Mining and Reclamation Permit Application
Willow Creek Mine
Volume 14

Prepared For:

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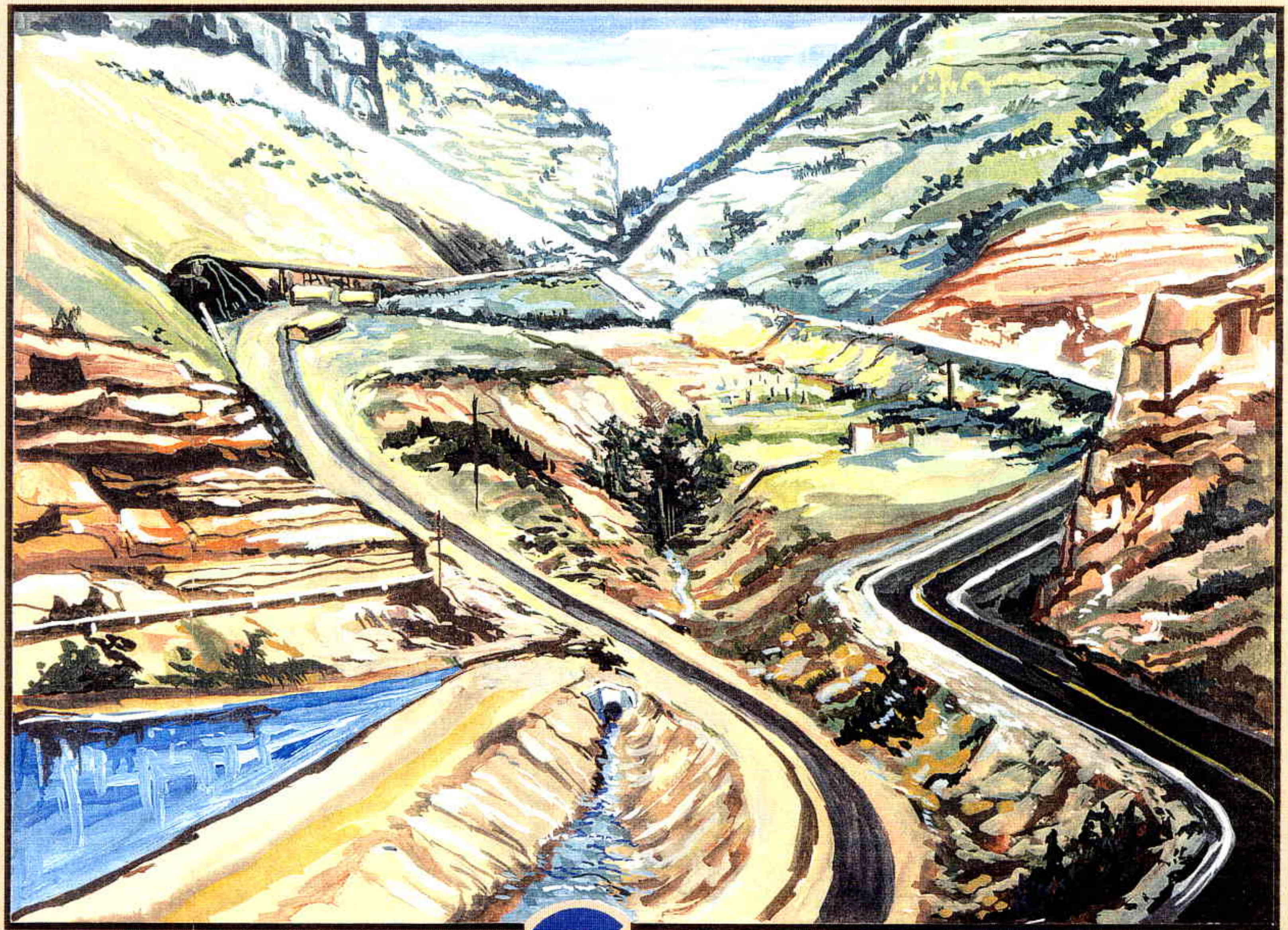

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LIST OF EXHIBITS

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CRANDALL CANYON OPERATIONS PLAN

CRANDALL CANYON
CASTLE GATE MINE

AMAX COAL COMPANY
Carbon County, Utah

Prepared by

EARTHFAX ENGINEERING, INC.
Midvale, Utah

February 1996

SECTION 3.7

CRANDALL CANYON

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[a] Information pertaining to Pond 015 embankment stability analysis and survey certification was originally submitted in July 1992, but was not incorporated into March 1994 revisions.

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3.7 CRANDALL CANYON SHAFT SITE

The Crandall Canyon shaft and support facility project was originally conceived in the 1976-211 Plan. Conceptual plans were prepared during the interim SMCRA Program and first submitted for review as a surface modification in September of 1980. More detailed plans followed in February of 1981, with a request for separate review of the Crandall project so that completion could be achieved reasonably close to dates originally projected under interim requirements.

Plan review proceeded until April, 1982, when the entire project was finally approved for completion. During the review process, several permits for portions of the project were granted to allow construction to proceed in a somewhat orderly fashion. The apparent completeness review caused some revision and inclusion of the new information to the plan.

The plan has been reorganized to include all revised or new information.

3.7-1 General

The following narrative was written by Price River Coal Company describing the facilities to be constructed in Crandall Canyon. Castle Gate will utilize this facility primarily as storage and access to the mine. Castle Gate will maintain this facility for the life of the No. 3 Mine but will not construct the buildings as proposed in this narrative unless market conditions warrant increased production.

Price River Coal Company (PRCC) proposes, as part of their overall mine plan (submitted to and approved by the U. S. Geological Survey in 1976), to construct two mine shafts in Crandall Canyon, together with certain buildings and facilities, all of which are described herein (Exhibit 3.7-4). In the original mine plan, the shaft location was generally stated. This document is a site-specific plan and complete description of the facilities to be constructed, including construction procedures to be followed, considerations for protection of environmental values and final reclamation of the affected areas to a stable and productive condition.

The mine shafts and associated facilities are required to allow the diligent development of the No. 3 Mine and the attainment of optimum levels of production from this mine. Primarily, the shafts are required to provide a much needed improvement in mine ventilation and to reduce the underground transportation time for men and materials. Projected duration of operation of this facility is 30 years.

The shafts are centrally located in the remaining minable reserves assigned to the No. 3 Mine. The new mine ventilation fan system installed at the No. 1 Shaft enables operation of twice the present complement of mine equipment in the mine, and the proposed hoisting system will reduce underground haulage distances for men and materials by up to 3 miles. The complete surface facilities are designed, as far as possible, to be accommodated within the canyon floor area and will require a minimum relocation of the existing stream channel now running through the area. Following completion of the Crandall Canyon facility, operations in Hardscrabble Canyon (Mines No. 3 and No. 4) and Sowbelly Gulch (Mine No. 5) will be phased out, and the affected surface areas reclaimed. This process will require approximately 3 years following completion of the Crandall Canyon facility to accomplish, and will ultimately result in a new reduction of surface acreage actively affected of approximately 30 acres.

Castle Gate Coal Company does not plan on moving to Crandall Canyon with surface facilities until market conditions warrant more space. The area will continue to be used for storage, ventilation fans and mine rescue training.

3.7-2 Phase I: Site Preparation

Site preparation will consist of the following:

a. Grading of existing jeep trail to minimum specification required by R614-301-527.200. (Completed)

b. Removal of vegetative matter from area to be impacted; including cutting disposal of timber and grubbing and removal of herbaceous and shrubby vegetation. (Completed)

c. Ongoing removal and subsequent storage of topsoil or other unconsolidated growth supporting (6) inches. (Completed)

d. Realignment of sections of the stream channel through main construction area. (Completed)

e. Installation of culverts and other temporary crossings. (Completed)

f. Re-contouring and pad construction to configurations shown on Exhibit 3.7-5B. (Completed)

g. Installation of drainage and sediment control facilities shown on Exhibit 3.7-6. (Completed)

h. Construct concrete work surfaces at main shaft. (Completed)

i. Initial shaft construction. (Completed)

3.7-3 Phase II: Construction

The mine facilities, as constructed, are shown on aerial photography maps labeled Exhibits 3.7-3A, 3.7-3B, 3.7-3C, and 3.7-3D. Topographic maps developed from the aerial photographs are presented as Exhibits 3.7-5A, 3.7-5B, and 3.7-5C. The total area encompassed within the disturbed area boundary is 38.2 acres.

3.7-3(1) Shaft Excavation

Two shafts were constructed in Crandall Canyon:

1. A 26′ finished-diameter, concrete-lined intake air and materials hoisting shaft, approximately 1,450′ deep;

2. A 20′ finished-diameter, concrete-lined return air shaft, approximately 1,400′ deep.

In each shaft, shaft stations were constructed at the shaft intersection with each of three minable coal seams, the D, A and Sub 3.

Any aquifers intersected by the shafts were grouted off or contained and collected in shaft water rings for later use in the mine. Water inflow in the shafts is minimal. The excavated materials removed from the shafts were of three types: (1) non-toxic alluvial deposits encountered in the first 50' or so; (2) non-toxic consolidated sandstones and shales; and (3) coal-bearing materials. All coal-bearing materials were separated from the main portion of the excavated materials and then processed.

The non-coal-bearing materials were spread in even layers and compacted as fill beneath the proposed bathhouse/office building, the parking lot, the access road at the intake shaft area, and exhaust shaft-sewage pumping station. Fill materials were compacted in two-foot lifts. Proctor compaction tests were conducted at regular intervals to assure design compaction. Samples from test hole "MC-207" were analyzed for structure and compressibility. The materials and plans for compaction have been reviewed by registered engineers and certified as acceptable (see Appendix 3.7C for physical analyses and engineer's certification).

Upon completion of the shaft construction and the fill process, the final grade, minus hard-surfacing and required dressing, was reached.

The materials excavated and used in fill construction were subjected to chemical analyses. Samples for analysis were obtained from test hole "MC 207" (see Appendix 3.7C).

The exhaust shaft is located on a lower bench east of the parking lot. An access ramp connects the exhaust shaft surface area with the parking lot. The concrete collar of the exhaust shaft protrudes 3'+ above the finished surface elevation surrounding the shaft. A safety fence surrounds the shaft.

Timing - Shaft construction was initiated based on approval granted by the correspondence of December 23, 1980, and continue until completion approximately twenty months hence.

Finished Surfaces in Shaft Area - The areas around the intake shaft and associated buildings will be hard-surfaced to facilitate movement of materials and equipment into and from the shaft through the airlock door systems on north and/or south sides of the shaft, and also to maintain ready access to either the hoist or mine ventilation systems.

3.7-3(2) Class II Access Road

An access road to Crandall Canyon existed in the form of a jeep trail. This was improved to a Class II road per existing regulations. The new access road, road P-1, will function as a right-of-way from the Utah State Route 6 to the shaft site permitting vehicular access for personnel and materials. The road is not a coal haul road. To facilitate safe access between the constructed Crandall Canyon road and Utah State Route 6 at the mouth of Crandall Canyon, a new intersection was constructed to Utah Department of Transportation specifications (see Exhibit 3.7-8A).

The new (or improved) access road through the canyon follows the general routing of the present trail. While adhering to the specifications for a Class II road, the road design will attempt to ensure the minimum amount of cut-and-fill and/or stream channel modification.

In general, the hard-surface roadway is 24' wide with 8' shoulders on each side. At the edge of the shoulders on the hillside, drainage ditches with crossroad culvert pipes have been constructed. A buried utility corridor exist within one or both shoulders.

All cuts, fills, channel relocations and culvert-receiving and outfall areas have been seeded, riprapped or otherwise treated as required to prevent erosion.

The completed new access road crosses the stream channel in three locations. In these locations, sufficient bridging has been placed to permit the flow of the peak runoff from a "one-hundred-year storm".

The bridges, as well as the access road, were designed to carry required H20-S16 loading.

Road alignment, plans and profiles are shown on Exhibits 3.7-8A through 3.7-8F. A slope stability analysis is included as Appendix 3.7A for road cuts and fills exceeding regulatory requirements.

Culvert Sizes for Crandall Canyon - Twenty-eight culverts were installed within Crandall Canyon to divert storm runoff from the undisturbed drainage areas and ditches beyond the disturbed area into Crandall Creek. These culverts were located in the field and are identified on Exhibit 3.7-6.

The adequacy of the existing culverts to pass the design flow rate was determined using the methods defined in Chapter 7. In addition, culvert flow velocities were calculated, and the adequacy of existing riprap was determined. Section 3.7-4(2) summarizes the culvert sizing calculations.

3.7-3(3) Water Line and Gas Line (Proposed)

When market conditions warrant expansion of facilities into Crandall Canyon, culinary water for bathing, etc., will be obtained from Helper City and will be piped to a holding tank located near Drill Hole No. MC-186. There are also proposed plans to drill a water well near this tank as a primary source. The pipeline will be adequately sized, located and buried in the berm alongside the access road at sufficient depth to avoid freezing once brought up the shaft through the mines.

A natural gas pipeline (3" and 4" diameter) will be installed by the gas company (Mountain Fuel Supply Company) through Crandall Canyon to a metering point adjacent to the bathhouse/office building. The natural gas distribution system and all devices and equipment consuming natural gas will be equipped with all necessary safety and monitoring devices and audible and visual alarm signals required to ensure their safe operation and compliance with state and federal regulations regarding their use.

3.7-3(4) Mine Ventilation System

A complete mine ventilation fan and air heating system that supplies the No. 3 Mine with required total ventilating air requirements has been installed at the intake air shaft. Exhibit 3.7-5B shows the general arrangement of these facilities.

The mine fans, operating as a blowing system, are mounted in parallel and are capable of providing the mine with up to 1,200,000 cubic feet per minute of air at up to 12" water gauge pressure.

Mine air heating is required to prevent shaft icing. Air entering the shaft is maintained above 32° F, at all times by an indirect, propane gas-fired heating system located on the intake side of the mine fans. Exhaust gases from the natural gas heaters will be exhausted through ducting which prohibits their entering the mine.

One supply fan has an emergency diesel power system that actuates upon power loss to the fan electrical system. This emergency system is completely automatic, starting and stopping upon loss or re-establishment of electrical power from the main power sources. The diesel system is capable of providing 600,000 cubic feet of air per minute to the mine.

3.7-3(5) Men and Materials Hoisting System

As shown in Exhibit 3.7-5B, a mine hoisting system has been installed at and over the main intake air shaft. The hoist is a fully automated ground-mounted (multi-rope) friction-type hoist with a large cage and counterweight in balance. The hoist system is used to raise and lower men, materials and mine equipment to any of the three mine levels.

Because of the "blowing" system of mine ventilation to be employed, access to and from the cage at the shaft collar (surface) elevation is through the airlock enclosing the headframe.

All automated systems dealing with the hoist, fans and heaters have audible and visual warning devices indicating failures or disruptions of service.

3.7-3(6) Bathhouse/Office Building

These facilities have not been constructed to date.

3.7-3(7) Sewage Treatment Plant & Waste Water Disposal (Proposed)

3.7-3(7).1 Introduction

After much re-evaluation, we have finally settled on a waste water handling plan which we feel is economically efficient, environmentally sound and acceptable to the Utah Department of Health. The system will be composed of a holding tank and pump, to be located near the No. 2 Shaft (see Exhibit 3.7-5B) and a leach field, to which waste water will be piped, about 3/4 miles further up canyon. The various technical data, pump, tank, and pipe designs, although proffered as a courtesy on October 14, 1981, are not being submitted for UDOGM/OSM review, since these items and the adequacy of the system in general has been reviewed in detail and approved by UDH, and in our opinion are outside the purview of regulation intended by the Mining and Reclamation Act.

We do, however, here provide additional information which we hope satisfied the concerns you may have with the construction and reclamation phases. Explanation will be provided under the headings of, "Construction Activities", "Environmental Protection", and "Reclamation". The new maps have been included depicting road alignment, leach field location, culvert and diversion location and road profile. These exhibits have been identified as 3.7-10A and 3.7-10B.

3.7-3(7).2 Construction Activities

Access Road - A Class III road, road A-1, has been constructed to provide access for construction equipment and routine inspection to the leach field. Average road width is 24 feet, including berms and ditch, and the average grade, about 8%. A typical cross section is provided on Exhibit 3.7-10B. The road starts near the proposed water tank site at MC-186 and follow an old road bed until about Station 14+00, shown on Leach Field No. 1. There is about 300 feet of road constructed, which includes the installation of an 84" corrugated metal pipe (CMP) for the intermittent stream crossing at Station 16+50 (hydrologic design and calculations were provided to UDOGM on July 20, 1981 for this culvert). About 80 feet beyond the 84" CMP, we intersected test hole pad MC-13 and proceeded on the existing road the remaining distance to the leach field. The waste water distribution pipes were installed in the road bed so as to deliver waste water to the up-canyon end of the field, which has not been used to date. Two additional culverts have been added; one at Station 16+50 and the other at Station 26+80 on Exhibit 3.7-10A and Exhibit 3.7-10B. The hydrologic calculations have been included with this submission. The road will be crowned and surfaced with gravel.

Leach Field - Construction of the leach field required progressive excavation of the area shown on Exhibit 3.7-10B to a depth of five feet. A sand bedding and the perforated pipe was installed and all excavated materials will be replaced. The topsoil, to a depth of 6", was removed prior to excavation, stored in the approximate locations shown on Exhibit 3.7-10B and replaced after replacement of other excavated materials. After construction, the surface of the leach field will be approximately one foot higher than original ground, but will settle considerably below that over time. A diversion, as shown on Exhibit 3.7-10B, will be needed to direct hillside runoff away from the field. The culvert at Station 26+80 will carry water from the diversion to the stream. Channel calculations are included with this submission.

The existing undisturbed area drainage diversions for the leach field area are located on Exhibits 3.7-6 and 7-3. The adequacy of the existing diversion ditches and culverts is discussed in Section 3.7-4(2).

3.7-3(7).3 Environmental Protection

Prevention of Sedimentation - Straw dikes were used to control runoff from the leach field area. They will be placed on the approximate location shown on Exhibit 3.7-10B. Bales will remain in place until the leach field area has been stabilized by vegetation. Other areas, such as road cuts and fills, were mulched and seeded immediately after construction. Culvert discharge points were riprapped to minimize erosion.

Topsoil Protection - Topsoil was salvaged prior to construction of the leach field, and some of the topsoil was used to cover the leach field once the drain piping was installed. A nutrient analysis was performed by the State Lab. Other soil information was in the form of SCS survey information which was submitted to UDOGM on October 20, 1981. It is expected that about 135 cubic yards of topsoil will be collected as part of new road construction between Stations 14+00 and 17+00. This material was moved to Gravel Canyon. There is no reason to expect that this soil will vary from the SCS information or the other tests taken nearby.

Wildlife Protection - We know of no "high value" wildlife habitat in the road corridor or leach field area (according to UDWR).

Air Quality Protection - During the construction phase, the road bed will be watered to reduce fugitive dust.

3.7-3(7).4 Contemporaneous Reclamation

Leach Field - After replacing topsoil, the area (including the diversion) was seeded with the following mixture:

Species	Lbs/Acre (PLS)
Great Basin Wildrye	1
Indian Rice Grass	1
Cicer Milkvetch	5
Strawberry Clover	5
Western Wheatgrass	10
Mountain Brome	5
TOTAL	27

The planting on the leach field has been restricted to grasses and forbs, because shrub or tree growth could interfere with the function of the leach field.

A straw mulch was spread and disced in after the leach field was seeded. Nitrogen was added to offset mulch decay at about 50 lbs/acre. Soil tests indicate low phosphorous (3 PPM).

Access Road - Berms, cut and fill banks, and ditches were re-seeded after construction of the road with the same mixture as the leach field, except that about 5 lbs/acre of the BLM mixture and 5 lbs./acre barley was added for quick cover. In the spring, the road bank planting was supplemented with bare root stock. The bare root stock supplement consisted of the Douglas Fir at a stock rate of 200 seedlings per acre and the Ponderosa Pine at a stock rate of 100 seedlings per acre. The vegetation work will also remain as permanent.

3.7-3(8) Workshop/Warehouse Building and Storage Area (Proposed)

A proposed workshop/warehouse building will be constructed at the upper end of the site. The building will contain office, storage, sanitary and maintenance facilities required to support the personnel working within.

An external loading ramp permitting tailgate unloading of large tractor-trailer combination will be built to the rear of the building, if needed.

Oils and other petrochemicals will be used and stored on the site in a designated area. No petrochemicals or related products will be disposed of on-site.

All sanitary effluents will be piped directly to the sewage pumping station located at the lower end of the main construction area.

The parking lot and storage area above the workshop/warehouse building will be covered with stone and hard-surfaced as required to support the loads handled. All surface runoff from the hard-surfaced area will be channeled through a sediment pond before being discharged to the stream channel.

3.7-3(9) Parking Area (Proposed)

To the east of the bathhouse/office building a proposed parking area will be constructed. The compacted and graded fill from the shafts will be topped with crushed stone and later with hard-surfacing. Intended parking capacity will be 200 cars.

Cuts and fills made in construction of the site, that have not been hard-surfaced or built upon, will be re-soiled and seeded or rip-rapped as required to reduce erosion.

3.7-3(10) Electrical Power Substation and Line

Electrical power required by the facilities was obtained by constructing an overhead power-line from Hardscrabble Canyon over the ridge on the south side of the intake shaft to a substation located approximately 200' from the shaft. The path of the power-line was cleared only of tall trees and only as required. There was minimal disturbance to soil and low growing vegetation as a result of this construction. The power-line traverses land under the aegis of the Bureau of Land Management. A permit was obtained from that agency for construction within a designated fifty (50) foot corridor (see Exhibits 3.7-3B and 3.7-5B).

The substation is of the oil-cooled type and will be erected on a crushed stone raised bench surrounded by protective fencing. Power-lines have been constructed as per requirements set forth in environmental criteria for electrical transmission systems (USDI, USDA, 1970).

3.7-3(11) Stream Channel Diversion

The existing stream channel diversion (CCRD-23) within Crandall Canyon was designed to be a permanent diversion structure. The existing cross section of the stream channel through the entire length of the diversion is capable of accommodating the peak runoff from a 100-year 24-hour storm event. The existing riprap within the channel is adequate for the resulting flow velocities. The channel flow and riprap sizing calculations are contained in Appendix 3.7H.

Three representative sections of the stream channel diversion were chosen for evaluation. Section 1 is located approximately 350 feet upstream of culvert CCC-7 (refer to Exhibit 3.7-6 for culvert location). Section 2 and 3 are located 250 feet upstream and 550 feet downstream of culvert CCC-8, respectively. The 100-year 24-hour storm event of 2.9 inches of precipitation (Miller et. al., 1973) was used to determine peak flow rates of 437, 511 and 514 cubic feet per second for Sections 1, 2 and 3, respectively. Hydrologic methodologies are presented in Chapter 7. Peak flow calculations are contained in Appendix 3.7H.

Average stream slopes at each channel section were measured from a topographic map of Crandall Canyon with a scale of 1 inch = 200 feet. Based on the channel cross sections presented in Appendix 3.7H, flow depths of 2.75 feet, 6.3 feet, and 2.85 feet were realized at Sections 1, 2 and 3, respectively. The resulting freeboard values are 18 feet, 8.7 feet and 14.6 feet for Sections 1, 2 and 3, respectively.

The flow velocities were determined at each section to evaluate the existing riprap in the channel. Flow velocities of 15.8, 15.1 and 14.2 feet per second were calculated for Sections 1, 2, and 3, respectively. The average required riprap size was calculated for each section to be 9, 5, and 6 inches. The existing average riprap at Sections 1, 2 and 3 was measured to be 10, 12, and 12 inches, respectively. the capacity and existing riprap design are adequate for the permanent stream diversion channel.

The capacity and existing riprap for each of the three pipe-arch culverts (CCC-7, CCC-8 and CCC-24, located on Exhibit 3.7-6) were also evaluated. In summary, all culverts were able to pass the 100-year 24-hour storm event. The exit velocities calculated for culverts CCC-7, CCC-8 and CCC-24 are 17.7, 10.3 and 13.1 feet per second, respectively. The riprap at each culvert exit was adequate with the exception of CCC-7. The existing riprap at the outlet of CCC-7 is approximately 12 inches in size, and the required riprap size is approximately 15 inches. Capacity and riprap sizing calculations are contained in Appendix 3.7H.

3.7-3(12) Retaining Wall

The choice of wall was made in late fall of 1981. The type of retaining wall constructed was the Hilfiker welded wire reinforced earth wall. A manufacturer's brochure is included as Appendix 3.7B to demonstrate installation.

3.7-4 Protection of the Environment

3.7-4(1) Topsoil Handling

Topsoil removal and storage procedures will be performed during all phases of site construction. Prior to construction activities for designated areas within the proposed area to be affected, the topsoil or upper six (6) inches of unconsolidated growth medium was removed and stored in designated locations (see Exhibits 3.7-3D and 3.7-5C). About 8,000 CY (cubic yards) are stored on-site in the lower two piles. Approximately 40,000 CY of subsoils were transferred to Gravel Canyon as per modification approved in April, 1982. The Gravel Canyon modification is included in Chapter 8, Soil Resources.

Existing organic materials will not be included in topsoil storage piles. Topsoil will only be collected from areas where collection is technologically feasible; considering degree of slope and percentage of large boulders as limiting factors. Specifically, topsoil removal will not occur in the rocky Pathead soil formations. This includes slopes above the colluvial/alluvial valley soil complexes. Access road development, as shown in Exhibits 3.7-8A through 3.7-8F, primarily disturbed the Curecanti and Uinta formation, with the exception of areas between State Route 6 and the first stream crossing. This stretch is "made land", previously disturbed by highway construction. Some suitable growth material may be obtainable.

In areas where suitable unconsolidated growth media exists in excess of six inches, a greater amount may be collected to provide resoiling material in areas for which topsoil is unavailable.

Topsoil Protection - Topsoil is stored in designated areas in stable piles. Measures to achieve rapid growth were undertaken soon after each stockpile was completed. Methodology included mechanical scarification, mulching, crimping and seeding with species of both an annual and perennial habit. Soil amendments were added to stimulate growth as per soil test recommendations. Topsoil stockpiles will remain intact for a minimum of thirty (30) years. Surrounding mature species will not be discouraged from colonization. The following species will be included in the planting plan:

COMMON NAME	SPECIES	HABIT	LBS. PER ACRE
Barley	Hordeum vulgare	Annual	26
Intermediate wheatgrass	Agrophyron intermedium	Perennial	4
Russian wildrye	Elymous junceous	Perennial	4
Woods rose	Rosa woosii ultramontana	Perennial	1/2
Bitterbrush	Purshia tridenta	Perennial	1/2
Curlleaf Mt.Mahogany	Cecocarpus ledifolus ledifolus	Perennial	1/2
Birchleaf Mt. Mahogany	Cecocarpus montanus montanus	Perennial	1/2

Surface and Ground Water Monitoring - The ground water monitoring station for Crandall Canyon, designated as B-22 Spring Monitoring Station, was monitored quarterly and was included in the monitoring plan submitted to all regulatory authorities during 1978. Surface water monitoring has occurred within the same time frames. The Crandall stations are B-25 and B-26 (see Exhibit 7-3). All surface water monitoring stations are sampled per the schedule in Chapter 7.

3.7-4(2) Hydrologic Balance

The existing facilities within Crandall Canyon were constructed in a manner which minimizes changes to the prevailing hydrologic balance. Effluent limitations set by R614-301-751 and present UPDES Permit limitations will not be exceeded if the discharge is the result of a precipitation event from the 10-year 24-hour storm or smaller.

Contributions of sediment to the stream channel are prevented by diverting drainage from undisturbed areas away from the site. In addition, existing sedimentation ponds collect disturbed area surface runoff, and a system of berms around the disturbed areas prevent drainage to the stream channel. Other measures taken to minimize potential erosion and subsequent sedimentation include or will include vegetative and riprap stabilization of cut and fill banks, and revegetation of all disturbed areas not under paving or buildings.

Design criteria for sediment control structures, diversions, and culverts comply with the requirements set forth in R614-742.300 and R614-742.200.

3.7-4(2).1 Storm Runoff Calculations

Peak discharge rates from the undisturbed and disturbed area drainages of Crandall Canyon were calculated for use in determining the adequacy of the existing diversion ditches and culverts. The storm runoff calculations for the temporary diversion structures were based on the 10-year 24-hour storm event of 1.9 inches of precipitation (Miller et. al., 1973). A description of the methods used to determine the peak discharge rates is presented in Chapter 7.

The disturbed and undisturbed drainage areas for Crandall Canyon are presented on Exhibit 3.7-6. Those drainage areas too large to fit on Exhibit 3.7-6 can be found on Exhibit 7-3. Each drainage area is labeled according to the drainage basin, watershed, and whether it is disturbed or undisturbed. For example, CCWS-U6 represents Crandall Canyon undisturbed watershed number 6.

Curve numbers were estimated from vegetation data presented on Exhibits 9-1 and 9-4, and by field observations. The north-facing slopes of Crandall Canyon are primarily vegetated with conifers and mixed brush. South-facing slopes are primarily vegetated with juniper and pinion, and mixed brush. Approximate vegetation cover densities are estimated from values contained in Chapter 9. Average cover densities for mixed brush, conifer, and juniper/pinion were 45 percent, 73 percent, and 55 percent, respectively. Based on information provided by the U.S. Soil Conservation Service (1972) and professional judgement, a curve number of 65 is estimated for the north-facing slopes and a curve number of 70 is estimated for the south-facing slopes. An average curve number of 68 is estimated for the entire drainage basin.

A summary of the runoff calculations is presented in Table 3.7-1. All runoff calculations are contained in Appendix 3.7D.

3.7-4(2).2 Diversion Structures

Diversion structures within the Crandall Canyon area include drainage ditches and culverts to convey storm runoff from disturbed and undisturbed drainage areas, and berms to contain disturbed-area drainage. These diversion structures are located on Exhibit 3.7-6. The peak discharge rates are based on the 10-year 24-hour storm event. A description of the methods used to calculate runoff is described in Chapter 7.

The dimensions of the existing diversion ditches and berms were measured in the field. The measurements approximate either a trapezoidal or triangular shape. Typical sections for each diversion identified on Exhibit 3.7-6 are contained in Appendix 3.7E. In addition, a summary of ditch geometry is presented in Table 3.7-2, and a summary of berm geometry is presented in Table 3.7-3.

The capacity of existing diversion ditches was determined by calculating the normal depth of flow based on a minimum ditch slope. The maximum flow velocity was calculated based on the maximum ditch slope. Ditch slopes were measured in the field or from a contour map of the Crandall Canyon area with a scale of 1 inch = 200 feet. A summary of ditch calculations is presented in Table 3.7-4. All ditch calculations are contained in Appendix 3.7E.

All calculations for the diversion ditches resulted in maximum velocities of less than 5 feet per second, with the exception of ditches CCD-2 and CCD-5. A flow velocity of less than 5 feet per second is considered non-erosive. The resulting flow velocity in ditch CCD-5 is 5.4 feet per second. The flow velocity in ditch CCD-2 is 7.3 feet per second. The required average riprap sizes for ditches CCD-2 and CCD-5 are 3 inches and 2 inches, respectively. The existing average riprap sizes in ditches CCD-2 and CCD-5 are 4 inches and 2 inches, respectively. Therefore, the ditch sections are adequate. Riprap calculations are presented in Appendix 3.7E.

Twenty-seven culverts were installed within Crandall Canyon to divert storm runoff from the disturbed and undisturbed drainage areas. These culverts were located in the field and are identified on Exhibit 3.7-6.

The adequacy of the existing culverts to pass the design flow rate was determined using the methods defined in Chapter 7. Table 3.7-5 summarizes the culvert sizing calculations. Because the resulting HW/D (headwater depth divided by the culvert diameter) ratio is less than one for each culvert, all existing culverts will adequately pass the 10-year 24-hour storm. Culvert calculations are presented in Appendix 3.7F.

The slope of each culvert, and the size of existing riprap at the outlet was measured in the field. Calculations were performed to determine the exit velocities at each culvert and the adequacy of existing riprap. A summary of the culvert flow velocity and riprap sizing calculations is presented in Table 3.7-6. Culvert flow velocity computations are presented in Appendix 3.7F.

All calculations for the culvert exit velocities resulted in adequate riprap at each culvert outlet with the exception of culvert CCC-26. The existing average riprap size at CCC-26 is 10 inches. The required riprap size, due to the steep exit slope, is approximately 21 inches. Riprap calculations at the culvert outlets are presented in Appendix 3.7F.

3.7-4(2).3 Sedimentation Ponds

Sedimentation Ponds 014 and 015 are located in Crandall Canyon and control the storm runoff from the disturbed drainage areas at the site. Survey of sedimentation Pond 014 was conducted in April 1990 by Bruce Ware (Registered Land Surveyor) of Price, Utah. Horizontal and vertical control bench marks were not available for the survey, so approximations of actual coordinates and elevations were made. The sediment Pond 015 was reconstructed in September-October of 1991 and resurveyed by a Professional Engineer. Horizontal and vertical control bench marks were not available for the survey, so initial coordinates and elevations were assumed, relative to an assumed elevation of the dam. The topography and cross sections for Ponds 014 and 015 are contained on Exhibits 3.7-9A and 3.7-9B, respectively. A description of the construction methods and the as-built pond survey certification for Pond 015 are contained in Appendix 3.7J.

Pond 014 - The stage-area and stage-capacity data for Pond 014 were determined from the pond topography contained in Exhibit 3.7-9A. A summary of these data is contained in Table 3.7-7. The stage-area and stage-capacity curves for Pond 014 are presented in Appendix 3.7G.

The required 3-year sediment storage volume of 1921 cubic feet (.044 acre-feet) was calculated as indicated in Appendix 3.7G using methods described in Chapter 7. The storm runoff volume from the 10-year 24-hour storm event is 29,038 cubic feet (.667 acre-feet). The computation of the runoff volume assumed a drainage area of 7.92 acres and a curve number of 90 for the disturbed area. No undisturbed areas contributed to the pond. Thus, the minimum capacity of the pond at the elevation of the primary spillway must be 30,957 cubic feet (assuming the spillway does not spill during the 10-year 24-hour storm). From the stage-capacity curve contained in Appendix 3.7G, the allowable storage at the primary spillway elevation (6765.6 ft) is 56,000 cubic feet. Therefore, additional volume is available for sediment storage. Subtracting the runoff volume from the existing pond capacity at the spillway results in a maximum sediment storage capacity of 26,900 cubic feet (.618 acre-feet). The elevation of the maximum sediment storage level at this capacity is 6762.5 feet

(3.1 feet below the primary spillway). The 60% clean-out volume for Pond 014 is 16,140 cubic feet (0.371 acre-feet). The 60% clean-out elevation is 6761.1 feet (4.5 feet below the primary spillway).

The 25-year 24-hour storm event (2.3 inches of precipitation (Miller, et. al., 1973)) was used to determine the adequacy of the primary spillway. The size of the disturbed watershed is 7.92 acres. The computation of the runoff volume assumed an average curve number of 90 and a time of concentration of 0.23 hours (see Appendix 3.7G). The calculation methods used are described in Chapter 7. The calculations for sedimentation Pond 014 are contained in Appendix 3.7G.

The 25-year 24-hour storm was routed through the primary spillway to determine the maximum stage and flow volume. Computations were conducted assuming that the pond contained the maximum allowable sediment volume of 29,100 cubic feet. In addition, the computer software program SEDIMOT II assumes that the pond is full of water up to the primary spillway elevation at the beginning of the storm event. This results in a conservative estimation of the maximum stage since, in general, the pond can be assumed to be empty at the beginning of a storm event.

From the analysis of the 25-year 24-hour storm event, the maximum inflow rate to the pond is 9.64 cubic feet per second (cfs) and the maximum outflow rate is 5.74 cfs. The corresponding high water level is 6766.32, 0.72 feet above the primary spillway, and 3.18 feet below the minimum embankment elevation of 6769.5. Thus, Pond 014 meets the requirements of R614-301-742.200.

The inlet channel to Pond 014 was evaluated to determine the adequacy of the existing riprap, and capacity of the channel during the 25-year 24-hour storm event. The calculations for the inlet channel are presented in Appendix 3.7G. Based on the minimum channel slope, the flow depth in the inlet channel is 0.26 feet, which provides 1.0 foot of freeboard. Based on the maximum channel slope, the flow velocity is 8.5 feet per second. This velocity requires an average riprap size of 8 inches. The existing average riprap size of 12 inches is adequate for this inlet channel.

The outlet of the primary spillway was evaluated to determine the suitability of the existing riprap. With a culvert slope of 5.1% and a peak discharge rate of 5.7 cubic feet per second during the 25-year 24-hour storm, the exit velocity was calculated to be 7.16 feet per second. The existing average riprap diameter of 6 inches is adequate for this flow velocity. The flow velocity and riprap sizing calculations are presented in Appendix 3.7G.

According to R614-301-742.221.34 (Utah Division of Oil, Gas and Mining, 1990) a non-clogging dewatering device must be installed in the pond. Because Pond 014 does not require reconstruction, it will be dewatered using a portable pump system. The inlet structure to the portable pump will float on the surface of the water. The system will include an oil skimmer to prevent floating matter from being discharged from the pond during dewatering. The pond will be dewatered to elevation 6762.5, the maximum sediment storage elevation. Prior to dewatering, the impounded water will be sampled and tested to insure that the discharge will meet UPDES effluent requirements.

Sediment removal from the sedimentation pond will be performed when the sediment reaches the 60% cleanout level. As shown on Exhibit 3.7-9A, the 60% cleanout level is at elevation 6761.1. The sediment will first be tested to determine if it contains any acid and/or toxic forming materials. If the sediment is non-toxic, it will be considered as spoil and properly disposed of. If the sediment is toxic, it will be buried under 4 feet of soil cover.

Pond 015 - A 3-year sediment storage volume of 4050 cubic feet (0.093 acre-feet) was calculated as indicated in Appendix 3.7G using methods described in Chapter 7. The storm runoff volume from the 10-year 24-hour storm event is 22,841 cubic feet (.524 acre-feet). The computation of the runoff volume assumed a drainage area of 6.23 acres and a curve number of 90 for the disturbed area. No undisturbed areas contribute to the pond. Thus, the minimum capacity of the pond at the elevation of the primary spillway must be 26,891 cubic feet (assuming the spillway does not spill during the 10-year 24-hour storm).

From the stage-capacity curve contained in Appendix 3.7G, the allowable storage at the primary spillway elevation (98.2 ft) is 45,287 cubic feet. Therefore, additional volume is available for sediment storage. Subtracting the runoff volume from the existing pond capacity at the spillway results in a maximum sediment storage capacity of 19,857 cubic feet.

The elevation of the maximum sediment storage level is 94.7 feet (3.5 feet below the primary spillway). The stage-area and stage-capacity data for Pond 015 were determined from the pond topography contained in Exhibit 3.7-9B. A summary of this data is contained in Table 3.7-8. The stage-area and stage-capacity curves for Pond 015 are presented in Appendix 3.7G.

The 25-year 6-hour storm event (1.6 inches of precipitation) was used to determine the adequacy of the primary spillway. The size of the disturbed watershed is 6.23 acres. The computation of the runoff volume assumed an average curve number of 90 and a time of concentration of 0.20 hours. The calculation methods used are described in Chapter 7. The calculations for sedimentation Pond 015 are contained in Appendix 3.7G.

The 25-year 6-hour storm was routed through the primary spillway to determine the maximum stage and flow volume. The computer software program SEDCAD assumes that the pond is full of water up to the primary spillway elevation at the beginning of the storm event. This results in a conservative estimation of the maximum stage since, in general, the pond can be assumed to be empty at the beginning of a storm event.

Using the assumption that the pond is initially full of water when the storm begins, the SEDCAD program calculated a maximum inflow rate of 3.96 cubic feet per second (cfs) and a maximum outflow rate of 3.00 cfs. The corresponding high water level is 98.5, 0.3 foot above the primary spillway, and 2.30 feet below the minimum embankment elevation of 100.8.

The north and south inlet channels to Pond 015 were evaluated to determine the adequacy of the existing riprap, and capacity of the channel during the 25-year 6-hour storm event. The calculations for the inlet channels are presented in Appendix 3.7G. Based on the minimum channel slope, the flow depth in the north inlet channel is 0.15 feet, which provides 0.85 feet of freeboard. The flow depth in the south inlet channel is 0.10 feet, which provides 0.73 feet of freeboard.

Based on the maximum channel slope, the maximum flow velocity in the north inlet channel is 5.66 feet per second. This velocity requires an minimum average riprap size of less than 6 inches. The maximum flow velocity in the south inlet channel is 4.5 feet per second.

Since the south inlet channel is well vegetated, and the design flow is very low (0.4 cfs), no riprap is required.

The outlet of the primary spillway was evaluated to determine the suitability of the existing riprap. With a culvert slope of 14.0% and a peak discharge rate of 3.0 cubic feet per second during the 25-year 6-hour storm, the exit velocity was calculated to be 8.51 feet per second. The flow velocity calculations are presented in Appendix 3.7G. The existing stream channel diversion contains cobbles and boulders large enough to meet the required riprap size of 6 inches at the culvert outlet.

An emergency spillway was added to Pond 015 based on R614-301-742.223 (Utah Division of Oil, gas and mining, 1990). The crest of the emergency spillway is located 1.4 feet above the primary spillway flowline, and 1.2 feet below the maximum embankment elevation. The spillway has a 5-foot bottom width, 2H:1V side slopes, and a median riprap size of 4 inches. The location of the emergency spillway is presented in Exhibit 3.7-9B.

The performance of the emergency spillway was evaluated in the event the primary spillway becomes inoperative. The 25-year 6-hour storm was routed through the emergency spillway assuming that the pond was initially full of water to the elevation of the emergency spillway when the storm occurred. A stage-discharge curve was calculated by SEDCAD for the emergency spillway. The SEDCAD input and output is contained in Appendix 3.7G. From the final (emergency spillway only) analysis of the 25-year 6-hour storm event, the maximum discharge out of the emergency spillway is 2.83 cfs with a maximum flow elevation of 99.9 (0.9 foot below the minimum embankment elevation).

