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FINAL
UPDATED MODEL RESULTS

GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODELING FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

Prepared for

U.S. Army Corps of Engineers
Buffalo District
1776 Niagara Street
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LIST OF ACRONYMS AND ABBREVIATIONS

1D	one-dimensional
3D	three-dimensional
Ac	Actinium
ARAR	Applicable or Relevant and Appropriate Requirements
As	arsenic
ASG	alluvial sand and gravel
AVI	Audio Video Interleave
Ba	Barium
B	Boron
BCT	Brown Clay Till
BOP	balance of plant
BRA	baseline risk assessment
Ca	Cadmium
cis-1,2-DCE	*cis*-1,2-dichloroethene
COPC	contaminants of potential concern
CWM	Chemical Waste Management, Incorporated
DNAPL	dense non-aqueous phase liquid
DCE	dichloroethene
EU	exposure unit
Fe	Iron
FUSRAP	Formerly Utilized Sites Remedial Action Program
GIS	Geographical Information System
GLC	glaciolacustrine clay
HGL	HydroGeoLogic, Inc.
IWCS	Interim Waste Containment Structure
K_d	distribution coefficient
L/kg	liters per kilogram
μg/L	micrograms per liter
Mn	manganese
ML	Modern Landfill Corporation
Mo	molybdenum
NFSS	Niagara Falls Storage Site

Pa	Protactinium
Pb	Lead
pCi/L	pico curries per liter
PCE	perchloroethene
Ra	Radium
RI	remedial investigation
RIR	Remedial Investigation Report
SAIC	Science Applications International Corporation
Sb	Antimony
SESOIL	Seasonal Soil Compartment Model
t	simulation time
TCE	trichloroethene
Th	thorium
U	Uranium
USACE	U.S. Army Corps of Engineers
USDOE	U.S. Department of Energy
VC	vinyl chloride

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1.0 INTRODUCTION

HydroGeoLogic, Inc. (HGL) was contracted by the U.S. Army Corps of Engineers (USACE)-Buffalo District to update the results of groundwater flow and contaminant transport modeling performed previously at the Niagara Falls Storage Site (NFSS), Lewiston, New York under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The work assignment was issued in 2010 and conducted under contract W912P4-09-C-0017. A brief summary of the previous work on which this update is based is presented in the following paragraphs.

In 2000, HGL was contracted by the USACE-Buffalo District to assist with the Data Management, Environmental Modeling, and Risk Communication tasks at the NFSS, Lewiston, New York. HGL's efforts were part of Remedial Investigations (RI) at the NFSS. HGL's efforts included development of local and regional conceptual models; use of geographical information system (GIS) technology; implementation of a database management system; and development, calibration, and application of a three-dimensional (3D) numerical groundwater flow and solute transport model. The NFSS model is a regional model, designed to simulate flow and transport of dissolved chemical and radiological contaminants present in groundwater in the multi-layered water-bearing units underlying NFSS over long-term (multi-hundred year) time-frames. The methodology used to represent the contaminant source terms and initial concentrations in the model included: (1) constituents contained within the Interim Waste Containment Structure (IWCS); (2) localized constituent plumes identified through groundwater sampling; and (3) constituents that have been found at elevated concentrations in soil.

The broader RI activities at the NFSS are documented in the Remedial Investigation Report (RIR) (USACE, 2007a); whereas HGL's environmental modeling and data management efforts are summarized in the Draft Groundwater Flow and Contaminant Transport Modeling report (USACE, 2007b).

Primary among HGL's contributions to the RI efforts were solute transport predictions for the 24 contaminants of potential concern (COPC) identified during the Baseline Risk Assessment (BRA) (USACE, 2007c). The solute transport predictions were obtained by applying the 3D NFSS model, developed by HGL, to simulate present-day (i.e., Baseline Case) conditions. The Baseline Case employed best estimate values of hydraulic material properties, physiochemical input parameters, and model source term concentrations, as determined from the RI or other site-specific field sources where available. Results from the Baseline Case simulations quantified the long-term transport of contaminants contained in the IWCS at NFSS and within soil and groundwater on the balance of plant (BOP) areas. Model results also provide an estimate of the operational life of the IWCS as 200-years.

Since submission of HGL's 2007 Final Groundwater Flow and Contaminant Transport Modeling Report, and completion of the RIR in 2007, supplementary RI activities have been performed and are summarized in the 2011 RIR Addendum (USACE, 2011). Included in the 2011 RI Addendum are results from 2009 and 2010 groundwater quality monitoring. Analysis of this supplementary water quality data, as well as revised data interpretations since the 2007 RIR, suggests that several of the groundwater contaminant plumes are not depicted accurately in the RIR. HGL's assignment described herein is to update the groundwater flow model to incorporate the most recent data set and data evaluations.

Pursuant to this assignment, water quality data from the original RIR and the RIR Addendum were compiled and reviewed to better define the nature and extent of contamination in several areas. Revised contaminant plume maps were produced and subsequently used to update the initial condition in the 3D model source term. Analysis of other supplementary RI activities led to further input revisions of the 3D model. The input revisions included updates to the Seasonal Soil Compartment Model (SESOIL) source term and justification for use of a revised value for the Uranium (U)-238 distribution coefficient (K_d) in the BOP areas, with input provided by Science Applications International Corporation (SAIC). It is also noted that in 2010 HGL prepared and submitted to USACE-Buffalo District a final report entitled: Evaluation of the Occurrence and Extent of Sand Lenses in Unconsolidated Subsurface Sediments at NFSS (see Appendix 12J of USACE [2011]). The findings of this report were also considered for this model update. The sand lens report concluded that after analysis of additional sand lens data obtained from recent NFSS investigations, no evidence was found to materially change the understanding of the unconsolidated sediments at NFSS. Nevertheless, updates to the model hydraulic conductivity were performed to provide greater assurance in the predictive ability of the model in the vicinity of EU4, near the IWCS and other areas of sand lens occurrence.

The objective of this Updated Model Results report is to present the results and analysis of the updated NFSS solute transport modeling for Baseline Case conditions. As stated above, the model updates include using a revised U-238 K_d value assigned to the isotopes and updated model source terms based on supplementary RI efforts. Details on model development and parameterization, however, are excluded from presentation herein. For information regarding the model domain, numerical grid, hydraulic flow properties, model calibration, and other construction details of the 3D NFSS model, the reader is referred to the 2007 Final Groundwater Flow and Contaminant Transport Modeling Report (USACE, 2007b). The 2007 report also provides a chronology and summary of previous environmental and data management efforts performed by HGL, dating back to 2000.

This report is organized into four sections:

Section 1: Introduction
Section 2: Groundwater Flow Model Update
Section 3: Solute Transport Model Update
Section 4: Conclusions

Section 2 summarizes updates to the hydraulic conductivity field of the Brown Clay Till (BCT), the uppermost water-bearing unit underlying the NFSS. The hydraulic conductivity in the BCT was updated in the groundwater flow model to more explicitly represent sand lenses where present in the study domain.

Section 3 summarizes the updates to the solute transport model and presents updated simulation results to 10,000 years for each constituent. The presentation of modeling results is detailed and extensive. Statistical data describing model results are presented in tabular form and highlight the time, location and initial occurrence of maximum concentrations for each constituent found on-site, at the property boundary, and from IWCS sources. Predicted concentrations that exceed respective constituent screening levels are denoted and discussed. In addition, graphical presentation and video animation of results depicting plume movement through time are provided and referenced in Section 3. Worst case scenario simulation results presented in USACE (2007b) were also not updated. The additional RIR Addendum data and sand lens evaluation would not significantly change the predictions for the worst case scenarios presented in USACE (2007b).

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2.0 GROUNDWATER FLOW MODEL UPDATE

The NFSS groundwater flow model was updated to explicitly represent sand lenses that exist within the BCT. The purpose of this update was to ensure that the model provides conservative estimates of contaminant migration. The approach that was used to update the groundwater flow model is described below.

Previously, as documented in USACE (2007b), the modeled BCT hydraulic conductivity field was based on 326 site-specific measurements, primarily derived from single-well response tests. The data were contoured as a single data set, undifferentiated based on variations in lithology, and five contoured intervals, each spanning one order of magnitude of field-measured values, were used as the basis for defining the hydraulic conductivity zones in the model. Each zone provided a representative estimate of the localized bulk hydraulic conductivity of the BCT, appropriate for the long-term, predictive solute transport modeling objectives of the study. Thus, sand lenses were not represented as discrete features in the model, but their presence was accounted for through the use of the zones of higher hydraulic conductivity, wherever areas of sand lens occurrence coincide with higher hydraulic conductivity. The numerical (modeled) representation of the BCT in USACE (2007b) is also consistent with the results of a statistical analysis which determined that sand lenses are isolated discontinuous features and not correlated over longer distances.

By and large, the subsurface lithologic and hydraulic conductivity data coverage across the NFSS is considered exceptional. Nevertheless, there were cases in which borehole locations, where sand lenses were known to exist, had not been characterized with respect to hydraulic conductivity and thus not accounted for in the modeled hydraulic conductivity flow field. At such locations, the hydraulic conductivity assigned to the model would likely underestimate localized groundwater velocities and associated solute transport. The revisions to the hydraulic conductivity field were centered on addressing this concern.

In the absence of characterization data, boreholes on the NFSS (Figure 3.1) and adjacent properties were reviewed for known sand lenses. A total of 336 sand lens occurrences were identified. Statistically, these sand lenses were described with a mean vertical thickness of 1.9 ft; a median thickness of 1.0 ft; and a standard deviation of 2.6 ft. Of the sand lenses occurrences, 250 had a vertical thickness equal-to-or-greater than 6 inches. At these locations, the corresponding (and entire) model cell was assigned a value of hydraulic conductivity equal to 141.7 ft/day (5×10^{-2} cm/s). A hydraulic conductivity value of 5×10^{-2} cm/s is in the mid-range of values for a clean sand, according to Freeze and Cherry (1979), and is in the 99.9 percentile of all measured values of hydraulic conductivity on the NFSS, Chemical Waste Management, Incorporated (CWM) and Modern Landfill Corporation (ML) properties, hence somewhat conservative.

The spatial distribution of the updated cells across the NFSS is presented in Figure 3.2. The model cells assigned with the updated value of hydraulic conductivity have minimum horizontal dimensions of 25×25 ft, such as those cells near the IWCS. For some cells, distant from the IWCS where the model discretization is coarser, the model was updated with, in effect a larger sand lens. Representation of the entire model cell, both horizontally and vertically, as a sand lens is grossly conservative. The upward revision to hydraulic conductivity in isolated model cells is otherwise consistent with the conceptual understanding of the sand lenses as localized features that are not spatially continuous.

A groundwater flow model simulation was completed with the updated hydraulic conductivity field. Calibration statistics were calculated and hydraulic head contours were prepared for the simulated water levels. The calibration statistics and hydraulic head contours were then compared to the results of the previous groundwater flow model calibration.

The change in calibration statistics was negligible. The percentage difference for all statistical parameters was less than 1 percent, with the exception of residual mean, which actually improved by 10 percent (i.e., closer to zero). The residual standard deviation [1.315 ft (0.40 m)] remained less than 2 percent of the range of simulated water level elevations for the entire model domain, and less than 12 percent of the range found on site. This provided assurance from a statistical point of view that the flow calibration remained sound.

A visual inspection of the hydraulic head contours revealed minor localized differences to the groundwater flow solution. In some of the locations where a higher value of hydraulic conductivity had been assigned, the hydraulic head decreased marginally in the localized vicinity of the modified cell. Across the site, there were some minor adjustments to groundwater flow contours. The revised flow contours are reflected in all subsequent figures and animations depicting solute transport results.

Although the statistical and visual comparisons exhibited a barely discernable difference in the flow field, simulated groundwater velocities likely increased where sand lenses are now explicitly represented in the model. The updated groundwater flow solution was subsequently used in all solute transport simulations presented in Section 3.0

3.0 UPDATES TO SOLUTE TRANSPORT MODEL

3.1 MODEL UPDATES

Updates to the solute transport model include: (1) the use of a revised K_d value for U, and (2) updated model source terms based on review of supplementary RI activities. Descriptions of the updates are presented below.

3.1.1 Distribution Coefficient

The K_d is a transport parameter that relates the adsorbed constituent concentration to the dissolved constituent concentration. More specifically, the K_d is expressed by the following equation:

$$K_d = \frac{\textit{mass of solute on the solid phase per unit mass of solid phase}}{\textit{concentration of solute in solution}}$$

K_d is related to the retardation of a solute in groundwater by the relationship:

$$R = 1 + K_d \frac{\rho_b}{n}$$

where R is the retardation factor, ρ_b is the bulk mass density of the porous medium and n is the porosity. Accordingly, higher values of K_d represent increased contaminant adsorption and therefore larger retardation factors.

HGL's RI modeling efforts described in USACE (2007b) assigned a model-wide K_d value of 3.6 liters per kilogram (L/kg) for U isotopes, including U-238, U-235 and U-234. This value had been obtained from laboratory testing of NFSS soil materials in high concentration U solutions (Seeley and Kelmers, 1984). This K_d value is therefore most applicable where dissolved U concentrations in groundwater are comparably high, such as may occur within the IWCS.

As part of BRA, SAIC evaluated groundwater and soil sampling data to determine a K_d value that was more representative of U adsorption in soils outside the IWCS. They conducted this analysis using reported U concentrations in collocated soil and groundwater samples collected from the same borings. The U concentrations in soil and groundwater were assumed to be in equilibrium. For each sampling location, a K_d value was then calculated using the formula provided above. Only saturated soil samples collocated at groundwater grab sample locations and/or soil samples from the bottom of monitoring well screen intervals were used in the analysis. The results of the analysis produced a median K_d value of 122 L/kg, which is deemed as the most appropriate K_d value for the BOP areas within the NFSS.

A higher K_d value indicates increased contaminant sorption and therefore greater retardation of plume movement. The revised K_d value proposed by SAIC was deemed appropriate for the BOP areas, while the original 3.6 L/kg value was re-affirmed as suitable for the IWCS only. The updated solute transport simulations thus use the combination of IWCS and BOP K_d values of 3.6 and 122 L/kg, respectively for all U isotopes.

3.1.2 Source Terms

As described in USACE (2007b), the source term in the NFSS model prescribes concentrations for 24 constituents, as one or all of the following:

1. mass flux through the soil as calculated from SESOIL;
2. groundwater plume initial concentrations; and
3. predicted mass flux through the IWCS.

The constituents are not simulated simultaneously in a single model, but, rather, as seven separate simulations organized by groupings of related constituents: U-238 series; U-235 series; thorium (Th)-232; metals and metalloids; chlorinated solvents; and other constituents. One reason that contaminants were simulated as groups was to account for decay and in growth of constituents derived from the same parent.

Contamination reported in unsaturated soils outside the IWCS was prescribed as a time-varying source term for the 3D transport model. To account for this contaminant source, the SESOIL model (Bonazountas and Wagner, 1981, 1984; Hetrick et al., 1993) was applied to predict the contaminant flux to the water table. SESOIL is a one-dimensional (1D) vertical transport model for unsaturated soil zones for use in determining solute distribution in soil profiles. The SESOIL modeling was conducted for soil plume maps determined for each exposure unit (EU) as described in the BRA (SAIC, 2006). For each soil plume map, a single set of initial contaminant concentrations in soil and transport parameters were specified in the SESOIL model. The SESOIL model was then used to provide conservative time-variant constituent concentrations at the water table. The predicted constituent concentrations were conservatively assumed to homogeneously represent the entire soil plume map. If the SESOIL model results indicated that a particular constituent may pose an unacceptable future risk, then that constituent was carried forward in the subsequent 3D model. The SESOIL model results provided a time-varying source term, for each soil plume map, representative of concentrations at the water table derived from the leaching of contaminants in soil. The SESOIL modeling was conducted by SAIC as part of the BRA effort (SAIC, 2006). Nine of the 24 constituents include a source-term component based on SESOIL results. Re-simulation of the SESOIL model was performed by SAIC to reflect updates in the BOP K_d and the predicted mass flux to the water table prescribed in the model was revised accordingly. The updated solute transport Baseline Case simulations include these updated SESOIL results.

A separate source term was prescribed in the 3D transport model as an initial condition, to account for groundwater contamination defined by plume maps developed by SAIC. The plume maps represent contoured regions of reported elevated levels of contamination in groundwater, away from the IWCS. Plume maps have been prepared for 11 of the 24 simulated constituents, as documented in the RIR. Supplementary groundwater monitoring data summarized in the RIR Addendum includes data from one round of water quality results from temporary well points installed and sampled in November and December 2009. In addition, the RIR addendum includes results from one round of water quality sampling from RIR monitoring wells, sampled in December 2009 through January 2010. Updates were made to 9 of the 11 constituent plume maps. The updated plume maps were then used to define the initial condition source term for the model, as depicted in Figures 3.3 to 3.13.

Key updates to the plume maps include the addition of a newly identified U plume in EU 4, and exclusion of the previously identified groundwater plume that represented the subsurface manhole and pipeline data in EU 10. Other plume shapes and concentrations were revised as appropriate.

The chlorinated solvents plumes in EU 4 were revised to account for elevated concentrations and dense non-aqueous phase liquid. After further investigation and review by USACE, a weight-of-evidence approach was used to determine an appropriate plume shape and concentration.

The updated plume maps provided by SAIC ensure that the transport of constituents already in groundwater are represented and simulated accurately using the model.

A third model source term was used to simulate the release of contaminants from sources within the IWCS and the transport of these contaminants to the water table. A time-varying source term was prescribed for each IWCS waste zone, representative of concentrations at the water table derived from the transport of contaminants through each waste zone. There were no updates to this model source term.

3.2 OVERVIEW OF UPDATED SIMULATION RESULTS

The updated 3D transport model was applied to predict contaminant migration and concentrations of 24 constituents in groundwater for 10,000 years under Baseline Case conditions. As described in the 2007 Groundwater Flow and Contaminant Transport Modeling Report, the Baseline Case simulation represents the best estimate of the current understanding of hydrogeological conditions and contaminant characterization at the NFSS and surrounding region. The modeling process accounts for various elements of the NFSS conceptual model including: hydraulic input parameters; IWCS waste zone configuration; contaminant sources; and solute transport input parameters and concentrations. The Baseline Case model development and input parameter selection process incorporated conservative judgment, which is important for the critical nature of the prediction provided by the model. Examples of conservative decisions include:

- Use of historical precipitation from Lewiston meteorological station, which was higher than precipitation recorded at the Modern Landfill meteorological station;
- Conservative estimates of irrigation water applied to the IWCS cap;

- The HELP model has been known to over-predict estimates of flow through layered systems; e.g., Murphy and Garwell (1998), Liggett and Allen (2010), Schroeder and Peyton (1988), etc. The amount of over prediction is problem-specific, though in some cases recharge rates 35% higher have been noted. Over prediction of recharge by any amount results in a conservative estimate of flow through the IWCS;

- Selection of values of dispersivity, K_d, and biodegradation coefficients based on conservative judgment.

The model is discretized into 121 incremental time periods (stress periods), including 101 50-year stress periods to represent the time from 0 to 5,000 years; and 20 250-year stress periods for 5,000 to 10,000 years. Constituent concentrations representing the contaminant source term are constant within any given stress period and the number of stress periods was sufficient to provide sufficient temporal resolution. Simulation results, including a comprehensive mass balance and solute concentrations for each contaminant, were output at the end of each stress period.

The simulation results capture various complex physical transport processes. For example, concentrations of a particular constituent may increase suddenly as a result of decay from a parent; emergence into a lower permeable unit; or as a result of the interaction from multiple prescribed sources in the model. The presentation of transport results in this section focuses on succinct identification of constituents predicted to pose a potential risk to human health over the long term, whether due to screening level exceedances within the NFSS, or at the NFSS property boundary.

The protective clay cap on the IWCS reduces, but does not eliminate, infiltration into the IWCS. The predicted water-flux through the clay cap carries water into the IWCS and gradually saturates the available pore spaces. The quantity of water predicted to infiltrate into the IWCS by the HELP model is very low. For example, in Bay A, the HELP model predicts that more than 100 years will be required for 1 inch of precipitation to infiltrate through the IWCS clay cap, downward through the layered wastes within Bay A, and through the concrete bottom of Bay A. By comparison, during this 100 year period, more than 3,000 inches of precipitation will have fallen on the IWCS.

The small amount of water predicted to infiltrate into the IWCS fills void spaces in the waste residues and other contained materials. Initially, the water flux through the concrete base of former Buildings 411, 413 and 414 is predicted to be zero. As the IWCS eventually becomes saturated from slowly-infiltrating precipitation, pressures within the cell increase and the HELP model predicts an increasing water flux through the concrete floor. Eventually, the net downward water flux through the concrete base is predicted to equal to the incoming water flux from precipitation.

Simulation results are most easily assessed, in a precursory sense, by reviewing the statistical model output summarized in columnar format in Table 3.1. The concentration magnitude, location, and time of occurrence in each of the four model layers are tabulated for each constituent. A description of the information presented in Table 3.1 is provided in the sections below.

The screening levels listed in Table 3.1 may not be representative of ultimate Applicable or Relevant and Appropriate Requirements (ARAR) determined for the site. It is expected that ARARs will be developed during the Feasibility Study stage and the appropriate action determined thereafter.

3.2.1 Maximum On-Site Constituent Concentrations

Maximum on-site constituent concentrations represent the highest model-predicted value throughout the NFSS property. For any given maximum concentration, the predicted value may be attributed to any of the three prescribed sources in the NFSS model. Although the source of the maximum concentrations is not specified in Table 3.1, the time of occurrence and specified row/column location can be used to infer the source origin. Figure 3.14 provides a reference showing the row/column numbering across the NFSS. Model row and column numbers are used in Table 3.1 and elsewhere in the report text to describe specific locations within the NFSS model domain. The MODHMS grid numbering convention has the row/column origin in the northwest corner of the model. Row and column numbers progressively increase to the south and east, respectively. For example, the IWCS waste zones occur in the vicinity of column 110, row 185.

Where available, the screening levels for each constituent are also summarized in Table 3.1 and provide a reference point of comparison against predicted concentrations. Constituent concentrations that exceed screening level limits are denoted in ***bold and italics*** in Table 3.1. Concentrations are reported for simulation times from simulation time (t)=0 to 1,000 years to identify earlier-time maximums and separately for times ranging from t=0 to 10,000 years.

The highest constituent concentrations occur in model layer one, which represents the BCT unit. A total of 12 of the 24 constituents are predicted to exceed the respective screening value in the BCT within 1,000 years. Occurrence of the maximum values in the BCT is to be expected because this is the model layer in which the source terms reside or are applied.

For many constituents, the maximum concentration occurs at late times, indicative of advective-dispersive transport of high-concentration constituents from within the IWCS. For many non-IWCS sources, the maximum concentration is predicted to peak at earlier times. For example, constituents in the organic decay chain PCE (perchloroethene) - TCE (trichloroethene) - DCE (dichloroethene) – VC (vinyl chloride), represented as an initial condition, may reach a maximum concentration at t=0 years.

The potential for contaminant migration vertically downward through the glaciolacustrine clay (GLC) unit into the more permeable alluvial sand and gravel (ASG) unit was assessed. While concentrations or screening level exceedances in the BCT can be used as a measure of the long-term effectiveness of the IWCS, the groundwater quality below the GLC may also be an indicator of the IWCS performance. Intuitively, elevated concentrations in the GLC would occur later than initial exceedances in the BCT. The underlying GLC is of low permeability, and inhibits solute migration. Below the GLC, however, is the more permeable ASG, with direct hydraulic connection to the Queenston Formation and greater potential for lateral transport. Using groundwater quality in the ASG as an indictor of the long-term effectiveness of the IWCS, or the time of a more probable threat to human health, 4 of the 24 simulated constituents are predicted to exceed the screening level within 1,000 years. Of these four exceedances, however, three are chlorinated solvents that reach their peak concentration at t=50 years. The fewer predicted exceedances below the GLC reflect the transport-inhibiting nature of this unit.

