Benefits of a Statewide GIS Hydrography Improvement Project

Introduction

Geospatial technologies continue to grow exponentially with geographic information systems becoming a core technology within organizations. Data accuracy and regularly maintained data are essential. Hydrography is defined as the science of measuring and attributing water bodies and adjoining land areas. This includes rivers, lakes and stream systems, coastlines, harbors, and seas. Hydrography data are represented as digital geometry representing surface water features with hydrography attributes. As the Great Lake State and a state with over 11,000 inland lakes greater than 5 acres in size, having a robust hydrography data layer is critical for business systems that need to leverage the location-based aspects of GIS hydrography datasets. These GIS are a key component to perform predictive analysis critical to managing water resources and providing safe fresh water to citizens of our state.

Background of Hydrography Data

Mapped information on rivers, lakes and streams is a necessary for any water resource management activity. Having accurate GIS datasets allows for additional data about lakes and river systems to be linked to specific locations along a water system. This results in the ability to conduct analysis and quickly and accurately display relationships among the state's water resources and potential impacts to these resources. Examples of additional data and analysis that are dependent on an accurate and well-maintained hydrography dataset are presented in table 1.

Program	Use of hydrography data	Benefits of improved data accuracy and more stream coverage
Natural Rivers Program	Hydrography data are used to generate buffers in which activities are restricted	Enhance management decision making, enhance enforcement activities, increase protection for natural rivers
Invasive Species Program	Hydrography data are used for stream connectivity and hydraulic connectivity important for modeling spread of aquatic invasive species	Enhance management decision making, provide better view of potentially infected areas, decrease response time and effort, increase knowledge of hydraulic connectivity. Increase accuracy of modeling.
Dam Management Program	Hydrography data are used for hydraulic modeling of water upstream of dam and modeling effects of drawdown	Increase accuracy of modeling, increase accuracy of flow network, increase hydraulic flow accuracy.
Habitat Management Program	Hydrography data are used for desktop analysis of stream stability, hydraulic modeling, and water resource management decisions	Decrease field time, increased efficiency, increase accuracy of modeling, increase accuracy of flow network, enhance water resource management decisions
Charter Fishing Program	Hydrography data are used for charter locations and tracking catch rates	Increase accuracy of charter fishing areas

Michigan Arctic Grayling Initiative	Hydrography data are used for habitat modeling and assessing stream conditions	Increase accuracy of modeling, increase accuracy of flow network, increased accuracy of habitat modeling
Fisheries Division / Program Overall	Hydrography data are used for habitat modeling, regulation development, water resource management decisions. Critical component of divisions workflows.	Fishing regulations guide, decrease field time, increase efficiency, increase accuracy of modeling, increase accuracy of flow network, enhance water resource management decisions
Forest inventory and planning	Hydrography data are used for land management decision making, forest management boundaries are driven by hydrography data. Regulations do not permit some forest activities within certain distances of hydrologic features.	Benefit forest audit procedure by creating a more accurate dataset, increase management activity decision making, simplify compartment boundary mapping
Forests for fish Program	Hydrography data are used for land management decision making,	Enhance management decision making, increase protection for natural rivers
Law Enforcement division	Hydrography data are used for enforcement	Enhance enforcement activities
EGLE Wetland Protection Program	Hydrography data are used for existing wetland inventory, modeling locations for wetland reconstruction, hydrogeomorphic modelling, and assessing functional lifts/benefits of wetland reconstruction locations. This program also supports Wetland Compliance and Enforcement program and Inland Lakes and Streams Regulatory Program using hydrography data.	Enhance management decision making, increase targeting accuracy for wetland creation, increase accuracy of modeling, increase accuracy of flow network, increase wetland stream functional lifts. Stream mapping is now a US Fish and Wildlife Service requirement and accurate stream networks would save time from having to rework existing inaccurate or missing streams and lead to more accurate inventory and data for decisions at all levels of government.
DNR and EGLE agency-wide uses	Hydrography data (including Streams, lakes, rivers) serves as base layers included on most maps. Influences multiple aspects of land and wildlife decision making, generally referenced in Land Use Orders from the Director.	Decrease field time, increase efficiency, increase accuracy of modeling, increase accuracy of flow network, enhance water resource management decisions, enhance land management decision making,
Public	Hydrography data are used for creating maps and developing models. The hydrography	Multiple organizations utilize the states data to develop maps and run analysis. Increase

