40-8907

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19 January 2004

Mark Purcell
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Subject: Transmittal of Report on Potential Tailings Cell Sourcing to Zone 3, Church Rock Site, Gallup, New Mexico

Mark:

We are sending the enclosed report for informational purposes. It contains the results of a study that UNC undertook last year to evaluate the likelihood that the tailings impoundment could still serve as a source of recharge to Zone 3. Though considered to be extremely unlikely, UNC wanted to make an unequivocal determination of this question before any revised remedy for Zone 3 is proposed. Also, it appears that the State of New Mexico subsequently brought up this question during the interview that you conducted for EPA's *Second Five-Year Review Report,* and so the report may be of special interest to the State.

The study involved a very detailed re-construction of the geology and hydrology of the tailings impoundment area using the best available information. UNC directed its consultant, U S Filter, to be very conservative. The result is a report which tends to support the premise that there is not an on-going source of recharge to Zone 3 from the tailings; however, it makes a few recommendations for follow-up work that should give the certainty that UNC is demanding. UNC would appreciate your review and agreement with the proposed recommendations.

As of September 1997, UNC became a wholly-owned, indirect subsidiary of the General Electric Company. GE Corporate Environmental Programs has been retained through a separate administrative services agreement to assist UNC

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both technically and administratively with environmental issues at the Church Rock site. Please contact me if you have any questions.

Sincerely,

Roy Blickwedel

Roy S. Blickwedel, P.G.
Remedial Project Manager

cc: Bill vonTill
Robin Brown
Dianna Malone
Larry Bush
Roger Florio

40-8907

USFilter

RATIONALE AND FIELD INVESTIGATION WORK PLAN TO EVALUATE RECHARGE AND POTENTIAL CELL SOURCING TO THE ZONE 3 PLUME CHURCH ROCK SITE, GALLUP, NEW MEXICO

GENERAL ELECTRIC - CORPORATE ENVIRONMENTAL PROGRAMS
KING OF PRUSSIA, PENNSYLVANIA

JANUARY 2004

VEOLIA
Environment

January 19, 2004
dll-524-6209-09

RATIONALE AND FIELD INVESTIGATION WORK PLAN TO EVALUATE RECHARGE AND POTENTIAL CELL SOURCING TO THE ZONE 3 PLUME CHURCH ROCK SITE, GALLUP, NEW MEXICO

Prepared for:

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USFilter Engineering and Construction
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Project No: d02-6209-09

January 2004

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1.0 INTRODUCTION

The Church Rock technical team met on April 30 and May 1, 2003 to discuss remediation alternatives for managing the groundwater plume in Zone 3 that is overall to the north and east of the North and Central Cells at the Church Rock site in Gallup, New Mexico. During that meeting and in subsequent discussions with GE, it was decided that the team needed a better understanding of the nature of any ongoing releases of constituents of concern into Zone 3 from the North and Central Cells in order to properly evaluate the remediation alternatives.

USFilter technical experts reviewed older technical information (in the project files we received from Earth Tech, Inc., in order to perform the Five-Year Review for the USEPA). Review of that information was used to focus and refine the conceptual model of fate and transport from the North and Central Cells to address questions of whether there may be ongoing sources of leachate, as well as the locations and potential significance of such sources, particularly as they may affect the Zone 3 hydrostratigraphic unit. The refined conceptual model was used to develop a plan for field work to verify the conceptual model. This report presents the refined conceptual model and a Zone 3 field investigation work plan.

The scope of this study did not include an evaluation of the design and construction of the tailings deposits and their cover system. Therefore, this report does not draw conclusions regarding the likelihood, or lack thereof, of surface water migrating through engineered barriers. Instead, the conceptual model uses the subsurface geometric relationships of Zone 3 and the tailings deposits to identify those areas more likely to be ongoing sources, *if* groundwater were present and capable of migration. The types of groundwater considered include residual pore water and groundwater potentially recharged from surface water.

Our original proposal work scope included the following:

- Inventory and evaluate older technical information
- Rerun the HELP model based on the older technical information
- Develop the most probable conceptual model for groundwater flow and constituent migration, with a few alternative model features to be tested via a pending field investigation, and
- Develop a scope of work to verify the conceptual model

In addition, the proposal suggested that the work plan would likely include new monitoring well or piezometer installation, water quality sampling, water level monitoring, and the application of one or more surface geophysical methods.

As the conceptual model was developed it became apparent that a rerun of the HELP model would provide limited benefit. This judgment was reached through an increased appreciation of controlling factors (e.g. the continuity and thickness of native clay deposits beneath the tailings) that would be difficult to adequately quantify or model with a 1-dimensional percolation simulator, such as HELP. Instead, it was recognized that a limited program of field investigation could more directly, and more appropriately, address the question of whether there are extant sources affecting Zone 3.

2.0 CONCEPTUAL MODEL

The geometry of the Church Rock tailings cells and substrate materials have been reconstructed from map, geophysical survey, and boring log data. These reconstructions are the central element of a conceptual model of the tailings cells that includes qualitative evaluation of their potential to generate leachate capable of entering surrounding geologic materials. The reconstructions were necessary because as-built diagrams of the bottoms of the tailings cells are not available. However, boring logs and topographic maps that were made before, during, and after the construction of the cells make it possible to estimate the configuration of the cells and the spatial relationships of tailings deposits with native subsurface formations, including the Zone 3 sandstone.

2.1 Data Sources

Over the past 20 years, various contractors have issued reports regarding the nature and geometry of the tailings deposits and the geologic materials with which they are in contact. Two of the more comprehensive studies were prepared by Bechtel National, Inc. (December 1984, *Church Rock Uranium Mill, Tailings Ponds, Conceptual Seepage Abatement Plans*) and Canonie Environmental (May 1987, *Reclamation Engineering Studies, Geohydrologic Report*). Much of the data used by these investigators was also employed to prepare the present conceptual model. Furthermore, the syntheses of information made by these investigations, particularly those of Canonie, were reviewed and adopted where appropriate. However, the present conceptual model also incorporates significant modifications of the tailings cells made during their interim and final reclamation, which occurred after these earlier studies.

Many borings and wells were drilled in the area of the tailings cells during the time of their planning and early phases of construction and use. For example, Sergent, Hauskins & Beckwith (S, H & B, October 1974, May 1976, July 1976, July 1978, October 1978, July 1979) reported geologic logs for 215 borings and wells made between 1974 and 1979 throughout the area of the cells. The locations of all of these borings are shown in Figure 1 on a 1978 topographic map with a construction plan of the area of the tailings deposits. Each of these logs was reviewed and incorporated into estimates made of the elevations of the contact between the alluvium and underlying rock formations. Geologic logs of 332 additional wells made in areas surrounding and between the cells were also incorporated in this analysis, as were the results of a 1976 seismic refraction survey that transected the length of the tailings deposit area (Figure 1). These data, and topographic maps made during the same period, allowed estimation of the topography of the base of the tailings cells. Most of these logs, and those of approximately 40 additional wells unavailable to this investigation, were taken into account by Canonie (May 1987) in their interpretation of the distribution of geologic formations in map view and in several cross sections. For this reason, Canonie's interpretations of the configuration of geologic materials beneath the tailings have been adopted in USFilter's study (rather than reconstructed from a subset of the same basic data). Instead, our study has focused on physical changes resulting from post-1987 reclamation of the cells and on the development of isopach maps for the tailings, cover materials, and the natural local unconsolidated materials (referred to collectively as alluvium by past investigators and in this report) that typically lay between the tailings and the underlying rock formations.

Topographic maps and several aerial photographs shown in Figures 1 through 6 illustrate stages from pre-development to final reclamation of the tailings cells. These data, supplemented by the logs of 15 borings that penetrated the tailings deposits, were used to reconstruct the base of the tailings deposits.

2.2 Estimates of the Distribution of Tailings and Underlying Geologic Materials

The reconstructions presented here divide the materials in and beneath the tailings cells into three categories: capping materials and tailings, alluvium, and rock formations. The order of this list of materials also describes the order in which they have typically been encountered in borings. The rock formations underlie the alluvium and the alluvium typically, but not everywhere, lies between the rock and the tailings deposits. The rock formation of particular interest to this study is the Zone 3 sandstone, which is a locally defined submember of the Upper Gallup Sandstone. Zone 3 has experienced more widespread distribution of tailings-affected groundwater than the other submembers (Zone 1 and Zone 2). Therefore, Zone 3 is expected to be the object of future mitigation measures and it is a focus of interest in the question of whether the tailings cells may continue to be a source of affected groundwater.

Figure 7 is a geologic map (reproduced from Canonie, May 1987, figure 2-3) that shows the distribution of various rock formations and the extent of the alluvium in the vicinity of the tailings cells. Most of the subsurface area of the tailings cells was originally (and probably remains) underlain by alluvium. Zone 3 and Zone 1 sandstones (labeled Z3 subcrop and Z1 subcrop in Figure 8) underlie the alluvium beneath most of the tailings deposit area. The Zone 1 subcrop occurs in two lobes; the larger lobe parallels the Pipeline Arroyo and straddles the long axis of the tailings pond dam. The other lobe extends east beneath the Central Tailings Cell. Zone 2, an aquitard, occupies a narrow band separating the areas of Zone 1 and Zone 3 subcrop. Cross section lines shown on Figure 7 refer to figures presented by Canonie (May 1987), but not reproduced in this report.

It should be noted that the definition of Zone 3 depicted in Figure 7 follows that of Canonie (May, 1987), which differs from that of previous workers. An explanation and rationale for this difference was given by Canonie:

> "Previous site investigators incorporated the uppermost part of Zone 3, also called the Torrivo Sandstone member, as part of the Dilco (SAI and Bearpaw, 1980). However, recent review of drilling and geophysical logging, as well as field investigations at the site, have indicated that the Torrivo Sandstone cannot be distinguished from the underlying Zone 3 of the Upper Gallup Sandstone. Moreover, these two sandstones are in hydraulic communication. Therefore, the Torrivo Member is considered to be part of Zone 3."

The differing definitions of Zone 3 are sufficient to affect considerations of which parts of the tailings deposits may overly or contact Zone 3. For example, SAI and Bearpaw (1980) stated this: "In the Central Cell and Borrow Pit areas the Dilco occurs on the flanks of the pits and is thought to underlie the eastern two thirds of the North Pond." We adopted the more recent definition of Zone 3 depicted in Figure 7, because of the reasons cited by Canonie and because the Dilco (exclusive of the Torrivo Sandstone member) is considered to be an aquitard, unlike Zone 3.

Figure 8 is a contour (isopach) map of the thickness of alluvium beneath the tailings cells. This Figure, like those that follow showing isopachs of the tailings deposits, employs a post-reclamation (circa 1997) aerial photographic base having geologic contacts traced from Figure 7. The thickness of alluvium is the calculated difference of two estimated surfaces: the top of rock (Figure 9) and the base of tailings (Figure 10). The top-of-rock surface was estimated from boring logs and a seismic refraction survey, the locations of which are shown in Figure 1. The base-of-tailings surface was also estimated from boring logs, but is primarily based on topographic maps from several stages in the development of the tailings deposits. Uncertainty in this reconstruction arises from the lack of definitive as-built maps of various excavations made to accommodate the tailings deposits. Therefore, the estimates of alluvium thicknesses made by this study are probably maximum values, because the available topographic maps may not have captured the full extent of excavation. For the same reason, estimates of the thickness of tailings are minimum values.

Figure 8 illustrates that the alluvium is thicker (as much as 110 feet) along the western margin of the tailings deposits. It thins to near zero thickness at the eastern margins of the North and South Cells and around the margins of a topographic divide between the North and Central Cells. The alluvium is also thick under most of a former erosional depression that underlies the Central Cell and is coincident with the Zone 1 subcrop beneath the Central cell (see Figure 9 for top-of-rock surface). However, in the eastern portion of the Central Cell much of the alluvium was removed prior to the placement of the tailings. The alluvium was partially to completely removed in the excavation of Borrow Pits 1 and 2 (see Figure 3 for location). This is significant, because it is interpreted that in these pits tailings and tailings leachate came into direct contact with the Zone 1 and Zone 3 sandstones.

Tailings thicknesses were estimated for two time periods: prior to interim reclamation in 1985 and following final reclamation in 1997. These isopach maps are shown in Figures 11 and 12. These estimates are based on the difference between the estimated base-of-tailings surface (Figure 10) and the ground surface topography in 1985 (Figure 3) and 1997 (Figure 5). In the latter case, the thickness also includes cover materials placed on the cells during reclamation.

