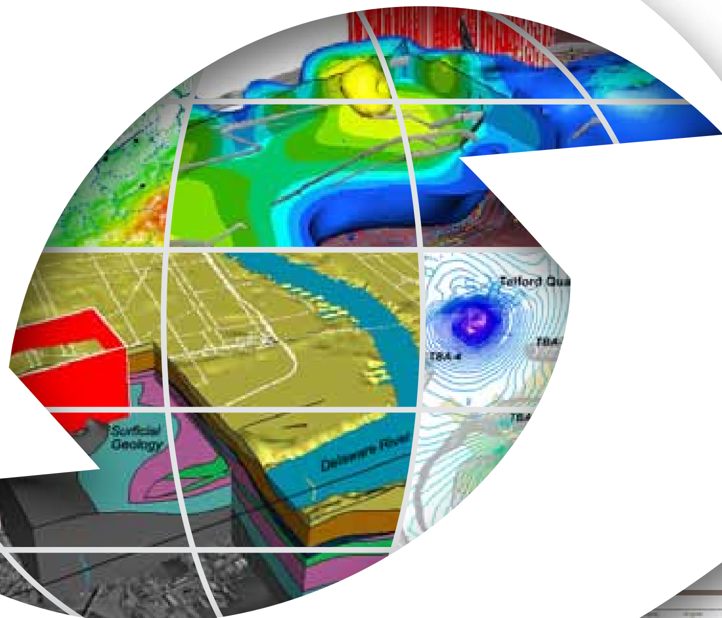
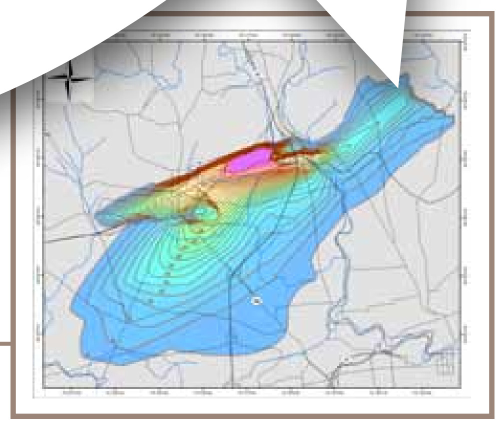
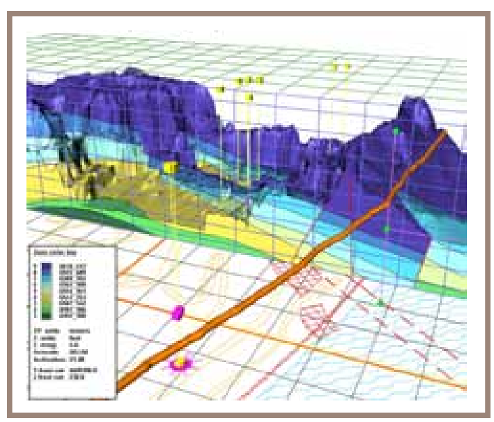
GeoHydros LLC

Specialized Geological Modeling





STATEMENT OF QUALIFICATIONS



About GeoHydros

GeoHydros is a small consulting firm specializing in geological and hydrogeological modeling, data visualization, GIS, and data management. Our expertise with and adept use of cutting-edge technologies form the basis for our growing reputation as a leader in modeling complex aquifers such as karst, fractured bedrock, and highly heterogeneous surficial sediments. Our business was founded in 1999 as Hazlett-Kincaid, Inc. in Reading Pennsylvania. We opened a Tallahassee Florida office in 2001 and then our current home office in Reno Nevada in 2002. We reorganized as GeoHydros, LLC in 2010. Our primary strength and the fundamental characteristic that sets us apart from other modelers and modeling firms is our Dual Modeling Approach™ to problem solving, which focuses on synthesizing site and regional data with sound professional interpretations into accurate digital conceptual models of the site as it fits into a regional hydrogeologic context. Those digital solids models then become the framework for flow and transport models and predictions as well as the basis for visualizing data and results in the context of site complexities such as geologic and/or engineered structures. We typically perform all services from our main office in Reno, Nevada, leveraging our secure website to facilitate effective communication with project team members regardless of their physical location, and to disseminate modeling results to our clients and project team-members and, when appropriate, to the responsible regulatory agencies.

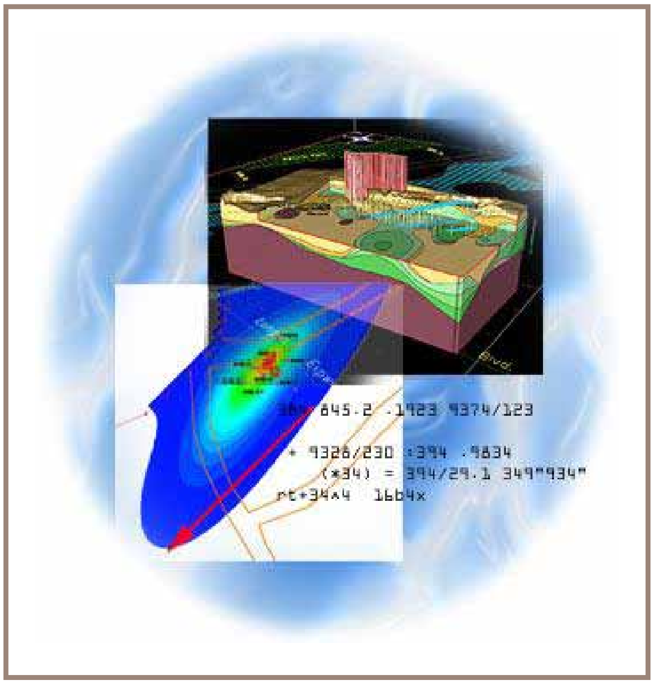
The GeoHydros group has worked for government and private clients on projects including: geotechnical and environmental engineering of new underground structures; characterization and remediation of Light and Dense Non-aqueous Phase Liquid plumes; quarry dewatering; karst aquifer characterization and modeling, and municipality water resource modeling. Some of our previous and existing clients include: USDOD; US-DOE; Tetra Tech EC; Parsons Brinkerhoff; STV Inc.; Coca-Cola North America; Florida DEP; Bucks County, Pennsylvania; Hardin County, Ohio; SM Stoller Corp.; TriHydro Corp.; Northwest Florida Water Management District; Borton-Lawson, Inc.; ERM Group Inc.; WRS Infrastructure & Environment, Inc.; Knik Construction Co.; Buzzi Unicem USA; HydroGeoLogic, Inc.; and Tilcon New York, Inc.

Dual Modeling Approach™

GeoHydros takes pride in our comprehensive and consistent approach to modeling for water resource management and environmental site characterizations. We developed and utilize our Dual Modeling Approach™ to link conceptual solids models developed in EarthVision with process models developed in FEFLOW or MODFLOW. This allows us to develop highly accurate conceptual models that are not subject to the limitations of the solids modeling tools packaged with the groundwater modeling programs.

The two fundamental components are the Geologic Framework Model (GFM) and the Groundwater Model (GWM). The purpose of the GFM is to incorporate geologic, hydraulic, contaminant, and structural data into grid-based, visual, and query-able interpretative models of existing conditions. The GWM uses the gridded data exported from the GFM to define the conceptual framework and initial conditions for predictive modeling. We use EarthVision to develop the GFM because it allows for deterministic and/or stochastic methods to model spatial relationships between geologic surfaces, parameter distributions and engineered features. A GWM can then be constructed with a variety of software such as FEFLOW or MODFLOW through the use of grids exported from the GFM.

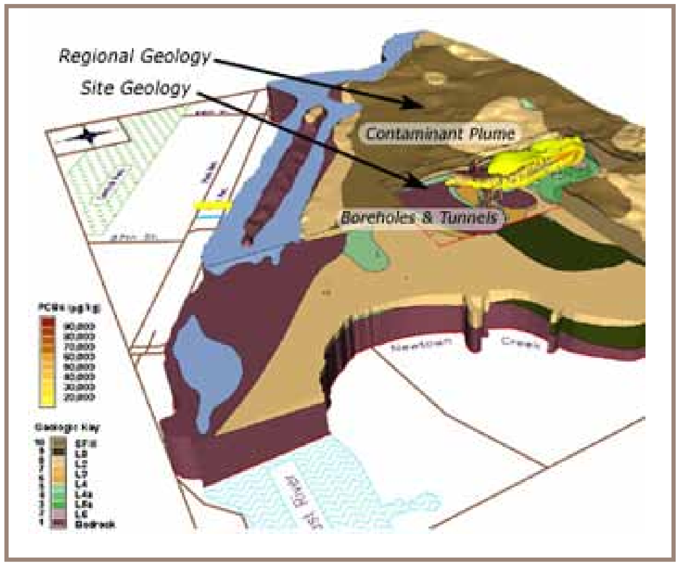
There are many benefits of a Dual Modeling Approach™ to groundwater resource management and site characterization efforts. The development of a GFM independently provides for better interpretations of site data, increased access to those interpretations, and the ability to rapidly update model interpretations



as new data becomes available. Incorporation of GFM grids into a GWM reduces model development time and provides for better and more rapid model calibrations because model frameworks can embrace more site complexities. We have successfully applied the Dual Modeling Approach™ to numerous site characterization projects including a large tunnel-construction project in New York City and industrial contamination sites in Florida, Illinois, and Pennsylvania, and to a number of groundwater resource management problems in New York, Pennsylvania, and an extensively karstified region of north Florida.

Services

GeoHydros is primarily a modeling specialty firm that provides geologic modeling, 2D & 3D visualization, and hydrologic modeling services under subcontract to larger environmental engineering firms as well as federal, state, and local government agencies, and private clients. We typically perform these services in concert through what we call our Dual Modeling Approach™ wherein we use in-house software to link modeling programs and facilitate output development and web-based presentation. We have also developed highly specialized skills in GIS, database development, and karst aquifer characterization that we perform independently or in conjunction with modeling projects. Our proprietary post-processing modeling software allows us to deliver high quality modeling visualizations for almost any environmental project: $5,000 to $500,000 in scope.



Geologic Characterization

- More than 20 years experience in developing computer generated Geologic Framework Models (GFMs), sometimes called Conceptual Site Models (CSMs), and 2D and 3D visualizations of data and process modeling results.
- Synthesize geologic, hydraulic, contaminant, & structural data into highly visual, readily query-able models.
- We use EarthVision - the most sophisticated commercially available solids modeling and 3D visualization software.
- Extensive experience with the Structure Builder, Workflow Manager, Graphic Editor, Formula Processor, Minimum Tension surface and isochore gridding, Base & Contour Mapping, and the Geostatistical Analyses tools.
- Extensive library of proprietary programs that automate data manipulation, model development, and output generation processes making our models uniquely cost effective and accessible to project teams.

Water Resource Management

- Numerical groundwater flow modeling to define aquifer vulnerability and well head protection zones.
- 2D & 3D particle tracking to delineate well capture zones in unconfined aquifers and specific recharge areas in confined aquifers.
- Surface water modeling to define watershed flows and assess hydraulic requirements for engineered structures.
- Extensive experience in modeling flow through karst, fractured rock, and extremely heterogeneous aquifers.
- Use numerous hydrologic modeling codes: MODFLOW-GMS, MODFLOW-Groundwater Vistas, FEFLOW, HydroCAD, MT3D, RT3D, and ArcGIS-Spatial Analyst.

Karst Characterization

- Numerical modeling of groundwater flow using dual-permeability frameworks.
- Delineation of probable conduit pathways, springsheds, and aquifer vulnerability zones.
- Simulation of spring flow response to groundwater pumping and contaminant transport for spring vulnerability assessments.
- Quantitative groundwater tracing using fluorescent dyes, automatic water samples, insitu optical fluorometers, and laboratory spectral fluorescence analysis.
- Interpretation of aquifer hydraulics from quantitative tracer recovery curves.
- Spring, swallet, and karst feature surveys.
- Hydraulic metering and data analysis.
- Cave survey, mapping, & 3D modeling.

