CHAPTER 2

CONTENT OF GEOTECHNICAL AND STABILITY ANALYSES

This chapter summarizes the components that should be considered parts of the geotechnical and stability analyses of a *waste containment facility* in Ohio. This chapter also summarizes the minimum information that should be reported to Ohio EPA once the analyses are complete. The specific contents for any given geotechnical and stability analyses report may change depending upon the specific set of circumstances surrounding each individual facility.

REPORT CONTENT

More details regarding report content can be found in the reporting section of each chapter of this policy. All drawings and cross sections should be referenced to the facility coordinate system, and northing and easting lines should be shown. Using tabs and a clear organizational format for the data will make it easier to find information when needed.

> Any drawings or cross sections referred to in this policy that are already present in another part of the geotechnical and stability analyses report can be referenced rather than duplicated in each section. It is helpful if the *responsible party* ensures the referenced items are easy to locate and marked to show the appropriate information.

Subsurface Investigation

Ohio EPA recommends that the results of the subsurface investigation be included in their own section of the geotechnical and stability analyses report (see Chapter 3 for more details). At a minimum, the following information about the subsurface investigation should be reported to Ohio EPA:

- A summary narrative describing the rationale behind the site investigation, assumptions used, methodologies used, the identification of the *critical layers*, *compressible layers*, temporal high *phreatic surfaces*, and temporal high *piezometric surfaces*, why they were selected, and what characteristics they have,

- One or more tables summarizing all field test data and laboratory test data gathered from all *borings* conducted and *samples* collected at the facility. The tables should clearly identify the *sample* locations and *borings* associated with each test result, the units of measurement of the test results, and test results associated with the *critical layers* and the *compressible layers* to be used in geotechnical and stability analyses,

- One or more topographic maps that show and identify each *boring* location and *sample* collection point at the facility. The maps can be used to identify the cross sections provided in the report. They can also be used to show the lateral extent of each *critical layer* and each *compressible layer* that exists at the facility, the elevations of the temporal high *phreatic surfaces*, and the elevations of the temporal high *piezometric surfaces*. Plan view maps should show the limits of the *waste containment unit(s)*,

- Cross sections that clearly show the *soil stratigraphy*, temporal high *phreatic surfaces*, and temporal high *piezometric surfaces* at the facility, and the characteristics of each *soil unit*,

- The preliminary investigation results, including a discussion of the findings of the preliminary investigation, and the sources of information used,

- A description of the site characterization results stating the activities, methods, and findings,

- A description of the investigation of *critical layers*, *compressible layers*, *phreatic surfaces*, and *piezometric surfaces*, and

- Any figures, drawings, or references relied upon during the investigation marked to show how they relate to the facility.

Materials Testing

Ohio EPA recommends that the results of all materials testing completed during the design of the *waste containment facility* be included in the subsurface investigation report. The subsurface investigation report is described in Chapter 3. At a minimum, the following information about materials testing results should be reported to Ohio EPA whenever testing is conducted (see Chapter 4 for more details):

- A narrative and tabular summary of the scope, extent, and findings of the materials testing,

- A description of collection and transport procedures for *samples*,

- The test setup parameters and protocols for each test,

- The characterization of each *specimen* used in each test,

- The intermediate data created during each test,

- The results of each test, and

- Any figures, drawings, or references relied upon during the testing marked to show how they relate to the facility.

> The results of *conformance testing* of materials completed after the design work, but prior to use of the materials in construction must be reported to Ohio EPA in their own report prior to use of the materials. In addition to the reporting requirements listed in this chapter and Chapter 4, a comparison of conformance test results to the requirements contained in rule, the authorizing document, or the assumptions used in the geotechnical and stability analyses should be included.

Liquefaction Potential Evaluation and Analysis

Ohio EPA recommends the liquefaction evaluation and analysis results be included in their own section of the geotechnical and stability analyses report (see Chapter 5 for more details). At a minimum, the following information about the liquefaction evaluation and analysis should be reported to Ohio EPA:

- A summary discussion of the findings of the liquefaction evaluation and analysis,
- A detailed discussion of the liquefaction evaluation including:
  - Evaluation of the geologic age and origin, fines content, plasticity index, saturation, depth below ground surface, and soil penetration resistance of each of the *soil units* that comprise the *soil stratigraphy* of the *waste containment facility*,
  - The scope, extent, and findings of the subsurface investigation as they pertain to the liquefaction evaluation,
  - A narrative description of each potentially liquefiable layer, if any, at the facility, and
  - Any figures, drawings, or references relied upon during the evaluation marked to show how they relate to the facility.
- If the liquefaction evaluation identifies potentially liquefiable layers, then the following information should be included in the report:
  - A narrative and tabular summary of the results of the liquefaction analysis completed for each potentially liquefiable layer,
  - Plan views of the facility that include the northings and eastings, the lateral extent of the potentially liquefiable layers, and the limits of the *waste containment unit(s)*,
  - Cross sections of the facility stratigraphic *soil units* that fully depict the potentially liquefiable layers, the characteristics that identify them as such, and show the engineered components of the facility,
  - The scope, extent, and findings of the subsurface investigation as they pertain to potentially liquefiable layers,
  - A description of the methods used to calculate the factor of safety (FS) against liquefaction,
  - Liquefaction analysis input parameters and assumptions, including the rationale for their selection,
  - The actual calculations and/or computer output, and
  - Any figures, drawings, or references relied upon during the analysis marked to show how they relate to the facility.