3.2.2 Maximum Constituent Concentrations at Property Boundary

The maximum constituent concentrations at the property boundary provide an additional means of reviewing transport simulation results. Property boundary maximum concentrations represent the highest predicted concentration value within model cells intersecting the NFSS property boundary. These data can be used to identify those constituents predicted to be at risk of migrating off site at concentrations that exceed screening levels. As was done for the maximum on-site constituent concentrations, predicted screening level exceedances at the property boundary are also denoted in ***bold and italics*** in Table 3.1.

Recognizing that the BCT is characterized as having limited capacity for advective solute migration, screening level exceedances in the BCT groundwater may be isolated and have limited lateral mobility. This is based on the fact that the BCT is primarily composed of low permeability clay; sand lenses, although present, are disconnected. As a conservative measure, however, it is noted that model cells coincident with known sand lenses were assigned a hydraulic conductivity representative of clean sand. Thus, there is greater assurance that the model will provide conservative estimates of contaminant migration in areas where sand lenses have been reported.

Nevertheless, given the transport limiting properties of the BCT and disconnected nature of the sand lenses, when constituent screening level exceedances occur below the IWCS, the threat to human health is likely minimal. This is because significant lateral transport is unlikely over short time frames and groundwater on the NFSS is not used for drinking water purposes. Model results indicate that there are no screening level exceedances at the NFSS property boundary due to IWCS sources for the first 1,000 years of simulation.

A total of 2 of the 24 constituents, U-238 and U-234, are predicted to exceed their respective screening values at the property boundary in the BCT within 1,000 years. Both exceedances, however, are due to the existing groundwater plume in EU1 that straddles the northwesternmost property boundary. The time of occurrence of t=0 years suggests the screening level exceedance is attributed to an initial condition.

Predicted concentrations in the ASG at the property boundary remain less than three orders of magnitude below the respective screening level, for all constituents, as denoted by the shaded cells in Table 3.1.

3.2.3 Initial Constituent Exceedances due to IWCS-Sources

For further analysis of initial screening level exceedances, the time, location, and concentration of the initial screening level exceedances due to IWCS sources is also presented in the far right columns of Table 3.1. These results provide insight into when exceedances first occur, and the location of their occurrence. The results also provide a basis for evaluating the operational life of the IWCS.

Insight into the long-term effectiveness of the IWCS can be gained from examining predicted constituent concentrations below the IWCS. When constituent concentrations within the BCT groundwater exceed their respective screening level, a measure of the IWCS long-term effectiveness is provided. Of the 16 constituents represented in the IWCS waste zone in solute transport simulations, three are predicted to exceed their respective screening levels in the BCT within the 1,000 years, these are:

1. U-238 with 6.45 pico curries per liter (pCi/L) at t=200 years;
2. U-234 with 26.1 pCi/L at t=250 years; and
3. U-235 with 1.23 pCi/L at t=200 years.

Two other constituents are predicted to exceed their respective screening levels in the BCT within 10,000 years, these are:

1. Th-230 with 0.39 pCi/L at t=2,500 years; and
2. Radium (Ra)-226 with 1.32 pCi/L at t=3,750 years.

All initial exceedances are predicted to occur below Bay D of former Building 411. Bay D was predicted by the HELP model to have a higher water flux than other Bays in the former Building 411.

The earliest screening level exceedance below the IWCS is predicted to occur after 200 years. Because the model represents the condition after the wastes were emplaced in Building 411 and the IWCS was constructed in 1986, the first screening level exceedance below the IWCS is predicted to occur in 2186. The transport simulations therefore estimate that the IWCS will adequately inhibit contaminant migration for 200 years, provided the IWCS is maintained and the cap retains its current level of flow-inhibiting characteristics, and all other factors being equal. As per the 1986 U.S. Department of Energy (USDOE) Environmental Impact Statement, site maintenance of the IWCS is to include mowing of the surface grass cover to prevent tree growth on the cap, repair of all cap failures, replacement of eroded soils from the cap, and ditch dredging and culvert cleaning to ensure site drainage.

The Design Report for the IWCS (USDOE, 1986) presents an expected service life between 200 to 1,000 years for the clay dike and cutoff walls surrounding the IWCS. This report also indicates that the natural GLC beneath the IWCS is expected to be an effective barrier for groundwater flow for the same time period. The cap was designed to be effective for a time period ranging from 25 to 50 years. As part of the design process, the USDOE conducted a sensitivity analysis using a numerical model to evaluate the effectiveness of the 3-foot thick compact clay cap atop the IWCS. The sensitivity analysis indicated that the cap would control infiltration throughout its anticipated 25 to 50 year design lifespan. The 200-year effective lifespan estimated using the recent model is consistent with the previous estimates that were presented in the Design Report (USDOE, 1986).

3.2.4 Review of Sources Contributing to Screening Level Exceedances

A summary of the screening level exceedances in 1,000 years, organized by model source term, is presented in Table 3.2. In Table 3.2, predicted on-site screening level exceedances are denoted by a black circle; a black triangle indicates a screening level exceedance has occurred at the property boundary; a double dash denotes that an on-site screening level exceedance was not predicted. Contaminant sources arising from the existing groundwater contamination depicted in plume maps are predicted to contribute to most screening level exceedances and are the only source of exceedances at the model boundary. A discussion of exceedances for each source is presented below.

IWCS-based Sources

For IWCS-based sources, on-site exceedances of the screening level are predicted to occur for U-238, U-234 and U-235. Property boundary exceedances are not predicted to occur for any of the IWCS-based sources within the first 1,000 years.

Soil-based Plume Sources

Soil-based plumes are predicted to cause on-site screening level exceedances within 1,000 years for U-234, arsenic (As) and boron (B). Of the constituents predicted to exceed on-site screening level values, none of these constituents exceed the screening level at the property boundary as a result of soil-based plumes. As shown in the animations presented in Appendix B-2, screening level exceedances occur in EU 10 and 11 for U-234 and EU 13 for B and As.

Groundwater Plume Sources

The prescribed initial condition for groundwater plumes cause on-site screening level exceedances at $t=0$ for U-238, U-234, manganese (Mn), PCE, TCE, and bis-2-ethylhexlpthalate.

Of the constituents predicted to exceed on-site screening level values, U-238 and U-234 also exceed the screening level at the property boundary, as indicated by black triangles in Table 3.2. The groundwater plumes are of immediate concern; specifically, the U-238 and U-234 plume within EU 1, as these plumes currently cross the NFSS property boundary at a concentration exceeding the screening level. Boundary exceedances also occur along the property boundary due to U-238 and U-234 plume maps.

3.2.5 Additional Presentation of Simulation Results

Additional data, and presentation of solute transport modeling results in graphical and video animation format, are available in Appendix A and B, which are subdivided as follows:

Appendix A-1: Initial Exceedance of Screening Level Value at NFSS Boundary
Appendix A-2: Maximum Simulated Concentrations at NFSS Boundary, t=0 to 1000 years
Appendix A-3: Maximum Simulated Concentration within 100 feet of NFSS Boundary

Appendix B-1: NFSS Environnemental Database
Appendix B-2: 3D Transport Simulation Animations
Appendix B-3: Screen Captures of Plumes at 0, 50, 200, and 1000 Years

The initial screening level exceedances at the property boundary presented in Appendix A-1 occur at t=0. These are based on initial plume maps presented in the RIR Addendum, imposed onto the numerical model mesh. Consequently, the presented results are subject to limitations with respect to the model cell resolution along the boundary, and averaging of concentrations between these and adjacent cells. For a more detailed assessment of plume concentrations and respective boundary exceedances at t=0, the user is referred to the original plume maps sources presented in the RIR Addendum. The images shown in Appendix A-1 are not modeling results; they are initial plume conditions provided by SAIC and are included here for comprehensive presentation.

The video animations in Appendix B-2 illustrate the complex transport characteristics that are predicted by the model. Areal views of contaminant plume migration with cross-sections through the IWCS provide a 3D perspective. The animations are in Audio Video Interleave (AVI) file format and can be run using standard windows-based software. The animations of plume transport demonstrate that for the first 1,000 years of simulation time, there is little-to-no plume movement of IWCS-derived wastes, and no solute migration is predicted across the NFSS boundary. The videos illustrate the slow and limited solute transport. Surface water concentrations in the Central and Western Drainage Ditches are predicted to remain below surface water screening levels through 1,000 years of simulation.

Collectively, Tables 2.1, 2.2, and Appendices A and B provide a comprehensive presentation of the simulation results. Additional discussion, on a constituent-by-constituent basis, is provided in Section 3.

3.3 SIMULATION RESULTS BY CONSTITUENT

3.3.1 U-238 Series

Maximum On-Site Constituent Concentrations within 1,000 Years

As shown in Table 3.1, for the BCT, the maximum predicted on-site constituent concentrations for U-238, U-234 and Th-230 exceed screening levels within 1,000 years. The U-238 and U-234 maximum concentration occurs at t=1,000 years and are nearly two orders of magnitude greater than the respective screening level values. These high concentrations are limited to the immediate vicinity below and surrounding the IWCS waste zones. The Th-230 on-site maximum occurs at t=1,000 and is attributed to a U-238 series composite groundwater contaminant plume North of the R-10 pile. Maximum on-site concentrations of Ra-226 and Lead (Pb)-210 remain below the screening level at t=1,000 years.

Maximum Constituent Concentrations at Property Boundary within 1,000 Years

Screening level exceedances are predicted at the NFSS boundary for U-238 and U-234 within 1,000 years. As presented in Table 3.1, the initial NFSS boundary exceedances for U-238 and U-234 occur at t=0, and are attributed to existing groundwater contamination that has been detected along the northern property boundary. The location of the initial screening level exceedance is given as model row/column 100/99.

Additional Salient Details of U-238 Transport

Nearly synchronous transport of U-238 and U-234 is expected to occur, and is demonstrated by model results and screening level exceedances. Both U-238 and U-234 are assumed to be in secular equilibrium and were prescribed as having identical concentrations in the IWCS model source terms. Both constituents were assigned the same K_d governing adsorption and both have comparable screening level values. The decay rates for these species may differ, but the half-lives for both are proportionately larger than the simulation duration. Consequently, they will have little effect on the predicted concentrations.

3.3.2 U-235 Series

Maximum On-Site Constituent Concentrations within 1,000 Years

Maximum on-site U-235 concentrations are predicted to exceed the screening level within 1,000 years due to high U-235 concentrations within the IWCS. The maximum on-site concentration of 414 pCi/L occurs at row/column 187/112 below the IWCS.

Maximum Constituent Concentrations at Property Boundary within 1,000 Years

The maximum U-235 concentration at the NFSS boundary of 0.51 pCi/L occurs at t=0 years at row/column 99/97. This maximum concentration is equivalent to the screening level value of 0.51 pCi/L.

3.3.3 Th-232 Series

Maximum On-Site Constituent Concentrations

Maximum Th-232 concentrations are predicted to be below screening level values throughout the entire model domain for all simulation times.

Maximum Constituent Concentrations at Property Boundary

Concentrations of Th-232 are not predicted to exceed screening level values at the NFSS property boundary.

3.3.4 Metals and Metalloids

Maximum On-Site Constituent Concentrations

Among the simulated metals and metalloids, concentrations of As, B and Mn are expected to exceed screening levels. Unlike the radionuclides and chlorinated solvents, metal concentrations in groundwater are not reduced in time by degradation or decay. Concentrations are reduced by other means, however, primarily dispersion and dilution.

The maximum on-site concentration of Mn occurs at t=0, and is attributable to elevated concentrations in groundwater. The maximum concentration of B and As occur later than Mn because they are governed by the release from SESOIL sources.

Maximum Constituent Concentrations at Property Boundary

Metals are not predicted to exceed screening levels at the NFSS property boundaries.

3.3.5 Chlorinated Solvents

Maximum On-Site Constituent Concentrations

The maximum on-site constituent concentrations for all four chlorinated ethenes (PCE, TCE, *cis*-1,2-dichloroethene [*cis*-1,2-DCE] and VC) are predicted to exceed established screening level values at early simulation times. These four constituents represent successive stages of dechlorination in a degradation process that eventually yields benign ethene. The maximum concentration for early chain members, PCE and TCE, occur at t=0 in EU 4. The maximum concentrations of degradation products, *cis*-1,2-DCE and VC, occur at t=50 years, as these constituents are produced through the degradation of PCE and TCE. The maximum on-site concentrations for all constituents are several orders of magnitude above the screening level values.

The maximum on-site concentrations for PCE, TCE and *cis*-1,2-DCE are degraded to concentrations below their respective screening level values in less than 200 years, and for VC in less than 300 years. Inherent in this prediction are the assumptions regarding the biodegradation half-lives assigned to each chlorinated ethene. Chlorinated ethane half-lives were determined based on values presented in Wiedemeier et al. (1999). Wiedemeier et al. (1999) provides multiple half lives for each constituent, based on the results of previous studies. To ensure a conservative model prediction, decay rates at the lower end of the reported range were used in the modeling analysis.

It is noted that the BCT unit, in the vicinity of the chlorinated plumes within EU4, is characterized by the presence of sand lenses. Based on the evaluation of sand lens continuity within the NFSS, the sand lenses within EU4 are not expected to be continuous over significant distances. Consequently, off-site migration of the chlorinated solvent plumes is considered to be unlikely.

Evaluation of Effects of a DNAPL Source

Chlorinated solvents plumes were represented in the model by assigning initial concentrations based on observed contaminant concentrations in groundwater. In the case of PCE, TCE and VC, the peak concentrations in groundwater were reported above the solubility limit at individual sampling locations. Concentrations above the solubility limit suggests the presence of a dense non-aqueous phase liquid (DNAPL) and the possibility of a continuing source of groundwater contamination. This raises concern whether the initial source term in the model adequately represents the transport risk, because it does not account for a continuous source. Additional simulation was performed to evaluate the effects of a DNAPL source.

A prescribed (fixed) concentration was set for the duration of the 10,000 year simulation period. In the absence of detailed field characterization data, conservative assumptions were made regarding the spatial extent of DNAPL. Fixed concentrations were prescribed over the area where the highest PCE, TCE and VC concentrations were observed. In most cases, the maximum observed concentration was assigned in the model at these locations. However, if the maximum concentration was found to exceed the solubility limit, then the solubility limit was assigned in the model to represent the source area. This approach represents a continuous release of mass throughout the duration of the simulation.

Video animation results presented in Appendix B-4 indicate that the chlorinated solvent plumes are predicted to reach steady-state conditions after approximately 350 years. The maximum extent of contamination is only slightly bigger than the DNAPL source area. The additional mass input from the fixed source is balanced by dispersive effects and the loss of mass due to biodegradation. Tabulated simulation results, also included in Appendix B-4, indicates that under a fixed concentration scenario, higher concentrations are predicted for each constituent in lower stratigraphic units, compared to the initial condition source term representation. Importantly, however, the fixed concentration source does not cause screening level exceedances at the NFSS property boundary. This approach provides a conservative prediction of the maximum extent of contamination for plumes originating from DNAPL sources.

Maximum Constituent Concentrations at Property Boundary

Due to degradation processes and slow groundwater velocities, chlorinated solvent concentrations are expected to be reduced below screening level values before notable constituent migration occurs, and chlorinated solvents are not predicted to exceed screening levels at the NFSS boundary within the simulation time period.

3.3.6 Other

Maximum On-Site Constituent Concentrations

The maximum on-site concentrations of bis(2-ethylhexyl)phthalate is predicted to exceed its established screening level at t=0 as a result of existing groundwater contamination. This maximum on-site concentration is predicted to remain constant at 12.0 micrograms per liter (μg/L) for the duration of the 10,000 year simulation. Bis(2-ethylhexyl)phthalate is highly adsorbed and is not expected to migrate significantly. Methylene chloride concentrations are not expected to exceed their screening levels.

Maximum Constituent Concentrations at Property Boundary

The maximum concentrations of bis(2-ethylhexyl)phthalate and methylene chloride are not predicted to exceed screening levels within the simulation time period.

4.0 CONCLUSIONS

The 3D NFSS groundwater flow and solute transport model has been updated and simulations of Baseline Case conditions have been presented.

To ensure that the groundwater flow and solute transport model conservatively predicts contaminant migration, the NFSS groundwater model was revised to more explicitly represent the distribution of sand lenses within the BCT. As part of this process, hydraulic conductivity values assigned in the model were adjusted in areas characterized by sand lenses. This involved increasing the hydraulic conductivity in these areas to a value representative of a clean sand. A total of 250 sand lenses were explicitly represented in the model. The groundwater flow field produced using the updated model was evaluated to determine whether the model adequately simulated observed conditions. The results of this evaluation confirmed that the model accurately simulates observed conditions, and subsequent transport simulations were performed using the updated groundwater flow solution.

The solute transport model updates include using a revised K_d value for U isotopes and updated model source terms based on supplementary RI efforts.

The updated modeling results are comparable with those presented in USACE (2007b) and serve to allay concerns about solute transport. Results indicate that residues in the IWCS do not pose an imminent threat to groundwater quality on or around the NFSS. The updated modeling results indicate that the IWCS sources are currently contained, and with continued care and protection of the IWCS clay cap, are not of immediate concern to the quality of groundwater on site or at the property boundary.

The updated model provides predictions of groundwater quality in areas where groundwater monitoring is difficult, such as below the IWCS. Concentrations of U-238 below the IWCS are predicted to remain below the screening level until t=200 years. Using this time of predicted screening level exceedances as a performance indicator, the estimated operational lifespan of the IWCS is 200 years.

The model results indicate that the BCT and GLC effectively inhibit the downward migration of constituents. None of the radionuclides are predicted to occur in ASG groundwater within 10,000 years. Only B is predicted to migrate through the GLC at concentrations that exceed screening level values. RI field investigations completed by SAIC indicate that U is present in groundwater offsite and near the NFSS boundary. The groundwater at these locations is not used for drinking water purposes, and the potential for transport from these localized regions is limited assuming the characteristic low permeability of the BCT observed on the NFSS and surrounding properties.

The model predicts that IWCS sources will not cause any screening level exceedances at the property boundary.

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5.0 REFERENCES

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TABLES

Table 3.1
Baseline Case Predicted Maximum Constituent Concentrations and Initial Screening Level Exceedances
Model Layer 1 - Upper Clay Till Unit

						Maximum On-Site Constituent Concentration								Maximum Constituent Concentration at Property Boundary								Initial Constituent Screening Level Exceedances							
						From t=0 to 1,000 years				From t=0 to 10,000 years				From t=0 to 1,000 years				From t=0 to 10,000 years				At Property Boundary				On-Site Due to IWCS Sources			
						Maximum		Location		Maximum	Time	Location		Maximum	Time	Location		Maximum	Time	Location			Time	Location			Time	Location	
Group	Constituent	Units	Screening Level	UTL[3]	MCL[4]	Conc.	Time	Row	Col	Conc.	(years)	Row	Col	Conc.	(years)	Row	Col	Conc.	(years)	Row	Col	Conc.	(years)	Row	Col	Conc.	(years)	Row	Col
U-238 (Uranium-Radium Series)	^{238}U	pCi/L	6.32	6.32	30 (5)	***2,242***	1,000	187	112	***27,052***	10,000	188	113	***12.0***	0	100	99	***12.0***	0	100	99	***6.32***	0	99	98	***6.45***	200	185	110
	^{234}U	pCi/L	8.94	8.94		***2,264***	1,000	187	112	***27,128***	10,000	188	114	***8.94***	1,000	101	103	***8.99***	10,000	101	103	***8.94***	0	100	99	***26.1***	250	185	110
	^{230}Th	pCi/L	0.39	0.23		***1.00***	0	149	112	***13.1***	10,000	189	116	0.013	1,000	101	103	0.13	10,000	101	103	0.00	0	0	0	***0.39***	2,500	193	111
	^{226}Ra	pCi/L	1.31	1.31	5 (6)	1.00	1,000	150	112	***22.6***	10,000	189	116	7.2E-03	1,000	104	113	0.28	10,000	101	103	0.00	0	0	0	***1.32***	3,750	193	111
	^{210}Pb	pCi/L	NA			7.1E-03	1,000	150	112	0.16	10,000	189	116	4.9E-05	1,000	104	113	2.0E-03	10,000	101	103	0.00	0	0	0	0.00	0	0	0
U-235 (Actinium Series)	^{235}U	pCi/L	0.51	0.51		***414***	1,000	187	112	***2,941***	7,250	188	115	***0.51***	0	99	97	***0.51***	0	99	97	***0.51***	0	99	97	***1.23***	200	185	110
	^{231}Pa	pCi/L	NA			7.3E-03	1,000	193	111	2.77	10,000	189	116	8.5E-04	1,000	103	109	7.7E-03	10,000	102	106	0.00	0	0	0	0.00	0	0	0
	^{227}Ac	pCi/L	NA			0.022	1,000	193	111	9.26	10,000	189	116	2.8E-03	1,000	103	109	0.026	10,000	102	106	0.00	0	0	0	0.00	0	0	0
Th-232	^{232}Th	pCi/L	0.229	0.39		3.4E-06	1,000	182	103	3.5E-05	10,000	182	103	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
Metals	As	µg/L	10	10	10	***411***	1,000	196	160	***1,114***	4,200	196	160	0.00	1,000	176	96	3.8E-06	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Ba	µg/L	42.8	42.8	2000	3.1E-04	1,000	182	103	2.9E-03	10,000	184	103	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	B	µg/L	4750	4750		***2,305,007***	450	196	155	***2,305,007***	450	196	155	1.2E-03	1,000	127	187	16.7	10,000	127	187	0.00	0	0	0	172	1,750	193	112
	Cd	µg/L	2.32	2.32	5	0.00	0	97	84	***16.3***	10,000	182	150	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	Fe	µg/L	9280	9280		5.44	1,000	182	103	49.8	10,000	184	103	0.00	1,000	176	96	9.1E-08	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Pb	µg/L	0.935	0.935	15	4.2E-05	1,000	182	103	4.5E-04	10,000	182	103	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mo	µg/L	40		40(7)	0.058	1,000	193	111	2.96	10,000	193	111	0.00	1,000	179	95	1.4E-08	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mn	µg/L	966	966		***1,250***	0	133	172	***1,250***	0	133	172	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Sb	µg/L	2.4	2.4		0.00	0	97	84	***113***	10,000	196	155	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
Chlorinated Solvents	PCE	µg/L	5		5	***100,000***	0	136	184	***100,000***	0	136	184	5.8E-09	50	124	182	5.8E-09	50	124	182	0.00	0	0	0	0.00	0	0	0
	TCE	µg/L	5		5	***100,010***	0	137	184	***100,010***	0	137	184	3.8E-07	50	124	182	3.8E-07	50	124	182	0.00	0	0	0	0.00	0	0	0
	cis-1,2-DCE	µg/L	70		70	***30,713***	50	137	184	***30,713***	50	137	184	5.3E-06	50	124	182	5.3E-06	50	124	182	0.00	0	0	0	0.00	0	0	0
	VC	µg/L	2	1	2	***58,517***	50	137	184	***58,517***	50	137	184	1.3E-03	100	124	182	1.3E-03	100	124	182	0.00	0	0	0	0.00	0	0	0
	2EHP[1]	µg/L	6		6	***12.0***	0	183	126	***12.0***	0	183	126	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	MC[2]	µg/L	5		5	1.72	50	185	158	1.72	50	185	158	0.00	50	127	187	0.00	50	127	187	0.00	0	0	0	0.00	0	0	0

Notes:

Shaded cells where predicted concentrations are less than three orders of magnitude below screening level, or less than 1.0E-5 pCi/L where no screening level is available

2.46E+03 Values in bolded italics where screening level exceeded

[1] bis-2-ethylhexyl phthalate

[2] methylene chloride

[3] UTL - 95% Upper Tolerance Limit for NFSS (NFSS RIR (USACE,2007a))

[4] MCL - Maximum Contaminant Level (USEPA)

[5] The MCL of 30 µg/L is for Total Uranium

[6] The MCL is for combined 226Ra and 228Ra

[7] The USEPA drinking water standard lifetime health advisory level for a 10 kg child.