The most prominent difference between the tailings isopach maps is the 15 to 55 feet of tailings introduced into Borrow Pit 2 by 1997. The thickness of tailings in former Borrow Pit 1 is based on limited information and may be underrepresented in Figure 12. The

1997 map (Figure 12) also illustrates a typically greater thickness of tailings and fill materials relative to the 1985 map (Figure 11), particularly in the eastern portion of the cells. Both maps show significantly thinner tailings deposits in the North Cell relative to the Central and South Cells.

2.3 Textural and Hydraulic Characteristics of the Tailings and the Alluvium

Our review of the S, H & B boring logs indicates that the tailings, where they have been penetrated by borings, have almost invariably been logged as loose sands or silty sands of typically fine or fine to medium grain size. Tailings logged as clay are rare and thin where found. In contrast, more than half of the native soils have been logged as clay and the sands are rarely clean (typically logged as clayey sand or silty, clayey sand). Gravels are very rare and appear only as an accessory where they are logged.

Logged observations of ubiquitous clay layers separating sand layers lead to the conclusion that the alluvium in most locations may be significantly more resistant to vertical as opposed to horizontal flow of groundwater. Canonie (1987) reports "representative" hydraulic conductivities of 1 x 10^{-2} cm/sec in the alluvium, 5 x 10^{-3} cm/sec in Zone 3, and 1 x 10^{-4} cm/sec in Zone 1. The nature of the pumping tests makes these estimates representative of horizontal rather than vertical hydraulic conductivities. These estimates were based on tabulated results (in Canonie, 1987) of six to eight tests in each hydrostratigraphic unit made by Billings & Associates, Inc. (1982; 1983; 1985). Geometric averages calculated from tabulated conductivity estimates are significantly lower in the alluvium and in Zone 3 than the "representative" values cited by Canonie: 2 x 10^{-3} cm/sec in the alluvium, and 6 x 10^{-4} cm/sec in Zone 3. An examination of more than 200 logs of the alluvium lead us to suspect that the geometric average of alluvium hydraulic conductivities may be closer to what is typical than the significantly higher "representative" value cited by Canonie. In support of this inference, we note that S, H & B reported an average hydraulic conductivity of the alluvium of 2.7 x 10^{-5} cm/sec, based on 27 borehole tests (May, 1976, *Geotechnical Investigation Report, United Nuclear Corporation Tailings Dam and Pond*). We further suspect, as did S, H & B, that the aggregate vertical hydraulic conductivity of the stratified alluvium is typically even lower.

It is concluded from this evaluation that the tailings are probably more permeable to vertical seepage than the alluvium. This conclusion echoes a prediction made by S, H & B (May, 1976) that, "...the tailings will be considerably more pervious than the underlying alluvium." This prediction was based on their testing of the alluvium and of a representative sample of the tailings, which resulted in a hydraulic conductivity estimate of 2.3 x 10^{-3} cm/sec for the tailings sediments. Their additional conclusion, that no potential exists for affecting present or potential producing aquifers by vertical or lateral seepage through the bedrock was, unfortunately, only accurate in the sense that the affected bedrock should not be construed as a "producing aquifer."

Although in situ testing of the hydraulic conductivity of the tailings does not appear to have been done, there are field data that illustrate the tendency of the alluvium to impede vertical seepage and perch groundwater in the tailings. This illustration comes from eight borings made at the northeast and southwest margins of the North Pond (later the North Cell) in 1979. The borings penetrated tailings into Zone 3 sandstone or into native sands that appear to have been in communication with Zone 3 sandstone. In two borings at the southwest margin of the pond, water levels are reported to have dropped from 10 feet depth (similar to the pond surface) to 30 and 35 feet depth within 2 hours. This is indicative of perched water in the tailings draining via the boring into a much lower water table in the Zone 3 sandstone. The logs for the five borings made at the northeast margin of the pond do not indicate a similar water level drop during drilling. However, the reported water levels in the borings are about 20 feet below the elevation of the reported pond water level. This indicates that by the time water levels were measured in the borings, which were open to Zone 3, they had dropped well below the head that probably existed in the tailings at that time.

These are only a few borings, made at the margins of the North Cell 24 years ago, so it is risky to generalize. However, water levels in the alluvium have dropped significantly since 1979, when these borings were made. For example, measured water levels in alluvial well 509D, located near the western part of the boundary between the North and Central Cells, have dropped 37 feet between July 1989 and October 2002. Water levels in well EPA 23, located near the Pipeline Arroyo adjacent to the South Cell, experienced a water level decline of 19.5 feet over the same time. By October 2002, water levels in the alluvium ranged from 40 to 70 feet below the estimated base of the tailings (see Figure 10 for this comparison). In other words, there is a significant thickness of unsaturated alluvium beneath the west side of the tailings deposits. This concept, taken with the likelihood that the tailings are more freely draining than the alluvium, suggests that significant drainage from the tailings into the alluvium had ceased well before October 2002.

Figure 13 summarizes the extents of the former ponds and borrow pits, the location of surface water drainages, and potential areas of groundwater recharge that could conceivably contact tailings and enter Zone 3. Based on this figure and the discussion presented above, the question of whether the tailings may represent an ongoing source of affected water to Zone 3 should be focused on the east side of the tailings deposits, where groundwater recharge could hypothetically occur where there is no tailings cover system to prevent infiltration. On the east side of the deposits the alluvium is generally thinner or absent where it has been removed by excavation. The data indicate that the principal areas where alluvium was replaced by significant thicknesses of tailings were Borrow Pits 1 and 2 on the east side of the Central Cell. The ramifications of this key historic conclusion for potential field investigations are discussed in the following section.

3.0 DISCUSSION OF RESULTS RELATIVE TO FUTURE FIELD INVESTIGATIONS

The results of this investigation indicate that areas having the potential of being future sources of leachate-affected groundwater are located on the east margin of the Central Cell, where Borrow Pits one and two were formerly located, and northeast of the North Cell. These areas are illustrated in Figure 13.

Of the two areas, the one northeast of the North Cell seems less likely to be an ongoing source of leachate generation. There are several reasons for this judgment. The area of potential groundwater recharge is 500 feet or more to the north of the northern extent of tailings in the North Cell. Also, this area is underlain by 30 to 40 feet of alluvium *below* the estimated elevation of the base of the tailings in the North Cell. Therefore, recharge in this area would not be expected to contact the tailings unless there was at least 40 feet of mounding of the groundwater table that extended 500 feet to the south of the area of recharge. There aren't available groundwater level measurements in the alluvium north of the North Cell. However, piezometric heads in Zone 3 directly beneath this area are 60 feet or more below the estimated elevation of the base of the tailings. Furthermore, the distribution of piezometric heads in Zone 3 indicates a flow direction to the north, not to the south. The top-of-rock surface, which might be expected to influence groundwater flow in the overlying alluvium, is inclined to the west-northwest (Figure 9) – not to the south.

The only potential areas of groundwater recharge (which might also contact tailings) that lie to the south are those around the margins of the eastern half of the Central Cell, where Borrow Pits 1 and 2 were formerly located, and to the south of the South Cell. The area to the south of the South Cell is probably too far removed from the known limits of contamination in Zone 3 to merit further field investigation. This may not be true of the potential recharge areas bordering the former borrow pits (Figure 13). The linear dark blue recharge areas shown in Figure 13, along the eastern perimeter of the site correspond with manmade surface channels for diversion of potential runon from the uplands to the covered cells. The northern portion of the channel slopes to the north, the southern portion slopes to the south.

The former borrow pits straddled an erosional "cut-out" that penetrated through Zones 3 and 2 into Zone 1. The borrow pits also contain relatively thick deposits of tailings. As a result of this geometry, groundwater, if it could recharge Zone 3 to the south and east of the former borrow pits, might migrate north and, if so, contact tailings. Tailings leachate might thence enter Zone 1 or reenter Zone 3 to the north of the former borrow pits. Borrow Pit 1 seems to have the greater potential to be an ongoing source of residual tailings leachate, because the tailings in it were placed "wet" and the native soil "floor" beneath the tailings slopes upward from Borrow Pit 1 toward the adjacent tailings deposits in the Central Cell. The place to investigate this potential may be to the north and northeast of the former borrow pits in the Central Cell. This can be done by constructing one or two monitoring wells screened in Zone 3 sandstone to the north of the former borrow pits. If the wells are dry then the question of whether there is an ongoing source will be resolved in the negative. If there remains measurable saturation in Zone 3 it will be proximal to the upgradient margin of the Zone 3 “cut-out” and the leachate source (the tailings in either former Borrow Pit 1 or Borrow Pit 2), if one exists. Therefore, a pumping test designed to dewater the monitoring well(s) would be an indirect measure of whether groundwater recharge is being sourced from the tailings. If, after being pumped down, the water levels in these wells do not fully recover and remain depressed, this will be an indication that there is not a significant source of recharge to the south of these wells (i.e., from the tailings).

Although this investigation has concluded that the North Cell is unlikely to be an ongoing source of leachate, there are several relatively simple measures that would tend to support or contradict this conclusion. Figure 3-5 from the 2002 annual report (Earth Tech, December 2002) illustrates the October 2002 piezometric surface contour map for Zone 3. It shows a cluster of Zone 3 wells near the northeast corner of the North Cell. The map was based on data from a small subset of these wells. As such it would be prudent to obtain water levels from as many of these wells as possible to better define the hydraulic gradients in this area of Zone 3. As it is presently drawn, the flux arrows labeled on this figure as "alluvial recharge" and "tailings seepage" are internally inconsistent. Based on the well water levels and the head contours shown, a south to north groundwater flux is indicated. The arrows shown on the map locally indicate fluxes from due west and seepage from the southwest. Those are the directions from which one would find the North Cell and the arroyo, but those are not the directions the hydraulic gradient indicates the flux should be coming from. A more complete set of water level measurements may better define the local hydraulics in this critical subarea. If the results of these measurements do not clarify this issue, it would be prudent to install a well screened in the base of Zone 3 located further west on the north margin of the North Cell cap. If the Canonie geologic map (Figure 7) is correct, the well should not be located more than a couple of hundred feet west of well 106D. Farther to the west, Zone 3 would be missing.

In summary, this analysis suggests two conceivable sources of groundwater recharge to Zone 3. One is the segment of diversion channel over Zone 3 subcrop bordering the borrow pits in the Central Cell. This is the potential source to the south and should be evidenced by a south to north gradient as shown on figure 3-5 from the 2002 Annual Report. This potential source of groundwater recharge is also a potential ongoing source of tailings leachate. The other source (of recharge, but probably not leachate) is the portion of the diversion channel north of the North Cell, where it also overlies Zone 3 subcrop (see Figure 14 for location). This would be evidenced by a groundwater mound centered on this segment of the diversion channel. If flux arrows shown on Earth Tech's (December 2002) figure 3-5 are correct, we should see an unambiguous west to east gradient to the north of the North Cell.

4.0 CONCLUSIONS

1) Zone 3 rock subcrop underlies nearly all of the North Cell and about half of the Central and South cells. Much of the remaining areas are underlain by Zone 1 subcrop.
2) With few exceptions, the tailings are separated from the rock subcrop by alluvium that contains significant (typically greater than 50%) sequences of clay which are interpreted to be an impediment to vertical drainage.
3) The thickness of alluvium between the tailings and the rock ranges from about 100 feet on the west side to zero feet on the east side and at the margins of two "spits" of elevated rock that separate the North Cell from the Central Cell and the Central Cell from the South Cell.
4) The thickness of alluvium was reduced to zero feet (by excavation) beneath Borrow Pit 2 and possibly to only a few feet beneath Borrow Pit 1 (definitive data are lacking regarding pit 1).
5) The thickness of tailings deposits is 25 to 40 feet on the west side of the South and Central Cells. The thickness decreases to 0 feet on the east side of the South Cell and to about 10 feet in the middle of the Central Cell. Up to 50 feet of tailings were deposited in Borrow Pits 2 and (with less certainty) 1 in the eastern portion of the Central Cell. Tailings thicknesses of 5 to 15 feet occur in the North Cell.
6) Borrow Pit 2 was used for the storage of mostly liquids, particularly in the late 1980s when water pumped from Zone 1 was stored there. It was drained in 1989, after which the placement of relatively dry wind blown tailings, building debris, and affected soils began. Until it was drained, pit 2 was an acknowledged source of inflow to Zone 1 and very likely also a source of inflow to Zone 3. The pit was completely filled and "reclaimed" by 1994. In other words, much of the fill in Borrow Pit 2 was probably fairly dry when placed. The same was probably not true of Borrow Pit 1, which received wet tailings and was an area of problematic consolidation during interim reclamation (1990-1991).
7) Areas of direct or nearly direct contact between tailings and Zone 3 rocks include the northeast and south margins of the North Cell (though tailings are only 5-10 feet thick there) and at the margins of the eastern extension of the Central Cell (where the alluvium thins significantly). Borrow Pits 1 and 2, in particular, are areas where significant thicknesses of tailings are present and probably in contact with Zone 3 where it subcrops along the north and south margins of both pits and the east margin of pit 2.
8) It is concluded (from very general descriptions) that the materials placed in Borrow Pit 2 after 1989 probably did not have high water contents and were not a likely source of direct recharge to Zone 3. This may not be true of the materials placed in Borrow Pit 1.