Contaminant Transport

- Numerical simulation of dissolved-phase transport in groundwater using FEFLOW, MT3DMS, & RT3D.
- Transient plume volume estimation and center-of-mass tracking derived from numerical odeling results.
- 2D & 3D visualization of simulated plume configuration and movement using EarthVision.
- Optimization and/or evaluation of remediation system design based on transport scenario analyses.
- Synoptic plume volume estimation & 3D visualization.
- Impacted soil volume calculation & 3D visualization.

Rapid Site Characterization

- Rapidly and accurately visualize geophysical, MIP, and soil & groundwater contaminant data in 2D & 3D.
- Correlate rapidly collected data (MIP & geophysical) with laboratory analytical and log analysis data to expedite analysis and interpretation.
- Develop data gap analyses to optimize data collection.
- Leverage secure website technologies to share data and model viusualizations with project team.
- Automate production of data and model visualization sets and website uploads to reduce turn around time.
- Standardize figure and presentation templates to reduce time and costs associated with reporting.

NAPL Characterization

- 3D LNAPL Plume Delineation & Volumetric Analysis
- 3D LNAPL & DNAPL plume delineations from thickness, concentration, or indicator data.
- Total recoverable LNAPL estimation using Van Genuchten approach and gridded soil parameter datasets.
- Impacted soil volume calculations & removal analyses.
- Automated volume updates using synoptic apparent LNAPL thickness and water table elevation data.
- Animated plume movement analyses along with volume and center-of-mass tracking.

Database & GIS

- More than 10 years experience in customized database and web-based database interface development.
- Proprietary geospatial database attributes:
  - geologic, hydraulic, and contaminant data in a single data model;
  - easy-to-use spreadsheet data upload templates;
  - queries and reports specifically designed to produce datasets formatted to conform to EarthVision and process modeling input requirements; and
  - web-based user interface that allows for data queries that deliver data files and graphical output over the Internet.
- Web-based interface allows anyone on a project team to develop graphical output on the fly from a single data source that provides for a full QA/QC history on all data entries.
- Data model is fully compatible with EPA's STORET and directly accepts transfers from emerging automated laboratory reporting formats.

Resources

GeoHydros maintains a small group of highly specialized professionals such that we can provide more in-depth knowledge and expertise than is typically available in larger firms. Our areas of expertise include: hydrogeology, karst hydrogeology, geochemistry, groundwater modeling, solids modeling, data visualization, and GIS. In calling on these skills, we pride ourselves on being able to use the most advanced and appropriate modeling tools to solve environmental problems for our clients.

Project Locations to Date *(Geographic Scope of Services)*

LOCATION	PROJECTS / YEARS WORKED	SERVICES PERFORMED
Florida – North	12 / 7	Karst Hydro, GFM, GWM, DB Dev., Pub Ed
Florida – Central	7 / 5	Karst Hydro, GFM, Data Viz, GWM, FTM
Illinois	1 / 3	GFM, Data Viz
Kansas	1 / 1	GFM, Data Viz
Nevada	1 / 1	GFM
New Jersey	3 / 2	GFM, Data Viz
New York – New York City	4 / 4	GFM, GWM, FTM
New York – Central	1 / 1	Karst Hydro, GFM
Pennsylvania – East	15 / 8	Hydro, Karst Hydro, GFM, GWM, FTM, Pub. Ed.
Pennsylvania – Central	4 / 3	Hydro, Karst Hydro
Wyoming	1 / 1	DB Dev, GWM
Colorado	2 / 2	Data Viz
New Mexico	2 / 2	Data Viz

Hydro: hydrogeology / Karst Hydro: karst hydrogeology / GFM: geologic framework modeling / GWM: groundwater flow modeling / FTM: fate and transport modeling / DB Dev: database development / Data Viz: data visualization / Pub. Ed: public education

Office Staffing

OFFICE	# STAFF	STAFF BY FUNCTION	SPECIALTY AREAS
Reno, NV 27 Keystone Avenue Reno, Nevada 89503 (775) 337-8803	5	2 Geologic Modeler 2 Groundwater Modeler 1 GIS Specialist	Geologic (solids & parameter) Modeling Groundwater / Fate & Transport Modeling 2D & 3D Visualization, GIS Database Development Physical Hydrogeology & Karst Hydrogeology
Tallahassee, FL 1549 Yancey Street Tallahassee, Florida 32303	2	2 Hydrogeologist	Karst Aquifer Characterization Groundwater Tracing

Software / Hardware Resource

SOFTWARE	QTY	HARDWARE	QTY
Dynamic Graphics EarthVision™ Version 7.5	2	Workstation Modeling Computers	4
FEFLOW™ Version 5.3	2	Laptop Presentation Computers	2
MODFLOW-GMS Version 6.5	1	File & Application Servers	3
MODFLOW-GMS Version 5	1	Large Fromat Legacy Paper Map Digitizer	1
MODFLOW-Groundwater Vistas Version 4	1	-	-
ESRI ArcGIS 9.3 – Arc View	2	-	-
ESRI ArcGIS 9.3 – Spatial Analyst	1	-	-

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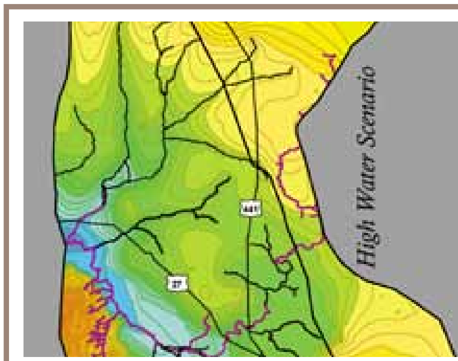
BIOS



Todd R. Kincaid, Ph.D.

Home Office:
Reno, NV
Title:
Group Leader / Geologic Modeler
Education:
Ph.D., Geohydrology, University of Wyoming, Laramie, WY 1999
M.S., Hydrogeology, University of Florida, Gainesville, FL, 1994
B.S., Geology, University of Florida, Gainesville, FL, 1991
Years with GeoHydros:
11 years
Modeling & Geological Experience:
14 years
Past Project Roles:
Project Manager
Geologic Modeler
Hydrogeologist
Geologist
Areas of Expertise:
Geologic modeling & data visualization
Karst Hydrogeology
Groundwater Tracing
Physical Hydrogeology

Dr. Kincaid leads GeoHydros. He has a diverse background in geology and hydrogeology and has extensive knowledge of karst hydrogeology. His experience includes: quantification of groundwater/surface water exchange; groundwater tracing using isotopic and artificial tracers; environmental site characterizations and remediation; aquifer characterization; and modeling complex geologic environments. Dr. Kincaid is currently managing a groundbreaking aquifer characterization study of the Woodville Karst Plain of north Florida with the Florida Geological Survey and the Florida DEP, which synthesizes groundwater tracing, cave mapping, and hydraulic data into one of the first numerical models that truly embraces karst complexities (www.geohydros.com/FGS). He has authored several professional reports as well as numerous professional and academic papers for national and international journals and symposia. He regularly participates in meetings with local and state agencies as well as legal proceedings to convey modeling results to regulatory and lay audiences.

Dr. Kincaid manages the Reno office where he provides scientific oversight for all GeoHydros modeling activities. In addition, he personally prepares most of our reports and presentations, delivers public presentations on our work, and provides expert testimony. As principal, he is also responsible for quality assurance, client management, and financial oversight.

Kevin E. Day, M.S., P.G.

Home Office:
Reno, NV
Title:
Hydrogeologic Modeler
Education:
M.S., Geology, University of Wyoming, Laramie, Wyoming 2000
B.S., Geology, Colgate University, Hamilton, New York 1993
Years with GeoHydros:
9 years.
Modeling & Geological Experience:
13 years
Past Project Roles:
Hydrogeologist
Software Designer
Areas of Expertise:
Geologic modeling & data visualization
Groundwater flow and fate and transport modeling
Database design and management
Computer programming
Registrations:
California P.G. - License # 8034
Florida P.G. - License # 2517

Mr. Day's is our primary geologic modeler having extensive knowledge of and experience with EarthVision and UNIX programming. His responsibilities include geologic and solids modeling, groundwater flow modeling, database design and management, software application development, GIS, and database management. He is fluent in the groundwater modeling programs: GMS-MODFLOW, MT3D, and FEMWATER, and ESRI GIS. His more notable project examples include the development of a combined regional and site-scale 3-D Geologic Framework Model (GFM) of the DSCP facility in Philadelphia, Pennsylvania for the USDOD; a regional-scale geologic model of a fractured rock aquifer containing 65 variably thick faulted and dipping stratigraphic units for Bucks County Pennsylvania; a detailed site-scale geologic model relating stratigraphic information from more than 150 boreholes and 2-D seismic data for a contaminated former industrial site in Gainesville Florida; and design and development of a relational database and data entry templates for the Florida DEP Hazardous Waste Program.

Mr. Day has written a library of programs to address complex subsurface computational problems and streamline communication between various software applications and our project database including a cutting edge program that solves the problem of partially penetrating wells in isopach-based geologic models.

Brent A. Meyer, M.S.

Home Office:
Reno, NV
Title:
Hydrogeologic Modeler
Education:
M.S., hydrogeology, University of Nevada, Reno, Nevada 2004
B.A., Geology, University of Montana, Missoula, Montana 1997
Years with GeoHydros:
6 years
Modeling & Geological Experience:
8 years
Past Project Roles:
Geochemical Database Developer
Head Laboratory Technician
Areas of Expertise:
Groundwater flow systems
Geochemical modeling
Data management

Mr. Meyer is our primary groundwater flow modeler having extensive experience with FEFLOW and the simulation of complex heterogeneous, anisotropic, and dual permeability aquifer systems. His responsibilities include groundwater flow and fate and transport modeling, geologic and solids modeling, geochemical modeling, and GIS. He is fluent in the ESRI suite of GIS software, and the geochemical modeling software, Visual MINTEQ and also has significant experience with EarthVision, MODFLOW, and surface water modeling with Spatial Analyst.

Mr. Meyer's more notable project examples include the design and calibration of a 3D regional-scale groundwater flow model for Bucks County, PA that embraced multiple lithologic units, regional scale faults, and anisotropic aquifer properties and was used to delineate wellhead protection zones through 3D particle tracking. He also developed two 3D dual-permeability regional-scale groundwater flow models for parts of north-central Florida that simulate the location and capacity of karst conduits, discrete spring discharges, and discrete swallet recharge and that calibrate to heads, spring flows, and tracer-defined groundwater velocities at both high and low water conditions. As a geochemist, Mr. Meyer was responsible for designing a geochemical/microbiological laboratory for the University of Nevada and the USGS that performed growth experiments involving anaerobic iron reducing bacteria.

Vanessa L. Belz

Home Office:
Reno, NV
Title:
Office Manager/GIS Technician
Education:
BA, Adventure Education, Prescott College, Prescott, AZ 1998
Certificate Program course work in Applied GIS, University of Utah, Salt Lake City, Utah 2003
Years with GeoHydros:
1 year
GIS Experience:
3 years
Past Project Roles:
GIS Technician
Areas of Expertise:
GIS, Office Management

Ms. Belz is our Office Manager as well as a GIS Technician. Her responsibilities include all aspects of office and financial management as well as developing GIS coverages in support of our modeling projects.

After obtaining her B.A. in Adventure Education from Prescott College, Arizona in 1998, Ms. Belz completed coursework in Applied GIS at the University of Utah in 2003. She enthusiastically proposed and executed her first GIS project by identifying backcountry access gates based on terrain analysis and field surveys at the Canyons Ski Resort in Park City, Utah. Her most recent notable GIS project includes working with the Mattole Restoration Council in Humboldt County, California to develop presentation- and professional-grade maps used to support funding of proposals, community education, cooperative management plans and field applications. She worked with the Mattole Restoration Council in securing funding from Department of Fish and Game, State Coastal Conservancy, State Water Quality Control Board and California Resources Agency and contributed to the watershed restoration efforts of a north coast community.

