Allegan County Water Study Workgroup

Meeting Minutes

Date of meeting	Wednesday, September 7, 2022 4:00 pm
Present:	Dean Kapenga, Doug Sweeris, Ric Curtis, Tom Kunetz, Zach Curtis
On Zoom:	Erick Elgin, Brian Talsma (arrived 2:15 pm)
Members not in attendance:	Chad Kraai, Jay Drozd, John Shagonaby
Guests and staff:	Jaclyn Hulst, Randy Rapp and Jill Dunham
Next meeting:	Wednesday, September 21, 2022

1. Approval of Agenda

Comment from Jaclyn: Asked whether the Phase 1 Study by Hydrosimulatics used the corrected Wellogic data. Zach with Hydrosimulatics stated that they did use the updated data provided in July 2020.

2. Action Items from previous meeting

a) Request for Action to Board of Commissioners: Water Study Workgroup recommendation for ARPA funds awarded to local units of government – Randy Rapp
Jill Dunham submitted the Request for Action and the Board of Commissioners voted to approve all recommendations and only recommended projects at their meeting on 8/25. Dean Kapenga stated that Rob Sarro had promised the Finance Director would get back to the local units of government by September 16th.

b) Private well count: Zach will work with Jill to determine the number of private wells in the county. Would also like to know the population or households served by private wells. City of Allegan has 1900 connections and just over 5,000 people.

c) Can ARPA funds be used for private wells? Jill researched ARPA and determined that ARPA can only be used by a local unit of government. Even though ARPA can be used to add people with contaminated wells to the municipal water system.

d) Well types: Randy supplied the EGLE infographic; it's attached to these minutes.

e) Monitoring wells - Randy
2 monitor wells installed so far

- Trowbridge Township Hall - 370 feet – to get the full profile - all the way to the bedrock (lots of sand)
- Allegan County Health Dep - 263 feet to Marshall Sand Stone. They set the screen. Will check back in a couple weeks to see if the static water level has equalized. Then they will start monitoring.

The crew can't finish the 3rd monitoring well, due to Trowbridge taking longer and some illness on the crew. John Yellich will speak to Chad Kraai about putting in the 3rd well in Shelbyville/Gun Lake area (close to Chad's office) end of Oct/early Nov.

USGS operates a national monitoring system. Michigan results are being shared with USGS.

EPA has a water quality portal per Erick Elgin. Erick will send the link to Randy Rapp. EPA scope is super fund and other clean-up sites they work on.

f) Jay Drozd has not attended any meetings since the first one. Jill and Randy will pursue removing and replacing him. [Note: After the meeting, Jill got Jay's number from his application and called Jay. Jay has been very busy and was not aware when he joined that there would be this many daytime meetings. He requested to be on the workgroup, because he is very concerned about the water situation. Jay will call Randy soon to discuss whether he will continue or resign.)

3. Discussion

BEST intelligent Decision Support System Tool – Review Proposal submitted by Hydrosimulatics INC

Zach presentation of DSS proposal (attached to minutes) and discussion.
Quantity – system has tools to show:

- How deep a well needs to be in a specific area.
- Expected yield. Water use in a specific area.
- General data captured that allows for site specific analysis.
- How thick is the aquafer today?
- How will it be affected if wells are added that pump x quantity of water/day?

Quality - automate water quality data collection

Soil data collected nationally will be included in the system. Significant big data is being collected nationally, which could potentially be included - as needed in the future.

Training - what kind of training comes with this proposal?

- Traditional documentation and user manual.
- Situational management guidebook system – within the DSS program there will be help buttons to explain terms, values used and links to relevant policy. Help button will tell you what goes into the analysis, data that went into the analysis and link to learn more on the topic.
- Workshops - Virtual webinar and In-person
- During development and customization phase, Hydrosimulatics will present and demonstrate a preliminary version (first opportunity to learn to administer the system)
- Included in proposal $8,000 for one week of virtual training unlimited attendees

Tom Kunetz asked Randy (County Health Department) and Doug (Allegan City) if they can see this being used. Doug and Randy did mention examples of how they could use it. Randy indicated he thought it would be used even more by townships.

This system will be a first of its kind, at least in Michigan. The system combines the water analysis tools with mapping. There are other systems that do mapping, but not the hydrological modeling tools.

Tom Kunetz asked, "Do we have the users that can benefit from this sophisticated tool?" Do we need a Ground Water Steward? Someone who can be the primary user of this tool and they are responsible for strategic planning for water. Education of townships on the effects of commercial businesses, agriculture and residential development on the aquifer and a driver for zoning decisions.

Brian Talsma has questions about longevity of the system. What happens if Hydrosimulatics discontinues the system or goes out of business? Zach agreed that this is an important issue. Further discussion is needed.

Steve was asked about IT support for DSS. Steve expressed a concern about paying Hydrosimulatics to "develop the product." Customization to meet the needs of Allegan County is expected, but it appears that the actual product is conceived, but not developed yet. This product once developed, could be sold to other counties.

Review Recommendation document prepared by Tom Kunetz:

- Phase 2: Screening Level Modeling, Risk Analysis and Ranking Study
- BEST Intelligent Decisions Support System Toll
- Water Supply Master Plan
- Water Table Monitoring Wells
- Private Well Water Quality Data Collection and Monitoring Program
- Public Education and Outreach Program
- New Position: Groundwater Steward
- Low Production Private Wells

4. Action Items

- Jill will send Tom the recommendation submitted to the Board of Commissioners
- Zach and Jill will determine the number of private wells.
- Randy and Jill will work on number of residents served by private wells.
- Jill to contact EGLE for Type 1 well test results (water quality.) Can we get regular test results? Send to Randy Rapp. Anita Ladoseur - contact for private well construction - Heather Bishop for Type 1
- Randy will check with Carolyn Hobbs Kreger about Type 2 water quality data. County using Water Track - changing to new system.
- Steve and Zach will discuss IT concerns about the DSS software.

Drinking Water Supply Types

Type 1
Community Public Water Supply

- Provides water to at least 25 residents or 15 living units year-round.
- Some examples are municipalities (cities, towns, etc.), apartments, nursing homes and manufactured housing communities.
- The water is pumped from surface water (lakes, rivers) or groundwater using water wells.

Type 2
Non-Transient Non-Community Public Water Supply

- Provides water to at least 25 of the same people for at least six months or more a year, but not for year-round residential living.
- Some examples are schools, daycares and office buildings that have their own water system.
- Water is typically pumped from groundwater using water wells.

Type 2
Transient Non-Community Public Water Supply

- Provides water to at least 25 people for at least 60 days a year, but does not serve the same 25 people for more than six months of the year.
- Some examples are hotels, restaurants, campgrounds, gas stations and churches.
- Water is typically pumped from groundwater using water wells.

Type 3
Public Water Supply

- All other public water supplies that provide drinking water not considered a Type 1 or Type 2 are considered a Type 3.
- Some examples are small apartment complexes or condominiums, duplexes and very small businesses. Ownership of multiple Type 3 wells may change the drinking water supply type.
- Water is pumped from groundwater using water wells.

Private Residential Well

- Provides water to a single-family residential home. Water is pumped from groundwater using a water well.

MDHHS
Michigan Department of Health & Human Services

Disclaimer: This document provides a generalization of drinking water supply type. The many factors reviewed in type classification decisions by local health departments and the Michigan Department of Environment, Great Lakes, and Energy (EGLE) could not all be included here. To learn more visit https://bit.ly/2SUZpBW.

EGLE
Michigan Department of Environment, Great Lakes, and Energy

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ALLEGAN COUNTY BIG DATA ENABLED SIMULATION TOOLS FOR INTELLIGENT DECISION SUPPORT

A Project Proposal
By
Hydrosimulatics INC

August 24, 2022

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EXECUTIVE SUMMARY

The proposed project represents an effort to significantly improve the County's ability to protect its groundwater – and the wellbeing of its citizens at it relates to water – enabling holistic management of growth, development, and water use, and protection of water quality. In particular, Hydrosimulatics INC. proposes an intelligent, data-driven, realtime decision support system (DSS) built on an Allegan-specific database and data service system, consisting of a comprehensive suite of management tools – Big-data Enabled Simulations Tools (BEST). The BEST Intelligent DSS is specifically designed for use by the County's professionals, including resource managers, planners, and decision-makers with general backgrounds in groundwater and/or hydrology, empowering users to address issues and concerns raised by the County's citizens and other stakeholders based on 2+ years of interactions with Hydrosimulatics INC.

Building on Past Work & Achievements

The project capitalizes on data and information previously not available (or severely underutilized) and innovative technologies enabling water system characterization at substantially reduced costs and in ways previously impractical. Specifically, the project intelligently and dynamically integrates and utilizes:

i) vast groundwater information assembled or generated from the Phase 1 Allegan County Groundwater Study (including raw datasets and "derived" maps and analyses);
ii) emerging (or only recently available) ultra-high resolution (1m) digital elevation or LiDAR data, offering new opportunities for environmental characterization and management;
iii) tools, technologies, and statewide datasets created from a 15-year collaboration with MDEQ (now EGLE) that has saved the State of Michigan substantially in their Source Water Protection initiative;
iv) realtime, cloud-based, BIG DATA-enabled groundwater modeling and visualization capabilities contained in the MAGNET4WATER (M4W) platform - originally funded through a number of cross-cutting National Science Foundation (NSF) project and significantly expanded by Hydrosimulatics INC. over the past 4 years.

The BEST Intelligent DSS allows "seeing the unseen", facilitating detailed mapping, 2D and 3D visualization, visual analytics, and rapid groundwater modeling / analysis at any location or scale of analysis – from countywide (in support of holistic management / big-picture understanding) to township-level, section-level, or even parcel-level.

Real-time Groundwater Management Tools

The following table presents a summary of the proposed set of user-friendly Realtime Groundwater Management Tools to be included in the BEST Intelligent DSS.

CATEGORY	INTERACTIVE TOOL	KEY MANAGEMENT QUESTIONS (LOCATION- OR REGION-SPECIFIC)
Water Quantity Management	Groundwater Flow Delineation	• How does groundwater move around underneath Allegan – in different aquifers (e.g., glacial and bedrock) and at different scales (e.g., countywide, in different townships, or at a local site/property)?)? • What is the depth-to-groundwater table in this area?
	Groundwater Recharge Area Delineation	• How are the glacial and bedrock aquifers recharged? • Where are the dominant replenishment areas? • Where are the secondary recharge areas? • Why does development in certain areas in Allegan have disproportionately large impacts on groundwater sustainability/future availability? • How can the county manage holistically growth and water use?
	Groundwater Use and Well Types Mapping and Analytics	• Where are the existing wells in my area? • What kind of wells are they (irrigation, industrial, public supplies, private, etc.)? • How deep are these wells? From which aquifer do they pump groundwater? • What is the estimated water use pattern? • How have this pattern changed over time? • Which areas/sections may be most likely to experience water shortage?
	Well Yield Modeling and Mapping	• What is the maximum yield (pumping) that can be sustained based on geology? • What is the maximum yield that can be sustained without interfering with my neighbor's water? • Is yield limited by nearby sources of groundwater contamination? • What is the hydrologically optimal development of water resources at this location, given geological, legal, and water quality constraints?
	Well Conflict Resolution Modeling	• What is the influence area of my pumping well? • Will an irrigation well impact the ability of wells nearby to pump groundwater? • How far does the pumping impact extend? • What are the implications of siting large-capacity pumping wells within large land parcels (e.g., agricultural lands)? • Can adverse impacts be avoided/eliminated based on strategic well placement? • What is the land use within the area of influence? • Will pumping mobilize / accelerate movement of contaminants?
	Land Surface Catchment and Drainage Pattern Delineation	• What is the surface drainage pattern in this area? • What is the land surface catchment? • How does the shape of the catchment impact surface drainage? • Where are the areas of poor surface drainage in the catchment? • What are the implications on development?
	GW Discharge Area Delineation & Basement Flooding Vulnerability Assessment	• Why does this property have persistent drainage issues? • Is it because the soil is too "tight"? • Is it the result of converging subsurface runoff? • Is it because the property is in a high-water table / groundwater discharge area? • Is it a combination of multiple factors? • Would a new development in this area experience flooding issues?
Water Quality Management	Wellhead Protection Area Delineation	• What is the land surface area contributing to my well? What is the land use in the contribution area? • What are the implications for development and zoning? • What are the implications for community involvement in wellhead protection? • Where should we place "last minute warning" monitoring wells (e.g. at 6-months or 1yr or travel)? • Where should we place "early warning wells (e.g., at 10year travel zone), especially if there are potential sites of environmental concern nearby?
	Critical GW-Dependent Ecosystem Mapping and Source Water Delineation	• Are there any critically important groundwater ecosystems in this area? Where is their water coming from? • How can we cost-effectively, holistically protect valuable groundwater-dependent ecosystem, taking into account the underlying hydrologic process (not just what's going on at the surface)? • What are the implications for land use and development? For community involvement?

Water Quality Management	Sites of Environmental Concern Mapping and Contaminant Tracking	• Are there nearby sites of contamination or sites of environmental concern? • Is the nearby gas station tank leaky? Where is the contaminant going? • What is the aquifer impact area? • What / where are the key groundwater receptors? • What is expected time-of-travel? • Where should we sample or monitor given limited resources and the need to be cost-effective?
	Groundwater Contamination Sources Tracing	• If contamination is detected in my well, groundwater fed lake, or a monitoring well, where does the contamination likely come from? • Who are the potential responsible parties? • Where should we sample or monitor given limited resources and the need to be cost-effective?
	Contamination Capture Well Design	• If an accidental spill occurs and an emergency capture well(s) need to be quickly installed to control / prevent plume spreading, where should the wells be placed? • How many wells are needed and how much should be pumped?
	Aquifer Vulnerability Mapping and Assessment	• Why are certain areas of Allegan's aquifers particularly vulnerable to contamination? Where are these areas? • Why are certain other areas of Allegan's aquifers almost "immune" to surface pollution (even if contamination site(s) are nearby)? Where are these areas? • What are the implications on monitoring, development, and well siting?
	Agriculture / Nitrate Contamination Risk Mapping & Analytics	• Where are the "hotspots" in terms of agricultural activities? • Is groundwater in this area degraded because of agricultural activities? • How likely is it that well water in this area contains elevated levels of nitrate? • What is the median and expected (average) nitrate concentration of groundwater in this area? What is the maximum observed concentration? • What percentage of wells in this area are above the Contaminant Level detrimental to crops? • What percentage of wells in this area are above the MCL (Maximum Contaminant Level)? • What are the implications for well siting (especially with respect to depth of the well, location on a land parcel, etc.)?
	Brine Upwelling / Chloride Contamination Risk Mapping & Analytics	• Is groundwater in this area influenced by the upwelling or mixing of deep brines with the shallow fresh groundwater? • How likely is it that well water in this area contains elevated levels of groundwater salinity? • What is the median and expected (average) chloride concentration of groundwater in this area? What is the maximum observed concentration? • What percentage of wells in this area are above the SMCL (Secondary MCL)? • What are the implications for well siting?
	Metals Metalloids Risk Mapping & Analytics	• How likely is it that well water in this area contains elevated levels of iron, arsenic, lead, etc.? • What is the median and expected (average) concentration of groundwater metals / metalloids in this area? What is the maximum observed concentration? • What percentage of wells in this area are above the MCL/SMCL?
Water System Characterization	3D Water / Aquifer System Visualization	• Without completing any field work, what are the characteristics of the site, especially with respect to geology, water quantity, and water quality? • How are properties of the land surface (topography, land use / cover, road and infrastructure, soil type, etc.) and subsurface (lithology, water table, groundwater quality, etc.) spatially distributed – both horizontally and vertically? • What do the spatial patterns tell us about relationships between various components of the environment? • Where should we sample or monitor given limited resources and the need to be cost-effective?
	Water and Aquifer System Cross-section	• How thick is the aquifer in this area? How does well lithology/geology vary locally? • How deep are the wells with respect to the aquifer bottom?
	Realtime Groundwater Monitoring & Analytics	• Is groundwater quantity (levels/storage) declining over time? • Is water quality improving or worsening over time? • What is the seasonal variability in water quality or water quantity?

Broader Impacts

Accessible on demand, anywhere and at any time through its cloud-powered delivery service, The BEST Intelligent DSS will allow going beyond one project, one site, or one problem related to groundwater management in Allegan County – now, and into the future.

The BEST Intelligent DSS will provide an efficient platform for risk-based, cost-effective, community-oriented decision making. The DSS will enable the informed participation of citizens and improve interactions between local government, their constituents, researchers, and consultants, bringing the following benefits to the stakeholders:

- *Resource managers and planners* will be able to evaluate the effectiveness and impact of their management plans to improve policy-making decisions. They can visually evaluate the impact of potential threats, land use, contamination, and water withdrawals. They can become more effective in identifying/prioritizing areas/sites for monitoring, development, conservation, or protection and will be able to design more focused, cost effective analysis and monitoring. They can also be more effective in engaging the public and informing high-level decision makers about the implications of a proposed development and the transport of contamination on sensitive receptors (e.g., drinking water wells, residential areas, groundwater dependent ecosystems).
- *Communities and stakeholders* will be able to visualize the invisible subsurface and experience and better understand the impact of proposed management measures in a vivid and interactive way. They can also visualize the potential impact of their own activities on the groundwater environment. Thus, they are motivated and empowered to engage in the intricate process of community-based ecosystem and water/land use management, planning, and protection.
- *Policymakers* can make more informed decisions regarding setting and enforcing laws and regulations for water resources management and use interactive tools to improve public relations and to evaluate future land use management plans related to zoning and new developments. They also will have an effective mechanism to communicate a solution, a policy, or strategy to their constituents.

The ability to visualize the surface and subsurface, groundwater flow patterns and surface water features, 3D water quality, and lithology and geology sparks pivotal insights into the complex interrelationships among components of the environment and human activities. This greater awareness gives rise to intuitive grasp of implications of management actions and policy decisions that can't be readily obtained otherwise. The seamless integration of modeling results, data from disparate sources, management analyses, and interactive visual communication will make it possible for resource managers and planners to focus on high level issues and to refine management strategies and policies quickly and iteratively.

Scope of Work

The process for developing the database and Best Intelligent DSS consists of the following steps:

- <u>Data integration, organization, an additional processing</u> (including multiscale data representation) to enable instant mapping/visualization and rapid groundwater modeling and analysis.
- <u>Database development</u>, involving intelligent storage schemes and intelligent access schemes in support of realtime mapping, visualization, and modeling/analysis, and built-in mechanisms for on-going data integration.

- Data service development, enabling nationally standardized web mapping services, or WMS (image retrieval), web feature services, WFS (vector/shapefile retrieval), and web coverage services, WCS (raster/tiled data retrieval). A number of government agencies (USGS, NSF, …) utilize web data services to provide GIS data at multiple resolutions and details.
- DDS Tools and Portal Development, enabling realtime interactive groundwater mapping, visualization, and modeling within the customized geospatial environment for the County.

Hydrosimulatics INC. will also provide documentation and training, including: online or "embedded" technical reference materials, user manuals / tutorials, realtime situational help pages and a management realtime situational "management guidebook system". Training will take place in the form of and virtual workshops, webinars, and hands-on training sessions.

Database & DSS Hosting

Two options are proposed for data hosting related to the DSS:

A. The database and data service system is hosted by Allegan County, while the web-application is hosted and maintained by Hydrosimulatics INC. Data "talks" to the DSS via Open Geospatial Consortium (OGC) protocols. Future updates to the database/data service system can be done by Hydrosimulatics "as needed".
B. Both the database/data services and web-application are hosted by Hydrosimulatics INC., allowing easier refinement/on-going maintenance by Hydrosimulatics.

Hydrosimulatics INC. will work with the County to determine and implement the most suitable solution for on-going use of the DSS for years to come. A proposal addendum will be submitted with complete technical details of the agreed upon solution.

MOTIVATION

A Ground Water Study Work Ad-Hoc Group was established to systematically review the Final Report from the (Phase 1) Allegan County Groundwater Study. The Phase 1 study analyzed existing regional groundwater data to better understand the groundwater conditions across the County and implications for management – both in terms of water quantity (availability and use) and water quality ("background" groundwater chemical concentrations and potential "point" sources of pollution). The Work Group is to assist in determining current and future water demands and sustainability of water supply relative to growth trends, and how to improve water quality and maintain the quantity required for human and agricultural use.

A very large amount of data and information was compiled, processed, and analyzed for the Phase 1 Allegan County Groundwater Study. These data /information/analyses are very useful for understanding groundwater conditions and managing groundwater, and were presented in a "static" Final Report prepare by Hydrosimulatics INC. This report format – while still useful – is a significant underutilization of the data/information/work because:

- important local or small-scale details of high-resolution maps when viewed at countywide scales;
- often, correlations or relationships between components of the environment and society are recognized only through simultaneous interactive overlay/analysis, but one cannot possibly exhaust all combinations in a written report; and
- the report contains information/data up to time of production (Fall 2020). It is time-consuming or impractical to update all maps/graphics/analyses every time more data is collected, but this would provide a more complete picture (especially at local scales).

Most importantly, there is a vast amount of "Big Data" that will be combined with the Phase 1 datasets to enable more thorough or holistic analysis, visualization, and modeling of groundwater conditions and possible management scenarios. Although extremely valuable for environmental management, Big Data is generally underutilized because it is time-consuming to process on a site-by-site basis. Not only are Big Data scattered, of variable formats and qualities / resolutions, and highly dimensional (many attributes / parameters), some of the most valuable datasets are also virtually immovable because of their massive size (e.g., LiDAR data). Too often, even without Big Data, most projects spend a majority of the time on data integration, processing, and manipulation (instead of management and characterization!).

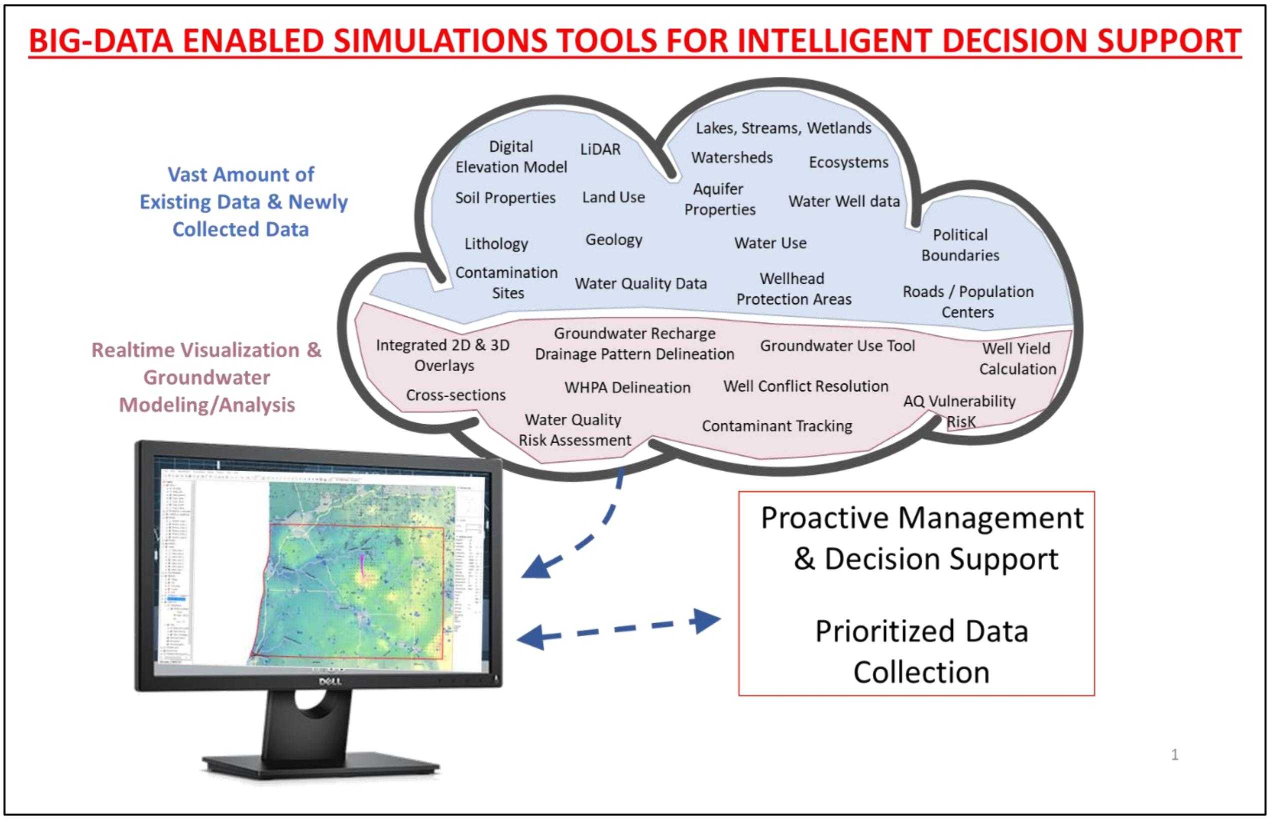
OBJECTIVE

In this project, Hydrosimulatics INC. proposes to develop a mechanism to enable the systematic and synergistic use of existing data as well as data collected in the future – with a goal to significantly improve the practical ability of county and local decision makers to understand, manage, and protect groundwater resources.

