6

6.0 CORRECTIVE ACTION PROGRAM

6.1 Introduction

United Nuclear was required to implement active seepage remediation at the Church Rock site because constituent concentrations in ground water exceeded the:

1. Ground water protection standards established by the NRC and documented in Condition 30 of United Nuclear's Source Materials License, and

2. Applicable or Relevant and Appropriate Requirements (ARARs) established by the EPA and documented in the Record of Decision (ROD) dated September 30, 1988.

This active seepage remediation program, referred to here as the CAP, evolved over two years, from 1987 through 1989, and was based on requirements established by the NRC and later, the EPA. License Condition 30B identified the ground water protection standards for the site and License Condition 30C required that a CAP be implemented because the standards were exceeded at the designated Point of Compliance (POC) wells.

The EPA initially became involved when the site was placed on the National Priorities List in 1981. EPA conducted a remedial investigation and feasibility study (RI/FS) for the site beginning in 1984, and completed it in 1988. The results of the RI/FS were used to develop ARARs and remedial action alternatives for areas impacted by tailings seepage. EPA prepared a ROD, documenting the selected remedial actions for the site, and listing the selected ARARs. Under an Administrative Order issued in mid-1989, EPA required that United Nuclear prepare a remedial action plan (RAP) and an RD.

NRC and EPA have entered into a Memorandum of Understanding (MOU), which delineates each agency's responsibilities for administering the remedial action at the site, which follow:

1. NRC - source control and on-site surface reclamation pursuant to the License,

2. EPA - off-site ground water remediation pursuant to the ROD, and

3. NRC and EPA - integration of ground water remediation pursuant to the NRC License and EPA's ROD.

6.1.1 Purpose

The CAP report provides the design detail of the corrective action, including the following components:

1. Delineation of the target areas, taking into consideration the hydrogeologic database, the NRC's ground water protection standards, and the EPA ARARs,

2. Detailed design of the remedial action systems, including design basis, engineering methods, and design specifications for the Zone 3 and Southwest Alluvium seepage extraction systems, limited remedial action in Zone 1, and the spray/evaporation system, including the water balance,

3. Performance monitoring program,

4. Criteria for decommissioning,

5. Remedial action schedule.

6.1.2 Objectives of the CAP

The objective of the CAP is to return the concentrations of the constituents identified in United Nuclear's NRC License to the ground water protection limits set forth in the License. Table 6.1 presents the ground water protection standards to be met at the POCs for Zone 3, Zone 1, and the Southwest Alluvium. This table also displays the exceedances of ground water protection standards identified by the NRC in Amendment 4 of United Nuclear's License, at certain locations in the formations of concern.

The objective of the CAP, consistent with the objective stated by the EPA in Appendix A to the ROD (EPA, 1988a), is also to capture seepage that has migrated from the tailings impoundment, and to abate future seepage migration so ground water outside the tailings impoundment is protected, to the maximum extent practicable and necessary, to protect public health and the environment. Performance of the remedial action will be measured against ARARs established by the EPA in its ROD. Table 6.2 contains the ARARs established for the Church Rock site. This table also displays the EPA-identified ARARs exceedances at certain locations in each of the formations of concern, and the constituents of primary concern to the EPA.

6.1.3 Summary of Corrective Action Program

This CAP for collecting tailings seepage was developed in response to the NRC License Condition No. 30, Amendment No. 4 to the Source Material License SUA-1475 issued on January 3, 1989, and to the EPA ROD for the United Nuclear Church Rock site, issued September 30, 1988 (EPA, 1988a). The CAP presents the technical basis for the detailed design of the tailings seepage active remedial action.

The CAP was presented to the NRC and EPA in April 1989 in the document titled "Remedial Design Report" (RD), prepared by Canonie (1989). The program was initiated in May 1989 and has been operating for almost two years. This section incorporates the RD, describing the CAP implemented, together with changes implemented as a result of annual performance reports and agency comments.

Throughout the remainder of Section 6.0, the terms "corrective action "and "remedial action" are used interchangeably. Typically, corrective action is a term used by the NRC and remedial action is a term used by the EPA. The RD (the basis for Section 6.0), while prepared specifically for the EPA under the Administrative Order, describes the components of the Zone 3, Zone 1 and Southwest Alluvium seepage cleanup program submitted to and approved by the NRC as the CAP.

Corrective action has been implemented for the geologic formations of concern identified as Zone 3 and Zone 1 of the upper Gallup Sandstone and the Southwest Alluvium in the GHR (Canonie, 1987a), the EPA's Feasibility Study (FS) (EPA, 1988b) and the EPA's Remedial Investigation (RI) (EPA, 1988c). Figure 6-1 is a site-orientation map providing an overview of the site and the areas where remedial action is occurring.

As stated in the RD (Canonie 1989d), United Nuclear proposed seepage remedial actions to the NRC as part of Amendment I to this Reclamation Plan (July 1988), consisting of the expansion of its then existing, seepage-extraction system in Zone 3, and continued operation of its then existing, seepage-extraction system in Zone 1, until the source of seepage to Zone 1 (i.e., Borrow Pit No. 2) was dewatered. It proposed natural attenuation processes in the alluvium i.e., natural pH buffering capacity, made it unnecessary to capture seepage from the South Alluvium. The remedial actions for Zone 3 and Zone 1 were approved by the NRC, and found by the EPA to be "at least consistent with" its ROD in September 1988. The ROD, however, indicates a seepage-extraction system should also be installed in the Southwest Alluvium. A similar requirement was subsequently prescribed by the NRC in License Amendment No. 4. United Nuclear proceeded with its design to accommodate these requirements.

In March 1989, United Nuclear submitted Amendment II to the Reclamation Plan for the NRC's consideration (at the same time it submitted the RD to EPA). This amendment proposed the desired seepage extraction system in the Southwest Alluvium. This CAP integrates remedial measures for Zone 3, Zone 1 and the Southwest Alluvium.

In the CAP, United Nuclear considers the hydrogeological properties of the formations, subject to remedial action in designing the methods to meet the NRC ground water protection standards and the EPA's ARARs established for this site. The CAP identifies target areas and POC within those target areas, for which remedial action will be implemented. It also provides details of remedial-action-design-performance monitoring program to observe and evaluate system performance, and identifies decommissioning criteria. The corrective action is designed to be performance-based and as such, is designed for flexibility to accommodate variability in conditions encountered and saturation changes occurring during system operation.

Seepage remedial action at the Church Rock site consists of extraction of tailings seepage from Zone 3 and the Southwest Alluvium, and limited seepage extraction from Zone 1 until dewatering of Borrow Pit No. 2, to remove the source of tailings seepage to Zone 1, is completed. The collected tailings seepage will be disposed of by evaporation. Figure 6-1 shows the location of the remedial activities. A summary of the remedial action for the three strata is presented below.

<u>6.1.3.1 Zone 3</u>

Tailings seepage in this stratum originated in the North Cell of the tailings impoundment and migrated to the northeast. Geohydrologic conditions and ARAR exceedances have been used to aid in identifying the Zone 3 target area and POCs. However, since Zone 3 has no acid-buffering capacity, acidic pH measurements provide the most reliable information about the extent of the target area in this formation.

Remedial action in Zone 3 consists of pumping 19 new wells in conjunction with the Zone 3 seepage-extraction wells, which have been in existence since 1983, to create a hydraulic barrier against further plume migration and to dewater the target area. The extractable volume of the target area in Zone 3 is estimated to be 200 million gallons or less, based on a target area of 100 acres, an observed average saturated thickness of 60 feet, and an extractable porosity of 10 percent. Monitoring hydrogeologic conditions during remediation will determine the duration and magnitude of pumping actually required.