BIOS

Kristie A. Connolly

Home Office:
Reno, NV
Title:
GIS Technician
Education:
BS, Geography, University of Wyoming, Laramie, WY 1994
GIS Certification, Pennsylvania State University, State College, PA 2002
Years with GeoHydros:
10 years
GIS & Mapping Experience:
12 years
Past Project Roles:
GIS Technician, Field Geologist
Areas of Expertise:
GIS, Map Production, Office Management

Ms. Connolly has worked for the GeoHydros group since the group's inception in 2000 on a part-time basis performing GIS, mapping, and data management services. She has combined ArcGIS, database, digitization, and spreadsheet technologies to convert data from various sources into the formats required for use in our EarthVision and FEFLOW modeling programs. She has also used ArcGIS and Adobe graphic editing software to render high quality map deliverables from our modeling output and used web development software to upload deliverables to client websites.

One of her project examples includes the development of a GIS database for subsurface utilities at a Department of Defense site in Philadelphia, Pennsylvania for Foster Wheeler Environmental Corporation that was used to render 3-D models of the features that were included in a site geological framework model.

GeoHydros LLC

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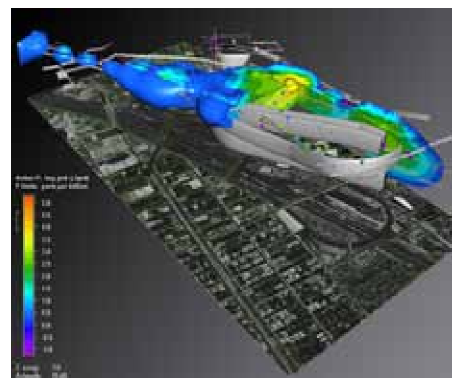
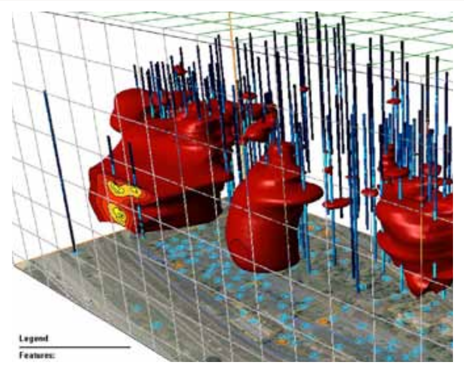
SKILLS



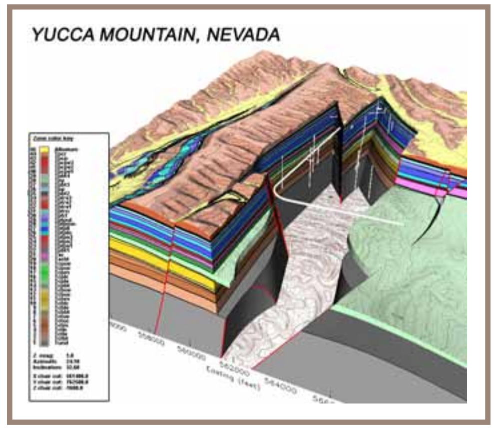


SKILLS

EarthVision™

Dynamic Graphics EarthVision The GeoHydros Modeling Group has more than 20 years of experience in the use of EarthVision (EV) for solids and parameter modeling, and data visualization. We have extensive experience with the Structure builder, Workflow Manager, Graphic Editor, Formula Processor, Minimum Tension surface and isochore gridding, and the Base & Contour Mapping modules and are adept in the use of most of the software's other components. In addition, we have developed an extensive library of UNIX shell scripts to automate various data manipulation processes, develop unique stratigraphic and property model development processes, and automate output generation and image website production. We've enjoyed numerous opportunities to work with Dynamic Graphics Inc. (DGI) technical support staff to develop modeling processes and have been invited by DGI to lecture on our modeling work and processes at their EV user meetings.

Complex Fault Blocks & VolcanicTuff



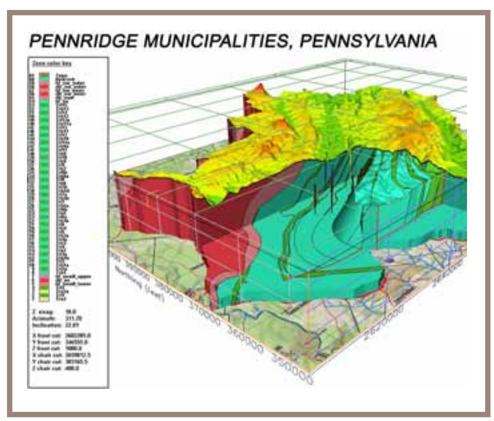
Example: *Yucca Mountain Project - Geologic Framework Model*

- 31 square kilometers (12 square miles)
- 42 stratigraphic units of variable thickness positioned across eighteen normal fault blocks
- 6-mile horizontal tunnel ~25 feet in diameter
- Constructed from published geologic maps, 101 boreholes, information from tunnel data, and measured stratigraphic sections from outcrop areas.

Example: *Nevada Test Site*

- Developing and revising geologic framework models to support contaminant transport modeling in the corrective action units.

Dipping Hydrostratigraphic Units & Intrusions



Example: *Pennridge Aquifer Protection Model, Bucks County PA*

- Developed comprehensive geologic framework model to support groundwater flow model designed to delineate well capture zones and aquifer vulnerability areas.
- Model simulated 60 interbedded lithologic units of varying thickness, geometry, and permeability that are structurally tilted in a synclinal basin, faulted at one end, and intruded by a diabase.
- Developed model using strike and dip information and outcrop boundaries obtained from published geologic maps.
- Exported framework to FEFLOW for groundwater flow modeling.

SKILLS

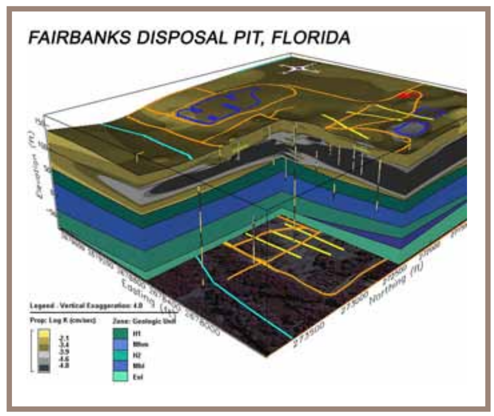
EarthVision™ *(cont'd)*

Severely Heterogeneous Contaminanted 3D Aquifer Systems

Example: *Defense Supply Center Philadelphia, Pennsylvania*

- Combined site- and regional-scale geologic framework model supporting groundwater flow and transport models.
- Integrated stratigraphic, lithologic, and electrical conductivity data from more than 1000 boreholes.
- 32 mi2 (regional-scale) and 4.75 mi2 (site-scale).
- 8 discontinuous and variably thick stratigraphic units over an eroded bedrock surface.
- Heterogeneous lithologies in upper 4 zones modeled probabilistically and independently of stratigraphy.
- Distribution of LNAPL, soil contamination, and dissolved phase contamination relative to geology and underground structures.

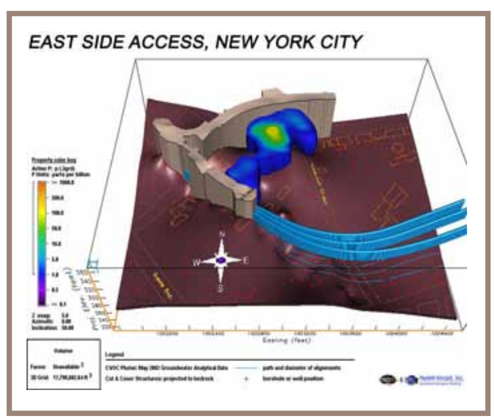
Siesmically Defined Karstic Flow Paths



Example: *Fairbanks Disposal Pits, Gainesville Florida*

- Delineated structural controls on possible vertical hydraulic communication between a surficial contaminated zone and underlying Floridan aquifer.
- Used borehole and seismic data to model confining layer surfaces relative to a heterogeneous distribution of soils.
- Identified contaminant migration pathways based on truncations in confining layers associated with karstic depressions.
- Six stratigraphic zones and variation in hydraulic conductivity defined by discrete soil sampled intervals.

3D Contaminant Plume Movement



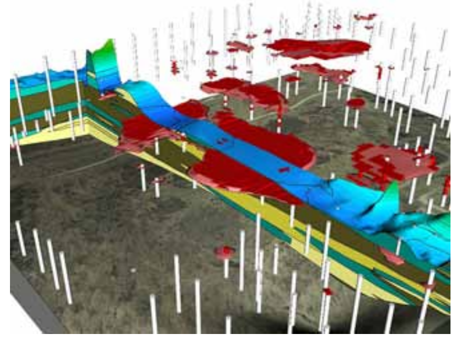
Example: *East Side Access Project, Long Island New York*

- Imported results from 3D contaminant transport model at 30 time-steps from FEFLOW to an EarthVision geologic framework model of stratigraphic units and underground engineered structures (right).
- Developed computer scripts to automate visualization modeling, output generation, and export to a secure project website.
- Visualization models used to track plume volumes at critical concentration levels, and center of mass movement.
- Animations created to visualize predicted plume movement over time under build and no-build scenarios for every model run to facilitate effective interpretation and evaluation.

EarthVision™ (cont'd)

Probablistic Zone / Parameter Delineation

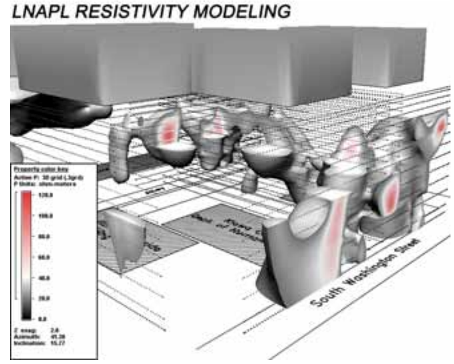
REFINERY TAR SLUDGE, ILLINOIS



- Developed probabilistic method similar to indicator kriging to define the 3D distribution of zones or parameters in the subsurface based on observation data.
- Method is useful for both lithologic zone delineations and non-aqueous phase contaminant delineations such as tar sludge (right) or LNAPL.
- Process defines the extent of the zone or contaminant at specific confidence levels i.e. 90% confidence, 75%, 50%, etc.
- Process is scripted to facilitate rapid updates with new or reinterpreted data.
- Developed visualization modeling scripts to rapidly and automatically generate image output and volumetric reports that are uploaded to a secure project website.

Geophysical & GeoProbe-MIP Data Visualization

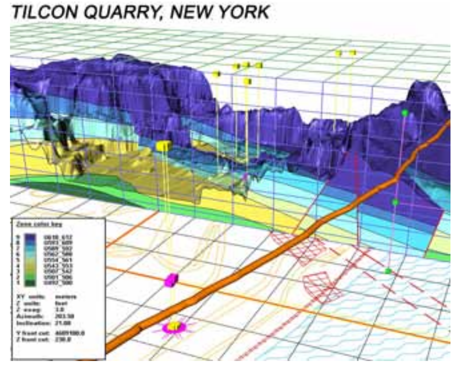
LNAPL RESISTIVITY MODELING



- Developed visualization modeling scripts to automatically read geophysical and GeoProbe-MIP data files.
- Integrate 3D grids with variable grid spacings to account for data that becomes progressively sparse in the z-direction.
- Initial modeling used to constrain interpretive contouring controls and establish standard visualization sets that include key underground and surface structures.
- Automate model generation, visualization production, and volumetric reporting and upload to a secure project website.
- Models and output processed in hours after receiving field data allowing modeling to help guide field characterization efforts.
- Right – LNAPL defined by surface resistivity relative to building locations on the surface.

