CRS SIRRINE

ARIZONA CANAL DIVERSION CHANNEL
TUNNEL ALTERNATIVE FEASIBILITY STUDY
STATION 895+50 TO STATION 945+50

March 1987

CRS Sirrine, Inc.
1817 North Seventh Street
Suite 250
Phoenix, Arizona 85006

Planning Design Construction

UNDERGROUND ENGINEERING DIVISION

CRS Sirrine Engineering Group

CRS SIRRINE

April 9, 1987

Mr. Edward A. Raleigh, P.E.
Project Engineer
Flood Control District of Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

Reference: ACDC, Tunnel Alternative Cost Comparison
Contract No. FCD 86-37

Dear Mr. Raleigh:

Attached are ten copies of our final report "Arizona Canal Diversion Channel Tunnel Alternative Feasibility Study, Station 895 + 50 to Station 945 + 50." Our study indicates that the construction of a gravity flow tunnel alternate is technically feasible but would entail on $6,792,000 increase in cost over the presently planned covered channel. During the study, a third alternate using an inverted siphon or sag pipe technique was identified. This alternative could possible cost $3 - $4 million less than the gravity tunnel investigated in this report.

We will be pleased to discuss our report with you at your convenience.

Very truly yours,

Robert L. McFarland

Robert L. McFarland
Vice President

RLM:kp

Ronald L. Thorstad, P.E.
Vice President
Infrastructure Group

CRS Sirrine, Inc.
Suite 250
1817 North Seventh Street
Phoenix, Arizona 85006
602 254-5543

TABLE OF CONTENTS

I. INTRODUCTION

1.1 Project Location

The project site is located in the south half of Sec. 10 and Sec. 11 and the north half of Sec. 14, T.2N., R.3E. in the Sunnyslope 7.5 minute topographic quadrangle, U.S. Geological Survey (1965-73). The project site is located within the City of Phoenix and is bound by Lincoln Drive on the north, the Arizona Canal on the south, 32nd Street on the east, and 20th Street on the west. The project transverses the properties of the Arizona Biltmore Hotel and Resort.

1.2 Purpose

Based upon authorization by the Flood Control District of Maricopa County (FCD), CRS Sirrine, Inc. (CRSS) prepared a conceptual cost comparison of the construciton of a gravity flow tunnel vs. a covered channel for the proposed Arizona Canal Diversion Channel (ACDC) through the Arizona Biltmore property. The limits and location of the tunnel alternative was based on the alignment and profile identified by the FCD through the golf course around the north side of the Biltmore Hotel. The purpose of this project was to prepare a conceptual cost comparison between a tunnel vs. covered channel alternative for the ACDC through the Biltmore property.

1.3 Scope of Work

The scope of work of this project consisted of four work items, which were listed in our proposal of December 12, 1986. Each work item is discussed in the following paragraphs:

- Perform a geotechnical investigation along the alignment of the tunnel alternative identified by the FCD. Prepare a geotechnical report based on the results of the investigation.

- Determine a conceptual line, grade and depth of tunnel based on the alignment identified by the FCD. Accomplish a conceptual design sufficient to allow an estimate of the cost of the tunnel scheme for a comparison with the covered channel alternative.

- Develop a cost estimate for that section of the channel alternative that would be replaced by the tunnel so that the direct construciton costs for both alternatives can be compared easily.

- Prepare a final report presenting an analysis of the feasibility of the two alternatives.

1.4 Report Organization

This feasibility study is divided into four major sections, as follows:

Section I - Introduction - Describes the project location, pupose and scope of work for this report.

Section II - Conceptual Tunnel Design and Estimate - Describes the construction methods, scheme and costs for the tunnel alternative.

Section III - Cut and Cover Alternative - Presents a construction cost estimate for the portion of channel that would be replaced by the tunnel alternate.

Section IV - Summary - Summarizes the construction cost comparison between the tunnel vs. cut and cover channel. Identifies a third alternate.

II. CONCEPTUAL TUNNEL DESIGN AND ESTIMATE

2.1 INTRODUCTION

The tunnel concept was developed as an alternate to the surface channel adjacent to the Arizona Canal as a means of mitigating the disruption of the Canals and activities in the area of the Biltmore Properties. The intent was to place as much of the diversion channel underground as possible without the use of cut and cover techniques. The result was a tunnel 5,200 feet long extending from station 898 + 50 to Station 950 + 50. The tunnel alternate was completed by surface channels of 300 feet on the downstream portal and 150 feet on the upstream portal. Please see Appendix A, General Plan & Boring Locations.

The Tunnel Alternate is estimated to require 14 months to construct at a cost of $19,500,000.

2.2 Tunnel Design & Construciton Concepts

The tunnel configuration was selected to provide a channel area essentially the same as the covered channel presently set forth for the ACDC. No hydrualic study was made to determine the exact requirements for width of channel but it was deemed the deminsions choosen would be sufficiently close to a final design for the purposes of this study. The rectangular shape was selected to handle the channel flow and to provide as much cover over the tunnel crown as practical. Please see Appendix A, Subsurface Profile.

The tunnel will be constructed in material of widely varing characteristics from both the aspects of ease of excauation and support of the ground.

In order to accommodate these variations in anticipated tunneling conditions a flexible approach to the project is required. As this is a relative large tunnel in cross sectional area and amount of material to move, it is necessary to have a scheme that will permit high productivity when possible. To best satisfy these conditions a conceptual tunneling method was selected with the following salient features.

- The tunnel would be basically a top heading and bench. The top heading would be driven as a pilot tunnel on one side to minimize opening unsupported ground. The top heading would be opened to full face after securing the ground in the pilot tunnel. The widening effort would follow the pilot face by 20 to 50 feet typically.

- The ground would be drilled with a rubber tired jumbo using hydrualic drills and blasted. Depending on the competence of the ground, the face would be completed to section using a road header type tunnelling machine. The purpose of this technique is to damage the periphery rock the least amount possible. Having both a road header a a drill jumbo permits the flexibility to apply differient excavation techniques depending on the rock conditions encountered.

- The ground support concept is to shotcrete the back and ribs immediately after opening the face. This will be followed by steel sets and a second treatment with shotcrete. The spacing of the steel sets and the depth of shotcrete will be adjusted to suit the conditions encountered. After the top heading has been completed and the tunnel crown secured, the bench will be removed. The loads supported by the steel sets will be transfered throgh wall plates to lower posts and to the invert.

2.3 Tunnel Concentual Estimate

The major cost elements for the Tunnel Alternate are listed below:

Tunnel:

Direct Labor	$ 3,648,000	
Direct Equipment	2,614,000	
Direct Materials	3,002,000	
Material Disposal	890,000	
Mobilization	300,000	
Overhead Costs	840,000	
Final Concrete	2,334,000	
Surface Channels (450 L. F.)	495,000	
Subtotal	$14,123,000	
Contingencies (@15%)	2,117,000	
Total, Tunnel		16,240,000
Engineering and design (@ 10% of tunnel)		1,630,000
Supervision and administration (@ 10%)		1,630,000
Total Construction Cost		$19,500,000

The costs were developed using an advance rate of 6 feet per shift, three shifts per day for the top heading for the initial 850 feet. (The portion of the tunnel beneath the streets). The steel sets were placed on 4 foot centers through this area. The section of tunnel from station 807 + 00 to 950 + 50 (beneath the golf course) was estimated at 12 feet per shift and sets at 6 feet on cetners. The bench excavation was set at 24 feet per shift advance also on a three shift basis.