The emergency spillway was evaluated to determine the necessity of riprap on the outlet slope. With a channel slope of 0.2 ft/ft, a Manning's roughness coefficient of 0.033 and a maximum discharge rate of 2.83 cfs during the 25-year 6-hour storm (emergency spillway only outflow), the flow velocity was calculated to be 4.64 feet per second (fps). An average riprap diameter of 3 inches is required at the outlet for this flow velocity.

R614-301-742.221.34 (Utah Division of Oil, Gas and Mining, 1992) requires a non-clogging dewatering device adequate to maintain the detention time required under R614-301-742.221.32. Pond 015 will be dewatered using a pump system. The inlet structure to the portable pump will float on the surface of the water. The system will include an oil skimmer to prevent floating matter from being discharged from the pond during dewatering. The pond will be dewatered to elevation 94.7, the maximum sediment storage elevation. Prior to dewatering, the impounded water will be sampled and tested to insure that the discharge will meet UPDES effluent requirements.

Sediment removal from the sedimentation pond will be performed when the sediment reaches the 60% cleanout level. As shown on Exhibit 3.7-9B the 60% cleanout level is at elevation 93.0. The sediment will first be tested to determine if it contains any acid and/or toxic forming materials. If the sediment is non-toxic, it will be considerd as spoil and properly disposed of. If the sediment is toxic, it will be buried under 4 feet of soil cover.

3.7-4(3) Pond Embankment Stability Analyses

3.7-4(3).1 General

Both the inslopes and outslopes of the embankments of Pond 015 in Crandall Canyon were analyzed for long term stability. These analyses were performed to address the requirements of R645-301-733.210 and R645-301-533.100, which stipulate that all embankments not under the jurisdiction of the Mine Safety and Health Administration (MSHA) shall have a minimum static factor of safety of 1.30.

A field survey of the pond embankments in Crandall Canyon was conducted to ascertain the most likely location of possible embankment failure. The field survey consisted of visually evaluating the embankments and noting specific slope geometry characteristics. Soil samples were taken from the embankments for later visual classification.

Since lab testing of soil sampled from the embankment is not included in the scope of this analysis, soil properties were assumed. The bases for those assumptions were visual classification of soil samples and typical soil properties presented by Hoek (1981) and NAVFAC DM-7 (1971). Soil parameter assumptions made in this analysis are generally conservative because of the absence of lab data.

Based on information gathered during the field survey and the results of visual classification of the soil samples, the slope stability computer software program GEOSLOPE (GEOCOMP, Inc.) was utilized to determine an in-situ factor of safety for each of the embankments. The resulting computer output is contained in Appendix 3.7I.

GEOSLOPE is a computer program based on the FORTRAN program STABL3 which was developed at Purdue University. GEOSLOPE utilizes the limit equilibrium procedure of slices to determine the safety factor of potential circular failure surfaces by the Modified Bishop's Method. Both deep failure surfaces and surfaces that generally pass through the toe of the embankments were analyzed. Only the analysis that produced the lowest factor of safety for each embankment is included in Appendix 3.7I.

3.7-4(3).2 Pond 015

Pond 015 is centrally located within the disturbed area of Crandall Canyon. The pond is partially incised, with the most critical outslope section of the embankment located on the side of the pond closest to the main stream channel diversion. The side of the pond closest to the road was analyzed for inslope stability. The critical sections that were analyzed are shown on Exhibit 3.7-9B.

The geometry of the Pond 015 outslope embankment is characterized by a nearly vertical gabion wall that forms the left side of the main stream channel diversion at the toe of the embankment. The embankment then slopes 28° to a fairly level bench ten feet in width. The outside of the embankment then slopes 15° to the top of the embankment, which is approximately 11 feet in width. The inside of the embankment slopes at 21°. The total length of cross section C - C' used to model the outslope embankment is 110 feet. The embankment is composed primarily of sandy gravel. The assumed soil strength parameters are identified in Table 3.7-9. The phreatic surface was assumed to be at the ground surface at the toe of the outslope, and at 1.5 feet below the top of the embankment on the inside of the embankment. This corresponds to the maximum water level in the pond during a 25-year 6-hour storm event, assuming the pond is full of water at the beginning of the storm. See

Section 3.7-4(2) for a description of the methods used to determine that water surface elevation. A sketch of the section geometry is included in 3.7I.

The existing embankment is stable with a factor of safety of 2.33. See Appendix 3.7I for GEOSLOPE computer results.

The inslope of Pond 015 closest to the road was analyzed for stability, as depicted by the 50 foot section D - D' of Exhibit 3.7-9B. The average slope is approximately 32° from the bottom edge of the pond to road above the pond. The phreatic surface was assumed to be horizontal at the maximum 25-year 6-hour level of 98.5. The pore pressure parameters were assumed to be equal to zero since it is anticipated that the pore pressures would dissipate quickly during pond dewatering, due to the granular nature of the soil. A summary of the soil strength parameters are listed in Table 3.7-9, and a detailed section cut is included in Appendix 3.7I.

The inslope of Pond 015 is stable with a factor of safety equal to 1.37. See Appendix 3.7I for GEOSLOPE computer output results.

3.7-4(4) <u>Disposal of Spoil</u>

The proposed fill described in Section 3.7-3(1) may comprise a situation as addressed in R614-301-528.310. Materials used in the fill have been tested for toxicity and other parameters and can be classed as non-acid/non-toxic forming. All water will be directed away from the fill by diversion ditches to remain in place for the life of the facility.

3.7-4(5) <u>Fish and Wildlife</u>

A survey of the mine permit area was performed in the spring of 1979 by the Utah Division of Fish and Wildlife Resources (Dalton, 1979). Additionally, a study of the bird population was conducted for the area around Crandall Canyon and the proposed power-line (Young, 1980). No threatened or endangered species were found to inhabit the area. Some impact to normally occurring species will occur by approximately 38 acres of habitat destruction caused by site development and the 8 to 10 acres affected by power-line construction (see 3.7-3(10)). Impact caused by the power-line will be minimal due to the infrequent maintenance required. The fish and wildlife plan for Crandall Canyon will conform to the intent of the plan for the entire mine plan area. (See Chapter 10, Wildlife Resources.)

NOTE: THE BALANCE OF THE PERMIT TEXT IN SECTION 3.7 HAS BEEN REVISED SINCE THE APRIL 1995 SUBMITTAL

3.7-4(6) Vegetation

The vegetation inventory (Mariah Associates, 1981) describes five major vegetation types within Crandall Canyon; conifer, pinyon-juniper, grassland-sagebrush, mixed brush, and riparian bottom. Portions of the canyon were previously disturbed, therefore surrounding undisturbed areas and aerial photographs were used to determine vegetative types. Mariah personnel encountered no threatened or endangered species.

Reference areas were designated with approval of UDOGM personnel (Kunzler, Linner and Wright, August 14, 1981). Crandall Canyon contains three of the ten vegetation reference areas designated for the Castle Gate permit area (pinyon-juniper, conifer, and riparian bottom). Vegetation types and reference areas for the canyon are delineated on Exhibits 9-4 and 9-5, and are described in Chapter 9.

3.7-4(7) Land Use

The land in Crandall Canyon was used as wildlife habitat and grazing (sheep, goats, and cattle) prior to mining. In addition, the historical studies discussed below indicate that several structures were built in the canyon in conjunction with residential use. The canyon was also used for recreation prior to mining, most notably picnicking and hunting. Pre-mining access to the canyon for recreational and occupational uses was provided by a jeep road which started at the state highway and extended through the leach field area (Exhibits 3.7-1 and 3.7-5A). Apparently, the canyon was not mined prior to the development of the existing facilities.

The approved premining land use designation for Crandall Canyon is undeveloped land.

3.7-4(8) Cultural, Historical and Archaeological Sites

Crandall Canyon has supported some past human activities as mentioned above. Several rock structures exist within the canyon, including a cistern (Exhibit 3.7-2). Some potential for significance as cultural or historical features was indicated in past surveys of the area. Ensuing, more detailed studies (Sargent, June 1980, and Utah Archaeological Research Corporation, December 1980) determined that these structures were not eligible for the National Register of Historic Places nor did they hold any particular historical or cultural value. The results of these studies were submitted to the Division and the Office of Surface Mining. Reviewers within the Division verbally concurred with the aforementioned results. Final clearance was provided in April 1981. The historical study reports constitute the appendices of Chapter 5.

3.7-4(9) Prime Farmland

The Soil Conservation Service has determined that no prime farmland exists within the disturbed area boundary (see letter of May 21, 1991 in Chapter 8, Figure 8-3.)

3.7-4(10) Air Quality

During construction activities, a potential for fugitive dust problems exists. Road P-1 will be the area of greatest concern when the mine is operational. Control of fugitive dust will be achieved by watering the roads and disturbed areas during dry periods. The master plan for the Crandall Canyon area includes surfacing the road from U.S. Highway 6 to the hoist facilities area with asphalt pavement. The Utah Department of Air Quality was consulted when the facilities layout was developed and they had no further requirements. Additional air quality and control information is presented in Chapter 11.

3.7-4(11) General Maintenance

Roads - Roads P-1 and A-1 will be inspected periodically for erosion, rutting, pothole formation and shoulder deterioration. Grading will be performed as necessary to minimize surface irregularities. Drainage ditches and culverts associated with road drainage will also be inspected periodically and cleaned of flow-impeding debris and sediment. If the roads are damaged by a catastrophic event, such as a flood or earthquake, they will be repaired as soon as practical after the damage has occurred.

Ponds - The ponds will be maintained as required by R645-301-742.221. Sediment will be removed when it reaches the 60% sediment cleanout level, as described in Section 3.7-4(2).3. Spillway culverts and channels will be inspected for deterioration and erosion, and corrective measures taken as necessary.

3.7-5 Reclamation Plan

3.7-5(1) General

Cyprus Plateau Mining, a subsidiary of Cyprus/Amax Coal (the parent company of Amax Coal Company), intends to develop the Willow Creek site approximately 1 mile east of the intersection of routes US 6 and 191. Development of that site and the associated underground mine workings will incorporate the use of the Crandall Canyon shafts. Therefore, reclamation and reclamation scheduling associated with the Crandall Canyon site will be coordinated with the reclamation of Willow Creek.

The reclamation topography plan is presented on Exhibit 3.7-7A, 7B, and 7C. The reclamation plan has been divided into 3 phases.

Phase I - Reclamation of Leach Field and Facilities Area

Reclamation activities will include removal of all surface structures, including the hoist, ventilation equipment, warehouse, culverts, hydrants, and above-ground electrical lines will be dismantled as necessary and disposed. Materials of value will be recycled, non-combustible material will be buried, and the remaining materials will be disposed of in an approved solid waste landfill. Both shafts will be permanently sealed, and they will be covered with a minimum of 4 feet of soil. The site will be graded to drain, covered with topsoil, and seeded. The facilities access road and the leach field road will be reclaimed beginning at approximately Station 5+00 as shown on Exhibit 3.7-7B. Ponds 014 and 015 will be removed. The LP gas tanks will be moved to the Willow Creek site in 1996 (tentative).

Phase II - Reclamation of the Facilities Pad Access Road

The remainder of the access road from Highway 6 & 50 to the facilities area will be reclaimed. This will include the removal and proper disposal of all culverts, asphalt, and guard rail and the backfilling of cutslopes where required. Riprap will be placed at appropriate locations where drainages cross the reclaimed surfaces.

Phase III - Vegetation Monitoring.

Phase III consists of monitoring vegetation growth and maintaining the reclamation channels and diversions. Phase III will be performed at the completion of Phase I and Phase II. The end of Phase III will be characterized by the establishment of vegetation as described in Chapter 9 and the compliance with regulation R645-301-880.320 relating to water quality.

3.7-5(2) Postmining Land Use

3.7-5(2)(1) General

Crandall Canyon has the potential of supporting wildlife habitat, grazing, and recreation. The reclamation plan supports both the designated pre- and postmining land use of undeveloped land and the potential land uses listed above. Since the proposed postmining land use is identical to the premining land use (Section 3.7-4(7)), a request for alternative land uses is not required.

Currently, the disturbed area in the canyon below elevation 7000 feet is zoned by Carbon County as Mining and Grazing (MG-1) land. Land above 7000 feet is zoned as Critical Environmental (CE-1) because of watershed characteristics. Both of these zoning classifications are in agreement with the potential postmining land uses.

3.7-5(2)(2) Permanent Features

Under the current reclamation plan, the only permanent feature of the operational mining plan to be retained will be leach field piping. This will remain in-place since the piping is covered by a minimum of four feet of soil and removing the piping would result in disturbance of established vegetation.

3.7-5(3) Engineering

3.7-5(3)(1) Backfilling and Grading

The reclamation topography plan is presented on Exhibits 3.7-7A, 7B, and 7C. The plan has been developed to be in compliance with the R645 requirements for obtaining approximate original contour, as discussed in Section 3.7-5(3)(2). The engineering issues of the reclamation plan pertaining to the walls, roads, shafts, and utilities are discussed in this section. The hydraulic and sediment control issues are presented in Section 3.7-5(4).

As part of Phase I reclamation activities, all surface structures will be removed. These include the main hoist building, emergency hoist, ventilation equipment, warehouse, substation, LP gas tanks, and above-ground utilities (except primary power poles that are being employed as raptor habitat). Additionally, all sections of the Hilfiker retaining walls not covered by a minimum of 4 feet of soil, will be removed. More specifically, the retaining wall supporting the Pond No. 014 embankment will be removed from approximately station 1+00 to station 10+00 (Exhibit 3.7-7B). Also, the retaining wall downgradient of pond No. 015 at approximately station 19+00 will be removed as needed. Access road A-1 will be reclaimed as well as a portion of the main access road (P-1). (The boundary between Phase I and Phase II is illustrated on Exhibit 3.7-7B.) All culverts and associated inlet works will be removed. Materials of value will be recycled, non-combustible waste generated from the demolition will be buried under a minimum of 4 feet of soil cover, and the remaining materials will be disposed of in an approved solid waste landfill.

The leach field access road (A-1) from the LP tanks to and through the leach field has been partially reclaimed. During final reclamation activities, a low ground pressure tracked excavator (or similar equipment) will be used to remove the culverts from this section of the road. This type of equipment will be used to minimize disturbance to existing vegetation and reduce soil compaction. The culvert farthest upgradient will be removed first and the road reclaimed as work progresses downgradient toward the facilities area. In areas where topsoil is currently stored adjacent to the road in berms, the berms will be knocked down and the topsoil spread across the road. Where soil compaction and rutting is evident in the road, the compacted and rutted soils will be loosed with the teeth of the backhoe bucket to a depth of at least 18 to 24 inches and the exposed soils roughened and revegetated following the procedures specified in Sections 3.7-5(4)(6) and 3.7-5(6).

As part of the Phase II reclamation activities, the remainder of the main access road (P-1) from Highway 6 & 50 to the Phase I/Phase II reclamation boundary will be reclaimed. If the road is surfaced with asphalt, the asphalt will be removed, placed against the cutslopes as fill material, and covered with a minimum of 4 feet of soil. Material used for reclamation of the road will be obtained from the current outslopes of the road. This will require the disturbance of vegetation that currently covers much of the outslope. During backfilling of the road, the best available soils within the outslope or base of the road will be used as final topsoil cover. The surface of the soils placed in the road and the disturbed portions of the outslopes will be reclaimed following the procedures detailed in Section 3.7-5(4)(6).

The volume of earthwork associated with Phase I and II reclamation activities is summarized in Table 3.7-10.

There are no highwalls in Crandall Canyon, since the only access to the underground workings is through the shafts. There are no spoil piles, refuse piles, or small depressions that will be retained in the reclamation plan.

The primary objectives of the backfilling and grading plan associated with Phase I and II of reclamation is to reclaim the main channel, reclaim cutslopes in the canyon where possible, sufficiently cover remaining building foundations with a minimum of 4 feet of soil, sufficiently cover the permanent seals of shafts No. 1 and No. 2., and reclaim existing access roads. No backfill will be placed in the shafts. Most slopes formed during grading will be significantly flatter than the angle of repose of the graded soil, and flatter than a 2:1 slope. No slopes will exceed the maximum safe angle of repose. A potentially worst-case reclamation slope was assumed for the area west of the existing hoist building and south of the channel centerline at approximately station 18+25. Assuming that the existing cutslope in this area were to be completely backfilled, the reclaimed soils would lie at a maximum slope of 36 degrees. As discussed in Section 3.7-5(3)(4) and Appendix 3.7R, the slope would have a critical safety factor of 1.4 under static conditions. However, since slopes greater than 2:1 can be erosionally unstable, slopes within the reclaimed area will generally be constructed to lie at or less than a 2:1 slope.

Cut material necessary to cover the facilities area will come from 2 on-site sources. Initially, topsoil was removed from the disturbed area and stored in stockpiles Nos. 1 and 2. However, stockpile No. 1 has apparently been invaded by noxious weeds and is suspect as a topsoil source. Therefore, topsoil will be taken from stockpile No. 2, located along access road P-1, and from soils located within the facilities area. If the volume of topsoil from stockpile No. 2 and the facilities pad is insufficient, then additional sources will be considered. For example, there is excess topsoil remaining along the south side of the leach field. Also, soils from stockpile No. 1 can be evaluated for the presence of noxious seeds, and if found acceptable, used as a topsoil source. Additional material needed to complete the reclamation grading will be excavated from within the disturbed area boundary. Additional discussions regarding topsoil are presented in Section 3.7-5(5).

The as-built reclamation topography should generally reflect the proposed reclamation topography within plus or minus 2 feet (one contour interval). Field adjustments to the reclamation grading plan will be presented on the as-built topographic drawings.

Any acid forming or toxic materials exposed during the grading operation, which may adversely affect water quality or vegetation, will be treated or buried at a depth of no less than four feet, in accordance with R645-301-731.111, 731.121, 731.300, and 745.113.

3.7-5(3)(2) Approximate Original Contour Compliance

The natural topography of Crandall Canyon, west of Shaft No. 1, is characterized by steep canyon side slopes and a relatively broad canyon bottom, as shown in Exhibits 3.7-1 and 3.7-2. Relative to the drainage flows of the geologic past, the recent flows are relatively small. Consequently, the main stream meanders on top of, and erodes slowly through, unconsolidated materials that were deposited previously during high flow, high energy events. These conditions have resulted in various configurations of stream alignments along the base of the canyon, including stream alignments against one side of the canyon, centered alignments, meandering alignments, and two alignments coexisting in the same reach of the canyon where subdrainages intersect the canyon bottom. The areas adjacent to the incised channel tend to be relatively flat in cross-section. Exhibit 3.7-7D presents sections A-A' through E-E', which were cut through the undisturbed areas of the canyon shown on Exhibit 3.7-7A. These sections depict the flat areas associated with the broad canyon bottom, and the steep slopes where the stream has recently eroded through unconsolidated materials.

To achieve AOC, the current reclamation plan specifies returning the channel to near the center of the canyon floor and the construction of concave fill slopes extending from the undisturbed boundary to the reclaimed channel. This has been done to allow for the fill slopes to be less than the angle of repose for the granular backfill, and flatter than a 2:1 slope. In the area of Shaft No. 1, a topographically high area will be constructed over the shafts. This high area will aid in maintaining the location of the reclaimed channel built for conveying runoff from watershed area CCWS-U32. This topographic high will be constructed in such a manner as to blend in with existing topographic features.

All cutslopes within the disturbed area will be reclaimed as per current UDOGM regulations. As allowed under existing UDOGM Approximate Original Contour Regulations, limited portions of cutslopes will remain where they mimic or blend with existing topography and where fully reclaiming the cutslopes would result in slopes with a static factor of safety less than 1.3. Exhibits 3.7-7A, 3.7-7B, and 3.7-7C illustrate the current location of cutslopes and the locations where portions of cutslopes are likely to remain. The cutslopes anticipated to remain are numbered PRCS-1 through PRCS-4 (PRCS- post reclamation cutslope). Appendix 3.7U contains a description of each of the cutslopes to remain with photographic evidence supporting the decision to leave the cutslopes. Typically, cutslopes will remain where complete backfilling would result in encroachment upon undisturbed channels, slopes greater than 2:1, or where the operator would be severely limited in its ability to construct acceptable reclamation channels. Remaining cutslopes will visually blend in with existing escarpments and ledges and will not detract from the aesthetics of the canyon as can be seen on photos in Appendix 3.7U. The portions of the existing cutslopes that will remain have experienced no signs of instability with the exception of the usual surface weathering.

3.7-5(3)(3) Shafts

By October 23, 1991, sealing of Shafts No. 1 and No. 2 was completed, according to a letter written by Amax Coal Industries, Inc. (Appendix 3.7M). The map referenced in the Amax letter depicts the sealing of the No. 3 Mine in both Hardscrabble Canyon and Crandall Canyon. Also presented in Appendix 3.7M is the sealing plan proposed by Castle Gate Coal Company (once a subsidiary of Amax Coal) in March 1991. The sealing plan consisted of placing 6 inch thick concrete slabs over the top of the openings to shafts No. 1 and 2. A 2 inch PVC vent pipe was installed through the seal of both shafts. The seals were intended to be temporary in the event that mining operations resumed. However, the seals appear to be in compliance with MSHA guidelines 30 CFR 75.1711-1.

Phase I of reclamation will include permanent sealing of Shaft No. 1 and Shaft No. 2. Each seal will consist of a reinforced concrete slab anchored to the shaft collar. Three slabs will be used to seal Shaft No. 1, two for the air intake openings, and one for the hoist opening. A single concrete cap will form the seal of Shaft No. 2. The permanent seals have been structurally engineered by Construction Survey Resources under the assumption that the existing seals will be removed when mining operations resume. Proposed details for the permanent seals, and calculations supporting the design, are contained in Appendix 3.7N. A permanent 2 inch diameter (galvanized steel) vent pipe will be installed through the slabs to vent mine gases. The vent pipes will be labeled, and will also be protected with bollards or fencing.

Assuming that the existing seals are removed to reactivate the mine in conjunction with Willow Creek development, water inflow and water level in the shafts will be measured prior to construction of the permanent seals. If the mine is not reopened, and the existing seals are not removed prior to reclamation, then the existing seals will remain in place to avoid exposure of workers to safety hazards. Under this scenario, the permanent seals will be cast directly over the existing seals, and water inflow and level measurements will not be taken.

The interception of groundwater by the shafts has been considered during development of the reclamation plan. According to Mr. Lane Adair, an employee of Price River Coal Company who was present during construction and early operation of the shafts, most of the water that initially seeped into the shafts came in at the interface between the unconsolidated soils and the bedrock (30 to 60 feet below the top of the shaft). As stated in Section 3.7-3(1), this aquifer was grouted. Water inflow was apparently reduced to approximately 3 gallons per minute (gpm) in Shaft No. 1 and 10 gpm in Shaft No. 2. The balance of the shafts were fairly dry, according to Mr. Adair, except that the "Sub 3" seam and the "D" seam both contained groundwater (Adair, 1995).

The small flow of water seeping in through the sides of the concrete-lined shafts is primarily from an unconfined aquifer. Undoubtedly, the water level in the shafts will rise and reach an equilibrium level determined by the potentiometric head, transmission of water through the Blackhawk formation, and by the elevation of mine outlets, such as Adit No. 1. Adit No. 1 periodically discharges water, although it is approximately 850 feet higher than the base of the shafts in Crandall Canyon. Unless the water going into the shafts backs up into the mine workings sufficiently to discharge through an adit, the intercepted water will recharge the regional aquifer. Under recharge conditions, the water will be removed from the Price River drainage system.

As explained in Section 7.1-10(5), water inflow into the No. 3 and No. 5 mines has been estimated at approximately 50 gpm. Although both of the shafts intersect the No. 3 mine, this inflow value probably excludes the infiltration into the shafts, since the shafts were installed after that portion of the permit was written. Infiltration into the shafts is approximately 13 gpm, with 50 gpm an expected upper inflow limit. Since the mean annual discharge rate for the Price River is 112 cfs, 50 gpm represents a loss of 0.1 percent to the Price River. If this value is added to the expected inflow rate of 289 gpm to the mine workings under full development conditions (Section 7.1-10(5)), the total loss would be 0.7 percent. Thus, the impact of allowing a minor amount of seepage water from the unconfined

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aquifer in Crandall Canyon to be transmitted through the shafts to the Blackhawk formation appears to be insignificant. Finally, Amax Coal Company has 1.7 cfs (763 gpm) of water right on the Price River to mitigate the minor reduction in yield of the drainage basin.

3.7-5(3)(4) Reclaimed Slope Stability

According to R645-301-553.130, reclamation slopes shall not exceed the angle of repose and shall have a minimum long-term static safety factor of greater than 1.3. The angle of repose of any soil is a function of the soil gradation, moisture content, and degree of compaction. It is expected that the reclamation fill will be fairly dry and will be placed without the benefit of compaction or moisture conditioning.

According to the soil sampling program conducted by EarthFax (1995a), residual and overburden soils in the Crandall Canyon area generally consist of sandy loam to loamy sand with 5 to 15% clay and 5 to 75% rock (gravel through boulders). Because of the variability in the soil texture, the angle of repose of the soil will also vary.

The angle of repose of a loose sand generally varies between 30 and 35 degrees (Holtz and Kovacs, 1981). According to Tomlinson (1986), the angle of repose for loose, dry sand can vary from 28.5 degrees for round uniform sand grains to 34 degrees for angular well-graded sand grains. Increasing the density of the sand can increase the angle of repose to 33 to 46 degrees, respectively. According to Bowles (1984), unsaturated, nonplastic remolded and undisturbed soils can have an angle of repose between 34 and 36 degrees.

Though slopes up to 36 degrees would have a critical safety factor of 1.4 under static conditions (see Appendix 3.7R), some sloughing of surface soils may occur, especially as the soils dry or if the soils are placed in a loose condition. As stated earlier in Section 3.7-5(3)(1), since soil may be erosionally unstable at inclinations greater than 2:1, reclamation slopes will be generally constructed at or less than 2:1. This reduction in slope will further increase the long-term static safety factor above the value of 1.4 calculated for a 1.4:1 slope (Appendix 3.7R). Hence, the requirements of R645-301-553 will be met by the reclamation plan presented herein.

3.7-5(3)(5) Electrical Power Lines

As mentioned in section 3.7-3(10), primary power is conveyed into Crandall Canyon via an electrical distribution line from Hardscrabble Canyon. The power enters the substation on the south side of the facilities pad, and is then distributed to various load centers. During Phase I of reclamation, all electrical equipment will be dismantled and salvaged to the extent possible. All secondary power poles and distribution lines will be removed. The primary power distribution wires and poles will be removed. However, any poles that are being used as raptor habitat at the time of reclamation will be left in place. Non-salvageable material will be disposed of in an approved solid waste landfill. Ground that is disturbed during reclamation of the power line right-of-way will be roughly regraded and seeded.

3.7-5(3)(6) Leach Field Piping and Other Underground Utilities

Underground utility piping (electrical, water, sewer, LP gas) will be removed only to the extent that it interferes with reclamation grading. The ends of the pipes to be abandoned in place will be capped. The approximate locations of the gas line and water lines are described on Exhibit 3.7-7B.

3.7-5(4) Reclamation Hydrology

3.7-5(4)(1) General

The reclamation hydrology plan was developed to complement the drainage pattern of the surrounding terrain. Culverts used during mine operation to route undisturbed area runoff under the facilities pad area will be removed. Runoff from the undisturbed drainages will be routed through the regraded facilities pad and into the reclaimed stream channel. The site area will be regraded, roughened, seeded and mulched to minimize sediment loading to both the undisturbed stream channel below the facilities area and to the Price River.

3.7-5(4)(2) Reclamation Channel

The reclamation channels were designed using the methods presented in Chapter 7. The natural channel sections were measured in the field and approximated with trapezoidal cross sections. The reclamation channels were designed to have a similar configuration as the natural channels. The hydraulic slope of each channel was measured from the postmining topographic maps, Exhibits 3.7-7A, 3.7-7B, and 3.7-7C (scale: 1" = 100').

The reclamation channel drainage areas for Crandall Canyon are presented on Exhibit 3.7-11. Each drainage area is labeled according to the mine area (CC = Crandall Canyon) and reclaimed watershed (RWS).

Curve numbers for the undisturbed drainage areas were estimated from vegetation data presented on Exhibit 9-1 and by field observations. The north-facing slopes of Crandall Canyon are primarily vegetated with conifers and mixed brush. South-facing slopes are primarily vegetated with juniper and pinyon, and mixed brush. Approximate vegetation cover densities are estimated from values contained in Chapter 9. Based on this information, tables provided by the U.S. Soil Conservation Service (1972), and professional judgement, curve numbers were estimated to vary from 65 to 70 for the undisturbed areas. A curve number of 80 was typically assumed for areas that will be reclaimed.

Peak discharge rates used to determine channel capacities and riprap sizes for the intermittent and perennial reclamation channels were calculated based on the 100-year, 6-hour precipitation event of 2.0 inches (Miller et. al, 1973). Permanent ephemeral drainage channels were designed for the 10-year 6-hour storm event of 1.4 inches (Miller et. al, 1973), in accordance with R645-301-742.333. A summary of the peak design flows is presented in Table 3.7-11. The supporting calculations are contained in Appendix 3.7O.

The following general approach was used during design of the reclamation channels:

- The design capacity of the perennial and intermittent reclamation channels was based on the 100-year, 6-hour storm and the minimum channel slope.

- The design capacity of the ephemeral reclamation channels was based on the 10-year, 6-hour storm and the minimum channel slope.

- Riprap was sized based on the 100-year, 6-hour storm and the maximum channel slope for perennial and intermittent channels.

- Riprap was sized based on the 10-year, 6-hour storm and the maximum channel slope for ephemeral drainage channels.

- The roughness coefficient (Manning's "n") for riprapped channels was determined according to the equation (Barfield et al., 1981):

$$n = 0.0395 D_{50}^{1/6}$$

where, n = Manning's roughness coefficient
D_{50} = median riprap diameter (ft)

- Riprap designs are based on channel construction on fill. Where the reclamation channel construction occurs on rock, riprap quantities will be reduced or eliminated (depending on the competency of the rock).

- For all channels, riprap sizing is based on the methodology presented in U.S. Department of Transportation Hydraulic Engineering Circular No. 11 (1967). The thickness of the riprap for these channels is twice the D_{50} of the riprap, or a minimum of 6 inches, as recommended by Barfield et al. (1981).

- When transitioning downstream from a steep channel slope to a mild channel slope, the larger riprap from the steep section will be extended into the channel section with the flatter slope for a distance of 15 feet to minimize scour (Simons, Li & Associates, 1982).

- The reclamation channels are designed to pass the peak discharge with an approximate freeboard of 1 foot.

Reclamation channel geometries are summarized in Table 3.7-12 and 3.7-13, respectively. Calculations supporting the design of the channels are presented in Appendix 3.7P.

3.7-5(4)(3) Reclamation Culvert Design

The existing culverts will be removed during reclamation activities. Culvert locations are shown on Exhibits 3.7-7A, 3.7-7B, and 3.7-7C. For the culverts which were located in the main stream channel (CCRC-5, CCRC-6, and CCRC-19), the reclaimed channel in these areas will be capable of passing the 100-year, 6-hour peak flow. For the balance of the culvert locations, which were located to pass ephemeral tributary drainage, the reclaimed channels will be capable of passing peak flows from the 10-year, 6-hour storm.

3.7-5(4)(4) Riprap and Filter Designs

Preliminary riprap sizing was determined based on the design drawings for the reclamation topography. These calculations are presented in Appendix 3.7P and summarized in Table 3.7-14. Detailed riprap gradations are not presented in this document because of the possibility that the constructed reclamation channel slopes may vary from the reclamation design. Upon completion of rough grading of each reclamation channel, survey data will be collected to verify the slope and geometry of each channel. The survey data will be used to verify the adequacy of the design riprap size. Riprap gradations will be prepared in accordance with procedures presented in Barfield, et al. (1981). Calculations that support the riprap and filter designs will accompany the reclamation as-built plans.

Detailed filter blanket designs are also not presented in this text since samples representative of the native soils that will comprise the subgrade of each proposed channel cannot be collected until the rough reclamation grading is complete. Amax Coal is committed to preparing detailed designs for the riprap and filter blankets. Samples will be taken once the reclamation grading has progressed sufficiently to expose the base of the reclamation channels. Both a granular filter and geotextile filter design will be prepared for each channel and a determination will be made as to which filter design is most appropriate. This decision will be based on the preference of the Division, the availability of granular filter materials, reasonable expectations of controlling the quality (in-place gradation) of the granular material, durability of the filter materials, and the cost to purchase and place the filter materials. The granular filter blanket gradations will be engineered based on methods presented in Barfield, et al. (1981). If a geotextile is selected for a filter material, then it will be installed in accordance with the manufacturer's recommendations.

For bonding purposes, it was assumed that the preliminary riprap sizing was adequate and that two 6-inch thick layers of filter blanket materials would be used for the reclamation. This provides a conservative estimate for the bond and ensures that adequate protection for riprap stability would be afforded.

3.7-5(4)(5) Primary Sediment Control (Ponds)

Both of the existing sedimentation ponds, Pond 014 and Pond 015, will be removed during the reclamation activities. Due to the topographic and hydraulic constraints of the final reclamation configuration, sedimentation ponds will not be a feasible sediment control option. The ponds will remain in-place as long as possible to assist in the sedimentation control efforts. However, once the drainage areas to the ponds are reduced to the point where the pond no longer functions or the area of the pond needs to be incorporated in the regrading of the surrounding area, the ponds will be removed.

3.7-5(4)(6) Alternative Sediment Control Measures

Alternative sediment control measures (ASCM) will be implemented during reclamation of the regraded and reclaimed site area. Generally, the areas where the ASCM's will be implemented consist of the leach field, topsoil stockpile No. 1, topsoil stockpile No. 2, reclamation channel CCRD-22, and the facilities area. These features are identified on Exhibits 3.7-7A, 3.7-7B, and 3.7-7C. Other small areas, such as where the road culverts will be removed, that are disturbed during reclamation will also require the implementation of ASCM's. One or more of the following ASCM's will be employed in varying degrees in these areas to control sediment erosion:

1. Surface ripping,
2. Contour furrowing,
3. Mulching,
4. Filter fabric (silt) fences,
6. Straw bales,
7. Seeding and fertilization where necessary,
8. Reseeding areas that do not exhibit successful germination, and
9. Surface roughening and mulch incorporation.

Based on Simons, Li & Associates (1983, Table 8.1), these methods constitute some of the best available control technology for the purpose of mining reclamation.

The following reclamation activities for areas of ASCM's will be employed in varying degrees to control sediment erosion:

1. Surface grading and ripping,
2. Mulching,
3. Surface roughening and mulch incorporation,
4. Seeding and fertilization where necessary,
5. Surface mulch distribution,
7. Monitoring,
8. Reseeding, refertilizing, and remulching areas that do not exhibit successful germination.
9. Straw bales, and
10. Filter fabric (silt) fences.

The proposed alternative sediment control measures can be classified into three categories: mechanical treatment, surface protection measures, and filtering structures. Mechanical treatment increases surface roughness thereby reducing overland flow velocity, which minimizes the sediment transport capacity. Detaining some of the would-be runoff also improves soil moisture for plant germination and plant growth. Surface protection measures include mulching, mulch binders, netting, and seeding. These measures are the most effective controls since they minimize the amount of soil detached by raindrop impact, and thus limit soil loss at the source. Surface protection measures also increase the surface roughness and increase water infiltration into the ground. Filtering structures inhibit runoff and sediment transport capacity by reducing flow velocity. They also physically trap sediment in the filter openings while allowing water to pass through.

Mechanical treatment will be performed following the topsoil spreading and mulching of the site area by gouging the soil to a depth of 12" to 18" using the bucket of a track-mounted backhoe. Gouging will loosen the soil, allow root penetration, increase surface roughness, and increase moisture storage. This will allow for quicker vegetation establishment, which will reduce erosion. The depressions from the gouging trap sediment dislodged by raindrop impact and overland flow. They also shorten the exposed reaches over which runoff will flow, thereby reducing the sediment carrying capacity of the runoff. Other surface roughening measures (trenching, pitting, mounding) may be used where gouging is impractical.

In regard to surface protection measures, the incorporation of the mulch into the surface roughening will ensure that the major portion of mulch is anchored on site. The mulch itself can significantly reduce the amount of sediment yield from an area (Simons, Li & Associates, 1983, p. 4.30) The mulch also helps retain moisture to allow for seed germination. Based on a rainfall intensity factor, for the 10-year, 6-hour storm event, of 0.61 inches per hour, the minimum mulch application rate is 0.9 tons per acre to prevent mulch removal by rainfall (Simon et al., 1983, Figure 4.14). For added protection, during the mulching prior to roughening, mulch will be applied at the rate of 2 tons per acre.

Permanent plant growth is the best method of controlling erosion from slopes, according to Simons, Li & Associates (1983, p.4.44). Upon completion of the grading in accordance with the plan depicted in Exhibit 3.7-7B, and mechanical treatment of the soil, the reclaimed area will be seeded with grasses, legumes, forbs, and shrubs. The species mix is specified in Chapter 9. Seeding will be performed at the appropriate time of the year in consideration of available moisture for germination. Reseeding will be done in areas in which the seed does not germinate. Following seeding and fertilization, the site area will be mulched again at a rate of 2 tons per acre.

Appendix 3.7-7Q presents calculations of sediment yield, using the Universal Soil Loss Equation (USLE), for the steepest reclaimed slopes comparing the sediment yield with no erosion protection, with natural vegetative cover, and with the proposed vegetative cover, mechanical treatment, and mulching that is proposed for the Crandall Canyon site. These calculations demonstrate that for the first two years, following reclamation, the sediment yield from the reclaimed surface will yield the least sediment. Therefore, the alternative sediment control measures will not result in additional contributions of sediment to the hydrologic system.

The alternative sediment controls constructed during Phase I and II reclamation activities will be inspected quarterly or after every major storm event. Observations made during these inspections, as well as corrective actions taken, will be recorded. Corrections to any weaknesses in the implementation of the sediment control plan will be remedied immediately to prevent future sediment runoff into the main stream channel. Corrective action will be taken when a gully greater than six inches in depth is created due to lack of vegetation establishment, or when the mulch and seed have been transported by wind or overland flow. Corrective action will consist of regrading of the ground surface only as necessary to fill in six inch gullies caused by erosion, and reseeding and mulching to reestablish vegetation.

3.7-5(5) Soils

A sampling and analysis plan was developed to evaluate the soils within the top four feet of the existing ground surface at the facilities area and in the 2 topsoil storage piles. the facilities area is defined as the area east of and including the propane storage tanks and west of and including sedimentation pond 014. Sampling and analyses addressed the existence of acid/toxic materials, the suitability of the soils as a growth medium, and the need for soil amendments. The samples were obtained as specified in the "Guidelines for Topsoil and Overburden Management" promulgated by the Division (1988). The samples were analyzed for the following parameters.

- pH
- Electrical Conductivity
- Saturation Percentage
- Particle Size Analysis
- Soluble Ca, Mg, and Na
- Sodium Adsorption Ratio
- Selenium
- Total Nitrogen
- Nitrate
- Boron
- Maximum Acid Potential
- Neutralization Potential
- Organic Carbon
- Exchangeable Sodium
- Available Water Capacity
- Rock Fragments

The analysis methods used by the laboratory to determine pH, electrical conductivity, soluble calcium, magnesium, and sodium, total nitrogen, and total organic carbon were not those recommended in Table 6 of the "Guidelines for Topsoil and Overburden Management". These parameters were determined using an EPA accepted laboratory method that allows for the use of soil sample extracts at soil/water ratios of 1:5. The Division guidelines recommend using approved ASA methods that require the use of saturated soil pastes. As described by Page (1982, page 168), though the paste extraction method is recommended for soil analyses used to determine soil characteristics and will provide more accurate results, the extracts of soil/water ratio of 1:5 can be used. Since the methods for analysis of the parameters listed in Table 6 of the guidelines are "recommended" but not required, the results of the analyses reported in the soil evaluation plan have been used to preliminarily determine the suitability and quantity of the soils in Crandall Canyon to be used as substitute topsoil. The soil sampling program and the results of the sample analyses are included as Appendix 3.7S.

The area encompassed by Phase I reclamation is approximately 24.6 acres and includes the leach field, the leach field access road (A-1), and the facilities area (Exhibits 3.7-7A and 3.7-7B). It is anticipated that only the facilities area, approximately 18 acres, will require application of additional topsoil during reclamation. At a depth of 6 inches, this area would require approximately 14,520 CY of topsoil. Topsoil stockpiles No. 1 and No. 2 were surveyed in the spring of 1995 (Blackhawk Engineering), and the topsoil available from the 2 topsoil stockpiles is 7890 CY (see Exhibit 3.7-5C and Table 3.7-10). However, there is some concern that stockpile No. 1 contains noxious weed seed. Therefore, only the 6680 cubic yards from stockpile No. 2 was considered available for reclamation. Consequently, sufficient stored topsoil is not available to cover the facilities area.

The results of the soil sampling program indicate that the soils west of Shaft No. 2 and east of Shaft No. 1 (lower pad area) contain as much as 60% rock in the upper 12 to 18 inches of soil. At the time of the sampling program, vegetation appeared to be very sparse in the areas where excessive coarse fragments where found in the soils of the lower pad. Additionally, a soil sample (EF-1-3) was obtained from test pit EF-1 at a depth of 30" to 48" below ground surface, contained selenium at a concentration of 0.11 mg/kg. This concentration slightly exceeds the maximum allowable concentration of selenium, 0.10 mg/kg, as put forth in current UDOGM guidelines.

The current reclamation plan for this area of the facilities pad includes establishing the reclamation channel near the middle of the lower pad. To avoid using material as substitute topsoil that has excessive coarse rock fragments and elevated selenium concentrations as substitute topsoil, the applicant will sample soils in the lower pad area prior to reclamation construction activities. At least three samples will be obtained from the soils in the lower pad. The location of the samples will be chosen based on the vegetation cover and apparent coarseness of the soils. The worst case soils will be sampled and analyzed for the following parameters in accordance with recommended UDOGM guidelines.

pH
Electrical Conductivity
Saturation Percentage
Particle Size Analysis
Soluble Ca, Mg, and Na
Sodium Adsorption Ratio
Selenium
Total Nitrogen
Nitrate
Boron
Maximum Acid Potential
Neutralization Potential
Organic Carbon
Exchangeable Sodium
Available Water Capacity
Rock Fragments

Soils found to be unacceptable to use as substitute topsoil will be used as backfill against cutslopes. In the unlikely event that none of the soils in the lower pad area are found to be acceptable substitute topsoil, the applicant will consider using the majority of the available topsoil from stockpile No. 2 to cover the area. The 6680 CY of topsoil in stockpile No. 2 would cover approximately 4 acres with 12 inches of topsoil.

