0031

MEMORANDUM

TO: Wendell Owens
Co-Op Mining Company

DATE: June 20, 1985

FROM: H. Lee Wimmer, P.E.
Hydrologist

SUBJECT: Responses to Memorandum by State of Utah Natural Resources, Division of Oil, Gas and Mining - Bear Canyon Mine

7.41 Hydrologic Balance: General Requirements - TM, RVS

Compliance

Surface Water - TM

The applicant is not in compliance at this time.

The surface water data collected to date is not adequate to characterize the baseline surface water quality and quantity and thereby allow a determination of minimal changes to the prevailing hydrologic balance. The Division requests that the applicant refer to Table 2 and Table 3 of the attached surface Water Guidelines for perennial streams. The applicant has submitted water quality data previous to this determination and this was taken into consideration.

The applicant indicates that Bear Creek is an intermittent stream. The data available indicate that Bear Creek is a perennial stream. The applicant must make the appropriate changes in the mine plan.

The applicant has not adequately discussed, in detail, reclamation of the natural drainage areas found on-site. To determine if the approved postmining land use of the permit area is not adversely affected is impossible at this time (see UMC 817.44 for specific analysis).

Ground Water - RVS

The applicant is not in compliance at this time.

The MRP presents a variety of incomplete and frequently, contradictory information that disallow delineation of the prevailing subsurface hydrologic balance within and adjacent to the mine plan area. For example, the MRP does not include data that:

1. Identify the geologic mechanism(s) providing recharge to Bear Canyon Spring, Birch Spring and COP Development Spring.

2. Characterize the quantity and quality of mine inflow and discharge.

FILE IN EXPANDABLE

Refer to Record No. 0031
in C/015/025, 1985, INCOMING
for additional information

3. Allow seasonal variation in spring and mine inflow to be identified.

4. Substantiate the depth to ground water.

Moreover, the applicant committed to drilling and submitting data from 12 boreholes by mid-November 1984 for the purpose of delineating the subsurface hydrologic regime (Appendix 7-D). Data from five of the boreholes are not presented in the MRP.

Accordingly, the assessment of whether mine activities have been planned and conducted to minimize changes to the prevailing groundwater hydrologic balance, in order to prevent long-term adverse changes in that balance cannot be achieved. Furthermore, the evaluation of whether changes in subsurface water quality and quantity and in depth to groundwater shall be minimized so that the approved postmining land use of the permit area is not adversely affected also cannot be achieved.

Surface Water Stipulations 817.41-(1, 2,)-TM

Prior to permit approval:

1. The applicant must change any statements in the mine plan that refer to Bear Creek as an "intermittent" stream to "perennial" stream.

2. The applicant must commit to sample the complete list of baseline parameters spelled out in the attached Table 2, once in each of the last two quarters in 1985 and each quarter (four times) in 1986 to adequately characterize baseline conditions for Bear Creek. The ongoing monitoring program which Co-Op has undertaken (i.e., monthly sampling) should continue concurrently with baseline data acquisition.

Ground Water Stipulations 817.41-(1, 2, 3, 4)-RVS

Prior to permit approval, the applicant must:

1. Provide the entire suite of data from the 12 boreholes described in Appendix 7-D.

2. Provide data that characterize the quantity and quality of mine inflow and discharge.

3. Commit to acquiring additional water quantity and quality data as described in the attached guidelines for the three springs.

4. Provide data to substantiate the depth to groundwater (Star Point-Blackhawk aquifer) and identify the geologic mechanism(s) operating to recharge Bear Canyon Spring.

Co-Op's Response:

Surface Water - (1) Bear Creek is now referred to as a perennial stream (see Section 7.2.2, page 37); (2) There will be quarterly baseline sampling in

addition to current monthly sampling (see Section 7.2.4, page 41 and Table 7.2-6, page 75).

Groundwater - (1) Data from boreholes is contained in Appendix 7-D (page 111-121); (2) Data characterizing mine inflow quantity and quality is contained on Table 7.1-3 (page 30); (3) Additional spring water quality parameters shall be measured (see Section 7.1.7 and Table 7.1-4, pages 20 and 31); (4) Aquifer characteristics and data are contained in Section 7.1.3.2.2 and Table 7.1-2 (pages 11-15 and 29).

UMC 817.42 Water Quality Standards and Effluent Limitations - TM

Compliance

The applicant is not in compliance at this time.

The applicant proposed plans showing all disturbed area drainage being passed through treatment facilities. The applicant must implement adequate designs for these treatment facilities. Sedimentation Ponds "A" and "B" have not been constructed adequately to meet regulatory requirements. Until the applicant completes this task, the treatment facilities are not in compliance (see UMC 817.46 for specific analysis).

Stipulations

None.

Co-Op's Response:

Designs for reconstruction of the sedimentation ponds are shown on Plates 7-2 and 7-3

UMC 817.43 Hydrologic Balance: Diversions and Conveyance of Overland Flow, Shallow Groundwater Flow and Ephemeral Streams - TM

Compliance

The applicant is not in compliance at this time.

The Division has analyzed the design calculations proposed by the applicant for the disturbed and undisturbed surface water drainage plan. The applicant has used an extended basin lag time in the MRP for all ditch and culvert calculations based on the conclusion that "different methods, different rainfall distributions, different computer programs will all generate different numbers and that too short a time of concentration or lag for generated hydrographs will give you an erroneously high indication of peak flow because of the difference between the theoretical computations and the actual channel and ground surface conditions found in nature" (Appendix 7-D, MRP).

The Division does not concur on the issue of using an artificially lengthened basin lag time in design calculations. However, the results produced by the applicant are not significantly different from the Division's calculations. Thus, the designs proposed by the applicant are deemed acceptable, especially in light of the fact that the structures (i.e., culverts,

ditches, etc.) are already in place. The structures associated with the surface water drainage plan will be monitored monthly by Division Inspection and Enforcement Staff. Should problems become evident, Co-Op will be required to replace or modify existing structures.

Stipulations

None.

Co-Op's Response:

Co-Op addresses these concerns in Sections 7.2.5.2.3 and .4, and Appendix 7-G (see pages 51-54, 305-313).

UMC 817.44 Stream Channel Diversions - TM

Compliance

The applicant is not in compliance at this time.

The MRP does not include specific plans for postmining drainage. The applicant has not included design specifications for the existing 60-inch concrete culvert in Bear Creek and plans for its removal. The applicant must include cross-sections of the stream channel and floodplain taken prior to placement of the 60-inch culvert in the creek, as well as specific plans (cross-sections, riprap sizes, filter blankets and placement) for channel restoration.

The applicant must also submit all of the necessary calculations, cross-sections and specific plans for any other disturbed drainages on site. They must meet the criteria given under UMC 817.44(d)(1)(2)(3). Reclaimed channels must have the same geomorphic characteristics and a capacity equivalent to that of the unmodified stream channel immediately upstream and downstream from the diversion.

The Postmining Topography map, Plate 3-2, shows restored drainages associated with Bear Creek located on the south side of the Bear Canyon Road across from the scalehouse facility. This is not an accurate representation of where the natural creek channel is currently located.

Stipulation 817.44-(1)-TM

Prior to permit approval:

1. The applicant must submit the necessary cross-sections, plans, calculations for restoration of postmining drainage. This must include:

   A. the longitudinal profile and cross-section of all postmining drainages;

   B. accurate location of channels;

   C. predicted flows and velocities;

D. protective measure for restored channels (i.e., riprap, vegetation, energy dissipators, etc.);

E. measures to restore a pattern of riffles, pools and drops rather than uniform depth that approximate natural stream channel characteristics.

Co-Op's Response:

Plans, profiles, cross-sections, etc. for reclamation of the mine plan area are contained in Section 7.3 (pages 78-83) and on Plates 7-7 and 7-8.

UMC 817.45 Sediment Control Measures - TM

Compliance

The applicant is not in compliance at this time.

The applicant has presented several sediment control methodologies to benefit erosion control during reclamation. The applicant needs to present specific plans for the placement of straw bales, silt fences, hygronomy blankets in channels, etc.

The applicant has certain methods of sediment control in place on-site which have not been specifically detailed in the MRP or on Plate 7-1. These measures must be included in the MRP and Plat 7-1. This must include a typical cross-section or drawing of the structure (i.e., silt fence, energy dissipator) and installation procedure.

The applicant uses silt fences in many of the ditches on the property. Frequently they are installed improperly and, therefore, are not effective in enhancing sediment control. The applicant also proposes the use of hygronomy blankets in reclaimed stream channels. Although they work well for the area they cover, head cuts form at the downstream end and can cause extensive damage to channel integrity. The Division recommends that hygronomy blankets not be used in lieu of riprap of more permanent measures during reclamation.

Stipulation 817.45-(1)-TM

Prior to permit approval:

1. The applicant must present specific plans for sediment control measures used during operation and postmining, including cross-sections, installation procedures and drawings for all sediment control measures to be implemented on-site (i.e., silt fences, straw bales, hygronomy blankets, riprap placement, check dams, vegetative sediment filters, dugout ponds, etc.)

Co-Op's Response:

Sediment control measures to be taken are outlined in Section 7.2.5.2.1 (page 51).

UMC 817.46 Hydrologic Balance: Sedimentation Ponds - TM

Compliance

The applicant is not in compliance at this time.

The applicant has adequate plans for the design of Pond "A" and, therefore, needs to implement this design as soon as possible during the 1985 construction season. The applicant currently does not have complete plans for Pond "B" which address Division concerns. The size requirements for riprap to be implemented at the road drainage culvert into the pond and an accurate description of protection for the spillway must be provided.

The applicant has currently encroached upon Bear Creek with Pond "B." When reconstructing Pond "B," the applicant must move this an adequate distance from the creek based on flood flow calculations for this reach of Bear Creek. Adequate protection must be provided for the outslope of Pond "B" to withstand velocities expected from flood flows associated with Bear Creek.

The applicant has not provided detailed plans for removal of the sedimentation ponds. The applicant has not provided detailed plans for diverting disturbed area flows going to the sedimentation ponds during reclamation to Bear Creek when the ponds are being removed and when drainages are being established in all ephemeral drainages.

Stipulation 817.45-(1, 2)-TM

Prior to permit approval:

1. The applicant must provide detailed plans for removal of the sedimentation ponds. The applicant must provide plans to divert flows going to and around the sedimentation ponds during reclamation and submit plans as to how this will be carried out.

2. The applicant must provide adequate plans for sediment Pond "B" that address the concerns identified in the compliance portion of this regulation. These concerns are as follows:

   A. location in relation to Bear Creek, including flood flow calculations (25-year, 24-hour event) for this reach of Bear Creek and outslope protection measures, if necessary, to withstand velocities expected from these flood flows;

   B. a decant pipe placed in the embankment with oil skimmer to provide decant capabilities;

   C. an adequately sized embankment to meet the requirements of UMC 817.46(1);

   D. protection from erosion for all inlets and spillways. Calculations show no outflow from the pond during the 25-year, 24-hour event, but minimal protection must be provided to protect bare soils from erosion.

Co-Op's Response:

(1) Reclamation plans for the sedimentation ponds are contained in Section 7.3.4 (page 80); (2) Reconstruction design for Pond "B" is shown on Plate 7-3. Computer runs for flow and velocity of Bear Creek during flood stage are in Appendix 7-H. Riprap protection for bare soils will be provided for the ponds' inlets and outlets (see Section 7.2.5.1, page 45).

UMC 817.47 Hydrologic Balance: Discharge Structures - TM

Compliance

The applicant is not in compliance at this time.

The applicant must identify what energy dissipators will be used, how they will be installed and where it will be located on Plate 7-1.

In order to resolve issues related to energy dissipation and achieve compliance with this regulation, the applicant has agreed to an on-site visit by Division Staff in the spring of 1985 (Appendix 7-D). The Division has identified several potential problem areas. These areas as well as other areas will be addressed during this site visit verification.

Stipulation 817.47-(1, 2)-TM

Prior to permit approval:

1. The applicant must identify what energy dissipators will be used and where they will be located on Plate 7-1.

2. The applicant must also provide the riprap size and installation method to be used for each area and the calculations supporting the size proposed.

Co-Op's Response:

(1) The energy dissipators that will be used are shown on Figure 7.2-6 (page 62) and locations are shown on Plate 7-1; (2) Riprap sizes are shown in tables on pages 49 and 50. Sizes are based on the velocities from these same tables and the nomograph on page 63.

UMC 817.49 Hydrologic Balance: Permanent and Temporary Impoundments -TM

Compliance

The applicant is not in compliance at this time.

The applicant has not proposed any permanent impoundments to be left on-site, therefore, does not need to meet the requirements associated with permanent impoundments. The applicant needs to specifically address certain requirements of UMC 817.46(e) - (u) as is stated in UMC 817.49(b) (see Compliance, UMC 817.46).

Stipulations

See UMC 817.46.

Co-Op's Response:

These stipulations have been addressed in the previous response contained in this memo.

UMC 817.50 Hydrologic Balance: Underground Mine Entry and Access Discharges - RVS

Compliance

The applicant is not in compliance at this time.

Information presented in the MRP and observed at the mine site suggest underground mine entry and access discharges are possible. Accordingly, the applicant must address the requirements of UMC 817.50.

Stipulation 817.50-(1, 2)-RVS

Prior to permit approval, the applicant must:

1. Submit information that demonstrates entries and accesses to underground workings are located, designed, constructed and utilized to prevent or control gravity discharge of water from the mine.

2. Commit to:

   A. sampling on a quarterly basis until bond release any discharges from the underground workings which occur after mining. Sampling will assess if discharges are in compliance with the effluent standards of UMC 817.42 and all other applicable state and federal regulations;

   B. provide treatment, if necessary, to any discharges to achieve compliance with applicable standards during the period of discharge.

Co-Op's Response

All water discharged from the mine is done so by pumping (see Section 7.1.4, page 16). Co-Op commits to monitor discharges and analyze samples in accordance with Figure 7.2-3, page 59.

UMC 817.52 Surface and Groundwater Monitoring - TM, RVS

Compliance

Surface Water - TM

The applicant is not in compliance at this time.

The operational monitoring plan proposal needs additional constituents to adequately address this regulation. Specific conductivity, total settleable solids, total hardness as $CaCo_3$, manganese, oil and grease and a cation anion mass balance should be added to the current monitoring proposal.

Groundwater - RVS

The applicant is not in compliance at this time.

The groundwater monitoring plans proposed in the MRP are incomplete with respect to identifying and selecting monitoring sites and the water quality parameters being derived. Furthermore, monitoring schedules are not consistent.

Surface Water Stipulation 817.52-(1)-TM

Prior to permit approval:

1. The applicant must add the following constituents to the surface water monitoring program:

   A. specific conductivity;

   B. total settleable solids;

   C. total hardness as $CaCo_3$

   D. manganese;

   E. oil and grease;

   F. a cation anion balance for each sample.

Groundwater Stipulations 817.52-(1, 2, 3, 4)-RVS

Prior to permit approval, the applicant must:

1. Submit baseline water quality and quantity data for mine inflows and discharges greater than one gpm, all three springs and boreholes that encountered water (see attached Groundwater Baseline and Operational Water Quality Parameter List). Moreover, the applicant must commit to acquiring and submitting a total of two years of baseline water quality and quantity data for the above-noted monitoring sites. Mine inflows and discharges must be monitored quarterly, whereas springs and boreholes must be monitored four times per annum at not less than monthly increments.

2. Provide a mine inflow survey that identifies wet areas on a mine workings map; including roof drips, wall weeps, seeps, sumps and flowing fractures and/or faults.

3. Commit to initiating an operational monitoring program that acquired water quality and quantity data as described in the attached guidelines. The operational monitoring schedule shall include

quarterly sampling of mine inflows and discharges and four spring and borehole samples per annum at not less than monthly increments.

4. Commit to providing DOGM with an Annual Hydrologic Monitoring Report that incorporates yearly water quality and quantity data and includes a yearly update of the mine inflow survey.

Co-Op's Response:

Surface Water - The parameters listed have been added to the sample analysis list (see Figure 7.2-3, page 59).

Groundwater - Co-Op commits to the above stipulations as outlined in Section 7.1.7, pages 20-21.

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SECTION 7

HYDROLOGY

7.1. GROUND WATER HYDROLOGY

7.1.1 SCOPE

The scope of this study consisted of an investigation of the ground water hydrology in the Bear Creek Coal Mine area, following the Utah Division of Oil, Gas, and Mining (DOGM) permit application guidelines. Information on existing ground water resources and regional ground water hydrology was compiled from available literature, personal communications, and site investigations. Aquifer characteristics (depth, uniformity, thickness, lithology, potentiometric surfaces, recharge movement, and water quality) in the mine plan area were estimated or determined from geologic information from drill holes, field investigations, field data collections, and available literature. The need for mine dewatering was similarly evaluated. The impacts of the mining operations on the regional ground water hydrologic balance and aquifer water quality were assessed within the limitations of the available data. A ground water monitoring plan was formulated on the basis of this assessment.

7.1.2 METHODOLOGY

This section outlines the basic methodology of the ground water hydrology investigations. The major tasks constituting the general approach are listed below:

1. Literature Review: Published and unpublished information on the geology

and hydrology of the Bear Creek area was collected and reviewed. The sources of information included U.S. Geological Survey (U.S.G.S.) investigation reports, engineering data obtained by Co-op Coal Company and data from prior mining and engineering investigations in the general area.

2. Site Specific Investigations:

A. Data Acquisition: Water quality data was collected from springs, surface seeps, mine roof seeps, mine sumps, and ground water discharging into drill holes in the mining area. This data was supplemented by the regional data from available literature. Data on the ground water occurrence at the permit area was collected at selected well locations drilled for this purpose. Information from test borings, including detailed interpretation of geophysical well logs, and field measurements were used to construct stratigraphic sections of mine permit area aquifers and to estimate aquifer physical characteristics. This information was also used to evaluate the affect of faulting in the area on ground water occurrence.

B. Impact on Hydrology: An assessment of the potential impacts of mining operations on the quantity and quality of ground water was made by (1) determining the controls and the likely directions of the ground water flow, (2) identifying the locations of potential contaminate sources, and (3) examining the likely response of the ground water system to the potential contaminate.

3. Monitoring Program

A tentative outline for the ground water monitoring program was made based on the impact assessment study. The criteria for the development of the monitoring program included (a) insuring the representativeness of the monitoring sites, (b) the selection of sampling frequency based on the accessibility of location, hydrologic conditions, and the potential for ground water contamination, (c) topographic and geologic considerations, and (d) existing and potential ground water use from the potentially affected aquifers.

7.1.3 EXISTING GROUND WATER RESOURCES:

Ground water exists under confined and unconfined conditions in the Bear Creek area. Unconfined conditions exist primarily as local perched zones, and in shallow alluvial deposits confined to the main drainage bottoms and in colluvial and residual soil deposits near the ground surface. The unconfined conditions are expressed as localized seeps. Confined conditions exist at depths, where (1) bedrock of relatively higher permeability underlies an impermeable rock unit, or (2) where a high permeability unit abuts an impermeable layer due to faulting, or (3) is predominantly channeled or controlled by faulting. The degree of saturation of the aquifers varies with time and distance from up gradient outcrop canyon areas and from overlying recharge from surface percolation through overburden material. Some limited zones of leakage and infiltration are present, indicated by the persistent, relatively unvarying seeps within three of the mine roof areas. Recharge from these seeps is predominantly from surface percolation. Fault zones in the area

are interpreted as functioning primarily as drains to water-bearing zones (perched and confined) in the area.

Flow volumes of the two large perennial springs and an intermittent spring near the permit area (Bear Springs, Birch Springs, and COP Development Spring, respectively) indicate fault zone(s) are also effective in draining aquifers at appreciable distances upslope from the permit area. This is indicated by a discharge curve for Bear Springs which indicates the flow is dictated predominantly by structural controls, i.e., delayed response to seasonal runoff (Figure 7.1-5). Surface seeps and surface stream flows will follow discharge curves coinciding closely with periods of snow melt and precipitation. Mine roof seeps do not appear to be directly influenced seasonally.

7.1.3.1 REGIONAL GROUND WATER HYDROLOGY

Danielson et. al. (1981) presents the results of the most recent U.S.G.S. hydrologic studies in the Huntington Creek drainage (inclusive of Bear Creek), with emphasis on the coal field areas.

The occurrence, availability, and movement of ground water in the permit and adjacent areas is controlled by structural, stratigraphic, and topographic factors. Snow melt is the source for most, if not all, of the ground water in the study area (Danielson, et. al., 1981). The same report states that, for the Cottonwood-Huntington area of this report, which includes the Bear Creek permit area, available data indicates the Star Point sandstone and, locally, the lower part of the Black Hawk formation is indicated to be an extensive aquifer. The same report states that many of the large springs in the area issue from this aquifer, including Bear Springs where it has been faulted. Data obtained

from our investigations, including drill hole data (Test Holes WM-C, and E, Plates 3.4-1) indicates minor to no perched water within the lower portion of the Blackhawk formation and essentially no ground water in the underlying Star Point Blackhawk aquifer (drill holes WM C, D and E, Appendix 7-D). No surface seeps from the Star Point-Blackhawk contract, with one exception discussed below, were noted within the permit area at outcroppings of this contact. The exception is a small perennial seep (S-1, Plate 3.4-1) noted at the approximate Star Point-Blackhawk contact. This seep is seasonal and emerges at a small, stranded drainage mouth whose temporary drainage base coincides with the Star Point-Blackhaw contact. Recharge is from the residual soil--colluvium within its drainage area. Our interpretation of the local ground water regime is that the Bear Creek fault and, to a lesser extent, the fault through Birch Springs are effective in draining the Star Point-Blackhawk aquifer throughout the Bear Creek drainage. Spring characteristics of the Star Point-Blackhawk aquifer are represented by Figure 7.1-5 (Danielson et. al). The maximum discharge corresponds closely with the period of maximum seasonal runoff. Figure 7.1-5 also presents the maximum discharge for Bear Springs with a peak considerably later in the season. We conclude from this that the springs emerging from the Star Point-Blackhawk aquifer respond quickly to surface runoff due to ready access to the aquifer through vertical joint systems, etc. The delay of maximum discharge of Bear Springs is due to its fault control and to receiving its major supply of water from higher site elevations north of the permit area and to delayed recharge from snow melt, (i.e. relatively flat topography at upper drainage portions in deeper soil cover which decreases surface runoff). Hydraulic connection between the Bear Springs fault and the adjacent fault to the west allows discharge to the surface at Bear Springs. Primary permeability and porosity of the rock units exposed

in the permit area, i.e., the Star Point sandstone, Blackhawk Formation, Castlegate sandstone, Price River formation and North Horn formation are, with the exception of the Castlegate sandstone, generally low. The Castlegate sandstone, with a porosity of .22 as determined from the quantitative geophysical well log analysis performed for this study, is moderately permeable with common solution cavities throughout its extent as based on outcrop and drill hole data. The Castlegate is estimated to also possess moderate to locally high secondary permeability due to vertical jointing. Most of the permeability in the remaining rock formations in the permit area is secondary, occurring primarily along the near-vertical joint planes and as lateral migrations along bedding places.

Base on the above data, we conclude the following:

1. The potentiometric surface is considerably below the Star Point-Blackhawk aquifer in the permit area.

2. The potentiometric surface and perched zones are essentially parallel to the regional bedding attitude (one to two degrees south-southeast in the permit and adjacent areas).

3. The Bear Springs and related subparallel faults poles are the control for the major amount of ground water occurring in the permit area.

4. Distinct, persistent zones constituting a permanent water table are at an appreciable but unknown depth below the permit area.

5. Areas of saturation within the Blackhawk formation are limited to localized perched zones as encountered within the mine, which occur as three localized roof drip areas which collect as sumps on the mine floor in their immediate area of occurrence.

6. The fault crossing the mine workings several hundred feet within the mine portal is "tight" and allows very minor seepage from the mine sump in that area through to the underlying sediments. No seepage, flow or areas of concentrated seeps were observed at the immediate fault area within the mine.

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7.1.3.2 MINE PLAN AREA AQUIFERS

7.1.3.2.1 AQUIFER CHARACTERISTICS - DEPTH, HORIZONTAL EXTENT, THICKNESS AND LITHOLOGY:

Plate 3.4-1 identifies the mine lease area, aquifer outcrops, springs, seeps, mine water occurrences, and drill holes. Logs of six of the original drill holes and logs of eight additional drill holes are presented on Figures 7D-1 through 7D-8, Appendix D. Locations and logs of four test holes, based on geophysical log data provided by Nevada Power & Light Company, are presented on Figures 7D-9 and 7D-10, respectively, Appendix 7-D. Figures 7.1-1 and 7.1-2 represent generalized stratigraphic sections in the mine lease area along Sections AA' and BB' identified in Plate 3.4-1. These sections are taken parallel and perpendicular to the bedding strike in the area. Figure 7.1-3 presents a generalized stratigraphic section of the rock units in the permit area. Figure 7.1-4 presents a stratigraphic description of the Castlegate sandstone, Blackhawk formation and Star Point sandstone based on detailed

geophysical log interpretation conducted for this investigation by Savage Energy Services (Drill Hole T-5, Figure 7D-10, Appendix 7-D).

Field measurements and drill hole data indicate the regional strike, dip, and bedding thicknesses are quite uniform in the mine lease area. Evidence of low displacement (5 to 10 feet) faulting was observed in the lease area within the mine at one location, which is also expressed at the surface in the near area, and at the Birch Springs area. Large displacement faulting (approximately 150 feet) is evident by the Bear Creek fault or fault zone out the east permit margin (Plate 3.4-1). Joint sets are near vertical and generally widely spaced. Regional and area dip is essentially south at 1 to 2 degrees but with a strong easterly component within the mine area proper. Based on this data, bed elevations were projected through the mine area, inclusive of drill hole data from the Nevada Power & Light holes north of the site. Close agreement was found between drill hole data, site observations, and the projections.

The Blackhawk formation, which contains the commercial coal seams, is approximately 925 feet thick in the mine lease area as determined from available information and drill hole data. Based on a detailed analysis of geophysical well log data (Hole T-5, Savage Bros., 1985), the formation consists of a series of interbedded, marginal marine sandstones, siltstones, and mudstones comprising 65%, 19%, and 16% by volume, respectively, of the formation. The commercial coal bearing portion is confined to the lower 100 feet of the Blackhawk and is made up of the uppermost Bear Canyon seam and the Blind Canyon, or Hiawatha seam, located 60 feet below the Bear Canyon in the permit area. The sandstones within the Blackhawk, based on geophysical well log data (Holes T-1, 2, 4, and 5, Figure 7D-11), are literally discontinuous, with one exception discussed below, and of low to locally moderate porosity.

The sandstone units are cyclically interlayered with relatively impervious siltstone and mudstone beds up to 200 feet thick. The above referenced, literally persistent sandstone unit consists of the moderately porous Aberdeen sandstone, a marine sandstone 50 to 100 feet in thickness that occurs north of the permit area (Holes T-1, 2, 4, and 5) and occurs within 100 to 200 feet over the coal bearing zone of the Blackhawk. The Aberdeen is overlain by a varying 75- to 125-foot thick section of siltstones-mudstones.

The contact between the Blackhawk and the overlying Castlegate sandstone (lower member of the Price River formation) is apparently conformable. Based on geophysical density logs of the Castlegate, the formation is moderately porous (.22 calculated) and, based on personal communications (W. Hull, Northwest Energy), zones of voids or open fractures were common within the unit on drilling holes T-1, 2, 4, and 5 and extensive to total drill fluid loss characterizes the unit in the general area. Thickness of the Castlegate encountered is quite uniform, on the order of 200 feet. Minor mudstone or siltstone layers were encountered within the Castlegate which consists of a fluvial, fine to medium-grained, thick bedded sandstone which exhibits both upwards and downwards crossing grain size. Depth measurements of the drill fluid levels (water and foams) in Holes T-1, 4, and 5 were in excess of 400 feet below the base of the Castlegate within a relatively short period after drilling. Drill fluid level in T-2 was measured at 125 feet below the Castlegate base due to bridging of the hole at that level. These appreciable depths, below the base of the Castlegate, of the drill fluids utilized indicate that secondary permeability and porosity, due to voids and open fractures, may occur essentially in a near-vertical direction.

The upper member of the Price River formation, which conformably overlies the Castlegate, consists of roughly 600 feet of thick-bedded to massive

sandstones of low to locally moderate porosity, regularly interlayered with 40% to 50% mudstones and silt-mudstone interbedded.

The Blackhawk formation is conformably underlain by the Star Point sandstone. Drill hole data (WM-E, Figure 7D-9) from the permit area indicates the Star Point is fine grained with occasional to common shale interlayers in its uppermost portion of the top 50 feet of the section. Below this 50-foot section, the Star Point grades to interlayered, fine silty sandstones, siltstones, and shale to an extensive section of siltstone, shale and claystone. A distinct break between the Star Point sandstone and the underlying Mancos shale could not be determined from the drill hole data.

The sandstone units encountered at the site and general area are generally low porosity with occasional areas of moderate and very minor areas of high porosity occurring.

The silty fine sandstones at the site and general area have low permeabilities. The siltstones, mudstones, claystones, and shales have very low permeabilities. Field observations indicate the joint systems and local bedding planes are the areas of highest permeability. Flow takes place along these surfaces and emerges randomly as seeps, or migrate downward via joint systems until trapped in laterally discontinuous sandstone lenses or until a laterally extensive impermeable formation is reached. The degree of rock fracturing in the Bear Canyon seam and overlying roof rock is relatively low based on visual observations of the rock quality within the mine and general lack of mine roof overbreak. Most fractures are not appreciably open or not extensively connected, as evidenced by outcrops in the permit area. Existing joint systems at the surface are enlarged by weathering and are expected to be healed or be essentially non-existent at depth. Thus, only minor, localized diversion of flow is expected to take place through the fracture with no

significant affect on regional flow patterns. The foregoing is exclusive of fault encounters by moving activities. These are not expected to occur, however, since known faults in the area trend essentially north-south, parallel to the direction of mining and interception by mining activities is not expected based on current information to date. It is noted that the fault interception by the access shaft encountered negligible amounts of water. The Aberdeen sandstone, inferred to be laterally persistent in the general area, occurs well above the Bear Canyon coal seam and is separated from it by an extensive section of relatively impermeable siltstones and mudstones. The lack of ground water encounters by the past and present mining activities indicate no hydraulic connection between the Aberdeen sandstone and the Bear Canyon seam, assuming the Aberdeen sandstone is water bearing.

7.1.3.2.2 AQUIFER RECHARGE, MOVEMENT, STORAGE, AND PIEZOMETRIC SURFACES

Base line information is generally lacking on the quantity of recharge and discharge from the aquifer system in the permit area. Published precipitation contours in the area indicate annual precipitation of 17 to 18 inches per year for the permit area. Evapo-transpiration is estimated to be on the order of three to four inches annually (Danielson, et. al., 1981). Surface runoff, based on a mean site elevation of 8000 feet and on the generally deeply incised nature of the permit area and the predominance of south-, east-, and west-facing slopes, is estimated to be 11 to 12 inches per year. These values correspond to estimates by others in the general area (Intermountain Consultants, 1977). Two and one-half inches average annual precipitation is thus available for recharge for 785-acre permit area resulting in an equivalent

65-acre feet per year. The large proportion of outcrops versus total surface of the permit area, in general, makes the outcrop and alluvium drainage channels the principal recharge courses within the permit area.

Ground water moves from recharge areas down gradient, controlled by the south- to southeast-sloping bedding attitudes and essentially south-trending drainage courses. Discharge of the ground water occurs as perennial seeps at deeper outcrop areas and at still deeper areas (lower elevations) where aquifers are intercepted by drainage channels. A contour map of the piezometric surface could not be prepared for the area due to the general lack of encounter of ground water in drill holes and the localized perched nature of visible ground water (mine roof seeps, surface seeps). Point measurements of water levels were made, however, together with approximate elevations of perched ground water occurrences and are presented in Table 7.1-1. Plate 3.4-1 identifies the site locations. The data indicates a distinct piezometric surface does not exist within the depths investigated at the permit area. Measurements of the static ground water encountered have been conducted over a four-month period (January to April) with no variation noted. Visible observations of the variability of the mine roof and outcrop seeps, as shown on Table 7.1-2, indicates a seasonal influence varying from direct response (outcrop seeps Seep-1, and Seep-2, Plate 3.4-1) to no response (mine seeps SU-1, SU-2, and SU-3, Plate 3.4-1). A more extensive data base concerning ground water encounters and their variation with time will be acquired through measurements in observation wells and drill holes and mining occurrences over the next several years. Floor, wall, and roof areas and the coal seeps within the mine are dry year-round with exception of the three roof areas (collected in the sump areas) shown on Plate 3.4-1. These areas, as previously indicated, are not affected seasonably and constitute the sole flow of ground

water into the mine. Recharge from each of these areas is on the order of three to five gpm. The sump area near the fault crossing the mine located approximately several hundred feet from the portal (Plate 3.4-1) receives most if not all of its recharge from an extensive area of very small roof seeps (individual drips) rather than from the fault.

The interpretation of the available data, in view of the area geology, suggests that the water in the rock units moves eventually south to southeast in the direction of the regional and local bedding dip. Three ground water flow conditions are hypothesized to exist at the site. The first condition occurs immediately or shortly after periods of high recharge and is expressed by surface seeps. Recharge from these seeps travels via vertical joint systems to bedding contacts or impermeable layers and flows downslope and laterally and emerges as seeps. A portion of these waters are presumed to eventually percolate downward and south to southeasterly, parallel to the bedding dip and eventually exist at the Bear Creek fault zone. Due to the extensive, impermeable units in the underlying area, the proportion of these ground waters is expected to be very low. The second condition is fault controlled and persists year-round. The large displacement (150 feet) of the Bear Creek fault or fault zone, the permeable zone created by faulting of at least a portion of the fault zone and the southeasterly component of the local and regional dips serves as a drain for ground water recharge, which occurs as perched zones, and also for downward and laterally migrating water obtained from surface percolation as mentioned in the first condition above. Appreciable amounts of surface water, percolating through stream channel alluvium is also believed to be drained by the Bear Creek fault zone. A portion of the ground water within the Bear Springs fault zone exits at Bear Springs through the hydraulic connection with a parallel fault through Bear

Springs. The third condition exists as local perched zones within the Blackhawk formation, expressed as mine roof seeps, which consist of laterally discontinuous lenses of sandstone or channel fill within the formation. Some hydraulic connection of these zones is believed to exist due to their relatively invarying volume flows. Permeability of the first two conditions is almost entirely secondary and is estimated to be on the order of several hundred feet per day. Permeability of the third condition is estimated to be mostly primary and to be very low, on the order of 10 to 20 feet per year.

No published estimates or quantitative data on the amount of water storage in the aquifer are available. The Castlegate sandstone, though exhibiting good porosity (approximately .22) and permeability characteristics, as determined by detailed geophysical well log interpretation and visual inspection, does not serve as a saturated or partially saturated aquifer in the permit area. Drill fluid levels (water with foam) have been determined to be 400 feet below the base of the Castlegate sandstone in four wells located one to two miles north of the mine. The Star Point sandstone, based on current drill hole data near the mine portal, also does not serve as a saturated or partially saturated aquifer. The Blackhawk formation, based on the four test holes located north of the site, (Drill Holes T-1, T-2, T-3, and T-5, Appendix 7-D) consist of approximately 30% generally discontinuous sandstone layers which may serve as perched, saturated to partially saturated zones. About one-third of the Blackhawk formation has been removed by natural drainage development in the mine area leaving approximately 520 acres of Blackhawk formation within the permit boundaries. Assuming dry to increasing saturation with depth of these sandstone lenses within the Blackhawk formation, an average 825-foot thickness for the Blackhawk formation in this area and based on relatively impervious, remaining intervening siltstone and mudstone layers, a storage

coefficient of 0.10 is assumed for this aquifer. This results in a storage of roughly 43,000 acre-feet within the Blackhawk formation in the mine area. The interception of ground water (roof seeps) by the mine workings is approximately three and one-half acre feet per year. The mining activities thus have no significant affect on the water storage in the principle aquifer (Blackhawk formation). The very low degree of hydraulic continuity between the mine workings and the Bear Springs faults results in essentially no impact on the ground water occurrence at Bear Springs.

7.1.3.2.3 AQUIFER WATER QUALITY - TDS, TSS, AND RELATED DATA

A water sampling program is currently being conducted at the mine and permit area. Additional samples have been collected during the course of this study from mine ground water sources, springs, surficial seeps, and test holes. Selected results of chemical quality analysis of these samples collected to date are presented in Table 7.1-1. The chemical characteristics of the ground water and surface water in the permit and adjoining areas are quite uniform in the parameters analyzed with the exception of higher suspended solid content in the surface waters. It is noteworthy that sulfate contents are lowest in the Bear Springs as compared to the surface water (Bear Creek) which is in contact with an appreciable section of the Star Point sandstone and its lower reaches. Danielson (1981) states that water derived from the Star Point formation is higher in sulfate content than the overlying rock units. This further indicates the Bear Springs supply is not derived from the Star Point-Blackhawk aquifer.

7.1.3.2.4 WELLS AND USERS

Figure 7-1.1 presents the locations of springs and wells in and adjacent to the mine plan area. All of the wells identified are observation wells or exploration wells owner by Co-op Coal Company and Nevada Power & Light, respectively.

7.1.4 GROUND WATER DEVELOPMENT AND MINE DEWATERING

No development of ground water through existing or future wells is planned within the mine permit area. Extensive use of ground water near the permit area consists of Bear Springs whose entire flow is diverted for culinary use by the community of Huntington, Utah. Birch Springs located southwest of the permit area flows uncontrolled into Huntington Creek. Intermittent activities for development of this spring for culinary water are being conducted by the Huntington community.

No dewatering of the mine aquifer is now contemplated. Water is pumped out intermittently from the water storage tank which obtains water from the sump located several hundred feet within the mine from the portal. The maximum flow is about 50 gpd and is discharged onto the surface and drains into Bear Creek through the sedimentation pond. A NPDES permit has been acquired for this purpose. This permit does not specifically limit the quantity of mine water discharge. The remaining two sumps within the mine are used regularly for dust control and discharge from these mine sumps has not been required in the past or is contemplated within the future. If additional ground water is not encountered as mining progresses, the current discharge from the mine to the surface will be utilized for dust control purposes.

7.1.5 AFFECTS OF MINING OPERATIONS ON THE GROUND WATER HYDROLOGIC BALANCE

The mining operations will be confined to coal-bearing strata within the basal portion of the Blackhawk formation. The coal strata are generally dry and are part of an undeveloped regional aquifer system which consists of a series of generally discontinuous perched water zones within the Blackhawk formation. Overlying and underlying formations are unsaturated. Negligible to no impacts are anticipated by mining activities in the permit area on the regional aquifers or existing ground water development areas.

7.1.5.1 QUANTITY

Mining affects on water quantities consist of interceptions of local perched zones, collected as sumps within the mine and diverted for dust control or discharge into Bear Creek. These waters, if undisturbed, would flow southeasterly and eventually be intercepted by the Bear Creek fault zone. Hydraulic continuity is expected between this fault and at least a portion of the Bear Creek drainage. The ground water quantities thus intercepted are small (total estimated 12 to 15 gpm) in relation to the storage of the aquifer system in the mine lease area. In effect, the ground water not required for dust control for mining purposes is returned to the surface water and ground water regime shortly after discharge from the mine. It is noted that the very low production of ground water from the aquifers intercepted makes well development uneconomical and such development unlikely.

It is possible for some fractures to develop or open at the consequence of subsidence subsequent to mining operations. A tightening of some fractures

or joints will also occur due to the compression affects associated with a portion of the subsidence mechanism. The reclamation plan proposes to control post-mining subsidence. It is planned that no subsidence will occur in a varying 100- to 200-foot wide corridor from outcrop areas. Subsidence in the rest of the mining area is expected to be on the order of 0.5 to 1.0 feet. Some localized diversion and interception of the present ground water flow is anticipated due to the subsidence. Considering that (a) both development and tightening of existing fractures will occur and that (b) plastic flow of the intercalated claystone-shale layers, in response to unbalanced compressional and tensile forces, will occur thereby sealing or partially sealing some fractures due to subsidence, the impacts on the regional ground water flow and regime are expected to be of short duration and insignificant.

7.1.5.2 QUALITY

No significant degradation of ground water quality is expected in the mine lease and adjacent areas due to coal mining activities as being practiced. As previously stated, the coal mining operations have been and are expected to be generally dry. The areas of water contact with contaminants is thus through mine water sumps. Unused portions of these waters could percolate through the mine floor through fractures and into the underlying silty fine sandstone (35 to 50 feet thick). The permeability through this sandstone, due to its fine silty nature, is estimated to be on the order of 10^{-4} cm/sec. Shale layers encountered by the drill hole near the mine portal (Drill Hole WM-E) will further reduce overall permeability within this sandstone layer. The water quality data presented on Table 7.1-3 shows that the mine sump waters are well within the range identified for other ground water occurrences in the mine

area and are of overall high quality. Noting that the bedding dip in the mine area has a strong easterly component, (from mine plan elevations) the eventual migration of these sump waters downward and eastward to the Bear Creek fault will not have a detectable impact on the quality of the ground water transported southerly along the Bear Creek fault zone.

7.1.6 MITIGATION AND CONTROL PLANS

No treatment of ground water occurrence in the mine or other control measures are planned. This is due to the observations in the preceding section that no significant impact on ground water quality is anticipated from mining operations.

No impact on the ground water supply (depletion), contamination or other interference is expected. No ground water rights are affected. Consequently, no need for the provision for alternate water supplies have been identified.

The only interference of the ground water regime by the mining activities to date is the interception of local perched zones within the Blackhawk formation and the surface discharge of a portion of these waters of the mine portal. The remaining waters intercepted continue to slowly percolate downward through the mine floor, relatively unaffected by their interruption. The extent of these water volumes and their quality were discussed in Sections 7.1.5.1. and .2. No action to curb or otherwise treat inflows to the mine are now contemplated.

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7.1.7 GROUND WATER MONITORING PLAN

Monitoring activities will focus on determining water levels, discharge and water quality fluctuations in relevant aquifers or ground water occurrences in the mine area. Data will be collected from mine roof seeps and sumps, future encounters, if any, by drill holes within the mine, observation wells and springs. Procedures to correlate ground water discharge and contamination of Bear Creek will also be used, following procedures by Waddell, et. al., (1983). The objectives of the monitoring plan are to (1) identify potential impacts during and after mining, and (2) provide on-going base line data on aquifer characteristics and ground water occurrences.

Four ground water sites are presently being monitored. These are shown on Plate 7-4a, as GW-1 (Mine Sump - Underground), GW-2 (Portal Drillhole), GW-3 (Formerly called Well #6), and GW-4 (Near the Co-Op Development Spring). The sites will be monitored per the schedule and for the parameters listed in Table 7.1-4.

The monitoring activities will be timed to determine the approximate seasonal variations with time for the piezometric heads and water volumes encountered and water quality parameters, for the declining and rising limbs of the annual weather cycle. It is proposed that samples will be collected at about February 1, May 1, August 1, and November 1, at all sites. In addition to these monitoring activities, data shall be routinely collected at all new drill holes and other encounters in the mine, where significant in-flows are encountered.

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Springs below the mines will be sampled to determine discharge and water quality parameters and their possible variation with time. These springs include Bear Springs, COP Development Springs, and Birch Springs (Plate 3.4-1). Water quality parameters to be measured are listed in Table 7.1-4. However, periodic checks will be made of the mine area to determine any possible impacts not currently expressed at the surface. This information will be used to estimate seasonal fluctuations, aquifer recharge, and consistent long-term changes and to confirm the formations contributing to spring flow.

The water levels in the mine sumps (Plate 3.4-1), will be recorded quarterly by level measurements and water samples submitted for quality analysis to a qualified laboratory. This information will be used to assess leakage rates and possible contamination. As mining progresses, three observation wells (WM-F, G, and H) will be drilled through the underlying Hiawatha coal seam, at the base of the Blackhawk Formation and a minimum of 25 feet into the underlying Star Point sandstone formation. These well locations are identified in Plate 3.4-1. Locations of these wells are approximate and site conditions and mine personnel will determine their exact locations. These stations are not located in the present permitted area; however, if the mining should progress into this area in the future, the holes will be drilled at that time. The purpose of these wells will be for the collection of piezometric surface and water quality data, as encountered. These three wells are located in areas of projected mining activity and will be drilled upon approval of these monitoring sites. These wells are located such as to determine the extent or occurrence

of ground water within the depths of impact of the mining activities on the ground water regime. Any ground waters encountered by these wells will be sampled and will be used to correlate with the water quality data from Bear Springs, Birch Springs, and COP Development Spring to provide a check on estimates of ground water contamination. These springs are focused on since their flow is the sole use of ground water to be possibly affected by the mining activities.

The existing and proposed data collection wites selected are expected to provide a representative cross section for hydrologic data across the mine area based on the flow directions projected.

An Annual Hydrologic Monitoring Report will be submitted yearly to DOGM summarizing water quality and quantity data gathered during the monitoring activities outlined above. In addition, the report shall include a yearly update of the mine inflow survey which incorporates a mine workings map identifying all wet areas of the mine and the type of inflow (seep, fractures, etc.).

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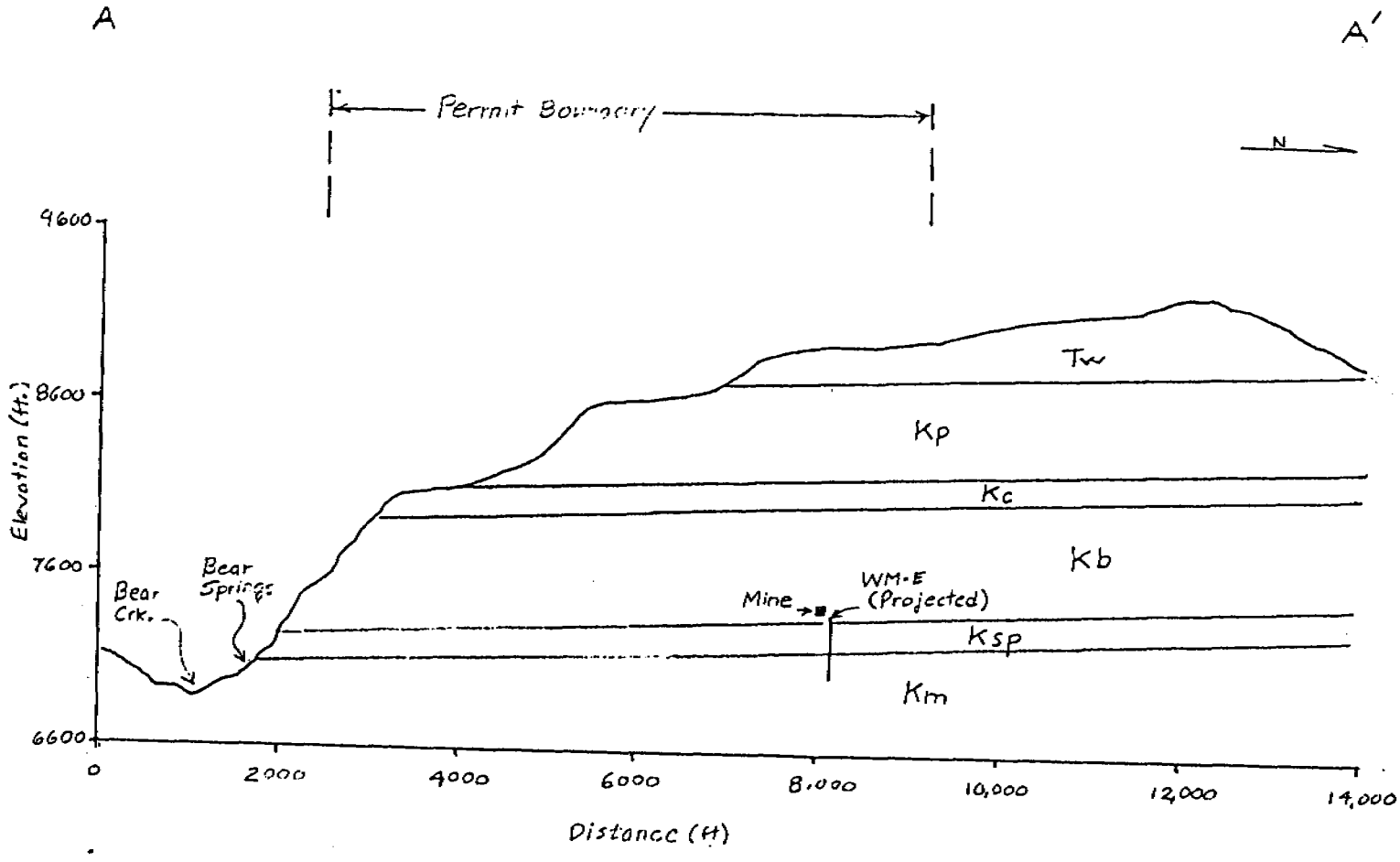
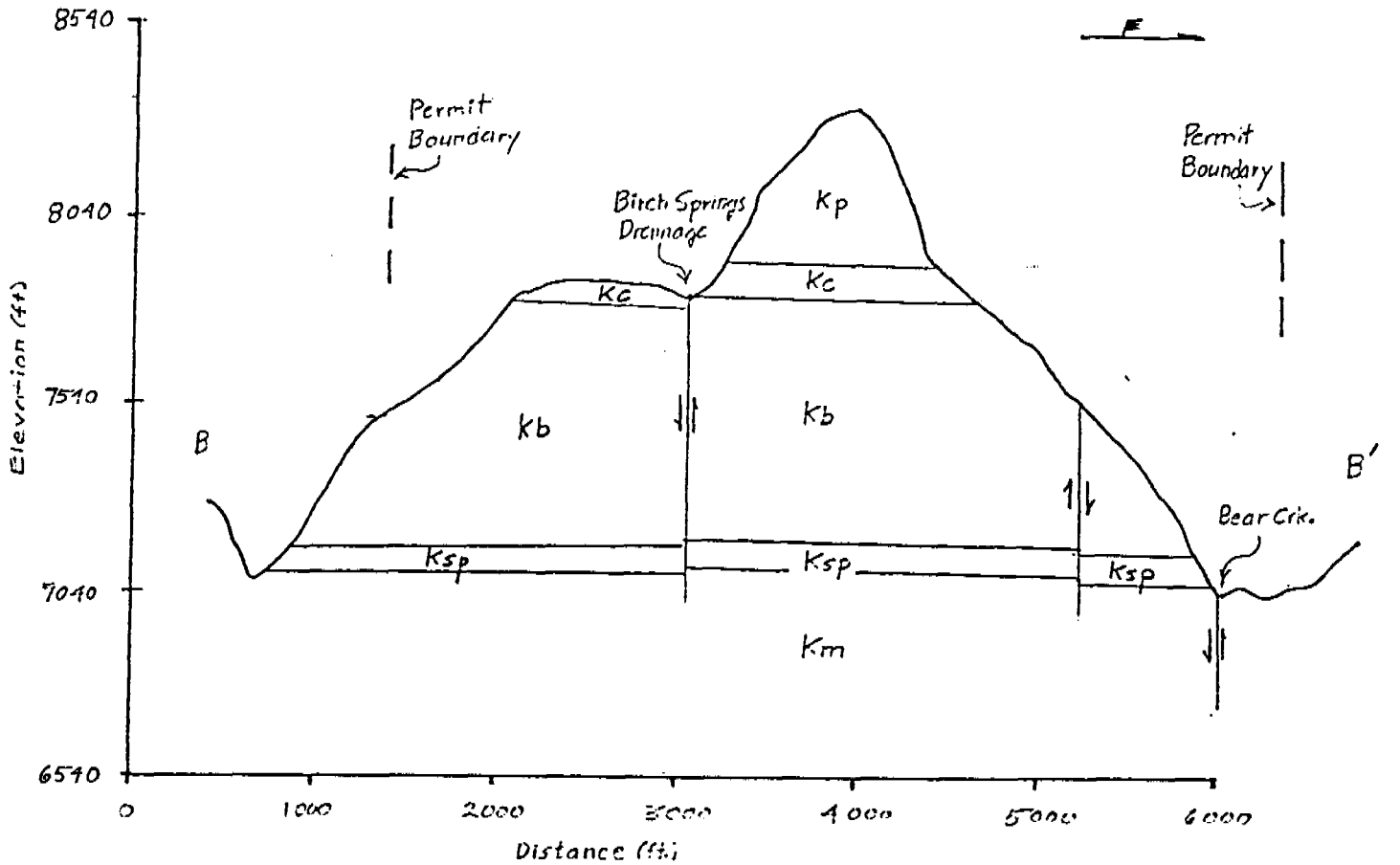


Figure 7.1-1

STRATIGRAPHIC SECTION A-A'



STRATIGRAPHIC SECTION B-B' Figure 7.1-2

System	Series	Formations and members	Thickness (feet)	Lithology and water-bearing characteristics
Quaternary	Holocene and Pleistocene		0-100	Alluvium and colluvium; clay, silt, sand, gravel, and boulders; yields water to springs that may cease to flow in late summer.
Tertiary	Eocene and Paleocene	Flagstaff Limestone	10-300	Light-gray, dense, cherty, lacustrine limestone with some interbedded thin gray and green-gray shale; light-red or pink calcareous siltstone at base in some places; yields water to springs in upland areas. (See table 9.)
	Paleocene	North Horn Formation	800±	Variegated shale and mudstone with interbeds of tan-to-gray sandstone; all of fluvial and lacustrine origin; yields water to springs. (See table 9.)
Cretaceous	Upper Cretaceous	Price River Formation	600-700	Gray-to-brown, fine-to-coarse, and conglomeratic fluvial sandstone with thin beds of gray shale; yields water to springs locally.
		Castlegate Sandstone	150-250	Tan-to-brown fluvial sandstone and conglomerate; forms cliffs in most exposures; yields water to springs locally.
		Blackhawk Formation	600-700	Tan-to-gray discontinuous sandstone and gray carbonaceous shales with coal beds; all of marginal marine and paludal origin; locally scour-and-fill deposits of fluvial sandstone within less permeable sediments; yields water to springs and coal mines, mainly where fractured or jointed.
		Star Point Sandstone	350-450	Light-gray, white, massive, and thin-bedded sandstone, grading downward from a massive cliff-forming unit at the top to thin interbedded sandstone and shale at the base; all of marginal marine and marine origin; yields water to springs and mines where fractured and jointed.
		Masuk Member Mancos Shale	600-800	Dark-gray marine shale with thin, discontinuous layers of gray limestone and sandstone; yields water to springs locally.

