic matter concentrations for the cover material are therefore representative of typical soil concentrations. These soils are not expected to consume significant amounts of oxygen and therefore oxygen diffusion profiles across the soil cover predicted by PYROX are considered a good representation of site conditions.

D-A.6 MODEL METHODOLOGY – INPUT PARAMETERS AND ASSUMPTIONS

PYROX requires definition of the following vadose zone parameters: moisture content, temperature, porosity, pyrite grain size, bulk density and the sulfide content of both the tailings and cover material. Input parameters to the model are summarized in Table D-A-10. Data sources for each parameter are summarized below.

- Porosity – Tailings and cover material porosity is equivalent to the value applied in the HELP infiltration modeling. Porosity values are assigned in HELP based on soil type.
- Moisture Content – Moisture content is an output from the HELP model. HELP assumes that clay layers are fully saturated.

- Temperature – A temperature of 10 °C was assumed.
- Bulk Density – The bulk density for the tailings was taken from Knight Piésold Co. (1994b). This value represents the average bulk density of approximately 20 samples taken from 7 borings in the West Fork Tailings Impoundment. The bulk density of the cover material was assumed to be equivalent to that of the tailings.
- Sulfide Content – The sulfide content of the tailings was assumed equal to 3%. This represents the average sulfide content from the Knight Piésold (1994a) sampling campaign. This value is also consistent with estimates provided by Joe Scheuering (personal communication with Doug Dunster). The sulfide content of the cover was estimated from the results of cover material sampling conducted by BMSG in December 2001 (0.02%). Because the overbank sampling indicated a higher average sulfide content, a second simulation was conducted assuming sulfide at the lower confidence limit for the field XRF (0.5%). This simulation is considered representative of the upper sulfide limit of cover material.
- Pyrite Grain Size – The diameter of pyrite grains was assumed equal to 50 microns. This value is within the range presented by Olsen (Camp Dresser and McKee, 1995) for cobaltite.

TABLE D-A-10
PYROX Model Input Parameters

Simulation	Moisture Content	Porosity	Temp. (°C)	Bulk Density (kg/m^3)	Sulfide Content (%)	Pyrite Grain Size (diameter in microns)
Tailings	T = 0.23	T = 0.47	10	1805	T = 3	50
Cover (0.02% sulfide)	T = 0.25 C = 0.18	T = 0.47 C = 0.46	10	1805	T = 3 C = 0.02	50
Cover (0.5% sulfide)	T = 0.25 C = 0.18	T = 0.47 C = 0.46	10	1805	T = 3 C = 0.5	50

T = tailings
C = cover

D-A.7 MODEL RESULTS

D-A.7.1 Tailings Simulation (34 years)

PYROX simulates the diffusion of oxygen through the surface of the tailings impoundment. Sulfides at the top of the tailings impoundment are therefore oxidized first. Initial oxidation rates are high, due to the fact that oxygen only needs to diffuse a short distance into the tailings. Through time, as the depth of the active oxidation layer increases, the rate of sulfide oxidation decreases as the concentration gradient for oxygen

flattens. This results in a decline in the quantity of reaction products (sulfate, iron and acidity) generated through time.

Model results for the base case tailings simulation are plotted in Figures D-A-14 and D-A-15. The PYROX model predicts complete oxidation of all sulfides within the top 1.6 meters (= 5 feet) of the tailings after 34 years of oxidation (Figure D-A-14). Figure D-A-15 shows the oxygen profile, with 100% oxygen concentration being equal to atmospheric conditions. It should be noted that oxygen ingress occurs to depths beyond 1.6 meters as not all oxygen is consumed as it diffuses downward. The oxygen reaction front reaches a depth of approximately 3.5 meters after 34 years.

The Knight Piésold (1994b) well log for WF-9 indicated a depth of oxidation of 3-feet. This observation is representative of conditions within the tailings in 1993. The PYROX model predicts complete sulfide depletion to a depth of 3.7 feet in 1993 following 25 years of oxidation. The model's predicted depth of oxidation therefore agrees quite well with the Knight Piésold (1994b) well logs. It should be noted that the 3-foot oxidized depth observed by Knight Piésold is considered approximate for a number of reasons. Because the Knight Piésold borings were installed as part of a geotechnical exploration, the focus of the field geologist would not have been on tailings characterization. This statement is supported by the fact that tailings were incorrectly identified as "sand" in the well logs. Sampling intervals were not noted on the well logs meaning that the accuracy of any observations regarding depths cannot be determined. Sample recovery at shallow depths for two of the wells (WF-2 and WF-3) was poor, resulting in an absence of color descriptions for these logs. For these reasons, the depth of oxidation noted in the logs is regarded as little more than anecdotal information.

The apparent overestimation in oxidation depth by PYROX may also simply reflect differences in the rate of pyrite, chalcopyrite and cobaltite oxidation. Over the 34-year period, sulfide oxidation results in the generation of 428 kg of sulfate (per m^2 of tailings). In the final year (i.e. year 34), 6.6 kg of sulfate (per m^2 of tailings) is produced.

Infiltration through the West Fork tailings is estimated to range from approximately 2 to 9 inches per year. Dissolution of 6.6 kg of sulfate into 2 to 9 inches of infiltrating water would result in a sulfate pore water concentration of between 129,000 mg/L and 29,000 mg/L. West Fork tailings pore water quality has not been characterized to date. Groundwater quality from wells completed in the alluvium beneath the West Fork Tailings Impoundment provides the best analogue for tailings pore water. Peak sulfate concentrations in these wells for the period of record (1995 to 1996) are approximately 1,000 mg/L. Predicted pore water sulfate concentrations are therefore significantly higher than measured. This apparent discrepancy may be attributed to one or a combination of the following factors:

1. Maximum pore water sulfate concentrations will be a controlled by sulfate mineral solubility. In mine waters, gypsum ($CaSO_4 \cdot 2H_2O$) precipitation typically limits tailings pore water concentrations to several 1000s of mg/L.

2. Groundwater quality data from the alluvium represent a mixture of tailings seepage and groundwater. The hydrogeologic evaluation of the West Fork area indicates that tailings seepage may be diluted by groundwater by a factor of 10 in the alluvium.

3. As noted previously, cobaltite and chalcopyrite oxidation rates differ from that of pyrite. A reduction in oxidation rate would result in an equivalent reduction in the amount of sulfate generated.

4. The ability of the PYROX model to accurately predict site conditions is dependent on accurate tailings characterization. The tailings definition for the PYROX model is based on the data set available. The available data set is very limited yet indicates significant variability. West Fork tailings were assumed to be homogenous for the purposes of modeling. Better definition of sensitive parameters such as sulfide content and pyrite grain size will likely result in a more accurate representation of current conditions.

Because the goal of oxidation modeling was to evaluate relative changes with and without a cover, an extensive effort to match predicted sulfate, iron and acidity to site conditions was not made. To accurately calibrate the model, tailings pore water data are required. In the absence of such data, an extensive calibration effort was deemed to be of limited value.

D-A.7.2 Cover Versus No Cover Simulations (54 years)

To evaluate the relative changes in sulfide oxidation rates following the placement of a three-meter cover on the West Fork Tailings Impoundment, two additional PYROX simulations were conducted. Results from the base case simulation were used to define the initial conditions of the tailings. Two cover simulations, assuming a cover thickness of three meters and sulfide contents of 0.02% and 0.5%, respectively, were run for a period of 20 years (i.e. to year 54 after initial tailings disposal).

The placement of sulfide-containing cover material on the tailings impoundment may result in an initial increase in the amount of sulfide oxidation products generated. Figures D-A-16 and D-A-17 compare sulfate production for both the cover and no cover scenario. For the 0.5% sulfide cover, oxidation of cover sulfides results in an initial increase in sulfate generation. Depletion of the cover sulfide source takes approximately 9 years after placement. The abrupt change in slope of the sulfate production curve in 2010 (Figure D-A-17) reflects this depletion. For the 0.02% sulfide cover, no initial increase in sulfide production is predicted.

Despite an initial increase in sulfate loading for the 0.5% sulfide cover, both cover simulations indicate that in the long run, sulfide oxidation rates will be slower for the covered tailings. Sulfate production is predicted to stabilize following depletion of the cover sulfide source. In comparison to the no cover simulation, a long-term reduction in loading of 40% is predicted. This is shown in Figure D-A-17, where the sulfate production for the two cover scenarios is expressed as a ratio relative to the no cover

simulation. At the end of the model simulation, the sulfate load is 60% of that for the no cover scenario (i.e. 0.6). This is caused by the addition of three meters of material, which depresses the oxygen concentration gradient and hence reduces the "driving force" for oxygen diffusion into the tailings.

D-A.7.3 Parameter Sensitivity Analysis

D-A.7.3.1 Pyrite Grain Size

Olsen's (Camp Dresser and McKee, 1995) data indicate a large range in cobaltite and chalcopyrite grain sizes. To determine the effect of particle size on PYROX pyrite oxidation rate, a sensitivity analysis was conducted. The Base Case tailings model simulation was conducted assuming a pyrite grain size of 50 microns (radius equal to 25 microns). Olsen (Camp Dresser and McKee, 1995) reported a range of cobaltite and chalcopyrite grain sizes in tailings samples from 4 to 100 microns (CoAsS) and 6 to 200 ($CuFeS_2$) microns, respectively. The Base Case model simulations were re-run assuming pyrite radii of 10 microns and 50 microns.

Model results are plotted in Figures D-A-18 through D-A-21. Figures D-A-18 and D-A-20 show the fraction of sulfide reacted with depth at 10 and 50 years, respectively. Figures D-A-19 and D-A-21 show oxygen concentration with depth for the same time periods. These plots illustrate an increase in the rate of oxidation with decreasing grain size. At early time (10 years), the variation in total sulfate generated between the 10 μm tailings and the 50 μm tailings is significant (33%). At later time (50 years), the variation in total sulfate generated for the 10 μm and 50 μm tailings is small (only a 6% difference). Less variability at later time is attributed to an overall decline in sulfide oxidation rates. As the oxidation front advances in the tailings, oxygen must diffuse to greater depths to contact unreacted sulfide. This results in a decline in the overall rate of oxidation.

Figures D-A-19 and D-A-21 also illustrate that as grain size decreases, the sulfide oxidation front sharpens and the maximum depth of oxygen diffusion decreases. Conversely, as grain size increases, a smearing of the oxidation front is observed and the depth of oxygen diffusion increases. This behavior is interpreted as an indication of a change in the rate-limiting step. For the smaller grain size simulation (10 μm), any oxygen that comes in contact with pyrite is quickly consumed. For the larger grain size simulation (50 μm), the rate at which oxygen diffuses to the sulfide grain exceeds the rate of diffusion into the grain. This results in deeper penetration of oxygen into the tailings as some of the oxygen essentially "bypasses" the pyrite grain without being consumed.

The most important conclusion of this sensitivity analysis with respect to the current study, is that at late time variation in sulfide grain size results in minimal variation in the loading of sulfide oxidation products. Because the oxidation simulations are concerned with 30-year old tailings, accurate definition of grain size appears therefore less important than accurate definition of the total sulfide content of the tailings.

D-A-7.3.2 Moisture Content

Because oxygen diffusion through water is considerably slower than oxygen diffusion through air (by approximately 4 orders of magnitude), an increase in saturation (moisture content) will result in a corresponding decline in sulfide oxidation. Percent reduction in sulfide oxidation versus moisture content for a 3-meter soil cover is shown in Figure D-A-22. This figure illustrates that even at a very low moisture content (0.01), a 3-meter cover is predicted to result in some reduction in sulfide oxidation (approximately 25%). As cover saturation increases, the rate of sulfide oxidation reduction is predicted to increase. For example, an increase in moisture content from 0.05 to 0.10 is predicted to result in a 6% reduction in sulfide oxidation; however for an equivalent increase in moisture content under more saturated conditions (0.30 to 0.35), an 18% reduction in sulfide oxidation is predicted.

For comparison, Figure D-A-22 also shows percent sulfide reduction versus moisture content for a 1-foot and 2-foot soil cover. The effect of cover thickness with respect to sulfide oxidation is discussed in detail below.

D-A.7.3.3 Cover Thickness

The predicted decline in sulfide oxidation rates following cover placement is a function of the cover thickness. Increasing the tailings cover thickness results in a longer path along which oxygen must diffuse to reach tailing sulfides. Fick's first law describes the diffusion of oxygen through a porous medium (Equation 8). The flux of oxygen (F) passing through a given cross section per unit time is equal to the product of the diffusion coefficient (D) and the concentration gradient (dC/dx). As cover thickness increases, path length (x) will increase resulting in a decline in the flux of oxygen and a coincident decline in the rate of sulfide oxidation.

$$F = -D\frac{\partial C}{\partial x} \qquad \text{(Equation 8)}$$

Although a three-meter cover is expected to cover almost 50% of the West Fork Tailings, the cover for the tailings area north of the West Fork channel (~30% of the total tailings area), will be thinner. The northern portion of the West Fork Tailings will in the future be covered by 1-foot of clay overlain by a minimum of 2 feet of overbank deposits. The remaining tailings area (~20% of the total area) is overlain by the West Fork channel, which is lined with two feet of clay (Knight Piésold, 1994c).

To evaluate the effect of a one-foot clay cover overlain by two feet of overbank materials, additional PYROX simulations were conducted. As for the 3-meter cover scenario, PYROX modeling was conducted assuming a range of moisture contents to produce a sulfide reduction versus clay moisture content curve (Figure D-A-23). Simulations were conducted for a range of moisture contents for the 2-foot soil cover overlying the clay (0.01 to 0.2). Up to approximately 70% clay saturation, the moisture content of the soil

cover shows an impact, albeit relatively minor, on the overall effectiveness of the composite cover. Above 70% clay saturation, predicted reductions in sulfide oxidation are essentially independent of the soil moisture content.

D-A.7.3.4 Infiltration Oxygen Source

The PYROX model does not account for oxidation by oxygen present in infiltrating recharge (precipitation). As the discussion below will illustrate, this source of oxygen is insignificant in comparison to sulfide oxidation by gaseous-phase oxygen.

Average annual infiltration through bare tailings with no surface slope is estimated to be 7.8 inches/year. It is predicted that placement of a sloped cover will reduce tailings recharge by 5.6 inches/year, resulting in an average recharge rate of 2.2 inches/year (Appendix D). For each square meter of tailings, this equates to a recharge volume of approximately 56 litres per year. The solubility of oxygen in water exposed to water-saturated air at atmospheric pressure and a temperature of 10 °C is approximately 11.3 mg/L. Assuming an oxygen concentration of 11.3 mg/L, recharge oxygen loading per meter square of tailings is 0.6 grams (0.02 mol). Based on the reaction stoichiometry for pyrite oxidation presented in Equation 4, 0.02 moles of oxygen will generate 0.01 moles of sulfate (1 g).

The PYROX modeling results predicted a sulfide loading rate of 6.6 kg/m^2 in year 34 of oxidation. Total sulfide generation over the 34-year period was 428 kg/m^2. Assuming 1 gram of sulfate is generated per year by dissolved phase oxygen, this source accounts for significantly less than 1% of the total sulfate generated in year 34 and over the 34-year period.

In addition, the PYROX model does not account for oxidation by oxidized groundwaters that flow beneath the impoundment or infiltrate along the sides of the impoundment. These sources of oxygen are, however, expected to result in only limited sulfide oxidation. With respect to groundwater flow beneath the tailings, the predominant groundwater flow path is believed to be through the alluvium, not through the tailings. This is supported by water level measurements in monitoring wells beneath the impoundment that indicate levels are within the natural unconsolidated deposits. Limited contact between oxygen in flowing groundwater and the tailings is therefore predicted. Dissolved oxygen concentrations in wells below the tailings impoundment were plotted to evaluate trends (Figure D-A-24), which may support or reject oxygen depletion due to sulfide oxidation. The dissolved oxygen concentration profiles in alluvium wells do not consistently support declining oxygen levels along this flow path, although declines may occur seasonally. Because the validity of groundwater oxygen measurements is questionable, particularly values that exceed 100% saturation with respect to atmospheric oxygen, the observed dissolved oxygen trends may not be particularly meaningful. In addition, oxygen consumption may also be attributed to other reactions (e.g., oxidation of organic material). Deposition of the West Fork tailings likely took place on top of organic materials present in the natural drainage system. Wood chips were indeed identified at the base of the West Fork tailings in two of the Knight Piésold (1994b) well logs (WF-3 and WF-4).

Infiltration along the sides of the impoundment may provide a source of oxygen; however, this source is expected to contact a limited tailings thickness. In addition, infiltration along the sides is likely limited due to a higher proportion of precipitation reporting to runoff than on the top surface. As sulfides in this zone are depleted, the significance of this source will lessen.

D-A.8 CUMMULATIVE BENEFITS OF COVER PLACEMENT

To estimate a reduction in sulfide oxidation for the entire tailings impoundment, predicted sulfide oxidation reduction rates were apportioned on the basis of relative surface area coverage. As mentioned previously, the 3-meter soil (10-foot), composite 1-foot clay/2-foot soil and clay cap provide coverage for 50%, 30% and 20%, respectively, of the tailings area. By assuming a range of moisture contents for each type of cover, a range of predicted reduction in sulfide oxidation was determined.

The expected range in moisture content for the 3-meter cover was determined by extracting the highest and lowest year-end moisture contents predicted by the HELP model for a 3-meter soil layer over a 50-year simulation. This resulted in a range in moisture content from 0.14 to 0.20 with an average of 0.18. This is predicted to result in a range of sulfide reduction from 37% to 46% (Figure D-A-22).

Because complete saturation for a clay layer is an inherent assumption in HELP, the HELP model could not be applied to predict a range of clay moisture contents. For the clay, a minimum saturation of 70% was assumed. This is equivalent to the minimum degree of saturation generally required to place a clay cover (personal communication with Frank Shuri, Golder). Average and high moisture contents of 80% and 90% were assumed based on typical design specifications for clay covers. Based on these moisture contents, for the 1-foot clay cover, reduction in sulfide generation was predicted to range from 30% to 90%. The 2-foot clay cover was assumed to provide an equivalent benefit. Additional PYROX modeling was performed to confirm the validity of this assumption.

Table D-A-11 presents the cumulative predicted effectiveness of the proposed cover for the West Fork Tailings Impoundment. The effectiveness of existing covers on part of the impoundment (2-foot clay and 3-meter soil) can also be identified from the table. For the proposed cover, the cumulative percent reduction in sulfide oxidation is predicted to range from approximately 30% to 70% relative to an uncovered scenario.

TABLE D-A-11
Cumulative Benefits of Tailings Cover

Cover Type	% Coverage	Moisture Content			% Reduction in Sulfide Oxidation		
		Low	Average	High	Low	Intermediate	High
2-ft clay	20%	0.30	0.34	0.37	30%	55%	92%
1-ft clay + 2-ft soil	30%	0.30	0.34	0.37	30%	55%	92%
3-m soil	50%	0.14	0.18	0.20	37%	41%	46%
Cumulative Predicted Reduction					**34%**	**48%**	**69%**

It is important to realize that the predicted reduction refers to the reduction in sulfide oxidation relative to a no-cover (bare tailings) simulation. Because the clay cap below the West Fork Tailings channel was constructed in the early 1990s, some of the benefits afforded from this cap may be reflected in the current water quality monitoring. This reduction should therefore not be interpreted as a reduction in comparison to current conditions. Figures D-A-25 and D-A-26 show cobalt loading to Blackbird Creek from the West Fork Tailings Impoundment over time as determined by the difference in load between BBSW-03A and BBSW-02. Between September 1995 and October 1998, a decline in fall loading was observed. Although this decline in loading may in part be attributed to a reduction in sulfide oxidation due to the clay cap below the West Fork Channel, it is more likely attributed to the installation of the cutoff wall upstream of the tailings impoundment in 1993. Between 1998 and 2001, fall cobalt loading from the West Fork Tailings Impoundment was relatively constant. Spring loading trends are different from those in the fall. Although a decline was observed between Spring 1995 and 1998, cobalt loading subsequently increased in 1999. Because travel times through the tailings are predicted to be on the order of years to tens of years, reductions in sulfide loading due to cover placement may not be observable for a number of years following placement of the cover.

It should also be noted that certain areas of the tailings will not benefit from any cover placement. For example, at this time no cover is planned for the tailings slope facing Blackbird Creek. This area has not been accounted for in the above calculations. This slope accounts for approximately 25% of the total tailings impoundment area (based on the plan view); however, the volume of tailings represented by this area is considerably less than 25%. Due to the uncertainties associated with the oxidation modeling, omission of this area was not considered significant.

D-A.9 SUMMARY OF MODEL ASSUMPTIONS AND LIMITATIONS

The PYROX modeling outlined in this memo was conducted to evaluate potential benefits to West Fork seepage quality from the placement of overbank materials as a cover on the West Fork Tailings Impoundment. This modeling began as a comparative evaluation of a no cover versus cover scenario. As the feasibility study progressed, it

became necessary to also evaluate the benefits of a clay cover. The goal of the modeling effort therefore changed from a sensitivity analysis of the factors affecting sulfide oxidation (e.g. moisture content, length of oxygen diffusion path, sulfide content, grain size) and an evaluation of the impacts of changes in these factors due to the placement of 3-meter cover, to a performance assessment for an engineered clay cover. The reader should be cognizant that the authors of this memorandum are not engineers with experience in the design of clay caps. Although this modeling effort is valid with respect to how oxygen may diffuse through a clay cap of a specific thickness and specific moisture content, this memorandum does not address the integrity of the clay cap. For example, the effect of freezing and thawing on cap performance was not evaluated as part of this study. It should also be noted that the HELP model, which provided input parameters necessary for the sulfide oxidation modeling with PYROX, may not be the ideal tool for rigorous performance evaluation of a clay cover.

As with any modeling effort that aims to predict future behavior using a representation of current conditions, there are a number of assumptions and limitations inherent in this analysis. These assumptions and limitations were discussed throughout this document. It should be noted that despite these limitations, this modeling is a valid tool in evaluating the potential relative benefits of a cover. Based on the basic principals of sulfide oxidation, a cover should result in an improvement in water quality. The magnitude of this improvement is difficult to quantify with a high degree of certainty without extensive characterization due to the complexity of the modeled system. Because estimates of travel times through the tailings vary from years to tens of years, the benefits of cover placement may not be observed for years. Finally, without knowledge of whether the current water quality reflects any benefits of the existing cover, a baseline from which to apply predicted reductions is difficult to establish. Although it is likely that the effects of the clay cap beneath the West Fork channel and the 3-meter overbank cover have not yet been realized, this statement cannot be proven.

D-A.10 MODEL SUMMARY AND CONCLUSIONS

In the long run, the placement of a cover on the West Fork Tailings Impoundment is predicted to result in a decline in sulfide oxidation rates, relative to the no cover alternative. Placement of a cover containing sulfides may result in an initial increase in the loading of sulfide oxidation products. The magnitude and duration of this increase is dependent on the sulfide content of the cover material. Based on the results of cover material sampling in 2001, which indicated an average cover sulfide content of 0.02%, no initial increase is predicted for a 3-meter cover. Once sulfides in the cover material are depleted, sulfide oxidation rates are expected to stabilize at a lower level than in the uncovered scenario. A reduction in loading of between 30% and 70% is predicted. For cobalt, this should result in an equivalent decline in loading. Due to secondary controls on copper concentrations (i.e. covellite precipitation), a 30% to 70% decline in copper loading is not expected. Instead, copper concentrations are likely to remain approximately constant.

D-A.9 REFERENCES

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FIGURE D-A-24
West Fork Groundwater Dissolved Oxygen Concentrations

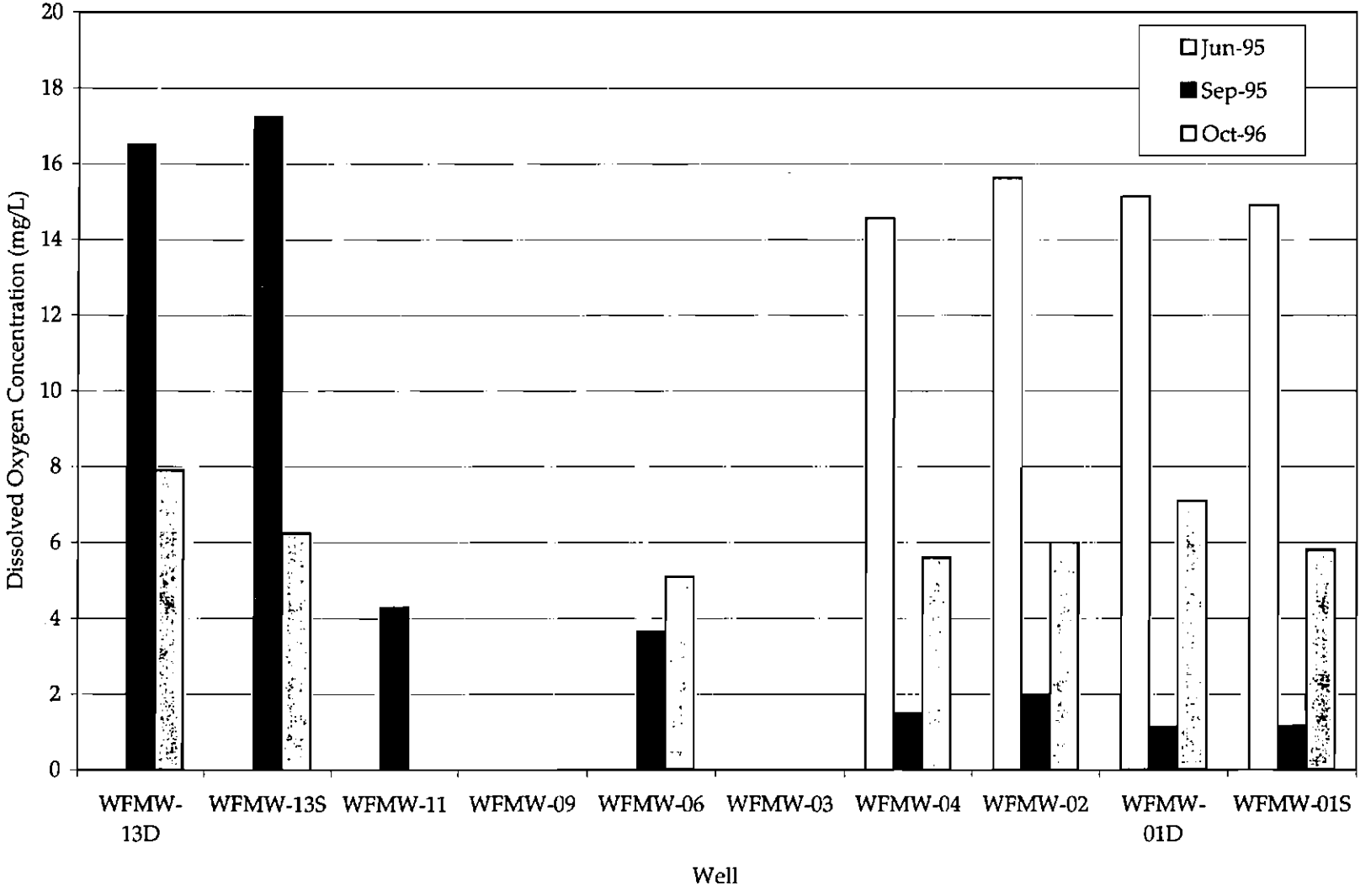


FIGURE D-A-25
Fall West Fork Impoundment Cobalt Loading to Blackbird Creek
Between BBSW-03A and BBSW-02

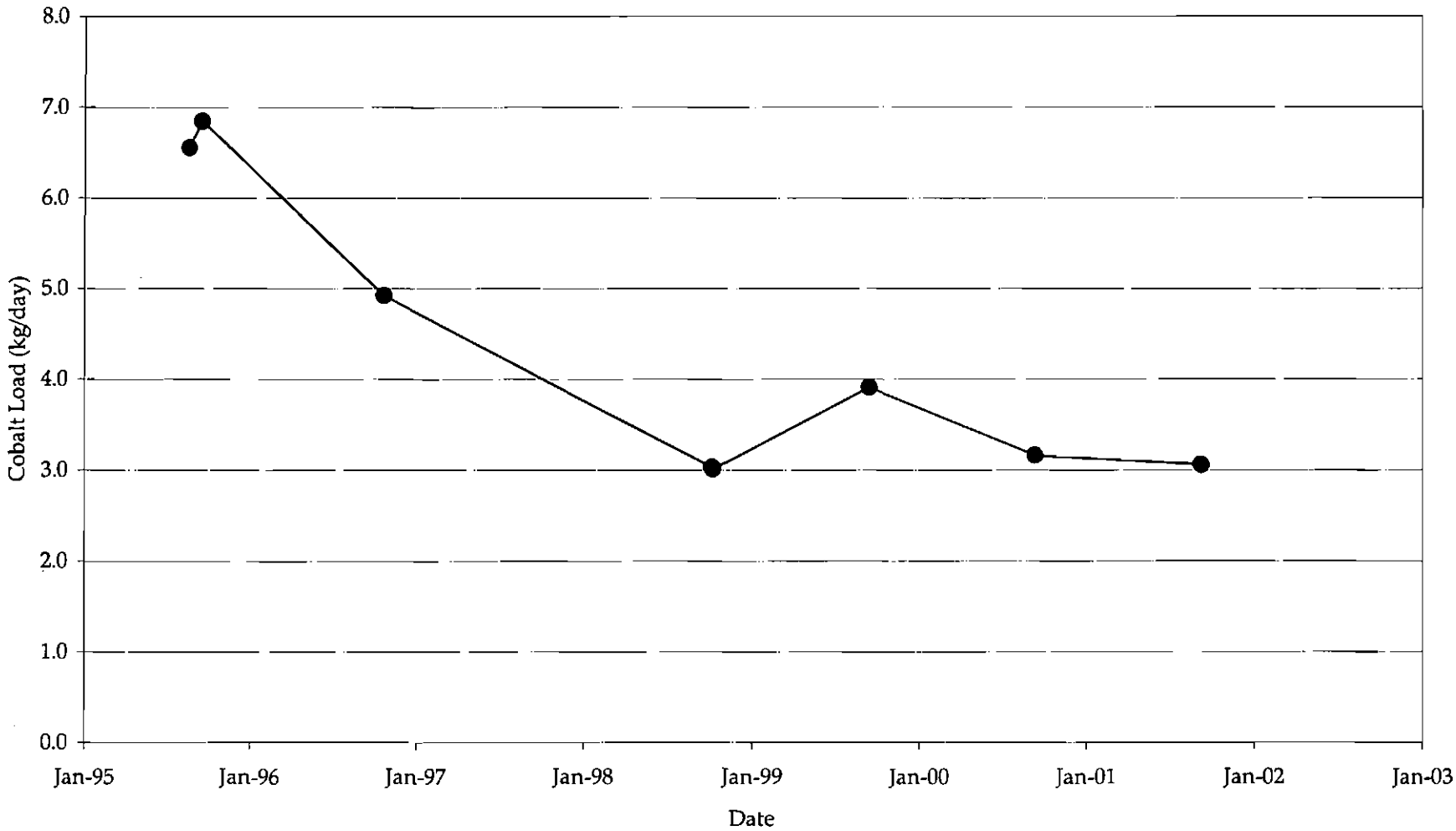


FIGURE D-A-26
Spring West Fork Impoundment Cobalt Loading to Blackbird Creek
Between BBSW-03A and BBSW-02

