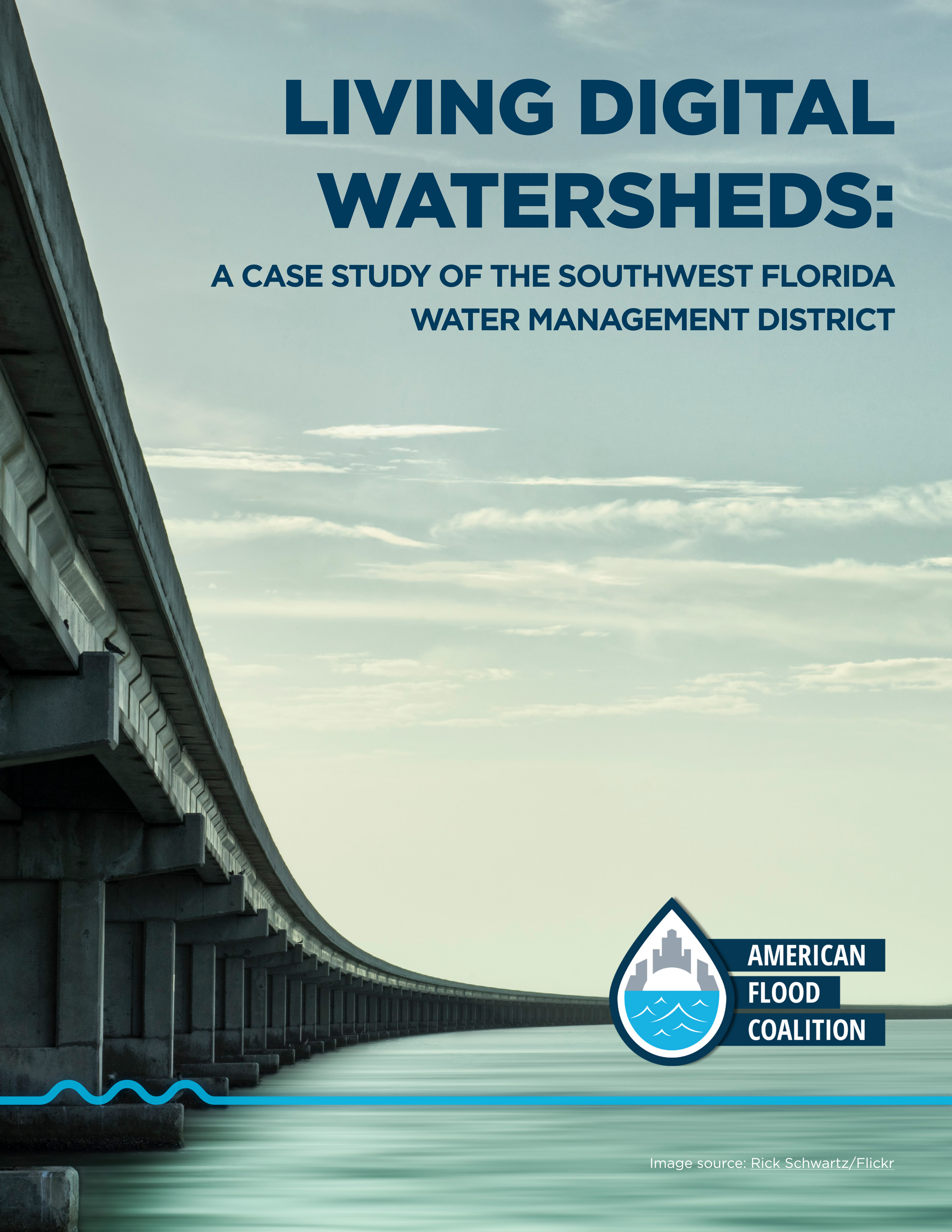
LIVING DIGITAL WATERSHEDS:

A CASE STUDY OF THE SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT



AMERICAN FLOOD COALITION

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Living Digital Watersheds

A case study of the Southwest Florida Water Management District

Executive summary

The Southwest Florida Water Management District (SWFWMD) oversees flood programs and provides technical analyses relating to water resource studies across 16 counties on the west coast of Florida. The district's Watershed Management Program (WMP) takes a watershed approach to assessing flood risk. The program standardizes how the district collects data and models flood hazard areas, putting the information in an accessible repository called the Geographic Watershed Information System.

