ANALYSIS OF APPROACHES AND REQUIREMENTS FOR LWI MODEL USE, STORAGE, AND MAINTENANCE - PART I

August 16, 2021

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PREFACE

This report represents Phase I of the LWI Model Use, Storage, and Maintenance (MUSM) Plan. The report presents analysis and evaluation of possible approaches to MUSM to support the long-term use sustainability of LWI watershed hydrologic and hydraulic (H&H) models. The following are key remarks that delineate the objectives, scope and expected use of the reported analysis and results:

- The development of this report involved a comprehensive iterative process that started in summer of 2020 and included five versions that were informed by multiple rounds of review by the TDQ, D&M TAG and LWI modeling consultants. The report will also be revised after the completion of the public comment period.
- The primary question that guided the MUSM analysis is: *What is the most effective and feasible strategy to support and sustain the use, storage, and maintenance of LWI models by all relevant stakeholders?* As such, the MUSM plan was informed by a rigorous process of outreach to potential users of LWI models, including local, regional, state and federal partners.
- The report presents an analysis of possible MUSM approaches and associated pros and cons, and does not recommend a specific MUMS approach.
- The report also includes a comprehensive cost analysis of different MUSM approaches, including costs and expected resource requirements for the development, deployment, and operation of the MUSM system. While the cost is only one evaluation criteria, the analysis is presented to inform the decision-making process for selecting a MUSM approach.
- The report presents a high-level system architecture for the MUSM system that focuses on the specific needs of the LWI modeling program, but also allows integration with existing and future platforms of LWI and other external partners. This proposed architecture is agnostic to the MUSM approach that is ultimately chosen.
- The report also outlines a Phase II that is intended to advance the development of the MUSM system. Phase II will include the development of a MUSM prototype, informed by a stakeholder beta-user group, and would lead to a full deployment and operation of the MUSM system.
- Phase II of the MUSM development is designed in such a way that doesn't necessarily depend on the selection of a certain approach (e.g., central, regional or other variations).
- The report highlights the importance of engaging with LWI user groups during Phase II. This engagement will be a critical activity for refining understanding of interest in and needs for MUSM by all LWI stakeholders, including local and regional entities as well as state and federal agencies.

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EXECUTIVE SUMMARY

INTRODUCTION AND OBJECTIVES

The purpose of this report is to provide analysis and evaluation of possible approaches to Model Use, Storage, and Maintenance (MUSM) for the watershed hydrologic and hydraulic (H&H) models of the Louisiana Watershed Initiative (LWI). The analysis presented in this report is primarily informed by stakeholder feedback and research of existing flood model management systems. The primary question that guided this analysis is:

What is the most effective and feasible strategy to support and sustain the use, storage, and maintenance of LWI models by all relevant stakeholders?

Therefore, the foundation of the LWI MUSM approach is a user-centered design. Model management policies, techniques, and tools must be carefully selected based on their suitability for supporting the use of LWI models by all relevant stakeholders. Together, the tools, techniques, and policies used to support model use, storage, and maintenance will be referred to in this document as the **model management system**.

This report represents Phase I of what is envisioned to be a two-phase set of analyses of LWI model management system design and implementation, followed by a long-term Phase III of deployment and operation. Phase I (the current report) focuses mostly on the "what" and the "why" of possible model management system designs, and to a lesser extent on the "how" of development and implementation, which will be the focus of Phase II. The third and final phase will deal with the deployment and long-term operation and maintenance of the system. See section 0 for more details on next steps to be addressed in Phase II and Phase III.

RESEARCH METHODOLOGY

The user-centered design approach used to answer the primary question and to provide a comprehensive analysis and evaluation of viable LWI MUSM approaches consists of the following components:

(1) Outreach to regional stakeholders and users of the anticipated LWI model management system (nine focus groups conducted from October 2020 through January 2021 with approximately 75 participants);
(2) Review of eight model management systems available in other states, including one system that is in-planning phase, as well as five interviews with administrators of a subset of these systems;
(3) Outreach to four LWI-affiliated state agencies (CPRA, LDEQ, DOTD, and LDWF)
(4) Interviews with two federal agencies, the U.S. Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA). An interview with a representative from the Governor's Office of Homeland Security and Emergency Management (GOHSEP) was not possible due to scheduling constraints during hurricane season (review by GOHSEP is forthcoming and will be incorporated in the next version of this report);
(5) Analysis of MUSM approaches and associated resource requirements and costs;
(6) Preliminary outline of MUSM system architecture.

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ANALYSIS OF MODEL USE, STORAGE, AND MAINTENANCE APPROACHES

LWI model management system design approaches consist of two primary dimensions:

(1) where H&H model maintenance (i.e., check-out; model updates; reviews and approvals; check-in) is implemented; and

(2) where IT infrastructure for model storage is deployed and managed.

Both dimensions can be implemented primarily at the regional level (e.g., by the LWI regional coalitions), primarily at the statewide central level (e.g., by an LWI-affiliated state agency), or in various degrees of a blended regional-central approach. The pros and cons of central versus regional H&H model maintenance and IT infrastructure implementation are summarized in Table 1.

Table 1. Primary design dimensions for LWI model management systems: central vs. regional H&H model maintenance and IT infrastructure administration.

Regional H&H Model Maintenance	**Regional IT infrastructure**
Pro: • Tap local knowledge (regional and local staff are familiar with specific intricacies of the watersheds) • Respond quickly to regional/local needs • Enables more regional buy-in • Consistent with the capacity building component of the LWI program Con: • Requires more staff • Recruiting sufficient number of regional modelers may be a challenge • Requires a way to ensure consistency across regions	Pro: • Able to tailor IT needs to regional model maintenance needs • Avoid single point of failure Con: • Requires regional staff to manage IT infrastructure • May lead to incompatibility across regions
Central H&H Model Maintenance	**Central IT infrastructure**
Pro: • Share some central staff to manage model reviews across regions • Ensure consistent maintenance of models for state agency uses • Ensure consistency across regions Con: • Makes regions reliant on state or central entities which may lead to poor capacity building in the long run • Central staff will likely lack knowledge of the various regions and watersheds • Lack of regional model management may impede buy-in and willingness to support with regional resources or funds • Vulnerable to changes in administrative priorities	Pro: • Share staff to manage IT infrastructure across regions, which may reduce costs • Consistent platform for supporting model use and management across the state • Enable regions to focus on H&H modeling efforts Con: • Lack of regional control may impede buy-in and willingness to support with regional funds • May impede regional innovation related to IT solutions unique to regional needs or priorities • State IT restrictions may slow development and increase costs • Vulnerable to changes in administrative priorities

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A particular model management system design can use variations of regional or central approaches. Possible approaches include a regional approach (represented by the top row of Table 1), a central approach (represented by the bottom row), and regional/central blended approaches that include a central H&H model maintenance and regional IT infrastructure (represented by the bottom left and top right quadrants of Table 1), or regional H&H model maintenance and central IT infrastructure (the top left and bottom right quadrants). Table 2 presents a typology of MUSM approaches consisting of differing combinations of the model maintenance and IT design dimensions described in Table 1. The Table also includes another potential approach (TWI-TDIS federated). Each of the potential MUSM approaches are described in the sub-sections that follow.

Table 2. Typology of MUSM approaches

<table>
<tr><th>MUSM Approach</th><th>Party responsible for IT Infrastructure for housing H&H LWI HUC8 Models</th><th>Party responsible for Maintenance of H&H LWI HUC8 Models (perform/review updates, approve revisions, check-in)</th><th>Next Steps</th><th>Party responsible for statewide consistency</th><th>Access to Models</th></tr>
<tr><td>Central Approach (C)</td><td>Central entity</td><td>Central entity</td><td rowspan="4">Short-term (Phase II, 1-year): develop system prototype and reference implementation

Long-term (Phase III): Operation of the MUSM system</td><td rowspan="5">Statewide Standards Advisory Committee
&
Federal & State Advisory Board</td><td rowspan="5">All LWI-affiliated entities (federal, state, regional, local, private firms)</td></tr>
<tr><td>Blended Approach (B1)</td><td>Regional coalitions</td><td>Central entity</td></tr>
<tr><td>Blended Approach (B2)</td><td>Central entity</td><td>Regional coalitions</td></tr>
<tr><td>Regional Approach (R)</td><td>Regional coalitions</td><td>Regional coalitions</td></tr>
<tr><td>TWI-TDIS Federated Approach (TTF)</td><td>Central entity</td><td>Central entity; with regional coalitions only responsible for maintenance of non-LWI H&H Models (e.g., HUC12 local models)</td><td>Short-term (3-5-years): Use temporary cloud model storage
Long-term: Use TDIS system when it becomes available</td></tr>
</table>

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Central (C): Central model maintenance / Central IT

The central approach entails central H&H model maintenance and IT infrastructure. This approach allows central H&H and IT staff to serve all regions. However, as summarized in Table 1, lack of regional control may impede regional buy-in (and local funding support), and any central funding would be subject to changes in administrative priorities. While regional funding is also subject to changing priorities, relying completely or mostly on central funding would introduce a single point of failure to the LWI sustainability approach.

Blended approach (B1): Central model maintenance / Regional IT

The first blended approach entails central maintenance of H&H models and regional management of IT infrastructure. This approach would allow some modelers to be shared across regions and would enable IT needs to be tailored to regional needs. However, this approach would suffer from the same downsides as the central approach, namely having modeling staff that lack region-specific knowledge, and potential for reduced regional buy-in and capacity building. This approach would also suffer from increased resource requirements to support regional IT infrastructure without the benefit of being able to synergize with regional model maintenance to better meet local modeling use, storage, and maintenance needs. Thus, this approach will not be considered in the remainder of this study.

Blended approach (B2): Regional model maintenance / Central IT

In this blended approach, H&H model management, including model check out, model revisions, reviews and approval of model revisions, would be the responsibility of each region (implemented and overseen by LWI regional coalitions). State or federal agencies are expected to be consulted as needed to ensure alignment with extra-regional initiatives. IT infrastructure would be centrally managed and shared across regions for consistency and to also allow regions to focus on model use and maintenance. Lack of regional control over IT could be mitigated if regional governance organizations see clear benefits from shared IT infrastructure. It is noted that other variations of this blended approached could be formulated. For example, for regions that are not initially ready to take on management of their H&H models, such regions can be supplemented by some central H&H modelers who can provide additional H&H support in the interim until these regions build sufficient capacity. As such, this approach can be considered an "interim" approach for certain regions until a complete Blended Approach B2 can be fully realized.

Regional Approach (R): Regional model maintenance / Regional IT

A regional approach can benefit from the ability to bring local knowledge to bear on model use and maintenance for the purpose of quickly addressing local needs using IT that can be tailored to those needs. The downside of a regional approach is the greater potential for lack of consistency in IT implementation across regions, and increased resources and number of staff needed for implementation for IT infrastructure.

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TDIS federated approach proposed by TWI (TTF)

A “federated” approach to model use storage and maintenance was proposed by The Water Institute for the Gulf (TWI) in the April 21, 2021 memorandum on LWI Model Use, Storage, and Maintenance Considerations. Recommendation no. 3 of the TWI memorandum proposes the establishment of a data governance structure for maintaining data, models, and tools. The proposed structure is defined as follows:

> *A federated data governance structure extends upon a centralized IT infrastructure to partition the presentation of the system such that there is a common, broadly accessible set of data, model, and tools which are administered by the state of Louisiana, in addition to separate partitions for autonomous regional and/or local uses. It is critical that regions, parishes, municipalities, and other authorized local partners be able to control their own data, as the Draft MUSM Plan outlines. However, a federated approach preserves the utility of statewide and even multistate use cases while keeping options open for specialized, differentiated access for different types of users. Simply put, a federated approach is recommended with the needs of local stakeholders in mind. A federated approach combines the benefits of a fully centralized IT infrastructure system with the benefits of state and regional governance of data and eliminates the downsides of a purely regional—or a purely centralized—concept.*

Further, the TWI memo advocates that LWI adopt the data and model management system being developed in Texas as part of the Texas Disaster Information System (TDIS). TDIS is sponsored by The Texas General Land Office and is under development by the Texas A&M Institute for Disaster Resilient Texas (IDRT). The TDIS project is currently in the planning phase and is intended to support resilient decision making at the Texas state level. In the TDIS approach, LWI would operate a copy of the TDIS system that is autonomous from and interoperable with that used by TDIS. According to TWI’s proposal, IDRT may be contracted to operate the system for LWI. The LWI TDIS-operated system itself would be shared across LWI regions.

During the review process for this document, we received further clarification of the TDIS federated approach from Tayler Payne (who serves on LWI D&M TAG) from the Texas General Land Office:

> *TDIS is a federated system. In a federated system, you can create any workflow to designate the authoritative data owner responsible for model (or dataset) updates. The benefit of the federated system is all of the other products that can be combined with the models to make them more useful.*

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According to information supplied by TWI and Texas Land Office, in the TDIS approach, LWI model storage and management would be subsumed into the broader decision support framework of TDIS. This implies that for LWI's purposes, the MUSM system will be a part of a larger set of systems that addresses decision support. However, according to the objectives of the MUSM plan, the focus is on the development of a MUSM platform that can be integrated with LWI decision support tools. Further, a key goal of the MUSM analysis is to define an initial phase of the system that can enable such integration through application programming interfaces (APIs) to support model discovery, retrieval, updating and versioning. With these fundamental pieces, any manner of integration with other LWI or non-LWI systems can be supported without requiring prior detailed design of every component in the overall decision support system. Only the general nature of the integrations need be known to allow the MUSM implementation to begin. This MUSM design approach was informed by lessons learned from analysis of existing model management systems in other states (see section 1.4 below), which are developing separate, simpler systems with functionality tailored to the specific needs of the MUSM.

In addition to subsuming MUSM into broader model management and decision support discussions, the TWI-TDIS approach would run the risk of subordinating the needs of LWI and Louisiana to the needs of TDIS and Texas. This concern can be seen in review comments for an earlier draft of this very document from both D&M TAG members and LWI modeling consultants. For example:

> *TDIS is an ambitious long-term project intend [sic] to improve the entire planning process by arming decision makers with the information they need. Concern: TDIS has an established mission and vision, if the TDIS vision is not aligned with Louisiana priorities it would likely cause problems. If Louisiana only wants to store and maintain the models, than [sic] TDIS might not be the best option (although it should work for that).*

And:

> *I don't necessarily think that it is useful to rely on a different system (TDIS) as the MUSM would then be tied to factors that are outside of the control of this program. If there was a change in the TDIS, for example, how would that impact the effectiveness of the LWI efforts.*

Thus, using a system or system(s) primarily developed for TDIS, in part due to perceived cost savings, would increase the likelihood that LWI stakeholders would go along with features developed to solve problems relevant to TDIS when those features may be less well-suited to solving problems relevant to LWI. It should be noted that collaboration with neighboring states (Arkansas, Mississippi, and Texas) can be accomplished with any of the central, regional, or blended approaches proposed in this report.

From the points of view of IT infrastructure and LWI regions, the TWI-TDIS approach does not appear to be an actual federated system where autonomous or semi-autonomous systems interoperate at the regional level.

Instead, the proposed approach appears to be a centralized approach where the LWI HUC8 regional models would be managed and maintained centrally, while the regional entities would only be responsible for managing their own local models (separate from the LWI regional models). As explained by TWI (June 2, 2021 comment by TWI on the May 14, 2021 draft of the MUSM report):

> *A federated system could enable regional buy-in and allow for regional control of some models in the region (e.g., high resolution HUC12 models that likely will not be developed under LWI funding but were conceived early on in the program), with state agencies managing models required for state uses (e.g., those developed with LWI funding per DOTD's comments during TDQ meetings) though collaborating closely with regional/local partners (in a similar way that the state committee would exist in a central maintenance concept)*

According to this explanation, the TWI-TDIS approach appears to be a system where ***two tiers*** of models would be housed: (1) LWI regional HUC8 models, which would be managed centrally by the state; and (2) smaller/local high-resolution (e.g., HUC12) models that had already been (or would be) developed and paid for by regions or by local entities, outside of LWI, which would be managed by regions. Currently, the LWI modeling program does not include development of high-resolution or HUC12 models. Thus, this two-tiered system runs the risk of alienating regional stakeholders and thereby undermining the watershed-based approach of the LWI, which requires strong buy-in from regional stakeholders in parishes, cities, and towns that share watersheds.

FINDINGS FROM EXISTING MODEL MANAGEMENT SYSTEM REVIEW

Most of the existing systems reviewed were developed 10-15 years ago. None were developed solely to support flood modeling. Instead, they were created to communicate flood risk by providing the general public with access to flood risk information, primarily in the form of web maps delivered as web-based GIS tools. Typically, the hydrologic and hydraulic models used to develop these flood risk maps are made available for download either directly through the flood risk systems, or by linked FTP or other file download services. During interviews with administrators of these existing systems, interviewees were asked if there were capabilities they wished their systems had but do not currently have. A notable reply came from Charlotte-Mecklenburg's respondent, who wished that they had spent more resources making model check-out and check-in more efficient to better support model revision. There was consensus in responses when respondents were asked what they would do differently if they were developing their systems today. ***Rather than developing combined flood risk communication and model management systems, the sentiment among respondents was that if they had to start all over, they would develop separate, simpler systems with functionality tailored to specific use cases and users.***

The cost to develop existing model management systems ranged from $580,000 to $1.4M in 2020 dollars. Ongoing operating and maintenance (O&M) costs were mainly due to staff needed to operate and maintain the

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system, which most respondents estimated to be two- to three-full-time equivalent (FTE) per year. Model management solution O&M tends to be funded by taxes or fees. North Carolina's FRIS funds their O&M with a fee tied to the recording deeds, which tends to provide stable funding. HCFCD relies on a property tax millage. Charlotte-Mecklenburg Storm Water Services is a stormwater management utility, and therefore can charge a utility fee, which is used to fund O&M.

FINDINGS FROM REGIONAL STAKEHOLDER OUTREACH

Stakeholder outreach to the eight LWI regions indicated a strong desire for most to manage their own model management systems, rather than relying on a central state-based entity to manage them. Many regions also have a strong desire to maintain and update their own models. This desire can also be seen in the recently produced LWI Provisional Governance Recommendations[1] regarding regional coalition responsibilities toward and governance of model use, storage, and maintenance (Table 3).

Table 3. Model use, storage, and maintenance recommendations from LWI Provisional Governance Recommendations

Region	MUSM governance recommendation
Region 1	"The Coalition should be enabled to house and operate the LWI watershed models in Region 1"
Region 2	"The coalition should manage modeling and other hydrological data"
Region 3	• "The coalition should be tasked with housing and operating the LWI watershed model [*sic*] for Region 3" • "The coalition should allow other entities to use the collected data and LWI modeling information in the development of projects that impact Region 3 and other regions"
Region 4	• "Coordinate data management with local stakeholders and create regional data repository" • "Store watershed models locally with entity in charge of day-to-day operation"
Region 5	"A resolution was passed in October 2020 which would allow an entity within Region 5 to house the regional models" (see LWI Region 5's "Resolution in Support of Developing a Regional Housing and Maintenance Watershed Model Plan" in the appendix)
Region 6	"The coalition should be tasked with housing and operating the LWI watershed model for Region 6"
Region 7	• "Models should initially be housed at the state-level and over time with support, capacity should be built at the regional level." • "The coalition should allow other entities to use the collected data and LWI modeling information in the development of projects that impact Region 3 and other regions"
Region 8	• "The coalition should be tasked with housing and operating the LWI watershed model for Region 8" • "The coalition should serve as hub or clearinghouse for other entities to submit and use collected data and modeling."

[1] https://watershed.la.gov/assets/docs/LWI_ProvisionalGovernanceRecommendations_Combined.pdf linked from https://www.watershed.la.gov/rcbg-program

Based on stakeholder outreach, it is clear that their preference is for LWI to pursue the development of model management systems built around regionally controlled model use, storage, and maintenance.

Based on analysis of stakeholder outreach research and review of existing systems, the preference a regional MUSM approach (i.e., managed and overseen by LWI regional coalitions) is driven by the following regional-level factors and benefits:

(a) Region-based entities possess intricate hydrologic and hydraulic knowledge of the watersheds and streams in their region and are best positioned to understand the implications of proposed development.

(b) Regions have the largest stake in ensuring that these models are maintained on an ongoing basis so that the models can be used to manage their own watersheds adequately.

(c) LWI regions in general feel very strongly that they have the ability to manage their own modeling activities (or to build the capacity needed to do so) and given that they are likely to provide financial support for housing and maintaining their models, they want to ensure that they retain direct control over the modeling activities.

(d) Maintenance of H&H models will be more effectively performed at the regional scale (overseen by LWI regional coalitions). Familiarity with the regional hydrologic complexity, direct knowledge of areas prone to flood risk, and authority to manage and approve developments are factors contributing in favor of a local/regional model maintenance system. Regions believe that these critical advantages would not be realized if model maintenance is implemented at a state level.

PROPOSED MODEL USE, STORAGE, AND MAINTENANCE SYSTEM ARCHITECTURE

To reduce the risk of developing a model management system that fails to meet user needs, it is important to use a software architecture that allows for incremental delivery of features and enables easy expansion in the future. Incremental delivery reduces project risks by enabling system functionality to be designed and implemented as specific user needs are understood, rather than trying to design the entire system ahead of time, and then implementing functionality to support requirements that may have changed since their design was completed. This will allow LWI to provide value to model users earlier while also making user feedback continuously available to inform the design and development of subsequent features. Easy expansion will enable more cost-effective changes or additions to system capabilities after initial work on the system

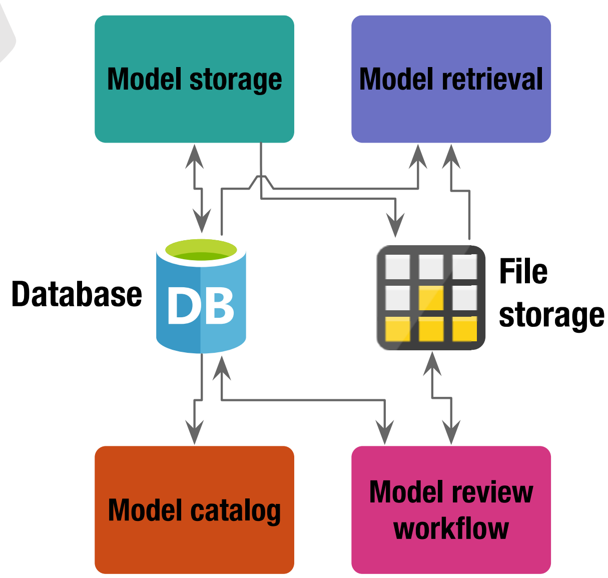

Figure 1. Core services of potential service-oriented architecture of LWI model management system. Arrows indicate data flow between components.

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has been completed while providing flexibility to use multiple teams to perform the work. **The proposed system architecture is intended to be flexible in terms of deployment model, regardless of whether a centralized, regional, or blended approach is chosen**.