A 1985 cost basis was used for development of the conceptual estimate. Tunneling costs are subject to wide variations depending on the economy in general and the state of the tunneling industry. In order to compare costs to other time frames, typical labor, material and equipment costs are listed.

Foreman	$26.50 per hour
Shifters	25.50 per hour
Miners	24.50 per hour
Laborers (Underground)	23.50 per hour
Operators (LHD)	28.75 per hour
Mechanic	28.75 per hour
Yardmen	24.00 per hour
Operator (Fork Lift)	27.75 per hour

Equipment rates include repair, labor, ownership and operating costs.

LHD	100.00 per hour
Roadheader	250.00 per hour
Drill Jumbo	52.60 per hour
Fan	4.45 per hour
Fork Lift	17.40 per hour

Material prices include Structural Steel at $0.44 per pound, Shotcrete at $200.00 cy and concrete for invert, walls and top slab as $57.20/cy, 80.00/cy, and $117.00/cy respectively.

III. CUT AND COVER ALTERNATIVE

CRSS examined the cut and cover alternative developed by the Corps of Engineers as presented in Design Memorandum No. 12, April 1986, and separated out the cost of the 5,000 feet section of Reach 4 between Statin 895+50 and Station 945+50 which would be replaced by the tunnel alternative. Costs associated with this section are as follows:

ACDC-CUT AND COVER (OCT. 1985 DOLLARS) STA. 895+50 TO STA. 945+50

Channel					
Clearing & grubbing	1	Job	LS	$ 10,000	
Shoring	1	Job	LS	263,000	
Excavation (blasting), channel	35,000	CY	$ 7.00	245,000	
Excavation, Channel	304,000	CY	2.95	896,800	
Compacted fill	111,500	CY	3.20	356,800	
Miscellaneous fill, compacted	43,400	CY	0.75	32,550	
Concrete, invert	5,225	CY	57.20	298,870	
Concrete, footing	10,005	CY	62.30	623,310	
Concrete, wall	14,433	CY	80.00	1,154,640	
Concrete, top slab	14,136	CY	117.00	1,653,910	
Portland cement	258,496	CWT	4.20	1,085,680	
Steel reinforcement	5,024,600	Lbs	0.34	1,708,360	
Invert access ladders	1,260	LF	30.00	37,800	
Aggregate base	1,760	CY	15.10	26,580	
Asphaltic concrete paving	1,740	Ton	36.40	63,340	
Fencing, channel	750	LF	30.00	22,500	
Manholes	1	Job	LS	6,310	
Side drain	1	Job	LS	19,700	
Drainage system	1	Job	LS	31,400	
Subtotal, channel				8,259,000	
Contingencies (15%)				1,226,000	
Total, channel					$ 9,485,000
Engineering & design (10% of channel)					950,000
Supervision & administratin (10% of channel)					950,000
Total, construction					$ 11,385,000
Utility Relocations					
Water	1	Job	LS	234,600	
Sewer	1	Job	LS	240,000	
Gas	1	Job	LS	8,400	
Electricity	1	Job	LA	90,000	
Total Utilities					$ 573,000
Relocation of Arizona Canal	1	Job	LS		750,000
TOTAL					$ 12,708,000

IV. Summary

The gravity flow tunnel alternative to the covered channel scheme as developed in the April 1986 study for the Arizona Canal Diversion Channel is estimated to be $19,500,000. The Channel reach replaced by the tunnel alternative was estimated to cost $12,708,000 based on the cost data supplied in the study.

The tunnel alternative would accomplish the goal of minimum disruption of the Biltmore area. The bulk of the construction activity would be centered west of 24th Street in the now vacant land adjacent to the Squaw Peak Filtration Plant. Some additionl construction will be required on the east side to connect the tunnel to the open channel.

During the course of this investigation a second tunnel alternative was identified that offered economies for the tunnel construction. We believe these economics to be in the range of three to four million dollars. The saving would be realized principally from reduced labor and material costs. Reductions in final concrete and equipment would also be expected.

This alternative would consist of sinking shafts at either end of the project and driving straight line tunnels between. The placing of the tunnels deeper underground will allow a significant reduction in ground support requirements. This is based upon existing geologic and geotechnical data that indicates the potential for encountering bedrock with depth. The straight line would allow the use of a tunnel boring machine with attendant savings in labor. The resulting channel would function as an inverted siphon or sag pipe and therefore require pumping to dewater when a dry tunnel is required.

Should the second tunnel alternative be deemed to have merit a study similar to this one could be provided to establish the feasibility of this concept.

NORTH
SCALE: 1" = 100'

N. 9:9000

N. 9:8000

N. 9:7000

E. 466000

E. 467000

E. 468000

STA 895+50.00
BEGIN TUNNEL

TUNNEL PORTAL
STA 896+50.00

℄ TUNNEL

℄ CHANNEL

TUNNEL PORTAL
STA 950+00.00

STA 952+00.00
END OF TUNNEL

STA 952+00.00
CHANNEL BEGINS

NOTE:
CONCRETE TO BE PLACED ON INVERT, WALLS, ROOF AND CENTER DIVIDER AFTER COMPLETION OF TUNNEL.

GROUND SURFACE

℄ TUNNEL

5' SHOTCRETE ON ROOF DURING TUNNEL DRIVE

2' SHOTCRETE ON WALLS DURING TUNNEL DRIVE.

W10x45

W8x40

20'-0"

40'-0"

TUNNEL SECTION (A)
NOT TO SCALE

℄ CHANNEL

D

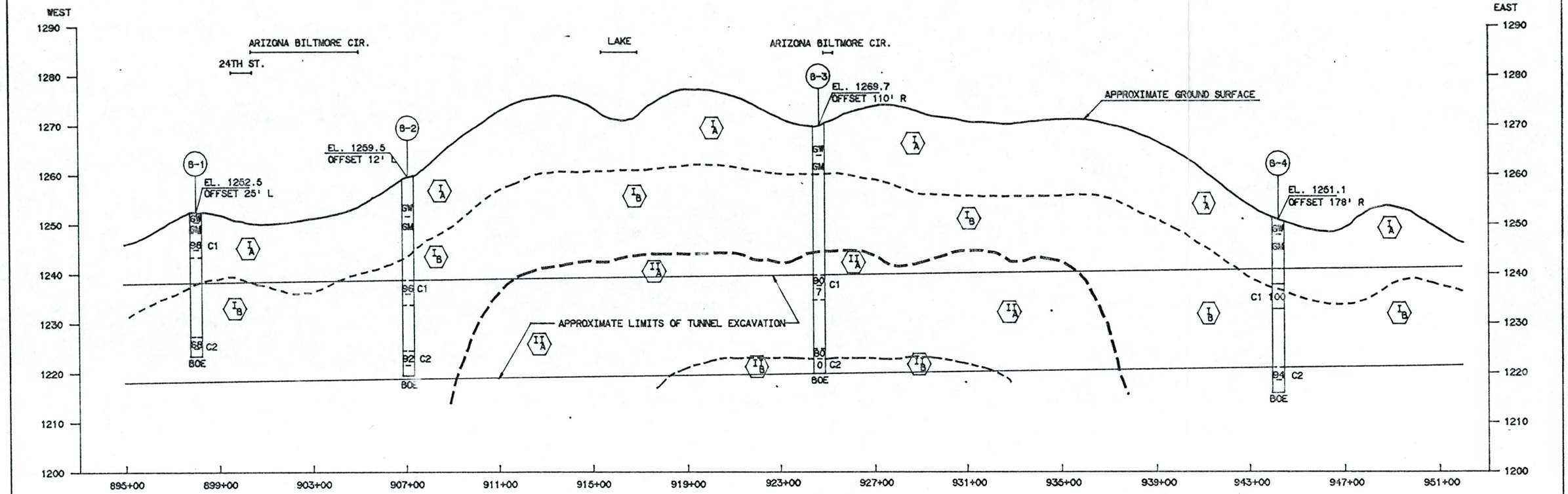
40'-0"