In particular, Hydrosimulatics INC. proposes to develop a unified groundwater information system that integrates the vast water well records and other groundwater/environmental Big Data collected for different purposes and accumulated in past decades. Hydrosimulatics INC. will preprocess the database and data service system, converting the raw datasets, maps, and other information into usable products and ultimately resulting in increased knowledge for the benefit of the managers, planners, developers, and the community.

Built directly on the processed database will be an interactive, web-based decision support system (DSS) - consisting of a comprehensive suite of management tools – Big-data Enabled Simulations Tools (BEST) for intelligent decision support - that can be used to guide water resources planning and permitting processes within agencies of Allegan County, the townships, and others (see Graphic 1). The Best Intelligent DSS will include a comprehensive suite of groundwater management tools enabling realtime interactive groundwater mapping, 3D visualization, and analysis via dynamic linkages to the processed spatial data, countywide maps, time-series sensor data, and other information related to groundwater and human activities.

In short, the BEST Intelligent DSS will allow going beyond one project, one site, or one problem related to groundwater management in Allegan County – now, and into the future, for a diverse set of end users.



Graphic 1: A conceptual representation of BEST Intelligent DSS. By combining existing data with various tools of analysis and visualization, and allowing users to add their own information / perspectives / expertise, the AGI-DSS allows not only addressing specific problems facing Allegan at different scales, but, perhaps more importantly, empowers future users to address these problems and more.

OVERVIEW OF METHODS

The project capitalizes on data and information previously not available (or severely underutilized) and innovative technologies enabling water system characterization in ways previously impractical. Specifically, the project intelligently and dynamically integrates and utilizes:

i) vast groundwater information assembled or generated from the Phase 1 Allegan County Groundwater Study (including raw datasets and "derived" maps and analyses);

ii) emerging (or only recently available) ultra-high resolution (1m) digital elevation or LiDAR data, offering new opportunities for environmental characterization and management;

iii) tools, technologies, and statewide datasets created from a 15-year collaboration with MDEQ (now EGLE) that has saved the State of Michigan substantially in their Source Water Protection initiative;

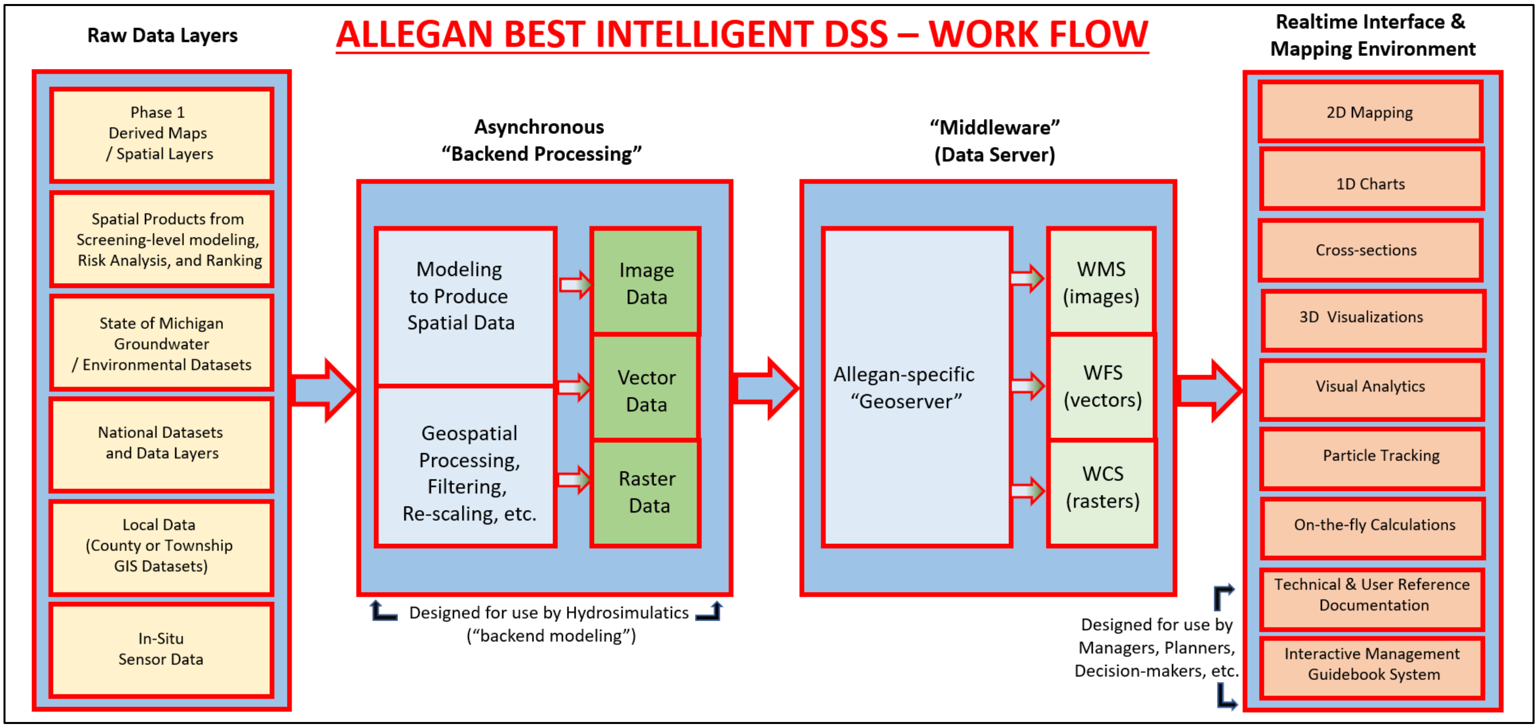
iv) realtime, cloud-based, BIG DATA-enabled groundwater modeling and visualization capabilities contained in the MAGNET4WATER (M4W) platform - originally funded through a number of cross-cutting National Science Foundation (NSF) projects and significantly expanded by Hydrosimulatics INC. over the past 4 years.

The proposed project also takes advantage of standard data services or server software services following international Open Geospatial Consortium (OGC) protocols. The data server software system will enable web mapping services, or WMS (image retrieval), web feature services, WFS (vector data retrieval), web coverage services, WCS (raster/tiled data retrieval), and live-linking to in-situ / wireless monitoring networks providing time-series data such as water level and water quality data (e.g., from National Groundwater Monitoring Network (NGWMN) wells), stream flow data from stream gaging stations, and water level and water quality data from surface water sampling/monitoring. In this way, the database continuously grows as more data are naturally added to the DSS from monitoring networks.

The process for developing the database and Best Intelligent DSS consists of the following steps:

- Data integration, organization, an additional processing (including multiscale data representation) to enable instant mapping/visualization and rapid groundwater modeling and analysis.
- Database development, involving intelligent storage schemes and intelligent access schemes in support of realtime mapping, visualization, and modeling/analysis, and built-in mechanisms for on-going data integration.
- Data service development, enabling nationally standardized web mapping services, or WMS (image retrieval), web feature services, WFS (vector/shapefile retrieval), and web coverage services, WCS (raster/tiled data retrieval). A number of government agencies (USGS, NSF, …) utilize web data services to provide GIS data at multiple resolutions and details.
- DDS Tools and Portal Development, enabling realtime interactive groundwater mapping, visualization, and modeling within the customized geospatial environment for the County.

Graphic 2 presents a work-flow diagram for the development of the proposed BEST Intelligent DSS.



Graphic 2: A work-flow diagram for the BEST Intelligent DSS. (From left to right): First, all relevant groundwater/environmental data layers from various sources are compiled in their "raw" format. The compilation of datasets – including image data, vector data (image, points, and lines) and raster data (grid- or tile-based layers) – is then processed, formatted, filtered, and in some cases re-scaled (e.g., DEM, river and stream networks, etc.) to facilitate efficient analysis/visualization at different spatial scales. Some datasets will be used by Hydrosimulatics INC. to create model output layers to be used in the DSS (e.g., Static Water Levels will be interpolated at high-resolution for the entire county to provide flow fields for particle tracking applications). The image, vector, and raster data are further processed into a format consistent with the data and modeling services proposed for this project (WMS, WFS, AND WCS data services). All converted data layers are dynamically linked to the realtime interactive mapping, visualization, and modeling/analysis environment used by DSS end-users.

Critical Water Well Datasets – Wellogic and WaterChem

The statewide Wellogic and WaterChem databases play a particularly important role in the proposed DSS system - both datasets are involved in several (or more) of the proposed realtime groundwater management tools (see below). Utilizing these existing water well datasets allows the county to save considerable money related to data sampling / monitoring.

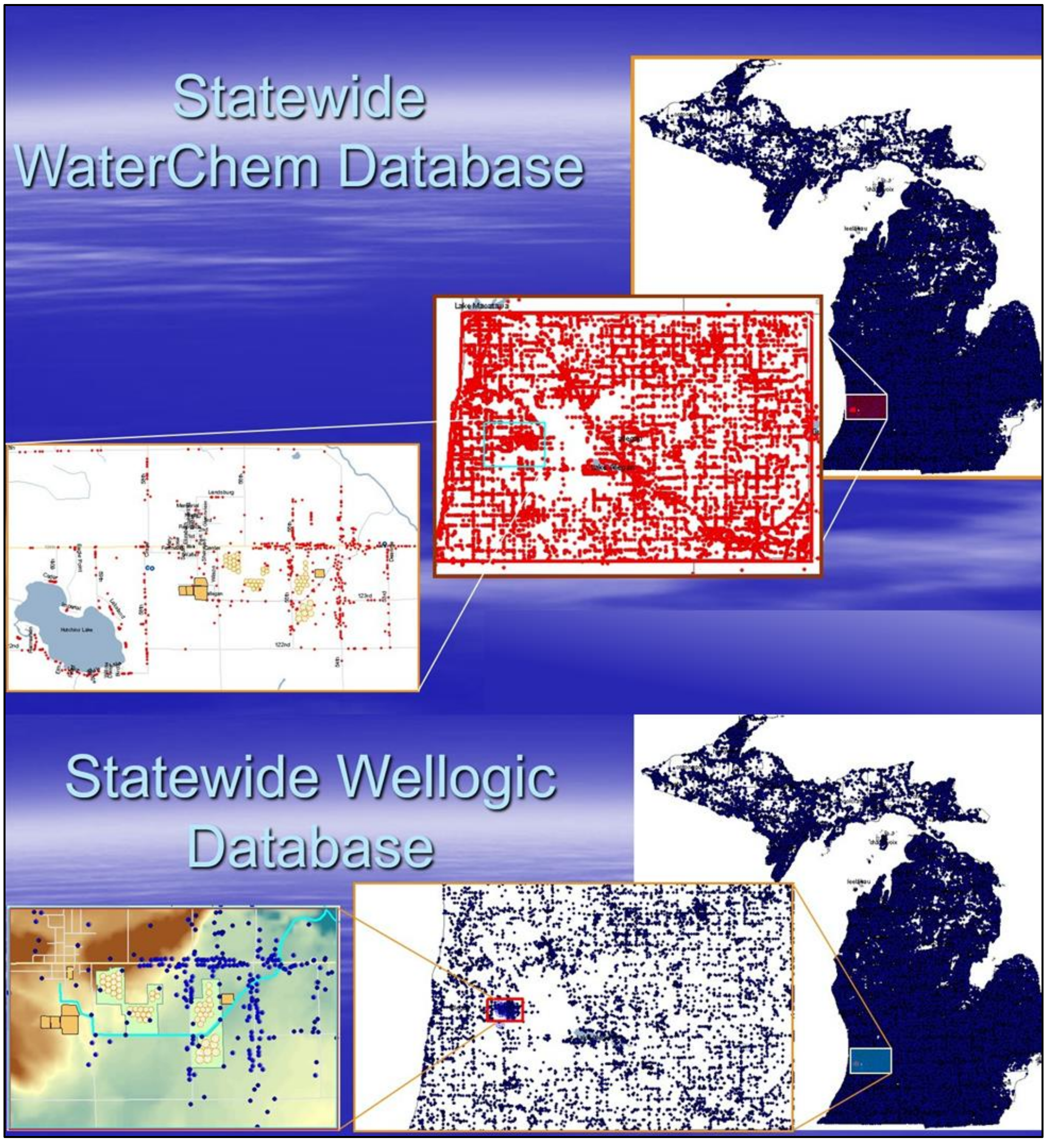
Wellogic is the internet-based data entry program developed by the State of Michigan to provide an easy method for water well drilling and pump installation contractors to submit water well words on a continuous basis. Information contained in the database includes Static water level, depth of the well, where it is screened, and a vertical description of the soils/lithology (e.g., sand or clay) that were encountered in the drilling of the well. The database now contains over 800,000 water wells from around the state, including private domestic wells, public supply wells, and wells used for agriculture and industry.

WaterChem is relatively recently assembled statewide water quality database that integrates and digitizes, on a continual basis, historical and new water quality data collected from Michigan's water wells and analyzed at the State of Michigan's Drinking Water Analysis Laboratory. The Laboratory was established under the authorization of the Michigan Safe Drinking Water Act (1976 PA 399) and is certified by the "Laboratory Certification Program" that ensure proper methods and quality controls are used in the testing of drinking water samples.

Water samples collected for various purposes since 1983 are included in the database. People typically get their private wells tested when they are selling or buying a home, when a new well is installed, an old well or well pump is maintained, or when they are having water quality problems (unusual color or odor), or when they wish to evaluate their drinking water source if posed with health-related problems.

Spatial coverages of the Wellogic and WaterChem wells (Graphic 3) are very high throughout most of the Lower Peninsula, especially in west-central Michigan.

The most up-to-date Wellogic and WaterChem data available will be downloaded, trimmed, integrated, and "published" (i.e., saved in web data service format) into the Allegan-specific DSS system.



Graphic 3: Spatial coverage of the WaterChem and Wellogic databases at different spatial scales – statewide, countywide, and site-specific.

EXPECTED OUTCOMES

User Capabilities

This BEST Intelligent DSS will enable resource managers and planners to zoom into any location in the county to:

- Visualize the complex 3D geology of the subsurface, including the aquifer elevations / extents and categorized borehole lithologies analyzed in Phase 1;

- Map groundwater level distributions, flow directions and drainage patterns, in both the shallow glacial aquifer and, where applicable, the deeper bedrock aquifer;
- Map aquifer recharge areas in support of land use / zoning decision-making;
- Map aquifer discharge areas to help identify groundwater-dependent ecosystem and potential vulnerability to groundwater salinization because of brine upwelling;
- Assess surface or subsurface flooding risk by mapping drainage catchment patterns and directions , depth-to-water, soil types/permeability, and, and surface seeps and subsurface drainage patters,
- Map water use patterns (in space and time), calculate well statistics, and analyze temporal trends (number of wells, groundwater levels, etc.)
- Assess vulnerability of a proposed development to insufficient water supply by mapping / analyzing sustainable yield;
- Evaluate potential impacts of pumping of new or existing well by performing well conflict modeling (drawdown analysis);
- Map or delineate Wellhead Protection Areas (WHPAs) capture zones / well-watersheds for pumping wells, which is critical for holistic management of aquifer protection and wellhead protection;
- Delineate contributing source water areas / capture zones / “groundwater-sheds” for groundwater-fed streams and wetlands, which is critical for ecosystem protection;
- Map sites of environmental concern, PFAS sites, and leaky underground storage tanks (LUSTs)
- Map or delineate potential impact areas of point-source pollutants for different assumed time-of-travel;
- Trace contamination sources from groundwater receptors with detections (i.e., monitoring wells, water wells, groundwater-fed surface water)
- Design a preliminary contaminant capture system as a first step to remediation of contaminated sites
- Map and assess aquifer vulnerability to surface pollution based on surface and subsurface conditions (soil type, recharge, depth to water table, aquifer hydraulic conductivity, etc.);
- Evaluate risk of agricultural / nitrate contamination by mapping concentrations, performing statistical analysis, and evaluating temporal trends.;
- Evaluate risk of brine upwelling / chloride contamination by mapping concentrations, performing statistical analysis, and evaluating temporal trends;
- Evaluate water quality with respect to metals and metalloids (iron, arsenic, lead, and magnesium) by mapping concentrations, performing statistical analysis, and evaluating temporal trends;
- Design sampling networks for collected data related to water quantity (levels, fluxes) and water quality.
- Observe realtime water levels and water quality (including early detection/warning of contamination) and analyze temporal trends collected from in-situ sensors / monitoring wells.
- Create water and aquifer system cross-sections to “see into the subsurface”
- Create 2D and 3D integrated overlays of raw, derived, and simulated data layers

Broader Impacts

Accessible on demand, anywhere and at any time through its cloud-powered delivery service, The BEST Intelligent DSS will allow going beyond one project, one site, or one problem related to groundwater management in Allegan County – now, and into the future.

The BEST Intelligent DSS will provide an efficient platform for risk-based, cost-effective, community-oriented decision making. The DSS will enable the informed participation of citizens and improve interactions between local government, their constituents, researchers, and consultants, bringing the following benefits to the stakeholders:

- *Resource managers and planners* will be able to evaluate the effectiveness and impact of their management plans to improve policy-making decisions. They can visually evaluate the impact of potential threats, land use, contamination, and water withdrawals. They can become more effective in identifying/prioritizing areas/sites for monitoring, development, conservation, or protection and will be able to design more focused, cost effective analysis and monitoring. They can also be more effective in engaging the public and informing high-level decision makers about the implications of a proposed development and the transport of contamination on sensitive receptors (e.g., drinking water wells, residential areas, groundwater dependent ecosystems).
- *Communities and stakeholders* will be able to visualize the invisible subsurface and experience and better understand the impact of proposed management measures in a vivid and interactive way. They can also visualize the potential impact of their own activities on the groundwater environment. Thus, they are motivated and empowered to engage in the intricate process of community-based ecosystem and water/land use management, planning, and protection.
- *Policymakers* can make more informed decisions regarding setting and enforcing laws and regulations for water resources management and use interactive tools to improve public relations and to evaluate future land use management plans related to zoning and new developments. They also will have an effective mechanism to communicate a solution, a policy, or strategy to their constituents.

The ability to visualize the surface and subsurface, groundwater flow patterns and surface water features, 3D water quality, and lithology and geology sparks pivotal insights into the complex interrelationships among components of the environment and human activities. This greater awareness gives rise to intuitive grasp of implications of management actions and policy decisions that can't be readily obtained otherwise. The seamless integration of modeling results, data from disparate sources, management analyses, and interactive visual communication will make it possible for resource managers and planners to focus on high level issues and to refine management strategies and policies quickly and iteratively.

SPECIFIC TASKS

Task 1 – Database Integration and Data Service System

The important first step in this proposed project is the development of a countywide groundwater resources database and data service system in support of secure, cyber-enabled, and real-time modeling, visualization, and analysis of Allegan County's groundwater. The types of data formats including images, vector data (e.g., shapefiles), raster data (tiled data layers), metadata, and other information.

Data will be compiled from several sources, including nationwide, statewide, or even countywide storehouses (e.g., Phase 1 products or county-generated GIS data). While there may be some "overlap" between sources, the multi-source/multi-scale approach to data integration provides the best complete package of data available with multiple levels of details / resolutions – to allow "big picture" analysis down to site-specific problem solving.

A significant aspect of this foundational task is intelligent processing, representation, scaling, re-delineations (e.g., streams and watersheds), maps generation, storage, and access – setting the stage for real-time, cyber-enabled modeling, visualization, and discovery, and enabling true capitalization on the global spatial revolution.

It is especially the high-resolution spatial datasets that require special / Intelligent processing to be used effectively in realtime interactive visualization modeling. As such, the project will include detailed work related to:

- multiscale Digital Elevation Model representation
- multiscale watershed delineation and representation
- multiscale lakes representation
- multiscale wetlands representation
- multiscale rivers system delineation and representation
- multiscale land use representation
- multiscale soil representation
- multiscale hydrogeology representation

Ready for instant use in 2D and 3D mapping and modeling at any scale, all data layers will include relevant metadata or theme (subject matter) attributes, including map title and abstract, keywords, symbol/color legend, location, resolution, data source, and projection system.

The data server software system will enable web mapping services, or WMS, web feature services, WFS, and web coverage services, WCS (raster/tiled data retrieval):

- Software Enabling Web Mapping Services – WMS – for image retrieval
- Software Enabling Web Feature Services – WFS – for vector data retrieval
- Software Enabling Web Coverage Service – WCS – for raster/tiled data retrieval

The system will provide scalable data and map extraction services, making use of dynamic tiling techniques that allow viewing detailed spatial datasets efficiently and in real-time. In other words, data are provided only for the window area of the mapping environment, and data resolution is automatically selected based on the scale of viewing area.

- Software Enabling Web Mapping Tiered Services – WMTS – for tiled image retrieval

Note that all datasets described in the following Subtasks involved processing to enable WMS, WFS and WCS services.

Subtask 1.1 – Phase 1 Derived Maps / Spatial Layers

Under this subtask, Hydrosimulatics INC. will integrate (and re-process, as necessary) the following countywide map products generated as part of the Phase 1 Allegan County Groundwater Study completed by Hydrosimulatics INC:

- Groundwater level maps - glacial and bedrock
- Depth-to-groundwater
- Distribution of recharge and discharge areas
- Aquifer yield
- Water use patterns
- Water quality severity rankings

Subtask 1.2 – Spatial Products from Screening-level Modeling, Risk Analysis, and Ranking

Under this subtask, Hydrosimulatics INC. will integrate the following countywide map products generated as part of the Phase 2 Allegan County Groundwater Study currently being completed by Hydrosimulatics INC.:

- Wellhead Protection Areas for Type I wells (for different assumed times-of-travel)
- Potential impact areas of known or contaminated sites (for different assumed times-of-travel)
- Countywide aquifer vulnerability
- Maps of site priority rankings

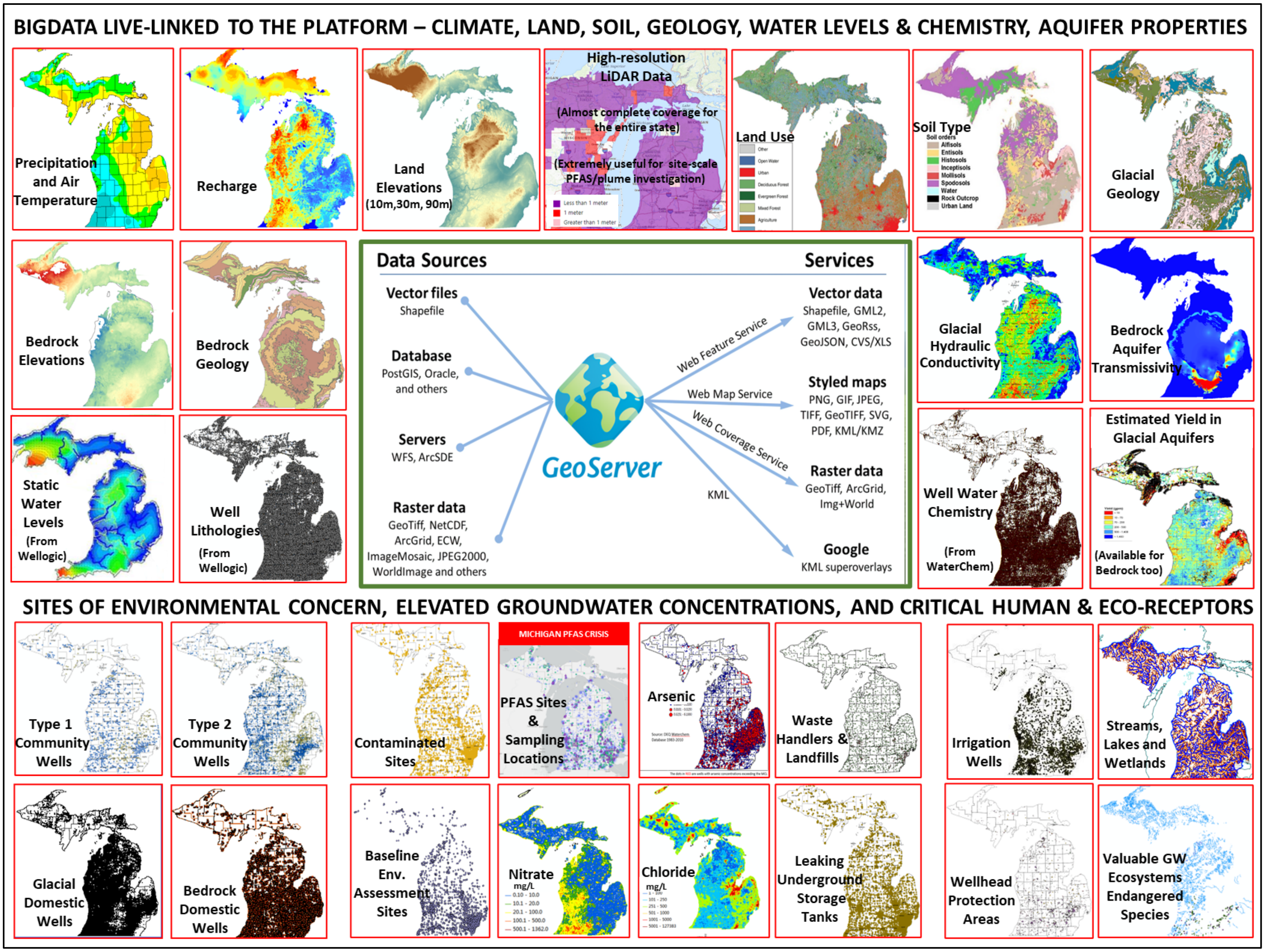
Subtask 1.3 – State of Michigan Groundwater Datasets

Under this subtask, Hydrosimulatics INC. will download, process (including trimming to Allegan County's extent), and integrate the following *essential* statewide groundwater/environmental datasets that are publicly available:

- Water wells from Wellogic (Type1, Type 2, private, etc.)
- Well lithologies from Wellogic (categorized in aquifer material types)
- Water quality data from WaterChem. <u>This requires significant processing</u>, e.g., to organize the database into a standard format, to deal with or filter our non-analytical results (e.g., "non-detect", "not tested", etc.), etc. Water quality parameters that will be processed include
  - Nitrate
  - Chloride
  - Sodium
  - Iron
  - Arsenic
  - Lead
  - Manganese
- Hydraulic conductivity / transmissivity
- Topography (90m,30m, 10m)
- Glacial land systems (large-scale spatial distribution)
- Bedrock formations (sub-crop areas and elevations)

- Mean long-term recharge
- Known & Potential Sites of Contamination (including PFAS sites)
    - Sites of Environmental Concern
    - Underground storage tanks (including Leaky USTs)
    - Historical & operational landfills and waste handlers
    - Oil and gas wells

Graphic 4 presents the statewide datasets (including the ones listed above that will be used in this project) that are linked to the M4W platform.



