Minimum Geotechnical Program Requirements

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The Geotechnical Program should provide a basis for design and preparation of the contract documents and will reduce the risk of construction claims and delays associated with encountering differing site conditions. To do this the field investigation should identify the potential for any conditions that present cost risks to the project and address those items so that design and construction methods can be identified that will reduce those risks. The Geotechnical Design shall comply with these minimum standards.

1. **Review of Available Data.** Suggested resources, including but not limited to:
    a. Geotechnical Mapping.
        i. U.S. Geological Survey. Geology and Seismic Maps. www.usgs.gov
        ii. California Division of Mines and Geology. Geology and Seismic Maps. www.consrv.ca.gov/dwg/
    b. Aerial Photography
        i. U.S. Department of Agriculture, Natural Resource Conservation Service (NRCS). Elk Grove.
        ii. U.S. Department of Agriculture, Soil Survey. (NRCS), Elk Grove
        iii. Radman Aerial Surveys, Sacramento
        iv. Pacific Aerial Surveys, Oakland
    c. Area Groundwater Data
        i. Regional Water Quality Control Board
        ii. Department of Water Resources
        iii. Sacramento County Environmental Management Division
        iv. Local Water Purveyors
    d. Previous Geotechnical Investigation in Area

2. **Site Reconnaissance**
    a. Verification of site location
    b. General access for equipment (truck, drill rig – truck mounted or all-terrain)
    c. Height restrictions (power lines, overhangs)
    d. Water Bodies or crossings
    e. Terrain
    f. Existing site improvements (pavement, concrete, structures)
    g. Restrictions on working hours (residential/commercial areas)
    h. Locked gates, access
    i. Location of existing underground or overhead utilities
    j. Storage and disposal of drilling materials

3. **Subsurface Investigation**
    a. Notify Underground Service Alert (USA) and utility companies for clearing of exploration areas for subsurface exploration.
    b. Boring Location
        i. Spacing – Borings, in-situ tests and pits along the trench alignments shall be located where recommended by the geotechnical consultant based on the review of site topography, knowledge of geology/soils in the area, trench alignment, special structure locations and profile grades. Minimum of 1/300 ft of pipes. The geotechnical consultant shall obtain the necessary encroachment permits and/or access approval to do the soil borings.
        ii. Depth – Depth of borings, in-situ tests and pits shall extend to at least 1.5D (1.5 times the outside diameter) or 5 ft below the pipe invert, whichever is greater, as shown on the preliminary drawings.
            1. Where groundwater is not encountered or where the bottom of structures is above groundwater, borings for structures shall extend at least 10 feet below the bottom of structures.
            2. Where groundwater is encountered above the bottom of proposed structures, borings for structures shall extend a sufficient depth below the bottom of structures to support seepage analyses, and/or the design of shoring embedments, groundwater cut-offs, or relief wells to prevent bottom instability.
        iii. All samples shall be screened with an Organic Vapor Analyzer (OVA) or Photo-Ionization Detector (PID) that has been calibrated to factory specifications within the last 3 months, and recalibrated with gas according to the manufacturer's specifications. The Project Manager shall be notified immediately if contamination is encountered (i.e. noticeable odor, visual staining, and/or PID/OVA readings greater than 50 parts per million).
        iv. Boring Logs – as outlined below in report section
    c. The method used to advance the boring should be compatible with the soil and groundwater conditions or the quality of the samples may be poor. Particular care should be exercised to properly remove all slough or loose soil from the boring before sampling.