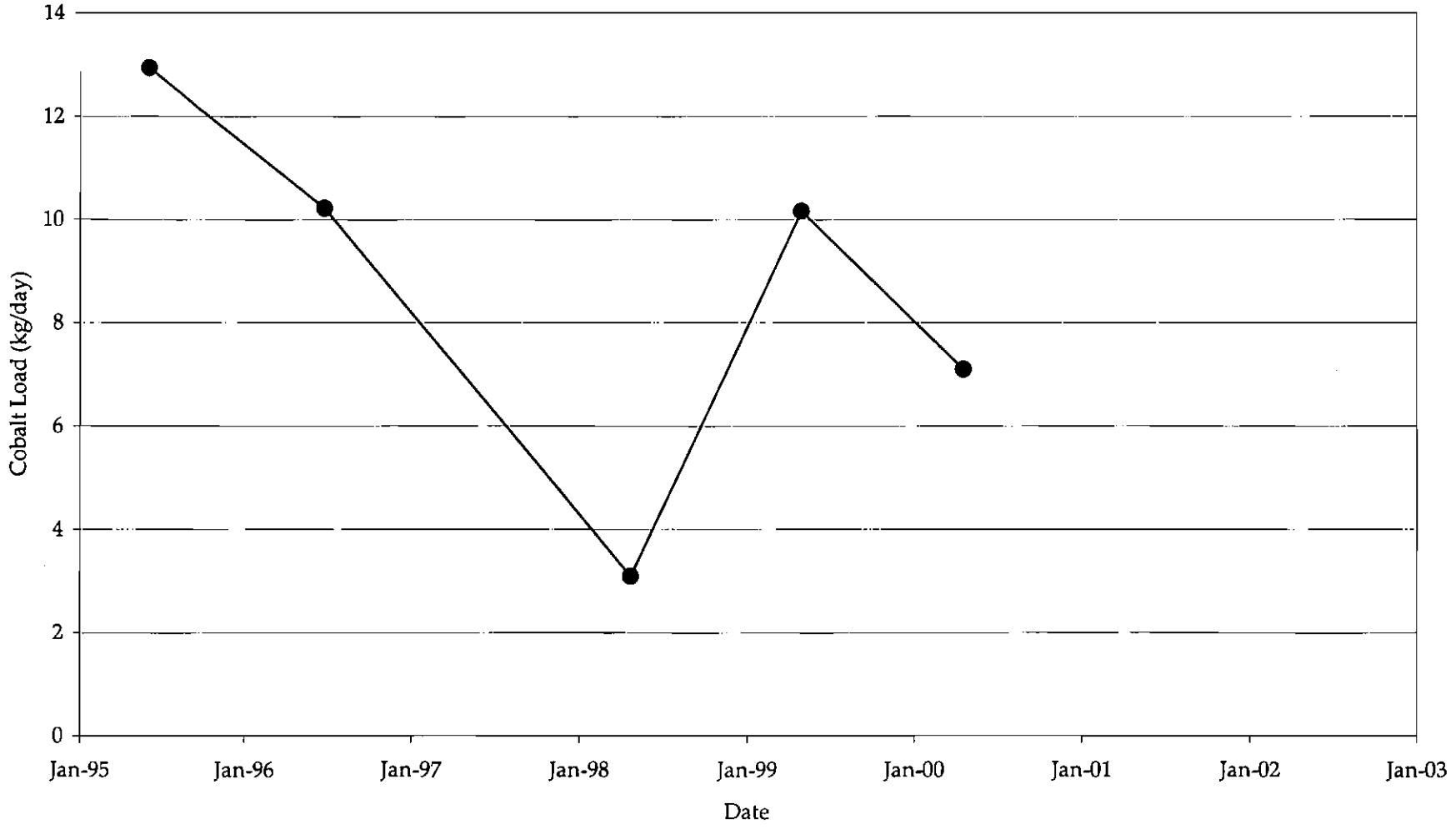


FIGURE D-A-1
Blackbird Dissolved Cobalt Concentrations

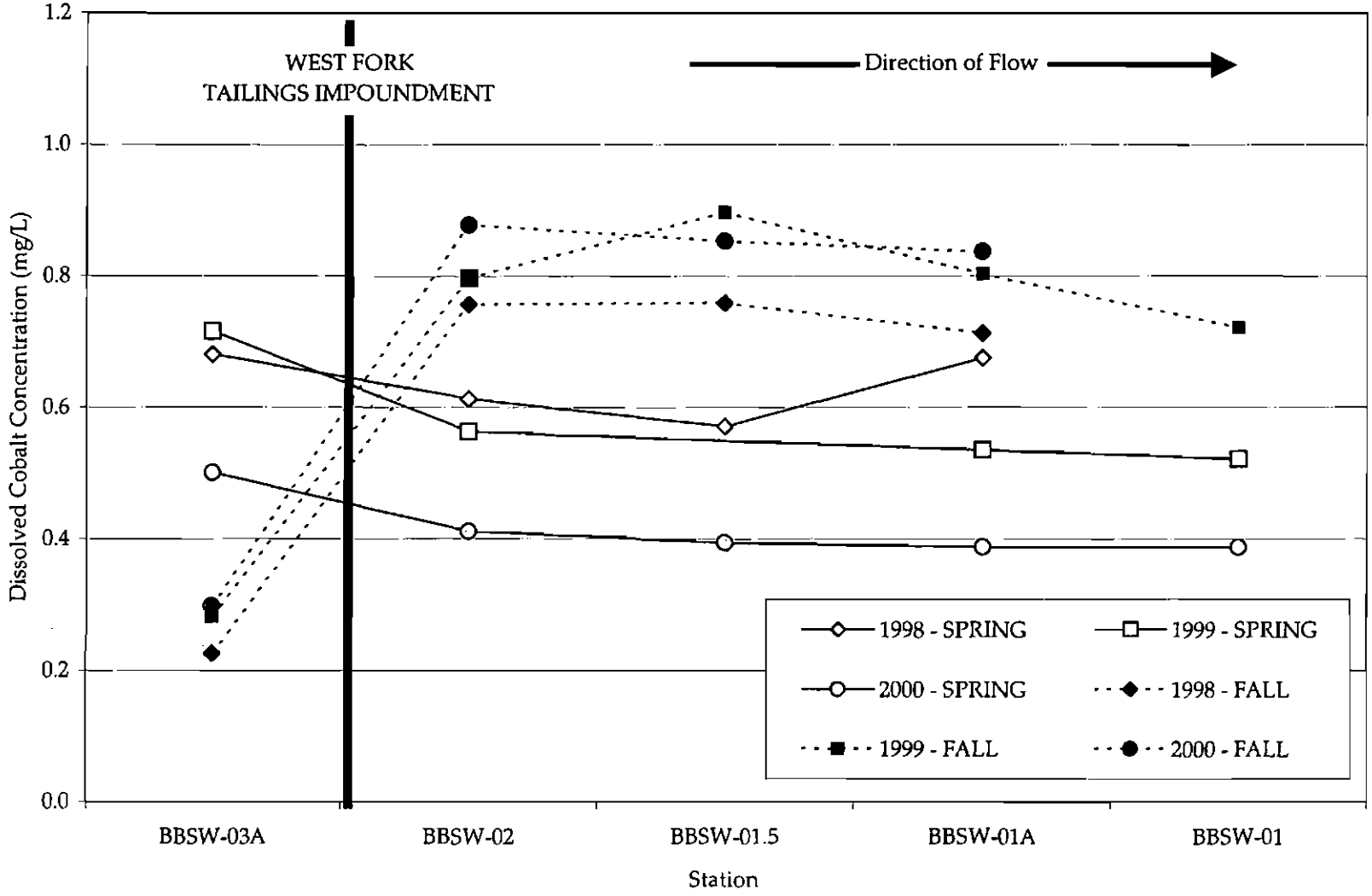


FIGURE D-A-2
Blackbird Dissolved Iron Concentrations

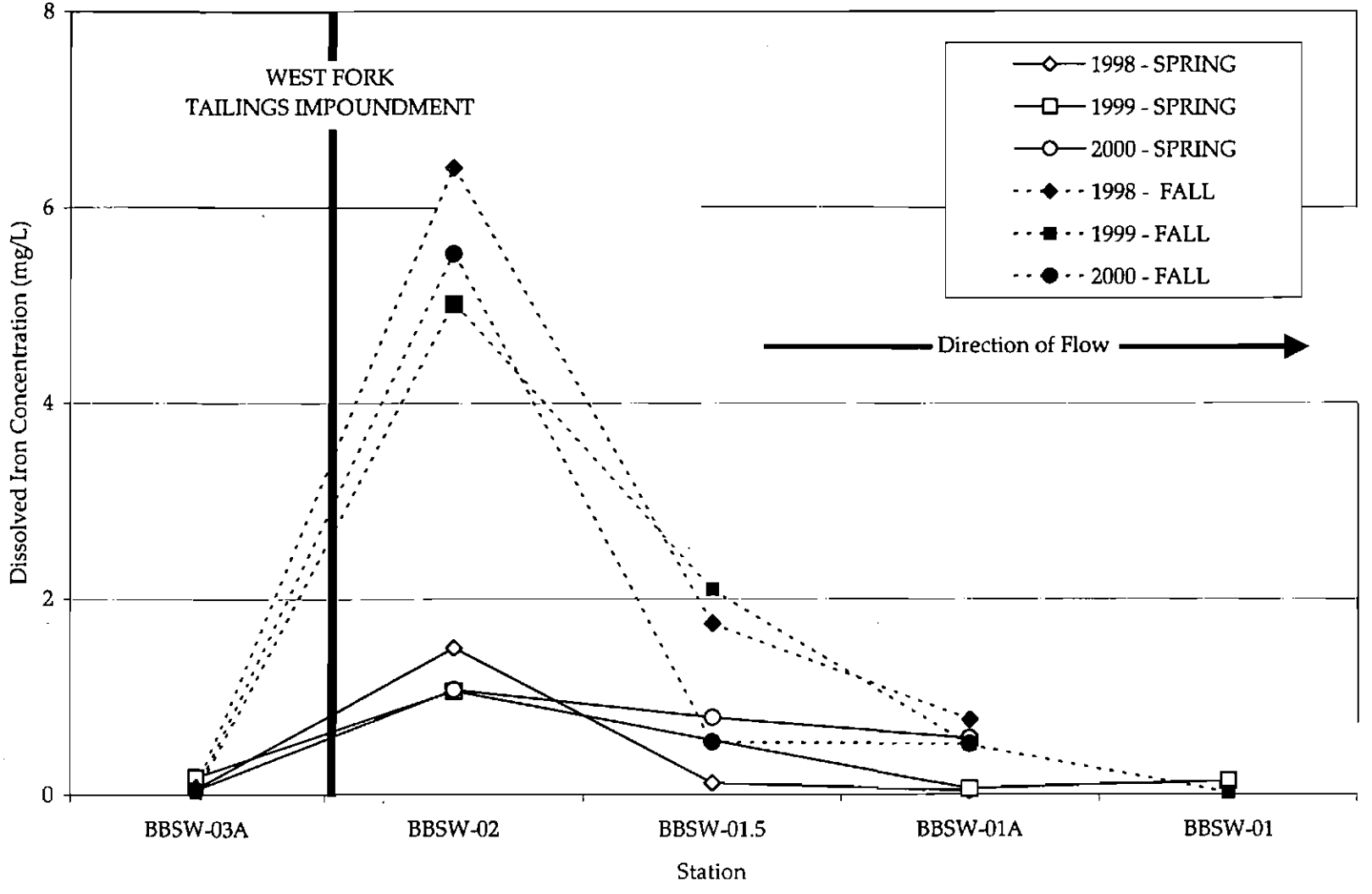


FIGURE D-A-3
Blackbird Dissolved Copper Concentrations

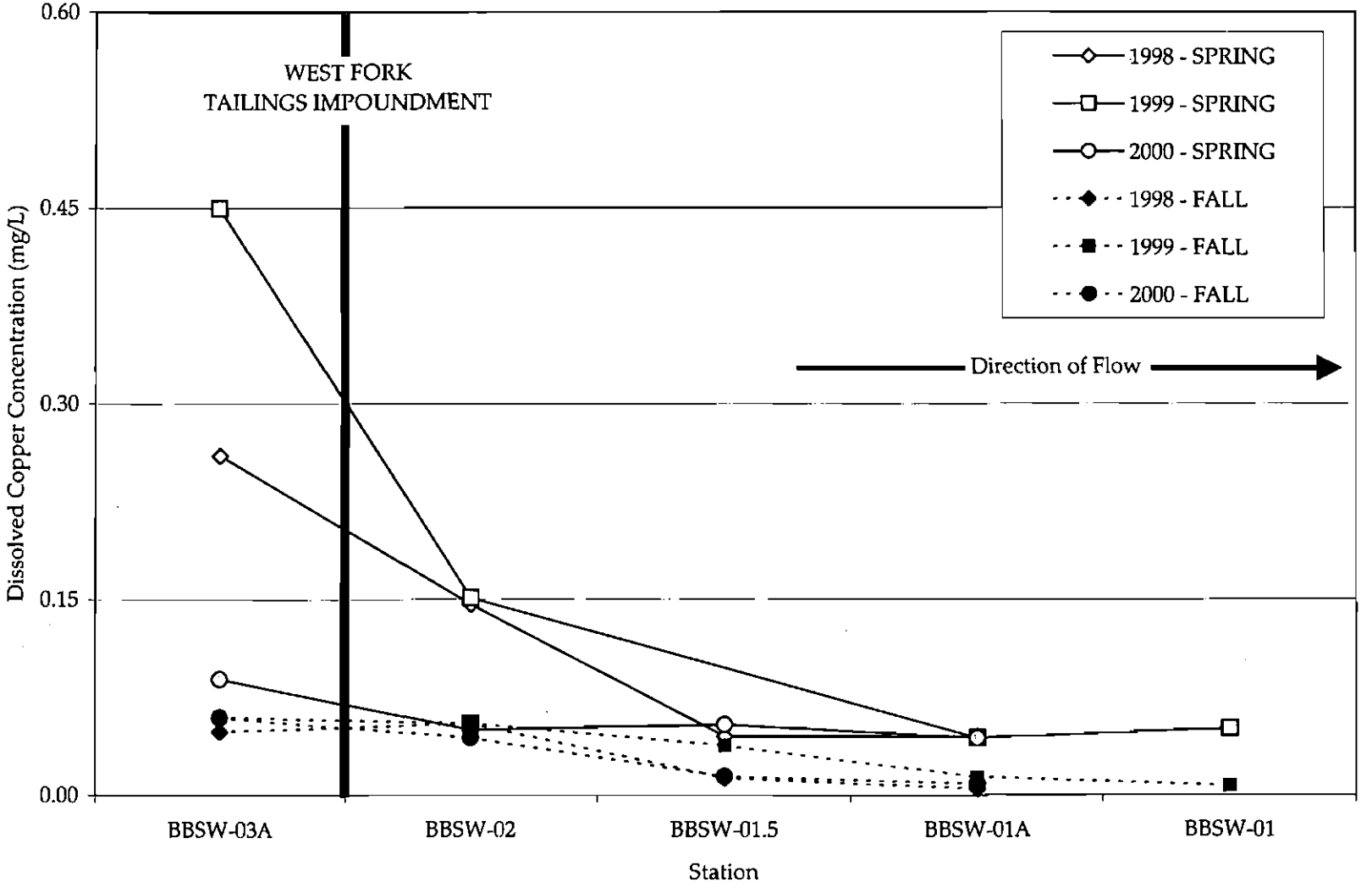
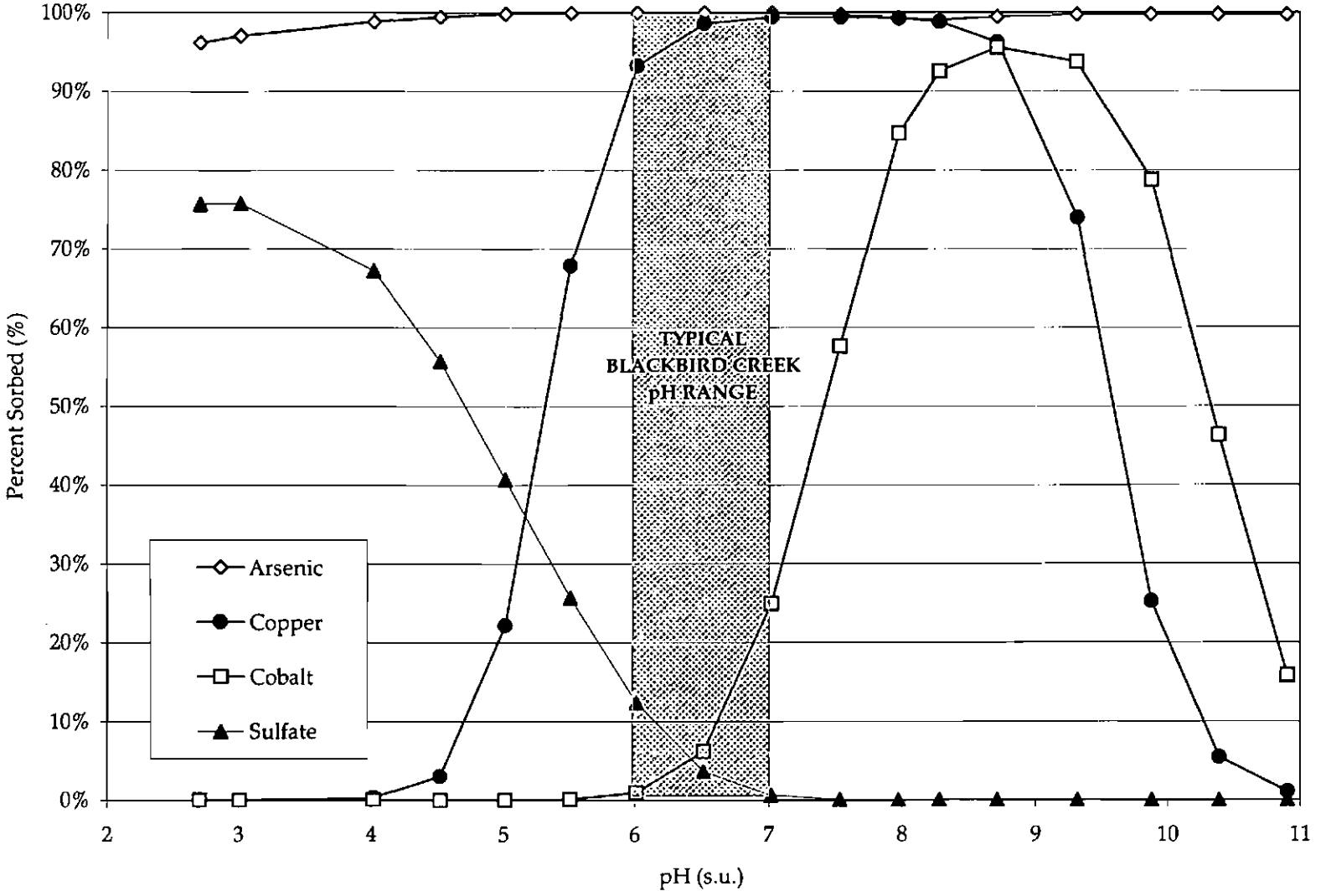
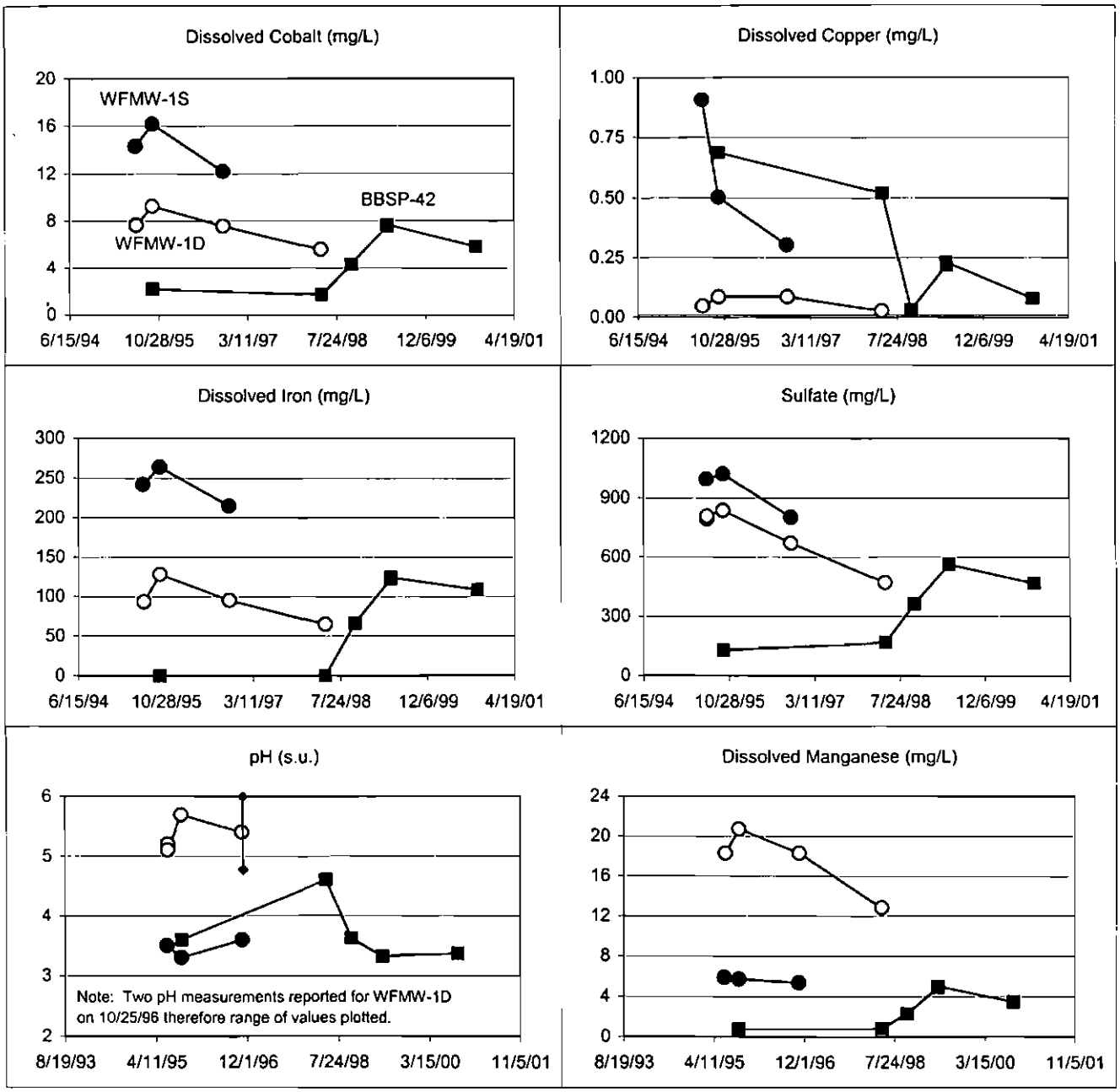


FIGURE D-A-4
Adsorption Edges



Note: Adsorption edges presented in this figure were created using PHREEQC for a specific water quality and adsorbent concentration.

FIGURE D-A-5
West Fork Water Quality



LEGEND

- ○ WFMW-1D
- ● WFMW-1S
- ■ BBSP-42

FIGURE D-A-9
Covellite SI for WFMW-01S Versus pe

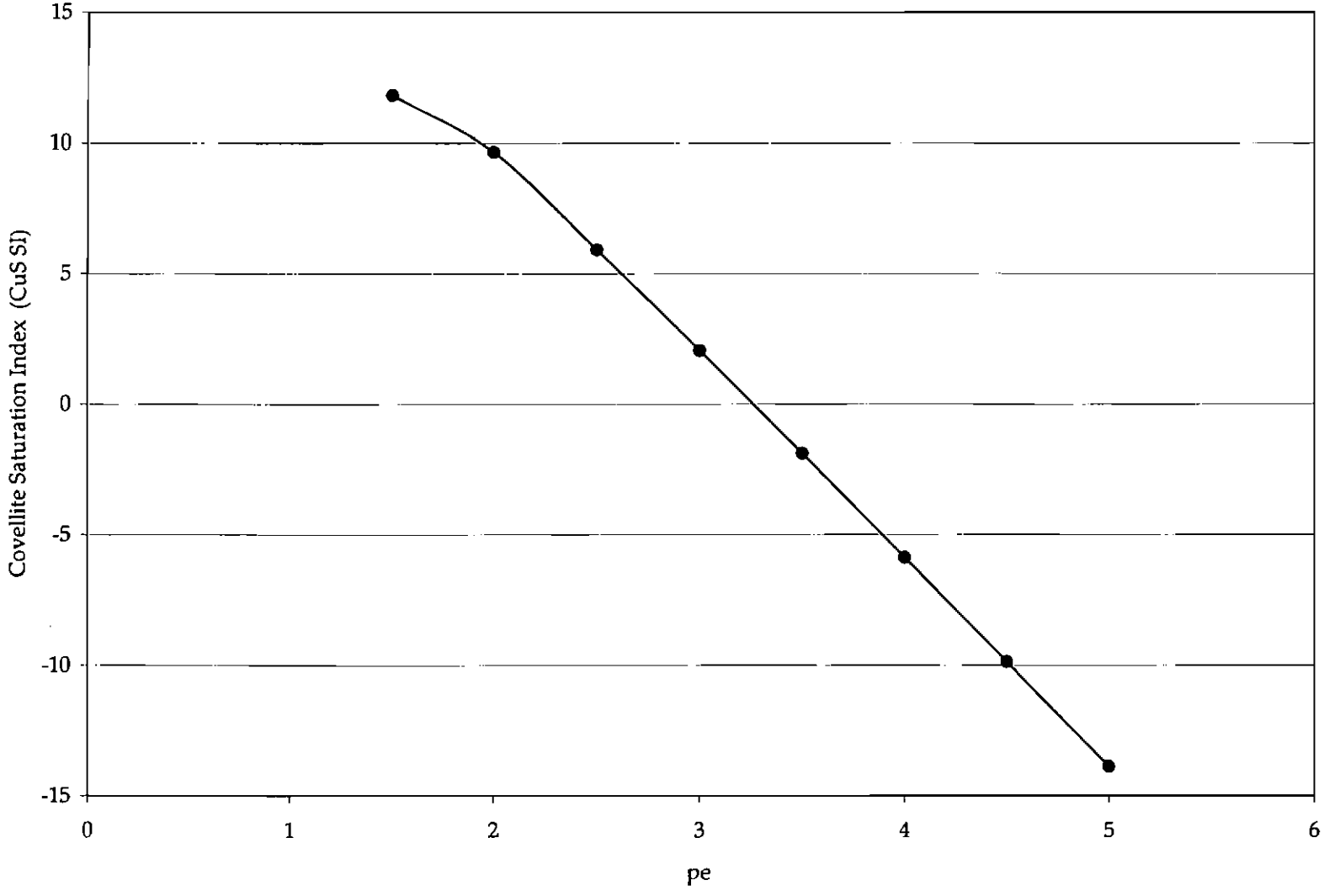


FIGURE D-A-10
Knight Piesold West Fork Tailings Sulfur Concentrations

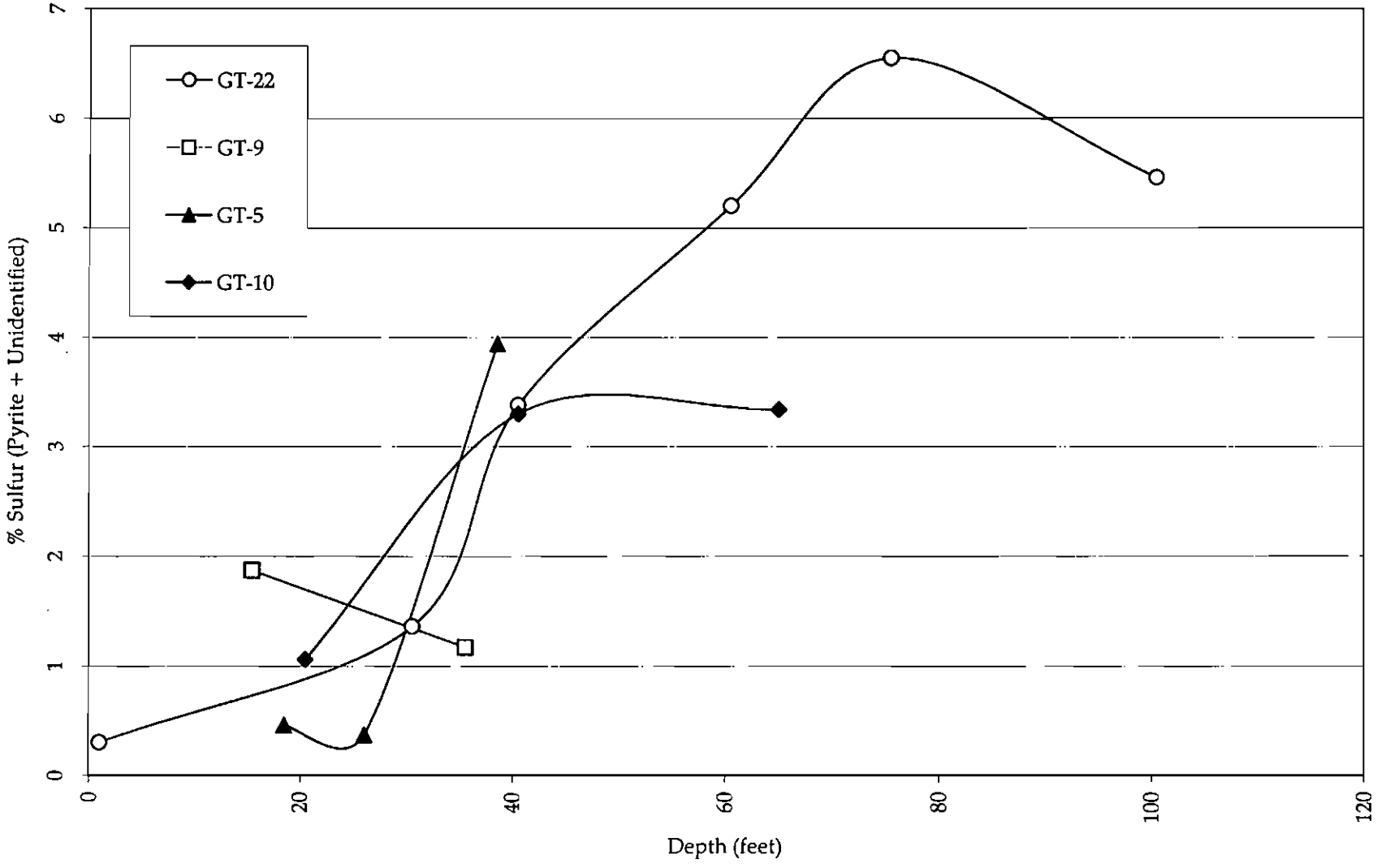


FIGURE D-A-11
Overbank Sulfur Concentrations Histogram

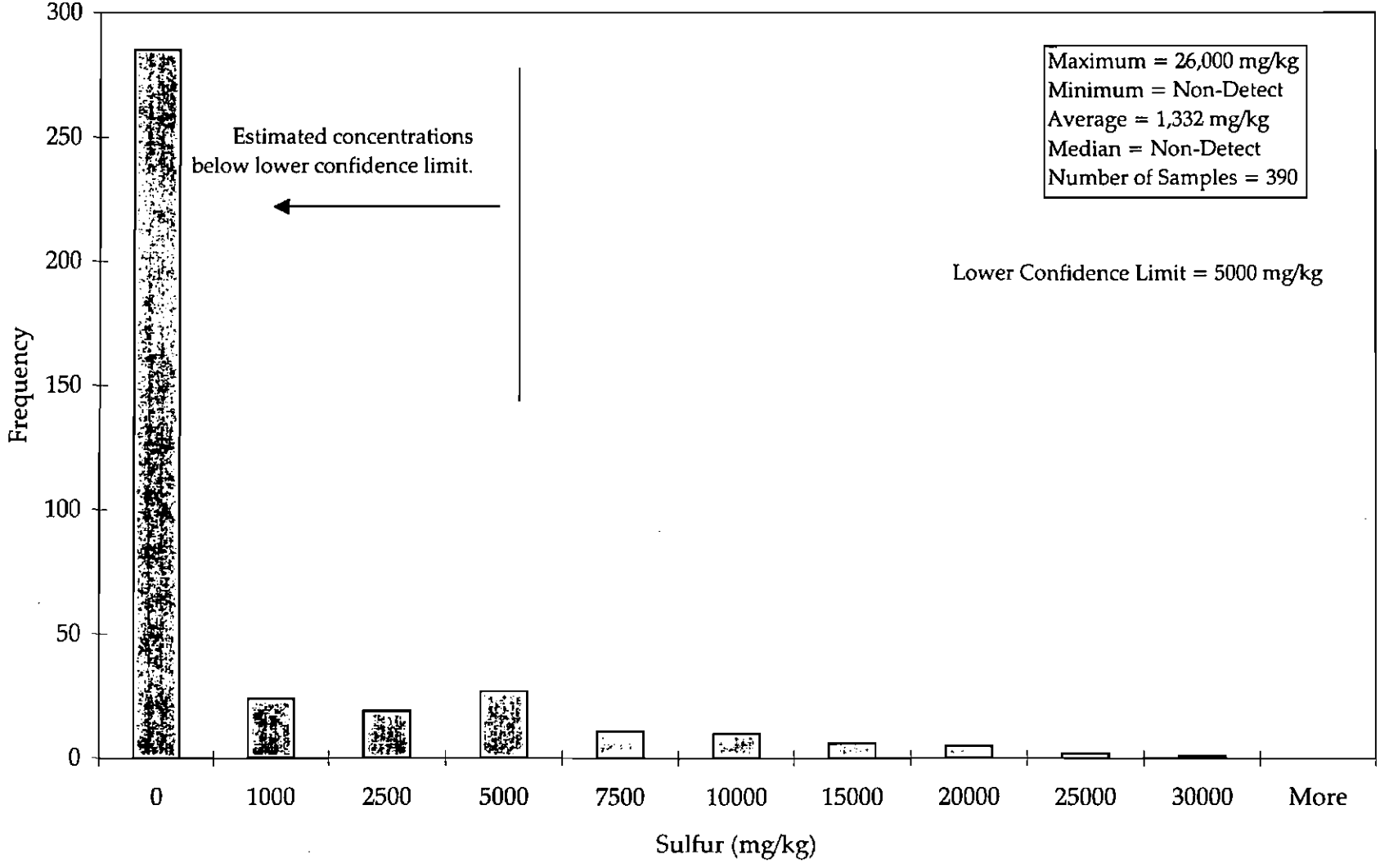


FIGURE D-A-12
Overbank Copper Concentrations Histogram

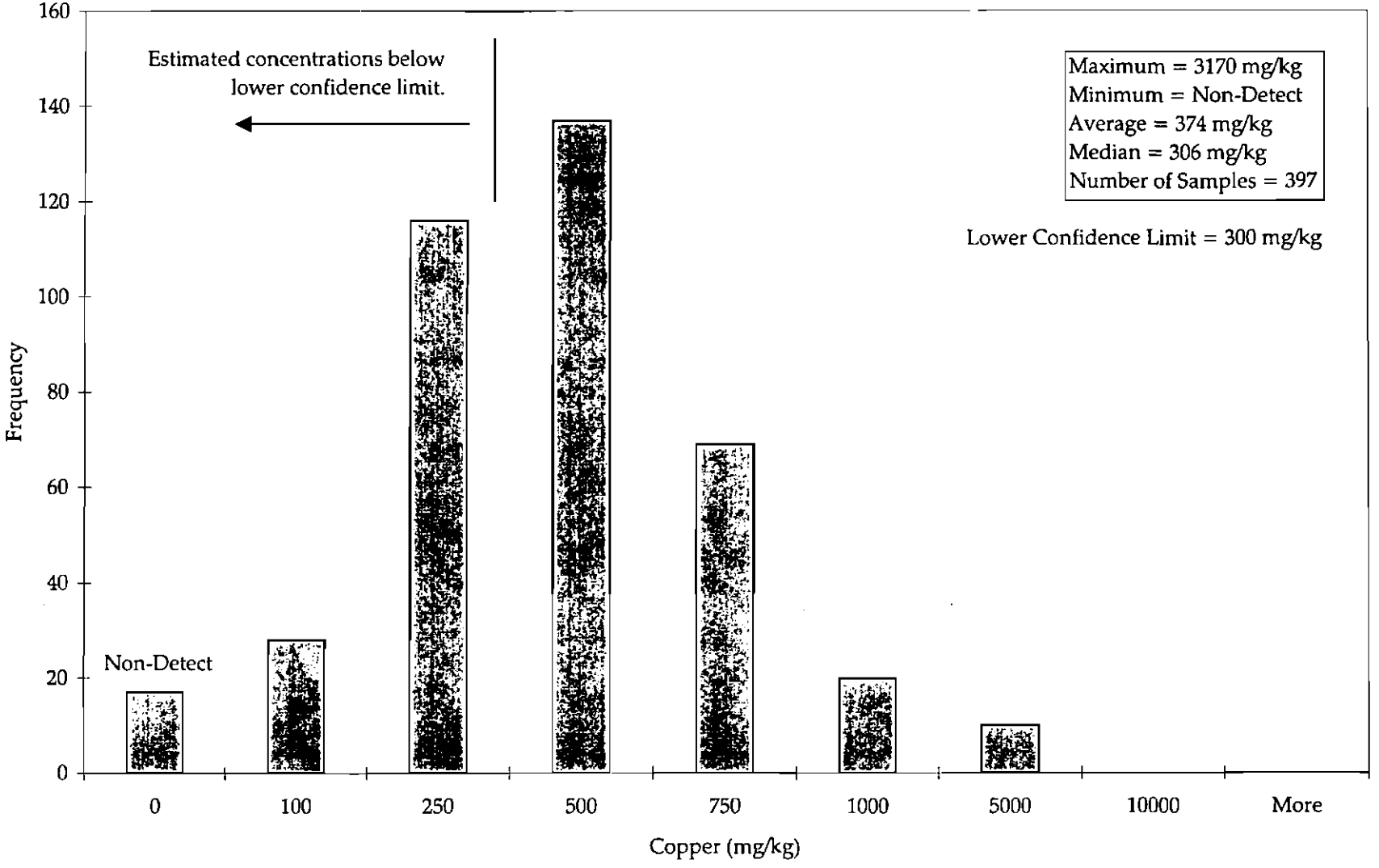


FIGURE D-A-13
Tailings Copper Concentrations Histogram

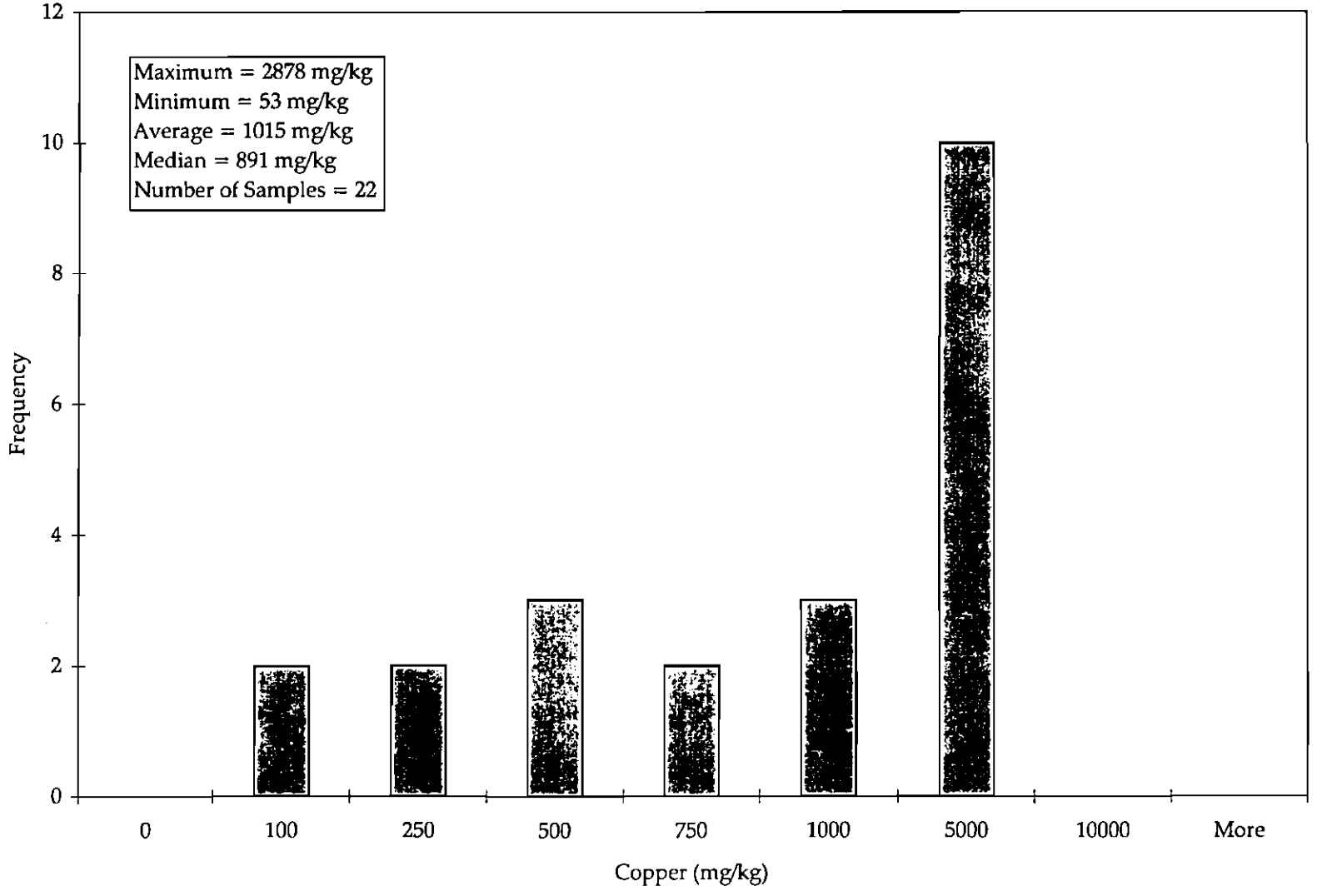


FIGURE D-A-14
Tailings PYROX Sulfide Oxidation Modeling - Reacted Sulfides
Time = 34 years

