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Upper Mississippi River Restoration Future Hydrology Meeting Series

Open-File Report 2025–1050

U.S. Department of the Interior
U.S. Geological Survey

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By Molly Van Appledorn and Lucie Sawyer

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Preface

This report was produced by the U.S. Army Corps of Engineers Upper Mississippi River Restoration program’s Long Term Resource Monitoring element. The Long Term Resource Monitoring element is implemented by the U.S. Geological Survey Upper Midwest Environmental Sciences Center, in cooperation with the five Upper Mississippi River System States: Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Upper Mississippi River Restoration program responsibility.

Acknowledgments

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

International System of Units to U.S. customary units

Multiply	By	To obtain
Flow rate		
centimeter per second (cm/s)	0.03281	foot per second (ft/s)

Supplemental Information

Radiative forcing from greenhouse gas emissions is given in watts per square meter (W/m^2).

Abbreviations

CHAT	Climate Hydrology Assessment Tool
CPR CoP	Climate Preparedness and Resiliency Community of Practice
HREP	Habitat Restoration and Enhancement Project
HUC	hydrologic unit code
LOCA	LOcalized Constructed Analogs
LTRM	Long Term Resource Monitoring
PI	principal investigator
RCP	representative concentration pathway
UMRR	Upper Mississippi River Restoration
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
VIC	Variable Infiltration Capacity

Upper Mississippi River Restoration Future Hydrology Meeting Series

By Molly Van Appledorn[1] and Lucie Sawyer[2]

Abstract

The Upper Mississippi River Restoration (UMRR) program, a broad partnership of State and Federal agencies administered by the U.S. Army Corps of Engineers, integrates ecosystem monitoring, research, and modeling to rehabilitate habitat and evaluate ecosystem trends over time in the Upper Mississippi River System. Hydrologic data are integral to the UMRR program because they are used in scientific research, decision-making, and restoration project planning. However, a lack of quantitative hydrologic data representing potential future conditions limits the ability to complete informative research on how future conditions may affect river ecology, achieve management goals, and design restoration projects for 50-year horizons.

The U.S. Geological Survey and the U.S. Army Corps of Engineers led a series of workshops with UMRR partners to (1) prioritize needs for understanding future hydrology, (2) discuss appropriate datasets that could address these needs, and (3) develop a plan for acquiring and distributing a hydrologic dataset of potential future conditions. Agency priorities for understanding future hydrology were broad, spanning ecologic, geomorphic, resource management, and engineering disciplines, and were identified for a range of spatial (project site, navigation pool, reach, system) and temporal (daily, seasonal, annual) scales. The LOcalized Constructed Analogs-Variable Infiltration Capacity-mizuRoute hydrologic data products were identified as a potential source of off-the-shelf data to meet UMRR priority needs but warranted a robust quantitative evaluation. The final meeting in the series scoped a proposal to evaluate the LOcalized Constructed Analogs-Variable Infiltration Capacity-mizuRoute hydrologic data products for use in UMRR applications, including contingencies if the data were determined to be unreliable.

Plain Language Summary

A series of workshops was held so participants from several agencies could work together to prioritize needs for understanding future hydrologic scenarios, discuss appropriate datasets that could address these needs, and develop a plan for acquiring and distributing a hydrologic dataset representing potential future conditions. Agency priorities for understanding future hydrology spanned ecologic, geomorphic, resource management, and engineering disciplines and were identified for a range of spatial (project site, navigation pool, reach, system) and temporal (daily, seasonal, annual) scales. Participants described desired characteristics of a hydrologic dataset of potential future conditions that could meet agency priority needs and developed a workflow to evaluate a readily available data product.

Introduction

The Upper Mississippi River System (not shown) is congressionally defined as the commercially navigable portions of the Mississippi River main stem north of Cairo, Illinois, and its commercially navigable tributaries, including the entire Illinois River (Water Resources Development Act of 1986, 33 U.S.C. § 652). The Upper Mississippi River System includes these rivers and their floodplains and comprises a variety of aquatic and floodplain habitats. The 1986 Water Resources Development Act created a program to monitor and rehabilitate the Upper Mississippi River System because of the system's recognized ecological and economic importance and ongoing stressors. The Upper Mississippi River Restoration (UMRR) program fulfills this function by integrating ecosystem monitoring, research, and modeling through two program elements: Habitat Restoration and Enhancement Projects (HREP) and Long Term Resource Monitoring (LTRM). The HREP element uses a variety of construction techniques and approaches (for example, water level management, shoreline protection, backwater dredging and floodplain restoration) to address specific ecological goals determined through a comprehensive planning process. The

[1]U.S. Geological Survey.

[2]U.S. Army Corps of Engineers.

LTRM element provides scientific leadership to the program by collecting, analyzing, and interpreting field data; leading applied ecosystem research; and managing datasets. The ecosystem understanding and over 30 years of monitoring data from the LTRM element are used in the HREP planning process to help identify management goals, inform restoration designs, and improve project effectiveness. The UMRR program is administered by the U.S. Army Corps of Engineers (USACE) and is implemented by a broad partnership of Federal and State agencies.

The hydrologic regime is a fundamental driver of ecosystem patterns and processes in the Upper Mississippi River System and is relevant for effective implementation of the UMRR program. Inter- and intra-annual variability in flow affects the nature of longitudinal and lateral connectivity, controlling variables that enable exchanges of materials and energy through the system (Bouska and others, 2018, 2019). Anthropogenic factors such as land-use changes, navigational infrastructure, protective levees, and active water level management have contributed to high-flow conditions outside of the historical spring flood pulse period (Yin and others, 1997; Sparks and others, 1998; Zhang and Schilling, 2006; Theiling and Nestler, 2010), and in certain areas, dam operations can cause higher water levels during summer and drier conditions during the spring and fall (Sparks and others, 1998). Evidence also exists that climatic changes in precipitation regimes interact with land-use changes to contribute to shifts in the hydrologic regime (Zhang and Schilling, 2006). Recent episodes of longer duration spring events and late season flood events and increases in average annual discharges (Van Appledorn, 2022) raise questions about the potential for such conditions to be the “new normal” and how such conditions may affect biota and habitats of the Upper Mississippi River System. Answers to such questions would inform implementation of the UMRR program, including project planning, habitat management and restoration activities, and scientific investigations.

Hydrologic data are foundational in anticipating how the Upper Mississippi River System ecosystem might respond to any potential future changes in the hydrologic regime and how to best manage for those potential conditions. Hydrologic data are necessary for describing historical environmental conditions, contextualizing contemporary conditions, projecting potential future conditions, completing scientific research on aquatic and floodplain organisms and processes, assessing alternative scenarios as required for UMRR restoration projects, and many other applications. Studies that explore the implications of projected hydrologic changes on ecological endpoints can use models of ecohydrologic relations that link hydrologic data to datasets such as the LTRM fish, water quality, and aquatic vegetation data, although careful attention to issues of uncertainty, model error, and scale is necessary in such studies (Rangwala and others, 2021). A substantial body of work describes ecohydrologic relations in the river, and ongoing projects further expand our understanding. For example, time series of water surface elevations and (or) discharge from USACE streamgage locations are used to drive simulations of aquatic vegetation distribution (Carhart and De Jager, 2019), inundation dynamics (Van Appledorn and others, 2021), and interactions between flooding and forest succession dynamics (De Jager and others, 2019); establish ecohydrologic relations with LTRM monitoring datasets (for example, Ickes and others [2014], Houser [2016], and Lund [2019]); and quantify indicators of resilience throughout the Upper Mississippi River System (De Jager and others, 2018; Bouska and others, 2019). Models relating hydrologic characteristics to successful habitat distribution are used by HREP teams to plan and design restoration projects. Upper Mississippi River System hydrologic data are also used to investigate fish passage through navigation dams (Montenero and others, 2018), spawning patterns of invasive carps (Larson and others, 2017), forest communities (Guyon and Battaglia, 2018), and other topics.

As of 2021, the UMRR program did not have ready access to hydrologic data representing potential future conditions for the main stem of the Upper Mississippi River System. The lack of quantitative information about plausible future hydrologic regimes has been a limitation in addressing an important recurring question within the partnership: How are geomorphic, hydrologic, and ecological patterns and processes likely to change in the future? Lacking quantitative projections of future hydrologic regimes has hindered the ability to identify and understand their implications for the structure, function, management, and restoration of the Upper Mississippi River System.

Purpose and Scope

In this report, we describe the activities and outcomes of work funded in fiscal year 2020 by the UMRR program to document its priorities for understanding potential future hydrology, identify potential datasets and (or) approaches for addressing those priorities, and develop a blueprint for acquiring a dataset of hydrologic projections for the Upper Mississippi River System. Our goal is to document the important discussions and their supporting materials related to future hydrology among the UMRR partners, including decision points for acquiring a dataset of hydrologic projections and directions for future research and applications.

Methods

We planned a series of three virtual meetings to discuss UMRR priorities for understanding future hydrologic conditions, identify potential datasets and (or) approaches for addressing priority needs, and develop a proposal for acquiring a dataset of hydrologic projections for the Upper Mississippi River System (table 1). The meeting series had two overarching goals: (1) to facilitate discussion among the UMRR partnership around specific needs, methodological approaches, and desired outcomes for understanding potential future hydrologic conditions in relation to the UMRR mission and (2) to develop a blueprint for acquiring hydrologic data projections for the Upper Mississippi River System.

All meetings were held through WebEx because of ongoing limitations related to the COVID-19 pandemic. Meetings were facilitated by Dr. Rebecca Seal-Soileau (USACE-St. Paul District), who had experience facilitating multiagency discussions on water related resources, interdisciplinary river management, and hydrology. Agendas (app. 3, 4, and 5, figs. 3.1, 4.1, and 5.1) were distributed to attendees in advance of each meeting by the organizers (Lucie Sawyer, USACE, and Molly Van Appledorn, U.S. Geological Survey [USGS]). In addition to meeting attendance, participants were also encouraged to complete a few activities outside of meeting times (for example, premeeting reading, homework activities, and a ranking exercise), which are described in the "Meeting Discussions and Outcomes" section.

UMRR partners had a high level of interest in the meeting series. To have productive conversations and achieve equitable representation across the partnership, however, organizers had to limit meeting attendance. Participation was extended to each A-team member (or designated substitute) to ensure each State in the UMRR partnership was represented: 1 biologist and 1 engineer from each of the 3 USACE districts; a select group of climate change experts from the USGS's Northeast Climate Adaptation Science Center (known in 2025 as the Midwest Climate Adaptation Science Center) and USACE's Climate Preparedness and Resiliency Community of Practice (CPR CoP); USGS LTRM scientists; representatives from the U.S. Fish and Wildlife Service with experience with either the UMRR program, hydrology, or both; UMRR program management and the LTRM management team; and representatives from the Upper Mississippi River Basin Association (app. 1, table 1.1). Attendees were encouraged to engage their agency colleagues in the meeting series subject matter throughout the duration of the meeting series, and specific opportunities for broader agency input were intentionally developed for the meeting series (for example, meeting 1 homework activities, app. 3). Open communication between attendees and meeting organizers was encouraged. In addition, meeting organizers presented updates on the meeting series to various outlets to keep the broader UMRR partnership informed, including the UMRR A-team (July 20, 2021), LTRM Management Team (numerous dates before and during meeting series), UMRR Coordinating Committee meeting (August 11, 2021), the USACE–USGS Flooding Small Working Group meeting (October 5, 2021), the UMRR Science in Support of Restoration Partnership Updates webinar series (December 2, 2021), and the UMRR Science Meeting (February 8–11, 2022). Materials collectively compiled during each meeting (for example, group-generated list of UMRR "needs") were distributed to attendees within a week of each meeting's conclusion.

A variety of tools including read-ahead materials and online capabilities were used to encourage the fullest engagement of meeting attendees in a virtual meeting platform. Details of some of these methods are provided in the "Meeting Discussions and Outcomes" section. First, organizers distributed read-ahead materials in the form of a briefing book and homework activities ahead of meeting 1. The goal of the briefing book was to familiarize attendees with diverse experiences in hydrology and climate change with relevant background information on these topics. The goal of the homework activities was to ensure agency perspectives were communicated and represented during the meeting. Homework activities were especially important given that logistical constraints prohibited everyone who was interested

Table 1. Summary of the Upper Mississippi River Restoration program's virtual meeting series to discuss Upper Mississippi River System future hydrology.

[Dates are given in month/day/year format. UMRR, Upper Mississippi River Restoration; *n*, number of people; USACE, U.S. Army Corps of Engineers; CPR CoP, Climate Preparedness and Resiliency Community of Practice]

Event	Dates and time	Purpose	Attendees	Outcomes
Meeting 1	9/21/2021, 9/23/2021 (8 hours)	Identify UMRR priorities for understanding climate-changed hydrology	UMRR partnership representatives (*n*=33)	Ranked list of UMRR priority needs
Meeting 2	11/1/2021, 11/2/2021 (8 hours)	Identify potential datasets and approaches to address UMRR priority needs; identify ideal outcomes of effort to acquire hydrologic data	UMRR partnership representatives and USACE CPR CoP technical experts (*n*=37)	Description of an ideal quantitative dataset of future hydrology projections
Meeting 3	1/18/2022, 1/19/2022, 1/26/2022, 1/27/2022 (16 hours)	Scope a proposal for evaluating an existing quantitative dataset	Subgroup of UMRR partnership representatives and USACE CPR CoP technical experts (*n*=17)	Proposal framework to be further developed by leadership team for submission to fiscal year 2022 UMRR Science in Support of Restoration funding mechanism (due April 2022)

in attending from participation in the meeting series. Second, organizers leveraged the WebEx platform and other online tools to make the virtual meeting format as participatory as possible and to encourage equitable representation of opinions among meeting attendees. Tools included concurrent break-out groups, round-robin discussions, interactive WebEx drawing and editing tools, live note taking, mind mapping via https://www.mindmeister.com/, and live polling via https://www.polleverywhere.com/.

Meeting 1 Activities

The purpose of meeting 1 was for the UMRR partnership to identify (1) what questions need to be answered and (2) what decision would be made with a future hydrologic dataset for the Upper Mississippi River System. Our expectation was to produce a prioritized list of program needs related to Upper Mississippi River System future hydrologic data and information by the end of meeting 1. Meeting participants were encouraged to review a briefing book and complete homework activities ahead of the meeting to facilitate productive discussions towards these goals. The meeting took place over 2 days for a total of 8 hours (app. 3). A total of 36 people representing the UMRR program attended at least part of meeting 1, including meeting organizers and the facilitator.

During meeting 1, participants discussed compiled responses from the homework activities (app. 2, table 2.13). A first step was to identify challenges faced by the UMRR program presented by an uncertain hydrologic future. This step was done by editing a composite mind map of challenges that was derived by meeting organizers from returned homework responses. Break-out teams that consisted of representatives from diverse roles within the UMRR program (for example, HREP practitioners, LTRM researchers, river-resource managers, and so on) edited the mind map to reflect relations or concepts that were missing or deemed incorrect from the original mind map. Based on the updated mind map of challenges faced by the UMRR program related to uncertain future hydrologic conditions, break-out group participants collectively compiled lists of important "needs" related to hydrology for addressing the challenges identified in the mind-mapping exercise through round-robin exercises. Members of each break-out group shared their progress with the entire meeting assembly, discussed how they arrived at their lists of needs, and participated in a question and answer session from the larger group.

After the meeting, organizers compiled the needs lists from each break-out group into a single, large needs list. The total list of 378 needs is provided in appendix 3 in a minimally edited format and in no particular order (table 3.1). Meeting organizers then combined similar needs to make the list more tractable for use in future meetings, including a subsequent ranking exercise. Organizers grouped needs into three themes that emerged during group discussions, from the mind-mapping exercise, and from the needs list itself: geomorphology, HREP and management decisions, and ecology.

Participants also collectively generated a list of potential criteria for ranking the needs list into UMRR program priorities. Each working group brainstormed potential criteria during the meeting, and criteria were compiled by meeting organizers after the meeting. A total of 34 potential criteria were generated across working groups, but not all were unique (app. 3, table 3.2). Meeting participants voted via https://www.polleverywhere.com/ on the question "What criteria should we use to rank needs for deep dive on details at meeting 2?" to identify important criteria (app. 3). The results of the poll indicate the importance of systemic applicability, relevance for multiple river system components, effect on the UMRR program's mission, and applicability to multiple uses (app. 3, table 3.3). Criteria related to logistics (for example, time sensitive, low-hanging fruit, sequencing) were considered less important in ranking UMRR program needs. Meeting organizers discussed the poll results and selected two criteria to make the subsequent ranking exercise tractable: "maximizes the effect on the program's capacity to meet the mission/vision/priorities" and "this need must be met before the other in sequencing the work." The former criterion is a compilation of the top polling criteria; the latter criterion ranked in the middle of the polled criteria but represented the top choice related to logistics (app. 3, table 3.2). The top-ranking criterion related to systemwide applicability was not included because of its focus on spatial scales that would presumably be discussed further in the context of data products or methodologies (meeting 2).

After meeting 1 and before meeting 2, participants completed a paired-ranking exercise outside of the meeting. In this exercise, participants assigned a rank order to each UMRR program need by comparing that need with each other need within a given theme (for example, "Geomorphology"). This was repeated for each criterion. Meeting organizers compiled ranking results from all participants and summed them to compute a ranking score for every UMRR program need. The final product was a prioritized list of UMRR program needs related to understanding Upper Mississippi River System future hydrology for three themes, geomorphology, HREP and management decisions, and ecology (app. 4, tables 4.1, 4.2, and 4.3).

Meeting 2 Activities

The goal of meeting 2 was for the UMRR partnership and external climate change experts to discuss appropriate datasets and approaches that could be used to meet the priority needs for understanding future hydrology identified in meeting 1. Two outcomes for the meeting were desired: (1) a description of an ideal quantitative future hydrologic dataset that meets the program priority needs (for example, time steps, metrics, spatial scales) and (2) a participant list for meeting 3. The meeting took place over 2 days for a total of 8 hours (app. 4). A total of 30 people representing the UMRR partnership attended at least part of meeting 2, including meeting organizers and the facilitator.

Meeting 2 began with a set of four presentations (app. 4, fig. 4.1). The presentations familiarized participants with the results of the UMRR program needs paired-ranking exercise, relevant homework responses for meeting 2 discussions, methods for assessing future hydrology, and examples of future hydrologic datasets. Participants then broke up into three working groups by discipline—geomorphology, HREP and management decisions, and ecology—with representatives from the USACE CPR CoP serving as technical experts in each group. Each working group was tasked with describing the time steps, time span, location of data, and hydrologic metrics of hypothetical hydrologic data that would be used to meet each ranked priority need within the disciplinary theme of the group. All participants joined together at the end of the meeting to discuss commonalities across hypothetical hydrologic data to reach a consensus about what an ideal dataset of projected hydrologic conditions would look like for the Upper Mississippi River System. Finally, a large group discussion was used to identify potential participants of meeting 3 or who may be good references as technical experts in future projects. Technical experts suggested an existing dataset for the starting point for a detailed discussion during meeting 3.

Meeting 3 Activities

The goal of meeting 3 was to discuss in detail the steps of how to acquire a dataset of future hydrology projections for the Upper Mississippi River System that would meet the UMRR program's priority needs. Because an existing dataset was identified as a potential starting point during the previous meeting, meeting 3 was used to discuss details about how to evaluate the dataset for UMRR program applications, how to disseminate any data determined to be of suitable use, and alternative actions for acquiring a dataset if the evaluation indicated the existing dataset was unsuitable. Two outcomes for the meeting were desired: (1) define action steps and necessary resources for completing each component of a suggested workflow for data acquisition, and (2) have a workplan in place for completing a draft proposal for the UMRR program's fiscal year 2022 Science in Support of Restoration funding opportunity by the March 2022 deadline. The meeting took place over 4 days for a total of 16 hours (app. 5, fig. 5.1). There were 16 participants, including the meeting organizers and facilitator, who were able to attend at least part of meeting 3. Participants included 7 LTRM scientists, a USGS scientist, 3 USACE personnel with past involvement in the UMRR program and 1 serving as meeting facilitator, a representative from the U.S. Fish and Wildlife Service, and 3 technical experts from the USACE CPR CoP (app. 1, table 1.1).

Meeting organizers worked with USACE CPR CoP technical experts before meeting 3 to develop an initial workflow for acquiring hydrologic projection data for the Upper Mississippi River System. The agenda of meeting 3 (app. 5, fig. 5.1) was organized around the workflow. Each workflow component was discussed in detail over the duration of the meeting. Participants collectively filled out a template to document which people, timeframes, resources, and other details would be necessary for completing each workflow component or "action step." This activity was meant to collect information that would be used in determining which components of the workflow were feasible to include in a proposal and which may be more suited as future work. The information was also intended to aid principal investigators (PIs) in writing a proposal for submission to the UMRR program's fiscal year 2022 Science in Support of Restoration funding opportunity. Finally, participants helped identify a workplan for completing the proposal writing, including who would serve as PI and who would serve as early draft reviewers.

Meeting Discussions and Outcomes

This section presents key outcomes and decision points from the meeting series. The first subsection describes the major challenges faced by the UMRR program that were identified from the homework activities and during a group mind-mapping exercise during meeting 1. The second subsection summarizes key meeting discussions on the topics of programmatic and agency priorities for understanding potential future hydrologic conditions and characteristics of an ideal hydrological dataset that could meet the UMRR program's priority needs. The third subsection describes a workflow for evaluating and disseminating an ideal hydrological dataset that was developed during meeting 3 in consult with technical experts.

What Challenges Are Presented by an Uncertain Hydrologic Future?

Major challenges facing the UMRR program were identified during the mind-mapping exercise (fig. 1), and homework exercises (app. 2) were along the themes of hydrology, geomorphology, ecology and biota, HREPs and management decisions, and general methods and data distribution. Uncertainty around future hydrologic conditions was believed to contribute to difficulties anticipating how geomorphological processes, ecological processes, and the biota would respond. Lack of understanding about potential future responses to hydrologic change could hamper effective river management decisions, including HREP planning and design, and present methodological challenges to those completing field work or modeling exercises aimed at improving decision making.

Challenges related to hydrology included issues of spatial and temporal scales, uncertainty and how it may be addressed in any modeling process, and where future hydrologic patterns should be summarized (fig. 2). Decisions about how to characterize future hydrology to capture aspects of the flow and flood regimes (for example, flow frequency or flood magnitude) also appeared as challenges. However, these decisions may be consequential given the importance of flow regime characterizations (which includes flood regime characterizations) to other challenges facing the UMRR program (fig. 2).

Challenges related to geomorphology included understanding how the river may respond to future flow conditions in terms of sediment dynamics and patterns of connectivity (fig. 3). Topics identified as being of particular interest include sediment transport, deposition, erosion (including wave action and island/bankline loss), and suspended sediment concentration. The importance of the geomorphic template to river ecology was indicated by connections to items in the ecology theme (fig. 3).

Anticipating ecological and biotic responses to future hydrologic conditions was identified as a major challenge during meeting 1 (fig. 3). Participants noted that ecological structure and function, including species composition and distributions, habitat availability, and ecosystem benefits, were particular examples of how future changes may manifest. Participants also identified the challenge of integrating existing datasets, especially LTRM monitoring datasets, with any projected hydrologic data the Program may invest in acquiring.

Challenges related to HREP and management decisions were numerous (fig. 4). An uncertain hydrologic future was expected to complicate decisions on water level management; the operation, effectiveness, and maintenance of infrastructure (for example, closing structures, locks and dams, pumps, levees); and navigation throughout the Upper Mississippi River System. Participants were also concerned that there may be a lack of funds to assess climate effects for projects, limiting HREP project development teams to qualitative climate change assessments instead of quantitative assessments. Uncertainty surrounding the Upper Mississippi River System's future hydrology also presented challenges to HREP planning, design, and assessment (for example, Will UMRR program projects that are designed [to] "hold up" be effective and useful with future hydrologic conditions?; app. 2). The challenges of how to decide where, what, and how to build to last in an uncertain hydrologic future were discussed at length. Participants also noted the difficulty of estimating project habitat benefits (and future-without-project conditions) and how they may change over a 50-year project design life given the lack of understanding about future hydrologic conditions.

Several challenges related to general methods and data distribution were identified in the mind-mapping exercise (fig. 5) and homework responses (app. 2). The challenges reflected the diversity of agencies within the UMRR program's partnership and their past experiences obtaining, handling, applying, and interpreting hydrologic data and communicating their meaning in various outlets (for example, scientific articles, public forums). First, related to general methodologies used by the UMRR program's partner agencies, an uncertain hydrologic future would likely affect field work, including the ability to sample and sampling success, and other hydrologically related work on the river and floodplain. For example, a future where water levels remained higher for longer periods, or where high-water events shifted in seasonality, could limit or change the periods for effective field sampling. Accessing and interpreting data and interpreting them was also identified as a challenge because of issues with existing databases, sampling methods, and data quality. It was also noted that gaps in expertise could exist in certain agencies and could hinder effective interpretation and data use, potentially causing some agencies to rely more heavily on partners rather than their own personnel. Finally, challenges were associated with effectively communicating about future hydrologic data. For example, social dynamics and past histories of interactions between agencies and the public may make productive conversations with the public about any projected high-water levels difficult.

Upper Mississippi River Restoration Program Priorities for Understanding Potential Future Hydrology

Agency priorities for understanding future hydrology were broad, spanning geomorphic, resource management, engineering, and ecological disciplines (table 2). The theme with the most priorities identified was ecology (11 priorities), followed by geomorphology (9 priorities) and HREP and management decisions (6 priorities). Top priorities for ecology were related to understanding how ecological patterns and processes may respond to future hydrologic conditions across a variety of habitats in the Upper Mississippi River System. Determining appropriate metrics to link hydrology and ecological endpoints, modeling frameworks, and scales of analysis were also important. Top priorities for geomorphology included understanding how general geomorphic responses, flood water conveyance, and backwater sedimentation may change under future conditions. Understanding sedimentation or sediment dynamics was the focus of most geomorphology priorities (5 of 9 priorities). For the HREP and management decisions theme, understanding how future hydrologic conditions may affect restoration design and planning guidance, including the consideration of new features, was important. Some priorities did not exclusively fall within a single theme. For example, the fourth ranking priority under HREP and management decision needs references understanding how the distribution of habitat suitability for plants may change under future hydrologic

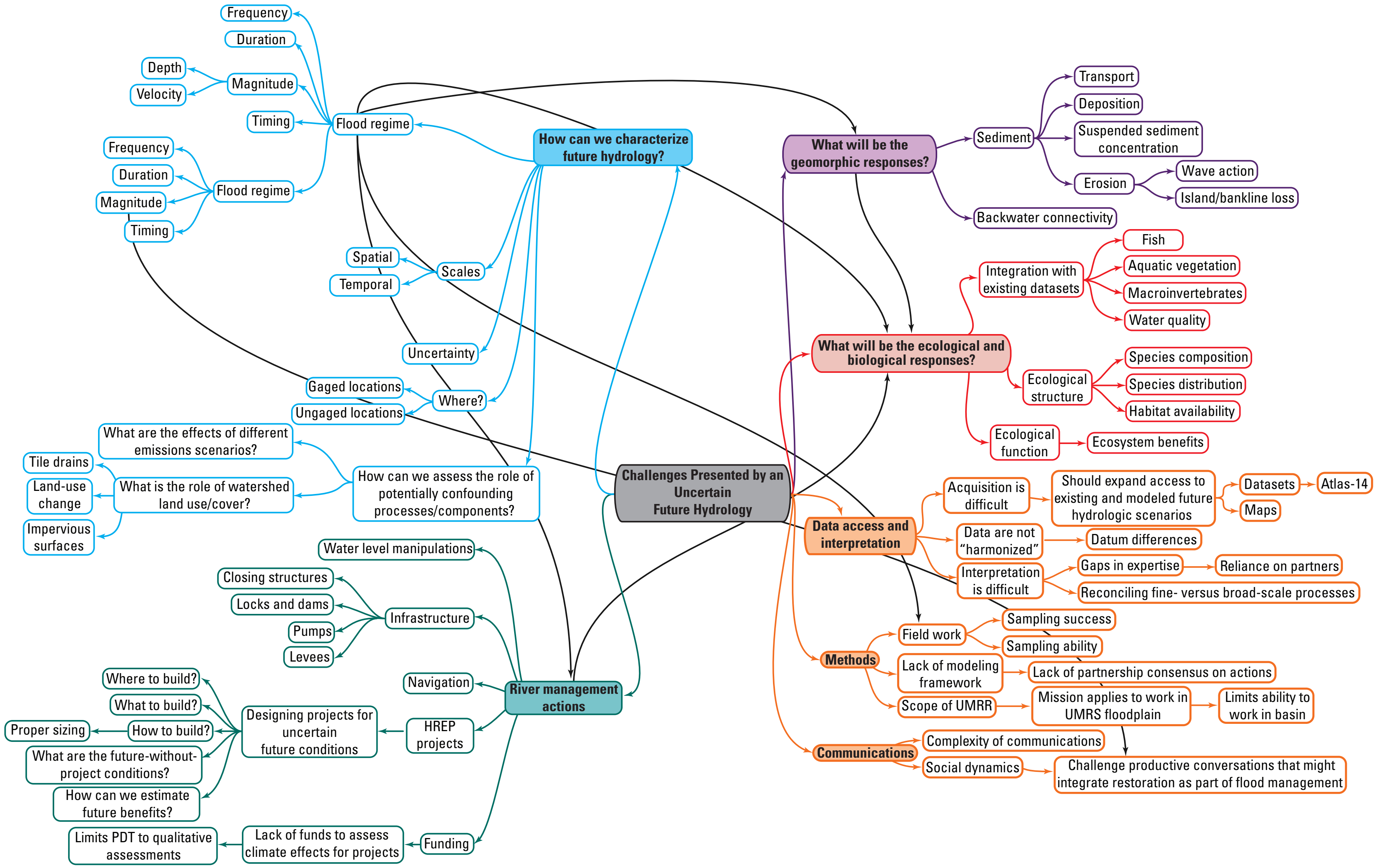

Figure 1. Mind map of challenges facing the Upper Mississippi River Restoration program that are presented by an uncertain hydrologic future. Challenges were related to the themes of hydrology (blue), geomorphology (purple), ecology and biota (red), Habitat Restoration and Enhancement Project and management decisions (teal), and general methods and data distribution (orange). The black lines indicate indirect connections between mind-map ideas. [HREP, Habitat Restoration and Enhancement Project; PDT, project delivery team; UMRR, Upper Mississippi River Restoration; UMRS, Upper Mississippi River System]

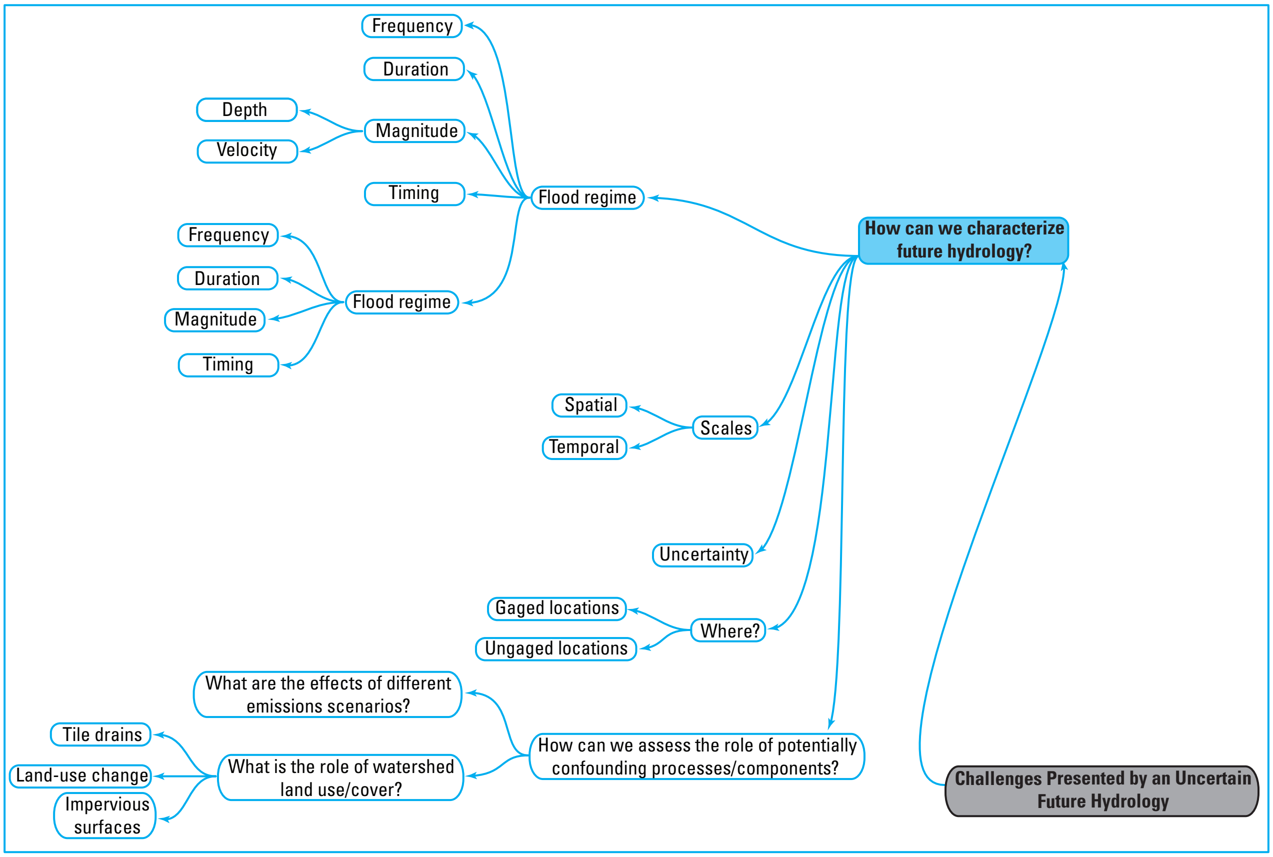

Figure 2. Subsection of mind map of challenges facing the Upper Mississippi River Restoration program that are presented by an uncertain hydrologic future related to the theme of hydrology. The blue box indicates mind-map items related to the theme of hydrology; blue lines indicate direct connections between mind-map ideas.

conditions, an ecological response. Such priorities reflect the integrative nature of the UMRR program and the complexity of the Upper Mississippi River System.