NA - Screening level not available

Figure 2.6 provides a reference showing the row/column numbering across the NFSS. Row and column numbers progressively increase to the south and east, respectively. For example, the IWCS waste zones occur in the vicinity of column 110, row 185.

Table 3.1
Baseline Case Predicted Maximum Constituent Concentrations and Initial Screening Level Exceedances
Model Layer 2 - Glaciolacustrine Clay Unit

						Maximum On-Site Constituent Concentration								Maximum Constituent Concentration at Property Boundary								Initial Constituent Screening Level Exceedances							
						From t=0 to 1,000 years				From t=0 to 10,000 years				From t=0 to 1,000 years				From t=0 to 10,000 years				At Property Boundary				On-Site Due to IWCS Sources			
						Maximum Conc.	Time	Location		Maximum Conc.	Time (years)	Location		Maximum Conc.	Time (years)	Location		Maximum Conc.	Time (years)	Location		Conc.	Time (years)	Location		Conc.	Time (years)	Location	
Group	Constituent	Units	Screening Level	UTL[3]	MCL[4]			Row	Col			Row	Col			Row	Col			Row	Col			Row	Col			Row	Col
U-238 (Uranium-Radium Series)	^{238}U	pCi/L	6.32	6.32	30 (5)	0.82	1,000	190	109	***167***	10,000	190	109	3.8E-03	1,000	100	99	0.038	10,000	100	99	0.00	0	0	0	***6.52***	2,050	190	109
	^{234}U	pCi/L	8.94	8.94		0.83	1,000	190	109	***167***	10,000	190	109	3.4E-03	1,000	136	107	0.033	10,000	136	107	0.00	0	0	0	***9.19***	2,350	190	109
	^{230}Th	pCi/L	0.39	0.23		5.2E-04	1,000	154	119	***0.88***	10,000	190	109	2.9E-06	1,000	136	107	2.8E-04	10,000	136	107	0.00	0	0	0	0.25	6,500	190	109
	^{226}Ra	pCi/L	1.31	1.31	5 (6)	1.0E-03	1,000	154	119	***1.43***	10,000	190	109	1.5E-06	1,000	136	107	6.0E-04	10,000	136	107	0.00	0	0	0	0.00	9,750	190	109
	^{210}Pb	pCi/L	NA			7.0E-06	1,000	154	119	0.010	10,000	190	109	9.9E-09	1,000	136	107	4.3E-06	10,000	136	107	0.00	0	0	0	0.00	0	0	0
U-235 (Actinium Series)	^{235}U	pCi/L	0.51	0.51		0.15	1,000	190	109	***16.1***	10,000	190	109	1.9E-04	1,000	143	105	1.9E-03	10,000	143	105	0.00	0	0	0	***0.53***	1,500	190	109
	^{231}Pa	pCi/L	NA			5.3E-05	1,000	190	109	0.11	10,000	190	109	1.7E-07	1,000	143	105	1.6E-05	10,000	143	105	0.00	0	0	0	0.00	0	0	0
	^{227}Ac	pCi/L	NA			1.5E-04	1,000	190	109	0.37	10,000	190	109	5.3E-07	1,000	143	105	5.3E-05	10,000	143	105	0.00	0	0	0	1.0E-07	0	0	0
Th-232	^{232}Th	pCi/L	0.229	0.39		1.0E-09	1,000	177	105	1.1E-07	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
Metals	As	µg/L	10	10	10	0.61	1,000	196	158	***38.4***	10,000	197	159	0.00	1,000	176	96	4.9E-08	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Ba	µg/L	42.8	42.8	2000	3.1E-07	1,000	177	105	3.0E-05	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	B	µg/L	4750	4750		***386,346***	1,000	193	148	***782,934***	4,500	193	149	2.5E-04	1,000	127	187	15.5	10,000	126	186	0.00	0	0	0	175	6,000	193	112
	Cd	µg/L	2.32	2.32	5	0.00	0	97	84	0.023	10,000	195	153	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	Fe	µg/L	9280	9280		7.8E-03	1,000	177	105	0.75	10,000	177	105	0.00	1,000	176	96	2.7E-10	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Pb	µg/L	0.935	0.935	15	2.7E-09	1,000	177	105	3.0E-07	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mo	µg/L	40		40(7)	2.0E-04	1,000	193	111	0.22	10,000	193	111	0.00	1,000	194	91	1.6E-10	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mn	µg/L	966	966		0.052	1,000	133	176	0.52	10,000	133	176	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Sb	µg/L	2.4	2.4		0.00	0	97	84	0.61	10,000	197	154	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
Chlorinated Solvents	PCE	µg/L	5		5	***42.4***	50	138	184	***42.4***	50	138	184	0.00	50	124	182	0.00	50	124	182	0.00	0	0	0	0.00	0	0	0
	TCE	µg/L	5		5	***336***	50	137	184	***336***	50	137	184	5.0E-10	100	124	182	5.0E-10	100	124	182	0.00	0	0	0	0.00	0	0	0
	cis-1,2-DCE	µg/L	70		70	***993***	50	137	184	***993***	50	137	184	1.5E-08	100	124	182	1.5E-08	100	124	182	0.00	0	0	0	0.00	0	0	0
	VC	µg/L	2	1	2	***6,148***	50	137	184	***6,148***	50	137	184	1.7E-05	100	125	184	1.7E-05	100	125	184	0.00	0	0	0	0.00	0	0	0
	2EHP[1]	µg/L	6		6	4.5E-04	1,000	184	122	4.5E-03	10,000	184	122	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	MC[2]	µg/L	5		5	4.6E-03	50	197	146	4.6E-03	50	197	146	0.00	50	127	187	0.00	50	127	187	0.00	0	0	0	0.00	0	0	0

Notes:

[shaded box] Shaded cells where predicted concentrations are less than three orders of magnitude below screening level, or less than 1.0E-5 pCi/L where no screening level is available

2.46E+03 Values in bolded italics where screening level exceeded

[1] bis-2-ethylhexyl phthalate

[2] methylene chloride

[3] UTL - 95% Upper Tolerance Limit for NFSS (NFSS RIR (USACE,2007a))

[4] MCL - Maximum Contaminant Level (USEPA)

[5] The MCL of 30 µg/L is for Total Uranium

[6] The MCL is for combined 226Ra and 228Ra

[7] The USEPA drinking water standard lifetime health advisory level for a 10 kg child.

NA - Screening level not available

Figure 2.6 provides a reference showing the row/column numbering across the NFSS. Row and column numbers progressively increase to the south and east, respectively. For example, the IWCS waste zones occur in the vicinity of column 110, row 185.

Table 3.1
Baseline Case Predicted Maximum Constituent Concentrations and Initial Screening Level Exceedances
Model Layer 3 - Alluvial Sand and Gravel Unit

						Maximum On-Site Constituent Concentration								Maximum Constituent Concentration at Property Boundary								Initial Constituent Screening Level Exceedances							
						From t=0 to 1,000 years				From t=0 to 10,000 years				From t=0 to 1,000 years				From t=0 to 10,000 years				At Property Boundary				On-Site Due to IWCS Sources			
								Location				Location				Location				Location				Location				Location	
Group	Constituent	Units	Screening Level	UTL[3]	MCL[4]	Maximum Conc.	Time	Row	Col	Maximum Conc.	Time (years)	Row	Col	Maximum Conc.	Time (years)	Row	Col	Maximum Conc.	Time (years)	Row	Col	Conc.	Time (years)	Row	Col	Conc.	Time (years)	Row	Col
U-238 (Uranium-Radium Series)	^{238}U	pCi/L	6.32	6.32	30 (5)	3.1E-03	1,000	193	147	3.65	10,000	190	109	2.6E-05	1,000	136	107	1.9E-03	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{234}U	pCi/L	8.94	8.94		4.2E-03	1,000	193	147	3.67	10,000	190	109	3.7E-05	1,000	136	107	2.6E-03	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{230}Th	pCi/L	0.39	0.23		2.7E-06	1,000	193	147	0.016	10,000	190	109	2.2E-08	1,000	136	107	1.6E-05	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{226}Ra	pCi/L	1.31	1.31	5 (6)	1.3E-06	1,000	154	119	0.029	10,000	190	109	9.8E-09	1,000	136	107	3.3E-05	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{210}Pb	pCi/L	NA			2.7E-08	0	97	84	2.1E-04	10,000	190	109	0.00	1,000	136	107	2.4E-07	10,000	136	107	0.00	0	0	0	0.00	0	0	0
U-235 (Actinium Series)	^{235}U	pCi/L	0.51	0.51		2.1E-04	1,000	195	149	0.41	10,000	190	109	7.8E-07	1,000	100	99	7.0E-05	10,000	100	99	0.00	0	0	0	0.00	0	0	0
	^{231}Pa	pCi/L	NA			1.4E-07	1,000	195	149	2.1E-03	10,000	190	109	4.8E-10	1,000	100	99	4.2E-07	10,000	100	99	0.00	0	0	0	0.00	0	0	0
	^{227}Ac	pCi/L	NA			4.4E-07	1,000	195	149	7.2E-03	10,000	190	109	1.5E-09	1,000	100	99	1.4E-06	10,000	100	99	0.00	0	0	0	0.00	0	0	0
Th-232	^{232}Th	pCi/L	0.229	0.39		0.00	1,000	177	105	2.9E-10	10,000	171	107	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
Metals	As	µg/L	10	10	10	0.013	1,000	191	148	4.69	10,000	191	148	0.00	1,000	176	96	6.0E-10	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Ba	µg/L	42.8	42.8	2000	1.8E-10	1,000	177	105	1.9E-07	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	B	µg/L	4750	4750		***120,777***	1,000	193	148	***575,281***	7,000	193	148	0.012	1,000	127	187	79.5	10,000	125	184	0.00	0	0	0	0.00	0	0	0
	Cd	µg/L	2.32	2.32	5	0.00	0	97	84	1.3E-04	10,000	195	153	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	Fe	µg/L	9280	9280		6.8E-06	1,000	177	105	6.6E-03	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Pb	µg/L	0.935	0.935	15	0.00	1,000	177	105	1.2E-10	10,000	177	105	0.00	0	0	0	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mo	µg/L	40		40(7)	1.6E-06	1,000	192	110	0.025	10,000	192	110	0.00	1,000	194	91	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mn	µg/L	966	966		3.0E-05	1,000	133	176	2.8E-03	10,000	133	176	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Sb	µg/L	2.4	2.4		0.00	0	97	84	9.4E-03	10,000	197	154	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
Chlorinated Solvents	PCE	µg/L	5		5	2.45	50	136	185	2.45	50	136	185	1.2E-10	50	124	182	1.2E-10	50	124	182	0.00	0	0	0	0.00	0	0	0
	TCE	µg/L	5		5	***30.3***	50	137	184	***30.3***	50	137	184	1.7E-08	100	124	182	1.7E-08	100	124	182	0.00	0	0	0	0.00	0	0	0
	DCE	µg/L	70		70	***107***	50	137	184	***107***	50	137	184	3.3E-07	100	124	182	3.3E-07	100	124	182	0.00	0	0	0	0.00	0	0	0
	VC	µg/L	2	1	2	***759***	50	137	184	***759***	50	137	184	3.7E-05	100	125	184	3.7E-05	100	125	184	0.00	0	0	0	0.00	0	0	0
	2EHP[1]	µg/L	6		6	1.5E-08	1,000	184	122	1.4E-06	10,000	184	122	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	MC[2]	µg/L	5		5	3.6E-05	50	197	146	3.6E-05	50	197	146	0.00	50	127	187	0.00	50	127	187	0.00	0	0	0	0.00	0	0	0

Notes:

[shaded] Shaded cells where predicted concentrations are less than three orders of magnitude below screening level, or less than 1.0E-5 pCi/L where no screening level is available

2.46E+03 Values in bolded italics where screening level exceeded

[1] bis-2-ethylhexyl phthalate

[2] methylene chloride

[3] UTL - 95% Upper Tolerance Limit for NFSS (NFSS RIR (USACE,2007a))

[4] MCL - Maximum Contaminant Level (USEPA)

[5] The MCL of 30 µg/L is for Total Uranium

[6] The MCL is for combined 226Ra and 228Ra

[7] The USEPA drinking water standard lifetime health advisory level for a 10 kg child.

NA - Screening level not available

Figure 2.6 provides a reference showing the row/column numbering across the NFSS. Row and column numbers progressively increase to the south and east, respectively. For example, the IWCS waste zones occur in the vicinity of column 110, row 185.

Table 3.1
Baseline Case Predicted Maximum Constituent Concentrations and Initial Screening Level Exceedances
Model Layer 4 - Queenston Formation

						Maximum On-Site Constituent Concentration								Maximum Constituent Concentration at Property Boundary								Initial Constituent Screening Level Exceedances							
						From t=0 to 1,000 years				From t=0 to 10,000 years				From t=0 to 1,000 years				From t=0 to 10,000 years				At Property Boundary				On-Site Due to IWCS Sources			
						Maximum Conc.	Time	Location		Maximum Conc.	Time (years)	Location		Maximum Conc.	Time (years)	Location		Maximum Conc.	Time (years)	Location		Conc.	Time (years)	Location		Conc.	Time (years)	Location	
Group	Constituent	Units	Screening Level	UTL[3]	MCL[4]			Row	Col			Row	Col			Row	Col			Row	Col			Row	Col			Row	Col
U-238 (Uranium-Radium Series)	^{238}U	pCi/L	6.32	6.32	30 (5)	7.3E-05	1,000	193	147	0.12	10,000	190	109	4.4E-07	1,000	136	107	2.8E-04	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{234}U	pCi/L	8.94	8.94		9.9E-05	1,000	193	147	0.12	10,000	190	109	6.2E-07	1,000	136	107	3.9E-04	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{230}Th	pCi/L	0.39	0.23		4.7E-08	1,000	193	147	4.3E-04	10,000	190	109	2.8E-10	1,000	136	107	1.8E-06	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{226}Ra	pCi/L	1.31	1.31	5 (6)	2.0E-08	1,000	193	147	7.2E-04	10,000	190	109	1.1E-10	1,000	136	107	3.5E-06	10,000	136	107	0.00	0	0	0	0.00	0	0	0
	^{210}Pb	pCi/L	NA			2.7E-08	0	97	84	5.2E-06	10,000	190	109	0.00	1,000	136	107	2.5E-08	10,000	136	107	0.00	0	0	0	0.00	0	0	0
U-235 (Actinium Series)	^{235}U	pCi/L	0.51	0.51		4.8E-06	1,000	193	147	0.016	10,000	190	109	8.9E-09	1,000	100	99	7.4E-06	10,000	100	99	0.00	0	0	0	0.00	0	0	0
	^{231}Pa	pCi/L	NA			2.4E-09	1,000	193	147	6.1E-05	10,000	190	109	0.00	1,000	100	99	3.4E-08	10,000	100	99	0.00	0	0	0	0.00	0	0	0
	^{227}Ac	pCi/L	NA			2.5E-08	0	97	84	2.0E-04	10,000	190	109	0.00	1,000	100	99	1.1E-07	10,000	100	99	0.00	0	0	0	0.00	0	0	0
Th-232	^{232}Th	pCi/L	0.229	0.39		0.00	1,000	171	107	0.00	10,000	171	107	0.00	0	0	0	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
Metals	As	µg/L	10	10	10	3.8E-04	1,000	191	148	1.51	10,000	191	148	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Ba	µg/L	42.8	42.8	2000	0.00	1,000	177	105	3.0E-09	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	B	µg/L	4750	4750		***58,411***	1,000	193	147	***527,606***	8,000	193	147	0.021	1,000	127	187	93.6	10,000	125	184	0.00	0	0	0	0.00	0	0	0
	Cd	µg/L	2.32	2.32	5	0.00	0	97	84	1.5E-06	10,000	195	153	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	Fe	µg/L	9280	9280		1.6E-08	1,000	177	105	1.5E-04	10,000	177	105	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Pb	µg/L	0.935	0.935	15	0.00	1,000	177	105	0.00	10,000	177	105	0.00	0	0	0	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mo	µg/L	40		40(7)	1.4E-08	1,000	192	110	3.2E-03	10,000	192	110	0.00	1,000	194	91	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Mn	µg/L	966	966		9.3E-08	1,000	136	171	8.3E-05	10,000	136	171	0.00	1,000	176	96	0.00	10,000	176	96	0.00	0	0	0	0.00	0	0	0
	Sb	µg/L	2.4	2.4		0.00	0	97	84	3.2E-04	10,000	197	154	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
Chlorinated Solvents	PCE	µg/L	5		5	0.44	50	136	185	0.44	50	136	185	0.00	100	124	182	0.00	100	124	182	0.00	0	0	0	0.00	0	0	0
	TCE	µg/L	5		5	***8.15***	50	137	184	***8.15***	50	137	184	2.1E-08	100	124	182	2.1E-08	100	124	182	0.00	0	0	0	0.00	0	0	0
	cis-1,2-DCE	µg/L	70		70	35.3	50	137	184	35.3	50	137	184	6.5E-07	100	125	184	6.5E-07	100	125	184	0.00	0	0	0	0.00	0	0	0
	VC	µg/L	2	1	2	***302***	50	137	184	***302***	50	137	184	1.3E-04	100	125	184	1.3E-04	100	125	184	0.00	0	0	0	0.00	0	0	0
	2EHP[1]	µg/L	6		6	0.00	1,000	184	122	8.9E-10	10,000	184	122	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0	0.00	0	0	0
	MC[2]	µg/L	5		5	5.1E-07	50	197	146	5.1E-07	50	197	146	0.00	50	127	187	0.00	50	127	187	0.00	0	0	0	0.00	0	0	0

Notes:

(shaded) Shaded cells where predicted concentrations are less than three orders of magnitude below screening level, or less than 1.0E-5 pCi/L where no screening level is available

2.46E+03 Values in bolded italics where screening level exceeded

[1] bis-2-ethylhexyl phthalate

[2] methylene chloride

[3] UTL - 95% Upper Tolerance Limit for NFSS (NFSS RIR (USACE,2007a))

[4] MCL - Maximum Contaminant Level (USEPA)

[5] The MCL of 30 µg/L is for Total Uranium

[6] The MCL is for combined 226Ra and 228Ra

[7] The USEPA drinking water standard lifetime health advisory level for a 10 kg child.

NA - Screening level not available

Figure 2.6 provides a reference showing the row/column numbering across the NFSS. Row and column numbers progressively increase to the south and east, respectively. For example, the IWCS waste zones occur in the vicinity of column 110, row 185.

Table 3.2
Screening Level Exceedance in 1,000 years, Organized by Model Source Term
Model Layer 1 - Upper Clay Till Unit

Group	Constituent	Plume Map Sources	SESOIL-based Sources[1] Exposure Unit 1	2	3	4	5	6	7	8	9	10	11	12	13	14	IWCS Sources
U-238 (Uranium-Radium Series)	^{238}U	▲	--	--	--	--	--	--	--	--	--	--	--	--	--	--	●
	^{234}U	▲	--	--	--	--	--	--	--	--	--	●[1]	●[1]	--	--	--	●
	^{230}Th	●															--
	^{226}Ra						--	--	--	--		--	--		--	--	--
	^{210}Pb																--
U-235 (Actinium Series)	^{235}U	▲	--			--	--		--	--		--	--		--	--	●
	^{231}Pa																--
	^{227}Ac																--
Th-232	^{232}Th																--
Metals	As					--								--	●	--	--
	Ba																--
	B	●													●		--
	Cd														--		
	Fe																--
	Pb																--
	Mo																--
	Mn	●															--
Chlorinated Solvents	PCE	●															
	TCE	●															
	cis-1,2-DCE	●															
	VC	●															
Other	Sb														--		
	2EHP[1]	●															
	MC[2]					--									--		

-- Source assigned to model, but an exceedance on-site is not predicted to occur within t=1000 years

● Screening level exceedance on-site within t=1,000 years

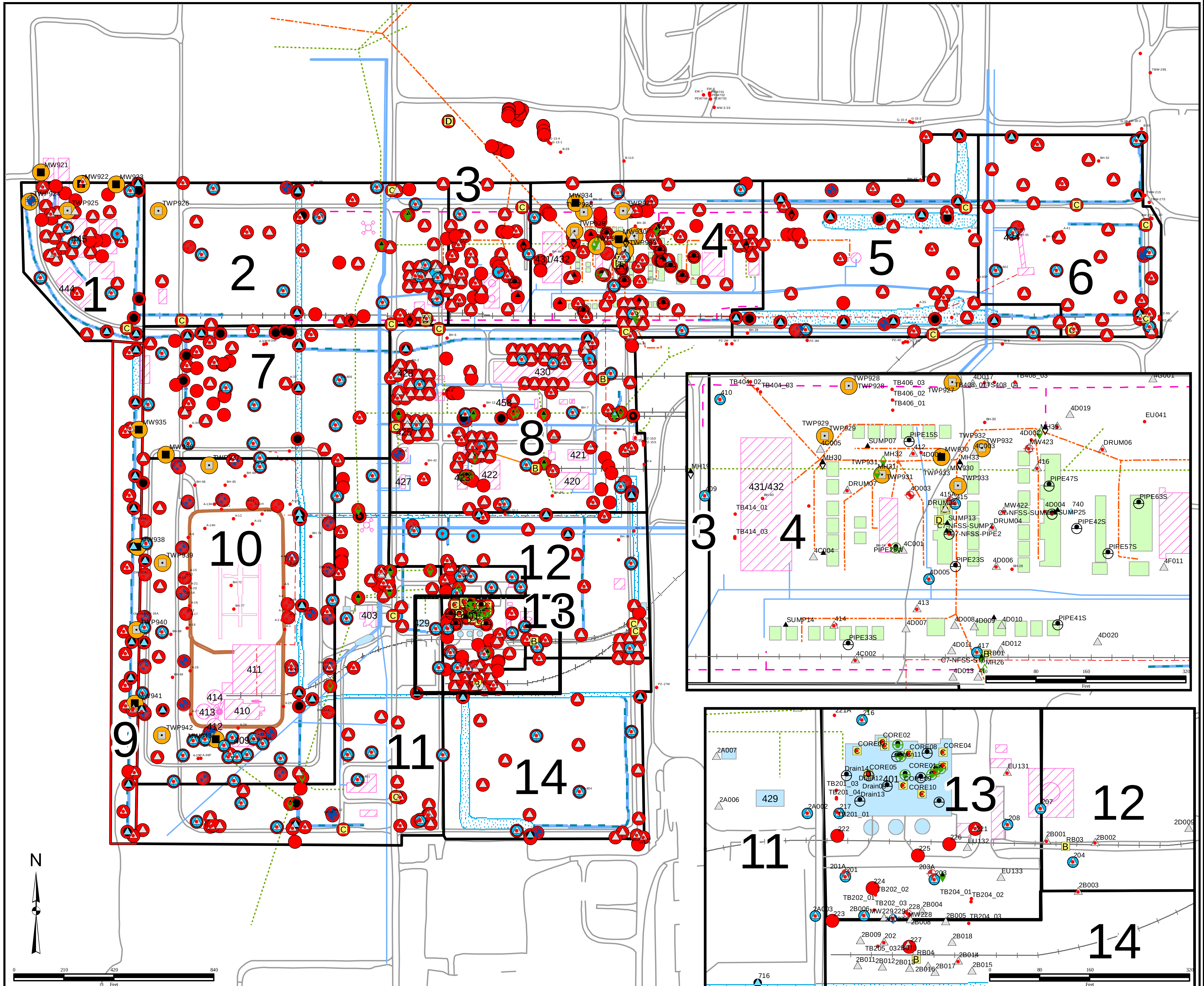
▲ Screening level exceedance on-site and at boundary

