© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6

# Process of integrating screening and detailed risk-based modeling analyses to ensure consistent and scientifically defensible results

J. W. Buck, J. P. McDonald, & R. Y. Taira
*Pacific Northwest National Laboratory, USA*

## Abstract

The United States Department of Energy manages several installations with waste sites having a potential to impact human health and the environment. The Hanford Site in south-central Washington state is one such installation. The Hanford Site has over 1,000 wastes site with 177 of them being underground storage tanks containing high-level radioactive waste. To support cleanup and closure of these tanks, modeling is performed to understand and predict potential impacts to human health and the environment. Pacific Northwest National Laboratory developed a screening tool for the United States Department of Energy, Office of River Protection that estimates the long-term human health risk, from a strategic planning perspective, posed by potential tank releases to the environment. This tool is being conditioned to more detailed model analyses to ensure consistency between studies and to provide scientific defensibility. Once the conditioning is complete, the system will be used to screen alternative cleanup and closure strategies. The integration of screening and detailed models provides consistent analyses, efficiencies in resources, and positive feedback between the various modeling groups. This approach of conditioning a screening methodology to more detailed analyses provides decision-makers with timely and defensible information and increases confidence in the results on the part of clients, regulators, and stakeholders.

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



## Introduction

The U.S. Department of Energy (U.S. DOE) Hanford Site is a large brownfield site that has radioactive, hazardous, and mixed waste associated with over 40 years of Cold War nuclear material production. Besides having over a thousand waste sites, the Hanford Site has 177 high-level radioactive waste tanks that need to be cleaned up and closed. Many of these tanks are suspected of leaking to the environment and the integrity of many of the tanks is in question. A major focus is the groundwater contamination of past, current, and future activities. The Hanford Site has some complex groundwater problems and issues that are being addressed using environmental and risk assessment models. In many cases, the problems are so complex and large that overall strategies are needed to meet the clean up and closure goals of the site. For many site-specific problems, screening or prioritization level and detailed level models could be used together to understand the environmental and human health risk ramifications of site clean up alternatives.

This paper discusses a process of linking screening level modeling results to more detailed modeling results to allow decision-makers to develop strategies quickly and efficiently while maintaining a certain level of scientific defensibility. In the case of environmental clean up and site closure, the timeframe for developing options and strategies is much shorter than the time it takes to conduct a detailed modeling assessment. Often detailed environmental modeling studies take several months or more to conceptualize, collect appropriate data, and perform the modeling. Also, because of their focused nature, detailed environmental modeling efforts are slow to respond to changing requirements and scenarios.

To provide decision-makers with environmental and risk information in a timely and responsive manner, prioritization-level environmental modeling systems can be used. These models quickly provide decision-makers with results that can be integrated easily into strategic plans. The results of these prioritization-level models can be used to focus the use of the detailed models. These screening level models are generally analytical or semi-analytical in nature and require major simplifications of the environmental problem. Unfortunately, because the screening models are simplified, their scientific defensibility is often questioned.

To meet the strategic planning needs and technical defensibility requirements of these environmental problems and issues, a combination of screening and detailed modeling must be conducted. This paper discusses the

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



process of integrating the screening and detailed modeling to provide decision-makers with understandable information that is timely, flexible, and scientifically defensible. An application of this process will also be presented to provide the reader with an understanding of its applicability.

## Benefits of integration

If a waste site has a simple geology, source terms, and/or is a single medium problem, it may not be reasonable to do multiple types of analyses (i.e., screening-level and detailed modeling) or to integrate analyses. But at a large brownfield site like Hanford, the complexity of the source terms and their environmental transport into multiple media (air, surface and subsurface soil, groundwater, and surface water) require different levels of modeling to help identify the key strategies that will effectively reduce human health impacts. In many cases, the clean up of a large brownfield site takes years, involves many specific waste sites, and costs many millions of dollars. Under this scenario, multiple levels of modeling and their integration are not only reasonable, but essential to provide the best overall clean up.

Prioritization-level and detailed modeling should be interconnected to ensure consistency and efficiency of the overall analysis. Unfortunately, it is common to have different groups or contractors performing the different levels of modeling under various programs. In this scenario, there is little, if any, coordination between those conducting the screening and detailed modeling. Neither of the analyses benefits from the other and inconsistencies and inefficiencies routinely occur. Therefore, it is beneficial to coordinate and plan the integration of different levels of modeling to provide decision-makers with information that can be used strategically as well as information that can feed directly into site-specific decisions.

