was discharged to the borrow pit beginning the end of January 1991 until April, when it was diverted to the spray evaporation system for disposal. During this period, a total of approximately 2.8 million gallons was discharged to the borrow pit. All the seepage temporarily stored in the borrow pit had been removed by the end of May 1991.

This interim use of Borrow Pit No. 2 was required because the water levels in the evaporation ponds had reached the maximum safe operating elevations. The volume stored, however, did not create enough hydraulic head to drive the seepage into Zone 1. A discussion of the use of Borrow Pit No. 2 is presented in Section 6.2.4 of this plan and will be presented in the 1991 Annual Review to be submitted to the NRC and EPA at the end of December, 1991.

6.2.2.5 Zone 1 Performance Criteria

The remedial action program for Zone 1 was designed to remove the source of seepage to the target area by dewatering Borrow Pit No. 2. Therefore, the performance monitoring of the remedial action program is focused on the dissipation of the mound in Zone 1 in response to dewatering of Borrow Pit No. 2. These performance criteria are consistent with the findings in the FS (EPA, 1988b) as previously stated.

6.2.2.6 Zone 1 Monitoring Program

The monitoring program focuses primarily on water level monitoring in wells located to the east of Borrow Pit No. 2. The objective of the program originally was to monitor and evaluate the effect of dewatering the borrow pit. This objective was later modified to monitor and evaluate the effects of continued operation of certain east system wells as required by NRC and EPA after review of the 1989 Annual Review (Canonie, 1989c). Water quality monitoring required by the NRC was also incorporated into this program to provide a database for application for ACLs and waivers, should they become necessary.

Table 6.11 and Figure 6-9 present the wells used for the monitoring program. Water quality monitoring is conducted for all the chemical constituents designated by the NRC for monitoring in United Nuclear's license and all constituents designated by the EPA for ARAR exceedances in Zone 1. Table 6.3 lists the constituents included in the monitoring program for Zone 1.

Water level data from the wells located along the east side of Borrow Pit No. 2 (Wells 515A, 516A, 604, 614, 619, EPA-5, and EPA-7) are used to evaluate the mound dissipation in Zone 1 in response to dewatering the pit. Since September 1990, EPA-7 is also used as a pumping well.

Following review by NRC and EPA of the 1989 Annual Review (Canonie, 1989c), both agencies required that United Nuclear continue to operate the east and north cross-dike pump-back wells to further demonstrate active remediation in Zone 1 was not feasible. The demonstration was required even though the performance monitoring data showed the seepage mound was dissipating as predicted and the pump-back wells were having no effect in accelerating the rate of dissipation or improving the quality of the water in the mound.

Several Zone 1 wells continue to pump as of July 1991 and are expected to continue operation at least until the end of December 1991. Also, the configuration of the pump-back wells has been revised twice (September 1990 and June 1991) in response comments from the NRC and EPA to the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a). A discussion of the operation of the Zone 1 wells was presented in the two annual reviews and is presented in Section 6.2.2.7.

Monitoring for all chemical constituents selected for the performance monitoring program is conducted quarterly, consistent with United Nuclear's NRC license. Results are reported semiannually and the monitoring program is re-evaluated annually in conjunction with the system performance evaluation required by the NRC and the EPA. The annual evaluation also allows determinations to be made regarding the efficacy of reducing the sampling frequency of the monitoring program. Annual evaluations of the system performance have been completed and submitted to the NRC and EPA in accordance with the requirements of the License and the ROD. These evaluations have been submitted as the 1989 and 1990 Annual Reviews prepared by Canonie (1989c, 1990a).

6.2.2.7 Implementation of Zone 1 Corrective Action Program

This section discusses the implementating the Zone 1 corrective action program through July 1991. This information was presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) and responses to NRC and EPA comments on the two annual review reports. Table 6.12 provides a list of the activities and dates associated with implementation of this program. For ease of discussion, the implementation is presented on a yearly basis covering the period from May 1989 through July 1991, and includes a summary of the results of the performance monitoring presented in the two annual reviews as well as a description of field activities completed in 1991. These field activities will be presented formally in the 1991 Annual Review to be submitted by December 31, 1991.

6.2.2.7.1 Zone 1 CAP Activity - 1989

CAP activity in 1989 consisted of dewatering Borrow Pit No. 2, continued operation of the then existing east and north cross-dike pump-back wells, and performance monitoring. As shown in Table 6.12, Borrow Pit No. 2 was completely dewatered by the end of April 1989, approximately six months earlier than predicted. The time required to dewater was accelerated mainly because the actual volume of water remaining in the pit was much less than predicted. Increased evaporation in 1989 as a result of drier than usual climatological conditions was also a factor.

Additional pit inflow did not occur because, as discussed in the 1989 Annual Review (Canonie, 1989c), the water level measured in wells located adjacent to the pit on the west and north sides was at or near the original bottom of the pit. Borrow Pit No. 2 remained dry until January 1991, when extracted seepage was temporarily discharged to Borrow Pit No. 2. Since the stored seepage was removed by the end of May 1991 no inflow from surrounding formations has been observed.

The then existing east and north cross-dike wells operated continuously throughout 1989. Figure 6-1 shows the general location of these wells. The east pump-back wells are the most important from the standpoint of evaluating plume migration because they are located adjacent to and downgradient from Borrow Pit No. 2. Because Zone 1 has very low permeability, the wells pumped at very low rates. Their effectiveness in removing seepage was negligible. As discussed in the 1989 Annual Review (Canonie, 1989c), the pumping rate of the wells as of October 1989 ranged from 0.16 gpm to 2.3 gpm with a combined average of 4.1 gpm for the 12 operating wells.

The system performance was evaluated for the 1989 Annual Review (Canonie, 1989c) based on three quarters (second, third, and fourth) of water level and water quality data. The second quarter data approximated initial conditions since Borrow Pit No. 2 was dewatered at the end of April, shortly after the second quarter monitoring data were collected. The evaluation indicated that, because of the low permeability of the formation, the response of the system to dewatering was small. Any impacts would not be observed until at least the end of 1989, after the fourth quarter measurements were taken.

For example, review of the water level data presented in Table 6.13 shows that, between second quarter and fourth quarter 1989, changes in water level ranged from 0.2 feet to 1.2 feet. Also, the only wells that exhibited declining water levels were Wells 516A, 604 and 614 which, as shown on Figure 6-9, are located closest to the borrow pit. The rising water levels in the remaining wells indicated these locations were still exhibiting a delayed response to the water in the borrow pit.

Documentation of the delayed response was presented in United Nuclear's responses to the NRC and EPA comments to the 1989 Annual Review and in the 1990 Annual Review (Canonie, 1990a). Canonie estimated the time for response in each of the monitoring wells, based on a comparison of water levels in each of the wells with water levels in Borrow Pit No. 2. Table 6.14 presents the results of the calculations, indicating most of the wells would not exhibit declining water levels in response to dewatering the borrow pit until the end of 1989. In fact, wells such as EPA 2 and EPA 8 are not expected to show a response to dewatering until 1993 or later.

Evaluation of the water quality data showed conditions remained stable for the six month period following dewatering of Borrow Pit No. 2. Figure 6-16 presents the isoconcentrations of pH for fourth quarter 1989. The plume, represented by acidic pH, had migrated approximately 150 feet downgradient from the extent of the remedial design target area shown on Figure 6-15. Based on a Zone 1 flow velocity of 115 feet per year to 148 feet per year calculated in the RD (Canonie, 1989d), the extent of the plume in 1989 would be expected to be 345 feet to 444 feet further downgradient from the target area, which was delineated based on 1986 data. The shorter travel distance is probably due to dewatering the borrow pit, which reduced the gradient in Zone 1. The pH values reported in 1989 were similar to those reported in 1986, as would be expected given the fact that the dissipation mound is very slow.