[1] Exceedances may be due to SESOIL source or groundwater plumes maps within the EU

FIGURES

HGL—Final Updated Model Results
Niagara Falls Storage Site, Lewiston, New York

Figure 3.1
Borehole and Well Locations



Legend

- Drum residue
- UWBZ TWP
- LWBZ well
- UWBZ well
- Manhole sediment
- Manhole water
- Pipe sediment
- Pipe water
- Railroad ballast
- Core
- Soil boring
- Sediment
- Surface soil
- Sump sediment
- Sump water
- Surface water
- boreholes4av
- RIR Addendum Monitoring Wells
- RIR Addendum Temporary Well Points
- 2009 Borehole
- Phase III Borehole
- National Grid Boundary
- EU boundary
- Structure abandoned above grade
- Existing structure
- Former structure
- Former K-65 Transfer Pipeline
- Acid sewer
- Water lines
- Fuel line
- Sanitary sewer
- Storm sewer
- WCS Cutoff Wall
- Roads
- Surface Water (inundated 50% of year)
- Ephemeral Ditch
- West_Ditch
- Excavation 91
- Former Railroad

Y:/NFSS/BU3/TO_01/Contaminant_Transport_Modelling/
Sample_Locs.mxd
Revised: 03/07/11 PD
Source: URS

HGL HydroGeoLogic, Inc

US Army Corps of Engineers® Buffalo District
BUILDING STRONG®

U.S. Army Corps of Engineers - Buffalo District

HGL—Final Updated Model Results—Niagara Falls Storage Site, Lewiston, New York

Y:\NFSS\BU3\TO_01\
Contaminant_Transport_Modelling\
Upper_Clay_Till_Unit.cdr
Revised: 03/07/11 PD
Source:

HGL

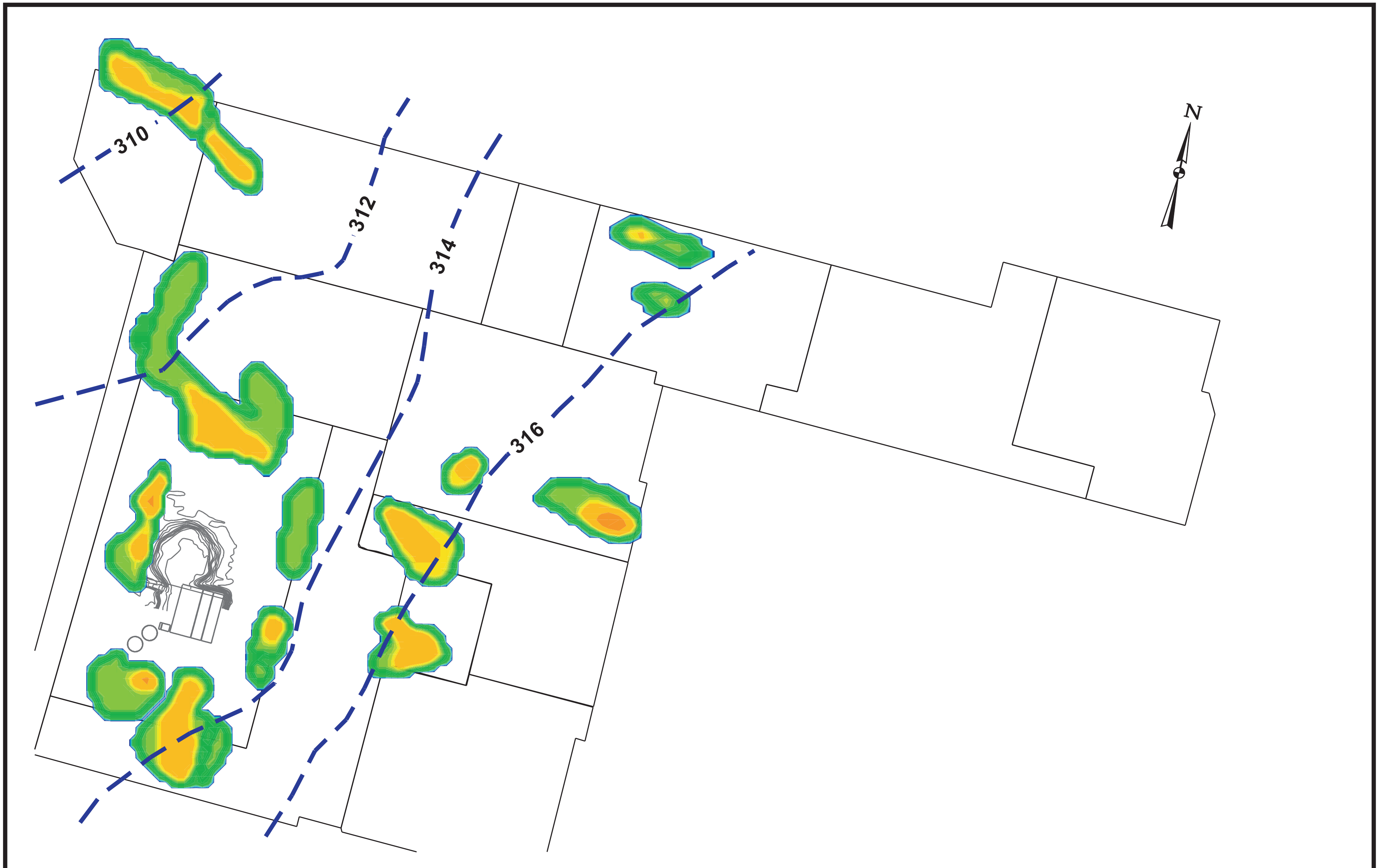
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

- $K_x = 2.8 \times 10^{-1}$ ft/day
- $K_x = 9.0 \times 10^{-4}$ ft/day
- $K_x = 2.845 \times 10^{0}$ ft/day
- $K_x = 8.213 \times 10^{-3}$ ft/day
- $K_x = 9.0 \times 10^{-2}$ ft/day
- $K_x = 1.417 \times 10^{2}$ ft/day (Sand Lens)

$K_z = K_x / 10$ throughout

Figure 3.2
Hydraulic Conductivity of the Brown Clay Till Unit



U.S. Army Corps of Engineers - Buffalo District

HGL—Final Updated Model Results—Niagara Falls Storage Site, Lewiston, New York

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Source:

HGL

US Army Corps of Engineers® Buffalo District BUILDING STRONG®

Legend

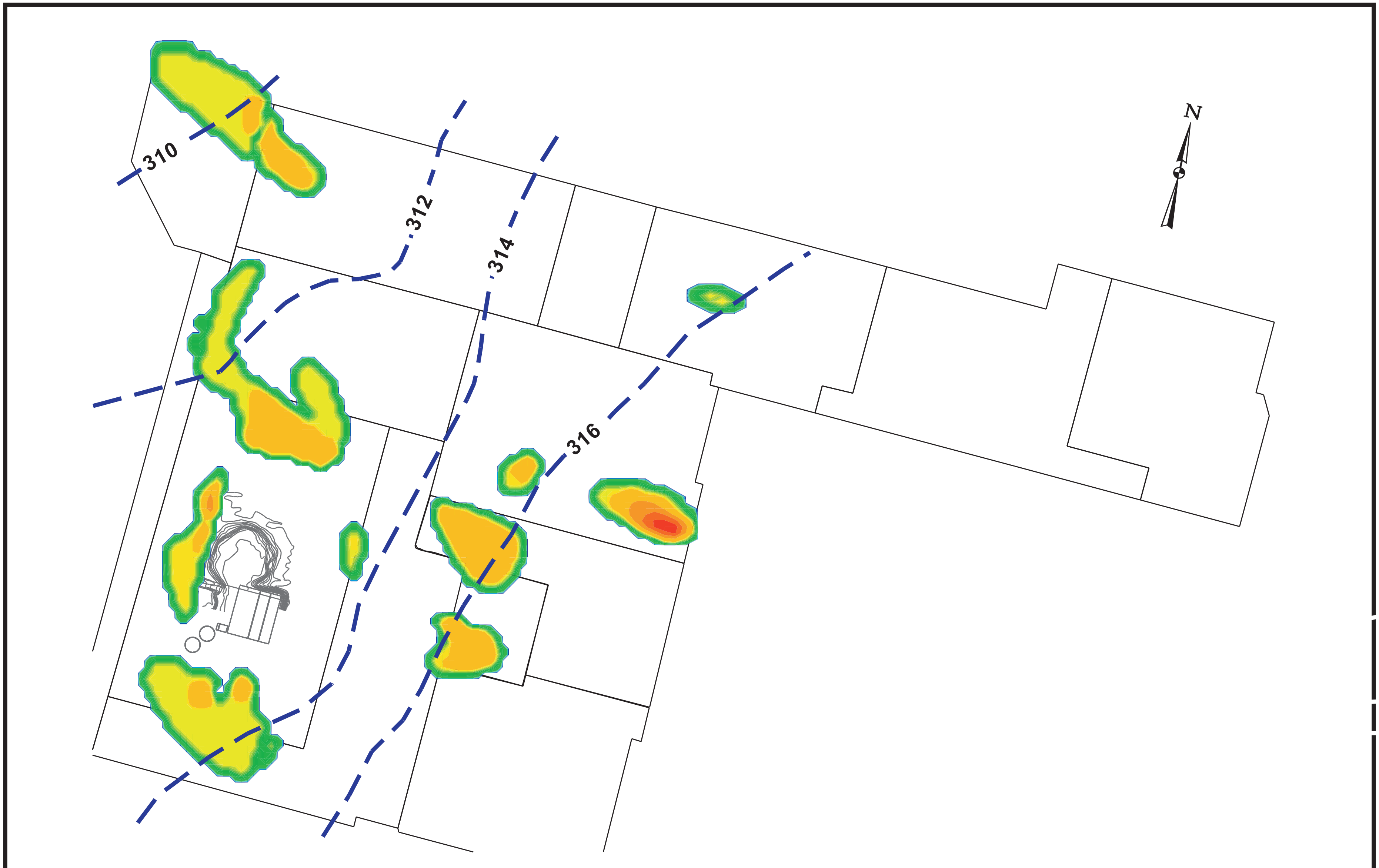
Simulated Hydraulic Head (approx.) (ft, NAD27)

0.1 0.5 1 5 10 50

U-238 screening level = 6.32 µg/L

Simulated Concentration (pCi/L)

Figure 3.3
Uranium-238
Groundwater Plume
Initial Concentrations



U.S. Army Corps of Engineers - Buffalo District

HGL—Final Updated Model Results—Niagara Falls Storage Site, Lewiston, New York

Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling
\Initial_Uranium234.cdr
Revised: 03/07/11 PD
Source:

HGL

US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

312 — Simulated Hydraulic Head (approx.) (ft, NAD27)

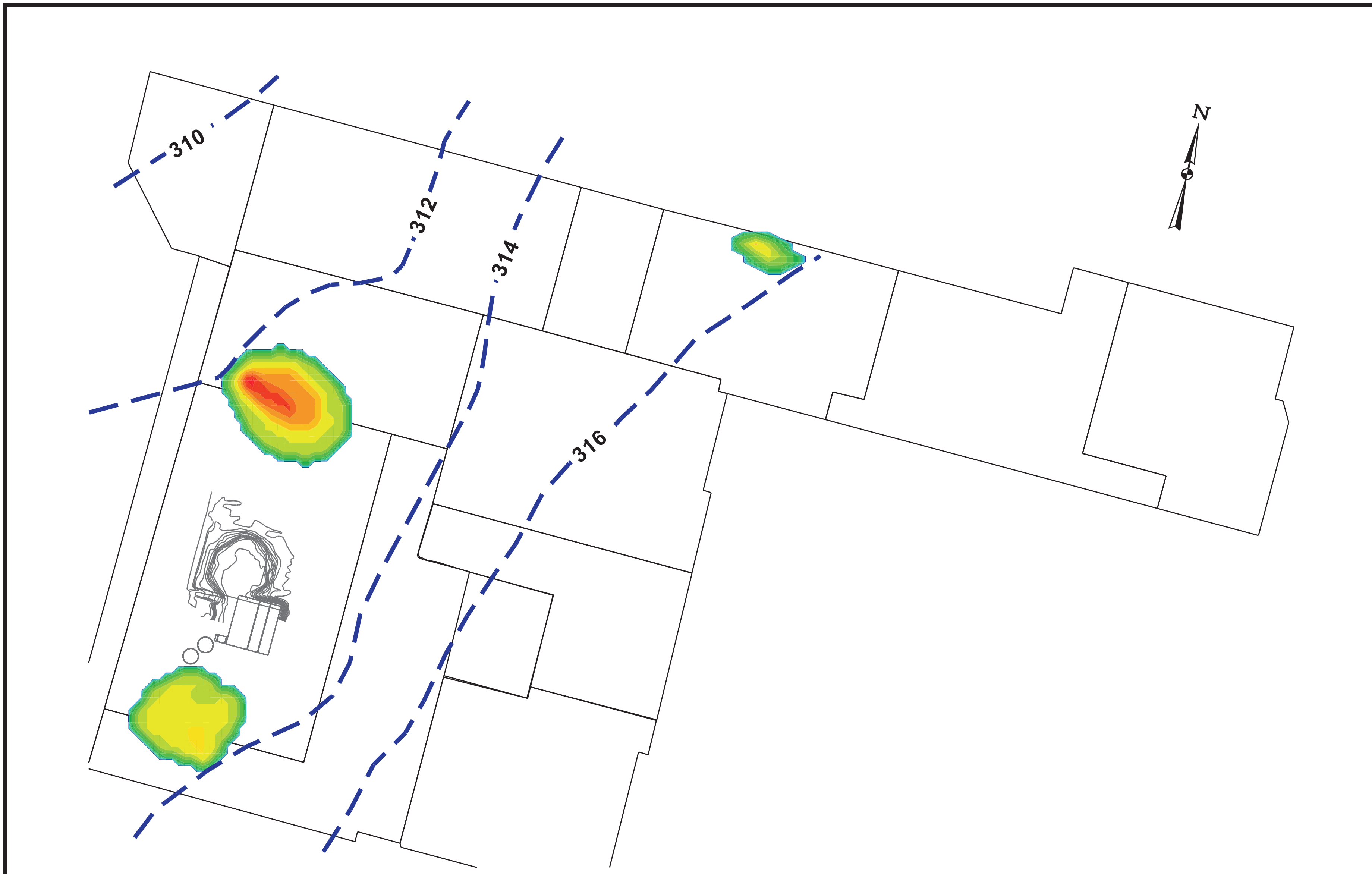
0.1 0.5 1 5 10 50

U-234 screening level = 8.94 μg/L

Simulated Concentration (pCi/L)

Figure 3.4
Uranium-234
Groundwater Plume
Initial Concentrations

U.S. Army Corps of Engineers - Buffalo District



HGL—Final Updated Model Results—Niagara Falls Storage Site, Lewiston, New York

Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling
\Initial_Thorium230.cdr
Revised: 03/07/11 PD
Source:

HGL

US Army Corps of Engineers
Buffalo District
BUILDING STRONG

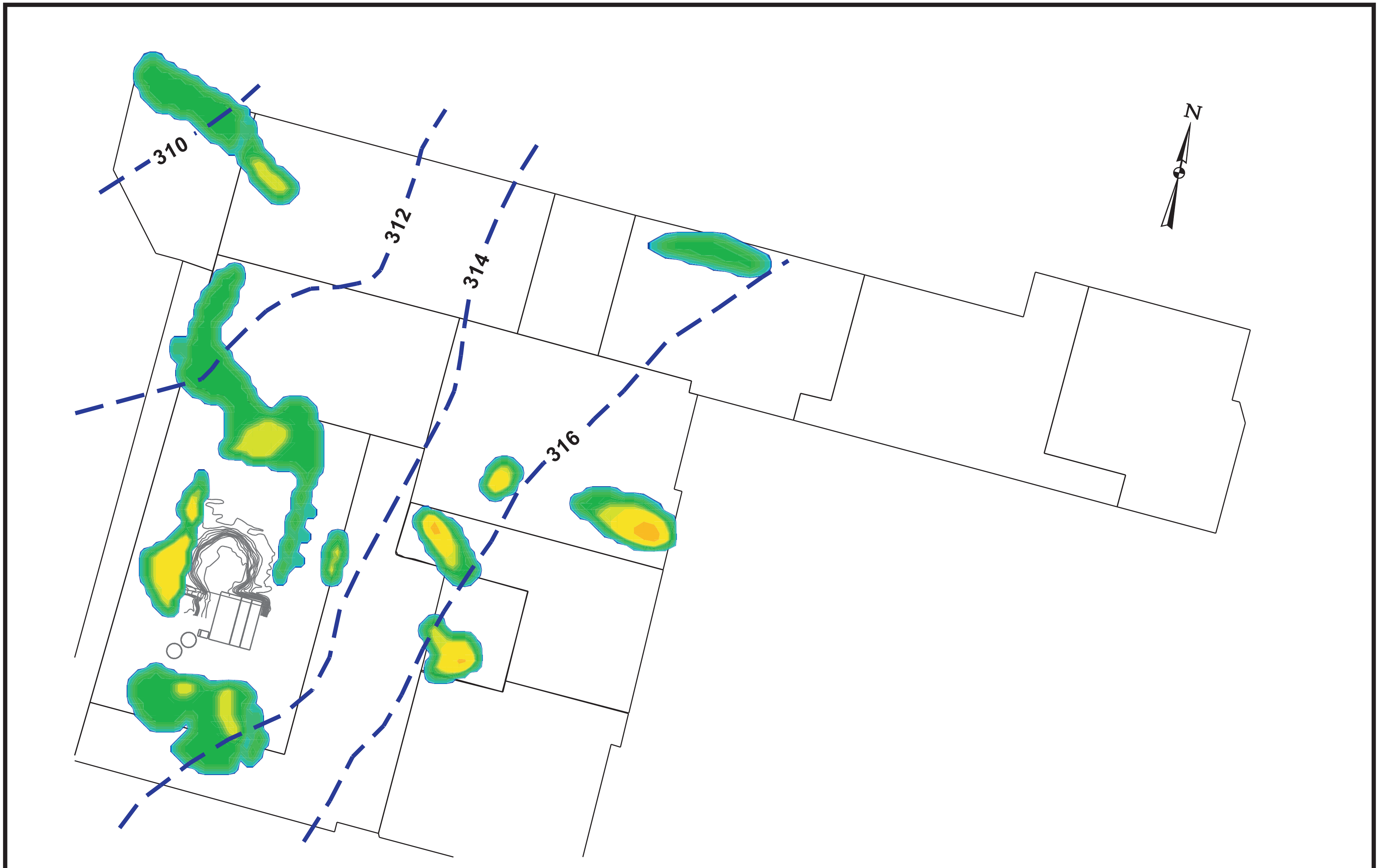
Legend

312 — Simulated Hydraulic Head (approx.) (ft, NAD27)

0.005 0.01 0.05 0.1 0.5 1 — Simulated Concentration (pCi/L)

Thorium-230 screening level = 0.39 µg/L

Figure 3.5
Thorium-230
Groundwater Plume
Initial Concentrations



Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\
\Initial_Uranium235.cdr
Revised: 03/07/11 PD
Source:

HGL

US Army Corps of Engineers
Buffalo District
BUILDING STRONG

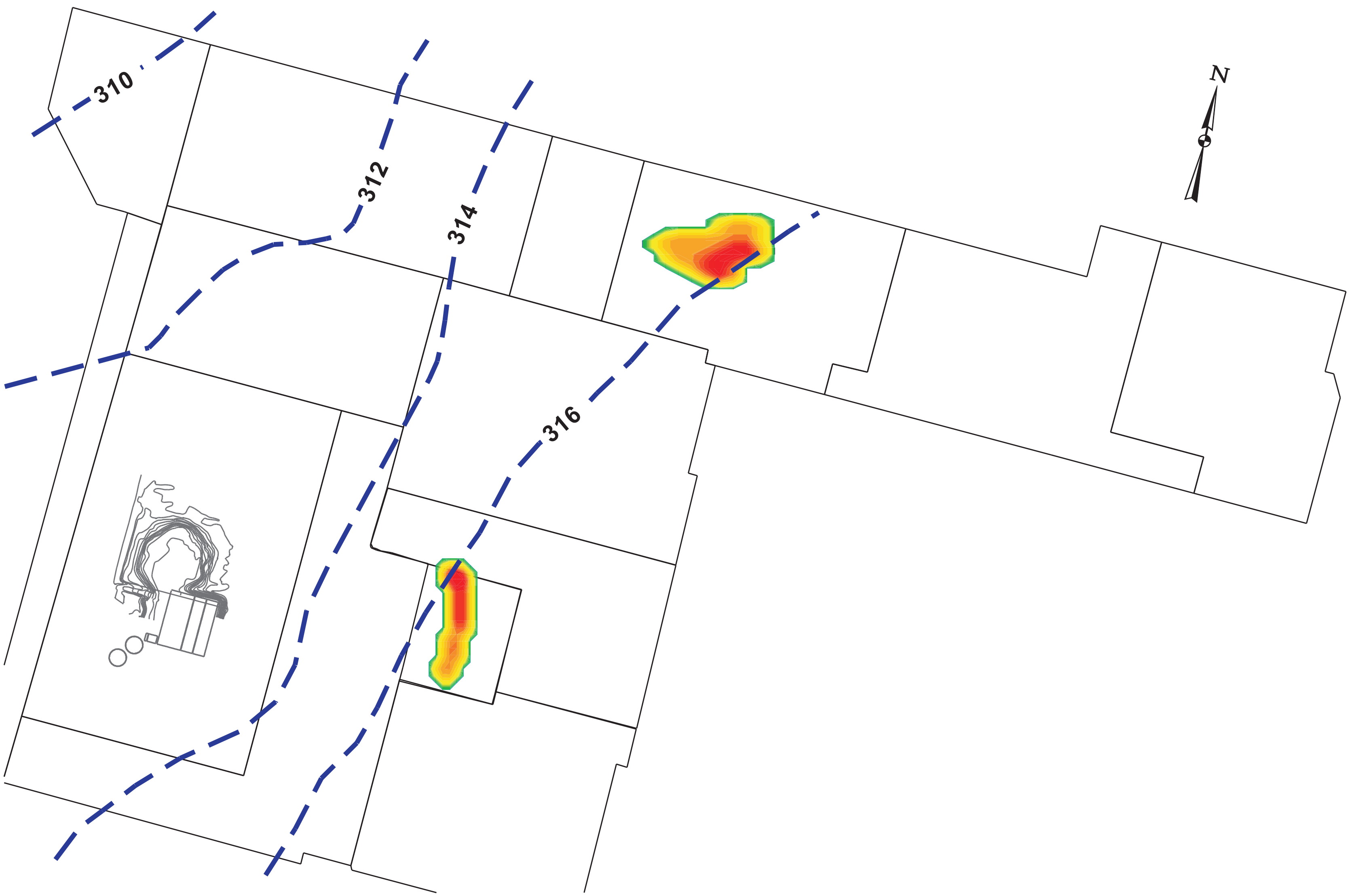
Legend

312 — Simulated Hydraulic Head (approx.) (ft, NAD27)