9) The drainage diversion channel along the east side of the tailings cells is over Zone 3 subcrop along much of its length. It also traverses areas where the alluvium is thin (particularly to the south of the Central Cell). This raises the possibility of groundwater recharge from the diversion channel into Zone 3. If it occurs, this recharge may encounter tailings in the borrow pits before moving through thin to no alluvium and into Zone 3.

10) The portion of the diversion channel near the northeast corner of the North Cell is a source of groundwater recharge to Zone 3. However, this investigation concludes that this area, and the North Cell generally, is unlikely to be an ongoing source of tailings affected groundwater (leachate).

11) In order accomplish effective long-term mitigation of the Zone 3 contaminant plume, it is important to determine: (a) whether groundwater recharge continues to cause flux through the covered cells; and (b) whether such flux is transporting tailings-impacted water (primarily or exclusively leachate) downgradient such that the Zone 3 plume continues to be sourced headward.

5.0 RECOMMENDATIONS

1) Install two new monitoring wells in the area shown in Figure 14 (just north of the former Borrow Pits 1 and 2 in the eastern half of the Central Cell). These two wells should be screened into the base of Zone 3.

   The presence of groundwater in these wells would indicate that recharge is occurring along either the adjacent diversion trench, the diversion trench segment along the southern perimeter of the Central Cell, or both.

   The quality of any water in these wells will indicate whether the eastern part of the Central Cell (areas of Borrow Pits 1 and 2) continues to source tailings-impacted groundwater.

   The groundwater elevations in these wells may aid understanding of the downgradient configuration of the Zone 3 piezometric field, including the relatively high, persistent head level at well EPA 9.

   If these new wells contain groundwater, then after the above information has been acquired these wells can be pumped dry (causing local dewatering of the Zone 3 aquifer). If, after being pumped down, the water levels in these wells do not fully recover and remain depressed, this will be an indication that there is not a significant source of recharge to the south of these wells (i.e., from the tailings).

2) Acquire groundwater elevation measurements in all of the Zone 3 wells shown in Figure 14. These wells are to the northeast of the northeast corner of the North Cell. This will allow better definition of the directions of the hydraulic gradient in this critical subarea, which should bolster the present conclusion that the North Cell is unlikely to be an ongoing source of affected groundwater.

   This subarea is located near the northern limit of the surface diversion trench (which ponds after heavy runoff events). The trench may be acting as a local source of groundwater recharge; however, it is unlikely that this groundwater fluxes through the North Cell tailings located to the south. Comprehensive well water-level measurements should show whether there is groundwater mounding beneath the diversion trench, and whether there is an easterly component to the groundwater flux (the latter has been suggested in recent technical reports concerning Zone 3).

   If the results of the comprehensive well water-level measurements are not definitive, then a new monitoring well should be installed approximately 250 feet to the west of existing well 106 D. This new well should be screened into the base of Zone 3. Head levels from this new well, in conjunction with the comprehensive set of head levels, should show whether there is locally an eastward direction to groundwater flow – or if the groundwater in this critical subarea is flowing northward, as suggested by recent potentiometric mapping.

6.0 REFERENCES

Bechtel, December 1984, Church Rock Uranium Mill, Tailings Ponds Conceptual Seepage Abatement Plans, United Nuclear Corporation, Church Rock, New Mexico.

Canonie Environmental, May 1987, Geohydrologic Report, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, April 1989, Seepage Travel Distance/Time Calculation – Amendment II, project file, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, January 1990, As-Built Report, North Cell Interim Stabilization, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, April 1992, As-Built Report, South Cell Interim Stabilization, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, April 1992, As-Built Report, Central Cell Interim Stabilization, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, June 1995, As-Built Report, Central Cell Final Reclamation, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Fletcher, J., October 11, 1985, Water Balance – NECR Tailings, Internal UNC Mining and Milling memo to C. Johnson.

Sergent, Hauskins & Beckwith, October 1974, Preliminary Geotechnical Investigation Report, Tailings Dam, Church Rock Uranium Mill, United Nuclear Corporation, Church Rock, New Mexico. (amended by frontice piece letter in January 1975)

Sergent, Hauskins & Beckwith, May 1976, Geotechnical Investigation Report, Tailings Dam and Ponds, Church Rock Uranium Mill, United Nuclear Corporation, Church Rock, New Mexico.

Sergent, Hauskins & Beckwith, July 1976, Seismic Refraction Investigations Report, Tailings Dam and Ponds, Church Rock Uranium Mill, United Nuclear Corporation, Church Rock, New Mexico.

Sergent, Hauskins & Beckwith, July 1978, Geotechnical and Design Development Investigation Report, Tailings Dam and Ponds, Church Rock Uranium Mill, United Nuclear Corporation, Church Rock, New Mexico.

Sergent, Hauskins & Beckwith, October 1978, Engineering Analysis Report, Tailings Disposal Systems Analysis, Church Rock Uranium Mill, United Nuclear Corporation, Church Rock, New Mexico.

Sergent, Hauskins & Beckwith, July 1979, Geotechnical Investigation Report, Stability and Integrity Assessment, Church Rock Uranium Mill, United Nuclear Corporation, Church Rock, New Mexico, Volume 1.

The following references were examined for the investigation, but not referenced in the report

Canonie Environmental, October 1985, Phase I Field Study, Remedial Investigation/Feasibility Study, Technical Memorandum, United Nuclear, Church Rock, New Mexico.

Canonie Environmental, April 1987, Reclamation Plan, Engineering Concepts, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, January 1988,Remedial Investigation, vol. 1, United Nuclear, Church Rock, New Mexico.

Canonie Environmental, July 1988, Reclamation Plan License No. SUA-1475, Amendment 1, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Canonie Environmental, December 1990, Response to Comments and Proposed Reclamation Plan Modifications, Vol. 1 – Text, Tables, and Figures, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Penick, Michael, May 1986, Southwest Alluvial: Resistivity Study, United Nuclear Corporation, Mining and Milling Division, Albuquerque, New Mexico.

Science Applications, Inc. and Bearpaw Geosciences, July 1980, Geology of the Church Rock Area, New Mexico, UNC Mining and Milling Division, Albuquerque, New Mexico.

Science Applications, Inc., November 1981, Status Report – Geology of the United Nuclear Corporation's N.E. Church Rock Tailings Area, United Nuclear Corporation, Mining and Milling Division, Albuquerque, New Mexico.

Smith Environmental Technologies Corporation, April 1996, As-Built Report, South Cell Final Reclamation, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Smith Environmental Technologies Corporation, March 1997, Draft As-Built Report, 1996 Final Reclamation Construction, Church Rock Site, UNC Mining and Milling, Gallup, New Mexico.

Western Technologies, Inc., December 1991, 1991 Reclamation Testing, United Nuclear Corporation, Church Rock, New Mexico.

ADDENDUM

After the preparation of the first draft of this workplan, additional relevant information was discovered in a project calculation file (Canonie, April 1989) and an internal UNC Mining and Milling memorandum (Fletcher, October 1985). This information is in the form of two map figures from Canonie (April 1989), which have been reproduced as Figures 15 and 16 of this report. The figures are reduced from their original scale and annotated for clarity. The information from the UNC memorandum describes the tailings handling process and the nature of the tailings deposited in the Central Cell, Borrow Pit 1 and Borrow Pit 2.

The following description is quoted from the UNC memorandum (Fletcher, October 1985):

> When the tailings slurry consisting of sands, slimes and liquid comes from the mill to the tailings area, it is deposited in the Central Pond either by spigotting or by cycloning. The cyclone method separates the tailings into two different portions, one consisting of largely coarse sands, called cyclone underflow, and the other consisting of fine sands, slimes (particles which are finer than sands) and tailings liquids. The whole tailings (sands, slimes, and liquids) are deposited without separation when the spigotting method is used. The methods are used intermittently
>
> During cycloning, the cyclone underflow (coarse sands) is deposited in the East Cell of the Central Pond area, where it remains. The overflow (fine sands, slimes, and liquid) is deposited in the West Cell of the Central Pond. The sands drop out of the overflow and largely remain in the western area of the Central Pond. The liquids, which are carrying the slimes and some fine sands, begin a gravity flow from west to east towards the borrow pits. Two trenches have been excavated to facilitate the flow through the central area. When the flow arrives in Borrow Pit No. 1, the slimes settle out and most of the liquid is pumped to Borrow Pit No. 2. Consequently, the central area contains sands, Borrow Pit No. 1 contains slimes, and Borrow Pit No. 2 mostly contains liquids.

The memorandum also states that, between 1980 and 1985, the Borrow Pit 1 had been almost entirely filled by slimes and fine overflow sands to a depth of approximately 20 feet, except for a two foot pond at it's eastern side. The memorandum concludes that much of this filling had occurred by January 1981, on the basis of aerial photography.

The significance of this information to the present study is that Borrow Pit 1 contains a significantly greater proportion of fine-grained tailings than other areas of the tailings deposits. Therefore, Borrow Pit 1 might be expected to have had a greater potential to retain pore fluids in it's approximately 20 feet of accumulated slimes than other most other areas. This includes Borrow Pit 2, which received primarily liquids, until it was drained and backfilled with local soil fill, mill building debris, and wind-blown tailings of relatively low moisture content. This newly reviewed information source also indicates that the thickness of tailings shown within the footprint of Borrow Pit 1 in Figures 11 and 12 is underestimated by about 20 feet. This underestimate resulted from the unavailability of a map showing Borrow Pit 1 fully excavated.

Taken as a whole, this information suggests that the former Borrow Pit 1 is an appropriate candidate site to investigate regarding the possibility that any portion of the tailings deposits might remain a source to Zone 3 of residual tailings-affected pore water.

Figure 15 shows contours of pH in Zone 3 groundwater based on sample data collected in 1989. The extent of the tailings affected groundwater plume, as interpreted by Canonie in 1989, is indicated by shading. The figure illustrates two points germane to conclusions drawn in this report on the bases of other data. The first point is that the Central Cell, and the former borrow pits in particular, were in hydraulic communication with Zone 3. The second point is our interpretation of the data shown in Figure 15: the plume in Zone 3 extended to the borrow pits and was probably sourced from those pits (as well as from the North Pond). Therefore, if there is residual pore fluid or recharged groundwater in contact with tailings in the former borrow pits it would be possible for the fluid to enter Zone 3.

We believe that the additional information tends to support conclusions reached in the report, which were based on other data. Therefore, our recommendations regarding field work have not changed.

Figure 16 shows a Zone 3 piezometric surface map based on 1987 measurements. It is a much broader aereal representation than more recent maps, encompassing the tailings area in addition to areas southwest and northeast of the tailings. The map shows an area of saturation that extends as far to the southwest of the Central Cell as it does to the northeast. A groundwater mound (in Zone 3) depicted beneath the tailings ponds is shown with its highest point beneath the former borrow pits. The depiction is interpretive in many areas. However, the depiction of a groundwater mound in Zone 3 in the vicinity of the borrow pits is supported by well water levels. This further supports the conclusion that the borrow pits were an important contributor of tailings-affected water to Zone 3. If the piezometric surface shown in Figure 16 is accurate, a wholly northeast gradient would have established only after the mound, and the southwestward hydraulic gradient it induced, had dissipated. Only then would the saturated portions of Zone 3 to the southwest have begun to drain to the north under the influence of the gentle dip of Zone 3.