6.1.3.2 Zone 1

Tailings seepage in Zone 1 originates from its subcrop in Borrow Pit No. 2. Since Zone 1 also has no acidic buffering capacity, the extent of the target area is also best defined on the basis of acidic pH. The remedial action for Zone 1 consists of dewatering Borrow Pit No. 2 and continuation of pumping from the existing north cross-dike and east pump-back wells. Pumping in Zone 1 after Borrow Pit No. 2 had been dewatered was considered impracticable and unnecessary because of the low transmissivity of the formation within the target area, as documented in the GHR and the ROD (Canonie, 1987a; EPA, 1988b). However, NRC and EPA have required the continued well operation, as discussed in more detail later.

6.1.3.3 Southwest Alluvium

The source of tailings seepage in the Southwest Alluvium is the South Cell of the tailings impoundment. Tailings seepage migrated to the southwest following the topographic dip of the site. The remedial action target area and POCs for the Southwest Alluvium are defined by the use of plume travel-time calculations together with chloride concentrations.

Remedial action for the Southwest Alluvium consists of a barrier/collection system of pumping wells completed in the target area. The system, which originally consisted of three wells and has since been expanded to include a fourth, is located downgradient of the southern edge of the South Cell of the tailings impoundment, and upgradient of the POC wells identified by the NRC in the Southwest Alluvium. The location, spacing and pumping rates for the wells were designed so an effective hydraulic barrier to further seepage migration through the alluvium could be established.

6.1.3.4 Disposal of Extracted Tailings Seepage

Seepage collected by the extraction wells is disposed of by evaporation. The system consists of two, 5-acre lined evaporation ponds equipped with an enhanced evaporation mist system and a separate mist or spray evaporation system installed on the tailings surface. The evaporation disposal system has been installed and is operated entirely within the tailings disposal area.

6.1.4 Performance Monitoring

A program of performance monitoring is used to evaluate the success of the remedial action in meeting design expectations. Performance monitoring may indicate the objectives have been met and the remedy is complete. The monitoring results may also indicate it is technically impractical to achieve all cleanup levels in a reasonable time period, and that it may be necessary to set ACLs and waive the requirements to meet certain contaminant-specific ARARs.

The objective of the monitoring program is to provide statistically valid water level and water quality data that can be used to evaluate the performance of the extraction system in meeting regulatory criteria. Water chemistry analysis for the monitoring program is conducted for the chemical constituents displayed in Table 6.3, including all constituents in exceedance of ground water protection standards and ARARs at the site. Water chemistry data are used 1) to monitor compliance with License Condition 30, Part B criteria at POC wells, 2) to monitor and assess trends in water quality that may develop in response to pumping, 3) to evaluate the effectiveness of cleanup within the target area, 4) to provide an adequate database for development of ACLs (NRC) and waivers to ARARs (EPA) if necessary, and 5) to supplement the existing database. In addition, background water quality plays a very important role in setting both the NRC's ground water protection standards and the EPA's ARARs. Therefore, the monitoring program is also designed to further aid in establishing background water quality conditions.

Water level data are used to determine the effects of the system on geohydrological conditions, including creation and performance of the hydraulic barriers and to monitor the decreases in saturation that will occur as pre-mining natural conditions are re-established.

6.1.5 System Decommissioning

The CAP presented in the RD and described in Section 6.2 of this plan sets forth conditions by which the system would be decommissioned. While these conditions set forth physical parameters used to define when systems become candidates for decommissioning, in accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC.

The objectives of the extraction systems in Zone 3 and the Southwest Alluvium are to create a hydraulic barrier to further migration of tailings seepage, and also concurrently to dewater the identified target area in Zone 3. In addition, system operations may provide an opportunity to clean up water quality in strata, subject to remedial action to the NRC ground water protection standards and the ARAR levels established by the EPA in the ROD. However, both agencies have recognized that modifications may have to be made to these standards. The NRC regulatory mandate recognizes the possibility of not achieving the cleanup standards by providing, in Appendix A, 10 CFR 40, the option of establishing ACLs. Further, the EPA also provides an alternative approach of establishing waivers to the ARARs, stated in Appendix A to the ROD (EPA, 1988a).

The systems in Zone 3, Zone 1 and the Southwest Alluvium are performance-based, i.e., their success will be measured against their ability to produce compliance with agency water quality standards, or in the case of Zone 3, dewater the target area. Achievement of either condition will merit decommissioning the system. In addition, the inability of the systems to meet the above performance criteria would necessitate the issuance of ACLs (NRC) and ARAR waivers (EPA).

6.1.6 Summary of CAP Implementation

Table 6.4 summarizes the CAP implementation from 1989 through July 1991. In accordance with the requirements of the License and the ROD, implementation and evaluation of the CAP performance are documented annually in a report submitted to the EPA and NRC. To date, two reports, the 1989 and 1990 Annual Review (Canonie; 1989c, 1990a), have been submitted to the agencies. The summary presented here is based on the information in these reports. For ease of discussion, the implementation is presented on a yearly basis covering the period from January 1989 through July 1991 and includes the field activities completed in 1991. These field activities will be presented in the 1991 Annual Review to be submitted December 31, 1991.

6.1.6.1 CAP Activities - 1989

The 1989 CAP activity included operation of the evaporation disposal system, dewatering of Borrow Pit No. 2, and the installation and operation of the new extraction wells for Zone 3 and the Southwest Alluvium. These activities were conducted in accordance with the design presented in Amendment I (Canonie, 1988b) and Amendment II (Canonie, 1989a) to the 1987 Reclamation Plan (Canonie, 1987a) and the RD (Canonie, 1989d).

The evaporation disposal system began operation in January 1989, when seepage from Borrow Pit No. 2 and the existing pump-back wells was directed into the lined ponds, which were constructed during the Fall and Winter 1988. From that time, with the exception of a period between January and April 1991, all extracted seepage has been disposed of through the evaporation disposal system.

Borrow Pit No. 2 was dewatered by the end of April 1989, completing the Zone 1 active remediation presented in the RD (Canonie, 1989d). As shown in Table 6.4, the dewatering was completed approximately six months earlier than anticipated. United Nuclear continued to operate the Zone 1 pump-back wells through the end of the year.

The new extraction wells for both Zone 3 and the Southwest Alluvium were installed and began operating in 1989. Table 6.4 shows that the Zone 3 wells began operating at the beginning of August, while the Southwest Alluvium wells began operating in the middle of October.

The 1989 Annual Review (Canonie, 1989c) was submitted at the end of December, as required by the NRC License and the EPA Administrative Order. The report described the 1989 CAP implementation and an evaluation of the performance of the remediation systems. The evaluation results indicated that the remedial action systems in all three formations were performing as designed.

6.1.6.2 CAP Activity - 1990

CAP activity in 1990 consisted of continued operation of the systems operating in 1989, with some revisions to monitoring in Zone 3 and to the pump-back system well configuration for Zone 1. These revisions were implemented in response to NRC and EPA comments to the 1989 Annual Review (Canonie, 1989c).

As shown in Table 6.4, Well 126 was added to the Zone 3 monitoring program to provide water level data to further aid in the evaluation of the extraction well performance. The Zone 3 extraction wells continued to pump throughout 1990 in accordance with the schedule established in the RD (Canonie, 1989d).

As required by NRC and EPA, United Nuclear continued to operate the Zone 1 pump-back wells, although the monitoring data demonstrated that continued well operation would have no effect in accelerating the dissipation of the seepage mound and reducing contaminant concentrations. The agencies, in their comments to the annual review, required United Nuclear continue operating the Zone 1 wells under a modified program. United Nuclear proposed and implemented the modified program in September 1990. As shown in Table 6.4, the modified program consisted of pumping the revised east pump-back system, which consists of wells located further to the east within the remedial action target area, where water quality monitoring had shown the highest concentration of constituents of concern.