Settlement Analyses and Bearing Capacity

The results of the settlement analysis for the facility, and the results of the bearing capacity analysis for vertical sump risers, if any are used, should be included in their own section of the geotechnical and stability analyses report (see Chapter 6 for more details). At a minimum, the following information about the bearing capacity analysis for vertical sump risers, if any are used, and the settlement analysis should be reported to Ohio EPA:

- A narrative and tabular summary of the results of the settlement analyses,
- A summary and a detailed discussion of the results of the subsurface investigation that apply to the settlement analyses and how they are used in the analyses,
- A summary of the approach, methodologies, and equations used to model settlement of the facility,
- If any of the settlement parameters were interpolated by using random generation or another method, then information must be provided that explains in detail, including equations and methodology, how the settlement parameters were generated,
- Plan view maps showing the top of the liner system, the liquid containment and collection system, the location of the points where settlement is calculated, the expected settlement associated with each point, and the limits of the *waste containment unit(s)*.
- Drawings showing the critical cross sections analyzed. The cross sections should include the:
    - *Soil stratigraphy*,
    - Temporal high *phreatic surfaces*,
    - The range of the tested settlement parameters of each layer,
    - Depth of excavation,
    - Location of engineered components of the facility that may be adversely affected by settlement,
    - The amount of settlement calculated at each point chosen along the cross section,
    - The detailed settlement calculations of the engineering components,
    - Any figures, drawings, or references relied upon during the analysis marked to show how they relate to the facility, and
    - The detailed tensile strain analysis.

- If vertical sump risers are included in the facility design, then include:
  - A narrative and tabular summary of the results of the bearing capacity analysis,
  - A summary and a detailed discussion of the results of the subsurface investigation that apply to the bearing capacity and how they were used in the analyses,
  - A summary of the approach, methodologies, and equations used to model the bearing capacity of the facility.

> Ohio EPA discourages the use of vertical sump risers in solid waste and hazardous *waste containment units*. This is due to the inherent difficulties they present during filling operations and the potential they create for damaging liner systems.

Hydrostatic Uplift Analysis

Ohio EPA recommends the results of the hydrostatic uplift analysis be included in their own section of the geotechnical and stability analyses report (see Chapter 7 for more details). At a minimum, the following information about the hydrostatic uplift analysis should be reported to Ohio EPA:

- A narrative and tabular summary of the results of the hydrostatic uplift analysis,
- A summary and discussion of the results of the subsurface investigation that apply to hydrostatic uplift analysis and how they were used in the analysis,
- A summary of the worst-case scenarios used to analyze the hydrostatic uplift potential of the facility,
- Isopach maps comparing excavation and construction grades with temporal high *phreatic surfaces* and temporal high *piezometric surfaces* as applicable to the facility. These drawings should show the limits of the *waste containment unit(s)*,
- The cross sections that were analyzed showing the characteristics of the *soil stratigraphy*, temporal high *phreatic surfaces*, temporal high *piezometric surfaces*, excavation grades, and engineered components, as applicable,
- The detailed hydrostatic uplift calculations, and
- Any figures, drawings, or references relied upon during the analysis marked to show how they relate to the facility.

Deep-Seated Failure Analysis

Ohio EPA recommends the results of the deep-seated failure analysis be included in their own section of the geotechnical and stability analyses report (see Chapter 8 for more details). At a minimum, the following information about the deep-seated failure analysis should be reported to Ohio EPA:

- A narrative summary of the results of the deep-seated failure analysis,
- One or more tables summarizing the results of the deep-seated failure analysis on all the analyzed cross sections,
- One or more tables summarizing the internal and interface shear strengths used to model the various components of the *internal*, *interim*, and *final slopes*,
- Graphical representations of the failure envelopes of each interface, material, and composite system,
- The scope, extent, and findings of the subsurface investigation as they pertain to the analysis of potential deep-seated failures at the *waste containment facility*,
- A narrative description of the logic and rationale used for selecting the critical cross sections for the *internal*, *interim*, and *final slopes*,
- A narrative justifying the assumptions made in the calculations and describing the methods and logic used to search for failure surfaces,
- Plan views of the *internal*, *interim*, and *final slope* grading plans clearly showing the location of the analyzed cross sections, the northings and eastings, and the limits of the *waste containment unit(s)*,
- The analyzed cross sections, showing the engineered components and the underlying *soil stratigraphy*, including the temporal high *phreatic surfaces* and the temporal high *piezometric surfaces*,
- Static stability calculations (both inputs and outputs) for *internal*, *interim*, and *final slopes*, assuming *drained conditions* in the *soil units* beneath the facility,
- As appropriate, static stability calculations for *internal*, *interim*, and *final slopes* assuming *undrained conditions* in the *soil units* beneath the facility. When a slope is underlain by a material that may develop excess pore water pressure during loading, the static factor of safety must be

The effective shear strength of a *soil unit* should be used when modeling conditions where excess pore water pressures have completely dissipated, or when the soil layers at the site will not become *saturated* during construction and filling of a facility.

The *unconsolidated-undrained shear strength* of a soil (as determined by shearing fully *saturated specimens* in a manner that does not allow for drainage from the *specimen* to occur) should be used whenever one or more *soil units* exist at a site that are or may become *saturated* during construction and operations. This will produce a worst-case failure scenario, since it is unlikely that in the field any given *soil unit* will exhibit less shear strength than this.

determined using the *undrained shear strength* of the foundation materials. The *undrained shear strengths* must be determined by shear strength testing of site-specific, undisturbed *samples* of all critical layers that may develop excess pore water pressure,

- Seismic stability calculations for *internal*, *interim*, and *final slopes* assuming *drained conditions*, and if applicable, *undrained conditions*, beneath the facility,

- Any other calculations used to analyze the deep-seated translational and rotational failure mechanisms for the facility, and

- Any figures, drawings, or references relied upon during the analysis marked to show how they relate to the facility.

Shallow Failure Analysis

Ohio EPA recommends the results of the shallow failure analysis be included in their own section of the geotechnical and stability analyses report (see Chapter 9 for more details). At a minimum, the following information about the shallow failure analysis should be reported to Ohio EPA:

- A summary narrative describing the results of the shallow failure analysis,

- One or more tables summarizing the results of the shallow failure analysis for each cross section analyzed,

- One or more tables summarizing the internal and interface shear strengths of the various components of the *internal slopes* and *final slopes*,

- Graphical portrayal of any non-linear failure envelopes being proposed for each interface and material,

- A narrative justifying the assumptions used in the calculations, including a discussion of the applicable data from the subsurface investigation,

- Plan views of the *internal slope* and *final slope* grading plans, clearly showing the location of the worst-case cross sections, and the limits of the *waste containment unit(s)*,

- The worst-case cross sections showing the engineered components, underlying *soil units*, waste, and the temporal high *phreatic surfaces*, and the temporal high *piezometric surfaces*,

- Stability calculations for *unsaturated internal slopes* and *unsaturated final slopes* assuming static conditions,

- Stability calculations for *saturated internal slopes* and *saturated final slopes* assuming static conditions,

- Stability calculations for *unsaturated final slopes* assuming seismic conditions,

- Any other necessary calculations used to evaluate shallow translational and rotational failure mechanisms at the facility, and

- Any figures, drawings, or references relied upon during the analysis marked to show how they relate to the facility.

