Review & Discussion of Integrated Site Characterization Approach

[Questions to ask in reviewing work as it is planned, executed, and documented]
Site Characterization Process

1. Inductive Reasoning
   - Hypothesize performance mechanisms
   - Develop geologic model
   - Refine hypotheses relating mechanisms, layers, spatial variability & properties

2. Scenario Assessment
   - Preliminary analysis to verify or eliminate possible scenarios

3. Site Investigation
   - Perform site investigation using in-situ & lab tools

4. Site Idealization
   - Assess/verify geologic model
   - Assess spatial variability & stratigraphic continuity
   - Sub-divide into critical zones & assign representative values

5. Analysis & Design
   - Continue design & perform sensitivity analysis
   - Construction observations
   - Performance monitoring
   - Observational Method

6. Observational Method
Step 0: ...Before You Start

- What areas of expertise are necessary for the project, and who will fill each role?
- Who has expertise/experience on similar projects, and are they sufficiently engaged?
- What past experience/knowledge do we have in the project’s geological setting (same or similar)?
- What analogs exist at/near the project site that indicate possible controlling mechanisms, performance issues, and design solutions?
- To what extent, and in what capacity, must a geologist be involved in formulating, and later revising, the geologic model?
- Have sufficient time and budget been allocated for stages besides the site investigation (SI) stage? If not, how must the scope of SI be reduced?
- After/during which stages should we perform internal/external project review?
What mechanisms influenced the performance of prior structures at or near the site?

What mechanisms have controlled the design or performance of similar structures in the region?

Given the current project design, what mechanisms likely control performance?

For each potential mechanism identified:
- what is the mechanism length scale?
- what soil zones are engaged in the mechanism?
- what are the relevant soil engineering properties?

How was the likelihood of the different potential mechanisms ranked?
Step 1.2: Develop Geologic Model

- How has prior geologic mapping (regional and site-specific) been incorporated into the model?
- What information from historical documentation (site work, construction photos, post-EQ reconnaissance, aerial photos) influenced the model?
- For each geologic and earthwork zone:
  - what were the depositional and weathering processes?
  - what is the expected spatial variability?
  - what is the expected composition (grain size, plasticity)?
  - what is the expected anisotropy (layering, fracturing, strike/dip)?
- Which soft/weak/permeable layers have been problematic in the past or may be in the future?
- What are the groundwater conditions and how do/will they vary in time?
- How was seismic activity assessed, and is it a concern?
Step 1.3: Refine Hypotheses Relating Mechanisms, Layers, Spatial Variability & Properties

- What information was primarily relied upon in refining certain hypothesized mechanisms and excluding others?
- For each mechanism how did the geologic model influence the ranked likelihood of occurrence and identification of zones expected to control performance?
- Are there particular stratigraphic layers that will (likely) control/limit/guide multiple mechanisms?
- What historic/regional data was used to develop estimates of spatial variability and soil properties?
- What representative value of soil properties have been selected considering the length scale of the mechanism relative to the stratigraphic continuity of the controlling zone(s)?
Step 2: Preliminary Analysis to Verify or Eliminate Possible Scenarios

- What is the simplified, idealized project cross-section that represents the most likely site conditions?
- For the critical soil layers, what are the range of best-case and worst-case conditions for soil layer extent, continuity, and properties?
- What simplified analysis methods were used, and are the simplifying assumptions required acceptable at this stage?
- Based on the sensitivity analysis, reducing the uncertainty of which conditions (layer extent, continuity, properties) would provide the greatest reduction in performance uncertainty?
- Based on the sensitivity analysis, is understanding the spatial variability or obtaining accurate soil property measurements more important?
- Would it be beneficial (if possible) to perform future detailed analyses in a probabilistic manner, or is a deterministic approach sufficient given the unknowns and criticality of the structure?
- Are the outcomes of this stage consistent with observations at similar structures in the region?
Given the expected spatial variability, what priority was given to mapping variability versus obtaining detailed engineering property characterization?

What best practices for in-situ testing, drilling & sampling, and laboratory testing were used given the soil types and stratigraphic layering anticipated?

Was the sequencing of field work appropriate for verifying the geologic model prior to detailed engineering property determination?

Was a systematic approach used to assess spatial variability (e.g. multiple CPTs performed at varying spacings)?