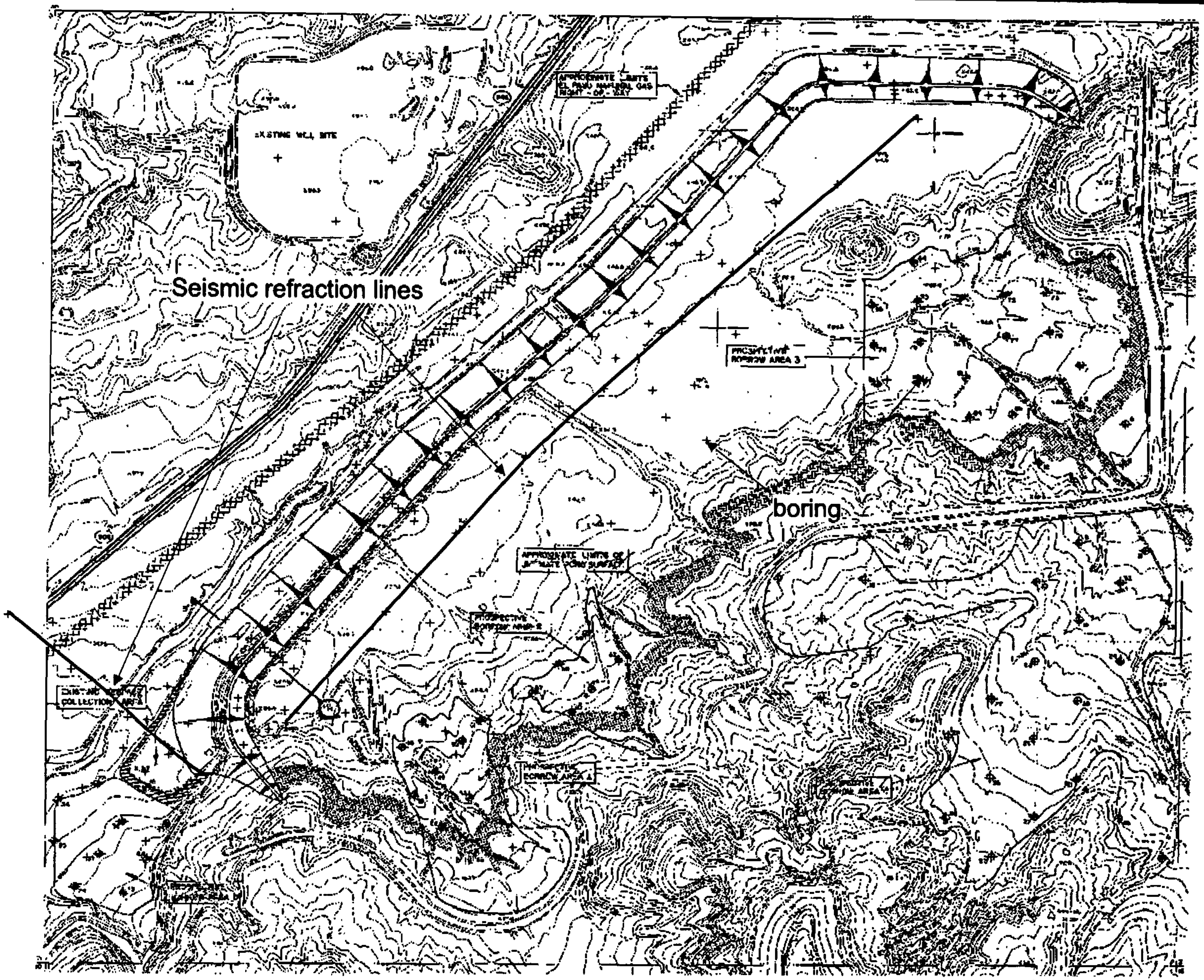

FIGURE 1
May 1978 Topographic map showing planned modification of the "starter" dam, 1974-1979 borings, and 1976 seismic refraction survey used to estimate top-of-rock and base-of-tailings elevations (topographic base reproduced from Sergent, Hauskins & Beckwith, October 1978; seismic refraction lines from Sergent, Hauskins & Beckwith, July 1976)

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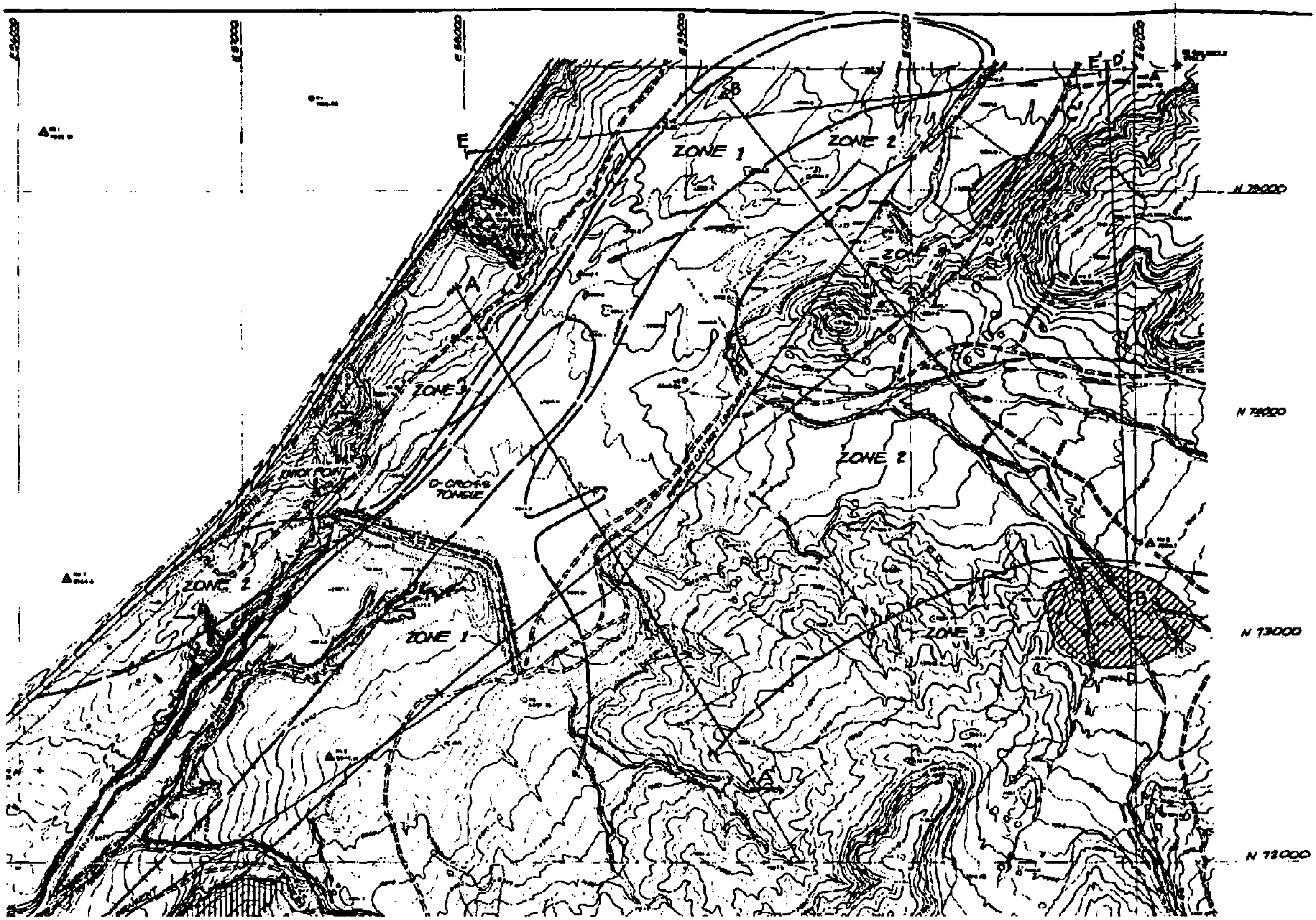

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FIGURE 2
Pre-tailings deposit (pre-1977) topographic map showing geologic interpretation
(reproduced from Bechtel, December 1984)

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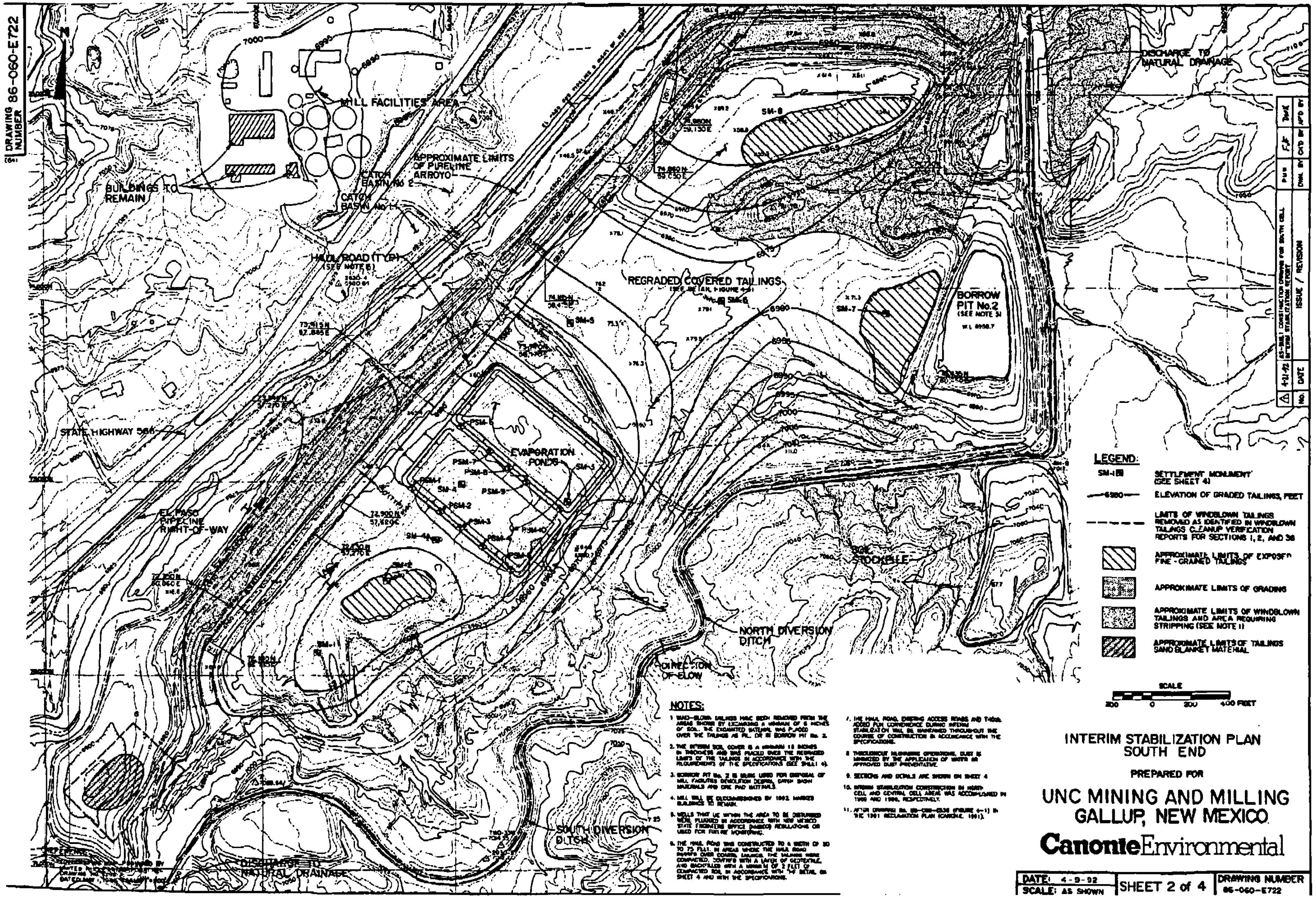
C01

FIGURE 3
Topography and geology (after Canonie, May 1987) on circa 1983 aerial photograph of tailings ponds
(5-foot contour interval)



NOTES:

1. WIND-BLOWN TAILINGS HAVE BEEN REMOVED FROM THE AREAS SHOWN BY EXCAVATING A MINIMUM OF 6 INCHES OF SOIL. THE EXCAVATED MATERIAL WAS PLACED OVER THE TAILINGS AS FILL OR IN BORROW PIT No. 2.
2. THE INTERIM SOIL COVER IS A MINIMUM 18 INCHES IN THICKNESS AND WAS PLACED OVER THE REGRADED LIMITS OF THE TAILINGS IN ACCORDANCE WITH THE REQUIREMENTS OF THE SPECIFICATIONS (SEE SHEET 4).
3. BORROW PIT No. 2 IS BEING USED FOR DISPOSAL OF MILL FACILITIES DEMOLITION DEBRIS, CATCH BASIN MATERIALS AND ORE PAD MATERIALS.
4. MILL WILL BE DECOMMISSIONED BY 1992. MARKED BUILDINGS TO REMAIN.
5. WELLS THAT LIE WITHIN THE AREA TO BE DISTURBED WERE PLUGGED IN ACCORDANCE WITH NEW MEXICO STATE ENGINEERS OFFICE (NMSEO) REGULATIONS OR USED FOR FUTURE MONITORING.
6. THE HAUL ROAD WAS CONSTRUCTED TO A WIDTH OF 30 TO 75 FEET. IN AREAS WHERE THE HAUL ROAD PASSES OVER COARSE TAILINGS, THE TAILINGS WERE COMPACTED, COVERED WITH A LAYER OF GEOTEXTILE, AND BACKFILLED WITH A MINIMUM OF 2 FEET OF COMPACTED SOIL IN ACCORDANCE WITH THE DETAIL ON SHEET 4 AND WITH THE SPECIFICATIONS.
7. THE HAUL ROAD, EXISTING ACCESS ROADS AND THOSE ADDED FOR CONVENIENCE DURING INTERIM STABILIZATION WILL BE MAINTAINED THROUGHOUT THE COURSE OF CONSTRUCTION IN ACCORDANCE WITH THE SPECIFICATIONS.
8. THROUGHOUT [illegible] OPERATIONS, DUST IS MINIMIZED BY THE APPLICATION OF WATER OR APPROVED DUST PREVENTATIVE.
9. SECTIONS AND DETAILS ARE SHOWN ON SHEET 4
10. INTERIM STABILIZATION CONSTRUCTION IN NORTH CELL AND CENTRAL CELL AREAS WAS ACCOMPLISHED IN 1989 AND 1990, RESPECTIVELY.
11. AFTER DRAWING No. 86-060-E536 (FIGURE 4-1) IN THE 1991 RECLAMATION PLAN (CANONIE, 1991).