* General Stratigraphic Relationships of Geologic Units in Bear Creek Permit Area

* Fron Danielson, et. al. (1981)

Figure 7.1-3

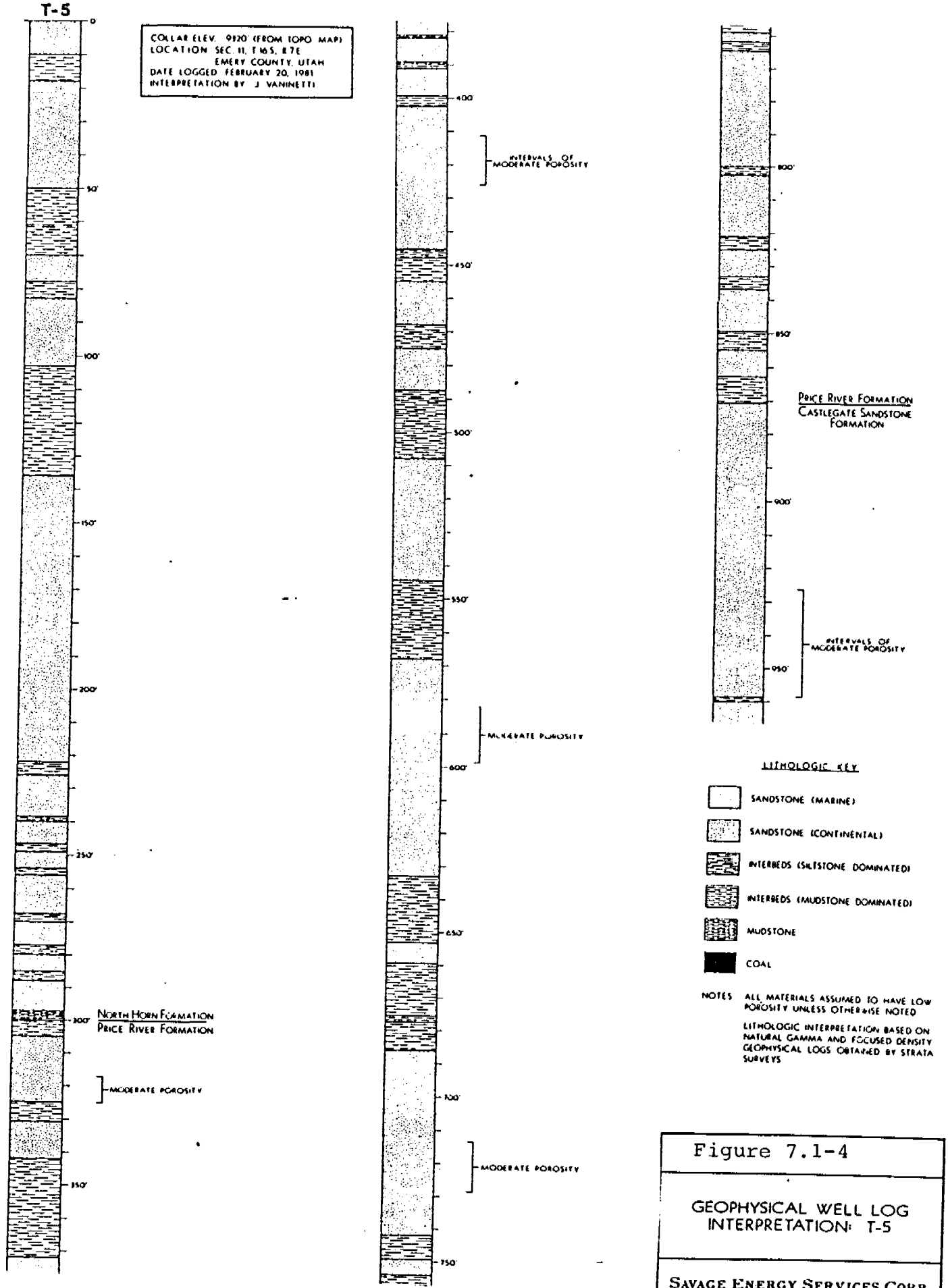


Figure 7.1-4

GEOPHYSICAL WELL LOG INTERPRETATION: T-5

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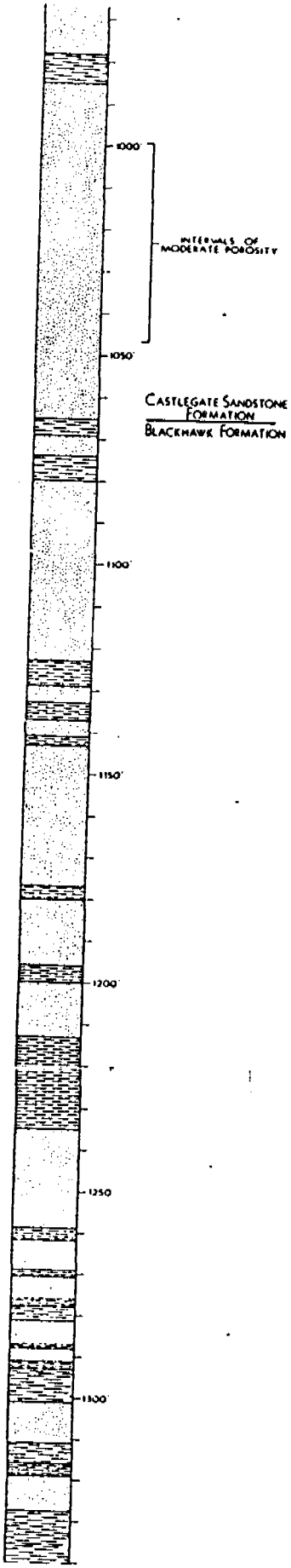
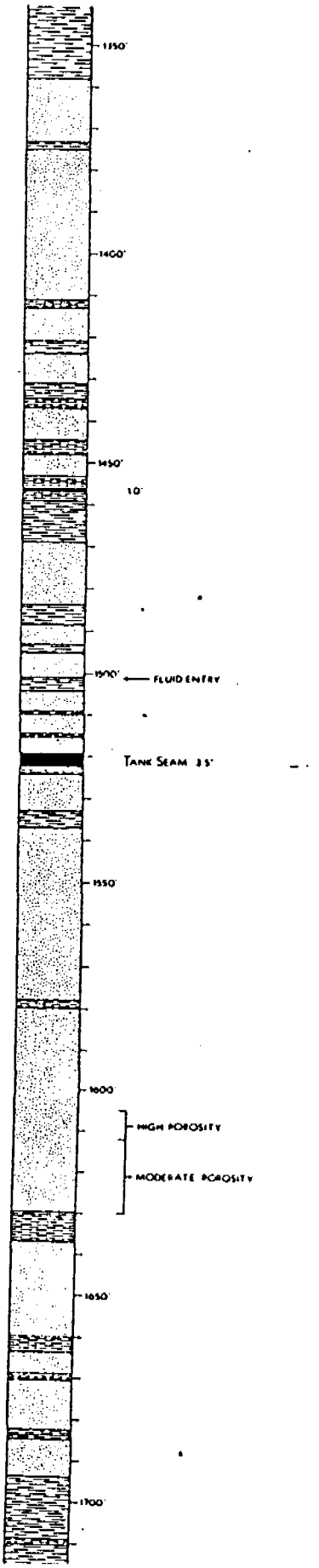

1000'
INTERVALS OF MODERATE POROSITY
1050'
CASTLEGATE SANDSTONE FORMATION
BLACKHAWK FORMATION
1100'
1150'
1200'
1250'
1300'


1350'
1400'
1450'
10'
1500'
FLUID ENTRY
TANK SEAM 35'
1550'
1600'
HIGH POROSITY
MODERATE POROSITY
1650'
1700'

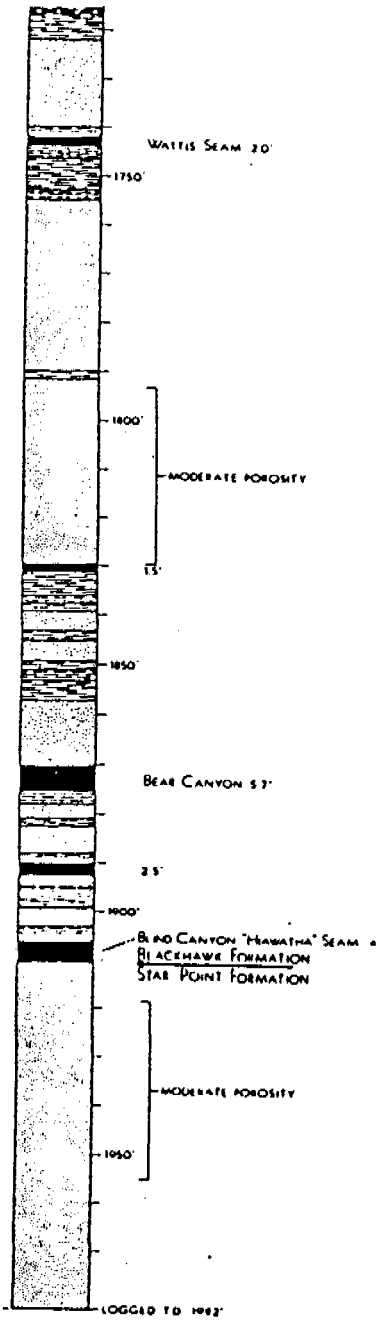
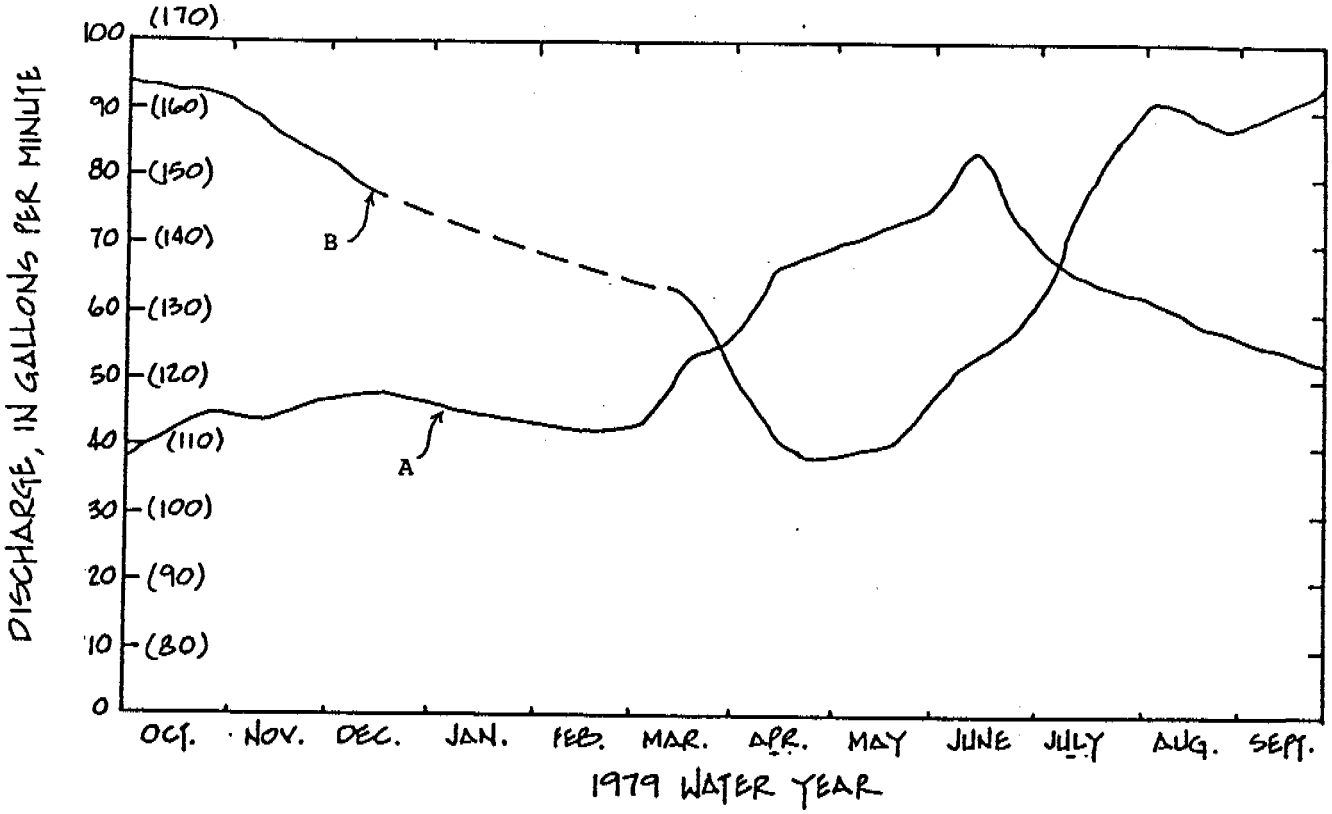

WATTIS SEAM 20'
1750'
1800'
MODERATE POROSITY
15'
1850'
BEAR CANYON 57'
25'
1900'
BLIND CANYON "HIAWATHA" SEAM
BLACKHAWK FORMATION
STAR POINT FORMATION
MODERATE POROSITY
1950'
LOGGED TD 1982'

Figure 7.1-4A

Discharge (gpm) - Curve A
Discharge (gpm) - Curve B



Curve A: Discharge of Spring (D-17-6) 23aaa-51, Water Year 1979 (Danielson, et. al., 1981)*

Curve B: Discharge of Bear Creek Spring, 1983-84.

* Presented by Danielson, et. al., as representative of springs issuing from Star Point-Blackhawk aquifer.

DWN.	R&M CONSULTANTS, INC. ENGINEERS GEOLOGISTS PLANNERS SURVEYORS	FLOW CHARACTERISTICS OF REPRESENTATIVE STAR POINT-BLACKHAWK AQUIFER AND BEAR SPRINGS	FB.
CKD.			GRID.
DATE.			PROJ.NO. 461082
SCALE.			DWG.NO.

Figure 7.1-5

TABLE 7.1-1

SELECTED CHARACTERISTICS OF AREA SPRINGS, SEEPS

Site	Elevation (feet)	Geologic Unit	Discharge (gpm) Min.	Max.	Number of Measurements
Bear Springs	7120	Fault Zone [1]	110	165	13[2]
COP Dev. Springs	7140	Fault Zone [1]	---	---	---
Birch Springs	6860	Fault Zone [1]	9.3	23	11[2]
Seep-1	7350	Blackhawk	0	<1	3[3]
Seep-2	7520	Blackhawk	0	<1	2
S-1	7450	Blackhawk	4-5	4-5	2
S-2	7480	Blackhawk	4-5	4-5	2
S-3	7490	Blackhawk	4-5	4-5	2

1 = Issues from colluvium, nearest bedrock outcrop is Star Point Sandstone.

2 = From Danielson, et. al (1981).

3 = Based on visual estimate due to inaccessibility.

TABLE 7.1-2
WATER LEVEL MEASUREMENTS

Site	Elevation (feet)	Water Level Elev. (ft.)	Discharge (gpm)	Drill Hole Depth (ft.)	Comments
1u	7497	None	--	200	Drilled vertical into mine roof
1d	7490	None	--	170	
2u	7492	None	--	200	Drilled vertical into mine roof
6d	7475	None	--	100	
7d	7465	None	--	100	
9d	7475	None	--	100	
11d	7320	None	--	20	
WM-A	7486	None	--	25	Drilled 45° up from horizontal into working face
WM-B	7493	None	--	60	
WM-C	7130	None	--	50	
WM-D	7220	None	--	46	
WM-E	7430	None	--	400	

Note: Holes 3, 4, 5, 8, and 10 not drilled.

TABLE 7.1-3
WATER QUALITY DATA

Date	TDS	TSS	Acidity (as $CaCO_3$)	Alkalinity (as $CaCO_3$)	Ca	Mg	Fe (dis.)	Na	K	HCO_3	SO_4	Cl	Nitrate	Ph	Flow (gpm)
10/84* (Sump Su-3)	300	5	0	234	36	36.0	.19	29.2	4.43	285.5	55	8.0	.06	7.3	---
10/84* (Roof Drips Above Sump Su-3)	380	17	0	314	60	38.4	.12	19.2	3.65	383.1	40	2.0	.03	7.3	3-5 gpm
2/85 (Roof Drips Above Sump Su-1)	235	1	0	216	46	35.0	.03	3.0	1.4	---	66	4.0	.06	8.1	3-5 gpm
10/84* (Su-1)	362	11	0	254	80	21.6	.33	26.0	0.97	309.8	27	50.0	.24	7.4	---
11/84 (Su-1)	175	54	5	141	15	36.0	.06	4.0	1.5	---	43	3.0	.22	8.4	---
12/84 (Su-1)	285	4	7	220	45	38.0	.09	6.0	1.6	---	56	4.0	.02	8.4	---
1/85 (Su-1)	320	16	0	209	43	36.0	.02	7.0	1.6	---	60	4.0	.02	7.9	---
11/84 (Up. Bear)	415	1620	0	200	43	57.0	4.8	8.0	3.5	---	161	4.0	.47	8.1	26.0
12/84 (Up. Bear)	405	862	0	209	63	59.0	7.4	8.0	5.8	---	158	5.0	.86	8.2	18.0
2/85 (Up. Bear)	485	1170	0	221	56	60.0	5.13	10.0	4.1	---	191	5.0	.48	8.0	---
10/84* (L. Bear)	375	1345	0	200	50	50.4	19.8	7.1	5.77	244.0	116	20.0	.14	8.1	---
11/84 (L. Bear)	160	2190	0	95	22	25.0	4.14	4.0	2.3	---	64	1.0	3.41	8.3	26.8
12/84 (L. Bear)	405	1080	0	207	47	56.0	8.95	8.0	3.6	---	163	5.0	.33	8.2	18.0
2/85 (L. Bear)	505	154	0	223	56	62.0	.92	11.0	4.3	---	202	5.0	.46	8.3	---
2/85 (Well WM-C)	320	46	0	269	68	29.0	.09	5.0	1.2	---	27	3.0	.21	8.2	---
10/84 (Bear Sp.*)	362	11	0	254	80	21.6	.33	26.0	.97	309.8	27	50.0	.24	7.4	---
10/84 (Birch Sp.*)	440	6	0	310	64	58.8	.12	12.2	1.97	378.2	80	30.0	.04	7.9	---

*Water Samples Analyzed at Control Lab.

000030

TABLE 7.1-4

GROUND WATER BASELINE AND OPERATIONAL
WATER QUALITY PARAMETER LIST

Field Measurements:

*	-	Water Levels or Flow
*	-	pH
*	-	Specific Conductivity (umhos/cm)
*	-	Temperature (C^o)

Laboratory Measurements: (mg/l)

*	-	Total Dissolved Solids
*	-	Total Hardness (as $CaCO_3$)
	-	Aluminum (Al)
	-	Arsenic (As)
	-	Barium (Ba)
	-	Boron (B)
*	-	Carbonate (CO_3^{-2})
*	-	Bicarbonate (HCO_3^-)
	-	Cadmium (Cd)
*	-	Calcium (Ca)
*	-	Chloride (CL^-)
	-	Chromium (Cr)
	-	Copper (Cu)
	-	Fluoride (F^-)
*	-	Dissolved Iron (Fe)
	-	Lead (Pb)
*	-	Magnesium (Mg)
*	-	Manganese (Mn)
	-	Mercury (Hg)
	-	Molybdenum (Mo)
	-	Nickel (Ni)
	-	Nitrogen: Ammonia (NH_3)
	-	Nitrate (NO_3^-)
	-	Nitrate (NO_2)
*	-	Potassium (K)
	-	Phosphate (PO_4^{-3})
	-	Selenium (Se)
*	-	Sodium (Na)
*	-	Sulfate (SO_4^{-2})
	-	Sulfide (S^-)
	-	Zinc (Zn)

-Baseline
*Operational

TABLE 7.1-4

(cont'd)

GROUND WATER SAMPLING

	Baseline	Operational	Postmining
Type of Sampling Site	Spring, In-Mine, Borehole, Observation Well	Spring, In-Mine, Borehole, Observation Well	Spring, Observation Well
Field Measurements (See Table 1)	Yes	Yes	Yes
Sampling Frequency Each Site	Four Total at Monthly Increments Per Annum	Quarterly for In-Mine; Four Total at Monthly Increments Per Annum for Other Sites	One Per Annum; Springs at Low Flow
Sampling Duration	Two years (One Complete Year of Data Before Submission of PAP)	Yearly Until Reclamation Initiated	Yearly Until Termination of Bonding
Type of Data Collected and Reported	Water Levels and/or Flow and Water Quality	Water Levels and/or Flow; One Water Quality Sample at Low Flow	Water Levels and/or Flow and Water Quality Per Operational Parameters
Comments	Spring and Seep Inventory Taken First Year and Every Fifth Year Year Preceding Re-permitting	Every Fifth Year Preceding Re-permitting; One Water Quality Sample at Low Flow Per Baseline Parameters	

N

Birch Springs

Bear Springs

COP DEV. Springs

Seep 1

Seep 2

Qal

Ksp

Kb

Kc

Kp

Tw

WM-A

WM-B

WM-C

WM-D

WM-E

WM-F

WM-G

WM-H

A

A'

B

B'

C

C'

D

D'

U

D

Creek

Canyon

Qal — Alluvium - Limited deposits of silts and sand with cobbles and boulders of sandstone, confined to drainage bases, most extensive but of short lateral and vertical extent along Bear Creek drainage where narrow intermittent flood plain deposits are included. Includes adjoining talus/colluvial deposits.

Tw — North Horn Fm. - Predominantly shales with common irregular beds and lenses of sandstone of varying texture and occasional thin limestones, minor, erratic conglomerates. Contact with Price River Fm. generally poorly defined. Approximately 1,500 feet thick.

Kp — Price River Fm., Upper Member - Thick bedded to medium bedded friable medium-grained sandstone with common to occasional interbedded brown to carbon shale, weathers step like. Approximately 650 feet thick.

Kc — Price River Fm., Lower Member (Castlegate Ss.) - Massive cliff forming sandstone, medium to locally coarse grained with grit matrix, contains occasional gray shale layers. Approximately 175 feet thick.

Kb — Blackhawk Fm. - Thick to massive cliff forming sandstones, fine to medium grained, well cemented with slopes forming clay to carbon shales comprising 1/3 to 1/2 interbedding of total thickness. Sandstones predominant in lower portion which also contains most coal beds. Approximately 725 feet thick.

Ksp — Star Point Ss (Storrs Member) - Thick, generally massive cliff forming sandstones, fine to medium grained, tan, with occasional separations by thin shale, siltstone layers. Approximately 120 feet thick.

- Permit Boundary
- Approximate formation contact.
- Approximate fault contact, with relative displacement shown.
- Vertical/steeply dipping joint(s).
- Bedding attitudes.
- Spring.
- Drill Hole; cuttle = indicates location (Con. Well; blue arrow road; d indicates approximately 50' below hole).
- Contour Interval = 80 ft.
- Proposed Observation Well
- Intermittent Seep
- Surface Projection of Mine Seep and related coordinate area

2/15/87

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33

P&M CONSULTANTS, INC.
ENGINEERS PLANNERS SURVEYORS GEOLOGISTS
[illegible] SOUTH 200 WEST, SUITE B-100
MURRAY, UTAH 84107 (801)262-8410

CO-OP MINING CO.
HUNTINGTON, UTAH

GEOLOGIC MAP

SCALE	DRAWN BY	DATE
1"=1000'	L.S.	1/1/85

BEAR CANYON | PLATE 3.4-1

7.2 SURFACE WATER HYDROLOGY

7.2.0 SCOPE

The purpose of this section is to provide background information on the surface hydrology characteristics of the Co-op Mining Company's Bear Canyon Mine permit area and the surrounding regional area. Also to present a plan of action for complying with the requirements of the Office of Surface Mining (OSM) and the Utah Division of Oil, Gas and Mining (DOGM). In particular, this section includes an evaluation of the geological and hydrological setting of the mine, its relation to the regional ground water and surface water hydrology and its probable impact on the groundwater and surface water systems.

Information from field reconnaissance and a review of data from various sources was used in compiling this surface water hydrology section. The data sources included information from the Co-Op Mining Company, reports by the U. S. Geological Survey, Utah Geological and Mineral Survey, U. S. Forest Service and mine application permits on file with OSM (specifically those in the Huntington Canyon area).

7.2.1 REGIONAL AND ADJACENT AREAS

The San Rafael River Basin of the Upper Colorado River Region is generally classified as an arid basin. The upper drainages along the

Wasatch Plateau receive enough snow precipitation to be classified as semi-arid to sub-humid with the amount of precipitation increasing with altitude.

There are eight major reservoirs in the basin. Seven are mainly for irrigation with a total capacity of 85,000 acre-feet and one, with a capacity of 30,530 acre-feet, is used as the water supply for a power plant. Diversions during irrigation season, April to November, from Huntington, Cottonwood, and Ferron Creeks nearly deplete flows downstream from these diversions. The flows downstream during this period are mainly irrigation return flows along with some groundwater seepage.

At points of major diversions on the Huntington, Cottonwood, and Ferron Creeks the water quality is excellent for irrigation, with dissolved-solids concentrations of less than 500 milligrams per liter. But water at the mouths of these creeks has markedly larger dissolved-solids concentrations. This is mainly due to two factors: 1) in the area between major diversions and the mouths of the creeks, they cross a belt of exposed Manos Shale 10 to 15 miles wide, 2) this area is also where practically all the intensive irrigation in the San Rafael River Basin is practiced. (Mundoff,'82)

The upper drainage of Huntington Creek encompasses about 200 square miles of mountainous country in the Wasatch Plateau. About 90 percent of the area is higher than 8,000 feet. The average channel gradient along the stream in the area is about 100 feet per mile. In its lower reaches the stream is in deep, narrow canyons, and surface relief between the

stream channel and the top of adjacent canyon walls is typically 2,000 feet or more. (Danielson,'81)

7.2.1.1 QUANTITY AND QUALITY OF SURFACE WATER

According to Danielson, "...about 65 percent of the annual discharge at the Huntington Creek station (0931800) occurs during the snowmelt period (April-July). Because most of the streamflow is derived from snowmelt, annual discharge at the gaging station correlates well with the April 1 snowpack water content," as shown in Figure 7.2-1. Figure 7.2-2 shows the discharge rate into Huntington Creek of the Tie Fork and Crandall Canyon streams, both major tributaries to Huntington Creek. Approximately 80 percent of the discharge from these streams is during the snowmelt from April to July. Table 7.2-1 is provided to show discharges on a daily basis for a few years, water years 1966-70 (Water Supply Paper #2125).

As part of the Danielson study, chemical analyses were performed on selected surface water samples from the area. Table 7.2-2 is a tabulation of the results. It should be noted that none of the analyzed chemical constituents were found in concentrations that exceeded the drinking water standards of the U. S. Environmental Protection Agency (1976). Danielson also noted that, "The predominant dissolved chemical constituents in water in Huntington Creek upstream from gaging station 0931800 were calcium and bicarbonate...The predominant dissolved chemical constituents in water in tributaries to Huntington Creek were usually calcium, magnesium, and bicarbonate. However, during periods of base flow the concentrations of

sulphate in water at the mouths (of the tributaries)...were significantly higher than sulphate concentrations in water in Huntington Creek...Water from the Star Point commonly contains slightly higher concentrations of both dissolved solids and sulphate than water from younger rocks in the area."

7.2.1.2 WATER USES

Most of the surface water from the drainage is diverted for use as crop irrigation. The only other major use is supply water to the Huntington Powerplant. The reservoirs in the area have been built to supplement this use. Some water in the area, particularly springs, is used for livestock watering or as culinary water.

Water rights have been obtained by Co-op Mines in sufficient quantities for all of the mine's needs. Appendix 7-C contains a listing of water rights in the area and Plate 7-6 indicates their various locations.

7.2.2 MINE PLAN AREA SURFACE WATER

The channel of Bear Creek is straddled by the mine plan area with the vast majority of the area, disturbed and undisturbed, west of the creek. Bear Creek is a perennial stream with flows often frozen during the winter. An intermittent tributary flows into Bear Creek from the east in the mine plan area, but this tributary does not pass through any disturbed area.

The Bear Canyon Springs' discharge is diverted by pipeline to Huntington City, never becoming "surface water." The different discharge characteristics of Bear Canyon Spring and Bear Creek denote the differences of their sources. Bear Canyon Spring which issues from the Star Point Sandstone has had relatively high, constant discharges rates, between 110 and 160 gpm (see Table 7.2-3), without predominant seasonal changes typical of a snowmelt impact. On the other hand, measurements at the mouth of Bear Creek made during the Danielson study indicate a significant impact to streamflow from snowmelt, between 18 and 153 gpm (see below),. The headwater springs of Bear Creek issue from the North Horn Formation, a locally recharged water zone. The Star Point Aquifer is a regionally recharged aquifer which explains the consistency of Bear Canyon Springs flows.

Streamflow measurements made during 1977-79

(Danielson,'81)

	Date	Discharge (cfs)
Bear Creek (site no. 81)	8-10-78	.09
	10-25-78	.08
	11- 8-78	.06
	12-13-78	.04
	6-27-79	.34
	7-16-79	.21
	10-30-79	.05

Measurement of suspended sediments were collected during the Danielson study. Below are the results from selected tributaries of Huntington Creek.

Stream	Site No.	Date	Concentration (mg/l)	Load (tons per day)
Huntington Creek (gaging station 09318000)	88	8-13-78	104	27
		11-17-78	72	2.5
		6-13-79	114	66
		8- 7-79	44	15
Crandall Canyon (gaging station 09317919)	51	8-12-78	49	.14
		11-18-78	60	.08
		6-14-79	15	.41
		8- 6-79	56	.15
Tie Fork Canyon (gaging station 09317920)	67	8-13-78	12	.03
		11-18-78	57	.12
		6-14-79	38	.68
		8- 6-79	66	.17
Bear Creek	81	10-25-78	8,860	1.9
		6-14-79	2,140	4.0
Deer Creek	87	6-14-79	609	3.1

Concerning the unusually high sediment loads in Bear Creek, Danielson stated the following:

> "Bear Creek transported large quantities of suspended sediment during 1978 and 1979. Springs emerging from the North Horn Formation in the headwaters of Bear Creek continuously erode the shales and mudstone and permit sloughing of large amounts of fine-grained material from the escapements."

As part of Co-Op Mining Company's monitoring program, water samples from Bear Creek, both above and below the mine plan area, have been chemically analyzed for the past 1½ years. The results are presented in Table 7.2-4. During the snowmelt (April-July) there is an increased in suspended sediments, as expected, due to the increased flows. The reasons for such poor quality water and changes in chemical concentrations are not

understood at this time. Further monitoring will be necessary before any conclusions can be drawn.

7.2.3 EFFECTS OF MINING ON SURFACE WATER

The operation of Bear Canyon Mine by Co-Op Mining Company is expected to have only a very minimal effect on surface water on the area. The quality of Bear Creek before passing through the mine plan area is poor. After passing through the mine area, as often as not, the quality is improved or unchanged. Generally, there is little difference in the surface water quality after passing through the mine site area. The greatest impact of mining operations is probably an increase in sediment loading to Bear Creek. Several control and diversions structures have been constructed to prevent sediment laden water from the roads and disturbed area from mixing with local surface water, to minimize the mining impacts on the receiving stream waters.

The headwater springs of Bear Creek are to the north and east of the mine plan area. Since groundwater movement in the area is in a southerly direction, any mine dewatering, which should be minimal, would have little or no effect on quantity or quality of flows in Bear Creek.

7.2.4 MONITORING PLANS

In the past, Co-Op Mining Company has monitored two stations on Bear Creek, one above (north) the mine plan area and one below (southwest). The monitoring location above the mining area is approximately 3000'

upstream from where the mine road crosses Bear Creek in the mine plan area. The monitoring location downstream is a Weir W-4. In addition to these a third monitoring location is being added. In the future the right-hand tributary of Bear Creek will be monitored just above its confluence with Bear Creek. (see plate 7-4)

Monitoring of the following parameters will be performed monthly: flow (gpm), ph, temperature (°C), total dissolved solids (mg/l), iron , magnesium potassium, chloride, nitrate sulphate, carbonates, bicarbonates, calcium, magnesium, sodium and total suspended solids (all in mg/l). On a quarterly basis the parameters list in Table 7.2-6 will be measured.

Flows will be determined by direct measurement (depth times width times 2/3 velocity) or, whenever feasible, by timed filling of a unit volume container. Chemical analyses will be performed by a certified laboratory. Reporting format will be as shown in Figure 7.2-3.

7.2.5 SURFACE WATER CONTROL AND DIVERSIONS

The vast majority of the disturbed area of the Bear Canyon Mine is on the west side of Bear Canyon (same side as the mine portal and to the south). The all run-off from this west side disturbed area is collected and channelled to Sedimentation Pond "A". The small amount of run-off from the disturbed area east of Bear Creek is channelled to Sedimentation Pond "B". In order to minimize the amount of water crossing the disturbed area, run-off from the undisturbed area above is diverted around or channelled through the disturbed area and into Bear Creek.

In addition, Co-Op Mines implemented an extensive interim revegetation program in October, 1983 wherein soil tackifiers and mulches were utilized to stabilize the soil until vegetation is established.

Plate 7-1 shows the arrangement of the various sedimentation and diversion structures.

7.2.5.1 SEDIMENTATION PONDS

Two sedimentation ponds have been constructed to hold the run-off from the disturbed area of the Mine Plan to facilitate settling and filtering of contaminated surface water from the mine site. In addition, any excess groundwater from the mine will be discharged through the sedimentation ponds (it is anticipated that practically all groundwater produced in the mine will be used on site -- see 7.1.4 Mine Dewatering).

The disturbed area west of Bear Creek was split into three section to facilitate calculations. The design calculations for both Pond "A" and "B" are as follows:

SEDIMENT STORAGE FROM DISTURBED AREA

Design Data

Site elevation	:	7150 feet (U.S.G.S.)
Runoff Area	:	See Plate 7-5 for individual areas
Average Slope Length	:	See table below
Average Slope Gradient	:	See table below
6 Hour-10 year Storm	:	1.4 inches

Soil Characteristics : 12% silt, 24% fine sand, 36% sand, 0% organic matter, course graded soil, moderate permeability

TABLE

Area #	Area* (acres)	Average Slope Length (feet)	Average Slope Gradient (%)
A1	2.24	420	36
A2	4.96	560	14
A3	3.51	640	11
B	1.79	520	10

*By Planimeter

Determinations

Use uniform soil loss equation, A=RKLSPC

R : From Figure 7.2-4; "Universal Soil Loss Equation", SCS, Jan. 1976, use R=40 (see figure included)
K : From Figure 7.2-5; "A Soil Erodability Nomograph", where % site plus % fine sand = 36%, K=0.32
LS : From Table 7.2-5; "Universal Soil Loss Equation", SCS, Jan. 1976, (see table included) for A1, LS = 22.06
A2, LS = 5.42
A3, LS = 4.14
B , LS = 3.12

C : Assume bare ground, USC, C=1
P : Assume no erosion control, USC, P=1

A_{A1}=(40)(0.32)(22.06)(1)(1)=282.4 tons/acre/year

A_{A2}=(40)(0.32)(5.42)(1)(1)= 69.4 tons/acre/year

A_{A3}=(40)(0.32)(4.14)(1)(1)= 53.0 tons/acre/year

A_{B} =(40)(0.32)(3.12)(1)(1)= 39.9 tons/acre/year

For areas, 3 years [OSM regulations 817.46(bx1)], Soil = 90 lbs/ft³

V_{A1}=(282.4)(2.24)(3)(2000/1)(1/90)=42,172 ft³*

V_{A2}=(69.4)(4.96)(3)(2000/1)(1/90)=22,948 ft³

V_{A3}=(53.0)(3.51)(3)(2000/1)(1/90)=12,402 ft³

V_{B} =(39.9)(1.79)(3)(2000/1)(1/90)= 4,761 ft³

*To high, this calculated figure is higher than will ever occur in practice because the soil type for this hillside would consist of large rocks and other particle sizes being larger also. This figure is reduced to the amount calculated for one (1) year, 14,057 ft³

For $A_1+A_2+A_3$, sediment storage volume = 14,057 + 22,948 + 12,402 = 49,407 ft³

For B, sediment storage = 4,761 ft³

RUNOFF STORAGE FROM DISTURBED AREA

Design Data

CN=80±, from Table 9.1, "SCS National Engineering Handbook", Section 4, "Hydrology"

Runoff from Figure 10.1, reference as above = 0.7 inches

Volume of runoff in ft³

$V_{A1}=(2.24)(43,560)(0.7)(1/12)= 5,692$ ft³

$V_{A2}=(4.96)(43,560)(0.7)(1/12)=12,603$ ft³

$V_{A3}=(3.51)(43,560)(0.7)(1/12)= 8,919$ ft³

$V_{B}=(1.79)(43,560)(0.7)(1/12)= 4,548$ ft³

Total volume in ponds required for sediment and runoff:

Pond A = 49,407 + 27,214 = 76,621 ft³
Pond B = 4,761 + 4,548 = 9,309 ft³

In a discussion with John Whitehead, hydrologist for DOGM, on 2-27-84 it was agreed to use his numbers in sizing Pond "A". The final design criteria for Pond "A" became as follows:

Design Criteria Pond "A"

Drainage Area: 14.35 Acres
SCS Curve #82
3-Year Sediment Storage: 41,444 ft^3
10-Year 24-Hour Runoff Storage: 42,714 ft^3
Total Storage Volume: 84,158 ft^3
Use Existing Spillway: 10 Foot Wide
Broad Crested Weir
Rainfall Data Base: Hiawatha Data by
E. Arlo Richardson

Also, in a letter to Wendell Owen, of Co-Op Mining, from DOGM, dated 6-16-83, the following design parameters were presented and have been used herein.

Design Criteria Pond "B"

Drainage Area: 1.82 Acres
SCS Curve #82
3-Year Sediment Storage: 2,156 ft^3
10-Year 24-Hour Runoff Storage: 8,182 ft^3
Total Storage Volume: 10,338 ft^3
Use Existing Spillway: 4 Foot Wide
Broad Crested Weir
Rainfall Data Base: Hiawatha Data by
E. Arlo Richardson

The exterior of sedimentation pond "B" is to be protected by 12" steed riprap. Computer analysis (print-outs are in Appendix 7-H) indicates that the maximum velocity of Bear Creek by pond "B" is 9.05 ft/sec. From Figure 7.2-7 the 12" riprap size was determined.

In order to protect bare soil from erosion, the inlet of both ponds "A" and "B" and the spillway and aculvert inlet of pond "B" will be lined with 6"-8" sized riprap.

The discharge from the sediment ponds to the Bear aCanyon stream channel flows through an existing natural drainage course which is heavily "ripraped" by nature's own hand with large rocks and boulders.

Plates 7-2 & 7-3 shows the required plan and sections of Sedimentation Ponds "A" and "B", respectively.

7.2.5.1.1 POND SLOPE STABILITY ANALYSIS

A computer slope stability analysis for pond "A" is contained in Appendix 7-E. The computer analysis of the sediment pond included the condition under which the most conservative factor of safety would be derived. This is a condition wherein the soil is saturated from the sediment pond being full of water and then the analysis is run with the sediment pond empty. This is the most conservative condition. This is the condition the analyses were run under. For purposes of analysis the soil was assumed saturated by the water occasionally held in the pond. The cross-sections towards the back of the Appendix indicate a division between soil No. 2 and soil No. 1. Referring back to the computer printout sheets, soil No. 2 is indicated to be in a saturated condition.

Again, this analysis provides for the most conservative results and is the worst condition; which would only occur after saturation due to the sediment pond being full and then after rapid "draw-down" or dewatering of the sediment pond.

7.2.5.1.2 POND MAINTENANCE

All embankments of temporary impoundments, the surrounding areas and diversion ditches, disturbed or created by construction shall be graded, fertilized, seeded and mulched to comply with the requirements of UMC 817.111-.117 immediately after the embankment is complete. Areas in which the vegetation is not successful, or where rules and gullies develop shall be repaired and revegetated.

In addition, all dams and embankments shall be routinely maintained during the mining operation. Any vegetative growth will be cut where necessary to facilitate inspection and repairs. Ditches and spillways shall be cleaned at least annually. Any combustible materials present on the surface shall be removed and all other appropriate maintenance procedures followed.

7.2.5.2 DIVERSION STRUCTURES

A number of ditches and culverts are utilized in the mine plan area. Ditches are used to: divert "undisturbed" run-off around the disturbed area and back into natural drainage channels, collect "disturbed" run-off and convey it to the sedimentation ponds, and to convey run-off, collected next to roads, between culverts. Culverts are used to: transfer undisturbed run-off underneath roads and into natural drainage, carry undisturbed run-off through disturbed areas, and move disturbed run-off across areas of high erosion.

The ditch and culvert sizing requirements were generated from two computer programs, one developed for general uniform flow calculations using the Manning equation, and one for uniform flow in circular conduits, again using the Manning equation. These programs were developed by Bradley M. Powell, P.E. in house at Horrocks Engineers, and are referenced in house under the terminology "UFICC" for the uniform flow in circular conduits. And "GUF" for the general uniform flow or open channel computations. These programs allow the hydrologist through either direct computations or interactive computations using the method of successive approximations to determine the required characteristics and sizes of the required channels or conduit as the case may be to convey the projected discharges.

Appendix 7-F contains the computer programs and printouts used in sizing the ditches and culverts. Refer to Plate 7-1 for locations of the various structures and Plate 7-5 for areas used in calculations.

The following pages contain summaries of the ditch and culvert sizes.

approximations to determine the required characteristics and sizes of the required channels or conduit as the case may be to convey the projected discharges.

Appendix 7-F contains the computer programs and printouts used in sizing the ditches and culverts. Refer to Plate 7-1 for locations of the various structures and Plate 7-5 for areas used in calculations.

The following pages contain summaries of the ditch and culvert sizes.

7.2.5.2.0 ADDITIONAL CONTROL FOR HIAWATHA SEAM MINING

As shown on Plate 2-2, the outslope of the proposed Hiawatha Seam portal pad will encroach upon the ephemeral channel between D-1D and D-2D on Plate 7-8. It is proposed to install a 15" flexible culvert as shown in Figure 7-F1, 7-F2, 7-F3, 7-F4 and 7-F5, and Plate 2-2 to convey the drainage from the upper areas of the channel beneath the pad. The outlet protection for the flexible culvert shown on Plate 2-2 will adhere to the specifications as indicated on pages 83-B3, B4 and page 64-A Bear Canyon MRP. The rip rap and filter blanket specification will be adhered to as specified.

The pad and channel will be constructed prior to placing the flexible culvert in the excavated channel. The culvert will be backfilled and all heavy equipment will be precluded from the area to avoid an accidental crushing of the buried culvert. The flexible culvert is designed to withstand being buried but will not hold up under

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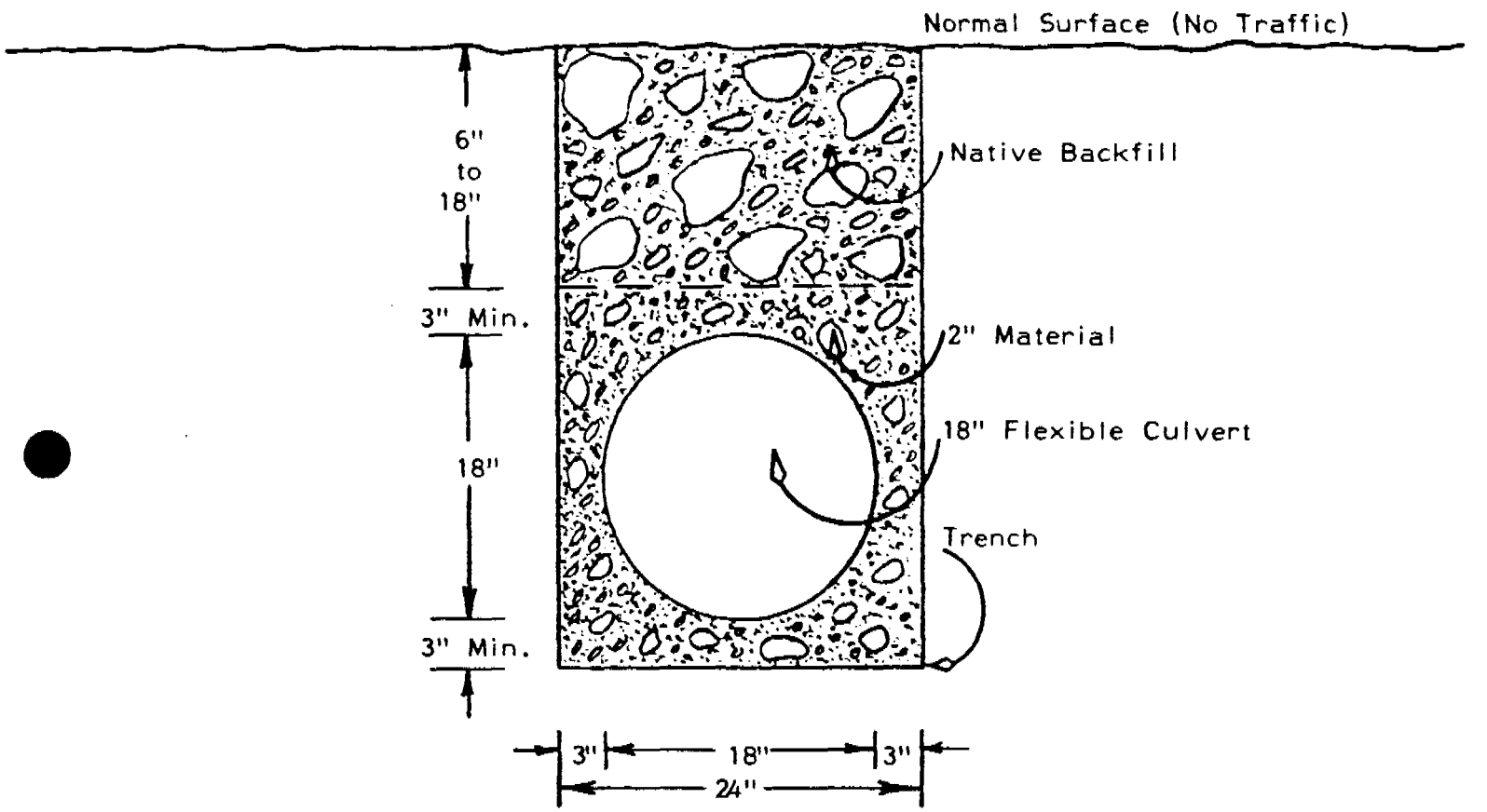
by T. [signature] date 9/19

Figure 7-F1

CROSS-SECTION OF
BURIED FLEXIBLE CULVERT



Scale 1" = 1'

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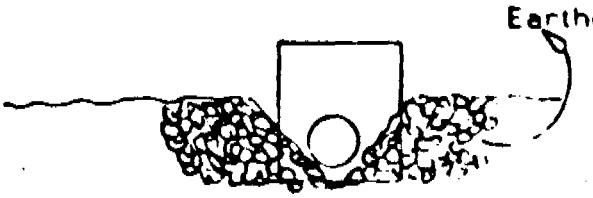
Figure 7F-2

DOWNSPOUT STRUCTURE



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No. 4548
DAN W.
GUY
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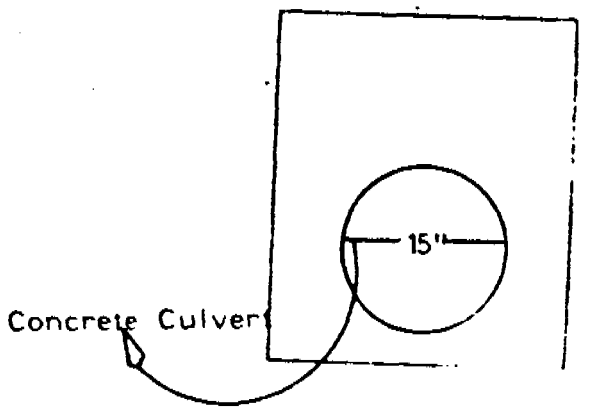
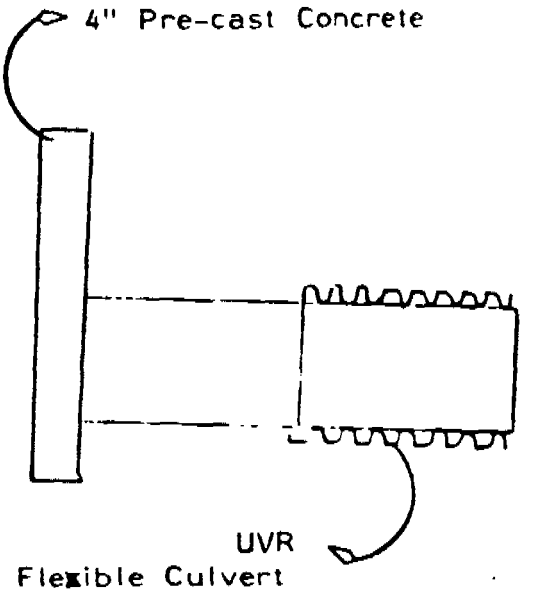
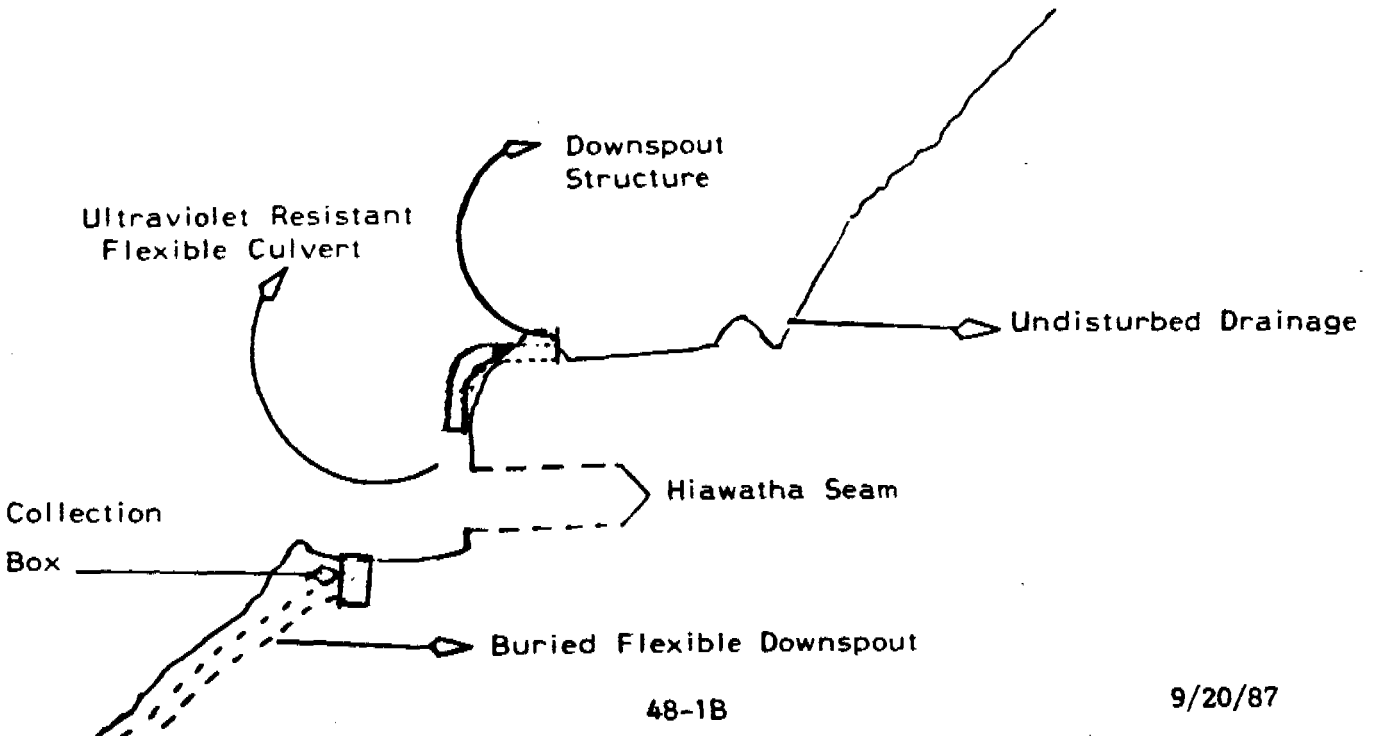
STATE OF UTAH

9/14/88







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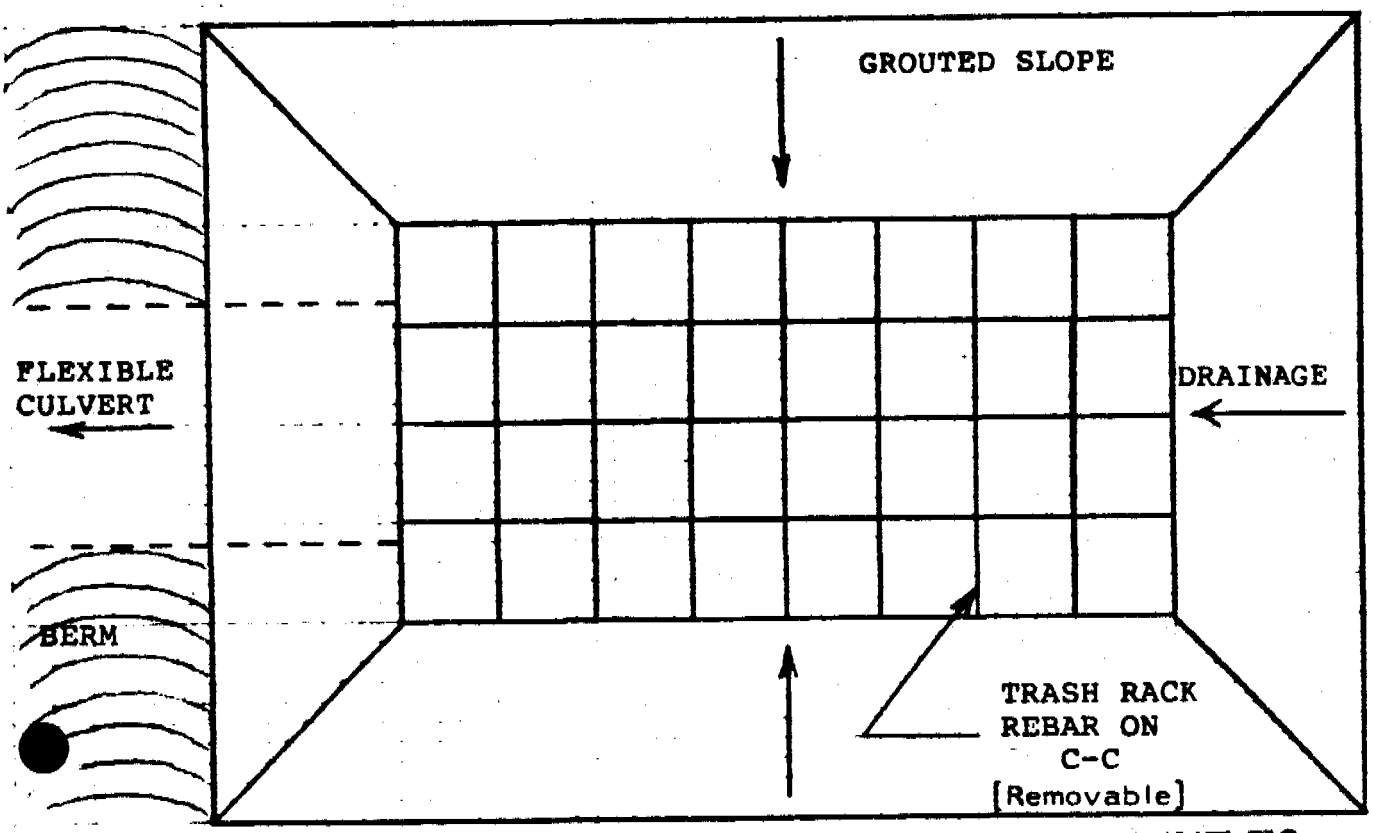
JOB NO. .....