Case study process

The American Flood Coalition worked with experts in Florida to interview current and former SWFWMD employees involved in the Watershed Management Program. After developing an initial draft, AFC spoke with city and county personnel who have been on the receiving end of the Cooperative Funding Initiative to understand how the program works on the ground. This case study represents AFC's analysis of the program based on these interviews, desk research, and technical expert review.

To fund SWFWMD flood studies, local governments apply for the Cooperative Funding Initiative. SWFWMD ranks applications by the measurable benefits of the study, including how studies improve safety. SWFWMD searches for scenarios with feasible solutions, then presents them to local governments to develop a project plan. So far, SWFWMD has modeled about 70% of the region, creating interoperable models and datasets that help municipalities plan better locally and regionally.

What did we find?

Since 2020, SWFWMD has spent roughly $90 million across the Watershed Management Program (WMP). Because they redesigned the program several times, SWFWMD learned the importance of model validation, coordination with local governments, and data collection and modeling standards.

Other states looking to replicate this program can save time and money by learning from where SWFWMD is today. But these same states must also consider how scaling to a full statewide operation will make things more complicated, time-intensive, and costly. Additionally, states without existing taxing entities, like Florida's water management districts, will need to think about budget concerns, such as funding and cost shares with local governments.

Program overview

The Southwest Florida Water Management District (SWFWMD) is one of five water management districts in Florida. Each district aims to preserve and protect water supply, resources, and natural systems. The districts protect public safety by implementing flood projects, as well as supporting local communities as they carry out flood projects. SWFWMD actively oversees flood programs and provides technical analyses on water resource studies across roughly 10,000 square miles. The district includes 16 counties, 11 major watersheds, 4 regional planning councils, and serves roughly 6 million people. The district can impose taxes, which make up roughly 60% of its annual budget. It also receives funding from federal and state programs.

SWFWMD leads several initiatives related to flooding, including the **Watershed Management Program** (WMP), one of the nation's most innovative and mature flood risk modeling initiatives. The WMP takes a watershed approach to assessing flood risk. It uses a consistent approach for collecting flood risk data, modeling flood hazard areas, and centralizing information in an accessible repository to create efficiencies and drive better decision-making.

The WMP combines **sophisticated flood hazard modeling with local engagement to enable data-driven planning across southwest Florida**. Flood modeling aids local governments when approving development applications, developers when determining where to put homes, and residents when choosing how to protect their properties. It also informs where and how communities should design and build infrastructure to ensure public safety. **Flood risk changes over time, meaning governments must constantly strive to update data.** The WMP relies on hydrologic and hydraulic (H&H) modeling to understand where water will flow and pool in simulations. To guarantee these models are consistent across watersheds, SWFWMD created the Geographic Watershed Information System (GWIS), which ensures that H&H data is stored in a single geodatabase and model. So far, SWFWMD has modeled approximately 70% of the region, creating interoperable models and datasets that help municipalities plan better locally and regionally.

Hydrologic & hydraulic modeling

Hydrologic & hydraulic (H&H) modeling is a type of flood hazard modeling that comprises two important sciences:

- **Hydrology**: studies how water occurs, flows, and is distributed above and below ground.
- **Hydraulics**: studies how water interacts with various systems (such as culverts, pipes, rivers, canals, open channels, pumps, structures, and bridges).

In other words, H&H modeling simulates where water is (hydrology) and where it will go (hydraulics). This modeling tends to focus on the relationship between rainfall and runoff but can cover all aspects of the hydrologic cycle. Such modeling can be used to design water infrastructure, study natural systems, regulate areas, or map floodplains.

Governments lacked clear data standards and management

By 2000, SWFWMD recognized that **agencies often used outdated flood risk information, which led to them making poor decisions for their growing counties**. To evaluate watersheds, these governments frequently relied on FEMA's flood insurance rate maps; however, the maps failed to properly address the needs of SWFWMD or local governments in the entire region. SWFWMD also determined that local governments lacked the expertise to properly build and maintain flood hazard models or to use sophisticated Geographic Information Systems (GIS).

After assessing stormwater and watershed study documents, SWFWMD found that, across the district, there was inconsistency in how governments collected and stored data and how they incorporated data into flood models. Early modelers struggled with evolving technologies and digitizing a paper-based system.