There are obvious cost efficiencies that occur if the different modeling levels are planned and integrated. A consistent conceptual site model is used for all modeling and data can be shared where appropriate (i.e., constituents of concern and their properties, source inventories, exposure scenarios and factors, and receptor locations and characteristics), which ensures a more beneficial result. If the different modeling teams share information and meet regularly on issues, a more cost effective, consistent, and scientifically defensible product can be developed.

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



## Technical approach

Models are integrated through the process of conditioning. To condition a screening-level model to a detailed model, means to identify a set of parameter values and boundary conditions such that the computational results of the screening-level model match that of the detailed model as close as is needed and practical. Conditioning is different from benchmarking, in which the results of two or more models are compared and the differences are documented and explained. This is contrasted to calibration whereby parameter values and boundary conditions are determined such that computational results match field-measured values. Conditioning is similar to calibration in that a set of input parameters is varied until the screening-level model results match a set of target values. The difference is that the target values are obtained from a detailed model.

An exact match of results during conditioning is not expected, because it is very difficult for the results of one model to exactly match another. Various models can be based on different assumptions and use a variety of mathematical methods. These differences need to be understood in order to 1) carefully select input parameters that will compensate, as much as possible, for these differences, and 2) determine which input parameters will be varied to achieve a match. In addition, it is also important to understand how the detailed model was applied. In other words, the same conceptual site model used for the detailed modeling should be employed for the screening-level model.

With knowledge of the assumptions and methods used by the models, as well as the assumptions employed in the application of the detailed model, a base case can be established for the screening-level model. This case will serve as a starting point for the conditioning. Then, the previously identified conditioning parameters are varied to obtain the best match.

The main challenge is the assumptions and mathematical methods of the screening and detailed models can be so different that a good match cannot be obtained. For instance, detailed groundwater flow models can simulate aquifer heterogeneity and transient flow conditions, whereas screening-level models typically simulate only uniform flow. One way of handling this type of situation is to try and capture the important aspects using the screening-level model. Matching a peak concentration and the time to the peak, while ignoring other aspects of a breakthrough curve, may be sufficient to meet the decision-goals of the assessment.

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



## Example application

The approach to integrating screening and detailed level models can vary depending on the type of environmental problem and the maturity of the analysis. In the case of the Hanford Site, groundwater modeling has been conducted at the site for several decades and a specific set of detailed models have been developed and maintained specifically for this site. These models have been peer reviewed extensively and site data have been collected for these specific models. These detailed models were used to develop the baseline clean up strategy. But because of funding changes, politics, and pressure from stakeholders, an accelerated clean up plan has been developed. To meet the changing needs of this new clean up plan, a screening-level modeling system has been developed to rapidly conduct analyses that can be used to determine the best path forward in meeting the new clean up schedule and budget (Lober et al. [1]).

Because a baseline analysis already exists at the Hanford Site using detailed models, the screening level models are being "conditioned" to the detailed modeling results and used to conduct "what if" analyses off the baseline. The conditioning process involves matching the results of the screening-level modeling to the results of the detailed modeling for the same waste site and conceptual site model. This process is covered in more detail in the next section. The conditioning of the screening-level model to detailed model results provides for a more scientifically defensible analysis.

The U.S. DOE's Strategic Analysis Project initiated development of an integrated risk-based strategy for the Office of River Protection (ORP). Simply, this strategy is to reduce the long-term health risk from Hanford's high-level tank waste as quickly and efficiently as possible while achieving interim safe harbor of the tank waste by year 2018 and permanent safe harbor by year 2028 (U.S. DOE [2]). The development of this strategy was driven by the need to protect human health and the environment. It was also driven by the objectives to 1) comply with federal and state regulations, 2) utilize the initial waste treatment and immobilization facilities, 3) maintain annual costs below $1 billion throughout the project life-cycle, and 4) complete waste retrieval, treatment and immobilization of all tank waste within the design life-times of the new facilities.