Graphic 4: Statewide datasets available for integration into the BEST Intelligent DSS, including those related to *climate* (historical daily and monthly precipitation and air temperature, aquifer recharge), *land* (surface topography/elevations, land use) *soil* (type, root zone depth), *geology* (glacial, bedrock, water well lithologies), *water levels* (Static Water Levels, or SWLs, from Wellogic records), *well water chemistry* (nitrate, chloride, arsenic, etc.), *aquifer properties* (hydraulic conductivity, transmissivity, yield), *sites of environmental concern* (contaminated sites, PFAS sites, leaky underground storage tanks, etc.) and *critical human and ecological receptors* (Type 1 and Type 2 community wells, irrigation wells, streams, lakes and wetlands, and valuable groundwater-dependent ecosystems).

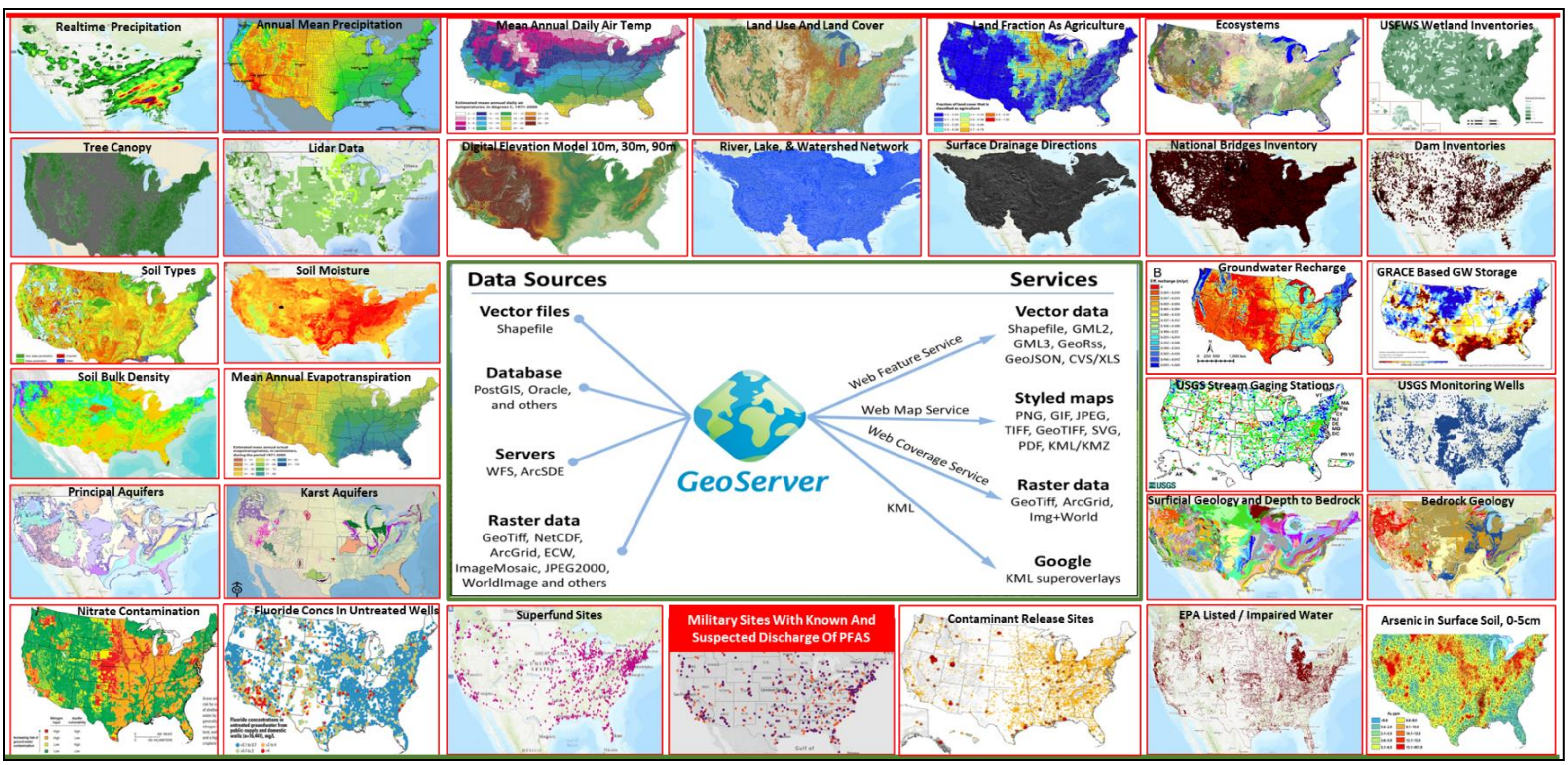
Subtask 1.4 – National Datasets and Data Layers

Under this subtask, Hydrosimulatics INC. will download, process (including trimming to Allegan County's extent), and integrate the following national groundwater/environmental maps and "static" datasets that are publicly available:

- Digital Elevation Models (DEM) – 30m, 10m
- LiDAR – high resolution land surface representations (1m or less)
- Rivers, Streams, Lakes and Wetlands
- Watersheds
- Land Use / Land Cover
- Soil Data
- Ecosystems data
- Flood maps (100-year return frequency storm events)

Graphic 5 presents the nationwide datasets (including the ones listed above that will be used in this project) that are linked to the M4W platform.

Again, while there may be some "overlap" between nationwide datasets and more local (statewide or county datasets), <u>the multi-source/multi-scale approach to data integration provides the best complete package of data available with multiple levels of details / resolutions</u>.



Graphic 5: Nationwide datasets available for integration into the BEST Intelligent DSS, including those related to *climate*, *land*, *soil*, *geology*, *water levels* (groundwater head from USGS monitoring wells), *well*

water and surface water chemistry, *aquifer properties*, *sites of environmental concern* (EPA listed /impaired water sites, contaminant release sites, etc.) and *critical human and ecological receptors*.

Subtask 1.5 – Local GIS data (County or Township Datasets)

Under this task, Hydrosimulatics INC. will integrate GIS-formatted data provided by local governments / municipalities (when available) for the BEST Intelligent DSS. This may include:

- Zoning / development distribution maps
- Political boundaries – townships, cities, villages, land parcels
- Water distribution systems
- Stormwater drainage systems
- Locations of known septic tanks
- Detailed land use/land cover
- Detailed soil data

Subtask 1.6 – In-situ Sensor Data

Under this task, Hydrosimulatics INC. will link the DSS to the in-situ / wireless national monitoring networks through their existing webservices. This includes :

- US Geological Survey (USGS) National Groundwater Monitoring Network (NGWMN) wells
- USGS steam gage data (if/when available)
- State of Michigan monitoring well network (proposed/under development)
- Other wireless sensor data available to the county (e.g., collected by consultants)

The linked sensor data will enable real-time monitoring and groundwater analytics (see Realtime Groundwater Modeling and Analytics Tool.

Summary Data Table

The following table summarizes the datasets and data layers to be integrated for the proposed project.

Category	Data Layer / Parameter	Source	Realtime Tools
Land and Soil	Digital Elevation Model (DEM)	National Maps / Datasets	Land Surface and Drainage Delineation; Groundwater Discharge and Basement Flooding Vulnerability Assessment; Aquifer Cross-section Visualization; 3D Water / Aquifer System Visualization; Aquifer Vulnerability Assessment; General 2D mapping and 3D visualization
	LiDAR - high resolution land surface representations (1m or less)	National Maps / Datasets	Same as DEM, but for very localized analysis/visualization
	Watershed boundaries	National Maps / Datasets	General 2D mapping and 3D visualization; Land Surface and Drainage Delineation; General 2D mapping and 3D visualization
	Surface water network - streams, lakes, and wetlands	National Maps / Datasets	General 2D mapping and 3D visualization; Critical Groundwater-Dependent Ecosystem Mapping and Source Water Delineation; Brine Upwelling / Chloride

Land and Soil			Contamination Risk Analytics Tool; General 2D mapping and 3D visualization
	Land Use / Land Cover	National Maps / Datasets, County GIS (?)	Groundwater Recharge Area Delineation; Wellhead Protection Area Delineation; Agriculture / Nitrate Contamination Risk Assessment; General 2D mapping and 3D visualization;
	Soil Data - type, and derived parameters	National Maps / Datasets, County GIS (?)	Groundwater Discharge Area and Basement Flooding Vulnerability Assessment; Groundwater Recharge Area and Flow Pattern Delineation; Aquifer Vulnerability Assessment; General 2D mapping and 3D visualization;
	Ecosystems Data	National Maps / Datasets	Critical Groundwater-dependent Ecosystem Mapping and Source Area Delineation; General 2D mapping and 3D visualization;
	Political boundaries	State of Michigan GW Datasets, County GIS (?)	General 2D mapping and 3D visualization
	Road network	State of Michigan GW Datasets	General 2D mapping and 3D visualization
	Zoning/development zones	County GIS (?)	General 2D mapping and 3D visualization
	Other GIS data from local government / municipalities	Allegan County	General 2D mapping and 3D visualization
Geology	Glacial land systems (large-scale spatial distribution)	State of Michigan GW Datasets	Metals/Metalloids Risk Assessment; Aquifer Vulnerability Assessment; General 2D mapping and 3D visualization;
	Bedrock formations (sub-crop areas and elevations)	State of Michigan GW Datasets	Metals/Metalloids Risk Assessment; Aquifer Vulnerability Assessment; General 2D mapping and 3D visualization;
	Well lithologies	State of Michigan GW Datasets	General 2D mapping and 3D visualization; Aquifer Cross-section Visualization
Aquifer Properties	Aquifer Top (DEM)	National Maps / Datasets	Same as DEM
	Aquifer Bottom (Bedrock surface)	State of Michigan GW Datasets	General 2D mapping and 3D visualization
	Hydraulic conductivity / transmissivity	State of Michigan GW Datasets	Groundwater Flow Delineation; Groundwater Recharge Area Delineation; Well Yield Modeling and Mapping; Well Conflict Resolution Modeling; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation; Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contaminant Source Tracing, Aquifer Vulnerability Assessment; Remediation Capture Well Design Tool

Water Quantity / Availability	Water wells from Wellogic	State of Michigan GW Datasets	Groundwater Use and Well Mapping Analysis; General 2D mapping and 3D visualization
	Groundwater level maps - glacial and bedrock	Phase 1 Derived Map / Analysis	Groundwater Flow Delineation; Groundwater Recharge Area Delineation Well Yield Calculation; Well Conflict Resolution; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation; Sites of Environmental Concern Mapping and Contaminant Tracking; General 2D mapping and 3D visualization; Remediation Capture Well Design Tool
	Depth-to-groundwater	Phase 1 Derived Map / Analysis	Groundwater Discharge Area and Basement Flooding Vulnerability Assessment
	Distribution of "master" recharge and discharge areas	Phase 1 Derived Map / Analysis	General mapping and visualization
	Aquifer yield	Phase 1 Derived Map / Analysis	Well Yield Modeling and Mapping; Well Conflict Resolution Modeling
	Mean long-term natural recharge	State of Michigan GW Datasets	General 2D mapping and 3D visualization
	Water Use Patterns	Phase 1 Derived Map / Analysis	Groundwater Use and Well Mapping Analysis
	Water levels from monitoring well sensors	Proposed work by MGS	Realtime Groundwater Monitoring & Analytics Tool
Contamination / Water Quality / Water Resource Protection	EGLE Sites of Environmental Concern	State of Michigan GW Datasets	Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contamination Source Tracing; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation
	PFAS sites	State of Michigan GW Datasets	Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contamination Source Tracing; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation
	Underground storage tanks (including Leaky USTs)	State of Michigan GW Datasets	Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contamination Source Tracing; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation
	Historical & operational landfills and waste handlers	State of Michigan GW Datasets	Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contamination Source Tracing; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation
	Oil and gas wells	State of Michigan GW Datasets	Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contamination Source Tracing; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation

Contamination / Water Quality / Water Resources Protection	Potential impact areas of known or contaminated sites (for different assumed times-of-travel)	Phase 2 Derived Map / Analysis (on-going)	Sites of Environmental Concern Mapping and Contaminant Tracking; Groundwater Contamination Source Tracing; Wellhead Protection Area Delineation; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation
	Countywide aquifer vulnerability map	Phase 2 Derived Map / Analysis (on-going)	Aquifer Vulnerability Assessment
	Maps of contaminated site priority rankings	Phase 2 Derived Map / Analysis (on-going)	General 2D mapping
	Nitrate concentrations	State of Michigan GW Datasets	Agriculture / Nitrate Contamination Risk Assessment; Wellhead Protection Area Delineation; Well Yield Modeling and Mapping
	Chloride concentrations	State of Michigan GW Datasets	Brine Upwelling / Chloride Contamination Risk Assessment; Wellhead Protection Area Delineation; Well Yield Modeling and Mapping
	Iron concentrations	State of Michigan GW Datasets	Metals/Metalloids Risk Assessment; Wellhead Protection Area Delineation; Well Yield Modeling and Mapping
	Arsenic concentrations	State of Michigan GW Datasets	Metals/Metalloids Risk Assessment; Wellhead Protection Area Delineation
	Lead concentrations	State of Michigan GW Datasets	Metals/Metalloids Risk Assessment; Wellhead Protection Area Delineation; Well Yield Modeling and Mapping
	Manganese concentrations	State of Michigan GW Datasets	Metals/Metalloids Risk Assessment; Wellhead Protection Area Delineation; Well Yield Modeling and Mapping
	Water quality severity rankings maps	Phase 2 Derived Map / Analysis (on-going)	General 2D mapping
	Water quality measurements from monitoring well sensors	Proposed work by MGS	Realtime Groundwater Monitoring & Analytics Tool; Agriculture / Nitrate Contamination Risk Assessment; Brine Upwelling / Chloride Contamination Risk Assessment; Wellhead Protection Area Delineation; Metals/Metalloids Risk Assessment; Critical Groundwater-Dependent Ecosystem Mapping and Source Area Delineation
	Wellhead Protection Areas for Type I wells	Phase 2 Derived Map / Analysis (on-going)	Sites of Environmental Concern Mapping and Contaminant Tracking; Wellhead Protection Area Delineation;

Task 2 – Realtime Groundwater Management Tools

Subtask 2.1 – Groundwater Flow Delineation Tool

<u>The work involved in this first subtask is significant/critical, as it serves as a foundation for many of the management tools described in this proposal</u>.

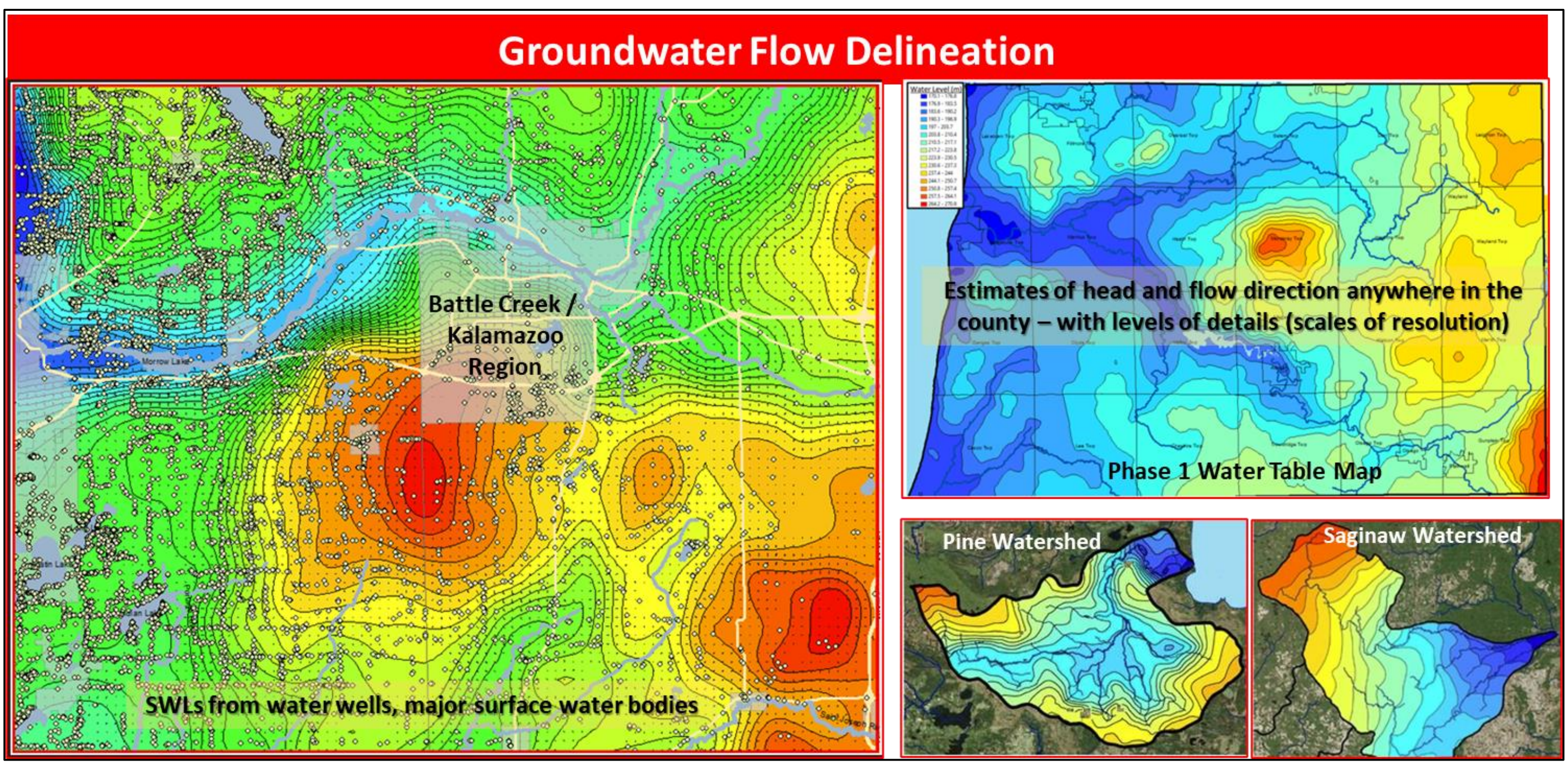
To effectively address the many groundwater management issues facing the county, different scales of groundwater level maps are needed, including for countywide and township-level holistic planning and more local-scale (e.g., section-based or site-specific) problem solving.

In addition to the countywide maps prepared in Phase 1, **Hydrosimulatics will develop refined subscale maps with higher resolutions and smaller extents, based on available static water level data and process-based modeling. These maps will be intelligently linked to the DSS such that a user can define an area of interest – anywhere in the county and at any spatial scale – to automatically extract and visualize the appropriate groundwater maps**.

Hydrosimulatics will also **develop capabilities and an interface to allow DSS users to dynamically / interactively superimpose the effect of well pumping** (e.g., based on Theis solution) on to groundwater level map (see more on this in Wellhead Protection Area Delineation Tool and Remediation Capture Well Design Tool).

The Groundwater Flow Delineation Tool will include options for specifying the area of interest (drawing a box or polygon); choosing the input SWL layer dataset (e.g., all glacial drift wells; drift wells with outliers removed, drift wells with outliers removed and surface water points; etc.); and smoothing of interpolated flow patterns (to remove local irregularities – or non-physical features – related to data density).

See Graphic 6 below.



Graphic 6: Groundwater Flow Delineation Tool. The Tool allows one to quickly map groundwater flow patterns and directions within a specified area - at any spatial scale within the county - in the glacial or bedrock aquifers.

Key management questions that can be addressed with this tool include:

- How does groundwater move around underneath Allegan – in different aquifers (e.g., glacial and bedrock) and at different scales (e.g., countywide, in different townships, or at a local site/property)?
- What is the depth-to-groundwater table in this area?

Subtask 2.2 – Groundwater Recharge Area Delineation Tool

The location of groundwater recharge areas has implications on aquifer protection/sustainability, land use planning (e.g., development in recharge areas disproportionately impacts aquifer sustainability) and waste disposal activities (e.g., spills in recharges areas have significantly more impact than in discharge areas).

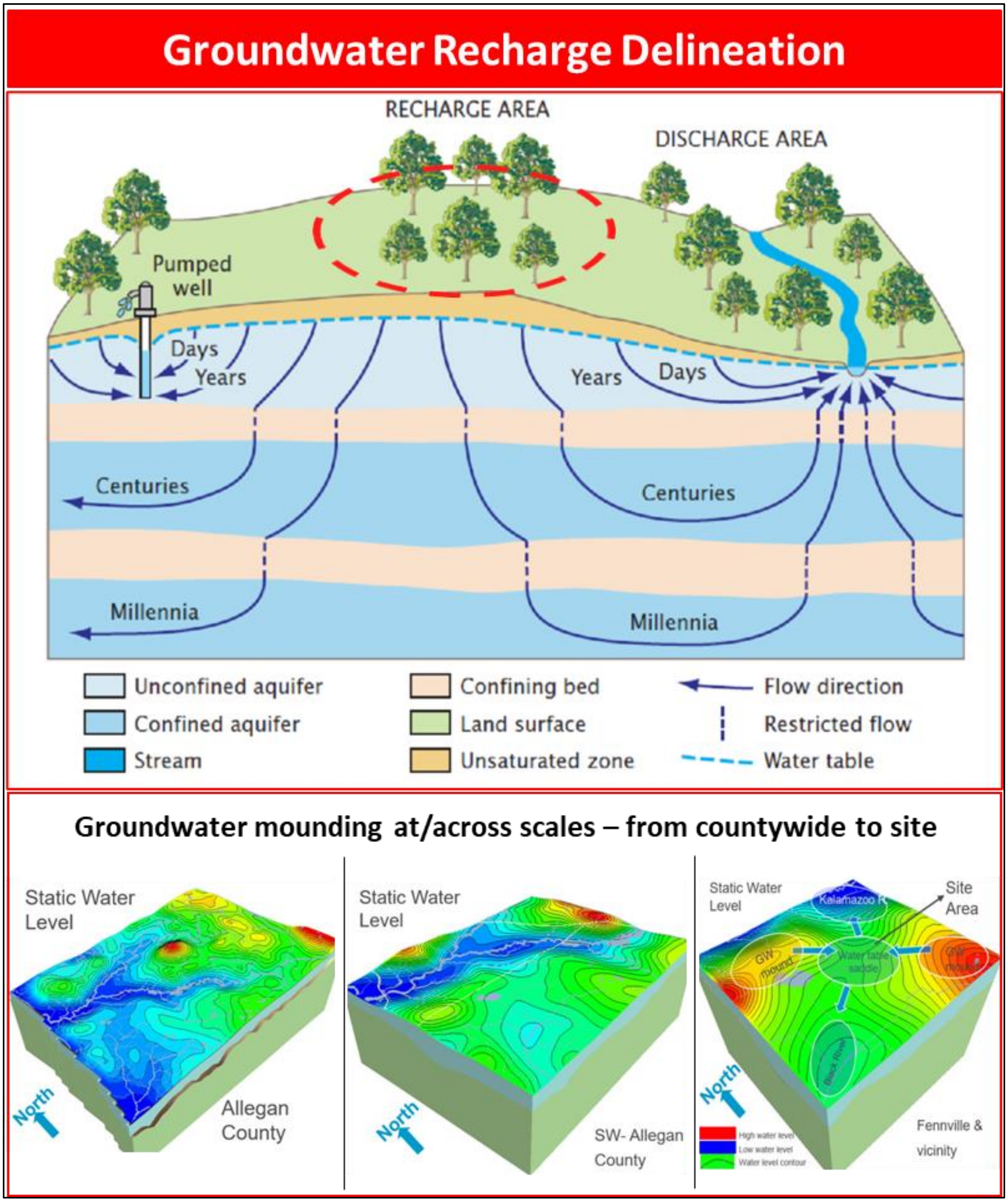
As part of the Phase 1 study, countywide and subregional ("quadrant") maps of groundwater levels were used to identify "master" recharge areas (groundwater mounds) where recharging water moves deep and travels regionally, feeding the entire aquifer. At more local scales, "secondary" groundwater mounds may exist, depending on local groundwater and land use/soil conditions.

