United States Department of the Interior

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MEMORANDUM

TO: Stephen Terracciano, Chief, Coram Program Office

FROM: Paul Misut, Hydrologist

DATE: 12/14/2010

SUBJECT: Preliminary Review Model used for Comprehensive Feasibility Study: Operable Unit 3, NYSDEC Site # 1-30-003A

Summary
A model was used to design remedial actions associated with the OU3 site in Bethpage, N. Y. This model is an updated version of a model used to study OU2. Available documentation indicates that contaminant arrival times at outpost monitoring wells predicted by the earlier (OU2) model were not borne out by observations. Nevertheless, recent modifications were put in place to address these and perhaps other shortcomings. The main update appears to be addition of a dual-domain porosity mechanism. Unfortunately, model sensitivity analysis of the dual domain parameters shows that representation of this mechanism does not improve predictions. Despite the best efforts of the modeling team, there appear to be several factors that likely contribute to inaccurate prediction of the fate of the OU3 contaminant plume. These factors include (1) lack of thorough calibration of parameters such as single-domain porosity, (2) lack of representation of aquifer heterogeneity, and (3) lack of representation of changes in hydrologic stress over time. The effects of these factors individually and (or) collectively on the model's ability to accurate predict future plume movement and capture were evaluated in this review.

Regional extent of OU3 Model
The size and shape of the model area seems to be incorrectly drawn and inconsistent with the stated purpose of the modeling study. This delineation does not encompass the area of significant threat to human health and the environment caused by OU3 site area sources. The

RAO statement should reference a study area delineation that includes the entire extent of the known solute distribution and its likely future trajectory. The model boundary does not extend as far as the likely future points of solute discharge at the Long Island south shore.

Inclusion of upper part of Raritan confining unit

The Bethpage model is structured to be bounded on the bottom by no flow conditions that were considered to coincide with the top of the Raritan confining unit. According to Figure A-2 [1], for a specific "*location immediately south of Bethpage Community Park*" *[1, fig. A-2]*, the bottom model layer has the following attributes:

Top Elevation: -563 ASL
Bottom Elevation: -669 ASL
Aquifer: Basal Magothy

However, figure 3-3*[1]* appears to locate the bottom of the basal Magothy aquifer at about -575 ASL. A USGS report entitled "Geohydrology of the Bethpage-Hicksville-Levittown Area, New York WRIR 88-4135" [2] also locates the bottom the Magothy aquifer at about -575 ASL. VOC's have been detected as deep as -775 ASL on figure 3-3 [*1*] at VP-104 and -650 ASL at VP-47. It appears that sand encountered near the bottom of these holes prompted the Magothy aquifer/ Raritan confining unit boundary to be redefined deeper so as to include these sandy, contaminated zones within the Magothy aquifer. USGS has found significant thicknesses of predominantly sandy materials within the Raritan confining unit in Bethpage [2, plate 1] and it may be that the Magothy aquifer has been misnamed in VP-104/ VP-47. The bottom of the Raritan confining unit may provide a suitable theoretical barrier to movement of VOC's into the Lloyd aquifer; however, VOC's appear to have entered some of the more transmissive upper zones of the Raritan confining unit in the study area.

USGS routinely measures a nearby Magothy/Lloyd aquifer well cluster (wells N11456 and N11457, accessible at http://nwis.waterdata.usgs.gov, also see http://pubs.usgs.gov/sim/3066/ [3] for how these field data may be extrapolated across the model domain). The measured head drop of about 40 ft from the Magothy to the Lloyd aquifer suggests the presence of a regionally extensive clay layer in the Raritan confining unit, but also a natural tendency for study area Magothy water to flow downward and southward to the base of the Magothy aquifer, in a similar trajectory to what has been observed of the VOC plume. Once water arrives at the Magothy base, some of it continues downward into Raritan sediments at a rate that is slower, on average by several orders of magnitude. The rate of movement into the Raritanconfining unit depends on hydraulic properties, stated to be not well known ("*Little data are available to estimate vertical hydraulic conductivities of the Raritan confining unit [1, pg. 2-6].* Movement across the entire Raritan confining unit is unlikely over the study time frame; however, solute diffusion into a top portion of the Raritan results in temporary storage. If solute concentrations decrease as a result of remedial action, the chemical diffusion gradient may reverse, causing release from storage back into more rapidly-flowing, mitigated flow zones. Lack of representation of the solute diffusion mechanisms may result in poor simulation of plume spreading.

Representation of clay lenses

Numerous, non-extensive clay layers have been observed locally within the plume in the Magothy aquifer. In operable unit 3 study area report dated October 2009, no fewer than 50 clay zones were delineated on one cross section *[4, figure 2].* Lack of continuity of clays from borehole to borehole make them difficult to represent explicitly. The model uses an implicit representation where a high level of bulk anisotropy between horizontal and vertical hydraulic conductivity is specified. However, this anisotropy is spread evenly throughout vast homogeonous model areas, failing to capture knowledge already gained through borehole analysis, or to structure an appropriate level of parameter estimation. The assumption of vast areas of homogenous aquifer system properties is an oversimplification and impairs the usability of the model to simulate remedial alternatives.