INTERIM STABILIZATION PLAN
SOUTH END

PREPARED FOR

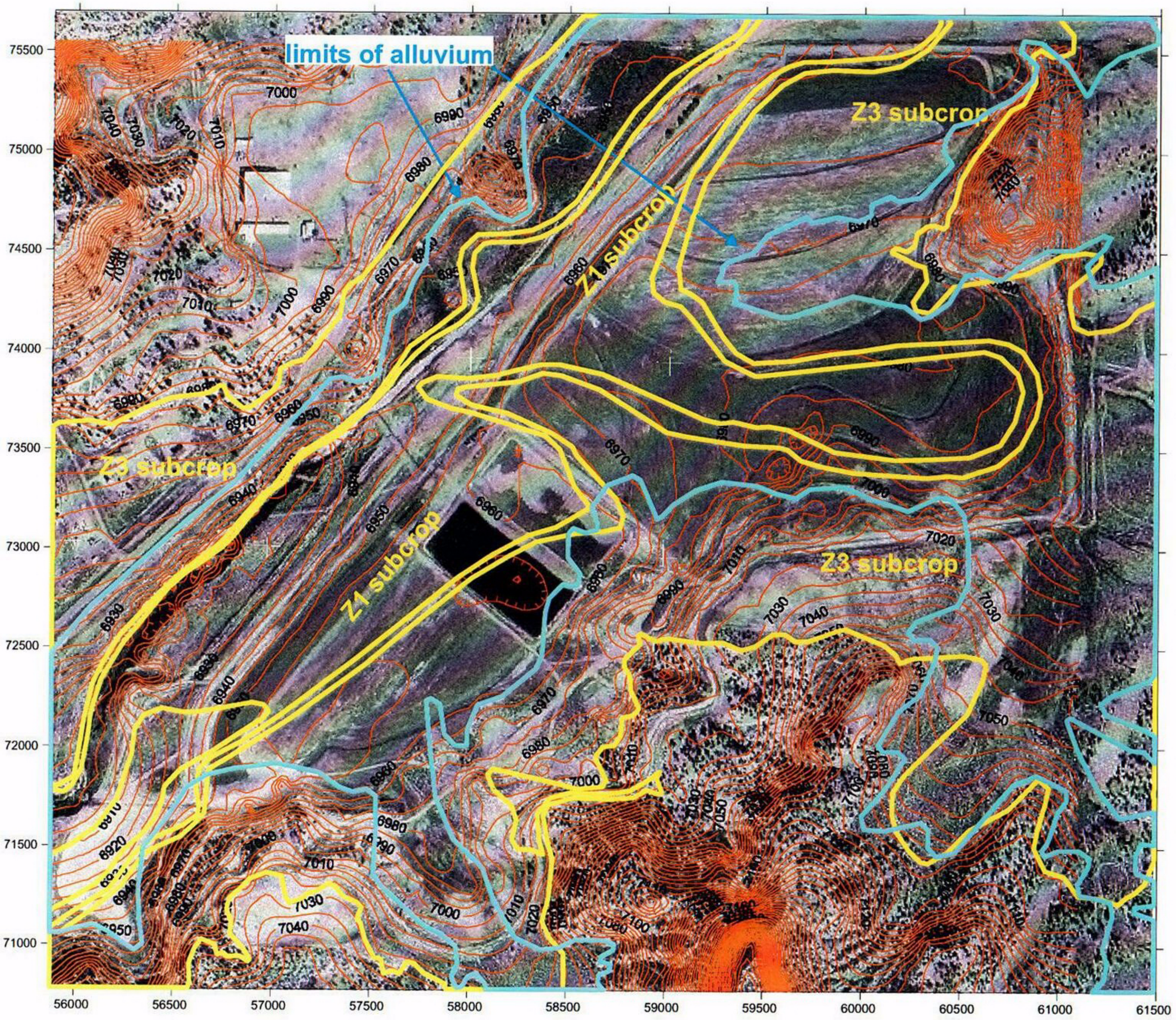
UNC MINING AND MILLING
GALLUP, NEW MEXICO

CanonieEnvironmental

DATE: 4-9-92 SCALE: AS SHOWN	SHEET 2 of 4	DRAWING NUMBER 86-060-E722

USFILTER

FIGURE 4
May 1985 Topographic map showing planned elevation contours for the interim reclamation of 1989 - 1991 (reproduced from Canonie, April 1987)



C02

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FIGURE 5
Topography and geology on circa 1997 aerial photograph of covered tailings following final reclamation
(5-foot contour interval; geology after Canonie, May 1987)

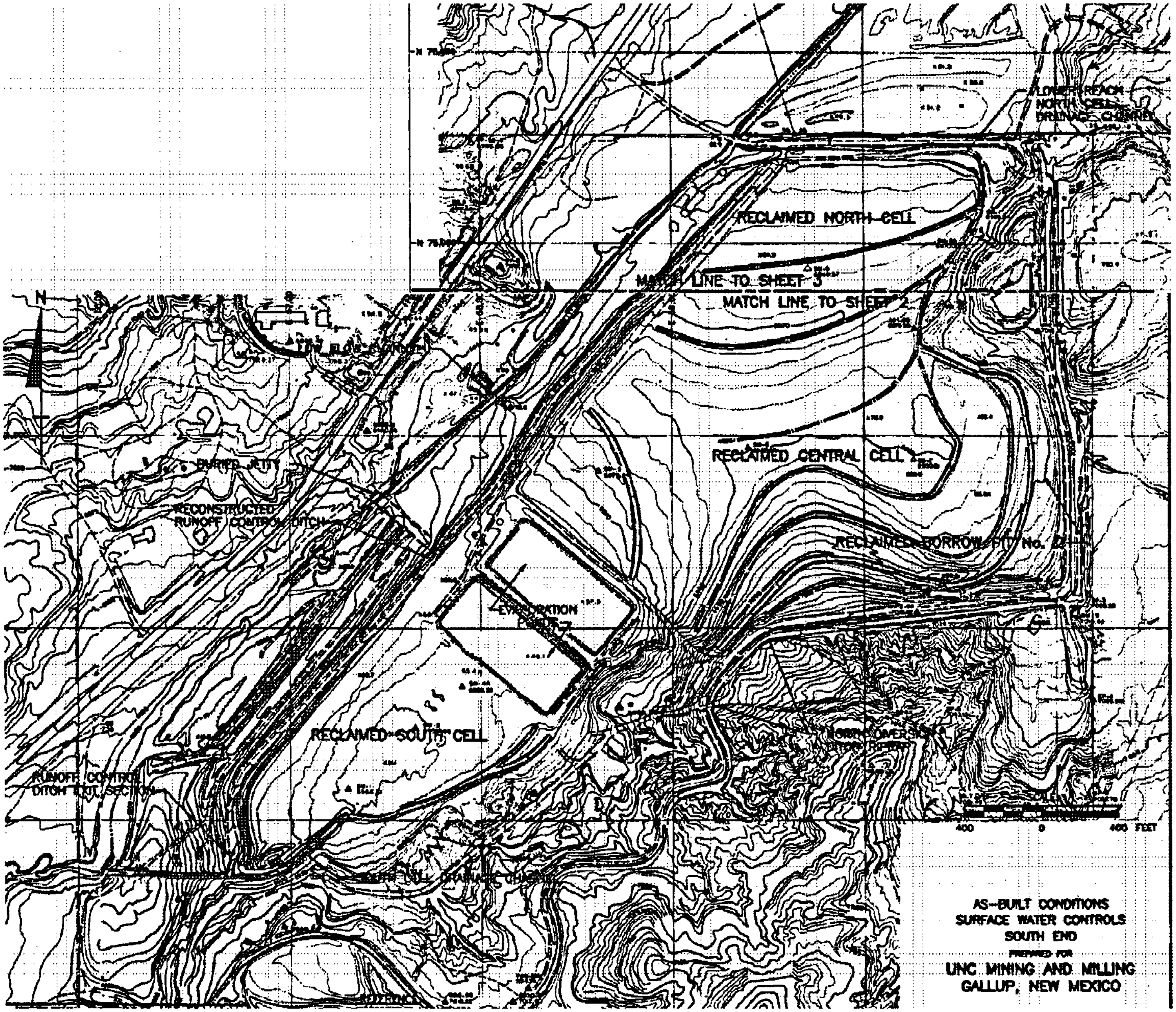

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FIGURE 6
August 1996 Topographic map showing final reclamation as-built elevations
(reproduced from Canonie, March 1997)

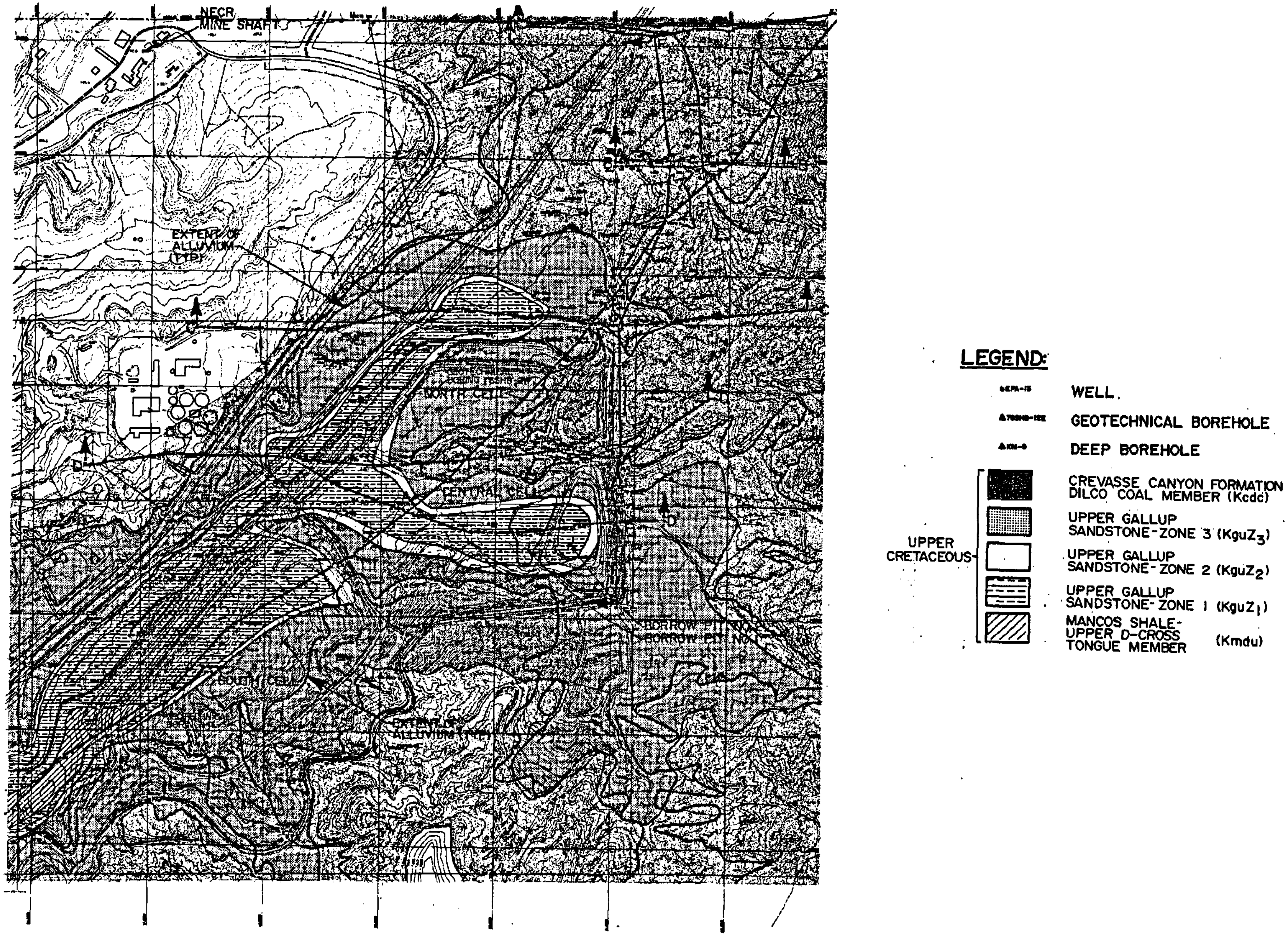

FIGURE 7
Geologic map on May 1985 topographic base
(reproduced from Canonie, May 1987)

