GEI Consultants, Inc.

GEOTECHNICAL AND DAM ENGINEERING SERVICES
CHIMNEY HOLLOW DAM AND RESERVOIR FEASIBILITY STUDY
LARIMER COUNTY, COLORADO

Submitted to:

Municipal Subdistrict,
Northern Colorado Water Conservancy District,
acting by and through
the Windy Gap Water Activity Enterprise

5660 Greenwood Plaza Blvd., Suite 202
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(303) 779-5565

April 25, 1997
Project 96293

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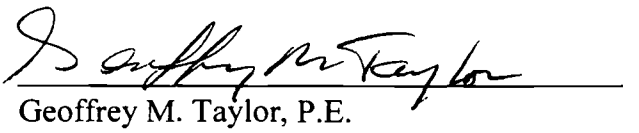

Geoffrey M. Taylor, P.E.
Project Manager

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1. INTRODUCTION

1.1 PURPOSE

This report presents the results of the Chimney Hollow Dam and Reservoir Feasibility Study performed by GEI Consultants, Inc. (GEI). GEI performed the study to evaluate the feasibility of providing water storage at the Chimney Hollow site. Water stored in Chimney Hollow Reservoir would be supplied from the Windy Gap Project and other approved sources. Storage at Chimney Hollow would provide drought protection, provide water management flexibility, and improve the reliability of water supplies available from the Windy Gap Project.

The Chimney Hollow Dam and Reservoir site is located about one-half mile west of Carter Lake in Larimer County, Colorado, about eleven miles west of Loveland, Colorado. A site location map and project features map are shown on Figures 1 and 2, respectively.

1.2 SCOPE OF WORK

GEI performed the following work for this study:

1. Reviewed and compiled available geologic and geotechnical information developed for this and other projects in the area.

2. Performed a geologic reconnaissance of the dam and reservoir site to supplement the findings from the data review.

3. Performed subsurface exploration and laboratory testing programs for the proposed dam site and reservoir borrow area.

4. Evaluated existing geologic and subsurface information to identify types and approximate quantities of available construction material within the reservoir basin.

5. Performed feasibility-level engineering evaluations of alternative dam types, identified a preferred (recommended) dam type, and developed opinions of probable construction cost for the selected dam type. The recommended dam type is an earthfill/rockfill dam. It was evaluated for a reservoir volume of approximately 60,000 acre-feet, about the maximum feasible storage potential at the site. Engineering evaluations and opinions of probable construction costs for appurtenant structures were not part of our scope of work.

6. Prepared this report summarizing our findings and opinions of probable construction cost.

1.3 AUTHORIZATION

This work was authorized by a Consulting Services Agreement between GEI and the Municipal Subdistrict, Northern Colorado Water Conservancy District, acting by and through the Windy Gap Water Activity Enterprise (Subdistrict). The agreement is dated October 11, 1996.

1.4 PROJECT PERSONNEL

The following personnel from GEI are responsible for the work summarized herein:

Project Manager	Geoffrey M. Taylor, P.E.
Project Engineering Geologist	Douglas D. Boyer, P.G., C.E.G.
Staff Engineers	Scott R. Cooper, E.I.T.
	Eric Johnson, E.I.T.
Technical Reviewer	Keith A. Ferguson, P.E.

Mr. Carl Brouwer, P.E., of the Northern Colorado Water Conservancy District (NCWCD) directed, coordinated, and reviewed the work for this project. Mr. Jeff Drager of the NCWCD provided valuable input during the course of this study. NCWCD personnel also provided project field survey information, including boring coordinates.

2. DATA REVIEW

2.1 GENERAL

Prior to initiating field or engineering evaluations for the project, we reviewed available information for various projects in the area. The review of information included:

1. Project and miscellaneous reports available from the National Archives [1-5]
2. Project reports available from the U.S. Bureau of Reclamation project files [6-9]
3. Reports and maps available from the U.S. Geological Survey [10]
4. Project and miscellaneous reports available from GEI files [11-13]

We reviewed these sources as they pertain to the proposed features and geologic setting of the Chimney Hollow Dam and Reservoir site. In particular, we reviewed the data from the Flatiron Dam and Reservoir project in greater detail due to its proximity, similar geologic setting, and foundation and embankment features.

2.2 SUMMARY OF FINDINGS

The following sections summarize pertinent information obtained from the data review. A discussion of the regional and site geology is included in Section 3.0.

Construction Materials Availability -

Previous Flatiron Dam Investigations

Flatiron Dam is a zoned earthfill and rockfill embankment located approximately 1 mile downstream from the proposed Chimney Hollow Dam site. Flatiron Dam contains approximately 380,000 cubic yards of material [2]. The embankment was designed with three zones: 1) a central impervious zone consisting of selected clay, sand, and gravel (zone 1); 2) a zone of selected sand, gravel, and cobbles upstream and downstream of the central zone (zone 2); and 3) an outer upstream zone of selected clay, sand, gravel, cobbles, and rock (zone 3). Borings performed at the site indicate that the thickness of the alluvial soils range from approximately 5 feet over the abutments to 25 feet over the valley floor [1]. Borings performed within the footprint of the dam indicate that bedrock was relatively shallow and consisted of

mostly hard sandstone with interbeds of micaceous shale. Grouting of the foundation bedrock was not included in the design of the dam [2].

The zone 1 impervious embankment material was derived mainly from an upstream borrow area located in the stream valley within the reservoir area [3,4]. The zone 1 material was also derived from the upper 5 feet of a downstream borrow area and from suitable materials derived from the excavation of the cutoff trench, spillway, and outlet works. The zone 2 material was obtained mainly from a downstream borrow source. This material was composed of sand, gravel, and cobbles. Approximately 30 percent of the total zone 2 material was derived from a riprap quarry source. The zone 3 material was obtained from a stockpile of material that had been excavated for the spillway and outlet works. Riprap was quarried from a Precambrian metamorphic formation composed predominantly of a massive schist located west of the dam site [4].

Flatiron Dam Foundation Treatments - The foundation materials exposed at the Flatiron Dam are the same rock formations as will be encountered at the Chimney Hollow Dam site. Little information was found in the available records concerning the foundation conditions encountered, and foundation treatments performed during construction. Excavation for the cutoff trench of Flatiron Dam consisted of removing the overburden materials along the slopes and stream valley. The excavation depths varied from a few feet on the abutment slopes to as much as 25 feet near the maximum section/stream valley area [3]. No grouting of the foundation bedrock was performed during construction [3].

3. GEOLOGIC RECONNAISSANCE

3.1 REGIONAL GEOLOGY

The proposed Chimney Hollow Dam and Reservoir are located in the Colorado Piedmont subdivision near the border of the Southern Rocky Mountains physiographic province to the west and the Great Plains physiographic province to the east. The Southern Rocky Mountains in Colorado consist predominantly of north-south trending mountain ranges. The individual ranges have central cores of Precambrian rocks, surrounded by Paleozoic and Mesozoic sedimentary rocks that dip away on all sides. The Front Range, the easternmost range of the Southern Rocky Mountain system, extends from the Colorado-Wyoming state line to the Arkansas River.

The oldest rocks in the region are Precambrian granites, schists, and gneisses. Above these rocks are mostly late Paleozoic to Mesozoic sandstones, shales, and limestones of continental and marine origin which have undergone several periods of uplift, folding, tilting, and erosion. Uplift and erosion from Laramide time (tertiary) through late Pliocene time have since modified the topography to its present configuration.

In historic time (the last 100 years or so), the area has been relatively quiet in a geologic sense, indicating that crustal movement has been relatively dormant, or that tectonic changes have not been detected.

3.2 RESERVOIR SITE GEOLOGY

The following discussion of site geology is based on:

1. Review of available geological information in Reclamation reports for the area [1,5-7],

2. Review of geological literature for the site available at the USGS library [10],

3. Review of 1" = 2000' black and white air photographs of the site available from the Earth Science Information Center (ESIC) at the USGS, and

4. Geologic reconnaissance of the dam and reservoir site conducted in October 1996.

A published geologic map of the Chimney Hollow area is shown on the USGS Map I-855-G, Miscellaneous Investigations Series, Boulder-Fort Collins-Greeley Area, Colorado [10]. This

USGS geologic map and our field reconnaissance provided the basis of the geologic information presented on Figures 3 and 4.

The dam and reservoir site are located near the base of a series of tilted sedimentary rocks that lie against older Precambrian granites and metamorphic rocks of the Front Range. Erosion of the tilted sedimentary units has left a series of parallel ridges of the harder upturned strata separated by longitudinal valleys in the softer layers. The rock units exposed in the reservoir area (from oldest to youngest and from west to east) include the: 1) Precambrian granitic and metamorphic rocks, 2) the Fountain Formation, and 3) the Ingleside Formation. The sedimentary rock units of the Fountain and Ingleside Formations dip downward to the east at 12 to 15 degrees. Quaternary soil deposits include alluvium in the central stream valley and colluvium along the valley slopes.

Below is a brief description of the rock units exposed within the proposed reservoir (from oldest to youngest):

Precambrian Metamorphic Rocks - The metamorphic rocks consist generally of hard, massive quartzofeldspathic schist and gneiss interbedded with mica schist and gneiss. Contains local thin beds of knotted mica schist and metaconglomerate.

Precambrian Granitic Rocks - The granitic rocks consist mostly of hard, massive, fine- to medium-grained yellowish-orange to reddish-grey, biotite-muscovite quartz monzonite. Locally known as the Silver Plume Quartz Monzonite.

Fountain Formation - Consists mostly of coarse (granitic) gritty conglomerates and cross bedded arkosic sandstones which are the erosional products of the Precambrian Crystallines. In addition, the formation contains lenticular interbeds of multi-colored micaceous shale. Permian to Pennsylvanian in age.

Ingleside Formation - Consists mostly of fine to medium grained arkose and sub-arkosic sandstone. Includes tongues of carbonate rock containing solution features such as collapse breccia, silica boxwork, and cubic salt-crystal molds. The depositional environment was dominantly nearshore marine, perhaps as offshore bars, and fluvial channel deposits in the more arkosic beds. Permian in age.

There are no known geologic hazards that would adversely affect the design or construction of the proposed dam and reservoir.

There are no known active or potentially active faults in the vicinity of the dam and reservoir [14-16]. According to current U.S. Bureau of Reclamation guidelines, a fault is classified as "active" if there is evidence for repeated surface displacement in deposits younger than 130,000 years (i.e., late Quaternary), and/or if it is associated with a moderate- to large-magnitude historical earthquake. According to the same guidelines, a fault is classified as "potentially active" if there is evidence for surface displacement during the late Quaternary but the age of the most recent event is unknown. In contrast, the Colorado Geological Survey (CGS) classifies a fault as "potentially active" if it displaces rock of Miocene or Pliocene age (2 to 23 million years before present) or if it offsets a late Eocene (38 to 45 million years before present) erosion surface [15].

A number of faults are mapped within 5 miles of the site, including the Blue Mountain Fault, the Carter Lake Anticline Fault, the Saddle Notch Gulch Fault, the Skinner Gulch Fault, The Bald Mountain Fault, and the Rattlesnake Park Fault [16]. These faults are shown on Figure 5. Based on recently completed evaluations for the U.S. Bureau of Reclamation, which included aerial photography interpretation and field reconnaissance of these features, these faults are considered to be not active [16]. Again, according to Reclamation guidelines, a fault is judged to be "not active" if there is no evidence of faulting during the late Quaternary (i.e., last 130,000 years).

An additional fault, the Drotar Ranch Fault, has been mapped in the vicinity of the reservoir to the south of the dam site [17]. This fault is not shown on the USGS geologic quadrangle map for the area [10], in the U.S. Bureau of Reclamation Seismotectonic Evaluation Report [16], or the Colorado Geologic Survey Map of potentially active faults in Colorado [15]. This fault includes a number of small northeast-trending normal faults mapped within the Fountain Formation and Lyons Sandstone on the north side of the Blue Mountain Fault. Offsets along the fault segments range from approximately 1 foot to less than 20 feet [17]. The Drotar Ranch Fault is likely caused by localized crustal readjustment and offset associated with shearing along the Blue Mountain Fault. The Drotar Ranch Fault is likely syngenetic (formed at the same time) with the Blue Mountain Fault and is therefore not considered to be active.

There are no identified landslides in the area of the dam and reservoir [10].

3.3 DAM SITE GEOLOGY

Two bedrock units are exposed at the dam site: the Precambrian granitic rocks and the Fountain Formation. The Fountain Formation forms the entire right (east) abutment, central valley section, and the majority of the left (west) abutment of the dam site. The granitic rocks form the upper left abutment of the dam site With the exception of a few scattered outcrops, the entire

right abutment is mantled by thin covering of colluvium. An unknown thickness of alluvium is restricted to the central stream valley.

No faults or no landslides were observed or have been mapped at the dam site. No other geologic hazards were identified at the dam site other than possible rock falls from the Fountain Formation high on the right (east) abutment ridge.

4. *FIELD INVESTIGATIONS*

4.1 GENERAL

A subsurface exploration program, consisting of borings within the footprint of the proposed dam and a potential borrow area within the reservoir basin, was performed between November 20 and 27, 1996. The purposes of the exploration program at the proposed dam site were to: 1) investigate the condition of the bedrock below the proposed dam, 2) establish the elevation of firm rock below the proposed dam, 3) obtain samples of the bedrock for observation, and 4) perform packer pressure tests in the rock portions of the borings to estimate the permeability of the foundation materials.

The purposes of the exploration program in the potential borrow area were to: 1) investigate the soil overlying bedrock in the borrow area, 2) establish the elevation of the top of rock, 3) obtain samples of the soils for laboratory testing, and 4) evaluate the suitability and availability of construction materials in the borrow area. The subsurface exploration program for the proposed dam and borrow areas is summarized in Tables 1 and 2.

Layne Environmental Services, Denver, Colorado, performed the drilling services under subcontract to GEI. GEI coordinated, observed, and logged all drilling and field-testing operations.

Results of the subsurface exploration programs are presented below.

4.2 DAM SITE

The drilling program at the proposed dam site consisted of two borings, designated B101 and B102. The location of the borings are shown on Figure 6. The borings were drilled with a truck-mounted CME 75 drill rig and advanced through the overburden soils and very intensely weathered bedrock with 4-¼-inch-inside-diameter hollow stem augers. HQ-wireline rock coring techniques were used to advance the boring in the bedrock. Compressed air was used to remove the cuttings during rock coring.

Samples of overburden soils and very intensely weathered bedrock were obtained and logged from auger cuttings and split spoon samples. In the rock portion of the borings, percent core recovery, Rock Quality Designation (RQD), coring time, and other observations were recorded for each core run and are presented on the boring logs in Appendix A.

Boring B101 was drilled near the maximum section of the dam slightly downstream from the proposed dam axis. The purpose of this boring was to investigate the thickness and type of alluvial materials in the central stream valley and the characteristics of the bedrock below the alluvium. This boring was drilled vertical to a depth of 49.5 feet. The boring encountered 24.5 feet of clayey sand and sandy gravel (alluvium), over slightly weathered sandstone with interbedded claystone and siltstone of the Fountain Formation. Ground water was encountered at approximately 14.5 feet below the ground surface in the boring. The boring logs in Appendix A contain detailed descriptions of the soil and rock encountered in Boring B101.

Boring B102 was drilled on the lower right (east) abutment slightly downstream of the proposed dam axis. The purpose of this boring was to investigate the thickness of overburden materials and the characteristics of the Fountain Formation below the overburden materials. This boring was drilled vertical to a depth of 61.0 feet. The boring encountered 34.5 feet of clayey sand, silty sand and gravelly sand over moderately to slightly weathered sandstone and claystone of the Fountain Formation. A 2-foot-thick very hard quartz dike was encountered in the boring at 42.5 feet below the ground surface. Ground water was encountered in the boring at approximately 25.5 feet below the ground surface during drilling. The boring logs in Appendix A contain detailed descriptions of the soil and rock encountered in Boring B102.

Upon completion of drilling, packer permeability tests were performed in the rock portion of the borings. The tests were performed at approximate 10-foot intervals. Two test pressures, approximately 80 and 100 percent of the existing effective overburden pressure, were used for each testing interval. Table 3 summarizes the results of the packer permeability tests. Detailed test results are presented in Appendix A. Results of the tests indicated rock mass permeabilities in the range of 31 to 55 feet per year in Boring B101 and 24 feet per year in Boring B102.

The borings were backfilled with non-shrink, cement-bentonite grout upon completion of the packer testing.

4.3 BORROW AREA

The drilling program at the proposed borrow area consisted of 20 borings drilled along seven cross section lines within the reservoir area. The location of the proposed borrow area and the cross section locations of the borings are shown on Figure 6. The borings were drilled with a truck mounted CME 75 drill rig and advanced with 4-¼-inch-inside-diameter hollow stem augers. Soil samples were obtained from auger cuttings and ahead of the augers by driving a split-spoon sampler according to the procedures of ASTM D1586. The borrow area borings were advanced to auger refusal.

The depth of the borrow area borings ranged from 1 to 29.5 feet below the ground surface. Table 2 summarizes the depth of each boring. The soils encountered ranged from sandy gravels to silty clays. Ground water was not encountered in any of the borings during drilling. The boring logs in Appendix B contain detailed descriptions of the soil encountered in each boring.

4.4 LABORATORY TESTING

Representative samples of the overburden soils and bedrock from the dam site borings and soils from the borrow area were selected for laboratory testing to confirm field classifications, characterize the physical properties, and assess the suitability of the materials for construction of the proposed dam.

Laboratory tests included moisture content determination, grain-size distribution, and Atterberg limits. The laboratory testing was performed by James L. Valentine, Inc., Niwot, Colorado, under subcontract to GEI.

Table 4 summarizes the results of the laboratory testing. Detailed test results are presented in Appendix B.