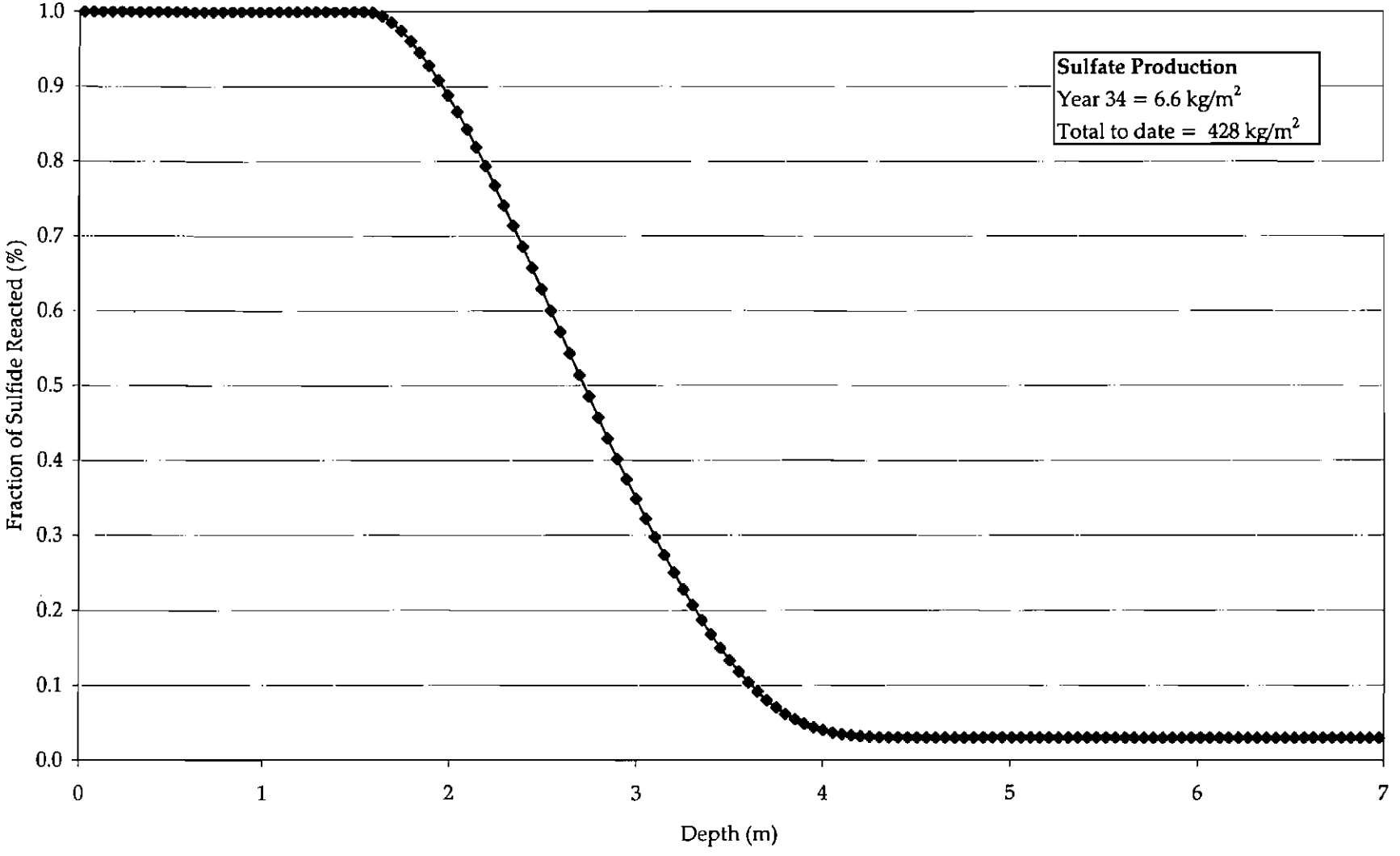


FIGURE D-A-15
Tailings PYROX Sulfide Oxidation Modeling - Oxygen Concentration
Time = 34 years

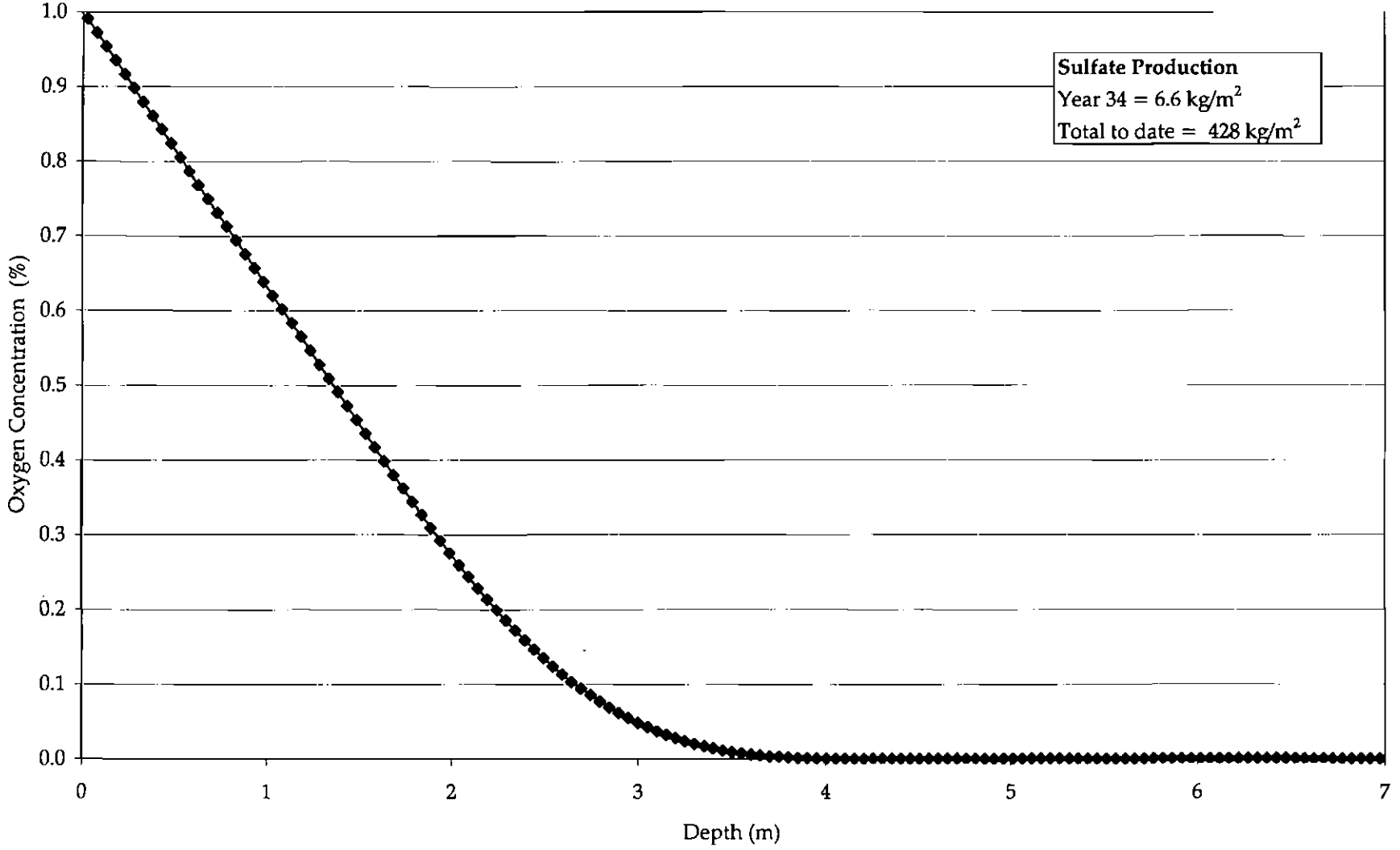


FIGURE D-A-16
No Cover Versus 3-Meter Cover Simulation

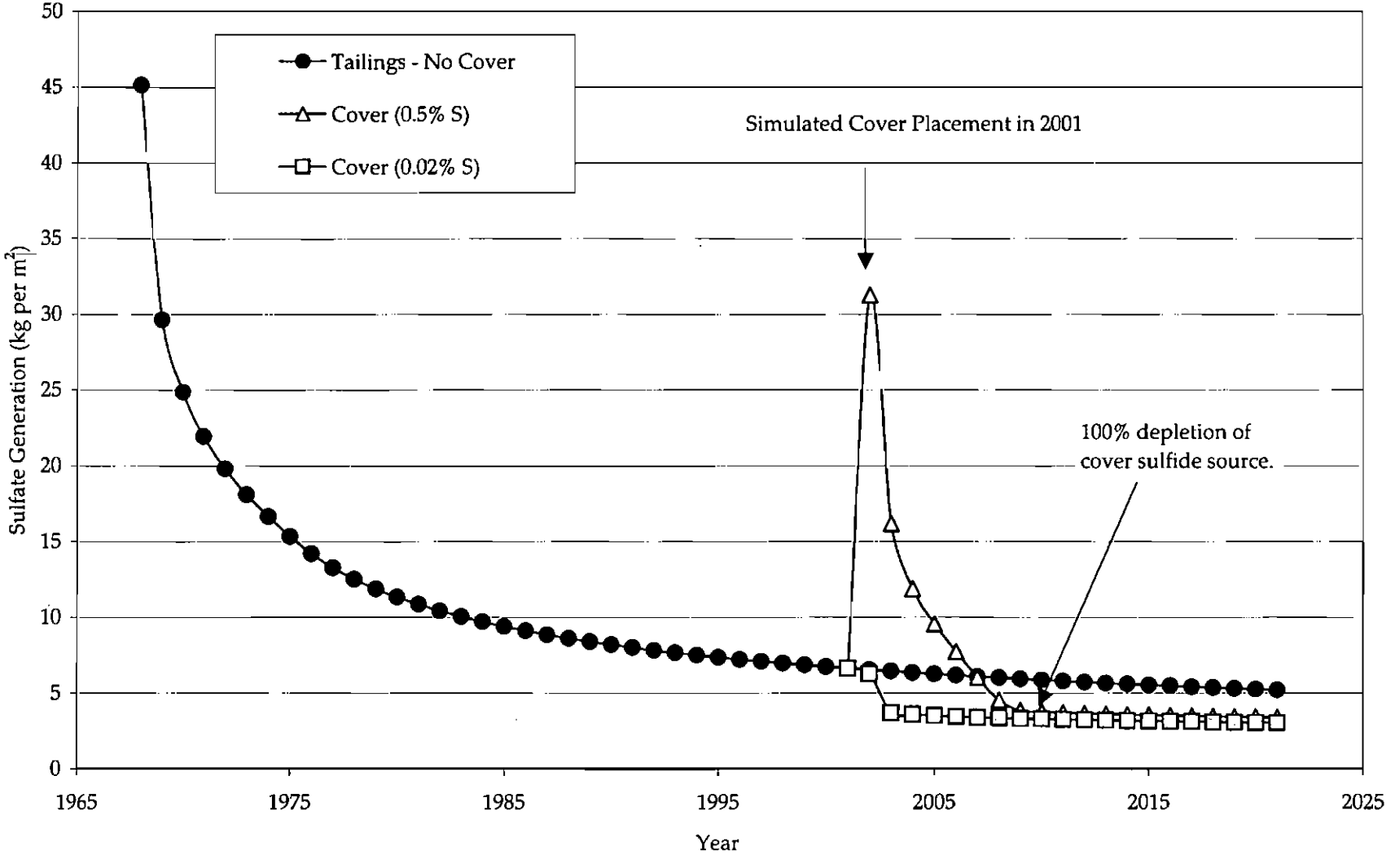


FIGURE D-A-17
Sulfate Generation Relative to No Cover Simulation

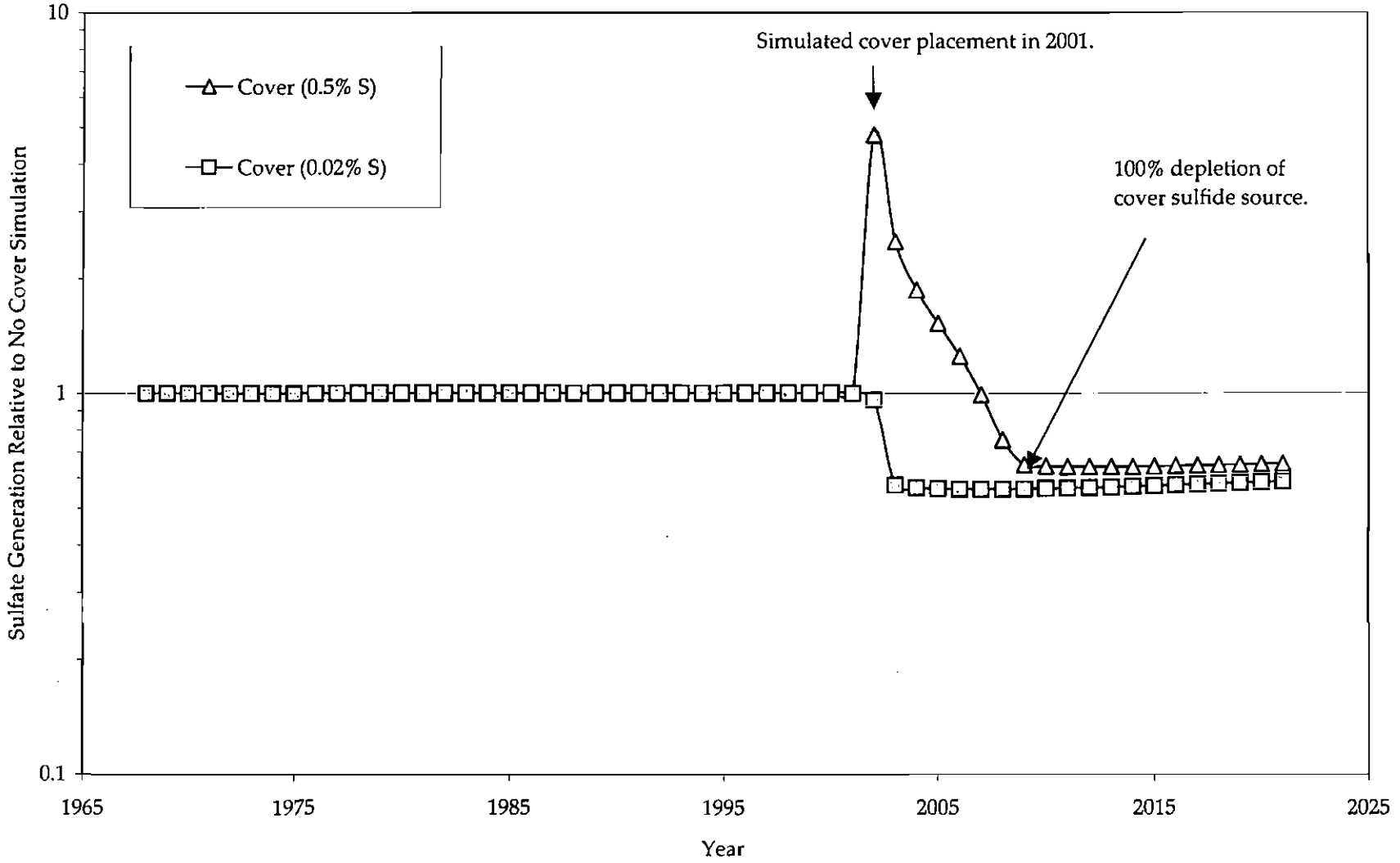


FIGURE D-A-18

Pyrite Grain Size Sensitivity Analysis - Reacted Sulfides

10 Years

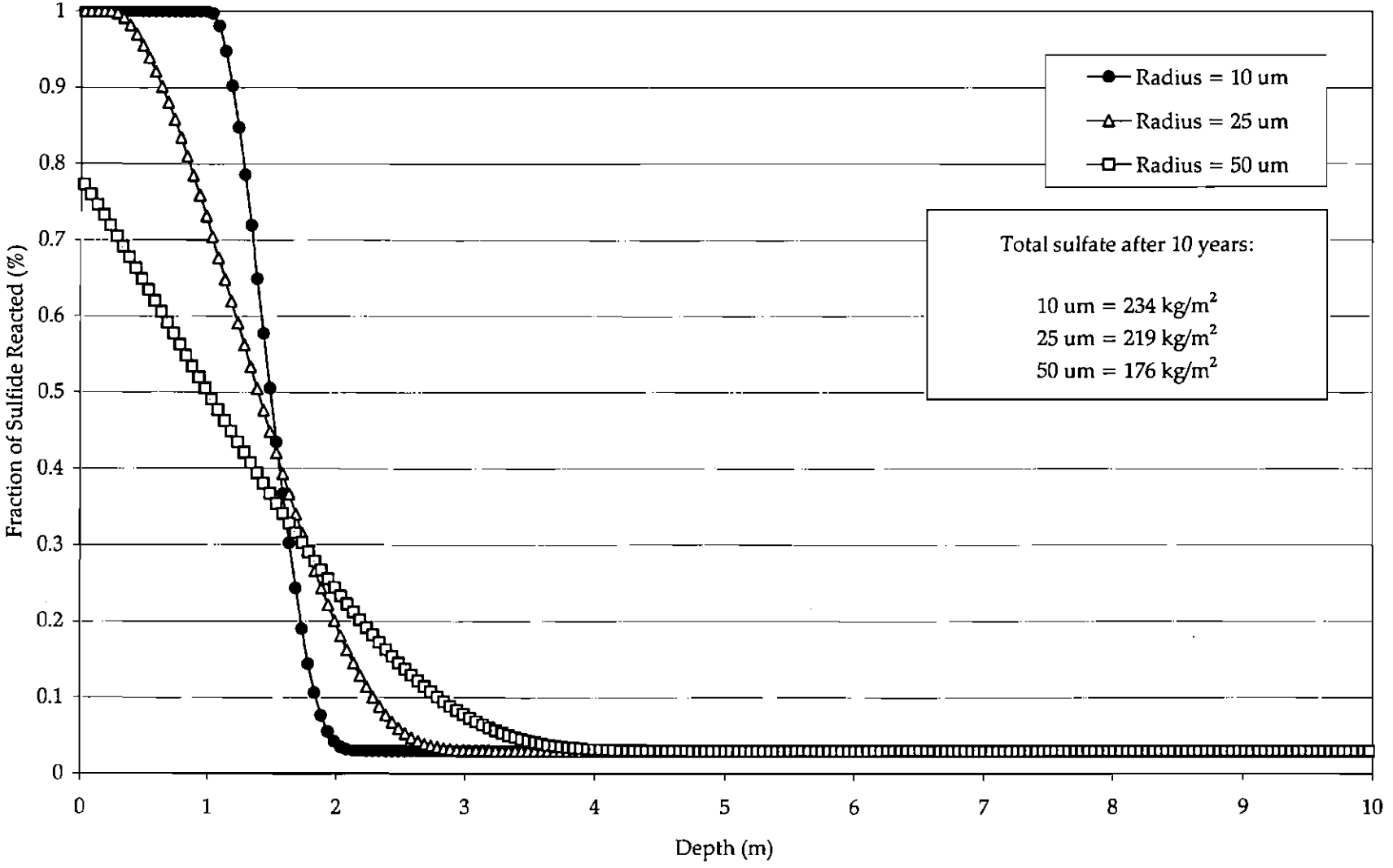


FIGURE D-A-19

Pyrite Grain Size Sensitivity Analysis - Oxygen Concentrations

Year 10

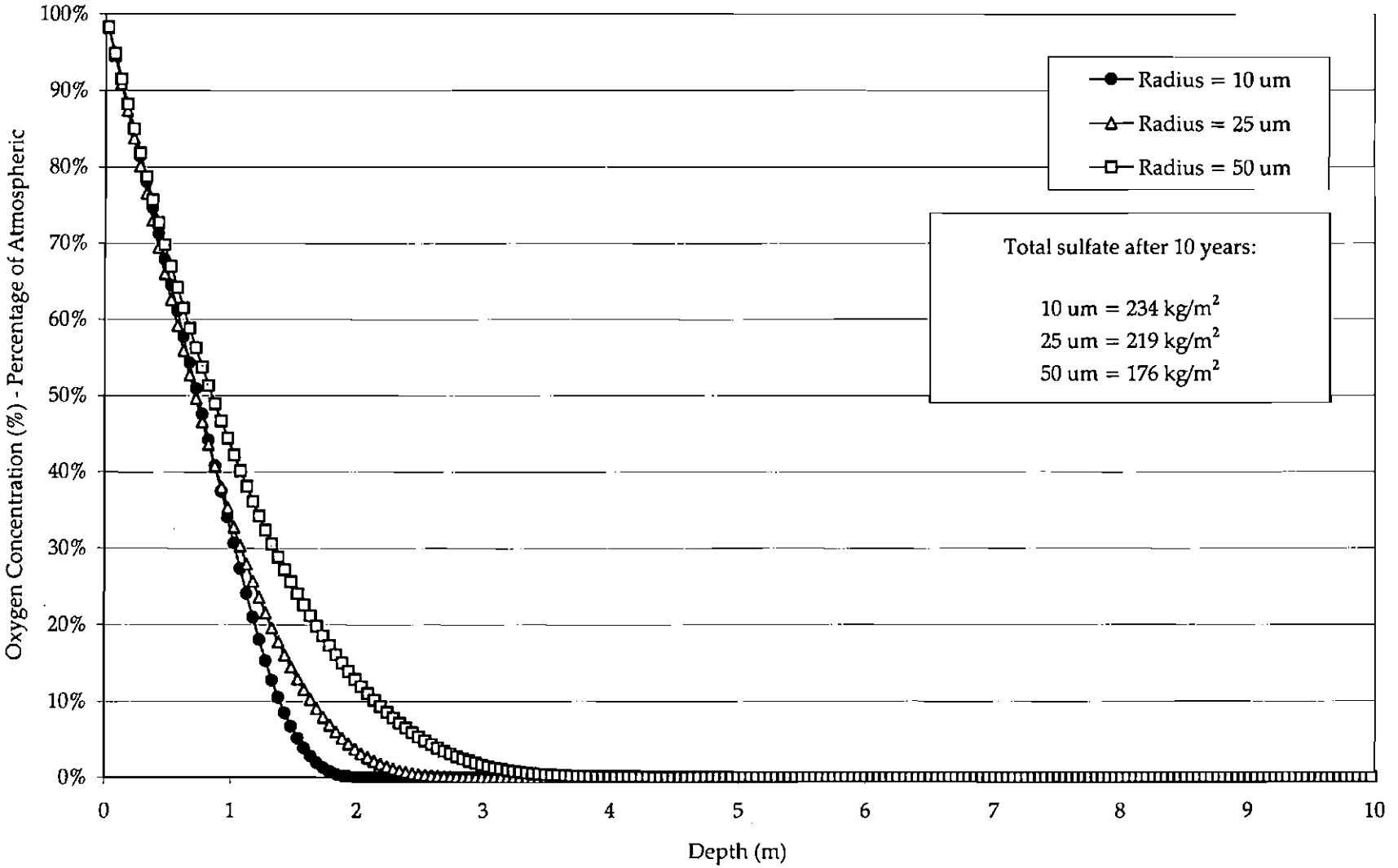


FIGURE D-A-20
Pyrite Grain Size Sensitivity Analysis - Reacted Sulfides
50 Years

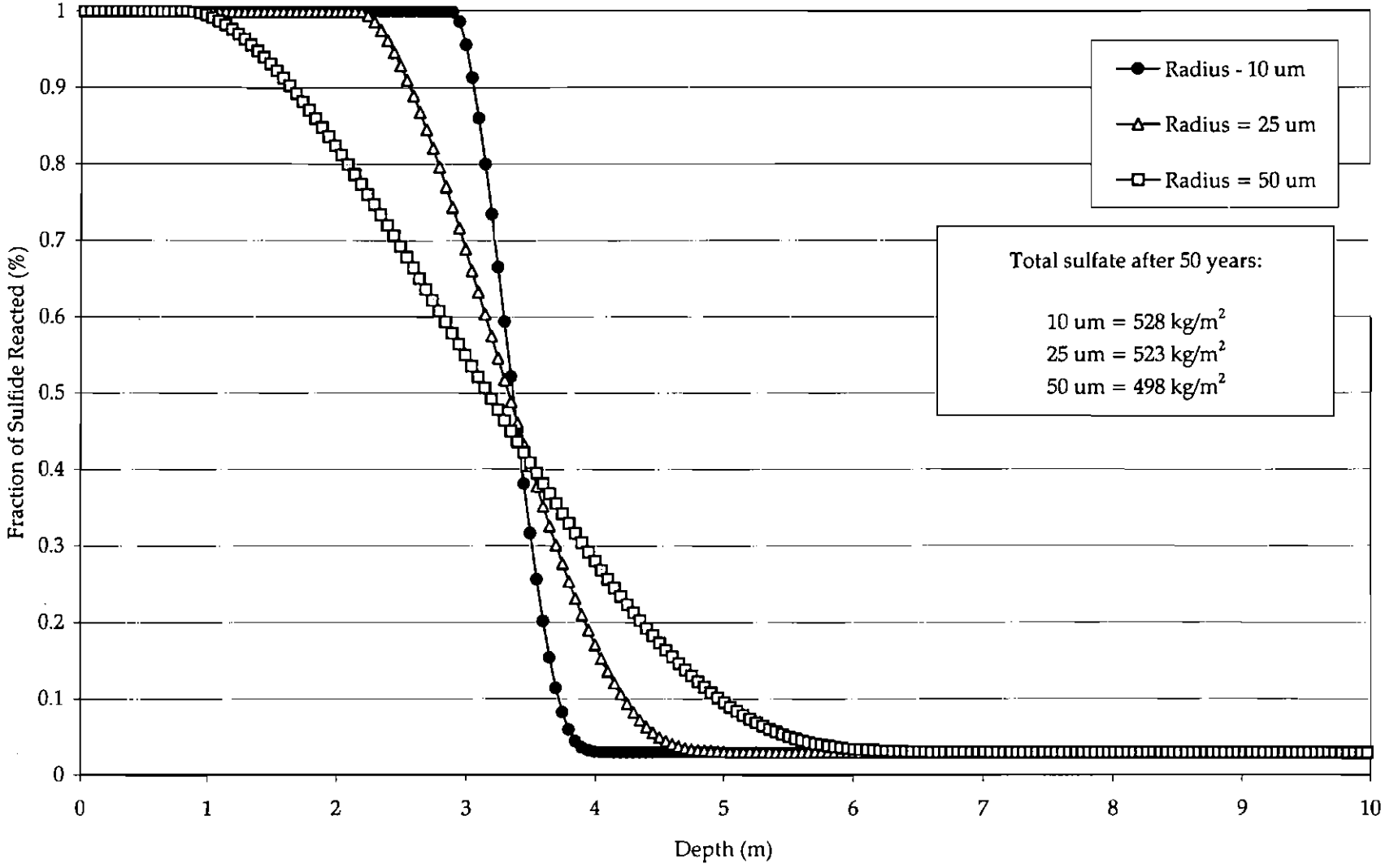


FIGURE D-A-21
Pyrite Grain Size Sensitivity Analysis - Oxygen Concentrations
50 Years