Priorities were identified for a range of spatial (project site, navigation pool, reach, system) and temporal (daily, seasonal, annual) scales during discussions, some of which were mentioned explicitly in the final priority listing (table 2). For example, understanding how future hydrology may affect HREP designs may be most applicable to individual project planning efforts (site scale), but understanding how future hydrology may affect where restoration is needed may be viewed at broader spatial scales, including across the entire system. Most priorities, however, did not specify a particular spatial or temporal scale of interest. Instead, priorities were more general in nature, reflecting the difficulty of synthesizing challenges faced by multiple partnering agencies of the UMRR program.

Ideal Dataset to Meet Upper Mississippi River Restoration Priority Needs

The ideal dataset for meeting the UMRR program's priority needs consists of discharge data at a daily time step for a minimum 50-year time horizon across the entire Upper Mississippi River System (table 3). Such a dataset would allow the greatest amount of flexibility for summarizing custom hydrologic metrics over various spatial and temporal scales, an important quality given the diversity of potential applications of the data (app. 2). A high priority was placed on systemic coverage of the Upper Mississippi River System so that the data could be available to all UMRR program partners and across LTRM study reaches. However, it was noted during discussions that there may be added challenges of acquiring and (or) evaluating existing datasets for the Mississippi River below the confluence with the Missouri River.

An off-the-shelf data product was discussed as a potential resource for the partnership as an alternative to new modeling efforts that would require substantially greater amounts of funding and development time. The LOcalized Constructed Analogs- (LOCA-) Variable Infiltration Capacity- (VIC-) mizuRoute hydrologic data products represent the

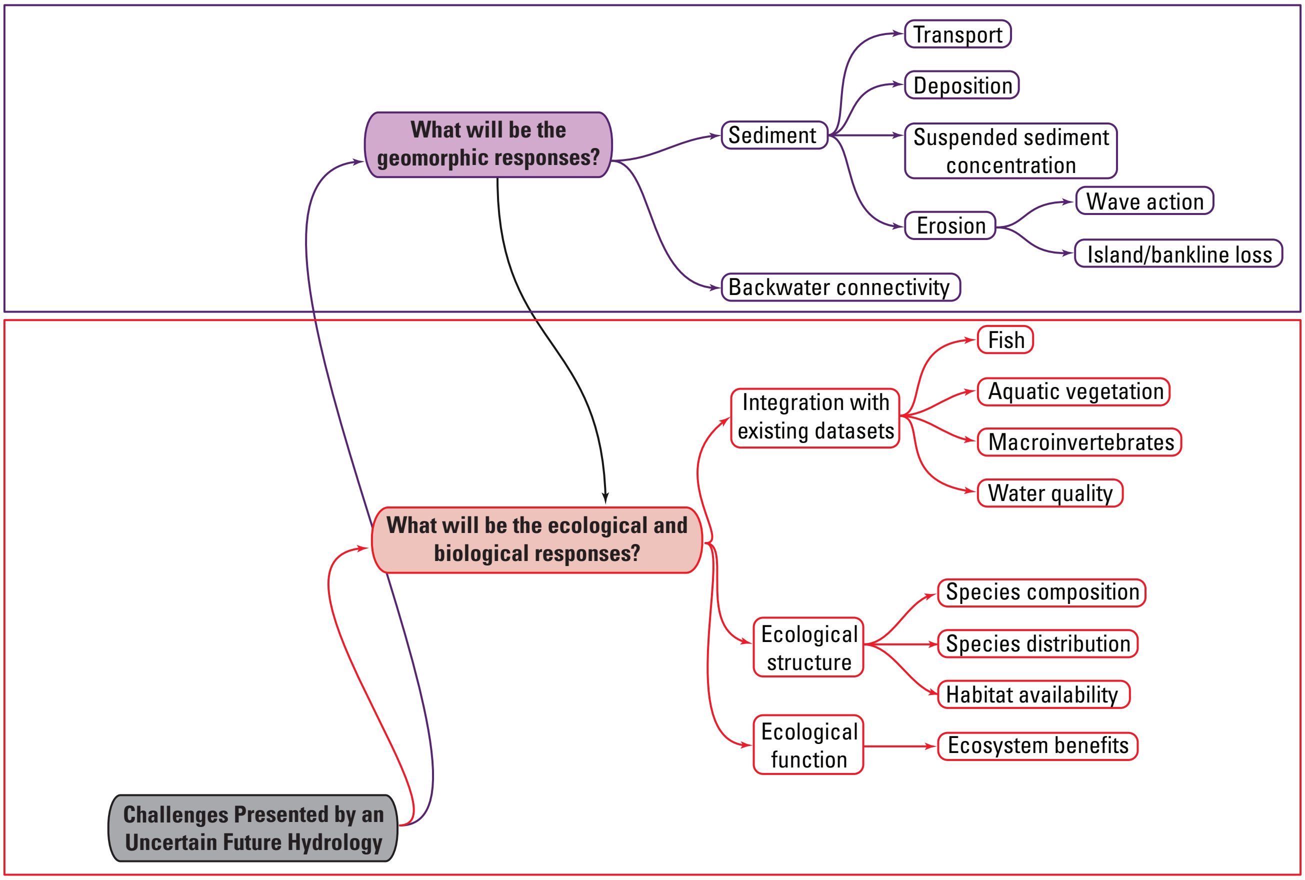

Figure 3. Subsection of mind map of challenges facing the Upper Mississippi River Restoration program that are presented by an uncertain hydrologic future related to the themes of geomorphology (purple box) and ecology (red box). Purple and red lines indicate direct connections between mind-map ideas related to the themes of geomorphology and ecology, respectively; the black line indicates an indirect connection between mind-map ideas.

most recent data produced by collaborators from Federal agencies, including the Bureau of Reclamation, USACE, USGS, and other academic and research institutions. The name “LOCA-VIC-mizuRoute” comes from the chain of models that produce the data: LOcalized Constructed Analogs (downscaled Coupled Model Intercomparison Project Phase 5 global climate data; Pierce and others, 2014; Vano and others, 2020), Variable Infiltration Capacity macroscale hydrological model (Liang and others, 1994), and the mizuRoute hydrologic routing model (Mizukami and others, 2016). The data products themselves represent a total of 64 time series projections of meteorology, hydrological fluxes, and routed river discharge from 1950 to 2099 for the conterminous United States. These datasets are derived from the simulations of global weather patterns from 32 global climate models for two emissions scenarios. These two emissions scenarios, or representative concentration pathways (RCPs), are a moderate emissions pathway where radiative forcing from greenhouse gas emissions levels off before the year 2100 at a level of 4.5 watts per square meter (RCP 4.5) and a high-emissions pathway where radiative forcing continues to rise, reaching 8.5 watts per square meter by 2100 (RCP 8.5). The hydrologic projections are available for every river segment in the conterminous Unites States in the USGS geospatial fabric (Viger and Bock, 2014). The data driving the LOCA-VIC-mizuRoute hydrologic data products are available at https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/, and the routed streamflow products are housed locally on USACE servers.

Workflow for Acquiring a Dataset of Future Hydrology Projections for the Upper Mississippi River System

A workflow was drafted before meeting 3 (app. 5, fig. 5.2) and was refined during meeting 3 (fig. 6) as a blueprint for acquiring future hydrologic projections of the Upper Mississippi River System for use by the UMRR Program. The workflow focused on an evaluation of the existing LOCA-VIC-mizuRoute hydrologic data products for use in the Upper Mississippi River System. Evaluation was determined to be a logical first step because the LOCA-VIC-mizuRoute hydrologic data products share

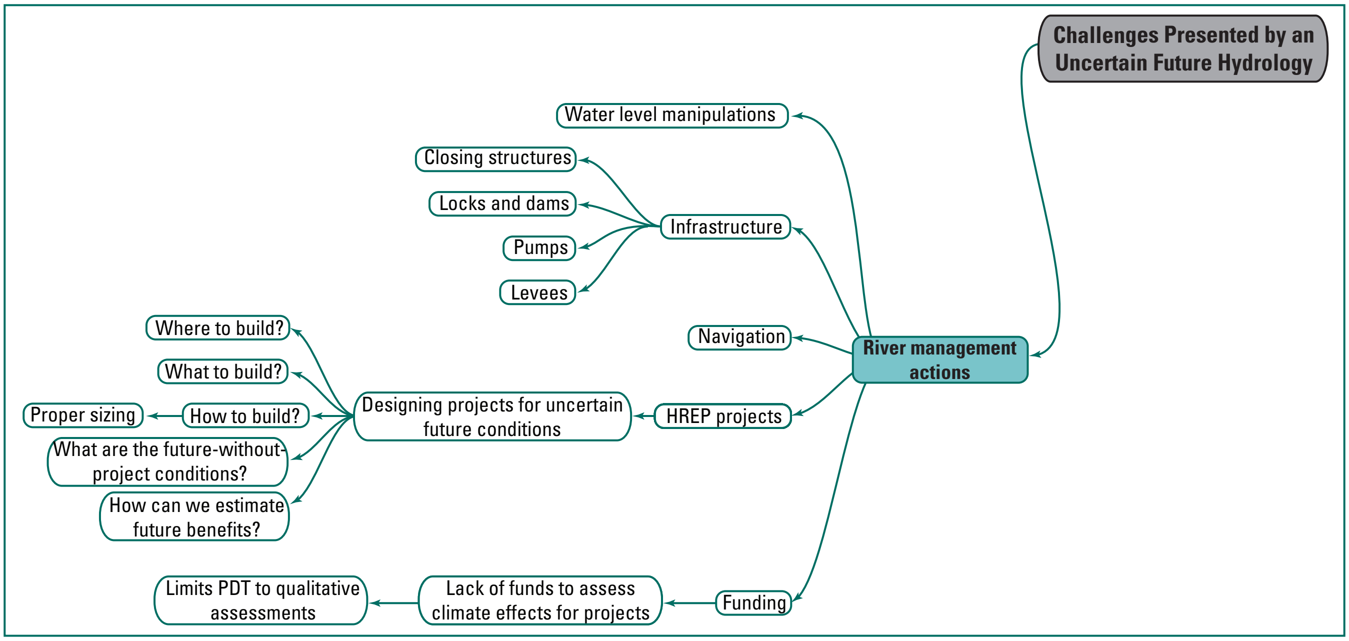

Figure 4. Subsection of mind map of challenges facing the Upper Mississippi River Restoration program that are presented by an uncertain hydrologic future related to the theme of Habitat Restoration and Enhancement Projects and management decisions (teal box). Teal lines indicate direct connections between mind-map ideas.

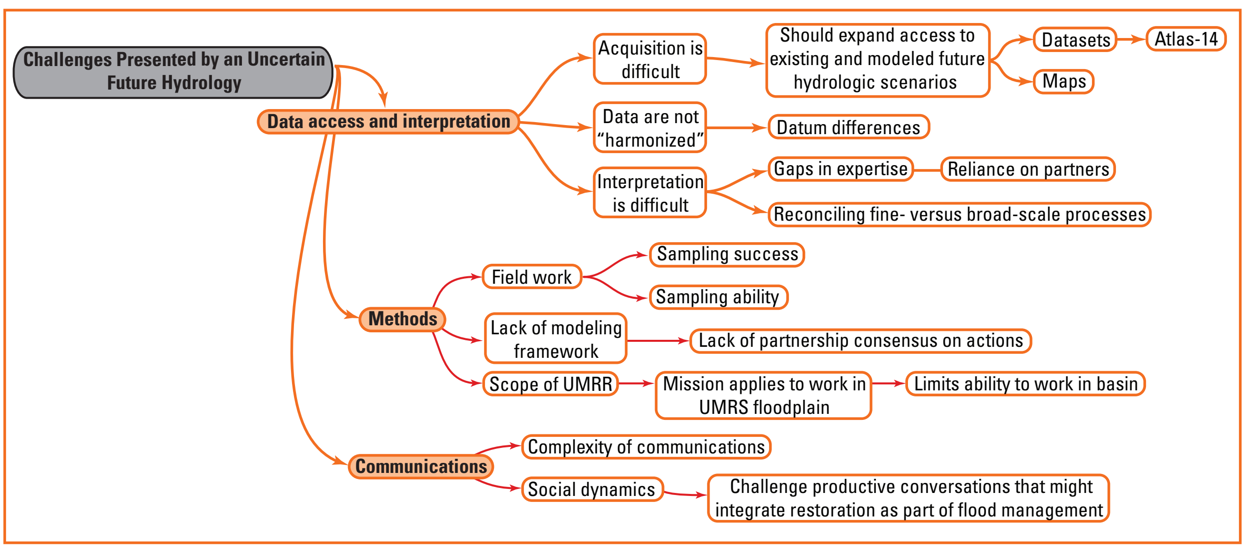

Figure 5. Subsection of mind map of challenges facing the Upper Mississippi River Restoration program that are presented by an uncertain hydrologic future related to the theme of general methods and data distribution (orange box). Orange lines indicate direct connections between mind-map ideas. [UMRR, Upper Mississippi River Restoration; UMRS, Upper Mississippi River System]

Table 2. Priority of Upper Mississippi River Restoration program needs related to the themes of geomorphology, Habitat Restoration and Enhancement Project and management decisions, and ecology.

[Values in parentheses represent scores computed from a paired-ranking exercise. Larger scores indicate higher ranking, and ranking scores are only comparable within each theme, not across themes. Note that fewer needs were identified for the geomorphology and Habitat Restoration and Enhancement Project (HREP) and management decision themes than for the ecology theme; --, no additional needs were discussed within the theme]

Priority	Geomorphology needs	HREP and management decision needs	Ecology needs
1	Understanding how future hydrology may affect geomorphic responses (for example, island loss, natural levees) in channels, shorelines, backwaters, and floodplains (131)	Understanding changes in hydrology and hydraulics (for example, water surface elevation, velocity) at varying spatial scales to guide river restoration designs (that is, building resiliency, achieving intended habitat benefits) (73.7)	Understanding how future hydrology may affect biologic responses, ecological structure, and ecological function in channels, shorelines, backwaters, and floodplains (143.3)
2	Understanding how natural geomorphic features and navigation infrastructure affect the conveyance of water across the river floodplain (108.9)	Understanding how future hydrology can drive our vision of future desired conditions and other planning guidance (for example, environmental pool plans) (54.4)	Understanding how future hydrology, including water surface elevation changes and seasonal shifts in hydrology, may affect floodplain forests, aquatic vegetation, and the distribution of their suitable habitats (for example, whether they may cross tipping points that could reduce their resilience) (137.3)
3	Assessing how changing hydrology may affect backwater sedimentation in the Mississippi and Illinois Rivers (103.1)	Understanding whether future hydrology provides opportunities for different/new restoration (HREP) features that are more self-sustaining (for example, riprap versus seed islands; self-scouring overwintering areas) (45.7)	Developing a better understanding of which hydrologic metrics are most influential on aquatic and floodplain vegetation responses (120.7)
4	Projecting sediment for major tributaries to identify which are most likely to change in the future (73.8)	Predicting or forecasting water surface elevations and changes in seasonality for evaluating suitability for different plant communities (44.2)	Understanding how climate-changed hydrology may affect habitat availability to the point that it affects ecological and critter resilience (116.7)
5	Assessing and mapping sediment mobility in the Mississippi and Illinois Rivers (72.5)	Understanding how, where, why, and what to restore given changing future hydrologic and hydraulic metrics (39.7)	Linking future hydrology with life history requirements of biota (walleye [*Sander vitreus*], zooplankton, backwater fishes, and others) (96.0)
6	Developing a bank-to-bank sediment budget to estimate what will be transported during high-water events in the Mississippi and Illinois Rivers (68.8)	Understanding how to fund and build features that can be easily modified or adapted to a change in future hydrology beyond the 10-year adaptive management timeframe (22.1)	Developing a modeling framework to link future hydrology with ecological response models, data from other disciplines (for example, fish, water quality, vegetation), and ecological concepts like resiliency and vulnerability (91)
7	Assessing whether Upper Mississippi River System geomorphic reaches may change over time or would require redefinition (52.3)	--	Assessing what scales are important to assess habitat conditions and how they may be affected by climate-changed hydrology (87.4)
8	Assessing how bathymetric changes contribute to deposition in the navigation channel in the Mississippi and Illinois Rivers (47.5)	--	Understanding timing, magnitude, and duration of flows and flood pulses and thermal effects in order to understand potential effects on managed biota and allow staff to either mitigate change or prepare the public in advance for likely unavoidable changes going forward (85.1)
9	Assessing how sediment will affect harbors in the Mississippi and Illinois Rivers (11.1)	--	Assessing whether we have enough deep-water habitats in the future and at what point in time that may change (61.4)

Table 2. Priority of Upper Mississippi River Restoration program needs related to the themes of geomorphology, Habitat Restoration and Enhancement Project and management decisions, and ecology.—Continued

[Values in parentheses represent scores computed from a paired-ranking exercise. Larger scores indicate higher ranking, and ranking scores are only comparable within each theme, not across themes. Note that fewer needs were identified for the geomorphology and Habitat Restoration and Enhancement Project (HREP) and management decision themes than for the ecology theme; --, no additional needs were discussed within the theme]

Priority	Geomorphology needs	HREP and management decision needs	Ecology needs
10	--	--	Understanding ice dynamics and how they would affect food for waterfowl, overwintering, harmful algal blooms, water quality, operations and management, and so on (53.3)
11	--	--	Projecting water quality for major tributaries (that is, determining which tributaries will be changing more) (41.9)

Table 3. Characteristics of an ideal future hydrology projection dataset for the Upper Mississippi River Restoration program's partnership.

[UMRR, Upper Mississippi River Restoration]

Characteristics included in the dataset	Rationale
Discharge	Commonly used in UMRR program activities; typical output from hydrologic models
Daily time step	Allows analytical flexibility, including the potential to summarize multiple aspects of flow regime
A 50-year minimum projection horizon	Engineering design for a 50-year performance period
Upper Mississippi and Illinois River main stem locations	UMRR program authorization area; high priority for systemic coverage
Available at locations with existing discharge data	Ease in relation to existing studies and projects

many of the characteristics of the ideal dataset (table 3). The data products are also readily available and would be less expensive to evaluate than an effort to generate custom hydrologic projections for the Upper Mississippi River System through an independent hydrologic modeling effort. Evaluation of the LOCA-VIC-mizuRoute hydrologic data products is necessary because the conterminous United States scale climate and hydrologic models are not calibrated for any specific drainage basin, including the Upper Mississippi River System. The lack of regionally calibrated models used to produce the LOCA-VIC-mizuRoute hydrologic data products could be problematic because important processes that drive the Upper Mississippi River System's regional climate or basin flow regime may not be well represented, leading to unreliable projections.

The workflow begins with an assessment of data reliability (fig. 6, black boxes) that would inform the pathway (fig. 6, green, blue, and red boxes) for subsequent steps. For example

1. If the LOCA-VIC-mizuRoute hydrologic data products were determined to be reliable for use in the Upper Mississippi River System with no further data processing necessary, the green pathway would be pursued.

2. If the LOCA-VIC-mizuRoute hydrologic data products were somewhat reliable and could be improved for use in the Upper Mississippi River System through postprocesses such as correcting for systematic biases or scaling applications, the blue pathway would be pursued.

3. If reliability issues of the LOCA-VIC-mizuRoute hydrologic data products could not be addressed through systematic bias correction or scaling, the red pathway would be pursued.

This workflow formed the basis for a proposal submitted to the UMRR program's fiscal year 2022 Science in Support of Restoration funding opportunity in March 2022 that was approved for funding. In the next subsections, we describe the workflow following the color scheme of figure 6.

Black Boxes

The black boxes represent the starting point of the LOCA-VIC-mizuRoute hydrologic data product evaluation process. The goals of the activities are to articulate the project's purpose (black box 1), identify metrics for evaluating model performance (black box 2), and quantify model performance (black box 3). The activities carried out in these boxes would determine which pathway would be subsequently followed given the results of model performance.

Progress through the black boxes was made via the UMRR program's future hydrology meeting series. During the meeting series, the partnership helped identify the questions and applications for which any projected future hydrologic dataset could be used. When the workflow is implemented, a small team of USACE district representatives would build on the partnership discussions to refine how a projected future hydrologic dataset could integrate with HREP planning and design. The outcome of these discussions would help guide the selection of data reliability metrics (fig. 6, black box 2) and inform documentation related to the data dissemination steps (fig. 6, green and blue boxes).

The bulk of the remaining research activities largely relate to defining data reliability metrics and completing the actual evaluation (fig. 6, black boxes 2 and 3). The reliability of the LOCA-VIC-mizuRoute hydrologic data products would be assessed using metrics identified through literature review completed by technical experts with input from the PIs. Metrics would be used to help identify any systematic biases in the LOCA-VIC-mizuRoute hydrologic data products. Examples of systematic biases may include a poor representation of hydrologic responses to precipitation events, insufficient accounting of groundwater contributions, or snowmelt timing and dynamics. Insufficiencies like these may manifest as biases in the LOCA-VIC-mizuRoute modeled historical discharge data that can be detected when compared to observed historical discharge data using selected metrics. Based on discussions during the UMRR program's future hydrology meeting series, evaluation metrics would assess annual, seasonal, and monthly flow duration, variability, magnitude, and timing to understand how well low and high

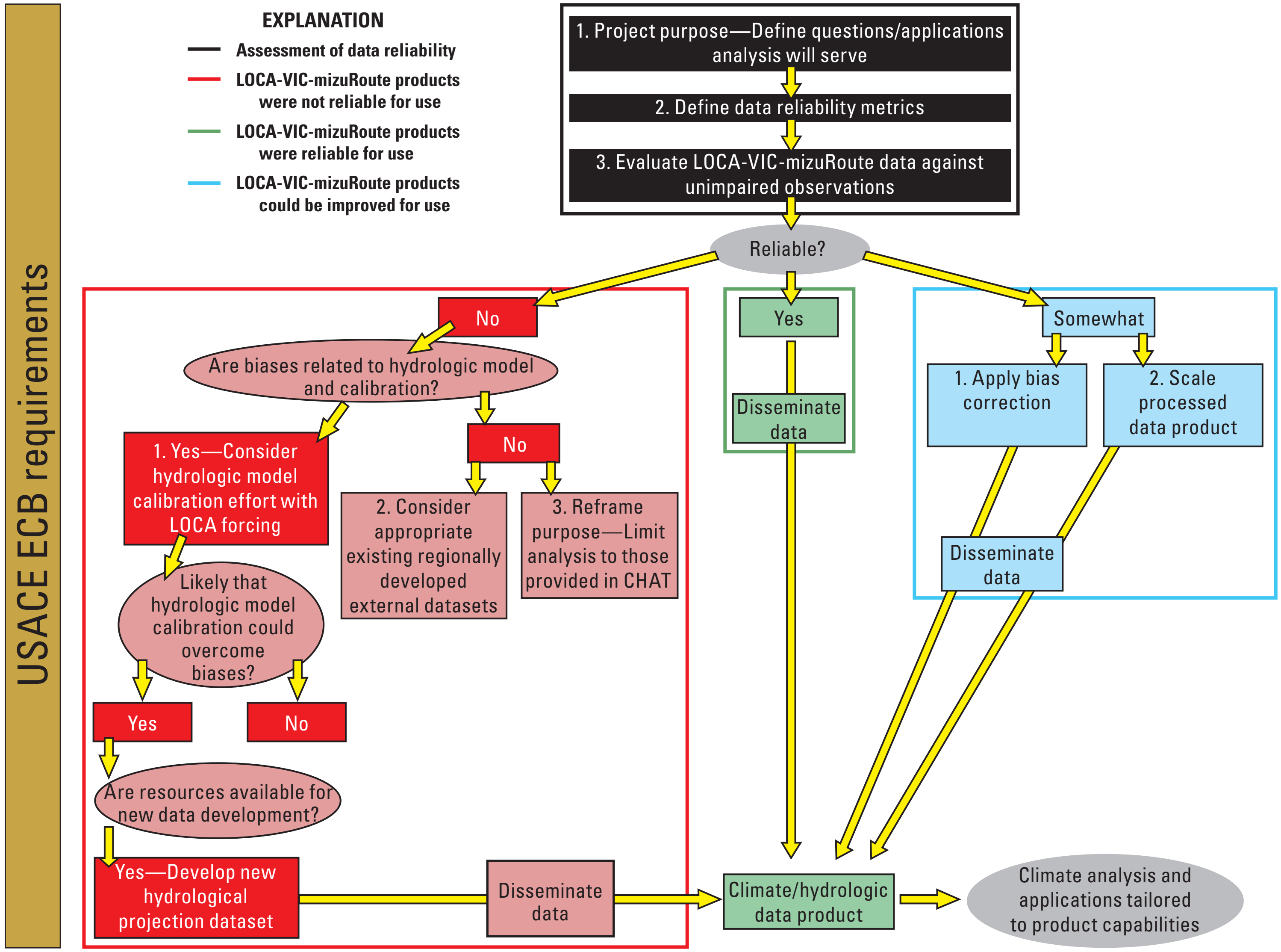

Figure 6. Workflow process for evaluating the LOcalized Constructed Analogs- (LOCA-) Variable Infiltration Capacity- (VIC-) mizuRoute data products. [USACE, U.S. Army Corps of Engineers; ECB, engineering and construction bulletins; CHAT, Climate Hydrology Assessment Tool; USACE ECB requirements refers to “Guidelines for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects” (U.S. Army Corps of Engineers, 2018)]

flows are simulated across a range of time steps. Metrics for observed and modeled historical discharge would be directly compared using nonparametric statistics (for example, Kolmogorov-Smirnov or Cramér-von Mises tests).

Once the metrics have been chosen, historical (1950–2005) modeled discharge data from the LOCA-VIC-mizuRoute hydrologic data products would be compared against observed unimpaired discharges using the chosen metrics (fig. 6, black box 3). The comparisons would be done at USGS streamgage locations selected by the technical experts to represent a range of physiographic conditions determined in the basin that are not affected by upstream regulation or land-use changes over the historical period. Modeled daily discharge data from the LOCA-VIC-mizuRoute products would be extracted using custom scripts. Streamgages that are not affected by regulation are being mapped and historical observed unimpaired discharge datasets are being compiled as part of the Upper Mississippi River and Missouri River flow frequency studies that are underway. The modeled and observed historical data would be summarized separately using the set of metrics established by the technical experts fig. 6, black box 2), allowing for quantitative comparisons (for example, nonparametric statistics) and qualitative comparisons (graphical comparisons of metrics) between the modeled and observed discharge datasets. The quantitative comparisons across multiple streamgage locations will offer insight as to whether the climate and (or) hydrologic models underlying the LOCA-VIC-mizuRoute hydrologic data products can sufficiently represent drainage basin processes that may vary spatially. The quantity and severity of deviations between modeled and observed metrics can indicate overall data reliability (fig. 6, green pathway), whether the modeled hydrologic data have a problematic degree of systematic biases and whether they can be corrected easily (fig. 6, blue pathway), or whether insurmountable issues relating to process fidelity with the data products may exist and would necessitate looking for alternative solutions (fig. 6, red pathway).

The outcome of the black boxes would be a quantitative analysis with data summaries in numeric and visual form that would be interpreted by a group of technical experts and the project PIs. The group would meet to discuss the results and agree on a level of data reliability, which determines the activities for the rest of the project. The possible outcomes are all data are reliable and no further modifications are necessary (green pathway), there are indicators of reliability, but the data require bias correction or scaling postprocessing (blue pathway), or the existing data seem unreliable for quantitative analysis and issues cannot be addressed through bias correction or scaling postprocessing (fig. 6, red pathway). The evaluation results and consensus formed during these discussions about the best path forward would be communicated to the LTRM management team.