The soils present west of Shaft No. 2 and east of the LP tanks (middle and upper pads) appear to sustain moderate vegetative growth. The chemical and physical results of the soil study indicate that these soils could be considered, with the proper amendments as necessary, as substitute topsoil. However, the vegetation currently present in these areas may not be of sufficient quality to meet the standards of the reference area described in Section 3.7-5(6). This may be due to several factors including over compaction of the soils, poor vegetative diversity, excessive grazing by wildlife, or adverse climatic conditions.

To determine the reason(s) for the apparent less-than-satisfactory establishment of vegetation in the middle and upper pads, a vegetation field study will be conducted in the spring or summer of 1996. The study will include qualitatively assessing the vegetation in selected areas of the middle and upper pads. Based on the qualitative assessment, a vegetation sampling program will be implemented in the middle pad, upper pad, and appropriate reference area. Statistical comparisons of the vegetative cover in the middle and upper pads with the reference area will be made. If the results of the comparison indicate adequate cover productivity is present to meet reclamation standards, no further work will be done. If the results of the comparison demonstrate inadequate vegetation, field trials may be conducted to establish the proper reclamation techniques needed to be implemented in those areas where soil from the middle and upper pads is used as substitute topsoil.

To further determine the suitability of the soils in the middle and upper pad to be used as substitute topsoil, Cyprus will sample these soils prior to reclamation construction activities. A random number table will be used to select 10 sample points from a grid which shall be established over the middle and upper pads on 100 foot centers. The samples will be analyzed for the parameters listed in Table 6 of the Division's "Guidelines for Topsoil and Overburden Management" using the recommended analyses methods including the saturated soil extract procedure for pH, electrical conductivity, soluble calcium, magnesium, and sodium and the sodium absorption ratio. The suitable topsoil identified in the upper, middle, and lower pad areas will be used to supplement the existing 6680 CY of topsoil and make-up for the shortfall of approximately 7840 CY of available topsoil for reclamation. Amendments to the soils based on the soils investigation, included as Appendix 3.7S, may be necessary. However, the soil samples obtained prior to reclamation construction will be analyzed and a final determination of the necessary amendments to be added will be made at that time.

During reclamation construction, soil sampling will be performed at a rate of 1 sample for every 2.5 acres of soil (at a depth of 6 inches). The following parameters will be analyzed according to Division guidelines: pH, electrical conductivity, texture, total nitrogen, available phosphorus, and potassium. Soil amendments will be added to the topsoil based on the results of the final soil analyses.

If adequate volumes of suitable substitute topsoil can not be located during reclamation construction, the operator may use soils from the south side of the leach field area to supplement the soils from the topsoil stockpiles. Immediately prior to the start of Phase I reclamation, the soil in stockpile No. 1 will be evaluated for noxious weed seed content. If the soil is deemed acceptable, it will be used in the Phase I reclamation area. The mass-balance calculations for topsoil are summarized in Table 3.7-10.

Prior to spreading topsoil, all accessible regraded areas will be scarified to a depth of 18 to 24 inches by deep ripping or other appropriate methods. These efforts will reduce the potential for slippage of the topsoil, increase moisture retention, and promote root penetration. The seed bed will be prepared using the mechanical treatments described in Section 3.7-5(4)(6). Seeding will commence immediately after seed bed preparation to minimize the potential for erosion damage. If seeding is expected to be delayed more than one month from the completion of final grading, then mulch will be applied at the rate of 2 tons per acre to protect the soil from wind and water erosion.

The main access road (P-1) will be reclaimed during Phase II reclamation activities. As indicated in Section 3.7-5(3)(1), topsoil used for reclamation of the road will be obtained from the outslopes and base of the road. The available topsoil will be sampled and analyzed at the same frequency and for the same parameters listed above. Surface preparation and seeding will also be accomplished using the same methods described above.

3.7-5(6) Biology

As discussed in Section 3.7-4(6), Mariah Associates conducted a vegetation inventory in Crandall Canyon (1981). Five major vegetation types were identified throughout the canyon: conifer, pinyon-juniper, grassland-sagebrush, mixed brush, and riparian bottom. The results of the study were used to develop reclamation seed mixes, delineate reference areas, and develop performance standards.

Seeding and Mulching - The seed mix defined by Species List No. 2 in Chapter 9 will be used to seed most of the area to be reclaimed. In addition, List No. 2 seeds will be used to seed the cut slopes along roads P-1 and A-1 to augment vegetation that has established itself since the mine was developed. Riparian species mix No. 5 will be used to seed the areas within 20 feet of the edge of reclamation channels CCRD-23A, CCRD-23B, and CCRD-23C. The seed mixes will be mechanically or hand broadcast according to the accessibility of the area to be seeded. When the area to be seeded is too steep or narrow for mechanical broadcast seeding to be feasible, the area will be hand broadcast. Revegetated areas will be fertilized and mulched. Section 9.4-1(4) describes mulching techniques. The rate of application for the straw if used for mulch will be 2 tons per acre, the rate for wood fiber will be 1 ton per acre. The seed mix and fertilizer application rates are discussed in Chapter 9, Section 9.4-1.

The riparian areas will be revegetated to a condition similar to those in the Crandall Canyon riparian reference area using the best technology available. The channels to be reclaimed with soil covered riprap will be seeded with Species List #2, however they will not be compared to a reference area as a success standard (verbal agreement made at a meeting with UDOGM personnel, 8/31/95).

Revegetation of the north-facing slopes will include the planting of shrub and tree seedlings. Species List #3 will be used on the north-facing slopes with willows and cottonwoods being replaced with ponderosa pine, juniper, and Douglas fir. The planting rate for ponderosa pine, Douglas fir, and juniper will be 300 seedlings/acre. Planting locations will be determined by the Applicant and UDOGM.

Reference Areas - Five vegetation types were identified within the proposed disturbed area boundary by Mariah (1981): conifer, riparian bottom, mixed brush, grassland-sagebrush, and previously disturbed areas. To establish standards for the successful reestablishment of vegetation on the areas to be reclaimed in Crandall Canyon, four reference areas were designated. The reference areas were selected on the basis of similarity of species, composition, cover, productivity, geology, soils, and slope. The reference areas have been approved by the Division. Two of the 4 reference areas are located within Crandall Canyon, and they correspond to the following vegetation types: conifer and riparian bottom. The remaining 2 reference areas, mixed brush and grassland-sagebrush, are located near the Castle Gate Preparation Plant. In addition, a pinyon-juniper reference area was delineated within Crandall Canyon for use in judging vegetation success for reclaimed areas outside of Crandall Canyon. The reference areas are shown on Exhibits 9-1, 9-4, and 9-5.

Performance Standards - The established revegetation standards will apply to all areas that are reclaimed within the disturbed area boundary. The applicant will meet diversity requirements for each of the reclaimed areas in accordance with their respective reference areas (Appendix 3-7T).

The leach field area was seeded immediately after the leach field was constructed using a seed mix that did not include shrub or tree seeds. The woody vegetation was excluded from the mix to discourage root penetration to the drain lines. To meet the diversity requirements discussed in Chapter 9 woody vegetation will be planted in the leach field area during reclamation. The existing vegetation is well-established and offers forage to wildlife. Consequently, no further seeding or planting in the leach field is proposed until final reclamation.

The north-facing slopes south of Shaft No. 1 were vegetated with conifer prior to mine development. The proposed reclamation topography for this area is relatively flat; and thus, the topography does not presently include north-facing slopes. Consequently, the area designated on Exhibit 9-4 as previously vegetated with conifers will be compared to the mixed-brush reference area to determine vegetation success.

The applicant proposes to control erosion through the use of properly designed and constructed sediment detention structures, recontouring of the reclamation soils, planting of approved reclamation and interim seed mixtures, soil enhancement, and moisture retention methods to ensure germination and establishment of vegetation. Should the reclaimed area show signs of excessive erosion, steps will be employed to remedy the situation (i.e., contour ripping, surface roughening, gouging, and/or mounding of the soils in the distressed area followed by reseeding with fast growing seed mix, erosion matting, etc.). The success of the methods used to control erosion will be measured by comparing runoff from the reclaimed areas with runoff from an undisturbed adjacent area. Erosion will be controlled such that contributions from the reclaimed area will be equal to or less than the sediment contributions from the undisturbed area.

3.7-5(7) Reclamation Surface and Ground Water Monitoring

The ground water monitoring station for Crandall Canyon, designated as B-22 on Exhibit 7-3 will continue to be monitored quarterly during and after completion of reclamation activities and until bond release is achieved. Samples from this monitoring point will be analyzed for the following parameters:

Flow
pH
Specific Conductance
Total Dissolved Solids
Total Hardness
Carbonate (CO_3^{-2})
Bicarbonate (HCO_3^{-2})
Calcium (Ca)
Chloride (Cl^-)
Iron (Fe) - Total and Dissolved
Magnesium (Mg) - Dissolved
Manganese (Mn) - Total and Dissolved
Potassium (K) - Dissolved
Sodium (Na) - Dissolved
Sulfate (SO_4^{-2})
Cation-Anion Balance.

When analysis of any sample obtained from this monitoring point indicates noncompliance with permit conditions, the UDOGM will be promptly notified and actions will be taken as provided in R645-300-145 and R645-301-731.

Both surface monitoring sites B-25 and B-26, located above Ponds 015 and 014 respectively, will be abandoned upon completion of the operational phase of mining since the sedimentation ponds will no longer be present. Instead, three new sites will be located at the beginning of the site reclamation. A surface water monitoring site, B-25A (Exhibit 3.7-7A), will be located just upstream of the leach field area to monitor flows entering the disturbed area. A second surface water sampling site, B-26A (Exhibit 3.7-7B), will be located a short distance downstream of the current location of Pond 014 to monitor flows discharged from the Phase I reclamation area. A third surface water monitoring site, B-26B, will be located near the terminus of the main access road P-1 (Exhibit 3.7-7C) to monitor discharges from the reclaimed disturbed area. Each of these sites will be monitored for the same parameters listed above for groundwater monitoring along with the following additional parameters:

Total Settleable Solids
Total Suspended Solids
Total Hardness
Oil and Grease.

When analysis of any sample obtained from these monitoring points indicates noncompliance with permit conditions or significant differences with runoff from adjacent undisturbed areas, UDOGM will be promptly notified and actions will be taken as provided in R645-300-145 and R645-301-731.

3.7-5(8) Reclamation Timetable

Contemporaneous reclamation and final reclamation is anticipated to proceed in accordance with the following schedule:

Phase I - Reclamation of Leach Field and Facilities Area

1. Demolition and structure removal	Week 1-8
2. Shaft Sealing	Week 8-12

3. Grading	Week 8-16
4. Seed Bed Preparation	Week 16-18
5. Seeding and Mulching	Week 18-20 (After Oct. 1)

Phase II - Reclamation of the Facilities Pad Access Road (P-1)

1. Culvert removal and regrading	Week 1-4
2. Seed bed preparation, seeding, and mulching	Week 4-6 (After Oct. 1)

Phase III - Reclamation monitoring

1. ASCE diversion maintenance	2-10 years
2. Vegetation monitoring	2-10 years
3. Water monitoring	2-10 years

3.7-5(9) Reclamation Costs

Table 3.1-18, Chapter 3, Section 3.1, was revised to summarize an estimate of reclamation activities for the purpose of determining the bond amount. The reclamation bond amount calculated for Crandall Canyon is presented in Table 3.1-2 of Chapter 3.1.

3.7-6 References

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TABLE 3.7-1

SUMMARY OF CRANDALL CANYON STORM RUNOFF CALCULATIONS FOR THE 10-YEAR 24-HOUR STORM

WATERSHED (CCWS-)	CURVE NUMBER	TIME OF CONCENTRATION (HR)	DRAINAGE AREA (MI^2)	RUNOFF DEPTH (IN)	PEAK DISCHARGE (CFS)
U1	70	.204	.038	.204	3.31
U2	70	.387	.359	.204	14.30
U3	70	.096	.012	.204	1.35
U3 & U4	70	.159	.053	.204	5.14
U5	70	.045	.002	.204	0.26
U5 & U6	70	.111	.019	.204	2.06
U7	70	.107	.013	.204	1.43
U8	70	.093	.009	.204	0.69
U8 & U9	70	.361	.178	.204	7.47
U10	70	.079	.015	.204	1.20
U12	70	.071	.007	.204	0.84
U36 & U13	70	.122	.031	.204	3.27
U14	70	.060	.003	.204	0.37
U15	70	.095	.016	.204	1.81
U16	70	.049	.003	.204	0.38
U16 & U17	70	.115	.021	.204	2.26
U18	70	.063	.004	.204	0.49
U18 & U19	70	.171	.068	.204	6.39
U20	70	.081	.004	.204	0.47
U20 & U21	70	.161	.044	.204	4.25
U22	70	.077	.004	.204	0.47

TABLE 3.7-1 (Continued)

SUMMARY OF CRANDALL CANYON RUNOFF CALCULATIONS FOR THE 10-YEAR 24-HOUR STORM

WATERSHED (CCWS-)	CURVE NUMBER	TIME OF CONCENTRATION (HR)	DRAINAGE AREA (MI^2)	RUNOFF DEPTH (IN)	PEAK DISCHARGE (CFS)
U22 & U23	70	.098	.017	.204	1.91
U24	70	.097	.015	.204	1.69
U25	70	.086	.008	.204	0.92
U26	70	.074	.009	.204	1.07
U27	70	.117	.014	.204	1.50
U29	65	.041	.002	.109	0.09
U29 & U30	65	.366	.363	.109	6.26
U31	65	.091	.008	.109	0.26
U31 & U32	65	.207	.080	.109	1.62
U33	65	.075	.004	.109	0.14
U34	65	.203	.060	.109	1.22
U37	70	.060	.002	.204	0.25
U1 THRU U9 & U28	68	.844	2.835	.162	77.91
U1 THRU U11 & U28 THRU U32	68	.852	3.333	.162	91.23
ALL SUBWATER-SHEDS	68	1.067	4.146	.162	101.81

TABLE 3.7-2
SUMMARY OF CRANDALL CANYON DIVERSION DITCH GEOMETRIES

DITCH (CCD-)	MINIMUM BOTTOM WIDTH (FT)[a]	MINIMUM TOP WIDTH (FT)	MINIMUM DEPTH (FT)	MINIMUM SLOPE	MAXIMUM SLOPE
1	3	7	1	0.067	0.067
2	3	6	1	0.100	.100
3	2	6	1	0.053	0.071
4	2	6	1	0.086	.100
5	2	6	1.25	0.074	.100
6	3	9	2.5	0.080	0.091
7A	4.5	11.5	3.5	0.053	.100
7B	5	12	4	0.350	.350
8A	2.5	5	0.67	0.057	0.077
8B	2.5	5	0.67	0.057	0.057
9	2.5	5.5	0.83	0.071	.143
10	2.5	6	1	0.040	0.043
11	2.5	6	1	0.071	0.091
12	2	5	0.83	0.048	0.059
13	1.5	4	0.67	0.060	0.077
14	1.5	4	0.67	0.048	0.050
15	1.5	4	0.67	0.043	0.045
16	1.5	4	0.67	0.050	0.067
17	1.5	4	0.67	0.065	0.077
18	1.5	4	0.67	0.050	0.050
19	3	9	3	0.050	0.050
20	4	12	4	0.046	0.046
21	4	12	3	0.100	.100
22	2	8	3	0.056	0.056
23A	8	13.5	3.75	0.070	0.070
23B	8	15	7.25	0.065	0.065
23C	10	17.5	3.85	0.056	0.056

[a] Minimum bottom width measured at minimum depth from top of channel.

TABLE 3.7-3

SUMMARY OF CRANDALL CANYON DIVERSION BERM GEOMETRIES

BERM (CCB-)	MINIMUM TOP WIDTH (FEET)	MINIMUM HEIGHT (FEET)
1	0.5	1.5
2	1.0	10.0
3	1.0	2.0
4	2.0	1.5
5	0.5	1.0
6	1.0	1.5
7	1.0	2.0
8	2.0	0.5
9	1.0	2.0

TABLE 3.7-4
SUMMARY OF CRANDALL CANYON DIVERSION DITCH CALCULATIONS

DITCH (CCD-)	CONTRIBUTING DRAINAGE AREA (CCWS-)	PEAK DISCHARGE (CFS)	AVERAGE FLOW DEPTH (FT)	FREEBOARD (FT)	MAXIMUM FLOW VELOCITY (FT/S)
1	U1	3.31	0.25	0.75	3.9[a]
2	U2	14.3	0.52	0.48	7.3[a]
3	U3	1.35	0.19	0.81	3.2
4	U5	.26	0.10	0.90	2.0
5	U7	1.43	0.36	0.91	5.4
6	U8	.69	0.10	2.4	2.5
7A	U10	1.20	0.12	3.38	2.7
7B	U10	1.20	0.10[b]	3.9	3.9
8A	U12	0.84	0.13	0.54	2.7
8B	U36	0.17	0.05	0.62	1.3[a]
9	U14	0.37	0.10	0.73	2.4
10	U15	1.81	0.22	0.78	2.9
11	U16	0.38	0.10	0.90	2.1
12	U18	0.49	0.11	0.72	2.1
13	U20	0.47	0.12	0.55	2.5
14	U22	0.47	0.13	0.54	2.1
15	U24	1.69	0.27	0.4	3.1
16	U25	0.92	0.18	0.49	3.0
17	U26	1.07	0.19	0.48	3.3
18	U27	1.50	0.24	0.43	3.1[a]
19	U29	0.09	0.10	2.9	0.9[a]
20	U31	0.26	0.10	3.9	1.2[a]
21	U33	0.14	0.10	2.9	1.2[a]
22	U34	1.22	0.19	2.81	3.0[a]
23A	U1 - U9, U28	437	2.75	1.0	15.8[a]
23B	U1-U11,U28-U32	511	6.25	1.0	15.1[a]
23C	U1-U12,U28-U33,U36	514	2.85	1.0	14.2[a]

[a] Velocity based on average ditch slope.
[b] Flow depth based on maximum velocity.

TABLE 3.7-5

CULVERT CAPACITY SUMMARY

CUL-VERT (CCC-)	SUBBASIN (CCWS-)	AREA (MI^2)	CURVE NUMBER	T_c (HR)	PEAK FLOW (CFS)	PIPE SIZE	INLET TYPE	HW[a]/D
1	U1	.038	70	.204	3.31	24"	MITERED	<.5
2	U2	.359	70	.387	14.3	84"	MITERED	<.5
3	U3 & U4	.053	70	.159	5.14	24"	MITERED	.55
4	U5 & U6	.019	70	.111	2.06	24"	MITERED	<.5
5	U7	.013	70	.107	1.43	24"	MITERED	<.5
6	U8 & U9	.178	70	.361	7.47	48"	HDWALL	<.5
7	U1 THRU U9 & U28	2.84	68	.844	77.9	P.ARCH 17.5' X 10.5'	HDWALL	<.35
8	U1 THRU U11 & U28 THRU U32	3.33	68	.852	91.2	P.ARCH 17.5' X 10.5'	HDWALL	<.35
9	U29 & U30	.363	65	.366	6.26	84"	HDWALL	<.5
10	U-29	.002	65	.041	0.09	24"	HDWALL	<.5
11	U31 & U32	.080	65	.207	1.62	48"	MITERED	<.5
12	U33	.004	65	.075	0.14	48"	MITERED	<.5
13	U34	.060	65	.203	1.22	36"	MITERED	<.5
14	U36 & U13	.031	70	.122	3.27	18"	MITERED	.68
15	U14	.003	70	.060	0.37	18"	MITERED	<.5
16	U15	.016	70	.095	1.81	18"	MITERED	<.5
17	U16 & U17	.021	70	.115	2.26	18"	MITERED	.54
18	U18 & U19	.071	70	.171	6.67	24"	MITERED	.65
19	U20 & 21	.044	70	.161	4.25	24"	PROJECT	<.5
20	U22 & U23	.017	70	.098	1.91	18"	PROJECT	<.5
21	U24	.015	70	.097	1.69	18"	PROJECT	<.5

(a) Headwater Depth in Diameters (HW/D).

TABLE 3.7-5 (Continued)

CULVERT CAPACITY SUMMARY

CULVERT (CCC-)	SUBBASIN (CCWS-)	AREA (MI²)	CURVE NUMBER	T_c (HR)	PEAK FLOW (CFS)	PIPE SIZE	INLET TYPE	HW[a]/D
22	U25	.008	70	0.086	0.92	18"	MITERED	<0.5
23	U26	.009	70	0.074	1.07	18"	MITERED	<0.5
24	ALL SUBWATER-SHEDS	4.05	68	1.067	101.8	P.ARCH 17.5' X 10.5'	HDWALL	<0.35
25	D1(A)	.004	90	0.134	2.46	18"	MITERED	0.57
26	U12	.007	70	0.071	0.84	18"	MITERED	<0.5
27	U37	.002	70	0.060	0.25	18"	MITERED	<0.5
28	U32	0.072	65	0.120	2.21	18"	MITERED	<0.5

[a] Headwater Depth in Diameters (HW/D).

TABLE 3.7-6

CRANDALL CANYON CULVERT FLOW VELOCITY SUMMARY

CULVERT (CCC-)	SIZE (IN)	SLOPE (%) (MEASURED IN THE FIELD)	FLOW VELOCITY (FT/SEC)	REQUIRED RIPRAP SIZE (IN)	EXISTING RIPRAP SIZE (IN)
1	24	9.6	7.5	6	8
2	84	1.7	5.3	1	0.5
3	24	7.9	8.1	7	8
4	24	0.9	2.8	None	4
5	24	0.9	2.5	None	12
6	48	0.9	3.9	None	1
7	PIPE ARCH, 17.5 FT X 10.5 FT	5.2	10.0	10	12
8	PIPE ARCH, 17.5 FT X 10.5 FT	0.9	5.4	1	6
9	84	0.9	3.4	None	6
10	24	culvert connects directly into CCC-11			
11	48	1.7	3.1	None	6
12	48	12.3	2.9	None	12
13	36	51.0	9.7	10	12
14	18	10.0	7.8	6	6
15	18	6.0	3.5	None	12
16	18	14.0	7.5	6	12
17	18	11.0	7.3	5	8
18	24	4.0	6.7	3	15
19	24	9.0	7.9	7	12
20	18	0.5	2.3	None	15
21	18	5.0	5.1	1	15

TABLE 3.7-6 (Continued)

CRANDALL CANYON CULVERT FLOW VELOCITY SUMMARY

CULVERT (CCC-)	SIZE (IN)	SLOPE (%) (MEASURED IN THE FIELD)	FLOW VELOCITY (FT/SEC)	REQUIRED RIPRAP SIZE (IN)	EXISTING RIPRAP SIZE (IN)
22	18	6.0	4.6	None	18
23	18	14.1	6.5	5	6
24	PIPE ARCH, 17.5' X 10.5'	1.7	7.1	2	8
25	18	21.3	9.3	None	Conc. Apron
26	18	154.0	14.1	21	10
27	18	111.0	8.5	7	8
28	18	15.4	8.1	5	-

TABLE 3.7-7

POND 014 STAGE-CAPACITY DATA

ELEVATION (FT)	AREA (FT^2)	INCREMENTAL VOLUME (FT^3)	CUMULATIVE VOLUME (FT^3)
6757.5	0		0
		534.5	
6758	2137.9		534.5
		3296.3	
6759	4454.7		3830.8
		5099.5	
6760	5744.3		8930.3
		6214.2	
6761	6684.1		15,144.5
		7159.9	
6762	7635.7		22,304.4
		8135.6	
6763	8635.4		30,440.0
		9161.4	
6764	9687.4		39,601.4
		10,029.3	
6765	10,371.1		49,630.7
		11,167.8	
6766	11,964.5		60,798.5
		12,517.3	
6767	13,070.1		73,315.8
		13,728.6	
6768	14,387.0		87,044.4
		15,209.2	
6769	16,031.4		102,253.6
		8200.8	
6769.5	16,771.8		110,454.4

TABLE 3.7-8

POND 015 STAGE-CAPACITY DATA

STAGE	ELEVATION (FT)	AREA (FT^2)	INCREMENTAL VOLUME (FT^3)	CUMULATIVE VOLUME (FT^3)
Bottom	89.2	2,312		0
			1,968	
	90.0	2,608		1,968
			2,854	
	91.0	3,100		4,822
			3,350	
	92.0	3,600		8,172
			3,716	
	93.0	3,832		11,880
			4,380	
	94.0	4,928		16,268
			5,282	
	95.0	5,636		21,550
			5,776	
	96.0	5,916		27,326
			6,460	
	97.0	7,004		33,786
			7,354	
	98.0	7,704		41,140
			1,558	
Primary Spillway	98.2	7,871		42,698
			6,564	
	99.0	8,540		49,262
			5,285	
Emergency Spillway	99.6	9,076		54,547
			3,685	
	100.0	9,348		58,232
			7,737	
Top of Embankment	100.8	9,994		65,969

TABLE 3.7-9

SLOPE PARAMETERS

SECTION	SOIL TYPE	MOIST UNIT WEIGHT (PCF)[a]	SATURATED UNIT WEIGHT (PCF)[a]	COHESION (PSF)[b]	ANGLE OF INTERNAL FRICTION (°)[b]	PORE PRESSURE PARAMETER	PORE PRESSURE CONSTANT
Pond 015 C - C'	Sandy Gravel (GP)	130	145	0	37	0	0
Pond 015 D - D'	Sandy Gravel (GP)	130	145	0	37	0	0

(a) See Appendix 3.7I for unit weight calculations based on NAVFAC DM-7, 1971, and Hoek, 1981.
(b) NAVFAC DM-7. 1971. TABLE 9-1. Typical Properties of Compacted Materials.

TABLE 3.7-10

MASS BALANCE EARTHWORK SUMMARY
CRANDALL CANYON RECLAMATION PLAN

AREA	CUT (CY)		FILL (CY)		NET (CY)	
	Subsoil	Topsoil	Subsoil	Topsoil	Subsoil	Topsoil
TOPSOIL STOCKPILE NO. 1	0	1210[a][b]	0	0	0	0[b]
TOPSOIL STOCKPILE NO. 2	0	6680[a]	0	0	0	6680 (C)
PHASE I [c][d]	106,836	0	115,485	6680	8649 (F)[e]	6680 (F)
PHASE II[d][f]	30,255	0	27,110	0	3145 (C)[e]	0
SUBTOTAL	137,091	6680	142,595	6680	5504 (F)[e]	0
TOTAL	143,771		149,275		5504 F[e]	

[a] The volume of topsoil was determined by field survey (Blackhawk Engineering, April 1995).

[b] The topsoil from stockpile No. 1 is not included in the earthwork calculations because of the presence of noxious weeds. If the noxious weed seed can be destroyed, the topsoil will be uniformly spread over the Phase II reclamation area, adding 2 inches to the thickness of the topsoil.

[c] Earthwork volumes include the facilities area, leach field access road (A-1), and a portion of the main access road (P-1). Phase I and II reclamation areas are illustrated on Exhibits 3.7-7A, 3.7-7B, and 3.7-7C.

[d] Volume calculation by GRID method with a node spacing of 25 feet, a tolerance of 0.5 feet, and a swell factor of 1.0. (Softdesk, Inc., formerly DCA Software, Inc.)

[f] Excess cut material and fill shortages will be compensated for in the field with minor excavation and backfill modifications during reclamation construction activities. Changes will be based on survey information generated during reclamation.

[e] Earthwork volumes for remaining main access road (P-1) after completion of Phase I reclamation.

TABLE 3.7-11

**CRANDALL CANYON
RECLAMATION HYDROLOGY PEAK FLOWS**

DIVERSION	CONTRIBUTING WATERSHEDS (CCRWS-)	AREA (ACRES)	PEAK WATERSHED FLOW[a] (CFS)
CCRD-2	2	43.50	0.45
CCRD-4	4	47.00	0.48
CCRD-6	6	238.90	2.41
CCRD-8	8	47.10	0.48
CCRD-11	11	24.22	0.52
CCRD-12	12	229.57	4.84
CCRD-14	14	26.17	0.57
CCRD-16	16	11.13	0.24
CCRD-19	19	121.4	2.55
CCRD-20	20	15.40	0.34
CCRD-21	21	23.80	0.40
CCRD-23	23	18.76	0.41
CCRD-25	25	9.92	0.22
CCRD-27	27	11.29	0.25
CCRD-30	30	41.52	0.90
CCRD-32	32	25.47	0.55

TABLE 3.7-11 (Continued)

CRANDALL CANYON
RECLAMATION HYDROLOGY PEAK FLOWS

DIVERSION OR MAIN CHANNEL SECTION [b]	CONTRIBUTING WATERSHEDS (CCRWS-)	AREA (ACRES)	PEAK WATERSHED FLOW[a] (CFS)
CCRD-34	34	8.08	0.18
35+80 - 34+70	10 - 16	1659.40	100.78
34+70 - 33+40	9 - 17	1670.70	105
33+40 - 31+90	9 - 18	1677.90	110
31+90 - 22+00	7 - 20	1874.30	120
22+00 - 16+80	7 - 20	1874.30	122
16+80 - 14+60	5 - 20	2117.30	128
14+60 - 9+10	3 - 21	2191.60	129
9+10 - 7+20	3 - 22	2198.80	130
7+20 - 5+85	3 - 22	2198.80	131
5+85 - 3+50	3 - 22	2198.80	132
3+50 - 2+10	2 - 22	2242.40	133
2+10 - 0+00	2 - 22	2242.40	134.75
replacement of culvert near highway	1 - 38	2716.49	159.42

[a] Diversions are designed for the 10-year, 6-hour storm (P = 1.4"), unless otherwise noted.
[b] Main channel designed for the 100-year, 6-hour storm (P = 2.1").

NOTE: See Appendix 3.70 for supporting calculations.

TABLE 3.7-12

CRANDALL CANYON
RECLAMATION HYDROLOGY CHANNEL GEOMETRIES

RECLAMATION W.S.[a]	MINIMUM BOTTOM WIDTH[b] (FT)	TOP WIDTH (FT)	MINIMUM DEPTH (FT)	MAXIMUM SLOPE (%)	MINIMUM SLOPE (%)	MAXIMUM FLOW DEPTH (FT)	FREEBOARD (FT)	MAXIMUM VELOCITY (FPS)	RIPRAP REQUIRED D_{50}[c] (IN)
CCRWS-2	0	8	1	32	8	0.21	0.79	4.38	3
CCRWS-4	0	8	1	40	4.9	0.55	0.45	4.84	3
CCRWS-6	0	8	1	9	2.9	0.47	0.53	4.14	3
CCRWS-8	0	8	1	16	6.4	0.22	0.78	3.43	3
CCRWS-11	0	8	1	10	10	0.21	0.79	2.93	NONE
CCRWS-12	0	8	1	6	6	0.53	0.47	4.23	3
CCRWS-14	0	8	1	13.3	13.3	0.21	0.79	3.34	3
CCRWS-16	0	8	1	12.1	12.1	0.15	0.85	2.60	NONE
CCRWS-19	0	8	1	16	5.3	0.43	0.57	5.70	3
CCRWS-21	0	8	1	5.3	3.2	0.24	0.76	2.17	NONE
CCRWS-23	0	8	1	17.6	17.6	0.17	0.83	3.42	3
CCRWS-25	0	8	1	24	24	0.13	0.87	3.29	3
CCRWS-27	0	8	1	27	27	0.14	0.86	3.68	3
CCRWS-30	0	8	1	17.5	17.5	0.23	0.77	4.15	3

(a) See Exhibit 3.7-7B for channel and reach locations.
(b) Minimum bottom width measured at minimum depth from top of channel. If zero then channel is triangular
(c) Riprap D_{50} calculated using the Searcy method developed for the U.S.D.O.T.

TABLE 3.7-12 (Continued)

CRANDALL CANYON
RECLAMATION HYDROLOGY CHANNEL GEOMETRIES

RECLAMATION CHANNEL[a] OR SECTION OF MAIN CHANNEL	MINIMUM BOTTOM WIDTH[b] (FT)	TOP WIDTH (FT)	MINIMUM DEPTH (FT)	MAXIMUM SLOPE (%)	MINIMUM SLOPE (%)	MAXIMUM FLOW DEPTH (FT)	FREEBOARD (FT)	MAXIMUM VELOCITY (FPS)	RIPRAP REQUIRED D_{50}[c] (IN)
CCRWS-32	0	8	1	9.3	9.3	0.22	0.78	2.89	NONE
CCRWS-34	0	8	1	27.3	27.3	0.14	0.86	3.66	3
35+80 - 34+70	8	20	2	9.1	7.7	0.99	0.97	9.33	12
34+70 - 22+00	8	20	2	7.7	5.1	1.23	0.77	9.23	9
22+00 - 16+80	8	20	2	3.8	3.5	1.32	0.68	7.98	6
16+80 - 7+20	8	20	2	5.5	4.5	1.32	0.68	8.72	9
7+20 - 3+50	8	20	2	8.5	7.4	1.20	0.80	9.87	12
3+50 - 0+00	8	20	2	6.7	5.0	1.32	0.68	9.44	9
REPLACEMENT OF CULVERT BY HIGHWAY	8	20	2	10	10	1.23	0.77	11.06	12

(a) See Exhibit 3.7-7B for channel and reach locations.
(b) Minimum bottom width measured at minimum depth from top of channel. If zero then the channel is triangular
(c) Riprap D_{50} calculated using the Searcy method developed for the U.S.D.O.T..
(d) D_{50} = 9 inches is required only on the steep reach of this diversion below Pond 014.

TABLE 3.7-13

CRANDALL CANYON
RECLAMATION HYDROLOGY BERM GEOMETRIES

RECLAMATION BERM[a]	MINIMUM TOP WIDTH (FT)	MAXIMUM SIDE SLOPE H:V	MINIMUM HEIGHT (FT)	FREEBOARD (FT)
CCRB-1	1.0	1.5:1	2.0	1.52
CCRB-2	1.0	1.5:1	1.5	1.02
CCRB-3	1.0	1.5:1	1.5	1.02
CCRB-4	1.0	1.5:1	2.0	1.52

[a] See Exhibit 3.7-7B for berm locations.

TABLE 3.7-14
RIPRAP AND FILTER VOLUMES
CRANDALL CANYON RECLAMATION HYDROLOGY

CHANNEL	RIPRAP D_{60} (IN)	LENGTH (FT)	PERIMETER (FT)	RIPRAP THICKNESS (IN)	RIPRAP VOLUME (FT^3)	FILTER THICKNESS (IN)	FILTER VOLUME (FT^3)
Main Channel							
0+00-3+50	9	350	29.9	18	13,300	12	11,651
3+50-7+20	12	370	33.3	24	19,980	12	13,542
7+20-16+80	9	960	29.9	18	36,480	12	31,958
16+80-22+00	6	520	26.6	12	12,480	12	15,584
22+00-34+70	9	1270	29.9	18	48,260	12	42,278
34+70-35+80	12	110	33.3	24	5,940	12	4,026
Tributary Channels							
CCRWS-2	3	130	9.0	6	683	6	1040
CCRWS-4	3	180	9.0	6	945	6	1440
CCRWS-6	3	440	9.0	6	2310	6	3020
CCRWS-8	3	130	9.0	6	683	6	1040
CCRWS-12	3	100	9.0	6	525	6	800
CCRWS-14	3	100	9.0	6	525	6	800
CCRWS-19	3	200	9.0	6	1050	6	1600
CCRWS-21	3	170	9.0	6	893	6	1410
CCRWS-25	3	125	9.0	6	656	6	1000

TABLE 3.7-14
RIPRAP AND FILTER VOLUMES
CRANDALL CANYON RECLAMATION HYDROLOGY

CHANNEL	RIPRAP D_{50} (IN)	LENGTH (FT)	PERIMETER (FT)	RIPRAP THICKNESS (IN)	RIPRAP VOLUME (FT^3)	FILTER THICKNESS (IN)	FILTER VOLUME (FT^3)
Tributary Channels							
CCRWS-27	3	90	9.0	6	473	6	720
CCRWS-30	3	80	9.0	6	420	6	640
CCRWS-34	3	110	9.0	6	578	6	880
TOTAL					146,181 (10,232 tons)[a]		133,430 (8,672 tons)[a]

[a] Unit weight of riprap is based on an in-place density of 140 pounds per cubic foot.
[b] Unit weight of granular filter is based on an in-place density of 130 pounds per cubic foot.

APPENDIX 3.7A

SLOPE STABILITY ANALYSIS

MINE ACCESS ROAD IN CRANDALL CANYON

CASTLE GATE, UTAH

SLOPE STABILITY ANALYSIS

MINE ACCESS ROAD IN CRANDALL CANYON

CASTLE GATE, UTAH

OCTOBER 1981

ROLLINS, BROWN AND GUNNELL, INC.

Professional Engineers

1435 West 820 North, P.O. Box 711

Provo, Utah 84603

cc6.chapter 3/7

RBG

ROLLINS, BROWN AND GUNNELL, INC.
PROFESSIONAL ENGINEERS

October 8, 1981

Horrocks Engineers
1 West Main
American Fork, UT 84003

Gentlemen:

In accordance with your request, a slope stability analysis has been performed for a mine access road in Crandall Canyon located southwest of Castlegate, Utah. The purpose of the investigation was to obtain an indication of the stability of existing slopes and the slopes contemplated for modifications to the highway.

The work has been completed in accordance with a verbal proposal submitted to our organization, and the results of the investigation are outlined in the following sections of this report. The information contained in the report is discussed under the following headings. (1) General Site Conditions and Investigated Approach, (2) The Results of Field and Laboratory Tests, (3) A Slope Stability Analysis, and (4) Conclusions and Recommendations.

1. General Site Conditions and Investigated Approach

The proposed access road begins in the vicinity of the Price River Coal Company Mine and extends for a distance of 6700 feet down the canyon. An existing road is located in the canyon and it is anticipated that this road will be widened and modified during the new construction program. Typical roadway cross sections along the proposed alignment is presented in Figure No. 1. The subsurface materials along the proposed alignment generally consist of large rock fragments with a matrix of sandy silt.

The existing roadway was constructed by dumping the excavated material along the roadway over the slope and permitting it to reach equilibrium with the surrounding conditions. Insofar as we can determine no major slope stability problems have occurred along the existing alignment, and repairs to the road have consisted of removal of relatively small amounts of material which have sluffed downward from the adjacent slopes. Since constructing drilling locations uphill and downhill from the roadway would be relatively difficult and could only be performed at a substantial cost, and since the cut into the hillside where the roadway is located generally defines the character of the material throughout the soil profile in this area, field investigations have been limited to determining the in-place density of the subsurface materials along the natural slopes and along the cut and fill slopes performed during the construction of the original facility.

It is our opinion that the in-place density of the subsurface materials at a depth of approximately 1 to 2 feet below the existing ground surface will be the lowest in-place unit weight of any material within the soil profile along the slope. Since the natural material contains a considerable amount of rock fragments, it is not possible to obtain satisfactory undisturbed samples in the subsurface material. It is our opinion, however, that the shearing strength of the subsurface soils will likely be determined by the fine grain fraction which exists within the overburden materials throughout the profile.

It is believed that a reasonable estimate of the in-place shearing strength can be obtained by performing triaxial shear tests on samples of the fine grain material compacted to its in-place unit weight and natural moisture content. The shearing strengths obtained by this approach have been utilized in stability calculations to provide an indication of the factor of safety for the existing and contemplated slopes.

2. The Results of Field and Laboratory Tests

Field and laboratory tests performed during this investigation to determine the physical characteristics of the subsurface material in the area have included in-place unit weight, natural moisture content, Atterberg limits, mechanical analysis, and triaxial shear tests. The summary of all test data performed during the investigation with the exception of the triaxial shear tests are presented in Table No. 1, Summary of Test Data.

It will be noted from this table that the in-place unit weight varies from about 82.4 pounds per cubic foot to 105.0 pounds per cubic foot and that the natural moisture content varies from 8.4 to 16.6 percent. The results of mechanical analysis performed on relatively large samples obtained in the field indicate that the amount of material passing at 200 sieve will likely range from 35 to 37 percent. The results of the Atterburg limits performed on representative samples of the subsurface material indicate that the fine grain fraction of the overburden materials have low plasticity characteristics.

Three triaxial shear tests were performed on representative samples of the sand and silt fraction compacted at the natural moisture content to an in-place unit weight of about 100 pounds per cubic foot. The results of these tests are presented in the form of a Mohr Envelope in Figure No. 2 and it will be observed that a cohesion of 6 pounds per square inch and a friction angle of 31 degrees was obtained.

Three triaxial shear tests were also performed on representative samples of the silt and sand fraction compacted at the initial moisture content to a density of 82.5 pounds per cubic foot. The results of these three tests are also presented in the form of Mohr Envelope in Figure No. 3. It will be noted that a cohesion of 5 pounds per square inch and a friction angle of 30 degrees was obtained for this sample.

It should be noted that materials for the two triaxial tests were obtained at Station 59+30. The results of these tests were used in a stability analyisis to obtain an indication of the slope stability of the materials throughout this general area.

3. Slope Stability Analysis

A computer slope stability analysis has been performed for slopes along the proposed alignment using a computer program based upon Spencers method and developed by Steven Wright at the University of Texas. Spencers method satisfies both force and moment equilibrium and is considered to be an exact slope stability method. The method is based upon two dimensional considerations and is only as accurate as the shear strength parameters used in the analysis.