CHANNEL SECTION (B)
NOT TO SCALE

(B-2) INDICATES BORING LOCATIONS

	DESIGN T.R.M.	FLOOD CONTROL DISTRICT OF MARICOPA COUNTY
	DRAWN W.L.	
	CHECKED T.R.M.	ACDC TUNNEL ALERNATIVE COST COMPARISON
	APPROVED R.L.M.	GENERAL PLAN & BORING LOCATION
CRS SIRRINE 1817 N. 7th Street Phoenix, Arizona 85006	ROUTE / MILEPOST / LOCATION OF STRUCTURE NO. STA 895+00 TO STA 952+00	DRG. NO.

PROJ. NO. 11121.00(001)
DATE: MARCH 12,1987



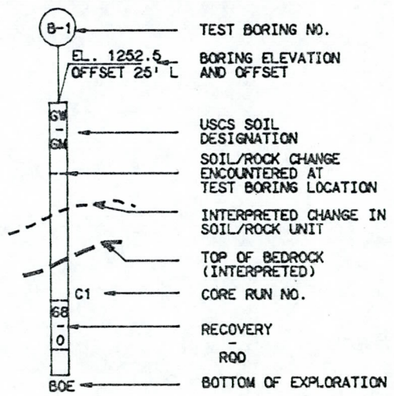
VIEW LOOKING NORTH

SCALE: HORIZ. 1"=200'
VERT. 1"= 10'

SOIL/ROCK UNIT LEGEND

- I_A — UPPER CALICHE UNIT, WELL CEMENTED
- I_B — LOWER CALICHE UNIT, POORLY CEMENTED
- II_A — UPPER QUARTZITE UNIT, WEATHERED ZONE
- II_B — LOWER QUARTZITE UNIT, FRESH ROCK ZONE

LEGEND



NOTES

1. SEE APPENDIX A FOR BORING LOCATIONS.
2. UNIFIED SOILS CLASSIFICATION SYSTEM (USCS) SYMBOLS ARE FROM BORING LOGS AND WERE INTERPRETED BY CRSS FOR BORINGS COMPLETED BY CRSS.
3. GROUND SURFACE AND STATIONING FROM FCD AERIAL SURVEY COMPOSITE.
4. FOR A MORE DETAILED DESCRIPTION OF SOIL AND ROCK UNITS SHOWN, REFER TO APPENDIX C, BORING REPORTS.
5. LIMITS OF SOIL AND ROCK UNITS ARE BASED ON INTERPRETATION OF SOIL AND ROCK CONDITIONS LOGGED AT EACH BORING.
6. VERTICAL TO HORIZONTAL EXAGGERATION 20 TO 1.
7. NO GROUNDWATER WAS ENCOUNTERED DURING DRILLING.
8. CORES TAKEN IN CALICHE WERE NOT ASSIGNED A RQD.

DESIGN	T R M
DRAWN	P P
CHECKED	T R M
APPROVED	R L M

CRS SIRRINE
1817 N. 7th Street
Phoenix, Arizona 85006

FLOOD CONTROL DISTRICT OF MARICOPA COUNTY

ACDC TUNNEL ALTERNATIVE
COST COMPARISON
SUBSURFACE PROFILE—CONCEPTUAL TUNNEL

LOCATION
STA. 895+00 TO STA. 952+00

PLOT DATE

1.0 INTRODUCTION

1.1 Purpose

Based upon authorization by the Flood Control District of Maricopa County (FCD), the Underground Engineering Department of CRS Sirrine, Inc. (CRSS) performed a geotechnical investigation as a portion of a tunnel alternative cost comparison under contract FCD 86-37. The purpose of the geotechnical investigation was to determine the subsurface conditions along the tunnel alternative alignment selected by the FCD.

The investigation consisted of accumulating existing information about the site area, conducting a geological reconnaissance, performing a subsurface exploration, preparing a site conditions report, and performing preliminary engineering analysis to provide geotechnical design recommendations. Based on the results of this investigation, site data and design recommendations were submitted to the design staff for the conceptual design of a tunnel through the golf course around the Arizona Biltmore Hotel.

1.2 Objectives

The objectives of the geotechnical investigation as stated in our proposal of December 12, 1986, are listed below:

1. Describe the subsurface soil conditions as revealed by the subsurface exploration.

2. Determine the extent and quality of the bedrock as revealed by the subsurface exploration.

1.3 Scope of Work

The scope of work of the geotechnical investigation consisted of four work items, which were listed in our proposal of December 12, 1986. Each work item is discussed in the following paragraphs:

1. Evaluation of existing reports about the site area and selection of exploration boring locations along the proposed tunnel alignment to the north around the Arizona Biltmore Hotel.

2. Provision of full-time technical monitoring of the field work by a geotechnical engineer. The geotechnical engineer prepared a detailed log of soils and rock encountered during drilling. Samples were collected with cores taken in the bedrock.

3. Laboratory testing was scheduled on the samples and cores taken but was eliminated when it became apparent that the soil and rock conditions present at the site didn't warrant testing at this time for a conceptual design.

4. Preparation of a geotechnical report describing the soil, rock and water conditions encountered.

1.4 Report Organization

This geotechnical report is divided into five major sections, as follows:

Section 1 - Introduction - Summarizes the purpose, objectives, and scope of work for the geotechnical investigation.

Section 2 - Project Information - Describes the location of the project site.

Section 3 - Previous Studies - Lists the previous reports reviewed by CRSS, which were prepared by others for the FCD and the City of Phoenix.

Section 4 - Geotechnical Investigation - Describes the procedures used in the subsurface explorations, including the drilling, boring log preparation and laboratory testing.

Section 5 - Summary of Site Conditions - Describes the subsurface soil, rock and water conditions as revealed by the geotechnical investigation and the review of previous studies.

2.0 PROJECT INFORMATION

The project site is located in the south half of Sec. 10 and Sec. 11 and the north half of Sec. 14, T.2 N., R.3 E. in the Sunnyslope 7.5 minute topographic quadrangle, U. S. Geological Survey (1965-73). The project site is located within the City of Phoenix and is bound by Lincoln Drive on the north, the Arizona Canal on the south, 32nd Street on the east and 20th Street on the west.

3.0 PREVIOUS STUDIES

Prior to this geotechnical investigation several investigations were conducted by others in the vicinity of the project site. These investigations are limited in number and scope due to the type of development in the area being mostly residential. The previous site investigations and studies reviewed by CRSS are listed below:

1. "Gila River Basin, Phoenix, Arizona and Vicinity (Including New River), Arizona Canal Diversion Channel, 40th Street to Cactus Road (Including Cudia City Wash Sediment Basin, Cave Creek Sediment Basin, and Cave Creek Channel), Design Memorandum No. 12, Feature Design for Arizona Canal Diversion Channel-40th Street to Cactus Road" by U. S. Army Corps of Engineers dated April, 1986 for the Flood Control District of Maricopa County.