Did the insitu and laboratory testing focus on the characterizing the correct properties, and if so, was there redundancy in characterization methods to cross-verify property estimates?

How do measurements obtained compare with historical data and standard literature values?

Have data obtained been presented in a transparent format that readily allows side-by-side comparison of different types of information?

What aspect of the geologic model was least characterized during SI?
Step 4.1: Assess/verify Geologic Model

- What important changes/updates to the initial geologic model were made based on the additional information obtained during the SI?
- What site investigation (SI) data conflicted with the initial geologic model?
- Did the SI lead to changes in the understanding of the depositional and weathering mechanisms?
- Did the SI reveal previously unknown/unexpected zones?
- What SI data forced zones/layers to be redefined?
- Was sufficient data collected to characterize these unknown/unexpected zones?
- Does the geologic model reasonably explain the soil characteristics encountered on-site (e.g. gravels, clays)?
How was the SI data used to quantitatively assess the spatial variability of critical zones?

Is the distribution (COV) of relevant property (e.g. GSD, \(N_1\)) measurements in critical zones consistent with typical literature values, more uniform, or more variable?

What 16%, 33%, and 50% values for critical design properties?

Were soil properties and penetration resistances amenable to normalization for dependence on overburden stress?

How does the spatial extent of the zones of interest compare with the length scale of the mechanism(s)?

Were particular zones identified that could be critical for seepage?

Were particular zones identified that may be amenable to sand-like liquefaction or clay-like strain softening during earthquake loading?
Step 4.3: Sub-divide into Critical Zones & Assign Representative Values

- What data led to some stratigraphic units being sub-divided based on difference in properties (e.g. gradation, strength, permeability, saturation)?
- Were continuous zones of weakness identified that may lead to localization of the failure mechanism, and if so, how were its properties selected?
- Was the length scale of the deformation mechanism comparable (or larger than) to the critical zone such that an average value is appropriate for analysis?
- Is the length scale of the deformation mechanism smaller than the critical zone such that a lower value is appropriate for analysis?
- If the mechanism intersects multiple zones, how was the interaction effects between zones handled?
- How was the final ‘baseline’ condition selected for analysis & design?
- How were differences in property estimates obtained by different methods resolved? (e.g. $\phi$' from lab and SPT)
How does the final ‘baseline’ condition differ from the simplified, initial ‘baseline’ condition, and are the changes important to design & analysis?

 Were the assumptions made in the initial analysis still acceptable, or were most sophisticated analyses warranted?

 How were scenario variations of the ‘baseline’ case selected and analyzed?

 Did the scenarios considered include variations in stratigraphic boundaries/zones, constitutive models, EQ input motions, etc. in addition to variations in soil properties?

 How were differences in performance estimates obtained by different methods resolved? (e.g. liq. Triggering from SPT or CPT)

 What opportunities exist during construction to further evaluate the design?
Step 6.1: Construction Observations

- Were the priority observations to be made during construction (excavation, construction, filling) documented and disseminated to field personnel?
- What observations during construction enabled (or could enable) verification of the developed geologic model?
- What observations during construction enabled (or could enable) identification of potential seepage issues?
- What observations during construction enabled (or could enable) an indirect evaluation (back calculation) of key properties?
- What observations during construction revealed (or could reveal) unexpected/unforeseen conditions, and how did these observations influence design/construction?
Step 6.2: Performance Monitoring

- What measurements, in what locations and how frequently, will be obtained to monitor the initiation and progression of the controlling mechanisms?
- Is the instrumentation system automated, sufficiently detailed to obtain critical measurements, and yet still maintainable?
- Is there a long term monitoring contract in place to obtain and interpret the data collected?
- Has a logic action decision structure been developed and put in place to trigger decisions and actions when measurement(s) cross pre-defined threshold levels?
- Is there a management plan installed to review data collected and update the decision structure on a regular basis?
Step 7: …As You Finish

- Is the project documentation and files organized, sufficiently detailed, and archived?
- Has the responsibility of the continued performance monitoring plan been clearly assigned/delegated?
- With an additional 20% budget supplement what stages and issues would you focus on refining, and what activities would you undertake?
- In hindsight, which activities and expenses were excessive and not necessary? Could this of been avoidable?
- How should have the geologist been engaged and utilized more effectively?
- At what stages during the process would have peer review (internal or external) been beneficial?
- What lessons learned on the project would be beneficial to the office/company? How will those lessons be shared?