Appendix B
Geologic Mapping Procedures Open Excavations

B-I. Purpose of Excavation Mapping

The primary purpose of the excavation map and/or foundation geologic map is to provide a permanent record of conditions during excavation. This permanent record will assist in making the most equitable contract adjustments, provide otherwise unattainable information for use in diagnosing postconstruction problems and in planning remedial action, and allow for a better interpretation of postconstruction foundation instrumentation data. An important prelude to performing geologic mapping of the final foundation and/or excavation is monitoring conditions during excavation. Condition monitoring during excavation provides the basis for discovering, at the earliest possible moment, those adverse conditions (differing from original predictions) that may cause expensive design modifications and construction delays. Foundation and other excavation surfaces should not be covered until mapping is complete and approved by the project geologist or geotechnical engineer.

A plan for monitoring also provides a basis for installing appropriate instrumentation and interpreting foundation instrumentation data as the excavation proceeds. The Instrumentation Data Package (Woodward-Clyde Consultants 1996), a PC-based program, which can store, retrieve, and graphically present instrumentation data related to construction monitoring, will soon be available through the U.S. Army Engineer Waterways Experiment Station..

B-2. Possible Adverse Conditions

a. Adverse conditions can affect the stability of excavated slopes during construction, the stability of permanent slopes, foundation settlement, foundation bearing capacity, sliding stability of structures, and planned water control measures such as grouting and drainage requirements. Such conditions can occur in both soil and rock. Features of engineering significance in both soil and rock frequently occur in geometrically predictable patterns. The prediction of geometry is enhanced by knowledge of the local geologic history.

b. Adverse conditions that occur in soils include soft compressible zones of clay or organic materials; lateral compositional changes related to variations in depositional environment; changes in the relative density of granular materials; fill containing trash or other undesirable materials; swelling or slaking in hard, fissured clays; and changes in permeability.

c. Adverse conditions that can occur in rocks include weathering, soft interbeds in sedimentary and volcanic rocks, lateral changes, presence of materials susceptible to volume change (e.g., swelling clay shales, sulfide-rich shales, gypsum, and anhydrite), adversely oriented fractures (e.g., joints, bedding planes, schistosity planes, and shear planes), highly fractured zones, faults, joints, and shear planes filled with soft materials, and exceptionally hard layers that inhibit excavation or grout/drain hole drilling.

d. Adverse conditions related to ground water include unexpectedly high cleft or pore pressures which reduce effective stress, swelling materials, slaking, piping, sand runs, and uplift pressures on partially completed structures. It should be noted that most water-induced problems stem from unanticipated changes in the ground water regime.

B-3. Monitoring and Mapping Procedures

a. The difference between excavation monitoring and record mapping is small; both involve the observation and reporting of natural conditions. The need for monitoring the condition of slopes during construction include safety during construction and the prediction of conditions at grade. Potential problem areas can be detected and avoided, or corrective treatment can be started before a problem becomes severe.

b. Depending on the speed of excavation, monitoring should be performed on a daily, twice weekly, or weekly basis. Because of increasing steepness, rock slopes become less and less accessible as excavation progresses. Table B-l is an excavation monitoring checklist, which, if followed, should ensure adequate coverage. Geologic sections can be constructed to assist in predicting the locations of features at grade. While many geologic features are arcuate or sinuous, many are planar. The location of a planar feature at grade can be found by graphic projection or by calculation as shown on Figure B-l.

c. Excavation and foundation mapping are generally performed on an intermittent and noninterference basis. If advantage is not taken of every mapping opportunity, the rock surface may be covered before another opportunity occurs or the contractor may be subjected to undue delay. Furthermore, systematic mapping makes for better monitoring. Thoroughness of mapping, type of mapping procedure, and sequence in which it is accomplished are functions of the purpose for which the mapping is required and of the construction schedule.

d A number of items should be done to prepare for mapping before the excavation is begun.

(1) The geologist with mapping responsibility should make an interpretation, or confirm the existing interpretation of the geologic conditions (a geologic model). The geologist should decide on a mapping strategy and prepare field base map sheets. The map scale is partially dependent on the amount of detail to be mapped. If the excavation will be in hard, fractured rock, a field scale of 1 cm = 0.6 m (1 in. = 5 ft) and a final compiled map scale of 1 cm = 1.2 m (1 in. = 10 ft) would be suitable. If the excavated material is a soil, a soft, lightly fractured sedimentary rock, or a glacial till, field and compiled scales of 1 cm = 1.2 m (1 in. = 10 ft) and 1 cm = 6 m (1 in. = 50 ft), respectively, could be suitable. The field base maps should have reference lines for location purposes. In structure foundation areas, the structure outline will be enclosed by concrete forms that are easily located, making handy reference lines. The location of features inside reference lines can be facilitated by use of cloth tape grids, or with differential GPS.

(2) Decide at what intervals to map as the excavation progresses. Mapping intervals will be affected by a number of factors including the rate of excavation, lift thicknesses, and the need for temporary slope protection. In most cases, the mapping should be done in the plane of slopes; projection to other planes can be made after the mapping is completed. An exception occurs if mapping is done with a plane table. In this case, a horizontal reference plane is required. Camera positions should be selected for sequential photographs during excavation. Reference lines for mapping can be provided by stretching tapes from the top to bottom of the slope at 3- to 6-m (10- to 20-ft) intervals. Final excavation topographic maps should be made that can be used as a base for the geologic map.