SWFWMD identified the need to help municipalities within the region by establishing a more efficient and accurate system for assessing flood risk and coming up with solutions. SWFWMD developed the Watershed Management Program to standardize data, support local governments, and integrate data and modeling into a district-wide repository.

Developing consistency across the district

Overview of the Watershed Management Program

Through the Watershed Management Program (WMP), SWFWMD coordinates and implements its priorities across 11 major watersheds. SWFWMD has spent over 20 years, and hundreds of millions of dollars, to develop the WMP; however, much of that time and money has gone to multiple iterations of the program as data and technology improve over time. Since 2020, SWFWMD has put roughly $90.1 million toward the WMP, including for:

- Modeling and developing watershed plans.
- Selecting communities for in-depth modeling.
- Communicating and implementing watershed plans.
- Maintaining standardized data through the Geographic Watershed Information System (GWIS).

Modeling and developing watershed plans

SWFWMD regularly collects data to model and better understand each watershed. Specifically, the district generates digital topographic maps, aerial photographs, and ground survey controls to determine surface features and boundaries of each watershed. When evaluating a watershed, SWFWMD collects data to model how water flows through each watershed. After modeling, the district combines this flood hazard data with data on the structures within the watershed to determine areas at risk.

The WMP uses event-based modeling, which focuses on specific flooding scenarios. These models consider the conditions leading up to an event, including the height of groundwater and the characteristics of surrounding water. Modelers can then simulate rainfall on top of these features, ranging from 24 hours to a month.

Based on the modeling and evaluation, SWFWMD determines how well the watershed can provide flood protection, good water quality, and adequate water for people and the environment. This information is also used to establish the level of service provided by the watershed. The district then develops a plan to improve the level of service for the watershed.

Level of service

SWFWMD grades characteristics of a watershed on a scale from "A" to "F." This grading system, referred to as "level of service," is part of a comprehensive plan by local governments to support growth and development in the area.

For example, an area with a flood protection grade of "A" has flooding, but during severe storms, buildings would not sustain flood damage and all streets would remain passable. Meanwhile, an area with a flood protection grade of "F" is subject to hazardous flooding. During a severe storm, buildings, including emergency shelters, would experience flood damage; and roads, including evacuation and emergency roads, would be impassable.

Selecting communities for watershed studies

SWFWMD selects communities to receive a flood risk study over a year in advance. Local governments request funding for flood studies by applying online for the **Cooperative Funding Initiative**. The district ranks these requests, measuring the studies' benefits — including the improved safety of the community — as well as the feasibility of solutions.

SWFWMD generally aims to model areas with outdated data. When selecting areas, SWFWMD considers resources available in different areas, such as funding. The district also determines if developed residential areas lack existing data, or if watersheds have extremely outdated FEMA floodplain maps. SWFWMD makes its final decision depending on its ability to provide funding.

Through the Cooperative Funding Initiative, SWFWMD typically price matches with local governments to evenly split the cost of watershed studies. In more rural areas, SWFWMD often funds 75% of the total project, with the local government funding 25%. Project funding largely depends on duration and frequency of projects, as well as who leads the project (i.e., whether the local government will lead the project with SWFWMD support or vice versa).

Communicating and implementing watershed management plans

After completing a study, SWFWMD presents its proposed solutions to local governments to develop a project plan. SWFWMD holds a public meeting to note how floodplain boundaries will change and what that means for local properties. The district uses GIS to determine affected properties, and individually invites property owners to these meetings to learn about how the change will affect them and provide feedback.

The district then develops structural or nonstructural solutions to improve the level-of-service grade assigned in the watershed management plan.[1] SWFWMD and local governments work together to select the most cost-effective and beneficial approaches. The district continually monitors projects for long-term success.

Maintaining standardized data through the GWIS

To standardize data and ensure consistency throughout the district, SWFWMD created GIS-based flood protection coordination documents for each municipality in the district. These documents inform flood risk models, by providing guidance about data type and format. Because the guidance allowed every model created by the Watershed Management Program (WMP) to be compared, the manuals made it easier for local governments to work with each other. By establishing data standards, SWFWMD also defined how input and output data is structured to inform intended flood projects. These data structures begin with basics, like topographic information, before diving into the broader watershed evaluation.