THE COMPONENTS OF GEOTECHNICAL AND STABILITY ANALYSES

The geotechnical analyses should include a subsurface investigation and evaluations of hydrostatic uplift, liquefaction, settlement, and bearing capacity. The stability analyses should include a static evaluation and a seismic evaluation for *internal*, *interim*, and *final slopes*, each for deep and shallow translational failure surfaces and deep and shallow rotational failure surfaces.

Several unique conditions should be evaluated for any given facility. Examples of these conditions include, but are not limited to:

- *drained conditions* (no excess pore water pressure exists in the soil),
- *undrained conditions* (excess pore water pressure exists in soil materials), and
- *saturated protective layers* causing head in the drainage layers during the design storm.

Figure 2-1 on page 2-9 and **Figure 2-2** on page 2-10 provide an overview of the components of stability analyses that should be completed for any given *waste containment facility*. **Figure 2-3** starting on page 2-11 is a flowchart of a complete geotechnical and stability analyses for a *waste containment facility*.

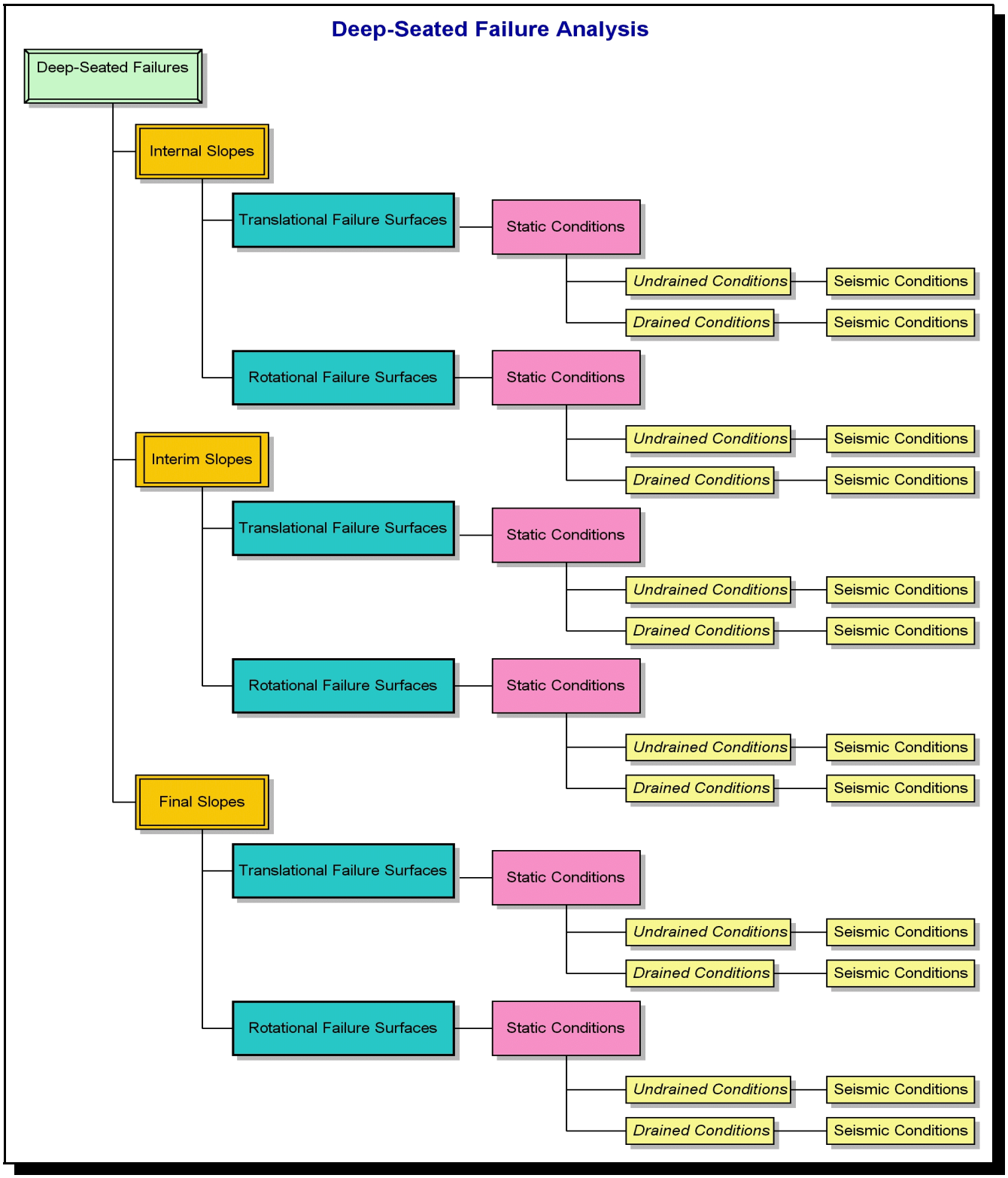


Figure 2-1 Organizational chart of the components of a deep-seated failure surface stability analysis. Note: If there are no *soil units* that may exhibit excess pore water pressure at a facility, then undrained analysis may not be required, and slope stability analysis of *internal slopes* and *interim slopes* under seismic conditions may not be necessary (see Chapter 8 for details).