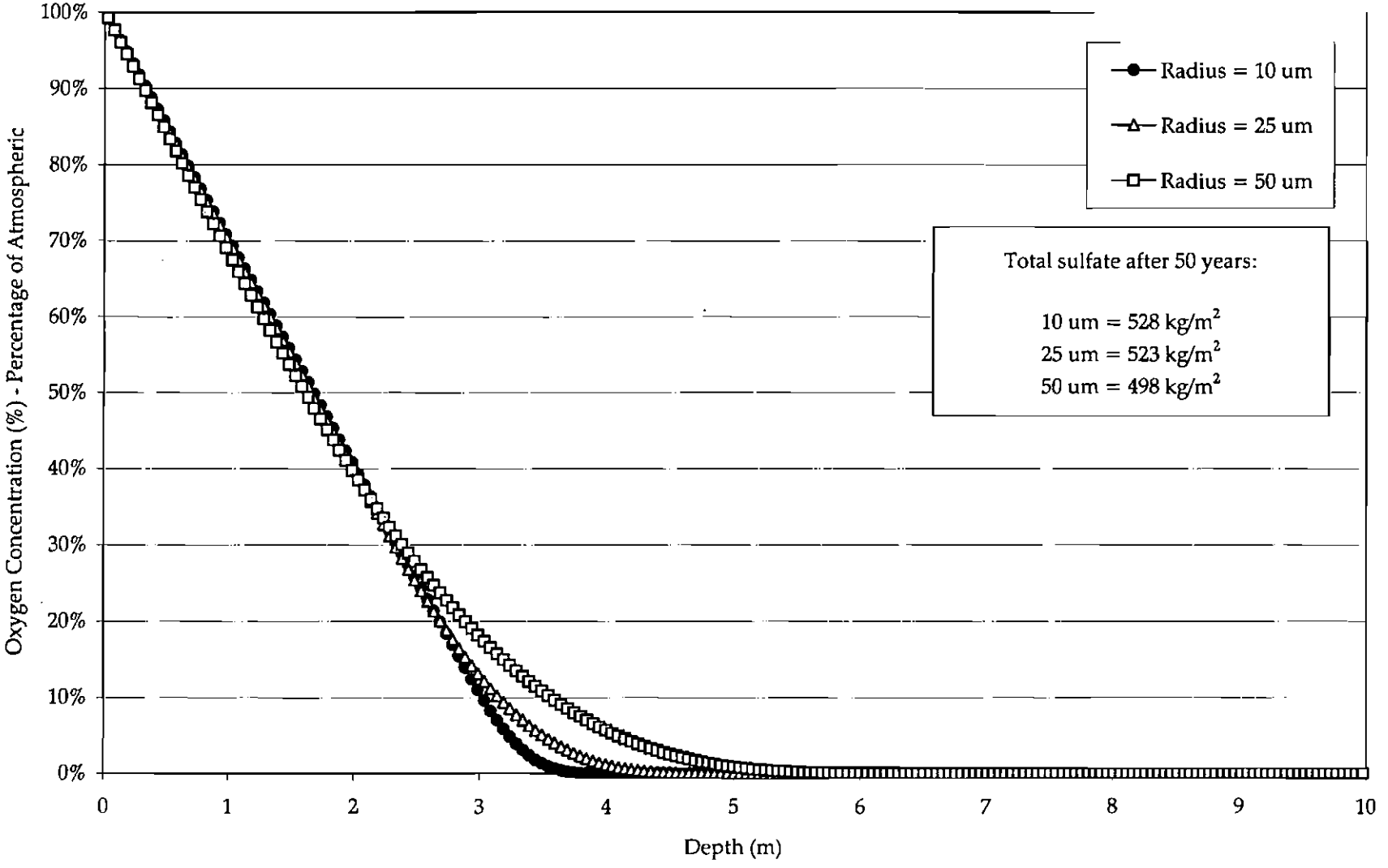


FIGURE D-A-22

Sulfide Oxidation Reduction Versus Moisture Content for a Soil Cover

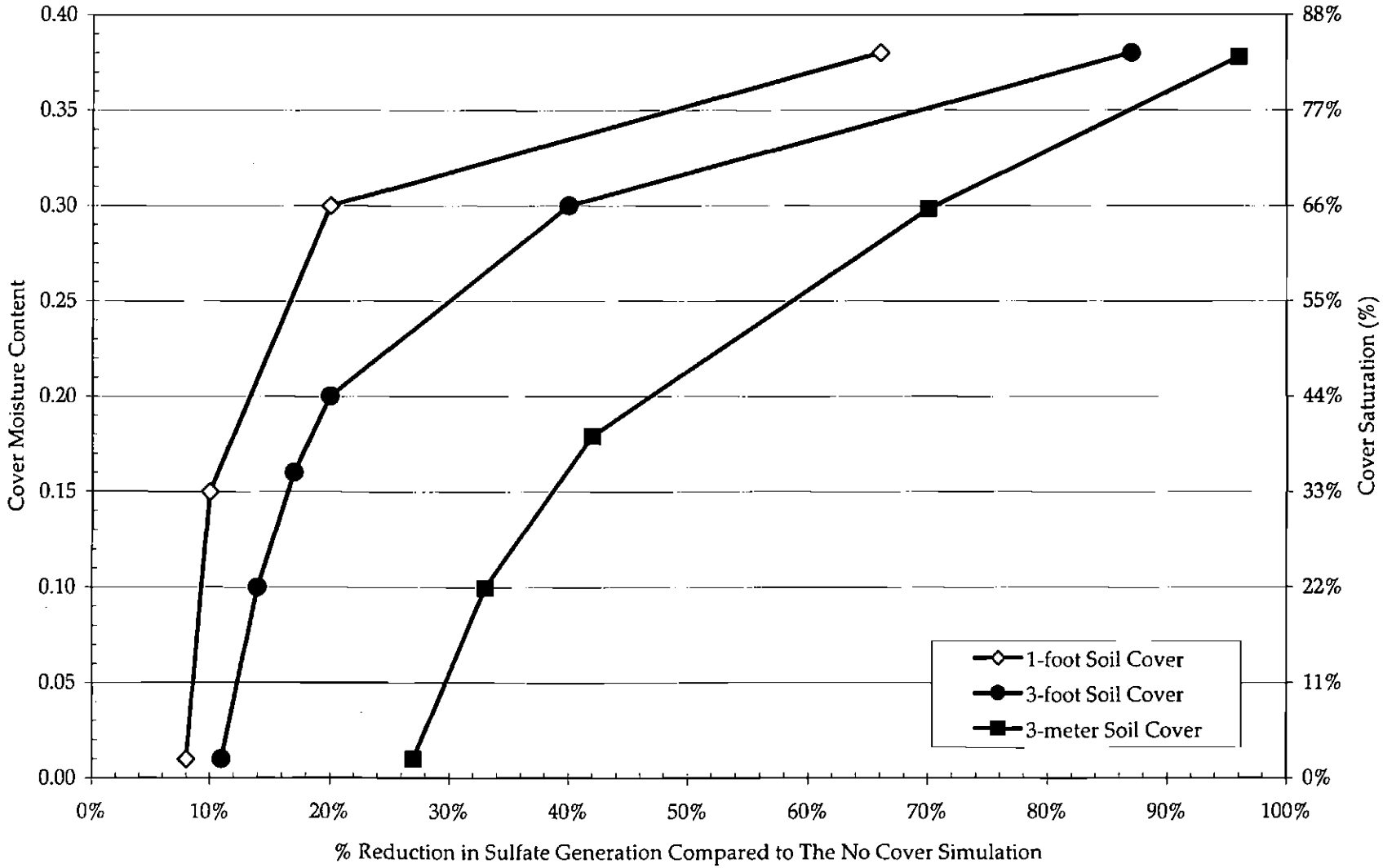
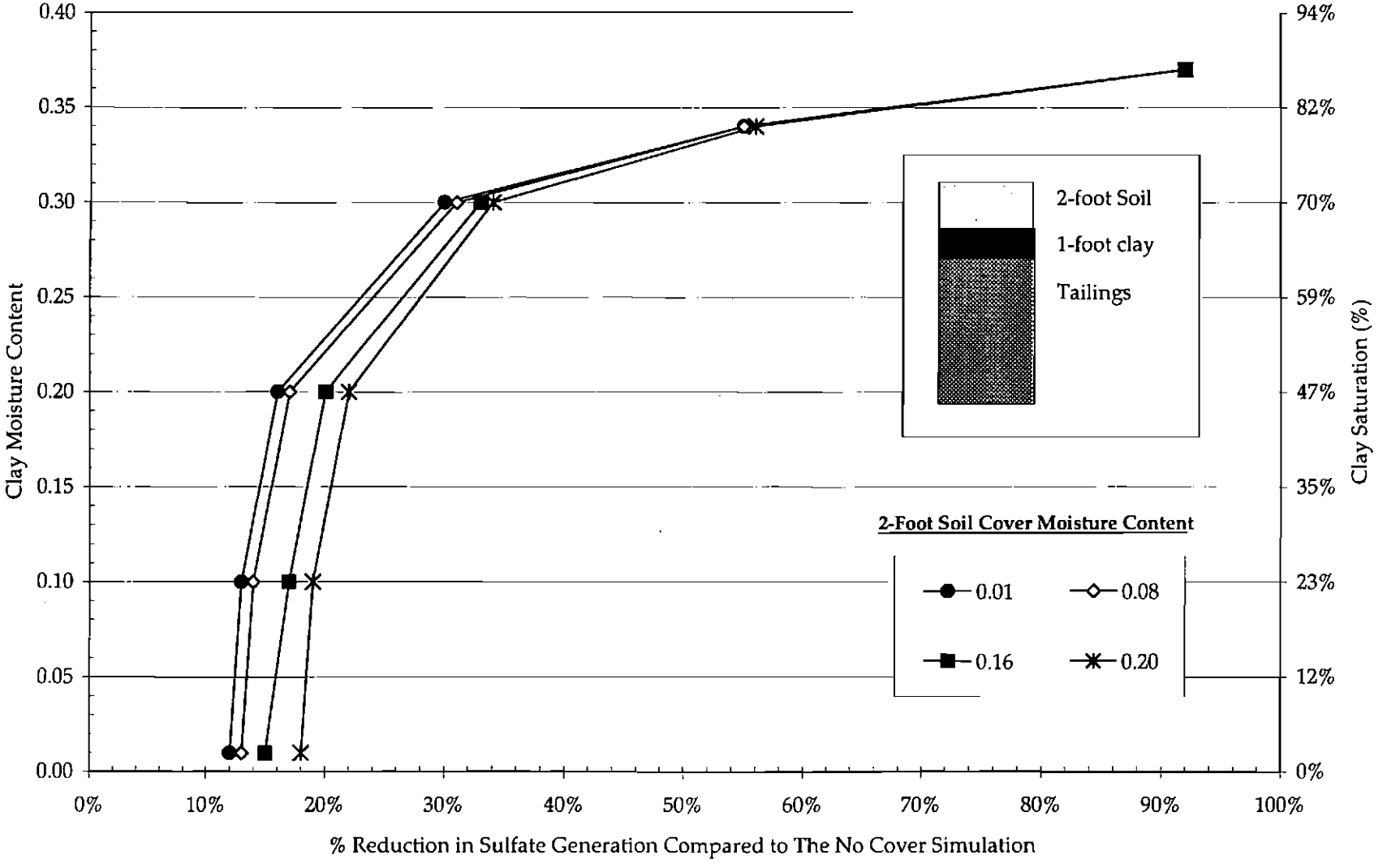


FIGURE D-A-23

Sulfide Oxidation Reduction Versus Moisture Content for a Composite Clay/Soil Cover



MEMORANDUM

ATTACHMENT B

TO:	Doug Dunster	April 19, 2002
FR:	Cheryl Ross, Rens Verburg	
RE:	WEST FORK IRON GEOCHEMICAL EVALUATION	943-1595.003 9000

D-B.1 INTRODUCTION

Placement of a cover on the West Fork Tailings Impoundment is predicted to result in a decline in iron loading to Blackbird Creek (Golder Associates, 2001). This decline will result from both a decrease in sulfide oxidation rates and a reduction in infiltration through the tailings. Iron loading from the West Fork Tailings Impoundment currently contributes to a net decline in copper concentrations in lower Blackbird Creek by acting as an adsorbent. Therefore, it was suggested by EPA (EPA, 2002) that placement of a cover on the West Fork tailing, which would reduce iron loading to the creek, could conceivably result in an increase in Blackbird Creek copper concentrations. In this memorandum, this hypothesis is evaluated through geochemical modeling.

D-B.2 GEOCHEMICAL MODELING - CURRENT CONDITIONS

Geochemical modeling using PHREEQC (Parkhurst and Appelo, 1999) was conducted to evaluate the effects of a decline in iron loading on Blackbird Creek water quality. PHREEQC is an equilibrium speciation and mass-transfer code developed by the United States Geological Survey (USGS). This model has the ability to simulate the pertinent processes occurring in Blackbird Creek, including precipitation/dissolution of selected solids, redox reactions, and adsorption/desorption of metals. PHREEQC was chosen because it combines the thermodynamic capabilities of MINTEQA2 with the ability to conduct mixing modeling. The MINTEQA2 thermodynamic database was selected for this project because it is considered by many in the geochemical and regulatory communities to be the most accurate geochemical database currently available. This database was modified by Golder to include cobalt.

Current conditions in Blackbird Creek were simulated first to verify the model's ability to accurately represent site conditions. Blackbird Creek water quality upstream of the West Fork Tailings Impoundment, represented by station BBSW-03A, was mixed with all measured sources of West Fork Tailings Impoundment seepage including: seeps (BBSP-42, BBSP-43 and BBSP-26), culvert discharge (WFSW-01), clean water diversion discharge (WFSW-02/WFSW-02.5) and West Fork Interceptor Ditch (WFINTDITCH) drainage. Mixing proportions were calculated based on the relative flow of each input. Following

mixing, precipitation of ferrihydrite and adsorption onto this phase was simulated. The number of available ferrihydrite adsorption sites was calculated assuming 0.005 strong bonding sites and 0.2 weak bonding sites per mole of ferrihydrite precipitated. A specific surface area of 600 m^2/g was assumed. These three values are default values developed by Dzombak and Morel (1990) and incorporated in PHREEQC as part of the standard thermodynamic database. The resultant modeled water quality was compared to measured lower Blackbird Creek water quality. This evaluation was conducted for both spring and fall synoptic sampling results from 1998, 1999 and 2000. In all simulations, concentrations below detectable limits were assumed equal to the detection limit.

Model results for 1998, 1999, and 2000 are presented in Tables D-B-1 through D-B-6. In each table, upstream water quality at BBSW-03A is presented followed by water qualities for the various measured West Fork Tailings Impoundment discharges. Measured flows and the resultant mixing proportions are provided in the first two rows of the table. Model results are presented under the heading "Simulated Water Quality". Results of conservative mixing (i.e. no attenuation) and non-conservative mixing (i.e. attenuation through adsorption onto ferrihydrite) are provided.

As shown in the tables, ferrihydrite precipitation results in a decline in both dissolved iron concentrations and pH. Although cobalt, copper, calcium, sulfate and arsenic are all allowed to adsorb on ferrihydrite, copper and arsenic generally dominate adsorption sites, resulting in reduced copper and arsenic concentrations relative to the conservative simulation. Finally, lower Blackbird Creek water quality data from stations BBSW-02, BBSW-01.5, and BBSW-01A are provided for comparison between model predictions and measured water quality.

In general, there is good agreement between predicted and measured Blackbird Creek water quality downstream of the West Fork Tailings Impoundment. On average, predicted dissolved cobalt concentrations are within 10% of the measured concentrations at BBSW-02, the first station downstream of the tailings. Good agreement (generally within 15%) is also noted between predicted and measured water quality for constituents that behave more or less conservatively (Ca, Mg, Mn and SO_4). Given the inherent uncertainties associated with laboratory analyses, flow measurements, and the thermodynamic parameters in the MINTEQA2 database, this agreement is considered excellent. Data from spring 1999 show the greatest variability between predicted and measured concentrations ranging from approximately 10% to 30%.

The model results for copper indicate that the observed declines in copper concentrations between BBSW-03A and BBSW-02 are attributed in part to dilution. Unlike for iron and cobalt, the West Fork Tailings Impoundment does not contribute significant amounts of copper. Dilution is greatest in the spring accounting for between 39% and 56% of the observed declines. In the fall, dilution accounts for only 35% to 37% of the decline.

Adsorption onto iron (oxy)hydroxides results in a further decrease in copper concentrations. The magnitude of copper adsorption predicted by the model is a

function of a number of factors including pH, number of adsorption sites and the concentration of other competing adsorption species (e.g. arsenic).

In all fall simulations, the model predicts lower dissolved copper concentrations than measured at BBSW-02; however, the model accurately predicts copper concentrations between BBSW-02 and BBSW-01. Because iron concentrations decline along this entire reach of lower Blackbird Creek (between BBSW-02 and BBSW-01), ferrihydrite precipitation is predicted to occur along this entire reach. This is consistent with field observations. Copper adsorption would therefore also be expected to occur along this entire reach. For the spring simulations, good agreement is noted between predicted copper concentrations and those measured at BBSW-02 in 1998 and 2000. The spring 1999 simulation over estimates copper concentrations. Because conservative species for spring 1999 showed the poorest agreement as well, it is not surprising that non-conservative behavior is also poorly predicted. The lack of agreement is likely caused by uncertainties associated with the flow measurements.

It should be noted that the model results consistently overestimate the amount of iron in solution. It was hypothesized that this discrepancy may be attributed to uncertainty in the thermodynamic constants for ferrihydrite. Thermodynamic data for amorphous phases are generally more poorly defined than for more ordered crystalline phases. For example, Stumm and Morgan (1996) present a range of two orders of magnitude for the solubility product of ferrihydrite (between $10^{3.0}$ and $10^{5.0}$). The solubility product for ferrihydrite in the MINTEQA2 database is $10^{4.89}$. Simulations of current conditions for the year 2000 were re-run using a ferrihydrite solubility product of $10^{3.0}$. Use of this thermodynamic constant resulted in minimal changes to the amount of ferrihydrite predicted to precipitate and to resultant aqueous iron concentrations (up to 1% change). Although in a pure water system, a two-order-of-magnitude change in the solubility product of ferrihydrite would result in an equivalent change in dissolved ferric iron, this is not true in the mine waters modeled. Complexation of iron results in only a fraction of total iron being present as the free ion, thereby limiting the amount of ferrihydrite that will precipitate. Because the model accurately represents the concentrations of other constituents in solution, specifically copper, poor agreement with respect to iron does not preclude the use of the model as a tool in evaluating geochemical processes at the Blackbird Site.

The geochemical modeling results indicate that the model quite accurately captures the geochemical processes occurring on site. The use of this model to predict future conditions under a hypothetical reduction in iron loading scenario is therefore considered appropriate.

D-B.3 GEOCHEMICAL MODELING – WEST FORK TAILINGS DECREASE IN IRON LOADING EVALUATION

The West Fork Interceptor Ditch (WFINTDITCH) accounts for a significant proportion of the iron load from the West Fork Tailings Impoundment to Blackbird Creek. Dissolved iron concentrations in WFINTDITCH are typically on the order of 100 mg/L. Measured

flows are relatively constant in the spring and fall, typically ranging from 0.2 to 0.3 cfs. This equates to an iron load of 50 to 70 kg/day. During the spring and fall synoptic events in 2000, the WFINTDITCH contributed greater than 90% of the measured West Fork dissolved iron load to Blackbird Creek.

To evaluate the effect of a decline in iron loading from the West Fork tailings on Blackbird Creek water quality, specifically copper concentrations, geochemical modeling was conducted. Two cases were simulated in which iron loading was reduced by 12% and 50%, respectively, by reducing the WFINTDITCH iron concentration. These percentages represent the anticipated reductions in iron loading related to the decrease in infiltration (12%) and the approximate decrease in infiltration + sulfide oxidation (50%) resulting from emplacement of a 3-meter thick cover (Appendix D, Golder Associates 2001). All other constituent concentrations and mixing proportions remained as measured. As in the initial simulations, after mixing, precipitation of ferrihydrite and adsorption onto this phase was simulated. These simulations were conducted for both spring and fall data from 2000. It should be noted that although the simulated removal of iron resulted in an increase in charge balance error for the WFINTDITCH solution, this error was considered acceptable.

The geochemical model simulations described in this memo are intended to provide insight into geochemical controls on metals mobility at the Blackbird Site. These simulations are not intended to represent the full impact of cover placement on Blackbird water quality. In addition to iron, cover placement is predicted to result in loading declines of other constituents to varying degrees (e.g. Co, SO_4 and Cu). Because these constituents do not all behave conservatively within the tailings, load reductions of these constituents to Blackbird Creek will be variable. Simulation of iron reductions without accounting for any coincident reduction in copper loading provides a conservative prediction of Blackbird Creek copper concentrations (i.e. an overestimate of the copper loading from the West Fork tailings).

Model results are presented in Tables D-B-7 and D-B-8. Copper and iron results are presented graphically in Figures D-B-1 through D-B-4. Results for both conservative mixing and non-conservative mixing (following ferrihydrite precipitation and adsorption) are presented. As mentioned above, ferrihydrite precipitation results in a decline in both dissolved iron concentrations and pH. Reductions in copper concentrations for the non-conservative case are attributed to adsorption onto ferrihydrite as the geochemical modeling has demonstrated that formation of copper-bearing mineral phases is not likely under the conditions observed in Blackbird Creek..

Model results suggest that a reduction in iron loading from the West Fork tailings generally does not result in a significant increase in copper concentrations in Blackbird Creek. The Fall 2000 simulations are the exception, with an increase in dissolved copper from 0.009 mg/L to 0.017 mg/L (Figure D-B-3) following a 50% reduction in iron load. However, for the Spring 2000 simulation, no significant increase in dissolved copper is predicted following 50% reduction in iron loading.

The difference in predicted copper behavior for the Spring and Fall 2000 cases is likely related to the fact that pH values in Fall 2000 are higher than in the Spring, which appears to have a more pronounced effect of ferrihydrite formation and adsorption of dissolved copper. At circumneutral values for pH (6 to 8), copper adsorption increases with increasing pH. In the Fall, higher iron concentrations in Blackbird Creek also results in greater ferrihydrite precipitation (more adsorbent).

D-B.4 SUMMARY AND CONCLUSIONS

A geochemical evaluation was conducted to simulate the effect of a reduction in iron loading (due to cover placement on the West Fork Tailings Impoundment) on Blackbird Creek water quality, specifically copper concentrations. Iron loading reductions of 12% and 50% were simulated using synoptic water quality data from the Spring and Fall of 2000. Model results generally predict that changes in copper concentrations resulting from reduced iron loadings are small. However, at certain times during the year, an increase in Blackbird dissolved copper concentrations may occur following a reduction in iron load.

D-B.5 REFERENCES

Dzombak, D.A. and F.M.M. Morel, 1990. Surface Complexation Modeling – Hydrous Ferric Oxide. John Wiley & Sons, New York.

Golder Associates, 2001. Focused Feasibility Study for the Blackbird Mine Site Lemhi County, Idaho, prepared for Blackbird Mine Site Group, December 28, 2001.

EPA, 2002. EPA Comments on the Draft Focused Feasibility Study, dated February, 2002.

Parkhurst, D.L., and C.A.J. Appelo, 1999. User's Guide to PHREEQC (Version 2) - A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations, U.S. Geological Survey Water-Resources Investigations Report 99-4259, Denver, CO.

Stumm, W. and J.J. Morgan, 1996. Aquatic Chemistry. Wiley-Interscience, New York.

TABLE D-B-1
West Fork Modeling
Spring 1998

		Upstream	*West Fork Tailings Impoundment*						*Simulated Water Quality*		*Downstream*		
Parameters	Units	4/28/98 BBSW-03A	4/28/98 WFSW-02.5	4/28/98 WFSW-02	4/29/98 BBSP-42	4/29/98 BBSP-43	4/28/98 WFSW-01	4/29/98 BBSP-26	Conservative Mix	Attenuation (with adsorption)	4/28/98 BBSW-02	4/28/98 BBSW 01.5	4/28/98 BBSW-01A
Flow	cfs	6.1	4.3	0.0067	0.0060	0.031	0.20	0.17			8.9	10.9	12.4
% of Total Flow	%	56.26%	39.92%	0.06%	0.06%	0.29%	1.84%	1.57%					
Alkalinity	mg/L	3	24.6	25.1	1	0	0	1.4	11.1	10.9	6.1	7.2	6
As	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.040	0.030	0.04	0.04	0.04
Ca	mg/L	35.6	7.01	119	39.5	59.9	71.9	20.8	24.7	24.7	25.4	22	23.5
Co	mg/L	0.681	0.007	5.88	1.7	6.1	7.94	0.668	0.565	0.565	0.613	0.571	0.675
Cu	mg/L	0.26	0.007	0.004	0.519	0.191	0.097	0.442	0.159	0.141	0.146	0.045	0.045
Fe	mg/L	0.057	0.08	123	0.084	67.1	115	0.019	2.45	2.29	1.5	0.121	0.038
Mg	mg/L	6.33	2.14	22.8	9.32	19.1	23.8	5.42	5.01	5.01	5.22	4.65	5.27
Mn	mg/L	0.173	0.001	3.68	0.796	3.4	4.64	0.124	0.198	0.198	0.215	0.178	0.197
pH	s.u.	6.2	6.9	6.43	4.6	3.3	3.5	5.9	6.61	6.59	6.4	6.6	6.5
SO_4	mg/L	105	4.9	525	168	409	562	59.7	73.9	73.9	74	68.6	65.7
Temp	°C	11	5	7.6	11	17	13.1	3			9	9.7	10

Detection Limits: Arsenic = 0.04 mg/L
Copper = 0.004 mg/L.

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-2
West Fork Modeling
Fall 1998

		Upstream	*West Fork Tailings Impoundment*						*Simulated Water Quality*		*Downstream*		
Parameters	**Units**	**10/13/98 BBSW-03A**	**10/13/98 WFSW-02.5**	**10/13/98 WFSW-02**	**10/14/98 BBSP-42**	**10/14/98 BBSP-43**	**10/13/98 WFSW-01**	**10/14/98 BBSP-26**	**Conservative Mix**	**Attenuation (with adsorption)**	**10/13/98 BBSW-02**	**10/13/98 BBSW-01.5**	**10/13/98 BBSW-01A**
Flow	cfs	0.9	0.8	0.011	0.1	0.008	0.100	0.010			1.9	2.4	2.6
% of Total Flow		49.20%	41.22%	0.60%	2.68%	0.42%	5.36%	0.54%					
Alkalinity	mg/L	9.4	10.6	24.4	0	0	35.9	1	8.7	8.0	1	1.8	4.4
As	mg/L	0.04	0.04	0.05	0.07	0.06	0.09	0.04	0.044	0.009	0.04	0.04	0.04
Ca	mg/L	10.2	8.76	96.2	45.5	55.5	63.4	16.8	14.1	14.1	15.6	16.2	16.1
Co	mg/L	0.226	0.006	4.91	4.26	5.38	6.76	0.709	0.646	0.645	0.757	0.759	0.713
Cu	mg/L	0.049	0.004	0.004	0.031	0.094	0.02	0.516	0.031	0.013	0.055	0.013	0.005
Fe	mg/L	0.074	0.071	116	66.4	72.5	114	0.019	8.95	8.16	6.41	1.75	0.77
Mg	mg/L	2.82	2.51	21.7	15.7	20.1	23.5	4.17	4.34	4.34	4.7	4.9	4.81
Mn	mg/L	0.069	0.004	3.05	2.3	3.42	3.92	0.129	0.341	0.341	0.417	0.373	0.334
pH	s.u.	6.86	9.01	7.59	3.62	3.38	4.18	4.74	6.93	6.77	7.75	6.31	7.99
SO_4	mg/L	37.6	6.5	526	362	455	573	72.2	67.0	67.0	72.2	73.7	71.7
Temp	°C	9	7.8	8.3	7.9	8.5	8.5	7.6			8.1	7.4	7.7

Detection Limits: Arsenic = 0.04 mg/L
Copper = 0.004 mg/L
Cobalt = 0.003 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-3
West Fork Modeling
Spring 1999

		Upstream	West Fork Tailings Impoundment						Simulated Water Quality		Downstream		
Parameters	Units	5/6/99 BBSW 03A	5/6/99 WFSW-2.5	5/7/99 WFINTDITCH	5/7/99 BBSP-43	5/7/99 BBSP-42	5/7/99 WFSW-01	5/7/99 BBSP-26	Conservative Mix	Attenuation (with adsorption)	5/6/99 BBSW-02	5/6/99 BBSW-01A	5/6/99 BBSW-01
Flow	cfs	6.57	8.42	0.18	0.005	0.03	0.01	0.028			15.74	15.23	14.09
% of Total Flow	%	43.10%	55.24%	1.18%	0.03%	0.20%	0.07%	0.18%					
Alkalinity	mg/L	4	21.9	0	0	0	35.8	2.3	13.6	13.4	6.1	8.4	8.8
As	mg/L	0.002	0.008	0.005	0.002	0.004	0.002	0.002	0.005	0.000	0.002	0.002	0.002
Ca	mg/L	58.4	5.27	61.3	49.6	71.3	98.5	12.6	29.1	29.1	34.5	30.8	28.1
Co	mg/L	0.716	0.005	6.53	3.22	7.51	3.87	0.456	0.408	0.408	0.563	0.535	0.521
Cu	mg/L	0.45	0.003	0.156	0.349	0.218	0.003	0.282	0.198	0.177	0.151	0.044	0.051
Fe	mg/L	0.18	0.08	118	7.53	122	57.7	0.13	1.80	1.60	1.06	0.06	0.14
Mg	mg/L	8.89	1.66	23.6	15.4	29.2	21.3	3.68	5.11	5.11	5.64	5.49	5.41
Mn	mg/L	0.246	0.002	4.17	1.97	4.9	2.49	0.079	0.169	0.169	0.254	0.22	0.207
pH	s.u.	6.46	6.96	3.74	3.47	3.32	6.32	5.32	6.80	6.77	6.1	6.76	6.79
SO_4	mg/L	188	3.6	506	243	562	349	43.2	90.5	90.5	111	97.2	94.7
Temp	°C	12.7	6.1	9.7	9.4	10.8	7.3	5			9.4	11.9	9.9

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.005 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-4
West Fork Modeling
Fall 1999

		Upstream	*West Fork Tailings Impoundment*					*Simulated Water Quality*		*Downstream*			
Parameters	**Units**	**9/21/99 BBSW-03A**	**9/21/99 WFSW-02**	**9/21/99 WFINTDITCH**	**9/22/99 BBSP-43**	**9/22/99 WFSW-01**	**9/22/99 BBSP-26**	**Conservative Mix**	**Attenuation (with adsorption)**	**9/21/99 BBSW-02**	**9/21/99 BBSW-01.5**	**9/21/99 BBSW-01A**	**9/21/99 BBSW-01**
Flow	cfs	0.906	0.700	0.196	0.008	0.006	0.002			2.327	1.996	2.328	2.058
% of Total Flow	%	0.499	0.385	0.108	0.004	0.003	0.001						
Alkalinity	mg/L	3.4	37.3	0.0	0.0	15.8	0.1	15.8	15.3	1.0	1.0	3.8	6.2
As	mg/L	0.002	0.009	0.007	0.002	0.003	0.002	0.005	0.000	0.002	0.002	0.002	0.002
Ca	mg/L	22.8	11.7	56.2	28.0	86.2	26.3	22.3	22.3	23.3	27.1	27.2	28.8
Co	mg/L	0.282	0.013	5.79	1.52	3.74	0.893	0.788	0.788	0.797	0.897	0.803	0.721
Cu	mg/L	0.060	0.003	0.046	0.179	0.007	0.695	0.038	0.026	0.055	0.038	0.014	0.007
Fe	mg/L	0.02	0.23	106	7.37	90	0.02	11.83	11.26	5.01	2.10	0.51	0.02
Mg	mg/L	4.36	2.61	18.5	8.27	17.3	6.79	5.27	5.27	5.85	5.95	6.61	5.99
Mn	mg/L	0.051	0.007	3.14	0.811	2.30	0.151	0.377	0.377	0.406	0.389	0.302	0.246
pH	s.u.	6.69	6.43	4.48	3.68	6.67	5.20	6.44	6.41	6.10	6.09	6.56	6.07
SO_4	mg/L	75.3	7.1	445	151	371	95	90.1	90.1	93.1	99.0	98.7	96.7
Temp	°C	16.5	10.4	11.5	13.6	14.4	14.8			13.3	11.4	10.3	10.9

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.005 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-5
West Fork Modeling
Spring 2000

		Upstream	*West Fork Tailings Impoundment*					*Simulated Water Quality*		*Downstream*			
Parameters	**Units**	**4/26/00 BBSW-03A**	**4/26/00 WFSW-02.5**	**4/25/00 WFINTDITCH**	**4/25/00 BBSP-43**	**4/25/00 WFSW-01**	**4/25/00 BBSP-26**	**Conservative Mix**	**Attenuation (with adsorption)**	**4/26/00 BBSW-02**	**4/26/00 BBSW-01.5**	**4/26/00 BBSW-01A**	**4/26/00 BBSW-01**
Flow	cfs	5.080	3.880	0.270	0.007	0.011	0.074			13.25	12.93	13.27	14.69
% of Total Flow	%	54.49%	41.62%	2.90%	0.08%	0.12%	0.79%						
Alkalinity	mg/L	8.0	19.0	0.0	0.0	16.2	6.6	12.2	12.1	8.7	9.9	10.5	10.4
As	mg/L	0.002	0.007	0.014	0.002	0.002	0.003	0.004	0.002	0.002	0.002	0.003	0.002
Ca	mg/L	52.2	5.2	47.5	29.2	81.1	11.3	32.2	32.2	29	26.5	23.9	24
Co	mg/L	0.501	0.005	5.170	1.750	2.700	0.272	0.432	0.432	0.411	0.394	0.387	0.387
Cu	mg/L	0.089	0.003	0.073	0.173	0.003	0.156	0.053	0.048	0.05	0.054	0.044	0.049
Fe	mg/L	0.050	0.030	93.700	4.410	36.900	0.030	2.81	2.73	1.07	0.79	0.58	0.6
Mg	mg/L	10.7	1.7	19.2	9.3	16.3	3.1	7.16	7.16	6.43	6.09	6.07	6.09
Mn	mg/L	0.505	0.002	2.820	0.937	1.630	0.032	0.361	0.361	0.336	0.296	0.284	0.278
pH	s.u.	6.59	7.08	4.10	3.47	5.21	5.87	6.77	6.75	6.17	6.58	6.98	6.75
SO_4	mg/L	158.0	3.7	391.0	154.0	273.0	34.9	99.7	99.7	87.8	80.3	78.9	78.7
Temp	°C	10.9	3.9	6.5	6.0	6.0	4.1			8.6	8.7	9.2	9.1

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.005 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-6
West Fork Modeling
Fall 2000

		Upstream	*West Fork Tailings Impoundment*						*Simulated Water Quality*		*Downstream*			
Parameters	**Units**	9/20/00 BBSW-03A	9/20/00 WFSW-02	9/20/00 WFINTDITCH	9/19/00 BBSP-43	9/19/00 BBSP-42	9/19/00 WFSW-01	9/19/00 BBSP-26	Conservative Mix	Attenuation (with adsorption)	9/20/00 BBSW-02	9/20/00 BBSW-01.5	9/20/00 BBSW-01A	9/20/00 BBSW-01A
Flow	cfs	0.910	0.932	0.250	0.004	0.022	0.004	0.035			1.780	2.750	2.390	2.470
% of Total Flow	%	42.19%	43.21%	11.59%	0.18%	1.00%	0.19%	1.64%						
Alkalinity	mg/L	5.5	39.7	0.0	0.0	0.0	60.6	1.1	19.2	16.2	1.0	2.7	4.8	5.0
As	mg/L	0.003	0.013	0.022	0.002	0.003	0.006	0.002	0.010	0.000	0.002	0.002	0.002	0.002
Ca	mg/L	24.1	12.2	45.1	27.0	45.5	65.9	23.2	21.7	21.7	23.1	27.2	27.5	29.0
Co	mg/L	0.298	0.006	5.51	1.49	5.78	1.56	0.685	0.842	0.833	0.878	0.853	0.800	0.837
Cu	mg/L	0.060	0.005	0.029	0.106	0.080	0.003	0.473	0.039	0.009	0.044	0.014	0.010	0.009
Fe	mg/L	0.040	0.020	114	8.03	109	58.5	0.020	14.45	10.94	5.53	0.54	0.30	0.52
Mg	mg/L	5.37	3.36	20.1	8.55	20.4	10.6	5.62	6.38	6.38	6.37	7.47	7.52	7.93
Mn	mg/L	0.071	0.005	3.19	0.867	3.44	1.19	0.093	0.442	0.442	0.513	0.348	0.316	0.343
pH	s.u.	7.260	7.950	5.180	3.300	3.370	6.510	5.180	7.23	6.83	6.34	6.59	6.84	6.44
SO_4	mg/L	84.7	8.7	405	162	466	190	89.2	93.2	93.0	96	111	112	107
Temp	°C	11.7	8.9	9.1	9.6	7.8	10.0	11.2			10.3	10.9	10.9	11.0

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.006 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-7
Iron Loading Evaluation
Spring 2000

Parameters	Units	*Simulated Current Conditions*		*12% Reduction in Iron Load*		*50% Reduction in Iron Load*	
		Conservative Mix	Attenuation (with adsorption)	Conservative Mix	Attenuation (with adsorption)	Conservative Mix	Attenuation (with adsorption)
Alkalinity	mg/L	12.2	12.1	12.2	12.1	12.2	12.1
As	mg/L	0.004	0.002	0.004	0.002	0.004	0.002
Ca	mg/L	32.2	32.2	32.2	32.2	32.2	32.2
Co	mg/L	0.432	0.432	0.432	0.432	0.432	0.432
Cu	mg/L	0.053	0.0484	0.053	0.0484	0.053	0.0485
Fe	mg/L	2.81	2.73	2.47	2.41	1.42	1.36
Mg	mg/L	7.16	7.16	7.16	7.16	7.16	7.16
Mn	mg/L	0.361	0.361	0.361	0.361	0.361	0.361
pH	s.u.	6.77	6.75	6.77	6.75	6.77	6.76
SO_4	mg/L	99.7	99.7	99.7	99.7	99.7	99.7

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-B-8
Iron Loading Evaluation
Fall 2000