Protection of groundwater recharge areas therefore requires characterizing different scales of groundwater mounding (groundwater level patterns) and dynamically overlaying them at different "zoom levels" on to soil types, soil permeability, surficial geology, aquifer conductivity, and land use / impervious areas. Groundwater mounding areas with high "effective surficial permeability" (all the way to the water table) are significant recharge areas and have important implications for development.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable one to **instantly overlay/map multiple layers of information to identify local groundwater recharge areas,** including:

- Occurrence of groundwater "mounds" in flow pattern delineation (see previous subtask)
- Soil permeability and aquifer hydraulic conductivity
- Land use and impervious land cover

See Graphic 7 below.



Graphic 7: Groundwater Recharge Delineation Tool. The Tool allows one to instantly overlay/map multiple layers of information to identify local groundwater recharge areas, including: occurrence of groundwater "mounds" in flow pattern delineation (see previous subtask); soil permeability and aquifer hydraulic conductivity; and land use and impervious land cover.

<u>Key management questions</u> that can be addressed with this tool include:

- How are the glacial and bedrock aquifers recharged?
- Where are the dominant replenishment areas?
- Where are the secondary recharge areas?
- Why does development in certain areas in Allegan have disproportionately large impacts on groundwater sustainability/future availability?
- How can the county manage holistically growth and water use?

Subtask 2.3 – Groundwater Use and Well Mapping and Analytics Tool

The Phase 1 study mapped the distribution of water wells across the entire county and over the past ~20 years to characterize (at a screening-level) growth of groundwater use and identify water use "hot-spots". The study also analyzed SWL temporal trends in hot-spot areas to see screen for pumping-induced groundwater decline.

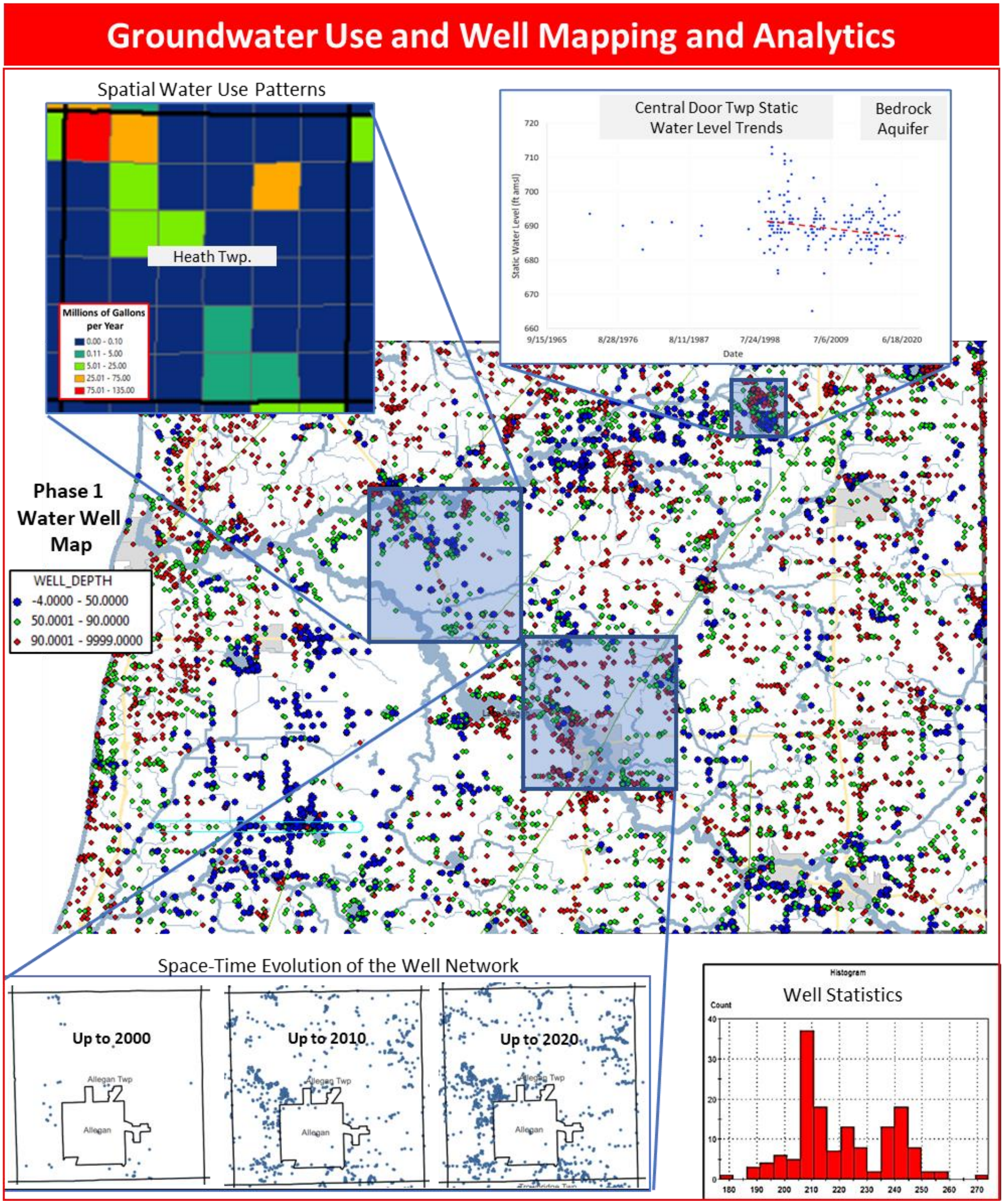
Although useful, the Phase 1 analysis is "static" – it quickly becomes outdated as more wells are installed or existing/older wells are identified to the database; the large-scale makes local dynamics/trends difficult to identify; and typical pumping rates are based on "countywide averages" whereas local pumping rates can vary significantly.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to **enable localized or more detail groundwater use analysis**. More specifically, the work involved in this subtask will enable (for any location or subregion in the county):

- Instant mapping of different types of wells (irrigation, public supply, industry, domestic; drift vs. bedrock; new and existing)
- Instant calculation of well statistics for various "well parameters" (SWL, depth, construction date, etc.)
- Instant mapping of spatial water use patterns (assuming different typical uses or pumping rates for different types, which can be adjusted with improved information)
- Instant analysis of temporal trends (number of wells over time, SWLs, …)

The Tool will include options for statistical analysis of well records, such as: filtering wells by SWL value (min. to max.) or by time period (from starting date to ending date); controlling the number of "bins" for histogram, probability density Function (PDF), or cumulative distribution function (CDF) analysis; and more.

See Graphic 8 below.



Graphic 8: Groundwater Use and Well Mapping and Analytics Tool. The tool enables localized or more detail groundwater use analysis, including: instant mapping of different types of wells (water sector, aquifer, etc.); instant calculation of well statistics for various "well parameters" (SWL, depth, construction

date, etc.); instant mapping of spatial water use patterns; and instant analysis of temporal trends (number of wells over time, SWLs, …).

Key management questions that can be addressed with this tool include:

- Where are the existing wells in my area?
- What kind of wells are they (irrigation, industrial, public supplies, private, etc.)?
- How deep are these wells? From which aquifer do they pump groundwater?
- What is the estimated water use and pattern?
- How have this pattern changed over time?
- Which areas/sections may be most likely to experience water shortage?

Subtask 2.4 – Well Yield Modeling and Mapping Tool

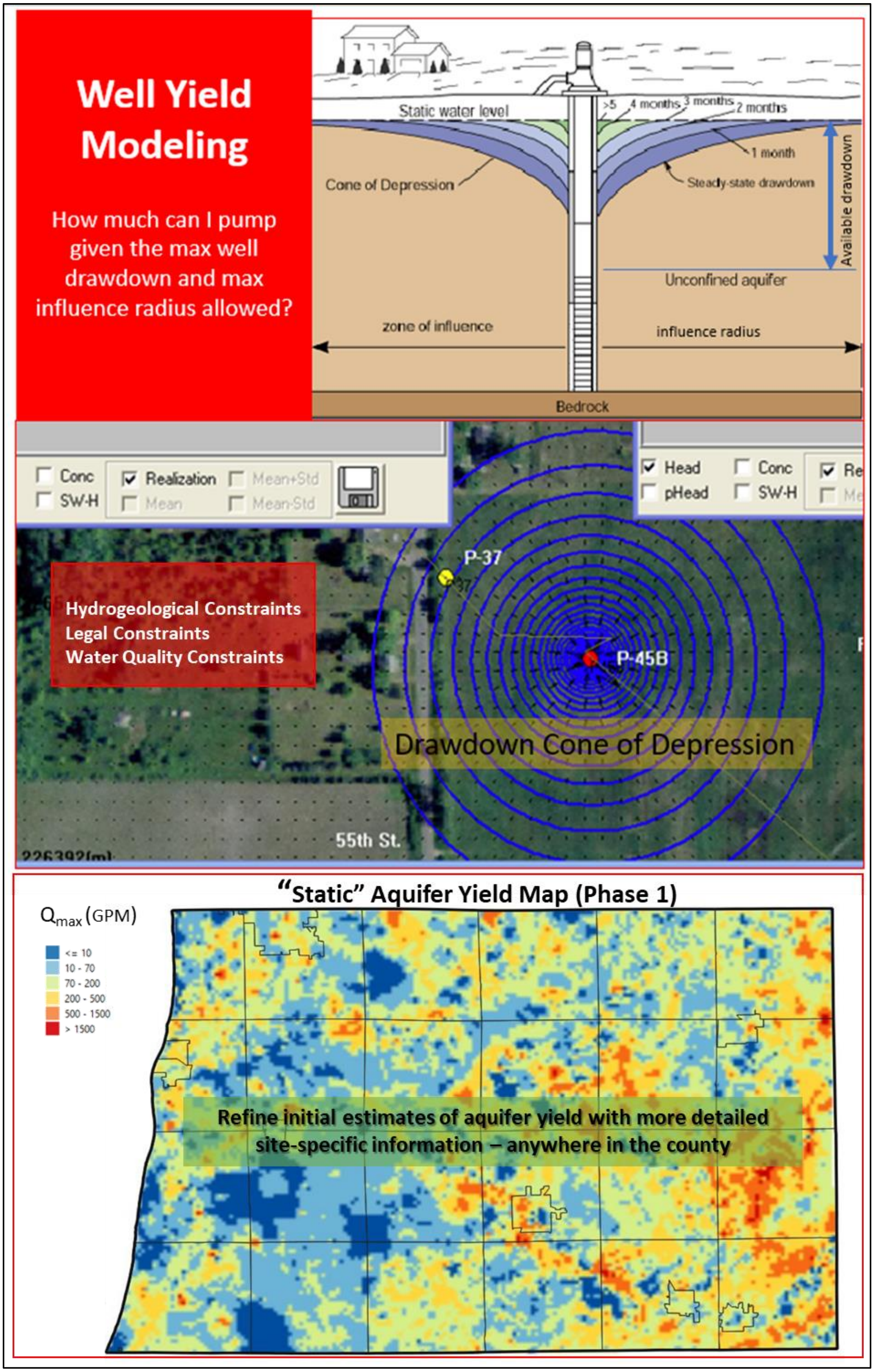
Well yield is the ability of the aquifer to produce water and is typically described as a pumping rate that would be required to lower the hydraulic head at the well to a specified percentage (e.g., 50%) of the available drawdown (or saturated thickness) over a reasonably long period of time (e.g., 3 months). In the Phase 1 study, well yield was calculated and mapped for the entire county at 300m resolution under a given set of management assumptions (acceptable level of drawdown, well efficiency, etc.). The analysis revealed that well yield can vary significantly over relatively short distances, although in general yield is small in the western-central Townships and large along most of the Lake Michigan coastline, along parts of the northern and southern borders of the county, and in the eastern Townships.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable one to:

- **Map in detail parameters used in Well Yield Calculation:**
  - Aquifer transmissivity, conductivity
  - Saturated aquifer thickness
  - Available drawdown
- **Interactively zoom into areas calculating specific yield at different scales/**resolutions based on input data layers and/or more accurate local information (field collected data, known well efficiencies, etc.)
- **Calculate / map yield based on drawdown constrains at some distance from the pumping well** (see next Subtask).
- **Map nearby sources of contamination and/or water quality**

The Tool will include options for specifying/changing: allowable drawn (Phase 1 assumed 50% of saturated thickness of the local aquifer); well efficiency (Phase 1: 70%); pumping duration (Phase 1: 100 days); aquifer Transmissivity (Phase 1: spatially-variable, based on data from countywide hydraulic conductivity and saturated thickness layers); original/pre-pumping Static Water Level (Phase 1: spatially-variable, based on countywide SWL layer); and aquifer bottom (Phase 1: spatially-variable, based on interpolation of the bedrock top surface from Wellogic borehole records).

See Graphic 9 below.


Well Yield Modeling
How much can I pump given the max well drawdown and max influence radius allowed?
Static water level
>5
4 months
3 months
2 months
1 month
Cone of Depression
Steady-state drawdown
Available drawdown
Unconfined aquifer
zone of influence
influence radius
Bedrock
Conc
SW-H
Realization
Mean+Std
Mean
Mean-Std
Head
pHead
P-37
P-45B
Hydrogeological Constraints
Legal Constraints
Water Quality Constraints
Drawdown Cone of Depression
55th St.
"Static" Aquifer Yield Map (Phase 1)
Q_{max} (GPM)
<= 10
10 - 70
70 - 200
200 - 500
500 - 1500
> 1500
Refine initial estimates of aquifer yield with more detailed site-specific information – anywhere in the county

Graphic 9: Well Yield Modeling and Mapping Tool. The tool will enable one to: map in detail parameters used in the well yield calculation; interactively zoom into areas calculating specific yield at different scales/resolutions based on input data layers and/or more accurate local information; calculate / map yield based on drawdown constrains at some distance from the pumping well; and map nearby sources of contamination and/or water quality

Key management questions that can be addressed with this tool include:

- What is the maximum yield (pumping) that can be sustained based on geology?
- What is the maximum yield that can be sustained without interfering with my neighbor's water?
- Is yield limited by nearby sources of groundwater contamination?
- What is the hydrologically optimal development of water resources at this location, given geological, legal, and water quality constraints?

Subtask 2.5 – Well Conflict Resolution Modeling Tool

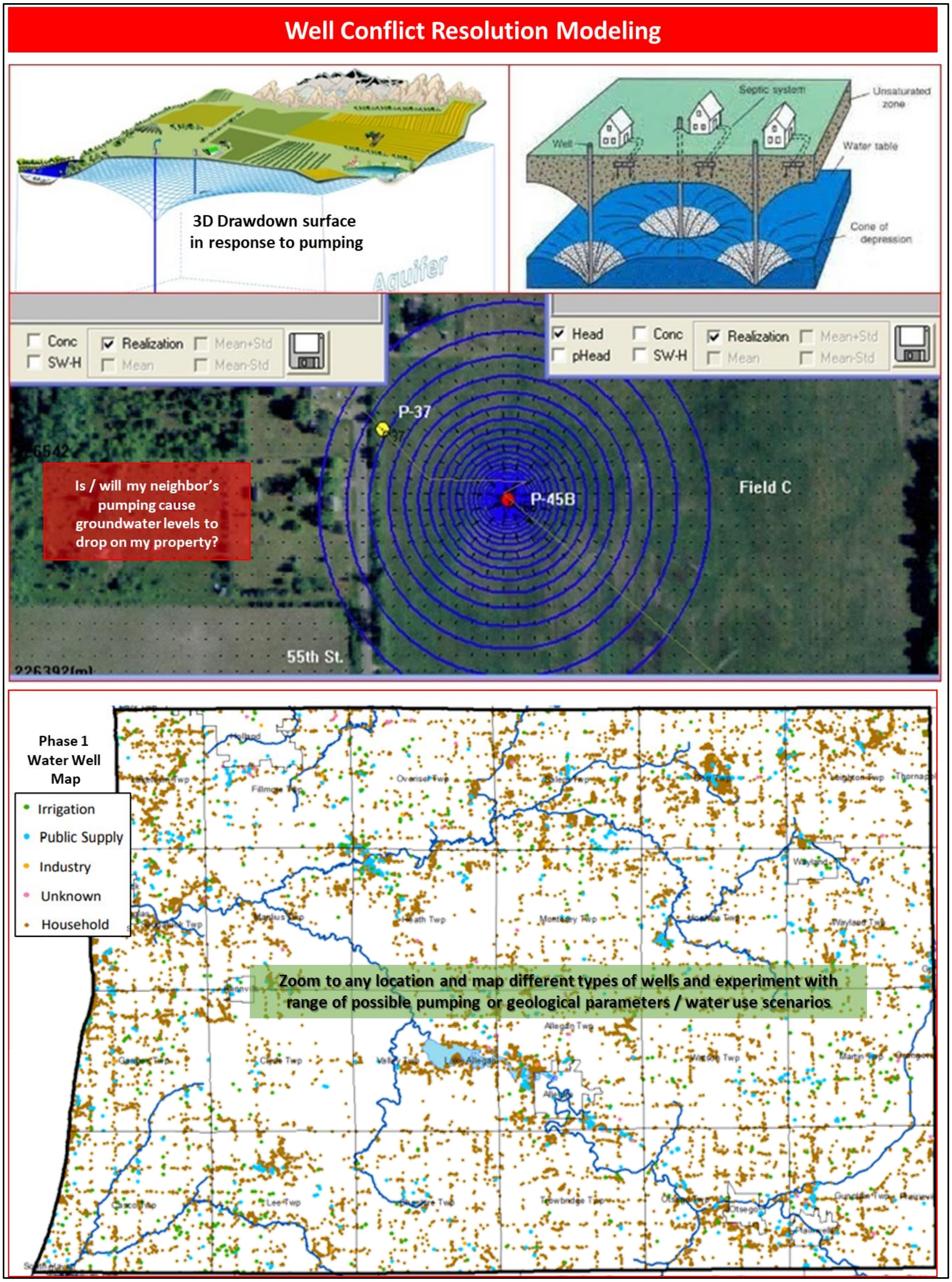
When a new high capacity well is installed and starts operating, it will cause water levels at and around the well to lower in response to pumping. As time goes on, the "cone of depression" or area of influence expands outward, eventually stabilizing after enough time passes. In some cases, the cone of depression may intersect existing water wells, having an adverse impact on its ability to produce groundwater. The degree to which a new well may conflict with an existing well can be determined by considering the aquifer properties and the mathematical relationship between pumping and resulting drawdown.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable;

- **Mapping wells of different types: irrigation, public supply, domestic; industry; new or existing**
- **Instant calculation of expected drawdown due to pumping of high-capacity well** (at/very near pumping well)
- **Instant calculation of expected drawdown at a nearby site,** some distance from the pumping well
- **Quick delineation of Area of Influence of over time**

The Tool will include options for specifying/changing the following parameters related to calculation of drawdown and area of influence: pumping rate of high-capacity well; pumping duration; aquifer hydraulic conductivity (also available countywide as spatial layer); aquifer thickness (also available countywide as spatial layer); and aquifer storage coefficient.

See Graphic 10 below.



Graphic 10: Well Conflict Resolution Modeling Tool. The tool enables mapping wells of different types; instant calculation of expected drawdown due to pumping of high-capacity well; instant calculation of

expected drawdown at a nearby site, some distance from the pumping well; and quick delineation of Area of Influence of over time.

Key management questions that can be addressed with this tool include:

- What is the influence area of my pumping well?
- Will an irrigation well impact the ability of wells nearby to pump groundwater?
- How far does the pumping impact extend?
- What are the implications of siting large-capacity pumping wells within large land parcels (e.g., agricultural lands)?
- Can adverse impacts be avoided/eliminated based on strategic well placement?
- What is the land use within the area of influence?
- Will pumping mobilize / accelerate movement of contaminants?

Subtask 2.6 - Land Surface Catchment and Drainage Pattern Delineation Tool

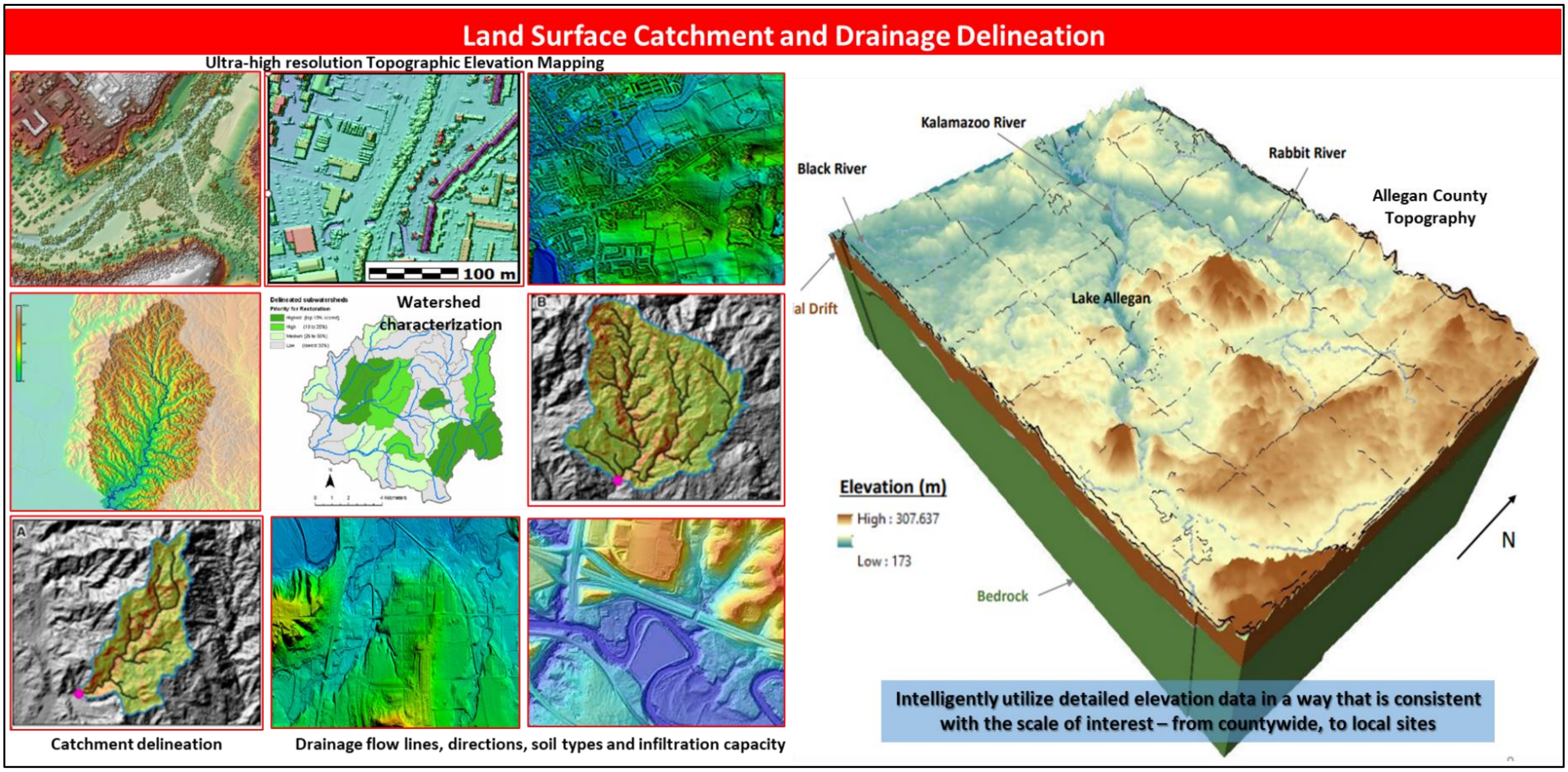
Areas of the land that drain rainfall to a common outlet are called land surface catchments (or subwatersheds or subcatchments). Delineation of land surface catchments and their drainage patterns is important for managing stormwater and transient flooding events (e.g., storage in depressions, ditches, and valleys), and for evaluating stream conditions and land use practices. A characterization of overland flow paths and drainage directions can also be used for identifying optimal water quality sampling locations and estimating flow and pollutant loading to streams. These types of information can be combined with information on soil types and infiltration capacity for characterizing or ranking/prioritizing sub watersheds across a larger area.

The emergence of ultra-high resolution LiDAR data provides an extremely valuable opportunity for environmental/water management, as it allows characterizing topographic elevations needed for drainage basin and overland flow delineation at the highest level of accuracy available. Yet, LiDAR datasets are “massive” (or so large in size that they are almost immovable) and are therefore very challenging to use without a user-friendly tool.

Under this subtask, HSAINC will program the DSS mapping environment and interface system **to enable interactive delineation of land surface catchments and catchment characterization - for any location (“point”) in the county.** More specifically, the work involved in this subtask will enable:

- Mapping topographic elevations in ultra-high resolution with LiDAR DEM or DSM (Digital Surface Model)
- Delineating land surface catchment boundary
- Calculating and visualizing land surface slope
- Calculating and visualizing drainage flowlines
- Mapping soil types and infiltration capacity

See Graphic 11 below.



Graphic 11: Land Surface Catchment and Drainage Delineation Tool. This tool enables mapping topographic elevations in ultra-high resolution with LiDAR DEM or DSM; delineating land surface catchment boundary; calculating and visualizing land surface slope; calculating and visualizing drainage flowlines; and mapping soil types and infiltration capacity.

Key management questions that can be addressed with this tool include:

- What is the surface drainage pattern in this area?
- What is the land surface catchment?
- How does the shape of the catchment impact surface drainage?
- Where are the areas of poor surface drainage in the catchment?
- What are the implications on development?

