CHAPTER 10.0
FOUNDATION INVESTIGATION REPORT

Throughout the foundation design and construction process good communication and interaction should exist between the foundation engineer, structural engineer, and construction engineer. For example, even before the exploration program can be planned, the structural engineer should provide the foundation engineer with the proposed span arrangement and approximate structural loads. This interaction must be continued throughout the design and construction process to insure that the foundation design developed is compatible with the proposed structure type and is cost-effective. The importance of this communication and interaction cannot be overemphasized. Many design and construction problems are prevented through good communication.

The Foundation Investigation Report is the tool used to "communicate" the site conditions and design and construction recommendations to the bridge, roadway design, and construction engineers. The data from subsurface investigations usually are referred to continuously and for many different purposes during the design period, construction period, and, frequently, after completion of the project (resolving claims). Therefore, the foundation report should be clear, concise, and accurate. It is an extremely important document whose preparation deserves special care and effort.

10.1 GUIDELINES FOR WRITING A GOOD REPORT

The following guidelines apply to writing a good foundation report:

1. The soils engineer responsible for the report preparation should have a broad enough background in engineering to have some knowledge of the foundation requirements and limitations for various types of structures.

2. The report should contain an interpretation of subsurface conditions.

3. The report should contain specific engineering recommendations for design.

4. The materials and conditions which may be encountered during construction should be discussed.

5. The soils engineer should attempt to anticipate possible design and construction problems and make recommendations for their solution.

6. Recommendations given should be brief, concise, and, where possible, definite; don't be "wishy-washy."

7. Reasons and supporting data for recommendations should be included.

8. Extraneous data which are no use to the designer or project engineer should be omitted.

9. The report should include any special notes which should be placed on the plans or in the special provisions.

10.2 FOUNDATION REPORT OUTLINE

The following outline may be used as a general guide for presenting data in the foundation investigation report. The outline includes key items for which specific recommendations should be made, if pertinent to the given project.

A. Text

1. Introduction

2. Scope of Investigations
   a. Field explorations
   b. Lab testing

3. Interpretation of subsurface conditions.

4. Approach Embankment Considerations (Primarily for fills over soft weak subsoils).
   a. Stability
      1. Excavation and replacement of unsuitable materials
      2. Counterberm
      3. Stage construction - time delay
      4. Other treatment methods - change alignment, lower grade, lightweight fill, etc.
      5. Estimated factors of safety with and without treatment - estimated costs for treatment alternates - recommended treatment
   b. Settlement of subsoils
      1. Estimated settlement amount
      2. Estimated settlement time
      3. Surcharge height
      4. Special foundation treatment - vertical drains, soil densification, etc.
      5. Waiting periods
      6. Downdrag on piles
      7. Lateral squeeze of soft subsoils
   c. Construction considerations
      1. Select fill material - gradation and compaction requirements
      2. Construction monitoring (instrumentation)
   d. Special notes

5. Spread footing support
   a. Elevation of bottom of footing - based on frost depth, scour depth, or depth to competent bearing material
   b. Allowable soil pressure - based on settlement or bearing capacity: considering soil, adjacent foundations, water table, etc.
   c. Width of footing used in computations
   d. Special notes

6. Pile support
   a. Friction or end bearing or both
   b. Suitable pile types - reasons for choice and/or exclusion of types

c. Pile tip elevations
    1. Estimated tip elevation
    2. Specified tip elevation - explain reasons, such as underlying soft layers, negative skin friction, scour, piles uneconomically long, etc.
d. Estimated pile lengths
e. Allowable pile loads (design load)
f. Estimate of pile group settlement - only of practical significance for pile groups in cohesive soils and large groups in a cohesionless soil deposit underlain by compressible soils
g. Test piles to establish order lengths - specify test locations for maximum utility
h. Static pile load tests
i. Dynamic pile load tests (pile analyzer)
j. Driving criteria - based on dynamic pile formula or wave equation analysis
k. Corrosion effects - of particular concern in marine environments
1. Special notes
m. Actual driving resistance to reach estimated pile length

