[Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	6: Understanding Site Groundwater Flow
Title	Three Dimensional Groundwater Modeling and Visualization
Submitted by	Westinghouse Electric Company, LLC/GZA GeoEnvironmental, Inc./Paul C. Rizzo Associates, Inc.

1. Overview of Technologies (features, specification, functions, owners, etc.)

Groundwater systems, like the one underlying the Fukushima Daiichi Plant, are inherently complex given largely to variability within the natural subsurface geological conditions as well as anthropogenic conditions such as the presence of deep foundations, soil backfill, underground utilities, perimeter drains, and potential leaks. Groundwater flow conditions can be further complicated by spatial and temporal variability of precipitation and the resulting distribution of infiltration throughout the overlying watershed. Since site investigators cannot peal back the ground surface to directly and easily observe subsurface conditions, they are forced to collect data indirectly through the use of geophysical methods and/or formulate wide-scale interpretations based on localized subsurface point data (e.g., borings, downhole testing and monitoring wells) in an effort to characterize the hydrogeology of the subsurface and understand the resulting groundwater flow regime and potential migration and fate of groundwater contaminants.

Westinghouse has been partnering with several firms with specific expertise in this field. Both Paul C. Rizzo Associates, Inc. (PCR) and GZA GeoEnvironmental, Inc. (GZA) are two such firms. PCR background in this area is included as an attachment. GZA background is enclosed. Westinghouse is eager to lead for either or both partners.

Beginning in the late 1970s and early 1980s, GZA was a pioneering firm with the initial development and utilization of Site Conceptual Models (SCMs)[1] to aid in this process, but SCMs

[1] Dean, A.R. and M.J. Barvenik, "Use of the Observational Method in the Remedial Investigation and Cleanup of Contaminated Land," The Seventh Geotechnique Symposium - Geotechnical Aspects of Contaminated Land, sponsored by the Institution of Civil Engineers, London, Volume XLII, Number 1, March 1992.

have their limitations and can be difficult to convey to stakeholders without the use of accompanying visualization models. GZA has subsequently applied this SCM approach to the release investigation and development of groundwater protection monitoring systems for radionuclides at nuclear power plants[2].

For more complex sites, three dimensional numerical groundwater modeling and data visualization (typically based on the SCM) can provide significant benefits, including

- improving the team's overall quantitative hydrogeological understanding of the site;
- testing the internal consistency of the SCM;
- identifying and prioritizing data gaps;
- visualizing, designing and evaluating mitigation measures; and
- communicating complex technical issues to internal and external stakeholders.

Numerical groundwater models provide a unique mechanism to assess the underlying assumptions of a SCM because they incorporate the disparate semi-qualitative (e.g., soil descriptions, observations made during plant construction) and quantitative (e.g., hydraulic conductivity estimates, groundwater elevations) data sets collected throughout an investigation into an integrated numerical framework, which can then be used to estimate groundwater elevations and flows across the model solution domain. The modeled elevations and groundwater flow directions can then be compared to measured elevations and estimated flow directions to assess the overall consistency of the SCM, and identify data gaps. Once calibrated and validated, the model can then be used in a predictive way to evaluate various mitigation measures (separately and together) and assess their overall effectiveness.

The groundwater modeling software that GZA has used at many sites, including some of the most high profile nuclear power generating sites in the United States, and would recommend for this effort, is the Groundwater Modeling System (GMS) developed by the Environmental Modeling Research Laboratory (EMRL) of Brigham Young University. GMS is based on the United States Geological Survey modular three-dimensional, finite-difference, groundwater flow model known as MODFLOW-2000, which is well documented and widely used around the world.

[2] Barvenik, M.J., "The Observational Method for Conceptual Site Model Development and Verification – Indian Point Energy Center", 2007 ANS/ENS International Meeting, Washington, D.C., Nov. 2007.

For three dimensional visualization software, we would recommend one or more of the following products: GMS, EVS or 3D Studio Max, depending on the specific needs of the project team. GZA is highly skilled at the effective use of these models at nuclear power plant projects, including two of the more visible and politically challenging plants in the US.