The stability analysis was performed for cross sections located at Station 10+50 and at Station 58+00. The cross sections at these two stations generally represent the steepest overall cross sections along the existing alignment. The cross sections for each of these stations are presented in Figures 4 and 5. The slopes along the various segments of the cross sections are presented in these figures. The shear strength parameters obtained from the triaxial tests were used in the stability analysis along with representative unit weights obtained from the in-place density tests. The factor of safety was determined for the overall slope conditions shown for the two cross sections shown in Figures 4 and 5. A localized slope stability analysis was performed for the slopes between points A and B in Figure No. 5. The results of the slope stability analysis are presented in Table No. 2 below. It will be observed that a factor of safety of 1.6 was obtained for the slope at Station 10+00 for a cohesion value of 200 psi and a friction angle of 30 degrees. A factor of safety of 1.5 was obtained for the overall slope at Station 58+00 assuming a cohesion of 400 psi and a friction angle of 30 degrees. The analysis performed for the left hand side of the cross section at Station 58+00 indicated a factor of safety of 1.5 for a cohesion of 200 psi and a friction angle of 30 degrees.

TABLE 2
STABILITY ANALYSIS RESULTS

Friction Angle	Cohesion (psf)	Factor of Safety
Station 10+00		
30°	100	1.4
30°	200	1.6
Station 58+00 (Entire Slope)		
30°	100	1.0
30°	200	1.2
31°	200	1.2
30°	400	1.5
30°	500	1.7
Station 58+00 (Left Side of Slope)		
30°	100	1.0
30°	200	1.5
30°	400	2.0

It should be recognized that the slope stability analysis performed above were based upon shear strength parameters determined for materials at their natural moisture content. It has also been assumed that no pore pressures exist within the soil profile at this location.

Based upon the analysis performed above, it is our opinion that slopes characteristic of the profile defined by Figures 4 and 5 will be stable under ordinary conditions. If the environmental conditions throughout the area are such that the slopes become saturated, a decrease in the shearing strength will occur and some pore pressures may develop throughout the profile. Under these conditions, slumping of the steeper slopes will likely occur. It is not anticipated, however, that any massive land movement will occur in this area.

4. Conclusions and Recommendations

Based upon the investigation indicated above, it is our opinion that the following conclusions are warranted:

A. The subsurface materials along the proposed alignment consist of angular fragments with a matrix of silty sands and sandy silts. The entire soil mass constituting the overburden will most likely perform like a granular-type soil.

B. The in-place unit weight of the overburden materials throughout the site will likely vary from about 82.4 pounds per cubic foot to 105 pounds per cubic foot.

C. The shear strength characteristics of the - No. 10 material is a reasonable estimate of the entire soil mass along the alignment and that a cohesion of 5 pounds per square inch and a friction angle of 30 degrees is a reasonable estimate of the strength of these materials in their insitu condition.

D. Slopes characteristic of those shown in Figures 4 and 5 have factors of safety of 1.5 or greater for cohesive values varying from 200 to 400 psi and a friction angle of 30 degrees. The actual cohesion determined in the triaxial shear tests is generally greater than that required for stability.

E. If the subsurface material becomes saturated throughout the life of the facility, the cohesion of the subsurface materials are likely to decrease and slope failures on the steeper slopes will likely occur. Massive slope stability failures do not appear likely in this general area.

Based upon the results of this investigation, the following recommendations are made:

A. Since the strength characteristics of the subsurface materials are sensitive to moisture conditions, every effort should be made in the modification of the proposed facility to prevent surface waters from infiltrating into the subsurface material. A positive drainage system including subsurface pipe drains and cross drains where required should be incorporated into the design of the proposed facility. Cross drains should terminate well below a point where the discharge water could infiltrate into the subsurface materials.

B. Where possible, the roadway materials dumped over the edge of the slope should be densified to increase the shearing strength of these materials. The subgrade in cut areas should also be densified where possible to reduce the liklihood of penetration of moisture into the subsurface materials beneath the roadway.

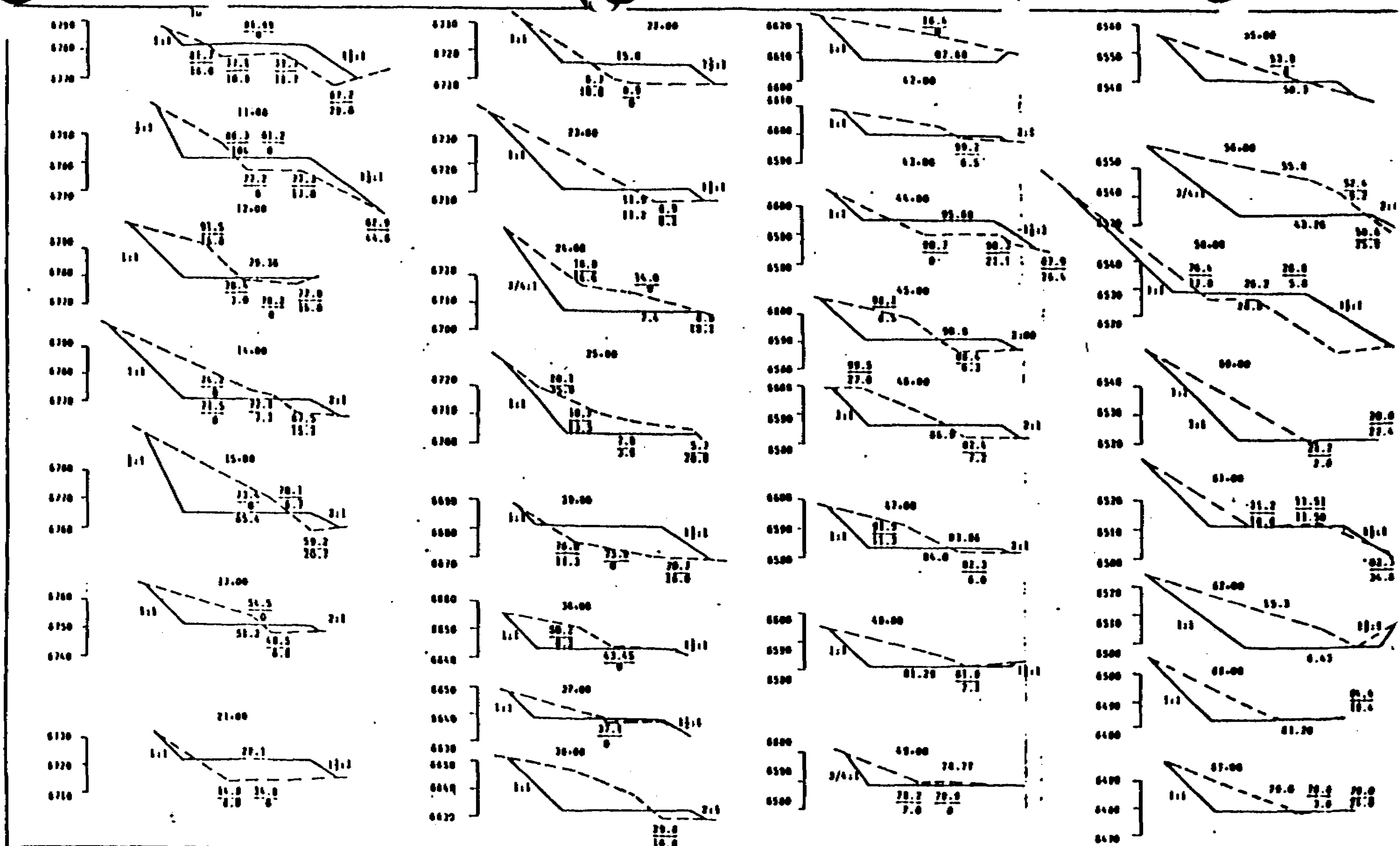
If there are any questions concerning the information contained herein, please contact our office.

Yours truly,

ROLLINS, BROWN AND GUNNELL, INC.

Ralph L. Rollins

dlh



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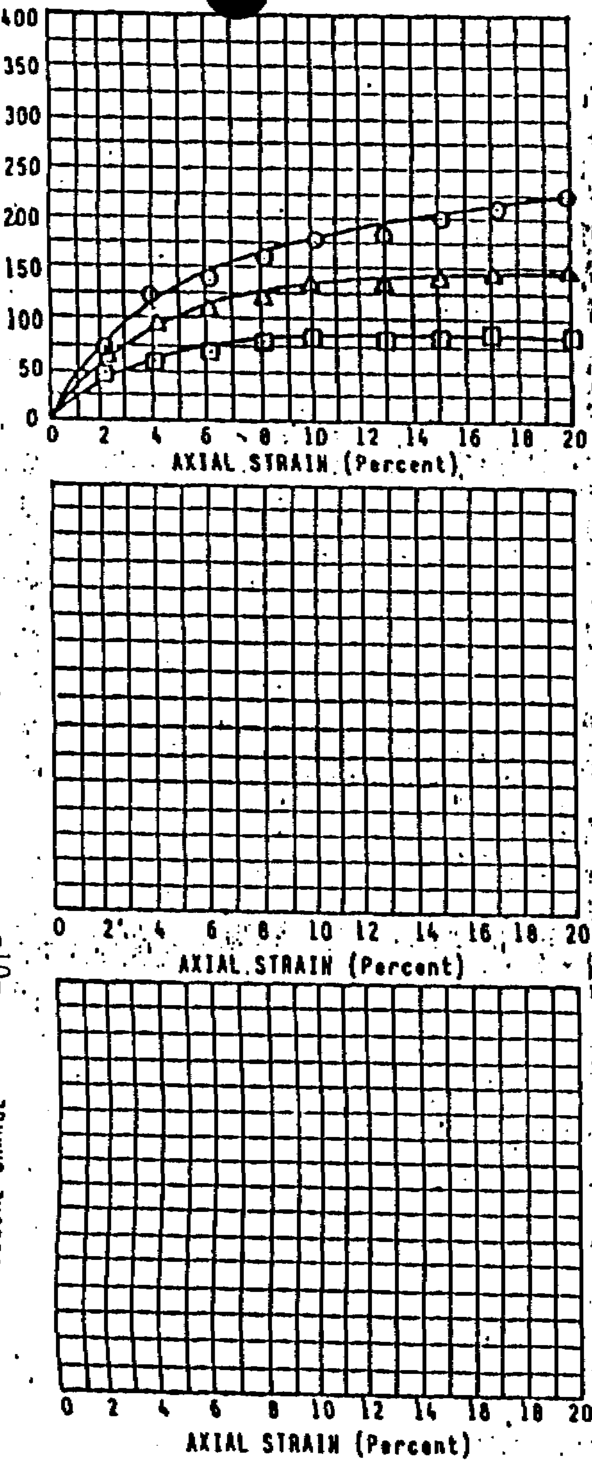
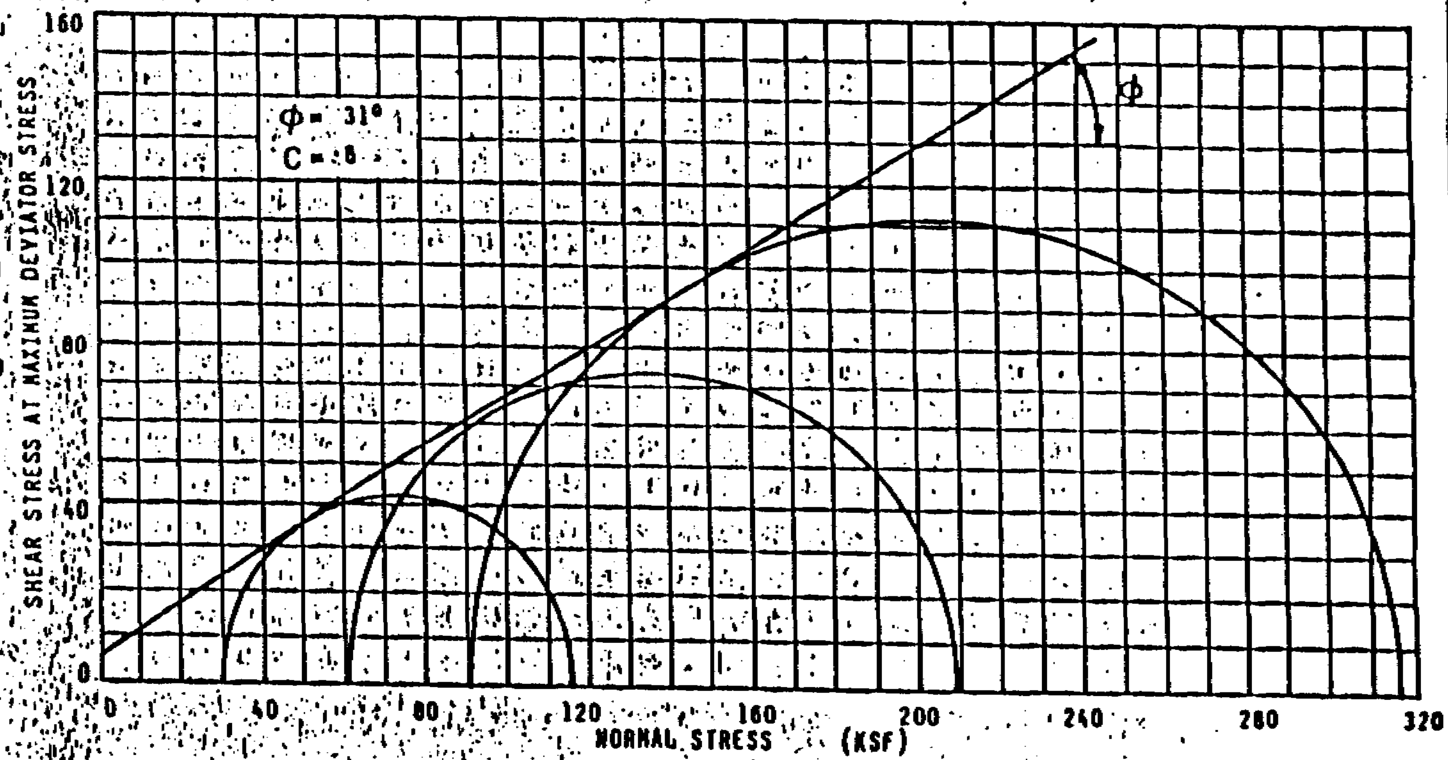
TYPICAL CROSS SECTIONS FOR ROADWAYS ALONG PROPOSED ALIGNMENT
Price River Coal Company Slope Stability Analysis

Figure No. 1



TRIAXIAL SHEAR TEST

SAMPLE NO.



TEST NO. OR SYMBOL	BORING NO. OR DEPTH	SAMPLE DATA: DRY DENSITY (pcf)	MOISTURE % Ini.	MOISTURE % Final	DEGREE OF SATURATION (%)	CONFINING PRESSURE IN PSI	MAXIMUM DEVIATOR STRESS	MAXIMUM PRINCIPAL STRESS RATIO	VALUES AT MOHR COULOMB FAIL.		SAMPLE SIZE LENGTH/DIA. INCHES	STRAIN RATE INCHES/MIN.
⊡	59+30	100.1	9.8		0	30						
△	3'up	100.2	9.8		0	60						
⊙	slope	100.2	9.8		0	90						

ROLLINS, BROWN AND GUNNELL, INC.
PROVO, UTAH

Consulting Engineers

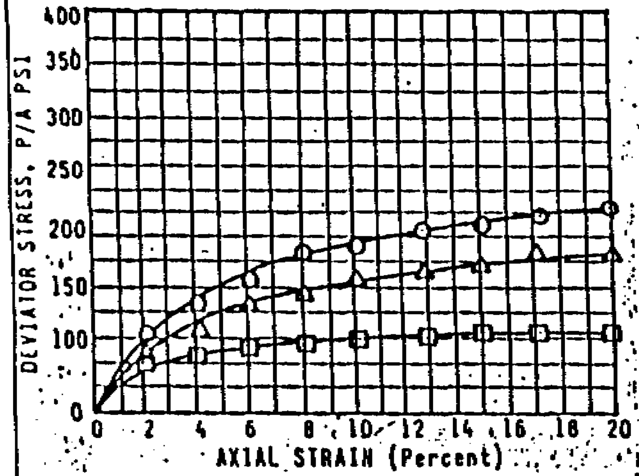
TRIAXIAL SHEAR TEST RESULTS

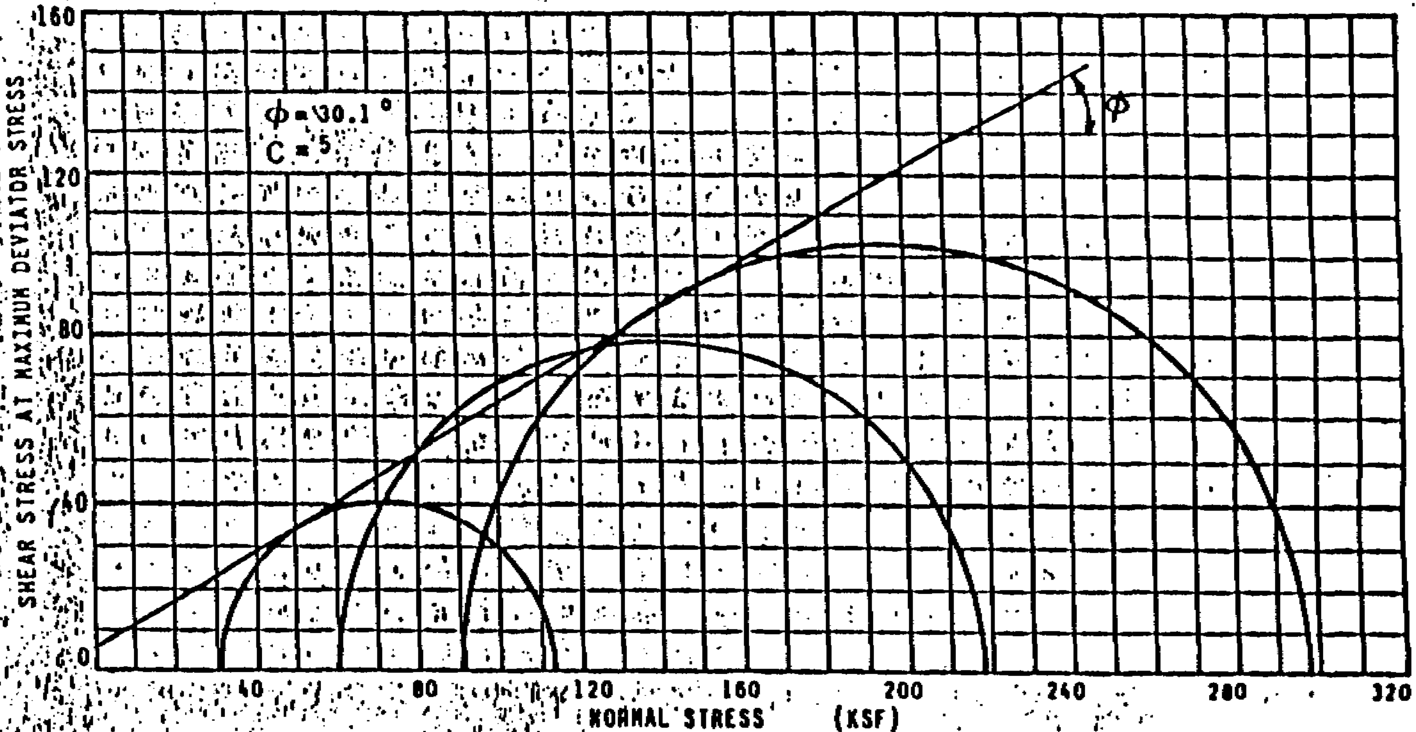
PRICE RIVER COAL

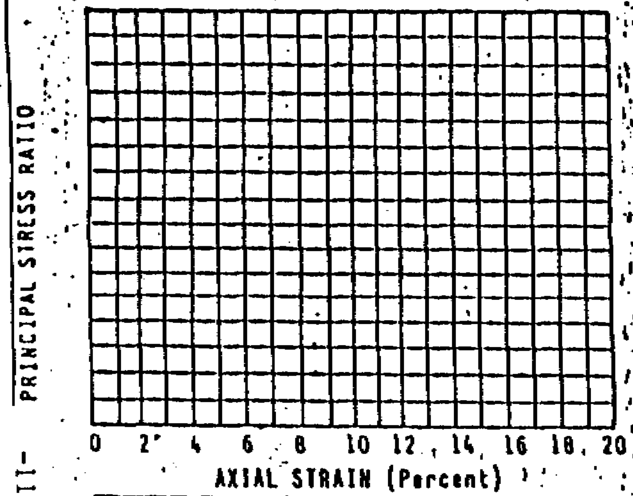
JOB NO.	DATE	FIGURE No. 2

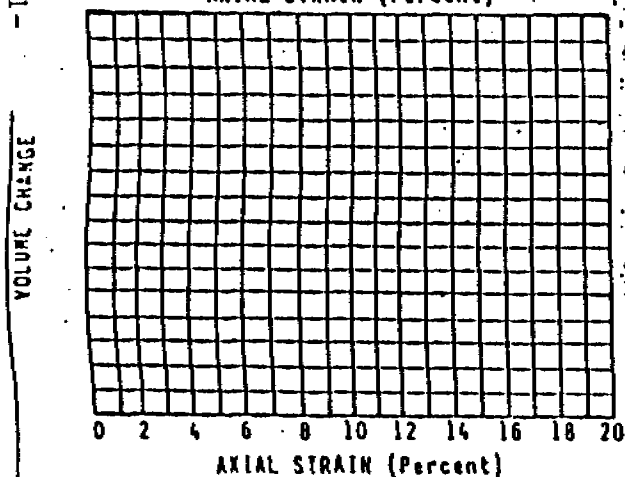
TRIAXIAL SHEAR TEST

SAMPLE NO.





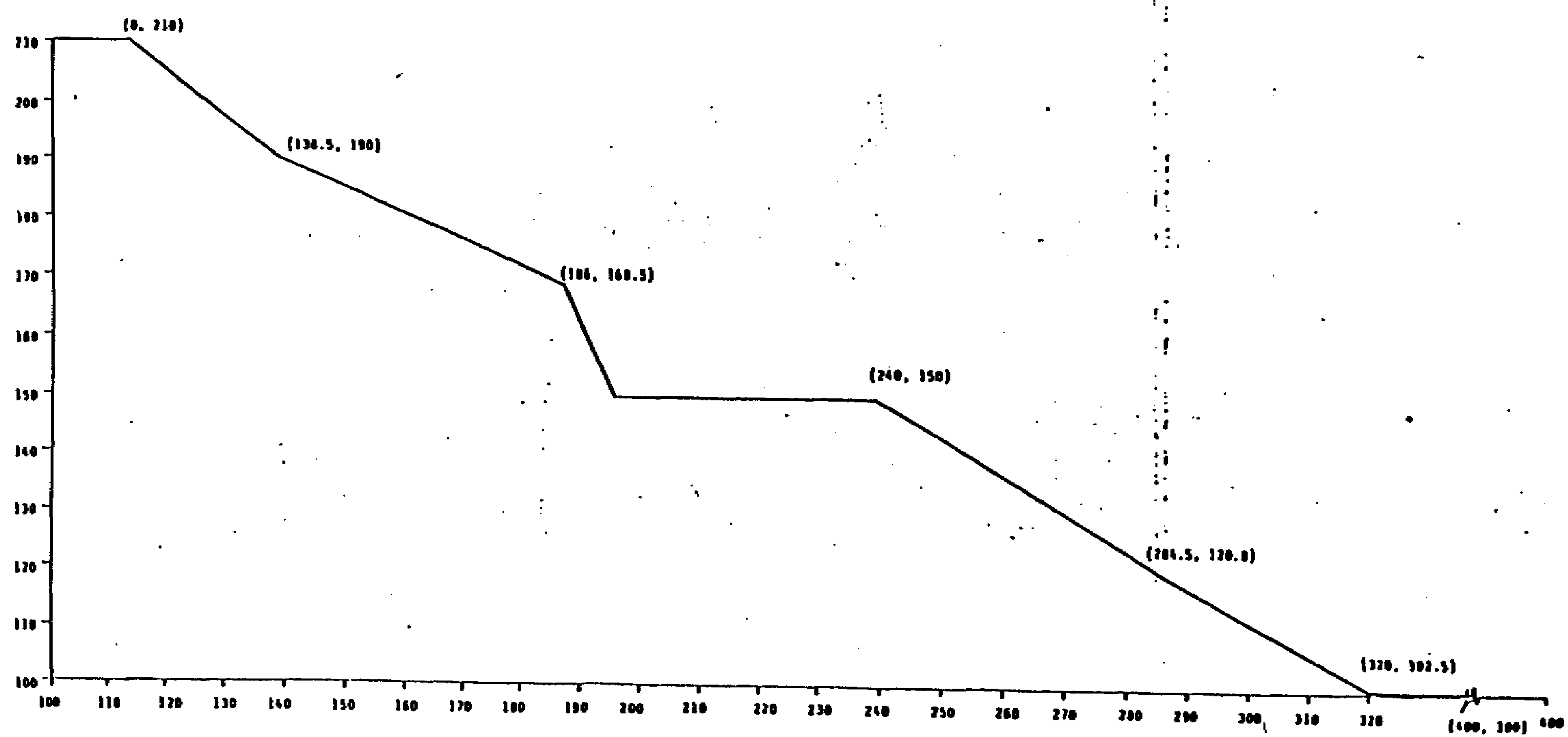




TEST NO. OR SYMBOL	BORING NO. OR DEPTH	SAMPLE DATA: DRY DENSITY (pcf)	MOISTURE % Ini.	MOISTURE % Final	DEGREE OF SATURATION (%)	CONFINING PRESSURE IN PSI	MAXIMUM DEVIATOR STRESS	MAXIMUM PRINCIPAL STRESS RATIO	VALUES AT MOHR COULOMB FAIL.		SAMPLE SIZE LENGTH/DIA. INCHES	STRAIN RATE INCHES/MIN.
□	59+30	82.4	11.7			30						
△	12'up	82.5	11.7			60						
○	slope	82.5	11.7			90						

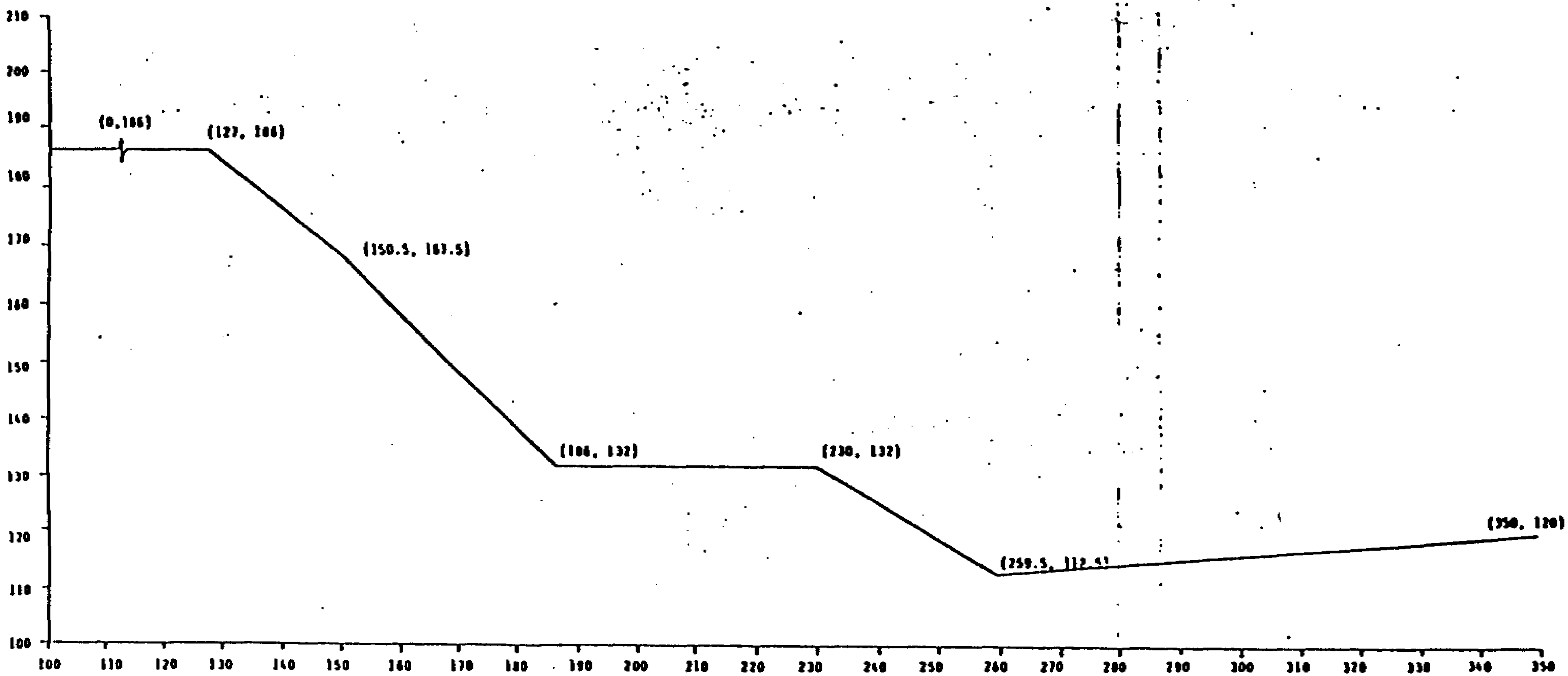
-11-

ROLLINS, BROWN AND GUNNELL, INC. PROVO, UTAH	TRIAXIAL SHEAR TEST RESULTS
	PRICE RIVER COAL
Consulting Engineers	JOB NO. / DATE / FIGURE No. 3



STA. 10 + 00

ROLLINS, BROWN & GUNNELL, Inc. CONSULTING ENGINEERS	Soil Profile Sta. 10+00 Price River Coal Company Slope Stability Analysis	Figure No. 4



STA. 58+00

ROLLINS, BROWN & GUNNELL, Inc. CONSULTING ENGINEERS	Soil Profile Sta. 58+00 Price River Coal Company Slope Stability Analysis	Figure No. 5

TABLE NO. 1 SUMMARY OF TEST DATA

PROJECT Price River Coal Company FEATURE Slopes LOCATION Castledale, Utah

HOLE NO.	STATIONS	LOCATIONS	IN-PLACE UNIT WEIGHT LB/FT³	IN-PLACE MOISTURE PERCENT	IN-PLACE VOID RATIO	UNCONFINED COMPRESSIVE STRENGTH LB/FT²	FRICTION ANGLE φ	CONSISTENCY LIMITS L.L. %	CONSISTENCY LIMITS P.L. %	CONSISTENCY LIMITS P.I. %	MECHANICAL ANALYSIS % GRAVEL	MECHANICAL ANALYSIS % SAND	MECHANICAL ANALYSIS % SILT & CLAY	UNIFIED SOIL CLASSIFICATION SYSTEM
	10+50	3' upslope	100-1	9.1										
		6' upslope	104.2	8.4										
		9' upslope	106.0	8.5										
		12' upslope	102.8	8.9										
	44+45	3' upslope	93.8	9.1				24.9	19.1	5.8				CL-ML
		6' upslope	97.6	9.8				23.3	16.7	6.6				CL-ML
	58+00	3' upslope	86.4	16.6										
		6' upslope	105.0	8.6										
		9' upslope	101.9	8.9										
		12' upslope	99.5	10.0										
		15' upslope	97.5	10.8										
		3' down-slope	100.2	9.8										
		6' down-slope	102.0	8.9										
		9' down-slope	104.7	10.3										

TABLE NO. 1 SUMMARY OF TEST DATA

PROJECT Price River Coal Company FEATURE Slopes LOCATION Castledale, Utah

HOLE NO.	STATIONS	LOCATIONS	IN-PLACE			UNCONFINED COMPRESSIVE STRENGTH LB/FT²	FRICTION ANGLE φ	CONSISTENCY LIMITS			MECHANICAL ANALYSIS			UNIFIED SOIL CLASSIFICATION SYSTEM
			UNIT WEIGHT LB/FT³	MOISTURE PERCENT	VOID RATIO			L.L. %	P.L. %	P.I. %	* % GRAVEL	% SAND	% SILT & CLAY	
	59+30	3' upslope	100.1	9.8				19.9	19.3	0.6	34.0	31.0	35.0	ML
		6' upslope	96.6	9.6				22.8	16.7	6.1	36.0	27.0	37.0	CL-ML
		9' upslope	92.4	9.7				26.5	19.6	6.9				CL-ML
		12' upslope	82.4	11.7				23.8	20.2	3.6				ML

NOTE: Visual observations indicate that approximately 30-40 percent of the overburden material consists of large size gravel and cobbles. This material was not included in the mechanical analysis shown in this table. The overall percent of the material in the silt and clay size range is somewhat less than the mechanical analysis shown herein.

*Less than 1 inch maximum.

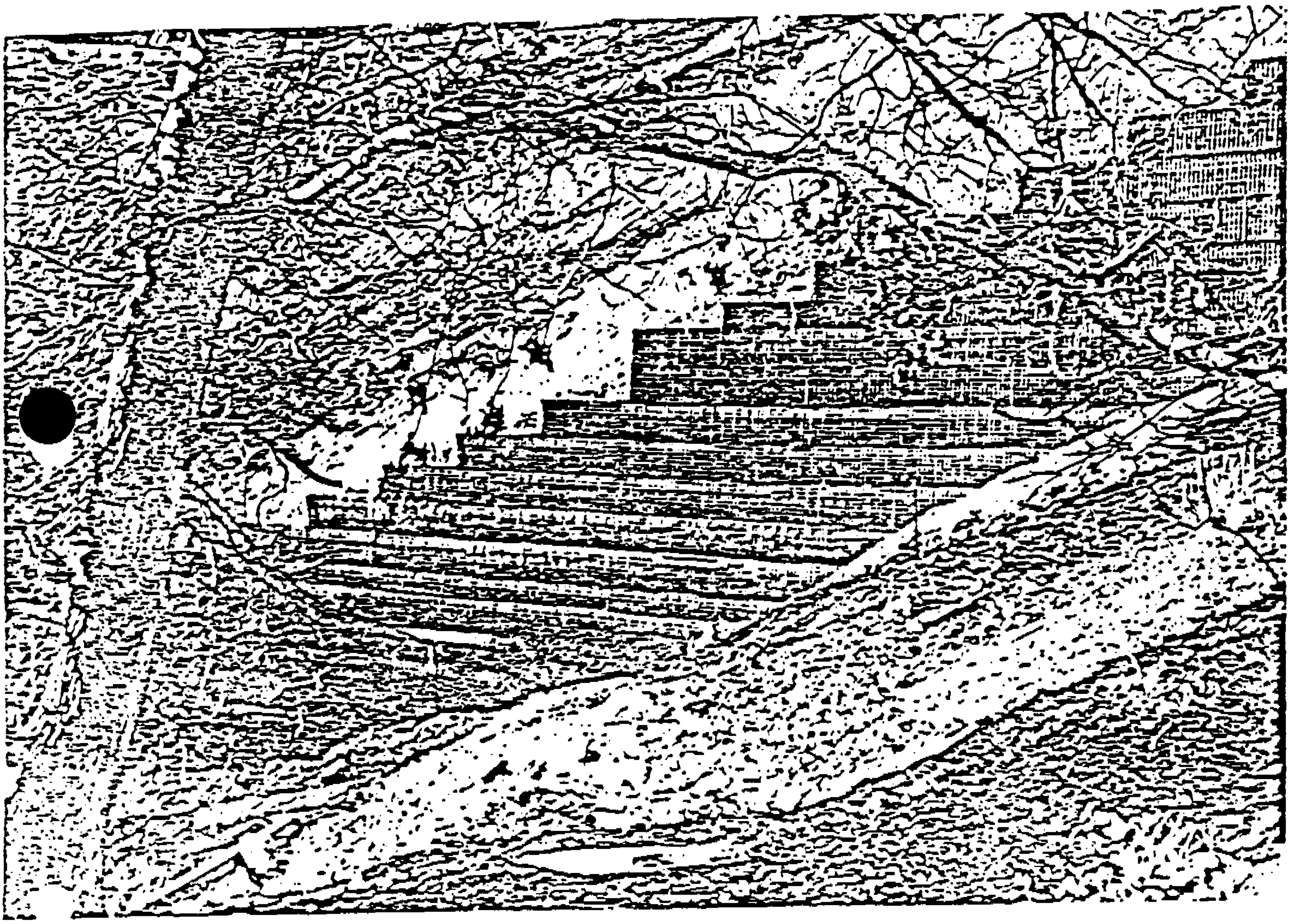
APPENDIX 3.7B

HIFIKER RETAINING WALL

HILFIKER

Welded Wire Wall*

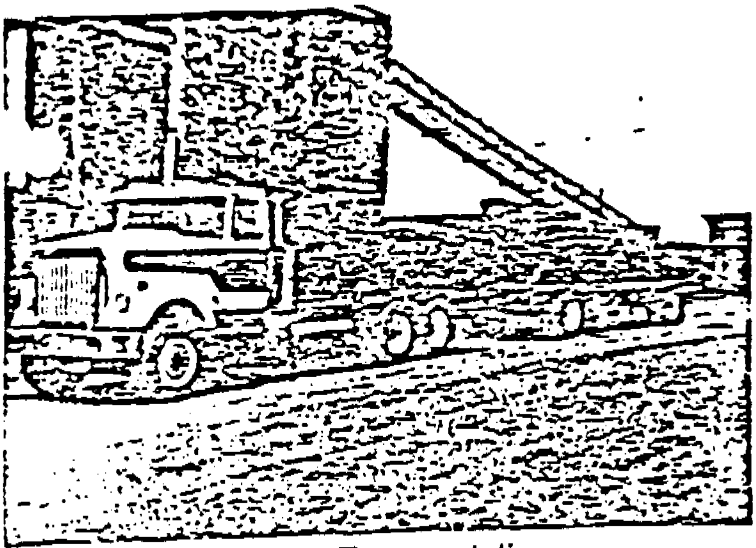
*Patent No. 4117686



Mountain High Ski Resort, Wrightwood, California

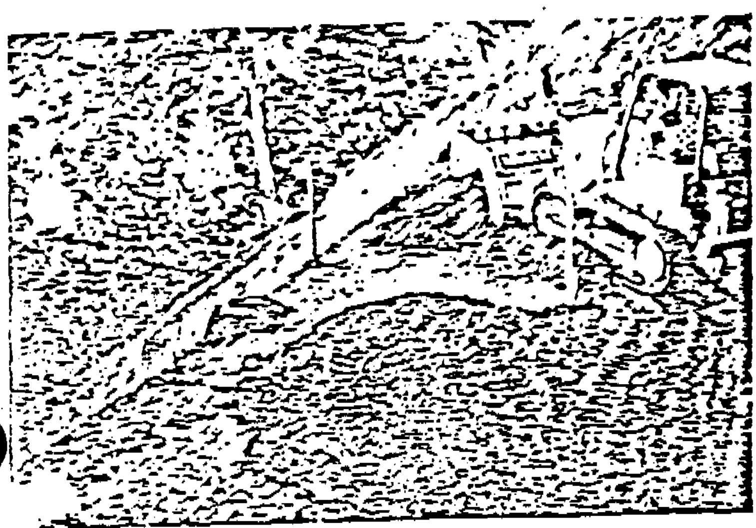
QUALITY PRODUCTS SINCE 1900 - CONCRETE CRIBWALLS SINCE 1947
WELDED WIRE WALLS SINCE 1978

• P.O. Drawer L, Eureka, Calif. 95501 • (707) 443-5091 •



Low Cost Transportation
Up to 5,000 face sq. ft. per load

Lightweight
Allows Hand Placement



Mechanical Equipment for Backfill
and Compaction

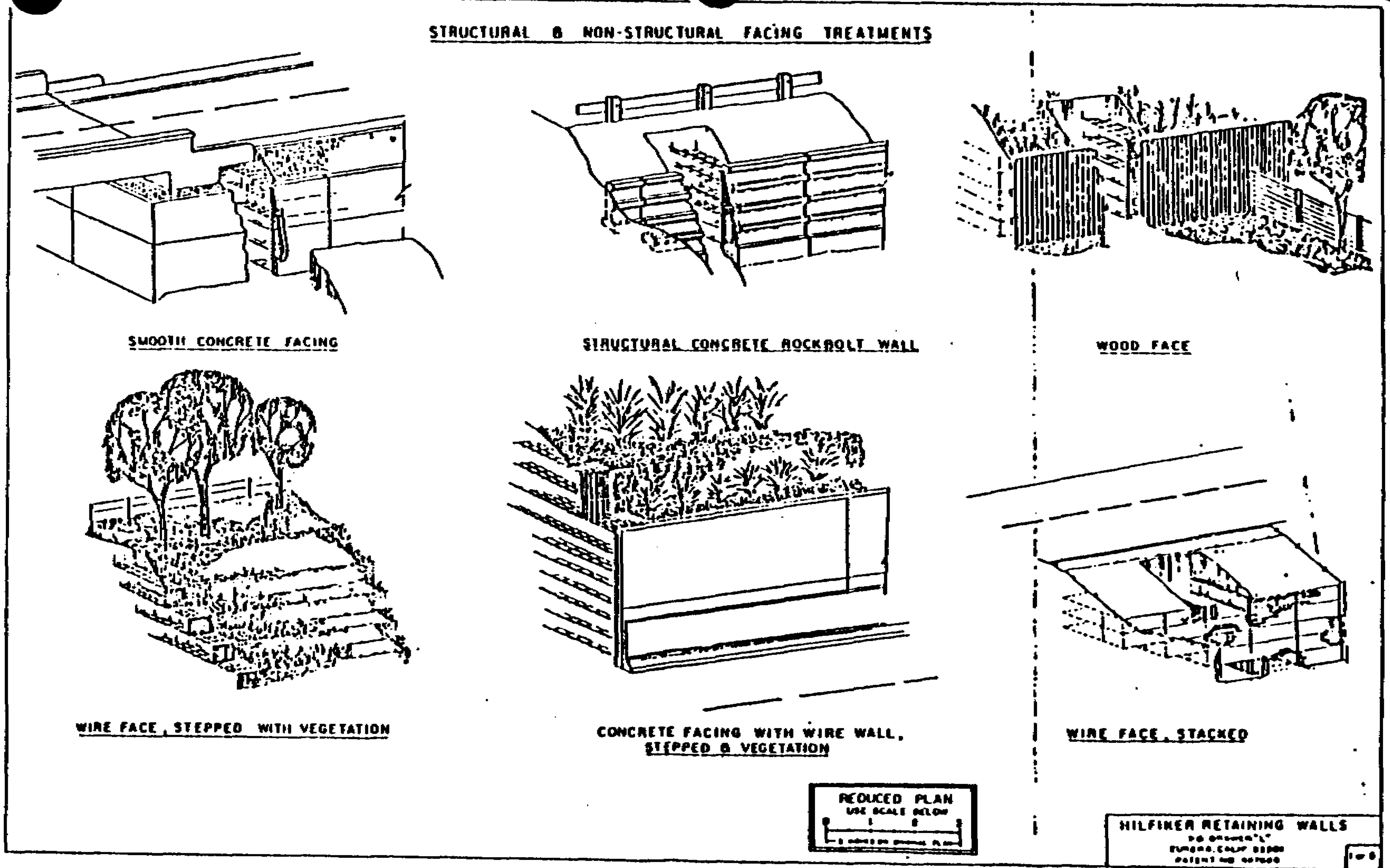
DEVELOPMENT

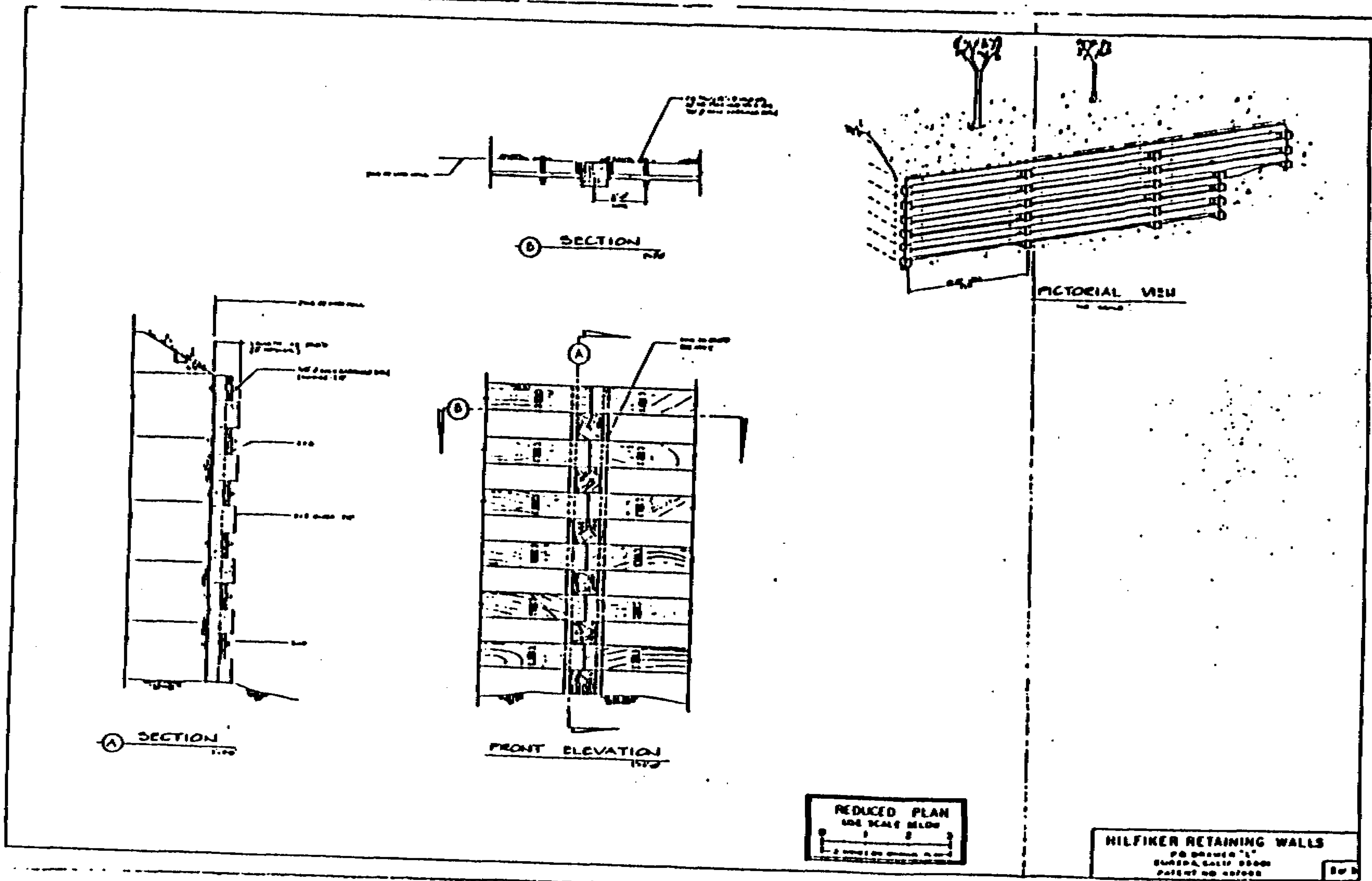
The Welded Wire Wall is the invention of William K. Hilfiker and is the third retaining wall system he has designed and patented. Mr. Hilfiker is the third generation to manage the family business of manufacturing concrete and steel products and is a general engineering contractor specializing in installing retaining walls. The Welded Wire Wall has undergone a five year research program at Utah State University, supervised by Dr. Loren R. Anderson. Dr. Anderson is an Associate Professor of Civil Engineering and is co-author of a textbook on fundamentals of geotechnical analysis. Jack Selvage, of the Selvage and Heber Engineering firm in Eureka, has worked closely with the practical development of the wire wall. He has developed standard wall designs as well as the TI-59 computer program for special designs.