The 1990 Annual Review (Canonie, 1990a) was submitted in December. The report indicated all three remedial action systems operated as designed. The Zone 3 wells continued to dewater the target area and control plume migration. The Southwest

Alluvium wells had created a barrier approximately 90 percent effective in preventing further seepage migration. Monitoring data from Zone 1 provided a further demonstration that active remediation in this formation is not feasible.

6.1.6.3 CAP Activity - 1991

CAP activity, as of July 1991, consisted of operation of the seepage cleanup wells, adjustment to the operation of evaporation disposal system, installation of Stage II of the remaining Zone 3 extraction wells, installation of a new Southwest Alluvium extraction well, and implementation of an as low as reasonably achievable (ALARA) demonstration program for Zone 1. This information will be presented formally in the 1991 Annual Review to be submitted in December 1991.

The well system continues to operate in 1991. Some adjustments to pumping rates were made during the winter to reduce inflow to the evaporation disposal system for the period between January and April 1991. Reductions in pumping rates were necessary because the water level in the evaporation ponds had reached the maximum safe operating level. During this period, the northeast pump-back wells were turned off, and the Zone 3 extraction wells were reduced to approximately half their normal rate. The Southwest Alluvium and Zone 1 revised east pump-back wells continued to pump at their 1990 rates.

In addition, beginning at the end of January 1991, extracted seepage was discharged to Borrow Pit No. 2 for temporary storage. Discharge to the borrow pit was necessary to allow continued operation of the extraction wells and, at the same time, prevent exceeding the capacity of the evaporation ponds. A total of approximately 2.8 million gallons was discharged to the borrow pit for temporary storage, until April when the spray evaporation system began operating. The stored seepage was removed from the borrow pit by the end of May 1991 and disposed of through the spray evaporation system.

The Stage II, Zone 3 wells and the new Southwest Alluvium well were installed in May and June. The Stage II, Zone 3 wells were installed as described in the CAP and RD. The Southwest Alluvium well was installed as a result of comments from NRC and EPA upon review of the 1990 Annual Review (Canonie, 1990a). The additional well was required to complete the creation of a hydraulic barrier against further seepage migration. The Southwest Alluvium well began operating June 26 and the Zone 3 wells in August 1991.

United Nuclear also proposed and implemented a program to provide an ALARA demonstration for Zone 1. The program is based on discussions with the NRC and EPA about their review comments to the 1990 Annual Review (Canonie, 1990a). The demonstration program consists of pumping four Zone 1 wells known to be the most prolific Zone 1 water producers and monitoring the quantity and quality of water extracted. The wells will be operated for a period of five months. The purpose of the program is to provide a final 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.

6.2 Corrective Action Program Details

This section presents a detailed description of the final CAP design as presented in the RD (Canonie, 1989d), as well as a description of the implementation and the status of the CAP through time. To date, the CAP status since implementation has been documented in two reports, the 1989 and 1990 Annual Reviews prepared by Canonie in accordance with the requirements of License Condition 30 and the ROD.

The original design of the remedial action systems presented in this section was based on data collected before implementing the CAP. Data collected since the CAP implementation have refined the understanding of site conditions and, at the same time, have validated the data on which the design was based. Continued monitoring of the performance of the systems will allow adjustments to system design, as necessary.

6.2.1 Zone 3 - Corrective Action Program

This section presents the technical basis for the design for the Zone 3 corrective action as originally presented in the RD (Canonie, 1989d), as well as the conditions that exist as of July 1991, approximately three years after implementation of the remedial action. Sections 6.2.1.1 through 6.2.1.6 incorporate much of the text, tables, and figures that were provided in the RD. Section 6.2.1.7 discusses system operation and performance, using the information presented in the 1989 Annual Review (Canonie, 1989c) and the 1990 Annual Review (Canonie, 1990a). This section also describes the installation of Stage II Zone 3 extraction wells completed in May 1991, in accordance with the schedule in the RD and the 1987 Reclamation Plan submitted in July 1987.

As described in the RD, the Zone 3 remedial action system was designed to create a hydrologic barrier against further tailings seepage migration and to dewater the target area. This design criterion was originally presented in Amendment I of United Nuclear's Reclamation Plan approved by the NRC. The EPA accepted this design as documented in the ROD.

6.2.1.1 Hydrogeology of Zone 3

The GHR (Canonie, 1987a) contains substantial detail about site hydrogeology and was the basis for design of the Zone 3 corrective action. As discussed in the GHR, Zone 3 was unsaturated in the target area before the onset of the mine dewatering in 1968.

Evidence for this condition is provided by the construction log for the northeast Church Rock mine shaft, water level data for the Indian Well located approximately 1.7 miles northeast of the site, and drilling logs for two deep geotechnical boreholes drilled in the tailings area. Figure 6-2 provides the locations of the mine shaft, well and boreholes.

Water levels reported in the mine shaft and Indian Well were projected into the tailings area to estimate the pre-mining and pre-milling water level. Figure 6-3 presents the results of this projection. The projection shown on Section A-A' indicates Zone 3 was unsaturated near the North Cell of the tailings impoundment.

The two deep geotechnical boreholes (HL-5 and SHB76-2W), drilled within the tailings area, support the conclusion that the near-surface geologic formations were unsaturated prior to mining and milling activities. Figure 6-2 shows the locations of Borehole HL-5, drilled in 1968 before mine dewatering and Borehole SHB76-2W, drilled in 1976 before tailings discharge. Both boreholes were drilled to an elevation of almost 6,800 feet, below the base of Zone 3, and both boreholes were reported dry when drilled. For more detailed discussion of these conditions, refer to the GHR (Canonie, 1987a).

After mining began in 1968, water discharged into Pipeline Arroyo percolated through the alluvium and into Zone 3, resulting in partial saturation and an attendant water quality (i.e., background). Tailings seepage then migrated into Zone 3 from the North Cell and, to a lesser extent, Borrow Pit Nos. 1 and 2, creating a ground water mound on top of the artificial system. Background water quality in the Zone 3 target area was then altered as seepage from the tailings impoundment commingled with the "background" water in the target area.

As identified by the EPA in the RI (EPA, 1988c), water migrated to the east-northeast at the northeast corner of the site. With increasing distance from the tailings site along this east-northeasterly flow path, Zone 3 approaches unsaturated flow conditions. This unsaturated condition is particularly evident in the vicinity of Well Nos. EPA-17 and EPA-1 where, in 1989 at the time the RD was prepared, less then 10 percent of the vertical section of Zone 3 was saturated. Well No. EPA-17 was reported dry when drilled (locations of these wells are shown on Figure 6-2). Zone 3 is dry in the area east of Borrow Pit No. 2.

Confirmation of the unsaturated condition is provided in the 1989 and 1990 Annual Reviews (Canonie; 1989c,1990a) which show that Zone 3 has already been dewatered near wells EPA-17 and EPA-18, in response to the pumping from the remedial action wells. Section 6.2.1.7 presents further discussion of dewatering Zone 3.

