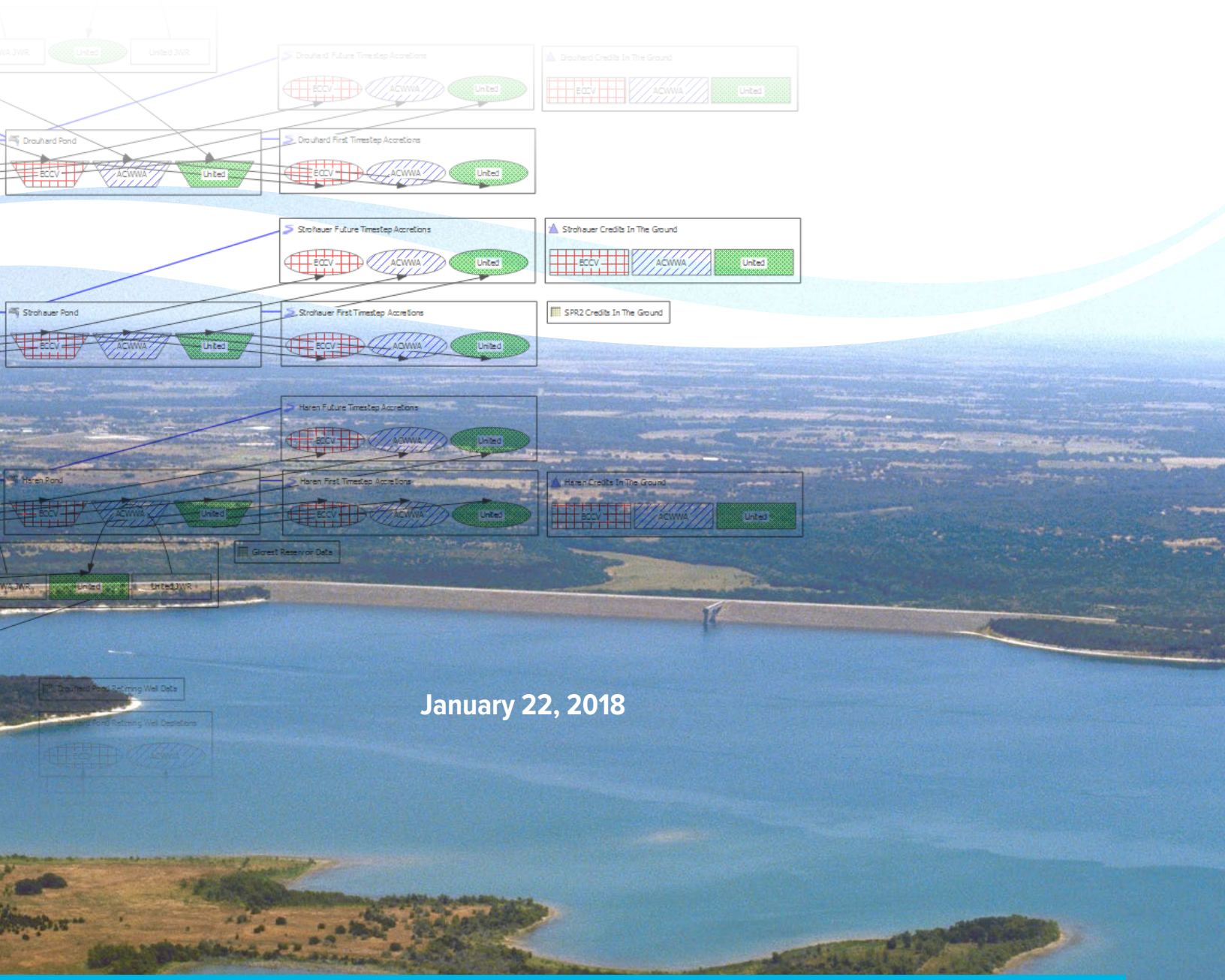
US Army Corps of Engineers®
Fort Worth District

Hydrologic Modeling Guidelines for Regulatory Permit Actions

FINAL TECHNICAL REPORT



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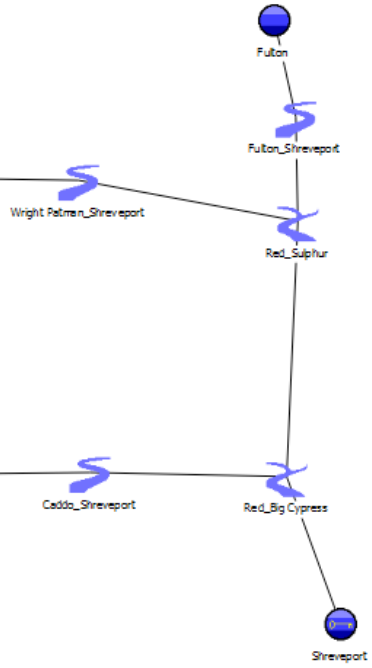

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FINAL TECHNICAL REPORT

January 22, 2018

prepared by DiNatale Water Consultants and Carollo Engineers
for the US Army Corps of Engineers — Fort Worth District

Front cover: Stillhouse Hollow Lake and Dam. Photo: USACE

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Lake Belton. Photo: USACE

Acronyms

404(b)(1)	Clean Water Act Section 404(b)(1)
A&M	Avoidance and Minimization
CFR	Code of Federal Regulations
CM	Compensatory Mitigation
CWA	The Clean Water Act
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESA	Endangered Species Act
H&H	Hydraulics and Hydrology
HMG	Hydrologic Modeling Guidelines
LEDPA	Least Environmentally Damaging Practicable Alternative
LPP	Lake Palo Pinto
LRH	Lake Ralph Hall
NEPA	National Environmental Policy Act
NISP	Northern Integrated Supply Project
NTMWD	North Texas Municipal Water District
NWP	Nationwide Permit
PPC	Palo Pinto Creek
PIR	Public Interest Review
RFFAs	Reasonably Foreseeable Future Actions
RPL	RiverWare Policy Language
TCEQ	Texas Commission on Environmental Quality
TPE	Turkey Peak Expansion
TRA	Trinity River Authority
TRWD	Tarrant Regional Water District
TPWD	Texas Parks & Wildlife Department
USACE	United States Army Corps of Engineers
USFWS	United States Fish & Wildlife Service
USGS	United States Geological Survey
WAM	Water Availability Model

Brazos River below Possum Kingdom County Lake, Palo Pinto County, TX.
https://commons.wikimedia.org/wiki/File:Brazos_River_below_Possum_Kingdom_Lake,_Palo_Pinto_County,_Texas.jpg

1.0 Introduction

This Technical Report presents technical information supporting development of a set of Hydrologic Modeling Guidelines (HMGs) for the U.S. Army Corps of Engineers Fort Worth District Regulatory Division (Corps). The HMGs are designed for discretionary application by Corps project managers and water supply permit Applicants to assist in identifying hydrologic analysis and modeling needs and requirements associated with water supply and management permit applications, with a focus on the RiverWare modeling platform for cases that require hydrologic modeling. The HMGs are intended to add predictability and transparency to the aspects of the permitting process related to hydrologic modeling but are not required to be used by Applicants or Corps regulators. These guidelines have been developed primarily for the Corps' Regulatory Program's (Regulatory) project managers who have limited experience associated with the topics covered.

The Corps Regulatory program evaluates hydrologic conditions to inform aquatic resource impacts analyses associated with water supply permit applications. Often, hydrologic analysis requires hydrologic modeling to adequately evaluate hydrologic conditions. Hydrologic analysis and modeling can also be used to develop and support the project need and define the project purpose, determine practicability of alternatives, and evaluate avoidance and minimization opportunities as well as compensatory mitigation strategies.

The Corps evaluates permits for various actions including water supply and management projects involving discharges of dredge and/or fill material into waters of the United States. The permit evaluation process must address the requirements of the National Environmental Policy Act (NEPA), Section 404 of the Clean Water Act, Public Interest Review (PIR) as well as other applicable statutes. To satisfy the requirements associated with these statutes, the Corps normally develops Environmental Assessments (EA) or Environmental Impact Statements (EIS) to disclose the effects, both detrimental and beneficial, caused by its permit decisions. Most permit actions typically involve a focus on the adverse impacts to aquatic resources that may be caused by the proposed project. However, project benefits to the aquatic environment can also be considered. The level of analysis required to evaluate potential impacts is determined on a case-by-case basis and can be influenced by the size and scope of the project, the natural and human resources potentially impacted, and public and agency input provided during public scoping opportunities as well as coordination efforts.

The HMGs and supporting technical information presented in this document can be used to assist in determining the level of evaluation necessary by the Corps to satisfy the requirements to comply with relevant law and regulations and to assist and guide Corps project managers and Applicants in developing or using hydrologic modeling associated with water supply permit applications.

1.1 Objectives

The HMGs were developed to meet the following objectives:

1) Develop a tool for Corps regulators and permit Applicants to identify and analyze data and modeling needs for water supply and management permit actions.
2) Increase transparency and predictability of the process associated with evaluating and rendering a permit decision requiring hydrologic analysis or modeling.
3) Focus on use and implementation of the RiverWare modeling platform for such hydrologic analysis and modeling.
4) Address some outstanding concerns raised in the Corps' 2016 report (CDM Smith 2016) related to the use of the Texas' existing Water Allocation Models (WAM) for hydrologic evaluation associated with a Corps permit.

1.2 Organization of Deliverables

To meet the objectives stated above, the HMGs project involves several deliverables:

1) Technical Report — The Technical Report is this document. It provides information about technical aspects of hydrologic analysis and modeling required for the Corps to evaluate project impacts as well as several case studies. The key aspects of the technical information are presented as a three-tiered set of HMGs, including supporting technical information and detail about the use and issues associated with each of the aspects presented as the HMGs.
2) Checklist — A concise and simplified version of the HMGs presented in a user-friendly format. The checklist is meant to assist Corps regulators and Applicants quickly identify key aspects and informational requirements for hydrologic modeling that may be associated with a permit action. The items on the checklist are derived directly from the more detailed discussion of the HMGs presented in the Technical Report.
3) Corps Workshops — Workshop No. 1 for Corps regulators that introduces the HMGs and uses case studies to apply the Guidelines (Ft. Worth, Texas, January 23, 2018). Workshop No. 2 for Corps regulators and Texas-based regulatory agency representatives, water providers, and stakeholders (Galveston, Texas, January 30, 2018).

The Technical Report provides the background, information, and details about the HMGs and describes the technical aspects that support the development of the HMGs. The Technical Report includes:

- The objectives and purpose of the HMGs (Section 1).
- Previous modeling efforts and the current modeling focus provided in the HMGs (Section 2).

- An overview of the applicable Corps Regulatory program requirements related to hydrological modeling (Section 3).
- An overview of hydrologic modeling in the Corps setting (Section 4).
- Sections 5, 6, and 7 provide the supporting information and detail associated with a three-tiered categorization of HMGs.
    - The Tier-1 HMGs (Section 5) include standard information needs and guidelines for all projects.
    - The Tier-2 HMGs rely on analysis of hydrologic modification and initial determination of aquatic resources potentially affected (Section 6).
    - Tier-3 HMGs address major projects and more detailed evaluations requiring hydrologic modeling (Section 7).
- Section 8 provides several case studies from Texas, Louisiana, and Colorado and show how the HMGs could be applied and could have assisted in increasing efficiency in the permit process in those instances.

The Technical Report includes a glossary of commonly used terms in hydrologic analysis and modeling. Throughout the report, terms denoted in bold font with an asterisk appear in the glossary. Several terms in the glossary are replicated from the 2017 Texas State Water Plan (TWDB 2016) or as updated for the 2022 Plan. Additional terms used in this report were added to this list, including a discussion for terms that may have differing meanings in different contexts.

The Technical Report includes three appendices that provide additional information relevant to the project. Appendix A is a document produced by the Center for Advanced Decision Support for Water and Environmental Systems (CADWES) that describes many features of the RiverWare modeling platform. Appendix A is intended to provide a broad overview of the available features and uses of RiverWare so that Corps project managers who have limited experience with RiverWare (or hydrologic modeling in general) can meaningfully engage in discussions with Applicants, Applicant modelers, and Corps Hydraulics and Hydrology (H&H) personnel.

Appendix B addresses issues related to the Texas WAM models raised in the Corps' 2016 report (CDM Smith 2016) in more detail. This appendix is especially useful within Texas where WAM modeling is required for obtaining a water right but is not always suitable for analyses required by the Corps. Appendix B includes several cautionary considerations when using WAM modeling in support of a Corps permit process.

Appendix C provides examples of permit conditions that were derived from hydrologic modeling analyses. These examples demonstrate the way that modeling or hydrologic analysis can be implemented to develop meaningful permit conditions.

The HMGs checklist is derived from the Technical Report. The HMGs checklist is intended for everyday use and reference by Regulatory project managers and Applicants. The checklist is intended to be a

simplified version of the more detailed information presented in this Technical Report that can be used by regulators and Applicants to quickly identify the Corps data needs and expected hydrologic analysis and modeling process. Information that supports the material in the checklist is included in the Technical Report.

The Corps regulator workshops provide a mechanism to distribute the HMGs to Corps regulators as well as other resource agencies, Texas water providers, and stakeholders who attend the Galveston workshop. The workshops are intended to foster discussion about the HMGs and assist in future application of the HMGs by regulators and Applicants to achieve the project objective of enhanced process predictability and transparency.

1.3 Intended Use of Deliverables

The deliverables from this project are intended to increase the level of predictability and transparency in the water supply and water management permitting process — in particular, the hydrologic analysis and any hydrologic modeling associated with these types of actions. The HMGs will be available to the public and serve as a basis to assist discussions to allow the Corps and Applicant to decide what level of hydrologic analysis and modeling is appropriate. The HMGs are not required to be used by Applicants or Corps regulators but will help all parties understand the hydrologic analysis and modeling needs associated with rendering a permit decision by the Corps.

The HMGs are configured into three tiers with increasing complexity and analysis discussed at each tier. Every project is unique and includes its own set of different conditions that must be evaluated on a case-by-case basis. Therefore, the tiered organization of the HMGs should not be construed as a restrictive organizational structure. Instead, the Corps regulator and Applicant should use the information in any of the HMGs that are appropriate for a specific project. The final HMGs in Tier-1 and Tier-2 include a decision point on whether additional detailed analysis should be undertaken and the next-tier HMGs should be applied, or whether sufficient hydrologic information has been gathered for the Corps permit decision using the information collected through the lower-tier analysis. In some cases, it would be appropriate to use some of the higher-tier HMGs to complete the evaluation, but this may not require all aspects to be considered at the more detailed level. For example, consider a project that requires detailed evaluation of a single aspect of the project, but other aspects are more straightforward and sufficient information has already been gathered through the application of lower-tiered HMGs. In that case, the Corps and Applicant can target specific higher-tiered HMGs that will appropriately address the area where more detail is needed, while not unnecessarily applying the more detailed HMGs to other aspects of the project that were sufficiently addressed through the lower-tiered HMGs.

The HMGs are intended to be scalable so that the Corps regulator and Applicant begin with the Tier-1 general guidelines and proceed to more detailed and in-depth hydrologic modeling if warranted by the project size, operations, and impacts. The HMGs help the Corps determine the information and level of detail to request from the Applicant. The HMGs can also be used by the Applicant to know what to expect in terms of Corps information requests and the purpose of such requests.

When familiar with the Technical Report and its content, the HMGs checklist should be used by both the Corps project manager and the Applicant as the initial reference and general guide to ensure that proper information topics are being addressed and to inform the anticipated level of hydrologic analysis and/or modeling. As more information is learned about the project or the Applicant seeks more detailed guidance on the hydrological modeling requirements, both the Corps and Applicant should refer to the Technical Report.

The HMGs are not a substitute for RiverWare documentation when use of that platform, or other modeling platform, is used. The HMGs describe how RiverWare can be implemented for hydrologic analysis and modeling associated with water supply and water management permit actions. Hydrological modelers, including those experienced with RiverWare or who understand the RiverWare framework, can use the information contained in the HMGs to assist in development of a hydrological model using the RiverWare platform, if warranted. A brief guide to the key RiverWare features is presented as **Appendix A**. This appendix is included to familiarize Regulatory project managers with basic information and aspects of the RiverWare platform.

2.0 Previous Efforts and Current Focus

2.1 Corps Review of WAM

In January 2016, the Corps released a report that evaluated the ability of Texas' WAM (CDM Smith 2016) to adequately address the Corps' hydrologic modeling needs in rendering permit decisions. The report found in general that the publicly available versions of the WAM may be adequate for the administration of water rights, but that the models and results may not be appropriate for the Corps' permitting process without modifications.

The report also cited several aspects that needed further investigation related to configuration of the state-developed WAM models, including assumptions made about current and future conditions, **return flows***, reservoir operations, timestep issues, and other issues. **Appendix B** provides a detailed discussion of these issues. In general, the Corps position remains that while WAM modeling is suitable for its intended use within the Texas water rights system, the modeling results may not be suitable for use in more detailed Corps hydrologic analysis without some level of modification, such as consideration for actual water rights operation, demand levels, reservoir operations, exchanges, in-stream flows etc. This report offers the ability to address such needs in other platform contexts with a focus on RiverWare. It should be recognized that modified WAM modeling may be able to provide various information needed to support Corps permit decisions, but such modifications are beyond the scope of this report. Corps regulators and Applicants are cautioned that pursuing modified WAM modeling may trigger the need for various efforts that do not achieve the intended efficiencies of the HMGs. Twelve specific WAM cautionary considerations are included in **Appendix B** concerning such actions.

It should be recognized that modified WAM modeling may be able to provide information needed to support Corps permit decisions, but such modifications are beyond the scope of this report.

In a more general sense, many state and local agencies throughout the United States have developed regional hydrologic models typically used for planning purposes. Many of the principles that apply to using the Texas WAM models for Corps permit evaluations are also applicable to other regional models. Corps regulators and permit Applicants using models other than WAM can benefit from understanding what types of data and information are useful to and needed for the Corps process as well as what additional or different types of data are required for the Corps' aquatic impacts analysis compared to data and modeling results that may be available from existing hydrologic planning models.

2.2 RiverWare

The HMGs provide a tiered approach to hydrologic analysis and modeling that allows for scaling of the Corps evaluation based on project size, complexity, geographic scope, and potential aquatic impacts. As the magnitude of these factors increases, the Corps will require more detailed information related to the hydrologic analysis in addition to the hydrologic modeling normally required for more complex projects.

The more detailed HMGs presented in this document focus on the use of the RiverWare modeling platform to address many modeling needs. The Corps 2016 report (CDM Smith 2016) identified advantages to the RiverWare platform relative to Regulatory permitting needs, which included:

- Incorporates prior appropriation doctrine and built-in water resources objects, including exchanges and in-stream flows.
- Provides extensive user interface, including tools for scenario and data management, debugging, output options, batch runs, and optimization.
- Offers highly customizable operating rules, including the ability to track water by owner, source, or other attribute throughout the system.
- Provides robust technical support from program developers.
- Is most-suited for projects where complex operations are critical to effects analysis.
- Offers simultaneous tracking of yields, operations, and output pertinent to effects analysis.
- Delivers moderate availability of models of major river basins in Texas.

While these advantages make RiverWare an appropriate choice for many applications, they are not intended to preclude use of other modeling platforms for Corps permit review. As previously noted for the potential to use modified WAM modeling, other platforms may also not yield efficiencies in the permit evaluation process.

This document does not provide step-by-step instructions for using RiverWare because each project is unique and will require consideration of the facts of each specific project. Qualified RiverWare modelers should be used to implement modeling with RiverWare if it is determined that a RiverWare model should be developed or modified for the permit review process. **Appendix A** provides a brief overview of the key features of RiverWare so that regulators and Applicants can discuss the applicability of various features of RiverWare with each other in the context of determining what level of analysis is appropriate, as well as to effectively communicate project needs to the modeler.

2.3 Other Modeling Platforms

As discussed in the Corps 2016 report (CDM Smith 2016), differing permit scenarios allow for adaptability in the utilization of differing hydrologic modeling. The Corps evaluated other modeling platforms in the 2016 report for suitability to the Corps permitting process, including MODSIM and STELLA and included a comparison of the strengths and weaknesses of the various platforms (**Table 1** *replica of Table 5-1 of CDM Smith 2016*). In addition, permit applications that are less complex may not require modeling or could use more simplistic spreadsheet analysis or modeling to provide the Corps with the level of detail appropriate for a given project.

The HMGs presented in this document are intended to provide general principles that can be applied to any modeling platform, although some guidelines are more specific to implementation using RiverWare. RiverWare-specific information typically can be generalized and applied to other modeling platforms, as many hydrologic modeling concepts discussed are features incorporated into other modeling platforms.

As discussed in Section 2.2, some existing hydrologic modeling developed by various state or local agencies may be suitable for some analyses, but may need modification or may not be suitable for the Corps permit process. It is important that the regulator and Applicant understand the original objectives of the model or model platform to assess whether it is an appropriate tool for the Corps permit process. The HMGs provided in this document will assist in this process, provided there is a level of familiarity with the modeling platform being assessed.

Similarly, existing RiverWare models of river basins may not be appropriate for Corps permit decisions. RiverWare has the flexibility to be constructed for many different purposes and varying degrees of complexity. The original model developers may not have included detail or aspects of hydrology that are critical to a Corps permit analysis. When evaluating an existing RiverWare model, regulators should not automatically assume that the model is suitable; rather application of the HMGs will help make this determination.

Table 1. Summary of modeling platforms *(replica of Table 5-1 of CDM Smith (2016))*

Software	Advantages	Disadvantages	Costs
WAM/WRAP (off-the-shelf)	• Incorporates prior appropriation doctrine and built-in water resources constructs, including in-stream flows • Existing models for all major river basins within Texas • Periodic model updates provided by TCEQ • Very efficient network-based solving algorithm, minimal computation time. • Ability to evaluate individual reservoir and water user accounts • Best for projects where unappropriated water calculations are critical	• Underlying assumptions geared toward water rights administration that conflict with objectives of regulatory modeling needs. • Moderately difficult to modify input datasets for the unaccustomed user. • Scenario management and input data structure can require significant efficiency and quality control efforts. • Minimal availability of training and support • Limited network interface	• Free
MODSIM	• Incorporates prior appropriation doctrine and built-in water resources objects, including exchanges and in-stream flows • "Least cost" network-based solving algorithm is efficient and can be used for water rights allocation or operating priority • Moderately easy to modify • User interface to display network structure and access input data • Best for projects where water rights yield calculations are critical	• Modeling customized operations alongside water rights allocation requires separate model networks or integration with external, custom software code • Scenario management and input data structure can require significant efficiency and quality control efforts • Minimal availability of training and support • No readily available models of major river basins in Texas	• Free

Table 1, cont.

Software	Advantages	Disadvantages	Costs
RiverWare	• Incorporates prior appropriation doctrine and built-in water resources objects, including exchanges and in-stream flows • Extensive user interface, including tools for scenario and data management, debugging, output options, batch runs, and optimization • Highly customizable operating rules, including the ability to track water by owner, source, or other attribute throughout the system • Robust support • Best for projects where complex operations are critical • Simultaneous tracking of yields, operations and output pertinence to effects analysis • Moderate availability of models of major river basins in Texas	• High degree of complexity - can take significant time and money to learn, develop or modify a model, and can be computationally intensive; not necessary or appropriate for all projects • High cost for software license, training, and support	• First license: $6,530 • Support: $115 per hour • Training courses: $1,200 ea.
STELLA	Intuitive interfaces for setting scenario options and operating rules, and for visualizing and organizing system structure • Can simultaneously model integrated systems e.g. costs, physical systems, social systems, with potential application to environmental resource analysis • Can use customized programming; model complexity can scale to meet project needs • Easy to modify • Robust support • Best for projects where STELLA's flexibility can be leveraged to scale modeling to the minimum complexity necessary, representing only fundamental elements, allowing for robust models with reduced complexity and data requirements.	• Not a "water-centric" model in nature; water rights rules and water resources objects must be custom-built • Level of potential customization requires detailed quality control and review. • Limited availability of models of major river basins in Texas	• First license: $2,500 • Online training courses: $150–200 ea. • Support: first year included with license, $500/ year thereafter

Table 1, cont.

Software	Advantages	Disadvantages	Costs
User-developed Spreadsheet Models	• Completely customizable via Visual Basic; can do simulation and explicit optimization • Familiar spreadsheet interface and formatted output/reporting • Best for relatively simple systems or when a widely-used interface is needed for broad user groups (e.g. stakeholder engagement)	• Not a "water-centric" model in nature • Changes are difficult with Visual Basic for Applications and Solver • Programming can be lengthy • No functional system graphics • Efficiency and quality control challenges for large datasets or multiple scenarios • No readily available models of major river basins in Texas	• Tiered prices of various Office 365 packages including Excel range from $12.00/user/month to $35.00/user/month • May need add-ons such as @Risk ($1,000+)

3.0 U.S. Army Corps of Engineers Regulatory Program and Overview

This section identifies some of the more pertinent aspects of the Corps' implementing and governing regulations that are most applicable to the topics and issues the HMGs relate to. This section also briefly describes the Corps' primary permit categories to comport with how the HMGs are structured to allow scalability with their application.

The Corps renders permit decisions primarily under the provisions of Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act (CWA). Typically, water supply and management project permit actions involve only Section 404 of the CWA. The primary regulations that the Corps needs to address relative to these types of permit decisions are the CWA Section 404(b)(1) Guidelines (**404(b)(1) guidelines***); the Public Interest Review (PIR); and NEPA. Another statutory requirement where hydrologic analysis can have substantial relevance and must be addressed (when applicable) is the Endangered Species Act (ESA). Each of these regulatory requirements oblige the Corps to evaluate and/or disclose a proposed action's impact to aquatic resources as well as other relevant factors.

It is stressed that nothing in the HMGs replaces the requirements of the referenced statutes and implementing regulations. Since the HMGs are applicable to a variety of permit evaluation scenarios associated with the Corps' Regulatory Program and there are differing requirements associated with each of these statutes, developing guidelines that accurately capture all requirements as well as reflect all potential scenarios that may occur is not possible. As previously stated, the HMGs are not mandatory nor comprehensive to address all applicable regulatory requirements. Rather, they should be considered and applied to achieve more efficient permit reviews as well as provide insight into the varying issues and circumstances that can occur with hydrologic modeling as it relates to aquatic resources analysis in the Corps' regulatory permit evaluation context.

3.1 404(b)(1) Guidelines (40 CFR 230)

These are the substantive regulations associated with Corps' permit evaluation process and are focused on discharges of dredge and/or fill material into waters of the United States and their associated effects. Specific sections of the 404(b)(1) guidelines identify prescriptive considerations as well as require formal determinations by the Corps, depending on the permit type, including the potential short-term and long-term effects of a proposed discharge of dredge or fill material on the physical, chemical, and biological components of the aquatic environment.

Permit actions reviewed in light of these regulations are required to successfully address four specific components to receive permit approval. These can be found at 40 CFR 230.10(a-d). The proposed action must be the least environmentally damaging practicable alternative (**LEDPA***); the action must not fail other statutory requirements including compliance with Section 401 of the CWA, the ESA, and Section 307 of the CWA; not result in significant degradation (after consideration of all **mitigation*** measures), and include appropriate avoidance, minimization, and **compensatory mitigation***. The Corps cannot issue a permit if a negative finding under any of these requirements occurs.

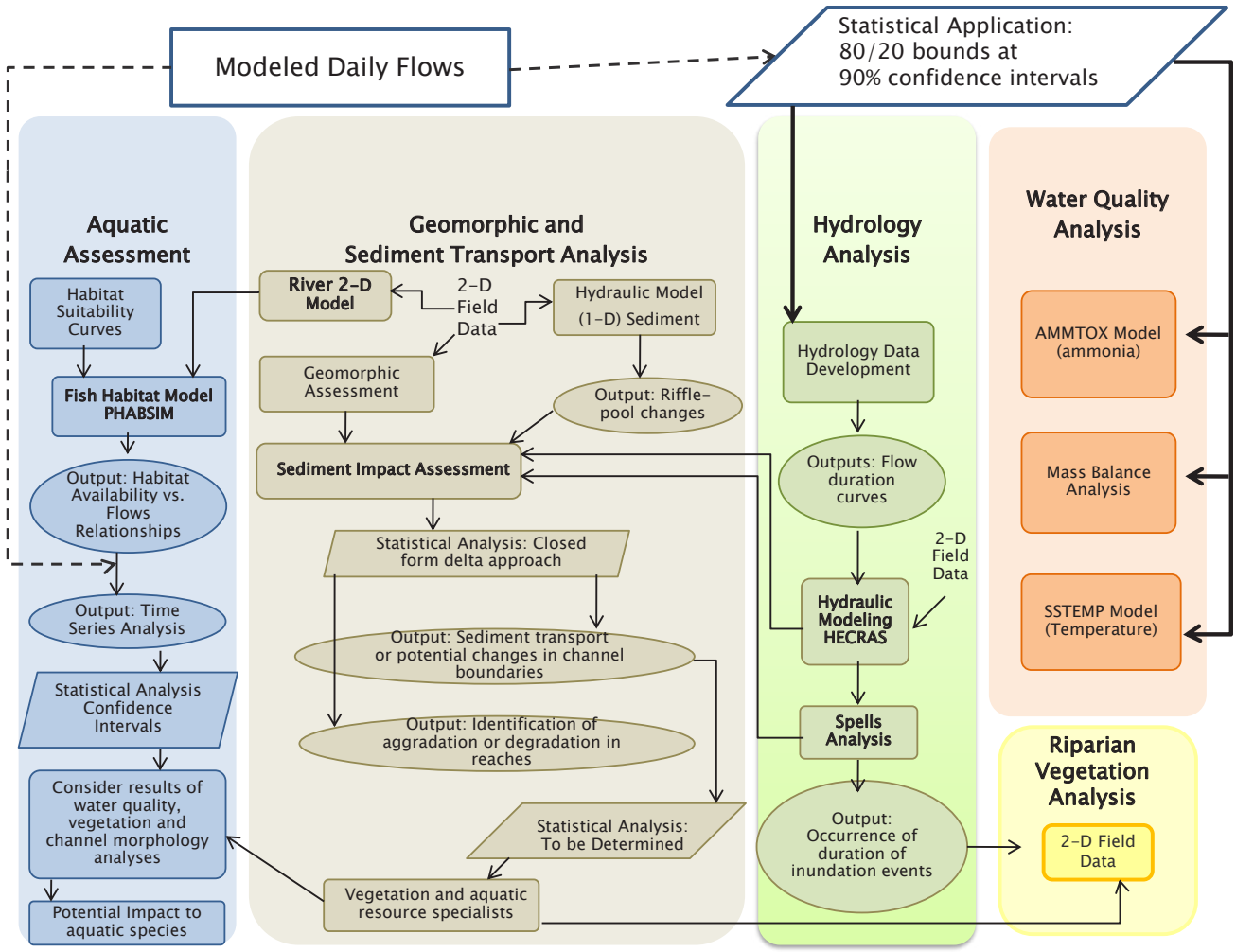
The 404(b)(1) guidelines specify certain evaluations, as applicable to each project, be undertaken in subparts C through F as well as at 40 CFR 230.11(a-h) and 230.23, .24, .25 and .77. While evaluation of both direct and indirect (secondary) effects are required, the primary applicability of the HMGs and related hydrologic analysis is to capture and be able to appropriately evaluate the causal secondary effects from a proposed water supply project and/or its alternatives. The 404(b)(1) guidelines define secondary effects as those effects on the aquatic ecosystem that are associated with a discharge of dredged or fill materials, but do not result from the actual placement of the dredged or fill material. The Corps is required to evaluate data and information about secondary effects on aquatic ecosystems prior to the time it takes final action on a permit decision. The 404(b)(1) guidelines also identify several examples of secondary effects on the aquatic ecosystem which include:

- Fluctuating water levels in an impoundment
- Areas downstream of an impoundment
- Other effects

Additionally, activities to be conducted on land created by the discharge of material in waters of the United States as well as reasonably foreseeable activities that may have secondary impacts within those waters should also be considered in evaluating the impact of creating those lands or features.

To assess many of the impacts on aquatic resources, the Corps relies on the hydrologic analysis and hydrologic modeling to inform and drive many of the effects assessments and analyses. To be able to accomplish this the development of current hydrologic conditions without and then with the project is needed as well as the ability to predict future hydrologic conditions, when necessary. The majority of the Corps' permit actions are made in light of current conditions. However, it is not uncommon for larger more complex actions to require the development of future hydrologic and resource conditions to adequately frame and disclose anticipated effects. The current and predicted hydrology can be used to inform analysis specific to each relevant aquatic resource category and allows for comparison of the predicted modifications to a pre-project **baseline condition***. Typical categories of the aquatic ecosystem to be evaluated include surface water, groundwater, water quality, geomorphology, fisheries, aquatics (including macro- and micro-invertebrates), and riparian areas. **Figure 1** reflects an example of the categories and kinds of analysis that can be informed by the hydrologic modeling.

Figure 1. Hydrologic modeling can support many resource factor evaluations.



In addition to the effects analysis, the 404(b)(1) guidelines (Subpart H) and associated implementing guidance further require that impacts be avoided and minimized and those impacts that cannot be are to be compensated. **Avoidance and minimization*** actions that may be relevant to or influenced by the HMGs include operations of the project involving diversions, **storage*** and/or **releases***. This is particularly true as it relates to dams as the 404(b)(1) guidelines at 40 CFR 230.77(b) state "in the case of dams, designing water releases to accommodate the needs of fish and wildlife" as specific components of how to avoid, minimize and compensate for the effects of the project. Subpart J, 40 CFR 230.93(b), 230.97(b) and 230.98(u)(4) of the 404(b)(1) guidelines (as well as the Corps' compensatory mitigation regulations at 33 CFR 332) further this aspect of compensatory mitigation and require that specific water sources (including water rights) be secured to meet the objectives and functions of the mitigation plan. Corps project managers and Applicants should be conscientious of being able to identify and track avoidance and minimization operational actions captured or reflected in the hydrologic analyses

and modeling compared to compensatory mitigation components and its operational actions to ensure compliance with the sequencing requirement of the 404(b)(1) guidelines.

3.2 Public Interest Review and General Regulatory Program Requirements (33 CFR 320-332)

The Corps' PIR is the main framework for the overall evaluation of projects and requires the careful weighing of all applicable PIR factors relevant to each particular permit application. The Corps' permit evaluations that trigger project-specific NEPA analysis (described below) normally result in similar resource category considerations and analysis. They encompass considerations of resources and factors that are broader in nature than those of the 404(b)(1) guidelines. However, it is noted that compliance with the requirements of the 404(b)(1) guidelines (when applicable to a project) is a prerequisite to the PIR determination. It is required that a permit be denied if the discharge that would be authorized by such permit would not comply with the 404(b)(1) guidelines. Further, the PIR cannot be used to overturn a negative finding under the 404(b)(1) guidelines.

The decision whether to issue a permit associated with the PIR is based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest. Evaluation of the probable impact that the proposed activity may have on the public interest requires a careful weighing of all those factors that are relevant in each case. The benefits which reasonably may be expected to accrue from the proposal must be balanced against its reasonably foreseeable detriments. The specific weight of each factor is determined by its importance and relevance to the proposal. Accordingly, how important a factor is and how much consideration it deserves varies with each proposal. A specific factor may be given great weight on one proposal, while it may not be present or as important on another. However, full consideration and appropriate weight will be given to all comments, including those of Federal, state, and local agencies and other experts on matters within their expertise. Thus, one specific factor (e.g., fish and wildlife values or economics) cannot by itself force a specific decision, but rather the decision represents the net effect of balancing all public interest factors, many of which are frequently in conflict. The decision whether to authorize a proposal, and if so, the conditions under which it will be allowed to occur, are therefore determined by the outcome of this general balancing process.

All factors which may be relevant to the proposal must be considered including the cumulative effects of the factors such as conservation; economics; aesthetics; general environmental concerns; wetlands; historic properties; fish and wildlife values; flood hazards; floodplain values; land use; navigation; shore erosion and accretion; recreation; water supply and conservation; water quality; energy needs; safety, food, and fiber production; mineral needs; considerations of property ownership; and, in general, the needs and welfare of the people. The PIR at 33 CFR 320.4(a)(2) also requires that the following general criteria be considered in the evaluation of every application:

(i) The relative extent of the public and private need for the proposed structure or work:

(ii) Where there are unresolved conflicts as to resource use, the practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed structure or work; and

(iii) The extent and permanence of the beneficial and/or detrimental effects which the proposed structure or work is likely to have on the public and private uses to which the area is suited.

Application of the HMGs to hydrologic analysis and modeling can inform and provide confidence in determining benefits and detriments associated with multiple resource categories and PIR factors including (but not necessarily limited to):

- Wetlands — Extensive wetland areas can exist in areas to be affected by water supply projects, especially those to be inundated by various projects as well as those that are located adjacent to streams and rivers that can be hydrologically modified due to altered streamflows. Hydrologic analysis and modeling developed in relation to the HMGs that address 404(b)(1) guidelines analyses will be usable to inform the PIR analysis.

- Fish and wildlife habitat — Fish habitat located at the project site, downstream as well as within other water bodies can be affected by water supply projects as well as other wildlife habitat in riparian and buffer areas. The Corps is required to consult with Federal and state fish and wildlife agencies with a view to the conservation of wildlife resources by prevention of their direct and indirect loss and damage due to the activity proposed in a permit application. The Corps gives full consideration to the views of those agencies on fish and wildlife matters in deciding on the issuance, denial, or conditioning of individual or general permits. Hydrologic analysis and modeling informs and can drive fish and wildlife habitat assessments and affects analyses for all of these, and PIR evaluations can rely upon such analyses.

- Water quality — As with fish and wildlife habitat, water quality considerations, and other relevant PIR categories and assessments related to water quality considerations are heavily influenced by hydrologic analysis. Water quality conditions and consequences can occur within the proposed reservoir to be constructed as well as receiving water features. Existing water quality can be affected in downstream watercourses and/or other reservoirs and lakes, and other areas affected by potential changes in operations, both detrimentally as well as beneficially by water supply projects. Evaluation and potentially necessary quantification of such benefits or detriments are the primary responsibility of the state water quality certification process but also can involve substantial involvement with the Environmental Protection Agency (EPA). Assessments to address these agencies' needs can rely upon hydrologic evaluations informed by the HMGs.

- Floodplain management and values — Wetlands, fish and wildlife habitat, and water quality evaluations all relate quite closely to floodplain considerations for the PIR. Therefore, applicability of the HMGs to hydrologic analysis and/or modeling and associated results can and will inform determinations of potential effects relative to this PIR factor.

- Water supply and water conservation — The PIR recognizes that water is an essential resource, basic to human survival, economic growth, and the natural environment. Project evaluations will still need to ensure that defined project needs are met when the HMGs are applied to appropriate projects.

- Mitigation — Mitigation that can be required to satisfy the PIR can mirror what is included in the 404(b)(1) guidelines as described above. Operational aspects of a project to avoid, minimize,

and/or compensate for effects can be included in a mitigation plan under the PIR as well as become permit conditions. In determining the adequacy of such actions, the Corps evaluates the ability to monitor and enforce such actions when developing permit conditions.

The decision whether to issue a permit is based on an evaluation of the probable impacts, including cumulative impacts, of the proposed activity and its intended use on the public interest. As part of the PIR, the Corps also evaluates the use and operation of certain facilities (33 CFR 325.6) that are authorized as needed to consider effects to the aquatic ecosystem, relevant public interest factors and the natural and human environment.

3.3 National Environmental Policy Act (NEPA) (40 CFR 1500-1508 and 33 CFR 325 Appendix B)

NEPA is a procedural statute that does not direct any specific outcome but requires that the Corps undertake certain processes and considerations as it renders decisions associated with its permitting program. The statute established numerous goals relative to the environment and defines it as including physical, chemical, biological, cultural, and socioeconomic components.

Similar to the 404(b)(1) guidelines and the PIR, NEPA requires consideration of direct, indirect, and cumulative effects associated with Federal actions, including Corps permit decisions. Federal agencies are required to consider such effects and disclose their significance. Indirect effects are specifically called out at 40 CFR 1502.16 and 40 CFR 1508.8 (b). NEPA defines them as those effects which are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. Effects and impacts as used in these regulations are synonymous. Effects may be ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative. Effects may also result from actions that may have both beneficial and detrimental effects, even if, on balance, the agency believes that the effect will be beneficial.

Hydrologic analysis and modeling, whether informed or directed by the application of the HMGs, provides data and information that allows the Corps to ensure that it appropriately addresses the requirements of NEPA. Overlapping of resource categories and factors between NEPA and the 404(b)(1) guidelines and PIR can also bring consistent scrutiny, as appropriate.

NEPA also contains provisions related to mitigation. Although it includes multiple terms to describe it (avoiding, minimizing, rectifying, reducing, and compensating), general commonality exists with the requirements of the 404(b)(1) guidelines and the PIR.

3.4 Endangered Species Act (50 CFR 402)

Many water supply Regulatory permit actions involve activities that affect threatened and/or endangered species and their critical habitats. Similar to the previous 404(b)(1) guidelines, PIR, and NEPA discussions, indirect effects from a proposed permit action in which the Corps undertakes consultation with the U.S. Fish and Wildlife Service (USFWS) can be a major component or focus of the ESA analysis. Modifications to hydrology caused by a permitted water supply project can result in the impact to listed species and critical habitats (i.e., Rio Grande, Brazos, Pecos and Arkansas River basins) and to the point of jeopardy (i.e., the Platte or Yampa/Green River basins).

Analysis of such potential effects can be captured in the hydrologic analysis and modeling informed by the HMGs related to resource categories that the Corps is required to assess for its 404(b)(1) guidelines, PIR, and NEPA analyses. However, Corps project managers and Applicants need to be cognizant that such hydrologic analyses that may be prepared for satisfying the 404(b)(1) guidelines, PIR, and NEPA may not be adequate for addressing the requirements of ESA. Existing species recovery plans may have established hydrology and required evaluation methods that must be adhered to. Additionally, the ESA implementing regulations have specific requirements relative to the establishment of the baseline for ESA consultation as described at 50 CFR 402.02.

3.5 Permit types (General and Individual Permits)

The structure of the Corps' permitting process and format is designed to generally reflect the severity of potential impacts to waters of the U.S. and other considerations that are required when making decisions. Permitting forms range from those that require no notification of the Corps for very simple and minimal impacting actions to evaluations that entail multi-year analyses and trigger the development of an EIS. To cover this wide range of possible project types, the Corps has developed differing permit categories.

Two general categories of permit types are established within the Corps' permitting process: General Permits and Individual Permits. Within each of these categories exist sub-types. The HMGs were developed in recognition of this permitting scheme. While they are not explicitly constrained to a permit type, they have been developed in scaled fashion with potential decision points suggested. Tier-1 HMGs are applicable to all permit actions but the degree of information that may be needed to appropriately address them is influenced by both the permit type and the specifics of the particular Applicant and proposed project. Tier-2 HMGs are also applicable to all permit types but less likely needed for smaller and lower-impacting actions that occur in the general permit category. Tier-3 HMGs are most applicable to the individual permit category and even more so for those permit actions that involve a robust EA or EIS. Application of specific HMGs from Tier-3 within a medium-level project (Tier-2 action) can occur as well as use of some Tier-2 HMGs within a simpler project (Tier-1 action).

The following sections generally describe various aspects of the two permit categories as they relate to the applicability of some HMGs.

3.5.1 General Permits (Nationwide, Regional and Programmatic Permits)

Most of the Corps' permit workload involves general permits. Because these permits are established and based on similar categories of activities with specific effects limitations, they can require minimal information to allow quick reviews and determinations. Some water supply and management actions qualify for various Nationwide Permits (NWPs) and Regional General Permits. Many of these permits do not require any notification to the Corps that a regulated activity is proposed while others trigger the need for notification to the Corps with the submission of various information to allow some evaluation to occur. This permit category typically does not require the provision of specific information concerning project need and purpose, alternatives, or coordination with agencies. However, the Corps is required to make a determination that the effects (direct, indirect, and cumulative) that result to aquatic resources and other factors are minimal to qualify for their use. Application of the 404(b)(1) guidelines and NEPA do not occur during project review, but targeted consideration of the PIR is involved. In making its minimal effects determination, the Corps may coordinate with resource agencies to inform them of the potential effects associated with certain types of activities, certain aquatic resources involved, and/or methods to be applied to assess impacts.

Avoidance, minimization, and compensatory mitigation can be required with these types of permits. They may also contain special conditions relative to project operations as well as monitoring.

As stated above, these types of permits will involve Tier-1 HMGs but may trigger the need for application of some Tier-2 HMGs, particularly agency coordination. In limited circumstances, all Tier-2 HMGs may need to be applied.

3.5.2 Individual Permits (Letters of Permission and Standard Individual Permits)

As the name implies, these types of permits are specific to a particular proposal rather than a group of activities that have similar characteristics and specified impact limitations. Also unlike general permits, these actions do not have to result in minimal direct, indirect, and cumulative effects.

These permits typically require the issuance of a public notice, designated comment period, potential for conducting public hearings, and inter-agency coordination that at times can be substantial. The 404(b)(1) guidelines, PIR, and NEPA requirements as described above apply to the evaluation of these types of permits, with limited exceptions. Adjustment in the intensity of their application occurs in relation to the severity of the impact proposed by a particular project. Other considerations such as controversy, historic losses, and other factors can also affect the degree of analysis required.

These types of permits will involve Tier-1 and Tier-2 HMGs with application of Tier-3 on a project-specific basis. As described elsewhere with the HMGs, utilization of some Tier-3 guidelines for actions in a Tier-2 evaluation can occur to ensure that appropriate information and analysis occurs with a project.

4.0 Hydrologic Analysis and Modeling Overview in Corps Regulatory Setting

Hydrologic analysis and modeling is a tool used by the Corps Regulatory program to assess and define as well as predict hydrologic properties of a stream or lake system under a proposed water supply or water management project. It informs the Corps whether to require additional analysis and effort to evaluate a proposed action and its impacts to aquatic resources.

The Corps strives to render permit decisions involving the simplest form of permit review. As described in Section 3, use of general permits of the Nationwide or Regional variety occur most frequently and typically involve less-detailed data, information, and analysis to allow for defensible determinations and permit verifications. The expected impact or relative magnitude of a project is not a formulaic determination, but rather made on a case-by-case basis. For example, a project that would divert 10,000 **acre-feet*** (AF) from a stream may be a significant impact to a drainage with an annual flow of 20,000 AF. However, this same diversion from a basin that has an annual flow of 2,000,000 AF would have less relative impact on the larger basin. Regulated projects that do not qualify for authorization under general permits must obtain authorization under an individual permit involving a Letter of Permission or Standard Permit. Such permit actions require the development of project-specific EAs or EISs. The Corps attempts to consistently "scale" its process, whether a general or individual permit is involved, which is reflected in the amount of information, data, and analysis required in light of the extreme variability in project types and their effects, Applicant distinctions, and permit categories. Such scaling is reflected in the HMGs in the tiered approach to applying the guidelines to each project.

It is recognized that as a general premise, the Corps considers reduction in-stream flow as an adverse effect to aquatic resource functions. The Corps also acknowledges that some hydrologic modifications can benefit aquatic resource functions. The need for the amount, accuracy, and sophistication of data, information, and analysis to assess causal detrimental and beneficial effects to aquatic resources increases as the scope or magnitude of a project increases as well as the potential impacts, both directly at the project site and indirectly to upstream, downstream, and other tangentially related water users, species, habitat, and aquatic resource functions. At the outset of a permit review, the Corps will initially use available hydrology data and any Applicant-prepared modeling to estimate the potential for modification of flows to waters of the United States to gauge the initial potential for effects of a project. This practice allows for the potential to avoid undertaking any additional specific hydrologic modeling designed to inform or evaluate impacts to aquatic resources from hydrologic modification. The Corps balances whether to forgo or require additional intermediate data or possibly quantitative stream and resource assessments — which can be a time consuming and expensive effort — associated with smaller permit actions.

Any available hydrologic data and modeling — even if provided in a format such as WAM modeling or other modeling or analysis — can afford substantial insights and information on the front end of the permit evaluation process due to Applicant efforts which can be used to gauge the potential for effects

to aquatic resources. The Corps is willing to make permit decisions in light of such data as warranted. However, a common theme that arises in permit evaluations is the variability in the degree and format of the data and information to allow for determinations on whether more is required or if the Corps can make conclusions relative to impacts solely in light of hydrologic changes. Such variability occurs in other aspects of the permit evaluation process which is a primary reason the Fort Worth District developed templates for standard information requirements associated with jurisdictional determinations, NWPs, IPs, and Compensatory Mitigation Plans. Such examples can be found at:
http://www.swf.usace.army.mil/Missions/Regulatory/Permitting/Application-Submittal-Forms/

Reducing the need to request additional information and undertake multiple reviews associated with a project increases time and cost efficiencies in the review process, which can result in lower costs to the Applicant. One of the primary objectives of developing the HMGs is to assist the Corps and permit Applicants in understanding what type of information is useful for the Corps' purposes, making the process more transparent and predictable while yielding increased efficiency.

Due to the need to scale the level and sophistication of analysis based on project specifics and how that affects the hydrologic modeling needs, the HMGs are subdivided into three tiers developed for this scaling process. The level of detail and sophistication of hydrologic analysis or modeling increases through each level of the HMGs. Through its permit evaluation process, the Corps has determined that there are standard categories and groups of information associated with most water supply and water management projects regardless of how small or major the project and permit type. The initial level of the HMGs is the Tier-1 Standard Information Needs and Guidelines for all projects. These guidelines should be addressed for all water supply and management project applications and provide basic information about the Applicant and project as well as identification of existing hydrologic data **(Section 5)**. The Tier-2 HMGs are based on hydrologic modification analysis and an initial determination of potentially affected aquatic resources. This portion of the HMGs is designed to collect and/or evaluate information related to the degree of hydrologic modification that may be caused by the project and potential impact on aquatic resources. The Tier-2 HMGs focus on quantifying potential changes to hydrology caused by the project using the presumption that streamflow reduction is an adverse impact **(Section 6)**. The Tier-3 HMGs pertain to major projects and detailed review of more complex projects that require detailed evaluation of changes to hydrology and the associated detrimental and beneficial effects to a variety of aquatic resources. This detailed level of analysis requires hydrologic modeling; the guidelines describe several key factors to consider when either developing new modeling for the effects analysis, or considerations with modification or use of existing modeling, with a specific focus on implementation using RiverWare **(Section 7)**. As noted previously, the different tiers are not restrictive, and certain aspects of higher-tiered HMGs may be applicable to a project that otherwise is sufficiently evaluated using primarily lower-tiered evaluations. Corps regulators and Applicants should utilize the HMGs that best fit the specific project as it is evaluated on a case-by-case basis.

Throughout the HMGs, inset boxes provide examples of the particular HMG based on a number of case studies. These inset boxes provide examples of the HMG's relevance to a specific situation. The examples are meant to support the principle or concept of the particular guideline. The case studies are only meant to be used for example purposes and do not necessarily represent the action that should be taken for a particular proposed permit review. Each proposed permit is different, and the level of effort and area of focus varies from permit to permit. It is important for the Corps regulator and the Applicant to discuss and potentially agree on the scope of assessment for the project being reviewed with such agreement being informed by the application of the HMGs. Ultimately, the determination of the scope remains with the Corps. Additional detail on the application of the HMGs to the case studies is presented in **Section 8**.