	data are made available via the State of Michigan's GIS Open Data Portal.	accuracy will benefit residents, visitors, colleges, and universities.
USGS/National benefits	Hydrography data are utilized to complete a national network of streams and lakes, creates a national hydraulic dataset.	NHD is the nationally recognized source for authoritative water data. Michigan has an agreement to keep states data updated in the NHD. More accurate data are necessary for increasing accuracy of flow/hydraulic modeling and prediction
Trails	Hydrography data are used for trail development, water trail locations are derived directly from hydrography data.	Increase data accuracy, enhance management decision making
Local controls program	Local controls frequently reference hydrography data	Enhance enforcement activities
Emergency management	Hydrography data are used for decision making and hydraulic modeling in disaster situations. Also used as way to identify potential sources of water, or contamination flow.	Enhance fire, spill response, flooding, and washouts emergency response.
Parks and recreation	Hydrography data are used for mapping park boundaries, and identifying recreational opportunities	Enhance recreational activity planning
Fish stocking	Hydrography data are used in assessing locations to stock fish	Enhance management decision making
Minerals	Hydrography data are used for siting locations, and determining management activities and compliance	Enhance management decision making, increase accuracy for siting, increase accuracy for runoff modeling
Real estates	Hydrography data for determining property boundaries	Ownership frequently dictated by streams and rivers, increase accuracy of ownership boundaries
MDARD	Hydrography data are used for nutrient load modeling and targeting areas for nutrient reduction.	Enhance nutrient load modeling, enhance runoff/nutrient loading modeling for WLEB, enhance runoff/nutrient loading modeling for state

Asset Management	Hydrography data are used to identify location of existing assets and assets needed. Can be used to calculate size and scope of required assets	Enhance management decision making
Endangered species program / MNFI	Hydrography data are used for habitat modeling and land management activities	Enhance management decision making
Fire Management	Hydrography data are referenced for fire suppression, creating break lines / burn lines, and as water sources	Enhance fire emergency response.
Floodplain Program	For estimating floodplain elevations on streams	Improve accuracy for estimating and modeling
Hydrologic Studies Program	Estimating high and low stream flows	Improve accuracy of flow models, provide an expanded water network for estimating flows
Oil & Gas, Mining	Hydrography data are used for evaluating permit applications and compliance	Improve accuracy and more thorough permit evaluations
Hydrogeology and Groundwater Modeling	Hydrography data are used for evaluating groundwater discharge areas, recharge areas, and internal drainage as well as flow volumes	Improve recharge/discharge evaluations and better differentiation of gaining and losing stream reaches
Geologic Mapping and Geomorphology	Geologic structure, competence, and lithology can often-times be inferred based on hydrography patterns	Improve geologic maps to improve understanding of the landscape and improve decision-making
Watershed Delineations	Assist in watershed delineations, especially in headwaters	Improve accuracy of water and sub-watershed delineations including more complete stream network in headwaters
Karst Mapping	Hydrography data is used in karst mapping and determining where streams go underground and when they come to the surface	Improve understanding of the local and regional karst systems and subtle karst features. Improve evaluation of aquifer vulnerability
Containment Investigations	Hydrography data are critical for land-based surface water based or non-point source pollution investigations	Improve contaminant investigations because or the more accurate hydrology network

Water Table Mapping	Appropriate hydrography used for additional control points where the surface water body is a reflection of the water table surface	Improve water table maps due to more detailed and higher accuracy hydrography as well as avoidance of perched hydrography
Coastal Management Program	Hydrography data is used to identify and map areas prone to coastal erosion and flooding	Enhance ability to identify hazard-prone areas and communicate information to local decision makers to inform local planning and policy.

Table 1 – Examples of uses for hydrography data and benefits of improved GIS mapping of hydrography

Definitions for the above table: NHD - National Hydrography Dataset, MNFI - Michigan Natural Features Inventory, WLEB - Western Lake Erie Basin, MDARD - Michigan Department of Agriculture and Rural Development

Project Description

Today, Michigan has a statewide hydrography layer depicting rivers, lakes, and stream that was digitized at 1:24,000 scale in the 2000s from USGS topographic quadrangles. At 1:24,000 scale, the location accuracy of features can be off as much as 40 feet.

For re-mapping hydrography data, the project leverages Light Detection and Ranging (LiDAR) data that have been collected through aerial acquisition projects over the past few years and is at a Quality Level 2 (QL2) which means it can provide an accuracy of between 2 to 5 feet and with elevations on the order of 4 to 6 inches. LiDAR will provide the elevation data needed to detect water channels and flow directions resulting in more accurate positioning of river, lake, and stream systems and more complete coverage of water features by providing the capability to map many more stream networks. Many ephemeral/headwater streams were not captured in the original MIRIS and NHD Hi-Resolution hydrology datasets. Increased density of flowlines, not currently represented in NHD in these headwater areas are expected to be captured in the newly developed elevation derived data sets. It is expected that the hydrography project would encompass the following activities:

Develop a more accurate stream network derived from QL2 LiDAR elevation data. This involves using a combination of automated and manual processes by watershed area to generate more accurate river, lake and stream networks. Once the proposed networks are generated, a quality control process will be used to review the position of the new hydrography network against digital elevation models (DEMs) and other sources such to validate results and make manual adjustments to the network as necessary.