6.2.1.1.1 Physical Characteristics of Zone 3

Zone 3 consists of fine- to coarse-grained, quartzose sandstone with a thin coal and shale seam along its base. The thickness of this unit at the site ranges from 70 to 90 feet. Zone 3 dips at approximately 2 degrees to the northeast, and subcrops in the north end of Borrow Pit No. 2 and in the northeast corner of the North Cell. Evaluation of hydrologic testing by Billings and Associates, Inc. (1982, 1983, 1984, 1985a, 1985b) and CH2M Hill (1985) showed that Zone 3 has an average permeability of 10^{-3} centimeters per second (cm/sec) with an average transmissivity of 1,000 gallon(s) per day (gpd) per foot. In addition, pumping test data indicate saturation in Zone 3 exists in an unconfined condition and the unit storativity is 0.05 (Canonie, 1987a).

These geologic and hydrologic properties were verified when drilling and testing the Stage I wells (Wells 701 through 713). The 1989 Annual Review also discusses these properties (Canonie, 1989c).

Structural features, particularly the fracture zones identified on the cross sections presented in the GHR, appear to influence the direction of the flow in areas where the fractures are present. The effect of fracture-influenced flow is illustrated on the pH isoconcentration map in the GHR (Canonie, 1987a; Figure 3-1). As shown on the figure, plume migration from the North Cell is concentrated to the northeast and east along these predicted fracture zones. The fluid movement in Zone 3 is thought, however, to be dominated by porous flow because the distance of tailings seepage migration predicted on the basis of porous flow coincides with the plume's observed migration distance. Thus, fractures appear to control direction of flow, but do not significantly affect the fluid transport rate.

Aquifer testing of Zone 3 during installation of the Stage I wells in May/June 1989 confirmed the conclusion that porous flow dominates the fluid movement in Zone 3. The results of the testing were presented in the 1989 Annual Review (Canonie, 1989c).

6.2.1.1.2 Flow in Zone 3

The hydrologic regime in Zone 3 created by the mine water discharge and tailings disposal is transient. The tailings seepage mound has been dissipating since tailings discharge ceased in 1982. Evidence for dissipation was presented in the GHR and documents a decline in Zone 3 hydraulic gradients of 0.001 to 0.003 feet/feet per year (Canonie, 1987a). Since contribution to the recharge to Zone 3 no longer exists because mine dewatering has ceased, mound dissipation will continue at ever-decreasing rates. This process would occur even if no remedial action were implemented. Also, because the sources of recharge and the potential for future recharge when the tailings are reclaimed will no longer exist, a finite volume of water is present in Zone 3 of the target area. Remedial action in Zone 3 is based on removing that finite volume.

Remedial action in Zone 3 has accelerated the mound dissipation as indicated by the increased rate of decline in water levels and dewatering certain areas, such as the vicinity of EPA-17 and EPA-18. The effect of the remedial action in Zone 3 is documented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a), and is discussed in Section 6.2.1.7 of this plan.

6.2.1.2 Zone 3 Target Area Delineation

In the ROD, the EPA identified the remedial action target area for Zone 3 be delineated as follows:

> "Active remediation of Zone 3 outside the tailings disposal site will be performed in areas contaminated by tailings seepage . . . The full extent of the tailings seepage plume will be determined . . . on the basis of ground water flow directions in the aquifer in conjunction with identification of the margin or amount by which standards are exceeded for hazardous constituents in ground water." (EPA, 1988a, page 3).

The chemistry of Zone 3 water is derived from two sources: the geochemical interaction of mine water discharged to the arroyo as it percolated through the alluvium and into Zone 3, and the tailings seepage. Despite the different origins of the saturation, water from both sources contains many of the same chemical constituents. Although tailings seepage is clearly much poorer quality than the water derived from mine discharge in Zone 3, the concentrations distinguishing the two water types is not always clear or consistent. For this reason, the Zone 3 target area, defined by the EPA's ROD based on ARAR exceedances, includes large areas saturated by mine water discharge, but not affected by tailings seepage. These areas represent background water quality.

Therefore, to ensure remedial action is completed in areas contaminated by tailings seepage, a water quality parameter must be used to define the tailings seepage plume, definitive in distinguishing between waters from the two sources. Since Zone 3 has no acid-buffering capacity, and the tailings seepage source is acidic in nature (Canonie, 1988a), pH measurements can be used to aid in defining the extent of the tailings seepage plume in that formation.

The Zone 3 target area can be further defined by considering travel distance and rate of seepage flow. The distance that particles of tailings seepage could travel northeastward from the tailings impoundment into Zone 3 was determined by the following calculation:

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

where:

V = velocity [length per time (L/T)]

K = permeability (L/T)

i = gradient (dimensionless)

n_e = effective porosity (dimensionless)

This calculation assumes porous media transport, rather than fracture flow conditions. As presented in the GHR (Canonie, 1987a), fracture flow does not significantly control the rate of fluid movement in Zone 3, although it may influence the direction of plume movement. This is substantiated by the calculations, as described below, because the distance calculated for plume migration based on porous flow coincides well with the observed migration distance. Aquifer test results reported in the 1989 Annual Review (Canonie 1989c) also substantiated this finding, as did water quality data collected since the RD was submitted in April 1989. Refer to Section 6.2.1.7 of this plan for a further discussion of the test results and water quality data.

The calculation is based on the permeability of Zone 3 (1.0×10^{-3} cm/sec) (Canonie, 1987a; Table 2.2), the average gradient in Zone 3 (0.03) (Canonie, 1987a, Figure 3-2), and the porosity of a sandstone (such as Zone 3) of 0.10 (Freeze and Cherry 1979, page 37). Considering that effective porosity may be 10 to 30 percent lower than the total porosity value (0.10), the formula produces values of velocity ranging from 345 feet/year to 444 feet/year. Tailings were first disposed of in the North Cell in 1980. Based on the six-year period available for plume migration, these velocities translate into plume travel distances of 2,000 feet to 2,500 feet. As shown on Figure 6-4, these calculated distances are consistent with the observed travel distance of 2,200 feet to the leading edge of the pH plume.

The target area determined from pH and seepage travel time, and shown on Figure 6-4, lies entirely within the more conservative target area determined by the EPA for Zone 3. The remedial action for this refined target area in Zone 3 is designed to extract and dispose of tailings seepage delineated in this manner.

6.2.1.3 Zone 3 System Design

As described in the RD, the remedial design for Zone 3 consisted of as many as 20 wells, installed in two stages. The first stage consisted of 12 new wells (originally 13) installed in 1989. The first five wells (708 through 712) were installed at the locations shown on Figure 6-5, and were tested to verify system performance as designed and the total number of new wells needed for this stage. As discussed in the 1989 Annual Review (Canonie, 1989c), the test results indicated one of the proposed wells (Well 704) should be eliminated from the system. The remaining seven wells (701 through 713, excluding 704) of the initial stage were installed at the locations shown on Figure 6-5.

As illustrated on Figure 6-5, the second stage consists of seven wells, installed in 1991. The well locations (Figure 6-5) are a refinement of those presented in Amendment I, based on the performance simulation presented here.

6.2.1.3.1 Zone 3 Design Criteria

In the ROD, the EPA identified in the ROD the criteria for design of a remedial action program for Zone 3 as follows:

> "Seepage collection in Zone 3 will be designed to create a hydraulic barrier to further migration of contamination. Final well locations will be guided by observed saturated thicknesses in Zone 3, and the extent of the tailings seepage plume as defined above. Data obtained during performance monitoring of the extraction system should be used to determine the optimum rate of pumping, and extent and duration of pumping actually required." (EPA, 1988a, page 3).

Therefore, the extraction system design was based on the following four criteria:

1. Capture and extract seepage in the target area, and create a hydraulic barrier against further migration of tailings seepage.

2. Locate wells in areas of maximum saturated thickness to ensure efficiency of extraction.

3. Space wells adequately to ensure efficient extraction rates and capture of the target zone.

4. Verify that predicted pumping rates for the system will dewater the target area within the reclamation period (by 1996).