Simulated Concentration (pCi/L): 0.05, 0.1, 0.5, 1, 5

U-235 screening level = 0.51 µg/L

Figure 3.6
Uranium-235
Groundwater Plume
Initial Concentrations



Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\
\Initial_Boron.cdr
Revised: 03/07/11 PD
Source:

HGL
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

Simulated Hydraulic Head (approx.) (ft, NAD27)

Simulated Concentration (µg/L)

1 10 100 1000 10000

Boron screening level = 4750 µg/L

Figure 3.7
Boron
Groundwater Plume
Initial Concentrations

Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling
\Initial_Manganese.cdr
Revised: 03/07/11 PD
Source:

HGL

US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

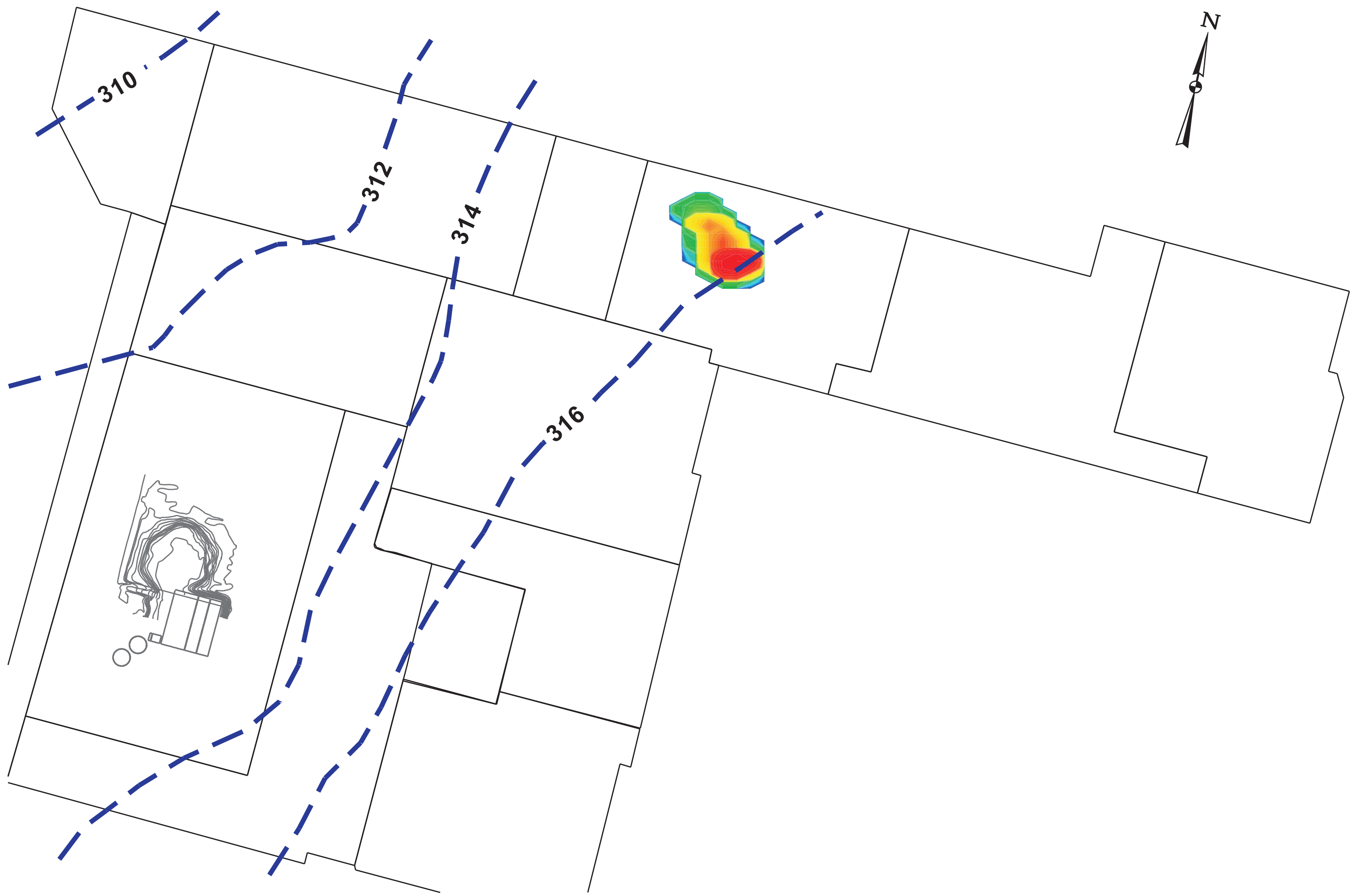
312 — Simulated Hydraulic Head (approx.) (ft, NAD27)

Simulated Concentration (µg/L)

5 10 50 100 500 1000 5000

Manganese screening level = 966 µg/L

Figure 3.8
Manganese
Groundwater Plume
Initial Concentrations



Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\
\Initial_PCE.cdr
Revised: 03/07/11 PD
Source:

HGL
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

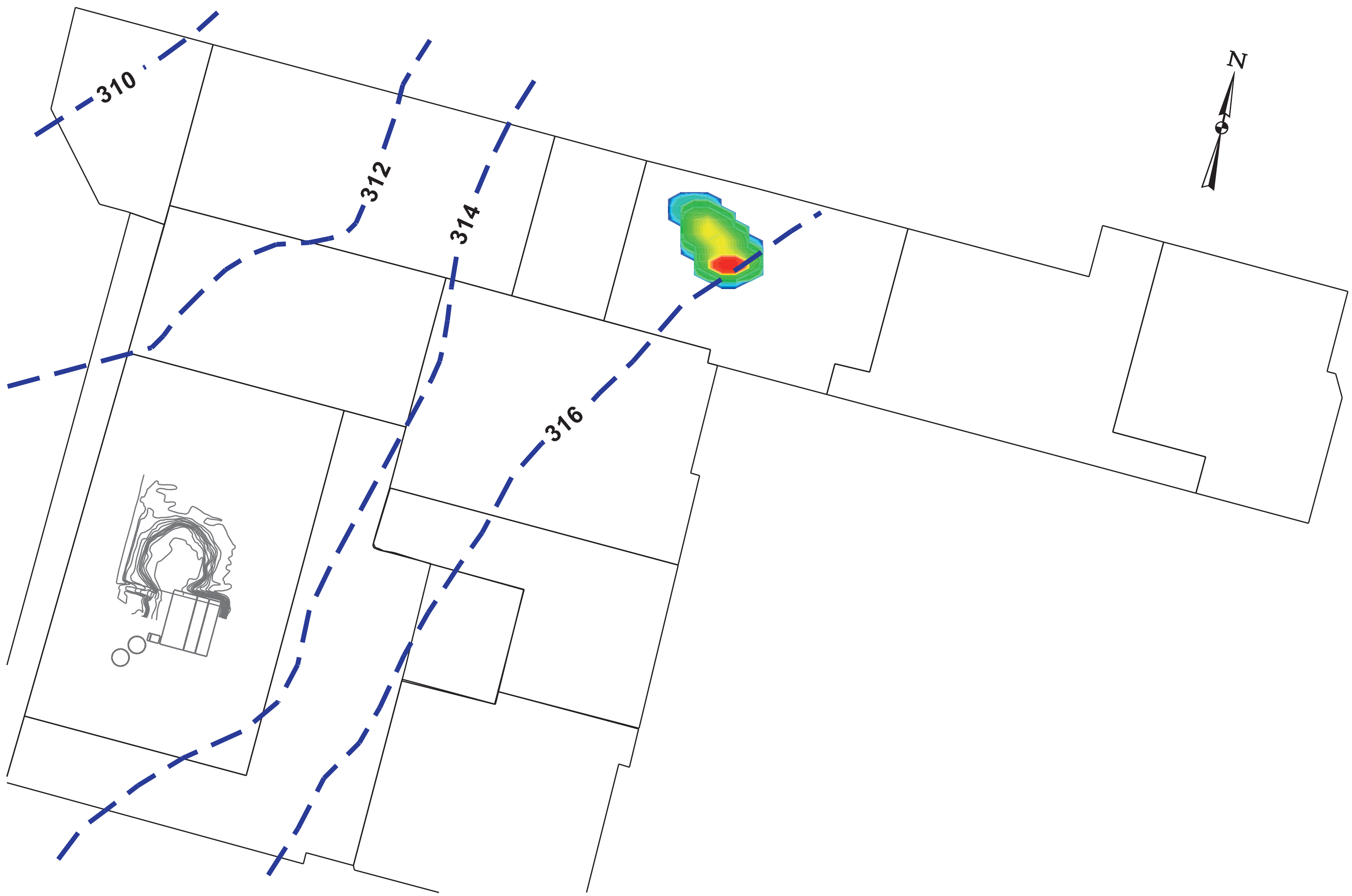
Legend

312 — Simulated Hydraulic Head (approx.) (ft, NAD27)

0.05 0.5 5 50 500 5000 50000 — Simulated Concentration (µg/L)

Tetrachloroethylene screening level = 5 µg/L

Figure 3.9
Tetrachloroethylene Groundwater Plume Initial Concentrations



Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\ \Initial_TCE.cdr
Revised: 03/07/11 PD
Source:

HGL
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

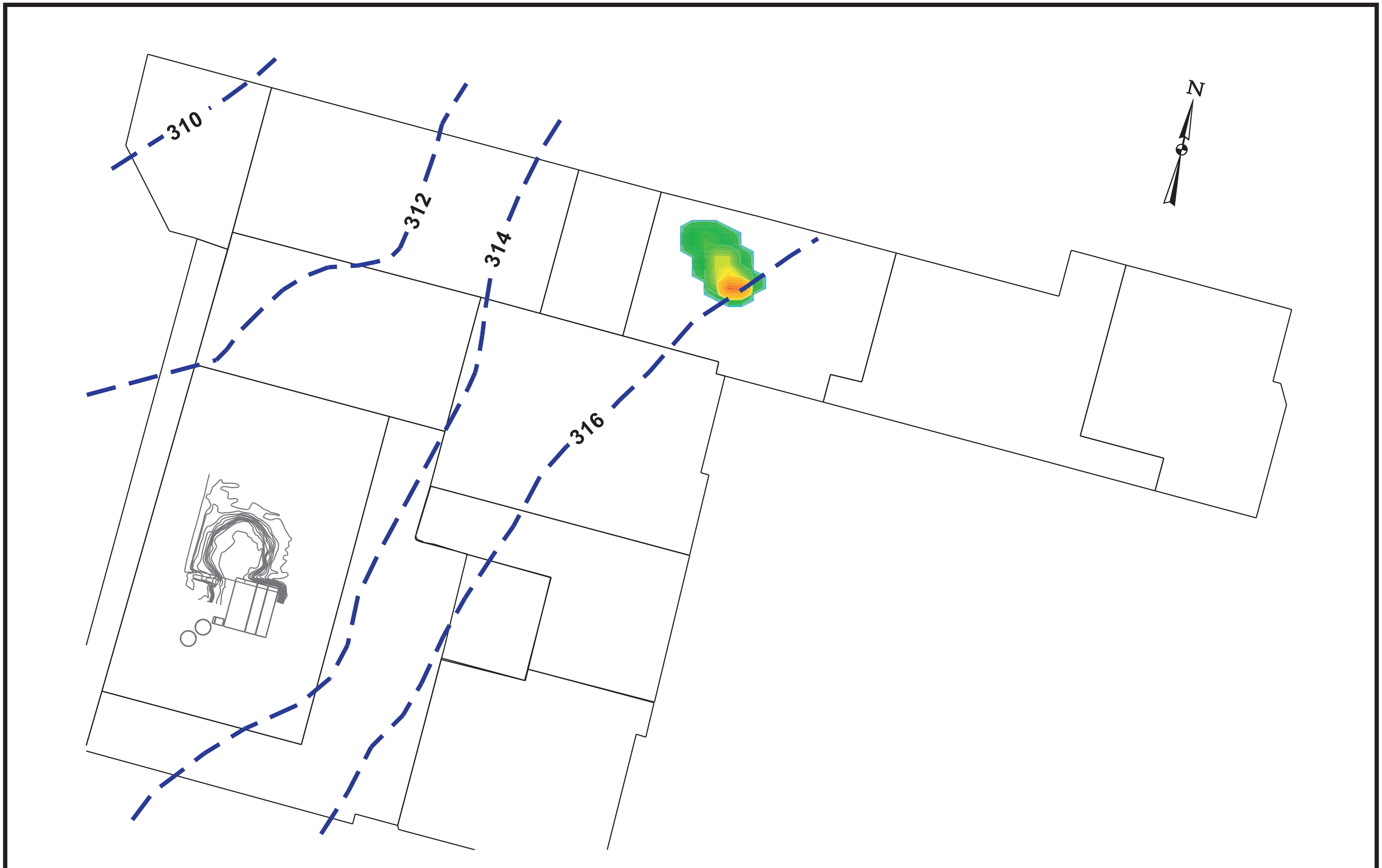
Simulated Hydraulic Head (approx.) (ft, NAD27)

Simulated Concentration (µg/L)

0.05 0.5 5 50 500 5000 50000

Trichloroethylene screening level = 5 µg/L

Figure 3.10
Trichloroethylene Groundwater Plume Initial Concentrations



Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\Initial_cis.cdr
Revised: 03/07/11 PD
Source:

HGL
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

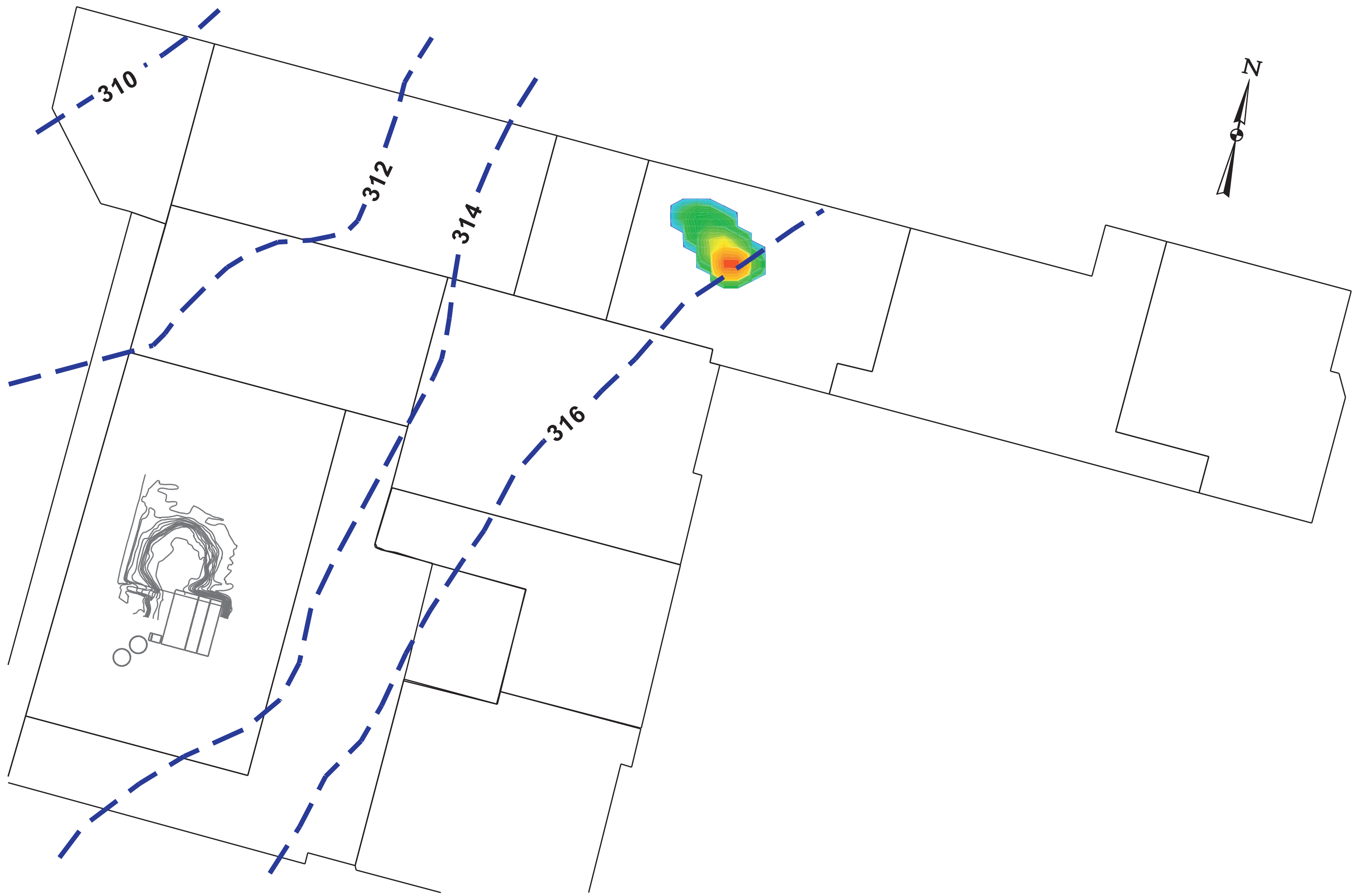
Simulated Hydraulic Head (approx.) (ft, NAD27)

Simulated Concentration (µg/L)

0.1 1 10 100 1000 10000

cis-1,2 dichloroethylene screening level =70 µg/L

Figure 3.11
cis-1,2 Dichloroethylene Groundwater Plume Initial Concentrations



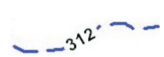
U.S. Army Corps of Engineers - Buffalo District

HGL—Final Updated Model Results—Niagara Falls Storage Site, Lewiston, New York

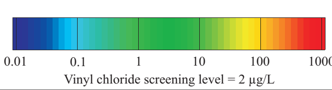
Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\ \Initial_VC.cdr
Revised: 03/07/11 PD
Source:

HGL
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

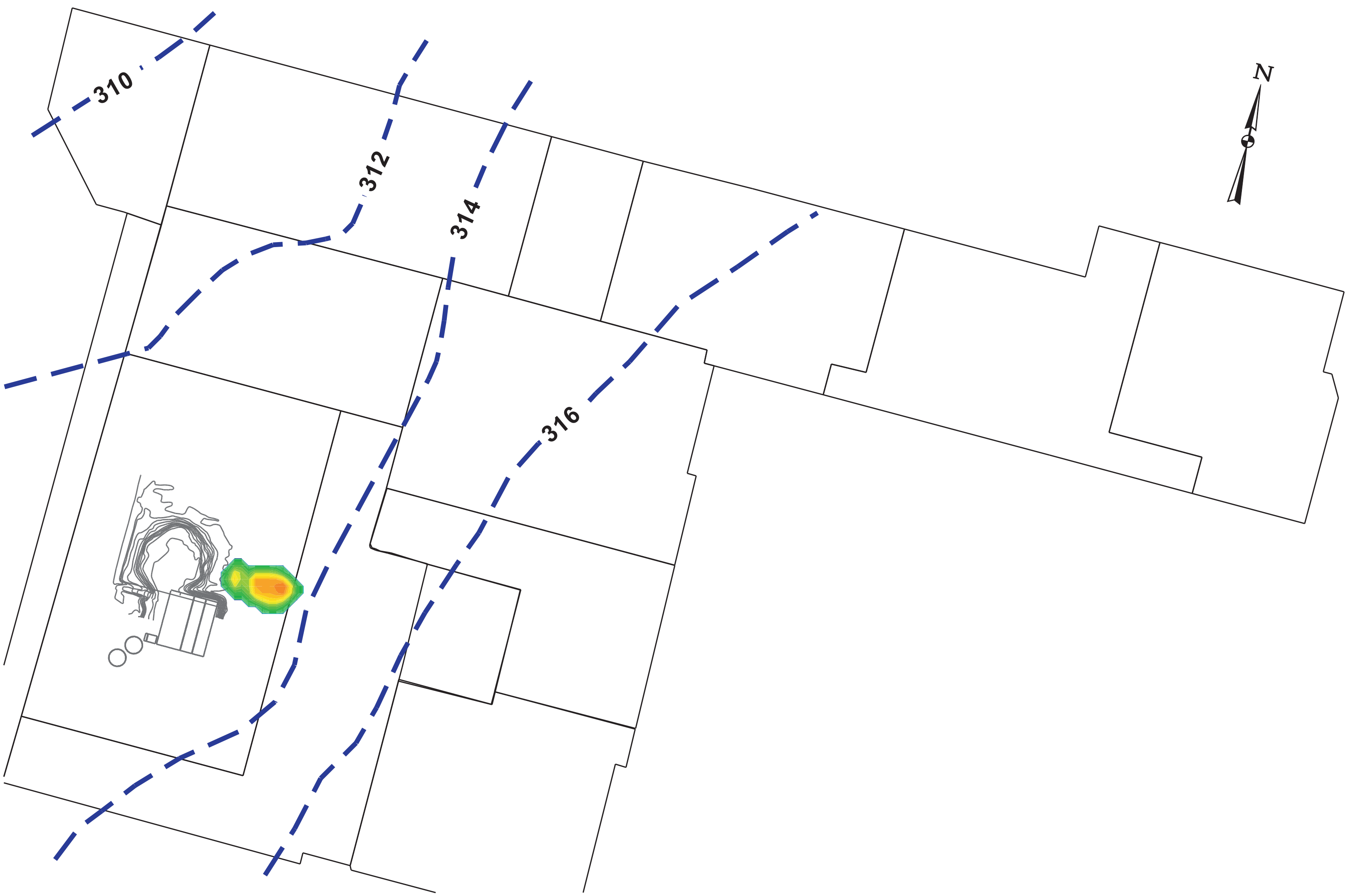


Simulated Hydraulic Head (approx.) (ft, NAD27)



Simulated Concentration (µg/L)

Figure 3.12
Vinyl Chloride Groundwater Plume Initial Concentrations



U.S. Army Corps of Engineers - Buffalo District

HGL—Final Updated Model Results—Niagara Falls Storage Site, Lewiston, New York

Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\
\Initial_BEPH.cdr
Revised: 03/07/11 PD
Source:

HGL
US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

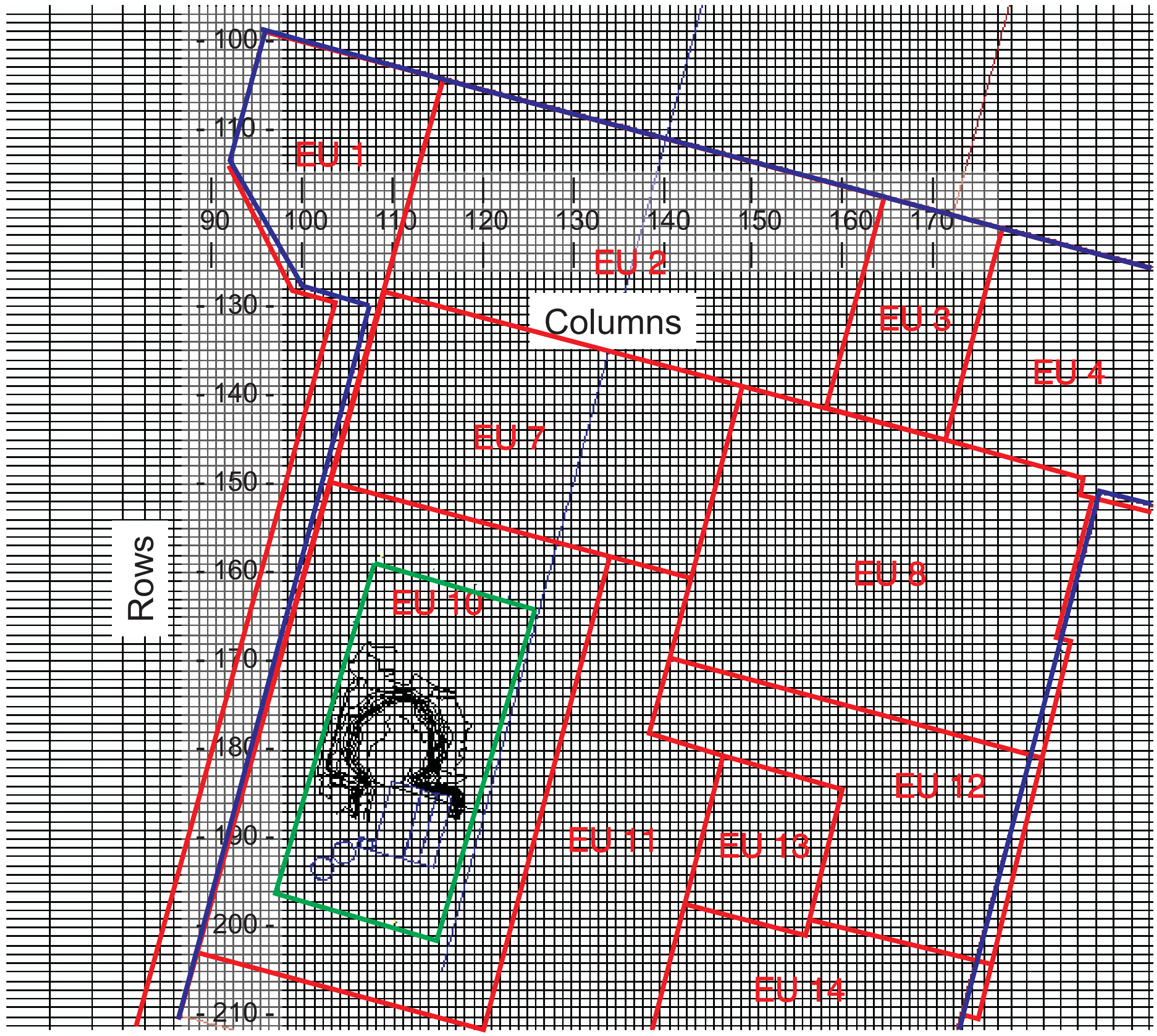
Simulated Hydraulic Head (approx.) (ft, NAD27)

Simulated Concentration (µg/L)

0.01 0.05 0.1 0.5 1 5 10 50

bis-2-ethylhexyl pthalate screening level = 6 µg/L

Figure 3.13
bis-2-ethylhexyl phtalate
Groundwater Plume
Initial Concentrations



Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling\grid.cdr
Revised: 03/07/11 PD
Source: SAIC

HGL

US Army Corps of Engineers
Buffalo District
BUILDING STRONG

Legend

- EU (Exposure Unit) Boundary
- IWCS Boundary
- Finite Difference Rows and Columns
- NFSS Property Boundary

Figure 3.14
Model Row and Column Numbering Convention

		Description	Hydrostratigraphic Unit	Numerical Model Layer
Fill			Upper Water-Bearing Zone Elevation Range (Feet above MSL): 329 to 278	1
UCT (BCT)		Upper Clay Till: Brown or reddish-brown clay with significant amounts of silt or sand and interspersed lenses of sand and gravel.		
GLC		Glacio-Lacustrine Clay: Homogeneous gray clay with occasional laminations of red-brown silt and minor amounts of sand and gravel.	Aquitard Elevation Range (Feet above MSL): 319 to 259	2
MST		Middle Silt Till: Gray to gray-brown silt with little sand and gravel.		
GLC		Glacio-Lacustrine Clay: Homogeneous gray clay with occasional laminations of red-brown silt and minor amounts of sand and gravel.		
ASG		Alluvial Sand and Gravel: Stratified coarse sands, non-stratified coarse silt and sand or interlayered silt, sand and clay.	Lower Water-Bearing Zone Elevation Range (Feet above MSL): 314 to 246	3
BRT		Basal Red Till: Reddish-brown silt and coarse to fine sand.		Quasi-3D Leakage Layer
QFM		Queenston Formation: Reddish-brown fissile shale.		4
			Aquitard Two	

Y:\NFSS\BU3\TO_01\Contaminant_Transport_Modelling
\hydrostratigraphy.cdr
Revised: 03/07/11 PD
Source: HydroGeoLogic, Inc., 2002

HGL

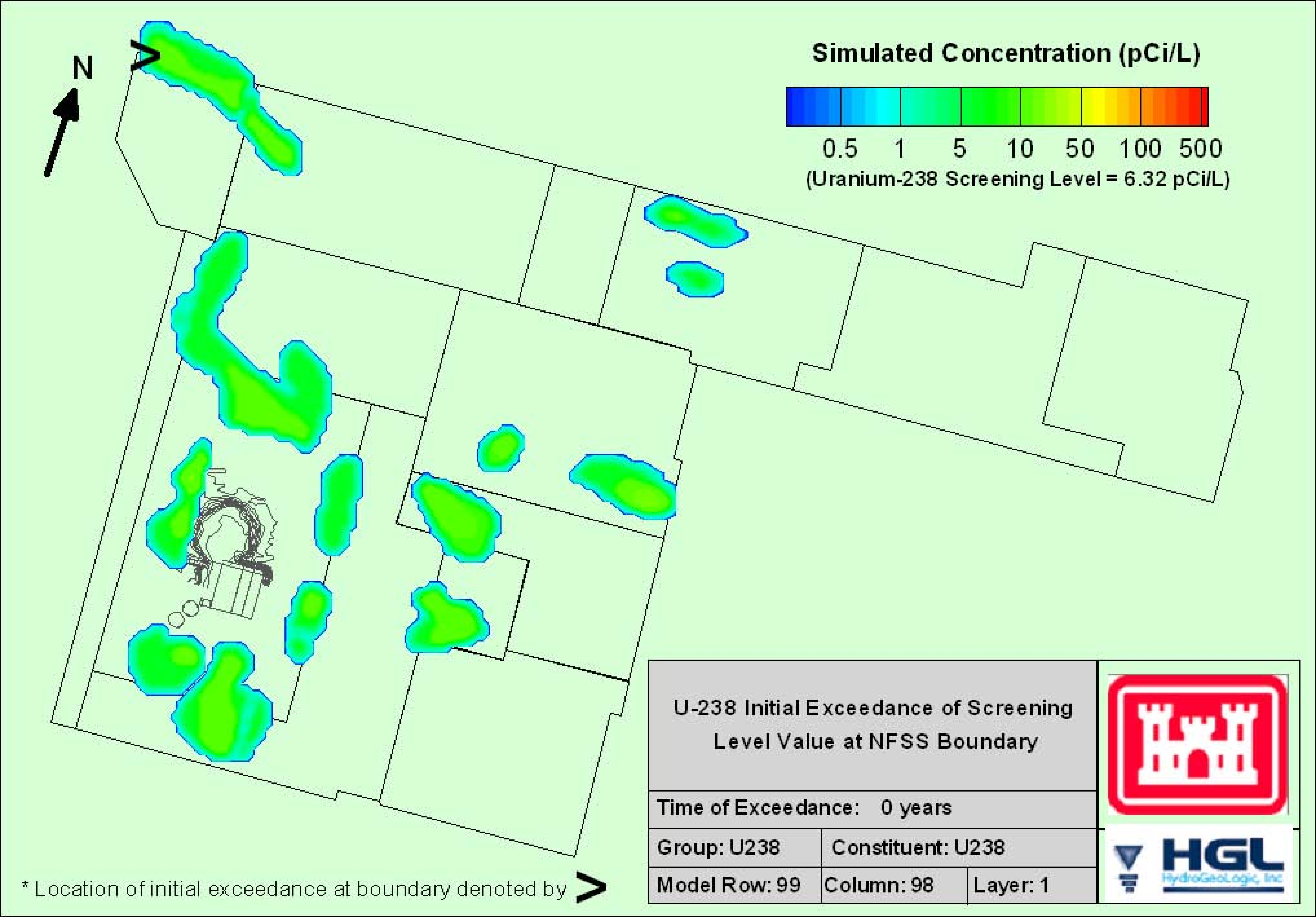
Figure 3.15
Schematic of Conceptual Hydrostratigraphic Units

APPENDIX A

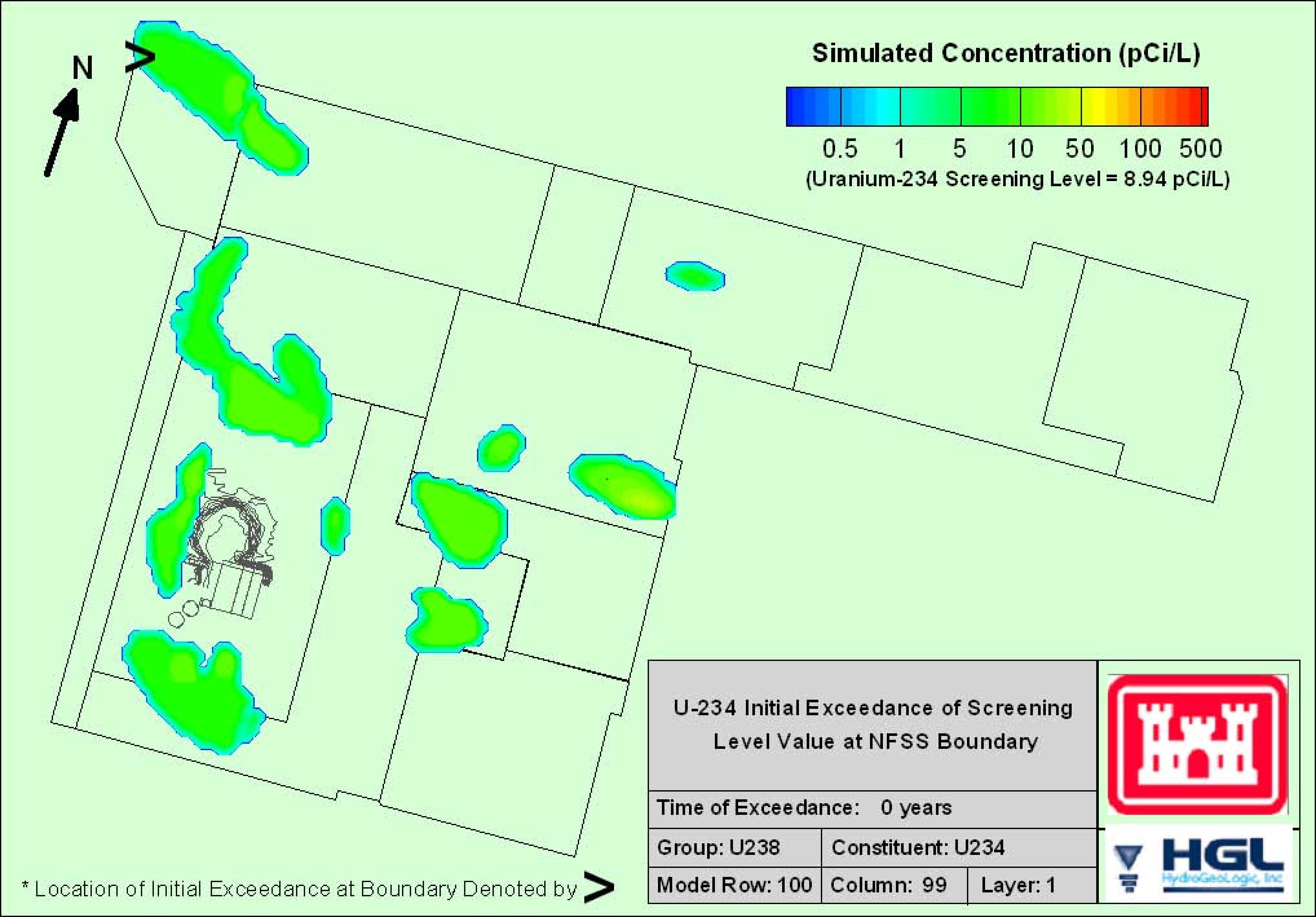
Screen Captures of Plumes at Time of Screening Level Exceedance

APPENDIX A-1

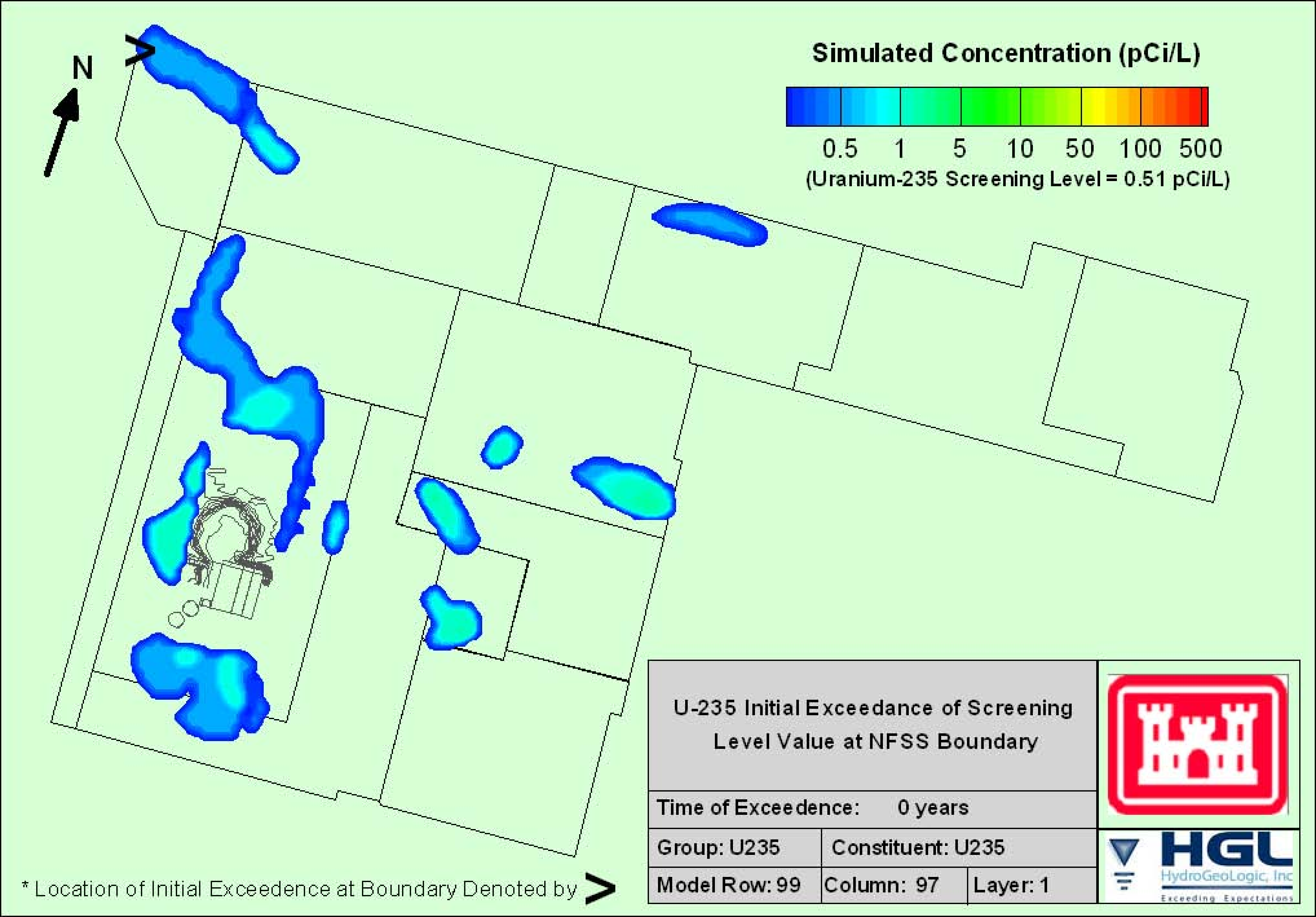
Initial Exceedance of Screening Level Values at NFSS Boundary



N
Simulated Concentration (pCi/L)
0.5
1
5
10
50
100
500
(Uranium-238 Screening Level = 6.32 pCi/L)
U-238 Initial Exceedance of Screening Level Value at NFSS Boundary
Time of Exceedance: 0 years
Group: U238
Constituent: U238
Model Row: 99
Column: 98
Layer: 1
HGL
* Location of initial exceedance at boundary denoted by >



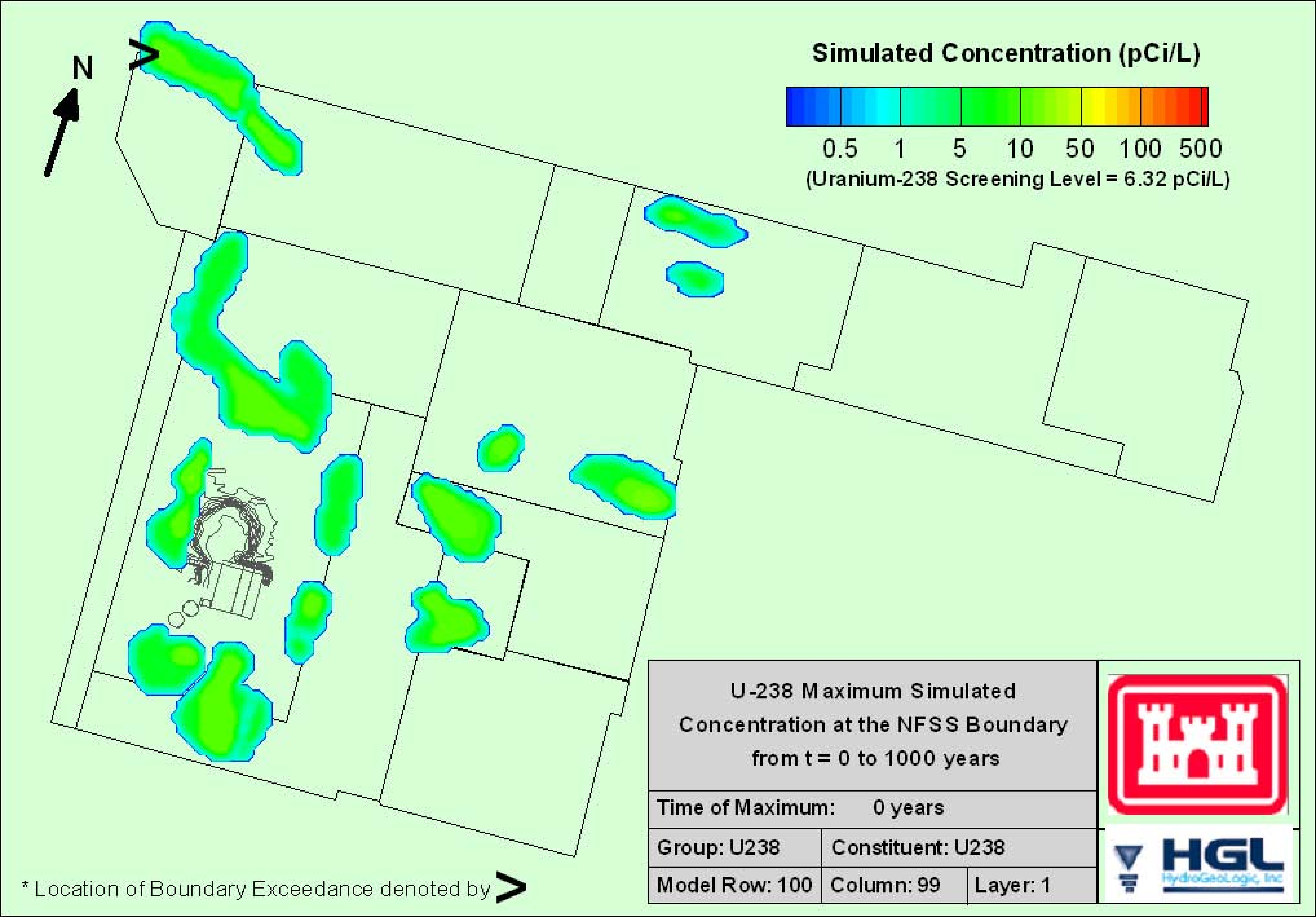
N
Simulated Concentration (pCi/L)
0.5 1 5 10 50 100 500
(Uranium-234 Screening Level = 8.94 pCi/L)
U-234 Initial Exceedance of Screening Level Value at NFSS Boundary
Time of Exceedance: 0 years
Group: U238
Constituent: U234
Model Row: 100
Column: 99
Layer: 1
HGL
HydroGeoLogic, Inc
* Location of Initial Exceedance at Boundary Denoted by >



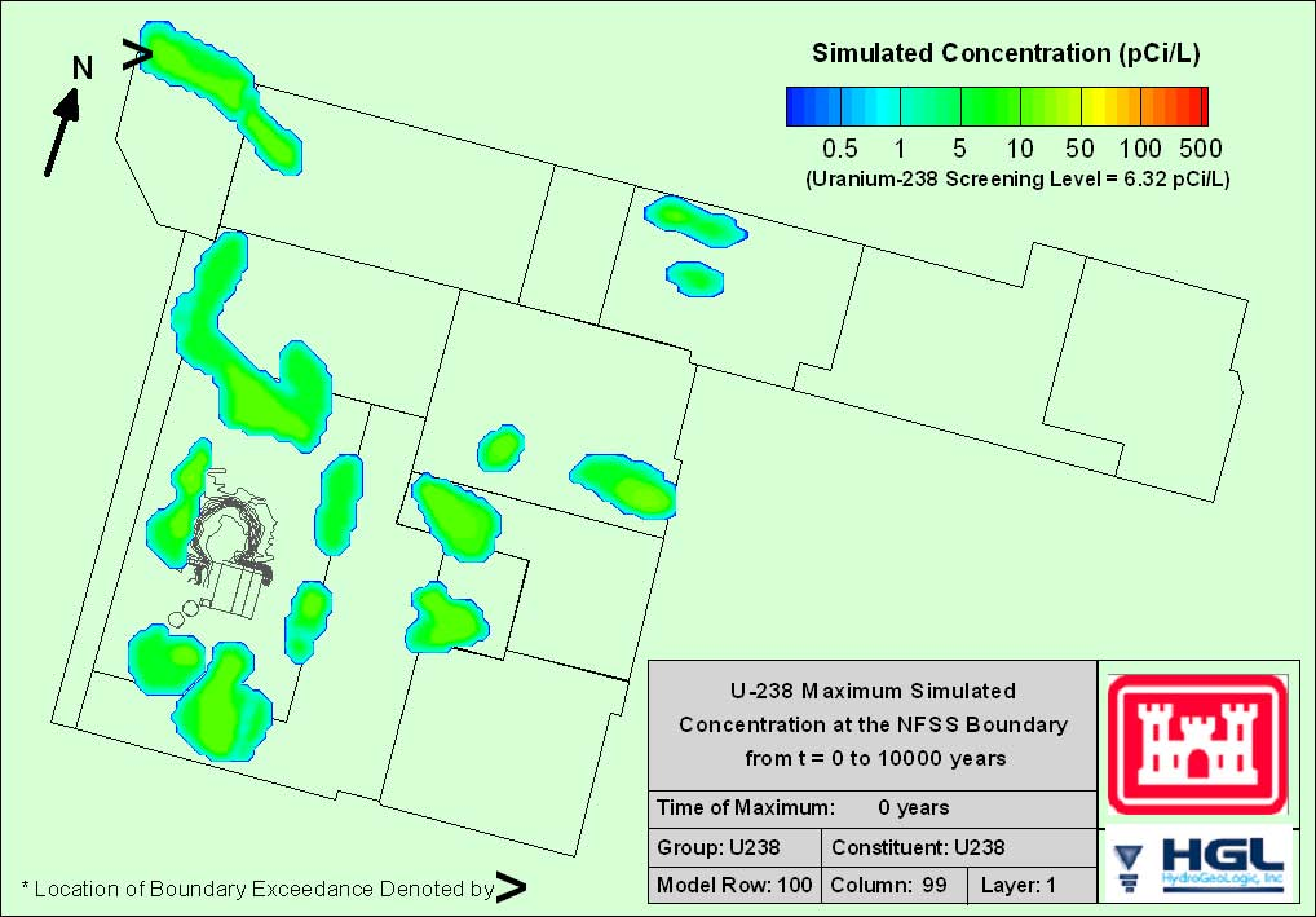
N
Simulated Concentration (pCi/L)
0.5
1
5
10
50
100
500
(Uranium-235 Screening Level = 0.51 pCi/L)
U-235 Initial Exceedance of Screening Level Value at NFSS Boundary
Time of Exceedence: 0 years
Group: U235
Constituent: U235
Model Row: 99
Column: 97
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Initial Exceedence at Boundary Denoted by >