To effectively hydro-enforce hydrography from LiDAR data it is important to know the location of culverts to determine where water flows. Knowing the location of culverts across the landscapes will help in accurately modeling water flows. This will necessitate gathering existing digital culvert and drain information from various stakeholders from government agencies and private sector firms, where possible. This activity will leverage the existing digital culvert data and map culverts in areas where data gaps exist.

Once the new hydrography network is derived, a process to conflate information from the previous hydrography sources to the new hydrography network will take place. Conflation is the merging of information from one dataset to another. In this case, existing attribute information will be conflated from the Unites State Geological Survey's (USGS) National Hydrography Dataset (NHD) and other sources to the newly derived hydrography network in areas of existing NHD. For newly derived hydrography data in areas where NHD features are not present, some of the attributes will likely need to be added in the future because other source data may not exist. This process will involve both automated and manual steps. This will require coordination with USGS to develop new IDs and naming conventions that align with the new USGS model.

Develop a long-term maintenance program to ensure sustainability of the data. This involves identifying a data steward to coordinate with authoritative contributors to the dataset among national, state, regional, and local organizations. A long-term maintenance solution also requires a process to manage data updates that will need to be reviewed before being added to the statewide dataset. The State of Michigan has an existing geospatial data integration system, the Michigan Geographic Framework (MGF), that will be leveraged as the centralized GIS repository for the statewide hydrography layer. The long-term data maintenance process will include how to leverage new USGS 3DHP tools for updating to the national dataset.

Systems Dependent on Accurate Hydrography Data

There is a current bias on maps that tends to show larger streams and streams in agricultural areas where trees are scarce. Many smaller streams are missing, which severely underestimates the total length of streams in a hydrologic network. Smaller streams and wetlands tend to comprise most headwaters of a stream/river network. Headwaters dominate surface water drainage networks and studies of headwater catchments have provided an understanding of various sources and controls on biogeochemistry in streams (Seibert et al., 2009; Tiwari et al., 2017). Headwater streams have a high amount of stream edge relative to stream surface area (Richardson and Danehy 2007) and local ground water discharge is a major contributor to water flow in these streams (Leach et al., 2017). Headwater streams and their riparian zones constitutes an interface between water and soil, and largely control inputs from surrounding landscapes to downstream ecosystems (Lidman et al., 2017). They also provide important ecosystem services such as nutrient cycling (Blackburn et al., 2017; Bormann and Likens, 1967) and buffering the impact of pollutants (Klaminder et al., 2006). Headwater streams function as important habitat for both invertebrates and plants and function as migration corridors (Freeman et al., 2007). This strong coupling between soils and streams raises critical issues regarding management of small streams. Any perturbation in headwaters will affect downstream environments; to protect large streams it is important to protect the headwater streams (Kuglerová et al., 2017; Wipfli et al., 2007). To give small streams needed protection, the first step is to know where they are. Studies have shown that current stream network maps are missing 58 % of perennial streams and 76 % of the of the stream network during high flows (Ågren et al., 2015). The expected increased density in stream networks in 3DHP data could improve the analysis in areas mentioned above.

An improved hydrography network makes for better analysis and decision-making capabilities for many processes that exist in state government. Systems that depend on hydrography data include, but are not limited to, the following:

Stream Fish Management Decision Support Tools
Fish Surveillance (FSIS) & tied to master angler and record
Catch Tracking System
Fish Prescription (Rx)
Fish Collection System
Fish Population Trends
Fish Stocking
DNR Enterprise Asset Management System
MiWaters Application
Stream Crossings (culverts and bridges)
GIS Hydro Analysis Tools (various COTS products)
Wetland Landscape Level Assessment Tools and Decision Support Systems
Wetland Inventory and Status and Trends
Hydrogeology and Groundwater Modeling
Contaminant Investigations
Great Lakes Coastal Management
Fish Production

Fishing Tournament Information System
Burn Permits (hydro accuracy key to determining fire risk)
Michigan Forest Inventory System (hydro key factor in determining compartments due to access for large vehicles)
Vegetation management system (VMS) and Timber Sales – Flow modeling and line accuracy improves management and access to timber
LOTS – Needed to accurately depict parcels for land management
Recreation Search - Key to determining water trails and effective management of recreation with conservation
Hydrologic Engineering Center's River Analysis System (HEC-RAS)

Table 2 – Systems and tools used or produced that leverage hydrography data

Conclusion

The objective of a statewide GIS hydrography improvement project is to develop a more accurate digital statewide GIS water network map that will integrate with dozens of existing IT systems, modeling software, and provide better decision-making capabilities through data analytics for stakeholders across all levels of government, academia, non-profit organizations, private sector, and citizens of the state. This project involves many stakeholders from across multiple sectors across the State. As outlined in this document there are many business cases for the use of hydrography data and each unique case can benefit from more accurate hydrography data and increased density to the water network. This is a multi-year project to develop the initial data statewide. It will also need the stakeholder community to continue to validate the data over time as it is used within their business systems and make needed request for data updates to maintain and enhance data quality for years to come.