(3) Determine whether the side slopes will be too steep for unassisted access. Temporary soil slopes usually range from lV on 3H to 1V on lH. Temporary rock slopes usually range from 1V on 1H to vertical. It is not possible to walk slopes steeper than 1V on 1-1/2H unless they are very irregular. Thus, safety lines will be needed on most rock slopes and on some soil slopes.

Table B-1
Suggested Geologic Excavation Monitoring Checklist

Project ____________________

Excavation for ____________________ Structure

Period: ____________ To ____________

1. Excavation Progress:

   a. Type Excavation: (common or rock)

   b. Location: Sta ____________ To ____________ Offset ____________

2. Rock or soil type: ____________
3. Rock or soil conditions: (hardness, stiffness, weathering, fracturing, sloughing, etc.)
4. Water inflow, locations and gpm: ____________
5. Significant features or defects: (those which may cause problems (and/or may extend to grade)
6. Slope protection: (protection or reinforcement, location, type thickness, etc.)
7. Blasting conditions: (presplitting locations and successes, production blasting, powder factor, hole spacing, delay patterns, deviations from approved rounds, fragment size, overbreak, etc.)
8. Ripping conditions: (single or multitooth, drawbar horsepower, easy or hard, disturbance below grade or slopes)
9. Additional remarks: (unusual incidents, accidents, explorations, etc.)
10. Mapping progress:

    a. Location ____________

    b. Adequacy of coverage (rock surface clean?, percent obscured by slope protection?, etc.)

    c. Photos taken: ____________ (where, or what) ____________

11. Instrumentation installed:

    a. Location ____________

    b. Type and amount ____________

12. Instrumentation read:

    a. Location ____________

    b. Type ____________

(4) Where the slopes are nearly vertical, consideration can be given to mapping on large-scale photographs. However, there must be time to produce the photographs for use as a map base.

e. It is desirable to have a contract provision for interim rock surface cleanup. The final foundation cleanup item will suffice for mapping purposes at final grade. However, the need may arise for detailed examination of particular areas during excavation. Excavation slopes may need sealing or other interim protection against weathering.

f. During mapping, complete descriptions of all geologic features should be made (e.g., rock types, bedding, fracturing, joints, shear zones, etc.). All features, geologic and otherwise (including ledges and breaks in slope), should be located and drawn on the base map. Table B-2 provides descriptive criteria for use during mapping.

g. To the maximum extent possible, U.S. Geological Survey (USGS) map symbols or variations of these symbols should be used. In most cases, the geologist should represent geologic features by showing the trace of the feature on the map. The trace will allow a reasonably accurate location of each significant feature.

h. Frequently, foundation maps and sections are prepared with rock type symbols covering the entire area of the particular rock type. However, if all the recognizable distinct geologic features are also located on the drawing, it will be cluttered and difficult to read. Thus, the primary purpose of the foundation record will be obscured. Each mark on the foundation map should have physical significance.

i. Records should be made of foundation treatment, such as grout hole locations, dental work, pneumatic concrete, rock-bolt locations, and wire mesh. Portrayal of such treatment can be included on the geologic map. However, if the resulting map is too cluttered, either the treatment should be portrayed in a series of transparent overlays, or the scale of the mapping should be enlarged. A Geographic Information System (GIS) is ideal for subdividing the geotechnical (and other construction) information into a series of data layers that can be digitally overlaid. In a GIS, map scales can easily be altered, and adjustments of the geotechnical information can readily be accomplished for presentation in a comprehensible format.

j. The importance of adequate photography and videos of the excavation process and the final slope and foundation conditions cannot be overemphasized. Complete video and photographic coverage is as important as the foundation maps. All are required for an accurate and complete record of encountered conditions. Photographs and videos can be readily incorporated into a GIS.

k. The photographic coverage should include unobstructed, medium-scale photographs of the entire foundation and closeup views of significant geologic features; a photograph through a mat of reinforcing steel is useless. All photographs should be annotated by the geologist and clearly sited on a photograph location map.

B-4 Examples of Foundation Maps

Figures B-2 through B-8 are examples of foundation maps. Figures B-2 and B-3 depict foundation maps for concrete structures in metavolcanic and igneous rocks where the geologists have attempted to portray the entire trace of all significant geologic features. Figure B-4 is a tunnel map in the same kinds of materials as portrayed in Figure B-3 and also provides a legend for Figure B-3. Figure B-5 is a smaller scale map of an excavation in metavolcanic rocks and also includes the foundation mapped in detail in Figure B-3. Figure B-6 is a foundation map for the impervious core of an earth dam founded on metavolcanic and igneous rocks. The geologist has mapped the full traces of shears, contacts, and igneous dikes but has shown joints and lineations by symbols only. Figure B-7 depicts a detailed foundation map for a concrete structure founded in sedimentary rocks. The geologist has located the full trace of all significant geologic features. Figure B-8 depicts the foundation for a cutoff trench in sedimentary rocks.

Table B-2
Descriptive Criteria, Excavation Mapping

1. Rock Type.

a. Rock Name (Generic).

b. Hardness.

(1) Very soft: can be deformed by hand.

(2) Soft: can be scratched with a fingernail.

(3) Moderately hard: can be scratched easily with a knife.

(4) Hard: can be scratched with difficulty with a knife.

(5) Very hard: cannot be scratched with a knife.

c. Degree of Weathering.

(1) Unweathered: no evidence of any mechanical or chemical alteration.

(2) Slightly weathered: slight discoloration on surface, slight alteration along discontinuities, less than 10 percent of the rock volume altered, and strength substantially unaffected.