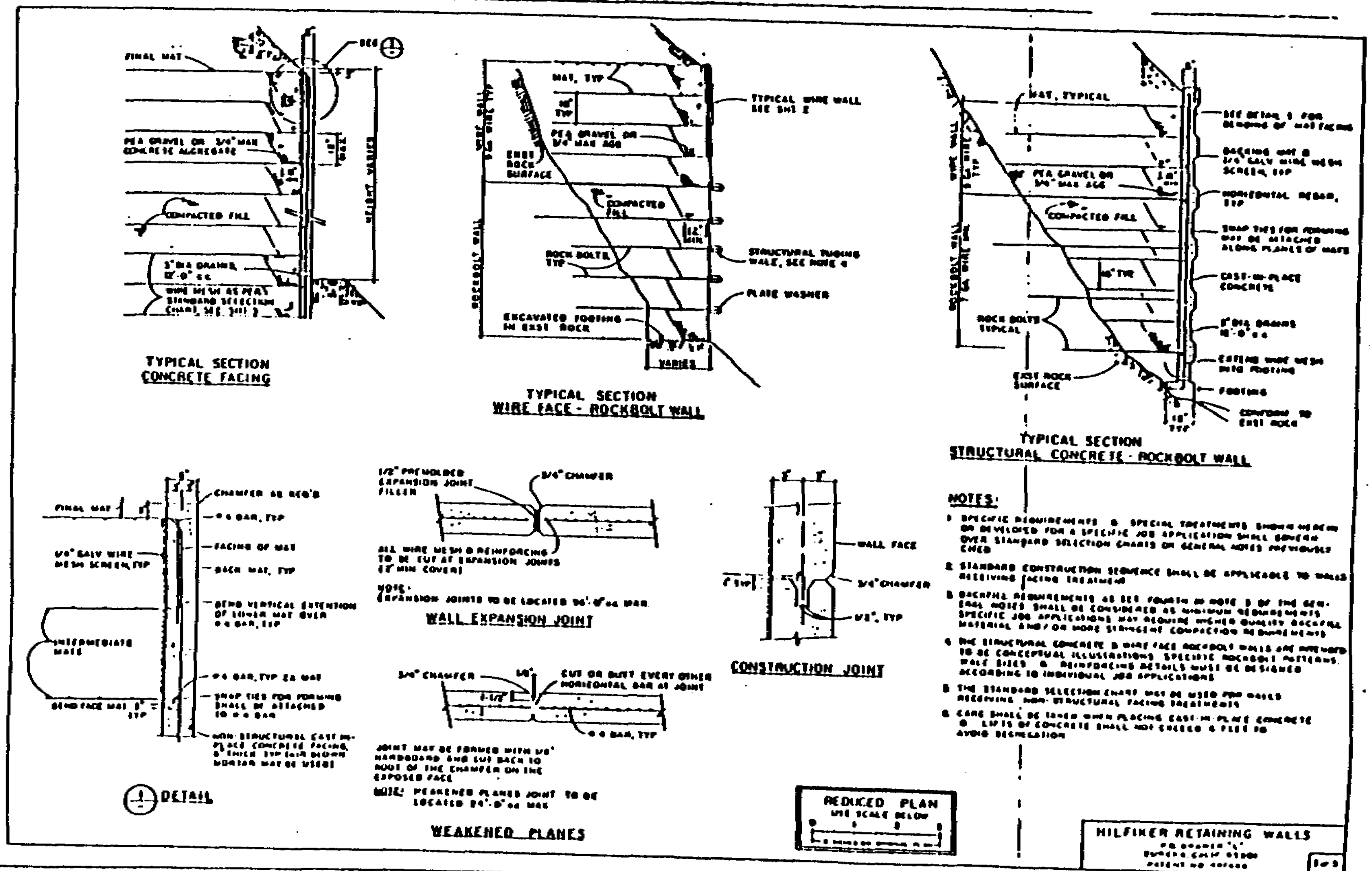
USE

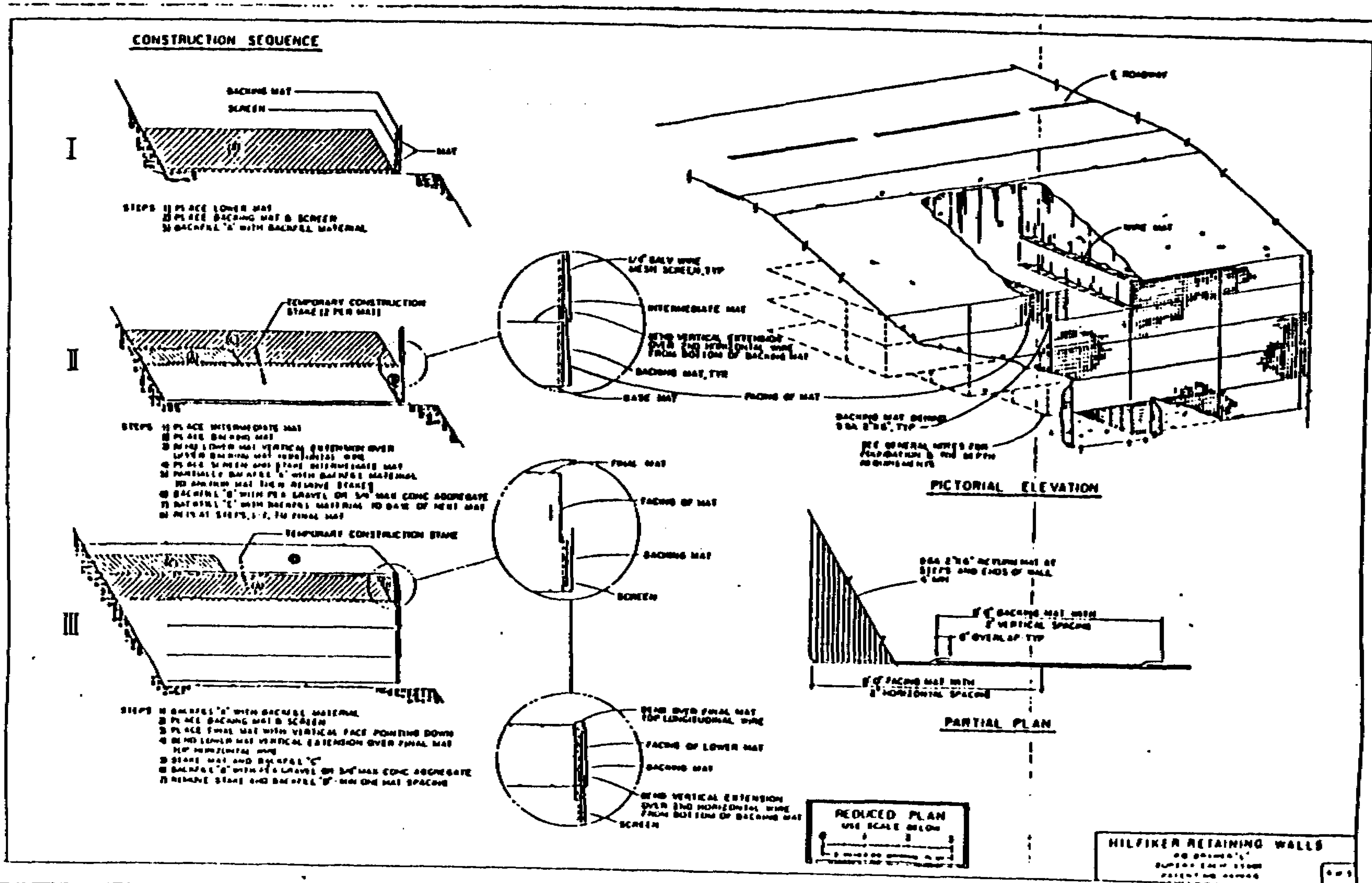
The Welded Wire Wall is an easily installed composite wire and granular soil structure. Because of the unique 2" x 6" spacing of the wire matting, a wide range of materials usually found at the jobsite can be used for backfill. The use of jobsite materials and simple hand-placed installation, plus backfilling that lends itself to mechanical placement and compaction, makes the Welded Wire Wall practical, economical, and affordable. Additional wall features you can choose are a blown mortar finish that can be colored to blend with the landscape, or you may plant with vegetation which will grow through the wire mesh.

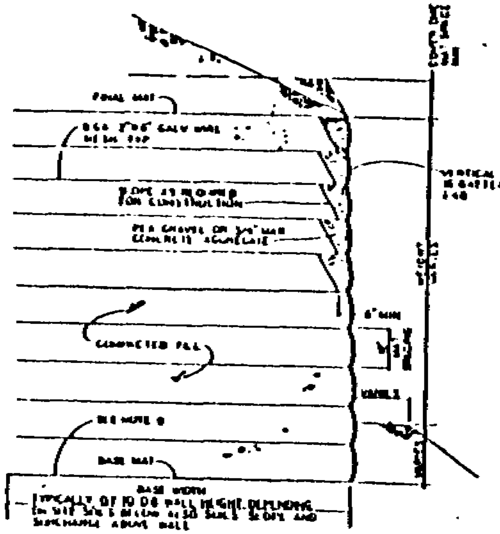
Upon request, we will send you our TI-59 computer design program and our illustrated, step-by-step, construction manual.


STRUCTURAL & NON-STRUCTURAL FACING TREATMENTS
SMOOTH CONCRETE FACING
STRUCTURAL CONCRETE ROCKBOLT WALL
WOOD FACE
WIRE FACE, STEPPED WITH VEGETATION
CONCRETE FACING WITH WIRE WALL, STEPPED & VEGETATION
WIRE FACE, STACKED
REDUCED PLAN
USE SCALE BELOW
HILFIKER RETAINING WALLS


B SECTION
PICTORIAL VIEW
A SECTION
FRONT ELEVATION
REDUCED PLAN
USE SCALE BELOW
HILFIKER RETAINING WALLS


TYPICAL SECTION
CONCRETE FACING
TYPICAL SECTION
WIRE FACE - ROCKBOLT WALL
TYPICAL SECTION
STRUCTURAL CONCRETE - ROCKBOLT WALL
DETAIL
WALL EXPANSION JOINT
WEAKENED PLANES
CONSTRUCTION JOINT
NOTES:
REDUCED PLAN
HILFIKER RETAINING WALLS


CONSTRUCTION SEQUENCE
I
BACKING MAT
SCREEN
MAT
II
TEMPORARY CONSTRUCTION STAKE (2 PER MAT)
INTERMEDIATE MAT
BACKING MAT, TYP
BASE MAT
FACING OF MAT
III
TEMPORARY CONSTRUCTION STAKE
FINAL MAT
FACING OF MAT
BACKING MAT
SCREEN
FACING OF LOWER MAT
BACKING MAT
SCREEN
WIRE MAT
PICTORIAL ELEVATION
PARTIAL PLAN
REDUCED PLAN
USE SCALE BELOW
HILFIKER RETAINING WALLS

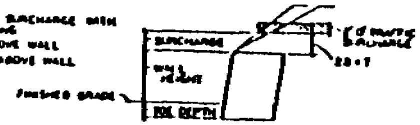


TYPICAL SECTION

LEGEND FOR CHART

2S+T = 2 FOOT LEVEL SURCHARGE WITH TRAFFIC LOADING
2:1 = 2:1 SLOPE ABOVE WALL
1 1/2:1 = 1 1/2:1 SLOPE ABOVE WALL

DESIGN SURCHARGE



STANDARD SELECTION CHARTS *

— VERTICAL —
9 GAGE WIRE WALL

MAXIMUM WALL HEIGHT -FT-	MAT SPACING -IN-	NONE BASE WIDTH -FT-	NONE MAX FTG PRESS -TSF-	2S+T * BASE WIDTH -FT-	2S+T * MAX FTG PRESS -TSF-	1 1/2:1 * BASE WIDTH -FT-	1 1/2:1 * MAX FTG PRESS -TSF-	2:1 * BASE WIDTH -FT-	2:1 * MAX FTG PRESS -TSF-
6	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.8
9		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3
12		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.8
15		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3
18		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.9
21		[illegible]	[illegible]	[illegible]	3.0	[illegible]	[illegible]	[illegible]	3.5
24	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.0

— 1:6 BATTER —
9 GAGE WIRE WALL

MAXIMUM WALL HEIGHT -FT-	MAT SPACING -IN-	NONE BASE WIDTH -FT-	NONE MAX FTG PRESS -TSF-	2S+T * BASE WIDTH -FT-	2S+T * MAX FTG PRESS -TSF-	1 1/2:1 * BASE WIDTH -FT-	1 1/2:1 * MAX FTG PRESS -TSF-	2:1 * BASE WIDTH -FT-	2:1 * MAX FTG PRESS -TSF-
6	10	5'0"	0.4	6'0"	0.7	5'0"	0.7	5'0"	0.5
9		[illegible]	0.6	[illegible]	1.1	[illegible]	1.0	[illegible]	[illegible]
12		[illegible]	0.8	[illegible]	1.4	[illegible]	1.4	[illegible]	1.3
15		[illegible]	1.1	[illegible]	1.7	[illegible]	1.8	[illegible]	1.7
18		[illegible]	1.3	[illegible]	2.0	[illegible]	1.8	[illegible]	[illegible]
21		[illegible]	1.7	[illegible]	2.4	[illegible]	2.1	[illegible]	[illegible]
24	10	[illegible]	1.9	[illegible]	2.6	[illegible]	2.6	[illegible]	2.7

* SEE NOTE 9

GENERAL NOTES

1. WALL SHALL BE CONSTRUCTED UPON ADEQUATE FOUNDATION
2. WALL BASE IN ORIGINAL GROUND. ALLOWABLE SOIL PRESSURE AT TOE OF WALL SHALL BE DETERMINED BY FOUNDATION SITE INVESTIGATION. WALLS THAT ARE TO RETAIN CUT SLOPES SHALL BE DESIGNED FOR LATERAL AND TOE PRESSURES DETERMINED FROM SITE INVESTIGATION DATA. OVERALL STABILITY OF SLOPE WITH WALL IN PLACE MUST BE ANALYZED IF ORIGINAL GROUND SLOPES AWAY FROM TOE OF WALL. REDUCTION IN ALLOWABLE BEARING CAPACITY DUE TO SLOPE MUST BE CONSIDERED.
3. PERMISSIBLE BACKFILL MATERIAL SHALL BE CLASSIFIED AS GW TO SC IN CONFORMANCE WITH ASTM DESIGNATION D-2487. MATERIAL SHALL BE COMPACTED TO 90% IN CONFORMANCE WITH ASTM METHOD [illegible]
4. SELECTION CHART CALCULATIONS ARE BASED UPON AN EQUIVALENT SOIL PRESSURE FROM NATIVE MATERIAL OF 40 PCF WITH A 2 FT LEVEL SURCHARGE PLUS TRAFFIC LOADING WHERE INDICATED. [illegible]
5. ADEQUATE SUBSURFACE DRAINAGE IS REQUIRED
6. TOE DEPTH MINIMUM 1'-6" TO MAXIMUM HEIGHT OF [illegible] AND 3'-0" FOR WALL WITH HEIGHT GREATER THAN [illegible]
7. OTHER BACKFILL MATERIAL MAY BE USED WHICH WILL REQUIRE SPECIAL DESIGN CONSIDERATIONS
8. MAT DIMENSIONS CAN BE ADJUSTED TO SITE GEOMETRIC CONSTRAINTS
9. FOR THE FOLLOWING SURCHARGE CONDITIONS AND WALL HEIGHTS [illegible]

SURCHARGE CONDITION	2S+T	1 1/2:1	2:1
WALL HEIGHT	[illegible]	[illegible]	[illegible]

10. INDICATED FOOTING PRESSURES CAN BE REDUCED BY INCREASING WALL BASE WIDTHS

ENGINEERING PLANS CAN BE DEVELOPED TO MEET SPECIFIC PROJECT REQUIREMENTS

[illegible] PROGRAM AND USER INSTRUCTIONS FOR WALL DESIGN ARE AVAILABLE UPON REQUEST

EXAMPLE PROBLEMS

EXAMPLE NO 1
GIVEN: WALL HEIGHT 10'
[illegible]
SELECT: [illegible]

EXAMPLE NO 2
GIVEN: WALL HEIGHT 24'
[illegible]
SELECT: [illegible]

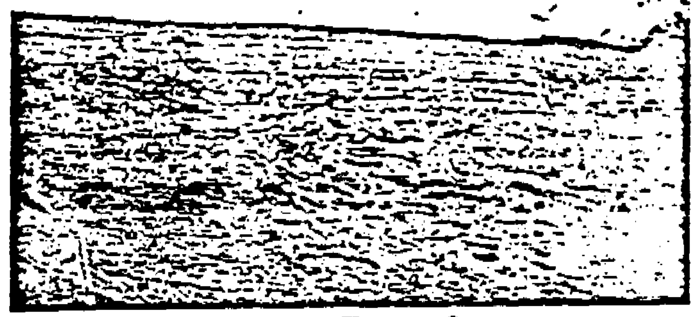
EXAMPLE NO 3
GIVEN: WALL HEIGHT 18'
A 4FT PERMANENT SURCHARGE IS TO BE APPLIED ON THE TOP OF THE WALL AND THE ALLOWABLE SOIL BEARING CAPACITY IS 2.0 TSF.
SELECT: [illegible]

EXAMPLE NO 4
GIVEN: WALL HEIGHT [illegible]
A 2 FT LEVEL SURCHARGE WITH TRAFFIC LOADING IS TO BE RETAINED.
SELECT: [illegible]

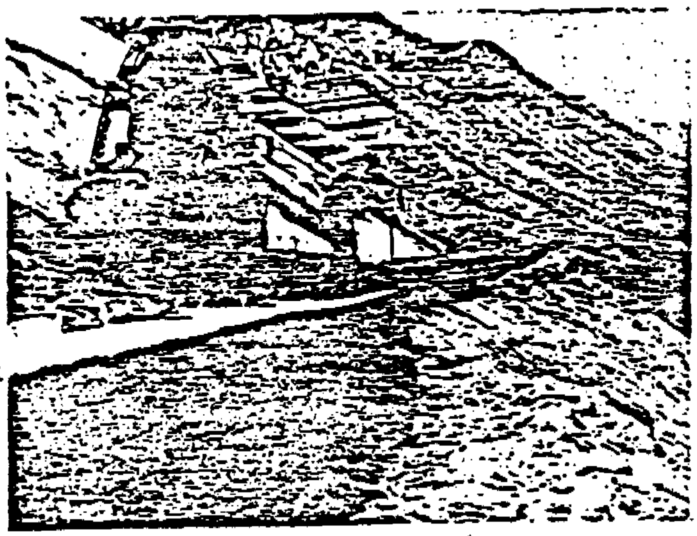
REDUCED PLAN

HILFIKER RETAINING WALLS

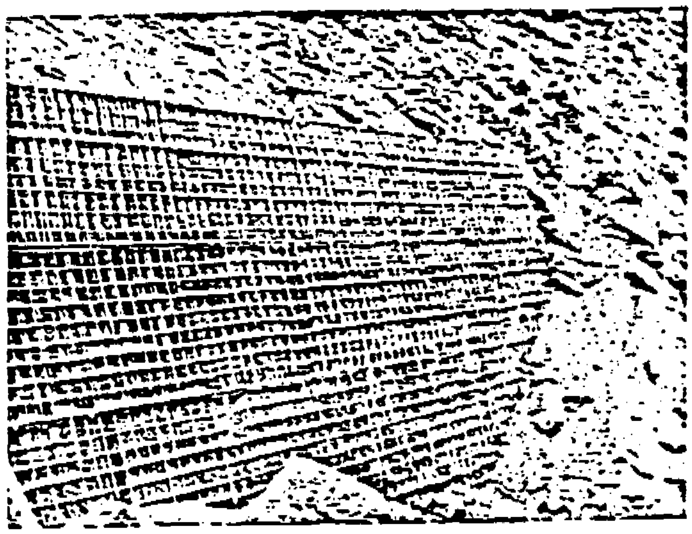
Road Slope Stabilization
Santa Clara Divide and Grizzly Fork Roads
Angeles National Forest, California



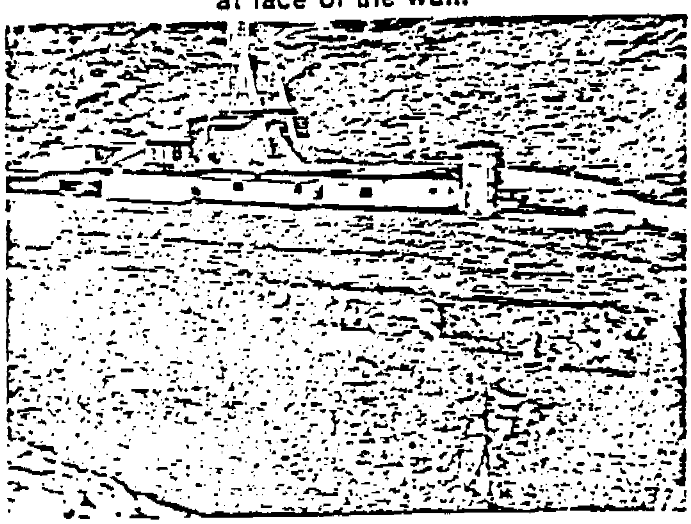
Transmission Tower Support
Southern California Edison
Angeles National Forest, California



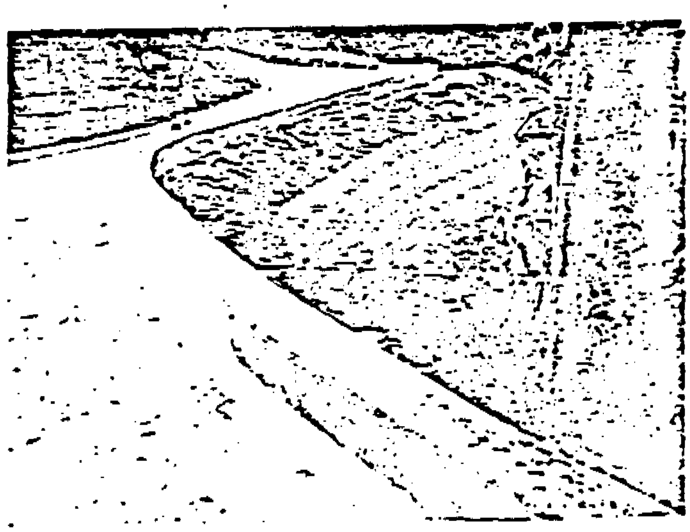
Mine Access Road
Rifle, Colorado
Using Readi Mix truck to pour pea gravel
at face of the wall.



Forest Access Road
Payette National Forest
Idaho



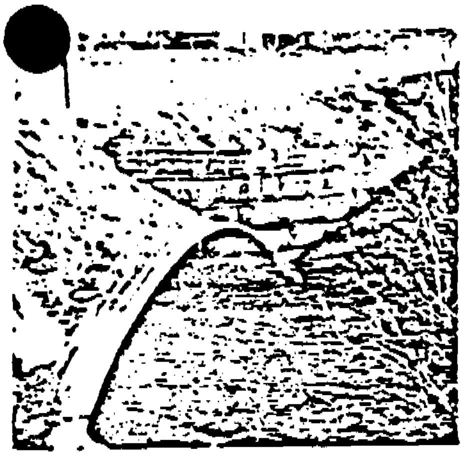
upport for American Quasar Oil Drilling Platform
Manti-La Sal National Forest
Chicken Creek Utah



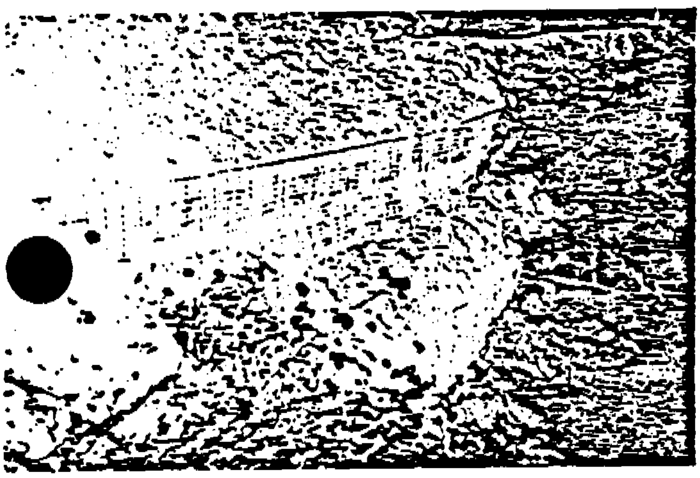
Private Driveway
Nicasio
Marin County, California

HILFIKER
Welded Wire Wall
P.O. Drawer L
Eureka, CA 95501

BULK RATE
U.S. POSTAGE
PAID
EUREKA, CA
PERMIT NO. 192

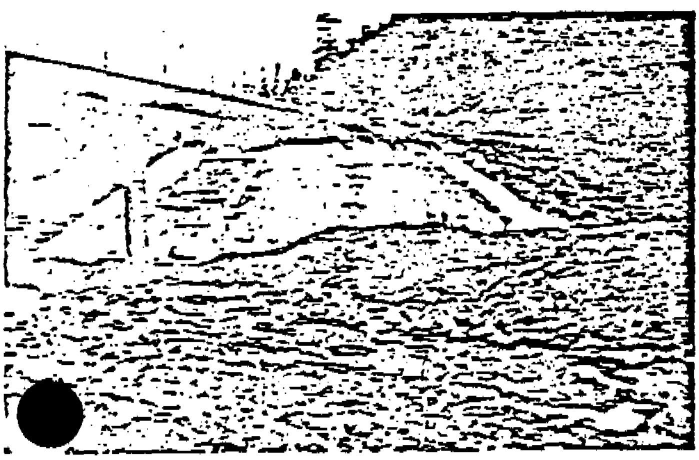


City of Redding, California
Welded Wire Wing Walls
on either end of the culvert.

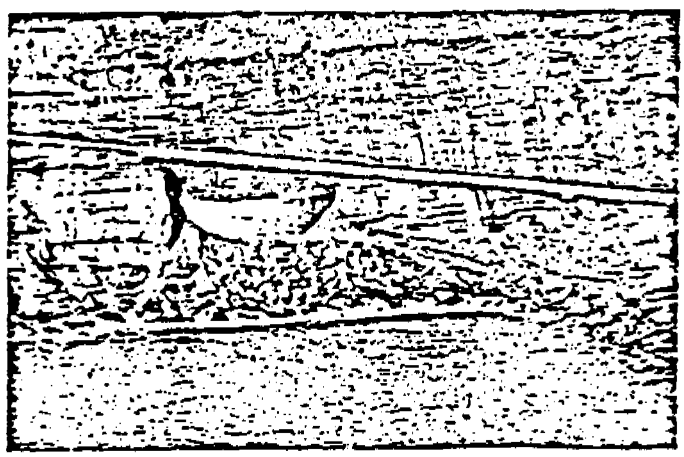


Power Line Access Road
Southern California Edison
Angeles National Forest, California
Fall 1978

Same Southern California Edison Wall
Spring 1981 - One and one half years later
— Showing Nature taking a hold.



Red Cap Creek Bridge
Orleans, California
Six Rivers National Forest
Blown Mortar Finish



Beach Access Road
Shelter Cove, California
Colored Brown Mortar Finish - Blending
with the natural color of the bluff.

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 · AREA CODE 312 726-8434

Reply to
Instrumental Analysis Division
490 Orchard Street
Golden, CO 80401

Phone: 303-278-952

April 7, 1981

Jack Blair
C T & E
139 South Main Street
Helper, Utah 84526

RE: IAD #97-F980-335-05 (1) - #5613
& IAD #97-G223-335-05 (5) - #5613

Revised Analytical Report

It seems as though the problems we've had checking the pH on these core samples may be due to several factors. The only way to get enough volume to run an Alkalinity titration (as well as an Acidity titration and a Conductance reading) is to extract the soil with at least an equal weight of water. Due to the small amount of sample remaining after the metals extraction, we decided to extract the soil 1:2 to make it as concentrated as possible and still have enough volume to titrate. When the sample was mixed with that amount of water it did, in fact, look like a saturated paste. This mixture was filtered and analyzed for Alkalinity. The first step of an an Alkalinity procedure is to take the initial pH of the solution. This was done with each sample in batch F980 and this was the pH reported on the report dated March 16, 1981, rather than a saturated paste pH as described in the text of that report. The difference between batch F980 and batch G223 results are that the former was a pH taken on a filtered 1:2 extract and the latter was a pH taken on a saturated paste. The fact that the paste looked so similar to the unfiltered extract led us to believe that the results should be similar. This was not the case. There are several possibilities that may account for the discrepancy:

1.) The pH reading on the original extract may have been wrong for whatever reason. We went back and re-extracted the original sample to check this possibility. The results of the analysis of this extraction are presented in Table No. I along with the data from the original analysis.

Table No. I

Parameter	F980-1 (first run)	F980-1 (second run)
pH (of extract)	4.3	5.7
Acidity (as $CaCO_3$ in mg/l)	62	112
Alkalinity (as $CaCO_3$ in mg/l)	≤ 1	3

Since both Acidity and Alkalinity titrations are based on the milliliters of standard base or acid (respectively) it takes to achieve a given end point, these results show fair reproducibility. They also show that the possibility of a gross error in the original pH measurement is less likely. But, this data does not address the difference between a water extract and a saturated paste.

2.) Sample G223-5 was then checked to determine if there was actually a difference. (Since there was no sample remaining for F980-1 this comparison could not be made for it also.) The results of this comparison are presented in Table No. II along with data included in the G223 report.

Table No. II

Parameter	Original Saturated Paste	Rerun Saturated Paste	1:2 Water Extract
pH	7.3	7.1	5.8
Alkalinity (mg/l as $CaCO_3$)	---	---	8

This data shows there is a difference in the pH values for this particular sample between the saturated paste and the 1:2 water extract. Furthermore, the results of both the pH and Alkalinity compare favorably with values obtained from the second run of F980-1 (see Table No. I) which solves the third problem of sample homogenity between the two samples sent different dates.

I am confident of the above data. The pH values obtained are both useful, but it should be stressed how they were obtained. I've never seen this discrepancy before and it surprised me. There is no charge for the above research effort. If you have any questions concerning this, feel free to call me.

Bruce A. Hale
Bruce A. Hale
Section Supervisor

M. W. Jacobs
M. W. Jacobs, Ph.D., Mngr.
Instrumental Analysis Div.

as

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 • AREA CODE 312 726-8434

ESTERN DIVISION MANAGER
XXXXXXXXXX.
PALMER

PLEASE ADDRESS ALL CORRESPONDENCE T
139 SOUTH MAIN, HELPER, UTAH 845
OFFICE TEL. (801) 472-35

April 1, 1981

PRICE RIVER COAL CO.
P. O. Box 629
Helper, Utah 84526

Sample identification by

Price River Coal Co.

Castle Gate #1
Castle Gate #2
Castle Gate #3
Castle Gate #4

Kind of sample reported to us: Rock Core

Sample taken at: Castle Gate

Sample taken by: Price River Coal Co.

Date sampled: 3-19-81

Date received: 3-20-81

Analysis report no. 57-5883, 57-5884, 57-5885 & 57-5886

SAMPLE	pH
Castle Gate #1	8.4
Castle Gate #2	8.8
Castle Gate #3	8.4
Castle Gate #4	8.8

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.
Jack Blair,

Manager, Helper Laboratory

JB/gp

APPENDIX 3.7C

ENGINEERS HYDROLOGICAL AND SOILS CERTIFICATION

AND

CHEMICAL ANALYSIS MC-207

HORROCKS & CAROLLO ENGINEERS
A JOINT VENTURE
ONE WEST MAIN
P. O. BOX 377
AMERICAN FORK, UTAH 84003

September 14, 1981

CRANDALL CANYON
SITE ACCESS ROADWAY DITCH

Paved Area Runoff
Diversions Around Site

HYDROLOGICAL CERTIFICATION

I, Harold Lee Wimmer, do certify that I am a registered professional engineer, and that I hold certificate No. 3535 as prescribed under the laws of the State of Utah. I further certify that I have a Bachelor of Engineering Science Degree in Civil Engineering from Brigham Young University and a Master of Science Degree in Civil Engineering from the University of Southern California, with an emphasis on Hydrology. I further certify that by authority of the owners I have reviewed or performed the attached hydrology computations and that said calculations and computations have been correctly performed in accordance with professional standards of practice relating to hydrology and that the conclusions contained herein are true and correct and represent use of current hydrologic and climatological information.

Harold Lee Wimmer

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

HORROCKS & CAROLLO ENGINEERS
A JOINT VENTURE
ONE WEST MAIN
P. O. BOX 377
AMERICAN FORK, UTAH 84003

CRANDALL CANYON SITE WORK

SOILS CERTIFICATION

I, Gilbert R. Horrocks, do certify that I am a registered Professional Engineer and that I hold certificate No. 2986 as prescribed under the laws of the State of Utah. I further certify by authority of the owners I have performed or caused to be performed various soil classifications and tests as required by the Office of Surface Mining regulations and that these tests as contained in the attached document are true and correct. I further certify that the A-3 material proposed for the canyon fill is acceptable for the use intended if properly compacted to 95% relative density (T-99) near optimum moisture.

Gilbert R. Horrocks, P.E.
Utah P.E. No. 2986

HORROCKS ENGINEERS
One West Main
P.O. Box 377
American Fork, Utah 84003
Telephone (801) 756-7628

MOISTURE-DENSITY RELATIONS

PROJECT NAME Price River Coal DATE 2/24/81

PROJECT No. ______ SAMPLE No. 81-07

METHOD OF COMPACTION T-180 "D"

TEST No.	1	2	3	4	5	6	7	8
CYL. & WET EARTH IN GRAMS	10140	10355						
CYLINDER WT. IN GRAMS	5613	5613						
WET EARTH IN GRAMS	4527.0	4742						
WET DENSITY IN LBS/CU. FT.	133.0	139.4						
DISH NUMBER	~	~						
DISH & WET SOIL WT. IN GRAMS	601.5	688.2						
DISH & DRY SOIL WT. IN GRAMS	578.6	655.2						
WATER WT. IN GRAMS	22.9	33.2						
DISH & DRY SOIL WT. IN GRAMS	578.6	655.2						
DISH WT. IN GRAMS	107.4	110.4						
DRY SOIL WT. IN GRAMS	471.2	544.8						
MOISTURE IN % OF DRY WT.	4.9	6.10						
DRY DENSITY IN LBS./CU. FT.	126.8	131.4						

132.0 pcf
9.0 % Op. Moisture

$$\text{DRY DENSITY} = \frac{\text{WET DENSITY}}{100 + \%\ \text{MOISTURE}} \times 100$$

TESTED BY: [illegible signature]

One West Main
P.O. Box 377
American Fork, Utah 84003
Telephone (801) 756-7626

Project Name: Price River Coal   Date: 2/24/81
Project No. ____ Station ____   Sample No. 81-02
Test For: Gradation - T-180

AS RECEIVED GRADATION			
Screen Size	Weight (g)	Percent Retained	Percent Passing
3"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
Wet Wt. -#4			
Dry Wt. -#4			
Total Wt. Dry			

SPECS.

WASHED GRADATION AFTER CRUSHING (2500 Gm. Dry Recombined Sample)					
Screen Size	Weight Retained	Percent Retained	Percent Passing	Total % Passing	SPECS.
1"					
¾"					
½"					
⅜"					
#4	9.4	3.5		96.5	
~~#8~~ #10	32.4	11.9		84.6	
#16					
#40 ~~#50~~	68.3	25.1		59.5	
#200	147.8	54.4		5.1	
-#200	13.8	5.1		Wt. before sieving	
Total Wt.	271.7			Wt. after sieving	

		A.A.S.H.O Classification
L.L.	N/P	
P.L.	N/P	A-3 (0)
P.I.	N/P	

One West Main
P.O. Box 377
American Fork, Utah 84003
Telephone (801) 756-7628

oject Name: Price River Coal — Date: 2-24-81
oject No.: — Station: Siltstone #4 Below Aberdeen S.S. — Sample No.:
Test For: Gradation

AS RECEIVED GRADATION			
Screen Size	Weight (g)	Percent Retained	Percent Passing
3"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
Wet Wt. -#4			
Dry Wt. -#4			
Total Wt. Dry			

SPECS.

WASHED GRADATION AFTER CRUSHING (2500 Gm. Dry Recombined Sample)					
Screen Size	Weight Retained	Percent Retained	Percent Passing	Total % Passing	SPECS.
1"					
¾"					
½"					
⅜"					
#4	0				
~~#8~~ #10	6.6	8.1	91.	91.9	
#16					
#40 ~~#30~~	47.2	44.4		47.5	
#200	39.4	37.0		10.4	
-#200	11.1	10.4		Wt. before sieving Wt. after sieving	
Total Wt.	106.3				

		A.A.S.H. Classific
L.L.	N/P	
P.L.	N/P	A-3(0
P.I.	N/P	

One West Main
P.O. Box 377
American Fork, Utah 84003
Telephone (801) 756-7628

Project Name: PRICE RIVER COAL Date: 8-24-81
Project No. ______ Station C.G.-SS # C.T Sample No. 81-06
Test For: GRADATION

AS RECEIVED GRADATION			
Screen Size	Weight (a)	Percent Retained	Percent Passing
3"			
1½"			
1"			
¾"			
½"			
⅜"			
#4			
Wet Wt. -#4			
Dry Wt. -#4			
Total Wt. Dry			

SPECS.