6.2.2.7.2 Zone 1 CAP Activity - 1990

CAP activity in 1990 consisted of continued operation of the pump-back wells and performance monitoring. The system operation and performance was presented in the 1990 Annual Review (Canonie, 1990a) and is summarized below.

Water levels in the monitoring wells continued to decline naturally with no apparent effect (i.e., increased magnitude of decline) related to the pumping. The data confirmed the existence of the delayed response to dewatering Borrow Pit No. 2. The data also confirmed predictions made in the Response to Comments (United Nuclear, 1990) that, because of the delayed response, dissipation of the seepage mound would not be observed until at least the beginning of 1990. As shown in Table 6.14, only five wells (604, 515 A, 516 A, 619, and 614) were expected to show a response to dewatering the borrow pit by the end of the 1990 reporting period.

The water level data confirm the predictions presented in Table 6.14. For example, the water level data presented in Table 6.13 show that the five wells located closest to Borrow Pit No. 2 exhibited water level declines of 1.0 to almost 4.0 feet between October 1989 and October 1990. In contrast, these same wells exhibited water level declines of less than 1.0 feet or, in the case of wells 515 A and 619, increases in water level between April 1989 (initial conditions) and October 1989. The reason for the contrast between the 1989 and 1990 data is that, because of the low permeability of the formation and the resulting slow seepage rates, the effect of dewatering of Borrow Pit No. 2 could not be observed in the wells until 1990.

As in 1989, the water quality in Zone 1 reported in 1990 remained unchanged from conditions reported in 1989. The shape and extent of the plume was similar to that presented on Figure 6-16 for the 1989 Annual Review (Canonie, 1989c).

The east and north cross-dike pump-back wells operated continuously until September 24, 1990. At that time, some of the wells were decommissioned and the revised east pump-back wells began operation. As shown in Table 6.12, United Nuclear requested in their response to NRC and EPA comments that these wells be turned off. This request was based on the performance monitoring data indicating water level declines were becoming evident in wells downgradient from Borrow Pit No. 2, and that continued pumping was having no effect on the natural dissipation of the seepage mound.

The NRC and EPA denied United Nuclear's request to turn off the pump-back wells and required pumping continue under a modified program. United Nuclear, in a letter dated June 1990, presented a proposed modified program. It was approved in July 1990 by NRC and EPA, and was included in Amendment 7 to the License.

The modified program consists of decommissioning the existing east and north cross-dike pump-back wells and pumping four other wells located east of Borrow Pit No. 2. Figure 6-17 shows the locations of these wells (615, 616, 617, and EPA 7), which are referred to as the revised east pump-back wells. The purpose of this program is to focus extraction from Zone 1 in the area of the greatest concentration of constituents of concern in an effort to further remove seepage emanating from Borrow Pit No. 2. The revised east pump-back system began operating on September 24, 1990.

Table 6.15 presents the operational data for the Zone 1 wells for the 1990 reporting period (October 1989 through October 1990). As shown, the 17 existing wells pumped at an average combined rate of only 8.2 gpm, and the four revised east pump-back wells pumped at a total combined rate of only 1.0 gpm. The total volume of water extracted by these wells between October 1989 and October 1990 was approximately 4 million gallons.

6.2.2.7.3 Zone 1 CAP Activity - 1991

Operation of the revised east pump-back wells continues in 1991. United Nuclear has also designed and implemented a demonstration program to conduct an ALARA demonstration. The program will support a future ACL application. This demonstration program was proposed by United Nuclear in June 1991, based on discussions with the NRC and EPA regarding their review comments to the 1990 Annual Review (Canonie, 1990a). NRC and EPA approved the program in July 1991.

The purpose of the program is to provide a demonstration that ALARA concentrations of chemical constituents in the Zone 1 target area have been achieved. The data collected during the performance monitoring of this system will be used to support an application for ACLs and a waiver to ARARs. The demonstration consists of operating four Zone 1 wells that have been shown to be the most prolific Zone 1 water producers. These wells are to be pumped for a period of approximately five months. During that time, water quality and quantity will be monitored to detect any changes. It is anticipated that none will occur.

Table 6.15 summarizes the activities for the ALARA demonstration program and Figure 6-18 shows the locations of the wells included in the demonstration. The demonstration will be conducted in three phases as shown in Table 6.15. The objective of the phased approach is to allow collection of data that can be used to compare the performance of the revised east pump-back wells (Phase I) with the performance of a different pumping scenario (Phase II), and to compare the performance of both of these scenarios with the original pump-back system that operated prior to September 1990.

Phase I was implemented at the beginning of July. All the samples for this phase were collected by August 8, 1991. Subsequently, Phase II was implemented and will continue through December, 1991 when the last sample will be collected. This demonstration program will be decommissioned in December after the final Phase II samples are collected.

6.2.3 Southwest Alluvium Remedial Action Program

This section presents the detailed technical design for the alluvial extraction system as originally presented in Amendment II (Canonie, 1989a) to the 1987 site Reclamation Plan and the RD (Canonie, 1989d), as well as the conditions that exist as of July 1991, after approximately three years of implementing the remedial action. Sections 6.2.2.1 through 6.2.3.6 incorporate much of the text, tables, and figures provided in the RD (Canonie, 1989d). The remaining Section 6.2.3.7 discusses system operation and performance using the information presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a). This section also includes a description of the installation of the new extraction well (Well 808) completed in June 1991, in accordance with Amendment 12 to the License.

As described in the RD (Canonie, 1989d), the design and configuration of the system complies with the objectives of both agencies, i.e., 1) operation will produce compliance with NRC License Condition 30, Part B criteria at the POC wells, and 2) the system will create a hydraulic barrier against further seepage migration, while the source is being remediated in accordance with the EPA's ROD.

6.2.3.1 Hydrogeology of the Southwest Alluvium

Figure 6-1 illustrates the area selected during the remedial design process for the location of the Southwest Alluvium extraction system. Before mining and milling activities, the alluvium in this area was largely unsaturated with only minor amounts of transient and perched ground water (Canonie, 1987a). Previously unsaturated conditions of the alluvium were evidenced by data from geotechnical borings indicating the alluvium was dry in the tailings area (Canonie, 1987a). After mining began in 1968, mine water was discharged to Pipeline Arroyo. Mine water percolated from the arroyo into the surrounding alluvium, resulting in its saturation and attendant water quality (i.e., background). Background water quality was then altered, beginning in 1977, by tailings liquid seepage.

Water in the alluvium flows to the southwest, adjacent to and beneath the South Cell of the tailings impoundment, and out of the site boundary into Section 3. During active site operations when mine water was discharged to Pipeline Arroyo, the flow rate in the alluvium was estimated to be several hundreds of gpm (Canonie, 1987a). As described in more detail later, water levels and gradients in the alluvium declined beginning in the early 1980s, in response to reductions in the rate of mine water discharge in March 1983 and cessation of the discharge in 1986. As a result, the flow rate in the alluvium has declined. Since recharge from mine water in the arroyo has been terminated permanently, this observed decline in alluvial flow rate is expected to continue in the future until pre-operational conditions are re-established.

Review of water level data collected since 1988 confirms the declining trend in water level and flow rate. Water levels have declined by 1.0 feet or more per year over the past three years, and several of the alluvial wells located closest to the mine water discharge point are dry (Well 645), or have little water (Well 643) as of July 1991.

6.2.3.1.1 Physical Characteristics of the Southwest Alluvium

The saturation conditions in the Southwest Alluvium, existing in 1988 when the remedial design was developed, presented a picture of variable saturated thickness, a sloping water table surface (unconfined), and a permeability typical of a silty sand.

Figure 6-19 displays the saturated thickness of alluvium in the Southwest Alluvium (as indicated by 1988 data) used for the remedial design in Amendment II (Canonie, 1989a) to the 1987 Reclamation Plan and in the RD (Canonie, 1989d). Table 6.17 presents the data used to determine the saturated thickness. These thicknesses are variable due to abrupt changes in topography on the surface of the underlying Mancos shale. A practical consideration in the extraction system design was locating wells in areas where the saturated thickness was sufficient to sustain pumping. Figure 6-19 was used as a basis for the system design.