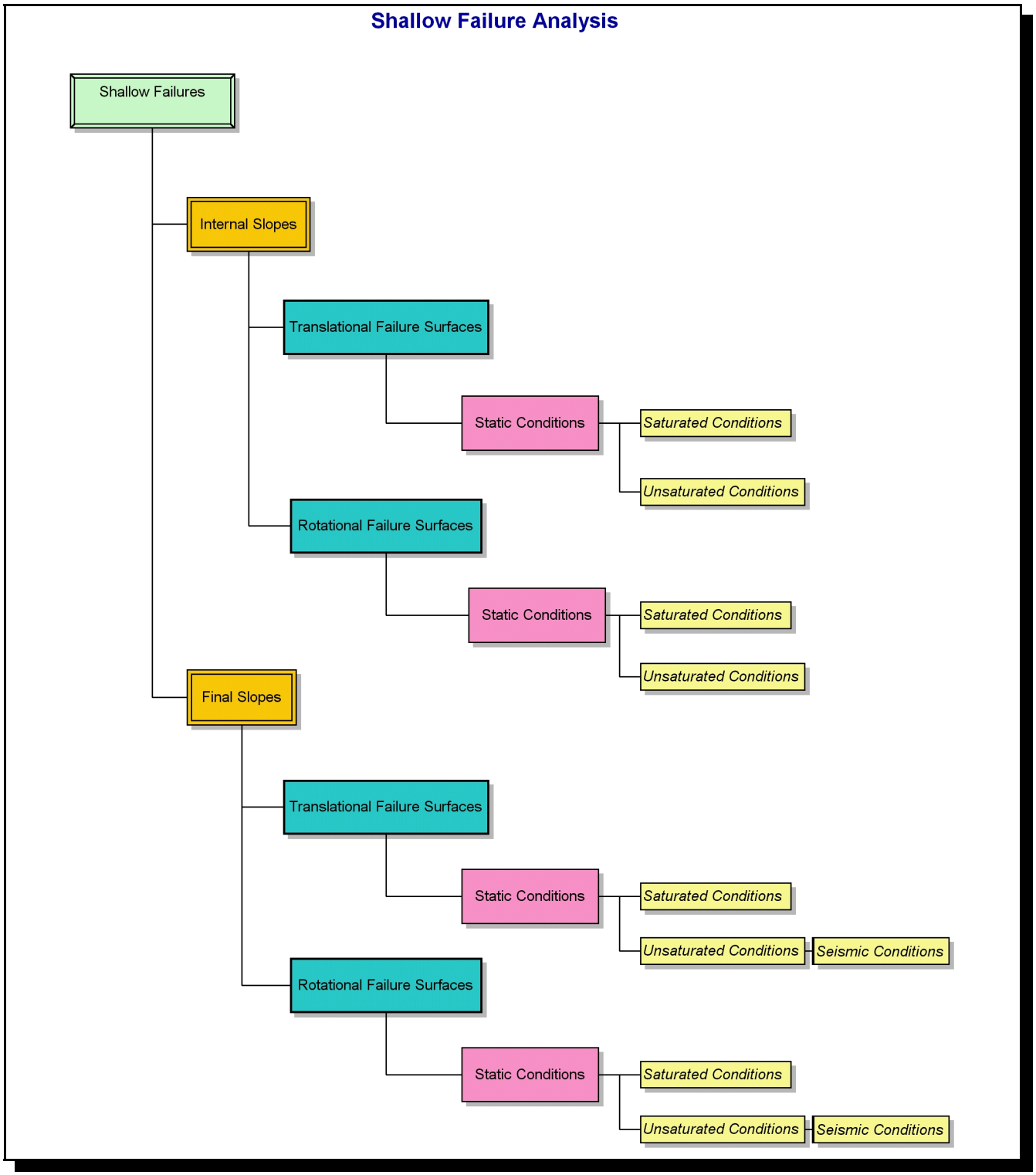


Figure 2-2 Organizational chart of the components of a shallow failure stability analysis. Note: Seismic analysis of *internal slopes* assuming *unsaturated* conditions may be required in some circumstances (see Chapter 9 for details).