A service-oriented architecture is a popular approach that allows for both incremental delivery and easy expansion by breaking the system into self-contained components for each major function (e.g., model storage, model retrieval, model catalog, and model review workflow, etc.) with well-defined machine-addressable Application Programming Interfaces (APIs) to facilitate communication between services and with outside systems (Figure 1).

We envision the MUSM system being independent from other LWI systems such as the All Things Flood Portal and data repository. **However, the APIs of the MUSM system, in particular the model catalog service, will enable systems such as the All Things Flood Portal to allow discovery of and linking to models managed by the MUSM system.** The APIs will also allow integration with non-LWI portals and model management systems.

RESOURCE REQUIREMENTS AND COST ANALYSIS

We recommend that the LWI model management system, regardless of regional vs. central vs. blended approach, be implemented using a phased approach with (1) Phase I being this report; (2) Phase II being the development of the MUSM model management system prototype, and a reference design and development; and (3) Phase II entails deployment of the MUSM reference design and implementation. Resource requirements for phases two and three are estimated in the sections below. All labor rates are based on actual recent rates for consultants in Louisiana and salaries (including benefits and overhead) of regional/state employees. Refinements and further details will be developed during Phase II of the MUSM system development.

Development of a prototype model management system

The second phase (over the next twelve months after phase one is complete) involves the development of a prototype model management system. This prototype should include the core tasks of storing, cataloging, retrieving, and updating models. The development of the prototype would be carried out by an IT consultant in collaboration with a LWI stakeholders beta group. The purpose of the prototype is to learn more about how to provide for model housing and maintenance needs in a way that is accessible to all regional and state stakeholders while working toward the development of a usable system that users can try out, in an adaptive or agile fashion, as features are being developed.

Discussions with US Army Corps of Engineers (USACE) and FEMA revealed that USACE is currently developing an open-source Model Library system that would address many of the MUSM needs of the LWI modeling program. Leveraging the USACE Model Library as a starting point for the LWI prototype model management system would likely save time and require fewer resources than creating a system from scratch. It would also bring the potential to harmonize LWI efforts with model housing practices at the federal level. The Model Library is also compatible with the proposed LWI MUSM architecture (see above) and does not pose any restrictions on regional vs. central vs. blended MUSM approach.

The USACE Model Library is designed to integrate with HEC-HMS and HEC-RAS models stored in existing cloud-based repositories, such as AWS S3 storage, without requiring model data to be organized in any particular way. This flexibility makes incremental adoption of the system possible without requiring data to be moved or reorganized, which could incur cloud data transfer fees if done incorrectly.

Development of a reference model management system

Once the prototype has been completed, the IT consultant will work with the stakeholder beta group to evaluate what works well with the prototype and what needs to be changed to better suit the needs of regional MUSM users. This evaluation will be used to further develop, in collaboration with the stakeholder beta group, the prototype LWI model management system into a reference system design. The reference design is intended to be deployable centrally or by LWI regions and used to support their model, use, storage, and maintenance programs.

The development of a prototype and reference design of the LWI model management system is estimated to take 12-months for a team of two software developers, one user experience designer, one Agile scrum leader as well as a project manager or product owner. The total cost for developing the LWI model management system is estimated to be $979,400 (Table 4). This includes the $785,200 for 12-months of software development staff, $15,000 for Software as a Service (SaaS)-based project management tools, as well as cloud-hosted IT resources, as well as $179,200 in estimated staff time for the stakeholder “beta” groups ($115,200 for the development group, and $64,000 for the testing group).

Table 4. Estimated cost of software development team to develop MUSM prototype and reference design over 12-months. Note: all hourly rates are assumed to be fully loaded and based on estimated yearly salary, including overhead/margin.

Role	Number in role (FTE)	Estimated consultant hourly rate	Estimated consultant cost
Software developer	2	$75.00	$312,000
User experience designer	0.5	$75.00	$78,000
Scrum leader	1	$90.00	$187,200
Product owner/project manager	1	$100.00	$208,000
Total	**4.5**		**$785,200**

Deployment, operations, and maintenance of MUSM system

Once the reference LWI model management system has been developed, phase three of the LWI model management development approach can begin. In phase three, the reference LWI model management system would be deployed either centrally or onto regionally managed IT infrastructure. If managed regionally, the IT infrastructure could be distinct to each region or shared among two or more regions if those regions so desired. Once deployed, the reference model management system would provide a common baseline of functionality necessary for supporting continuous model use, storage, and maintenance, while enabling interoperability across all LWI regions. These systems would also support periodic full updates to H&H models (i.e., hydrology and hydraulic models), for example every six- to eight-years. Given the need to maintain system integrity amidst evolving cybersecurity threats, both regional and central model management system deployments would require continuous IT operations and maintenance support, similar to the anticipated updates to the H&H models.

Resource requirements to implement, operate and maintain H&H modeling tasks and IT infrastructure for LWI model management system were estimated for three approaches: (1) central (C) approach using centrally managed H&H models and IT infrastructure; (2) regional (R) approach using regionally managed H&H models and IT infrastructure; and (3) blended approach (B2) using regionally managed H&H models and centrally managed IT. Within these approaches, costs were estimated for two staffing options: (1) work done by staff members of LWI regional coalitions, state agencies, or central entities; and (2) work done by consultants to be hired by regional or central agencies (Table 5). Note: All costs in Table 5 are LWI program-wide totals. Estimated costs for individual regions can be found in Table 29 and Table 30 of the main text in this document.

Table 5. Summary of deployment, operations, and maintenance costs for different MUSM approaches. Costs are LWI program-wide totals. Estimated costs for individual regions are shown in Table 29 and Table 30 in this document.

Staffing Option	Program-Wide Costs	Central Approach (C) (Central IT & central H&H)	Blended Approach (B2) (Central IT & regional H&H)	Regional Approach (R) (Regional IT & regional H&H)
Regional/central agency staff	Total 1st year cost	$2,855,054	$3,245,054	$3,666,451
	Total subsequent year cost	$2,823,854	$3,213,854	$3,427,251
Consultants	Total 1st year cost	$6,116,494	$6,980,734	$7,818,131
	Total subsequent year cost	$5,877,294	$6,741,534	$7,162,931

For each approach and staffing option, resources requirements for the following MUSM program elements were estimated: (1) H&H modelers; (2) IT personnel for deploying and operating cloud resources; (3) cloud storage; (4) cloud compute and networking; and (5) software maintenance. Resource requirements were estimated to differ during year one and subsequent years in the following ways: (1) additional IT personnel will likely be needed during deployment in year one; and (2) resources for software maintenance will be needed in subsequent years to allow bug fixes and security updates to be made to the LWI model management system. Cost estimates are based on fully burdened rates for consultants in Louisiana and on average salary (including fringe and overhead) of regional or state agencies.

First year deployment, operations and maintenance costs were estimated to be $3,666,451 total for a regional approach (R), with H&H modeling and IT implementation by staff members of LWI regional coalitions, compared to an estimated $2,855,054 for central approach with H&H and IT implementation done by staff members of central entity. The corresponding estimates for the blended approach, with regionally managed H&H models and centrally managed IT infrastructure, are $3,245,054. Subsequent year costs were estimated to be $3,427,251, $2,823,854 and $3,213,854 for the regional approach (R), the central approach (C) and the blended approach (B2), respectively.

Implementation by consultants was estimated to cost $7,818,131 total for the regional approach (R) in the first year ($7,162,931 in subsequent years), $6,116,494 for the central approach (C) in the first year ($5,877,294 in subsequent years), and $6,980,734 for the blended approach (B2) in the first year ($6,741,534 in subsequent years).

For all the approaches, the H&H modeling resource requirements account for approximately 75-85% of the total cost, while the IT personnel accounted for approximately 15%. It is worth mentioning that the cloud storage accounted for a small amount of the total cost (<5%). It is important to note that the MUSM team envisions regionally located modelers (as the case for approaches R and B2) becoming H&H modeling resources to their regions, supporting the gamut of activities of the LWI modeling program including accessing models, to running and using models for permitting and planning purposes, to modifying, reviewing and approving model updates.

Synthesis: MUSM resource requirements

Central Approach (C): Central H&H model maintenance and cloud IT implementation is estimated to cost roughly $2.8M per year ($5.9M-$6.1M if done by consultants) and would allow all IT staff and H&H modeling staff to serve all regions. However, H&H model management will be controlled centrally and not by the regions and thus limits the ability to draw on local knowledge of regions and watersheds. This may severely hinder regional stakeholder buy-in and would therefore jeopardize the success of the watershed-based approach of the LWI modeling program. Also, lack of regional control will reduce the sense of regional ownership over the program, which will work against capacity building and erode support for local support for the LWI program.

Blended approach (B2): Regional model maintenance / Central IT: In this blended approach, central cloud IT management is paired with regional H&H implementation. For this case, resource requirements are estimated to have costs intermediate to the central approach (C) and the regionalized (R) approaches. Costs are estimated to be roughly $3.2M per year if the work is done by staff of central and regional entities (costs are estimated to range from $6.74M and $6.98M per year if done by consultants). Regionalized H&H model maintenance (e.g., via the LWI regional coalitions) would retain the pros and cons outlined in Table 1. Pairing this with centrally managed cloud IT infrastructure is estimated to lead to roughly 5% reduction in total IT and H&H implementation costs (compared to regional IT infrastructure management) and would make it easier to ensure a consistent approach across regions (though the downsides of central IT management listed above would still apply, e.g., risk due to changes in executive priorities, potential increase in costs and reduced flexibility of state-managed IT resources). To ensure that the IT resource needs of regional H&H programs are successfully met with centralized cloud IT, a cross-regional governance structure would be needed (e.g., through a proposed Statewide Standards Advisory Committee).

Regional Approach (R): Regional model maintenance / Regional IT: Regional H&H model maintenance and cloud IT implementation is estimated to cost between $3.4M-$3.6M per year ($7.1M-$7.8M if done by consultants) for all eight regions and would allow local knowledge to be tapped while further building knowledge of local and regional watersheds. The regional approach would put the LWI modeling program in the best position to quickly respond to local needs, in part by tailoring IT needs to local modeling needs. Greater regional autonomy would require a mechanism to ensure consistency in model use, storage, and maintenance approach across LWI regions (e.g., through a proposed Statewide Standards Advisory Committee). However, this autonomy will empower regions to truly own their model use, storage, and maintenance programs, which will bolster capacity building and increase support for regional funding of the program.

TDIS federated approach proposed by TWI (TTF): The resource requirements of the pseudo-federated approach with TDIS would be similar to central approach (C) proposed above (with LWI H&H models managed centrally, and centralized IT infrastructure). However, it should again be noted that blended approach B2 would give regional stakeholders a much more substantial role in the maintenance and review of regional HUC8 models, which the TTF approach sees as primarily the province of state stakeholders.

CAPACITY BUILDING NEEDS

Through outreach to regional stakeholders, needs for capacity building were identified as critical factors to establish an effective MUSM system and for sustainable model use, housing, and maintenance by LWI regional stakeholders. Capacity needs were identified in three primary components: hardware, technical personnel, and training/education.

NEXT STEPS

The LWI model management system implementation strategy could use a three-phase approach (see Figure 9 in Section 9 of this report). The first phase represents the current report. Following the completion of the first phase, the second phase, which is expected to last 12 months with the support of a procured IT firm, will involve: (1) convening of the Stakeholders Beta User Group; (2) development of MUSM prototype; (3) development of MUSM Reference Design; and (4) developing a detailed MUSM deployment and operations and maintenance (O&M) planning and resource needs based on lessons learned from the MUSM prototyping and Reference Design implementation. The second phase could leverage the USACE open-source Model Library system as a starting point for the LWI prototype that addresses many of the MUSM needs of the LWI program. The second phase will also include designing linkage between MUSM systems and other LWI resources, such as All Things Flood Portal. With the completion of the second phase, the MUSM system enters the third and final phase, which involves deployment of the MUSM reference design, as well as operations and maintenance over the long term. Phase three will include both updating and maintaining the models as well as security updates and bugfixes for the IT components of the MUSM system.

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INTRODUCTION

The purpose of this report is to provide analysis and evaluation regarding possible approaches to Model Use, Storage, and Maintenance (MUSM) for the watershed modeling program of the Louisiana Watershed Initiative (LWI). The analysis presented in this report is primarily informed by stakeholder feedback and research of existing flood model management systems.

By models, this document is referring to: (1) geospatial and other input datasets processed for the purpose of parameterizing US Army Corps of Engineers (USACE) Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS) models and River Analysis System (HEC-RAS) hydraulic models (e.g., topographic and bathymetric datasets, land use and landcover; CAD data on hydraulic structures; rainfall and streamflow data for calibration; design and historical storms; etc.); (2) other model setup and configuration files; and (3) model output data for design and historical storms for one or more model runs (e.g., project scenario analyses). Storage of model outputs should be coordinated with the future LWI All Things Flood Portal to ensure proper integration and avoid unnecessary duplication. Also, to avoid duplication of storage or effort on behalf of LWI, similar coordination needs to happen regarding storage of other large-scale datasets (e.g., statewide LiDAR, landcover) in their original formats before being processed for watershed-specific HEC-HMS and HEC-RAS models.

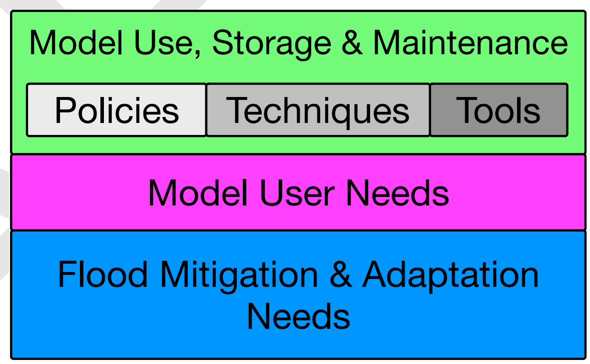

Figure 2. Overview of user-centered approach to model management system design

By use, storage, and maintenance approach, this document is referring to the policies, techniques, and tools used to store, retrieve, and update LWI models (Figure 2). Policies refer to rules governing who can access, upload, or manage what models and for what purposes (e.g., what models are public, who can download large raw datasets and how often, etc.). Techniques refer to standard procedures for cataloging and storing data, including metadata standards or organization schemes (e.g., hierarchical taxonomies vs. relational ontologies). Tools refer to specific software packages, databases, data stores, computation, networking, etc., used to physically store, process, and transfer data. Together, the tools, techniques, and policies used to support model use, storage, and maintenance will be referred to in this document as the model management system.

The foundation of the LWI MUSM approach is user-centered design. Model management policies, techniques, and tools must be carefully selected based on their suitability for supporting the use of LWI models by all relevant stakeholders. These stakeholders include: (1) city, parish and other local government staff and their contractors; (2) regional watershed organizations or LWI fiscal agents; (3) State agencies in the Watershed Council; and (4) other state and Federal agencies as needed. The user-centered design approach used in this report consists of four primary components: (1) outreach to stakeholders and users of the anticipated LWI model management system; (2) review of existing model management systems available in other states and

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interviews with administrators of existing model management systems; (3) outreach to state agencies; and (4) interviews with U.S. Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA). These components are described in detail in the methodology section below.

OBJECTIVES AND RESEARCH QUESTIONS

The analysis of LWI MUSM approaches is limited in scope to evaluation of high-level design principles for key aspects of viable model management systems rather than producing a detailed system design. Specifically, the analysis and evaluation focus on: (1) model maintenance workflows; (2) system architecture; (3) implementation strategy and expected resource requirements; and (4) regional capacity needs.

The primary question used to guide the LWI MUSM design evaluation is:

> *What is the most effective and feasible strategy to support and sustain the use, storage, and maintenance of LWI models by all relevant stakeholders?*

This primary question was in particular used to guide discussions with stakeholders. Input from stakeholders was solicited through outreach activities such as focus groups, interviews, and surveys. During these interactions, the following guiding questions were used:

1. Who are the modeling stakeholders in your area, and how will they use LWI models? (e.g., directly by developing or running new model scenarios; indirectly by interpreting model outputs)
2. What are the primary reasons that models will need to be updated, and how frequently will these updates need to occur? (e.g., to follow land use changes; to reflect new drainage infrastructure; to reflect flood mitigation projects; to track regulatory changes)
3. What level of interest and capacity do local and regional stakeholders have for storing and maintaining hydraulic or hydrologic models?

These questions were broken into more detailed operational questions asked during focus groups, surveys, and interviews. These detailed questions can be found in relevant sections of the methodology.

METHODOLOGY

The model use, storage and maintenance design analysis evaluated in this plan were informed by a combination of: (1) outreach to regional stakeholders; (2) review of existing model management systems from other states; (3) outreach to state agencies; and (4) interviews with federal agencies (USACE and FEMA). Regional stakeholder outreach was conducted primarily with LWI regional steering committee members as well as regional coordinators. Review of existing systems took the form of desk-based research, as well as interviews with managers of select systems. Desk-based research involved scoring how each existing system supports the modeling lifecycle from development to model check-out, execution, modification, check-in, and review. State agency outreach consisted of a focus group discussion. Details on the methodology used for regional stakeholder outreach, existing system review, state agency outreach, and interviews with USACE and FEMA are described in the following subsections.

REGIONAL STAKEHOLDER OUTREACH

Focus groups, surveys, and follow-up interviews

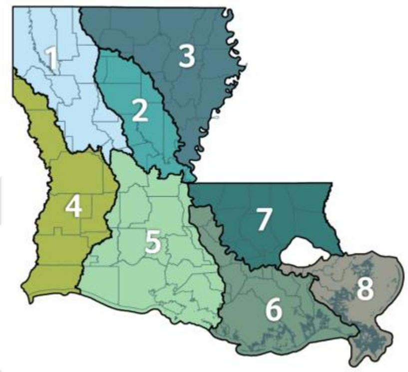

Figure 3. LWI watershed regions

Outreach was conducted with regional stakeholders using a mix of focus groups, web-based surveys, and follow-up interviews with a subset of focus group participants. Two types of focus groups were conducted. First, two pilot focus groups were held with LWI regional coordinators; the first pilot focus group was conducted with coordinators from watershed regions five through eight (Figure 3), and the second was with regions one through four. Next, eight regional focus groups were held with LWI regional steering committee members. Regional steering committees (RSC) were chosen as the pool of participants as they offered rapid access to current and likely future LWI model program stakeholders across LWI regions. Focus groups were in general held as part of existing RSC meetings to economize stakeholder time.

Each focus group consisted of approximately eight to 15 participants and was primarily held virtually using web video conference tools, though some participants were connected to the videoconference as a group from a single location. These focus groups were generally 30-45-minutes in length and were scheduled to coincide with existing regional steering committee meetings (though one was a standalone meeting one-and-a-half hours in duration; it was not possible for all focus groups to be of this length due to stakeholder availability constraints). All focus groups were recorded, and live notes were taken to provide data for analyses.

The primary goals of the pilot focus groups of regional coordinators were to: (1) help the research team test and refine the focus group process; and (2) educate regional coordinators on model use, storage, and maintenance so that they could help garner participation among regional steering committee members in subsequent focus groups. The primary goal of the regional steering committee focus groups was to learn about regional interest in and capacity for hosting and maintaining LWI models (this was a secondary goal of the pilot focus groups).

Surveys were used before and/or after focus groups. The pre-surveys were meant both to collect data to inform understanding of stakeholder needs for model use, storage, and maintenance, and also to stimulate participant thinking in advance of the focus group. Pre-survey results for a focus group cohort were reviewed during the respective focus group and used as a starting point for discussion. After each focus group, participants were asked to fill out a post-survey that asked additional questions related to model use, storage, and maintenance. The post-surveys were used to allow the research team to cover more topics than the limited focus group time allowed, and to give participants an opportunity to provide more information after reflecting on what they learned during the focus group discussion. Focus groups were used to identify commonalities and differences between regions, allow for participants to be introduced to new concepts from other participants, and to foster brainstorming and to stimulate new ideas among group members. After the focus groups were complete, four

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semi-structured follow-up interviews were conducted with a subset of focus group participants to allow the research team to ask clarifying questions to help guide the drafting of the LWI MUSM recommendations.

Data analysis

Each focus group was conducted by two to four members of the research team, with one serving as a moderator and the others taking notes and asking follow-up questions. The moderator led participants through a series of predetermined questions covering different themes. In addition to the recorded answers of focus group meetings and pre- and post-survey results, notes from each focus group served as data to be analyzed to identify concepts and themes in responses to each question. The themes allow patterns to be identified between questions and across regions.

REVIEW OF EXISTING MODEL MANAGEMENT SYSTEMS

Identification of existing systems

Approximately seven existing systems for model management were analyzed to inform the development of the LWI Model Use, Storage, and Maintenance Plan (Table 6). These existing systems were identified based on: (1) professional experience; (2) web searches; (3) consulting with peers and LWI partners; and (4) asking managers of these systems what other existing systems the research team should be examining.

Table 6. Existing systems reviewed

Model Management System	Location/jurisdiction	URL
Harris County Flood Control District (HCFCD) Model and Map Management (M3) system	Harris County, TX	https://www.hcfcd.org/Interactive-Mapping-Tools/Model-and-Map-Management-M3-System
North Carolina Flood Risk Information System (FRIS)	North Carolina	https://fris.nc.gov/fris/Home.aspx?ST=NC
Charlotte-Mecklenburg Storm Water Services (Data and Apps) 3D Floodzone Interactive Floodzone Mapping tool (3Dfz)	Charlotte, Mecklenburg County, North Carolina	https://charlottenc.gov/StormWater/Pages/DataDownloads.aspx
Interagency Flood Risk Management (InFRM) – Estimated Base Flood Elevation (estBFE)	FEMA	https://webapps.usgs.gov/infrm/estBFE/
Digital Data & Modeling Repository (D2MR)	San Antonio River Authority, TX	https://gis.sara-tx.org/D2MR/

DelftFEWS systems (NWS, TVA, Australia, Netherlands, England, Canada, Ireland)	Deltares (code developer)	https://oss.deltares.nl/web/delft-fews/
Iowa Flood Information System	Iowa Flood Center, University of Iowa	https://ifis.iowafloodcenter.org/ifis/
Texas Disaster Information System (TDIS)	Texas A&M Institute for a Disaster Resilient Texas	https://idrt.tamug.edu/tdis/

Existing system scoring

Analyses of existing systems consisted of: (1) desk-based evaluation where each system was given a score indicating how well it supported typical stages of hydraulic/hydrologic model development, use, sharing, and maintenance life cycles; and (2) interviews with managers of existing systems whose functionality had some degree of alignment with technical requirements of the LWI modeling program. The modeling lifecycle stages used in the desk-based evaluation are summarized in Table 7.