The Receptor Risk Model (RRM) was developed to assist in evaluating the potential human health risk for different receptor types (e.g., different activity patterns and land use) and locations (e.g., on-site, boundary, off-site, intruder, individual and population) associated with Hanford's high-level waste tanks and

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



related sources. As ORP moves forward, one of the driving issues that needs to be addressed is risk to human health and environment from past, current and future operations. The RRM will address, at a screening level, key questions associated with ORP operation decisions, such as:

- What level of retrieval for each tank and/or tank farm is required to meet performance objectives?
- Considering risk, inventory, and waste volume, which tanks are the highest priority for clean up?
- What is the relative risk-based performance of the different retrieval technologies and options?

The RRM will support decisions that need to be made quickly, at a screening level, which is useful given the changing nature of clean up operations. This work, integrated with other efforts, can also help define and support a consistent risk methodology for activities associated with ORP and the Hanford Site.

**Description of the Receptor Risk Model**

The RRM is a macro-scale, risk analysis tool that can provide for a comprehensive risk analysis while meeting the schedule and resource requirements for the ORP mission. It is not meant to replace more detailed or site-specific analyses. The RRM produces areal risk contours, as well as constituent concentration contours, for specific tank farms, times, exposure scenarios, and release types. These contours are useful for displaying a large amount of data to decision makers and stakeholders. A key effort of this task is to use information and data from more detailed projects and programs related to the ORP mission to ensure consistency with these other efforts.

The RRM includes the following characteristics:

- It is a macro-level scoping tool for long-term human health risk.
- It is deterministic in nature for this analysis, with an option to be stochastic in the future.
- It builds on information and approaches used by previous and current projects related to the RPP.
- It tiers with more detailed project results as they become available.
- It is coordinated with tank and tank farm risk analyses being performed in the Single-Shell Tank Program.
- It provides an enhanced capability to plan alternative analyses.
- It is linked to schedule and budget models.
- It provides a choice of receptor types, locations, time of interest, and receptor activities.
- It is flexible enough to consider source terms and additional receptor locations beyond those required by the ORP.

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



The process of integrating a screening-level model with a detailed model is further explained in the following section. To strategically assess remedial alternatives for cleanup and closure of Hanford's high-level waste tanks, the RRM is conditioned to a previous fate and transport assessment.

**Conditioning to a detailed model**

The Tank Waste Remediation System Environmental Impact Statement (TWRS-EIS) is the generally accepted risk assessment performed on the tank farm complex at the Hanford Site (U.S. DOE and WDOE [3]). For the RRM to provide meaningful information to support strategic decision making regarding tank farm remedial options, it was conditioned to the modeling performed for the TWRS-EIS. The TWRS-EIS modeling was not calibrated, but it was designed to be conservative in nature.

The TWRS-EIS assessment simulated the release of contaminants from the waste tanks, transport through the vadose zone to the aquifer, and computation of concentrations in the aquifer for a human health risk assessment. Subsurface water flow and contaminant transport, in both the vadose and saturated zones, was simulated using the Variably Saturated Analysis Model in Two Dimensions (VAM2D). This is a 2-dimensional, finite element code that simulates both saturated and unsaturated flow and transport.

The 177 high-level waste tanks at Hanford are grouped into 18 separate tank farms. These farms were aggregated into eight source areas for the TWRS-EIS. Modeled constituent concentrations were available for the vadose zone/saturated zone interface beneath each source area and for a 2-dimensional grid in the aquifer. The RRM was conditioned to the vadose zone first, because the results of the vadose zone conditioning will be used as input to the aquifer modeling (at the time of publication, only the vadose zone conditioning was complete).

The first step of the vadose zone conditioning was to research the TWRS-EIS documentation to identify the pertinent differences between VAM2D and the MEPAS vadose zone module. The Multimedia Environmental Pollutant Assessment System (MEPAS) (Whelan et al. [4], McDonald and Gelston [5]) contains separate modules for source release, vadose zone transport, aquifer transport, riverine transport (not used in this assessment), and human health exposure, intake, and impact computations. The task of matching the results from a semi-analytical model (MEPAS vadose zone module) to the results of a 2-dimensional, finite element model (VAM2D) was made easier because VAM2D was applied in a 1-dimensional mode (i.e., 1-dimensional advection and

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



1-dimensional dispersion) to the vadose zone. The MEPAS vadose zone module is also a 1-dimensional advective, 1-dimensional dispersive model.