Data collected during installation of the extraction and monitoring wells confirmed the 1988 data used to generate Figure 6-19. In most locations, the saturated thickness was within 5 to 10 feet of the thickness estimated based on Figure 6-19.

Figure 6-20 is a water-table elevation map of the Southwest Alluvium used for the remedial design. This figure illustrates that, based on the 1988 data used for the remedial design, ground water in the Southwest Alluvium exhibited a gradient of approximately 0.01 in a southwesterly direction. Figure 6-20 was also used as a basis for extraction system design in determining well capture zone size and orientation.

Water level data presented in the 1989 Annual Review (Canonie, 1989c) confirm the configuration of the gradient, based on 1988 data, used in the remedial design. The configuration of the gradient, based on the fourth quarter 1989 data, is similar to that presented on Figure 6-20.

As shown in Table 6.18, permeabilities in the alluvium determined from pumping test data collected before the remedial design varied from a maximum of 1.6×10^{-2} cm/sec to a minimum of 8.1×10^{-5} cm/sec. The system was designed using a permeability of 2.6×10^{-3} cm/sec, a mid-range value. This permeability was measured by the EPA at

Well EPA-28, the closest datum to the system, and was reported in the EPA's RI (EPA, 1988c). This permeability is typical of silty sand (U.S. Department of Interior, 1981).

The permeability of the alluvium near the extraction wells was determined from an aquifer test conducted in the remedial action extraction wells before operating the system. As discussed in the 1989 Annual Review (Canonie, 1989c), the permeability determined from the aquifer test was 2.0×10^{-2}, an order of magnitude higher than the value of 2.6×10^{-3} used for the system design. A discussion of the effect of the higher permeability on the system performance was presented in the 1989 Annual Review (Canonie, 1989c) and is summarized in Section 6.2.3.7.

6.2.3.1.2 Alluvial Flow Rate

Flow rates in the alluvium were evaluated during the remedial design to determine 1) whether sufficient flow was available for operation of pump-back wells, 2) the number of wells and pumping rate required to capture the flow, and 3) whether well design and design pumping rates must be adjusted over time to account for changing flow rates.

The flow rate in the alluvium, calculated near the proposed extraction system has declined steadily since the early 1980s as the rate of mine water discharge to the arroyo decreased and eventually ended in 1986. Figure 6-21 displays the calculated flow rates for the Southwest Alluvium. The pre-1988 flow rates, shown on Figure 6-21, document a decline in the alluvial flow, occurring from 1982 until the present time. This decline in flow occurred over the same period when the primary source of alluvial water (mine water discharge to the arroyo) decreased. Since this source has been permanently terminated, the flow rates will continue to decline until pre-operational conditions are re-established.

A comparison of the projected flow rate declines, shown on Figure 6-21 with the actual declines, is not feasible because the extraction wells are now affecting the cross-sectional area (described below) used to develop Figure 6-21. Also, Well 513 AD, which provided water level data, was plugged in 1988 in accordance with License requirements.

However, review of water level data from well EPA 23, located upgradient from the extraction wells, provides evidence that water level decline, and the associated flow rate decline, continue as predicted. For example, review of water level data for Well EPA 23 presented to the agencies between 1987 (when the water level was first measured) and 1990 shows the water level has declined from an elevation of 6900.3 feet in October, 1987 to 6894.5 feet in October 1990. The total in water level decline for this three-year period was almost 6 feet, a decline of approximately 2 feet per year.

Water level data from July 1991 confirm the declining trend continues. The water level in EPA 23 measured on July 9, 1991 was at an elevation of 6892.9 feet, again a decline of almost 2 feet over a nine-month period.

The estimates of flow rates were generated using Darcy's Law:

$$Q = KiA$$

where:

Q = discharge (L^3/T)

K = permeability (L/T)

i = gradient (dimensionless)

A = area (L^2)

Permeability - For the purpose of this calculation a range of 1×10^{-3} cm/sec to 1×10^{-2} cm/sec was used. The higher end of the range (1×10^{-2} cm/sec) was included to provide a more conservative estimate of potentially required pumping rates.

Gradient - The water-table gradient was estimated from water-level data for wells located in the Southwest Alluvium. Figure 6-22 presents the water levels measured in five representative monitoring wells for 1980 through 1988. As shown, the water levels have declined over this period.

The wells used to provide the water level data for Figure 6-22 have either been plugged, or are no longer included in the monitoring program. Therefore, the figure cannot be updated. However, as discussed previously, data for Well EPA 23 confirm water levels continue to decline as the alluvial system returns to pre-operational conditions.

Figure 6-23 displays the average annual discharge of mine water to the arroyo. This figure illustrates that the mine water source of alluvial water decreased in rate from 1979 until 1986. From 1986, when mine discharge was permanently terminated until the present, no source of recharge water has been available to the alluvium other than natural recharge.

Water-level gradients have decreased in response to the water level declines. Figure 6-24 illustrates the decline in water-table gradients in the Southwest Alluvium. The gradients were calculated from 38 well pairs in the Southwest Alluvium. Appendix D of the RD (Canonie, 1989d) documents the specific data used in preparating Figure 6-24. The gradient decline is expected to continue, since the source of water has been removed.

Future flow rates in alluvium were predicted by projecting the documented declines in gradients, using a linear regression. Figure 6-24 displays the best-fit line for data on gradients in the Southwest Alluvium. Extending this line into the future projected gradients based on the observed trend. The data points, marked on this projected gradient line, were used in the calculation of future flow rates in the Southwest Alluvium, and are displayed in Table 6.19.

Again, Figure 6-24 cannot be revised to account for actual conditions since 1988 when the remedial design was developed. Well 513 AD was plugged in 1988 and, as a result, no post-1988 data is available.

Cross Sectional Area - Computation of flow rates also required the use of a representative cross sectional area through which the flow occurs. Section A-A' (Figure 6-19) was selected for calculating the cross-sectional area. This section was chosen because it was close to the proposed pumping well locations. Also the lithological logs and water level data for Wells 511D and 513AD, which were located on each end of the cross section, provided reasonable certainty of the saturation limits.

Well 513AD was utilized to determine water-level elevation along the Section A-A'. Figure 6-25 displays the documented water levels in Well 513AD. The marked points on the projected trend, shown on Figure 6-25, were used to calculate the cross-sectional area for computation of flow rates for the time after 1988 (i.e., after Well 513AD was plugged). Table 6.19 lists the predicted future cross-sectional areas along cross section A-A'.

6.2.3.2 Southwest Alluvium Target Area Delineation

Tailings seepage water has a unique chemistry resulting largely from the milling process. Alluvial water derived from mine discharge, by contrast, reflects a chemistry resulting from mineral dissolution as it percolated through alluvium (Canonie, 1988a). Therefore, the area where ground water has the chemical characteristics originating from the tailings disposal area is defined as the Southwest Alluvium target area. Figure 6-26 depicts the target area and POCs location defined in this manner.

While tailings liquids contain a variety of chemical constituents, chloride was used as the chemical indicator to delineate the extent of the tailings seepage plume in the Southwest Alluvium because of its unique properties, which are clearly associated with tailings seepage. These properties include:

1. Chloride is a conservative species:

   "The chemical behavior of chloride in natural water is tame and subdued compared with the other major ions. Chloride ions do not significantly enter into oxidation or reduction reactions, form no important solute complexes with other ions unless the chloride concentrations is extremely high, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles.

   The circulation of chloride ions in the hydrologic cycle is largely through physical processes. The lack of complications is illustrated by experiments with tracers in ground water described by Kaufman and Orlob (1956). These investigators found that chloride ions moved with the water through most soils tested with less retardation or loss than any of the other tracers tested - including tritium that had actually been incorporated into the water molecules." (United States Geological Survey Water Supply Paper No. 2254, p. 118).