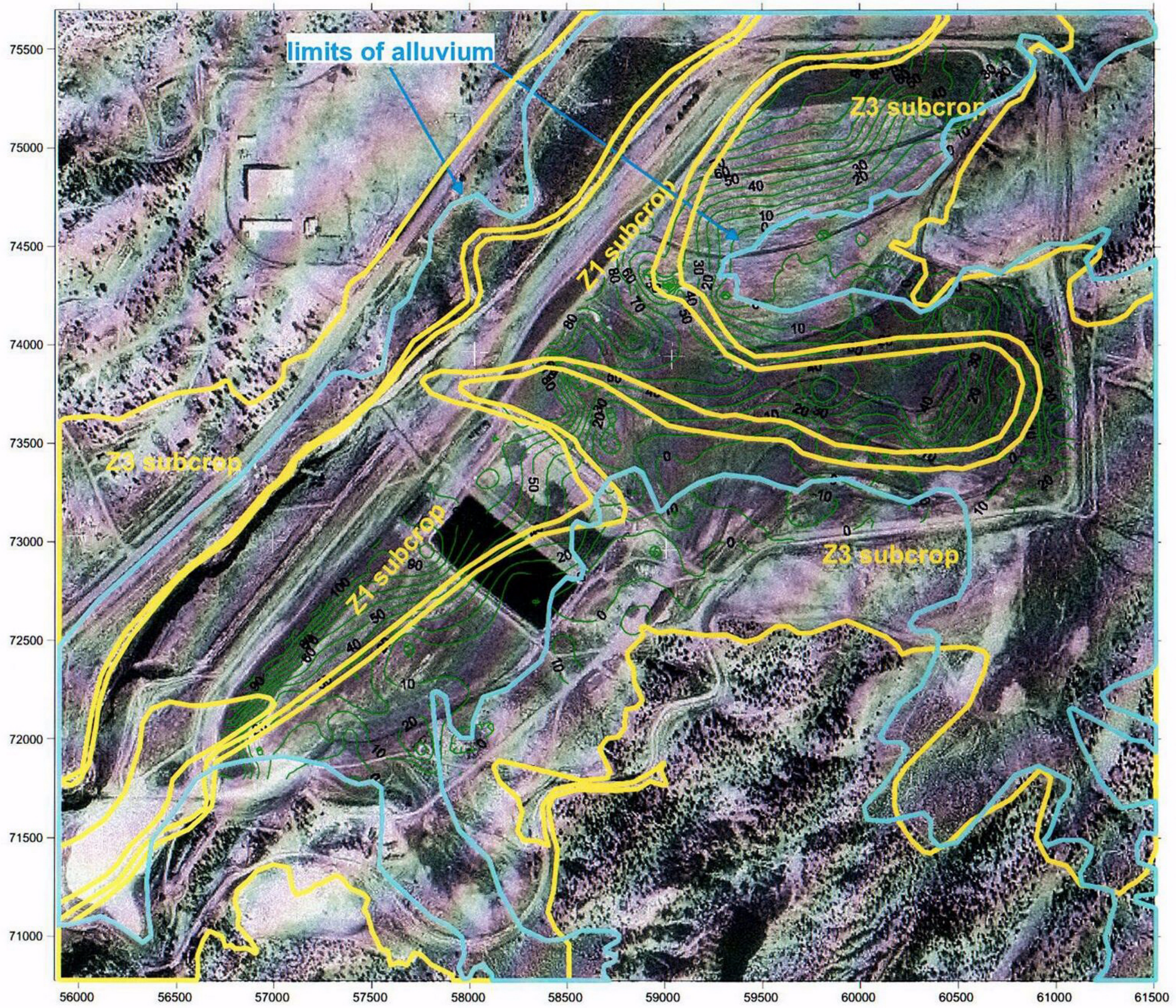

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FIGURE 8
Estimated thickness of alluvium between tailings and rock on circa 1997 aerial photographic base
(10-foot contour interval; geology after Canonie, May 1987)

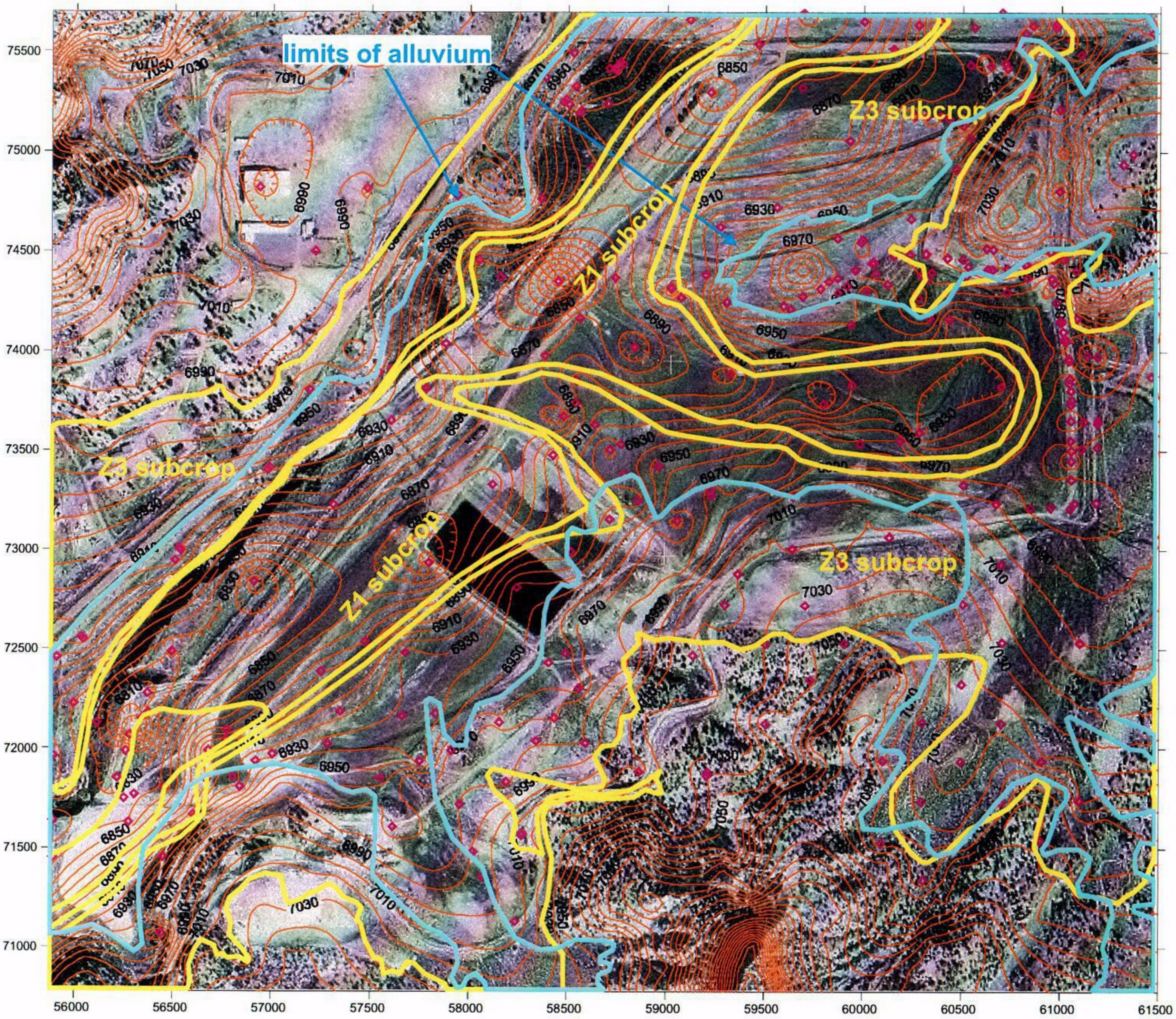

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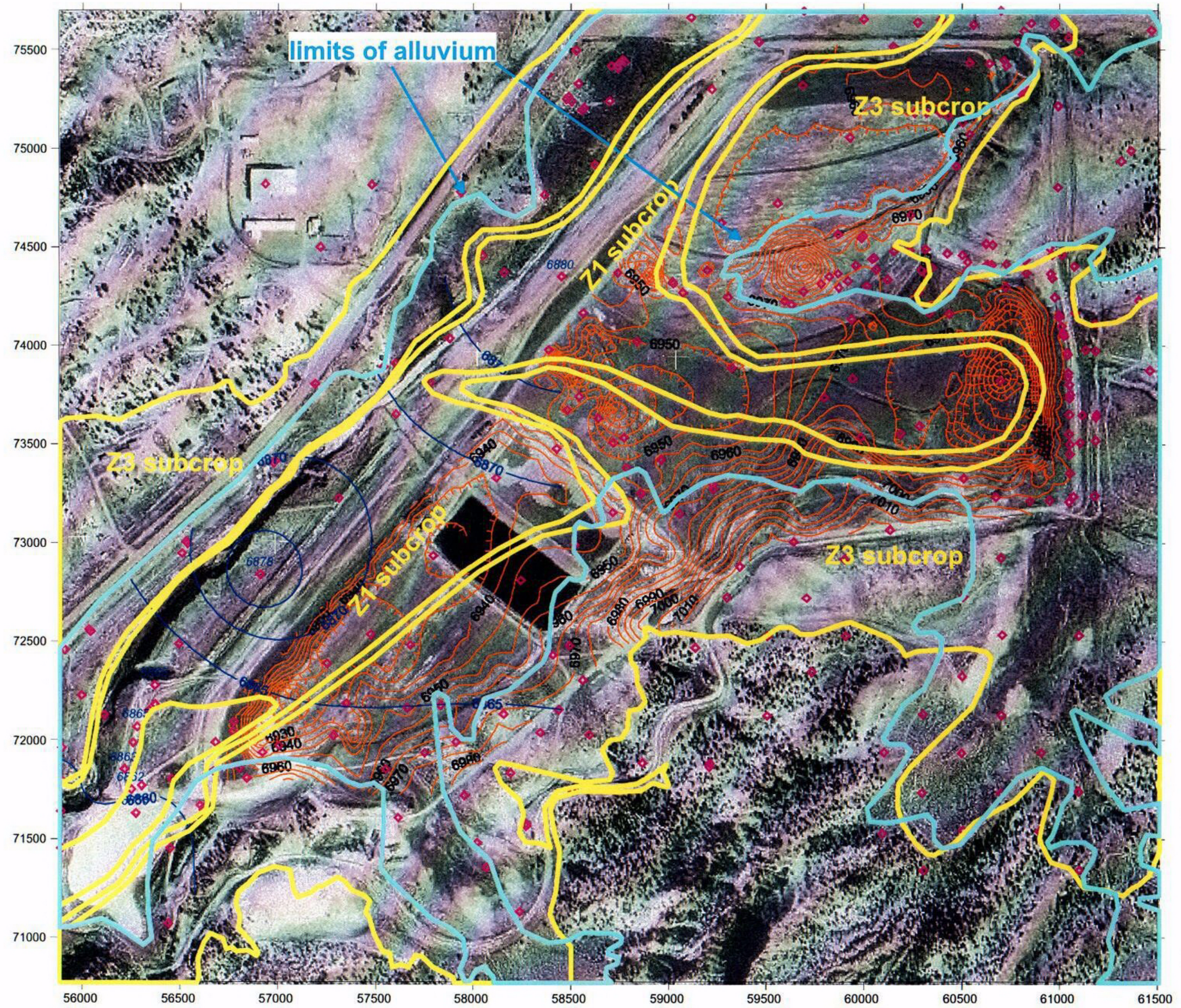
FIGURE 9

Estimated elevation contours at the top of rock on circa 1997 aerial photographic base
(10-foot contour interval; geology after Canonie, May 1987)