5.0 Tier-1 HMGs: Standard Information Needs and HMGs for all Projects

The following standard information needs HMGs form the first tier of the HMGs and should be applied to all water supply and management projects. These HMGs provide the Corps with much of the basic information about the project and Applicant and help identify areas that may be impacted by the project. Much of the information requested in the first tier of the Guidelines will be information that the Applicant is either already familiar with or has provided either through the permit application itself or through the Applicant's review and completion of the relevant checklist in the "General Recommendations for Department of Army Permit Submittals June 11, 2001" or other applicable permit template options available on the Fort Worth District website.

These Tier-1 standard information needs HMGs assist the Corps in determining what information is available and what level of additional information may be available or should be required as part of the permit evaluation process. These HMGs also inform an Applicant as to what type and level of detail of information the Corps initially requires in making its permit decisions.

It is important to recognize that scalability can occur in the level of information associated with each of these initial standard information HMGs. Smaller and less complex projects may need less information in order for the Corps to render a permit decision, whereas larger projects will need more thorough descriptions and/or analysis. The information gathered through the Tier-1 HMGs assist the Corps in deciding the level of hydrologic analysis or modeling required to render a permit decision for the project.

Projects that involve only Tier-1 HMGs typically do not involve coordination with other agencies. While larger projects may have other agencies involved from the outset, a determination by the Corps that the project does not need additional evaluation (see HMG 1.F), may not always be acceptable to other agencies that may be involved in the project.

5.1 GUIDELINE 1.A: Describe the organizational structure of the Applicant

This HMG is meant to gather information on the type of Applicant. This information provides insights into the level and sophistication of hydrologic data, analysis, and potentially, modeling that the Applicant has already performed and can provide in support of its permit application. In addition, the type of Applicant also provides awareness of the potential magnitude of hydrologic impacts due to the proposed project. For example, a river authority or other regional water management entity is more likely to be seeking approval for a project with large and significant impacts than a wholesale water customer that has limited independent raw water supply infrastructure. Organizational structure types may include:

This information provides insights into the level and sophistication of hydrologic data, analysis, and potentially, modeling that the Applicant has already performed and can provide in support of its permit application.

- River authority
- Municipal water provider with its own raw water system
- Municipal wholesale customer that receives raw water from another provider and has its own treatment facilities
- Municipal provider that receives wholesale treated water from another provider
- Industrial user with its own raw water supplies
- Industrial user that receives wholesale raw water
- Industrial user that receives treated water from another provider
- Agricultural user
- Private developers or entities
- Other Applicants, such as a non-governmental organization seeking a project for environmental or recreational purposes

This HMG informs the Corps on the likelihood of available existing hydrologic analysis or hydrologic modeling and the likelihood that the Applicant has knowledge of or has used the existing modeling. Certain Applicants may be familiar with hydrologic modeling, but may not have used it, while others may have used hydrologic modeling extensively; yet others may have no knowledge that hydrologic modeling exists.

This information can also assist in defining the project purpose as well as identification and evaluation of potential alternatives, if applicable. Applicant information provided in this guideline can further allow for adjustment in the amount and complexity of the hydrologic information that may be needed for the permit evaluation. This is based on the Corps' familiarity and recognition that large scale or more experienced water provider Applicants are likely to have accomplished some level of analysis prior to approaching the Corps concerning the project need, alternatives, and other requirements associated with obtaining a permit.

5.2 GUIDELINE 1.B: Describe the existing system and operations

A description of the Applicant's existing system that the water supply or management project will supplement should be provided. Knowledge of the **existing water supply*** system and operations will help inform how and where water is being used as well as how it will be used, for what purpose(s), and when and where the usage relates to existing aquatic resource conditions. If the project will not supplement an existing system, the Applicant should describe the new system to which the project relates.

This information informs the Corps on existing aquatic resource conditions.

The Applicant's description should include specific details about the existing and proposed system and operations and the associated features or **infrastructure***. Infrastructure may include, but are not limited to: existing dams, intakes, ponds, treatment plants, lakes, and release structures. Water sources and operations information should include specific water rights or permits, leases, trades, swaps, exchanges, or other sources that are used in the system, including any water accounting associated with these facilities. Maps or schematics of the existing and proposed system are useful at this stage.

The Applicant should also include the integration of the proposed system with other existing system components. The Applicant may be adding a relatively small component to an existing system, but that component may change operations of existing infrastructure and operations that could cause effects to aquatic resources at a location outside the project area. For example, a proposed project may entail a new intake that will change operations at an existing upstream or out-of-basin intake. The changes to operations and possible effects to aquatic resources should be evaluated at all locations.

In addition, any known water quality and/or low-flow issues should be included in the system description. It is important that the Applicant provide as much detail as possible about the existing system, operations, and aquatic resource issues. A known environmentally sensitive area of the existing system operation may be worsened by the proposed project. Without a description of the entire system both upstream and downstream of the proposed project and operations, identification of potential resource impacts may be missed which can add time to the review process when identified later. This description can also help identify if and where there may be indirect impacts at locations outside of the project area basin that would also be affected by the addition and operation of the new feature.

5.3 GUIDELINE 1.C: Describe the proposed project and anticipated operations

Through this HMG, the Applicant should describe the proposed project and how the project will operate. This information informs the Corps about where and when the proposed project operations may impact aquatic resources. This HMG should dovetail into HMG 1.B by adding any additional information about the proposed project and operations not included in 1.B. Initial general operational descriptions can help the Corps make preliminary evaluations and determinations relative to the appropriate level of analysis on a project-by-project basis. For instance, a project that has a narrow operational window (e.g., operates during high-flow conditions only) has less impact on aquatic resources during low-flow periods and may likely need a less-detailed description and associated analysis compared to a project that operates throughout the year with great variability and has potential for large impacts.

This information informs the Corps about where and when the proposed project operations may impact aquatic resources.

The Applicant should describe the anticipated operations of the project, including descriptions of variability in the amounts of water to be used or diverted. For example, the Applicant should describe any differences in seasonal or monthly use and should also describe the expected level of variability in day-to-day use and whether they anticipate significant variability within a single day. The Applicant should also describe any anticipated variability based on hydrologic conditions. For example, if water will be diverted only during low-flow periods or under other specified circumstances, this should be included in the description. Projects with little variability in operations are relatively simpler to evaluate than projects with variable operations that may impact aquatic resources differently given similar hydrologic conditions. This description will assist the Corps in identifying potential **critical periods*** when a project will have the maximum impact, such as periods of highest diversion or periods of operation when flows are lowest in the project area.

This description should also include how the anticipated project operations will interface with existing system operations, as applicable. If not already described adequately in 1.B, any interaction between the proposed project operations and the existing system should be identified. These interactions can include, but are not limited to, a release from an existing part of the system being diverted at the proposed project, or an existing part of the system curtailing or modifying operations when the proposed project is operating.

5.4 GUIDELINE 1.D: Identify existing relevant hydrologic data and hydrologic models

Hydrologic data, analyses, and modeling can inform the Corps how the proposed project will alter flows in the stream.

The Applicant should identify any relevant existing hydrologic data and hydrologic models that they have used or are aware of within the project area. Often an Applicant will have done some level of hydrologic analysis for their project prior to approaching the Corps for a permit. This information is a reasonable starting point to assess the potential magnitude of impacts resulting from project operations and may include more detailed information than the project descriptions from HMGs 1.B and 1.C. Often the Applicant's prior analysis likely focused on water **availability*** or project yield, and the Corps may determine that the modeling is not suitable for the aquatic resources effects analysis (see HMG 2.D and 3.C). However, even if the model as used by the Applicant cannot be directly used by the Corps, data and information used in the Applicant's models may be used to determine periods of low flow or times when project operations would have the potential for higher impact on aquatic resources. Typically, hydrologic models use stream gage flow, known discharges, and other relevant hydrologic information as model inputs that can be used in the Corps' evaluation.

In some cases, an Applicant has not completed any analysis related to the proposed project. Under this circumstance, the Applicant should identify and collect all stream flow gage data within the project area. This data is typically from U.S. Geological Survey (USGS) gages, but other entities may maintain stream gages as well. If available, stream flow data should be collected at a daily timescale. The Applicant should include other relevant information such as water use or diversion data; measured discharge data, such as from wastewater treatment plants in the region; and any other information that will aid in the evaluation of a project such as accounting plans associated with Texas Commission on Environmental Quality (TCEQ) water rights requirements.

When evaluating stream gage data, the Corps should be aware of a gage's location relative to the project location. Gaged streamflow may require modification to account for intervening inflows (such as tributaries of stream gains) or outflows (such as diversions or stream losses). There are reasonable methods to address such considerations. Outflows and inflows can typically be simply added or subtracted from the upstream gage data. Gains and losses calculated between gage stations should be pro-rated along the reach unless other hydrologic features would indicate areas of higher gain or loss. Ungaged tributary inflows can be estimated from a variety of methods appropriate to the specific situation, such as contributing basin area and elevation, neighboring-gage correlation, land use or soil analysis, precipitation-runoff modeling, or other methods. Additionally, changes in flows that have occurred over the period of record, such as new large diversions or the introduction of water from other river basins, can warrant a narrowing of the appropriate period of record of data to consider. Such limitations in the relevance, adjustments, or accuracy of gage data should be documented, as applicable.

Applicants may have information or modeling used in proceedings with state or local agencies to obtain water use permits or water rights. In Texas, water rights are issued by the TCEQ. Relevant data that should be documented through this guideline include the water rights permits and any associated terms

and limitations on the existing water rights; accounting plans, results of any WAM modeling and project yield assumptions used in issuing the water right; and any Environmental Flow (**E-Flow***) or other environmental analysis associated with the proposed project. Terms and limitations of the water right may provide insight into potential impacts resulting from project operations. E-Flow analysis may help identify critical periods, depending on where the project is located in relation to the E-flow study area, and river flow conditions that are needed to sustain fresh water ecosystems and when additional diversions from the river would impact critical species. Such information can assist the Corps in making determinations relative to the need for additional analysis or that the information provided is adequate to support a conclusion that there would be little or no effect.

If not already described with the water rights or water use permit information, the Applicant should identify how the project **yield*** was determined and any additional analysis that it has performed to-date. Generally, **firm yield*** is determined by the amount of water available during the most severe **drought*** period or periods. Insight into how the project yield was calculated can shed light on drought conditions, critical periods, and critical flow locations. If an Applicant has analyzed a specific time period, set of operations, or possible future conditions, this analysis may provide details on the potential range of effects resulting from project actions.

It is important to recognize that any models that are relied upon under Tier-1 actions need to reflect the appropriate geographic scope of the Applicant's system. If the Applicant's system spans several watershed basins or river systems, then the Applicant should provide information or models for each basin and system (see also HMG 1.E). The Corps may determine that some aspects of the Applicant's system or existing modeling can be truncated or not used for the purposes of analyzing the project effects on aquatic resources if the proposed project will not modify system operations in other areas. Any such exclusion of certain aspects of the Applicant's system or the proposed project area should be identified and described to the extent not already discussed under Guidelines 1.B and 1.C.

5.5 GUIDELINE 1.E: Determine the geographic scope of assessment

The geographic scope of the system plays an important part in the permitting process as it defines an area where potential impacts will be evaluated. The information obtained through HMGs 1.A, 1.B, 1.C, and 1.D will have provided insight into the geographic extent. The Corps and the Applicant should identify the streams, river, lakes, and reservoirs that could potentially be modified, directly and indirectly, by the project location and operations. Water bodies both upstream and downstream of the proposed project should be identified, as downstream operations may indirectly affect upstream lakes and reservoirs. Maps of the project area are useful at this stage to identify areas that the project may potentially impact.

Information gathered under this HMG should inform the Corps about all areas where the proposed project can affect the aquatic environment.

The analysis of geographic scope includes identification and use of water rights associated with the project and potential impacts that the project's use of those water rights may cause to streams and lakes. Water

rights or water use permits may be located distant from a proposed project site, especially if the project includes diversions in a different watershed than the place of use, or water exchanges or swaps that may affect several miles of stream length and are distant from the location of dredge or fill that necessitated the Corps permit. In such instances, the affected streams should be included in the geographic scope of the analysis.

The Applicant should initially determine the downstream extent of the project and its potential impacts. The geographic scope may be difficult to determine in some cases because all downstream rivers and lakes are potentially impacted to some extent, although the impacts may lessen further downstream if there are additional inflows to the river basin. The downstream extent will need to be decided on a case-by-case basis, but factors for determining the extent may include the magnitude of downstream inflows and senior water right diversions, interstate river compact commissions, and any environmental considerations, such as an existing E-Flows analysis.

Under this HMG, the Corps and Applicant should document the methods and rationale for the limits used to assess a reasonable geographic extent for the particular project scale. For example, geographic limits based on specific low-flow thresholds should be evaluated in light of the most severe drought. Reservoirs several hundred miles downstream may be impacted by a project's operations, even if volumetrically small in comparison, due to drought or flood conditions. Climate conditions in a basin may vary greatly and may dictate a need to extend the geographic scope of the assessment. Timing of operations can also influence the geographic extent of assessment, as during different times of the year, the nearest downstream water user or critical segment of stream habitat could vary from near the project site to many miles away. If any aquatic resources of concern have been identified at this stage, the geographic extent of analysis can be driven by the range of flows that impact these resources relative to the location of such resources from the project area. Potential impacts from the proposed project should be relatively small at the geographic termini.

If the geographic scope of assessment cannot be determined using basic evaluation methods, or if there is uncertainty about critical periods, modeling may help to determine the geographic scope. Although modeling may not always be available or suitable for a detailed effects analysis (see guideline 1.D), information from existing models may be used to estimate the relative size of impacts of the proposed project at various locations away from the project site.

5.6 GUIDELINE 1.F: Minor-level project analysis and determination

The prior Tier-1 HMGs (1.A through 1.E) are intended to lead to a decision point at which the Corps will be able to determine whether sufficient hydrological information has been provided in order to render a permit decision or whether additional analysis or modeling will be required to adequately evaluate the project impacts to aquatic resources. Typically, a determination that sufficient information has been provided at this level of analysis should be able to be rendered for minor-level projects with relatively straightforward operations.

A determination by the Corps that additional analysis is not required (or is required) should be supported by the information gathered in the Tier-1 Guidelines:

- Relevant information about the Applicant's organizational structure (Guideline 1.A).
- Clear understanding of existing system that will be modified by the proposed project, or description of new system the project is part of (Guideline 1.B).
- Thorough description of the proposed project and operations, including potential changes to operations at other facilities due to the proposed project operations (Guideline 1.C).
- Use of relevant stream gage data, straightforward adjustments and estimates of hydrology, or available hydrologic modeling data (e.g., WAM model runs) to analyze changes in hydrology, such as stream flow or lake levels, due to the project operations, and to identify critical periods of analysis, typically during low flow (Guideline 1.D).
- Geographic extent of project impacts identified through estimates of hydrologic change at the proposed evaluation boundaries and consideration of indirect operations of the proposed project and critical flow periods (Guideline 1.E).

It is important that the Corps project manager strive to determine if he or she can draw a conclusion about relative changes in flow from the general project information and available data. Generally, the greatest project impacts and effects occur during critical periods in the historical analysis. At this Tier-1 level of determination, typically the evaluations will focus on critical periods to quantify a conservative "worst-case" scenario, but may not have evaluated effects within the full range of flows expected at the project area. Discussions between the Applicant and Corps can further inform whether other periods or locations are relevant for analysis, based on available stream hydrology. If the critical period or periods have been identified, it may be possible for the Corps to evaluate and draw conclusions relative to the impact of the project.

In some instances, additional information that would be provided through the Tier-2 or Tier-3 HMGs would be beneficial at this decision point, but the project does not need or warrant full application of all the Tier-2 or Tier-3 HMGs. The tiered system is not intended to restrict use of more detailed HMGs for certain aspects of otherwise simpler projects when such information is available and appropriate. If certain aspects of the Tier-2 or Tier-3 HMGs would increase the Corps' ability to render a permit decision, then those higher-tiered HMGs should be applied even if other aspects of the project do not require the same level of analysis.

Based on the above information, the Corps project manager should be able to determine if additional

Case Study

Case Study 8.1.1 involved an intake located at the tail end of a large reservoir. Based on information provided by the Applicant related to the intake location and elevation relative to the reservoir stage through drought conditions, the relative magnitude of the proposed withdrawals compared to reservoir inflows and outflows, and input from other agencies, the Corps made a determination of minimal detrimental impacts to aquatic resources and the public interest without additional hydrologic analysis or site-specific in-channel resource assessments. This type of information would be provided by applying the Tier-1 HMGs.

hydrological analyses are required. Occasionally, coordination with resource agencies may be warranted and will be influenced by the resources potentially involved and more importantly by the permit type (e.g., Standard Permits compared to certain Nationwide Permits). Note, at this level of assessment, coordination with other agencies is expected to be extremely limited and on a case-by-case basis for permit actions that do not require a public notice or agency coordination, but if additional hydrologic data and analysis are required to make a determination, coordination with resources agencies may occur.

The outcome of this final Tier-1 HMG (1.F) should be a determination by the Corps on whether sufficient documentation and analysis has been performed to adequately characterize the project impacts without additional detailed hydrologic analysis or modeling. If the Corps determines that documentation and analysis is sufficient, the permitting process should continue without additional hydrologic analysis or modeling. If the Corps determines it is not sufficient, the Corps and the Applicant would proceed to Tier-2 HMGs (Section 6).

6.0 Tier-2 HMGs: Medium-Level Project and Effects Analysis

If the result of the Tier-1 Standard Information Needs and HMGs (Section 5.0, HMG 1.F) indicates that additional hydrologic analysis or modeling is required, the Tier-2 Medium-level Project and Effects Analysis HMGs should be followed. As with the previous section, application of these HMGs can be scaled from small to large projects and can involve General and Individual Permits. To appropriately assess effects to aquatic resources, the Corps will evaluate an increasingly sophisticated level of data and analysis commensurate with the scope of the project. The Tier-2 HMGs are intended to evaluate hydrologic data and information at a more detailed level than the Tier-1 HMGs, focusing on **hydrologic modification*** to inform determinations of potential effects to aquatic resource functions. This includes more rigorous investigation and analysis of data and available modeling that occur under the Tier-1 evaluation. In addition, the Corps will make an initial determination of aquatic **resource factors*** that are most pertinent for assessment (e.g., fisheries, water quality, water-based recreation, geomorphology, and sediment transport, etc.).

The purpose of a hydrologic modification analysis is to compare existing hydrologic conditions at the project site to conditions expected when the proposed project is operational. The current hydrologic conditions are often referred to as baseline conditions. Project operations are then superimposed on the baseline, and differences from the baseline are attributed to the project. Hydrologic modification analysis can be performed as relatively straightforward spreadsheet analysis, or it can use existing modeling or other Applicant-produced materials, as appropriate.

Throughout the Tier-2 HMGs, Applicant-provided information should be evaluated, and, where necessary and practicable, translated into a structure that conforms to the Corps' regulatory requirements for developing a hydrologic modification analysis. This translation will require professional judgment to ascertain the relative degree of differences that exist between Applicant efforts and regulatory needs within each of the Tier-2 HMGs. In some cases, differences may be minor and require straightforward reformatting of data or evaluating assumptions made in the Applicant-provided materials or modeling. Other cases could require significant efforts to modify Applicant-provided data or analysis into a suitable structure for the Corps' evaluation. Complex translation of data or analysis originally intended for a different purpose could ultimately introduce more uncertainty and potential error to the Corps' effects analysis than initiating the analysis with the Corps' purposes in mind. The Tier-3 HMGs are intended to assist in new analysis or modification of existing information for projects with complex requirements or large expected impacts. As described above, if certain aspects of a project require more detailed analysis, individual Tier-3 HMGs should be applied even if other aspects of the project are adequately addressed through the Tier-2 HMGs.

As described in Section 4, as a general premise, the Corps considers reduction in streamflow as an adverse effect to aquatic resource functions, which holds true for the hydrologic modification analysis as well.

Additionally, potential benefits that may occur due to increases in streamflow associated with operations of the project can require additional analysis to determine their sufficiency. The Corps will use available hydrologic data, and to the extent possible, will use Applicant-prepared modeling or analysis to evaluate the level of hydrologic modification that will occur due to the proposed project and regulated activity. The degree of hydrologic modification guides the Corps in deciding if additional or more detailed information is warranted, or whether the information gained solely from the hydrologic modification analysis is sufficient to render a permit decision.

In conjunction with the analysis of hydrologic modification, the Corps' initial determination of likely effects to aquatic resource factors should be evaluated in light of the degree and extent of the hydrologic modification caused by the proposed project's operation. As with the scalability of the application of the HMGs, judgment is required in determining which aquatic resource factors are of greatest importance on a project-specific basis. Such considerations and determinations of aquatic resource factors normally require coordination with resource agencies to identify and inform the selection of factors. Once the Corps determines that a project requires analysis described in the Tier-2 HMGs, it should start coordination with resource agencies that can provide additional insight into which aquatic resources factors are of importance in the project area (see Guideline 2.F).

6.1 GUIDELINE 2.A: Gather the best available hydrologic data for the project area

Through this HMG, the Applicant should identify and gather the best available hydrologic data for the project area. The purpose of gathering this information is to determine if there is sufficient available information to evaluate the degree of hydrologic modification that will be caused by the project. Some of this information may have been collected in HMG 1.D above, but additional and more detailed information should be sought. In this HMG description, types of hydrologic data to be sought are described ***in order of priority*** for water supply projects. Each project requires case-by-case consideration, so all types of data included in this HMG description may not be necessary. The Corps, in conjunction with the Applicant and with resource agencies (see also HMG 2.F and 3.B), should determine which data best serves the needs of the Corps analysis based on knowledge of the project and information garnered through the Tier-1 HMGs. The following items should be considered when collecting additional data, but should not be considered an exhaustive list, as those familiar with the project area may have additional information.

Hydrologic data, reports, and modeling may provide sufficient information to evaluate the degree of hydrologic modification caused by the proposed project.

Streamflow, reservoir, other existing data, reports, and mapping should be circulated by the Applicant and verified by the Corps so that this information becomes foundational for the project. Having agreed-upon data and other undisputed facts readily available reduces the risk for confusion and error as the permit evaluation proceeds.

Stream Gage Data: If not already collected in HMG 1.D, the Applicant should identify and collect all stream flow gage data within the project area. This data is typically from USGS gages, but other entities may maintain stream gages as well, such as the state or regional water providers within a watershed. The Corps may have data available from other sections of the District Office which may be relevant to the evaluation and should be obtained and provided to the Applicant. Stream gages with a limited period of record may not have been collected previously but can be useful for neighboring-gage correlations if needed to identify flows affected by the project. In addition to streamflow gages, known measurements of discharges in the region, such as wastewater effluent, should be collected if applicable to the project area, or have affected streamflow patterns over time. If available, stream flow and discharge data should be collected at a daily timescale. When available, any stream stage measurements and rating table data should also be collected.

Reservoir Data: The Applicant should identify and collect all reservoir level, inflow, and release data within the project area. The Corps may have data available from other sections of the District Office which may be relevant to the evaluation and should be obtained and provided to the Applicant. If available, collect data at a daily timescale. This information can provide insight as to when and at what rates reservoirs are storing inflows, making releases from storage, and passing flows through, which helps inform the proposed project's impacts and effects in relation to current reservoir operations. In addition, any hydrologic modeling that uses **naturalized flows*** should be developed with (or checked against) historical reservoir operations. Relevant reservoir data may also be available from accounting plans associated with various water rights or reservoirs as mandated by the TCEQ or other state agency. This information should be provided by the Applicant or requested from the TCEQ.

Case Study

Case study 8.1.4 involved multiple requests and responses for data and information during the permit process. After reviewing initial data supplied in the permit application, the Corps determined additional information was needed for its evaluation because daily average flows over a multiple decade period was provided but it did not evaluate lowest historical flows. Through the course of five separate memoranda, the Corps attempted to request and the Applicant provided the data the Corps required.

HMG 2.A would have made it clearer what the type of information the Corps needed at the outset and what to request. It may have resulted in more information than needed, but once all available information was provided, the Corps and Applicant would have been able to more efficiently determine what information is relevant and required for the permit review.

Other Existing Reports or Studies: The Applicant should identify and collect relevant available reports on water use, water demand, hydrology, water quality, development plans, or other relevant topics related to water use or planning in the project area. The Corps may have data available from other sections of the District Office which may be relevant to the evaluation and should be obtained and provided to the Applicant. Relying on existing work or analysis performed in the study area by others (or by the Applicant) can reduce time and expense of the permitting process. In addition, this information can help the Corps make its initial determination of potentially affected aquatic resources factors and coordination with resource agencies to the extent such factors are identified in existing reports and studies. Information may also include plans for future development in the region which can guide the Corps with regards to anticipated changes in hydrology or other factors (such as water quality) based on anticipated future development.

Mapping: Collect available mapping of the watershed where the project is located, including tributary areas and downstream of the project area. Federal Emergency Management Agency (FEMA) floodway and floodplain mapping can also provide useful information. Mapping should also include any relevant schematics or diagrams of the Applicant system (existing and proposed), as discussed in HMGs 1.B and 1.C.

Modeling: To the extent not already collected as part of the HMG 1.D, existing modeling for the project area should be gathered and evaluated for the permitting process. Often, an Applicant will have performed some modeling or hydrologic analysis for their project prior to approaching the Corps. However, other state or regional agencies may have performed hydrologic modeling of the project area (for example, the WAM models in Texas), or other modeling used to support a water rights or water use permit application. The Corps may also have developed models for the basin in question.

Any modeling data gathered under this HMG should be evaluated in light of the remaining Tier-2 HMGs to establish the suitability of the modeling for the Corps' permitting process. Some modeling may be able to be translated into useful information for the Corps permitting process. However, many hydrologic models that are developed by an Applicant will not be sufficient without some level of modification or analysis because Applicant-developed models tend to focus on project yield or the Applicant's operations without consideration of others' operations within the same basin.

Any hydrologic modeling used or prepared by the Applicant should be provided to the Corps, including yield models, **operational models***, or other types of modeling. In some instances, other agencies have developed models that Applicants may have used directly or used with modifications. In Texas, Applicants obtain a water right by using the official Texas WAM models. In its 2016 report (CDM Smith 2016), the Corps determined that while the WAM modeling is sufficient for water rights issuance, WAM models would typically need some level of modification or additional hydrologic analysis in order to be used in the Corps' permitting process (see Section 2.1 and **Appendix B**). In addition to the WAM modeling used for water rights, water providers in Texas often develop other models used for operational, forecasting, or predictive purposes. These additional models can often provide insights into actual stream conditions that are not always accurately reflected in the WAM planning models. The Corps and Applicant should be cognizant that hydrologic modeling does not always reflect streamflow within the channel for a variety of reasons, including assumptions about past, current, and future operations. (See **Appendix B** for additional information and cautionary considerations). Any knowledge of the Applicant's or others' operations that deviate from modeled demands, return flows, reservoir operations, etc., should also be disclosed through this HMG. In Texas, many water rights holders are required to submit accounting forms or other reporting to the TCEQ. These documents can be used to support the accuracy of hydrologic modeling Corps' permitting process.

6.2 GUIDELINE 2.B: Determine critical hydrologic period for analysis

The selection of the critical period should correlate with times when the proposed project may most heavily impact aquatic resources.

Hydrologic data gathered under HMG 2.A may span multiple decades and encompass time periods with potentially different hydrologic characteristics depending on the regional growth and development of water resources. It is not always practical or necessary to consider the potential effects of a project throughout the entire period of record. A reasonable study period should be selected by choosing a time that includes a range of flow conditions that were experienced in the project area. Often, a period of record is developed around a **critical period*** in history — typically a prolonged drought. Water supply systems are typically designed to perform through drought conditions expected for the area. Additionally, the critical period can have substantial effects in the definition of project purpose statements and determining the practicability of alternatives.

Any trends or changes through the study period may be indicators of regional water resources development. In the analysis of hydrologic modification, the project should use the most recent hydrologic conditions that still include a reasonable range of hydrologic conditions. Generally, the critical period of analysis for hydrologic analysis is defined as times when the operation of a proposed project will have the maximum reduction in flows that affect aquatic resource factors. Absent other specific information relative to local resource factors, including analyses of their flow needs, the critical period should typically be assumed to correspond with dry periods when flows are lowest. The critical period should represent a maximum reduction in flow expected from the operation of the proposed project.

However, it is important to recognize that some aquatic resource factors may have other flow conditions that are critical periods for that resource and may dictate that other periods be included in the critical hydrologic period for analysis. Often the Applicant will have defined a critical period for a water supply project based on historical drought conditions. This selection of a critical period is valid for determining the critical period for the yield of a project and may also be sufficient for an aquatic resource effects evaluation. However, the Corps may need to evaluate other times within the study period that include low flows of shorter duration or other periods of hydrologic modification by the project that may be critical to aquatic habitat or other functions, even if not critical to a project's yield.

For example, a shorter-duration dry period may be inconsequential to the long-term yield of a larger reservoir but could have a significant impact on aquatic life in the project area. If an Applicant provides hydrologic analysis or modeling with a defined critical period, the Corps should review how this critical period was defined and whether other periods should also be evaluated for critical conditions for aquatic resources. For instance, native and/or threatened or endangered fish species may require one set of flow conditions to spawn and a different flow regime once eggs are fertilized. Fish may spawn during different times of the year, so the fish that are present in the project area will dictate when certain flow conditions are necessary. Low-flow periods or droughts may be less critical to the fish habitat than a minimum flow during the spawning season. Similarly, riparian habitats may also require distinct flow conditions to ensure that health and stability is not defined by a period of drought. It is common to include both periods

that are critical to the project yield and other periods that are critical to various aquatic resources within the overall study period for the project; it is not necessary to select one period over another when both (or multiple) periods can be evaluated.

Critical periods may vary from project to project and may not occur on the same timescale. For some projects, critical periods may be during multi-year droughts, while others may be during seasonal low flows. For example, the lowest flow conditions historically may have occurred during a two-year drought period, or low flows may occur every August during the end of the irrigation season.

In addition to identifying a critical period based on periods of low flow, the Corps should also evaluate times when the proposed project will withdraw the most water from the aquatic system. To determine these times, the Corps needs to understand the Applicant's project demand and operations, for example, whether the proposed project demand is relatively constant, seasonally variable, or used only during drought or other times of shortage. If maximum withdrawal does not occur during low-flow events, analysis should define the critical period as the time during which withdrawal creates the largest percentage change in hydrology. For instance, a project may not operate during the lowest flows, but instead diverts water during wet or average flows. These operations may produce the biggest percentage change in hydrology and the effects to aquatic resources should be evaluated through these periods.

When analyzing critical periods, variability in flows is typically more important than the length of the period of record. To determine the critical period, operations at a variety of flow regimes need to be examined. If the hydrologic period of record chosen by the Applicant is several decades long but includes mainly average and wet years with very few or only slightly dry years, it can be difficult for the Corps to determine the critical period. A period of record that includes the lowest flows as well as average and high flows will result in a more thorough evaluation, even if it is only a few years long. As described above, shorter periods of records are sometimes appropriate if development of water resources has changed the hydrology over time. Such a change could be a long-term trend, such as increasing wastewater return flows over several decades, or a distinct event such as a reservoir coming online. Consideration of continuation or modification of such trends should be included. However, some data and observations associated with aquatic resource conditions may be reflective of longer-term trends, such as geomorphology and riparian conditions. If such information is available, or if aquatic resource factors are being evaluated that have apparent long-term trends, a longer period of record would be appropriate. Further discussion of this issue can be found in HMG 3.B.

Case Study

Shortening the period of record to determine a critical period was appropriate for Case Study 8.1.4 due to a long-term trend of increasing wastewater effluent generated in the basin in recent decades. Use of lower flows in the historical record prior to this increase no longer represented current hydrology.

Lengthening the period of record for Case Study 8.1.2 was important because the drought of the early 2010s proved to be the new drought of record. The study period was extended to include the recent drought in a daily RiverWare model. The project size was increased to provide for the project need through the new drought. In this case, extending the period of record was critical to accurately capturing hydrology that supported the project purpose as well as accurately representing current conditions.

Hydrologic models are developed with data that are available at the time of model development. As more time passes between the model development date and the present, critical periods used in the model may become out-of-date. For example, severe drought conditions of the early 1950s were used as a critical period for many water providers in Colorado. In 2002, a drought worse than the 1950s drought saw extreme stress on municipal and agricultural water supply systems, as the assumption that the critical period would not be superseded crumbled. Most water providers in Colorado now also consider the drought of 2002 in their planning efforts. Similarly, drought conditions in Texas in the early 2010s may supersede the 1950s drought as the critical period in some areas in Texas. However, many of the WAM models were developed prior to the early 2010s drought and do not yet include this period. Accordingly, hydrologic analysis and modeling should be updated as necessary to incorporate a critical period that has occurred recently.

The Corps should use discretion when considering extending the period of record of existing hydrologic modeling or analysis to include years between the period of record used in the model or analysis and the present time. Extension of hydrologic modeling can be a costly and time-intensive effort. Reasons to extend the period of record would include significant changes to hydrology caused by infrastructure or changes to land use, or new extreme events that expand the range of hydrology that should be assessed. If there have been no major changes to the hydrology and the existing period of record reasonably captures the hydrologic variability of the system, the Corps may not need to extend the period of record to adequately evaluate the effects to aquatic resources.

6.3 GUIDELINE 2.C: Determine the timestep required for hydrologic modification analysis

The selected timestep should provide adequate detail to evaluate potential effects to aquatic resources caused by the proposed project.

A timestep is simply the measure of the interval of time between measurements. For hydrologic analysis and modeling, timesteps can range from sub-hourly to annually, but daily and monthly timesteps are most common. To assess the hydrology of a proposed project, the hydrologic modification analysis can use the longest timestep that provides adequate detail for the information and resources potentially affected. In HMG 2.A, it is recommended that data be collected on a daily timescale. A daily timestep is typically the shortest timestep needed to evaluate hydrologic modification, though shorter timesteps may be necessary if project-specific conditions warrant and data are available. Data provided on daily timescales are a good target for Applicants to collect because data can easily be aggregated into monthly or annual data if a monthly or annual timestep is determined to be adequate. However, disaggregation of monthly or annual data back to daily form is much more difficult and typically relies on statistical methods rather than using observed data. Such efforts can result in concerns relative to the reliability and accuracy of flow data for use with aquatic resource analysis.

Monthly data is often available from hydrologic modeling developed to compute the yield of a project. If the resources that will be affected can be reasonably evaluated using monthly data, there may be little

benefit to converting to a daily timestep and could result in significant cost and time savings to not covert existing data. The determination to rely on monthly data as compared to a shorter timestep can be made when considering the resources to be affected and potential benefits to higher temporal resolution data. Resource specialists and other regulatory agencies may be able to assist in such a determination (see HMG 2.F).

At any timestep length, the data is representative of an average over that timestep. Monthly and annual data can hide more severe impacts that could occur daily. Using monthly data, for example, river flows may have been quite low during part of a month before a reservoir made a larger release, an agricultural user stopped irrigating for the season, or junior water user diversions were curtailed. On a monthly scale, these large changes to flow mid-month will simply average out. In some areas where surface infiltration rates are lower, such as urban areas or where soils are clayey and infiltrate less, flows may be flashy, with large and rapid changes in flowrate that may last for a matter of hours or days, but would hardly be noticed on a monthly timestep.

Case Study

In Case Study 8.1.2, modeling and analysis was initially performed on a monthly basis using a regional water rights and yield model. Through the course of the project, the Applicant updated the model to a daily RiverWare model. The daily model was able to quantify the number of no-flow days with and without the project below the reservoir site, which would not have been possible using a monthly model. The decrease in the number of no-flow days was one of the key considerations in the impact analysis.

In order to determine the appropriate timescale required for hydrologic modification analysis, the Corps must have adequate knowledge of hydrologic flow variations in the project area. This information should be available from the data collection efforts of HMGs 1.D and 2.A. If the hydrology in the project area is highly variable from day-to-day, then a daily timescale should be used. If the streamflow is characterized as being relatively consistent, then a monthly timescale may be adequate. If flows are regulated by upstream reservoir releases, the variability of the releases should be investigated to support a decision on timestep length.

With regard to the proposed project operations, the timestep required for analysis will need to take into account whether the change in flow due to project operations will be consistent over longer timesteps or if project operations will vary depending on flow conditions. If diversions from the stream vary substantially and peak diversion rates are significantly larger than average diversion rates, the time over which that change occurs needs to be considered when deciding the appropriate timestep length. Longer periods of steady diversions or reservoir releases may warrant a monthly timestep, while variable short diversions or releases require a daily timescale.

Note that monthly flows are often used to determine the yield of a project. For example, the official Texas WAM models were originally developed with monthly flows, although some basins now have daily model capability. For project yield, a monthly timestep is generally adequate because system storage levels act as a buffer to intra-monthly flow variability. However, many biological and chemical aquatic resource impacts are important on a sub-monthly scale. For example, fish cannot survive several days of zero flow within a month, even if there is flow the rest of the month. Therefore, unless evaluation of the resources likely affected by the proposed project determines otherwise, the Corps should use a daily timestep as the default.

6.4 GUIDELINE 2.D: Understand assumptions included in any modeling used

Information used in any existing hydrologic modeling can be useful for the hydrologic modification analysis, but assumptions that went into the existing model must be understood to ensure appropriate use. The old adage says: "All models are wrong, some models are useful." A model cannot incorporate all the nuances of river flows and operations. Assumptions are inherent in any hydrologic model, and these assumptions can range from diversion and release operations within a project area, water demands by other water users, and return flows to the interpretation of agreements between entities. Different types of assumptions are made during model development appropriate for the intended purpose of the model. In addition to understanding what the assumptions are in a hydrologic model, it is important to know what the original intent of the modeling was and to comprehend how the assumptions could impact the modeling results.

The simplest and most straightforward way to understand modeling assumptions is to obtain adequate documentation for the model. Model documentation should describe the model purpose, development of all input data; including raw source data; how the data was processed into model input; any methods used to estimate data when observed data was missing; model configuration; and other relevant information. If the models include any regulatory requirements, such as water rights conditions or Corps permit conditions, the model documentation should describe these conditions or restrictions, and how they were simulated in the model. For example, TCEQ requires water rights accounting for some water rights, and the degree to which the model simulates operations to comply with the accounting requirements should be described. A clear understanding of how any restrictive conditions already imposed on the Applicant are simulated and operated can lead the Corps to a determination that abiding by existing conditions will adequately protect potentially affected resources (see also HMG 3.G, project operations).

Case Study

In Case Study 8.1.5, the modeling performed using a monthly water rights model included releases to a downstream senior reservoir's operational rule curve based on strict interpretation of the prior appropriation system. The model documentation stated this may not occur in actual operations because the operational rule curve at the downstream reservoir may not precipitate curtailment of upstream rights in normal operations. Although appropriate for yield modeling, this assumption resulted in over-prediction of flows below the project, particularly during dry periods. This resulted in the Corps performing additional analysis to determine the significance of this over-prediction.

Application of this HMG may have helped identify this issue at an earlier stage in the project and either allowed for modification to the model, adaptation of a different model altogether, or at a minimum brought the issue to light earlier in the process to increase overall efficiency in the effects analysis.

Although Case Study 8.1.5. involved an EIS and therefore would also be evaluated with the Tier-3 HMGs, application of Tier-2 HMGs to complex projects can assist in identifying important issues.

To the extent possible, hydrologic modeling should represent any such restrictions, conditions, and operations.

Different types of modeling tools are developed for different purposes. One model may be used as a project yield model that considers water available to an Applicant's water rights through a critical period in order to quantify a project's yield. However, this model may not accurately reflect operations of the project in other non-critical periods or even at all. Some Applicants have developed **system models*** or **operational models*** that may track or guide an entity on operations or fulfill other operational requirements imposed by a water right or permit, even if these operations were not part of hydrologic modeling that determined the project yield. Whenever using hydrologic modeling, the Corps should evaluate how accurately real-world operations and flows are represented — which may differ from model results depending on the purpose and assumptions used in the model.

Hydrologic modeling is often used in support of water rights issued by a state agency or water court. The assumptions included can vary significantly from state to state. For example, Texas uses WAM to determine if there is a reliable supply for an Applicant under future development conditions that typically are not representative of current river conditions, and the impacts on existing flows are generally not evaluated. Oklahoma issues permits based on a tool that computes average water supply availability, with a carve-out for future domestic water demands, but evaluation of hydrologic impacts during dry periods is not required to issue a water permit. In contrast, in Colorado, water rights are issued by water courts if the Applicant can show water is available and the water can and will eventually be put to beneficial use. The evaluation is typically performed using current river flow conditions but acknowledges that during dry (or even average) periods, the water right may not yield any water. In Colorado, Oklahoma, and Texas, other water rights holders may oppose a new or change of water right if they feel it will injure their water rights. This may result in terms and conditions that put additional limitations on how a water right can operate. Use of these types of models must be evaluated for assumptions and the purpose for which the model was originally developed that may affect the degree to which the model results reasonably represent changes to hydrology that can be assessed for effects to aquatic habitat.

6.5 GUIDELINE 2.E: Hydrologic modification analysis should preferentially use observed data for a baseline and modeled data secondarily

For a Tier-2 medium-level analysis of a proposed project's degree of hydrologic modification, the Corps should preferentially use observed data to define baseline conditions and use output from hydrologic models secondarily. The use of observed data provides an accurate picture of actual hydrologic conditions under existing circumstances and operations at that time. Observed data illustrate hydrologic conditions that are not modified or processed for a specific modeling purpose. Changes to the observed data baseline to estimate the degree of hydrologic alteration are often simpler and less prone to issues that can arise from various assumptions made in hydrologic modeling.

The Corps should preferentially use observed data or well-documented modifications to observed data to define baseline conditions and use output from hydrologic models secondarily.

Observed data, however, is not always available or sufficient to characterize a project's operations and associated impacts to streamflows. Information used from existing hydrologic modeling can be beneficial for an analysis of hydrologic modification, but assumptions that went into the model must be understood to ensure appropriate use (see HMG 2.D). The same holds true of data that has been modified from naturally observed or raw data. For instance, if a project is proposed upstream of an existing stream gage, and the Applicant has developed **naturalized flows*** or other modification of historical observed flows to determine how the operations would impact the natural stream, it is important to understand how flows were developed, including what source data were used. The Corps should have the raw streamflow data (from HMGs 1.D and 2.A) in addition to the naturalized or modified flows and the assumptions used to reconstruct the flows for the hydrologic modification analysis.

If data from existing hydrologic models is used, adjustments should be made based on the assumptions identified in HMG 2.D that will adjust towards baseline flow conditions in the area of interest. Any such adjustments should be well documented and understood by the Corps. The Corps should request that any such adjustments be provided in a time-series format conducive to a relatively simple hydrologic modification analysis. Most models can provide outputs in a time-series format that can then be analyzed for various critical periods or statistics outside of the model if needed. Applicant-provided summaries, averages, or statistics of model output should be avoided because these may make critical period information unavailable or mask extreme events. Summaries and statistical analyses can be readily computed from time-series data externally.

Complex methods to make data modifications are more conducive to detailed analysis described in the Tier-3 HMGs, specifically HMG 3.C.

Case Study

In Case Study 8.1.4, use of unadjusted historical observed data was not appropriate due to changes in hydrology over several decades at the project site. However, large amounts of observed data were available, such as stream gages just above and below the project area, and wastewater treatment plant discharges in the region. Use of these multiple observed data sources to adjust the historical hydrology allowed for a reasonable hydrologic alteration analysis that adjusted historical flows based on observed data, rather than requiring the time and expense of developing a full hydrologic model.

6.6 GUIDELINE 2.F: Coordination with resource agencies

In a Tier-2 evaluation, the Corps may be able to make an ***initial*** determination of potential aquatic resource factors and functional areas to be potentially affected by the proposed project. Such a determination would be based on the initial information that the Applicant provided to address the Tier-1 and Tier-2 HMGs. Depending on the permit type, the Corps must coordinate with key resource agencies (i.e., EPA, USFWS, Texas Parks and Wildlife Department, and TCEQ - Water Quality Division) or issue a public notice to solicit comments, many of which typically come from these agencies. Applicants should recognize that coordination with the corresponding resource agency staff can include the following:

- Identification of the desired and target resource factors as well as the specifics of each factor to be evaluated — Factors can include fisheries, aquatics, macroinvertebrates, water quality, geomorphology/sediment transport, or riparian connectivity. The specifics of each factor can include particular fish or macroinvertebrate species, water quality constituents, aspects of geomorphological condition(s), or other component to assess. Representative analysis based on professional judgment will likely be common.

- Addressing various details associated with the Tier-2 medium-level HMGs 2.A to 2.E. — For instance, details such as the determination of critical periods, the timestep used in modification analysis, and the assumptions that are included in any modeling used could be addressed.

- Hydrological model outputs used to inform professional judgment determinations related to effects on targeted resource factors and/or their specifics — The Corps should seek to obtain other agency staff agreement relative to which model output data should be used to inform determinations of potential effects on targeted resource factors. For instance, the Corps may focus on the flowrate during the critical period while resource agency staff may view water level as a more significant output.

- Hydrological model outputs needed for input to specific assessment methods, if such methods are being employed — As described in the Tier-3 HMGs, specific resource evaluation tools will use the hydrologic modeling results as input. The format, location, frequency, and other relevant information needed by the resource agency should be discussed during agency coordination.

- Operational actions needed to avoid, minimize, and possibly compensate impacts to aquatic resources — For example, a diversion from the proposed project in an upstream reach of the project system may impact critical flows at another location, but releases can be made in an intervening reach from a different part of the system to compensate for these impacts.

Based on the above, the Corps should have sufficient and complete data to share with resource agencies if an initial determination of affected resources has been made and the permit sought requires coordination with resource agencies.

Case Study

For Case Study 8.1.4, the Corps coordinated with multiple agencies to identify key resource categories to assess based on hydrologic modifications. Discussions included understanding desired hydrologic information needs and desired locations. Based on coordination, decisions about the level of detail needed in the hydrologic alteration analysis could be made for these resources and the resource impact evaluations and conclusions were completed.

The Corps should have sufficient and complete data to share with resource agencies if an initial determination of affected resources has been made and the permit sought requires coordination with resource agencies.

6.7 GUIDELINE 2.G: Simplify hydrologic modification analysis as much as possible to make determination of adequacy of analysis

The Tier-2 HMGs rely primarily on an analysis of hydrologic modification and allow the Corps to make a determination whether additional, more detailed analysis is necessary, or whether relevant permit requirements are adequately addressed based on the results of the hydrologic modification analysis. The results of the hydrologic modification analysis should be considered in light of the initial determination of potentially impacted aquatic resource factors to assist in that decision.

The Corps will normally use the simplest technique that allows for a reasonable representation of the hydrology in the area of interest and the modified hydrology based on the project operations. Use of existing modeling or hydrologic analysis that is not specifically designed for resource effects analysis may provide sufficient information to make a determination of whether additional detail is needed or not to adequately assess potential project effects. For example, if flows are conservatively low through the critical period in existing project modeling but still show no adverse impact to aquatic resources, increasing the flow to more realistic flowrates for an aquatic effects scenario would most likely also show no adverse impact (see also HMG 3.G, project operations). Complicated techniques and analyses may make it challenging for the Corps to make a conclusion about the impacts and effects of the project. When determining how simple the evaluation can be, the information gathered through implementation of HMGs 2.A to 2.F should be considered to ensure that the selected technique is representative of hydrologic impacts.

The analysis of hydrologic modification can use relatively straightforward techniques such as a spreadsheet analysis, or relatively simple implementation of hydrologic modeling software such as RiverWare may be the most appropriate, provided the information used in the analysis follows HMGs 2.A to 2.F. The advantage of a spreadsheet analysis or a RiverWare model is that either can be as simple or as complicated as the modeler makes it, and both are flexible enough to encompass a wide range of system inputs and operations. Models such as RiverWare are also suited to more complex and detailed evaluations that can be beneficial if it is determined that such analysis is required based on the initial efforts and results of the modeling or as new issues become known in the review process.

The outcome of this final Tier-2 HMG (2.G) is a determination by the Corps on whether the analysis of hydrologic modification adequately characterizes the project impacts without additional detailed hydrologic analysis or modeling. If the Corps determines it is sufficient, the permitting process can continue without additional hydrologic analysis or modeling. If the Corps determines it is not sufficient, the Corps and the Applicant should proceed to Tier-3 Guidelines (Section 7).

Outcome is a determination whether the analysis of hydrologic modification adequately characterizes the project impacts without additional detailed hydrologic analysis or modeling.

Toledo Bend Dam Overflow. Photo courtesy of Toledo-Bend.com

7.0 Major Project and Detailed Effects Analysis

Some projects are large and are expected to have more substantial impacts to aquatic resources than smaller projects. As projects are evaluated through the Tier-1 and Tier-2 HMGs (Sections 5 and 6), the Corps may determine that additional detailed analysis is required to reasonably assess impacts to aquatic resources. Generally, projects that require a larger Standard Individual Permit and may include an EIS will require detailed hydrologic modeling to support evaluation of specific resources. Much of the information gathered and analysis performed in the initial and medium-sized project-level HMGs are re-examined in more detail for the detailed analysis of project effects.

These HMGs were designed with RiverWare in mind for the hydrologic modeling platform for more detailed analyses. The Tier-3 HMGs presented below can be readily applied in a general sense to several other modeling platforms, provided the features, assumptions, and limitations of the modeling platform are well understood. Where appropriate, specific RiverWare features are included that pertain to topics of importance to the Corps and the Applicant that may be useful in the planning or evaluation stages of hydrologic modeling needs for the project.

Hydrologic modeling can be applied to several different purposes, such as project yield, flood control evaluation, water quality, or effects on aquatic resources. The primary purpose of the regulatory process is to evaluate the effects on aquatic resources while ensuring that project yields are still met for water supply and management projects; the process therefore focuses on simulating streamflow or other hydrologic conditions (e.g., reservoir levels, inflow and outflow rates) at time frames and scales that are appropriate for assessment of effects on aquatic resources. Achievement of other types of project purposes (if applicable), such as power generation, flood risk management and water-based recreation, would also need to be assured if adequately reflected in the purpose statement. All decisions involved in the process of selecting and designing a hydrologic model or in the process of using or modifying an existing model, should keep in the forefront the need for realistic stream flow simulation at ranges of flow levels that are critical for aquatic resources. Generally, this includes low flows as discussed above in HMG 2.B, but can also include high flows for certain resources, such as geomorphology or out-of-bank frequency and duration analyses, in addition to species-specific flow ranges for various life cycle stages of biota in the project area and/or water quality constituent analyses.

A significant difference in the use of hydrologic modeling in the Tier-3 HMGs as compared to the Tier-1 and Tier-2 HMGs is the use of the model output. In Tier-1 and Tier-2, the Corps can make decisions based on changes to hydrology with the general assumption that decreases in flow will have an adverse effect on resources (Section 4 and HMG 1.F), or that the degree of hydrologic modification in light of likely affected resources can be used to render appropriate determinations in relation to the permit decision (HMG 2.G).

In contrast, Tier-3 HMGs recognize that hydrologic model output is often used as an input for resource-specific models or analyses. Evaluation of specific aquatic resources will use a wide variety of hydrologic

data as input (see Figure 1 in Section 3.0). For example, some models require statistical input, while others require only critical flow periods, or a time-series of hydrology, or are only concerned with flows in a single location. To maintain consistency across all resource effects analyses, it is important that the same underlying hydrologic modeling is used in the evaluation for all different types of specific resources being evaluated for a project, even if different locations or periods of time are used by different resources. The hydrologic modeling results can be formatted to suit individual aquatic resource evaluations, but should always come from the same underlying dataset to maintain consistency throughout the effects analysis. Rare exceptions can occur with this such as addressing threatened and endangered species which may have certain hydrologic modeling constructs associated with recovery plans.