P.S.I. 6000.

WASHED GRADATION AFTER CRUSHING (2500 Gm. Dry Recombined Sample)					
Screen Size	Weight Retained	Percent Retained	Percent Passing	Total % Passing	SPECS.
1"					
¾"					
½"					
⅜"					
#4	7.8	4.6		95.4	
~~#8~~ #10	21.5	12.7		82.7	
#16					
#30 #50	22.6	13.5		69.2	
#200	116.2	69.0		.2	
-#200	.3	.2		Wt. before sieving	
Total Wt.	168.4			Wt. after sieving	

		A.A.S.H.O Classification
L.L.	N/P	
P.L.	N/P	A-3(0)
P.I.	N/P	

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES, 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 · AREA CODE 312 726-8434

Reply to
Instrumental Analysis Division
490 Orchard Street
Golden, CO 80401

Phone: 303-278-952

March 16, 1981

Mr. Jack Blair
C T & E
139 South Main Street
Helper, Utah 84526

RE: IAD #97-F980-335-06

Analytical Report

Six core samples were received for analyses on February 18, 1981. These samples were given our identification IAD #97-F980-335-06.

Approximately 100 g of each of the samples were extracted by the procedures of EPA Test Methods for Evaluating Solid Wastes/SW-846, (1980). The diluted and filtered extract was then analyzed for Cadmium, Lead, Chromium, Barium, Manganese, Iron and Silver by flame atomic absorption and for Arsenic and Selenium by hydride generation atomic absorption. Mercury was determined on the extract using the methods of EPA Methods for Chemical Analysis of Waters and Wastes, 1979, (Method 245.1-Manual Cold Vapor) using gold amalgamation to concentrate the Mercury.

The pH was determined on the saturated paste according to U.S. Department of Agriculture Handbook No. 60 procedures.

Acidity and Alkalinity were determined by the procedures of Standard Methods, 14th edition using a 1:2 water extract as outlined in the Agriculture Handbook No. 60.

Salinity was calculated from conductivity measurements taken on the 1:2 extract.

The results of these determinations are presented in Table No. I and are reported in milligrams per litre (from the respective extracts) (mg/l) except pH or as otherwise noted.

Table No. I
(mg/l)

Parameter	#1 Castle Gate Sandstone 57-5613	#2 Blackhawk Formation 57-5614	#3 Aberdeen SS 57-5615	#4 Shale & Sandstone Aberdeen 57-5616	#5 Starpoint 57-5617	#6 Coluvial material 57-5627
Arsenic	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury	0.00003	0.0012	0.0005	0.00006	0.0002	0.0012
Cadmium	<0.008	<0.008	<0.008	<0.008	<0.008	<0.008
Lead	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chromium	<0.01	<0.01	0.05	0.05	<0.01	0.04
Barium	0.3	0.5	2.1	2.5	0.5	2.4
Manganese	1.06	1.71	4.72	4.52	2.01	8.46
Iron	29.7	1.78	0.09	1.90	40.1	8.3
Silver	<0.005	<0.005	0.033	0.23	0.005	0.025
Acidity (as $CaCO_3$)	62	-284	13	-63	-29	-98
Alkalinity (as $CaCO_3$)	<1	378	43	157	108	119
pH	4.3	8.4	7.1	7.8	7.5	7.7
Salinity (%)	0.045	0.058	0.083	0.037	0.022	0.029

If there are any questions concerning these results, please call.

Bruce A. Hale
Bruce A. Hale
Section Supervisor

M. L. Jacobs by [illegible]
M. L. Jacobs, Ph.D., Mngr. 16 Nov 81
Instrumental Analysis Div.

APPENDIX 3.7D

UNDISTURBED AREA
RUNOFF CALCULATIONS

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Crandal Canyon - Undisturbed Watershed Areas

Watershed No.	Area (Acres)	Watershed No.	Area
CCWS-U1	24.22	CCWS-U25	5.11,
CCWS-U2	229.57	CCWS-U26	5.81
CCWS-U3	7.59	CCWS-U27	9.07
CCWS-U8	5.70	CCWS-U28	1,396.69
CCWS-U9	108.36	CCWS-U29	1.21
CCWS-U10	9.55	CCWS-U30	230.72
CCWS-U11	25.99	CCWS-U31	4.95
CCWS-U12	4.59	CCWS-U32	46.37
CCWS-U13	18.76	CCWS-U33	2.82
CCWS-U14	2.08	CCWS-U34	38.22
CCWS-U15	9.92	CCWS-U35	316.12
CCWS-U16	1.85		
CCWS-U17	11.29	CCWS-U4	26.17
CCWS-U18	2.31	CCWS-U5	1.16
CCWS-U19	41.52	CCWS-U6	11.13
CCWS-U20	2.82	CCWS-U7	8.00
CCWS-U21	25.46	CCWS-U36	0.97
CCWS-U22	2.81	CCWS-U37	1.58.
CCWS-U23	8.08	CCWS-D1(A)	2.68 Ac
CCWS-U24	9.50		

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Crandall Canyon

Curve No. Estimation

From Vegetation maps (exhibit 9-1 and 9-4) and field observations, North-facing slopes are vegetated w/ Conifers and Mixed Brush. South-facing slopes vegetated w/ Juniper + pinion and mixed brush. Equal distributions of each.

Approximate cover densities are estimated in Chapter 9 of the permit document. Density of mixed brush (ave for all areas surveyed) is 45%. Density for Conifer is 73% and Juniper/Pinion is 55%.

North-Facing slopes ⇒ From Figure 9.5 and 9.6 (SCS, 1972), and approximate veg. cover densities, a professional estimate of the curve No. is 65. (Soil group C)

South Facing Slopes ⇒ From Figure 9.5 + 9.6 (SCS, 1972), approximate veg. cover densities, and proffessional judgement, the curve number is estimated as 70. (Soil Group C)

Disturbed areas ⇒ CN = 90. Typical CN for dirt roads w/ hydro. soil group B is 89 - see Table 9.1 (SCS, 1972)

Ref: U.S. Soil Conservation Service. 1972. National Engineering Handbook, Section 4: Hydrology. U.S. Government Printing Office. Washington, D.C.

Table 9.1.--Runoff curve numbers for hydrologic soil-cover complexes

(Antecedent moisture condition II, and $I_a = 0.2\ S$)

Land use	Cover: Treatment or practice	Cover: Hydrologic condition	Hydrologic soil group: A	B	C	D
Fallow	Straight row	----	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	"and terraced	Poor	66	74	80	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	"and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes 1/ or rotation meadow	Straight row	Poor	66	77	85	89
	" "	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	"and terraced	Poor	63	73	80	83
	"and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	"	Fair	25	59	75	83
	"	Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		----	59	74	82	86
Roads (dirt) 2/		----	72	82	87	89
(hard surface) 2/		---	74	84	90	92

1/ Close-drilled or broadcast.
2/ Including right-of-way.

Disturbed Areas

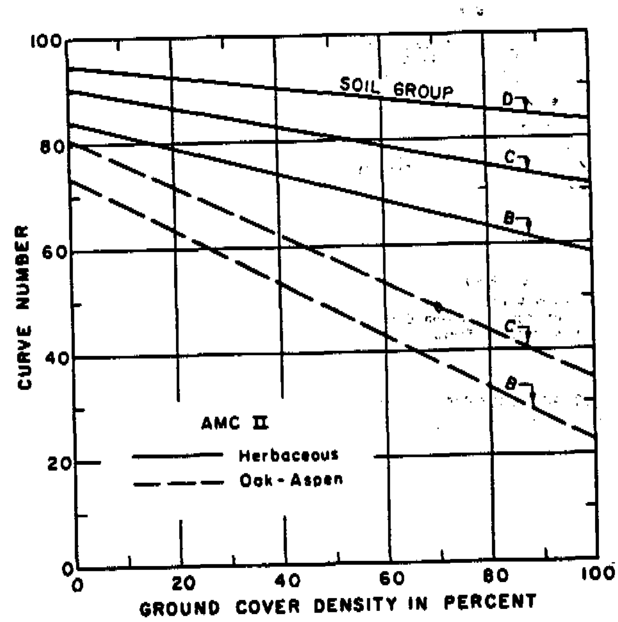

Figure 9.5.--Graph for estimating runoff curve numbers of forest-range complexes in western United States: herbaceous and oak-aspen complexes.

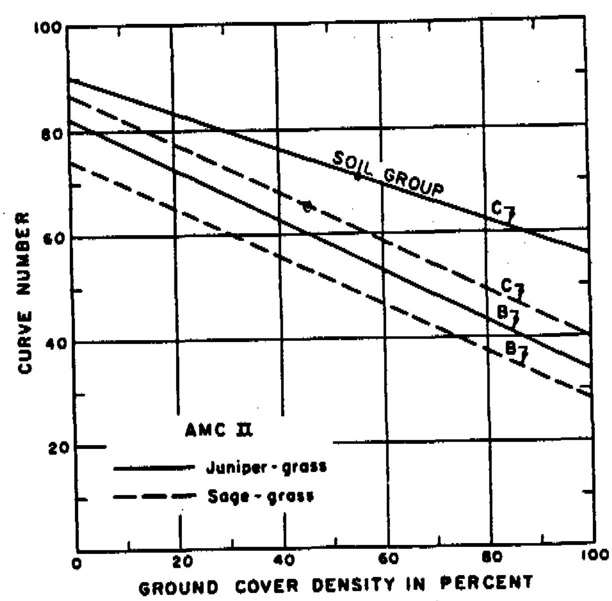

Figure 9.6.--Graph for estimating runoff curve numbers of forest-range complexes in western United States: juniper-grass and sage-grass complexes.

Crandall Canyon - % Slope Calcs

CCWS-U1 A- 1,055,023.2 C.I. 200 L- 3.3 x 1000 = 3300

$$\frac{(3300)(200)}{1055023.2} \times 100 = \boxed{62.56\%}$$

CCWS-U2 A- 10,000,069.2 CI- 200 L- 22000'

$$\frac{(22000)(200)}{10,000,069.2} \times 100 = \boxed{44.00\%}$$

CCWS-U3 A- 2 160 140.4 CI. 200 L- 7.5 x 1000 = 7500

$$\frac{(7500)(200)}{2160140.4} \times 100 = \boxed{69.44\%}$$

CCWS-U8 A- 248 292.0 C.I. 50' L- 20.8 x 200 = 4160

$$\frac{(4160)(50)}{248292} \times 100 = \boxed{83.77\%}$$

CCWS-U9 A- 4,720,161.6 C.I. 200 L- 9.6 x 1000 = 9600

$$\frac{(9600)(200)}{4720161.6} \times 100 = \boxed{40.68\%}$$

CCWS-U10 A- 415,998 C.I.-50 L- 36.2 x 200 = 7240

$$\frac{(7240)(50)}{415998} \times 100 = \boxed{87.02\%}$$

CCWS-U11 A- 1132124 C.I. 100 L- 41.3 x 200 = 8260'

$$\frac{(8260)(100)}{1132124} \times 100 = \boxed{72.97\%}$$

~~CCWS-U12 A- 242,193.6 C.I. 50' L- 20.9 x 200 = 4180~~

$$\cancel{\frac{(4180)(50)}{242193.6} \times 100 = 86.30\%}$$

CCWS-U13 A- 817,185.6 C.I. 100' L- (29.7 + 6.0) x 200 = 7140

$$\frac{(7140)(100)}{817,185.6} \times 100 = \boxed{87.37\%}$$

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Crandall Canyon – % Slope Calcs

CCWS-U14 A- 90,604.8 C.I. 50' L- 8.9 x 200 = 1780

$$\frac{(1780)(50)}{90,604.8} \times 100 = \boxed{98.23\%}$$

CCWS-U15 A- 432 115.2 C.I.- 100' L- 20.4 x 200 = 4080'

$$\frac{(4080)(100)}{432,115.2} \times 100 = \boxed{94.42\%}$$

CCWS-U16 A- 80586 C.I. 50' L- 7.4 x 200 = 1480

$$\frac{(1480)(50)}{80586} \times 100 = \boxed{91.83\%}$$

CCWS-U17 A- 491,792.4 C.I.- 100 L- 19.2 x 200 = 3840'

$$\frac{(3840)(100)}{491792.4} \times 100 = \boxed{78.08\%}$$

~~CCWS-U18 A- 169,448.4 C.I. 50' L- 11.6 x 200 = 2320'~~

$$\cancel{\frac{(2320)(50)}{169448.4} \times 100 = \boxed{68.46\%}}$$

CCWS-U19 A- 1,808,611.2 C.I. 200 L- 32.7 x 200 = 6540

$$\frac{(6540)(200)}{1808611.2} \times 100 = \boxed{72.32\%}$$

CCWS-U20 A- ~~[illegible]~~ 122839.2 CI- 50' L- 6.5 x 200 = 1300

$$\frac{(1300)(50)}{122839.2} \times 100 = \boxed{52.91\%}$$

CCWS-U21 A- 1109037.6 C.I. 200 L- 20.2 x 200 = 4040

$$\frac{(4040)(200)}{1109037.6} \times 100 = \boxed{72.86\%}$$

CCWS-U22 A- 122403.6 CI- 50' L- 8.8 x 200 = 1760

$$\frac{(1760)(50)}{122403.6} \times 100 = 71.89\%$$

CCWS-U23 A- 351,964.8 CI- 100' L- 14.3 x 200 = 2860

$$\frac{(2860)(100)}{351,964.8} \times 100 = 81.26\%$$

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Crandall Canyon - % Slope Calc's

CCWS-U24 A - 413,820.0 CI-100' L- 16.9 x 200 = 3380

$$\frac{(3380)(100)}{413,820.0} \times 100 = \boxed{81.68\%}$$

CCWS-U25 A- 222591.6 C.I.- 100' L- 8.2 x 200 = 1640

$$\frac{1640 \times 100}{222591.6} \times 100 = \boxed{73.68\%}$$

CCWS-U26 A 253083.6 ~~CI~~- 100 L- 11.6 x 200 = 2320

$$\frac{(2320)(100)}{253083.6} \times 100 = \boxed{91.67\%}$$

CCWS-U27 A- 395,089.2 C.I.- 200 L- 1250

$$\frac{(1250)(200)}{395,079.2} \times 100 = \boxed{63.28\%}$$

CCWS-U28

CCWS-U29 A- 52,707.6 C.I. 50' L- 4.7 x 200 = 940

$$\frac{(940)(50)}{52,707.6} \times 100 = \boxed{89.17\%}$$

CCWS-U30 A- 10,050,163.2 CI. 200 L- 29.7 x 1000 = 29700'

$$\frac{(29700)(200)}{10\,050\,163.2} \times 100 = \boxed{59.10\%}$$

CCWS-U31 A- 215 622 C.I.- 50 L- 17.0 x 200 = 3400

$$\frac{(3400)(50)}{215\,622} \times 100 = \boxed{78.84\%}$$

CCWS-U32 A- 2019 877.2 C.I.- 200 L- 6.5 x 1000 = 6500'

$$\frac{(6500)(200)}{2019\,877.2} \times 100 = \boxed{64.36\%}$$

CCWS-U33 A- 122 839.2 C.I. 50' L- 9.9 x 200 = 1980

$$\frac{(1980)(50)}{122\,839.2} \times 100 = \boxed{80.59\%}$$

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Crandall Canyon – % Slope Calcs

CCWS-U34 A- 1,664,863.2 C.I. 200 L- 4.8 x 1000 = 4800

$$\frac{(4800)(200)}{1\,664\,863.2} \times 100 = \boxed{57.66\%}$$

CCWS-U35 A- 13,770,187.2 C.I.- 200 L- 28.5 x 1000 = 28500'

$$\frac{(28500)(200)}{13\,770\,187.2} \times 100 = \boxed{41.39\%}$$

CCWS-U8 & U9 A- 4,968,454 ft² C.I. 200' L- 10 640'

$$\frac{(10640)(200)}{4\,968\,454} \times 100 = \boxed{42.8\%}$$

CCWS-U12 & U13 A- 1,059,379 ft² C.I. 100' L- 9230'

$$\frac{(9230)(100)}{1\,059\,379} \times 100 = \boxed{87.1\%}$$

CCWS-U16 & U17 A- 572,378 ft² CI- 100 L- 4580'

$$\frac{(4580)(100)}{572\,378} \times 100 = \boxed{80.0\%}$$

CCWS-U18 & U19 A- 1,978,060 ft² CI- 200' L- 7120'

$$\frac{(7120)(200)}{1\,978\,060} \times 100 = \boxed{72.0\%}$$

CCWS-U20 & U21 A- 1,231,877 ft² C.I. 200' L- 4365'

$$\frac{(4365)(200)}{1\,231\,877} \times 100 = \boxed{70.9\%}$$

CCWS-U22 & U23 A- 474368 ft² CI= 100' L- 3740'

$$\frac{(3740)(100)}{474\,368} \times 100 = \boxed{78.8\%}$$

CCWS-U31 & U32 A= 2,235,500 ft² CI= 200' L- 7350'

$$\frac{(7350)(200)}{2\,235\,500} \times 100 = \boxed{65.8\%}$$

CCWS-U1 - U9 + U28 A- 7.9 x 10⁷ ft² CI = 1000'

L- 35250

$$\frac{(35250)(1000)}{7.9 \times 10^7} \times 100 = \boxed{44.6\%}$$

CCWS U1 → U11 & U28 → U32 CI = 1000' A = 2137 Acres

L- 45500'

$$\frac{(45500)(1000)}{2137\,(43560)} \times 100 = \boxed{49.0\%}$$

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Crandall Canyon

All SubWatersheds $A = 2658.0$ Acres $C.I. = 1000'$

$L = 61,750'$

$$\frac{(61750)(1000)}{2658.0\,(43560)} \times 100 = \boxed{53.4\ \%}$$

CCWS-U3 + U4 $CI = 200'$ $L = 5545$ $A = 1,470,600\ ft^2$

$$\frac{5545\,(200)}{1,470,600} \times 100 = \boxed{75.4\ \%}$$

CCWS-U3 $CI = 100'$ $L = 3090'$ $A = 330,600\ ft^2$

$$\frac{3090\,(100)}{330,600} \times 100 = \boxed{93.5\%}$$

CCWS-U5 $CI = 50'$ $L = 840'$ $A = 50,400\ ft^2$

$$\frac{840\,(50)}{50,400} \times 100 = \boxed{83.3\%}$$

CCWS-U5 + U6 $CI = 100$ $L = 4200'$ $A = 535,200\ ft^2$

$$\frac{4200\,(100)}{535,200} \times 100 = \boxed{78.5\%}$$

CCWS-U7 $CI = 100'$ $L = 2920'$ $A = 348,600\ ft^2$

$$\frac{2920\,(100)}{348,600} \times 100 = \boxed{83.8\%}$$

% Slope calcs

Use simplified Contour - length Method

$$\% \text{ Slope} = .25(EM - EN)(LC_{25} + LC_{50} + LC_{75})/A \quad \times 100$$

EM = Max Elev
EN = Min Elev
LC_{25} = contour length @ 25% of EM-EN
A = Area of watershed.

CCWS-U12

$EM - EN = 7320 - 6780 = 540'$

LC_{25} (6900') = 440'
LC_{50} (7050') = 420'
LC_{75} (7200') = 180'
1040'

$A = 199{,}940 \text{ ft}^2$

$\% \text{ Slope} = .25(540)(1040)/A \times 100 = \underline{\underline{70.2}}$

CCWS-U36

$EM - EN = 7090 - 6730 = 360'$

LC_{25} (6820) = 210'
LC_{50} (6910) = 120'
LC_{75} (7000) = 80'
410'

$A = 42{,}253 \text{ ft}^2$

$\% \text{ Slope} = .25(360)(410)/A \times 100 = 87.3\%$

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CCWS-U37 EM−EN = 6950 − 6650 = 300'

LC_{25} (6725') = 240'
LC_{50} (6800) = 170'
LC_{75} (6875) = 150'
560'

A = 68,825 ft²

% slope = .25 (300)(560)/A × 100 = 61%

CCWS-U18 EM−EN = 7000 − 6650 = 350

LC_{25} (6740) = 250'
LC_{50} (6825) = 240'
LC_{75} (6910) = 150'
640'

A = 100,624 ft²

% slope = .25 (350)(640)/A × 100 = 55.7%

CCWS-D1(A) EM−EN = 6926 − 6864 = 62'

LC_{25} (6880) = 180'
LC_{50} (6896) = 150'
LC_{75} (6910) = 120'
450'

3"
5.24

A = 2.68 Ac = 116,800 ft²

% slope = .25 (62)(450)/A × 100 = 6.0%

Crandall Canyon - Undisturbed Areas - Time of Concentration (T_c)

Watershed or Watershed Combination	Hyd. Length l (ft.)	CN	$S = \frac{1000}{CN} - 10$	Y % Slope	$L = \frac{l^{0.8}(S+1)^{0.7}}{1900 Y^{0.5}}$ (hr.)	$T_c = 1.67 L$ (hr)
CCWS - U1 (CCD-1 + CCC-1)	2800'	70	4.29	62.6	0.122	0.204
CCWS - U2 (CCD-2 + CCC-2)	5000'	70	4.29	44.0	0.232	0.387
CCWS - U3 (CCD-3)	1400'	70	4.29	93.5	0.057	0.096
CCWS - U3 + U4 (CCC-3)	2300'	70	4.29	75.4	0.095	0.159
CCWS - U5 (CCD-4)	560'	70	4.29	83.3	0.027	0.045
CCWS - U5 + U6 (CCC-4)	1500'	70	4.29	78.5	0.066	0.111
CCWS - U7 (CCD-5 + CCC-5)	1500'	70	4.29	83.8	0.064	0.107
CCWS - U8 (CCD-6)	1250'	70	4.29	83.8	0.055	0.093
CCWS - U8 + U9 (CCC-6)	4500'	70	4.29	42.8	0.216	0.361
CCWS - U10 (CCD-7a + 7b)	1050	70	4.29	87.0	0.047	0.079

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Crandall Canyon - Undisturbed Areas - Time of Concentration (T_c)

Watershed or Watershed Combination	Hyd. Length ℓ (ft.)	CN	$S = \frac{1000}{CN} - 10$	Y % Slope	$L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900\, Y^{0.5}}$ (hr.)	$T_c = 1.67\, L$ (hr)
CCWS - U12 (CCD-8)	800	70	4.29	70.2	0.042	0.071
CCWS - U36 + U13 (CCC-14)	1800	70	4.29	87.1	0.073	0.122
CCWS - U14 (CCD-9, CCC-15)	800	70	4.29	98.2	0.036	0.060
CCWS - U15 (CCD-10, CCC-16)	1400	70	4.29	94.4	0.057	0.095
CCWS - U16 (CCD-11)	600	70	4.29	91.8	0.029	0.049
CCWS - U16 + U17 (CCC-17)	1600	70	4.29	80.0	0.069	0.115
CCWS - U18 (CCD-12)	600	70	4.29	55.7	0.038	0.063
CCWS - U18 + U19 (CCC-18)	2450	70	4.29	72.0	0.102	0.171
CCWS - U20 (CCD-13)	800	70	4.29	52.9	0.049	0.081
CCWS - U20 + U21 (CCC-19)	2250	70	4.29	70.9	0.096	0.161

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ENGINEERS / SCIENTISTS

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Tc (continued)

Watershed or Watershed Combination	Hyd. Length l (ft.)	CN	$S = \frac{1000}{CN} - 10$	Y % Slope	$L = \frac{l^{0.8}(S+1)^{0.7}}{1900\,Y^{0.5}}$ (hr.)	$T_c = 1.67\,L$ (hr)
CCWS-U22 (CCD-14)	900	70	4.29	71.9	0.046	0.077
CCWS-U22 + U23 (CCC-20)	1300	70	4.29	78.8	0.059	0.098
CCWS-U24 (CCD-15, CCC-21)	1300	70	4.29	81.7	0.058	0.097
CCWS-U25 (CCD-16, CCC-22)	1050	70	4.29	73.7	0.051	0.086
CCWS-U26 (CCD-17, CCC-23)	1000	70	4.29	91.7	0.044	0.074
CCWS-U27 (CCD-18)	1400	70	4.29	63.3	0.070	0.117
CCWS-U29 (CCD-19, CCC-10)	400	65	5.38	89.2	0.025	0.041
CCWS-U29 + U30 (CCC-9)	4750	65	5.38	59.1	0.219	0.366
CCWS-U31 (CCD-20)	1000	65	5.38	78.8	0.054	0.091
CCWS-U31 + U32 (CCC-11)	2500	65	5.38	65.8	0.124	0.207

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

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Tc (continued)

Watershed or Watershed Combination	Hyd. Length ℓ (ft.)	CN	$S = \frac{1000}{CN} - 10$	Y % Slope	$L = \frac{\ell^{0.8}(S+1)^{0.7}}{1900 Y^{0.5}}$ (hr)	$Tc = 1.67 L$ (hr)
CCWS-U33 (CCD-21, CCC-12)	800	65	5.38	80.6	0.045	0.075
CCWS-U34 (CCD-22, CCC-13	2250	65	5.38	57.7	0.122	0.203
CCWS-U1 thru U9, U28 (CCC-7)	12,500	68	4.71	44.6	0.506	0.844
CCWS-U1 thru U11 and U28 thru U32 (CCC-8)	13,400	68	4.71	49.0	0.510	0.852
All Subwatersheds (CCC-24)	18,750	68	4.71	53.4	0.639	1.067
CCWS-U37 (CCC-27)	600	70	4.29	61.0	.036	0.060
CCWS-D1(A)	850	90	1.11	6.0	.080	0.134

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Crandall Canyon

Calculation of Peak Discharges

Ref: Miller, J.F., R.H. Frederick, + R.J. Tracey. 1973. Precipitation - Frequency Atlas of the Western United States. Volume VI - Utah. National Oceanic + Atmospheric Administration. Silver Spring, Maryland.

Hawkins, R.H. + K.A. Marshall. 1979. Storm Hydrograph program. Final report to the Utah Division of Oil, Gas + Mining. Utah State University. Logan, Utah.

10-Year, 24-hour Storm @ Castlegate Area + canyons = 1.9 in (Miller et al, 1973).

Peak discharge rates are computed using the Storm Hydrograph program developed by Hawkins + Marshall (1979). A summary table and computer print-outs are attached.

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Crandall Canyon - Peak Flow Calcs

Watershed	CN	T_c (hr)	Area (mi²)	Runoff Depth (in)	Peak Q (cfs)
CCWS-U1	70	.204	.038	.204	3.31
CCWS-U2	70	.387	.359	.204	14.30
CCWS-U3	70	.096	.012	.204	1.35
CCWS-U8	70	.093	.009	.204	0.69
CCWS-U8+U9	70	.361	.178	.204	7.47
CCWS-U10	70	.079	.015	.204	1.20
CCWS-U12	70	.071	.007	.204	0.84
CCWS-U36+U13	70	.122	.031	.204	3.27
CCWS-U14	70	.060	.003	.204	0.37
CCWS-U15	70	.095	.016	.204	1.81
CCWS-U16	70	.049	.003	.204	0.38
CCWSU16+U17	70	.115	.021	.204	2.26
CCWS-U18	70	.063	.004	.204	0.49
CCWS-U18+U19	70	.171	.068	.204	6.39
CCWS-U20	70	.081	.004	.204	0.47
CCWS-U20+U21	70	.161	.044	.204	4.25
CCWS-U22	70	.077	.004	.204	0.47
CCWS-U22+U23	70	.098	.017	.204	1.91
CCWS-U24	70	.097	.015	.204	1.69
CCWS-U25	70	.086	.008	.204	0.92
CCWS-U26	70	.074	.009	.204	1.07

EARTHFAX ENGINEERING, INC.
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Peak flow calc's (con't)

Watershed	CN	T_c (hr)	Area (mi²)	Runoff Depth (in)	Peak Q (cfs)
CCWS-U27	70	0.117	0.014	.204	1.50
CCWS-U29	65	.041	.002	.109	0.09
CCWS-U29 + U30	65	.366	.363	.109	6.26
CCWS-U31	65	.091	.008	.109	0.26
CCWS-U31 + U32	65	.207	.080	.109	1.62
CCWS-U33	65	.075	.004	.109	0.14
CCWS-U34	65	.203	.060	.109	1.22
CCWS-U1 thru U9 + U28	68	.844	2.835	.162	77.91
CCWS-U1 thru U11 + U28 thru U32	68	.852	3.333	.162	91.23
All Subwatersheds	68	1.067	4.146	.162	101.81
CCWS - U3 + U4	70	.159	.053	.204	5.14
CCWS - U5	70	.045	.002	.204	0.26
CCWS - U5 + U6	70	.111	.019	.204	2.06
CCWS - U7	70	.107	.013	.204	1.43
CCWS - U37	70	.060	.002	.204	0.25
CCWS - D1 (A)	90	.134	.004	1.01	2.46

```
******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************


IDENTIFICATION:  CCWS-U1

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.038 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.20 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     3.31 CFS  ( 0.1349 IN/HR)
     TIME TO PEAK =  12.08 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*        METHODOLOGY          *
******************************
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```
IDENTIFICATION:  CCWS-U2

INPUT SUMMARY:
************************************************************
     STORM:                        WATERSHED:
 DIST.=SCS TYPE II                                    AREA =  0.359 SQ. MI.
        DEPTH =  1.90 IN.                  CN = 70.0
        DURATION = 24.0 HR.                TIME OF CONC. =  0.39 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =    14.30 CFS  ( 0.0617 IN/HR)
     TIME TO PEAK =   1.23 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
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```
IDENTIFICATION:  CCWS-U3

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.012 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.10 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     1.35 CFS  ( 0.1746 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*    USING SCS CURVE NUMBER   *
*          METHODOLOGY        *
******************************


IDENTIFICATION:  CCWS-U3 & U4

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.053 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.16 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      5.14 CFS  ( 0.1501 IN/HR)
     TIME TO PEAK =  12.05 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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*****************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*    USING SCS CURVE NUMBER   *
*         METHODOLOGY         *
*****************************


IDENTIFICATION:  CCWS-US

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.002 SQ. MI.
        DEPTH =  1.90 IN.            CN = 70.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.05 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.26 CFS  ( 0.2002 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
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```
IDENTIFICATION:  CCWS-U5 & U6

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.019 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.11 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      2.06 CFS  ( 0.1683 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*    USING SCS CURVE NUMBER   *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U7

INPUT SUMMARY:
************************************************************
    STORM:                        WATERSHED:
       DIST. = SCS TYPE II             AREA =  0.013 SQ. MI.
       DEPTH =  1.90 IN.               CN = 70.0
       DURATION = 24.0 HR.             TIME OF CONC. =  0.11 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.43 CFS  ( 0.1700 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*        METHODOLOGY          *
******************************
```

```
IDENTIFICATION:  CCWS-U8

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
 DIST.=SCS TYPE II                                  AREA =  0.009 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.09 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.69 CFS  ( 0.1190 IN/HR)
     TIME TO PEAK =   1.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************


IDENTIFICATION:  CCWS-U8 & U9

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
 DIST.=SCS TYPE II                                   AREA =  0.178 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.36 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      7.47 CFS  ( 0.0650 IN/HR)
     TIME TO PEAK =   1.20 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U10

INPUT SUMMARY:
***********************************************************
     STORM:                       WATERSHED:
 DIST.=SCS TYPE II                                   AREA =  0.015 SQ. MI.
        DEPTH =  1.90 IN.                 CN = 70.0
        DURATION = 24.0 HR.               TIME OF CONC. =  0.08 HR.
***********************************************************


***********************************************************


OUTPUT SUMMARY:
***********************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.20 CFS  ( 0.1235 IN/HR)
     TIME TO PEAK =   1.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
***********************************************************
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*****************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*****************************
```

```
IDENTIFICATION:  CCWS-U12

INPUT SUMMARY:
************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.007 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.07 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.84 CFS  ( 0.1851 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U36 & U13

INPUT SUMMARY:
************************************************************
     STORM:                     WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.031 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.12 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     3.27 CFS  ( 0.1637 IN/HR)
     TIME TO PEAK =  12.03 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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********************************
* EARTHFAX ENGINEERING, INC.   *
*                              *
* HYDROGRAPH GENERATION MODEL  *
*   USING SCS CURVE NUMBER     *
*        METHODOLOGY           *
********************************
```

```
IDENTIFICATION:  CCWS-U14

INPUT SUMMARY:
**************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.003 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.06 HR.
**************************************************************


**************************************************************


OUTPUT SUMMARY:
**************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.37 CFS  ( 0.1929 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
**************************************************************
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*******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
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```
IDENTIFICATION:  CCWS-U15

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II               AREA =  0.016 SQ. MI.
        DEPTH =  1.90 IN.                 CN = 70.0
        DURATION = 24.0 HR.               TIME OF CONC. =  0.10 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.81 CFS  ( 0.1755 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
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```
IDENTIFICATION:   CCWS-U16

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.003 SQ. MI.
        DEPTH =  1.90 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.05 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.38 CFS  ( 0.1982 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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*****************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*****************************
```

```
IDENTIFICATION:  CCWS-U16 & U17

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.021 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.12 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      2.26 CFS  ( 0.1669 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

```
IDENTIFICATION:  CCWS-U18

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.004 SQ. MI.
        DEPTH =  1.90 IN.            CN = 70.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.06 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     0.49 CFS  ( 0.1899 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************


IDENTIFICATION:  CCWS-U18 & U19

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.068 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.17 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      6.39 CFS  ( 0.1455 IN/HR)
     TIME TO PEAK =  12.05 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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*******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
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```
IDENTIFICATION:  CCWS-U20

INPUT SUMMARY:
************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II             AREA =  0.004 SQ. MI.
        DEPTH =  1.90 IN.               CN = 70.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.08 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     0.47 CFS  ( 0.1816 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
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******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
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```
IDENTIFICATION:  CCWS-U20 & U21

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II           AREA =  0.044 SQ. MI.
        DEPTH =  1.90 IN.             CN = 70.0
        DURATION = 24.0 HR.           TIME OF CONC. =  0.16 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      4.25 CFS  ( 0.1497 IN/HR)
     TIME TO PEAK =  12.05 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

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******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U22

INPUT SUMMARY:
*************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.004 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.08 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.47 CFS  ( 0.1836 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
*************************************************************
```

```
*****************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*****************************


IDENTIFICATION:  CCWS-U22 & U23

INPUT SUMMARY:
************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.017 SQ. MI.
        DEPTH =  1.90 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.10 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =     1.91 CFS  ( 0.1738 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************


IDENTIFICATION:  CCWS-U24

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.015 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.10 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.69 CFS  ( 0.1743 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

```
********************************
* EARTHFAX ENGINEERING. INC.   *
*                              *
* HYDROGRAPH GENERATION MODEL  *
*   USING SCS CURVE NUMBER     *
*         METHODOLOGY          *
********************************


IDENTIFICATION:   CCWS-U25

INPUT SUMMARY:
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II                AREA =  0.008 SQ. MI.
        DEPTH =  1.90 IN.                  CN = 70.0
        DURATION = 24.0 HR.                TIME OF CONC. =  0.09 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.92 CFS  ( 0.1790 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
*************************************************************
```

```
******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************


IDENTIFICATION:  CCWS-U26

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.009 SQ. MI.
        DEPTH =  1.90 IN.                CN = 70.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.07 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.07 CFS  ( 0.1851 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U27

INPUT SUMMARY:
************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II            AREA =  0.014 SQ. MI.
        DEPTH =  1.90 IN.              CN = 70.0
        DURATION = 24.0 HR.            TIME OF CONC. =  0.12 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      1.50 CFS  ( 0.1656 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*    USING SCS CURVE NUMBER   *
*         METHODOLOGY         *
******************************


IDENTIFICATION:  CCWS-U29

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II               AREA =  0.002 SQ. MI.
        DEPTH =  1.90 IN.                 CN = 65.0
        DURATION = 24.0 HR.               TIME OF CONC. =  0.04 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1091 INCHES
     INITIAL ABSTRACTION =  1.0769 INCHES
     PEAK FLOW =      0.09 CFS  ( 0.0669 IN/HR)
     TIME TO PEAK =  12.01 HOURS
     RUNOFF VOLUME CHECK =  0.1093 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING. INC.   *
*                              *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER     *
*         METHODOLOGY          *
******************************
```

```
IDENTIFICATION:  CCWS-U29 & U30

INPUT SUMMARY:
************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II                AREA =  0.363 SQ. MI.
        DEPTH =  1.90 IN.                  CN = 65.0
        DURATION = 24.0 HR.                TIME OF CONC. =  0.37 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1091 INCHES
     INITIAL ABSTRACTION =  1.0769 INCHES
     PEAK FLOW =      6.26 CFS  ( 0.0267 IN/HR)
     TIME TO PEAK =  12.49 HOURS
     RUNOFF VOLUME CHECK =  0.1093 INCHES
************************************************************
```

```
*******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

```
IDENTIFICATION:  CCWS-U31

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II          AREA =  0.008 SQ. MI.
        DEPTH =  1.90 IN.            CN = 65.0
        DURATION = 24.0 HR.          TIME OF CONC. =  0.09 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1091 INCHES
     INITIAL ABSTRACTION =  1.0769 INCHES
     PEAK FLOW =      0.26 CFS  ( 0.0505 IN/HR)
     TIME TO PEAK =  12.03 HOURS
     RUNOFF VOLUME CHECK =  0.1093 INCHES
************************************************************
```

```
*******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************
```

```
IDENTIFICATION:  CCWS-U31 & U32

INPUT SUMMARY:
*************************************************************
     STORM:                        WATERSHED:
        DIST. = SCS TYPE II                AREA =  0.080 SQ. MI.
        DEPTH =  1.90 IN.                  CN = 65.0
        DURATION = 24.0 HR.                TIME OF CONC. =  0.21 HR.
*************************************************************


*************************************************************


OUTPUT SUMMARY:
*************************************************************
     TOTAL RUNOFF DEPTH =  0.1091 INCHES
     INITIAL ABSTRACTION =  1.0769 INCHES
     PEAK FLOW =     1.62 CFS  ( 0.0315 IN/HR)
     TIME TO PEAK =  12.12 HOURS
     RUNOFF VOLUME CHECK =  0.1093 INCHES
*************************************************************
```

```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U33

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II               AREA =  0.004 SQ. MI.
        DEPTH =  1.90 IN.                 CN = 65.0
        DURATION = 24.0 HR.               TIME OF CONC. =  0.08 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1091 INCHES
     INITIAL ABSTRACTION =  1.0769 INCHES
     PEAK FLOW =      0.14 CFS  ( 0.0548 IN/HR)
     TIME TO PEAK =  12.02 HOURS
     RUNOFF VOLUME CHECK =  0.1093 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U34

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II              AREA =  0.060 SQ. MI.
        DEPTH =  1.90 IN.                CN = 65.0
        DURATION = 24.0 HR.              TIME OF CONC. =  0.20 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1091 INCHES
     INITIAL ABSTRACTION =  1.0769 INCHES
     PEAK FLOW =      1.22 CFS  ( 0.0315 IN/HR)
     TIME TO PEAK =  12.12 HOURS
     RUNOFF VOLUME CHECK =  0.1093 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
******************************
```

```
IDENTIFICATION:  CCWS-U37

INPUT SUMMARY:
************************************************************
     STORM:                       WATERSHED:
        DIST. = SCS TYPE II               AREA =  0.002 SQ. MI.
        DEPTH =  1.90 IN.                 CN = 70.0
        DURATION = 24.0 HR.               TIME OF CONC. =  0.06 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.2041 INCHES
     INITIAL ABSTRACTION =  0.8571 INCHES
     PEAK FLOW =      0.25 CFS  ( 0.1929 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  0.2045 INCHES
************************************************************
```

```
********************************
* EARTHFAX ENGINEERING. INC.   *
*                              *
* HYDROGRAPH GENERATION MODEL  *
*   USING SCS CURVE NUMBER     *
*        METHODOLOGY           *
********************************
```

```
IDENTIFICATION:  CCWS-U1 THRU U9 & U28

INPUT SUMMARY:
************************************************************
     STORM:                     WATERSHED:
        DIST. = SCS TYPE II             AREA =  2.835 SQ. MI.
        DEPTH =  1.90 IN.               CN = 68.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.84 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1623 INCHES
     INITIAL ABSTRACTION =  0.9412 INCHES
     PEAK FLOW =    77.91 CFS  ( 0.0426 IN/HR)
     TIME TO PEAK =  12.80 HOURS
     RUNOFF VOLUME CHECK =  0.1626 INCHES
************************************************************
```

```
*******************************
* EARTHFAX ENGINEERING. INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*         METHODOLOGY         *
*******************************


IDENTIFICATION:  CCWS-U1 THRU U11 & U28 THRU U32

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II             AREA =  3.333 SQ. MI.
        DEPTH =  1.90 IN.               CN = 68.0
        DURATION = 24.0 HR.             TIME OF CONC. =  0.85 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1623 INCHES
     INITIAL ABSTRACTION =  0.9412 INCHES
     PEAK FLOW =    91.23 CFS  ( 0.0424 IN/HR)
     TIME TO PEAK =  12.80 HOURS
     RUNOFF VOLUME CHECK =  0.1626 INCHES
************************************************************
```

```
                    ******************************
                    * EARTHFAX ENGINEERING, INC.  *
                    *                             *
                    * HYDROGRAPH GENERATION MODEL *
                    *   USING SCS CURVE NUMBER    *
                    *         METHODOLOGY         *
                    ******************************


IDENTIFICATION:  ALL SUBWATERSHEDS

INPUT SUMMARY:
************************************************************
     STORM:                         WATERSHED:
        DIST. = SCS TYPE II                 AREA =  4.146 SQ. MI.
        DEPTH =  1.90 IN.                   CN = 68.0
        DURATION = 24.0 HR.                 TIME OF CONC. =  1.07 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  0.1623 INCHES
     INITIAL ABSTRACTION =  0.9412 INCHES
     PEAK FLOW =   101.81 CFS  ( 0.0381 IN/HR)
     TIME TO PEAK =  13.00 HOURS
     RUNOFF VOLUME CHECK =  0.1626 INCHES
************************************************************
```