Subtask 2.7 – Groundwater Discharge Area and Subsurface Flooding Vulnerability Assessment Tool

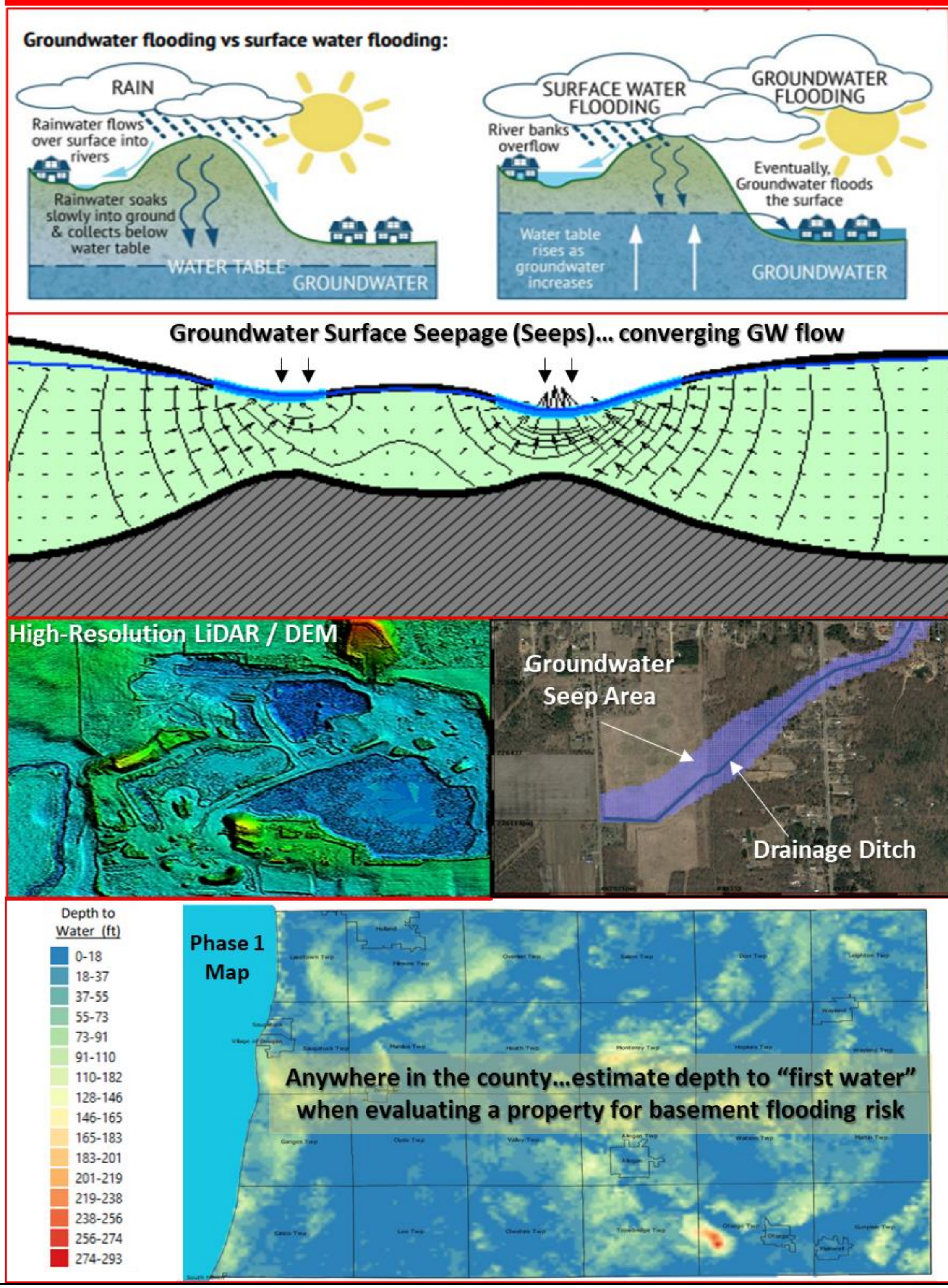
Issues related to reoccurring / frequent subsurface flooding typically occur in areas where: i) the "invisible" water table is high or close to the land surface); ii) subsurface drainage patterns converge or groundwater seepage/discharge occurs; iii) soils are less permeable or suspectable to ponding; and/or iv) the aquifer is "tight" (i.e., of low permeability).

Under this subtask, HSAINC will program the DSS mapping environment and interface system **to enable multi-perspective assessment of basement flooding risk**. More specifically, the work involved in this subtask will enable (for any location of subregion in the county):

- Instant mapping Depth-to-Water
- Instant delineation of surface seeps (groundwater discharge)
- Instant delineation of subsurface drainage pattern
- Instant mapping soil types/permeability
- Instant assessment of subsurface flooding potential
- Instant assessment of basement flooding risk (when combined with knowledge of surface runoff patterns – see previous Subtask/Tool).

See Graphic 12 below.

Groundwater Discharge Area and Subsurface Flooding Vulnerability Assessment



Graphic 12: Groundwater Discharge Area and Subsurface Flooding Vulnerability Assessment. This tool enables instant mapping Depth-to-Water; instant delineation of surface seeps (groundwater discharge); instant delineation of subsurface drainage pattern; instant mapping soil types/permeability; instant assessment of basement flooding risk.

Key management questions that can be addressed with this tool include:

- Why does this property have persistent drainage issues?
- Is it because the soil is too "tight"?
- Is it the result of converging subsurface runoff?
- Is it because the property is in a high-water table / groundwater discharge area?
- Is it a combination of multiple factors?
- Would a new development in this area experience subsurface flooding issues?

Subtask 2.8 – Wellhead Protection Area Delineation Tool

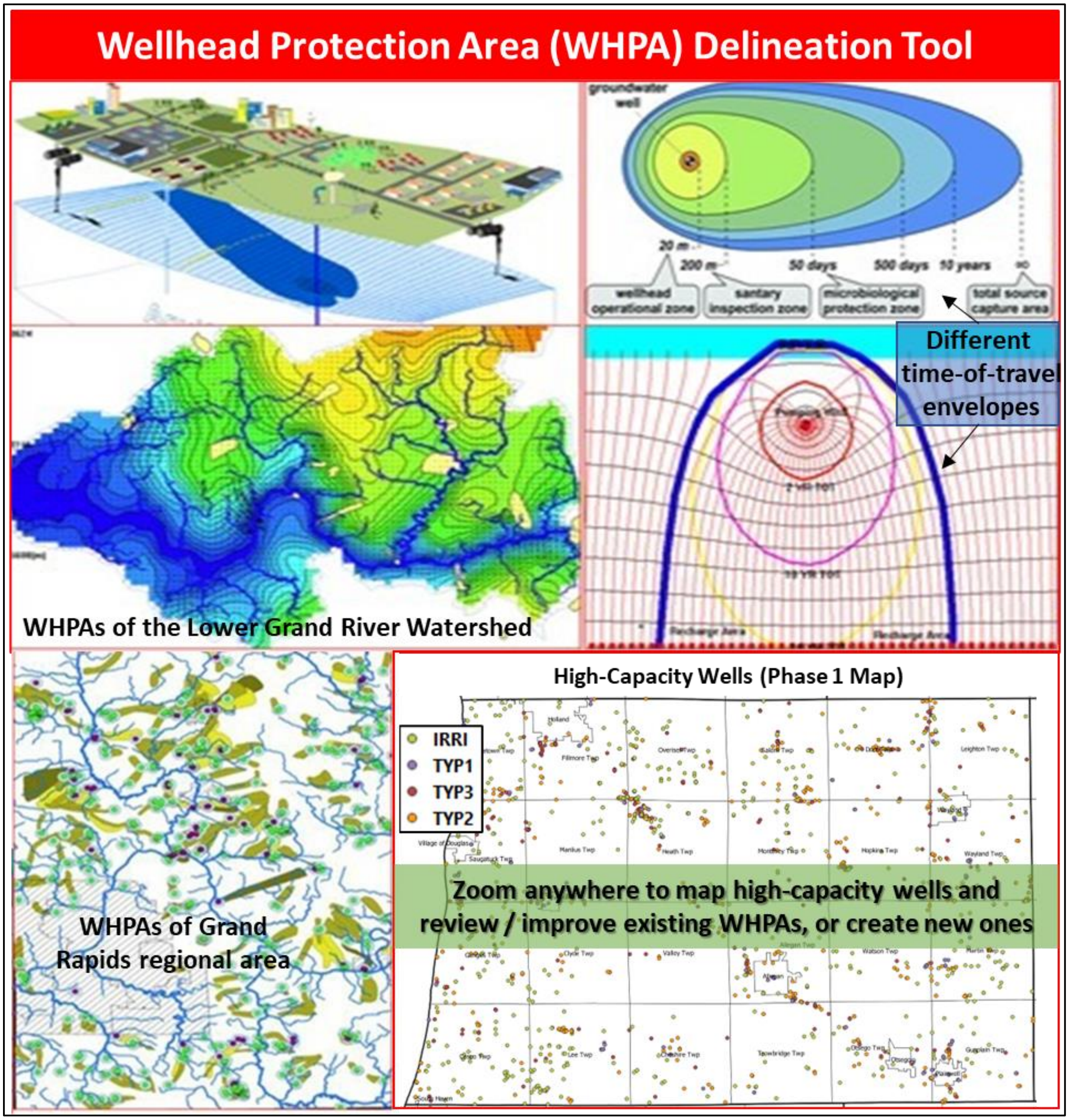
Presently, there are 126 active Type 1 Wells identified within Allegan County (based on analysis of the Wellogic water well database). The State of Michigan GIS Portal includes 62 WellHead Protection Areas (WHPAs), or the source water area or well-watershed of the wells, located within the County. Hydrosimulatics INC. will (as part of a separate on-going project) delineate WHPAs for the remained 64 Type 1 wells, but there are numerous (hundreds) of Type II or Type III community water-supply wells and irrigation wells in the county that may also require characterization of its well-watershed. (Even domestic wells may need well-watershed delineation, e.g., if a nearby land use/contamination sites threatens the water supply). Additionally, new (future) wells (of any type) will lack WHPA characterization, making it difficult to protect the groundwater source area.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to **enable WHPA delineation at any (new or existing) well of interest**. More specifically, the work involved in this subtask will enable one to zoom to any location in the county to:

- Instantly map different types of water wells (Type I, II, III community wells; irrigation wells, etc.)
- Instantly map *existing* WHPAs in the county (by EGLE, or completed by Hydrosimulatics as part of a separate, on-going project)
- Quickly delineate local groundwater flow patterns
- Superimpose the effect of well pumping (e.g., based on Theis solution) to the groundwater level map
- Track flow backwards from water wells (new or existing)
- Delineate Capture zones or Wellhead Protection Areas (WHPA) for different assumed times-of-travel
- Instantly map aquifer vulnerability or sensitivity to surface pollution (from countywide analysis or DSS Tool)
- Instantly map land use and sources of known or potential sources of contamination
- Instantly map "background" groundwater quality (nitrate, chloride, and metals/metalloids concentrations

The Tool will include particle tracking options such: controlling the analysis duration; starting or pausing the analysis: resetting particles to their original position; particle color; and exporting/downloading results.

See Graphic 13 below.



Graphic 13: Wellhead Protection Area Delineation Tool. The tool enables one to instantly map different types of water wells; instantly map *existing* WHPAs in the county; quickly delineate local groundwater flow patterns; track flow backwards from water wells; delineate Capture zones or Wellhead Protection

Areas (WHPA) for different assumed times-of-travel; map aquifer vulnerability; instantly map land use and sources of known or potential sources of contamination; and instantly map “background” groundwater quality.

<u>Key management questions</u> that can be addressed with this tool include:

- What is the land surface area contributing to my well? What is the land use in the contribution area?
- What are the implications for development and zoning?
- What are the implications for community involvement in wellhead protection?
- Where should we place “last minute warning” monitoring wells (e.g. at 6-months or 1yr or travel)?
- Where should we place “early warning wells (e.g., at 10year travel zone), especially if there are potential sites of environmental concern nearby?

Subtask 2.9 – Critical Groundwater-Dependent Ecosystem Mapping and Source Water Delineation Tool

The Phase 1 study included countywide mapping of all surface water bodies (rivers, lakes and wetlands) and known groundwater-dependent ecosystems (e.g., trout streams and fens). Because Allegan County sits in low-lying region along the Lake Michigan coastline, groundwater discharges to most of the surface water bodies (i.e., practically all rivers, streams, and wetlands are “gaining” surface water bodies). Therefore, sustainable management of critical surface water bodies in the county requires protecting the “upstream “ groundwater source area.

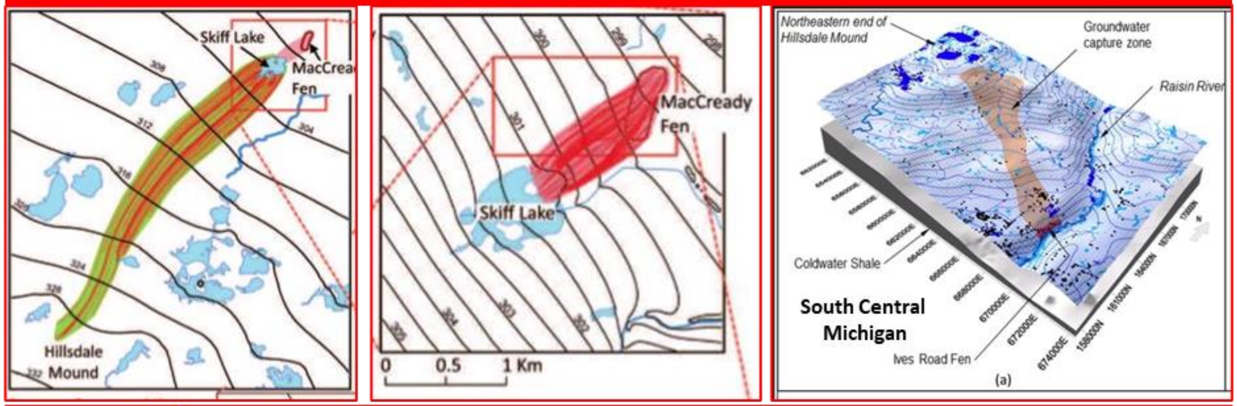
Under this subtask, HSAINC will program the DSS mapping environment and interface system to **enable critical groundwater-dependent ecosystem mapping and source water delineation**. More specifically, the work involved in this subtask will enable:

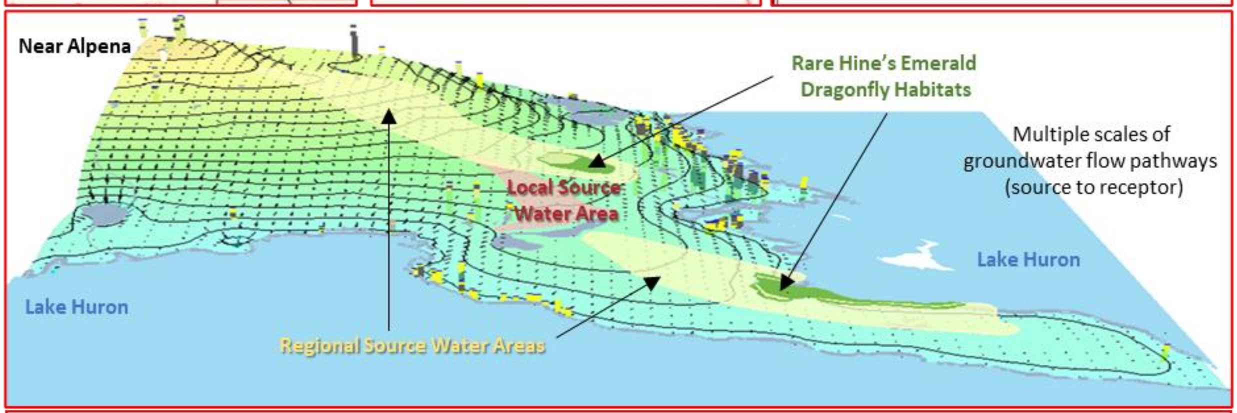
- Instant mapping of critical groundwater-dependent ecosystems:
    - Lakes, rivers and streams
    - Wetlands, springs, and fens (new/recently identified or existing)
- Quick delineation of underlying groundwater flow patterns
- Backward tracking of flow from lakes, streams, or wetlands
- Source Water Area delineation for different assumed times-of-travel

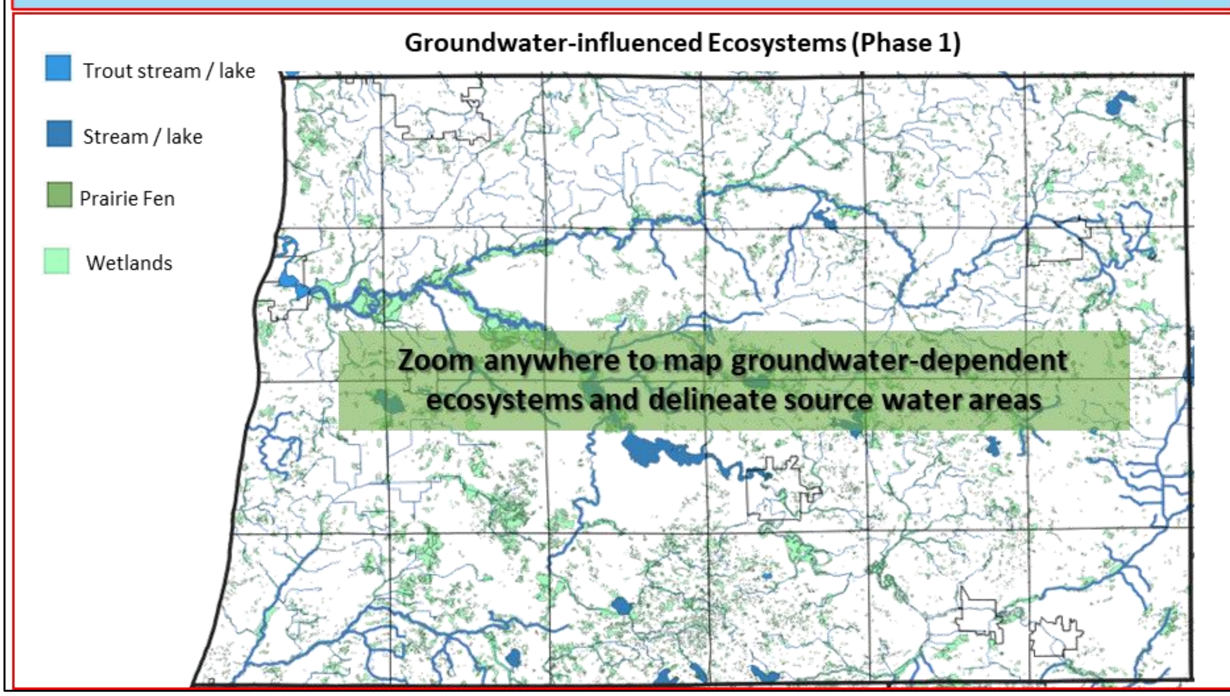
The Tool will include particle tracking options such as: controlling the analysis duration; starting or pausing the analysis: resetting particles to their original position; particle color; and exporting/downloading results.

See Graphic 14 below.

Critical Groundwater-Dependent Ecosystem Mapping and Source Water Delineation Tool







Graphic 14: Critical Groundwater Ecosystem Mapping and Source Water Delineation Tool. The enables instant mapping of critical groundwater-dependent ecosystems; quick delineation of underlying groundwater flow patterns; backward tracking of flow from lakes, streams, or wetlands; and source Water Area delineation for different assumed times-of-travel.

Key management questions that can be addressed with this tool include:
- Are there any critically important groundwater ecosystems in this area? Where is their water coming from?
- How can we cost-effectively, holistically protect valuable groundwater-dependent ecosystem, taking into account the underlying hydrologic process (not just what's going on at the surface)?
- What are the implications for land use and development? For community involvement?

Subtask 2.10 – Sites of Environmental Concern Mapping and Contaminant Tracking Tool

The Phase 1 Study inventoried and mapped about 250 known or potential sites of groundwater contamination in nearly all parts of the County, including PFAS sites, EGLE Sites of Environmental Concern, and Leaky Underground Storage Tanks, or LUSTs. Dozens of oil and gas wells and over 40 landfills / waste handlers were also identified as potential sources of contamination. Hydrosimulatics INC. will map the potential impact areas of these sites of environmental concern as part of a separate, on-going project ("Phase 2"), although this will be for all *existing* wells and there will almost certainly be more sites identified in the future.

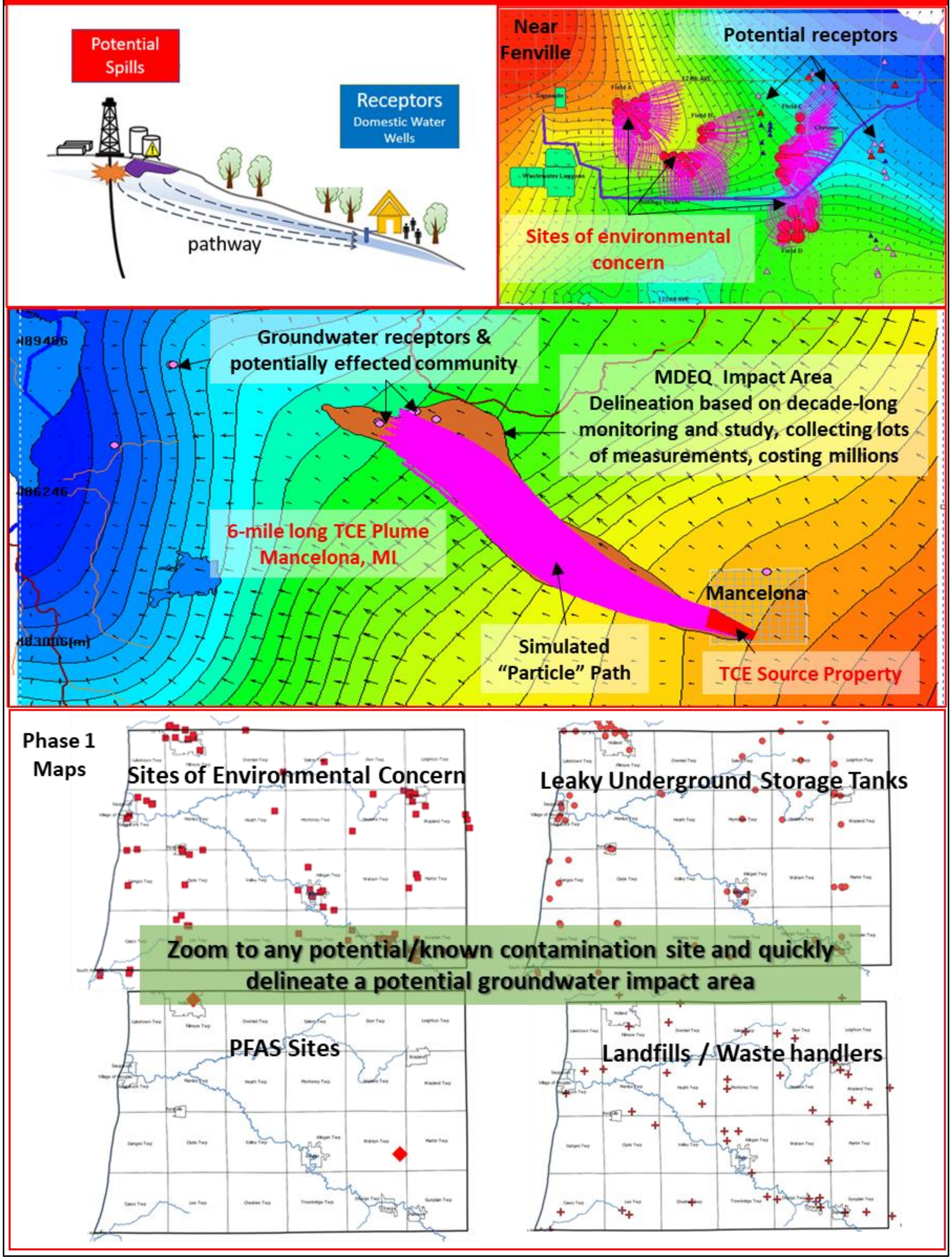
Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable:

- **Instant mapping of (EGLE) sites of environmental concern, PFAS sites, leaky underground storage tanks (LUSTs) and landfills / waste handlers** (existing or new/recently identified)
- **Instant mapping of previously delineated impact areas** (as part of a separate, on-going project by Hydrosimulatics INC.)
- **Instant mapping of key groundwater receptors** – drinking water wells & critical groundwater-dependent ecosystems (and their WHPAs / source water areas, if available).
- **Instant mapping of aquifer vulnerability** or sensitivity to surface pollution (from countywide analysis or DSS Tool)
- **Quick delineation of groundwater flow patterns** underlying known or potential contamination sites
- **Forward tracking of flow from known/suspected contamination sources** (where is it going?)
- **Impact area delineation for different assumed times-of-travel** (e.g., 2 yr., 5 yr., 10yr.,, …)

The Tool will include particle tracking options such: controlling the analysis duration; starting or pausing the analysis: resetting particles to their original position; particle color; and exporting/downloading results.

See Graphic 15 below.

