WHITE RIVER STORAGE FEASIBILITY STUDY PHASE 2A REPORT

W. W. WHEELER & ASSOCIATES, INC.
Water Resources Engineers

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September 30, 2018

Prepared for the

RIO BLANCO WATER CONSERVANCY DISTRICT

EXECUTIVE SUMMARY

The White River Storage Feasibility Study Phase 2A Report provides additional refinements to provide water storage within the Rio Blanco County Water Conservancy District (RBWCD) by building upon previously completed Phase 1 and 2 studies. The Phase 2A Study Report was prepared by W. W. Wheeler & Associates, Inc. and was managed by EIS Solutions for the RBWCD. The RBWCD encompasses the lower White River basin in western Rio Blanco County, in northwestern, Colorado. The White River basin currently does not have storage to meet the current water needs during drought conditions or reliably provide water for future needs.

The White River Storage Feasibility Study (Phases 1 and 2) included a purpose and need evaluation for the White River basin which identified future water demands by year 2065 ranging from about 20,000 to 90,000 acre-feet for municipal and industrial, energy, and environmental purposes. Phase 1 and 2 screened 25 potential reservoir storage alternatives to select the preferred alternative of the Wolf Creek Dam site, located on Wolf Creek immediately upstream of its confluence with the White River.

The Phase 2A Study refined the Wolf Creek Dam feasibility design to include gravity fill facilities for two different flow rates and refined the pump facility designs. The Phase 2A Study also developed feasibility-level designs of the White River Dam, located on the White River immediately downstream of the Wolf Creek tributary. Phase 2A included refinements to the storage pools in the White River Reservoir and Wolf Creek Reservoir to include storage for long-term reservoir sedimentation, dedicated recreation storage, and insurance storage. Table No. ES-1 provides an overview of the feasibility-level design opinion of probable costs for the Wolf Creek Dam and White River Dam options.

ES-1 – Alternative Comparison Cost Summary [1]

Size:	20,000 acre-foot Working Pool				90,000 acre-foot Working Pool		
Dam Site:	Wolf Creek			White River	Wolf Creek		White River
Fill Method:	Canal	Pipeline	Pump	Direct	Canal	Pump	Direct
Construction	$195M	$329M	$119M	$275M	$318M	$191M	$360M
Cost per acre-foot[2]	$4,800	$8,000	$2,900	$4,000	$2,400	$1,500	$2,600
Average Annual Operation & Maintenance	$300,000	$100,000	$263,000	$100,000	$300,000	$638,000	$100,000

[1] Costs based on 2018 dollars. [2] Based on construction costs and total reservoir storage.

Based on a preliminary review of the impacts associated with the White River Dam and the Wolf Creek Dam, the Wolf Creek Dam has less environmental and private land impacts. The most economical alternative is the Wolf Creek Dam with a pump fill station for construction costs. If hydropower is considered in the future, the White River Dam will provide more revenue than the Wolf Creek Dam. The unit cost per acre-foot of reservoir storage at either the Wolf Creek Dam or the White River Dam is considered to be very economical in comparison with other regional water projects. The RBWCD's preferred alternative for providing storage for future water needs is the Wolf Creek Dam with a pump station. The secondary alternative is the White River Dam.

As part of the Phase 2A Study, preliminary engineering was performed for a dam and reservoir that could produce the maximum water storage topographically available at the Wolf Creek Dam and the White River Dam locations. Based on this information, it is possible to build a larger reservoir in either location if the needs are identified and documented in the future.

If storage is not developed in the White River Basin, the Town of Rangely will be at a significant risk in a severe drought; storage water will not be available for the identified future water needs; the target flows for endangered fish may not be able to be met; and the projected tax benefits and recreational opportunities for northwestern Colorado that are associated with the project will not be available. The next project phase is Pre-Permitting which will define the site disturbance area, establish the reservoir size for the permitting, and confirm the financial plan for funding the project. The Pre-Permitting Phase tasks are also structured to make the Permitting Phase as efficient as possible based on a recent Department of the Interior directive requiring that Environmental Impact Statements be completed in less than 150 pages and within 365 days of the issuance of the Notice of Intent (NOI). The RBWCD is working towards the NOI issuance at the end of 2019.

WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A REPORT

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1.0 INTRODUCTION

1.1 Objective

The objective of the White River Storage Feasibility Study Phase 2A Report (Phase 2A Study) was to further refine the alternatives for providing water storage within the Rio Blanco Water Conservancy District (RBWCD). The Phase 2A Study expands upon the analyses that were performed and comments that were received on the previously completed Phase 1 and 2 studies (Wheeler, 2015).