Table 7. Typical model lifecycle stages

Model Lifecycle Stage
Acquisition of raw geospatial and time series data
Data preparation/processing into formats that models can directly import/use
Model setup
Model calibration and validation
Model scenario development
Model execution
Visualization of results
Model discovery (i.e., browsing and searching)
Model download/check-out
Model modification
Model upload/check-in
Review and approval of model modifications
Notification of proposed/approved model updates

Each system was scored according to the degree to which it supports a given lifecycle stage. These scores are meant to give a rough qualitative assessment to facilitate comparison of existing model management systems (Table 8). It is not expected that any system being analyzed will support all or even a majority of the model lifecycle stages. However, consideration of each of these stages is important to help build understanding of what parts of the lifecycle different systems treat as more important to helping model users accomplish their goals. Note that it was not possible to score the Texas Disaster Information System (TDIS) because it is in the early

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stages of development, but it is included in the analysis to compare its proposed approach to model use, storage, and maintenance.

Table 8. Model management lifecycle stage support scoring

Score	Explanation
NC	Exhibits none of the specified characteristic
C	Partly exhibits the specified characteristic
C+	Exhibits the specified characteristic to a large degree

Interviews with managers of existing systems

In addition to desk-based analysis, interviews were conducted with managers of five existing systems (Table 9). The research team was unable to meet with representatives of the Federal Emergency Management Agency (FEMA) due to scheduling conflicts. The team did meet with representatives U.S. Army Corps of Engineers (USACE) regarding model management systems in use to support USACE modeling; the team is working to schedule a follow-up meeting with USACE representatives with direct knowledge of these systems.

Table 9. Existing model management system managers interviewed

Model Management System	Interviewee
Harris County Flood Control District (HCFCD) Model and Map Management (M3) system	Ataul Hannan, P.E., CFM Director, Planning Division Harris County Flood Control District
North Carolina Flood Risk Information System (FRIS)	Thomas E. Langan, P.E., CFM Engineering Supervisor North Carolina Floodplain Mapping Program (NCFMP) Risk Management Section NC Emergency Management
Charlotte-Mecklenburg Storm Water Services (Data and Apps)	Timothy J. Trautman, P.E., CFM, Program Manager, Engineering & Mitigation Program Charlotte-Mecklenburg Storm Water Services
Iowa Flood Information System (IFIS)	Witold Krajewski, Ph.D. Director, Iowa Flood Center Rose & Joseph Summers Chair in Water Resources Engineering The University of Iowa
Deltares Delft-FEWS	Edwin Welles, Ph.D. Hydrologist/Director, Deltares USA

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The semi-structured interviews with system managers were one-hour in length and were conducted using web video conferencing tools. Detailed notes were taken during interviews and video conference recordings were used for reference as needed. A general set of questions was used to guide the interview conversation (Table 10), with additional questions asked as they arose throughout each conversation. A description of each system for which an interview was conducted follows.

Table 10. Interview questions for managers of existing systems

Question text
Why was <SYSTEM> originally developed?
How much did it cost to develop?
What are on-going maintenance costs?
What would you do differently if developing today?
Who are the users of the system? Who are the users of the models? How are they using the system? What are they using it for?
Do agencies (e.g., FEMA) use the system to interact with models, if so how?
Does <SYSTEM> offer extensibility/observability via APIs/notifications?
Does the system allow model check-out and check-in? Does the system provide formal workflows for model review and approval?
What functionality in the system have they found to be the most/least useful?
Are there any surprises after developing and deploying the system? [i.e., didn't realize X would be important; thought Y was important, but was not]
What has caused the most difficulty with the system?
Are there things you wish you could do with the system but cannot?
RAS and HMS version support
How would you characterize the architecture of the system? Is it a single application/code base, or is it developed as a series of interacting components that can be updated more or less independently?
How do you decide when to accept models of a new version of HMS or RAS?
What software tools were used to build the system [e.g., ArcGIS Server, ArcGIS Online, GeoServer, custom, etc.]
Hosting on premises now, plans to look at cloud hosting?
How easily extensible is the system?
Are there open source components of their system that others can adapt?

Where is <SYSTEM> going? What are the next steps? Is additional work planned, or is the system in maintenance mode?
How are decisions on future features to be added to the system made?
What is the long-term sustainability model? [how is system O&M funded]
Are there any other systems we should be looking at/people we should be talking to in other places?
Is there anything else you would like to add?

The managers of systems from Harris County, TX, the State of North Carolina, and Charlotte-Mecklenburg, North Carolina Storm Water Services (Table 9) were selected for interviews because these systems have the most support for stages of the modeling lifecycle most closely related to model maintenance (e.g., model catalog, download/check-out, modification, upload/check-in, and notification of proposed/approved model updates). An interview was conducted with the director of the Iowa Flood Center, where the Iowa Flood Information System (IFIS) is housed, because of the robust custom cyberinfrastructure underlying IFIS as well as its innovative flood risk communication design (despite using a markedly different flood risk modeling approach than that proposed for the LWI). Lastly, a representative of Deltares, the developer of Delft-FEWS, was interviewed because Delft-FEWS is used extensively as a platform for flood model operations and this platform provides a good example for potential LWI model management system implementations.

STATE AGENCY OUTREACH

Outreach to state agencies consisted of a semi-structured focus group with representatives of the following Louisiana state agencies: (1) Coastal Protection and Restoration Authority (CPRA); (2) Department of Transportation and Development (DOTD); (3) Department of Environmental Quality (LDEQ); and (4) Department of Wildlife and Fisheries (LDWF). Representatives of these agencies who participated in the focus group are listed in Table 11. An interview with a representative from the Governor's Office of Homeland Security and Emergency Management (GOHSEP) was not possible due to scheduling constraints during the 2020 hurricane season.

Table 11. Representatives from state agencies who took part model use, storage, and maintenance focus group

Agency	Representative
Coastal Protection and Restoration Authority (CPRA)	Sam Martin, Coastal Resource Scientist Senior
Department of Environmental Quality (DEQ)	Chuck Berger, Senior Engineer – WQM/TMDL Technical Advisor
Department of Transportation and Development (DOTD)	Ian Trahan, P.E., Engineer 6, Public Works & Water Resources

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Department of Wildlife and Fisheries (LDWF)	Robby Maxwell, Inland Fisheries Technical Advisor

The focus group was semi-structured allowing for natural conversation to arise among participants and facilitators. However, the questions listed in Table 12 were used to guide the discussion.

Table 12. Questions used to guide semi-structured focus group with state agency representatives

Question number	Question text
Q1	What are your agency's needs from LWI H&H models? / How do you see your agency using the models?
Q2	How often should LWI models be updated and who should do it?
Q3	From your perspective as a state agency, how do you see your agency interacting with these models? / Do you have staff with proper expertise? / Does your organization employ modelers?
Q4	What functionality or services should the model housing system provide?
Q5	Where do you think LWI model should be housed (central vs regional)? [regional meaning something like a modeling regions not a local municipality e.g., Lafayette city]. Follow-up: What barriers or difficulty do you foresee arising if models were to be housed regionally? What about centrally?

INTERVIEWS WITH USACE AND FEMA

A total of three semi-structured interviews were conducted with representatives from U.S. Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA) from January 2021 to March 2021. Participants are listed in Table 13. During these interviews, participants were asked to describe current model management systems in use at USACE and FEMA, why these systems were developed, whether the systems were available for others to use via free or open source licenses, how the systems are deployed (on premises or cloud-based hosting), and what technologies the systems were built with.

Table 13. Representatives from USACE and FEMA who took part in interviews

Agency	Representative
FEMA	David Bascom, Chief, Engineering Resources Branch Alan Johnson, Region 6 Regional Engineer Christina Lindemar, Coastal Engineer, Engineering Resources Branch Lauren Schmied, Coastal Engineer, Engineering Resources Branch
USACE	Randal Goss, Cold Regions Research and Engineering Laboratory (CRREL) Will Lehman, Hydrologic Engineering Center (HEC) Dave Ramirez, Chief, Water Management, New Orleans District

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	Jason Sheeley, Chief, Mapping Branch, MMC Production Center Alexandra Ubben, Cartographer, Geospatial Branch Cory Winders, Hydraulic Engineer

FINDINGS

REGIONAL STAKEHOLDER OUTREACH

In total, eight focus groups were conducted from October 2020 through January 2021. The focus group participants, 64 in total, included representatives from all eight LWI watershed regions, made up of LWI regional steering committee members as well as watershed coordinators, and fiscal agent staff (Table 14). In some focus groups, modeling consultants under contract with regional or local entities were also among the participants. Of these participants, approximately 67% completed pre- or post-focus group surveys that provided additional feedback.

Table 14. Regional focus group participants

Represented Region	Participant & Affiliation
Region 1	Matt Johns, Rapides Parish Planning Commission Robin Ramagos, Coordinating & Development Corporation Heidi Stewart, Northwest Louisiana COG
Region 2	Heather Smoak-Urena, Kisatchie Delta Regional Planning & Development District
Region 3	Lisa Richardson, Ouachita Parish Police Jury Karen Cupit, Ouachita Parish Police Jury Dale Powell, Caldwell Parish Emergency Planning Committee Stuart Hodnett, City of West Monroe Sandi Burley, Concordia Parish Police Jury Kay King, Morehouse Parish Ashley Peters, Franklin Parish Doug Mitchell, NDRPDD Cheryl Lively, Caldwell Parish Mark Black, Caldwell Parish, President
Region 4	Edward Anthony, QES, LLC Jennifer Cobian, Calcasieu Parish Terry Frelot, Calcasieu Parish Alberto Galan, Calcasieu Parish Gary O'Neal, CFM – Sr. Project Manager, QES, LLC – Regional Steering Committee Consultant for Calcasieu Watershed

Region 5	Donald Bergeron, Evangeline Parish Kelia Bingham, Acadiana Planning Commission Monique Boulet, CEO of Acadiana Planning Commission Fiscal Agent Chester Cedars, St. Martin Parish John Clark, Iberville Parish Rachel Godeaux, Acadiana Planning Commission Kimberly Heise, CSRS Garland Pennison, HDR Bradley Spiegel, LWI Ian Trahan, LA DOTD Mark Ward, Pointe Coupee Parish Stephanie Weeks, LCG
Region 6	Kevin Belanger, CEO South Central Planning & Development Commission Pat Gordon, Chief Planning Officer South Central Planning & Development Commission Adam Lefort, SCPDC Devin Foil, St. John the Baptist Parish Government Earl Matherne, St. Charles Parish Mark Ward, Pointe Coupee Parish Kasey Courville, St. Martin Parish Scott Sonnier, Iberia Parish Tim Matte, St. Mary Levee District Allison Haertling, UNO-CHART Kevin Durbin, West Baton Rouge Parish Michelle Gonzales, TK Hilda Lott, Independent/Grant Contractor Plaquemines Parish Nicolette Jones, City of New Orleans Kyle Galloway, GIS Engineering Laci Melancon, CTAC Jenny Schexnayder, Nicholls State University Leroy Blanchard, Assumption Parish Dori Turner, LA DOTD John Boudreaux, Entergy Amanda Voisin, Lafourche Parish Beryl Gomez, PBCIA Group Maggie Talley, Jefferson Parish
Region 7	Dietmar Rietschier, Amite River Basin Commission Rachelle Sanderson, Capital Region Planning Commission Jamie Setze, CRPC Gary Mego, West Feliciana Parish Donna O'Dell, St. Tammany Parish deEtte Smythe, St. Tammany Parish Chuck Berger, DEQ

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	Mike Enlow, Ascension Parish Devin Foil, St. John the Baptist Parish John Sheehan, LDEQ Larry Bankston, Bankston & Associates Washington Parish OEP Binh Dao, LDEQ Helen Waller, LWI Dean Wallace, Ascension Parish Ronny Carter, Pontchartrain Conservancy
Region 8	Malissa Dietsch-Givhan, N.O. RPC Tom Haysley, N.O. RPC Stephanie Steele, New Orleans Regional Planning Commission

In each focus group, participants were asked a series of questions related to their interest in and needs regarding the use and maintenance of LWI models. As stated above in the "Objectives and Research Questions" section, questions in the focus group were segmented into three main areas: (1) regional modeling stakeholders; (2) model update needs and frequency; and (3) interest in and capacity for regional model storage and maintenance. Detailed research questions asked during focus groups as well as on pre- and post-surveys are listed in Table 15. A summary of focus group responses is listed in Table 31 of the appendix.

Table 15. Focus group questions grouped by overarching research questions

Question text	**Venue**
Q1: Who are the modeling stakeholders in your area, and how will they interact with models?	
Q1.1: What local and/or regional organizations in your region do you foresee making use of LWI models?	Pre-survey, focus group
Q1.2: How do you foresee local and/or regional organizations in your region planning to use LWI models?	Pre-survey, focus group
Q1.3: Are there any barriers that you foresee to these organizations being able to use LWI models in this way?	Pre-survey, focus group
Q2. What are the primary reasons that models will need to be updated, and how frequently will these updates need to occur?	
Q2.1: Are there any federal, state, or local laws/regulations/ordinances/grant programs driving the need/desire to use LWI models in your region?	Post-survey

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Q2.2: What kinds of projects or policies do you want to evaluate using LWI models in your region? [e.g., structural: regional detention; non-structural: stormwater regulations/utility]	Post-survey
Q2.3: How often do you think LWI watershed models will need to be updated to remain useful for informing decisions about floodplain and watershed management in your region? [every few years, yearly, several times per year, monthly, continuously]	Post-survey
Q3: What level of interest and capacity do local and regional stakeholders have for storing and maintaining LWI models?	
Q3.1: Thinking regionally, are organization(s) in your region interested in storing LWI models and enabling model users to access, use, and modify these models?	Pre-survey, focus group
Q3.2a: To the best of your knowledge, do these organizations have the capacity to do this?	Pre-survey, focus group
Q3.2b: If such organizations do not have the capacity, are they interested in building capacity (assuming additional resources would be available to help)?	Pre-survey, focus group
Q3.3: What information technology (IT) resources (e.g., IT staff, computational or storage, software) do organizations in your region currently have access to that could help to support storage and maintenance of LWI watershed models?	Pre-survey, focus group
Q3.4: Do organizations in your region employ modelers (either full time or those who can/do spend part of their time on modeling)?	Pre-survey
Q3.5: Do organizations in your region currently hire, or have they in the past hired, consultants to perform modeling?	Pre-survey
Additional follow-up questions	
F1: In your opinion, what types of resources would be needed at the regional level to allow for the housing and updating of LWI models?	Post-survey
F2: In your opinion, what sources of funding do you think can be used for supporting the housing and updating of LWI models at the regional level?	Post-survey
F3: In your opinion, what types of organizations would be most suitable for implementing model housing and updating?	Post-survey
F4: After having participated in this focus group, in your opinion, what is the most effective way of housing LWI models in your region?	Post-survey
F5: Is there anything you would like the moderators to know that would assist them in developing the LWI Model, Use, Storage, and Maintenance plan? (or that you did not get a chance to say during the meeting)	Post-survey

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Four semi-structured follow-up interviews were held with seven focus group participants representing five LWI watershed regions (Table 16). The purpose of these interviews was to ask clarifying questions as the research team was working on the LWI MUSM recommendations. Pertinent responses from these interviews are discussed in the results below as well as in the discussion of the MUSM recommendations that follows.

Table 16. Follow-up interviews with subset of focus group participants

Interviewees	Regions represented
Acadiana Planning Commission (Monique Boulet, Rachel Godeaux, Kelia Fontenot Bingham)	5
Amite River Basin Commission (Dietmar Rietschier, Bob Jacobson)	7
Lafayette Consolidated Government (Jessica Cornay)	5
Rapides Area Planning Commission (Matt Johns)	1, 2, 4, 5

Regional modeling stakeholders

The first set of questions (Questions 1.1-1.3, Table 15) asked about the interest in using LWI models within each region. Specifically, participant groups were asked whether organizations in a region would use LWI models, what types of organizations might use them, and what types of barriers stood in the way of use within regions. For all eight focus groups, participants indicated that a variety of organizations would use LWI models in the state. The most common users of these models were identified to be local governmental planners, engineers and floodplain managers, private developers, and watershed regulators. University educators and researchers were also identified as possible users of the LWI models. Of primary importance was meeting the needs of planning commissions, levee and drainage districts, and municipal, parish, and state governmental entities to use models for regulatory decision making (e.g., FEMA LOMR, etc.). Without use in regulatory decision making the fear was that the models will not gain long-term use, nor would they be properly maintained and updated. Participants of the focus groups expressed several primary categories for use of these models. They stated that models could be used to review and evaluate development permit applications and ensure compliance with local drainage ordinances and FEMA regulations. Participants indicated that models could also be used to evaluate individual development applications, as well as cumulative impacts to the entire watershed. They would also use these models to assist in educational and outreach efforts to inform community members, developers, modelers, and educators about flood risks, development activities, programmatic changes, and changes to their watersheds that would influence flood risk. Third, they would use these models to inform and evaluate larger programmatic efforts, including managing long-term development strategies, project evaluation, proposed policy changes, and the implementation of master drainage plans. Finally, they would use LWI models to assist in emergency response and mitigation efforts such as the forecasting of extreme events or in assessing

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cumulative impacts of alterations to watersheds, and to assist in understanding or to couple with other models that show hazard impacts (e.g., storm surge models).

In the eight focus group discussions, it was stressed that there was a notable difference between using the models for planning purposes versus using the models for permitting purposes (permitting may require more detailed an precise models than would planning activities). These two different model uses would likely impact how frequently they would need to be updated to reflect changes in land use and landcover as well as to incorporate “permitted” drainage projects. It was also stressed in the focus groups that running the models day-to-day would be a regional task, but the benefits of model use would be realized at individual parish or municipality levels due to the variation in the policies and ordinances.

The major barriers to using LWI models foreseen by regions include the cost of running such models (e.g., computer hardware and software), staff requirements to support model use, and usability concerns that extend to both private and public sectors (e.g., access to sufficient broadband Internet to download models in a timely manner). The more uncommon barriers pointed out by participants included the need to communicate to community members, including public and private sector users, what the models can and cannot do. There was a suggestion that a series of introductory workshops and training sessions could help explain the best methodologies to incorporate new watershed features in existing models and new models or policies and that follow-up workshops should be offered as changes are made to the models in the future. Additionally, most participants were concerned about software knowledge gaps and the computational costs of running and housing models in regions with less capacity in these areas.

Model update needs and frequency

A second set of questions focused on the reasons models would need to be updated and the frequency of updates needed (Questions 2.1-2.3 as well as Additional Follow-Up Questions F1-F5, Table 15) was asked to focus groups, both in-person and through pre- and post-meeting surveys.

In pre- and post-focus group surveys, as well as follow up discussion in the eight focus groups, the vast majority of respondents stated that structural flood mitigation (e.g., regional detention, pumping systems, control structures, drainage improvements, etc.) was most important to include in models as they would have the largest impact on the types of projects or policies that would benefit from model use. Secondary to this was non-structural and adaptation measures (e.g., stormwater regulations or utilities, conservation easements, buyouts, structure raising, etc.). These uses were identified as important because local entities and parishes are looking for science-based tools to better manage flood risk and guide decisions on new developments. These models would provide valuable data to justify policies to local jurisdictions.

Participants indicated that there is a need for LWI models to be used for projects that require floodplain analysis at a regional and local level, including development, drainage studies, climate change adaptation decisions, project prioritization for grant purposes, and individual permitting or planning decisions. Indeed, during the follow-up interview with the representative from Lafayette Consolidated Government, it was noted that models would be of little value if they are not compatible with FEMA standards and used to meet FEMA-mandated requirements.

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Participants expressed that models would have a finite shelf life and thus would need to be updated frequently. The frequency of full model updates required, as inferred from the eight focus groups, ranged from yearly to every few years, with the largest percentage of participants indicating that models would need to be updated approximately every three years. Participants indicated that the rate of update was largely dependent on availability of funding and technical assistance to do these updates, as well as staff and computing capacity. This process of full model updates (including adding major mitigation projects, updating LiDAR and land use and land cover data, and upgrading to new major versions of model codes) should be distinguished from the continuous model updates to capture new developments and large-scale land-use changes (usually without updating or adding major projects, or upgrading model code to a new major version number).

Interest and capacity for regional model storage and maintenance

In the final set of focus group questions (Questions 3.1-3.5, Table 15), participants were asked about the level of interest and capacity local and regional stakeholders have for storing and maintaining models. Most focus group participants were interested in seeing their region's models hosted on IT systems administered regionally and enabling model users to access, use, review and modify models. This sentiment was expressed succinctly during the follow-up interview with Acadiana Planning Commission staff; to successfully manage water at the watershed scale, regions need to build modeling expertise at the regional and local level. Hosting and maintaining models regionally was seen as a foundational to building regional capacity. During the same conversation, it was suggested that use and maintenance of models by regional entities can help support continued learning about how local and regional watersheds behave and respond to development and extreme events. In the follow-up interview with the representative of Rapides Area Planning Commission, the interviewee noted that regional entities have much greater capacity than state agencies to be on the ground, attending local meetings, gathering updated model data directly from towns, cities, and parishes, and also being accessible to modeling stakeholders in the public and private sectors via phone or in person.

The types of organizations who would implement model housing and maintenance within each region could vary, according to participants, from existing regional planning commissions, metropolitan planning organizations, regional universities, and drainage or levee districts. There was a preference across several, though not all, regions to implement model housing and maintenance through partnerships with regional universities. The desire for regional university partnerships was due to their ability to provide technical and education assistance for model updating and use and to take advantage of existing computational and staff resources.

Some regions have already begun investing in local-scale models (e.g., ~HUC12) and the hiring of modelers on an as-need basis. However, some regions are better equipped than others to provide these services. A common suggestion in the focus groups across regions was to use regional universities (e.g., UL Lafayette; McNeese; LSU; LSU Shreveport; Louisiana Tech, Tulane, Nicholls, UNO) as a primary place to store and maintain models in partnership with regional agencies that over time can become equipped to handle this type of model use and storage requirement (e.g., Northwest Louisiana Council of Governments and The Coordinating & Development Corporation in Region 1; Rapides Area Planning Commission and Kisatchie-Delta Regional Planning and

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Development District in Region 2; Acadiana Planning Commission and UL Lafayette's Watershed Flood Center in Region 5; the Water Institute of the Gulf, or LSU's Center for River Studies in Region 7; Meraux Foundation in Region 8; or the DOTD or CPRA for all regions). During the follow-up interview with Amite River Basin Commission representatives, the potential for universities to play a role in model housing and updating was seen as positive due to their ability to be impartial. However, there was also a question of whether universities are currently equipped to provide services, and that providing services is necessarily a different mode of operation with different timelines and expectations than doing research.

In a few focus groups, it was suggested that organization(s) able to store and maintain these models do not yet exist but could be built as part of the watershed initiative. The same focus groups suggested that, in the interim, use of the aforementioned regional universities or partnerships would provide a way to quickly enable model use and storage for the initial phase of the LWI modeling program.