Sites of Environmental Concern Mapping and Contaminant Tracking



Graphic 15: Sites of Environmental Concern Mapping and Contaminant Tracking Tool. The tool enables instant mapping of EGLE sites of environmental concern, PFAS sites, leaky underground storage tanks and landfills / waste handlers; instant mapping of previously delineated impact areas; instant mapping of key groundwater receptors' instant mapping of aquifer vulnerability or sensitivity to surface pollution; quick delineation of groundwater flow patterns underlying known or potential contamination sites; forward tracking of flow from known/suspected contamination sources; and impact area delineation for different assumed times-of-travel.

Key management questions that can be addressed with this tool include:

- Are there nearby sites of contamination or sites of environmental concern?
- Is the nearby gas station tank leaky? Where is the contaminant going?
- What is the aquifer impact area?
- What / where are the key groundwater receptors?
- What is expected time-of-travel?
- Where should we sample or monitor given limited resources and the need to be cost-effective?

Subtask 2.11 – Groundwater Contamination Sources Tracing Tool

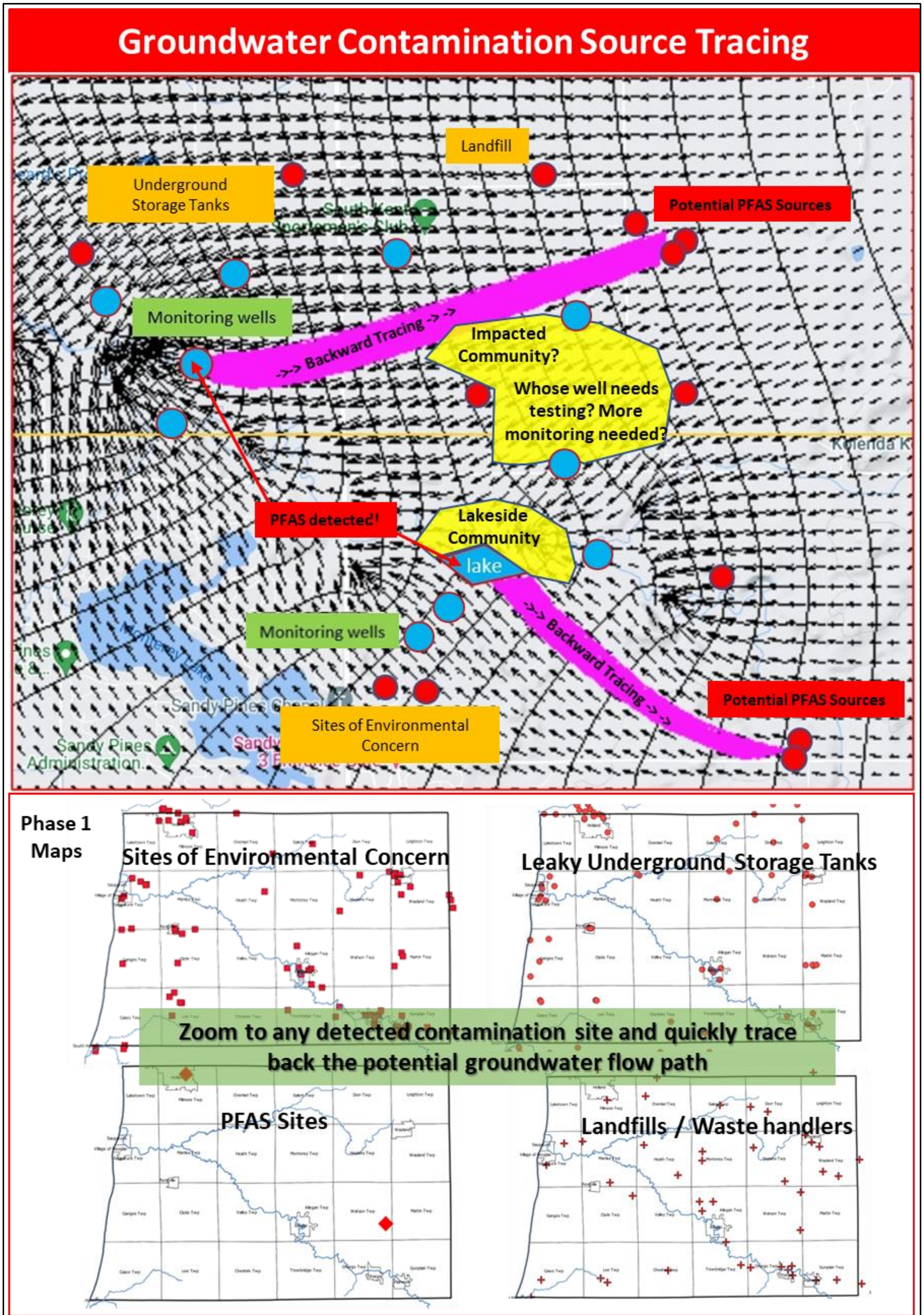
If contamination is detected in a drinking water well, a groundwater fed water bodies, or a monitoring well, questions that immediately arise are:

- **Where does the contamination come from?**
- **Who are the potential responsible parties?**
- **Who else may be affected?**
- **Where else should be monitored?**

This tool will allow addressing this type of questions cost effectively – in real time. In particular, the tool will allow:

- Mapping instantly sites of known contamination in Allegan or sites of environmental concern
- Mapping instantly critical receptors in the area of interest
- Mapping groundwater patterns in the areas
- Tracking backward contamination represented as "particles" as a function of time
- Identifying likely sources of contamination

See Graphic 16 below.


Groundwater Contamination Source Tracing
Landfill
Underground Storage Tanks
Potential PFAS Sources
Monitoring wells
->-> Backward Tracing ->->
Impacted Community?
Whose well needs testing? More monitoring needed?
PFAS detected!
Lakeside Community
lake
Monitoring wells
->-> Backward Tracing ->->
Potential PFAS Sources
Sites of Environmental Concern
Phase 1 Maps
Sites of Environmental Concern
Leaky Underground Storage Tanks
Zoom to any detected contamination site and quickly trace back the potential groundwater flow path
PFAS Sites
Landfills / Waste handlers

Graphic 16: Groundwater Contamination Sources Tracing Tool. The tool enables mapping sites of known contamination; mapping instantly critical receptors; mapping groundwater patterns; tracking contamination backwards; and identifying likely sources of contamination

Key management questions that can be addressed with this tool include:

- If contamination is detected in my well, groundwater fed lake, or a monitoring well, where does the contamination likely come from?
- Who are the potential responsible parties?
- Where should we sample or monitor given limited resources and the need to be cost-effective?

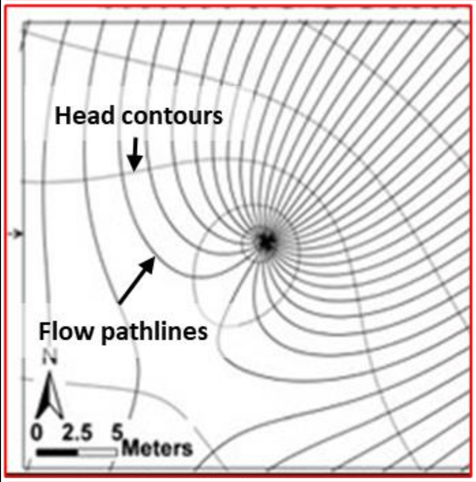
Subtask 2.12 – Contamination Capture Well Design Tool

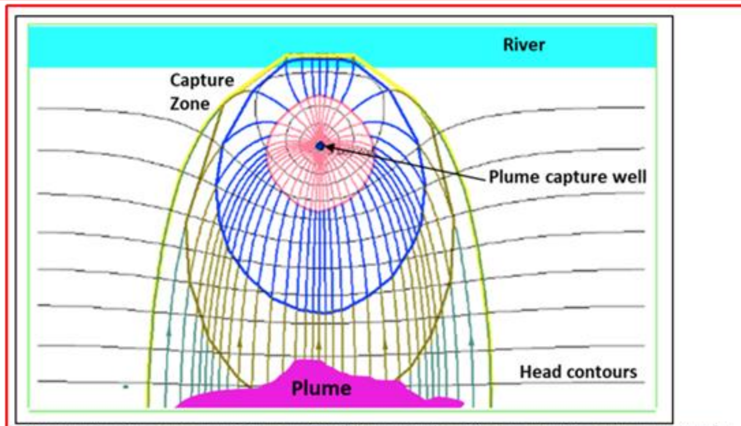
When accidental spills occur or groundwater contamination is detected, and critical receptors are found to be immediately downstream, capture wells are often installed to control the situation, stabilizing the plume, and preventing the contamination from spreading. This tool **allows designing cost effectively, in real time, a preliminary contaminant capture system**. HSAINC will program the DSS mapping environment and interface system to enable;

- mapping sites of environmental concern
- mapping critical groundwater receptors
- mapping groundwater flow in the area of interest
- virtually "installing" capture wells and computing capture well drawdown and superimposing the effect of well pumping to the groundwater level map
- visualizing contaminant particle migration in response to contaminant extraction systems

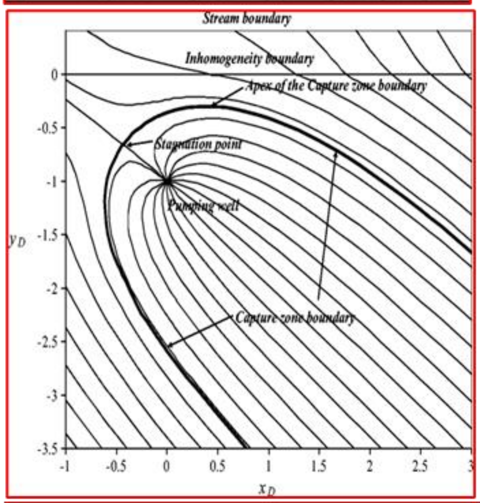
See Graphic 17 below.

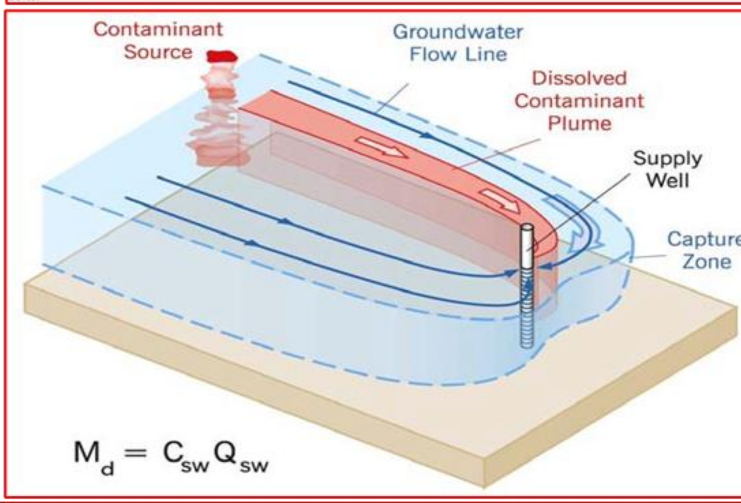
Contamination Capture Well Design

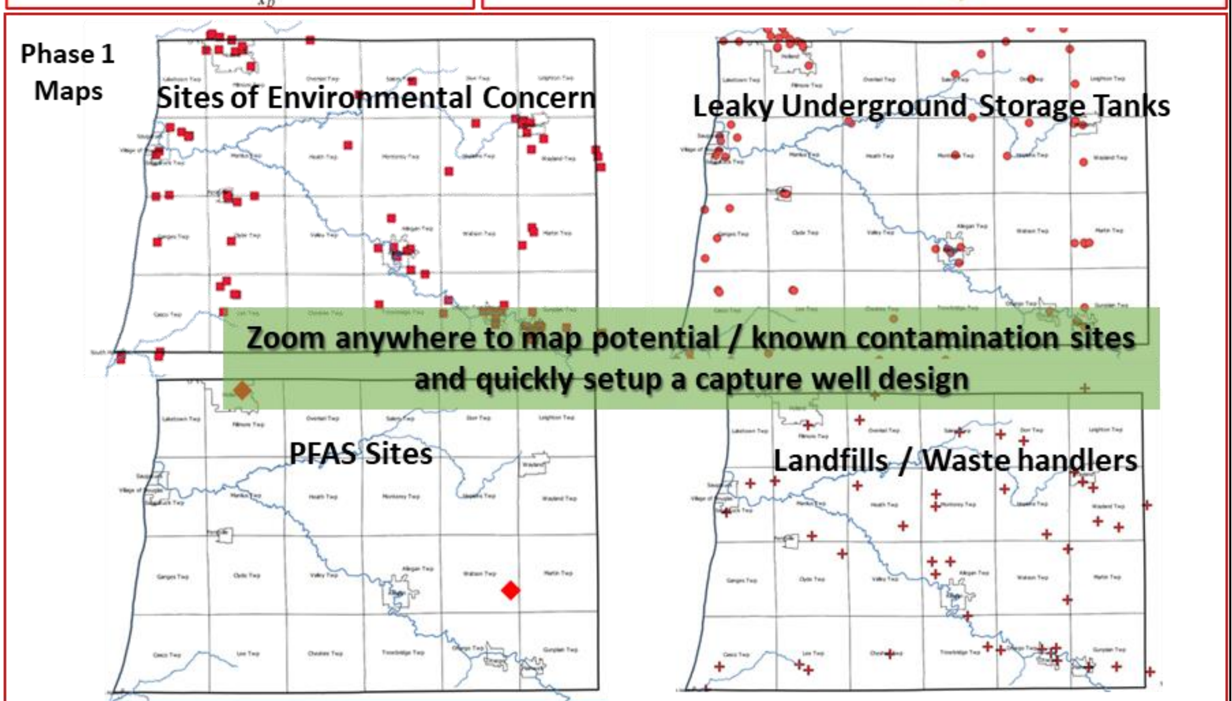




: Plan-view of a plume capture zone delineation. The different colored zones/lines represent the capture zone extent for periods of groundwater travel: red=2 yr. capture zone; blue = 10 yr. capture zone; yellow=long-term (steady-state) zone.







Graphic 17: Contamination Capture Well Design Tool. The tool enables virtually “installing” capture wells and computing capture well drawdown and superimposing the effect of well pumping to the groundwater level map, as well as visualizing contaminant particle migration in response to contaminant extraction systems.

Key management questions that can be addressed with this tool include:

- If an accidental spill occurs and an emergency capture well(s) need to be quickly installed to control / prevent plume spreading, where should the wells be placed?
- How many wells are needed and how much should be pumped?

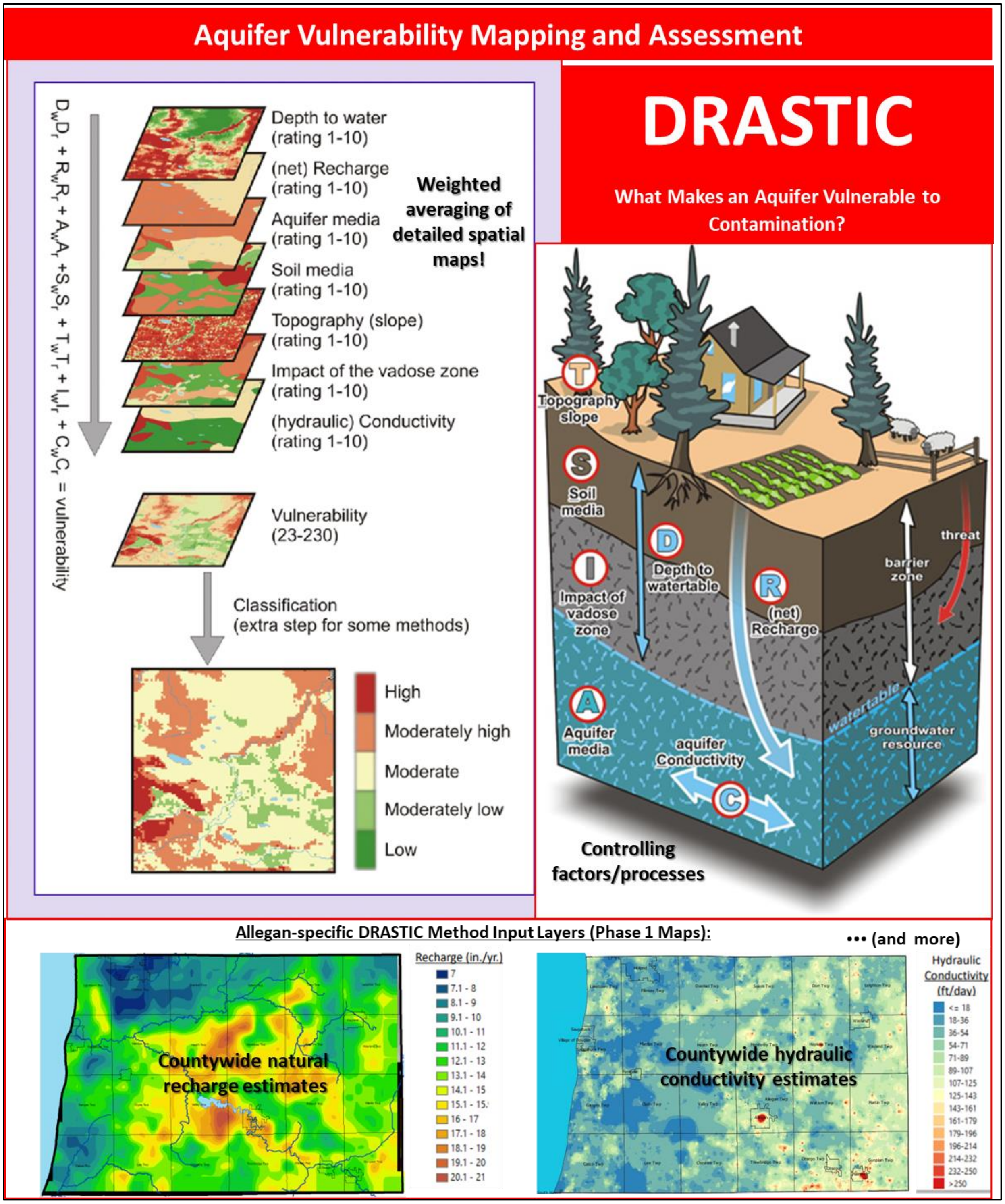
Subtask 2.13 – Aquifer Vulnerability Mapping and Assessment Tool

Contamination at the surface must first pass through the unsaturated zone before it gets into the aquifer. Depending on the soil and other hydrogeological conditions, it can be very difficult (or sometimes, practically impossible) for the contamination to make it to the aquifer.

In a separate, on-going project, Hydrosimulatics INC. will map for the entire county a screening-level estimate of aquifer vulnerability (or sensitivity to surface pollution) using county-level input data layers. In this current project, HSAINC proposes to **program the DSS mapping environment and interface system to enable interactive mapping of aquifer vulnerability at different scales or locations of interest**. More specifically, the work involved in this subtask will enable:

- Instantly map in detail parameters used in Vulnerability calculation:
    - Topography and Depth to Water Table;
    - Net Recharge;
    - Aquifer Media and Hydraulic Conductivity of the aquifer
    - Soil Media; Impact of Vadose (unsaturated) zone; and
- Interactively zoom into areas mapping vulnerability at different scales/resolutions based on input data layers and/or more accurate local information (field collected data, higher quality/resolution spatial data, etc.)
- Instantly map locations of critical groundwater receptors (water wells, GW ecosystems) and their WHPA/source water areas (if they are available) as well as contamination sites and their impact areas.

See Graphic 18 below.



Graphic 18: Aquifer Vulnerability Assessment Tool. The tool enables one to instantly map in detail parameters used in vulnerability calculation: interactively zoom into areas mapping vulnerability at different scales/resolutions based on input data layers and/or more accurate local information; and instantly map locations of critical groundwater receptors and their WHPA/source water areas as well as contamination sites and their impact areas.

<u>Key management questions</u> that can be addressed with this tool include:

- Why are certain areas of Allegan's aquifers particularly vulnerable to contamination? Where are these areas?
- Why are certain other areas of Allegan's aquifers almost "immune" to surface pollution (even if contamination site(s) are nearby)? Where are these areas?
- What are the implications on monitoring, development, and well siting?

Subtask 2.14 – Agriculture / Nitrate Contamination Risk Analytics Tool

The Phase 1 countywide study identified nitrate contamination as a significant issue in the shallow aquifer predominantly due to agricultural activities (runoff from fertilizer), but also possibly from leaking from septic tanks/sewage. Samples with concentrations above the Maximum Contaminant Level (MCL) of 10 mg/L are found throughout the county, and almost 10% of samples are above 5 mg/L, which can be considered more than twice the expected "natural" nitrate concentration in groundwater (about 2 mg/L or less).

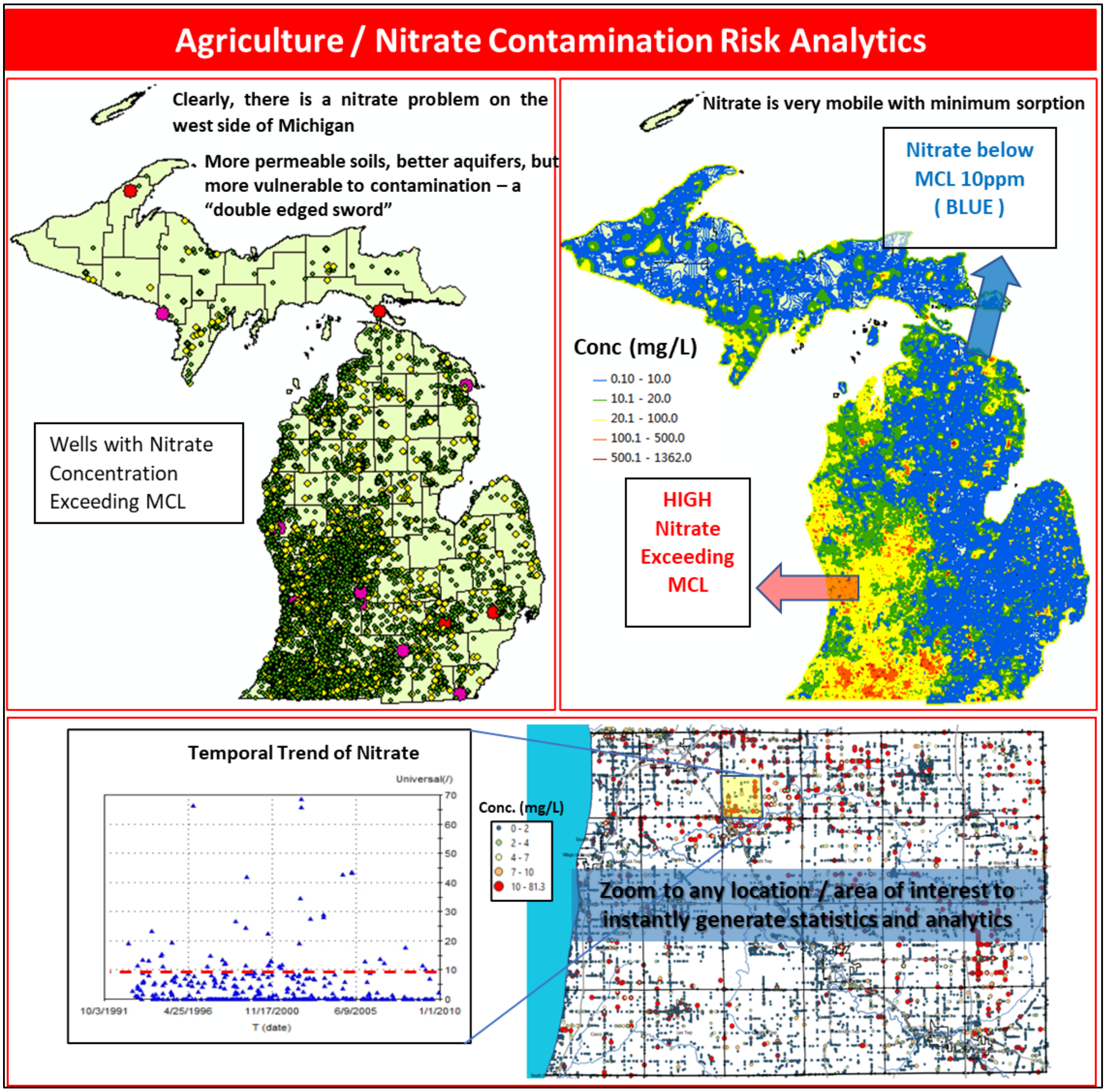
Nitrate concentrations in drinking water above the MCL is known to cause adverse impacts on human health, specifically the risk of methemoglobinemia – a condition in which blood lacks the ability to carry sufficient oxygen to body cells. Additionally, concentrations at a level significantly lower than the MCL can begin to cause eutrophication in groundwater-connected / groundwater-fed surface water bodies.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable zooming to any township, section, etc. to instantly:

- **Map land use / cropland and crop type distribution** (if available)
- **Map drinking water well depths** (shallow vs. deep)
- **Map nitrate concentrations** (different times/thresholds)
- **Perform realtime statistical analysis** (different thresholds/percentiles/sub-sets of data)
- **Evaluate temporal trends** (different time periods)
- **Characterize risk with respect to standards** (different water uses)
- **Compare water quality (nitrate contamination) severity across townships, sections, etc.**

The Tool will include options for statistical analysis of nitrate concentration data, such as for filtering samples by concentration values (min. to max.) or by time period (from starting date to ending date); and controlling the number of "bins" for histogram, probability density Function (PDF), or cumulative distribution function (CDF) analysis.