The pertinent difference between the two codes is the method used to describe the relationship between unsaturated hydraulic conductivity and moisture content. For the TWRS-EIS, the van Genuchten relations of hydraulic conductivity versus moisture content was used for the vadose zone flow modeling, while the MEPAS vadose zone module makes use of a power curve (Campbell [6]). The van Genuchten relations account for the hysteresis in the drying and wetting curves, whereas the power curve does not. Because of these two different methods, it was expected that moisture content and its effect on pore-water velocity, and thus travel times, would be the major difference in the vadose zone transport between the two models. The power curve makes use of a soil type coefficient, which was used as the conditioning parameter to match the vadose zone travel times computed by VAM2D. Due to the presence of numerical dispersion in VAM2D, which is not present in the MEPAS vadose zone module, longitudinal dispersivity was selected as a conditioning parameter to match the mass flux values entering the aquifer. The conditioning was performed for technetium-99, the constituent believed to be the primary constituent of concern for the tank farms. The TWRS-EIS no action alternative was selected for the initial conditioning.

Once the differences between the two models were understood, the TWRS-EIS documentation was examined to determine the conceptual site model used for the assessment and to obtain input parameter values used by VAM2D. Then, the modeling scenarios were recreated using the MEPAS vadose zone module. Initially, the module was set up with exactly the same input parameter values as used in VAM2D, except that the recommended MEPAS default value was used for the soil type coefficient (after Clapp and Hornberger [7]). A strong emphasis was placed on using TWRS-EIS vadose zone data directly, whenever possible, to ensure that both models were as close to solving the same problem as possible. The initial longitudinal dispersivity was the same as used for the TWRS-EIS.

Both the magnitude and time of the peak mass flux entering the aquifer served as conditioning targets, and the soil type coefficient and the longitudinal dispersivity were varied to achieve a best match. All eight source areas were conditioned simultaneously by minimizing the average error. For each run, the ratios of the time to peak and the peak mass flux to their target values were computed to evaluate the match. Then, the average ratios for all eight sources were computed. The objective was to minimize the error by iterating towards an average of 1.0 for the eight targets collectively. The default values for the soil

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



type coefficients were all uniformly changed by a certain percentage until the average of the time to peak ratios equaled 1.0. To achieve this, the soil type coefficient values were reduced to 44.67% of their initial values. The same methodology was used to set the longitudinal dispersivity values. It was determined that to achieve an average ratio of 1.0 for the peak mass fluxes, the longitudinal dispersivity values needed to be increased to 140% of their initial values. The vadose zone conditioning results for two of the eight sources are given in Figure 1, showing the range in the quality of the matches achieved.

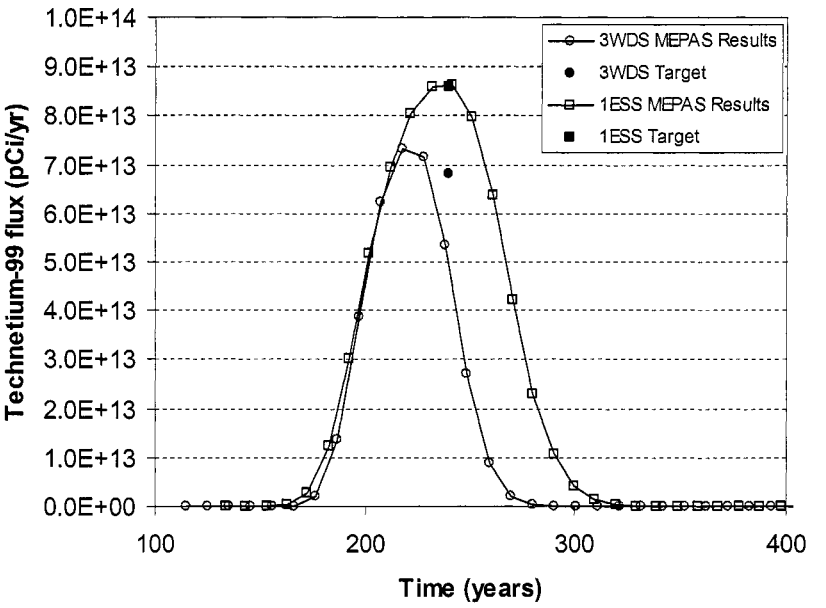



Figure 1: Simulated flux of technetium-99 from the vadose zone to the aquifer compared to the time and magnitude of the target peak flux for both the 3WDS and 1ESS source areas. These two sources demonstrate the range in the quality of the matches achieved.