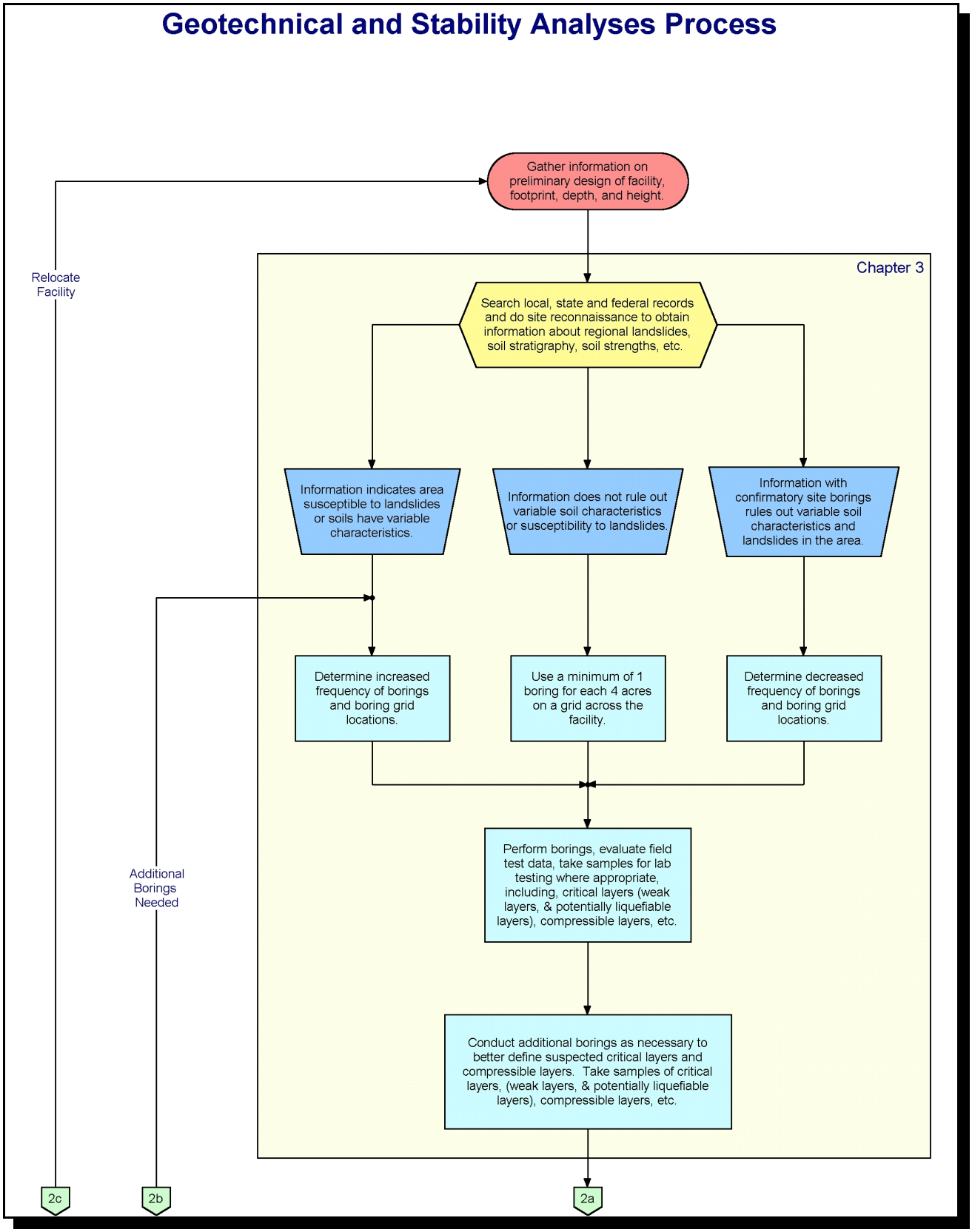
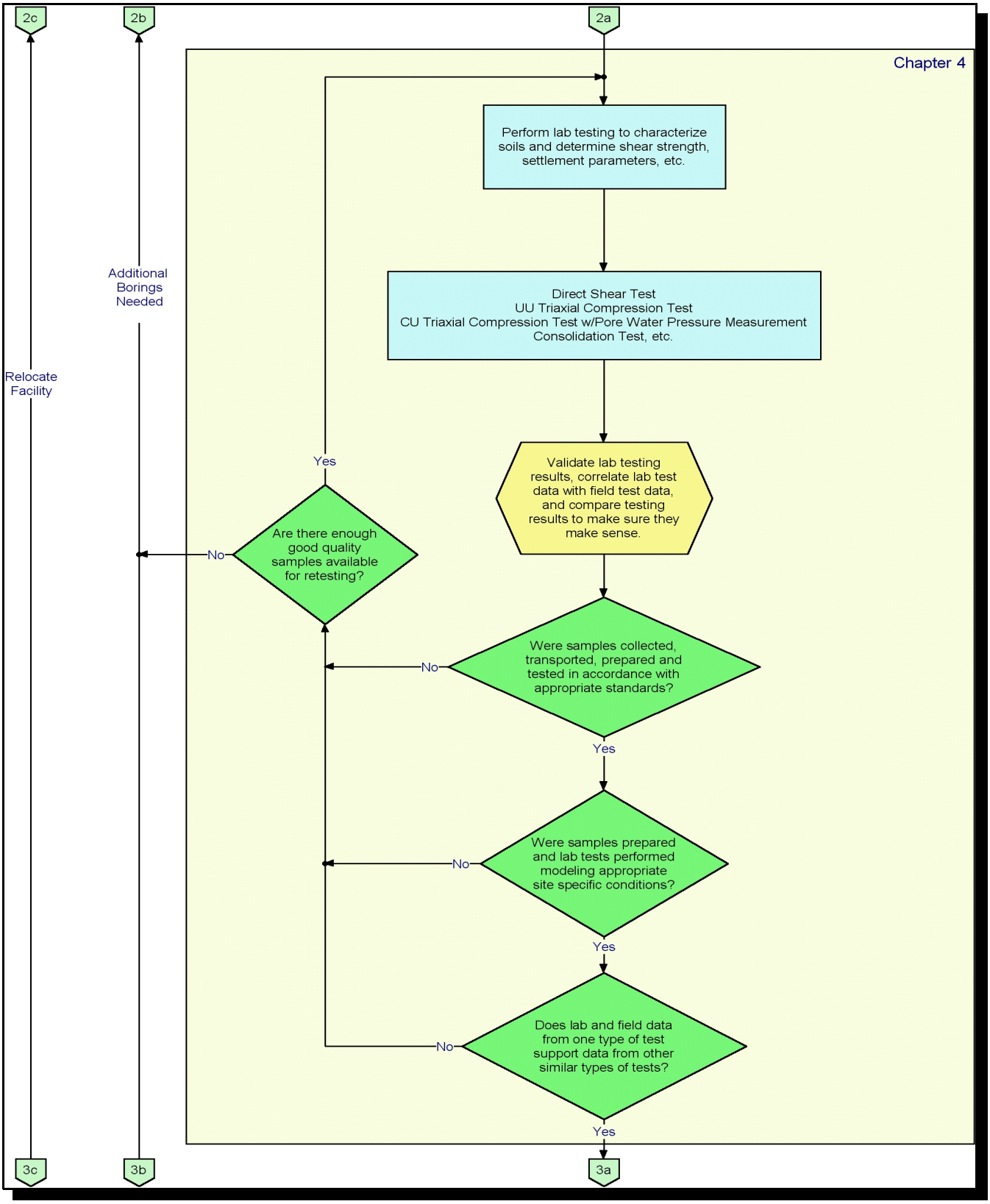
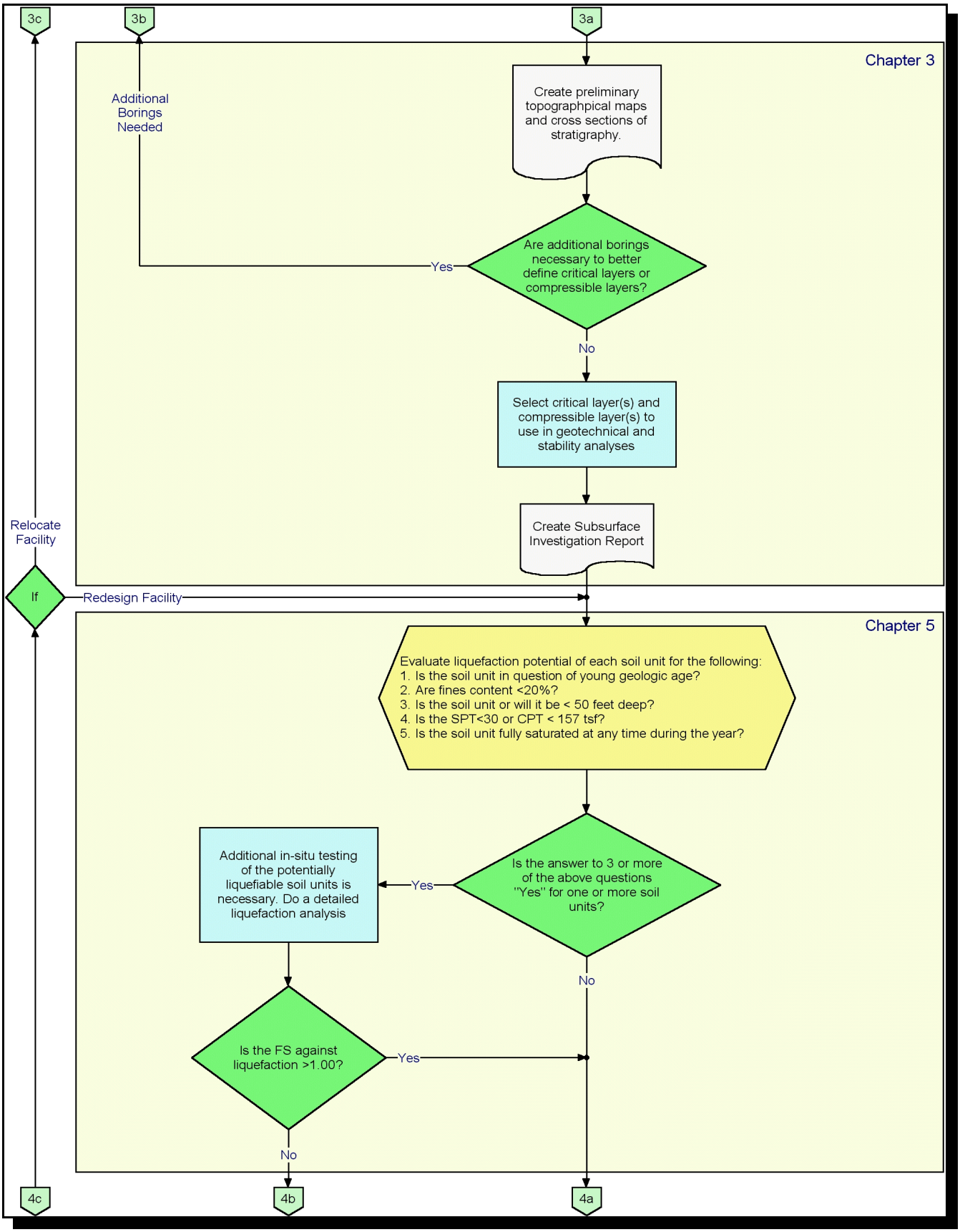