4.5 FIELD INVESTIGATIONS CONCLUSIONS

Significant findings of the field investigation and laboratory testing programs include:

1. The borings performed at the proposed dam site indicate that the depth to bedrock at the location of the borings is relatively shallow, on the order of approximately 30 feet below the ground surface in the central stream valley. In general, the bedrock of the Fountain Formation is moderately to slightly weathered and moderately to very intensely fractured. Pressure packer tests in the borings indicate low to moderately low rock mass permeabilities within this formation. The proposed dam site should provide a suitable foundation for an embankment dam.

2. The laboratory tests performed for selected materials obtained from the dam site borings indicate that overburden materials within the central stream valley vary from low permeable clays and silts to moderate to high permeable sands and gravels.

3. The laboratory test performed for the proposed earthen borrow area indicate that sands and clays are available in this area. Although it does not appear the depth

of excavation in the proposed borrow area will be limited by ground water, seasonal fluctuations in ground water may require limited dewatering or diversion to excavate materials near the central stream valley.

4. The laboratory tests performed for selected materials obtained from the proposed earthen borrow area indicate that silts, clays, and sands in this area would be suitable for construction of a low permeability earth core and/or earthen embankment.

5. *RECONNAISSANCE-LEVEL ENGINEERING EVALUATIONS*

5.1 GENERAL

Preliminary engineering evaluations were made to assess the type of dam(s) that would be suited for the site, and of the types of dams suited to the site, the one that appears to be preferred based on technical and cost considerations. Four dam types were considered: earthfill, earthfill/rockfill, concrete-faced rockfill, and roller-compacted concrete (RCC). The evaluations were performed based on: 1) data gathered from the review of available geologic and geotechnical information, 2) geologic reconnaissance of the dam and reservoir site, 3) subsurface information and laboratory test data from the field exploration and laboratory test programs, 4) field survey profiles and cross sections provided by the Subdistrict, and 5) our experience in geologic, geotechnical and dam engineering. The evaluations were performed for a 290-foot-high dam corresponding to a reservoir storage of approximately 60,000 acre-feet.

5.2 DAM TYPES

The following sections briefly describe the general configuration of the dam types considered for the preliminary evaluations.

5.2.1 Earthfill

The earthfill dam type would require the largest footprint and largest quantity of construction materials of the dam types considered. The configuration of the earthfill dam includes a 3H:1V upstream slope, a 30-foot-wide crest, and a 2.5H:1V downstream slope. The upstream slope of the embankment would be protected with riprap and bedding. The central core (Zone 1) would consist of low-permeability clays and silts with a 1H:1V upstream slope and a 0.5H:1V downstream slope. A sand filter/drain system would be provided immediately downstream of the low permeability core and below the downstream shell. The upstream and downstream shells would consist of a mixture of clay, sand, and gravel. Preliminary engineering evaluations of this dam type indicate that about 14 million cubic yards of earthfill materials would be required to construct the dam for this alternative.

5.2.2 Earthfill/Rockfill

The earthfill/rockfill dam would require a smaller footprint than the earthfill dam type. The configuration of the earthfill/rockfill dam includes a 2.2H:1V upstream slope, a 30-foot-wide crest, and a 2.0H:1V downstream slope. The central core (zone 1) would consist of low-permeability clays and silts with a 0.5H:1V upstream and downstream slope. A sand filter/drain

system would be provided immediately upstream and downstream of the low permeability core and below the downstream shell. The upstream and downstream shells would consist of well-compacted rockfill materials. Preliminary engineering evaluations for this dam type indicate that about 11 million cubic yards of of earthfill materials would be required to construct the dam for this alternative.

5.2.3 Concrete-Faced Rockfill

The concrete-faced rockfill dam type would require a smaller footprint than either the earthfill or the earthfill/rockfill dam types. The configuration of the rockfill dam includes a 1.5H:1V upstream slope, a 30-foot-wide crest, and a 1.5H:1V downstream slope. The upstream concrete slope facing would have an average thickness of 1.5 feet, over a 10-foot-wide crusher run base and a 10-foot-wide transition zone. The upstream two-thirds of the embankment would be well-compacted rockfill since essentially all the reservoir load is transferred to the upstream half of the embankment. The downstream one-third of the embankment would consist of essentially the same rockfill material except less compaction would be required. A large boulder facing would cover the downstream slope.

A structural concrete plinth would be constructed along the upstream toe of the embankment. The concrete plinth provides a means to anchor the concrete facing slab to the foundation and maintain continuity of seepage control between the embankment and foundation. The plinth would be constructed on slightly weathered to fresh bedrock and anchored into the bedrock.

Preliminary quantity estimates for a 290-foot-high concrete-faced rockfill dam indicated that approximately 8 million cubic yards of rockfill would be required for construction of such a structure.

5.2.4 Roller-Compacted Concrete

The configuration of the RCC dam includes a vertical upstream face, a 20-foot-wide crest, and a 0.8H:1V downstream slope. It may be possible to slightly steepen the downstream slope after detailed stability analyses have been performed in future design phases. The RCC dam would be founded on slightly weathered to fresh bedrock after removal of overburden and weathered bedrock materials.

Seepage control in the foundation was assumed to consist of two rows of consolidation grout holes and two rows of deep curtain grout holes. Seepage barriers in the dam would consist of a 5-foot-wide facing element (conventional concrete) at the upstream face of the dam, 2-foot-wide leveling concrete (conventional concrete) at the dam/abutment contacts, a 5-foot-thick layer

of leveling concrete (conventional concrete) at the dam/foundation contact and a 1/2- to 3/4-inch-thick, 20-foot-wide layer of bedding mix concrete (mortar mix) immediately downstream of the upstream facing element concrete between each RCC lift. Drainage provisions were assumed to consist of foundation drain holes, a drainage gallery, and abutment galleries and manifolds, and drain holes in the dam.

Based on similarity of the Chimney Hollow valley configuration with the Meadow Hollow valley configuration, and the similar size structures, previous evaluations at the Meadow Hollow site [13] indicated that this dam type would likely be approximately 50 percent more expensive than the next closest alternative dam type. Therefore, an RCC dam was not considered further for the size of dam currently being considered for this site.

5.3 CONSTRUCTION MATERIALS AVAILABILITY

Potential sources for construction materials for Chimney Hollow Dam are shown on Figure 7. These sources include earthfill, rockfill, and drain/concrete aggregate materials. Each of these sources are discussed further in the sections below.

5.3.1 Earthfill Materials

The preliminary engineering evaluation of the earthfill dam type indicated that about 14 million cubic yards of earthfill materials would be required to construct the dam for the largest reservoir alternative currently being considered for this site (60,000 acre-feet). Based on the results of the subsurface exploration and laboratory testing programs, an evaluation of the borrow area was performed to estimate the availability of on-site earthen materials for construction of an earthfill dam.

The potential borrow area would be located within the proposed reservoir, as shown on Figure 7. The borrow area would include about 230 acres and stretch from the south end of the proposed reservoir to the dam site. Based on the borrow area borings performed as part of this study , we estimate that a maximum of about 5.3 million cubic yards of earthfill is available in the borrow area. Because of uncertainties in the quality and quantity of potential borrow materials between the limited number of borings performed for the borrow investigations, we assumed the amount of available earthfill borrow materials is 50 percent of the maximum estimated borrow quantity, or about 2.7 million cubic yards.

Because of potential social and economic constraints, no potential borrow areas were identified or investigated outside the limits of the proposed reservoir. Within the reservoir area there is an

insufficient volume of on-site earthfill materials available to construct a dam of all earthen materials for the sizes considered for this project.

5.3.2 Rockfill Materials

With the limited availability of earthfill construction materials at the site, the potential quantity of suitable rockfill becomes an important consideration.

There are two potential sources for rockfill from rock outcrops: 1) sandstones from the Fountain Formation within the reservoir basin, and 2) gneiss from the Precambrian rocks exposed along the left (west) side of the reservoir basin. The estimated rockfill borrow areas are shown on Figure 7.

Based on exposures of the Fountain Formation in the reservoir area, geologic information available in the literature, and results of the dam site borings, it appears that the sandstones within the Fountain Formation are slightly weathered to fresh and weakly cemented. Because of the weakly cemented nature of the sandstones within the Fountain Formation it is expected that these materials would rapidly breakdown to sand and gravel material during quarrying, hauling, and placing operations. In addition, because of the interbedded nature of the sandstones with siltstones and claystones select quarrying and overexcavation of the siltstones and claystones would be required to obtain sufficient quantity of sandstone materials. Therefore. the use of sandstones from the Fountain Formation is not recommended as rockfill material. Ripping and processing of the Fountain Formation could be considered for a supplemental earthfill source. However, additional site explorations and evaluations would have to be performed to confirm these materials for use as earthfill.

It should also be noted, that during construction of Flatiron Dam, sandstones of the Fountain Formation were not selected for riprap or rockfill material. Instead, quarrying of the metamorphic rocks upstream of the dam was performed to obtain suitable riprap rockfill materials for embankment construction.

The second potential rockfill borrow area within the reservoir basin includes granites from the Precambrian rocks exposed along the west side of the reservoir basin. Based on exposures of this rock within the reservoir area, it appears that the granites are slightly weathered to fresh, hard to very hard, and would be suitable for use as rockfill in dam construction. Preliminary estimates of available rockfill from the gneiss along the west side of the reservoir indicates that over 25 million cubic yards of rockfill is available along the western side of the reservoir area. All of this borrow area would be located below the proposed reservoir water surface. Therefore,

it appears that there is sufficient quantity of rockfill material available at the site, including appropriate borrow uncertainties.

5.3.3 Drain Material and Concrete Aggregates

No sources were identified for potential drain materials and concrete aggregates within the reservoir basin. Crushing of the granitic rocks to the gradations required for drain material and concrete aggregates would be costly. Therefore, we have assumed that all drain material and concrete aggregates would be supplied from an off-site commercial source.

Because of potential social and economic constraints and that sufficient rockfill quantities appear to be available within the reservoir area, no potential borrow areas were identified or investigated outside the limits of the proposed reservoir.

5.4 RECOMMENDED DAM TYPE

Based on the results of the construction materials availability discussed above, there is an insufficient quantity of earthfill material within the proposed reservoir area to construct an earthfill dam. Based on the evaluation of the available construction materials at the site, two dam types could be constructed at the site, a combination earthfill/rockfill dam and a concrete-faced rockfill dam. Based on recently completed economical comparisons of a combination earthfill/rockfill dam and concrete-faced rockfill dam of similar size as being considered for this site at the Meadow Hollow Dam site, located approximately 2 miles southeast of this dam site, the costs for each dam type were nearly identical [13]. The estimated construction costs for the earthfill/rockfill dam type for the Meadow Hollow Dam site were only slightly less than for the concrete-faced rockfill dam. Because of the similarities of these sites, including foundation treatments, dam heights, and location of the rockfill material in proximity of the dam, we would expect the costs for each of these dam types at the Chimney Hollow site to be very similar as well.

However, one difference between these sites is the type and extent of the interbedded rock in the respective foundations. At the Meadow Hollow Dam site, the majority of the left abutment is interbedded claystones and siltstones with minor sandstones. The entire right abutment of the dam is on hard sandstones. The majority of the foundation at the Chimney Hollow Dam site is interbedded sandstones, siltstones, and claystones. The much more intensely interbedded nature of the foundation materials below the Chimney Hollow Dam site could potentially make construction of a structural concrete plinth and facing slab more expensive for the concrete-faced rockfill dam alternative at the Chimney Hollow site versus the Meadow Hollow site. Therefore, it is our opinion that, based on the limited information gathered to date, a combination

earthfill/rockfill dam would be the more suitable for the Chimney Hollow site than a concrete-faced rockfill dam.

Figures 8 and 9 show the plan view and typical cross section of the earthfill/rockfill dam. The dam would have a crest elevation of 5850 feet with a normal reservoir pool at elevation 5840. The configuration of the dam includes a 2.25H:1V upstream slope, a 30-foot-wide crest, and a 2H:1V downstream slope. The low permeability central core would consist of clays and silts with 0.5H:1V upstream and downstream slopes and a 30-foot-deep cutoff trench. The upstream and downstream shells would consist of compacted rockfill with a maximum diameter of 12 inches. A 10-foot-wide transition zone consisting of sandy gravel would be provided between the core and upstream rockfill zone. A downstream transition zone and filter/drain system would be required between the core and downstream rockfill zone.

Figure 10 shows the centerline profile of the earthfill/rockfill dam. Foundation preparation would consist of excavating a cutoff trench to the top of slightly weathered bedrock. The remainder of the area under the embankment would be stripped to firm soil or weathered rock. Depths to slightly weathered bedrock were estimated to range between 30 feet near the maximum section of the dam to about 5 feet on the upper abutment areas. Seepage control through the foundation and abutments would be accomplished with two rows of curtain grout holes in the cutoff trench. The depths of the curtain grout holes would typically be between 60 and 70 percent of the hydraulic height.

The embankment cross section for the earthfill/rockfill dam was proportioned to limit the central low permeability core to not greater than 2.7 million cubic yards. The cross section, foundation treatment, and seepage control were designed based on our understanding of the site conditions, our experience in dam engineering, and guidelines published by Reclamation [18] and the Colorado State Engineer's Office [19].

6. OPINIONS OF PROBABLE CONSTRUCTION COST

6.1 GENERAL

An opinion of probable construction cost was developed for the 60,000 acre-foot reservoir formed by construction of a earthfill/rockfill dam described in Section 5. The opinion of probable construction cost is for the embankment-related features only and does not include costs associated with appurtenant structures or other related project features.

6.2 ESTIMATED CONSTRUCTION COSTS

Table 5 summarizes the itemized cost table for the earthfill/rockfill dam. Our opinions of probable construction cost summarized below are referenced to February 1997 and correspond to an Engineering News Record, Construction Cost Index of 5755.71.

The opinion of probable construction costs includes features related to the dam construction, including furnishing and placing embankment materials, excavation, foundation grouting, dewatering, stream diversion, clearing and grubbing, and reclamation of disturbed areas. The opinion of probable construction costs do not include costs associated with outlet works, spillways, pipelines, roads, pumping plants, etc.

In addition, the opinion of probable construction costs do not include costs for mobilization, bonds and insurance, unscheduled items, construction contingencies, land and right-of-way acquisition, environmental mitigation, engineering, administration, legal or other costs.

Appendix C summarizes the assumptions used to prepare the opinion of probable construction cost for the earthfill/rockfill dam alternative for Chimney Hollow Dam and Reservoir project. Construction cost estimates are based on estimated quantities for embankment-related project features and work items and estimated unit prices. Unit prices for construction items were estimated assuming that standard equipment and conventional construction practices would be used. Allowances for estimated contractors' overhead and profit are included in the estimated unit prices for the items and in estimates for lump sum items.

Cost estimates for lump sum items were prepared based on estimated quantities. Unit prices were refined to reflect local conditions and material availability at the site. Estimated unit prices for major work items were developed from the following sources:

1. Published and non-published bid data for similar construction projects

2. R.S. Means Heavy Construction Cost Data for 1997

3. Engineering New Record

4. GEI's experience on recent dam design and construction projects

5. Quotes from local and regional suppliers, manufacturers, and contractors

A contingency for unscheduled items has been included in the construction cost estimate. A contingency for unscheduled items is typically included at this stage of work as a cost provision for construction items that could be expected to be added to the final design construction bid list due to additional information and engineering evaluations. A construction contingency would also typically be included in the estimate to account for potential change orders during construction, however, we have not included a cost for this at this time.

Project administrative and engineering costs have not been included in the opinions of probable construction cost for the Chimney Hollow Dam and Reservoir project. Several administrative and engineering costs that are typically considered during the planning and budgeting phases of a construction project include engineering final design, construction management, owner administrative costs, legal fees, permitting, environmental studies, NEPA compliance, mitigation, and land acquisition.

6.3 ESTIMATED CONSTRUCTION SCHEDULE

An estimated construction schedule is shown on Figure 10. The schedule depicts estimated sequencing and durations of major construction activities. Based on our understanding of the project, we estimate the duration of construction will be approximately 30 months.

7. *LIMITATIONS*

This report has been prepared for the exclusive use of the Municipal Subdistrict, Northern Colorado Water Conservancy District, acting by and through the Windy Gap Water Activity Enterprise for the specific application to the Chimney Hollow Dam and Reservoir Feasibility Study. GEI Consultants, Inc. (GEI) has endeavored to comply with generally accepted engineering practice common to the local area. GEI makes no other warranty, express or implied.

The engineering evaluations, analyses, designs, and estimation of probable construction costs are based on GEI's understanding of the project location, project features and available information referenced in Section 5. The analyses contained in this report are based on data obtained from subsurface explorations. The methods used indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect the strata variations that usually exist between sampling locations.

This report includes opinions of the probable construction cost. GEI's opinions of probable construction cost have been based solely upon its experience or knowledge of similar work. GEI's opinions of probable cost rest on: 1) a number of assumptions about the actual conditions that will be encountered on site; 2) the means, methods, sequences, equipment, safety programs, et al., that contractors will employ; 3) the cost and extent of labor, equipment, and materials that contractors will employ; 4) contractors' methods for determining prices and market conditions at the time; and 5) a variety of other factors over which GEI has no control.

8. REFERENCES

[1] U.S. Bureau of Reclamation, "Geological Report on Flatiron Reservoir," October 1943.

[2] U.S. Bureau of Reclamation, "Technical Record of Design and Construction," Colorado-Big Thompson Project, Volume II, February 1962.

[3] U.S. Bureau of Reclamation, "Final Construction Report on Flatiron Power and Pumping Plant and Flatiron Afterbay Dam," August 1955.

[4] U.S. Bureau of Reclamation, "Construction Materials Report, Flatiron Afterbay Dam, Colorado-Big Thompson Project," April 24, 1951.

[5] U.S. Bureau of Reclamation, "Geologic Summary of the Colorado-Big Thompson Project," April 1956.

