

Three-Dimensional Geological Modeling of Complex Glacial Deposits

Kopczynski, S.E.¹, D.E. Lawson¹, D. Finnegan¹, S. Bigl¹ and E. Evenson²

¹Cold Regions Research and Engineering Laboratory, Hanover NH 03755; ²Earth Sciences, Lehigh University, Bethlehem, PA; E-mail: S.E. Kopczynski at sarahk@crrel.usace.army.mil

Developing three-dimensional models to represent subsurface geological conditions is inherently wrought with a large degree of uncertainty. Modelers attempt to interpolate between ‘knowns’ and ‘unknowns’ because the geological system is not fully understood nor represented with adequate data. In many instances, only a portion of a system is known through a series of carefully selected geological cross sections. Interpolations are made based on acquired knowledge of the site geology and three-dimensional relationships between geological facies from multiple depositional environments.

Extremely complex subsurface stratigraphy characterizes contaminated sites requiring remedial investigations on many Alaskan installations. Preliminary interpretations are generally derived from borehole geologic databases, geophysical studies, ground water studies, and the migration of pollutants. Yet these subsurface conditions cannot be adequately defined by drilling boreholes, nor can geophysical data be readily interpreted using existing conceptual models, especially in formerly glaciated terrains as exist beneath Fort Richardson and the Haines Fuel Terminal. Textbook models of glacial and periglacial environments are too idealized to serve as adequate analogs to interpret subsurface information at many environmental remediation sites. Textbook models are generally devised to provide an all-encompassing perspective of glacial and periglacial processes at larger scales. While these models are helpful to understand generalities, they are insufficient to provide geologic information at the scales and levels of refinement necessary for three-dimensional modeling at environmental remediation sites.

Our approach has been to merge on site investigations of the subsurface geology with investigations of modern environments representing those formerly active in developing the depositional sequences. Process studies at modern glacier locales, such as the Matanuska Glacier and Glacier Bay, allow us to apply actual field-process observations at a variety of scales to characterize site-specific stratigraphy. This work has greatly enhanced our ability to map the vertical and lateral distribution of confining layers in our investigative areas. The data and process observations are synthesized as three-dimensional models allowing us to predict the probable spatial distribution and relationships that exist among aquifers and their confining units. This approach allows us the ability to accurately develop subsurface models that are essential for ground water modeling and contaminant migration pathways identification.

Our models have been successfully applied to remedial investigations at Fort Richardson. On Fort Richardson, for example, complex end and ground moraine sequences associated with both tidewater and terrestrial glaciers are juxtaposed with glaciofluvial and glaciomarine deposits, some of which probably resulted from large magnitude outburst floods. Here, interpretation of the subsurface distribution of glacial deposits is especially complicated because ample outcroppings are not available.

The geological studies of the Poleline Road Disposal Area, Fort Richardson AK, used a combination of geophysical techniques, limited borehole geologic data, hydrological data and three-dimensional modeling techniques and conceptual interpretations gleaned from field studies at the Matanuska Glacier. The site is located about two km south of Eagle River, AK and situated in a topographic low surrounded by a wooded hill to the west, a large wetland to the south and southwest, and low wooded hills to the north and east. At this site, several glacial, glacial-marine and glacial-alluvial depositional events of Quaternary age deposited a complex system of interfingering deposits on bedrock.

These deposits are further complicated by a series of outburst floods that eroded some deposits completely while reworking others and depositing a cap of glaciofluvial materials.

Various geophysical techniques, including ground-penetrating radar, DC resistivity, and shallow seismics were used to map the vertical and lateral extent of the deposits. Ground truth data were obtained from limited deeply penetrating borehole geological logs in conjunction with hydrological data. A conceptual model of the glacial deposits was developed and integrated with field observations from the Matanuska Glacier. This modern environment defined the vertical and lateral distribution of proglacial and ice-marginal debris flows, outwash materials, supraglacial materials and basal diamictons, thereby refining the conceptual geological model.

Without these modern analogues, our conceptual models would be limited to idealized textbook examples possibly leading to erroneous interpretations that would waste funds while also misdirecting further investigations and remediation efforts. This innovative approach allows us to develop more accurate subsurface models necessary in turn to develop ground water models and identify contaminant migration pathways. Knowledge gained in studying modern glacial environments permits sound judgment and interpretations based on fundamental geologic principles