(3) Moderately weathered: discoloring evident, surface pitted and altered with alteration penetrating well below rock surfaces, weathering "halos" evident; 10 to 50 percent of the rock altered, and strength noticeably less than fresh rock.

(4) Highly weathered: entire mass discolored, alteration pervading nearly all of the rock with some pockets of slightly weathered rock noticeable, some minerals leached away, and only a fraction of original strength retained (with wet strength usually lower than dry strength).

(5) Decomposed: rock reduced to a soil with relict rock texture (saprolite), and generally molded and crumbed by hand.

d. Lithology, Macro Description of Mineral Components. Use standard adjectives such as shaly, sandy, silty, and calcareous. Note inclusions, concretions, nodules, etc.

e. Texture and Grain Size.

(1) Sedimentary rocks:

Texture	Grain Diameter	Particle Name	Rock Name
*	80 mm	Cobble	Conglomerate
*	5 to 80 mm	Gravel	
Coarse grained	2 to 5 mm		
Medium grained	0.4 to 2 mm	Sand	Sandstone
Fine grained	0.1 to 0.4 mm		
Very fine grained	0.1 mm	Clay, silt	Shale, claystone, siltstone

* Use clay-sand texture to describe conglomerate matrix.

(2) Igneous and metamorphic rocks:

Texture	Grain Diameter
Coarse grained	5 mm
Medium grained	1 to 5 mm
Fine grained	0.1 to 1 mm
Aphanite	0.1 mm

(Sheet 1 of 3)

Table B-2 (Continued)

(3) Textural adjectives: Use simple standard textural adjectives such as porphyritic, vesicular, pegmatitic, granular, and grains well developed, but not sophisticated terms such as holohyaline, hipidiomorphic granular, crystalloblastic, and cataclastic.

2. Rock Structure.

a. Bedding.

(1) Massive: 3 ft thick.

(2) Thick bedded: beds from 1 to 3 ft thick.

(3) Medium bedded: beds from 0.3 ft to 1 ft thick.

(4) Thin bedded: beds less than 0.3 ft thick.

b. Degree of Fracturing (jointing).

(1) Unfractured: fracture spacing 6 ft.

(2) Slightly fractured: fracture spacing 3 to 6 ft.

(3) Moderately fractured: fracture spacing 1 to 3 ft.

(4) Highly fractured: fracture spacing 0.3 to 1 ft.

(5) Intensely fractured: fracture spacing 0.3 ft.

c. Shape of Rock Blocks.

(1) Blocky: nearly equidimensional.

(2) Elongated: rodlike.

(3) Tabular: flat or bladed.

3. Discontinuities.

a. Joints.

(1) Type: bedding, cleavage, foliation, schistosity, and extension.

(2) Separations: open or closed; how far open.

(3) Character of surface: smooth or rough; if rough, how much relief; average asperity angle.

(4) Weathering or clay products between surfaces.

b. Faults and Shear Zones.

(1) Single plane or zone: how thick?

(2) Character of sheared materials in zone.

(3) Direction of movement, and slickensides.

(4) Clay fillings.

c. Solution Cavities and Voids.

(1) Size.

(Sheet 2 of 3)

Table B-2 (Concluded)

(2) Shape: planar, irregular, etc.

(3) Orientation: (if applicable) developed along joints, bedding planes, at intersections of joints and bedding planes, etc.

(4) Filling: percentage of void volume and type and of filling material (e.g., sand, silt, clay, etc.).

(Sheet 3 of 3)

$$B = \frac{D}{\tan\beta \sin\alpha} - d \text{ and}$$

$$H = \frac{D - d\,(\tan\beta \sin\alpha)}{1 - \cot\lambda \tan\beta \sin\lambda} \text{ or}$$

$$B = H\left(\frac{1}{\tan\beta \sin\alpha} - \frac{1}{\tan\alpha}\right) \text{ where:}$$

α = acute angle between strike of planar feature and section
β = true dip of planar feature
λ = acute angle of excavation slope
B = distance, in section, from toe of excavation slope to outcrop at excavation grade
d = distance, at section, from toe of excavation slope to surface outcrop of feature
D = depth of excavation
H = height in section of feature outcrop above grade