Figure 7-F3



TOP VIEW

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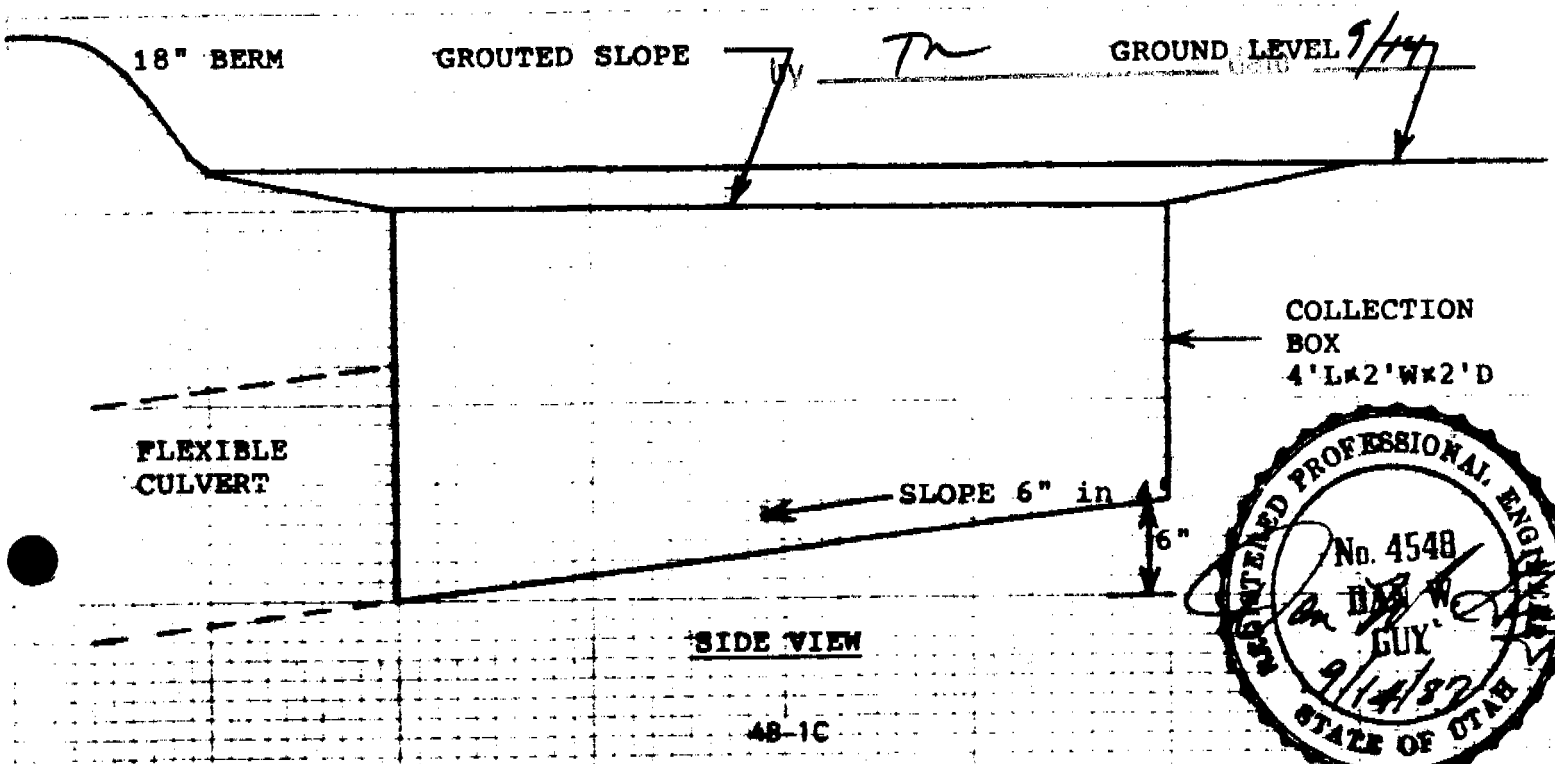

SIDE VIEW

48-1C

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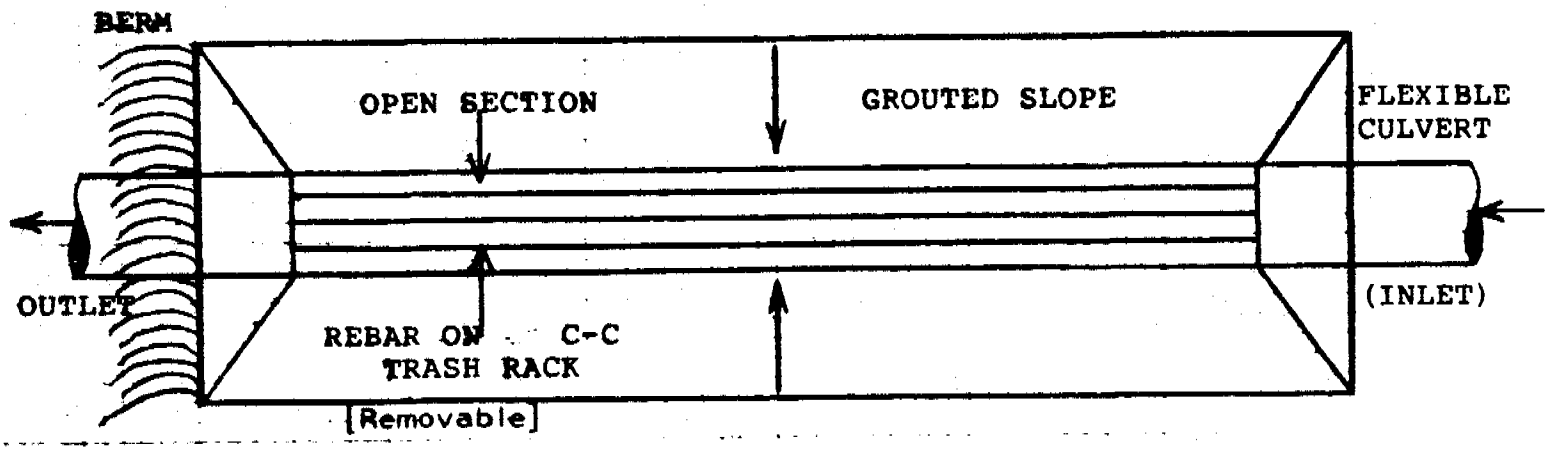
Figure 7-F4



TOP VIEW

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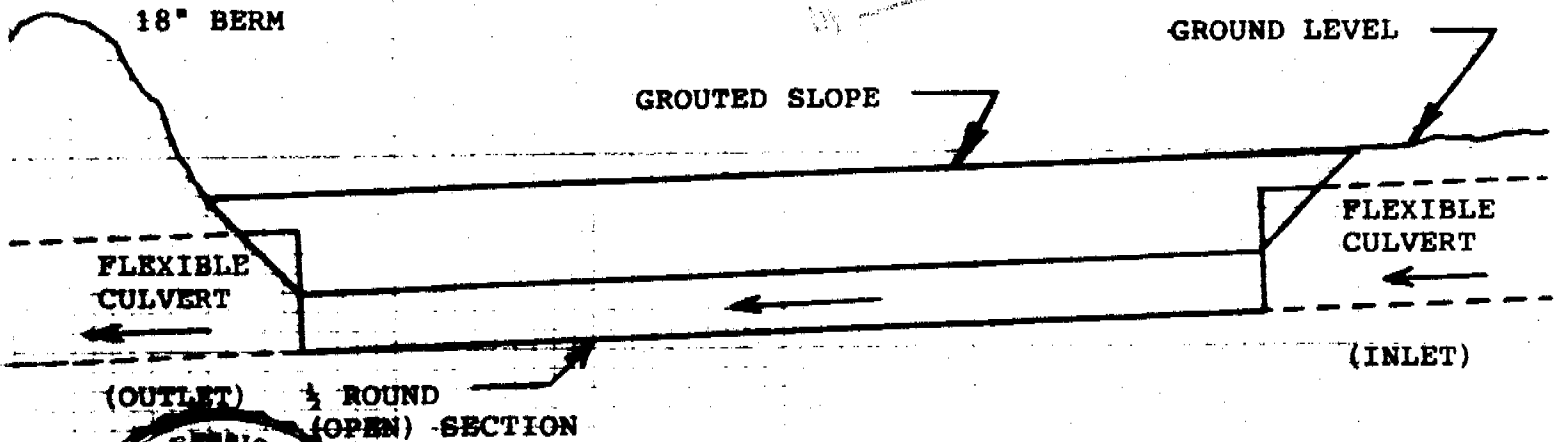

SIDE VIEW

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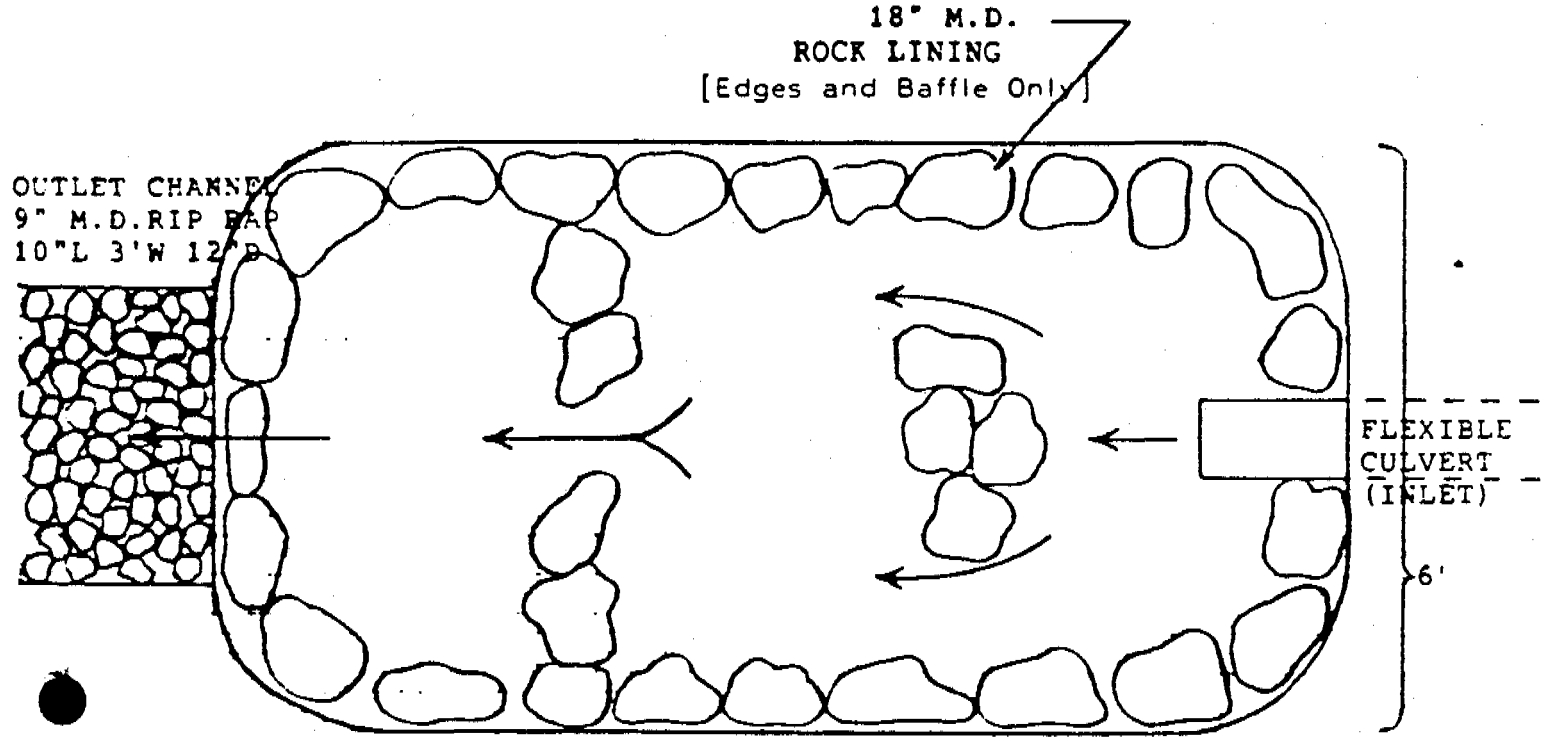
BY D. GUY DATE 5/29/87 SUBJECT LATER BASIN/ ENERGY DISSAPATOR SHEET NO. 1 OF 1

CHKD: BY _____ DATE _____ JOB NO. _____

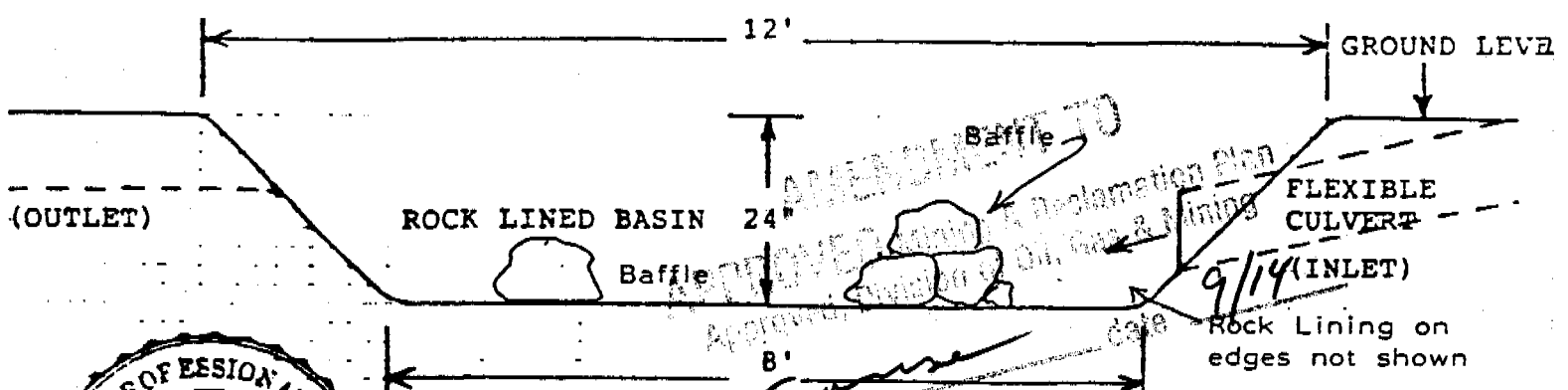
Revised 4/26/88 SCALE: 1"=2'

* REVISED 8/26/88

Figure 7-F5



TOP VIEW



SIDE VIEW

* BOTTOM OF BASIN TO BE ROCK LINED (18" M.D.) IF BEDROCK IS NOT FOUND DURING INSTALLATION.

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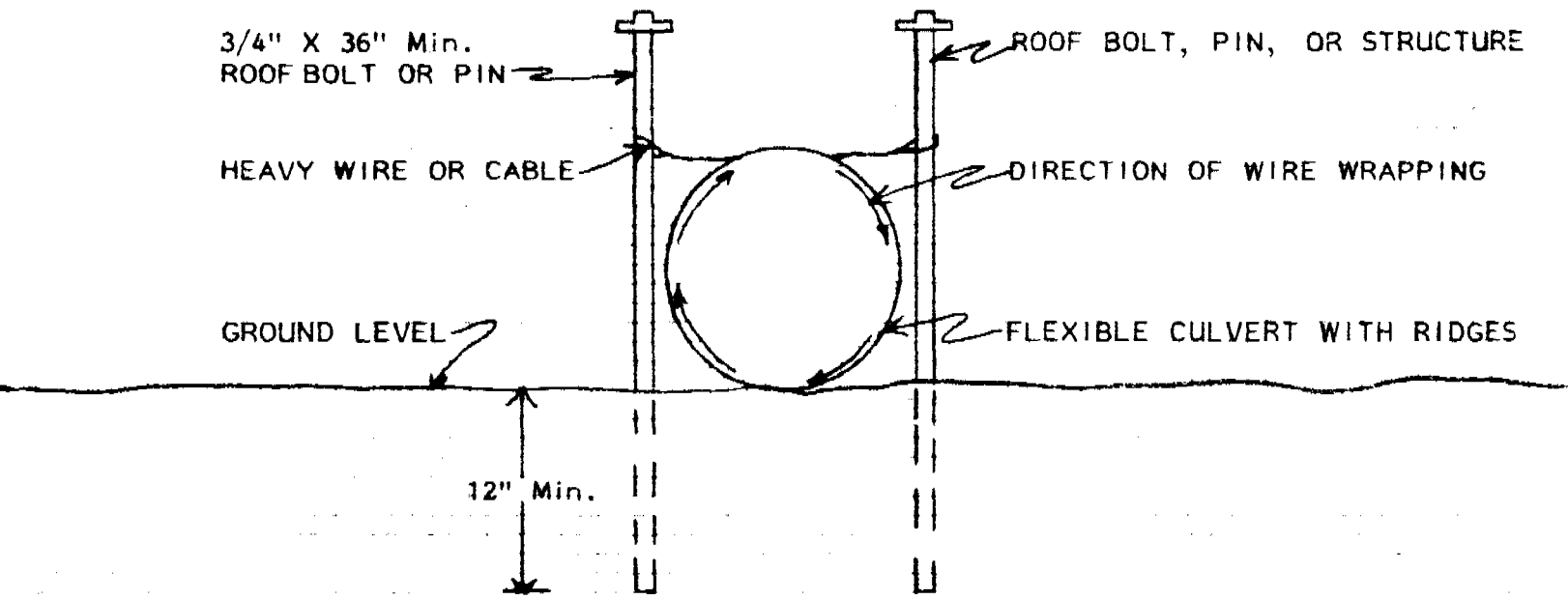
* 8/26/88 KCM

FIGURE 7-F6

TYPICAL ANCHOR FOR

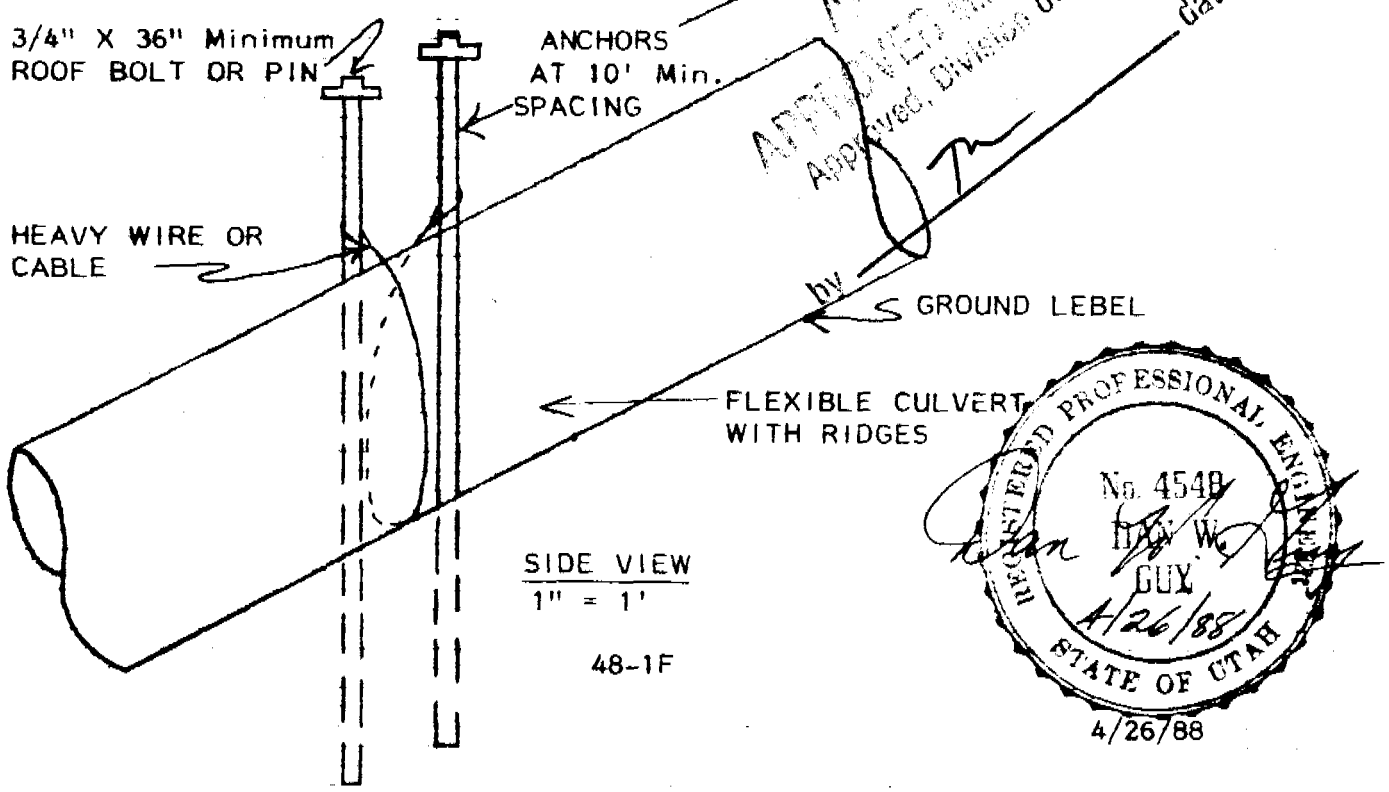
EXPOSED FLEXIBLE CULVERT

NOTE: In all areas where the flexible culvert is not buried, it will be anchored per this typical.



END VIEW

1" = 1'



SIDE VIEW

1" = 1'

48-1F

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GUY
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heavy equipment traffic. This channel is included in drainage area AD-1 (Plate 7-5). The maximum water this channel is calculated to flow is shown on Table 7.2-8 as 1.5 cfs (Ditch D-2D). Calculations for this ditch are shown in Appendix 7-F under Runoff Ditch Sizing. Based on this flow, the culvert is sized as shown on Table 7.2-7 (Revised Summary of Culvert Sizes). The new culvert is designated C-4D, and matches the criteria for culvert C-1D. The headwater depth above the top of the culvert inlet is proposed to be 1' more than adequate to carry the expected flow. Energy dissipators will be placed as indicated in the following sections (7.2.5.2.1 and 7.2.5.2.2)

The outslope of the pad will be protected by the installation of 6" M.D. rock along the area where drainage will occur. The only drainage that will reach the toe of the pad is that from the upper pad to the lower; the majority of the drainage above will be conveyed through the culvert. The 6" rock will be more than adequate, since the approved plan calls for natural 6" rip-rap in the post-mining channel that will carry not only the disturbed drainage AD-1, but the undisturbed drainage from AU-3 as well.

The ditch in this area has been measured, and typical section is shown on Plate 7-8 as cross-section D-D. The ditch profile is also shown on this plate as Profile "F". Plate 7-8A is a typical section of the proposed channel restoration in the area of the portal pad and culvert after their removal and upon final reclamation.

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48-2

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10-3-86

Drainage Control System
Bear Canyon No.1 Mine
Lower Seam Portal Area

The proposed method of handling the drainage in and around the lower seam portal area is described in the following steps, starting from the top [upper pad] area and ending at the bottom [lump coal] area:

[1] Upper Pad - Drainage from the disturbed area on the upper pad from the sub-station to culvert C-OD, will continue to flow into culvert C-OD, as approved; the only change will be the outlet location of the flexible culvert will be moved approximately 20' to the west to direct runoff onto the rock ledge above the Lower Seam [Hiawatha] portals; water will then flow over the rock ledge to the portal pad below;

[2] Portal Pad - The north east corner of the bin will be bermed a minimum of 30" high over to the highwall. Runoff water from the upper pad will flow southward around the bin and into a collection box at the edge of the portal pad area; the pad will be sloped to flow to the box;

[3] Flexible Culvert - The collection box at the portal pad will discharge into a flexible culvert with a minimum diameter of 15" [a larger pipe may be used, depending on availibility]; the culvert will drop onto the next lower pad area [Conveyor Support Pad];

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[4] Conveyor Support Pad - This pad will be sloped to drain to the flexible culvert area; the flexible culvert will be opened [or replaced with $\frac{1}{2}$ round culvert] for a distance of at least 10' to allow surface water to enter the culvert; the entrance to the culvert will be protected by a trash rack and grouted as shown on the attached typical drawing; water will then flow down the flexible culvert to the Coal Processing pad area;

[5] Coal Processing Pad - This pad will also be sloped to drain to the culvert; another 10' opening will be left in the culvert for the surface runoff; water will then be conveyed down to the lower [Lump Coal] pad area;

[6] Lump Coal Pad - The flexible culvert will parallel the conveyor down to the lump coal bin, pass beneath the bin supports, and empty into a catch basin/energy dissipator just south of the bin; runoff will then flow south into ditch D-4D and pass through culvert C-2D and onto Sediment Pond "A". Note: Table 7.2-7 shows the flow for culvert C-2D as 4.8 cfs with a required headwater of 15". Since this is an 18" culvert buried at least 18" below ground, adequate headwater is available.

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The revised drainage is shown on Plate 2-2. Detailed drawings of the various drainage controls are shown in the attached typicals. Sizing calculations are summarized on the following sheet: "Lower Seam Portal Area - Drainage Sizing Calculations".

Lower Seam Portal Area

Drainage Sizing Calculations

Drainage sizing for the flexible culvert is discussed under section 7.2.5.2.0 [p, 48-1] of Chapter 7 of the Bear Canyon MRP. The main change to that discussion will be that the 15" flexible culvert and inlet structures will replace existing culvert C-1D, with the new culvert being designated C-1D. The following is a summary of the sizing criteria for this culvert:

[1] Flow: 1.5 cfs

a. Based on calculated total flow for ditch D-2D [Plate 7-5], shown in Table 7.2-8 and Appendix 7-F.

[2] Velocity: 10.9 fps

a. Based on 1.5 cfs flow and 20% slope as previously determined.

[3] Rip-Rap: 18" Med. Diam.

a. Based on Figure 7.2.7 [p.63] for 10.9 fps. velocity.

[4] Slope: 20.0%

a. Based on measurement of steeper portion of slope at previous location of C-1D.

[5] Diameter: 15"

a. Based on diameter of previous culvert C-1D and on

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common size availability of flexible culvert.

Note: 15" is a minimum diameter; larger culvert may be used depending on availability.

[6] Required Headwater: 9"

a. Based on nomograph and equation described in Section 7.2.5.2.4, p. 53.

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-Summary of Ditch Sizes-

All ditches are triangular "V ditch" with 1:1 side slopes. (See Plate 7.1 for typical.)

	Flow(cfs)	Vel.(fps)	Rip Rap Size**	Slope(%)	Depth Of Ditch	Depth Of Water
D-1R	10.2	6.8	6"	6.0	2'-0"	1'-6"
D-2R	12.1	6.8	6"	6.0	2'-0"	1'-6"
D-3R	10.4	6.8	6"	6.0	2'-0"	1'-6"
D-1U	1.5	3.5	N/R	4.0	1'-3"	0'-9"
D-2U	1.5	3.9	N/R	5.0	1'-3"	0'9"
D-3U	6.1	5.5	4"	5.0	1'-9"	1'-3"
D-4U	11.8	6.6	6"	5.0	2'-0"	1'-6"
D-5U	.9	3.5	N/R	7.0	1'-0"	0'-6"
D-6U	.9	3.5	N/R	7.0	1'-0"	0'-6"
D-7U	10.3	6.6	6"	5.0	2'-0"	1'-6"
D-8U	2.3	4.4	N/R	6.25	1'-3"	0'-9"
D-9U	1.8	5.0	4"	8.3	1'-3"	0'-9"
D-10U	1.5	5.7	6"	18.0	1'-0"	0'-6"
D-11U	7.6	7.9	9"	14.0	1'-6"	1'-0"
D-1D	.8	4.0	N/R	9.0	1'-0"	0'-6"
D-2D	1.5	5.5	4"	10.0	1'-3"	0'-9"
D-3D	1.0	5.2	4"	15.0	1'-0"	0'-6"
D-4D	4.8	5.3	4"	6.25	1'-6"	1'-0"
D-5D	7.2	6.2	6"	6.4	1'-9"	0'-9"
D-6D	1.2	4.4	N/R	6.25	1'-3"	0'-9"

*6" freeboard added to required flow depth.
** see Plate 7.1 for location of rip rap.
N/R - not required

-Summary of Culvert Sizes-

	Flow(cfs)	Vel.(fps)	Rip Rap	Slope(%)	Diameter	Required Headwater**
C-1R	10.2	9.5	12"	8.0	18"	27"
C-2R	12.1	9.5	12"	8.0	18"	36"
C-3R	16.4	9.5	12"	8.0	18"	27"
C-1U	8.8	12.3	24"+	15.0	30"	18"
C-2U	1.5	8.4	9"	15.0	15"	9"
C-3U	7.9++	5.7	6"	5.0	12"	36"*
C-4U	6.1++	5.1	6"	5.1	10"	36"*
C-5U	6.1++	5.0	N/R	4.8	10"	36"*
C-6U	.9	4.4	N/R	3.7	10"	12"
C-7U	10.3	9.7	12"	8.3	12"***(18")	27"
C-8U	8.8	13.0	24"+	15.0	18"	24"
C-9U	1.5	8.0	9"	7.3	15"	9"
C-1D	1.5	10.9	16"+	20.0	15"	9"
C-2D	4.8	9.6	12"	12.0	18"	15"
C-3D	1.2	5.2	6"	4.2	12"	9"
60" CMP	231.2	13.8	24"	3.4	60"	102"

*When capacity of culvert is exceeded flow continues down ditch to next culvert.

**From invert elevation.

***Existing 12" CMP to be replaced with 18" CMP at 8.3% slope.

+ Energy dissipating device could be used instead of rip rap.

++ A two foot high check dam of rip-rap is used to develop the headwater necessary for maximum flow through the culvert, excess flow continues down the ditch.

N/R - Not required

7.2.5.2.1 CULVERT AND DITCH SEDIMENT CONTROL

For the various energy dissipating devices are available. Co-Op is presently investigating several types and does commit to use one that will work in those areas where it is required. Figure 7.2-6 is a cross-section of a relatively simple corrugated metal energy dissipating device which can be used. Location of the energy dissipators is indicated on the preavious culvert summary and on Plate 7-1.

At all points along constructed ditches where excessive erosion occurs silt fences shall be installed (as per Figure 7.2-8) in order to eliminate the excessive erosion.

7.2.5.2.2 RIPRAP SIZING

Where the velocity of flow exceeds 5 fps but is less than 15 fps riprap will be placed. The size of riprap used will be based on the graph, by Peterka Figure 7.2-7. For flows above 15 fps an energy dissipating device will be used.

7.2.5.2.3 COMPUTER ANALYSIS

The SCS definition page 15-4, SCS National Engineering Handbook, Section 4, Hydrology, is as follows, "In simple hydrograph analysis, lag is the time from the center of mass of excessive rainfall to the peak rate of runoff." Also quoting from the same page, "The role of channel and valley storage are important in the development and translation of a flood wave and the estimation

of lag. Both the hydraulics and storage may change from storm to storm, so that an average lag may have a large error. The problem of evaluating lag is sufficiently complex that theoretical hydraulic analysis must be complimented with a hydrologic appraisal of the relative effect of basin characteristics in order to make the best estimate." Also quoting from page 15-4, "Time of Concentration. This is the time it takes for runoff to travel from the hydraulically most distant part of the storm area to the water shed outlet or other point of reference downstream. In hydrograph analysis, Tc is the time from the end of excess rainfall to the point on the falling limb of the hydrograph (point of inflection) where the recession curve begins."

Both the computer program written by Richard H. Hawkins, professor at Utah State University, used by the Division to verify hydrograph analyses and the program used by Mr. Wimmer, use the SCS method. Both of them compute lag according to equation 15-4, page 15-7 previous reference. However, the program used by Mr. Wimmer stops you if it computes a lag less than .25 hours or 15 minutes with the suggestion that 15 minutes be considered the minimum. The reasons for this are many and complex. It is related to the time distribution of rainfall used in the SCS method. The figure in Appendix 7-G shows various distributions of rainfall commonly used within the Utah area by hydrologists to compute hydrographs and peak flows. Also in Appendix 7-G is a comparison of various peak flows that you get depending on the type of rainfall distribution you assume. Even using a SCS Type "B" with a 10 year 24 hour rainfall occurring in a single six hour storm, the peak flow generated using the theoretically computed lag of 10.7 minutes 13.99 cfs. The SCS Type 2 rainfall distribution assumptions produces the highest peak flow.

The only point here is to show that using different methods, different distributions, different computer programs, will all generate different numbers. In my nearly 20 years in the profession, one of the cautions I have always observed is to not use to short a time of concentration, or lag, for generating hydrographs; as it will give you an erroneously high indication of peak flow because of the difference between the theoretical computations and the actual channel and ground surface conditions found in nature. In my professional opinion, using a computed lag time of less than 15 minutes on a natural occurring water shed area will generate peak flows which will not be found in actual field conditions.

It is my professional opinion that the peak flows, velocities, and resultant riprap sizes submitted are adequate and represent correct hydrologic principles properly applied. H. Lee Wimmer

7.2.5.2.4 HEADWATER DEPTHS

The nomograph used by the Division in checking the headwater depths was generated based on laboratory research of models and verified in some instances by prototype tests by the U.S. Bureau of Public Roads. This nomograph has a built in factor of safety. In addition, the nomograph was generated based on the assumption of no upstream velocity. Where you have significant upstream velocity and you have a significant depth of water above the top of the culvert, a more accurate estimation of the true situation is generated by Torricelli's equation which is $Q = CdA\sqrt{2gh.}$ For a sharp edged

entrance, the coefficient Cd is approximately 0.6. This is the formula that was used to generate the required headwater depths for the "summary of Culvert Sizes" table. Tables 7.2-7 and 8 indicate ditch and culvert sizes based on DOGM calculations. DOGM has agreed to use Co-op's sizing until problems become evident, at which time Co-op will replace or modify existing structures.

Co-Op agrees to a site field verification for location of riprap and location and necessity for silt fence (Figure 7.2-8) placement with the site field verification to be held in the spring of 1985 as soon as weather conditions permit.

7.2.5.2.5 DESIGN PARAMETERS

Listed below are the various parameters, along with and the procedures used to obtain them, which were supplied to the computer programs used in calculating the runoff hydrographs and routings and the ditch and culvert sizings.

The equations used in the Hydro Plus III - SCS hydrograph program are listed in Appendix 7-F. The parameters that were used are as follows:

Basin Area - the areas where calculated, using a planimeter, from those outlined on Plate 7-5.

Basin Curve Number - this SCS runoff curve number was estimated using "A Guide to Hydrologic Analysis Using SCS Methods," Section 5. This section is included in the reference section. The soil of the mine plan area is best described by soil group "C." For the undisturbed areas the land use description is "woods or forest land" and the hydrologic condition "fair." Using these descriptions a curve number

of "73" was obtained. For disturbed areas the curve number "82" was used.

24-Hour Precipitation - the precipitation amounts for the various storm frequencies came from E. Arlo Richardson's "Estimated Return Period for Short-Duration Precipitation in Utah," the Hiawatha area.

Average Basin Slope - the slopes of the various areas outlined on Plate 7-5 were derived by dividing the total change in elevation by the hydraulic length.

Hydraulic Length - this length, also from Plate 7-5, is the length from the area outlet or mouth to the divide or point of highest elevation.

Basin Lag - this value was computed by the computer program with the computer using a minimum of 15 minutes.

The hydrograph reservoir routing program used the appropriate runoff hydrograph routed through the appropriate sedimentation pond, "A" or "B." Pond capacity per elevation and spillway capacity were determined from the cross sections and criteria shown on Plates 7-2 and 7-3.

From the parameters listed above, the computer program was able to generate runoff hydrographs. From these hydrographs the peak or maximum flow was used in the sizing of the ditches. For sizing the ditches and culverts the parameters used are as follows:

Ditch Depth - various ditch depths were tried, in 3" increments, until a depth was found that would handle the maximum flow.

Culvert Diameter - the diameters were obtained by field measurement, unless noted otherwise. If the flow was larger than could be handled by the culvert a check dam 2' high of rip-rap is used to develop headwater for maximum flow through the culvert, excess flow continues down the ditch.

Manning Coefficient - the coefficients came from Van Te Chow's "Open-Channel Hydraulics," for corrugated metal pipes and flumes, n=.023; for natural channels-straight, full stage, no pools with weeds and stones, n=.035.

Slope - for ditches the total change in elevation was divided by the total length, both values were obtained from Plate 7-1. For culverts the slope was obtained from field measurements.

To determine the headwater necessary for maximum flow through the various culverts, the orifice computer program was run for the different size culverts being used in the mine plan area. The equations used in the program are listed on the individual printouts. The parameters supplied the programs are as follows:

D - diameter of culvert size being considered.

C - the coefficient of contraction for orifices was obtained from King and Brater's "Handbook of Hydraulics."

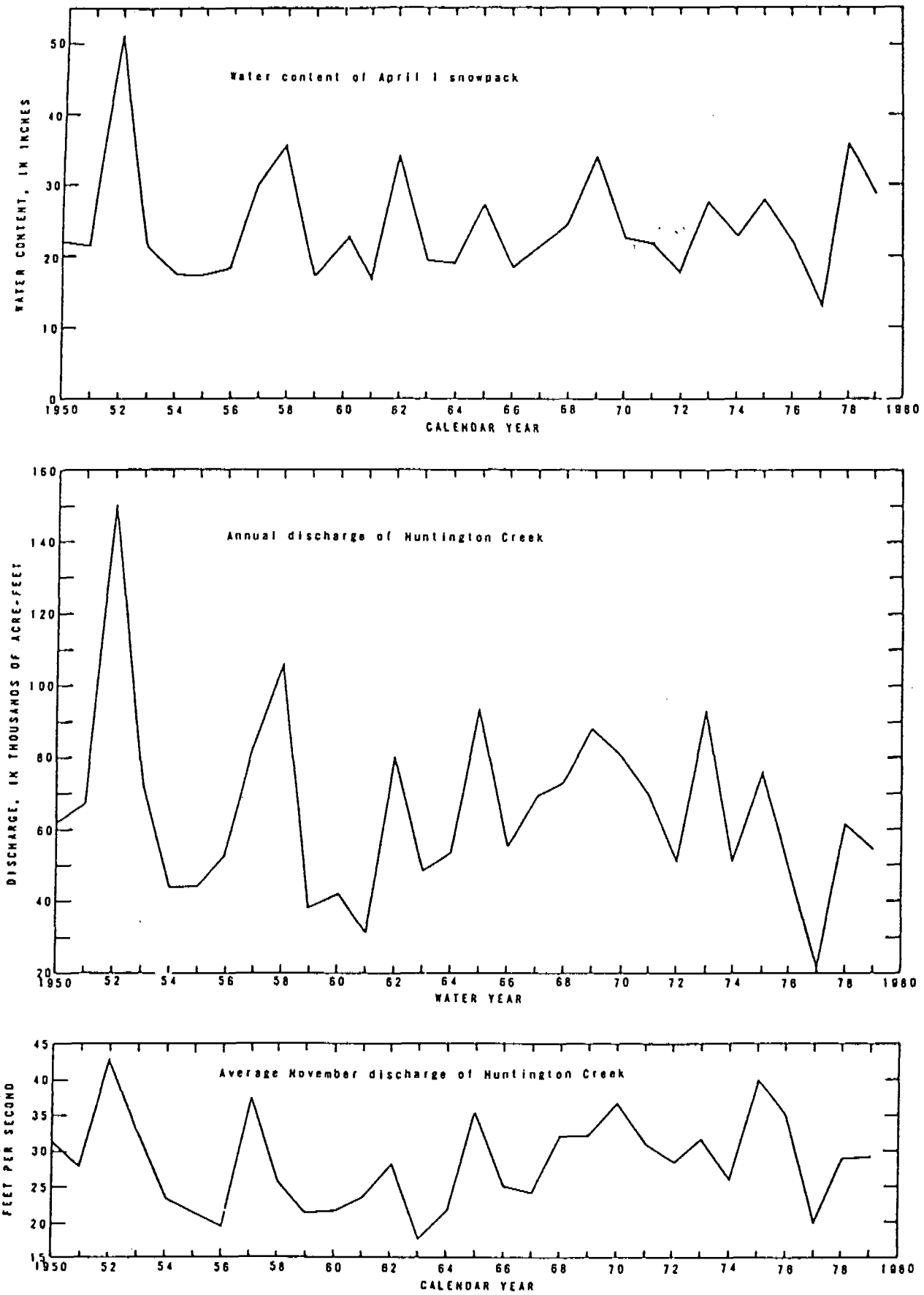


Figure 7.2-1 --Water content of April 1 snowpack at the Huntington Horseshoe snow course and the annual discharge of Huntington Creek at gaging station 09318000, 1950-79.

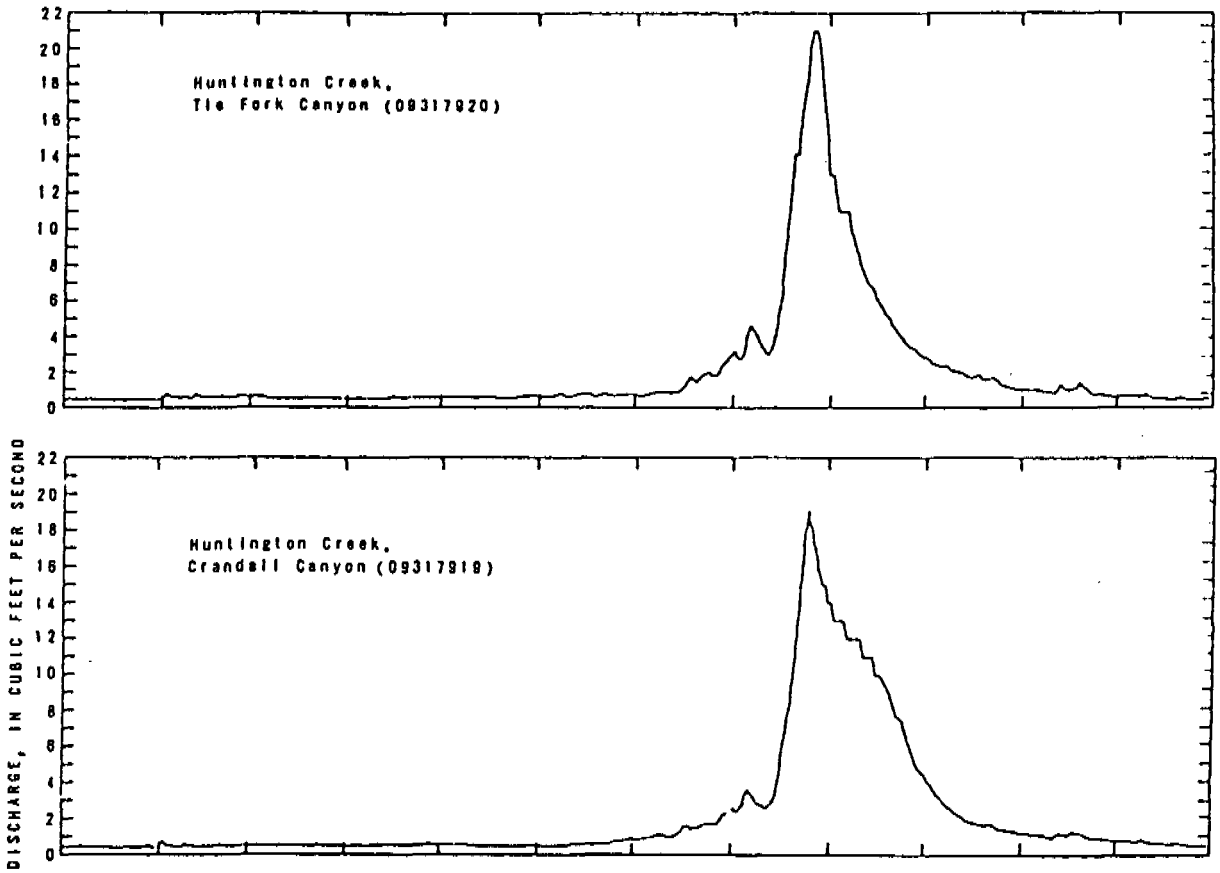


Figure 7.2-2 —Stream discharge at gaging stations in the drainage of Huntington Creek, water year 1979.

Co-Op Mining Company

Bear Canyon Mine

-Water Sample Analysis-

Date:

Station Location:
(circle one)

Bear Creek Upstream
Bear Creek Downstream (Weir W-4)
Bear Creek Right-hand Tributary
C O P Development Spring
Mine Underground Storage
Mine Discharge
Mine Inflow - Point #_____

Parameters and Quantities

Flow (gpm)_____ Temperature (°C) _____

pH _____ Total Suspended Solids (mg/l)_____

Specific
Conductivity _____ Total Settleable Solids (mg/l)_____

-Chemicals-

Cations (mg/l):	Anions (mg/l):	Balance:
Calcium_____	Carbonate _____	Cations_____
Magnesium_____	Bicarbonate_____	Anions_____
Iron_____	Sulphate_____	Total_____
Sodium_____	Chloride_____	Difference_____
Potassium_____	Nitrate_____	Sigma_____

Hardness $CaCO_3$_____
Manganese_____
Oil and Grease_____
Total Dissolved Solids (mg./l)_____

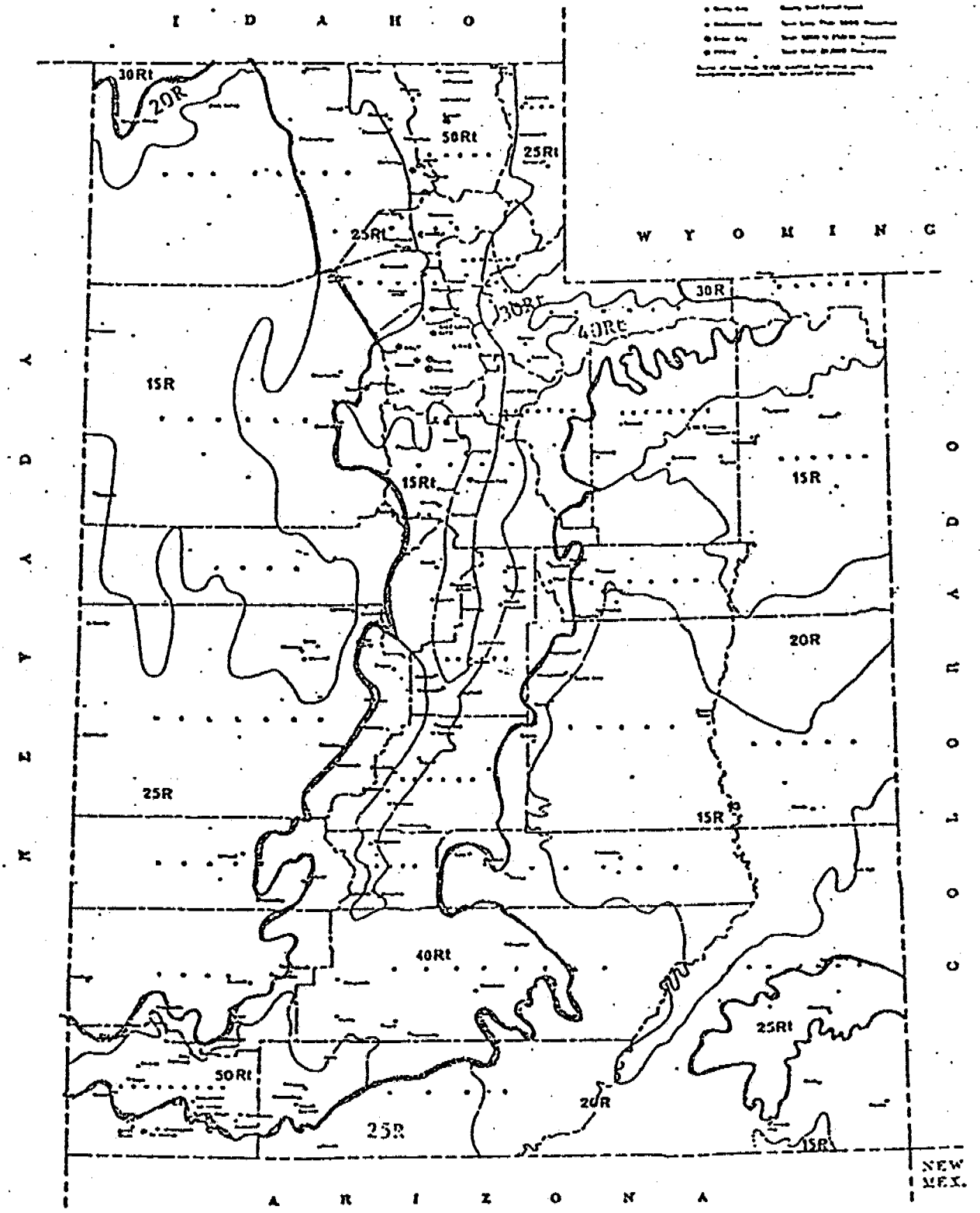
Figure 7.2-3
Water Analysis Reporting Format

FIGURE 7.2-4

SOIL CONSERVATION SERVICE

UNIVERSAL SOIL LOSS EQUATION

AVERAGE ANNUAL VALUES FACTOR R and Rt



R - Rainfall Only

Rt - Rainfall and Snowmelt

0000060

Figure 7.2-5

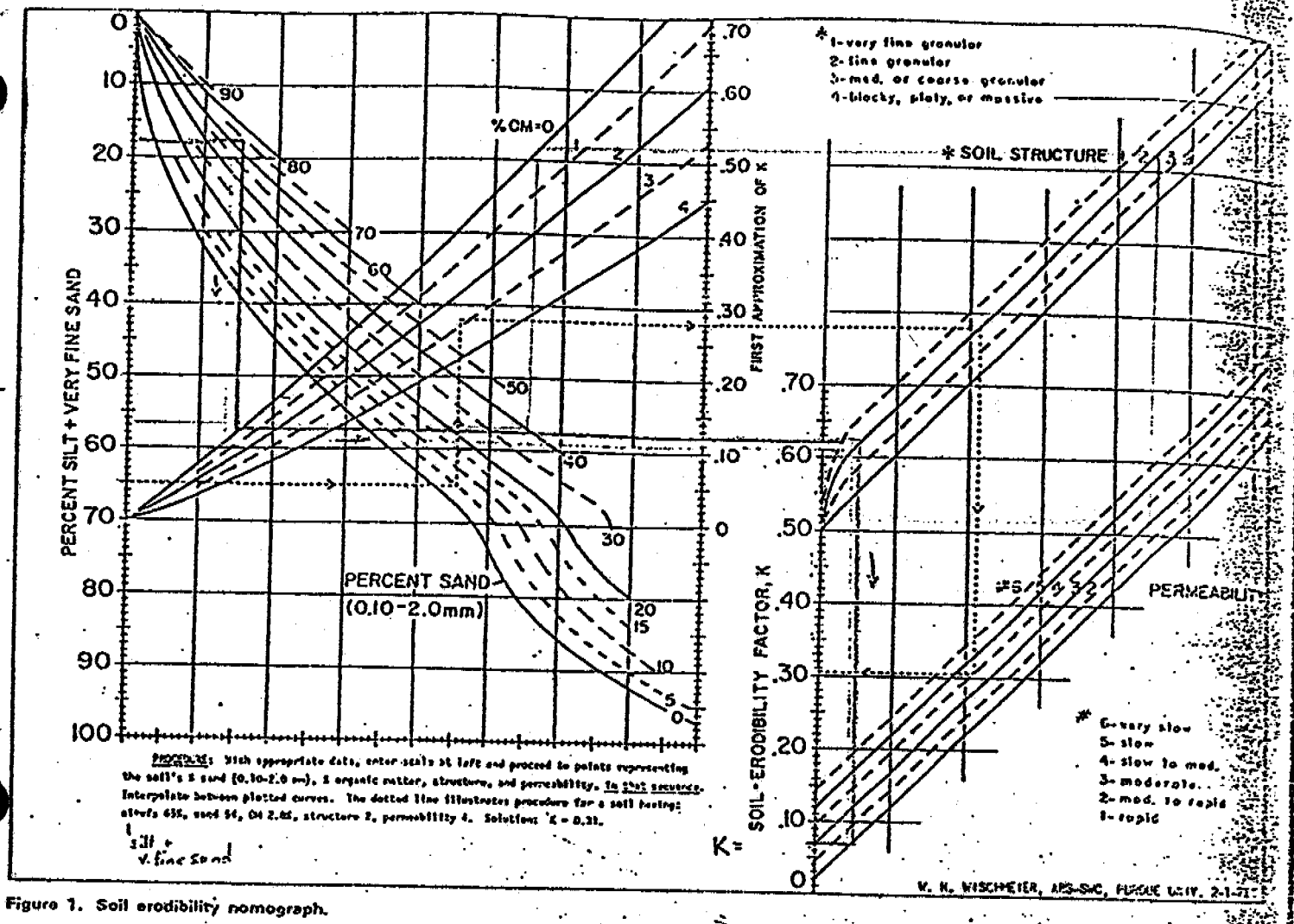


Figure 1. Soil erodibility nomograph.

line between sand and silt classifications and a new particle-size distribution parameter.

Analyses of the rainulator and natural-rain soil-erodibility data showed conclusively that particles in the very fine sand classification (0.05-0.10 mm) behave more like silt than like larger sand. When we redefined silt to include very fine sand and defined sand as particles from 0.10 to 2.0 mm, the prediction values of the two parameters improved appreciably.

This revised classification concept is not entirely new. Family groupings in the U. S. Department of Agriculture's Soil Classification System, Seventh Approximation, recognize very fine sand as having silt properties. The American Association of State Highway Officials, in a 1961 report (*1*), used the midpoint of the very fine sand category as the dividing line between their granular and silt-clay classifications.

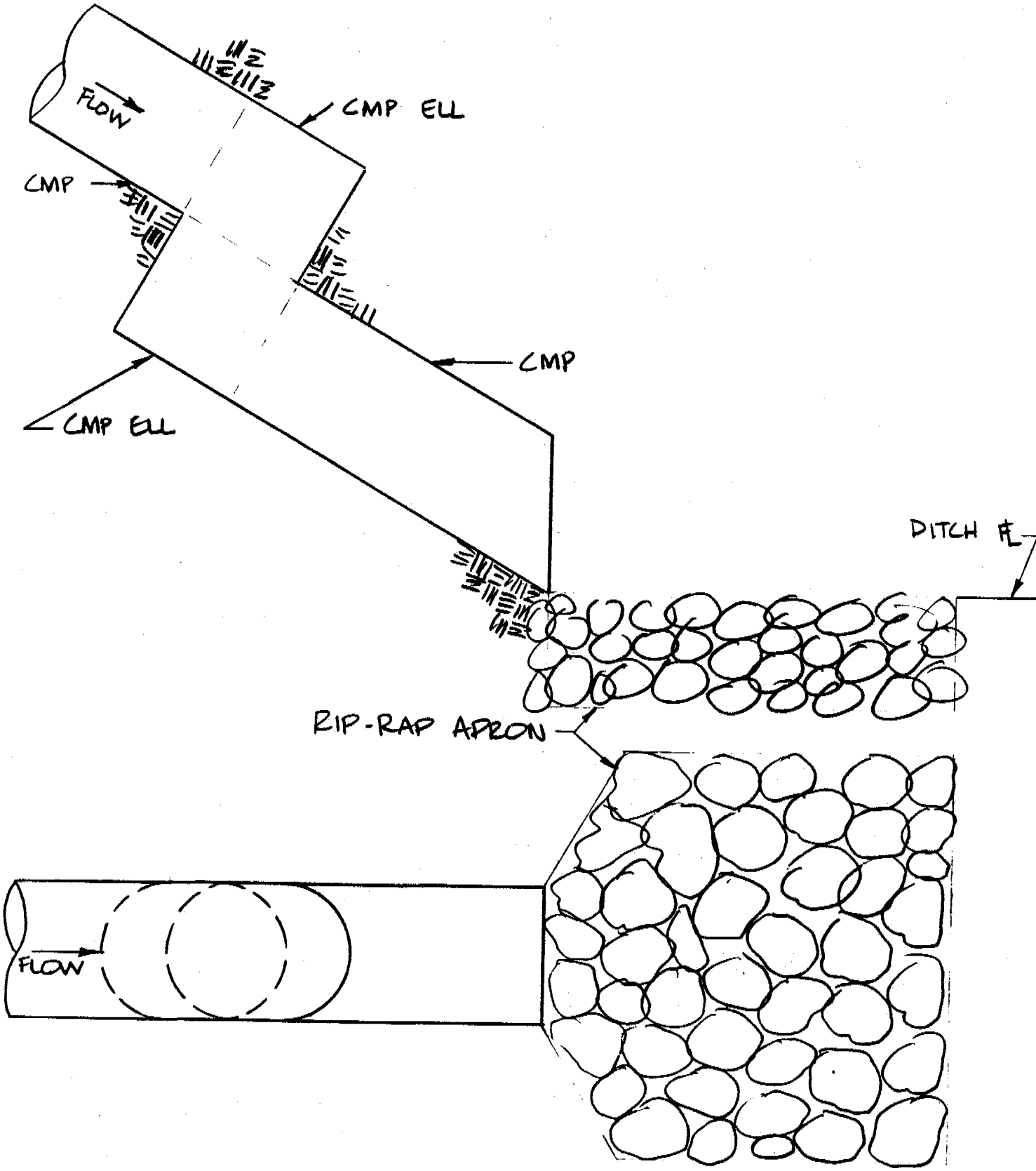
Even with the improved classification criteria, however, the relation of erodibility to a given percent silt or percent clay depends considerably on the particle-size distribution in the remainder of the soil mass. The erodibility of a 60-percent-silt soil relative to that of a 40-percent-silt soil, for example, depends on the associated sand-to-clay ratios and the levels at which other properties are combined in the soil. The number and complexity of these interrelations account for the large number of terms in the previously published multiple regression equation for soil erodibility (*6*). Discovery of a parameter that adequately describes the whole particle-size distribution for a given soil sample made it possible to drop many of the previously significant terms from the equation without appreciable loss in accuracy.

The new particle-size parameter, which we have designated as M, is the product of percent silt and percent sand-and-silt. When the very fine sand component was included in the percent silt, the M accounted for 85 percent of the variance in observed K values for the 55 rainulator-tested soils. Its relationship to erodibility was curvilinear.

Close consideration of the parameter M showed that it is quite descriptive. For soils with a low or medium silt fraction, the M increases for each additional percent silt depends very much on the soil's sand-to-clay ratio. As sand content becomes high, silt content decreases and M declines in value, but it remains a function of the silt-to-clay ratio. When clay content is high, M assumes a low value which is a function of the sand-to-silt ratio.

Even though the parameter is not identified in the nomograph (Figure 1), the left-hand section of the graph is based on the relation of M to K. The scale on the horizontal axis is the M scale, with values from 0 to 8,000. The K-approximation curves for five levels of organic matter were plotted against this scale. The curve marked "%OM = 2" shows the relationship that accounted for 85 percent of the variance in observed K values. To eliminate manual computation of M for

0000061



ENERGY DISSIPATOR DEVICE

FIGURE 7.2-6

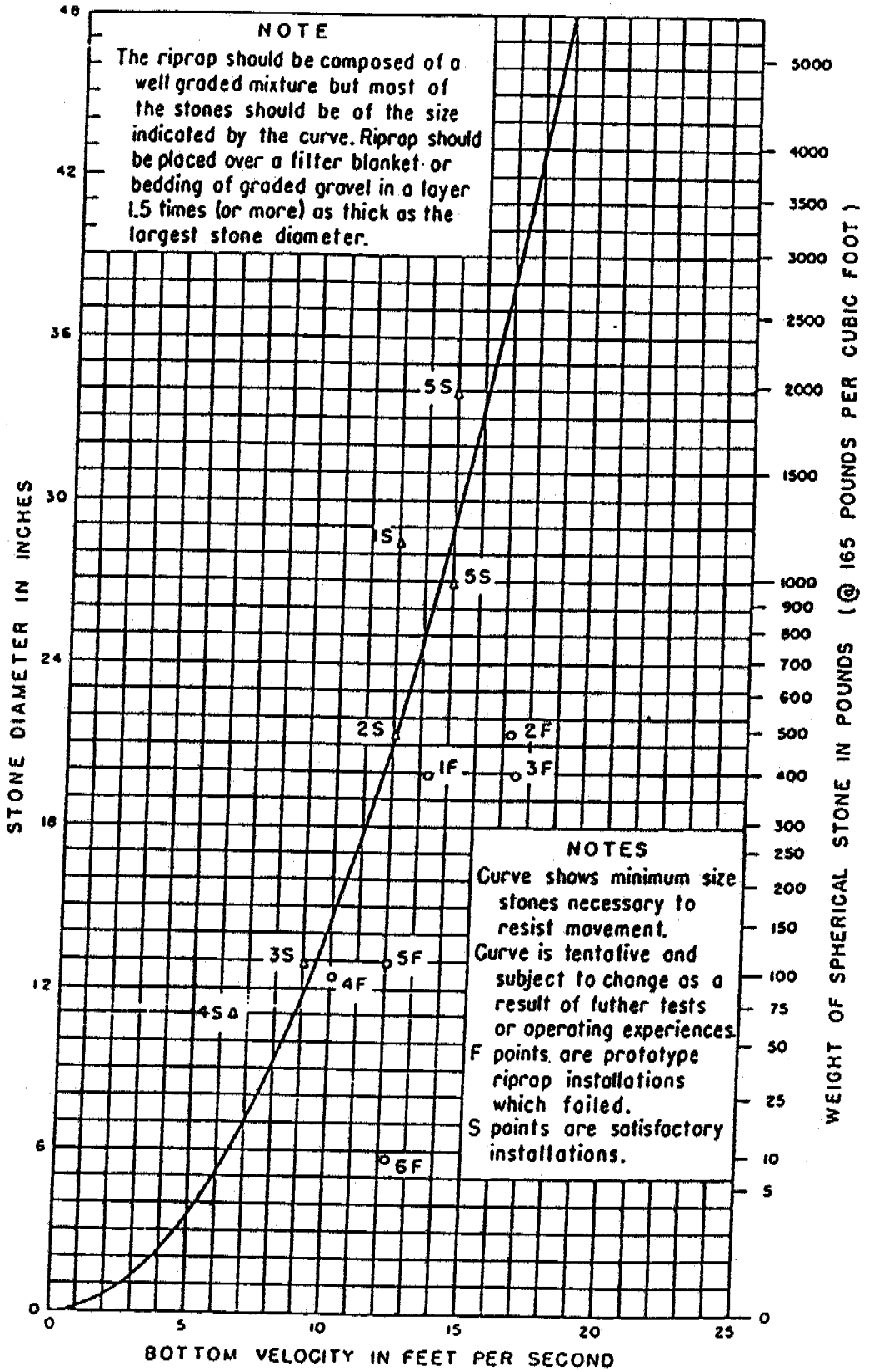


FIGURE 165.—*Curve to determine maximum stone size in riprap mixture.*

From: Peterka, A.J., "Hydraulic Design of Stilling Basins and Energy Dissipators", U.S. Bureau of Reclamation, Engineering Monograph No. 25.