Report

4. **Introduction** – Identifies the project that the report is intended to address (purpose). Include a brief description of the project location and any special conditions.
    a. Project Description – Include information regarding length and related pipe diameters, pipe depths, invert elevations, open trench segments, trenchless trench segments, manhole locations and depths and special areas (jacking and receiving pits, pump stations etc.)

b. Purpose and Scope of Services – The scope of the geotechnical program and the specific information presented in the report.
c. Project Organization – (If Design Project)
d. Geologic Setting
    i. Regional Geology – Provide a description of the regional geology.
    ii. Site Geology – Provide a description of the local site geology.
    iii. Faulting, Seismicity and Seismic Hazards– Present and discuss known and potential seismic hazards including fault locations, anticipated peak ground accelerations from a maximum credible event and potential for liquefiable soils in the investigation area.
e. Previous Investigations – Briefly describe and provide location of any previous explorations that could affect this alignment. The boring logs and laboratory testing results from previous reports should be included as an appendix to this report.

5. Site Conditions

a. Site Description – Include vicinity map, site location map, map presenting topographic information, and map showing boring locations. Discuss location of project and the proposed alignment(s).
b. Surface Conditions – Provide a description of the surface conditions that are applicable to the pipeline alignment. Identify paving, concrete slabs, traffic, landscaping, residential, structures, or any other surface feature or improvement that would affect the construction.

6. **Subsurface Exploration and In-situ testing -** Describe the subsurface exploration. Include date, weather conditions, Equipment Company, equipment type and size, drilling/excavation methods, subsurface exploration locations, depths explored, backfill/sealant material, problems encountered, sampling method, detailed logs should be included in the appendix.
    a. Subsurface Exploration
        i. Describe the soil conditions with generalized stratigraphy. Describe the soil/rock as they relate to the main geologic formation existing along the alignment.
        ii. Describe the depth from the ground surface to specific soil units and variations in thickness, consistency and texture across the site and delineate areas of similar conditions.
        iii. Describe the groundwater levels encountered, state whether piezometers were installed. Present interpretation of the groundwater data which may include profiles or contours.
        iv. Discuss if groundwater level is likely to vary from depths measured that the time of the subsurface exploration or if levels varied during the measurement period.
        v. Compare the groundwater data for the project area.
    b. Insitu testing - Describe the in situ testing performed for the subsurface exploration program (e.g. vane shear tests, pressuremeter tests, electronic cone penetration tests).

i. Reference the test methods used. Include modifications of existing test methods or unpublished test methods in the appendix. Explain why that test method was used instead of a published method.
ii. Where the in situ test results lend themselves to a concise summary include a summary, otherwise summarize as appropriate in the Appendix.

c. Laboratory testing – Describe laboratory testing performed for this report.
   i. Include a listing of the testing performed such as consolidation tests, triaxial tests, Atterberg Limit tests, sieve analysis etc.
   ii. Test methods used are to be referenced. Include modifications of existing test methods or unpublished test methods in the Appendix.
   iii. Where laboratory tests lend themselves to a concise summary include the summary in this section, otherwise summarize as appropriate in the Appendix.

d. Soil Descriptions and Sampling
   i. Soil descriptions shall include the type of soil (gravel, sand, silt, clay, etc.), USCS symbol, approximate percentages of each type of soil, a description of the consistency and/or relative density, degree of moisture, range of particle sizes, angularity of sands and gravels, and plasticity of silts and clays. Pocket Penetrometer tests shall be performed on all clay samples immediately after sample recovery.
   ii. The logs shall note indications of cobbles, boulders and relative drilling resistance. Other information on drill rig response to drilling such as chatter, and bouncing, shall be used to provide an estimate of the thickness of any encountered gravel, cobble and/or boulder layers. Bag samples of any cobbles observed in the drill cuttings shall be collected.
   iii. Drive samples shall generally be obtained at changes in material type and at five foot depth intervals. For tunneling projects, continuous sampling, or alternating Standard Penetration Tests (SPT) and relatively undisturbed samples (California split spoon sampler or equivalent) at 2-1/2 foot intervals, shall be performed from 10-feet above to 10 feet below the anticipated tunneling zone as shown on the project plans. The type, weight and drop height of the hammer used to drive the samplers shall be reported on the logs. Blow counts shall be recorded for each 6-inch advancement of the samplers. Shelby tube samplers shall be collected of all clayey soils to minimize disturbance. Large quantity bulk samples of the near-surface soils and soil materials encountered throughout the depth of the borings shall also be collected.