7.1 GUIDELINE 3.A: Use any Applicant-provided modeling where appropriate to save time and money in hydrologic model development

A main focus of the Tier-2 HMGs was to translate Applicant efforts into a format suitable for hydrologic modification analysis, including evaluating assumptions in any hydrologic modeling provided by the Applicant. This HMG 3.A extends the process and logic laid out in the Tier-2 HMGs to evaluate Applicant-provided hydrologic modeling to be used for a major project that may have complex operational attributes or other assumptions that require evaluation and potentially adjustment. Use of existing modeling can provide significant time and cost savings if the data and model configuration is appropriate for the Corps' purposes.

The key to this HMG is using existing modeling "where appropriate." Application of all the Tier-3 HMGs will help determine what portions of Applicant-provided modeling is appropriate for use by the Corps for the aquatic resources effects analysis. However, professional judgment and case specifics should impact which Tier-3 HMGs should be employed.

Any Applicant-provided modeling should be reviewed for the original purpose for which the model was designed (see also HMG 3.C). If the purpose was not primarily to accurately simulate streamflow, the model will likely need modification to correct any assumptions that would result in inaccurate streamflow representations. Such modification may include changes to model inputs (such as streamflow or demands) or to better simulate operational factors not considered for the original modeling purpose. Model documentation should be provided by the Applicant and used to identify these assumptions and model configuration.

If the purpose was not primarily to accurately simulate streamflow, the model will likely need modification to correct any assumptions that would result in inaccurate streamflow representations.

The Corps and Applicant should be aware that modification of existing hydrologic models originally designed for a different purpose can be more complex and ultimately more costly than developing a new model. The allure of what may seem like minor modifications to existing modeling and an Applicant's understandable desire to minimize time and costs associated with perceived duplication of previous efforts will often influence a

decision that ultimately can result in hydrologic modeling either not suited for the Corps' regulatory permit review or that has become more complex and costly than a new model.

If the Corps determines that an Applicant-provided model is unsuitable for the streamflow simulation needed for the aquatic resources effects analysis, the underlying input to such models has usually been vetted to some degree. This may include data or conclusions based on observed streamflow, rainfall, evaporation, demand, use, diversion, return flows, etc. This is valuable information that can be used in a new model. A significant portion of model development is gathering and vetting relevant data. To the extent that data was collected under the Tier-1 and Tier-2 HMGs and is available in any Applicant-developed modeling, the cost of developing a new model for the Corps' regulatory purposes is reduced. Complete model documentation that includes detailed information related to input sources and development can significantly improve the efficiency in determining the usefulness of existing model inputs. Ultimately, the Corps will need to determine if additional verification and/or validation is required for use of such data.

Case Study

For Case Study 8.2.1, four models with differing purposes were combined and modified into a single modeling process. Multiple iterations between models and modification for a number of operational differences were required that resulted in a highly complex modeling system. Although time and cost considerations were initially given as reasons for combining existing models, the complexity involved in developing a working modeling system may have outweighed the time and cost of developing a new single model designed specifically for the effects analysis.

In contrast, for Case Study 8.2.2, a single model that encompassed the multiple watersheds where the Applicant operated developed with a daily timestep for river conditions was used and resulted in a shorter hydrologic modeling verification process.

Underlying model inputs from existing models can be easily imported to the RiverWare platform through data objects or into corresponding model objects such as stream gage, reservoir, and water user objects. Prior to blanket acceptance of model inputs, the Corps should verify the data from existing models that is to be used in a new model from model documentation or direct comparison to observed data. Observed data that can be verified (such as historical stream gage data or wastewater discharge volumes) should not need significant amounts of verification.

Other inputs, such as Applicant and other in-basin users' water use demands, simulation of water rights administration, project diversion rates, and inclusion or exclusion of key operational features should be more closely scrutinized before being used directly in a new model. These inputs are typically developed based on several assumptions, estimates, and projections, and are not always based directly on historically observed data. See other Tier-3 HMGs for additional detail on potential differences between existing model data and model configuration appropriate for the Corps Regulatory process. The Corps' District H&H branch can provide additional support with development and review of existing modeling as needed. If an EIS is involved, support from a third-party contractor familiar with hydrologic modeling in general and RiverWare specifically will support the Corps regulator's understanding and decision-making with regards to use of Applicant-supplied hydrologic modeling and documentation.

In RiverWare, model data can be imported into the model using RiverWare data objects. Data objects are useful for a model that will be used for different scenarios as model inputs can be varied as a different scenario may require (e.g., future-conditions baseline, various alternatives analyses, or multi-run management scenarios). The RiverWare rule-based policy language (RiverWare Policy Language or **RPL***) or the RiverWare multiple-run management system can be used to import different datasets and run multiple scenarios. The decision to use this type of functionality within RiverWare is a matter of preference by the RiverWare modeler but can facilitate development of multiple scenarios more easily than multiple models with different inputs corresponding to each scenario.

7.2 GUIDELINE 3.B: Hydrologic model should be designed around known or anticipated needs of aquatic resources to be evaluated.

Through the process of following the Tier-2 HMGs, the Corps will have made an initial determination of likely aquatic resource factors that should be considered. A hydrologic model to be used for the proposed project should be designed around the anticipated needs of the aquatic resource effects analysis. If the needs of the other resources are not considered ahead of time, a model that does not provide all the necessary information for the resources of concern will introduce delays and increased costs to the project. Often, the hydrologic model provides hydrology inputs to models that are specific to the various resources. Therefore, to the extent the resource modeling needs can be known beforehand, the model should be developed to fulfill those specific data needs. It needs to be recognized that some Standard Individual Permit actions, particularly those that involve an EIS, will likely not have undertaken all Tier-2 HMG efforts or resource factor identification determinations since they will normally be informed as part of the public notice and/or EIS scoping process. In these cases, once resources are identified through the scoping process, new hydrologic modeling can be designed around these resource needs, or existing modeling can be evaluated considering the data needs for the resource evaluations.

To the extent the resource modeling needs can be known beforehand, the model should be developed to fulfill those specific data needs.

Through HMGs 2.A and 2.F, the Corps should have gathered relevant information that may point to specific resources to consider, as well as made initial inquiries with other agencies into specific concerns about aquatic resources within the project area. If the aquatic resource conditions have already been well documented within the area of interest, the Corps and the agencies should be able to determine the hydrologic needs of the aquatic resources effects analyses so that the hydrologic model produces the needed output type. If aquatic resource conditions are generally not known or have only limited data, the Corps will typically require additional investigation into these resources.

Aquatic resource factor categories typically considered in detailed project analyses include surface water, groundwater, water quality, geomorphology, fisheries, aquatics including macro- and micro-invertebrates, and riparian functions as well as their associated uses such as water-based recreation or aesthetics. Modeling needs can be estimated by conservatively assuming that more detail on temporal and spatial

scales will be needed. For example, coordination with agencies should confirm modeling items such as the location, frequency, timestep, critical period, sensitive flow ranges, and other resource-specific model hydrologic input needs. These needs may differ between resources, but the underlying hydrologic model should be designed to be able to provide the required information to evaluate all resources from a single hydrologic modeling dataset.

7.3 GUIDELINE 3.C: Model purpose should be centered on reasonably representing streamflows under a variety of conditions, including critical periods.

As has been discussed above, entities develop hydrologic models for a wide variety of purposes, such as determining the yield of a project, risk and reliability analysis, flood control evaluation, operations analysis, forecasting, short- and long-term planning, aquatic resources evaluation, and others uses. For the Regulatory Program, the Corps requires a model that can adequately represent the effects of a proposed project on aquatic resources. This requires reasonably accurate simulation of streamflows (or other relevant hydrologic parameters such as reservoir stage) at locations where aquatic resources could be affected (see HMG 3.B).

When the underlying assumptions and focus of a model were not originally designed to simulate streamflows in the project area, the results may be inaccurate or misleading. The following provides details on two common types of modeling and their intended purposes.

The Corps requires a model that can adequately represent the effects of a proposed project on aquatic resources through accurate simulation of streamflows or other relevant hydrologic parameters.

7.3.1 Project Yield Models

Project yield models are often the first model type an Applicant will develop in the course of a major project. Yield models determine how much water is reliably available, and can be used to determine infrastructure size needed for the project. Yield models may be **basin-wide models*** or may be an Applicant's system model or some combination thereof. Yield models do not necessarily need to simulate actual streamflows to be effective. For example, an Applicant's system model may only track water available to the Applicant through a larger river basin and need not consider operations of others. Project yield models often focus on critical drought periods and often do not require analysis of daily flowrates because storage vessels buffer daily variability from a yield perspective. In addition, yield models tend to be conservative regarding assumptions about others' use of water (and future use of water) and may have demands on the stream system that are significantly larger than what is expected in reality. These assumptions can be reasonable methods of introducing risk considerations into water supply and water management planning (e.g., a **safety factor***, **safe yield*** etc.) and make conservative assumptions about project yield. Many of these risk considerations can be the industry standard for determining the **reliable yield*** or safe yield of a project, recognizing that different entities use different methods and metrics for mitigating risk in their planning efforts.

Whenever a model is proposed that was initially designed to compute the reliable yield (or firm yield) of a project, the Corps should carefully review all model inputs that are not directly derived from observed data. Typical inputs include water demands of the Applicant and other entities included in the model, return flows from the Applicant and other users, and reservoir target elevations. Model review should also consider operational constraints required by special water rights conditions or other regulatory requirements, or other operations such as contract supplies (long- and short-term), exchanges, and trades that could affect actual operations when compared to conservative assumptions made in a yield model. In addition, streamflow inputs should be compared to historical gaged data to determine if model inputs include any modification for future conditions, such as assumed reduction for climate change.

Although the Applicant may choose to evaluate the **yield*** of a project using different assumptions (or may be required to use a certain tool to compute yield, such as WAM in Texas to obtain a water right), the Corps' regulations require evaluation of aquatic resources effects caused by the project, which requires hydrologic modeling without conservative assumptions about the future availability of water that yield models typically employ. Such conservative assumptions can mask causal effects in relation to other actions which are the result of the project. Additionally, such conservative assumptions may indicate overall greater effects to aquatic resources that may be concluded as having significant degradation, increasing the need for compensatory mitigation or possible negative findings in the permit evaluation. The Corps and Applicant need to be cognizant of how these assumptions are included in existing models and be able to explain and document why certain assumptions were included, and others rejected for the effects analysis. Certain aspects of the conservative assumptions may be appropriate if a future-conditions baseline is developed (see HMG 3.H).

Since yield models typically assume more conservative conditions for computing project yield as part of the safety factor, relaxation of those assumptions for the aquatic impacts evaluation should still indicate that the project yield can be met since more water is available. Yield models are designed to stress a water supply system to the point of failure. This point of failure is not an expected condition during normal operations. The aquatic resources effects analysis is more concerned with normal operations than at one system failure condition. However, such worst-case analysis may be needed on a project specific basis. The analysis of hydrologic modification (Tier-2 HMGs) will provide insight into the relative magnitude of anticipated effects. It may show that changing certain conservative assumptions used in a yield model may not alter the effects analysis. For example, if flows are conservatively low through the critical period in the yield model, but still show no adverse impact to aquatic resources, increasing the flow to more realistic flowrates for an aquatic effects scenario would most likely also show no adverse impact. As projects become more complex and other operations within the basin change based on the proposed project operations, the Corps and Applicant should consider a different model or different scenario than the model used to compute the yield of a project for the effects analysis.

Case Study

For the Case Study in 8.2.1, the project yield was quantified with a model scenario that included conservative assumptions about future use. These assumptions were relaxed in current-conditions aquatic effects scenarios to better represent current conditions hydrology, while still sizing the project based on reasonable planning parameters.

To the extent the project yield and the aquatic effects models can use the same model configuration, there are cost and time-saving efficiencies to be gained. RiverWare is able to simulate different scenarios, such as a yield scenario that includes some conservative assumptions about inflows, demands, return flow etc., and an effects scenario that better represents expected operational flows where these assumptions are relaxed to better simulate current conditions in the project area.

Alternatively, if the Applicant is satisfied with the results of an independent yield model (such as WAM results from a water rights application, or a separate stochastic analysis of hydrology as it relates to project yield), the Corps may choose to develop a modeling scenario for aquatic effects using the RiverWare platform (or other) to simulate hydrology to be used for analysis of effects to aquatic resource factors and rely on the yield computed by the other model. If separate models are used, the Corps and Applicant will need to evaluate, explain, and document potential inconsistencies between the yield model and the effects model. Since the project yield model is typically more conservative about the amount of water available, the effects model should be able to demonstrate that the need is met, even if the system is not stressed to the point of failure in the effects model as is done in a yield model. If the effects model shows that the project need is not met, the Corps and Applicant should re-evaluate differences between the two models and make any corrections as necessary to maintain consistency.

7.3.2 Flood Control Models

In several basins in the United States, the Corps or other agencies have developed flood control models to assist in operational planning and facility sizing to control floods. For a water supply or water management permit action in one of these basins, it may be beneficial to use the flood control model as a starting point for an aquatic resources effects analysis, provided that the Corps and Applicant are aware of the features commonly used in models originally designed for flood control that may require modification for an effects analysis.

Flood control models focus on large-flow events, while low-flow events are not important for flood control evaluation. Low-flow data and model operations may not have received quality assurance or control efforts and may be susceptible to errors during low-flow events that are often critical periods for aquatic resources. Often, operations that would occur at the proposed project or other facilities within the model domain are not portrayed for flowrates outside of flooding conditions and therefore are not effective for evaluating impacts to aquatic resources at times outside of high-flow flood events.

Flood control models can be modified to account for normal operations that are important for an aquatic resources effects analysis, but may require significant modification of the model itself to incorporate operations and accurately simulate flows during a wide range of hydrologic

Case Study

In Case Study 8.1.5, a flood control model was available for the project area and included the proposed reservoir. The flood control model simulated the reservoir with an uncontrolled spillway and unable to pass flows at lower lake elevations. This representation was appropriate for a flood control model, but was a poor representation for evaluating the impacts at low flows below the dam. Understanding this limitation in the flood control model allowed the Corps to take this limitation into account and make appropriate adjustments to the impacts analysis.

conditions. Nonetheless, the model structure and model inputs (e.g., inflows, **naturalized flows***, reservoir capacities, rainfall, and evaporation rates) may be useful information in making modifications to the model, or for importing into a new aquatic effects model. If a project is intended for multiple purposes, such as flood control and water supply, the Corps and Applicant must ensure that the model used for the effects analysis reasonably simulates hydrology through a range of conditions that addresses individual purposes as well as collectively if a multi-purpose project, even if the project yield and flood control capabilities are confirmed through other models or modeling scenarios.

7.4 GUIDELINE 3.D: Simulate Avoidance and Minimization actions separate from Compensatory Mitigation

In any project involving an individual permit subject to the 404(b)(1) Guidelines, the Corps can only permit the LEDPA. When making the determination of the LEDPA, the Corps can consider aspects of the proposed project to avoid and minimize impacts to aquatic resources but cannot consider the potential beneficial impacts of compensatory mitigation proposed by (or required of) the Applicant.

To comply with this requirement, a hydrologic model developed for the aquatic resources effects analysis must be able to distinguish between avoidance and minimization of impacts and compensatory mitigation. This distinction can be done by developing different models or different scenarios for each and comparing the results of the different model runs. The RiverWare platform is well-suited to build this distinction directly into the model. RiverWare includes a feature called "RiverWare Policy Language," or RPL. RPL allows the model developer to write policy rules that change the project operations being simulated. A proposed mitigation plan can be written as an independent set of policy rules and switched on and off for different model scenarios. One model run would be executed with the compensatory mitigation policy group turned off, and then a second run would be made with the policy group turned on. The effects analysis is performed using the results from the first model run without the compensatory mitigation plan. The differences between the model run with compensatory mitigation and corresponding differences to aquatic resource effects and the model run without would be attributed to the mitigation plan. Distinctions between avoidance and minimization operations and compensatory mitigation operations are needed to appropriately

Case Study

Case Studies 8.2.2 and 8.1.2 both involved reservoir expansion projects where compensatory mitigation was accomplished by increasing the reservoir size and providing environmental releases from this environmental pool in the reservoir. In Case Study 8.2.2, the project was first simulated without the increased environmental pool so that the project effects – after avoidance and minimization, but before compensatory mitigation – could be compared to other alternatives for the LEDPA determination. Once the LEDPA was determined, additional analysis was undertaken to quantify the effects of the compensatory mitigation plan.

In Case Study 8.1.2, the project size was based on the need prior to considering compensatory mitigation. The effects associated with the additional storage for compensatory mitigation in that project were small enough that additional modeling was not needed.

categorize the effects of the operations and ensure that avoidance and minimization operations are included in the LEDPA determination while the compensatory mitigation operations are kept separate to comply with the 404(b)(1) guidelines sequencing requirement as well as be reflected in the mitigation plan. In some instances, a second model run with compensatory mitigation may not be necessary, provided the project impacts are evaluated based on avoidance and minimization efforts. Both avoidance and minimization and compensatory mitigation operations would likely be the subject of permit conditions.

7.5 GUIDELINE 3.E: Model domain should encompass geographic extent and a sufficient study period to accurately reflect the range of effects.

The spatial extent of the effects analysis was initially considered in the Tier-1 HMGs, (HMG 1.E). Several maps and a discussion of how the geographic extent was determined are presented in the Case Studies section. Hydrologic modeling can be used to evaluate the effects at the initially proposed boundaries of the study area to determine if the extent should be expanded, or if it could be reduced. If effects at the initially proposed boundaries are small, expansion is not needed. If effects at the initially proposed boundaries are large, the Corps should consider enlarging the geographic extent of the model. Similarly, if simulated effects at the initially proposed boundaries are negligible, the boundaries may be reduced. Professional judgment, rationale, and documentation for the established limits is needed, supported by hydrologic modeling data and consideration of aquatic resources at the boundaries. Detailed discussions with the Applicant will provide further understanding of system operations and may allow the Corps to limit the geographic extent if the proposed project will not affect certain areas of the Applicant's system.

The majority of hydrologic effects from a proposed water supply project will occur downstream of the proposed feature to be constructed. However, there are some cases where upstream areas could be affected, such as backwater effects from a dam, or potential water rights or other operational changes at upstream locations. The potential upstream operational changes were initially identified under HMGs 1.B and 1.C. For major projects, these descriptions should be reviewed in more depth and supported

Case Study

In Case Study 8.2.2, the Applicant developed a hydrologic model that included several river basins in which it operates. The Applicant has several sources of water within a large river basin and conveys this water through an inter-basin transfer to the river basin that contains its service area. In the source basin, the hydrologic modeling extended to the downstream-most water right that could affect the availability of water to the Applicant. In the receiving basin, the modeling extended downstream past the Applicant's wastewater treatment plant discharge location to simulate the downstream effects of the new water source in the receiving basin.

In Case Study 8.1.5, the modeled study time period ended before a recent severe drought. In order to assess the potential impacts of the drought, the Corps performed a statistical analysis of the observed flow characteristics for the modeled study period and the recent drought period. The analysis showed that flows through the more recent drought were statistically similar to the modeled droughts, and therefore, the model did not require extension through the more recent drought to accurately evaluate project effects.

by hydrologic modeling that evaluates potential impacts at upstream locations in a similar manner as for downstream study area effects.

The study period used in the hydrologic modeling should encompass a period that includes a wide range of observed hydrologic conditions. The study period should evaluate dry, average, and wet periods that represent a reasonable range of expected conditions. In HMG 2.B, critical periods for various initially identified aquatic resources were identified. For a major project, more information will be available on aquatic resources, and the critical periods for each resource should be evaluated again to ensure that the study period used in the modeling adequately captures the range of flow conditions critical to each resource.

As was described in HMG 2.B, if there have been significant changes in regional hydrology, it is important to either adjust or not use out-of-date data. For example, if a reservoir was built upstream from the area of interest recently, the observed hydrology from the pre-reservoir period will likely not provide a good representation of expected conditions at the area of interest. In these cases, a shortened study period can be considered, provided a reasonable range of hydrologic conditions, including critical flow conditions for the various resources, are still captured within the study period.

Shortening the study period may not be acceptable if the resulting study period does not adequately capture a range of flows and critical flow conditions or accurately capture longer-term trends of some resources, such as geomorphology or long-term vegetation trends. In these cases, modified or reconstructed hydrology that accounts for the recent changes to water resources in the region may be an appropriate substitute. For a major project that requires detailed analysis, any reconstruction or adjustment to the hydrologic inputs should be documented. In addition, if reconstructed or adjusted flows are required to evaluate critical periods, a **sensitivity analysis*** should be performed on the assumptions or parameters used in the reconstruction of flows. Although the hydrologic modeling may not be used for reconstruction or adjustment of the inputs, the model can be used to evaluate the influence of the methods and assumptions of such a reconstruction relatively quickly and efficiently.

7.6 GUIDELINE 3.F: Model timestep should reflect the critical timescale of the aquatic resources being evaluated.

As discussed in HMG 2.C, a daily timestep is the default needed to accurately simulate the effects to aquatic impacts. In theory, hydrologic modeling can be performed at any temporal timestep but in reality, is limited to the temporal resolution of available data, which often is daily. Data averaged over longer periods of time (e.g., weekly or monthly) may mask potential effects to aquatic resources that occur within that timestep.

The Corps and Applicant should be aware that models that are operated on a daily timestep may not be using daily model input. For example, if only monthly precipitation or evaporation rates were available, the model may simply use the average daily rate for each day of the model. Daily model inputs should be verified back to source data reported on a daily basis if possible. When daily source data is not available, the Corps should evaluate the method used to develop daily inputs for the hydrologic modeling. The

simplest method is to use the daily average, but other inputs may be interpolated between monthly values or correlated to other daily-variable data.

For a major project, particularly one involving an EIS, specific aquatic resources will have been identified for evaluation. Hydrologic model developers should consult with resource specialists about timestep requirements prior to hydrologic model development. This consultation should include discussion of any known model inputs that are not available on the timescale required for the aquatic resource evaluation. All parties should discuss appropriate methods to develop inputs at the required timestep so that all assumptions and potential issues about inputs to the hydrologic modeling are known *a priori* to resource analysis. Similar to the discussion in HMG 2.E about reconstruction of flows, any assumptions used to adjust or modify source data to develop model inputs at the required timestep should be evaluated through a sensitivity test. A sensitivity test provides assurances that assumptions made have minor impact on the results at the shorter timestep or provides insight into which assumptions need additional consideration before the resulting model inputs are incorporated into the hydrologic modeling.

Some aquatic resources may only require data at longer timesteps than other resources. Model output can be easily summed over longer time periods, but disaggregation into smaller timesteps is much more difficult. Therefore, the model timestep should be set to the shortest timestep required for the effects analysis for any of the aquatic resources.

The model timestep should be set to the shortest timestep required for the effects analysis for any of the aquatic resources.

7.7 GUIDELINE 3.G: Proposed operations and administration should be incorporated into the hydrologic modeling.

An Applicant can typically be required to submit an operations plan to the Corps for larger or more complicated projects. Smaller actions may also require an operations plan as well and may be associated with a Tier-2 sized project and will have been initially addressed through the Tier-1 HMGs (see HMG 1.C). An operations plan often includes detailed information about operations under various conditions. Applicants can make commitments associated with project operations, either in relation to limitations or additions that avoid and minimize impacts to aquatic resources as well as allow for the elimination of certain geographic and/or resource effects evaluations during the permit evaluation process. The operations, commitments, and assumptions included in an operations plan should be incorporated into the hydrologic model used for the aquatic resource effect analysis. Such operational considerations typically become permit conditions and require monitoring to ensure that the project functions as evaluated in the permit analysis.

The operations, administration, commitments, and assumptions included in an operations plan should be incorporated into the hydrologic model used for the aquatic resource effect analysis.

7.7.1 Project Operations

Hydrologic models often use simplified methods instead of complex operations if the operations have little impact on the model's original purpose, such as yield or flood control (see HMG 3.C). For an aquatic resources effects analysis, the project operations will generally have a significant impact on the outcome since the amount of water in the stream on a daily basis is the critical simulated parameter. Differences between the operations plan and the hydrologic modeling will result in computation of different impacts to aquatic resources than will occur under the proposed operations.

Not all hydrologic modeling platforms are able to simulate proposed operations or are only able to simulate operations in a simplified manner. The Corps and Applicant should consider the complexity of the proposed operations when selecting a modeling platform. If the model platform cannot reasonably simulate the proposed operations, a different modeling platform should be used. The Corps has determined that RiverWare is generally suitable to simulate water supply projects, in part because of the flexibility inherent in the platform to simulate different types of water rights and administration, as well as custom developed RPL policy rules.

RiverWare has several built-in functions to simulate a variety of standard operational procedures. If operations are reasonably represented by these built-in functions, they should be used preferentially because they reduce the overall complexity of the model. There are several hundred of these built-in functions that are specific to the different modeling objects available in RiverWare. The Applicant and Corps should refer to the RiverWare user's manual provided by the developer of RiverWare, for detailed information about available built-in functions (available at **http://www.riverware.org/PDF/RiverWare/documentation/index.html**).

For more complicated operations that are not conducive to the built-in functions, RiverWare has a customizable "RiverWare Policy Language (RPL)" that allows complicated operations to be simulated through what RiverWare refers to as "rules." If the built-in functionality in RiverWare is not sufficient for a project's operation, RPL should be used to accurately portray operations. RiverWare rules can also be used to simulate other conditions such as water rights conditions or other regulatory restrictions. The RiverWare rules can also be formulated in a manner that can be relatively easily converted into Corp permit

Case Study

In Case Study 8.2.1, several iterations of portions of the model structure were necessary because a single iteration of the model sequence would not reasonably represent operations by some of the major water users in the basin. Application of HMG 3.G would have helped identify this issue earlier during model configuration and could have led to a more streamlined modeling process. Later in the project process, the Applicant's operations plan showed different operations than were initially modeled. This required post-processing of model output to incorporate into the effects analysis. Incorporation of the operations plan could have occurred during initial modeling, or if a more streamlined modeling process had been adopted, would have allowed for straightforward introduction into the model rather than using post-processing.

In Case Study 8.1.5, the Applicant provided revisions to its initial operations plan after modeling for the effects analysis was completed. The plan differed from the assumptions used in the modeling used for the effects analysis. The Corps had to re-evaluate the effects of the operations plan relative to the model output used in the effects analysis. Incorporation of the operations plan into the effects analysis would have avoided this additional step.

conditions. If project conditions permit, both the RiverWare RPL rule construction and Corp permit condition should be related to a measurable quantity, such as a stream flow gage or a reservoir stage so that compliance with the modeled and permitted condition can be demonstrated during actual operations. (Example permit conditions are in an **Appendix C,** which provides examples of what has been done and can be required).

In addition, in situations where water must be tracked by different owners or designated uses, RiverWare has an accounting feature that runs simultaneously with the simulation of the physical features of the model. RiverWare RPL rules can be applied to both the physical features of the model as well as the accounting features. This feature allows for complex water trades, swaps, and exchanges to occur "on paper" while continuing to simulate the physical flow of water that is necessary for the aquatic resources effects analysis.

7.7.2 Water Administration and Water Rights

Many water supply projects are subject to administration by local water authorities. For example, in Texas, water users are subject to the water rights system and any terms and conditions of the specific water right, often with reporting requirements to the TCEQ through accounting plans. Administration of water rights may be a significant driver of a proposed project's operations, especially in areas where there is competition for water resources. The Corps and Applicant should be aware of specific requirements associated with an Applicant's water right(s) to ensure that they are reasonably portrayed in the modeling. In some cases, a water right can be modified such that the project need is met (or an alternative can generate the needed amount to address the purpose and need) and allow the ability to avoid, minimize, and possibly compensate for adverse effects of a proposed project. Potential modifications can be evaluated using hydrologic modeling.

Some hydrologic models do not simulate water rights. RiverWare has a water rights solver package, but absent use of this package, will not allocate water based on water rights. Actual water rights administration may impact the operations of a project and will differ from model results that do not include water rights administration. In regions where water rights are actively administered and affect a proposed project's operations, models that do not simulate water rights should be avoided or at a minimum evaluated carefully to determine the magnitude of potential error introduced by ignoring water administration practices.

Some hydrologic models that simulate water rights administration may miss other operational factors that would affect administration. Modification of the water rights solver can be challenging or impossible in some model platforms because these features are "hard-wired" into the model code. For example, many water rights models used by water providers in Colorado reasonably represent administration of water rights but lack the ability to include operations that may change based on other conditions within the basin.

RiverWare includes a water rights solver package that can be paired with other model functionality (built-in functions or RPL and accounting features) that provides much more capacity to simulate a wide variety of operations that fall outside of standard "hard-wired" categories. However, RiverWare's water rights solver can be much slower than other linear solvers used in other modeling platforms. The time required to simulate water rights in RiverWare increases as the number of water rights and RPL rules increases. In

instances where the RiverWare water rights package increases model execution time to an unacceptable level (for example, several hours or even multiple days), other options may be available. For example, a simple RiverWare model run or another model platform that can quickly solve for base-level water diversions according to water rights can be used and then imported into RiverWare as diversion demands for subsequent analysis. This type of modification can result in other inefficiencies and compatibility issues and should be avoided if possible.

7.8 GUIDELINE 3.H: The study period time frame should consider reasonably foreseeable future actions for the development of a future-conditions baseline.

Hydrologic modeling for a proposed project must consider other risk factors that influence hydrology within the project area. A proposed project located in an area, watershed, or drainage basin that is expected to experience significant changes in water use, management, and possibly land use must consider how those expected changes in the future will alter the hydrology relative to current or historical conditions. While many of these actions need to be captured in the cumulative effects analysis associated with the Corps' 404(b)(1), NEPA, and PIR analyses, particular influences on hydrology are of substantial importance when developing future conditions and determining associated impacts of a proposed project and its alternatives that are not constrained to the cumulative effects analysis but are project specific.

Assessing potential future changes can be a difficult task due to the uncertainty of completion of a different proposed project and the level of development of hydrologic modeling (if any) of the other project(s). Broad and unqualified speculation must be avoided to maintain integrity in the analysis as well as the decision that it supports. The Corps must use professional judgment as well as local knowledge to determine to what level (if any) of analysis is required to incorporate the potential changes to hydrology from other proposed projects. A key consideration here is to appropriately determine which effects are caused by the project, which are relevant to other actions, as well as the overall cumulative effects to the aquatic ecosystem.

Several different model runs may be needed to quantify the effects to aquatic resources from a project as well as its alternatives. In basins where significant changes to water use and management are reasonably foreseeable, the Corps should develop two baseline conditions: one that simulates the current conditions, and one that represents the expected future conditions without the proposed project (**future conditions baseline***). Several model runs with the project

Case Study

In Case Study 8.2.2, the Applicant developed a future conditions baseline that included the potential impacts from 21 different water development activities occurring in the watersheds where the Applicant project and alternatives would operate. Several of the activities would have minimal influence on the proposed project, and were discussed qualitatively. Other projects located within the same watersheds that would likely influence flows within the geographic extent were expressly simulated in the hydrologic modeling. These reasonable foreseeable future actions (RFFAs) were also included in the cumulative effects analysis.

active (or its alternatives) may be needed to quantify the effects to aquatic resources that are attributable to the proposed project, as compared to being attributed to other anticipated changes in the basin. Development of a current conditions baseline and future-conditions baseline allows for a bracketing of potential effects to occur from the proposed project. The measured aquatic resource conditions that exist in the subject waterbody (i.e., types and numbers of fish, geomorphic conditions, etc.) are reflective of the current conditions baseline hydrology. Projected "future-conditions baseline hydrology" instills the need to project future resource conditions without the ability to measure those conditions, introducing substantial doubt as to the validity of what aquatic resource status and functions will exist at that future time. Such projections greatly increase the potential for various degrees of speculation and reduce the confidence in understanding and determining the causal effects of the project. The bracketing of conditions through the current and future-conditions baseline comparisons allows for a determination that the effects are captured in the outputs of the hydrologic analysis. The "future without-project baseline" also can be used to address cumulative effects associated with a single-permit decision. Further, a more complex series of cumulative effects runs may be required if multiple water-related projects in the same watershed or drainage basin to be developed over a period of time are proposed, or if the project is an extension of an existing water supply system. The Corps project manager and Applicant should further recognize that if a proposed project and its alternatives occur in differing watersheds or drainage basins, modeling efforts can possibly increase exponentially.

Future-conditions modeling may also need to consider the effects of climate change on the proposed project. If already included in the needs analysis for the project and the yield analysis, consistency in predictive effects analysis and conditions must be maintained. In many areas of the country, climate change is predicted to bring more extreme weather events than seen historically — prolonged drought and shorter, higher-intensity precipitation events. To the extent that these changes are sufficiently quantified, they can be evaluated in the context of the proposed project within the hydrologic modeling.

8.0 Case Studies

Throughout the previous sections, references were made to specific case studies where a particular HMG would have been applicable. This section uses seven case studies and shows in each instance how considerations of and information identified with the HMGs was or would be applied and in many instances resulted in or could have produced a more efficient permitting process with respect to information related to the project as well as hydrologic data and modeling. The purpose of these case studies is to demonstrate how the HMGs were or could be applied within the context of several different projects of different sizes and complexity.

These case studies include projects involving Corps permit evaluations from Texas, Louisiana, and Colorado that have a sufficient level of documentation of the process used to gather hydrologic data and in some cases modeling associated with the project. The case studies also show some of the modeling and communication challenges encountered with these projects for the effects analyses and in some cases the alternatives analysis. These case studies provide examples of the application of the HMGs and demonstrate where Applicants and the Corps may have been able to arrive at the needed information more efficiently. It needs to be recognized that there are extensive amounts of information associated with each of the case studies relative to the Corps' process and coordination requirements. Additionally, the amount of detail for each project that could be included is too abundant to mention or describe. Therefore, the information associated with each of the case studies has been limited to focus on demonstrating how the HMGs relate to the key aspects of the examples.

Table 2. HMGs described with each case study.

HMG	HMG Description	Sabine River Intake	Turkey Peak Expansion	Stillhouse Hollow	Trinity River Intake	Lake Ralph Hall	NISP	Moffat
1.A	Describe the organizational structure of the applicant	✓	✓	✓				
1.B	Describe the existing system and operations		✓	✓	✓	✓		
1.C	Describe the proposed project and anticipated operations	✓	✓	✓	✓	✓		
1.D	Identify existing relevant hydrologic data and hydrologic models	✓	✓	✓	✓	✓		
1.E	Determine the geographic scope of assessment	✓	✓	✓	✓	✓		
1.F	Minor level project analysis and determination	✓	✓	✓	✓	✓		
2.A	Gather the best available hydrologic data for the project area		✓		✓	✓		
2.B	Determine critical hydrologic period for analysis		✓		✓	✓		
2.C	Determine the time-step required for hydrologic modification analysis		✓		✓	✓		
2.D	Understand assumptions included in any modeling used		✓		✓	✓		
2.E	Hydrologic modification analysis should preferentially use observed data for a baseline and modeled data secondarily		✓		✓	✓		
2.F	Coordination with resource agencies		✓		✓	✓		
2.G	Simplify hydrologic modification analysis as much as possible to make determination of adequacy of analysis		✓		✓	✓		
3.A	Use any applicant-provided modeling where appropriate to save time and money in hydrologic model development					✓	✓	✓
3.B	Hydrologic model should be designed around known or anticipated needs of aquatic resources to be evaluated					✓	✓	

Table 2, Cont.

HMG	HMG Description	Sabine River Intakes	Turkey Peak Expansion	Stillhouse Hollow	Trinity River Intake	Lake Ralph Hall	NISP	Moffat
3.C	Model purpose should be centered on reasonably representing stream flows under a variety of conditions, including critical periods		✓			✓	✓	
3.D	Simulate avoidance and minimization actions separate from compensatory mitigation		✓*					✓
3.E	Model domain should encompass geographic extent and a sufficient study period to accurately reflect the range of effects					✓		✓
3.F	Model time-step should reflect the critical time-scale of the aquatic resources being evaluated					✓		✓
3.G	Proposed operations and administration should be incorporated into the hydrologic modeling					✓	✓	✓
3.H	The study period time frame should consider reasonably foreseeable future actions for the development of a future conditions baseline						✓	✓

* Simulation of compensatory mitigation was not expressly simulated for the Turkey Peak Expansion, but distinction between avoidance and minimization and compensatory mitigation was made in the evaluation

Checks indicate case studies where the HMG is discussed in this report. Blank boxes indicate HMGs were not included in this report for the specific project, but does not indicate that information addressed by the HMG was not developed through the course of the project.

8.1 Fort Worth District Water Supply Projects

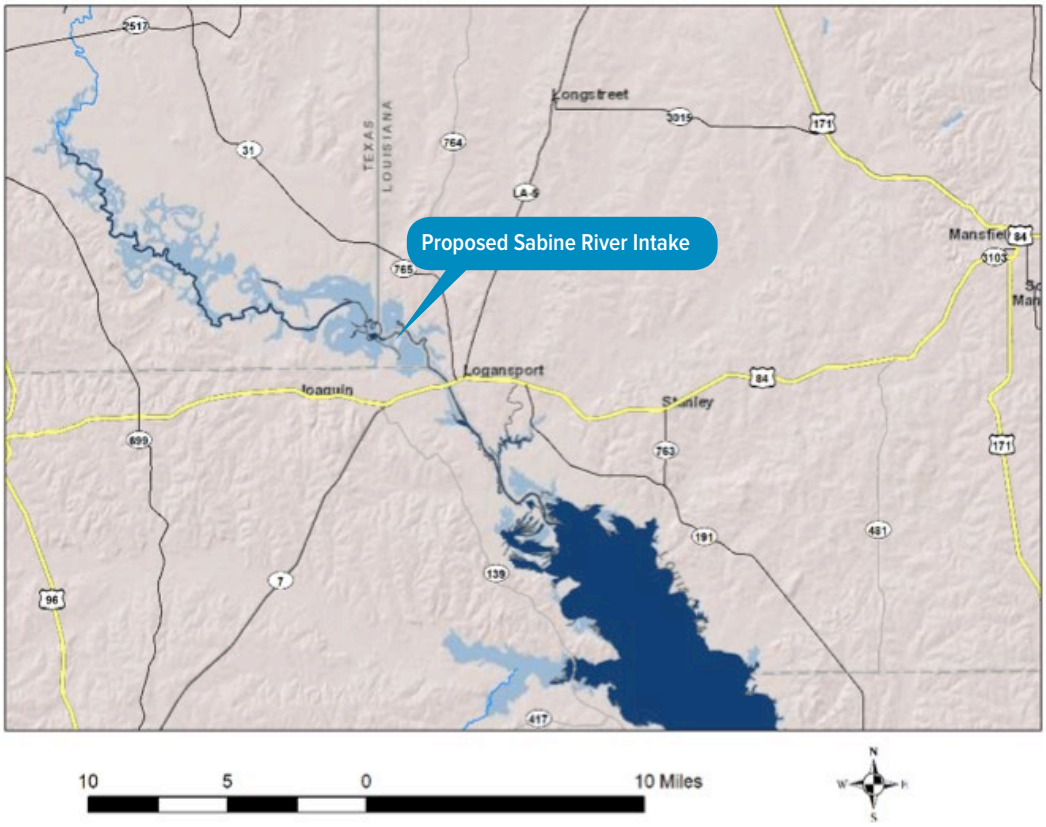
In the Fort Worth District, we examine five different projects that run the spectrum from a relatively simple river intake permit associated with an NWP verification to a Standard Individual Permit with a full EIS. One of the case studies occurred in Louisiana, and the remaining four occurred within Texas. In the four Texas projects, a water right issued by the TCEQ had already been obtained by the Applicant prior to or during evaluation of the Corps permit, or water had been secured or was in the process of being secured by contract or other form of agreement from other water providers. Each case study includes a

general description of the project and pertinent documentation contained in the Corps' administrative record, and then a step-wise guide through implementation of all or some of the most relevant HMGs with associated indications on where HMGs could have improved the process.

8.1.1 Sabine River Intake

The Sabine River Intake project involved a proposed water intake for oil and gas development to be evaluated under the provisions of an NWP. As described in Section 3, while relevant 404(b)(1), NEPA, and PIR evaluations have already been completed for NWPs, the Corps is required to determine if proposed actions to occur under such permits result in minimal adverse effects to the aquatic ecosystem as well as the public interest. The project is located near Logansport, Louisiana, shown in Figure 2. This pump station is located on the Louisiana side of the Sabine River that forms the border between Texas and Louisiana and therefore did not have a Texas water right. Information submitted by the Applicant to the Corps provided information about potential changes in flow at the location of the proposed pump station. This information was part of a larger discussion between the Corps and the Applicant about the hydrology at the point of diversion from the Sabine River. The permit application provided additional information

Figure 2. The Sabine River Intake location is near Logansport, LA, which is adjacent to the border of Texas and Louisiana.



about the Applicant and the proposed project that addresses several of the Tier-1 HMGs' (Standard Information Needs) sections. Much of this information was initially discussed during a pre-application meeting between the Applicant, the consultant, and the Corps. Use of the HMGs could have facilitated these pre-application discussions and resulted in an improved application and more efficient review process through the elimination of review efforts by more than one Corps project manager.

Application of Guideline 1.A: Describe the organizational structure of the Applicant

The Applicant is M5 Midstream LLC. M5 Midstream proposed to install intake pipes to withdraw water from the Sabine River at the tail end of Toledo Bend Reservoir in DeSoto Parish, Louisiana, to facilitate fractionation operations as part of their Fresh Water Project. The Applicant is a new industrial water provider with a narrow target area and limited water source. The Applicant provided information that multiple end users will be able to use water from the project as oil and gas development continues to grow in the area. Since this action is an NWP, project need information was exceptionally limited and considered to generally be unnecessary. No additional information was requested by the Corps relative to their organizational structure.

Application of Guideline 1.C: Describe the proposed project and anticipated operations

The Fresh Water Project will provide a steady source of water for fractionation companies to use in operations. Water for the diversion will come from a future water sales contract between the Applicant and the Sabine River Authority from Toledo Bend Reservoir, which stated that such sale would be subject to approval by the Federal Energy Commission due to the reservoir's involvement. The proposed project entails the construction of an intake point in the Sabine River near the upstream end of the Toledo Bend Reservoir. The facility will be 150′ × 135′ along the banks of the Sabine River, and the water will be pumped through 51,092′ of pipeline to a 3-million-barrel (387 AF) storage pond at the pipeline terminus. The facility can be accessed via an existing gravel road, and the property is owned by the Sabine River Authority of Louisiana. Overhead electric lines (7,350′) will also be installed to support the three pumps. With the three pumps, the anticipated maximum amount of withdrawal is 10 cfs. The pumps will perform at their highest capacity for the first month until the storage pond is filled, and then be used only to replenish water withdrawn for fractionation. The operations will vary based on the number of rigs the water is supporting — up to 7 or 8 rigs (150,000 barrels/day or about 19 AF/day) at the highest rate. 19 AF per day is approximately equivalent to 10 cfs for 24 hours.

Application of Guideline 1.D: Identify existing hydrology models and relevant data

The Applicant provided information about the hydrology at the proposed pump station site. The Corps also obtained specific stream gage data on the Sabine River above and below the project site and Toledo Bend Reservoir from USGS site 08022040 (Sabine Rv nr Beckville, TX) and USGS site 08022040 (Sabine Rv at Toledo Bd Res nr Burkeville, TX). Average flows over the past 45 years at the downstream gage indicate that flows are typically several thousand cfs with lowest average flows in October of several hundred to the low 1000's cfs. The upstream gage indicates flows average several thousand cfs in winter and spring months, with October showing the lowest average flows

of several hundred cfs. The upstream gage is located several miles above the proposed intake and there is significant additional contributing area downstream of the gage and upstream of the intake. The average annual volume of flow below Toledo Bend Reservoir (based on Gage 0802630) is approximately 4,000,000 AF. The average annual flow at the upstream gage (Gage 08022040) is approximately 1,800,000 AF.

The submission included other information showing that the Sabine River bottom at the project site is at a lower elevation than the lowest historical elevation of Toledo Bend Reservoir (November 2011), and therefore, the pump station is within the reservoir, not the flowing channel of the Sabine River. No flow data is available at the pump station because the reservoir's backwater effects make this area a submerged area of the reservoir rather than a flowing stream. The Applicant provided survey data and correlated historical low lake elevation at the dam with the historical low river stage measurement at the Highway 84 bridge at Logansport, further supporting the backwater effect conclusion. Soil maps, topographic maps, USGS gages, and historical reservoir levels were provided for the impacted area. No hydrologic modeling was performed due to the intake effectively being on a reservoir, where water levels can be monitored and maintained while not affecting other parts of the river.

Application of Guideline 1.E: Determine the geographic scope of assessment

The initial area of interest for hydrologic assessment included an upstream gage location and downstream gage location as well as the river reach below Toledo Bend Reservoir. Due to the project involving a single new intake that was not tied into an existing system, the amount of water to be withdrawn in relation to an exceptionally large reservoir, and the potential for effects to the aquatic ecosystem to a localized area, the geographic scope of assessment was narrowed by the Corps to just the project vicinity.

Application of Guideline 1.F: Minor-level project analysis and determination

Based on the information provided by the Applicant and additional information gathered by the Corps that reflect Tier-1 HMGs, the Corps made a determination of minimal detrimental impacts to aquatic resources and the public interest without additional hydrologic analysis or site-specific in-channel resource assessments. This determination was based on these factors:

1) The intake location is below the high-water elevation of Toledo Bend Reservoir and is below the historical lowest elevation of Toledo Bend Reservoir. Therefore, streamflow will not be affected by withdrawals at this location, even when inflows to the reservoir are low during drought periods.
2) The volume of water proposed to be used by the Applicant is very small compared to the overall reservoir mass balance. The pond that will be filled has a capacity of approximately 387 AF and will be filled at a rate of no more than 10 cfs (19 AF/d). Expected annual usage was not provided, but at 10 cfs, the maximum potential use is 7,200 AF. Average annual outflows from the reservoir are approximately 4,000,000 AF. Dry-year outflows are significantly less (356,000 AF in 1996). Upstream inflows are also significantly lower in dry years, (200,000 to 500,000 AF).

3) Even in dry years, the reservoir stage was several feet above the proposed intake elevation and removal of the proposed amount of water would have a negligible impact on reservoir stage and overall reservoir mass balance.
4) Agency coordination and involvement was required for this particular action. The Louisiana Department of Natural Resources commented and requested information similar to that reviewed by the Corps. They also identified concerns relative to cumulative effects due to other intake actions reasonably foreseeable in the project area. Water quality impacts were considered to not occur by the state during low-flow and low-reservoir conditions. The state did request that monitoring occur during operations and suggested other contingencies. No special conditions were determined to be warranted by the Corps relative to operation of the project and its effects.
5) This case study resulted in a Corps action occurring within established and allowable time frames for NWP reviews. However, some greater efficiencies could possibly have been achieved associated with better identification by the Corps of submission materials such as the location and data from the evaluated gages.

8.1.2 Turkey Peak (Complex EA with Standard IP)

The Turkey Peak Reservoir Expansion project (TPE) is located in the Brazos River Basin in Texas near Mineral Wells, TX, shown in Figure 3. The proposed project will expand an existing reservoir (Lake Palo Pinto) by constructing a new dam downstream of the existing Lake Palo Pinto dam, lowering a portion of the existing dam, and maintaining the same conservation pool elevation. In addition to creating new storage and firm yield, the expansion is intended to also restore usable capacity of the reservoir lost in Lake Palo Pinto to approximately 50 years of sedimentation.

The project was approved by the Texas Water Development Board in 2008 as a Recommended Water Management Strategy. The original permit application was submitted to the Corps in 2009. The Corps did not request hydrologic information or analysis until 2015 to address effects to occur to the aquatic ecosystem which also captured the new drought of record for the 2012–2015 period affecting the water supply of the basin. The Applicant developed and submitted a daily RiverWare model associated with the project. In May 2016, the Corps had the USGS review the updated modeling for the project, and the modeling was found to be adequate for the purposes of the project. The Corps requested additional information related to the proposed operations and mitigation. Availability of the HMGs at the outset of the process would have notified and informed the Corps and Applicant of the types of information that was needed to evaluate a project of this type.

Figure 3. Map of the Brazos River Basin and location of proposed Turkey Peak Expansion.

Application of Guideline 1.A: Describe the organizational structure of the Applicant

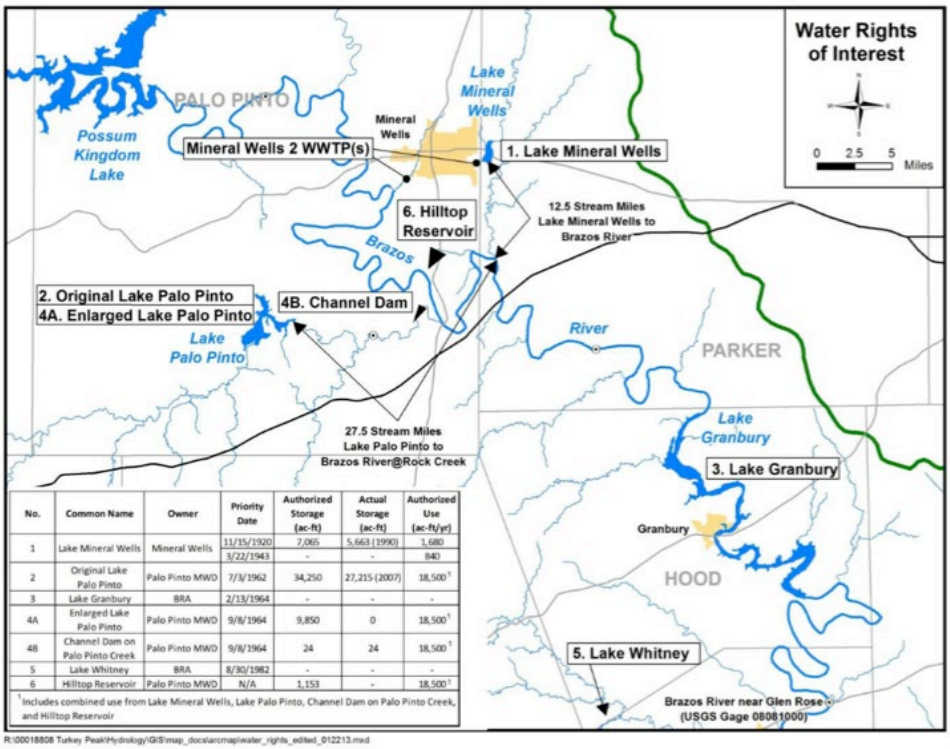
The Applicant is Palo Pinto County Municipal Water District No. 1. The organization serves water to approximately 30,000 customers and other water providers. They are located near Mineral Wells, Texas and provide water to the city and its surrounding area. The Applicant's system and proposed project will serve a major industrial user as well as proposed growth in the Applicant's designated service area. Additional requests by the Corps to clarify who was to be served by the project and the Applicant's responsibilities to provide water occurred during the permit review. A more thorough discussion at the outset of the review potentially fostered by this HMG could have yielded some efficiencies and possibly avoided the need to request and submit additional information as the process progressed.