See Graphic 19 below.



Graphic 19: Agriculture/Nitrate Contamination Risk Analytics Tool. The tool enables zooming to any township, section, etc. to instantly: map land use / cropland and crop type distribution; map drinking water well depths; map nitrate concentrations; perform statistical analysis; evaluate temporal trends; characterize risk with respect to standards; and compare water quality severity across townships, sections, etc.

<u>Key management questions</u> that can be addressed with this tool include:

- Where are the "hotspots" in terms of agricultural activities?
- Is groundwater in this area degraded because of agricultural activities?
- How likely is it that well water in this area contains elevated levels of nitrate?
- What is the median and expected (average) nitrate concentration of groundwater in this area? What is the maximum observed concentration?

- What percentage of wells in this area are above the Contaminant Level detrimental to crops?
- What percentage of wells in this area are above the MCL (Maximum Contaminant Level)?
- What are the implications for well siting (especially with respect to depth of the well, location on a land parcel, etc.)?

Subtask 2.15 – Brine Upwelling / Chloride Contamination Risk Analytics Tool

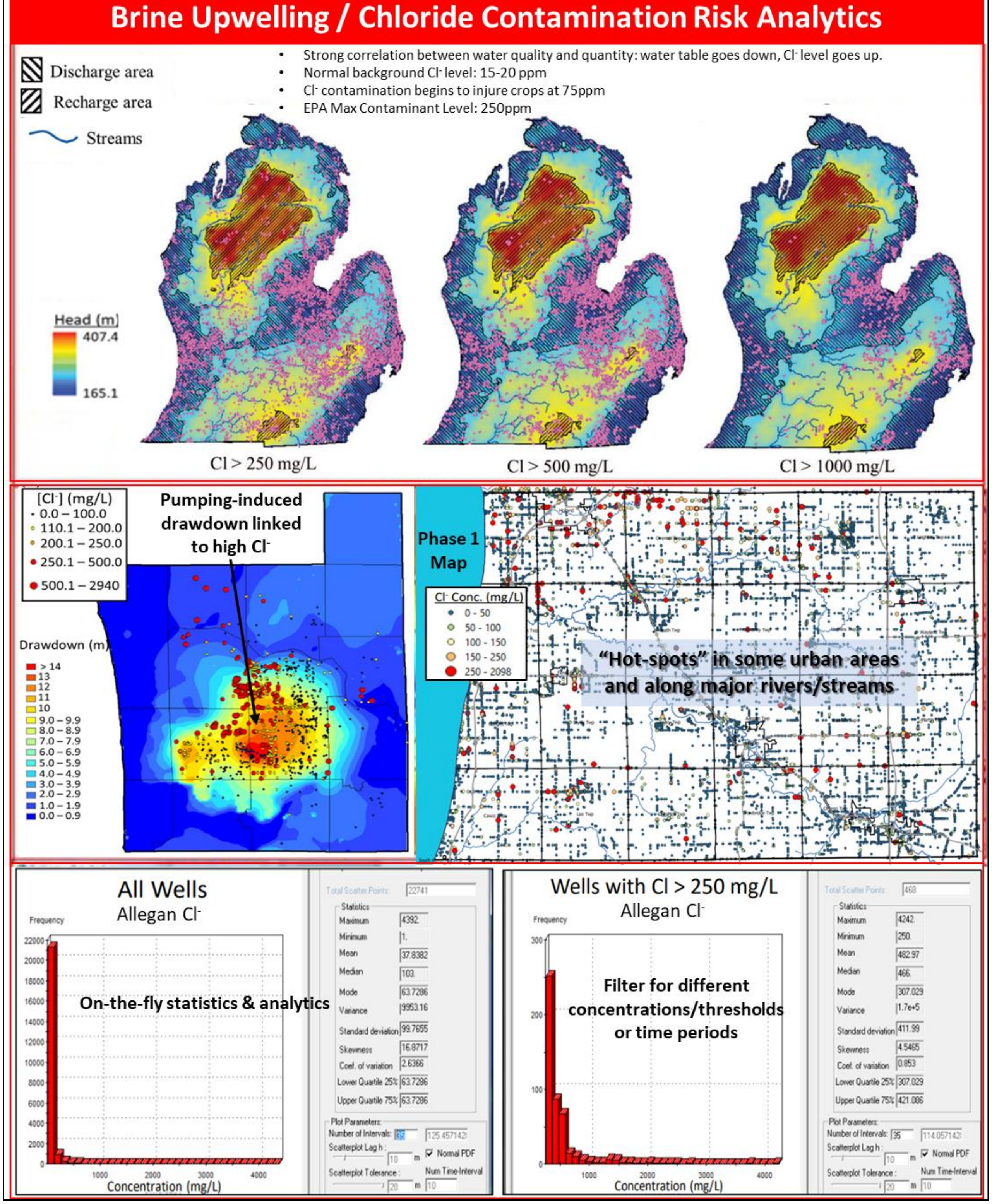
Michigan's fresh groundwater sits on a pool of brine, slowly inching toward the surface to significantly impact groundwater quality in discharge areas (e.g., along large streams and rivers) where groundwater is predominantly moving upwards. This phenomenon was well documented in neighboring Ottawa County and is suspected to be impacting Allegan County's groundwater resources (albeit to a lesser degree) based on the Phase 1 countywide analysis.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable zooming to any township, section, etc. to quickly:

- **Map streams, wetlands, and other groundwater discharge areas**
- **Map groundwater drainage patterns**
- **Map land use and the road network** (highway and residential)
- **Map chloride concentrations** (different times/thresholds)
- **Perform realtime statistical analysis** (different thresholds/percentiles)
- **Evaluate temporal trends** (different time periods)
- **Characterize risk with respect to standards** (different water uses)
- **Compare water quality (chloride contamination) severity across townships, sections, etc.**

The Tool will include options for filtering samples by concentration values (min. to max.) or by time period (from starting date to ending date); and controlling the number of "bins" for histogram, probability density Function (PDF), or cumulative distribution function (CDF) analysis.

See Graphic 20 below.



Graphic 20: Brine Upwelling / Chloride Contamination Risk Analytics Tool. The tool enables zooming to any township, section, etc. to quickly: map streams, wetlands, and other groundwater discharge areas; map groundwater drainage patterns; map land use and the road network (highway and residential); map

chloride concentrations (different times/thresholds); perform statistical analysis (different thresholds/percentiles); evaluate temporal trends (different time periods); characterize risk with respect to standards (different water uses); and compare water quality (chloride contamination) severity across townships, sections, etc.

Key management questions that can be addressed with this tool include:

- Is groundwater in this area influenced by the upwelling or mixing of deep brines with the shallow fresh groundwater?
- How likely is it that well water in this area contains elevated levels of groundwater salinity?
- What is the median and expected (average) chloride concentration of groundwater in this area? What is the maximum observed concentration?
- What percentage of wells in this area are above the SMCL (Secondary MCL)?
- What are the implications for well siting?

Subtask 2.16 – Metals / Metalloids Risk Analytics Tool

The Phase 1 study mapped across the county concentrations for common metals/metalloids found in groundwater: iron; manganese, lead, and arsenic. Iron and manganese are considered secondary drinking water standards (guidelines for the minimum level for color and/or staining and metallic taste). It is not uncommon for these SMCLs to be exceeded, especially in deeper aquifers. In Allegan County, this is indeed the case. Lead and arsenic are primary (legally enforceable) standards based on known impacts to human health. The Phase 1 analysis identified concentrations exceeding primary standards for lead at isolated locations in different townships across the county.

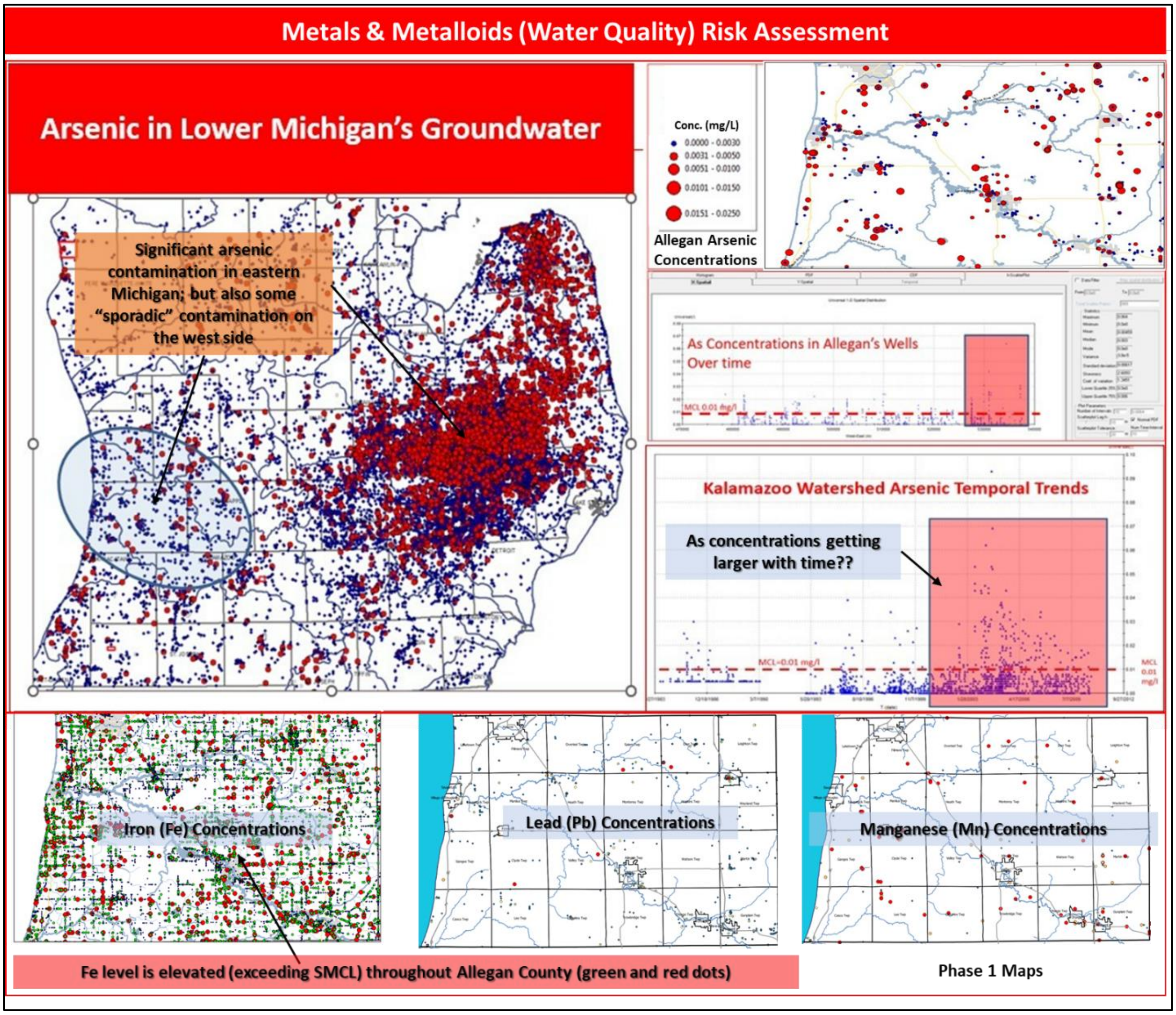
A relatively recent report by DEQ (now EGLE) demonstrated that Michigan has an arsenic problem of nearly statewide scale. The worst area with elevated arsenic in groundwater is the “thumb” area in southeast Michigan where the maximum occurrences in 8 counties exceed or significantly exceed 50ug/L (MCL of arsenic). The second worst area is southwest Michigan where the maximum arsenic concentrations in 11 counties (that include Allegan) exceed or significantly exceed 20 ug/L. In the Phase 1 analysis, almost 14% of samples exceeding drinking water standards for arsenic, with some indication of a problem that is becoming worse with time.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to enable zooming to any township, section, etc. to instantly:

- **Map land use, glacial geology, bedrock geology, and water well depths** (shallow vs. deep)
- **Map Fe, As, Pb, or Mn concentrations** (different times/thresholds)
- **Perform realtime statistical analysis** (different thresholds/percentiles)
- **Evaluate temporal trends** (different time periods)
- **Characterize risk with respect to standards** (different water uses)

The Tool will include options for statistical analysis of samples, such as: filtering by concentration values (min. to max.) or by time period (from starting date to ending date); and controlling the number of “bins” for histogram, probability density Function (PDF), or cumulative distribution function (CDF) analysis.

See Graphic 21 below.



Graphic 21: Metals/Metalloids (Water Quality) Risk Assessment Tool. The tool enables zooming to any township, section, etc. to instantly map land use, glacial geology, bedrock geology, and water well depths; map Fe, As, Pb, or Mn concentrations (different times/thresholds); perform statistical analysis; evaluate temporal trends; and characterize risk with respect to standards.

<u>Key management questions</u> that can be addressed with this tool include:

- How likely is it that well water in this area contains elevated levels of iron, arsenic, lead, etc.?
- What is the median and expected (average) concentration of groundwater metals / metalloids in this area? What is the maximum observed concentration?
- What percentage of wells in this area are above the MCL/SMCL?

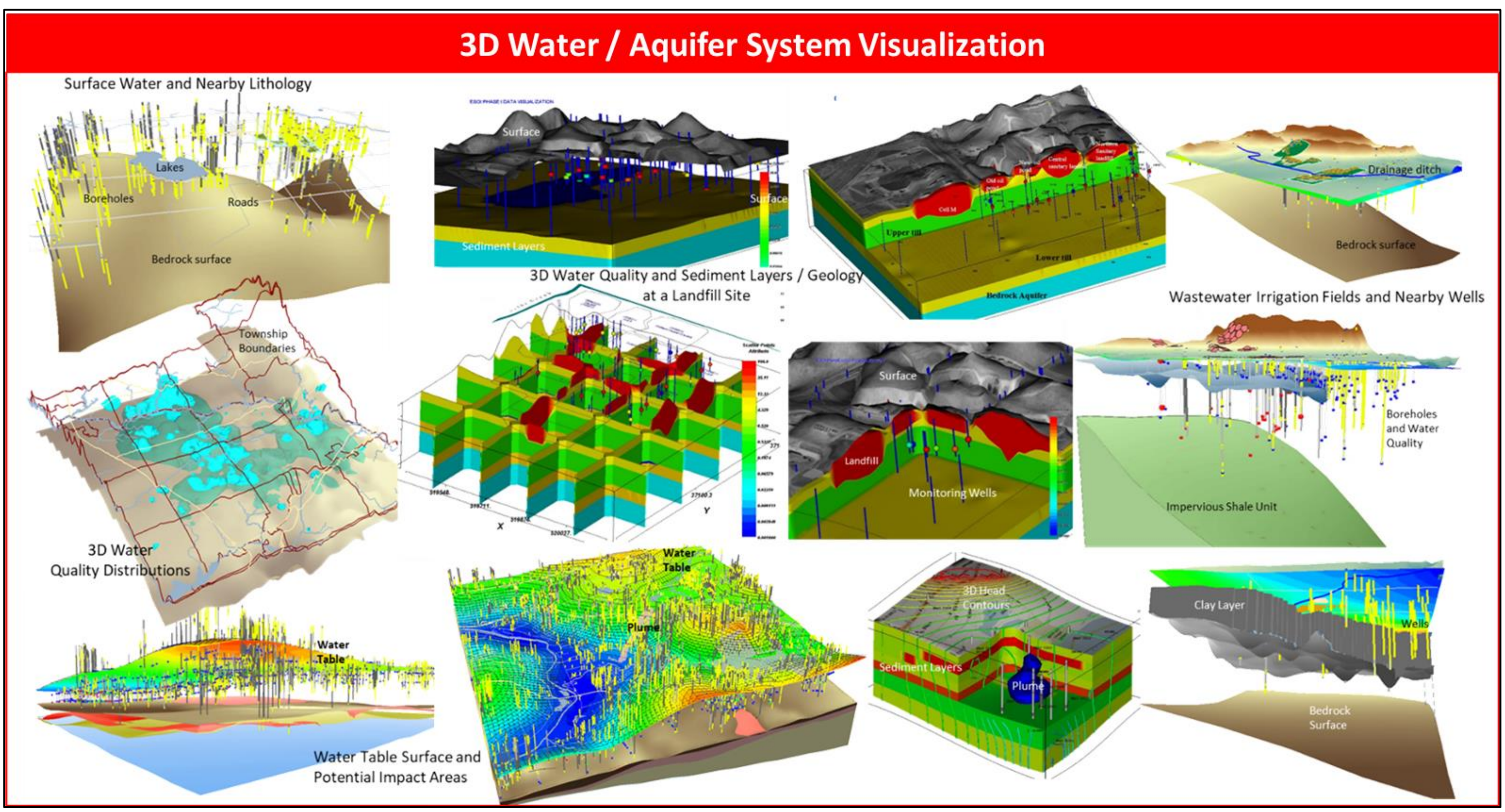
Subtask 2.17 – 3D Water/ Aquifer System Visualization

Under this subtask, HSAINC will program the DSS mapping environment and interface system to **enable integrated 3D visualizations/overlays of disparate data layers, including:**

- Aquifer Top (DEM)
- Aquifer Bottom (Bedrock)
- Surface layers:
  - "Vector layers": Rivers, lakes, streams; road network, political boundaries, etc.
  - "Draped images" – land use, soil type, satellite imagery, etc.
- Water table/groundwater levels
- Boreholes / lithology
- Groundwater monitoring network
- Water quality samples (colored/sized to concentrations)

The BEST Intelligent DSS will provide users with a unique, vivid "virtual field experience" (or the ability to develop a "living" conceptual model based on existing data). Users will be able to zoom in anywhere within the County, see into the earth, and interact with the data - capitalizing on M4W's advanced visualization capabilities. The capability to interactively visualize any combination / presentation of data leads to an intuitive grasp of implications of human activities, management actions, and policy decisions that can't be readily obtained otherwise.

See Graphic 22 below.



Graphic 22: Diverse examples of integrated 3D overlays of disparate data layers – from regional flow patterns to surface water features, 3D water quality, and lithology.

Key management questions that can be addressed with this tool include:

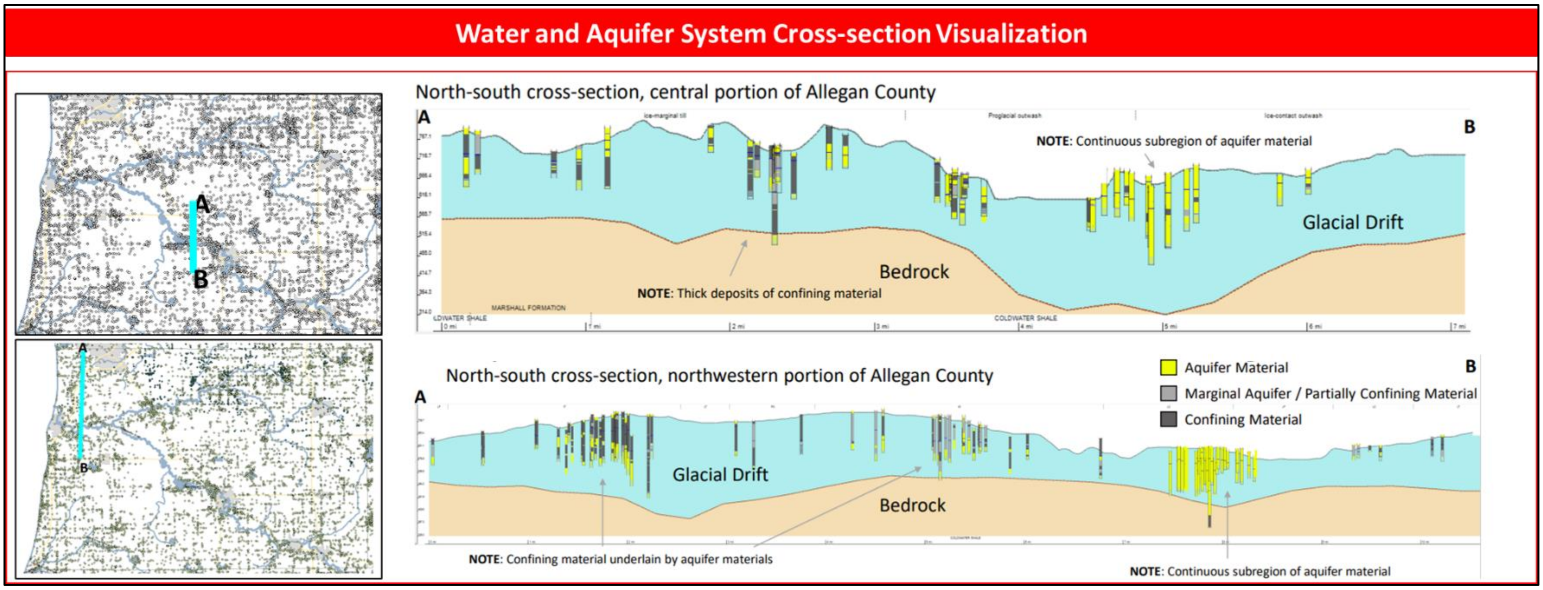
- Without completing any field work, what are the characteristics of the site, especially with respect to geology, water quantity, and water quality?
- How are properties of the land surface (topography, land use / cover, road and infrastructure, soil type, etc.) and subsurface (lithology, water table, groundwater quality, etc.) spatially distributed – both horizontally and vertically?
- What do the spatial patterns tell us about relationships between various components of the environment?
- Where should we sample or monitor given limited resources and the need to be cost-effective?

Subtask 2.18 – Water and Aquifer System Cross-section Tool

Under this subtask, HSAINC will program the DSS mapping environment and interface system to **enable "seeing into the earth" by interactively creating (drawing) vertical profiles or cross-sections anywhere within the county**. The specific layers that will be displayed in cross-section view include:

- Aquifer top (DEM)
- Aquifer bottom (Bedrock)
- Water well boreholes / lithology

See Graphic 23 below.



Graphic 23: Site Cross-section Visualization Tool.

<u>Key management questions</u> that can be addressed with this tool include:

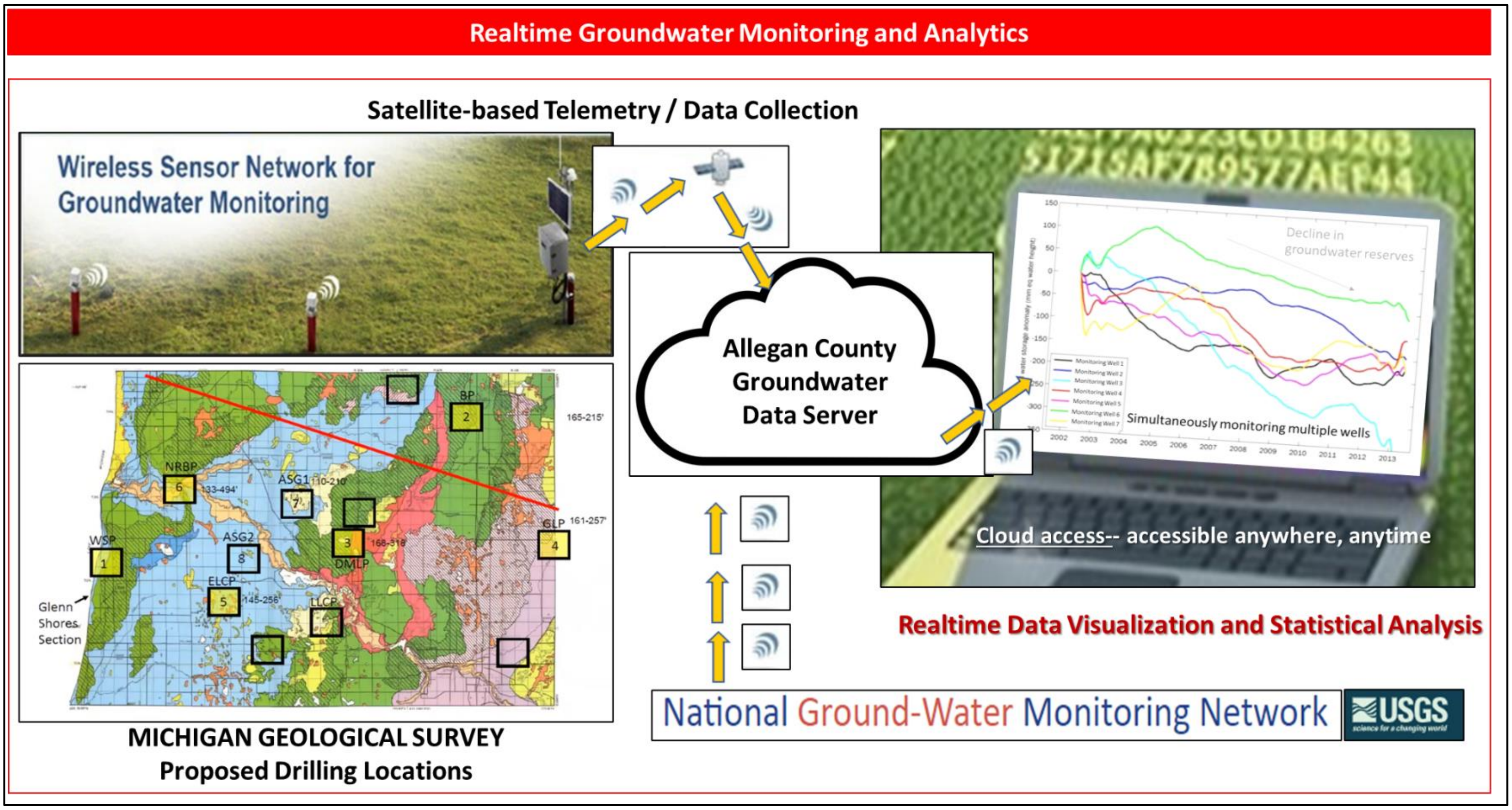
- How thick is the aquifer in this area? How does well lithology/geology vary locally?
- How deep are the wells with respect to the aquifer bottom?