Structural Modeling for Mining & Quarrying

TILCON QUARRY, NEW YORK

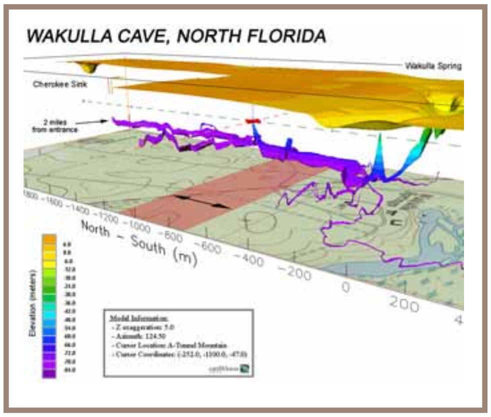


- Model faults, fault zones, and fault displacements in addition to stratigraphic units, and land surface elevations.
- Use multiple data sources including borehole logs, geophysical surveys, and outcrop mapping.
- Can also incorporate mineralogic zonation within stratigraphic units and fault blocks using parameter data.
- Use models to identify target zones, infiltration problems, structural assessments, and as the framework for subsequent groundwater flow modeling used for environmental impact assessments.
- Right – 3D model of the Tilcon Quaryadjacent to the Hudson River in New York that was used to delineate areas in the river contributing infiltration to the quary.

SKILLS

EarthVision™ (cont'd)

Cave & Conduit Modeling



- Developed 3D structural and parametric model of complex subsurface features such as karstic caves (right) using non-standard data such as cave survey data.
- Used models to relate underground features to land surface locations to guide decisions on land-use and development.
- Used models as platform to evaluate trends in measured parameters such as water chemistry, flow, etc.
- Used modes for public presentations to increase awareness of environmental vulnerability as well as development risks.
- Used models to support detailed flow and transport assessments.

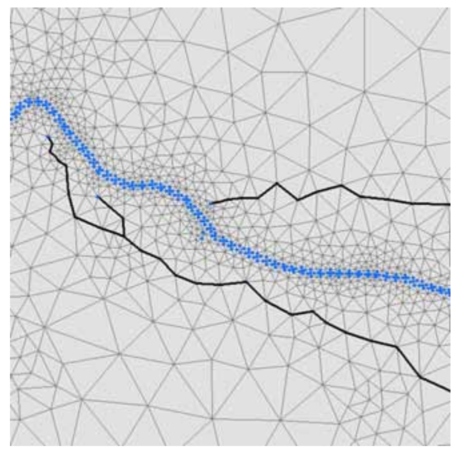
SKILLS

FEFLOW

WASY-DHI FEFLOW

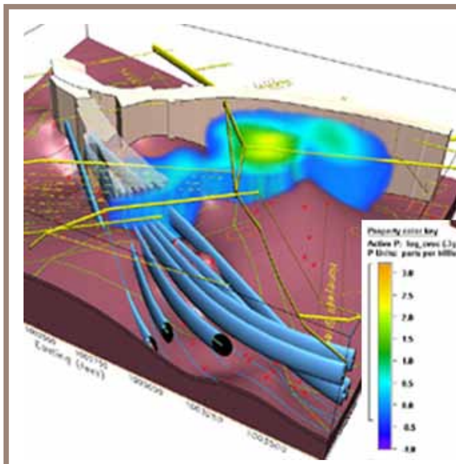
The Geohydros Modeling Group has more than 8 years of experience in the use of DHI-Wasy FEFLOW software including the most current version, 6.0. FEFLOW is our software of choice when developing groundwater flow or contaminant transport models because of its superior ability to solve large, sparse matrix systems using PCG-type or algebraic multigrid solvers and because of the flexibility of finite element gridding when simulating systems with complex geologic and hydrologic characteristics. In addition, FEFLOW is fully integrated with ArcGIS allowing for fast and accurate model design and time efficient model calibration and scenario runs. The following sections provide brief examples of our group's FEFLOW skill sets and how those skills have been applied successfully for our clients.

Discrete Element Features



- Developed dual-permeability model using discrete element package to simulate conduit and matrix flow in a karst aquifer (right).
- Karst conduits defined as two-dimensional (horizontal and vertical) linear elements assigned along mesh element limbs.
- Conduits defined between known swallets (infiltration nodes) and springs (discharge nodes) and up-gradient from springs into matrix.
- Flow through conduits defined using Manning-Strickler equation.
- Cross-sectional area used to define capacity of conduit conveyance.
- Roughness factor used to control velocity of water flow (degree to which feature represents a single conduit or zone of conduits).
- Conduit locations and dimensions determined through calibration to groundwater levels, spring discharges, and tracer-defined groundwater velocities.

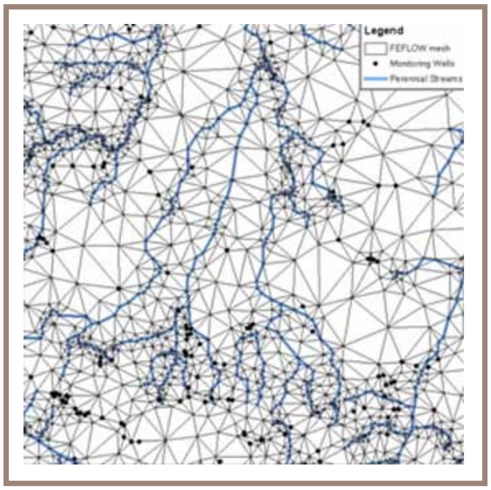
Free Surface Modeling & Contaminant Transport



- Used free and movable surface option to simulate transport through variably saturated hydrostratigraphic units and units that pinch out laterally across large model domains.
- Used shock capturing (non-linear anisotropic damping) to stabilize transport simulations affected by numerical oscillations.
- Simulated both simple mass transport and reactive transport through 2D and 3D groundwater flow model domains.
- Simulated both point source and non-point source contaminant transport through 2D and 3D groundwater model domains including nitrate transport through karst aquifers and CVOC transport through extremely heterogeneous mixed glacial surficial aquifers.
- Exported FEFLOW mass transport results by time-step to EarthVision™ (right) to visualize 3D mass transport relative to underground structures and to estimate resulting impacted earth volumes.

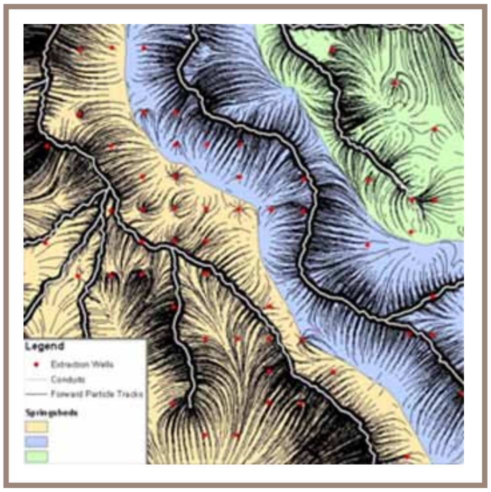
FEFLOW *(cont'd)*

Complex Mesh Designs



- Integrated FEFLOW mesh building with ArcGIS to facilitate complex mesh design and refinement.
- Developed complex meshes to simulate lateral and vertical geometries of complex natural and man-made structures that impact groundwater flow including dendritic karst conduits that converge to springs and rivers (right).
- Simulated features include: thin, discontinuous lenses of different material properties, large domes and dikes, steeply dipping lithologies with varying material properties; streams, rivers, springs, and lakes; and sewers and grout walls.
- Ensure that all meshes conform to minimum element angle criteria to promote convergence and minimize model errors.
- Integrate mesh design with EarthVision™ such that lithologic heterogeneities can be defined directly from detailed geologic modeling.

Particle Tracking



- Use 2D and 3D backward particle tracking to define capture zones for wells and springs.
- Use 3D particle tracks to define recharge areas (contributing zones) for wells and springs.
- Use 2D particle tracks to delineate traditional EPA Zone II wellhead protection zones.
- Export 3D particle tracks to EarthVision™ to develop animations showing flow paths through geologic structure.
- Use forward particle tracking to delineate groundwater basins, springsheds, and vulnerability zones such as contributing zones to conduits that convey groundwater to springs and rivers (right).
- Export 2D particle tracks to ArcGIS for map and figure production.

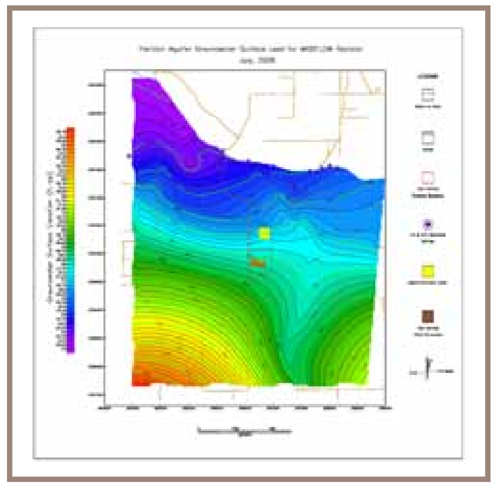
SKILLS

MODFLOW

MODFLOW (GMS)

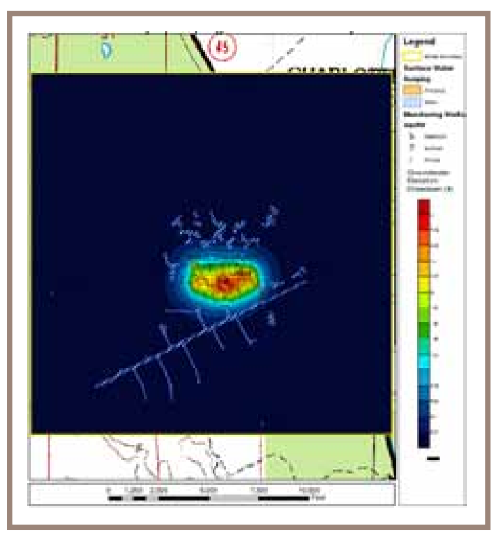
The GeoHydros Modeling Group has over ten years experience using MODFLOW and several of its modules to provide answers to a range of groundwater flow as well as 2D and 3D contaminant fate and transport questions. MODFLOW is the US Geological Survey's modular finite-difference computer code that solves the groundwater flow equation, and has been repackaged with a graphical interface by several software development companies. GeoHydros licenses the most recent version of GMS (6.5), developed by AquaVeo, and also maintains a license of Groundwater Vistas. In addition, the GeoHydros Group has extensive experience with several MODFLOW modules that we use to address more complex problems including: MT3DMS (multi-species mass & reactive transport in 3D) , SEEP2D (a finite-element cross-sectional modeling package), PEST (parameter estimation / optimization), MODPATH (particle tracking), RT3D (reactive transport in 3D), and T-PROGS (transition probability geostatistical package for lithologic modeling).

Parameter Estimation (PEST)



- A model-independent, non-linear parameter estimator. The purpose of PEST is to assist in data interpretation, model calibration, and predictive analyses.
- Used PEST to delineate high permeability zones in a karst aquifer by optimizing the permeability structure to achieve a best-possible calibration to groundwater levels recorded in a dense monitoring well network (right shows resulting steady-state flow field).
- GMS PEST allows modeler to revise parameter settings such as permeability zone delineations during the optimization process and to assign pilot points to provide a continuous rather than stepwise distribution of parameters where appropriate.
- Use composite and relative sensitivity reporting to rank the significance of parameters to the final model results.

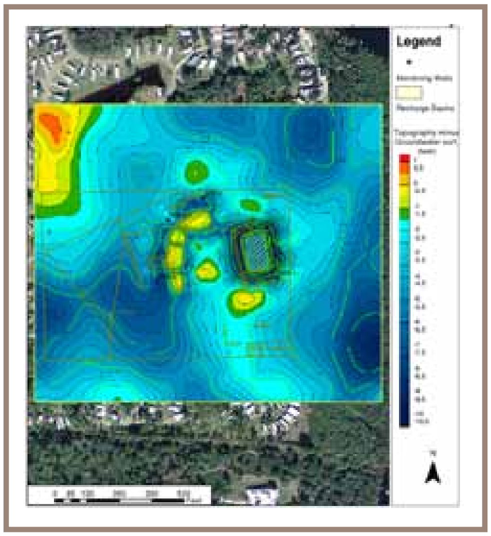
Drawdown / Zone of Influence Delineation



- Used GMS MODFLOW to predict the cone-of-depression created by proposed well installations on a water table surface (right).
- Developed scenario analyses to predict impact of pumping on private supply well water levels in confined and unconfined aquifers; and impacts to wetland water levels and hydroperiods in unconfined aquifers during wet, dry, and average conditions.
- Developed transient models to determine threshold time periods in support of permit application processes.
- Integrated model construction and output processes with EarthVision™ and ArcGIS to facilitate model framework construction in complex geologic settings, map and figure production, as well as definition of surficial features into the groundwater simulation such as River, Lake, Drain, General Head, Well, Horizontal Flow Barrier, Stream, Time Variable Specified Head, Recharge and Evapotranspiration boundary conditions.