0000063

Table 7.2-7

REVISED SUMMARY OF CULVERT SIZES

	Adjusted Flow (cfs)	Slope (%)	Diameter	Required Headwater From Bottom of Culvert	HW/D	HW=(HW/D)XD	Adjusted Required Headwater Above Top Of Culvert
C-1R	13.3	8.0	18"	27"	2.62	3.93	29"
C-2R	16.22	8.0	18"	36"	3.65	5.5	48"
C-3R	14.76	8.0	18"	27"	3.2	4.8	40"
C-1u	11.4	15.0	30"	18"	.66	1.65	NA
C-2u	2.24	15.0	15"	9"	.70	.68	NA
C-3u	10.06	5.0	12"	36"	6.0+	6.0+	60+
C-4u	8.12	5.1	10"	36"	6.0+	6.0+	60+
C-5u	8.12	4.8	10"	36"	6.0+	6.0+	60+
C-6u	1.46	3.7	10"	12"	1.3	1.1	3.2"
C-7u	13.15	8.3	12"-18"	27"	2.6	3.9	28"
C-8u	11.4	15.0	18"	24"	1.92	2.9	18.8
C-9u	2.3	7.3	15"	9"	.725	.83	NA
C-1D	2.24	20.0	15"	9"	.725	.83	NA
C-2D	6.23	12.0	18"	15"	1.05	1.6	1.2"
C-3D	1.52	4.2	12"	9"	.825	.825	NA

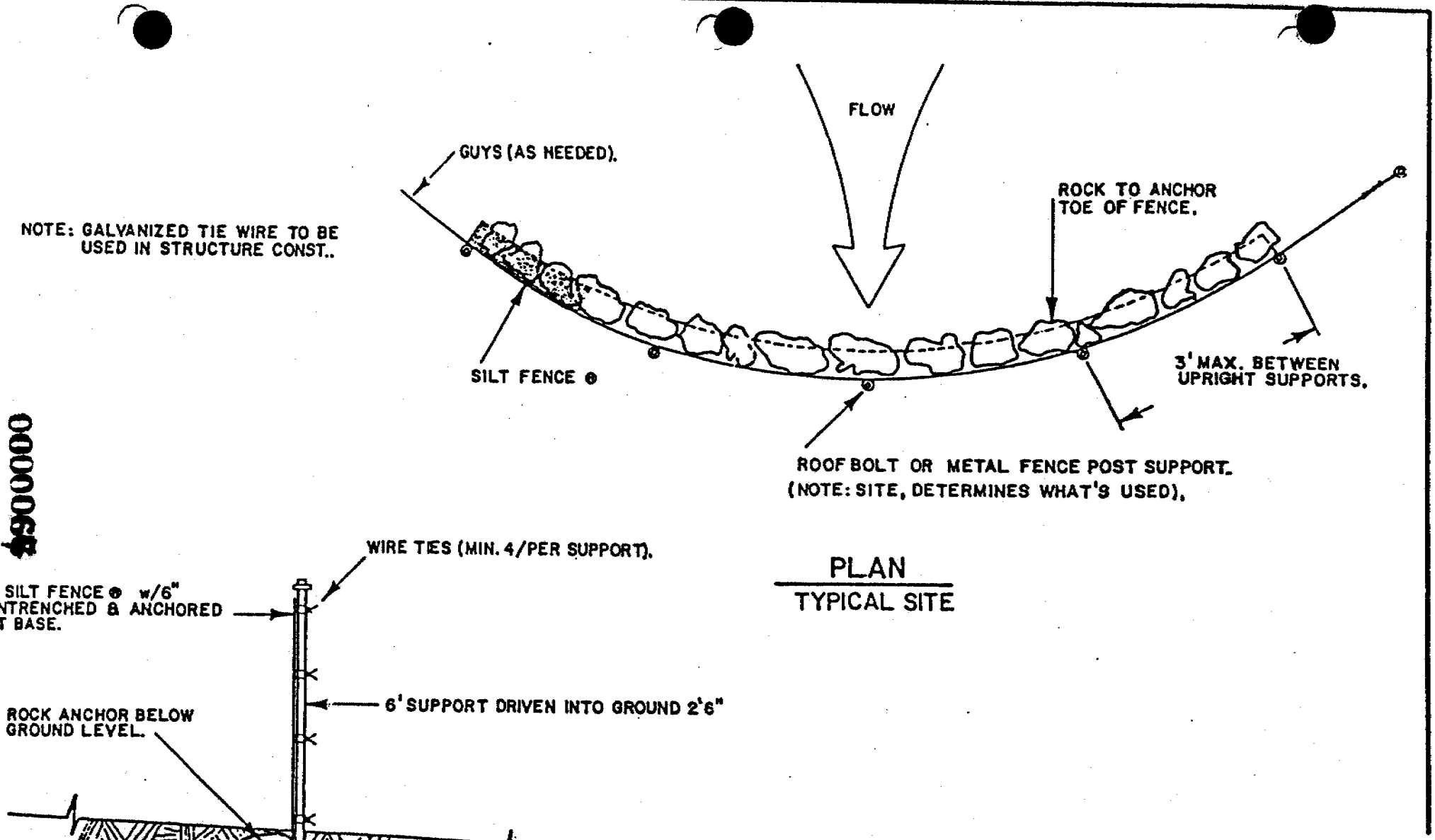
0000690-A

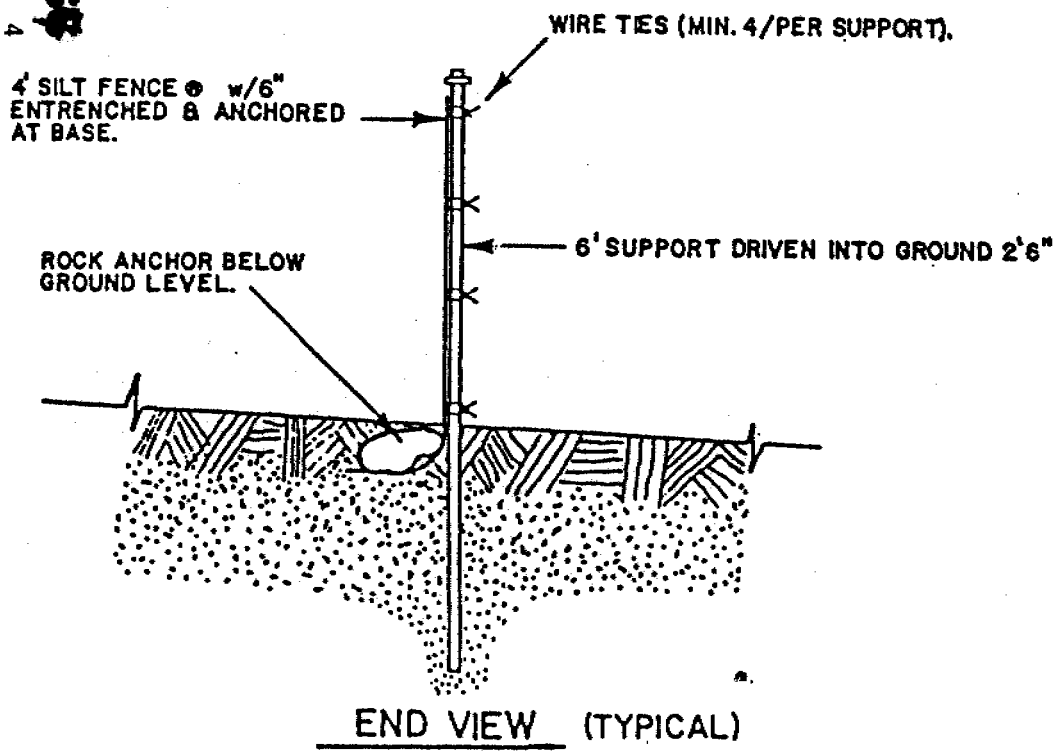
Table 7.2-8
-Revised Summary of Ditch Sizes-

All ditches are triangular "V ditch" with 1:1 side slopes. (See Plate 7.1 for typical.)

	Flow (cfs)	Vel. (fps)	Rip Rap Size	Slope (%)	Depth Of Ditch	Depth Of Water
D-1R	10.2	6.8	6"	6.0	2'-0"	1'-6"
D-2R	12.1	6.8	6"	6.0	2'-0"	1'-6"
D-3R	10.4	6.8	6"	6.0	2'-0"	1'-6"
D-1U	1.5	3.5	N/R	4.0	1'-3"	0'-9"
D-2U	1.5	3.9	N/R	5.0	1'-3"	0'-9"
D-3U	6.1	5.5	4"	5.0	1'-9"	1'-3"
D-4U	11.8	6.6	6"	5.0	2'-0"	1'-6"
D-5U	.9	3.5	N/R	7.0	1'-0"	0'-6"
D-6U	.9	3.5	N/R	7.0	1'-0"	0'-6"
D-7U	10.3	6.6	6"	5.0	2'-0"	1'-6"
D-8U	2.3	4.4	N/R	6.25	1'-3"	0'-9"
D-9U	1.8	5.0	4"	8.3	1'-3"	0'-9"
D-10U	1.5	5.7	6"	18.0	1'-0"	0'-6"
D-11U	7.6	7.9	9"	14.0	1'-6"	1'-0"
D-1D	.8	4.0	N/R	9.0	1'-0"	0'-6"
D-2D	1.5	5.5	4"	10.0	1'-3"	0'-9"
D-3D	1.0	5.2	4"	15.0	1'-0"	0'-6"
D-4D	4.8	5.3	4"	6.25	1'-6"	1'-0"
D-5D	7.2	6.2	6"	6.4	1'-9"	0'-9"
D-6D	1.2	4.4	N/R	6.25	1'-3"	0'-9"

*6" freeboard added to required flow depth.
** see Plate 7.1 for location of rip rap.
N/R - not required


FLOW
GUYS (AS NEEDED).
NOTE: GALVANIZED TIE WIRE TO BE USED IN STRUCTURE CONST..
ROCK TO ANCHOR TOE OF FENCE.
SILT FENCE ⊕
3' MAX. BETWEEN UPRIGHT SUPPORTS.
ROOF BOLT OR METAL FENCE POST SUPPORT.
(NOTE: SITE, DETERMINES WHAT'S USED).
PLAN
TYPICAL SITE


WIRE TIES (MIN. 4/PER SUPPORT).
4' SILT FENCE ⊕ w/6" ENTRENCHED & ANCHORED AT BASE.
6' SUPPORT DRIVEN INTO GROUND 2'6"
ROCK ANCHOR BELOW GROUND LEVEL.
END VIEW (TYPICAL)

-Figure 7.2-8-

TABLE 7.2-1

09314000 HUNTINGTON CREEK NEAR HUNTINGTON, UTAH

LOCATION.--Lat 39°22'17", long 111°03'43", in SW¼NE¼SE¼ sec.6, T.17 S., R.8 E., Emery County, on left bank 300 ft (revised) downstream from farm road bridge, 1 mile upstream from Fish Creek, and 7 miles northwest of Huntington.

DRAINAGE AREA.--190 sq mi, approximately.

PERIOD OF RECORD.--May 1909 to September 1917, October 1918 to November 1920 (fragmentary), April 1921 to May 1930, October 1930 to September 1970.

GAGE.--Water-stage recorder. Altitude of gage is 6,210 ft (from river-profile map). Prior to Apr. 30, 1913, nonrecording gage 3 ft downstream at different datum. May 1, 1913, to Sept. 10, 1917, water-stage recorder at site 95 ft upstream at same datum as preceding gage.

AVERAGE DISCHARGE.--55 years (1910-17, 1921-29, 1930-70), 96.7 cfs (70,060 acre-ft per year).

EXTREMES.--Maximums and minimums (discharge in cubic feet per second, gage height in feet).

Annual maximum discharge (*) and peak discharges above base (400 cfs), water years 1966-70

Date	Time	Disch.	G.H.	Date	Time	Disch.	G.H.	Date	Time	Disch.	G.H.
July 11, 1966	1300	*387	3.97	May 30, 1968	2300	724	4.74	Sept.10, 1969	0400	757	4.65
				June 19, 1968	0100	548	4.31	Sept.15, 1969	1500	617	4.35
May 22, 1967	2230	604	4.42	July 30, 1968	2030	*1,640	6.33				
Sept. 8, 1967	2200	556	4.34	Aug. 1, 1968	1730	408	3.92	May 19, 1970	0100	*817	4.83
Sept. 9, 1967	2100	*782	4.83					June 10, 1970	1700	622	4.48
				May 13, 1969	2300	*777	4.71				
May 21, 1968	2400	526	4.32	July 19, 1969	1900	644	4.55				

Annual minimum discharge, water years 1966-70

Wtr yr	Date	Disch.	G.H.	Wtr yr	Date	Disch.	G.H.
1966	Mar. 3, 1966	11	2.07	1969	Jan. 24, 1969	7.8	1.70
1967	Feb. 20, 1967	6.1	1.96	1970	Feb. 19, 1970	8.7	1.64
1968	Nov. 27, 1967	12	2.03				

Period of record: Maximum discharge, 2,500 cfs Aug. 2 or 3, 1930 (gage height, 7.5 ft, from floodmark), from rating curve extended above 600 cfs; minimum recorded, 2 cfs Nov. 5, 1926.

REMARKS.--Records good except those for winter periods and those for periods of no gage-height record, which are fair. Small diversions for irrigation above station, including transmountain diversions to tributaries of San Pitch River (Sevier Lake basin). Slight regulation by small reservoirs above station.

REVISIONS.--WSP 1925: Drainage area.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1965 TO SEPTEMBER 1966

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	51	37	32	35	38	28	79	147	130	143	112	78
2	62	36	36	38	39	27	96	179	124	150	87	64
3	73	36	39	31	30	21	101	192	143	146	97	58
4	70	36	39	34	34	24	87	208	150	143	108	56
5	78	36	38	36	37	27	77	220	146	141	82	57
6	78	36	35	36	40	33	78	228	143	132	82	56
7	78	36	34	36	45	36	84	244	141	141	79	70
8	78	36	38	36	40	36	97	255	146	139	79	58
9	76	36	37	36	38	36	116	268	140	132	81	57
10	73	35	36	36	29	37	122	284	135	120	79	58
11	60	35	36	36	23	37	108	295	146	135	79	60
12	60	36	30	36	22	36	94	217	137	128	79	61
13	60	37	37	36	21	37	90	167	132	110	79	57
14	58	35	37	36	20	40	94	172	132	103	78	62
15	60	35	27	36	19	41	106	162	141	103	78	62
16	60	36	33	33	19	41	122	172	160	103	81	57
17	66	44	35	29	20	37	148	182	162	104	81	55
18	62	38	38	25	21	37	150	177	148	101	81	54
19	60	37	40	23	22	38	128	182	141	101	84	54
20	58	36	40	22	22	37	120	172	143	97	82	52
21	57	36	41	27	23	37	114	172	152	94	79	52
22	57	38	41	31	24	34	110	172	150	94	78	51
23	57	40	35	32	27	35	106	162	146	92	73	51
24	56	39	30	33	29	36	118	152	143	94	52	50
25	55	39	31	34	30	36	137	162	139	84	52	48
26	62	30	33	35	28	38	140	146	135	84	54	47
27	64	28	35	34	29	44	157	132	128	92	51	49
28	59	25	37	36	27	48	150	135	124	89	48	55
29	37	29	38	36	------	52	150	150	128	94	49	55
30	37	30	40	37	------	58	160	146	132	101	52	55
31	36	------	39	38	------	66	------	137	------	99	80	------
TOTAL	1,886	1,059	1,119	1,033	784	1,170	3,459	5,791	4,245	3,493	2,356	1,703
MEAN	60.8	35.1	36.1	33.3	28.0	37.7	115	187	142	113	76.0	56.8
MAX	78	44	41	38	45	66	160	284	162	150	112	78
MIN	36	25	27	22	19	21	77	132	124	84	48	47
AC-FT	3,740	2,090	2,220	2,050	1,560	2,320	6,860	11,490	8,420	6,930	4,670	3,380

CAL YR 1965 TOTAL 49,126 MEAN 135 MAX 646 MIN 15 AC-FT 97,440
WTR YR 1966 TOTAL 28,092 MEAN 77.0 MAX 284 MIN 19 AC-FT 55,720

TABLE 7.2-1 Continued

09318000 HUNTINGTON CREEK NEAR HUNTINGTON, UTAH--CONTINUED

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1966 TO SEPTEMBER 1967

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	52	24	22	19	22	25	36	58	353	244	152	118
2	73	24	24	19	18	27	34	57	346	238	159	110
3	73	24	24	19	18	27	34	57	342	235	139	91
4	57	24	19	19	18	27	36	57	342	220	124	89
5	45	23	22	19	18	27	38	56	371	200	118	89
6	40	24	30	18	18	24	37	68	375	180	118	87
7	35	26	28	19	18	26	36	79	346	170	118	84
8	32	27	27	19	17	25	41	104	336	169	124	124
9	32	21	22	19	18	31	38	124	314	150	124	110
10	32	26	20	19	20	28	38	135	308	145	118	81
11	32	27	20	19	18	29	41	124	311	148	120	78
12	32	28	20	19	18	30	40	97	336	150	118	59
13	36	24	20	19	17	30	37	90	339	158	114	56
14	35	27	20	19	17	29	37	81	357	134	110	55
15	32	27	20	19	16	27	40	89	368	159	120	55
16	29	27	20	19	16	32	44	135	346	171	120	54
17	27	27	20	19	17	33	41	196	336	176	120	53
18	27	27	20	19	16	37	44	288	339	148	116	53
19	27	24	20	19	17	36	52	353	368	137	116	53
20	27	26	20	20	16	32	46	412	386	126	116	52
21	27	28	20	21	17	31	44	434	378	110	116	61
22	27	27	19	22	18	33	41	465	378	137	120	70
23	27	23	19	22	18	35	38	493	386	150	120	81
24	27	18	19	23	19	35	37	465	364	157	116	64
25	27	17	19	22	20	36	38	457	353	141	118	64
26	27	24	19	22	21	36	36	427	342	139	118	64
27	27	21	19	22	23	35	58	465	332	135	124	63
28	23	25	19	22	24	34	66	461	314	137	122	64
29	27	28	19	22	------	36	62	446	291	152	118	63
30	25	26	19	23	------	33	58	415	278	157	122	61
31	25	------	19	23	------	34	------	382	------	154	122	------
TOTAL	1,070	749	648	625	515	962	1,270	7,592	10,335	5,030	3,760	2,178
MEAN	34.5	25.0	20.9	20.2	18.4	31.0	42.3	245	345	162	122	72.6
MAX	73	29	30	23	24	37	66	493	386	244	159	118
MIN	25	17	19	19	16	24	34	56	278	110	118	52
AC-FT	2,120	1,490	1,290	1,240	1,020	1,910	2,520	15,060	20,500	9,980	7,500	4,320

CAL YR 1966 TOTAL 26,501 MEAN 72.6 MAX 264 MIN 17 AC-FT 52,560
WTR YR 1967 TOTAL 34,754 MEAN 95.2 MAX 493 MIN 16 AC-FT 68,930

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1967 TO SEPTEMBER 1968

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	59	29	19	22	22	30	46	114	539	188	146	65
2	55	29	18	21	22	31	50	145	539	176	121	72
3	55	21	19	19	22	31	43	161	548	146	74	70
4	55	25	20	19	22	32	40	184	548	141	65	89
5	54	32	21	18	22	31	41	207	624	154	70	92
6	58	27	22	17	22	31	41	221	626	150	69	91
7	53	26	22	16	22	32	34	191	543	150	69	91
8	53	26	23	16	22	31	36	174	497	141	75	96
9	53	26	23	16	22	30	34	164	436	137	68	100
10	53	27	23	16	22	30	38	191	397	135	75	106
11	53	26	23	16	22	28	42	184	386	124	80	106
12	48	26	23	17	22	27	50	202	386	116	84	112
13	48	26	23	18	22	31	53	191	434	112	82	112
14	48	24	23	19	22	29	45	168	461	104	104	112
15	46	24	23	20	22	28	51	154	465	110	89	87
16	47	24	21	20	22	30	52	157	473	122	80	87
17	47	24	19	21	22	30	49	159	481	122	58	86
18	47	23	20	21	22	29	44	196	495	126	60	84
19	46	22	22	21	22	29	42	230	510	122	50	86
20	45	24	22	21	22	26	42	311	493	124	46	82
21	45	24	21	21	23	28	42	393	457	148	45	82
22	45	21	20	21	24	29	41	438	423	152	47	78
23	45	22	19	21	24	30	41	382	397	148	52	76
24	45	23	18	21	25	30	44	304	366	135	45	76
25	41	24	19	22	27	32	41	272	328	157	43	74
26	36	16	19	22	28	32	41	304	278	141	56	74
27	33	17	20	22	29	30	43	371	241	139	59	72
28	32	19	21	22	29	32	41	469	236	139	68	72
29	28	20	22	22	30	34	86	514	230	122	67	80
30	28	20	22	22	------	41	99	560	213	143	65	82
31	31	------	23	22	------	43	------	582	------	124	65	------
TOTAL	1,432	725	653	612	679	957	1,532	9,291	13,040	4,268	2,177	2,604
MEAN	46.2	24.2	21.1	19.7	23.4	30.9	51.1	267	435	138	70.2	86.8
MAX	59	32	23	22	30	43	99	582	624	188	146	112
MIN	28	16	18	16	22	24	34	114	213	104	43	65
AC-FT	2,840	1,440	1,300	1,210	1,350	1,900	3,040	16,450	25,880	8,470	4,320	5,170

CAL YR 1967 TOTAL 35,077 MEAN 96.2 MAX 493 MIN 16 AC-FT 69,610
WTR YR 1968 TOTAL 36,978 MEAN 101 MAX 626 MIN 16 AC-FT 73,350

* NOTE.--NO GAGE-HEIGHT RECORD OCT. 9 TO NOV. 8, JAN. 6 TO FEB. 14.

TABLE 7-2.1 Continued

09315000 HUNTINGTON CREEK NEAR HUNTINGTON, UTAH--CONTINUED

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1968 TO SEPTEMBER 1969

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	75	72	25	26	26	33	62	335	469	171	102	61
2	74	72	25	26	26	30	63	389	449	154	101	63
3	68	72	25	26	26	28	64	417	427	150	99	65
4	74	35	25	26	26	31	60	420	404	145	104	78
5	72	31	25	26	26	30	67	411	386	141	102	67
6	68	32	26	26	26	28	74	402	375	135	99	63
7	68	27	26	26	26	31	61	424	366	135	99	76
8	68	28	26	26	26	29	59	391	332	161	118	56
9	67	34	26	26	26	22	58	398	318	159	109	58
10	65	32	26	26	26	25	65	431	298	154	110	101
11	63	28	26	26	26	27	74	458	272	152	112	75
12	63	30	26	26	27	26	84	459	253	148	110	67
13	63	30	26	26	27	25	91	456	247	148	101	64
14	60	26	26	26	27	30	82	452	235	148	86	63
15	64	27	26	26	27	29	72	431	247	143	84	67
16	60	28	26	26	27	34	64	545	272	137	86	62
17	76	26	26	26	27	35	62	554	272	130	86	63
18	76	29	26	26	26	35	82	569	266	130	89	62
19	72	31	26	26	30	34	93	574	244	150	97	60
20	64	26	26	26	31	32	109	569	224	145	91	59
21	64	24	26	26	32	34	143	559	213	132	72	62
22	61	28	26	26	30	34	187	573	197	126	70	65
23	61	30	26	26	28	35	225	535	196	108	69	61
24	61	22	26	26	31	34	258	503	291	102	67	64
25	60	24	26	26	30	30	246	516	259	101	67	80
26	59	21	26	26	29	34	210	539	235	96	67	78
27	58	23	26	26	23	36	190	591	213	87	65	75
28	59	23	26	26	32	40	199	600	204	89	68	74
29	58	23	26	26	------	43	236	582	191	116	76	64
30	70	23	26	26	------	48	287	578	184	120	75	64
31	74	------	26	26	------	50	------	548	------	104	67	------
TOTAL	2,105	955	801	806	766	1,012	3,627	17,109	8,541	4,117	2,741	1,759
MEAN	67.9	31.8	25.8	26.0	27.4	32.6	121	552	285	133	88.4	58.6
MAX	84	72	26	26	32	50	287	659	469	171	112	101
MIN	58	21	25	26	23	22	58	335	184	87	65	39
AC-FT	4,180	1,890	1,590	1,600	1,520	2,010	7,190	33,940	16,940	8,170	5,440	3,490

CAL YR 1968 TOTAL 38,029 MEAN 104 MAX 626 MIN 16 AC-FT 75,430
WTR YR 1969 TOTAL 44,341 MEAN 121 MAX 659 MIN 21 AC-FT 87,959

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1969 TO SEPTEMBER 1970

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	63	60	30	25	30	36	24	110	493	182	136	85
2	64	55	29	25	30	38	24	113	495	170	104	77
3	67	36	29	25	30	36	55	125	505	156	101	73
4	64	33	34	25	30	35	49	146	473	150	100	72
5	59	33	29	75	33	36	42	177	513	152	108	107
6	60	33	30	25	37	34	42	213	457	148	113	97
7	75	35	30	25	34	38	45	239	450	159	109	64
8	70	31	30	25	33	39	41	223	482	139	105	79
9	58	33	30	25	32	39	58	224	485	137	83	75
10	74	33	30	25	37	38	79	224	549	141	89	83
11	75	30	30	25	36	38	84	238	470	119	92	90
12	75	32	30	25	37	38	73	245	410	116	105	93
13	72	31	30	25	37	36	72	259	376	108	111	97
14	72	30	30	25	35	35	75	301	342	101	111	91
15	76	30	30	25	35	37	70	322	319	129	110	87
16	79	35	32	30	34	33	67	405	311	125	108	87
17	84	26	30	30	34	34	68	503	318	124	109	86
18	85	25	32	30	29	31	65	584	332	115	108	86
19	78	28	35	30	23	32	66	623	367	114	110	85
20	43	38	34	33	36	34	62	572	377	178	115	85
21	42	30	34	35	47	35	64	495	375	176	116	74
22	46	27	35	40	36	34	63	448	352	183	109	73
23	44	25	34	43	37	33	62	493	345	176	77	73
24	46	26	35	39	36	33	65	490	300	172	73	72
25	48	29	33	37	36	32	108	500	283	171	70	69
26	41	29	34	37	36	31	129	491	269	173	71	65
27	38	24	20	37	36	30	129	497	250	143	74	64
28	43	24	25	28	37	29	118	521	230	140	73	63
29	60	30	25	30	------	29	116	488	220	132	72	63
30	56	30	25	30	------	27	112	469	200	142	71	65
31	59	------	25	30	------	26	------	500	------	140	82	------
TOTAL	1,916	961	939	916	963	1,056	2,123	11,258	11,344	4,511	3,015	2,402
MEAN	61.8	32.0	30.3	29.5	34.4	34.1	70.8	363	378	146	97.3	80.1
MAX	85	60	36	43	47	39	129	623	549	183	116	107
MIN	38	24	20	25	23	26	24	110	200	101	70	63
AC-FT	3,800	1,910	1,860	1,820	1,910	2,100	4,210	22,330	22,500	8,950	5,980	4,760

CAL YR 1969 TOTAL 44,296 MEAN 121 MAX 659 MIN 20 AC-FT 87,860
WTR YR 1970 TOTAL 41,406 MEAN 113 MAX 623 MIN 20 AC-FT 82,130

TABLE 7.2-2

Chemical Analyses of Selected Surface Water Samples 1977-79

Concentration: In milligrams per liter, unless otherwise indicated; <, less than.
Site No.: Shown on plate 1.
Discharge: Measured except E, estimated.
Specific conductance: In micromhos per centimeter at 25 degrees Celsius.
Other data available: SQS, semiquantitative determination of trace elements reported in table 12.

Stream	Site No.	Date	Temperature (degrees C)	Discharge (ft^3/s)	Alkalinity (as $CaCO_3$)	Bicarbonate	Dissolved boron (µg/L)	Dissolved calcium	Carbonate	Dissolved chloride	Dissolved fluoride
Huntington Creek	21	8-15-77	15.0	16	140	200	10	49	0	2.5	0.1
		6- 6-78	5.5	45	160	190	20	49	0	2.9	.1
Spring Creek	22	8-15-77	15.0	0.25	110	140	20	38	0	2.9	.1
		6- 6-78	4.5	25.0	130	160	10	45	0	2.9	.1
Left Fork of Huntington Creek	23	8-15-77	19.5	1.8	110	130	40	50	0	3.5	.1
Lake Canyon	24	8-15-77	15.0	1.6	160	200	20	57	0	2.1	.1
Left Fork of Huntington Creek	34	10-12-77	4.0	8E	170	210	5	54	1	2.3	.1
		7-28-78	16.1	–	130	160	20	45	1	1.7	.1
		10-17-78	3.4	10E	190	–	20	49	–	2.1	.1
		7-18-79	8.0	70	130	–	30	40	–	1.7	.1
		10-15-79	11.0	45E	131	160	20	36	–	1.5	.1
	39	10-12-77	5.6	10E	200	240	10	55	1	2.8	.1
		7-26-78	–	–	140	170	10	44	0	1.7	.1
		10-17-78	4.7	12E	180	–	20	50	–	2.8	.1
		7-19-79	7.5	80	140	–	40	41	–	1.8	.1
		10-15-79	10.0	45E	146	178	20	38	–	1.7	.1
Huntington Creek	41	7-26-78	18.5	–	140	170	30	47	0	2.6	.1
		10-17-78	5.5	30E	180	–	30	51	–	3.4	.1
		7-19-79	7.5	100	140	–	20	43	–	2.2	.1
		10-15-79	9.5	65	153	186	20	41	–	2.1	.1
Crandall Canyon (gaging station 09317919)	51	10-12-77	3.0	1.0E	220	270	30	59	1	7.6	.2
		7-26-78	18.2	–	190	230	20	54	0	3.8	.1
		10-18-78	4.9	.7E	230	–	30	53	–	4.7	.1
		7-19-79	9.5	1.9	200	–	40	48	–	4.4	.1
		10-15-79	6.0	.54	–	288	20	54	–	4.7	.1
Wild Cattle Hollow	61	10-13-77	7.5	70E	200	240	10	67	0	5.0	.1
		7-27-78	10.1	–	210	250	20	60	0	5.5	.1
		10-17-78	6.0	.1E	250	–	50	64	–	5.2	.1
		7-19-79	9.0	1.5	210	–	30	48	–	4.1	.1
		10-15-79	8.0	.25	249	303	20	62	–	4.8	.1
Tie Fork (gaging station 09317920)	67	10-13-77	6.3	.43	190	230	30	63	1	4.4	.1
		6- 9-78	5.3	8.8	–	–	–	68	–	3.6	–
		7-26-78	16.3	–	200	240	20	53	–	4.4	.1
		10-17-78	6.4	50E	250	–	30	64	–	4.6	.1
		7-19-79	12.5	1.8	200	–	50	49	–	4.3	.1
		10-15-79	8.0	.51	–	302	20	58	–	4.5	.1
Huntington Creek	68	7-27-78	16.1	420	150	170	20	47	4	2.2	.1
		10-18-78	6.0	30E	180	–	30	51	–	3.2	.1
		7-19-79	12.0	105	150	–	30	51	–	2.4	.1
		10-15-79	9.5	70E	156	190	30	42	–	2.3	.1
	69	7-27-78	15.8	–	150	180	20	46	0	2.1	.1
		10-18-78	5.7	30E	190	–	30	53	–	3.0	.1
		7-19-79	11.5	110	140	–	20	40	–	2.1	.1
		10-16-79	6.5	70E	159	194	20	44	–	2.2	.1
Little Bear Canyon	70	7-27-78	15.5	–	230	280	30	54	0	5.6	.1
		10-18-78	7.1	.5E	190	230	40	65	–	6.3	.2
		7-19-79	13.5	1.0	240	–	40	47	–	6.5	.1
		10-16-79	5.0	.75	276	337	30	58	–	6.2	.1
Huntington Creek	71	7-27-78	17.6	–	140	170	20	49	0	4.7	.1
		10-18-78	5.6	30E	180	–	20	52	–	3.1	.1
		7-19-79	13.5	110	140	–	50	40	–	2.2	.1
		10-16-79	7.0	70E	160	195	20	43	–	2.3	.1
Mill Fork	76	7-27-78	18.2	–	250	300	30	53	0	7.9	.1
		7-19-79	14.5	14	250	–	60	46	–	9.4	.2
		10-16-79	6.0	.04	295	360	40	58	–	10	.1
Huntington Creek	77	7-28-78	13.2	–	150	180	20	49	0	2.5	.1
		10-18-78	5.7	30E	160	–	30	50	–	4.6	.1
		7-19-79	14.0	110	140	–	50	40	–	2.3	.1
		10-16-79	8.0	75E	157	191	20	44	–	2.4	.1
Rilda Canyon	78	7-15-76	12.0	.50	279	340	40	62	–	11	.2
		7-26-78	15.2	–	230	280	40	59	0	6.6	.1
		10-18-78	6.4	.35E	360	–	80	73	–	8.6	.2
		7-18-79	11.5	2.0	170	–	60	50	–	7.6	.2
		10-16-79	7.0	< 1.0	336	410	50	75	–	10	.2
Huntington Creek	80	8-15-77	17.0	25	160	200	30	43	0	3.8	.1
		6- 6-78	6.0	360	150	180	10	50	0	2.7	.1
Meetinghouse Canyon	84	8- 6-79	18.5	.21	180	–	50	39	12	5.8	.2
Deer Creek	86	8-26-79	8.6	.26	270	–	110	110	–	7.2	.2
	87	7-28-78	15.2	–	210	260	60	55	0	22	.7
		7-18-79	17.0	1.0	230	0	120	65	–	16	.2
Huntington Creek (gaging station 09318000)	88	6- 9-77	15.0	–	160	190	30	55	0	3.9	.1
		8-15-77	19.0	13	170	210	40	57	0	15	.2
		6- 6-78	6.5	360	160	190	20	51	0	9.1	.1
		11-14-78	2.5	16	210	250	50	60	0	6.8	.1
		6-13-79	13.0	216	140	–	20	52	2	3.3	.2
		11-11-79	0	19	250	–	20	59	0	4.4	.1
Cottonwood Creek	103	10-13-77	2.8	1.0E	180	210	30	66	7	7.6	.1
		7-27-78	10.0	–	220	270	30	57	0	8.2	.1
		10-19-78	4.7	.2E	284	–	40	59	–	8.6	.1
		7-18-79	14.0	.97	240	–	60	47	–	9.9	.2
		10-16-79	5.0	–	287	350	30	60	–	9.4	.1
Cottonwood Creek (gaging station 09324200)	104	10-13-77	2.3	1.0E	220	260	30	56	1	7.8	.1
		7-27-78	12.4	–	220	270	30	46	0	8.2	.1
		10-19-78	4.7	.8E	260	–	50	52	–	9.8	.1
		7-18-79	16.0	.97	210	–	50	37	–	9.9	.2
		10-16-79	5.0	.51	277	330	30	51	4	9.5	.1
Grimes Wash	107	8-26-79	13.3	.10	260	–	40	78	–	12	.2
	108	9-29-76	14.5	< .01	256	312	110	97	0	22	.2

TABLE 7.2-2 Continued

Concentration													
Hardness (as $CaCO_3$)	Noncarbonate hardness (as $CaCO_3$)	Dissolved iron (µg/L)	Dissolved magnesium	Dissolved potassium	Dissolved silica	Dissolved sodium	Dissolved solids	Dissolved sulfate	Dissolved strontium (µg/L)	Sodium adsorption ratio	pH (units)	Specific conductance	Other data available
180	20	–	1.3	0.8	3.3	2.9	154	5.7	–	0.1	8.2	330	–
180	20	–	.9	1.3	3.1	2.5	193	20	–	.1	7.8	300	–
120	3	–	5.5	.8	2.7	2.0	130	8.9	–	.1	7.5	220	–
140	8	–	6.8	.7	3.9	1.6	147	7.5	–	.1	7.5	230	–
150	42	–	5.8	1.2	22	2.8	191	41	–	.1	7.3	300	–
180	13	–	8.5	.6	3.9	1.9	179	6.6	–	.1	8.0	290	–
200	31	–	17	.8	5.2	1.5	192	6.5	–	0	8.7	340	–
150	15	–	8.7	.6	2.7	1.5	147	6.1	–	.1	8.8	240	–
170	2	20	12	.7	3.3	1.7	176	4.2	100	.1	8.7	303	–
130	1	10	7.6	.5	3.1	1.2	140	7.7	–	0	7.8	273	–
140	4	10	11	.5	1.0	1.6	136	5.5	–	.1	8.1	270	–
220	25	–	21	1.2	5.6	3.3	220	12	–	.1	8.4	420	–
150	12	–	10	.7	2.6	1.7	152	6.6	–	.1	8.4	260	–
200	15	< 10	17	.9	3.7	2.8	197	11	120	.1	8.4	400	–
140	0	10	8.7	.7	3.0	1.5	150	8.8	–	.1	7.9	285	–
140	0	10	12	.5	1.4	1.7	150	7.2	–	.1	8.1	267	–
170	31	–	13	1.1	3.4	2.2	169	15	–	.1	8.8	300	SOS
190	8	40	15	1.1	3.5	2.6	201	16	100	.1	8.3	380	–
150	6	60	9.4	.8	3.0	1.4	154	10	–	.1	7.8	307	–
180	3	20	13	.7	2.1	1.9	165	12	–	.1	8.1	290	–
290	68	–	35	2.0	7.0	7.2	287	35	–	.2	8.6	470	SOS
220	33	–	21	1.3	5.6	4.3	234	30	–	.1	8.6	480	–
250	22	10	29	1.3	6.1	4.9	273	35	180	.1	7.8	500	–
220	23	0	25	1.2	5.2	5.2	240	31	–	.1	7.9	450	–
260	22	20	30	1.4	6.2	5.3	282	38	–	.1	8.2	470	–
260	61	–	22	1.4	6.5	4.4	251	26	–	.1	8.3	520	–
260	52	–	26	1.3	5.8	3.8	266	38	–	.1	7.8	390	–
280	29	< 10	29	1.3	6.1	4.5	273	26	200	.1	7.9	560	–
210	0	0	21	1.1	5.4	3.3	224	15	–	.1	7.6	426	–
270	17	40	27	1.4	6.0	4.3	281	26	–	.1	8.0	485	–
310	120	–	36	1.8	6.9	3.8	265	35	–	.1	8.6	500	SOS
250	–	–	19	3.3	–	2.6	185	13	–	–	8.6	410	–
250	55	–	29	1.6	5.9	3.8	247	30	–	.1	8.8	450	–
290	62	20	32	1.8	6.7	3.0	289	38	270	.1	8.2	543	–
230	29	10	26	7.3	6.3	3.9	234	23	–	.1	8.1	450	–
270	25	40	31	1.8	6.3	4.1	293	38	–	.1	8.2	501	–
170	21	–	12	.8	2.9	1.9	166	11	–	.1	8.5	260	–
200	18	40	17	1.1	3.6	3.1	201	19	120	.1	8.4	378	–
170	23	10	11	.8	3.2	1.8	174	13	–	.1	8.0	308	–
160	7	10	14	.8	2.2	2.1	171	14	–	.1	8.3	301	–
160	17	–	12	.8	2.9	1.8	165	10	–	.1	8.2	280	–
210	21	30	18	1.2	3.5	3.4	209	18	120	.1	8.3	380	–
140	1	10	10	.6	3.1	1.7	154	12	–	.1	7.9	273	–
170	8	10	14	.8	2.1	2.1	175	14	–	.1	8.1	309	–
290	62	–	38	1.8	6.6	7.1	291	39	–	.2	8.7	500	–
210	22	< 10	12	1.8	6.8	7.4	250	36	250	.2	8.2	575	–
270	34	10	38	1.8	6.5	8.1	292	40	–	.2	7.8	548	–
300	25	< 10	38	1.7	6.7	7.5	326	42	–	.2	8.2	538	–
180	36	–	13	.9	2.9	2.0	175	18	–	.1	8.8	270	–
200	24	30	18	1.1	3.2	3.1	205	16	120	.1	8.6	370	–
150	5	10	11	.4	3.1	2.0	155	12	–	.1	8.1	296	–
170	5	20	14	.8	2.1	2.1	174	13	–	.1	8.2	302	–
280	39	–	37	2.0	7.1	11	318	52	–	.3	8.7	440	–
280	34	0	41	5.2	6.8	10	327	58	–	.3	8.0	514	–
340	47	10	48	3.0	7.4	12	391	75	–	.3	8.3	612	–
170	24	–	12	.9	2.8	2.2	170	11	–	1	8.4	285	–
200	39	30	18	1.2	3.2	3.6	203	26	120	.1	8.3	390	–
140	–	10	10	.8	3.1	1.7	154	12	–	.1	8.4	302	–
170	11	< 10	14	.8	2.0	2.3	176	16	–	1	8.2	316	–
380	98	20	54	2.5	8.2	17	424	100	–	.4	–	–	–
310	82	–	40	2.0	6.4	10	326	63	–	.2	8.9	500	–
410	65	20	54	3.1	8.8	18	429	99	430	.4	8.1	840	–
290	120	–	39	1.1	6.7	13	292	72	–	.3	8.1	620	–
420	82	20	56	3.2	8.6	18	503	130	–	.4	8.1	730	–
180	17	–	18	1.7	4.3	4.1	196	22	–	.1	8.3	332	–
170	27	–	12	.6	3.0	2.1	173	14	–	.1	7.8	280	–
230	50	0	32	3.9	5.3	10	260	43	310	.3	8.6	438	–
410	140	190	33	1.1	6.4	19	< 372	32	–	.4	8.4	490	–
380	170	–	59	4.0	10	29	476	160	–	.6	8.8	650	SOS
360	130	0	47	4.1	7.9	25	474	170	–	.6	8.1	790	–
200	43	–	15	1.1	3.4	4.6	200	23	–	.1	8.3	390	–
250	73	–	25	1.9	5.8	13	289	67	–	.4	8.1	478	–
180	21	–	12	.8	4.0	2.9	183	14	–	.1	7.8	290	–
250	44	20	24	1.4	5.7	9.2	278	47	160	.3	8.2	470	–
140	3	10	3.1	.5	3.2	4.2	175	21	190	.2	8.4	365	–
230	34	10	21	1.4	4.7	5.8	251	33	150	.2	8.3	435	–
330	150	–	41	2.0	7.0	10	276	32	–	.2	8.5	540	–
300	81	–	39	1.7	6.7	12	306	47	–	.3	7.8	470	–
300	54	20	38	1.8	6.9	12	317	40	330	.3	8.6	620	–
280	38	10	39	1.8	6.9	18	319	52	–	.5	7.9	640	–
310	23	20	39	2.0	6.8	14	355	51	–	.3	8.0	583	–
310	94	–	41	2.1	7.0	11	286	32	–	.3	8.5	540	SOS
280	58	–	40	1.8	6.5	12	294	45	–	.3	8.3	470	–
290	31	10	39	2.0	6.9	12	319	40	330	.3	8.7	512	–
240	35	0	37	2.1	6.2	18	290	53	–	.5	8.0	610	–
290	15	20	40	2.1	6.7	15	343	52	–	.4	8.4	550	–
370	110	150	43	1.4	8.0	22	< 384	63	–	.5	8.3	580	SOS
580	320	20	82	4.8	8.9	31	763	360	700	.6	8.0	1,200	–

TABLE 7.2-3

Field determinations of discharge, specific conductance, pH, water temperature and alkalinity at selected springs -- Continued

LOCATION	GEO-LOGIC UNIT	DATE OF SAMPLE	ALTI-TUDE	DIS-CHARGE (GAL/MIN)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	ALKA-LINITY FIELD (MG/L) AS $CACO_3$
(D-16-7) 26ADC-S1	211SRPN	78-04-27	7120.00	110	--	--	--	--
	211SRPN	78-05-26	7120.00	110	--	--	--	--
	211SRPN	78-06-09	7120.00	120	--	--	--	--
	211SRPN	78-06-23	7120.00	130	--	--	--	--
	211SRPN	78-07-06	7120.00	150	--	--	--	--
	211SRPN	78-07-28	7120.00	150	--	--	--	--
	211SRPN	78-08-10	7120.00	160	--	--	--	--
	211SRPN	78-08-30	7120.00	155	--	--	--	--
	211SRPN	78-10-13	7120.00	165	--	--	--	--
	211SRPN	78-10-25	7120.00	160	--	--	--	--
	211SRPN	78-11-01	7120.00	155	--	--	--	--
	211SRPN	78-12-13	7120.00	145	--	--	--	--
	211SRPN	79-03-07	7120.00	135	--	--	--	--
(D-16-7) 26BCA-S1	211SRPN	78-05-25	6860.00	23	--	--	--	--
	211SRPN	78-08-10	6860.00	19	--	--	11.0	--
	211SRPN	78-10-11	6860.00	19	--	--	11.0	--
	211SRPN	78-11-07	6860.00	19	--	--	10.5	--
	211SRPN	78-12-13	6860.00	19	--	--	10.0	--
	211SRPN	79-06-14	6860.00	10	--	--	11.0	--
	211SRPN	79-06-28	6860.00	10	720	8.0	11.0	--
	211SRPN	79-07-20	6860.00	9.3	660	7.0	11.5	--
	211SRPN	79-08-22	6860.00	21	750	--	10.5	--
	211SRPN	79-09-17	6860.00	19	750	--	10.5	--
	211SRPN	79-10-16	6860.00	20	680	--	11.5	--
(D-16-7) 26CBB-S1	211SRPN	78-08-10	6950.00	57	--	--	11.0	--
	211SRPN	78-10-11	6950.00	57	--	--	10.0	--
	211SRPN	78-11-07	6950.00	57	--	--	10.0	--
	211SRPN	78-12-13	6950.00	57	--	--	10.0	--
	211SRPN	79-05-10	6950.00	44	--	--	--	--
	211SRPN	79-06-28	6950.00	30	820	7.6	10.5	--
	211SRPN	79-07-16	6950.00	27	710	7.0	12.5	--
	211SRPN	79-09-18	6950.00	65	760	--	9.5	--
	211SRPN	79-10-18	6950.00	60	750	--	11.0	--

	211SRPN	78-07-06	7120.00	150	--	--	--	--
	211SRPN	78-07-28	7120.00	150	--	--	--	--
	211SRPN	78-08-10	7120.00	160	--	--	--	--
	211SRPN	78-08-30	7120.00	155	--	--	--	--
	211SRPN	78-10-13	7120.00	165	--	--	--	--
	211SRPN	78-10-25	7120.00	160	--	--	--	--
	211SRPN	78-11-01	7120.00	155	--	--	--	--
	211SRPN	78-12-13	7120.00	145	--	--	--	--
	211SRPN	79-03-07	7120.00	135	--	--	--	--
(D-16-7) 26BCA-S1	211SRPN	78-05-25	6860.00	23	--	--	--	--
	211SRPN	78-08-10	6860.00	19	--	--	11.0	--
	211SRPN	78-10-11	6860.00	19	--	--	11.0	--
	211SRPN	78-11-07	6860.00	19	--	--	10.5	--
	211SRPN	78-12-13	6860.00	19	--	--	10.0	--
	211SRPN	79-06-14	6860.00	10	--	--	11.0	--
	211SRPN	79-06-28	6860.00	10	720	8.0	11.0	--
	211SRPN	79-07-20	6860.00	9.3	660	7.0	11.5	--
	211SRPN	79-08-22	6860.00	21	750	--	10.5	--
	211SRPN	79-09-17	6860.00	19	750	--	10.5	--
	211SRPN	79-10-16	6860.00	20	680	--	11.5	--
·16-7) 26CBB-S1	211SRPN	78-08-10	6950.00	57	--	--	11.0	--
	211SRPN	78-10-11	6950.00	57	--	--	10.0	--
	211SRPN	78-11-07	6950.00	57	--	--	10.0	--
	211SRPN	78-12-13	6950.00	57	--	--	10.0	--
	211SRPN	79-05-10	6950.00	44	--	--	--	--
	211SRPN	79-06-28	6950.00	30	820	7.6	10.5	--
	211SRPN	79-07-16	6950.00	27	710	7.0	12.5	--
	211SRPN	79-09-18	6950.00	65	760	--	9.5	--
	211SRPN	79-10-18	6950.00	60	750	--	11.0	--

TABLE 7.2-3
Continued

(D-16-7) 27ADC-S1	211SRPN	78-08-10	7000.00	15	--	--	11.0	--
	211SRPN	78-10-11	7000.00	5.8	--	--	11.0	--
	211SRPN	78-11-07	7000.00	4.9	--	--	10.0	--
	211SRPN	78-12-13	7000.00	5.4	--	--	10.0	--
	211SRPN	79-05-10	7000.00	.0	--	--	--	--
	211SRPN	79-06-28	7000.00	.0	--	--	--	--
	211SRPN	79-08-22	7000.00	2.0	870	--	10.0	--
	211SRPN	79-09-18	7000.00	3.4	780	--	10.0	--
	211SRPN	79-10-18	7000.00	3.1	730	--	11.5	--
16-7) 35ABC-S1	111ALVM	78-10-13	6620.00	22	--	--	--	--
	111ALVM	78-11-08	6620.00	20	--	--	--	--
	111ALVM	78-12-11	6620.00	23	--	--	--	--
	111ALVM	79-05-11	6620.00	26	--	--	--	--
	111ALVM	79-06-28	6620.00	20	960	8.1	10.5	--

TABLE 7.2-4

Chemical Analysis of Water Samples Taken
by Co-Op Mining Company from Bear Creek

Date	Location*	Flow (gpm)	Temp. (°C)	pH	Iron (mg/l)	Manganese (mg/l)	Suspended Solids (mg/l)
11-15-82	1	25	--	8.0	1.50	.32	706
	2	30	--	7.9	1.51	.33	688
12-20-82	1	no flow					
	2	no flow					
2-22-83	1	no flow					
	2	no flow					
3-22-83	1	400	--	--	1.91	.35	5,581
	2	400	--	8.0	1.80	.30	7,980
4-25-83	1	425	--	7.5	.17	.36	20,000
	2	425	--	7.5	.15	.07	20,000
5-24-83	1	1,125	--	7.7	43.10	5.00	15,880
	2	1,125	--	7.9	36.30	3.80	14,740
6-17-83	1	1,125	--	8.1	7.63	.05	8,326
	2	1,125	--	--	6.50	.05	14,060
7-31-83	1	N/A					
	2	N/A					
8-26-83	1	N/A					
	2	N/A					
9-20-83	1	9.4	17	8.2	5.40	.80	3,437
	2	11.8	17	8.2	*.05	*.08	2,616
10-24-83	1	32.6	1	7.4	2.66	.35	1,349
	2	36.0	1	7.7	2.66	.32	1,238
11-29-83	1	no flow	0	8.2	.80	.18	686
	2	40	0	8.3	.86	.13	512
12-29-83	1	1.2	--	8.1	1.17	.20	553
	2	---	0	8.05	1.13	.21	500

TABLE 7.2-4 Continued

Date	Location*	Flow (gpm)	Temp. (°C)	pH	Iron (mg/l)	Manganese (mg/l)	Suspended Solids (mg/l)
1-26-84	1	---	2	7.8	6.57	1.19	4,928
	2	---	2	8.05	4.41	.94	4,020
2-14-84	1	13.8	2	*1.9	1.65	.27	830
	2	14	2	7.85	2.50	.27	1,168
3-7-84	1	16.7	2	8.0	1.49	.07	342
	2	14.2	1	8.2	3.00	.44	1,568
4-11-84	1	27.0	--	8.1	2.36	.60	4,950
	2	28.2	--	8.1	1.68	.33	1,922

*Location #1 is upstream, below Bear Creek Falls. Location #2 is downstream, at Bear Creek Weir W-4.

TABLE 7.2-5

Percent Slope	Slope Length in Feet													
	300	400	500	600	700	800	900	1000	1100	1200	1300	1500	1700	2000
0.2	0.11	0.12	0.13	0.14	0.15	0.15	0.16	0.16	0.17	0.17	0.18	0.19	0.19	0.20
0.3	0.12	0.13	0.14	0.15	0.16	0.16	0.17	0.18	0.18	0.18	0.19	0.20	0.21	0.22
0.4	0.13	0.14	0.15	0.16	0.17	0.17	0.18	0.19	0.19	0.20	0.20	0.21	0.22	0.23
0.5	0.14	0.15	0.16	0.17	0.18	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24
1.0	0.18	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.27	0.28	0.29	0.30	0.32
2.0	0.28	0.31	0.33	0.34	0.36	0.38	0.39	0.40	0.41	0.42	0.43	0.45	0.47	0.49
3.0	0.40	0.44	0.47	0.49	0.52	0.54	0.56	0.57	0.59	0.61	0.62	0.65	0.67	0.71
4.0	0.62	0.70	0.76	0.82	0.87	0.92	0.96	1.01	1.04	1.08	1.12	1.18	1.24	1.33
5.0	0.93	1.07	1.20	1.31	1.42	1.52	1.61	1.69	1.78	1.86	1.93	2.07	2.21	2.40
6.0	1.17	1.35	1.50	1.65	1.78	1.90	2.02	2.13	2.23	2.33	2.43	2.61	2.77	3.01
8.0	1.72	1.98	2.22	2.43	2.62	2.81	2.98	3.14	3.29	3.44	3.58	3.84	4.09	4.44
10.0	2.37	2.74	3.06	3.36	3.62	3.87	4.11	4.33	4.54	4.74	4.94	5.30	5.65	6.13
12.0	3.13	3.61	4.04	4.42	4.77	5.10	5.41	5.71	5.99	6.25	6.51	6.99	7.44	8.07
14.0	3.98	4.59	5.13	5.62	6.07	6.49	6.88	7.26	7.61	7.95	8.27	8.89	9.46	10.26
16.0	4.92	5.68	6.35	6.95	7.51	8.03	8.52	8.98	9.42	9.83	10.24	11.00	11.71	12.70
18.0	5.95	6.87	7.68	8.41	9.09	9.71	10.30	10.86	11.39	11.90	12.38	13.30	14.16	15.36
20.0	7.07	8.16	9.12	9.99	10.79	11.54	12.24	12.90	13.53	14.13	14.71	15.80	16.82	18.24
25.0	10.20	11.78	13.17	14.43	15.59	16.66	17.67	18.63	19.54	20.41	21.24	22.82	24.29	26.35
30.0	13.78	15.91	17.79	19.48	21.04	22.50	23.86	25.15	26.38	27.55	28.68	30.81	32.80	
40.0	21.92	25.31	28.30	31.00	33.48									
50.0	30.87													
60.0														

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TABLE 7.2-

SURFACE WATER BASELINE AND OPERATIONAL
WATER QUALITY PARAMETER LIST

Field Measurements:

*	-	Water Levels or Flow
*	-	pH
*	-	Specific Conductivity (umhos/cm)
*	-	Temperature (C^o)
*	-	Dissolved Oxygen (ppm)

Laboratory Measurements: (mg/l)

*	-	Total Settleable Solids
*	-	Total Suspended Solids
*	-	Total Dissolved Solids
*	-	Total Hardness (as $CaCO_3$)
	-	Aluminum (Al)
	-	Arsenic (As)
	-	Barium (Ba)
	-	Boron (B)
*	-	Carbonate (CO_3^{-2})
*	-	Bicarbonate (HCO_3^-)
	-	Cadmium (Cd)
*	-	Calcium (Ca)
*	-	Chloride (Cl^-)
	-	Chromium (Cr)
	-	Copper (Cu)
	-	Fluoride (F^-)
*	-	Dissolved Iron (Fe)
	-	Lead (Pb)
*	-	Magnesium (Mg)
*	-	Manganese (Mn)
	-	Mercury (Hg)
	-	Molybdenum (Mo)
	-	Nickel (Ni)
	-	Nitrogen: Ammonia (NH_3)
	-	Nitrate (NO_3^-)
	-	Nitrate (NO_2)
*	-	Potassium (K)
	-	Phosphate (PO_4^{-3})
	-	Selenium (Se)
*	-	Sodium (Na)
*	-	Sulfate (SO_4^{-2})
	-	Sulfide ($S^=$)
	-	Zinc (Zn)
*	-	Oil and Grease
*	-	Cation-Anion Balance

-Baseline
*Operational

Surface Water Sampling

TABLE 7.2-
(cont'd)

	Baseline	Operational	Postmining
Type of Sampling Site	Surface Water Bodies	Surface Water Bodies	Surface Water Bodies
Field Measurements (See Table 1)	Performed during water level/flow measurements	Performed during water level/flow measurements	Performed during water level/flow measurements
Sample Frequency	Quarterly for lakes, reservoirs and impoundments (water level and quality); monthly flow measurements and quarterly water quality measurements (one sample at low flow and high flow each) for perennial streams. Monthly flow and water quality measurements during period of flow for intermittent streams. Sampling for ephemeral streams determined at pre-design conference.	Quarterly for lakes, reservoirs and impoundments (water level and quality); monthly flow measurements and quarterly water quality measurements (one sample at low flow and high flow each) for perennial streams. Monthly flow and water quality measurements during period of flow for intermittent streams. Sampling for ephemeral streams determined at pre-design conference.	Two per annum for perennial streams (high & low flow); two per annum during snowmelt and rainfall for intermittent streams.
Sampling Duration	Two years (one complete year of data before submission of PAP.	Yearly until two years after surface reclamation activities have ceased.	Until termination of bonding.
Type of Data Collected and Reported	Flow and/or water levels and water quality.	Flow and/or water levels and water quality.	Flow and/or water levels and water quality per operational parameters.
Comments	All field measurements should be performed concurrently with water level/flow measurements.	All field measurements should be performed concurrently with water level/flow measurements.	All field measurements should be performed concurrently with water level/flow measurements

TABLE 7.2-
(cont'd)

	Baseline	Operational	Postmining
Comments		For every fifth year preceding repermitting, one sample at low flow and high flow each should be taken for baseline water quality parameters.	

Table 7.2-7

REVISED SUMMARY OF CULVERT SIZES

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	Adjusted Flow (cfs)	Slope (%)	Diameter	Required Headwater From Bottom of Culvert	HW/D	HW=(HW/D)XD	Adjusted Required Headwater Above Top Of Culvert
C-1R	13.3	8.0	18"	27"	2.62	3.93	29"
C-2R	16.22	8.0	18"	36"	3.65	5.5	48"
C-3R	14.76	8.0	18"	27"	3.2	4.8	40"
C-1u	11.4	15.0	30"	18"	.66	1.65	NA
C-2u	2.24	15.0	15"	9"	.70	.68	NA
C-3u	10.06	5.0	12"	36"	6.0+	6.0+	60+
C-4u	8.12	5.1	10"	36"	6.0+	6.0+	60+
C-5u	8.12	4.8	10"	36"	6.0+	6.0+	60+
C-6u	1.46	3.7	10"	12"	1.3	1.1	3.2"
C-7u	13.15	8.3	12"-18"	27"	2.6	3.9	28"
C-8u	11.4	15.0	18"	24"	1.92	2.9	18.8
C-9u	2.3	7.3	15"	9"	.725	.83	NA
C-1D	2.24	20.0	15"	9"	.725	.83	NA
C-2D	6.23	12.0	18"	15"	1.05	1.6	1.2"
C-3D	1.52	4.2	12"	9"	.825	.825	NA
C-4D	2.24	20.0	15"	9"	.725	.83	NA

HORROCKS
CAROLLO
ENGINEERS

September 27, 1985

MEMORANDUM

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DIVISION OF OIL
GAS & MINING

TO: Wendell Owens
Co-op Mining

FROM: H. Lee Wimmer, P.E.
Hydrologist

SUBJECT: Responses to Questions (from Meeting September 17, 1985) by State of Utah Natural Resources, Division of Oil, Gas and Mining - Bear Canyon Mine

The questions raised during the September 17th meeting, between Lee Wimmer and Evan Nixon of Horrocks/Carollo Engineers, and John Whitehead, Tom Munson and John Fricke of DOGM, were concerning Section 7.3 Reclamation Hydrology. Items of particular concern were:

1. Filter blanket analysis for riprap, accompanied by a gradation analysis of soils in the Bear Creek channel.

   Response: Analysis showed that filter blankets are necessary to prevent crosion of sediments under rip-rap. Gradation requirements are indicated in Figure 7.3-4 along with the base material gradation analysis.

2. References in the text to cross-section configurations to be used in the reclaimed channel.

   Response: Specific references have been made to the reclaimed cross-sections and profiles in the text.