7. Drilled shaft support
    a. Shaft diameter
    b. Shaft length
    c. Allowable load
    d. Estimated settlement
    e. Load tests or integrity tests
    f. Special notes

8. Special design considerations
    a. Pile or drilled shaft lateral load capacity
    b. Seismic design - design earthquake ground acceleration, liquefaction potential (loose saturated sands and silts)
    c. Lateral earth pressures against retaining walls and high bridge abutments

9. Construction considerations
    a. Water table - fluctuations, control in excavation, pumping, tremie seals, etc.
    c. Excavations - safe slopes for open excavations, need for sheeting, shoring, etc.
    d. Drilled shafts - water table location, artesian water, boulders or obstructions, likely construction method (dry, casing, or slurry)
    e. Adjacent structures - protection against damage from excavation, pile driving, drainage, etc.
    f. Special notes.

B. Graphic Presentations

1. Map showing project location

2. Detailed plan of the site showing proposed structure(s), borehole locations, and existing structures

3. Laboratory test data

4. Finished boring logs and/or interpreted soil profile

Report Distribution

Copies of the completed Foundation Investigation Report should go to:

1. Bridge design section
2. Roadway design section
3. Construction section
4. Project engineer
5. Residency or maintenance group
6. Others as required by agency policy

10.3 TYPICAL SPECIAL CONTRACT NOTES

The foundation engineer should include in the Foundation Investigation Report any special notes which should be placed in the contract plans or special provisions. The purpose of such special notes is to bring the contractor's and/or project engineer's attention to certain requirements of the design or construction. Typical special notes relating to pile driving and embankment construction are as follows:

1. "Difficult driving of piles may be encountered and mechanical equipment may be necessary to remove consolidated material or boulders from the location of piles. This may be accomplished by various types of earth augers, well drilling equipment, or other devices to remove the consolidated material to permit piles to be driven to the desired depth or rated resistance without damage."

2. "If any obstructions to pile driving are encountered ten (10) feet or less from the bottom of the footing, the contractor shall, if so ordered by the engineer, pull the partially driven pile or piles and remove the obstruction, backfilling the hole with approved suitable material which shall be thoroughly compacted to the satisfaction of the engineer. However, no partially driven pile shall be removed until the engineer is satisfied that the contractor has made every effort to drive the pile through the obstruction. Payment for excavation will be made at the unit price bid for the Structure Excavation Item and for the temporary sheeting under Item _____ when sheeting is used. No other extra payment will be made for this work."

3. "The ordered length of pile shall be measured below the cut-off elevation shown on the plans. Any additional lengths of pile or splices above the cut-off elevation necessary to facilitate the contractor's operation shall be at his own expense."

4. "Piles for _____ are driven because of possible future scour of stream bed and shall be driven to the minimum lengths shown on the plans regardless of the resistance to driving. The actual driving resistance is estimated to be ___ tons."

5. "Piles will be acceptable only when driven to pile driving criteria established by the Chief Bridge Engineer. Prerequisite to establishing these criteria, the contractor shall submit, to the Chief Bridge Engineer, and others as required, Form _____ 'Pile and Driving Equipment Data'. All information

listed on Form _____ shall be provided within fourteen (14) days after the award of the contract. Each separate combination of pile and pile driving equipment proposed by the contractor will require the submission of a corresponding Form _____."

6. "Piles for the existing structure should be removed where they interfere with the pile driving for the new structure."

7. "It shall be the contractor's responsibility to place the cofferdams for _____ so that they will not interfere with the driving of batter piles. Pay lines for the cofferdams shall be as shown on the plans."

8. "The general subsurface conditions at the site of this structure are as shown on Drawing No._____."

9. "Pile driving will not be allowed at the abutments until fill settlement is complete. Estimated settlement time is _____ months after placement of the _____ foot surcharge."

10. "The contractor shall coordinate the project construction schedule to allow installation of embankment monitoring instrumentation by the State forces."