Green Pathway

Under the green pathway, the LOCA-VIC-mizuRoute hydrologic data products would be determined to be reliable for applications in the Upper Mississippi River System without any additional postprocessing, and the project team would proceed with disseminating the LOCA-VIC-mizuRoute hydrologic data products. The spatial resolution at which resulting streamflow projections would be made available cannot be determined in advance of the evaluation (fig. 6, black box 3). However, providing projections of streamflow will be prioritized for locations along the main stem Upper Mississippi and Illinois Rivers and major tributaries, where streamflow observations are available for the same historical modeling period as the LOCA-VIC-mizuRoute hydrologic data products (that is, 1950 or earlier). At each location, we would intend to serve the modeled daily discharge values from 1950 to 2099 for both emissions scenarios and 32 global climate models, resulting in a total of 64 time series per location.

Data products would be made publicly available through a website with features to help users navigate, explore, and interpret the large amount of data. Website construction would be led by the USACE Engineer Research and Development Center, that has completed a similar project for the Columbia River Basin. Features would likely include data queries by map and location list, graphical summaries of aggregated projection results across the entire period of record (1950–2099) at each location, and graphical summaries of projections by season for each location. Data would be made available to download via the website by individual locations or groups of locations. All 64 time series datasets would be served at each location to allow for maximum flexibility for end users, but website visualization tools would summarize aggregate patterns across all datasets for interpretability and clarity to allow users to explore the model outputs before downloading the packaged datasets for their desired location(s). The project team would develop documentation to help describe the data and their appropriate uses. Documentation will accompany the data products on the website and would likely summarize the models underlying the LOCA-VIC-mizuRoute data products, the emissions scenarios, and issues with uncertainty. Strengths and limitations of the data would be discussed at length to assist stakeholders in understanding how best to interpret and use the data.

Finally, the principal investigators would host a webinar for the UMRR partnership to showcase the results of the project. The goal of the webinar would be to educate attendees on how to access, interpret, and use the data given the diversity of experiences working with hydrologic data across the UMRR partnership. Topics discussed would likely include the results of the evaluation, an introduction to the data themselves and how to access them on the website, an overview of the documentation and review of best practices for use (including appropriate time scales of analyses), a discussion of uncertainty in modeled hydrologic data, and a question and answer session to address specific concerns from the partnership.

Blue Pathway

The blue pathway would be followed in the event the LOCA-VIC-mizuRoute hydrologic data products were determined to adequately represent the hydrological processes in the Upper Mississippi River System but still display some systematic underlying biases that would limit the intended interpretations and applications. In this pathway, the effects of these systematic biases could be reduced by applying a bias-correction technique or scaling the intended applications of the processed data product.

Bias correction (fig. 6, blue box 1) is a statistical adjustment of the data to correct for the systematic biases that arise during a model simulation. Examples of correctable systematic biases include consistent underestimations of annual peak flows, underestimates of low flows, or misrepresentation of flow conditions during a certain season. There are several bias-correction methods. Different methods are used to correct for different types of biases. There are several steps to apply a bias-correction technique. First the systematic biases that require correction would be identified by the technical experts reviewing the results of the data product evaluation. Then, the technical experts would identify the most appropriate bias-correction method to use given the biases present. Third, the bias-correction method would be applied to the data products, including cross-checks that the bias has been corrected to an acceptable degree.

When results from the evaluation look good overall but indicate that the data may not be suited for all intended data applications, then some constraints for application must be defined. This outcome is referred to as “scale processed data product” (fig. 6, blue box 2). In this situation, quantitative analysis using the LOCA-VIC-mizuRoute hydrologic data products would be limited to a certain time interval (duration) or to certain locations. The outcome of this scenario is either a list of appropriate uses for the data products or a filter of the data to certain locations for which the data are most appropriate. If the former is necessary, results from the evaluation would be shared with a larger group of UMRR program partners to gain consensus on which applications are most appropriate for the data.

After completion of either blue box 1 or blue box 2 (fig. 6), the resulting datasets would be packaged up for dissemination. Data dissemination would largely follow the dissemination steps described in the green pathway. If the scale processed data product methods are used (fig. 6, blue box 2), then any limitations would be communicated through the data documentation.

Red Pathway

The red pathway would be followed if the comparisons of the LOCA-VIC-mizuRoute hydrologic data products to observed hydrological datasets (fig. 6, black box 3) indicated that no postprocessing could rectify the data. If the evaluation results also indicated that the data had significant deficiencies in representing key hydroclimatic processes in the basin, the red box 1 (fig. 6) pathway would be followed. Under this scenario, we would complete a quantitative evaluation of the likelihood that a recalibration of the VIC model could overcome these biases. The results of the evaluation would then be shared in a virtual workshop format among project PIs, CPR CoP members, and UMRR program participants who attended meeting 3. The purpose of the workshop would be to discuss the test calibration results and implications for meeting UMRR program priorities and to scope an appropriate modeling effort for generating projected Upper Mississippi River System hydrology if the results indicated likely success of this pursuit. Depending on the outcome of the test calibration, modeling efforts could include full basin calibration of the VIC model and development of a new hydrological projection dataset or consideration of a different hydrologic model for the Upper Mississippi River System, preferably existing, to generate a new projection dataset. Any efforts to generate projected Upper Mississippi River System hydrology would be guided by the outcomes of the Upper Mississippi River System future hydrology meeting series, including descriptions of UMRR program priorities for a future hydrologic dataset, ideal dataset description, and emphasis on acquiring systemic data.

It is possible that data issues could not be improved through systematic bias correction, scaling of applications, or hydrologic modeling and calibration. Under this scenario, the project team would first consider the availability, strengths, and limitations of existing regionally developed datasets that may meet some of the UMRR program’s priority needs for understanding future Upper Mississippi River System hydrology (fig. 6, red box 2). During meeting 3, it was noted that there may be efforts within the region to develop regional downscaled climate and hydrologic products. Although conterminous United States derived products like the LOCA-VIC-mizuRoute hydrologic datasets would have comprehensive coverage for the Upper Mississippi River System, the entire Upper Mississippi River System may not necessarily be in the domain of a regional downscaled climate and hydrologic product. In addition, regional hydrologic products may not necessarily have all the characteristics the UMRR program partners identified as ideal for meeting their priority needs (table 3). Any potential regional products would need to be identified and evaluated for their suitability in the Upper Mississippi River System within the context of the UMRR partnership’s priority needs and desirable dataset characteristics. Evaluation of any regionally developed streamflow product would follow the same process used for evaluation of the LOCA-VIC-mizuRoute hydrologic data products (fig. 6, black box 3) and finish with an update to the LTRM project management team to determine appropriate next steps.

If alternative downscaled products tailored for the region are not available, then the project purpose would be reframed and the use of the existing LOCA-VIC-mizuRoute hydrology would be limited to qualitative comparisons such as those provided in the Climate Hydrology Assessment Tool (CHAT; fig. 6, red box 3). CHAT summarizes metrics at the hydrologic unit code (HUC) 08 scale and as of meeting 3 of the series reports the annual-maximum value of the average monthly in-channel routed runoff, and various summaries of precipitation and temperature projections. The project team would host a virtual workshop for the UMRR partnership (attendance list similar to the UMRR program's future hydrology meeting series) to introduce partners to the CHAT, describe its strengths and weaknesses, and identify how it could be appropriately used in research and management.

Gold Box

The gold title box in figure 6 represents fulfillment of Engineering and Construction Bulletin 2018–14, "Guidelines for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects," requirements (USACE, 2018). This effort would involve coordination with the USACE CPR CoP. The qualitative assessment of climate change required by Engineering and Construction Bulletin 2018–14 will be completed by a PI and includes a literature review of observed and projected trends in climate change, trend analysis and nonstationarity detection in observed hydrology, and relevant climate variables. The CHAT would be used to evaluate trends in the projected annual maximum of average-monthly streamflow at the 8-digit HUC scale for the Upper Mississippi River (HUC 07) and Missouri River (HUC 10) drainage basin, and a drainage basin vulnerability assessment would be completed at the 4-digit HUC scale using the vulnerability assessment tool. Recent qualitative assessments completed for the Upper Mississippi River and Missouri River flow frequency updates would be leveraged to support the qualitative assessment proposed herein. As a result of this existing body of work, the primary focus of this effort would be to provide consistency, particularly in the use of the CHAT tool, between the Mississippi River and Missouri River analyses that would be completed independently. Updates to the vulnerability assessment would be required to meet USACE guidance for their ecosystem restoration business line.

Discussion

The Upper Mississippi River System future hydrology meeting series represented the first comprehensive and topical discussion among UMRR program partners about future hydrology and the challenges it presents to carrying out the mission of the UMRR program. Participants accomplished the two goals for the meeting series: (1) to discuss specific needs, methodological approaches, and desired outcomes for understanding climate-changed hydrology in relation to the UMRR program's mission and (2) to develop a blueprint for acquiring future hydrology projections for the Upper Mississippi River System. The results, described previously, and the appendixes provide important documentation of discussions and decision points made by the partnership in working towards acquiring a dataset of projected hydrologic data for the Upper Mississippi River System.

Meeting Series Outcomes

The challenges presented by an uncertain hydrologic future were specific to the Upper Mississippi River System and can serve as a useful reference for the UMRR partnership to frame further discussions. In particular, challenges associated with HREP and management decisions were rooted in the years of experience since the inception of the UMRR program. HREP designs are tailored to specific places within the Upper Mississippi River System and often require site-specific hydrologic information in the planning process (U.S. Army Corps of Engineers, 2012). There remain, however, questions of exactly how any quantitative dataset of projected future hydrology would integrate with existing workflows of the HREP planning and design process. Discussions planned for the early part of the LOCA-VIC-mizuRoute hydrologic data product evaluation (fig. 6, black box 1) are intended to initiate communications on the role and use of any projected future hydrologic dataset in HREP planning and design. Future discussions will be held after the black box evaluation, in consultation with the USACE CPR CoP, because of the complexity of the issue, wide range of HREP designs, and uncertainty about the nature of any projected future hydrologic dataset (for example, uncertainty or spatial and temporal scales).

Although crafted with the Upper Mississippi River System in mind, many of the challenges identified are like those facing other river ecosystems, especially other large, multiuse rivers. Common challenges include those related to modeling potential ecological and geomorphic responses and developing management strategies in the face of uncertain hydrologic futures. Modeling potential future responses to altered flows remains difficult in any river system because of the unprecedented nature of flow regime change expected in many systems, complex relations among river systems' ecological and geomorphic components, dynamic interactions among biota themselves, difficulty untangling natural variability from the effects of climate change, and differences in model complexity across linked model frameworks (Vaughan and others, 2009; Olden and others, 2010; Angert and others, 2013; Filipe and others, 2013; Palmer and Ruhi, 2019; John and others, 2021). A variety of modeling approaches linking hydrology to ecological endpoints exist. However, interactions between hydrologic variation and ecological responses should be explicitly captured in a modeling framework by combining ecological and hydrologic methods of comparable complexity in order for the risks of climate change to river ecosystems to be properly represented (John and others, 2021). Developing management strategies in the face of uncertain hydrologic futures is a key challenge for river managers around the world (Krysanova and others, 2010). Several frameworks aid in these efforts (for example, scenario planning [Miller and others, 2022] and resist, accept, or direct [Thompson and others, 2021]), but effective climate change adaptation relies upon understanding projected changes including the full range of potential trajectories. The LOCA-VIC-mizuRoute hydrologic data products, if reliable, will provide managers and researchers with a critical component needed for successful climate change adaptation planning efforts to ensure that restoration and management actions are appropriate and suitable for future conditions.

Agency priorities for understanding future hydrology were broad, which reflected the diversity of perspectives among meeting attendees and their respective agencies. The broadness of the priorities also was an artifact of the ranking process itself, in which more general ideas were ranked higher because they encompassed more specific issues that may have been raised in separate priorities. Although more specific priorities may have been more tractive to link to specific qualities of a hydrologic dataset or intended dataset applications, the generality of the priorities gives space for the partnership to address them in a variety of ways, depending on the skill sets and resources available at any point in time. Within the rankings, some clear breaks were in the degree of support. For example, understanding geomorphic responses to changing hydrology was ranked as the top geomorphology priority with a score of 131 points, but the next two priorities were clumped lower together (rankings between 108 and 103) and a second break was between the next clump of priorities (staring with a score of 73.8). Priorities under the theme of HREP and management decisions also had breakpoints in the distribution of ranking scores. In contrast, ecological priorities were more evenly distributed in their ranking scores. These results indicate that a preference may exist for putting more resources toward addressing a limited number of geomorphic and HREP/management decision priorities in the future and a more distributed effort to address several ecological priorities.

The topic of scale came up repeatedly during the meeting series. Issues of scale are fundamental to understanding ecological patterns and processes, but no single spatial or temporal scale exists over which to best describe ecological phenomena (Wiens, 1989; Levin, 1992; Chave, 2013). It was apparent from homework responses and meeting discussions that agencies differed in their experience working with hydrologic data at various spatial and temporal scales. This fact affected the desired characteristics of a projected hydrologic dataset. Ideally, hydrologic data would be available at the daily scale to allow for the greatest degree of flexibility in subsequent processing; for example, daily data can be summarized at coarse time steps such as weekly, monthly, seasonally, annually, and coarser depending on the intended outcome, application, or analysis. In addition, any future dataset would ideally be available systemically and for locations with existing hydrologic data. These characteristics would allow comparisons of river hydrology across the entire Upper Mississippi River System (spatial comparisons) and comparisons of specific streamgage locations through time (temporal comparisons). It should be noted that the appropriateness of any comparison should be evaluated in the context of the LOCA-VIC-mizuRoute hydrologic data product evaluation results, especially with regards to the degree of uncertainty.

Uncertainty is inherent in any modeling exercise, especially those related to projecting future hydrologic conditions. Understanding the potential sources of uncertainty and how they contribute to modeling outcomes is an emerging practice (Dobler and others, 2012). A full assessment of uncertainty, its sources, and its effect on model results is not a focus of the blueprint for acquiring a dataset of future hydrology projections for the Upper Mississippi River System. However, a future study could provide ample opportunity to pursue these topics. The issue of uncertainty was raised on several occasions during the meeting series; technical experts emphasized the importance of communicating uncertainty in any final hydrologic data product deemed suitable for use by the UMRR program’s partnership. Doing so would help guide the appropriate uses and interpretation of hydrologic patterns. It was recommended that any accompanying documentation related to a data dissemination effort include a discussion of uncertainty and appropriate uses of the data product.

We learned that the input of technical experts was invaluable to the success of the meeting series. Navigating guidance that informs climate-related work within the USACE can be difficult because of changing guidance, lack of official documents, and other issues. Early communication with the USACE CPR CoP was important to help develop expectations for any subsequent climate-change-related work that would be required to meet USACE guidance. Early communication also helped build positive relations and understanding that led to productive meeting discussions with the UMRR program’s partnership, as well as helping to identify related projects from other parts of the country and contacts who could aid Upper Mississippi River System work. Should any additional climate-related projects be taken on in the future by the UMRR program’s partnership, early and frequent communication with the USACE CPR CoP is encouraged.

Blueprint for Acquiring a Dataset of Projected Hydrologic Conditions for the Upper Mississippi River System

The workflow described previously (fig. 6) represents a path towards acquiring a dataset of projected hydrologic conditions for the Upper Mississippi River System. The workflow is rooted in the discussions from the meeting series on challenges faced by the UMRR program's partnership by an uncertain future, priorities for understanding future hydrology in the context of the UMRR mission, and the landscape of modeling approaches and datasets available at the time of the meeting series and identified with the help of technical experts. Although crafted with the LOCA-VIC-mizuRoute hydrologic data products in mind, the workflow is a series of generic steps that can be applied for evaluating a variety of datasets that represent potential future hydrologic conditions. The workload may be substantially reduced if the workflow is reapplied to alternative datasets after an evaluation of the LOCA-VIC-mizuRoute hydrologic data products. This is because initial implementation of steps within the black boxes are designed to generate guiding information and quantitative processing scripts that could be reused in subsequent evaluations. It is possible that even with repeated evaluations, there is no hydrologic data product that fully reliable. In this case, this report and workflow offer insights into reasonable next steps like applying bias correction methods, reassessing the intended use of the data products, or developing custom hydrologic models (fig. 6).

If the UMRR program's partnership acquires projected hydrologic data for the Upper Mississippi River System in the future, careful attention to how the data would be disseminated will be necessary. The wide variety of experience accessing, working with, and interpreting hydrologic data by UMRR program partners was evident in homework responses and in meeting discussions. Issues with data access and communication were also identified as challenges to the partnership. In response, data dissemination plans discussed during meeting 3 were affected by the diverse experiences of UMRR program partners with hydrologic data. The framework for data dissemination outlined in the "Meeting Discussions and Outcomes" section prioritized flexibility in distribution methods (for example, data linked to mapped locations or data made searchable by sites). Distribution methods discussed include premade interpretive graphs for easier data exploration, thorough documentation to help users interpret and work with the data and a webinar to discuss the results and how they can be accessed. Exact details of these components would need to be worked out with technical experts involved in the data evaluation process and website developers involved with the data dissemination process, with input from the broader partnership as needed.

Summary

The Upper Mississippi River Restoration (UMRR) program integrates ecosystem monitoring, research, and modeling to rehabilitate habitat and evaluate ecosystem trends over time in the Upper Mississippi River System. Hydrologic data are foundational to the UMRR program's scientific and management activities, especially those that consider the river system's potential future conditions. A lack of quantitative hydrologic data representing potential future conditions limits the ability to complete informative research on how future conditions may affect river ecology, achieve management goals, and design restoration projects for 50-year horizons.

The U.S. Geological Survey and the U.S. Army Corps of Engineers (USACE) led a series of three virtual meetings with UMRR program partners to (1) prioritize needs for understanding future hydrology, (2) discuss appropriate datasets that could address the UMRR program's needs, and (3) develop a plan for acquiring and distributing a hydrologic dataset of potential future conditions. Participants included representatives from State agencies in the UMRR partnership; biologists and engineers from USACE districts spanning the Upper Mississippi River System; technical experts from the U.S. Geological Survey and USACE; representatives from the U.S. Fish and Wildlife Service with experience in the UMRR Program, hydrology, or both; UMRR Program management; and representatives from the Upper Mississippi River Basin Association.

Agency priorities for understanding future hydrologic conditions were identified in meeting 1. Participants began by identifying challenges presented to the UMRR program by an uncertain hydrologic future along the themes of hydrology, geomorphology, ecology and biota, Habitat Restoration and Enhancement Projects and management decisions, and general methods. Participants then discussed and defined agency priorities to understanding potential future hydrologic conditions and developed criteria for ranking the priorities. The criteria were applied in a ranking exercise, producing a list of top priorities related to understanding potential future hydrologic conditions for the UMRR program.

In meeting 2, participants defined characteristics of an ideal quantitative dataset that could be used to address the top-ranking priorities. The ideal dataset would consist of daily discharge data available for a minimum 50-year time horizon into the future across the Upper Mississippi River System. The LOcalized Constructed Analogs-Variable Infiltration Capacity-mizuRoute hydrologic data products were identified by technical experts as an existing dataset with these characteristics that might be potential resource for the UMRR program.

A subset of participants from the meeting series drafted a workflow for acquiring a hydrologic dataset of potential future conditions during meeting 3. The workflow focused on evaluating the LOcalized Constructed Analogs-Variable Infiltration Capacity-mizuRoute hydrologic data products to meet UMRR program priorities identified in the meeting

series. However, it included generic steps that could be adapted and applied to other datasets. The workflow includes an initial data reliability assessment and then describes various pathways for data dissemination, data correction options, and other actions that are dependent on the outcome of the reliability assessment. The workflow represents a blueprint for the UMRR program that is rooted in the discussions from the meeting series on challenges faced by the UMRR program's partnership by an uncertain future, priorities for understanding future hydrology in the context of the mission of the UMRR program, and the landscape of modeling approaches and datasets available at the time of the meeting series.

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Appendix 1. Participant List

The Upper Mississippi River System future hydrology meeting series was attended by participants from several Federal and State agencies and the Upper Mississippi River Basin Association. The series consisted of three meetings. Participant attendance for each session is listed in table 1.1.

Table 1.1. List of participants of the Upper Mississippi River Restoration program's future hydrology meeting series and their affiliations. Participants are listed alphabetically by agency.

[FWS, U.S. Fish and Wildlife Service; X, indicates meeting attendance, even if partial; --, absent; IA DNR, Iowa Department of Natural Resources; IL DNR, Illinois Department of Natural Resources; MN DNR, Minnesota Department of Natural Resources; MDC, Missouri Department of Conservation; WI DNR, Wisconsin Department of Natural Resources; UMRBA, Upper Mississippi River Basin Association; USACE, U.S. Army Corps of Engineers; CPR CoP, Climate Preparedness and Resilience Community of Practice; LTRM, Long Term Resource Monitoring; MVP, St. Paul District; MVR, Rock Island District; *, indicates meeting facilitator; +, indicates meeting organizer; MVS, St. Louis District; USGS, U.S. Geological Survey; MWCASC, Midwest Climate Adaptation Science Center; UMESC, Upper Midwest Environmental Sciences Center; UMWSC, Upper Midwest Water Science Center]

Name	Agency	Meeting 1	Meeting 2	Meeting 3
Josh Eash	FWS	X	X	X
Sharonne Baylor	FWS	X	X	--
Stephen Winter	FWS	X	X	--
Karen Osterkamp	IA DNR	X	--	--
Matt O'Hara	IL DNR	X	X	--
Matt Vitello	MDC	X	X	--
Jason Carlson	MN DNR	X	--	--
Nick Schlesser	MN DNR	X	X	--
Andrew Stephenson	UMRBA	X	--	--
Kirsten Wallace	UMRBA	X	--	--
Chanel Mueller	USACE CPR CoP	X	X	X
Christopher Frans	USACE CPR CoP	X	X	X
Jeffrey Arnold	USACE CPR CoP	X	X	--
Will Veatch	USACE CPR CoP	X	X	X
Karen Hagerty	USACE–LTRM	X	X	X
Rebecca Seal-Soileau*	USACE-MVP	X	X	X
Dave Potter	USACE–MVP	X	--	--
Dillan Laaker	USACE–MVP	--	X	--
Eric Hansen	USACE–MVP	--	X	--
Jon Hendrickson	USACE–MVP	X	X	X
Kara Mitvalsky	USACE–MVR	X	X	--
Lucie Sawyer+	USACE–MVR	X	X	X
Nicole Manasco	USACE–MVR	X	X	--
Jasen Brown	USACE–MVS	X	X	--
Lane Richter	USACE–MVS	X	X	--
Brian Ickes	USGS LTRM	X	--	--
Danelle Larson	USGS LTRM	X	X	--
Jeff Houser	USGS LTRM	X	X	X
Jennifer Sauer	USGS LTRM	X	X	X
John Delaney	USGS LTRM	X	X	X
KathiJo Jankowski	USGS LTRM	X	X	X
Kristen Bouska	USGS LTRM	X	X	X
Molly Van Appledorn+	USGS LTRM	X	X	X
Nathan De Jager	USGS LTRM	X	X	X
Olivia LeDee	USGS MWCASC	X	--	--
Mark Gaikowski	USGS UMESC	X	--	--
Jessica LeRoy	USGS UMWSC	X	X	X
Shawn Giblin	WI DNR	X	X	--

Appendix 2. Compiled Responses to Homework Activities

This appendix contains responses to homework activities submitted by partners in the Upper Mississippi River Restoration (UMRR) program. Submissions were received in September 2021 before the first meeting. The goal of the homework activities was to ensure agency perspectives were communicated and represented during the meeting.

The homework activities consist of two parts. The goal of activities in the first part are to understand priorities of the UMRR program and its partnering agencies, existing uses of hydrologic data, and potential uses of a future hydrologic dataset. The second part of the homework activities collected specific ideas about the utility of a future hydrologic dataset for the UMRR program.

Summaries of participant responses are presented along with responses minimally edited to retain their original context. Geographic features referenced within the responses are not mapped. References to “current” or “existing” should be interpreted in relation to the time of submission, September 2021.

Part 1. Understanding Upper Mississippi River Restoration Program Priorities, Current Use of Hydrologic Data, and Potential Uses of a Future Hydrologic Dataset

The purposes of this activity are to (1) gather information on broad partnership needs and priorities for understanding climate-changed hydrology, (2) understand how hydrologic data and information are used in partnership activities, and (3) capture the ways a dataset of Upper Mississippi River System future hydrology might be useful. Responses to homework activities were submitted in September 2021. References to “current” or “existing” should therefore be interpreted in relation to this timeframe.

Section 1. Understanding Upper Mississippi River Restoration Program Priorities

Question 1A.—In your opinion, what are the top three challenges facing your or your agency’s ability to accomplish the Upper Mississippi River Restoration (UMRR) program’s mission with regards to understanding future hydrologic conditions (to enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem)?

Participant responses emphasized that the uncertainty around characterizing future hydrologic conditions was a challenge for carrying out their agency’s mission. Responses also pointed out that this uncertainty also meant that anticipating how geomorphological processes, ecological processes, and the biota would respond was difficult. Together, these factors can hamper effective river management decisions, including Habitat Restoration and Enhancement Project (HREP) planning and design, and present methodological challenges to those completing field work or modeling exercises aimed at improving decision making. Compiled responses are listed in table 2.1 and are organized under general topical headings.

Question 1B.—What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.

Responses typically fell into one of three classes: responses related to hydrology and (or) geomorphology, responses related to ecological processes and (or) biota, or responses related to river management. Many questions mentioned certain attributes of a river’s flow regime (for example, flow magnitude, frequency, or duration) or flood regime (for example, depth, timing, or duration). Compiled responses are listed in table 2.2 and are organized under general topical headings. Word clouds were constructed for each topic to indicate the relative frequency of word mentions (figs. 2.1, 2.2, and 2.3).

Section 2. Understanding Use of Hydrologic Data

Question 2A.—How do you use hydrologic information in your decision making, research, or other work?

Hydrologic information is used in a variety of ways by the partnership. For example, HREP planning, design, and construction are informed by information about flow frequencies, inundation periods, seasonality of flows, and so on. Hydrologic information is also used for regulatory purposes, water level management, operation of pumps or other management actions, developing agency reports, and planning field work campaigns. Hydrologic information is also used in developing other models of river function such as hydraulic models, ecological models, and geospatial models of water depth. The time step of hydrologic information necessary for completing these tasks varies depending on the task but can include daily, monthly, seasonal, or annual time steps. Compiled responses are listed in table 2.3 and are organized by general topic.

Table 2.1. Responses to question 1A (In your opinion, what are the top three challenges facing your or your agency's ability to accomplish the Upper Mississippi River Restoration program's mission with regards to understanding future hydrologic conditions [to enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem]?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.

[UMESC, Upper Midwest Environmental Sciences Center; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; O&M, operations and maintenance; USFWS, U.S. Fish and Wildlife Service; watershed, term used to describe drainage basin; NOAA, National Oceanic and Atmospheric Administration]

Participant responses
Responses related to hydrology and (or) geomorphology
There is a need for an understanding of future hydrologic conditions at a variety of scales; systemically across the Upper Mississippi River System and within project-specific areas/local watersheds.
Quantifying future variability in hydrologic conditions
Uncertainty of future flood frequencies
Uncertainty of future flood durations
Assessing hydrologic conditions at ungaged locations
Hydrologic data analysis
Uncertain future hydrologic conditions and geomorphic response
Scientists at UMESC do not fully understand how climate change and (or) changes in basinwide land-use practices are projected to affect river flows.
UMESC does not have any tools or models in use that simulate effects of different emissions scenarios on river flows/depth and thus cannot extend existing climate change forecasts to the Upper Mississippi River System.
Uncertainty of future land-use changes in the watershed that could affect future hydrological events and frequencies (for example, changes in farming methods—tiling fields, changes in amount of paved surfaces)
The effects of hydrologic change on other river processes is unknown.
Uncertainty of sediment transport associated with future flood frequencies
Unknown effects on other processes. How does future hydrology affect watershed and in-channel sediment transport and geomorphic processes, including suspended sediment concentration, wave action, island/bank line loss/erosion, backwater connectivity, and sediment deposition.
Responses related to river ecology/biota
Flow magnitude and frequency affecting sampling ability and success
Biologic change in response to future hydrologic conditions
Integration of hydrologic data into additional datasets such as fish, vegetation, macroinvertebrates, and water quality
Lack of tools/models to simulate effects of different emissions scenarios on river flows/depth makes it impossible to assess ecological outcomes of future scenarios that do not include management actions, as well as scenarios that include management actions, such as manipulating water depth or velocity through dredging, altering connectivity, building islands, or water level manipulations.
Linking biological endpoints to hydrologic metrics
Magnitude, frequency, duration, and timing affecting species composition and distribution
Timing, magnitude, and duration of flows shifting timing and distribution of habitat availability
Increased/extended frequency of high-water events negatively affecting establishment, presence, and density of aquatic vegetation beds (wiping out or severely hindering aquatic vegetation and its associated habitat and water quality benefits)

Table 2.1. Responses to question 1A (In your opinion, what are the top three challenges facing your or your agency's ability to accomplish the Upper Mississippi River Restoration program's mission with regards to understanding future hydrologic conditions [to enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem]?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[UMESC, Upper Midwest Environmental Sciences Center; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; O&M, operations and maintenance; USFWS, U.S. Fish and Wildlife Service; watershed, term used to describe drainage basin; NOAA, National Oceanic and Atmospheric Administration]

Participant responses
Responses related to river ecology/biota—Continued
Assessing the resilience of habitats in the face of climate change
The substantial resources and habitats affected by hydrologic change and river processes is unknown.
We do not have a good framework for capturing ecosystem benefits.
Responses related to river management issues (for example, HREP design, infrastructure, and dam operations)
UMRR project effectiveness in the future—Will UMRR projects that are designed "hold up" and be effective and useful with future hydrologic conditions? For example, elevation enhancement or closing structures need to be designed for the future (50 years). If data are limited, we are really guessing what the future might be for hydrology and building around that. More accurate modelling would help the UMRR Program.
Where, what, and how to build to last
Unknown future hydrologic conditions make analysis of future without project conditions challenging, making project benefit calculations more challenging.
Designing resilient projects for uncertain future hydrologic conditions
Making good decisions in the face of uncertain geomorphic change
We do not have enough information to assess how design of HREP features will perform over the long term. For example, how much additional sedimentation in backwater fish overwintering areas will result from increased flows?
Without a rigorous modelling framework, agencies are left to come up with their own hypotheses regarding anticipated effects of climate change, making it difficult to come to a consensus on how to manage the river system in the face of a changing climate. Having a common understanding of future hydrologic projections and uncertainty across the partnership will be beneficial as conversations move forward on how to adapt to these changes.
Proper sizing of water control structures, pumps, levees, and so on is difficult.
Understanding O&M responsibilities of sponsors is difficult.
HREP habitat benefits—A lack of understanding of future with and without project conditions makes it difficult to estimate habitat benefits and how they may change over the 50-year design life of the project.
HREP feature design—Without knowledge of future hydrology, we do not know what range of flow/stage conditions our features should be designed to perform under. We therefore do not know which project features are more or less vulnerable/robust to climate change.
Responses related to hydrologic data access and interpretation
It can be difficult to apply and translate existing hydrologic information in a way that is directly and obviously applicable to the specific resource management problems that need to be informed. For example, river streamgage information can be difficult to translate into what things look like out on the river. Also, stage readings vary across different locations. Finally, because there can be a great distance between different streamgages, or tributaries between successive streamgages, there is a need to interpolate, and the best available interpolation still may not be very reliable. Different streamgages may use different datums, but the actual datum is not often provided with the data that are available on the internet.
Hydrologic data access
Getting the data (standardized data source; data are not served in real time and in a standardized output).