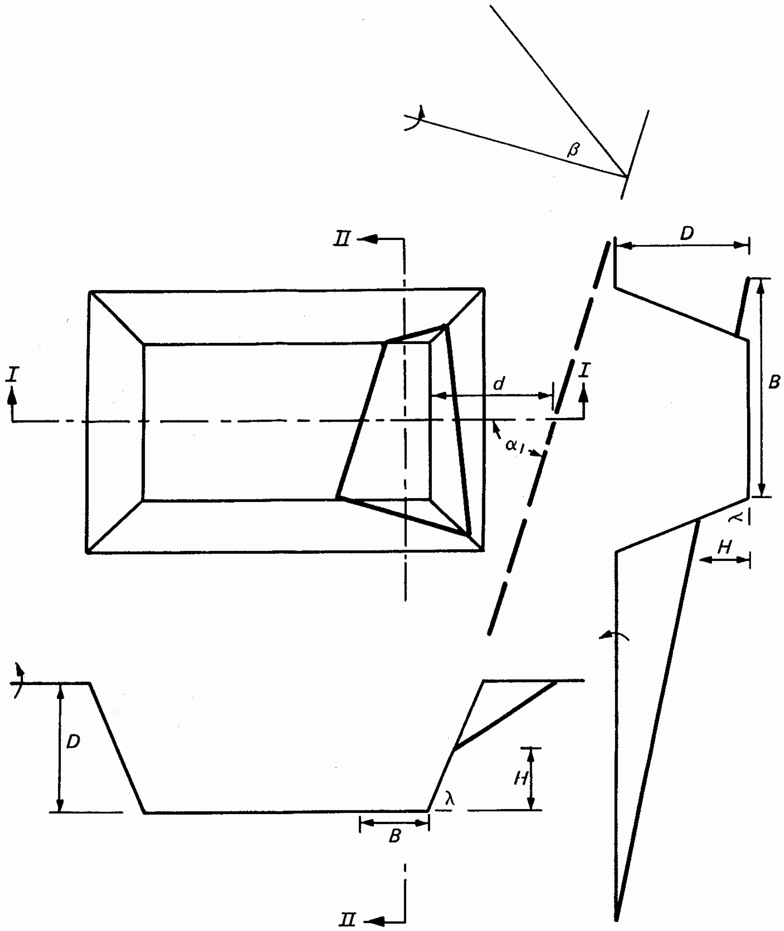

Figure B-1. Excavation plan and sections showing intersecting planar feature

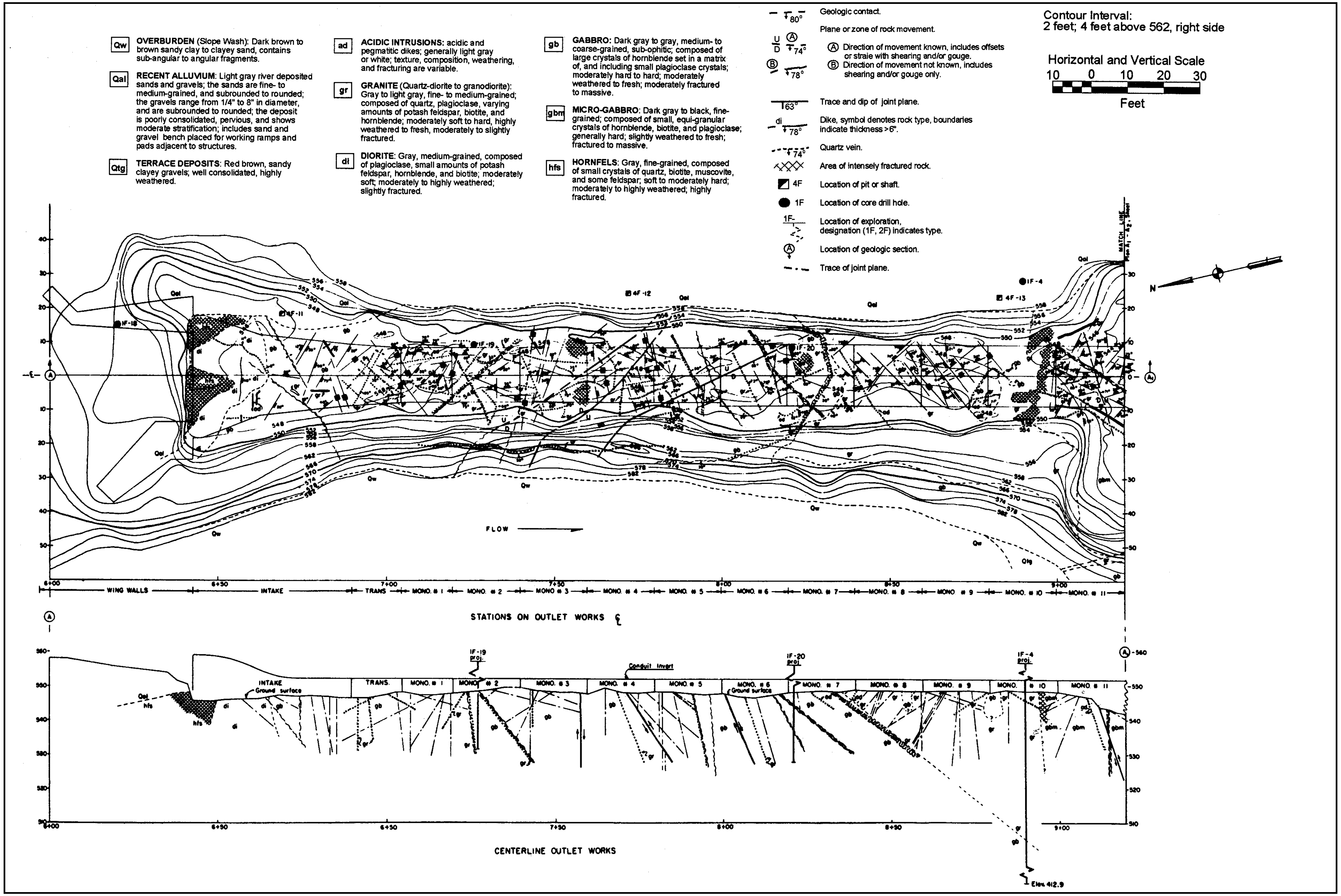

Figure B-2. Example of a foundation map for concrete structure on metavolcanic and igneous rocks