11. "Instrumentation damaged by contractor personnel shall be repaired or replaced at the contractor's expense. All construction activity in the area of any damaged instrument shall cease until the damage has been corrected."

12. "The contractor's attention is directed to the soil sample gradation test results which are shown on Drawing No._____. Soil sample gradation test results have been furnished to assist the contractor in determining dewatering procedures if necessary."

13. "The actual soil resistance to be overcome to reach estimated pile tip elevation is as shown below for each abutment and pier. The contractor shall size his pile driving equipment to install piles to the estimated length without damage."

14. "The south embankment shall be constructed to final grade and a month waiting period observed before pile driving begins. The actual length of the waiting period may be reduced by the Engineer based on an analysis of settlement platform and piezometer data."

10.4 SUBSURFACE INFORMATION MADE AVAILABLE TO BIDDERS

The finished boring logs and/or generalized soil profile should be made available to bidders and included with the contract plans. Other subsurface information, such as soil and rock samples and results of field and lab testing, should also be made available for inspection by bidders. The invitation for bids should indicate the type of information available and when and where it may be inspected. The highway agency should have a system for documenting what information each contractor inspects. Such documentation can be of major importance in later claim action.

The information developed during the foundation investigation is very useful in the selection of effective construction procedures, and for estimating construction costs. Such information is, therefore, of value to knowledgeable contractors bidding on the project. There has been much disagreement among owners and engineers as to what information should be made available to bidders, and how. The legal aspects are conflicting. In general, the owner's best interests are served by releasing pertinent information prior to the

bid. Indeed, some courts have held that failure to reveal information can weaken the owner's position in the event of dispute. On the other hand, some engineers are fearful that the release of information will imply guarantees on their part that the information is fully representative of the actual conditions which will be encountered.

One of the best surveys of the problem has been prepared by Standing Subcommittee No. 4 of the U.S. National Committee on Tunneling Technology. The Subcommittee was composed of engineers and attorneys having experience dealing with owners, engineering firms, and contracting organizations.

The following is excerpted from their recommendations:

> "In sum, all subsurface data obtained for a project, professional interpretations thereof, and the design considerations based on these data and interpretations should be included in the bidding documents or otherwise made readily available to prospective contractors. Fact and opinion should be clearly separated.
>
> The bidder should be entitled to rely on the basic subsurface data, with no obligation to conduct his own subsurface survey.
>
> It is considered, however, that specific disclaimers of responsibility for accuracy are appropriate, with respect to the following categories:
>
> - Information obtained by others, perhaps at other times and for other purposes, which is being furnished prospective bidders in order to comply with the legal obligation to make full disclosure of all available data.
>
> - Interpretations and opinions drawn from basic subsurface data, because equally competent professionals may reasonably draw different interpretations from the same basic data."

Additional information on this topic is included in the FHWA Geotechnical Engineering Notebook; Geotechnical Guideline No. 15 – Geotechnical Differing Site Conditions.

10.5 USE OF DISCLAIMERS

The validity which courts give disclaimer clauses varies from State to State. In general, however, the courts have given much more validity to "specific" versus "general" disclaimer clauses. "General" disclaimer clauses are the type that say, in effect - subsurface information was gathered for use in design, however, the contractor should not rely on this information in preparing his bid. It is no big surprise, therefore, that judges give little validity to such general disclaimer clauses - since common sense dictates that if the subsurface information is good enough to base the design on, then the contractor should be able to place some reliance on the information in preparing his bid. Dr. Ralph Peck, noted geotechnical engineer, put it succinctly when asked his opinion concerning general disclaimer of subsurface information on a recent large Interstate project. He stated, "If the State or engineers it has engaged to develop the contract documents have accepted certain information as the basis for those documents, that information should not be disclaimed."

As mentioned previously, the courts have upheld the use of "specific" disclaimer clauses. The use of specific disclaimer clauses is strongly recommended over the use of a general disclaimer clause. An example of a specific disclaimer would be a statement such as - the boring logs are representative of the conditions at the location where the boring was made but conditions may vary between borings.