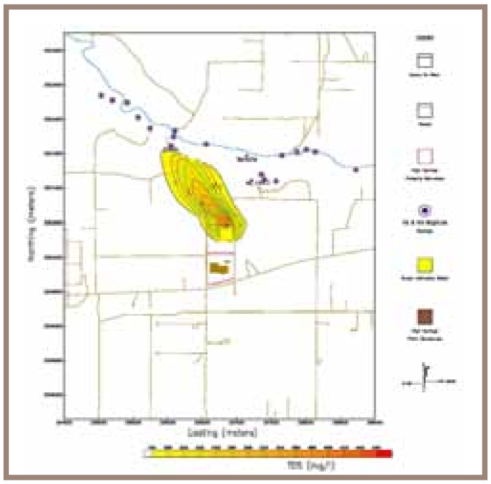
MODFLOW *(cont'd)*

Mounding Evaluation & Prediction



- Used GMS MODFLOW to quickly evaluate the potential impact of engineered infiltration basins on surficial aquifer water levels (right).
- Rapidly developed quantitative scenario analyses to provide clients and regulators with map-based predictions that facilitated design and permitting decisions.
- Used scenario analyses to test effectiveness of proposed mitigation strategies when the proposed activities were predicted to generate unacceptable surficial groundwater levels or flooding.
- Performed similar analyses to determine the transient effects on adjacent wetlands of drawing down engineered lake features to supply dry-season irrigation water.

Mass Transport (MT3DMS)



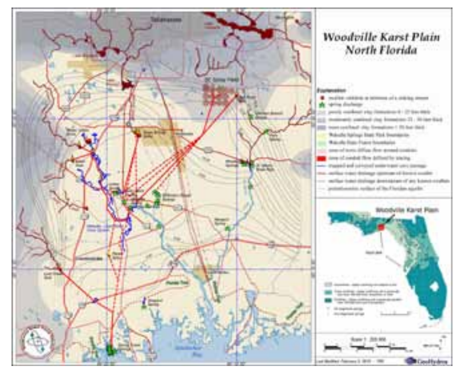
- Simulates multi-species transport by advection, dispersion, and chemical reactions of dissolved constituents in groundwater.
- Used MT3DMS to simulate advection, dispersion, and chemical reactions of dissolved constituents in groundwater systems.
- Projects include: simulation of TDS transport from reverse osmosis wastewater ponds (right); and benzene and MTBE transport from LUST sites.
- Routinely capitalize on GMS/MT3DMS interface to configure separate zones of dispersion and chemical reactions based on field observations or estimations.

ESRI ArcGIS™

ESRI ArcGIS

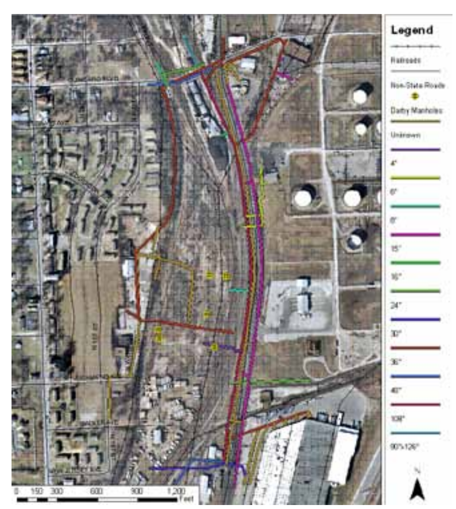
The GeoHydros Modeling Group has more than 10 years of experience in the use of ESRI ArcGIS software including all versions between ArcView 3.2 and ArcGIS 9.3 as wells as Spatial and 3D Analyst. ArcGIS is an instrumental tool in our workflow wherein we use it for pre-processing geospatial data into the required modeling formats, exchange of data and results between modeling platforms, analysis and interpretation of modeling results, and ultimately for the presentation and delivery of data files and final modeling results. Our group's expertise includes spatial projection, geo-spatial analysis and database manipulation, visual basic programming, and publication quality map production. Our group has also performed several GIS specific projects ranging from mine green field site selection to city utilities management.

Publication Quality Map Development



- Efficient and accurate production of quality print-ready maps for reports, articles and independent publication.
- Relating multiple datasets and modeling results to proprietary and publically available basemaps, and aerial photographs.
- Identifying and synthesizing publically available basemap data such as US, State and local roadways, rivers, watershed boundaries, and high resolution aerial photography.
- Porting unprojected or improperly projected maps and images into project projections and datums.
- Post-processing maps with high end image editing or graphic illustration software such as Adobe Photoshop (right).

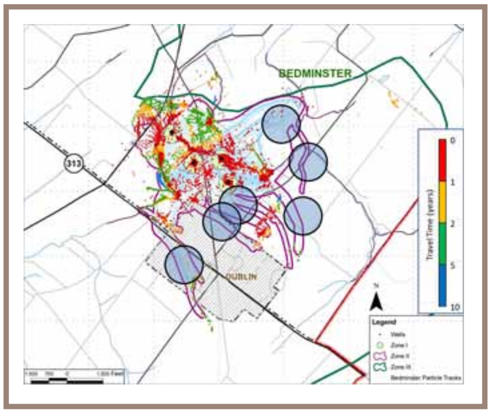
Interfaceing with Modeling Programs



- Developed computer programs to integrate results and output from MODFLOW, FEFLOW, and EarthVision into GIS compatible coverages that provide a standardized presentation interface.
- Developed computer programs that allow for rapid updates to model files and GIS output.
- Rapidly updated GIS allows for near real-time data gap analyses that our clients have used to optimize field characterization efforts.
- Developed computer programs to automatically port model output, GIS coverages, and maps to secure project website for rapid delivery to project6 team members.
- Our proprietary automated model and GIS update process significantly improves rapid site characterization (Triad) projects.

ESRI ArcGIS™ *(cont'd)*

Visualization & Analysis

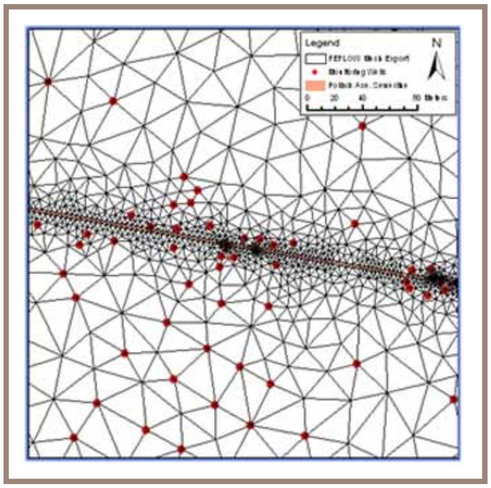


- Adept at porting all manners of model output and data into GIS coverages with standardized projections.
- Use GIS and Spatial Analyst to modify data and model results to facilitate interpretations and dissemination to project team members and regulatory agencies.

Example: *GIS interpretation and visualization of particle tracks*

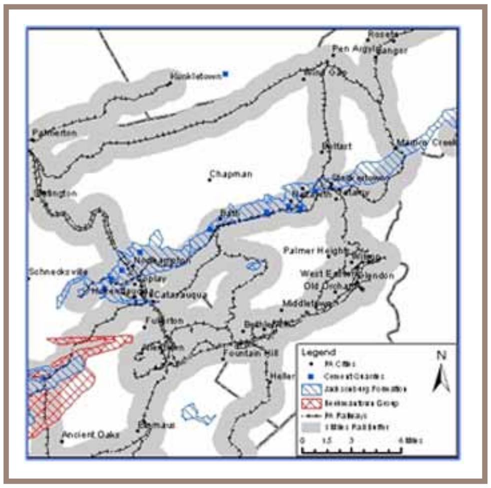
- 2D and 3D particle tracks exported from FEFLOW as polyline layers with data fields for depth of flow and groundwater velocity.
- Intersected paths with the land surface to identify model-defined recharge areas for the wells that were used for vulnerability mapping along with sources of potential contamination such as industrial zones, transportation systems, population centers, and mining regions.

Flow Model Development



- Use ArcGIS to delineate key spatial data such as wells, rivers, sewers, and hydrogeologically defensible parameter zones.
- Port hydraulically significant points, polylines, and polygons into MODFLOW or FEFLOW for grid/mesh development (right).
- Export mesh to ArcGIS to facilitate grid/mesh modifications to most accurately represent key features.
- Interpolate hydraulic conductivity, recharge, layer elevation and other hydrologic variables across model layers from points representing known measurement locations.
- Assign boundary condition values such as constant head, constant flux, and pumping / injection rates to model nodes.
- Manipulate parameter values on a zone-by-zone basis in between model runs during model calibration process.

Zone of Interest Delineation



- Develop formulaic approach for delineating specific regions of interest based on combinations of desirable characteristics defined in multiple lines of geo-spatial data.

Example: *Quarry green field site selection*

- Compiled and synthesized all forms of relevant data including surface and near surface geology, transportation corridors, and municipality boundaries and regulations.
- Developed formula that defined and ranked target zones based on criteria for each dataset (right)
- Developed maps with corresponding data tables from the GIS that were used to facilitate client decisions.

ESRI ArcGIS™ (cont'd)

Metadata Production

- Develop comprehensive meta-data files for all components of ArcGIS map sets including spatially projected maps and data streams supporting the maps.
- Developed proprietary tools for creating web-accessible metadata for project maps and data as well as publically available but not easy accessible datasets.

Example: *Florida Geological Survey Web Data Portal*

- Developed browser-based metadata catalog using Javascript and an XML data model http://www.geohydros.com/FGS/HydroPortal/.
- Developed computer program that produces metadata tables that can be updated with changes or added data in minutes.

User Interface Development

- Developed custom web-applications, online databases and web-based GIS interfaces.

Example: *Map Browser*

- Web interface that allows users to browse pre-constructed ArcGIS maps as small (quick loading) and large (viewable details) images and download full-scale versions of the maps as pdfs.
- Maps are organized by category and are rendered accessible by drop-down menus off of the Map Browser website.
- Developed Map Browsers for several water resource modeling projects with Coca-Cola, the Florida Geological Survey, and Hardin County, Ohio.
- Main benefits include low cost, ease of use, and that it is rapidly updatable as new maps are created or existing maps are modified.