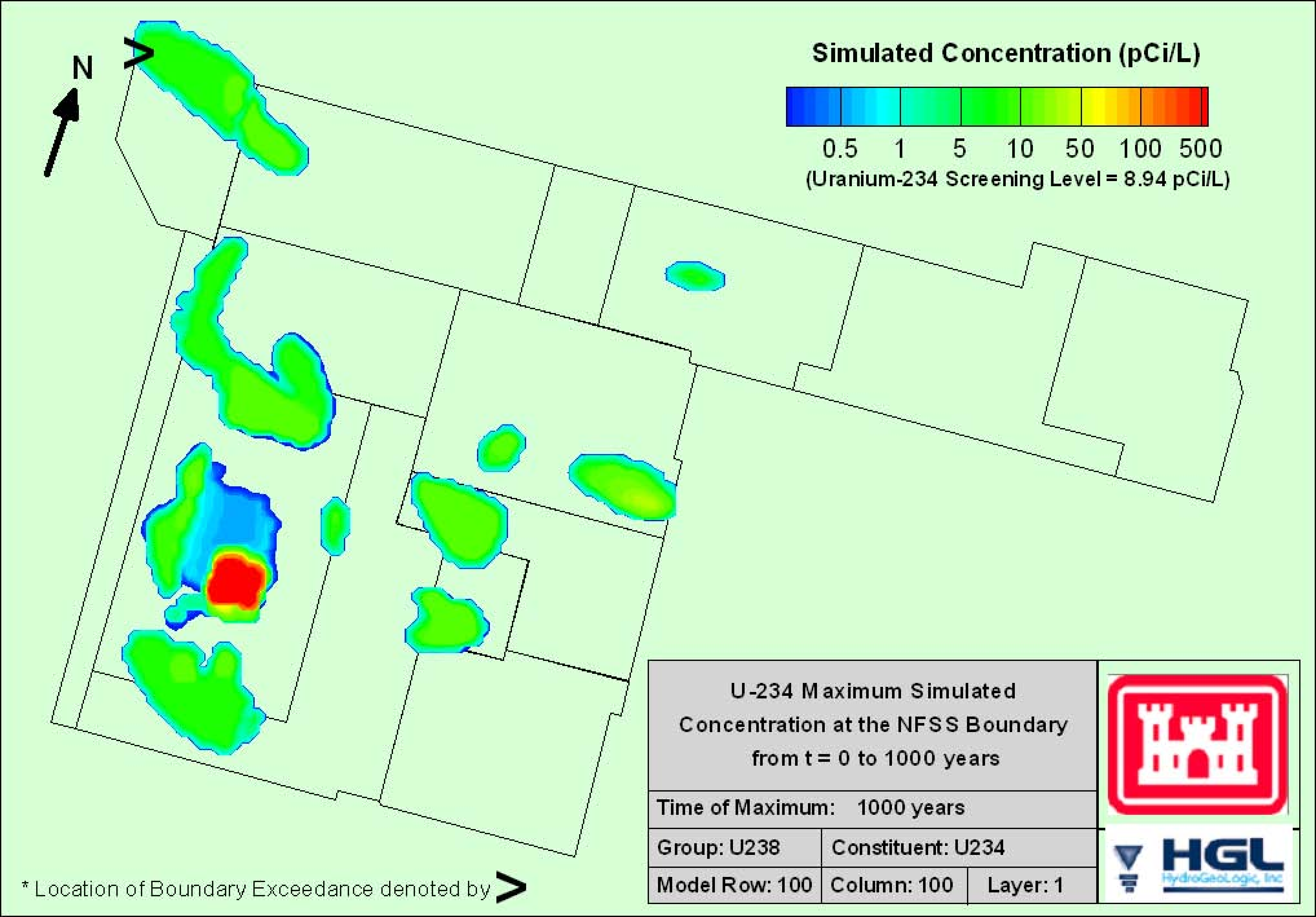
APPENDIX A-2

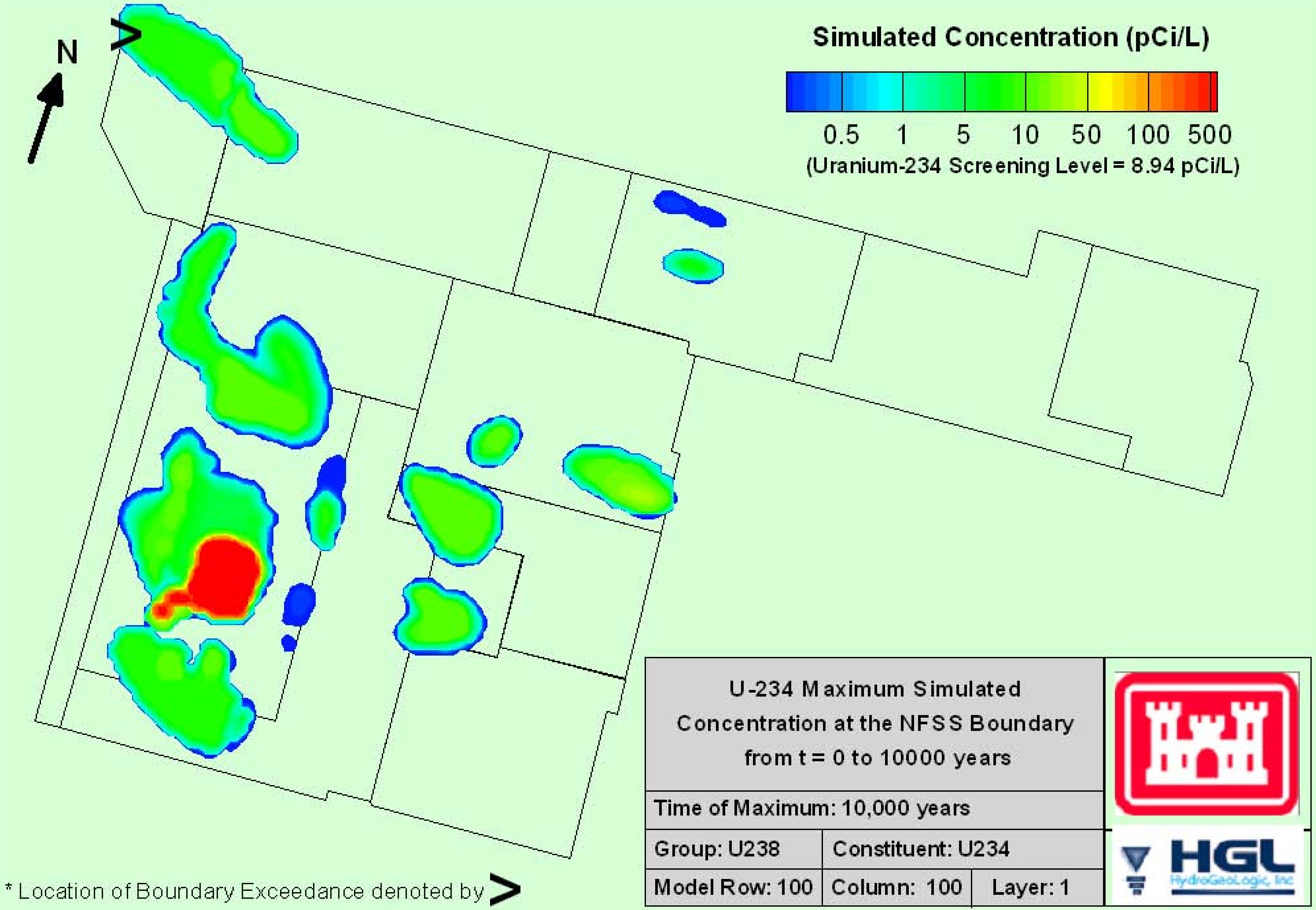
Maximum Simulated Concentrations at NFSS Boundary from t=0 to 1000 years



N
Simulated Concentration (pCi/L)
0.5 1 5 10 50 100 500
(Uranium-238 Screening Level = 6.32 pCi/L)
U-238 Maximum Simulated Concentration at the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 0 years
Group: U238
Constituent: U238
Model Row: 100
Column: 99
Layer: 1
HGL
HydroGeoLogic, Inc
* Location of Boundary Exceedance denoted by >

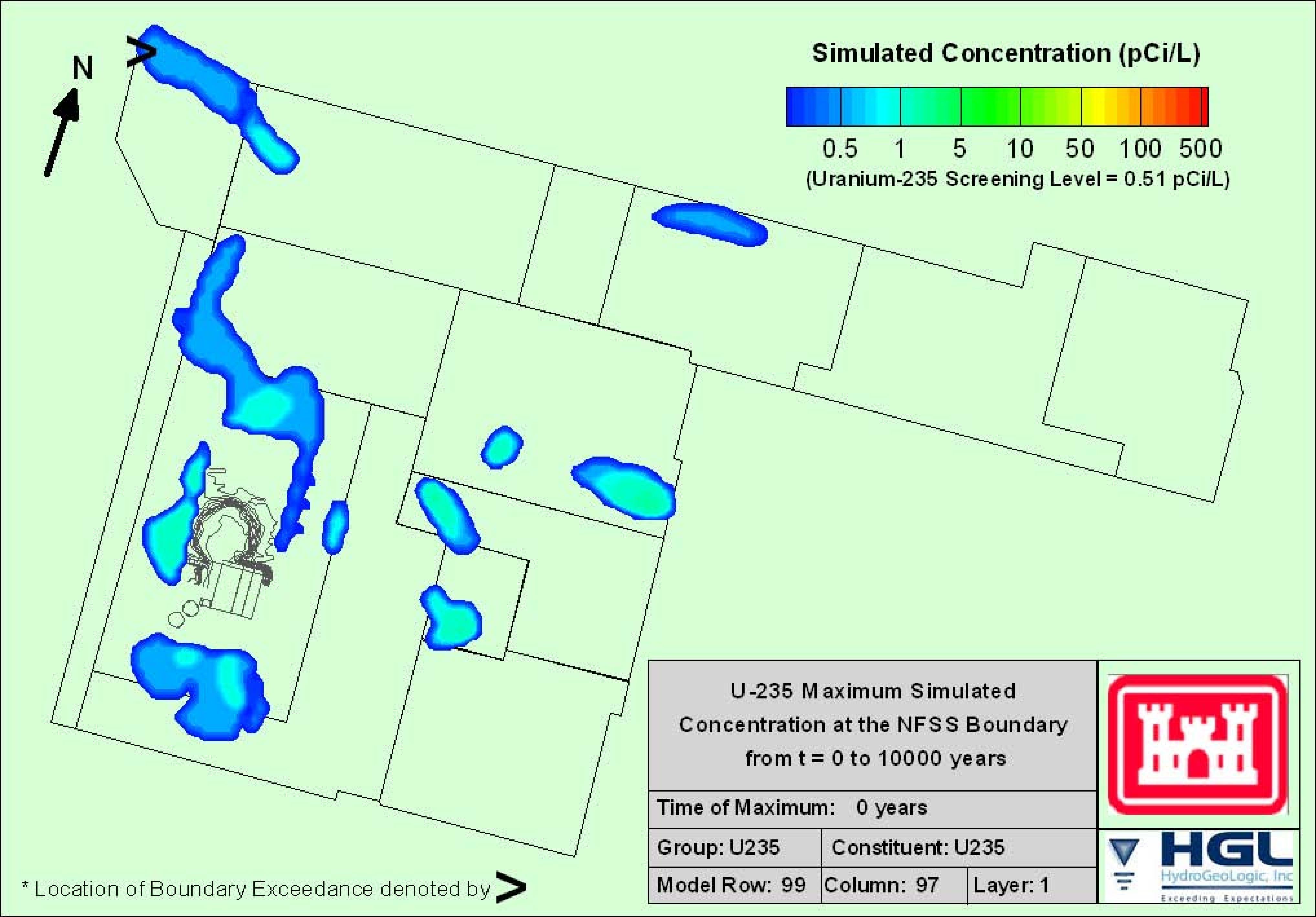

Simulated Concentration (pCi/L)
0.5
1
5
10
50
100
500
(Uranium-238 Screening Level = 6.32 pCi/L)
N
U-238 Maximum Simulated Concentration at the NFSS Boundary from t = 0 to 10000 years
Time of Maximum: 0 years
Group: U238
Constituent: U238
Model Row: 100
Column: 99
Layer: 1
HGL
* Location of Boundary Exceedance Denoted by >


N
Simulated Concentration (pCi/L)
0.5 1 5 10 50 100 500
(Uranium-234 Screening Level = 8.94 pCi/L)
U-234 Maximum Simulated Concentration at the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 1000 years
Group: U238
Constituent: U234
Model Row: 100
Column: 100
Layer: 1
HGL
HydroGeoLogic, Inc
* Location of Boundary Exceedance denoted by >



U-234 Maximum Simulated Concentration at the NFSS Boundary from t = 0 to 10000 years

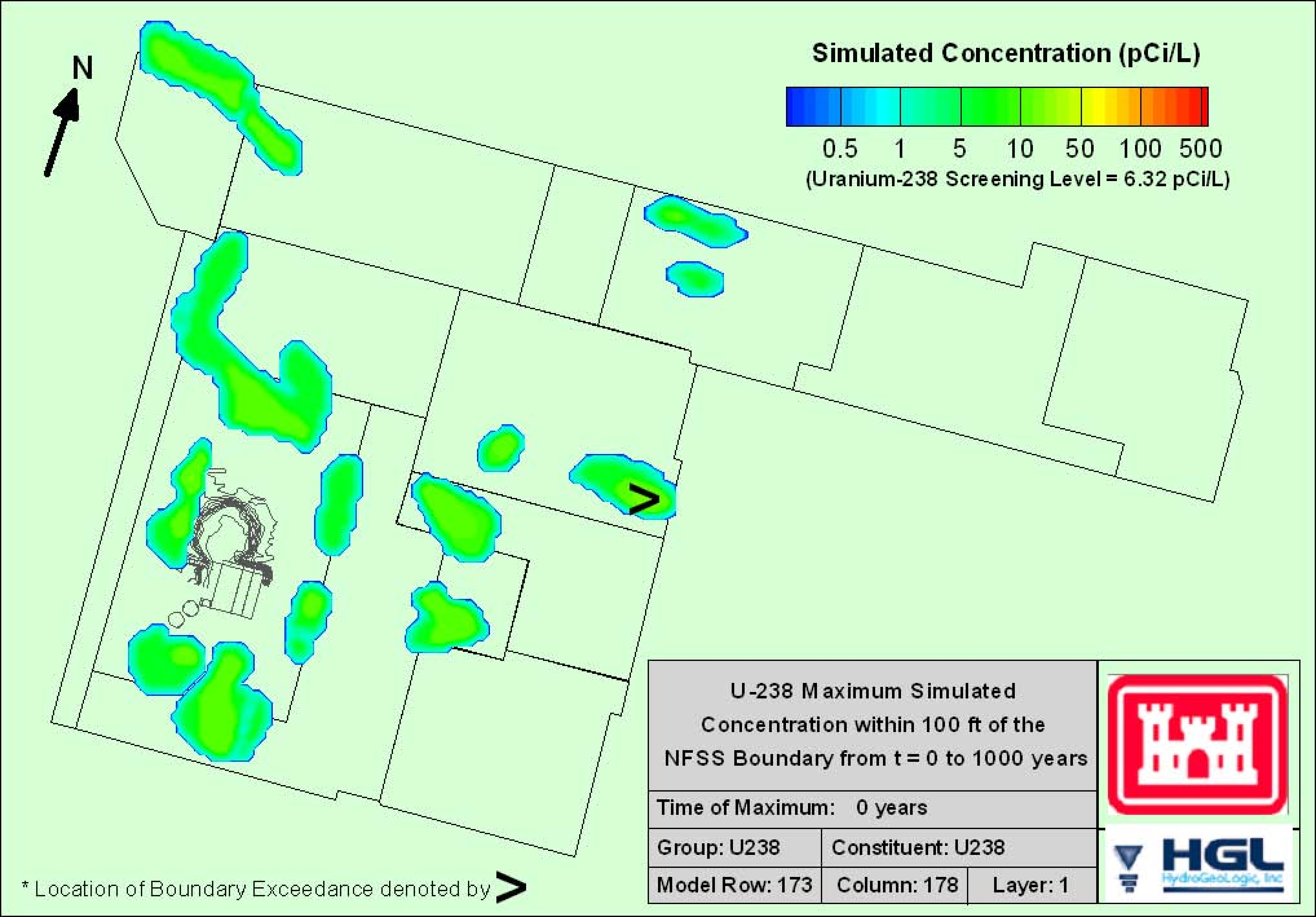
Time of Maximum: 10,000 years		
Group: U238	Constituent: U234	
Model Row: 100	Column: 100	Layer: 1

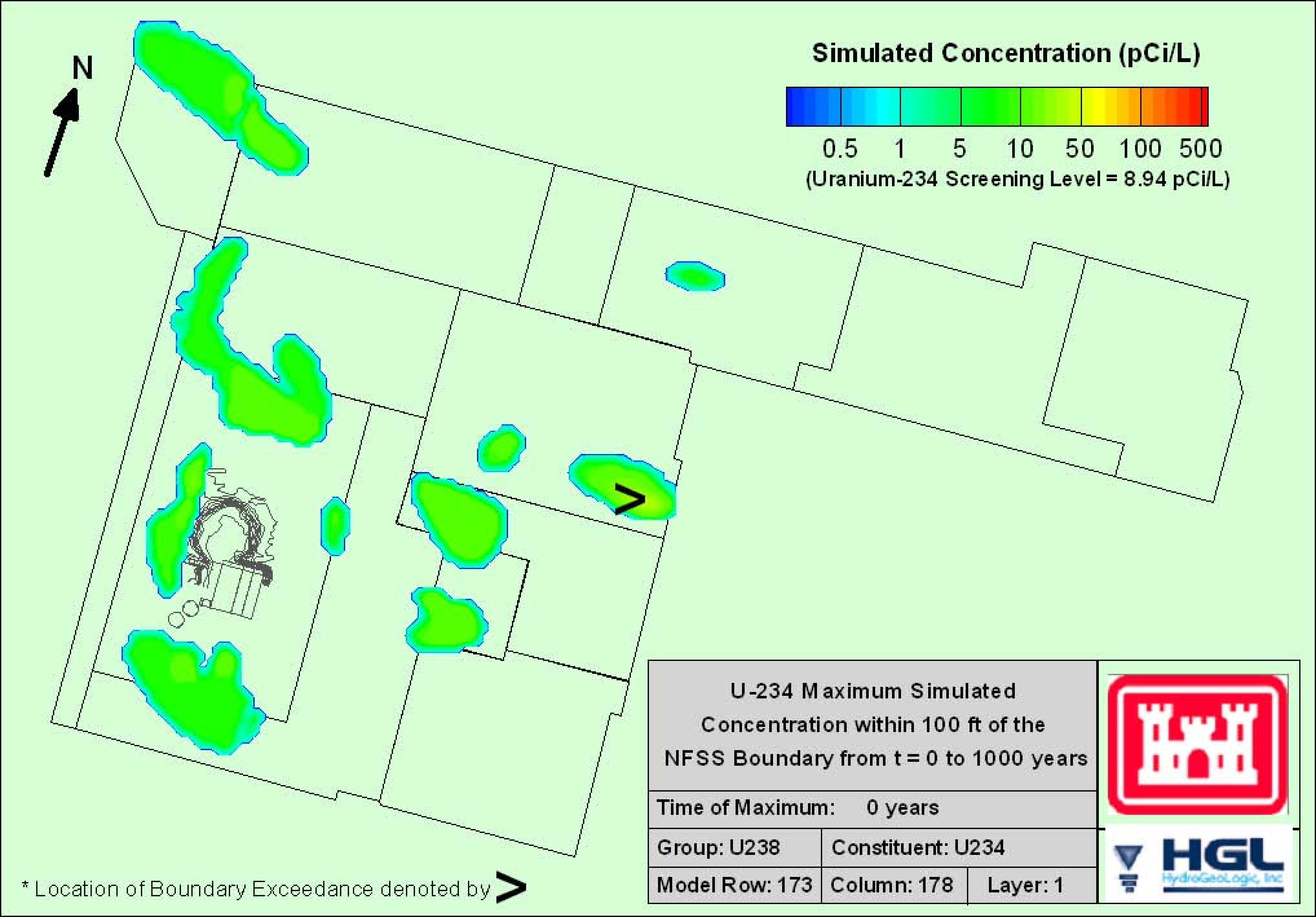


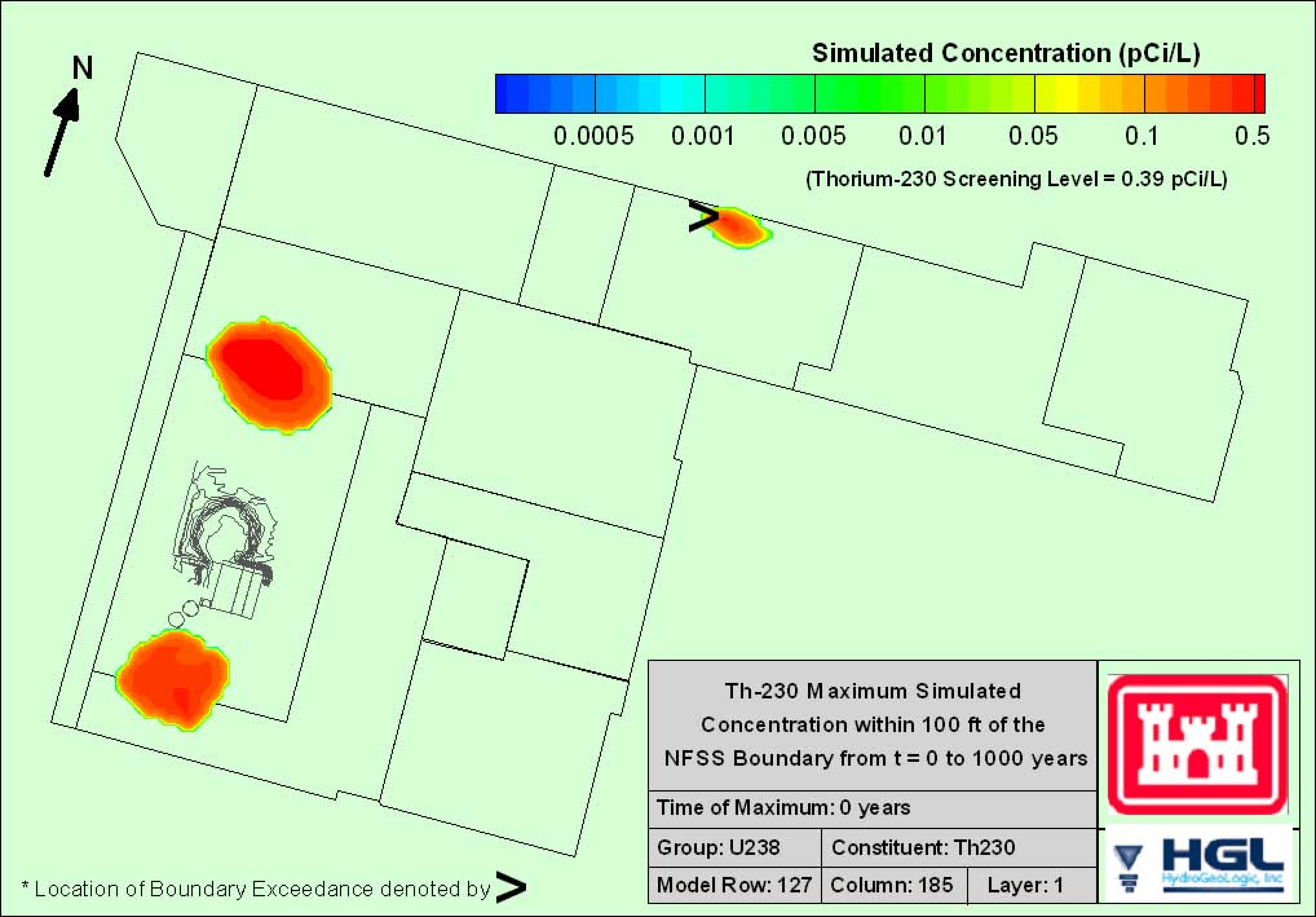
N
Simulated Concentration (pCi/L)
0.5
1
5
10
50
100
500
(Uranium-235 Screening Level = 0.51 pCi/L)
U-235 Maximum Simulated Concentration at the NFSS Boundary from t = 0 to 10000 years
Time of Maximum: 0 years
Group: U235
Constituent: U235
Model Row: 99
Column: 97
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Boundary Exceedance denoted by >

