## Measurements in Feet (Imperial System)

**Guidelines for Geotechnical Investigations**

### Geotechnical Investigations

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>Study level or expected foundation type</th>
<th>Minimum suggested number of borings</th>
<th>Suggestions for depths of exploration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Large concrete structures, such as warehouses, commercial centers and manufacturing facilities.</td>
<td>Preliminary</td>
<td>Every 10,000 ft²</td>
<td>Take at least one boring or sounding every 10,000 ft² of area. The expected final borings may be taken every 20,000 ft² if desired.</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>Every 2,000 to 3,000 ft², typical spacing 40-120 feet in each direction, 4 corners and center.</td>
<td>Boreholes should extend to at least 3 depths below the expected depth of loading, except for special situations, such as analysis of fills that might cause settlements.</td>
</tr>
<tr>
<td>2. Two-story and 3-story structures, rectangular towers, multi-story commercial centers, walkups, apartment buildings, small parking buildings and small industrial buildings.</td>
<td>Preliminary</td>
<td>One boring per building - generally depends on building geometry and soil conditions; structure on slopes will require greater investigation density and cross sections.</td>
<td>The boring should be taken to a depth no less than twice the building width.</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>Three borings in line or diagonal, no less than one boring per 2,000 ft², minimum spacing 70 feet, as allowed greatly depends on building geometry and soil conditions; structure on slopes will require greater investigation density and cross sections.</td>
<td>The depth of the final-study borings depends on conditions found while drilling and the geometry of fill to be placed. For foundation placements, take at least 16 to 20 feet per plate. For loadings, take at 2 to 3 times the footing width, while at least one boring taken to a depth equal to the footing width.</td>
</tr>
<tr>
<td>3. Buildings taking 4 or 5 stories, hospitals, large parking buildings, large housing units or subdivisions, small parking lots, apartment buildings and small or large industrial buildings.</td>
<td>On-site boring</td>
<td>Every 4,000 ft²</td>
<td>If possible, every 2,500 ft² for large tanks (diameter ~300 feet or more).</td>
</tr>
<tr>
<td></td>
<td>On-plains</td>
<td>Every 4,000 ft²</td>
<td>See #2.</td>
</tr>
<tr>
<td>4. Buildings under 4 stories, such as single-family homes, small stores, small apartment buildings, small parking lots, small commercial buildings, small office buildings, small industrial buildings.</td>
<td>Preliminary</td>
<td>One boring for each 10,000 ft² of building footprint. For a final investigation, do one boring every 5,000 ft² minimum 150 feet apart.</td>
<td>For preliminary investigations, take at least one boring on 10 to 15 times the expected footing width. For a final report, go to 3 times the net width. If a preliminary investigation was not done before the final report, also include deep borings as specified for preliminary report.</td>
</tr>
<tr>
<td></td>
<td>Final</td>
<td>One boring every 8,000 to 18,000 square feet</td>
<td>The depth of borings should exceed the length of plates or 10 to 20 times plate diameter. Although investigation depth might be less for foundation borings, beware of thin layers of soil or specialty applications.</td>
</tr>
</tbody>
</table>

**Note:** On most jobs it is necessary to reasonably estimate the water level. This task usually requires observation wells that must be read for some time. The client should make aware of the importance of reliably determining the approximate water level. Be aware that several water levels may exist with perched water tables.
13. Notes, parking lots or similar, running tracks, community centers

Final report

One boring every 20,000 ft² of test area or one boring every 2,500 square feet of structure area

Sheet baring will generally be sufficient, say 15 feet, and 3 times the structure widths. However, the borehole densities will also depend on other factors, such as thickness and settlements induced.

14. Major pipelines (~6-inch diameter, 600 mm, or larger); small or short pipelines require special analysis, culverts, electrical bus lines

On-site boring, usually on boring or sounding investigations.

