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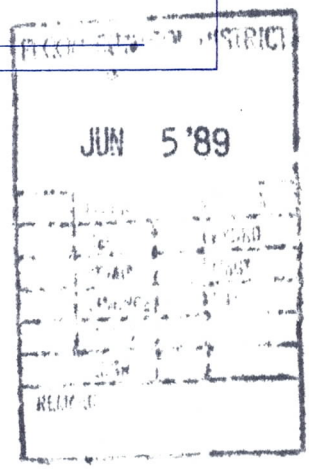
ACDC-SQUAW PEAK WATER MAIN AND TREATMENT FACILITY RECONSTRUCTION

24th Street & Arizona Canal
Phoenix, Arizona

Prepared for

John Carollo Engineers
3877 North 7th Street, Suite 400
Phoenix, Arizona



THOMAS-HARTIG & ASSOCIATES, INC.
GEOTECHNICAL, MATERIALS TESTING, AND ENVIRONMENTAL CONSULTANTS

A118.944

THOMAS-HARTIG & ASSOCIATES, INC.

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25 May 1989

John Carollo Engineers
3877 North 7th Street, Suite 400
Phoenix, Arizona 85014

Attention: George Shirley, P.E., Partner

Project: ACDC-Squaw Peak Water Main and Treatment Facility Reconstruction
24th Street & Arizona Canal
Phoenix, Arizona

Project No: 89-0326

In accordance with your request, we have performed geotechnical services at the subject site to determine subsurface conditions and to develop design recommendations for the proposed pipeline and structures. The services performed provide an evaluation at selected locations of the soil and bedrock materials throughout the zone of significant foundation influence. Our services have not included determination of geologic conditions or evaluation of potential geologic hazards such as seismic activity or faulting.

SITE AND PROJECT DESCRIPTION

The proposed reconstruction is planned adjacent to the Water Treatment Facility near 24th Street and the Arizona Canal in Phoenix, Arizona. Reconstruction will be required to deepen existing and future pipelines where the future ACDC (Arizona Canal Diversion Channel) will be excavated. We performed field exploration to provide subsurface information at the following four areas:

1. An existing 66" water main running along the west side of 24th Street will be deepened to about 35 feet below existing grade to accommodate the ACDC.

2. An inlet structure, 72" pipeline, a structure housing bar screens and a grit sump, a meter vault, and a premix structure will be constructed to convey water from the Arizona Canal to the existing sedimentation basin. The 72" pipe will be installed to maximum depth of about 40 feet below existing grade to allow for excavation of the ACDC.

3. A discharge pipeline will be constructed from the sedimetation basin to the ACDC. The size and depth of the pipe has not been finalized.

4. An existing 60" water main running NE-SW near the west end of the sedimentation basin will be deepened to about 35 to 40 feet below grade to accommodate the ACDC.

The four areas described above are illustrated on the attached 4 site plans, respectively. The site is relatively flat, sloping gently down to the south. Embankment fills were present along the existing Arizona Canal banks to depths varying from about 2 to 7 feet.

EXPLORATION

Field exploration included test drilling and seismic refraction surveys. The test drilling consisted of nine (9) test borings at the locations shown on the attached site plans. At each test boring location, field electrical resistivity tests were performed to provide information on corrosion potential of the site soils and bedrock materials. During the test drilling, the materials were visually classified and representative samples were obtained at selected depths. The results of the test drilling and field resistivity test results are presented in Appendix A.

Seismic refraction surveys were conducted at tweleve (12) locations as shown on the attached site plans. The primary purpose of the seismic refraction surveys was to supplement the test hole information, to provide additional information on stratigraphy and to provide seismic wave velocities of the various strata. These seismic velocities can be used to provide an indirect estimate of rippibility, based on published correlations from excavation equipment manufactuers. The seismic refraction surveys were performed for Thomas-Hartig & Associates by Ggeological Consultants. Detailed discussions and results of the seismic

refraction surveys are presented in Appendix C.

Soil and bedrock samples obtained during the test drilling were subjected to the following laboratory analyses:

Test	Sample(s)	Purpose
Unconfined Compression	Undisturbed rock core (1)	Strength Characteristics
Sieve Analysis and Atterberg Limits	Surface Soil (3)	Classification and correlation to engineering properties
ASTM D698	Surface Soil (3)	Maximum compacted density and optimum moisture content determination
pH, Chlorides, Sulfates	Soil and Rock Fragments (11)	Corrosion Potential
*Dry Density and Moisture Content	Undisturbed Soil (11)	In-situ density and moisture determination

*Reported on boring logs.

The test results are presented in Appendix B.

SOIL AND ROCK CONDITIONS

As illustrated on the graphical boring logs presented in Appendix A, the soil and bedrock stratigraphy is somewhat variable at the boring locations. In general, about 2 to 13 feet of soil cover overlies a deposit of cemented breccia fanglomerate. At Test Borings B-6 and B-7, the breccia fanglomerate was exposed at the ground surface, with little or no soil cover present. At Test Boring B-5, a schist bedrock was encountered below the breccia fanglomerate at a depth of 43 feet.

The surface soils encountered were somewhat variable, but consisted primarily of medium dense to dense clayey sands and gravels. However, at Test Borings B-1 and B-4, fine sands and silty clays were also encountered.

The breccia fangolmerate encountered at the site consisted of angular gravel and cobble-sized rock clasts cemented in a matrix of claiche-cemented angular sand, with the degree of cementation generally varying from moderate to heavy. Zones of concrete-like consistency, with refusal to auger penetration, were encountered.

The underlying schist bedrock was generally hard, with numerous joints and fractures.

DISCUSSION AND RECOMMENDATIONS

Foundations: Four structures will be constructed along the proposed inlet pipeline between the Arizona Canal and the sedimentation basin - the inlet structure, the bar screen and grit sump structure, the meter vault, and the pre-mix structure. The foundation of these structures will be between about 15 and 40 feet below existing grades. Soil cover in the area is only about 2 to 5 feet thick; therefore, foundations will bear in an underlying hard, cemented breccia fanglomerate and may possibly penetrate schist bedrock at the deepest structure (the grit sump). Footings on the hard, relatively incompressible materials will support the light foundation loads with negligible settlements. The following tabulation presents footing depth and allowable bearing pressures:

Footing Depth Below Finished Grade	Bearing Material	Allowable Foundation Bearing Pressure
1.0 ft.	Cemented Breccia Fanglomerate or Schist Bedrock	6000 psf

Finished grade is defined as the lowest adjacent grade with 5 feet of foundations.

The recommended foundation bearing pressure should be considered as an allowable maximum for dead plus design live loads and may be increased by one-third when considering total loads including transient loads such as seismic forces. The weight of the foundation below grade may be neglected. Two (2.0) feet and 1.0 foot are recommended as the minimum width of column and continuous wall footings, respectively.

Lateral Design Parameters: The following tabulation presents recommendations for lateral stability analyses:

[1]Foundation Toe Pressures----------1.33 x allowable
[2]Lateral Backfill Pressures:
Unrestrained walls----------30 psf/ft.
Restrained walls----------60 psf/ft.
Lateral Passive Pressures:
Continuous walls/footings:
embedded in soil----------250 psf/ft. of depth
embedded in fanglomerate or bedrock--500 psf/ft., but not to exceed 10,000 psf
Spread columns/footings:
embedded in soil----------350 psf/ft.
embedded in fanglomerate or bedrock--700 psf/ft. but not to exceed 10,000 psf
Coefficient of Base Friction:
Independent of passive resistance------0.40
In conjunction with passive resistance-0.30

[1]Increase in allowable foundation bearing pressure (previously tabulated) for foundation toe pressures due to eccentric or lateral loading. The entire footing bearing surface should remain in compression.

[2]Equivalent fluid pressures for vertical walls and horizontal backfill surfaces. Pressures do not include temporary forces imposed during compaction of the backfill, swelling pressures developed by over-compacted clayey backfill, hydrostatic pressures from inundation of backfill, or surcharge loads. Walls should be suitably braced during backfilling to prevent damage and excessive deflection.

Compaction of the backfill soils against embedded footings or walls designed to provide passive resistance should be accomplished to a minimum 95 percent of the maximum ASTM D698 density to develop this resistence with low strains.

Concrete Slab Support: Site grading should be accomplished within the building areas as recommended in the "Site Grading" section of this report to provide support for concrete slabs. The site soils are highly stratified, with zones of medium plasticity clay soils encountered at Test Borings B-1 and B-4. The granular clayey sand and gravel soils encountered at other areas will probably exhibit low expansion potentials. The existing on-site clay soils are probably moderately expansive when compacted. We, therefore, do not recommend reusing the clay site soils from areas of excavation as compacted fill below concrete slabs. For fills in these areas, imported fill soils exhibiting low expansive potentials or selectively stockpiles granular site soils would be preferred. The use of a sand and gravel base course (ABC) below slabs overlying breccia of bedrock is not

required. However, the use of a minimum 4-inch thickness of ABC below concrete slabs may be desirable for use as a leveling course.

Excavation Conditons: The test drilling and seismic refraction surveys at the site were performed primarily for design purposes. It is not possible to accurately correlate drilling results with the ease or difficulty of digging for various types and sizes of excavation equipment. However, the seismic velocities of the various strata as determined by the seismic refraction surveys provide an indirect, approximate indication of excavatability based on correlations published by excavtion equipment manufacturers. The information presented in Table 1 on page 9, provides a brief summary of estimated excavatability. A more detailed discussion of the results and interpretation of the seismic survey data is presented in Appendix C. More accurate information regarding excavatability should be evaluated by contractors or other interested parties from test excavations using the intended equipment. Excavations should be braced or sloped as required to provide personnel safety and satisfy local safety code regulations.

Deep Backfills: Backfill intended for structural support or intended to provided passive lateral resistance should be compacted to density criteria presented in the "Site Grading" section of this report. Compaction of all structural fill adjacent to structural walls should be done by mechanical methods. If backfills are not compacted as recommended, subsidence may results in areas adjoining backfilled structures or over utilities. Even for well compacted granular backfills, long term settlements may approach 1/2 precent of the fill height, or more if water is introduced into the fill after construction. Even properly compacted deep backfills may tend to settle differentially relative to structural walls and should not be used for support of adjoining facilities or utilities prone to damage from differential settlements.