   Therefore, chloride can be used as a reference for movement of the tailings seepage water (i.e., it will be transported at approximately the same rate as the plume).

2. Tailings fluids and tailings seepage contain very high chloride concentrations. Chloride concentrations of 608 parts per million (ppm) and 730 ppm were measured in the tailings liquid in January 1981 (Personal Communication,

United Nuclear Management, 1989b). In water samples taken at locations immediately adjacent to the tailings impoundment, chloride values are in the 200 ppm range. The high chloride character of the source is clearly distinguishable from the surrounding ground water derived from mine dewatering.

3. Billings (1986) identified pre-tailings disposal chloride values in the alluvial water, which had a peak value of 86 ppm. In addition, upgradient alluvial wells north of the site (i.e., Wells 644 and 645) demonstrated background chloride values of 100 ppm and 113 ppm, respectively. This information suggests that delineation of areas currently in exceedance of the range of 86 ppm to 100 ppm as being associated with the tailings seepage plume.

These characteristics (i.e., chemical conservatism, and the established peak value of background chloride before tailings disposal) aided in delineating the target zone in the Southwest Alluvium. The further downgradient from the tailings impoundment, the lower the chloride value becomes. Table 6.20 contains chloride analyses from the tailings and wells located progressively further to the southwest away from the tailings impoundment. Figure 6-26 displays the location of the wells identified in Table 6.20. The data indicate the gradual decrease of chloride until it reaches background conditions.

Data collected since 1988 confirm chloride concentrations decreased with increasing distance from the tailings disposal area. Table 6.20 has been revised to reflect the chloride data collected in 1989 and 1990 and reported in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a). As shown, chloride concentrations in water from the wells are similar for the period between 1988 and 1990. Also, the concentration decrease in Well EPA 28, which is located at the greatest distance downgradient. Data for Wells 513 AD and EPA 26 are not available after 1988 because Well 513 AD was plugged, and Well EPA 26 is no longer monitored.

The target area can also be defined by considering the travel distance and seepage flow rate in the Southwest Alluvium. The distance to which particles of tailings seepage could travel from the tailings impoundment into the Southwest Alluvium was determined by the following calculation:

$$V = \frac{Ki}{n_e}$$

where:

- V = velocity (L/T)
- K = permeability (L/T)
- i = gradient (dimensionless)
- n_e = effective porosity (dimensionless)

The calculation is based on the permeability of the alluvium (2.6×10^{-3} cm/sec), a value observed by the EPA in its pumping tests, the average gradient in the alluvium over the post tailings disposal period (0.018) (Figure 6-24), and the porosity of the alluvium (0.39) determined in the Reclamation Plan (Canonie, 1987b). Considering effective porosity may be 10 to 30 percent lower than the total porosity value (0.39), the formula produces values of velocity ranging from 138 feet/year to 179 feet/year. Tailings were first disposed of in the impoundment in 1977.

Based on the 11-year period for plume migration before implementation of seepage extraction, these velocities translate into plume travel distances of 1,520 feet to 1,970 feet. As shown on Figure 6-26, these calculated distances are consistent with the observed travel distance of 1,600 feet, defined by chloride concentrations in excess of 100 ppm. The target area determined from chloride concentrations and seepage travel time lies entirely within the more conservative target area as determined by the EPA for the Southwest Alluvium.

The EPA's target area is defined largely on the presence of ARAR exceedances at scattered locations, with no apparent relationship between the source and observed water quality. The Billings background study (1986) and Canonie Geochemistry Report (1988a) demonstrate that other natural sources exist that can and do cause ARAR and ground water protection standard exceedances.

6.2.3.3 Southwest Alluvium System Design

The detailed system design is based on three considerations. First, is the objective to meet License Condition 30, Part B criteria at POC wells. This criterion requires extraction wells be placed upgradient of POC Wells EPA-28, GW-1, GW-2, and 632, to intercept alluvial flow, which may be derived from tailings seepage before it can reach these wells. Second, the system must create a hydraulic barrier against further migration of tailings seepage as specified in the EPA's ROD (EPA, 1988a). Furthermore, in compliance with the ROD, the number and location of wells was determined from the observed saturated thickness and extent of tailings seepage, to the extent it could be defined (EPA, 1988a). Last, the system design balances the first two considerations within the constraints of practical and technical considerations imposed by the hydraulic properties of the saturated alluvium.

6.2.3.3.1 Southwest Alluvium Design Criteria

In accordance with the above stated considerations, the following technical criteria were used as a design basis:

1. Placement of extraction wells northeast (upgradient) of Wells GW-1, GW-2, EPA-28, and 632; and southwest (downgradient) of the South Cell, in areas suitable for drilling and construction activities.

2. Determination of sustainable pumping rates and practically acceptable water level drawdown for extraction wells, given the permeability and thickness of the saturated alluvium.

3. Determination of the number of wells required to adequately capture the alluvial flow and create a hydraulic barrier considering the gradient observed in the water table in 1988.

4. Selection of pumping well locations so the operational capture zones of adjacent wells overlap, creating an effective hydraulic barrier against further seepage migration.

5. Selection of a location that affords an opportunity for meeting the objective of returning the concentrations of the NRC identified hazardous constituents in the alluvium to the concentration limits specified in License Condition 30, Part B.

6.2.3.3.2 Southwest Alluvium Design Methods

Three analytical methods were employed in the system design:

1. Drawdown analysis using the Theis equation to determine optimum pumping rates for different saturated thicknesses and the corresponding water level drawdowns.

2. Generation of capture curves, using a dimensionless-type curve method presented in Javandel and Tsang (1986), which can be used to determine the number and location of wells required to create a hydraulic barrier.

3. Performance evaluation using a Theis well field simulator to predict the hydraulic effects of the entire system.

The first step in the drawdown analysis consisted of determining optimum achievable pumping rates for the range of possible initial saturated thicknesses. The analysis consisted of using the Theis non-equilibrium equation, in conjunction with a range of possible drawdowns, and compensating the transmissivity value for the reduced thicknesses, to produce values of corresponding discharge. Table 6.21 displays the derived values of peak discharge rates calculated for the range of possible initial saturated thicknesses, using this method.

Capture curves were constructed for the predicted peak pumping rates and their corresponding thicknesses (Table 6.21) using the dimensionless-type curve method from Javandel and Tsang (1986). The developed curves were then superimposed on the isopach map of saturated thickness (Figure 6-19) in the area downgradient of the South Cell tailings and upgradient of POC Wells GW-1, GW-2, EPA-28, and 632. The combination of wells was rearranged to minimize the number of wells, while producing overlapping capture zones that covered the portion of the valley east of the arroyo.

The result of this process was the determination that an effective hydraulic barrier could be produced by three extraction wells pumping at an aggregate rate of 17 gpm. Figure 6-27 displays the locations of the three wells, their respective pumping rates and the overlapping zones of capture. The operating performance of the entire system was then evaluated, as described below.

The design of the system was later modified to include an additional extraction well (Well 808), in accordance with NRC and EPA comments to the 1990 Annual Review (Canonie, 1990a). Well 808 was installed and began operating in June 1991. A description of the installation and operation of this well will be included in the 1991 Annual Review.

6.2.3.3.3 Southwest Alluvium System Performance Simulation

The performance of the pump-back wells was evaluated using a Theis well-field simulator and is described in Appendix E of the RD (Canonie, 1989d). The purpose of the simulation was to evaluate what the composite hydraulic effect of the system would be during the first year of operation, and to determine if the well interference effects of adjacent wells would render the proposed pumping rates infeasible.

The simulation results produced two conclusions verifying the feasibility of the design. First, the pumping rates will be sustainable. Appendix E of the RD (Canonie, 1989d) presents the projected operational drawdowns for each well after a year of operation. Second, the system produces an effective hydraulic barrier against further migration of seepage. Figure 6-27 displays the projected operational capture of the entire system, which was predicted to extend across the width of saturation in the southwest alluvial valley east of Pipeline Arroyo.