The following are examples of good "specific" disclaimer clauses used by one highway agency. These disclaimer clauses are placed on the interpreted soil profile which is included in the contract plans:

General Notes

1. The subsurface explorations shown hereon made between _____ and _____ by the regional soils section.

2. General soil and rock (where encountered) strata descriptions and indicated boundaries are based on an engineering interpretation of all available subsurface information by the Soil Mechanics Bureau and may not necessarily reflect the actual variation in subsurface conditions between borings and samples. Detailed data and field interpretation of conditions encountered in individual borings are shown on the subsurface exploration logs.

3. The observed water levels and/or conditions indicated on the subsurface profiles are as recorded at the time of exploration. These water levels and/or conditions may vary considerably, with time, according to the prevailing climate, rainfall or other factors and are otherwise dependent on the duration of and methods used in the explorations program.

4. Sound engineering judgment was exercised in preparing the subsurface information presented hereon. This information was prepared and is intended for State design and estimate purposes. Its presentation on the plans or elsewhere is for the purpose of providing intended users with access to the same information available to the State. This subsurface information interpretation is presented in good faith and is not intended as a substitute for personal investigation, independent interpretations or judgment of the contractor.

5. All structure details shown hereon are for illustrative purposes only and may not be indicative of the final design conditions shown in the contract plans.

6. Footing elevations shown are as indicated at the time of this drawing's preparation.

10.6 APPLE FREEWAY DESIGN EXAMPLE – FOUNDATION INVESTIGATION REPORT

A typical example of a Foundation Investigation Report is presented in the following section with reference to the Apple Freeway Design Example. The report illustrates the inclusion of various items discussed in the preceding sections of this chapter and summarize the pertinent results and conclusions obtained from the various analysis/design stages in the preceding chapters.

Foundation Investigation Report

To: Mr. A. J. Jones
Chief Engineer

From: Mr. A. B. Smith
Chief Foundation Engineer

Subject: Interstate 0 Structure over the Apple Freeway

The Geotechnical section has completed an analysis of the foundation conditions at the site of the subject structure. Our analysis is based on the following information:

1. A 1-inch equals 20 feet plan and profile prepared by the Bridge Division and received in this office April 1, 1992.

2. An interpretation of the boring logs and analysis of soil samples from three drill holes numbered BAF-1 thru 3, nine auger holes numbered EA-1 thru 9, and one drill hole numbered BAF-4 from which undisturbed samples were taken.

3. Laboratory testing on undisturbed samples from BAF-4.

Subsurface Conditions:

The general subsurface conditions are shown on Drawing No. 5 GS 331.

Foundation Recommendations:

1. Elevation Assumptions

   The foundation recommendations are based on the following bottom of footing elevations:

   West Abutment 1011
   Pier 992
   East Abutment 1012

Changes to footing elevations may affect the foundation recommendations and should be discussed with this office.

2. Embankment Construction

   A. Unsuitable Subexcavation

      An approximate 1 to 3-foot thick organic layer exists between approximate stations 92+70 to 94+00 in the area of the east approach embankment. This organic layer should be removed

and replaced with granular embankment material in accordance with Bridge Design Data Sheet 80-1.

B. Embankment Material and Placement

The approach embankment shall be constructed of materials placed in accordance with Bridge Design Data Sheet 80-1.

C. Embankment Settlement

An estimated 12 inches of fill settlement will occur due to consolidation of the 35-foot thick clay layer underlying the proposed 30-foot high east approach embankment. Estimated settlement time for 90 percent primary settlement is 14 months. Settlement time can be reduced to, (1) 6 months by use of a 10-foot surcharge fill or (2) 2 months through use of either 12-inch diameter sand drains at 9 foot center to center spacing or wick drains at 7.5 foot center to center spacing. Estimated cost for each of these treatments is:

Treatment	**Estimated Settlement Time**	**Estimated Extra Cost**
Fill only	14 months	$ ---
Fill w/10 foot surcharge	6 months	120, 000
Fill w/wick drains	2 months	172,000
Fill w/sand drains	2 months	385,000

It is understood the construction schedule will not allow a 14-month waiting period but will allow up to an 8-month waiting period, therefore, the 10-foot surcharge treatment is recommended as the most cost-effective method to reduce settlement time. The surcharge should be placed full height for a length of 500 feet back of the bridge ends on both the east and west approach and sloped at 1 vertical to 1.5 horizontal down to the embankment grade.