Funding and governance moving forward were major concerns raised by focus group participants. Understanding how much funding will be required to support regional model use, storage, and maintenance, and where that funding will come from, remain key questions to be answered. In the follow-up interview with the representative from Lafayette Consolidated Government, it was noted that the success of regional model housing and updating depends on establishing sustainable regional governance and funding, without which, model housing and updates would have to be handled at the state level. During the follow-up interview, representatives from the Amite River Basin Commission noted that implementing regional governance across watersheds in a region would be less likely to succeed than governance scoped at the watershed level. Most focus groups mentioned their preference for participating in regional coalitions or planning committees that could draw on regional expertise and leverage existing funding resources (in addition to new funding). One focus group described this as akin to making a gumbo, where each regional entity could bring something to the table that would benefit all. This would likely require having in place collaborations between engineers, developers, grant managers, floodplain managers, parish and municipality staff, and consultants.

In terms of avenues for raising capital to fund updates, participants indicated that it would be possible to raise funds via sales tax, property tax millage, permitting fees, stormwater utility fees, and fees for developer use of the models to evaluate development. Permitting fees were deemed to be particularly attractive during the follow-up interview with the representative from Rapides Area Planning Commission. However, they specifically indicated that besides permitting fees, it would largely depend on what voters would support in particular regions. Because voter support by region could vary, it was indicated that it would be preferable to have autonomy over model use and storage at each region so that regions could justify maintenance as a regional concern and not just a state concern. This would allow each region to raise funds in ways that would appeal to voters within that region. This would also prevent model updates or model use and storage from being tied to state budgetary decisions that may fluctuate depending on larger economic and political interests.

Recommendations from LWI regions

Stakeholder outreach to the eight LWI regions indicated a strong desire for most regions to manage their own model management systems, rather than relying on a central state-based entity to manage them. Many regions

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also have a strong desire to maintain and update their own models. This desire can also be seen in the recently produced LWI Provisional Governance Recommendations[2] regarding regional coalition responsibilities toward and governance of model use, storage, and maintenance (Table 17).

Table 17. Model use, storage, and maintenance recommendations from LWI Provisional Governance Recommendations

Region	MUSM governance recommendation
Region 1	"The Coalition should be enabled to house and operate the LWI watershed models in Region 1"
Region 2	"The coalition should manage modeling and other hydrological data"
Region 3	• "The coalition should be tasked with housing and operating the LWI watershed model [*sic*] for Region 3" • "The coalition should allow other entities to use the collected data and LWI modeling information in the development of projects that impact Region 3 and other regions"
Region 4	• "Coordinate data management with local stakeholders and create regional data repository" • "Store watershed models locally with entity in charge of day-to-day operation"
Region 5	"A resolution was passed in October 2020 which would allow an entity within Region 5 to house the regional models" (see also LWI Region 5's "Resolution in Support of Developing a Regional Housing and Maintenance Watershed Model Plan" in the appendix)
Region 6	"The coalition should be tasked with housing and operating the LWI watershed model for Region 6"
Region 7	• "Models should initially be housed at the state-level and over time with support, capacity should be built at the regional level."
Region 8	• "The coalition should be tasked with housing and operating the LWI watershed model for Region 8" • "The coalition should serve as hub or clearinghouse for other entities to submit and use collected data and modeling."

Based on stakeholder outreach, it is clear that their preference is for LWI to pursue the development of model management systems built around regionally controlled model use, storage, and maintenance.

Based on analysis of stakeholder outreach research and review of existing systems, the preference for a regionally controlled MUSM approach is driven by the following regional-level factors and benefits:

(a) Region-based entities possess intricate hydrologic and hydraulic knowledge of the watersheds and streams in their region and are best positioned to understand the implications of proposed development.

(b) Regions have the largest stake in ensuring that these models are maintained on an ongoing basis so that the models can be used to manage their own watersheds adequately.

(c) LWI regions in general feel very strongly that they have the ability to manage their own modeling activities (or to build the capacity needed to do so) and given that they are likely to be asked to

[2] https://watershed.la.gov/assets/docs/LWI_ProvisionalGovernanceRecommendations_Combined.pdf linked from https://www.watershed.la.gov/rcbg-program

provide financial support housing and maintaining their models, they want to ensure that they retain direct control over the modeling activities they will be funding.

(d) Model maintenance (e.g., check-out and -in, periodic updates and upgrades to models, reviewing model updates done by city/parish engineers or by modeling contractors) will be far more effectively performed at the regional scale. Familiarity with the local/regional hydrologic complexity, direct knowledge of areas prone to flood risk, and authority to manage and approve developments are factors contributing in favor of a local/regional model maintenance system. These critical advantages would not be realized if the system is implemented at a state level.

Finally, capacity building, which is a foundational principle of LWI, is another important factor in considering a regional housing and maintenance approach. It is imperative to long-term model buy-in and use to develop knowledge and expertise at the local and regional level. Training for local and regional engineers and planners on effective use of LWI models is imperative to improving the overall watershed management process. Housing and maintaining the models at the regional scale aligns with LWI capacity-building objectives. Investments in regional model storage and operation would strengthen existing regional capacity, and create new capacity, that is key to ensuring long-term sustainability of LWI models and continued usage and maintenance by LWI stakeholders. Building regional capacity through training and outreach programs, with initial support from LWI to establish the program, is beneficial to the long-term sustainability of LWI models. These training programs would enhance local and regional expertise and knowledge to use LWI (and other) models to better manage watersheds both in the short and long term.

REVIEW OF EXISTING MODEL MANAGEMENT SYSTEMS

Results of scoring of existing systems

A desk-based evaluation of existing model management systems was performed for existing systems where each system was given a score indicating how well it supported typical stages of hydraulic and hydrologic model development, use, sharing, and maintenance life cycles. Table 18 summarizes the comparison for eight existing model management systems analyzed. It shows that, as expected, no existing management system reviewed covers all model lifecycle stages. Delft-FEWS systems focus on the early stages from data preparation to model execution, though most did not enable model setup or construction (except the TVA FEWS implementation does some of this), while the Harris County and San Antonio River Authority systems focus on the latter stages from model discovery to model approval. The remaining systems only cover some model lifecycle stages. All systems allow model results to be visualized, while none of them include model setup/construction. In terms of the best systems for each stage, Delft-FEWS systems have excellent capabilities in raw data acquisition and preparation, as well as model scenario development. USACE HEC and Delft-FEWS are good at model execution. FEMA InFRM estBFE provided good results visualization, model discovery and download. The San Antonio River Authority is strongest in model discovery. Most existing systems did not support either model calibration and validation nor model modification, save for limited capabilities in some Delft-FEWS implementations (calibration and validation: TVA, Australia, Netherlands and Ireland; modification: National Weather Service and Canada). Among all systems, Harris County stands out as providing the most capabilities across the most model lifecycle stages, i.e., model download/check-out, modification/approval, and model update notification.

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Table 18. Existing system comparison matrix. A score of NC indicates no capability, C indicates some capability, and C+ indicates significant capability

Model Lifecycle Stage	Harris Co., TX	North Carolina	USACE HEC	FEMA InFRM-BLE	Charlotte-Mecklenburg, North Carolina	Iowa Flood Information System	San Antonio River Authority	Delft-FEWS systems
Raw geospatial and time series data acquisition	NC	NC	NC	NC	NC	NC	NC	C+
Data preparation/processing into format that the model can directly import/use	NC	NC	NC	NC	NC	NC	NC	C+
Model setup/construction	NC	NC	NC	NC	NC	NC	NC	NC
Model calibration/validation	NC	NC	NC	NC	NC	NC	NC	C
Model scenario development	NC	NC	NC	NC	NC	NC	NC	C
Model execution	NC	NC	C+	NC	NC	C+	NC	C+
Results visualization	C	C+	C+	C	C	C+	C	C+
Model discovery	C	C	NC	C	C	NC	C+	NC
Model download/check-out	C+	C	NC	C	C	NC	C	NC
Model modification	C	NC	NC	NC	NC	NC	NC	C
Model upload/check-in	C+	NC	NC	NC	NC	NC	NC	NC
Model modification review/approval process	C+	NC	NC	NC	NC	NC	NC	NC
Notification of proposed/approved model updates	C+	NC	NC	NC	NC	NC	C	NC

In the following sections, we describe in detail existing systems that, based on the above scoring (Table 18), most closely align with the model use, storage, and maintenance needs of the LWI modeling program.

HARRIS COUNTY FLOOD CONTROL DISTRICT MODEL AND MAP MANAGEMENT (M3) SYSTEM

The Harris County Flood Control District's (HCFCD) Model and Map Management system (M3) was built circa 2005 as a tool to help protect HCFCD's investment in modeling by keeping models up to date. M3 allows engineers and planners to discover watershed models (Figure 4), download/checkout models, and then check in models revised according to HCFCD standards. The system also allows users to view current and recently completed flood control or other projects and their locations. If the system detects more than one project that will affect the same model, it will notify HCFCD staff so that they can help coordinate model use and updates with both model requestors.

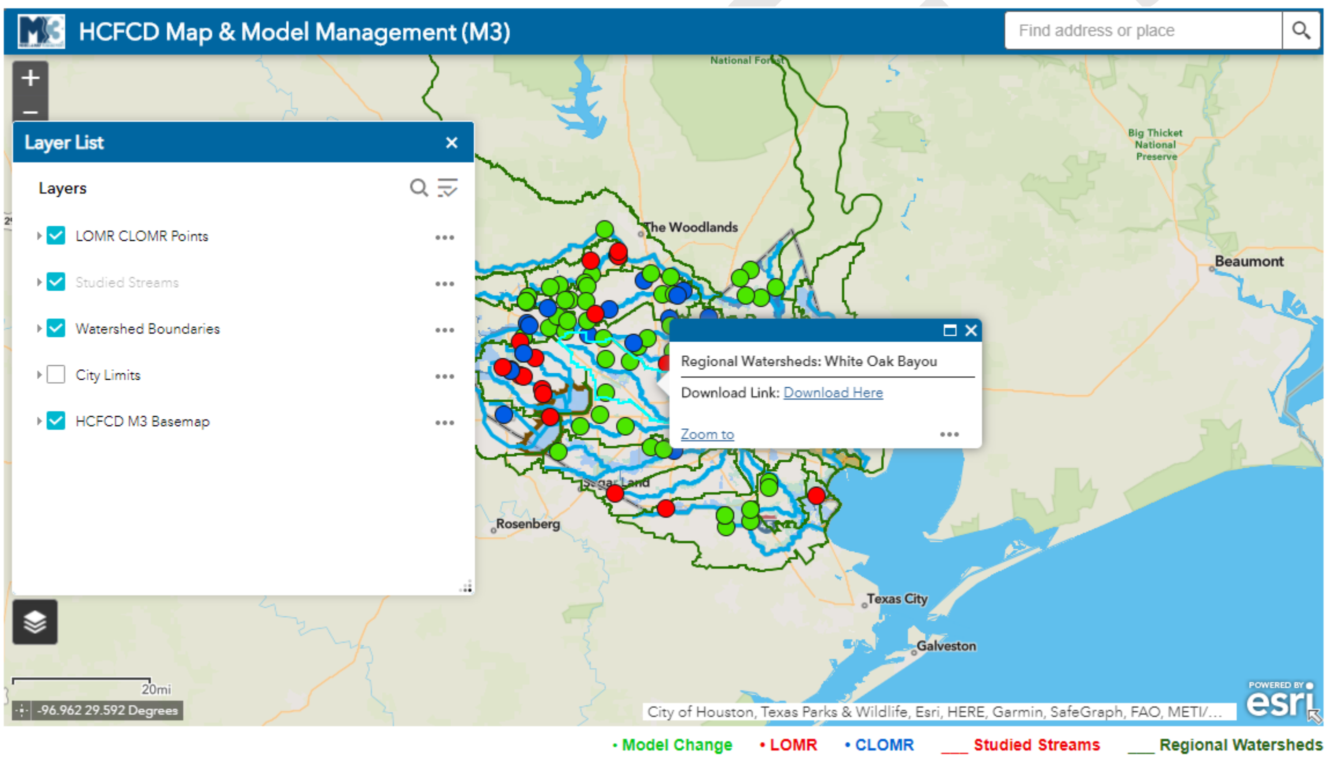

Figure 4. Screenshot of HCFCD M3 website, a selected model is highlighted and a prompt for model download message is displayed.

HCFCD models, including HEC-RAS and HEC-HMS models, are available for download by the general public (Figure 4). However, users who are planning to submit official changes to a model will need to check out the model of interest using the following process:

- The user will login to the HCFCD website for model checkout.
- The user will provide required information to identify the requestor, the purpose and type of study, study area and requested models.

- The user will submit the request to HCFCD for processing.
- The system will assign a tracking number that will be used for all subsequent submittals and correspondence.
- The system will determine if notifications of potentially conflicting studies are required and send any relevant notifications.
- HCFCD staff will process the request and provide the requested data via FTP or DVD depending on the size of the data request. This expiration date can be adjusted during the course of the study at the request of the requestor.

M3 HYDROLOGIC AND HYDRAULIC MODELING AND MANAGEMENT STANDARDS

The HCFCD M3 system relies on the model management policy of requiring that modeling standards be followed when HEC-HMS (hydrologic) and HEC-RAS (hydraulic) model updates will result in revision of or updates to Flood Insurance Maps for Harris County (e.g., a change in the base flood elevation or in the aerial extent of the floodplain). These can include but are not limited to models that support the following types of projects:

- Bridge/Culvert crossings on a studied stream
- Channel modifications on a studied stream
- Fill in the floodway on a studied stream
- Fill or other construction in the 1% exceedance probability (100-year) floodplain that will affect the conveyance of a studied stream or floodplain
- Permanent changes in watershed and/or subbasin boundaries
- CLOMR and LOMR submittals

NORTH CAROLINA FLOOD RISK INFORMATION SYSTEM (FRIS)

The Flood Risk Information System (FRIS) is operated by the North Carolina Floodplain Mapping Program (NCFMP) of North Carolina Emergency Management. Originally developed in 2011, FRIS is focused on communicating flood risk information to the general public, nevertheless, it has some advanced capabilities that are oriented to engineers and modelers. The system hosts the following services:

- Flood information: The Flood Information function allows users to select a location on the map and then view detailed flood-related information for that location including regulatory flood zones and base flood and multi-frequency elevations (BFEs). Regulatory and non-regulatory flood elevations are provided by FRIS through Esri, Inc. raster mosaic datasets developed during program floodplain mapping updates.
- Risk information: The Risk Information function allows users to view detailed flood risk data for a location, to learn how to reduce risk from flooding, and to access additional natural hazard information through iRISK. Risk analysis and damage estimates are provided using statewide building footprints in conjunction with estimates of field- (regulatory flood zone extents) or LiDAR-derived first floor elevations (FFEs). The Risk Information function also allows user to evaluate various building level mitigation strategies to reduce risk at an individual structure including customization of building values, FFEs and other parameters used to calculation the cost-benefit of individual mitigation strategies.

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- Financial vulnerability: The Financial Vulnerability function allows users to view a personal vulnerability assessment to determine an individual's ability to financially survive potential flood damages and losses.
- Flood insurance: The flood insurance tool provides an estimate of flood insurance premium for a given address based on FFE estimates tied to building footprints and current FEMA NFIP insurance rating tables. The tool allows user to customize their flood insurance premium estimates by allowing users to modify building FFE elevations, amount of coverage and other important factors used to calculate flood insurance rates.
- Customize FIS reports: The FIS Reports function allows users to
    - view and print Floodway Data.
    - view and print a Summary of Discharges.
    - use the FIS Report Builder.
- Engineering Models: The engineering models tools allows advanced users to download effective FEMA/NCFMP hydraulic models for a select location that is serviced by FRIS. In order to get the hydrologic model associated with this hydraulic model, users must contact NCFMP directly.
- Map export: The Map Export function allows users to create a printable PDF-format map. Users can create a regulatory map or a map of the view currently shown on the FRIS map.
- Data export: The Data Export function allows users to download geospatial flood risk information and LiDAR topographical data.
- FRIS services can be accessed through the FRIS toolbar (Figure 5)

Figure 5. Screenshot of FRIS system (North Carolina) capabilities including the FRIS toolbar (right side)

IOWA FLOOD INFORMATION SYSTEM (IFIS)

The Iowa Flood Information System (IFIS) is a web platform developed circa 2010 by the Iowa Flood Center (IFC) at the University of Iowa. IFIS provides a user-friendly and interactive environment for over 1,000 communities in Iowa regarding flood conditions, flood forecasts, data visualizations, and flood-related data, information and applications.

IFIS is a one-stop web-based platform to access community-scale flood conditions, forecasts, visualizations, inundation maps and flood-related information. The IFIS application focuses on the needs of communities with regard to flood preparedness and current upstream conditions. Currently IFIS delivers real-time flood monitoring for over 200 communities, and more communities are being included over time.

IFIS provides the following services:

- My community/my watershed: Community-based flood conditions, data resources, and upstream watershed characteristics.
- Flood inundation maps: Inundation maps provide information on the extent and depth of flood waters
- Flood conditions and forecasts: Real-time water levels and stage heights with flood alert levels, and flood forecast.
- Flood risk calculator: Calculate risk of flooding based on annual chance and duration.
- Weather conditions: Real-time rainfall maps displaying current conditions, and past rainfall accumulation.
- Rainfall frequency maps: Compare daily rainfall accumulation with frequency in real-time.
- Interactive visualizations: Visualizations of water levels and stream gauge readings with 3D/2D interactive animations.
- IFIS data resources: Data from IFC's bridge sensors, rain gauges, and data sources with real-time and historical information. The sensor data can also be downloaded using the IFIS API web service (https://ifis.iowafloodcenter.org/ifis/ws/)

Additional system features can be accessed at https://ifis.iowafloodcenter.org (Figure 6).

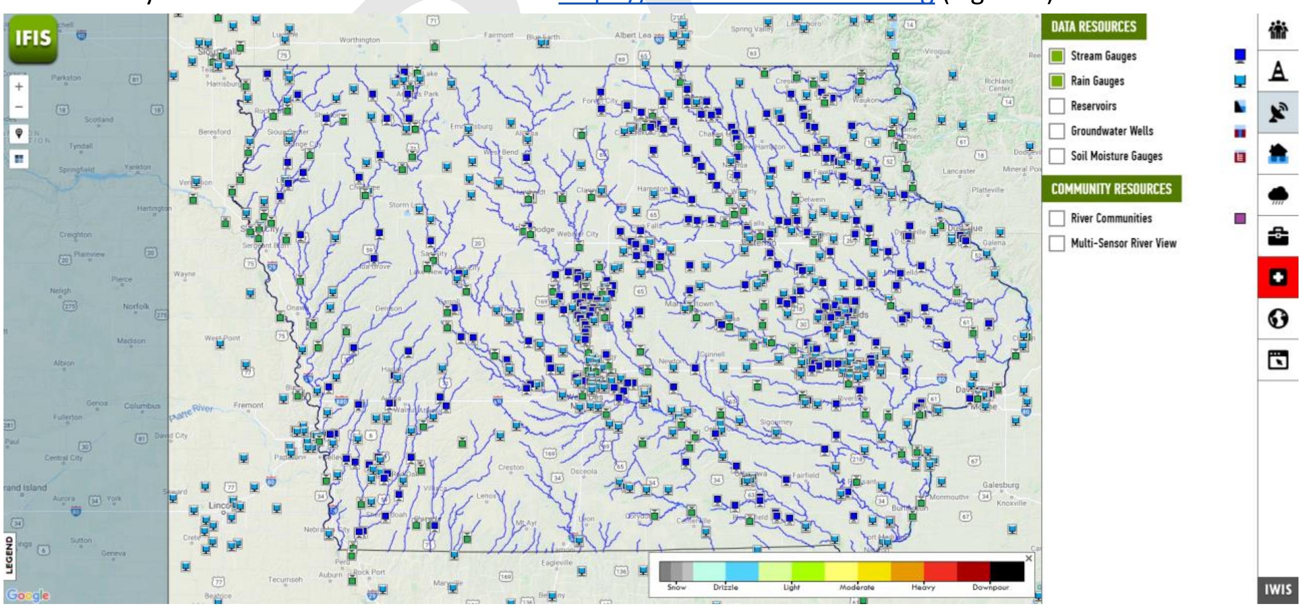

Figure 6. Screenshot of the IFIS system (Iowa) and some of the capabilities available at the IFIS sidebar on the right side.

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TEXAS DISASTER INFORMATION SYSTEM (TDIS)

Texas Disaster Information System (TDIS) is a project of the Texas A&M Institute for a Disaster Resilient Texas. Currently in the planning phases, TDIS will purportedly be an "interactive, analytical, and visual web-based spatial data system design to support more resilient decision making at the state level"[3] It was not possible to score TDIS using the criteria listed in Table 18 because TDIS is in the planning stages. TDIS is included in this analysis to compare its alleged approach to model use, storage, and maintenance to that of actual systems in use over the last decade-and-a-half. It should be noted that no resource requirement estimates, or associated costs are available for TDIS at the time of writing this report, which did not allow comparisons to costs for existing systems in other states or to costs of possible LWI MUSM approaches. Efforts are underway to gather cost information from TDIS staff, which can be considered by LWI in future phases of the MUSM development. Based on information provided by The Water Institute of the Gulf[4], TDIS will store and manage models alongside other data sets (e.g., LiDAR data, rainfall frequencies like Atlas 14) and decision support tools in a single system (rather than integrating across modular components). This system would be hosted in a hybrid cloud-based IT infrastructure using both private data centers as well as commercial cloud-hosted resources.

Using hybrid cloud-based IT infrastructure can potentially be advantageous for reducing dependence on cloud vendors and perhaps also for reducing costs, assuming IT needs are great enough to offset the substantial costs involved in building or acquiring and then operating data center space. Given these substantial costs, the choice of hybrid cloud infrastructure must be carefully considered with detailed cost estimates provided. Additionally, the wisdom of hosting IT resources in small private data centers must be questioned given recent well-documented vulnerability to natural hazards, especially in Gulf states (e.g., yearly hurricanes and tornadoes as well as sub-decadal catastrophic freeze events), which tax the disaster mitigation abilities of small data centers.

Results of interviews with managers of existing systems

A full list of questions used to guide the semi-structured interviews with managers of existing systems can be found in Table 15. The following is a summary of responses to key interview questions relating to LWI model use, storage, and maintenance.

ORIGINS, PURPOSES, AND COSTS

The first set of key questions focused on understanding the origins, purposes, and costs behind creating each solution. Most of the systems were developed 10-15 years ago. None were developed solely to support flood modeling. Instead, they were created to communicate flood risk by providing the general public with access to flood risk information, primarily in the form of web maps delivered as web-based GIS tools. Typically, the hydrologic and hydraulic models used to develop these flood risk maps are made available for download either directly through the flood risk systems, or by linked FTP or other file download services. The Harris County M3

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[3] https://idrt.tamug.edu/tdis/

[4] Memorandum on LWI Model Use, Storage, and Maintenance Considerations, April 21, 2021.