The actual system performance was initially evaluated immediately after installation and continues to be evaluated on an annual basis. The productivity of each well was tested after installation. The testing procedure was described in detail in Section 3.4, Appendix E, RD (Canonie, 1989a). The permeability of the alluvium and the operational performance of the entire system was also tested as part of the performance monitoring. The test results were presented in the 1989 Annual Review (Canonie, 1989c) and are discussed in Section 6.2.2.7 of this plan.

It was predicted that with continual operation of the system, the pumping rates required to maintain an effective hydraulic barrier would be reduced. While system monitoring has not indicated rates can be reduced, reduction in pumping rates is still anticipated due to the natural flow decline in the Southwest Alluvium, documented on Figure 6-21 and discussed in Section 6.2.3.1 of this report.

6.2.3.4 Southwest Alluvium Well Design and Construction

The technical specifications for extracting and monitoring well design and construction, pumps, and surface conveyance systems are presented in Appendix E of the RD (Canonie, 1989d). The design is based on the predicted aggregate pumping rate of 17 gpm (801:2 gpm; 802:5 gpm; 803:10 gpm). The as-built construction of the Southwest Alluvium Wells 801 through 807 was presented in the 1989 Annual Review (Canonie, 1989c) and the as-built for Well 808 will be presented in the 1991 Annual Review to be submitted to the agencies by December 31, 1991. The actual operational pumping rates have been presented in the two annual reviews. See Section 6.2.3.7 for presentation of the operational data.

6.2.3.5 Southwest Alluvium Monitoring Program

Table 6.22 and Figure 6-9 display the wells proposed and approved for monitoring system performance. Table 6.3 displays the list of chemical constituents utilized in the monitoring program. This list is inclusive of the NRC ground water protection standards and other required constituents contained in License Condition 30, Part A. The wells listed in Table 6.22 are divided into three groups: 1) wells monitored as required by the NRC in License Condition 30, Parts A and B; 2) wells that monitor the performance of the pumping system, and 3) wells that provide the data needed to complete the hydrogeologic evaluation. Note Table 6.22 has been revised to include extraction Well 808, which was added to the system in June, 1991.

The seven alluvial POC wells as identified by the NRC in License Condition 30, Part B, are used to monitor compliance with the NRC ground water protection standards. In conjunction with the water quality monitoring program, water level measurements are also taken in all wells identified in Table 6.22 before collecting the sample. Water levels are used to assess dewatering of the alluvium by monitoring the declines in saturated thickness.

Only water levels are monitored in the system monitoring wells (804, 805, 806, and 807). These water levels, together with the water level in 632, are used to verify the creation of a hydraulic barrier near the extraction wells. As shown on Figure 6-27, these wells are located between the extraction wells and along the capture zone boundary. Figure 6-28 shows water levels from these wells are used to define the gradients between the pumping wells, verifying that the water table slopes towards the pumping wells in these areas.

In addition to the wells required for compliance monitoring (NRC) and for monitoring system performance, six wells were selected to quantify the spatial variation of water quality in the alluvium. Data from these wells will be used in additional background studies. These are Wells 639, 642, 644, and 645 located north (upgradient) of the tailings impoundment; and Wells 627 and 624 located to the southwest of the target area.

6.2.3.6 Southwest Alluvium System Decommissioning

In accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC. This section discusses the conditions presented in the RD (Canonie, 1989d) for determining when the system could be considered for decommissioning.

The objective of the system operation is to clean up to the ground water standards established by the NRC in License Condition 30, Part B and the ARARs established by the EPA in the ROD. However, both agencies recognize modifications may have to be made to these standards. The NRC, in Appendix A, 10 CFR 40 provides the option of establishing ACLs. The EPA recognizes the possibility of not achieving the cleanup standards by providing an alternative approach of establishing waivers to the ARARs in Appendix A to the ROD (EPA, 1988a).

This system is designed to be performance-based (i.e., its success is measured against its ability to meet agency standards). However, as discussed in the RD (Canonie, 1989d), the longest the system is anticipated to operate is the end of reclamation activities. The EPA established that: "seepage collection in the Southwest Alluvium will be designed to create a hydraulic barrier to further migration of contamination while the source is being remediated" (EPA, 1988a, page 3). The documented declines in flow rate, as described in Section 6.2.3.1.2 and illustrated on Figure 6-21, provide technical support demonstrating the system may not be capable of operating beyond the end of reclamation because the depleting available water may limit the feasibility of pumping the Southwest Alluvium by the mid-1990s. By that time, the source (i.e., the tailings) will be remediated by installation of a low permeability cover.

However, other aspects of system operation, as determined by actual performance, may allow it to be decommissioned earlier than the end of reclamation activities. For example, faster than predicted dewatering of the alluvium may occur. Also monitoring may determine that compliance with the NRC and the EPA standards has been attained. Alternatively, monitoring may determine that it is appropriate to waive ARAR requirements and set ACLs.

Decommissioning - Condition 1

In the event that system operation results in meeting the NRC ground water protection standards at the POCs and cleaning up to the EPA ARARs in the identified Southwest Alluvium target area, the system will be considered as a candidate for decommissioning.

Decommissioning - Condition 2

Individual wells and/or the system may be considered candidates for decommissioning before tailings reclamation because of the lack of available saturated thickness near the pump-back wells. The saturated thickness was predicted to decline steadily because the primary source of recharge to the alluvium (i.e., discharge of mine water), ceased in 1986. Water-level data collected for performance monitoring will be used to determine when the saturated thickness declines to a level where an individual well or the system can no longer operate. If the water level near a well(s) declines to a point where the well(s) can no longer produce water at rates greater than 1 gpm continuously, and this condition of low saturation persists for one month, the well and/or system of wells will be considered as candidates for decommissioning.

Decommissioning - Condition 3

The system may also become a candidate for decommissioning before tailings reclamation because of its lack of effectiveness in reducing constituent concentrations to the ground water protection standards established by the NRC and ARAR levels established by the EPA in the ROD. If system operation does not result in a statistically valid trend towards water quality improvement, the system may be considered for decommissioning and the need for ACLs and waivers to ARARs will be evaluated. The database for statistical evaluation will include the data collected for the performance monitoring program. Evaluation of the effectiveness of the system in reducing constituent concentrations is conducted on an annual basis together with evaluation of the compliance monitoring as mandated by the NRC in the License.

6.2.3.7 Implementation of Southwest Alluvium Remedial Action Program

This section discusses the implementation of the Southwest Alluvium corrective action program through July 1991. This information was presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) and responses to NRC and EPA comments on the two annual review reports. Table 6.23 lists the activities and dates associated with implementing this program. For ease of discussion, the implementation is presented on a yearly basis covering the period from May 1989 through July 1991, and includes a summary of the results of the performance monitoring presented in the two annual reviews, as well as a description of field activities completed in 1991. These field activities will be presented formally in the 1991 Annual Review to be submitted by December 31, 1991.

6.2.3.7.1 Southwest Alluvium CAP Activity - 1989

As shown in Table 6.23 the extraction and monitoring wells were installed, tested, and began operation in 1989. Installation commenced and was completed in August. Figure 6-29 shows the well locations, which are similar to the proposed locations shown on Figure 6-27.

The aquifer test results showed the aquifer permeability is approximately 2×10^{-2} cm/sec. This value is an order of magnitude higher than the value of 2.6×10^{-3} cm/sec used to predict pumping rates for the system design. Normally, the higher permeability would mean higher pumping rates would be required to create the same drawdown as would be achieved with the lower permeability. However, as discussed in the 1989 Annual Review (Canonie, 1989c), a no-flow boundary was identified along the southeast

edge of the alluvial valley. The boundary is expected to counteract the effect of the higher permeability by causing an increase in the water level declines in response to pumping, enhancing the effectiveness of the hydraulic barrier.
The distribution lines connecting the extraction wells with the evaporation disposal system were installed and tested during September and October, and the wells began operation on October 16, 1989. As discussed in the 1989 Annual Review (Canonie, 1989c), operational pumping rates averaged 19.7 gpm during the four-week period that data was collected, compared to 17 gpm assumed for the system design in Amendment II (Canonie, 1989a) and the RD (Canonie, 1989d). Table 6.24 (Table 2.10, 1989 Annual Review) presents the 1989 operational data the Southwest Alluvium extraction wells.

