MEMORANDUM

From: Deni Chambers, CEM
Josh Otis, CEM

Date: April 25, 2012

To: Shannon Harbour, PE
Nevada Division of Environmental Protection

RE: Hydrogeologic Flow Model, Supporting Documentation, and Response to Comments on the Model for the Nevada Environmental Response Trust Site, Henderson, Nevada

INTRODUCTION

On March 15, 2012, the Nevada Division of Environmental Protection (NDEP), ENVIRON International Corp. (ENVIRON), and Northgate Environmental Management, Inc. (Northgate) participated in a conference call to discuss comments provided by NDEP in their April 5, 2011 letter regarding the *Capture Zone Evaluation Report, Tronox LLC, Henderson, Nevada dated December 10, 2010* (CZE Report) and the associated groundwater flow model (the model) for the Nevada Environmental Response Trust Site (the Site). During this call, NDEP requested that the following items be submitted for review: the groundwater flow model, supporting documentation, and the subset of responses to comments on the CZE Report from the April 5, 2011 letter that pertain only to the model.

This memorandum and the associated attachments provide the files and documentation requested by NDEP. The model files and the supporting documentation are provided in the attachments, the contents of which are described below. Responses to the April 5, 2011 NDEP comments regarding the model are provided below.

RESPONSE TO NDEP COMMENTS REGARDING THE MODEL

NDEP's letter dated April 5, 2011, contained twenty-eight comments regarding the CZE Report. As agreed during the March 15, 2012 conference call, only responses to comments specifically pertaining to the model are included in this memo. After reviewing all the comments, only comments #15 and #16 were identified as being directly related to the model development and inputs. Comments that address the application of the model to the CZE analysis will be addressed in the complete response to all twenty-eight comments, which will be submitted separately.

15. *Section 6.2.3, page 37, NDEP noted the use of no flow boundaries; please clarify whether these boundaries were tested for induced boundary effects.*

Response:

The eastern and western edges of the active model domain were chosen to coincide as closely as possible with observed streamlines. This allowed the lateral boundaries to be treated as no-flow boundaries. The lateral extent of the model domain was selected to be sufficiently large such that potential induced boundary effects from the no flow boundaries, if present, would not impact model results at the NERT well fields. The computed hydraulic heads in the central portions of the model domain, which contain the NERT well fields and are the areas of interest for the CZE, show good agreement with observed hydraulic heads. The good match between the observed and computed hydraulic heads in the center of the domain gives us confidence that the lateral boundaries are not interfering with the capture zone evaluation results.

16. *Section 6.2.4, page 38, NDEP noted the use of harmonic and arithmetic means to set bounds for hydraulic conductivity during model calibration. While the use of the harmonic mean appears to allow for the effects of lower conductivities, the use of the arithmetic mean would appear to preclude the effects of higher conductivities. Please discuss whether this method of calibration would skew model results towards that of lower hydraulic conductivity.*

Response:

The hydraulic conductivity field was modeled based on the concept of effective conductivity. As discussed in a number of references (e.g., Matheron, 1967; Batchelor, 1974; de Marsily, 1986, Rubin, 2003), effective hydraulic conductivities are bounded between the harmonic mean and the arithmetic mean of the local scale hydraulic conductivities. This applies when groundwater flow is uniform and regardless of the spatial correlation of the hydraulic conductivity and the number of dimensions. Therefore, using the harmonic and arithmetic means as upper and lower bounds is appropriate and does not skew the results towards that of lower hydraulic conductivity.

SUPPORTING DOCUMENTATION TO THE MODEL

Supporting documentation for the model is included in Attachment 1, including the *Hydrogeologic Model Report* (model report), originally submitted as Appendix E to the CZE Report and specifically requested by NDEP. In addition, we have provided the *REVISED Hydrogeologic Modeling Work Plan, Tronox, LLC, Henderson, Nevada* dated June 7, 2010 and the *Technical Memorandum: Hydrogeologic Groundwater Model*

Inputs, Tronox LLC dated October 29, 2010 to give additional information and context regarding the development of the model. All the figures and tables and responses to comments associated with the enclosed documents have also been included.

NERT MODEL FILES

The MODFLOW model files are provided in Attachment 2. Two sets of model files are included in the attachment. One set of files is for the coarse grid model and the other set is for the model that was refined locally at the three NERT extraction well fields. The files are consistent with MODFLOW and Groundwater Vistas, Version 5 (ESI, 2007) as described in Section 3 of the model report. As discussed in Section 3.10.2 of the model report, model calibration was performed on the regional model with the 200 feet by 200 feet grid discretization (coarse grid model).

- Coarse grid model: This folder contains the modeling files for the coarse model that was developed. The MODFLOW input files, the GWV file, and the output files with the drawdown, heads, and cell by cell flows are included.
- Refined grid model: This folder contains the modeling files for the locally refined model that was developed. The MODFLOW input files, the GWV file, and the output files with the drawdown, heads, and cell by cell flows are included.

ATTACHMENTS

1 Model documentation

2 NERT model files

REFERENCES

Batchelor, G.K., 1974. Transport properties of two-phase materials with random structure, Ann. Rev. Fluid Mech., 6, 227-254.

de Marsily, G., 1986. Quantitative Hydrogeology: Groundwater Hydrology for Engineers, Academic Press, New York, 440 p.

Environmental Simulations Inc. (ESI), Guide to using Groundwater Vistas – Version 5, 2007.

Matheron, G., 1967. Elements pour une théorie des milieux poreux, Masson, Paris.

Rubin, Y., 2003. Applied Stochastic Hydrogeology, Oxford University Press, USA, 416 p.