Table 2.1. Responses to question 1A (In your opinion, what are the top three challenges facing your or your agency's ability to accomplish the Upper Mississippi River Restoration program's mission with regards to understanding future hydrologic conditions [to enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem]?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[UMESC, Upper Midwest Environmental Sciences Center; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; O&M, operations and maintenance; USFWS, U.S. Fish and Wildlife Service; watershed, term used to describe drainage basin; NOAA, National Oceanic and Atmospheric Administration]

Participant responses
Responses related to hydrologic data access and interpretation—Continued
Access to existing and modeled future hydrologic condition datasets and maps must be expanded. With climate change, the use of past experience to estimate effects of seasonal flows and the effects of acute rain events will be less useful, and the user base for these data within the USFWS will expand significantly.
Hydrology is a technical area that most or all refuge staff have little to no background in, or have a very limited understanding of the technical aspects involved. This requires a great amount of reliance on partners to do and explain all things hydrology that are involved with working on a river.
Long-term climate projections; for example, updated NOAA Atlas 14 (Bonnin and others, 2006; Perica and others, 2013)
Responses related to other topics (at the beginning of each entry, a topic assigned by meeting organizers is in brackets)
{Scale} When working on small-scale projects (for example, a single HREP) within a larger scale watershed (the entire Upper Mississippi River System), the phenomena inherent to such a large scale are a substantial barrier to understanding existing and potential future hydrologic conditions at the smaller scale.
{Funding} Limited project funds for assessing climate change effects for each project limits the project delivery team to the use of currently available qualitative analysis tools.
{Scope of UMRR} The UMRR mission applies to work done in the river floodplain, but so much of the work we do is affected by things that are happening in the huge watershed-scale landscape, particularly agricultural land-use practices and their effects on soil health. The "partnership" has a very limited ability to address those issues (USFWS Fish and Wildlife Conservation Office being an exception).
{Communications} Complexity in communications
{Hydrology versus anthropologic drivers} In addition to climate-changed components of hydrology, there are confounding anthropogenic components of hydrology that are also changing. The anthropogenic components can be very important, but it can often be difficult to know which component is being expressed in any hydrology metric that is exhibiting change. Additionally, the anthropogenic response to climate-changed hydrology may contribute to a feedback that further affects the total amount of change.
{Social dynamics} The social dynamic that challenges productive conversations that might integrate floodplain restoration as part of flood management; that is, risk reduction, control, and so forth

Table 2.2. Responses to question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) submitted in September 2021. References to "current" or "existing' should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.

[DO, dissolved oxygen; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; HEC–RAS, Hydrologic Engineering Center-River Analysis System; AdH, Adaptive Hydraulics; OHWM, ordinary high-water mark]

Participant responses
Responses related to hydrology and (or) geomorphology
What does the future look like under a projected future conditions? Are there temporal patterns (for example, drier in summer, wetter in winter)?
Will past trends continue in the future? Will average annual discharge continue to increase? Magnitude, duration, timing?
How are future river discharges expected to change?
Changes to the timing of peak discharge?
How will timing of extreme flows (high and low) shift?
Will duration of peak flows extend?
What will inundation levels, durations, and seasonality be like in the future?
How are the timing and intensity of spring runoff events going to shift over time? Important because many fish species use this as a reproductive cue, but critical food sources (zooplankton) may not shift their peak abundances in sync with hydrology, leaving critical early life stages of fish with less available food.
How will these changes affect the exchange of water and sediment between main and off-channel areas?
How will hydrologic seasonality shift in the future, particularly in relation to flow volume timings?
How will the frequency and severity of drought conditions change?
Will low flows be more common or extreme?
How will the frequency, duration, and seasonality of drought and low flows change? What important hydrology metrics will be affected by drought and low flows (for example, DO, temperature, velocity, and so on), and where might these effects be most pronounced in relation to the location of priority resource areas?
What is the expected change in peak flow volume and duration in our changing climate?
How will changing climate affect hydrologic delivery and conveyance, and what will future floods look like on the Upper Mississippi River? Will larger flood events become more common; will there be a change in flood recurrence intervals? Can we project future flood frequencies and water levels?
How might changes in flows/hydrology affect key geomorphic processes?
How will climate-changed hydrology change things like water residency, connectedness, and velocities in backwaters, as well as things like velocities in secondary and tertiary channels, all of which are very important habitat for many priority species?
Quantification of altered water exchange and sediment loading to backwater (off-channel) areas (existing and future)
How is future precipitation expected to change?
What are the expected contributions for flow on the significant tributaries; that is, the Missouri River?
How might soil moisture change, including the distance of surface elevation to the groundwater level? This could be applicable in drought and "normal pool" periods.
How will future hydrology affect the geomorphology of the river and related processes?
Can we predict an equilibrium between hydrology altered by pattern tiling and sediment transport (likely more of an issue in the tributaries of the Mississippi River but could play a significant role in the sediment loading experienced by the Mississippi River, especially in the upper stretch of the river and Lake Pepin)?
How will assumptions of future hydrology consider nonpoint reduction or other flood-related infrastructure projects?
Geomorphic response to increasing discharge (bank erosion, backwater deposition, water exchange rates, sediment movement patterns)?

Table 2.2. Responses to question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) submitted in September 2021. References to "current" or "existing' should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[DO, dissolved oxygen; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; HEC–RAS, Hydrologic Engineering Center-River Analysis System; AdH, Adaptive Hydraulics; OHWM, ordinary high-water mark]

Participant responses
Responses related to hydrology and (or) geomorphology—Continued
There are some very important phenomena (for example, sediment and nutrient dynamics) directly related to hydrology that are already difficult to understand. How will those dynamics change with climate? {Note: The meeting organizers also included this response in river ecology/biota section.}
How will updated/improved drain tile systems affect watershed yield and the magnitude, timing, duration of river flows.
What will ice cover dynamics be like in the future?
Responses related to river ecology/biota
Will the river ecosystem (floodplain, lentic, lotic areas) be resilient to anticipated hydrologic stressors?
What species are most negatively affected by (or sensitive to) increased hydrology?
How might changes in flows/hydrology affect key ecological components of the river system, including aquatic and floodplain vegetation, fish communities, nutrient delivery, and dynamics?
There are some very important phenomena (for example, sediment and nutrient dynamics) directly related to hydrology that are already difficult to understand. How will those dynamics change with climate? {Note: The meeting organizers also included this response in hydrology/geomorphology section.}
Future effects to fisheries, vegetation, ecosystem health, invasive species
Seasonal life history habitat needs for floodplain and aquatic biota
How will these changes affect the distribution of aquatic vegetation?
More frequent high-water events also uproot, fragment, and disperse invasive aquatic vegetation species (for example, the spread of flowering rush over the past couple of years).
What are the effects of changes to Upper Mississippi River hydrology on floodplain forest health in the next 100 years?
What existing forested areas should we expect to lose the ability to naturally regenerate or convert to more shallow marsh conditions?
Quantification of forest loss and effect of that loss (historical, existing, and future)
How will future inundation levels, durations, and seasonality affect bottomland forests?
How might vegetation communities change, and perhaps transition from one community to another, in response to climate-changed hydrology; for example, how much of what is currently considered and managed as bottomland forest could be expected to transition to reed canarygrass meadow?
What are the effects of changes to Upper Mississippi River hydrology on native and invasive fish species' life history and habitat requirements?
Increased/extended frequency of high-water events allowing upstream movement of invasive carps because of extended "open river" conditions at many locks and dams
We have a general lack of specific understanding of how various flow regimes affect fish populations (positively or negatively) and at what life stage or through what mechanism is that effect felt. This obviously ties to habitat in that various flow patterns or water levels will affect habitat (natural or constructed) based on its elevation, resilience to flow, and type of material. One of the few relations we have a fairly good understanding of is bluegill (*Lepomis macrochirus*) overwintering habitat and its relation to water levels/flow (probably also invasive carp species because of mitigation efforts). Outside of that, even for gamefish, we are largely in the dark, much less for commercial species or native nongame species.
What will ice cover dynamics be like in the future, will changing ice cover dynamics affect the staging and wintering behavior of waterfowl, and will the availability of waterfowl food resources in the spring be different?
Will changing ice cover dynamics affect the staging and wintering behavior of waterfowl, and will the availability of waterfowl food resources in the spring be different?

Table 2.2. Responses to question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) submitted in September 2021. References to "current" or "existing' should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[DO, dissolved oxygen; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; HEC–RAS, Hydrologic Engineering Center-River Analysis System; AdH, Adaptive Hydraulics; OHWM, ordinary high-water mark]

Participant responses
Responses related to river management issues (for example, HREP design, infrastructure, dam operations)
Forecasts of future management scenarios against future altered hydrology. "How bad might conditions get and how can we successfully adapt?"
How can we build resiliency into our projects?
Future effects to restoration efforts
Floodplain restorations are dependent upon understanding projected flood frequencies and inundation.
Will future hydrological changes affect the ability or timing to complete environmental pool management?
What changes will we need to make to improve resilience–for management and restoration? What actions can we take in the floodplain?
Planning and design decisions; for example, how much money should be spent stabilizing relic landforms (those that had formed before lock and dam construction)?
How can we factor these projected changes into HREP design to ensure structural and functional integrity into the future?
Can we factor these projected changes into determining locations for HREPs that will maximize benefits?
How does future hydrology change our feature design? For example, flood frequency—How does more frequent flooding affect feature designs? Flood duration—How does prolonged higher water affect feature designs? Drought duration —How do prolonged droughts affect feature designs?
How/at what rate will feature benefits for different HREP features change throughout the 50-year project life as a result of future hydrology?
How can we be confident that our restoration features will be present in 50 years without understanding future hydrology?
Existing and future HREP features being overwhelmed by or unable to "stand up to" increased/extended periods of high water
Can UMRR HREP planning and execution be successful in achieving stated project goals (for example, fish overwintering or creating/enhancing/protecting aquatic vegetation beds) under a potentially climate-changed hydrologic regime?
Will existing (non-HREP) habitat conditions be significantly altered/affected under a climate-changed hydrologic regime?
How will previously completed projects perform under a different, climate-changed hydrologic scenario? This could be particularly important for projects that incorporated infrastructure such as dikes, water control structures, pumps, and so on.
What management alternatives are possibly viable for delivery and conveyance?
Future effects to navigation?
Adapting management of the navigation system to future hydrology
Future changes to operation procedure (releases) on Great Lakes?
Will vegetation changes associated with hydrologic changes affect roughness estimates for numerical modeling (HEC–RAS, AdH)?
Will there be additional opportunities to advocate for restoration as an effective strategy to mitigating the effects of climate induced flooding?
How might changing ice cover change the regulation of waterfowl hunting, particularly the setting of season dates?
Responses related to other topics (each entry begins with brackets that list a topic assigned by meeting organizers)
{Data interpretation/analysis} I understand discharge has increased and is expected to continue to increase, but what do those increases look like or mean on the ground across the floodplain?

Table 2.2. Responses to question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) submitted in September 2021. References to "current" or "existing' should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[DO, dissolved oxygen; HREP, Habitat Restoration and Enhancement Project; UMRR, Upper Mississippi River Restoration program; HEC–RAS, Hydrologic Engineering Center-River Analysis System; AdH, Adaptive Hydraulics; OHWM, ordinary high-water mark]

Participant responses
Responses related to other topics (each entry begins with brackets that list a topic assigned by meeting organizers)—Continued
{Scale} What is the appropriate spatial and temporal resolution to infer hydrologic responses to climate change?
{Uncertainty} How confident are you in projections of precipitation and discharge changes?
{Uncertainty} Accuracy/precision—How close do we really thing we can get? There is a "threshold" for usefulness.
{Land-use changes} What land-use changes should be expected when looking out 50 or 100 years?
{Weather} What are the expected weather patterns on the Upper Mississippi River?
{Legal} How might climate-changed hydrology change what is considered an OHWM? For example, in Iowa, the State claims sovereign lands below the OHWM. Additionally, the definition of the OHWM is, in part, tied to the permanency of vegetation on the shoreline. If the OHWM changes, this might change (increase or decrease) the amount of land/water owned and jurisdictionally administered by non-State owners.

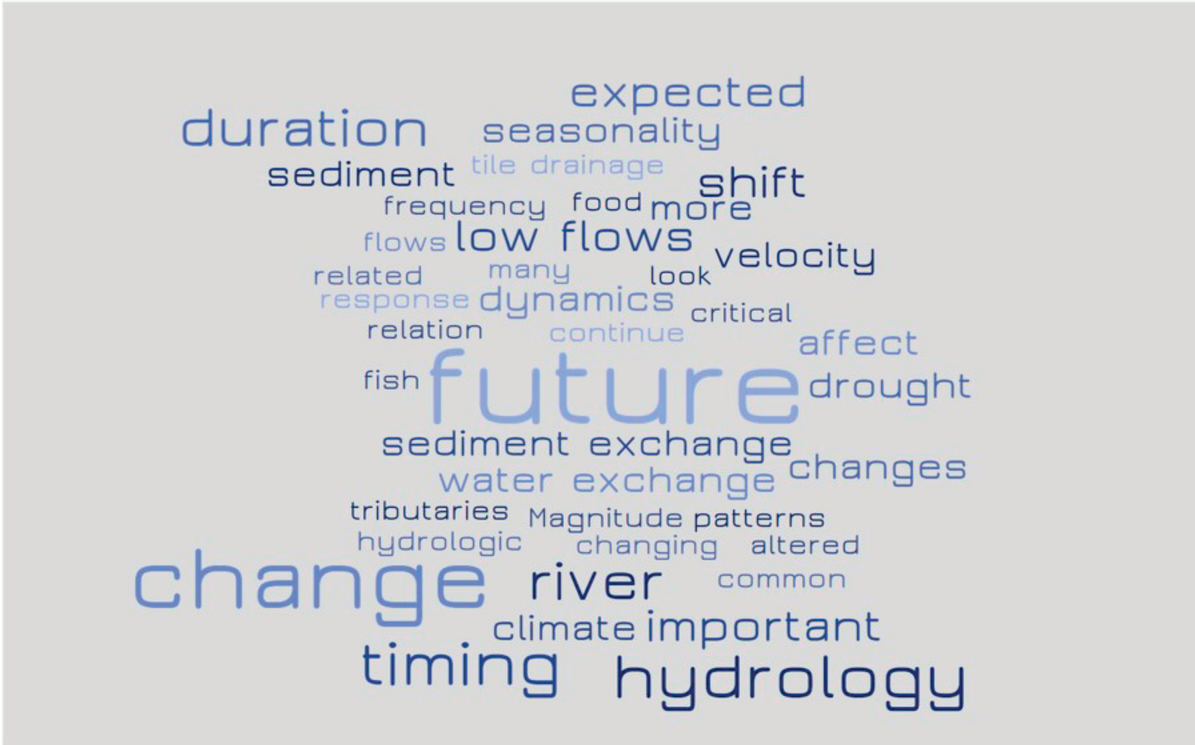

Figure 2.1. Top 40 most frequently used words in question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) responses related to hydrology or geomorphology. All words have at least two mentions. Font size is proportional to frequency of mentions (fig. generated by WordItOut, licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International license; https://creativecommons.org/licenses/by-nc-nd/4.0/. No changes were made to the material generated by WordItOut.).

Question 2B.—Are there certain hydrologic criteria you use in your decision making, research, or other work (for example, thickness of ice cover, timing of peak discharge, number of days of discharge greater than or less than a given threshold)? Please be as specific as possible.

A river's hydrologic regime can be described using several qualities including frequency, duration, timing, and magnitude among others. For example, frequency may refer to the likelihood of certain flows in any given year, duration may capture the number of days a particular floodplain inundation event may last, timing may refer to the seasonality of flow conditions, and magnitude may refer to water depths or peak flows. Compiled responses are listed in table 2.4 and are organized by the quality of hydrologic regime to which the variables/criteria mentioned are most closely related, as interpreted to the best abilities of the meeting organizers. A word cloud was constructed to indicate the relative frequency of word mentions (fig. 2.4).

Question 2C.—If you use hydrologic data in your work, where do you acquire Upper Mississippi River System hydrologic data and in what format?

Users obtain hydrologic data from a variety of sources. A summary bar chart shows the distribution of sources based on response mentions (fig. 2.5). Data are often, but not always, in a "raw" format that facilitates direct, quantitative analysis of some kind. Specific hydrologic variables were often mentioned in the responses. Compiled responses are listed in table 2.5 and are organized into the topics of sources, formats, and hydrologic variables (some responses may be listed under more than one topic heading).

Question 2D.—If you use hydrologic data in your work, what spatial and (or) temporal scales do you use (for example, daily time steps, annual summaries, one streamgage location, multiple streamgages, 2-dimensional data)? Please be as descriptive as possible.

There is a wide diversity of spatial and temporal scales that are used when dealing with Upper Mississippi River System hydrologic data. This diversity reflects the variety of applications for which the data are being used and the diversity of hydrologic metrics analyzed. Compiled responses are listed in table 2.6 and are organized by topical relevance.

Section 3. Potential Uses of a Future Hydrologic Dataset

Question 3A.—How would a projected hydrologic dataset benefit your ability to accomplish your job?

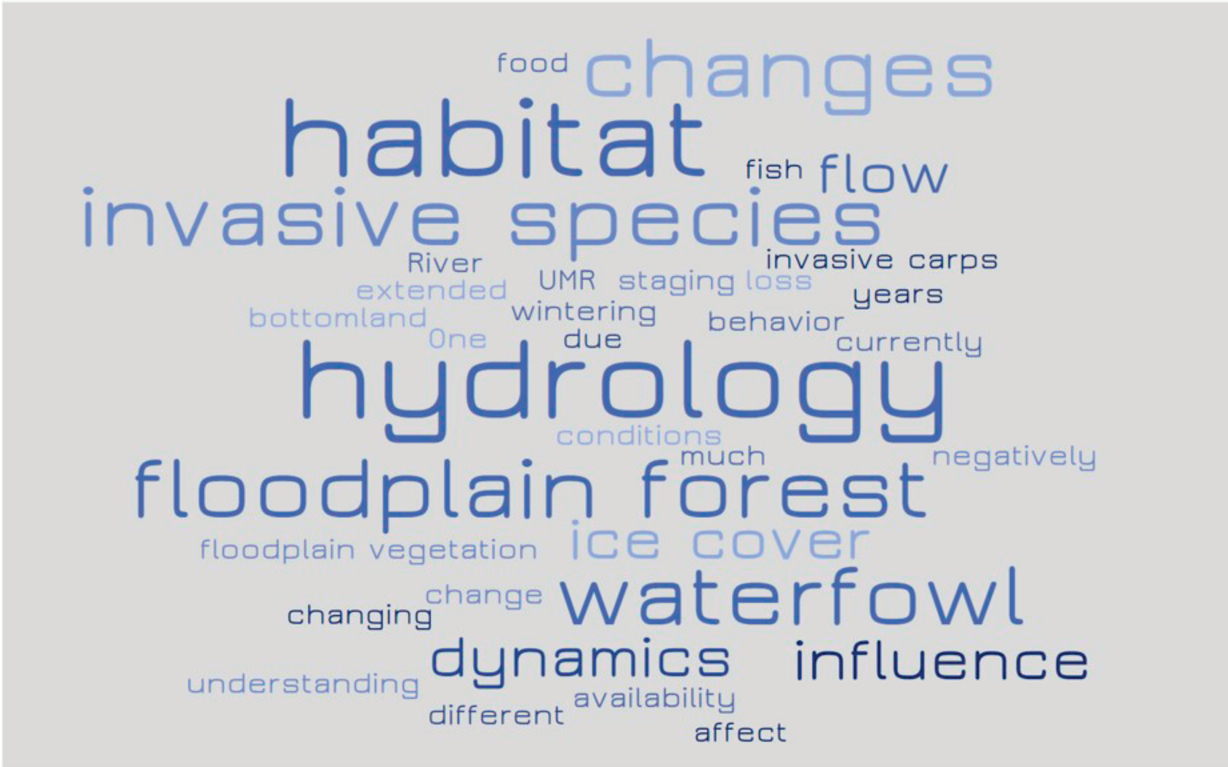

Figure 2.2. Word cloud of the 40 most frequently used words in question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) responses related to river ecology and biota. All words have at least two mentions. Font size is proportional to frequency of mentions (fig. generated by WordItOut, licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International license; https://creativecommons.org/licenses/by-nc-nd/4.0/. No changes were made to the material generated by WordItOut.). [UMR, Upper Mississippi River]

Most responses described how a projected hydrologic dataset would benefit aspects of the HREP process, including project planning, cost analyses, design, project ranking, and siting. Other responses described the importance of a future hydrologic dataset to assess ecological responses to climate change, evaluation of strategic realty decisions, and advocation. Compiled responses are listed in table 2.7 and are organized by topical relevance.

Question 3B.—To what extent would a future hydrologic dataset improve your decisions? What information is required to make a different decision?

Responses indicate a future hydrologic dataset would benefit the HREP and LTRM sides of the UMRR program's partnership, as well as other activities carried out by partnering organizations (for example, communications, river management decisions, risk assessment). Some responses acknowledged that the benefit of any dataset would be weighed in part by its assumptions, certainty/uncertainty, accuracy and precision, confidence/trustworthiness, and interpretability. Compiled responses are listed in table 2.8 and are organized by general topic.

Question 3C.—What level of certainty should a future hydrologic dataset have for it to be useful in your work?

Answers ranged widely, likely reflecting the difficulty in answering this question. Compiled responses are listed in table 2.9 and are organized into responses that offered numerical estimates, that were more descriptive, and that mentioned a way to convey certainty.

Question 3D.—How far into the future would you want to understand Upper Mississippi River System hydrology?

Most responses offered a specific period of interest, typically a 50- or 100-year period. Such responses tended to be linked to agency guidance of some kind (for example, HREP design life span, conservation, or management plans). Other responses were more descriptive and offered considerations for deciding an appropriate timeframe of projections (for example, considering the life span of species of interest, the degree of certainty/uncertainty of the projections, and trends in climate change). Compiled responses are listed in table 2.10 and are organized into responses referencing specific periods and responses offering descriptive insights.

Question 3E.—What aspects of future hydrology are of most use for you (for example, discharge at lock/dam locations, monthly peak water surface elevation, annual average discharge, and so on)?

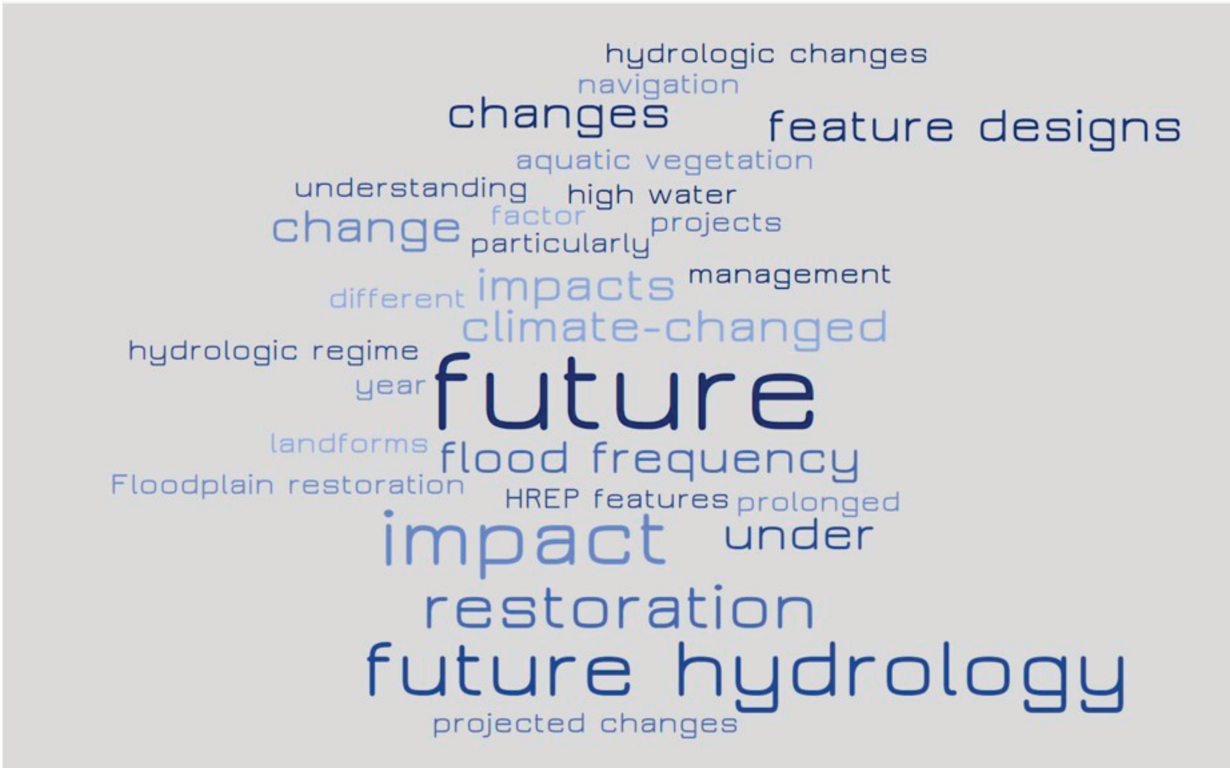

Figure 2.3. Top 40 words in question 1B (What are at least three of the most important or outstanding questions you or your agency has with regards to understanding the future hydrology of the Upper Mississippi River System? Feel free to list more if you wish.) responses related to river management issues. All words have at least two mentions. Font size is proportional to frequency of mentions (fig. generated by WordItOut, licensed under the Creative Commons Attributio n-NonCommercial-NoDerivatives 4.0 International license; https://creativecommons.org/licenses/by-nc-nd/4.0/. No changes were made to the material generated by WordItOut.). [HREP, Habitat Restoration and Enhancement Project]

A river's hydrologic regime can be described using several qualities including frequency, duration, timing, and magnitude (among others). For example, frequency may refer to the likelihood of certain flows in any given year, duration may capture the number of days a particular floodplain inundation event may last, timing may refer to the seasonality of flow conditions, and magnitude may refer to water depths or peak flows. Compiled responses are listed in table 2.11 and are organized by the quality of hydrologic regime to which the variables/criteria mentioned are most closely related, as interpreted to the best abilities of the meeting organizers.

Question 3F.—What spatial and temporal scales should a future hydrologic dataset be in order to be useful for your work? Are they the same as you currently use, or are there other scales of interest?

There is a wide diversity of spatial and temporal scales that may be of interest for a future Upper Mississippi River System hydrologic dataset. This diversity reflects the variety of applications the data could be used for and the diversity of hydrologic metrics that could be analyzed. Compiled responses are listed in table 2.12 and are organized by topical relevance. Some responses are included in both topic areas.

Table 2.3. Responses to question 2A (How do you use hydrologic information in your decision making, research, or other work?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.

[HREP, Habitat Restoration and Enhancement Project; LSOH, Lessard-Sams Outdoor Heritage Council; OHWM, ordinary high-water mark; D, dimensional; USGS, U.S. Geological Survey; HUC, hydrologic unit code; Q, discharge; UMESC, Upper Midwest Environmental Sciences Center; SAV, submerged aquatic vegetation; <, less than; cm/s, centimeter per second; LTRM, Long Term Resource Monitoring; WSE, water surface elevation; WRTDS, Weighted Regressions on Time, Discharge, and Season; N, nitrogen; UMRR, Upper Mississippi River Restoration program]

Participant responses
Responses related to HREPs/projects, management, and regulatory issues
HREP constraints
HREP feature design
Designing HREPs
Discharge—Frequency affects design of HREP features such as height, depth, or size.
Mainly restoration effort design
We use hydrologic data to help determine constructability of project features.
Project ideas/designs (LSOH or other funding) to know elevations and inundation periods for a location
Accounting for inundation frequencies and durations when making project decisions about restoring natural function
Determining top elevations of significant infrastructure such as pump stations, and so on
Determining elevations associated with tree plantings, grade controls, river training structures, and so on
Determining stone protection requirements
Determining construction windows for project features
HREP performance monitoring and potential effect of discharge/water exchange on biotic response
Floodplain impact analysis typically using published flow frequencies (ensuring things we build do not cause a rise in the floodplain)
Wetland analysis (ensuring things we build do not convert wetland to nonwetland habitat)
Hydrologic data are used to establish flood control and water level control areas of need, vulnerability, and opportunity.
OHWM is used to define regulatory responsibility in Iowa.
Hydrologic data are used to determine things such as what size rock is used in a project feature so that it can withstand predicted or probable velocities and stresses.
For water level management, poolwide and localized, the interagency teams have looked at how often drawdowns would have been successful in the past, which can inform us if water level management could be effective in the future.
Evaluating pumping needs to manage wetlands
Streamgage data used to determine elevations for water control structures and other features
Suitability of sites for certain vegetation classes
Setting elevations for projects (island heights, water control structure elevations, slotted stoplog elevations, and so on)
Water level management
Peak discharge (annual, monthly intervals), hydrograph, hyetographs related back to channel dredging. Standard statistical outputs (1-, 2-, 5-, 50-, 100-year recurrence interval)
Responses related to hydrologic, hydraulic, and geomorphic applications (many related to previous category too)
1-D and 2-D hydraulic modeling
Velocity analysis—Can we build a self-scouring channel?