2. "Environmental Geology of the Phoenix Mountains, Maricopa County, Arizona," by Douglas C. Shank and Troy L. Pewe of the Geology Department, Arizona State University, dated 1973, for the City of Phoenix.

4.0 GEOTECHNICAL INVESTIGATION PROGRAM

Four exploratory borings were drilled and logged between February 10, 1987 and February 16, 1987. One additional exploratory boring was proposed but was not drilled due to inaccessibility to the site by the drill rig. All four borings were located as close to the proposed alignment as conditions allowed. Limiting factors encountered during boring location included: moist, soft ground on the golf course, shallowly buried sprinklers on the golf course and lack of direct access due to dense development. All borings were drilled to approximate tunnel invert elevation. The lcoations of the borings, labeled B-1 through B-4, are shown in Appendix A, General Plan and Boring Locations. The logs of the exploratory borings are presented in Appendix C, Boring Reports.

One boring, B-1, was stopped five feet above the tunnel invert elevation due to drilling difficulty. As the boring was advanced beyond 25 feet, the strata changed from a well cemented caliche to and caliche. This change lead to the fine-grained material washing out, resulting in clasts jamming in the bit. One boring, B-4, was advanced five feet below tunnel invert elevation in anticipation of encountering bedrock.

4.1 Drilling Methods

The exploratory borings were drilled using a CME 75 truck mounted drill rig. All borings were initiated by hydraulically advancing a five foot section of a four and one quarter inch inside diameter hollow stem auger three to four feet. The hollow stem auger was then removed from the boring. Bentonite and water were combined to create a mud mixture in the bottom of the boring. The mud mixture was used to seal the void between the casing and borehole annulus. A quarter inch thick, seven inch inside diameter, five foot section of casing with a side outlet for return flow was inserted into the borehole next. The borehole was then advanced by rotary drilling with a three and one-eighth inch outside diameter tricone rock bit to a predetermined coring depth. Water with "E-Z Mud" added was used as a drilling fluid during rotary drilling and coring to stabilize the uncased portion of the boring hole. The drilling fluid was pumped at a rate just enough to bring cuttings to the surface. Once at the coring depth, the borehole was flushed clean until no further cuttings came to the surface. After the borehole was flushed, the drill rig was set up to core. A five foot long, NX (2 inch inside diameter) core barrel with a split inner tube and a diamond core bit were used. Once coring had begun only minimal vertical pressure and rotation were used. Recirculated drilling fluid was pumped down the drill rods during coring. Upon advancement of the core barrel to its full length, the core was pulled, placed in a core tray, logged, and photographed. The same methods were repeated when drilling continued with rotary drilling to the next coring depth and the second core was taken. The boreholes were then backfilled and the sites cleaned up.

4.2 Logging Methods

A geotechnical engineer was assigned to the drill rig to sample soils during drilling and to prepare a log consisting of classification of the soils encountered. During auger drilling representative grab samples were taken of the soils from the bottom flight of the hollow stem auger. Soil descriptions and log formats were developed following ASTM Specification D-2488, Description and Identifation of Soils (Visual-Manual Procedure), and ASTM Specification D-2487, Classification of Soils for Engineering Purposes (Unified Soil Classification System, USCS). The procedures and terminology used for describing soil samples is presented on the first page of Appendix C, Boring Reports. The first page of each Boring Report was developed during auger drilling.

During rotary drilling with the tricone rock bit, the geotechnical engineer logged the boring and collected representative grab samples from the return flow pipe. The grab samples consisted of cuttings and drilling fluid. The cuttings were continuously monitored for changed in soil or rock type during advance of the boring. Correlation of the grab samples was accomplished by taking samples during the last foot of rotary drilling completed just prior to rock coring. This provided comparison of the cuttings' composition with the rock core. As rotary drilling advanced from one soil or rock type to another, the color and composition of cuttings and drilling fluid changed. In addition, drilling rates, vertical pressure, rotation and drilling fluid loss was monitored.

During rock coring, the geotechnical engineer observed drilling fluid loss, drilling rates, vertical pressure, and rotation. Upon completion of the coring the core was examined, logged and photographed prior to transferring to a core box. Two five foot cores were taken from each boring. The first core in each borehole was taken near the planned crown of the tunnel. The second core in each borehole was taken near the planned invert of the tunnel. All coring and descriptions were performed following ASTM Designation D 2113-70. The procedure and terminology used for describing rock cores is presented on the second page of Appendix C, Boring Reports. Pages two and three of each Boring Report was developed during rotary drilling and rock coring.

The grab samples and rock cores were removed from the site each day and transported by the geotechnical engineer to the CRSS office for temporary storage. Additional potographs and review of ther samples and cores were performed in order to finalize descriptions and assign laboratory testing. The grab samples and rock cores were then transported by CRSS personnel to T.E.S.T., 2125 S. 16th Street, Phoenix, Arizona, for storage. Arrangements have been made for storage at T.E.S.T. for a three month period, ending June 30, 1987.

4.3 Laboratory Testing

Originally laboratory testing was planned on the rock cores. These tests were to consist of the following:

1. Unconfined compression tests.
2. Point load.
3. Petrographic thin section.

The purpose of these tests was to determine the mechnical properties of the rock. Upon examination of the cores retrieved it was determined to be impossible to prepare a specimen for any kind of mechnical property test. However, visual examination of the cores provided information on the structural properties and mechanical defects of the subsurface rock. These properties and defects are covered in Section 5.

5.0 SUMMARY OF SITE CONDITIONS

5.1 General

As stated in the Introduction, the project site is located in the northeastern part of the City of Phoenix, Arizona. The area is roughly bound by Lincoln Drive to the north, 32nd Street to the east, the Arizona Canal to the south, and 24th Street to the west. The proposed tunnel alignment falls largely within three fairways of the Arizona Biltmore Golf Course, whereas a shorter portion crosses four City of Phoenix streets and a portion of the Squaw Peak Water Treatment Plant.

5.2 Regional Geology

Geologically, the project site is located in the Salt River Valley in the desert region of the Southern Basin and Range physiographic province. This province is characterized by rugged mountain ranges separated by flat valley floors. The mountian ranges are composed mostly of Precambrian metamorphic and granitic rock. The valleys are underlain by variable thicknesses of unconsolidated sediments. The mountain ranges are erosional remanents of uplifted fault blocks of folded and intruded Precambrain metasediments. The faulting occurred in early Cenozoic time and was followed by partial burial of the Precambrian units by flow basalts and coarse angular alluvial deposits. Extensive erosion of the uplifted blocks and deposition into the down-dropped blocks has continued to the present (Shank and Pewe, 1973).

5.3 Geomorphology and Topography

Geomorphologically, the project site is located on the southeastern pediment of the northwest-trending Phoenix Mountains. The pediment is mantled by a discontinuous alluvial deposit, a bajada, which varies in thickness. The bajada is the result of lateral coalessence of proximal depositions of detritus transported from their source rocks to the north and northeast. The mechanism of transport of the detritus was apparently ephemeral flow confined largely to fanhead trenches. The nature of flow resulted in spasmodic deposition across the fan surface. Five fanhead trenches are evidenced dissecting the project site in a pre-development aerial photo taken in 1955. These erosional gulleys are no longer evident due to grading during construction.