Application of Guideline 1.B: Describe the existing system and operations

The Applicant draws its water supplies from existing reservoirs, Lake Palo Pinto (LPP) and Hilltop Reservoir. LPP is located along Palo Pinto Creek (PPC) south of the primary service area. The conservation pool elevation of LPP is 867 feet above mean sea level. The Applicant has a 1962 (amended 1964) water right to divert up to 18,500 AF per year from LPP. The Applicant currently delivers this water into PPC and diverts this water at a downstream diversion dam approximately 10 miles downstream of the LPP dam shown in Figure 4, and to Hilltop Reservoir which functions as a staging reservoir. The Applicant states that based on its water right, it could divert this water directly from LPP through a new pipeline rather than continuing the historical practice of releasing to PPC for downstream diversion. The Applicant obtained a new water right in 2015 for the proposed TPE. The water right references a Lake Mineral Wells which is not discussed in any of the initial Applicant's information. Additionally, water rights associated with the proposed reservoir refer to exchanges occurring in the Brazos River as well as some relationship to Possum Kingdom Reservoir, which can create additional requirements to pursue information and understand their inter-relationship. The water rights of interest are shown in Figure 5. Lake Mineral Wells was later found to not be part of the operational system and was not reflected in the modeling, but its later identification and potential

Figure 4. Lake Palo Pinto Dam is located near Mineral Wells, Texas. The proposed project would expand the storage by creating another reservoir immediately downstream from Lake Palo Pinto.

addition to the modeling could have resulted in additional delays and costs. It is believed that having the HMGs and associated checklist could have contributed to earlier identification of these potential components to allow earlier discussions relative to their inclusion or exclusion.



No.	Common Name	Owner	Priority Date	Authorized Storage (ac-ft)	Actual Storage (ac-ft)	Authorized Use (ac-ft/yr)
1	Lake Mineral Wells	Mineral Wells	11/15/1920	7,065	5,663 (1990)	1,680
			3/22/1943	-	-	840
2	Original Lake Palo Pinto	Palo Pinto MWD	7/3/1962	34,250	27,215 (2007)	18,500[1]
3	Lake Granbury	BRA	2/13/1964	-	-	-
4A	Enlarged Lake Palo Pinto	Palo Pinto MWD	9/8/1964	9,850	0	18,500[1]
4B	Channel Dam on Palo Pinto Creek	Palo Pinto MWD	9/8/1964	24	24	18,500[1]
5	Lake Whitney	BRA	8/30/1982	-	-	-
6	Hilltop Reservoir	Palo Pinto MWD	N/A	1,153	-	18,500[1]

[1] Includes combined use from Lake Mineral Wells, Lake Palo Pinto, Channel Dam on Palo Pinto Creek, and Hilltop Reservoir

R:\00018808 Turkey Peak\Hydrology\GIS\map_docs\arcmap\water_rights_edited_012213.mxd

Figure 5. Water rights of interest located near the proposed Turkey Peak Expansion.

Within the PPC watershed, there are few other water rights, summing to a total of 3.2 cfs, which can be considered negligible when calculating unregulated streamflow and water availability in this watershed. In addition, many of these water rights are not active or do not use the full amount allotted, so the 3.2 cfs is a conservative estimate for modeling purposes. All of these water rights were operational during the most recent drought, so any inflows into LPP reflect actual drought-period use of these other rights.

The population served by the Applicant is expected to increase by 18% from 2020 to 2070. The water supply of LPP is expected to decrease due to ongoing sedimentation. The effects of the recent drought reduced the firm yield of LPP by approximately 2,000 AF as shown in Figure 6, which further supports the need for the expansion project to meet future demands. Additional information concerning the Applicant's needs for the project and confirmation of the project purpose occurred, including outside verification of the municipal demands projected for the project, but not until well into the project review process. It is anticipated that use of the HMGs and supporting information could have contributed to the earlier identification of these needs.

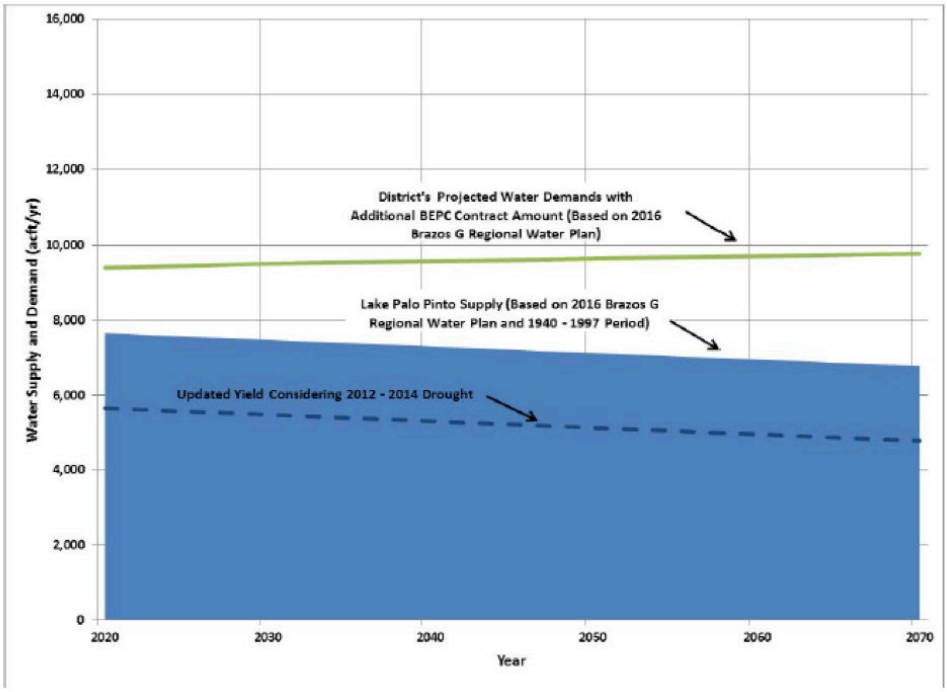
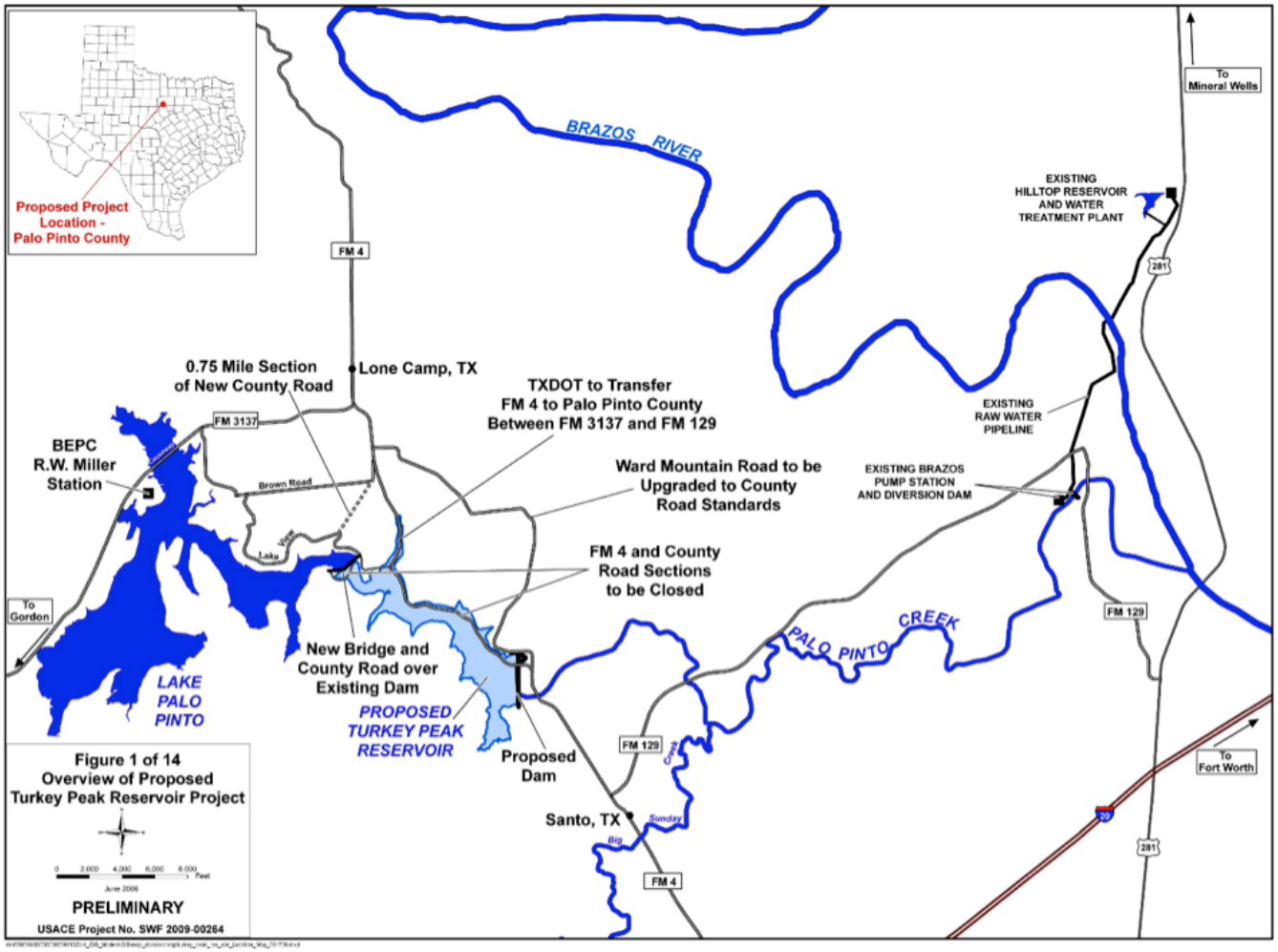


Figure 6. Summary of water demands for Palo Pinto County Municipal Water District No. 1 and results of early 2010s drought on supply.

Application of Guideline 1.C: Describe the proposed project and anticipated operations

The proposed project's purpose is to provide approximately 6,000 AF of water per year of new annual yield to the Applicant's service area for municipal and industrial uses. Part of that purpose includes restoring the permitted capacity to LPP lost due to sedimentation. The TPE spillway would be uncontrolled, but the multi-level outlet tower can control water releases from the dam. The pool elevation of the expansion will be the same level as LPP (867 feet above mean sea level), and a portion of the existing LPP dam will be removed to allow for boat passage between the TPE portion and the existing LPP. The proposed project operations would release water into PPC as has been done historically. The Applicant initially proposed making a continuous release of 8 cfs from the expansion associated with state analysis, whereas historically there have been several days (more than 30) where no flow has been released from LPP. Modifications to this condition occurred due to hydrologic and aquatic resource analysis as project review continued. The location of the existing LPP and proposed TPE are shown in Figure 7.

Figure 7. Map of Lake Palo Pinto and proposed Turkey Peak Expansion. Brazos River Basin.



The Applicant also evaluated several alternative reservoir sites, including raising the existing LPP dam elevation, but has stated that construction of other sites will cause more impacts to aquatic resources and may change operations from the historical practice of releasing water into PPC. Instead, it could use a pipeline to withdraw its water from LPP to avoid stream losses between LPP and its downstream diversion location.

The project would result in the discharge of approximately 10,115 CY of fill material into 1.3 acres (1,750 LF) of Palo Pinto Creek. Approximately 17.64 acres of various stream types (12.98 acres, 22,624 LF of perennial stream; 2.32 acres, 5,983 LF of intermittent stream; 2.24 acres, 16,711 LF of ephemeral stream) and 0.1 acre of wetland would be inundated by the impounded water at conservation pool elevation. The project includes operational releases and habitat improvement for

aquatic life downstream of the TPE, which is expected to increase due to the multi-level outlet tower increasing the dissolved oxygen and a minimum and pulse flow release operational framework.

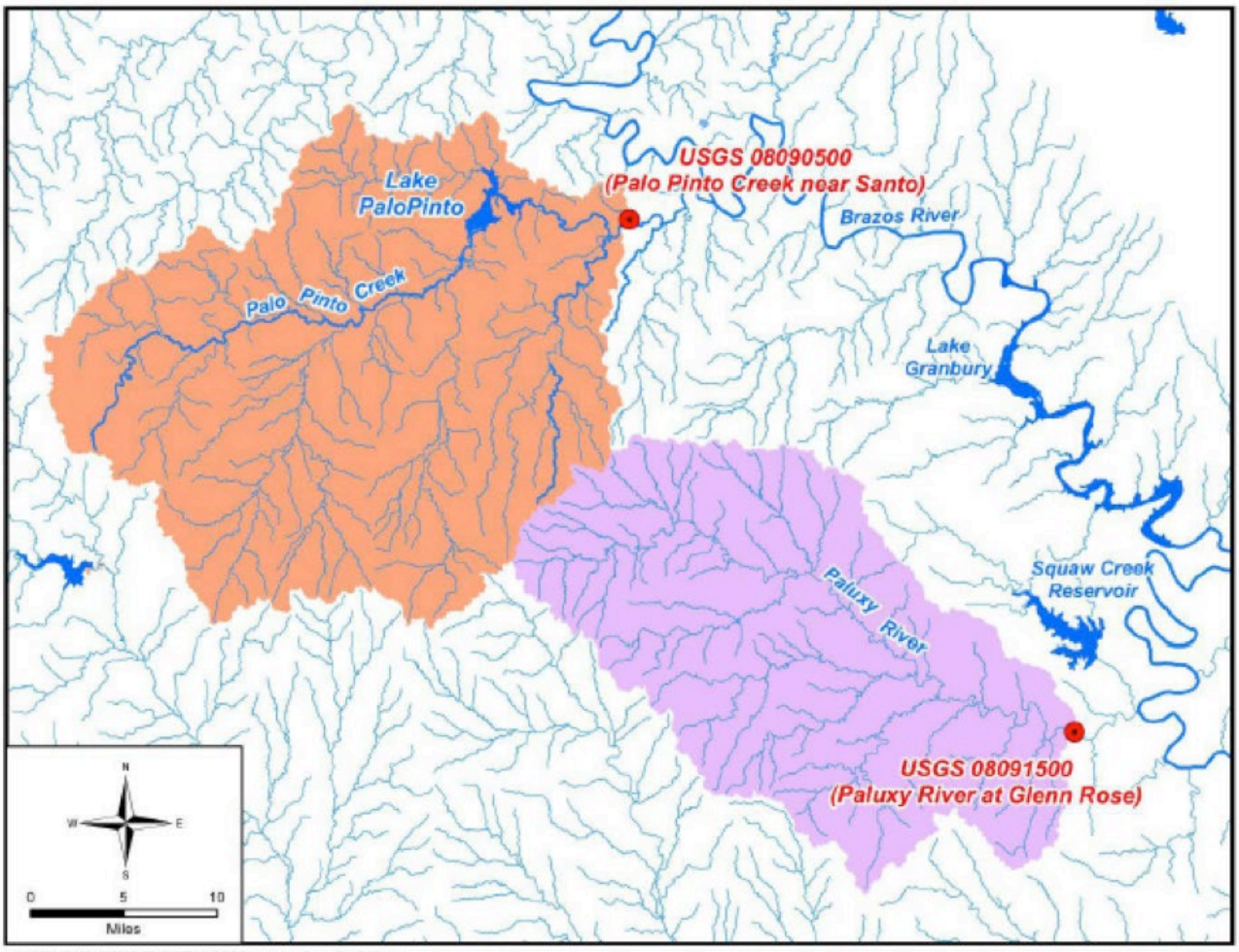
Application of Guideline 1.D: Identify existing hydrology models and relevant data

The Applicant provided data from two streamflow gages for comparison and correlation purposes, shown in Figure 8, one on the PPC (USGS 08090500; Santo Gage) and one on the river in the neighboring basin (USGS 08091500; Paluxy River Gage). Prior to the construction of LPP in 1964, the PPC gage is reflective of the natural conditions of PPC. After the reservoir construction, the Applicant used the neighboring Paluxy River Gage to estimate streamflows in PPC. Beginning in 1999, monthly reservoir records were available to reconstruct the flows in PPC upstream of LPP.

Monthly reservoir, evaporation, precipitation, and channel loss data were also available but not initially provided to the Corps. Information about other water rights in the basin was provided to the Corps. The Applicant has a TCEQ water rights permit and certification for the project. The Applicant included soil maps and data, maps of alternative storage sites and pipelines, maps of proposed clearing areas, and a map of project with contours, cross-sectional areas, road construction details, and topographic maps.

The Applicant originally used the Texas WAM model for the Brazos River (BWAM) to compute the yield of the project in support of its water right. Following the drought of the early 2010s, the Applicant updated modeling to a daily RiverWare model. The RiverWare model was evaluated by the USGS on behalf of the Corps. Existing information and reports as well as requests for additional evaluation associated with hydrology and modeling occurred over a period associated with the permit review. It is believed that availability of the HMGs would have resulted in earlier identification by the Corps to request hydrology and other information and allowed for more timely review.

Figure 8. Palo Pinto Creek and Paluxy River drainages used for neighboring-gage correlation analysis.



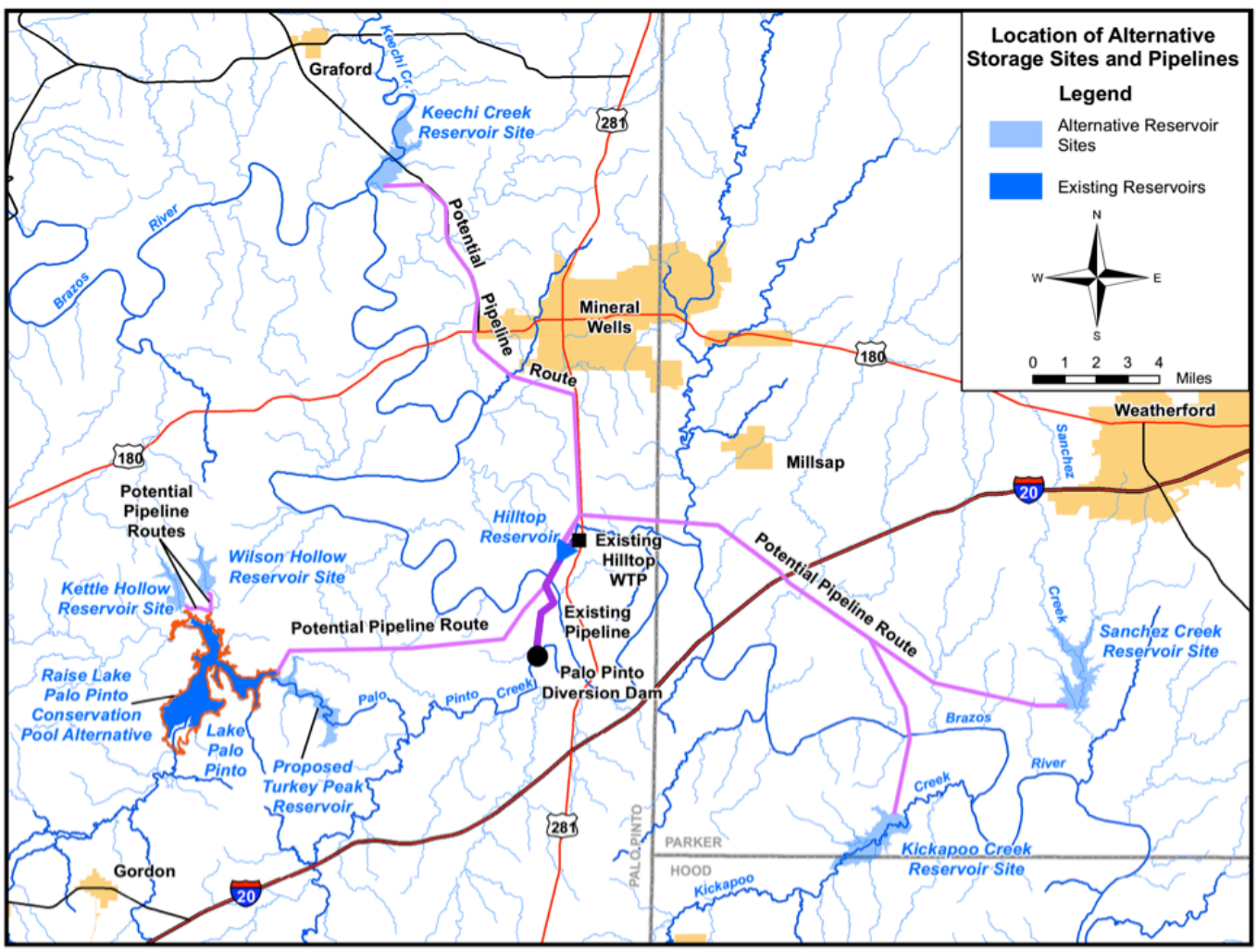
Application of Guideline 1.E: Determine the geographic scope of assessment

The TPE will have direct effects on the inundated area. In addition, the flows below LPP and the TPE will be changed due to the proposed operations of the project, including the initially proposed continuous release of at least 8 cfs that was later modified to lower proposed and required flow conditions. The District also proposed to bypass all inflows into the TPE from the watershed below the existing LPP. While all water delivered into PPC from the new reservoir will be diverted at the existing diversion structure, potential effects elsewhere were initially considered by the Corps based on information contained in the water rights to be used by the project for industrial purposes, which mentioned future return flow points of delivery relative to locations "in a water course in the Brazos River Basin." Downstream of the diversion dam, backwater from the Brazos River is often present in the channel. No analysis of the reach below the diversion dam was proposed by the Applicant due to this condition. Concerns raised by agencies during the Standard Individual Permit process did

result in consideration of potential effects below the diversion dam due to variations in Brazos River conditions, but the Corps concluded that detailed hydrologic analysis was not warranted. Therefore, the downstream extent of potential hydrologic modification was terminated at the diversion dam near the confluence with the Brazos River.

Evaluation of the effects at alternative reservoir sites and their associated streams (e.g., Keechi, Kickapoo, and Sanchez Creeks), shown in Figure 9, may be required in addition to the analysis to PPC if evaluation of streamflow below these locations is required. This level of analysis was not needed because some options were unable to generate the required yield, or initial comparisons of direct effects between the alternative sites and the proposed project revealed TPE would have fewer impacts to aquatic resources. Such considerations are evaluated to address the LEDPA requirement and should be accomplished rather than attempting to assess indirect hydrologic effects from such options.

Figure 9. Map of Turkey Peak Expansion site and alternative sites.



Application of Guideline 1.F: Minor-level project analysis and determination

Based on the information gathered in the Tier-1 HMGs, additional detail is required to reasonably assess the changes to the hydrologic system below the proposed project. In addition, if alternative sites are determined to be practicable alternatives and do not have less damaging direct effects compared to the Applicant's preferred option, additional analysis below these structures would be required. This project is a large project with proposed changes to the existing hydrologic system as well as the hydrologic regime created by the operation of the existing LPP over the past 50 years. Therefore, more detailed analysis will be needed to determine how the changes in operations will impact the watershed, and Tier-2 HMGs should be applied. In addition, due to the presence of existing hydrologic modeling, some Tier-3 HMGs will also be applicable.

Application of Guideline 2.A: Gather the best available hydrologic data for the project area

In addition to the streamflow and reservoir data described in 1.D, the Applicant provided channel losses calculated from a water balance approach, net evaporation, precipitation, and the operating plan for the reservoir system. Water rights, delineation maps, site photographs, stream data sheets, and a table of water bodies impacted by the proposed project were also included.

The Applicant provided detailed information about how inflows to LPP were computed or estimated based on historical gage data, neighboring-gage correlation, reservoir records, and monthly to daily flow pattern application. Historical reservoir records were used in developing reservoir inflows but were not provided. The Corps should obtain these records for verification purposes.

Streamflow information for the alternative sites was not provided. If additional evaluation of aquatic resources downstream of these facilities is warranted, additional investigation should occur.

The Applicant performed a Hydrology-Based Environmental Flow Regime (HEFR) analysis on the USGS Santo Gage prior to LPP construction to determine minimum environmental releases if the Applicant changed the historical operation of releases to PPC and instead diverted water directly from LPP by pipeline. This analysis indicated that releases would be small (1 to 2 cfs) and would likely result in reduction of fish species diversity and a change in riparian habitat.

Application of Guideline 2.B: Determine critical hydrologic period for analysis

Initially, the Applicant used the Brazos Water Availability Model with a period of record from 1940–1997. However, a drought from 2012–2015 forced a re-evaluation of the critical period and resulted in a new drought of record for this area. The new drought of record was re-evaluated with a RiverWare model. Using a period from 1949–2015 includes the severe droughts in the 1950s and the new drought of record in the 2010s.

At this stage, no specific aquatic resource factors have been identified for detailed evaluation. Therefore, a longer period of record that includes a wide range of hydrologic regimes (including wet, average, and dry) is appropriate so that detailed hydrologic information is available if specific resource factors are examined in more depth. The Applicant cites potential benefits to PPC

downstream of the reservoir based on the proposed continuous release from the enlarged LPP as compared to current operations. To the extent that this benefit needs to be quantified, it would be important to include this range of hydrology.

Application of Guideline 2.C: Determine the timestep required for hydrologic modification analysis

The Applicant chose to use daily timesteps when using the model to more accurately see impacts from alternative scenarios. Desired daily streamflow frequency curves at the Santo Gage were used to determine the amount of time a stream segment will see low or no flow.

Some reservoir data was available only in monthly format but was converted to daily format for modeling by correlating to a neighboring stream gage data as a pattern to apply to the monthly flow volume. Daily flows are important for this project based on the potential downstream aquatic resources.

Application of Guideline 2.D: Understand assumptions included in any modeling used

The Applicant had a monthly model used to obtain its water right (Brazos River WAM) developed by the TCEQ. This model was converted to a daily RiverWare model to extend the period of record to include the new drought of record and to conform to the Corps' desired modeling platform for evaluating effects to aquatic resources.

Inputs for the RiverWare model were developed using a variety of data and assumptions when data were not directly available. Reservoir inflows were computed from a combination of gage data, neighboring-gage correlation, and monthly reservoir records with a daily disaggregation method applied to monthly data. The neighboring-gage correlation was calibrated and various adjustments were made to create a better match during the two gage's overlapping time period. The raw data was obtained from USGS gages and from the District's reservoir records.

The RiverWare model assumes a conservative evaporation rate where no data is available. Channel and evaporation losses are affected by climate conditions in the model. The conservative assumptions about channel loss and evaporation assumptions will tend to show lower flows than would occur if actual losses are less. This is an appropriate assumption for this analysis. Channel loss in PPC was estimated using a mass balance approach and was correlated to net evaporation rates. The correlation is poor (Figure 10), so a sensitivity analysis may be useful to further quantify the potential impact of this assumption if resource factors within PPC are near known thresholds of adverse impacts.

The RiverWare model assumes that the incoming sediment will be captured by LPP and that the TPE sediment quantities will be negligible. The LPP sediment volume accumulations are assumed to be 42 AF per year, which is an estimate from the Texas Water Development Board. This assumption is reasonable.

Available documentation is not clear about how water demands for the Applicant are simulated in the model. It would be appropriate for high demands to be simulated to verify the yield of the project. However, if the Applicant intends to use its Hilltop Reservoir or Mineral Wells Lake as a supply, it is possible that a release of 8 cfs from LPP would not be needed to satisfy the Applicant's demand. As this release is assumed in the model at all times, this condition should be considered as a permit condition, or the simulation should account for any times where demand potentially would be met from the Applicant's other sources first. Additional analysis and efforts associated with the Corps' permit review resulted in modification to the proposed 8 cfs continuous flow proposal and lower flow conditions were incorporated. This includes times when releases will be halted from LPP during drought conditions as well as for maintenance of LPP outlet works. The revised flow conditions are included as permit conditions (see Appendix C, Example 6).

Application of Guideline 2.E: Hydrologic modification analysis should preferentially use observed data for a baseline and modeled data secondarily

Observed data downstream of LPP at the Santo Gage is appropriate to evaluate current hydrologic conditions based on the Applicant's historical operations of releasing water from the reservoir for diversion at the downstream diversion dam. A relatively simple hydrologic modification could be made to evaluate the initially proposed 8 cfs release by simply setting any flow less than 8 cfs to 8 cfs. This would assist in evaluations of low-flow conditions in PPC.

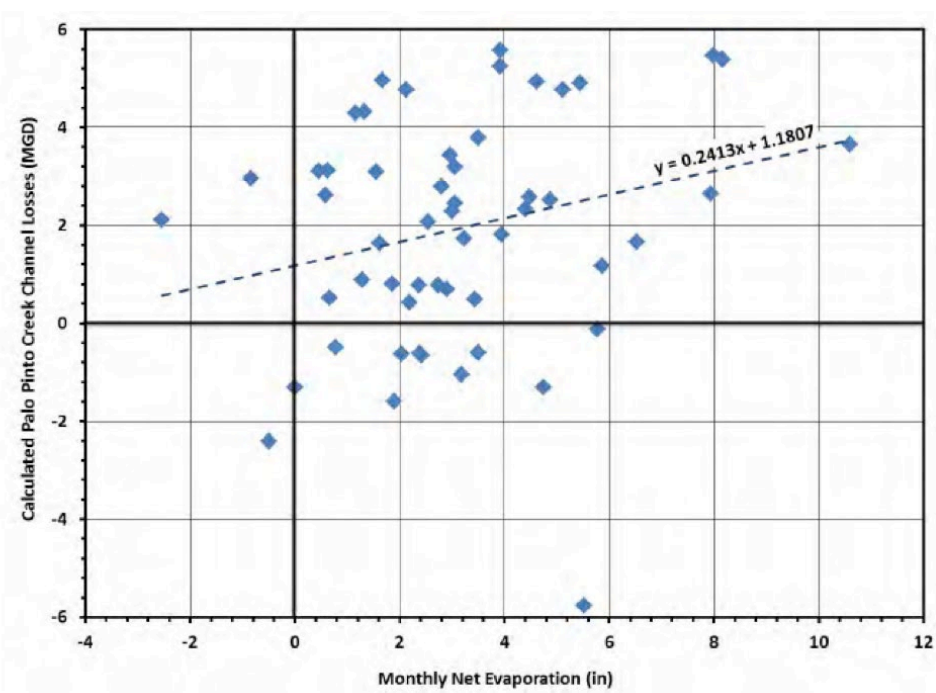


Figure 10. Comparison of evaporation and channel losses at Palo Pinto Creek.

However, as discussed in HMG 2.B, aquatic resources may be more affected by flows at different times of year or at different flow levels. Therefore, hydrologic modeling can provide a more robust dataset to evaluate potential changes to flow, such as changes to peak flows due to the reservoir enlargement or increased releases into PPC due to increased Applicant water demands. In addition, the Applicant has already performed hydrologic modeling so more complex effects can be evaluated using modeled data if the simple hydrologic modification described above is insufficient for the resources present.

Application of Guideline 2.F: Coordination with resource agencies

Because the project triggered the need for a Standard Individual Permit, coordination with the agencies was required and included the EPA, USFWS, TCEQ, and Texas Parks and Wildlife Department (TPWD). The Applicant also provided multiple mitigation plans that were coordinated with these agencies. Coordination and comments focused on aspects of resource assessment methods that are dependent upon hydrology but detailed evaluation of the hydrologic modeling remained with the Corps. Additional agency comments related to fish habitat within the reservoir itself (e.g., the decree of clearing of existing vegetation within the inundation area). Downstream impacts on aquatic habitat were discussed in the context of the Applicant's mitigation plan and the Applicant's assertion that they could construct a pipeline rather than continue the historical practice of releases. No analysis was accomplished to determine what the effects of a pipeline option would be since its indirect effects to aquatic resources would be substantially greater than the Applicant's proposed action and the alternative would not provide the required yield as reflected in the project purpose. Substantial time and additional site visits did occur relative to proposed compensatory mitigation in the downstream area from the project. Areas of evaluation and comment focused on actions to be undertaken in adjacent buffer areas, some in-channel modifications, and proposed flow conditions.

Application of Guideline 2.G: Simplify hydrologic analysis as much as possible to make determination of adequacy of analysis

An analysis of hydrologic modification as discussed in HMG 2.E could have been used to assess changes to low-flow conditions below the proposed LPP. This analysis would be useful for determining any potential effects to aquatic resources downstream of the proposed project. However, operations of the project included different release rates instead of the constant 8 cfs release as initially proposed and were informed by the modeling that was completed for the project.

While a simpler hydrologic analysis would characterize low-flow conditions, it will not fully characterize other flow conditions that will change based on the increased storage capacity of the proposed reservoir expansion, nor will it evaluate lake levels in LPP. Many of the early agency comments were related to aquatic habitat that was initially proposed within portions of the reservoir itself. That proposal was later rejected and eliminated. The RiverWare model developed for this project is better suited for an evaluation of lake levels and other potential changes to downstream hydrology than the simpler hydrologic modification analysis option. Additionally, no hydrologic modeling was performed for alternative sites, but in some cases may be necessary if direct impacts quantified for the alternative sites or practicability factors do not eliminate the other alternatives from consideration.

Due to the existing RiverWare modeling performed, it is appropriate to apply some additional Tier-3 HMGs — specifically, HMGs 3.C and 3.D.

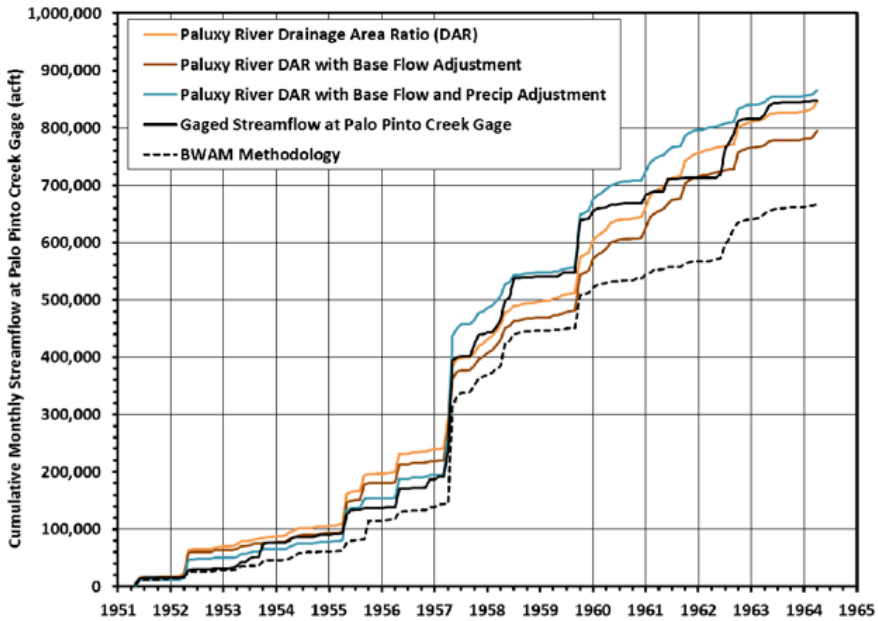
Application of Guideline 3.C: Model purpose should be centered on reasonably representing streamflows under a variety of conditions, including critical periods

Two hydrologic models were developed for the proposed project. The first model was the Texas model for the Brazos River (BWAM). The BWAM model was used to obtain the Applicant's water right for the expanded reservoir. The WAM models are yield models that include several conservative assumptions about water availability and regional demands and could result in reservoir and flow levels that are different than what would be anticipated from actual operations of the project. The conservative assumptions used in the BWAM model for the PPC basin are shown in Figure 11, an analysis performed by the Applicant when developing LPP reservoir inflows from historical stream gage data. The BWAM flows were consistently below historical gaged flows even in the absence of more recent significant water rights development. In addition, BWAM uses a monthly timestep which may not be sufficient for simulating flows below LPP at a temporal resolution useful for quantifying impacts to aquatic species. The BWAM model did not include the recent drought in the early 2010s. The drought caused shortages at LPP, causing the electrical generation plant located on the lake to shut down due to lack of available water. Provided the water users were all operating within the limits of their water rights, this clearly indicates that a new and more severe critical period occurred at LPP. For this reason, it would also be important to update the modeling to include this new period.

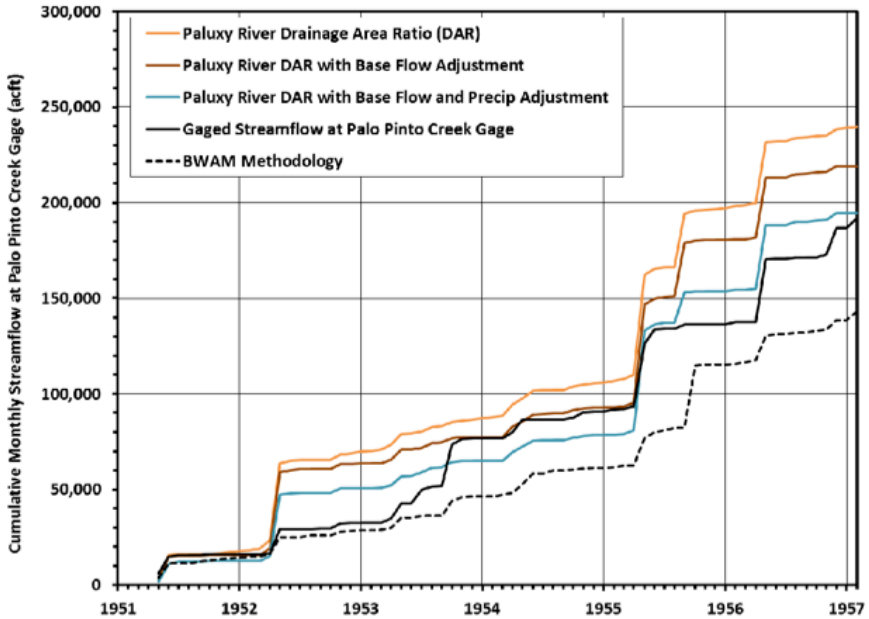
The Applicant next developed a RiverWare model for the basin. The model was able to simulate flows below LPP and reservoir levels in LPP. The model used a combination of historical gage data, neighboring-gage correlation, monthly reservoir mass balance, and a daily pattern to disaggregate monthly flows derived from the neighboring-gage correlation. The model was extended to consider the new critical period drought. Inflows to the model considered the use of water by other upstream water rights in the basin (a minimal amount — maximum of 3.2 cfs) by simply making no adjustments to inflows during the critical period when it was known that all water rights were active. Some model inputs were derived from monthly data (e.g., evaporation and precipitation) and would have little effect on the results if daily varying data had been used because these are much smaller components of the overall water budget than reservoir inflows. The simulated flows released from LPP were based on the proposed operations of the Applicant (8 cfs minimum release). It is not clear what demands were used by the Applicant in the modeling. If the future firm-yield demands were used, this could result in higher simulated releases than would occur under demands that are more representative of current conditions.

The USGS reviewed the RiverWare model and found the model to be adequate for the purposes of the effects analysis, although additional detail could be added if desired.

Figure 11. Palo Pinto Creek and Paluxy River have an overlapping period of record, which allows for comparison when modeling Palo Pinto Creek from the Paluxy River data.



Comparison of Gaged and Estimated Cumulative Monthly Streamflow at the Palo Pinto Creek Gage for Overlapping Period (May 1951–April 1964)



Comparison of Gaged and Estimated Cumulative Monthly Streamflow at the Palo Pinto Creek Gage for Drought Period (May 1951–January 1957)

Application of Guideline 3.D: Simulate Avoidance and Minimization actions separate from Compensatory Mitigation.

In addition to avoidance and minimization actions relative to aquatic resources, the Applicant submitted multiple conceptual mitigation plans for the proposed project. The primary way this project characterized avoiding impacts to waters of the U.S. was by avoiding alternate sites that would inundate larger areas of waters of the US. These avoidance measures cannot be quantified with a hydrologic model. In addition, the Applicant claimed the stream channel riparian functions downstream of LPP are more degraded due to construction and operation of LPP compared to the more natural settings of the alternate sites. Hydrologic modeling could be used to evaluate floodplain and geomorphology of the streams at the various sites if the relative quality of riparian resources factors is needed to render a permit decision.

The Applicant also initially stated that continuous releases of 8 cfs would be made to PPC, thereby enhancing aquatic resources downstream of the proposed reservoir. Further, the mitigation plan warns that the historical practice of releasing to PPC for downstream diversion could be stopped if an alternate site were selected that would require a pipeline and could reduce flows below LPP significantly.

The Applicant provided several methods of minimizing or compensating impacts at the proposed site, including:

- the aforementioned initially proposed minimum flow release of 8 cfs that was subsequently modified and now includes specific but lower flow releases that result in an exceptionally minor expansion of the reservoir (less than 100 AF) beyond the project need
- bypassing flows that accrue to the expanded reservoir from the portion of the watershed downstream of the original dam
- including measures to increase dissolved oxygen in the released water through construction of riffle pool and other structures to aerate released water
- a multi-level outlet tower that will help maintain acceptable temperature levels

In addition, the Applicant offered measures to limit future clearing of native vegetation along the shoreline of the expanded reservoir. This latter item was evaluated, rejected, and eliminated from the plan.

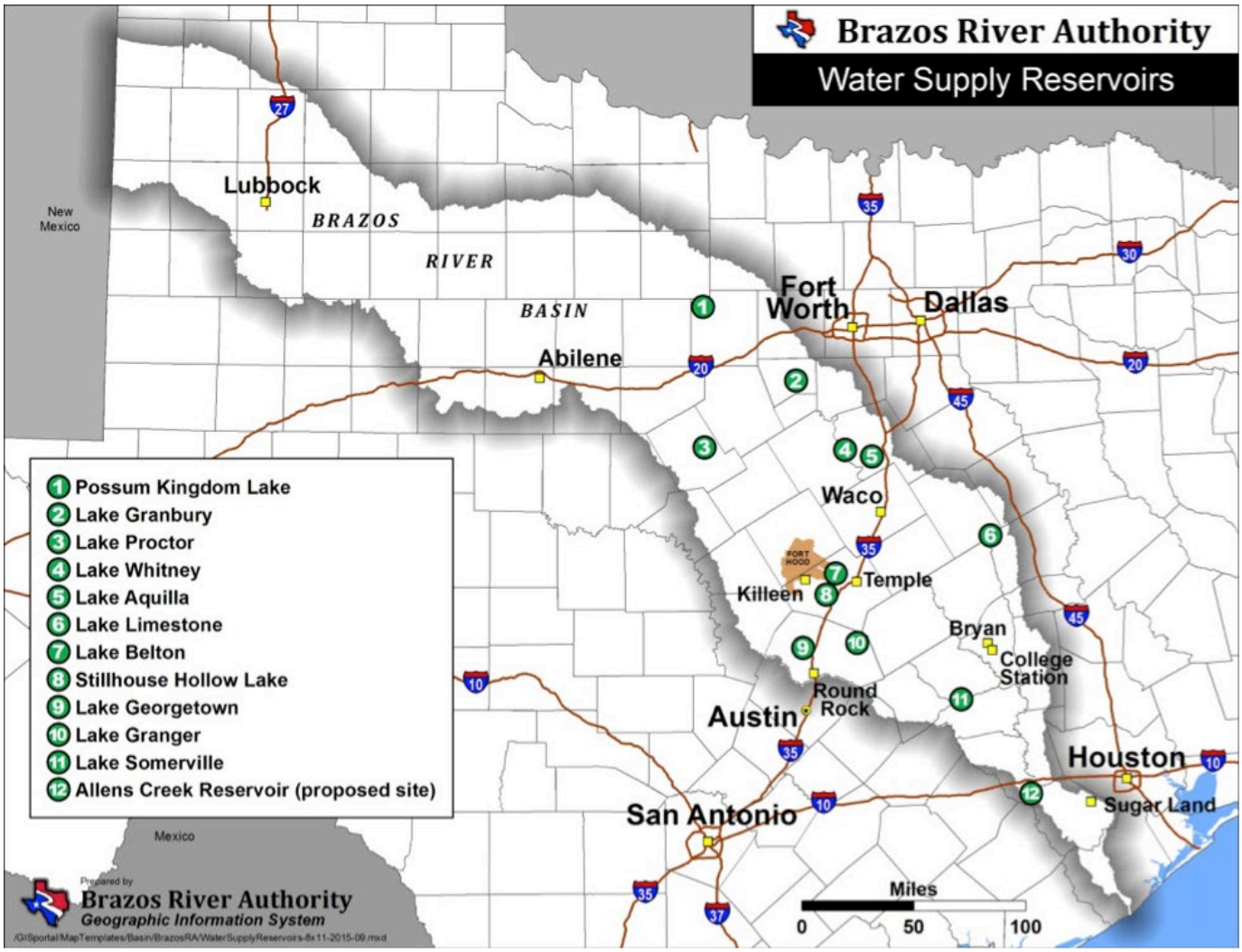
The conceptual mitigation plan combines avoidance and minimization with compensatory mitigation strategies related to construction (e.g., slightly larger dam and in-channel habitat features) and flow components of the plan (e.g., minor portions of the minimum flow releases). The RiverWare model could be modified to isolate these different activities and their associated effects when warranted, particularly as it relates to the additional minor flows. For this project, however, the direct impacts due to the reservoir site selection was the primary driver in determining the LEDPA and the impacts to occur from a minor increase in storage for minimum flows was so slight that a detailed separation of avoidance and minimization from compensatory mitigation was not necessary. The Applicant did provide a discussion of how much the compensatory mitigation for flows increased storage volumes.

While there are numerous circumstances surrounding the time it took to evaluate this particular project not specifically related to hydrologic analysis and modeling, as previously stated, had the HMGs been available and applied in the permit review process, efficiencies would have been achieved.

8.1.3 Stillhouse Hollow Lake

The Stillhouse Hollow Lake intake project involved an application from a local water provider to take delivery of 10,000 AF per year from Stillhouse Hollow Lake, a Corps reservoir located on the Lampasas River. The water provider currently withdraws water from a neighboring Corps reservoir, Lake Belton,

Figure 12. Brazos River Authority water supply reservoirs. Lake Belton and Stillhouse Hollow Lake (7 and 8) are part of the Little River system, located near Killeen and Temple, Texas.



located on the Leon River. The Leon and Lampasas Rivers confluence is several miles downstream of both lakes and forms the Little River which eventually discharges into the Brazos River. Both Stillhouse Hollow Lake and Lake Belton are part of the Brazos River Authority (BRA) system and are two of four lakes in BRA's Little River system. Water Supply reservoirs within the BRA are shown in Figure 12, with Lake Belton and Stillhouse Hollow Lakes shown as Nos. 7 and 8 in the figure. Lake Belton and Stillhouse Hollow Lake are used for flood control and water supply and are located on different streams.

As with NWP actions, the Corps attempted to keep the initial permit evaluation narrow and, based on the information provided, focused on the Stillhouse Hollow Lake from which the intake would be drawn. However, as information was provided through the permit process and questions were addressed concerning potential impact to other water bodies, consideration of Lake Belton and other stream reaches were added. Initial information from the Applicant suggested that water would be provided for the project from Lake Belton. Water from Lake Belton to serve the new intake was identified as questions were posed by the Corps concerning what the water source(s) would be for the project. After several discussions with the Applicant, it was determined that there would be no direct transfers between the two lakes. It was disclosed that the regional water authority — BRA — owns the water which was contracted by the Applicant, a local water provider. Because of questions the Corps posed concerning water use, any existing modeling, and how flow and operational changes may occur resulting from the use of the 10,000 AF/year, the BRA provided modeling. This modeling included Belton, Stillhouse Hollow, and two other lakes associated with the region that related to the water to be used with the intent of focusing in Stillhouse Hollow but also addressing changes that may occur with other waterbodies. BRA noted the relatively small amount of water this represented in their overall system. Through the BRA modeling and review of gage and release data, the Corps was able to eventually determine that no adverse effects would occur downstream of Stillhouse Hollow Lake, Lake Belton, and other areas that might be causally affected by the project. Significant time and energy was dedicated to determining where the effects could occur that are attributable to the proposed withdrawal of 10,000 AF. Application of Tier-1 HMGs may have provided enough additional information and facilitated more specific questions and responses at the onset of the project to ensure that needed information was identified as well as avoid confusion and multiple information requests. In this particular case, the source water and its current use/non-use to be diverted by the project was important information.

Application of Guideline 1.A: Describe the organizational structure of the Applicant

The Applicant for the Stillhouse Hollow Lake operation is Bell County Water Control & Improvement District No. 1 (WCID #1). WCID #1 provides water to Fort Hood, City of Killeen, City of Parker Heights, City of Belton, City of Copperas Cove, Bell County WCID No. 3 (Nolanville), 439 Water Supply Corporation, and Lake Belton Outdoor Recreation Area.

Currently, the Applicant serves over 250,000 people and has the ability to treat and transport over 90 million gallons per day (MGD). The Applicant currently uses water solely from Lake Belton but wants to expand its water supply by constructing a project that uses water from Stillhouse Hollow Lake.

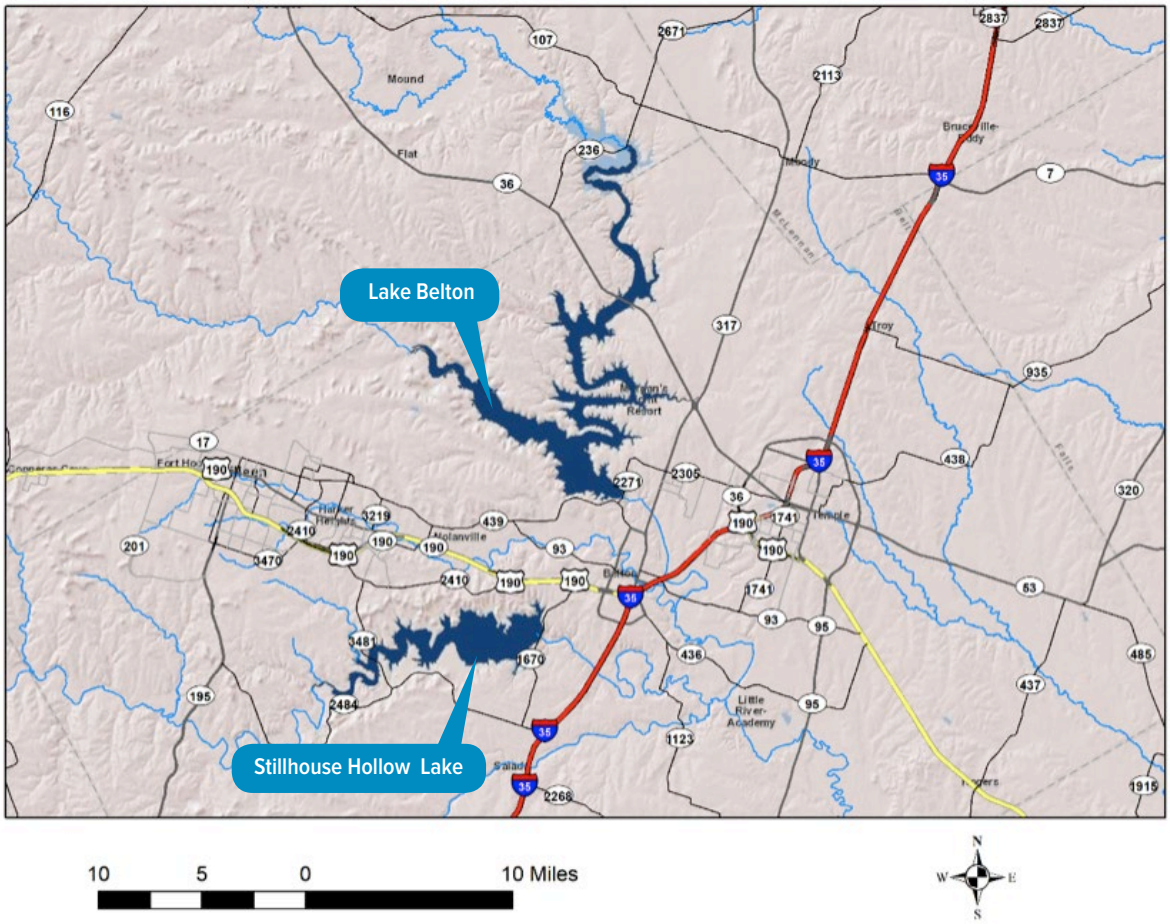
The Applicant contracted for 10,000 AF of water from Stillhouse Hollow Lake from the regional water authority, BRA. The BRA manages 11 larger reservoirs throughout the Brazos River Basin (shown in Figure 12), which encompasses a large area extending from northwest Texas to the Gulf

of Mexico near Houston, Texas. Although not the Applicant, the BRA is providing the water to the Applicant at Stillhouse Hollow Lake. As a regional water authority, BRA will likely have a significant amount of hydrologic information, modeling, and analysis that may assist in this project. Applicant arrangements relative to a proposed project, both to users they may supply beyond themselves and associated with the water rights to be used, can add complications to a permit evaluation. Information associated with this HMG can provide insights and information needed to ensure that relevant aspects are addressed upfront rather than later in the process.

