Groundwater Corrective Action Assessment Using Fate and Transport Modeling

Brian Hennings, PG\textsuperscript{1}, Glenn Luke, PE\textsuperscript{1}, and Jacob Walczak, PG\textsuperscript{1}

\textsuperscript{1} O’Brien & Gere Engineers, Part of Ramboll (OBG), 234 W. Florida Street, Floor 5, Milwaukee, WI 53204

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INTRODUCTION

The CCR Rule (Title 40 Code of Federal Regulations Part 257, Subpart D, Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments) stipulates that an assessment of corrective measures must be initiated within 90 days of identifying a constituent listed in Appendix IV at a statistically significant level exceeding the groundwater protection standard (when an alternate source is not identified), or immediately upon detection of a release. The assessment must consider factors including performance, reliability, safety, and time needed for implementation. The results are to be publicly available and discussed in a public meeting. Based on the assessment, the owner/operator must select a remedy that meets objectives including protection of human health and environment, meet groundwater protection standards, and control/eliminate future releases.

Previously-collected data characterizing the plume, fate of contaminants, and hydraulic properties of the aquifer obtained during the detection and assessment monitoring phases can be combined with hydrogeologic assessment/site characterization reports to develop a conceptual site model and translated into a three-dimensional numerical model for efficient assessment and side-by-side comparisons of various corrective actions (referred to as corrective measures in this paper for consistency with the Rule). This paper presents groundwater corrective measure strategies (e.g., capping, containment and extraction systems, or in situ solidification/stabilization) that have been simulated using a numerical model; and, methods to compare corrective measure performance in a format that is presentable and understood by all stakeholders.

ORGANIZATION

This paper provides a discussion of the timeline for corrective measures assessment, metrics for evaluating corrective measures, methods for modeling assessment of common corrective measures, and presentation of corrective measure performance metrics for stakeholders.
TIMELINE FOR CORRECTIVE MEASURES ASSESSMENT

The trigger for the corrective measures assessment timeline is either detection of a parameter above the groundwater protection standard listed in Appendix IV of the Rule at any new or existing CCR unit, or detection of a release from a CCR unit. The assessment must be initiated immediately; or, following an unsuccessful 90-day period to evaluate alternate sources (other than the CCR unit) for the detection of the Appendix IV parameter above the groundwater protection standard. Following detection of a release, completed assessment is required within 90 days, or 150 days with an extension (additional 60 days maximum). The corrective measures assessment must include certification from a qualified professional engineer attesting that the demonstration is accurate. The assessment has been completed when it is placed in the facility’s operating record. A remedy must be selected as soon as feasible following the completion of the corrective measures assessment; however, the results of the assessment must be discussed in a public meeting at least 30 days prior to remedy selection.

METRICS FOR CORRECTIVE MEASURES

The corrective measures assessment includes evaluation of the following criteria: 1) performance, reliability, ease of implementation, potential safety impacts, potential cross-media impacts, and control of exposure to any residual contamination; 2) time required to initiate and complete the remedy; 3) institutional requirements that may affect implementation of the remedy.

The selected remedy must be protective of human health and the environment, attain the groundwater protection standards established in the Rule, control the source of the release to reduce or eliminate further releases, and remove as much of the contaminated material as possible without inappropriate disturbance of sensitive ecosystems. In selecting a remedy, the owner/operator must consider, among other criteria specified in the Rule, the following items that are readily evaluated through three-dimensional computer modeling: long and short-term effectiveness of potential remedies, time until full protection is achieved, evaluation of contaminant loading to neighboring receptors (e.g., surface waterbodies), and potential risks to current and future users of the aquifer.

MODELING ASSESSMENT OF CORRECTIVE MEASURE PERFORMANCE

Corrective measures commonly evaluated include capping, containment and extraction systems, in-situ solidification/stabilization, or closure by removal. It is also useful to simulate a “no action” scenario as a benchmark for comparison of performance. Development of a model starts with establishment of a conceptual site model that is translated into a three-dimensional model grid. The model is constructed and calibrated to represent groundwater flow and contaminant concentrations collected from the monitoring well network and the conceptual site model. Once a calibrated model is created it can be used to quickly simulate various corrective measures for assessment.

Three-dimensional models have a reputation for being expensive to create. A significant portion of that cost (upwards of 30% for poorly characterized sites) is commonly associated with the data collection and literature research required to develop the conceptual site model and calibration targets. Previous work reported during identification of the uppermost aquifer,
development of the monitoring well network, alternate source evaluations, and characterization of the nature and extent of the release should provide most, if not all, of the supporting information and documentation necessary to create a three-dimensional model of the site, significantly reducing the cost and time needed to construct and calibrate the model.