6.2.1.3.2 Zone 3 Design Methods

The conceptual well layout was presented in Amendment 1 to the 1987 site Reclamation Plan (Canonie, 1988b), as approved by the NRC, using a well spacing of 150 to 200 feet. This configuration focused on surrounding the target area and the POCs, while maintaining most well locations north of the plume, to create a hydraulic barrier against the northeastern movement of tailings seepage. The well spacing was based on an initial calculation of required well distance to produce overlapping depression cones by two pumping wells, pumping at a rate of 5 gallons per minute (gpm). (5 gpm is known to be a feasible pumping rate in Zone 3, based on field observation.) The location and spacing of the wells was refined as a result of the performance simulation conducted for the RD, which identified inadequacies of the conceptual design presented in Amendment I (Canonie, 1988b).

Detailed design proceeded using the target area displayed on Figure 6-4. An isopach map of saturated thickness was constructed using water levels from October 1987. Data developed by United Nuclear when preparing the RD was used to adjust the 1987 data where necessary. Table 6.5 lists the water level data used to construct the isopach map. As shown on Figure 6-6, at the time the design was developed, the area of saturated thickness was greatest directly north of the North Cell, in areas that had become saturated by mine water discharge. The complex distribution of saturation shown on Figure 6-6 is a result of the intermittent and transient sources of recharge to the formation, the northeastern dip of the strata which is of unequal thickness, and the effects of the northeast pump-back system near the North Cell. Figure 6-6 also illustrates that Zone 3 saturation is reduced to the northeast, in the direction of flow.

As discussed in the 1989 Annual Review (Canonie 1989c), the saturated thicknesses used to design the system were confirmed by further field observations during installation of the Stage I wells. Initial saturated thickness conditions determined from field data before the start of pumping, matched closely with those presented in the RD and on Figure 6-6.

A complex response of Zone 3 to pumping-well extraction was anticipated, due to the variability of the saturated thickness and the irregular northeasterly directed gradient.

To account for the complexity, a computer model was used to simulate the initial response to pumping by the extraction system. The objective of the computer simulation was to demonstrate hydraulic control of the plume target area during the initial years of system operation, and to refine the system's well spacing and pumping rates.

The model used to simulate system performance was the Prickett and Lonnquist finite difference model (Illinois State Water Survey, 1971). The version used simulates non-steady flow in a two-dimensional aquifer, where transmissivity changes as a function of aquifer thickness. The Fortran code used is contained in Appendix A of the RD (Canonie, 1989d).

The model simulation assumed the following aquifer parameters for Zone 3:

Hydraulic Conductivity: 1.0×10^{-3} cm/sec (Canonie, 1987a, Table 2.2)

Storativity: 0.05 (Canonie, 1987a, Table 2.2)

Figure 6-6 displays the boundary conditions of the model and the initial conditions of saturated thickness. No-flow boundaries were placed in areas to the south and east of the model to simulate the limit of Zone 3 saturation. A no-flow boundary was also placed on the western edge of the model, limiting the investigation to the area of concern, namely, the tailings seepage target area, including the POCs. Given the overall northward direction of flow in this formation, the boundary approximates the orientation of a flow line in the system and, therefore, flow will occur parallel to this boundary and not across it. As a result, the boundary approximates an area where neither recharge or discharge from the modeled area will occur, and its no-flow designation is appropriate. A constant head boundary was placed at the northeastern end of the model where the saturated thickness decreases and where flow to the northeast is directed. The constant head boundary acts to simulate the constant, northeasterly directed flow of water.

The initial saturation conditions shown on Figure 6-6 were based on the site-specific data presented in Table 6.5. For the purposes of model input, water levels and basement elevations were contoured and the resulting values were assigned to each model node.

6.2.1.3.3 Zone 3 System Performance Simulation

The first well configuration tested consisted of 20 wells, including the 14 wells presented in Amendment I, together with the current drawdown effects of the existing Zone 3 extraction wells. These wells were pumped at 5 gpm during the computer simulation. The results of this initial run demonstrated that the wells to the south became unpumpable during the first year and significant quantities of water remained in the southern portion of the target area.

The model was then refined in two ways. First, the pumping rates were varied to simulate a decline in pumping rates for each well due to losses in efficiency. Table 6.6 shows the revised pumping schedule. Second, well locations were changed to those shown on Figure 6-6 to focus more of the extraction in areas of greater saturated thickness. Thirteen wells were pumped during the first two years of simulation. The remaining seven wells were used beginning in the third simulation year. This configuration allowed the southern wells, which are essential to dewatering the southeastern portion of the target area, to continue operating.

The results of the refined well configuration are displayed on Figure 6-7. This figure illustrates that significant dewatering of the target area was predicted to occur during the first 2.5 years of simulated operation (i.e., two years with 13 wells operating, and one-half year with 20 wells operating). Comparison of Figure 6-6, depicting initial conditions, and 6-7 shows that much of the target area was predicted to be dewatered to less than 10 feet of saturation in the first 2.5 years of operation.

The simulation indicated the system would not only dewater the target area and the POCs, but would also create a barrier against further migration of tailings seepage. Figure 6-8 displays the capture zone of the well system after 2.5 years of modeled operation. This figure shows that the capture zone of the system will encompass the entire target area, preventing the northeastern migration of tailings seepage until target area dewatering is completed.

The results of the modeling effort indicated several refinements of the conceptual system design described in Amendment I:

1. The entire system would be pumped at a uniform 5 gpm rate. A variable pumping schedule, similar to that shown in Table 6.6, based on conditions of saturation and permeability encountered at each well location, would be used.

2. Figure 6-8 demonstrates that, if the system modeled were to be pumped at the rates prescribed in Table 6.6, the capture of water in the target area would be successful. In addition, over the course of the reclamation period, the system would extract approximately 200 million gallons, the estimated volume of the target area, as presented in Amendment I (Canonie, 1988b). The system would also capture Zone 3 seepage to a significant distance (800 feet) north of the defined target area, as shown on Figure 6-8, providing an additional margin of cleanup benefits.

3. The seven northern-most wells (714 through 720) would not be necessary during the initial extraction phases. However, as extraction proceeds, wells

to the south would successively become unpumpable due to a loss of saturated thickness. The seven northern wells would become necessary in later stages of the extraction process to complete target area dewatering.

4. To verify design adequacy, the initial 13 wells would be installed in stages. The first five wells installed, (708 through 712), would be tested for individual capacity and well interference. The testing procedure, contained in Appendix B of the RD (Canonie, 1989d), would allow verification of predicted pumping rates and adequate well spacing. Modifications to the design would be considered, based on the results of the test. Potential modifications would include adjustments in well spacing, or the operation of existing Wells, such as 608 and 672, in place of modeled Wells 703 and 704.

   As discussed in the 1989 Annual Review (Canonie, 1989c), testing of the first five wells resulted in deletion of Well 704 from the system. Also, pumping rates in the individual wells are different than predicted because of variability of the physical properties of Zone 3.

5. The previously existing northeast Zone 3 pump-back Wells (608, 610, 613, 672) would be operated and decommissioned in conjunction with the new system.

Evaluation of the system performance presented in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a) demonstrated that the computer simulation was representative of conditions in Zone 3 and that predictions of the response to pumping were reliable. Section 6.2.1.7 of this plan discusses the comparison of the computer model predictions with the performance monitoring data.