Corrosion: Corrosion is most likely to occur in fills and natural soils with high moisture contents and low electrical resistivity. Laboratory tests were performed on selected samples to determine pH, soluble salts, soluble sulfates, and soluble chloride content. Also, field electrical resistivity tests were performed at each boring location. Soluble sulfates content of the tested soils ranged from 0.01 percent to 0.07 percent. Based on these values, the corrosion potential to concrete is low. Therefore, concrete in contact with soils should use Type II cement. A low to moderate potential for corrosion of buried metal conduits is indicated in areas where soil moisture contents are high. Thus, special

protection may be necessary were dissimilar metals are placed in close proximity or are joined.

Fill Materials: All fill materials should be soils free of vegetation, debris, organic contaminants, or fragments larger than 6* inches in size. The existing site soils are highly stratified, with some zones of clay with moderate expansion potentials. The on-site clay soils should not be used for fills below footings or concrete slabs and should either be wasted or used only as pipe cover or exterior fills not intended to provide passive resistacne or support for structures or utilities. For structural fills, imported fill soils exhibiting low expansion potentials or selectively stockpiled granular site soils should be used. Care should be taken to remove or break down boulder-size fragments and blend with finer soil as necessary to minimize voids between large nested fragments.

Any imported fill or backfill soils for use beneath footings or concrete slabs should conform to the following specification requirements:

Maximum particle size ---------- 6 inches*
Maximum percent expansion ---------- 1.5 **

*Maximum size may be reduced at architect's direction to satisfy trenching and landscaping requirements, etc.

**Performed on sample remolded to 95% of the maximum ASTM: D698 density at 2% below optimum moisture under a 100 psf surcharge pressure.

Site Grading: The following recommendations are presented for site grading for the inlet structures area. All phases of the earthwork should be performed under the observation and testing directed by the geotechnical engineer.

1. After mass excavation, observe the construction site and remove any remaining unstable (loose, disturbed, wet, etc.) soils encountered.

2. Widen any depressions as necessary to accommodate compaction equipment and provide a level base for placing fill.

3. Clean the exposed surface of all loose or disturbed soils.

4. Place fill materials required to elevate site areas to specified grade. Fill materials should be placed and compacted in horizontal lifts of thicknesses compatible with the compaction equipment being

used.

5. Compaction of exposed surface soils and fills should be accomplished to the following density criteria.

Material	Percent Compaction (ASTM D698)
*Fill, exposed surface soils, and structural backfill:	
Structural fills and backfills shallower than 5 feet below finished grade	95 min.
Structural fills and deep backfills deeper than 5 feet below finished grade	100 min.
**Miscellaneous backfill	90 min.

*Deep structural wall backfills should not be used for support of facilities which are susceptible to damage from differential settlements of the fill section relative to walls.

**Utility trench and exterior wall backfill not intended to provide passive resistance for pipeline, or for foundation or pavement support.

Compaction of on-site soils or imported fill materials with low expansive potentials should be accomplished at a moisture content of optimum -1 to optimum +3 percent.

Please call if you have any questions or if we may be of further service.

Respectfully submitted,

THOMAS-HARTIG & ASSOCIATES, INC.

By: _____ Reviewed by: _____

Steven A. Haire, P.E. Kenneth L. Ricker, P.E.

/sb

Copies to: Addressee (5)

TABLE 1. SOIL AND ROCK STRATIGRAPHY AND APPROXIMATE EXCAVATABILITY
(Page 1 of 2)

		**Approximate Depth Range (ft)/Excavatability:		
*Location	Depth Investigated	Soil	Cemented Breccia Fanglomerate	Bedrock
B-1	37	0 - 13	13 - 37+	---
S-1	23+	0 - 3/Easy	3 - 21/Easy 21+/Difficult	---
S-2	19+	---	0 - 2/Easy 2 - 19/Difficult	19+/Difficult
S-3	27+	0 - 5/Easy	5 - 27/Moderate	27+/Difficult
B-3	19	0 - 2	2 - 19+	---
S-4	24+	0 - 4/Easy	4 - 24/Moderate	24+/Difficult
S-5	24+	0 - 7/Easy	7 - 24/Moderate	24+/Difficult
B-4	17	0 - 5	5 - 17+	---
S-6	18+	0 - 8/Easy	8 - 18/Moderate	18+/Difficult
S-7	48+	0 - 8/Easy	8 - 48/Difficult	48+/Difficult
B-5	49	0 - 3	3 - 43	43 - 49+
S-8	30+	0 - 3	3 - 16/Easy to Moderate	30+/Difficult
B-6	19	---	0 - 19+	---
S-9	13+	0 - 3/Easy	3 - 13/Moderate 13+/Difficult (may be bedrock)	---
B-7	15	---	0 - 15+	---
S-10	30+	0 - 9/Easy	9 - 30/Moderate 30+/Difficult	---
B-8	49	0 - 5	5 - 49+	---
B-9	37	0 - 7	7 - 37+	---
S-12	44+	0 - 9/Easy	9 - 44/Difficult	44+/Difficult
S-11	32+	0 - 6/Easy	6 - 32/Moderate	32+/Difficult

(continued)

TABLE 1. SOIL AND ROCK STRATIGRAPHY AND APPROXIMATE EXCAVATABILITY
(Page 2 of 2)

* S = Seismic refraction line location
B = Boring location

** At seismic refraction locations, a preliminary estimate of excavatability is presented based on the following approximate correlation:

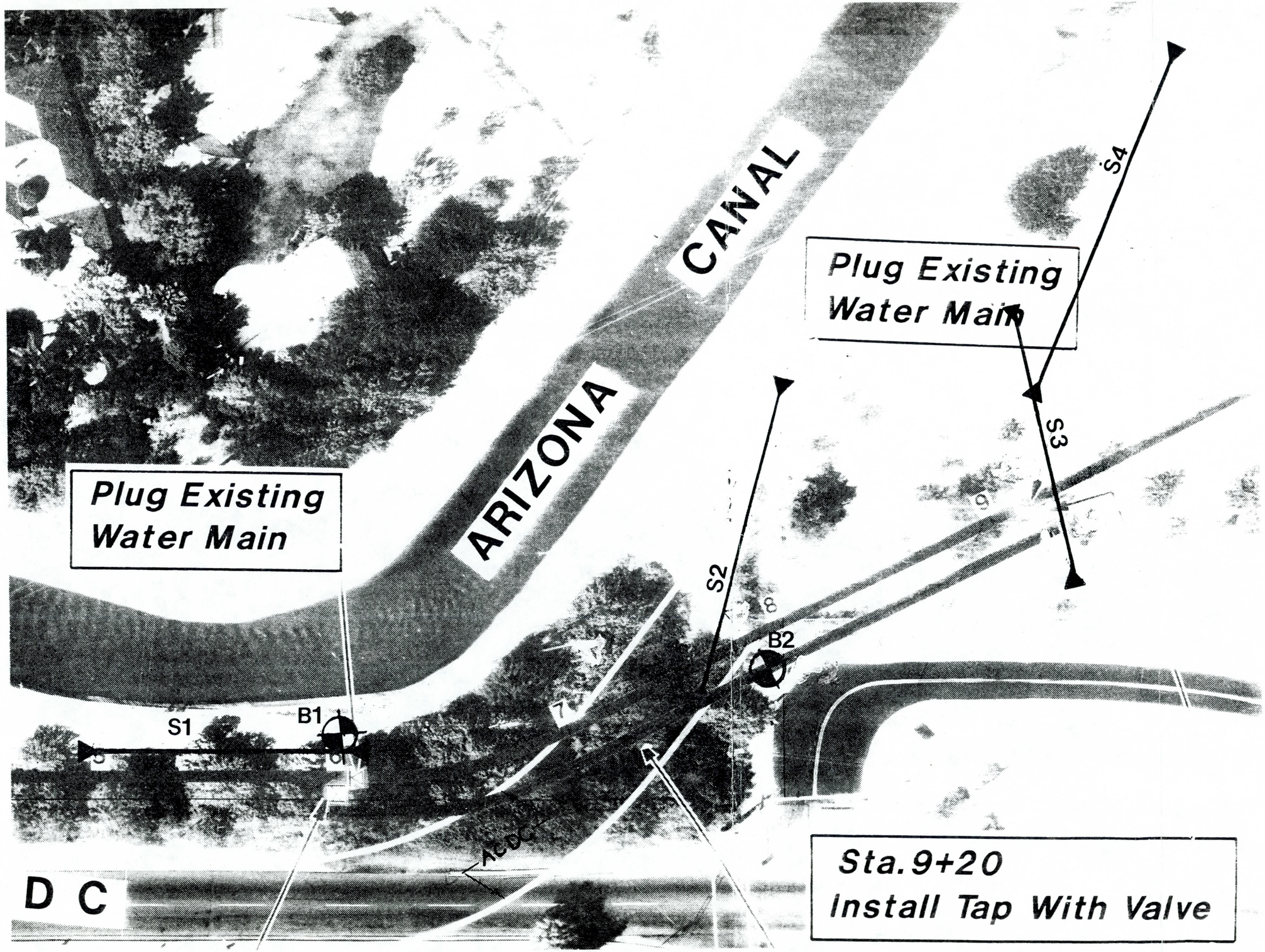
Seismic Velocity	Estimated Ease of Excavation
0 - 2750 fps	Easy: easy to rip
2750 - 5000 fps	Moderate: difficult ripping
5000+ fps	Difficult: blasting probably necessary

More accurate information regarding excavatability should be evaluated from test excavations using the intended equipment and methods.

The depth ranges shown are approximate values for the portion of the seismic refraction line nearest the pipe centerline.