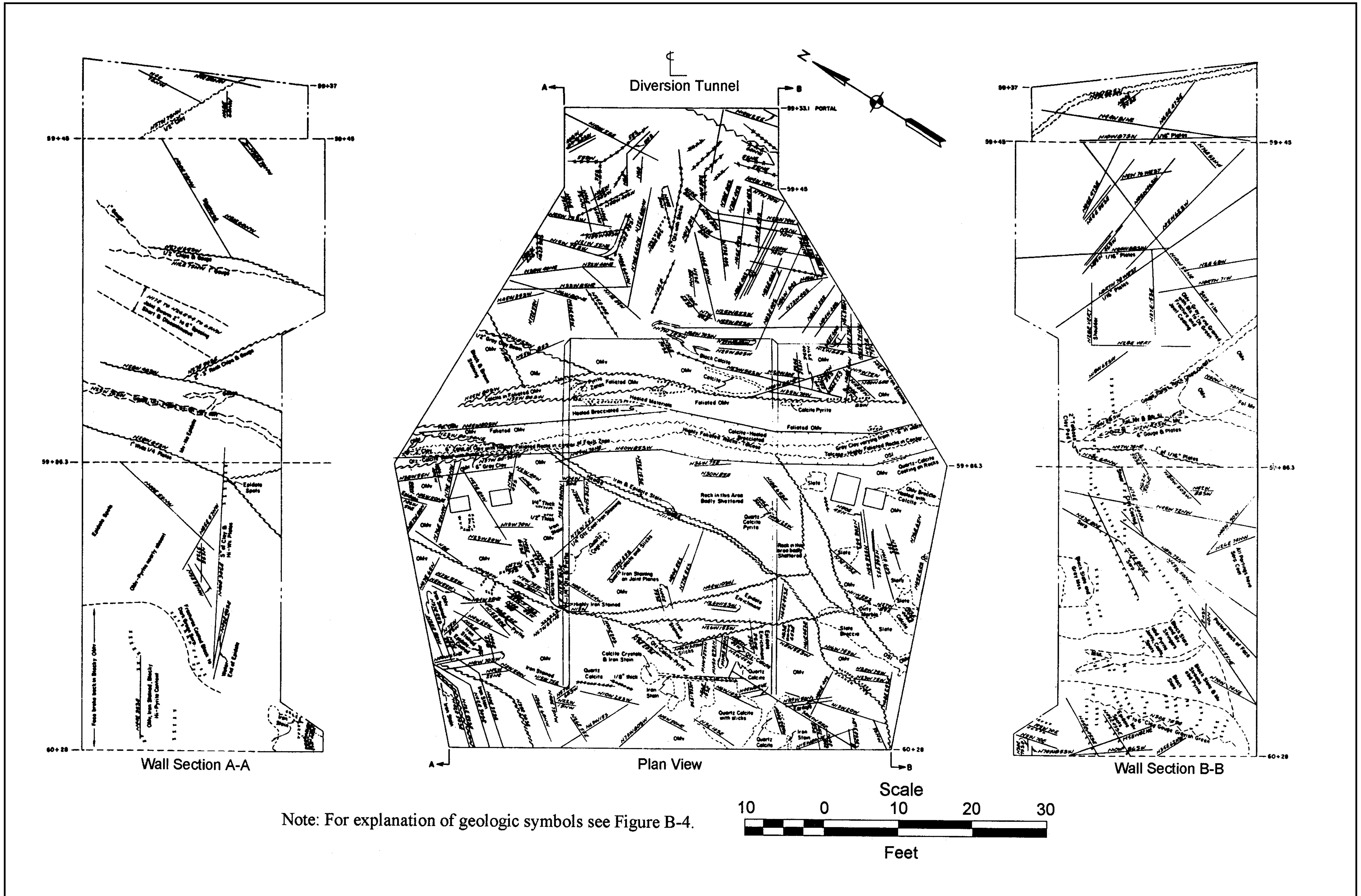

Figure B-3. Example of foundation map for structure on metamorphic rocks

EXPLANATION OF SYMBOLS FOR FIGURE B-3

Mv	**METAVOLCANICS**: Grayish green, moderately hard to hard; fine-grained to fragmented; contains visible amounts of dark green pyroxene, calcite, quartz,and epidote.
Mss	**METASANDSTONE**: Black to dark gray, moderately hard to hard; fine-grained; massive; variable amounts of metavolvanic fragments and black slate.
S1	**SLATE**: Black, moderately hard; fine-grained; moderately fissile; contains variable amounts of calcite and pyrite.
S1br	**SLATE BRECCIA**: Black with gray streaks; moderately hard; contains layers and fragments of metasandstone and metavolvanic rock in a slaty groundmass; crudely foliated.

OLDER METAMORPHICS

OMv	**METAVOLCANICS**: Light gray to gray; moderately soft to moderately hard; fine-grained; crudely to moderately foliated; contains black slate streaks.
TOMv	**METAVOLCANICS**: Partially replaced by soapstone or talc.
OS1	**SLATE**: Black; moderately soft to moderately hard; fine-grained; moderately fissile to fissile.
OTS1	**SLATE**: Partially replaced by soapstone or talc.
OS1br	**SLATE BRECCIA**: Dark gray to black; moderately hard; contains angular fragments of metasandstone and metavolvanic; moderately fissile.
OMvc	**METAVOLCANICS**: **CONGLOMERATE**: Greenish gray, moderately hard to hard; fine-grained metavolvanic groundmass enclosing rounded fragments of metavolvanic, metasandstone, chert, marble, and slate.
OMss	**METASANDSTONE**: Gray, fine- to medium-grained; moderately hard.
Mar	**MARBLE**: Gray; moderately hard; finely crystalline.
Serp	**SERPENTINE**: Dark green to black; soft to moderately hard; waxy luster; partially to completely replaces surrounding rock types.
Md	**MICRODIORITE DIKES**: Gray; moderately hard; fine- to medium-grained; contains numerous transverse quartz calcite seams and are from 5 to 46 cm (2 to 18 in.) wide.
xxx	**QUARTZ-CALCITE**: Veins.

cont.	contorted
fol.	foliated
stks.	streaks
crud.	crudely
○	grout hole
●	IF-1 core hole
N69W / 50S	strike and dip of joint
N10W / 60E	strike and dip of cleavage
- - - - -	geologic contact
	fault
	shear

Notes:

1. Hard - difficult to scratch with a knife.
2. Moderately Hard - can be easily scratched with a knife.
3. Moderately Soft - can be carved with a knife.
4. Soft - can be gouged with a copper penny.
4. Very Soft - can be gouged with a finger nail.
6. See text for detailed rock description.