Topographically, the project site is located on gently rolling slopes in a highly developed area dominated by the Arizona Biltmore Golf Course and adjoining residences. The degree of slopes are approximately one to two percent. Maximum and minimum elevations are 1279 feet and 1243 feet, respectively (National Geodetic Vertical Datum of 1929). Natural vegetation on the project site is nearly nonexistent and limited to Saguaro Cacti, Burr Sage, Creosote Bush and Palo Verde Trees. The climate is an arid continental one with extremely hot summers and moderate, pleasant winters.

5.4 Soil Conditions

The bajada is Quaternary in age and is uniformally a coarse-grained alluvium consisting of "gray to buff, poorly sorted, moderately stratified, unconsolidated, moderately to highly calichified alluvium with approximately 50-60 percent angular gravel (two to twelve inch diameter), 20-25 percent sand and 20-25 percent silt and clay. Thickness is one to several hundred feet" (Shank and Pewe, 1973).

Geological reconnaissance of the project site revealed outcrops of the caliche in a road cut made on 24th Street and the sediment basin of the Squaw Peak Water Treatment Plant. Both outcrops consisted of alternating layers of well cemented and poorly cemented caliche with varying percentages of clasts. A core was taken at four feet in an adjacent boring, B-1, in order to correlate retrieved cores with the observed outcrop.

Based upon CRSS's geotechnical investigation conducted at the project site the bajada is classified as a well-graded gravel with sand and silt. Grab samples of the bajada taken during augering are describe it as "dense, light brown, dry, mostly coarse to fine angular gravel, little sand, trace silt and clay, calcium carbonate cementation."

Cores taken in the bajada are described as "moderately hard, moderately weather, sound, light brown (matrix) to light gray (clasts), fine to very coarse-grained CALICHE; moderately dipping, tight fractures at matrix/clast interfaces, varing degree of calcium carbonate cementation." Prior to commencing the drilling, the geotechnical engineer determined that assigning a Rock Quality Designation (RQD) to the cores taken in the caliche would result in a misleading and invalid measure of rock quality. This decision was based upon inspection of the lithology at the aforementioned outcrops.

Borings B-1, B-2 and B-4 encountered only the bajada for their entire depth. Boring B-3 encountered the bajada to a depth of 25.5 feet.

5.5 Rock Conditions

Four outcrops of Precambrian age rock are present just north of the project site where the bajada merges with the pediment. The outcrops are described by Shank and Pewe, 1973 as follows:

1. "Buff to gray, fractured, fine to coarse grained (1/16 to 1/8 inch), thin to thick bedded (1/2 to 40 inch), locally massive, compositional group of highly siliceous, micacous, or quartz-rich schists with locally interbedded quartz-pebble (1/4 to 2 inch diameter) conglomerates and local greenschist and basalt dikes."

2. "Light gray, fractured, medium to coarse grained (1/16 to 1/8 inch) cross bedded, thickbedded (5 to 50 inches), metaorthoquartzite with locally interbedded phyllite and quartz-mica schist."

3. "Blue to gray green, fractured, fine to medium grained (less than 1/16 to 1/16 inch), slightly schistose greenstone with locally greenschist units and locally interbedded feldspathic quartz-biotite schists."

4. "Gray to tan, fractured, fine grained (less than 1/16 inch), laminated (0.1 to 1/2 inch), locally slaty and/or schistose phyllite with intercolated quartz-mica schists and basalt dikes."

During CRSS's geotechnical investigation at the project site, only one rock type was encountered. The Precambrian Quartzite was encountered in boring B-3 after penetrating 25.5 feet of alluvium. The first signs of nearing bedrock came from grab samples taken during advancement of the borehole. The return flow changed from a light brown color to a earthy red. A grab sample taken from 25.5 feet to 27 feet contained red clay and light gray rock chips. This indicated a moderate severely weathered zone of bedrock from 25.5 feet to 28.5 feet. Grab samples taken from 28.5 feet to 30 feet revealed less red clay and more light gray rock chips of quartzite. The rock cored from 30 feet to 35 feet, C-1, is described as a "hard, moderately weathered, extremely to moderately fractured, light gray, medium to fine grained QUARTZITE; very close, tight, randomly oriented, rough continuous, clay filled fractures."

Continued rotary drilling with accompanying grab sampling from 35 feet to 45 feet produced dark gray quartzite rockchips in the return flow. The second rockcore, C-2, is described as a "hard, very slightly weathered, extremely fractured, light to dark gray, medium to fine grained QUARTZITE; very close, tight, randomly oriented, rough, continuous, mostly open, trace healed fractures."

The bedrock profile along the exposed tunnel alignment is believed to be irregular based on the following observations:

1. Bedrock encountered in boring B-3 at depth of 25.5 feet.

2. Bedrock outcrop approximately 100 feet northwest of boring B-3.

3. No bedrock encountered in borings B-1, B-2, and B-4.

4. Bedrock outcrops approximately 700 feet northeast of alignment.

5. Bedrock outcrops approximately 800 feet southwest of alignment.

6. Geologic history of site; i.e., faulting, folding, intruding, and extensive erosion of bedrock.

Weathering of the quartzite along the proposed tunnel alignment has been generalized into the following profile based upon observations of adjacent outcrops and boring B-3:

0 - 2 feet	=	severe
2 - 5 feet	=	moderately severe
5 - 12 feet	=	moderate
12 - 17 feet	=	slight
17 - 25 feet	=	very slight
> 25 feet	=	fresh

The above listed weathering profile is the result of excellerated mechanical and chemical erosional processes. The limit of the weathering profile is believed to be approximately 25 feet.

The cores taken from the quartzite exhibited extreme to moderate fractures resulting in Rock Quality Designations (RQD) of seven and zero for boring B-3 rock cores C-1 and C-2, respectively. The fractures are believed to be the result of sudden faulting and folding of the Precambrian metasediments during the basin and range faulting during early Cenozoic time. A trace of healed fractures were observed in core C-2. The fractures were healed with a calcium carbonate, silica and clay cement. The fractures are randomly oriented and continuous with rough and irregular surfaces.

5.6 Groundwater Conditions

No groundwater was encountered during drilling of the four boreholes. It was noted, however, that each borehole lost drilling fluid during advancement of the holes. Borings B-2 and B-3 experienced significant loss of drilling fluid at depths in excess of 30 feet. This indicated that the groundwater table is below the planned invert of the proposed tunnel.

Data was obtained from the Arizona Department of Water Resource's (DWR) Basic Data Unit regarding the groundwater levels in the project area. This data was obtained from existing wells in the proximity of the project area which are monitored by the DWR. This date is continued in the DWR's "Groundwater Site Inventory Water Level Table Listing" dated July 30, 1986. This data suggests a general rise in the groundwater level in the project area of about three feet in the past two years. This rise is attributed to a decrease in pumping by the Salt River Project and the City of Phoenix and a minor increase in area precipitation over the past several years (Recterand Remick 1986). Current DWR water readings indicate tht the depth to groundwater in the project area is approximately 50 feet.

SELECTED REFERENCES

1. Reeter, R.W., Remick, W.H., 1986 Maps Showing Groundwater Conditions in the West Salt River, East Salt River, Lake Pleasant, Carefree and Fountain Hills Sub-Basins of the Phoenix Active Management Area, Maricopa, Pinal and Yavapai Counties, Arizona: Arizona Department of Water Resources, Hydrolic Map Series Report Number 12.

2. Reynolds, S.J., 1985, Geology of the South Mountains, Central Arizona: The Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch, Bulletin 195.