Application of Guideline 1.B: Describe the existing system and operations

The proposed diversion is on Stillhouse Hollow Lake (see Figure 13), which is a Corps reservoir located near Bell County, Texas. The lake is an impoundment along the Lampasas River, which eventually flows into the Brazos River. The Applicant has an existing intake and water treatment

Figure 13. Proposed Stillhouse Hollow Lake and existing Lake Belton intake locations near Killeen and Temple, Texas.



plant that treats water from a nearby lake (Lake Belton). Lake Belton is on the Leon River, which flows downstream and joins with the Lampasas River downstream of Stillhouse Hollow Lake and eventually flows into the Brazos River.

Although releases from Stillhouse Hollow Reservoir that are designated for water supply purposes are rare, much of the inflow to the reservoir is passed through the reservoir except in dry years, with flows often in the 10 to 100 cfs range, but increasing to several thousand cfs during wet conditions. There are several large water users that take water from Stillhouse Hollow Lake, including a pipeline that connects to Georgetown Lake to the south. A complicating aspect of this case study is that while the Applicant has a relatively straightforward and simple system, the use of another entities' contract water adds considerations beyond the Applicant's. The causal effects the Corps is looking to address are related to the project and the water it will be using, not just the Applicant's system. Therefore, the operations aspect is of greater interest and should be clearly described.

Application of Guideline 1.C: Describe the proposed project and operations

The Applicant proposes to construct a reservoir intake on Stillhouse Hollow Lake, a new water treatment plant, and a treated water transmission line from the treatment plant to its existing distribution system. The water treatment plant will have a capacity of 17 MGD, will be located on 38 acres near the Kempner water treatment plant, and will deliver treated water through a separate 50,000-foot treated water pipeline to the Applicant's customers.

Water diverted from Stillhouse Hollow Reservoir for use by the Applicant will be withdrawn from the reservoir and will reduce the volume of water released from the reservoir annually by approximately the withdrawal amount, on average. Since water will be withdrawn from the conservation pool, the timing in the reduction in outflows will not typically match the timing of the withdrawal from the lake. Much of the treated water will be used for municipal uses.

Although generally identified but not evaluated in this project, return flows from wastewater treatment plants discharge into the lake and possibly the river system. If such discharges are to be the subject of reuse, no returns will occur to the system. However, if such discharges are not associated with reuse, such returns can partially offset the reduction of flows depending on where they occur and whether they are managed. Where such returns occur can be captured in the modeling to determine if stream reaches receive measurable benefits from such discharges. Considerations of changes in water quality should be included in addition to increases in some flows when effects are evaluated.

Application of Guideline 1.D: Identify existing relevant hydrologic data and hydrologic models

The USGS has streamflow gages upstream and downstream of Stillhouse Hollow Lake. The reservoir is a Corps facility managed by BRA. The Corps District office and/or BRA should have reservoir mass balance accounting data available that can be provided to an Applicant. Annual water balance summaries for 2014, 2015, and 2016 are available on the BRA website.

The BRA provided hydrologic modeling for its Little River system that includes Belton and Stillhouse Hollow Lakes. The modeling eventually provided to the Corps included a with-project run that added the 10,000 AF withdrawal to Stillhouse Hollow Lake. Modeling is used for operations and various demand levels can be used, but 2017 demands were selected by the Applicant to simulate current conditions. Because the project is the subject of an NWP evaluation, such a determination was considered reasonable compared to other project types. The models simulate four reservoirs in the Little River system, but results were eventually focused on Stillhouse Hollow. The Corps also looked at potential changes to occur to Lake Belton from the modeling to conclude that no discernible effects occurred to those areas as a result of the project. None of the other three lakes flow into Stillhouse Hollow, so there are no dependencies on the Stillhouse Hollow inflows that would result from simulated operations at the other reservoirs.

Application of Guideline 1.E: Determine the geographic scope of assessment

Although initial identification of use and/or possible connection between Lake Belton to Stillhouse Hollow Lake occurred, development of hydrologic modeling reflecting both lakes as well as two others allowed the Corps to determine that Stillhouse Hollow Lake would be primarily affected by this proposed project. Flow information below the reservoir, as well as coordination with a state resource agency, allowed for the determination that a very short reach of the Lampasas River needed to be considered for the geographic scope-of-effects assessment. The Applicant stated that the proposed project would reduce the demand on Lake Belton slightly, but this was not simulated and would result in more flow discharged from Lake Belton than a pre-project condition. Although not stated, this increase in flow from Lake Belton would occur only until such time that the Applicant's demand increases by the new proposed diversion amount such that withdrawals from Lake Belton are at the same levels as current withdrawals. The Corps considered the potential benefits that may occur with such increased flows, from a general assumption perspective, but the information provided allowed for the conclusion that benefits to the Leon River below Lake Belton would be too minimal to attempt to quantify for effect assessment.

Much of the annual inflow is passed through Stillhouse Hollow Lake except in dry years, although it is possible that withdrawals may be able to increase due to the pipeline to Georgetown Lake. Flows in the Lampasas River will be reduced by approximately the withdrawal amount on an average annual basis. The Lampasas River joins with the Leon River to form the Little River several miles downstream of Stillhouse Hollow Lake, where annual flows average 775,000 AF (median 428,000 AF, minimum 85,000 AF) (USGS 08104500 Little Rv nr Little River, TX). The 10,000 AF withdrawal is a relatively small fraction of the flow at this location except in dry years. The reach of the Lampasas downstream of Stillhouse Hollow to the confluence with the Leon should be evaluated. Downstream of the Leon, the streamflows become a decreasing fraction of the flow. However, given that the 10,000 AF reduction is about 12% of the dry-year flow, this may require further evaluation as additional water supply releases may be made during dry years that would partially offset this reduction or the conservation pool may simply be drawn down in Stillhouse Hollow Lake, which would have no effect on downstream flows and would only impact reservoir levels.

Application of Guideline 1.F: Minor-level project analysis and determination

Based on the information provided above, the proposed project will reduce total outflows from Stillhouse Hollow Lake by 10,000 AF per year on average, and would likely not change flows below the reservoir in dry years. The flow into the lake is highly variable year to year. Thus, the timing of the reduction to the outflows is based on several factors and BRA's operations of a portion of the reservoir. Additional analysis into the reservoir operations and timing of the reduced downstream flows could be further evaluated using some Tier-2 HMGs. However, the Corps did not require such evaluation in light of the information it had.

The availability of gage data immediately upstream and downstream of the reservoir suggests that a hydrologic modification analysis may be appropriate during critical periods, provided hydrologic modeling or other operational descriptions can be incorporated into the analysis (see HMGs 2.B, 2.D and 2.E). No permit conditions were included in the authorization relative to operations.

8.1.4 Trinity River Intake (EA with Regional General Permit)

The Trinity River intake project involves a new intake on the Trinity River downstream of the Dallas/Ft. Worth metro area by the North Texas Municipal Water District (NTMWD). Because the project entailed only an intake and possibly qualified for a general permit authorization, the Corps attempted to minimize upfront information requests. As more of the project was learned, additional meetings, conference calls, and discussions were required to assess the project and move through the evaluation process. Most pertinent to the HMGs was that between February 20, 2015 and October 9, 2015, five separate memoranda were provided by the Applicant to the Corps, responding to questions and information requests that describe various aspects of the project. Based on meeting minutes and these memoranda, it was apparent that there was information lacking as well as misunderstanding about the exact type of information the Corps had requested and the best way to respond to these requests. As outlined in the sample application of the HMGs below, the information provided in the fifth memoranda (which was substantially relied upon in the permit decision) could have been obtained initially, saving time and money in the process.

Application of Guideline 1.B: Describe the existing system and operations

The Applicant operates a large water supply system, shown in Figure 14, that serves the northeast portion of the Dallas-Fort Worth metropolitan area. It derives its water supplies from four major reservoirs in the region (Lavon Lake, Lake Texoma, Lake Tawakoni, and Chapman Lake) and has plans to draw water from a proposed Lake Bois D'Arc. In addition to the reservoirs, the Applicant has constructed the East Fork Reuse Project.

The East Fork Reuse Project, a project previously permitted by the Corps, includes a pump station that diverts water from the Trinity River downstream of many wastewater treatment plants in the Dallas-Fort Worth Area. Water is then pumped from this location several miles to the north to the East Fork Reuse Project wetlands. The wetlands are approximately 2,000 acres that filter the water diverted from the Trinity River that is composed primarily of wastewater effluent. Once filtered through the wetlands, the water is pumped back upstream to Lavon Lake for treatment and delivery to the Applicant's customers.

The wetlands project has an existing intake on the East Fork of the Trinity River, located upstream of the proposed Mainstem Pump Station. Additional effluent exists and is also projected to be available on the mainstem of the Trinity River downstream of the confluence with the East Fork for delivery into the wetlands, and then subsequent delivery to Lavon Lake. The proposed Mainstem Pump Station was permitted with special conditions in February 2016.

From a water rights perspective, the proposed project will divert wastewater effluent produced at two Trinity River Authority (TRA) wastewater treatment plants and two Dallas wastewater treatment plants. There are four stream gages referenced for this project: Trinidad (USGS 08062700), Oakwood (USGS 08065000), Rosser (USGS 08062500), and Crandall (USGS 08062000). Crandall is upstream from the proposed site, Rosser is immediately below the proposed pump station, and Trinidad and Oakwood are farther downstream gages along the Trinity River.

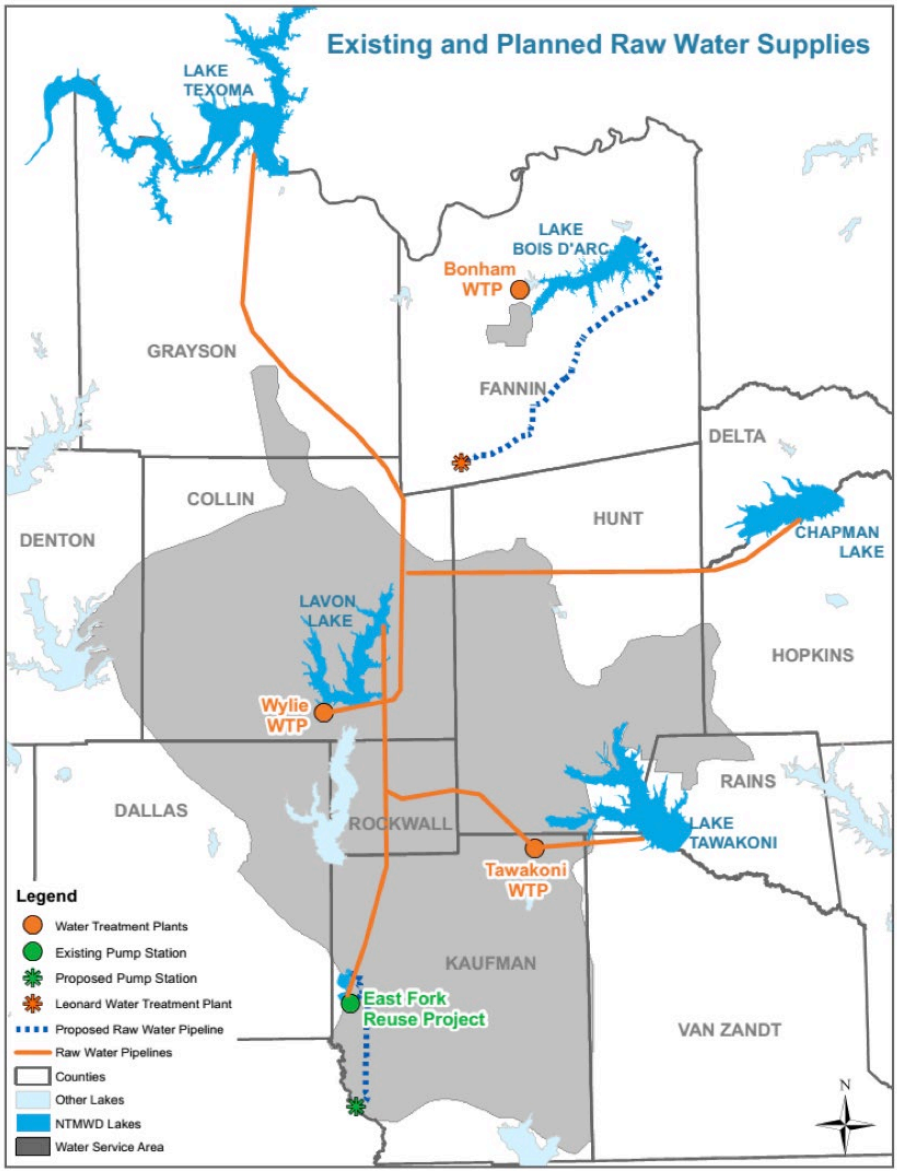


Figure 14. Map of NTMWD water sources and proposed Trinity River Mainstem Pump Station.

Application of Guideline 1.C: Describe the proposed project and anticipated operations

The purpose of the proposed project, Trinity River Main Stem Raw Water Pump Station and Pipeline Project, is to provide additional water supply to the NTMWD for the demands of the growing population within its service area. The Trinity River intake and pump station will be located along the main stem of the Trinity River upstream of an existing but abandoned lock and dam structure, west of Rosser, Texas. The conveyance pipeline will be 72 inches in diameter and stretch 16.5 miles through some wetlands within a 60-foot easement. The pump station facility would be built on approximately two acres of land on the eastern banks of the Trinity River. Two 48-inch diameter pipes with screens will be installed to extend 90 feet into the river from the pump facility.

The anticipated operation will allow diversions from the Trinity River at up to 114 MGD (176 cfs). The amount withdrawn will vary on a daily basis because it is limited to the amount of wastewater effluent that NTMWD is legally or contractually entitled to in the river at upstream locations the previous day.

The water diverted at the pump station is restricted to effluent water from several upstream wastewater treatment plants: TRA's Central, Red Oak, Ten Mile Creek, Dallas Water Utilities' Central, and Southside Wastewater Treatment Plants. Effluent from the two Dallas plants may be exchanged at Lake Ray Hubbard through what is referred to by the Applicant as the "Dallas swap". The Dallas swap allows NTMWD to divert Dallas' effluent at the proposed pump station, and in return Dallas will divert a like amount of NTMWD's effluent from Lake Ray Hubbard. This operation will reduce streamflows between Lake Ray Hubbard and the proposed diversion point because NTMWD's effluent has historically been passed through Lake Ray Hubbard. The Dallas swap is limited to approximately 18 MGD. The East Fork Wetlands can accept up to 120 MGD from a combination of the existing East Fork Pump Station or the proposed Main Stem Pump Station. The Main Stem and East Fork pump stations and the wetland diversion are shown in Figure 15.

Dallas Utilities' water right to reuse its water has certain conditions that require that 114,000 AF per year of water is bypassed to downstream flows and that certain minimum streamflow requirements are met at the Trinidad and Rosser gages. These conditions are expected to be applied to TRA's wastewater effluent that could be diverted at the proposed project site. Tarrant Regional Water District (TRWD) has a similar constructed wetland system that diverts water lower on the Trinity River. Wastewater effluent from TRWD wastewater treatment plants will comprise a portion of the flow through the project area, and a portion will be diverted downstream of the project area at the TRWD wetland site.

Information associated with the Applicant's existing system and how the proposed project ties into it and may affect its operations was learned over a period of time. This was due in part to the Corps' initial preference to evaluate proposals with the minimal information potentially needed to support its permit decisions. Availability of the HMGs could have identified and informed the discussions and assisted in the earlier development of information resulting in greater efficiency to the permit review process.

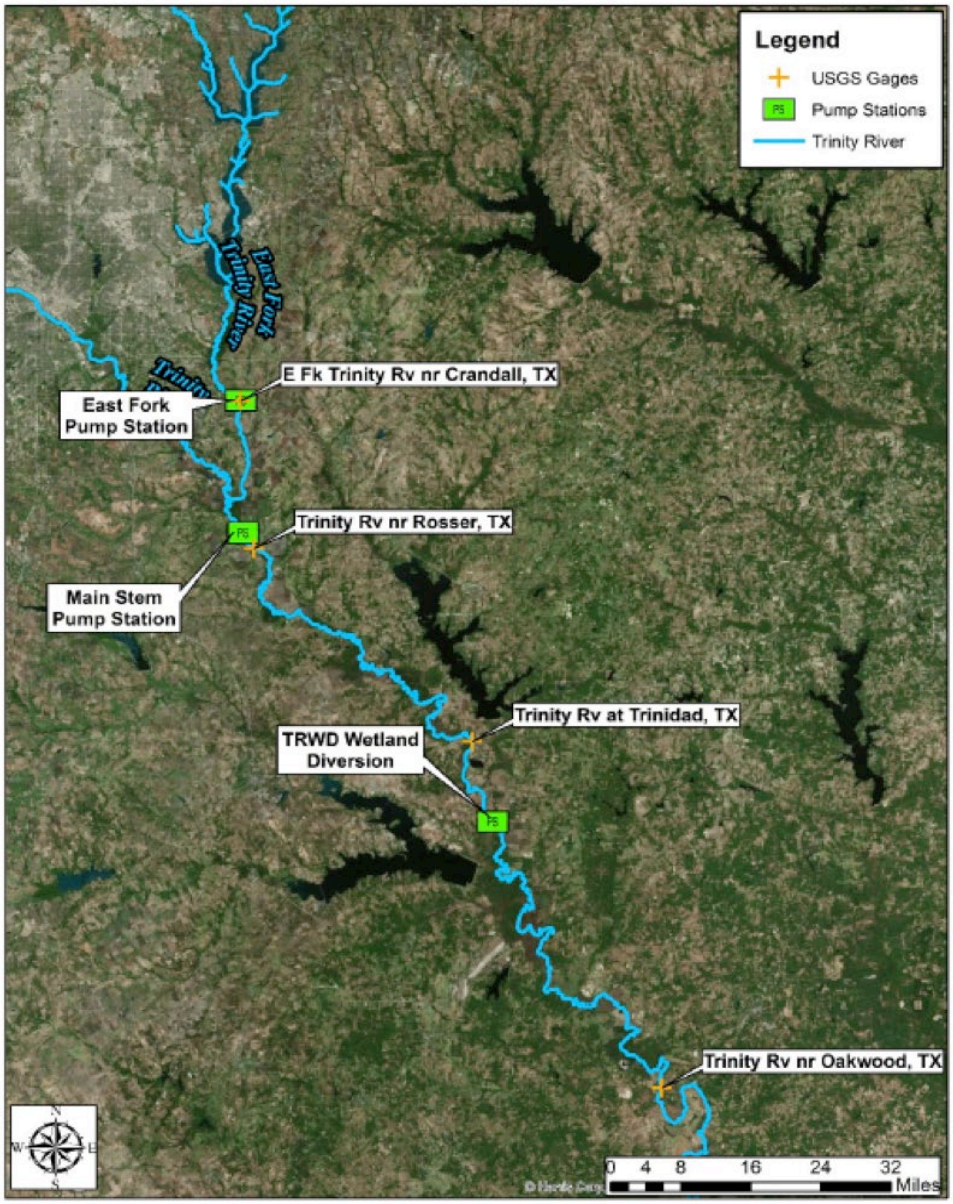


Figure 15. NTMWD Main Stem and East Fork Pump Stations and Wetland Diversion. The proposed pump station location is near Rosser, Texas along the Trinity River.

Application of Guideline 1.D: Identify existing hydrology models and relevant data

There are several stream gages in the Trinity River basin as described in HMGs 1.B and 1.C that have periods of record that extend for several decades. The Rosser gage is located just downstream of the proposed Mainstem Pump Station and therefore can provide information related to availability of flows at the proposed project and effects to streamflow.

Wastewater effluent discharges into the Trinity River basin are available. These data show an increasing volume over the past several decades due to municipal growth. This wastewater treatment

effluent has increased the flow in the Trinity River due to water imports from other basins that increase the overall water supply in the Trinity River basin. In addition, reservoir data is available and several water rights and contracts are important to the proposed project's operation, including a contract with TRA to divert effluent, an agreement with Dallas to swap or exchange effluent available at the pump station, and certain environmental flow requirements associated with the water reuse rights.

The Trinity WAM model is available. The current version of the Trinity WAM is a monthly model from 1940 to 1996 and was last updated in 2014. Information in the model, such as stream channel loss factors and other configuration aspects, may be useful for evaluation of the proposed project. Recent increases in wastewater effluent may be included in the WAM model because the model superimposes current or fully authorized water right use onto the historical hydrology. The fully authorized water use model may overstate wastewater effluent compared to current conditions because it assumes full use of authorized water rights. Water providers may not have implemented the full amount of authorized water rights. More recent use patterns are likely available through the WAM Run 3 current conditions model run but may not incorporate the water use seen through the early 2010s drought.

Application of Guideline 1.E: Determine the geographic scope of assessment

The proposed project will divert water from the Trinity River near the Rosser gage. Diversions at this location are to be based on wastewater treatment effluent from the previous day. While no natural flow of the Trinity River (as categorized in water rights designations) can be diverted, the volume of water that will be diverted attributable to effluent discharges has been part of the stream hydrology for many years or decades. There are also state environmental flow considerations at downstream locations based on conditions in Dallas Utilities' water reuse water right and expected conditions in TRA's water reuse water right. The proposed maximum diversion rate of 114 MGD (176 cfs) is a relatively small percentage of the flow at the Rosser Gage for average and wet conditions. During dry conditions, this amount comprises a larger portion of the flow: up to 32% of the minimum flow at the Rosser Gage (176 cfs / 557 cfs minimum flow). River stage reductions even at these higher percentage reductions are small: approximately 3 inches at the maximum flow reduction (10% of river depth) and much less at higher flowrates. Information such as described here, if provided earlier in the process, could have assisted in determining if additional analysis was required.

The Applicant's operations of the project will be coordinated with the existing East Fork Pump Station on the East Fork of the Trinity River so that combined deliveries to the wetlands will not exceed 120 MGD. Water delivered to the wetlands from the proposed pump station, after filtration through the wetlands, is pumped into Lavon Lake and then pumped out into NTMWD's Wylie water treatment plant. As shown in Figure 14, the NTMWD's system covers a large geographic area, which extends upstream of the proposed pump stations. The overall system should be viewed as the initial area of interest where hydrological modifications may occur associated with the overall system that the proposed system is tying into. The application started by looking at the intake and downstream and grew to capture other parts as more was learned about the proposed project. For example, the potential swap of effluent with Dallas Utilities could alter the release rate from Lake Lavon and Lake Ray Hubbard. Use of the Mainstem Pump Station could potentially impact operations at other NTMWD raw water supply facilities because a new source is being introduced into the system. It is

anticipated that diversions at other NTMWD reservoirs would be reduced due to the introduction of a new source to the system. Based on the likely reduction of withdrawals at other facilities, evaluation of changes to hydrology at these locations is likely not necessary and the area of interest was limited to the diversion locations and downstream. It is better to disclose the potential area of interest where hydrological modifications may occur and then narrow down through additional analysis.

The pipeline route will cross some areas of wetlands. However, the pipeline route and construction are not expected to alter river hydrology.

Application of Guideline 1.F: Minor-level project analysis and determination

The diversions from the Mainstem Pump Station are dependent on effluent from upstream wastewater treatment plants. Some portion of the effluent may be exchanged or swapped with Dallas Utilities. The proposed operations are determined in part by daily and seasonal variation in available effluent, coordinated operations with the East Fork Pump Station, numerous water rights and associated special conditions, and contractual obligations.

A more detailed analysis should be performed because simplifying assumptions such as average diversion rates and the impact of increasing wastewater effluent in the basin over the past several decades may not provide an adequate characterization of the changes in streamflow due to the complex operational factors described above. Therefore, Tier-2 HMGs should be applied.

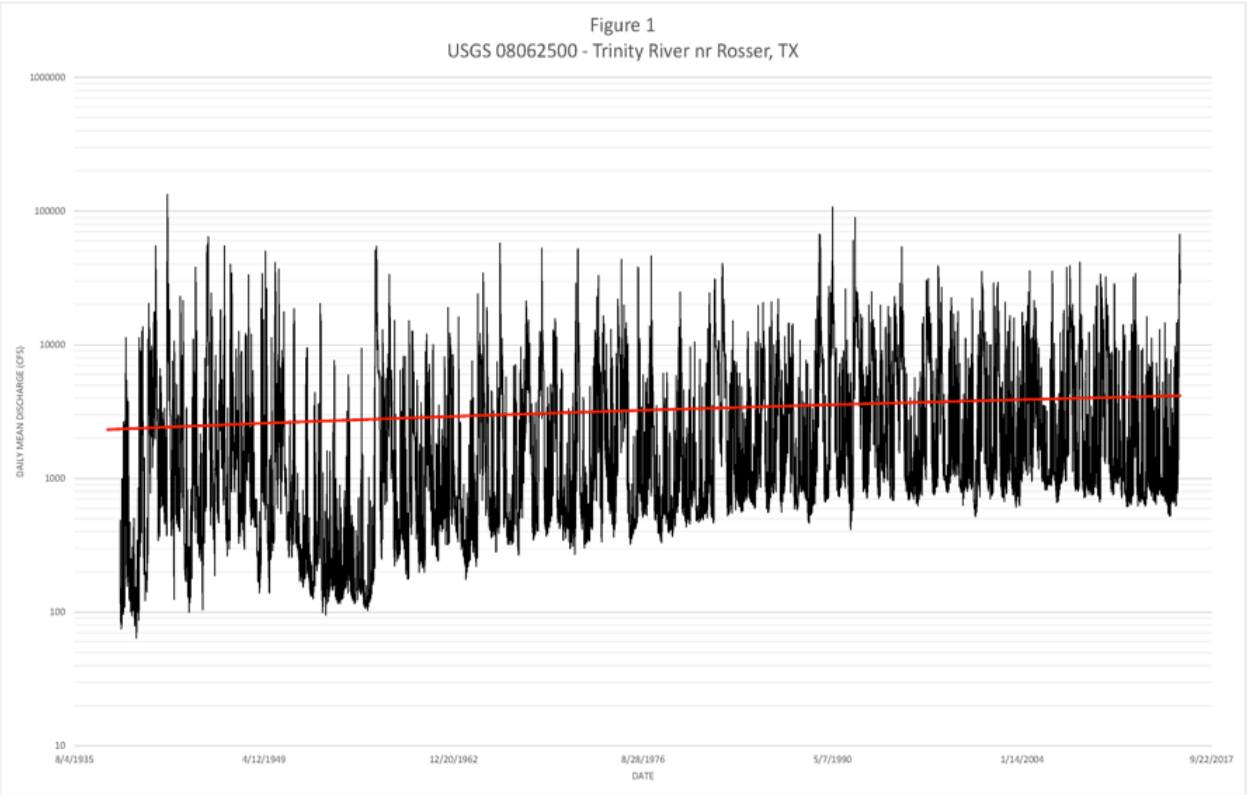
Application of Guideline 2.A: Gather the best available hydrologic data for the project area

The Rosser, Texas USGS gage is located just downstream of the Mainstem Pump Station, which allows the effect of the project to be simulated and readily observed using gage data near the project location. Analysis of the gaged flows, shown in Figure 16, indicates an increasing trend over the last several decades, particularly an increase in low flows, due to the increasing amount of wastewater return flows in the metropolitan area and the introduction of raw water from other basins into the Trinity basin to supply the metropolitan area. For this reason, more recent records are appropriate to use as a baseline to compute project effects. Use of a recent period of record includes a severe drought from 2012–2015.

As discussed in HMG 1.D, records of wastewater treatment plant historical discharge and reservoir release data are available. In addition, data for the East Fork Pump Station should be obtained. The Palmer Hydrologic Drought index data can be used to identify periods of dry, average, and wet hydrology.

The Trinity WAM model includes stream loss factors and the characterization of downstream water users that may depend to some extent on the decades-long increase in return flows to the Trinity River.

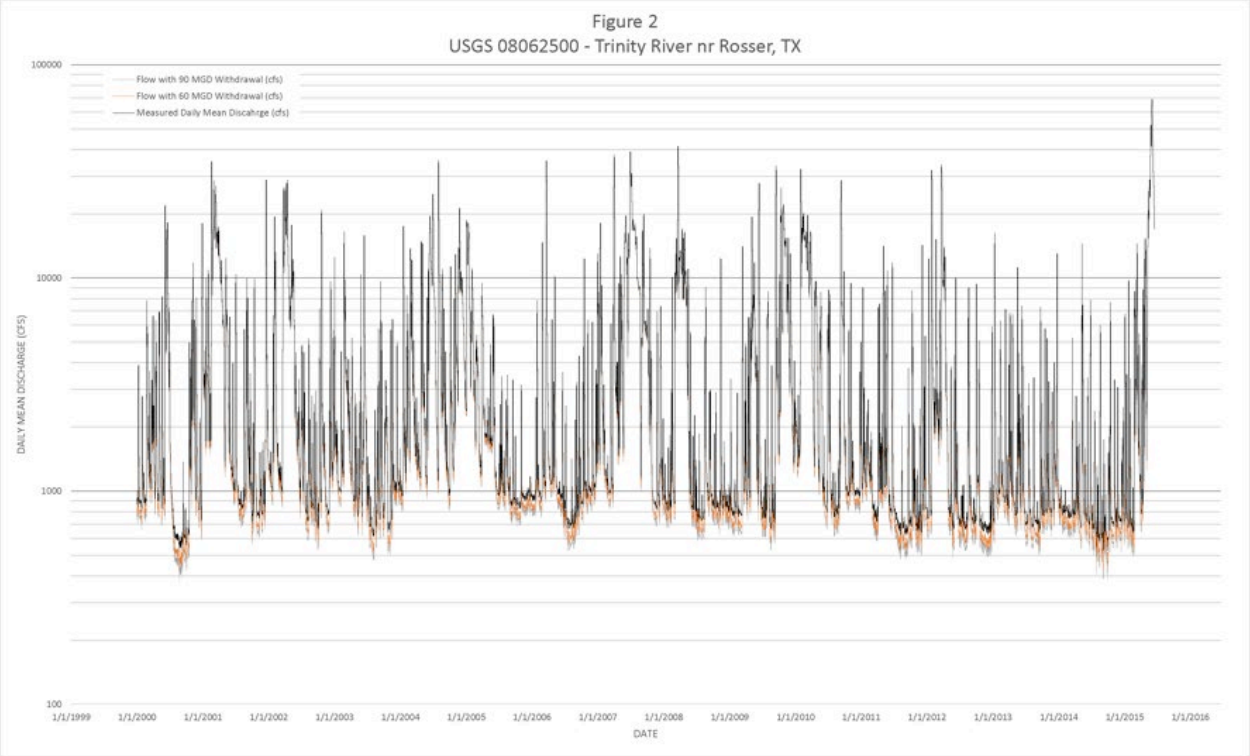
Figure 16. Trinity River near Rosser, TX gaged flows show an increase in streamflow over the past few decades.



Application of Guideline 2.B: Determine critical hydrologic period for analysis

The recent drought of 2012–2015 is a critical period of analysis. This period had some of the lowest recorded flows since the 1970s despite the increase in wastewater effluent as development has occurred in the upstream metro area. An analysis of flows at the Trinity River near Rosser gage from 2000–2015 with potential 60 MGD and 90 MGD withdrawals was submitted by the Applicant and is shown in Figure 17. Potential impacts to fish species would likely occur in the summer when flows are generally lower, leading to higher water temperatures and lower dissolved oxygen. Three fish species identified for evaluation (see HMG 2.F) have spawning seasons in late winter or early spring (Largemouth Bass) and April to June (Bigmouth Buffalo and Gizzard Shad). Therefore, hydrologic analysis should evaluate March through September for spawning season and summer flows for effects on the fish species.

Figure 17. Trinity River near Rosser gage with 60 MGD and 90 MGD withdrawals from 2000–2015.



Application of Guideline 2.C: Determine the timestep required for hydrologic modification analysis

Diversions at the proposed pump station are determined on a daily timestep by the amount of wastewater effluent discharged to the stream system the previous day. Trinity River streamflows can vary significantly day to day, so averaged monthly values are not appropriate. Some monthly data may be appropriately used as a monthly-average rate. For example, Dallas releases water from Lake Ray Hubbard at a constant rate based on the previous month's volume of water stored. If daily wastewater effluent data is not available, monthly data is typically adequate as wastewater effluent does not typically vary significantly day to day.

Application of Guideline 2.D: Understand assumptions included in any modeling used

Applicants developed an Excel model for the proposed operation of the pump station. The model simulates the streamflow at several locations on a daily basis for a with- and without-project scenario. The model assumes historical 2014 wastewater effluent discharges superimposed on an adjusted historical hydrology. This will simulate what flows would have been if wastewater effluent had been at 2014 levels throughout the entire study period. This is a reasonable method of quantifying the current conditions impact of a proposed operation while maintaining the historical variability in the natural hydrology of the river basin.

A memorandum explaining modeling methods and assumptions was provided by the Applicant that included detailed documentation of input development and adjustments to historical hydrology. Corps review by its H&H Branch identified additional needs and clarifications.

Adjustments to historical hydrology included subtraction of historical wastewater effluent, addition of 2014 effluent, and addition of the East Fork Pump Station diversions and the TRWD wetland diversions. The additions and subtractions were adjusted for stream losses based on the stream loss coefficients from the Trinity WAM model. Water available at the East Fork Pump Station is computed pursuant to its water rights using the adjusted flows and then subtracted from the flows. The adjusted streamflows, minus the East Fork Pump Station diversions, formed the baseline conditions for the model.

The model then computed water available at the Mainstem Pump Station. This amount was assumed to be constant over an entire month. Adjusted flows on the East Fork were computed assuming a 25.8 cfs in-stream flow requirement was met. In some instances, negative naturalized flows were computed, which indicates some inaccuracy in data, assumptions on losses, or daily variability in the wastewater treatment plant discharges not captured in the assumed constant monthly rate.

The model does not allow East Fork flows to be diverted at the Mainstem Pump Station. This appears to be a water rights condition since the Mainstem Pump Station was intended to divert flows from the Trinity River, not the East Fork of the Trinity River.

The "Dallas swap" is included in the model and assumes that the swap occurs at a rate of 17.4 MGD. This reduces the releases from Lake Ray Hubbard by this amount. In addition, in-stream flow requirements associated with the Dallas reuse water right and anticipated requirements with the TRA reuse water right were included in the modeling that specifies certain minimum flows by season at the Trinidad and Rosser gages. The modeling showed that flows did not approach these limits, so diversions were not curtailed. Furthermore, the model simulated the requirement that Dallas pass 114,000 AF of wastewater effluent downstream associated with its reuse water right.

Application of Guideline 2.E: Hydrologic modification analysis should preferentially use observed data for a baseline and modeled data secondarily

In this case, observed historical data was not reasonable to use in the model because of the long-term increasing trend of wastewater effluent in the Trinity River. Adjustments made to the observed historical stream gage data were reasonable and were then superimposed onto the historical data. This approach incorporates observed data well, rather than attempting to rely on other methods to simulate or estimate streamflows.

The availability of data was very useful in the hydrologic modification analysis for this project, with four stream gages, two of which are located near two of the major diversion points simulated. In addition, the availability of wastewater discharge data and other reservoir release data in forming the adjustments for model input hydrology provides a high level of confidence of the results and enforceability of potential permit conditions based on the proximity of the stream gages to the diversion points.

Application of Guideline 2.F: Coordination with resource agencies

Agency coordination was initiated in the summer of 2016. Through the agency coordination, the Applicants were asked to provide information related to representative game and non-game fish species, mussels, and water quality constituents. In addition, agencies requested information on out-of-bank frequency and duration and potential effects on riparian wetland function. A concern was also raised related to a potential to violate the E-flow standard base flow recommendation from middle Trinity River Reach at the Oakwood Gage.

Daily data used in the hydrologic modification analysis is simulated at multiple locations where effects on the aquatic resources could be evaluated. Corps project managers should verify whether there are other major diversions within the study reach that could mischaracterize the effects analysis at the gage locations.

Applicant's response includes a discussion about channel structure and morphology that includes pools connected by riffles that act as grade control and maintains pool depth, even at lower flows. Therefore, it was postulated that the reduction in streamflow results in relatively little loss of pool volume. Spawning seasons were identified along with other species characteristics and the modeled data was evaluated during these seasons. The Applicant did not address potential effects to mussels using the hydrologic modification analysis because little is known about the effects of hydrology on the mussels and due to the small changes in water level elevation, concluded that there would be no effects to the mussels.

The Applicant also addressed water quality concerns by citing that diversion of water would not change the concentration of nutrients left in the stream. The volume of water is reduced downstream of the diversion and the potential for increased temperature may have more of an impact on dissolved oxygen levels. However, the change in river stage is small and changes in temperature are not anticipated to be large, so concentrations of dissolved oxygen are expected to be similar below the diversion point.

The Applicant demonstrated with the hydrologic model that environmental flow standards were met throughout the study period at both the Trinidad and Oakwood Gage.

Application of Guideline 2.G: Simplify hydrologic modification analysis as much as possible to make determination of adequacy of analysis

Initial submittals by the Applicant used simplified constant annual average diversion rates and daily averaged flows at the Rosser Gage. As more complexity in the system and operations were added to the correspondence, it became clear that a more detailed analysis of hydrologic conditions would be necessary to adequately characterize streamflows in the proposed project area. This reflects the Corps' efforts to require the minimal amount of information at the outset of a project review process and to render a decision with such information. However, as the project review process proceeded, the need for additional information became more apparent. Such situations and circumstances will likely continue but availability of the HMGs would be expected to trigger conversations concerning the potential for more detailed analysis earlier, potentially yielding process efficiencies.

A relatively simple model was developed to simulate the project operations using historical gage flow, wastewater treatment plant discharges, and imposing key operational restriction from various water rights. This model was able to reasonably simulate with- and without-project flows relying to a significant degree on observed data, adjusted for the purposes of the analysis. Instrumental in this conclusion was the density of available data in and near the project area and proximity of stream gages to the proposed project locations.

Coordination with other regulatory agencies resulted in initial identification of potentially affected resources. The critical periods for potentially affected resources were identified and hydrologic analysis was performed for these periods. The analysis was sufficient to determine that there would be no adverse impacts.

No additional modeling or analysis was required to adequately characterize the impacts on streamflows and aquatic resources for this project, provided the project operates within the assumptions identified in the model. Permit conditions reflected the operations described, particularly the maximum operational limits based on flow conditions at the Rosser Gage. Due to the proximity of the pump station to the Rosser stream gage, flow-based permit conditions were referenced to this gage.

8.1.5 Lake Ralph Hall (EIS with Standard IP)

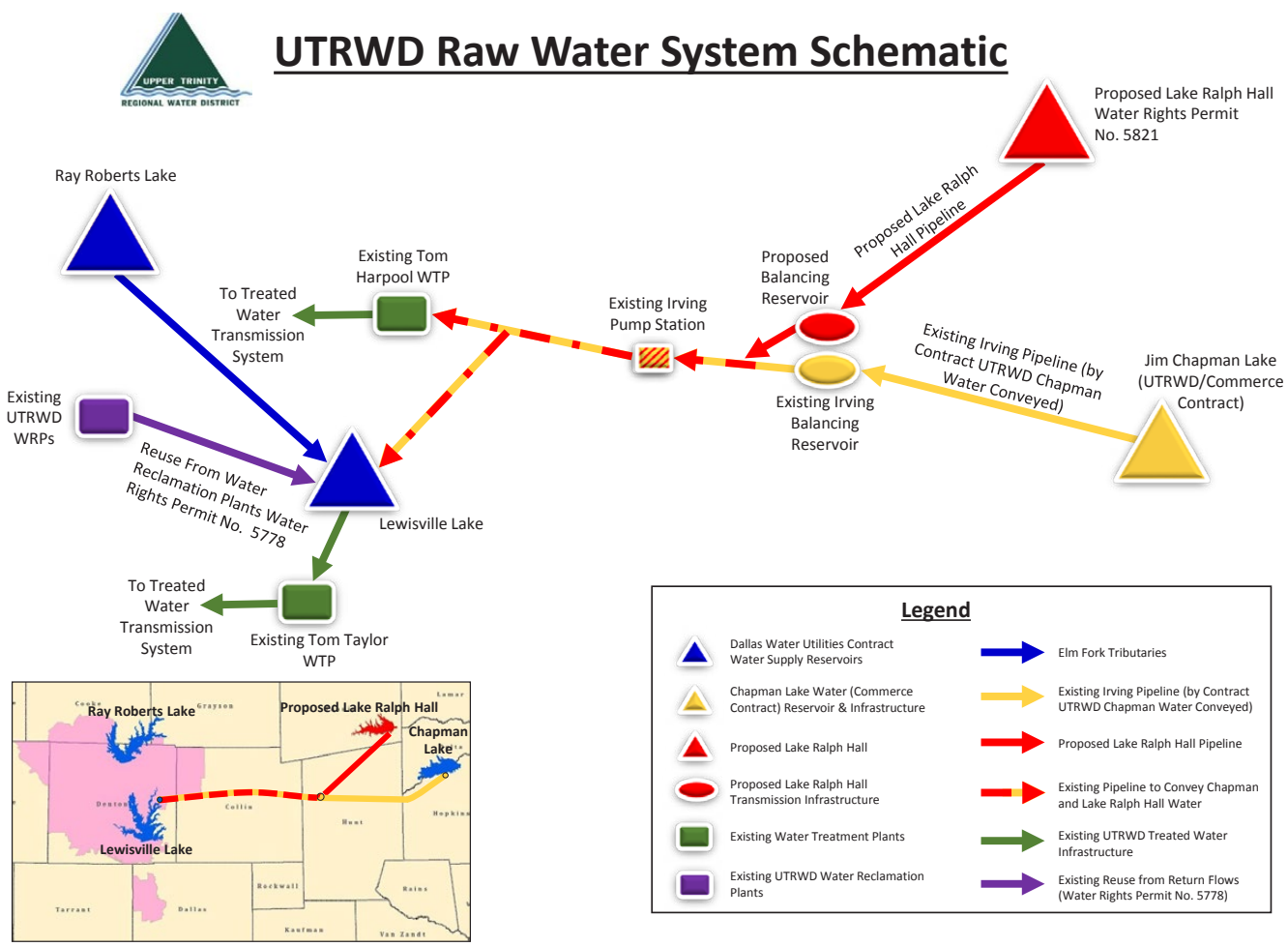
The Lake Ralph Hall (LRH) project proposes to construct a new reservoir on the North Sulphur River near Ladonia, Texas. The proposed conservation pool is 160,000 AF with a surface area of approximately 7,560 acres. Several models of the region exist and were evaluated for use and suitability for quantifying effects to aquatic resources. The project required development of an EIS by the Corps. As of the date of this report, the permitting process for this project is still ongoing. The Sulphur River WAM model was used to initially characterize effects to hydrologic resources. Due to the extreme variability in daily flows, the Corps subsequently requested additional modeling using an existing daily RiverWare model for impact analysis. Evaluation of the results from the WAM and the RiverWare model found that both models contained certain biases related to simulation of streamflows downstream of the proposed reservoir. The Corps was able to characterize the effects to aquatic resources using a combination of the results from both models as well as using simpler hydrologic modification methods for out-of-bank storage. Use of the HMGs in this project may have allowed the Corps and Applicant to more quickly understand the shortcomings of the available models and arrive at an acceptable approach more efficiently, and also alerted the Corps to request specific information and analysis earlier in the process.

Because the project involved an EIS, information requirements associated with Tier-1 guidelines were addressed for full disclosure in the EIS. Development of this type of NEPA document ensures that such required information is documented. However, timing of this information is important relative to the EIS process. Corps project managers should be contemplating the applicability of much of this information as it relates to development of the various EIS chapters and supporting appendices. This is particularly relevant since some information needs to be reflected in chapter 1 of the EIS as it relates to the type of Applicant and their project purpose(s) compared to project benefits. It also pertains to the identification of alternatives, practicability determinations, and prioritization of data and information development as the EIS process progresses. Such considerations are critical to a more efficient overall process.

Application of Guideline 1.B: Describe the existing system and operations

The Applicant operates two water treatment plants that are supplied from a variety of sources, including Chapman Lake, Lewisville Lake, Ray Roberts Lake, and some reusable return flows. Intake to one plant is a direct pipeline connection from Chapman while the other intake is located in Lake Lewisville. Most of this water is available through contracts with other water providers. Chapman Lake is located in the Sulphur River Basin, and a pipeline from that lake to the Applicant's water treatment plant will be used to convey water from the proposed LRH as shown in Figure 18 . This map was provided several months after the EIS process started. The HMGs would likely have resulted in the identification of the need for such visual representation much earlier in the process.

Figure 18. Lake Ralph Hall and Upper Trinity Regional Water District raw water system schematic.



Application of Guideline 1.C: Describe the proposed project and anticipated operations

The proposed LRH will be used to supply water to the Applicant in the Trinity River Basin as well as other local users within the county. The proposed maximum capacity of LRH is 180,000 AF. Up to 45,000 AF per year will be diverted, but this will vary by the needs of the Applicant's water consumption. Pumping facilities will be built along the perimeter of the lake to distribute water to consumers through a new pipeline that will connect to an existing pipeline from Chapman Lake to the Applicant, southwest of the lake. The District obtained a water right for LRH that identifies a firm yield of approximately 35,000 AF but allows for over-drafting of up to 45,000 AF when lake levels are maintained above a certain elevation.

The proposed project is located on the North Sulphur River in Fannin County near Ladonia, Texas. The river experiences flashy discharges, going from almost no flow to several thousand cfs after a precipitation event, and the flow recedes to a few cfs within a couple of days. There are pools and puddles that remain in the channel even when there is little or no flow occurring in the river. In the 1930s, the original river channel was dredged and straightened to drain surrounding lands for cultivation. The dredged and straightened channel has eroded and incised significantly over the past 80 years and the river channel is in some places 60 feet below the surrounding ground surface. Many miles downstream of the proposed site below the confluence with the South Fork of the Sulphur River, the channel returns to a more typical meandering riverine system and eventually discharges into Lake Wright Patman near the Arkansas border.

Application of Guideline 1.D: Identify existing hydrology models and relevant data

There is one USGS stream gage on the North Sulphur River, located downstream of the dam site near Cooper, Texas (USGS 07343000; Cooper Gage). There are two other USGS gages on the Sulphur River near Talco and Dalby Springs (USGS 07343200; Talco Gage and USGS 0734350; Dalby Springs Gage). The Sulphur River at the project site is flashy, with quick increases and decreases after precipitation — often going from almost no flow to several thousand cfs and back to little flow within a span of a few days.

One model was initially used to evaluate flows at the project site. The Texas WAM modeling was modified by the Applicant to include the proposed LRH. This model was used to obtain the water right for the project. The model is focused on water supply reliability and simulates flows on a monthly basis. This model considers senior water rights downstream, including the senior water rights of Lake Wright Patman. Due to the consideration of water rights, the model indicated releases from LRH during periods of low flow. Monthly flows are reasonable for computing the yield of the project but do not capture the extreme daily variability common in this watershed, and therefore are likely not adequate for simulating effects to aquatic resources.

A second model that existed and was applied to evaluate the project was a RiverWare model. This model was a flood control model for the larger Red River Basin. The Sulphur River is a tributary of the Red River. The model used daily inputs which were derived from USGS stream gages and monthly evaporation and precipitation data. The RiverWare model does not factor in downstream

senior water rights and was originally used as a flood control model. Therefore, low-flow releases are not simulated because the flood control model was focused on system response to high-flow events.

The WAM model used a time period of 1940–1996, while RiverWare had a somewhat longer period of record. Both models included wet, average, and dry hydrologic periods. Water resources development upstream of the proposed site is minimal, so stream gage data is representative of naturalized conditions at the site. Lake Chapman on the South Fork of the Sulphur River was constructed in the 1990s, and therefore, gage flows downstream of the confluence are affected by Lake Chapman operations and will not necessarily indicate naturalized flow conditions.

The Corps also developed a HEC-RAS river hydraulic flow model for the Sulphur River Basin. The HEC-RAS model can be used to evaluate the change in river stage at various locations based on reduced flows that are diverted or stored at the proposed project site.

Application of Guideline 1.E: Determine the geographic scope of assessment

The drainage area above the proposed LRH site is about 100 square miles. The Cooper, Talco, and Dalby Springs gages are approximately 20, 51, and 98 miles downstream of the proposed LRH and have drainage areas of 311, 1,382, and 1,976 square miles, respectively. Lake Chapman is downstream and located on a separate channel from the North Sulphur River and does not affect the operations of LRH. Immediately downstream from the LRH site, there are pools and puddles in the North Sulphur River that support fish and benthic organisms in the riverbed. Due to the small drainage area of LRH relative to the rest of the basin, the operations of LRH were anticipated to have limited impacts on the Talco and Dalby gages, even if LRH stored all water available at the site. However, the Corps performed hydrologic analysis to inform determinations relative to the degree of these effects. Change in river stage at the downstream gages is small even if all water available at the project site is assumed to be stored or diverted. Therefore, project impacts are expected to be prevalent along the North Sulphur but diminish in relative magnitude quickly below the confluence with the South Fork.

Water from the project will be delivered to Lake Lewisville and then the Applicant's Tom Taylor water treatment plant as well as directly to the Tom Harpool treatment plant, all in the Trinity River basin via pipeline. No hydrologic evaluation of the introduction of water to the Trinity River basin has been performed by the Corps including no evaluation of any changes in hydrology in the Trinity River basin due to the introduction, use, and reuse of the LRH project. Changes in the Trinity River basin are expected to be small in a relative sense. LRH will deliver up to 45,000 AF per year directly to the Tom Harpool water treatment plant or into the approximate 600,000 AF Lake Lewisville as well as into a river system with several other large reservoirs and multiple large municipal raw water inflows from other river basins. The Corps did evaluate the introduction of said water in Lake Lewisville under its 408 authority. Therefore, the geographic scope for the 404 permit evaluation is limited to the Sulphur River Basin.

Application of Guideline 1.F: Minor-level project analysis and determination

Due to the size of the project, permit type, and the extreme daily variability in the hydrology, additional modeling needs to be done apart from WAM. The existing Corps RiverWare model was designed for flood control and therefore will not adequately simulate streamflows during dry periods when impacts to aquatic resources may occur within the stream channel. The HEC-RAS model may be used to evaluate river stage, including the extent of out-of-bank events that support riparian function. However, the HEC-RAS model would require realistic estimates of without-project flow that could be supplied from model outputs or simpler estimation methods.

Tier-2 and Tier-3 HMGs should be applied for hydrologic modeling that supports the aquatic effects analysis for this project.

Application of Guideline 2.A: Gather the best available hydrologic data for the project area

Stream gage data is available as described in HMG 1.D. Some reservoir operation data is available for Lake Chapman. Stream gages are relatively sparse and the nearest gage to the proposed reservoir site (Talco Gage) is several miles downstream and has a much larger contributing area. Regional soil maps and precipitation maps are available and show little difference between the basin above the proposed reservoir and the basin above the Talco Gage. Therefore, a simple drainage-area ratio would be an appropriate method to estimate streamflows available at the project site.

WAM modeling is available for the basin for 1940 to 1996. The model includes several water users, water rights, precipitation, evaporation, and naturalized streamflows on a monthly basis. The model was used to obtain the water right for LRH and determine the firm yield of the project.