D. Embankment Stability

The estimated immediate end of construction factor of safety for the proposed 30' high east approach embankment is 1.63. The estimated immediate end-of-construction factor of safety for the proposed 30-foot fill plus 10 foot temporary surcharge is 1.33. Both factors of safety are adequate and no special approach embankment treatment is necessary. Long-term factor of safety will increase as consolidation of the foundation soils occur. The factor of safety for the west approach embankment will be higher as the fill height is 10' less. An analysis of highway borings confirms that no stability problems will occur due to the 500’ extension of the surcharge.

E. Embankment Monitoring

Fill settlement is recommended to be monitored with settlement plates and piezometers. Settlement plates should be installed at existing ground elevation at centerline stations 90+00, 93 + 50, and 96 + 50. Piezometers to monitor excess pore pressure buildup and dissipation in the clay subsoil are recommended at centerline stations 93 + 50 and 96 + 50. A total of three piezometers should be installed at each location - one each at 20, 28, and 36 foot depths. Instrumentation will be installed by State forces.

3. Abutment Foundation

A. Spread Footings

The abutments may be supported on spread footings placed on compacted select material with a maximum allowable bearing capacity of 3 tons per square foot assuming a footing width of 7' is used. Changes to the footing width affect both bearing capacity and settlement and should be discussed with this office. The total settlement of the east and west abutments respectively will be 2.6 and 1.9 inches which occurs over respective time periods of 14 months and 7 months. About 60 percent of the settlement will occur in 2 months after structure construction. This settlement may be reduced by extending the surcharge period. For 90 percent consolidation the surcharge should remain in place a total of 8 months; 2 months longer than required for embankment considerations. If vertical drains are installed during embankment construction, these drains will reduce the time for abutment settlement such that only ¼" will remain 30 days after all abutment loads have been placed

B. Piles

Two pile types were analyzed at the abutment; a displacement pile (12" diameter closed end pipe) and a non-displacement pile (12 x 84 H-pile). Displacement type piles are not recommended due to their inability to be driven through the fill and the uncertainty of obtaining penetration in the dense gravel stratum. Non-displacement H-piles are recommended. However, to insure that the pile can be driven to rock without damage, the section should not be less than a 12 x 84 H-pile. A 12 x 84 H-pile driven to rock may be designed for a maximum load of 120 tons. Tip reinforcement, such as APF 75500, should be used to prevent tip damage by boulders in the gravel stratum and to insure penetration to rock. Estimated pile lengths are 60 feet at the west abutment and 75 feet at the east abutment.

At the abutments, negative skin friction may be expected if the piles are installed before fill settlement is complete. In addition lateral squeeze of the clay subsoil will occur as the clay consolidates. Therefore, to prevent increased vertical downdrag pile loads, bending of abutment piles and rotation of the abutment toward the fill, the abutment piling should not be installed until embankment settlement is complete.

The actual driving resistance estimated to develop the design load for the H-pile at the estimated length is 345 tons at the east abutment and 290 tons at the west abutment. The contractor should size his equipment to achieve this resistance without damaging the pile.

4. Pier Foundation

A. Spread Footings

The pier may be supported on spread footings placed 4 feet below ground on natural undisturbed soil and designed for a maximum allowable bearing capacity of 3 tons per square foot assuming a footing width of 7' is used. Changes in footing width should be discussed with this office. Approximately 2.8 inches of settlement is expected at this location over about 7 months with 1 inch occurring immediately and 2 inches occurring in less than 2 months. If a spread footing foundation is chosen, consideration should be given to increasing the structure clearance over the Apple Freeway to account for these settlements. Settlement along the footing axes will be uniform. However a short term differential settlement of 1.5" can be

expected between the abutment and pier footings if spread footings are used.