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system was designed to include substantial model management components alongside flood risk communication tools. According to the interviewee, HCFCD decided that a model management system was needed to protect investments made in modeling. The implication being that the model management system supports keeping models up to date, which ensures that models will remain useful.

The flood risk communication components of systems were typically used by a variety of users from citizens to real estate agents, to planners and engineers. However, the model management components of systems tended only to be used by engineers and researchers. Representatives from state and federal agencies such as FEMA were also likely to use model management functionality.

The cost to develop existing model management systems ranged from $580,000 to $1.4M in 2020 dollars. Ongoing operating and maintenance (O&M) costs were mainly due to staff needed to operate and maintain the system, which most respondents estimated to be two- to three-full-time equivalent (FTE) per year. Model management solution O&M tends to be funded by taxes or fees. North Carolina’s FRIS funds their O&M with a fee tied to the recording deeds, which tends to provide stable funding. HCFCD relies on a property tax millage. Charlotte-Mecklenburg Storm Water Services is a stormwater management utility, and therefore can charge a utility fee, which is used to fund O&M.

FEATURES AND FUNCTIONALITY

Most systems allow models to be downloaded, and while some can track users who download models for particular purposes (e.g., to complete a flood risk study), none support formal workflows for check-in and review (i.e., automatically facilitating review by a list of reviewers, and after reviewers approve model changes, automatically publishing a new version of the model). In general systems do not currently offer extensibility via Application Programming Interfaces (APIs). The exception would be FEWS, which is a robust platform that allows for extension and adaptation to new use cases, and does so through APIs. The HCFCD M3 system does allow users to be notified of updates to models, however these are emails meant for modelers or engineers not machine-to-machine notifications, which would be necessary to allow automated integration of systems designed to take actions based on model updates (e.g., publishing new models, archiving old models, automatically running models to produce new flood risk maps).

Respondents were asked if there were capabilities they wished their systems had but do not currently have. A notable reply came from Charlotte-Mecklenburg’s respondent, who wished that they had spent more resources making model check-out and check-in more efficient to better support model revision. When asked about unexpected difficulties encountered with systems as well as surprises after development and deployment, Charlotte-Mecklenburg’s respondent noted that substantial data cleaning needed to keep data consistent as well the need for continuous maintenance required for the system to maintain usefulness: “You can’t just develop it and forget it.”

There was consensus in responses when respondents were asked what they would do differently if they were developing their systems today. Rather than developing combined flood risk communication and model management systems, the sentiment among respondents was that if they had to start all over, they would develop separate, simpler systems with functionality tailored to specific use cases and users. Most flood

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management agencies already do this to some degree (e.g., having flood monitoring/alert systems be separate from flood risk planning tools), but further decomposition of flood risk communication and model management tools was deemed to be warranted. This sentiment was most clearly articulated by HCFCD, whose respondent indicated that model management systems should be very focused on doing a limited number of things well (e.g., discovery, download, check-out, check-in), rather than trying to do too many things (e.g., visualization of data/model output, etc.). The following quote exemplifies this: "we built a Christmas tree with too many ornaments. Some things worked well, but other functionality was not needed. We made too many things to make users' lives easier, but it made our lives much harder". As an antidote to this, the respondent suggested that one needs to decide what the core functionality of a model management system should be and to build a strong foundation based on that. In Harris County's case, those core features were: (1) easy model download; (2) easy model update and upload; and (3) model notifications. Over time, HCFCD has winnowed down the functionality of their M3 system to focus on these core features.

INFORMATION TECHNOLOGY IMPLEMENTATION APPROACHES

In terms of Information Technology (IT) system architecture, the model management systems tended to be developed as monolithic applications (e.g., one code base deployed as a single application addressing many use cases), which was a typical design decision for systems developed 10-15 years ago as these systems were. This can be contrasted with a more modular service-based approach where a system would be developed as a series of interacting components that are more-or-less independent of one another. In general respondents indicated that their current monolithic systems are being updated or replaced with service-based modular systems (see Planning and next steps for existing systems section below).

The existing systems reviewed were built with a mix of custom software as well as ArcGIS Server/Online tools. These systems were deployed on a mix of legacy on-premises resources (e.g., servers purchased by and housed in a data center owned and operated by the owner of the system) as well as cloud-based hosting. Older systems tended to be hosted on premises while newer systems, or updates to existing systems, relied more on cloud-based hosting.

PLANNING NEXT STEPS FOR EXISTING SYSTEMS

When asked how decisions are made on future features to be added to their systems, respondents in general indicated that they currently use formal stakeholder processes or indicated they would like to do so. Even when managers determine new features themselves, they do so after reflecting on end-user feedback using what is essentially an informal, ad hoc stakeholder process. Based on such stakeholder feedback, the trend for existing systems analyzed in this study is to develop new systems as a series of related though independent applications that share underlying data. The previous approach of integrating model management with flood decision support tools has been tried by existing systems developed over the last 15 years, most notably the M3 system in Harris County, Texas, and the FRIS system in North Carolina. Managers of these systems have found that tightly coupling model management with other functions adds complexity and risk to system development efforts by making the systems more difficult to develop, test, and maintain. These individual applications would

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each be tailored to a specific set of use cases or users, for example allowing home buyers or real estate agents to view flood risk for a property or allowing engineers to download hydrology or hydraulic models. This approach of multiple tailored applications contrasts with previous iterations of flood risk management systems that tended to combine multiple use cases into a single, more complex tool. The benefit of the newer approach is that each application can be simpler while user experience can be optimized for each particular user group, making the applications easier for all to use.

Key takeaways from review of existing systems

- Model management system were developed to protect investments made in modeling;
- The cost to develop existing model management systems ranged from $580,000 to $1.4M in 2020 dollars;
- Ongoing operating and maintenance (O&M) costs were mainly due to staff needed to operate and maintain the system, which most respondents estimated to be two- to three-full-time equivalent (FTE) per year;
- Model management components of systems tended only to be used by engineers and researchers;
- No existing systems support formal workflows for check-in and review, though these were noted as features that system managers are planning to add or would add if they were building their systems again (to better support model quality assurance and versioning);
- Rather than developing combined flood risk communication and model management systems, the sentiment among respondents was that if they had to start all over, they would develop separate, simpler systems with functionality tailored to specific use cases and users; and
- In general respondents indicated that their current monolithic systems are being updated or replaced with service-based modular systems.

STATE AGENCY OUTREACH

Findings from the semi-structured focus group with four state agency representatives (Table 11) are reported in the following sections, which correspond to each question used to guide the discussion (Table 12).

Agency needs from LWI models

Agency representatives reported various mission-specific uses for LWI watershed models, including: making sure the Coastal Master Plan is consistent with LWI models, performing transition zone analysis, supporting levee districts to issue permits, and helping with the design of flood protection systems (CPRA); dam breach analysis and design of hydraulic structures (DOTD); supporting comments on permit evaluation as well as assessing the environmental impacts of culverts and fish passage (LDWF); TMDL analyses as well as testing the modification of water bodies (e.g., dredging; LDEQ).

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Update frequency of LWI models

Respondents did not comment on how often small updates should be made to models (e.g., implementation of small projects). All respondents agreed that models should be periodically reviewed to make sure potential errors introduced in serial smaller updates do not compound and lead to nonsensical model output. This review would need to be performed by experienced hydrology and hydraulic modelers and would require a dedicated budget. A suggested interval for full update was five- to 10-years.

Agency interaction with models

Most state agencies represented in the focus group have limited in-house modelers capable of performing combined hydrologic and hydraulic modeling (i.e., H&H modelers) and so would be unlikely to modify LWI models on a routine basis (i.e., without hiring or contracting H&H modelers). DOTD and CPRA employ H&H modelers, while LDEQ employs hydrologic modelers, but all these agencies routinely contract H&H modeling activities to private consulting firms.

Where should LWI models be housed? What are the barriers or difficulties foreseen with central (state-level) or regional model storage and maintenance?

The focus group with representatives from the four state agencies provided varying insights on the different housing options, whether state-level or regional. They indicated that a major potential problem identified with regionally hosted models is striking a balance between providing easy access to models while ensuring the integrity of model data. Organizations that host the models will need to make sure that erroneous changes do not make their way into models, but should avoid locking models down so much that they become inaccessible to the community. Concerns were also raised about regional hosting having more points of failure, the implication being that the more people there are managing models, the greater the chance for human error. The remedy for this was perceived to be central hosting.

However, participants also identified potential difficulties if LWI models were to be centrally hosted by a state entity. These difficulties were related to: (1) cost charged by Department of Administration Office (DOA) of Technology Services (OTS) for data storage (purported to be $0.64 per GB stored per year, which is roughly 200% more than what commercial cloud providers would charge, not including data egress fees charged by most cloud storage providers); and (2) high degree of control over software systems required by OTS. Respondents feared that these issues would make a state hosted LWI model management system inflexible and difficult to sustain. The agency representatives indicated that a central, state-level housing option could be considered during the initial phase of the program. After the modeling program is established, and assuming there is a common framework for model housing and maintenance, then it was thought that regions could host their own models as desired.

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Functionality to be provided by model management system

In terms of the functionality required of a model management system, respondents felt that the system should allow anyone to download models, however, only select authorized users should have the ability to check in modified versions of models. Further, these modified versions should be required to undergo expert review before being made available for subsequent download.

When asked whether the model management system should run LWI models on users' behalf there were conflicting responses. Some worried that this would require additional storage (HEC models must be duplicated for each run to avoid changing the main copy of the model), which would increase costs (though it should be noted that that storage could be temporary to reduce increased costs). Others warned that repeated downloading of models will incur data egress fees, which will increase hosting costs. One respondent suggested that to support use cases where users want to modify and execute models, a web services interface could be built to allow model modification and execution on the model host site, which would reduce the need for model downloads.

RESULTS OF INTERVIEWS WITH USACE AND FEMA

Historically, model management at USACE has been conducted independently on a region-by-region basis. USACE hydraulic and hydrologic models generally fall into two categories: (1) models that are used to operate dams or other control structures; and (2) models used to evaluate proposed construction projects. Operational models are typically of lower detail so that they are guaranteed to run faster than real time.

Early on, USACE models were stored on hard drives of modelers' computers. In recent years, local file sharing has been used to store models. Currently, USACE Mapping Model and Consequences (MMC) group is developing the Model Library tool for storing, indexing, discovering, and downloading HEC-RAS and HEC-HMS models. Scheduled to be available October 2021, the Model Library provides a unified web-based interface for discovering models and viewing model components, including geospatial visualization of model features such as rivers, cross sections, two-dimensional areas, etc. Models can be stored on local file stores, or on cloud-based storage allowing for models from different groups at USACE to be made available. Model Library supports setting group-based permissions so that multiple independent groups can use the system while honoring group-specific access restriction policies. Model Library also supports automatic discovery of models regardless of how model repositories are organized, as well as automated indexing of model metadata, thus reducing the effort needed for models to be ingested. Model Library does not currently support model check-in, check-out, or versioning (versioning models is left up to users in current versions). However, these features could be added on by third parties, and may be added by the USACE Model Library team at a later date.

FEMA is currently evaluating Model Library to better understand where it fits into their model management practices, which currently include a range of systems for storing models, from computer-based systems for tracking regulatory digital models, to paper-based flood-prone quad maps stored in hard-copy files.

The USACE Model Library will be released under an open-source license, and the developers at USACE MMC noted that they intend for the Model Library to be used and built onto by adopters outside of USACE. Model

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Library is built using a modern container-based foundation that hosts services written in the Go programming language. The web-based user interface is developed in React and Redux. Model metadata is stored in a PostgreSQL database, and model data is accessible via S3-compatible cloud storage (Microsoft Azure Bucket Support could be added easily), as well as by traditional local file sharing servers.

ANALYSIS OF MODEL USE, STORAGE, AND MAINTENANCE APPROACHES

LWI model management system design approaches consist of two primary dimensions: (1) where model maintenance (i.e., check-out, update, and review) is implemented; and (2) where IT infrastructure is deployed and managed. Both components can be implemented primarily at the regional level, primarily at the statewide or central level, or in a blended regional-central approach. The pros and cons of central versus regional model maintenance and IT infrastructure implementation are summarized in Table 19.

Regional implementation of model maintenance benefits from better access to local knowledge and the ability to respond quickly to local needs and would require regionally based staff to manage model review processes. It would also nurture a better integration of LWI models into existing local operations (e.g., permitting). A more centralized model maintenance program would likely require fewer total H&H modeling staff to manage the entire state. However, lack of regional control over model maintenance and review processes may impede local buy-in and willingness to provide support with regional funding. It would also reduce incentives for regional entities to commit to capacity building efforts that the LWI plans to invest in.

Regional administration of IT infrastructure would allow tailoring to local model maintenance needs; communication across regions would be required to ensure consistency and to maintain compatibility. Regional IT infrastructure would require regional staff to manage, while central IT management would allow shared staff to manage systems used by all regions. However, if implemented by a state agency, State IT restrictions may increase development time and cost (even if the work is contracted out). Also, as with central model management, centralized IT may impede regional buy-in and reduce the willingness of regional stakeholders to provide regional funding to support the IT infrastructure necessary for successful model management system implementation. Further, long-term maintenance of state-run programs is more vulnerable to changes in administrative priorities, which could compromise all regions at once in a centralized model.

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Table 19. Primary design dimensions for LWI model management systems: central vs. regional model maintenance and IT infrastructure administration.

Regional H&H Model Maintenance	**Regional IT infrastructure**
Pro: • Tap local knowledge (regional and local staff are familiar with specific intricacies of the watersheds) • Respond quickly to regional/local needs • Enables more regional buy-in • Consistent with the capacity building component of the LWI program Con: • Requires more staff • Recruiting sufficient number of regional modelers may be a challenge • Requires a way to ensure consistency across regions	Pro: • Able to tailor IT needs to regional model maintenance needs • Avoid single point of failure Con: • Requires regional staff to manage IT infrastructure • May lead to incompatibility across regions
Central H&H Model Maintenance	**Central IT infrastructure**
Pro: • Share some central staff to manage model reviews across regions • Ensure consistent maintenance of models for state agency uses • Ensure consistency across regions Con: • Makes regions reliant on state or central entities which may lead to poor capacity building in the long run • Central staff will likely lack local knowledge of the various regions and watersheds • Lack of regional model management may impede buy-in and willingness to support with regional resources or funds • Vulnerable to changes in administrative priorities	Pro: • Share staff to manage IT infrastructure across regions, which may reduce costs • Consistent platform for supporting model use and management across the state • Enable regions to focus on H&H modeling efforts Con: • Lack of regional control may impede buy-in and willingness to support with regional funds • May impede regional innovation related to IT solutions unique to regional needs or priorities • State IT restrictions may slow development and increase costs • Vulnerable to changes in administrative priorities

A particular model management system design can use variations of regional or central approaches. Possible approaches include a regional approach (represented by the top row of Table 19), a central approach (represented by the bottom row), and regional/central blended approaches that include a central H&H model maintenance and regional IT infrastructure (represented by the bottom left and top right quadrants of Table 19), or regional H&H model maintenance and central IT infrastructure (the top left and bottom right quadrants). Table 20 presents a typology of MUSM approaches consisting of differing combinations of the model maintenance and IT design dimensions described in Table 19. The Table also includes another potential approach (TWI-TDIS federated). Each of the potential MUSM approaches are described in the sub-sections that follow.

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Table 20. Typology of MUSM approaches

<table>
<tr><th>MUSM Approach</th><th>Party responsible for IT Infrastructure for housing H&H LWI HUC8 Models</th><th>Party responsible for Maintenance of H&H LWI HUC8 Models (perform/review updates, approve revisions, check-in)</th><th>Next Steps</th><th>Party responsible for statewide consistency</th><th>Access to Models</th></tr>
<tr><td>Central Approach (C)</td><td>Central entity</td><td>Central entity</td><td rowspan="4">Short term (Phase II, 1-year): develop system prototype and reference implementation

Long term (Phase III): Operation of the MUSM system</td><td rowspan="5">Statewide Standards Advisory Committee & Federal & State Advisory Board</td><td rowspan="5">All LWI-affiliated entities (federal, state, regional, local, private firms)</td></tr>
<tr><td>Blended Approach (B1)</td><td>Regional coalitions</td><td>Central entity</td></tr>
<tr><td>Blended Approach (B2)</td><td>Central entity</td><td>Regional coalitions</td></tr>
<tr><td>Regional Approach (R)</td><td>Regional coalitions</td><td>Regional coalitions</td></tr>
<tr><td>TWI-TDIS Federated Approach (TTF)</td><td>Central entity</td><td>Central entity; with regional coalitions only responsible for maintenance of Non-LWI H&H Models (e.g., HUC12 local models)</td><td>Short-term (3-5-years): Use temporary cloud model storage
Long-term: Use TDIS system when it becomes available</td></tr>
</table>

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CENTRAL APPROACH (C): CENTRAL MODEL MAINTENANCE / CENTRAL IT

The central approach entails central H&H model maintenance and IT infrastructure. This approach allows central H&H and IT staff to serve all regions. However, as summarized in Table 19, lack of regional control may impede regional buy-in (and local funding support), and any central funding would be subject to changes in administrative priorities. While regional funding is also subject to changing priorities, relying completely or mostly on central funding would introduce a single point of failure to the LWI sustainability approach.

BLENDED APPROACH (B1): CENTRAL MODEL MAINTENANCE / REGIONAL IT

The first blended approach entails central maintenance of H&H models and regional management of IT infrastructure. This approach would allow some modelers to be shared across regions and would enable IT needs to be tailored to regional needs. However, this approach would suffer from the same downsides as the central approach, namely having modeling staff that lack region-specific knowledge, and potential for reduced regional buy-in and capacity building. This approach would also suffer from increased resource requirements to support regional IT infrastructure without the benefit of being able to synergize with regional model maintenance to better meet local modeling use, storage, and maintenance needs. Thus, this approach will not be considered in the remainder of this study.

BLENDED APPROACH (B2): REGIONAL MODEL MAINTENANCE / CENTRAL IT

In this blended approach, H&H model management, including model check out, model revisions, reviews and approval of model revisions, would be the responsibility of each region (implemented and overseen by LWI regional coalitions). State or federal agencies are expected to be consulted as needed to ensure alignment with extra-regional initiatives. IT infrastructure would be centrally management and share across regions for consistency and to also allow regions to focus on model use and maintenance. Lack of regional control over IT could be mitigated if regional governance organizations see clear benefits from shared IT infrastructure. It is noted that other variations of this blended approached could be formulated. For example, for regions that are not initially ready to take on management of their H&H models, such regions can be supplemented by some central H&H modelers who can provide additional H&H support in the interim until these regions build sufficient capacity. As such, this approach can be considered an “interim” approach for certain regions until a complete Blended Approach B2 can be fully realized.

REGIONAL APPROACH (R): REGIONAL MODEL MAINTENANCE / REGIONAL IT

A regional approach can benefit from the ability to bring local knowledge to bear on model use and maintenance for the purpose of quickly addressing local needs using IT that can be tailored to those needs. The downside of a regional approach is the greater potential for lack of consistency in IT implementation across regions, and increased resources and number of staff needed for implementation for IT infrastructure.

TDIS FEDERATED APPROACH PROPOSED BY TWI (TTF)

A “federated” approach to model use storage and maintenance was proposed by The Water Institute for the Gulf (TWI) in the April 21, 2021 memorandum on LWI Model Use, Storage, and Maintenance Considerations. Recommendation no. 3 of the TWI’s memorandum proposes the establishment of a data governance structure for maintaining data, models, and tools. The proposed structure is defined as follows:

> *A federated data governance structure extends upon a centralized IT infrastructure to partition the presentation of the system such that there is a common, broadly accessible set of data, model, and tools which are administered by the state of Louisiana, in addition to separate partitions for autonomous regional and/or local uses. It is critical that regions, parishes, municipalities, and other authorized local partners be able to control their own data, as the Draft MUSM Plan outlines. However, a federated approach preserves the utility of statewide and even multistate use cases while keeping options open for specialized, differentiated access for different types of users. Simply put, a federated approach is recommended with the needs of local stakeholders in mind. A federated approach combines the benefits of a fully centralized IT infrastructure system with the benefits of state and regional governance of data and eliminates the downsides of a purely regional—or a purely centralized—concept.*

Further, the TWI memo advocates that LWI adopt the data and model management system being developed in Texas as part of the Texas Disaster Information System (TDIS). TDIS is sponsored by The Texas General Land Office and is under development by the Texas A&M Institute for Disaster Resilient Texas (IDRT). The TDIS project is currently in the planning phase and is intended to support resilient decision making at the Texas state level. In the TDIS approach, LWI would operate a copy of the TDIS system that is autonomous from and interoperable with that used by TDIS. According to TWI’s proposal, IDRT may be contracted to operate the system for LWI. The LWI TDIS-operated system itself would be shared across LWI regions.

During the review process for this document, we received further clarification of the TDIS federated approach from Tayler Payne (who serves on LWI D&M TAG) from the Texas General Land Office, who said:

> *TDIS is a federated system. In a federated system, you can create any workflow to designate the authoritative data owner responsible for model (or dataset) updates. The benefit of the federated system is all of the other products that can be combined with the models to make them more useful.*

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According to information supplied by TWI and Texas Land Office, in the TDIS approach, LWI model storage and management would be subsumed into the broader decision support framework of TDIS. This implies that for LWI's purposes, the MUSM system will be a part of a larger set of systems that addresses decision support. However, according to the objectives of the MUSM plan, the focus is on the development of a MUSM platform that can be integrated with LWI decision support tools. Further, a key goal of the MUSM analysis is to define an initial phase of the system that can enable such integration through application programming interfaces (APIs) to support model discovery, retrieval, updating and versioning. With these fundamental pieces, any manner of integration with other LWI or non-LWI systems can be supported without requiring prior detailed design of every component in the overall decision support system. Only the general nature of the integrations need be known to allow the MUSM implementation to begin. As other systems are developed and integrated, the MUSM API details may need minor adjustments, but the fundamental architectural components of model discovery, retrieval, updating and versioning would remain. Thus, the proposed agile approach for developing the MUSM system is much preferred over traditional waterfall approach where detailed design of all components is done up front. With an agile approach, we begin developing the minimal system components that are known to be needed and adjust course as more is learned through integrating with other systems and adding additional functionality.