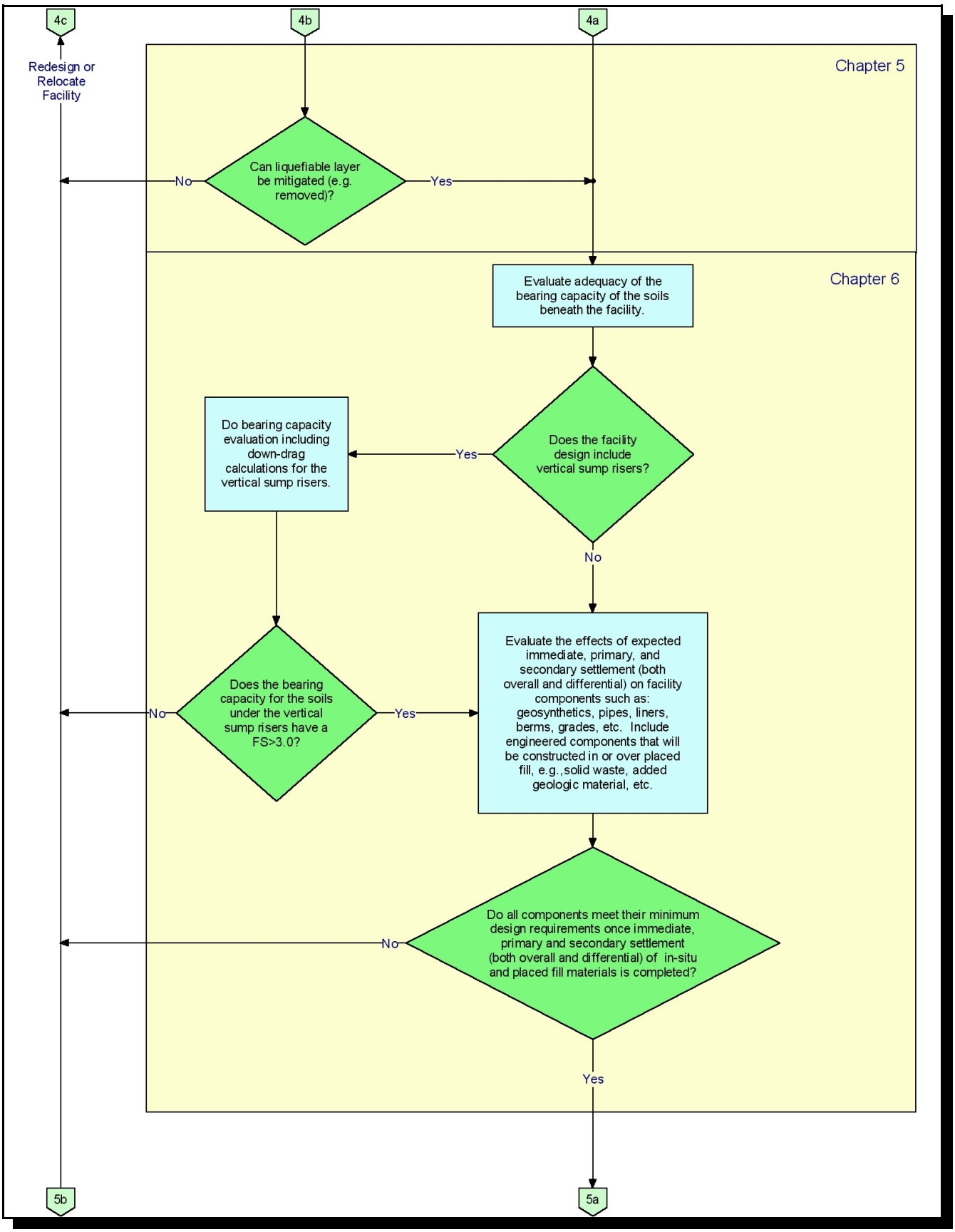
Figure 2-3 Page 1. Geotechnical and stability analyses flow chart.