[6] Goodson & Associates, "Engineering Geological Report for Flatiron Dam, Colorado-Big Thompson Project, Colorado, Lower Missouri Region," prepared for U.S. Bureau of Reclamation, October 16, 1981.

[7] U.S. Bureau of Reclamation, "Seismotectonic Analysis for SEED Report," Technical Memorandum No. 3610-89-18, Flatiron Dam, Colorado-Big Thompson Project, draft 1989.

[8] Goodson & Associates, "Technical Data Workbook, Abstract Report for Flatiron Dam, Colorado-Big Thompson Project, Colorado, Lower Missouri Region," prepared for U.S. Bureau of Reclamation, September 4, 1981.

[9] U.S. Bureau of Reclamation, "Seismotectonic Evaluation, Rattlesnake and Flatiron Dams, Colorado - Big Thompson Project," prepared by William Lettis & Associates, January 1996.

[10] U.S. Geological Survey, "Miscellaneous Investigations Series," Boulder-Fort Collins-Greeley Area, Colorado, Map I-855-G.

[11] GEI Consultants, Inc. "Geological/Geotechnical Technical Memorandum, Flatiron Dam, Colorado, Colorado-Big Thompson Project, Great Plains Region," prepared for U.S. Bureau of Reclamation, November 13, 1990.

[12] GEI Consultants, Inc. "Geological/Geotechnical Technical Memorandum, Rattlesnake Dam, Colorado," prepared for U.S. Bureau of Reclamation, October 15, 1990.

[13] GEI Consultants, Inc., "Geotechnical and Dam Engineering Services, Meadow Hollow Reservoir Project Feasibility Study, Larimer County, Colorado," prepared for Municipal Subdistrict, Northern Colorado Water Conservancy District, acting by and through the Windy Gap Water Activity Enterprise, July 15, 1996.

[14] Denver Water Department, "Geologic and Seismotectonic Investigations, Central Front Range, Colorado, Summary Report," prepared by Geotechnical Advisory Committee, January 1986.

[15] Colorado Geologic Survey, "Earthquake Potential in Colorado," Bulletin 43, 1981.

[16] William Lettis & Associates, "Seismotectonic Evaluation: Rattlesnake and Flatiron Dams, Colorado-Big Thompson Project", prepared for U.S. Bureau of Reclamation, 1996.

[17] Anders, Mark H., and Wiltsohko, David D., "Microfracturing, Paleostress and the Growth of Faults," Journal of Structural Geology, Vol. 16, No. 6, pp 795-815, 1994.

[18] U.S. Bureau of Reclamation, Design of Small Dams, Third Edition, 1987.

[19] Colorado Office of the State Engineer, "Rules and Regulations for Dam Safety and Dam Construction," August 1988.

Tables

TABLE 1
SUMMARY OF BORING LOCATIONS
CHIMNEY HOLLOW DAM AND RESERVOIR PROJECT FEASIBILITY STUDY

Boring Number	Location	Coordinates[1]		Ground Surface Elevation[2]
		Northing	Easting	
B101	Stream Valley	16899 647	21231.387	5562.885
B102	Left Abutment	16831 914	21453.787	5575.215
BA-1	Reservoir	15581 124	21175.190	5614.399
BA-2	Reservoir	15637.978	20794.015	5592.006
BA-3	Reservoir	15711.252	20400.892	5618.772
BB-1	Reservoir	13629 517	21071.528	5656.871
BB-2	Reservoir	13589 754	20769.657	5632.236
BB-3	Reservoir	13534.284	20359.986	5668.686
BC-1	Reservoir	12026.739	19958.703	5700.738
BC-2	Reservoir	11925.573	20244.120	5678.144
BC-3	Reservoir	11738.644	20470.397	5676.570
BE-1	Reservoir	10325.802	20642.391	5731.875
BE-2	Reservoir	10395.470	20293.341	5713.354
BD-1	Reservoir	8549.225	20952.476	5770.888
BD-2	Reservoir	8531.876	20706 084	5759.793
BD-3	Reservoir	8375.576	20311.203	5795.458
BF-1	Reservoir	6622.521	20865.242	5830.780
BF-2	Reservoir	6636.538	20627.988	5812.279
BF-3	Reservoir	6411.223	20089.784	5848.190
BG-1	Reservoir	5781.217	20007.618	5882.583
BG-2	Reservoir	5826.606	20685.134	5838.466
BG-3	Reservoir	5893.720	21033.282	5855.189

NOTES:

(1) Coordinates are based on the Colorado State Plane Coordinate System, North Zone.
(2) Elevations are based on the North American Vertical Datum - 83/92

TABLE 2
SUMMARY OF SUBSURFACE EXPLORATION PROGRAM
CHIMNEY HOLLOW DAM AND RESERVOIR PROJECT FEASIBILITY STUDY

Boring Number	Location	Depth			Packer Permeability Tests
		Total (ft)	Overburden (ft)	Rock (ft)	
B101	Stream Valley	61.0	35 3	29 7	Yes
B102	Left Abutment	61.0	34.5	26.5	Yes
BA-1	Reservoir	15.2	15.2	0	No
BA-2	Reservoir	26.0	26 0	0	No
BA-3	Reservoir	9.8	9.5	0.3	No
BB-1	Reservoir	21.0	21.0	0	No
BB-2	Reservoir	25.2	24 0	1.2	No
BB-3	Reservoir	20.0	18.5	1.5	No
BC-1	Reservoir	21 0	21.0	0	No
BC-2	Reservoir	30 5	29.0	1.5	No
BC-3	Reservoir	25.0	24.0	1.0	No
BE-1	Reservoir	9.5	8.0	1.5	No
BE-2	Reservoir	29.7	29.5	0.2	No
BD-1	Reservoir	11.0	11.0	0	No
BD-2	Reservoir	15.0	12.5	2 5	No
BD-3	Reservoir	20.9	19.5	1.4	No
BF-1	Reservoir	15.7	14 0	1.7	No
BF-2	Reservoir	19.8	17.5	2.3	No
BF-3	Reservoir	4.9	1.0	3.9	No
BG-1	Reservoir	16.0	15.0	1.0	No
BG-2	Reservoir	11.0	9.5	1.5	No
BG-3	Reservoir	9.0	7.0	2.0	No

GENERAL NOTES:

(1) Drilling in overburden was continuous using 4-1/4-inch-inside-diameter hollow-stem augering techniques

(2) Drilling in rock was continuous using HQ-wireline rock coring with air-water mixture as drilling fluid.

(3) Packer permeability tests were conducted continuously at 10-foot intervals in the rock portion of the dam axis borings

(4) The dam axis borings were backfilled with non-shrink, cement-bentonite grout. Borrow area borings were backfilled with auger cuttings

TABLE 3
SUMMARY OF PACKER PERMEABILITY TEST RESULTS
CHIMNEY HOLLOW DAM AND RESERVOIR PROJECT FEASIBILITY STUDY

Boring Number	Depth Interval (ft)	Applied Pressure (psi)	Measured Inflow (gpm)	Calculated Permeability (ft/yr)
B101	36.2 - 46.8	14.0 - 15.0[a]	0.325	30.1
	28.5 - 39.1	14.0	0.550	54.5
B102	48.8 - 58.8	16.0	0.325	24 7

NOTES:

(a) Pressure dropping during test

TABLE 4
SUMMARY OF LABORATORY TEST RESULTS
CHIMNEY HOLLOW DAM AND RESERVOIR PROJECT FEASIBILITY STUDY

Boring Number	Sample Depth (ft)	Grain Size Analysis			Liquid Limit (%)	Plasticity Index	Natural Moisture Content (%)	Unified Soil Classification
		Gravel 3" - R4 (%)	Sand P4 - R200 (%)	Silt-Clay P200 (%)				
B101	20.0	52.1	42.2	5.7	--	--	--	GW
BA-2	24.5	33.9	57.9	8.2	--	--	--	SW
BB-2	14.5	26.2	45.7	28.1	32	15	8.1	SC
BC-1	4.5	0	34.4	65.6	46	26	12.7	CL
BD-2	9.5	--	--	--	27	12	17.0	CL
BE-2	14.5	0	37.2[a]	62.8	33	16	17.9	CL
BF-1	4.5	0	35.1	64.9	35	18	10.1	CL
BG-1	10.0	0	58.1	41 9	--	NP[b]	12 4	SM

NOTES:

(a) Sample included a 1-inch-thick layer containing elevated levels of medium coarse sand; actual sand content in surrounding clay matrix may be lower

(b) NP = Non-Plastic

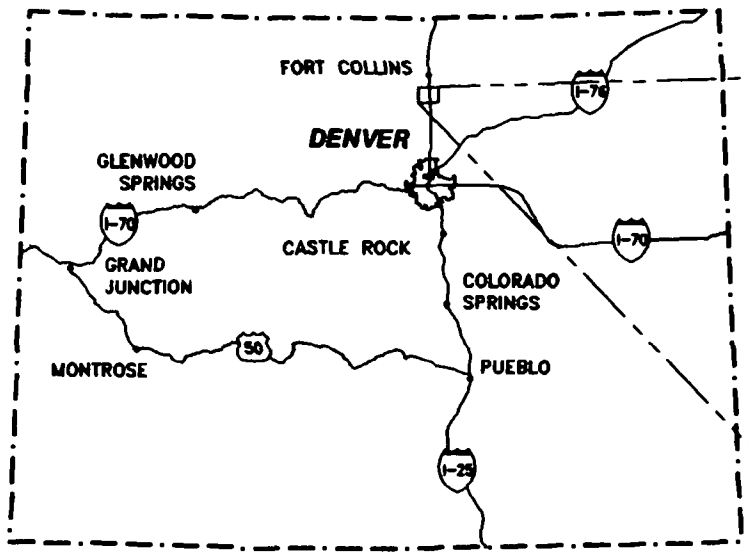
TABLE 5 - FEASIBILITY OPINION OF PROBABLE CONSTRUCTION COSTS

MUNICIPAL SUBDISTRICT, NORTHERN COLORADO WATER CONSERVANCY DISTRICT
CHIMNEY HOLLOW RESERVOIR PROJECT FEASIBILITY STUDY

Earthfill/Rockfill Dam **RESERVOIR CAPACITY = 60,000 ACRE-FEET**

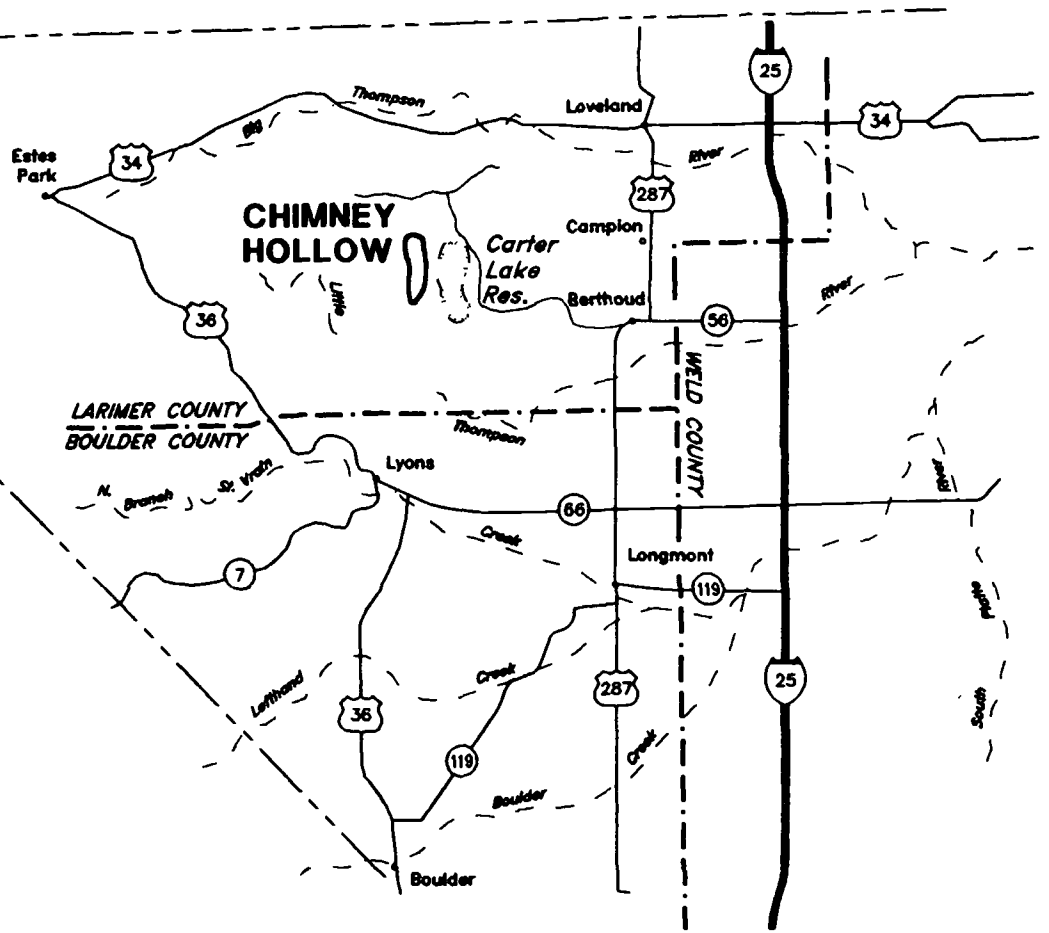
Item No.	Description	Quantity	Unit	Unit Price	Total Cost
1	Stream Diversion	1	LS	$270,000	$270,000
2	Clearing and Grubbing	52	ACRE	$3,300	$171,600
3	Dewatering	1	LS	$200,000	$200,000
4	Stripping and General Excavation	223,000	CY	$3.00	$669,000
5	Foundation Preparation	27,000	SY	$8.50	$229,500
6	Foundation Grouting	92,000	LF	$35.00	$3,220,000
7	Furnishing and Placing Embankment Zone 1	2,420,000	CY	$3.00	$7,260,000
8	Furnishing and Placing Embankment Zone 2A	160,000	CY	$10.50	$1,680,000
9	Furnishing and Placing Embankment Zone 2B	330,000	CY	$13.00	$4,290,000
10	Furnishing and Placing Embankment Zone 2C	390,000	CY	$10.50	$4,095,000
11	Furnishing and Placing Embankment Zone 3	5,790,000	CY	$6.00	$34,740,000
13	Instrumentation	1	LS	$400,000	$400,000
14	Reclamation of Disturbed Areas	15	ACRE	$2,200	$33,000
	Base Construction Subtotal (BCS)				$57,258,100
	Unscheduled Items @ 15% BCS				$8,588,715
	Direct Construction Subtotal (DCS), except Mobilization, Bonds, and Insurance				$65,847,000

Figures



PROJECT LOCATION MAP

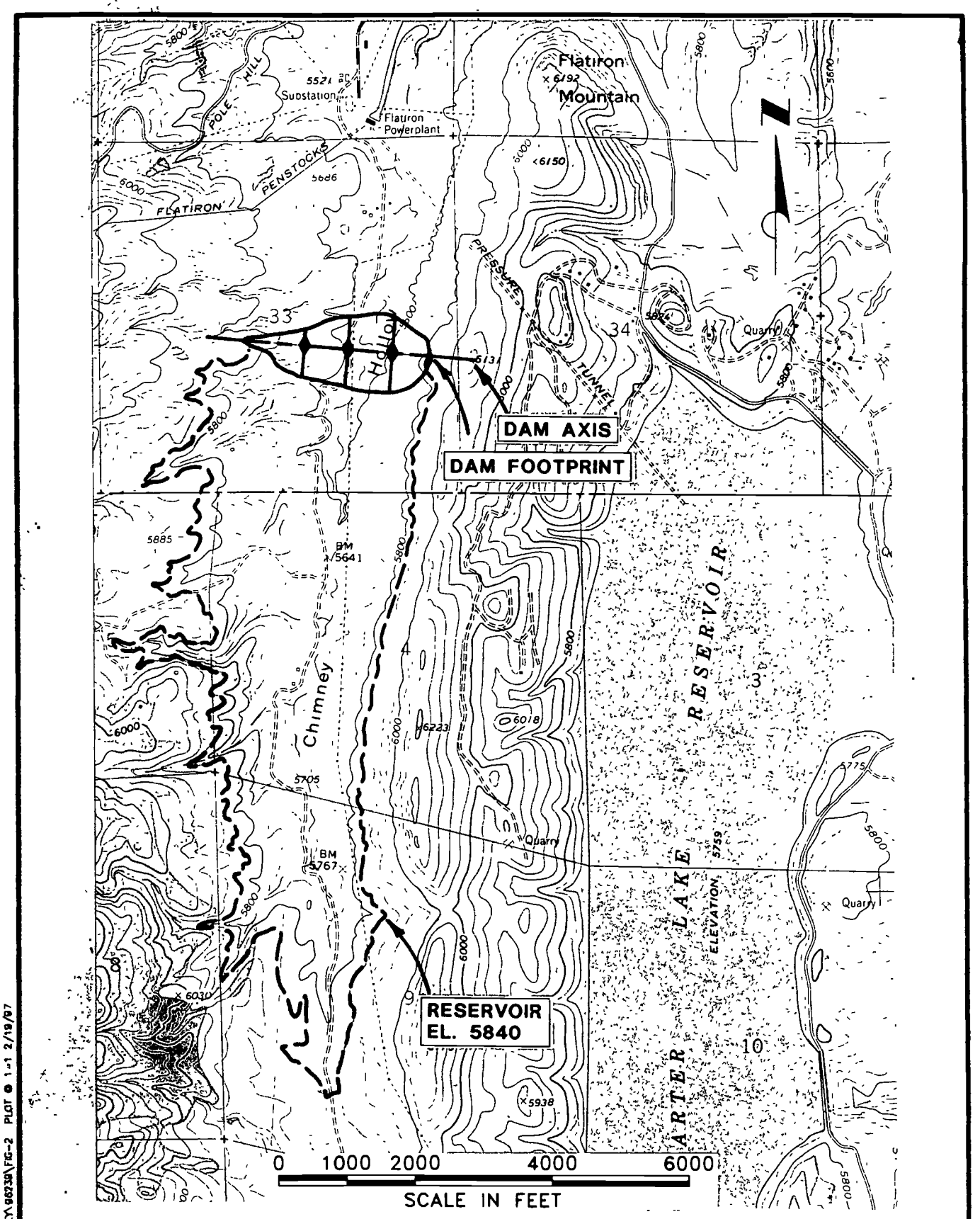
(NOT TO SCALE)