e. Bedrock Descriptions and Sampling
   i. Bedrock shall be continuously cored to the planned drilling depth. Each lithologic unit in the core shall be logged. The classification and description of each unit shall be as complete as possible. Rock descriptions shall include the rock type and lithology, hardness, relative strength, degree of weathering, texture, structure, degree of

dipping with respect to a horizontal plane, and color. Any discontinuities, infilling or coating, and/or staining shall be noted. Any other observations such as occurrence and/or indication of faults, fossils, fractures, inclusions, joints, seams, and shearing shall also be recorded. Shear and joint surfaces shall be described with notation on asperities and striations.

ii. The logger shall make observations of the drilling process and make notes correlating drilling depths to drilling characteristics including any indications of texture (smooth versus rough) of the material being cored, circulation of drilling water and/or loss of circulation, changes in circulation water color, rate of penetration, occurrence of voids as indicated by dropping of the drill rods, and quality of recovery. The Percent Recovery and Rock Quality Designation (RQD) shall be calculated and recorded for each coring run. In measuring the RQD, core segment lengths should be measured along the centerline of the core axis and shall be performed at the time the core is retrieved. Mechanical breaks resulting from the handling, removal and recovery of cores shall be disregarded when calculating RQD. Core loss should be shown on the graphic log and blocks or spacers shall be placed in the core box at the estimated depth of core loss based on the drilling action and examination of the core.

iii. A color digital photograph of all core samples should be made in the field prior to removal from the core sampler. Core samples shall be handled, boxed (waxed-lined boxes are required), and photographed in accordance with the procedures identified in the "Engineering Geology Field Manual" (Chapter 10) by the U.S. Department of the Interior, Bureau of Reclamation. After filling of each core box, color digital photos of each filled core box shall be made with the boring number and core depth clearly identified.

f. Borings, excavations, and pit tests shall be abandoned as required by the governing jurisdiction.

7. Recommendations

a. Design Criteria – Identify the design criteria used to establish the basis of pipeline design

b. Alignment Evaluations – If more than one alternate alignment has been evaluated include discussion of the geotechnical advantages and disadvantages of each alternative evaluated.

c. Site Preparation
   i. Existing Pavements – condition, thickness, reuse
   ii. Stripping and Grubbing
   iii. Existing Utilities, Wells and/or Foundations
   iv. Scarification and Compaction
   v. In-Situ Moisture Content

d. Anticipated Excavation Conditions – Include a discussion regarding site preparation and exactions, rippability if hard rock formations, groundwater

and surface water control, requirements trench stability and excavation support requirements, and handling and disposal of oversized material.

i. Temporary Excavations – methods and requirements, Soil type OSHA.
ii. Temporary Dewatering – Discuss potentially suitable dewatering methods, anticipated pumping rates, extent of drawdown. (Actual dewatering systems design shall be by the constructing contractor).
iii. Permanent Dewatering – Discuss potential drainage systems and waterproofing.
iv. Shoring – (Actual shoring design shall be by the construction contractor):
    1. Recommended type of Shoring
    2. Lateral Earth Pressures (active/passive/at-rest)
    3. Lateral Resistance
    4. Trench Bottom Instability
    5. Surcharge Pressures
    6. Protection of Existing Facilities
    7. Monitoring
    8. Construction Vibrations
    9. Shoring Removal
v. Trench Preparation and Backfill –
    1. Subgrade Preparation
    2. Trench Bottom Stability
    3. Pipe Bedding (and bedding factor) material and compaction requirements
    4. Geotextile Fabric
    5. Pipe zone backfill material and compaction requirements
    6. Trench zone backfill and compaction requirements – meet jurisdiction requirements (materials, relative compaction, optimum moisture content, lift thickness)
    7. Trench Dam (seepage barrier)