APPENDIX A

FIELD RESULTS



SITE PLAN

(sheet 1 of 4)

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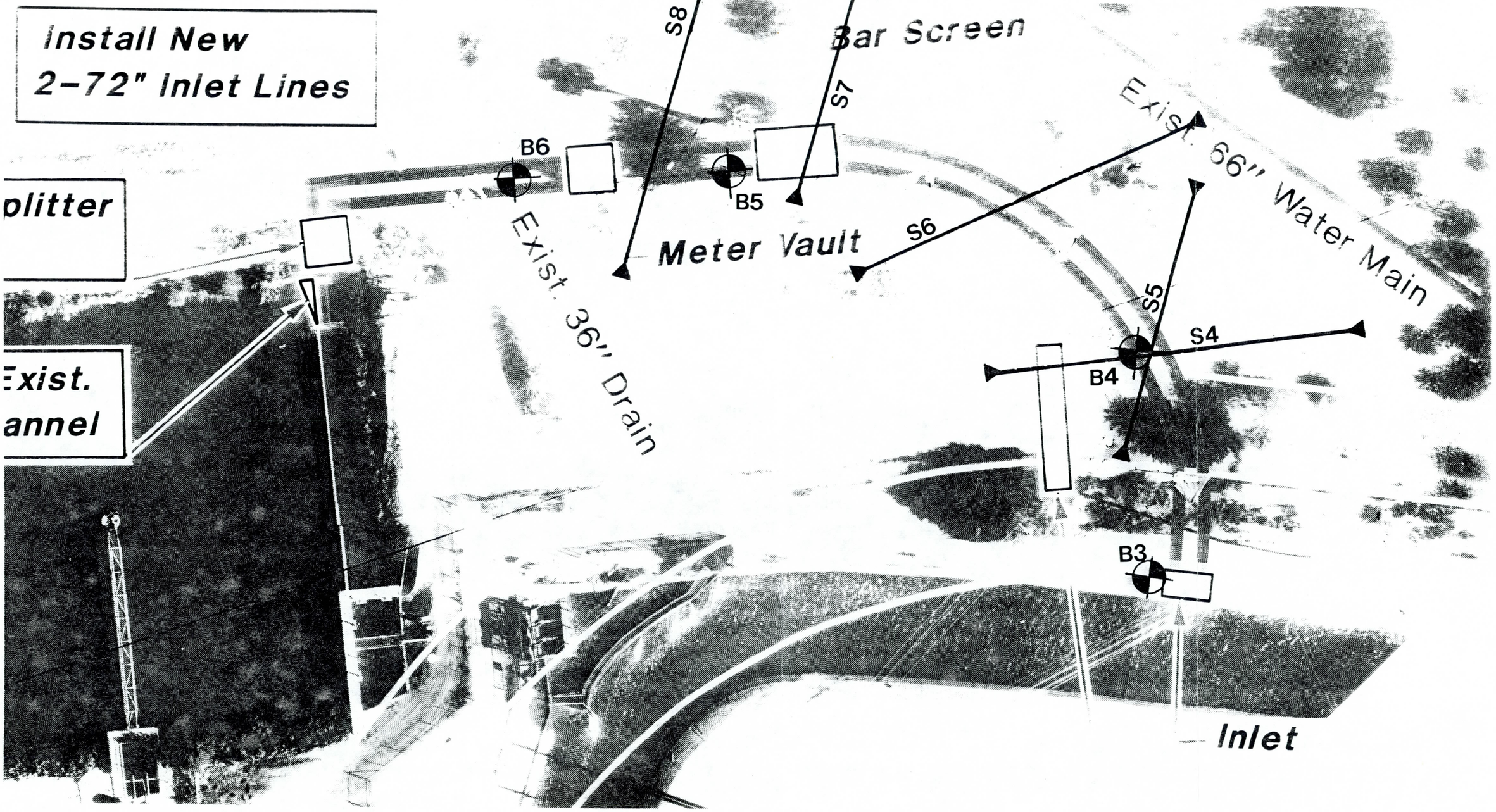
Project No. 89-0326



SITE PLAN

(sheet 2 of 4)
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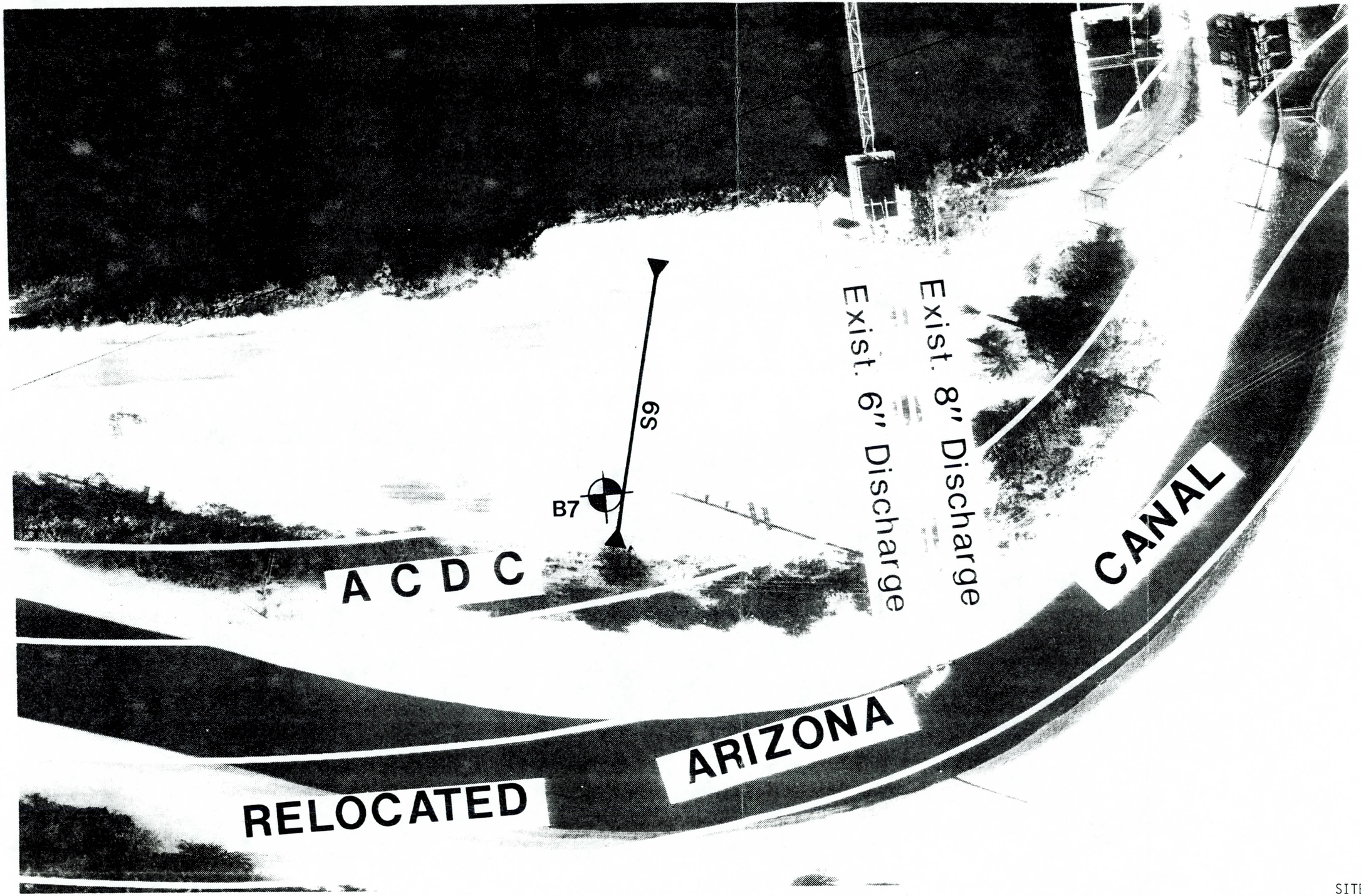
Project No. 89-0326



SITE PLAN

(sheet 3 of 4)
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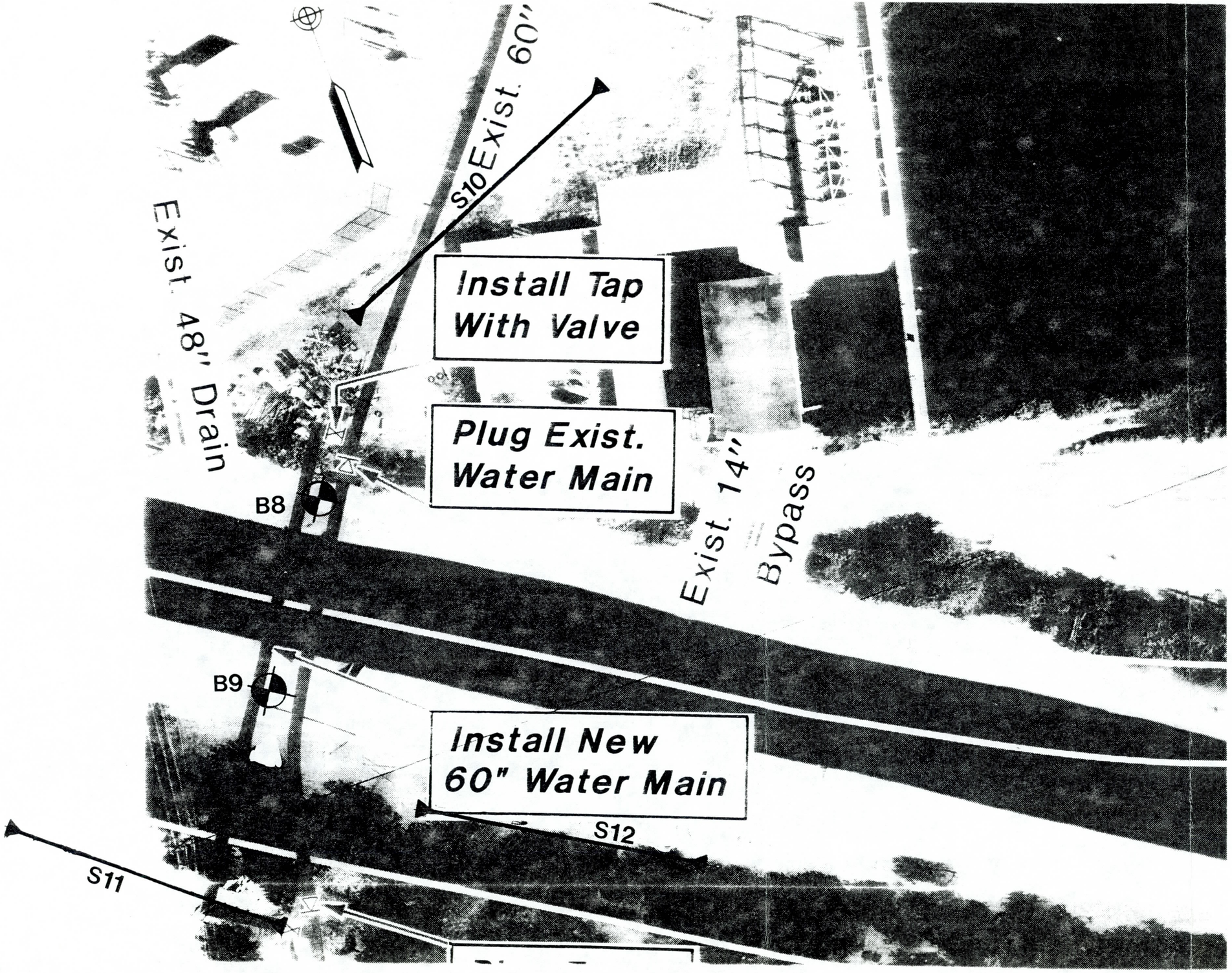
Project No. 89-0326