Every 300 feet for final reports; every 1,500 feet for preliminary reports. Add a boring or test pit every 15 feet or change in direction if any occur. Consider at least one boring per field or plot area.

Take bores to 3 times external pipe diameter. If zone is to be covered with new RE, external investigation below and compressible zones.

15. Tunnels

Preliminary study

Every 300 ft to 1,000 ft; geological characterization of the area, e.g., presence of voids; will be quite important. Depending on the tunnel size, consider horizontal borings along the tunnel axis.

Vertical bores should be taken at least one diameter below tunnel floor.

16. Pump stations, dry docks

Final report

Every 150 feet, unless supplemented with seismic reflection lines or surface or cross-hole seismic reflection, or horizontal boring.

The boring must be taken at least one diameter below tunnel bottom. Seismic refraction will be of great help. Consider horizontal bores and pilot holes. Tunnel width will require additional requirements.

17. Excavation designs, stabilizing (Certain situations might require pump lifts).

Open cut excavations

One boring per 500 ft of excavation footprint for preliminary design, or every 50 ft if for food design. Area is horizontal, calculated at surface level, including additional area required by slope.

Take bores to a depth equal to 2 times the excavation depth. Continuous sampling is required to permit the large impact of surface features such as rock. For preliminary-level estimates, use half footing tests. For important deepening and excavation projects, pump tests in wells are highly recommended.

Sheeted excavations

One boring per 1,000 ft of footprint for preliminary design or every 500 ft if for food design, based on structure footprint.

18. Shallow, retaining structures, reinforced concrete or mechanically-stabilized earth walls, embankments, walls or rock anchors or soil nails

Firm

Every 75 feet along wall or 2 or 3 borings or soundings per generally to wall soil profile should restrict core in length equal to twice the doubling depth, or 2 times the vertical distance from the bottom of embankment, wall or trench to the bottom of the footing or pipe. For secondary structures, use 15 feet or 250 feet. Check FHWA guidelines (24C-FCA5-LD and Soil Nail Manual), which suggest wall boring at 30 feet intervals, plus a line of borings directly to the 150 feet below expected cut. Depth of borings depends on stability and the project, e.g., earthquake-resistant design.

A single boring should be at least one diameter below the wall height. Take borings below any potential failure zones. In case of pipelines, take at least 20 feet below its centerline. For backfilling walls, use passive analyses and the investigation should include the zone of the compression. Minimum depth will require greater investigation density for shallow pipeline or medium depth. 10 to 20 feet will be used. For tunnels, 10 to 15 feet for 200 feet, or others.

19. Embankments, bridges and highway embankments, walls

Embarkments

One boring every 150 to 500 feet for viaducts or bridges, considering at least one boring per depending on width of path. Consider need for traverses, separate sections for 3 profiles or sections.

Borings should be taken a depth equal to 2 times the embankment plus 50 ft (%). (8 ft); elsewhere.

20. Bridges and viaducts

If drilled shafts are used, follow FHWA guidelines (24C-FCA5-LD and Soil Nail Manual) one boring per 3 to 5 diameters below the pile tips. If bored piles are 8 to 10 ft diameter, one boring per 3 to 4 diameters below the pile tips are sufficient. If bored piles are 4 to 6 ft diameter, one boring per 2 to 2.5 diameters below the pile tips are sufficient. In case of used, follow FHWA guidelines (24C-FCA5-LD and Soil Nail Manual) one boring per 3 to 5 diameters below the pile tips. If bored piles are 8 to 10 ft diameter, one boring per 3 to 4 diameters below the pile tips are sufficient. If bored piles are 4 to 6 ft diameter, one boring per 2 to 2.5 diameters below the pile tips are sufficient.

For pipelines, borings should be taken at least 10 diameters below the pile tips. As capacity increases, more borings might be required. In case of walls, the depth of borings should be taken 20 feet below the pile tips and that they extend below top line of piles by twice the pile width.