The Geographic Watershed Information System (GWIS) standardized methodology simplifies how SWFWMD can collect and develop data. This lets local governments easily collect data, even during staff turnover, and allows for easy migration of other models in the GWIS. This migration promotes the idea of "living digital watersheds" that can be continually updated and refined as new information becomes available.

The GWIS is beneficial because it applies to and scales most stormwater modeling scenarios, from small urban drainage systems to large regions across the district. Because GWIS provides a consistent data structure for modeling a complex range of scenarios, districts throughout Florida have widely adopted the methodology.[2] For more on how GWIS was developed, see the **Technical Appendix**.

1 Structural approaches may include development and maintenance of water management facilities. Nonstructural approaches may include land acquisition, permitting, regulation, and education. Solutions may address multiple watershed issues (e.g., flood protection, water quality).
2 The GWIS methodology is also used by the Northwest, Suwannee River, and St. Johns River Water Management Districts, as well as Orange County.

Early lessons learned led to program improvements

Quality control checks highlighted the importance of validating models.

Early in the program, SWFWMD found that models failed to reflect recent floods. SWFWMD discussed this issue at public meetings, which allowed community members to identify errors and discuss solutions. Validating models became a priority, and **SWFWMD recognized the need to develop a database that stored qualitative data, like flooding history of properties, and other quantitative data, like high-water marks.**

SWFWMD also asked counties and local governments to produce a database of their flood complaints, which included information on where flooding previously occurred. While responding to flooding, SWFWMD conducted field work, gathering information like indicators of high-water marks on properties. By combining this field work with data from real events, SWFWMD strengthened its data repositories and improved the models. The district also found it important that models should be approved by FEMA and replace the existing information for high-risk floodplains. SWFWMD is a Cooperating Technical Partner of FEMA, with access to grant funds to make new flood insurance rate maps for the region.

Coordinating with local governments helped ensure success of the program.

Early on, some local government staff did not know how to use the information gathered by the Watershed Management Program. SWFWMD faced resistance from communities, who were reluctant to update their initial plans to accommodate changes in the model. To ensure the models and resulting watershed management plans were used, SWFMWD worked closely with local governments.

Once the WMP had local buy-in, SWFWMD stayed in touch with local governments to **keep up with changing environmental systems and infrastructure projects**. SWFWMD also needed to understand how much local governments' GIS teams knew to ensure the user interface of the Geographic Watershed Information System (GWIS) was accessible. SWFWMD staff designed system permissions and trainings to ensure local government staff were comfortable using the information. While the full GWIS is functionally impressive, the data viewer is often simplified to aid the user. This can prevent local government personnel from feeling overwhelmed, while ensuring they can still effectively use the data for planning.

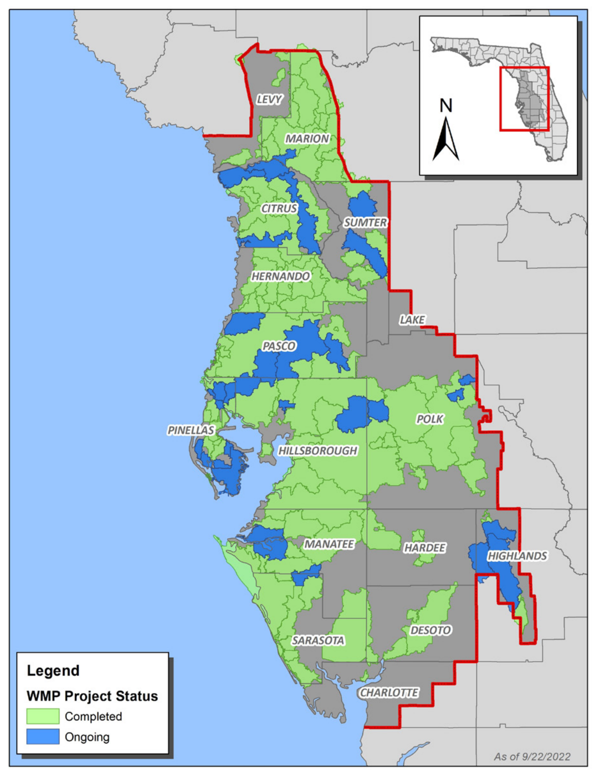
Data collection and modeling standards provided consistency for watershed studies.