The system performance was evaluated for the 1989 Annual Review (Canonie, 1989c), based on approximately six weeks of water level data and one quarter of water quality data. The fourth quarter data represented initial conditions and data collected on December 4 represented conditions after six weeks of pumping.

The evaluation indicated the extraction wells were performing as designed and were beginning to create a hydraulic barrier to flow. Figures 6-30 and 6-31, which were originally presented in the 1989 Annual Review (Canonie, 1989c), illustrate the potentiometric surface of the alluvium for initial conditions (fourth quarter 1989) and after pumping for 1.5 months (October 16 through December 4, 1989), respectively. Comparison of the figures shows the extraction wells were causing a reversal in the slope of the water table near the system wells.

Chemical data reflecting conditions after pumping started was not available because the wells were turned on after collection of the fourth quarter water quality samples. However, initial conditions of chloride concentration were presented and are shown on Figure 6-32. As shown, the extent of the chloride plume in fourth quarter 1989, represented by concentrations of 100 mg/l, is the same as the extent of the remedial action target area (shown on Figure 6-26), which was based on fourth quarter 1988 data.

6.2.3.7.2 Southwest Alluvium CAP Activity - 1990

CAP activity during 1990 consisted of operation and monitoring of the performance of the extraction wells. The system operation and performance was presented in the 1990 Annual Review (Canonie, 1990a) and is summarized here.

The wells pumped continuously through 1990 with some adjustments to flow rates. Table 6.25 summarizes the operational data for the extraction wells during 1990. As shown, between October 1989 and October 1990, the wells pumped at an average rate of 14.3 gpm, with a total of 7.4 million gallons extracted. These pumping rates are similar to those predicted in Amendment II (Canonie, 1989a) and the RD (Canonie, 1989d).

Review of the water level data indicated the system was operating as designed and was creating a hydraulic barrier to flow. Comparison of Figure 6-33 (fourth quarter 1990), with initial conditions presented on Figure 6-30, illustrates the hydraulic barrier that had been created.

As discussed in the 1990 Annual Review (Canonie, 1990a), a hydraulic gradient towards the pumping wells existed through approximately 90 percent of the cross-sectional area of the barrier. Figures 6-33 and 6-34 present the water level data used to evaluate the effectiveness of the Southwest Alluvium extraction wells in creating a barrier. The plan view shown on Figure 6-33 indicates some of the water may have passed between pumping Wells 802 and 803 near Wells 805 and 806. Review of the cross section presented on Figure 6-34 indicates the hydraulic barrier gradient for approximately 10 percent of the cross-sectional area of the barrier may not have been directed toward the pumping wells. As a result of NRC and EPA review, the system was modified by adding Well 808, shown on Figure 6-34, to ensure that the hydraulic barrier is complete.

The 1990 water quality data indicated the configuration and extent of the seepage plume in 1990 was similar to the initial conditions in fourth quarter 1989 shown on Figure 6-32. Figure 6-35 presents the chloride concentrations reported for fourth quarter 1990. Comparison of Figure 6-32 and 6-35 illustrates the similarity of the plume configuration in 1989 and 1990.

The 1990 chloride data exhibited a small increase in concentration, typically less than 10 percent. The cause of the increase is believed to be natural conditions, especially considering that the increases were identified in both upgradient and downgradient wells. As shown on Figure 6-35, subtraction of the apparent effect of natural factors caused the extent of the 100 mg/l isoconcentration line to closely resemble that shown on Figure 6-32.

A statistical evaluation of the water quality data further demonstrated the primary exceedances of the EPA standards, nitrate, TDS and sulfate are due to the fact that the ARARs established for these constituents are inappropriate given the evolution of the alluvial water geochemistry. Previously, evidence for the appropriateness of higher background concentrations was presented in reports by Billings (1986) and Canonie (1988a).

As described in the 1990 Annual Review (Canonie, 1990a), the statistical evaluation used two different procedures ("t" test and analysis of variance) to test the data from wells located upgradient (Wells 639, 642, 644, and 645), wells located within the remedial action target area (Wells 801, 802, 803, 632, GW-1, GW-2, and GW-3), and wells located downgradient from the target area (Wells 624, 627, and EPA-25). Chemical data used for the evaluation were reported for the first quarter 1988 through fourth quarter 1990. The constituents included were chloride, nitrate, TDS and sulfate, which are the primary constituents reported in concentrations exceeding the ARARS in the Southwest Alluvium.

The results of both tests confirm that the 100 mg/l chloride concentration is an appropriate value for delineating the plume in the Southwest Alluvium. Both tests also confirmed that the elevated concentrations of nitrate, TDS, and sulfate are not indicative of seepage and are representative of background conditions. Refer to the 1990 Annual Review (Canonie, 1990a) for a discussion of the test procedures and more detail concerning the test results.

6.2.3.7.3 Southwest Alluvium CAP Activity - 1991

CAP activity as of July 1991 consists of operating the extraction wells and installing an additional extraction well (Well 808). NRC and EPA required installation of Well 808 in their responses to the 1990 Annual Review (Canonie, 1990a). The well is designed to enhance the effectiveness of the hydraulic barrier created by the existing extraction wells.

Figures 6-29 and 6-34 show the location of Well 808 with respect to the other extraction and monitoring wells. As shown, this well is located between Wells 802 and 803 and is designed to enhance the effectiveness of the hydraulic barrier near Monitoring Wells 805 and 806. A discussion of the installation, testing, and operation of this well will be included in the 1991 Annual Review, which will be submitted by December 31, 1991.

6.2.4 Evaporation Disposal System

This section discusses the evaporation disposal system designed and constructed to dispose of water collected from the seepage collection well systems in Zone 3, Zone 1 and the Southwest Alluvium, and from Borrow Pit No. 2. The system was originally described in Amendment I (Canonie, 1988b) and re-evaluated in Amendment II (Canonie, 1989a) to the 1987 Reclamation Plan (Canonie, 1987b). Construction began in the fall/winter of 1988, when the evaporation ponds were built. The ponds have been operating since January 5, 1989. The operational performance of the system has been presented in two reports, the 1989 Annual Review (Canonie, 1989c) and the 1990 Annual Review (Canonie, 1990a) submitted to the agencies.

Figures 6-36, 6-37, and 6-38 show the site conditions and the components of the evaporation disposal system. The components of the system include the following:

1. Two 5-acre, lined evaporation ponds equipped with misters located on the embankments of the ponds to enhance evaporation.

2. Mist evaporation system consisting of several lines of misters located in the Central Cell.

3. Spray evaporation system consisting of a series of spray guns also located on the Central Cell.

The mist evaporation system operated only before and during 1989. It was dismantled in Spring 1990 to allow construction of the interim reclamation cover in the Central Cell. The spray evaporation system, which replaced the mist evaporation system, was installed at the end of the 1990 construction season on top of the Central Cell interim reclamation cover. See Appendix G of the RD (Canonie, 1989d), Technical Specifications (Canonie, 1988c), and the Engineer's Report (Canonie, 1990b) for detailed drawings and specifications for these components.

