Solute Transport Modeling

Work Plan

BMI Upper and Lower Ponds Area

Submitted to:

September 8, 2009

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION

protecting the future for generations

Prepared for:

Basic Remediation COMPANY

Daniel B. Stephens & Associates, Inc.

6020 Academy NE, Suite 100 • Albuquerque, New Mexico 87109

Responsible CEM for this Project

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state, and local statutes, regulations, and ordinances.

Stephen J. Cullen, Ph.D., C.E.M. (No. 1839, Exp. 11/12/09)
Daniel B. Stephens & Associates, Inc.

Individuals Who Provided Technical Input to this Document

T. Neil Blandford, P.G.
Daniel B. Stephens & Associates, Inc.

John J. Dodge, P.G.
Daniel B. Stephens & Associates, Inc.

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1. Introduction

This document is a proposed work plan for solute transport modeling at the Basic Remediation Company (BRC) Eastside property (the Site) delineated in Figure 1. The modeling is to be completed by Daniel B. Stephens & Associates, Inc. (DBS&A) on behalf of BRC for submittal to the Nevada Division of Environmental Protection (NDEP). The model developed under this work plan will be referred to as the BRC Eastside Site solute transport model. The Site solute transport model will be based on the groundwater flow model documented in DBS&A (2009) and approved by NDEP on July 24, 2009, with some modifications to recharge as discussed in Section 5 below. This work plan is consistent with the previous modeling work plan submitted by BRC (DBS&A, 2006), with appropriate updates or revisions based on the simulation results of the BRC Eastside Site groundwater flow model.

The term “Site” as used in this document refers specifically to the BRC Eastside property, which includes the Upper and Lower Ponds area (Figure 1). Some areas that are not owned by BRC, but are adjacent to the BRC property, are included in the model domain in order to develop a physically reasonable groundwater flow and solute transport model. Where a distinction in terms is important, the terms “Site” and “model domain” will be used to convey the relevant distinction.

The remainder of this work plan consists of the following sections:

- Section 2. Statement of Model Purpose
- Section 3. ASTM Standard Guides
- Section 4. Computer Code Selection
- Section 5. Numerical Model Development
- Section 6. Predictive Simulations
- Section 7. Sensitivity Analysis
- Section 8. Documentation

It is BRC’s intent to coordinate with NDEP during model development. BRC will be responsible for coordinating and scheduling all meetings and conference calls as appropriate.

2. Statement of Model Purpose

The intended purpose of the solute transport modeling is stated in DBS&A (2006) as follows:

> Evaluate the current and future transport and discharge of dissolved contaminants in groundwater from the Site to the Las Vegas Wash, either directly or indirectly. This also includes evaluation of the potential effects that a rising water table may have on future contaminant transport, including remobilization of contaminants that potentially exist in the vadose zone beneath source areas. In addition, this includes evaluation of contaminant mass flux to the upper unconfined water-bearing zone through leaching of contaminants in the vadose zone due to recharge.

The predictive solute transport simulations will be based on the predictive groundwater flow simulations, where expected changes at the land surface across the Site are accounted for. The predictive simulations documented in DBS&A (2009) indicate that water levels within the uppermost water-bearing unit, the Quaternary alluvium (Qal), are expected to decline in the future, rather than rise above current or recent levels. This result is true even for the case where greater than expected recharge is applied across the Site. This result is due primarily to the elimination or reduction of significant sources of recharge on or adjacent to the Site, such as the City of Henderson (CoH) Southern and Northern Rapid Infiltration Basins (RIBs). Consequently, BRC believes that the potential remobilization of contaminants in the vadose zone due to a rising water table is no longer a significant potential process of concern.

In addition, the proposed approach to conducting estimates of contaminant mass flux to the water table through leaching of contaminants in the vadose zone due to recharge is not presented in this work plan. This component of the modeling is being conducted by another BRC consultant (ERM), and the approach and results of these computations are or will be documented separately. The results of these analyses will be incorporated into the Site solute transport model as described in Section 6.