3. Shank, D.C., Pewe, T.L., 1973, "Environmental Geology of the Phoenix Mountains, Maricopa County, Arizona, "Arizona State University Geology Department Study for the City of Phoenix.

4. Thorpe, D.G., Burt, D.M., 1978, "Precambrian Metavolcanic Rocks of the Squaw Peak Area, Maricopa County, Arizona, "74th Cordilleran Section Meeting of the Geological Society of America, Special Paper No. 2, State of Arizona, Bureau of Geology and Mineral Technology.

PROCEDURES AND TERMINOLOGY FOR DESCRIBING SOIL SAMPLES

Soils are described as to density, color, moisture, grain size, and angularity, other pertinent properties and geologic interpretation.

Soil Component	Size Range
Boulders	Above 12 inches
Cobbles	3 to 12 inches
Gravel:	
Coarse	3/4 to 3 inches
Fine	No. 4 (4.75 mm) to 3/4 inch
Sand:	
Coarse	No. 10 (2.0 mm) to No. 4 (4.75 mm)
Medium	No. 40 (0.425 mm) to No. 10 (2.0 mm)
Fine	No. 200 (0.075 mm) to No. 40 (0.42 mm)
Silt	< No. 200 (0.075 mm) non-plastic, low dry strength
Clay	< No. 200 (0.075 mm) plastic, high dry strength

VISUAL SOIL CLASSIFICATION

Description	Percentage
Mostly	50 - 100%
Some	30 - 45%
Little	15 - 25%
Few	5 - 10%
Trace	Particles are present but estimated to be less than 5%

Example: Gravelly lean clay with sand (CL)
Hard, brown, moist, mostly clay, some silt, little coarse to fine subrounded gravel, sand, shattered cobble in nose of spoon. -GLACIAL TILL-

PROCEDURES AND TERMINOLOGY FOR DESCRIBING ROCK SAMPLES

Rocks are described as to field hardness, weathering, rock continuity, color, texture, lithology, discontinuities, bedding/foliation, cavities/voids and other pertinent properties.

Characteristic	Descriptions
Field Hardness:	A measure of resistance to scratching or abrasion.
Weathering:	The effect of rock alteration by chemical and mechanical processes.
Rock Continuity:	Any natural break in a rock.
Color:	Including degree.
Texture:	Used to identify size, shape and arrangement of constituents.
Lithology:	Identify geologic name.
Discontinuities:	Surfaces representing breaks or fractures.
Bedding/Foliation:	Describes vertical spacing of planes.
Cavities/Voids:	Describes open spaces in subsurface.

SUMMARY OF EXPLORATORY BORINGS

Boring Number	Station Number	Offset	Collar Elevation	Depth of Boring	BOE Elevation	Tunnel Invert Elevation *
B-1	898+00	25'R	1252.5	29'	1223.5	1218
B-2	907+10	12'L	1259.5	40'	1219.5	1218.5
B-3	924+61	110'R	1269.7	50'	1219.7	1220
B-4	944+15	178'R	1251.1	35.0'	1216.1	1221

---

* Tunnel invert elevations are to the nearest one-half foot, based on FCD Aerial survey plan of desired tunnel alignment with a slope of 0.0007.

CRS SIRRINE

TEST BORING REPORT

BORING NO. B-1

PROJECT: Biltmore Tunnel Alternative Cost Comparison
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Western Technologies, Inc.
EQUIPMENT USED: CME 75 Truck Mounted Drill Rig

JOB NO. 11121.00(001)
PAGE NO. 1 of 3
LOCATION: Sta. 898+00, R25'
ELEVATION: 1252.5
DATE START: 2/11/87
DATE FINISH: 2/11/87
DRILLER: M. Hernandez
PREPARED BY: T. Manton

GROUNDWATER		DEPTH TO:			CASING	SAMPLER	CORE BARREL
DATE	HRS AFTER COMP	WATER	BOTTOM OF CASING	BOTTOM OF HOLE	TYPE	HSA	G	NX
2/11/87	WD	NE	4'	29'	SIZE ID	4-1/4"	--	2"
--	--	--	--	--	HAMMER WT	--	--	
--	--	--	--	--	HAMMER FALL	--	--	

DEPTH IN FEET	CASING BLOWS PER FOOT	SAMPLER BLOWS PER 6 INCHES	SAMPLE NUMBER	SAMPLE DEPTH RANGE	FIELD CLASSIFICATION AND REMARKS
					1 Poorly-graded gravel with silt and sand (GW-GM) Loose, light brown, dry, mostly coarse to fine angular gravel, little angular sand, trace silt. -FILL-
				1 --	
			G1	2.5	Poorly-graded gravel with silt and sand (GW-GM) Dense, light brown, dry, mostly coarse to fine angular gravel, little angular sand, trace silt and clay, $CaCO_3$ cementation.
					4 -ALLUVIUM-
					See Core Boring Report Page 2
5					
10					
15					
20					

BLOWS/FT.	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
51+	VERY DENSE

BLOWS/FT.	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
31+	HARD

SAMPLE ID.	
S	SPLIT SPOON
T	TUBE
U	UNDISTURBED PISTON
G	GRAB SAMPLE
X	OTHER
NR	NO RECOVERY

COMPONENT %	
MOSTLY	50-100 %
SOME	30-45 %
LITTLE	15-25 %
FEW	5-10 %
TRACE	<5 %

GROUNDWATER ABBREV.
WD - WHILE DRILLING
NE - NOT ENCOUNTERED
UR - NOT READ

BORING NO. B-1

CRSS

CRS SIRRINE

CORE BORING REPORT

BORING NO. B-1 PAGE 2 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						4 See Test Boring Report Page 1
5	9	4				C1 - Moderately hard, moderately weathered, sound, light brown (matrix) to light gray (clasts), fine to very coarse grained CALICHE; moderately dipping, tight fractures at matrix/clast interfaces, varying degree of $CaCO_3$ cementation in matrix evidenced by degree of reaction with dilute HCl.
	6					
	6	C1	4.9	98	--	
	9					NOTE: C1 taken at 4 ft in order to correlate rock core with outcrop of same rock in adjacent open cut.
	11	9				NOTE: Hold down pressure at 475 psi.
10	--					NOTE: Rotary drilled with 3-1/8" Tricone Rock Bit from 9 ft to 25 ft.
	--					
	--					NOTE: Drilling rate and smoothness varies due to alternating layers of well cemented and poorly cemented CALICHE and varying percentages of clasts.
	--					
	--					
15	--					
	--					
	--					NOTE: Minor loss of water during drilling.
	--					
	--					
	--					G2 19.5/20 From return flow: -DO-
20	3					
	--					
	--					
	--					
	5					G3 23/24 From return flow: -DO-
25	--					

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-1

CRSS SIRRINE

CORE BORING REPORT

BORING NO. B-1 PAGE 3 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
	6	25				C2 -DO- except significant decrease in $CaCO_3$ cementation.
	16					NOTE: Pulled core at 29 ft due to extreme decrease in drilling rate. Upon examining core found that matrix had washed out during coring leaving clasts behind to wedge in bit.
	5	C2	2.7	68	--	
	18	29				
30						Bottom of Exploration at 29 ft.