SKILLS

GeoHydros LLC

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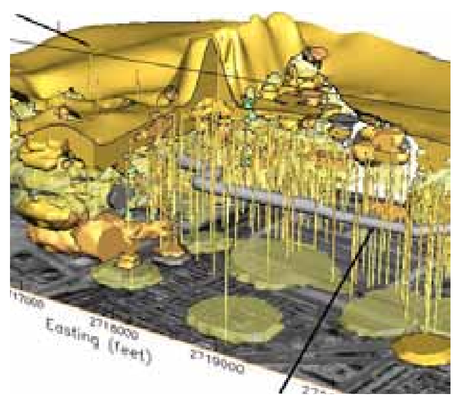
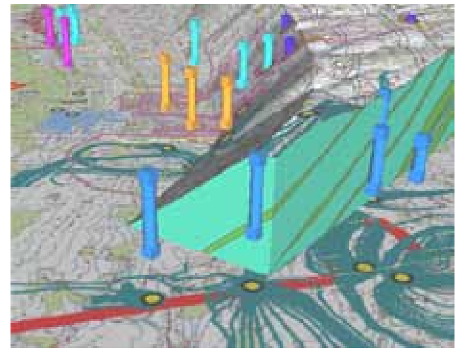
PROJECT EXPERIENCE





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GEOLOGIC CHARACTERIZATION

PROJECT NAME & LOCATION	DATE STARTED	DATE COMPLETED
DSCP Groundwater Remediation Philadelphia, PA	June 2001	On Going
ACTIVITY TITLE	**INITAL CONTRACT PRICE**	**FINAL AMOUNT INVOICED**
Geologic & Groundwater Flow Modeling	$450,000	~700,000

CLIENT NAME & ADDRESS	TECHNICAL CONTACT
Brian Blanchard / (215) 702-4066 Tetra Tech EC, Inc. / Langhorne, PA Brian.Blanchard@tteci.com	DESC / Hasan Dogrul / hasananddebbie@aol.com TTEC / Derek Pinkham / (215) 702-4070 Derek.Pinkham@tteci.com

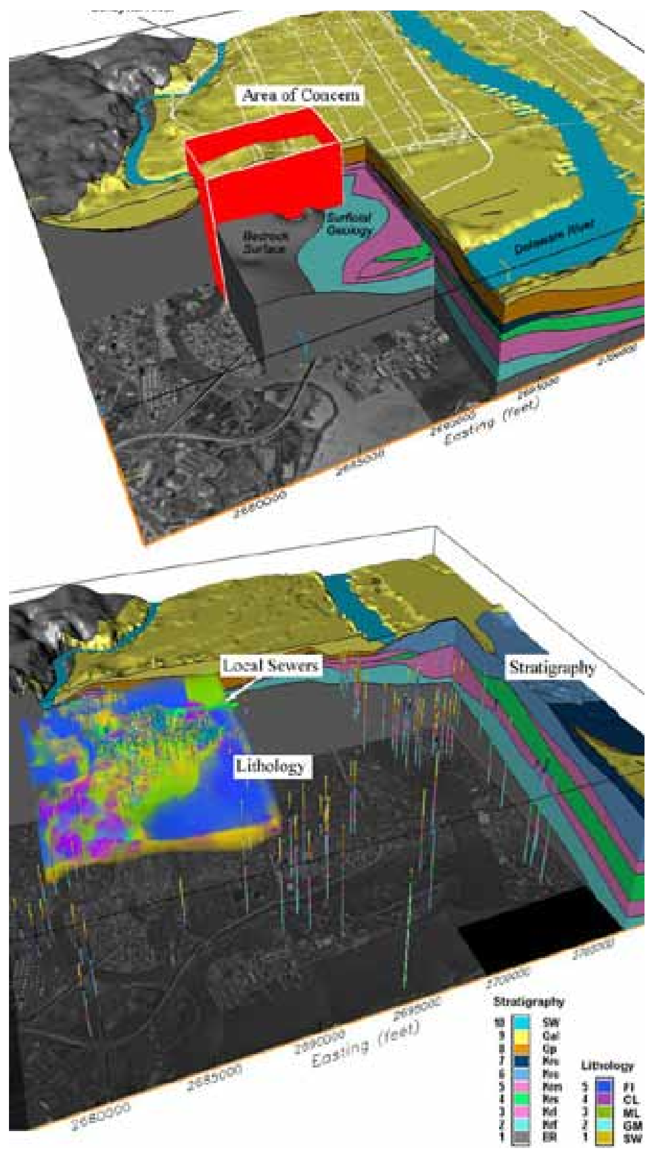
PROJECT DESCRIPTION

The Defense Energy Support Center (DESC), in collaboration with Tetra Tech EC, contracted the GeoHydros modeling group to construct a comprehensive geological framework model (GFM) for the Defense Supply Center Philadelphia (DSCP) and use the model as the basis for groundwater flow and contaminant transport assessments. The primary purpose of the GFM is to synthesize disparate datasets describing the stratigraphy and lithology of the site and region into a consistent interpretation of hydrostratigraphic controls on groundwater flow and dissolved and free-phase contaminant movement.

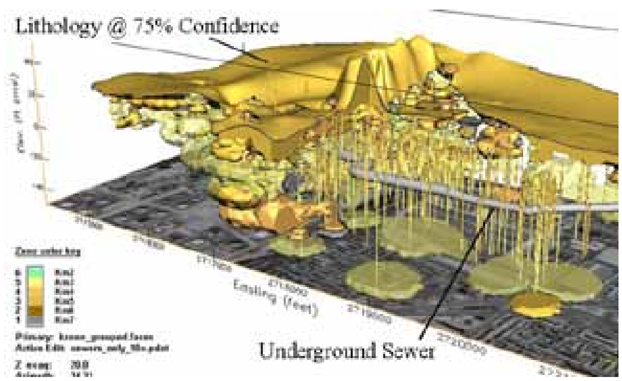
We first developed a scalable database to manage all site and regional geologic and hydraulic data. We then used EarthVision™ to develop surface, isochore, and parameter grids to evaluate the trend of regional stratigraphic units relative to reported lithologic variation. We used a telescoping gridding technique to identify and preserve regional trends at the boundaries of higher-resolution site-scale grids. We then developed an iterative grid stacking routine to insure that both thicknesses and surface elevations were honored in the final model simulation. This was done by adding isochore grids to the lower bedrock surface, checking the resulting surface elevations against all non-fully penetrating boreholes, and then distributing any error into the underlying units.

We developed and used a probabilistic approach to simulate 26 soil/sediment types that were defined across the site and group them into 5 groups having similar hydraulic conductivity. Each group was defined by its presence or absence at each data point and then unit probability grids were developed for each unit. The grids were then compared on a node-by-node basis to arrive at a model of lithology marking the 3D distribution of the units by their respective probabilities.

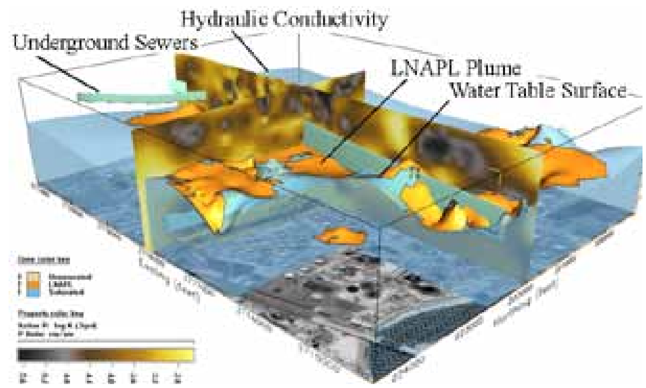
Confidence in the model simulation was defined by the distance to the closest data point. The probability model



Stratigraphic & Lithologic Framework Models
Site and Regional Scales of Analysis



Probabilistically Defined Lithology



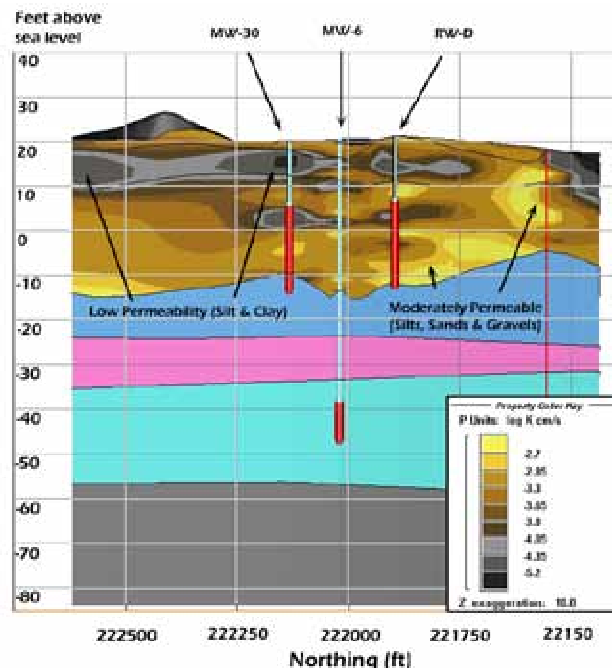
LNAPL vs Water Table, Sewers, & K

was then used to map hydraulic conductivity heterogeneity relative to underground structures and synoptic models of LNAPL morphology.

Overall, the GFM consolidated data from more than 1000 wells & borings collected over more than 15 years, paper maps and CAD files describing underground structures, digital topographic maps and surveys, aerial imagery, and published geologic maps. Perspective views, x, y, and z slices, and cross-sections were compiled to document and explain the model-simulated geo-spatial relationships.

Lithology, Stratigraphy & Well Screens

In 2009, work began on importing the stratigraphic and lithologic framework from EarthVision into FEFLOW. The regional stratigraphic horizons were imported directly to create the lower layers of the flow model. A program was written to assign the upper FEFLOW layers such that they intersect every lithologic contact described in the 3D grid resulting in a nearly perfect match between the conceptual and flow models. Both hydraulic conductivity and recharge in the flow model will be optimized to achieve a global calibration. Fate and transport modeling will then be performed to determine how dissolved-phase VOCs will migrate through the surficial aquifer away from the LNAPL and the extent to which contamination may travel vertically into a lower potable aquifer.



Lithology, Stratigraphy & Well Screens

SELF ASSESSMENT

We have met or exceeded all project expectations. The expanded budget reflects additional modeling work requested to meet evolving project requirements. Our most significant problems stemmed from managing data inconsistencies and adapting to evolving objectives or limitations imposed by a litigation effort. We developed database comparison protocols to ensure that all database changes enacted by the litigation team are identified and appropriately addressed in the modeling database. We automated model development processes that have allowed us to rapidly rebuild the GFM and all relevant visualizations to accommodate new data and/or revised interpretations. We also adopted a milestone approach to modeling to allow for periodic review with the remediation and litigation teams and adopt course adjustments as necessary.

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WATER RESOURCE MANAGEMENT

PROJECT NAME & LOCATION	DATE STARTED	DATE COMPLETED
Pennridge Wellhead Protection, Bucks Co. PA	January 2005	May 2007
ACTIVITY TITLE	**INITAL CONTRACT PRICE**	**FINAL AMOUNT INVOICED**
Geological & Groundwater Flow Modeling	$85,000	$85,000

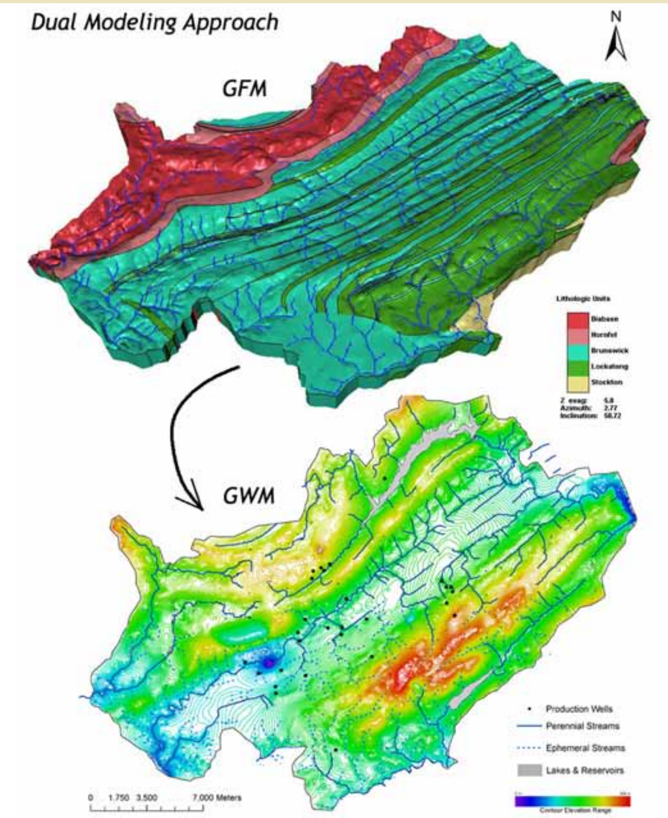
CLIENT NAME & ADDRESS	TECHNICAL CONTACT
Borton Lawson Engineering Wilkes-Barre, PA (570) 821-1999	Dennis Livrone – Bucks Co. Planning (215) 345-3422 dplivrone@co.bucks.pa.us

PROJECT DESCRIPTION

The GeoHydros modeling group developed a numerical groundwater flow model to assist six Philadelphia area municipalities managed by the Bucks County Planning Commission with the design of a comprehensive aquifer protection strategy. The basic objectives of this project were to: (1) compile and synthesize all available geologic and hydrologic data into a comprehensive Geologic Framework Model (GFM) describing structural controls on groundwater flow through the regional fractured rock aquifer; (2) convert the GFM into a basin-scale numerical groundwater flow model (GWM); and (3) use the GWM to develop wellhead protection zones (WHPZ) for 19 Bucks County municipal wells.