Table 2.3. Responses to question 2A (How do you use hydrologic information in your decision making, research, or other work?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[HREP, Habitat Restoration and Enhancement Project; LSOH, Lessard-Sams Outdoor Heritage Council; OHWM, ordinary high-water mark; D, dimensional; USGS, U.S. Geological Survey; HUC, hydrologic unit code; Q, discharge; UMESC, Upper Midwest Environmental Sciences Center; SAV, submerged aquatic vegetation; <, less than; cm/s, centimeter per second; LTRM, Long Term Resource Monitoring; WSE, water surface elevation; WRTDS, Weighted Regressions on Time, Discharge, and Season; N, nitrogen; UMRR, Upper Mississippi River Restoration program]

Participant responses
Responses related to hydrologic, hydraulic, and geomorphic applications (many related to previous category too)—Continued
Duration analysis and velocity analysis–How high to build a chevron or bullnose dike to rebuild an island and what size rock
Duration analysis and velocity analysis—How much of the time can we gravity drain or fill isolated project area to meet water level management goals and what size rock is needed to protect structure?
Sediment analysis—How much sediment is coming into a river reach?
Stage duration and frequency analysis for water level management objectives (that is, pool 13 HREP)—How frequently and for how long of a duration can we expect to maintain water level management drawdowns? How will a shifting climate change these answers?
Frequency analysis for assessing overtopping risk to isolated (behind berms/levees) water level management projects
HREP projects use hydrologic data to identify areas of differing flow velocity, which helps inform where habitat features may or may not be needed, or where they may be optimally located, within a project area.
Use streamgage data to identify trends or recompute recurrence intervals.
Water level management is tied to flow conditions (that is, you need enough flow to maintain the pool). If flows were to increase, we could see more opportunity for successful drawdowns. Environmental pool management is similar but different in that it works within the already-established operating band of pools in the St. Louis District.
A large component of some HREPs is flow and velocity manipulation. Hydrology information not only allows us to identify where existing conditions are not ideal, but models also help us visualize positive or negative flow or velocity effects on surrounding habitat areas resulting from proposed project features.
Water exchange rates at side channel connections
Analysis of coincidental flooding on tributaries and main stem
We use long-term USGS hydrologic datasets at HUC 08 watershed outlets paired with watershed averaged gridded precipitation data to assess changes in annual peak Q, precipitation, and discharge. We identify relevant points of nonstationarity and select a single "breakpoint" year to assess conditions pre and postchange to communicate relevant hydrologic change within major watersheds to guide comprehensive watershed management activities.
UMESC uses hydrologic information to simulate water depth. Water depth is used in bathymetric models, aquatic vegetation models, to characterize aquatic habitats and in models of flood inundation.
Sedimentation projections
Responses related to understanding river ecology and biota
Stage duration and frequency analysis for topographic diversity and floodplain forest restoration (how high to plant trees) based on growing season inundation duration
Velocity analysis—downstream velocities optimized for SAV (growing season), fish overwintering (winter season), mussel habitat (annual)
Duration analysis for fish overwintering habitat to ensure little to no winter flow (<1-cm/s velocity) closure structure overtopping analysis, connectivity of backwater inlets
We use elevation and inundation data to determine where different species of trees, and other vegetation, could be planted or managed for.
Bathymetry and topography data are used with information about flood recurrence intervals to determine areas suitable for different habitat types and to design suitable infrastructure.
We estimate stability of mussel-occupied habitat under high flow and sediment transport as a predictor of stability at variable flows.
Use water quality data for threat identification

Table 2.3. Responses to question 2A (How do you use hydrologic information in your decision making, research, or other work?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[HREP, Habitat Restoration and Enhancement Project; LSOH, Lessard-Sams Outdoor Heritage Council; OHWM, ordinary high-water mark; D, dimensional; USGS, U.S. Geological Survey; HUC, hydrologic unit code; Q, discharge; UMESC, Upper Midwest Environmental Sciences Center; SAV, submerged aquatic vegetation; <, less than; cm/s, centimeter per second; LTRM, Long Term Resource Monitoring; WSE, water surface elevation; WRTDS, Weighted Regressions on Time, Discharge, and Season; N, nitrogen; UMRR, Upper Mississippi River Restoration program]

Participant responses
Responses related to understanding river ecology and biota—Continued
We also use the flow in mid-April as a predictor of walleye (*Sander vitreus*) year class strength, though it is the weakest of the predictors we include in the model behind abundance of spawning adults and temperatures in the preceding August.
LTRM—Pretty research centric; I frequently relate historical, daily hydrological data (WSE, Q) to LTRM monitoring data (for example, aquatic vegetation, water quality) for research purposes and envision this only increasing going forward.
Water elevation—duration for vegetation on new islands and floodplain forests
Discharge is summarized at different temporal resolutions to represent an independent variable for various ecological response models.
UMESC uses hydrologic information in water quality models (for example, nutrient load estimation with WRTDS models).
Flow weighted (WRTDS) water quality parameter trend analysis
UMESC plans to assess seasonal hydrologic drivers of fish recruitment.
Backwater residence time (flushing, in days), water quality work
Projections of photic zone depth to establish submersed vegetation (water surface elevation needed)
Potential for cyanobacteria/cyanotoxin production—flushing rate is a central determinate of this.
Backwater fish overwintering potential—changing residence times are altering winter temperature/oxygen dynamics in backwaters.
Understanding water quality trends
Backwater residence time for N uptake/denitrification potential (supply versus assimilative capacity)
Backwater internal phosphorus loading
Fisheries year class strength (for example, why are recent walleye year classes so weak—climate related? Why do certain years' classes of backwater fishes largely disappear after high-flow winters?)
Aquatic plant projections
Responses related to field work and agency operations
Advancing multipurpose collaboration
Justifying investments in UMRR and other river-related programs
We use it constantly when determining sampling accessibility and conditions (for example, depth, substrate, velocities).
Annual reports (explaining data blips and general discussion material) for interactions with the public and other stakeholders
Field planning and safety—Should we go out, should we sample?
From a fisheries management perspective, our primary use is simply as part of a daily assessment of what we can or cannot do for field work and as part of the "art" in the "art and science of fisheries management" in determining where a particular species might be located on a given day at a given flow in order to effectively target them for sampling or monitoring.
I track historical water levels for logistical planning (watercraft access).
Monitoring connectivity and access to side channels in the open river correlating to sampling events

Table 2.4. Responses to question 2B (Are there certain hydrologic criteria you use in your decision making, research, or other work [for example, thickness of ice cover, timing of peak discharge, number of days of discharge greater than or less than a given threshold]? Please be as specific as possible.) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.

[F, frequency; HREP, Habitat Restoration and Enhancement Project; D, duration (length of time); DO, dissolved oxygen; T, timing (seasonality); M, magnitude; USACE, U.S. Army Corps of Engineers; WSE, water surface elevation; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; O, other; ~, about; TSS, total suspended solids; N, nitrogen; P, phosphorus; Q, discharge; NWIS, National Water Information System database; HAB, harmful algal bloom; EPA, U.S. Environmental Protection Agency]

Participant responses	Closest related hydrologic regime variable/criterion
Peak annual streamflow for frequency analysis to support overtopping analysis	F
Inundation frequency and duration and the number of days discharge is greater than or less than a given threshold. This information is critical for the successful design of HREPs. Examples of applications include determining design elevation and sizing of notches in closing structures to ensure oxygenation without introducing too much flow into backwaters during the winter, determining the design elevation for emergency spillways at moist-soil management areas to ensure levee stability and longevity, and determining elevations required for long-term forest sustainability and to determine what type of trees to plant where.	F, D
Frequency of overtopping events, October through March—backwater fish to get velocities, and temperature and DO as affected by hydrology in backwater areas during winter months	F, T
Exceedance probabilities by Julian date and duration of peak discharge	F, D, T
Frequency of berm overtopping water surface elevations	F, M
Inundation days—based on floodplain/land elevation, total number of days (as was developed for HREP planning at McGregor Lake)	D
Daily water surface elevation for duration analysis to support inundation determination for real estate acquisition	D
Daily water surface elevation for winter duration analysis to determine how deep to dredge for overwintering habitat (winter pool/seasonal duration, thickness of ice, sedimentation over 50 years plus 4 feet)	D, T
Daily water surface elevation for growing season inundation duration and frequency—how high to plant different tree species to ensure their planting elevation meets a specified growing season exceedance duration and frequency threshold	D, F, T
Daily water surface elevation for duration and frequency analysis—number of days of water surface elevation greater than or less than a given threshold and frequency of success (for water level management)	D, F
Daily water surface elevation for duration analysis—Assess opportunities for gravity drainage.	D
The Upper Mississippi River National Wildlife and Fish Refuge Habitat Management Plan uses a threshold of 40 days of inundation during the growing season to determine what tree species to plant or manage for at a given location.	D, T
Middle Mississippi River National Wildlife Refuge uses a threshold of 30 days of inundation to determine what tree species to plant or manage for in a specific location.	D
Some HREP projects in the USACE St. Louis District use a threshold of 22–24 days of inundation during the growing season to determine what trees to plant and manage for in specific locations.	D, T
Number of days discharge or WSE exceeded during growing season—floodplain forest	D, T
Number days greater than a threshold (for example, water elevation) to measure if sufficient light reaches bottom for submersed vegetation potential/development/persistence	D
Number of days of inundation is a key factor for vegetation selections to ensure high survival rates.	D
Discharge conditions during the sampling season, which can affect aquatic vegetation, water quality, and fish catchability by our gear	T

Table 2.4. Responses to question 2B (Are there certain hydrologic criteria you use in your decision making, research, or other work [for example, thickness of ice cover, timing of peak discharge, number of days of discharge greater than or less than a given threshold]? Please be as specific as possible.) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[F, frequency; HREP, Habitat Restoration and Enhancement Project; D, duration (length of time); DO, dissolved oxygen; T, timing (seasonality); M, magnitude; USACE, U.S. Army Corps of Engineers; WSE, water surface elevation; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; O, other; ~, about; TSS, total suspended solids; N, nitrogen; P, phosphorus; Q, discharge; NWIS, National Water Information System database; HAB, harmful algal bloom; EPA, U.S. Environmental Protection Agency]

Participant responses	Closest related hydrologic regime variable/criterion
Individual refuges use localized streamgage data to make decisions about when to impound and when to release water from individual management units.	T
UMESC is currently using climatic and hydrologic variables to predict aquatic vegetation and ecosystem states across the Upper Mississippi River System (6 LTRM study pools). These are plant growing season and annual hydrologic summaries from multiple streamgages.	T, O
Backwater residence time goals differ by season and desired biological response (that is, general rule of thumb 12 days in winter for backwater fish overwintering habitat, less [~3–6 days] in summer for dissolved oxygen endpoints, although can be site specific based on local factors).	T, O
Timing of peak discharge, number of days greater than threshold, average high stage, maximum stage over period of record, frequency of days greater than threshold	T, M, D, F
Discharge/stage to determine project risk as it relates to seasonal flows, constructability, and operational parameters	T, M, O
UMESC has done extensive research to identify thresholds related to water flow velocity and flood inundation. Such thresholds relate to the distribution and dynamics of important components of the river system (for example, nutrient distributions and cycling, plant communities, and so on).	M
Percentiles of daily discharge have been used to characterize extreme events (for example, high flow, low flow) to represent independent variables.	M
Simple summaries of annual discharge have been used as independent variables in analyses of Upper Mississippi River ecosystem metabolism and assessments of the magnitude and direction of main channel versus off-channel contrasts in basic LTRM water quality parameters (TSS, N, P, and so on).	M
UMESC uses flow velocity information and modeling in empirical analyses and modeling of a variety of purposes. Velocity is obtained from the LTRM fish and water quality datasets and has been interpolated to capture velocity predictions between sampled points.	M
Residence time (water velocity) as driver of cyanobacteria problems because of limited flushing	M
Residence time (water velocity) as a predictor of free-floating plant (duckweeds and filamentous algae) dominance	M
Velocity targets for shoreline erosion for 1-, 2-, 5-year events	M, F
Setting heights for constructed islands (terrestrial vegetation versus protected areas), water control structures, and so on. Also, to determine what materials islands are constructed with	M
Floodplain impact analysis—less than 0.01-foot flood rise at 100-year flood event	M
The Upper Mississippi River National Wildlife and Fish Refuge Habitat Management Plan has an objective of providing water depths of 0.5–10 inches in marsh habitats managed for moist-soil conditions during the spring or fall migration season.	M, T
Water depth, velocity, and water temperature are variables used in the bluegill (*Lepomis macrochirus*) model, which quantifies habitat units achieved with overwintering habitat restoration/enhancement/creation.	M, O, T
Near-bed velocities and durations (for mussel beds)	M, D
Average discharge or WSE for September, October, November—migrating waterfowl	M, T

Table 2.4. Responses to question 2B (Are there certain hydrologic criteria you use in your decision making, research, or other work [for example, thickness of ice cover, timing of peak discharge, number of days of discharge greater than or less than a given threshold]? Please be as specific as possible.) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[F, frequency; HREP, Habitat Restoration and Enhancement Project; D, duration (length of time); DO, dissolved oxygen; T, timing (seasonality); M, magnitude; USACE, U.S. Army Corps of Engineers; WSE, water surface elevation; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; O, other; ~, about; TSS, total suspended solids; N, nitrogen; P, phosphorus; Q, discharge; NWIS, National Water Information System database; HAB, harmful algal bloom; EPA, U.S. Environmental Protection Agency]

Participant responses	Closest related hydrologic regime variable/criterion
Fisheries use discharge on April 15th as part of a predictive model of walleye (*Sander vitreus*) recruitment in Lake Pepin/pool 4 because of walleye in pool 4 seemingly preferring flooded terrestrial vegetation as spawning substrate.	M, T
Peak discharge, days of inundation for a given elevation, WSE at a location, general flow/discharge patterns	M, D, T
LTRM uses daily average, number of low and high discharge days (Q10 and Q90) per growing season	M, T
UMESC is currently analyzing integrated datasets to understand aquatic vegetation community changes over the past 25 years in response to hydrology, climate, and water quality changes. Datasets and primary metrics include PRISM climate data (19 metrics of temperature and precipitation at 30-, 60-, and 90-day time stamps from vegetation sampling), hydrology (NWIS daily discharge data summarized at multiple time stamps like daily, monthly, growing season, and annual), LTRM water quality variables, and LTRM aquatic vegetation community variables.	M, T, O
Daily streamgage reading to means for month, or specific timeframe of sampling	M, T
Modeled water temperature changes under new hydrology and forecasted temperature regimes	O
UMESC is planning to evaluate sensitivity of fish species recruitment to different hydrologic variables to better understand ecologically relevant hydrologic metrics.	O
I would be interested in learning more about how ice, temperature, chloride, and hydrology relate to HAB potential and on tributary effects to the system's hydrology.	O
We reference water quality criteria (State or EPA) for determining if there are threats to resources.	O
Ice cover and thickness conditions during winter water quality sampling or fish telemetry work	O, T
We look at a range of hydrologic metrics to inform comprehensive watershed management decisions. Percentage of magnitude change and percentage of change in occurrence rate within the interquartile range are calculated using the Indicators of Hydrologic Alteration and other methods. Changes in annual volumes of precipitation and discharge, instantaneous peak discharge; 7-day minimum; August median base flows; 10-, 50-, 90-percent flow duration values; 1.5-, 5-, 10-year return interval flow changes; 3-day maximum; Julian day maximum and minimum flows; high and low pulse counts (at 25th and 75th percentiles); number of reversals; and rise rate.	O, M, T
UMESC is interested in having better estimates of ice cover and duration.	O, D

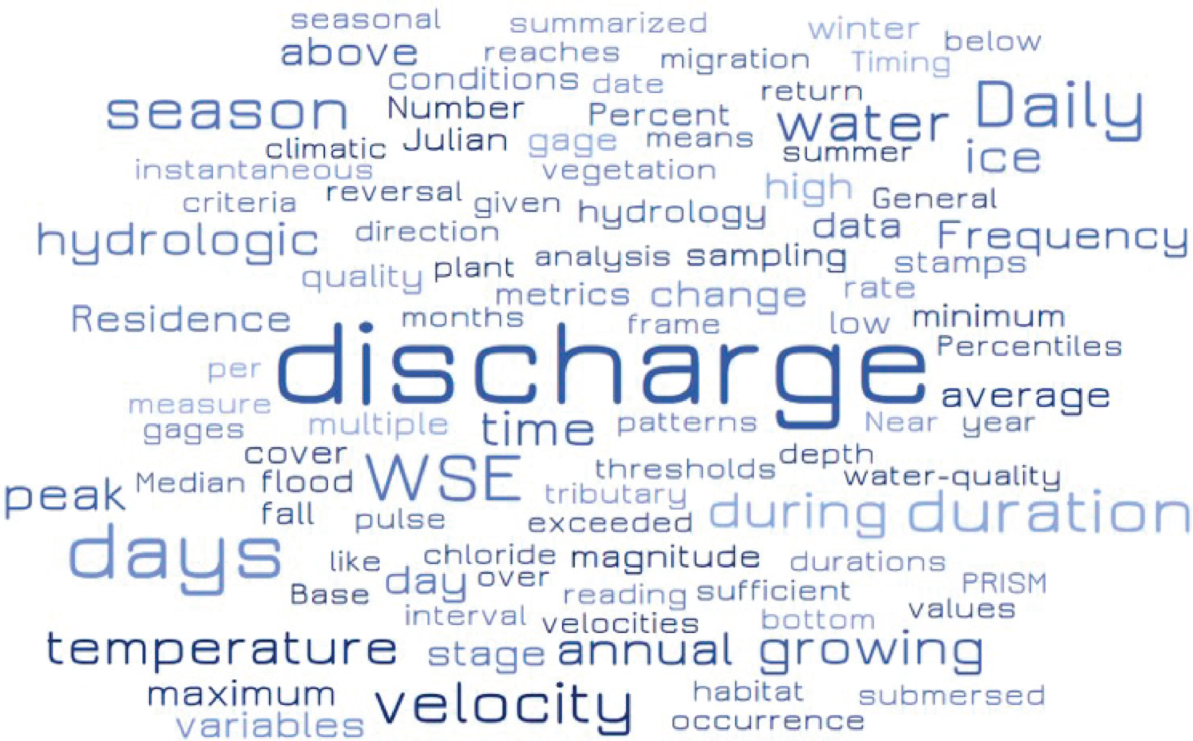

Figure 2.4. Word cloud of specific variables or criteria listed in responses to question 2B (Are there certain hydrologic criteria you use in your decision making, research, or other work [for example, thickness of ice cover, timing of peak discharge, number of days of discharge greater than or less than a given threshold]? Please be as specific as possible.). Font size is proportional to frequency of mentions (fig. generated by WordItOut, licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International license; https://creativecommons.org/licenses/by-nc-nd/4.0/. No changes were made to the material generated by WordItOut.). [WSE, water surface elevation; gages, streamgages]

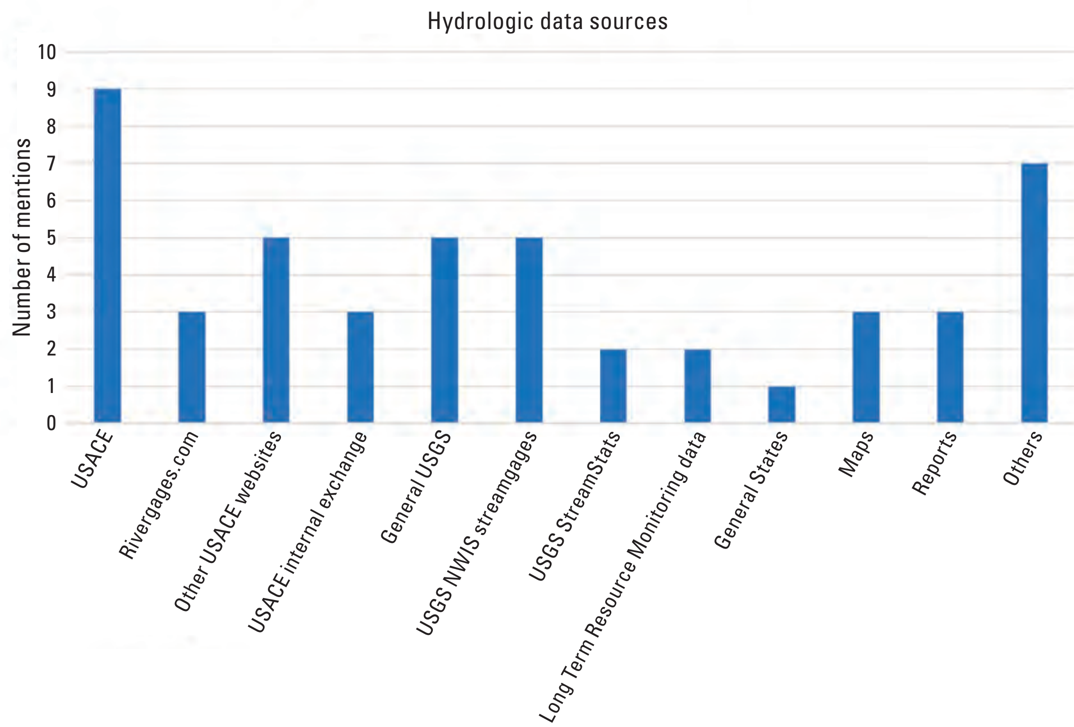

Figure 2.5. Distribution of sources used to obtain hydrologic data. [USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; NWIS, National Water Information System; "general" indicates no additional specified information was mentioned, "reports" also includes appendices, and "other" includes direct acquisition from unspecified personnel, other governmental sources (for example, National Weather Service), or otherwise unspecified sources; Rivergages.com refers to USACE website https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm]

Table 2.5. Responses to question 2C (If you use hydrologic data in your work, where do you acquire Upper Mississippi River System hydrologic data and in what format?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.

[MVR, USACE Rock Island District; EC–HW, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Control Section; WSE, water surface elevation; DSS, Data Storage System; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; NWIS, National Water Information System; NWS, National Weather Service; CSV, comma separated values; lidar, light detection and ranging; HEC–DSS, Hydrologic Engineering Center-Data Storage System; VBA, Visual Basic for Applications; QAQC, quality assurance and quality control; H&H, hydrology and hydraulic; MVS, USACE St. Louis District; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; %, percent; GIS, geographic information system; CWA, Clean Water Act; --, not applicable; NOAA, National Oceanic and Atmospheric Administration; ADCP, acoustic Doppler current profiler; EC–HQ, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Quality and Sedimentation Section; ft, foot; ft^3/s, cubic foot per second; HEC–SSP, Hydrologic Engineering Center-Statistical Software Package]

Participant responses	Hydrologic data source, format, or variable
Responses specifying data sources	
MVR Water Control (EC–HW) daily WSE and discharge in DSS format	MVR Water Control
River streamgages—daily WSE and discharge in Excel format	River streamgages
USGS or USACE	USGS, USACE
USACE websites	USACE
USGS streamgages—stage, discharge	USGS streamgages
USGS websites	USGS websites
USGS streamgages for daily and peak stage/discharge and water quality parameters	USGS streamgages
USGS StreamStats—estimates of streamflow for ungaged sites	USGS StreamStats
USGS StreamStats	USGS StreamStats
USGS NWIS streamgage data	USGS NWIS
USGS data (https://waterdata.usgs.gov/wi/nwis/sw)—high quality but not in every pool. Also lack of discharge data at McGregor is a major problem. Stage only data need to be related back to discharge	USGS (https://waterdata.usgs.gov/wi/nwis/sw)
USACE Access to Water Resources Data website (https://water.usace.army.mil/), NWS hydrographs, and whatever the USACE gives us for specific projects	USACE Access to Water Resources Data website (https://water.usace.army.mil/); NWS
Stage elevations are obtained from the USACE locks and dams.	USACE
Streamflow and stage data from streamgages operated by the USGS, USACE, and States; graphs, CSV files, and so on	USGS, USACE, and States
Lidar data in ArcGIS from a variety of sources	Lidar
USACE Rivergages.com website (https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm)	USACE Rivergages.com website (https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm)
USACE Rivergages.com stage website (https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm)	USACE Rivergages.com stage website (https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm)
Directly from USACE personnel or district website.	USACE personnel or district websites
USACE Water Management website (https://www.mvp-wc.usace.army.mil/)—this site is problematic because data are not current for much of the year, winter months especially; occasional errors as well	USACE Water Management website (https://www.mvp-wc.usace.army.mil/)
USACE recurrence intervals	USACE

Table 2.5. Responses to question 2C (If you use hydrologic data in your work, where do you acquire Upper Mississippi River System hydrologic data and in what format?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[MVR, USACE Rock Island District; EC–HW, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Control Section; WSE, water surface elevation; DSS, Data Storage System; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; NWIS, National Water Information System; NWS, National Weather Service; CSV, comma separated values; lidar, light detection and ranging; HEC–DSS, Hydrologic Engineering Center-Data Storage System; VBA, Visual Basic for Applications; QAQC, quality assurance and quality control; H&H, hydrology and hydraulic; MVS, USACE St. Louis District; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; %, percent; GIS, geographic information system; CWA, Clean Water Act; --, not applicable; NOAA, National Oceanic and Atmospheric Administration; ADCP, acoustic Doppler current profiler; EC–HQ, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Quality and Sedimentation Section; ft, foot; ft³/s, cubic foot per second; HEC–SSP, Hydrologic Engineering Center-Statistical Software Package]

Participant responses	Hydrologic data source, format, or variable
Responses specifying data sources—Continued	
USACE and USGS discharge and WSE are available at daily or more frequent time scales and can be obtained and analyzed as HEC–DSS files, CSV, or spreadsheets	USACE and USGS
Sending emails to USACE districts to request data because data served are not current (especially during the winter months)—frustrating and time consuming	USACE district emails
Water exchange rates and WSE are measured by USACE staff as needed for projects.	USACE measurements
In management, we acquire most of our hydrological data from the USACE via the Water Management website (https://www.mvp-wc.usace.army.mil/Data.shtml). Typically, this website is accessed using an Excel program specific to the streamgage in question, which runs VBA code to scrape the data from the website and assemble a hydrograph for the selected streamgage. Limits to this method include minimal QAQC and issues with sometimes extensive shutdowns of these websites by the USACE.	USACE
I either get it from our H&H folks or download it from the USACE water control website.	H&H staff; USACE water control website
MVS Water Control	MVS Water Control
UMESC compilation database of daily water surface elevations	UMESC
LTRM water quality data	LTRM
LTRM fish and water quality datasets	LTRM
Some from LTRM website for specifics (for example, 75% exceedance levels in GIS or viewer)	LTRM
LTRM—Seems like I get them from a different place every year (for example, Rivergages.com [https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm]), but all have fatal flaws (reliability issues, ability to download select periods or periods that are more than 1 year old, and so on).	LTRM
USACE hydraulic model and H&H appendices for projects is often sole data source for locally scaled hydrologic relations	USACE hydraulic model and H&H appendices
I do not use it, but want to, with respect to progress tracking for nutrient reduction, and potentially, setting chloride criteria as well as thresholds for CWA designated-use assessments.	--
Anecdotal evidence from sponsor/local stakeholder	Anecdotal evidence
Annual maximum rainfall—published values (NOAA Atlas 14, Illinois updated Bulletin 70)	NOAA Atlas 14 (Bonnin and others, 2006; Perica and others, 2013), Illinois updated Bulletin 70 (Angel and Markus, 2019)
ADCP velocity measurements (for hydraulic model calibration) from MVR Water Quality Section EC–HQ, Excel/GIS shapefile format	Measurements from MVR Water Quality Section

Table 2.5. Responses to question 2C (If you use hydrologic data in your work, where do you acquire Upper Mississippi River System hydrologic data and in what format?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[MVR, USACE Rock Island District; EC–HW, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Control Section; WSE, water surface elevation; DSS, Data Storage System; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; NWIS, National Water Information System; NWS, National Weather Service; CSV, comma separated values; lidar, light detection and ranging; HEC–DSS, Hydrologic Engineering Center-Data Storage System; VBA, Visual Basic for Applications; QAQC, quality assurance and quality control; H&H, hydrology and hydraulic; MVS, USACE St. Louis District; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; %, percent; GIS, geographic information system; CWA, Clean Water Act; --, not applicable; NOAA, National Oceanic and Atmospheric Administration; ADCP, acoustic Doppler current profiler; EC–HQ, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Quality and Sedimentation Section; ft, foot; ft^3/s, cubic foot per second; HEC–SSP, Hydrologic Engineering Center-Statistical Software Package]

Participant responses	Hydrologic data source, format, or variable
Responses specifying data sources—Continued	
Watershed Erosion Prediction Project	Watershed Erosion Prediction Project
A recent report (Kerkhoff and others, 2021) used streamgage height (ft) and discharge (ft^3/s) data obtained from USGS streamgage 05378500 in pool 6 and streamgage 05389500 in pool 10 to characterize the study environment. The data were obtained from the USGS NWIS database (https://waterdata.usgs.gov/nwis/%5d). The format was screenshots of graphs provided on the USGS website.	USGS NWIS database
We have used an inundation model, provided by the USACE foresters, to work on forestry projects.	USACE inundation model
Primarily bathymetry maps served by USGS UMESC that we plug into ArcGIS to generate sampling maps	Bathymetry maps from USGS UMESC
Responses specifying data formats	
MVR Water Control (EC–HW) daily WSE and discharge in DSS format	DSS
River streamgages—daily WSE and discharge in Excel format	Excel
ADCP velocity measurements (for hydraulic model calibration) from MVR Water Quality Section EC–HQ, Excel/GIS shapefile format	Excel/GIS shapefile
Primarily bathymetry maps served by USGS UMESC that we plug into ArcGIS to generate sampling maps	ArcGIS
A recent report (Kerkhoff and others, 2021) used streamgage height (ft) and discharge (ft^3/s) data obtained from USGS streamgage 05378500 in pool 6 and streamgage 05389500 in pool 10 to characterize the study environment. The data were obtained from the USGS NWIS database (https://waterdata.usgs.gov/nwis/%5d). The format was screenshots of graphs provided on the USGS website.	Screenshots of graphs provided on the USGS website
USACE Access to Water Resources Data website (https://water.usace.army.mil/), NWS hydrographs, and whatever the USACE gives us for specific projects	Hydrographs
Streamflow and stage data from streamgages operated by the USGS, USACE, and States; Graphs, CSV files, and so on	Graphs, CSV files
Lidar data in ArcGIS from a variety of sources	ArcGIS
USACE and USGS discharge and WSE are available at daily or more frequent time scales and can be obtained and analyzed as HEC–DSS files, CSV, or spreadsheets	HEC–DSS files, CSV or spreadsheets

Table 2.5. Responses to question 2C (If you use hydrologic data in your work, where do you acquire Upper Mississippi River System hydrologic data and in what format?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[MVR, USACE Rock Island District; EC–HW, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Control Section; WSE, water surface elevation; DSS, Data Storage System; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; NWIS, National Water Information System; NWS, National Weather Service; CSV, comma separated values; lidar, light detection and ranging; HEC–DSS, Hydrologic Engineering Center-Data Storage System; VBA, Visual Basic for Applications; QAQC, quality assurance and quality control; H&H, hydrology and hydraulic; MVS, USACE St. Louis District; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; %, percent; GIS, geographic information system; CWA, Clean Water Act; --, not applicable; NOAA, National Oceanic and Atmospheric Administration; ADCP, acoustic Doppler current profiler; EC–HQ, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Quality and Sedimentation Section; ft, foot; ft^3/s, cubic foot per second; HEC–SSP, Hydrologic Engineering Center-Statistical Software Package]

