USE OF THE DOD GROUNDWATER MODELING SYSTEM IN SITE CLEANUP

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ABSTRACT

Activities at Department of Defense (DoD) installations have produced contamination of groundwater resources that may pose problems for human health and the environments adjacent to or on these posts. Estimates for environmental remediation of these sites range from tens to hundreds of billions of dollars. The U.S. Army Engineer Waterways Experiment Station, in concert with the U.S. Army Environmental Center and Headquarters, Army Corps of Engineers, leads a consortium of Department of Defense, Department of Energy, Environmental Protection Agency, industry, and academic researchers in the development of the DoD Groundwater Modeling System (GMS). The GMS provides a single, comprehensive means for DoD and other organizations to use advanced subsurface modeling and simulation assets in site characterization, contaminant transport/fate assessment, and evaluation of differing remedial action strategies at groundwater cleanup sites. The capabilities of this system to support site cleanup are presented. Future development plans for the GMS are also

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INTRODUCTION

The effective use of advanced subsurface modeling and simulation technology is of vital importance in the Department of Defense's (DoD's) environmental restoration and stewardship activities. DoD has responsibility for the cleanup of almost 9,000 contaminated sites on its active installations. In support of environmental management objectives, the U.S. Army Engineer Waterways Experiment Station (WES), as the DoD lead in the research and development of environmental quality modeling and simulation (EQM) technology, leads a consortium of DoD, Department of Energy (DOE), Environmental Protection Agency (EPA), and academic researchers in the development of the DoD Groundwater Modeling System (GMS). Collaboration with other researchers, such as those within the U.S. Geological Survey (USGS), further extends the capabilities of the GMS. The GMS provides a single, comprehensive means for DoD to use advanced environmental quality modeling and simulation assets in site characterization, contaminant transport/fate assessment, and evaluation of differing remedial action strategies at DoD installations. The system also has high dual-use capabilities as exemplified by its application for salinity intrusion, wellhead protection, and dredged material facility design.

Increased productivity in the use of subsurface modeling and simulation by cleanup specialists, ranging from 50% to 75%, can be achieved from use of the GMS. For example, setup for a given subsurface model can now be accomplished in hours, rather than days or weeks, via the GMS. This empowers cleanup specialists to efficiently evaluate many more scenarios (e.g., differing site hydrogeologic conditions and remediation alternatives) than possible previously. This, in turn, increases DoD and regulatory confidence in site-specific remedial designs. For example, WES and

the U.S. Army Environmental Center have used the GMS to design a pump-and-treat system for Schofield Army Barracks, Hawaii. The use of GMS modeling technology to rigorously consider site characterization uncertainty, and to present modeling results in a manner amenable to regulators, resulted in regulatory acceptance of a lower-cost remedial system that is technically equal to more expensive proposed systems. Cost savings from this one application were estimated to range from $7.5M to $10.0M. Based on experience in industrial and military cleanups, between 10% and 20% of characterization and remediation costs can be saved through the use of GMS technologies at many cleanup sites. This could result in cleanup cost reductions in the billions of dollars within DoD alone. Extension of these savings to DOE sites could easily be an order of magnitude larger.

GMS Status

Version 2.1 of the GMS has been fielded and is in use by over 600 U.S. government user groups and over 1300 commercial users worldwide. The system provides single look-and-feel access to six multi-dimensional groundwater models (MODFLOW, MT3D, FEMWATER, MODPATH, RT3D, and SEEP2D) presently. This number will increase to 12 with the addition of ADH, NUFT, and PARFLOW by the end of 1998, and the addition of UTCHEM, SEAM3D, and SWGW by the end of 1999. The ability to model surface water/groundwater interactions is undergoing verification and will be fielded in 1998 as well.