C05

FIGURE 10

Estimated elevation contours at the base of the tailings (orange) and
water levels in the alluvium measured in October 2002 (blue; data from Earth Tech, December 2002)
(5-foot contour intervals; geology after Canonie, May 1987)

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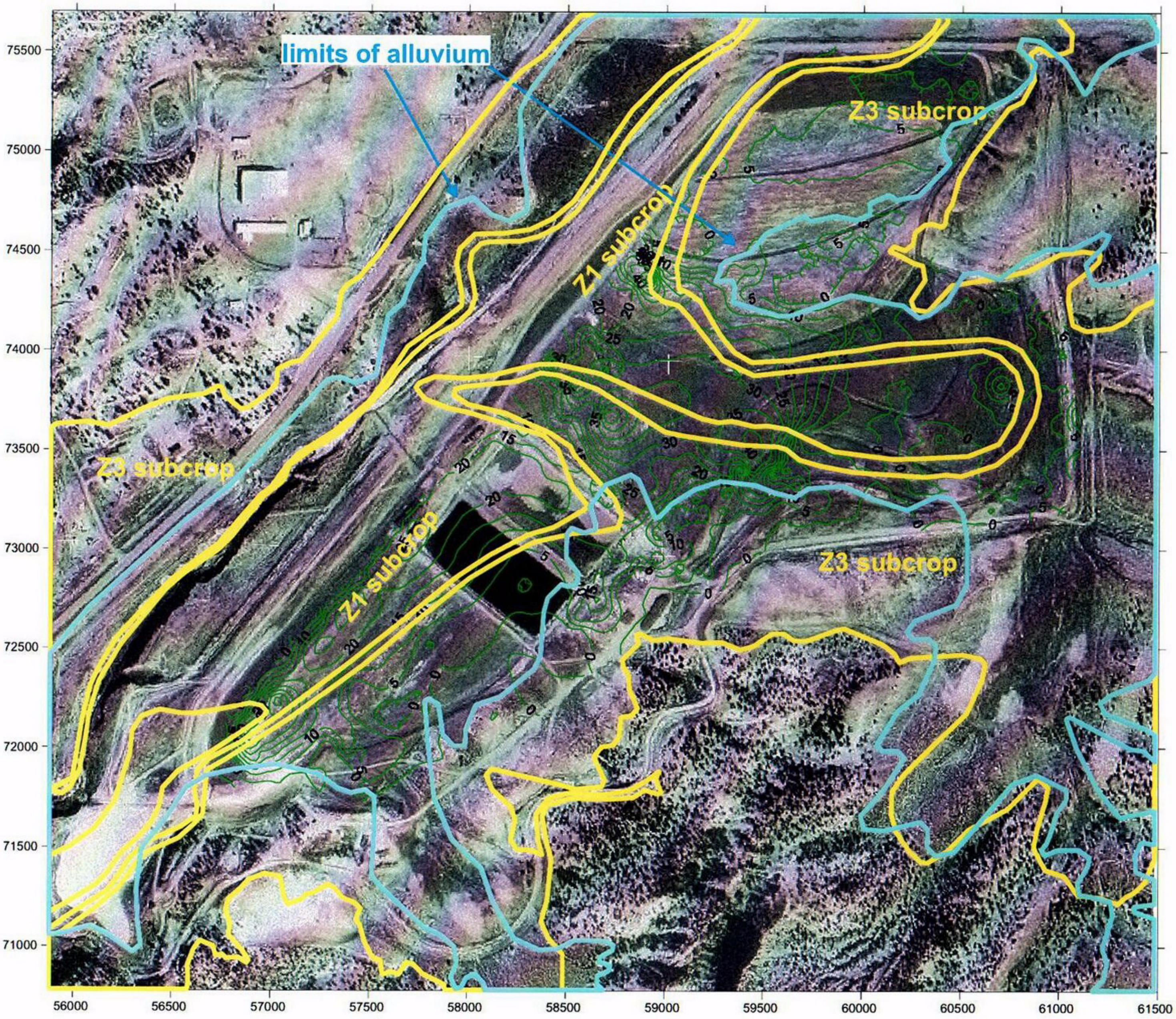

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FIGURE 11
Estimated thickness of tailings in 1985, prior to interim regrading and cover,
on circa 1997 aerial photographic base
(5-foot contour interval; geology after Canonie, May 1987)

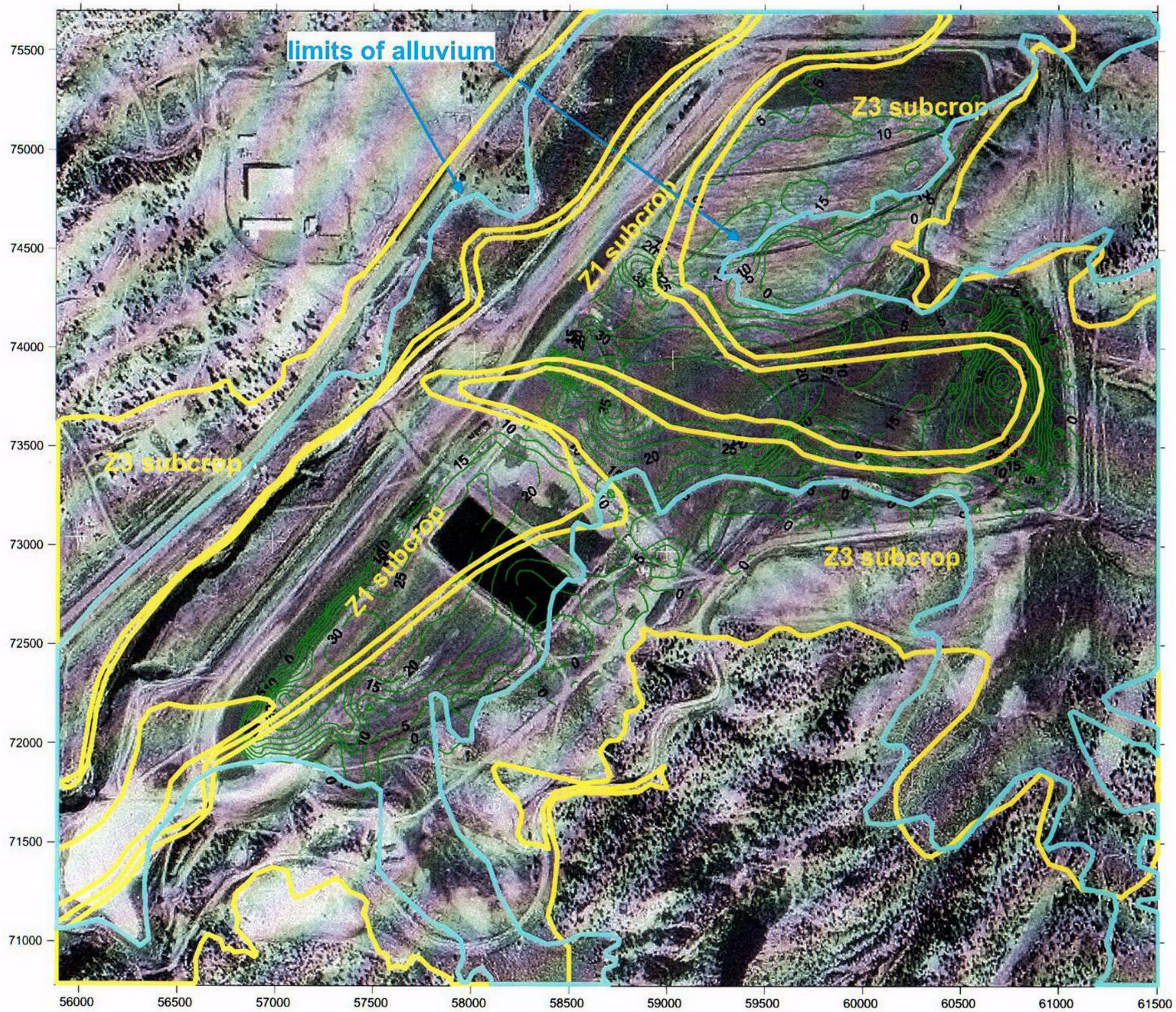

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FIGURE 12
Estimated thickness of tailings and cover in 1997, following final reclamation, on circa 1997 aerial photographic base
(5-foot contour interval; geology after Canonie, May 1987)

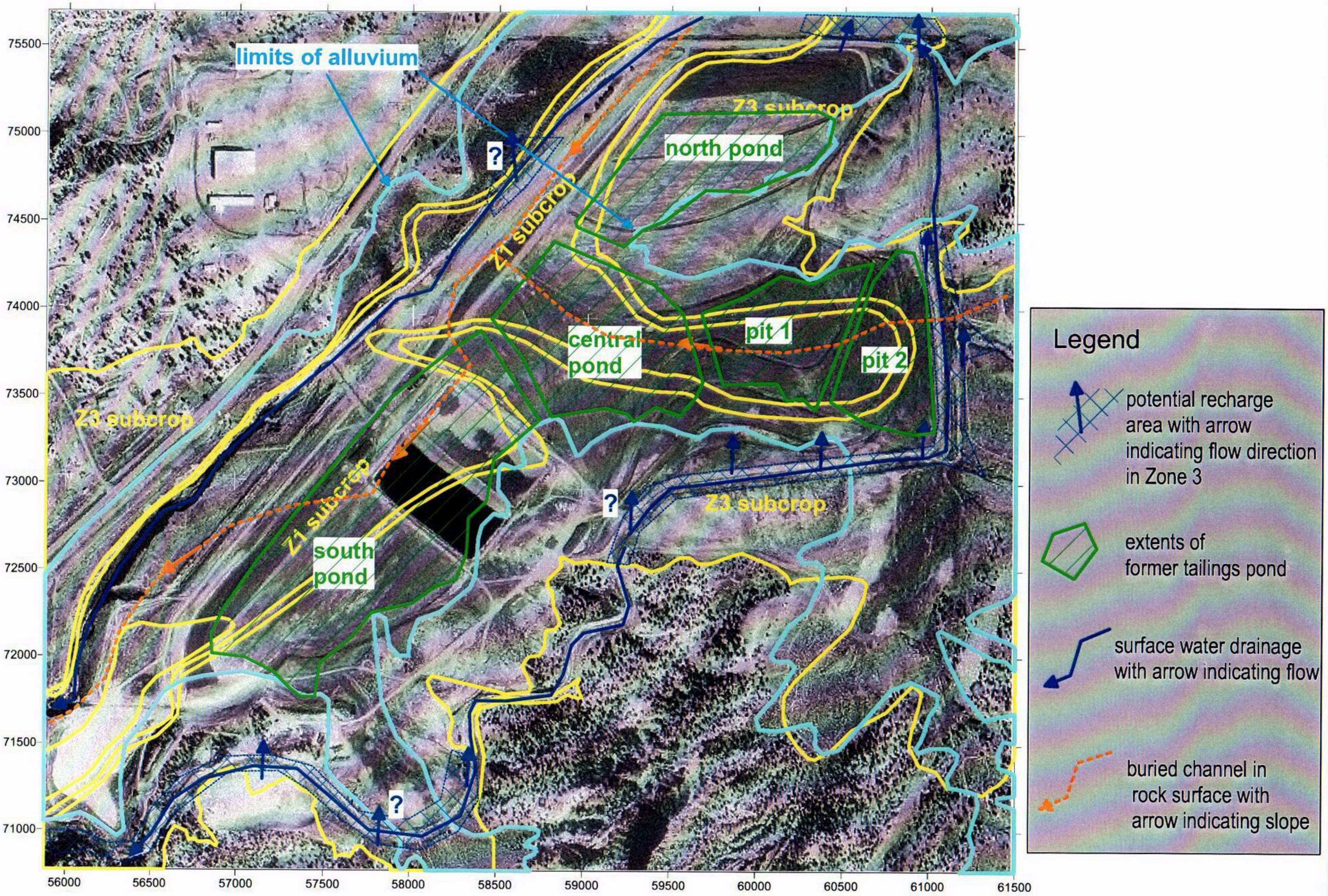

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FIGURE 13
Summary of tailings cell features, surface water channels and potential areas of recharge to zone 3, on circa 1997 aerial photographic base
(geology after Canonie, May 1987)