3. ASTM Standard Guides

The American Society for Testing and Materials (ASTM) has developed a series of Standard Guides for certain aspects of groundwater flow and solute transport modeling. At the request of NDEP, these Standard Guides were consulted and used as appropriate during development and application of the BRC Site groundwater flow model. ASTM Standard Guide D-5880-95, Subsurface Flow and Transport Modeling, will be followed during application of the BRC Site solute transport model.

It should be noted that the above documents were specifically developed as Standard Guides, rather than standards, in recognition of the state of the art of groundwater model development and with appreciation for the site-specific nature of modeling applications. Due to site-specific conditions and complexities, available data, computer code limitations, and a variety of other factors, the ASTM development committees recognized that it is not possible or appropriate to prescribe every step or detail in the modeling process in a set of formal standards. As such, BRC will use the ASTM Standard Guide D-5880-95 as a guidance document, consistent with its intended use.

4. Computer Code Selection

In accordance with the Groundwater Modeling Work Plan (DBS&A, 2006) and the completed BRC Site groundwater model (DBS&A, 2009), the MODFLOW-SURFACT code developed by HydroGeoLogic, Inc. of Herndon, Virginia will be used to simulate saturated zone solute transport. MODFLOW-SURFACT is an upgraded, proprietary version of the U.S. Geological Survey (USGS) MODFLOW code that can be commercially purchased. The code includes all of the functionality of the standard MODFLOW-98 software developed by the USGS, but also includes a number of added simulation capabilities and advanced simulation algorithms that will be useful for simulating groundwater flow and solute transport beneath the Site. MODFLOW-SURFACT has been employed by numerous governmental and private entities since 1996, and contains the following primary simulation capabilities and advantages:

- Saturated or variably saturated three-dimensional groundwater flow for water of uniform density and temperature for steady-state or transient conditions. The saturated groundwater flow module will be used for the Site.

- Advanced solution algorithm for rigorous simulation of model cell drying (simulated water level below the base elevation of the cell) and rewetting that conserves mass balance. This capability is very useful for simulating groundwater flow in hydrogeologic units of limited saturated thickness, such as occurs within the alluvium at the Site.

- Full three-dimensional transport simulation capability for saturated or variably saturated groundwater flow that accounts for advection, dispersion, linear and non-linear retardation, and constituent decay.

A full description of the MODFLOW-SURFACT code is available online at www.hgl.com. Once at the home page, the user can browse to “modeling”, then “software”, then “MODFLOW SURFACT”.

5. Numerical Model Development

This task involves development of the solute transport model so it can be used for predictive simulations. The groundwater flow model is documented in DBS&A (2009) and associated NDEP comments and BRC responses to comments related to that report. As agreed to in BRC's response to comments dated June 16, 2009, the recharge applied to developed and undeveloped areas for the current condition groundwater flow model need to be updated prior to use of the model for new predictive simulations, including solute transport simulations. The overall proposed approach to the solute transport model development is outlined below. Note that the solute transport model is based to a very large extent on the existing groundwater flow model. Details of the groundwater flow model are provided in DBS&A (2009) and are not reproduced or explained further in this work plan.

5.1 Groundwater Flow Model Update

The current version of the groundwater flow model will be updated to adjust the prescribed recharge beneath developed and undeveloped areas as agreed to in BRC's response to comments dated June 16, 2009. Specifically, prescribed recharge beneath undeveloped areas will be adjusted downward to 2 percent of average annual precipitation, which is about 4 inches per year or less, and prescribed recharge beneath developed areas will be increased in order to maintain model calibration. Once the current period model is recalibrated to the adjusted recharge values, the base case predictive simulation will be rerun based on the updated recharge values. Previous parameter estimation runs conducted using the inverse parameter estimation code PEST (Watermark Numerical Computing, 2004) indicate that this adjustment will not cause a significant change in the current period simulation results.