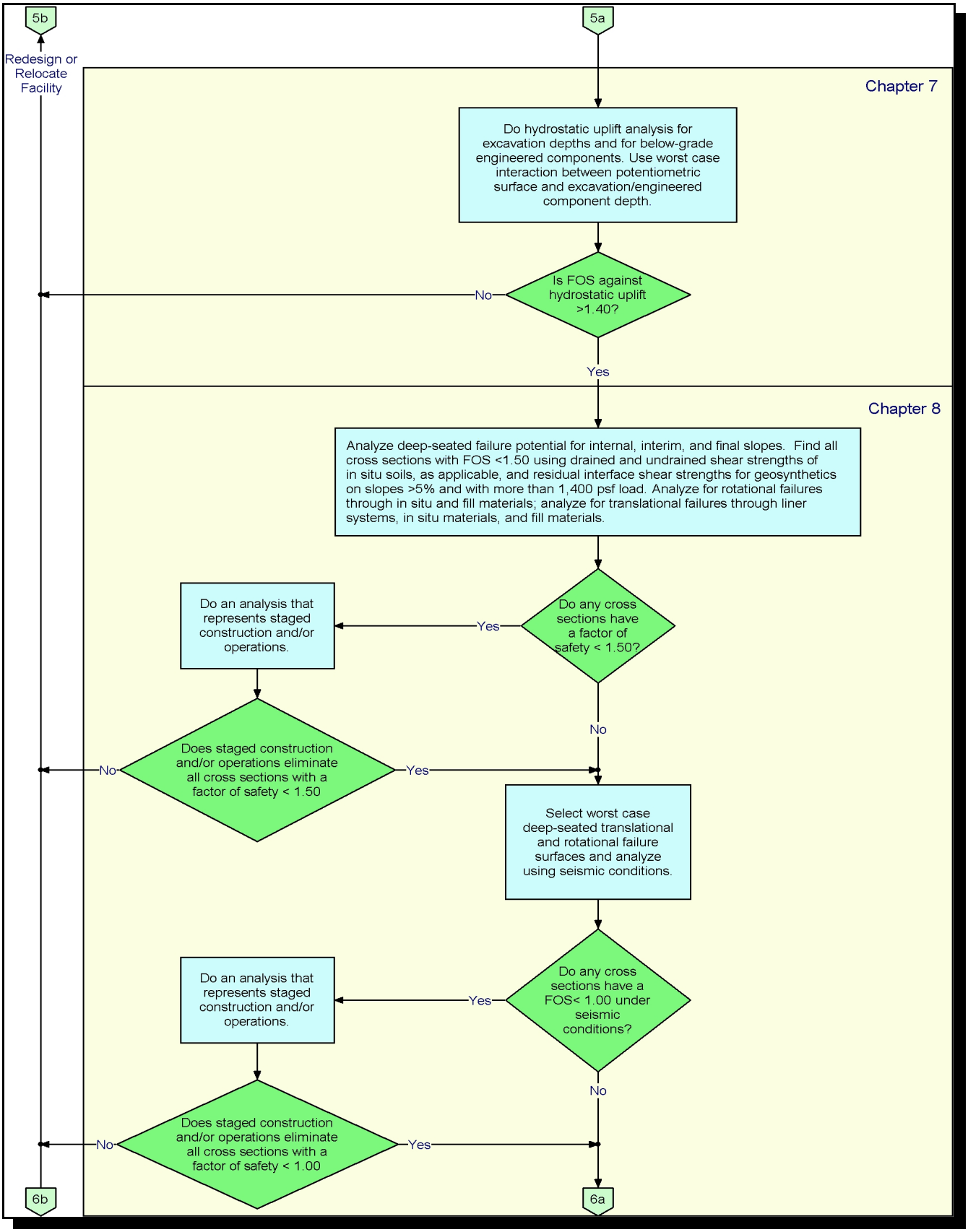
Page 2. Geotechnical and stability analyses flow chart.