SITE PLAN

(sheet 4 of 4)
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Project No. 89-0326

LEGEND

SOIL CLASSIFICATION

COARSE-GRAINED SOIL

More than 50% larger than 200 sieve size

SYMBOL	LETTER	DESCRIPTION	MAJOR DIVISIONS
	GW	WELL-GRADED GRAVELS OR GRAVEL-SAND MIXTURES. LESS THAN 5% - #200 FINES	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size
	GP	POORLY-GRADED GRAVELS OR GRAVEL-SAND MIXTURES. LESS THAN 5% - #200 FINES	
	GM	SILTY GRAVELS. GRAVEL-SAND-SILT MIXTURES. MORE THAN 12% - #200 FINES	
	GC	CLAYEY GRAVELS. GRAVEL-SAND-CLAY MIXTURES. MORE THAN 12% - #200 FINES	
	SW	WELL-GRADED SANDS OR GRAVELLY SANDS. LESS THAN 5% - #200 FINES	SANDS More than half of coarse fraction is smaller than No. 4 sieve size
	SP	POORLY-GRADED SANDS OR GRAVELLY SANDS. LESS THAN 5% - #200 FINES	
	SM	SILTY SANDS. SAND-SILT MIXTURES MORE THAN 12% - #200 FINES	
	SC	CLAYEY SANDS. SAND-CLAY MIXTURES MORE THAN 12% - #200 FINES	

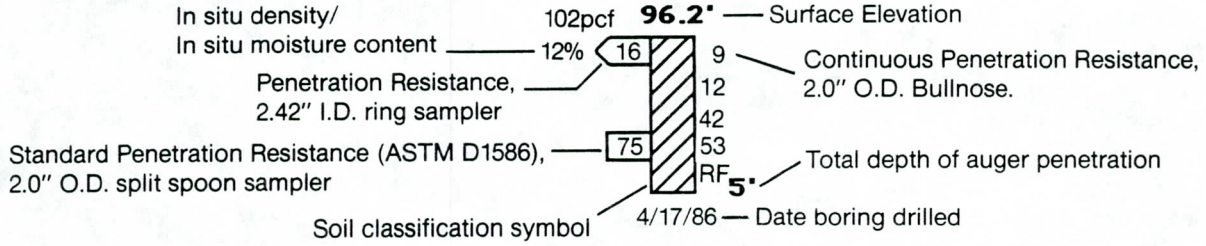
FINE-GRAINED SOIL

More than 50% smaller than 200 sieve size

SYMBOL	LETTER	DESCRIPTION	MAJOR DIVISIONS
	ML	INORGANIC SILTS. ROCK FLOUR. AND FINE SANDY OR CLAYEY SILTS OF LOW TO MEDIUM PLASTICITY	SILTS AND CLAYS Liquid limit less than 50
	CL	INORGANIC CLAYS. GRAVELLY CLAYS. SANDY CLAYS. SILTY CLAYS. AND LEAN CLAYS OF LOW TO MEDIUM PLASTICITY	
	OL	ORGANIC SILTS AND ORGANIC SILT-CLAY MIXTURES OF LOW TO MEDIUM PLASTICITY	
	MH	INORGANIC SILTS. MICACEOUS OR DIATOMACEOUS. AND FINE SANDY OR CLAYEY SILTS OF HIGH PLASTICITY	SILTS AND CLAYS Liquid limit greater than 50
	CH	INORGANIC CLAYS. FAT CLAYS. AND SILTY CLAYS OF HIGH PLASTICITY	
	OH	ORGANIC CLAYS AND ORGANIC SILTS OF MEDIUM TO HIGH PLASTICITY	
	PT	PEAT AND OTHER HIGHLY ORGANIC SOILS	

LEGEND FOR GRAPHICAL BORING LOGS:

Log denotes visual approximation unless accompanied by mechanical analysis and Atterberg limits.



PENETRATION RESISTANCE: Blows per foot using 140 lb. hammer with 30" free-fall unless otherwise noted.

GRAIN SIZES

U.S. STANDARD SERIES SIEVE				CLEAR SQUARE SIEVE OPENINGS			
200	40	10	4	3/4"	3"	12"	
SILTS & CLAYS DISTINGUISHED ON BASIS OF PLASTICITY	SAND			GRAVEL		COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	COARSE		

MOISTURE CONDITION (INCREASING MOISTURE →)

DRY — SLIGHTLY DAMP — DAMP (Plastic Limit) — MOIST — VERY MOIST — WET (SATURATED) (Liquid Limit)

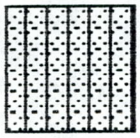
CONSISTENCY CORRELATION		RELATIVE DENSITY CORRELATION	
CLAYS & SILTS	BLOWS/FOOT*	SANDS & GRAVELS	BLOWS/FOOT*
VERY SOFT	0-2	VERY LOOSE	0-4
SOFT	2-4	LOOSE	4-10
FIRM	4-8	MEDIUM DENSE	10-30
STIFF	8-16	DENSE	30-50
VERY STIFF	16-32	VERY DENSE	OVER 50
HARD	OVER 32		

*Number of blows of 140 lb. hammer falling 30" to drive a 2" O.D. (1-3/8" I.D.) split-spoon sampler (ASTM D1586).

LEGEND OF SOIL TYPES

PROBABLE FILL, CLAYEY GRAVELLY SAND (SC); brown; fine to coarse sand size; angular; dense; low plasticity; slightly damp.

CLAYEY SAND & GRAVEL (SC & GC); brown to light brown; stratified; fine to coarse sand size; medium dense to dense; low plasticity; angular; scattered cobbles and boulders.



SILTY SAND (SM); brown; fine; medium dense; non-plastic; damp.

SILTY CLAY (CL); light brown to dark brown; very stiff; medium plasticity; blocky; vesicular.

BRECCIA FANGLOMERATE; white to grey; angular gravel-and cobble-size rock clasts cemented in a matrix of caliche-cemented angular sand; degree of cementation generally varies from moderate to heavy; with zones of concrete-like consistency.

SCHIST; grey; generally hard but with some soft zones; numerous joints and fractures.

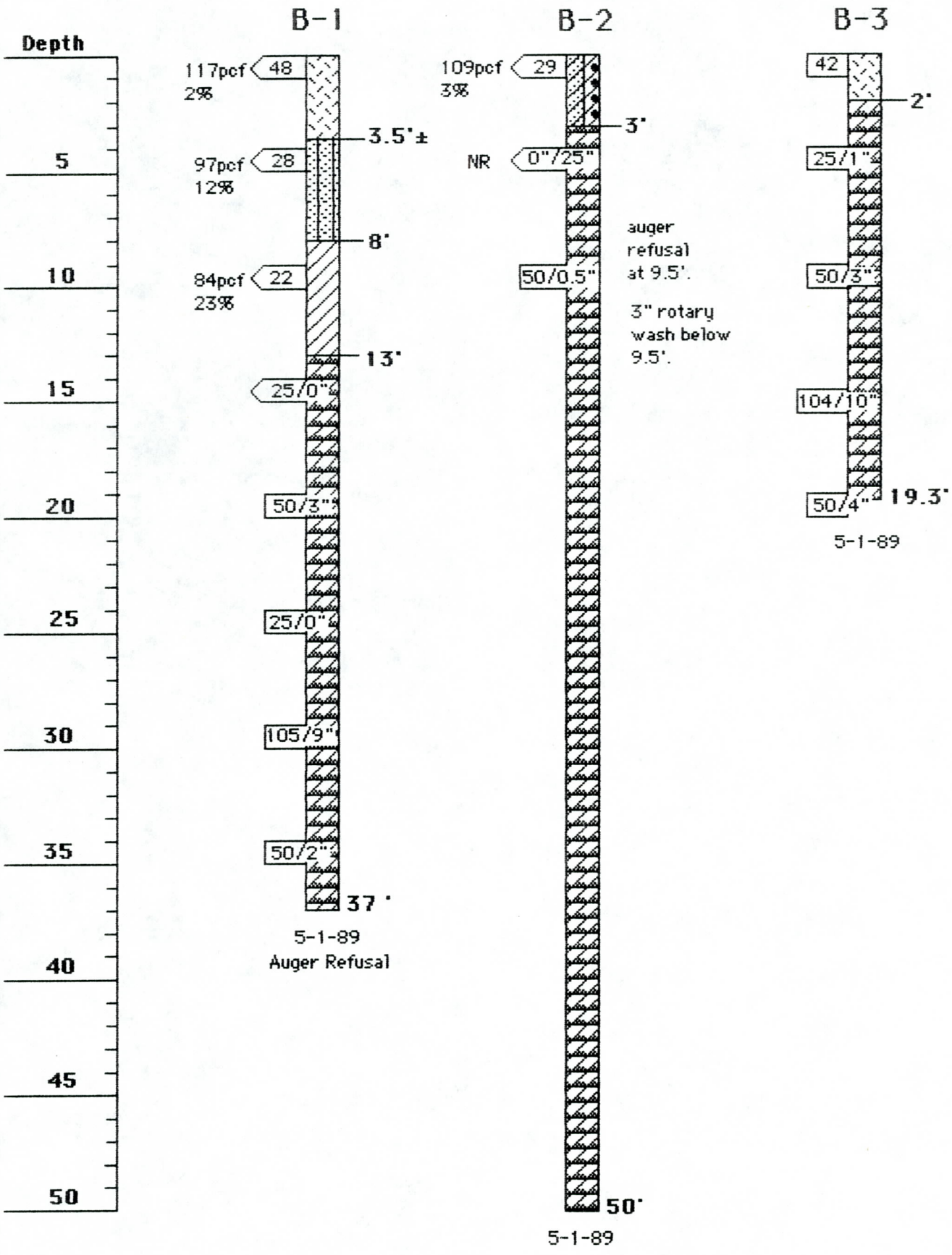
No free groundwateer was encountered in any of the borings during drilling.