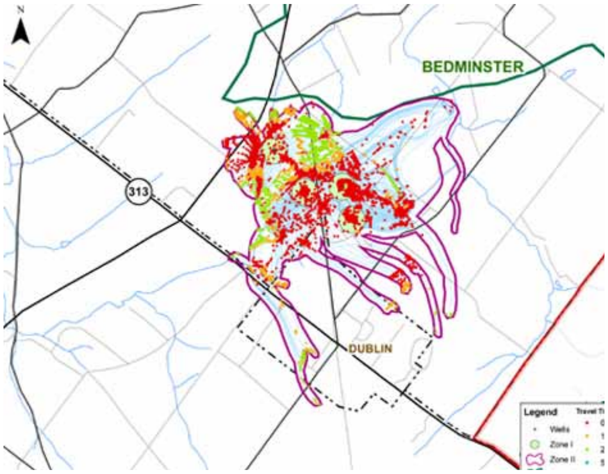
These objectives were achieved through numerical modeling using FEFLOW™ that was based on a detailed geological framework model (GFM) developed in EarthVision™. The GFM correlated fracture controls on groundwater flow throughout the basin with bedding orientations and contacts separating three geologic units: the Brunswick and Lockatong Formations and a diabase intrusion. The model incorporated strike and dip data and outcrop boundaries from geologic maps and cross-sections, borehole logs, and soil survey data to simulate 60 interbedded lithologic units of varying thickness, geometry, and permeability that have been structurally tilted The framework was then exported to FEFLOW for groundwater modeling where the geologic structure could be seen to exert significant control on simulated groundwater flow paths and velocities across the basin. Particle tracks were used to define well capture zones and then integrated back into the GFM in 3D to define the specific recharge areas contributing flow to the municipal water supply wells, which were used together to define the EPA Zone II WHP Zones.

GeoHydros successfully generated rapidly updatable, very high resolution, 3D models (0.05 foot vertical interval) of soil contamination that were considered by the project management and the regulatory agency to significantly expedite an effective rapid site characterization (Triad) approach that saved money and time and facilitated better decision making.

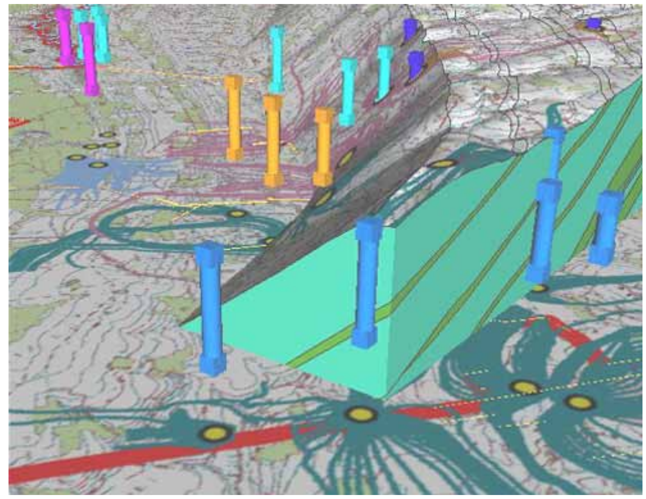


(Top) Geologic framework defining the 3D orientation of 60 dipping interbedded stratigraphic units intruded by an igneous dike and dissected by streams.

(Below) Simulated groundwater flow field based on the hydrostratigraphic framework from the GFM and hydraulic conditions created by streams, quarry dewatering, and municipal groundwater pumping.



Delineation of standard EPA Zone II WHP boundaries (purple line) as defined by 2D particle tracks and alternate Zone II boundaries (colored points) defined by 3D particle tracks intersecting the bedrock surface.



Orientation of water bearing (blue) and confining units (green) relative to the position and depth of municipality water supply wells and the well capture zones simulated in FEFLOW.

Deliverables included: (1) delineation of wellhead protection zones based on 3D particle tracks, (2) incorporation of model results & wellhead protection zones into appropriate ordinance language, (3) four quarterly presentations to the Municipality authorities and project management on the status and results of the modeling effort, and (4) a final report on model development, calibration, results, and wellhead protection zone delineation. in a synclinal basin, faulted at one end, and then intruded by the diabase.

SELF ASSESSMENT

GeoHydros successfully developed a regional 3D model of groundwater flow bounded by established no-flow boundaries. The model was developed with sparse data but calibrated well to water levels measured in 19 municipal groundwater supply wells under both static and pumping conditions. Particle tracks exported from the pumping conditions model were used to define well capture zones that were, in turn used to delineate standard EPA Zone II WHP boundaries for all the well fields. The modeling, particle track exports, and reporting were all completed on time and on budget. After the modeling was completed and our budget exhausted, we continued to support the project during a lengthy public review and comment period. Part of that support included developing an alternative set of Zone II boundaries that encircled the recharge areas for the wells as defined by the intersection of 3D particle tracks with the bedrock surface. In the end, the model was well received and the Pennsylvania Department of Environmental Protection stated that it marked a new standard for wellhead protection projects in Pennsylvania.

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RAPID SITE CHARACTERIZATION

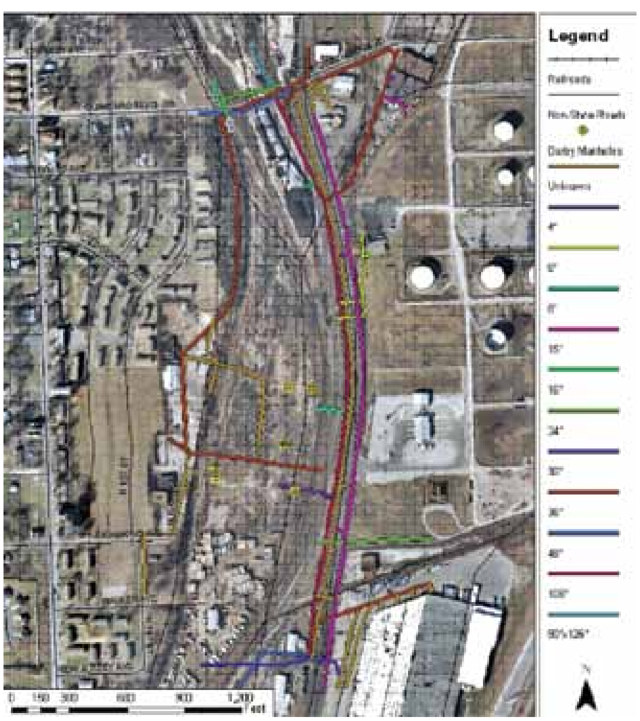
PROJECT NAME & LOCATION	DATE STARTED	DATE COMPLETED
Darby Site Overland Park, Kansas	March 2007	September 2009
ACTIVITY TITLE	**INITAL CONTRACT PRICE**	**FINAL AMOUNT INVOICED**
Geophysical Modeling & GIS	$25,000	$111,905

CLIENT NAME & ADDRESS	TECHNICAL CONTACT
Delta Environmental Consultants Kansas City Office (800) 477-7411	Roger Lamb, R.G. (913) 422-3555 x553 rlamb@environmentalworks.com

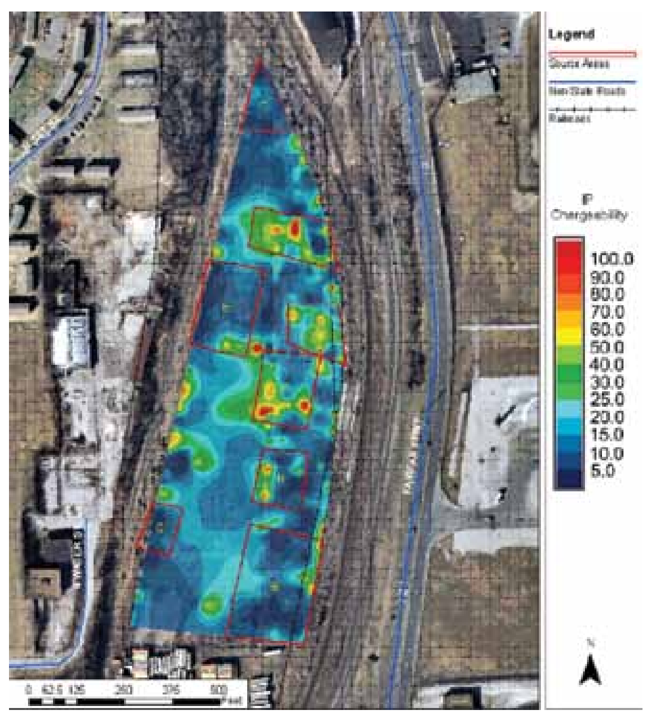
PROJECT DESCRIPTION

The Darby site is a former oil refinery in Kansas where GeoHydros has produced a GIS integrated with an in-house relational database containing lithologic, geophysical, soil analytical, and GeoProbe-MIP data, as well as EarthVision 3-D solids models of subsurface lithologic variations and contaminant distributions. The goal of the project was to produce a rapid, robust and comprehensive analysis of the site using a rapid site characterization (Triad) program and 3-D visualization of the data to guide the field work. Approximately 420,000 surface geophysics and Geoprobe-MIP measurements were modeled in 3-D. Computer scripts were written to automate model updates, output development, and project website uploads on a daily basis. The maps and visualizations provided a detailed and cost-effective 3-D understanding of the extent and magnitude of fuel impact in the subsurface that guided the field characterization program.

Many different types of spatial data were incorporated into the Site GIS such as, municipal utility lines, sewer and water mains, historical aerial images, and historical site engineering plans. Non-projected historical maps were digitized and spatially projected by identifying reference locations on roads and features common to both the historical maps and spatially projected aerial images. The GIS then provided a consistent set of diagrammatic and aerial photographic basemaps onto which all data and model output was projected for report and presentation figures.



Digitized sewers and attributes from city drawings over aerial photo where line color marks sewer diameters.



Spatial analysis of geophysical survey data related to key Site features and an aerial photograph.

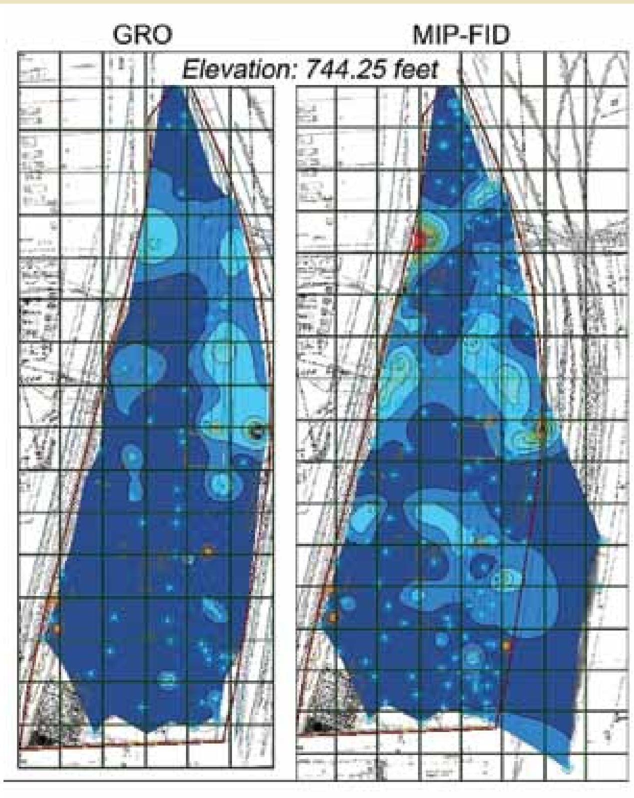
We then developed a desktop, relational, geospatial database for the project that provided a single central repository for all lithologic, geophysical, MIP, groundwater level, and laboratory analytical data collected at the Site. The database was developed using Microsoft Access and Visual Basic and linked to the Site GIS thereby reducing the time required to update maps and figures with new or changed data. Additional queries were developed to produce lithologic and parametric datasets formatted for immediate upload to 3D modeling software and to develop QA/QC reports designed to confirm all data uploads and application datasets.