SWFWMD increased documentation and developed formalized training for employees, but still struggled to gain support from the modeling community. The community tended to prefer methods and technologies that its staff already knew how to use. This made it hard to establish a consistent product, as staff needed to be retrained whenever new contracting firms joined the district. SWFWMD, however, relied on contractors using GWIS's format and tools to produce consistent models and data across the district's 11 watersheds.

SWFWMD found it essential to develop standards on why the data was being produced, how data was developed and maintained, and who was responsible for what parts of the model. By creating consistency between modeling teams, these standards made it easier for the district to work with its contractors. And with documented data standards, SWFWMD could better require contractors to use the GWIS.

The Watershed Management Program reduces time and cost of local planning

The Watershed Management Program (WMP) is widely cited as a strong program for assessing regional flood risk — largely because of its standardized approach to formatting, collecting and aggregating data, modeling and assessing risk, and aiding data-driven decision making. Much of the program's success, including the GWIS methodology, evolved through the years, with each iteration streamlining data collection and flood risk modeling.



While the program early on focused on digitizing paper-based data collection and risk assessments, it ultimately evolved into an efficient way to create watershed studies that are accessible to modelers and local governments. As of late 2022, **SWFWMD has modeled roughly 70% of the district**, including re-modeling large stretches of heavily populated areas multiple times. In this modeling, SWFWMD used the GWIS methodology to consistently incorporate new data, which has helped SWFWMD become more efficient over time.

SWFWMD's watershed approach highlights how water ignores political boundaries. The WMP helps SWFWMD understand how flood control projects affect downstream areas and how they use that information to work across local governments. It can be extremely costly for local governments to collect flood data, model and map watersheds, and conduct risk assessments. By standardizing these processes and giving the data to communities, SWFWMD reduced the cost and time of local planning and engineering, building local capacity and more equitable flood resilience across the district.

Conclusion: States replicating the Watershed Management Program can do it faster and cheaper

SWFWMD spent over 20 years, and hundreds of millions of dollars, developing the Watershed Management Program. Initially, SWFWMD was limited by the technology of the time. Since then, the program has advanced to include evolving technology. Other states looking to replicate this program can save time and money by learning from where SWFWMD is today.

Establishing data standards for regional modeling makes it much easier to compare model results across watersheds. This includes standardizing what data is collected (e.g., elevation, size and type of infrastructure) and how it is stored (e.g., file type, file naming conventions). While standardizing data requires higher up-front costs, the benefits are reaped over time: For each new modeling effort, local governments build on existing standards rather than starting from scratch.

At the start of a new modeling effort, developers should establish why the model is being run; how data is developed, collected, and maintained; and who is responsible for each part of the model. Setting these standards allows for greater coordination and consistency between modeling teams and prevents costly rework and delays. To create stronger data repositories, teams should also ensure real-world events inform models. To do so means developing and maintaining a database of high-water information, qualitative flood history, and other historical quantitative flood data.

To keep up with the changing natural and built environment, models should be approved by FEMA and replace the existing information for high-risk floodplains. While FEMA retains the authority to approve flood maps, state and local agencies can more consistently update these maps with funds from FEMA's Cooperating Technical Partner Program. When deciding to update flood maps, states should consider how updates will affect the mandatory purchase requirements of flood insurance.

Recommendation: States must consider scale and cost.

Other states looking to replicate this program should consider the following. First, the Watershed Management Program is not a statewide program. The program only exists within the roughly 10,000 square miles of the Southwest Florida Water Management District. Second, SWFWMD has taxing authority to help fund the WMP and other district operations.

States must consider how scaling to a statewide operation will affect cost, complexity, and timescale. Additionally, states without existing taxing entities like Florida's water management districts will need to consider funding mechanisms, such as cost shares with local governments.

Technical appendix

SWFWMD uses the Geographic Watershed Information System (GWIS) as a standard methodology for capturing hydrologic and hydraulic (H&H) information into a single geodatabase and model. The GWIS simplifies how SWFWMD can collect and develop data, making it easier for local governments to maintain the system, even during staff turnover, and allows for easy migration of other GWIS models. This migration promotes the idea of "living digital watersheds" that can be continually updated and refined as new information becomes available.