6.2.1.4 Zone 3 Well Design and System Construction

Appendix C of the RD presented the technical specifications for the Zone 3 extraction well design, construction and pumps (Canonie, 1989d). The design was based on the predicted maximum aggregate pumping rate of 65 gpm. The as-built construction of the Stage I wells was presented in the 1989 Annual Review (Canonie 1989c) and the as-built for the Stage II wells will be presented in the 1991 Annual Review, to be submitted to the agencies by December 31, 1991.

The possibility of placing a sump below the screen and extending beneath the contact of Zone 3 and Zone 2, was considered as a design option. However, calculations showed that a 50 percent efficient well would drop in production to 1 gpm with 5 feet of remaining saturated thickness (assuming an initial thickness of 40 feet). The decline in the pumping rate would occur from a loss of both efficiency and the decrease in saturated thickness with attendant reductions in the well's specific capacity. Neither of these two factors are altered or enhanced by sump installation. Therefore, the use of sumps below the screen was not incorporated in the Zone 3 well design.

6.2.1.5 Zone 3 Performance Monitoring Program

Table 6.7 and Figure 6-9 display the wells used for monitoring the performance of the system. The wells listed in Table 6.7 are of two types: 1) wells currently monitored in Zone 3 as required by the NRC in License Condition 30, Parts A and B; and 2) system extraction wells that monitor the dewatering performance of the pumping system. Table 6.3 displays the list of chemical constituents that are utilized in the monitoring program.

Only water levels are monitored in the 19 system extraction wells (701 through 720). These water levels, together with the water levels from the 20 other monitoring wells listed in Table 6.7, are used to verify the creation of a hydraulic barrier to future migration of the tailings seepage plume contained by the target area. These wells provide the water level data necessary to confirm successful dewatering of the target area and the eventual decommissioning of the system.

As of the Third Quarter 1991 sampling event, several changes had been made to the list of wells included for performance monitoring of Zone 3. First, as shown in Table 6.9, Well 704 was deleted because it was not installed. Aquifer testing during installation of the Stage I wells indicated that inclusion of this well would detract from the performance of the system. Second, Well TWQ 126 was added to the program in April 1990 at the request of the NRC and EPA in their comments to the 1989 Annual Review (Canonie, 1989c). This well is used to monitor water levels only. Finally, Well EPA 11 was deleted from the list because, as of second quarter 1990, Well EPA 11 could no longer be sampled. The water level near the well has declined in response to pumping the Zone 3 extraction wells and, as a result, the water level is below the pump intake. After contacting the NRC and EPA, United Nuclear attempted to lower the pump in the well. This attempt was unsuccessful and NRC and EPA agreed via telephone conversations in July 1990, to exclude this well from further monitoring.

Monitoring for all chemical constituents selected for the performance monitoring program is conducted quarterly, consistent with United Nuclear 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 system performance evaluations 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 and 1990a).

6.2.1.6 Zone 3 System Decommissioning

The objective of the Zone 3 extraction system is, as stated previously, to create a hydraulic barrier against further migration of tailings seepage, and to concurrently dewater the identified target area. In addition, the operation of the system may provide an opportunity to clean up water quality in Zone 3 to the NRC ground water protection standards and the ARAR levels established by the EPA in the ROD. However, both agencies recognize modifications may have to be made to these standards. The NRC regulatory mandate recognizes the possibility of not achieving the cleanup standards by providing (in Appendix A, 10 CFR 40) the option of establishing ACLs. Further, the EPA also provides an alternative approach of establishing waivers to the ARARs as stated in Appendix A to the ROD (EPA, 1988a).

This system is performance-based, i.e., its success is measured against its ability to 1) produce compliance with agency water quality standards, or 2) dewater the target area. Achievement of either condition will merit decommissioning the system. In addition, the inability of the system to meet the above performance criteria would necessitate the issuance of ACLs (NRC) and ARAR waivers (EPA). While these conditions set forth physical parameters used to define when the system becomes a candidate for decommissioning, in accordance with NRC License Condition 30C, no program component meeting the decommissioning criteria will be decommissioned without prior approval from NRC.

The three conditions for which the system, or parts thereof, become candidates for decommissioning are discussed in further detail as follow:

Decommissioning - Condition 1

In the event that system operation results in meeting the NRC ground water protection standards at the POCs, as set forth in the License, and cleaning up to the EPA's ARARs as set forth in the ROD in the Zone 3 target area identified here, the system will become a candidate for decommissioning.

Decommissioning - Condition 2

Individual wells may become candidates for decommissioning because of the lack of available saturated thickness in the formation. The system may become a candidate for decommissioning based on the successful dewatering of the target area. The saturated thickness is predicted to decline steadily in response to pumping because the primary source of recharge to Zone 3 no longer exists. 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.

Once a well begins to lose its ability to pump efficiently, it will be evaluated for stimulation to improve productivity or, if its productivity declines to or below 1 gpm for a period of one month, possible replacement. The well will be stimulated and cleaned, then turned off and allowed to recover, to determine whether the formation can produce sufficient water to merit well replacement. If the water level recovers sufficiently to produce 1 gpm but the well efficiency does not allow production of 1 gpm or more, the well will be replaced. If the water level in the well does not recover sufficiently to allow production of water in amounts greater than 1 gpm, the well will be considered for decommissioning.

The 1 gpm criteria accounts for yearly declines of 20 percent pumping rate, based on long-term pumping records for existing Zone 3 wells. The target area is expected to be dewatered i.e., approximately 200 million gallons extracted, over the 6-1/2-year remedial action period. Over this 6-1/2-year period, the annual 20 percent production loss will reduce pumping rates at individual wells to approximately 1 gpm. As of July 1991, approximately 37 million gallons have been extracted from Zone 3. While this volume is approximately 30 percent less than predicted, the system is performing as predicted during the remedial design.

Decommissioning - Condition 3

The system may also become a candidate for decommissioning because of its inability to reduce constituent concentrations to the NRC ground water protection standards and the EPA ARAR levels. As discussed in Section 6.2.1.2, the standards set for the site are below background concentrations and may not be representative of the actual site conditions. If system operation does not result in successful dewatering of the target area, or in a statistically valid trend towards water quality improvement cannot be established, the system will be considered for decommissioning and the need for ACLs and Waivers to ARARs will be evaluated.

6.2.1.7 Implementation of Zone 3 Corrective Action Program

This section discusses the implementation of the Zone 3 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 6.8 provides a list of 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 performance monitoring results 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, as required by the NRC License.

6.2.1.7.1 Zone 3 CAP Activity - 1989

As shown in Table 6.8, the Stage I wells were installed, tested and began operation in 1989. Installation commenced in May and was completed by the end of June. Figure 6-5 shows the well locations. Well 704 was excluded from the system based on the results of the aquifer test conducted in the first five wells installed, Wells 708 through 712.

The distribution lines connecting the extraction wells with the evaporation disposal system were installed during July. The wells began operation on August 7 and 8, 1989. As discussed in the 1989 Annual Review, operational pumping rates averaged 43 gallons per minute (gpm) during the three months, compared to 60 gpm assumed for the system design in the RD. The operational pumping rates are lower because the hydraulic properties of the formation limit the productivity of the wells. Table 6.9 presents the operational data for the Zone 3 Stage I wells.

The system performance was evaluated for the 1989 Annual Review (Canonie, 1989c) based on three months of water level data and two quarters of water quality data. The third quarter data represented initial conditions before starting operation and the fourth quarter data represented conditions after almost three months of operation. The evaluation indicated that the extraction wells were performing as designed and were successful in :

1. Capturing and extracting seepage in the remedial action target area, and

2. Creating a hydraulic barrier against further migration of seepage.

Figures 6-10, 6-11, and 6-12, originally presented in the 1989 Annual Review (Canonie, 1989c), illustrate the effect of the wells in capturing seepage and creating a hydraulic barrier against further migration. For example, Figure 6-10 shows the change in saturated thickness between third and fourth quarter 1989. In the area, drawdown (decrease in saturated thickness equaled or exceeded 10 feet) was approximately 52 acres which incorporates 90 percent of the Zone 3 target area.