Figure B-4. Explanation of symbols

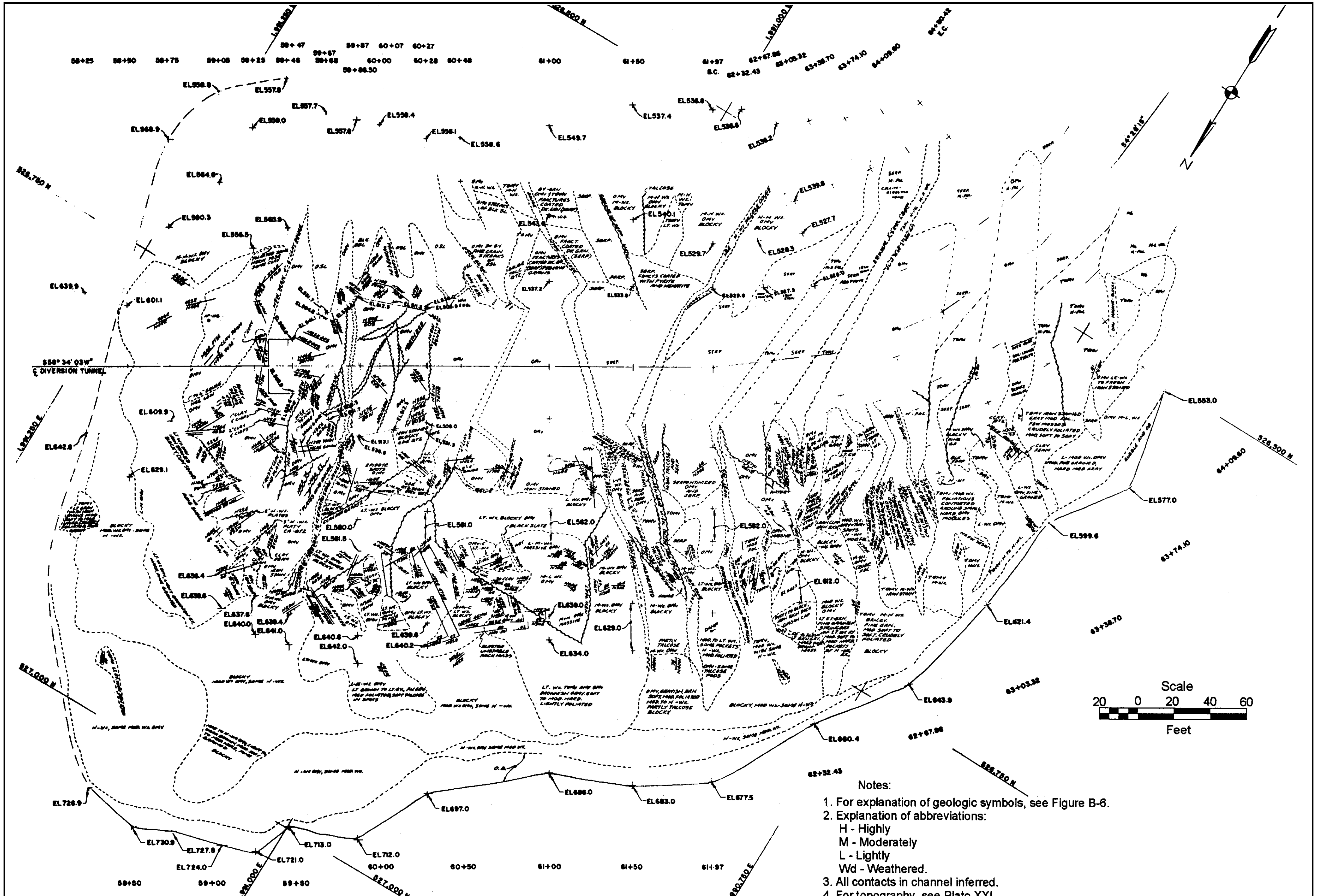

Figure B-5. Example of excavation map including area covered by Figure B-3

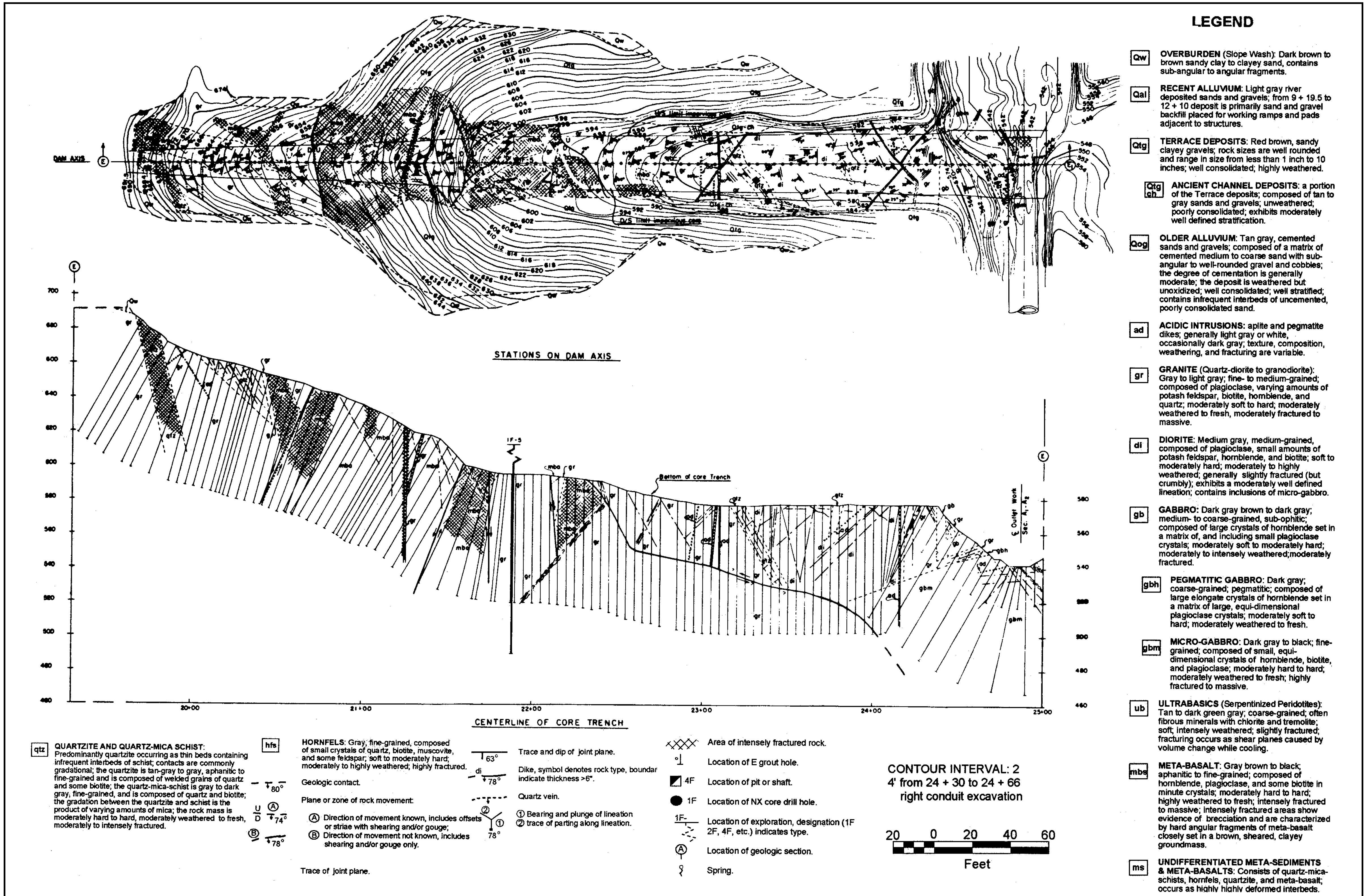

Figure B-6. Example of foundation map for earth dam impervious core on meta-volcanic and igneous rocks