1.2 Authorization

This feasibility report was commissioned by the RBWCD. The funding for this work was provided by the following entities:

- Colorado Water Conservation Board (CWCB)
- Yampa/White/Green Basin Roundtable
- Rio Blanco Water Conservancy District
- Town of Rangely
- Town of Meeker
- Rio Blanco County

1.3 Phase 2A Study Scope of Work

The scope of work for the Phase 2A Study is provided in Appendix C. Key work tasks completed in the Phase 2A Study are summarized below:

1. Performed continued stakeholder outreach, public meetings, and project management.
2. Performed preliminary engineering to refine the Wolf Creek Dam including providing storage for long-term reservoir sedimentation, recreation storage, and insurance storage. The Wolf Creek Dam is located on Wolf Creek immediately upstream of its confluence with the White River.
3. Performed preliminary engineering for the White River Dam, which also included storage for recreation and future reservoir sedimentation. The White River Dam is located on the White River immediately downstream of the Wolf Creek tributary.
4. Performed preliminary engineering for a dam and reservoir that could produce the maximum water storage topographically available at the Wolf Creek Dam location and the White River Dam location.
5. Performed an estimate of the long-term sediment volumes anticipated at both dam sites.
6. Participated in the review committee for the Yampa/White/Green Basin Roundtable Basin Implementation Plan Modeling of the White River, which included the Wolf Creek Dam.

7. Prepared a draft report of the work and held a public workshop to present the report.
8. Prepared a Final Report for the Phase 2A Study.

1.4 Project Personnel

The following personnel contributed to the work documented in this report:

1. Brad McCloud, Project Manager, EIS Solutions
2. Steve Jamieson, P.E., Engineering Project Manager, W. W. Wheeler and Associates, Inc. (Wheeler)
3. Danielle Hannes, P.E., Project Engineer, Wheeler
4. Kit Choi, Ph.D., P.E., Senior Engineer, Wheeler
5. John Treacy, P.E., Dam Safety Engineer, Wheeler
6. Gary Thompson, P. E., Water Rights Engineer, Wheeler
7. Alan Tipton, EI, Junior Engineer, Wheeler
8. Ed Olszewski, Olszewski, Massih & Maurer, P.C.
9. Robin Dornfest, P.G., C.P.G., Geologist, Lithos Engineering
10. Nate Soule, P.E., P.G., Geologist, Lithos Engineering

Wheeler gratefully acknowledges the valuable input provided by the RBWCD Board of Directors and the RBWCD District Manager, Alden Vanden Brink. The RBWCD Board of Directors and RBWCD District Manager also participated in numerous key stakeholder meetings during the Phase 2A Study.

The Yampa/White/Green Basin Roundtable (BRT) contracted with Wilson Water Group to refine a model of the White River using the Colorado Decision Support System (CDSS) water rights allocation model, StateMod. The model included the 90,000 acre-foot Wolf Creek Dam and White River Dam in several of its modeling scenarios and provided valuable information on how the Wolf Creek Dam or White River Dam could mitigate future water shortages.

2.0 BACKGROUND

2.1 General Project Information

The White River watershed encompasses approximately 3,750 square miles of land in Rio Blanco and Moffat Counties in northwestern Colorado (see Figure No. 1-1). The White River flows into the Green River south of Vernal, Utah. Approximately 500,000 acre-feet of water flows out of the White River annually into Utah, and the total consumptive use by water users along the White River in Colorado is approximately 30,000 acre-feet (Y/W/G Roundtable, 2015). The watershed ranges in elevation from about 11,000 feet[1] on the east end to approximately Elevation 5000 at the Utah State Line. Major sub-drainages to the White River include Piceance Creek, Douglas Creek, Wolf Creek, Yellow Creek, and Crooked Wash.