In addition to subsuming MUSM into broader model management and decision support discussions, the TWI-TDIS approach would run the risk of subordinating the needs of LWI and Louisiana to the needs of TDIS and Texas. This concern can be seen in review comments for an earlier draft of this very document from both D&M TAG members and LWI modeling consultants. For example:

> *TDIS is an ambitious long-term project intend* [sic] *to improve the entire planning process by arming decision makers with the information they need. Concern: TDIS has an established mission and vision, if the TDIS vision is not aligned with Louisiana priorities it would likely cause problems. If Louisiana only wants to store and maintain the models, than* [sic] *TDIS might not be the best option (although it should work for that).*

And:

> *I don't necessarily think that it is useful to rely on a different system (TDIS) as the MUSM would then be tied to factors that are outside of the control of this program. If there was a change in the TDIS, for example, how would that impact the effectiveness of the LWI efforts.*

Thus, using a system or system(s) primarily developed for TDIS, in part due to perceived or hoped for cost savings, would increase the likelihood that LWI stakeholders would go along with features developed to solve problems relevant to TDIS when those features may be less well-suited to solving problems relevant to LWI. It should be noted that collaboration with neighboring states (Arkansas, Mississippi, and Texas) can be accomplished with any of the central, regional, or blended approaches proposed in this report.

From the points of view of IT infrastructure and LWI regions, the TWI-TDIS approach does not appear to be an actual federated system where interoperable autonomous or semi-autonomous systems interoperate at the regional level. Instead, the proposed approach appears to be a centralized approach where the LWI HUC8 regional models would be managed and maintained centrally, while the regional entities would only be responsible for managing their own local models (separate from the LWI regional models). As explained by TWI (June 2, 2021 comment by TWI on the May 14, 2021 draft of the MUSM report):

> *A federated system could enable regional buy-in and allow for regional control of some models in the region (e.g., high resolution HUC12 models that likely will not be developed under LWI funding but were conceived early on in the program), with state agencies managing models required for state uses (e.g., those developed with LWI funding per DOTD's comments during TDQ meetings) though collaborating closely with regional/local partners (in a similar way that the state committee would exist in a central maintenance concept).*

According to this explanation, the TWI-TDIS approach appears to be a system where ***two tiers*** of models would be housed: (1) LWI regional HUC8 models, which would be managed centrally by the state; and (2) smaller/local high-resolution (e.g., HUC12) models that had already been (or would be) developed and paid for by regions or by local entities, outside of LWI, which would be managed by regions. Currently, the LWI modeling program does not include development of high-resolution or HUC12 models. Thus, this two-tiered system runs the risk of alienating regional stakeholders and thereby undermining the watershed-based approach of the LWI, which requires strong buy-in from regional stakeholders in parishes, cities, and towns that share watersheds.

As discussed above, a true federated system architecture entails the interoperation of autonomous or semi-autonomous systems that will be able to share data via a common data model and APIs. These autonomous systems can be operated with distinct policies that dictate who can and who cannot access these systems as well as who can or cannot perform particular model workflow functions (e.g., download models, submit revised models for review, approve revised models, etc.). In essence, the TWI-TDIS approach is similar to the central approach (C) described above with the exception that the regional approach does not impose a two-tier model maintenance system where regional LWI models would primarily be maintained by state and federal agencies. It should be noted that collaboration with neighboring states (Arkansas, Mississippi, and Texas) can be accomplished with any of the central, regional, or blended approaches proposed in this report.

In the sections that follow, the proposed model management system design approach will be further discussed, including consideration of the following elements:

- More detail on the "what" of MUSM implementation:
    - Model maintenance workflows;
    - Architecture for model management system;

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- Detailed discussion of the "how" of MUSM implementation:
    - Implementation strategy;
    - Resource requirements for system development;
    - Resource requirements for deployment, operations, and maintenance;
    - Needs for regional and local capacity building; and
- Finally, next steps.

MODEL MAINTENANCE WORKFLOWS

For LWI models to be usable over the long term for informing flood mitigation and adaptation strategies, regional and local entities must be central to and heavily involved in the use and maintenance of the models. Model maintenance entails making regular updates to models to reflect ongoing changes in each watershed (e.g., land use change, new developments, implementation of flood control structures such as regional detention storage). A suggested workflow for such modifications is depicted in Figure 7. A brief overview of model use and maintenance workflows follows:

- Models will be checked out from model repositories (either central or regional). Models are then modified by local, regional, or state users (e.g., consulting engineers, city, parish, or state agency engineers, regional modeling coordinators)
- After modifications are implemented, models should undergo technical review and be verified by LWI-affiliated entities (e.g., regional coalitions, state, regional and local agencies) who have experience in modeling and detailed knowledge of local watersheds and drainage intricacies. As part of this review, regional reviewers are expected to consult with state or federal agencies to ensure consistency with relevant state and federal modeling standards. The purpose of the technical review is to ensure that the changes are properly implemented and adequately documented, and as such, result in models that conform to local ordinances, are aligned with applicable LWI modeling standards, or other state or federal modeling standards or regulations. These reviews should also include representatives from two or more watersheds in the region to ensure that model standards are implemented uniformly across the region. It is anticipated that a dialogue would be established between the reviewing entity and the developer or local engineer proposing the new development to resolve issues and until the development is in compliance with local ordinances. It is expected that more details on the check-out and check-in process will be developed at a later stage of the MUSM effort and in collaboration between LWI, regional entities, and state agency model users.
- The MUSM workflows are related to the LWI monitoring and observation system. The hydrologic data generated by the observational gauge network should be used by those maintaining models to improve the calibration and validation of H&H models through periodic updates.
- The general public will have access to the system. The general public may be interested in using the MUSM system to view the status of flood modeling studies in their area, and to be updated when model updates are available. The use of the system in this manner by the general public is critical to foster transparency and garner long-term support for this effort.

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- The academic and science community will also have access to the system and support it in various ways, including: (a) offer periodic recommendations and input on updates and upgrades as the state of knowledge and modeling evolve; (b) participate in training and continuing education programs; and (c) engaging students in these activities to create new generations of technical expertise at the local and regional level.
- The Performance measures component of the workflows refers to a set of evaluation tools to ensure models comply with regulatory standards, technical standards (e.g., LWI Guidance on Modeling Methodology), and effectively providing the services and utilities intended. These quantitative tools will provide the foundation for periodic improvements and upgrades to the system.
- Two key components of the workflows are the Statewide Standards Advisory Committee and the Federal & State Advisory Committee. The former is composed of representatives from each of the eight watershed regions. The primary role of this committee is to ensure consistency among the eight regions in terms of quality and standards. The committee will also help to exchange knowledge and lessons learned among members. The Federal & State Advisory committee will provide high-level input and feedback to the various regions on topics related to federal and state regulatory issues, and possible funding streams.

In some regions and localities, implementing regional aspects of the model use and maintenance workflows will require significant investment in capacity building. However, this capacity building is key to enabling ongoing use of models in flood policy implementation (see Regional capacity needs section below). It should be noted that the models stored in the model repository (which is part of the LWI model management system; see Architecture for model management system section) are envisioned to be accessible to potential model users at the local, regional, state, and national levels.

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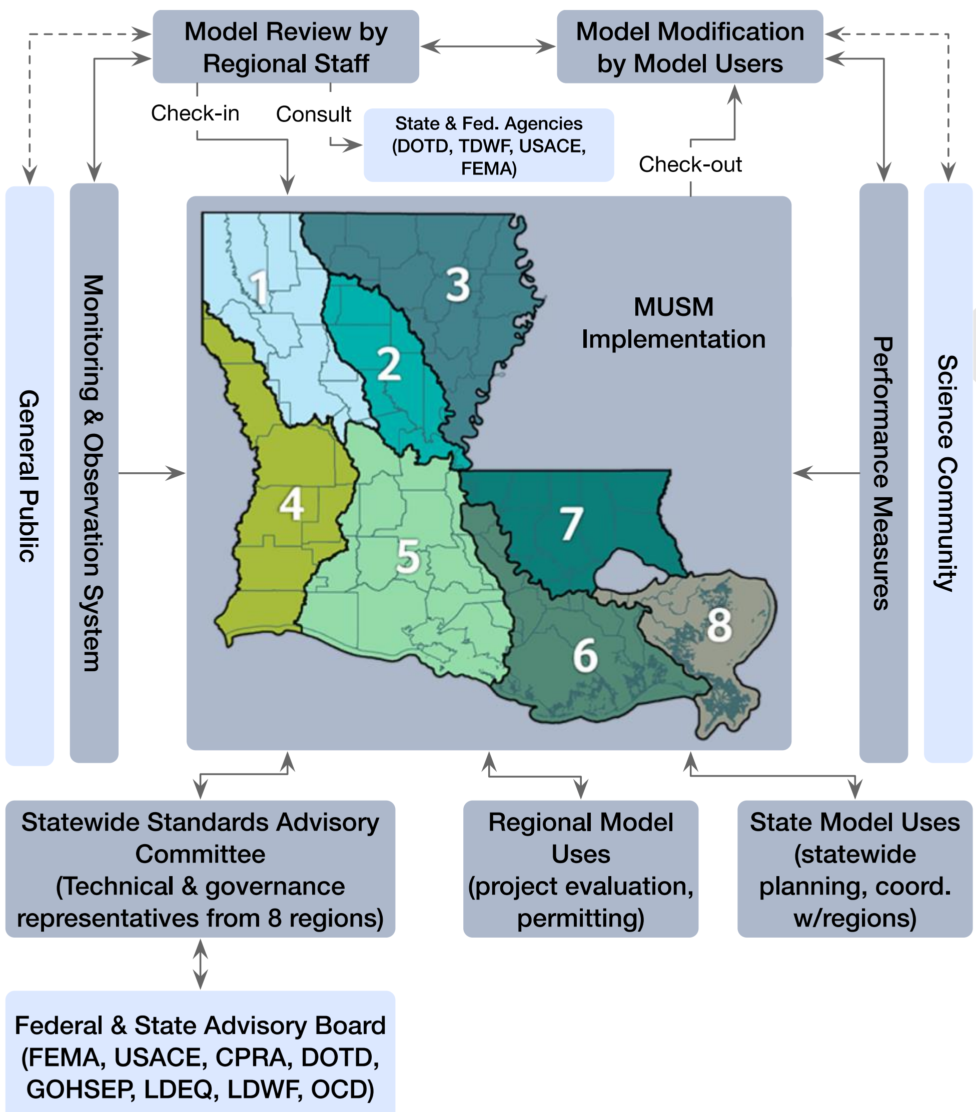

Figure 7. Model maintenance workflows driven via local and regional capacity, regional coordination, with state support and alignment, as well as federal alignment. The numbers in each region of the map (i.e., 1 through 8) represent LWI regions.

PROPOSED MODEL USE, STORAGE, AND MAINTENANCE SYSTEM ARCHITECTURE

The following proposed model use, storage, and maintenance system architecture is chiefly informed by the key takeaways from the review of existing systems (see section "Key takeaways from review of existing systems" above). To reduce the risk of developing a model management system that fails to meet user needs, it is important to use a software architecture that allows for incremental delivery of features and enables easy expansion in the future. Incremental delivery reduces project risks by enabling system functionality to be designed and implemented as specific user needs are understood, rather than trying to design the entire system ahead of time, and then implementing functionality to support requirements that may have changed since their design was completed. This will allow LWI to provide value to model users earlier while also making user feedback continuously available to inform the design and development of subsequent features. Easy expansion will enable more cost-effective changes or additions to system capabilities after initial work on the system has been completed while providing flexibility to use multiple teams to perform the work.

A service-oriented architecture is a popular approach that allows for both incremental delivery and easy expansion by breaking the system into self-contained components for each major function (e.g., model storage, model retrieval, model catalog, and model review workflow, etc.) with well-defined machine-addressable Application Programming Interfaces (APIs) to facilitate communication between services and with outside systems (Figure 8).

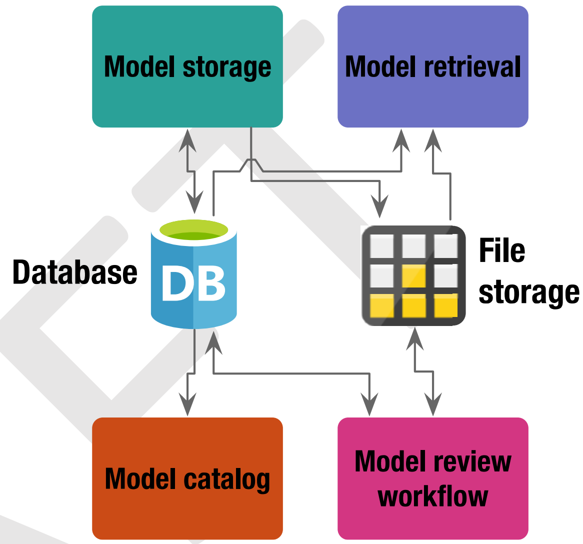

Figure 8. Core services of potential service-oriented architecture of LWI model management system. Arrows indicate data flow between components.

Each component of the suggested service-oriented architecture is discussed in the subsections that follow. Note that these services could be developed as a monolith or as separate pieces of software deployed independently to multiple servers. Each service will provide a Representational state transfer (REST) interface to allow interaction with the service. The LWI model management system will also need to include one or more web-based user interfaces to allow users to use the services. Note that a single user interface may interact with more than one service.

Common core components of the architecture include a database as well as a file storage system capable of storing large volumes of model data (e.g., ca. 100 GB per model). Other common components (e.g., authentication and authorization services, load balancing, etc.) are not shown but are likely to be needed in the final design. The database system can be implemented as a relational database management system (e.g., PostgreSQL, MariaDB, etc.). Given the geospatial nature of some metadata and data associated with LWI models, a database with strong geospatial data support is recommended (i.e., PostgreSQL). The file storage system could be implemented using an object storage product provided by a commercial cloud provider, though other options can be considered as well (e.g., block storage, on-premises storage, etc.).

MODEL STORAGE

The model storage service will be responsible for registering new models or new versions of existing models with the system, and for maintaining a history of model versions. Model registration primarily involves recording metadata for a model (e.g., name, region, watershed identifier, contact information of model developer, etc.) into the model management system database. Model metadata will be used by other services to interact with models (e.g., model search, model retrieval, and model review workflow engine). The model storage service should also allow for the creation of new versions of an existing model. When a new version is created, the old version should be linked to the new version so that previous models can still be accessed. It may also be required that the service should allow only certain users to access previous models. Further, to save on storage costs, the storage system may also need to facilitate moving model data to lower-cost higher-latency archival storage solutions.

In addition to storing model metadata, the model storage service will also be responsible for storing model data in the file storage system used by LWI model management system. Given the large volume of data associated with each model (e.g., ca. 100 GB), synchronous upload of model data directly to the model storage service will not likely be reliable or performant. Instead, the model managers wishing to store models with the model management system will likely need to upload the data to cloud storage themselves (e.g., Amazon S3, Backblaze B2, Wasabi, Box, Dropbox, etc.). Then, as part of registering a model with the system, they can direct the model storage service to asynchronously copy the data, on the user's behalf, from the original upload location to the LWI model management system file storage system. Integrating with arbitrary third-party cloud storage providers is possible, but doing so will add complexity and expense to the model storage service that may not be warranted. An alternative would be to provide write-only scratch space within the model management system's file storage system so that users can upload their models there using third party tools (e.g., CloudBerry, Cyberduck, S3 Browser, etc.) and then refer to the uploaded model while registering model metadata. Then the model storage service can move the model data into permanent storage and update the model metadata with its new location. Data uploaded to the write-only drop box can be automatically deleted after a period of time (e.g., 24-hours, three-days, one-week, etc.) to reduce storage costs.

MODEL CATALOG

The model catalog service is responsible for enabling browsing and searching of models (i.e., discovery). The service will allow select model metadata necessary for discovery (e.g., name, region, watershed identifier, geographic location and extent, etc.) to be queried in ways necessary to support common model catalog user interfaces, including, but not limited to: (1) web-based geographic map (enabled by a GeoJSON view of model locations); and (2) hierarchical list of models in each region (enabled by querying select metadata for all models, or filtering by region, or other attributes).

Model catalog application programming interfaces (APIs) will allow integration of LWI model management system(s) (either deployed regionally or centrally) with other LWI systems (e.g., **All Things Flood** Portal) as well as third-party model management systems in neighboring states (e.g., Texas) or at federal agencies (e.g., FEMA, USACE, etc.).

MODEL RETRIEVAL

The model retrieval service is responsible for allowing model contents to be retrieved. Depending on the model retrieval requirements as well as how the file storage system of the LWI model management system is implemented, downloading of model contents over HTTPS may already be provided by the underlying storage solution (e.g., Amazon S3), obviating the need for the model retrieval service. However, if the requirements for model retrieval are more sophisticated (e.g., protocols other than HTTPS, restricting access to certain models or model versions), then the model retrieval service will need to be developed to support these requirements. It should be noted that the model retrieval service could be implemented and deployed alongside the model storage service as a single service as these services may share many components.

MODEL REVIEW WORKFLOW

The model review workflow service handles the specification and execution of the LWI model review workflow. This is not intended to be a general workflow engine. Rather, it will provide a simplified approval workflow that ensures that the appropriate people are notified of the need to review model changes. Once an updated model is "routed" for approval, the review workflow service could provide the following functionality: (1) viewing approval workflow status; (2) canceling approval workflow in progress; (3) providing documentation of review and review approval or rejection by one or more reviewers; (4) notifying model revision submitters of model review result (e.g., denied, approved); and (5) automatically publishing approved revised models and archiving the previous model version (though this could be modified to require final sign off by a system administrator before publishing).

RELATIONSHIP TO OTHER LWI SYSTEMS

We envision the MUSM system being independent from other LWI systems such as the All Things Flood Portal and data repository. However, the APIs of the MUSM system, in particular the model catalog service, will enable systems like the All Things Flood Portal to allow discovery of and linking to models managed by the MUSM system. As part of the prototyping phase of MUSM system development, we recommend that consideration be given to how the All Things Flood Portal will need to integrate with the LWI model management system (e.g., what queries and data will the portal need to make). In addition, this linkage should be explored further in the Phase II of MUSM planning and development.

IMPLEMENTATION STRATEGY

The LWI model management system implementation strategy could use a phased approach (Figure 9) with Phase I being this report, Phase II being the development of the MUSM prototype, and reference design and development (including developing a report planning logistics and estimating costs to launch, operate, and maintain the MUSM systems), and phase three being deployment of the MUSM reference design to allow model use, storage, and maintenance over the long term by all LWI stakeholders.

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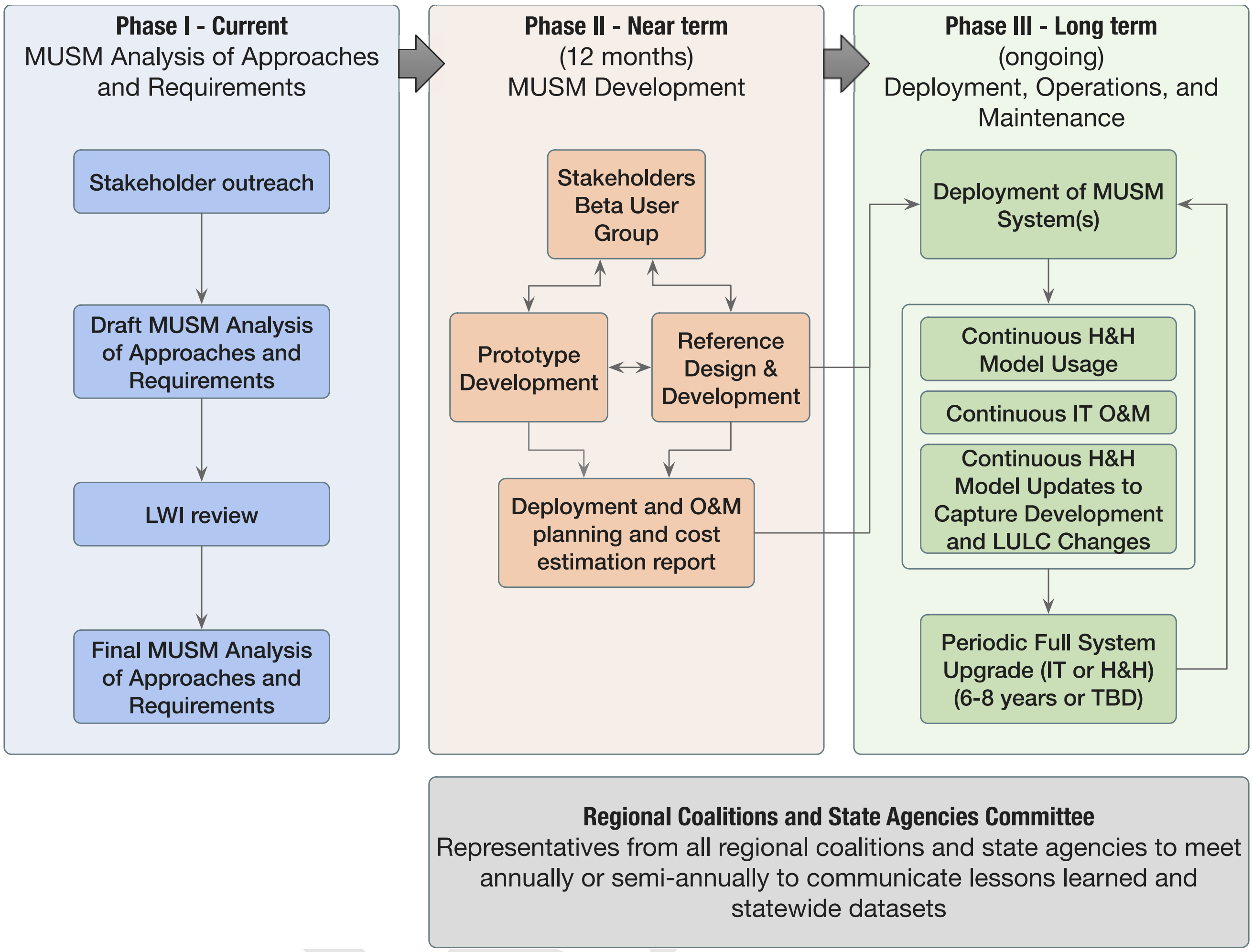

Figure 9. Conceptual overview of proposed phased development and implementation of LWI model management system.

The proposed phased approach to model management system implementation is described in the next sub-section.

PHASED APPROACH TO MODEL MANAGEMENT SYSTEM IMPLEMENTATION

We recommend a three-phase approach to the development and implementation of a LWI model management system that is flexible and meets the needs of diverse stakeholders across LWI regions while ensuring that resources are used wisely, and duplications of effort are reduced (Figure 9). The first phase of this process is the development and revision of the MUSM alternatives analysis found in this document.

The second near-term phase (over the next twelve months after phase one is complete) involves the development of a prototype model management system. This prototype should include the core tasks of storing, cataloging, retrieving, and updating models. ***Discussions with USACE and FEMA (see Results of interviews with USACE and FEMA above) revealed that USACE is currently developing an open-source Model Library system***

that would address many of the MUSM needs of the LWI modeling program. Leveraging the USACE Model Library as a starting point for the LWI prototype model management system would likely save time and require fewer resources than creating a system from scratch. It would also bring the potential to harmonize LWI efforts with model housing practices at the federal level. The Model Library is also compatible with the proposed LWI MUSM architecture (see above) and does not pose any restrictions on regional vs. central vs. blended MUSM approach.