All borings drilled with 7" hollow stem augers unless otherwise noted.

Project No. 89-0326
Thomas-Hartig & Associates, Inc.

NOTE: The data presented on the boring logs represents subsurface conditions only at the specific locations and at the time designated. This data may not represent conditions at other locations and/or times. Contacts between soil strata are approximate and changes between soil types may be gradual rather than abrupt. This boring data was compiled primarily for design purposes and should not be construed as part of the plans governing construction or defining construction techniques. Bidders are fully responsible for interpretations or conclusions they draw from the boring log.

GRAPHICAL BORING LOGS



Project No. 89-0326

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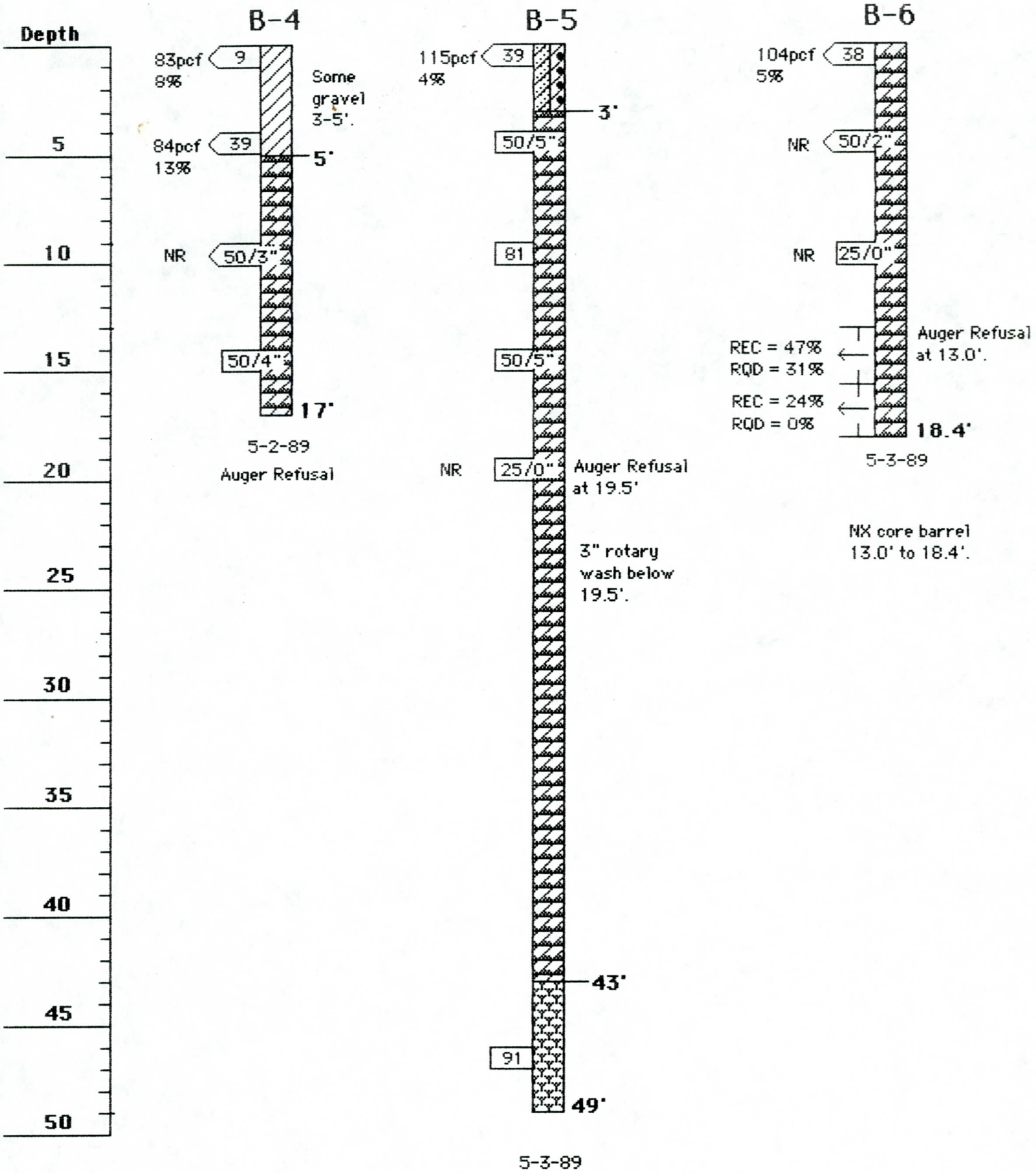
GRAPHICAL BORING LOGS



Project No. 89-0326

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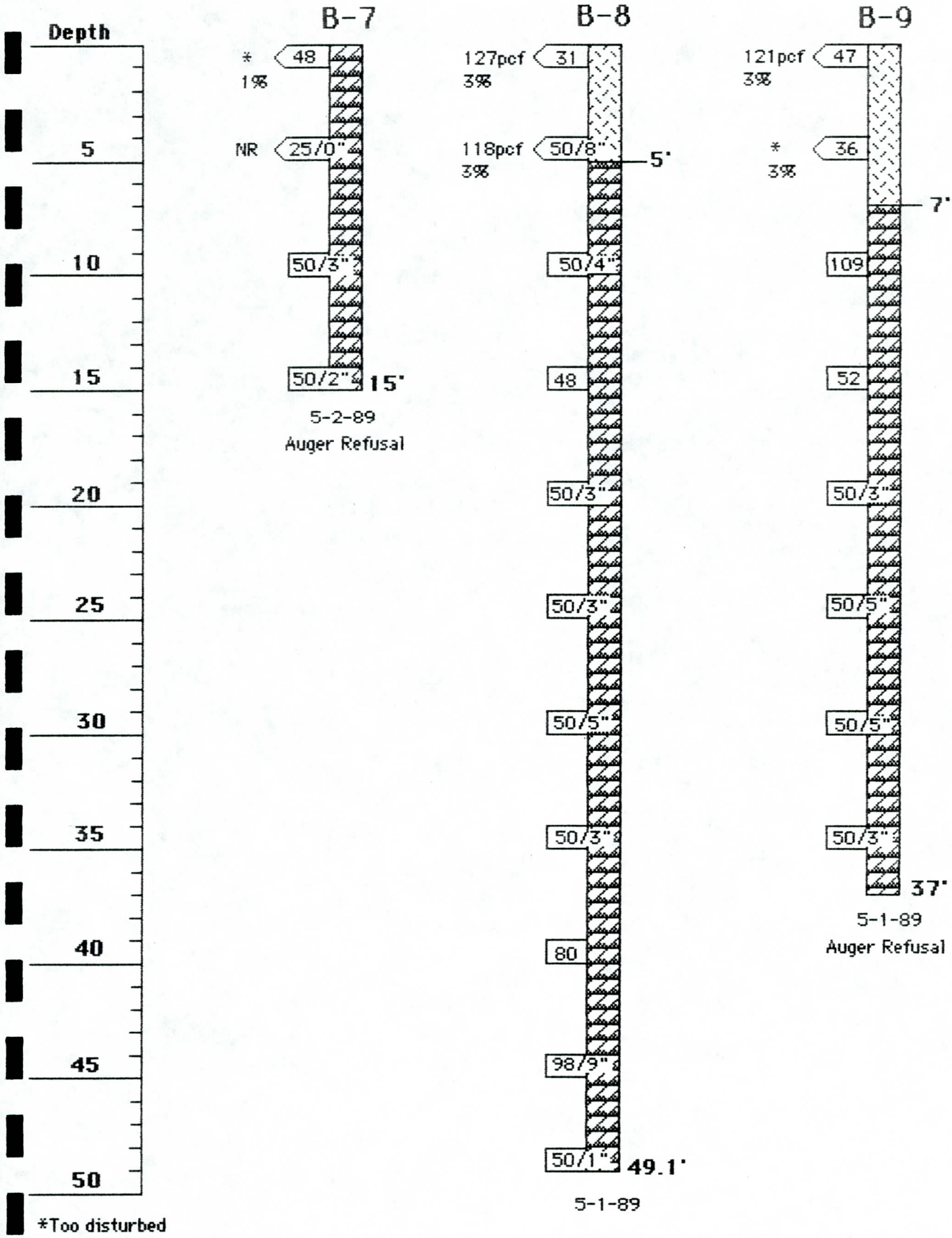
GRAPHICAL BORING LOGS



*Too disturbed to determine density.

Project No. 89-0326

Thomas - Hartig & Associates

REPORT ON FIELD TESTS

DESCRIPTION: Date: 22 May 1989

Location: Noted Below

Material: Native soil and/or rock

Performed By: TH/Perry

TESTED: Field resistivity using the 4-probe method

RESULTS:

Location	Depth Interval (ft)	Resistivity (ohm-cm)
B-1	0 - 16	6440
	0 - 32	30640
B-2	0 - 16	8890
	0 - 32	8580
B-3	0 - 16	9190
	0 - 32	5520
B-4	0 - 16	21450
	0 - 32	12260
B-5	0 - 16	21450
	0 - 32	30640
B-6	0 - 16	5750
	0 - 32	19150
B-7	0 - 16	76600
	0 - 32	24510
B-8	0 - 16	15320
	0 - 32	12260
B-9	0 - 16	18390
	0 - 32	30640

APPENDIX B

LABORATORY RESULTS

REPORT ON LABORATORY TESTS

SAMPLE: Date 22 May 1989

Source Noted Below

Type NX rock core

Material cemented angular clasts of schist (fanglomerate)

Sampled By TH/Perry

TESTED: Unconfined Compressive Strength

RESULTS:

Sample	Unconfined Compressive Strength	Length/Diameter Ratio
B-6; 14.0 - 14.3'	4330 psi	2.0

REPORT ON LABORATORY TESTS

SAMPLE: Date 19 May 1989

Source Noted Below

Type Auger Cuttings

Material Soil

Sampled By TH/Perry

TESTED: Sieve analysis and Atterberg Limits

RESULTS:

Sample	LL	PI	Sieve Size - Accum. % Passing 200	100	50	30	16	8	4	3/4"	1"	2"	3"	* Class
B-1; 0 - 8'	NP		30	47	51	54	58	63	70	92	100			SM
B-4; 0 - 3'	44	17	60	68	70	72	74	77	81	100				CL
B-8&B-9;0-3'	26	8	25	30	34	39	45	54	66	100				SC