3. Miner additions and corrections to Plates 7-7 and 7-8 and Figure 7.3-2.

   Response: The corrections and additions to the check dam figure and the addition of Bear Creek's profile have been made.

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4. More check dam design details and text.

   Response: More check dam text (Section 7.3.3) and design details (Figure 7.3-5) have been added.

5. Maximum rip-rap size (i.e. D_{100})

   Response: A maximum natural rip-rap size (D_{100}) has been specified as 18 inches. Recommended gradations for well-graded rip-rap are contained in Figure 7.3-4.

To incorporate the revised Section 7.3 into the present Chapter 7, remove all pages between 7.8 and 8.5 inclusive, and replace with the enclosed material.

lh

85093992/coop

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7.3 RECLAMATION HYDROLOGY

7.3.1 POST MINE REHABILITATION

Upon completion of mining activities all diversion structures (ditches, culverts, ponds) shall be reclaimed as close to original configurations as possible. Sequencing of this reclamation shall be from the highest points in elevation to the lowest ones. In addition, the lower disturbed area collection ditches and the sedimentation ponds shall not be removed until the reclaimed areas have stabilized.

7.3.2 RESTORATION OF NATURAL CHANNELS

There are two drainages in addition to Bear Creek whose channels have been disturbed by mining activities. Reclamation of these channels shall include placement of meandering, naturally configured channels, based on other natural channels in the immediate area. Measures shall be taken to restore a pattern of riffles, pools and drops approximate to natural stream channel characteristics. These channels shall be reconstructed in the locations, and to the dimensions shown in the cross-sections (C-C and D-D) and profiles (E and F) of Plates 7-7 and 7-8. Hydraulic computer simulations were run to insure the adequacy of this configuration for the required 100-year storm (see Appendix I). Table 7.3.1 contains a summary of the results.

The soil of the area contains naturally occurring rip-rap which will be used along with the meandering, riffles, pools, and drops of the channel to control sediment erosion. Where the channels steepen as they drain into Bear Creek well-graded riprap, of the sizes indicated on Plate 7-7, shall be placed

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(based on figure 7.2-7). The native material excavated from the reclaimed channels shall be sorted to provide riprap with a D_{100} of 18". Filter blankets will be placed under the rip-rap. Gradation requirements of the filter blankets are indicated in figure 7.3-4. Filter gradations are based on gradation analysis of native material (2" minus), figure 7.3-5, and standard riprap gradations, and riprap, filter and base material ratios from Haan and Barfield, "Applied Hydrology and Sedimentology of Disturbed Lands," page 195.

7.3.3 BEAR CREEK CHANNEL RECLAMATION

The methodology which the Co-Op Mining Company shall implement upon final abandonment and reclamation of that portion of Bear Creek in the vicinity of the Scale house are as follows:

1. To use a large track mounted excavator in conjunction with a small backhoe and crawler tractor to remove the 60" culvert and to regrade the channel to the pre-mining configuration. The channel side-slopes will be on approximately a 3 to 1 slope to facilitate revegetation and to enhance the establishment of a riparian zone. (Note Figure 7.3-1 for the present stream configuration and projected after reclamation).
2. To construct small holding ponds along the channel utilizing native materials. The actual methodology is to build rock check dams 24" to 30" high incorporating boulders and 12" to 24" in diameter. A keyway, 24" wide and deep, shall be excavated into the stream bed and banks of the creek channel. The boulders shall be placed so as to form an 18" wide by 5" deep notch in the center of the creek channel, to create a centralized spillway. Once the dams are in place, 6" to 12" rock rip-rap shall be laid on the upstream

How much deep - 24"?

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side to a height equal to the height of the boulders and continued upstream for a distance of 36" decreasing in height so as to be level with the original rip-rapped channel. Then by utilizing a backhoe, a pit approximately 3' in diameter will should be dug at the fall line of the spillway and lined with large rock 2'+. An apron, 36" to 45" in length across the width of the dam, composed of 6" to 12" rock shall be used to protect the downstream side of the dam. The check dam-pond configuration will be repeated at 70' to 100' intervals along the course of the creek channel to create a stepped configuration along the area of disturbance. Sizing and spacing of dams is based on Heede's "Gully Development and Control." See figure 7.3-5 for details. Construction and placement of the check dams will be as shown on Figure 7.3-2 and Plate 7-7. Typical undisturbed cross-sections and the profile of Bear Creek to be used in reconstruction are shown on Plate 7-8 (cross-sections A-A and B-B). Rock sizing is based on velocities from Table 7.3-2 and Figure 7.2-7.

The intent of the holding ponds created by the check dams is to fill with sediment and minimize the downstream migration of this potentially detrimental source of silt and convert it into a potentially beneficial, enriched, growth media to facilitate the enlargement and establishment of riparian vegetation. Over a course of time the water holding capability of the ponded area will decrease as the ponds fill with sediment, however, the small ponds at the base of the spillway should remain relatively free from sediment and due to the small surface areas and depth, they will hold water over an extended period during dry seasons.

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The methodology is one which has been successfully implemented in various areas to facilitate both water holding and enhancement of riparian zones and has been proven successful.

7.3.4 SEDIMENTATION PONDS RECLAMATION

The sedimentation ponds will be the last structures reclaimed. Reclamation of the ponds shall not be implemented until all reclaimed disturbed areas have stabilized. At that time the embankments shall be removed and the material spread to conform to the area's natural contours. Placement of topsoil and reseeding of the area will provide final reclamation.

7.3.5 POST-MINING MINE DISCHARGES

In the event there are any discharges from the underground workings after mining has stopped and before bond release, the discharges will be sampled on a quarterly basis and, if necessary, treatment will be provided to achieve compliance with applicable standards.

Since the Bear Canyon No. 1 Mine slopes to the surface at approximately 2.5%, there is a potential for gravity discharge of mine water after reclamation. It is proposed to place one 4" PVC pipe through the lowest entry seal (belt entry) and run it out of the mine to a discharge point at the edge of the reclaimed pad. The pipe will be placed through the seal 24" from the floor to allow for sediment collection behind the seal. The pipe will then be laid along the floor and existing pad and covered with12" of granular (sand) backfill to prevent crushing. Discharge will be into a 6' diameter by 2' deep catch basin lined with 6" rip-rap. See Figure 7.3-3for construction details.

Co-Op will sample any discharges from the underground workings on a quarterly basis until bond release. If the sampling shows the discharge is not in compliance with UMC 817.42 and all other applicable regulations treatment will be applied to achieve compliance with applicable standards, for the Period of the Discharge.

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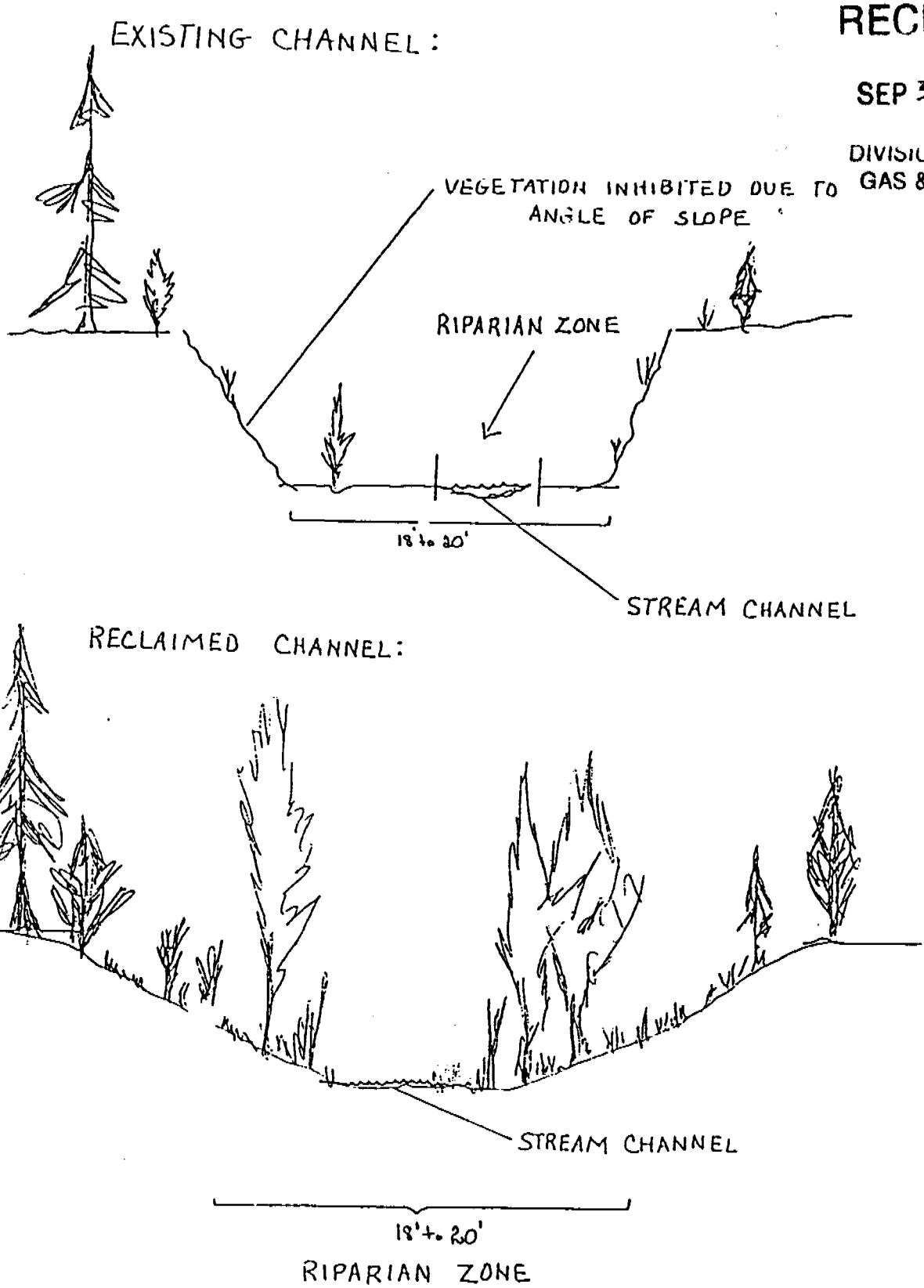

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Figure 7.3-1

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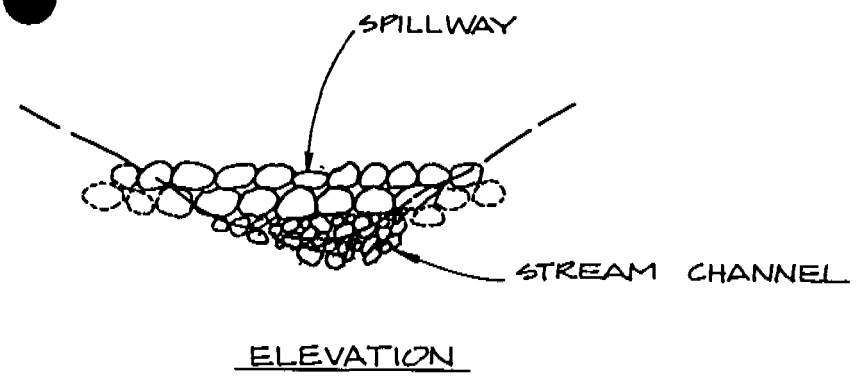
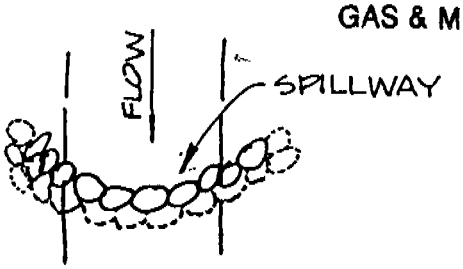
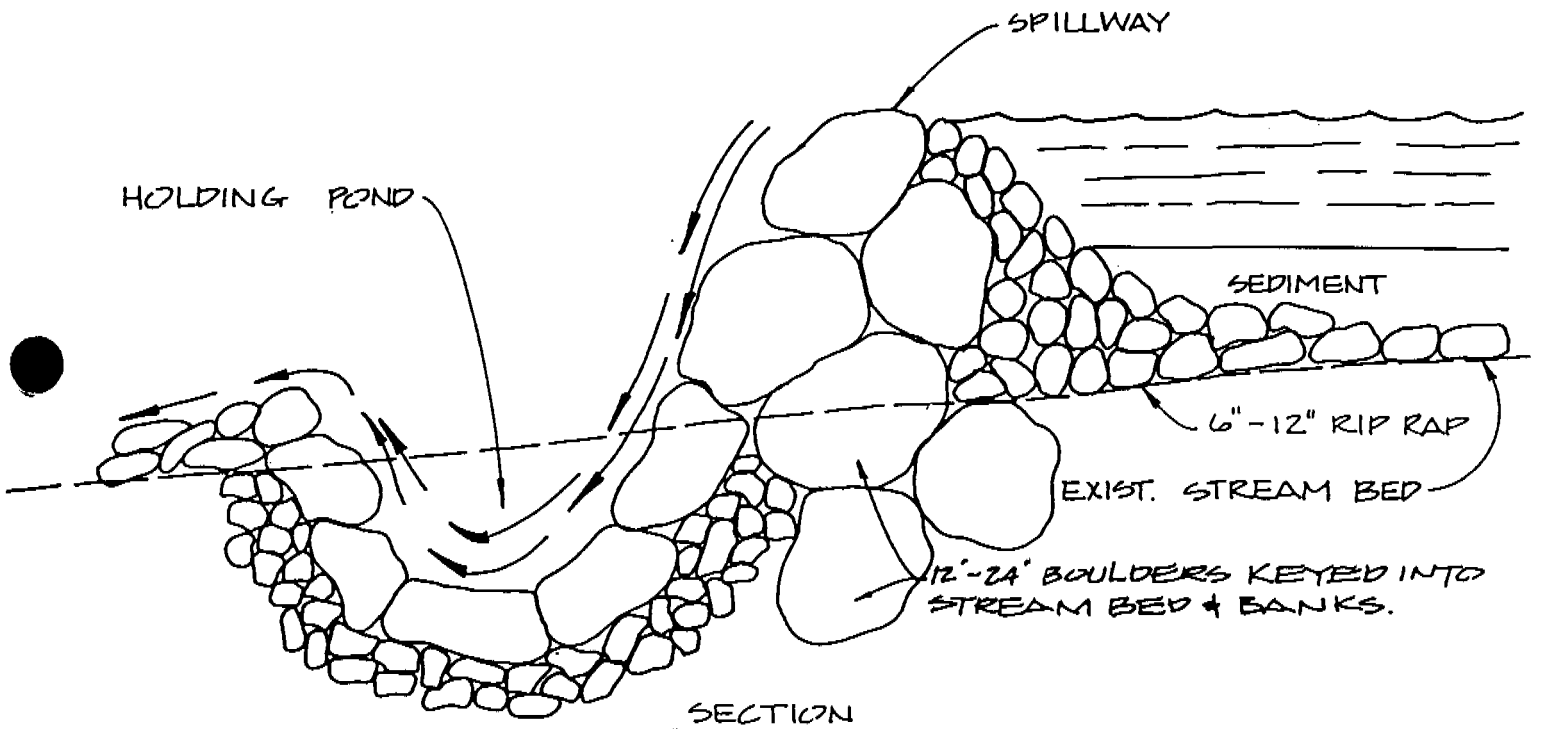


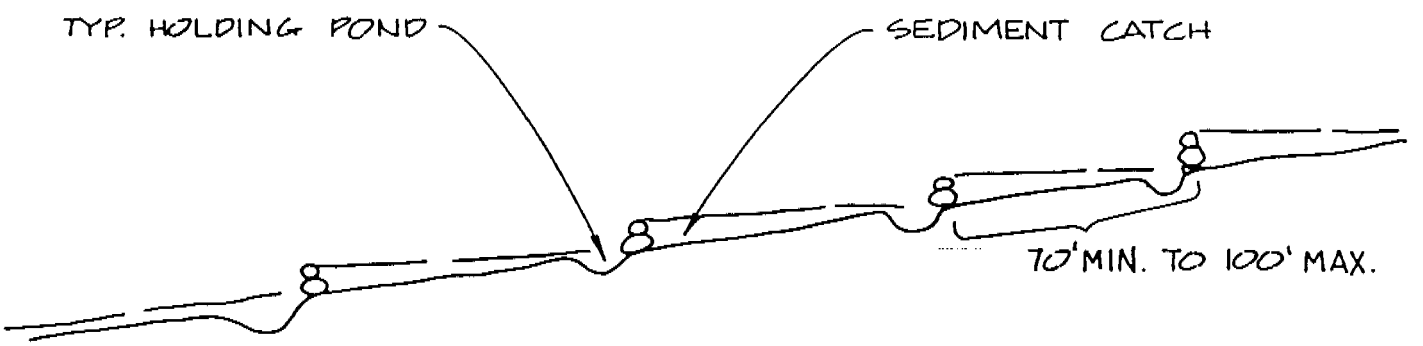
ELEVATION



PLAN



SECTION



RANDOM PLACEMENT

FIGURE 7.3-2

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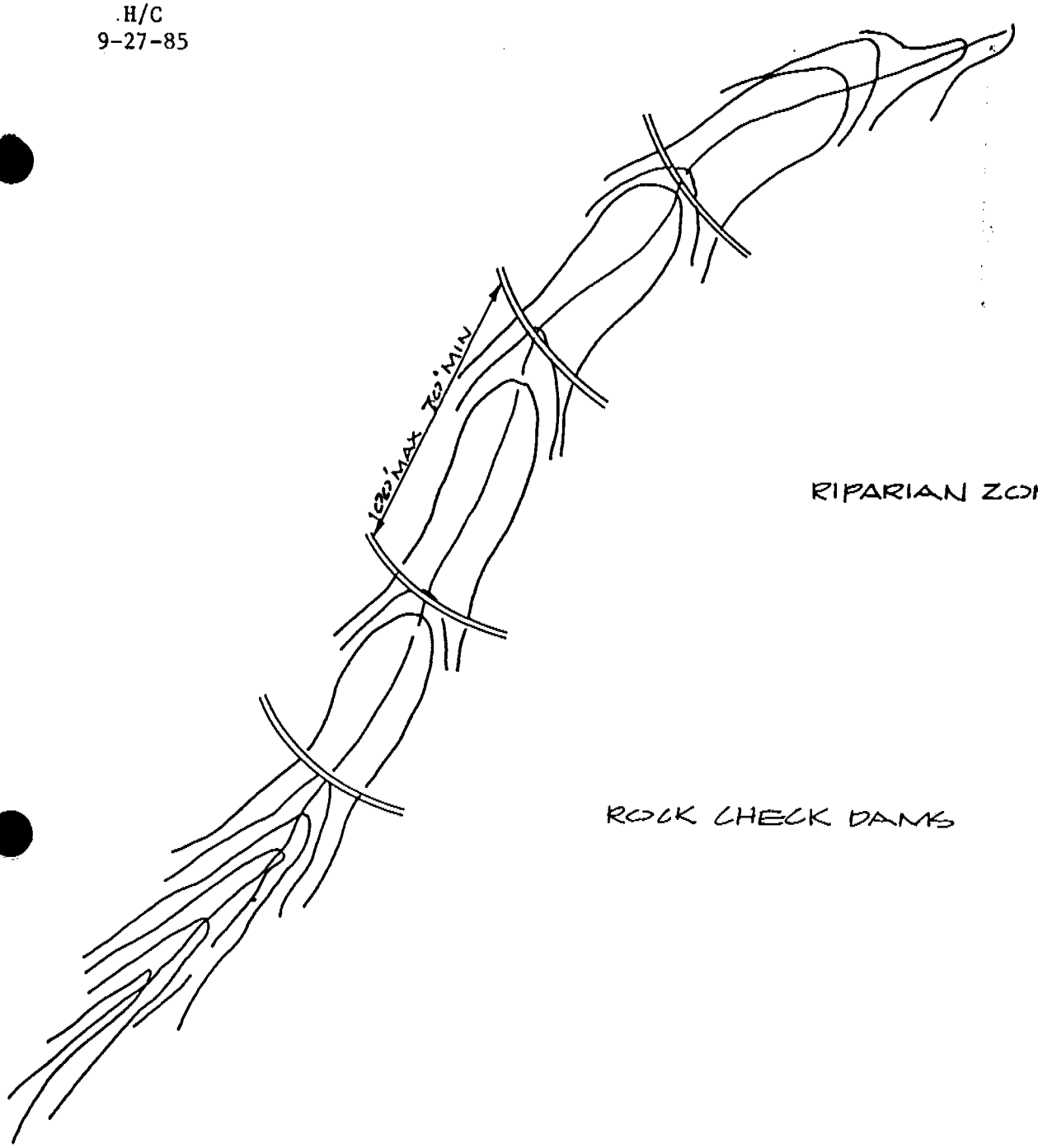

ENHANCED STREAM CHANNEL

FIGURE 7.3-2A

BY ..... DATE ..... SUBJECT ..... SHEET NO. ..... OF.....

CHKD. BY ..... DATE ..... Bear Canyon No. 1 Mine JOB NO. .....

Belt Entry

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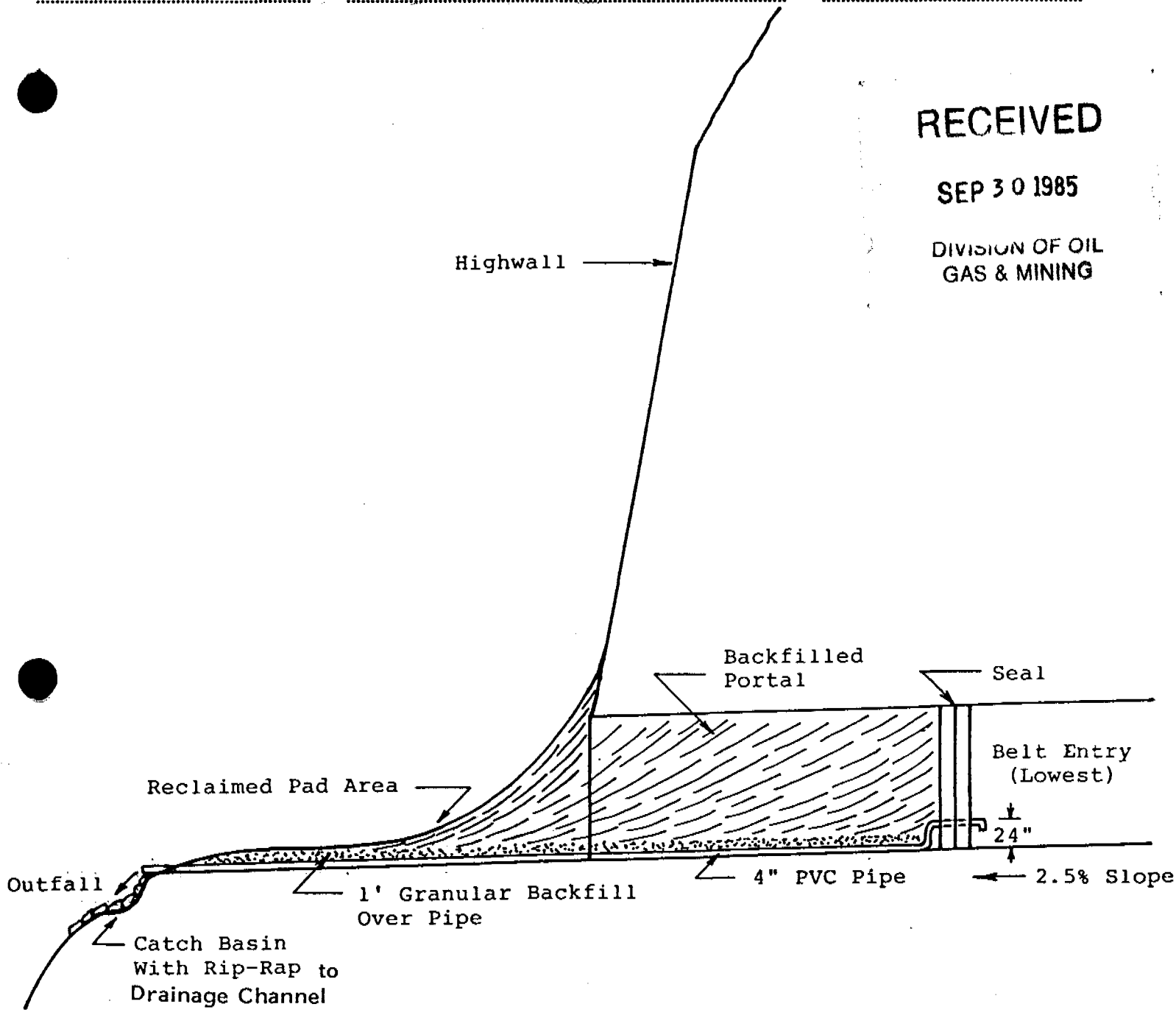

Scale: 1'=10'

Figure 7.3-3
83-A

HORROCKS/CAROLLO ENGINEERS

BY..... DATE ..... SUBJECT Co-Op Mines SHEET NO. 1 OF 4
CHKD. BY..... DATE ..... JOB NO. .....
Filter Blanket Material

Filter Blanket Requirements for 12" Riprap:

Gradations

12" Riprap (from fig. 3.1.7) – $D_{100} = 24"$, $D_{85} = 20"$, $D_{50} = 12"$, $D_{15} = 5"$

Base Mat'l. (2" minus) – $D_{100} = 2"$, $D_{85} = 1.25"$, $D_{50} = .50"$, $D_{15} = .033"$

Barf uses metric units - do these eqns hold for English units

1.) $D_{50(riprap)}/40 < D_{50(filter)} < D_{50(base)} \times 40$

$12"/40 = .30"$ $\qquad$ $20" = .50 \times 40$

$$.30" < D_{50(filter)} < 20"$$

2.) $5 \times D_{15(riprap)} > D_{15(filter)} > D_{15(base)}/5$

$5 \times 5" = 25" > \quad " \quad > .007" = .033/5$

– and –

$D_{15(riprap)}/40 < D_{15(filter)} < D_{15(base)} \times 40$

$5"/40 = .125" < \quad " \quad < 1.32" = .033 \times 40$

$$1.32" > D_{15(filter)} > .125"$$

(cont'd)

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FIGURE 7.3-4 FILTER BLANKET GRADATIONS

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HORROCKS/CAROLLO ENGINEERS

BY.....DATE.....SUBJECT.....SHEET NO. 2 OF 4
CHKD. BY.....DATE.....JOB NO.

Filter Blanket (cont'd)

3) $D_{15(riprap)}/5 < D_{85(filter)}$

$5''/5 = 1'' \therefore \underline{D_{85(filter)} > 1''}$

- and -

$D_{85(base)} \times 5 > D_{15(filter)}$

$1.25'' \times 5 = 6.25 \therefore \underline{D_{15(filter)} < 6.25''}$

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Filter Thickness:

Riprap thickness = $1.5 \times 12'' = 18''$

Filter thickness = $18''/2 = \underline{9''}$

Summary:

Gradation

$D_{85} > 1''$

$D_{50} > .30''$

$1.32'' > D_{15} > .125''$

Thickness

$9''$

← filter criteria (w/ 12" riprap)

FIGURE 7.3-4 (cont'd)

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HORROCKS/CAROLLO ENGINEERS

BY..... DATE ..... SUBJECT Co-Op Mines SHEET NO. 3 OF 4
CHKD. BY..... DATE ..... JOB NO. .....
Filter Blanket

Filter Blanket Requirements for 6" Riprap:

Gradations

6" riprap (from fig. 3.1.7)	$D_{100} = 12"$		Base Mat'l. (2" minus)	$D_{100} = 2"$
	$D_{85} = 8.5"$			$D_{85} = 1.25"$
	$D_{50} = 6"$			$D_{50} = .50"$
	$D_{15} = 2.5"$			$D_{15} = .033"$

1.) $D_{50(riprap)}/40 < D_{50(filter)} < D_{50(base)} \times 40$

$6"/40 = .15" < D_{50(filter)} < 20" = .50" \times 40$

2.) $5 \times D_{15(riprap)} > D_{15(filter)} > D_{15(base)}/5$

$5 \times 2.5 = 12.5" > \quad " \quad > .007" = .033/5$

- and -

$D_{15(riprap)}/40 < D_{15(filter)} < D_{15(base)} \times 40$

$2.5"/40 = .063" < \quad " \quad < 1.32" = .033 \times 40$

$.063 < D_{15(filter)} < 1.32"$

3.) $D_{15(riprap)}/5 < D_{85(filter)}$; $2.5"/5 = .50"$

$D_{85(filter)} > .50"$

$D_{15(base)} \times 5 > D_{15(filter)}$; $1.25" \times 5 = 6.25"$

$D_{15(filter)} < 6.25"$ (cont'd.)

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FIGURE 7.3-4 (cont'd)

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HORROCKS/CAROLLO ENGINEERS

BY.....DATE .....SUBJECT .....SHEET NO. 4 OF 4
CHKD. BY.....DATE .....JOB NO. .....

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Filter Blanket (cont'd)

Filter Thickness:

Riprap thickness = 1.5 × 6" = 9"

Filter thickness = 9"/2 = 4.5" : use 6"

Summary:

Gradation

$D_{85} > .50"$

$D_{50} > .15"$

$1.32" > D_{15} > .063"$

← filter criteria (w/ 6" riprap)

Thickness

6"

FIGURE 7.3-4 (cont'd)

HORROCKS ENGINEERS

H/C
9-27-85

Project Name CO-OP MINE Date SEPT. 27, 1985
Project No. Station 25' up stream of Sed. Pond "B"
Test For Filter Sample No. L-010

AS RECEIVED GRADATION			
Screen Size	Weight (g)	Percent Retained	Percent Passing
2"	0	0	100
1 1/2"	1371	7.1	92.9
3/4"	5527	28.7	64.2
1/2"	2486	12.9	51.3
3/8"			
#4	4070	21.1	30.2
Wet Wt. -#4	5810		
Dry Wt. -#4	5805.1	30.1	
Total Wt. Dry	19259.1		

SPECS.

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WASHED GRADATION AFTER CRUSHING (2500 Gm. Dry Recombined Sample)					
Screen Size	Weight Retained	Percent Retained	Percent Passing	Total % Passing	SPECS.
# 4	0	0	100	30.2	
#10	287.9	28.3	71.7	25.6	
#20	250.0	24.6	47.1	14.2	
#40	209.4	20.6	26.5	7.9	
#100	209.1	20.5	6.0	1.8	
#200	37.3	3.6	2.4	.7	
-#200	20.1	2.0			
Total Wt.	1018.0				

Wt. before washing
Wt. after washing

L.L.		A.A.S.H.O. Clasification
P.L.		
P.I.		

Tested By

FIGURE 7.3-4 (cont'd)

H/C
9-27-85

HORROCKS/CAROLLO ENGINEERS

BY EGW DATE SUBJECT Co-Op Mines SHEET NO. 1 OF
CHKD. BY DATE JOB NO.
Check Dams

Check Dams: (Referenced from Heede's, "Gully Development and Control")

Spacing: - Gully gradients between: 5 + 6%
- Effective dam height: .6m
from figure 8 : Spacing ≈ 30m (100')

Keys: from pg. 196 Keys = .6 m (24") deep and wide

Height: channel geometry in relation to spillway requirements limits dam heights to .6m to .75m.

Height = .6 to .75m (24" to 30")

Spillway: because of large flows for small channel, entire length of dam is used as a spillway. A small centralized spillway is provided for small flows.

Apron: Length - 1.5 × height : Length = 36" to 45"
Width = Width of dam

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83-B6

FIGURE 7.3-5: CHECK DAM DESIGN

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TABLE 7.3-1

PARAMETERS OF RECLAIMED CHANNELS

	AU-2 DRAINAGE ("E") PROFILE	AU-3 & AD-1 DRAINAGE ("F") PROFILE
100 Year Storm (cfs)	22.6	8.9
Manning coefficient (pg.371)	.050	.050
Slope (ft/ft)		
Upper section	.0833	.1136
Lower section	.2344	.1786
Velocity (fps)		
Upper section	6.36*	5.30*
Lower section	9.12	6.17*
Rip-rap		
Upper section	N/R	N/R
Lower section	12"	N/R

* These velocities are based on straight, uniform channels. Actual velocities shall be significantly less due to meanderings, riffles, pools and drops of the reclaimed channels.

N/R: not required

Note: This table is a summary of information from Plates 7-7 and 7-8 and Appendix I.

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TABLE 7.3-2

SUMMARY OF BEAR CREEK

CHANNEL FLOWS*

Flow (25yr storm): 365.7 cfs

Section	Slope	Velocity (fps)	Depth (ft)
1	.0541	7.35	3.83
2	.0513	1.04	8.26
3	.0513	1.38	8.26
4	.0611	4.28	6.25
5	.0632	9.05	4.60
6	.0432	5.35	4.52
7	.0496	6.37	3.90
8	.0619	6.88	3.65
9	.0640	6.47	4.24
10	.0484	7.66	2.98

* From Appendix H.

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APPENDIX 7- A

BEFORE THE BOARD OF OIL, GAS AND MINING

DEPARTMENT OF NATURAL RESOURCES

in and for the STATE OF UTAH

- - - - - - - - - - - - - -

IN THE MATTER OF THE APPROVAL OF NOTICE OF INTENT AND RECLAMATION) PLAN SUBMITTED BY CO-OP MINING COMPANY.)

CAUSE NO. ACT/015/025

- - - - -

BE IT REMEMBERED that on the 18th day of June, 1980, a hearing was held before the Board of Oil, Gas and Mining in the above-entitled matter and said hearing was taken before Athena Moore, a Certified Shorthand Reporter and Notary Public in and for the State of Utah, holding Utah C.S.R. License No. 88, commencing at the hour of 10:20 a.m. in the Wildlife Resources Auditorium, 1596 West North Temple, Salt Lake City, Utah.

0000087

Q Please give us your name and address and by whom you are employed?

A Bruce N. Kaliser, 2951 [illegible], Salt Lake City. Employed by the State of Utah, Division of Utah Geological and Mineral Survey.

Q (By Mr. Feight) You have heard the testimony before the Board this morning and you have some comments to make relative to this and your own experience in the area?

A Yes. Briefly, my work consisted of examination of the literature, a field examination of the sites of the three springs; Bear Canyon, Little Bear Canyon, and Birch Spring in this vicinity in question.

Examination of the existing mine to which they will enter and expand and the geology in the vicinity of the field. This was done about a month ago at the request of Castle Valley Special Services District.

In brief, my conclusion is that it is highly unlikely that the mine plan as presented to me by the Co-op Company would interfere with the quantity or quality of any of those springs, particularly the one in question, the Bear Canyon

Spring.

Q What do you base this conclusion on?

A I base that on the hydrogeologic regime which I believe prevails in the vicinity. The source of the spring is the Star Point Sandstone. There is a very predominant northeast striking joint and fault system that they parallel. The water contributory to this spring exists in my opinion to the north of the mine in the area of the Gentry Mountain. I believe that faults are a guiding, a strong guiding influence to the migratory pattern of groundwater regime in this area. But in entering the mine that Co op will be going into, it appears that the faults evident in that mine underground are tight, and water is only a distant near the canyon wells. In other words, near the entry, near the portal, not further in. There is no evidence of any water further in.

I don't believe that at that locality there is precipitation recharging the aquifer, and so I am of the opinion that the mining operation will not affect the discharge of the spring.

Now I do have other data. I've looked at the data. I believe what's been presented here

this morning I have not been given copies of what you have. I don't know for a fact that I have seen everything in identical fashion that you have been presented. But it's probable the same data that I have been provided by the improvement district and the mine.

Q Mr. Kaliser, if you look at Protestant's Exhibit No. 2, could you kind of draw a fault line for the Board and tell them where you think the faults are to the mining operation, and from what I understand, you are saying that the faults are so tight in the area of the mine that there is no migration of water through the fault system, am I correct?

A At the elevation of the mine, the fault gauge is sufficiently tight, and the relief, the runoff that would occur in the vicinity of the mine, I don't believe you would get a contribution at that point. I'm not saying that the faults--quite opposite--I'm not saying that the faults don't influence the groundwater pattern, but I'm saying that there is no evidence from what I see of the faults and in the mine that that is having any influence on the vertical migration of water down to the water table. There is no water table in

the mine.

Q Is the Star Point Formation, which is I understand is the water formation in the area, is above or below the coal seam?

A Below the coal seam. The coal seam is in the Blackhawk, so the mine is in the Blackhawk. I do believe there is hydraulic connection there between most of those formations because of that very prominent joint pattern that exists in this part of the plateau. And, of course, the area, this vicinity that we are speaking of is right in the present valley fault zone, so there are individual fault strands. Some of which are identified on existing geologic maps and some of which are in the field. In other words, identified faults not heretofore mapped and some showing presently on maps.

Q Approximately how many faults are there in the vicinity of the mine?

A In the vicinity of the mine I would say there could be three.

MR. BOX: Could you put them on the exhibit?

THE WITNESS: This map is sufficiently small in scale. I could, with a little time, but

I don't know if you want me to take up the time.

This is the larger scale.

MR. McINTYRE: Are they [illegible] northeast?

THE WITNESS: They are about [illegible]th 10 Degrees East. They are about vertical in attitude.

MR. McINTYRE: And what about displacement?

THE WITNESS: Displacement, we've measured in the mine displacements of two and a half feet, four feet two inches and one foot three inches in each case down to the east toward the canyon and the strikes that we measured varied from North 8 East to North 11 East. These were all taken in the mine underground.

The greatest fault appears to be at about 600 feet west of the mine portal, the existing mine portal.

Now if that fault maintains its strike, it would not strike into the spring and examination of the immediate vicinity of the spring reveals no trace of the fault, interestingly enough it does show that the water is emerging from joints from this which are parallel to the fault, but a third interestingly enough, no fault is [illegible] in the

immediate vicinity of the spring. You can see seepage being emitted from three distinct joints at the spring site. So it's quite an interesting situation.

I'm going to sketch on here some of the faults. I can do that, although the scale is such that you can't hold me to it. Birch Spring which is just around the corner, it's actually slightly northwest of Bear Canyon, but it is around the corner, cliffwise, and appears also to be emitted from a shear zone, a zone of closely spaced faults, but not distinct displacement. I can't observe any distinct fault displacements. It's an area that's highly deformed and has created this very prominent joint set, but you don't need displacement to create the channels, the secondary permeability roots.

MR. DANIELS: Can you hypothesize that this point produces the actual charge into the spring is from horizontal movement through the joint at or in the Star Point from areas to the north or to the west?

THE WITNESS: I think what happens to the north where principally the snow accumulates on Gentry Mountain, there is a recharge that is

vertical down to the water table through the Blackhawk, and there is a recharge also from those channels which are from those drainages which are lying along the joint and the fault trend. That vertical migration then reaches the Star Point and travels laterally along shear zones, prominent joints or faults and emerges where the topography disects the formation. I think all this is happening well below the mine.

MR. DANIELS: Essentially what you're saying is the water is dropping down to the next formation below and falling in under the mine?

THE WITNESS: Right.

MR. McINTYRE: In your opinion is it highly probable that additional activity underground in the mine could actually increase the flow of water to the spring in question?

THE WITNESS: Depending upon the use of the water in the mine and how they go about mining. It's possible. I think it would have a negligible effect at this site. It might have a greater effect should they go up to the north.

MR. DANIELS: Have you got an opinion on subsidence of the mine whether actual subsidence of the roof of the mine would affect the water flow

to the spring?

A I don't believe that subsidence would have an effect, because I think the runoff over the slopes above the mine--the rule is the greater the slope is -- and it is to the north, and I don't think it would make a difference.

There was one or two locations within the mine where there was roof collapse. No water was observed, however.

MR. DANIELS: Thank you.

MR. CHAIRMAN: Bruce, are you through?

THE WITNESS: Yes.

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APPENDIX 7-B

AGREEMENT

THIS AGREEMENT entered into this 22nd day of January, 1982, by and between Co-op Mining Company, a Utah partnership, C.O.P., INC., a Utah corporation, hereinafter jointly referred to as "Co-op", and Huntington City, a municipal corporation, hereinafter called "City".

WITNESSETH:

THAT WHEREAS, Co-op is undertaking to develop and put into operation a coal mine in Big Bear Creek Canyon, in Emery County, Utah;

AND WHEREAS, City has received in the past and is now receiving a significant portion of its culinary water supply from a spring in Big Bear Creek Canyon in the general proximity of the proposed mining operation;

AND WHEREAS, the parties to this Agreement wish to cooperate with each other so as to assure that Co-op activities will not in any manner result in a loss or diminution of the water supply available to the City from the Spring, the parties do hereby AGREE and COVENANT between themselves as follows:

1. That, at the option of City, representatives of City and the Co-op will make inspections underground in the old Bear Canyon Mine and any other mine operated in Bear Canyon by Co-op, to check for water.

2. That the City will maintain a flow meter at the Spring site and shall take measurements from the meter on a continuing basis so that any interference with the water supply or diminution in the flow can be readily determined, and the flow figures as measured shall be made available to Co-op.

3. That in the event that the quality of water at the Big Bear Creek Spring site decreases below the standards set by the Utah State Board of Health for culinary water, or in the event that the quantity of water at the Big Bear Spring decreases in flow 25% below the flow for the month immediately preceding, in any 30-day period; or 50 per cent below the average flow for the preceding 180 days in any 180-day period and such decrease cannot reasonably be ac-

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Utah State Board of Health for culinary water. Co-op agrees to use all reasonable diligence to take the required action or make the required replacement of a permanent acceptable nature as rapidly as feasible, not to exceed one year, unless a greater time is required by law, and further agrees to maintain such temporary measures until permanent measures are completed, at Co-op's sole expense. In the event that water treatment is required to bring the water obtained by Co-op up to Utah State standards for culinary water, Co-op further agrees to pay the proportionate share of the cost for treatment of said water as long as the interruption continues. In the event it is later determined that such decrease in the flow or quality of water is not a result of Co-op's mining activities, City agrees to reimburse Co-op for its reasonable and necessary expenses incurred pursuant to this paragraph. Co-op further agrees that if said mining operations diminish or interfere with the flow of or quality of water from the above Spring to the extent that mechanical water treatment plant is necessary, said Co-op shall pay a percentage of the plant cost related to said plant, proportional to the water needing treatment as a result of the diminution in quality or quantity of the Big Bear Springs, compared to the total water being treated by the City.

4. The parties further agree that the figures of 25% and 50 per cent relative to a decrease in flow of the Big Bear Creek Spring cited in paragraph 3 above as the trigger for Co-op's obligation to replace said diminution of flow may be altered from time to time by mutual agreement of the parties after a period of three years, after which time the parities will have sufficient spring flow data to more accurately establish that point at which the diminution of flow at the Spring site is likely to have been caused by the Co-op's mining operations.

5. In the event that there is a good faith dispute between the parties hereto whether or not Co-op's mining activities are the cause of a diminished flow or quality in Big Bear Creek Spring, the parties shall cooperate in taking immediate corrective measures reasonably necessary to restore said flow or quality of water. Each party shall bear one-half of the cost thereof, provided that if it can

able time for City's costs already paid pursuant to this Agreement.

6. In the event of good faith dispute between the parties as to the cause of any diminution in flow or quality of said Spring, the parties agree to appoint an arbitration committee and to be bound by the decision of said committee. This committee shall consist of five menbers: one Co-op representative, one City representative, and three representatives chosen by the other two members. The arbitration committee shall immediately meet and within 30 days make a preliminary decision as to the cause of any diminution in flow or quality of said Spring which preliminary decision shall bind the parties until the committee has had time to make a full investigation and reach a final decision. Nothing in this Agreement shall be construed as depriving either party of a right of action against any other non-parties including any insurance company issuing insurance pursuant to paragraph 9 hereof.

7. In the event any other mining operation or other activity of any other person or entity is proposed or planned in the area which may affect the flow of the Big Bear Creek Spring, City will require such person or entity to sign an agreement similar to this Agreement, binding such other person or entity to bear responsibility for any adverse effect such other person's or entity's activities may have upon the flow or quality of said Spring. In the event any diminution in the flow or quality of the Spring may be attributable to the activities of any person or entity other than Co-op, Co-op shall have the right to establish the same to City's reasonable satisfaction and thereby shall be entitled to reimbursement by City within a reasonable time from such establishment for reasonable costs incurred by Co-op for corrective action required under this Agreement to the extent it is established that such other person or entity is responsible for the diminished flow or quality. In that event City agrees to look to such other person or entity for such corrective action as it deems necessary.

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8. This Agreement shall terminate and Co-op shall have no further obligation hereunder with respect to any diminution of flow of Big Bear Creek Spring, one year after the final termina-

10. In the event legal action is brought to enforce the terms of this Agreement, the losing party in such action agrees to pay all costs thereof, including the reasonable attorney's fees of the prevailing party.

11. This Agreement shall cover the proposed mining operation on the Six Hundred Eighty (680) acres covered by and described in Cause No. ACT - 015-025, before the Utah Board of Oil, Gas and Mining, Department of Natural Resources.

12. As a condition to entering into the foregoing Agreement, the City agrees that it will withdraw its protest in Cause No. ACT - 015-025 before the Board of Oil, Gas and Mining, Department of Natural Resources of the State of Utah, and also it agrees that it will not protest the proposed mining operation on the the Six Hundred Eighty (680) acres as heretofore filed as a mining plan with the Board of Oil, Gas and Mining, Department of Natural Resources of the State of Utah, or protest the issuance by Emery County of any necessary building permits or approvals for Co-op's mining operations in Bear Canyon.

13. The City hereby specifically reserves its rights to protest any and all other legal remedies on all other mining plans or proposals on land not included in the acreage covered by this Agreement.

14. Co-op agrees that the transfer or assignment of the premises affecting said Spring or this Agreement shall not release Co-op from any obligations in this Agreement unless Huntington City has in writing consented to said release, which consent shall not be unreasonably withheld.

15. The parties shall not assign their obligations or rights under this Agreement without the mutual consent of each other.

16. It is agreed by the parties that this Agreement applies to and binds the heirs, executors, administrators, successors and assigns of the respective parties hereto.

IN WITNESS WHEREOF, the said parties to this Agreement have here unto affixed their signatures, the day and year first above written.

CO-OP MINING COMPANY

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By

APPENDIX 7-C

INCORPORATED UNDER
THE LAWS OF THE STATE OF UTAH

SHARES

Huntington-Cleveland Irrigation Company

Capital $150,000 150,000 Shares

This Certifies that C. W. Kingston is the owner of
*****Three Hundred Thirty Three and 77/100***** Shares of the Capital Stock of
Huntington-Cleveland Irrigation Company
transferable only on the books of the Corporation by the holder hereof in person or by Attorney upon surrender of this Certificate properly endorsed.

IN WITNESS WHEREOF, the said Corporation has caused this Certificate to be signed by its duly authorized officers and its Corporate Seal to be hereunto affixed this 16 day of February A.D. 19 62

Secretary

President

SHARES PAR VALUE

0000102

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-140 NAME: Utah State Division of State Lands INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Trail Canyon Creek MAP: 15

POINT OF DIVERSION: Stockwatering directly on stream from a point in NE¼SW¼ Sec 2, T16S, R7E, SLBM, to a point in SW¼SW¼ Sec 2, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 500, page 61.

###STOCKWATERING: 400 Equivalent Livestock Units PERIOD OF USE: 01/01 TO 12/31

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 4.70 acre-feet.

WUC: 93-188 NAME: U.S. Forest Service INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Crandall Canyon Creek MAP: 14

POINT OF DIVERSION: Stockwatering directly on stream from a point in SE¼NW¼ Sec 5, T16S, R7E, SLBM, to a point in SE¼NW¼ Sec 4, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-190 NAME: U.S. Forest Service INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Crandall Canyon Creek MAP: 14

POINT OF DIVERSION: Stockwatering directly on stream from a point in Lot 4 Sec 6, T16S, R7E, SLBM, to a point in NE¼SE¼ Sec 6, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1408 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Humphrey Spring MAP: 14

POINT OF DIVERSION: Stockwatering directly on spring located in NW¼NE¼ Sec 6, T16S, R7E, SLBM.

000103

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 1403,

###STOCKWATERING: 153 Equivalent Livestock Units PERIOD OF USE: 07/06 TO 09/25

Crandall Canyon Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned .97 acre-feet.

WUC: 93-193 NAME: U.S. Forest Service INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Little Bear Canyon Creek MAP: 14

POINT OF DIVERSION: Stockwatering directly on stream from a point in SW¼SE¼ Sec 8, T16S, R7E, SLBM, to a point in NW¼SE¼ Sec 9, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 198, page 137.

###STOCKWATERING: 207 Equivalent Livestock Units PERIOD OF USE: 07/01 TO 09/30

Crandall Ridge Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 1.47 acre-feet.

WUC: 93-254 NAME: Huntington Cleveland Irrigation Company INT: 100% FLOW: 150 cfs*

TYPE OF RIGHT: Diligence** PRIORITY: 1876 SOURCE: Little Bear Canyon Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SW¼ Sec 9, T16S, R7E, SLBM.

REMARKS:

*A total of 150 cfs can be diverted under any, each, or all of the following claims: 219,220,221,222,224,226,228,239,240,243,253, 254,272,303,304,309,310.

**A.H. Christensen Decree 1st Class.

For Points of Rediversion and additional remarks, see WUC 1137, page 64.

For all irrigation, the period of use is March 2 to November 14.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 1137, page 64.
For PURPOSE, see WUC 1137, page 64.

WUC: 93-1411 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Little Bear Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SW¼ Sec 9, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 198, page 137.

###STOCKWATERING: 207 Equivalent Livestock Units PERIOD OF USE: 07/01 TO 09/30

Crandall Ridge Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 1.47 acre-feet.

000104

WUC: 93-2193 NAME: Huntington Cleveland Irrigation Company INT: 100% FLOW: 45 cfs*

TYPE OF RIGHT: Decree** PRIORITY: 1879 SOURCE: Little Bear Canyon Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SW¼ Sec 9, T16S, R7E, SLBM.

REMARKS:

*A total of 45 cfs can be diverted under any, each, or all of the following claims: 2190,2193,2196,2199,2202,2205,2208,2211,2214, 2217,2220,2223,2226,2229,2232,2235,2238.

**A. H. Christensen Decree 3rd Class.

For Points of Rediversion and additional remarks, see WUC 1137, page 64.

For all irrigation, the period of use is from March 2 to November 14.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 1137, page 64.
For PURPOSE, see WUC 1137, page 64.

WUC: 93-2194 NAME: Huntington Cleveland Irrigation Company INT: 100% FLOW: 77.25 cfs*

TYPE OF RIGHT: Diligence** PRIORITY: 1884 SOURCE: Little Bear Canyon Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SW¼ Sec 9, T16S, R7E, SLBM.

REMARKS:

*A total of 77.25 cfs can be diverted under any, each, or all of the following claims: 93-2191,2194,2197,2200,2203,2206,2209,2212, 2215,2218,2221,2224,2227,2230,2233,2236,2239.

**A. H. Christensen Decree 3rd Class.

For Points of Rediversion and additional remarks, see WUC 1137, page 64.

For all irrigation, the period of use is from March 2 to November 14.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 1137, page 64.
For PURPOSE, see WUC 1137, page 64.

WUC: 93-2195 NAME: Huntington Cleveland Irrigation Company INT: 100% FLOW: 80.0 cfs*

TYPE OF RIGHT: Diligence** PRIORITY: 1888 SOURCE: Little Bear Canyon Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SW¼ Sec 9, T16S, R7E, SLBM.

REMARKS:

*A total of 80.0 cfs can be diverted under any, each, or all of the following claims: 93-2192,2195,2198,2201,2204,2207,2210,2213, 2216,2219,2222,2225,2228,2231,2234,2237,2240.

**A. H. Christensen Decree 4th Class.

For Points of Rediversion and additional remarks, see WUC 1137, page 64.

For all irrigation, the period of use is March 2 to November 14.

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CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 1137, page 64.
For PURPOSE, see WUC 1137, page 64.

WUC: 93-192 NAME: U.S. Forest Service INT: 100% FLOW:
TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Little Bear Canyon Creek MAP: 15
POINT OF DIVERSION: Stockwatering directly on stream from a point in NW¼SE¼ Sec 9, T16S, R7E, SLBM, to a point in NE¼SE¼ Sec 9, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.
###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30
Gentry Mountain Allotment
Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1435 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs
TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Left Fork Trail Canyon Spring MAP: 15
POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SE¼ Sec 10, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.
###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30
Gentry Mountain Allotment
Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-139 NAME: U.S. Forest Service INT: 100% FLOW:
TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Trail Canyon Creek MAP: 15
POINT OF DIVERSION: Stockwatering directly on stream from a point in NW¼NW¼ Sec 11, T16S, R7E, SLBM, to a point in SE¼SE¼ Sec 10, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.
###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30
Gentry Mountain Allotment
Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1436 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs
TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Surface Runoff Spring MAP: 15
POINT OF DIVERSION: Stockwatering directly on spring located in NW¼NW¼ Sec 11, T16S, R7E, SLBM.

0000106

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1434 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: MaCadden Ridge Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NW¼SW¼ Sec 11, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1432 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Unnamed Stream MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in SE¼NE¼ Sec 12, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

Storage from 01/01 to 12/31, inclusive, in McCadden Flat Pond #1 with a maximum capacity of .1 acre-feet, located in:

	NORTH-EAST¼ NE NW SW SE	NORTH-WEST¼ NE NW SW SE	SOUTH-WEST¼ NE NW SW SE	SOUTH-EAST¼ NE NW SW SE
Sec 12 T 16S R 7E SLBM	* : : : X*	* : : : *	* : : : *	* : : : *

WUC: 93-1431 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Unnamed Stream MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SE¼ Sec 12, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

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Storage from 01/01 to 12/31, inclusive, in McCadden Flat Pond #2 with a maximum capacity of .1 acre-feet, located in:

	NORTH-EAST¼				NORTH-WEST¼				SOUTH-WEST¼				SOUTH-EAST¼			
	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE	NE	NW	SW	SE
Sec 12 T 16S R 7E SLBM													X			

WUC: 93-1433 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Tuttle Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NW¼SE¼ Sec 12, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1430 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Boundary Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in SE¼SE¼ Sec 12, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-151 NAME: U.S. Forest Service INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Bear Creek MAP: 15

POINT OF DIVERSION: Stockwatering directly on stream from a point in NE¼NW¼ Sec 13, T16S, R7E, SLBM, to a point in SW¼SW¼ Sec 13, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119.

###STOCKWATERING: 1440 Equivalent Livestock Units PERIOD OF USE: 06/21 TO 09/30

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-1429 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Wild Horse Flat Spring MAP: 15

POINT OF DIVERSION: Stockwatering directly on spring located in NE¼SE¼ Sec 13, T16S, R7E, SLBM.

000108

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119. PERIOD OF USE: 06/21 TO 09/30

###STOCKWATERING: 1440 Equivalent Livestock Units

Gentry Mountain Allotment

Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-141 NAME: Peabody Coal Company INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: McCadden Hollow Stream MAP: 15

POINT OF DIVERSION: Stockwatering directly on stream from a point in NW¼NW¼ Sec 14, T16S, R7E, SLBM, to a point in SE¼NE¼ Sec 15, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: 129,131,138,141,143,146,149,390,1182 PERIOD OF USE: 01/01 TO 12/31

###STOCKWATERING: 30 Equivalent Livestock Units

Diversion any, each, or all claims; total yearly diversion under all claims mentioned .85 acre-feet.

WUC: 93-138 NAME: Peabody Coal Company INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Trail Canyon Creek MAP: 15

POINT OF DIVERSION: Stockwatering directly on stream from a point in NE¼NE¼ Sec 15, T16S, R7E, SLBM, to a point in SE¼NE¼ Sec 27, T16S, R7E, SLBM.

Group No. 1
CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 141, page 146. PERIOD OF USE: 01/01 TO 12/31

###STOCKWATERING: 30 Equivalent Livestock Units

Diversion any, each, or all claims; total yearly diversion under all claims mentioned .85 acre-feet.

Group No. 2
CLAIMS USED FOR PURPOSE DESCRIBED: 138 PERIOD OF USE: 01/01 TO 12/31

###DOMESTIC: 1 Family

Annual water allowed .45 acre-feet.

WUC: 93-129 NAME: Peabody Coal Company INT: 100% FLOW:

TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Huntington Creek MAP: 15

POINT OF DIVERSION: Stockwatering directly on stream from a point in NW¼NW¼ Sec 15, T16S, R7E, SLBM, to a point in NW¼NW¼ Sec 15, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 141, page 146. PERIOD OF USE: 01/01 TO 12/31

###STOCKWATERING: 30 Equivalent Livestock Units

Diversion any, each, or all claims; total yearly diversion under all claims mentioned .85 acre-feet.

0000109

WUC: 93-130 NAME: U.S. Forest Service INT: 100% FLOW: MAP: 15
TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Huntington Creek
POINT OF DIVERSION: Stockwatering directly on stream from a point in SW¼NW¼ Sec 15, T16S, R7E, SLBM, to a point in SE¼NW¼ Sec 22, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119. PERIOD OF USE: 06/21 TO 09/30
###STOCKWATERING: 1440 Equivalent Livestock Units
Gentry Mountain Allotment
Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-259 NAME: U.S. Forest Service INT: 100% FLOW: .011 cfs MAP: 14
TYPE OF RIGHT: Diligence PRIORITY: 1875 SOURCE: Spring #3
POINT OF DIVERSION: Stockwatering directly on spring located in NW¼SW¼ Sec 17, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: See WUC 116, page 119. PERIOD OF USE: 06/21 TO 09/30
###STOCKWATERING: 1440 Equivalent Livestock Units
Gentry Mountain Allotment
Diversion any, each, or all claims; total yearly diversion under all claims mentioned 11.28 acre-feet.

WUC: 93-196 NAME: Hiatt, Marena Madden, et al. INT: 100% FLOW: MAP: 14
TYPE OF RIGHT: Diligence PRIORITY: 1902 SOURCE: Mill Fork Huntington Creek
POINT OF DIVERSION: Stockwatering directly on stream from a point in SW¼SE¼ Sec 17, T16S, R7E, SLBM, to a point in SW¼SE¼ Sec 17, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: 196,260 PERIOD OF USE: 05/16 TO 10/15
###STOCKWATERING: 20 Equivalent Livestock Units
Diversion any, each, or all claims; total yearly diversion under all claims mentioned .24 acre-feet.