PROJECT VICINITY MAP

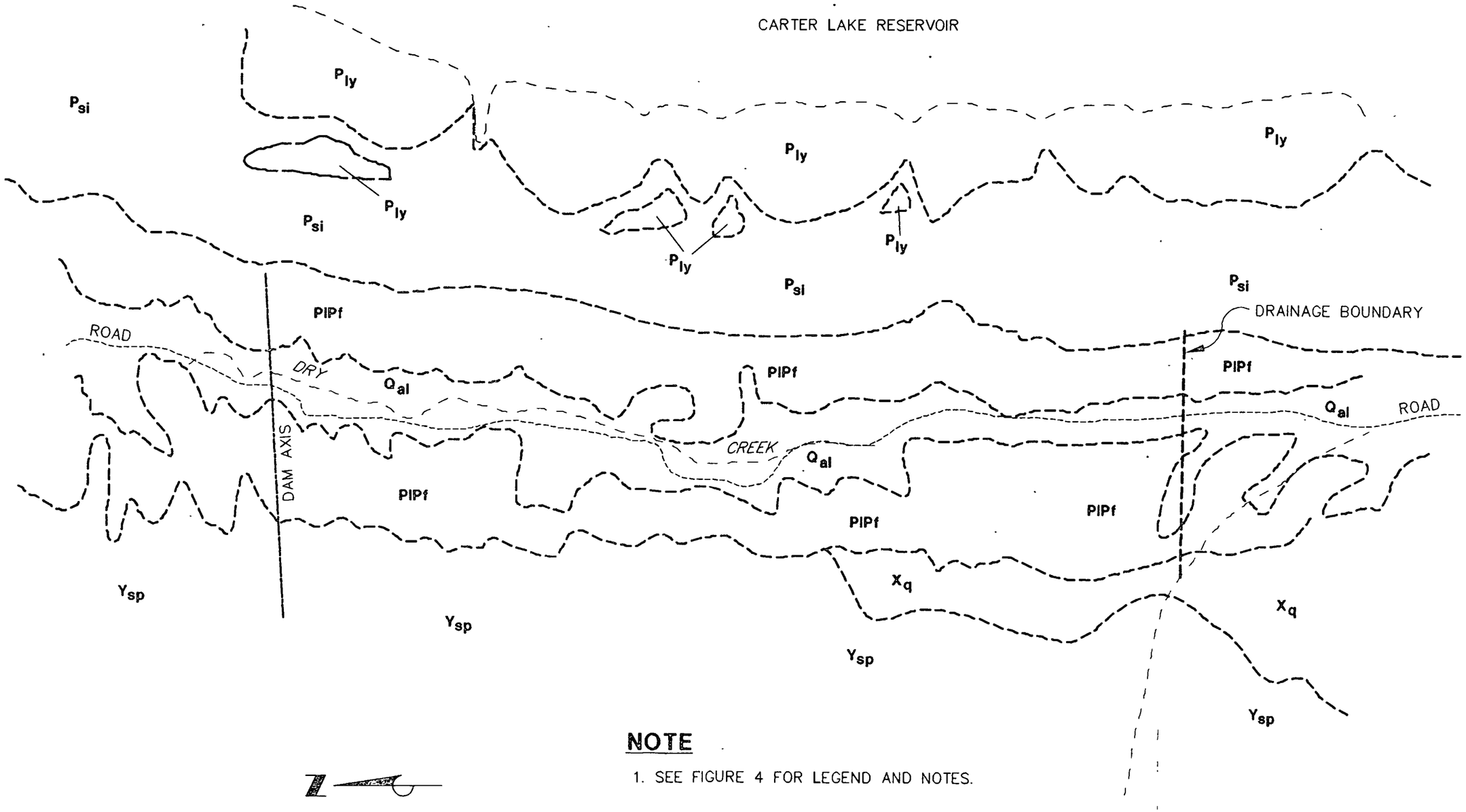
0 2 4 6 8 10

Municipal Subdistrict Northern Colorado Water Conservancy District	Chimney Hollow Dam Feasibility Study	**SITE LOCATION MAP**
GEI Consultants, Inc.	Project 96293	March 1997 — Figure 1



Municipal Subdistrict Northern Colorado Water Conservancy District	Chimney Hollow Dam Feasibility Study	**PROJECT FEATURES MAP**
GEI Consultants, Inc.	Project 96293	March 1997 | Figure 2

FILE: P:\PROJECTS\CHIMNEY\96293\FG-2 PLOT @ 1=1 2/19/97



NOTE

1. SEE FIGURE 4 FOR LEGEND AND NOTES.

Municipal Subdistrict Northern Colorado Water Conservancy District	Chimney Hollow Reservoir Feasibility Study	**GEOLOGY MAP OF RESERVOIR AREA**
GEI Consultants, Inc.	Project 96293	March 1997 | Figure 3

LEGEND

Q_{al} — ALLUVIUM (UPPER HOLOCENE) – Brown, humic, sandy to gravelly alluvium containing silt, clay and scattered plant remains.

P_{ly} — LYONS SANDSTONE (PERMIAN) – Moderate orange to pink to pinkish–gray, fine–to medium–grained , firmly cemented, well sorted, cross–stratified, quartzose sandstone.

P_{si} — SATANKA AND INGLESIDE FORMATIONS (PERMIAN) – Red siltstone and fine–grained thin–bedded ripple–laminated sandstone over red calcareous fine–to medium–grained well sorted crossbedded sandstone.

PIP_f — FOUNTAIN FORMATION (PENNSYLVANIAN) – Moderate reddish–brown, iron oxide stained, interstratified arkosic conglomerate and moderately coarse grained feldspathic sandstone containing thin layers of dark reddish–brown to purplish shale.

Y_{sp} — SILVER PLUME QUARTZ MONZONITE – (PRECAMBRIAN) – Yellow–orange to reddish gray, fine to medium grained, biotite–muscovite quartz monzonite.

X_q — METASEDIMENTARY ROCK (PRECAMBRIAN) – Quartzofeldspathic schist and gneiss interbedded with mica schist and gneiss. Contains thin beds of knotted mica schist and granule to pebble metaconglomerate.

GEOLOGIC CONTACT – Dashed where approximate, dotted where inferred.

FAULT – Dashed where approximate

STREAM OR DRAINAGE COURSE

ROAD

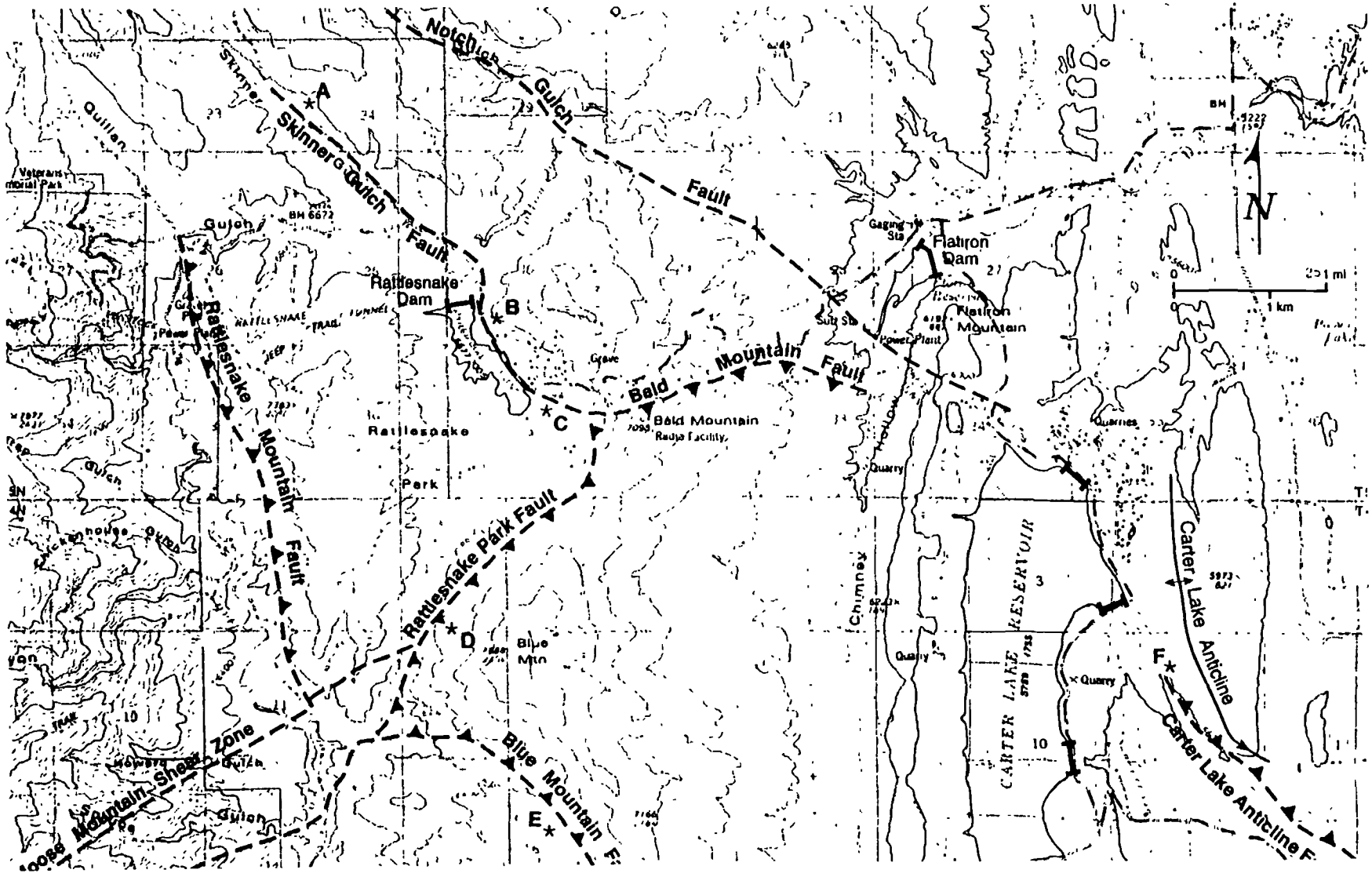
80° STRIKE AND DIP OF BEDDING

NOTES

1. Geologic map of Chimney Hollow Reservoir based on geologic field reconnaissance performed in October 1996; review of available black and white aerial photographs from the Earth Science Information Center (USGS); and USGS mapping of the area (Map I–855–G).

Municipal Subdistrict, Northern Colorado Water Conservancy District	Chimney Hollow Reservoir Feasibility Study	**GEOLOGIC LEGEND AND NOTES**
GEI Consultants, Inc.	Project 96293	March 1997 | Figure 4

FILE P:\PROJECTS\CHIMNEY\96293\FIG-4.DWG PLOT @ 1=1 2/27/97



MAP SOURCE:
SEISMOTECTONIC EVALUATION –
RATTLESNAKE AND FLATIRON DAMS
SUBMITTED TO U.S. BUREAU
OF RECLAMATION, JAN 1996

Municipal Subdistrict
Northern Colorado Water
Conservancy District

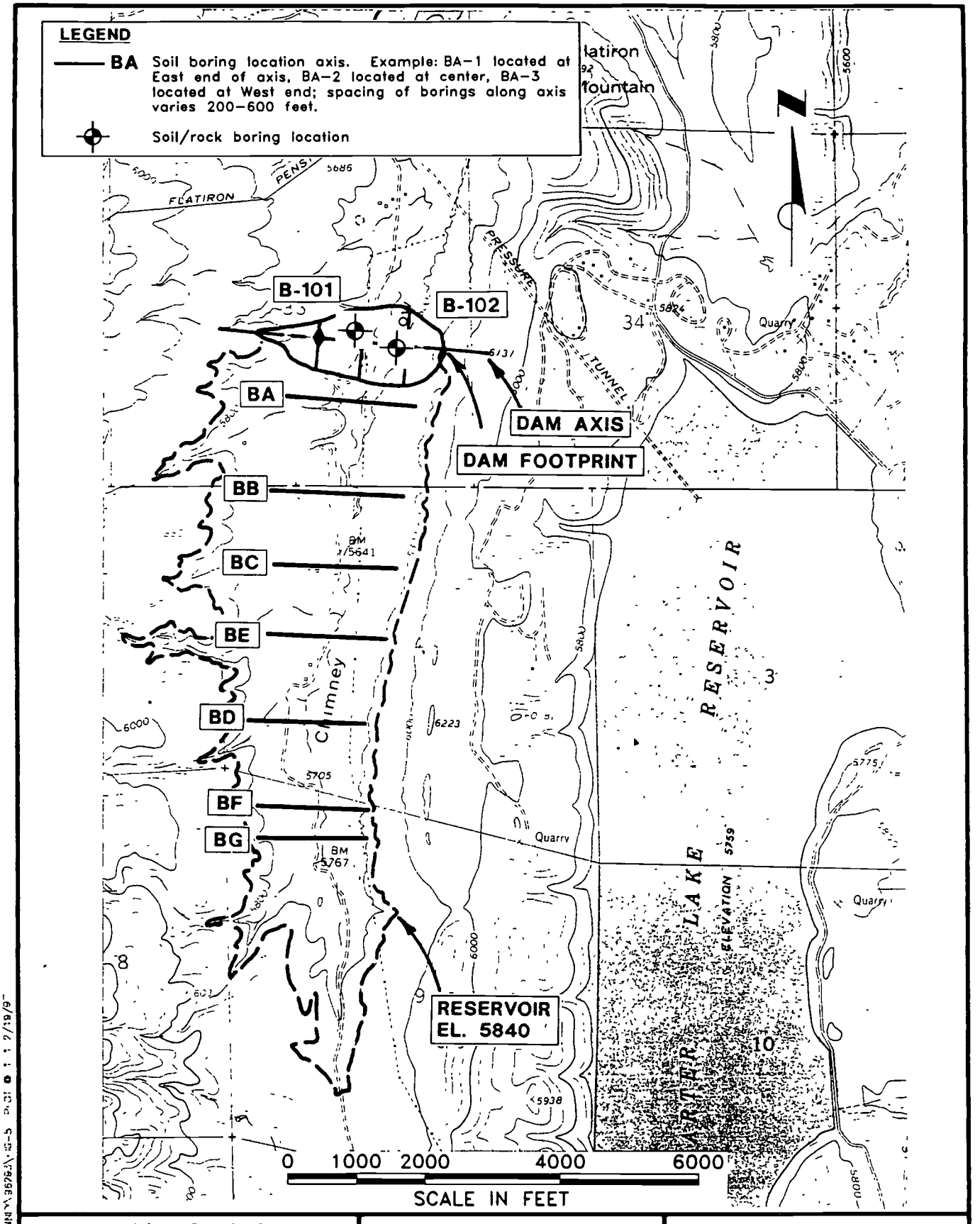
GEI Consultants, Inc.