Comparison of actual field conditions and conditions predicted by the computer simulation provide additional confirmation of the well system performance. As discussed in the 1989 Annual Review (Canonie, 1989c), the location and configuration of the contours of saturated thickness, based on the fourth quarter 1989 water level data, are similar to those generated by the computer simulation. The similarity of the contour plots indicates the system was operating as predicted in the RD (Canonie, 1989d).

Finally, the pH data presented on Figures 6-11 and 6-12, confirm the wells are extracting seepage. Comparison of the data from the third quarter (Figure 6-11) and fourth quarter (Figure 6-12) sampling events indicates that the areal extent of tailings seepage represented by acidic pH was reduced by half, from approximately 72 acres to 34 acres, during the first three months of operation.

6.2.1.7.2 Zone 3 CAP Activity - 1990

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

The wells pumped continuously through 1990 with some adjustments to the flow rates. Table 6.10 summarizes the operational data for the Zone 3 Stage I wells during 1990.

As shown, between October 1989 and October 1990, the wells pumped at an average cumulative rate of 30 gpm with a total of 15.3 million gallons extracted. This operational rate was less than the predicted design rate of 34 gpm. The total volume of water extracted from Zone 3 by the new and existing wells during the 1990 reporting period was 22.1 million gallons. This volume represents almost 10 percent of the 200 million gallons predicted to be removed for the RD.

A comparison of Tables 6.10 (1990 data) and 6.9 (1989 data) indicates the effects of dewatering on system operation. The dewatering effects are indicated by the lower operational pumping rate (i.e., 30 gpm versus 43 gpm) and the fact that five additional wells (701, 703, 705, 709, and 710) required installation of automatic controllers. These controls automatically turn off the pumps for a preset time period when the water level in the wells declines to the level of the pump intake. Initially, only low-yield wells 702, 712, and 713 were equipped with the controls. Due to declines in water level, the five additional wells were equipped with the controls during 1990.

The system continued to perform as designed throughout the 1990 reporting period. As discussed in the 1990 Annual Review (Canonie, 1990a), water levels continued to decline, dewatering of Zone 3 progressed to the point that several areas are dry, and the acidic plume was maintained at the areal extent shown in the 1989 Annual Review (Canonie, 1989c) and shown on Figure 6-12.

For example, as discussed in the 1990 Annual Review, a distinctive cone of depression had developed along the entire northern boundary of the target area. Furthermore, between October 1989 and October 1990, the cone of depression had expanded by as much as 400 feet to the northeast. Since ground water flow within the cone of depression was toward the pumping wells, seepage within the target area was captured and extracted by the wells.

The effect of dewatering is illustrated by the change in saturated thickness between October 1989 and October 1990. As shown on Figure 6-13, the area of Zone 3 dewatered by the extraction wells, represented by the contour of 10 feet reduction in saturated thickness, had expanded by an area of approximately 13 acres during 1990. The total area of intense dewatering was delineated by the 10-foot contour of reduced saturated thickness and incorporated approximately 60 percent of the remedial action target area, compared to 47 percent in October 1989.

Figure 6-14 further illustrates the effect of the extraction wells in dewatering the remedial action target area. Wells EPA 17, EPA 18, EPA 3, and 106 D, which penetrate Zone 3 to its bottom, were dry or had less than 5 feet of water as of fourth quarter 1990, proving that the aquifer in these areas has been nearly dewatered. Also, although Wells EPA 3 and 106 D still had up to 5 feet of water, projection of the trend of declining water levels indicates that Zone 3 may be dewatered near these wells by the end of 1991.

As in 1989, comparison of actual field conditions and conditions predicted by the computer simulation provide additional confirmation of the well system performance. As discussed in the 1990 Annual Review (Canonie, 1990a), the location and configuration of the contours of saturated thickness, based on the fourth quarter 1990 water level data, are similar to those generated by the computer simulation. The similarity of the contour plots indicates the system was operating as predicted in the RD (Canonie, 1989d).

Finally, as discussed in the 1990 Annual Review (Canonie, 1990a), comparison of figures presenting isoconcentrations of pH indicates that the area of tailings seepage represented by acidic pH in fourth quarter 1990 was similar in both shape and extent to that shown for 1989. The fact that the extent of the acidic plume is not expanding indicates the extraction wells are performing as designed and creating a barrier against further migration of tailings seepage.

6.2.1.7.3 Zone 3 CAP Activity - 1991

CAP activity as of July 1991 consisted of installing and testing the Stage II wells designed in the RD. Figure 6-5 shows the locations of the wells. These locations are the same as the design locations presented in the RD. Revision of the locations was considered unnecessary because the system has been performing as predicted.

As shown in Table 6.8, installation was started in mid-May and completed in mid-June. The wells will begin operation in August 1991. Details of the operation and performance of these wells and the existing wells will be presented in the 1991 Annual Review, which will be submitted at the end of December, 1991.

6.2.2 Zone 1 - Remedial Action Program

This section presents the technical basis for the design for the Zone 1 remedial action as originally presented in the RD (Canonie 1989d), as well as the conditions that exist as of July 1991, after approximately three years implementing the remedial action. Sections 6.2.2.1 through 6.2.2.6 incorporate much of the original text, tables, and figures provided in the RD. Section 6.2.2.7 discusses the system operation and performance using the information presented in the 1989 Annual Review (Canonie 1989c) and the 1990 Annual Review (Canonie 1990a). This section also includes a description of the revisions made to the Zone 1 pump-back well configuration in response to NRC and EPA comments on the two annual reviews (Canonie; 1989c, 1990a), including those implemented in June 1991 as part of United Nuclear's program for an ALARA demonstration in Zone 1.

As described in the RD, remedial action in Zone 1 consists of eliminating the source of seepage to Zone 1 by dewatering Borrow Pit No. 2, and continuing seepage extraction from the then existing east and north cross-dike pump-back wells. Their location is shown on Figure 6-1. The EPA's FS (EPA, 1988b) determined that the alternative of pumping Zone 1 "... does not provide a substantial reduction in contaminant concentrations... as compared to institutional controls and natural flushing" (page 8-24). This finding is in accordance with the remedial action for Zone 1 approved by the NRC and the EPA.

Additional seepage extraction in Zone 1 was considered to be impractical and unnecessary because of the low permeability of the formation. Also, after Borrow Pit No. 2 was dewatered, no additional recharge from the pit to Zone 1 was expected to take place, eliminating the need for pumping. Water level data collected in February 1989 from the alluvium adjacent to the pit indicated that pit dewatering should be permanent as discussed in Section 6.2.2.4. Water levels had declined below the bottom of the pit, so that inflow after dewatering was not anticipated.

Performance monitoring data, collected from when Borrow Pit No. 2 was dewatered in April 1989 until the present time, confirm the design considerations presented in the RD (Canonie 1989d). As anticipated, the seepage mound has been dissipating over time at the rates calculated based on the measured changes in Zone 1 water levels. Also, United Nuclear has continued to pump the Zone 1 wells as required by the NRC and EPA. As expected, the performance monitoring data indicate operating the wells has no effect on the rate of dissipation or the quality of the seepage mound. Therefore, United Nuclear has implemented a program, approved in NRC Amendment 12 to License Condition 30, of pumping and sampling to provide a demonstration that active seepage remediation is not feasible and that ALARA water quality criteria have been met.