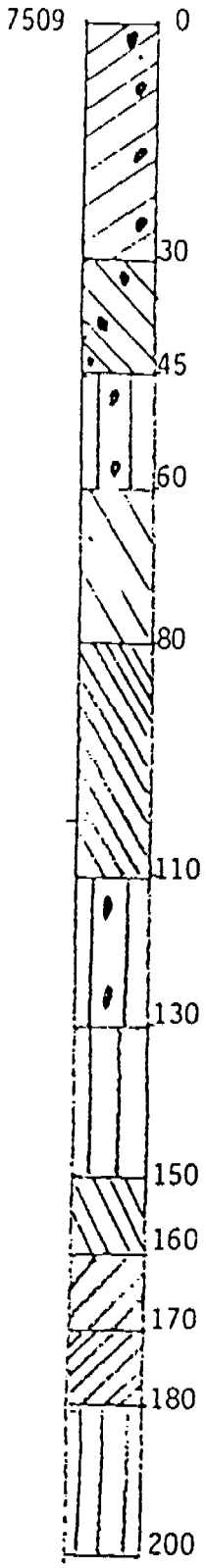
WUC: 93-260 NAME: Hiatt, Marena Madden, et al. INT: 100% FLOW: .011 cfs MAP: 14
TYPE OF RIGHT: Diligence PRIORITY: 1902 SOURCE: Spring #2
POINT OF DIVERSION: Stockwatering directly on spring located in SW¼SE¼ Sec 17, T16S, R7E, SLBM.

CLAIMS USED FOR PURPOSE DESCRIBED: 196,260 PERIOD OF USE: 05/16 TO 10/15
###STOCKWATERING: 20 Equivalent Livestock Units
Diversion any, each, or all claims; total yearly diversion under all claims mentioned .24 acre-feet.

000110

APPENDIX 7-D

Hole 1 Up



Grey Sandy Shale, some carbon and coal

Grey-Brown Shale, some carbon and coal

Grey Siltstone, some carbon and coal

Grey-Brown Silty Shale, no carbon

Dark Grey Shale, no carbon

Grey Siltstone, some carbon and coal

Grey-Tan Siltstone, no carbon

Grey-Tan Silty Shale, no carbon

Yellow-Tan Shale, no carbon

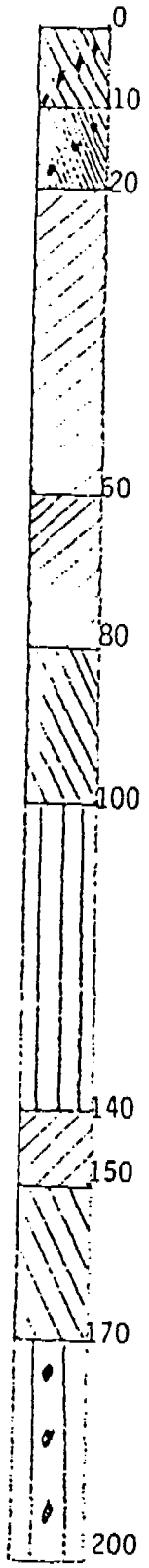
Yellow Clayey Shale, no carbon

Yellow-Tan Siltstone, no carbon

DRILL HOLE LOGS
FIGURE 1 (7-D)

Elev.
7492

Hole 2 Up



Grey-Clayey Shale, some carbon and coal

Grey Clay, some carbon and coal

Yellow-Tan Silty Shale, no carbon

Yellow-Tan Shale, no carbon

Yellow-Tan Clayey Shale, no carbon

Tan Siltstone, no carbon

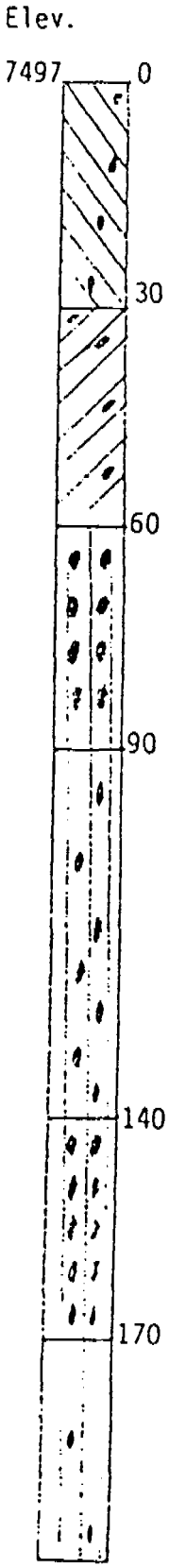
Tan-Grey Silty Shale, no carbon

Grey Shale, no carbon

Grey Siltstone, some carbon and coal

FIGURE 2 (7-D)

Hole 1 Down



Grey Shale, some carbon and coal

Grey Sandy Shale, some carbon and coal

Grey Siltstone, much carbon and coal

Grey-Light Brown Siltstone, some carbon and coal

Grey-Light Brown Siltstone, much carbon

Grey Siltstone, very little carbon

FIGURE 3 (7-D

Hole 6 Down

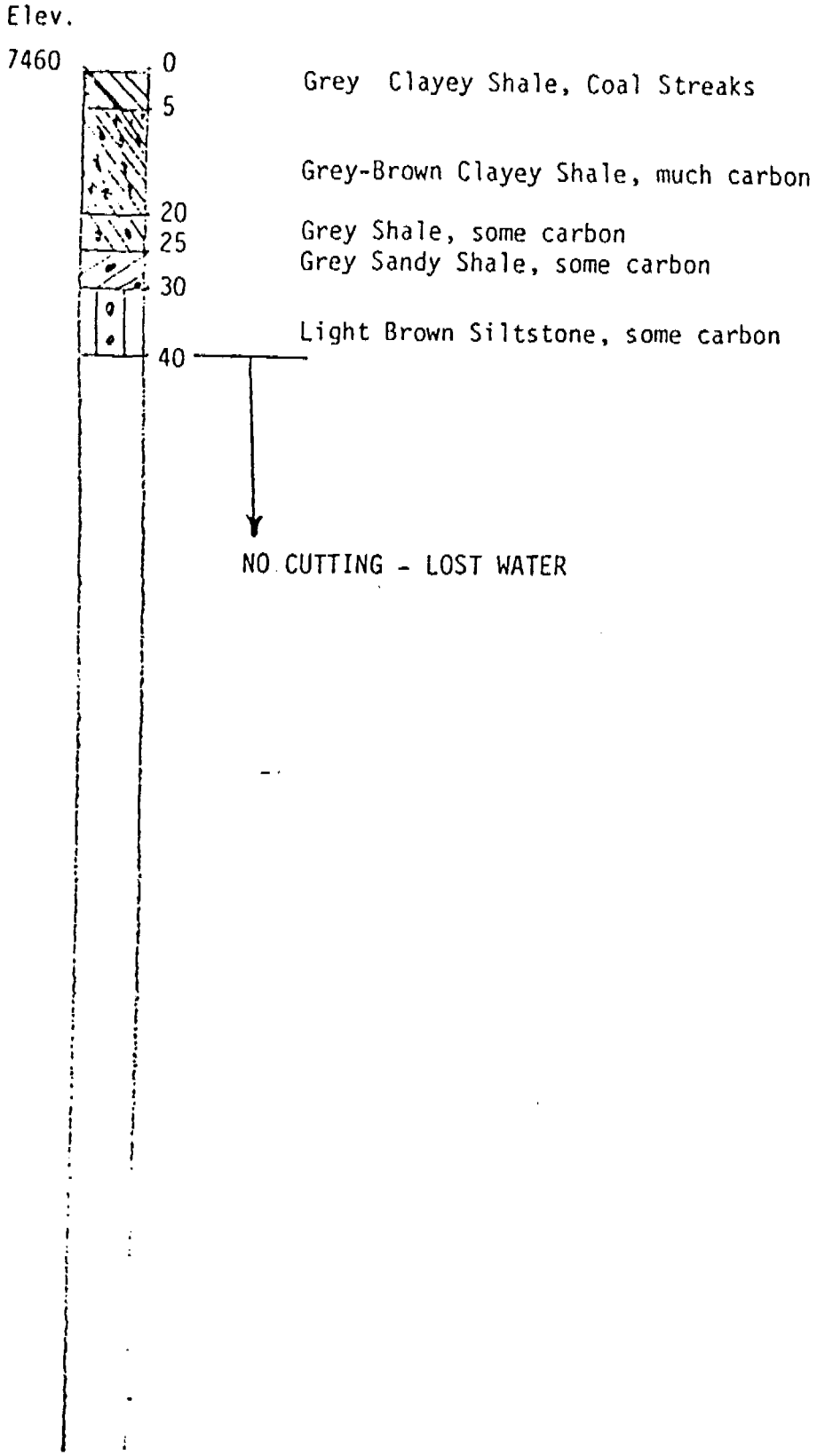
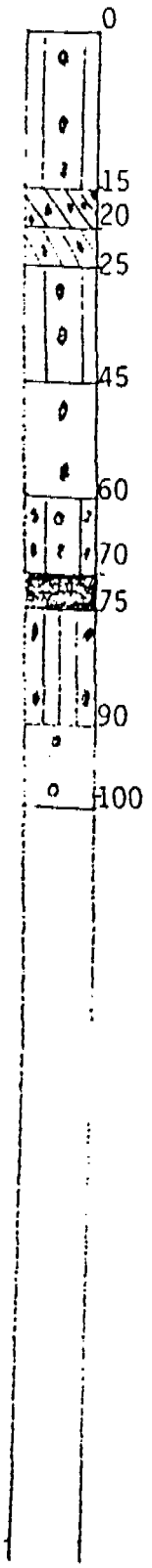


FIGURE 4 (7-D)

Hole 7 Down



Light Brown Siltstone, some carbon

Light Brown Clayey Shale, much carbon
Light Brown-Grey Shale, some carbon

Light Brown Siltstone, some carbon

Light Brown Sandstone, some carbon

Light Brown Siltstone, much carbon and coal
Coal (95%), Light Brown Siltstone (5%)

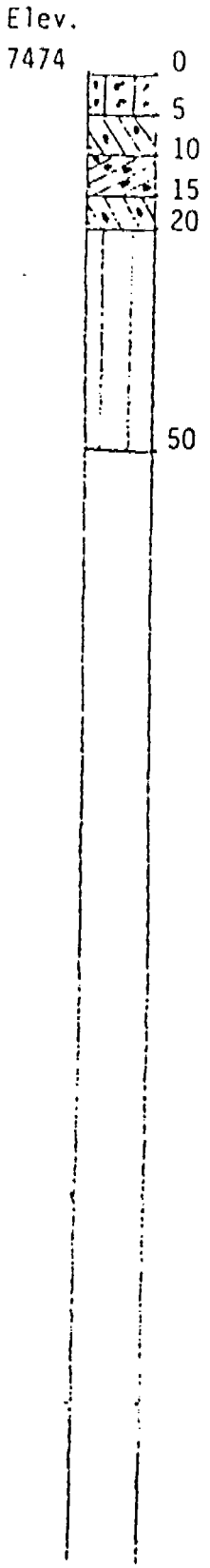
Brown Siltstone, some carbon

Brown Sandstone, some carbon

NO CUTTING - LOST WATER

FIGURE 5 (7-I

Hole 9 Down



Brown Siltstone, much carbon

Grey-Brown Shale, some carbon

Grey Clay Shale, much carbon

Light Brown-Grey Shale, some carbon

Light Brown Siltstone, no carbon

NO CUTTING - LOST WATER

FIGURE 6 (7-D)

Hole 10 Down

Elevation 7,509

0-3 Coal

3-13 Gray Shale

13-19 Coal

19-40 Gray Shale

40 (Trace Coal)

40-65 Red Sandstone

65-70 Coal

70-200 White Sandstone

RECEIVED
FEB 17 1987
DIVISION OF
OIL, GAS & MINING

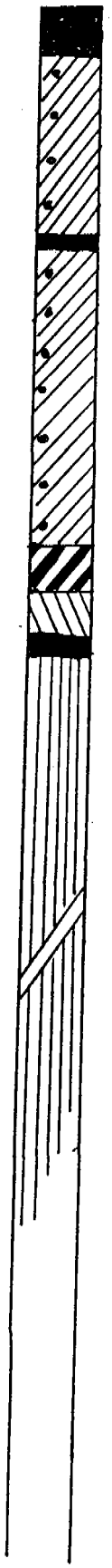
No water encountered

Figure 6-A (7-D)

2/15/87

Hole 11 Down

Elevation 7,494.2'



0 - 5 Coal

5 - 25 Gray Shale

25 - 27 Coal

27 - 60 Gray Shale

60 - 70 Black Slate (some coal)

70 - 80 Soft Brown Shale

80 - 82.5 Coal

RECEIVED
FEB 17 1987
DIVISION OF
OIL, GAS & MINING

80 - 100 White Sandstone

(Lost circulation at 80' - regained with drill mud)

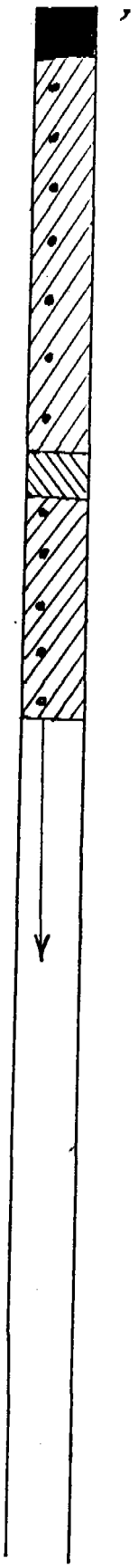
No water encountered

Figure 6-B (7-D)

2/15/87

Hole 12 Down

Elevation 7,516



0 - 5 Coal

5 - 50 Gray Shale

50 - 55 Black Slate

55 - 80 Gray Shale

80 - Lost circulation

(2 additional holes drilled same area - lost circulation on each at approximately 80')

FEB 17 1987
DIVISION OF

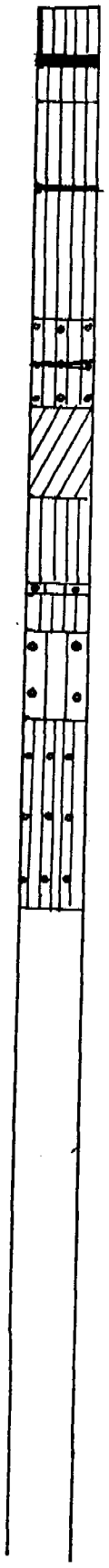
No water encountered

Figure 6-C (7-D)

2/15/87

Hole 13 Down

Elevation 7,505'.4"



0 - 5	Hard White Shale
5 - 6	Coal
6 - 20	Hard White Shale
20 - 20.3	Coal
20 - 35	Hard White Shale
30 - 35	Hard White Shale/Mixed Brown Shale
35 - 40	Brown Shale
40 - 50	Tan Shale
50 - 60	Hard White Shale
60 - 61	(Oxidized Coal) Mixed Brown Slate
60 - 65	Hard White Shale
65 - 75	Brown Slate mixed Sandstone
75 - 100	Brown Slate mixed White Shale

No water encountered

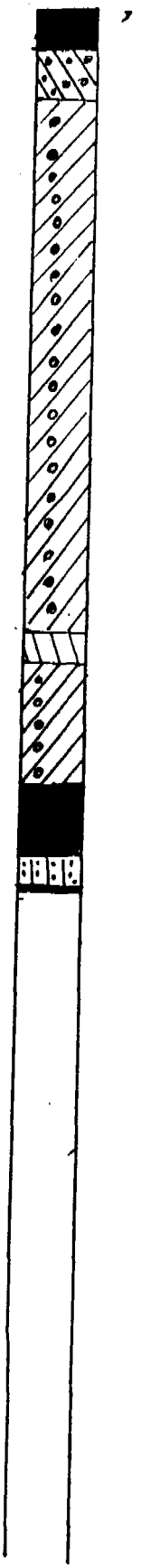
FEB 17 1987

Figure 6-D (7-D)

2/15/87

Hole 14 Down

Elevation 7,507.8



0 - 5 Coal

5 - 10 Brown Shale (Some coal)

10 - 70 Gray Shale

70 - 76 Soft Brown Shale

76 - 88'9" Gray Shale

88'9" - 95' Coal

95 - 98 Brown Shale with some coal

98 - 100 Coal

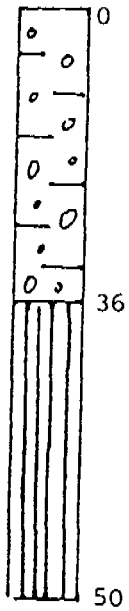
FEB 17 1987

No water encountered

Figure 6-E (7-E)

2/15/87

Hole WM-C

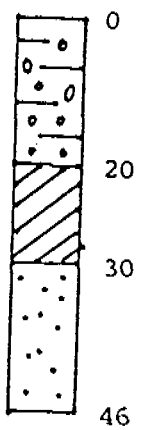


Colluvium - Clay and gravel, very moist, tan.

Small seeps, 30 to 36 feet

Gray siltstone with interbedded tan, fine sandstone, dry to slightly moist

Hole WM-D

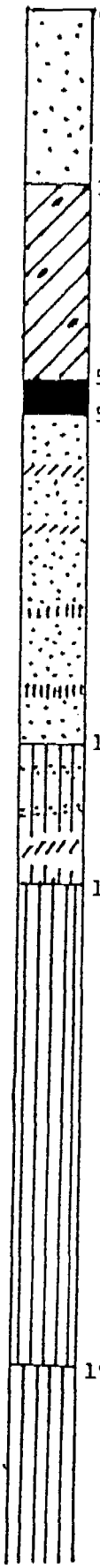


Alluvium - Clay and gravel

Gray silty claystone

Tan sandstone, fine, moist zone at 42 feet

Hole WM-E



Tan sandstone, fine, slightly silty, slightly moist, few thin siltstone layers - increase to 30%, 25 to 30 feet

Dark gray shale, carbon., 30% fine sandstone layers at base, slightly moist

Coal

Gray, fine sandstone with gray shale, trace coal, slightly moist

Shale layers decrease with depth to trace

Few siltstone layers, 70 to 105 feet

Gray, fine sandstone, slightly silty, shale, interbedded, dry

Gray siltstone, trace shale layers, dry

Gray siltstone, with shale and claystone beds, dry

0000118

Figure 7 (7-D)

Hole WM-E (Cont.)

Gray siltstone with shale and claystone beds - dry

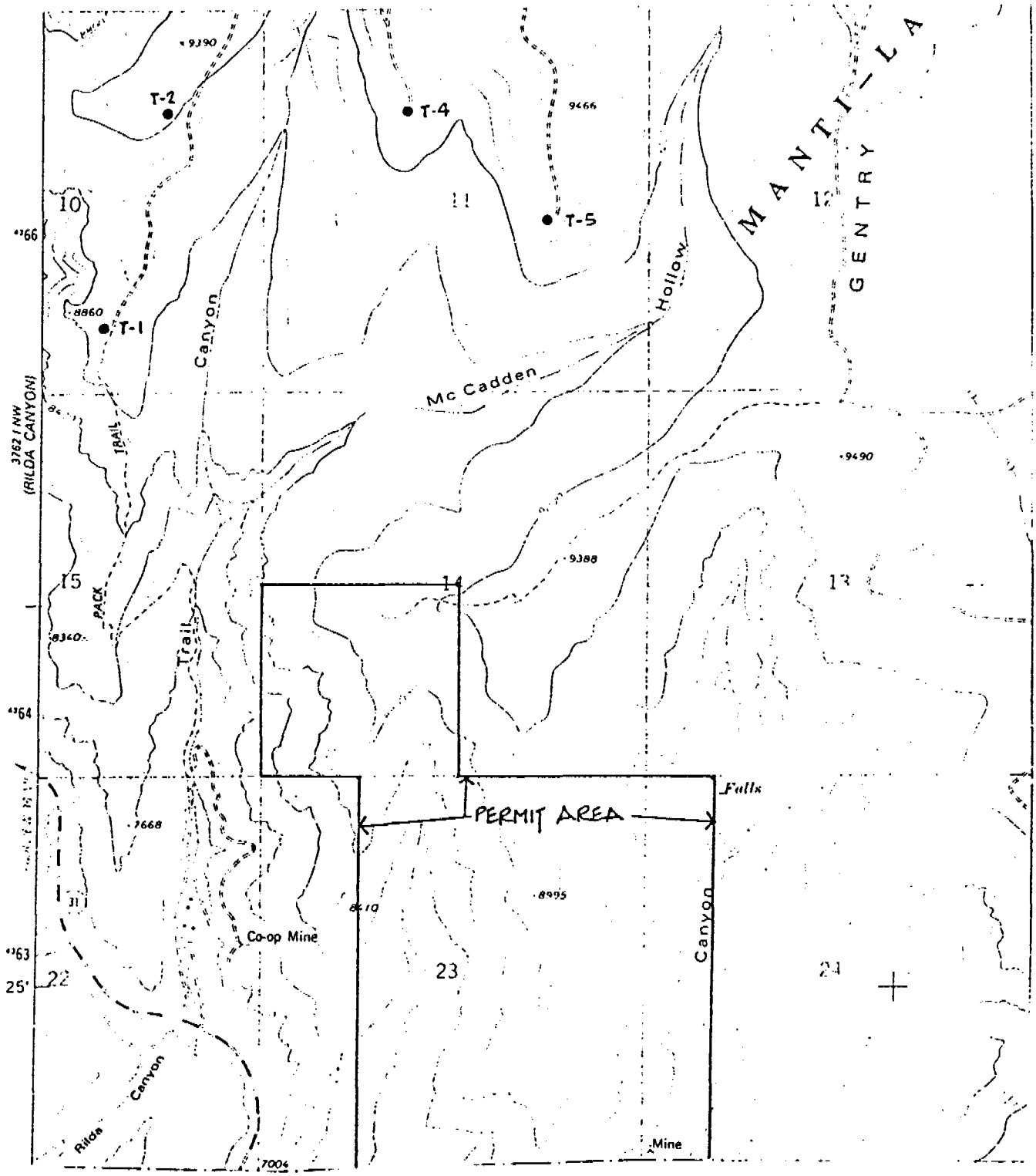
Gray siltstone, uniform, dry

Few gray shale and claystone interbeds, 280 to 400 feet, dry

Dry

Few moist to very moist zones, 370 to 400 feet

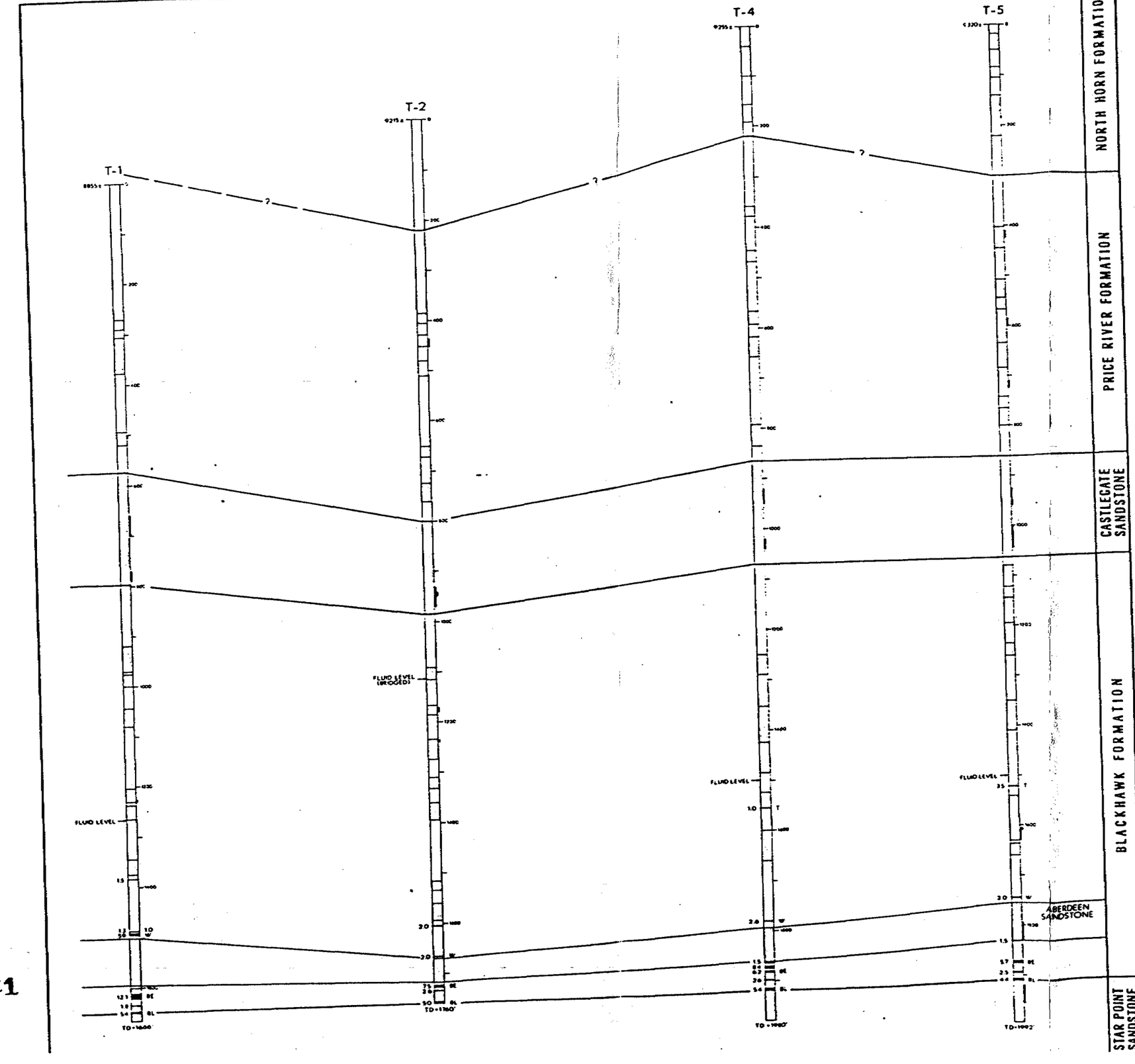
Figure 8 (7-D)



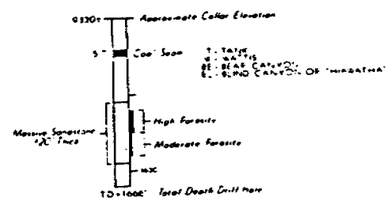
0030120

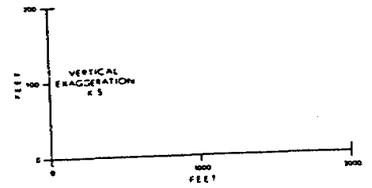
LOCATION MAP
NEVADA POWER & LIGHT CO.S HOLE NOS. T-1, 2, 4 and 5

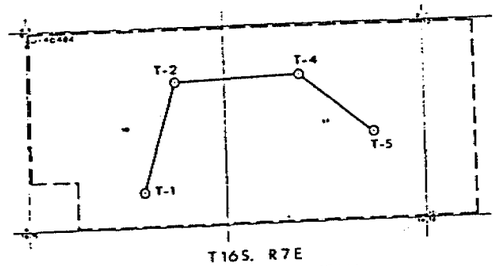
Figure 9 (7-D)



EXPLANATION







T16S. R7E
EMERY COUNTY, UTAH

Figure 10 (7-D)

STRATIGRAPHIC CORRELATION DIAGRAM

SAVAGE ENEGY SERVICES CORP.

0000121

APPENDIX 7-E

SLOPE STABILITY ANALYSIS
ON
EMBANKMENT OF SEDIMENTATION POND "A"
BEAR CREEK CANYON MINE SITE
CO-OP MINING COMPANY

JULY 1984

Prepared by
Harold Lee Wimmer, P. E.
Utah P.E. No. 3535

HORROCK & CAROLLO ENGINEERS
One West Main
American Fork, Utah 84003
801-756-7628

0000123

SECTION I

In conjunction with the redesign of sedimentation pond "A" of the Bear Creek Canyon Mine site, various in place and laboratory soil tests were performed. Using the parameters obtained from these tests, slope stability analyses were performed to confirm the stability of the 2H:1V interior slope and to determine a stable angle for the exterior slope.

SECTION II

CONSTRUCTION

On September 29, 1983, I visited the site in conjunction with Wendell Owens of the Co-Op Mining Company and reviewed in detail the provisions taken at the site during construction. I also reviewed with Mr. Owen the construction procedures which enabled me to determine how the embankment was constructed to its present slope.

SECTION III

MATERIAL TESTING

While at the site, using a Troxler 3411B nuclear density gauge, I determined the in-place density of the embankment material. I also obtained moisture density samples and samples of the embankment material, which I returned to the lab for additional testing. The results of these in-place determinations indicate that the average in-place density of the material varied from 89% to 94% of the laboratory obtained T-99 standard proctor.

I submitted a sample of the embankment material to Chen and Associates, a consulting soil and foundation engineering firm, to determine the relationship of the loading to the shear stress, and to determine the internal cohesion. These results are included in the Appendix. The material gradation results are also included in the Appendix. The gradation results indicate that the material is free draining confirming the on site tests.

SECTION IV

OCCURRENCE OF GROUND WATER

The results of the gradation analysis indicate that the material is free draining. This was further observed at the site through reviewing the existing material in place and performing percolation tests in the embankment. Because of the geology of the mine plan area the embankment is not effected by ground water, but for purposes of analysis the soil was assumed saturated by the water occasionally held in the pond. This assumed extent of saturation provides for conservative results.

SECTION V

FACTOR OF SAFETY

A computer model was constructed to analyze the stability of the embankment and the following conditions were assumed.

1. The soil below the maximum water elevation on the interior slope to the toe of the exterior slope (soil #2) was assumed saturated.
2. In-place soil density of 118 pounds per cubic foot.
3. 2H:IV angles were used for both interior and exterior slopes.

A computer simulation was then applied to this situation to determine various failure planes. The "Method of Slices" is the basis for the modified Bishop method computer program. Various failure planes were investigated to determine a minimum factor of safety. The results of these computer runs and a copy of the computer listing is attached in the Appendix. The results of these computer simulations indicate that the minimum factor of safety with a .1 g earthquake loading is 3.8 for the interior slope and 2.8 for the exterior slope at the point of maximum length.

SECTION VI

CONCLUSIONS

In conclusion the sedimentation pond "A" embankment as now existing is:

1. Free draining.
2. No water was encountered in test holes dug in embankments.
3. No movement of the embankment has been detected.
4. The computer simulation on failure planes indicates that the factor of safety is at least 2.8 with a .1 g earthquake loading for 2H:IV slopes for both the interior and exterior of the embankment.

APPENDIX

ENGINEERS

Project Name: Coop Mine Date: 10/6/85
Project No.: Station or Pit Location:
Sample No: #2 Requisted by: HLW
Native material, Pond dikes

AS RECEIVED GRADATION

Screen Size	Weight (a)	Percent Retained	Percent Passing	SPECS.
3"				
2"	0	0	100%	
1½"	1132.1	14.0	86.0	
3/4"	875.8	10.9	75.1	
1/2"	466.3	5.8	69.3	
~~3/8"~~				
#4	1112.1	13.8	55.6	
~~Wet Wt. #4~~				
Wt. -#4	4483.1	55.6		
Total Wt. Dry	8069.9			

WASHED GRADATION AFTER CRUSHING (2500 GM. DRY SAMPLE)

Screen Size	Weight Retained	Percent Retained	Percent Passing	Total % Passing	SPECS.
#8	141.7	8.9	91.1	19.7	
#10	31.1	2.0	89.1	17.9	
#16	69.5	4.4	84.7	17.5	
#20	40.7	2.6	82.2	16.7	
#30	31.8	2.0	80.1	16.2	
#40	47.9	3.0	77.1	15.8	
#50	91.4	5.8	71.4	15.2	
#100	350.3	22.1	49.3	14.0	
#200	146.4	9.2	40.1	9.7	
-#200	635.7	40.1	0		
Total Wt.	1586.8				

MOISTURE DETERMINATION	
	-#4
Container & Wet Soil Weight (gm.)	
Container & Dry Soil Weight (gm.)	
H_2O Loss	
% Moisture	

A.A.S.H.O Classification

Wt. before washing
Wt. after washing

COPIES TO:

0000131

Tested by: Kirk I. Beecher

ENGINEERS

Project Name Coop Mine Date 10/6/8-
Project No. Station or Pit Location
Sample No #1 (COAL PARTICLES) Requisted by HLW
2 sediment in pond

AS RECEIVED GRADATION

Screen Size	Weight (a)	Percent Retained	Percent Passing	SPECS.
3"				
2"				
1"	0	0	100%	
3/4"	63.0	0.8	99.2	
1/2"	94.7	1.2	98.1	
~~3/8"~~				
#4	317.[illegible]	3.9	94.1	
Wet Wt. -#4				
Wt. #4	7654.4	94.[illegible]		
Total Wt Dry	8131.9			

WASHED GRADATION AFTER CRUSHING (2500 GM. DRY SAMPLE)

Screen Size	Weight Retained	Percent Retained	Percent Passing	Total % Passing	SPECS.
#8	126.3	8.5	91.5	18.3	
#10	37.6	2.5	89.0	16.8	
#16	121.7	8.2	80.8	16.3	
#20	79.7	5.4	75.5	14.8	
#30	60.4	4.1	71.4	13.8	
#40	67.1	4.5	66.9	13.1	
#50	95.8	6.4	60.5	12.3	
#[illegible]0	328.3	22.[illegible]	38.4	11.1	
#200	113.2	7.6	30.8	7.0	
-#200	459.0	30.8	0		
Total Wt.	1489.1				

Wt. before washing
Wt. after washing

MOISTURE DETERMINATION	-#4
Container & Wet Soil Weight (gm.)	
Container & Dry Soil Weight (gm.)	
H_2O Loss	
% Moisture	

A.A.S.H.O Classification

C000132

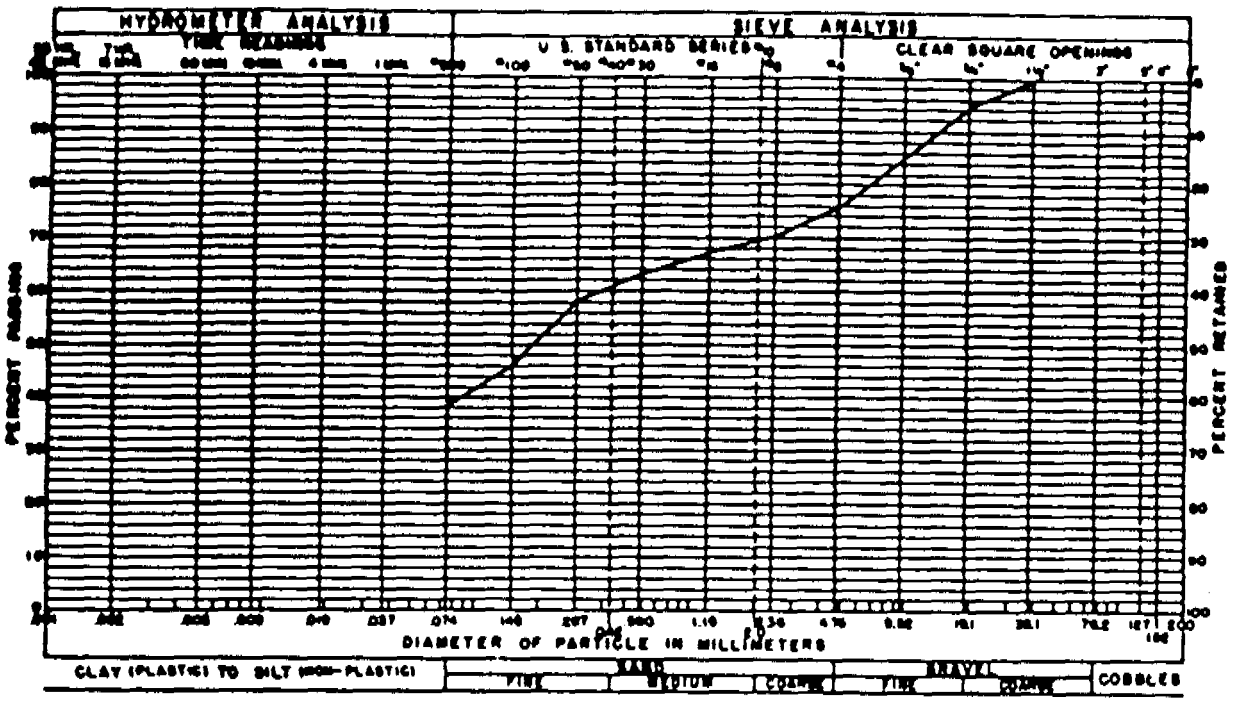
COPIES TO:

Tested by KIRK L. FEECHAN

CHEN AND ASSOCIATES

Consulting Engineers

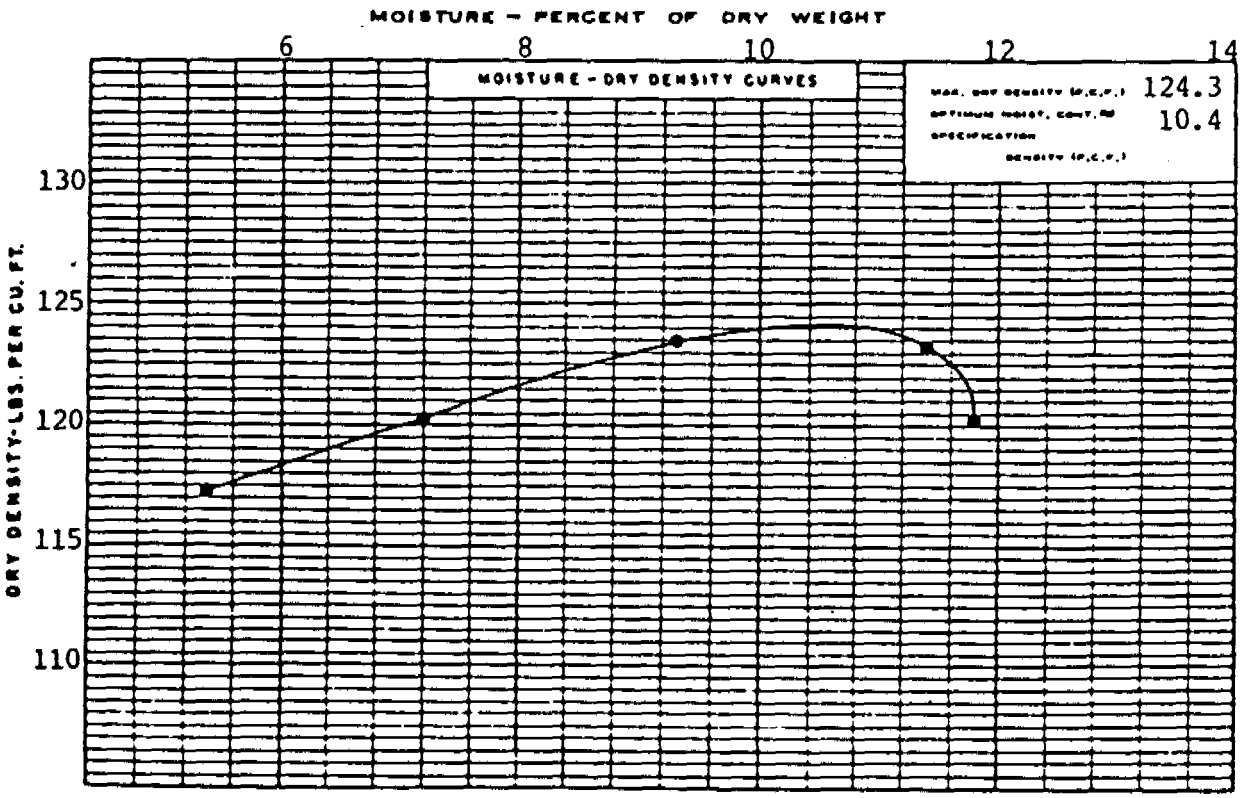
Soil and Foundation Engineering



GRADATION TEST RESULTS

GRAVEL 25 % SAND 37 % SILT AND CLAY 38 %

LIQUID LIMIT % PLASTICITY INDEX %



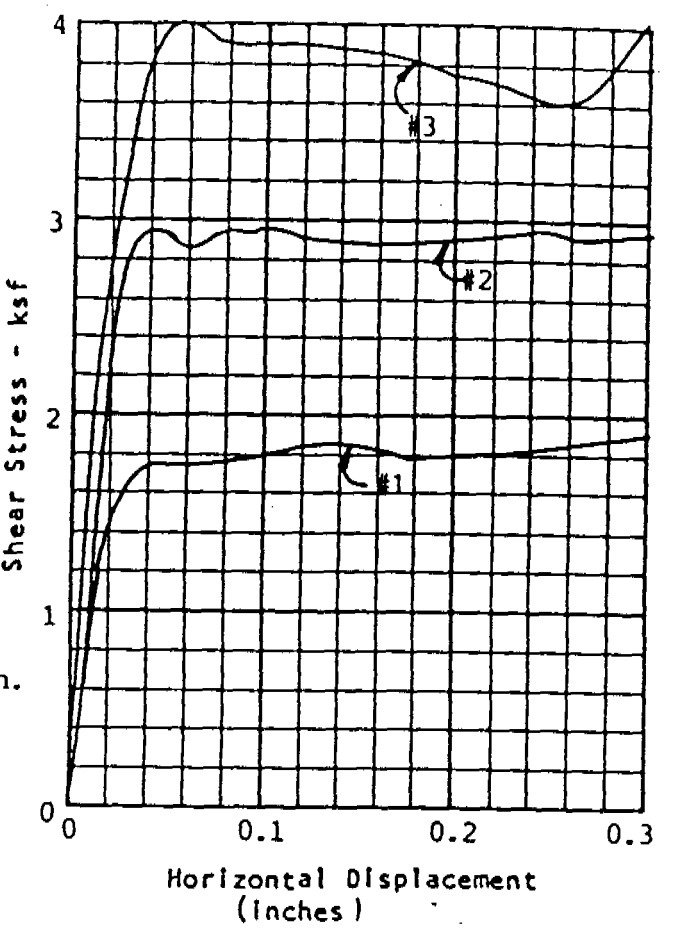
COMPACTION TEST RESULTS

COMPACTION TEST PROCEDURE ASTM D-698 Method C

SAMPLE OF Clayey Sand and Gravel

#525284 FROM DEPTH C000133

TEST NUMBER	1	2	3	4
LOCATION				
HEIGHT-INCH	.75	.75	.75	
DIAMETER-INCH	1.925	1.925	1.925	
WATER CONTENT - %	10.0	10.0	10.0	
DRY DENSITY - pcf	117.8	117.8	117.8	
CONSOL. LOAD - ksf	2.0	4.0	6.0	
NORMAL LOAD - ksf	2.0	4.0	6.0	
SHEAR STRESS - ksf	1.8	3.0	4.0	



TYPE OF SPECIMEN Remolded @ 95% Std.Proctor Den.

SOIL DESCRIPTION Clayey Sand and Gravel

TYPE OF TEST Consolidated-Undrained

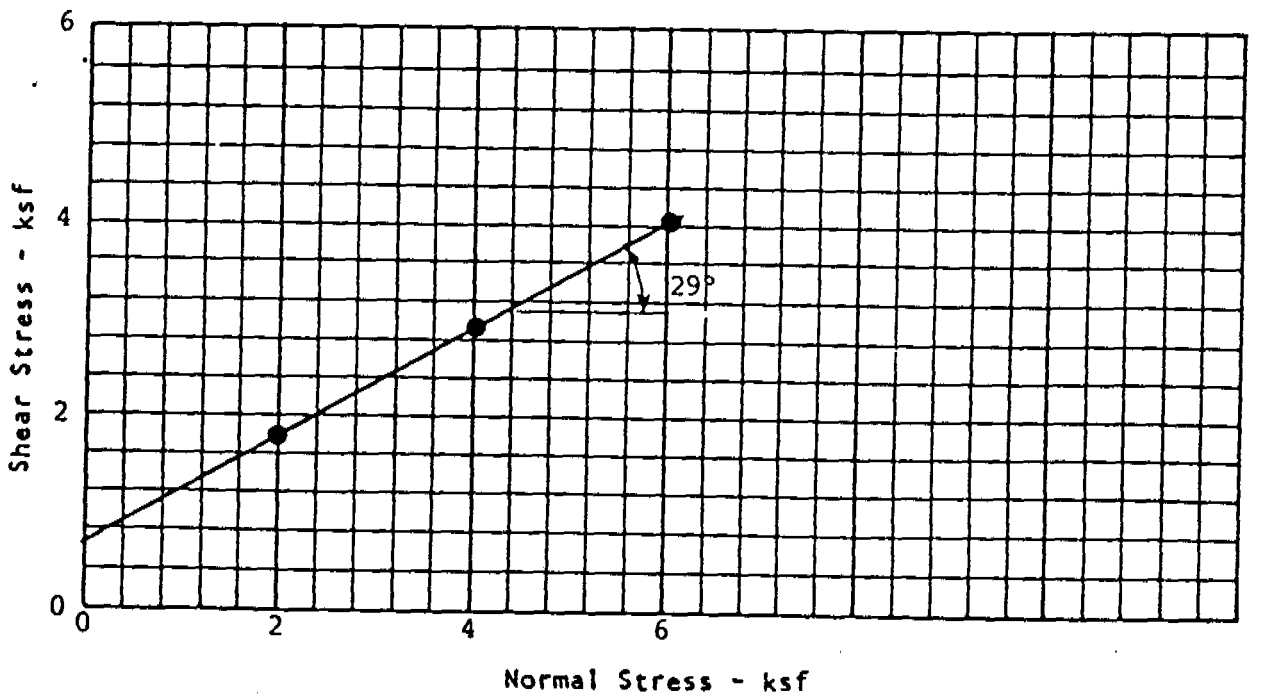
Saturated

Strain Rate 0.02 in/sec

TAN Ø

Ø 29°

COHESION - ksf 0.7



C000134

#525284

DIRECT SHEAR TEST RESULTS

HORROCKS ENGINEERS

7/12/83

SLOPE STABILITY ANALYSIS

for

CO-OP MINE - SLOPE STABILITY ** SEDIMENT POND A

DATA FILE: "CPSLOA:T14"

PROJECT NUMBER: 8309-42

by: EGN

Interior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	108.0	94.0	10.0	4.57

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	255.8	-41.3	700	1.7	120.3	29	101.4
2	670.6	-29.1	700	1.7	315.4	29	103.2
3	994.6	-18.3	700	1.7	467.8	29	104.9
4	1248.6	-8.2	700	1.7	587.2	29	106.6
5	1441.1	1.7	700	1.7	677.7	29	108.3
6	1573.8	11.6	700	1.7	740.1	29	110.0
7	1642.9	21.9	700	1.7	772.6	29	111.7
8	1636.9	33.1	700	1.7	769.8	29	113.4
9	1527.4	46.0	700	1.7	718.3	29	115.1
10	702.7	58.1	700	.9	352.0	29	116.5
11	555.8	71.0	700	.9	326.0	29	117.4
12	69.9	83.6	700	.2	50.6	29	117.9

ITERATION	INITIAL	CALCULATED
1	1.0000	4.3859
2	4.3859	4.5570
3	4.5570	4.5669
4	4.5669	4.5674

FACTOR OF SAFETY= 4.57 AT X= 108 Y= 94 R= 10
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	110.0	98.0	10.0	5.71

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	119.8	-26.5	700	1.4	56.3	29	105.5
2	327.1	-17.9	700	1.4	153.8	29	106.9
3	497.2	-9.6	700	1.4	233.8	29	108.3
4	633.8	-1.6	700	1.4	298.1	29	109.7
5	738.4	6.5	700	1.4	347.2	29	111.1
6	810.3	14.6	700	1.4	381.1	29	112.5
7	846.8	23.1	700	1.4	398.2	29	113.9
8	842.0	32.1	700	1.4	396.0	29	115.3
9	571.3	40.6	700	1.0	294.8	29	116.5
10	514.1	48.8	700	1.0	320.2	29	117.5
11	423.2	59.6	700	1.1	331.7	29	118.6
12	94.5	72.3	700	.7	94.5	29	119.5

ITERATION	INITIAL	CALCULATED
1	1.0000	4.9462
2	4.9462	5.6651
3	5.6651	5.7085
4	5.7085	5.7108

FACTOR OF SAFETY= 5.71 AT X= 110 Y= 98 R= 10
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	104.0	98.0	10.0	10.14

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	35.5	-7.0	700	1.0	16.7	29	102.8
2	98.5	-1.5	700	1.0	46.3	29	103.7
3	150.9	4.1	700	1.0	71.0	29	104.7
4	192.6	9.6	700	1.0	90.6	29	105.7
5	223.2	15.3	700	1.0	105.0	29	106.6
6	242.0	21.1	700	1.0	113.8	29	107.6
7	247.7	27.2	700	1.0	116.5	29	108.6
8	238.3	33.6	700	1.0	112.1	29	109.5
9	210.4	40.6	700	1.0	99.0	29	110.5
10	158.0	48.4	700	1.0	74.3	29	111.5
11	68.2	57.8	700	1.0	32.1	29	112.4

ITERATION	INITIAL	CALCULATED
1	1.0000	8.2214
2	8.2214	10.0653
3	10.0653	10.1340
4	10.1340	10.1361

FACTOR OF SAFETY= 10.14 AT X= 104 Y= 98 R= 10
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	109.0	98.0	15.0	3.94

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	74.3	-39.9	700	1.2	34.9	29	99.4
2	632.5	-31.7	700	2.3	297.4	29	101.1
3	1249.7	-21.9	700	2.3	587.7	29	103.4
4	1748.2	-12.7	700	2.3	822.2	29	105.7
5	2145.1	-3.8	700	2.3	1008.8	29	108.0
6	2446.9	4.9	700	2.3	1150.8	29	110.3
7	2653.4	13.8	700	2.3	1247.8	29	112.6
8	2756.6	23.1	700	2.3	1296.4	29	114.9
9	2400.4	32.3	700	2.0	1233.4	29	117.0
10	2639.8	43.5	700	2.5	1569.2	29	119.3
11	1738.0	59.6	700	2.5	1277.1	29	121.8
12	209.5	75.7	700	.9	209.5	29	123.4

ITERATION	INITIAL	CALCULATED
1	1.0000	3.6937
2	3.6937	3.9291
3	3.9291	3.9432
4	3.9432	3.9440

FACTOR OF SAFETY= 3.94 AT X= 109 Y= 98 R= 15
EARTHQUAKE= .10

Interior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	106.0	94.0	15.0	4.09

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	549.4	-54.2	700	2.4	258.4	29	93.9
2	1283.4	-40.2	700	2.4	603.6	29	96.4
3	1755.6	-28.9	700	2.4	825.7	29	98.8
4	2488.6	-18.2	700	2.7	1170.4	29	101.3
5	3099.3	-7.7	700	2.7	1457.5	29	104.0
6	3555.5	2.6	700	2.7	1672.1	29	106.7
7	3861.2	12.9	700	2.7	1815.9	29	109.3
8	4004.5	23.7	700	2.7	1883.3	29	112.0
9	3950.6	35.5	700	2.7	1857.9	29	114.7
10	2756.1	47.5	700	2.0	1400.7	29	117.0
11	1680.6	58.4	700	1.4	961.8	29	118.7
12	1178.1	73.0	700	1.4	768.7	29	120.1
13	48.8	84.9	700	.1	42.6	29	120.9

ITERATION	INITIAL	CALCULATED
1	1.0000	5.0280
2	5.0280	4.1140
3	4.1140	4.0898
4	4.0898	4.0892

FACTOR OF SAFETY= 4.09 AT X= 106 Y= 94 R= 15
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	105.0	101.0	15.0	4.90

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	3.3	-20.3	700	.4	1.5	29	99.8
2	182.2	-15.9	700	1.8	85.7	29	100.9
3	450.4	-9.0	700	1.8	211.8	29	102.7
4	672.6	-2.1	700	1.8	316.3	29	104.4
5	850.5	4.7	700	1.8	400.0	29	106.2
6	983.6	11.6	700	1.8	462.6	29	108.0
7	1069.7	18.6	700	1.8	503.0	29	109.8
8	1103.5	26.0	700	1.8	519.0	29	111.6
9	1076.2	33.8	700	1.8	506.1	29	113.3
10	970.8	42.6	700	1.8	456.5	29	115.1
11	457.1	50.1	700	1.0	241.1	29	116.5
12	358.3	56.6	700	1.0	246.9	29	117.5
13	93.8	61.6	700	.4	84.3	29	118.2
14	89.2	66.8	700	.8	89.2	29	118.8

ITERATION	INITIAL	CALCULATED
1	1.0000	4.1830
2	4.1830	4.8519
3	4.8519	4.8964
4	4.8964	4.8990

FACTOR OF SAFETY= 4.90 AT X= 105 Y= 101 R= 15
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	106.0	102.0	15.0	5.22

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	153.5	-14.2	700	1.8	72.2	29	102.3
2	422.0	-7.1	700	1.8	198.5	29	104.2
3	641.7	-.1	700	1.8	301.8	29	106.0
4	813.8	6.9	700	1.8	382.7	29	107.8
5	937.2	14.0	700	1.8	440.8	29	109.6
6	1008.4	21.3	700	1.8	474.2	29	111.4
7	1020.4	29.1	700	1.8	479.9	29	113.3
8	960.7	37.4	700	1.8	451.8	29	115.1
9	466.7	44.5	700	1.0	245.6	29	116.5
10	398.2	50.1	700	1.0	265.7	29	117.5
11	215.7	55.6	700	.7	184.1	29	118.4
12	124.6	62.3	700	1.0	124.6	29	119.2

ITERATION	INITIAL	CALCULATED
1	1.0000	4.4326
2	4.4326	5.1679
3	5.1679	5.2127
4	5.2127	5.2151

FACTOR OF SAFETY= 5.22 AT X= 106 Y= 102 R= 15
EARTHQUAKE= .10

Interior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	109.0	100.0	20.0	3.78

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	591.0	-43.3	700	3.1	277.9	29	95.4
2	1457.2	-32.0	700	3.1	685.3	29	98.5
3	2405.2	-21.8	700	3.2	1131.2	29	101.6
4	3375.3	-12.2	700	3.2	1587.4	29	104.8
5	4137.1	-2.9	700	3.2	1945.6	29	108.0
6	4703.9	6.3	700	3.2	2212.2	29	111.2
7	5072.8	15.7	700	3.2	2385.7	29	114.4
8	3258.4	23.6	700	2.0	1636.9	29	117.0
9	4602.0	31.8	700	3.0	2572.6	29	119.5
10	3801.3	42.7	700	3.0	2385.6	29	122.5
11	2580.8	56.4	700	3.0	2001.1	29	125.5
12	1.2	64.2	700	.0	1.2	29	127.0
13	453.1	70.3	700	1.4	453.1	29	127.7

ITERATION	INITIAL	CALCULATED
1	1.0000	3.7806
2	3.7806	3.7785

FACTOR OF SAFETY= 3.78 AT X= 109 Y= 100 R= 20
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	106.0	106.0	20.0	4.41

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	1.1	-17.8	700	.2	.5	29	99.9
2	261.9	-14.1	700	2.3	123.2	29	101.1
3	686.1	-7.4	700	2.3	322.7	29	103.4
4	1038.0	-.8	700	2.3	488.2	29	105.7
5	1319.3	5.7	700	2.3	620.4	29	108.0
6	1528.9	12.4	700	2.3	719.0	29	110.3
7	1662.7	19.2	700	2.3	782.0	29	112.6
8	1712.6	26.3	700	2.3	805.4	29	114.9
9	1461.5	33.4	700	2.0	791.8	29	117.0
10	1055.6	40.0	700	1.7	701.8	29	118.8
11	742.9	46.7	700	1.7	614.1	29	120.5
12	353.9	55.1	700	2.0	353.9	29	122.3

ITERATION	INITIAL	CALCULATED
1	1.0000	3.8643
2	3.8643	4.3791
3	4.3791	4.4085
4	4.4085	4.4100

FACTOR OF SAFETY= 4.41 AT X= 106 Y= 106 R= 20
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	102.0	104.0	20.0	4.95

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	269.2	-27.2	700	2.8	126.6	29	92.9
2	667.8	-18.3	700	2.8	314.1	29	95.7
3	906.6	-9.9	700	2.8	426.4	29	98.6
4	1148.3	-1.9	700	2.7	540.0	29	101.3
5	1539.2	5.8	700	2.7	723.9	29	104.0
6	1816.1	13.5	700	2.7	854.1	29	106.7
7	1970.8	21.6	700	2.7	926.8	29	109.3
8	1985.5	30.1	700	2.7	933.7	29	112.0
9	1825.4	39.5	700	2.7	858.5	29	114.7
10	1114.1	48.8	700	2.0	628.5	29	117.0
11	462.2	56.4	700	1.3	366.0	29	118.6
12	141.8	63.0	700	1.1	141.8	29	119.8

ITERATION	INITIAL	CALCULATED
1	1.0000	4.5173
2	4.5173	4.9325
3	4.9325	4.9501
4	4.9501	4.9508

FACTOR OF SAFETY= 4.95 AT X= 102 Y= 104 R= 20
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	87.00
2	100.00	87.00
3	116.00	95.00
4	118.00	96.00
5	127.00	96.00
6	156.00	81.50
7	200.00	81.50

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	3	2
3	3	6	2
4	6	7	2
5	3	4	1
6	4	5	1
7	5	6	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	102.0	107.0	20.0	6.40

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	103.9	-2.7	700	1.8	48.8	29	101.0
2	287.4	2.3	700	1.8	135.2	29	102.8
3	438.8	7.4	700	1.8	206.4	29	104.6
4	557.3	12.5	700	1.8	262.1	29	106.3
5	641.2	17.7	700	1.8	301.5	29	108.1
6	687.9	23.1	700	1.8	323.5	29	109.8
7	693.2	28.7	700	1.8	326.0	29	111.6
8	650.7	34.7	700	1.8	306.0	29	113.4
9	550.2	41.1	700	1.8	258.7	29	115.1
10	346.6	47.8	700	1.6	228.6	29	116.8
11	57.2	52.2	700	.4	57.2	29	117.8
12	42.8	54.9	700	.7	42.8	29	118.4

ITERATION	INITIAL	CALCULATED
1	1.0000	5.2973
2	5.2973	6.3473
3	6.3473	6.4019
4	6.4019	6.4043

FACTOR OF SAFETY= 6.40 AT X= 102 Y= 107 R= 20
EARTHQUAKE= .10

Exterior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	53.0	86.0	10.0	4.67