* Unified Soil Classification

Project No. 89-0326

REPORT ON LABORATORY TESTS

SAMPLE: Date 22 May 1989

Source Noted Below

Type auger cuttings, split-spoon samples

Material Soil and rock fragments

Sampled By TH/Perry

TESTED: pH, Soluble Chlorides, Soluble Sulfates

RESULTS:

Sample	pH	Percent Chloride	Percent Sulfates
B-1; 0 - 8'	8.1	0.02	0.02
B-1; 34 - 35'	8.2	0.01	0.01
B-2; 3 - 5'	8.0	0.05	0.04
B-3; 0 - 6'	8.2	0.02	0.02
B-3; 14 - 15.5'	8.6	0.02	0.01
B-4; 9 - 11'	7.9	0.01	0.05
B-5; 9 - 10.5'	7.7	0.06	0.07
B-6; 4 - 5'	7.8	0.05	0.04
B-7; 0 - 3'	7.9	0.02	0.01
B-8; 0 - 3'	7.9	0.01	0.02
B-9; 14 - 15.5'	7.9	0.02	0.01

REPORT ON LABORATORY TESTS

SAMPLE: Date 22 May 1989

Source Test Boring B-1; 0 - 8'

Type auger cuttings

Material Silty Gravelly Sand (SM)

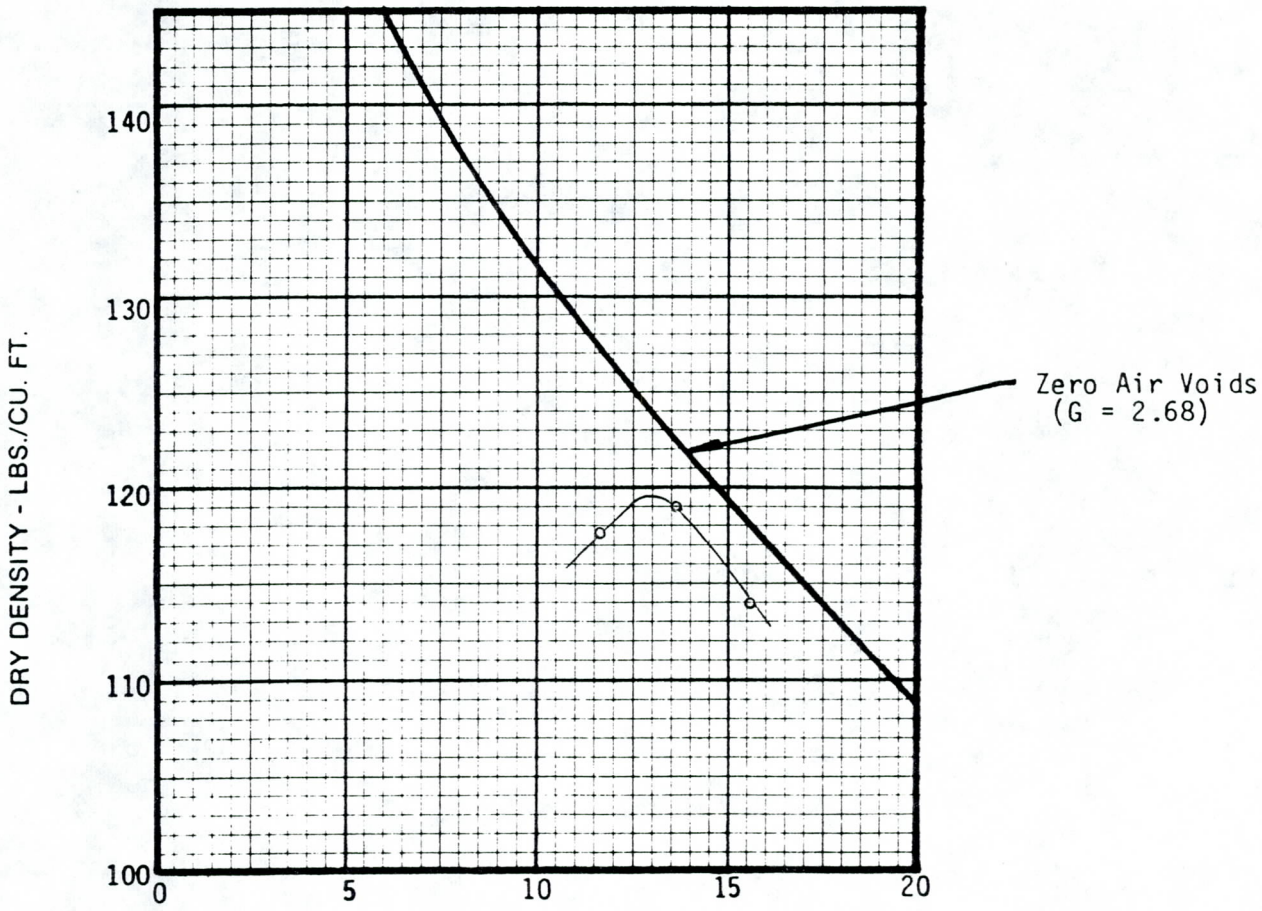
Sampled By TH/ Perry

TESTED: Moisture-Density Relationship Curve, ASTM D698, Method A

RESULTS:

Max. Dry Density, lbs./cu. ft. 119.5

Optimum Moisture Content, % 13.0



Project No. 89-0326

THOMAS-HARTIG & ASSOCIATES, INC.

REPORT ON LABORATORY TESTS

SAMPLE: Date 22 May 1989

Source Composite of B-8; 0 - 3' & B-9; 0 - 3'

Type Auger cuttings

Material Clayey Gravelly Sand (SC)

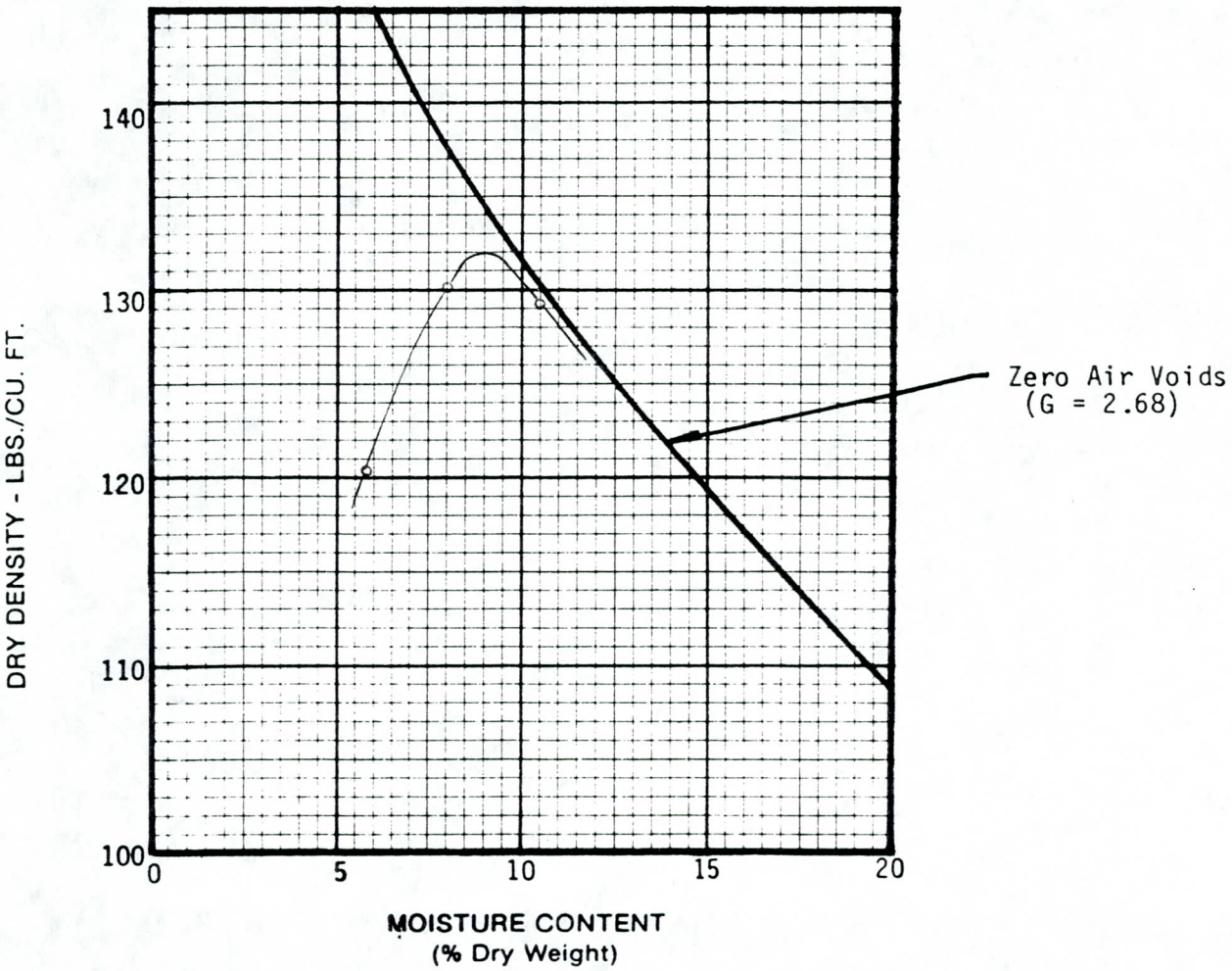
Sampled By TH/Perry

TESTED: Moisture-Density Relationship Curve, ASTM D698, Method A

RESULTS:

Max. Dry Density, lbs./cu. ft. 132.0

Optimum Moisture Content, % 9.0



Project No. 89-0326

THOMAS-HARTIG & ASSOCIATES, INC.

APPENDIX C
Seismic Refraction Surveys

GEOLOGICAL CONSULTANTS

Kenneth M. Euge, R.G.