e. Soil Parameters and coefficients
    i. Rigid Pipes
        1. Design Values
            a. Soil Unit Weight (wet)
            b. Ku' – Lateral Pressure times the coefficient of friction
        2. Trench Width
    ii. Semi-Rigid Pipes (Ductile Iron)
        1. Unit weight of soil (dry and saturated)
        2. Soil Bearing Pressure
        3. DIPRA soil Designation (ductile iron pipe)
        4. Density of the soil
        5. Soil Passive Pressure
        6. Angle of friction (granular)
        7. Cohesion (cohesive soils)
        8. Trench Width

iii. Flexible Pipes
    1. Unit weight of soil (dry and saturated)
    2. Deflection Evaluation
    3. Soil Modulus (E')
    4. Constrained Soil Modulus (M_s)
    5. Soil Strain
    6. Angle of friction (granular)
    7. Cohesion (cohesive soils)
    8. Thrust Blocks – available net passive pressure
    9. Trench Width

iv. Structures
    1. Unit weight of soil (dry and saturated)
    2. Subsurface (ex. Manholes, wet wells)
    3. Subgrade Preparation
    4. Allowable Bearing Pressure
    5. Estimated Settlements
    6. Buoyant Forces
    7. Lateral Earth Pressures (passive/active/at-rest)
    8. Structure Backfill

v. Mat Foundations
    1. Unit weight of soil (dry and saturated)
    2. Subgrade Preparation
    3. Allowable Bearing Pressures
    4. Estimated Settlements

vi. Spread Footings
    1. Unit weight of soil (dry and saturated)
    2. Subgrade Preparation
    3. Allowable Bearing Pressures
    4. Estimated Settlements
    5. Lateral Resistance
    6. Construction Considerations
    7. Pipeline and Structure Connections

vii. Concrete Slabs supported-on-grade (interior and exterior)
    1. Subgrade preparation
    2. Rock Capillary Break (interior)
    3. Construction Considerations

viii. Pavements
    1. Asphalt Concrete Pavement Recommended Sections
    2. Subgrade Stability
    3. Portland Concrete Pavement Recommended Sections
    4. Access Roads
    5. Geotextile Fabric
    6. Aggregate Base

ix. Seismic Considerations
    1. Liquefaction/Dynamic
    2. Ground Shaking

3. Fault Crossing

x. Seismic Design Parameters per UBC
    1. Seismic Zone
    2. Source
    3. Distance to Fault

xi. Trenchless – Discuss suitability of soil & groundwater for application of trenchless methods, if applicable:
    1. Excavation Methods
    2. Anticipated Ground Behavior
    3. Groundwater
    4. Bearing Pressures
    5. Design Values for Jacked Conduits
    6. Estimated Pipe Jacking Forces
    7. Estimated Ground Surface Settlement
    8. Lateral Earth Pressures
    9. Lateral Deflections
    10. Shaft Dewatering
    11. Construction Considerations

xii. Soil Corrosivity - Tests to predict the effect of corrosion associated with the types of materials anticipated to be used for construction. This will include determination for both concrete and metal corrosion potential. At a minimum the following field and laboratory testing will be performed along the proposed alignment at grade, at invert and 5-feet below pipe invert on selected samples to adequately characterize the corrosion potential. If this preliminary testing indicates a corrosive condition to either metal or concrete, then further testing is required by a corrosion specialist.
    1. Minimum Resistivity
    2. pH
    3. Chloride Concentration (not required is soil resistivity exceeds 5,000 ohm-cm)
    4. Sulfate Concentration (not required is soil resistivity exceeds 5,000 ohm-cm)

xiii. Special site assessment
    1. Locations where there may be contamination
    2. Railroad Crossings
    3. Other utility crossings
    4. Waterways (channels, rivers, creeks, drainage ditches, etc.)
    5. Special Coatings
    6. Corrosion Protection
    7. Cathodic Protection

f. Limitations – The limitation of the data presented within this report shall be clearly identified in this section. This includes the identification of all assumptions and criteria that would affect the use of the data.
g. References – Include all reference used
h. Appendices