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	.0	-63.4	700	.0	.0	29	44.1
2	403.4	-54.5	700	1.8	207.0	29	45.0
3	984.1	-39.0	700	1.8	512.6	29	46.7
4	1413.9	-26.7	700	1.8	747.1	29	48.5
5	1747.3	-15.6	700	1.8	936.3	29	50.3
6	2004.4	-5.1	700	1.8	1089.7	29	52.1
7	2192.7	5.2	700	1.8	1210.7	29	53.9
8	2312.3	15.6	700	1.8	1299.3	29	55.7
9	2355.5	26.7	700	1.8	1352.1	29	57.5
10	2302.3	39.1	700	1.8	1359.5	29	59.3
11	2097.9	54.6	700	1.8	1295.8	29	61.1
12	846.5	71.4	700	.9	562.6	29	62.4

ITERATION	INITIAL	CALCULATED
1	1.0000	5.9845
2	5.9845	4.6933
3	4.6933	4.6741
4	4.6741	4.6738

FACTOR OF SAFETY= 4.67 AT X= 53 Y= 86 R= 10
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	50.0	92.0	10.0	7.29

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	15.8	-19.6	700	.6	15.8	29	46.6
2	143.2	-14.2	700	1.3	112.5	29	47.5
3	270.5	-6.9	700	1.3	188.3	29	48.8
4	373.8	.3	700	1.3	252.9	29	50.1
5	453.8	7.6	700	1.3	306.5	29	51.3
6	509.8	14.9	700	1.3	348.8	29	52.6
7	539.8	22.5	700	1.3	378.9	29	53.8
8	540.1	30.6	700	1.3	395.0	29	55.1
9	503.4	39.4	700	1.3	393.7	29	56.3
10	415.0	49.7	700	1.3	368.1	29	57.6
11	162.0	59.2	700	.7	162.0	29	58.6
12	72.6	68.8	700	.7	72.6	29	59.3

ITERATION	INITIAL	CALCULATED
1	1.0000	6.0224
2	6.0224	7.2216
3	7.2216	7.2876
4	7.2876	7.2907

FACTOR OF SAFETY= 7.29 AT X= 50 Y= 92 R= 10
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	52.0	94.0	10.0	9.24

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	36.9	-11.2	700	.9	36.9	29	50.1
2	103.3	-5.8	700	.9	103.3	29	51.0
3	174.9	-.3	700	1.0	163.3	29	52.0
4	228.9	5.5	700	1.0	198.9	29	53.0
5	270.8	11.3	700	1.0	228.9	29	54.0
6	299.9	17.3	700	1.0	252.8	29	55.0
7	315.3	23.5	700	1.0	270.3	29	56.0
8	315.1	29.9	700	1.0	280.5	29	57.0
9	296.4	36.8	700	1.0	281.9	29	58.0
10	232.0	44.1	700	.9	232.0	29	58.9
11	173.4	51.9	700	.9	173.4	29	59.8
12	75.7	61.6	700	.9	75.7	29	60.8

ITERATION	INITIAL	CALCULATED
1	1.0000	7.5257
2	7.5257	9.1670
3	9.1670	9.2357
4	9.2357	9.2381

FACTOR OF SAFETY= 9.24 AT X= 52 Y= 94 R= 10
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	46.0	92.0	10.0	13.12

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	6.4	-4.0	700	.4	6.4	29	45.3
2	48.3	-.3	700	.9	39.8	29	45.9
3	89.1	4.7	700	.9	66.6	29	46.8
4	122.1	9.7	700	.9	89.7	29	47.7
5	147.1	14.8	700	.9	109.0	29	48.5
6	163.6	20.0	700	.9	124.4	29	49.4
7	171.0	25.3	700	.9	135.5	29	50.3
8	168.0	31.0	700	.9	141.6	29	51.1
9	152.7	37.0	700	.9	142.1	29	52.0
10	101.1	42.8	700	.7	101.1	29	52.8
11	71.7	48.5	700	.7	71.7	29	53.5
12	28.7	54.9	700	.7	28.7	29	54.2

ITERATION	INITIAL	CALCULATED
1	1.0000	10.5338
2	10.5338	13.0454
3	13.0454	13.1176
4	13.1176	13.1192

FACTOR OF SAFETY= 13.12 AT X= 46 Y= 92 R= 10
EARTHQUAKE= .10

Exterior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	57.0	90.0	15.0	3.50

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	.2	-56.4	700	.0	.2	29	44.5
2	771.2	-48.6	700	2.7	412.6	29	45.9
3	1918.5	-34.7	700	2.7	1023.9	29	48.5
4	2790.9	-23.0	700	2.7	1505.9	29	51.2
5	3470.9	-12.2	700	2.7	1897.5	29	53.8
6	3991.0	-2.0	700	2.7	2213.8	29	56.5
7	4361.8	8.3	700	2.7	2460.0	29	59.2
8	4578.8	18.8	700	2.7	2633.8	29	61.8
9	4619.4	30.0	700	2.7	2724.6	29	64.5
10	4426.6	42.9	700	2.7	2705.7	29	67.1
11	3832.4	60.1	700	2.7	2498.0	29	69.8
12	894.7	78.3	700	.8	658.1	29	71.5

ITERATION	INITIAL	CALCULATED
1	1.0000	3.6880
2	3.6880	3.5051
3	3.5051	3.4972
4	3.4972	3.4969

FACTOR OF SAFETY= 3.50 AT X= 57 Y= 90 R= 15
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	58.0	98.0	15.0	4.45

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	105.4	-26.1	700	1.3	105.4	29	51.4
2	558.7	-19.0	700	2.1	458.1	29	53.1
3	959.9	-10.7	700	2.1	691.9	29	55.2
4	1282.8	-2.5	700	2.1	889.0	29	57.3
5	1531.3	5.6	700	2.1	1051.0	29	59.5
6	1704.3	13.8	700	2.1	1177.6	29	61.6
7	1796.2	22.3	700	2.1	1266.0	29	63.7
8	1793.9	31.4	700	2.1	1310.1	29	65.8
9	1670.8	41.5	700	2.1	1297.4	29	67.9
10	1365.3	53.8	700	2.1	1198.9	29	70.0
11	624.6	71.3	700	1.8	624.6	29	72.0

ITERATION	INITIAL	CALCULATED
1	1.0000	3.8124
2	3.8124	4.4023
3	4.4023	4.4514
4	4.4514	4.4550

FACTOR OF SAFETY= 4.45 AT X= 58 Y= 98 R= 15
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	52.0	96.0	15.0	4.70

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	7.3	-23.9	700	.4	7.3	29	45.9
2	264.1	-19.3	700	1.9	182.7	29	47.0
3	593.0	-11.8	700	1.9	373.9	29	48.9
4	864.7	-4.5	700	1.9	538.1	29	50.8
5	1082.3	2.8	700	1.9	676.8	29	52.7
6	1246.0	10.1	700	1.9	790.2	29	54.6
7	1353.5	17.6	700	1.9	877.2	29	56.5
8	1398.9	25.4	700	1.9	934.9	29	58.4
9	1371.1	33.8	700	1.9	958.3	29	60.3
10	1248.9	43.1	700	1.9	937.2	29	62.2
11	985.1	54.3	700	1.9	849.5	29	64.1
12	412.6	69.1	700	1.6	412.6	29	65.9

ITERATION	INITIAL	CALCULATED
1	1.0000	3.9771
2	3.9771	4.6404
3	4.6404	4.6925
4	4.6925	4.6961

FACTOR OF SAFETY= 4.70 AT X= 52 Y= 96 R= 15
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	220.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	47.0	97.0	15.0	8.30

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	7.2	-6.0	700	.4	7.2	29	45.4
2	113.9	-2.4	700	1.4	88.1	29	46.4
3	233.3	3.1	700	1.4	165.0	29	47.8
4	329.4	8.6	700	1.4	231.0	29	49.2
5	401.6	14.2	700	1.4	285.8	29	50.7
6	448.4	19.9	700	1.4	328.6	29	52.1
7	467.3	25.9	700	1.4	358.3	29	53.5
8	454.3	32.2	700	1.4	373.0	29	55.0
9	403.0	38.9	700	1.4	369.7	29	56.4
10	302.2	46.4	700	1.4	302.2	29	57.8
11	128.9	55.2	700	1.4	128.9	29	59.3

ITERATION	INITIAL	CALCULATED
1	1.0000	6.7507
2	6.7507	8.2322
3	8.2322	8.2974
4	8.2974	8.2998

FACTOR OF SAFETY= 8.30 AT X= 47 Y= 97 R= 15
EARTHQUAKE= .10

Exterior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	58.0	95.0	20.0	3.00

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	35.8	-46.0	700	.8	16.8	29	43.6
2	1141.1	-38.5	700	3.2	589.3	29	45.6
3	2540.2	-27.4	700	3.2	1352.6	29	48.8
4	3653.0	-17.4	700	3.2	1981.2	29	52.1
5	4537.0	-7.8	700	3.2	2502.2	29	55.3
6	5216.8	1.4	700	3.2	2927.2	29	58.5
7	5698.1	10.8	700	3.2	3258.8	29	61.7
8	5970.0	20.4	700	3.2	3491.9	29	64.9
9	5999.8	30.7	700	3.2	3611.2	29	68.2
10	5713.3	42.3	700	3.2	3581.8	29	71.4
11	3659.4	54.7	700	2.4	2377.4	29	74.2
12	2355.2	72.4	700	2.4	1638.0	29	76.7
13	25.1	85.6	700	.1	25.1	29	77.9

ITERATION	INITIAL	CALCULATED
1	1.0000	2.8932
2	2.8932	2.9918
3	2.9918	2.9982
4	2.9982	2.9986

FACTOR OF SAFETY= 3.00 AT X= 58 Y= 95 R= 20
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	50.0	100.0	20.0	4.21

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	58.1	-19.9	700	1.6	27.3	29	43.2
2	468.3	-13.7	700	2.5	252.9	29	45.3
3	981.2	-6.3	700	2.5	559.4	29	47.8
4	1395.7	1.0	700	2.5	819.6	29	50.3
5	1713.5	8.3	700	2.5	1034.4	29	52.9
6	1931.5	15.8	700	2.5	1202.2	29	55.4
7	2040.9	23.5	700	2.5	1319.0	29	58.0
8	2024.6	31.7	700	2.5	1376.5	29	60.5
9	1849.6	40.8	700	2.5	1359.5	29	63.0
10	1446.3	51.5	700	2.5	1235.2	29	65.6
11	603.2	65.0	700	2.3	603.2	29	68.0

ITERATION	INITIAL	CALCULATED
1	1.0000	3.6025
2	3.6025	4.1625
3	4.1625	4.2063
4	4.2063	4.2093

FACTOR OF SAFETY= 4.21 AT X= 50 Y= 100 R= 20
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	52.0	102.0	20.0	4.61

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	21.2	-14.9	700	.7	21.2	29	46.9
2	355.1	-10.6	700	2.3	266.6	29	48.3
3	733.9	-4.0	700	2.3	496.7	29	50.6
4	1043.7	2.5	700	2.3	694.3	29	52.9
5	1284.8	9.0	700	2.3	859.6	29	55.1
6	1454.7	15.7	700	2.3	991.5	29	57.4
7	1547.7	22.6	700	2.3	1087.2	29	59.7
8	1553.5	29.8	700	2.3	1141.9	29	61.9
9	1453.8	37.6	700	2.3	1146.9	29	64.2
10	1214.3	46.5	700	2.3	1086.2	29	66.4
11	581.7	55.0	700	1.5	581.7	29	68.4
12	250.1	64.0	700	1.5	250.1	29	69.9

ITERATION	INITIAL	CALCULATED
1	1.0000	3.8773
2	3.8773	4.5600
3	4.5600	4.6115
4	4.6115	4.6148

FACTOR OF SAFETY= 4.61 AT X= 52 Y= 102 R= 20
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	46.0	102.0	20.0	7.88

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	6.6	-2.1	700	.5	6.6	29	45.3
2	125.4	.9	700	1.6	97.1	29	46.3
3	263.6	5.6	700	1.6	189.0	29	47.9
4	376.1	10.3	700	1.6	268.7	29	49.6
5	461.9	15.1	700	1.6	335.9	29	51.2
6	519.5	20.0	700	1.6	389.8	29	52.8
7	546.5	25.0	700	1.6	429.3	29	54.4
8	539.3	30.3	700	1.6	452.8	29	56.1
9	492.6	35.9	700	1.6	457.6	29	57.7
10	338.0	41.3	700	1.3	338.0	29	59.2
11	239.0	46.7	700	1.3	239.0	29	60.5
12	94.8	52.7	700	1.3	94.8	29	61.9

ITERATION	INITIAL	CALCULATED
1	1.0000	6.4094
2	6.4094	7.8126
3	7.8126	7.8758
4	7.8758	7.8782

FACTOR OF SAFETY= 7.88 AT X= 46 Y= 102 R= 20
EARTHQUAKE= .10

Exterior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	57.0	99.0	25.0	2.82

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	330.9	-41.8	700	2.4	155.6	29	40.4
2	876.6	-34.7	700	2.4	412.3	29	42.8
3	2938.2	-26.0	700	4.1	1468.8	29	46.1
4	4718.6	-15.8	700	4.1	2480.1	29	50.2
5	6119.1	-6.1	700	4.1	3312.9	29	54.4
6	7176.4	3.5	700	4.1	3984.1	29	58.5
7	7894.5	13.1	700	4.1	4495.8	29	62.6
8	8246.7	23.1	700	4.1	4835.5	29	66.8
9	8162.1	34.1	700	4.1	4969.8	29	70.9
10	7138.5	47.0	700	4.3	4419.6	29	75.1
11	4073.3	66.5	700	4.3	2595.1	29	79.4
12	35.2	81.0	700	.3	35.2	29	81.7

ITERATION	INITIAL	CALCULATED
1	1.0000	2.7148
2	2.7148	2.8136
3	2.8136	2.8196
4	2.8196	2.8200

FACTOR OF SAFETY= 2.82 AT X= 57 Y= 99 R= 25
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	50.0	100.0	25.0	3.27

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	633.0	-37.1	700	3.6	297.7	29	35.0
2	1590.7	-27.2	700	3.6	748.1	29	38.6
3	2230.1	-18.2	700	3.6	1048.8	29	42.2
4	3526.1	-9.1	700	4.1	1745.3	29	46.1
5	4688.1	.5	700	4.1	2465.8	29	50.2
6	5512.7	10.1	700	4.1	3027.7	29	54.4
7	5983.5	20.0	700	4.1	3423.1	29	58.5
8	6046.2	30.5	700	4.1	3626.6	29	62.6
9	5573.1	42.5	700	4.1	3578.2	29	66.8
10	4216.0	57.9	700	4.1	3114.0	29	70.9
11	302.4	68.5	700	.5	284.9	29	73.2
12	376.3	75.4	700	1.2	376.3	29	74.1

ITERATION	INITIAL	CALCULATED
1	1.0000	3.0608
2	3.0608	3.2527
3	3.2527	3.2655
4	3.2655	3.2663

FACTOR OF SAFETY= 3.27 AT X= 50 Y= 100 R= 25
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	48.0	106.0	25.0	4.72

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	10.8	-10.3	700	1.0	5.1	29	43.5
2	283.9	-6.3	700	2.5	164.9	29	45.2
3	692.3	-.6	700	2.5	419.6	29	47.7
4	1028.1	5.1	700	2.5	640.2	29	50.2
5	1290.4	10.9	700	2.5	826.3	29	52.7
6	1475.9	16.7	700	2.5	976.3	29	55.2
7	1578.7	22.8	700	2.5	1087.3	29	57.7
8	1588.6	29.2	700	2.5	1154.6	29	60.2
9	1488.9	36.0	700	2.5	1170.4	29	62.6
10	1251.1	43.4	700	2.5	1121.3	29	65.1
11	687.7	50.9	700	1.9	687.7	29	67.4
12	284.9	58.7	700	1.9	284.9	29	69.3

ITERATION	INITIAL	CALCULATED
1	1.0000	3.9636
2	3.9636	4.6680
3	4.6680	4.7174
4	4.7174	4.7203

FACTOR OF SAFETY= 4.72 AT X= 48 Y= 106 R= 25
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	42.0	106.0	25.0	11.03

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	56.9	-8.8	700	2.3	26.7	29	38.2
2	124.8	-3.4	700	2.3	58.7	29	40.5
3	133.1	1.9	700	2.3	62.6	29	42.8
4	210.3	7.0	700	2.1	121.7	29	45.1
5	386.5	12.0	700	2.1	250.1	29	47.2
6	514.6	17.0	700	2.1	355.9	29	49.3
7	591.2	22.2	700	2.1	437.5	29	51.4
8	611.2	27.5	700	2.1	492.5	29	53.5
9	566.4	33.2	700	2.1	517.0	29	55.7
10	477.6	39.5	700	2.3	477.6	29	57.9
11	202.3	46.9	700	2.3	202.3	29	60.2

ITERATION	INITIAL	CALCULATED
1	1.0000	9.4221
2	9.4221	10.9930
3	10.9930	11.0292
4	11.0292	11.0299

FACTOR OF SAFETY= 11.03 AT X= 42 Y= 106 R= 25
EARTHQUAKE= .10

Exterior Slope

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	55.0	102.0	30.0	2.77

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	763.6	-42.2	700	3.6	359.1	29	34.9
2	1963.7	-33.4	700	3.6	923.5	29	38.5
3	2836.0	-25.4	700	3.6	1333.7	29	42.2
4	5382.9	-16.7	700	4.8	2650.0	29	46.4
5	7339.0	-7.2	700	4.8	3806.8	29	51.3
6	8837.8	2.1	700	4.8	4748.5	29	56.1
7	9889.4	11.4	700	4.8	5480.0	29	60.9
8	10466.6	21.1	700	4.8	5988.3	29	65.8
9	10491.6	31.5	700	4.8	6236.9	29	70.6
10	8552.9	42.7	700	4.5	5132.4	29	75.3
11	5806.7	56.4	700	4.5	3414.4	29	79.8
12	1006.1	69.7	700	2.0	577.7	29	83.0
13	6.3	75.8	700	.2	3.0	29	84.1

ITERATION	INITIAL	CALCULATED
1	1.0000	2.7349
2	2.7349	2.7707
3	2.7707	2.7723

FACTOR OF SAFETY= 2.77 AT X= 55 Y= 102 R= 30
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	50.0	100.0	30.0	3.00

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	1302.1	-45.9	700	4.4	612.4	29	28.6
2	3222.5	-34.7	700	4.4	1515.5	29	33.0
3	4525.5	-24.9	700	4.4	2128.3	29	37.4
4	5373.3	-15.9	700	4.4	2527.0	29	41.8
5	7113.4	-6.9	700	4.8	3463.8	29	46.4
6	8596.8	2.4	700	4.8	4398.3	29	51.3
7	9632.8	11.7	700	4.8	5122.4	29	56.1
8	10192.6	21.4	700	4.8	5622.5	29	60.9
9	10196.3	31.8	700	4.8	5861.2	29	65.8
10	9460.9	43.7	700	4.8	5752.2	29	70.6
11	4878.3	55.3	700	3.1	3112.1	29	74.6
12	2775.9	68.9	700	3.1	1916.7	29	77.7
13	80.3	79.8	700	.5	80.3	29	79.5

ITERATION	INITIAL	CALCULATED
1	1.0000	3.0347
2	3.0347	2.9976
3	2.9976	2.9960

FACTOR OF SAFETY= 3.00 AT X= 50 Y= 100 R= 30
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	45.0	105.0	30.0	3.77

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	827.9	-33.4	700	4.4	389.4	29	28.6
2	2069.8	-23.7	700	4.4	973.4	29	33.0
3	2867.2	-14.8	700	4.4	1348.4	29	37.4
4	3289.0	-6.2	700	4.4	1546.8	29	41.8
5	4095.7	2.5	700	4.6	2031.9	29	46.3
6	5028.9	11.3	700	4.6	2682.2	29	50.8
7	5562.9	20.4	700	4.6	3144.8	29	55.4
8	5638.5	30.1	700	4.6	3391.7	29	60.0
9	5126.7	40.9	700	4.6	3362.5	29	64.5
10	3713.4	54.2	700	4.6	2909.2	29	69.1
11	614.8	65.3	700	1.6	614.8	29	72.2
12	67.7	70.8	700	.6	67.7	29	73.3

ITERATION	INITIAL	CALCULATED
1	1.0000	3.5111
2	3.5111	3.7524
3	3.7524	3.7651
4	3.7651	3.7657

FACTOR OF SAFETY= 3.77 AT X= 45 Y= 105 R= 30
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	52.0	112.0	30.0	3.84

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	18.1	-10.6	700	.7	18.1	29	46.5
2	481.0	-7.1	700	2.9	352.3	29	48.3
3	1055.4	-1.6	700	2.9	708.2	29	51.2
4	1532.7	4.0	700	2.9	1018.5	29	54.1
5	1912.4	9.6	700	2.9	1282.8	29	57.0
6	2190.9	15.3	700	2.9	1499.7	29	59.9
7	2361.4	21.2	700	2.9	1665.6	29	62.8
8	2412.2	27.3	700	2.9	1775.3	29	65.7
9	2324.4	33.7	700	2.9	1819.9	29	68.6
10	2067.1	40.8	700	2.9	1784.7	29	71.5
11	594.6	45.8	700	1.0	570.9	29	73.5
12	674.7	49.7	700	1.7	674.7	29	74.9
13	247.9	55.0	700	1.7	247.9	29	76.5

ITERATION	INITIAL	CALCULATED
1	1.0000	3.3179
2	3.3179	3.8044
3	3.8044	3.8394
4	3.8394	3.8416

FACTOR OF SAFETY= 3.84 AT X= 52 Y= 112 R= 30
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

Exterior Slope

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	55.0	105.0	35.0	2.77

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	1457.3	-42.3	700	5.0	685.4	29	31.6
2	3654.5	-32.0	700	5.0	1718.7	29	36.5
3	5159.2	-22.7	700	5.0	2426.3	29	41.5
4	8198.8	-13.4	700	5.8	4026.3	29	46.9
5	10777.7	-3.8	700	5.8	5580.3	29	52.7
6	12690.9	5.8	700	5.8	6821.2	29	58.5
7	13932.5	15.5	700	5.8	7746.2	29	64.3
8	14433.5	25.7	700	5.8	8322.9	29	70.1
9	10361.9	35.5	700	4.5	5983.1	29	75.3
10	8347.7	45.2	700	4.5	4609.4	29	79.8
11	2709.4	53.2	700	2.0	1378.7	29	83.0
12	2466.0	63.0	700	3.9	1159.7	29	85.9

ITERATION	INITIAL	CALCULATED
1	1.0000	2.7941
2	2.7941	2.7726
3	2.7726	2.7720

FACTOR OF SAFETY= 2.77 AT X= 55 Y= 105 R= 35
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	58.0	108.0	35.0	2.79

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	919.2	-36.3	700	4.4	432.3	29	37.4
2	2358.1	-27.7	700	4.4	1109.0	29	41.8
3	4404.6	-19.4	700	4.8	2189.9	29	46.4
4	6529.5	-11.1	700	4.8	3426.1	29	51.3
5	8249.6	-3.1	700	4.8	4471.9	29	56.1
6	9586.2	4.8	700	4.8	5337.4	29	60.9
7	10536.8	12.8	700	4.8	6021.3	29	65.8
8	11075.0	21.1	700	4.8	6511.3	29	70.6
9	9782.4	29.6	700	4.5	5710.6	29	75.3
10	8174.9	38.6	700	4.5	4528.1	29	79.8
11	2826.0	45.6	700	2.0	1433.6	29	83.0
12	3608.6	55.7	700	5.3	1697.1	29	86.7

ITERATION	INITIAL	CALCULATED
1	1.0000	2.7363
2	2.7363	2.7910
3	2.7910	2.7928

FACTOR OF SAFETY= 2.79 AT X= 58 Y= 108 R= 35
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	50.0	100.0	35.0	2.93

SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	2844.9	-50.4	700	5.9	1337.9	29	23.3
2	6727.7	-36.7	700	5.9	3164.0	29	29.2
3	9199.3	-25.3	700	5.9	4326.3	29	35.1
4	10706.7	-14.9	700	5.9	5035.2	29	41.0
5	12170.2	-5.1	700	5.8	5894.0	29	46.9
6	14174.3	4.4	700	5.8	7177.7	29	52.7
7	15511.0	14.1	700	5.8	8147.4	29	58.5
8	16121.3	24.2	700	5.8	8775.6	29	64.3
9	15853.2	35.3	700	5.8	8990.6	29	70.1
10	10727.7	46.4	700	4.5	6155.1	29	75.3
11	7653.3	58.9	700	4.5	4282.8	29	79.8
12	1687.3	71.2	700	2.0	898.1	29	83.0
13	128.2	78.8	700	.6	60.3	29	84.3

ITERATION	INITIAL	CALCULATED
1	1.0000	3.2239
2	3.2239	2.9346
3	2.9346	2.9289
4	2.9289	2.9287

FACTOR OF SAFETY= 2.93 AT X= 50 Y= 100 R= 35
EARTHQUAKE= .10

WATER UNIT WEIGHT= 62.40

POINT	X-ORD	Y-ORD
1	0.00	81.50
2	44.00	81.50
3	73.00	96.00
4	82.00	96.00
5	84.00	95.00
6	100.00	87.00
7	200.00	87.00

LINE	LEFT	RIGHT	SOIL
1	1	2	2
2	2	5	2
3	5	6	2
4	6	7	2
5	2	3	1
6	3	4	1
7	4	5	1

SOIL	UNIT WEIGHT	COHESION	ø	SATURATED
1	118	700	29	NO
2	118	700	29	YES

CIRCLE	X-ORD	Y-ORD	RADIUS	FACTOR OF SAFETY
	45.0	105.0	35.0	3.20

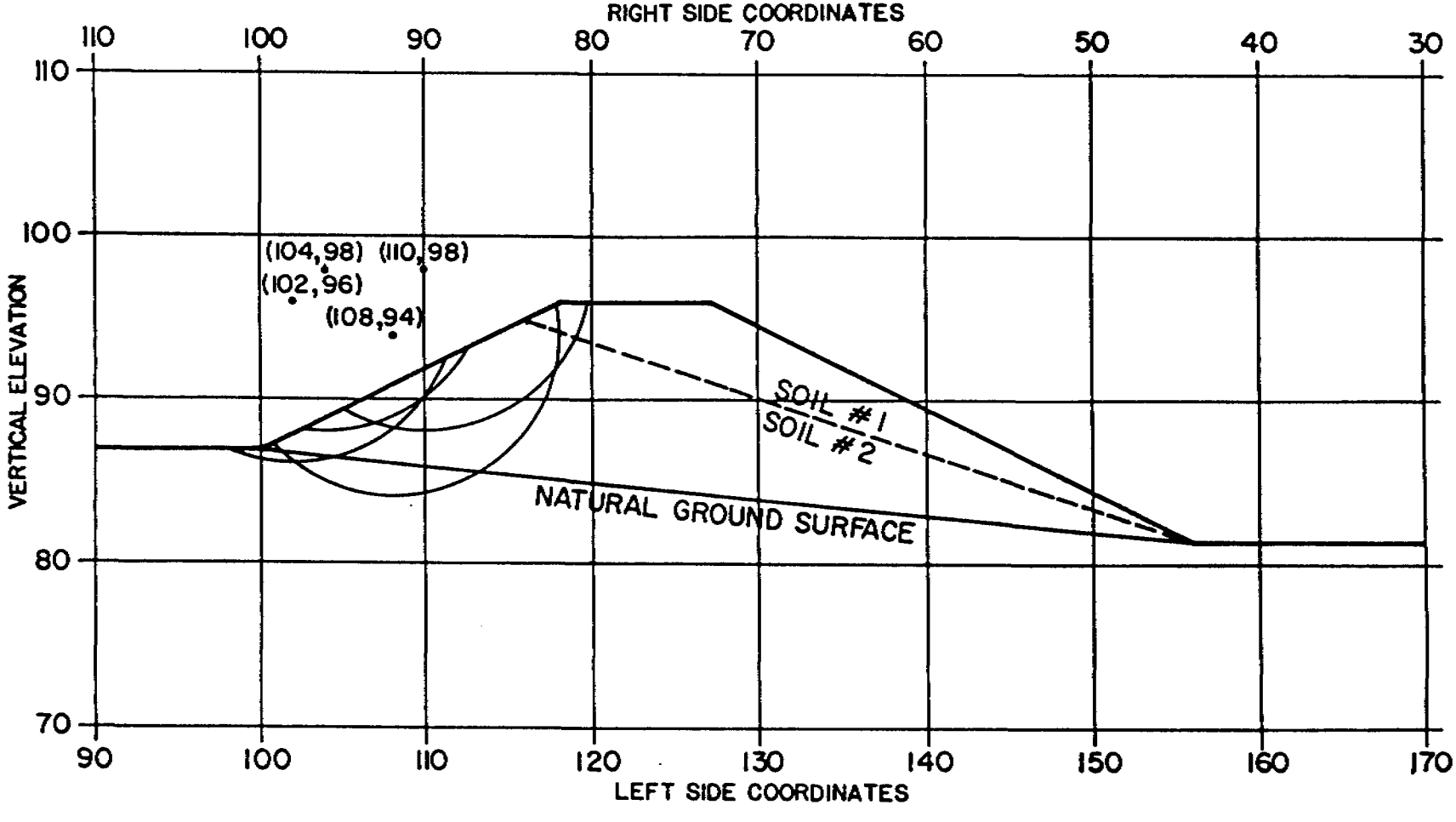
SLICE	WEIGHT	INCLINATION	COHESION	WIDTH	EFF WEIGHT	ø	X
1	1462.0	-42.3	700	5.0	687.5	29	21.6
2	3665.2	-32.0	700	5.0	1723.7	29	26.5
3	5173.0	-22.7	700	5.0	2432.8	29	31.5
4	6143.7	-14.1	700	5.0	2889.3	29	36.5
5	6653.8	-5.7	700	5.0	3129.2	29	41.5
6	8812.7	3.1	700	5.8	4315.1	29	46.9
7	10243.5	12.8	700	5.8	5329.1	29	52.7
8	10960.3	22.8	700	5.8	6007.3	29	58.5
9	10827.8	33.7	700	5.8	6286.1	29	64.3
10	9526.0	46.2	700	5.8	6015.0	29	70.1
11	4743.0	61.5	700	4.9	3409.3	29	75.4
12	190.1	72.5	700	1.0	190.1	29	78.3

ITERATION	INITIAL	CALCULATED
1	1.0000	3.1718
2	3.1718	3.1953
3	3.1953	3.1962

FACTOR OF SAFETY= 3.20 AT X= 45 Y= 105 R= 35
EARTHQUAKE= .10

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



T21000

CO-OP MINING COMPANY

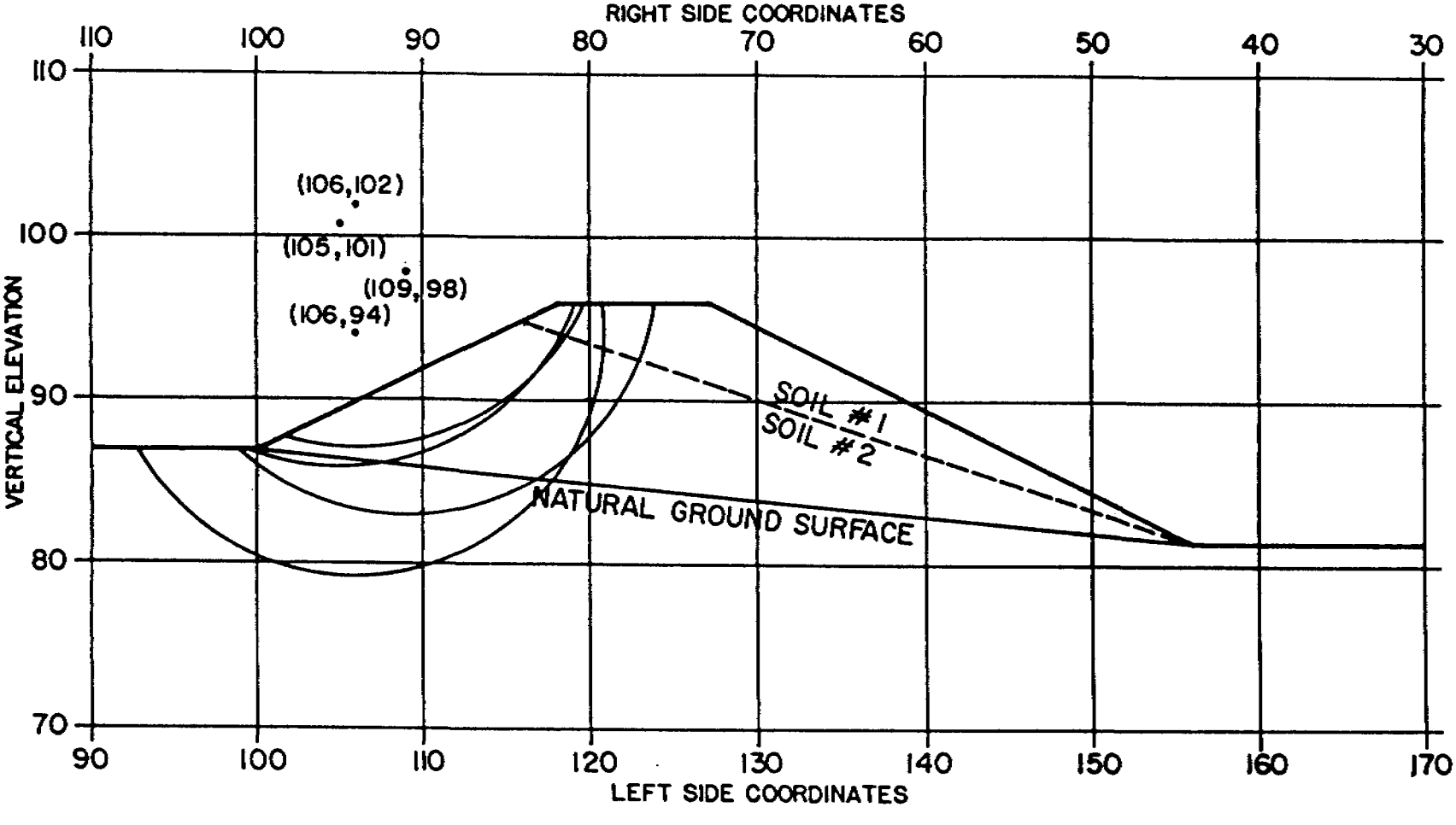
RADIUS = 10'

SCALE 1" = 10'

HORROCKS CARDILLO ENGINEERS

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



2210000

CO-OP MINING COMPANY

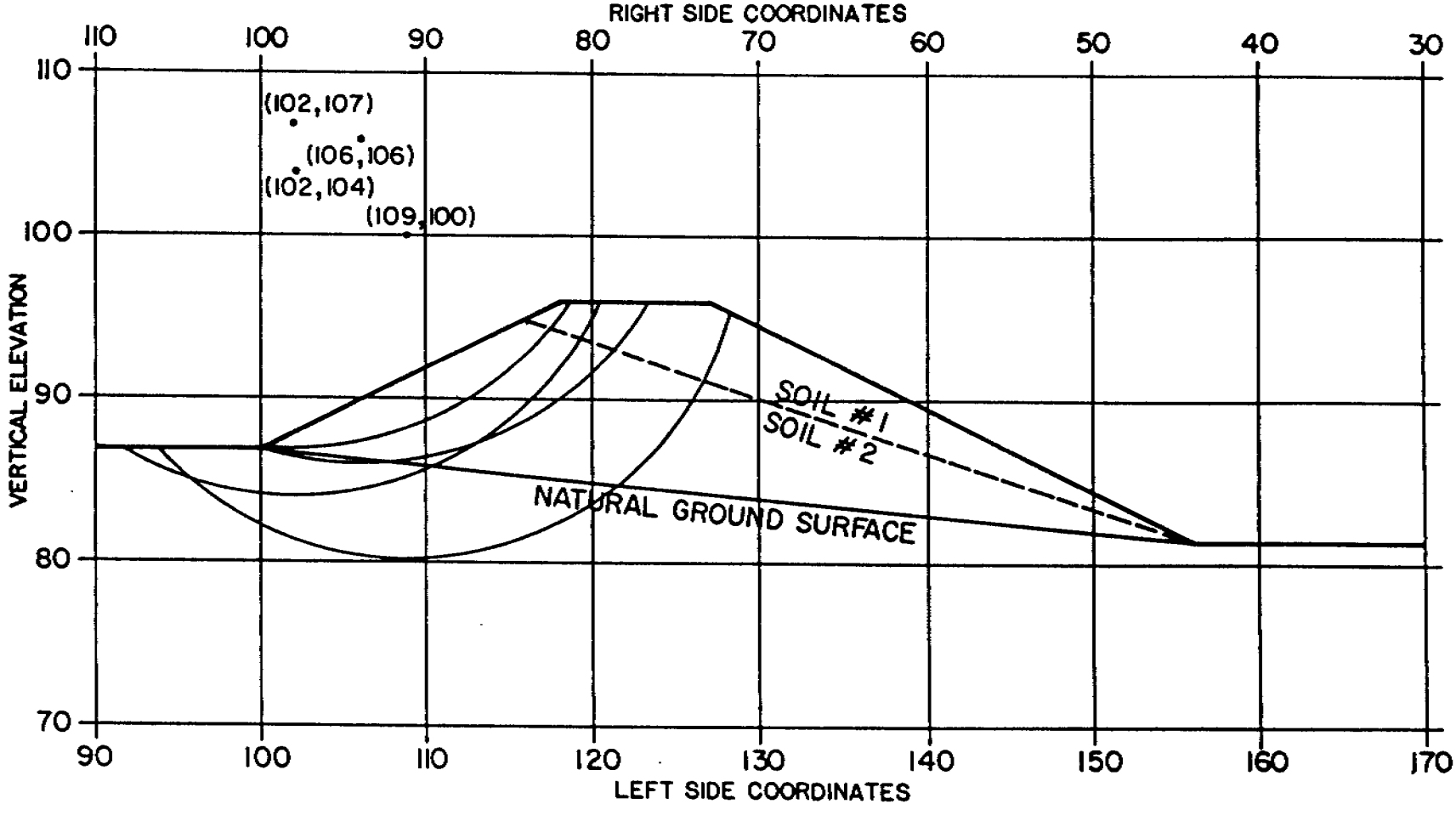
RADIUS = 15'

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

BEAR CREEK CANYON MINE – SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



0001723

RADIUS = 20'

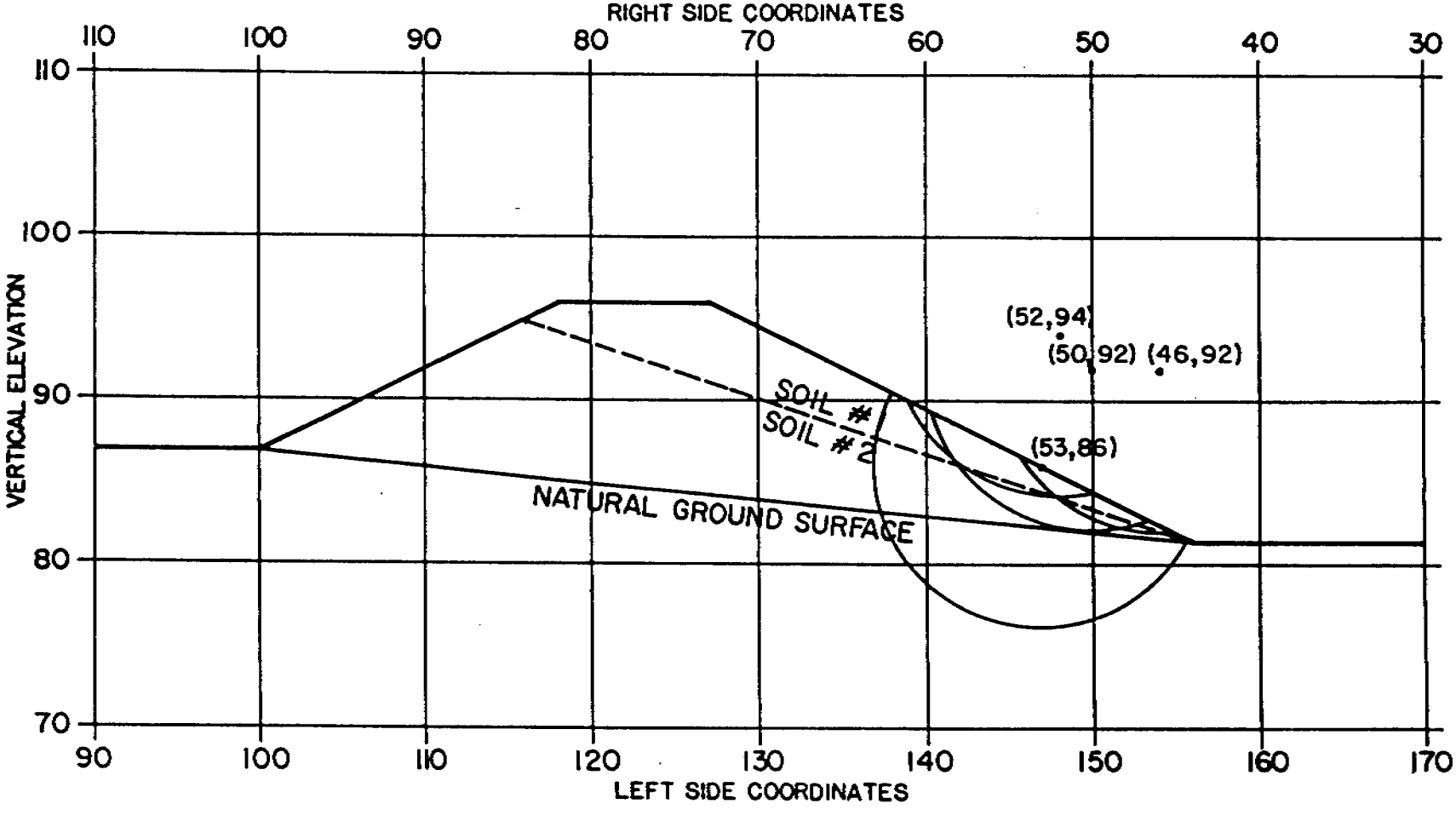
CO-OP MINING COMPANY

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



RADIUS = 10'

CO-OP MINING COMPANY

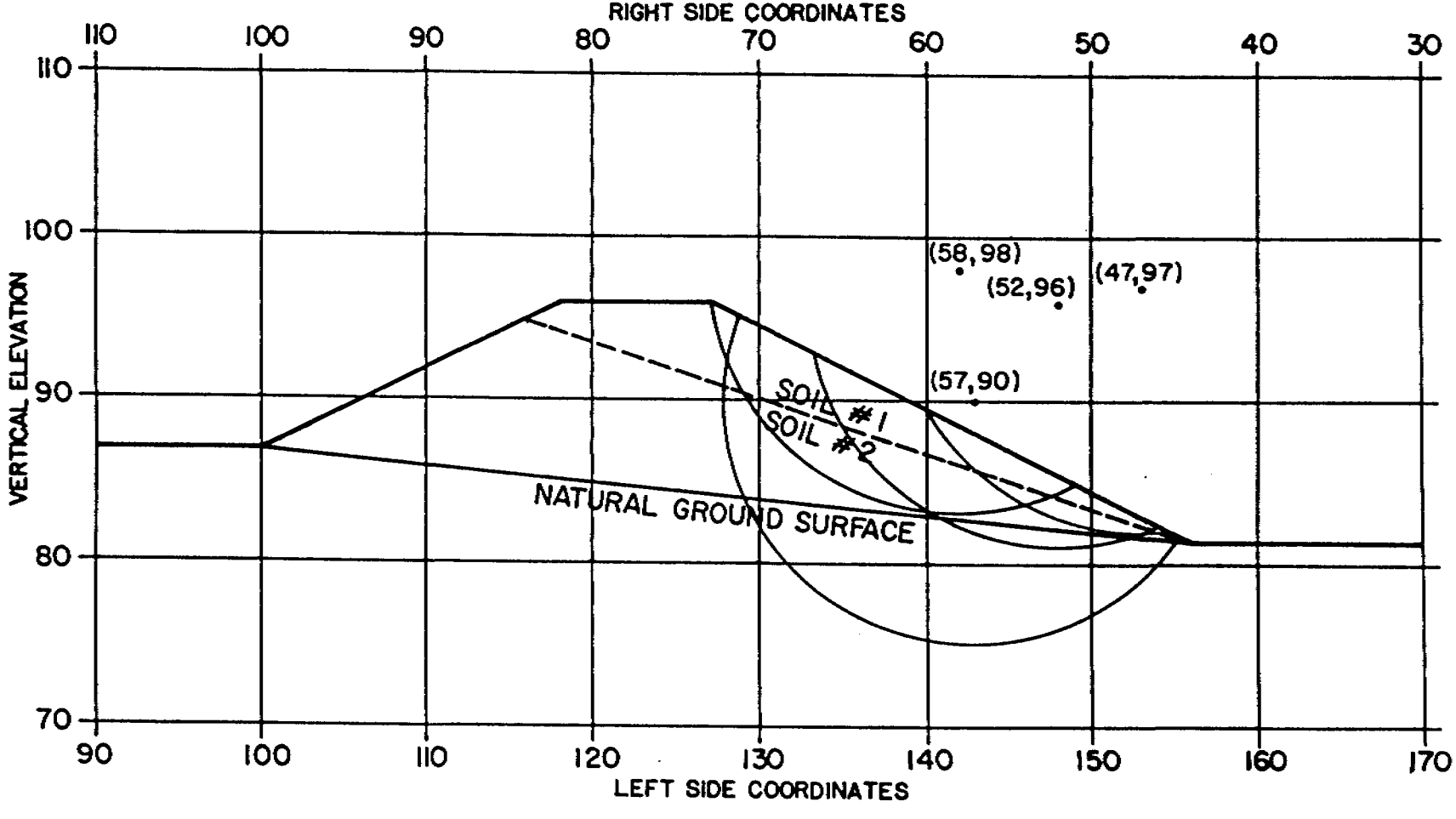
SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

00001724

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



CO-OP MINING COMPANY

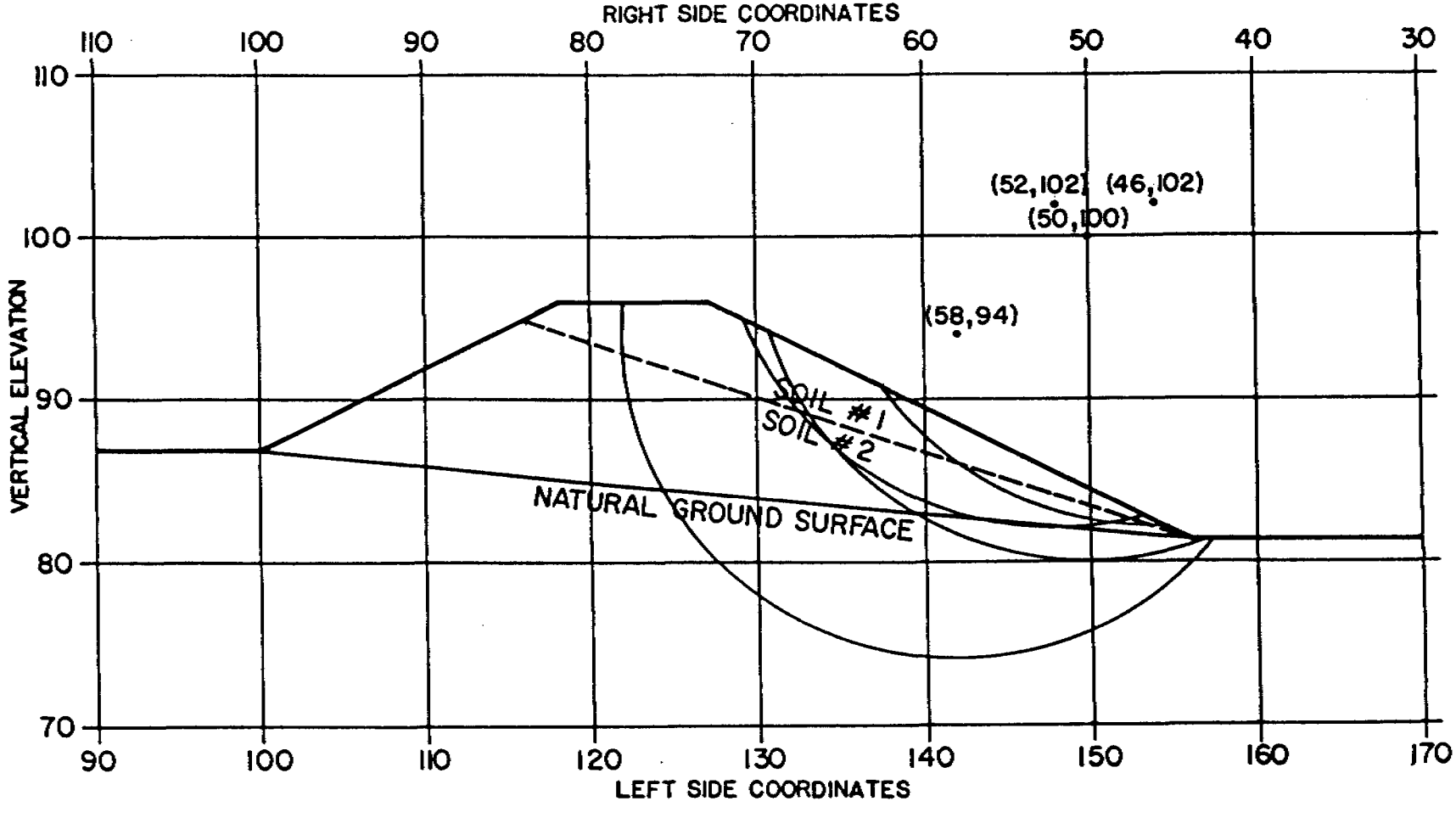
RADIUS = 15'

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



9210000

CO-OP MINING COMPANY

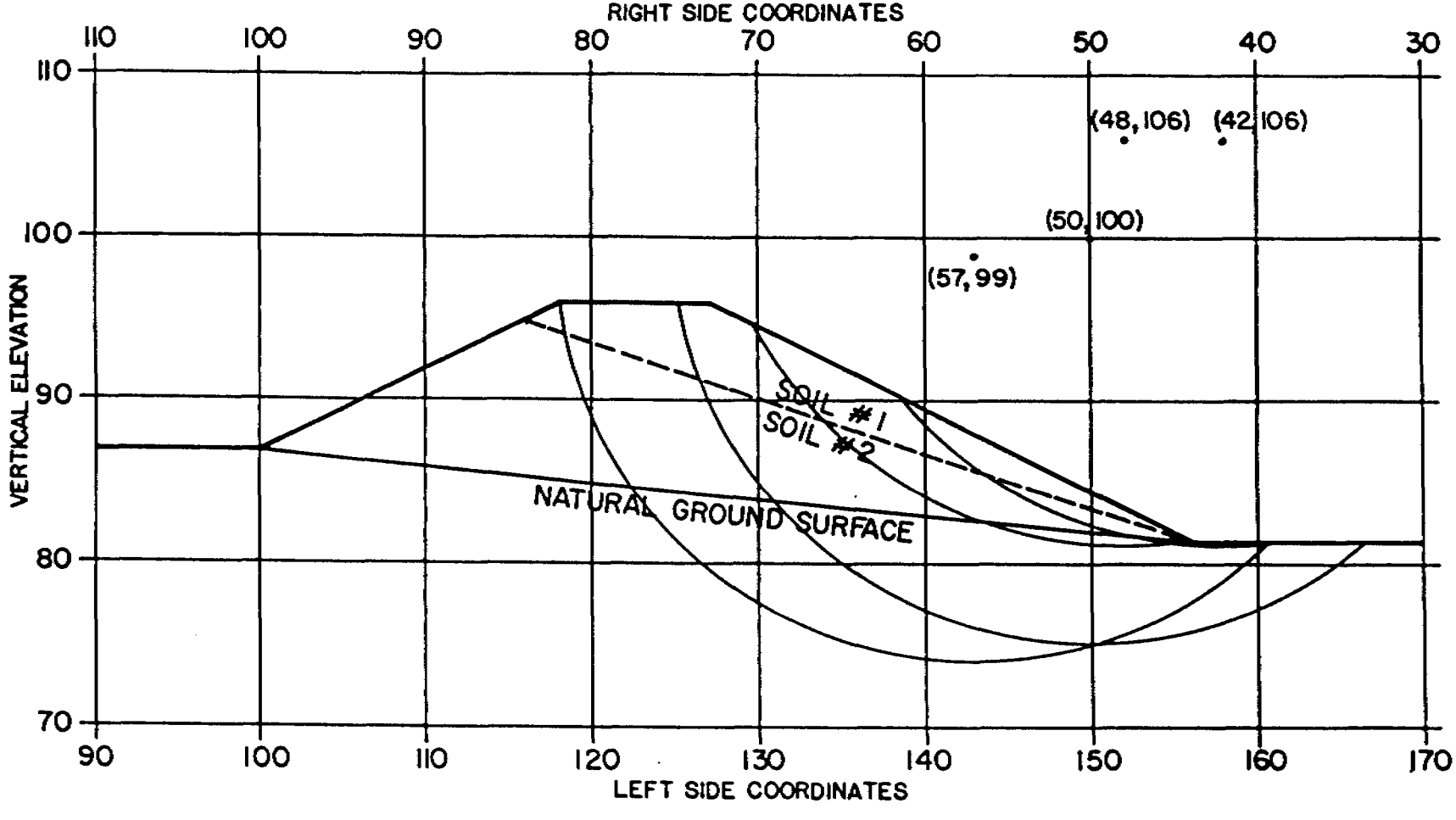
RADIUS = 20'

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



RADIUS = 25'

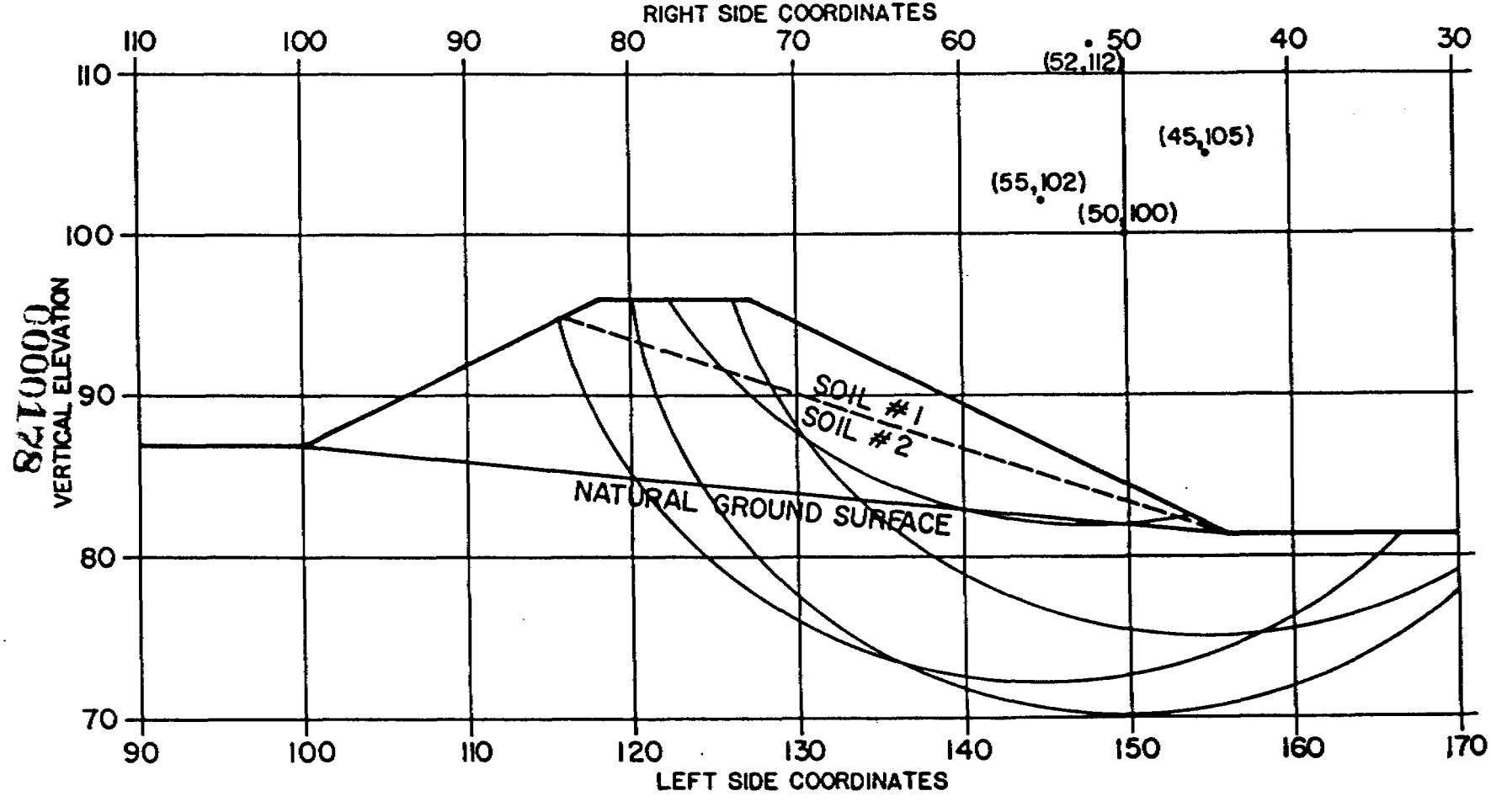
CO-OP MINING COMPANY

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



8210009

CO-OP MINING COMPANY

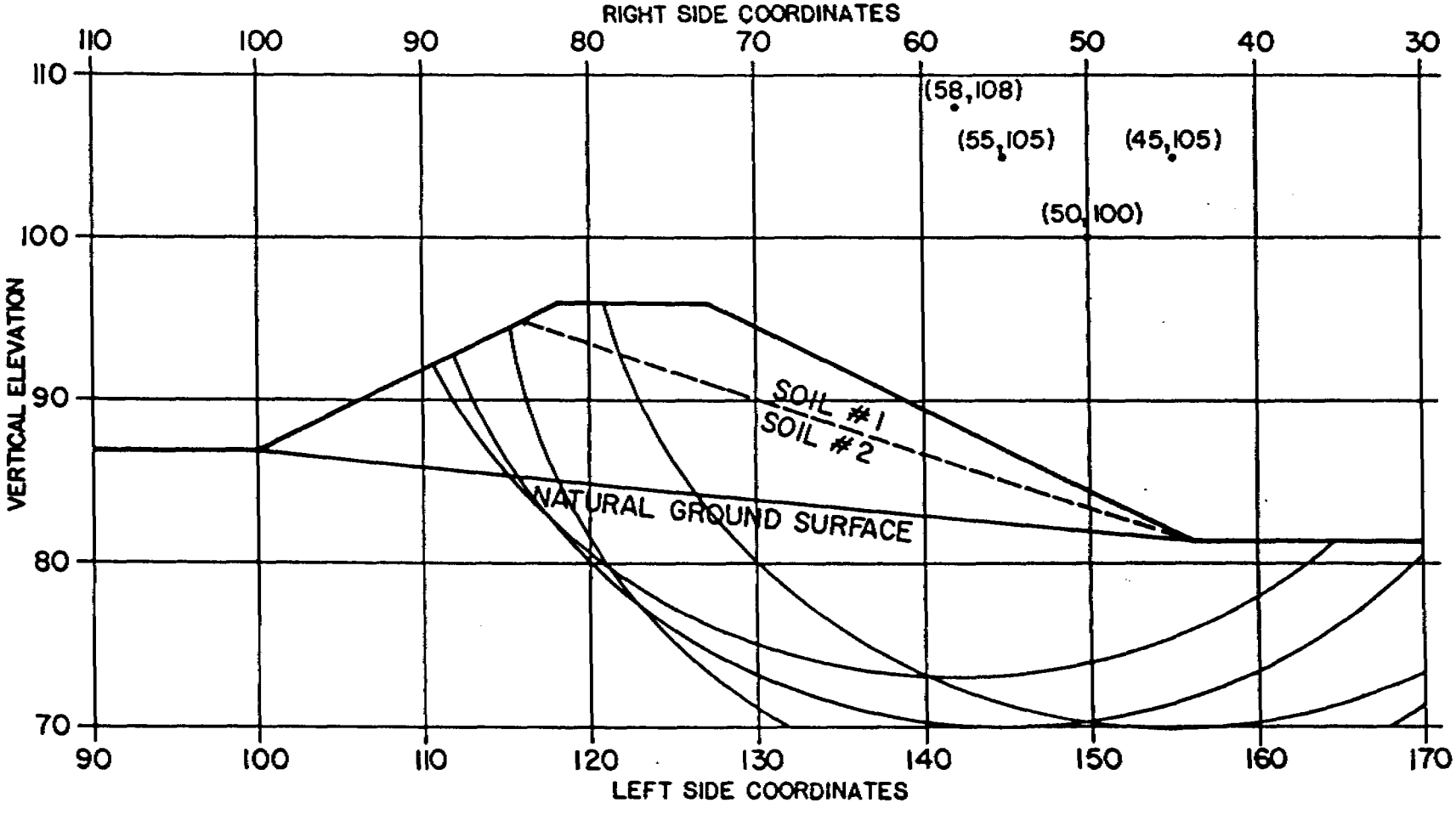
RADIUS = 30'

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

BEAR CREEK CANYON MINE - SEDIMENTATION POND "A"

CROSS SECTION THROUGH EMBANKMENT



CO-OP MINING COMPANY

RADIUS = 35'

SCALE 1" = 10'

HORROCKS CAROLLO ENGINEERS

"SLOPE"

A slope stability program utilizing the simplified or "modified Bishop" method.