6.2.2.1 Hydrogeology of Zone 1

The GHR (Canonie, 1987a) contains a detailed discussion of the hydrogeology of Zone 1 and was the basis for the design of the Zone 1 corrective action. A summary is presented here. The remedial action program focuses on the hydrogeologic conditions of Zone 1 in the area east of Borrow Pit No. 2, i.e., the identified target area and POCs shown on Figure 6-15.

Tailings seepage was introduced directly to Zone 1 in the target area through its subcrop in Borrow Pit No. 2. As discussed in the GHR, the subcrop in Borrow Pit No. 2 is the only location in the tailings disposal area where Zone 1 is in hydraulic contact with acidic tailings liquid. In the remaining areas, Zone 1 is separated from this liquid either geochemically by alluvium buffering the seepage, or hydraulically by Zone 2 which is impermeable.

Tailings liquid stored in Borrow Pit No. 2 seeped to the east in Zone 1. However, the low permeability of Zone 1 limited the extent of seepage migration. The permeability of Zone 1 is an order of magnitude lower than the permeability of Zone 3. Despite the steep gradient created by the 30 feet to 40 feet of water stored in Borrow Pit No. 2, which drove seepage into the subcrop of Zone 1, by 1986 the seepage had migrated only approximately 700 feet from the pit.

Also, fractures influence flow rates and direction in Zone 1 east of Borrow Pit No. 2. The GHR identified two fracture zones along the east side of the pit. These fractures provide a more permeable flow path for the liquids migrating from Borrow Pit No. 2. The water level contours presented in the GHR (Canonie, 1987a, Figure 3-3) are distorted near these fracture zones, causing flow directions to be directed to the east-southeast across the dip of the strata, rather than to the northeast and down the dip, as is the condition in the remaining saturated parts of Zone 1. The influence of the fracturing is also evident on the pH contour map of Zone 1 presented in the GHR (Canonie, 1987a, Figure 4-9), and also depicted on Figure 6-15 of this plan. The shape of the plume appears to follow the preferential flow path created by the fracturing.

6.2.2.2 Zone 1 Target Area Delineation

The Zone 1 target area was defined for the RD in 1989 based on the travel distance and rate of seepage flow from Borrow Pit No. 2, assuming that porous media flow conditions exist. The distance that tailings seepage could migrate to the east from Borrow Pit No. 2 was estimated 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 was based on the permeability of Zone 1 (1.0×10^{-4} cm/sec) (Canonie, 1987a, Table 2.3), the average gradient in Zone 3 to the east from Borrow Pit No. 2 (0.10) (Canonie, 1987a, Figure 3-3), and the porosity of a sandstone, such as Zone 1, of 0.10 (Freeze and Cherry, 1979, page 37). Considering that effective porosity may be 10 to 30 percent lower than the total porosity value of 0.10, the equation produces a velocity ranging from 115 feet/year to 148 feet/year. Since tailings liquids were first discharged to Borrow Pit No. 2 in 1980, these velocities translate into a plume travel distance of 690 feet to 890 feet for the 6-year period available for plume migration. Review of Figure 6-15 indicates that these calculated travel distances coincide with the

700 foot distance to the leading edge of the tailings seepage plume defined by acidic pH.

The travel distance calculations have been confirmed by performance monitoring data collected since 1989. The water level data indicate that the mound is dissipating at or below the rates anticipated given the hydraulic properties of the formation. Also, water quality data indicate that the downgradient boundary of the target area has migrated at a rate three times less than those discussed above.

The Zone 1 target area was also delineated by acidic seepage as presented in the GHR (Canonie, 1987a). Figure 6-15 presents the target area and POCs defined on this basis and represents a refinement of the target area presented by the EPA in its FS (EPA, 1988b). The EPA's target area was based on ARAR exceedances. However, as discussed in previous reports (Canonie, 1987a; Canonie, 1988a), acidic pH can be tied directly to the tailings seepage because of the lack of buffering capacity in Zone 1.

The smaller size of the refined target area in Zone 1, compared with the area delineated in Zone 3 is due to several factors. These factors include the operational history of Borrow Pit No. 2, the low permeability of Zone 1 and the limited area of Zone 1 exposed to tailings liquids. As stated in the GHR, acidic discharges to Borrow Pit No. 2 occurred only during the period from 1980 to about mid-1982. After mid-1982, all water was neutralized before discharge to the borrow pit so that by 1983, the pH of Borrow Pit No. 2 was neutral. Since only neutralized water was recharging Zone 1, the acidic water that had previously migrated into Zone 1 was apparently diluted and neutralized (Canonie, 1987a, page 35).

6.2.2.3 Zone 1 System Design

The remedial action program for Zone 1 is based on the program presented in Amendment I to the Reclamation Plan (Canonie, 1988b), submitted to the NRC in July 1988, and approved by the NRC in September 1988. The EPA has determined that Amendment I is "at least consistent with" the requirements contained in the ROD. The program consists of dewatering of Borrow Pit No. 2, and continued pumping from the existing pump-back wells until the pit is dewatered.

The low productivity of Zone 1 is the controlling factor that defines the remedial actions technically feasible for this formation. The low productivity of the formation was addressed in the GHR (Canonie, 1987a) and confirmed by the EPA in their FS when it states that ". . . the limited hydraulic conductivity of Zone 1 is prohibitive to pumping large quantities of water" (EPA, 1988b, page 8-3).

The east pump-back wells, pumping from Zone 1 before 1987 and adjacent to Borrow Pit No. 2, demonstrate the very low productivity of this formation. These 12 pump-back wells were pumping at a total rate of less than 5 gpm with the maximum rate of 0.7 gpm in Well 620 in 1986. The maximum total flow from all wells measured in the east system was 14 gpm in 1984 when the wells first operated.

The low-flow rates have been confirmed during continued operation of the Zone 1 pump-back wells since 1989. The operational performance of the wells was discussed in the 1989 and 1990 Annual Reviews (Canonie; 1989c, 1990a), and is discussed in Section 6.2.2.7 of this plan.

6.2.2.4 Dewatering Borrow Pit No. 2

The remedial action for Zone 1 consists of dewatering of Borrow Pit No. 2 in conjunction with continued seepage extraction from the seepage-extraction wells. Tailings seepage, collected from wells operated by United Nuclear before implementation of the CAP, stored in the pit was removed by the end of April 1989.

Dewatering Borrow Pit No. 2 served two purposes. First, the tailings liquid was removed and disposed of via evaporation. Second, the hydraulic head (i.e., height of the water in the pit above the Zone 1 subcrop), which was driving the seepage into Zone 1, was eliminated. As a result, the tailings seepage mound began to decline and the plume is dissipating naturally as the flow system in Zone 1 returns to the unsaturated conditions believed to exist before mining and milling operations.

Additional inflow to the pit from surrounding formations once the pit was dewatered was not expected and did not occur. Water level data collected in February 1989 from Wells B-3 and B-4 adjacent to the west side of Borrow Pit No. 2 (Figure 6-15) indicate the alluvium was unsaturated to a depth below the bottom of the pit (personal communication, United Nuclear Management 1989a).

As discussed in the 1989 Annual Review (Canonie, 1989c) Borrow Pit No. 2 was dewatered by the end of April 1989, approximately six months earlier than anticipated. Seepage into the pit from surrounding formations after dewatering was not observed. Also, water levels in the monitoring wells located adjacent to the pit began to decline in response to dewatering. A more detailed discussion of the system performance is presented in Section 6.2.2.7.

In the winter of 1990-1991, as provided for as a contingency in the plan, Borrow Pit No. 2 was utilized to temporarily store seepage from the extraction wells. The seepage