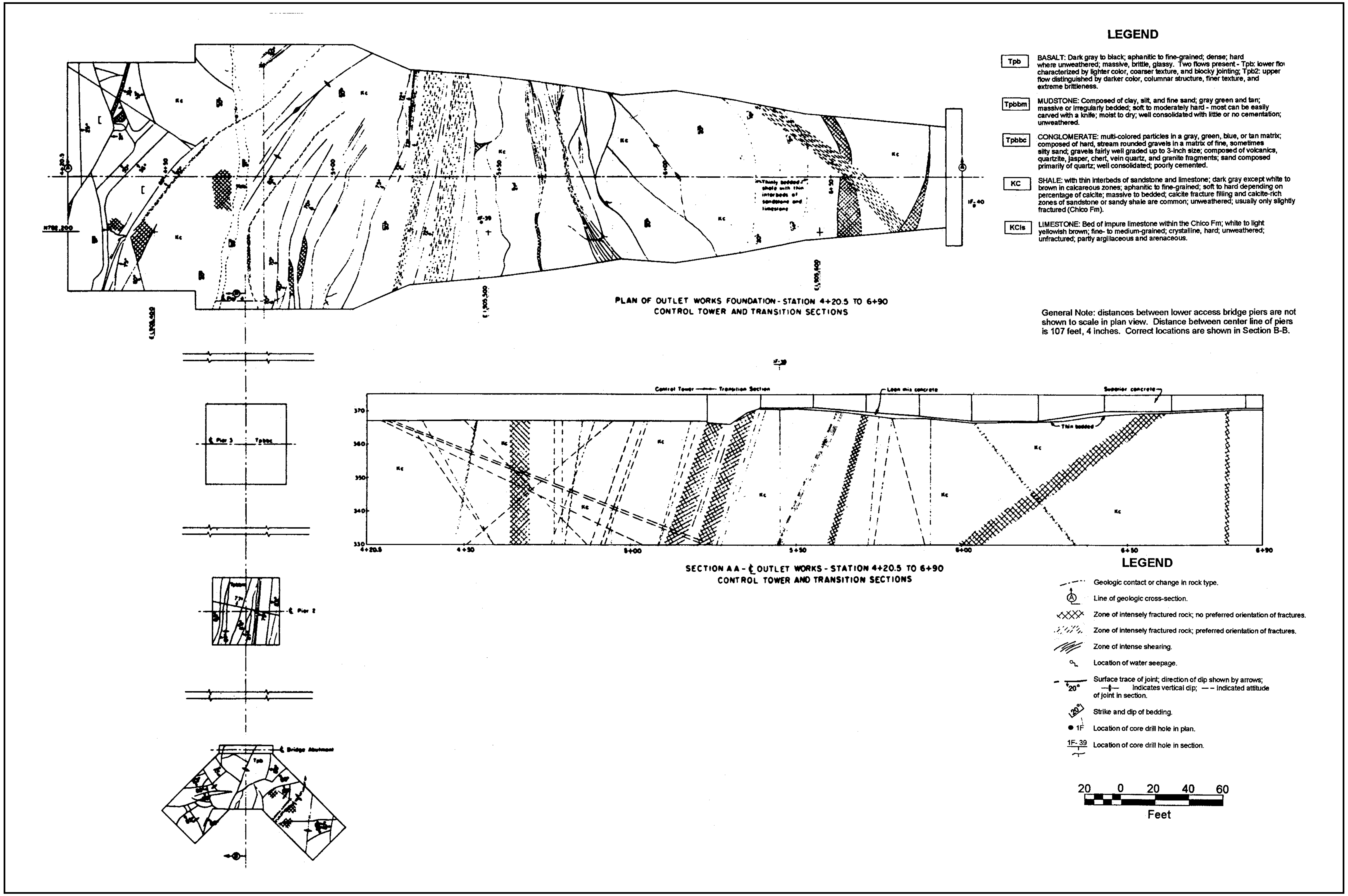

Figure B-7. Example of foundation map for concrete structure on sedimentary rocks