Once this task is completed, a brief letter report that summarizes the updated groundwater model calibration for the current simulation period (2007) will be provided to NDEP. The letter report will describe the adjusted recharge values used and will provide several plots to illustrate that the updated model has remained reasonably calibrated to observed Qal and Upper Muddy Creek Formation (UMCf) water levels. BRC intends to obtain NDEP's concurrence on the updated groundwater flow model simulations prior to conducting the solute transport simulations.

5.2 Solute Transport Boundary Conditions

In order to conduct solute transport simulations, all model boundary conditions need to be assessed with regard to solute concentration. This section summarizes the boundary conditions that will be applicable to the predictive simulation model and the proposed approach to assigning solute concentration. Prescribed solute concentration is only required for boundary types that allow for the inflow of groundwater. Where groundwater exits the model domain, the concentration of the exiting water is simulated by the model. Examples of boundary conditions used in the Site groundwater model that allow for the efflux of water include general head, prescribed head, prescribed flux (including wells), and drains.

Boundary conditions applied in the Site groundwater model that allow for the inflow of groundwater include general head (model layers 1 and 2), prescribed head (model layer 2), and prescribed flux, including wells (model layers 1 and 2). For each of these boundary types, the prescribed concentration will be determined based on observed conditions and monitoring data. For example, constituent concentrations assigned to prescribed influx boundaries will be based on contour maps developed from monitor well data (note that prescribed solute concentration can be zero). Prescribed solute concentration for recharge will be zero, with the exception of known or potential source areas as described in Section 6. Zero solute concentration will also be assigned to CoH facilities such as the RIBs and the Birding Preserve. Solute concentration assigned to the AMPAC injection wells will also be based on reported data; it is expected to be zero or very low.

In the predictive simulations provided in DBS&A (2009), evapotranspiration is set to zero. The same approach is proposed for the solute transport model; therefore, there will be no evapotranspiration flux. In the MODFLOW-SURFACT code, evapotranspiration will not remove solutes from the groundwater system, but may have the effect of increasing concentrations through removal of water. This approach is conservative for some constituents from the aspect that it may simulate greater solute concentrations in regions of evapotranspiration than would actually occur. For example, perchlorate can be removed from groundwater through evapotranspiration and be retained in plant tissue. If consideration of this physical process is determined to be a significant issue during the modeling, an adjustment to the simulation approach will be determined and presented to NDEP.

5.3 Solute Transport Hydraulic Properties

Hydraulic inputs required for solute transport modeling include effective porosity and longitudinal, lateral, and vertical dispersion coefficients. These parameters will be estimated based on published literature values and relevant site information. For example, the effective porosity will be less than total porosity as measured from core samples. The lateral and vertical dispersion coefficients will be 10 and 100 times less than the longitudinal value, respectively (Gelhar et al., 1992). Effective porosity will be calculated for layer-specific soils from measurements of total porosity and field capacity water content made on the soil cores acquired in the field; it will also be estimated based on material type, literature values, and possibly analytical calculations of solute transport.

Simulation of the transport of conservative constituents, such as perchlorate, does not require consideration of the retardation coefficient (R). For conservative constituents, solute transport is assumed to occur at the same rate as the pore velocity of the groundwater. For constituents that exhibit a transport velocity less than that of groundwater, such as various forms of arsenic, the simulation approach requires consideration of R. R is constituent dependent, and will be calculated using the retardation equation (Dragun, 1988) incorporating distribution coefficients (K_d) calculated from the product of Site-specific values (e.g., fraction organic content [f_{oc}]) and published scientific literature values (e.g., organic carbon partition coefficient [K_{oc}]) for modeled organic constituents. K_d values for inorganic constituents will be determined using published scientific literature values for the appropriate redox (eH-pH) range for the Site.