i. Boring Logs – The boring logs shall include the following:
    1. Project Name
    2. Drilling/Excavation Company
    3. Type of Equipment
    4. Sampling type and locations
    5. Date
    6. Time
    7. Method of Drilling/Excavation
    8. Hammer Weight and Fall
    9. Blow Counts
    10. Name of Personnel logging the boring/excavation
    11. Weather Description
    12. Groundwater Levels Observed (initial/final)
    13. Surface Elevation
    14. Location – indicated on a map included in the report.
    15. Description of Soil/Rock

ii. Soils should be logged using ASTM D2487 and D2488. At minimum a soils description should include the following:
    1. Consistency (cohesive soils)
    2. Relative Density (granular soils)
    3. Moisture Condition
    4. Color
    5. Type
    6. Grain Size
    7. Cementation

iii. Rock should be logged according to the "Engineering Geology Field Manual" (Chapter 16) by the U.S. Department of the Interior, Bureau of Reclamation.

iv. Laboratory testing of selected soil, bedrock, and/or groundwater samples shall be performed as necessary to support engineering analyses and the development of geotechnical recommendations for the project. Testing shall be performed in accordance with the appropriate American Society for Testing and Materials (ASTM), Colorado School of Mines (CSM), Environmental Protection Agency (EPA), State of California, and other appropriate standards. Types of testing to be performed shall include the following as appropriate for the project.
    1. Typical Soil Tests
        a. In-Place Density and Field Moisture tests per ASTM* D2216 and ASTM D2937
        b. Atterberg Limits per ASTM D4318
        c. Sieve Analysis, 3-inch to No. 200 Sieve per ASTM D422
        d. Percent Passing No. 200 Sieve per ASTM D1140
        e. Sieve plus Hydrometer per ASTM D422
        f. Sand Equivalent per California Test 217

g. Expansion Index per ASTM D4829
h. Three-Point Direct Shear Test tests per ASTM D3080
i. Unconfined compression tests per ASTM D2166
j. Consolidation tests per ASTM D2435
k. Falling Head Permeability tests per ASTM D5084
l. Chemical Tests for corrosion potential per CA DOT Methods.
m. Specific Gravity per ASTM D854

2. Typical Rock Tests
    a. Unconfined Compression Tests per ASTM D 2938
    b. Specific Gravity per ASTM D 6473
    c. Cherchar abrasivity tests per CSM procedure
    d. Brazil tensile strength per ASTM D 3967
    e. Point Load Test per ASTM D 5731
    f. Slake Durability Tests per ASTM D 4644
    g. Thin section Petrographic Analyses with full Petrographic report including Quartz content. These tests shall include the type, content and percentages of minerals as determined by point count method; grain size, shape, elongation, orientation, interlocking; and point count and proper classification of rock by the International Union of Geological Sciences (IUGS).
3. In addition to the above listed soil and bedrock tests, appropriate chemical tests shall be performed to evaluate the disposal options for soil, bedrock and groundwater. Typical chemical tests for soil and groundwater include:
    a. Common Chemical Tests for Soil:
        i. EPA Method 1664 TRPH
        ii. EPA Method 8260- VOCs
        iii. EPA Method 8270- Semivolatiles
        iv. EPA 8081-Pesticides and PCBs
        v. EPA Method 6010B – Heavy metals
        vi. CAL DHS/EPA Method 8015-Carbon chain fuel screen/chromatogram
    b. Common Chemical tests for Groundwater:
        i. EPA Method 1664 TRPH or equivalent
        ii. EPA Method 8260B or equiv.- VOCs
        iii. EPA 6010B/Title 22 Metals
        iv. ASTM Method D 1946 and D 2820M for H2S
        v. General water quality (pH, TDS, turbidity, carbonates, sulfates, chlorides, nitrates)
    c. All chemical analyses shall be performed by a California Department of Health Services certified laboratory.

v. Previous reports – Include copies of previous geotechnical reports.