The program was written by John P. Cross, P.E., Processing Manager of STS Consultants, Northbrook, Illinois. This program was printed in the October 1982 issue of "CIVIL ENGINEERING."

This version was copied from "CIVIL ENGINEERING" and edited for the Hewlett-Packard 9845 desk-top computer by Horrocks Engineers in March 1983. The format for the input and the output was changed from the original version, however, the program itself was not changed.

HORROCKS ENGINEERS
ONE WEST MAIN STREET
AMERICAN FORK, UTAH 83003
TELEPHONE (801)756-7628

```
 42    OPTION BASE 1
 44    OVERLAP
 46    PRINTER IS 16
 48    PRINT "SLOPE STABILITY ANALYSIS"
 50    DIM P(50,2),L(50,3),S2(5,4),A(50),F(50,7),Z(50,4),H$[80],Sbit$(0:1)[3]
 52    INTEGER Logo(2)
 54    Sbit$(1)=" NO"
 56    Sbit$(0)="YES"
 58    S9=10
 60    J6=0
 62    OUTPUT 5;"R"
 64    ENTER 5;M,D,Time$
 66    Date$=VAL$(M)&"/"&VAL$(D)&"/83"
 68    PRINTER IS 0
 70    PRINT "",LIN(4),TAB(80-LEN(Date$));Date$,LIN(0);
 72    GOSUB Logo    ! PRINT HORROCKS ENGINEERS' LOGO
 74    PRINT LIN(5),TAB(28),"SLOPE STABILITY ANALYSIS",LIN(2),TAB(38),"for",LIN(2
);


*** INPUT OF PROGRAM VARIABLES ***

 78    INPUT "ENTER THE DATA FILE NAME",File$
 79    INPUT "ENTER THE PROJECT NUMBER",Pn$
 82    INPUT "ENTER THE USER'S INITIALS",User$
186    LINK File$,5000
190    READ H$
191    PRINT TAB(40-LEN(H$)/2);H$
195    PRINT LIN(30),TAB(30),"DATA FILE: "&CHR$(34)&File$&CHR$(34),LIN(1)
200    PRINT TAB(25),"PROJECT NUMBER: "&Pn$,LIN(1)
201    PRINT TAB(37),"by: "&User$
203    PRINTER IS 16
210    READ S0
211    IF S0=0 THEN 270
230    READ S6
250    READ S7
270    READ W0
290    READ E1
310    READ P1
311    PRINTER IS 16
315    PRINT "POINT      X-ORD       Y-ORD"
320    FOR I=1 TO P1
331      PRINT SPA(2),I;
```

```
332     IMAGE 3X,2(7D.3D,2X)
350     READ P(I,1),P(I,2)
371     PRINT USING 332;P(I,1),P(I,2)
380   NEXT I
400   READ L1
401   PRINT LIN(1),"LINE    FROM       TO    SOIL BENEATH"
402   IMAGE 3X,2(4D,3X),2X,2D
410   FOR I=1 TO L1
421     PRINT I;
440     READ L(I,1),L(I,2),L(I,3)
480     PRINT USING 402;L(I,1),L(I,2),L(I,3)
490   NEXT I
510   READ S1
511   PRINT LIN(1),"SOIL   UNIT WEIGHT  COHESION    "&CHR$(210)&"   SATURATION"
512   IMAGE 3X,4D.DD,2X,9D,3X,3D,3X,3A
520   FOR I=1 TO S1
531     PRINT I;
550     READ S2(I,1),S2(I,2),S2(I,3),S2(I,4)
610     PRINT USING 512;S2(I,1),S2(I,2),S2(I,3),Sbit$(S2(I,4))
620   NEXT I


*** CIRCLE DEFINITION  ***

640   F9=0
641   PRINTER IS 16
650   PRINT "CIRCLE DEFINITION"
660   INPUT "ENTER THE X-ORD, Y-ORD, AND RADIUS OF THE FAIL SURFACE  FORMAT X,Y,
R ",X,Y,R


*** CHECK TO SEE IF CIRCLE EXCEEDS TOP LINE END POINTS ***

730   U1=P1
740   FOR I=2 TO P1
750     IF (P(I,1)<P(I-1,1)) AND (U1=P1) THEN 770
760     GOTO 780
770     U1=I-1
780   NEXT I
790   J1=R*R-(P(1,2)-Y)^2
800   J2=R*R-(P(U1,2)-Y)^2
810   IF J1<=0 THEN 830
820   IF (J1>0) AND (P(1,1)>X-SQR(J1)) THEN 860
830   IF J2<=0 THEN 850
840   IF (J2>0) AND (P(U1,1)<X+SQR(J2)) THEN 860
850   GOTO 880
860   DISP "CIRCLE EXCEEDS TOP LINE END POINTS";
870   GOTO 4380


*** DEFINE INTERSECTION OF CIRCLE WITH LINES ***

890   FOR I=1 TO L1
900     X1=P(L(I,1),1)
910     Y1=P(L(I,1),2)
920     X2=P(L(I,2),1)
930     Y2=P(L(I,2),2)
940     IF X2=X1 THEN 960
950     GOTO 970
960     S=9.99E10
970     IF X2<>X1 THEN 990
980     GOTO 1000
990     S=(Y2-Y1)/(X2-X1)
1000    IF ABS(S)<1.0E-5 THEN 1150
```

```
1010    C1=X1-Y1/S
1020    C2=1/S^2+1
1030    C3=2*C1/S-2*X/S-2*Y
1040    C4=C1^2-2*X*C1+X^2+Y^2-R^2
1050    C5=C3^2-4*C2*C4
1060    IF C5<0 THEN 1080
1070    GOTO 1090
1080    Z(I,1)=0
1090    IF C5<0 THEN 1630
1100    Q1=(-C3+SQR(C5))/(2*C2)
1110    Q2=(-C3-SQR(C5))/(2*C2)
1120    Q3=Q1/S+C1
1130    Q4=Q2/S+C1
1140    GOTO 1240
1150    C5=R^2-(Y-Y1)^2
1160    IF C5<0 THEN 1180
1170    GOTO 1190
1180    Z(I,1)=0
1190    IF C5<0 THEN 1630
1200    Q3=X+SQR(C5)
1210    Q4=X-SQR(C5)
1220    Q1=Y1
1230    Q2=Y1
1240    J1=0
1250    J2=0
1260    IF (ABS(S)<=9.99E9) AND (Q3>=X1) AND (Q3<=X2) THEN 1280
1270    GOTO 1290
1280    J1=1
1290    IF (ABS(S)<=9.99E9) AND (Q4>=X1) AND (Q4<=X2) THEN 1310
1300    GOTO 1320
1310    J2=1
1320    IF (S<-9.99E9) AND (Q1>=Y2) AND (Q1<=Y1) THEN 1340
1330    GOTO 1350
1340    J1=1
1350    IF (S<-9.99E9) AND (Q2>=Y2) AND (Q2<=Y1) THEN 1370
1360    GOTO 1380
1370    J2=1
1380    IF (S>9.99E9) AND (Q1>=Y1) AND (Q1<=Y2) THEN 1400
1390    GOTO 1410
1400    J1=1
1410    IF (S>9.99E9) AND (Q2>=Y1) AND (Q2<=Y2) THEN 1430
1420    GOTO 1440
1430    J2=1
1440    Z(I,1)=J1+J2
1450    IF J1=1 THEN 1470
1460    GOTO 1480
1470    Z(I,2)=Q3
1480    IF J1=1 THEN 1500
1490    GOTO 1510
1500    Z(I,3)=Q1
1510    IF (J1=0) AND (J2=1) THEN 1530
1520    GOTO 1540
1530    Z(I,2)=Q4
1540    IF (J1=0) AND (J2=1) THEN 1560
1550    GOTO 1570
1560    Z(I,3)=Q2
1570    IF (J1=1) AND (J2=1) THEN 1590
1580    GOTO 1600
1590    Z(I,4)=Q4
1600    IF (J1=1) AND (J2=1) THEN 1620
1610    GOTO 1630
1620    Z(I,3)=Q2
1630  NEXT I
1640  X4=0
1650  X5=9.99E20
1660  I1=1
1670  FOR I=1 TO L1
```

```
1680    IF Z(I,1)>=1 THEN 1700
1690    GOTO 1710
1700    A(I1)=Z(I,2)
1710    IF Z(I,1)>=1 THEN 1730
1720    GOTO 1740
1730    I1=I1+1
1740    IF Z(I,1)=2 THEN 1760
1750    GOTO 1770
1760    A(I1)=Z(I,4)
1770    IF Z(I,1)=2 THEN 1790
1780    GOTO 1800
1790    I1=I1+1
1800  NEXT I
1810  IF I1=1 THEN 1830
1820  GOTO 1840
1830  PRINT "CIRCLE DOES NOT INTERSECT SLOPE"
1840  IF I1=1 THEN 4380


*** SET UP SLICE ARRAY ***

1860  FOR I=1 TO I1-1
1870    IF A(I)>X4 THEN 1890
1880    GOTO 1900
1890    X4=A(I)
1900    IF A(I)<X5 THEN 1920
1910    GOTO 1930
1920    X5=A(I)
1930  NEXT I
1940  FOR I=1 TO P1
1950    IF (P(I,1)<X4) AND (P(I,1)>X5) THEN 1970
1960    GOTO 1980
1970    A(I1)=P(I,1)
1980    IF (P(I,1)<X4) AND (P(I,1)>X5) THEN 2000
1990    GOTO 2010
2000    I1=I1+1
2010  NEXT I
2020  I1=I1-1
2030  FOR I=1 TO I1
2040    FOR J=1 TO I1-1
2050      IF A(J+1)>A(J) THEN 2090
2060      J1=A(J+1)
2070      A(J+1)=A(J)
2080      A(J)=J1
2090    NEXT J
2100  NEXT I
2110  U1=0
2120  FOR I=1 TO I1-1
2130    IF A(I)<A(I+1) THEN 2150
2140    GOTO 2160
2150    U1=U1+1
2160    IF A(I)<A(I+1) THEN 2180
2170    GOTO 2190
2180    A(U1)=A(I)
2190  NEXT I
2200  U1=U1+1
2210  A(U1)=A(I1)
2220  I1=U1


*** DEFINE SLICE BOUNDARIES ***

2240  Q1=A(I1)-A(1)
2250  Q2=Q1/S9
2260  U1=I1
```

0000183

```
2270  FOR I=1 TO U1-1
2280    Q3=A(I+1)-A(I)
2290    Q4=INT(Q3/Q2)+1
2300    C1=Q3/Q4
2310    C2=A(I)
2320    FOR J=1 TO Q4
2330      IF J<Q4 THEN 2350
2340      GOTO 2360
2350      I1=I1+1
2360      IF J<Q4 THEN 2380
2370      GOTO 2390
2380      A(I1)=C2+C1
2390      IF J<Q4 THEN 2410
2400      GOTO 2420
2410      C2=C2+C1
2420    NEXT J
2430  NEXT I
2440  FOR I=1 TO I1
2450    FOR J=1 TO I1-1
2460      IF A(J+1)>A(J) THEN 2500
2470      J1=A(J+1)
2480      A(J+1)=A(J)
2490      A(J)=J1
2500    NEXT J
2510  NEXT I


*** DEFINE SOIL PARAMETERS FOR EACH SLICE ***

2530  F1=I1-1
2540  FOR I=1 TO F1
2550    F(I,4)=A(I+1)-A(I)
2560    X6=F(I,4)
2570    F(I,7)=(A(I+1)+A(I))/2
2580    X3=F(I,7)
2590    Y1=Y-SQR(R^2-(A(I)-X)^2)
2600    Y2=Y-SQR(R^2-(A(I+1)-X)^2)
2610    A5=ATN(ABS(Y2-Y1)/F(I,4))
2620    IF Y2<Y1 THEN 2640
2630    GOTO 2650
2640    A5=-A5
2650    F(I,2)=A5
2660    IF A5=0 THEN 2680
2670    GOTO 2690
2680    F(I,2)=1.0E-5
2690    Y3=Y-SQR(R^2-(X3-X)^2)
2700    I4=0
2710    FOR J=1 TO L1
2720      L5=L(J,1)
2730      L6=L(J,2)
2740      IF (P(L5,2)<=Y3) AND (P(L6,2)<=Y3) THEN 2840
2750      IF (P(L5,1)<X3) AND (P(L6,1)<X3) THEN 2840
2760      IF (P(L5,1)>X3) AND (P(L6,1)>X3) THEN 2840
2770      Y6=P(L5,2)+(P(L5,2)-P(L6,2))/(P(L5,1)-P(L6,1))*(X3-P(L5,1))
2780      IF Y6<=Y3 THEN 2840
2790      I4=I4+1
2800      Z(I4,1)=Y6
2810      Z(I4,2)=L(J,3)
2820      W=0
2830      E=0
2840    NEXT J
2850    IF I4=1 THEN 2970
2860    FOR J=1 TO I4
2870      FOR J1=1 TO I4-1
2880        IF Z(J1,1)>=Z(J1+1,1) THEN 2950
2890        L5=Z(J1,1)
```

0000184

```
2900          L6=Z(J1,2)
2910          Z(J1,1)=Z(J1+1,1)
2920          Z(J1,2)=Z(J1+1,2)
2930          Z(J1+1,1)=L5
2940          Z(J1+1,2)=L6
2950        NEXT J1
2960      NEXT J
2970      I4=I4+1
2980      Z(I4,1)=Y3
2990      FOR J1=1 TO I4-1
3000        IF (I=1) AND (J1=1) AND (X3)=S6) THEN 3020
3010        GOTO 3030
3020        I6=S0-Y1
3030        IF (I=F1) AND (J1=1) AND (X3)=S6) AND (X3(=S7) THEN 3050
3040        GOTO 3060
3050        J6=S0-Y2
3060        W=W+(Z(J1,1)-Z(J1+1,1))*X6*S2(Z(J1,2),1)
3070        IF (Z(J1,1)(S0) AND (X3)=S6) AND (X3(=S7) THEN 3090
3080        GOTO 3100
3090        W=W+(S0-Z(J1,1))*X6*W0
3100        IF S2(Z(J1,2),4)).95 THEN 3120
3110        GOTO 3130
3120        E4=S2(Z(J1,2),1)
3130        IF S2(Z(J1,2),4)(.95 THEN 3150
3140        GOTO 3160
3150        E4=S2(Z(J1,2),1)-W0
3160        E=E+(Z(J1,1)-Z(J1+1,1))*X6*E4
3170      NEXT J1
3180      F(I,1)=W
3190      F(I,5)=E
3200      F(I,3)=S2(Z(I4-1,2),2)
3210      F(I,6)=2*PI*(S2(Z(I4-1,2),3)/360)
3220    NEXT I
3221    NORMAL
3230    IF F9=0 THEN 3360
3240    PRINT USING 3250;CHR$(210)
3250    IMAGE "SLICE   WEIGHT   INCLINATION   COHESION   WIDTH    EFF WEIGHT    "A
"         X"
3280    O=360/(2*PI)
3290    FOR I=1 TO F1
3300      PRINT USING 3320;I,F(I,1),F(I,2)*O,F(I,3),F(I,4),F(I,5),F(I,6)*O,F(I,7)
3320      IMAGE 3D,10D.D,7D.D,12D,9D.D,11D.D,7D,7D.D
3340    NEXT I
3350    PRINT
3360    D=0
3361    PRINTER IS 0
3370    FOR I=1 TO F1
3380      D=D+F(I,1)*SIN(ABS(F(I,2)))*(F(I,2)/ABS(F(I,2)))
3390      D=D+E1*F(I,1)*COS(ABS(F(I,2)))
3400    NEXT I
3410    IF I6>0 THEN 3430
3420    GOTO 3440
3430    I7=W0*I6*I6*(R-I6/3)/(2*R)
3440    IF I6>0 THEN 3460
3450    GOTO 3470
3460    D=D-SGN(D)*I7
3470    IF (I6>0) AND (F9=1) THEN 3490
3480    GOTO 3510
3490    PRINT USING 3500;I7
3500    IMAGE "DRIVING FORCE COUNTER BALANCE OF",10D.2D
3510    IF J6>0 THEN 3530
3520    GOTO 3540
3530    I7=W0*J6*J6*(R-J6/3)/(2*R)
3540    IF J6>0 THEN 3560
3550    GOTO 3570
3560    D=D+SGN(D)*I7
3570    IF (J6>0) AND (F9=1) THEN 3590
```

```
3580  GOTO 3610
3590  PRINT USING 3600;I7
3600  IMAGE "DRIVING FORCE INCREASE OF",10D.2D


*** ITERATIVE SOLUTION FOR FACTOR OF SAFETY ***

3620  F0=1
3630  R4=0
3640  I6=0
3650  FOR I=1 TO F1
3660    R1=F(I,3)*F(I,4)+F(I,5)*TAN(F(I,6))
3670    R2=1/COS(ABS(F(I,2)))
3680    R3=1+TAN(F(I,6))*TAN(F(I,2))/F0
3690    R4=R4+R1*(R2/R3)
3700  NEXT I
3710  F2=R4/D
3720  I6=I6+1
3730  IF F9=1 THEN 3750
3740  GOTO 3820
3750  IF I6=1 THEN 3770
3760  GOTO 3800
3770  PRINT
3780  PRINT USING 3790
3790  IMAGE "ITERATION",11X,"INITIAL",10X,"CALCULATED"
3800  PRINT USING 3810;I6,F0,F2
3810  IMAGE 3X,3D,13X,3D.4D,12X,3D.4D
3820  IF I6>10 THEN 3840
3830  GOTO 3850
3840  PRINT "WILL NOT CLOSE"
3850  IF I6>10 THEN 3970
3860  IF ABS(ABS(F0)-ABS(F2))<.005 THEN 3900
3870  F0=ABS(F2)
3880  R4=0
3890  GOTO 3650
3900 !
3901  IF NOT F9 THEN
3902    PRINTER IS 16
3903  ELSE
3904    PRINTER IS 0
3905  END IF
3910  PRINT
3920  PRINT USING 3930;F2,X,Y,R
3930  IMAGE "FACTOR OF SAFETY= ",5D.2D,"  AT X= ",4D," Y= ",4D, " R= ",4D
3940  PRINT USING 3950;E1
3950  IMAGE "EARTHQUAKE= ",2D.2D
3951  IF F9 THEN 4380
3960  PRINT
3961  A$=""
3970  INPUT "DO YOU WISH A FORMAL PRINTOUT (Y/N)",A$
3990  IF UPC$(A$[1,1])="N" THEN 4320
3991  PRINTER IS 0
4030  IMAGE @"WATER UNIT WEIGHT=",3D.2D
4040  PRINT USING 4030;W0
4041  IF S0 THEN
4050    PRINT
4060    IMAGE "SUBMERGENCE AT "3D.2D,"  FROM  ",3D.1D,"  TO  ",3D.1D
4070    PRINT USING 4060;S0,S6,S7
4071  END IF
4080  PRINT
4090  PRINT " POINT   X-ORD     Y-ORD"
4100  IMAGE 4D,7D.2D,7D.2D
4110  FOR I=1 TO P1
4120    PRINT USING 4100;I,P(I,1),P(I,2)
4130  NEXT I
4140  PRINT
```

```
4150  PRINT "     LINE     LEFT    RIGHT     SOIL"
4160  IMAGE 4(8D)
4170  FOR I=1 TO L1
4180    PRINT USING 4160;I,L(I,1),L(I,2),L(I,3)
4190  NEXT I
4200  PRINT
4210  PRINT "SOIL        UNIT WEIGHT        COHESION      "&CHR$(210)&"      SATURAT
ED"
4220  IMAGE 3D,15D,17D,9D,7X,3A
4230  FOR I=1 TO S1
4240    PRINT USING 4220;I,S2(I,1),S2(I,2),S2(I,3),Sbit$(S2(I,4))
4250  NEXT I
4260  PRINT
4270  PRINT "CIRCLE   X-ORD     Y-ORD    RADIUS  FACTOR OF SAFETY"
4280  IMAGE 12D.D,7D.D,7D.D,8D.2D
4290  PRINT USING 4280;X,Y,R,F2
4300  PRINT
4310  PRINT
4311  A$=""
4320  INPUT "DO YOU WISH A DIAGNOSTIC RUN (Y/N)",A$
4340  IF UPC$(A$[1,1])="N" THEN 4370
4360  F9=1
4370  IF UPC$(A$[1,1])<>"N" THEN 720
4371  A$=""
4380  INPUT "DO YOU WANT TO CONTINUE (Y/N)",A$
4400  IF UPC$(A$[1,1])<>"N" THEN 630
4401  DISP " FINISHED "
4410  STOP
4520 Logo:PLOTTER IS 13,"GRAPHICS"
4530  GRAPHICS
4540  SCALE 0,559,0,454
4550  LORG 2
4560  FOR I=0 TO 5
4570    Logo(1)=-2175
4580    Logo(2)=-4352
4590    R=454-I
4600    GLOAD Logo(*),0,R
4610  NEXT I
4620  FOR I=6 TO 14
4630    Logo(1)=-2115
4640    Logo(2)=-4352
4650    R=454-I
4660    GLOAD Logo(*),0,R
4670  NEXT I
4680  FOR I=15 TO 21
4690    Logo(1)=-2175
4700    Logo(2)=-4352
4710    R=454-I
4720    GLOAD Logo(*),0,R
4730  NEXT I
4740  CSIZE 15/4.54,9/15
4750  MOVE 27,450
4760  LABEL "HORROCKS"
4770  MOVE 27,437
4780  CSIZE 15/4.54,8/15
4790  LABEL "ENGINEERS"
4800  DUMP GRAPHICS 430,454
4810  GCLEAR
4820  EXIT GRAPHICS
4830  RETURN
```

Slope stability program

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FOR NATURAL or man-made slopes, the index of stability with respect to a sudden failure is known as the safety factor of the slope. The safety factor may be defined as the ratio of the potential resisting forces to the drive forces tending to cause movement. A slope on the verge of failure would have a safety factor of 1.0. The analysis of slope stability is, therefore, the analytical procedure of determining the most critical, i.e., the lowest, factor of safety of given or proposed slope.

Manual methods of slope stability analysis were developed prior to the advent of the electronic computer. These approaches resulted in high analysis costs and conservative slope configurations. Repetitive calculations lended themselves to computerized methods and numerous programs exist that have been written for large computer systems to perform slope stability analysis according to a number of theoretical methods.

The simplified or modified Bishop method is reasonably accurate for most purposes where the slope under analysis can be assumed to fail along a circular failure surface. The factor of safety is defined as the ratio of the resisting moments to driving moments around the center of the failure arc. Initially, a cross-section of the slope is drawn detailing soil strata and piezometric surfaces. A center point is then chosen from which an arc is taken through the cross-section. This arc represents the failure surface under evaluation. This failure zone is broken down into a series of slices which can be individually evaluated for their weight and strength characteristics. An illustration of a slope cross-section being defined by a series of slices is shown in Figure 1.

The forces acting on each slice are illustrated in Figure 1, where ΔX is the width of the slice, W is the weight of the slice, T is the force acting along the failure surface at the bottom of the slice, $\bar{N}$ is the effective force acting normally to the base of the slice and Θ is the inclination of the failure surface or slice base. The factor of safety is defined as:

$$F = \frac{\Sigma \dfrac{(C\,\Delta X + \bar{N} \tan \Phi) \sec \Theta}{1 + \dfrac{\tan \Phi \tan \Theta}{F}}}{\Sigma W \sin \Theta}$$

Where C is the cohesion, Φ is the friction angle and the summation occurs over each slice of the failure zone. As the factor of safety, F, occurs on both sides of the equation. An interactive solution where F is initially estimated and then back substituted until the calculated F and estimated F close within a specified tolerance.

The equation can be modified to handle two additional conditions by adding additional factors to the term defining the driving force. These two conditions are standing pools, i.e., submergence of a portion of the slope, and earthquake loading. For submergence, the weight of water acting above the slice is added to the weight of the slice itself. The total driving force is increased or decreased by the weight of water above or below the exit of the failure surface from the slope. The second condition of earthquake loading can be handled by increasing the driving force calculated for each slice by $EW\cos\Theta$, where E is the earthquake loading factor. Similarly the resisting force is decreased by a decrease in the normal force due to the earthquake loading.

Following the calculation of the safety factor for this arc, the center or radius of the arc is modified to generate a new failure surface. The previously mentioned procedure is again followed with a new factor of safety being deter-

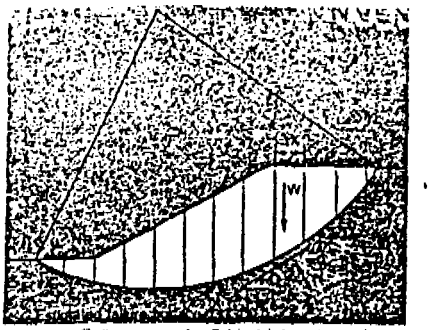

Figure 1. Failure zone is divided into slices; forces acting upon a slice are indicated.

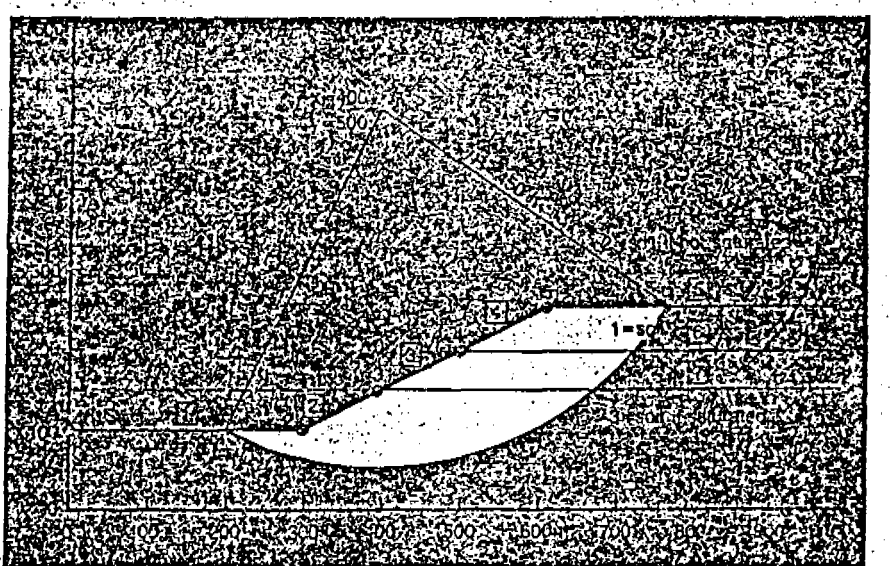

Figure 2. shows a typical cross-section and the input parameters required to define the cross-section for the program.

Table for Figure 2

Point	X	Y	Line	Left	Right	Soil	Soil	α	Cohesion	Phi	Saturated
1	0	100	1	1	2	3	1	127	2000	20	No
2	300	100	2	2	3	3	2	130	1000	33	No
3	400	150	3	3	4	2	3	130	1000	33	Yes
4	500	200	4	4	5	1					
5	600	250	5	5	6	1					
6	1000	250	6	4	7	2					
7	1000	200	7	3	8	3					
8	1000	150									

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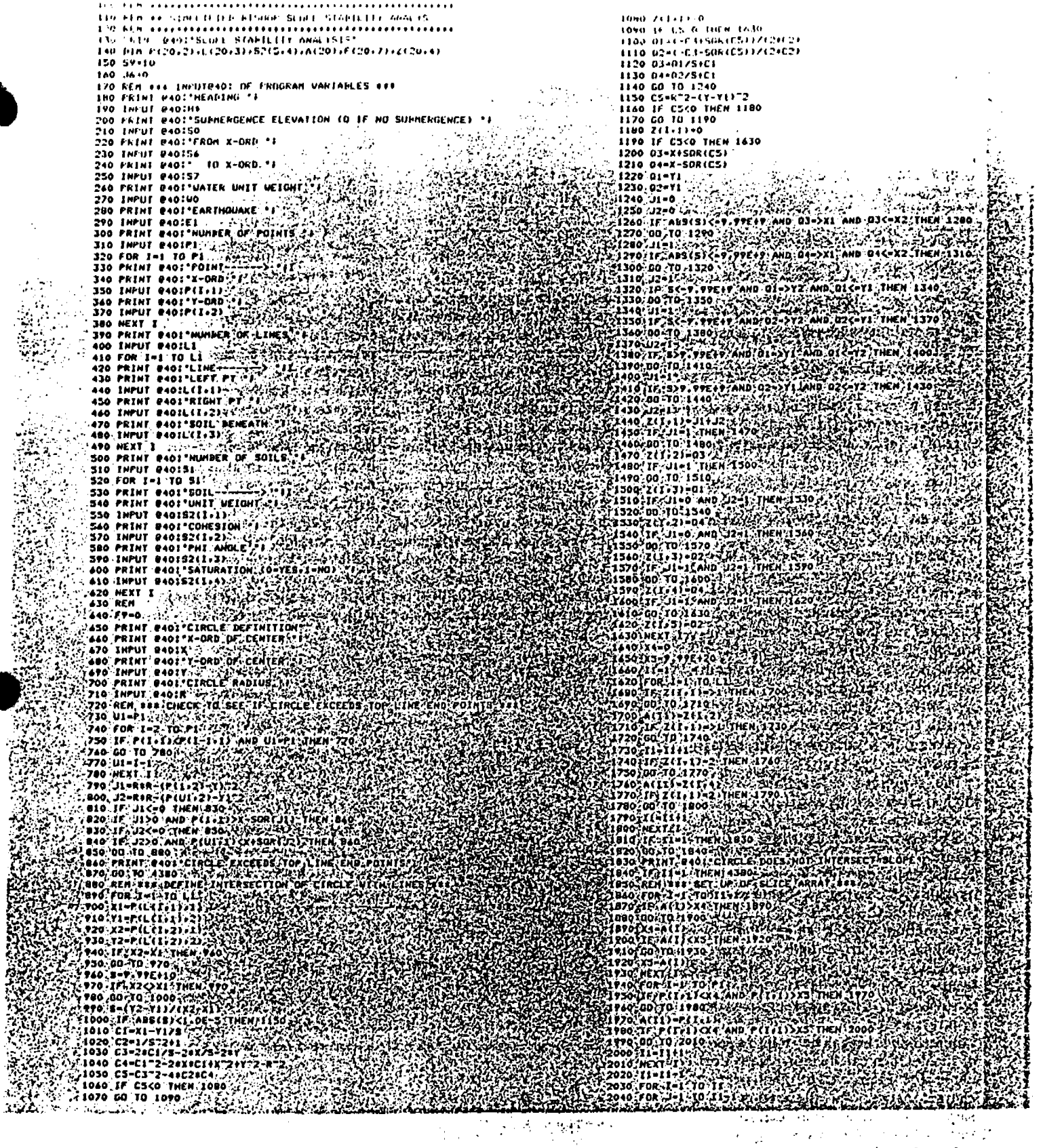

```
100 REM ********************************************
110 REM **  SIMPLIFIED BISHOP SLOPE STABILITY ANALYS
120 REM ********************************************
130 '410  '0491'SLOPE STABILITY ANALYSIS'
140 DIM P(20,2),L(20,3),S2(5,4),A(20),F(20,7),Z(20,4)
150 S9=10
160 J6=0
170 REM *** INPUT@401 OF PROGRAM VARIABLES ***
180 PRINT @401'HEADING *)
190 INPUT @401;H$
200 PRINT @401'SUBMERGENCE ELEVATION (0 IF NO SUBMERGENCE) *)
210 INPUT @401;S0
220 PRINT @401'FROM X-ORD *)
230 INPUT @401;S6
240 PRINT @401'  TO X-ORD. *)
250 INPUT @401;S7
260 PRINT @401'WATER UNIT WEIGHT *)
270 INPUT @401;W0
280 PRINT @401'EARTHQUAKE *)
290 INPUT @401;E1
300 PRINT @401'NUMBER OF POINTS *)
310 INPUT @401;P1
320 FOR I=1 TO P1
330 PRINT @401'POINT------> *)I
340 PRINT @401'X-ORD *)
350 INPUT @401;P(I,1)
360 PRINT @401'Y-ORD *)
370 INPUT @401;P(I,2)
380 NEXT I
390 PRINT @401'NUMBER OF LINES *)
400 INPUT @401;L1
410 FOR I=1 TO L1
420 PRINT @401'LINE------> *)I
430 PRINT @401'LEFT PT *)
440 INPUT @401;L(I,1)
450 PRINT @401'RIGHT PT *)
460 INPUT @401;L(I,2)
470 PRINT @401'SOIL BENEATH *)
480 INPUT @401;L(I,3)
490 NEXT I
500 PRINT @401'NUMBER OF SOILS *)
510 INPUT @401;S1
520 FOR I=1 TO S1
530 PRINT @401'SOIL------> *)I
540 PRINT @401'UNIT WEIGHT *)
550 INPUT @401;S2(I,1)
560 PRINT @401'COHESION *)
570 INPUT @401;S2(I,2)
580 PRINT @401'PHI ANGLE *)
590 INPUT @401;S2(I,3)
600 PRINT @401'SATURATION (0=YES,1=NO) *)
610 INPUT @401;S2(I,4)
620 NEXT I
630 REM
640 F9=0
650 PRINT @401'CIRCLE DEFINITION'
660 PRINT @401'X-ORD OF CENTER *)
670 INPUT @401;X
680 PRINT @401'Y-ORD OF CENTER *)
690 INPUT @401;Y
700 PRINT @401'CIRCLE RADIUS *)
710 INPUT @401;R
720 REM,***CHECK TO SEE IF CIRCLE EXCEEDS TOP LINE END POINTS***
730 U1=P1
740 FOR I=2 TO P1
750 IF P(I,1)>P(I-1,1) AND U1=P1 THEN 770
760 GO TO 780
770 U1=I-1
780 NEXT I
790 J1=R*R-(P(1,2)-Y)^2
800 J2=R*R-(P(U1,2)-Y)^2
810 IF J1<=0 THEN 830
820 IF J1>0 AND P(1,2)>X-SQR(J1) THEN 840
830 IF J2<=0 THEN 880
840 IF J2>0 AND P(U1,1)<X+SQR(J2) THEN 860
850 GO TO 880
860 PRINT @401'CIRCLE EXCEEDS TOP LINE END POINTS'
870 GO TO 4380
880 REM,***DEFINE INTERSECTION OF CIRCLE WITH LINES***
890 FOR I=1 TO L1
900 X1=P(L(I,1),1)
910 Y1=P(L(I,1),2)
920 X2=P(L(I,2),1)
930 Y2=P(L(I,2),2)
940 IF X2=X1 THEN 960
950 GO TO 970
960 S=9.99E+19
970 IF X2<>X1 THEN 990
980 GO TO 1000
990 S=(Y2-Y1)/(X2-X1)
1000 IF ABS(S)<1.0E-5 THEN 1150
1010 C1=X1-Y1*S
1020 C2=1/S^2+1
1030 C3=2*C1/S-2*X/S-2*Y
1040 C4=C1^2-2*X*C1+X^2+Y^2-R^2
1050 C5=C3^2-4*C2*C4
1060 IF C5<0 THEN 1080
1070 GO TO 1090
1080 Z(I,1)=0
1090 IF C5<0 THEN 1630
1100 Q1=(-C3+SQR(C5))/(2*C2)
1110 Q2=(-C3-SQR(C5))/(2*C2)
1120 Q3=Q1/S+C1
1130 Q4=Q2/S+C1
1140 GO TO 1240
1150 C5=R^2-(Y-Y1)^2
1160 IF C5<0 THEN 1180
1170 GO TO 1190
1180 Z(I,1)=0
1190 IF C5<0 THEN 1630
1200 Q3=X+SQR(C5)
1210 Q4=X-SQR(C5)
1220 Q1=Y1
1230 Q2=Y1
1240 J1=0
1250 J2=0
1260 IF ABS(S)<9.99E+19 AND Q3=>X1 AND Q3<=X2 THEN 1280
1270 GO TO 1290
1280 J1=1
1290 IF ABS(S)<9.99E+19 AND Q4=>X1 AND Q4<=X2 THEN 1310
1300 GO TO 1320
1310 J2=1
1320 IF S<-9.99E+19 AND Q1=>Y2 AND Q1<=Y1 THEN 1340
1330 GO TO 1350
1340 J1=1
1350 IF S<-9.99E+19 AND Q2=>Y2 AND Q2<=Y1 THEN 1370
1360 GO TO 1380
1370 J2=1
1380 IF S>9.99E+19 AND Q1=>Y1 AND Q1<=Y2 THEN 1400
1390 GO TO 1410
1400 J1=1
1410 IF S>9.99E+19 AND Q2=>Y1 AND Q2<=Y2 THEN 1430
1420 GO TO 1440
1430 J2=1
1440 Z(I,1)=J1+J2
1450 IF J1=1 THEN 1470
1460 GO TO 1480
1470 Z(I,2)=Q3
1480 IF J1=1 THEN 1500
1490 GO TO 1510
1500 Z(I,3)=Q1
1510 IF J1=0 AND J2=1 THEN 1530
1520 GO TO 1540
1530 Z(I,2)=Q4
1540 IF J1=0 AND J2=1 THEN 1560
1550 GO TO 1570
1560 Z(I,3)=Q2
1570 IF J1=1 AND J2=1 THEN 1590
1580 GO TO 1600
1590 Z(I,4)=Q4
1600 IF J1=1 AND J2=1 THEN 1620
1610 GO TO 1630
1620 Z(I,5)=Q2
1630 NEXT I
1640 X4=0
1650 X5=9.99E+20
1660 J1=1
1670 FOR I=1 TO L1
1680 IF Z(I,1)=1 THEN 1700
1690 GO TO 1710
1700 A(J1)=Z(I,2)
1710 IF Z(I,1)=2 THEN 1730
1720 GO TO 1740
1730 J1=J1+1
1740 IF Z(I,1)=2 THEN 1760
1750 GO TO 1770
1760 A(J1)=Z(I,4)
1770 IF Z(I,1)=2 THEN 1790
1780 GO TO 1800
1790 J1=J1+1
1800 NEXT I
1810 IF J1=1 THEN 1830
1820 GO TO 1840
1830 PRINT @401;'CIRCLE DOES NOT INTERSECT SLOPE'
1840 IF J1=1 THEN 4380
1850 REM,*** SET UP OF SLICE ARRAY ***
1860 FOR I=1 TO J1
1870 IF A(I)>X4 THEN 1890
1880 GO TO 1900
1890 X4=A(I)
1900 IF A(I)<X5 THEN 1920
1910 GO TO 1930
1920 X5=A(I)
1930 NEXT I
1940 FOR I=1 TO P1
1950 IF P(I,1)<X4 AND P(I,1)>X5 THEN 1970
1960 GO TO 1980
1970 A(J1)=P(I,1)
1980 IF P(I,1)<X4 AND P(I,1)>X5 THEN 2000
1990 GO TO 2010
2000 J1=J1+1
2010 NEXT I
2020 J1=J1+1
2030 FOR I=1 TO J1
2040 FOR J=1 TO J1-1
```

mined. This entire sequence is repeated until the failure surface for the minimum factor of safety is determined.

The program included in this article follows the same general procedure as previously defined. The program can be broken down into nine segments. Lines 100-620 are input routines for the entry of data defining the cross-section, lines 630-710 define the circle that will generate the failure surface, lines 720-860 perform a verification that the failure arc falls fully within the cross-section and lines 880-1840 define the intersection points between the line segments and the failure arc. The slice array is set up between line 1850 and 2220, with slice boundaries defined in lines 2230-2510. Lines 2520-3600 include the definition of the soil parameters for each slice and the actual iterative solution for the factor of safety occurs between lines 3610 and 3950. The remainder of the program is the formal output of the results.

The program includes a diagnostic print-out where all the slice parameters can be displayed for any given failure surface. As currently configured the program can handle models including

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```
2050 IF A(J+1)<A(J) THEN 2090
2060 J1=A(J+1)
2070 A(J+1)=A(J)
2080 A(J)=J1
2090 NEXT J
2100 NEXT I
2110 U1=0
2120 FOR I=1 TO I1-1
2130 IF A(I)<A(I+1) THEN 2150
2140 GO TO 2160
2150 U1=U1+1
2160 IF A(I)<A(I+1) THEN 2180
2170 GO TO 2190
2180 A(U1)=A(I)
2190 NEXT I
2200 U1=U1+1
2210 A(U1)=A(I1)
2220 I1=U1
2230 REM *** DEFINE SLICE BOUNDARIES ***
2240 B1=A(I1)-A(1)
2250 B2=B1/S9
2260 U1=I1
2270 FOR I=1 TO U1-1
2280 B3=A(I+1)-A(I)
2290 B4=INT(B3/B2)+1
2300 C1=B3/B4
2310 C2=A(I)
2320 FOR J=1 TO B4
2330 IF J<B4 THEN 2350
2340 GO TO 2360
2350 I1=I1+1
2360 IF J<B4 THEN 2380
2370 GO TO 2390
2380 A(I1)=C2+C1
2390 IF J<B4 THEN 2410
2400 GO TO 2420
2410 C2=C2+C1
2420 NEXT J
2430 NEXT I
2440 FOR I=1 TO I1
2450 FOR J=1 TO I1-I-1
2460 IF A(J+1)>A(J) THEN 2500
2470 J1=A(J+1)
2480 A(J+1)=A(J)
2490 A(J)=J1
2500 NEXT J
2510 NEXT I
2520 REM *** DEFINE SOIL PARAMETERS FOR EACH SLICE ***
2530 F1=I1-1
2540 FOR I=1 TO F1
2550 F(I,4)=A(I+1)-A(I)
2560 X6=F(I,4)
2570 F(I,7)=(A(I+1)+A(I))/2
2580 X3=F(I,7)
2590 Y1=Y-SQR(R^2-(A(I)-X)^2)
2600 Y2=Y-SQR(R^2-(A(I+1)-X)^2)
2610 A3=ATN(ABS(Y2-Y1)/F(I,4))
2620 IF Y2<Y1 THEN 2640
2630 GO TO 2650
2640 A3=-A3
2650 F(I,2)=A3
2660 IF A3=0 THEN 2680
2670 GO TO 2690
2680 F(I,2)=1.0E-5
2690 Y3=Y-SQR(R^2-(X1-X)^2)
2700 I4=0
2710 FOR J=1 TO L1
2720 L3=C(J,1)
2730 L4=L(J,2)
2740 IF P(L3,2)<Y3 AND P(L4,2)<Y3 THEN 2840
2750 IF P(L3,1)<X3 AND P(L4,1)<X3 THEN 2840
2760 IF P(L3,1)>X3 AND P(L4,1)>X3 THEN 2840
2770 Y6=P(L3,2)+(P(L3,2)-P(L4,2))/(P(L3,1)-P(L4,1))*(X3-P(L3,1))
2780 IF Y6<Y3 THEN 2840
2790 I4=I4+1
2800 Z(I4,1)=Y6
2810 Z(I4,2)=L(J,1)
2820 U=0
2830 E=0
2840 NEXT J
2850 IF I4=0 THEN 2970
2860 FOR J=1 TO I4
2870 FOR J1=1 TO I4-1
2880 IF Z(J1,1)>Z(J1+1,1) THEN 2930
2890 L3=Z(J1,2)
2900 L4=Z(J1,1)
2910 Z(J1,1)=Z(J1+1,1)
2920 Z(J1,2)=Z(J1+1,2)
2930 Z(J1+1,1)=L4
2940 Z(J1+1,2)=L3
2950 NEXT J1
2960 NEXT J
2970 I4=I4+1
2980 Z(I4,1)=Y3
2990 FOR J1=1 TO I4-1
3000 IF J1=1 AND J1=1 AND X3>B4 THEN 3020
3010 GO TO 3030
3020 I4=B0-Y1
3030 IF J1=F1 AND J1=F1 AND X3<B7 THEN 3050
3040 GO TO 3040
3050 W4=B0-Y2
3060 W=W+(Z(J1,1)-Z(J1+1,1))*X6*S2(Z(J1,2),1)
3070 IF Z(J1,1)<B0 AND X3>B4 AND X3<B7 THEN 3090
3080 GO TO 3100
3090 W=W+(B0-Z(J1+1))*X6*W0
3100 IF S2(Z(J1,2),4)>0.95 THEN 3120
3110 GO TO 3130
3120 E4=S2(Z(J1,2),1)
3130 IF S2(Z(J1,2),4)<0.95 THEN 3150
3140 GO TO 3160
3150 E4=S2(Z(J1,2),1)-W0
3160 E=E+(Z(J1,1)-Z(J1+1,1))*X6*E4
3170 NEXT J1
3180 F(I,1)=W
3190 F(I,5)=E
3200 F(I,3)=S2(Z(I4-1,2),2)
3210 F(I,6)=2*PI*(S2(Z(I4-1,2),3)/360)
3220 NEXT I
3230 IF F2=1 THEN 3340
3240 PRINT @40: USING 3250:
3250 IMAGE "SLICE  WEIGHT   INCLINATION "+5
3260 PRINT @40: USING 3270:
3270 IMAGE " COHESION  WIDTH  EFF WEIGTH     PHI     K"
3280 D=360/(2*PI)
3290 FOR I=1 TO F1
3300 PRINT @40: USING 3320:I,F(I,1),F(I,2)*D,F(I,3),F(I,4),F(I,5)
3310 PRINT @40: USING 3330:F(I,6)*D,F(I,7)
3320 IMAGE (3D.09D.1D,07D.1D,12D.07D.1D,,09D.1D),5
3330 IMAGE   70.1D ,5D.2D
3340 NEXT I
3350 PRINT @40:
3360 D=0
3370 FOR I=1 TO F1
3380 D=D+F(I,1)*SIN(ABS(F(I,2)))*(F(I,2)/ABS(F(I,2)))
3390 D=D+E1*F(I,1)*COS(ABS(F(I,2)))
3400 NEXT I
3410 IF I<0 THEN 3430
3420 GO TO 3440
3430 I7=W0*I6*I6*(R-I6/3)/(2*R)
3440 IF I<0 THEN 3460
3450 GO TO 3470
3460 D=D-SGN(D)*I7
3470 IF I<0 AND F9=1 THEN 3490
3480 GO TO 3510
3490 PRINT @40: USING 3500:I7
3500 IMAGE "DRIVING FORCE COUNTER BALANCE OF ",10D.2D
3510 IF J<0 THEN 3530
3520 GO TO 3540
3530 J7=W0*J6*J6*(R-J6/3)/(2*R)
3540 IF J<0 THEN 3560
3550 GO TO 3570
3560 D=D+SGN(D)*I7
3570 IF J<0 AND F9=1 THEN 3590
3580 GO TO 3610
3590 PRINT @40: USING 3600:I7
3600 IMAGE "DRIVING FORCE INCREASE OF ",10D.2D
3610 REM *** ITERATIVE SOLUTION FOR FACTOR OF SAFETY ***
3620 F0=1
3630 R4=0
3640 I4=0
3650 FOR I=1 TO F1
3660 R1=F(I,3)+F(I,4)+F(I,5)*TAN(F(I,6))
3670 R2=1/COS(ABS(F(I,2)))
3680 R3=1+TAN(F(I,6))*TAN(F(I,2))/F0
3690 R4=R4+R1*(R2/R3)
3700 NEXT I
3710 F2=R4/D
3720 I4=I4+1
3730 IF F9=1 THEN 3750
3740 GO TO 3820
3750 IF I4=1 THEN 3770
3760 GO TO 3800
3770 PRINT @40:
3780 PRINT @40: USING 3790:
3790 IMAGE " I ","ITERATION",10X,"INITIAL",10X,"CALCULATED"
3800 PRINT @40: USING 3810:I4,F0,F2
3810 IMAGE " ",3D,3D,3X,3D.4D,12X,3D.4D
3820 IF I4>10 THEN 3840
3830 GO TO 3850
3840 PRINT @40:"WILL NOT CLOSE"
3850 IF I4>10 THEN 3970
3860 IF ABS(ABS(F0)-ABS(F2))<0.005 THEN 3900
3870 F0=ABS(F2)
3880 R4=0
3890 GO TO 3650
3900 REM
3910 PRINT @40:
3920 PRINT @40: USING 3930:F2,X,Y,R
3930 IMAGE "FACTOR OF SAFETY= ",2D.2D," AT X= ",4D," Y= ",4D," R= ",4D
3940 PRINT @40: USING 3950:E1
3950 IMAGE "EARTHQUAKE= ",2D.2D
3960 PRINT @40:
3970 PRINT @40:"DO YOU WISH A FORMAL PRINTOUT (Y OR N)"
3980 INPUT @40:A$
3990 IF A$="N" THEN 4320
4000 PRINT @40:
4010 PRINT @40:H$
4020 PRINT @40:
4030 IMAGE "WATER UNIT WEIGHT= ",3D.2D," EARTHQUAKE= ",2D.2D
4040 PRINT @40: USING 4030:W0,E1
4050 PRINT @40:
4060 IMAGE "SUBMERGENCE AT ",3D,2D," FROM ",3D,1D," TO ",3D,1D
4070 PRINT @40: USING 4060:S0,B4,B7
4080 PRINT @40:
4090 PRINT @40:" POINT","X-ORD","Y-ORD"
4100 IMAGE "  ",7D,2D,7D,2D
4110 FOR I=1 TO F1+1
4120 PRINT @40: USING 4100:I,P(I,1),P(I,2)
4130 NEXT I
4140 PRINT @40:
4150 PRINT @40:" SLICE","LEFT","RIGHT","SOIL"
4160 IMAGE 4(8D)
4170 FOR I=1 TO L1
4180 PRINT @40: USING 4160:I,L(I,1),L(I,2),L(I,3)
4190 NEXT I
4200 PRINT @40:
4210 PRI @40:" SOIL","UNIT WEIGHT","COHESION","PHI","SATURATED"
4220 IMAGE 3D,15D,17D,9D,9D
4230 FOR I=1 TO S1
4240 PRINT @40: USING 4220:I,S2(I,1),S2(I,2),S2(I,3),S2(I,4)
4250 NEXT I
4260 PRINT @40:
4270 PRINT @40:"CIRCLE","X-ORD","Y-ORD","RADIUS","FACTOR OF SAFETY"
4280 IMAGE 12D.1D,7D.1D,7D.1D,8D.2D
4290 PRINT @40: USING 4280:X,Y,R,F2
4300 PRINT @40:
4310 PRINT @40:
4320 PRINT @40:"DO YOU WISH A DIAGNOSTIC RUN (Y OR N)"
4330 INPUT @40:A$
4340 IF A$="Y" THEN 4360
4350 GO TO 4370
4360 F9=1
4370 IF A$="Y" THEN 720
4380 PRINT @40:"CONTINUE (Y OR N)"
4390 INPUT @40:A$
4400 IF A$="Y" THEN 630
```


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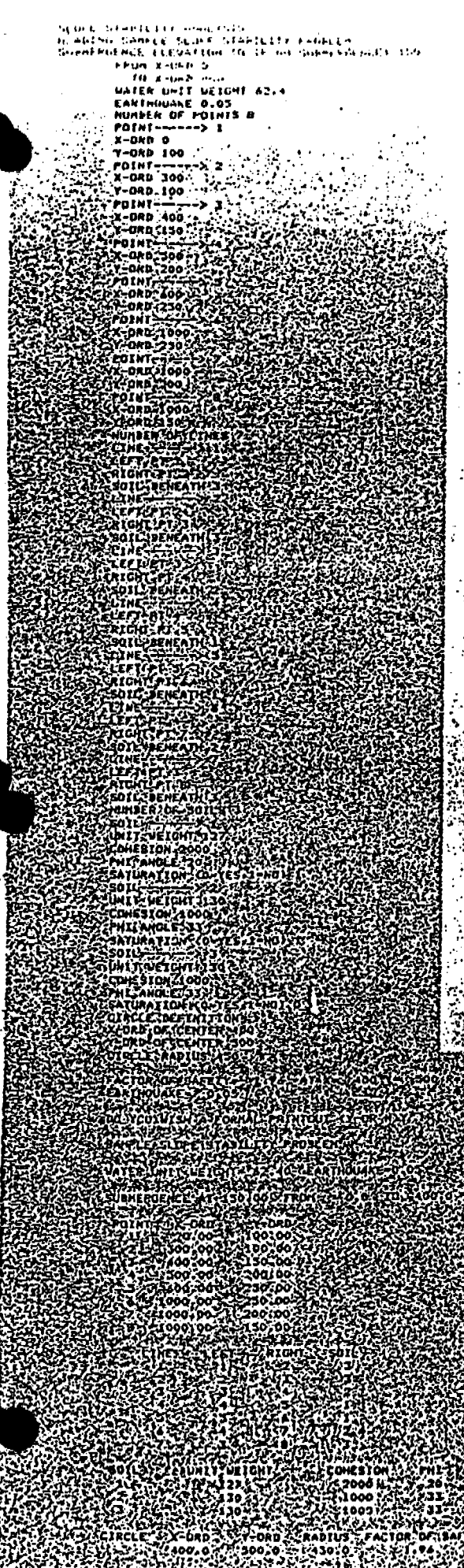

up to 20 points, 20 lines, and 5 soil types. The minimum number of slices is set at 10, but can be changed by modifying the value of S9 at line 150 and changing the dimensioning of arrays A, F and Z.

A cross-section is drawn of the slope showing all soil strata and piezometric surfaces. Each intersect point between lines on the cross-section is numbered, with the constraint that all points along the top line must be numbered consecutively from left to right initiating with point 1. Points beneath the top line may be numbered in any order. These points are then defined with X and Y coordinates (the entire cross-section must fall in the first quadrant).

Lines are then specified by assigning line numbers for each line occurring between two end points. These lines are defined by a left point, a right point and the number of the soil type occurring beneath the line. Vertical lines are not allowed and should be modeled by offsetting the X-coordinate of one end point by a small amount, i.e., .01. Piezometric surfaces within the cross-section are treated as any other soil strata interface with saturated soil beneath and unsaturated soil above the line segment. Soil types are defined by specifying a unit weight, cohesion, phi angle and an indication of whether the soil is saturated.

Additional information that must be supplied includes the unit weigh' of water, the earthquake loading factor and information defining any standing pool of water. This pool is specified by inputting the Y-coordinate of the pool elevation and the left and right X-coordinates defining the extent of the pool. The only remaining input parameters are the center coordinates and radius of the failure arc. The input can be in any consistent set of units.

Figure 2 shows a typical cross-section and the input parameters required to define the cross-section for the program. The sample execution in the box shows the typical input sequence and output formats. This result is not necessarily the minimum factor of safety for this slope, but the factor of safety for the specified failure surface. Additional runs should be made using different centers and radii until the minimum factor of safety is located.

The program presented here is the nucleus from which system specific enhancements should be made. These enhancements are not included in this version for the purpose of minimizing the size of the program presented. Particularly valuable enhancements include the ability to edit interactively, save input on a disc or tape and perform a search for the minimum factor of safety without manually inputting each circle definition. Additional enhancements could include plotting capabilities and more detailed diagnostic features.

A computerized evaluation of slope stability should never take place apart from a complete evaluation of the geophysical conditions involved. Likewise, the results should always be subjected to evaluation and interpretation based on current engineering practice and experience. ▢

Cross received his M.S. degree in civil engineering from Rose-Hulman Institute of Technology, Terre Haute, Indiana in 1973. Currently data processing manager/project engineer, Cross has been with STS (formerly Soil Testing Services) for 10 years. He holds a Master of Divinity from Trinity Evangelical Divinity School and is working on an MBA at the Keller Graduate School of Management.

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