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	< 2"	V. CLOSE	< 2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-1

CRS SIRRINE

TEST BORING REPORT

BORING NO. B-2

PROJECT: Biltmore Tunnel Alternative Cost Comparison
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Western Technologies, Inc.
EQUIPMENT USED: CME 75 Truck Mounted Drill Rig

JOB NO. 11121.00 (001)
PAGE NO. 1 of 3
LOCATION: Sta. 907+10,L12'
ELEVATION: 1259.5
DATE START: 2/16/87
DATE FINISH: 2/16/87
DRILLER: M. Hernandez
PREPARED BY: T. Manton

GROUNDWATER		DEPTH TO:			CASING	SAMPLER	CORE BARREL
DATE	HRS AFTER COMP	WATER	BOTTOM OF CASING	BOTTOM OF HOLE	TYPE	HSA	G	NX
2/16/87	WD	NE	3'	40'	SIZE ID	4-1/4"	--	2"
--	--	--	--	--	HAMMER WT	--	--	
--	--	--	--	--	HAMMER FALL	--	--	

DEPTH IN FEET	CASING BLOWS PER FOOT	SAMPLER BLOWS PER 6 INCHES	SAMPLE NUMBER	SAMPLE DEPTH RANGE	FIELD CLASSIFICATION AND REMARKS
					Poorly-graded gravel with silt and sand (GW-GM) Medium dense, light brown, dry, mostly coarse to fine angular gravel, little sand, trace silt and clay, $CaCO_3$ cementation. -ALLUVIUM-
				3	See Core Boring Report Page 2
5					
10					
15					
20					

BLOWS/FT.	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
51+	VERY DENSE

BLOWS/FT.	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
31+	HARD

SAMPLE ID.	
S	SPLIT SPOON
T	TUBE
U	UNDISTURBED PISTON
G	GRAB SAMPLE
X	OTHER
NR	NO RECOVERY

COMPONENT %	
MOSTLY	50-100 %
SOME	30-45 %
LITTLE	15-25 %
FEW	5-10 %
TRACE	<5 %

GROUNDWATER ABBREV.
WD - WHILE DRILLING
NE - NOT ENCOUNTERED
UR - NOT READ

BORING NO. B-2

CRSS

CRS SIRRINE

CORE BORING REPORT

BORING NO. B-2 PAGE 2 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						3 See Test Boring Report Page 1
	3					NOTE: Rotary drilled with 3-1/8" Tricone Rock Bit from 3 ft to 21 ft.
	3					G1 3.5/5 From feturn flow: -DO-
5	3					
	2					
	2					
	2					
10	2					
	2					
	2					NOTE: Drilling rate and smoothness varies due to alternating layers of well cemented and poorly cemented CALICHE and varying percentages of clasts.
	2					
	5					
15	4					
	2					
	4					
	8					
	4					
	4					
20	5					G2 20/21 From return flow: -DO-
	9	21				C1 - Moderately hard, moderately weathered, sound, light brown (matrix) to light gray (clasts), fine to very coarse grained CALICHE; moderately dipping, tight fractures at matrix/clast
	4					
	9	C1	4.8	96	--	interface, varying degree of $CaCO_3$ cementation in matrix evidenced by reaction with dilute HCl.
	7					
25						NOTE: Hold down pressure at 425 psi.

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-2

CRSS SIRRINE

CORE BORING REPORT

BORING NO. B-2 PAGE 3 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
	12	26				
	--					NOTE: Rotary drilled with 3-1/8" Tricone Rock Bit from 26 ft to 35 ft.
	3					
	4					
30	--					
	--					NOTE: Minor loss of water during drilling.
	5					
	4					
	3					NOTE: Sudden loss of water drilling from 34 ft to 36 ft.
35	--	G3 34/35				From return flow: -DO-
	5	35				C2 - Moderately hard to medium hard, moderately weathered, moderately fractured, light brown (matrix) to light gray (clasts), fine to very coarse grained CALICHE; moderately dipping, open fractures at matrix/clast interfaces, increase in percent clasts from C1 to C2.
	10					
	4	C2	4.6	92	--	
	12					NOTE: Continued loss of water to 40 ft.
40	14	40				
						Bottom of Exploration at 40 ft.

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-2

CRS SIRRINE

TEST BORING REPORT

BORING NO. B-3

PROJECT: Biltmore Tunnel Alternative Cost Comparison
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Western Technologies, Inc.
EQUIPMENT USED: CME 75 Truck Mounted Drill Rig

JOB NO. 11121.00 (001)
PAGE NO. 1 of 3
LOCATION: Sta. 924+61, R110'
ELEVATION: 1269.7
DATE START: 2/13/87
DATE FINISH: 2/13/87
DRILLER: M. Hernandez
PREPARED BY: T. Manton

GROUNDWATER		DEPTH TO:			CASING	SAMPLER	CORE BARREL
DATE	HRS AFTER COMP	WATER	BOTTOM OF CASING	BOTTOM OF HOLE	TYPE	HSA	G	NX
2/13/87	WD	NE	3'	50'	SIZE ID	4-1/4"	--	2"
--	--	--	--	--	HAMMER WT	--	--	
--	--	--	--	--	HAMMER FALL	--	--	

DEPTH IN FEET	CASING BLOWS PER FOOT	SAMPLER BLOWS PER 6 INCHES	SAMPLE NUMBER	SAMPLE DEPTH RANGE	FIELD CLASSIFICATION AND REMARKS
				0.4	Crushed granite landscaping. -FILL-
					Poorly-graded gravel with silt and sand (GW-GM) Medium dense, light brown, dry, mostly coarse to fine angular gravel, little sand, trace silt, $CaCO_3$ cementation. -ALLUVIUM-
				3	
					See Core Boring Report Page 2
5					
10					
15					
20					

BLOWS/FT.	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
51+	VERY DENSE

BLOWS/FT.	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
31+	HARD

SAMPLE ID.	
S	SPLIT SPOON
T	TUBE
U	UNDISTURBED PISTON
G	GRAB SAMPLE
X	OTHER
NR	NO RECOVERY

COMPONENT %	
MOSTLY	50-100 %
SOME	30-45 %
LITTLE	15-25 %
FEW	5-10 %
TRACE	<5 %

GROUNDWATER ABBREV.
WD - WHILE DRILLING
NE - NOT ENCOUNTERED
UR - NOT READ

CRSS SIRRINE

CORE BORING REPORT

BORING NO. B-3 PAGE 2 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						3 See Test Boring Report Page 1
	--					NOTE: Rotary drilled with 3-1/8 " Tricone Rock Bit from 3 ft to 30 ft.
5	3					
	2					G1 5/6 From return flow: Light brown sand and silt with rock chips.
	2					-CALICHE-
	3					
	3					NOTE: Hold down pressure at 325 psi.
10	--					
	--					
	5					
	--					
	--					NOTE: Drilling rate and smoothness varies due to altering layers of well cemented and poorly cemented CALICHE and varying percentages of clasts.
15	--					
	--					
	5					
	--					
	3					
	3					G2 19/20 From return flow: -DO-
20	--					
	3					
	4					NOTE: Minor loss of water during drilling.
	5					
	6					
25						

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-3

CRSS SIRRINE

CORE BORING REPORT

BORING NO. B-3 PAGE 3 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						25.5
	5					G3 25.5/27 From return flow: Red clay and rock chips.
	5					
	7					
	4					G4 28.5/30 From return flow: Light gray quartzite chips and red clay.
30	6					
	3	30				C1 - Hard, moderately weathered, extremely to moderately fractured, light gray, medium to fine grained QUARTZITE; very close, tight, randomly oriented, rough, continuous, clay filled fractures.
	3					
	4	C1	4.5	90	7	
	4					
35	11	35				
	--					NOTE: Rotary drilled with 3-1/8" Tricone Rock Bit from 35 ft to 45 ft.
	--					
	--					
	--					
40	--					
	5					
	4					NOTE: Hold down pressure at 325 psi.
	5					
	6					43.5
	6					G5 43.5/45 From return flow: Dark gray quartzite chips. -QUARTZITE-
45		45				
	7					C2 - Hard, very slightly weathered, extremely fractured, light to dark gray, medium to fine grained QUARTZITE; very close, tight, randomly oriented, rough, continuous, mostly open, trace healed fractures.
	10					
	6	C2	4.0	80	0	
	11					NOTE: Observed significant loss of drilling water.
	17	50				
50						Bottom of Exploration at 50 ft.