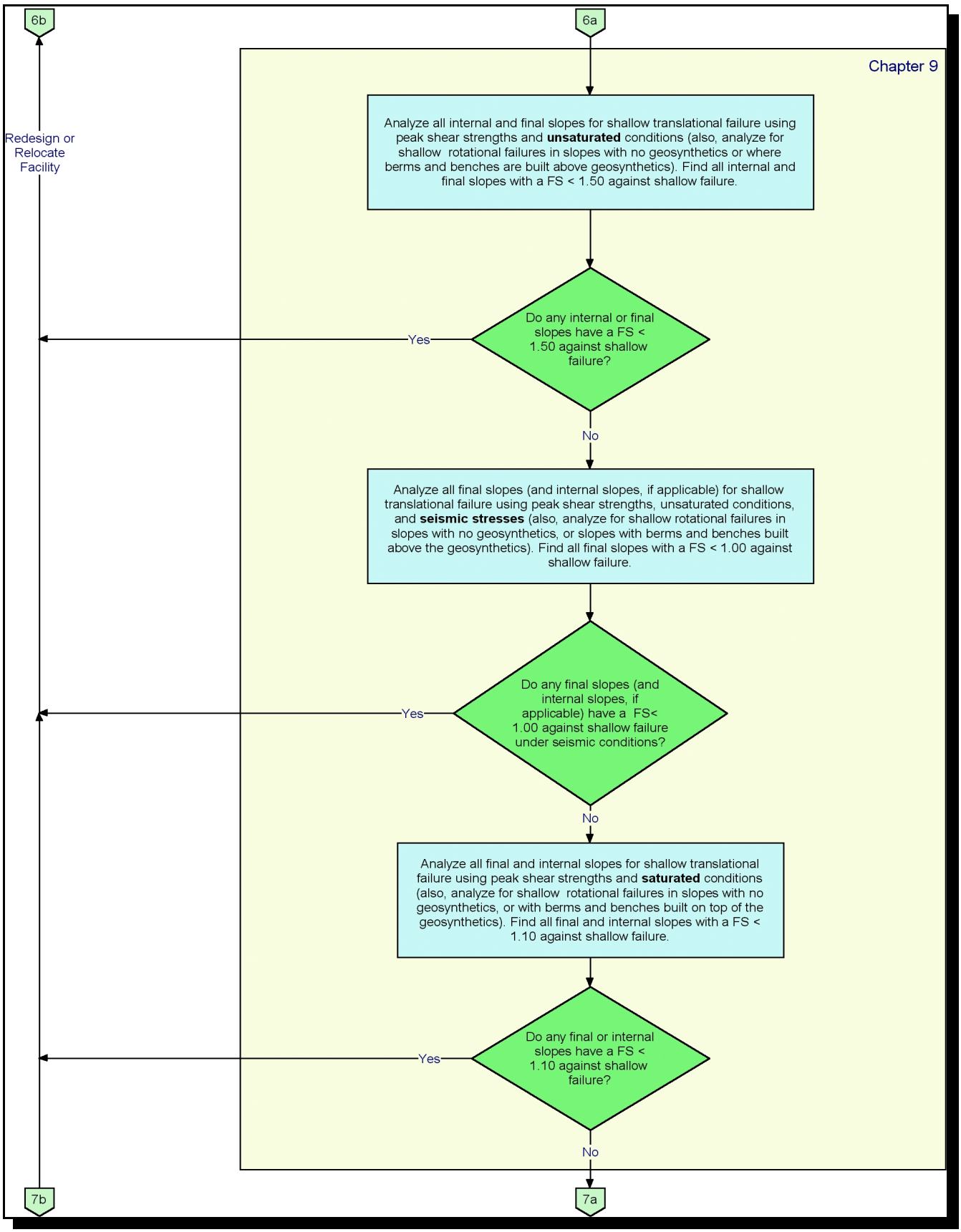
Page 3. Geotechnical and stability analyses flow chart.



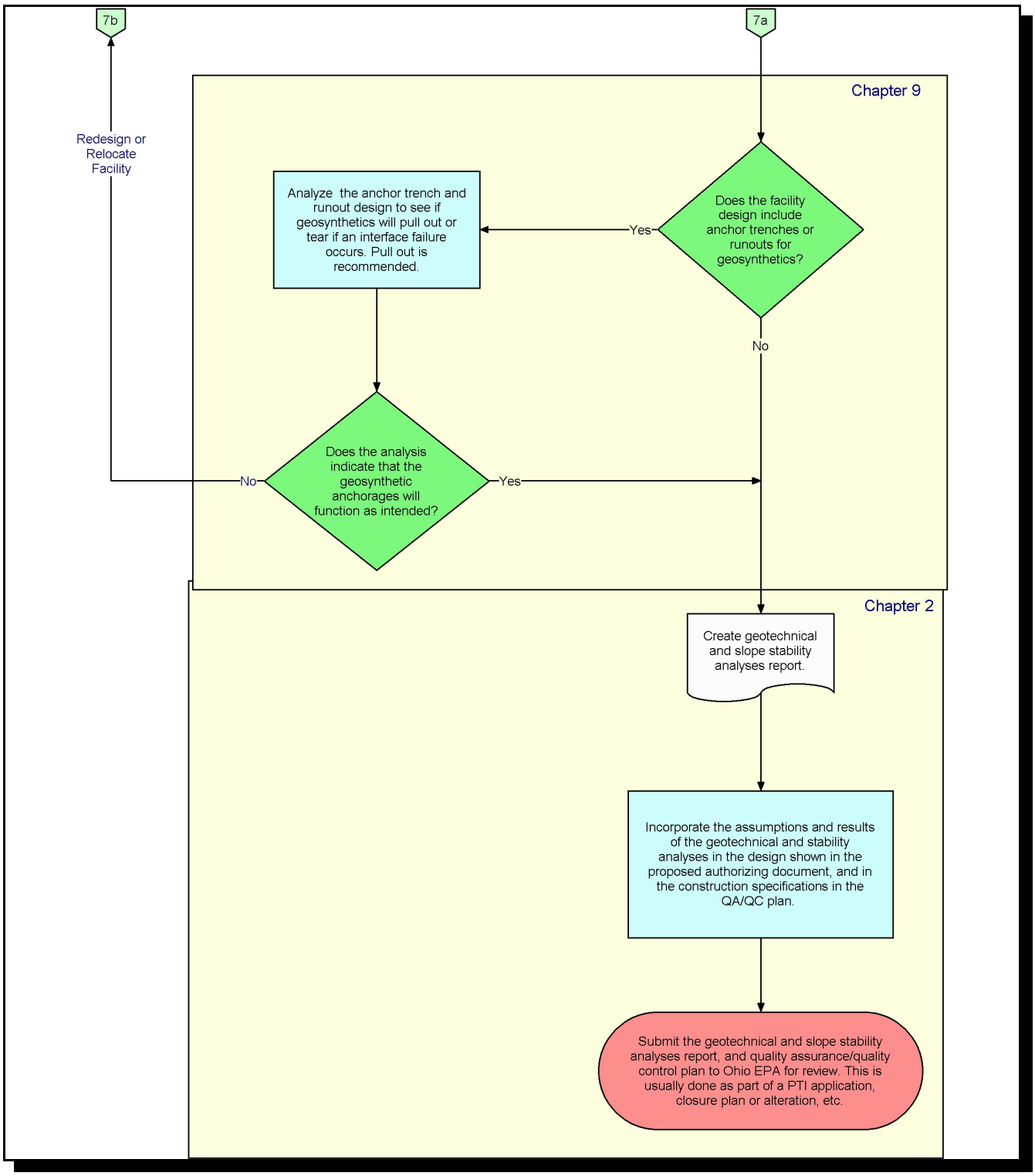
Page 4. Geotechnical and stability analyses flow chart.



Page 5. Geotechnical and stability analyses flow chart.



Page 6. Geotechnical and stability analyses flow chart.



Page 7. Geotechnical and stability analyses flow chart.

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