Parameters	Units	*Simulated Current Conditions*		*12% Reduction in Iron Load*		*50% Reduction in Iron Load*	
		Conservative Mix	Attenuation (with adsorption)	Conservative Mix	Attenuation (with adsorption)	Conservative Mix	Attenuation (with adsorption)
Alkalinity	mg/L	19.2	16.2	19.2	16.5	19.2	17.7
As	mg/L	0.010	0.000	0.010	0.000	0.010	0.000
Ca	mg/L	21.7	21.7	21.7	21.7	21.7	21.7
Co	mg/L	0.842	0.833	0.842	0.833	0.842	0.835
Cu	mg/L	0.039	0.009	0.039	0.010	0.039	0.017
Fe	mg/L	14.45	10.94	12.73	9.65	7.25	5.56
Mg	mg/L	6.38	6.38	6.38	6.38	6.38	6.38
Mn	mg/L	0.442	0.442	0.442	0.442	0.442	0.442
pH	s.u.	7.23	6.83	7.25	6.88	7.31	7.06
SO_4	mg/L	93.2	93.0	93.2	93.1	93.2	93.1

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

FIGURE D-B-1
Simulated Copper Concentrations - Spring 2000

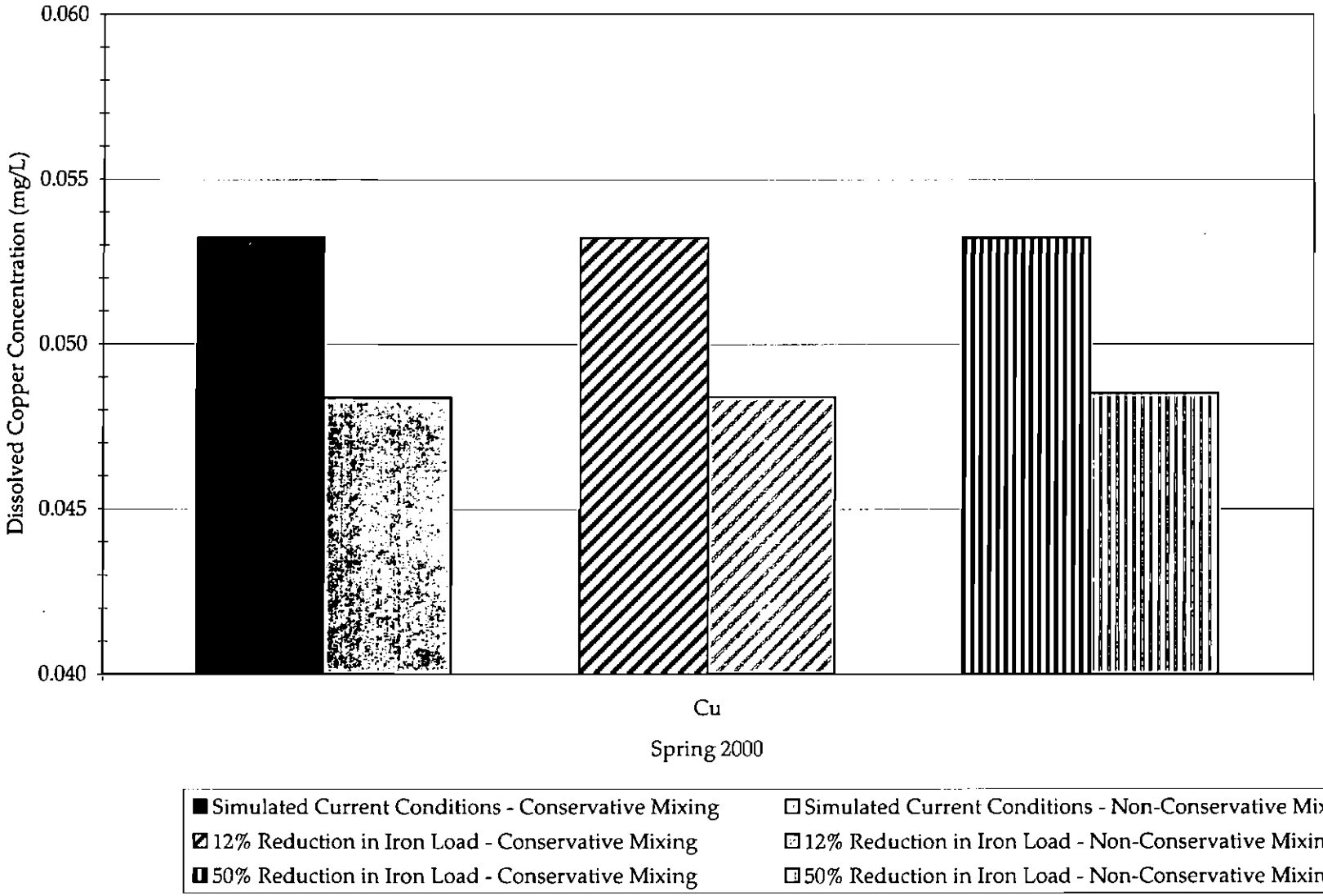


FIGURE D-B-2
Simulated Iron Concentrations - Spring 2000

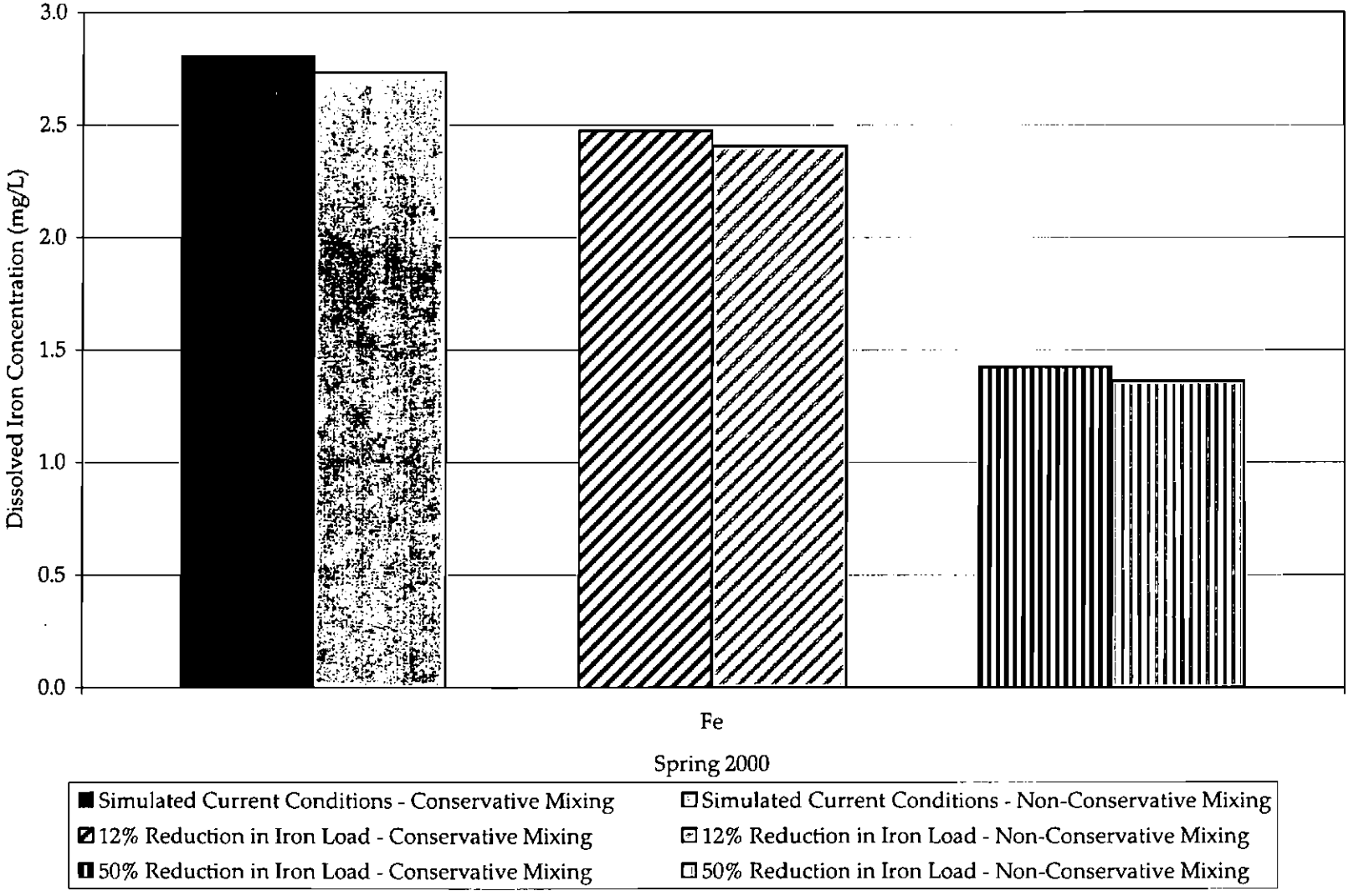


FIGURE D-B-3
Simulated Copper Concentrations - Fall 2000

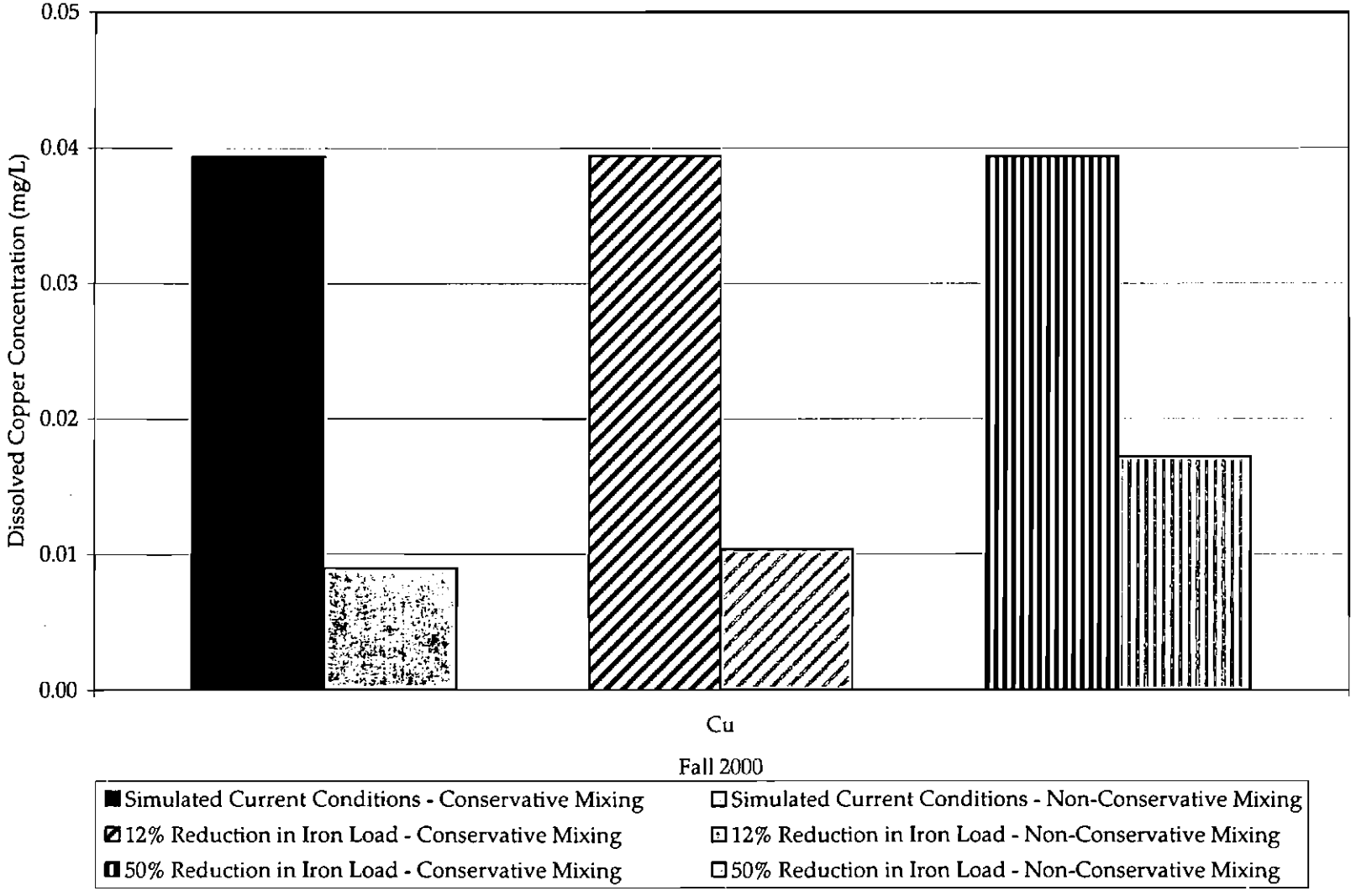
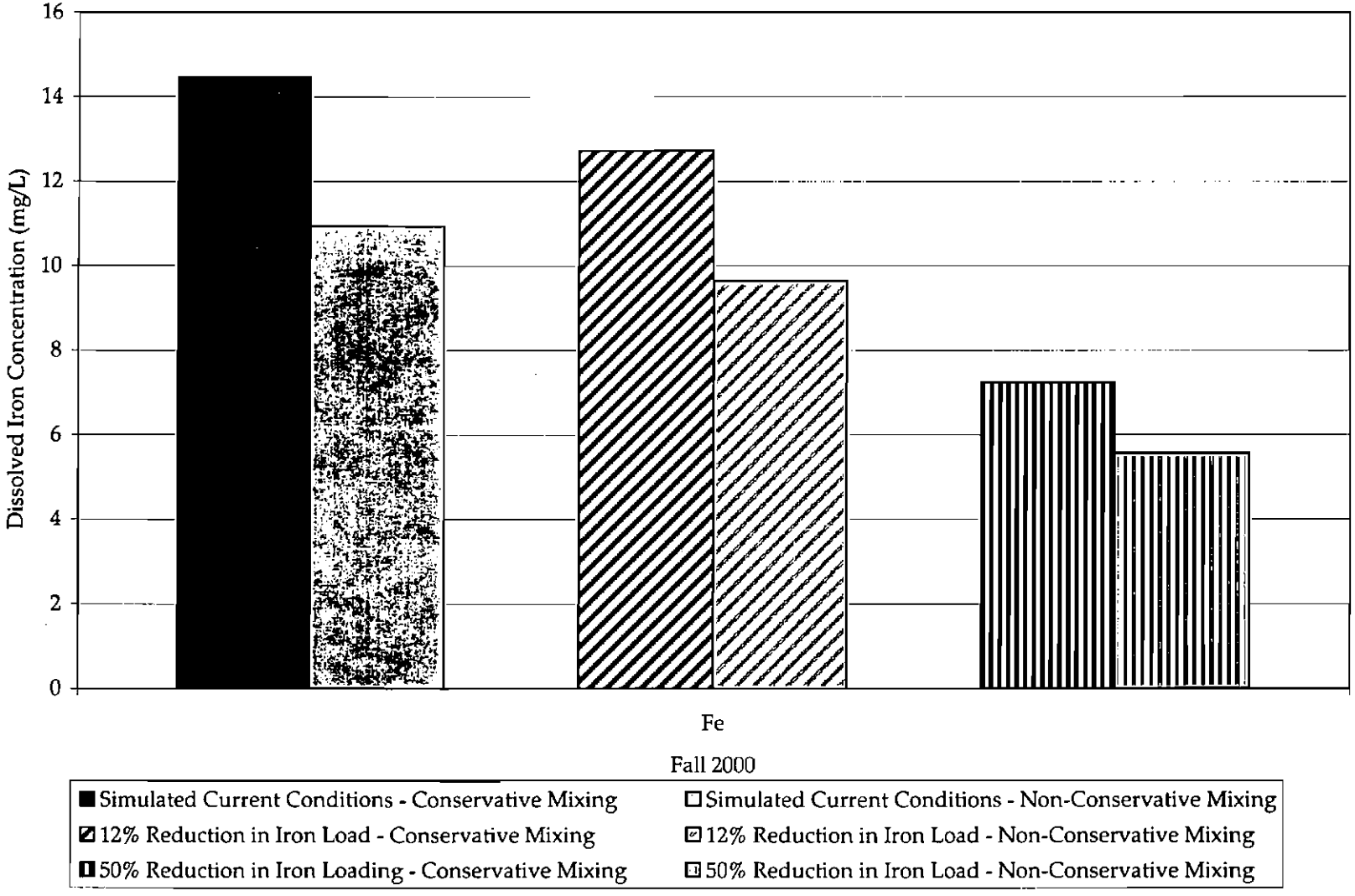


FIGURE D-B-4
Simulated Iron Concentrations - Fall 2000



MEMORANDUM

ATTACHMENT C

TO:	Doug Dunster	April 19, 2002
FR:	Cheryl Ross, Rens Verburg	
RE:	WEST FORK TREATMENT GEOCHEMICAL EVALUATION	943-1595.003 9000

D-C.1 INTRODUCTION

To reduce cobalt concentrations in Blackbird and Panther Creeks, collection and treatment of West Fork Tailings Impoundment seepage is one alternative being considered. Because cobalt behaves conservatively in Blackbird Creek, the beneficial effect of this alternative on Blackbird cobalt loading is easily evaluated. Any cobalt load removed will result in an equivalent load loss in the creek. The effect of collection and treatment of West Fork Tailings seepage on copper concentrations, however, is not as straightforward. Iron loading from the West Fork Tailings Impoundment currently contributes to a net decline in copper concentrations in lower Blackbird Creek by acting as an adsorbent. Therefore, collection of tailings seepage, which would reduce iron loading to the creek, could conceivably result in an increase in Blackbird Creek copper concentrations. In this memorandum, this hypothesis is evaluated through geochemical modeling.

D-C.2 GEOCHEMICAL MODELING – CURRENT CONDITIONS

Geochemical modeling using PHREEQC (Parkhurst and Appelo, 1999) was conducted to evaluate the effects of collection and treatment of tailings impoundment seepage on Blackbird Creek water quality. PHREEQC is an equilibrium speciation and mass-transfer code developed by the United States Geological Survey (USGS). This model has the ability to simulate the pertinent processes occurring in Blackbird Creek, including precipitation/dissolution of selected solids, redox reactions, and adsorption/desorption of metals. PHREEQC was chosen because it combines the thermodynamic capabilities of MINTEQA2 with the ability to conduct mixing modeling. The MINTEQA2 thermodynamic database was selected for this project because it is considered by many in the geochemical and regulatory communities to be the most accurate geochemical database currently available. This database was modified by Golder to include cobalt.

Current conditions in Blackbird Creek were simulated first to verify the model's ability to accurately represent site conditions. Blackbird Creek water quality upstream of the West Fork Tailings Impoundment, represented by station BBSW-03A, was mixed with all measured sources of West Fork Tailings Impoundment seepage including: seeps (BBSP-

42, BBSP-43, BBSP-26), culvert discharge (WFSW-01), clean water diversion discharge (WFSW-02/WFSW-02.5) and West Fork Interceptor Ditch (WFINTDITCH) drainage. Mixing proportions were calculated based on the relative flow of each input. Following mixing, precipitation of ferrihydrite and adsorption onto this phase was simulated. The number of available ferrihydrite adsorption sites was calculated assuming 0.005 strong bonding sites and 0.2 weak bonding sites per mole of ferrihydrite precipitated. A specific surface area of 600 m^2/g was assumed. These three values are default values developed by Dzombak and Morel (1990) and incorporated in PHREEQC as part of the standard thermodynamic database. The resultant modeled water quality was compared to measured lower Blackbird Creek water quality. This evaluation was conducted for both spring and fall synoptic sampling results from 1998, 1999 and 2000. In all simulations, concentrations below detectable limits were assumed equal to the detection limit.

Model results for 1998, 1999, and 2000 are presented in Tables D-C-1 through D-C-6. In each table, upstream water quality at BBSW-03A is presented followed by water qualities for the various measured West Fork Tailings Impoundment discharges. Measured flows and the resultant mixing proportions are provided in the first two rows of the table. Model results are presented under the heading "Simulated Water Quality". Results of conservative mixing (i.e. no attenuation) and non-conservative mixing (i.e. attenuation through adsorption onto ferrihydrite) are provided.

As shown in the tables, ferrihydrite precipitation results in a decline in both dissolved iron concentrations and pH. Although cobalt, copper, calcium, sulfate and arsenic are all allowed to adsorb on ferrihydrite, copper and arsenic generally dominate adsorption sites, resulting in reduced copper and arsenic concentrations relative to the conservative simulation. Finally, lower Blackbird Creek water quality data from stations BBSW-02, BBSW-01.5, and BBSW-01A are provided for comparison between model predictions and measured water quality.

In general, there is good agreement between predicted and measured Blackbird Creek water quality downstream of the West Fork Tailings Impoundment. On average, predicted dissolved cobalt concentrations are within 10% of the measured concentrations at BBSW-02, the first station downstream of the tailings. Good agreement (generally within 15%) is also noted between predicted and measured water quality for constituents that behave more or less conservatively (Ca, Mg, Mn and SO_4). Given the inherent uncertainties associated with laboratory analyses, flow measurements, and the thermodynamic parameters in the MINTEQA2 database, this agreement is considered excellent. Data from spring 1999 show the greatest variability between predicted and measured concentrations ranging from approximately 10% to 30%.

The model results for copper indicate that the observed declines in copper concentrations between BBSW-03A and BBSW-02 are attributed in part to dilution. Unlike for iron and cobalt, the West Fork Tailings Impoundment does not contribute significant amounts of copper. Dilution is greatest in the spring accounting for between 39% and 56% of the observed declines. In the fall, dilution accounts for only 35% to 37% of the decline.

Adsorption onto iron (oxy)hydroxides results in a further decrease in copper concentrations. The magnitude of copper adsorption predicted by the model is a function of a number of factors including pH, number of adsorption sites and the concentration of other competing adsorption species (e.g. arsenic).

In all fall simulations, the model predicts lower dissolved copper concentrations than measured at BBSW-02; however, the model accurately predicts copper concentrations between BBSW-02 and BBSW-01. Because iron concentrations decline along this entire reach of lower Blackbird Creek (between BBSW-02 and BBSW-01), ferrihydrite precipitation is predicted to occur along this entire reach. This is consistent with field observations. Copper adsorption would therefore also be expected to occur along this entire reach. For the spring simulations, good agreement is noted between predicted copper concentrations and those measured at BBSW-02 in 1998 and 2000. The spring 1999 simulation over estimates copper concentrations. Because conservative species for spring 1999 showed the poorest agreement as well, it is not surprising that non-conservative behavior is also poorly predicted. The lack of agreement is likely caused by uncertainties associated with the flow measurements.

It should be noted that the model results consistently overestimate the amount of iron in solution. It was hypothesized that this discrepancy may be attributed to uncertainty in the thermodynamic constants for ferrihydrite. Thermodynamic data for amorphous phases are generally more poorly defined than for more ordered crystalline phases. For example, Stumm and Morgan (1996) present a range of two orders of magnitude for the solubility product of ferrihydrite (between $10^{3.0}$ and $10^{5.0}$). The solubility product for ferrihydrite in the MINTEQA2 database is $10^{4.89}$. Simulations of current conditions for the year 2000 were re-run using a ferrihydrite solubility product of $10^{3.0}$. Use of this thermodynamic constant resulted in minimal changes to the amount of ferrihydrite predicted to precipitate and to resultant aqueous iron concentrations (up to 1% change). Although in a pure water system, a two-order-of-magnitude change in the solubility product of ferrihydrite would result in an equivalent change in dissolved ferric iron, this is not true in the mine waters modeled. Complexation of iron results in only a fraction of total iron being present as the free ion, thereby limiting the amount of ferrihydrite that will precipitate. Because the model accurately represents the concentrations of other constituents in solution, specifically copper, poor agreement with respect to iron does not preclude the use of the model as a tool in evaluating geochemical processes at the Blackbird Site.

The geochemical modeling results indicate that the model quite accurately captures the geochemical processes occurring on site. The use of this model to predict future conditions under a hypothetical treatment scenario is therefore considered appropriate.

D-C.3 GEOCHEMICAL MODELING – WEST FORK TAILINGS TREATMENT EVALUATION

The West Fork Interceptor Ditch (WFINTDITCH) accounts for a significant proportion of the copper, cobalt and iron load from the West Fork Tailings Impoundment to Blackbird

Creek. To evaluate the effect of a collection and treatment alternative, model simulations were conducted in which West Fork Interceptor Ditch flow was decreased by 50 and 90 percent, respectively. This results in a decrease in the mixing proportion of WFINTDITCH relative to the other West Fork Tailings inputs. As in the initial simulations, after mixing, precipitation of ferrihydrite and adsorption onto this phase was simulated. These simulations were conducted for both spring and fall data from 1999 and 2000. Modeling using 1998 data was not performed because the Interceptor Ditch had not been constructed at the time.

Model results are presented in Tables D-C-7 through D-C-10. Cobalt, copper and iron results are presented graphically in Figures D-C-1 through D-C-3. As expected, collection of West Fork tailings seepage is predicted to result in a decline in cobalt concentrations in lower Blackbird Creek. For the two years modeled, a 50% reduction in flow from the West Fork Interceptor Ditch results in a 10% to 15% reduction in spring cobalt concentrations. In the fall, a much larger reduction in dissolved cobalt concentration (~35%) is predicted.

Collection and treatment of West Fork seepage is not predicted to have a significant impact on lower Blackbird Creek copper concentrations. For three of the four periods modeled (spring 1999, spring 2000 and fall 1999), predicted copper concentrations after 50% and 90% collection of West Fork Interceptor Ditch drainage are essentially equal to those predicted in the simulation of current conditions. Only the fall 2000 model results predict an adverse impact to copper concentrations. In this simulation, copper attenuation due to adsorption is predicted to decrease as collection of West Fork Interceptor Ditch increases. Predicted copper concentrations for the base case, 50% treatment and 90% treatment cases are 0.009 mg/L, 0.017 mg/L and 0.029 mg/L respectively. The reason for this behavior is likely related to the fact that pH values in fall 2000 are higher than for the other simulations, which appears to have a more pronounced effect of ferrihydrite formation and adsorption of dissolved copper and other aqueous species.

D-C.4 SUMMARY AND CONCLUSIONS

A geochemical evaluation was conducted to evaluate the effect of collection and treatment of West Fork seepage on Blackbird Creek water quality. Significant reductions in cobalt loading to Blackbird Creek are predicted following collection and treatment. It is expected that collection would result in greater declines in Blackbird Creek cobalt concentrations downstream of the impoundment in the fall than in the spring. Treatment will have a lesser impact on copper concentrations.

D-C.5 REFERENCES

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Parkhurst, D.L., and C.A.J. Appelo, 1999. User's Guide to PHREEQC (Version 2) - A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations, U.S. Geological Survey Water-Resources Investigations Report 99-4259, Denver, CO.

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FIGURE D-C-1

Treatment Simulation Results - Cobalt

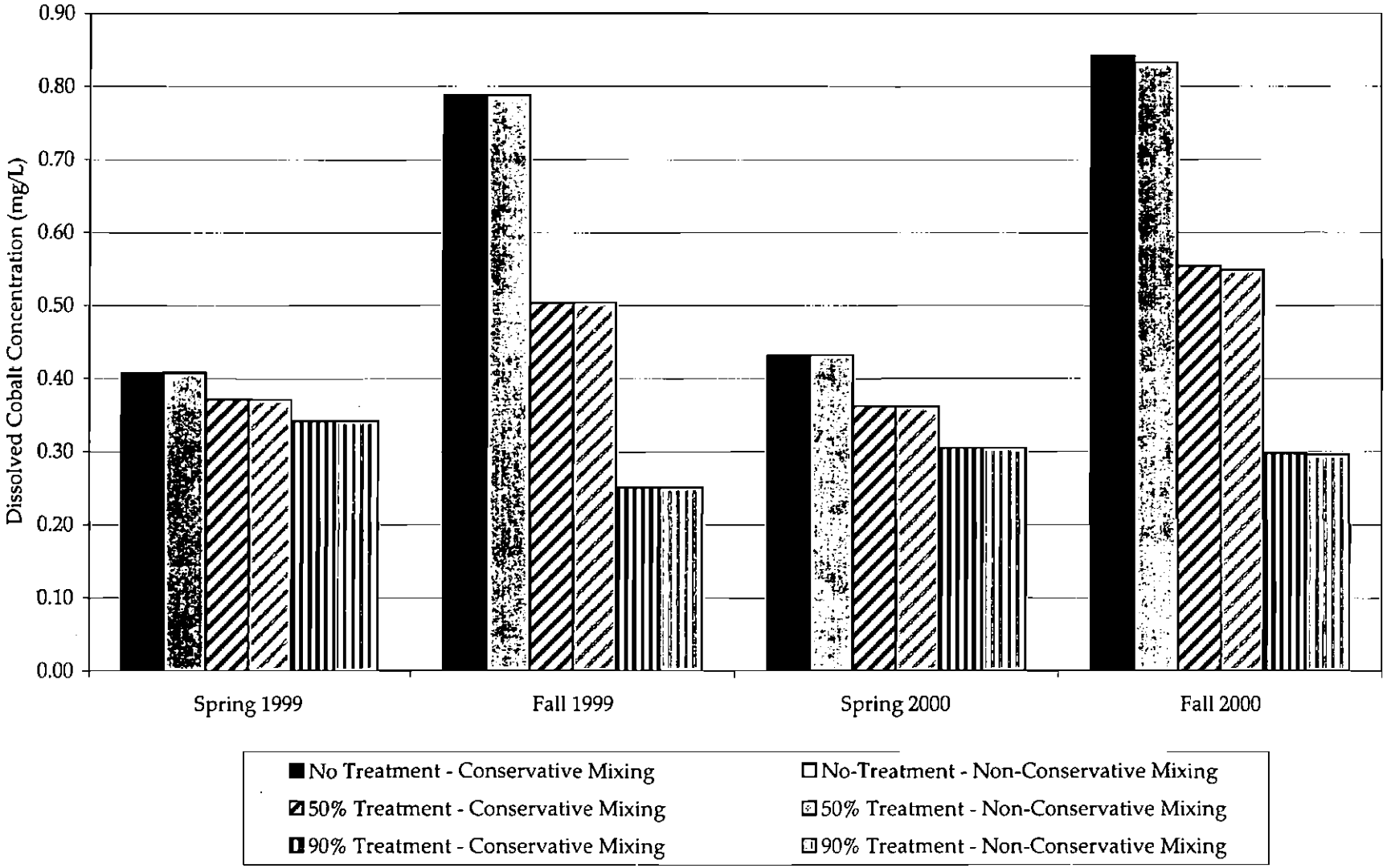

FIGURE D-C-2

Treatment Simulation Results - Copper

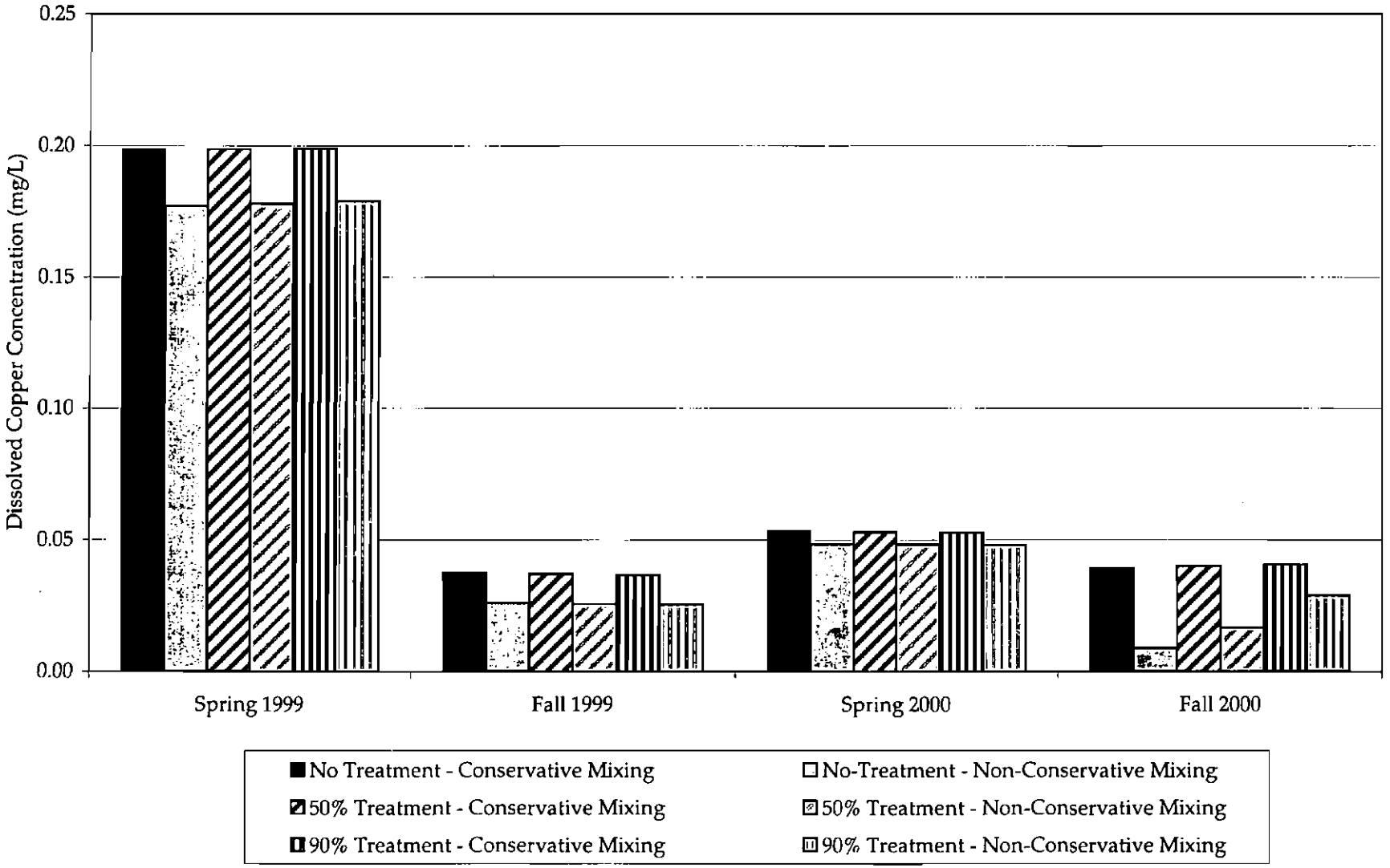

FIGURE D-C-3

Treatment Simulation Results - Iron

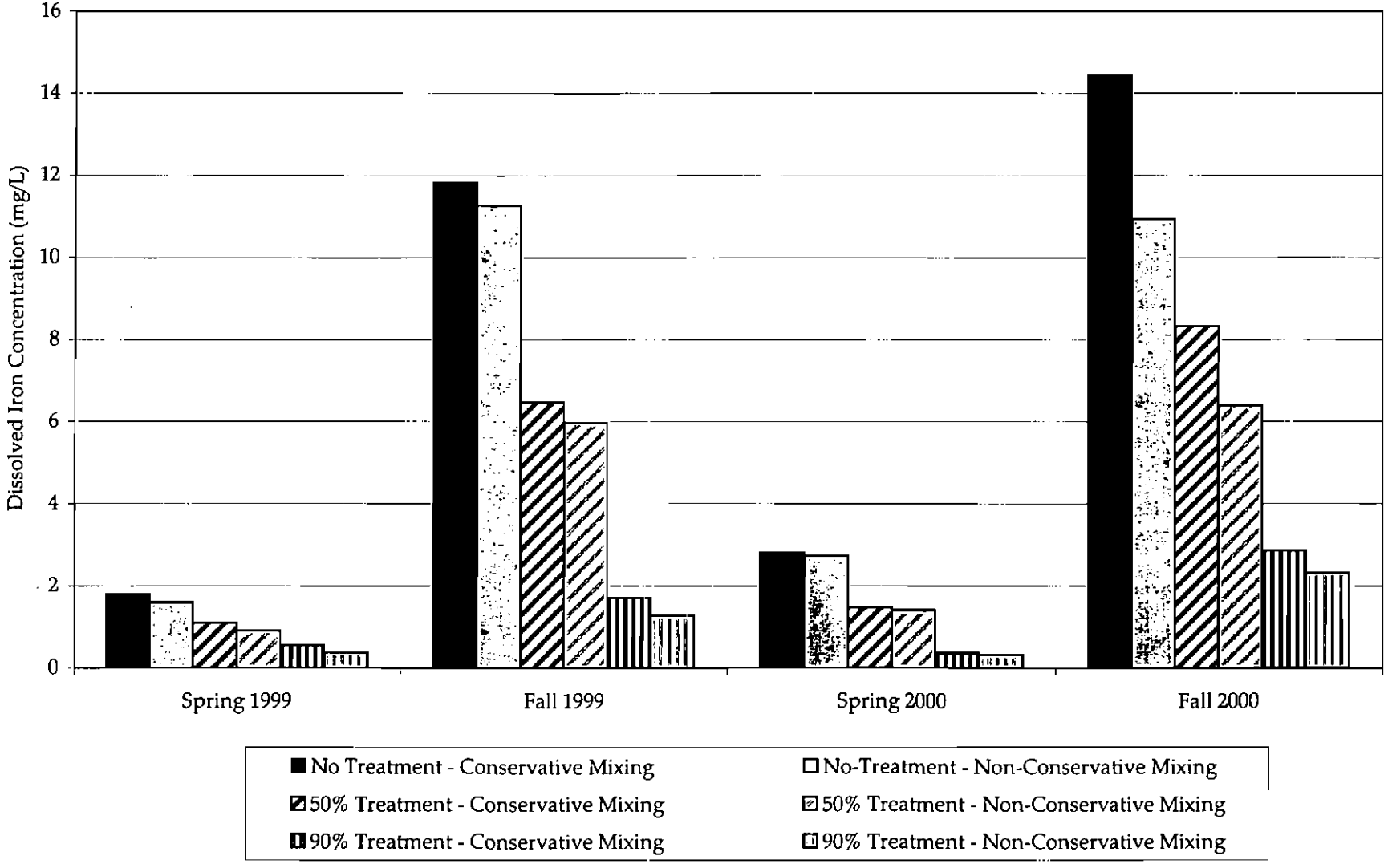

TABLE D-C-1
West Fork Modeling
Spring 1998

		Upstream	*West Fork Tailings Impoundment*						*Simulated Water Quality*		*Downstream*		
Parameters	**Units**	**4/28/98 BBSW-03A**	**4/28/98 WFSW-02.5**	**4/28/98 WFSW-02**	**4/29/98 BBSP-42**	**4/29/98 BBSP-43**	**4/28/98 WFSW-01**	**4/29/98 BBSP-26**	**Conservative Mix**	**Attenuation (with adsorption)**	**4/28/98 BBSW-02**	**4/28/98 BBSW-01.5**	**4/28/98 BBSW-01A**
Flow	cfs	6.1	4.3	0.0067	0.0060	0.031	0.20	0.17			8.9	10.9	12.4
% of Total Flow	%	56.26%	39.92%	0.06%	0.06%	0.29%	1.84%	1.57%					
Alkalinity	mg/L	3	24.6	25.1	1	0	0	1.4	11.1	10.9	6.1	7.2	6
As	mg/L	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.040	0.030	0.04	0.04	0.04
Ca	mg/L	35.6	7.01	119	39.5	59.9	71.9	20.8	24.7	24.7	25.4	22	23.5
Co	mg/L	0.681	0.007	5.88	1.7	6.1	7.94	0.668	0.565	0.565	0.613	0.571	0.675
Cu	mg/L	0.26	0.007	0.004	0.519	0.191	0.097	0.442	0.159	0.141	0.146	0.045	0.045
Fe	mg/L	0.057	0.08	123	0.084	67.1	115	0.019	2.45	2.29	1.5	0.121	0.038
Mg	mg/L	6.33	2.14	22.8	9.32	19.1	23.8	5.42	5.01	5.01	5.22	4.65	5.27
Mn	mg/L	0.173	0.001	3.68	0.796	3.4	4.64	0.124	0.198	0.198	0.215	0.178	0.197
pH	s.u.	6.2	6.9	6.43	4.6	3.3	3.5	5.9	6.61	6.59	6.4	6.6	6.5
SO_4	mg/L	105	4.9	525	168	409	562	59.7	73.9	73.9	74	68.6	65.7
Temp	°C	11	5	7.6	11	17	13.1	3			9	9.7	10

Detection Limits: Arsenic = 0.04 mg/L
Copper = 0.004 mg/L.