Conditioning the vadose zone simulations to the TWRS-EIS no action alternative represents only the first step of this process. The vadose zone was further conditioned to a cap alternative, and conditioning of the aquifer simulations is planned. The aquifer conditioning will follow a similar process of identifying conditioning targets as well as the input parameters to be varied.

## Screening of tank waste remedial alternatives

The RRM can be used as a stand-alone software package or integrated with other modeling software such as life cycle models that evaluate budgets and schedules

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



associated with clean up operations. The RRM operates on an IBM or compatible personal computer and is very easy to operate. The knowledge required is the actual problem and alternative to be simulated. The RRM can be deployed via the Internet as a download or as a CD that will automatically install the software.

The RRM was originally designed to evaluate any problem or alternative that involves high-level waste tanks but it is planned to be used for other types (i.e., buried waste, landfills, trenches, and liquid disposals) of waste sites at the Hanford Site and other U.S. DOE installations. This includes covers and waste removal, as well as various waste form options. The RRM can easily be updated to deal with other types of waste sites that are commonly associated with brownfield sites.

## Conclusions

This paper demonstrates that the use of both screening and detailed level environmental modeling is critical to the clean up and closures of complex brownfield sites like the U.S. DOE Hanford Site. When developing strategic plans for such sites, it is imperative that an integrated plan is developed between the screening and detailed level modeling efforts. The integrated planning and use of data and conceptual site models provides consistent analyses and results, as well as efficiencies in the use of resources. This gives decision-makers the information they need, when they need it, and still have scientifically defensible results for developing strategic plans. These plans can then be more easily translated to detailed clean up and closure plans, because the detailed modeling process has been integrated into the strategic plan.

## References

[1] Lober, R. W., Yasek R. M., Morse, J. G. Buck, J. W., Bunn A. L., Henderson, C. C., Sams, T. L., and Vaughn, P. Integrating Risk Analyses and Tools at the U.S. Department of Energy Hanford Site. *Waste Management Symposium 2002*, Tucson Arizona, February 24 –28, 2002, in press.

[2] U.S. Department of Energy (U.S. DOE). *A Review of the Environmental Management Program*, U.S. Department of Energy: Washington D.C., February 4, 2002 (http://www.energyca.org/EMReview.pdf).

[3] U.S. Department of Energy (U.S. DOE) & Washington State Department of Ecology (WDOE). *Tank Waste Remediation System, Hanford Site,*

© 2002 WIT Press, Ashurst Lodge, Southampton, SO40 7AA, UK. All rights reserved.
Web: www.witpress.com Email witpress@witpress.com
Paper from: *Brownfield Sites*, CA Brebbia, D Almorza & H Klapperich (Editors).
ISBN 1-85312-918-6



*Richland, Washington, Final Environmental Impact Statement (DOE/EIS-0189)*, U.S. Department of Energy: Richland, Washington, 1996.

[4] Whelan, G., Buck, J. W., Strenge, D. L., Droppo, J. G., Jr., & Hoopes, B. L. Overview of the Multimedia Environmental Pollutant Assessment System (MEPAS). *Hazardous Waste & Hazardous Materials*, **9(2)**, pp. 191-208, 1992.

[5] McDonald, J. P., & Gelston, G. M. Commentary on fate and exposure models: description of the Multimedia Environmental Pollutant Assessment System (MEPAS) version 3.2, with application to a hypothetical soil contamination scenario. *Journal of Soil Contamination*, **7(3)**, pp. 283-300, 1998.

[6] Campbell, G. S. A simple method for determining unsaturated conductivity from moisture retention data. *Soil Science*, **117**, pp. 311-314, 1974.

[7] Clapp, R. B., & Hornberger, G. M. Empirical equations for some soil hydraulic properties. *Water Resources Research*, **14(4)**, pp. 601-604, 1978.