The GWIS is beneficial because it applies to and scales most stormwater modeling scenarios, from small urban drainage systems to large regions across the district. Because the GWIS provides a consistent data structure when modeling a complex range of scenarios, districts throughout Florida have widely adopted the methodology.[3]

Developing the Geographic Watershed Information System (GWIS)

In 2000, SWFWMD began developing a storage structure for Geographic Information Systems (GIS) data, digitizing topographic information and using that as the basis for digitizing other data. Developers selected a coverage data model to store geographic features through lines and polygons, with tabular information stored in dBase database (*.dbf) files. Modelers edited coverages with Esri ArcInfo and ArcEdit and viewed the data in ArcView. At this point, the GIS data was independent of any specific model.

In 2002, the district went beyond setting data standards for the GIS data and offered its first guidelines and specifications that defined all components of the Watershed Management Program.[4] SWFWMD also began to migrate this data into a geodatabase, introducing new advantages with relationship classes. The linkage of components between tables and feature classes (previously called coverages) could now be found together within the geodatabase, resulting in a cleaner package approach. In 2004, the district opted to use established data standards, in combination with concepts from the ArcHydro data model, as the roots of the GWIS.

In 2006, the first release of the Geographic Watershed Information System (GWIS) included multiple tools designed for the functionality of ArcHydro. These components included:

- **HydroIDs**: relates features to one another and to time series associated with them.
- **RelatedIDs**: establishes a relationship between the "from" and "to" feature class.
- **Catchment delineation**: calculates the direct catchment area or sub-basin from a specific input location or pour point.

3 The GWIS methodology is also used by the Northwest, Suwannee River, and St. Johns River Water Management Districts, as well as Orange County.

4 Topographic information, watershed evaluation, watershed management plans, implementation of best management practices, and maintenance of watershed information.

- **Network connectivity**: models multimodal transportation systems through interconnecting network sources.

By expanding from the domains already built into the geodatabase, SWFWMD allowed users to build stronger connections between everything in the database. Early in the rollout of the GWIS, SWFWMD found the modeling results in high percolation and sandy areas, which could infiltrate large amounts of rain, to be inaccurate. SWFWMD concluded they could not rely on basic engineering formulas and standard equations with typical rates and values. Instead, it needed to tailor its data collection and H&H modeling for the region's flat terrain and geology.

It was essential for the district's model to adapt and grow. The model was originally designed for a purely dendritic drainage system. While that worked well, the tools did not translate easily to the terrain in Florida, which has a mixed hydrology with many deranged watersheds. SWFWMD identified major deficiencies in the system and developed tools to improve the model. With consistent guidelines and formatting, SWFWMD made it easier for local governments to navigate the changing model.

Integrating the GWIS with flood risk models

In 2009, SWFWMD began integrating the Geographic Watershed Information System (GWIS) with the Interconnected Channel and Pond Routing Model (ICPR). At that point, most of the SWFWMD watershed studies used ICPR3, so SWFWMD transitioned to a single model that could support those studies. Modelers began incorporating model-specific features (e.g., classes, tables, attributes, domains) into the GWIS. From there, SWFWMD developed the process for how data was exchanged from GWIS to ICPR3. This operation allowed the features from GWIS to be exported to Extensible Markup Language (XML) files, which then could be loaded into ICPR3; however, this export was one-sided. The files could not be exported from ICPR3 back to the GWIS due to ICPR's limitations regarding spatial component storage.

By 2018, SWFWMD completed the full integration between the GWIS 2.0 and ICPR4. Starting from one-dimensional elements, developers built new feature datasets to house all groundwater overland flow information and two-dimensional elements. The GWIS 2.1 has all the capabilities of ICPR4, allowing for full import and export capabilities between the two models. Modelers can export GWIS features in ICPR4

Drainage systems

Topography, geology, and the gradient of the land all affect water runoff, throughflow, and groundwater flow. These collectively create patterns in a particular drainage basin.

Dendritic systems are the most common form of drainage system. They are characterized by many sub-tributaries (like the twigs of a tree) that merge into tributaries of a main river (like the branches and trunk of a tree).

Deranged systems are drainage systems with no coherent pattern to the rivers and lakes. They typically form in areas of porous rock, where surface streams can disappear into groundwater.

through comma-separated value (CSV) files, which show attribute and spatial information as XY coordinates. Modelers can run and change their own models and then import these CSV files back into the GWIS geodatabase, where it can be accessed and viewed by others. This greatly simplifies how users can update information about the watershed as it becomes available, allowing the district to keep up with ongoing changes to the built and natural environment.