The RiverWare model was originally designed as a flood control model by the Corps. LRH was simulated with an uncontrolled spillway and did not make any releases to downstream water rights during dry periods. The model included daily streamflow data, but precipitation and evaporation are monthly-average values. The inflows estimated for LRH were on average 9,000 AF more that was used in the WAM model. This may be due to small differences in the assumed contributing area of the basin above LRH.

The Corps developed a HEC-RAS model to compute stream stage at many locations in the Sulphur River Basin. Although the model was originally intended for very high flows, the model can be adapted for a wide range of flows, and a comparison of flows with and without LRH, to analyze the project effects on out-of-bank flow.

The Applicant has developed a mitigation plan that would deliver some water to a downstream abandoned channel of the Sulphur River (that is not incised like the main channel).

Application of Guideline 2.B: Determine critical hydrologic period for analysis

The WAM model has a period of record from 1940 to 1996. The RiverWare model has a period of record from 1938 to 2014. The drought of record from 1951 to 1957 had a larger cumulative deficit than the more recent 2010 to 2014 drought in the Sulphur Basin. Periods of low flow are important for aquatic resources. The primary aquatic resources below the proposed site are pools and puddles that form after larger precipitation events. There is very little to no baseflow in the North Sulphur River, so prolonged periods without precipitation result in the pools shrinking due to evaporation and little flow between them. For project yield calculations, the 1950s drought of record is still considered the critical period.

Application of Guideline 2.C: Determine the timestep required for hydrologic modification analysis

The WAM model uses a monthly timestep and is used for calculating water availability and project yield. The RiverWare model uses daily data for streamflow, but used monthly-averaged rates for other parameters, such as precipitation and evaporation. Monthly timesteps do not capture peak flows and their effects as well as daily timesteps, especially with the flashy nature of the North Sulphur River where flows can vary by thousands of cfs within a few days. While monthly timesteps are appropriate for computing the yield of the project, they are not appropriate for computing the effects to aquatic resources. Daily flows should be simulated.

Application of Guideline 2.D: Understand assumptions included in any modeling used

The WAM modeling used for project yield assumes full use of other authorized water rights in the basin, no (or reduced) return flows, and a strict administration of the seniority of water rights. Downstream senior water rights at Lake Wright Patman are simulated by calling water past LRH during dry periods to meet storage targets at Lake Wright Patman. WAM model documentation for the Sulphur River acknowledges that this occurs in the modeling but states that this may not occur in actual operations or it may occur to a lesser degree. Therefore, the WAM modeling will be biased in over-predicting releases from LRH during the critical dry periods. Evaluation of the effects to streamflows below the dam must consider this over-prediction.

In contrast, the RiverWare model is a flood control model that does not simulate low-flow operations because low flows are unimportant to a flood control model analysis. The RiverWare model therefore simulates no releases from LRH during critical dry periods.

Releases are expected from LRH during dry periods as either a release to downstream senior water rights (though not to the extent simulated in the WAM model) or for the mitigation plan. The WAM model and the RiverWare model, therefore, serve as bookends to actual expected flows (i.e., as limits to flows during dry periods: Flows would likely not exceed the WAM-computed flows and would not likely be lower than the RiverWare-computed flows).

If the effects to aquatic resources are found to be at an acceptable level when using the RiverWare model, that implies that actual effects would be less impactful because more flow is anticipated to be released from the reservoir than the RiverWare model simulates.

The Corps developed an Excel model to simulate the effect of the project on pools and puddles downstream of the project site. The model used the RiverWare model outflows from LRH, but used downstream watershed characteristics developed for the WAM model to estimate inflows from tributary areas. The model assumed a distribution of pools based on work presented as testimony associated with the Applicant's water rights. The model used a period of 1994–2014 because daily precipitation and evaporation data were available for this period, which is important for the pool analysis due to the RiverWare model's low release rates from the reservoir. The without-project scenario used gage data adjusted for drainage basin size.

Application of Guideline 2.E: Hydrologic modification analysis should preferentially use observed data for a baseline and modeled data secondarily

Daily precipitation and evaporation data was necessary to evaluate the effects to the pools and puddles downstream of LRH. Prior to this time period, only monthly-averaged data was readily available. The daily timestep aided in determining the quantitative impacts on the benthic organisms and fish that rely on the pools of water below the LRH site.

Evaluation of out-of-bank frequency used observed gage height data and used very conservative estimates of flow modification at each gage location to estimate the change in river stage.

Application of Guideline 2.F: Coordination with resource agencies

Because the project was the subject of an EIS, the Corps engaged multiple Federal and state agencies as cooperating agencies as required by NEPA. The EPA, USFWS, TPWD, TCEQ-WQ, and U.S. Forest Service were engaged throughout the process. Previous resources of concern related to hydrology that were raised in the Applicant's water rights permit process included the benthic organisms and fish that survive in pools and puddles downstream of the proposed project site between precipitation events that typically drive flow in the incised river channel. In addition, out-of-bank flow frequency near the dam site and downstream nearer to Lake Wright Patman was of concern.

After coordination, some agencies expressed concern about the ability to simulate the pools and puddles immediately downstream of the project area. The hydrologic analysis revealed that farther from the project site, more tributary inflow contributed to the maintenance of the pools and puddles. It further informed initial decisions by the Corps relative to the need for additional resource-specific analyses to address effects to these resources of concern.

Application of Guideline 2.G: Simplify hydrologic modification analysis as much as possible to make determination of adequacy of analysis

As described in HMG 2.D, two existing models (WAM and the RiverWare Red River flood control model) serve as upper and lower limits to flows anticipated during low-flow events. This conclusion required additional evaluation immediately below the dam site based on feedback from other regulatory agencies.

Hydrologic modification is appropriate to evaluate the out-of-bank frequency by using downstream stream gages, observed flows, and assumed maximum impact of LRH on the flows at downstream sites. The resulting change in river stage computed at downstream gages based on this hydrologic modification can be entered into the HEC-RAS model to simulate the lateral extent of high-flow events at these known locations.

Application of Guideline 3.A: Use any Applicant-provided modeling where appropriate to save time and money in hydrologic model development

Available modeling was described in HMG 2.D. Based on agency coordination, additional modeling was undertaken to simulate effects to the pools and puddles immediately below the project site. For the downstream pool volumes, a spreadsheet from on-site fieldwork data developed as part of the analysis associated with the Applicant's obtaining its water right was used to develop new model inputs.

Because this project involved an EIS, thorough independent verification and validation of Applicant-prepared modeling was conducted. Also, the third-party contractor undertook additional modeling efforts to address agency concerns and the Corps' needs for disclosure in the EIS process. Due to the unique circumstances associated with EIS-level actions, Corps project managers need to use informed judgment as to which entity (third-party contractor, Applicant, or Corps' H&H branch) may be able to accomplish additional modeling efforts most expeditiously while satisfying and maintaining its independence role.

Application of Guideline 3.B: Hydrologic model should be designed around known or anticipated needs of aquatic resources to be evaluated

The Corps and other cooperating agencies focused on the project's effects on geomorphology and sediment transport, floodplain pools and puddles with benthic organisms and fish, floodplain resources, water quality and temperature, and groundwater. The scoping process associated with the EIS, in addition to professional judgment, informed the identification of these factors. There is little groundwater interaction with the stream due to high clay content, so it was considered negligible for hydrologic modeling purposes. A daily timestep was required for the EIS analysis due to the flashy nature of the stream; the potential impacts of these large changes in flow will impact geomorphology, sediment transport, the pools, water quality, and water temperature as opposed to monthly averages. The analysis provided quantitative results for the impacts on benthic organisms and fish and floodplain resources using the new Excel model to better simulate the in-channel pools. Hydrologic modification was used to evaluate stream stage changes as part of the floodplain resources analysis.

Based on site conditions, the Corps determined that qualitative results for geomorphology, sediment transport, water quality and temperature, and groundwater resources were adequate to issue the Draft EIS.

Application of Guideline 3.C: Model purpose should be centered on reasonably representing streamflows under a variety of conditions, including critical periods

As described in HMGs 2.D, 2.F, and 3.A, additional modeling was required to simulate the pools and puddles immediately downstream of the proposed reservoir. There was no available data for the flows below the proposed reservoir except for the monthly WAM model and the daily RiverWare model (see HMG 2.D). As described above, the WAM and RiverWare outputs each had biases to over- and under-predict flows below the project site.

An Excel model refined the modeling analysis on the pools and puddles by using available daily evaporation and precipitation data that was not used in either the WAM or RiverWare models. For the pools and puddles downstream of the proposed site, other than inflows from upstream, the two largest hydrologic factors are evaporation and precipitation. Simulating these factors on a daily basis while assuming inflows from the more conservative of the two hydrologic models allowed for the detailed evaluation of the effect on the pools and puddles. The daily analysis captured the potential effects of the normal variability in weather conditions, rather than using a monthly average.

For example, consider a scenario where a rainfall event occurs on the first day of a month, and it does not rain again until the last day of the subsequent month. This results in nearly 60 days without rain. In contrast, the WAM and RiverWare models both used monthly-average evaporation and precipitation values, so every day for these same two months would show a non-zero precipitation event. Using a daily model of precipitation and evaporation will more accurately simulate the increased drawdown of the pool volume (and likely surface area) as compared to a model that used the daily average that is continually replenishing the pools.

At the larger scale of the basin hydrology, the monthly-averaged values were appropriate and would result in negligible differences in model results. However, when the primary hydrologic driver — river inflows — was not considered due to assumed storage at the upstream reservoir through a critical drought period, the smaller-magnitude inputs of evaporation and precipitation became more important for determining effects.

Application of Guideline 3.E: Model domain should encompass geographical extent and a sufficient study period to accurately reflect the range of results

The geographic area identified in the Tier-1 evaluation was confirmed with an analysis of change in river stage at downstream gages (see HMG 2.D). This analysis showed the small effect on stream stage at the existing geographic extent. Comparison of the flowrates and flow volumes at the downstream gages indicated that the LRH withdrawals become a rapidly diminishing component of the overall water balance due to the relatively small size of the catchment of LRH. Note: This conclusion was limited to the proposed project area and did not consider hydrology in the receiving basin (Trinity) as previously explained in HMG 1.E.

The study period used in the two hydrologic models (WAM and RiverWare) encompass several decades of hydrology, including periods of drought and periods of high flows. The WAM model does not include the recent 2010s drought period. The Excel model used a shorter period of record beginning in 1994 when daily evaporation and precipitation data were readily available. A statistical

analysis of daily flows over the longer period of record was compared to the shorter 1994–2014 period used in the Excel model. The statistics were substantially similar, indicating the shorter but more recent period of record included a similar range of hydrology as the longer models. No significant water resources development has occurred in the North Sulphur River since the 1930s when the river was channelized that would bias results depending on the period of record.

Application of Guideline 3.F: Model timestep should reflect the critical timescale of the aquatic resources being evaluated

Monthly timesteps were adequate for evaluating the effects of drought on water supply, especially in the critical period of the 1950s. However, for the EIS, a smaller timestep was required, especially due to the flashy nature of the river near the project site and the need for adequate information and data to describe the current conditions of the aquatic resources located below the dam and the potential effects anticipated to occur to them. Daily data was sufficient for the effects analysis for this project. Some monthly-averaged data was acceptable for smaller components of the water budget. However, when only the effects of these smaller water-budget components were considered (evaporation and precipitation on the pools and puddles within the river channel), monthly-average data was insufficient and daily data was required.

Application of Guideline 3.G: Proposed operations and administration should be incorporated into the hydrologic modeling

After modeling described in the foregoing HMGs was performed, the Applicant provided an operations plan that indicated that diversions at the reservoir would be lower than the amounts previously assumed (35,000 AF per year, constant, as compared to 45,000 AF with lower diversions in dry years). In general, this operation will result in higher flows at the dam site due to the lower withdrawal rate. However, in dry years, the withdrawal of 35,000 AF would be higher than the withdrawal in the 45,000 AF overdraft scenario because diversions are reduced in drought years in the over-draft scenario. An additional set of model runs was made to simulate the proposed operations. Effects were primarily seen in reservoir levels, as the same biases in the WAM and RiverWare models described above were evident in the new runs as well. During dry periods, the RiverWare model did not simulate any outflow, and the WAM model simulated releases to downstream water rights at approximately the same amounts as in the overdraft scenario. Therefore, the conclusions of the original modeling did not change for effects downstream of the reservoir based on this difference between proposed operations and modeled assumptions. Inclusion of a final operations plan would be part of appropriate permit conditions.

8.2 Colorado water supply EIS projects

To further demonstrate the applicability and potential usefulness of the HMGs, some of the case studies include actions that occur in Colorado. It is recognized that stark differences exist in water rights administration and other factors between Colorado and Texas. However, these do not diminish the applicability of the HMGs and offer the ability to provide greater insights into their application.

There were five water supply EIS projects occurring in the South Platte River basin in Colorado (Denver is located in the South Platte River basin). Of these five projects, the Corps was the lead agency on four EISs, while functioning as a major cooperating agency on the fifth EIS, which was being led by the U.S. Bureau of Reclamation. Two of these actions have been selected as case studies. The Moffat Project Final EIS was released in April 2014 and the Record of Decision was issued in July 2017. Additionally, the Corps issued a Draft EIS (DEIS) in September 2008 and a Supplemental Draft EIS (SDEIS) for the Northern Integrated Supply Project (NISP) in 2015. This area of Colorado has grown rapidly in the past several decades, and growth is expected to continue. Some key attributes of these two projects involve aspects of simulating future conditions in the EIS process to distinguish between effects caused by the project and other hydrologic changes that are likely to occur due to actions others are proposing to take to meet water demands. They also involve substantial geographic areas with large existing systems as well as effects to threatened and endangered species and their critical habitats wherein required consultations to comply with Federal statutes require the use of other established hydrology.

8.2.1 Northern Integrated Supply Project (NISP)

The NISP is a proposed project that involves construction of two new reservoirs, Glade Reservoir (170,000 AF) and Galeton Reservoir (45,000 AF), in northern Colorado. Glade Reservoir would divert water from the Cache la Poudre River, which is a tributary to the South Platte River. Galeton Reservoir would divert water from the South Platte River just downstream of the confluence with the Cache la Poudre River. The Applicant would "relocate" water stored in Galeton Reservoir into Glade Reservoir by means of several different river exchanges, whereby water is pumped from Galeton Reservoir to water users on the Cache la Poudre River and in exchange, the Applicants would divert a like amount of water at the upstream Glade Reservoir. The project required an EIS. As of the date of this report, the Corps has published a DEIS and SDEIS, and anticipates publishing the Final EIS (FEIS) in the near future.

One of the factors complicating the evaluation of NISP is that two other EIS actions are occurring in the same river basin that will be affected by NISP (Cache la Poudre). The Halligan Water Supply Project and Seaman Water Supply Project involve the proposed expansion of two municipal reservoirs upstream of the Glade Reservoir diversion point. As of the date of this report, the Corps has not yet published a Draft EIS for either of these projects. However, early in the process of the NISP, Halligan, and Seaman EISs, the Corps determined that all three projects should use the same underlying hydrology so that the effects computed between all projects would be comparable and equitably divisible. This led to the Common Technical Platform (CTP), a series of hydrologic models that are used by all three projects.

A complicating factor associated with the project involved differing hydrological data and analysis associated with the Endangered Species Act, which the project was subject to, and the hydrologic analysis being developed for the Poudre River. Recovery plans existed for a number of species and critical habitat which relied upon the established hydrology for the purposes of the ESA. This was not reflected in the development of the CTP. This lead to differing resource analyses being dependent upon differing hydrological assessments.

The NISP project involved several issues that would be addressed by the HMGs. Information gathered through the Tier-1 and Tier-2 HMGs would provide necessary information related to the hydrology of the project. However, in this report, we focus on HMGs 3.A, 3.B, 3.C, 3.G, and 3.H because they are particularly insightful to hydrologic modeling used for this project.

Application of Guideline 3.A: Use any Applicant-provided modeling where appropriate to save time and money in hydrologic model development

The Applicant had developed a model of the Cache la Poudre basin using the MODSIM modeling platform. The model used a monthly timestep and represented several municipal water users in a relatively simplified manner. Since the Corps was simultaneously evaluating two other reservoir expansion EIS projects that would serve five other municipal water providers and one irrigation company, the Corps required that a common modeling platform be used for all projects in order to reasonably compare effects of each project and the cumulative effects.

To develop a common hydrology, the water rights and operations of the municipal providers needed to be incorporated into the modeling. Each of the other water providers and irrigation company had developed more detailed system models in order to more accurately simulate individual operations than was represented in the Applicant's MODSIM model.

Applicants from all three EIS projects proposed combining the basin model and the more detailed system models by running a series of model runs, where outputs from one model would serve as inputs to the next model. Final flows within the river would be computed by post-processing the last model's output. It was anticipated by all parties that using existing models would save both time and money.

At the request of a cooperating agency, the Corps evaluated the possibility of developing a new RiverWare model that would simulate the features in the basin model for the Applicant, as well as the more detailed municipal operations from the system models. However, at the time, RiverWare did not have a water rights solver and was ultimately not selected due to this critical need for the Cache la Poudre basin.

The Common Technical Platform was ultimately developed using a combination of the basin model and four system models. The Corps and Applicants spent a considerable amount of time and money reconciling the model inputs and assumptions from the multiple Applicants as well as developing a modeling routine that met the Corps' needs for the EIS. This involved running models through multiple iterations when outputs from one model would change the results of the first model. In retrospect, developing a single model may have saved both time and money, even though at the time, it appeared the use of existing modeling would be more efficient.

Application of Guideline 3.B: Hydrologic model should be designed around known or anticipated needs of aquatic resources to be evaluated

As described in the application of HMG 3.A, existing modeling was implemented because it was anticipated to be more efficient. The models were originally designed to simulate the yield to water rights and not necessarily designed to accurately simulate streamflows. Therefore, as work on hydrologic modeling proceeded, the model configuration was not closely examined for the data needs of the resources that were to be evaluated. The hydrologic model outputs were monthly flow volumes through reaches that are critical for water rights administration.

Concurrent with the hydrologic modeling generation, geomorphology and aquatic species needs were being developed by resource specialists. Based on public scoping and other known data in the basin, these resource specialists identified locations within the basin for analysis that did not align with an explicitly computed stream flow from the model.

Later in the project, it was determined that stream temperature and water quality modeling was needed. The hydrologic model developed for the project did not distinguish between the different sources of water entering the stream at all locations, which is a critical input for the temperature and water quality models.

The Corps was able to develop methods to address these issues through various methods of interpolation, regressions, and sensitivity analyses. However, had the hydrologic modeling needs been known at the outset of the hydrologic modeling effort, these factors could have been included in the model design and would have eliminated several difficulties encountered when the resource modeling needs were known after the modeling had been completed.

Application of Guideline 3.C: Model purpose should be centered on reasonably representing streamflows under a variety of conditions, including critical periods

As described in HMG 3.A, the hydrologic modeling was developed using a combination of existing models that were originally designed to compute the yield of the proposed projects. In many cases, the streamflows computed within the model were accurate, but since the model was designed primarily to compute project yield, several modeling assumptions were made that are extremely useful in computing the maximum yield available to certain water rights but that do not correctly simulate streamflows.

For the Common Technical Platform modeling, an overall basin model that included most water rights in the basin was the first model run in the modeling series. The model included large demands set with junior priorities to simulate water potentially available for diversion under the associated junior water rights. In the basin model, this water was simply diverted from the river, and this amount would then become an input into the more detailed system models.

The system models were designed to consider all sources of water available and simulate how the system performs with a given amount of water available under each water right and the particular configuration of the system (e.g., with or without a proposed reservoir enlargement). If the system model was not able to use certain sources of water, this water was considered “spilled” or lost to the

system. For a yield and operational model, this lost water is a measure of overall system efficiency. However, in reality, the "lost" water would simply not have been diverted from the stream in the first place and would have been available to other water users in the basin or simply would have remained in the river. This type of feedback loop to the basin model required multiple iterations of the basin model and system model to reasonably simulate streamflows rather than to compute the yield and operational efficiency.

A single model that included the general nature of the basin model and the detailed operational aspects required for the municipal water providers could have simplified the hydrologic modeling process by simulating streamflows without the need for multiple-model iteration and feedback loops.

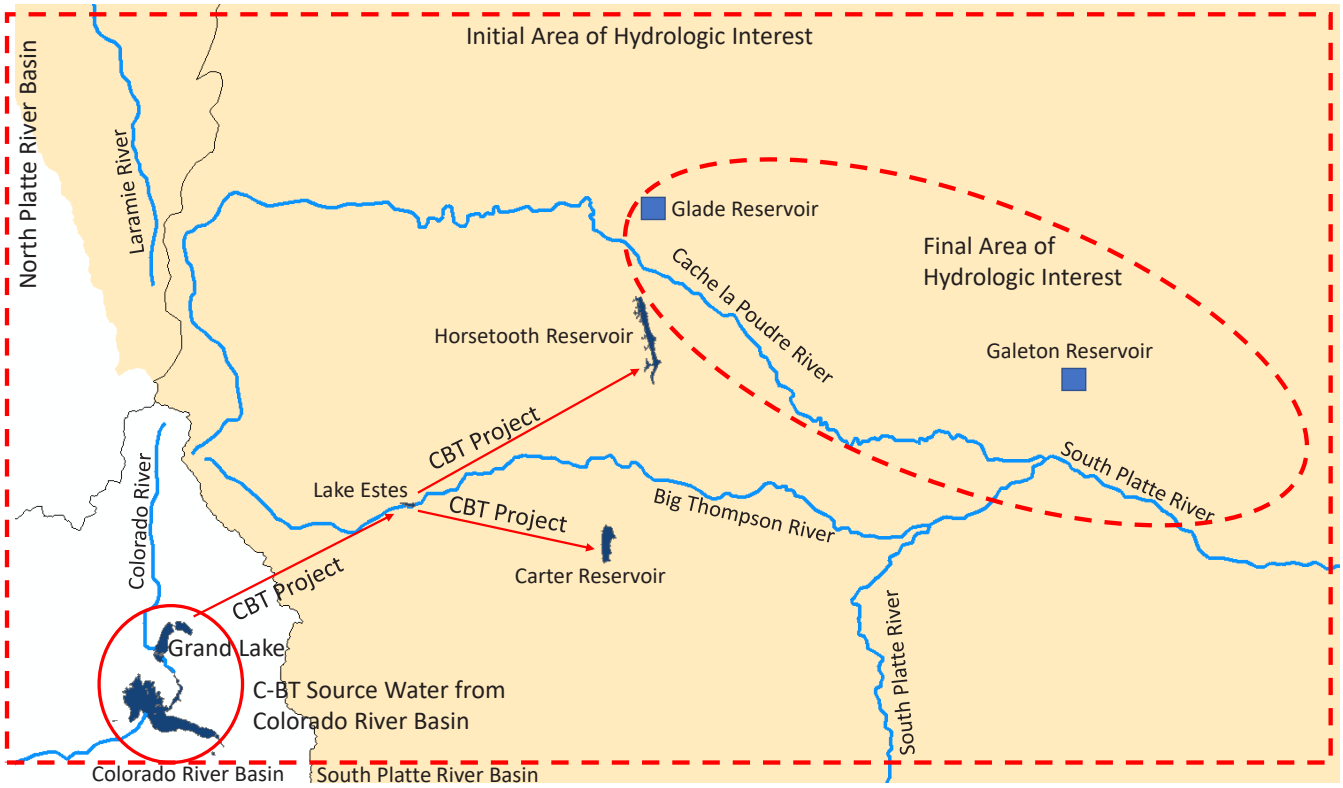
Application of Guideline 3.G: Proposed operations and administration should be incorporated into the hydrologic modeling

One of the key considerations in the Corps' decision to not develop a RiverWare model was that, at the time, RiverWare did not include a water rights solver. In Colorado, water rights administration is highly complex and several water users and state agencies have developed specialized models to reasonably simulate the water rights system. A model without a water rights solver simply could not reasonably represent stream conditions under proposed conditions involving the proposed project or alternatives to the project. In addition, the municipal system models incorporated into the Common Technical Platform were custom-designed models specific to each providers' system. While individually these system models would potentially be used or relied upon by the Corps, together they proved problematic. Some of these water providers' complex operations models would be challenging to simulate using the standard water rights modeling platforms commonly used in the region.

Now that RiverWare includes a water rights solver, it is a good choice for simulating both algorithm-based issues such as water rights and adding special-case flexibility needed for more complex operations through its RPL (RiverWare Policy Language) ruleset. RiverWare rules allow the modeler to set certain policy rules that can simulate complex operations, while the water rights solver can simulate water availability to water rights in accordance with the regional water administration practices.

Figure 19 is a map of Northern Colorado showing two major river basins (Colorado River to the west, and South Platte River to the east) and shows the initial area of hydrologic interest and the final area of interest. The Applicant operates a large water supply project called the Colorado-Big Thompson Project (C-BT Project) that diverts water from the Colorado River basin and delivers it to the Big Thompson River, a tributary of the South Platte River Basin. A portion of the C-BT water is delivered to the stream in the vicinity of one of the proposed reservoirs associated with NISP. The Applicants agreed that no C-BT water would be stored in the proposed NISP reservoirs, and therefore operations of the C-BT system would not be changed due to NISP. This operational commitment was included in the hydrologic modeling and allowed the Corps to reduce the study area for NISP and exclude the Colorado River Basin from the effects analysis.

Figure 19. Map of initial area of hydrologic interest and the final area of hydrologic interest with key Applicant infrastructure.



Application of Guideline 3.H: The study period time frame should consider reasonably foreseeable future actions for the development of a future-conditions baseline

The Cache la Poudre basin is rapidly changing from an agricultural-dominated past to an increasingly urban and suburban environment. Projected municipal water demands are rapidly increasing, and water providers are taking steps to increase their water supplies on multiple fronts. For the NISP project, the hydrology was initially developed using current conditions with and without the project. The measured aquatic resource conditions that exist in the Poudre River (e.g., fish species and populations, geomorphologic conditions, etc.) to be impacted by NISP are reflective of the current conditions hydrology and need to be disclosed in the EIS as well as to determine causal effects and render a LEDPA determination. However, to appropriately capture the full range of effects when NISP is in full-demand operations (as well as other in-basin EISs) and to address cumulative effects, all reasonably foreseeable future actions (RFFAs) specific to hydrologic modifications in the basin from other projected actions were identified and included in the modeling. This resulted in the Corps' developing two baseline conditions — a current conditions baseline (without the proposed project) and a future-conditions baseline (without the proposed project, but considering the hydrologic effects of each project as well as the RFFAs).

An example that furthers this point involves the transfer of water currently delivered to agricultural users over to municipal water providers. Such action will diminish the flow in several reaches of the Cache la Poudre River compared to current conditions, without the proposed project. Since these future conditions are reasonably predicted to occur, the Corps must also consider what the proposed project's effects will be under those conditions. In addition, the cumulative impacts of the proposed project and the other two proposed reservoir expansion projects in the basin must be similarly considered to understand the potential aggregate effect of the projects.

The projected future-conditions baseline hydrology instills the need to project future resource conditions without the ability to measure such conditions. Numerous views are provided and doubts are raised relative to the validity of the aquatic resource status and functions at that future time. Development of a current conditions baseline and future-conditions baseline allows for a bracketing of known and potential conditions and the effects to occur from NISP. This bracketing of hydrologic conditions through "with-project" conditions added to both baselines allowed for increased confidence in determining the causal effects. Causal and cumulative effects runs for the other proposed projects were also to be accomplished, ensuring that impacts are appropriately ascribed to each project as well as to address threshold determinations.

Hydrologic modeling in general is well-suited to this type of future-conditions analysis because any number of assumptions can be changed within the modeling. The modeling platform is less important for this analysis than the assumptions and adjustments made to the model input to simulate the RFFAs. RiverWare's scenario management tools and the configuration of the RPL rule sets can assist in managing this data, but they are not a replacement for a thorough understanding of the regional trends, operations, and water supply systems in determining reasonable modifications to model inputs to simulate future conditions.

For the NISP project, the Applicant developed an external spreadsheet model that projected a trend of the changing nature of water deliveries from a large U.S. Bureau of Reclamation Project from primarily agriculture deliveries historically to increasingly higher percentage to municipal providers. Deliveries to agricultural water users were conveyed in the Cache la Poudre River (and other regional streams) from a large reservoir near the foothills. Municipal water providers have water treatment plants at the foot of the reservoirs and therefore, the deliveries through the natural stream will continue to decrease. This was an important factor in computing stream effects because this trend is not attributable to the project, but had to be quantified to reasonably assess the impacts the proposed project will have on future river conditions.

8.2.2 Moffat Collection System Project

The Denver Water Moffat Project is a proposed expansion of Gross Reservoir in Boulder County, Colorado. The expansion would raise the level of the dam by 131 feet and increase the capacity of the reservoir by 77,000 AF. The Applicant seeks to increase its reliability and flexibility while decreasing vulnerability to hydrologic variability. Water will be diverted from the Colorado River headwater tributaries and then delivered to Gross Reservoir via the existing Moffat Water Tunnel, which delivers water into the headwaters of South Boulder Creek. The additional withdrawals from the Colorado River Basin are expected to only occur during average and wet years because the Applicant already diverts all its legally available flows during dry periods.

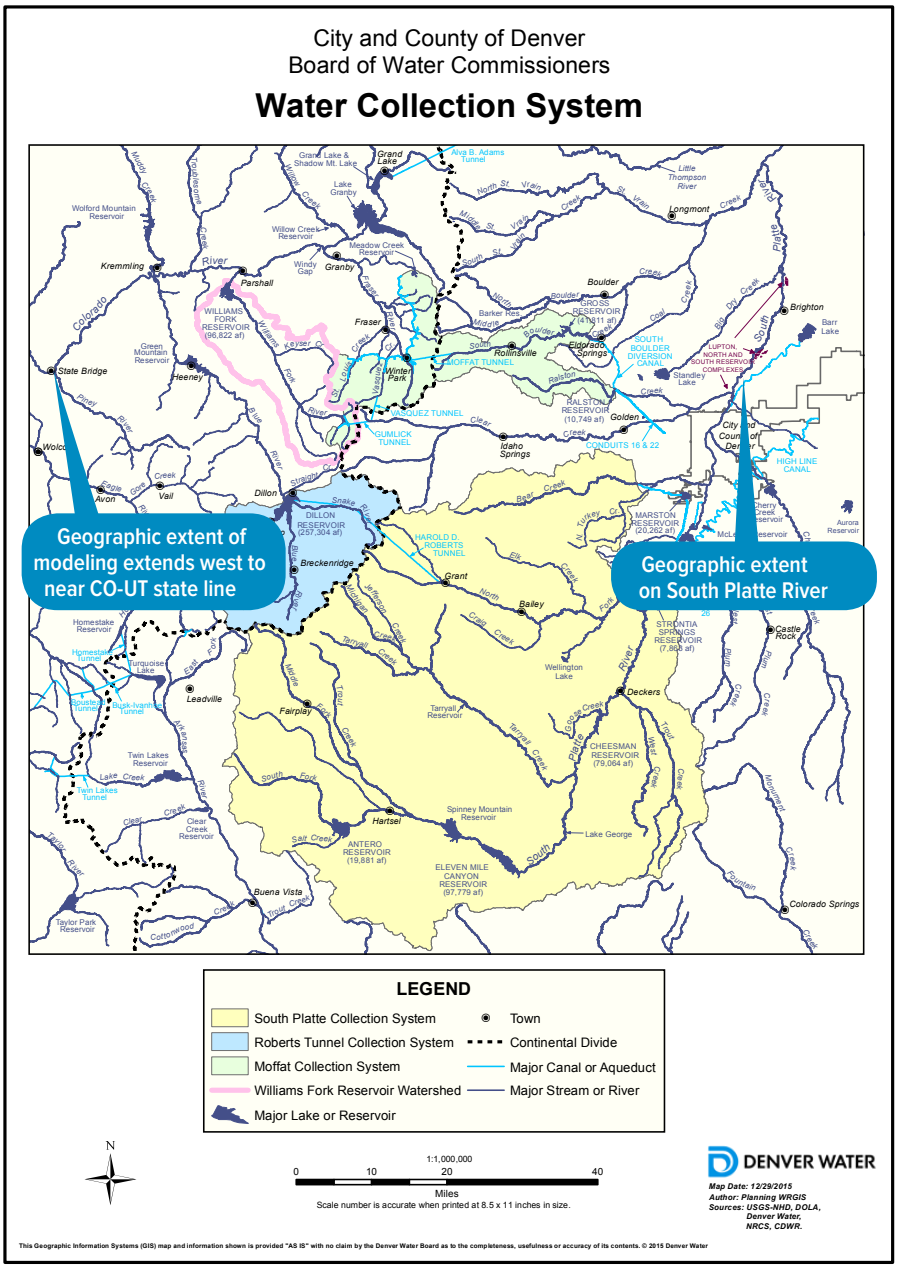


Figure 20. Map of Denver Water raw water collection system and geographic extent of area of hydrologic interest.

The Moffat Project involved an EIS and significant information that would be associated with Tier-1 and Tier-2 level HMGs was included in the EIS. For this case study, we focus on six Tier-3 HMGs that were especially relevant during the hydrologic modeling review and development.

Application of Guideline 3.A: Use any applicant-provided modeling where appropriate to save time and money in hydrologic model development

The Applicant had previously developed a hydrologic model called PACSM (Platte and Colorado Simulation Model) for its system operations. The Corps reviewed the model and compared it to other existing models. A thorough review of the model was made, which determined that PACSM was appropriate for the EIS effect analysis based on several factors, including geographic extent, timestep, and current and future scenario development (see below, 3.E, 3.F, and 3.H).

This project is an example of where a model was determined to be appropriate for use in the EIS setting through a review of the key features that the Corps requires for the effects analysis. In addition to the key factors identified above, the model was reviewed for the critical period, modeled demands and inputs from other water users in the basin, and where appropriate, adjusted for current and future conditions (see 3.H). While specific resources were not identified in the model review, the model outputs were used in other resource evaluations (aquatic habitat, temperature, etc.). The Corps review of the model identified a number of model inputs and configurations that required minor modifications to appropriately simulate conditions for the Corps effects analysis. These revisions were made by the Applicant and the model was used for the effects analysis.

Due to the complexity of the Applicant's system and that the system spans multiple watersheds, development of a new model or extension of other existing models would have been a multi-year task. Appropriate review of the factors discussed in the Tier-3 HMGs led to significant time and cost savings for the Applicant.

Application of Guideline 3.D: Simulate Avoidance and Minimization actions separate from Compensatory Mitigation

The proposed action for the Gross Reservoir expansion (Applicant's proposed project) was simulated with a capacity of 72,000 AF, which is the size required to meet the project's purpose and need. This size included measures to avoid and minimize impacts, and was compared to other alternatives for the project effects analysis. The LEDPA was determined from this comparison.

As a part of the compensatory mitigation plan, the Applicant proposed increasing the size of the reservoir by 5,000 AF for a total size of 77,000 AF. This would require a 6-foot raise to the dam as compared to the 72,000 AF reservoir evaluated for the effects analysis. The additional storage would be used to make minimum stream flow releases below the dam during dry periods. Separate modeling was performed to evaluate the effects of the proposed compensatory mitigation. This modeling was not performed on all other alternatives because the LEDPA had already been determined without considering the effects of compensatory mitigation. In other words, avoidance and minimization were modeled separately from the compensatory mitigation effects.

The hydrologic modeling for compensatory mitigation indicated times when flows would be reduced relative to the simulated flows in modeling used for primary effects analysis to fill the 5,000 AF compensatory mitigation pool. Similarly, the modeling indicated times releases would be made from this pool to increase flows during low-flow periods to meet targeted instream flows below the dam to benefit aquatic habitat. The Applicant agreed that it would not store any of its project water in the 5,000 AF pool used for compensatory mitigation, and that all water stored in that pool would be used for the minimum flow releases.

Application of Guideline 3.E: Model domain should encompass geographical extent and a sufficient study period to accurately reflect the range of results

The geographic extent of the model encompasses the entirety of the Applicant's water collection system, including facilities in multiple watersheds. The model extended to locations downstream of the Applicant's facilities because water rights located downstream of the Applicant's facilities could also have a significant impact on the project operations and model results. The Corps evaluated the geographic extent at upstream and downstream extents of the model. The upstream extents extended into the headwaters of adjacent watersheds, and upstream areas were therefore considered in the modeling.

On the downstream boundaries, the Corps confirmed that the water rights and operations of others that could impact the Applicant's operations were included in the modeling. This included a model domain that extended to close to the Colorado-Utah state line on the Colorado River, and to the Henderson Gage on the South Platte River, which is located approximately 10 miles downstream of Denver's primary wastewater treatment plant. Significant modeling detail was devoted to the upper reaches of the headwaters areas due to the importance of streamflows in these areas to the yield of the project (Figure 20).

The Corps evaluated eight other models that had been used by other entities that overlapped at least a portion of the Applicant's water collection system. Most of these models simulated a single watershed, and none encompassed the Applicant's entire system. Combination of multiple models or extension of any of the other models would have resulted in delays and additional costs.

Application of Guideline 3.F: Model time-step should reflect the critical time-scale of the aquatic resources being evaluated

The Corps evaluated eight other models that had been used by other entities that overlapped at least a portion of the Applicant's water collection system. All of these other models used a monthly timestep. The PACSM model uses a daily timestep. Therefore, while specific aquatic resources were not identified during this stage, the model used by the Corps was already in a daily timestep which facilitated use of the hydrologic modeling output in the aquatic habitat and temperature modeling used later in the EIS process. This selection of a daily timestep would also have been determined through HMG 2.C before all aquatic resource factors were identified.

Application of Guideline 3.G: Proposed operations and administration should be incorporated into the hydrologic modeling

The modeling platform used by the Applicant (PACSM) is able to adequately represent the Applicant's large and complex system. The model spans multiple watersheds where the Applicant operates its raw water collection system. The model represents the Applicant's and other entities storage rights, instream flow rights, reservoir-governing rights, exchanges, and substitution and payback accounting in each of the affected watersheds. The modeling included over 2,000 operational rights in the PACSM model. The water is allocated in PACSM based on available flow, water rights, water demand, and diversion and storage capacities, and other administrative and operational aspects of the basin. All limits, operations and administration needs are reflected in the modeling and outputs reasonably simulate streamflow at locations of interest.

Application of Guideline 3.H: The study period time frame should consider reasonably foreseeable future actions for the development of a future conditions baseline

The Applicant developed a future conditions baseline that included the potential impacts from 21 different water development activities occurring in the watersheds where the Applicant project and alternatives would operate. Several of the activities would have minimal influence on the proposed project, and were discussed qualitatively. Other projects located within the same watersheds that would likely influence flows within the geographic extent were expressly simulated in the hydrologic modeling. These reasonably foreseeable future actions (RFFAs) were also included in the cumulative effects analysis. The project effects were determined by evaluating flow conditions with the RFFAs because the proposed project was anticipated to be online at approximately the same time as other RFFAs were expected to be implemented.

View of the Toledo Bend Reservoir from South Toledo Bend State Park near Anacoco, Louisiana. Photo: Chris Miceli
https://upload.wikimedia.org/wikipedia/commons/8/85/Reservoir_of_South_Toledo_Bend_State_Park.jpg

9.0 Glossary for Hydrologic Modeling Guidelines

Terms in this glossary are indicated in bold font and an asterisk in the Hydrologic Modeling Guidelines technical report where they first appear. These terms are indicated with an asterisk in the list below.

Because this document was developed for the Fort Worth District, Texas, it is anticipated that many of the users will be from Texas. Therefore, we included terms (in italic font) as presented in the glossary of the 2017 Texas State Water Plan by the Texas Water Development Board. In some instances, where we are aware that a term has been updated for use in the 2022 Texas State Water Plan, we included the updated definition. Users should be consult the latest information available from various resources in Texas, such as the Texas Water Code, Texas Administrative Code, or any subsequent updates to the Texas State Water Plan for the latest definitions as used by the state of Texas.

For some of these entries, we included a note below the entry where we are aware of different uses or meanings by water resources engineers in other parts of the country. Entries in italics and marked with an asterisk appear in both the Texas State Water Plan and the Hydrologic Modeling Guidelines.

Definitions contained in the glossary reflect language within various regulations, policy and guidance. Descriptions contained in the glossary are not controlling if there is ambiguity or differences in use of terms.

404(b)(1) Guidelines*

Section 404(b)(1) of the Clean Water Act. Contained at 40 CFR 230 and are the substantive regulations associated with the Corps' permit evaluation process and are focused on discharges of dredge and/or fill material into waters of the United States and their associated effects.

Acre-foot

Volume of water needed to cover 1 acre to a depth of 1 foot. It equals 325,851 gallons.

Aquifer

Geologic formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. The formation could be sand, gravel, limestone, sandstone, or fractured igneous rocks.

Availability

The maximum amount of raw water that could be produced by a source during a repeat of the drought of record, regardless of whether the supply is physically connected to or legally accessible by water user groups (2022 updated definition).

Note: The Texas State Water Plan definition of "availability" may have different meanings. The term as defined above is also referred to as "yield" by water resources engineers. Availability may also mean the amount of water physically and legally available to a water user at any specific time of interest.

Avoidance and minimization*

Contained and defined in NEPA, Public Interest Review and the 404(b)(1) guidelines which require projects to first avoid and minimize impacts of a project and it alternatives.

Baseline conditions*

Existing conditions; the standard against which project alternatives are compared. Baseline conditions are often based on historical hydrology, but may be adjusted to impose current conditions (such as demands, return flows etc.) on historical hydrology.

See also Future Conditions Baseline (below)

Basin-wide model (or basin model)*

Hydrologic model designed to simulate flows and operations over an entire watershed or basin, or large portion of a basin. These models are typically planning-level models and will have varying degrees of detail and purposes.

Brackish water

Water containing total dissolved solids between 1,000 and 10,000 milligrams per liter.

Capital cost

Portion of the estimated cost of a water management strategy that includes both the direct costs of constructing facilities, such as materials, labor, and equipment, and the indirect costs associated with construction activities, such as engineering studies, legal counsel, land acquisition, contingencies, environmental mitigation, interest during construction, and permitting.

Compensatory mitigation*

Refers to regulations in the 404(b)(1) guidelines and Corps Regulations at 33 CFR Part 332 that require projects to mitigate for unavoidable impacts caused by the project in order to compensate for loss of resources. Compensatory mitigation should be assessed after the LEDPA is determined based on impacts that cannot be avoided and minimized.

Conjunctive use

Combined use of surface water, groundwater and/or reuse sources that optimizes the beneficial characteristics of each source (2022 updated definition).

County-other

An aggregation of utilities that provide less than an average of 100 acre-feet per year, as well as rural areas not served by a water utility in a given county (2022 updated definition).

Critical period*

A period of high stress on a hydrologic system. This can be a long drought period or a shorter period when the flows stress aquatic life. Note that the critical period may be different for different purposes or resources. For example, the critical period for the yield of a project is typically through a drought period, but the critical period for certain fish species may be during the spawning season.

Desalination

Process of removing salt and other dissolved solids from seawater or brackish water (2022 updated definition).

Desired future condition

The desired, quantified condition of groundwater resources (such as water levels, spring flows, or volumes) within a management area at one or more specified future times as defined by participating groundwater conservation districts within a groundwater management area as part of the joint planning process.

*Drought**

Generally applied to periods of less than average precipitation over a certain period of time. Associated definitions include meteorological drought (abnormally dry weather), agricultural drought (adverse impact on crop or range production), and hydrologic drought (below-average water content in aquifers and/or reservoirs).

*Drought of record**

The period of time when historical records indicate that natural hydrological conditions would have provided the least amount of water supply (2022 updated definition).

Note: Some water providers opt to use synthetic or stochastic methods to develop a drought of record that may differ from historical conditions.

Environmental Assessment (EA)*

Environmental Assessments are concise public documents that a Federal agency prepares under NEPA to provide sufficient evidence and analysis to determine whether a proposed agency action would require preparation of an environmental impact statement or a finding of no significant impact. An EA is used by the Corps to disclose the effects, both detrimental and beneficial, caused by its permit decisions. An EA is typically developed with small and medium-level projects that do not qualify for coverage under a general permit.

*Environmental flows (E-Flow)**

An amount of water that should remain in a stream or river for the benefit of the environment of the river, bay, and estuary, while balancing human needs.

Environmental Impact Statement (EIS)*

A document prepared to describe the effects for proposed Federal government activities and decisions that will have a significant effect on the environment. An EIS is used by the Corps to disclose the effects, both detrimental and beneficial, caused by its permit decisions. An EIS is typically associated with major projects.

Estuary

A bay or inlet, often at the mouth of a river and may be bounded by barrier islands, where freshwater and seawater mix together providing for economically and ecologically important habitats and species and which also yield essential ecosystem services.

Existing water supply

The maximum amount of water that is physically and legally accessible from existing sources for immediate use by a water user group under a repeat of drought of record conditions (2022 updated definition).

Note: Some water providers would use this definition for “system yield”, “firm yield”, or “system firm yield”. See notes on “firm yield” and “yield” below

*Firm yield**

The maximum water volume a reservoir can provide each year under a repeat of the drought of record using anticipated sedimentation rates and assuming that all senior water rights will be totally utilized and all applicable permit conditions met (2022 updated definition).

Note: The above definition used in the Texas State Water Plan can have other meanings. Many water providers refer to firm yield as the Texas State Water Plan defines “existing water supply (above).” Generally, firm yield does not necessarily refer to the yield of water from a reservoir, but refers to the amount of water from any given supply that is reliably available through a

severe drought condition. When the yield of an integrated water supply system is determined (e.g. from multiple water rights, reservoirs, infrastructure, contracts etc.), this can also be referred to as "system yield" or "system firm yield."

Often, water providers determine the firm yield by replicating a severe historical hydrologic condition (drought), but may also compute the firm yield of a water supply or system using statistical methods to determine specific return periods (e.g. one-in-fifty year drought) or other conditions known to stress a specific system or supply. Water providers will often include safety factors or risk mitigation factors to the firm yield (which may sometimes be referred to as "safe yield."

See also "yield" (below)

Future conditions baseline*

Projected baseline conditions with reasonably foreseeable future actions (RFFAs) that affect hydrology incorporated.

See also "Reasonably Foreseeable Future Actions" (below)

Groundwater availability model

A regional groundwater flow model approved by the executive administrator.

Groundwater management area

Geographical region of Texas designated and delineated by the TWDB as an area suitable for management of groundwater resources.

Hydrologic modification*

Analysis of the degree of modification in hydrology caused by a proposed project. This analysis helps the Corps determine whether additional detailed hydrologic modeling is necessary, or if sufficient information has been provided about the change in hydrology and the potential impact on aquatic resources.

Infrastructure

Physical means for meeting water and wastewater needs, such as dams, wells, conveyance systems, and water treatment plants.

Instream flow

Water flow and water quality regime adequate to maintain an ecologically sound environment in streams and rivers.

Note: Instream flow is often used to describe minimum flow requirements or a flow regime based on regulatory actions (e.g. permit conditions), water rights, other administrative mechanism. It is not necessarily an amount quantified to maintain an ecologically sound environment as defined Texas State Water Plan by the Texas Water Code §11.1471 if referring only to the flow that must be maintained pursuant to regulations or other administrative requirement.

Interbasin transfer of surface water

Defined and governed in Texas Water Code §11.085 (relating to Interbasin Transfers) as the diverting of any state water from a river basin and transfer of that water to any other river basin and transfer of that water to any other river basin (2022 updated definition).

Note: Generally, this is also referred to as a "transbasin transfer" or "transbasin diversion" when not specifically referring to the definition for Texas in the Texas State Water Plan or Texas Water Code.

Least environmentally damaging practicable alternative (LEDPA)*

The alternative that results in the least adverse effect to waters of the United States as required by the 404(b)(1) guidelines at 40 CFR 230.10(a). A 404 permit can only be issued for the LEDPA unless the LEDPA results in other significant adverse environmental consequences. The LEDPA must be determined after considering all avoidance and minimization measures, but does not include compensatory mitigation.

Major reservoir

Reservoir having a storage capacity of 5,000 acre-feet or more.

Note: Although defined in the Texas State Water Plan as 5,000 acre-feet of more, the size of a major reservoir varies by region and use throughout the country.

Mitigation*

Avoidance, minimization, and compensation for adverse impacts. See also "avoidance and minimization" and "compensatory mitigation."

Modeled available groundwater

The amount of water that the TWDB executive administrator determines may be produced on an average annual basis to achieve a desired future condition.

Naturalized flow*

Streamflow that would occur without the influences of upstream reservoirs, diversions, or return flows. This is also referred to as unregulated flow, baseflow, or virgin flow. Naturalized flow is often used as a model input into hydrologic models to simulate conditions that differ from historical operations of reservoirs, diversions etc. To compute naturalized flow, typically historical diversions are added to observed flow, imports and return flows from other basin removed, and change in storage at upstream reservoirs accounted for or removed entirely.

See also "reconstructed flow."

Needs

Projected water demands in excess of existing water supplies for a water user group or a wholesale water provider.

Note: Although the Texas State Water Plan defines "needs" as for a water user group or wholesale provider, in a more general sense, any entity with water demand can have a water need.

Project Yield*

See "firm yield" and "yield."

Operational model*

Model used to simulate detailed operations or make decisions about infrastructure operations for a reservoir, diversion, or larger integrated system. Operational models typically consider only the system of interest and may not simulate streamflows or impacts to other water users if such simulation is not required for decision-making purposes. For example, an operational model may only simulate the amount of water available to a single entity within the stream system, rather than the full amount of water in the stream system.

Reasonably foreseeable future actions (RFFAs)*

Actions that are reasonably projected to occur in basins that result in measurable changes to water use and management and should be reflected in a future conditions hydrology baseline. RFFAs include actions by others and but can include the Applicant. RFFAs are integral to the cumulative effects analysis but their inclusion in the future conditions hydrology baseline are instrumental in isolating and bracketing hydrologic effects of an Applicant's project.

Recharge

Water that infiltrates to the water table of an aquifer.

Reconstructed Flows*

Adjustment to historically observed flows used to superimpose current or future conditions on historical hydrology. Similar to "naturalized flows" but may modify historical hydrology based on a single parameter while leaving other historical operations unchanged. For example, historical gage data can be adjusted for increasing wastewater effluent over time, but not adjusted for upstream reservoir operations.

Regional water planning group

Group designated pursuant to Texas Water Code §16.053.

Relevant aquifer

Aquifers or parts of aquifers for which groundwater conservation districts have defined desired future conditions.

Release*

Outflow of water from a reservoir or dam. This term can take on multiple qualifiers, such as flood release, water supply release, uncontrolled release, spills, withdrawals, etc. For the Corps Regulatory Program which is concerned with total streamflow at various locations, it is important to differentiate between types of releases and to ensure that data obtained from dam operators includes all types of releases. For example, releases may be considered by the dam owner only as water released from storage, and not include any reservoir inflow that was passed through the dam's outlet facilities. Additionally, releases may include both flows out of a dam's outlet facilities and withdrawals from pipeline intakes located in the reservoir but not located at the dam.

Caution should be used when reviewing release data to carefully understand what release data truly represents in comparison to the Corps Regulatory goals that often include evaluating total streamflow immediately below a dam.

Reliable yield*

See "yield."

Reliability

Measure of frequency, probability, percent-of-time, of meeting water supply, instream flow, hydropower, and/or reservoir storage targets. In general, there are several methods for computing reliability that may be appropriate.

In Texas, two typical types of reliability evaluated are Volume Reliability and Period Reliability. Volume reliability is the percentage of the total target demand amount that is actually supplied. Period reliability is based on counting the number of periods of a simulation during which the specified demand target is either fully supplied or a specified percentage of the target is equaled or exceeded.