The Model Library is designed to integrate with HEC-HMS and HEC-RAS models stored in existing cloud-based repositories, such as the short-term AWS S3 storage being used by LWI currently, without requiring model data to be organized in any particular way. This flexibility makes incremental adoption of the system possible without requiring data to be moved or reorganized, which could incur cloud data transfer fees if done incorrectly. Thus, while the LWI model management system is being developed in the prototyping and subsequent phases, the short-term LWI AWS S3 storage can continue to be used as an interim model housing solution.

The prototyping process will be important in the discovery of system design requirements such as how models are to be stored, what model metadata needs to be indexed and thus searchable, how versioning and model check-in, and check-out can be most simply implemented to meet regional model maintenance workflow needs, etc. The development of the prototype would be carried out by an IT consultant in collaboration with the LWI stakeholders beta group (see below for description of this group). The purpose of the prototype is to learn more about how to provide for model housing and maintenance needs in a way that is accessible to all regional stakeholders while working toward the development of a usable system that users can try out, in an adaptive or agile fashion, as features are being developed.

The LWI stakeholders beta group should be comprised of representatives from each LWI region as well as from state agencies and their designees. The beta group will be instrumental in helping the software development team to develop and test detailed software features as well as user interface/user experience (UI/UX) designs. The user group will also be critical for performing user acceptance testing (UAT) once software features have been implemented and before they are completed.

Once the prototype has been completed, the IT consultant will work with the stakeholder beta group to evaluate what works well with the prototype and what needs to be changed to better suit the needs of regional MUSM users. This evaluation will be used to further develop, in collaboration with the stakeholder beta group, the prototype LWI model management system into a reference system design. The reference design is intended to be deployable either centrally or in two or more regional instances for use by LWI regions and used to support their model, use, storage, and maintenance programs. The reference design is also intended to be flexible in terms of deployment model, allowing centralized as well as regional deployment if one or more regions decide it is beneficial to host their own model management systems the future. In addition to enabling the core tasks of storing, cataloging, retrieving, and updating models, the reference design should include comprehensive system documentation (including tutorials to help beginners get started, how-to guides to show how to solve specific problems, and reference documentation of APIs) as well as automated test suites (including: unit, functional, and integration or end-to-end tests of back-end and user interface components).

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Once the reference LWI model management system has been developed, phase three of the LWI model management development approach can begin. Phase three will focus on implementing the reference LWI model management system onto cloud-based IT infrastructure. Depending on the final recommendations adopted by the LWI program, the MUSM reference design and its infrastructure could be centrally implemented, or implemented distinctly by each region, or shared among one or more regions if those regions so desire. Once deployed, the reference model management system would provide a common baseline of functionality necessary for supporting continuous model use, storage, and maintenance, while enabling interoperability across all LWI regions. The system would also support periodic full updates to H&H models, for example every six- to eight-years. Given the need to fix bugs and maintain system integrity amidst evolving cybersecurity threats, the model management system deployments would require continuous software maintenance after development of the reference design. Larger model management system updates (re-platforming or re-architecting) may also need to be carried out on a similar timeframe to periodic full updates of H&H models (i.e., approximately every five- to seven-years). LWI regions would be free to collaborate on both continuous software maintenance of as well as major updates to the LWI reference model management system (e.g., using peer-to-peer collaboration tools like Git to disseminate bug fixes and security updates).

It should be noted that it will be beneficial for LWI to sponsor the creation of a MUSM advisory committee composed of regional coalitions and state agencies to help guide implementation of MUSM program (both regional H&H modeling and central IT implementation). We envision this committee operating during phases two and three (see grey box at the bottom of Figure 9) and potentially meeting annually or semi-annually to provide oversight and guidance.

Details of the LWI model management system implementation strategy are described in the following sections: (1) stakeholder “beta” user group; and (2) technology considerations.

STAKEHOLDER “BETA” USER GROUPS

To successfully apply an agile software development approach for the development of the LWI model management system, it is necessary to have a group of people who represent the needs and interests of the eventual users of the system. This “beta” user group will be instrumental in helping the software development team to develop software features as well as user interface/user experience (UI/UX) designs. The user group will also be critical for performing user acceptance testing (UAT) once software features have been implemented and before they are accepted as complete into the software codebase.

There are two levels of user group suggested. The first level is a small group of approximately 12 stakeholders (i.e. at most one per region, plus additional representatives from state agencies or their designees) who will commit to providing in-depth guidance on the development of the model management system prototype, including attending bi-weekly Agile meetings (e.g. sprint reviews and retrospectives). We anticipate that participation on this development stakeholder team will require a time commitment of four- to six-hours per week per participant over the 12 months of the development of the MUSM system prototype and reference design development.

The second level beta user group will be composed of a larger group of LWI regional and statewide stakeholders (ca. 20 people across all regions) who will periodically perform testing and review of the LWI model management prototype and reference design. We anticipate the time required of participants of this testing stakeholder team to be four- to eight-hours every six weeks (i.e. every three Agile sprints) over the 12 months of the development of the MUSM system prototype and reference design development.

The development and testing user groups of the beta user group would ideally be composed of members of the Statewide Standards Advisory Committee and the Federal & State Advisory Committee (see above), for example: (1) one to two members per region of LWI regional steering committees (or successor organizations); (2) one regional watershed coordinator for each region; and (3) one or more staff members from agencies of the Council on Watershed Management. Modeling consultants who are developing LWI models as well as educators and researchers from regional universities should also be included in beta user group.

TECHNOLOGY CONSIDERATIONS

To reduce duplication of IT effort, the deployment of the LWI model management reference design can be standardized and automated using a combination of cloud computing, containerization, and infrastructure as code. Cloud computing has rapidly matured over the last decade to provide cost effective pay-for-what-you-use IT infrastructure such as computation servers (i.e., virtual machines), storage, and networking using hardware and software managed by cloud providers. Containers (e.g., Docker, LXC) provide lightweight virtualized software environments that include executable documentation of all the software required to run one or more software services. Infrastructure as code (IaC) allows for IT storage, computation, and networking infrastructure to be provisioned and managed using machine-readable scripts (rather than by using hard-to-replicate interactive configuration tools). Together, cloud computing, containerization, and IaC will allow the LWI model management reference system to be rapidly and reproducibly instantiated either centrally or in multiple modeling regions.

RESOURCE REQUIREMENTS: SYSTEM DEVELOPMENT

SOFTWARE DEVELOPMENT TEAM

Developing the reference LWI model management system is estimated to take 12-months for a team of two software developers, one user experience designer, one Agile scrum leader, and a project manager or product owner. One of the software developers would focus on developing back-end services, with one developer focused on building web-based front-end user interfaces, or one or both developers could be full-stack developers who could work on either front-end or back-end components as needed. One or both of the developers should have some experience with: data engineering and geospatial data management. An Agile scrum leader is critical in day-to-day project implementation, performing tasks such as creating a backlog of user stories for each two-week sprint, organizing and running daily stand-up meetings as well as bi-weekly sprint meetings (reviews and retrospectives), and for liaising with a project manager/product owner (PM hereafter),

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who would primarily be responsible for coordinating the stakeholder user group. The PM would also be responsible for developing user requirements as a series of user stories. Total staff expenses to develop the prototype and reference LWI model management systems—four-and-a-half full-time equivalent employees (two developers, one-half-time user experience designer, one scrum leader, and one PM) for 12-months—is estimated to cost $785,200 (Table 21).

Table 21. Estimated cost of software development team to implement MUSM prototype and reference design over 12-months. Note: all hourly rates are assumed to be fully loaded and based on estimated yearly salary, including overhead/margin.

Role	**Number in role (FTE)**	**Est. consultant hourly rate**	**Est. consultant cost**
Software developer	2	$75.00	$312,000
User experience designer	0.5	$75.00	$78,000
Scrum leader	1	$90.00	$187,200
Product owner/project manager	1	$100.00	$208,000
Total	**4.5**		**$785,200**

PROJECT MANAGEMENT TOOLS AND TEMPORARY CLOUD HOSTING

In addition to staff requirements, development of the prototype and reference design would require budget for Software as a Service (SaaS)-based project management tools, as well as cloud hosting resources to host LWI model management system prototype and reference design systems. These cloud resources would be needed temporarily during development and for as long as the prototype and reference systems are operated by LWI after initial development (i.e. before deployment for use by regions). The software development team would need full control over this cloud hosting environment so that they can rapidly instantiate resources as needed, rather than having to wait for a third-party to create resources for them (which could substantially delay development and increase costs). Costs for project management tools and cloud hosting for 12-months is estimated to be $15,000.

STAKEHOLDER “BETA” USER GROUPS

Estimated costs of stakeholder “beta” user group involvement in the LWI MUSM prototyping and reference system development are summarized in Table 22. We estimate the cost of staff time for the development beta group to be $115,200 (12-people working eight-hours per week for 24-weeks, at a fully loaded rate of $50 per hour). Staff time for the testing beta group is estimated to be $64,000 (20-people, working eight-hours per week for eight-weeks, at a fully loaded rate of $50 per hour). These user group effort and costs are assumed to be distributed more or less evenly throughout the 12-month development time period.

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Table 22. Estimated cost of stakeholder "beta" user groups during 12-month development of LWI MUSM system

User group	Number in role	Hours per week engaged	Weeks engaged	Total hours	Est. staff hourly rate	Est. staff cost
Development beta group	12	8	24	2,304	$50.00	$115,200
Testing beta group	20	8	8	1,280	$50.00	$64,000
Total						**$179,200**

SUMMARY OF DEVELOPMENT COSTS

The total cost for developing the LWI model management system is estimated to be $965,900 (Table 23). This includes the $785,200 for direct development costs, $179,200 in staff time for the stakeholder "beta" groups, and $1,500 for temporary cloud hosting and project management tools.

Table 23. Summary of estimated LWI MUSM prototyping and reference system development costs over 12-months.

Item	Cost
Development team	$785,200
User groups	$179,200
Temporary cloud hosting and project management tools	$15,000
Total	**$979,400**

Developing the prototype into the reference design of the LWI model management system should include the following elements (in addition to the functional features of the system): (1) documenting the system for future developers and operations teams; (2) additional automated test code to ensure that key functionality is adequately tested; (3) building robust infrastructure as code (IaC) scripts to make future deployment rapid, predictable, and reliable; (4) ensuring security policies are sufficient to protect data integrity of models and personally identifiable information of users, and that those security policies are being properly applied to cloud-hosted computing resources.

RESOURCE REQUIREMENTS: DEPLOYMENT, OPERATIONS AND MAINTENANCE

Once the reference design of the LWI model management system is developed, additional resources will be required to deploy the system either centrally or regionally. Once the system(s) is deployed, operations and maintenance (O&M) resources will be needed to ensure that LWI models are living models and to protect the investment made in these models. The major O&M resource requirements are, in descending order: H&H

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modelers, IT personnel for model management operations, and software maintenance for bug fixes and security updates to model management system. These resources support specific LWI model management system functions as summarized in Table 24. If a given LWI model management system function is deemed to be not needed, then the corresponding O&M resource requirement(s) could be reduced or eliminated.

Table 24. Summary of LWI model management system primary functions and corresponding operations and maintenance resources needed.

LWI model management system function	O&M resources needed
Model use	• H&H modelers
Model storage and cloud infrastructure operations	• IT personnel
Model upgrades and maintenance	• H&H modelers • Software maintenance consultants • IT personnel

Operations and maintenance funding will support: (1) H&H modeling; (2) IT personnel to deploy and manage cloud resources; (3) cloud storage needed to store LWI models; (4) cloud computing and networking needed to host LWI model management system servers (this does not include the ability to execute model scenarios, which is outside the scope of the MUSM system); and (5) maintenance of LWI model management system software codes (e.g. bug fixes and security updates). Each of these resource requirements are described in detail in the following sub-sections.

Table 25 summarizes three approaches that have been developed for these resource requirements: (1) central (C) approach using centrally managed H&H models and IT infrastructure; and (2) regional (R) approach using regionally managed H&H models and IT infrastructure ; and (3) blended approach (B2) using regionally managed H&H models and centrally managed IT. Within each approach, two staffing options are explored: (1) H&H modeling and IT administration provided by regional coalition or state agency staff; and (2) H&H modeling and IT administration provided by consultants. Within these sub approaches, first and second year costs are distinguished to account for increased IT personnel required during the first year to deploy LWI model management system, and the need during subsequent years for model management system software bug fixes and security updates. All labor rates are based on actual recent rates for consultants in Louisiana and salaries (including benefits and overhead) of regional/state employees. Refinements and further details will be included in Phase two of the MUSM system development.

Table 25. Summary of deployment, operations, and maintenance costs for different MUSM approaches. Costs are LWI program-wide totals. Estimated costs for individual regions are shown in Table 29 and Table 30 in this document.

Staffing Option	Program-Wide Costs	Central Approach (B2) (Central IT, central H&H)	Blended Approach (B2) (Central IT & regional H&H)	Regional Approach (R) (Regional IT & regional H&H)
Regional/central agency staff	**Total 1st year cost**	$2,855,054	$3,245,054	$3,666,451
	Total subsequent year cost	$2,823,854	$3,213,854	$3,427,251
Consultants	**Total 1st year cost**	$6,116,494	$6,980,734	$7,818,131
	Total subsequent year cost	$5,877,294	$6,741,534	$7,162,931

Descriptions of these approaches are found in the sections that follow and are summarized in Table 29 and Table 30. Detailed calculations and assumptions behind these approaches can be found in the Excel spreadsheet titled "MUSM_CostEstimation_OandM-2021-04-28.xlsx" available in the supplemental materials.

H&H MODELERS NEEDED PER REGION

The number of H&H modelers needed for regional model use and maintenance implementation was determined by considering three criteria of each LWI governance region: (1) number of HUC8 watersheds to be modeled in the region; (2) total area of the HUC8 watersheds to be modeled in the region; and (3) average percent impervious area in HUC8 watersheds in the region (used a proxy for urbanization and the amount of development to be evaluated using LWI models). Results of these criteria are listed in Table 26. Given these criteria, the following regions are estimated to need three H&H modelers: one, three, four, five, six, and seven. Region two has somewhat smaller number of HUC8s to model, average HUC8 area, total HUC8 area, and percent impervious than average, so was deemed to need fewer H&H modelers (two) than most other regions. Region eight was determined to only need one modeler as it contains only one HUC8 to be modeled, and its high degree of impervious is largely the result of Orleans Parish, which by and large cannot use HEC-HMS and HEC-RAS models for permitting decisions due to high degrees of piped and pumped stormwater infrastructure (which require models such as SWMM outside the scope of the LWI modeling program). It is important to note that the MUSM team envisions region-based modelers becoming H&H modeling resources to their regions, supporting the gamut of activities of the LWI modeling program from: accessing models, to running and using models for permitting and planning purposes, to modifying, and reviewing model updates.

Table 26. Derivation of estimated number of H&H modelers needed per LWI governance region and statewide

Governance Region	Number of HUC8 models	Average HUC8 area in LA (km2)	Total HUC8 area (km2)	Avg. % impervious	Number of H&H modelers (FTE)
1	10	1,580	15,801	1.89	3
2	5	2,007	10,035	0.82	2
3	8	2,421	19,372	1.08	3
4	8	2,261	18,087	1.47	3
5	5	5,281	26,405	1.68	3
6	3	5,715	17,145	2.00	3
7	8	1,724	13,792	2.63	3
8	1	8,962	8,962	2.33	1
Regional Total	**48**	**n/a**	**129,600**	**n/a**	**21**
Regional Average	**6**	**3,744**	**16,200**	**1.74**	**2.625**
Central H&H program					**18**

For the Central Approach (C) H&H program implementation, it is estimated that some economies of scale could be achieved resulting in 18 total H&H personnel being required for the entire state compared to 21 total H&H personnel for the regional H&H program implementation (Table 26). This includes one H&H modeler located in each LWI governance region (eight total), and 10 H&H modelers centrally housed. The eight regional H&H modelers are critical to drawing local knowledge and can help to build some degree of local capacity. The 10 centrally housed H&H modelers would be responsible for assisting LWI regions with model usage and maintenance. The assumption behind 18 central or 21 regional FTEs is that LWI models will be made part of the process of reviewing and approving permits for development. This is an effective way to ensure the models will continue to reflect the LULC changes. These FTEs will also be managing a suite of local models derived from the HUC8 models. This number of the FTEs is estimated to be what is needed to keep up with model use and medication demands and is in line with the number of modeling FTEs at various municipalities.

If the regional H&H modeling were to be carried out by staff members of LWI regional coalitions (Table 29) yearly costs are estimated to be $2,730,000. Under the Central Approach (C) H&H modeling approach, the yearly costs are estimated to be $2,340,000. For consultants to implement a regional H&H program with 21 total H&H modelers, the yearly costs are estimated to be $6,049,680; a centralized H&H program staffed by consultants is estimated to cost $5,185,440 per year. (Table 30). In addition to costing substantially more, implementing the H&H modeling program primarily with consultants would seem to work against the goal of building regional capacity for LWI model use and maintenance.

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IT PERSONNEL

IT personnel are necessary for provisioning and maintaining the cloud storage, compute, and networking resources needed to store and support the download (check-out), uploading (check-in), and versioning of LWI models. IT personnel resource requirements for both regionally and centrally administered cloud resources are summarized in Table 29 (assuming IT personnel are staff members of LWI regional coalitions/state agencies) and (assuming consultants are used to fill IT personnel roles). For either regionally or centrally administered cloud resources needed to support LWI model management, it is likely that more resources will be required during the first year due to additional work needed for initial provisioning and configuration of resources.

For regionally administered cloud resources, first-year IT personnel resources are estimated to be one full-time equivalent (FTE) per region, with a total cost across regions of $832,000 for the staff option, and $1,664,000 for the consultant option. In subsequent years, it is estimated that 0.5 FTE would be required for ongoing cloud resource O&M, with an estimated total cost across regions of $416,000 for the staff option, and $832,000 for the consultant option. It is recommended that for the staff options, the FTE resources be distributed among two-to-three staff members of LWI regional coalitions to allow for time off and redundancy. It is assumed that these IT staff members would be staff of existing regional organizations such as regional planning commissions, thus one- to two-FTE can be distributed across multiple people.

IT personnel resource needs for centrally administered cloud resources would garner substantial economies of scale, with an estimated 4 FTE needed for the first year, and 2 FTE needed for subsequent years. If this work were done by staff of a centralized entity, the first-year cost is estimated to be $416,000, and $208,000 for subsequent years. If this work were to be done by consultants, it is estimated to cost $832,000 and $416,000 for the first and subsequent years respectively.

CLOUD STORAGE

Estimates of data storage volume requirements for LWI H&H models were made using the Amite River Basin H&H models as a reference (Table 27).

Table 27. Estimation of LWI H&H model data size requirements per unit HUC8 area (GB per km^2)

Area of Amite HUC8 in LA (km^2)	3,385
Data size of Amite HMS and RAS models (GB)	148
Data size per unit HUC8 area (GB/km^2)	0.043657

Using the estimated H&H model data size per unit HUC8 area calculated above, estimated data storage requirements for each LWI region were calculated using the total in-Louisiana area of HUC8s to be modeled per region (Table 28). In addition to storage required for the base model, we assume that storage will be required for a total of 21 versions of the model at any one time. The final row of Table 28 shows the total estimated storage requirements per region and across all regions in terabytes (TB) per month (it is assumed that the cloud storage volume required to store and make available for download LWI H&H models will be the same regardless of whether the IT resources and H&H modeling are managed regionally or centrally).

Table 28. Estimated LWI H&H model storage requirements by region.

	State-wide / Regional total	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
Number of HUC8	48	10	5	8	8	5	3	8	1
Total area of HUC8s in LA (km^2)	129,600	15,801	10,035	19,372	18,087	26,405	17,145	13,792	8,962
Est. total model size (GB)	5,658	690	438	846	790	1,153	749	602	391
Est. total storage size (TB)	5.66	0.69	0.44	0.85	0.79	1.15	0.75	0.60	0.39
Est. number of versions per model	21	21	21	21	21	21	21	21	21
Est. total storage size for all versions (TB) per month	**118.82**	**14.49**	**9.20**	**17.76**	**16.58**	**24.21**	**15.72**	**12.64**	**8.22**

It should be noted that storage requirements are likely to be lower during the first few years of the LWI modeling program as not all models will be completed upon launch of the LWI model management system, and not all models will have multiple versions stored.

Total estimated costs for cloud storage for each region and statewide are summarized in Table 29 and Table 30 (note that storage estimates do not differ between staff and consultant implementation estimates). These costs include the cost of the storage requirements summarized in Table 28, as well as data retrieval (i.e. bandwidth) costs for downloading as well as querying the data (for details see the Excel spreadsheet titled "MUSM_CostEstimation_OandM-2021-04-28.xlsx" available in the supplemental materials). For the sake of this estimate, it is assumed that 50% of stored model data would be downloaded per month. Standard commercial rates for Amazon Web Services (AWS) S3 standard frequent access cloud object storage (US East region) were assumed in all cost estimates; on-premises storage provided by Louisiana Office of Technology Services (OTS) is estimated to cost 232-238% more than storage procured directly through AWS (based on the rate of $0.64/GB cited by state agency members), however this only accounts for storage costs, not data transfer costs (it is unclear whether or how OTS accounts for bandwidth costs for its hosted storage). AWS storage provisioned through OTS is subject to a 20% markup.

Given the estimated volume of storage and current S3 pricing structure, there would be roughly 3% savings from storing all LWI H&H model data under the same AWS account as the first pricing tier is 50 TB per month, with a

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slightly lower price for the next 450 TB per month stored. Storage costs could also be reduced by using S3 infrequent access storage tiers for archived versions of LWI models, however these options were not explored in the current estimate due to lack of knowledge over how often old model versions would need to be accessed. As such the current estimate errors on the high side to provide a conservative estimate. It may also be possible to reduce cloud storage costs by using third-party S3-compatible cloud storage such as Backblaze B2 or Wasabi cloud storage. However, for simplicity's sake, we recommend using cloud object storage solution integrated with the other cloud compute and networking infrastructure (see below) used to host the LWI model management system servers. Additionally, AWS offers grants under its Open Data on AWS program, which could mean LWI models could be stored at no cost. Finally, we recommend that costs for cloud storage should be re-evaluated after the LWI model management system reference design has been completed. This will give an opportunity to compare pricing among competing cloud vendors (e.g. Amazon AWS, Microsoft Azure, Google Cloud Platform, etc.). That is, the current estimate uses Amazon AWS as a convenient starting point for cost estimation and should not be interpreted as an endorsement or recommendation of AWS.