The design of the evaporation disposal system is based on a water balance providing that all seepage collected from Zone 3, Zone 1, the Southwest Alluvium, and stored in Borrow Pit No. 2 would be evaporated between 1989 and 1996. The water balance accounted for the following inflows and outflows from:

1. Inflow

   - Pump-back and extraction wells
   - Borrow Pit No. 2
   - Precipitation

2. Outflow by evaporation from:

   - The surface of the evaporation ponds
   - The pond misters located on the evaporation pond embankments
   - The mist and spray evaporation systems

Table 6.26 presents the monthly net evaporation rates used to estimate the outflow from the system for the remedial design. Based on performance evaluations of the system, these rates provided a reasonable design guide.

Tables 6.27 and 6.28 present the predicted and actual values for the inflows and outflows of the water balance for the first three years of operation. The predicted values were used for the system design and were originally presented in the RD (Canonie, 1989d). The actual values were determined from performance monitoring of the system.

The water balance is based on the premise that maximum disposal occurs during the summer months when evaporation rates are highest. During the winter months, when evaporation rates are low, or there is net precipitation, the inflow must be regulated so the pond capacity is not exceeded. For example, as shown in Table 6.27, the total inflow volume for 1989 was predicted at 40.6 million gallons, while outflow was predicted at 33.3 million gallons. The difference of 7.3 million gallons represented the volume of water stored in the ponds during the non-evaporative months when outflow would be nearly zero.

6.2.4.1 Evaporation Ponds

Figure 6-36 shows the location and configuration of the evaporation pond system. As discussed in Amendment I of the Reclamation Plan, (Canonie, 1988b) the pond size was determined based on the volume required during non-evaporative months to store water pumped from the pump-back wells, Borrow Pit No. 2 and precipitation. The ponds were completed in January 1989. Details of the pond construction are presented in the As-Built Construction Report (Canonie, 1989b) and are included on the drawings in Appendix G of the RD (Canonie, 1989d).

Storage Capacity - The constructed storage capacity of the ponds is approximately 13.7 million gallons, assuming that under normal operating conditions the ponds are filled to a maximum depth of 4 feet. This depth allows for adequate freeboard to provide additional storm water capacity for as much as 3.6 million gallons per pond. The additional freeboard is adequate to store the probable maximum precipitation event of approximately 8.5 inches of rainfall or approximately 6.7 million gallons of water. Appendix G of the RD (Canonie, 1989d) provides the as-built area/capacity curves for each pond.

Evaporative Capacity - As discussed in Amendment I, evaporation from the surface of the ponds is estimated to be 9.2 million gallons per year. This evaporation volume is based on the net evaporation rates presented in Table 6.26 and conservatively assumes the surface area of the ponds is 10 acres. The actual surface area is slightly greater, approximately 11 acres, because as the ponds fill, the sloped sides create increased surface area and, therefore, increased evaporation capacity.

The evaporation pond system is equipped with two lines of atomizing mist nozzles. The specifications for the pond misters were presented in the Technical Specifications (Canonie, 1988c) and on the drawings included in Appendix G of the RD (Canonie, 1989d). However, the specified nozzle was not available. Therefore, United Nuclear elected to revise the design presented in the Technical Specifications to maintain system efficiency using replacement nozzles.

The misters are designed to operate at a maximum rate of approximately 350 gpm, at least 10 hours per day, 7 days per week during the evaporation season. For design purposes, the evaporative efficiency of the pond mist system was estimated at 35 percent, or 123 gpm, based on the observed efficiencies of similar systems operating at other sites. Evaporation from the misters was predicted to be 15 million gallons per year based on the design efficiency. However, as discussed in Section 6.2.4.3, field operation indicates evaporation efficiency is less than predicted.

The estimates of design efficiency accounted for the climatic conditions prevailing at the site and the evaporative capacity of the mister systems to be installed. Climatic information for the United Nuclear site was obtained from Climates of the States, Gale Research Company 1981, and from the Uranium Mill License Renewal Application (D'Appolonia, 1981).

The pond misters have been monitored during operation to evaluate system efficiency and to determine what adjustments can be made to improve efficiency. These adjustments may include charging the lines with compressed air, selecting a different nozzle, further elevation of the nozzles above the pond dike, or other operational adjustments.

6.2.4.2 Tailings Mist and Spray Evaporation Systems

Additional evaporative capacity was provided initially by the mist evaporation system, which was located on the tailings surface in the Central Cell of the tailings disposal area. This system consisted of several lines of mist nozzles, which sprayed water over tailings to control dust. The mist system was installed and operating at the time of the RD (Canonie, 1989d) and continued to operate until May 1990. At that time, the mist system was dismantled to make way for interim reclamation construction activities.

At the end of the 1990 construction season, a spray evaporation system was installed and began operating. This system consists of a series of 26 spray guns located in the Central Cell. A description of the operation of the two systems was provided in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a).

6.2.4.2.1 Tailings Mist System

In 1989, the mist evaporation system located in the Central Cell with a maximum capacity of 350 gpm (4.2 gpm per nozzle) was being used to evaporate water stored in Borrow Pit No. 2. Figure 6-36 shows the general location and configuration of this system. This system was approved for operation by the NRC and began operation in the 1988 evaporative season. The mist system operated until May 1990, when it was removed, so tailings grading and soil-cover placement for interim stabilization could commence in that area.

6.2.4.2.2 Spray Evaporation System

In accordance with Amendment I, a spray evaporation system replaced the mist evaporation system after interim stabilization grading and cover placement were completed in the Central Cell. The spray system is designed so no infiltration into the cover soils will occur. The system consists of a series of spray guns that can each wet an area of approximately 1 acre. Figures 6-37 and 6-38 show the system layout. Appendix G of the RD (Canonie, 1989d) presents a schematic of a typical spray gun.

Experience in designing similar systems indicates that, to achieve adequate spray coverage of the approximate 15 to 20 acres available at the Central Cell for system placement, 20 to 30 guns may be required. At present, the system consists of 26 guns. The spray guns are operated sequentially to balance application rates and evaporation rates. The maximum application rates vary depending on the month, and may approach up to 6,000 gpd per acre based on the evaporation rates listed in Table 6.26.

Specifications for the spray guns and piping were presented to NRC after the evaporation disposal system had operated and been monitored for performance efficiency. NRC approved the installation of the spray evaporation system in Amendment 7 to the License.

The spray system was selected to replace the mist system for this site because of greater flexibility of operation. The capacity of the spray system is greater than the anticipated volume of seepage predicted to be discharged to the system. Therefore, if the volume from the seepage collection system is greater than anticipated, the spray system will be able to accommodate the additional volume. Spray guns can also be added or subtracted from the system to adjust to changes in climatic conditions, such as dry or wet years, or to changes in volumes pumped from the seepage collection system.

Initially, 16 spray guns were installed in accordance with the design specifications presented in the "Enhanced Evaporation System Engineer's Report" (Canonie, 1990b). Figure 6-37 shows the initial layout of the system in 1990. Ten additional spray guns were added in the spring of 1991 to increase the system capacity. Figure 6-38 shows the system layout with the additional spray guns.

6.2.4.3 Operational Water Balance

This section discusses the predicted and actual operational water balance. The predicted water balance was presented in the RD (Canonie, 1989d) for the design of the evaporation disposal system. The water balance has been updated annually so the need for adjustments to system operation can be identified, and the adjustments can be implemented in a timely manner. The 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) presented discussions of the actual operational water balances for those two years. A revised water balance was also presented in the ALARA demonstration proposal (United Nuclear, 1991) to account for the additional water from Zone 1 and the Southwest Alluvium. Tables 6.27 and 6.28 present the predicted and actual values for the water balance for 1989 through July 1991.

6.2.4.3.1 Inflow

Inflow to the system consists of 1) water pumped from Zone 3, Zone 1 and the Southwest Alluvium seepage extraction systems, 2) water pumped from Borrow Pit No. 2, and 3) precipitation. The contribution from each of these components is described below.

Seepage Extraction System - Pumping volumes from the pump-back wells and extraction wells vary from year to year, depending on the number of wells operating and the anticipated decline in pumping rates due to well productivity. Table 6.27 presents the predicted and actual total volumes pumped each year from the wells and Borrow Pit No. 2, and Table 6.28 presents details of predicted and actual pumping rates and volumes from Zone 3, Zone 1 and the Southwest Alluvium.