```
******************************
* EARTHFAX ENGINEERING, INC.  *
*                             *
* HYDROGRAPH GENERATION MODEL *
*   USING SCS CURVE NUMBER    *
*        METHODOLOGY          *
******************************


IDENTIFICATION:  CCWS-D1(A)

INPUT SUMMARY:
************************************************************
     STORM:                      WATERSHED:
        DIST. = SCS TYPE II         AREA =  0.004 SQ. MI.
        DEPTH =  1.90 IN.           CN = 90.0
        DURATION = 24.0 HR.         TIME OF CONC. =  0.13 HR.
************************************************************


************************************************************


OUTPUT SUMMARY:
************************************************************
     TOTAL RUNOFF DEPTH =  1.0093 INCHES
     INITIAL ABSTRACTION =  0.2222 INCHES
     PEAK FLOW =      2.46 CFS  ( 0.9517 IN/HR)
     TIME TO PEAK =  12.00 HOURS
     RUNOFF VOLUME CHECK =  1.0114 INCHES
************************************************************
```

APPENDIX 3.7E

AS-BUILT CALCULATIONS FOR DRAINAGE DIVERSION DITCHES

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

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Calculations for Undisturbed area drainage ditches.

Methodology:

Use Manning's Equation (Chow, 1959) to determine:

1. Ditch capacity + freeboard using Minimum slope values
2. Maximum velocity using maximum slope values.

Assumptions:

Manning's n value assumed to be 0.035 for irregular ditches, w/ gravel or rock cut, + vegetation (Chow, 1959)

Calculations performed by TRAP1 program (Weider et al. 1983).

Ditch slopes were approximated from contour map of Crandall canyon (scale: 1" = 200'). In some cases it was difficult to estimate a max slope due to the kind of detail on the topo map.

Ditch Dimensions measured in the field + approximated as trapezoids.

Ref: Chow, V.J. 1959. Open Channel Hydraulics. McGraw-Hill. New York City, New York.

Weider, M.F., K.G. Kirk, + L.E. Welborn. 1983. Simplified Analysis Routines for Surface Water + groundwater Hydrology Applications in Surface Mining. Proceedings of the 1983 Symposium on Surface Mining Hydrology, Sedimentology + Reclamation. U. of Kentucky. Lexington, KY.

EARTHFAX ENGINEERING, INC.
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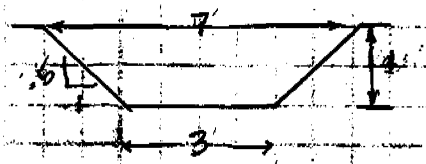
Crandall Canyon
Ditch Adequacy Calculations

Ditch	Max Slope (ft/ft)	Min Slope (ft/ft)	Peak Q (cfs)
CCD-1	0.067	0.067	3.31
CCD-2	0.100	0.100	14.3
CCD-3	0.071	0.053	1.35
CCD-4	0.10	0.086	0.26
CCD-5	0.10	0.074	4.45
CCD-6	0.091	0.080	0.69
CCD-7a	0.10	0.053	1.20
CCD-7b	0.35	—	1.20
CCD-8	0.077	0.057	0.89
CCD-9	0.143	0.071	0.37
CCD-10	0.043	0.040	1.81
CCD-11	0.091	0.071	0.38
CCD-12	0.059	0.048	0.49
CCD-13	0.077	0.060	0.47
CCD-14	0.050	0.048	0.47
CCD-15	0.045	0.043	1.69
CCD-16	0.067	0.050	0.92
CCD-17	0.077	0.065	1.07
CCD-18	0.050	0.050	1.50
CCD-19	0.050	0.050	0.09
CCD-20	0.046	0.046	0.26
CCD-21	0.10	0.10	0.14
CCD-22	0.056	0.056	1.22

Ditch calc's

CCD-1

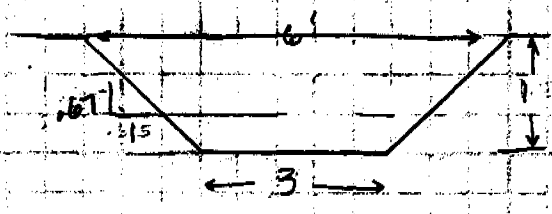


n = .035

Ave. Slope = .067 ft/ft

Bed Slope =	.067	
Manning's N =	.035	
Bottom Width =	3	feet
Channel Side Slope =	.5	
Flow Depth =	.2452231	feet OK
Cross Sectional Area =	.8559378	square feet
Wetted Perimeter =	4.096671	feet
Hydraulic Radius =	.208935	feet
Discharge =	3.31	cubic feet/sec
Velocity =	3.867103	feet/sec OK
Froude Number =	1.376186	

CCD-2



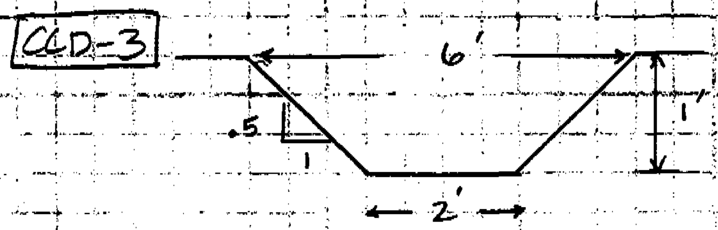
$n = .035$

Ave. Slope = 0.10 $d_{50} \sim 4"$

Bed Slope =	.1	
Manning's N =	.035	
Bottom Width =	3	feet
Channel Side Slope =	.67	
Flow Depth =	.5168264	feet OK
Cross Sectional Area =	1.94915	square feet
Wetted Perimeter =	4.857031	feet
Hydraulic Radius =	.4013049	feet
Discharge =	14.3	cubic feet/sec
Velocity =	7.336531	feet/sec
Froude Number =	1.798418	HIGH

Note: An accurate ditch slope was unattainable from the topo maps, so a worst-case 0.10 slope was assumed here. A slope of 0.10 was also measured in the field.

Velocity is High. Check Adequacy of Riprap: Calcs @ end of this appendix indicate riprap is OKAY.



$n = .035$

Min. Slope = 0.053

Bed Slope =	.053	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.193964	feet OK
Cross Sectional Area =	.463172	square feet
Wetted Perimeter =	2.867433	feet
Hydraulic Radius =	.1615284	feet
Discharge =	1.35	cubic feet/sec
Velocity =	2.914684	feet/sec
Froude Number =	1.166281	

Max Slope = 0.071

Bed Slope =	.071	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	.1781185	feet
Cross Sectional Area =	.4196896	square feet
Wetted Perimeter =	2.79657	feet
Hydraulic Radius =	.150073	feet
Discharge =	1.35	cubic feet/sec
Velocity =	3.216664	feet/sec OK
Froude Number =	1.343146	

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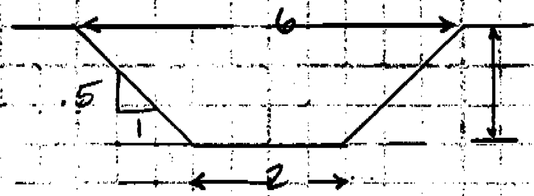

n = .035

MIN. Slope = .086

Bed Slope =	.086	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	6.396607E-02 OK	feet
Cross Sectional Area =	.1361155	square feet
Wetted Perimeter =	2.286065	feet
Hydraulic Radius =	5.954138E-02	feet
Discharge =	.26	cubic feet/sec
Velocity =	1.910143	feet/sec
Froude Number =	1.330954	

Max Slope = 0.10

Bed Slope =	.1	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.5	
Flow Depth =	6.114727E-02	feet
Cross Sectional Area =	.1297725	square feet
Wetted Perimeter =	2.273459	feet
Hydraulic Radius =	5.708153E-02	feet
Discharge =	.26	cubic feet/sec
Velocity =	2.003506	feet/sec OK
Froude Number =	1.427823	

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ENGINEERS / SCIENTISTS

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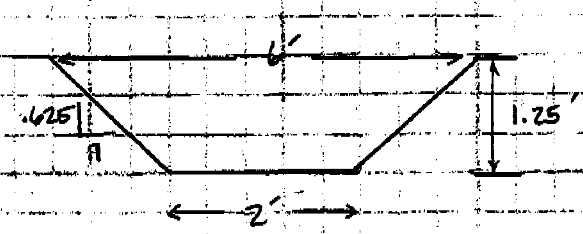
CCD-5



n = .035

Existing d_{50} = 2"
Well vegetated.

Min Slope = .074

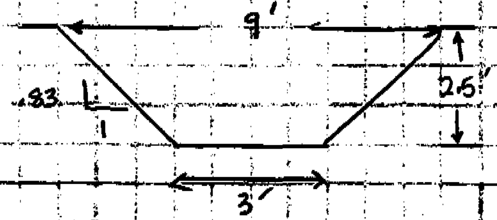
Bed Slope =	.074	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.625	
Flow Depth =	.3557479	feet OK
Cross Sectional Area =	.9139863	square feet
Wetted Perimeter =	3.342448	feet
Hydraulic Radius =	.2734482	feet
Discharge =	4.45	cubic feet/sec
Velocity =	4.868782	feet/sec
Froude Number =	1.438538	

Max Slope = 0.10

Bed Slope =	.1	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.625	
Flow Depth =	.3266401	feet
Cross Sectional Area =	.8239903	square feet
Wetted Perimeter =	3.232607	feet
Hydraulic Radius =	.2548996	feet
Discharge =	4.45	cubic feet/sec
Velocity =	5.400549	feet/sec High
Froude Number =	1.665234	

From Calc's in back — Existing riprap is adequate.

CCD-6



$n = .035$

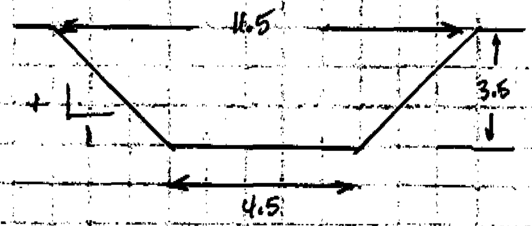
Min Slope = 0.080

Bed Slope =	.08	
Manning's N =	.035	
Bottom Width =	3	feet
Channel Side Slope =	.83	
Flow Depth =	9.321851E-02	OK feet
Cross Sectional Area =	.2901251	square feet
Wetted Perimeter =	3.291915	feet
Hydraulic Radius =	8.813261E-02	feet
Discharge =	.69	cubic feet/sec
Velocity =	2.378285	feet/sec
Froude Number =	1.372729	

Max Slope = 0.091

Bed Slope =	.091	
Manning's N =	.035	
Bottom Width =	3	feet
Channel Side Slope =	.83	
Flow Depth =	.0897107	feet
Cross Sectional Area =	.2788285	square feet
Wetted Perimeter =	3.28093	feet
Hydraulic Radius =	8.498459E-02	feet
Discharge =	.69	cubic feet/sec
Velocity =	2.47464	feet/sec OK
Froude Number =	1.456002	

CCD-7A



n = .035

Min. Slope = 0.053

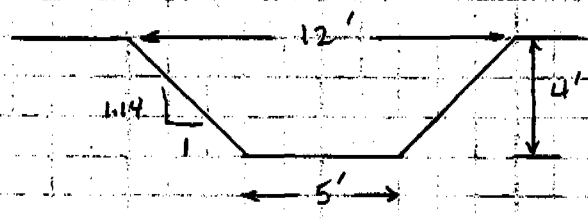
Bed Slope =	.053	
Manning's N =	.035	
Bottom Width =	4.5	feet
Channel Side Slope =	1	
Flow Depth =	.1155533	feet OK
Cross Sectional Area =	.5333425	square feet
Wetted Perimeter =	4.826834	feet
Hydraulic Radius =	.1104953	feet
Discharge =	1.2	cubic feet/sec
Velocity =	2.249962	feet/sec
Froude Number =	1.166423	

Max Slope = 0.10

Bed Slope =	.1	
Manning's N =	.035	
Bottom Width =	4.5	feet
Channel Side Slope =	1	
Flow Depth =	9.510831E-02	feet
Cross Sectional Area =	.4370331	square feet
Wetted Perimeter =	4.769007	feet
Hydraulic Radius =	9.164026E-02	feet
Discharge =	1.2	cubic feet/sec
Velocity =	2.745788	feet/sec OK
Froude Number =	1.569025	

CCD-7B inlet to culvert CCC-7.
evaluate for Max velocity only.

Max. Slope ~ 0.35 – measured in field w/ Brunton.



Existing riprap
$D_{50} \approx 24"$

$Q = 1.2$ cfs

Bed Slope =	.35	
Manning's N =	.035	
Bottom Width =	5	feet
Channel Side Slope =	1.14	
Flow Depth =	6.154035E-02 ok	feet
Cross Sectional Area =	.3110239	square feet
Wetted Perimeter =	5.163724	feet
Hydraulic Radius =	6.023248E-02	feet
Discharge =	1.2	cubic feet/sec
Velocity =	3.858225	feet/sec ok
Froude Number =	2.740815	

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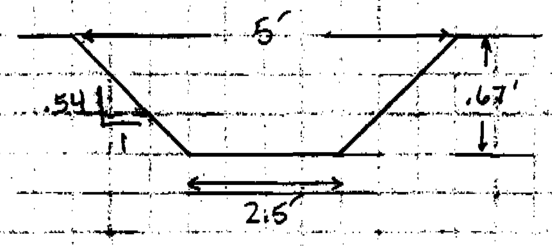
CCD-8



n = .035

Min Slope = .057

Bed Slope =	.057	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.54	
Flow Depth =	.1274914	feet
Cross Sectional Area =	.3488285	square feet
Wetted Perimeter =	3.036637	feet
Hydraulic Radius =	.1148733	feet
Discharge =	.84	cubic feet/sec
Velocity =	2.40806	feet/sec
Froude Number =	1.1885	

OK

Max Slope = .077

Bed Slope =	.077	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.54	
Flow Depth =	.1165698	feet
Cross Sectional Area =	.3165885	square feet
Wetted Perimeter =	2.990667	feet
Hydraulic Radius =	.1058588	feet
Discharge =	.84	cubic feet/sec
Velocity =	2.653287	feet/sec
Froude Number =	1.369504	

OK

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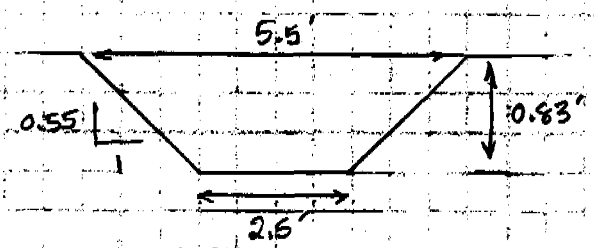
CCD-9



$n = .035$

Min. Slope = .071

Bed Slope =	.071	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.55	
Flow Depth =	7.369825E-02	OK feet
Cross Sectional Area =	.194121	square feet
Wetted Perimeter =	2.805853	feet
Hydraulic Radius =	6.918429E-02	feet
Discharge =	.37	cubic feet/sec
Velocity =	1.906028	feet/sec
Froude Number =	1.237294	

Max Slope = .143

Bed Slope =	.143	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.55	
Flow Depth =	6.022804E-02	feet
Cross Sectional Area =	.1535197	square feet
Wetted Perimeter =	2.744382	feet
Hydraulic Radius =	5.593964E-02	feet
Discharge =	.37	cubic feet/sec
Velocity =	2.410114	feet/sec OK
Froude Number =	1.730654	

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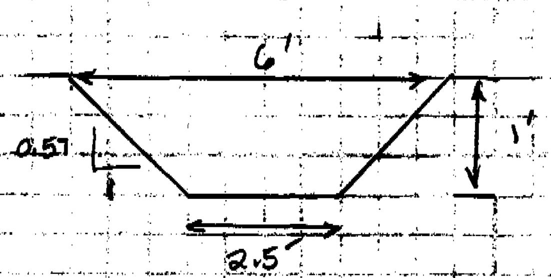
CCD-1D



n = .035

Min. Slope = .040

Bed Slope =	.04	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.57	
Flow Depth =	.2224918	feet OK
Cross Sectional Area =	.643076	square feet
Wetted Perimeter =	3.398588	feet
Hydraulic Radius =	.1892186	feet
Discharge =	1.81	cubic feet/sec
Velocity =	2.814597	feet/sec
Froude Number =	1.051553	

Max Slope = .043

Bed Slope =	.043	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.57	
Flow Depth =	.2177684	feet
Cross Sectional Area =	.6276194	square feet
Wetted Perimeter =	3.379512	feet
Hydraulic Radius =	.185713	feet
Discharge =	1.81	cubic feet/sec
Velocity =	2.883913	feet/sec OK
Froude Number =	1.089073	

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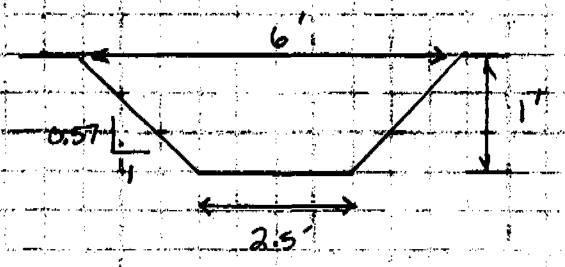
CCD-1A



n = .035

Min. Slope = .071

Bed Slope =	.071	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.57	
Flow Depth =	7.458104E-02	feet
Cross Sectional Area =	.1962111	square feet
Wetted Perimeter =	2.801214	feet
Hydraulic Radius =	7.004501E-02	feet
Discharge =	.38	cubic feet/sec
Velocity =	1.93669	feet/sec
Froude Number =	1.249735	

OK

Max Slope = .091

Bed Slope =	.091	
Manning's N =	.035	
Bottom Width =	2.5	feet
Channel Side Slope =	.57	
Flow Depth =	6.960491E-02	feet
Cross Sectional Area =	.182512	square feet
Wetted Perimeter =	2.781117	feet
Hydraulic Radius =	6.562544E-02	feet
Discharge =	.38	cubic feet/sec
Velocity =	2.082055	feet/sec OK
Froude Number =	1.390735	

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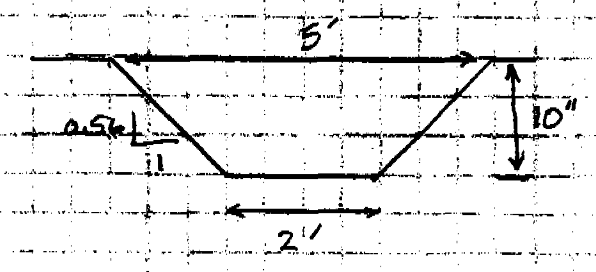
CCD-12



n = .035

Min Slope = .048

Bed Slope =	.048	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.56	
Flow Depth =	.1114034	feet OK
Cross Sectional Area =	.2449687	square feet
Wetted Perimeter =	2.456007	feet
Hydraulic Radius =	9.974265E-02	feet
Discharge =	.49	cubic feet/sec
Velocity =	2.000256	feet/sec
Froude Number =	1.056108	

Max Slope = .059

Bed Slope =	.059	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	.56	
Flow Depth =	.1048592	feet
Cross Sectional Area =	.2293531	square feet
Wetted Perimeter =	2.42922	feet
Hydraulic Radius =	9.441429E-02	feet
Discharge =	.49	cubic feet/sec
Velocity =	2.136444	feet/sec
Froude Number =	1.162681	

OK

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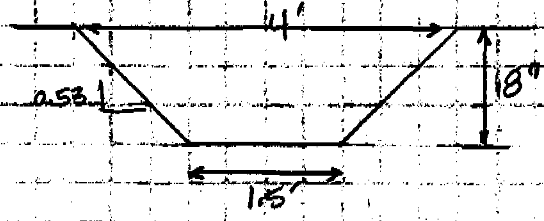
CCD-13



n = .035

Min Slope = .060

Bed Slope =	.06	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.119577	feet OK
Cross Sectional Area =	.206344	square feet
Wetted Perimeter =	2.010692	feet
Hydraulic Radius =	.1026234	feet
Discharge =	.47	cubic feet/sec
Velocity =	2.27775	feet/sec
Froude Number =	1.160792	

Max Slope = .077

Bed Slope =	.077	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1112417	feet
Cross Sectional Area =	.1902111	square feet
Wetted Perimeter =	1.975094	feet
Hydraulic Radius =	9.630483E-02	feet
Discharge =	.47	cubic feet/sec
Velocity =	2.470939	feet/sec OK
Froude Number =	1.30557	

Ditch Sections CCD-14 thru 18 have the same geometry as CCD-13, but varying slopes and peak flows.

CCD-14 Min Slope = .048

Bed Slope =	.048	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1275499	feet OK
Cross Sectional Area =	.222021	square feet
Wetted Perimeter =	2.044743	feet
Hydraulic Radius =	.1085814	feet
Discharge =	.47	cubic feet/sec
Velocity =	2.116917	feet/sec
Froude Number =	1.044566	

Max Slope = .050

Bed Slope =	.05	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1260535	feet
Cross Sectional Area =	.2190603	square feet
Wetted Perimeter =	2.038352	feet
Hydraulic Radius =	.1074693	feet
Discharge =	.47	cubic feet/sec
Velocity =	2.145528	feet/sec OK
Froude Number =	1.064949	

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$\boxed{\text{CCD-15}}$

Min Slope = .043

Bed Slope =	.043	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.2728489	feet OK
Cross Sectional Area =	.5497385	square feet
Wetted Perimeter =	2.66529	feet
Hydraulic Radius =	.2062584	feet
Discharge =	1.69	cubic feet/sec
Velocity =	3.074189	feet/sec
Froude Number =	1.03715	

Max Slope = .045

Bed Slope =	.045	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.2695497	feet
Cross Sectional Area =	.5414132	square feet
Wetted Perimeter =	2.651199	feet
Hydraulic Radius =	.2042144	feet
Discharge =	1.69	cubic feet/sec
Velocity =	3.121461	feet/sec OK
Froude Number =	1.059524	

CCD-16

Min. Slope = .050

Bed Slope =	.05	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1848651	feet OK
Cross Sectional Area =	.341779	square feet
Wetted Perimeter =	2.289527	feet
Hydraulic Radius =	.1492793	feet
Discharge =	.92	cubic feet/sec
Velocity =	2.691798	feet/sec
Froude Number =	1.103284	

Max Slope = .067

Bed Slope =	.067	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1708148	feet
Cross Sectional Area =	.3112744	square feet
Wetted Perimeter =	2.22952	feet
Hydraulic Radius =	.139615	feet
Discharge =	.92	cubic feet/sec
Velocity =	2.955592	feet/sec OK
Froude Number =	1.260241	

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CCD-15

Min. Slope = .065

Bed Slope =	.065	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1869996	feet OK
Cross Sectional Area =	.3464782	square feet
Wetted Perimeter =	2.298642	feet
Hydraulic Radius =	.1507317	feet
Discharge =	1.07	cubic feet/sec
Velocity =	3.088217	feet/sec
Froude Number =	1.258519	

Max Slope = .077

Bed Slope =	.077	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.1789107	feet
Cross Sectional Area =	.3287605	square feet
Wetted Perimeter =	2.264096	feet
Hydraulic Radius =	.1452061	feet
Discharge =	1.07	cubic feet/sec
Velocity =	3.254649	feet/sec OK
Froude Number =	1.355995	

CCD-1B

Ave Slope = 0.1050

Bed Slope =	.05	
Manning's N =	.035	
Bottom Width =	1.5	feet
Channel Side Slope =	.53	
Flow Depth =	.2438136	feet OK
Cross Sectional Area =	.477881	square feet
Wetted Perimeter =	2.541285	feet
Hydraulic Radius =	.188047	feet
Discharge =	1.5	cubic feet/sec
Velocity =	3.138857	feet/sec OK
Froude Number =	1.120249	

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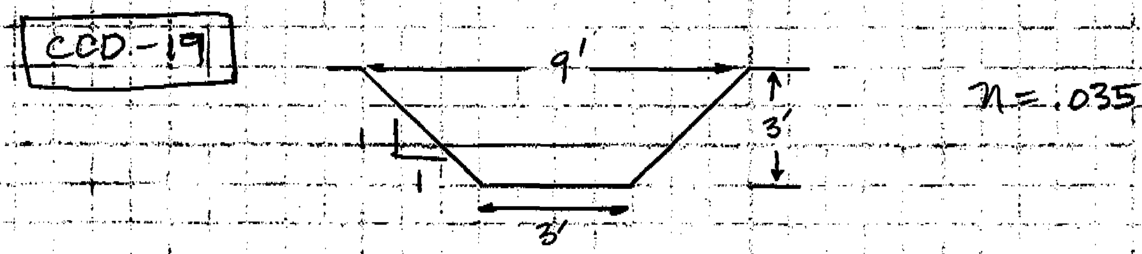
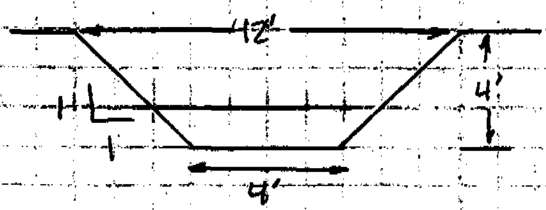


Ave. Slope = 0.050

Bed Slope =	.05		
Manning's N =	.035		
Bottom Width =	3	feet	
Channel Side Slope =	1		
Flow Depth =	3.166598E-02		feet OK
Cross Sectional Area =	9.600068E-02		square feet
Wetted Perimeter =	3.089565	feet	
Hydraulic Radius =	3.107256E-02		feet
Discharge =	9.000001E-02		cubic feet/sec
Velocity =	.9374934	feet/sec OK	
Froude Number =	.9284185		

CCD-20



n = .035

Ave. Slope = .046

Bed Slope =	.046	
Manning's N =	.035	
Bottom Width =	4	feet
Channel Side Slope =	1	
Flow Depth =	5.141492E-02	feet
Cross Sectional Area =	.2083032	square feet
Wetted Perimeter =	4.145424	feet
Hydraulic Radius =	5.024895E-02	feet
Discharge =	.26	cubic feet/sec
Velocity =	1.248181	feet/sec OK
Froude Number =	.9700743	

ok

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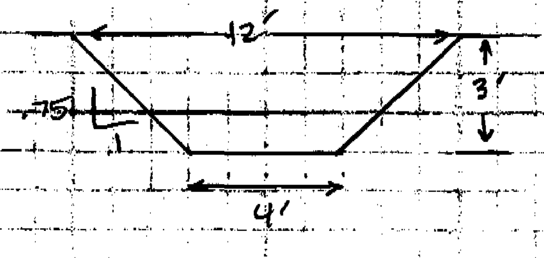
CCD-127



n = .035

Ave Slope = 0.10

Bed Slope =	.1	
Manning's N =	.035	
Bottom Width =	4	feet
Channel Side Slope =	.75	
Flow Depth =	2.818076E-02	OK feet
Cross Sectional Area =	.1137819	square feet
Wetted Perimeter =	4.093936	feet
Hydraulic Radius =	2.779279E-02	feet
Discharge =	.14	cubic feet/sec
Velocity =	1.230424	feet/sec OK
Froude Number =	1.291667	

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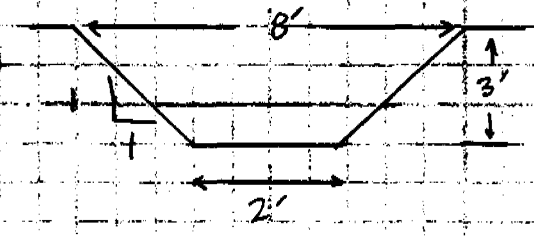
CCD-22



n = .035

Ave. Slope = .056

Bed Slope =	.056	
Manning's N =	.035	
Bottom Width =	2	feet
Channel Side Slope =	1	
Flow Depth =	.1864237	feet OK
Cross Sectional Area =	.4076012	square feet
Wetted Perimeter =	2.527286	feet
Hydraulic Radius =	.1612802	feet
Discharge =	1.22	cubic feet/sec
Velocity =	2.993122	feet/sec OK
Froude Number =	1.221647	

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Crandall Canyon

Riprap Calculation for Ditch CCD-2

$V = 7.3$ ft/second depth $= .5' = d$

~~Assume a riprap size of~~ 4" $= K$

$\frac{K}{d} = \frac{4''}{6''} = .67$

from chart 1 →

$\frac{V_s}{V} = 0.85$

$\therefore V_s = .85(7.3 \text{ ft/s}) = 6.2 \text{ ft/s}$

from chart 2 →

equiv stone diam. $= 0.25' = 3''$

Verify 3" stone size:

$\frac{K}{d} = \frac{3}{6} = .5$

$\frac{V_s}{V} = .78 \quad V_s = .78(7.3) = 5.7$

equiv stone diam $= 3''$ OKAY

∴ Existing riprap ($d_{50} = 4''$) is adequate

Ditch CCD-5

$V = 5.4$ ft/sec $d = 0.33'$

Try 1: Assume $k = 2'' = .17'$

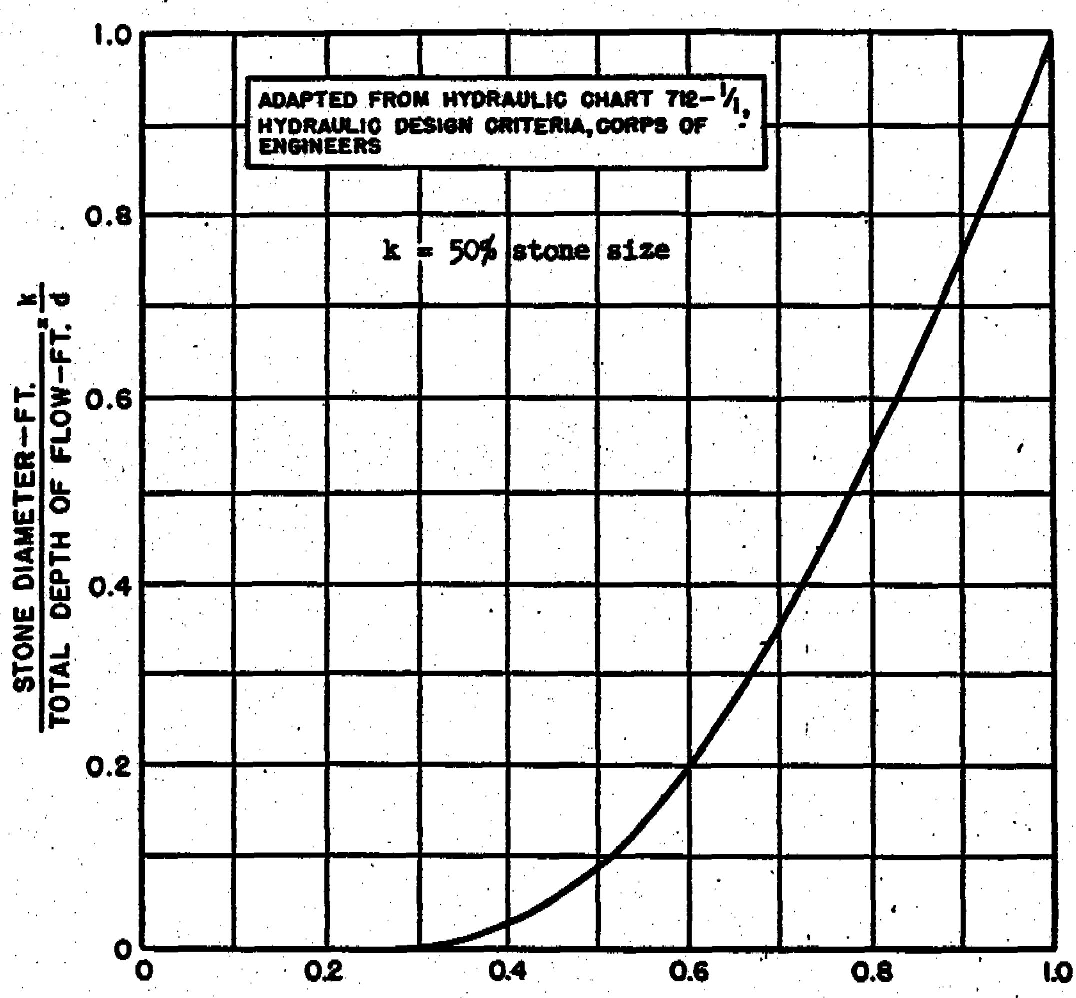
$$\frac{k}{d} = \frac{.17}{.33} = 0.5$$

From Fig 1: $\frac{V_s}{V} = .78$

$V_s = .78(5.4) = 4.2$ ft/sec

From Fig. 2: req'd $d_{50} \sim .15'$

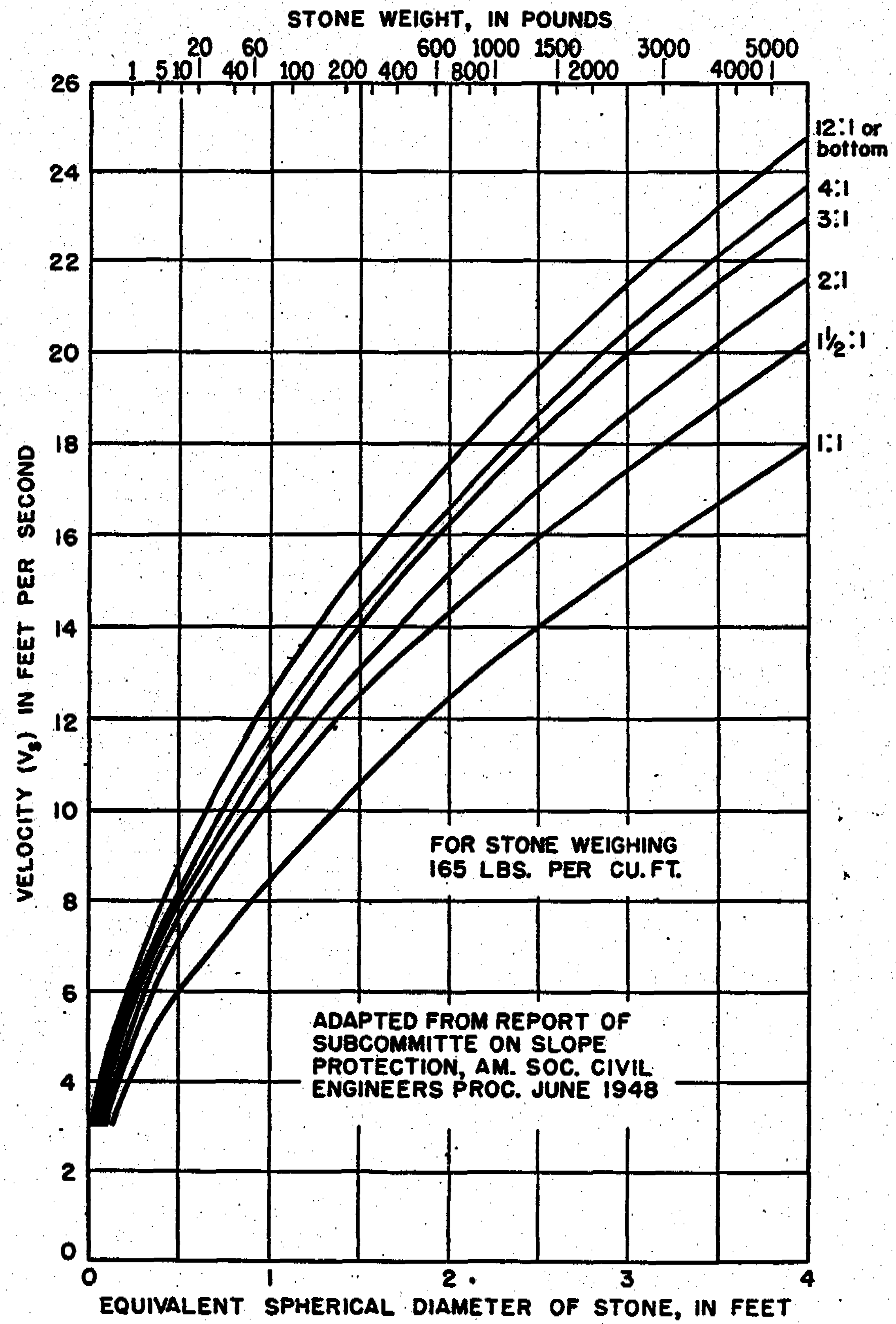
∴ existing riprap is Adequate



$\frac{\text{Velocity Against Stone - F.P.S.}}{\text{Average Velocity In Channel - F.P.S.}} = \frac{V_s}{V}$

VELOCITY AGAINST STONE ON CHANNEL BOTTOM

FIGURE 1



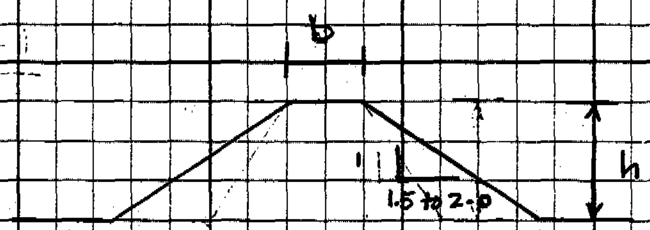
SIZE OF STONE THAT WILL RESIST DISPLACEMENT FOR VARIOUS VELOCITIES AND SIDE SLOPES

FIGURE . 2

Crandall Canyon

Berm Dimensions

See Exhibit 3.7-7 for locations



Berm	b (feet)	h (feet)
CCB-1	.5	1.5
CCB-2	1.0	1.0
CCB-3	1.0	2.0
CCB-4	2.0	1.5
CCB-5	.5	1.0
CCB-6	1.0	1.5
CCB-7	1.0	2.0
CCB-8	2.0	0.5
CCB-9	1.0	2.0

Chapter 3, Section 3.7
Castle Gate Mine
Crandall Canyon

April 1995

ADDENDUM TO
APPENDIX 3.7E

AS-BUILT CALCULATIONS FOR DRAINAGE DIVERSION DITCHES

REGISTERED PROFESSIONAL ENGINEER
NO. 11350
WILLIAM S. HENDRICKSON
STATE OF

4/20/95

007/004

EARTHFAX ENGINEERING, INC.
HYDROGRAPH GENERATION PROGRAM OUTPUT
BASED ON SCS CURVE NUMBER METHODOLOGY

INPUT FOR: CCWS-8B

STORM :	WATERSHED :
Dist.=SCS Type II - 24 Hr	Area = 0.97 acres
Depth = 1.90 inches	CN = 70.00
Duration = 24.00 hrs	Time conc.= 0.122 hrs

OUTPUT SUMMARY

Runoff depth	0.20410	inches	
Initial abstr	0.85714	inches	
Peak flow =	0.17	cfs	(0.17351 iph)
at time	12.037	hrs	

Trapezoidal Channel Analysis & Design
Open Channel - Uniform flow

Worksheet Name: CRANDALL CANYON

Comment: CCD-8B (AVERAGE SLOPE)

Solve For Depth

Given Input Data:

Bottom Width.....	2.50 ft
Left Side Slope..	2.00:1 (H:V)
Right Side Slope.	2.00:1 (H:V)
Manning's n......	0.035
Channel Slope....	0.0570 ft/ft
Discharge........	0.17 cfs

Computed Results:

Depth............	0.05 ft
Velocity.........	1.32 fps
Flow Area........	0.13 sf
Flow Top Width...	2.70 ft