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-3

CRSS

CRS SIRRINE

TEST BORING REPORT

BORING NO. B-4

PROJECT: Biltmore Tunnel Alternative Cost Comparison
CLIENT: Maricopa County Flood Control District
CONTRACTOR: Western Technologies, Inc.
EQUIPMENT USED: CME 75 Truck Mounted Drill Rig

JOB NO. 11121.00 (001)
PAGE NO. 1 of 3
LOCATION: Sta. 944+15, R178'
ELEVATION: 1251.1
DATE START: 2/12/87
DATE FINISH: 2/12/87
DRILLER: M. Hernandez
PREPARED BY: T. Manton

GROUNDWATER		DEPTH TO:			CASING SAMPLER CORE BARREL			
DATE	HRS AFTER COMP	WATER	BOTTOM OF CASING	BOTTOM OF HOLE	TYPE	HSA	G	NX
2/12/87	WD	NE	3'	35'	SIZE ID	4-1/4"	--	2"
--	--	--	--	--	HAMMER WT	--	--	
--	--	--	--	--	HAMMER FALL	--	--	

DEPTH IN FEET	CASING BLOWS PER FOOT	SAMPLER BLOWS PER 6 INCHES	SAMPLE NUMBER	SAMPLE DEPTH RANGE	FIELD CLASSIFICATION AND REMARKS
			G1	0/1	Poorly-graded gravel with silt and sand (GW-GM) Medium dense, light brown, dry, mostly coarse to fine subangular to angular gravel, little angular sand, trace silt, $CaCO_3$ cementation. -ALLUVIUM-
3					See Core Boring Report Page 2
5					
10					
15					
20					

BLOWS/FT.	DENSITY
0-4	VERY LOOSE
5-10	LOOSE
11-30	MEDIUM DENSE
31-50	DENSE
51+	VERY DENSE

BLOWS/FT.	CONSISTENCY
0-2	VERY SOFT
3-4	SOFT
5-8	MEDIUM STIFF
9-15	STIFF
16-30	VERY STIFF
31+	HARD

SAMPLE ID.	
S	SPLIT SPOON
T	TUBE
U	UNDISTURBED PISTON
G	GRAB SAMPLE
X	OTHER
NR	NO RECOVERY

COMPONENT %	
MOSTLY	50-100 %
SOME	30-45 %
LITTLE	15-25 %
FEW	5-10 %
TRACE	<5 %

GROUNDWATER ABBREV.
WD - WHILE DRILLING
NE - NOT ENCOUNTERED
UR - NOT READ

CRSS

CRS SIRRINE

CORE BORING REPORT

BORING NO. B-4 PAGE 2 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
						3 See Test Boring Report Page 1
	--					NOTE: Rotary drilled with 3-1/8" Tricone Rock Bit from 3 ft to 13 ft.
5	5					
	3					
	3					
	3					
	4					
	3					G2 9/10 From return flow: Light brown sand and silt with rock chips.
10	--					-CALICHE-
	--					NOTE: Hold down pressure at 475 psi.
	4					G3 12/13 From return flow: -DO-
	8	13				C1 - Moderately hard, moderately weathered, sound, light brown (matrix) to light gray (clasts), fine to very coarse grained CALICHE; moderately dipping, tight fractures at matrix/clast interfaces, varying degree of $CaCO_3$ cementation in matrix evidenced by degree of reaction with dilute HCl.
15	8					
	6	C1	5	100	--	
	3					
	7	18				
	--					NOTE: Rotary drilled with 3-1/8" Tricone Rock Bit from 18 ft to 30 ft.
20	--					
	--					
	7					
	3					
	2					
25	11					G4 24.5/25 From return flow: -DO-

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-4

CRSS SIRRINE

CORE BORING REPORT

BORING NO. B-4 PAGE 3 OF 3

PREPARED BY: T. Manton

DEPTH IN FEET	DRILL RATE MIN. PER FOOT	CORE NO. / DEPTH RANGE	RECOVERY FT.	RECOVERY %	RQD	FIELD CLASSIFICATION AND REMARKS
	3					NOTE: Minor loss of water during drilling.
	2					
	3					
	2					
	3					G5 29/30 From return flow: -DO-
30	7	30				C2 -DO- except significant decrease in $CaCO_3$ cementation.
	6					
		C2	4.7	94	--	
	5					
	5					
35	6	35				Bottom of Exploration at 35 ft.

CRSS FORM 104 11-15-85

FIELD HARDNESS		BEDDING		DISCONTINUITIES JOINT/SHEAR/FRACTURE		WEATHERING	
V. HARD	-KNIFE CAN'T SCRATCH	V. THIN	<2"	V. CLOSE	<2"	FRESH	MOD. SEVERE
HARD	-SCRATCHES DIFFICULT	THIN	2"-12"	CLOSE	2"-12"	V. SLIGHT	SEVERE
MOD. HARD	-SCRATCHES EASILY	MEDIUM	12"-36"	MOD. CLOSE	12"-36"	SLIGHT	V. SEVERE
SOFT	-GROOVES	THICK	36"-120"	WIDE	36"-120"	MODERATE	COMPLETE
V. SOFT	-CARVES	V. THICK	>120"	V. WIDE	>120"	BORING NO.	B-4

TUNNEL ALTERNATIVE COST COMPARISON
PHOTO LOG

Slide	Date	Subject
1	2/10/87	Tunnel Alignment Looking North from Sta. 949+00
2	2/10/87	Tunnel Alignment Looking East from Sta. 933+00.
3	2/13/87	Tunnel Alignment Looking West from Sta. 925+00.
4	2/10/87	Tunnel Alignment Looking West from Sta. 917+00.
5	2/10/87	Tunnel Alignment Looking West from Sta. 912 +00.
6	2/10/87	Outcrop of Caliche @ Squaw Peak Water Treatment Plant.
7	2/10/87	Closeup of Slide No. 6.
8	2/10/87	Outcrop of Caliche Along 24th Street.
9	2/10/87	Outcrop of Caliche @ Sta. 924+00.
10	2/10/87	Outcrop of Weathered Quartzite 700 Ft. NE of Alignment.
11	2/11/87	Auger Drilling @ Boring B-1.
12	2/11/87	Tricone Rock Bit and Drill Steel.
13	2/16/87	Examining Core in Tray @ Boring B-2.
14	2/13/87	Setting Up to Drill Boring B-3.
15	2/16/87	Rotary Drilling with Tricone Bit @ Boring B-2.
16	2/17/87	Core Runs from Boring B-1.
17	2/17/87	Core Runs from Boring B-2.
18	2/17/87	Core Runs from Boring B-3.
19	2/17/87	Core Runs from Boring B-4.
20	2/17/87	Grab Samples from Boring B-3.

"PHOTOS INCLUDED IN REPORT ORIGINAL"