The GMS has been designed specifically to aid users in the evaluation, design, and operation of differing subsurface remediation methods (ranging from traditional pump-and-treat to bioremediation to natural attenuation) for site-specific hydrogeologic conditions. This design objective is the primary criterion governing selection of the models listed above for integration into the GMS. The system has state-of-the-art visualization (for both two- and three-dimensional data), animation (through the AVI video file format), grid generation, conceptualization (including an extensive geostatistical library), and parameterization capabilities onboard that access modeling results directly without external software requirements. The GMS runs seamlessly, and with the same look and feel (developed through a WES-Brigham Young University [BYU] collaboration), on UNIX workstations, personal computers running Windows 3.1, 95, and NT, and supercomputers.

A key component of the system, the Map Module (also a joint WES-BYU development), increases the productivity of subsurface conceptualization, flow/transport modeling, and remedial design simulation by more than a factor of 10. This is accomplished through the GMS's use of standardized geographic information system (GIS) constructs (e.g., arcs, polygons, points, objects, etc.) which empower the direct import and export of existing data within digital elevation, hydroenvironmental, and installation management databases directly and rapidly. The Map Module also empowers graphical assignment of initial and boundary conditions, and site conceptual features (such as rivers, land cover, material properties, subsurface stratigraphy, lakes, etc.). Further, the Map Module effectively decouples the selection of numerical model and site conceptual model

development, thereby allowing use of the best, or several, subsurface models for a given site without requirements for redeveloping the site conceptual model. The desktop of the GMS, with a contaminant plume from a U.S. military installation visualized, is shown in Figure 1.

Both finite difference and finite element grid generation tools are resident within the GMS for both structured (Figure 2) and unstructured grids (Figure 3). In addition, grids developed external to the GMS can be imported within the system. The system also has a series of new calibration tools that enhance the parameterization and calibration of a GMS-supported subsurface model for a given site implementation.

GMS Remedial Simulators

As noted above, the GMS has been specifically developed to support DoD (and other agency) environmental restoration activities related to contaminated groundwater resources. This driving force underscores the reason for selection of the models scheduled for inclusion in the GMS: each has a unique capability for modeling a particular set or subset of remediation technologies. Listed below is the current schedule for fielding direct simulation capabilities for specific remediation technologies. Note that this schedule is based on a number of factors including availability of funds, state of treatment technologies at the time of simulator development, and assumption of achieving a level of confidence in simulating a given cleanup technology. Also note that multiple dates are listed for certain technologies representing the presence of existing capabilities within GMS and planned future additions.

- Pump & Treat, Hydraulic Barriers - FY97
- Steam Injection/Vapor Ext., Electrical Heat. - FY98
- Natural Attenuation for Explosives - FY98, 00
- Bioremediation for Fuels, Solvents, Explosives - FY97 - 99
- Surfactant-Enhanced Remediation - FY99 - 00
- Bioventing, Soil Vapor Extraction - FY98 - 99
- Air Sparging - FY99
- Multi-Component Simulation - FY99 - 00
- In-Situ Chem. Simulator - FY99 - 00
- Electrokinetics - FY99 - 01

GMS Development Path

Synopsized below is the planned GMS development. This development path is specifically developed to produce coupled EQM systems in support of DoD environmental quality management that provide an ever-increasing level of computational and scientific sophistication. The development path also includes integration of components of three of WES's hydroenvironmental modeling systems: the GMS, the Watershed Modeling System, and the Surface Water Modeling System. The

reader is referred to the WES modeling web site, http://chl.wes.army.mil/software, for details and demonstrations of these individual systems. Note, however, that these systems will be linked in a web-based framework, with linkages to remote databases and differing computational assets.

The environmental quality modeling and simulation challenges of the future will require significant development, especially if the development path listed above is to be followed. These challenges include the following:

- Key basic science investigations and numerical formulations of processes associated with military-unique impacts upon the ecosystem (e.g., explosives contamination).
- Coupling of surface water and groundwater modeling tools, both dynamically and passively, in two and three dimensions in support of the cleanup and conservation of natural resources (land, water, groundwater, etc.). This coupling will require development of methods for numerically handling differing time and spatial scales associated with surface water hydrodynamics, watershed runoff and erosion, infiltration, and subsurface flow and transport.
- Incorporation of uncertainty and risk into all environmental quality modeling systems to support risk-based design and environmental assessments.
- Coupling of three-dimensional surface water and subsurface flow and transport modeling tools with remediation alternative simulators and highly sophisticated hydrogeochemical speciation models.
- Incorporation of NEXRAD weather radar and remotely-sensed data directly into model calibration / verification methodologies.
- Linkage of modeling and simulation tools with decision support and resource management tools to facilitate the use of modeling results by resource managers and decision makers.