Wetted Perimeter.	2.72 ft
Critical Depth...	0.05 ft
Critical Slope...	0.0492 ft/ft
Froude Number....	1.07 (flow is Supercritical)

APPENDIX 3.7F

AS-BUILT CALCULATIONS FOR DRAINAGE DIVERSION CULVERTS

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Crandall Canyon Culverts

Purpose: Check existing culvert sizes for adequate capacity and outlet velocities

Methodology:

(1) Culvert size verified in the field

(2) Use 10-yr, 24-hour peak discharge for flow rates

(3) Use chart 5 + 6 from USDOT (1977) to determine existing HW/D ratio (Headwater / Diameter). If HW/D ≤ 1.0 the existing culvert is adequate without a headwall.

(4) Use culvert slopes (measured in the field) to check outlet velocities.

(5) Verify adequacy of existing riprap

Ref: U.S. Dept. of Transportation. 1977. Hydraulic charts for the selection of Highway Culverts. Hydraulic Engineering Circular No. 5. Federal Highway Administration. Washington, D.C.

Summary of Culverts

Culvert	Diameter	10-yr, 24-Hr Peak Q (cfs)	Entrance Type	HW/D (from Nomograph)
CCC-1	24"	3.31	Mitered	<.5
CCC-2	84"	14.30	Mitered	<.5
CCC-3	24"	5.14	Mitered	.55
CCC-6	48"	7.47	Concrete Headwall	<.5
CCC-7	Pipe Arch 17'6" x 10'6"	77.91	Concrete Headwall	<.35
CCC-8	Pipe Arch 17'6" x 10'6"	91.23	Concrete Headwall	<.35
CCC-9	7.0'	6.26	Concrete Headwall	<.5
CCC-10	24"	0.09	Concrete Headwall	<.5
CCC-11	48"	1.62	Mitered	<.5
CCC-12	48"	0.14	?	<.5
CCC-13	36"	1.22	?	<.5
CCC-14	18"	3.27	?	0.68
CCC-15	18"	0.37	?	<.5
CCC-16	18"	1.81	Mitered	<.5
CCC-17	18"	2.26	Mitered	.54
CCC-18	24"	6.39	Mitered	0.65
CCC-19	24"	4.25	Projecting	<.5
CCC-20	18"	1.91	Projecting	<.5
CCC-4	24"	2.06	Mitered	<.5
CCC-5	24"	1.43	Mitered	<.5

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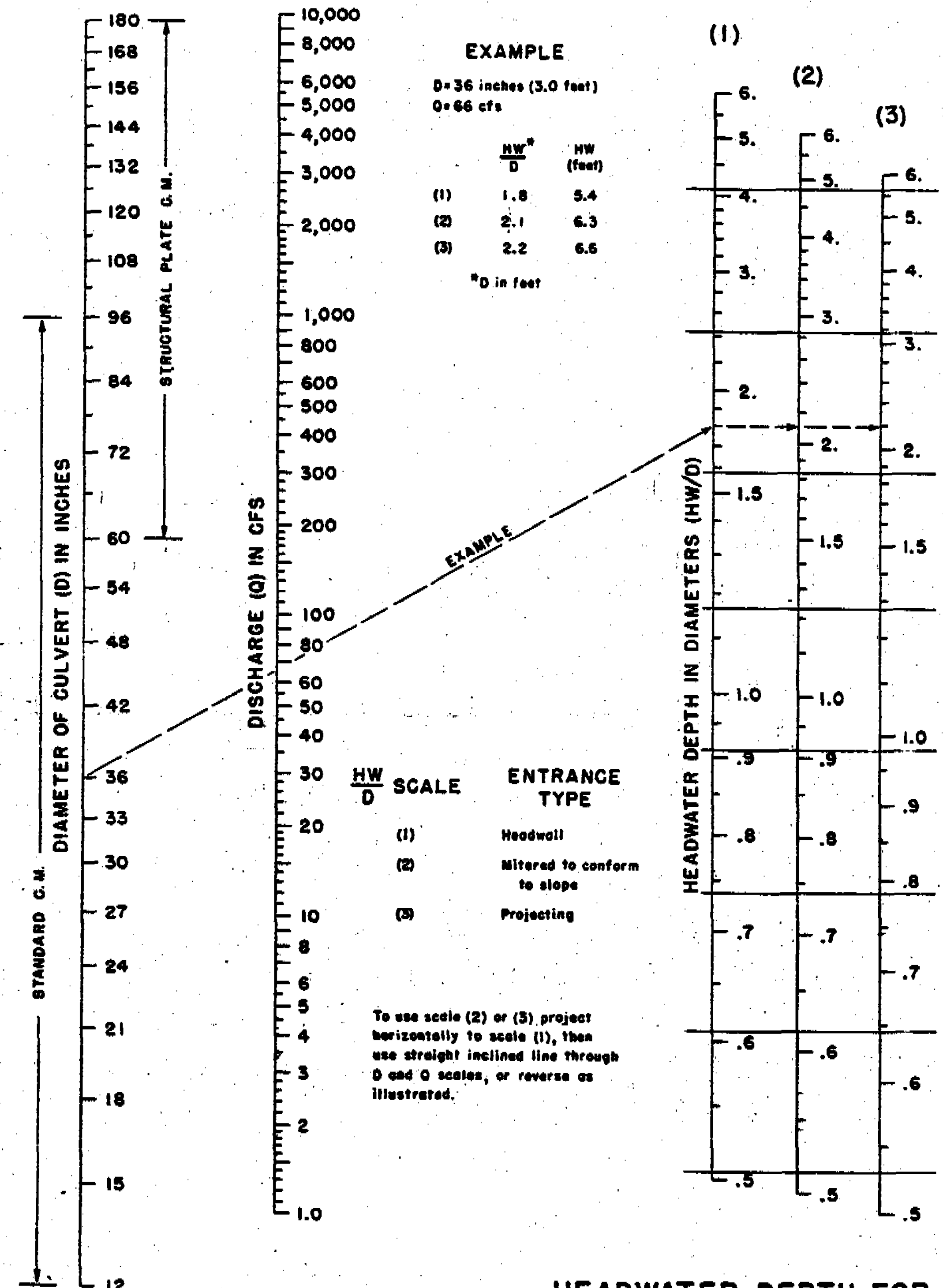
Culvert	Diameter	10-yr, 24-hr. Peak Q (cfs)	Entrance Type	HW/D (from Nomograph)
CCC-21	18"	1.69	Projecting	<.5
CCC-22	18"	0.92	Mitered	<.5
CCC-23	18"	1.07	Mitered	<.5
CCC-24	Pipe Arch ~[illegible]	101.8	Headwall	<.35
CCC-25	18"	2.46	Mitered	0.57
CCC-26	18"	0.84	Mitered	<.5
CCC-27	18"	0.25	Mitered	<.5

Results: All culverts are adequate to handle the 10-year, 24-hour storm.

CHART 5



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

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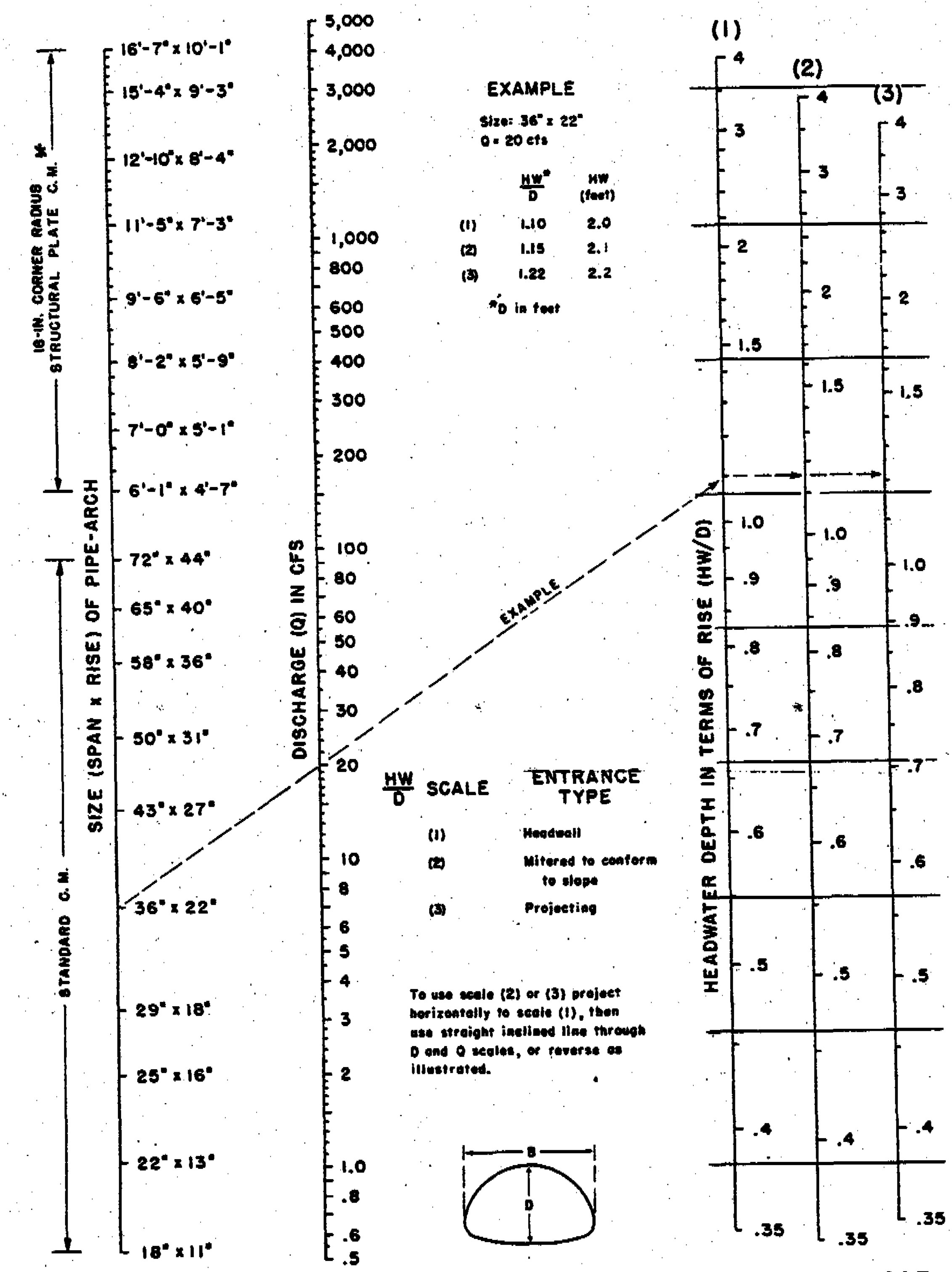
CHART 6



*ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG

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HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

Culverts - Crandall Canyon

Determine Exit Velocities
(assume n=.024 for CMP's)

Culvert (CCC-)	Size (	Peak Q (cfs)	Slope (%)	Velocity (ft/s)	Existing d_{50} (in)	Req'd d_{50} (in)	Normal Depth (ft)
1	24"	3.31	9.6%	7.5	8"	6"	.4'
2	84"	14.30	1.7%	5.3	1/2"	~1"	.85'
3	24"	5.14	7.9%	8.1	8"	7.2"	.51'
4	24"	2.06	0.9%	2.8	4"	None	.57'
5	24"	1.43	0.9%	2.5	12"	None	.47'
6	48"	7.47	0.9%	3.9	1"	None	.84'
7	Pipe Arch 17.5'x10.5'	77.91	5.2%	10.0	12"	10.2"	.84'
8	↓	91.23	0.9%	5.4	6"	~1"	1.7'
9	7.0 ft.	6.26	0.9%	3.4	6"	None	.66'
10	24"	0.09	Connects to CCC-9				
11	48"	1.62	1.7%	3.1	6"	None	.34'
12	48"	0.14	12.3%	2.9	12"	None	.07'
13	36"	1.22	51.0%	9.7	12"	9.6"	.15'
14	18"	3.27	10%	7.8	6"	6"	.43'
15	18"	0.37	6%	3.5	12"	None	.16'
16	18"	1.81	14%	7.5	12"	6"	.29'
17	18"	2.26	11%	7.3	8"	5.4"	.35'
18	24"	6.39	4%	6.7	15"	3"	.69'

Culvert (CCC)	Size	Peak Q (cfs)	Slope (%)	Velocity (fps)	Exist. d_{50} (in)	Req'd d_{50} (in)	Normal Depth
19	24"	4.25	9%	7.9	12"	6.6"	.45'
20	18"	1.91	0.5%	2.3	15"	None	.72'
21	18"	1.69	5%	5.1	15"	1"	.37'
22	18"	0.92	6%	4.6	18"	None	.26'
23	18"	1.07	14.1%	6.5	6"	4.8"	.22'
24	Pipe Arch 10.5x17.5'	101.8	1.7%	7.1	8"	2.4"	1.2'
25	18"	2.46	21.3%	9.3	Concrete Apron	OK	.31'
26	18"	0.84	134%	14.1	10"	21"	.11'
27	18"	0.25	111%	8.5	8"	7.2"	.07'

Ref: Hydrology Program developed by Thomas J. Suchoski Based on Methods by Chow (1959).

Note: Culvert slopes + existing riprap measured in the field.

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-1

Normal Flow

Channel Characteristics:

Diameter	= 2.0 ft	Design Discharge	= 3.3 cfs
Manning's n	= 0.0240	Channel Slope	= 0.096

Design Characteristics:

Depth	= 0.397 ft	Velocity	= 7.486 fps
Area	= 0.44 ft^2	Top Width	= 1.60 ft
Wetted Perimeter	= 1.847 ft	Froude Number	= 2.506

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-2

Normal Flow

Channel Characteristics:

Diameter	= 7.0 ft	Design Discharge	= 14.3 cfs
Manning's n	= 0.0240	Channel Slope	= 0.017

Design Characteristics:

Depth	= 0.853 ft	Velocity	= 5.343 fps
Area	= 2.68 ft^2	Top Width	= 4.58 ft
Wetted Perimeter	= 4.993 ft	Froude Number	= 1.232

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-3

Normal Flow

Channel Characteristics:

Diameter	=	2.0 ft	Design Discharge	=	5.1 cfs
Manning's n	=	0.0240	Channel Slope	=	0.079

Design Characteristics:

Depth	=	0.514 ft	Velocity	=	8.050 fps
Area	=	0.64 ft^2	Top Width	=	1.75 ft
Wetted Perimeter	=	2.127 ft	Froude Number	=	2.347

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-4

Normal Flow

Channel Characteristics:

Diameter	=	2.0 ft	Design Discharge	=	2.1 cfs
Manning's n	=	0.0240	Channel Slope	=	0.009

Design Characteristics:

Depth	=	0.567 ft	Velocity	=	2.810 fps
Area	=	0.73 ft^2	Top Width	=	1.80 ft
Wetted Perimeter	=	2.247 ft	Froude Number	=	0.777

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-5

Normal Flow

Channel Characteristics:					
Diameter	=	2.0 ft	Design Discharge	=	1.4 cfs
Manning's n	=	0.0240	Channel Slope	=	0.009
Design Characteristics:					
Depth	=	0.471 ft	Velocity	=	2.534 fps
Area	=	0.56 ft^2	Top Width	=	1.70 ft
Wetted Perimeter	=	2.027 ft	Froude Number	=	0.774

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-6

Normal Flow

Channel Characteristics:					
Diameter	=	4.0 ft	Design Discharge	=	7.5 cfs
Manning's n	=	0.0240	Channel Slope	=	0.009
Design Characteristics:					
Depth	=	0.842 ft	Velocity	=	3.881 fps
Area	=	1.92 ft^2	Top Width	=	3.26 ft
Wetted Perimeter	=	3.813 ft	Froude Number	=	0.890

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-11

Normal Flow

Channel Characteristics:

Diameter	= 4.0 ft	Design Discharge	= 1.6 cfs
Manning's n	= 0.0240	Channel Slope	= 0.017

Design Characteristics:

Depth	= 0.342 ft	Velocity	= 3.122 fps
Area	= 0.52 ft^2	Top Width	= 2.24 ft
Wetted Perimeter	= 2.373 ft	Froude Number	= 1.142

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-9

Normal Flow

Channel Characteristics:

Diameter	= 7.0 ft	Design Discharge	= 6.3 cfs
Manning's n	= 0.0240	Channel Slope	= 0.009

Design Characteristics:

Depth	= 0.658 ft	Velocity	= 3.422 fps
Area	= 1.83 ft^2	Top Width	= 4.09 ft
Wetted Perimeter	= 4.363 ft	Froude Number	= 0.901

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-12

Normal Flow

Channel Characteristics:

Diameter	= 4.0 ft	Design Discharge	= 0.1 cfs
Manning's n	= 0.0240	Channel Slope	= 0.123

Design Characteristics:

Depth	= 0.069 ft	Velocity	= 2.917 fps
Area	= 0.05 ft^2	Top Width	= 1.04 ft
Wetted Perimeter	= 1.053 ft	Froude Number	= 2.394

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-13

Normal Flow

Channel Characteristics:

Diameter	= 3.0 ft	Design Discharge	= 1.2 cfs
Manning's n	= 0.0240	Channel Slope	= 0.510

Design Characteristics:

Depth	= 0.145 ft	Velocity	= 9.712 fps
Area	= 0.13 ft^2	Top Width	= 1.29 ft
Wetted Perimeter	= 1.330 ft	Froude Number	= 5.478

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-14

Normal Flow

Channel Characteristics:

Diameter =	1.5 ft	Design Discharge =	3.3 cfs
Manning's n =	0.0240	Channel Slope =	0.100

Design Characteristics:

Depth =	0.432 ft	Velocity =	7.756 fps
Area =	0.42 ft^2	Top Width =	1.36 ft
Wetted Perimeter=	1.700 ft	Froude Number =	2.454

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-15

Normal Flow

Channel Characteristics:

Diameter =	1.5 ft	Design Discharge =	0.4 cfs
Manning's n =	0.0240	Channel Slope =	0.060

Design Characteristics:

Depth =	0.164 ft	Velocity =	3.540 fps
Area =	0.10 ft^2	Top Width =	0.94 ft
Wetted Perimeter=	1.010 ft	Froude Number =	1.866

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-16

Normal Flow

Channel Characteristics:

Diameter	= 1.5 ft	Design Discharge	= 1.8 cfs
Manning's n	= 0.0240	Channel Slope	= 0.140

Design Characteristics:

Depth	= 0.292 ft	Velocity	= 7.491 fps
Area	= 0.24 ft^2	Top Width	= 1.19 ft
Wetted Perimeter	= 1.370 ft	Froude Number	= 2.926

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-17

Normal Flow

Channel Characteristics:

Diameter	= 1.5 ft	Design Discharge	= 2.3 cfs
Manning's n	= 0.0240	Channel Slope	= 0.110

Design Characteristics:

Depth	= 0.347 ft	Velocity	= 7.305 fps
Area	= 0.31 ft^2	Top Width	= 1.26 ft
Wetted Perimeter	= 1.505 ft	Froude Number	= 2.603

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-18

Normal Flow

Channel Characteristics:					
Diameter	=	2.0 ft	Design Discharge	=	6.4 cfs
Manning's n	=	0.0240	Channel Slope	=	0.040
Design Characteristics:					
Depth	=	0.688 ft	Velocity	=	6.679 fps
Area	=	0.96 ft^2	Top Width	=	1.90 ft
Wetted Perimeter	=	2.507 ft	Froude Number	=	1.659

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-19

Normal Flow

Channel Characteristics:					
Diameter	=	2.0 ft	Design Discharge	=	4.3 cfs
Manning's n	=	0.0240	Channel Slope	=	0.090
Design Characteristics:					
Depth	=	0.454 ft	Velocity	=	7.931 fps
Area	=	0.54 ft^2	Top Width	=	1.68 ft
Wetted Perimeter	=	1.987 ft	Froude Number	=	2.472

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-20

Normal Flow

Channel Characteristics:

Diameter	= 1.5 ft	Design Discharge	= 1.9 cfs
Manning's n	= 0.0240	Channel Slope	= 0.005

Design Characteristics:

Depth	= 0.722 ft	Velocity	= 2.270 fps
Area	= 0.84 ft^2	Top Width	= 1.50 ft
Wetted Perimeter	= 2.300 ft	Froude Number	= 0.534

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-21

Normal Flow

Channel Characteristics:

Diameter	= 1.5 ft	Design Discharge	= 1.7 cfs
Manning's n	= 0.0240	Channel Slope	= 0.050

Design Characteristics:

Depth	= 0.366 ft	Velocity	= 5.062 fps
Area	= 0.33 ft^2	Top Width	= 1.29 ft
Wetted Perimeter	= 1.550 ft	Froude Number	= 1.753

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-22

Normal Flow

Channel Characteristics:					
Diameter	=	1.5 ft	Design Discharge	=	0.9 cfs
Manning's n	=	0.0240	Channel Slope	=	0.060
Design Characteristics:					
Depth	=	0.257 ft	Velocity	=	4.570 fps
Area	=	0.20 ft^2	Top Width	=	1.13 ft
Wetted Perimeter	=	1.280 ft	Froude Number	=	1.908

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-23

Normal Flow

Channel Characteristics:					
Diameter	=	1.5 ft	Design Discharge	=	1.1 cfs
Manning's n	=	0.0240	Channel Slope	=	0.141
Design Characteristics:					
Depth	=	0.224 ft	Velocity	=	6.485 fps
Area	=	0.17 ft^2	Top Width	=	1.07 ft
Wetted Perimeter	=	1.190 ft	Froude Number	=	2.909

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-25

Normal Flow

Channel Characteristics:

Diameter	=	1.5 ft	Design Discharge	=	2.5 cfs
Manning's n	=	0.0240	Channel Slope	=	0.213

Design Characteristics:

Depth	=	0.310 ft	Velocity	=	9.345 fps
Area	=	0.26 ft^2	Top Width	=	1.21 ft
Wetted Perimeter	=	1.415 ft	Froude Number	=	3.537

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-26

Normal Flow

Channel Characteristics:

Diameter	=	1.5 ft	Design Discharge	=	0.8 cfs
Manning's n	=	0.0240	Channel Slope	=	1.540

Design Characteristics:

Depth	=	0.112 ft	Velocity	=	14.062 fps
Area	=	0.06 ft^2	Top Width	=	0.79 ft
Wetted Perimeter	=	0.830 ft	Froude Number	=	9.002

Circular Channel Design Evaluation
Based on Methods in:

OPEN-CHANNEL HYDRAULICS
BY CHOW, 1959

Results for: CCC-27

Normal Flow

Channel Characteristics:

Diameter	=	1.5 ft	Design Discharge	=	0.3 cfs
Manning's n	=	0.0240	Channel Slope	=	1.110

Design Characteristics:

Depth	=	0.069 ft	Velocity	=	8.510 fps
Area	=	0.03 ft^2	Top Width	=	0.63 ft
Wetted Perimeter	=	0.650 ft	Froude Number	=	6.944

Exit Velocity Calcs for
Pipe Arch Culverts

Ref: American Iron + Steel Institute, 1983.

$\boxed{\text{CCC-7}}$ Q = 77.9 cfs, Slope = 5.2%, Size ~ 10.5' x 17.5'

Based on Full flow calculations

use a 16'7" x 10'1" culvert size from attached table.

Area = 130 ft² Slope = 5.2%
Hyd. Rad. = 2.98 ft.

Calculate $Q_{full} = \frac{1.49}{n} A R^{2/3} S^{1/2}$

$Q_{full} = \frac{1.49}{.024} (130)(2.98)^{2/3}(.052)^{1/2}$

$Q_{full} = 3800$ cfs $V_f = \frac{Q}{A} = \frac{3800}{130} = 29.2$

$\frac{Q}{Q_{full}} = \frac{77.9}{3800} = .021$

from Attached figure;

% of rise = 8%

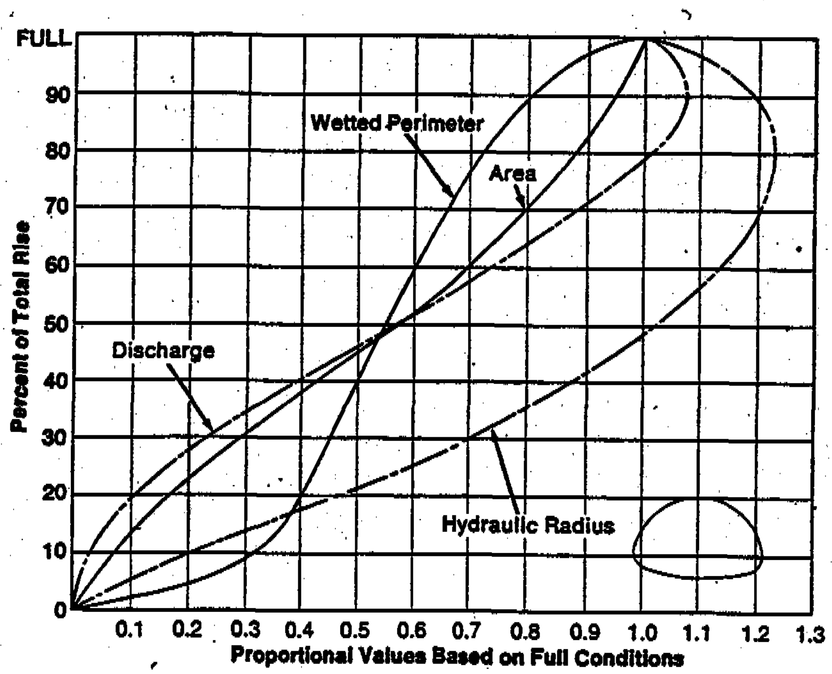
$\frac{Area}{Area_{full}} = .06$ Area = .06 (130 ft²)
= 7.8 ft²

$V = \frac{Q}{A} = \frac{77.9}{7.8} = 10$ ft/s

depth of flow ~ 0.08(10.5') = .84'

Full-Flow Data for Structural Plate Pipe-Arches
Corrugations 6 × 2 in.
Corner Plates 9 pl　　Radius (Rc) = 18 in.

Dimensions, ft-in.		Waterway Area, ft²	Hydraulic Radius, ft
Span	Rise		
6-1	4-7	22	1.29
6-4	4-9	24	1.35
6-9	4-11	26	1.39
7-0	5-1	28	1.45
7-3	5-3	30	1.51
7-8	5-5	33	1.55
7-11	5-7	35	1.61
8-2	5-9	38	1.67
8-7	5-11	40	1.71
8-10	6-1	43	1.77
9-4	6-3	45	1.81
9-6	6-5	48	1.87
9-9	6-7	51	1.93
10-3	6-9	54	1.97
10-8	6-11	57	2.01
10-11	7-1	60	2.07
11-5	7-3	63	2.11
11-7	7-5	66	2.17
11-10	7-7	70	2.23
12-4	7-9	73	2.26
12-6	7-11	77	2.32
12-8	8-1	81	2.38
12-10	8-4	85	2.44
13-5	8-5	88	2.48
13-11	8-7	91	2.52
14-1	8-9	95	2.57
14-3	8-11	100	2.63
14-10	9-1	103	2.67
15-4	9-3	107	2.71
15-6	9-5	111	2.77
15-8	9-7	116	2.83
15-10	9-10	121	2.89
16-5	9-11	125	2.92
16-7	10-1	130	2.98



Hydraulic properties of corrugated steel and structural plate pipe-arches.

Ref: American Iron + Steel Institute, 1983.

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CCC-8 $\quad Q = 91.2$ cfs $\quad$ Slope = .9%
size ~ 10.5' x 17.5'

Full Flow conditions ⇒

use 16'7" x 10'1" culvert size from table.

Area = 130 ft²
Hyd. rad. = 2.98 ft $\qquad$ slope = 0.9%

$$Q_{full} = \frac{1.49}{.024}(130)(2.98)^{2/3}(.009)^{1/2}$$

$Q_{full} = 1586$ cfs $\qquad V_{full} = \frac{Q_{full}}{A} = \frac{1586}{130} = 12.2$ ft/s

$$\frac{Q_{actual}}{Q_{full}} = \frac{91.2}{1586} = .06$$

From attached Figure:

% of rise = 16%

$\frac{Area}{Area_{full}} = 0.13 \qquad Area = .13(130) = 16.9$ ft²

$$V = \frac{Q}{A} = \frac{91.2}{16.9} = \underline{5.4 \text{ ft/sec}}$$

depth of flow ~ .16(10.5') = 1.7 ft

CCC-24 $Q = 101.8$ cfs slope = 1.7%
size ~ 10.5' x 17.5'

Based on Full flow calcs ⇒

use 16'7" x 10'1" culvert size from attached table. Conservative calculation.

Area = 130 ft² Slope = 1.7%
Hyd. Rad. = 2.98 ft

$$Q_{full} = \frac{1.49}{.024}(130)(2.98)^{2/3}(.017)^{1/2}$$

$Q_{full} = 2179.2$ cfs

$$\frac{Q_{actual}}{Q_{full}} = \frac{101.8}{2179.2} = .047$$

From attached figure:

% of rise = 14%

$$\frac{Area}{Area_{full}} = 0.11 \qquad Area = 130(.11) = 14.3\ ft^2$$

$$V = \frac{Q}{A} = \frac{101.8}{14.3} = \underline{7.1\ ft/sec}$$

$$d = .11(10.5') = \underline{1.2\ ft}$$

Riprap Sizing Calculations
for Crandall Canyon Culverts

Use Figures 1 + 2 (attached) for Calculations.

Ref: U.S. Department of Transportation (1978)

CCC-1 $V = 7.5$ fps $d = 0.4' =$ depth

Try 1: Assume $\frac{K}{d} = 1$

$\frac{V_s}{V} = 1$ $V_s = 7.5$

→ assume 2:1 side slopes for all calculations

$K = 0.5$

Try 2: $\frac{K}{d} = \frac{.5}{.4} > 1$ okay

req'd $d_{50} = 0.5' = 6''$ existing riprap okay

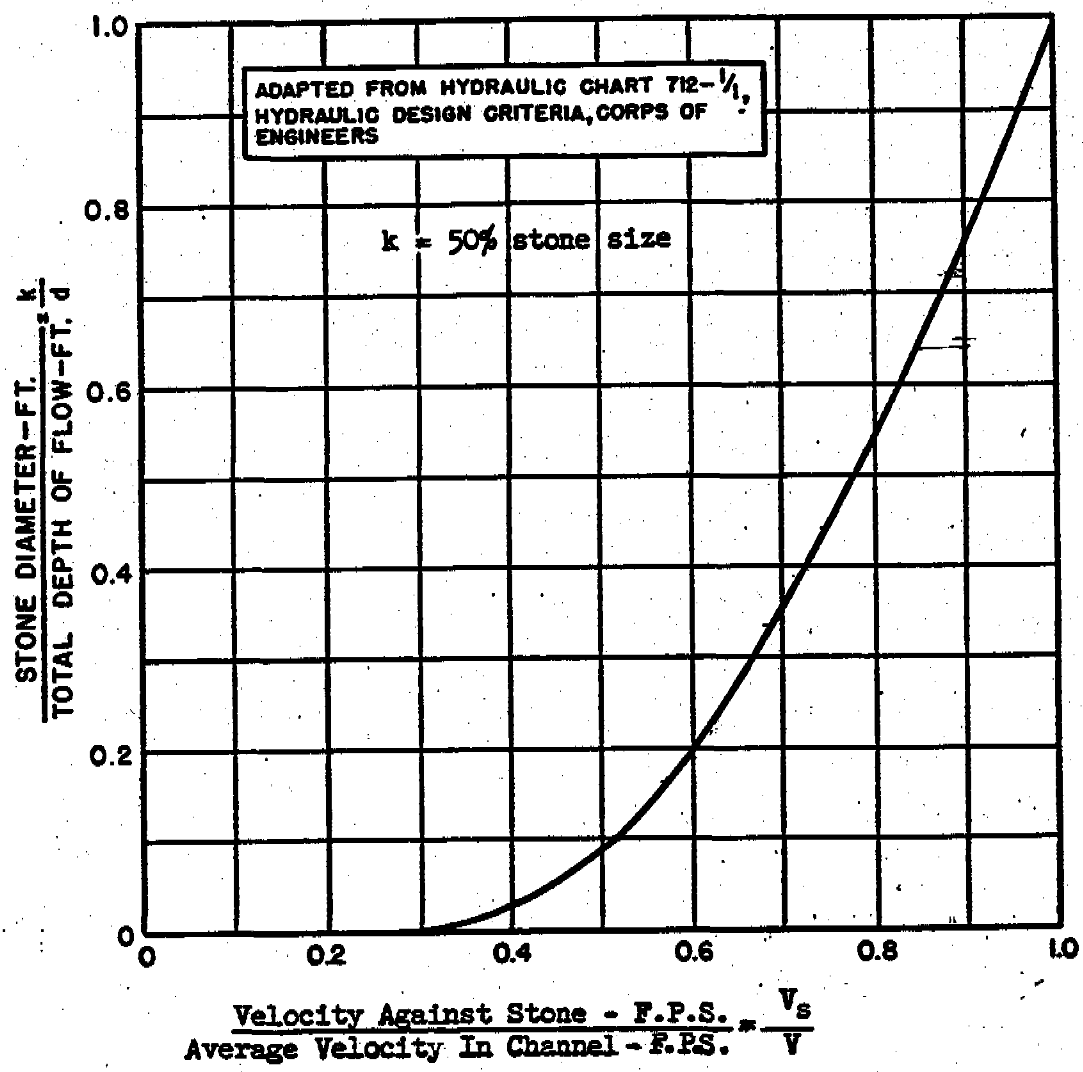
CCC-2 $V = 5.3$ ft/s $d =$ depth $= .85'$

Try 1: Assume $\frac{K}{D} = \frac{.5}{.85} = .59$

$\frac{V_s}{V} = .82$ $V = .82(5.3) = 4.3$ ft/s

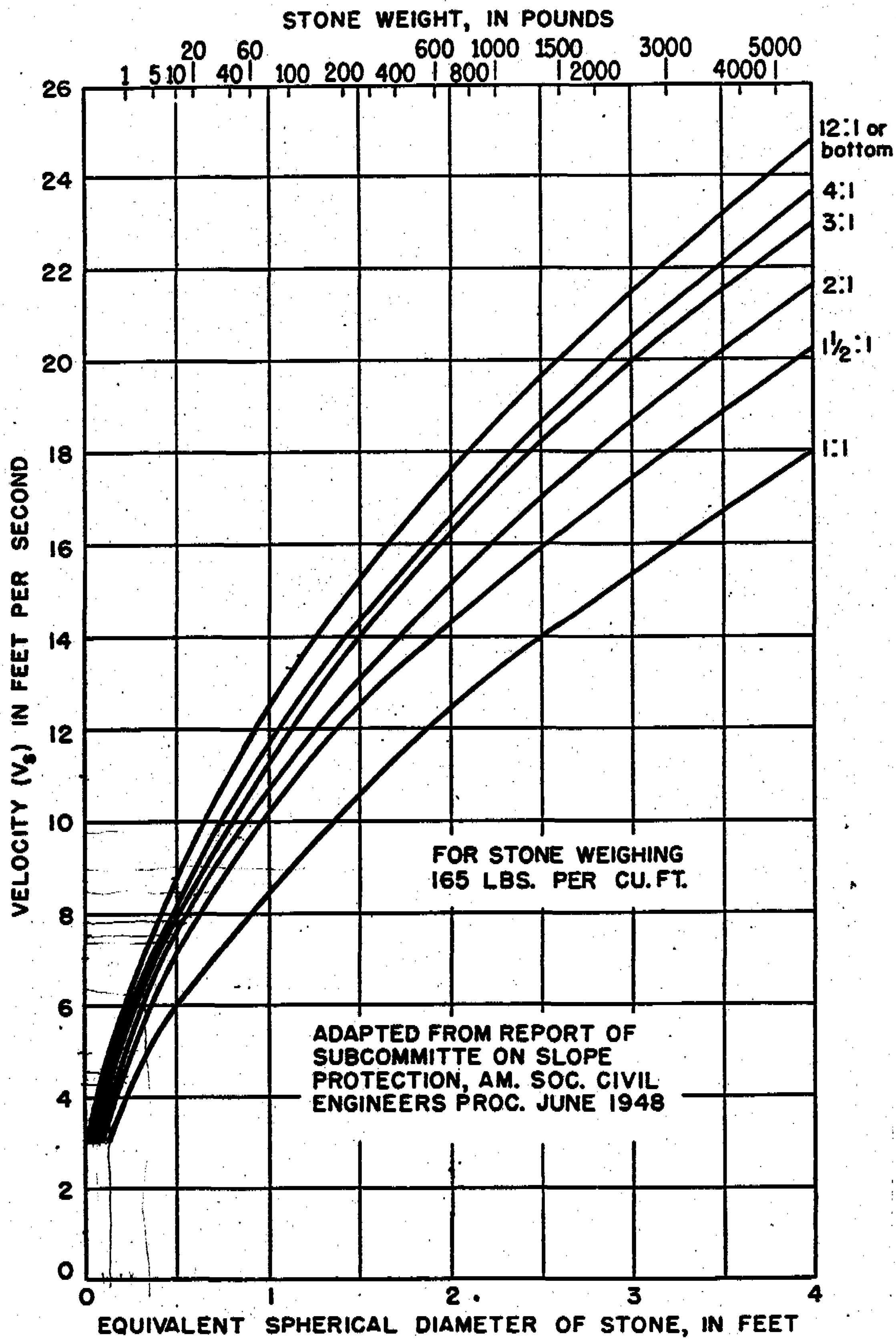
$K = 0.2$ ft

→



VELOCITY AGAINST STONE ON CHANNEL BOTTOM

FIGURE 1



SIZE OF STONE THAT WILL RESIST DISPLACEMENT
FOR VARIOUS VELOCITIES AND SIDE SLOPES

FIGURE 2

Try 2: $\frac{k}{d} = \frac{.2}{.85} = .24$

$\frac{V}{V_s} = .62 \quad V_s = .62(5.3) = 3.3$ ft/s

d_{50} req'd ≈ 0.1 ft $\approx 1"$

<u>Existing riprap okay</u>

$\boxed{\text{CCC-3}}$ $V = 8.1$ ft/s depth $= .51$ ft

Assume $\frac{k}{d} > 1$

$\frac{V_s}{V} = 1 \quad V_s = 8.1$ ft/s

req'd $d_{50} = 0.6$ ft $= 7.2$ in

<u>Existing riprap OK</u>

$\boxed{\text{CCC-13}}$ $V = 9.7$ ft/s depth $= .15'$

Assume $\frac{k}{d} > 1$

$\frac{V_s}{V} = 1 \quad V_s = 9.7$ ft/s

d_{50} req'd $= 0.8' = 9.6"$

<u>Existing riprap OK</u>

Check Riprap

$\boxed{CCC-7}$

$V = 10$ ft/s $\quad d = .84'$

try $k = 12"$ $\quad \frac{k}{d} > 1$

$\frac{V_s}{V} = 1$ $\quad V_s = 10$ ft/s

from Fig 2, assume side slopes 3:1

d_{50} req'd $= 0.85' = 10.2"$

Existing riprap OK

$\boxed{CCC-8}$

$V = 5.4$ ft/s $\quad d = 1.7'$

assume $k \doteq 3"$ $\quad \frac{k}{d} = 0.15$

$\frac{V_s}{V} = 0.57$ $\quad V_s = .57(5.4) = 3.1$ ft/s

req'd $d_{50} \sim 0.1' \sim 1"$

∴ Existing riprap okay

CCC-14 $V = 7.8$ ft/s $d = .43'$

Assume $\frac{k}{d} > 1$

$\frac{V_s}{V} = 1$ $V_s = 7.8$ ft/s

req'd $d_{50} = 0.5$ ft $= 6''$

Existing riprap OK

CCL-16 $V = 7.5$ $d = .29'$

Assume $\frac{k}{d} > 1$

$\frac{V_s}{V} = 1$ $V_s = 7.5$ ft/s

req'd $d_{50} = 0.5' = 6''$

Existing riprap OK

CCC-17 $V = 7.3$ ft/s $d = .35'$

Assume $\frac{k}{d} > 1$

$\frac{V_s}{V} = 1$ $V_s = 7.3$ ft/s

req'd $d_{50} = .45' = 5.4''$

Existing Riprap OK

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CCC-18

$V = 6.7$ ft/s $d = .69'$

try $k = .5'$

$\frac{k}{d} = \frac{.5}{.69} = .725$

$\frac{V_s}{V} = 0.88$ $V = .88(6.7) = 5.9$ ft/s

$d_{50} \sim 0.3$ ft

try 2: $\frac{k}{d} = \frac{.3}{.69} = .44$

$\frac{V_s}{V} = .75$ $V = 5$ ft/s

Req'd $d_{50} = .25' = 3"$

Existing riprap OK

CCC-19

$V = 7.9$ ft/s $d = .45'$

Assume $\frac{k}{d} > 1$

$V_s = V = 7.9$ ft/s

req'd $d_{50} = 0.55' = 6.6"$

Existing riprap OK

$\boxed{CCC-21}$ $V_s = 5.1$ ft/s $d = .37'$

Assume $k = 1'' = .08'$

$\frac{k}{d} = \frac{.08}{.37} = .23$

$\frac{V_s}{V} = 0.62$ $V_s = 3.2$ ft/s

Req'd $d_{50} \sim 0.1$ ft $\approx 1''$

Existing riprap OK

$\boxed{CCC-23}$ $V = 6.5$ ft/s $d = 0.22'$

assume $\frac{k}{d} \geq 1$

$\frac{V_s}{V} = 1$ $V_s = 6.5$ ft/s

req'd $d_{50} = 0.4$ ft $= 4.8''$

Existing riprap Okay

$\boxed{CCC-26}$ $V = 14.1$ ft/s $d = 0.11$

$\frac{k}{d} \geq 1$

$\frac{V_s}{V} = 1$ $V_s = V = 14.1$ ft/s

d_{50} req'd $= 1.75' = 21''$

Existing riprap is NOT Adequate

$\boxed{\text{Cle-24}}$ $V = 7.1$ ft/sec $d = 1.2$ ft

assume $k = 4''$ $\frac{k}{d} = 0.28$

$\frac{V_s}{V} = 0.66$ $V_s = 4.7$ ft/s

from Fig 2 → Slope 2:1

req'd $d_{50} \sim 0.25'$

check → $\frac{k}{d} = \frac{.25}{1.2} = .21$

$\frac{V_s}{V} = .62$ $V_s = 4.4$ ft/s

req'd $d_{50} \sim 0.2$ ft $= 2.4''$

Existing riprap OK

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$\boxed{\text{CC-27}}$ $V = 8.5$ ft/s $d = 0.07'$

$\frac{k}{d} > 1$ $\frac{V_s}{V} = 1$ $V_s = 8.5$ ft/s

d_{50} req'd $= 0.6' = 7.2''$

Existing riprap OK

ADDENDUM TO
APPENDIX 3.7F

AS-BUILT CALCULATIONS FOR DRAINAGE DIVERSION CULVERTS

REGISTERED PROFESSIONAL ENGINEER
NO. 11350
WILLIAM S.
HENDRICKSON
STATE OF UTAH

EARTHFAX ENGINEERING, INC.
HYDROGRAPH GENERATION PROGRAM OUTPUT
BASED ON SCS CURVE NUMBER METHODOLOGY

INPUT FOR: CCWS-U32

STORM :	WATERSHED :
Dist.=SCS Type II - 24 Hr	Area = 46.08 acres
Depth = 1.90 inches	CN = 65.00
Duration = 24.00 hrs	Time conc.= 0.120 hrs

OUTPUT SUMMARY

Runoff depth	0.10913	inches	
Initial abstr	1.07692	inches	
Peak flow =	2.21	cfs	(0.04748 iph)
at time	12.064	hrs	

4/95

Circular Channel Analysis & Design
Solved with Manning's Equation

Open Channel - Uniform flow

Worksheet Name: CRANDALL CANYON

Comment: CCC-28

Solve For Actual Depth

Given Input Data:

Diameter..........	1.50 ft
Slope.............	0.1540 ft/ft
Manning's n.......	0.024
Discharge.........	2.21 cfs

$\frac{HW}{D} < 0.5$

Computed Results:

Depth.............	0.32 ft
Velocity..........	8.06 fps
Flow Area.........	0.27 sf
Critical Depth....	0.56 ft
Critical Slope....	0.0169 ft/ft
Percent Full......	21.25 %
Full Capacity.....	22.33 cfs
QMAX @.94D........	24.02 cfs
Froude Number.....	3.00 (flow is Supercritical)

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CCC-2B (CHECK RIPRAP).

D = 0.32 FT
V = 8.06 FPS
(BASED ON AVERAGE SLOPE VELOCITY).

ASSUME $\frac{K}{D} > 1$

$\frac{V_S}{V} = 1$ $V_S = 8.06$ FPS

$\boxed{d_{50} \text{ REQUIRED} = 0.40' = 5 \text{ INCH RIPRAP.}}$

CULVERT	DIAMETER	10-YR - 24 HR PEAK Q (CFS)	ENTRANCE TYPE	HW/D (FROM NOMOGRAPH)
CCC-2B	18"	2.21 CFS	MITERED	<0.5

CULVERT	SIZE	PEAK Q (CFS)	SLOPE (%)	VELOCITY (FPS)	EXIST d50 (in)	REQUIRED d50 (in)	NORMAL DEPTH (FT)
CCC-2B	18"	2.21	15.4	8.06	—	5	0.32