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-2
West Fork Modeling
Fall 1998

		Upstream	*West Fork Tailings Impoundment*						*Simulated Water Quality*		*Downstream*		
Parameters	Units	10/13/98 BBSW-03A	10/13/98 WFSW-02.5	10/13/98 WFSW-02	10/14/98 BBSP-42	10/14/98 BBSP-43	10/13/98 WFSW-01	10/14/98 BBSP-26	Conservative Mix	Attenuation (with adsorption)	10/13/98 BBSW-02	10/13/98 BBSW-01.5	10/13/98 BBSW-01A
Flow	cfs	0.9	0.8	0.011	0.1	0.008	0.100	0.010			1.9	2.4	2.6
% of Total Flow		49.20%	41.22%	0.60%	2.68%	0.42%	5.36%	0.54%					
Alkalinity	mg/L	9.4	10.6	24.4	0	0	35.9	1	8.7	8.0	1	1.8	4.4
As	mg/L	0.04	0.04	0.05	0.07	0.06	0.09	0.04	0.044	0.009	0.04	0.04	0.04
Ca	mg/L	10.2	8.76	96.2	45.5	55.5	63.4	16.8	14.1	14.1	15.6	16.2	16.1
Co	mg/L	0.226	0.006	4.91	4.26	5.38	6.76	0.709	0.646	0.645	0.757	0.759	0.713
Cu	mg/L	0.049	0.004	0.004	0.031	0.094	0.02	0.516	0.031	0.013	0.055	0.013	0.005
Fe	mg/L	0.074	0.071	116	66.4	72.5	114	0.019	8.95	8.16	6.41	1.75	0.77
Mg	mg/L	2.82	2.51	21.7	15.7	20.1	23.5	4.17	4.34	4.34	4.7	4.9	4.81
Mn	mg/L	0.069	0.004	3.05	2.3	3.42	3.92	0.129	0.341	0.341	0.417	0.373	0.334
pH	s.u.	6.86	9.01	7.59	3.62	3.38	4.18	4.74	6.93	6.77	7.75	6.31	7.99
SO_4	mg/L	37.6	6.5	526	362	455	573	72.2	67.0	67.0	72.2	73.7	71.7
Temp	°C	9	7.8	8.3	7.9	8.5	8.5	7.6			8.1	7.4	7.7

Detection Limits: Arsenic = 0.04 mg/L
Copper = 0.004 mg/L
Cobalt = 0.003 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-3
West Fork Modeling
Spring 1999

		Upstream	*West Fork Tailings Impoundment*						*Simulated Water Quality*		*Downstream*		
Parameters	**Units**	**5/6/99 BBSW 03A**	**5/6/99 WFSW-2.5**	**5/7/99 WFINTDITCH**	**5/7/99 BBSP-43**	**5/7/99 BBSP-42**	**5/7/99 WFSW-01**	**5/7/99 BBSP-26**	**Conservative Mix**	**Attenuation (with adsorption)**	**5/6/99 BBSW-02**	**5/6/99 BBSW-01A**	**5/6/99 BBSW-01**
Flow	cfs	6.57	8.42	0.18	0.005	0.03	0.01	0.028			15.74	15.23	14.09
% of Total Flow	%	43.10%	55.24%	1.18%	0.03%	0.20%	0.07%	0.18%					
Alkalinity	mg/L	4	21.9	0	0	0	35.8	2.3	13.6	13.4	6.1	8.4	8.8
As	mg/L	0.002	0.008	0.005	0.002	0.004	0.002	0.002	0.005	0.000	0.002	0.002	0.002
Ca	mg/L	58.4	5.27	61.3	49.6	71.3	98.5	12.6	29.1	29.1	34.5	30.8	28.1
Co	mg/L	0.716	0.005	6.53	3.22	7.51	3.87	0.456	0.408	0.408	0.563	0.535	0.521
Cu	mg/L	0.45	0.003	0.156	0.349	0.218	0.003	0.282	0.198	0.177	0.151	0.044	0.051
Fe	mg/L	0.18	0.08	118	7.53	122	57.7	0.13	1.80	1.60	1.06	0.06	0.14
Mg	mg/L	8.89	1.66	23.6	15.4	29.2	21.3	3.68	5.11	5.11	5.64	5.49	5.41
Mn	mg/L	0.246	0.002	4.17	1.97	4.9	2.49	0.079	0.169	0.169	0.254	0.22	0.207
pH	s.u.	6.46	6.96	3.74	3.47	3.32	6.32	5.32	6.80	6.77	6.1	6.76	6.79
SO_4	mg/L	188	3.6	506	243	562	349	43.2	90.5	90.5	111	97.2	94.7
Temp	°C	12.7	6.1	9.7	9.4	10.8	7.3	5			9.4	11.9	9.9

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.005 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-4
West Fork Modeling
Fall 1999

		Upstream	*West Fork Tailings Impoundment*					*Simulated Water Quality*		*Downstream*			
Parameters	Units	9/21/99 BBSW-03A	9/21/99 WFSW-02	9/21/99 WFINTDITCH	9/22/99 BBSP-43	9/22/99 WFSW-01	9/22/99 BBSP-26	Conservative Mix	Attenuation (with adsorption)	9/21/99 BBSW-02	9/21/99 BBSW-01.5	9/21/99 BBSW-01A	9/21/99 BBSW-01
Flow	cfs	0.906	0.700	0.196	0.008	0.006	0.002			2.327	1.996	2.328	2.058
% of Total Flow	%	0.499	0.385	0.108	0.004	0.003	0.001						
Alkalinity	mg/L	3.4	37.3	0.0	0.0	15.8	0.1	15.8	15.3	1.0	1.0	3.8	6.2
As	mg/L	0.002	0.009	0.007	0.002	0.003	0.002	0.005	0.000	0.002	0.002	0.002	0.002
Ca	mg/L	22.8	11.7	56.2	28.0	86.2	26.3	22.3	22.3	23.3	27.1	27.2	28.8
Co	mg/L	0.282	0.013	5.79	1.52	3.74	0.893	0.788	0.788	0.797	0.897	0.803	0.721
Cu	mg/L	0.060	0.003	0.046	0.179	0.007	0.695	0.038	0.026	0.055	0.038	0.014	0.007
Fe	mg/L	0.02	0.23	106	7.37	90	0.02	11.83	11.26	5.01	2.10	0.51	0.02
Mg	mg/L	4.36	2.61	18.5	8.27	17.3	6.79	5.27	5.27	5.85	5.95	6.61	5.99
Mn	mg/L	0.051	0.007	3.14	0.811	2.30	0.151	0.377	0.377	0.406	0.389	0.302	0.246
pH	s.u.	6.69	6.43	4.48	3.68	6.67	5.20	6.44	6.41	6.10	6.09	6.56	6.07
SO_4	mg/L	75.3	7.1	445	151	371	95	90.1	90.1	93.1	99.0	98.7	96.7
Temp	°C	16.5	10.4	11.5	13.6	14.4	14.8			13.3	11.4	10.3	10.9

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.005 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-5
West Fork Modeling
Spring 2000

		Upstream	*West Fork Tailings Impoundment*					*Simulated Water Quality*		*Downstream*			
Parameters	**Units**	**4/26/00 BBSW-03A**	**4/26/00 WFSW-02.5**	**4/25/00 WFINTDITCH**	**4/25/00 BBSP-43**	**4/25/00 WFSW-01**	**4/25/00 BBSP-26**	**Conservative Mix**	**Attenuation (with adsorption)**	**4/26/00 BBSW-02**	**4/26/00 BBSW-01.5**	**4/26/00 BBSW-01A**	**4/26/00 BBSW-01**
Flow	cfs	5.080	3.880	0.270	0.007	0.011	0.074			13.25	12.93	13.27	14.69
% of Total Flow	%	54.49%	41.62%	2.90%	0.08%	0.12%	0.79%						
Alkalinity	mg/L	8.0	19.0	0.0	0.0	16.2	6.6	12.2	12.1	8.7	9.9	10.5	10.4
As	mg/L	0.002	0.007	0.014	0.002	0.002	0.003	0.004	0.002	0.002	0.002	0.003	0.002
Ca	mg/L	52.2	5.2	47.5	29.2	81.1	11.3	32.2	32.2	29	26.5	23.9	24
Co	mg/L	0.501	0.005	5.170	1.750	2.700	0.272	0.432	0.432	0.411	0.394	0.387	0.387
Cu	mg/L	0.089	0.003	0.073	0.173	0.003	0.156	0.053	0.048	0.05	0.054	0.044	0.049
Fe	mg/L	0.050	0.030	93.700	4.410	36.900	0.030	2.81	2.73	1.07	0.79	0.58	0.6
Mg	mg/L	10.7	1.7	19.2	9.3	16.3	3.1	7.16	7.16	6.43	6.09	6.07	6.09
Mn	mg/L	0.505	0.002	2.820	0.937	1.630	0.032	0.361	0.361	0.336	0.296	0.284	0.278
pH	s.u.	6.59	7.08	4.10	3.47	5.21	5.87	6.77	6.75	6.17	6.58	6.98	6.75
SO_4	mg/L	158.0	3.7	391.0	154.0	273.0	34.9	99.7	99.7	87.8	80.3	78.9	78.7
Temp	°C	10.9	3.9	6.5	6.0	6.0	4.1			8.6	8.7	9.2	9.1

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.005 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-6
West Fork Modeling
Fall 2000

		Upstream	West Fork Tailings Impoundment						Simulated Water Quality		Downstream			
Parameters	Units	9/20/00 BBSW-03A	9/20/00 WFSW-02	9/20/00 WFINTDITCH	9/19/00 BBSP-43	9/19/00 BBSP-42	9/19/00 WFSW-01	9/19/00 BBSP-26	Conservative Mix	Attenuation (with adsorption)	9/20/00 BBSW-02	9/20/00 BBSW-01.5	9/20/00 BBSW-01A	9/20/00 BBSW-01A
Flow	cfs	0.910	0.932	0.250	0.004	0.022	0.004	0.035			1.780	2.750	2.390	2.470
% of Total Flow	%	42.19%	43.21%	11.59%	0.18%	1.00%	0.19%	1.64%						
Alkalinity	mg/L	5.5	39.7	0.0	0.0	0.0	60.6	1.1	19.2	16.2	1.0	2.7	4.8	5.0
As	mg/L	0.003	0.013	0.022	0.002	0.003	0.006	0.002	0.010	0.000	0.002	0.002	0.002	0.002
Ca	mg/L	24.1	12.2	45.1	27.0	45.5	65.9	23.2	21.7	21.7	23.1	27.2	27.5	29.0
Co	mg/L	0.298	0.006	5.51	1.49	5.78	1.56	0.685	0.842	0.833	0.878	0.853	0.800	0.837
Cu	mg/L	0.060	0.005	0.029	0.106	0.080	0.003	0.473	0.039	0.009	0.044	0.014	0.010	0.009
Fe	mg/L	0.040	0.020	114	8.03	109	58.5	0.020	14.45	10.94	5.53	0.54	0.30	0.52
Mg	mg/L	5.37	3.36	20.1	8.55	20.4	10.6	5.62	6.38	6.38	6.37	7.47	7.52	7.93
Mn	mg/L	0.071	0.005	3.19	0.867	3.44	1.19	0.093	0.442	0.442	0.513	0.348	0.316	0.343
pH	s.u.	7.260	7.950	5.180	3.300	3.370	6.510	5.180	7.23	6.83	6.34	6.59	6.84	6.44
SO_4	mg/L	84.7	8.7	405	162	466	190	89.2	93.2	93.0	96	111	112	107
Temp	°C	11.7	8.9	9.1	9.6	7.8	10.0	11.2			10.3	10.9	10.9	11.0

Detection Limits: Arsenic = 0.002 mg/L
Copper = 0.003 mg/L
Cobalt = 0.006 mg/L

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-7

West Fork Treatment Modeling

Spring 1999

		Base Case Simulated Water Quality		*Treating 50% of West Fork Interceptor Ditch Simulated Water Quality*		*Treating 90% of West Fork Interceptor Ditch Simulated Water Quality*	
Parameters	**Units**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**
WFINTDITCH Flow	cfs	0.18	0.18	0.09	0.09	0.02	0.02
% of Measured Ditch Flow	%	100	100	50	50	10	10
Alkalinity	mg/L	13.6	13.4	13.8	13.6	13.9	13.7
As	mg/L	0.005	0.000	0.005	0.000	0.005	0.000
Ca	mg/L	29.1	29.1	28.9	28.9	28.7	28.7
Co	mg/L	0.408	0.408	0.371	0.371	0.342	0.342
Cu	mg/L	0.198	0.177	0.199	0.178	0.199	0.179
Fe	mg/L	1.80	1.60	1.11	0.92	0.55	0.38
Mg	mg/L	5.11	5.11	5.00	5.00	4.91	4.91
Mn	mg/L	0.169	0.169	0.145	0.145	0.126	0.126
pH	s.u.	6.80	6.77	6.81	6.79	6.82	6.80
SO_4	mg/L	90.5	90.5	88.0	88.0	86.0	86.0

WFINTDITCH - West Fork Interceptor Ditch

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-8

West Fork Treatment Modeling
Fall 1999

		Base Case Simulated Water Quality		*Treating 50% of West Fork Interceptor Ditch Simulated Water Quality*		*Treating 90% of West Fork Interceptor Ditch Simulated Water Quality*	
Parameters	**Units**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**
WFINTDITCH Flow	cfs	0.196	0.196	0.098	0.098	0.0196	0.0196
% of Measured Ditch Flow	%	100	100	50	50	10	10
Alkalinity	mg/L	15.8	15.3	16.9	16.4	17.8	17.4
As	mg/L	0.005	0.000	0.005	0.000	0.005	0.000
Ca	mg/L	22.3	22.3	20.4	20.4	18.7	18.7
Co	mg/L	0.788	0.788	0.504	0.504	0.251	0.251
Cu	mg/L	0.038	0.026	0.037	0.026	0.037	0.025
Fe	mg/L	11.83	11.26	6.48	5.98	1.71	1.28
Mg	mg/L	5.27	5.27	4.52	4.52	3.85	3.85
Mn	mg/L	0.377	0.377	0.220	0.220	0.080	0.080
pH	s.u.	6.44	6.41	6.45	6.42	6.46	6.44
SO_4	mg/L	90.1	90.1	69.9	69.9	52.0	52.0

WFINTDITCH - West Fork Interceptor Ditch

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-9

West Fork Treatment Modeling

Spring 2000

		Base Case Simulated Water Quality		*Treating 50% of West Fork Interceptor Ditch Simulated Water Quality*		*Treating 90% of West Fork Interceptor Ditch Simulated Water Quality*	
Parameters	**Units**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**
WFINTDITCH Flow	cfs	0.27	0.27	0.135	0.135	0.027	0.027
% of Measured Ditch Flow	%	100	100	50	50	10	10
Alkalinity	mg/L	12.2	12.1	12.4	12.4	12.6	12.6
As	mg/L	0.004	0.002	0.004	0.002	0.004	0.002
Ca	mg/L	32.2	32.2	32.0	32.0	31.8	31.8
Co	mg/L	0.432	0.432	0.362	0.362	0.305	0.305
Cu	mg/L	0.053	0.048	0.053	0.048	0.053	0.048
Fe	mg/L	2.81	2.73	1.47	1.40	0.37	0.32
Mg	mg/L	7.16	7.16	6.98	6.98	6.83	6.83
Mn	mg/L	0.361	0.361	0.324	0.324	0.295	0.295
pH	s.u.	6.77	6.75	6.78	6.77	6.79	6.78
SO_4	mg/L	99.7	99.7	95.4	95.4	91.9	91.9

WFINTDITCH - West Fork Interceptor Ditch

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

TABLE D-C-10

West Fork Treatment Modeling

Fall 2000

		Base Case Simulated Water Quality		*Treating 50% of West Fork Interceptor Ditch Simulated Water Quality*		*Treating 90% of West Fork Interceptor Ditch Simulated Water Quality*	
Parameters	**Units**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**	**Conservative Mix**	**Attenuation (with adsorption)**
WFINTDITCH Flow	cfs	0.25	0.25	0.125	0.125	0.025	0.025
% of Measured Ditch Flow	%	100	100	50	50	10	10
Alkalinity	mg/L	19.2	16.2	20.4	18.7	21.5	21.0
As	mg/L	0.010	0.000	0.009	0.000	0.008	0.000
Ca	mg/L	21.7	21.7	20.2	20.2	18.9	18.9
Co	mg/L	0.842	0.833	0.554	0.549	0.298	0.296
Cu	mg/L	0.039	0.009	0.040	0.017	0.041	0.029
Fe	mg/L	14.45	10.94	8.33	6.38	2.86	2.31
Mg	mg/L	6.38	6.38	5.53	5.53	4.78	4.78
Mn	mg/L	0.442	0.442	0.272	0.272	0.121	0.121
pH	s.u.	7.23	6.83	7.31	7.05	7.41	7.31
SO_4	mg/L	93.2	93.0	74.0	73.9	56.9	56.9

WFINTDITCH - West Fork Interceptor Ditch

Results for the following constituents are for the dissolved phase: As, Ca, Co, Cu, Fe, Mg and Mn.

Appendix E

APPENDIX E

COSTS

APPENDIX E

REMEDIATION ALTERNATIVE COST ESTIMATES

BLACKBIRD MINE SITE
LEMHI COUNTY, IDAHO

Prepared for:

Blackbird Mine Site Group

Submitted by:

Golder Associates Inc.
Redmond, Washington

June 21, 2002

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Final Report App E cost intro.doc

APPENDIX E

REMEDIATION ALTERNATIVE COST ESTIMATES

The appendix contains the detailed cost estimates for the remediation alternatives under consideration for the Blackbird Mine Site. For each alternative, capital, operation, and maintenance, and monitoring costs have been estimated. Alternative costs are compared on a net present value basis. The interest rate of 7% (net of inflation) used for present value calculations is the rate recommended by the EPA for feasibility study cost estimates.

The cost estimates in this FS are based on the description of the alternatives and associated design assumptions in Chapter 6. The design assumptions used here are representative and sufficient for the purposes of comparative evaluation of the alternatives, but are not necessarily the same as the design basis that would be used for the final, detailed design. Pre-design investigations would be included in the final design phase for any of these remedial actions, and the results of these investigations could result in changes from the preliminary designs presented in this FS.

EPA guidance suggests a target accuracy of +50%/-30%. The cost estimates in the FS were developed to meet this target to the extent practical. The design basis is subject to change during final, detailed design of the selected alternative, and these changes would affect the cost of the remedy. Changes in design assumptions could result in costs outside the target precision range. For small cost items, an allowance was sometimes used instead of a specific estimate where it was believed that use of an allowance would not significantly affect the accuracy of the estimate.

The uncertainties in the FS designs and associated cost estimates are such that actual costs could vary significantly from these estimates. However, the uncertainty in the relative cost of the alternatives is much less than the uncertainty in the magnitude of the costs, and these cost estimates are suitable for comparative evaluation of the alternatives.

Tables E-1 through E-9 present the cost estimates for the Blackbird Creek alternatives. Tables E-10 through E-14 present the cost estimates for the Bucktail Creek alternatives. Tables E-15 through E-17 present the cost estimates for the Panther Creek alternatives. The cost estimates for all of the alternatives are summarized in Table 7-14.

In the cost estimate tables for the alternatives, several cost items were estimated as percentages rather than specific detailed estimates for the line item. These items were:

- Contractor overhead and profit – 20% – mid-range of values for site remediation work.
- Engineering and construction surveillance – 25% – within the range observed for CERCLA sites.

- Agency oversight – 10% – based on BMSG experience.
- Project management and legal (costs incurred by BMSG) – 10% – based on BMSG experience.
- Contingency – 25% – appropriate for FS cost estimates.

Most of these alternatives use more detailed cost estimates for components, which are presented in Tables E-18 through E-29. The component cost tables do not include contractor overhead and profit, engineering, and other such items contained in the alternative cost estimates. Thus, the component cost estimates are not intended as "stand-alone" estimates for the component. "Basic" unit costs used in the estimates are generally documented in Table E-30. However, some unit costs are documented only in the table where they are used and are not found in Table E-30. The cost estimate tables contain short notes to assist the reader. However, not every backup calculation is presented in these cost tables. Rather, it is assumed that any detailed review of these costs is performed by an experienced cost estimator capable of assessing the reasonableness of the estimates and/or performing the necessary calculations based on the descriptions of the alternatives in Chapter 6 (including the associated figures and tables).

TABLE E-1
ESTIMATED COST FOR ALTERNATIVE BB-1

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS				**$0**	
OPERATIONS AND MAINTENANCE COSTS					
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$900,000	
Project management			5%	$45,000	
Agency oversight			10%	$90,000	
Contingency			25%	$225,000	
NET PRESENT VALUE O&M COST				**$1,260,000**	
TOTAL ALTERNATIVE COST				**$1,260,000**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-2
ESTIMATED COST FOR ALTERNATIVE BB-4

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek Seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Clay for north portion of soil cover (1 ft)	6,900	cy	$35	$241,500	Under 2 ft of vegetative cover
Armoring of overbank deposits	9,800	cy	$40	$392,000	Vol. estimated from Chapter 6 figures
Removal of selected overbank deposits	8,800	cy	$20	$176,000	Vol. estimated from Chapter 6 figures
Armoring residual above human health PRG	1,000	cy	$40	$40,000	Allowance
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$1,124,300	
Contractor overhead and profit			20%	$225,000	
Engineering and construction surveillance			25%	$281,000	
Agency oversight			10%	$112,000	
Project management and legal			10%	$112,000	
Contingency			25%	$281,000	
TOTAL CAPITAL COSTS				**$2,135,300**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Inspection and monitoring of armoring	30	yr	$20,000	$248,000	Allowance
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Sediment cleanout of Blackbird channel near PCI	30	yr	$4,000	$50,000	Allowance for infrequent event
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$1,508,000	
Project management			5%	$75,000	
Agency oversight			10%	$151,000	
Contingency			25%	$377,000	
NET PRESENT VALUE O&M COST				**$2,111,000**	
TOTAL ALTERNATIVE COST				**$4,246,300**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-3
ESTIMATED COST FOR ALTERNATIVE BB-5a

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Treatment of Tailings Impoundment seepage				$802,000	In-situ sorption; 50% removal; Table E-22
Armoring of overbank deposits	9,800	cy	$40	$392,000	Vol. estimated from Chapter 6 figures
Removal of selected overbank deposits	8,800	cy	$20	$176,000	Vol. estimated from Chapter 6 figures
Armoring residual above human health PRG	1,000	cy	$40	$40,000	Allowance
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$1,684,800	
Contractor overhead and profit			20%	$337,000	
Engineering and construction surveillance			25%	$421,000	
Agency oversight			10%	$168,000	
Project management and legal			10%	$168,000	
Contingency			25%	$421,000	
TOTAL CAPITAL COSTS				**$3,199,800**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Tailings Impoundment seepage treatment	30	yr	$67,000	$831,000	Table E-22
Inspection and monitoring of armoring	30	yr	$20,000	$248,000	Allowance
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Sediment cleanout of Blackbird channel near PCI	30	yr	$4,000	$50,000	Allowance for infrequent event
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$2,339,000	
Project management			5%	$117,000	
Agency oversight			10%	$234,000	
Contingency			25%	$585,000	
NET PRESENT VALUE O&M COST				**$3,275,000**	
TOTAL ALTERNATIVE COST				**$6,474,800**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-4
ESTIMATED COST FOR ALTERNATIVE BB-5b

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Treatment of Tailings Impoundment seepage				$1,920,000	Pump to WTP; 80% removal; Table E-20
Armoring of overbank deposits	9,800	cy	$40	$392,000	Vol. estimated from Chapter 6 figures
Removal of selected overbank deposits	8,800	cy	$20	$176,000	Vol. estimated from Chapter 6 figures
Armoring residual above human health PRG	1,000	cy	$40	$40,000	Allowance
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$2,802,800	
Contractor overhead and profit			20%	$561,000	
Engineering and construction surveillance			25%	$701,000	
Agency oversight			10%	$280,000	
Project management and legal			10%	$280,000	
Contingency			25%	$701,000	
TOTAL CAPITAL COSTS				**$5,325,800**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Tailings Impoundment seepage treatment	30	yr	$144,000	$1,787,000	Table E-20
Inspection and monitoring of armoring	30	yr	$20,000	$248,000	Allowance
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Sediment cleanout of Blackbird channel near PCI	30	yr	$4,000	$50,000	Allowance for infrequent event
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$3,295,000	
Project management			5%	$165,000	
Agency oversight			10%	$330,000	
Contingency			25%	$824,000	
NET PRESENT VALUE O&M COST				**$4,614,000**	
TOTAL ALTERNATIVE COST				**$9,939,800**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-5
ESTIMATED COST FOR ALTERNATIVE BB-6

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Clay for north portion of soil cover (1 ft)	6,900	cy	$35	$241,500	Under 2 ft of vegetative cover
Armoring of overbank deposits	2,900	cy	$40	$116,000	Vol. estimated from Chapter 6 figures
Removal of selected overbank deposits	37,000	cy	$20	$740,000	Vol. estimated from Chapter 6 figures
Armoring residual above human health PRG	1,000	cy	$40	$40,000	Allowance
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$1,412,300	
Contractor overhead and profit			20%	$282,000	
Engineering and construction surveillance			25%	$353,000	
Agency oversight			10%	$141,000	
Project management and legal			10%	$141,000	
Contingency			25%	$353,000	
TOTAL CAPITAL COSTS				**$2,682,300**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Inspection and monitoring of armoring	30	yr	$10,000	$124,000	Allowance
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Sediment cleanout of Blackbird channel near PCI	30	yr	$4,000	$50,000	Allowance for infrequent event
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$1,384,000	
Project management			5%	$69,000	
Agency oversight			10%	$138,000	
Contingency			25%	$346,000	
NET PRESENT VALUE O&M COST				**$1,937,000**	
TOTAL ALTERNATIVE COST				**$4,619,300**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-6
ESTIMATED COST FOR ALTERNATIVE BB-7a

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Treatment of Tailings Impoundment seepage				$802,000	In-situ sorption; 50% removal; Table E-22
Armoring of overbank deposits	2,900	cy	$40	$116,000	Vol. estimated from Chapter 6 figures
Removal of selected overbank deposits	37,000	cy	$20	$740,000	Vol. estimated from Chapter 6 figures
Armoring residual above human health PRG	1,000	cy	$40	$40,000	Allowance
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$1,972,800	
Contractor overhead and profit			20%	$395,000	
Engineering and construction surveillance			25%	$493,000	
Agency oversight			10%	$197,000	
Project management and legal			10%	$197,000	
Contingency			25%	$493,000	
TOTAL CAPITAL COSTS				**$3,747,800**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Tailings Impoundment seepage treatment	30	yr	$67,000	$831,000	Table E-22
Inspection and monitoring of armoring	30	yr	$10,000	$124,000	Allowance
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Sediment cleanout of Blackbird channel near PCI	30	yr	$4,000	$50,000	Allowance for infrequent event
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$2,215,000	
Project management			5%	$111,000	
Agency oversight			10%	$222,000	
Contingency			25%	$554,000	
NET PRESENT VALUE O&M COST				**$3,102,000**	
TOTAL ALTERNATIVE COST				**$6,849,800**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-7
ESTIMATED COST FOR ALTERNATIVE BB-7b

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Treatment of Tailings Impoundment seepage				$1,920,000	Pump to WTP; 80% removal; Table E-20
Armoring of overbank deposits	2,900	cy	$40	$116,000	Vol. estimated from Chapter 6 figures
Removal of selected overbank deposits	37,000	cy	$20	$740,000	Vol. estimated from Chapter 6 figures
Armoring residual above human health PRG	1,000	cy	$40	$40,000	Allowance
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$3,090,800	
Contractor overhead and profit			20%	$618,000	
Engineering and construction surveillance			25%	$773,000	
Agency oversight			10%	$309,000	
Project management and legal			10%	$309,000	
Contingency			25%	$773,000	
TOTAL CAPITAL COSTS				**$5,872,800**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Tailings Impoundment seepage treatment	30	yr	$144,000	$1,787,000	Table E-20
Inspection and monitoring of armoring	30	yr	$10,000	$124,000	Allowance
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Sediment cleanout of Blackbird channel near PCI	30	yr	$4,000	$50,000	Allowance for infrequent event
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$3,171,000	
Project management			5%	$159,000	
Agency oversight			10%	$317,000	
Contingency			25%	$793,000	
NET PRESENT VALUE O&M COST				**$4,440,000**	
TOTAL ALTERNATIVE COST				**$10,312,800**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-8
ESTIMATED COST FOR ALTERNATIVE BB-8a

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Treatment of Tailings Impoundment seepage				$802,000	In-situ sorption; 50% removal; Table E-22
Stream diversion and dewatering treatment				$5,000,000	Allowance
Complete sediment removal	650,000	cy	$20	$13,000,000	Entire channel; including hauling
Sediment disposal				$2,740,000	New disposal cell; see Table E-27
Restoration backfill and revegetation	200,000	cy	$20	$4,000,000	Assume 30% of removal volume
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$25,816,800	
Contractor overhead and profit			20%	$5,163,000	
Engineering and construction surveillance			25%	$6,454,000	
Agency oversight			10%	$2,582,000	
Project management and legal			10%	$2,582,000	
Contingency			25%	$6,454,000	
TOTAL CAPITAL COSTS				**$49,051,800**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Tailings Impoundment seepage treatment	30	yr	$67,000	$831,000	In-situ sorption, Table E-22
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Monitoring and reporting for sediment disposal cell	30	yr	$50,000	$620,000	Table E-27
Subtotal				$2,661,000	
Project management			5%	$133,000	
Agency oversight			10%	$266,000	
Contingency			25%	$665,000	
NET PRESENT VALUE O&M COST				**$3,725,000**	
TOTAL ALTERNATIVE COST				**$52,776,800**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-9
ESTIMATED COST FOR ALTERNATIVE BB-8b

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collect Meadow Creek seeps				$116,000	See Table E-18
Tailings Impoundment soil cover - grading	11.4	ac	$5,000	$57,000	Material already placed
Revegetation for soil cover	11.4	ac	$2,000	$22,800	Impoundment area less creek channel
Treatment of Tailings Impoundment seepage				$1,920,000	Pump to WTP; 80% removal; Table E-20
Stream diversion and dewatering treatment				$5,000,000	Allowance
Complete sediment removal	650,000	cy	$20	$13,000,000	Including hauling
Sediment disposal				$2,740,000	New disposal cell; see Table E-27
Restoration backfill and revegetation	200,000	cy	$20	$4,000,000	Assume 30% of removal volume
Channel for Blackbird Creek near PCI				$29,000	See Table E-23
Establish institutional controls				$50,000	Allowance
Subtotal				$26,934,800	
Contractor overhead and profit			20%	$5,387,000	
Engineering and construction surveillance			25%	$6,734,000	
Agency oversight			10%	$2,693,000	
Project management and legal			10%	$2,693,000	
Contingency			25%	$6,734,000	
TOTAL CAPITAL COSTS				**$51,175,800**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Tailings Impoundment soil cover maintenance	30	yr	$4,000	$50,000	Allowance
Meadow Creek treatment	30	yr	$20,000	$248,000	Diversion option; see Table E-18
Tailings Impoundment seepage treatment	30	yr	$144,000	$1,787,000	Pumpback to WTP, Table E-20
Maintenance of existing fencing	30	yr	$1,000	$12,000	Allowance
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Monitoring and reporting for sediment disposal cell	30	yr	$50,000	$620,000	Table E-27
Subtotal				$3,617,000	
Project management			5%	$181,000	
Agency oversight			10%	$362,000	
Contingency			25%	$904,000	
NET PRESENT VALUE O&M COST				**$5,064,000**	
TOTAL ALTERNATIVE COST				**$56,239,800**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-10
ESTIMATED COST FOR ALTERNATIVE BT-1

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS				**$0**	
OPERATIONS AND MAINTENANCE COSTS					
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$900,000	
Project management			5%	$45,000	
Agency oversight			10%	$90,000	
Contingency			25%	$225,000	
NET PRESENT VALUE O&M COST				**$1,260,000**	
TOTAL ALTERNATIVE COST				**$1,260,000**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-11
ESTIMATED COST FOR ALTERNATIVE BT-3

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collection and treatment of Bucktail Creek seeps				$190,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps				$879,000	Phase 2; see Table E-25
Subtotal				$1,069,000	
Contractor overhead and profit			20%	$214,000	
Engineering and construction surveillance			25%	$267,000	
Agency oversight			10%	$107,000	
Project management and legal			10%	$107,000	
Contingency			25%	$267,000	
TOTAL CAPITAL COSTS				**$2,031,000**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Collection and treatment of Bucktail Creek seeps	30	yr	$39,000	$484,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps	30	yr	$25,000	$310,000	Phase 2; see Table E-25
Sediment dam maintenance or removal				$50,000	Allowance
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$1,744,000	
Project management			5%	$87,000	
Agency oversight			10%	$174,000	
Contingency			25%	$436,000	
NET PRESENT VALUE O&M COST				**$2,441,000**	
TOTAL ALTERNATIVE COST				**$4,472,000**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-12
ESTIMATED COST FOR ALTERNATIVE BT-4

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collection and treatment of Bucktail Creek seeps				$190,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps				$879,000	Phase 2; see Table E-25
Stream diversion and dewatering treatment				$150,000	Allowance
Sediment removal and disposal at Blacktail Pit	2,300	cy	$50	$115,000	S. Fork Big Deer Creek [c]
Restoration backfill and revegetation	2,300	cy	$20	$46,000	S. Fork Big Deer Creek [c]
Subtotal				$1,380,000	
Contractor overhead and profit			20%	$276,000	
Engineering and construction surveillance			25%	$345,000	
Agency oversight			10%	$138,000	
Project management and legal			10%	$138,000	
Contingency			25%	$345,000	
TOTAL CAPITAL COSTS				**$2,622,000**	
OPERATIONS AND MAINTENANCE COSTS				*Present value calculation, 7% net interest*	
Collection and treatment of Bucktail Creek seeps	30	yr	$39,000	$484,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps	30	yr	$25,000	$310,000	Phase 2; see Table E-25
Sediment dam maintenance or removal				$50,000	Allowance
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$1,744,000	
Project management			5%	$87,000	
Agency oversight			10%	$174,000	
Contingency			25%	$436,000	
NET PRESENT VALUE O&M COST				**$2,441,000**	
TOTAL ALTERNATIVE COST				**$5,063,000**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

[c] 3100-ft channel length x 10-ft width x 2-ft depth.