These challenges are both scientific (e.g., modeling subsurface hydrogeologic and biogeochemical heterogeneity effectively in engineering-scale continuum models) and institutional (e.g., lack of regulatory or management acceptance of modeling and simulation results, especially for innovative cleanup technologies). These challenges, however, can be overcome in part through the conduct of focused research investigations planned and executed by the DoD services and its technical partners (e.g., DOE, EPA, USGS, academia).

SUMMARY

The Department of Defense has at its disposal a cadre of modeling and simulation technology, typified by the Groundwater Modeling System, in support of hydroenvironmental analysis and decision support. Effective use of this technology, by over 600 Federal government users and 1300 commercial users worldwide, has been shown to result in significant cost savings, and results in more timely acceptance of DoD activities by regulatory agencies. A focused development path for the GMS is being followed that will increase the system's capabilities well beyond those presently in place.

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Figure 1. GMS desktop with visualization of a contaminant plume and associated well field.

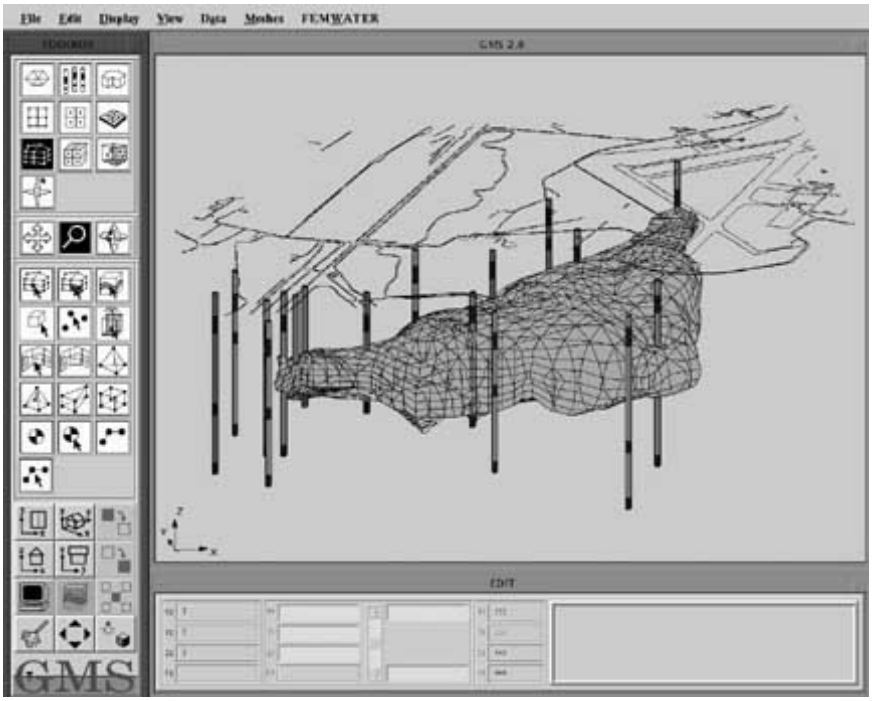

Figure 2. A MODFLOW structured grid automatically constructed from the site conceptual model