Chimney Hollow Dam
Feasibility Study

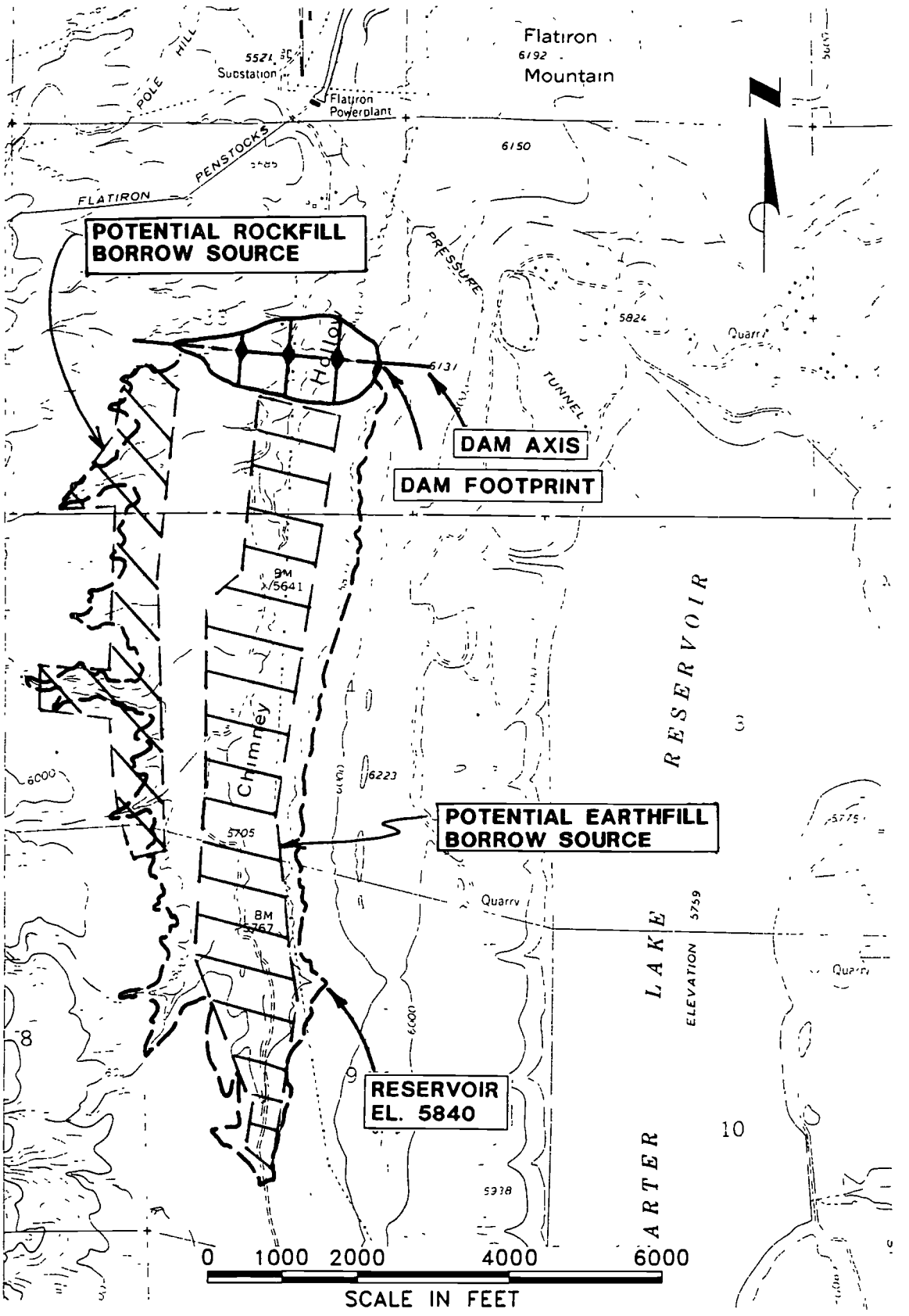
Project 96293

LOCATION OF FAULTS IN PROXIMITY TO THE CHIMNEY HOLLOW SITE

March 1997 | Figure 5

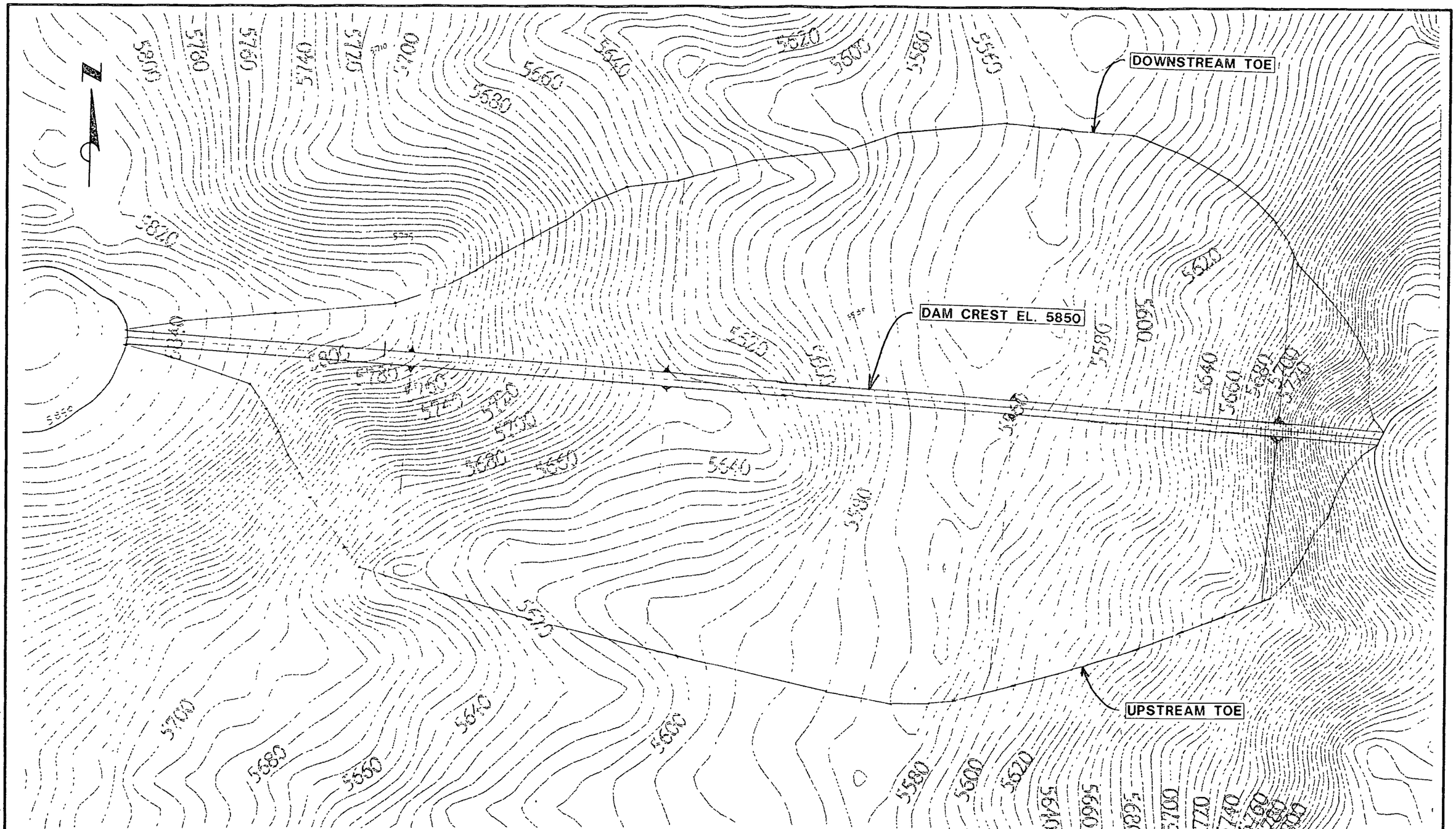


Municipal Subdistrict Northern Colorado Water Conservancy District	Chimney Hollow Dam Feasibility Study	**BORING LOCATION PLAN**	
GEI Consultants, Inc.	Project 96239	March 1997	Figure 6



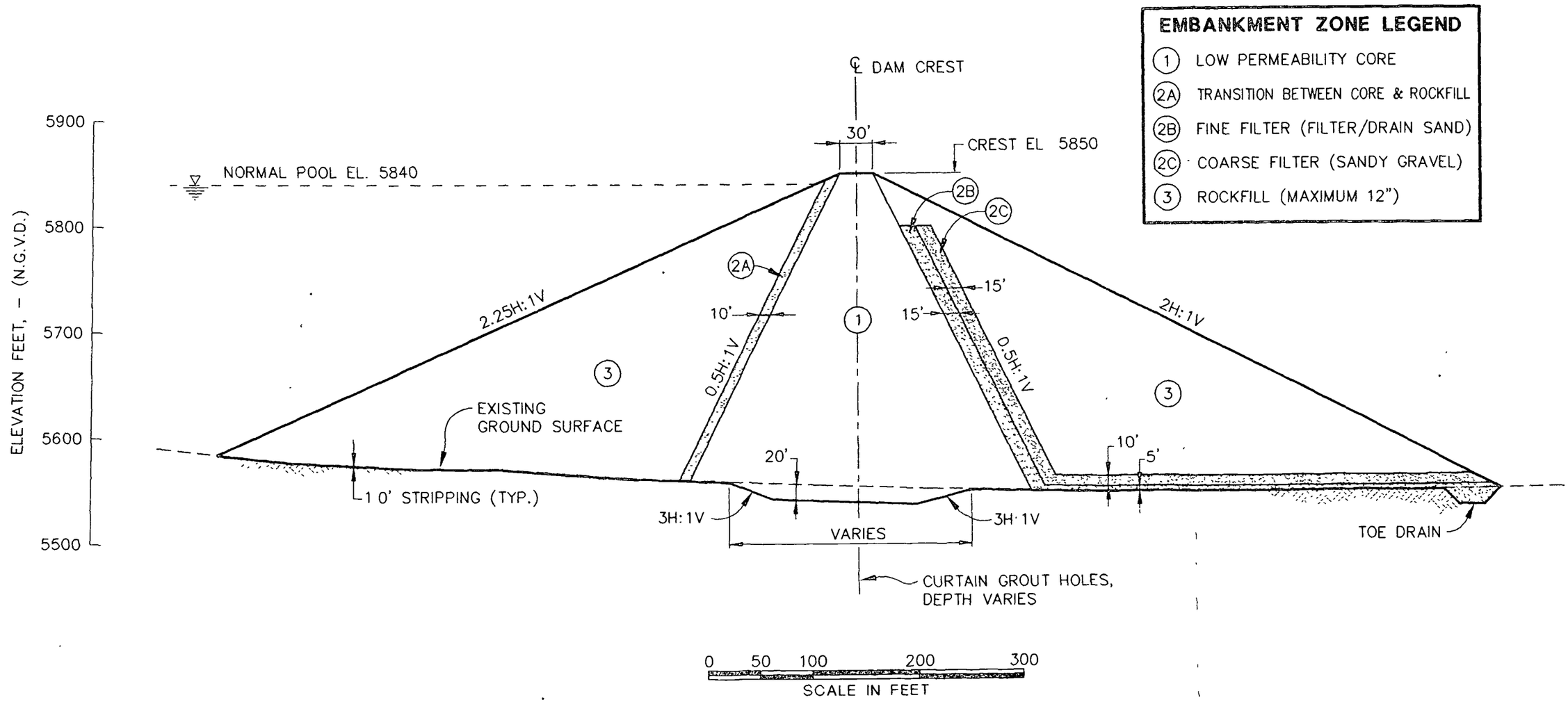
Municipal Subdistrict Northern Colorado Water Conservancy District	Chimney Hollow Dam Feasibility Study	**POTENTIAL BORROW LOCATION**
GEI Consultants, Inc.	Project 96293	March 1997 | Figure 7

FILE P:\PROJECTS\CHIMNEY\96293\FIG\G-2 PLOT @ 1=1 2/27/97

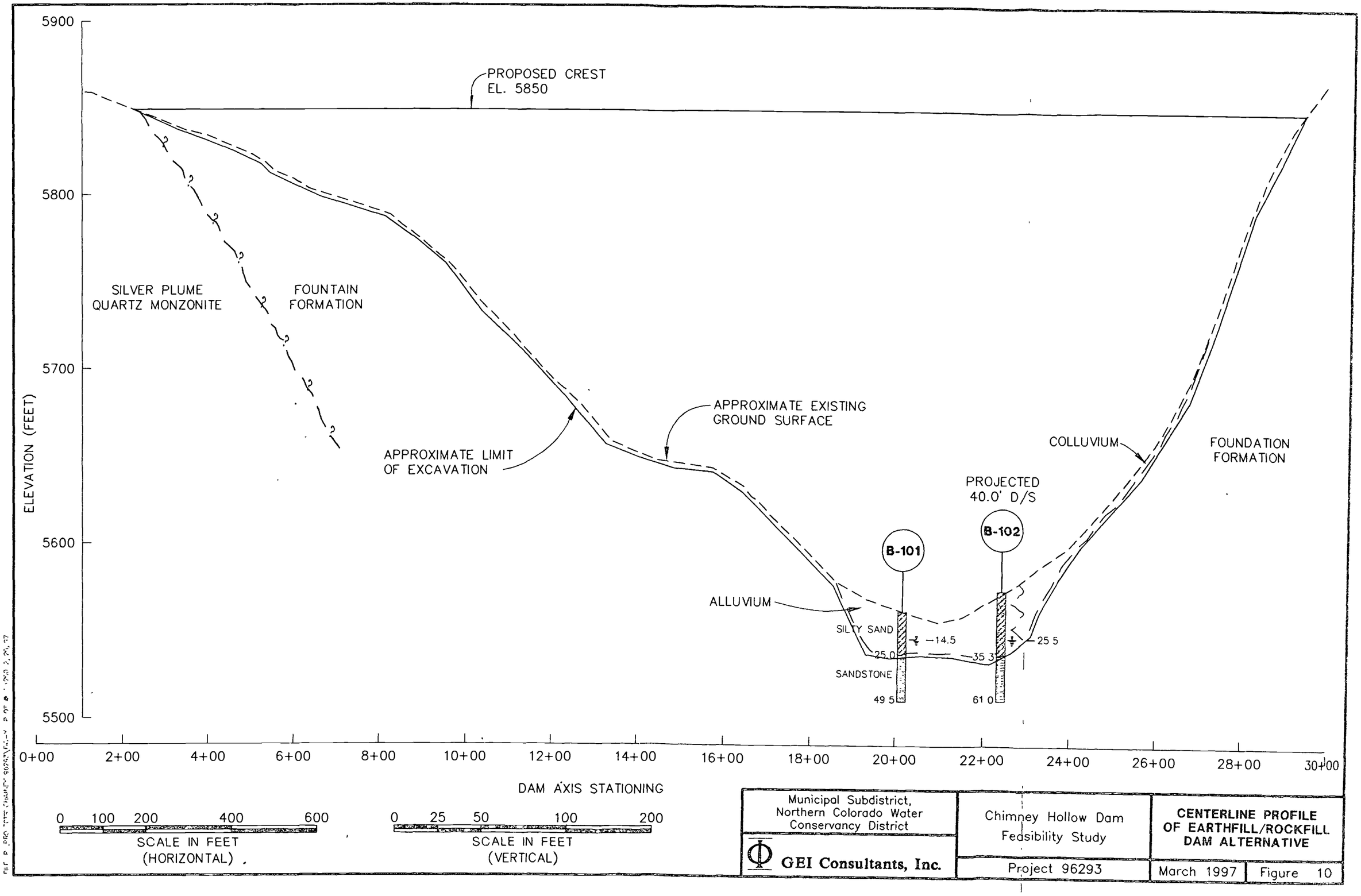


Municipal Subdistrict, Northern Colorado Water Conservancy District	Chimney Hollow Dam Feasibility Study	**PLAN VIEW OF EARTHFILL/ROCKFILL DAM ALTERNATIVE**
GEI Consultants, Inc.	Project 96293	March 1997 | Figure 8

FILE P:\PROJECTS\CHIMNEY\96293\FIG-8 PLOT @ 1:1-60 2/27 37



Municipal Subdistrict, Northern Colorado Water Conservancy District	Chimney Hollow Dam Feasibility Study	**CROSS SECTION OF EARTHFILL/ROCKFILL DAM DAM ALTERNATIVE**
GEI Consultants, Inc.	Project 96293	March 1997 — Figure 9



Municipal Subdistrict,
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Conservancy District

GEI Consultants, Inc.

Chimney Hollow Dam
Feasibility Study

Project 96293

CENTERLINE PROFILE OF EARTHFILL/ROCKFILL DAM ALTERNATIVE

March 1997 | Figure 10

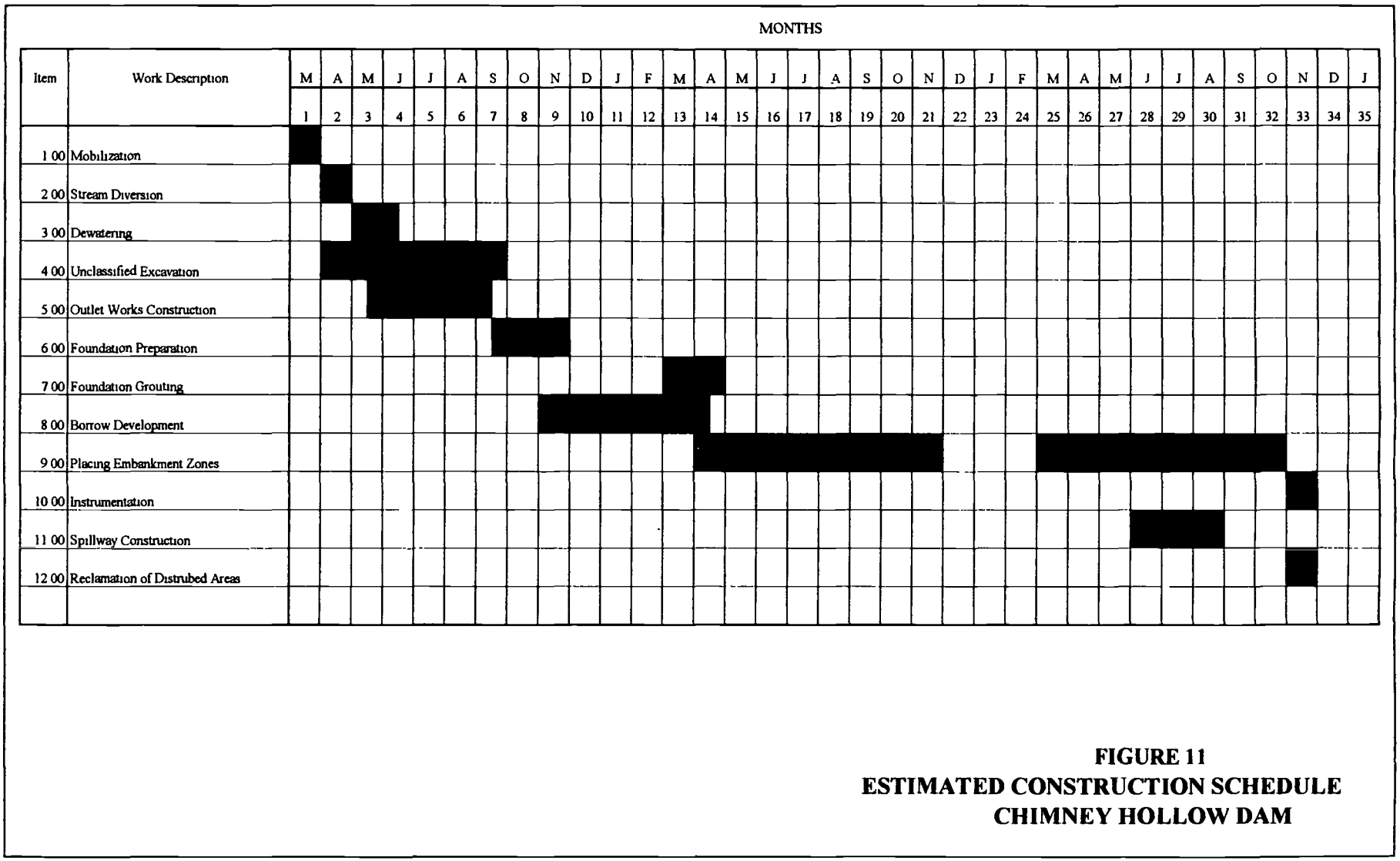


FIGURE 11
ESTIMATED CONSTRUCTION SCHEDULE
CHIMNEY HOLLOW DAM

Appendix A

DAM SITE BORINGS

GEI Consultants, Inc.