Cuts and slopes

In cut surfaces, need groups of at least 3 borings to cut to define profiles. These profiles should be obtained at least 150 to 200 feet from slope.

Take borings below cut and below potential failure surface.

21. Earth walls or levees

Usual earth banks or riverbank areas

Do borings every 100 feet for preliminary review. Final report will require investigation points at 150 to 300 feet spacing. Keep in mind that new walls will include young compressible soils, and that a detailed investigation should be performed. Consider seismic exploration with 3D grids. Borings should be taken through the full exploration.

For structures such as embankments and culverts, see other sections of the table. For stability analyses it is usually necessary to reach competent layers. Minimum depth of exploration should exceed three times width of slope or levee. Consider explorations with both SPT and CPT.

22. Open cut excavations, isolated or sporadic investigations.

Emergency cases

Need at least one longitudinal profile. The minimum investigations should include at least one boring per 2 to 3 times the structure length, every 2010 to 2020.

Depth of borings depends on the problems. Slope analysis will require borings taken in at least equal to 1.5 times the slope height. The analysis should consider results from inclinometers, piezometers and continuous sampling.

23. Airports fields

Generally

Need at least one boring or sounding every 2,500 square feet. Investigation depth depends on substrates and need for cores or pipe fill, presence of compressible soils or possibility of liquefaction. Consider continuous sampling with SPT or CPT with seismic cone.

Conceptual design

At every stage, should try to perform one or two borings of site to determine relevant soil profiles, initial depth and layer. For preliminary analysis, use 3 to 5 test holes. Consider 3 to 5 test holes, with compaction testing and other installations.

Drill a depth that exceeds probable base width by a factor of two, or 15 to 25 feet into rock with RQD>65. Never continuous sampling necessary to define zones or liquefiable layers or soft layers. Depth of steel piles or impervious layers will affect depth of investigation.

24. Shallow foundations, isolated or sporadic investigations.

Preliminary

Depends on type of dam and potential problems - earth dams and embankment more exploration bottom holes. Final study will require at least 2 borings every 150 to 300 feet for principal area. In slope foundation, the number of borings should be approximately every 100 feet along the cross wall, twice the wall length.

Depends on potential problems with liquefaction, slope stability or flow that have been identified in the preliminary investigation. In this phase, geophysical investigations will be of great value. Numerous tests to test trenches will be necessary along potential problem areas or borrow pit areas.

Final

Depends on type of dam and potential problems - earth dams and embankment more exploration bottom holes. Final study will require at least 2 borings every 150 to 300 feet for principal area. In slope foundation, the number of borings should be approximately every 100 feet along the cross wall, twice the wall length.

Depends on potential problems with liquefaction, slope stability or flow that have been identified in the preliminary investigation. In this phase, geophysical investigations will be of great value. Numerous tests to test trenches will be necessary along potential problem areas or borrow pit areas.

25. Remodeling and additions to existing structures

In general

Investigation density will greatly increase previously-mentioned situations and great depth and quality of previous design and construction. Continue previous suggestions, depending on specific case. Geotechnical fees will greatly exceed cost of investigation densely.

26. Quaywalls

Consider seismic refraction. Borings or trenches. If necessary, should reach bedrock. Rock fragmentation important. Space at least two line borings every 250 feet of wall.

Take borings below expected out depth. For seismic reflection, length of survey should generally be 3 to 4 times expected excavation depth.

27. Piling areas, embankments only

Preliminary study

Space borings or soundings at least every 150 feet for preliminary study, every 50 feet for final study.

Borings depths depend on probable depth of RQD and type of underlying soils. Use continuous sampling. Require greater boring or sounding density.

28. Miscellaneous

In general

Depends on type and width of base and fill. For boring or sounding every 75 to 150 feet of dock length.

Borings will depend on expected loads. Take borings or sounding at least 30 feet below expected pile tips. A detailed investigation could reduce subsequent pile load test requirements.