3D solids and parameter models were then developed to define the lithologic structure underlying the site and the distribution of soil contaminant values that were measured in the field. Correlations were developed between parametric models of the laboratory soil analytical data and the field measured parameters FID and PID. The parametric models were then used directly to define the horizontal and vertical extent of the soil contamination and estimate contaminated soil volumes above critical threshold levels specified by the Kansas Department of Health and the Environment.

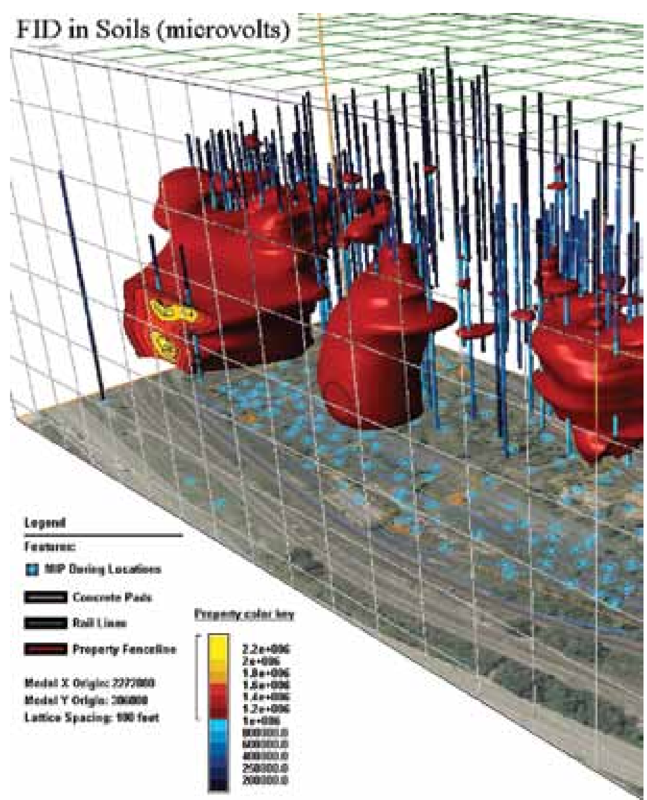
We used EarthVision™ for 3D modeling and visualization to capitalize on the software's advanced visualization and most importantly its batch processing capabilities wherein computer scripts were used to automate model development, output generation, and export to a secure project website. Automation allowed the models to be updated daily, hourly in some cases, which enabled the project manager and field team to effectively use the modeling results to guide the Site characterization objectives. Model output downloaded from the project website was then used in conjunction with the GIS-generated maps and figures for project reporting and presentations wherein the automation enabled rapid edits over the ensuing year-plus reviewing period.

SELF ASSESSMENT

GeoHydros successfully generated rapidly updatable, very high resolution, 3D models (0.05 foot vertical interval) of soil contamination that were considered by the project management and the regulatory agency to significantly expedite an effective rapid site characterization (Triad) approach that saved money and time and facilitated better decision making.



Comparison of MIP & laboratory analytical data from 3D models sliced at a specific elevation



3D distribution of FID in soils where VOC contamination is above the State-defined threshold

GeoHydros LLC

Specialized Geological Modeling

KARST CHARACTERIZATION

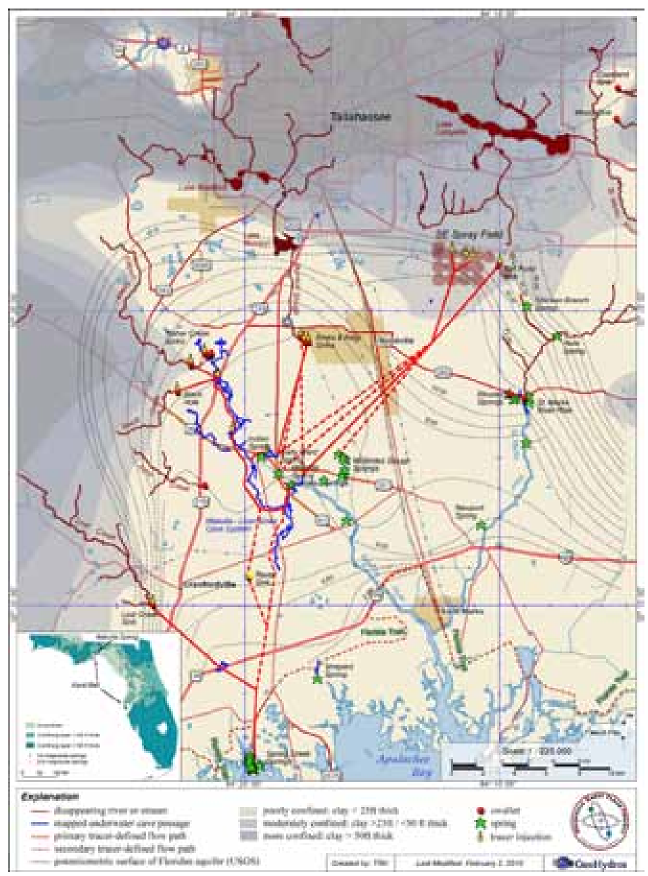
PROJECT NAME & LOCATION	DATE STARTED	DATE COMPLETED
Woodville Karst Plain Characterization, North Florida	July, 2002	On Going
ACTIVITY TITLE	**INITAL CONTRACT PRICE**	**FINAL AMOUNT INVOICED**
Groundwater Tracing & Modeling	$50,000	$1,100,000

CLIENT NAME & ADDRESS	TECHNICAL CONTACT
Florida Geological Survey Florida Department of Environmental Protection Tallahassee, Florida	Dr. Rodney DeHan (850) 488-9380 Rodney.DeHan@dep.state.fl.us

PROJECT DESCRIPTION

The GeoHydros group has been conducting a comprehensive hydrogeological characterization of the Woodville Karst Plain (WKP) of North Florida with the Florida Geological Survey (FGS) that includes quantitative groundwater tracing, hydraulic instrumentation of underwater caves, and dual-permeability (karst) groundwater flow modeling. The purpose is to develop improved methodologies for characterizing and modeling karst controls on groundwater flow and groundwater/surface water interactions in the upper Floridan aquifer and support State TMDL (total maximum daily load) and MFL (minimum flows and levels) programs.

Our quantitative tracing has revealed extremely rapid groundwater flow to Wakulla Spring from several sources of contamination including a swallet that receives 60% of Tallahassee's runoff and the City's waste water spray field; identified the hydraulic mechanisms responsible for varying source water contributions to the spring discharge; and a mechanism responsible for extensive saltwater intrusion to the upper Florida aquifer via large conduits that extend to coastal springs. Tracer-defined flow paths and velocities combined with head, flow, and parameter data being collected from an instrument network installed in various parts of the underwater cave system are being used to develop a new numerical karst groundwater modeling process.



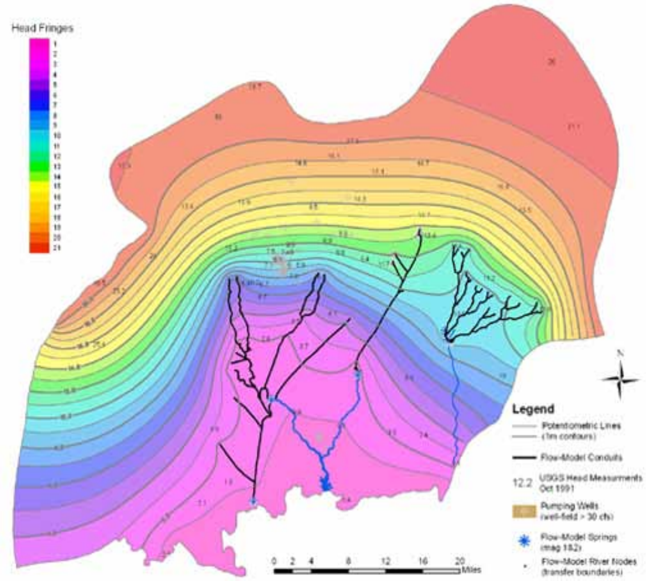
Map of the WKP showing mapped underwater caves (blue), tracer-defined groundwater flow paths (red), springs (green stars), swallets (red dots), streams (brown and light blue lines), and the distribution and thickness of an upper confining layer (shades of gray).

Traces include:

- Fisher Creek swallet to the Leon Sinks cave system *(1.2 miles/0.51 mi/day)*;
- Black Creek swallet to the Leon Sinks cave system *(1.6 miles / 0.50 mi/day)*;
- Leon Sinks cave system to Wakulla cave and Wakulla Spring *(10.6 miles / 1.2 mi/day)*;
- Ames Sink, which receives ~60% of the runoff from Tallahassee, to Indian, Wakulla, and Sally Ward Springs *(~6 miles/ ~0.25 mi/day)*
- Tallahassee's waste water spray field to Wakulla, Springs *(~11 miles / ~0.2 mi/day)*.
- Lost Creek swallet to both Spring Creek and Wakulla, Springs (0.2 – 1.2 mi/day).

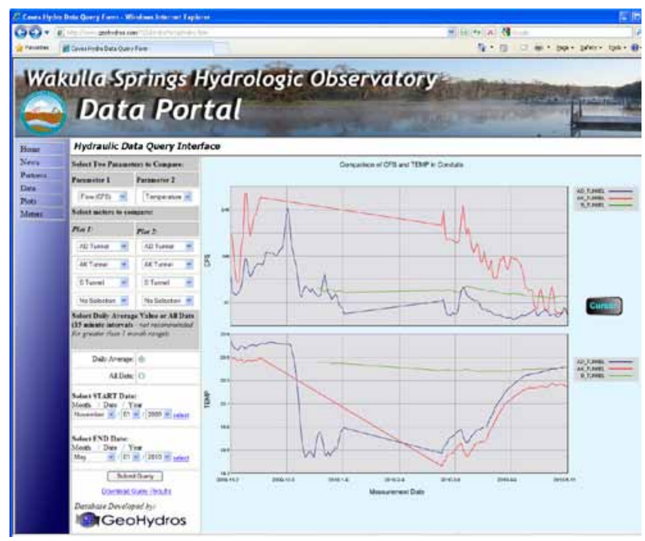
GeoHydros has established and maintains a network of hydraulic instruments in the basin that continuously measure head, temperature, conductivity and flow at several natural windows into the conduit network underlying the WKP (right). We developed a custom web interface for the project that allows users to access the data from any combination of meters, generate plots over the Internet and download the data files from any period of interest.

The numerical modeling work being performed here is revolutionary because it uses a dual-permeability framework to simulate conduit and matrix flow, calibrates to discrete spring discharges as well as heads, and simulates the location and size of the conduits through the calibration process. The modeling techniques devised here are intended to establish new protocols for modeling in karstic parts of the aquifer throughout the rest of the State.



Model simulated head field and saturated conduit network for the upper Floridan aquifer in the WKP.

Map showing the location of hydraulic meters and water level transducers in the WKP.



Web interface providing graphical access to the data being collected from longterm monitoring stations.

SELF ASSESSMENT

This project is widely recognized as ground-breaking in terms of its contribution to our understanding of karstic controls on groundwater flow in the upper Floridan aquifer. The tracing results have been instrumental in land-use decisions including the City of Tallahassee's decision to upgrade to an advanced wastewater treatment system at the cost of approximately $200 million; and Wakulla County's decisions on where to delineate a springs protection zone in their zoning ordinances. In addition, the modeling work performed here has defined the methodologies necessary to develop an effective numerical model of karstic groundwater flow and was the precursor to the model completed for the Western Santa Fe River Basin. The fact that this project has persisted in the face of severe budget cuts is testament to its success and perceived utility to the state of Florida.