B. Piles

A 12" diameter closed end pipe pile and a 12 x 84 H-pile were analyzed at the pier. The closed end pipe may be designed for 70 tons with a safety factor of 2 if driven into the dense gravel layer. The estimated length is 36 feet. However a minimum wall thickness of 0.375 inches should be used to prevent overstress during driving. A driving resistance of 170 tons is estimated to reach the estimated length. A conical reinforced point should be used to prevent tip damage due to boulders. The cost per ton on a per foot basis equals $11.

A 12 x 84 H-pile may be designed for 120 tons with a safety factor of 2 if driven to rock. The estimated length is 46 feet. A driving resistance of 280 tons is estimated to obtain design resistance at the estimated length. A reinforced tip similar to APF 75500 should be used to prevent tip damage due to boulders. The cost per ton on a per foot basis equals $8.

We recommend that H-piles be chosen if piles are used because of cost advantages and installation advantages.

5. Special Notes

The following special notes are recommended to be included in the contract documents.

1. The general subsurface conditions at this site are shown on Drawing No. 5 GS 331.

2. A 6-month waiting period will be imposed between completion of the 10-foot surcharge on the east embankment. The actual length of the waiting period may be reduced by the Engineer based on an analysis of settlement platform and piezometer readings.

3. The contractor shall coordinate his construction schedule to allow installation of instrumentation by State forces.

4. Instrumentation damaged by contractor personnel shall be repaired or replaced at the contractor's expense. All construction activity in the area of any damaged instrument shall cease until the damage has been corrected.

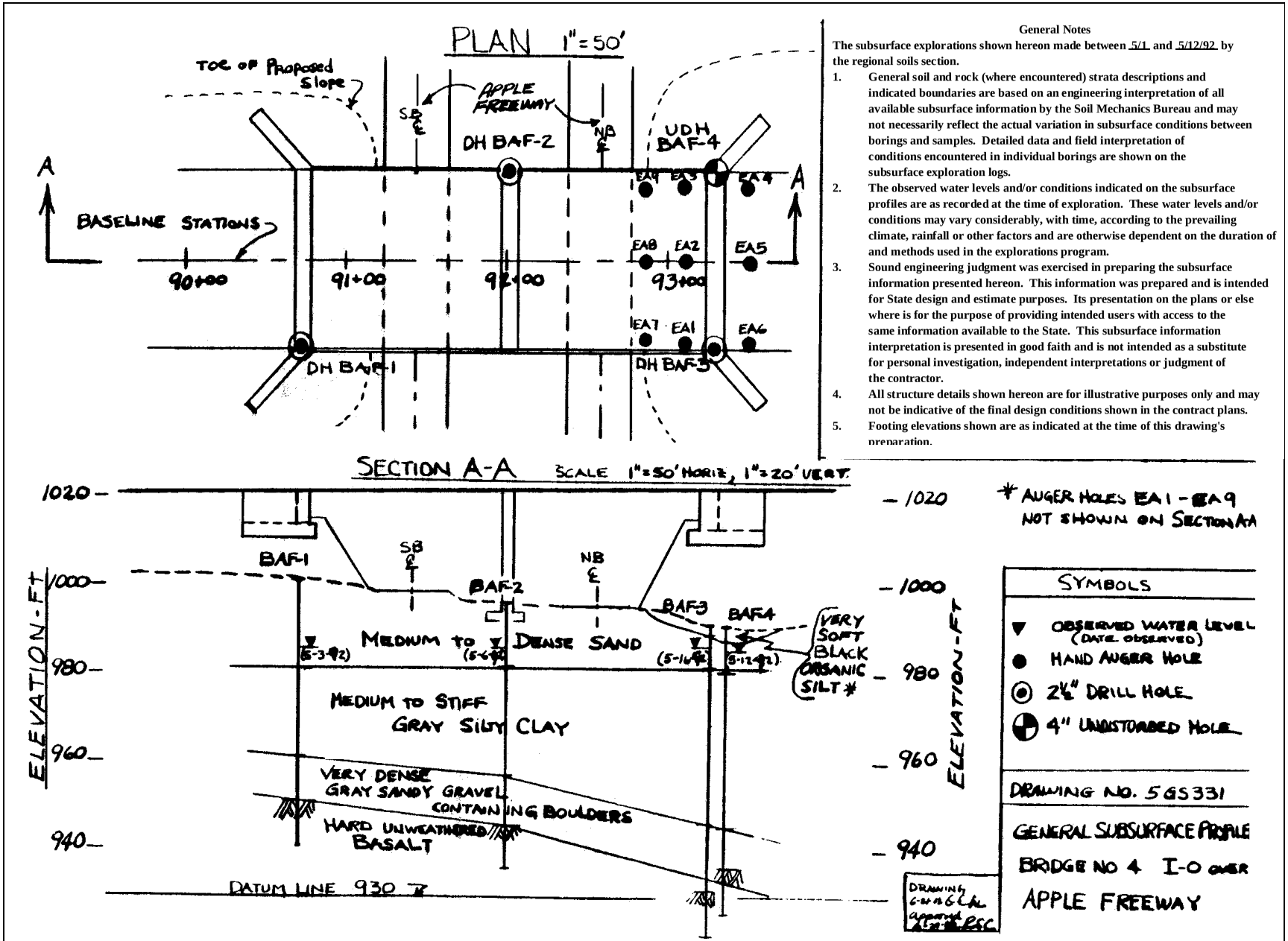
If piles are used the additional special notes should be provided.