TABLE E-13
ESTIMATED COST FOR ALTERNATIVE BT-5

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collection and treatment of Bucktail Creek seeps				$190,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps				$879,000	Phase 2; see Table E-25
Divert Bucktail Creek directly to Big Deer Creek	3,400	lf	$45	$153,000	24-inch HDPE pipe
Flow Splitter				$10,000	Estimate
Diffuser				$30,000	Discharge into Big Deer Creek
Subtotal				$1,222,000	
Contractor overhead and profit			20%	$244,000	
Engineering and construction surveillance			25%	$306,000	
Agency oversight			10%	$122,000	
Project management and legal			10%	$122,000	
Contingency			25%	$306,000	
TOTAL CAPITAL COSTS				**$2,322,000**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Collection and treatment of Bucktail Creek seeps	30	yr	$39,000	$484,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps	30	yr	$25,000	$310,000	Phase 2; see Table E-25
Sediment dam maintenance or removal				$50,000	Allowance
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Subtotal				$1,744,000	
Project management			5%	$87,000	
Agency oversight			10%	$174,000	
Contingency			25%	$436,000	
NET PRESENT VALUE O&M COST				**$2,441,000**	
TOTAL ALTERNATIVE COST				**$4,763,000**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-14
ESTIMATED COST FOR ALTERNATIVE BT-6

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Collection and treatment of Bucktail Creek seeps				$190,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps				$879,000	Phase 2; see Table E-25
Stream diversion and dewatering treatment				$1,000,000	Allowance
Sediment removal (including hauling)	36,000	cy	$50	$1,800,000	Bucktail, S.Fork, & Big Deer Creeks
Sediment disposal				$350,000	New disposal cell, Table E-28
Restoration backfill and revegetation	10,000	cy	$20	$200,000	Assume 30% of removal volume
Subtotal				$4,419,000	
Contractor overhead and profit			20%	$884,000	
Engineering and construction surveillance			25%	$1,105,000	
Agency oversight			10%	$442,000	
Project management and legal			10%	$442,000	
Contingency			25%	$1,105,000	
TOTAL CAPITAL COSTS				**$8,397,000**	
OPERATIONS AND MAINTENANCE COSTS				Present value calculation, 7% net interest	
Collection and treatment of Bucktail Creek seeps	30	yr	$39,000	$484,000	Phase 1; see Table E-24
Collection and treatment of Bucktail Creek seeps	30	yr	$25,000	$310,000	Phase 2; see Table E-25
Sediment dam maintenance or removal				$50,000	Allowance
Monitoring and reporting (see Table E-29)	30	yr		$900,000	Present value cost of cash flow
Monitoring and reporting for sediment disposal cell	30	yr	$30,000	$372,000	Table E-28
Subtotal				$2,116,000	
Project management			5%	$106,000	
Agency oversight			10%	$212,000	
Contingency			25%	$529,000	
NET PRESENT VALUE O&M COST				**$2,963,000**	
TOTAL ALTERNATIVE COST				**$11,360,000**	Net present value [b]

[a] Costs are for early 2002. Costs do not included current O&M costs.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-15
ESTIMATED COST FOR ALTERNATIVE P-1

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS				**$0**	
OPERATIONS AND MAINTENANCE COSTS					
Monitoring and reporting (see Table E-29)	30	yr		$0	Present value cost of cash flow
Subtotal				$0	
Project management			5%	$0	
Agency oversight			10%	$0	
Contingency			25%	$0	
NET PRESENT VALUE O&M COST				**$0**	
TOTAL ALTERNATIVE COST				**$0**	Net present value [b]

[a] Costs are for early 2002.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-16
ESTIMATED COST FOR ALTERNATIVE P-2

Item	Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS					
Establish instutional controls				$50,000	Allowance
Subtotal				$50,000	
Agency oversight				$20,000	Allowance
Project management and legal				$20,000	Allowance
Contingency			25%	$13,000	
TOTAL CAPITAL COSTS				**$103,000**	
OPERATIONS AND MAINTENANCE COSTS					
Institutional controls monitoring (allowance)	30	yr	$5,000	$62,000	Present value cost of cash flow
Monitoring and reporting (see Table E-29)	30	yr		$0	Present value cost of cash flow
Subtotal				$62,000	
Project management			5%	$3,000	
Agency oversight			10%	$6,000	
Contingency			25%	$16,000	
NET PRESENT VALUE O&M COST				**$87,000**	
TOTAL ALTERNATIVE COST				**$190,000**	Net present value [b]

[a] Costs are for early 2002.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-17
ESTIMATED COST FOR ALTERNATIVE P-3

Item		Quantity	Units	Unit Cost	Cost [a]	Notes
CAPITAL COSTS						
Selective removal - Rogers #1		9,600		$50	$480,000	Vol. estimated from Chapter 6 figures
Selective removal - Rogers #2		1,000		$50	$50,000	Vol. estimated from Chapter 6 figures
Selective removal - Rogers #3		3,000		$50	$150,000	Vol. estimated from Chapter 6 figures
Selective removal - Rufe		800		$50	$40,000	Vol. estimated from Chapter 6 figures
Selective removal - Strawn		300		$50	$15,000	Vol. estimated from Chapter 6 figures
	Subtotal	14,700			$735,000	
Contractor overhead and profit				20%	$147,000	
Engineering and construction surveillance				25%	$184,000	
Agency oversight				10%	$74,000	
Project management and legal				10%	$74,000	
Contingency				25%	$184,000	
TOTAL CAPITAL COSTS					**$1,398,000**	
OPERATIONS AND MAINTENANCE COSTS						
Monitoring and reporting (see Table E-29)		30	yr		$0	Present value cost of cash flow
	Subtotal				$0	
Project management				5%	$0	
Agency oversight				10%	$0	
Contingency				25%	$0	
NET PRESENT VALUE O&M COST					**$0**	
TOTAL ALTERNATIVE COST					**$1,398,000**	Net present value [b]

[a] Costs are for early 2002.

[b] The sum of capital costs and the net present value of long-term O&M costs.

TABLE E-18
ESTIMATED COST FOR MEADOW CREEK DIVERSION

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Pre-design investigations				$20,000	Allowance
Stormwater diversion ditch and access road	1,600	lf	$32	$51,200	See Figure 6-3
Meadow Creek clean water dam and connection				$25,000	Connect to 7800 diversion pipe
Inlet structure for diversion ditch				$15,000	
Regrade 7350 dam				$5,000	Connect to existing 7100 West diversion pipe Creek to discharge to 7100 Reservior
TOTAL CAPITAL COSTS				**$116,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
WTP treatment costs	10,000	K gal	$2.00	$20,000	Average year hydrograph
ANNUAL O & M COSTS				**$20,000**	Rounded

[a] Costs are for early 2002.
[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-19
ESTIMATED COST FOR MEADOW CREEK SEEP COLLECTION

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Pre-design investigations				$40,000	Allowance
Interception trench length	300	lf			Length of trench
Trench excavation	3,644	cy	$10	$36,444	Volume of trench excavation
Clay	800	cy	$40	$32,000	See Figure 6-4
Rock, free-draining, site source	2,844	cy	$15	$42,667	See Figure 6-4
HDPE, 6" perforated	300	lf	$20	$6,000	See Figure 6-4
HDPE, 6" transfer pipe	50	lf	$35	$1,750	See Figure 6-4
Access manhole	1	ea	$5,000	$5,000	Estimate
TOTAL CAPITAL COSTS				**$164,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
WTP treatment costs	6,000	K gal	$2.00	$12,000	10 gpm fall; 15 gpm spring
ANNUAL O & M COSTS				**$12,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-20
ESTIMATED COST FOR COLLECTION OF TAILINGS IMPOUNDMENT SEEPAGE AND PUMPBACK TO WTP

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
Flow collected (50% removal assumed)	100	gpm			Annual average
CAPITAL COSTS					
Pre-design investigations				$40,000	Allowance
Interception trench length	300	lf			Length of trench
Trench excavation	1,844	cy	$10	$18,444	Volume of trench excavation
Rock, free-draining, site source	1,844	cy	$15	$27,667	Trench volume
Clay trench cap	128	cy	$35	$4,472	See Figure 6-6
Pump station (incl. backup generator)	4	ea	$200,000	$800,000	West Fork + 3 booster stations; including pumps
Electrical line (WTP to West Fork)	16,000	lf	$20	$320,000	Length to WTP
Pipeline (West Fork to 7100 dam)	20,300	lf	$35	$710,500	6" HDPE, buried
TOTAL CAPITAL COSTS				**$1,920,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
WTP treatment costs	53,000	K gal	$2.00	$106,000	Annual flow; assume WTP O&M costs
Treatment plant monitoring and reporting				included in WTP costs	
Electricity (pump to WTP)	462,000	KWH	$0.06	$27,720	Power req'd from pumping head
Maintenance, supplies, &misc.				$10,000	Allowance
ANNUAL O & M COSTS				**$144,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-21
ESTIMATED COST FOR EX-SITU TREATMENT OF TAILINGS IMPOUNDMENT SEEPAGE AT WEST FORK

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
Flow collected (50% removal assumed)	100	gpm			Annual average
CAPITAL COSTS					
Pre-design investigations				$70,000	Allowance
Interception trench length	300	lf			Length of trench
Trench excavation	1,844	cy	$10	$18,444	Volume of excavation
Rock, free-draining, site source	1,844	cy	$15	$27,667	Trench volume
Clay trench cap	128	cy	$35	$4,472	Similar to Figure 6-6
Pump station				$60,000	Estimate
Package treatment plant (lime precip. & oxidation)				$250,000	Vendor quote, FOB site
Sludge storage tank	20,000	gal	$2.50	$50,000	Estimate
Sludge pump	1	each	$5,000	$5,000	Estimate
Piping and instrumentation				$50,000	15% of major equipment
Controls and telemetry				$100,000	Estimate
Backup generator				$150,000	Estimate based on site costs
Building (25'x60')	1,500	sf	$200	$300,000	Metal building, concrete slab
Installation labor	1,600	hr	$75	$120,000	40 person-weeks
Installation supervision	400	hr	$100	$40,000	25% of labor hours
Electrical line (WTP to West Fork)	16,000	lf	$20	$320,000	Length to WTP
TOTAL CAPITAL COSTS				**$1,570,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
Treatment costs	53,000	K gal	$2.00	$106,000	Annual flow; assume WTP O&M costs
Sludge hauling	90,000	gal	$0.06	$5,400	To mine / disposal cell
Treatment plant monitoring and reporting				$50,000	Allowance
ANNUAL O & M COSTS				**$161,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-22
ESTIMATED COST FOR IN-SITU TREATMENT OF TAILINGS IMPOUNDMENT SEEPAGE

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
Flow intercepted (50% removal assumed)	100	gpm			Annual average
CAPITAL COSTS					
Pre-design investigations & treatability study				$100,000	Allowance
Slurry wall	300	lf			Seepage collection
Mobilization for slurry wall		LS		$100,000	Estimate
Slurry wall	9,000	sf	$40	$360,000	30 ft avg depth
Concrete vault for sorption material				$50,000	Estimate for apatite volume
Apatite sorption material	800	cy			8 hr contact time; 30% porosity
	320	ton	$600	$192,000	30 lb/ft3 = 0.4 ton/cy
TOTAL CAPITAL COSTS				**$802,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
Apatite replacement	77	ton	$600	$46,200	assume 2% wt for 7 mg/L Co+Cu
	193	cy	$5	$963	Excavate old apatite and replace
Technology royalties, if applicable				---	Not included
Treatment system monitoring and reporting				$20,000	Allowance
ANNUAL O & M COSTS				**$67,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-23
ESTIMATED COST FOR BLACKBIRD CREEK CHANNEL NEAR PCI

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Sediment removal in Blackbird channel near PCI	1,140	cy	$20	$22,800	Excavate, haul to West Fork
Restoration backfill and revegetation	300	cy	$20	$6,000	Assume 30% of removal volume
TOTAL CAPITAL COSTS				**$29,000**	Rounded

[a] Costs are for early 2002.
[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-24
ESTIMATED COST FOR BUCKTAIL CREEK SEEP COLLECTION AND TREATMENT (Phase 1)

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Pre-design investigations				$50,000	Allowance
Replace pumps in existing pump station	2	ea	$50,000	$100,000	100 gpm each
Pumped drain pipe to portal, 4" HDPE	635	lf	$25	$15,875	
Interception Trench					
Return water pipe, 6" HDPE	200	lf	$35	$7,000	gravity drain to pump station
Interception trench length	50	lf			Length of trench
Trench excavation	287	cy	$10	$2,870	Volume of trench
Clay core	102	cy	$50	$5,093	See Figure 6-14
Collector pipe, 6" perf. HDPE	50	lf	$20	$1,000	See Figure 6-14
Rock, free-draining, site source	139	cy	$15	$2,083	See Figure 6-14
Clay trench cap	2	cy	$50	$93	See Figure 6-14
Manhole, 48"	1	ea	$6,000	$6,000	Estimate
TOTAL CAPITAL COSTS				**$190,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
Flow collected	26	gpm			65% of base flow
WTP treatment costs	14,000	K gal	$2.00	$28,000	Annual flow; assume WTP O&M costs
Electricity (pump to WTP)	20,000	KWH	$0.06	$1,200	Power req'd from pumping head
Maintenance, supplies, &misc.				$10,000	Allowance
ANNUAL O & M COSTS				**$39,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-25
ESTIMATED COST FOR BUCKTAIL CREEK SEEP COLLECTION AND TREATMENT (Phase 2)

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Pre-design investigations				$50,000	Allowance
Pump station (incl. backup generator)	1	ea	$200,000	$200,000	Including pumps
Electrical power line	1,400	lf	$20	$28,000	Golder 1995 cost + inflation
Interception Trenches (two)					Unit cost derived from Phase 1 estimate
Trench construction, West Fork Bucktail	50	lf	$343	$17,139	Clean water interception; gravity drain
Trench construction, Bucktail	50	lf	$343	$17,139	Base flow collection
Pumped water pipe, 4" PVC	1,500	lf	$25	$37,500	To existing (upgraded) pump station
Separation of Stormwater and Base Flow					See Figure 6-14
12' Access Road	800	lf	$15	$12,000	
36" HDPE with 1" holes	1,660	lf	$70	$116,200	Surface water flow
6" Collection drain pipe	1,660	lf	$20	$33,200	Base flow drain
FML liner, 60 mil	33,200	sf	$1.00	$33,200	Liner
Geotextile	33,200	sf	$0.50	$16,600	Liner
Sand	1,230	cy	$60	$73,778	Sand under liner
Rock, free-draining, site source	2,306	cy	$15	$34,583	Base flow as groundwater
Energy dissipation feature				$50,000	Allowance
Remove existing sediment dam	3,200	cy	$50	$160,000	Assume contamined
TOTAL CAPITAL COSTS				**$879,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
Flow collected	14	gpm			Remainder of 40-gpm base flow
WTP treatment costs	7,000	K gal	$2.00	$14,000	Annual flow; assume WTP O&M costs
Electricity (pump to WTP)	19,000	KWH	$0.06	$1,140	Power req'd from pumping head
Maintenance, supplies, &misc.				$10,000	Allowance
ANNUAL O & M COSTS				**$25,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-26
ESTIMATED COST FOR DISPOSAL CELL WTP SLUDGE

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CONSTRUCTION COSTS					
Pre-design investigations				$10,000	Allowance
Sludge generation (annual)	680	cy			Estimate
Concrete drying beds (2)	300	cy	$600	$180,000	20' x 300' x 3', 6 inch walls and slab
Haul to disposal cell	12,300	cy	$10	$123,000	Over 23 years
Disposal cell in Blacktail Pit					23-yr life
Containment berm (30 ft high)	30,000	cy	$10	$300,000	12,300 cy of storage [d]
TOTAL COSTS [c]				**$613,000**	Rounded
Net Present Value of Construction Costs				**$381,746**	Assuming one-time cost in year 7

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

[c] Assume operation and maintenance (O&M) costs covered by WTP O&M costs.

[d] Rough volume to constuct a containment berm in the mouth of the Blacktail Pit.

TABLE E-27
ESTIMATED COST FOR DISPOSAL CELL FOR BLACKBIRD CREEK COMPLETE SEDIMENT REMOVAL

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Pre-design investigations				$40,000	Allowance
Excavation	222,833	cy	$3.00	$668,499	See Note c
Outer berm	222,833	cy	$2.00	$445,666	See Note c
Grade cell bottom and sides	487,216	sf	$0.05	$24,361	See Note c
FML liner, 60 mil	487,216	sf	$1.00	$487,216	Bottom of cell, includes slopes
Closure cover (geotextile, topsoil, vegetation)	536,076	sf	$2.00	$1,072,152	See Note c
TOTAL CAPITAL COSTS				**$2,740,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
Monitoring, inspection, and reporting				$50,000	Allowance
ANNUAL O & M COSTS				**$50,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

[c] Sized to hold 650,000 cy of excavated sediments.
Dimensions 500 ft wide by 500 feet long by 53 feet deep; excavation depth 21 feet; interior side slopes 2:1.

TABLE E-28
ESTIMATED COST FOR DISPOSAL CELL FOR BUCKTAIL CREEK COMPLETE SEDIMENT REMOVAL

Item	Quantity	Units	Unit Cost	Cost [a,b]	Notes
CAPITAL COSTS					
Pre-design investigations				$20,000	Allowance
Excavation	16,735	cy	$5.00	$83,675	See Note c
Outer berm	16,735	cy	$2.00	$33,470	See Note c
Grade cell bottom and sides	53,773	sf	$0.05	$2,689	See Note c
FML liner, 60 mil	53,773	sf	$1.00	$53,773	Bottom of cell, includes slopes
Closure cover (geotextile, topsoil, vegetation)	79,872	sf	$2.00	$159,744	See Note c
TOTAL CAPITAL COSTS				**$350,000**	Rounded
OPERATION AND MAINTENANCE (O&M) COSTS					
Monitoring, inspection, and reporting				$30,000	Allowance
ANNUAL O & M COSTS				**$30,000**	Rounded

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

[c] Sized to hold 36,000 cy of excavated sediments.
Dimensions 150 ft wide by 100 feet long by 35 feet deep; excavation depth 19 feet; interior side slopes are 2:1.

TABLE E-29
ESTIMATED COST FOR MONITORING AND REPORTING (All Alternatives)

Item	Annual Cost	PV Cost [a,b]	Notes
Base Year Estimate			
Water quality monitoring	$90,000		Approximate estimate
Invertebrate monitoring	$10,000		Approximate estimate
Fish monitoring	$20,000		Approximate estimate
Panther Creek sediment monitoring	$10,000		Blackbird Creek remobilization
QA/QC and data management	$10,000		Approximate estimate
Evaluation and reporting	$40,000		Approximate estimate
Total Annual	$180,000		
MONITORING AND REPORTING COSTS		Present value calculation, 7% net interest	
Years 1 to 5	$180,000	$738,036	Base year cost
Years 6 to 10	$135,000	$394,657	75% of base year
Years 11 to 30	$90,000	$484,691	50% of base year
Years 31 to 100	$90,000	$167,419	50% of base year
TOTAL NET PRESENT VALUE COST		**$1,800,000**	Rounded
Total duration of monitoring assumed	30	years	
Allocated to Blackbird Creek alternatives		$900,000	1/2 of cost
Allocated to Bucktail Creek alternatives		$900,000	1/2 of cost
Allocated to Panther Creek alternatives		$0	None of cost
		$1,800,000	

[a] Costs are for early 2002.

[b] Costs do not include engineering, contractor overhead and profit, or contingency.

TABLE E-30
BASIC UNIT COSTS

Item	Unit Cost	Units	Source/Comments
Diversion ditches with access road	$32	lf	From 7800 ditch/road (1995) + inflation
Dirt road, 12-ft width	$15	lf	Estimate based on site experience
Basic excavation	$5	cy	Estimate based on site experience
Trench excavation	$10	cy	Estimate based on site experience
Slurry wall mobilization	$100,000	LS	Estimate
Slurry wall unit cost (without mobilization)	$40	sf	From actual cost for 1995 WTP cutoff wall + inflation
Removal (excavation, haul, & place)	$20	cy	Estimate based on site experience
S. Fork Big Deer Creek Sediment Removal	$50	cy	Estimate based on site experience
Panther Creek Removal	$50	cy	Estimate based on site experience
Armoring (excavation, haul, & place)	$40	cy	Estimate based on site experience
Backfill, site source, no spec.	$10	cy	Estimate based on site experience
Clay for West Fork (excavate, haul & place)	$35	cy	Estimate based on site experience (Forney source)
Clay for Meadow Creek (excavate, haul & place)	$40	cy	Estimate based on site experience (Forney source)
Clay for Bucktail Creek (excavate, haul & place)	$50	cy	Estimate based on site experience (Forney source)
Drainage rock, site source	$15	cy	Estimate based on site experience
Sand/gravel for West Fork (excavate, haul & place)	$50	cy	Estimate based on site experience (Salmon source)
Sand/gravel for Meadow Creek (excavate, haul & place)	$55	cy	Estimate based on site experience (Salmon source)
Sand/gravel for Bucktail Creek (excavate, haul & place)	$60	cy	Estimate based on site experience (Salmon source)
Grade Tailings Impoundment cover	$5,000	ac	Estimate based on site experience
Revegetation	$2,000	ac	per Dan Myers
Stream channel backfill and restoration	$20	cy	Estimate based on site experience
PVC pipe, 4", installed, buried	$25	lf	Estimate
HDPE pipe, 6"	$20	lf	Placed in already-excavated trench
HDPE pipe, 6", installed, buried	$35	lf	Perforated or not
Pipe for Bucktail bypass - 24" HDPE pipe	$45	lf	Installed (shallow trench)
HDPE pipe, 36" with 1" holes	$70	lf	Estimate
Pump station, incl. backup generator & instrumentation	$200,000	ea	Actual costs for BT pump station + inflation
60 mil FML liner, installed	$1.00	sf	Estimate
Manhole, 48"	$6,000		Estimate
Geotextile liner, installed	$0.50	sf	Estimate
Electrical power line	$20	lf	Golder 1995 (Table 5-5) + inflation
Apatite sorption material	$600	ton	Delivered to site; vendor quote
Connection structure (for drop inlet)	$4,000	ea	Estimate
Maintenance of existing fencing	$1,000	yr	Approximate per Dan Myers
Electricity	$0.06	KWH	Blackbird Rate
WTP operating costs	$2.00	K gal	per Dan Myers
Establish Panther Creek institutional controls	$50,000	ea	Allowance
Establish Blackbird Creek institutional controls	$50,000	ea	Allowance
Tailings Impoundment soil cover inspection/maintenance	$4,000	yr	Allowance
Annualized periodic sediment removal from PCI channel	$4,000	yr	Infrequent

NOTE: All costs are installed costs, including labor and materials.

Appendix F

APPENDIX F

WATER BALANCE MODELING

Golder Associates Inc.

18300 NE Union Hill Road, Suite 200
Redmond, WA 98052-3333
Telephone (425) 883-0777
Fax (425) 882-5498

APPENDIX F

WATER BALANCE MODELING

BLACKBIRD MINE SITE
LEMHI COUNTY, IDAHO

Prepared for:

Blackbird Mine Site Group

Submitted by:

Golder Associates Inc.
Redmond, Washington

June 24, 2002

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F-1 INTRODUCTION

During the early action phase of this project, a water balance model was developed to facilitate sizing of the water treatment plant (WTP) and the storage facilities. This appendix describes several changes and updates to the model. The updated model is used to determine if additional storage is required for the alternatives proposed in the Focused Feasibility Study that produce more runoff for treatment at the WTP than the current conditions. Other changes to the model include: decreasing the assumed mine storage volume and modifying the "operating rules" (when the Water Treatment Plant draws water from the mine and the 7100 dam).

F-2 MODEL DESCRIPTION

The water balance model uses the STELLA program, a modeling and simulation software. The model routes snowmelt through the site's surface water diversion, collection and retention structures. It allows various snowmelt events, dam sizes, pumping rates, and water treatment plant capacities to be evaluated. The sizes of dams and the water treatment plant rate are set based on the early action design.

F-2.1 Input Parameters

The maximum storage of the 7000 Dam is 2.9 acre-feet as constructed based on the Final Design Report, Phase IIIA Early Action Facilities, Bucktail Creek Water Storage and Conveyance Facilities (Golder, 1997). The dam was designed to convey the 500-year thunderstorm event resulting in 2.9 acre-feet of live storage[1], 3.1 acre-feet of sediment storage, 2 feet of flood surcharge and 1.5 feet of freeboard.

The maximum live storage in the 7100 Dam is 49 acre-feet, with an additional 2 feet for flood storage, 1 foot of freeboard, and 4.4 acre-feet of sediment storage. It was designed to handle the 100-year snowmelt event. Note that the dam has the capacity to contain both the average year snowmelt and the 500-year thunderstorm event at the same time, but this was not the controlling factor for sizing the dam (Golder, 1996).

In this model, the mine storage is specified to be 30 acre-feet, a reduction from the previously estimated 50 acre-feet. See Section 2.2.2 for further discussion of changes to the available mine storage.

The diversion ditch effectiveness is assumed to be 80%, except for the 7100 West Diversion piping system, which is assumed to have 90% effectiveness. The collection ditches are assumed to have 90% effectiveness, since the ditches are lined.

In the model, the water treatment plant is operating at 800 gpm, but if necessary, it can be operated at up to 1,000 gpm for short periods at reduced treatment performance.

[1] Live storage is defined as the amount of water the dam can hold above the sediment (dead) storage and below the flood surcharge and freeboard.

Sources of potentially contaminated water that are included in the current water balance model (pre-FS) include:

- Surface water collected from both Meadow Creek and Bucktail Creek basins. This includes contact water collected from below the waste dumps via the collection ditches, direct runoff from nearby waste dumps, as well as leakage water through the site clean water diversion ditches. The snowmelt hydrographs are shown on Figure F-1;
- Surface water, which drains into Bucktail Pit, then directly into the mine workings. This flow is derived using the snowmelt hydrograph, as shown on Figure F-1;
- The Bucktail Creek Springs and Seeps hydrograph was originally derived from measurements made during the investigation of Bucktail springs and seeps conducted in September 1996. The original seep hydrograph ranged from 10 to 30 gpm. However, site operation data indicates more flow is being collected at the Bucktail Pumpback pumping station. The hydrograph has been revised to 30 gpm in the fall, increasing to 50 gpm during peak snowmelt (see Figure F-2);
- The mine groundwater hydrograph, see Figure F-2. This mine groundwater hydrograph is based on actual flows measured at the 6850 portal measured at the water treatment plant during the winter of 1996-1997;
- The groundwater collected above the Meadow Creek cutoff wall, the Phase IIA tightlines, and the capping foundation drains that discharge directly to the sump below the water treatment plant. This hydrograph, is also shown on Figure F-2, and was estimated based on observed flows during 1998. Flows vary from a peak of 35 gpm, to a low of 15 gpm;
- A contingency of 3 gpm from the West Lobe area. These seeps are not currently being collected, however, there is a chance that these seeps may be collected in the future, and
- The mine and 7100 Dam are assumed to have a starting volume of 10 acre-feet each, which is the maximum allowable storage build-up prior to spring start-up as discussed in the Post Fire Report (Golder 2001). Treatment will begin on March 1, the latest start up date allowed in the post-fire scenario.

Table F-1 summarizes the inputs to the model.

F-2.2 Changes to the Model Specific to the Feasibility Study

F-2.2.1 Flows

F-2.2.1.1 Meadow Creek

Water will be collected in the Meadow Creek basin to address contaminated seeps entering the 7100 West collection system at the 7350 Detention Pond. There are currently two options being evaluated as potential solutions to the contaminated seeps

in this area. The first involves collecting the discreet seeps believed to be contaminating surface runoff in the drop structure. The second involves diverting the clean water at the top of the drop structure to the 7100 West Diversion System and allowing the contaminated water to flow into the 7100 Dam Reservoir.

Option 1: Collection of 7800 Seeps

To collect the seeps, a new collection trench and cutoff wall would be installed below the 7800 Waste Rock Dump, and the collected water would be drained to the 7100 Reservoir. The quantity of water to be collected from the seeps is important to the water balance because it impacts the volume of storage available.

To determine the quantity of water from the seeps, a calculation involving the flows in the drop structure was performed. The flow between MCSW-EA04.34 and the mouth of the drop structure was determined to be 35 gpm. This flow includes not only the groundwater flow but also the surface flow in the area. The flow was scaled down by the size of the basin to only include the groundwater contribution of the seeps. The flow from the seeps was calculated to be 10 gpm during low flow conditions. During high flow conditions, there is expected to be additional flow collected due to infiltration of surface flow. The high flow condition was increased to 15 gpm.

The flow was estimated to be 15 gpm in April, May and June and 10 gpm for the remainder of the year. This translates into collecting and treating an additional 6 million gallons of water per year.

Option 2: Diversion of Clean Water Above the 7800 Seeps

This option involves allowing the natural drainage of the creek to discharge into the 7100 Dam Reservoir and diverting the clean water around the Dam. By allowing the creek to discharge into the reservoir, additional water is stored for treatment.

To determine the amount of additional water that would be collected, an assessment of the drainage basin is made. The drainage basin that is directly affected is Basin B (see Figure F-3). The entire basin is currently collected and bypassed around the 7100 Dam. This option would involve collecting any surface runoff from the contaminated area below the 7800 waste rock dump in the existing creek and conveying it to the 7100 Dam. To calculate the surface runoff, the area of Basin B above the Drop Structure was calculated (13.9 acres) and the average year hydrograph created for Meadow Creek was applied. By multiplying the feet of average snowmelt by the area of the basin, a total volume of snowmelt on the basin was calculated. This totals 4 million gallons of water that would require treatment annually.

Four million gallons of surface water is added to the 6 million gallons of groundwater seep collection for a total of 10 million gallons of additional snowmelt runoff water collected annually.

F-2.2.1.2 Blackbird Creek

In the Blackbird Creek basin, one of the main sources of contamination is the seepage from the West Fork Tailings Impoundment. Several FS alternatives contain a component that involves collecting this water and pumping it to the 7100 Dam for storage before treatment.