Subtask 2.19 – Realtime Groundwater Monitoring & Analytics Tool

The Michigan Geological Survey has proposed to drill several (up to 15) monitoring wells throughout the county to collect precise geological data and for subsequent groundwater monitoring. These wells (and any others installed in the county) can be equipped with wireless sensors to provide realtime water level monitoring (and potentially other parameters such as water quality indicators) to remote applications.

Under this subtask, HSAINC will program the DSS mapping environment and interface system to **enable realtime visualization and statistical analysis of monitoring well data collected within the county and transmitted wirelessly to the DSS**.

See Graphic 24 below.



Graphic 24: Realtime Groundwater Monitoring Tool. The tool enables instant plotting of current and recent groundwater conditions – for one or many monitoring wells; instant calculation and display of monthly, seasonal, annual, or long-term averages; instant calculation and display of monthly, seasonal, annual, or long-term minimum of maximum values; and Instant filtering by time period or parameter values.

Key management questions that can be addressed with this tool include:

- Is groundwater quantity (levels/storage) declining over time?
- Is water quality improving or worsening over time?
- What is the seasonal variability in water quality or water quantity

Task 3 – ENGAGEMENT DOCUMENTATION AND MANAGEMENT GUIDE SYSTEM

Subtask 3.1 – Technical Documentation and Training

Under this Subtask, Hydrosimulatics INC. **will prepare reference documentation for DSS users and carry out trainings for perspective users**. Specific subtasks include:

- Presentations to the Groundwater Work Group
- Presentations to the County Commissioners
- Preparation of an online BEST Intelligent DSS users' manual

- Preparation of online tutorials/examples
- Preparation of online, realtime help pages and user reference materials
- End user training (virtual workshops and webinars)
- Technical support

Subtask 3.2 – Realtime Situational Management Guidebook System

Hydrosimulatics will make a special effort to connect data, science, modeling, visualization with policies and management decision making - working with the County - for EACH of the proposed realtime groundwater management tools.

Specifically, Hydrosimulatics INC. will program the DSS interface system to **include a Realtime Situational Management Guidebook System, or a collection of intelligently linked management materials and relevant policy and/or scientific contents to be in used in conjunction with the groundwater mapping and modeling tools**. The various "pages" of the Guidebook System will be accessible within the interface for which it is supporting – in this way the contents are providing situationally, at the time when the end-user needs the information during the creative process of problem-solving and data exploration. (A hierarchical access interface of the Guidebook System contents will also be available within the DSS.)

The specific types of information/contents to be included in the Management Guidebook System include:

- Easy-to-understand explanations of groundwater/environmental parameter(s) being mapped/visualized
- Typical parameter values with reference to relevant sources/publications
- Relevant laws, regulations, and policies (both state and federal), when applicable
- Mitigation strategies – including policy, landscape and irrigation practices, and household conservation strategies
- Links to other relevant online materials

Hydrosimulatics ICNC. will work with the county / stakeholders / groundwater work group to refine the management topics / questions / contents / etc.

DATABASE & DSS HOSTING

Two options are proposed for data hosting related to the DSS:

A. The database and data service system is hosted by Allegan County, while the web-application is hosted and maintained by Hydrosimulatics INC. Data "talks" to the DSS via Open Geospatial Consortium (OGC) protocols. Future updates to the database/data service system can be done by Hydrosimulatics "as needed". Documentation for database and data service system deployment and maintenance will be provided by Hydrosimulatics INC. if this option is selected.
B. Both the database/data services and web-application are hosted by Hydrosimulatics INC., allowing easier refinement/on-going maintenance by Hydrosimulatics.

Hydrosimulatics INC. will work with the County to determine and implement the most suitable solution for on-going use of the DSS for years to come. A proposal addendum will be submitted with complete technical details of the agreed upon solution.

BUDGET AND SCHEDULE

Proposed Budget

The proposed project budget is presented in the table below.

The total budget for the project is $499,000, if the County wishes for all Realtime Groundwater Management Tools to be included in the BEST Intelligent DSS.

The County can also customize the set of Tools to be included. (In this case, Hydrosimulatics INC. can present a budget with narrower scope.)

ALLEGAN COUNTY BEST INTELLIGENT DECISION SUPPORT SYSTEM		
1	**Database Integration, Processing, and Web Service Development**	**$70,000**
Task	Description	Cost
1.1	Phase 1 Derived Maps / Spatial Layers	$10,000
1.2	Spatial Products from Screening-level Modeling, Risk Analysis, and Ranking*	$7,000
1.3	State of Michigan Groundwater Datasets	$20,000
1.4	National Datasets and Data Layers	$15,000
1.5	Local data (County or Township GIS Datasets)	$9,000*
1.6	In-situ Sensor Data	$9,000
2	**Realtime Groundwater Management Tools**	**$369,000**
2.1	Groundwater Flow Delineation	$35,000
2.2	Groundwater Recharge Area Delineation	$15,000
2.3	Groundwater Use and Well Types Mapping and Analytics	$20,000
2.4	Well Yield Modeling and Mapping	$20,000
2.5	Well Conflict Resolution Modeling Tool	$15,000
2.6	Land Surface Catchment and Drainage Pattern Delineation	$25,000
2.7	Groundwater Discharge Area and Subsurface Flooding Vulnerability Assessment	$25,000
2.8	Wellhead Protection Area Delineation	$20,000
2.9	Critical GW-dependent Ecosystem Mapping and Source Water Delineation	$15,000
2.10	Sites of Environmental Concern Mapping and Contaminant Tracking Tool	$25,000
2.11	Groundwater Contamination Sources Tracking	$10,000
2.12	Contamination Capture Well Design	$14,000

2.13	Aquifer Vulnerability Mapping Assessment	$20,000
2.14	Agriculture / Nitrate Contamination Risk Mapping & Analytics	$10,000
2.15	Brine Upwelling / Chloride Contamination Risk Mapping & Analytics	$10,000
2.16	Metals Metalloids Risk Mapping & Analytics	$15,000
2.17	3D Water / Aquifer System Visualization	$40,000
2.18	Water and Aquifer System Cross-section	$15,000
2.17	Realtime Groundwater Monitoring & Analytics Tool	$20,000
3	**Engagement, Documentation, and Management Guide System**	**$60,000**
3.1a	Presentations / demonstrations to the Groundwater Work Group	$3,000
3.1b	Presentations / demonstrations to the County Board of Commissioners / public communities	$3,000
3.1c	Meetings with managers / stakeholders; users/management needs assessment	$6,000
3.1d	Preparation of BEST Intelligent DSS online users' reference materials	$20,000
3.1e	End user training	$8,000
3.2	Development of Realtime, Interactive Situational Management Guidebook System	$20,000

* The cost of processing Local data (County or Township GIS Datasets) may change depending on the amount of data made available by the county to Hydrosimulatics INC.

Proposed Schedule

The development of the Allegan-specific database/data server system and BEST Intelligent DSS is expected to take approximately 12 calendar months from Notice to Proceed (NTP).

The process is highly iterative, starting with initial programming related data integration, database development, and data server system development, followed by to interface development and tool-data linkages, and then testing and error reporting, further development and refinement, and so on.

Hydrosimulatics INC. will meet with potential end-users and county professional for feedback and constructive criticism, at the start of the project and throughout the project with regularly scheduled "milestone" meetings.

The following is an estimate of the timing of completing key milestones.

Time from NTP (months)	Activities / Milestones
0	Project Kick Off
	1st Payment to HSAINC
0 to 1	Meet with potential end users, planners, and decision makers - operational aspects, needs assessment, local data availability, etc.

0 to 3	Data Integration, processing and web service development
3	Allegan Database and Data Service Presentation/Demonstration
	2nd Payment to HSAINC
0 to 6	DSS - Water Quantity Management Tools (Subtasks 2.1 – 2.9, 2.19)
6	Preliminary version (Beta)
	Presentation / Demonstration
	3rd Payment to HSAINC
5 to 11	DSS - Water Quality Management and System Visualization Tools (Subtasks 2-10 – 2.18)
10	Preliminary version (Beta)
	Presentation / Demonstration
	4th payment to HSAINC
9 to 11	Management Guidebook System (Subtask 3.2)
9	Finalization of Management Questions
11	DSS - version 1
	Presentation, demonstration of DSS v1 with Management Guidebook System
	5th Payment to HSAINC
11 to 12	Documentation and Tutorials (Subtask 3.1)
13	Final DSS deployed
	Final presentation / demonstration
	End User training
	6th Payment to HSAINC

PROJECT TEAM

Zachary Curtis, Ph.D. (Project Manager)

Chief Operating Officer, Hydrosimulatics INC.

Ph.D., Environmental Engineering, Environmental Science and Policy, Michigan State University

Areas of expertise:

- Groundwater flow and contaminant transport modeling
- Water resources systems, interactions, and long-term sustainability
- Water and societal issues
- Water/environmental science education and innovation
- Storm- and sewer- water system analysis and modeling

Shu-guang Li, Ph.D., P.E, F.ASCE, F.GSA

Chief Executive Officer and Chairperson Hydrosimulatics INC., Professor of Civil and Environmental Engineering Michigan State University

Ph.D., Environmental and Water Resources Engineering, Massachusetts Institute of Technology

Areas of expertise:

- Realtime data fusion and immersive hydrologic and hydraulic modeling
- Multiscale modeling to inform sustainable water resources management
- Network thinking and smart environmental service systems
- Data-enabled science and action-oriented water resources curriculum
- Stochastic modeling of groundwater flow and contaminant transport

Hua-Sheng Liao, Ph.D.

Chief Technology Officer, Hydrosimulatics INC.

Ph.D., Hydraulics, Chengdu University of Science and Technology, China

Areas of expertise:

- Application software development
- Client-server programming
- Numerical modeling of subsurface flow and contaminant transport
- Engineering hydraulics
- Computational fluid dynamics and turbulence modeling

Theodore Eyster

Senior Modeler and Programmer, Hydrosimulatics INC.

M.S. Resources, Environment and Sustainability, University of Brisish Columbia, Canada

B. Eng, Civil and Environmental Engineering, Princeton University

Areas of expertise:

- Groundwater flow and contaminant transport modeling
- Surface water-groundwater modeling
- Natural/built environment interactions
- Environmental and water sustainability
- Watershed restoration and environmental design

Umesh Adhikari

Senior Modeler and Programmer, Hydrosimulatics INC.

Ph.D., Biosystems Engineering, Michigan State University

- Watershed hydrology and surface water modeling
- Spatial data processing, integration, and web services
- Non-point source pollution modeling
- Climate change impacts on water resources and food security
- Environmental restoration and sustainability

Ezequiel Mussambe

GIS Programmer, Hydrosimulatics INC.

B.S., Geographic Information Science and Cartography, Michigan State University

Areas of expertise:

- GIS Big Data Programming
- Web-based, desktop, and mobile application development
- Environmental geostatistics and applied mathematics

Zhentao Wang, Ph.D.

Modeler and Programmer, Hydrosimulatics INC.

Ph.D., Water Resources and Hydraulics, University of Missouri-Columbia

Areas of expertise:

- Realtime hydrological and hydraulic modeling
- Overland flow simulation and dynamic flow direction
- Infiltration modeling during transient rainfall events
- Drinking water distribution system and sewer system management

Monica Wu, Ph.D.

Programmer, Hydrosimulatics INC.

Ph.D., Computational Sciences, Northeastern University

Areas of expertise:

- Database and web development
- Client-server programming
- Data- and technology-mediated collaboration

Recommendations

Date: XXXXXXX

Phase 2: Screening Level Modeling, Risk Analysis, and Ranking Study

Hydrosimulatics, Inc. has been retained by the county to prepare the Phase 2 groundwater study. The project will enable to County to rank and prioritize sites of environmental concern across its entire site portfolio – from high-risk sites requiring "immediate" action (e.g., oversight, groundwater sampling and analysis, and possible remediation), to low risk sites that can be addressed later (perhaps years in the future), or everything in between. The project will also provide additional information regarding source water areas (or "well-watersheds") of critical public water supply wells in the County (Type I community supply wells).

The deliverables of this project (maps of pollution site impact areas, source water areas of critical groundwater receptors, a countywide aquifer vulnerability map, and risk rankings) can be used to guide long-term planning relative to groundwater use and growth trends, allowing the county to answer questions such as:

- Which critical groundwater receptors are threatened by known or potential sources of groundwater pollution because of proximity to a pollution impact area?
- Which receptors are most vulnerable because of aquifer and soil properties?
- Which ones require "immediate attention" or close monitoring?
- Which ones might have an issue sometime later in the future?
- Which areas being considered for future development face water supply issues because of impaired water quality?
- What are the time-scales involved?

At this date there are no recommendations from the Groundwater Work Group, as the study is in progress. The study will be completed in early 2023. After reviewing the conclusions and list of recommendations from the final report, the Groundwater Work Group will report to the Board of commissioners in first quarter 2023 with its recommendations.

For Discussion:

1. *How much of the remediation would be EGLE's responsibility, how much County responsibility?*
2. *The Board of Commissioners needs to know if the county needs to be setting aside funds for eventual remediation projects, and if so, how much money? Hundreds of thousands? Millions? Tens of millions? More?*
3. *Should the Work Group at least alert the Board of this possible expense?*

BEST Intelligent Decision Support System Tool

The Phase 1 Allegan County Groundwater Study analyzed existing regional groundwater data to better understand the groundwater conditions across the County and implications for management – both in terms of water quantity (availability and use) and water quality ("background" groundwater chemical concentrations and potential "point" sources of pollution). This study was the starting point to assist the County in determining current and future water demands and sustainability of water supply relative to growth trends, and how to improve water quality and maintain the quantity required for human and agricultural use.

A very large amount of data and information was compiled, processed, and analyzed for the Phase 1 Allegan County Groundwater Study. These data /information/analyses are very useful for understanding groundwater conditions and managing groundwater, and were presented in a "static" Final Report prepare by Hydrosimulatics INC. This report format – while still useful – is a significant underutilization of the data, information, and work product.

In this project, Hydrosimulatics INC. proposes to develop a mechanism to enable the systematic and synergistic use of existing data as well as data collected in the future – with a goal to significantly improve the practical ability of county and local decision makers to understand, manage, and protect groundwater resources. In particular, Hydrosimulatics INC. proposes to develop a unified groundwater information system that integrates the vast water well records and other groundwater/environmental Big Data collected for different purposes and accumulated in past decades. Hydrosimulatics INC. will preprocess the database and data service system, converting the raw datasets, maps, and other information into usable products and ultimately resulting in increased knowledge for the benefit of the managers, planners, developers, and the community.

Built directly on the processed database will be an interactive, web-based decision support system (DSS) - consisting of a comprehensive suite of management tools – Big-data Enabled Simulations Tools (BEST) for intelligent decision support - that can be used to guide water resources planning and permitting processes within agencies of Allegan County, the townships, and others. The Best Intelligent DSS will include a comprehensive suite of groundwater management tools enabling real-time interactive groundwater mapping, 3D visualization, and analysis via dynamic linkages to the processed spatial data, countywide maps, time-series sensor data, and other information related to groundwater and human activities. In short, the BEST Intelligent DSS will allow going beyond one project, one site, or one problem related to groundwater management in Allegan County – now, and into the future, for a diverse set of end users.

The Groundwater Work Group recommends that the Board of Commissioners authorizes the award of a contract to Hydrosimulatics INC for the preparation of the BEST Intelligent Decision

Support System Tool as presented in their written proposal dated August 24, 2022. The total cost of the project is $499,000.00. The overall schedule for the project is approximately 13 months from Notice to Proceed.

Included in the project scope is training for County and local users. Therefore Work Group recommends that during the preparation of the DSS, the County Health Department sets up a meeting with Hydrosimulatics INC and local units of government to educate the local units on the tool, and how the local units can use it to their benefit. Keeping local units involved in the development process is an important element for the success of the DSS tool.

Water Supply Master Plan

The availability of water for all users in the County—residential, commercial, industrial, agriculture—is of utmost priority for the health and economic well-being of the County. All users share the aquifer beneath our feet. The essential question is: Will there be enough water for all users in the future; and if not, what actions should the County take today or in the near future to mitigate water shortages? In as much as potential solutions to future water demand may require a long-lead time--such as developing a water intake and treatment plant at Lake Michigan—it would be prudent for the County to embark on the master planning process within one year.

The Groundwater Work Group recommends that the Board of Commissioners authorize the Health Department to retain a qualified consultant to create a Water Supply Master Plan for the County. The Water Supply Master Plan should estimate the current usage of groundwater by various categories of users, including residential, municipal, industrial, commercial, and agriculture. Using a predetermined event horizon, such as forty years, the plan should project future use by category. The consultant should actively include local units of government in the development process to learn local nuances and insure buy-in of the final product.

While it is not possible to accurately predict what the water demand will be in forty years, by establishing a baseline today, the Master Plan can be revisited at five-year intervals to identify if projections are under-estimated, on-target, or over-estimated. Furthermore, external factors such as increasing or decreasing groundwater recharge rates, or contaminated wellhead areas, should be considered in the projections to provide “worst case,” “best case” and “most likely” scenarios.

The cost of retaining a specialist to produce a Water Supply master Plan is estimated to be on the order of $150,000-$200,000.

It is recommended that the County issue a Request for Proposals no later than the first quarter of 2023 to be proactive. The contract will be administered in the Health Department.

Water Table Monitoring Wells

Understanding how much groundwater is available in the aquifer is important for the County to be able to make decisions with respect to meeting groundwater demand. Unfortunately, this is not a precise science. Water supply can be estimated by calculations based on measurements of the water table. Because the geology of the County is variable, the more (accurate) data points there are, the better prediction a hydrogeologist can make about the available water supply and its changes over time. For example, if the groundwater table shows a downward trend over time, it means that the water supply is shrinking. Therefore, it is necessary for the County to establish water table monitoring wells at numerous points throughout the County, and to collect and monitor this data over time, so that proactive actions can be taken before a crisis exists.

Siting water table monitoring wells is challenging in that not only is in necessary to find sites that offer valued information from a geologic perspective, but access is also needed for County personnel to drill the well, and then for subsequent periodic access to the level sensors and data loggers. For this reason, public property is typically preferred over private property. To date, the Health Department has collaborated with the Michigan Geologic Survey to site two monitoring wells on County government property. However, the County government does not own enough property across Allegan County to satisfy the need for monitoring well sites. Therefore, the county will have to work in cooperation with other public entities to make arrangements for establishing monitoring wells across the County.

The Groundwater Work Group recommends that the Board of Commissioners approve the funding for installing XX monitoring wells across Allegan County. The Work Group further recommends that the Department of Health approach public land holders including the County Road commission, DNR, public school districts, and local units of government to seek cooperative agreements for siting the necessary number of monitoring wells.

While it is understood that it will be a challenge to work with other public entities to get cooperative agreements to site monitoring wells, the hard reality is that the only way for the County to truly understand the groundwater situation is through a well-distributed array of data points. This further underscores the importance of keeping local units of government involved in the Water Supply Master Plan process and the DSS tool development.

For Discussion:

1. *How many monitoring wells are needed? –(Zach)*
2. *Should we provide a map of preferred or potential locations as a starting point? Is this something Zach can create?*
3. *Cost?*
4. *Schedule?*
5. *Who will maintain the data loggers and sensors? Who will collect and maintain the database? Who will post the information on the county website?*

Private Well Water Quality Data Collection and Monitoring Program

Contamination that enters the aquifer stays in the groundwater and migrates from its source. Eventually, contamination may appear in wells distant from the source of contamination. Therefore, it is important for all well users to know the health of their water, and to know if levels of contaminants are increasing over time, so that remedial action can be taken. Municipal water system owners are mandated by MI EGLE to periodically sample their water for contaminants and report this data to the state. However, private well owners are not under such a mandate. Most residential well owners are unaware of the quality of their drinking water. They are neither educated nor proactive in monitoring their wells.

The Groundwater Work Group recommends that the Board of Commissioners authorize the funding for the Health Department to create a Private Well Water Quality Data Collection and Monitoring Program to encourage and assists private well owners with collecting groundwater samples from their wells. Under this program. the County would offer sample collection kits free of charge to the well owners. Instructions where to send the sample for analysis will be provided. The County Health Department would receive the results from the laboratory, and pass them onto the well owner. Participation in this program would be strictly voluntary.

With the data that is collected, the County Health Department will maintain a database of the sample results including date and locations, thus creating a county-wide map of groundwater quality with current data. This information can be used by the County, local units of government, municipal water supply utilities, and private residents to make decisions about the health of their drinking water, such as whether treatment systems are needed. The information will allow the County's Health Department to identify new sources of contamination so that they may be addressed. For example, failing septic systems or accumulation of agricultural chemicals can be pinpointed.

This program is in support of the Health Department's overarching guidelines, including:

"The Allegan County Health Department believes in a County wide community assessment and improvement plan to align collective resources and maximize impact to health outcomes."

For Discussion:

1. *Can ARPA funds be used for this program? If so, how much funds should be set aside?*
2. *Which parameters should the kits analyze? What do we base this decision upon? Suggestions: pH, nitrates, salinity, pesticides, PFAS, VOCs, arsenic, dioxins, PAHs*
3. *Do the private well owners get to pick and choose which parameters can be analyzed, or is every kit the same suite of parameters for simplicity and good data collection?*
4. *Who is eligibile: Only Private wells as defined by EGLE? Or Type 2, Type 3 also?*
5. *Cost per kit? --(Jill)*
6. *Est. cost per year to the county? (Cost per kit times number of estimated kits per year.)*
7. *Is there an estimated number of samples that the County should set as a target to achieve a good sample pool?*
8. *Media and outreach program to communicate to the county residents and local units?*

Public Education and Outreach Program

The Allegan County Health Department's Vision Statement declares that it will "promote a safe clean, and healthy environment in which to live work and play." One of the best ways the Health Department can meet this vision is to provide the information and tools that allow the residents of the county to make good decisions. Good health starts with a good education. The more that Allegan County residents know about their drinking water the better they will be at making important decisions at both the individual and community level. Therefore, a robust community education and outreach program about water supply and water quality is instrumental in achieving the Vision. The Health Department is well-situated to be the prime transmitter of information that is based in science and trustworthy.

The Groundwater Work Group recommends that the Board of Commissioners provide the funding to the Health Department to create a public education and outreach program concerning water supply and water quality. As the expertise does not exist within the County to develop such a program, the Work Group recommends that the County retain a consultant experienced in community education and outreach to develop the program. The targets of the program should be all residents of Allegan County, businesses, and local units of government. The program should include the following elements and activities:

- Education about where the county's drinking water comes from, and why it is important to protect both water quantity and water quality.

- Ways in which residents can help protect the aquifer.
- Outreach to private well owners about the free water sampling program
- Online County-wide map showing up-to-date information on groundwater levels derived from the monitoring wells program.
- Outreach to local units of government educating them on how to use the Decision Support System tool.
- Serve as a clearinghouse for assistance to residents and local units of government as to where to go for technical support and how to apply to other agencies for loans and grants.

For Discussion:

1. *What other elements and activities should this program include? (Erick?)*
2. *Cost?*
3. *Schedule?*

<u>New Position: Groundwater Steward</u>

The recommendations of the Groundwater Work Group, if accepted by the Board of Commissioners, will increase the demands on the Allegan County Health Department resources. Therefore, the Groundwater Workgroup recommends that the County Health Department create a new full-time technical position of "Groundwater Steward" to administer these programs:

- BEST Intelligent Decision Support system Tool
- Water Supply Master Plan
- Water Table Monitoring Wells
- Private Well Water Quality Data Collection and Monitoring Program
- Public Education and Outreach

Other needs that may arise with respect to groundwater stewardship within the County, particular those needs that will emerge as a result of the above programs, will also fall within the duties of the Groundwater Steward.

The annual cost for this position is approximately $XXXXXX

For Discussion:

1. *Annual cost of this new position? –(Randy)*
2. *Other information the Board should know?*

Low-Production Private Wells

Private wells within certain areas in the County are known as "low production wells" because the aquifer is not able to regularly produce enough water for a typical private residence. These homeowners are in a bind because further well drilling will not solve the problem. A solution would be to connect the homes to a municipal water supply system. However, extending the infrastructure out to these homes is not considered because they are not located within the service area of a municipal water utility.

Allegan County government can be the bridge that assists the homeowners and local water utility by providing seed funding to help pay for the infrastructure extension from the utility service boundary to the homeowners in need.

For Discussion:
This item needs more development.

1. *Need to map the known low production wells and dry well locations, based on EGLE data base. Who can do this?*
2. *Look for geographic areas where these areas could potentially be served by an expanded municipal water system. Who can do this?*
3. *From what sources can the County or local water utility secure funds to help with engineering and construction costs for expanding municipal systems? Are ARPA funds available? (County lobbyist?)*