Resource factors*

Attributes related to aquatic resources evaluated by the Corps under the 404(b)(1) guidelines and other resources under NEPA and the Public Interest Review. For example, fisheries, water quality, water-based recreation, wetlands, geomorphology, sediment transport, floodplains, water supply and conservation, etc.

Return flows*

Diverted flows that are returned to the system, such as effluent from a wastewater treatment plant, runoff from irrigation, percolation of water from irrigation to an aquifer, industrial water use discharge to a stream, etc.

Reuse

Use of surface water that has already been beneficially used once under a water right or the use of groundwater that has already been used (for example, using municipal reclaimed water to irrigate golf courses).

Note: Reuse can have different meanings and may be treated differently in terms of streamflow, depending on the specific application. Reuse can refer to both the second use or successive uses of water discharged to the stream and re-diverted, or can be water delivered directly from the primary use to a secondary use. For example, a water provider may have a right to divert its wastewater effluent many miles away from the discharge point after it has been introduced back to the stream system. Or a water provider may deliver treated wastewater effluent (typically after additional treatment) directly to larger irrigation demands, such as parks and golf courses without ever discharging the water to the stream system.

RiverWare*

RiverWare is a general river basin modeling tool that allows river basin modeling that can be modified to add features or simulate changing policies. RiverWare's development has been sponsored by the Corps and it is the Corps' preferred model platform for Regulatory permit decisions if other suitable modeling is not available.

RPL (RiverWare Policy Language)*

A RiverWare feature that allows the modeler to develop specific rules to reflect operational policies in place for a stream system. RPL provides significant flexibility in simulating a wide variety of operational goals, considerations, restrictions, limitations, mitigation proposals or permit conditions.

Run-of-river diversion

Water right permit that allows the permit holder to divert water directly out of a stream or river.

Note: This definition can vary significantly by region. For example, this type of diversion can also be referred to as a direct flow water right in regions that use the prior appropriation system (generally more western states). This type of use is inherent in regions that use the riparian rights system (generally more eastern states)

Safe yield*

See "safety factor" and "firm yield." Additionally, safe yield is often used in the context of groundwater withdrawals, where the safe yield is the rate at which groundwater can be withdrawn without causing long-term decline of water levels.

Safety factor*

A means of mitigating risk of water supply failure when computing firm yield or system yield for a water supply system. Different water providers incorporate a variety of methods to assess a safety factor, such as adding a certain percentage of annual demand, requiring a certain amount of water in storage at all times, etc. Some water providers define the safe yield as the firm yield reduced by a safety factor.

Sedimentation

Action or process of depositing sediment in a reservoir, usually silts, sands, or gravel.

Sensitivity analysis*

The study of how the uncertainty of the output of a mathematical model or system can be apportioned to different sources of uncertainty in its inputs. Useful for determining the relative impact of estimating specific parameters or validity of assumptions when observed data is limited or not available.

Storage

Natural or artificial impoundment and accumulation of water in surface or underground reservoirs, usually for later withdrawal or release.

System model*

See "operational model"

Unmet needs

The portion of an identified water need that is not met by recommended water management strategies (2022 updated definition).

Note: The above definition for the Texas State Water Plan can be generalized to the remaining demand after incorporation of any water supply project is evaluated.

*Water Availability Model (WAM)**

Numerical computer program used to determine the availability of surface water for permitting in Texas.

Note: This definition is applicable to the State of Texas' official water availability models (WAM). Outside its naming convention in Texas, the term "water availability model" is a general term that describes a computer model that simulates water that is physically and legally available at certain points within a stream system, typically subject to local water administration practices. There are numerous modeling platforms that can be used to simulate water availability.

Water management strategy

A plan or specific project to meet a need for additional water by a discrete water user group, which can mean increasing the total water supply or maximizing an existing supply.

Water user group

Identified user or group of users for which water demands and existing water supplies have been identified and analyzed and plans developed to meet water needs. These include: a. privately-owned utilities that provide an average of more than 100 acre-feet per year for municipal use for all owned water systems, b. water systems serving institutions or facilities owned by the state or federal government that provide more than 100 acre-feet per year for municipal use; c. all other retail public utilities not covered in paragraphs (a) and (b) that provide more than 100 acre-feet per year for municipal use; d. collective reporting units, or groups of retail public utilities that have a common association and are requested for inclusion by the regional water planning group; e. municipal and domestic water use, referred to as county-other, not included in subparagraphs (a)–(d) of this subsection; and, f. non-municipal water use including manufacturing, irrigation, steam electric power generation, mining, and livestock watering for each county or portion of a county in a regional water planning area (2022 updated definition).

Wholesale water provider

Any person or entity, including river authorities and irrigation districts, that delivers or sells water wholesale (treated or raw) to Water User Groups (WUG) or other Wholesale Water Providers (WWP) or that the Regional Water Planning Group (RWPG) expects or recommends to deliver or sell water wholesale to WUGs or other WWPs during the period covered by the plan. The RWPGs shall identify the WWPs within each region to be evaluated for plan (2022 updated definition).

Yield*

See also "firm yield" and "reliability" above. Within the context of water resources, yield means the amount of water available from a water source through a critical period. Typically, the critical period is a time of hydrologic stress (such as during drought conditions). Yield can refer to the amount of water available from any water source being evaluated, but in some contexts (such as the Texas State Water Plan), yield is applied to sources derived from reservoirs, whereas reliability is applied to other sources.

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Figure 1. Hydrologic modeling can support many resource factor evaluations. Prepared for USACE by Western EcoSystems Technology, Inc. 2010.

Page 52. Toledo Bend Dam Overflow. Courtesy of Toledo-Bend.com. Accessed January 2018.

Figure 2. Map of Sabine River Intake area. Produced by DiNatale Water Consultants. Map data source from one or more of the following: Esri, Garmin, HERE, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Esri, DeLorme, USGS, NPS. December 2017.

Figure 3. Map of Brazos River within Texas. Brazos River Authority website. Accessed January 2018. https://www.brazos.org/About-Us/Education/Water-School/ArticleID/266.

Figure 4. USACE Project SWF-2009-00264 Official Record, PDF page 154. Figure 1 from Joint Public Notice; Army Corps of Engineers, Fort Worth District and Texas Commission on Environmental Quality. March 11, 2010.

Figure 5. USACE Project SWF-2009-00264. Map of Water Rights of Interest within Study Area. Received from USACE December 13, 2017.

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Figure 14. Map of North Texas Municipal Water District (NTMWD) water sources. NTMWD website. Accessed December 2017. https://www.ntmwd.com/wp-content/uploads/2016/05/Water-System-Raw-Existing-Proposed-labeled.pdf.

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Figure 16. USACE Project SWF-2011-00514 Official Record, Volume 3, PDF page 94. Figure 1 of Memorandum from David Coffman, Jon Albright, and Loretty Mokry to Darvin Messer, USACE. September 17, 2015 (updated October 2, 2015 and October 9, 2015).

Figure 17. USACE Project SWF-2011-00514 Official Record, Volume 3, PDF page 437. Figure 2 of Memorandum from David Coffman and Steve Watters to Loretta Mokry. June 18, 2015.

Figure 18. Schematic of Upper Trinity Regional Water District raw water system. Received from USACE December 12, 2017.

Figure 19. Map of initial and final areas of hydrologic interest for NISP. Produced by DiNatale Water Consultants. Map data source from one or more of the following: Esri, Garmin, HERE, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community, Esri, DeLorme, USGS, NPS. January 2018.

Figure 20. Map of Denver Water raw water collection system. Moffat Collection System Project Final Environmental Impact Statement. USACE. April 2014.

Page 126. View of the Toledo Bend Reservoir from South Toledo Bend State Park near Anacoco, Louisiana. Photo: Chris Miceli. Accessed January 2018. https://upload.wikimedia.org/wikipedia/commons/8/85/Reservoir_of_South_Toledo_Bend_State_Park.jpg.

Inside back cover. Photo of Toledo Bend Dam. Courtesy of Toledo-Bend.com. Accessed January 2018.

Back cover. Photo of Toledo Bend Dam. Courtesy of Toledo-Bend.com. Accessed January 2018.

Appendix A: Information on RiverWare

RiverWare®
for Water Supply Permit Analysis

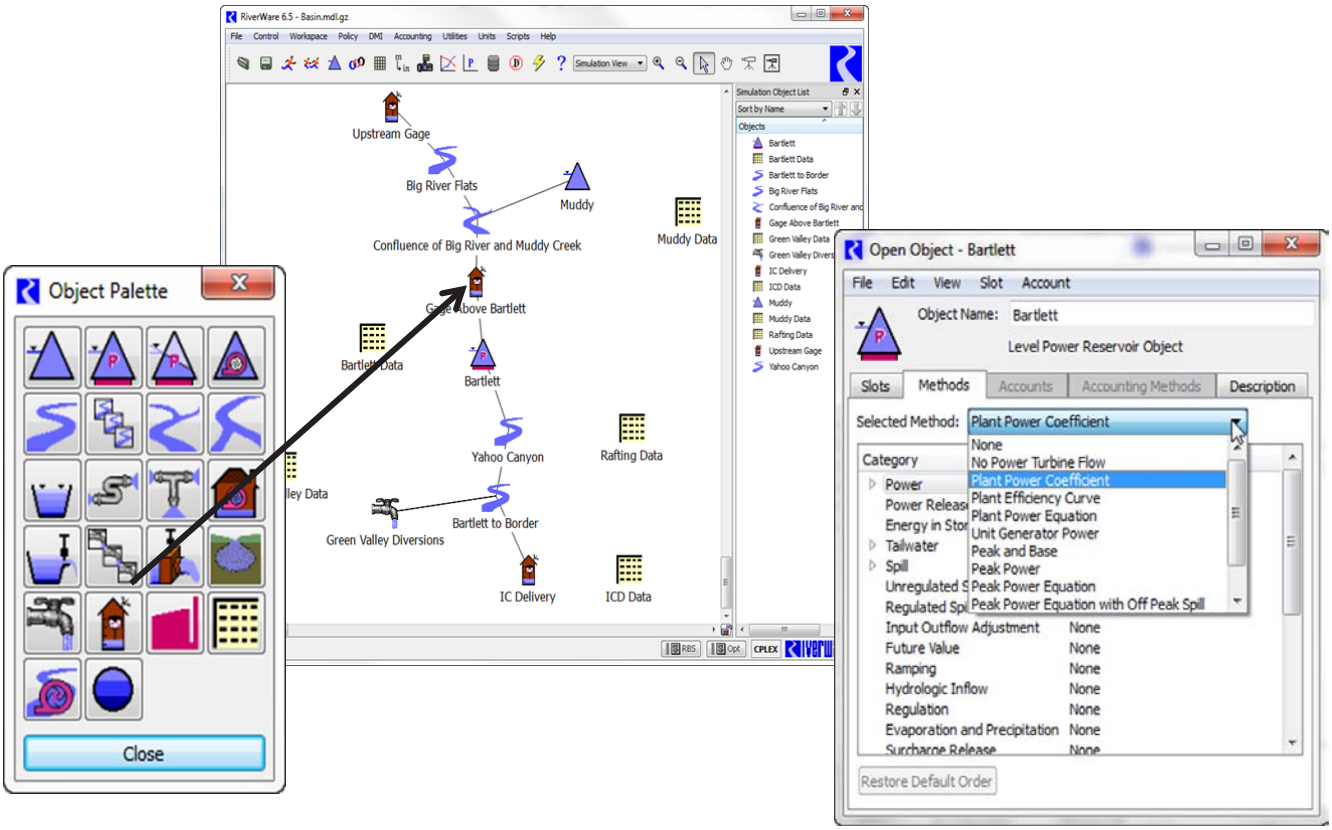
RiverWare is a general river system modeling tool that is widely used for long term planning studies and operations of river and reservoir systems. It is an ideal tool for water supply permitting analysis - its detailed hydrologic process simulator, powerful water accounting and water rights solver, and flexible operating rules come together to accurately solve even the most complex problems.

Who can use RiverWare?

RiverWare is developed and maintained by the University of Colorado (CU) CADSWES. It is funded primarily by sponsors Bureau of Reclamation, TVA and the U.S. Army Corps of Engineers, who have free and unlimited access to the software. CU and sponsors have an agreement that promotes the distribution of RiverWare to other agencies, utilities, universities, consultants and the global water management community for modest fees that offset some sponsor costs of software maintenance. Ease of sharing and comparing RiverWare models among agencies, stakeholders and others have elevated the level of negotiation and collaboration in many basins.

Build a hydrologic model

Select simulation object types from a palette, drag to workspace, name and link together to form your river system network. Select appropriate methods for modeling the physical processes such as reach routing, hydro generation, evaporation, spill, consumptive use and return flow, and groundwater – surface water interaction.



CADSWES

RiverWare

Add water accounts

RiverWare models the type and ownership of water and tracks these through the system, so at every point you know whose water is passing by or being stored.

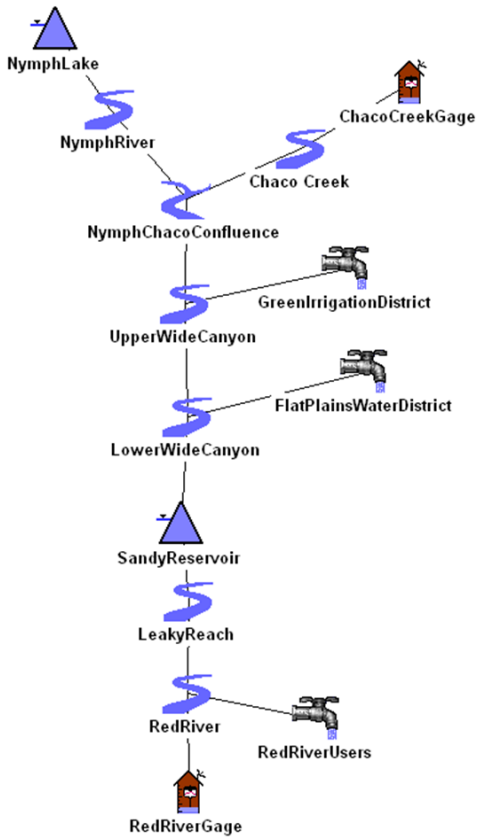
Add accounts to your simulation objects for legal rights:

- **Storage account** – right to store water in a reservoir
- **Diversion account** – right to divert/consume water
- **Instream Flow account** – right to ensure a flow at a point

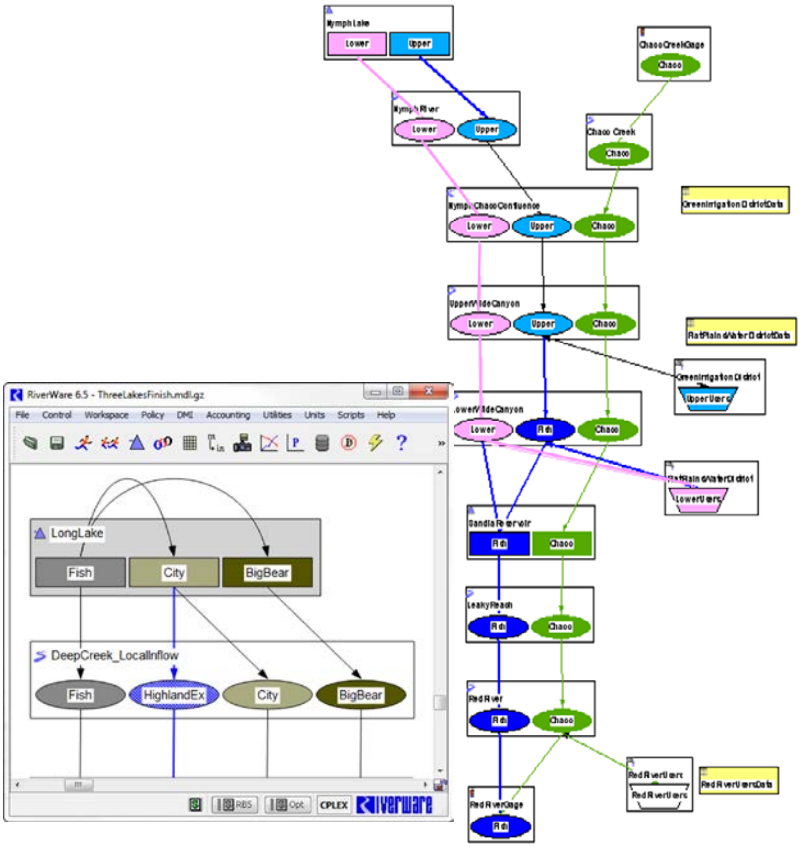
Passthrough accounts track the water as it propagates through the river network.

Visualize the accounts – configure display to see types, owners and links where transfers are permitted

HYDROLOGY SIMULATION VIEW



ACCOUNTING VIEW



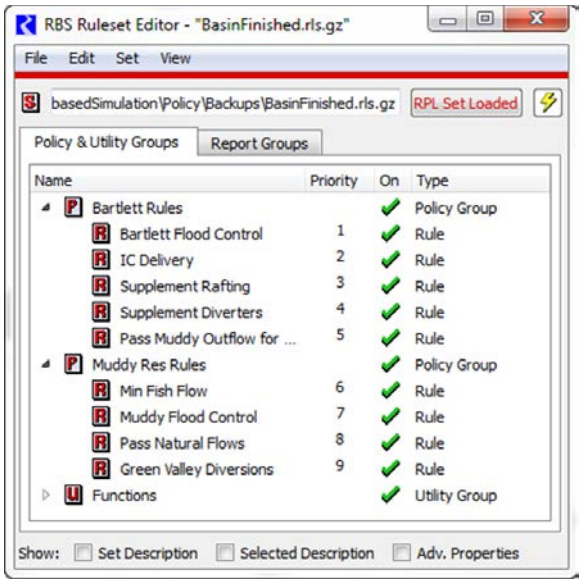
RiverWare's accounting features can model most water right functions:

- Rulebased Allocation
- Priority Water Rights Allocation; minimum bypass; subordination
- accrual, carryover, transfers
- exchanges
- diversions, return flow, depletion
- gains/losses, time lags

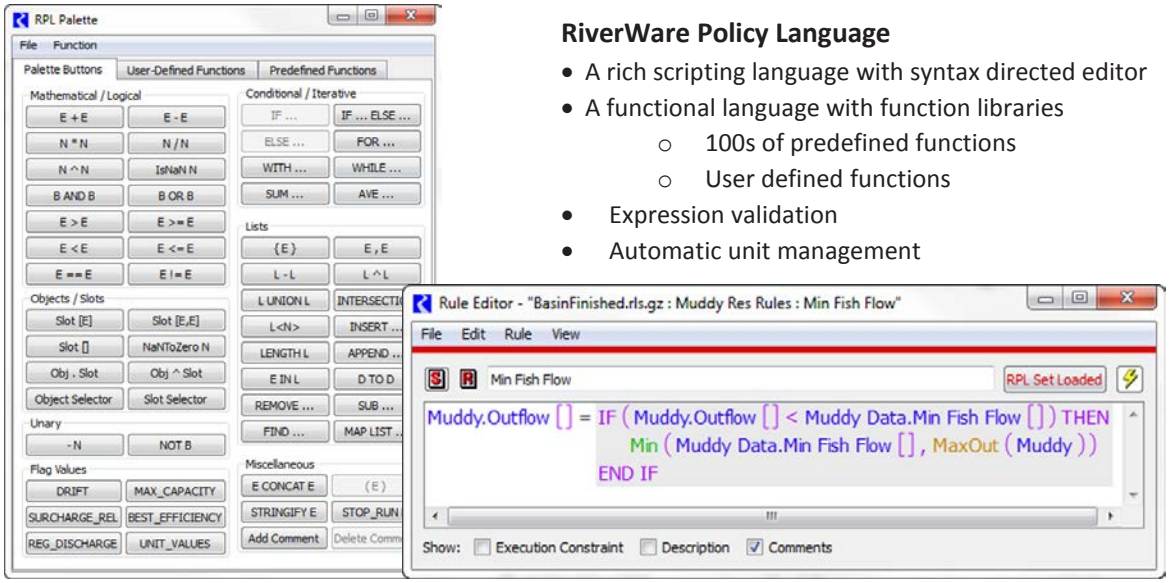
Express multi-objective operating policies in prioritized rule set

With RiverWare's rulebased simulation toolset you can develop a set of prioritized rules of IF… THEN structure that reflect all the objectives of the operating policies, such as water allocation, flood control, environmental compliance, hydropower generation, recreation, etc. The flexible and powerful rule language allows you to express almost any possible logic – all the richness that exists in real world operating policies.

The RiverWare Policy Language (RPL) expresses policies in easy-to-understand statements, convenient for transparency for managers, stakeholders and permit agencies.



The syntax-directed Rule Editor and function libraries make writing rules fast and easy.



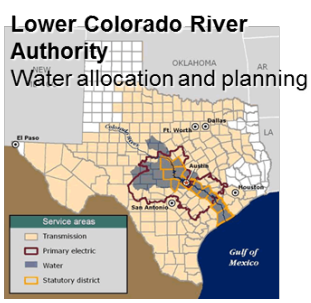
RiverWare Policy Language

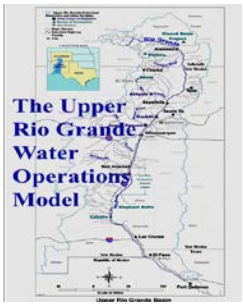
- A rich scripting language with syntax directed editor
- A functional language with function libraries
  - 100s of predefined functions
  - User defined functions
- Expression validation
- Automatic unit management

Integrate water accounting and priority water rights allocation in the operating policies

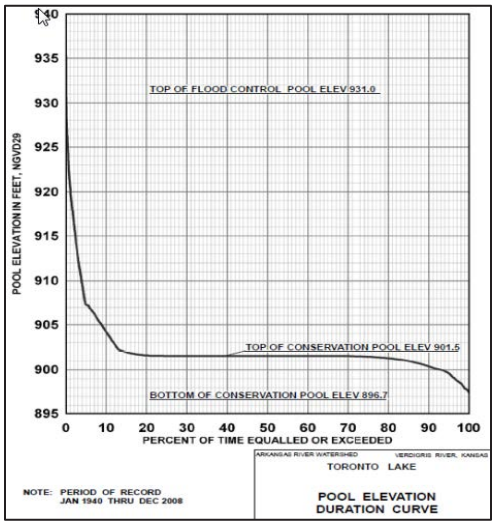
- Prioritized Water Rights Solver fits into the priority scheme of your rules.
- Understand the solution: The solver uses an iterative algorithm that yields detailed information about the logic of the solution
- For new permit analysis, it is easy to turn the new permit on/off and compare results

Selected basins that use RiverWare's rulebased simulation with water rights solver





View and analyze the results of your runs with quick and easy utilities



Statistical functions

For a period of record (single) run, use statistical output with performance criteria such as cumulative distribution.

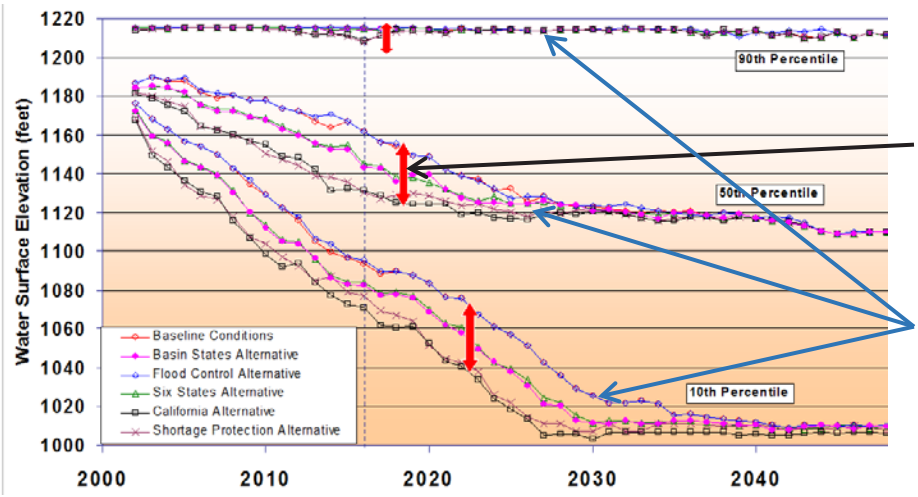
RiverWare has many built in statistical functions.

Results can be numerical, plots or exported to other tools.

Multiple Run Management

RiverWare's Multiple Run Manager (MRM) automates running a scenario with an input ensemble of hydrologic inflows for example to generate probabilistic results or sensitivity analysis

Use MRM with the Graphical Policy Analysis Tool (GPAT) or other post processor for comparison of results of complex studies. Results are saved automatically and formatted for quick plotting/analysis.

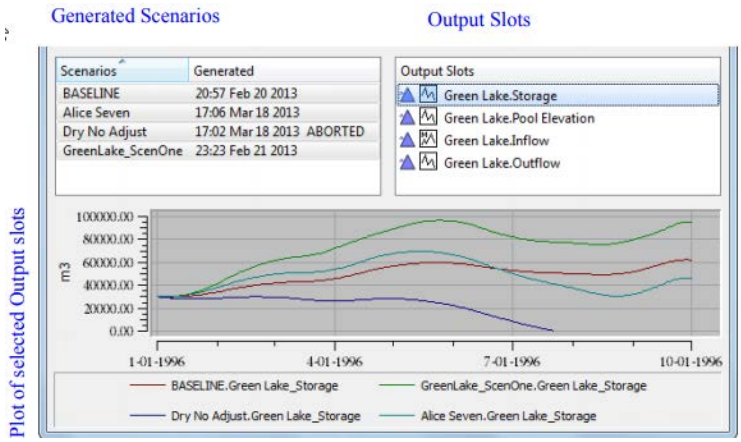


Compare several different policies, e.g., different permit levels and/or one or more hydrologic scenarios (observed, climate change, etc.)

Compare the scenarios over the future at different hydrologic exceedance levels

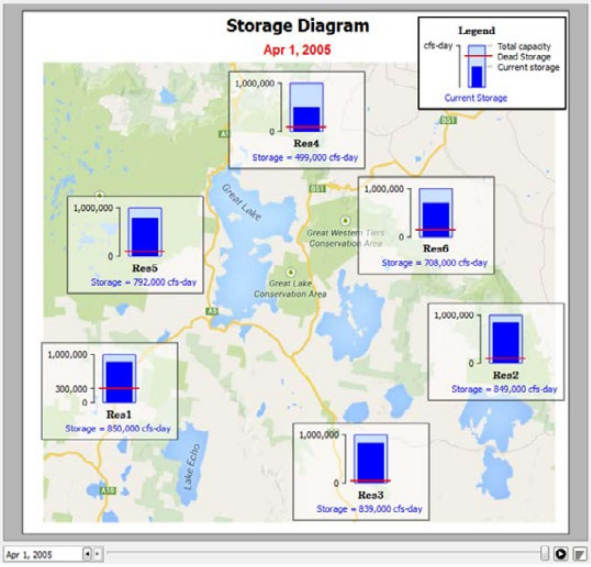
(This example from the Colorado River Interim Surplus Guidelines EIS, 2001)

In the Scenario Sandbox create and compare alternatives on the fly by adjusting input values



Animate Teacups on the Output Canvas and the Geospatial View

Select reservoirs for teacup outputs and add to an output canvas or geospatial view. Export animations along with other animated outputs such as pie charts.



RiverWISE – new (v7.2 January 2018) application for stakeholders to run alternative scenarios

Starting with RiverWare 7.2, RiverWare model developers can generate model files with selected inputs and output that stakeholders can load into RiverWISE, a freely available application, to create and run alternative scenarios. This new feature allows agencies to share results with a much wider group of stakeholders.

RiverWare Management

RiverWare can be obtained from the University of Colorado CADSWES

Releases

RiverWare is released about two times per year with new features. Patches are released as needed to address issues. RiverWare is downloaded from riverware.org. To run the executable, a license file issued by CADSWES must be installed.

User Support and Training classes

Help desk, modeling support and training classes are available. See riverware.org

For more information

Visit riverware.org
Email rwinfo@colorado.edu
Phone: 303-492-2189 or 303-492-3972

Appendix B: Water Availability Model (WAM) Specific Considerations for Texas Applications

B.1 Purpose

Given the prominence of its application towards potential water supply projects in Texas, it is informative to consider the potential use and applicability of the State of Texas' official surface water modeling approach, the Water Availability Model (WAM), in the context of the Corps of Engineers Regulatory (Corps Regulatory) modeling needs and objectives. There exists the potential for such models to be used by Applicants, and a thorough understanding of the Texas official modeling approach, model objectives, assumptions, and technical underpinnings is warranted for an appropriate interpretation of their output in the context of the above-stated Corps objectives.

Corps Regulatory Project Managers (PMs) and Applicants must recognize that differences in state and Corps processes and analyses exist and that their respective requirements and objectives will result in the need to undertake additional efforts. Such distinctions require care and caution when determining if WAM outputs and information should be used in the Corps permitting process. The intent of this Appendix is to assist Corps Regulatory PMs and some Applicants in understanding the necessary considerations associated with the use of such models and outputs in the context of the Corps' objectives for hydrologic data and modeling in support of its permitting actions. These considerations do not suggest that the models are inappropriate for their originally designed use in the Texas surface water permitting process, but rather for their utility in the Corps permitting evaluation.

This Appendix provides information about WAM, its origins, the modeling approach, and finally a discussion related to the 13 WAM cautionary considerations listed below. This document is in addition to the set of 21 Hydrologic Modeling Guidelines (HMGs) developed for the Corps. The HMGs were designed to assist the Corps and Applicants with determining hydrologic modeling needs and requirements to support water supply permit actions. The HMGs were developed for the Fort Worth, Texas District and may have some general applicability to hydrologic modeling in any region of the country. However, given the common use of WAM in Texas, this Appendix is also provided to specifically address potential hydrologic modeling needs for Applicants that are familiar with the WAM modeling process and may have obtained a Texas water right using a WAM model. It is reiterated that this Appendix is primarily for Corps Regulatory PMs to understand the variations of WAMs they may see and highlights where caution should

be exercised if and when WAM modeling and outputs are intended to be relied upon to address the HMGs or relevant permit evaluation needs.

In 2016, the Corps produced a report that evaluated the applicability and accuracy of the WAMs to 404 Permit Resource Impacts analyses; to EIS Model Run Series (Existing Baseline, Future Baseline, and Existing and Future with Projects); and the general applicability of the WAM in terms of temporal and spatial considerations and relative to resource category requirements. The report identified 10 concerns and potential issues with using WAM models to support the Corps regulatory work listed below; these issues are addressed in Section 4 of this Appendix:

1) The update frequency of "off-the-shelf" WAM
2) The appropriateness of assumptions in WAM Run 8, Current Conditions, in capturing "real-world" water use and streamflow
3) The appropriateness of assumptions in WAM Run 3, full authorization, in capturing "real-world" water use in the future?
4) The suitability of assumed monthly diversion patterns (no wet/avg/dry use)
5) The suitability of assumptions about return flows from agricultural, municipal, and industrial uses in Runs 3 and 8
6) The ability of the WAMs to simulate instream flow targets
7) The ability of the WAMs to customize reservoir operations
8) The suitability of the monthly-to-daily disaggregation approach employed to develop daily WAM models
9) Level of calibration of the WAMs
10) The appropriateness of the WAM's assumption of priority flows (potential timestep issues)

B.2 WRAP, WAM, and Texas Surface Water Permitting

It is the public policy of the Texas to provide for the conservation and development of the State's natural resources, including, but not limited to, the control, storage, preservation, and distribution of the State's storm and floodwaters and the waters of its rivers and streams for irrigation, power, and other useful purposes (Texas Water Code, Sec. 1.003). The Texas Commission on Environmental Quality (TCEQ) is the State's regulatory agency responsible for the permitting and regulation of surface water supplies in accordance with the Texas Water Code. The TCEQ administers water rights in Texas, issues new and amended water rights and certificates of adjudication, and cancels water rights.

The process for permitting surface water use in Texas is based upon the prior-appropriation doctrine (TWC 11.027), introduced in the late 1800s, whereby a permit with the earliest priority date is considered "senior" to permits granted on a later date. This is described as "first in time, first in right," with the priority date determined by the date the application is accepted for filing by the State.

Various methodologies (and modeling approaches) for evaluating surface water availability have been used for decades by regulators, planners, and water users as a basis for far-reaching decisions regarding water availability, permitting, and the future use of water for existing and new users. The application of such

methods in Texas has evolved over time, and in 1997 with the passage of Senate Bill 1 by the 75th Texas Legislature, the State formally adopted the surface water modeling approach still in use today.

B.2.1 Water Rights Analysis Package (WRAP)

In 1998 the Water Rights Analysis Package (WRAP) software developed at Texas A&M University (Wurbs 2015) was selected to model the TCEQ's surface water permitting framework, after an evaluation of a suite of available river system simulation models. A WRAP simulation's input data set for a particular river basin or river/reservoir system combined with the generalized WRAP simulation model is called a Water Availability Model (Wurbs 2015). As further described by Wurbs (2015):

> WRAP simulates management of the water resources of river/reservoir systems subject to priority-based water allocation. The modeling system facilitates assessment of hydrologic and institutional water availability and reliability for specified water use requirements. Basin-wide impacts of water resources development projects and management strategies may be evaluated. The software package is generalized for application to any river/reservoir system, with input files being developed for the particular river basin of concern…

Documentation of the WRAP software is published as Texas Water Resources Institute (TWRI) technical reports, which include Reference, Users, Fundamentals, Daily, Hydrology, Salinity, and Programming Manuals accessible at **https://ceprofs.civil.tamu.edu/rwurbs/wrap.htm**. These reports are as follows:

- WRAP Modeling System Reference and Users Manuals by R. Wurbs, TWRI TR-255 and TR-256, First Edition, August 2003; Second Edition, April 2005; Third Edition, September 2006; Fourth Edition, March 2008; Fifth Edition, August 2008; Sixth Edition, January 2009; Seventh Edition, July 2010; Eighth Edition, Sep 2011; Ninth Edition, August 2012; 10th Edition, August 2013; 11th Edition, August 2015.
- Fundamentals of Water Availability Modeling with WRAP by R. Wurbs; TWRI TR283; First Edition, April 2005; Second Edition, September 2006; Third Edition, May 2007; Fourth Edition, March 2008; Fifth Edition, July 2010; Sixth Edition, September 2011; and Seventh Edition, August 2013.
- WRAP Daily Modeling System, by R. Wurbs and R. Hoffpauir, TWRI Technical Report 430, First Edition, August 2012; Second Edition, August 2013.
- WRAP River System Hydrology by R. Wurbs, TWRI TR-431, First Edition, November 2012 and Second Edition, August 2013.
- Salinity Simulation with WRAP, by R. Wurbs, TWRI TR–317, First Edition, July 2009.
- WRAP Programming Manual, by R. Wurbs and R. Hoffpauir, TWRI TR-388, First Edition, July 2010; Second Edition, August 2012' Third Edition, August 2013; and Fourth Edition, August 2015.

The WRAP software package is currently composed of the following FORTRAN programs (Wurbs 2015):

- SIM and SIMD simulate river/reservoir water allocation/management systems for input sequences of monthly or daily naturalized flows and net evaporation rates.
- TABLES develops tables, data listings, and reliability/frequency indices for organizing, summarizing, and displaying simulation results.

- HYD assists in developing monthly naturalized stream flow volume and monthly reservoir net evaporation-precipitation depth data for the SIM hydrology input files.
- DAY assists in developing routing coefficients and other daily input data for SIMD.
- SALT tracks salinity loads and concentrations through the river/reservoir system.
- WinWRAP is an interface that facilitates execution of the WRAP programs within Microsoft Windows along with Microsoft programs and HEC-DSSVue.

B.2.2 Water Availability Model (WAM)

A WAM, as defined by TCEQ, is "a computer-based simulation predicting the amount of water that would be in a river or stream under a specified set of conditions." The modeling approach used by TCEQ therefore consists of two parts:

- The modeling program "WRAP
- Text files that contain basin-specific information for WRAP to process (input files, typically described as the WAM)

The input files for a WAM include information about the natural river basin hydrology and the details of surface water resources development, management, allocation, and use (Wurbs 2013). Development and expansion of the WRAP software itself has been sponsored by the TCEQ in collaboration with other agencies and the Texas water management community (Wurbs 2015). An array of WAM information, including WRAP input datasets for all the river basins of Texas, was originally developed in the years subsequent to the passage of Senate Bill 1 (generally 1998-2003) for all 23 river basins in Texas. These input data sets have been occasionally updated dependent upon new or revised water rights permits and modifications in modeling capabilities and are continually used by TCEQ in the surface water permitting process for the State.

B.2.3 Other Modeling Efforts employing Modified WAMs

Water planning within Texas is organized and overseen by the Texas Water Development Board (TWDB). Historically, the TWDB itself developed the State Water Plan for Texas, but again with the passage of Senate Bill 1, the Texas Legislature revised the State's planning process to its present, bottom-up, stakeholder-driven process, wherein every five years 16 regional planning groups — with the assistance of technical consultants — develop official regional water plans identifying projected water demands, supply availability, projected needs, identified feasible water management strategies, and recommended water management strategies to meet the identified needs.

Within the State and regional planning process in Texas, the assessment of existing and potential future available firm supplies is largely based upon the previously mentioned official WAM for each river basin under evaluation. While based on the official WAM, the TWDB allows modifications to the official WAM unique to each river basin and/or regional planning group. Such variations may be based upon projected future sedimentation conditions, new hydrologic conditions such as a new drought-of-record, contractual agreements, or return flows expected to be available during the drought-of-record. Individual water users and providers also develop unique WAM modeling approaches to address specific situations where greater detail is necessary beyond the representation of the State's official WAM.

The official TCEQ WAMs are based on a monthly computational timestep. Daily WRAP modeling capabilities described in the Daily Manual (TR-430) are still in a developmental status. The daily WAMs include disaggregation of monthly naturalized flows to daily using daily-flow-pattern hydrographs; disaggregation of other model variables to daily; routing of flow changes; and flow forecasting (TR-430). Further additions include simulation of flood control operations of selected large multiple-purpose reservoirs and environmental flow standards established and implemented by TCEQ. A case study daily version of WAM datasets and reports for the Brazos, Colorado, Trinity, Neches, Sabine, and Guadalupe and San Antonio (GSA) River Basins have been developed by Texas A&M but have not been formally adopted for official use by TCEQ in surface water permitting.

Due to recent severe droughts throughout Texas, concerns have arisen regarding the potential for new droughts-of-record in Texas river basins. Such recent droughts may have established a new critical period that is not presently captured in the hydrologic period used in the official WAMs. If a new critical drought period has indeed occurred, this could affect the calculation of firm yield not only for future water supply projects, but existing water supplies. Extending the hydrologic period of record of naturalized flows used in the WAMs is labor-intensive and data-dependent (CDM Smith 2016). Thus, there have been recent efforts to develop a simplified approach to extending the hydrologic period of record within the WAMs (TR-430). This approach uses complex statistical regression algorithms relating the original naturalized flows to parameters of evaporation and precipitation to predict new naturalized flows in the more recent time period. These methods have been developed for six river basins' daily Run 3 model scenarios. However, these methods and models have, to date, not been formally adopted by the TCEQ for use as the official WAMs for these basins. A brief discussion considering the recent modeling efforts in this regard (development of a daily timestep WAM and simplified extension of the WAM's hydrologic period of analysis) is provided in Section 4.1.

Thus, there exist a number of altered WAM modeling approaches; however, as these daily WAMs, regional planning WAMs, extended WAMs, and individual users' WAMs have not been formally adopted by the State's regulatory agency (TCEQ), the focus herein is thus upon the use of the official WAM models based on a monthly timestep, their fundamental assumptions, and their relevance to Corps regulatory modeling needs.

B.3 WAM Characteristics

B.3.1 Objective

The objective of the official WAM modeling approach is the prediction of the amount of water that would be in a river or stream under a specified set of conditions to facilitate the state's administration of surface water permitting. Said another way, the official WAMs are designed for the purpose of meaningfully simulating water availability and reliability for the State's existing surface water permits and for the permitting of potential future water supplies. It is thus the specification of modeled conditions (e.g., representation of the proposed project and accordant operational characteristics, geographic scope, modeled period, extent of authorized diversion and discharge amounts, characterization of watershed and

reservoir characteristics) within the WAMs that represents the key factor(s) for consideration by the Corps Regulatory PM when contemplating their objectives during the permit evaluation of proposed projects. A brief summary of the specification of such conditions within Texas WAM models is presented here. Subsequent subsections consider these specifications in greater individual detail within the context of the Corps regulatory framework.

B.3.2 WAM Modeling Approach

The WAM allows for the evaluation of water availability and reliability by applying key characteristics of existing surface water permits in a priority sequence to a historically-based, naturalized hydrologic period of record in a monthly timestep. Thus, the model is based on historical hydrology and allocates water in accordance with the prior-appropriation doctrine. A geospatial framework of significant locations (e.g., diversions, discharges, reservoirs, streamflow gauges, etc.) is established within the WAM as primary and secondary control points to establish spatial connectivity. Accordant watershed characteristics (e.g., drainage area, net evaporation) are assigned for each control point.

Key characteristics of surface water permits can include the diversion amount; assumed monthly distribution of the annual diversion (generally based on type of use — municipal, industrial, irrigation, etc.); priority date; location (by control point) of diversions, discharges, and storage; storage capacity; storage location; storage area/capacity; and certain special conditions (e.g., environmental flow conditions). It is important to note that while those aspects of a water right that are critical to the determination of water availability and reliability are represented, the WAM does not model all components of a water right (e.g., special conditions). Water quality modeling within WRAP is limited to certain simulations of salinity concentration.

The historical hydrology upon which the surface water permitting framework is applied is based upon a "naturalized" flow regime. These naturalized flows, calculated and used as an input to the model for each of the model's primary control points, are defined within the WAM context as the amount of water in the stream that would be there if not for the influence of man's activities. Although these naturalized flows cannot be directly measured (except if in a completely undisturbed watershed), they are used as the fundamental component for the accounting and allocation of water availability in the WAM.

The typical hydrologic period of data used in the WAMs in Texas is approximately from 1940–1996, although several river basins have updated hydrology (e.g., the Colorado). This use of nearly 60 years of historic hydrologic data within the official WAM assumes that this period captures the watershed's characteristics of hydrologic variability sufficiently to represent a probable range of future hydrologic conditions. The use of this period is intended to capture the historic drought-of-record, allowing for the consideration of water availability and reliability during critical drought conditions. Generally, such critical drought periods can vary from basin to basin, which is related to not just climatological conditions (such as drought severity and duration), but also the specific characteristics of a watershed and configuration of the particular storage/diversion under consideration.

The WAM is not a picture of what happened in a given year in its record, such as 1942, or 1975. Rather, the WAM is a depiction of what would have happened in each month over the modeled period of record if a given representation of existing surface water permits were present. The WAM is thus a theoretical, modeled representation of the function of a scenario representing certain permitting conditions in

the basin within the historical hydrologic regime (as characterized by naturalized flows). WAMs can include water rights management strategies, environmental flow requirements, and interstate compact requirements. The WAM uses the prior-appropriation accounting to determine how much water can be impounded or diverted by a given water right.

Two WAM modeling scenarios (frequently referred to as "runs") are maintained and used by TCEQ in the evaluation of surface water permitting. These scenarios represent alternative representations of the implementation of surface water permits, and are generally described as follows (from CDM Smith 2016):

> Run 3 (Full Authorization) — Maximum authorized amounts diverted, as-built reservoir area-capacity information, and no return flows (i.e., discharges). Run 3 is used by TCEQ to evaluate the availability of water for new or modified perpetual allocations.
>
> Run 8 (Current Conditions) — Current conditions demands, reservoir capacities, and return flows. Run 8 is used to evaluate applications with term water rights and amendments, demonstrating the amount of water that would be available for appropriation if all currently permitted water rights, including both term and perpetual, withdrew the amount they are currently using. Current use is typically determined based on self-reported maximum use over a recent 10-year period, year-2000 area-capacity information, and minimum reported discharge over a recent 5-year period.

The computation of availability is performed for each month in the period of record, wherein naturalized flows are distributed to the control point locations within the model, then amounts of water are allocated to water rights in order of priority (the "priority loop") within the given month. At the end of the given month, the process begins anew for the next month, where again naturalized flows for that month are distributed, water allocated to water rights, in order of priority, and so on, until each month in the period of record within the WAM has been computed. Thus, water availability for a water right under a given scenario is thus calculated in the WAM by taking the amount of flow in the stream and subtracting the amount of flow appropriated to other water rights. Output from the WAM can generally include:

- Unappropriated flows
- Storage and net evaporation
- Firm yield
- Reliability of water rights, including diversions and shortages
- Reservoir/System operations — end-of-month storage
- Hydroelectric power produced, shortages
- Naturalized and regulated flows
- Instream flow targets and shortages

B.3.3 Management of the Official State WAMs

The TCEQ is responsible for obtaining or developing updated input files for all 23 river basins. Due to continually evolving conditions in water permitting administration at the state level, the WAMs can become dated, thus requiring updating (CDM Smith 2016). As noted previously, the official WAMs are occasionally updated to reflect new water rights, amendments, corrections, and model capabilities. This

updating occurs on an as-needed basis and is often driven by specific needs for ongoing permitting processes.

Model input files for the above mentioned scenarios, along with WRAP executables and relevant GIS maps for each model's control point framework, are made publicly available through the TCEQ website at **https://www.tceq.texas.gov/permitting/water_rights/wr_technical-resources/wam.html**. The WAMs may also be requested directly from TCEQ staff, although the availability of particular models can be affected by the significance of updates occurring from new model capabilities, permit approvals, and corrections.

B.4 WAM Issues Relative to the Corps Regulatory Modeling Needs

Within their evaluation of the WRAP/WAM modeling system for the Corps, CDM Smith (2016) considered the applicability and accuracy of the WAMs to 404 Permit Resource Impacts analyses, to EIS Model Run Series (Existing Baseline, Future Baseline, and Existing and Future with Projects), and the general applicability of the WAM in terms of temporal and spatial considerations and relative to resource category requirements.

CDM Smith (2016) further identified a summary list of 10 concerns and potential issues with utilizing WAMS to support the Corps regulatory work (CDM Smith 2016), listed in Section 1 of this document. As noted therein, "[t]he identification of an issue or concern does not mean the off-the-shelf WAMs are unequitable for their original purpose and intent of administering water rights in the State of Texas." Each of these concerns is considered in detail within the context of the Corps regulatory modeling needs by subsection below.

B.4.1 Update Frequency of the "Off-the-Shelf" WAM

As noted previously, management of the official WAMs generally occurs on an as-needed basis, as there is a constant need for updating of the WAM input files as the administration of surface water permits evolves, new permits and amendments are granted, and model capabilities are introduced. As noted previously, official WAM models for both Runs 3 and 8 are available from the TCEQ website. However, at a given time, the availability of these WAMs can be limited. Table B1 is a summary of the present availability of the WAMs from the TCEQ website for Texas' 23 river basins (May–December 2017), wherein 14 out of the 40 official model runs (or approximately 35%) are not available from the site.

While the official WAMs may be obtained by verbal request to TCEQ, there exists the concern that the latest publicly available official WAM may potentially not reflect the latest up-to-date information or could significantly change as model inputs are revised, updated, and/or corrected.

WAM CAUTIONARY CONSIDERATION 1: Management and use of WAM scenarios and input data require significant efficiency and quality-control efforts. Corps Regulatory PMs need to ensure that when a WAM model is employed, the latest available official WAM is being used and an appropriate characterization of any modifications to the official model are recognized and appropriately characterized for proper

interpretation of model results. Areas of the WAM most subject to revision include, but are not limited to, incorporation of recently granted water rights and/or amendments, new model approaches possibly affecting model inputs, adjustments to representations of existing projects, watershed parameters, representation of diversion and discharge magnitude and timing, incremental flow adjustments, and the hydrologic period represented in the WAM. The assumptions employed when establishing the WAM ultimately dictate the extent to which WAM outputs may be used by the Corps Regulatory PMs.

WAM CAUTIONARY CONSIDERATION 2:
Several WAM models have been more recently updated employing a simplified approach to extending naturalized flows represented in the WAM (generally based on a statistical approach, detailed in TR-430). These WAMs, with hydrologic periods of record that have been extended using this statistical approach, should be employed with caution, as the technical underpinnings and uncertainties associated with the "extended" naturalized flows may differ from that of the "original" naturalized flows in the WAM. Depending upon the rigor of analysis necessary, the extended WAMs may be used, but uncertainties related to high and low flows during the extended period should be appropriately scrutinized to ensure that results are appropriately interpreted.

Table B1. Availability of WAM Runs 3 and 8 for Texas' 23 River Basins

Basin	Available?	
	Run 3	Run 8
Canadian	Yes	Yes
Red	Yes	Yes
Sulphur	Yes	Yes
Cypress	Yes	No
Sabine	Yes	No
Neches	Yes	Yes
Neches-Trinity Coastal	Yes	Yes
Trinity	Yes	Yes
Trinity-San Jacinto	Yes	Yes
San Jacinto	Yes	No
Brazos and San Jacinto-Brazos	No	No
Colorado and Brazos-Colorado Coastal	No	No
Colorado-Lavaca Coastal	No	No
Lavaca	Yes	No
Lavaca-Guadalupe	No	No
Guadalupe and San Antonio	Yes	No
San Antonio-Nueces	Yes	Yes
Nueces	Yes	Yes
Nueces-Rio Grande	Yes	Yes
Rio Grande	Yes	No

WAM CAUTIONARY CONSIDERATION 3:
WRAP models based on a daily timestep have been more recently developed through a cooperative effort between TCEQ and Texas A&M University. Presently, the TCEQ has not formally adopted these models for use in the State's permitting process. However, these daily timestep models offer expanded capabilities beyond the official monthly WAM models. From Wurbs (2015):

> "The daily WRAP includes all of the capabilities of the monthly modeling system plus an array of additional major new features. This expanded version of WRAP allows each of the 12 months of the year to be subdivided into multiple time intervals with the default being daily. Simulation input may either include daily naturalized flows or options may be activated for disaggregating monthly flows to daily. Future days extending over a forecast period are considered in the simulation in determining both water availability from a supply perspective and remaining flood control channel capacity. Routing methods reflecting flow attenuation effects are added for use with daily computational timesteps. Calibration methods

for determining routing parameters are included in the modeling package. The daily WRAP model system incorporates pulse flow environment instream flow requirements and reservoir operations for flood control."

Each of the above features (division into multiple time intervals, extension of future days, routing methods, and pulse flows), should be carefully considered by the Corps Regulatory PM. The means by which the naturalized flows are disaggregated should be appropriately vetted. The methods for forecasting and routing are critical for establishing the calculated daily flow and should be carefully studied to ensure that the underlying assumptions appropriately depict streamflow characteristics relevant to Corps permitting regulatory modeling needs.

B.4.2 Assumptions of WAM Run 8

The Corps may use hydrologic model output that simulates a proposed project area to develop a without-project baseline condition and then superimposes a with-projects condition on the baseline. WAM Run 8 is dubbed the "Current Conditions" model scenario maintained by the TCEQ for permit evaluations (both term and perpetual permits for State water). **The assumptions within WAM Run 8 may differ from the understanding of "Current Conditions" in the Corps regulatory context.**

The intent of the WAM Run 8 scenario is not to model a representation of actual current hydrologic conditions in a basin. Rather, Run 8 is a modeled representation of approximate current permitted levels of use, storage, and discharges — a characterization of present permitted water use conditions — overlaid upon a historical natural hydrologic regime. For a given month (e.g., January 1940), the output of WAM Run 8 depicts water availability and reliability if all currently permitted term and perpetual water rights, reservoirs, and discharges were operating at present levels in that month's naturalized hydrologic conditions.