Transient simulation

The Bethpage model is structured as a steady state in time. Lack of representation of changes in hydrologic stresses know to vary in time may lead to underestimation of plume spreading. It can be useful to assume steady state in the study of remedial systems operating at constant pumping rates, and to superimpose the simulated stress response with representations of changing natural conditions. This approach fails if changes in natural conditions overwhelm the gradients resulting from remedial system stress response. As distance increases from remedial stresses, this failure becomes more likely to occur. No convincing argument was given for adoption of a limited steady state within a given zone or set of conditions. Furthermore, the natural system was characterized as steady state, and boundary conditions were averaged. Not a single time series graphic of historical change in any of the stresses mentioned above were found in the documentation. In reality the hydrologic system changed dramatically throughout the 2nd half of the 20th century. Pumpage increased, massive stormwater diversions and stream channel alterations were made, prolonged drought occurred, and a regional sanitary sewer network was constructed.

Calibration and sensitivity analysis

Just because a model is constructed and calibrated, does not ensure that it is an accurate representation of the system. The appropriateness of the boundaries and the system conceptualization is frequently more important than achieving the smallest differences between simulated and observed heads. Sensitivity analysis was reported as follows [5]:

Table 5-3. **Summary of Sensitivity Analysis Statistics**, Groundwater Flow **Model**, Northrop Grumman Corporation, Bethpage, New York.

Parameter Tested	Calibrated Value	Type of Change	Parameter Changed to	Normalized Residual Mean
Upper Glacial K(h)	300 ft/d	Increase	400 ft/d	+ 0.264
		Decrease	200 ft/d	- 0.294
Shallow Magothy K(h)	200 ft/d	Increase	300 ft/d	- 0.156
		Decrease	100 ft/d	+ 0.166
Magothy K(h)	30 ft/d	Increase	50 ft/d	+ 0.485
		Decrease	20 ft/d	- 0.317
Transitional Zone K(h)	120 ft/d	Increase	180 ft/d	+ 0.017
		Decrease	60 ft/d	- 0.049
Upper Glacial K(v)	60 ft/d	Increase	90 ft/d	- 0.004
		Decrease	30 ft/d	- 0.008
Magothy K(v)	2 ft/d	Increase	4 ft/d	+ 0.23
		Decrease	1 ft/d	- 0.43
Groundwater Recharge	22.36 in/yr	Increase	24.36 in/yr	- 0.380
		Decrease	20.36 in/yr	+ 0.367

ft/d feet per day
in/yr inches per year
K(h) Horizontal hydraulic conductivity
K(v) Vertical hydraulic conductivity

There is no recognition of the nonuniqueness of the calibrated parameter values. For example, increasing a K or decreasing recharge typically result in the same net effect on the residual mean – to lower simulated heads. It is likely impossible to decide which parameter adjustments are more appropriate in the effort to match observations; thus, it is prudent to discuss alternative model conceptualization (not done here). Furthermore if a parameter adjustment results in a counterintuitive effect, this should be acknowledged and an explanation sought. In the above table, some adjustments are counterintuitive. Why, for example, does simulated head increase when shallow K (h) is increased?

Beyond evaluation of head target residuals, there is no evaluation of other targets types such as vertical head gradients or solute concentrations.

Dual-domain Porosity

Dual domain processes were treated as follows :

…it was evident that dual domain processes were a significant factor in solute transport within the aquifer system. The solute transport model used for this modeling effort was therefore updated to simulate dual domain mass transport. [1, pg. A-3]

There are no further details, such as simulated/observed comparisons, to justify use of the dual domain process. Sensitivity analysis starting from parameters values *"selected based on literature values judged appropriate for the local hydrogeologic conditions" [1, pg. A-4]* resulted in the following:

In general, the model is insensitive to changes in the mass transfer coefficient or adjustments to the mobile to immobile porosity ratio over the ranges described above. Therefore, slight differences between the model input values and actual field data, if any, would only slightly change the overall model results and not affect the conclusions *reached in the FS. [1, pg. A-4]*

Insensitivity suggests that the simulation of the dual domain process is unnecessary.

Other mechanisms affecting fate and transport

The fate of the study area plume is dependent on other mechanisms than what are modeled here, such as geochemical reactions of solutes and water with the aquifer matrix. Because these mechanisms can depend on the unique molecular structure of each contaminant chemical compound, lumping into designations such "TVOC" is inadvisable.

REFERENCES CITED

[1]
ARCADIS. 2010. DRAFT Comprehensive Feasibility Study Volume 2 – Study Area Feasibility Study, Operable Unit 3 (Former Grumman Settling Ponds) Bethpage, New York. November 10, 2010.

[2]
Smolensky, D.A. and S.M. Feldman 1990. Geohydrology of the Bethpage-Hicksville-Levittown area, Long Island, New York. U.S. Geological Survey Water-Resources Investigation Report 88-4135

[3]
Monti, Jack, Jr., and Busciolano, Ronald, 2009, Water-Table and Potentiometric-Surface Altitudes in the Upper Glacial, Magothy, and Lloyd Aquifers beneath Long Island, New York, March-April 2006: U.S. Geological Survey, Scientific Investigations Map 3066, 4 sheets

[4]
ARCADIS. 2009. DRAFT Study Area Report, Operable Unit 3 (Former Grumman Settling Ponds) Bethpage, New York. October, 2009.

[5]
ARCADIS G&M, Inc., 2003. Comprehensive Groundwater Model Report, U.S. Naval Weapons Industrial Reserve Plant/Northrop Grumman, Bethpage, New York.