CLOUD COMPUTE & NETWORKING

In addition to cloud storage required to store LWI H&H models, additional cloud computing and networking resources will be required to host the LWI model management system that will support model searching, check-out, check-in, and versioning (this does not include computational resources for executing models in the cloud). These resources include: (1) compute for hosting the database needed to store and query model metadata; (2) compute for hosting the application servers that will provide APIs needed to implement model management business logic (e.g. check-in workflows, versioning, etc.); and (3) load balancing between application server instances for fault tolerance and scalability. In addition to these compute and networking resources, a small amount of storage would be required for hosting application containers and for static files (e.g., HTML, CSS, JavaScript, images) needed by the LWI model management system web interface (these costs are estimated to be trivial, i.e., $2-$3 per month).

Estimates of cloud compute and networking resource requirements were made using best judgement based on prior experience deploying container-based cloud applications. Different resource requirements were estimated for regionally and centrally administered cloud resources. For the regional deployment approach, each regional deployment of the LWI model management system would require the following services: (1) a database instance; (2) two API application servers for the production environment; and (3) one API application server for the test environment. The central deployment approach would require the same mix and number of services, however these could be shared among all regions. To allow for adequate system responsiveness and performance, the amount of CPU and/or memory resources for the central approach would need to be increased.

Standard commercial AWS region US East pricing was used to estimate the costs associated with the cloud compute and networking resources required under both regional and central deployment approaches (for details see the Excel spreadsheet titled "MUSM_CostEstimation_OandM-2021-04-28.xlsx" available in the supplemental materials). Under the regional deployment approach, the estimated yearly cost is estimated to be

$877 for each region, or $7,016 across all regions (Table 29 or Table 30; the cost estimates are the same for either staff-based or consultant-based options). For the central deployment approach, the cost is estimated to be $2,444 per year for the entire state. While the regional deployment approach is estimated to cost 2.9-times as much as central deployment, the absolute value of estimated cloud compute and networking costs is very small compared to the H&H modeler or IT personnel resource requirements. This makes sense given the large economies of scale already afforded by using cloud computing in the first place. There is not much additional economy of scale, from the point of view of compute and networking resources, to be gained by centralizing onto a single set of centrally provisioned cloud compute and networking resources shared across regions.

SOFTWARE MAINTENANCE

Once the LWI model maintenance reference system is developed during the first year, additional resources will be required to maintain the reference system to ensure that it can continue to support LWI model use, storage, and maintenance. Software maintenance will be required for: (1) bug fixes to code that implements MUSM business logic (e.g., check-out, check-in, versioning, etc.); (2) minor enhancements to existing features; and (3) to apply security updates to software dependencies. It is estimated that this software maintenance will require a software development team made up of members with the following roles: (1) software developer (0.25 FTE/year); (2) user experience designer (0.25 FTE/year); (3) scrum leader (0.25 FTE/year); and (4) product owner/project manager (0.25 FTE/year). It is estimated that providing such a team using consultants would cost roughly $176,800 per year, not factoring in yearly inflation, starting in year two (Table 29 or Table 30).

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Table 29. LWI MUSM system estimated yearly operations and maintenance resource requirements if resources provided by regional coalition/state agency staff (except for software maintenance, which is assumed to be provided by consultants). Note: first year resources are estimated to be slightly higher for IT personnel due to effort needed for initial deployment.

Program Element	Central Approach (C) (Central IT & central H&H)	Blended Approach (B2) (Central IT & regional H&H)	Regional Approach (R) (Regional IT & regional H&H)	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
H&H Modelers	$2,340,000	$2,730,000	$2,730,000	$390,000	$260,000	$390,000	$390,000	$390,000	$390,000	$390,000	$130,000
IT Personnel 1st year	$416,000	$416,000	$832,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000
IT Personnel subsequent year	$208,000	$208,000	$416,000	$52,000	$52,000	$52,000	$52,000	$52,000	$52,000	$52,000	$52,000
Cloud Storage	$96,610	$96,610	$97,435	$11,881	$7,568	$14,552	$13,591	$19,814	$12,887	$10,378	$6,765
Cloud Compute & Networking	$2,444	$2,444	$7,016	$877	$877	$877	$877	$877	$877	$877	$877
Software Maintenance (year 2 & on)	$176,800	$176,800	$176,800	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total 1st year costs	**$2,855,054**	$3,245,054	**$3,666,451**	$506,758	$372,445	$509,429	$508,468	$514,691	$507,764	$505,255	$241,642
Total subsequent year costs	**$2,823,854**	$3,213,854	**$3,427,251**	$454,758	$320,445	$457,429	$456,468	$462,691	$455,764	$453,255	$189,642

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Table 30. LWI MUSM system estimated yearly operations and maintenance resource requirements if resources provided by consultants to regional coalition/state agencies. Note: first year resources are estimated to be slightly higher for IT personnel due to effort needed for initial deployment.

Program Element	Central Approach (C) (Central IT & central H&H)	Blended Approach (B2) (Central IT & regional H&H)	Regional Approach (R) (Regional IT & regional H&H)	Region 1	Region 2	Region 3	Region 4	Region 5	Region 6	Region 7	Region 8
H&H Modelers	$5,185,440	$6,049,680	$6,049,680	$864,240	$576,160	$864,240	$864,240	$864,240	$864,240	$864,240	$288,080
IT Personnel 1st year	$832,000	$832,000	$1,664,000	$208,000	$208,000	$208,000	$208,000	$208,000	$208,000	$208,000	$208,000
IT Personnel subsequent year	$416,000	$416,000	$832,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000	$104,000
Cloud Storage	$96,610	$96,610	$97,435	$11,881	$7,568	$14,552	$13,591	$19,814	$12,887	$10,378	$6,765
Cloud Compute & Networking	$2,444	$2,444	$7,016	$877	$877	$877	$877	$877	$877	$877	$877
Software Maintenance (year 2 & on)	$176,800	$176,800	$176,800	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Total 1st year costs	**$6,116,494**	**$6,980,734**	**$7,818,131**	$1,084,998	$792,605	$1,087,669	$1,086,708	$1,092,931	$1,086,004	$1,083,495	$503,722
Total subsequent year costs	**$5,877,294**	**$6,741,534**	**$7,162,931**	$980,998	$688,605	$983,669	$982,708	$988,931	$982,004	$979,495	$399,722

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REGIONAL CAPACITY, TRAINING, AND EDUCATION NEEDS

A primary objective of the LWI modeling program is to build regional and local buy-in and capacity for flood model use in decision making. Providing technical training and continuing education to local engineers and planners is also a key component of the LWI. Through outreach to regional stakeholders, capacity needs were identified related to regional model use, storage, and maintenance. There are three primary components needed to establish effective regional engagement with model use, storage, and maintenance, namely: hardware, technical personnel, as well as training and education.

Hardware requirements include sufficient storage capacity to host the models temporarily while they are being worked with and before being uploaded to the cloud, access to adequate broadband internet to download and upload models, and adequate computing capacity to perform numerical simulations. In terms of personnel, numerical modelers skilled in performing, updating, and reviewing H&H models are needed. Regional participation in a MUSM program requires funding for storage, bandwidth, computation, modeling staff and IT staff (if regional model storage is pursued). Some organizations already have IT and staff that they could leverage to an extent but will need funding to enhance existing capacity. For example, while some IT staff may have experience with cloud hosting, others may need additional training, or new staff with such skills may need to be hired. As expressed during regional outreach meetings, opportunities for enhancing regional capacity-building could be realized via partnerships with LA universities and leveraging of education, outreach, research, and IT resources. Regional MUSM participants will need to have strong lines of communication with parishes, cities, and towns. This will require both social capital, as well as tools for collaboration (e.g., ticketing or issue tracking software such as Jira).

Overall, the availability of either the computing hardware and software or technical personnel is highly variable among the regional and local entities across the state. Building and sustaining local and regional capacity requires careful planning and thoughtful allocation of resources especially to rural parishes that lack planning departments or commissions. Therefore, it is critical for LWI to: (a) assess the current capacity for each region; (b) work collaboratively with regional steering committees and successor organizations to develop a plan to establish adequate regional capacities to initiate regional MUSM programs; and (c) develop a rigorous long-term training and continuing-education program to establish and sustain local and regional technical capacity. A follow-up phase of MUSM planning should detail the specific hardware and technical staffing requirements to initiate and sustain effective participation in model use, storage, and maintenance program. Finally, in terms of technical training and education, regional universities with support from LWI can play a key role in establishing and maintaining workshops for local engineers, floodplain managers, and planners on how to use and review LWI models.

NEXT STEPS

The LWI model management system implementation strategy could use a three-phase approach (see Figure 9). The first phase represents the current report. Phase II of the MUSM planning and development would take place over a twelve-month period starting after the completion of the current Phase (this report). Phase two will involve: (1) convening of the Stakeholders Beta User Group; (2) development of MUSM prototype; (3) development of MUSM Reference Design; and (4) developing a detailed MUSM deployment and operations and maintenance (O&M) planning and resource needs report based on lessons learned from the MUSM prototyping and Reference Design implementation. The second phase could leverage the USACE open-source Model Library system as a starting point for the LWI prototype that addresses many of the MUSM needs of the LWI program. Phase two is expected to last 12 months. The development of the MUSM prototype and reference design would be done by an IT firm, which would need to be procured. The Stakeholders Beta User Group and development of MUSM prototype and reference design are described above (Section 10). The deployment and O&M planning and cost estimation report would consist of the following elements:

1. Develop timelines for:
    - Deploying reference design for use by regional model maintenance workflows
    - Capacity building and user training
    - Loading completed models into MUSM systems
2. Develop estimated level of effort and budgets for:
    - Operating and maintaining MUSM model management systems (based on estimates provided in Phase I)
    - Operating Statewide Standards and Federal and State Advisory Committees
3. Design linkage between MUSM systems and other LWI resources, such as All Things Flood Portal

With the completion of the second phase, the MUSM system enters the third and final phase, which involves the deployment, operation, and maintenance of the MUSM reference design over the long term. Phase three will include both updating and maintaining the models as well as security updates and bugfixes for the IT components of the MUSM system.

APPENDIX

FOCUS GROUP RESPONSES

Table 31. Summary of focus group responses

Q1.1: What local and/or regional organizations in your region do you foresee making use of LWI models?	Most common answers included: · Planning commissions · Levee Districts · Drainage Districts · Municipal, Parish, and State governments · Individuals/developers for permitting and development purposes Second most common answers included: · Levee boards · Universities Third most common answers included: · Police juries · Private sector · Regional watershed governance boards (LWI created), CZM boards, CRS groups · Hazard and emergency management agencies (e.g., Office of Emergency Preparedness, NWS river forecasting offices)
Q1.2: How do you foresee local and/or regional organizations in your region planning to use LWI models?	· Checking to make sure that upstream does not influence downstream and vice versa across regions · Helping/educating community members about threats, development, programming, and changes to their environs (like the MRGO closure) · Reviewing interactions with other state models (DOTD, MPO, etc.) · Developing statewide CRS strategy and helping communities join CRS (such as homeowners and flood insurance) · As a means of project evaluation (planning and development) · Emergency response (if surge models could work better, for example) · Policy changes at the regional level (recognizing that local level might be too much to ask). Ex: rules along rivers, localities minimums · Land use planning · Implementing drainage plans (including other types of drainage besides water such as sewage drainage and treatment) · As prediction of 50- 100- 500-year events at the regional level · To inform programmatic efforts · · For research (at university or governmental level)

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Q1.3: Are there any barriers that you foresee to these organizations being able to use LWI models in this way?	· Cost and sustainability of funding to run this/upkeep this · Some regions being better equipped to run these things/keep this updated · How to staff this thing · How to best communicate what the models can and can't do · Leveraging untapped storage capacity · Timing and apathy that might come with it · Cooperation with housing agency, also linked to timing and apathy · Internet speed capacity · How user friendly will it be · Software knowledge gaps · Computational costs · How to keep updated on software/update requirements · Private sector vs. public sector use – Will they need to be stamped by the PE? · Need to have realistic goals for what the models can and can't do · How long it will take to run a model, timing and apathy, realistic goals here too · Proprietary software issues related to models · · Network security (breeches, ransomware attack, and security concerns)
Q2.1: Are there any federal, state, or local laws/regulations/ordinances driving the need/desire to use flood/watershed models in your region?	· Drainage studies · Development impact studies · Major projects that require floodplain analysis · Permits for development/eval on a case-by-case basis · Climate migration with FEMA models, surge models · Especially for grants, modeling would be very beneficial in project prioritization · Need for consistent floodplain analysis techniques · Overall concern that the models have "shelf life" and thus will need to be updated as soon as they are released · We already have FEMA ones, but would like to update them. · Yes, floodplain administration regulations, subdivision development ordinances, Stormwater Pollution Prevention regulations, as well as state drainage regulations
Q2.2: What kinds of projects or policies do you want to include in your models? (survey question)	· Primary vote (8 total): Structural · Secondary vote (4 total): Non-structural · Other vote (2 total): do not want the models to be public vs. private sector, and that local jurisdictions would still need to do policy making, but they need expertise and capacity behind these policies to justify them
Q2.3: How often do you think flood/watershed models will be used to inform decisions about floodplain/watershed	· Yearly (3 votes) · Every few years (6 vote) · Continuously (1 vote) · Other (1 vote): at least every 3 ½ years

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management in your region?	
QF.1: In your opinion, what types of resources would be needed at the regional level to allow for the housing and updating of LWI models?	· Staff capacity, server and computing capacity · Funding and technical assistance · Knowledge and capacity · Personnel and funding · Server and computing capacity, staff expertise and time · Very highly trained and savvy engineer. Housing is one thing, updating is another. · Staff with the expertise to update the models and make the data available to those that need it. A central location within Area 5 that can accommodate the necessary equipment and staff. · Staff capacity and reliable internet · Computer hardware and software with skilled technicians, IT personnel or professionals to maintain and administer the models
QF.2: In your opinion, what sources of funding do you think can be used for supporting the housing and updating of LWI models at the regional level?	· Sales tax (1 vote) · Property tax/milage (4 votes) · Permitting fees (6 vote) · Stormwater utility fees (4 vote) · Other (6 votes): grants, state or federal funding, some type of proportionate assessment to agencies that use the models, whatever the voters would support
QF.3: In your opinion, what types of organizations would be most suitable for implementing model housing and updating? (Please check all that apply)	· Regional planning commission (6 votes) · Metropolitan Planning Organization (4 votes) · Parish governments (0 votes) · City governments (0 votes) · Drainage districts (1 vote) · Levee boards (0 votes) · Watershed associations/riverkeepers (0 votes) · Partnerships with regional Universities (10 votes) · Other (2 votes): something specific to this; the majority of choices listed above do not have the expertise and understanding of what this data is and what it will be used for. They also inherently lean one way or another politically based on their makeup as they are either appointed by or heavily involved in politics. Regional Universities are the easiest, most, “neutral ground” for the models in my opinion.

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QF.4: After having participated in this focus group, in your opinion, what is the most effective way of housing LWI models in your region?	· Centralized state-based housing (0 votes) · Decentralized region-based housing (10 votes) · Other (1 vote): Academia-based regional solution
QF.5: Is there anything you would like the moderators to know that would assist them in developing the LWI Model, Use, Storage, and Maintenance plan? (or that you did not get a chance to say during the meeting)	· We need minimum standards for what the Regions plan to do or what the Regions should be expected to do with this data from a policy, procedure, ordinance or law perspective. Once we understand expectations, then we can begin to stretch out and understand how we can use the data to achieve those ends. But with many folks on these RSC's not familiar with Watershed or Floodplain Management, we must have clear-cut ideas and understanding of minimum expectations · Better understanding what a HUC8 H&H model capabilities and limitations · I think the need for cost estimates was brought up in the meeting. I think a detailed projection of what will be needed and how much it will cost must be determined up front. · The LWI model needs to be within our region to be able to be easily assessed and updated. · Funding is crucial · If possible for each region, housing the model with the same staff that will act as the coordinator and fiscal agent for the regional coalition makes a lot of sense (this is similar to the MPO model). In regions where that is not an option, a partnership with a capable university could be a great solution.
Q3.1: Are organization(s) in your region interested in storing LWI models and enabling model users to access, use, and modify these models?	· Regionally, it is generally preferred to store and use models · Some regions are better equipped than others to do this · The regions that are most equipped already include Region 5, any located near a university, NOPRC, Meraux Foundation, St. Charles Parish, NLCOG, Region 2, RAPC · Universities, where possible should store and maintain models (stated in multiple regions) · Some regions are already investing in small-scale models · Most organizations have to hire modelers, this would help to streamline. · Organizations in the region are interested in hosting, and often have some capacity to host. In the case of NLCOG and CDC, they have recently merged and signed MOU to move forward to cover the entire area. · Would like to push permitting and support of permitting through the models · Concern over splitting data regionally, especially for regions that span multiple regions (such as St. Charles) · Previous modeling efforts have required shuttling data on hard drives across the state

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	· For long term sustainability, all the models should be deposited in one place and a clear plan for who gets to modify, review, keep models updated to reflect new development sketched out ahead of time
	· Would also like to have a place to store other watershed data in one place (such as a repository)
	· Since it will be a regional model, there should be a regional entity to house the model. Local government housing could lead to confusion.
	· The more decentralized, you would have to re-create the check-in/check-out process
	· Centralized or statewide, or within region?
	  · If statewide, one place to store models with one check-in/check-out process
	  · If regional, one process per region
	  · If finer grained than that, it gets to be a lot of entities doing the same thing
	  · If decentralized, centralized back-up/disaster recovery would be needed
	  · If one region doesn't have the resources to store and maintain, pooling resources could accomplish the goal
	· Do think all models should be held by the state, even if they don't want to
	· Models need to be publicly available but with strict policies on alterations to models

Q3.2: To the best of your knowledge, do these organizations have the capacity to do this? W/follow-up: If such organizations do not have the capacity, are they interested in building capacity (assuming additional resources would be available to help)?	· Will need to know storage, software, and hardware requirements in order to respond fully.
	· Is there a regional entity being proposed that could host the models? – such as a Regional Coalition?
	· Orleans, Jefferson, and St. Tammany would still want to run their own and participate regionally
	· The more you can tie in university systems, the easier it is to provide capacity
	· Need other things to make it happen:
	  · Regional contacts with other parishes
	  · Established relationships
	  · Technical committee with experts to assist when needed
	  · Engagement by:
	    · Engineers
	    · Developers
	    · Grant managers
	    · Floodplain managers
	    · Parish and municipality staff
	    · Consultants
	  · Financial capacity is the most limiting factor in considering these questions
	  · Need to think of ways to fund this if state/federal funding not possible
	    · Ex: International Building Code Compliance
	· LWI regional approach a priority
	· Not sure what it will look like for one entity to do this modeling work
	· Compared it to a Gumbo – one region brings the Roux, another the Rice….

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	· Funding always a concern · Most hire consultants already, but irregularly and as minimally as they can get away with it · Regional watershed management planning is important · Would like to know the capacity requirements moving forward · Would also like to know how frequently the models will need to be updated and encouraged thinking of them as similar in updates to the transportation models · Would like to maintain a version history for models at some level so that the historical versions could be accessed over time. Maybe in an archive hosted by the state. · It could be an option to start centrally and move regionally over time. Ex: Might make sense for DOTD to initially house models to give regions the time to build capacity and assume housing responsibilities · Pontchartrain Conservancy, ARBC, and maybe LSU have capacity to do this. Or CPRA, Water Institute, Center for River Studies. · Whoever houses the models needs to have good communication with the parishes and municipalities. That would give the local level participation we need. · Some watersheds have little current or planned development, so some models may change very infrequently.
Q3.3: What information technology (IT) resources (e.g., IT staff, computational or storage, software do organizations in your region currently have access to that could help to support storage and maintenance of LWI watershed models? Follow-up: Do you know if these organizations have existing plans to acquire any of these resources?	· Most have access to GIS, computers, modeling staff, servers, university connections, some cloud computing resources · Others have interest in investing to support these resources, especially in forming cooperative relationships between public and private sector through the use and management of these resources. · Do lack H&H modelers · Others say that the only resources they have would be private industry companies which have the ability to do modeling. · A problem is having to rely on federal/state resources. · Maybe the organization to store models doesn't exist yet, but should · As we are trying to build something like a watershed coalition at the regional level, this might be the appropriate group to do it, so that all parishes, rural, urban, etc. can work with this organization to use and manage models.

REGION 5 RESOLUTION IN SUPPORT OF DEVELOPING A REGIONAL HOUSING AND MAINTENANCE WATERSHED MODEL PLAN

LOUISIANA WATERSHED INTIATIVE REGION 5 STEERING COMMITTEE
A RESOLUTION IN SUPPORT OF DEVELOPING
A REGIONAL HOUSING AND MAINTENANCE WATERSHED MODEL PLAN

BE IT RESOLVED, by the LWI Region 5 Steering Committee of the Louisiana Watershed Initiative (LWI) that:

WHEREAS, the Louisiana Watershed Initiative was established in 2018 introducing a new watershed-based approach to reducing flood risk in Louisiana, guided by the following principles: using scientific tools and data; enabling transparent, objective decision-making; maximizing the natural function of floodplains; and establishing regional, watershed-based management of flood risk; and

WHEREAS, LWI is developing computer models to better understand flood risk and help select projects best suited for investment in each watershed region to better safeguard our communities and culture for generations to come, as well as provide an example for other states facing similar flood risk challenges.; and

WHEREAS, these models will support greater regional collaboration around shared water management challenges and build an objective, science-based understanding of how projects, policies and other measures will reduce flood risk.; and

WHEREAS, the LWI Region 5 Steering Committee was formed to help guide the watershed region to build staff capacity for regional watershed management; to provide technical assistance to municipal partners throughout each region; to support strong and effective governance for each watershed region and ensure each region operates in a way that maximizes flood mitigation efforts and funds for risk-reduction projects as they become available.

WHEREAS, the Louisiana Watershed Initiative is tasked with developing a sustainable approach to a model use storage and maintenance plan and recognizes that all regional stakeholders should have the capacity to retrieve and utilize the models; and

WHEREAS, the desire of the Region 5 Steering Committee is to utilize these models to enhance data driven, water management decision-making at the local and regional level; to build expertise and capacity in our local government jurisdictions and local private sector firms; to build community understanding of existing and potential green infrastructure; to develop local watershed modeling expertise that can be leveraged for all local and regional comprehensive, strategic and community planning efforts in addition to watershed planning;

WHEREAS, the Region 5 Steering Committee recognizes that the success of these models is dependent on long term usage of the models by the local and region entities;

WHEREAS, the Region 5 Steering Committee recognizes that the success of these models is dependent on the development of regional capacity and local technical expertise for the long term sustainable use, storage, and maintenance of these scientific models; and

NOW, THEREFORE, BE IT FURTHER RESOLVED, the Region 5 Steering Committee fully supports and requests the development of a decentralized, regional approach to a model use, storage, and maintenance plan.

And the resolution was declared to be a formal recommendation of the Region 5 Steering Committee on the 22 of October in the year 2020.

Signed and Confirmed by: Donald Bergeron

Donald Bergeron, Representative of Evangeline Parish
LWI Region 5 Steering Committee, Chairman