The diversion amounts used within Run 8 are based on the maximum monthly uses for a given permit over the most recent 10-year period. Discharge amounts are based upon the minimum monthly discharge over the most recent 5-year period. Reservoir storage is based upon most recently surveyed conditions, and further, Run 8 does not include flood control storage in reservoirs. Thus, output from Run 8 is not intended to mimic existing or historic conditions, as the uses and discharges are assumed to be in place over the entire modeled period of record.[1]

Evaluations performed by CDM Smith (2016) conclude that the ability of WAM Run 8 to match historical data was overall variable and appears to be "significantly affected by modeling of reservoir operations." Additionally, it was noted that the suitability of the monthly diversion patterns (discussed in further detail in Section 7.2.4 below) warrants concern as well.

It is possible to modify the WAM Run 8 to address these concerns. However, the amount of effort and expertise necessary to accomplish such modifications will likely vary by permitting application. Such modifications would likely include:

1 While the Run 8 representation of current conditions does not lend itself to modeling of observed historical streamflows, it should be noted that it would be expected that the modeled representation of streamflow would improve as one approaches present conditions, as more recent observations would reflect the modeled use conditions based on recent records.

- Adjustments to target diversions for each water right, based on projected use
- Adjustments to reservoir and water right representations within the model to more accurately reflect real-world operations and conditions, including
  - Reservoir area/capacity relations reflecting existing sedimentation conditions
  - Diversion patterns reflecting varying existing usage patterns between wet and dry conditions
- Incorporation of detailed return flows (i.e., discharges) at all appropriate locations (see Section 7.2.5)
- Post-processing of output, particularly focusing upon the need and method for disaggregation of the monthly WAM outputs to a daily pattern if a daily temporal resolution is necessary for the assessment of aquatic impacts (see Section 7.5.8).

WAM CAUTIONARY CONSIDERATION 4: ***The use of WAM Run 8 to represent existing baseline conditions should be considered with caution.*** It is likely that some less complex proposed projects (e.g., simple diversion) could benefit from the use of WAM Run 8, although potential effects on a more complex downstream reservoir may still be affected. There are concerns with the use of WAM Run 8 for more complex projects, especially those involving existing and proposed reservoirs, as the underlying assumptions in this WAM scenario may not accurately reflect a baseline existing condition for analysis without further adjustments to ensure that Current Conditions are adequately represented. However, such adjustments to the WAM Run 8 model scenario may offer opportunities for increased consistency between Corps regulatory and State permitting modeling approaches.

B.4.3 Assumptions of WAM Run 3

Several key assumptions within WAM Run 3 must be considered when evaluating the use of the WAM in the context of the Corps regulatory modeling needs, particularly as it relates to representing "real-world" water use in future conditions.

WAM Run 3 represents the full authorization of existing permits, and assumes no return flows (i.e., discharges) in order to calculate a conservative estimate of water availability and reliability in a state permitting context. Also, a single set of monthly use factors are assumed within the WAM for each water right to establish monthly target diversions for each water right. These factors are assumed within the WAM to not vary based on differing hydrologic conditions (e.g. wet, average, or dry conditions). Lastly, reservoirs are assumed to be their original capacity within WAM Run 3. Although relevant for the State's water rights accounting, these assumptions may not be fully applicable for use by the Corps for regulatory purposes.

In general, within a Corps' evaluation of future conditions, there is a need to include reasonably foreseeable future actions for future conditions and address potential cumulative effects in permit evaluations. The assumption in the official WAMs of the full use of each water right is not likely to be reflective of actual (or projected) water use, and with no representation of return flows (e.g., municipal

or non-municipal), caution should be used when interpreting a WAM's capability to represent projected streamflow conditions. Further, as noted by CDM Smith (2016):

> "…because Run 3 is not associated with a planning horizon in terms of changing population, climate, and water use, the model input would require a significant amount of modification to arrive at a realistic future water use scenario. Environmental Impact Statements (EISs) have specific planning horizons associated with other analyses (e.g., socioeconomic, reasonably foreseeable future actions) which are not readily assignable to off-the-shelf WAM models; therefore, additional work would be required to convert the Run 3 target diversions to a planning horizon based demand."

Given that some Corps' permits can typically require a specific future planning horizon be established, the assumptions within Run 3 should play a key role in a Corps Regulatory PM's consideration of the use of the official WAMs for representing future conditions when evaluating a permit involving an Environmental Analysis (EA) or Environmental Impact Statement, EIS.

To more accurately represent a future condition for identifying potential project impacts, the official WAM Run 3 scenario would need to be significantly modified. Such modifications would likely include:

- Adjustments to target diversions for each water right, based on projected use
- Adjustments to reservoir and water right representations within the model to more accurately reflect real-world operations and conditions, including
  - Reservoir area/capacity relations reflecting future sedimentation conditions
  - Diversion patterns reflecting varying use between wet and dry conditions
- Incorporation of return flows (i.e., discharges) at all appropriate locations (see Section 7.2.5)
- Future projections of evaporation and precipitation conditions, including development conditions potentially affecting watershed runoff and allocation of net evaporation/precipitation
- Post-processing of output, particularly focusing upon the need and method for disaggregation of the monthly WAM outputs to a daily pattern if a daily temporal resolution is necessary for the assessment of aquatic impacts (discussed in more detail in Section 7.5.8)

WAM CAUTIONARY CONSIDERATION 5: Careful consideration should be given to the validity of the assumptions within WAM Run 3, specifically those regarding 100% consumptive use, the use of original reservoir capacities, and no return flows in the context of characterizing a realistic future condition upon which a potential project would be evaluated. The full consumptive use of all permitted water supplies is a highly conservative assumption, one that may be necessary for the regulation of available water but not necessarily representative of a realistic future condition. Also consideration should be given to ensure that if a WAM Run 3 is used, other future projects permitted by the State, but not necessarily constructed yet, are appropriately represented in the model. While modifications to a WAM are feasible, an evaluation will need to be made to determine which actions are "reasonably foreseeable" and assess that such modifications sufficiently characterize "real-world" projected uses, conditions, and operations, as opposed

to the conservative representations built into the official WAM Run 3 scenario. Use of the WAM Run 3 scenario may lead to over-prediction of project effects due to the conservative assumptions.

B.4.4 Assumptions of WAM Monthly Diversion Patterns

The WAMs apply an assumed monthly pattern of use to calculate monthly diversion targets for each right. These patterns are highly customizable; however, the bulk of modeled water rights generally fall into general patterns developed to characterize municipal, industrial, and irrigation use categories, and the patterns are repeated annually for each water user. During the original development of the WAMs, available historic diversions for each of these water use categories were evaluated by basin to determine a monthly use pattern that reflects seasonality for large sections of a river basin. Multiple defined water use patterns for each category are also used in some of the official WAMs.

For the WAMs, a temporal resolution finer than a monthly scale was assumed to not likely be beneficial for the originally intended purposes of the WAM. Municipal water use was assumed likely to maintain a fairly constant diversion rate over time based on water treatment capacities, varied monthly by customer demand. Similarly, industrial uses were assumed likely to maintain a constant diversion rate, as the industry using the water was assumed to likely be in operation each day of each month. Irrigation use was assumed to be directly related to growing seasons with peak use in summer months and a high likelihood of diverting water only when needed.

The resultant monthly use factors for each use category apply invariably to each year in the modeled period of record. Thus, due to the repetition of equivalent use-coefficients from one year to the next, the WAMs may not capture the effects on water use due to the cycling of wet and dry periods (such as changes in water use during drought conditions).

WAM CAUTIONARY CONSIDERATION 6: Monthly use factors employed in the official WAMs do not vary from year to year. Caution should be used in interpreting results from the WAM unless it can be demonstrated that the use factors employed in the WAM adequately represent actual use conditions.

B.4.5 Representation of Return Flows in WAM Runs 3 and 8

Another significant set of assumptions within the WAMs that warrants additional scrutiny is related to the modeled representation of permitted discharges (i.e., return flows). As noted previously, the WAMs were developed for surface water permitting and were thus developed with conservative assumptions in order to assess water availability within the Texas legal and regulatory framework. These conservative assumptions can act as a safety factor that reduces the risk of the water supply falling below the permitted amount. The two WAM scenarios (Runs 3 and 8) are typically used for the evaluation of water availability for perpetual surface water permits and term-permits, respectively.

For the model evaluation of availability for permitting of perpetual surface water rights (i.e., Run 3), the assumption was made that senior water rights (in terms of priority date) have the legal capability to directly reuse permitted water supply as long as it is not discharged back into waters of the State. Therefore, even if a water right holder does not presently have the infrastructure or physical ability for direct reuse, it was determined that all discharges would be assumed to be 100% reused in order to conservatively

estimate available surface water for permitting perpetual water rights. This assumption of 100% reuse, or 0% return flow, is one of the key assumptions within WAM Run 3.

Although not considered return flows in the WAM context, consideration should also be given to the representation of channel gains and losses in the WAM. Typically, these characteristics are specific to a particular reach of a stream and are incorporated into the WAM via stream flow naturalization adjustments. Various means of applying such adjustments to accurately reflect channel gains (such as spring flows) and channel losses can be employed within the model. The application of these adjustments can vary in time and space within the model, and should be assessed to confirm if a relevant stream reach is appropriately represented.

Consideration should also be given to what, if any, adjustments have been made in the model (directly, or to the underlying naturalized flows employed as an input to the model) to address negative incremental flows.

From Wurbs (2013):

> "Total, rather than incremental, naturalized flows are provided as an input to [the WAM]… The incremental local flow at a control point is defined as the total flow at the control point minus the corresponding flow at control point(s) located immediately upstream. Since flows normally increase going downstream, incremental flows are usually positive. However, flows may be greater upstream than downstream for various reasons."

The means by which negative incremental flows are addressed, if at all, should be considered by the Corps Regulatory PM if it is determined that such negative incremental flows exist at a location relevant to a proposed project.

In considering a future condition scenario, Corps Regulatory PMs should consider the validity of the conservative assumption within WAM Run 3 that no discharges would occur. That said, WAM Run 3 can, and has been, modified in the past with various representations of assumed return flows. Methods have included representations of return flows as constant inflows at the beginning of each monthly timestep and as return flow factors individually assigned to each modeled water right. If such assumptions are incorporated into a proposed WAM model for a characterization of a future condition, significant attention should be given to the magnitude, location, original source, use, and frequency of the discharges to ensure that such a characterization represents a realistic, accurate depiction of real-world conditions.

WAM Run 8 — the TCEQ "Current Conditions" scenario — includes a modeled representation of return flows. Within this WAM scenario, municipal and industrial return flows are conservatively based on a 5-year minimum of recorded monthly discharges. The selected five-year period varies from basin to basin but is generally based upon reported recent conditions. Agricultural return flows within Run 8 are assumed to be zero, based on the premise that water diverted for irrigation will seep into the subsurface for uptake by irrigated crops and not simply drain directly back into the river. This assumption should be considered carefully, as there exist agricultural rights that have been assessed with percentages sometimes higher than 50% making it back to the river. Farming practices, varying soil conditions, and local groundwater conditions will impact the amount and timing of water that seeps below the rooting depth of irrigated crops. For purposes of the WAM Run 8 model, this amount is considered less quantifiable than the municipal and industrial effluent return flows. Representations of return flows from agricultural

diversions could be modeled in WAM Run 8, although their derivation would need to be carefully evaluated locally for accuracy with existing conditions.

Without modification, the assumed representation of return flows within WAM Run 8 is a conservative representation of existing discharge conditions. However, with each monthly discharge representing a 5-year minimum for that given month, the resultant annual regime of monthly discharges may not represent any historically observed discharge regime (unless the 5-year monthly minimum for each month is found to have occurred in the same calendar year). Further, the assumed return flows within the official WAM do not vary from year to year, and thus do not represent variations in use under different hydrologic conditions (e.g., drought). As such, significant modifications to the representation of the return flows in WAM Run 8 would be necessary to accurately reflect existing hydrologic conditions for the Corps regulatory modeling purposes.

WAM CAUTIONARY CONSIDERATION 7: The assumed representation of no return flows (100% reuse) in WAM Run 3 should be considered with extreme caution in the context of establishing a realistic future conditions scenario for the Corps regulatory modeling purposes.

WAM CAUTIONARY CONSIDERATION 8: The assumed representation of municipal, industrial, and agricultural return flows in WAM Run 8 should be considered with caution in the context of establishing an existing conditions scenario for the Corps regulatory modeling purposes.

B.4.6 WAM Simulation of Instream Flow Targets

Targets for instream flow needs can vary from simple, single threshold amounts of flow to complex environmental flow regimes varying by season with multiple flow components (peak flow, volume, duration, frequency, or rate of onset) and levels (subsistence, base flow, high-flow pulses, and/or flood flows) for varying hydrologic conditions at varying timescales. The implementation of such environmental targets within the WAM warrants consideration for those employing the WAM.

Instream flow targets are only represented in the official WAM if they are identified within the state surface water permit. Targets for instream flow established outside of the state permit, such as required minimum flow releases by the Corps for a given reservoir, may not be represented in the official WAM. While this assumption may be sufficient for the original purposes of the WAM, care should be given to ensure that a WAM accurately reflects all flow requirements upon not only future projects, but existing projects as well. Corps Regulatory PMs need to also ensure that specific determinations are made in relation to instream flow requirements based on whether they are part of the project purpose or if they are a potential mechanism to avoid, minimize, and/or compensate impacts to the aquatic ecosystem. Such considerations and determinations need to be appropriately reflected within the modeling for the Corps permit evaluation.

Secondly, since the WAM was designed as a tool for evaluating surface water availability in a permitting context for the State, certain assumptions are made regarding the annual use of a water right. It is assumed that a water right is used throughout each given year, up to its maximum permitted diversion amount/storage. This assumption is important for the implementation of instream flows in the WAM, as this means that an instream flow requirement applied to a given permit is engaged year-round. In reality, a permit (such as an irrigator) might only make a call for water during those times the permit is in use

(for example, during the summer). Similarly, a water right may be operated in a manner where its annual diversion target is met within the first few months of a calendar year. These cases are not reflected in the WAM; rather, the instream flow requirement may affect all junior water rights even in instances such as the examples provided above. These effects may manifest in all modeled junior permits, not merely those up/downstream, and potentially affect the WAM's capability to accurately reflect existing or future conditions.

With regards to the implementation of instream flow targets within the WAM, simple instream flow targets can be readily represented. Single inflow targets can be specified at a given location, can vary monthly or seasonally, and are necessarily translated to a monthly volumetric target when implemented within the official WAM, given the WAMs' monthly timestep.

More complex instream flow regimes, particularly those incorporating representations of pulse flows with parameters of peak flow, volume, duration, and frequency, which may be specified in daily or hourly units, cannot be readily represented within the context of the official monthly WAM model without significant assumptions regarding the timing and frequency of pulse events. The official WAMs currently represent such complex instream flow targets as the total monthly volume of flow to be passed in any given month, whereby the monthly volume is derived from a combination of daily instream flow target characteristics (base flow, pulse volume, pulse duration, timing, and frequency). This modeling approach represents a high-level, general estimation of instream flow targets.

Recognizing the need for a more accurate representation of these more sophisticated instream flow targets, recent efforts have been underway to develop a daily simulation execution of WAM. This daily WAM approach was developed to more accurately model instream flow targets and their effects on water availability; however, these daily WAMs have not been adopted by TCEQ for use in its water permitting process.

WAM CAUTIONARY CONSIDERATION 9: For the Corps regulatory modeling purposes, modeling of instream flows using the official WAMs should be considered with caution, as the monthly timestep necessitates generalization of more complex instream flow targets, and thereby their effects, upon existing water supplies and future projects. While simple instream flow targets can be readily implemented in the WAM, careful attention should be given to the assumptions in the WAM regarding the actual use of water rights throughout a given calendar year and/or hydrologic condition and the resultant effects of instream flow requirements based on those assumptions. The assumption in WAM that instream flow requirements will be used throughout the year — instead of just during operation of the water right — may indicate flows at times that may not actually occur. If using WAM modeling results, any instream flow requirements or restrictions within the Corps' study area should be evaluated against actual operation of the right and associated minimum flows through the affected reach. Further, Corps Regulatory PMs also need to exercise caution when determining if instream flows are being offered and considered as avoidance and minimization and/or compensatory mitigation components.

B.4.7 Ability to Customize Reservoir Operations in WAM

The components for representing reservoirs and diversions within the WAM allow for flexibility in representing a variety of potential project operations. However, as noted by CDM Smith (2016), reservoir operations in the WAM are based only on water rights yields and demands. Thus, the creation of more

sophisticated, customized operations rules (such as optimization) to represent other system operations may be a challenge.

Since the designed purpose of the WAM is for the calculation of water availability, water right reliability, and reservoir yield within the State's regulatory context, reservoirs are generally modeled at their original design conditions with storage up to the conservation pool. Generally, reservoir operations are represented within the WAM based on the presence of water (regulated or unappropriated) either at a location in the stream, or as storage and water rights targets and yields.

The WAM allows the capability to specify multiple-reservoir system operating rules based on user-specified storage zones within a given reservoir (or reservoirs). Such storage zones can be established to represent specific operational criteria, diversion limitations, multiple diversions, and/or the presence of flood storage. The WAM further has the capability to model a seasonal (monthly) rule curve operating policy that typically involves an allocation of storage capacity between conservation and flood control pools by raising and lowering the designated top of conservation pool elevation. Simulation of rule curves at a monthly timestep may unintentionally pull water past upstream water users to satisfy a relatively sudden increase in the monthly rule curve due to strict adherence to the priority system in WAM, when such operations may not actually occur at the precise time or rate specified in the model. Modifications to the area/capacity curves for reservoirs can also be made to represent the loss of storage due to sedimentation. WAM models can also simulate hydropower operations. Regulatory PMs should ensure that if a proposed permit application involves a multi-purpose project, distinct evaluations and modeling for each purpose can be required.

The official WAMs do not currently model flood control operations, as flood events typically cause significant fluctuations in flow over short-term intervals not captured within the monthly timestep of the official WAMs. However, a daily WAM simulation has been developed and implemented for several Texas river basins. This daily WAM does include a representation of flood control operations, but due to uncertainties in the technical underpinnings of the modeling approach, the daily WAMs have not yet been formally adopted by TCEQ and should thus be considered with caution.

More sophisticated reservoir operations can be represented using WAM in conjunction with customized post-processing tools, although such tools should be rigorously evaluated.

WAM CAUTIONARY CONSIDERATION 10: The WAM may be suitable for simple reservoir operations based on the presence of flow (instream/storage) and water rights yields and demands. Other more sophisticated operations (e.g., rule curves, multiple storage zones, multi-reservoir systems, hydropower) can also be represented within a WAM but may present issues when operated on a monthly timestep. However, given the other limitations of the WAMs discussed herein, significant review of the application of the WAM for a project evaluation would be needed to ensure that model output appropriately reflects changes and effects caused by a project. Corps Regulatory PMs need to also be cautious about incorporation of operations for multiple purposes and uses in light of its defined project purpose statement.

B.4.8 Disaggregation of Monthly-to-Daily Flow in the Daily WAM

As noted previously, the official TCEQ WAM is modeled at a monthly timestep. Development of daily WAM capabilities to possibly supplement analyses employing the monthly WAMs has been motivated by the establishment of more complex environmental flow standards necessitating daily modeling capabilities. These daily modeling capabilities (as described in the Daily Manual TR-430) are still in a developmental status. A case study daily version of WAM datasets and reports for the Brazos, Colorado, Trinity, Neches, Sabine, and GSA River Basins have been developed by Texas A&M, but the daily WAM approach has not been formally adopted for official use by TCEQ in surface water permitting. Nevertheless, given their potential relevance to aquatic resource effects analysis associated with Corps' permitting, a brief consideration of this daily WAM modeling approach is presented here.

The daily WRAP software has the same capabilities as the official monthly WAM, plus an array of new features. From Wurbs (2015):

> WRAP allows each of the 12 months of the year to be subdivided into multiple time intervals with the default being daily. Simulation input may either include daily naturalized flows or options may be activated for disaggregating monthly flows to daily. Future days extending over a forecast period are considered in the simulation in determining both water availability from a supply perspective and remaining flood control channel capacity. Routing methods reflecting flow attenuation effects are added for use with daily computational timesteps. Calibration methods for determining routing parameters are included in the modeling package.

Conversion of the monthly WAM to a daily WAM necessitates significant additional calculations, including disaggregation of monthly naturalized flows to daily flows, routing of flow changes, and flow forecasting. Additional inputs necessary for the development of a daily WAM include daily flow pattern hydrographs. Approaches must be selected for the aforementioned flow disaggregation, forecasting, routing, next-day placement of routed flows, and establishment of daily water supply targets. Routing parameters must then be calibrated, which can represent a further source of uncertainty in the simulation results.

Presently, the developed daily WAMs can be considered as being similar to the above described Run 3 scenario, with similar assumptions but now with daily capabilities. No daily WAMs have been developed to date featuring Run 8 "Current Conditions" assumptions.

With the development of these daily WAMs, additional capabilities have been introduced. These capabilities include simulation of flood control operations of selected large, multi-purpose reservoirs, and more refined representations of the environmental flow standards established and implemented by the TCEQ. Flood control modeling drastically benefits from daily intervals because the short-term flow rate fluctuations associated with floods can be correctly captured (Wurbs and Hoffpauir 2013).

The daily WAM offers multiple alternative approaches to disaggregate the monthly naturalized flows into daily flows. Within the daily WAMs, the disaggregation approach employed is governed by the knowledge of natural flow behaviors (i.e., how much daily flow data are available for analysis). These daily flow hydrographs form the fundamental basis for the flow disaggregation. Flows are distributed over a month in proportion to the daily pattern of flows, while preserving the total monthly flow volumes. This approach

was determined to be the method that most realistically captures the extreme variability of river flows during the development of the daily WAMs. Evaporation and precipitation values used in the respective monthly reservoir input dataset are simply uniformly distributed to daily values (Wurbs and Hoffpauir 2013).

For daily flow patterns in the Brazos, Colorado, and Trinity daily WAMs, the Corps provided unregulated daily flows from the Corps daily modeling system developed to support operations of the Corps multiple-purpose reservoirs. For the Neches, Sabine, and GSA River Basins, results from a separate modeling effort using the Soil and Water Assessment Tool, SWAT, were applied to develop daily flow patterns for use in the daily WAM (Wurbs 2015).

Use of the daily WAM is possible but may be particularly difficult, as many of the records necessary to confirm appropriate representations of streamflow, operations, and use (e.g., diversions and discharges) may only be available at a monthly or annual resolution, if available at all. As the complexity of a given watershed increases, so too does the complexity of deriving information to sufficiently calibrate the model.

WAM CAUTIONARY CONSIDERATION 11: The daily WAMs have not been adopted by TCEQ for use in permitting and are thus still under development. Their utility appears promising when compared to the monthly WAMs, but significant evaluations regarding their technical underpinnings and underlying assumptions are necessary before they should be employed for Corps regulatory modeling purposes. While the daily WAMs offer a greater level of sophistication to the hydrologic modeling of the monthly WAM, the designed objective of the daily WAMs remains the same as that of the official monthly WAMs — the administration of surface water permitting and availability. This difference in model objectives, and the resultant effects on the modeling approach and output, should be thoroughly evaluated prior to use for Corps permitting. Attention should be paid to the validity of the disaggregation of the monthly-to-daily flows, the routing parameters employed, and model calibration. It should also be noted that at present, daily WAMs have only been developed representing Run 3 assumptions — no daily WAMs have been developed representing Run 8 "Current Conditions" assumptions.

B.4.9 Calibration of WAMs

The official WAMs "have not undergone any calibration procedures to ensure that the models accurately represent actual river basin operations or can reproduce gaged flows" (CDM Smith 2016). This is by design, as the intended use of the official WAMs is specifically for state water rights permitting administration, and thus the modeling objective of the WAM is not intended to represent actual conditions within the watershed. Rather, the WAM was developed for quantifying the availability of water for permitting purposes. **It is this difference between the state's objectives for permitting surface waters vs. the Corps regulatory objectives that does not readily lend the official WAM to be immediately effective for the Corps' purposes of capturing real-world water supply operations and resource conditions.**

Calibration of the official WAMs to more accurately portray existing use and streamflow conditions would likely require a substantial effort. Diversion and discharge data are largely only available in a monthly context. Significant calculations and assumptions would be necessary to develop accurate representations of each permitted diversion and discharge, flood-control storage, flow routing, and reservoir operations. If a more refined depiction of daily flow variation is necessary for an appropriate assessment, then a methodology would need to be implemented to disaggregate the monthly computations to a daily

timestep. Compounding this difficulty would be the WAM's fundamental objective of accounting flows under priority conditions. WAM models are basin-wide models that involve hundreds of water users over hundreds to thousands of square miles. Calibration over this large a model is first not necessary for the WAM's purposes, but secondly difficult due to the sheer size of the models. For use within the Corps regulatory format, a subset of the WAM model could be developed and calibrated, provided other considerations discussed in this document are also addressed.

WAM CAUTIONARY CONSIDERATION 12: The official WAMs have not been calibrated to represent "real-world" conditions. If a WAM is to be solely used for a regulatory impact analysis, ensure that the model has been calibrated accurately enough that any representation of project operations is meaningful and that streamflow results differ from baseline conditions in a statistically significant fashion.

B.4.10 Assumptions of WAM Priority Flows

As noted previously, the surface water permitting process in Texas is based on the prior-appropriation doctrine. Thus, a permit granted earlier in time is senior to permits granted on a later date and has the capability to make priority calls upon a junior water right holder. For several river basins in Texas, the TCEQ has implemented a watermaster program to manage surface water and enforce water rights during times of shortage. In those basins without a watermaster program, permit holders still have the capability to make a priority call for water from junior water right holders.

In average and wet conditions, generally such calls by a senior water right holder are not necessary, as during such conditions there has been sufficient available water for both senior and junior permit holders. Thus, in actual practice during such conditions, the permitted use of surface water supplies may be unaffected by priority. During dry conditions, the extent of the effect of priority calls on the operations of a water right can vary. The TCEQ (or its watermaster) has the discretionary capability to pursue enforcement actions during drought conditions to ensure that permit conditions, including priority, are met. The timing and extent of such enforcement actions are variable, and any reasonable action may be undertaken to appropriately alleviate emergencies.

Consequently, depending upon the hydrologic condition, the real-world effects of priority calls to the actual operations of water rights (e.g., diversion, streamflow depletion to refill reservoir storage) are significantly variable. Variability may occur in at least three ways: Priorities may have no effect on the operation of a water right during wet or average conditions; they may have varying impacts depending upon the enforcement of priority calls during dry conditions; or they may have significant effects during critical drought conditions. Such variation has occurred in the past and is likely to remain a factor in the consideration of characterizing existing and future streamflow conditions.

In contrast to this variation of the effects of priority in the real world, by design the fundamental assumption of the official WAMs is a consistent application of the prior-appropriation water right permit system. In other words, within the official WAMs it is assumed that senior water rights are always met (unless conditions specific to a given permit warrant a change in this behavior, such as subordination) before the next junior water right is met. Such an assumption is valid for the WAM's originally intended use as a surface water permitting tool, as the evaluation is focused upon calculations of water availability, permit reliability, and yield and the State's legal framework affecting these considerations. However, this assumption conflicts with the real-world operations described above.

Indeed, the WAMs provide a direct means of modeling effects from implementation of the prior appropriations doctrine (or other frameworks). With appropriate vetting to ensure consistency in the underlying assumptions of the hydrology, output from the WAMs could be employed as inputs to other model approaches representing the effects of a legal permitting framework.

The resultant flows derived from application of the WAM thus represent a theoretical allocation of water based upon the legal priority framework established by the State, but are not likely representative of flow conditions that existed historically, at present, or in the future — the conditions of primary import for the Corps regulatory modeling purposes. The impacts of this assumption manifest in all resultant model calculations as priority determines the presence of water at a given location, and thus all subsequent calculations representing water right operations (e.g., diversion, streamflow depletion, storage, etc.) are affected. Modification of the WAMs to represent actual implementation of water rights, operations, and enforcement is possible but would represent a significant modification to the official modeling framework established in the official WAM that would warrant a detailed review.

WAM CAUTIONARY CONSIDERATION 13: The official WAM can serve as a starting point for developing a project-specific evaluation, however significant modifications to the WAM are necessary to facilitate the level of project operation effects on streamflow required by the Corps. The WAM may be useful in developing effects of states' regulatory framework to be used as input for modeling scenarios focused upon project yield, but in such cases, a significant focus should be placed upon consistency in the underlying hydrologic conditions employed between models.

B.5 Conclusions

As can be observed from the above deliberations, a critical consideration when evaluating the utility of the official WAMs is the contrast between the objective function of the WAM and the objectives of the Corps regulatory modeling objectives.

As noted previously, the Corps often relies upon hydrologic modeling to characterize present conditions and predict future hydrologic conditions under a proposed project's operations to assess the impact of an action on aquatic resources. The current and predicted hydrology then informs analyses specific to each aquatic resource and allows for comparison of the predicted condition to the pre-project or baseline condition. The Texas WAMs serve a different function: the application of a permitting framework — in this case based on the prior appropriations doctrine — to facilitate the administration of surface water permitting and the determination of water availability within this framework.

Due to this difference in objectives, use of the official WAMs for Corps regulatory purposes must be performed with caution, as significant modifications to many aspects of the WAMs may be necessary to be used to adequately represent existing or predict future streamflow conditions necessary for a Corps regulatory permitting evaluation.

Appendix C: Permit Condition Examples

The following are examples of permit conditions that were derived from hydrologic modeling analyses associated with Corps permit actions. These examples demonstrate the way that modeling or hydrologic analysis can be implemented to develop meaningful permit conditions. See also HMGs 2.D and 3.G in the main body of the Technical Report.

Example 1

1. The permittee shall install a water flow measuring (gaging) station in the River immediately below the diversion structure of the Project Reservoir as authorized by this permit. Additionally, the supply canal to the Project is to have recording capability similar to this required gage as detailed below.

The proposed gage location and design is to be submitted to the Corps for review and approval. The gage is to be designed to allow fish passage and is to be installed and functioning prior to completion of construction of the Project. Details relative to the measuring capabilities of the Project supply canal are to be submitted concurrently with the gage design.

Monitoring equipment at the gage and supply canal must be able to accurately measure flow on a continual basis. Data is to be provided in an annual report form (Jan - Dec) showing daily flows. Reports are to be submitted to the Corps and the State Game and Fish Agency no later than March 1 of each year, as long as the authorized project is in operation.

2. The permittee cannot divert water into the supply canal for the Project any time flows in the River at the gage, required under special condition #1 above, reach 50 cfs or less.

3. The permittee will install a staff gage or similar marker in Another Reservoir which accurately shows the 10,000 and 5,000 acre-foot levels the next time the reservoir water level is drawn down to a level which allows physical construction of such a marker. Regardless of the marker's presence, the permittee must contact the State Game and Fish Agency each time water levels reach 10,000 acre-feet and 5,000 acre-feet from reservoir draw down. Each time the water level in Another Reservoir reaches elevation 6524.24 feet due to reservoir draw down, the permittee must pay the State Game and Fish Agency $5,000 per occurrence.

Example 2

1. Any request for formal modification of Water Right Permit #----- as it pertains to the 788.44 acre-foot minimum pool will require notification and approval of the Corps.

2. Continuous minimum flow releases from the reservoir shall total 6.8 cfs or match inflows, whichever is lower. Additionally, a minimum bypass flow of 6 cfs must be maintained at all times past the city's existing diversion structure located -----. Water releases from the reservoir will be made to maintain the 6 cfs bypass flow at the diversion when natural flows fail to maintain 6 cfs at that location. The permittee shall install four (4) monitoring (gaging) stations at the following locations: (1) immediately downstream from the outlet of the dam, (2) immediately downstream from the city's diversion structure, (3) immediately upstream of the reservoir high water line on South Creek, and (4) immediately upstream of the reservoir high water line on North Creek. Monitoring equipment must be able to accurately measure flow on a continual basis. Monitoring stations 1 and 3 will measure temperature on an hourly basis. Release temperature goals are between 55 and 65 degrees Fahrenheit from July 1 through September 15; within 3 degrees Fahrenheit of inflow water from September 16 through October 31 and April 1 through July 1. Releases from November 1 through March 31 should be no cooler than temperature inflow. Temperature readings should be referenced to the maximum daily temperature. Revisions of these goals will be coordinated with the State Game and Fish Department, subject to Corps approval. Data gathered from the monitoring stations is to be provided to the Corps, the Environmental Protection Agency, the State Game and Fish Department, and the US Forest Service, in report form for a period of five years. After that, reports are to be provided to the State Game and Fish Department for the life of the project. Monitoring stations are to be maintained in a serviceable manner at all times.

3. The permittee must measure dissolved oxygen (DO) and pH levels at the monitoring station located immediately downstream from the dam outlet for a period not to exceed 5 years. Samples must be taken bi-weekly from July 1 to September 15 as well as January 1 to February 28 of each year. Sampling needs to be done within 2 hours after sunrise. Adjustments to reservoir releases via the multi-level outlet shall be made if DO concentrations and pH levels of releases fail to meet minimum State Environmental Quality Department water quality standards for a Class II stream, regardless of any exemptions for dam releases.

Example 3

1. The permittee will install waterflow measuring (gaging) stations at the following locations:

a. In Creek 1 above the proposed reservoir high water line as authorized by this permit.
b. In Creek 2 above the proposed reservoir high water line as authorized by this permit.
c. In Creek 3 above the proposed reservoir high water line as authorized by this permit.
d. In Creek 4 immediately downstream from the proposed dam and reservoir as authorized by this permit.

Those gages located upstream from the proposed reservoir are to be designed to block upstream fish passage at times specified and controlled by the State Game and Fish Department, and to allow upstream passage at other times to minimize genetic contamination of Cutthroat Trout (CT) within the reservoir. The gage located downstream from the proposed reservoir will be designed to allow for fish passage upstream and downstream past the gage at all times and flows. All gages are to be installed and functioning prior to completion of construction of the Dam and Reservoir.

2. Monitoring equipment at the four stream gaging stations must be capable of accurately measuring flow and water temperature on a continual basis. Monitoring stations are to be maintained in a serviceable manner at all times. Data are to be provided in an annual report (from Jan to Dec) showing daily flows and temperature (see Special Condition VIII, 3). Release temperature goals are between 55 and 65 degrees Fahrenheit from July 1 through September 15. From September 16 through March 31 releases should be from as near the surface of the reservoir as possible (within the epilimnion) to allow water temperature patterns and ice-forming processes downstream of the dam in Creek to approximate natural patterns and processes and to minimize the negative effects on aquatic communities and habitats. Temperature readings should be referenced to the maximum daily temperature. Revisions of these goals must be coordinated with the State Game and Fish Department, subject to Corps approval.

3. The permittee will incorporate in the construction of the dam and reservoir a multi-level intake/outlet works structure to allow water releases to be made from several differing elevations within the reservoir. Releases must comply with state water quality temperature discharges, regardless of exemptions for reservoir releases. The multi-level outlet works must be built to allow releasing water from within the epilimnion of the reservoir between September 16 and March 31. Ports must be spaced to allow mixing of water during the summer (July 1 to September 15) to achieve target temperatures as described below. Data sensors must be installed near each outlet port to allow for water temperature data throughout the depths of the reservoir. The State Game and Fish Department must have instantaneous access to temperature data year-round. The sensors must be linked to the Supervisory Control and Data Acquisition (SCADA) system. State Game and Fish Department will determine where the outlet settings are placed in order to achieve optimum temperature releases for downstream fisheries from June 15th until September 15th of each year. Target temperature releases during this period will be 55 to 65 degrees Fahrenheit. This condition does not give the State Game and Fish Department the ability to dictate release amounts from the dam.

4. The permittee must measure dissolved oxygen (DO) levels and temperature at the monitoring station located immediately downstream from the dam outlet for a period not to exceed 5 years. Samples must be taken twice weekly from July 1 to September 15 as well as January 1 to February 28 of each year. Sampling needs to be done within 2 hours after sunrise. Adjustments to reservoir releases via the multi-level outlet will be made if DO concentration levels and/or temperatures of releases downstream of the dam fail to meet the minimum State Department of Environmental Quality water quality standard for a Class II stream, regardless of any exemptions for dam releases. The permittee must provide the G&FD with continuous real-time review capabilities of DO, temperature, and flows.

5. The permittee will install a staff gage and instrumentation to provide for monitoring of the reservoir levels on a daily basis. Reservoir water temperature data will be made instantaneously available to the State Game and Fish Department on a daily basis via the sensors in the SCADA system installed at each outlet port on the multi-level out let works and in the stream below the dam. Reservoir-level data will be submitted along with stream gaging data reports referred to in Special Condition #2.

6. The permittee cannot store any water coming into the reservoir when the combined inflows are 12 cubic feet per second (cfs) or less. From the period of July 15 to September 30 each year, the permittee must maintain a minimum flow downstream from the proposed dam of 10 cfs, regardless of inflows. Releases of outflow must be accomplished by stepping up and down irrigation releases over an extended period (i.e., flow release changes will be done in equal increments over a 3-day period) to avoid dramatic changes in volume and temperature of releases.

7. The permittee will maintain an inviolate minimum pool of 5,724 acre-feet. The permittee will designate in writing to the State Game and Fish Department that a specific portion of the permittee's water right for the project is for the exclusive purpose of providing a minimum pool of 5,724 acre-feet for fisheries. This will be accomplished prior to commencing to fill the reservoir. This minimum pool will be maintained at all times, except for the following:

a. To facilitate pre-approved downstream channel maintenance flows (see special condition I, 10),

b. To allow the State Game and Fish Department the ability to renovate the fishery,

c. In emergency conditions or for dam safety inspections, which may be required on a periodic basis.

To gain approval to release any water from the minimum fishery pool, the permittee must, except in emergency conditions, provide a written request to the State Game and Fish Department and the Corps 14 days, or as soon as practically possible, in advance of the date when the release will be made. The letter must describe in detail the need for releasing of those waters and request written approval from the State Game and Fish Department and the Corps prior to doing so.

8. The permittee will release flows that result in out-of-bank conditions for riparian rejuvenation and channel maintenance. Releases will occur in those years where water demand is less than storage and the out-of-bank occurrence interval documented in the EIS can be approximated (i.e., once every 10.3 years). Use of agricultural and minimum pool water can be used on a prorated basis to achieve this condition, when implemented. Prior to release of channel maintenance flows, both the permittee and State Game and Fish Department will jointly agree and share in ensuring that detrimental impacts associated with the stream immediately downstream from the reservoir operation would be offset and benefited by such flushing releases. Written approval must be obtained from the Corps, with coordination with State Game and Fish Department prior to the release. Releases must be timed to correlate to normal periods of high flows (as practical) and controlled such that they do not threaten wetland, grade control and bank stabilization mitigation strategies. Post-channel maintenance flow assessments of these features must be accomplished to determine appropriate releases. If damage occurs from such releases to grade control structures or mitigation sites, the permittee remains responsible for the life of the project for the appropriate maintenance or repairs needed. The permit requires such releases, with the understanding that such releases reflect shared responsibility between the permittee and State Game and Fish Department. Monitoring assessments must be coordinated with and approved in advance of any such releases by the Corps, with concurrence of the State Game and Fish Department. If releases are found to be damaging and not beneficial, this condition will become invalid.

Example 4

1. The Project can only divert water that has been identified in the Corps permit application associated with only the treated effluent from a XYZ's Wastewater Treatment Plant discharges and Another Entity's Wastewater Treatment Plant discharges. Any additional diversions at the Project beyond these treated effluent discharges must be provided to and reviewed by the Corps and permit conditions modified concerning the Project's operations prior to changes being implemented.

2. The permittee must not operate the Project if readings at the USGS Gage (--------) fall below 387 cfs.

3. When operating the Project, the maximum pumping rate cannot exceed 114 MGD. Any additional diversions must be provided to and reviewed by the Corps and permit conditions modified concerning operations prior to increases being implemented.

4. Data from the Project authorized under Department of the Army permit and USGS Gage must be available online showing instantaneous readings for these three locations at a single website allowing for comparison. The amount of treated effluent being diverted at the Project must be identified in relation to the previous day's discharges from the wastewater treatment plants identified in condition 1.

Example 5

1. The permittee shall provide continuous minimum flow releases from the reservoir of 3.2 cfs or match inflows, whichever is less.

2. The permittee will stock the reservoir with 200 catchable-sized trout per full-capacity surface acres any time the reservoir capacity drops below the conservation pool (elevation 8,542) by any amount. The permittee is responsible for the entire cost, delivery and stocking of catchable trout. The specific details of stocking dates, species and technique must be coordinated and approved by the State Game and Fish Department within 90 days following the end of any year in which the minimum pool is entered. The permittee shall install a permanent water elevation marker in the reservoir below the ordinary highwater line which identifies the minimum pool elevation (staff gage). The marker must be visible when the reservoir water elevation is within 3 (elevation 8,545) feet of the minimum pool (elevation 8,542). The permittee will submit a summary of weekly reservoir elevations for the entire water year to the State Game and Fish Department on or before November 1 of each year.

3. The permittee shall install two (2) monitoring (gaging) stations at the following locations: immediately downstream from the outlet of the dam (Station 1), and immediately upstream from the design normal water elevation of the reservoir on State Creek (Station 2). Monitoring equipment at both locations must be able to accurately measure flow on a continual basis. Both monitoring stations will measure temperature on an hourly basis. Release temperature goals are between 55 and 65 degrees Fahrenheit from

July 1 through September 15; within 3 degrees Fahrenheit of inflow water from September 16 through October 31 and April 1 through July 1. Releases from November 1 through March 31 should be no cooler than temperature inflow. Temperature readings should be referenced to the maximum daily temperature. Revisions of these goals will be coordinated with the State Game and Fish Department, subject to Corps approval. Data gathered from the monitoring stations is to be provided to the Corps of Engineers, Environmental Protection Agency, the State Game and Fish Department, and the US Forest Service in report form for a period of five (5) years or until the State Game and Fish Department determines that monitoring is no longer needed, whichever is longer. The monitoring stations are to be maintained in a serviceable manner at all times.

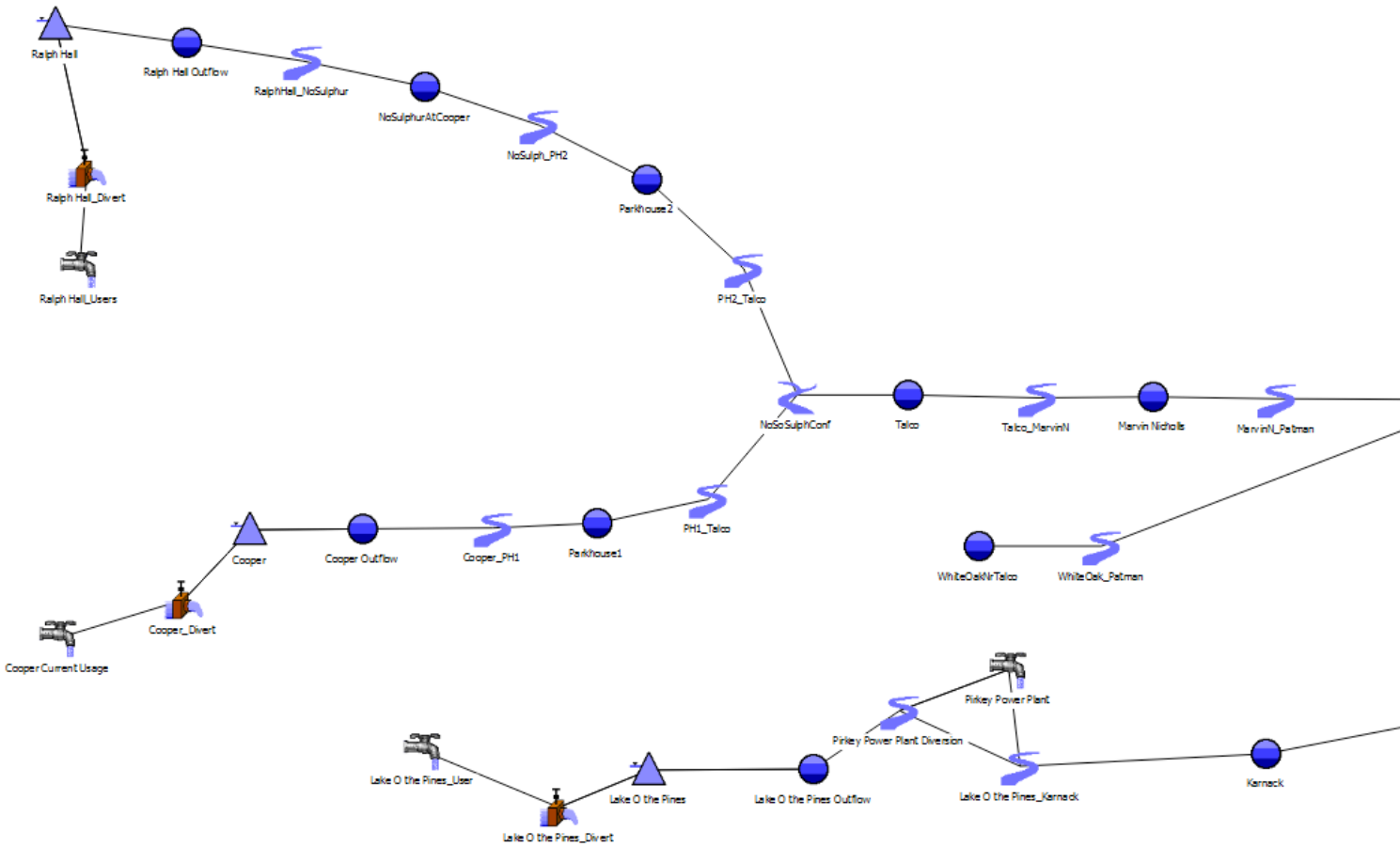
4. The permittee must measure dissolved oxygen (DO) and pH levels at monitoring Station 1 until the State Game and Fish Department determines that monitoring is no longer needed. Samples must be taken bi-weekly from July 1 to October 15. Sampling needs to be done within 2 hours after sunrise. Adjustments to reservoir releases via the multi-level outlet shall be made if DO concentrations and pH levels of releases fail to meet minimum State Environmental Quality Department water quality standards for a Class II stream, regardless of any exemptions for dam releases.

Example 6

1. The permittee is required, after the Project fills, to provide a continuous minimum flow release of 1 cfs except during critical drought conditions (i.e. when reservoir storage is less than 50%) when the minimum flow release will be 0 cfs for a maximum of 5 consecutive days and then a minimum flow of 1 cfs for a minimum of 5 continuous days prior to a new 5 day period of no flow (and so on).

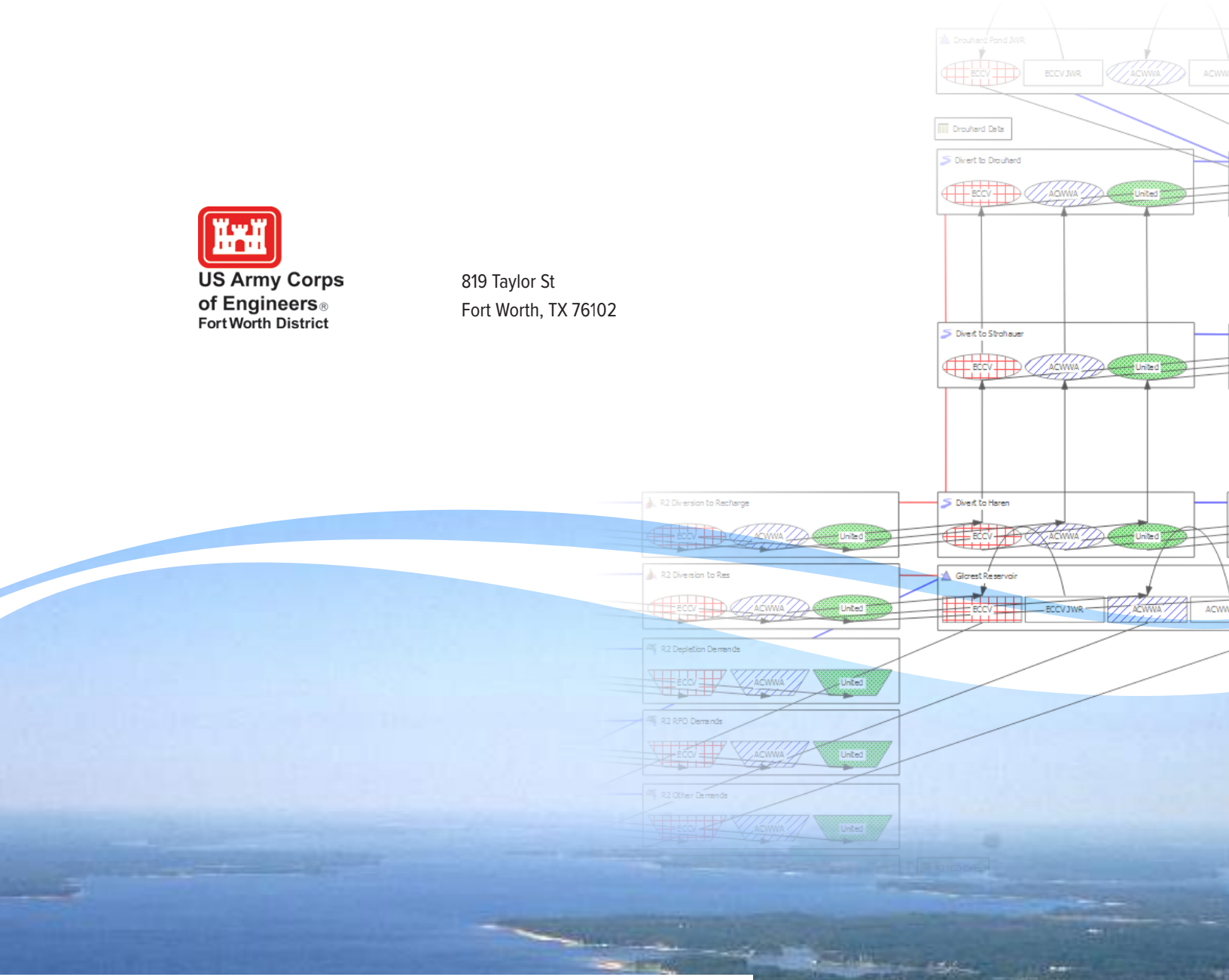
2. The permittee is required, after the project fills, to provide a 9-hour, 85 cfs pulse flow release during the first week of June in those years when a peak flow of 85 cfs or more has not occurred during the previous 12 months at the new streamflow gage. The permittee will coordinate the timing of this release with the State Game and Fish Department and will notify Department staff (by email) on or about May 15th in years a release is required. By May 25th the State Game and Fish Department will notify the permittee to either proceed with the pulse flow release the first week of June or delay the release until no later than October 31st of that year. If during the State Game and Fish Department requested delay period a natural flow event occurs that exceeds 85 cfs at the new streamflow gage or if the reservoir level drops to less than 50%, then the permittee will not be required to make the pulse flow release that year. During critical drought conditions, when reservoir storage is less than 50%, pulse flow releases are not required.

3. The permittee must construct a gaging station approximately 260 feet downstream of Highway 123 at the existing channel dam. The proposed gage design is to be submitted to the Corps for review and approval. The gage is to be designed, installed, and functioning prior to completion of construction of the Project. Monitoring equipment at the gage must be able to accurately measure flow on a continual basis and be viewed in real time via the Internet.



Toledo Bend Dam. Photo courtesy of Toledo-Bend.com

Back cover: Toledo Bend Reservoir. Photo courtesy of Toledo-Bend.com



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