Participant responses	Hydrologic data source, format, or variable
Responses specifying data formats—Continued	
In management, we acquire most of our hydrological data from the USACE via historical data from the Water Management website (https://www.mvp-wc.usace.army.mil/Data.shtml). Typically, this website is accessed using an Excel program specific to the streamgage in question, which runs VBA code to scrape the data from the website and assemble a hydrograph for the selected streamgage. Limits to this method include minimal QAQC and issues with sometimes extensive shutdowns of these websites by the USACE.	Excel, VBA code
Some from LTRM website for specifics (for example, 75% exceedance levels in GIS or viewer)	GIS or LTRM data viewer (https://umesc.usgs.gov/data_library/tools/data_visualization_tools.html)
We use daily discharge data (tabulated) from USGS streamgages acquired through NWIS, annual peak flow data from DSS-Vue, and daily discharge data for duration analysis through HEC–SSP. We acquire monthly, watershed averaged, gridded precipitation data from the Minnesota State Climatology office (tabulated format). These data are derived from high-density statewide local monitoring program data along with other long-term precipitation streamgages. Additionally, PRISM gridded data are used for other analysis within an R scripted analysis package.	Tabulated, DSS, HEC, gridded
Excel format	Excel
Responses specifying hydrologic variables	
Standardization of vertical datum needs to be completed. It is a frustrating mix currently.	--
MVR Water Control (EC–HW) daily WSE and discharge in DSS format	Daily WSE
River streamgages—daily WSE and discharge in Excel format	Daily WSE and discharge
LTRM water quality data	Water quality
USGS streamgages for daily and peak stage/discharge and water quality parameters	Peak stage/discharge and water quality
USGS StreamStats—estimates of streamflow for ungaged sites	Streamflow
Annual maximum rainfall—published values (NOAA Atlas 14, Illinois updated Bulletin 70)	Annual maximum rainfall
ADCP velocity measurements (for hydraulic model calibration) from MVR Water Quality Section E–-HQ, Excel/GIS shapefile format	Velocity
A recent report (Kerkhoff and others, 2021) used streamgage height (ft) and discharge (ft^3/s) data obtained from USGS streamgage 05378500 in pool 6 and streamgage 05389500 in pool 10 to characterize the study environment. The data were obtained from the USGS NWIS database (https://waterdata.usgs.gov/nwis/%5d). The format was screenshots of graphs provided on the USGS website.	Streamgage height and discharge

Table 2.5. Responses to question 2C (If you use hydrologic data in your work, where do you acquire Upper Mississippi River System hydrologic data and in what format?) submitted in September 2021. References to “current” or “existing” should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[MVR, USACE Rock Island District; EC–HW, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Control Section; WSE, water surface elevation; DSS, Data Storage System; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; NWIS, National Water Information System; NWS, National Weather Service; CSV, comma separated values; lidar, light detection and ranging; HEC–DSS, Hydrologic Engineering Center-Data Storage System; VBA, Visual Basic for Applications; QAQC, quality assurance and quality control; H&H, hydrology and hydraulic; MVS, USACE St. Louis District; UMESC, Upper Midwest Environmental Sciences Center; LTRM, Long Term Resource Monitoring; %, percent; GIS, geographic information system; CWA, Clean Water Act; --, not applicable; NOAA, National Oceanic and Atmospheric Administration; ADCP, acoustic Doppler current profiler; EC–HQ, Engineering and Construction Division, Hydrology and Hydraulics Branch, Water Quality and Sedimentation Section; ft, foot; ft^3/s, cubic foot per second; HEC–SSP, Hydrologic Engineering Center-Statistical Software Package]

Participant responses	Hydrologic data source, format, or variable
Responses specifying hydrologic variables—Continued	
Stage elevations are obtained from the USACE locks and dams.	Stage elevations
Streamflow and stage data from streamgages operated by the USGS, USACE, and States; graphs, CSV files, and so on	Streamflow and stage
USACE recurrence intervals.	USACE recurrence intervals
USACE and USGS discharge and WSE are available at daily or more frequent time scales and can be obtained and analyzed as HEC–DSS files, CSV, or spreadsheets	Discharge and WSE
Water exchange rates and WSE are measured by USACE staff as needed for projects.	Water exchange rates and WSE
Some from LTRM website for specifics (for example, 75% exceedance levels in GIS or viewer)	75% exceedance levels
We use daily discharge data (tabulated) from USGS streamgages acquired through NWIS, annual peak flow data from DSS-Vue, and daily discharge data for duration analysis through HEC–SSP. We acquire monthly, watershed averaged, gridded precipitation data from the Minnesota State Climatology office (tabulated format). These data are derived from high-density statewide local monitoring program data along with other long-term precipitation streamgages. Additionally, PRISM gridded data are used for other analysis within an R scripted analysis package.	Daily discharge; annual peak flow; monthly, watershed averaged, gridded precipitation data; PRISM gridded data
USGS streamgages—stage, discharge	Stage, discharge
USACE Rivergages.com stage website (https://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm)	Stage

Table 2.6. Responses to question 2D (If you use hydrologic data in your work, what spatial and [or] temporal scales do you use [for example, daily time steps, annual summaries, one streamgage location, multiple streamgages, two-dimensional data]? Please be as descriptive as possible.) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.

[HREP, Habitat Restoration and Enhancement Project; D, dimensional; LTRM, Long Term Resource Monitoring; UMESC, Upper Midwest Environmental Sciences Center; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WSE, water surface elevation; WQ, water quality; <, less than; LD, lock and dam; MC, main channel; ADCP, acoustic Doppler current profiler; watershed, a term used to describe a drainage basin]

Participant responses	Scale reference
Responses related to spatial scales	
Depending on the HREP location, objectives, and modeling extent, daily stage and discharge data are typically evaluated at the bounding upstream and downstream streamgages.	Bounding upstream and downstream streamgages
Mostly use a specific pool-level spatial scale (for example, pool 13), an annual temporal scale, and pool-specific streamgage data	Pool-level spatial scale; pool-specific streamgage data
We typically use this at the individual project scale for HREPs, but we need it systemically.	Individual project scale for HREPs; need it systemically
The previously mentioned report (Kerkhoff and others, 2021) used daily data collected during 2013–19 from two streamgages that spanned the upper and lower limits of the study area.	Two streamgages that spanned the upper and lower limits of the study area
We use all the examples provided in this question's examples, as indicated by the long list we provided in response to the previous question.	All the examples provided in this question's examples
Project scale (1–10 miles) to navigation pool scale (20–40 miles)	Project scale; navigation pool scale
Valleywide	Valleywide
Tributaries	Tributaries
2D horizontal parameters are measured and modeled.	2D
Assumption of vertical mixing is usually done, but winter thermal stratification is a consideration for backwater fish projects. Vertical sediment gradients are considered.	Backwater fish projects
Annual summaries, individual/multiple streamgages, 2D data for inundation/flood stage models	Individual/multiple streamgages, 2D data
LTRM—daily time steps, multiple streamgages	Multiple streamgages
We assess daily and annual values at a single streamgage location. When multiple streamgages are located within a watershed, we will assess them together. Adjacent watersheds may be used for comparative analyses as well, or when an ungaged watershed is assessed for resources planning. Comparing upstream to downstream streamgages is also valuable in assessing change dynamics within major watersheds to develop strategies.	Single streamgage location; multiple streamgages; upstream to downstream streamgages
For modeling purposes, UMESC aggregates information upward (for example, from daily to weekly, monthly, or yearly time scales). But it is important to start with the finest scale possible to allow for maximum flexibility. Daily time step, for every streamgage possible (USACE streamgages ideally but also USGS streamgages and major tributary streamgages). This information is then interpolated using some form of model to provide information between streamgages. If doing this "system wide" causes problems, perhaps pick a few pools (for example, key pools) to make it more manageable. Providing summaries/data for major tributaries that are between streamgages may also be important to consider.	Start with the finest scale possible; every streamgage possible
Generally, annual summaries at nearest streamgage locations to sampling areas	Streamgage locations
Daily time steps, streamgage locations dependent on sampling location	Streamgage locations

Table 2.6. Responses to question 2D (If you use hydrologic data in your work, what spatial and [or] temporal scales do you use [for example, daily time steps, annual summaries, one streamgage location, multiple streamgages, two-dimensional data]? Please be as descriptive as possible.) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[HREP, Habitat Restoration and Enhancement Project; D, dimensional; LTRM, Long Term Resource Monitoring; UMESC, Upper Midwest Environmental Sciences Center; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WSE, water surface elevation; WQ, water quality; <, less than; LD, lock and dam; MC, main channel; ADCP, acoustic Doppler current profiler; watershed, a term used to describe a drainage basin]

Participant responses	Scale reference
Responses related to spatial scales—Continued	
Generate exceedance probabilities (discharge and elevation), sometimes one streamgage but frequently multiple streamgages to interpolate WSE	One streamgage, multiple streamgages
Many uses of hydrologic data are to investigate WQ and biotic responses at scales <1,000 acres (quite often <10 acres); however, in most cases, hydrologic data used are limited to what is available at a pool or even reach scale (that is, now difficult to get discharge data from LD, so Winona discharge is used for a reach of pools instead of discharge from or into a pool).	Scales <1,000 acres; pool or even reach scale
Tool to look at lateral water surface elevation slope across floodplain MC to lateral backwaters (across a range of discharge values)	Across floodplain MC to lateral backwaters
Derive wetted perimeter and cross-sectional area	Wetted perimeter, cross-sectional area
Typically use period of record for one streamgage location	One streamgage location
Multiple streamgages as needed to cover the project area.	Multiple streamgages, project area
Up-to-date 3D bathymetry and topographic information	3D
Responses related to temporal scales	
Depending on the HREP location, objectives, and modeling extent, daily stage and discharge data are typically evaluated at the bounding upstream and downstream streamgages.	Daily
Daily water surface elevation or daily discharge for duration analysis (planting elevations, water level management analysis)	Daily
Daily water surface elevation data, daily discharge data, and instantaneous ADCP velocity data for hydraulic model calibration (used to determine flow velocities)	Daily
Daily data are often used to develop annual or seasonal duration curves.	Daily
Discharge data (usually daily)	Daily
Stage data (usually daily)	Daily
Daily time steps, streamgage locations dependent on sampling location	Daily
Mostly use a specific pool-level spatial scale (for example, pool 13), an annual temporal scale, and pool-specific streamgage data	Annual
Typically use daily time step data	Daily
LTRM—daily time steps, multiple streamgages	Daily
The previously mentioned report (Kerkhoff and others, 2021) used daily data collected during 2013–19 from two streamgages that spanned the upper and lower limits of the study area.	Daily
Daily, growing season, to annual time scales are considered	Daily, growing season, annual
Seasonal discharge/stage trends	Seasonal
Annual summaries, individual/multiple streamgages, 2D data for inundation/flood stage models	Annual

Table 2.6. Responses to question 2D (If you use hydrologic data in your work, what spatial and [or] temporal scales do you use [for example, daily time steps, annual summaries, one streamgage location, multiple streamgages, two-dimensional data]? Please be as descriptive as possible.) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[HREP, Habitat Restoration and Enhancement Project; D, dimensional; LTRM, Long Term Resource Monitoring; UMESC, Upper Midwest Environmental Sciences Center; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; WSE, water surface elevation; WQ, water quality; <, less than; LD, lock and dam; MC, main channel; ADCP, acoustic Doppler current profiler; watershed, a term used to describe a drainage basin]

Participant responses	Scale reference
Responses related to temporal scales—Continued	
We assess daily and annual values at a single streamgage location. When multiple streamgages are located within a watershed, we will assess them together. Adjacent watersheds may be used for comparative analyses as well, or when an ungaged watershed is assessed for resources planning. Comparing upstream to downstream streamgages is also valuable in assessing change dynamics within major watersheds to develop strategies.	Daily; annual
For modeling purposes, UMESC aggregates information upward (for example, from daily to weekly, monthly, or yearly time scales). But it is important to start with the finest scale possible to allow for maximum flexibility. Daily time step, for every streamgage possible (USACE streamgages ideally but also USGS streamgages and major tributary streamgages). This information is then interpolated using some form of model to provide information between streamgages. If doing this "system wide" causes problems, perhaps pick a few pools (for example, key pools) to make it more manageable. Providing summaries/data for major tributaries that are between streamgages may also be important to consider.	Daily, weekly, monthly, yearly; finest scale possible
Generally, annual summaries at nearest gauge locations to sampling areas	Annual
Annual maximum discharge data for flow frequency analysis (are relevant to floodplain analysis, inundation frequency analysis, overtopping frequency determinations)	Annual
Annual summaries	Annual
Hydrologic data usage ranges from daily to annual data, depending on the analysis/study. For example, assessment of backwater fisheries overwintering habitat often uses January–February hydrologic data, but aquatic vegetation investigations may use May–June if interest is in drivers affecting germination. However, June–August may be more appropriate for assessment of driver effect on aquatic vegetation growth.	From daily to annual; January–February, May–June, June–August
It would be useful to have a tool that could point to an area and generate summary information automatically. Tool should be able to accommodate user-defined time scales.	User-defined time scales
Typically use period of record for one streamgage location.	Period of record
We use all the examples provided in this question's examples, as indicated by the long list we provided in response to the previous question.	All the examples provided in this question's examples

Table 2.7. Responses to question 3A (How would a projected hydrologic dataset benefit your ability to accomplish your job?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.

[HREP, Habitat Restoration and Enhancement Project; USACE, U.S. Army Corps of Engineers; UMRR, Upper Mississippi River Restoration; FPMS, Floodplain Management Services; O&M, operations and maintenance; DQC, district quality control; ATR, agency technical review; watershed, a term used to describe a drainage basin; LTRM, Long Term Resource Monitoring; UMESC, Upper Midwest Environmental Sciences Center; WQ, water quality]

Participant responses
Responses related to HREPs, operations, and river management decisions
A projected hydrologic dataset could allow for the design of more resilient HREP features.
A projected hydrologic dataset could allow for improved estimates of habitat benefits achievable for the different features, allowing project delivery teams to make more climate-risk informed decisions when selecting which project features to construct.
Currently, we assess projected hydrology on a project-by-project basis. A systemic analysis of projected hydrology with greater spatial and temporal resolution throughout the Upper Mississippi River System would enable us to evaluate effects to the hydrologic criteria most relevant to HREP project features and provide uniformity in how USACE is assessing climate change effects to the UMRR Program (I think the flow frequency [peak annual streamflow] part of this is already proposed for the FPMS-updated flow frequency study).
Projected rainfall frequencies (location specific, not much available for most locations) could support hydrologic modeling to determine effects of climate on smaller watersheds (projects like the Keithsburg Division HREP).
I anticipate that it would be most useful in the context of HREP planning and future habitat suitability.
Increase HREP success and longevity
We need to create, restore, and manage habitat that will persist through projected future climate scenarios.
We need to know what is realistic to try and accomplish versus what might be a waste of resources, given future climate scenarios.
We need to ensure our work demonstrates resilience in the face of future stresses.
We need to capture costs of protecting Federal infrastructure (for example, hatchery dikes) and predict future costs for infrastructure.
This is outside of the UMRR, but hydrology projections can be used to inform species recovery and restoration.
Hydrologic data can help us rank potential projects.
Hydrologic data could help a refuge decide if it wants to take on O&M for a project.
A reviewed (DQC, ATR) and approved hydrologic dataset would provide project delivery teams with a tool to assess risk to UMRR projects. The reviewers should include experts in climate change including USACE National Climate Center personnel.
It would help forecast HREP performances over the long term.
Big help for project plans/designs and identifying future problem areas to protect before conditions become poorer for a given spot (for example, shoreline protection from erosion). So in that sense, it would help protect habitat and improve our ability to restore/enhance the river through projects.
It would help us understand potential future conditions and provide us a quantifiable understanding of watershed needs related to resource management. Watershed storage is of particular interest with this dataset in those terms.
Allow for more in-depth analysis and management reports
Provide insight into potential habitat effects and opportunities to guide management objectives or restoration efforts to pursue
Inform projections for future operations or adaptation efforts of intensively managed wetlands
Multiple staff are doing redundant work related to discharge and elevation.
Helpful in sizing water control structures and other project features. Depending on what our requirements for climate change analysis end up being, having more published information on anticipated future conditions would be extremely helpful in meeting our analysis requirements.
It would allow for more resilient designs that should hold up to changing hydrologic conditions, building USACE and sponsor confidence in project performance.

Table 2.7. Responses to question 3A (How would a projected hydrologic dataset benefit your ability to accomplish your job?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context.—Continued

[HREP, Habitat Restoration and Enhancement Project; USACE, U.S. Army Corps of Engineers; UMRR, Upper Mississippi River Restoration; FPMS, Floodplain Management Services; O&M, operations and maintenance; DQC, district quality control; ATR, agency technical review; watershed, a term used to describe a drainage basin; LTRM, Long Term Resource Monitoring; UMESC, Upper Midwest Environmental Sciences Center; WQ, water quality]

Participant responses
Responses related to science in support of restoration
LTRM—A reliable source for historical (daily) data for any period of interest and Upper Mississippi River streamgage would be an invaluable time saver.
UMESC has proposed to complete modeling work that would evaluate the potential effects of climate change on the Upper Mississippi River System since at least as early as 2011. Developing a future hydrological dataset for streamgages would allow UMESC to complete such modeling work and improve our ability to assess potential ecological responses to hydrologic change. Assuming that ongoing studies make substantial progress in our understanding of where the Upper Mississippi River System geomorphology is most likely to change given current hydrologic conditions, reduced uncertainty regarding future hydrologic conditions would better enable us to forecast where geomorphic change is most likely and what, if any, management actions should be attempted.
Responses related to other topics
In so many ways
Advocacy, WQ trends, improving flood-related planning
We need data that can inform decisions about assisted range expansion as a mitigation measure for species persistence in a climate-changed world.
There might be a use of hydrologic data for informing realty decisions (acquisition of new properties), which might be affected by future climate/hydrology scenarios.
Need easy access to historical and current information
Would be very helpful, especially if the data are served in nearly real time; State river managers usually need to know things unexpectedly and in real time.

Table 2.8. Responses to question 3B (To what extent would a future hydrologic dataset improve your decisions? What information is required to make a different decision?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.

[HREP, Habitat Restoration and Enhancement Project; L&D, lock and dam; O&M, operations and maintenance; >, greater than; %, percent; watershed, a term used to describe a drainage basin; USACE, U.S. Army Corps of Engineers; UMESC, Upper Midwest Environmental Sciences Center; WQ, water quality]

Participant responses
Responses related to HREPs/projects and river management decisions
For poolwide water level management projects, climate change is likely to change frequency of achieving success in a given year somewhat, but probably not the engineering decisions we end up making because of operational constraints at the L&D.
Not having this information makes it difficult to design resilient features and makes quantifying the benefits of designing for climate change difficult. Not knowing how the benefits/performance of different project features change with future hydrology makes it difficult to identify the best investment in restoration dollars.
Knowledge of how the relevant hydrologic criteria (that is, duration, frequency information) are expected to change over the 50-year project life allows for assessing the vulnerability of each feature to climate change. This information can help us design more resilient features and more accurately account for their benefits.
To a great extent in HREP planning and siting
It would be useful if it greatly improved decision making relative to the types of habitats and infrastructure targeted for different areas. However, the extent to which it informs our decision making is dependent on the confidence of the dataset and the magnitude of the decision. Decision makers will have to trust and understand the data to use them.
Floodplain forest—Elevation is probably the key parameter. Having a future hydrologic dataset would allow project delivery teams to assess risk and perhaps choose a different elevation. There has to be a balance between future hydrology assumptions, cost, flood stage effects.
It would contribute to our understanding of long-term O&M requirements of certain HREP features. Features that are more expensive initially, but that have less O&M across the long term, may be favored.
Similarly, would help us make more informed decisions for the future and might give us an idea what to expect. Required information includes accuracy and precision at some level. Even if it's a future probability (for example, >50% probability a particular elevation would be affected).
Information on timing, volumes, and frequencies of occurrence will all help make decisions in watershed management goal setting and strategy development. Current hydrologic forecasting through the USACE Climate Hydrology Assessment Tool is too coarse to be of much value for decision making. Additionally, a future hydrologic dataset may be able to inform other modeling efforts in our State, which are currently developed for resource management decision making.
Would improve proper sizing of project features and would improve climate change analysis. Need to know magnitude of anticipated changes in stages, precipitation, and so on at project locations and in watershed in general
Every project is reliant on hydrologic information to design for project success. Ensuring we have a high level of confidence in future hydrologic conditions would be a significant contribution to HREPs.
The dataset would give decision makers an added layer of information.
Risk identification
Responses related to science in support of restoration
UMESC could begin to identify/improve methods to extend a future hydrologic dataset to forecasting ecological changes in the system.
Having a future hydrologic dataset would alleviate decisions regarding how to derive hydrologic forecasts and metrics for ecological response models and allow different response models to be used in tandem.
Need to know how changing hydrology is affecting water exchange and sediment loading to backwaters
Research related to WQ trends and criteria and assessment
How do future conditions compare with current and past trends in hydrology?

Table 2.8. Responses to question 3B (To what extent would a future hydrologic dataset improve your decisions? What information is required to make a different decision?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[HREP, Habitat Restoration and Enhancement Project; L&D, lock and dam; O&M, operations and maintenance; >, greater than; %, percent; watershed, a term used to describe a drainage basin; USACE, U.S. Army Corps of Engineers; UMESC, Upper Midwest Environmental Sciences Center; WQ, water quality]

Participant responses
Responses related to other topics (at the beginning of each entry, the general topic interpreted by meeting organizers is in brackets)
{Data as a communication tool} Changing our construct from what we know collectively about the river (based on historical assumptions and knowledge) to what we need to expect from our future. Let us all get on the same page with that and figure out how we are going to work together.
{Data as a communication tool} A future dataset would allow for discussions of potential shifts in management objectives; essentially, do we continue with business as usual and potentially fight hydrologic changes or do we change how we manage to accept a new paradigm.
{Requirements for being useful} A future hydrologic dataset that would improve our decisions if it were consistent across the entire Upper Mississippi River System (for example, the stage and datum inconsistency problems noted earlier), easily used and understood by river managers, or easy for river managers to get technical assistance in using and understanding the dataset.
{Information gap} We need wide-scale, systemwide residence time estimates for backwater areas.
{Information gap} Need site-specific water velocity and stage information under future hydrologic scenarios
{Data distribution} It would be very useful to have a tool that could point to an area and generate discharge and elevation information automatically.

Table 2.9. Responses to question 3C (What level of certainty should a future hydrologic dataset have for it to be useful in your work?) submitted in September 2021. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.

[%, percent; >, greater than; USACE, U.S. Army Corps of Engineers]

Participant responses
Responses conveying numerical estimates
75%??? (just spitballing this!!)
Not sure, see some previous comments. >50 percent accuracy would be nice? Probably more like 75?
The USACE needs to be able to predict/model 1/100th-foot rise in flood elevation. That seems like a pretty certain level of uncertainty.
Descriptive responses
The answer could range widely depending on the question asked.
I will defer to the subject matter experts to determine the appropriate level of certainty.
I assume it would be possible to assess the vulnerability of different project features under a range of different but likely future conditions to improve our understanding of which features are most resilient under future hydrology.
Information used to make longer term and (or) higher profile decisions should be of a higher certainty.
A level of certainty that does not necessarily give us the single best outcome but gives us the best chances of acceptable outcomes.
Is "certainty" the right word, given that there is so much uncertainty in climate projections? Perhaps certainty that the range of possible conditions has been covered and that the effects tied to those scenarios will help identify project risks (because of extreme precipitation events, higher temperatures, droughts, and so on). There is a statistically significant positive trend in average annual discharge at Upper Mississippi River main stem streamgages from the 1940s to the present. Is that the worst case scenario to assume that trend will continue?
A high level of certainty would be ideal, but more importantly, the realization of where the modeling decisions sits on the spectrum of climate forcing and emission scenarios would give context to what the modeled data represent. Moderate to severe scenarios seem the most appropriate for management decision making.
A future hydrologic dataset should have less certainty than existing climate libraries. Climate change forecasts for temperature and precipitation already have uncertainty. Extending these forecasts to river discharge or stage information will introduce additional sources of uncertainty.
Not sure how to answer this one. Ideally, absolute certainty would be most ideal, but that is unrealistic.
If the level of certainty is not quite high, it might do more harm than good. Do not be afraid to say that we cannot predict future conditions.
Fairly high, especially given the significance of hydrology on the ecosystem and people and businesses.
Unsure, but knowing the level of certainty is important.
Any increase in certainty would be useful. It would also help our engineers "right-size" designs to account for climate change without going too far.
I am not sure it is necessary to have a high level of certainty in future hydrology, but an understanding of the general trend will allow for more robust design and adaptive management plans.
Descriptive responses with insights for conveying uncertainty
Whatever the level of certainty, the level should be explicitly identified when the data is distributed.
I just need to know what the certainty is. The certainty needs to be displayed for any model dataset and with a description of the source of variance, if available.
The level of acceptable uncertainty should first be informed by sensitivity analyses that identify ranges of possible outcomes under different parameter settings. Understanding uncertainty at different resolutions will be important to determining best resolution to aggregate data in development of metrics.
Maybe better to give a range of certainties to inform
Include confidence bands

Table 2.10. Responses to question 3D (How far into the future would you want to understand Upper Mississippi River System hydrology?) submitted in September 2021. Responses are minimally edited to retain original context.

[HREP, Habitat Restoration and Enhancement Project; --, no data or not applicable]

Participant responses	Considerations for deciding an appropriate period of forecasting
At least into the next 50 years (HREP project life)	--
At least 50, but preferably 100 years	--
100 years…longer? I will defer to the subject matter experts to determine the appropriate scale.	--
HREP projects have 50-year planning horizons.	--
The greatest lifespan of a taxa of interest. So 50–100 years for spectaclecase mussels (*Cumberlandia monodonta*).	Greatest lifespan of a taxa of interest
Forests and large infrastructure issues might be well addressed by a 50-year perspective.	--
Refuge Comprehensive Conservation Plans and Habitat Management Plans have a 15-year planning horizon.	--
HREPs are planned assuming a 50-year life. Some consideration is given to project performance beyond the planning life, so 100 years may be appropriate.	--
Hmm. 50 years for HREPs because that is the project design specifications—supposed to last 50 years. However, that might be very, very tough. 5–10 years might be more relevant, but I am not sure what scale they really can do right now?	--
2099 is probably as far into the future as would be useful with the minimum modeled dataset length extending to 2050.	--
100–150 years	--
100 years?	--
At minimum 30 years. Periods of 30, 50, 75, and 100 years would be useful.	--
Several intervals; 5 through 50-year intervals. Should try to projecting 100 years out	--
20 years, 40 years, 100 years	--
Our typical period of analysis is 50 years. Some analyses require 100-year projections.	--
50–100 years	--
A consideration for answering this question is at what point is the projection far enough out that the associated lowered level of confidence is no longer useful for our purposes?	At what point is the projection far enough out that the associated lowered level of confidence is no longer useful?
It might depend on how long we expect the climate to change. Does climate stabilize at some point and then hydrology also stabilizes? I can see scenarios where hydrology will be very variable for a very long time, and trying to predict anything is not very useful.	Depends on how long we expect the climate to change
Short horizon projections would be useful in many situations; for example, when contractors can expect to do work.	When contractors can expect to do work
This connects to previous questions regarding certainty and the form of the modeled projection. Long-term projections that predict changes in patterns and overall minimum and maximum flows, and so on, might have value for long-lived species or long-lasting projects. Conversely, long-term projections may not have the same value for daily flows, and so on. This may create a threshold for required certainty.	Value for long-lived species or long-lasting projects; long-term projections may not have the same value for daily flows; a threshold for required certainty.

Table 2.11. Responses to question 3E (What aspects of future hydrology are of most use for you [for example, discharge at lock/dam locations, monthly peak water surface elevation, annual average discharge, and so on]?) submitted in September 2021. Responses are minimally edited to retain original context.

[F, frequency; M, magnitude; lidar, light detection and ranging; D, duration (length of time); T, timing (seasonality); O, other; WSE, water surface elevation; watershed, a term used to describe a drainage basin; DO, dissolved oxygen]

Participant responses	Closest related hydrologic regime variable/criterion
Frequency of flows that result in a geomorphic response by streams and rivers (for example, formation of deltas).	F
Discharge, water surface elevations, inundation frequencies	F, M
Projected changes in flood frequencies, projected changes in seasonal and annual stage, periodic lidar, long-term streamgage data	F, M
All	F, M, D, T, O
All of the above plus backwater residence time estimates	F, M, D, T, O
Frequency and duration of very high and very low discharge events, as well as updated WSEs associated with various discharges	F, D, M
Information about frequency, duration, and timing of drought and low discharge	F, D, T, M
All listed. Days of inundation for a given elevation too for floodplain work	F, M, D, T, O
Certain precipitation and hydrologic patterns (days in flood stage, daily streamgage readings) would be useful, what specific watersheds and areas are driving hydrologic patterns	D, M
Seasonal or monthly average discharge/stage	T, M
Seasonal distribution of different water elevations	T, M
Peak annual streamflow would support frequency analysis.	M
Monthly peak and minimum water surface elevation	M
WSE at the river mile scale (current and projected)	M
Annual average discharge at each pool	M
Cumulative discharge statistics	M
Some information is available for average annual peak flows. A lot of the work we do is based on daily duration data, and it is more difficult to find “precanned” projected data on that time scale.	M, D
Daily water surface elevation/discharge to support duration analysis	M, D
Flow duration curves at lock/dam locations and streamgages (decadal?)	M, F
Average annual hydrograph, range indicated over period of analysis	M, T
Projected changes in exceedance probabilities for discharge and elevation are needed. How will magnitude and timing of high-and low-water events change?	M, F, T
Streamgage height and discharge at locks and dams, annual average discharge, potential of increased tributary inputs, flood frequency, and timing	M, F, T
Magnitude, duration, timing of discharge and WSE at all scales including the growing season	M, D, T
Velocities and temperatures and DO as affected by hydrology in backwater areas during winter months	M, O
Near-bed velocities and durations (for mussel beds)	M, D

Table 2.11. Responses to question 3E (What aspects of future hydrology are of most use for you [for example, discharge at lock/dam locations, monthly peak water surface elevation, annual average discharge, and so on]?) submitted in September 2021. Responses are minimally edited to retain original context.—Continued

[F, frequency; M, magnitude; lidar, light detection and ranging; D, duration (length of time); T, timing (seasonality); O, other; WSE, water surface elevation; watershed, a term used to describe a drainage basin; DO, dissolved oxygen]

Participant responses	Closest related hydrologic regime variable/criterion
Annual average discharge, monthly discharge volumes, annual precipitation volumes, and modeled discharge at current gaged locations, as well as at ungaged tributary outlets	M, O
Daily stage at streamgages or watersheds, tied to date, temperature, and precipitation for different emissions scenarios, given the appropriate level of uncertainty	M, T, O
Not just future, relate historical hydrologic data to past biology	O
Need to link changing water exchange in backwater areas to changes in primary (phytoplankton) and secondary (zooplankton) productivity	O
Also need to link it to success/failure of recruitment of various fish species (for example, is altered hydrology causing walleye [*Sander vitreus*] year class failure, and so on?)	O
Ice trends	O
Increase in ice could lead to damage of existing habitat (trees) and existing features (river training structures, berms, and so on).	O
Inundation of terrestrial habitats—how much, how long, and when	O, F, M, T, D

Table 2.12. Responses to question 3F (What spatial and temporal scales should a future hydrologic dataset be in order to be useful for your work? Are they the same as you currently use, or are there other scales of interest?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.