GEOLOGIC LOG OF DRILL HOLE

HOLE NO. B-101

PROJECT NAME Chimney Hollow PROJECT NO. 96293 SHEET 1 OF 3

LOCATION Stream valley GROUND ELEV. 5562.885 BEARING — PLUNGE 90°

DATE STARTED/FINISHED 11-19-96 / 11-20-96 DRILLED BY Layne Env. LOGGED BY EMJ

GROUNDWATER EL 14.5 DATE 11-20-96 OVERBURDEN DEPTH 24.7 TOTAL DEPTH 49.5

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION ETC.	CORING (SEE LEGEND): INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	RQD (FT)	RQD. %	CORING TIME (MIN.)	NO. OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
2																	
4																	
5.0																	
6	3-4-3	S1	18"	18"	100												S-1: CLAYEY SAND. Mostly fine sand, ~40% non- and low plastic fines, loose, sl. moist, red-brown. (SC)
6.5																	
8																	
10																	
10.0																	
10	3-3-4	S2	18"	18"	100												S-2: LEAN CLAY WITH SAND. Mostly low to med. plastic fines, ~15%fine sand, medium stiff, moist, brown. (CL)
11.5																	
12																	
14																	
15.0																	
16	2-5-5	S3	18"	0	0												S-3: No Recovery. On surface of spoon, mostly fine sand, <15% non-plastic fines, wet, brown.
16.5																	
18																	
20																	

REMARKS/COMMENTS:

FILE: C:\ACAD12\SYMBOLS\DRILLOG.DWG PLOT @ 1-1 9/9/96

GEI Consultants, Inc. | **GEOLOGIC LOG OF DRILL HOLE** | HOLE NO. B101

PROJECT NAME Chimney Hollow | PROJECT NO. 96293 | SHEET 2 OF 3

LOCATION Stream valley | GROUND ELEV. 5562.885 | BEARING – | PLUNGE

DATE STARTED/FINISHED 11-19-96 / 11-20-96 | DRILLED BY Layne / D. Werner | LOGGED BY EMJ

GROUNDWATER EL. 14.5 | DATE 11-20-96 | OVERBURDEN DEPTH 24.7 | TOTAL DEPTH 49.5

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION, ETC.	CORING (SEE LEGEND): INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	RQD (FT)	R.Q.D %	CORING TIME (MIN.)	NO OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
20		20.0 S4	16"	16"	100												S-4: WIDELY GRADED SAND WITH SILT AND GRAVEL. Mostly fine to coarse sand, ~40% fine to coarse subrounded gravel, max. size 3", <10% non-plastic fines, dense, saturated, red-brown. (SW)
22		21.3															
24		24.7															S-5: SANDSTONE. Weathered, mostly fine-grained sand, 15% non-plastic fines, sl. moist, gray.
	31/5"	HQ 1 25.0 S5 25.4	5"	5"	100												
26		HQ 1	4.8	3.9	81	2.0	42	4	12	0.9	0.1	H4					24.7 - 32.3': SANDSTONE. Mostly fine to coarse grained sand, silty in parts, arkosic, indistinct bedding, moderately to poorly cemented, slightly to moderately weathered, slightly to moderately fractured, gray - maroon.
28																	
		29.5															
30																	32.3 - 34.5': CLAYSTONE. Mostly low plastic and silty fines, slightly weathered, moderately fractured, very thin bedding, ~20 deg. dip, red-brown. Slickenside at bottom.
32		HQ 2	5.0	5.0	100	4.2	84	4	9	1.4	0.1	H4					
34																	
		34.5															34.5 - 36.4': SANDSTONE. Similar to above.
36												H3					
																	36.4 - 39.2': CLAYSTONE. Similar to above.
38												H4					
40		HQ 3	10.0	8.0	80	4.7	47	11	8	3.2	0.1						

REMARKS/COMMENTS:

FILE: C:\ACAD12\SYMBOLS\DRILLOG.DWG PLOT @ 1-1 9/9/96

GEI Consultants, Inc. | **GEOLOGIC LOG OF DRILL HOLE** | HOLE NO. B-101

PROJECT NAME Chimney Hollow | PROJECT NO. 96293 | SHEET 3 OF 3
LOCATION Stream valley | GROUND ELEV. 5562.885 | BEARING - | PLUNGE 90°
DATE STARTED/FINISHED 11-19-96 / 11-20-96 | DRILLED BY Layne/D.Werner | LOGGED BY EMJ
GROUNDWATER EL 14.5 | DATE 11-20-96 | OVERBURDEN DEPTH 24.5' | TOTAL DEPTH 49.5

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION, ETC.	CORING (SEE LEGEND) INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	R Q D (FT)	R Q.D. %	CORING TIME (MIN.)	NO OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
40																	
42		HQ 3										H4					39.2 - 44.5': SANDSTONE. Similar to above, except contains fine to coarse subrounded gravel, max. size 1-3/4", indistinct bedding, slightly to intensely weathered, lt. gray.
44																	
44.5																	44.5 - 45.3': CLAYSTONE. Similar to above.
46		HQ 4	5.0	4.9	98	4.6	92	4	3+	3.5	0.1	H5 — H4					45.3 - 49.5': SANDSTONE. Similar to above, 1 joint, 20 deg. with very thin sulfate or calcite infilling.
48																	
49.5	Bottom of Boring																
50																	
52																	
54																	
56																	
58																	
60																	

REMARKS/COMMENTS:

FILE C:\ACAD12\SYMBOLS\DRILLOG.DWG PLOT @ 1=1 9/8/96

GEI Consultants, Inc. | **GEOLOGIC LOG OF DRILL HOLE** | HOLE NO. B-102

PROJECT NAME Chimney Hollow | PROJECT NO. 96293 | SHEET 1 OF 4
LOCATION Left Abutment | GROUND ELEV. 5575.215 | BEARING — | PLUNGE 90°
DATE STARTED/FINISHED 11-21-96 / 11-22-96 | DRILLED BY Layne/D.Wemer | LOGGED BY EMJ
GROUNDWATER EL. 25.5 | DATE 11-22-96 | OVERBURDEN DEPTH 34.5 | TOTAL DEPTH 61.0

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION, ETC.	CORING (SEE LEGEND): INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	RQD (FT)	R.Q.D. %	CORING TIME (MIN.)	NO OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
2																	
4																	
4.5	2-3-3	S1	18"	14"	78												S-1 CLAYEY SAND WITH GRAVEL. Mostly fine to coarse sand, ~35% subangular fine gravel, ~15% non- to low plastic fines, max. size 1/4", loose, moist, red-brown. Increasing plasticity towards bottom. (SC)
6.0																	
8																	
9.5	3-5-10	S2	18"	15"	83												S-2: Similar to S-1 except contains fine gravel in upper 9" only and red sandstone in lower 2", medium dense. (SC)
10																	
11.0																	
12																	
14																	
14.5	4-5-5	S3	18"	18"	100												S-3: Similar to S-1 except upper 4" non-plastic, orange-red, and dry; max. gravel size 1/2", loose. (SC)
16																	
16.0																	
18																	
19.5	5-6-8	S4	18	18	100												S-4: SANDY LEAN CLAY. Mostly low to med. plastic fines, 30% fine to med. sand, <15% fine subrounded gravel, max. size 1/4", stiff, moist, brown. (CL)
20																	

REMARKS/COMMENTS:

FILE: C:\ACAD12\SYMBOLS\DRILLOG.DWG PLOT @ 1-1 9/9/96

GEI Consultants, Inc. | **GEOLOGIC LOG OF DRILL HOLE** | HOLE NO. B-102

PROJECT NAME Chimney Hollow | PROJECT NO. 96293 | SHEET 2 OF 4
LOCATION Left Abutment | GROUND ELEV. 5575.215 | BEARING — | PLUNGE 90°
DATE STARTED/FINISHED 11-21-96 / 11-22-96 | DRILLED BY Layne D. Wemer | LOGGED BY EMJ
GROUNDWATER EL 25.5' | DATE 11-22-96 | OVERBURDEN DEPTH 34.5 | TOTAL DEPTH 61.0

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION, ETC.	CORING (SEE LEGEND): INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	R.Q.D. (FT.)	R.Q.D. %	CORING TIME (MIN.)	NO. OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
20		S4															
21.0																	S-5: WIDELY GRADED SAND WITH GRAVEL. Mostly fine to coarse sand, ~15% subangular gravel, <10% non-plastic fines, loose to medium dense, dry at top, saturated at bottom, brown. (SW)
22																	
24																	
24.5		S5	18	6	33												S-6: UPPER 6": CLAYEY SAND. Mostly fine to med. sand, ~25% low to med. plastic fines, <15% coarse sand and fine gravel, dense, very moist, brown. (SC) LOWER 3": WIDELY GRADED SAND WITH GRAVEL. Mostly med. to coarse sand, subrounded to subangular gravel, max. size 1". ~10% non-plastic fines, dense, very moist, brown. (SW)
26																	
26.0																	
28																	
29.5																	
30	15-30/3"	S6	9"	9"	100												
30.3																	
32																	
34																	
34.5		S7	8"	8"	100												S-7: UPPER 4": SILTY SAND WITH GRAVEL, Similar to lower 3: of S-6 except contains ~20% non-plastic fines and angular gravel, dense, moist, brown. (SM) LOWER 4": SANDSTONE. Mostly fine to coarse sand, ~10% non-plastic fines, very hard, moist, lt. gray.
35.3																	
36												H6					35.0 - 37.1: SANDSTONE. Mostly fine to coarse grained sand, silty in parts, gravelly in parts with fine to coarse subrounded gravel, max. size 1". arkosic, moderately to poorly cemented, moderately to slightly weathered, moderately fractured, maroon and gray.
		HQ 1	4.0	3.8	95	2.0	50	5	7+	1.7	<0.1	H4					
38												H5					
40		HQ 2	3.5	1.5	43	0.7	20	12	5	0.7	<0.1	H4/H5					

REMARKS/COMMENTS:

FILE: C:\ACAD12\SYMBOLS\DRILLOG.DWG PLOT @ 1-1 9/8/96

GEI Consultants, Inc. | **GEOLOGIC LOG OF DRILL HOLE** | HOLE NO. B-102

PROJECT NAME Chimney Hollow | PROJECT NO. 96293 | SHEET 3 OF 4
LOCATION Left Abutment | GROUND ELEV. 5575.215 | BEARING — | PLUNGE 90°
DATE STARTED/FINISHED 11-21-96 / 11-22-96 | DRILLED BY Layne/D.Werner | LOGGED BY EMJ
GROUNDWATER EL. 25.5' | DATE 11-22-96 | OVERBURDEN DEPTH 34.5 | TOTAL DEPTH 61.0

CORING (SEE LEGEND)

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION, ETC.	INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	RQD (FT.)	RQD %	CORING TIME (MIN.)	NO. OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
40		HQ 2										H4/H5					37.1 - 42.3': CLAYSTONE. Mostly low plastic and silty fines, sandy in parts, moderately weathered, indistinct bedding, red-brown.
42												H2					
	42.5	HQ 3	1.5	0.6	40	0	0	14	3 pcs	0.1	< 0.1	H2					42.3 - 44.0: QUARTZ DIKE. Slightly weathered, extremely fractured, embedded claystone clasts, subangular pieces, max. size 1". white-pink.
44	44.0											H4					
		HQ 4	5.0	4.3	86	3.1	62	9	9+	1.4	< 0.1	H5					44.0 - 50.7: CLAYSTONE. Similar to above, except slightly weathered, faint bedding @15 deg. from horiz., maroon. Some slickensided joint surfaces.
46																	
48												H4					
	49.0																
50		HQ 5	5.0	4.8	96	2.4	48	12	13+	1.3	< 0.1	H4					50.7 - 59.6: SANDSTONE. Similar to above, slightly weathered.
52												H3					
	54.0																
54		HQ 6	4.8	4.8	100	4.8	100	13	4	2.1	< 0.1	H3					
56																	
58	58.8																59.6 - 61.0: CLAYSTONE. Similar to above, faint bedding @ 25 deg. from horiz. Some slickensided joint surfaces.
60		HQ 7	2.2	2.2	100	1.5	68	6.	5+	6.9	< 0.1	H3/H5					

REMARKS/COMMENTS:

FILE C:\ACAD12\SYMBOLS\DRILLOG.DWG PLOT @ 1-1 9/9/96

RESERVOIR BORROW BORINGS

GEI Consultants, Inc. | **GEOLOGIC LOG OF DRILL HOLE** | HOLE NO. B-102

PROJECT NAME Chimney Hollow | PROJECT NO. 96293 | SHEET 4 OF 4

LOCATION Left Abutment | GROUND ELEV. 5575.215 | BEARING — | PLUNGE 90°

DATE STARTED/FINISHED 11-21-96 / 11-22-96 | DRILLED BY Layne/D.Werner | LOGGED BY EMJ

GROUNDWATER EL 25.5' | DATE 11-22-96 | OVERBURDEN DEPTH 34.5 | TOTAL DEPTH 61.0

DEPTH FT.	NOTES: GROUNDWATER CONDITIONS, DRILLING CONDITIONS, HOLE COMPLETION, ETC.	CORING (SEE LEGEND): INTERVAL	PENETRATION (FT.)	RECOVERY (FT.)	RECOVERY %	R.Q.D. (FT)	R.Q.D. %	CORING TIME (MIN.)	NO. OF PIECES	LONGEST (FT.)	SHORTEST (FT.)	HARDNESS	IN-SITU TESTING	JOINT DESCRIPTION	JOINT SYMBOL	GRAPHIC LOG	ENGINEERING AND GEOLOGIC DESCRIPTION & CLASSIFICATION
60		HQ 7										H4					
	Bottom 61.0 of Boring																
62																	

REMARKS/COMMENTS:

FILE C:\ACAD12\SYMBOLS\DRILL00.DWG PLOT @ 1-1 9/9/96

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5614.399
GROUNDWATER EL — DATE —
DATE START/FINISH 11-23-96/11-23-96
DRILLED BY Layne Environmental, Inc. (Denver)
LOGGED BY EMJ TOTAL DEPTH (FT) 15.6

BA-1

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5	S1	6 6 6	18	18			S-1: NARROWLY GRADED SAND WITH CLAY. Mostly fine grained sand. 10 - 15% low to med. plastic fines, <10% fine subrounded gravel, max. size 1", loose, dry, red. (SC)
	6.3							
	9.8	S2	5 6 8	18				S-2: LEAN CLAY. Mostly low to med. plastic fines, <10% fine sand, soft, moist, maroon color. (CL)
	11.3							S-3 UPPER 6": LEAN CLAY WITH SAND. Mostly low to medium plastic fines, 15 - 25% fine to coarse sand, <15% fine subrounded gravel, max. size 1/2", soft, moist, red. (CL)
	14.8	S3	8 20/4"	10	9			LOWER 4": CLAYSTONE. Slightly weathered, mostly low to med. plastic fines, sandy, stiff, dry, red-brown. (CLS)
	15.6							Bottom of boring = 15.6
	20							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-20-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow | DATE START/FINISH 11-25-96 / 11-25-96 | BA-2

GROUND ELEVATION (NGVD) 5592.006 | DRILLED BY Layne / D. Werner

GROUNDWATER EL. — DATE — | LOGGED BY EMJ | TOTAL DEPTH (FT) 26.0 | PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.8 5 6.3	S1	4 4 4	18	17			S-1 CLAYEY SAND. Mostly fine to coarse sand, ~30% low plastic fines, <10% subangular to subrounded gravel, max. size 1/4", slightly moist, loose, brown. (SC)
	9.5 10 11.0	S2	8 17 11	18	17			S-2 WIDELY GRADED SAND WITH SILT AND GRAVEL. Mostly med. to coarse sand, ~10% quartz gravel, max. size 1/2", ~10% nonplastic fines, dry, dense, tan to lt. gray. (SW-SM)
	14.5 15 16.0	S3	3 4 7	18	4			S-3 Similar to S-2, except slightly moist near top to very moist near bottom, medium dense, light brown. (SW-SM)
	19.5 20 21.0	S4	3 5 18	18	17			S-4 CLAYEY SAND WITH GRAVEL. Mostly fine to medium sand, widely graded, approx. 40% low plastic fines, ~15% fine to coarse, subangular to subrounded gravel, max. size 2", vy. moist to wet, loose (?) to medium dense, gray to brown. (SC)
	24.5 25 26.0	S5	5 17 22	18	18			S-5 UPPER 12": Similar to S-2 except saturated, brown. (SW-SM) MID 4": SANDY LEAN CLAY WITH GRAVEL. Mostly med. plastic fines, ~30% fine to med. sand, ~15% subangular to subrounded gravel, max. size 1", vy. moist, red. (CL) BOTTOM 2": CLAYSTONE, weathered, similar to mid. 4" with less sand. (CLS)
								Bottom of Boring = 26.0

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5618.772
GROUNDWATER EL — DATE —
DATE START/FINISH 11-25-96/11-25-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 9.8

BA-3

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	4.5							
	5	S1	11 23 17	18	18			S-1 GRAVELLY LEAN CLAY. Mostly low to med. plastic fines, ~15% fine subrounded gravel, max. size 1/8", stiff, sl. moist, red. (CL)
	6.0							
	9.5	S2	35/3"	3"	3			S-2: SANDSTONE. Mostly fine sand, ~20% non-plastic fines, powdered, slightly moist, lt. gray.
	10 9.8							Bottom of boring = 9.8'
	15							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5656.871
GROUNDWATER EL — DATE —
DATE START/FINISH 11-23-96/11-23-96
DRILLED BY Layne / D. Werner
LOGGED BY E.M.J TOTAL DEPTH (FT) 21.0