5. Pile driving will not be allowed at the abutments until fill settlement is complete. Estimated maximum settlement time is 6 months after placement of the 10-foot surcharge. This time may be reduced based on interpretation by the State of settlement plate readings.

6. Piles will be acceptable only when driven to pile driving criteria established by the Deputy Chief Engineer (Structures). Prerequisite to establishing these criteria, the contractor shall submit, to the Deputy Chief Engineer (Structures) and others as required, Form entitled, "Pile and Driving Equipment Data." All information listed on the Form shall be provided within 14 days after the award of the contract. Each separate combination of pile and pile driving equipment proposed by the contractor will require the submission of a corresponding Form.
7. The actual driving resistance to install the 12 x 84 H-piles to the estimated lengths shown on the plans is estimated to be 280 tons at the pier, 345 tons at the east abutment and 290 tons at

the west abutment. The contractor's equipment shall be capable of overcoming these resistances without inflicting pile damage.

A B.Smith
Chief, Foundation Engineer



General Notes

The subsurface explorations shown hereon made between 5/1 and 5/12/92 by the regional soils section.

1. General soil and rock (where encountered) strata descriptions and indicated boundaries are based on an engineering interpretation of all available subsurface information by the Soil Mechanics Bureau and may not necessarily reflect the actual variation in subsurface conditions between borings and samples. Detailed data and field interpretation of conditions encountered in individual borings are shown on the subsurface exploration logs.
2. The observed water levels and/or conditions indicated on the subsurface profiles are as recorded at the time of exploration. These water levels and/or conditions may vary considerably, with time, according to the prevailing climate, rainfall or other factors and are otherwise dependent on the duration of and methods used in the explorations program.
3. Sound engineering judgment was exercised in preparing the subsurface information presented hereon. This information was prepared and is intended for State design and estimate purposes. Its presentation on the plans or else where is for the purpose of providing intended users with access to the same information available to the State. This subsurface information interpretation is presented in good faith and is not intended as a substitute for personal investigation, independent interpretations or judgment of the contractor.
4. All structure details shown hereon are for illustrative purposes only and may not be indicative of the final design conditions shown in the contract plans.
5. Footing elevations shown are as indicated at the time of this drawing's preparation.