Using previously reported information and existing conceptual site model, a three-dimensional model can be created for simulation of groundwater flow and transport using a combination of software codes that are widely used including:

- MODFLOW-2005 (Harbaugh et al., 2017), for groundwater flow
- MT3DMS (Zheng and Wang, 1998), for contaminant transport
- Hydrologic Evaluation of Landfill Performance (HELP) (Schroeder, et al., 1994), for simulating the rate of percolation of leachate from the CCR unit to the underlying aquifer

Models are calibrated to represent groundwater flow based on measurements of groundwater level at monitoring wells and the conceptual site model, which incorporates percolation rates from the HELP model. Groundwater concentrations in the model are calibrated to observed concentrations of the contaminant(s). If there are multiple contaminants with exceedances, one of them can typically be identified as a conservative surrogate for all the contaminants. The surrogate selected generally has the greatest exceedance and/or the largest plume footprint.

Following calibration of the model to observed conditions, the various corrective measures can be simulated using transient modeling to evaluate the performance metrics. The time frame for the selected corrective measure to reach performance goals may be estimated using the calibrated transient model. A common start date is selected for balanced comparison between the various corrective measure alternatives and the no-action scenario. Some examples of corrective measures typically simulated with transient contaminant transport models include:

- Capping using HELP models to estimate reductions in percolation that would take effect in the three-dimensional model 2 years after approval (estimated time required to complete the cap following selection)
- Containment barriers and pumping wells can be placed in the model to capture and remove groundwater that would take effect 5 years after selection
- Stabilized/solidified soils can be placed in the model to reduce CCR contact with groundwater that would take effect 5 years after selection
- Removal of CCR materials from the model that would take effect 7 years after selection

Following simulation of the various corrective measures, the results can be quickly summarized for internal or external presentation and discussion.
PRESENTATION OF CORRECTIVE MEASURE PERFORMANCE METRICS

Three-dimensional model output may rapidly provide plan-view illustrations of groundwater flow, geologic surfaces, and separation distances between sources and receptors (plume maps). The model calculates contaminant mass as it travels from sources to sinks and can be used to quantify the incremental loading of contaminants to receptors (such as surface water bodies). Concentration versus time plots also provide clear side-by-side comparisons of corrective measure performance. For example, the predicted time for groundwater concentrations to meet the groundwater protection standards at compliance points can be illustrated for multiple scenarios on concentration versus time plots, which convey the expected time until full protection is achieved (Figure 1 below). These graphs, combined with plume maps, provide clear visual aids for rapid evaluation of risk to current and future users, and the extent and duration of institutional controls that may be required.

![Graph](image)

Figure 1: Example graph illustrating expected times for various alternatives to reach a groundwater protection standard. Corrective Measures 6 and 7 attain the standard within 70 and 25 years respectively.

Significant efficiencies are realized when the modeler collaborates with the certifying engineer and the owner/operator in an iterative process to refine the design of the corrective measures to determine the most cost-effective solution that meets the requirements of the Rule. In the model, the degree and extent of contaminant concentration is updated in real-time as the model runs.
corrective measures assessment progresses, eliminating the need for continuously redrawing plume maps and other presentation materials using drafting software programs.

CONCLUSIONS

Three-dimensional modeling provides an efficient means to evaluate and present long and short-term effectiveness of potential remedies, estimated time frame for full compliance with groundwater protection standards, estimated contaminant loading to neighboring receptors (e.g., surface waterbodies), and potential risks to current and future users of the aquifer. Efficiency and adaptability are valuable components of corrective measure assessments given the short timelines established for evaluation (90-150 days) of corrective measures. Figures and graphics generated from the model improve communication between stakeholders (internally and externally) and may reduce the time required for selection and regulatory approval of a corrective measure.

Further, for sites subject to the CCR Rule, previous work reported during identification of the uppermost aquifer, development of the monitoring well network, alternate source evaluations, and characterization of the nature and extent of the release should provide most, if not all, of the supporting information necessary to create a three-dimensional model of the site, significantly reducing the cost and time needed to complete the modeling.

REFERENCES


Zheng, Z., and P.P. Wang, 1998, MT3DMS, a Modular Three-Dimensional Multispecies Transport Model, Model documentation and user’s guide prepared by the University of Alabama Hydrogeology Group for the US Army Corps of Engineers.