BB-1

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5							
	5	S1	5 5 5	18	18			S-1: CLAYEY SAND WITH GRAVEL. Mostly fine sand, ~25% low plastic fines, ~15% fine subangular to subrounded gravel, max. size 1", loose, dry, brown. (SC)
	6.0							
	9.5							
	10	S2	7 8 7	18	18			S-2: Similar to S-1 except max. size 1/4", moist at bottom. (SC)
	11.0							
	14.5							
	15	S3	5 12 36	18	18			S-3: SANDY LEAN CLAY. Mostly low to med. plastic fines, ~15% fine sand, ~10% fine subangular to subrounded gravel, max. size 1/4", stiff, sl. moist, red. Piece of sandstone bottom 3". (CL)
	16.0							
	19.5							S-4: UPPER 17": Similar to S-1 except medium dense and slightly moist. Spoon bouncing near bottom. (CL)
	20	S4	8 12 18	18	18			BOTTOM 1": SANDSTONE, weathered, dense, red-brown.
	21.0							Bottom of boring = 21.0'
	25							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5632.236
GROUNDWATER EL — DATE —
DATE START/FINISH 11-25-96/11-25-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 25.2

BB-2

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5							
	5	S1	8 10 8	18	14			S-1: SILTY SAND WITH GRAVEL. Mostly fine to med. sand, ~20% non- to low plastic fines, ~15% subrounded to subangular gravel, max. size 3" (broken rock), loose, sl. moist, brown. (SM)
	6.0							
	9.5							
	10	S2	5 12 20	18	15			S-2: UPPER 9": WIDELY GRADED SAND WITH CLAY. Mostly fine to coarse sand, ~10% low plastic fines, loose, sl. moist, brown. (SW-SC) LOWER 6": WIDELY GRADED GRAVEL. Coarse grained sandstone, max. size 2", lt. gray. (GW)
	11.0							
	14.5							
	15	S3	3 15 22	18	17			S-3: CLAYEY SAND WITH GRAVEL. Mostly fine to coarse sand, ~40% med. plastic fines, ~25% fine to coarse subangular to subrounded gravel and rock fragments, max. size 2", med. dense, moist to very moist, brown-gray. (SC)
	16.0							
	19.5							
	20	S4	13 17 15	18	15			S-4: Similar to S-3. (SC)
	21.0							
	24.5							
	25	S5	32 18/2"	8"	8"			S-5: CLAYSTONE. Weathered, mostly lean clay with med. plastic fines, sandy, very stiff, maroon. (CLS)
	25.2							Bottom of boring = 25.2

BLOWS PER 6 IN.—140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN—PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC—RECOVERY LENGTH OF SAMPLE
RQD—LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S—SPLIT SPOON SAMPLE
U—UNDISTURBED SAMPLES, UF—FIXED PISTON UO—OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Grimsey Hollow | DATE START/FINISH 11-25-96/11-25-96 | BB-3

GROUND ELEVATION (NGVD) 5668.686 | DRILLED BY Layne/D. Werner

GROUNDWATER EL. — DATE — | LOGGED BY EMJ | TOTAL DEPTH (FT) 20.0 | PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5 5 6.0	S1	7 12 12	18	18			S-1: LEAN CLAY. Mostly low to med. plastic fines, ~10% fine sand, very stiff, sl. moist, lt. brown. (CL)
	9.5 10 11.0	S2	8 15 24	18	17			S-2: LEAN CLAY WITH SAND. Mostly low to med. plastic fines, ~15% med. to coarse sand, ~10% fine subangular to subrounded gravel, max. size 3/4", very stiff, sl. moist, red-brown. (CL)
	14.5 15 16.0	S3	4 6 10	18	18			S-3: Similar to S-2 except stiff. (CL)
	19.5 20 20.0	S4	33/6"	6				S-4: SANDSTONE. Moderately weathered, mostly med. to coarse sand, red-brown.
								Bottom of boring = 20.0

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

96293
PROJECT
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5700.738
GROUNDWATER EL — DATE —
DATE START/FINISH 11-25-96/11-25-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 21.0

BC-1

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5 5 6.0	S1	9 22 21	18	18			S-1: SANDY LEAN CLAY. Mostly low to med. plastic fines, ~35% fine to coarse sand, very stiff, moist, brown. (CL)
	9.5 10 11.0	S-2	4 8 12	18	18			S-2: Similar to S-1 except red-brown. (CL)
	14.5 15 16.0	S-3	3 4 6	18	18			S-3: Similar to S-2. (CL)
	19.5 20 21.0	S4	4 12 20	18	15			S-4: SANDSTONE. Moderately weathered, mostly fine to coarse sand, ~10% non-plastic fines, med. dense, sl. moist, red-gray.
	25							Bottom of boring = 21.0'

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5678.144
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-26-96/11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 30.5

BC-2

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5	S1	3 4 5	18	18			S-1: SILTY SAND. Mostly fine to med. sand, ~20% non- to low plastic fines, loose, moist, dark brown. (SM)
	6.0							
	9.5	S2	8 12 21	18	14			S-2: WIDELY GRADED SAND WITH SILT AND GRAVEL. Mostly med. to coarse sand, ~15% fine to coarse subangular to subrounded gravel, max. size 2" (broken rock), <10% non-plastic fines, dense, moist, brown. (SW-SM)
	11.0							
	14.5	S3	3 4 5	18	14			S-3: SANDY LEAN CLAY. Mostly low to med. plastic fines, ~30% fine to coarse sand, stiff, moist, marbled brown-gray. (CL)
	16.0							
	19.5	S4	5 7 5	18	18			S-4: LEAN CLAY. Mostly low to med. plastic fines, ~10% fine to med. sand, stiff, very moist, gray. (CL)
	21.0							
	24.5	S5	9 14 12	18	16			S-5: CLAYEY SAND WITH GRAVEL. Mostly med. to coarse sand, ~20% low plastic fines, ~15% fine to coarse subrounded gravel, max. size 1-1/4", med. dense, saturated, gray. (SC)
	26.0							
	29.5		56 8-35	12	12			S-6: CLAYSTONE. Moderately weathered, low to med. plastic fines, hard, moist, maroon. (CLS)
	30							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED. %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▼ GROUNDWATER

NOTES:

96293
PROJECT DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5678.144
GROUNDWATER EL — DATE —
DATE START/FINISH 11-29-96 | 11-29-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 30.5

BC-2

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	30.0 30.5	SG	8 35	12				Bottom of boring = 30.5'
	35							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5676.570
GROUNDWATER EL — DATE —
DATE START/FINISH 11-26-96/11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 25.0

BC-3

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5	S1	4 6 6	18	15			S-1: TOP 5": WIDELY GRADED SAND WITH GRAVEL. Mostly fine to coarse sand, ~15% fine subangular gravel, max. size 1/4", medium dense, moist, brown. (SW) MID 5": SANDY ORGANIC SOIL. Mostly fine to med. sand, ~25% non-plastic fines, medium dense, moist, organic, black. (OL) BOTTOM 5": Similar to top 5". (SW)
	6.0							
	9.5	S2	2 3 3	18	2			S-2: CLAYEY SAND. Mostly fine to med. sand, ~20% non- to low plastic fines, loose, moist, brown. (SC)
	11.0							
	14.5	S3	2 5 7	18	8			S-3: Similar to S-2 except with ~30% low to med. plastic fines, medium dense. (SC)
	16.0							
	18.5	S4	2 2 4	18	18			S-4: SANDY LEAN CLAY WITH GRAVEL. Mostly med. plastic fines, ~10% fine to med. sand, ~15% fine subangular to subrounded gravel, max. size 1/2", medium stiff, very moist, brown. (CL)
	21.0							
	24.5	S5	40	6	6			S-5: SANDSTONE. Weathered, mostly fine to coarse sand, ~15% fine subangular to subrounded gravel, max. size 1/2", ~30% low plastic fines, hard, very moist, red-brown.
	25.0							Bottom of boring=25.0
	30							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5770.888
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-26-96/11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 11.0

BD-1

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5 / 5	S1	4, 8, 10	18	18			S-1 SANDY LEAN CLAY WITH GRAVEL. Mostly low to med. plastic fines, <10% fine to med. sand, ~15% fine subrounded gravel, max. size 1/8", very stiff, dry, red. (CL)
	6.0							
	9.5 / 10	S2	8, 18, 24	18	18			S-2: Similar to S-1 except hard. (CL) Laminated structure of sandstone or claystone, weathered, apparent in tip of spoon.
	11.0							Bottom of boring = 11.0'
	15							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow | DATE START/FINISH 11-26-96/11-26-96 | BD-2

GROUND ELEVATION (NGVD) 5759.793 | DRILLED BY Layne / D. Werner | PG. 1 OF 1

GROUNDWATER EL — DATE — | LOGGED BY EMT | TOTAL DEPTH (FT) 15.0

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5	S1	4 8 8	18	18			S-1 LEAN CLAY. Mostly low to med. plastic fines, ~10% med. to coarse sand, very stiff, moist, maroon. (CL)
	6.0							
	9.5	S2	3 4 5	18	18			S-2: Similar to S-1. (CL)
	11.0							
	14.5							S-3: SANDSTONE. Moderately weathered, mostly med. to coarse sand, ~20% low to med. plastic fines, very hard, sl. moist, red.
	15.0	S3	30/6"	6	3			Bottom of boring = 15.0'
	20							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5795.458
GROUNDWATER EL — DATE —
DATE START/FINISH 11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 20.9

BD-3
PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5							
	5	S1	4 9 8	18	17			S-1: LEAN CLAY. Mostly low plastic fines, <10% fine to med. sand, very stiff, sl. moist, red-brown. (CL)
	6.0							
	9.5							
	10	S2	9 12 15	18	18			S-2: Similar to S-1 except contains <10% coarse sand and fine subangular gravel, max. size 1/8". (CL)
	11.0							
	14.5							
	15	S3	12 17 19	18	18			S-3: SANDY LEAN CLAY WITH GRAVEL. Mostly low to med. plastic fines, ~30% fine to coarse sand, ~15% fine subrounded gravel, max. size 1", hard, moist, red. (CL)
	16.0							
	19.5							
	20	S4	10 27 30/5"	17	16			S-4: CLAYSTONE. Moderately weathered, mostly low to med. plastic fines, <15% fine sand, hard, moist, maroon. (CLS)
	20.9							Bottom of boring = 20.9'
	25							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▼ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow | DATE START/FINISH 11-26-96/11-26-96 | BE-1

GROUND ELEVATION (NGVD) 5731.875 | DRILLED BY Layne / D. Werner | PG. 1 OF 1

GROUNDWATER EL — DATE — | LOGGED BY EMJ | TOTAL DEPTH (FT) 9.8

EL FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5 / 5	S1	5 10 9	18	18			S-1: LEAN CLAY WITH SAND. Mostly low to med. plastic fines, ~10% fine sand, ~10% fine subangular gravel, max. size 1/4", medium dense, dry, red-brown. (CL)
	6.0							8.0': Top of CLAYSTONE, based on drill rig response and flaked rock lamina in auger cuttings. (CLS)
	9.5	S2	30/4"	4	0			
	10							Bottom of boring = 9.8'
	15							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow | DATE START/FINISH 11-27-96 / 11-27-96 | BE-2

GROUND ELEVATION (NGVD) 5713.354 | DRILLED BY Layne / D. Werner

GROUNDWATER EL. — DATE — | LOGGED BY EMJ | TOTAL DEPTH (FT) 29.7 | PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5	S1	4 4 5	18	18			S-1: LEAN CLAY. Mostly low plastic fines, <10% fine to med. sand, stiff, sl. moist, brown. (CL)
	5 6.0							
	9.5	S2	4 5 4	18	17			S-2: Similar to S-1 except low to med. plastic fines, moist. (CL)
	10 11.0							
	14.5	S3	5 4 4	18	18			S-3: Similar to S-2, except contains a 1"-thick layer of clay with ~30% med. to coarse sand. (CL)
	15 16.0							
	19.5	S4	3 4 3	18	3			S-4: SANDY LEAN CLAY WITH GRAVEL. Mostly low to med. plastic fines, ~30% fine to coarse sand, ~15% fine subangular gravel, max. size 1/8", medium stiff, moist, red. (CL)
	20 21.0							
	24.5	S5	4 12 12	18	18			S-5: Similar to S-4 except contains ~20% fine to coarse sand, very stiff, very moist, brown. (CL)
	25 26.0							
	27.5	S6	32/3"	3	3			S-6: SANDSTONE. Weathered, med. to coarse sand, <10% fines, lt. gray to maroon.
	30 29.7							Bottom of boring = 29.7'

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5830.780
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-26-96 / 11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 15.7

BF-1
PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5 / 5	S1	7 14 12	18	17			S-1: LEAN CLAY. Mostly low to med. plastic fines, <10% fine to med. sand, very stiff, sl. moist, red-brown. (CL)
	6.0							
	9.5 / 10	S2	6 7 6	18	18			S-2: SANDY LEAN CLAY WITH GRAVEL. Mostly low to med. plastic fines, ~20% fine to coarse sand, ~15% fine subangular to subrounded gravel, max. size 1" (sandstone fragment), stiff, sl. moist, red. (CL)
	11.0							
	14.5 / 15	S3	8 28 25/3"	15	15			S-3 CLAYSTONE. Weathered, mostly low to med. plastic fines, hard, dry, red. (CLS)
	15.7							Bottom of boring=15.7'

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow | DATE START/FINISH 11-26-96 / 11-26-96 | BF-2

GROUND ELEVATION (NGVD) 5812.279 | DRILLED BY Layne / D. Werner

GROUNDWATER EL — DATE — | LOGGED BY EMJ | TOTAL DEPTH (FT) 19.8 | PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	BLOWS PER 6 IN.	PEN IN.	REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5 / 5	S1	6 9 11	18	18			S-1: LEAN CLAY. Mostly non- to low plastic fines, <10% fine to med. sand, very stiff, sl. moist, brown. (CL)
	6.0							
								S-2: Sim. to S-1 except low to med. plastic fines, hard, red-brown. (CL)
	9.5 / 10	S2	12 20 22	18	18			S-3: UPPER 10": SANDY LEAN CLAY Mostly low to med. plastic fines, ~30% fine to coarse sand, very stiff, moist, red-brown. (CL)
	11.0							LOWER 8": CLAYEY SAND WITH GRAVEL. Mostly fine to coarse sand, ~15% fine to coarse subrounded gravel, max. size 2", ~25% low to med. plastic fines, medium dense, sl. moist, red-brown. (SC)
	14.5 / 15	S3	3 10 11	18	18			
	16.0							17.5': Top of CLAYSTONE, weathered, based on drill rig response and flaked rock lamina in auger cuttings. (CLS)
	18.5 / 20 19.8	S4	25/3"	3	0			S-4: No Recovery.
								Bottom of boring = 19.8'
	25							
	30							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5848.190
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-26-96/11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 4.9

BF-3

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							1.0': Top of CLAYSTONE, based on drill rig response and flaked rock lamina in auger cuttings. CLAYSTONE, mostly low to med. plastic fines, dry, red-brown.(CLS)
	4.5	S1	35/5"	5	0			S-1: No Recovery.
	5 4.9							Bottom of boring = 4.9'
	10							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5882.583
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-26-96/11-26-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 16.0

BG-1

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	4.5							
	5	S1	17 40	12	12			S-1: CLAYEY SAND WITH GRAVEL. Mostly med. to coarse sand, ~30% low plastic fines, ~15% fine to coarse subangular to subrounded gravel, max. size 2", dense, brown-gray. (SC)
	10 10.0	S2	8 17 24	18	18			S-2: SILTY SAND. Mostly fine to medium sand, ~40% non-plastic fines, dense, sl. moist, brown. (SM)
	11.5							S-3: CLAYSTONE. Weathered, mostly low to med. plastic fines, very hard, dry, red. (CLS)
	15 15.0	S3	18 50	12	10			
	16.0							Bottom of boring = 16.0
	20							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

96293
PROJECT DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5838.466
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-27-96/11-27-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 11.0

BG-2

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	5	S1	12 10 15	18	16			S-1: LEAN CLAY, Mostly low to med. plastic fines, <10% fine to med. sand, hard, sl. moist, red-brown. (CL)
	10	S2	12 19 42	18	18			S-2: CLAYSTONE. Weathered, mostly low to med. plastic fines, hard, dry, red. (CLS)
								Bottom of boring = 11.0'
	15							
	20							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

BORING LOCATION Chimney Hollow
GROUND ELEVATION (NGVD) 5835.189
GROUNDWATER EL. — DATE —
DATE START/FINISH 11-27-96/11-27-96
DRILLED BY Layne / D. Werner
LOGGED BY EMJ TOTAL DEPTH (FT) 9.0

BG-3

PG. 1 OF 1

EL. FT.	DEPTH FT.	SAMPLE TYPE and NO.	SAMPLE BLOWS PER 6 IN.	SAMPLE PEN IN.	SAMPLE REC IN.	REMARKS	GRAPHIC LOG	SOIL AND ROCK DESCRIPTIONS
	0							
	5	S1	6 12 10	18	18			S-1: SANDY LEAN CLAY. Mostly low to med. plastic fines, ~20% fine to coarse sand, ~10% fine subrounded gravel, max. size 1/2", very stiff, sl. moist, red. (CL)
								7.0': Top of CLAYSTONE, based on drill rig response and flaked rock lamina in auger cuttings. (CLS)
	9.0							Auger refusal @ 9.0 ft Bottom of boring = 9.0 ft
	10							

BLOWS PER 6 IN.–140 LB. HAMMER FALLING 30 IN. TO DRIVE A 2.0 IN. OD SPLIT SPOON SAMPLER
PEN–PENETRATION LENGTH OF SAMPLER OR CORE BARREL
REC–RECOVERY LENGTH OF SAMPLE
RQD–LENGTH OF SOUND CORES >4 IN./LENGTH CORED, %
S–SPLIT SPOON SAMPLE
U–UNDISTURBED SAMPLES, UF–FIXED PISTON UO–OSTERBERG
▽ GROUNDWATER

NOTES:

PROJECT 96293
DATE 2-18-97

GEI Consultants, Inc.