Site data as reported in the Closure Plan (BRC et al., 2006) indicate that volatile organic constituents are of minor concern at the Site and within the model domain. Therefore, Site vapor transport in the vadose zone will not be simulated.

The relative effects of alternative values of hydraulic transport parameters will be evaluated in a sensitivity analysis (Section 7).

6. Predictive Simulations

Predictive groundwater flow simulations will be conducted using the simulated groundwater flow field from the current conditions simulation (as updated for recharge as described in Section 5) as the starting point for the predictive simulation. Predictive simulations will be conducted for a period of 50 years. The hydrologic effects of anticipated changes in land use will be incorporated into the model through anticipated changes in groundwater recharge, as was done in DBS&A (2009).

Predictive solute transport simulations will be conducted based on the results of the groundwater flow predictive simulations. Initial constituent concentrations (representative of current conditions) within each model layer will be entered into the model based on observed data and interpreted contaminant plume maps. This approach requires that an estimated solute concentration be provided for every active model cell (note that the estimated concentration can be zero). In addition, solute concentration associated with boundary inflow terms, such as prescribed flux, recharge, or general head boundaries also need to be prescribed. Estimation of boundary term solute concentrations will also be based on observed data.

BRC does not plan to simulate the migration of all potential constituents of concern. Rather, BRC plans to conduct a series of solute transport simulations based on observed data for a conservative constituent that will migrate at a velocity the same or nearly the same as groundwater, and a non-conservative constituent that migrates significantly more slowly than the rate of groundwater. For the conservative constituent, BRC plans to use perchlorate; the non-conservative constituent will be one of the more mobile forms of arsenic. This approach will provide a range of potential solute transport predictions for the Site. The potential migration of other constituents of concern can be simulated if requested by NDEP.

BRC intends to conduct two sets of predictive solute transport simulations for each selected constituent, as described below:

- *Base Case Simulation*: The base case simulation will consider the future migration of each selected constituent that already exists in groundwater. This approach will assume that inputs of additional contaminants due to recharge from the surface are zero, although mass input may occur at various model boundaries, depending on observed data.

- *Added Source Simulation*: The added source simulation will consist of the base case simulation with potential sources of contaminant due to recharge added through time, as indicated by the results of the vadose zone leaching models that have been, or will be, completed for the multiple source investigation sub-areas. The first sub-area (Mohawk) has already been completed using the approach where the leaching model is based on a maximum soil concentration column, which is the combination of the results from multiple soil cores. The area over which each source term is applied will need to be estimated. Although the first set of transport model simulations will be completed prior to completion of the full set of vadose zone models, selected example source term inputs will be used for non-completed source term inputs pending completion of final source term characterization.

Conducting the solute transport simulations in this manner will allow for the comparison of the two sets of simulation results, thereby allowing evaluation of the potential effects of continuing near-surface sources on solute concentrations in groundwater.

7. Sensitivity Analysis

Sensitivity analysis will be conducted for all key model input parameters, and the results will be reported in the model documentation. Expected solute transport model input parameters that will be considered in the sensitivity analyses include effective porosity, dispersion coefficients, retardation coefficients, and solute source term strength. The sensitivity analysis will be conducted in accordance with ASTM Standard Guide D-5611.

8. Documentation

All of the modeling tasks presented above will be thoroughly documented in a completion report. The report and electronic model input and output files will be provided to NDEP in draft form for review and comment prior to completion of the final report and submission of the final modeling electronic files.