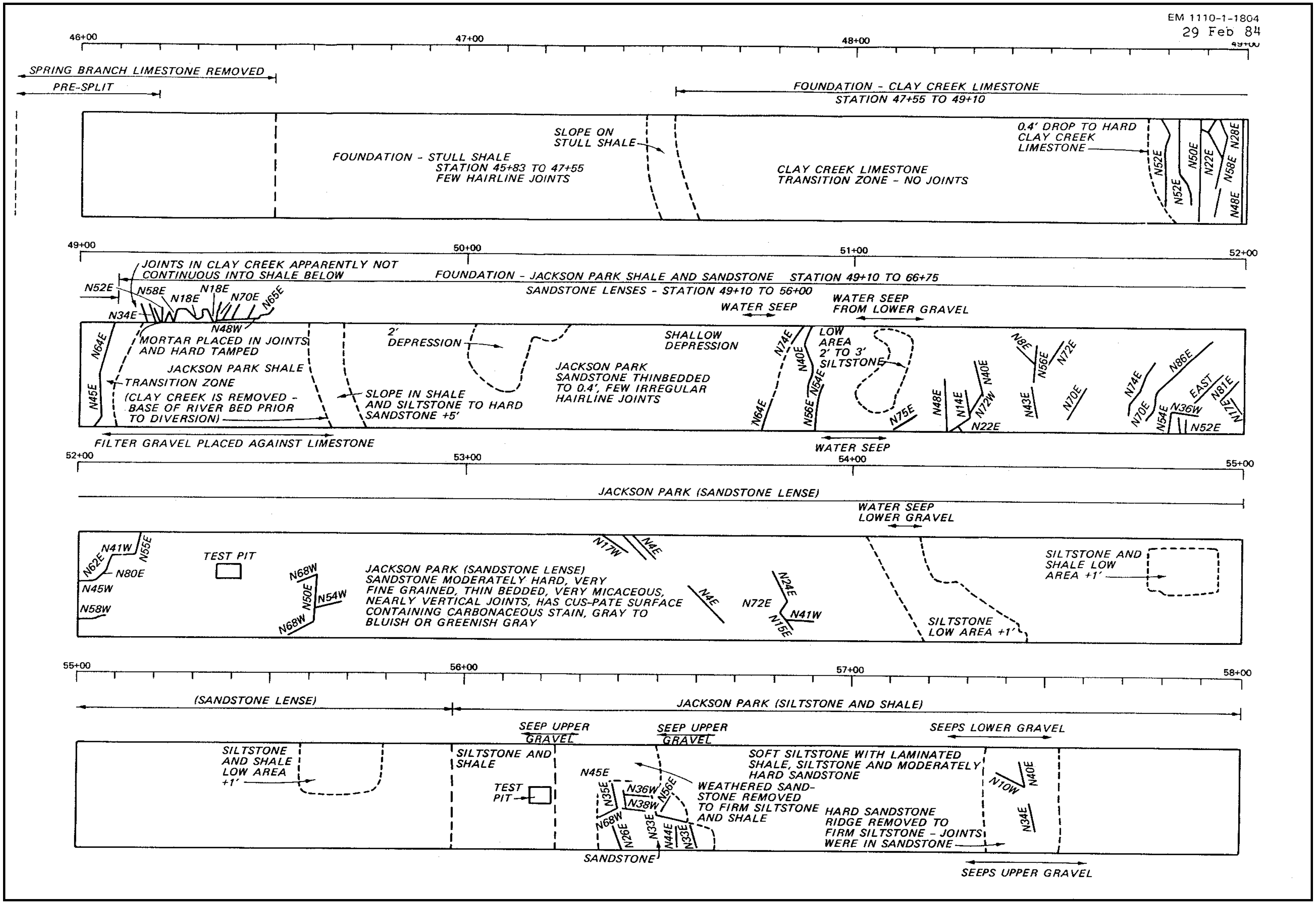

Figure B-8. Foundation map for earth dam impervious core on sedimentary rocks (note: 1 ft = 0.3 m)