Predicted pumping volumes from the new extraction wells were based on an expected initial total pumping rate of 60 gpm for the Zone 3 wells and 17 gpm for the Southwest Alluvium. Pumping rates for the northeast (Zone 3) and east and north cross-dike (Zone 1) pump-back wells were based on actual rates reported in 1988, and assuming these rates would decline over time. Also, the Zone 1 pump-back wells were expected to be decommissioned at the end of 1989.

The actual pumping rates have varied from the predicted rates. For example, as discussed in Section 6.2.1.7, many of the Zone 3 wells pump at lower rates than predicted because the physical conditions of the aquifer limit the well productivity. Also, the Zone 1 wells have continued to operate through 1990 and 1991, rather than being decommissioned at the end of 1989 as predicted for the remedial design water balance.

Tables 6.27 and 6.28 list the total volumes and the pumping rates for the wells. As shown, the Zone 3 and Zone 1 pump-back wells produced more water than predicted in 1989 and 1990.

The Zone 3 extraction wells have produced less than predicted, in part because of limited aquifer productivity. Another factor, which became evident in 1990, is the reduced saturated thickness near the extraction wells, which reduces well efficiency and lowers productivity. As shown in Table 6.27, the actual volume pumped from the Zone 3 extraction wells was approximately half the volume predicted. Table 6.28 shows that by the end of 1990, a total of approximately 46 million gallons of seepage was extracted from Zone 3, which is less than the 64 million gallons predicted. However, the system continues to operate as predicted in terms of dewatering the target area and capturing the plume.

The Southwest Alluvium wells have been pumping at rates similar to those predicted for 1989 and 1991. As a result, the actual volumes extracted, shown in Tables 6.27 and

6.28 approximate the predicted volumes. Also, since Well 808 was added to the system in 1991, the volumes pumped in future years are expected to exceed the predicted volumes.

Borrow Pit No. 2

The water stored in Borrow Pit No. 2 before implementing the CAP was discharged to the evaporation ponds, beginning January 1989. As discussed in Section 6.3, Borrow Pit No. 2 was dewatered by the end of April 1989, approximately six months earlier than anticipated. Table 6.27 shows that only 4 million gallons of seepage were removed, compared to the 12 million gallons predicted for the water balance.

Additional inflow to Borrow Pit No. 2 after the volume of stored seepage was removed came from precipitation only. Inflow from the surrounding alluvium did not occur. Water levels measured February 1989 in Wells B-3 and B-4 located on the west side of Borrow Pit No. 2, indicated the alluvium was unsaturated to a depth below the current bottom of the pit near the pit (Personal Communication, United Nuclear Management, 1989b).

During the winter months of 1990-1991, Borrow Pit No. 2 was used to temporarily store seepage from the extraction wells. As shown in Table 6.27, by the end of December 1990, the volume of water stored in the evaporation ponds was 12.2 million gallons. By the end of January, the maximum safe operating capacity of the ponds had been reached. Borrow Pit No. 2 was used for temporary storage so the extraction and pump-back wells could continue operating throughout the winter months. This interim use of the borrow pit to augment the available capacity of the evaporation ponds was addressed in Amendment I (Canonie, 1988b), the RAP (United Nuclear, 1989), and the RD (Canonie, 1989d) to allow for flexibility in the CAP operation.

As shown in Table 6.27, a total of approximately 2.8 million gallons was discharged to the borrow pit between January and April 1991. The seepage temporarily stored in Borrow Pit No. 2 was diverted to the evaporation disposal system beginning April 1991, when the spray evaporation system began operating. All stored seepage was removed by the end of May 1991.

Precipitation - Inflow to the evaporation pond from precipitation was estimated from the on-site average monthly net evaporation data presented in Table 6.26. Total inflow from precipitation is estimated to be 300,000 gallons per year for a 10-acre pond surface area.

The estimated precipitation volume has been reasonable for the actual operational water balance. The only exception was the snowfall occurring in December 1990. As shown in Table 6.27, this snowfall was estimated to contribute as much as 1.3 million gallons to the volume stored in the evaporation ponds.

6.2.4.3.2 Outflow

Outflow from the system includes evaporation from the evaporation pond surfaces, evaporation from the pond-mist system, and evaporation from the mist and spray evaporation systems located on tailings (depending on which system is in operation). The following describes each of these components.

Pond Surface - Evaporation from the pond surfaces was calculated from the average monthly net evaporation rates presented in Table 6.26 for a surface area of 10 acres. Table 6.27 shows that the water volume predicted to evaporate from the pond surface each year is 9.2 million gallons.

Pond-Mist System - The pond-mist system is designed to achieve an average evaporation rate of 123 gpm, assuming 35 percent efficiency. The estimated maximum volume disposed of through the pond-mist system is 15 million gallons per year.

The total volume predicted to evaporate from the pond surfaces and the pond misters is approximately 24.2 million gallons per year. As shown in Table 6.27, the actual amount evaporated in 1989 was estimated to be 7.3 million gallons, and in 1990 this volume was estimated to be 14.4 million gallons. The lower actual volume in 1989 occurred because for most of the evaporation season only one cell of the ponds contained water and the full evaporative capacity of neither the pond surface nor the pond misters was utilized. In 1990, the lower actual volume was attributed to actual operating efficiency of the pond misters, which was estimated to be 5 to 10 percent, compared to the 35 percent predicted for the design.

Mist and Spray Evaporation Systems - The volume of water discharged through the mist and spray evaporation systems varies depending on the evaporation requirements during the period considered. For the original design, these systems were estimated to discharge up to 20 million gallons. Also, the volumes discharged through the mist and spray evaporation systems were predicted to decline corresponding to the declining discharge rates from the seepage collection systems, including the alluvial extraction system.

Table 6.27 shows the predicted and actual volumes of seepage discharged through the mist and spray evaporation systems in 1989 and 1990. The mist evaporation system operated during the 1989 evaporation season and discharged approximately 9.4 million gallons of seepage over the tailings. The system was predicted to discharge up to 20 million gallons. However, this capacity was not utilized because of the reduced volume of water stored in Borrow Pit No. 2, and the lower than predicted volume of water from the pump-back and extraction wells.

In 1990, the mist evaporation system was scheduled to operate in April and May before initiating construction activities. The system was then to be dismantled and, after placement of the interim reclamation cover, the spray evaporation system was to be installed. The spray evaporation system was originally scheduled to start operation at the beginning of August and continue through October. As shown in Table 6.27, the two systems were predicted to discharge a combined total of 11.6 million gallons in 1990. However, the total volume discharged through the two systems was only 2.4 million gallons in 1990. This reduced volume occurred because of the following factors:

1. The mist evaporation system did not operate in 1990 because the construction schedule was revised to begin in March rather than June. As a result, the mist evaporation system was dismantled before the onset of the evaporation season.

2. The spray evaporation system began operation in mid-September rather than at the beginning of August. Therefore, more than a month of evaporation time was lost and evaporation rates were lower because the system operated after the peak of the evaporation season.

Table 6.27 shows the reduced outflow to the mist-spray evaporation systems was offset by the approximately 11.2 million gallons utilized for construction purposes.

The capacity of the spray evaporation system was expanded in 1991 with the installation of 10 additional spray guns. These guns were added to increase the capacity of the evaporation disposal system to handle the additional water from the continued pumping of the Zone 1 wells and Well 808. The operational capacity of the spray evaporation system will be evaluated in the 1991 Annual Review

6.2.5 Remedial Action Schedule

The schedule of the corrective action to be conducted at the Church Rock site was presented in the RD. The dates presented in this schedule are subject to change depending on the performance success of the remedial action plan. The schedule remains unchanged, with the exception of the schedule for decommissioning the Zone 1 wells and a few other minor modifications.