While the modeling and visualization software is important, the experience and expertise of the modeling team is even more so. Hydrogeology, combined with geotechnical/foundation engineering, is a core technical discipline at GZA, and we have provided groundwater protection related services to our Client's for over 35 years. In 2006, when the US Nuclear Power Industry, with support from the Nuclear Energy Institute (NEI) and the Electric Power Research Institute (EPRI), made a commitment to implement the Groundwater Protection Initiative (GPI) at each of its plants, GZA was at the forefront of this initiative through our on-going assignment at the Indian Point Energy Center (IPEC) in New York[3], as well as our experience with GPI type services at thousands of other industrial sites. GZA has worked closely with the applicable industry guidance documents since the evolution of the GPI program in the US, including serving on the American Nuclear Society's (ANS's) Working Group for the *Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Plants* guidance document (ANSI/ANS-2.17-2010)[4]. GZA is also involved with two additional ANS guidance documents related to groundwater supply and remediation, and we have served as a technical resource to the American Nuclear Insurers (ANI). GZA also routinely presents at GPI-related industry conferences.

Over the years, we have provided groundwater, flood hydrology, and other engineering support at over 30 Nuclear Power Plant (NPP) sites, including two very high profile GPI projects at nuclear power plants in the northeastern United States: IPEC which provides electricity to New York City and the Vermont Yankee Nuclear Power Station (VY) in Vermont. Modeling and 3D visualization played a key role in understanding the interplay of hydrogeology and anthropogenic

---

3 Barvenik, M.J., Powers, M.A. and Thompson V., "Use of the Observational Method in the Investigation and Monitoring of a Spent Fuel Pool Release", EPRI / NEI Technical Information Workshop, Nuclear Plant Groundwater Monitoring, September 13, 2006.

4 American Nuclear Society ANS-2.17 Working Group, Bollinger (cochair), Rasmussen (cochair), Barvenik, et al, "Evaluation of Subsurface Radionuclide Transport at Commercial Nuclear Power Plants", ANSI/ANS-2.17-2010, American Nuclear Society, La Grange Park, Ill., December 2010.

features, as well as in stakeholder communications at both sites. Through this work we have developed expertise in the fate and transport of not only tritium, but also other radionuclides that are less mobile and less commonly detected in groundwater, such as cesium and strontium. As environmental and geotechnical consultants, we bring a cross-disciplinary approach to our hydrogeologic projects giving us a deeper appreciation and understanding of various anthropogenic factors associated with built structures that effect groundwater flow – a key consideration at nuclear power plants.

In addition to groundwater modeling, GZA's hydrologists and hydraulic engineers are well versed in surface water / storm water modeling, including coastline modeling. For the nuclear power industry, we use our surface water modeling expertise in support of the NRC's fleet-wide requirement for flood hazard reevaluations. To date we have completed or are working on, flood hazard reevaluations at fifteen nuclear power plants. In addition, GZA is well versed in evaluating the interaction between surface water and groundwater, including integrating the results of numerical groundwater and surface water models.

2. Notes (Please provide following information if possible.)

- <u>Technology readiness level (including cases of application, not limited to nuclear industry, time line for application):</u> The software tools described above are well documented, readily accessible, and have been applied by GZA at numerous industrial sites including two very high profile nuclear GPI sites as discussed above. Model development time would vary depending on the size, site field conditions, scope and objectives of the final effort – models can be designed with varying levels of complexity. Given the time sensitive nature of this effort, it would probably make sense to develop a first-order model of moderate complexity to evaluate the current SCM, assess data gaps and provide first-order assessment of initial mitigation actions. The model could then be refined concurrent with, and following, the supplemental data collection efforts to fill data gaps.
-
- <u>Challenges:</u> The most significant challenge would be adequate data availability and the overall representativeness of the data set. A thorough review of the existing data set (including site surficial and bedrock geology, structural geology and faults, groundwater elevations with depth, hydraulic conductivities of major strata, plant construction information, groundwater chemistry, local precipitation records, tidal records, etc.) would be needed to develop model input parameters. An initial first-order model could be used to identify and prioritize data gaps to mitigate these challenges. Some data could be obtained from outside/around plant to statistically capture some input parameters. If not already

deployed, pressure transducers should be installed in select monitoring wells to automatically record groundwater elevation information in real time across the site area.

- <u>Others (referential information on patent if any)</u>: References and additional supporting documentation can be provided upon request.

【Areas of Technologies Requested】

(1) Accumulation of contaminated water (Storage Tanks, etc.)
(2) Treatment of contaminated water (Tritium, etc.)
(3) Removal of radioactive materials from the seawater in the harbor
(4) Management of contaminated water inside the buildings
(5) Management measures to block groundwater from flowing into the site
(6) Understanding the groundwater flow