SEISMIC REFRACTION GEOPHYSICAL SURVEY

Squaw Peak Water Treatment Plant
Pipeline Relocations at the ACDC
City of Phoenix, Arizona

Flood Control District of Maricopa County
Project No. FCD 88-40

(Performed as Part of the Geotechnical Investigation)

Prepared for:

Thomas-Hartig and Associates, Inc
7031 West Oakland Street
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Prepared by:

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Geological Consultants
2822 West Northern Avenue, Suite B
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May 19, 1989

Project No. 89-107

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SEISMIC REFRACTION GEOPHYSICAL SURVEY

Squaw Peak Water Treatment Plant
Pipeline Relocations at the ACDC
City of Phoenix, Arizona

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Project No. FCD 88-40

(Performed as Part of the Geotechnical Investigation)

1.0 INTRODUCTION

This report presents the results of a seismic refraction geophysical field investigation and analysis performed to assess the depth to bedrock or bedrock-like materials along the proposed pipeline relocation alignments in the vicinity of the Squaw Peak Water Treatment Plant. The purpose of the geophysical survey is to provide supplemental subsurface information for the geotechnical investigation performed by Thomas-Hartig and Associates (T & H) of Chandler, Arizona and to provide for a higher level of confidence to the evaluation of depth to bedrock, relative ease of excavation, thickness of weathered zones, and rock competence.

The proposed pipeline excavations are expected to range in depth from about 20 feet to 40 feet below existing grades. The seismic refraction program is designed to obtain representative induced seismic wave velocities which are used to establish qualitative estimates of the soil and rock strata excavateability. The determination of seismic velocities of the subsurface materials will facilitate the computation of the depths to velocity interfaces or boundaries that may be identified within the range of the proposed excavation depths. To enhance the reliability of the seismic survey data, it is correlated with the findings of the drilling and materials testing programs performed by T & H and with the ACDC Deep Tunnel investigation made by CRS Sirrine (1988).

The seismic refraction geophysical program was performed by Geological Consultants, under the direction of Mr. Kenneth M. Euge, R.G., Principal Investigator, for T & H in accordance with Geological Consultants Proposal for Services dated February 1, 1989. The field seismic investigations were performed from May 3 through May 6, 1989.

1.1 SCOPE OF WORK

In accordance with the Proposal for Services, Geological Consultants performed services that included the following:

- review of published and unpublished geology and soils data pertaining to the study area;
- discussion with City of Phoenix personnel regarding Water Treatment Plant operations whereby the seismic surveys could be performed during 'quiet' plant operation periods;

1.1 SCOPE OF WORK (continued)

- o discussions with Thomas-Hartig & Associates relative to their geotechnical investigation made along the proposed pipeline alignment;
- o examination of soil and rock samples obtained by T&H during the exploratory drilling program;
- o the running of 12 seismic refraction survey lines along the proposed pipeline alignment;
- o analysis and interpretation of the seismic velocity data obtained at each survey site and correlation of these data with the results of other site investigations; and
- o preparation of this report presenting the survey findings, conclusions, and recommendations.

1.2 LOCATION

The seismic survey area are located within or immediately adjacent to the Squaw Peak Water Treatment Plant facilities and along portions of the Arizona Canal in the southeast one-quarter of Section 10, Township 2 North, Range 3 East. The Treatment Plant is south of Lincoln Drive, bounded on the east by 24th Street and on the the south by the Arizona Canal. Easy access to the study area is provided by Maryland Avenue east from 16th Street.

1.3 SITE CONDITIONS

Topography of the seismic survey sites is generally flat lying to very gently sloping with relief along each survey line of about 5 feet or less. Vegetation is sparce to almost lacking along the proposed alignments except along a portion of 24th Street where a thick stand of Palo Verde trees and underbrush parallels the alignment on the upstream side of the canal; wet, saturated ground conditions, caused by runoff from an unknown source, were found in the same area during the evening of May 6th. Numerous man-made structures (buried pipelines, concrete structures, roadways, etc.) necessitated field adjustments to the survey line orientations.

2.0 GEOLOGIC SETTING

The site region is in south-central Arizona within the Phoenix Basin portion to the Sonoran Desert Section of the Basin and Range Physiographic and Structural Province. The area is typified by relatively low bedrock hills (including Squaw Peak) north and east of the site. The ground surface slopes towards the south from the bedrock highs until it intersect a gently sloping alluvial fan/rock pediment surface. The pediment is partially buried by shallow thicknesses of coarse grained sediments that are penetrated by bedrock knobs and protuberences.

2.1 BEDROCK

The bedrock in the site area includes light gray and bluish gray, strongly foliated, hard, interbedded metamorphic quartzites and schists. The rock is fine to medium grained and exhibits both granulose and schistose texture. The well developed foliation strikes (trends) in a northeast direction and dips at steep angles to both the southeast and northwest. The rock is also broken with numerous close to moderately close spaced joints and fractures.

2.2 ALLUVIUM

The alluvial sediments, referred to in this report as fanglomerate, represent the remnents of an old alluvial fan complex consisting of coarse grained sandy gravel and gravelly sand that is light brown to brown and moderately dense to very dense. The sediments are poorly sorted, moderately consolidated and poorly to moderately stratified. The gravel- and cobble-size clasts, composed of locally-derived metamorphic rock types, are angular to subangular and set in a matrix of caliche- cemented coarse angular sand and silt. The degree of caliche cementation varies throughout the unit causing the fanglomerate to be uncemented to very strongly cemented locally taking on a concrete-like consistency.

2.3 OTHER SITE MATERIAL

Man-placed accumulations of earth fills, consisting of heterogeneous mixtures of variably compacted soils probably derived from both onsite and offsite sources, are found along various segments of the proposed pipeline alignments within the Treatment Plant property in the vicinity of survey lines S5 through S10. Canal embankment fills are present in the vicinity of survey lines S1, S2, and S12. Construction debris and organic material may be incorporated into some of the randomly dumped fills.

3.0 SEISMIC REFRACTION SURVEY

In general, seismic wave velocities are related to the hardness, consolidation, and density of the materials through which the seismic waves travel. Seismic velocities of subsurface soils and bedrock can be correlated to some of the physical properties of the material with reasonable levels of confidence. As with rock rippability, for example, the Caterpillar Tractor Company has correlated ranges of seismic velocities in different rock and soil materials to qualitative estimates of rippability for their D-9 tractor with a mounted hydraulic No. 9 ripper.

The use of induced seismic wave velocities measured in soils and rock are considered reasonably conservative for the purposes of evaluating soil and rock characteristics by "indirect" shallow geophysical seismic methods:

- Soil, loose surface material and highly weathered and broken bedrock have velocities ranging from 500 feet per second (fps) to 1,200 fps;
- Moderately hard, slightly to moderately cemented, dense sediments and moderately weathered and broken bedrock range from 1,200 fps to 3,000 fps;
- Very dense, hard, well cemented soils and moderately competent bedrock range from 3,000 fps to 5,000 fps, (water-saturated, unconsolidated soil can exhibit seismic velocities on the order of 5,000 fps);
- Sound, relatively homogeneous bedrock and uniformly / strongly cemented soils (silica hardpan, caliche, calcrete, etc.) have seismic velocities in excess of 5,000 fps.

Tpyically, soils and rock with velocities of less than 3,000 fps can usually be excavated with conventional earth moving equipment. The intermediate materials with velocities between 3,000 fps and 5,000 fps would likely require heavy equipment and possibly localized jack-hammering, ram-hoeing, or selective blasting to provide cost effective excavation. Materials with velocities in excess of 5,000 fps could require blasting to provide economical fragmentation; however, if the rock is variably cemented, thinly bedded, jointed, and/or fractured, it may be possible to break the rock with heavy ripping using a Caterpillar D-9 tractor (or equivilent) with a single shank ripper or a large ram-hoe. The resulting fragments will be of a size consistent with the bedding, joint, and fracture spacings or the extent of strong cementation.

3.1 EQUIPMENT AND FIELD PROCEDURES

Travel-time data for the seismic traverses were obtained using a Bison Instruments, Inc. Model 1570C Signal Enhancement Seismograph. Seismic wave arrivals were detected with high sensitivity, hum-bucking, low impedence geophones responsive between 5 and 2,000 hertz. The seismic shock was produced by repeated impacts of either a 12-pound sledge hammer onto an aluminum striking plate Impacts were made at 5- to 20-foot intervals along the traverse lines. The seismic traverse lengths are selected based upon the depth of investigation required along the specific traverse. A generally accepted 'rule-of-thumb' is about 3 to 1 (traverse length to penetration depth). Where site limitations (trees, heavy brush, saturated ground, structures, etc.) could restrict traverse length or possibly influence the seismic wave arrival times, field modifications of the survey(s) are made in an effort obtain the best possible data.

The distances from the impact station to the geophone and the travel times recorded for each station were plotted and graphed in the field as the data were obtained. If the field seismic data plots indicate the possible presence of an anomalous subsurface condition or extraneous noise coincident with the hammer impacts, repeated impacts and/or closer impact spacings were used to varify the initial data reading or to correct the data. Topography, rock outcrops, and other natural or man-made features found along the traverse line that might influence the data interpretations are anotated on the data plots.

3.2 SITE SPECIFIC SEISMIC SURVEYS

Twelve seismic refraction surveys were made along and adjacent to the proposed pipeline relocation alignments (refer to Site Plan) to evaluate the excavateability of the site soils and bedrock and determine the approximate depth along the alignments that conventional excavation methods could be employed. The traverse end-points were approximately located by Geological Consultants by taping from local landmarks.

Forward and reverse traverses were run at each site to evaluate possible non-horizontal subsurface boundary conditions (sloping bedrock surface, cementation zones, etc.), which are expected in this type of geologic terrain, and to improve the level of accuracy of the seismic wave velocity determinations. The seismic traverses were run over a lengths ranging from 120 feet to 160 feet to achieve the best depth penetration possible consistent with the site limitation (see Section 3.1) in order to envelop the approximate zones of interest that would normally be expected to be influenced by site excavations for the pipeline relocations.

Daytime noise levels, with respect to running seismic surveys, was excessive at the Treatment Plant due to pump and motor operations and

3.2 SITE SPECIFIC SEISMIC SURVEY (continued)

along 24th Street due to vehicular traffic. The prosecution of the surveys was accomplished during night-time hours between 1800 hours and 0200 hours when the noise levels were lowest.

3.3 RESULTS OF THE SEISMIC SURVEY

The geological information available for the site area and the exploratory drill logs provided by T&H, combined with the interpretations of the seismic survey data indicates the general stratigraphic profile of the site consists of the following:

- Variably compacted earth fills and topsoil (residual soils);
- Weakly to strongly caliche-cemented fanglomerate; and
- Weathered to unweathered bedrock (schist and quartzite).