PACKER PERMEABIILTY TEST DATA

WATER PRESSURE PACKER TEST

GEI Consultants, Inc.

Project	Chimney Hollow Dam and Reservoir	BORING NO.	B101
Project No.	96293	TEST NO.	1
Field Test By:	EMJ	Date:	11/20/96
Calculated By	AMA	Date	2/16/97
Checked By:		Date:	

PACKER SYSTEM DATA

Packers: Number	Double
Type	Pneumatic
Packer Pressure (psi)	100
Packer Length (in)	24 0
Water Pipe I D (in)	1.00
Type of Pipe	Steel
Manning's Coeff (n)	0 014

TEST INTERVAL DATA

(All depths/heights measured from ground surface)

Diameter of Borehole (in)	3 000
Depth to Ground Water (ft)	14 5
Angle from Horizontal, Dip (Deg)	90.0
Depth to Top of Test Zone (ft)	36.2
Depth to Bottom of Test Zone (ft)	46 8
Test Interval (ft)	10 6
Gage Height above Ground Surface (ft)	2 2

Gage Pressure	Elapsed Time	Volume	Change in Volume	Flow Rate		Rock Mass Hydraulic Conductivity (K)		
(psi)	(min)	(gal)	(gal)	(gal/min)	(cf/min)	(ft/min)	(ft/yr)	(cm/sec)
7.0	0.0	15.2						
7.0	0.5	15.2	0.0	0 0	0.00	*	*	*
7.0	1.0	15.2	0 0	0.0	0.00	*	*	*
7.0	2.0	15 2	0.0	0.0	0.00	*	*	*
17 5	0.0	24.4						
17 5	0 5	24.9	0.5	1.0	0.13	1.6E-04	82.2	7 9E-05
17.5	1 0	25.5	0.6	1 2	0.16	1 9E-04	98.7	9 5E-05
17.5	2.0	26.3	0.8	0.8	0.11	1.2E-04	65.7	6.3E-05
16.0	3.0	26.8	0.5	0.5	0.07	8.3E-05	43.7	4.2E-05
15.0	4.0	27.1	0.3	0.3	0.04	5.2E-05	27.4	2.6E-05
15 0	5.0	27.5	0 4	0.4	0 05	6.9E-05	36 5	3.5E-05
14.5	6.0	27.8	0 3	0 3	0.04	5.3E-05	28.0	2.7E-05
14.0	7.0	28 1	0 3	0 3	0.04	5.5E-05	28.7	2.8E-05

1.- Water pressure, p, was measured with gauge at 2 2 ft. above ground level.

2.- Hydraulic Conductivity, K = q*ln(2*L/D)/(2*Pi*L*Hc), as per Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G, for isotropic conditions (m=1), and for L/D not less than 4

3.-* Indicates very low conductivity.

WATER PRESSURE PACKER TEST

Φ GEI Consultants, Inc.

Project	Chimney Hollow Dam and Reservoir		BORING NO. B101
Project No	96293		TEST NO. 2
Field Test By:	EMJ	Date. 11/20/96	
Calculated By:	AMA	Date 2/16/97	
Checked By		Date:	

PACKER SYSTEM DATA

Packers Number	Double
Type	Pneumatic
Packer Pressure (psi)	100
Packer Length (in)	24 0
Water Pipe I D (in)	1 00
Type of Pipe	Steel
Manning's Coeff (n)	0.014

TEST INTERVAL DATA

(All depths/heights measured from ground surface)

Diameter of Borehole (in)	3.000
Depth to Ground Water (ft)	14.5
Angle from Horizontal, Dip (Deg)	90.0
Depth to Top of Test Zone (ft)	28 5
Depth to Bottom of Test Zone (ft)	39 1
Test Interval (ft)	10.6
Gage Height above Ground Surface (ft)	0 5

Gage Pressure	Elapsed Time	Volume	Change in Volume	Flow Rate		Rock Mass Hydraulic Conductivity (K)		
(psi)	(min)	(gal)	(gal)	(gal/min)	(cf/min)	(ft/min)	(ft/yr)	(cm/sec)
7.0	0.0	30 1						
7.0	0.5	30.2	0 1	0 2	0.03	5 7E-05	30 1	2 9E-05
7 0	1.0	30.3	0.1	0 2	0.03	5 7E-05	30.1	2 9E-05
7.0	2.0	30 6	0.3	0.3	0.04	8 6E-05	45.1	4.4E-05
7.0	3.0	30.8	0.2	0.2	0.03	5.7E-05	30.1	2 9E-05
7 0	4 0	31.0	0.2	0.2	0.03	5.7E-05	30.1	2.9E-05
14 0	0 0	33 6						
14 0	0 5	33.9	0.3	0.6	0 08	1 1E-04	59 4	5.7E-05
14.0	1 0	34.2	0.3	0.6	0 08	1 1E-04	59 4	5.7E-05
14.0	2.0	34.8	0.6	0.6	0 08	1 1E-04	59.4	5.7E-05
14 0	3.0	35.4	0.6	0.6	0.08	1.1E-04	59 4	5.7E-05
14.0	4.0	35 9	0.5	0.5	0.07	9.4E-05	49.5	4 8E-05
14.0	5 0	36.4	0.5	0 5	0.07	9.4E-05	49.5	4 8E-05

1 - Water pressure, p, was measured with gauge at 2.2 ft above ground level.

2.- Hydraulic Conductivity, K = q*ln(2*L/D)/(2*Pi*L*Hc), as per Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G, for isotropic conditions (m=1), and for L/D not less than 4

3.-* Indicates very low conductivity.

WATER PRESSURE PACKER TEST
GEI Consultants, Inc.

Project	Chimney Hollow Dam and Reservoir	BORING NO.	B102
Project No	96293	TEST NO	1
Field Test By:	EMJ	Date:	11/22/96
Calculated By:	AMA	Date:	2/16/97
Checked By:		Date.	

PACKER SYSTEM DATA

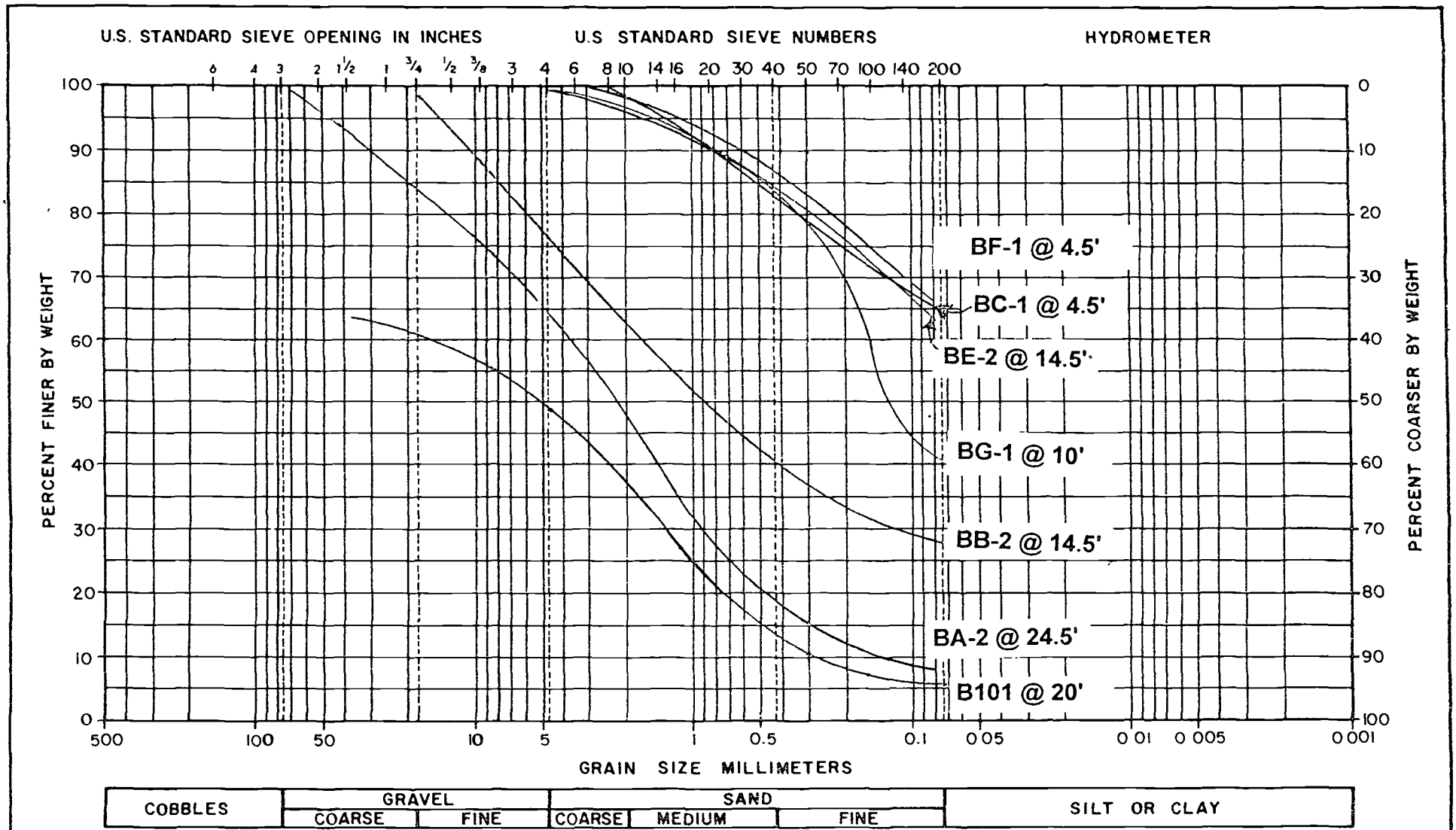
Packers. Number	Double
Type	Pneumatic
Packer Pressure (psi)	100
Packer Length (in)	24 0
Water Pipe I D (in)	1 00
Type of Pipe	Steel
Manning's Coeff (n)	0 014

TEST INTERVAL DATA
(All depths/heights measured from ground surface)

Diameter of Borehole (in)	3 000
Depth to Ground Water (ft)	25 5
Angle from Horizontal, Dip (Deg)	90 0
Depth to Top of Test Zone (ft)	48 8
Depth to Bottom of Test Zone (ft)	58.8
Test Interval (ft)	10.0
Gage Height above Ground Surface (ft)	2 0

Gage Pressure	Elapsed Time	Volume	Change in Volume	Flow Rate		Rock Mass Hydraulic Conductivity (K)		
(psi)	(min)	(gal)	(gal)	(gal/min)	(cf/min)	(ft/min)	(ft/yr)	(cm/sec)
7.0	0 0	40 5						
7 0	0 5	40 6	0.1	0.2	0 03	4 3E-05	22 4	2 2E-05
7 0	1 0	40.7	0 1	0 2	0.03	4.3E-05	22.4	2.2E-05
7.0	2.0	40.9	0 2	0 2	0 03	4.3E-05	22.4	2.2E-05
7.0	3.0	41.0	0.1	0 1	0 01	2.1E-05	11 2	1.1E-05
7.0	4.0	41.2	0.2	0.2	0.03	4.3E-05	22 4	2 2E-05
7.0	5 0	41.2	0.0	0.0	0.00	*	*	*
7 0	6.0	41.3	0.1	0 1	0.01	2.1E-05	11 2	1.1E-05
7.0	7.0	41.3	0 0	0.0	0 00	*	*	*
16.0	0.0	43.5						
16 0	0 5	43.9	0.4	0.8	0 11	1 2E-04	60 9	5.9E-05
16.0	1 0	44.2	0.3	0 6	0.08	8 7E-05	45 7	4.4E-05
16.0	2.0	44.9	0.7	0.7	0 09	1 0E-04	53.3	5 1E-05
16.0	3 0	45.5	0.6	0.6	0 08	8 7E-05	45.7	4.4E-05
16.0	4.0	46.0	0.5	0 5	0.07	7.2E-05	38.0	3.7E-05
16.0	5.0	46.4	0.4	0.4	0.05	5.8E-05	30 4	2.9E-05
16 0	6.0	46.7	0 3	0.3	0.04	4.3E-05	22 8	2.2E-05
16.0	7.0	47.0	0.3	0 3	0.04	4 3E-05	22 8	2.2E-05
16 0	8.0	47.4	0.4	0.4	0.05	5.8E-05	30 4	2 9E-05
16 0	9.0	47.7	0.3	0.3	0.04	4.3E-05	22.8	2 2E-05

1.- Water pressure, p, was measured with gauge at 2 2 ft. above ground level
2.- Hydraulic Conductivity, K = q*ln(2*L/D)/(2*Pi*L*Hc). as per Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G, for isotropic conditions (m=1), and for L/D not less than 4.
3.-* Indicates very low conductivity



NCUCD	Chimney Hollow	Sieve Analysis Results
GEI Consultants, Inc. ENGLEWOOD, COLORADO	Project 96293	March 1997 Fig.

Appendix C

COST ESTIMATING ASSUMPTIONS

This appendix summarizes the assumptions used to prepare the feasibility opinions of probable construction cost for the earthfill/rockfill dam alternative for the Chimney Hollow Dam and Reservoir project. Probable costs for this work are referenced to February 1997 and correspond to an Engineering News Record, Construction Cost Index of 5755.71.

CONSTRUCTION COST ITEMS

Construction cost items include construction items and activities that would typically be included in a project bid abstract or bid summary. Item numbers correspond to numbers used in the cost spreadsheets. See Table 5.

1. Stream Diversion

Stream diversion includes upstream and downstream cofferdams and culvert pipe to divert the existing stream to maintain dry conditions for construction. This item includes furnishing and placing about 13,000 cubic yards of fill and 1,800 feet of 48-inch diameter culvert pipe. The cost associated with removing these structures is also included.

2. Clearing and Grubbing

Clearing and grubbing includes removing trees, roots, shrubs, and other vegetation from within the footprint of the proposed dam.

3. Dewatering

Dewatering will be required for local excavations for structures and for the central valley of the core cutoff trench. Dewatering includes labor, equipment, and materials needed to dewater these areas.

4. Unclassified Excavation

Unclassified excavation includes 1-foot of stripping over the dam footprint and excavation for the core cutoff trench. Existing soils can be excavated with normal construction equipment and procedures (scrapers, dozers, front-end loaders). It was assumed that 70 percent of the materials can be excavated with scrapers and 30 percent with front-end loaders and most of the excavated material can be reused in embankment construction.

5. Foundation Preparation

Foundation preparation includes proof-rolling the cleared foundation to identify soft, wet, or yielding areas. Such areas will be over-excavated to stable, firm foundation and backfilled appropriately.

6. Foundation Grouting

Foundation grout holes will be drilled into the foundation bedrock to a depth of about two-thirds the hydraulic height of the dam. Grout holes will be spaced at 10 foot centers. The work includes contractor mobilization and demobilization, drilling, grouting, and secondary drilling and grouting. A grout take of 0.5 cubic feet per linear foot of drilled hole is assumed. Foundation grouting would be from the subgrade of the core cutoff trench.

7. Furnishing and Placing Embankment Zone 1 (Central Core)

Zone 1 fill will consist of on-site silts and clays. Assumes that sufficient quantity and quality of Zone 1 fill is available within the proposed reservoir. Excavating, hauling, placing, and compacting costs are included. Assumes that Zone 1 fill can be excavated and placed with normal construction equipment and procedures such as scrapers, dozers, and sheepsfoot rollers.

8. Furnishing and Placing Embankment Zone 2A (Upstream Transition Material)

Zone 2A fill will consist of processed gravel from on-site rockfill quarries. Assumes that sufficient quantity and quality of Zone 2A fill is available on-site. Excavating, processing, hauling, placing, and compacting costs are included. Assumes that Zone 2A fill can be hauled and placed with normal construction equipment and procedures such as loaders, trucks, dozers, and vibratory rollers.

9. Furnishing and Placing Embankment Zone 2B (Downstream Fine Filter)

Zone 2B fill will consist of sand meeting the requirements of ASTM C-33 imported from an off-site source. Material, hauling, placement, and compaction costs are included. Assumes that Zone 2B fill can be hauled and placed with normal construction equipment and procedures such as trucks, dozers, and vibratory rollers.

10. Furnishing and Placing Embankment Zone 2C (Downstream Coarse Filter)

Zone 2C fill is similar to Zone 2A and will consist of processed gravel from the on-site quarries. Assumes that sufficient quantity and quality of Zone 2C fill is available on-site. Excavating, processing, hauling, placing, and compacting costs are included. Assumes that Zone 2C fill can be hauled and placed with normal construction equipment and procedures such as trucks, dozers, and vibratory rollers.

11. Furnishing and Placing Embankment Zone 3 (Rockfill)

Zone 3 fill will consist on-site rock quarried from the granitic rocks along the west side of the reservoir. Assumes that sufficient quantity and quality of Zone 3 fill is available on-site within 1.5 miles of the dam. Excavating, processing, hauling, placing, and compacting costs are included.

Assumes that Zone 2C fill can be excavated, hauled, and placed with normal construction equipment and procedures such as blasting, backhoes, trucks, and dozers.

12. Instrumentation

Instrumentation includes the labor, equipment, and materials required to install piezometers, reservoir level indicators, structural monitoring points, settlement plates, and horizontal and vertical monitoring points.

13. Reclamation of Disturbed Areas

Reclamation includes topsoil replacement, seeding, fertilizing, and mulching all areas disturbed during construction.