[HREP, Habitat Restoration and Enhancement Project; HUC, hydrologic unit code; watershed, a term used to describe a drainage basin; USGS, U.S. Geological Survey; WSE, water surface elevation]

Participant responses	Scale reference
Responses related to spatial scales	
Daily and monthly scales are of interest and not currently available at the spatial resolution needed for HREP analysis and design.	HREP analysis and design
Daily scales would support duration analysis and would be most beneficial at the streamgages at the locks and dams and midpool.	Locks and dams and midpool
To be specifically useful to our work, it would be at the pool-specific scale. But overall, it would be great to have the dataset capture the entire Upper Mississippi River System.	Pool-specific scale; capture the entire Upper Mississippi River System
The dataset should be systemic but usable at the project scale.	Systemic; project scale
The scale of a project or management unit/area may be the most readily applicable scale. We need to know and be able to predict hydrologic conditions for the area encompassed by and immediately surrounding the project.	Project or management unit/area
Pool scale is useful because pools are fairly easy to conceptualize in terms of bounding space.	Pool scale
River reach/geomorphic reach	River reach/geomorphic reach
The spatial scale of National Wildlife Refuge System acquisition boundaries could be important. Acquisition boundaries are the boundaries within which a refuge may acquire property, as determined by legislative and executive actions.	National Wildlife Refuge System acquisition boundaries
There are many areas, such as at Clarence Canon National Wildlife Refuge, or the Black River Bottoms upstream from La Crosse, that are not encompassed within current hydrologic datasets. So a scale that expands beyond the historical Upper Mississippi River "between the railroad tracks" would be useful.	Expands beyond the historical Upper Mississippi River "between the railroad tracks"
Spatial—mesohabitat level (for example, pool, run, riffle) project, navigation pool	Mesohabitat level project; pool
Entire floodplain? At least for water surface elevation and inundations	Entire floodplain
HUC 08 watershed scale or USGS streamgage location breakdowns would be ideal.	HUC 08 watershed; USGS streamgage location
Watershed, regional, pool scales	Watershed, regional, pool
Daily at existing streamgage locations would allow for most analyses	Existing streamgage locations
Including lock/dam locations and midpoint of pools would further inform	Lock/dam locations; midpoint
Mangers typically need small-scale information that is rarely provided; the 10,000-foot view is interesting but not very useful for day-to-day activities for State staff that are already overworked.	Small scale
We typically need elevation, discharge, and residence time data at the individual backwater scale. We need a large effort to generate rating curves for major and minor (feeder channels to individual backwaters) channel cross sections. Jon Hendrickson's effort needs to be expanded upon to minor channel cross sections.	Individual backwater scale

Table 2.12. Responses to question 3F (What spatial and temporal scales should a future hydrologic dataset be in order to be useful for your work? Are they the same as you currently use, or are there other scales of interest?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[HREP, Habitat Restoration and Enhancement Project; HUC, hydrologic unit code; watershed, a term used to describe a drainage basin; USGS, U.S. Geological Survey; WSE, water surface elevation]

Participant responses	Scale reference
Responses related to spatial scales—Continued	
For usefulness at HREP planning, the model outputs should match up with a specific physical attribute that affects habitat and can be managed for/measured at the microhabitat scale. For example, frequency of connectivity at a local scale (microhabitat) during a specified temporal scale (that is, December–February) can be tied to predictions of changes in discharge events.	Habitat; microhabitat scale
HREPs do not necessarily need a model that predicts water surface elevation because within-floodplain attributes change over time, which can change flow distribution and WSE within a given backwater. However, when planning an HREP, the teams can take predicted discharge and estimate WSE at the project scale more precisely and efficiently than a systemic or pool-level model (it would cost a lot of money to have a system level model predict WSE changes at all potential project scale needs).	Project scale
All	All
To accommodate work on the "open river" below the Chain of Rocks dam, future hydrologic information should include data associated with this southern stretch of the Upper Mississippi River.	Open river
Responses related to temporal scales	
Daily and monthly scales are of interest and not currently available at the spatial resolution needed for HREP analysis and design.	Daily, monthly
Daily scales would support duration analysis and would be most beneficial at the streamgages at the locks and dams and midpool.	Daily
I guess a minimum of a 10-year temporal scale, but also projected out to 50 and 100 years, would be great to have.	10-year, projected out to 50 and 100 years
The temporal scale of a period of record + projections 50 years into the future. Currently, not using long-term projections for hydrologic data	Period of record + 50-year projections
Temporal—daily, monthly, growing season, annual	Daily, monthly, growing season, annual
Temporally, the longer the better, but specifics for near term are helpful for project construction/expectations. Similar to current scales, but monthly estimations would be helpful?	Longer the better; monthly
As for the temporal scale, annual at the coarsest, but daily would be useful with the caveat of understanding the inherent reduction in certainty at such a fine scale. Monthly may provide a better balance of model compute requirements to ability of seasonality assessments.	Annual at the coarsest, daily, monthly

Table 2.12. Responses to question 3F (What spatial and temporal scales should a future hydrologic dataset be in order to be useful for your work? Are they the same as you currently use, or are there other scales of interest?) submitted in September 2021. References to "current" or "existing" should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[HREP, Habitat Restoration and Enhancement Project; HUC, hydrologic unit code; watershed, a term used to describe a drainage basin; USGS, U.S. Geological Survey; WSE, water surface elevation]

Participant responses	Scale reference
Responses related to temporal scales—Continued	
Similar scales as currently used (daily stage at river streamgages) because those are the basis for our understanding of how climate and hydrology shaped the river in the recent past. Note that a data viewer in addition to tabular/time series information might be valuable.	Daily
Daily at existing streamgage locations would allow for most analyses	Daily
For usefulness at HREP planning, the model outputs should match up with a specific physical attribute that affects habitat and can be managed for/measured at the microhabitat scale. For example, frequency of connectivity at a local scale (microhabitat) during a specified temporal scale (that is, December–February) can be tied to predictions of changes in discharge events.	Temporal scale (that is, December–February)
All	All
Seasonal discharge/stage trends to easily produce figures/graphs for exporting and including in reports.	Seasonal

Part 2. Brainstorming Uses for an Upper Mississippi River System Future Hydrologic dataset

The purpose of this exercise was to collect specific ideas about the utility of an Upper Mississippi River System future hydrologic dataset. For example, what kinds of projects would benefit from researchers knowing something about future hydrology? What kinds of questions would you like to be able to answer with a future hydrologic dataset? Participants were invited to consider how a climate-changed hydrologic dataset for the Upper Mississippi River System might be useful for carrying out the UMRR program's mission and to brainstorm particular situations, decision points, research projects, or other activities that might benefit from a knowledge of future hydrologic conditions. Compiled responses submitted by participants in September 2021 are listed in table 2.13.

Table 2.13. Compiled responses describing what projects, research, or other work may benefit from a climate-changed hydrologic dataset for the Upper Mississippi River System. Responses were submitted in September 2021. References to “current” or “existing” should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.

[%, percent; --, no data or not applicable; HREP, Habitat Restoration and Enhancement; cm/s, centimeter per second; <, less than; SAV, submerged aquatic vegetation; ft, foot; >, greater than; RCG, reed canary grass; XXX, a generic example; UMRR, Upper Mississippi River Restoration program; DO, dissolved oxygen; NWR, National Wildlife Refuge; C, degree Celsius]

Location List project location/geographic scope	Project goal(s) Describe the project’s goal, objective, and (or) purpose(s)
Project scale	
Beaver Island	Island building/restoration through chevron/bullnose dike construction—crest of structure recommended to be overtopped 30% of the time
Beaver/Steamboat Island	Mussel habitat
Huron Island, Beaver Island, Steamboat Island (various overwintering habitat HREPs)	Create overwintering habitat by ensuring overwintering velocities are less than 1 cm/s.
Lower pool 13 HREP	Still being finalized, but currently include maintaining and enhancing the distribution and abundance of wild celery in the impounded area
Lower pool 13 HREP	Improve water clarity to maintain and enhance aquatic vegetation, benefitting migratory waterfowl.
Lower pool 13 water level management (feasibility stage)	Protect and improve emergent aquatic vegetation in the project area.
Lower pool 13 southwest corner (feasibility stage)	Protect and improve submergent aquatic vegetation in the project area.
Huron Island, Beaver Island, Steamboat Island (various floodplain forest HREPs)	Floodplain forest restoration using topographic diversity
Black River Bottoms HREP, pool 8 HREP, maybe pool 12 HREP	Maintain and enhance existing forest habitat, reestablish forest in areas where it has been converted to RCG, raise floodplain elevation in low RCG patches to establish forest, improve wet meadow habitat
XXX HREP	Restore flows throughout complex.
XXX HREP	Improve waterfowl habitat by increasing the coverage of submersed, rooted floating-leaved, and emergent aquatic vegetation.
Harpers Slough, Capoli, pool 8 islands, Ambrough Slough, and so on	Establish fish overwintering sites.

Table 2.13. Compiled responses describing what projects, research, or other work may benefit from a climate-changed hydrologic dataset for the Upper Mississippi River System. Responses were submitted in September 2021. References to “current” or “existing” should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

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Example question(s) that should be answered List questions that the project should answer upon completion	Other thoughts
Project scale	
How will the 30% annual exceedance duration flow/water surface elevation change under future hydrology?	--
How does bed shear stress change in areas with existing mussel habitat under future hydrology?	--
How high must closure structures be built to eliminate flow to overwintering areas during the overwintering period and maintain velocities <1 cm/s?	--
What discharge range should be considered in determining the designing and location of the physical structures to be constructed or rehabilitated?	A key factor for the project is creating acceptable flow conditions for wild celery. The dimensions and locations of the physical structure that will modify flows, depend on knowing the range of flows likely to be experienced.
How will SAV in lower pool 13 change 50 years from now under a climate-changed hydrology?	This could be important information for our closed areas and other waterfowl (that is, canvasbacks [*Aythya valisineria*]) areas. This could apply to many HREPs.
Can a 30-day, 1-ft drawdown at lock and dam 13 be implemented at least 1 in 5 years?	Maximum flow for which water level management can be implemented is controlled by the lock and dam 13 structure. Minimum flow for which water level management can be implemented is controlled by the navigation authority requirement to maintain a 9-ft navigation channel. Climate change will not affect the mechanics of how water level management is implemented, but it may affect how often implementation of a drawdown is possible—and therefore, project success.
How can built features improve velocities and turbidity (background and wind-wave driven) in the lower pool 13 southwest corner to be more ideal for submergent vegetation?	Parsing out the effects and relations of hydrology, wind-driven waves, turbidity, and submergent vegetation growth has proven difficult. Shifts in future hydrology add another layer of complexity to this feasibility study.
How high must we plant floodplain forest species with minimal flood tolerance to ensure they are only wet >25 days during the growing season 1 time per 4 years?	Different floodplain forest species have different vulnerabilities to climate change (that is, thresholds/ranges for success). Scrub shrub may be more vulnerable to drought compared to hard mast trees that can withstand low water.
How many acres of forest will be lost to hydrophication in the next 50 years and where? To which elevation should the project target topographic enhancements to mitigate conversion to RCG? Can we predict a future change in depth to groundwater during various time steps? How/where will future hydrologic conditions affect priority wet meadow communities?	Any predictive services that can be rendered to model how much and where forest mortality is caused by hydrophication would be a benefit to any Upper Mississippi River System forest project; pool 12 HREP may be too far along in the planning, but pool 8 and the Black River Bottoms project are still a few years out. Wet meadow and forest habitat enhancement features may have a limited footprint, and prioritization will be feasible with an improved hydrologic dataset.
How will flows change over 50 years? What scenarios might result in reduced flows or increased flows?	Riverine conditions for mussels and fish
In 50 years, where will hydrodynamic conditions be conducive for the maintenance, establishment/expansion of diverse aquatic vegetation beds?	This could be important information for our closed areas and other waterfowl (that is, canvasbacks) areas.
How long will it take for sedimentation to fill in sites that have been dredged for overwintering?	Can such sites be designed to self-maintain (scour) under high flows?

Table 2.13. Compiled responses describing what projects, research, or other work may benefit from a climate-changed hydrologic dataset for the Upper Mississippi River System. Responses were submitted in September 2021. References to “current” or “existing” should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

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Location List project location/geographic scope	Project goal(s) Describe the project's goal, objective, and (or) purpose(s)
	Project scale—Continued
Peterson Lake (pool 4) HREP/modifications	Monitor effectiveness of HREP modifications as per stated objectives (increased overwinter fish habitat) under various discharge regimes.
	Reach scale
Open river	Maintain connectivity to side channels and backwaters.
	Systemic scale
Upper Mississippi River System—systemwide	Provide current and future floodplain inundation mapping resources to natural resource managers and communities on the Upper Mississippi River System.
Regional waterfowl habitat conservation planning	Quantify where waterfowl food resources are or will be available in the Upper Mississippi River System during the fall and spring migration.
Upper Mississippi River System—systemwide	Develop a framework in which HREP benefits are quantified in terms of ecosystem services as related to hydrology.
Upper Mississippi River System—systemwide	Assess the vulnerability various cool water fish species (particularly walleye [*Sander vitreus*] and northern pike [*Esox lucius*] for recreational commercial importance).
Upper Mississippi River System—systemwide	Assess the effect of various flow regimes on fish species in the Upper Mississippi River System. This will allow better integration of predicted flow data with population dynamics and vital rates of Upper Mississippi River System fish species.
Upper Mississippi River System—systemwide	Better understanding of where, and at what rates, the geomorphology of the Upper Mississippi River System is changing

Table 2.13. Compiled responses describing what projects, research, or other work may benefit from a climate-changed hydrologic dataset for the Upper Mississippi River System. Responses were submitted in September 2021. References to “current” or “existing” should therefore be interpreted in relation to this timeframe. Responses are minimally edited to retain original context. Referenced geographic features are not shown on a corresponding map.—Continued

[%, percent; --, no data or not applicable; HREP, Habitat Restoration and Enhancement; cm/s, centimeter per second; <, less than; SAV, submerged aquatic vegetation; ft, foot; >, greater than; RCG, reed canary grass; XXX, a generic example; UMRR, Upper Mississippi River Restoration program; DO, dissolved oxygen; NWR, National Wildlife Refuge; C, degree Celsius]

Example question(s) that should be answered List questions that the project should answer upon completion	Other thoughts
Project scale—Continued	
What is the amount of suitable overwintering habitat during various discharge regimes (for example, low, moderate, high)?	--
Reach scale	
Do extreme low flows become more common? How will this affect connectivity of side channels and backwaters in the open river? Is loss of connectivity for extended duration?	Interested in magnitude of low flows, duration of low flows, and frequency of low flows.
Systemic scale	
What are the probability and duration of floodplain inundation along the Upper Mississippi River System, now and in the future? Can this information be compiled into an interactive standardized format for use in determining appropriate and resilient locations for habitat restoration?	Ideally, this would be an interactive mapping layer that could be related to streamgages along the Upper Mississippi River. Elevation data should be standardized. The probability (frequency) of various flood levels now and in the future could be delineated on the map, as well as average number of days during growing season. Habitat restoration emphasis but could benefit communities as well. Similar to https://fim.wim.usgs.gov/fim/ but with future projections and aspects specific to restoration decisions.
How will changing ice cover affect waterfowl use of staging and wintering habitats used in the fall, during the winter, and in the spring?	In many, perhaps most, of the refuges and wildlife management areas of the Upper Mississippi River System, waterfowl use the habitats in the fall as a staging area where they feed, rest, and gain weight before continuing their migration to wintering areas farther south or east. The waterfowl foods that were not consumed in the fall are available for consumption in the spring. If ice cover develops later in the fall/winter, waterfowl may stage for longer periods before departing to their wintering grounds, which may result in less food being available in the spring. If ice cover fails to develop, waterfowl may stay throughout the winter, which would result in even more food being consumed before the spring migration.
What is the value (monetary or nonmonetary) of HREPs (individual or collectively) to the human population in terms of flood risk management, water treatment, recreation, and so on?	Demonstrating the long-term value of the UMRR in ways other than habitat units will enhance support for the program.
How often and for what duration are water temperatures expected to exceed incipient lethal temperatures for these species? Under what future scenario does this occur? Where is this expected to happen within the Upper Mississippi River System?	Water temperature, duration, and timing of predicted peaks in water temperature
Are there critical flow periods for the species? How do changes in flow/temperature affect growth, reproduction, mortality, and so on for each species?	Water temperature, duration, magnitude, and timing of predicted peaks in water temperature and flow data
How should currently observable locations and rates of change be expected to change in response to a changing hydrograph?	--

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Location List project location/geographic scope	Project goal(s) Describe the project’s goal, objective, and (or) purpose(s)
General questions/issues	
Backwater residence time—various projects	Characterize backwater residence time for all backwater areas greater than 3 acres.
Link between altered hydrology and backwater health (flushing, sedimentation, productivity, fisheries recruitment)	Characterize linkage between elevated discharge and backwater sedimentation, flushing, and rates of productivity.
Forest loss projections	Characterize where and when we are likely to lose forest.
Navigation channel maintenance	Characterize how much sediment will be generated to maintain the navigation channel and increases in outflows from main channel.
Island loss	Determine where islands will be lost and at what rate.
Breaches in natural levees	Breaches in natural levees are causing significant damage to quiescent backwater habitat. Characterize when, where, and rate at which this is happening.
Cyanobacteria/cyanotoxin	Certain areas effectively leveed off from the river are unable to be operated efficiently during the current high-discharge era (for example, Trempealeau NWR).
Climate consequences	
Future discharge and water surface elevation projections	Characterize what discharge and water surface elevation will look like in 50 years.
Assessing vulnerability of aquatic vegetation—Upper Impounded Reach	Assess the vulnerability of aquatic vegetation to changes in water levels, discharge, temperature associated with climate change. Predict the spatial distribution of aquatic vegetation under different hydrologic conditions (State changes, community changes, biomass changes).
Assessing vulnerability of aquatic fish	Assess the vulnerability of various fish species to changes in water levels, discharge, temperature associated with climate change.
Assessing vulnerability of mussels	Assess vulnerability of mussels to changes in water temperature, discharge, and so on.

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Example question(s) that should be answered List questions that the project should answer upon completion	Other thoughts
General questions/issues	
Is measured residence time likely to result in the correct mix of temperature/DO for backwater fish in the summer and winter months? How will measured residence time affect zooplankton production, cyanobacteria production, walleye (and other fish species) production? How is changing residence time altering backwater sedimentation patterns?	Future projection of how backwater residence time will change in the next 50 years is needed. Which backwaters have higher potential to be maintained and which will we have to walk away from? Which areas could benefit from a project to target optimal water exchange (residence time)?
Make linkage between projected hydrology and future backwater conditions (flushing rate, primary, secondary and fisheries production)?	It is clear we are in trouble. How bad will conditions become? What species/biotic guilds are likely to be winners and losers under future projections?
It is clear we will have to tolerate some level of forest loss. Which areas can be protected and are worth the resources to protect?	We need to know where it is sensible to use our finite resources.
How quickly will problem areas develop under future hydrologic scenarios?	Again, how bad will this get? Is the current trajectory sustainable? What are the predicted lock closures related to high and low river levels and frequency of these closures?
Where will islands be lost? Which ones should be saved, and where should new ones be established or reestablished?	--
Where are breaches in natural levees likely and how quickly do they accumulate enough flow to cause changes in residence time, sedimentation patterns, or main channel competency?	These seem to be happening with increasing frequency under the high-discharge climate-change era. The cost benefit of correcting (and preventing) these breaches is very high.
What areas similar to Trempealeau NWR would benefit from reconnection to the river from a cyanobacteria/cyanotoxin production standpoint?	Some in the north, but many of these areas would be quite far south.
To what degree would maximum temperatures and days >20 C change?	Water temperature increase will also magnify cyanobacteria/cyanotoxin problems.
How will discharge and water surface elevation look in 50 years (timing, duration, frequency, and associated sediment load)?	We need some reasonable projections if they are likely accurate enough to be useful. We will need this to account for island design heights and other habitat project variables. If this is unknowable, we need to state this. Inaccurate projections could do more harm than good.
Are there hydrologic thresholds or certain scenarios where aquatic vegetation habitat is more at risk of degradation? Thresholds that cause ecological shifts and (or) community changes?	Increased frequency and duration of high water decreases the light availability for aquatic plants and reduces the band of elevations suitable for submersed vegetation. Yin's model uses growing season daily water level. It is important to be able to predict changes in aquatic vegetation communities/ecological states (for example, migrating waterfowl populations depend on this resource).
What species are likely to become imperiled under likely future hydrologic scenarios?	It is important to be able to predict changes in the fish community under future hydrologic/climate conditions.
Combine hydrology with life history thresholds and pathogens	It is important to be able to predict changes in the mussel community under future hydrologic/climate conditions.

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Appendix 3. Meeting 1 Agenda and Outcomes

This appendix contains materials associated with meeting 1. The goal of meeting 1 was for the Upper Mississippi River Restoration program's partnership to use the homework and other experiences to consider what questions need to be answered and what decisions would be made with a future hydrologic dataset to address the following problem statement: How do we enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem in uncertain future hydrologic conditions? The desired outcome for meeting 1 was a prioritized list of program needs to focus meeting 2. The agenda for meeting 1 is shown in figure 3.1, and the outcomes of meeting 1 are listed in tables 3.1, 3.2, and 3.3.

Meeting 1 Agenda

Day 1—Tuesday, September 21, 2021		
12–12:30 p.m.	Opening of meeting	Lucie Sawyer, Molly Van Appledorn, and others
12:30–1:30 p.m.	Introductions and poll everywhere	Rebecca Seal-Soileau, lead facilitator
1:30–2 p.m.	Overview of briefing book and homework activities and their use in the meeting	
2–2:15 p.m.	Stretch break	
2:15–2:45 p.m.	Introduction to meeting process	Rebecca Seal-Soileau
2:45–3:45 p.m.	Working group session I—Complete needs list building on the homework	
3:45–4 p.m.	Large group—Recap of day (with https://www.polleverywhere.com/) and preview of tomorrow	
Day 2—Thursday, September 23, 2021		
12–12:30 p.m.	Welcome and review of meeting agenda	
12:30–1:30 p.m.	Working group session II—Finalize needs list and criteria for ranking	
1:30–2 p.m.	Plenary session—5-minute working group presentations on needs and criteria	
2–2:15 p.m.	Stretch break	Facilitators combine lists from work groups
2:15–3:30 p.m.	Large group work—Prioritize list of needs	
3:30–4 p.m.	Next steps, round robin (with https://www.polleverywhere.com/) and meeting adjourn	

Figure 3.1. Agenda for meeting 1 (2-day meeting held on September 21 and 23, 2021).

Table 3.1. Unranked, complete list of Upper Mississippi River Restoration program needs for understanding future hydrology generated by five working groups at meeting 1. Needs listed are minimally edited to retain original context and are in no particular order.

[UMRR, Upper Mississippi River Restoration program; H&H, hydrology and hydraulics; WQ, water quality; HREP, Habitat Restoration and Enhancement; LTRM, Long Term Resource Monitoring; DQC, district quality control; ATR, agency technical review; O&M, operations and maintenance; HEC–RAS, Hydrologic Engineering Center-River Analysis System]

UMRR needs for future hydrology
How will main stem Mississippi hydrologic and hydraulic metrics (duration, frequency, magnitude and timing, and so on) change with climate, land-use, and management change and how does that guide how, where, why, and what we restore? Need for model assessing changes in velocities (predict change 25, 30 years in the future). Need for assessment of spatial scale of hydrologic changes. Provide future hydrologic datasets using multiple scenarios for use in finer scale H&H modeling. Projections of future flood conditions (frequency, magnitude, trends/nonstationarities, and so on). Daily/monthly projections of discharge at streamgages under different climate scenarios. Updated hydrologic models. Water surface elevation probabilities for any point on the river (current and projected under climate scenarios). There is a need for different (mapped) land cover change/use scenarios, including urban expansion, forest loss, tile drainage, and agricultural intensity. Future annual flow regime (averaged?). Modeling high- and low-flow conditions, 2-year events, not just high flows. Understanding future potential for droughts and effects on water resources. There is a need to understand changes in hydrology (historical and future) to guide river restoration designs at varying spatial scales (that is, small streams to main stem channels).
How would we apply future hydrology to ecological response models? What would a modeling framework look like? A modeling framework that can integrate hydrology, biology, and ecological concepts like resiliency and vulnerability to inform river management actions. How will hydrologic data connect to other disciplines (for example, fish, WQ, vegetation)?
What is the relative risk that future hydrology poses to different habitat, HREP features, biota, and so on?
What is the spatial distribution of this risk to different habitat because of future hydrology throughout the Upper Mississippi River System?
How do we design HREP projects that will provide their intended habitat benefits under future hydrologic conditions (that is, backwater sedimentation and maintaining fish overwintering, floodplain forest plantings)?
How do we build features that can be easily modified/adapted to a change in future hydrology? Beyond the 10-year adaptive management timeframe? Need some sort of tool to help with HREP planning for future projects and current projects to help predict/plan for durability or maintenance needs over the typical planned 50-year life of the projects.
Does future hydrology provide opportunities for different/new restoration (HREP) features that are more self-sustaining (for example, riprap versus seed islands, self-scouring overwintering areas)?
How can future hydrology drive our vision of future desired conditions? Are the environmental pool plans realistic given potential future-changed hydrology?
How do projected changes in hydrology affect ecological structure and function? How does future hydrology affect geomorphic and biologic response in channels, shorelines, backwaters, and floodplains? How will changing hydrology affect island loss and natural levees? Water residence time estimates (flushing in days) for all Upper Mississippi River System backwaters and side channels; needs gaging and rating curves
Need a dataset that provides future hydrologic information at relevant scales in space and time for a suite of different climate models and emissions scenarios to understand hydrologic change and uncertainty spatially. I would prefer at streamgages to compare to contemporary data and temporally at a daily (if possible) scale out 100 years. Quantitative dataset of projected hydrology that has the temporal resolution to allow flexibility when used with other datasets (for example, LTRM, HREP monitoring) or applications (for example, hydraulic models, mapping, and so on). Need a framework to characterize uncertainty in projections in a place-based way. There is a need for different time series of flow or stage at select (maybe all) streamgages in the Upper Mississippi River System for different emissions scenarios from 2025 to 2125. Understanding of uncertainty of projections at different temporal and spatial scales
Scientifically sound, reviewed, and accepted method of integrating climate change scenarios into planning and design to facilitate DQC, ATR, and division level reviews
Ice dynamics and how that would affect food for waterfowl, overwintering, harmful algal blooms, water quality, O&M, and so on
One-stop shop for distributing historical, contemporary, projected hydrologic datasets. Need for accessibility/usability for scientists and managers
How will future hydrology affect the forestry and aquatic vegetation? Will forests or aquatic vegetation cross tipping points that may reduce their resilience? Need to predict/forecast water elevations and changes in seasonality for evaluating suitability for different plant communities. Linking future hydrology to biota life history requirements (walleye [*Sander vitreus*], zooplankton, backwater fishes, and so on)

Table 3.1. Unranked, complete list of Upper Mississippi River Restoration program needs for understanding future hydrology generated by five working groups at meeting 1. Needs listed are minimally edited to retain original context and are in no particular order.—Continued

[UMRR, Upper Mississippi River Restoration program; H&H, hydrology and hydraulics; WQ, water quality; HREP, Habitat Restoration and Enhancement; LTRM, Long Term Resource Monitoring; DQC, district quality control; ATR, agency technical review; O&M, operations and maintenance; HEC–RAS, Hydrologic Engineering Center-River Analysis System]

UMRR needs for future hydrology
How will climate change (different hydrology in the river) affect habitat availability to the point that it affects ecological and critter resilience? In other words, do we have enough deep water habitats and when will we not have those habitats? Or floodplain forests? Is this a helpful question and at what scale?
Develop a better understanding of which hydrologic metrics are most influential on aquatic and floodplain vegetation responses.
Sediment mobility, bank to bank sediment budget transportable that will be transported during high-water events (affecting harbors, bathymetry changes contributing to deposition in navigation channels, mapping mobile sediments). Assessment of changing hydrology effects on backwater sedimentation
Water quality and sediment projections for major tributaries (that is, which tributaries will be changing more? not just the main stem; maybe that is inherent in making predictions for the main stem though)
Can UMRR's hydrology information be used with other stakeholders? Or should the data and such just be tailored to the UMRR Program? In other words, is there a difference in how the information/data are served? Can UMRR help advance integrated management in ways that are beneficial to UMRR/habitat?
Predictive hydrologic models that can summarize where most of the hydrologic instability occurs in a basin
What is the band of future hydrology predicted into the future? Do we assume the past 10 years, 30 years, or just project it extremely? What is the band (elevation/velocity) so we can build in resiliency?
Future inundation (elevation and duration) models that would reflect future-changed hydrology. Depth and duration of floodplain inundation (mapping)
Need future hydrologic datasets at more streamgages (finer spatial distribution) throughout the Upper Mississippi River System main stem and tributaries for nutrient and other loading projections (would you need this for the main stem for full routing of the model?)
Need a future hydrologic dataset at a more refined time step than annual (seasonal, storm event)
Redefine geomorphic reaches over time (are they changing?)
Need projections of future flow duration curve (averaged?)
Need descriptions of assumptions and limits of downscaling methodologies. Probabilistic descriptions (ranges)
Need to develop methods to use the range of future hydrologic data to make more informed decisions (how to incorporate this into risk management/selection of preferred plan and so on). Forethought on how this information will be integrated into guidance and assistance on adaptation once the hydrologic datasets have been completed
Data collection—Gaging in off-channel areas and understanding of changing hydrology affects flows in off-channel areas (for model calibration?)
Consider indirect changes because of land use, infrastructure, management, and so on will affect the Mississippi River in either qualitative or quantitative ways? (Increasing tile drainage, impervious surfaces, irrigation, and cropping changes)
Need to understand future evapotranspiration rates
Need to understand timing and magnitude of flood pulses and thermal effects (help to inform potential effects on managed biota and allow staff to either mitigate change or prepare public for likely unavoidable changes going forward in advance)
Need to understand and predict/forecast changes in the timing (seasonality), magnitude, and duration of flood and flow pulses and thermal effects for evaluating effects to biota and allow managers to mitigate expected changes
Need to understand how natural geomorphic features and navigation infrastructure affect conveyance of water across the river floodplain and develop scenarios of geomorphic and (or) infrastructure changes to develop management alternatives
There is a need to develop, select an existing method, or work with someone/agency to model the flow of water from the landscape to the river system under different climate change and land-use scenarios.