To determine the flow from the West Fork Tailings Impoundment Seepage, an analysis of cobalt loading between BBSW-03A and BBSW-01A was done. The load difference between these two stations consists only of the seepage from the West Fork Tailings Impoundment. Using varying flow rates (1 to 200 gpm), the observed load difference was converted to average concentrations of cobalt in the seepage corresponding to each flow rate. The calculated concentrations were then compared with the average concentration of the West Fork Tailings Impoundment seepage, 11.5 mg/L cobalt, to determine the flow of the seepage.

According to the analysis, the flow rate of the West Fork Tailings Impoundment seepage ranges from 100 and 200 gpm. In order to meet the cobalt PRG at PASW-09, only half of the flow would require treatment. Thus, an additional year round flow rate of 100 gpm has been assumed for modeling purposes.

F-2.2.1.3 Bucktail Creek

Some of the Bucktail Creek options involve the collection of seeps from below the 7000 Dam. By collecting groundwater seeps in the Bucktail Creek basin, downstream concentrations of cobalt and copper would be reduced. The additional water collected would have to be treated at the WTP, which affects the water balance.

It was determined that the flow in the fall at BTSW-01.6, 40 gpm, can be completely contributed to additional groundwater seeps below the 7000 Dam. Approximately 65% to 90% of these seeps need to be collected in order to meet the PRGs in Bucktail Creek. Phase 1 of the design would involve collecting 65% of the base flow, or about 26 gpm. Phase 2, if implemented, would involve collecting an additional 10 gpm. Thus, a minimum of 26 gpm, with a possible additional 10 gpm, would need to be pumped into the mine workings and treated at the WTP. These flows are in addition to the revised base flows currently being collected by the Bucktail Pumpback station.

F-2.2.2 Mine Storage

The storage of the mine workings was recently reevaluated using drawings of the mine. Two drawings were used to help evaluate available capacity. The first was an old hand drawn map of the mine and the second was an AutoCAD drawing of the mine. These two drawings resulted in an estimated mine storage of 33 and 28 acre-feet, respectively.

It is reasonable to assume that the available storage in the mine is about 30 acre-feet. This value can be modified in the future as additional data is collected at the WTP.

F-2.2.3 Release Rules

Release rules govern the way water is balanced between the storage reservoirs in the model. In the previous model, the WTP preferentially drew water from the 7100 dam, allowing more storage to occur in the mine. Because the estimated storage in the mine is 20 acre-feet smaller than previously modeled, the release rules were adjusted.

When the mine storage is over 15 acre-feet and the storage in the 7100 Dam is less than 40 acre-feet, the WTP draws water only from the mine. This means that more water is stored in the 7100 dam and less in the mine than in previous models. Running the model under this release rule ensures that neither the mine nor the 7100 Dam exceed their storage limitation.

The purpose of the release rules is to simulate the decisions that a WTP operator would make with respect to drawing water from facilities with higher volumes. They are not intended to be recommendations on how the plant should be operated.

F-3 DISCUSSION

A summary of the modeling is presented in Tables F-2 through F-4 and Figures F-4 through F-6. Table F-2 and Figure F-4 show the modeling results without the additional flows from sources identified for collection in the FS. The maximum storage in the mine is 29.4 acre-feet, the maximum storage in the 7100 Dam is 23 acre-feet, and the maximum storage in the 7000 Dam is 2.9 acre-feet.

The following sections reference the results presented in Tables F-3 and F-4 and Figures F-5 and F-6. These results show the storage in each dam and the mine for two possible scenarios based on alternatives presented in the FS (Meadow Creek Seep Collection or Diversion, Bucktail Creek Phases 1 and 2, treating flows from West Fork Tailings Impoundment). The only difference in these modeled scenarios is whether discrete seeps are collected in upper Meadow Creek, or whether clean water is diverted which would result in slightly more water collected for storage and treatment.

F-3.1 Evaluation of Potential to Exceed Mine and Dam Capacities

The maximum storage in the mine, the 7100 dam or the 7000 dam is never exceeded in the modeling exercise. As shown in Figure F-6, if the largest amount of snowmelt is collected and treated (Meadow Creek diversion, treating West Fork Tailings Impoundment seepage, and treating 90% of the additional groundwater seeps in Bucktail Creek) no storage facility exceeds its design capacity. Under all scenarios, the 7000 Dam reaches its maximum capacity, 2.9 acre-feet. The mine reaches a maximum storage of 27.9 acre-feet under the Meadow Creek diversion scenario and a maximum of 23.5 acre-feet under discrete seep collection. Under both scenarios 100 gpm at the West Fork Blackbird Creek and 90% of the Bucktail Seeps are assumed to be collected. The maximum storage in the 7100 Dam is dependent on the combination of removal alternatives, but ranges from 25 to 41 acre-feet.

F-3.2 Meadow Creek

The two options in Meadow Creek, collection of 7800 seeps or diversion of clean water, affects the storage of the mine and the 7100 dam in different ways. For the mine, diversion results in the storage of more water, but only when the West Fork seepage is collected at 100 gpm. When the West Fork seepage is not collected and treated, there is no difference between the maximum storage in the mine under collection and diversion. For the 7100 Dam, discrete collection of seeps always results in a smaller maximum required storage volume than the diversion option. Overall, diversion would require between 3 and 7 acre-feet of extra peak storage. The model predicts that diversion requires an extra 4 million gallons per year be treated at the WTP.

F-3.3 Blackbird Creek

If the West Fork Tailings Impoundment seepage needs to be treated it will either be collected and treated at 100 gpm or treated *in situ*. In terms of mine storage treating the seepage results in the same peak storage required as *in situ* treatment under the Meadow Creek seep collection. If diversion is chosen for the Meadow Creek seeps, then treatments results in the storage of extra water in the mine. For the 7100 dam, treating the West Fork Impoundment seepage always requires more peak storage. The amount of water treated at the WTP would increase by approximately 52 million gallons annually, if West Fork Tailings Impoundment Seepage is treated at the WTP.

F-3.4 Bucktail Creek

For Bucktail Creek, additional seeps below the 7000 Dam are collected with an estimated range of flows from 26 to 36 gpm. The additional seeps collected increase storage in the 7100 Dam as well as the mine. When 36 gpm is collected and treated, the model predicts approximately 5 million gallons more of water is treated at the WTP.

F-3.5 Summary

The additional storage requirements due to collection of water, as outlined in the Feasibility Study, can be accommodated by the existing storage and treatment facilities. By adjusting when the water is drawn from the mine and the 7100 dam for treatment, the water level in each storage reservoir can be kept below the maximum.

F-4 REFERENCES

Golder Associates, 1996. Final Design Report, Phase IIB Early Action Facilities, Meadow Creek Water Storage and Conveyance Facilities, Blackbird Mine Site. September 13, 1996.

Golder Associates, 1997. Final Design Report, Phase IIIA Early Action Facilities, Bucktail Creek Water Storage and Conveyance Facilities, Blackbird Mine Site. March 21, 1997.

Golder Associates, 1999. Final Report, 7100 Dam Operation and Maintenance Plan, Blackbird Mine Site, Early Removal Actions. August 14, 1999.

Golder Associates, 2000. Revised Ditch Effectiveness Analysis. February 9, 2000.

Golder Associates, 2001. Post Fire Report, Blackbird Mine Site. May 11, 2001.

TABLE F-1
Model Inputs

	Value	Units
Ditch Effectiveness	80	%
7100 West Pipe Effectiveness	90	%
All Other Ditches	90	%
Available Mine Storage	30	ac-ft
Available 7100 Dam Storage	49	ac-ft
Available 7000 Dam Storage	2.9	ac-ft
Water Treatment Plant Rate	800	gpm
Feasibility Study Flow from Bucktail Creek Groundwater Seeps Below 7000 Dam	Range of 26 to 36[a]	gpm
Feasibility Study Flow from West Fork Tailings Impoundment Cutoff Wall	Either 0 or 100[a]	gpm
Feasibility Study Flow from Meadow Creek Seeps Below 7800 Waste Rock	April, May, June: 15	gpm
	Rest of the Year: 10	gpm

[a] These values vary depending on FS scenario selected.

TABLE F-2
Current Conditions

Variables	**Current Conditions[a]**
Water Treatment Plant rate (gpm)	800
Bucktail Creek Seeps and Springs Pump Back (gpm)	30 to 50
Mine Groundwater (gpm)	60 to 70
Seeps from the West lobe (gpm)	3
Groundwater Above Meadow Creek Cutoff Wall (gpm)	10 to 30
Outputs	
Maximum Storage in the Mine (ac-ft)	21.9
Maximum Storage in 7100 dam (ac-ft)	24.0
Maximum Storage in 7000 dam (ac-ft)	2.90
Total Volume of Snowmelt Water Treated (million gallons)	140
Days that the mine storage is greater than 30 ac-ft	0

[a] These results are without any additional flows due to FS alternatives

TABLE F-3
Summary of Outputs from Stella Model, Meadow Creek Diversion

Variables	*Case 1*	*Case 2*	*Case 3*	*Case 4*
Water Treatment Plant rate (gpm)	800	800	800	800
Bucktail Creek Seeps and Springs Pump Back (gpm)	30 to 50	30 to 50	30 to 50	30 to 50
Mine Groundwater (gpm)	60 to 70	60 to 70	60 to 70	60 to 70
Seeps from the West lobe (gpm)	3	3	3	3
Groundwater Above Meadow Creek Cutoff Wall (gpm)	10 to 30	10 to 30	10 to 30	10 to 30
Feasibility Study Flows from Bucktail Creek Seeps (gpm)	26	36	26	36
Feasibility Study Flow from West Fork (gpm)	100	100	0	0
Feasibility Study Flows from Meadow Creek (gpm)	15 then 10	15 then 10	15 then 10	15 then 10
Outputs				
Maximum Storage in the Mine (ac-ft)	25.5	27.9	23.0	23.5
Maximum Storage in 7100 dam (ac-ft)	40.0	41.0	31.0	32.0
Maximum Storage in 7000 dam (ac-ft)	2.90	2.90	2.90	2.90
Total Volume of Snowmelt Water Treated (million gallons)	216	221	164	169
Days that the mine storage is greater than 30 ac-ft	0	0	0	0

TABLE F-4
Summary of Outputs from Stella Model, Meadow Creek Seep Collection

Variables	*Case 5*	*Case 6*	*Case 7*	*Case 8*
Water Treatment Plant rate (gpm)	800	800	800	800
Bucktail Creek Seeps and Springs Pump Back (gpm)	30 to 50	30 to 50	30 to 50	30 to 50
Mine Groundwater (gpm)	60 to 70	60 to 70	60 to 70	60 to 70
Seeps from the West lobe (gpm)	3	3	3	3
Groundwater Above Meadow Creek Cutoff Wall (gpm)	10 to 30	10 to 30	10 to 30	10 to 30
Feasibility Study Flows from Bucktail Creek Seeps (gpm)	26	36	26	36
Feasibility Study Flow from West Fork (gpm)	100	100	0	0
Feasibility Study Flows from Meadow Creek (gpm)	15 then 10	15 then 10	15 then 10	15 then 10
Outputs				
Maximum Storage in the Mine (ac-ft)	23.0	23.5	23.0	23.5
Maximum Storage in 7100 dam (ac-ft)	36.0	38.0	25.0	25.0
Maximum Storage in 7000 dam (ac-ft)	2.90	2.90	2.90	2.90
Total Volume of Snowmelt Water Treated (million gallons)	212	217	160	165
Days that the mine storage is greater than 30 ac-ft	0	0	0	0

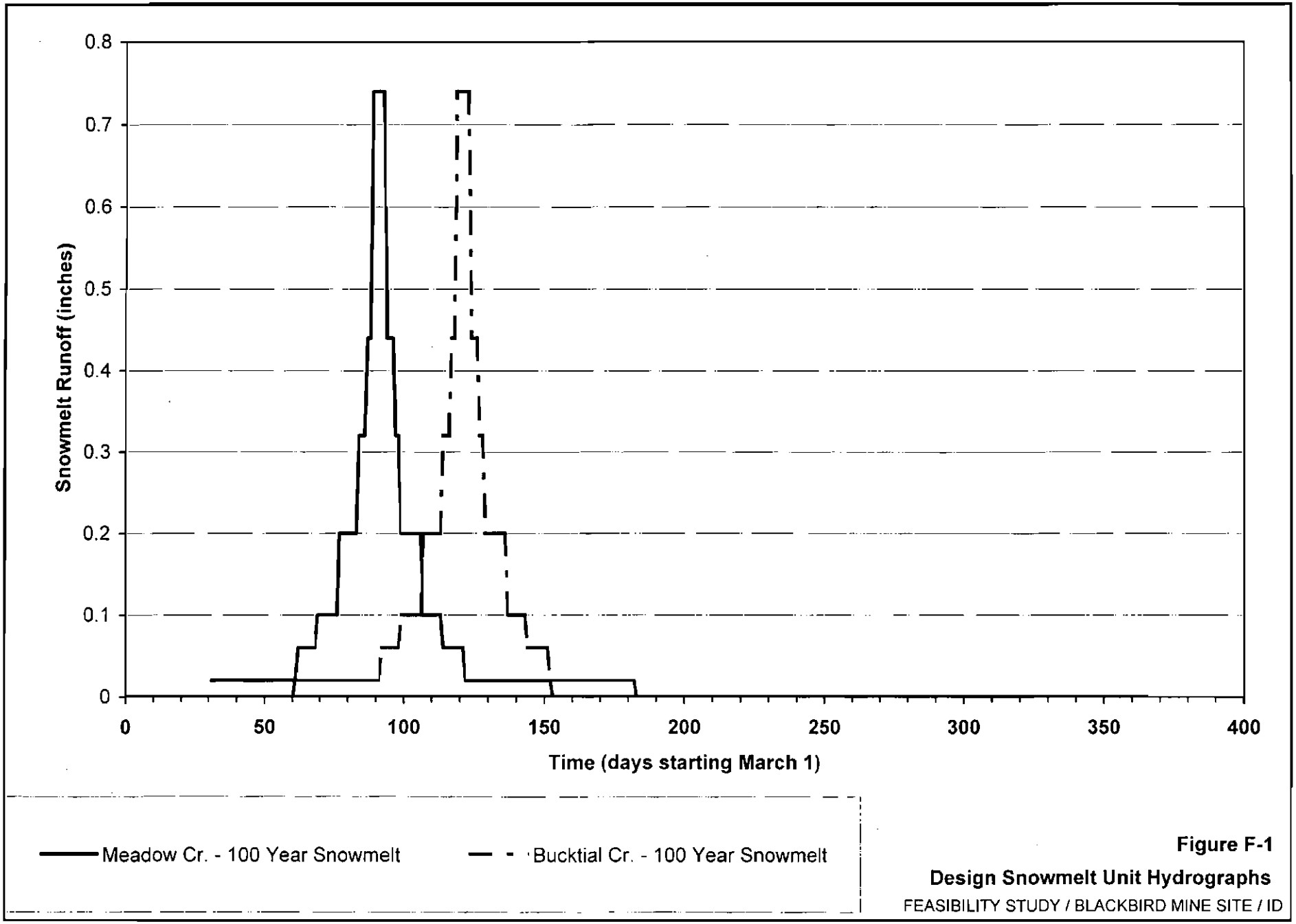

Figure F-1

Design Snowmelt Unit Hydrographs

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

Golder Associates

Golder Associates

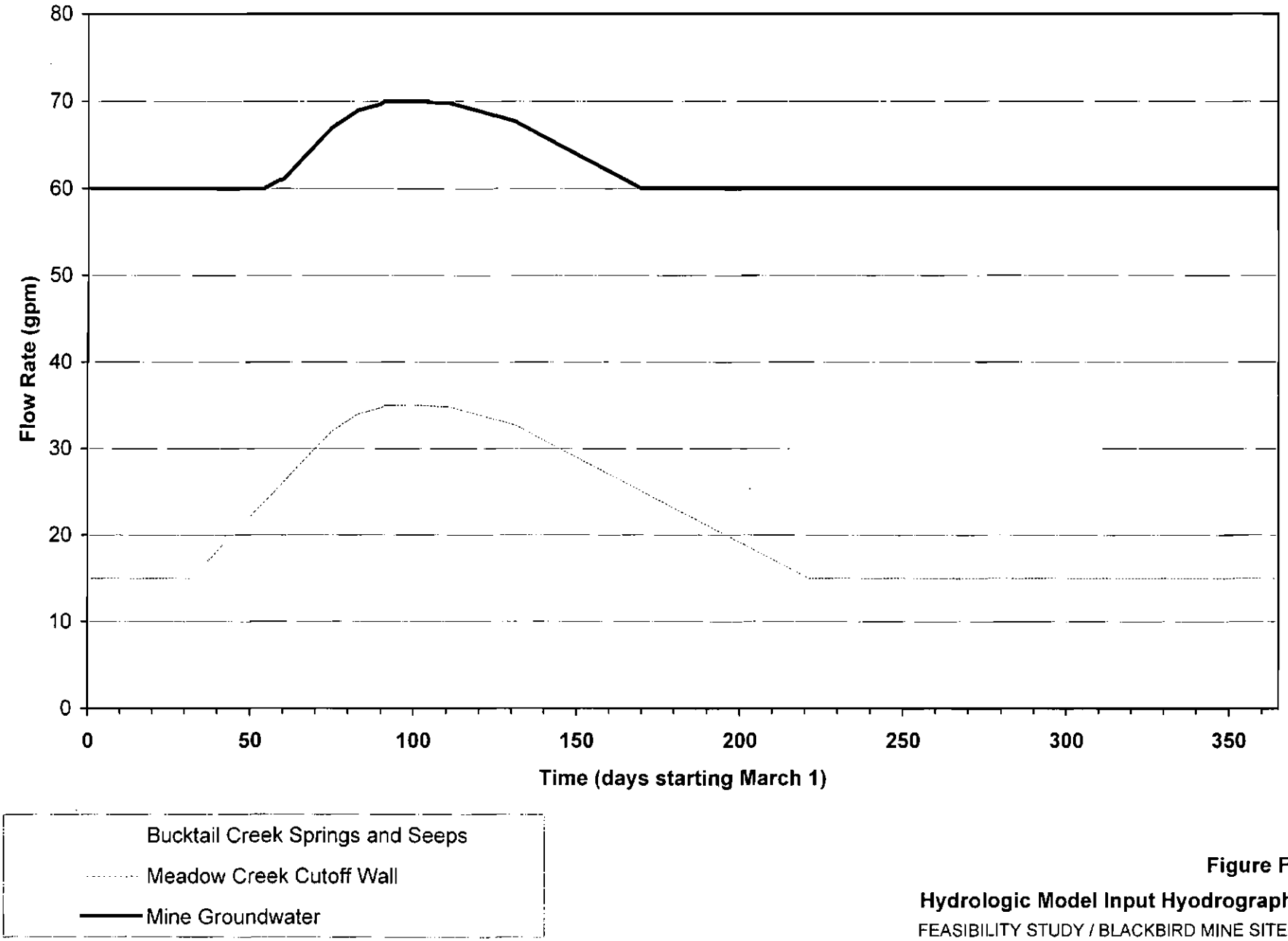

Figure F-2

Hydrologic Model Input Hyodrographs

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

Golder Associates

Golder Associates

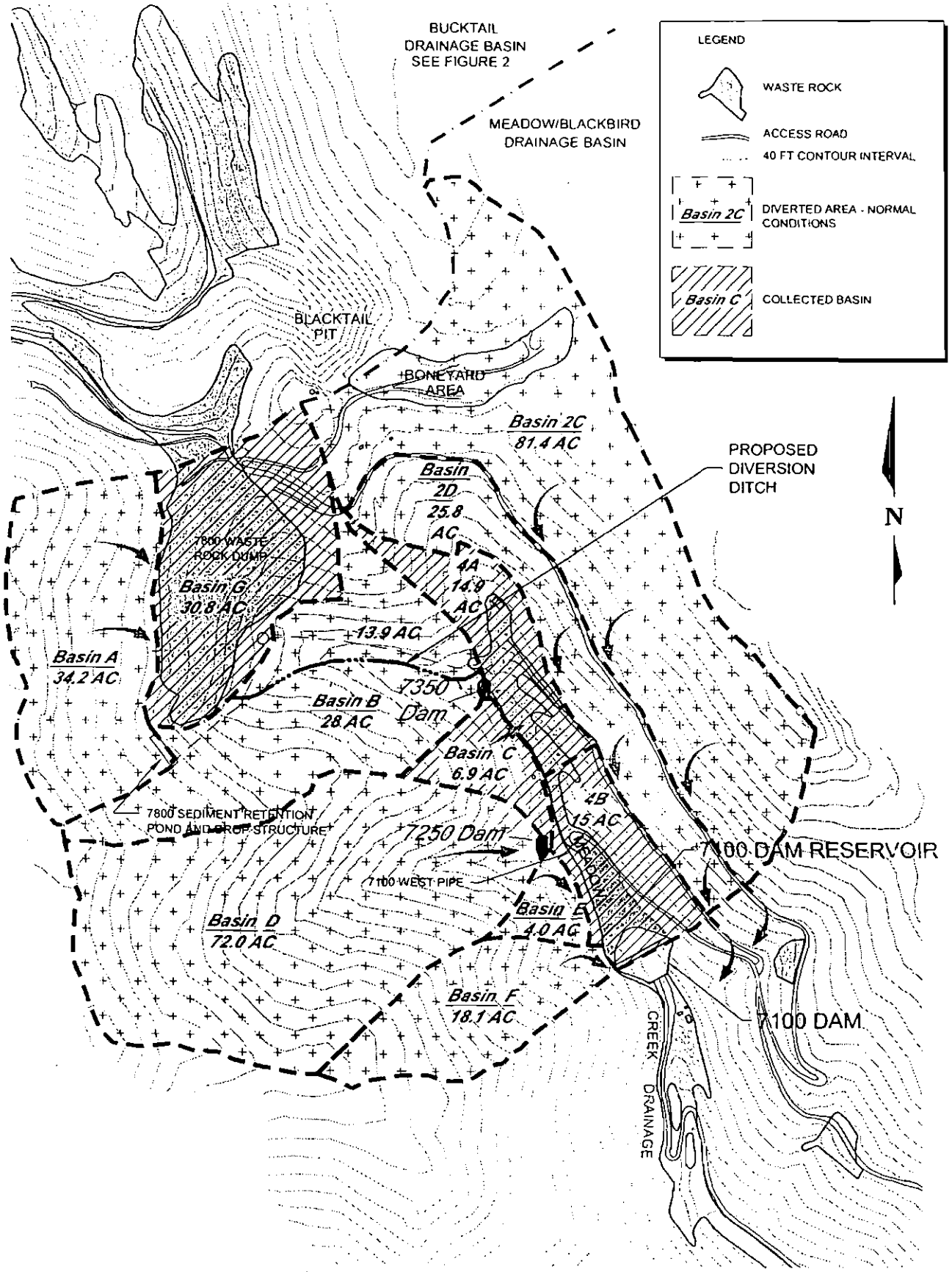

FIGURE **F-3**

7100 DAM BASIN MAP

BMSG/BLACKBIRD MINE/ID

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Golder Associates

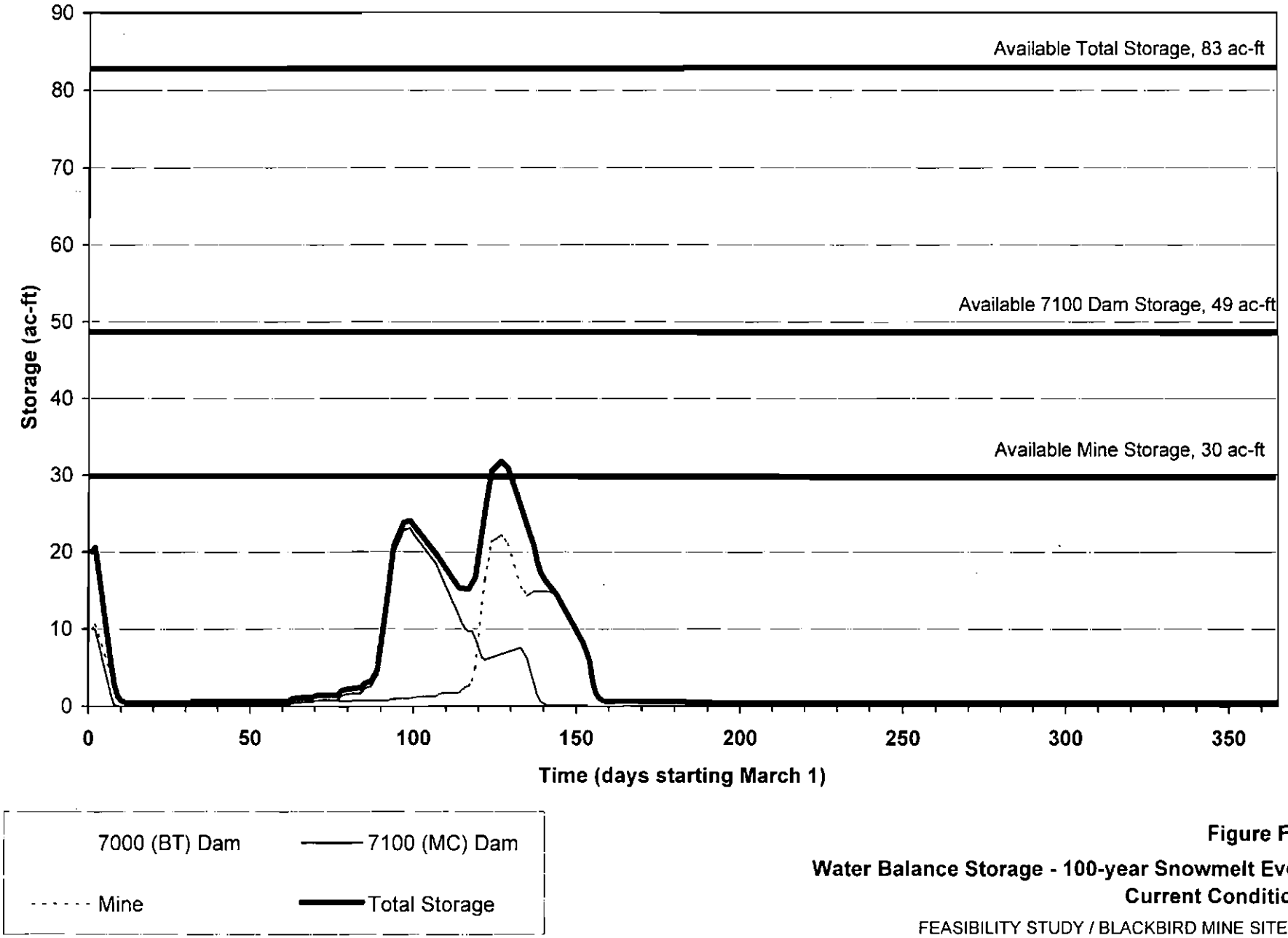

Figure F-4

Water Balance Storage - 100-year Snowmelt Event
Current Conditions

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

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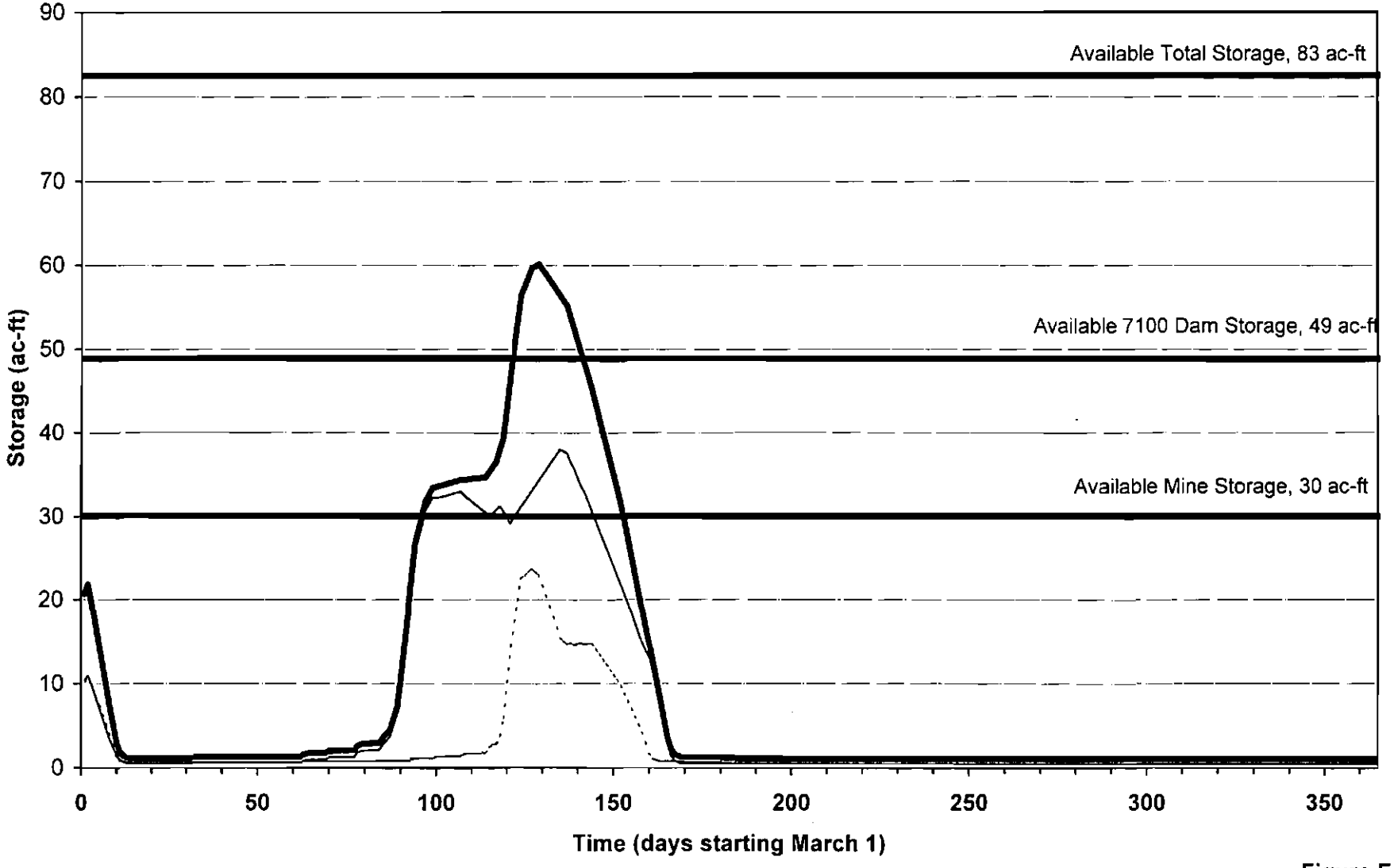

7000 (BT) Dam — Total Storage

7100 (MC) Dam - - - - - Mine

Figure F-5

Water Balance Storage - 100-year Snowmelt Event
Meadow Creek Seep Collection, Bucktail Creek Phase 1 and 2, WF Tailings Impoundment Treated

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

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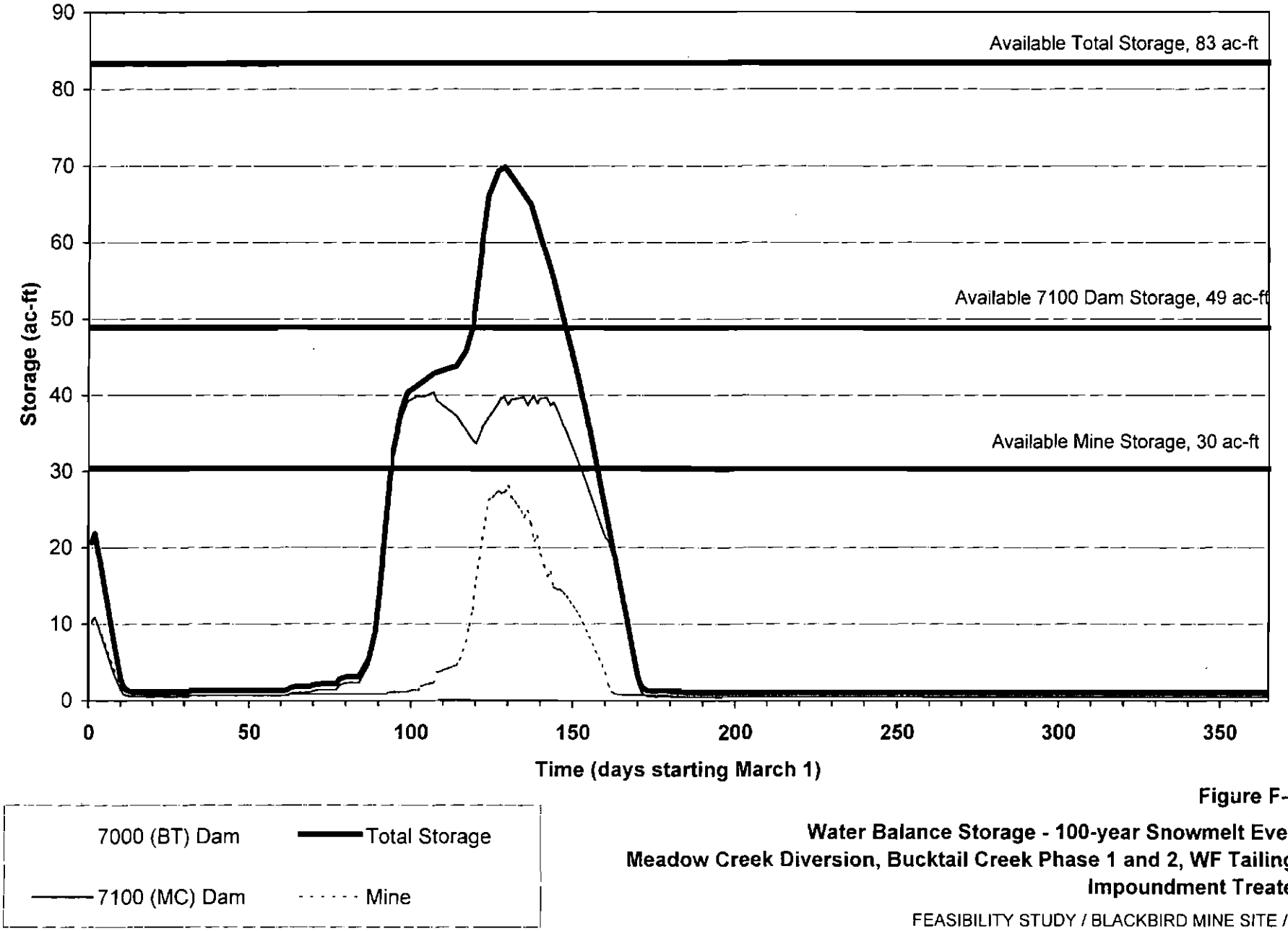

Figure F-6

Water Balance Storage - 100-year Snowmelt Event
Meadow Creek Diversion, Bucktail Creek Phase 1 and 2, WF Tailings Impoundment Treated

FEASIBILITY STUDY / BLACKBIRD MINE SITE / ID

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