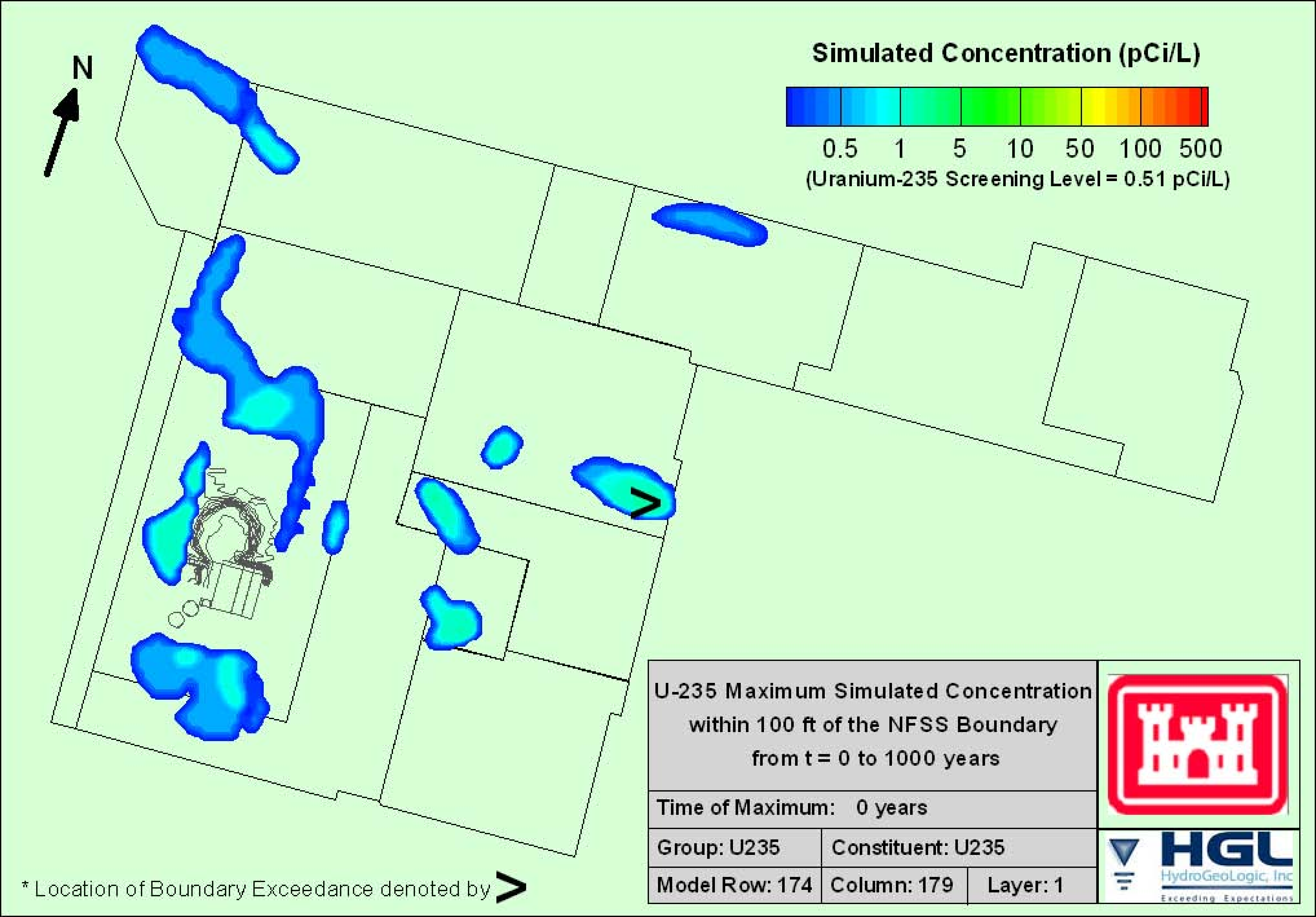
APPENDIX A-3

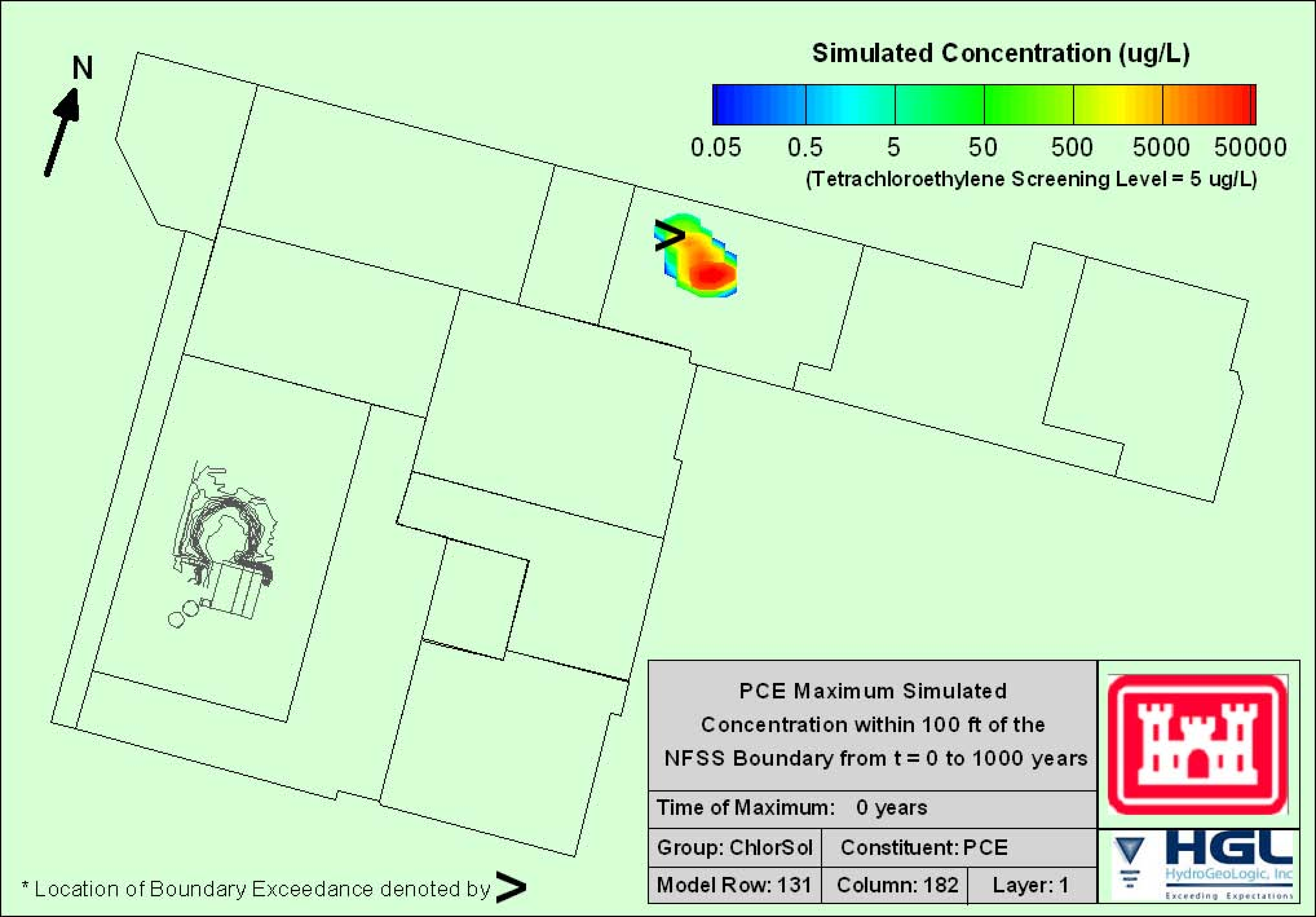
Maximum Simulated Concentrations within 100 feet of NFSS Boundary

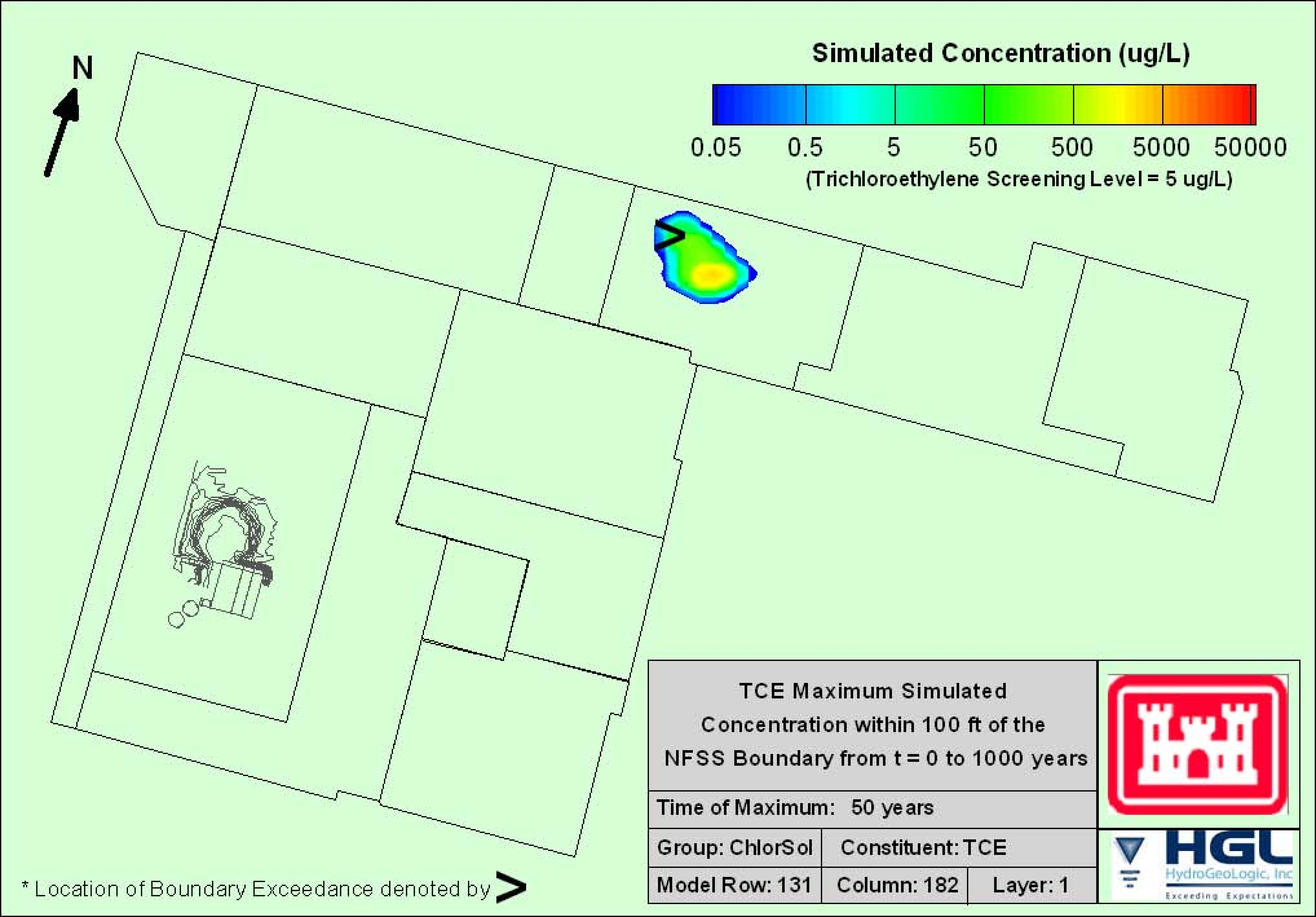

N
Simulated Concentration (pCi/L)
0.5 1 5 10 50 100 500
(Uranium-238 Screening Level = 6.32 pCi/L)
U-238 Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 0 years
Group: U238
Constituent: U238
Model Row: 173
Column: 178
Layer: 1
HGL
HydroGeoLogic, Inc
* Location of Boundary Exceedance denoted by >

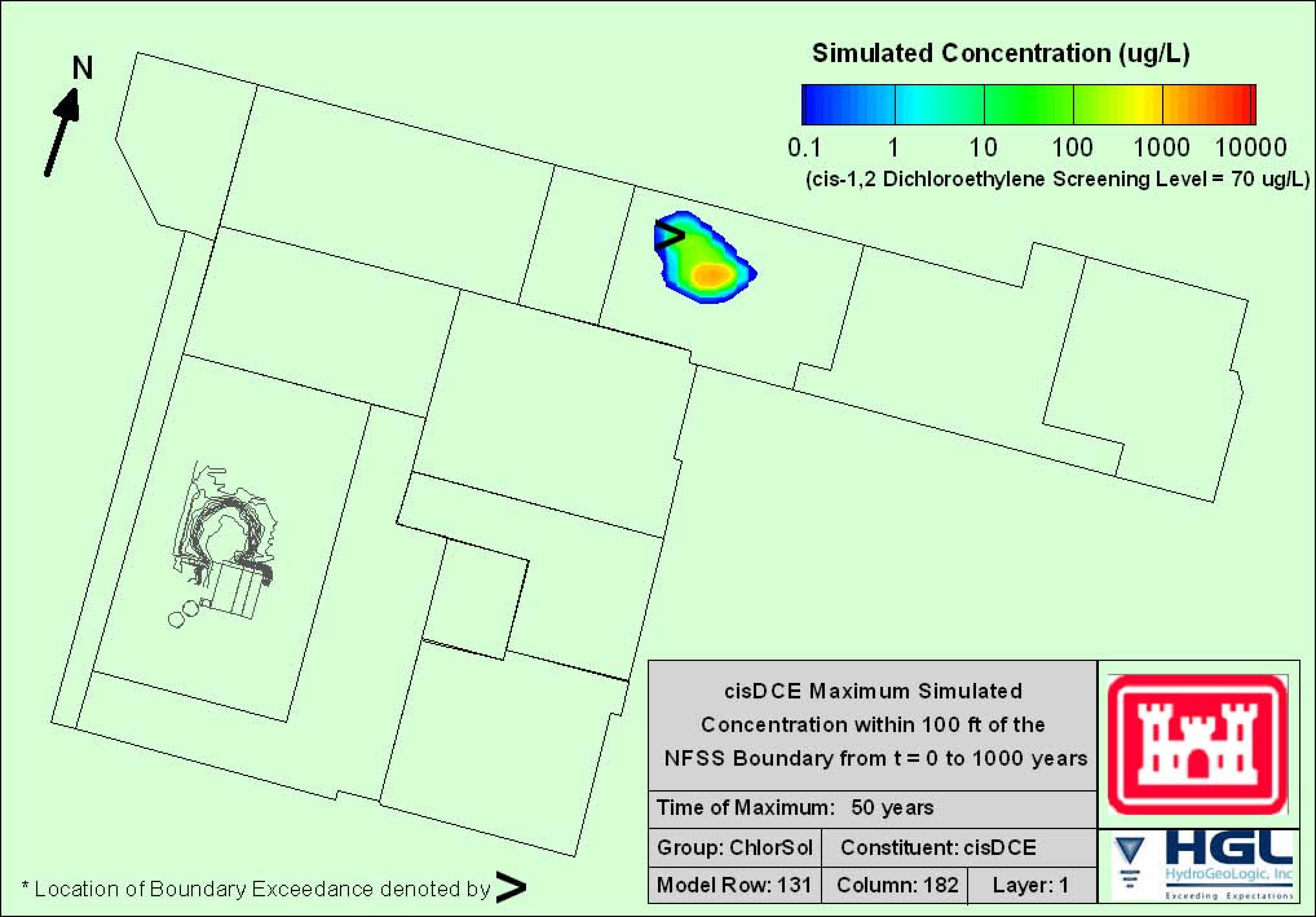

N
Simulated Concentration (pCi/L)
0.5 1 5 10 50 100 500
(Uranium-234 Screening Level = 8.94 pCi/L)
U-234 Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 0 years
Group: U238
Constituent: U234
Model Row: 173
Column: 178
Layer: 1
HGL
HydroGeoLogic, Inc
* Location of Boundary Exceedance denoted by >


N
Simulated Concentration (pCi/L)
0.0005
0.001
0.005
0.01
0.05
0.1
0.5
(Thorium-230 Screening Level = 0.39 pCi/L)
Th-230 Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 0 years
Group: U238
Constituent: Th230
Model Row: 127
Column: 185
Layer: 1
HGL
HydroGeoLogic, Inc
* Location of Boundary Exceedance denoted by >

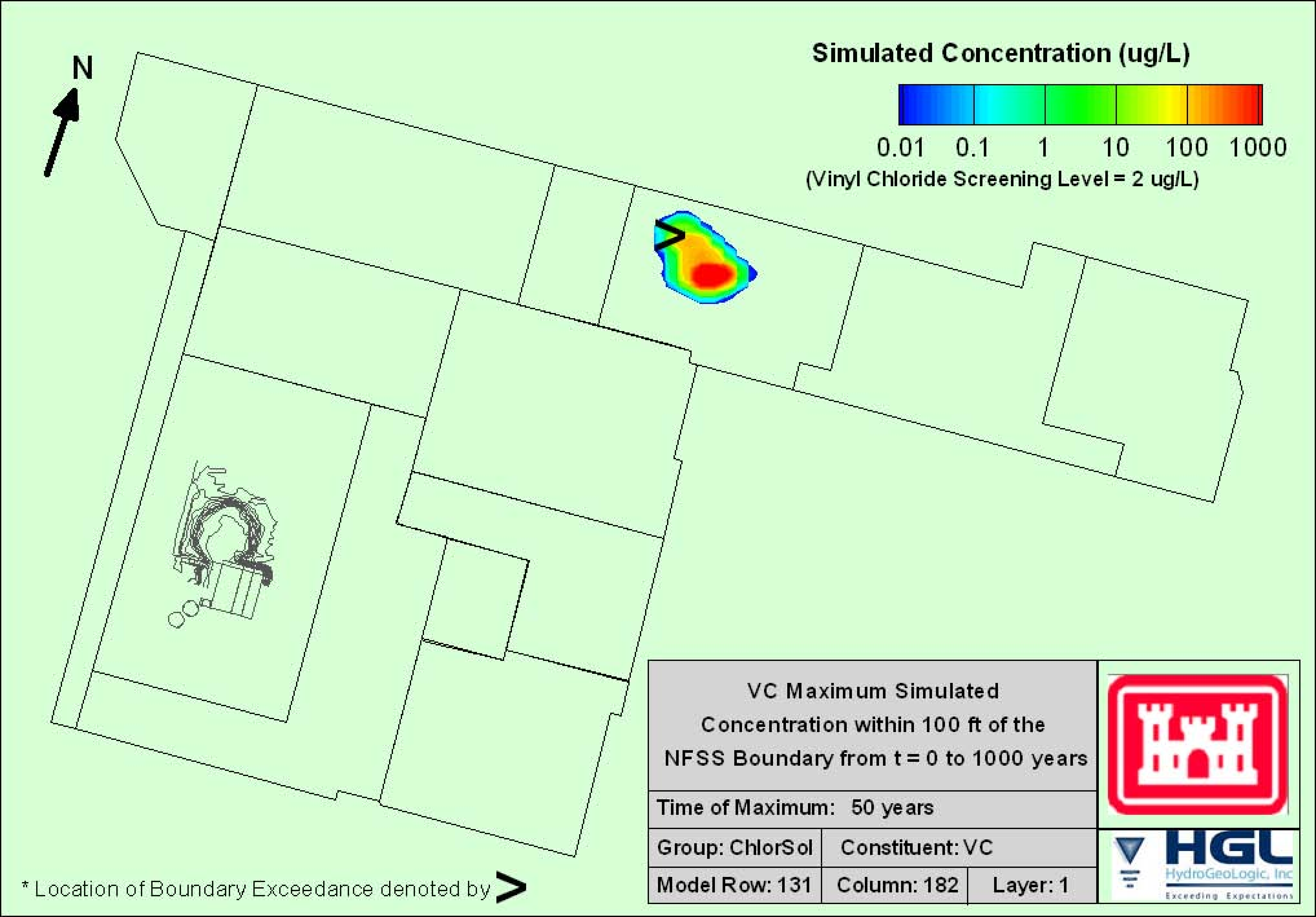

N
Simulated Concentration (pCi/L)
0.5
1
5
10
50
100
500
(Uranium-235 Screening Level = 0.51 pCi/L)
>
U-235 Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 0 years
Group: U235
Constituent: U235
Model Row: 174
Column: 179
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Boundary Exceedance denoted by >


N
Simulated Concentration (ug/L)
0.05
0.5
5
50
500
5000
50000
(Tetrachloroethylene Screening Level = 5 ug/L)
>
PCE Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 0 years
Group: ChlorSol
Constituent: PCE
Model Row: 131
Column: 182
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Boundary Exceedance denoted by >


N
Simulated Concentration (ug/L)
0.05
0.5
5
50
500
5000
50000
(Trichloroethylene Screening Level = 5 ug/L)
TCE Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 50 years
Group: ChlorSol
Constituent: TCE
Model Row: 131
Column: 182
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Boundary Exceedance denoted by >



N
Simulated Concentration (ug/L)
0.1
1
10
100
1000
10000
(cis-1,2 Dichloroethylene Screening Level = 70 ug/L)
cisDCE Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 50 years
Group: ChlorSol
Constituent: cisDCE
Model Row: 131
Column: 182
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Boundary Exceedance denoted by >


N
Simulated Concentration (ug/L)
0.01
0.1
1
10
100
1000
(Vinyl Chloride Screening Level = 2 ug/L)
VC Maximum Simulated Concentration within 100 ft of the NFSS Boundary from t = 0 to 1000 years
Time of Maximum: 50 years
Group: ChlorSol
Constituent: VC
Model Row: 131
Column: 182
Layer: 1
HGL
HydroGeoLogic, Inc
Exceeding Expectations
* Location of Boundary Exceedance denoted by >

APPENDIX B

Digital Information

APPENDIX B-1

NFSS Environnemental Database

APPENDIX B-2

3D Transport Simulation Animations

APPENDIX B-3

Screen Captures of Plumes at 0, 50, 200, and 1000 Years

APPENDIX B-4

DNAPL Simulation Results

This appendix or attachment
can be found on the enclosed disk in its entirety.