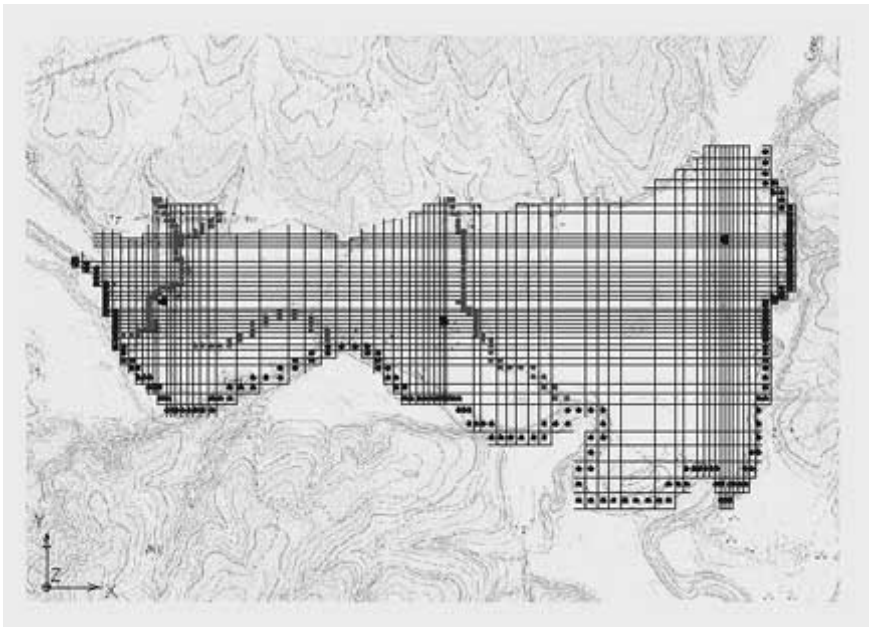

Figure 3. An unstructured finite-element mesh automatically constructed from the site conceptual model via GMS.

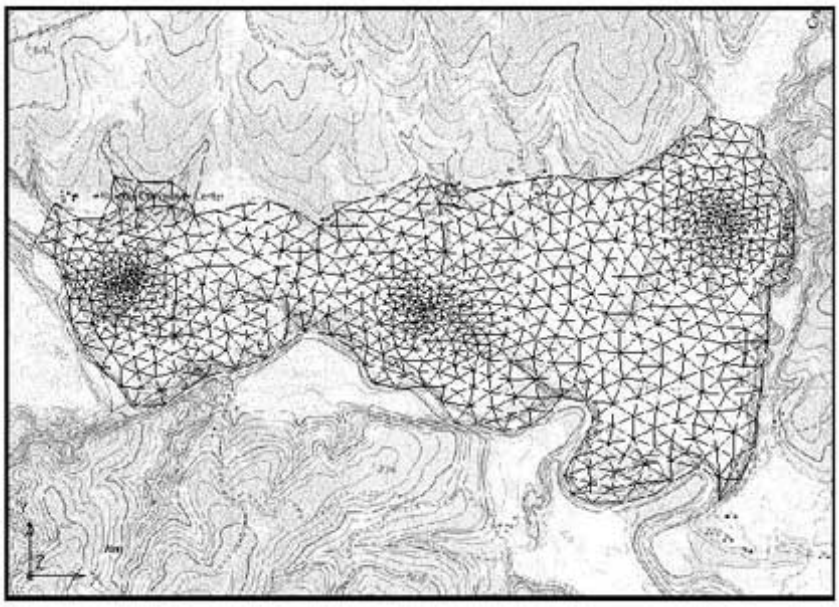

Table 1. Development path for the GMS and related WES EQM systems.

M & S System Capability	Deliverable Dates
Addition of optimal remedial design modules for ten to fifteen technologies, with optimization, to the GMS.	FY98-01
Integration of watershed and groundwater modeling tools within the GMS and Watershed Modeling System.	FY98-99
Coupling of surface water and groundwater modeling tools for multi-scale phenomena. Integration of tools under a comprehensive modeling environment (CME).	FY99-00
Integrated surface water/groundwater/watershed investigations empowered across a heterogeneous, networked environment.	FY99-01
Full ecosystem modeling and simulation under CME with risk and uncertainty for both human and ecological receptors.	FY00-02