Table 3.1. Unranked, complete list of Upper Mississippi River Restoration program needs for understanding future hydrology generated by five working groups at meeting 1. Needs listed are minimally edited to retain original context and are in no particular order.—Continued

[UMRR, Upper Mississippi River Restoration program; H&H, hydrology and hydraulics; WQ, water quality; HREP, Habitat Restoration and Enhancement; LTRM, Long Term Resource Monitoring; DQC, district quality control; ATR, agency technical review; O&M, operations and maintenance; HEC–RAS, Hydrologic Engineering Center-River Analysis System]

UMRR needs for future hydrology
Updated land cover data—HEC–RAS models, changing roughnesses with changing water levels. Specific to individual projects. Forest to farmland and so on. Frequency—Is 10 years frequent enough?
How will changing land use, infrastructure, management affect future hydrology in responses to climate scenarios (increasing tile drainage, impervious surfaces, irrigation, and cropping changes)?

Table 3.2. Unranked, complete list of potential ranking criteria generated by five working groups at meeting 1. Needs listed are minimally edited to retain original context and are in no particular order.

[UMRR, Upper Mississippi River Restoration; US, upstream; DS, downstream; PDT, project delivery team; WQ, water quality; HREP, Habitat Restoration and Enhancement]

UMRR criteria for ranking needs
Systemwide applicability (reach coverage [US, DS]; broad scale information needs); longitudinal extent
Provides modeling capability for multiple system functions/components (that is, back channel, main, and floodplain)? More detailed in a reach
Time sensitive
Effect to the program's capacity to meet mission/vision (consideration of existing UMRR partnership consensus/stakeholder priority)
Sequencing of work (that is, modeling—need future hydrology before main stem hydraulic routing, established modeling framework to know future hydrology/routing fits into ecological model). How much processing beyond basic projections of discharge data needed to address the need (less additional processing is better)? Some needs are derived products where these are most basic. How much more would need to be done to meet the need?
Does this need help PDTs plan, design, construct more resilient projects or implement management actions that meet objectives? Is there direct and immediate application into project planning process (for example, determine timing and heights of flood pulses, determine inundation days for forestry)?
Seamless integration of additional critical datasets (fish, WQ, vegetation, invertebrates, and so on) into the hydrologic data
Relevance to multiple end-use applications (for example, HREPs, scientific community, levee districts, soil and water districts)
Number of questions/challenges/unknowns addressed by dataset (focused versus broad); multiple benefits beyond identified need
Likelihood of accomplishing a specific goal/end product that can be added to with additional work/features/data in a logical sequence
Low-hanging fruit; for example, compile existing climate models that can be easily integrated for forecasting
Total cost—accessibility of additional funding and (or) ability to bring in additional resources
Sequencing of work
Critical step
Ecological resilience at broad scale
Likelihood of finding funding support
Project sponsor priority
Analysis/results would be meaningful, useful to Congress
Confidence level of data or projections
Is project selection by river teams enhanced?
Applicability to UMRR, external stakeholders, other river users, and other river groups
Is this work authorized under the UMRR program funding authority?
Wide spatial applicability of dataset/tool/projection is preferred.
Stakeholder priorities
Informs priority restoration needs
Process or new data can interact with existing datasets
Lower level of uncertainty with dataset should rank higher than high level of uncertainty
How general (widely shared) is the need (more is better)?
Informs policy changes

Table 3.2. Unranked, complete list of potential ranking criteria generated by five working groups at meeting 1. Needs listed are minimally edited to retain original context and are in no particular order.—Continued

[UMRR, Upper Mississippi River Restoration; US, upstream; DS, downstream; PDT, project delivery team; WQ, water quality; HREP, Habitat Restoration and Enhancement]

UMRR criteria for ranking needs
Time sequential
Biggest effect
Public/stakeholder interest and expectations
Cost-benefit (broadness of application across districts) ratio
Satisfies climate change EC requirements

Table 3.3. Results of live polling (via https://www.polleverywhere.com/) to identify criteria by which to rank Upper Mississippi River Restoration program needs. Criteria listed are minimally edited to retain original context of the criteria presented to voters in https://www.polleverywhere.com/.

[UMRR, Upper Mississippi River Restoration program]

Potential ranking criteria	Votes
Systemwide applicability, reach coverage, broad-scale information needs, longitudinal extent	16
Provides modeling capability for multiple system functions/components; that is, back channel, main channel, and floodplain? More detailed in reach	14
Effect to the program's capacity to meet mission/vision (consideration of existing UMRR partnership consensus/stakeholder priority)	12
Relevance to multiple end uses	11
Sequencing of work	10
Multiple benefits beyond identified needs, number of questions addressed	7
Resilient and immediate application	2
Time sensitive	2
Low-hanging fruit	1
Likelihood of accomplishing in a logical sequence	1
Seamless integration of additional data	1
Total cost/accessibility of additional funding	0

Appendix 4. Meeting 2 Agenda and Outcomes

This appendix contains materials associated with meeting 2. The goal of meeting 2 was for the Upper Mississippi River Restoration program's partnership and external climate change experts to discuss appropriate datasets and approaches that could be used to meet the priority needs for understanding future hydrology identified in meeting 1 to address the following problem statement: How do we enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem in uncertain future hydrologic conditions? The desired outcomes for meeting 2 were a description of the ideal quantitative future hydrologic dataset that meets the program priority needs (for example, time steps, metric, spatial scales) and a participant list for meeting 3. The agenda for meeting 2 is shown in figure 4.1, and the outcomes of meeting 2 are listed in tables 4.1, 4.2, and 4.3.

Meeting 2 Agenda

Day 1—Monday, November 1, 2021		
12–12:30 p.m.	Opening of meeting	Lucie Sawyer, Molly Van Appledorn
12:30–1 p.m.	Introductions and poll everywhere	Rebecca Seal-Soileau, lead facilitator
1–2 p.m.	Presentations	
	1. Meeting 1 outcome—Priority Upper Mississippi River Restoration needs by theme	Rebecca Seal-Soileau
	2. Homework responses	Molly Van Appledorn
	3. Methods for assessing future hydrology	Lucie Sawyer
	4. Example future hydrology datasets	Chris Frans
2–2:15 p.m.	Stretch break	
2:15–2:30 p.m.	Meeting process description	Rebecca Seal-Soileau
2:30–3:45 p.m.	Working group session I—Describe future hydrology datasets to meet priority needs for each theme	
3:45–4 p.m.	Large group—Recap of day (with https://www.polleverywhere.com/) and preview of tomorrow	
Day 2—Tuesday, November 2, 2021		
12–12:30 p.m.	Welcome and review of meeting agenda	
12:30–1:30 p.m.	Working group session II—Finalize description of future hydrology datasets	
1:30–2 p.m.	Plenary session—10-minute working group presentations on hydrologic datasets	
2–2:15 p.m.	Stretch break	Organizers regroup
2:15–3:30 p.m.	Large group work • Discussion of Resulting Future Hydrology Dataset needs and Existing Future Hydrologic Datasets • Identify meeting 3 participants	
3:30–4 p.m.	Next steps and meeting adjourn	

Figure 4.1. Agenda for meeting 2 (2-day meeting held on November 1 and 2, 2021).

Table 4.1. Ranked list of geomorphology needs and hydrologic characteristics for the theme's top three priority needs. The list reflects participant responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated geomorphology needs?" Responses are minimally edited to retain original context, and referenced geographic features are not shown on a corresponding map.

[IL-R, Illinois River; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; LOCA, LOcalized Constructed Analogs; no., number; GCM, global climate model; RCP, representative concentration pathway; TSS, total suspended solids; NGWOS, next generational water observing system; CoP, community of practice; ppt, precipitation; LCR, Little Colorado River]

Rank	Geomorphology needs	Temporal resolution		Spatial resolution
		Time steps	Time span	Location of desired data
1	To understand how future hydrology may affect geomorphic responses (for example, island loss, natural levees) in channels, shorelines, backwaters and floodplains	Input data at a daily time step. The conclusions (output) will be made at an annual and seasonal time step for these features for large scale geomorphic features.	(2020–70) 50 years from when planning was done	Upper Mississippi River from Anoka to above the Ohio River and IL-R. Reach scale is resolution. For specific features, we would need data at the scale of the feature. Predict subpool scale in 50-year life of project. USACE and USGS streamgage locations (LOCA currently available at 14-square-mile scale)
2	To understand how natural geomorphic features and navigation infrastructure affect the conveyance of water across the river floodplain	Input data are needed at a daily time step. The conclusions (output) will be made at annual and seasonal time steps for these features for large-scale geomorphic features.	(2020–70) 50 years from when planning was done	Upper Mississippi River from Anoka to above the Ohio River and IL-R. Reach scale is resolution. For specific features, we would need data at the scale of the feature. Predict subpool scale in 50-year life of project. USACE and USGS streamgage locations (LOCA currently available at 14-square-mile scale)
3	To assess how changing hydrology may affect backwater sedimentation in the Mississippi and Illinois Rivers	Input data are needed at a daily time step. The conclusions (output) will be made at annual and seasonal time steps for these features for large-scale geomorphic features.	(2020–70) 50 years from when planning was done	Linking data at streamgages with residence time and other changes in the backwaters

Table 4.1. Ranked list of geomorphology needs and hydrologic characteristics for the theme's top three priority needs. The list reflects participant responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated geomorphology needs?" Responses are minimally edited to retain original context, and referenced geographic features are not shown on a corresponding map.—Continued

[IL-R, Illinois River; USACE, U.S. Army Corps of Engineers; USGS, U.S. Geological Survey; LOCA, LOcalized Constructed Analogs; no., number; GCM, global climate model; RCP, representative concentration pathway; TSS, total suspended solids; NGWOS, next generational water observing system; CoP, community of practice; ppt, precipitation; LCR, Little Colorado River]

Hydrologic metrics			Approach for evaluating future	Notes
Flow metrics	Flood metrics	Other metrics		
Annual peak discharge, flow duration curves, velocity	Flood frequency analysis, duration, depth, velocity, flow duration curves	Shear stress, water surface slope between streamgages. Sediment mobility and vegetation (see Geomorphology Needs no. 5 in table 2); change in ice effects	Climate change scenario study, outputs would be input for the geomorphic study	(Hydraulic model to generate velocity) Look at what is sensitive first. Where inputs cause effects. Sensitivity guides in-depth modeling needs. Identify areas that will be stressed first (for example, island loss) so that even if you do not know how the hydrology will change they will indicate effects earliest. Consider continuing result of channel training structures.
Annual peak discharge, water surface elevations, flow duration	Flood frequency analysis, duration, depth, flow duration curves	--	Climate change scenario study, outputs would be input for the geomorphic study. Including temperatures (LOCA daily; different GCM and RCP)	Inputs are the same but asking different questions of the model. This is just hydraulics instead of geomorphology. Baseline interactions of features with the conveyance, regardless of future or historical climate. What if we doubled the frequency of a flood? Thought experiment—If there were information, what would we need to know to interpret effect on landscape? Low-flow management will vary up and downstream on the river. Extreme highs will affect sediment mobilization.
Annual peak discharge, water surface elevations, flow duration, TSS	When is the flood happening, how many in a year? Rate of rise and fall? May be inferred from increases in variance	Sedimentation rates, snow to rain shift, timing of ice- out conditions, thaw effects on sediment delivery, response to rain on snow, winter rain events	--	How much do we know about current sedimentation rate? Is there a sediment budget analysis? Some scaled up to backwater scale. There is work to be done on sediment source tracking. For example, part of NGWOS program. Will be related to vegetation on land and delivery of sediment to backwater areas. Have climate models been used to drive sediment transport and delivery models? The CoP can provide ppt and hydrology information to drive the local models on these issues. There can be a difference from using precipitation data. USGS and Eric Grossman has done some related research in the Skagit River and lower Columbia River.

Table 4.2. Ranked list of Habitat Restoration and Enhancement Project (HREP) and management decision needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated HREP and management decision needs?" Responses are minimally edited to retain original context.

[WSE, water surface elevation; RCP, representative concentration pathway; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; Q, discharge; MVP, St. Paul District, U.S. Army Corps of Engineers; --, no response was generated; 1D/2D, one dimensional/two dimensional; <, less than; LOCA, LOcalized Constructed Analogs; VIC, Variable Infiltration Capacity; SAV, submerged aquatic vegetation; LTRM, Long Term Resource Monitoring; MACA, multivariate adaptive constructed analogs]

Rank	HREP and management decision needs	Temporal resolution		Spatial resolution
		Time steps	Time span	Location of desired data
1	To understand changes in hydrology and hydraulics (for example, water surface elevation, velocity) at varying spatial scales to guide river restoration designs (that is, building resiliency, achieving intended habitat benefits)	Daily discharge and WSE. Monthly still useful, growing season, annual	50 years (2020–70) is HREP project life. Can 50 years be broken up into 10-year segments? Can you get a more resolved time step on shorter term projections? Uncertainty outside of 50 years increases because of diverging RCPs after 30 years	USGS streamgages, USACE streamgages, WSE and Q at backwater sites and main channel. MVP has generated these relations; these need to be repeated every 5 years.
	Floodplain forest planting (topographic diversity)	How high must we plant floodplain forest species with minimal flood tolerance to ensure they are only wet <25 days during the growing season 1 time per 4 years? Daily WSE during growing season. We can use existing rating curves to get from modeled Q to modeled WSE	50 years (2020–70) is HREP project life, consider forests long outlive the HREP project life and that forest succession model looks out 100 years	USACE and USGS streamgages. USGS streamgages have more reliable rating curves and have longer period of record. Note if mizuRoute data are applied, may not line up with USGS streamgages
	Overwintering habitat—limit flow into the overwintering areas during November and December to 1 time per 10 years	Daily WSE and Q	50 years	USGS and USACE streamgages
	SAV/emergent vegetation	Daily and seasonal (during the growing season and migration)	50 years	USGS and USACE streamgages and LTRM vegetation/velocity sampling locations
	Beaches to natural levees/island loss	--	50 years	USGS and USACE streamgages
	Protecting existing/restoring lotic habitat/mussel beds	--	50 years	USGS and USACE streamgages
2	To understand how future hydrology can drive our vision of future desired conditions and other planning guidance (for example, environmental pool plans)	--	----	

Table 4.2. Ranked list of Habitat Restoration and Enhancement Project (HREP) and management decision needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated HREP and management decision needs?" Responses are minimally edited to retain original context.—Continued

[WSE, water surface elevation; RCP, representative concentration pathway; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; Q, discharge; MVP, St. Paul District, U.S. Army Corps of Engineers; --, no response was generated; 1D/2D, one dimensional/two dimensional; <, less than; LOCA, LOcalized Constructed Analogs; VIC, Variable Infiltration Capacity; SAV, submerged aquatic vegetation; LTRM, Long Term Resource Monitoring; MACA, multivariate adaptive constructed analogs]

Hydrologic metrics			Approach for evaluating future	Notes
Flow metrics	Flood metrics	Other metrics		
Q, WSE, low-flow frequency, stage/flow duration at different scales, timing, annual peak Q	Frequency, duration, timing	Residence time, water temperature	--	Hydraulic model (1D/2D?)
Growing season inundation duration exceedance probability, consider flood timing during other seasons, flood timing, frequency (annual and interannual)	Frequency, duration, depth, timing	--	Comparative analysis—this is a rate of change analysis that could be used to compare two discrete periods, a 30-year period versus a 30-year moving window, to compare; that is, continuous change analysis. This transient change analysis helps to identify timing of implementing adaptation measures.	LOCA-VIC-mizuRoute dataset available today; identify discharge threshold rather than relying on WSE threshold. Compare modeled historical with projected to observe trends in Q and number of days threshold is exceeded. Hydraulic modeling is an alternative option
Q, velocity, WSE	Frequency, duration, timing, depth	Residence time, water temperature	--	--
Q, velocity, WSE, duration	Frequency, duration, timing, depth	Turbidity, wind driven waves (projections may not be available or valuable because of oversimplification—could look at MACA datasets)	--	--
--	--	Wind driven waves (projections may not be available or valuable because of oversimplification—could look at MACA datasets)	--	--
--	--	--	--	--
--	--	--	--	--

Table 4.2. Ranked list of Habitat Restoration and Enhancement Project (HREP) and management decision needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated HREP and management decision needs?" Responses are minimally edited to retain original context.—Continued

[WSE, water surface elevation; RCP, representative concentration pathway; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; Q, discharge; MVP, St. Paul District, U.S. Army Corps of Engineers; --, no response was generated; 1D/2D, one dimensional/two dimensional; <, less than; LOCA, LOcalized Constructed Analogs; VIC, Variable Infiltration Capacity; SAV, submerged aquatic vegetation; LTRM, Long Term Resource Monitoring; MACA, multivariate adaptive constructed analogs]

Rank	HREP and management decision needs	Temporal resolution		Spatial resolution
		Time steps	Time span	Location of desired data
3	To understand whether future hydrology provides opportunities for different/new restoration (HREP) features that are more self-sustaining (for example, riprap versus seed islands; self-scouring overwintering areas)	--	--	--
4	To predict or forecast water surface elevations and changes in seasonality for evaluating suitability for different plan communities	--	--	--
5	To understand how, where, why, and what to restore given changing future hydrologic and hydraulic metrics	--	--	--
6	To understand how to fund and build features that can be easily modified or adapted to change in future hydrology beyond the 10-year adaptive management timeframe.	--	--	--

Table 4.2. Ranked list of Habitat Restoration and Enhancement Project (HREP) and management decision needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated HREP and management decision needs?" Responses are minimally edited to retain original context.—Continued

[WSE, water surface elevation; RCP, representative concentration pathway; USGS, U.S. Geological Survey; USACE, U.S. Army Corps of Engineers; Q, discharge; MVP, St. Paul District, U.S. Army Corps of Engineers; --, no response was generated; 1D/2D, one dimensional/two dimensional; <, less than; LOCA, LOcalized Constructed Analogs; VIC, Variable Infiltration Capacity; SAV, submerged aquatic vegetation; LTRM, Long Term Resource Monitoring; MACA, multivariate adaptive constructed analogs]

Hydrologic metrics			Approach for evaluating future	Notes
Flow metrics	Flood metrics	Other metrics		
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Table 4.3. Ranked list of ecology needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated ecology needs?" Responses are minimally edited to retain original context, and referenced geographic features are not shown on a corresponding map.

[--, no response was generated; ~, about; watershed, a term used to describe a drainage basin; VIC, Variable Infiltration Capacity; O&M, operations and maintenance]

Rank	Ecology needs	Temporal resolution		Spatial resolution
		Time steps	Time span	Location of desired data
1	To understand how future hydrology may affect biologic responses, ecological structure, and ecological function in channels, shorelines, backwaters, and floodplains	Daily, seasonal (as fine as possible)	100 years into the future	All possible streamgages
1A	Example—need to understand how future hydrology would affect floodplain forest succession	Daily because desired output from hydrologic model that could then be coarsened as needed	100 years (~2099)	The larger the scale the better (given the climate data), but total size may be constrained by cost. As a result, there may be some section(s) that are excluded, likely the south. A strategy could be building from upper to lower with the understanding that cost grows as basin grows.
2	To understand how future hydrology, including water surface elevation changes and seasonal shifts in hydrology, may affect floodplain forests, aquatic vegetation, and the distribution of their suitable habitats. For example, whether they may cross tipping points that could reduce their resilience	--	--	--
3	To develop a better understanding of which hydrologic metrics are most influential on aquatic and floodplain vegetation responses.	--	--	--
4	To understand how climate-changed hydrology may affect habitat availability to the point that it affects ecological and critter resilience	--	--	--

Table 4.3. Ranked list of ecology needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated ecology needs?" Responses are minimally edited to retain original context, and referenced geographic features are not shown on a corresponding map.—Continued

[--, no response was generated; ~, about; watershed, a term used to describe a drainage basin; VIC, Variable Infiltration Capacity; O&M, operations and maintenance]

Hydrologic metrics			Approach for evaluating future	Notes
Flow metrics	Flood metrics	Other metrics		
Response/process/function of interest; timing and duration of peak events, low-flow patterns including timing and frequency; mean seasonal patterns can be helpful for certain processes; daily data can give most flexibility in metrics	--	Water temperature	Approach could capture snowfall	Temporal resolutions change depending on process or organisms of interest; the most detailed information is ideal for use in the broadest range of applications, but there are some limits to useful resolution (for example, not coarser than seasonal for certain biota; trees may be okay with annual time steps). Relevant time steps are not known for many organisms. A minimum requirement for spatial resolution may be downstream of major tributary (that is, places where shift in hydrology is most expected) compared to everywhere/all possible streamgages. For important hydrologic metrics, existing hydrologic analysis can be used to generate metrics, then build out potential measures we could generate but currently do not.
--	--	--	--	If areas of Upper Mississippi River System cannot be modeled given budget constraints, we should propose to assess VIC-derived data to determine applicability/reliability to region (and other existing models/data). To help investigate cost limitation versus modeling domain, it was suggested to graph cost (y-axis) versus watershed area, expecting jumps in costs with addition of fairly large subwatersheds (for example, Wisconsin River, Illinois River, Missouri River) given more data requirements, model calibration, and the rest.
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Table 4.3. Ranked list of ecology needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated ecology needs?" Responses are minimally edited to retain original context, and referenced geographic features are not shown on a corresponding map.—Continued

[--, no response was generated; ~, about; watershed, a term used to describe a drainage basin; VIC, Variable Infiltration Capacity; O&M, operations and maintenance]

Rank	Ecology needs	Temporal resolution		Spatial resolution
		Time steps	Time span	Location of desired data
5	To link future hydrology with life history requirements of biota (walleye [*Sander vitreus*], zooplankton, backwater fishes, and others)	--	--	--
6	To develop a modeling framework to link future hydrology with ecological response models, data from other disciplines (for example, fish, water quality, vegetation), and ecological concepts like resiliency and vulnerability	--	--	--
7	To assess what scales are important to assessing habitat conditions and how they may be affected by climate-changed hydrology	--	--	--
8	To understand timing, magnitude, and duration of flows and flood pulses and thermal effects in order to understand potential effects on managed biota and allow staff to either mitigate change or prepare public for likely unavoidable changes going forward in advance	--	--	--
9	To assess whether we have enough deep-water habitats in the future and at what point in time that may change	--	--	--
10	To understand ice dynamics and how they would affect food for waterfowl, overwintering, harmful algal blooms, water quality, O&M, and others	--	--	--
11	For water quality projections for major tributaries (that is, which tributaries will be changing more?)	--	--	--

Table 4.3. Ranked list of ecology needs and hydrologic characteristics for the theme's top three priority needs. The list reflects responses to the question, "What are the characteristics of a future hydrologic dataset necessary in order to meet the stated ecology needs?" Responses are minimally edited to retain original context, and referenced geographic features are not shown on a corresponding map.—Continued

[--, no response was generated; ~, about; watershed, a term used to describe a drainage basin; VIC, Variable Infiltration Capacity; O&M, operations and maintenance]

Hydrologic metrics			Approach for evaluating future	Notes
Flow metrics	Flood metrics	Other metrics		
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Appendix 5. Meeting 3 Agenda and Outcomes

This appendix contains materials associated with meeting 3. The goal of meeting 3 was to identify which dataset analysis/development workflow components are suitable for proposing a research plan by March 2022 and which should be postponed for a blueprint that addresses the following problem statement: How do we enhance habitat and advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem in uncertain future hydrologic conditions? The agenda for meeting 3 is shown in figure 5.1, and the outcomes for meeting 3 are shown in figure 5.2. The desired outcomes for meeting 3 were to define action steps for each dataset analysis/development workflow component (fig. 5.2) and to have a workplan in place for completing a research proposal by the March 2022 deadline.

Meeting 3 Agenda

Day 1—Tuesday, January 18, 2022		
1–1:30 p.m.	Opening of meeting	Lucie Sawyer, Molly Van Appledorn, and Rebecca Seal-Soileau
1:30–2:30 p.m.	Introductory presentations	Molly Van Appledorn, Chris Frans, and Lucie Sawyer
2:30–2:40 p.m.	Stretch break	
2:40–3:50 p.m.	Meeting process description and black boxes 1 and 2 discussion	Rebecca Seal-Soileau
3:50–4 p.m.	Recap of day and preview of tomorrow	Rebecca Seal-Soileau
Day 2—Wednesday, January 19, 2022		
11–11:15 a.m.	Welcome and review of meeting agenda	Rebecca Seal-Soileau
11:15 a.m.–12 p.m.	Black box 3 discussion (evaluate LOcalized Constructed Analogs-Variable Infiltration Capacity-mizuRoute data)	Rebecca Seal-Soileau
12–1 p.m.	Gold box discussion (U.S. Army Corps of Engineers Engineering and Construction Bulletin 2018–14 requirements)	Rebecca Seal-Soileau
1–1:45 p.m.	Green box discussion (for reliable outcome)	Rebecca Seal-Soileau
1:45–2 p.m.	Stretch break	
2–3:30 p.m.	Blue box discussion (for “sort of reliable outcome”)	Rebecca Seal-Soileau
3:30–4 p.m.	Next steps and meeting adjourn	Rebecca Seal-Soileau
Day 3—Wednesday, January 26, 2022		
12–12:15 p.m.	Welcome and review of meeting agenda	
12:15–1:30 p.m.	Complete blue box discussion (for “sort of reliable outcome”)	
1:30–1:45 p.m.	Stretch break	
1:45–3:45 p.m.	Start red box discussion	
3:45–4 p.m.	Preview of tomorrow	
Day 4—Thursday, January 27, 2022		
12–12:15 p.m.	Welcome and review of meeting agenda	
12:15–1:15 p.m.	Proposal framework	
1:15–2 p.m.	Revisit data reliability metrics and data dissemination steps	
2–2:15 p.m.	Stretch break	
2:15–3:45 p.m.	Work plan discussion	
3:45–4 p.m.	Next steps and meeting adjourn	

Figure 5.1. Agenda for meeting 3 (4-day meeting held on January 18, 19, 26, and 27, 2022). [U.S. Army Corps of Engineers Engineering and Construction Bulletin 2018–14 refers to “Guidelines for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects” (U.S. Army Corps of Engineers, 2018)]

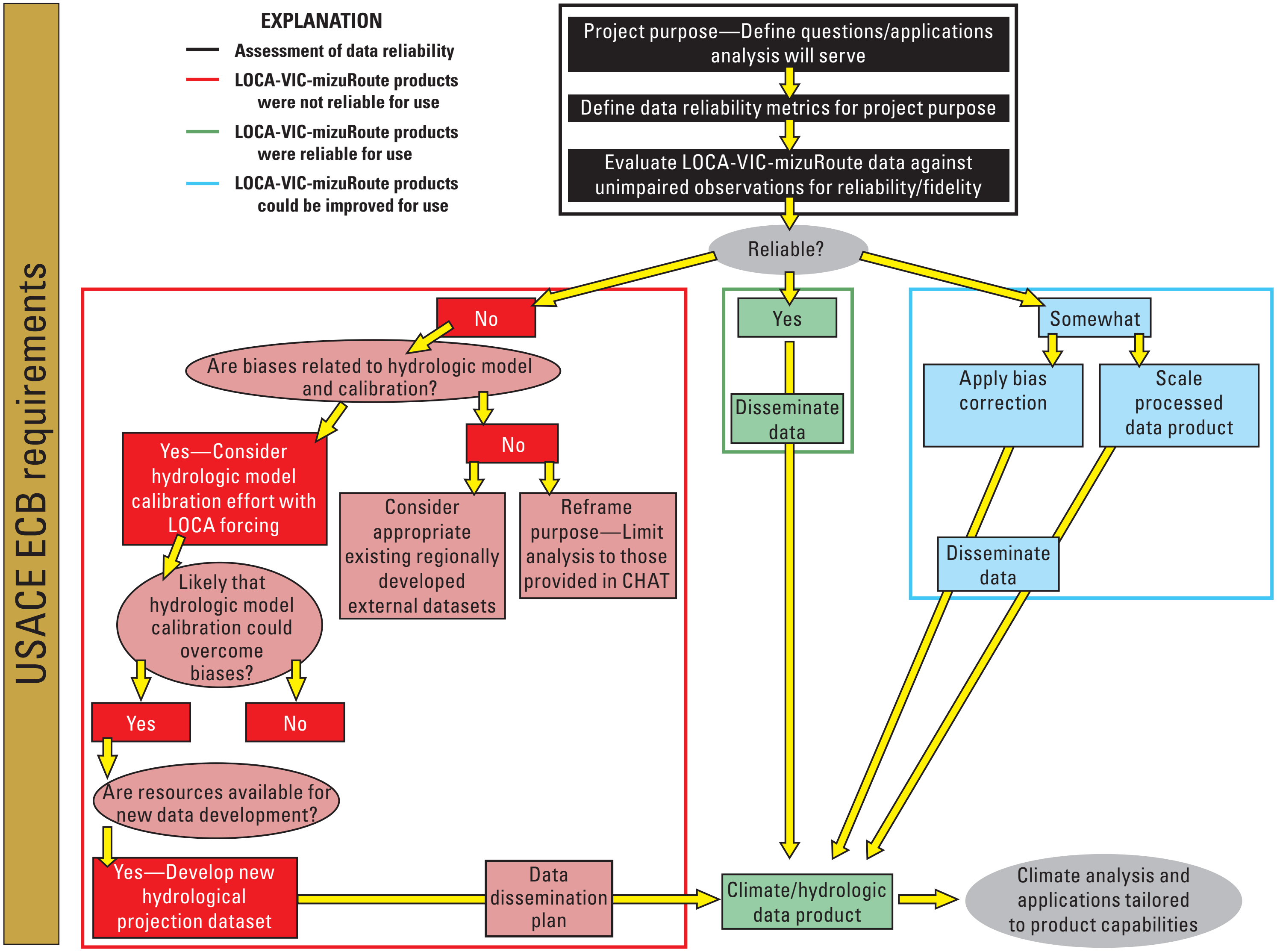

Figure 5.2. Initial draft of workflow for evaluating the LOcalized Constructed Analogs- (LOCA-) Variable Infiltration Capacity- (VIC-) mizuRoute dataset that was revised and discussed on day 1 of meeting 3. The final workflow is shown in figure 6 of the main report. [USACE, U.S. Army Corps of Engineers; ECB, engineering and construction bulletins; CHAT, Climate Hydrology Assessment Tool]

Reference Cited

U.S. Army Corps of Engineers, 2018, Guidance for incorporating climate change impacts to inland hydrology in civil works studies, designs, and projects (revision 2): U.S. Army Corps of Engineers Engineering and Construction Bulletin 2018–14, 15 p., accessed June 12, 2025, at https://www.wbdg.org/FFC/ARMYCOE/COEECB/ARCHIVES/ecb_2018_14_rev_2.pdf.

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