C 08

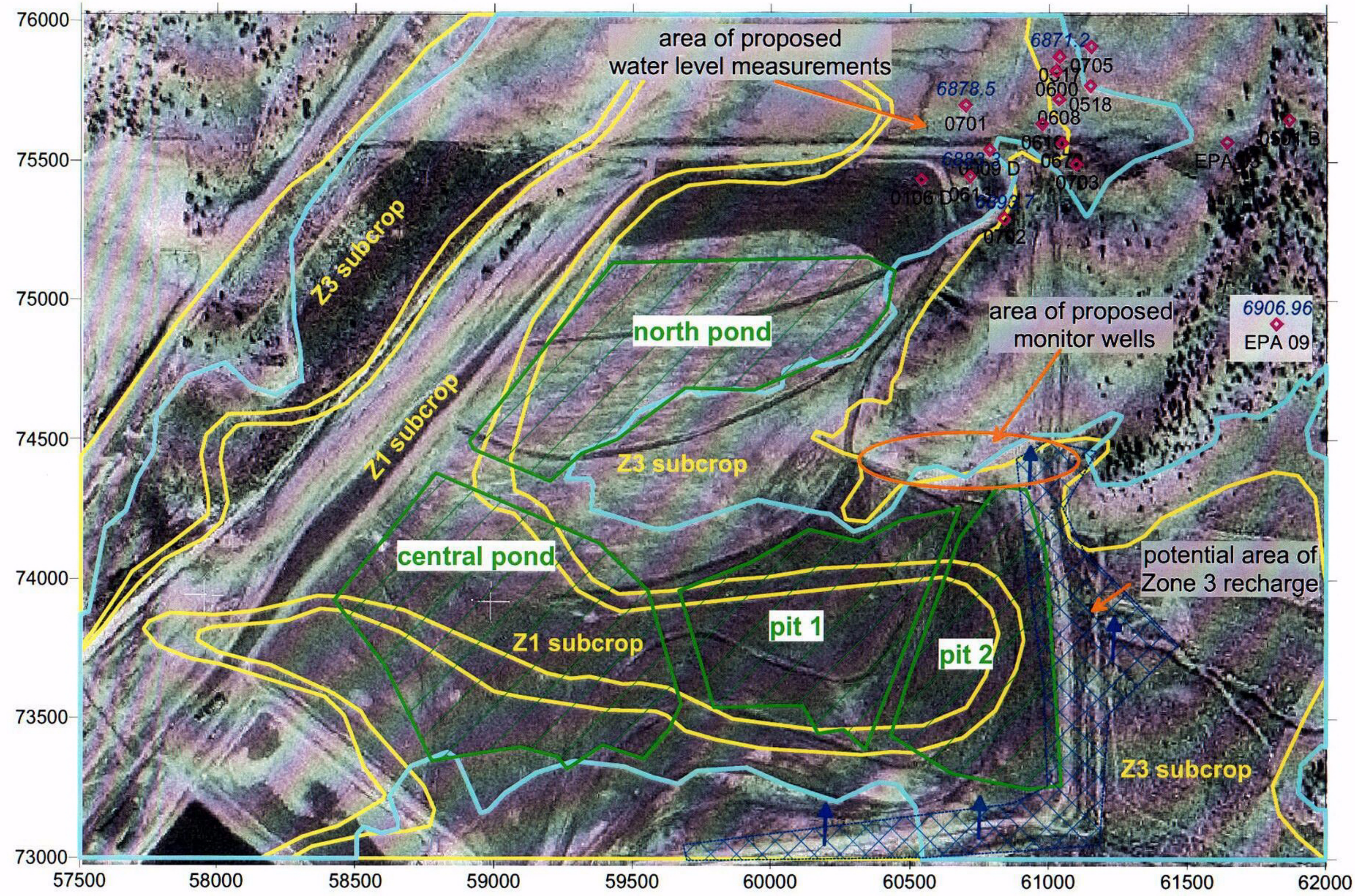

FIGURE 14
Detail from Figure 13 showing potential areas of Zone 3 field investigation,
on circa 1997 aerial photographic base
(geology after Canonie, May 1987)

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C09

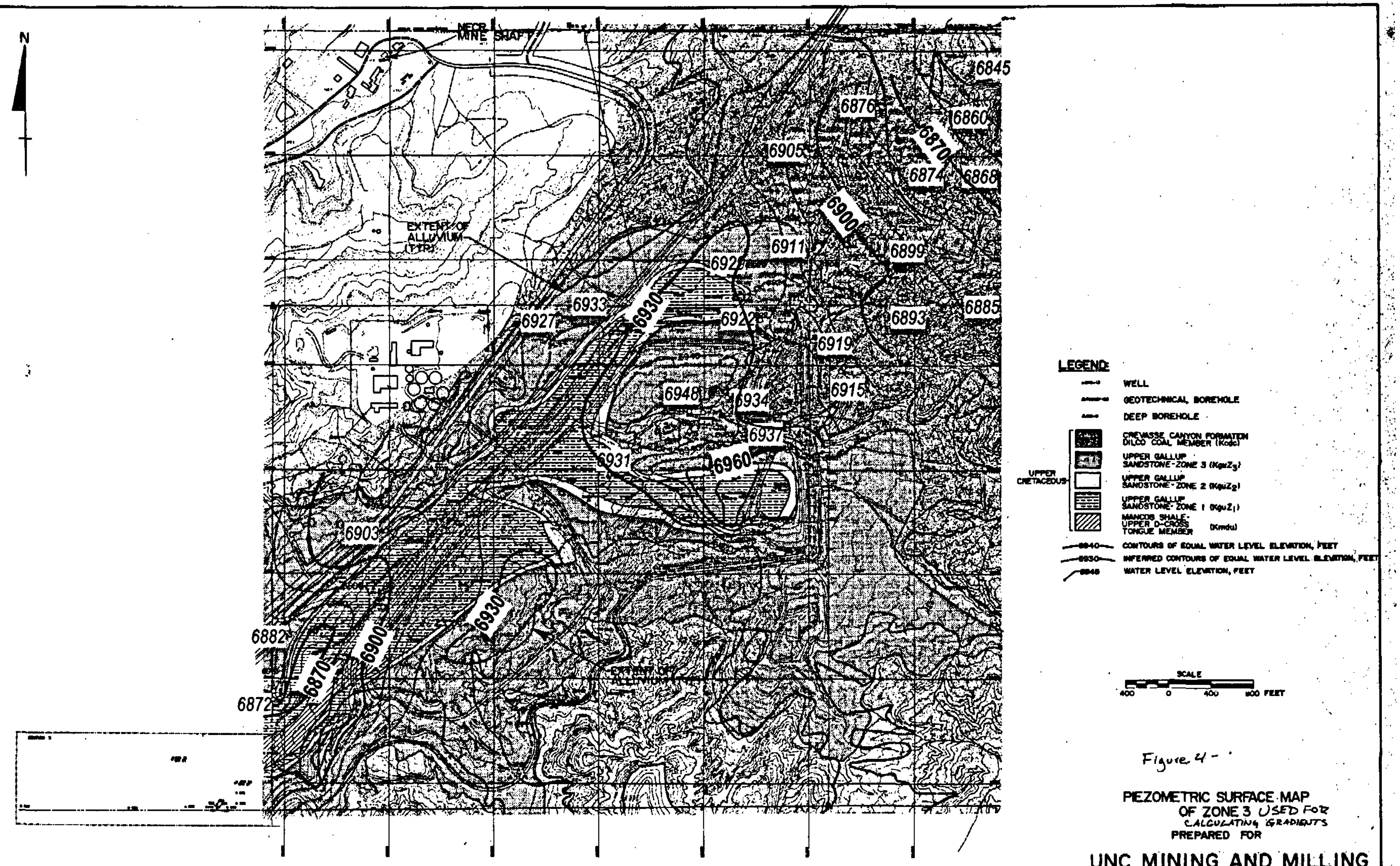

Figure 4 -

PIEZOMETRIC SURFACE MAP
OF ZONE 3 USED FOR
CALCULATING GRADIENTS
PREPARED FOR

UNC MINING AND MILLING
GALLUP, NEW MEXICO

CanonieEnvironmental

DATE: 1-30-87	~~FIGURE 3-2~~	DRAWING NUMBER RM86-060-E28
SCALE: AS SHOWN		

REFERENCE:
- COMPOSITE OF TOPOGRAPHIC MAPS PROVIDED BY UNITED NUCLEAR CORP. DRAWING NOS. 1796-A, AND C-1797-B DATED: MAY 1, 1985, SCALE: 1"=200'.
- GEOLOGY FROM FIGURE 84-5 TITLED "GEOLOGIC MAP, SEC 2, T16 N, R16 W, NEW MEXICO, SCALE 1"=275', D'APPOLONIA, 1980. REVISIONS 1986 BY CANONIE.

DRAWN BY	J.M.M.	1-30-87
CHECKED BY		5/29/87
APPROVED BY	RJP	5-29-87
DRAWING NUMBER	RM86-060-E28	

NO.	DATE	REVISIONS

FIGURE 15
Zone 3 piezometric surface map (1987) and geology on May 1985 topographic base (reproduced from Canonie, April 1989)

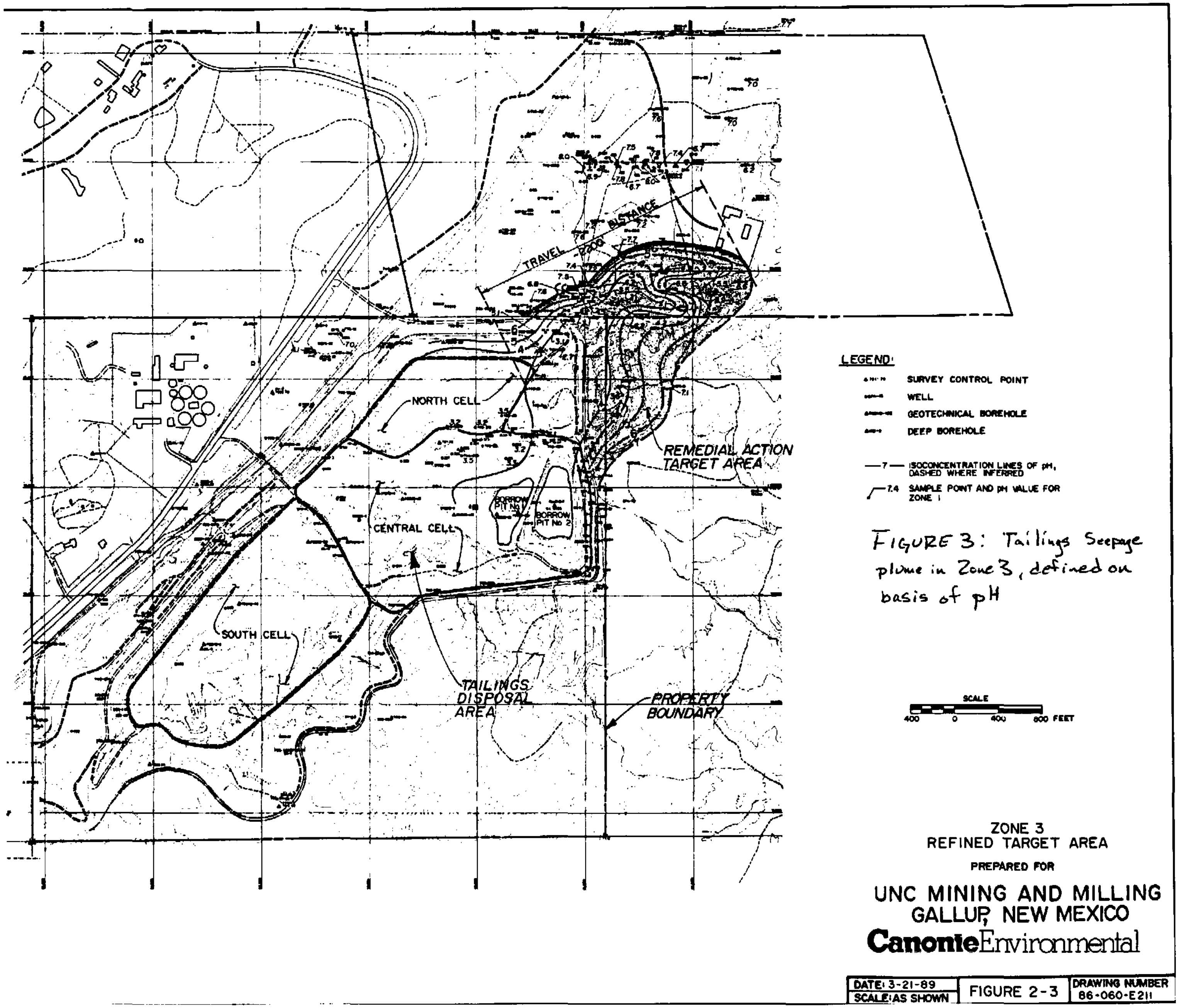

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FIGURE 16
Contours of pH in Zone 3 in 1989 on May 1985 topographic base
(reproduced from Canonie, April 1989)