References

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Figure

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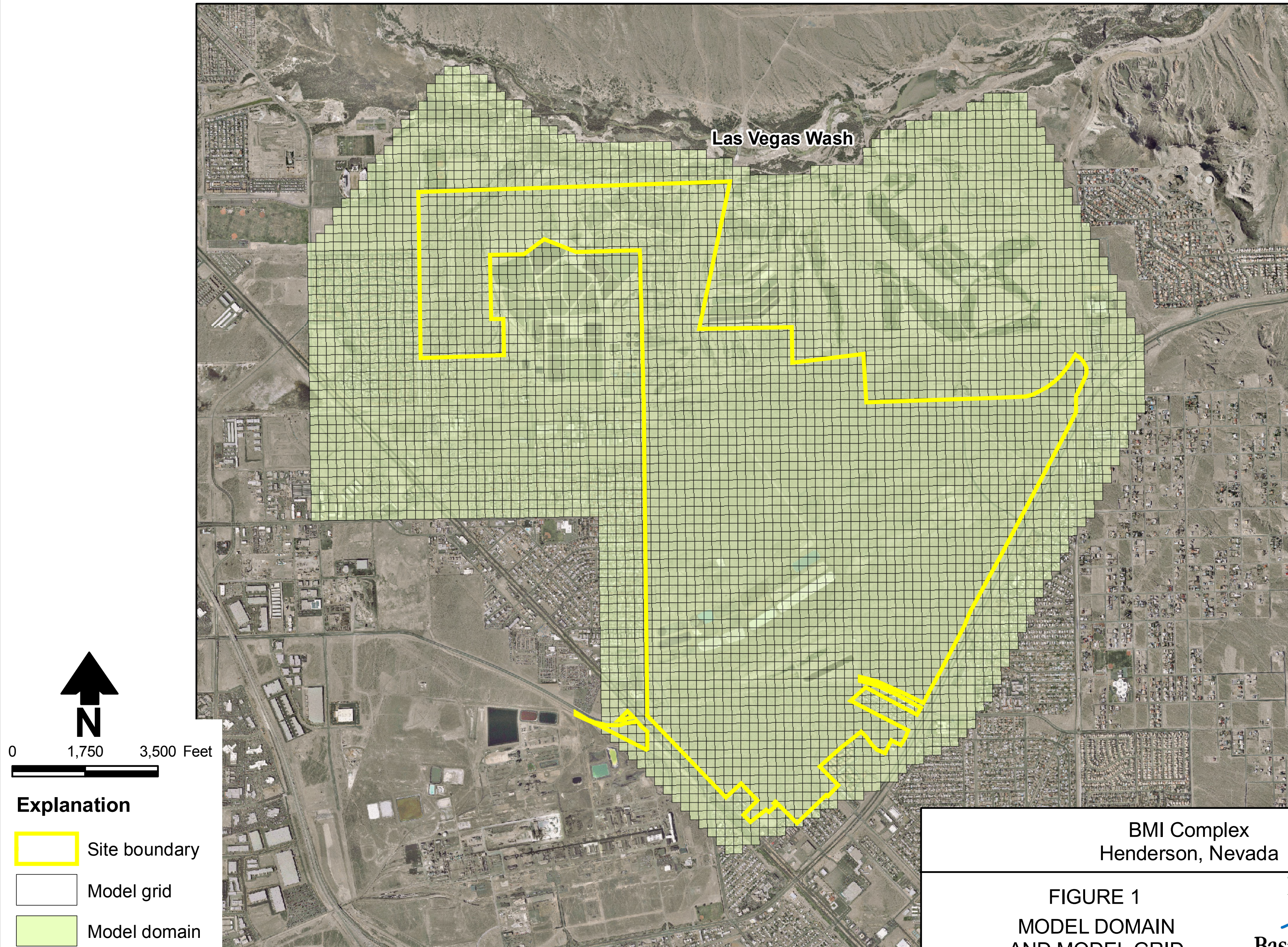

Source: Aerial photograph, April 2004

BMI Complex
Henderson, Nevada

FIGURE 1
MODEL DOMAIN
AND MODEL GRID

Basic Remediation
COMPANY

Prepared by: DBS&A GJ

Date 9/8/09

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Daniel B. Stephens & Associates, Inc.
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Figure 1