The fill/residual soils are found to locally mantle the fanglomerate to shallow depths. The intermediated horizon (the weakly to strongly cemented fanglomerate) exhibits variable seismic velocity response which probably indicates the variations in the degree of cementation throughout the unit. "Hidden zone" or shadow conditions (high velocity horizon overlying a low velocity horizon) may be present as a result of the caliche cementation forming wedges or lenses of discontinuous rock-like zones over 'soil-like' zones of fanglomerate.

The fanglomerate overlies an irregular to gently sloping weathered, calichified bedrock surface which is indicated by the increase or decrease in seismic wave travel times over short traverse distances as depicted in the data plots. Below the fanglomerate/bedrock boundary, a less weathered and less broken bedrock is believed to be present.

Travel time-distance field data plots are presented in Figure 1. The seismic velocities, calculated depths to velocity boundaries, and velocity/material type correlations are presented in Table 1. These data are also depicted in the Velocity Profiles (Figure 2).

3.3 RESULTS OF THE SEISMIC SURVEY (continued)

Table 1

SEISMIC REFRACTION GEOPHYSICAL SURVEY
DATA INTERPRETATIONS

(a) 66" Water Main Relocation Alignment

Seismic Survey No.	S1		S2		S3	
Profile Direction	F	R	F	R	F	R
V1 (fps)	1000	1000	1250	1350	1150	800
Material	t/f	t/f	wfg	wfg	t/f	t/f
Depth to Base (ft)	2	3	4	2	5	2
V2 (fps)	2200	2400	4300	3800	2900	6000
Material	wfg	wfg	mfg	mfg	mfg	sfg
Depth to Base (ft)	19.1	22.8	19.6	19.2	26.6	33.4
V3 (fps)	8000	8000	7800	9500	14,000	13000
Material	sfg	sfg	sfg	rock	rock	rock

Seismic Velocity Interpretation / Material Correlation:

t	Topsoil (residual soil)
t/f	Topsoil/fill
f/wfg	Fill/weakly cemented fanglomerate
wfg	Weakly cemented fanglomerate
mfg	Moderately cemented fanglomerate
sfg	Strongly cemented fanglomerate
sfg/rk	Strongly cemented fanglomerate (?) (possibly rock)
rock	Bedrock (probably schist; possibly quartzite)

3.3 RESULTS OF THE SEISMIC SURVEY (continued)

Table 1 (continued)

SEISMIC REFRACTION GEOPHYSICAL SURVEY
DATA INTERPRETATIONS

(b) Intake Pipeline Relocation Alignment

Seismic Survey No.	S4		S5		S6		S7		S8	
Profile Direction	F	R	F	R	F	R	F	R	F	R
V1 (fps)	1000	750	800	900	800	1000	800	1000	800	1000
Material	t	t	t/f	t/f	f/wfg	f/wfg	t/f	t/f	t/f	t/f
Depth to Base (ft)	2	4.5	5	11	6.5	9.5	8	5	3	2
V2 (fps)	4400	3400	4000	2250	2600	9500	6800	2700	3800	2100
Material	mfg	mfg	mfg	wfg	wfg	sfg	sfg	wfg	mfg	wfg
Depth to Base (ft)	42.8	13	33.5	22.8	19.7	--	--	18.1	12.7	11.5
V3 (fps)	17000	13000	8500	8000	9000	--	--	5200	5300	5300
Material	rock	rock	rock	rock	rock	--	--	sfg	sfg	sfg
Depth to Base (ft)	--	--	--	--	--	--	--	56	32.3	28.5
V4 (fps)	--	--	--	--	--	--	--	15000	15000	8000
Material	--	--	--	--	--	--	--	rock	rock	rock

3.3 RESULTS OF THE SEISMIC SURVEY (continued)

Table 1 (continued)

SEISMIC REFRACTION GEOPHYSICAL SURVEY
DATA INTERPRETATIONS

(c) Discharge Line and 60" Water Main Relocation Alignments

Seismic Survey No.	S9		S10		S11		S12	
Profile Direction	F	R	F	R	F	R	F	R
V1 (fps)	950	950	1350	1350	1750	1000	1500	1025
Material	t	t	wfg	wfg	mfg	wfg	wfg	wfg
Depth to Base (ft)	4	1	9	9.5	6	2.5	8.5	6
V2 (ft)	4000	5000	4600	5200	3500	3500	5600	5500
Material	mfg	mfg	mfg	sfg	mfg	mfg	sfg	sfg
Depth to Base (ft)	9.5	16.9	29.7	--	32.4	19.1	43.9	45.4
V3 (fps)	8000	8000	6000	--	8000	5700	15000	15000
Material	sfg/rk	sfg/rk	sfg	--	rock	sfg	rock	rock

Seismic Velocity Interpretation / Material Correlation:

t	Topsoil (residual soil)
t/f	Topsoil/fill
f/wfg	Fill/weakly cemented fanglomerate
wfg	Weakly cemented fanglomerate
mfg	Moderately cemented fanglomerate
sfg	Strongly cemented fanglomerate
sfg/rk	Strongly cemented fanglomerate (?) (possibly rock)
rock	Bedrock (probably schist; possibly quartzite)

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the seismic survey, reconnaissance of the site, and data interpretations, the following summary of conclusions and recommendations are provided:

4.1 The geologic conditions of the pipeline relocation sites include a stratigraphic sequence consisting of (1) local accumulations of variably compacted man-placed fills, (2) thin pockets of residual gravelly topsoils, (3) sandy to gravelly and weakly to strongly cemented fanglomerate, and (4) strongly foliated and fractured metamorphic bedrock.

The predominent surficial geologic unit is the fanglomerate. No bedrock outcrops were found along the proposed alignments; however, the subsurface explorations by others and the results of the seismic survey indicate the presence of a buried bedrock surface ranging from about 9 feet to about 56 feet below ground surface (average about 30 feet).

4.2 The fills and residual soils (low velocity horizon) locally mantle the fanglomerate to calculated depth ranging from about one foot to 11 feet below ground surface. The average depth is about 5 feet.

4.3 Intermediate to high velocity horizons are included within the fanglomerate unit. The wide range of seismic wave velocities are interpreted to be related to the extensive variability of the consolidation and cementation within the unit. Seismic velocities range from 1,000 feet per second (fps) to 9,500 fps. Thicknesses of the fanglomerate, which varies from place to place across the site, range from about 5 feet to at least 50 feet (or more) and averages about 32 feet (or more) along the twelve survey lines.

4.4 The metamorphic bedrock (high velocity horizon) is expected to be encountered at depths ranging from about 9 feet to at least 56 feet below ground surface. Interpretations of the seismic data suggest the bedrock could be encountered along portions of pipeline relocations at the following depths:

- o 66" water main - about 19 feet to 33 feet;
- o Intake pipeline - about 13 feet to 56 feet;
- o Discharge line - about 9 feet to 17 feet; and
- o 60" water main - about 32 feet to 45 feet.

4.0 CONCLUSIONS AND RECOMMENDATIONS (continued)

4.5 The excavateability of the site materials based on the results of the seismic refraction geophysical surveys (Figure 2) made along the pipeline relocation alignments are summarized as follows:

Seismic Velocity (feet per second)	Geologic Materials	Qualitative Estimate Ease of Excavation
750 to 1,150	Fill; residual soils; uncemented, some weakly cemented fanglomerate	Easy
1,000 to 1,500	Weakly cemented fanglomerate	Easy
1,500 to 2,750	Weakly to moderately cemented fanglomerate	Easy
2,750 to 5,000	Moderately cemented fanglomerate	Moderate; heavy ripping
5,000 to 9,500	Strongly cemented fanglomerate	Difficult; expect to blast
8,000 to 17,000	Bedrock	Difficult; blasting required

4.6 Excavated steep slopes made in the fills and residual soil materials may be unstable due to lack of consolidation, cohesion, and/or cementation. It is recommeded that either trench boxes, shoring, or slope lay-back be employed to mitigate the potential for slope failure during construction and to protect workers.

Cut slopes made in the fanglomerate should perform adequately depending upon the degree of caliche cementation; therefore, construction slopes should be evaluated on a case-by-case basis as excavations progress to determine if temporary stabilization is required.

Construction cut slope stability in the bedrock units will depend upon the orientation of the potential planes of weakness in the rock (ie. foliations, bedding, joints, etc.) relative to the orientation of the cut slope. If the planes of weakness dip out of the slope face (daylight) at an angle flatter that the cut slope face angle, adequately designed trench boxes, shoring, and/or slope lay-back should be employed to mitigate the potentially unstable slope condition(s).

4.0 CONCLUSIONS AND RECOMMENDATIONS (continued)

4.7 Blasting is expected to be required to efficiently complete the excavations to proposed grades. Due to the proximity of the Treatment Plant structures and residential properties to areas where blasting may be performed, pre-blast surveys of the structures and blast monitoring (peak particle velocity and blast overpressures) should be performed.

5.0 GEOPHYSICAL SURVEY LIMITATIONS

The seismic survey data presented in this report are derived from and interpreted from indirect geophysical investigative techniques employed at the specific locations indicated, from observations made of the surficial geologic conditions exposed at the site, and from the analysis of maps and reports prepared by other. No exploratory boring or test excavations were made by Geological Consultants during this study; however, data from test borings made by T & H as part of their geotechnical investigation were included in the data base to aid with the interpretations of the seismic survey data.

The interpretation made at the specific seismic survey sites are believed to be reasonable based on the information available at the time of this study; however, the interpretations may not represent subsurface conditions at other locations. Geologic contacts between rock, soil units, and/or velocity zones (horizons) are approximate and may be either gradual or abrupt. No exploratory borings or test excavations were made by Geological Consultant during this study to confirm the geophysical interpretations.

The conclusions and professional opinions expressed in this report were developed by Geological Consultants for Thomas-Hartig and Associates Inc. in accordance with generally accepted geological principals and practices. The data, conclusions, and recommendations should be considered to relate to the specific project and locations referenced in this report. Geological Consultant does not accept liablity for interpretations made by other parties who may use the data presented herein. If any changes are made in the project as outlined in this report, the conclusions and/or recommendations contained in this report shall not be considered valid unless the changes are reviewed and the conclusions and recommendations of this study are modified and/or approved in writing by Geological Consultants.

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