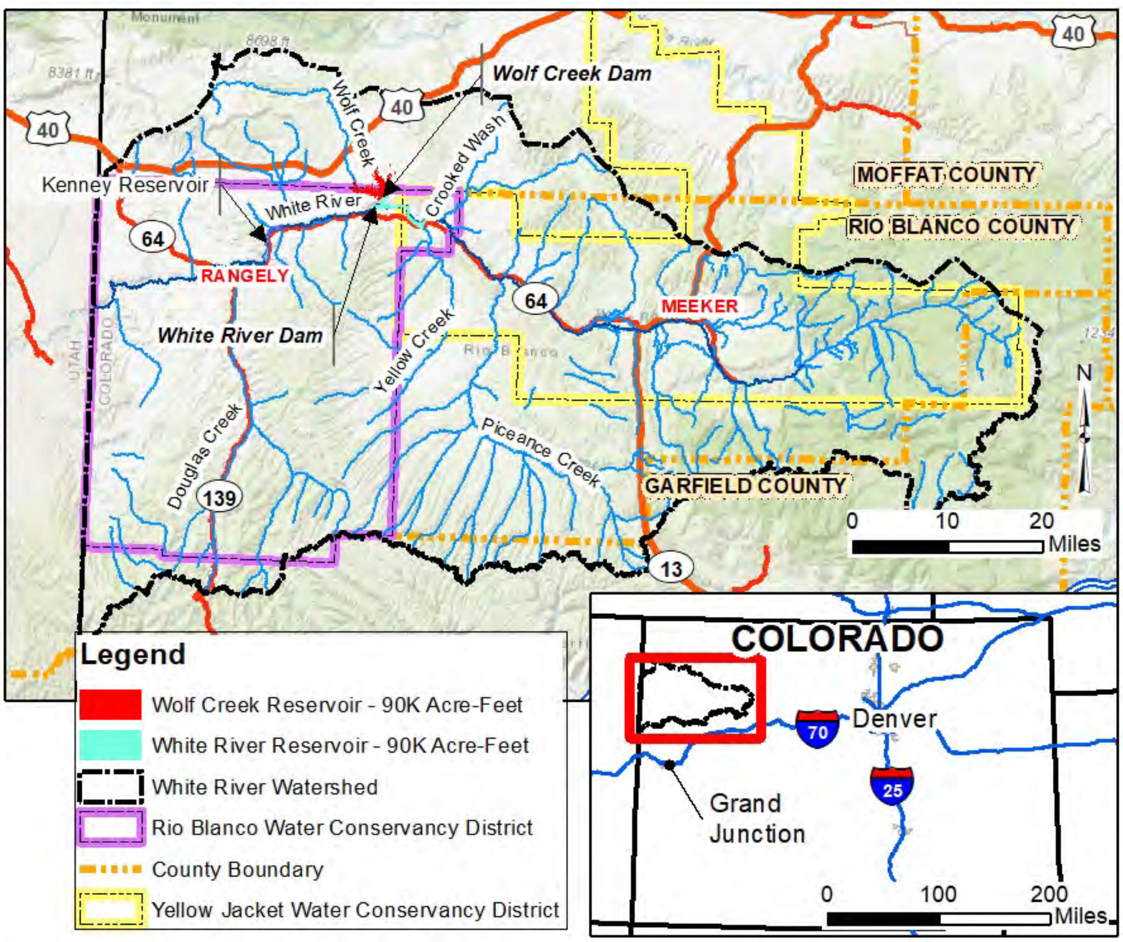

Figure 1-1 – White River Basin – Location Map

[1] Elevations in this report are reported in feet above the 1988 North American Vertical Datum.

The White River basin currently does not have significant storage to meet the current water needs during drought conditions or any additional future water needs within the basin. The only significant water storage reservoirs within the White River Basin include Kenney Reservoir, Lake Avery, and Rio Blanco Lake. Kenney Reservoir, located on the White River about 6 miles upstream of the Town of Rangely, has been accumulating about 315 acre-feet of sediment every year (GEI, 1999). It is estimated that the 2018 active storage in Kenney Reservoir is about 3,400 acre-feet, which is significantly less than its original 13,800 acre-feet storage capacity. The storage in Lake Avery is about 7,658 acre-feet (WWG, 2018). Lake Avery is owned and operated by Colorado Parks and Wildlife (CPW) for recreation. Rio Blanco Lake stores about 1,036 acre-feet. Both Lake Avery and Rio Blanco Lake have decreed uses for recreation and do not have the storage capacity or decreed water rights to provide water for drought protection or long-term future development in the White River basin. The RBWCD has been proactive in its planning to provide drought protection for its constituents as well as having water available for the protection and enhancement of endangered species habitat and future economic development within northwestern Colorado. If future water storage is not immediately addressed, a future water crisis is expected in the White River Basin.

The RBWCD is aware that the planning, permitting, financing, design, and construction of a new water supply reservoir can take several years. Most of the land within the RBWCD is owned by the U. S. Department of Interior, Bureau of Land Management (BLM), so any new reservoir construction will require a right-of-way approval from the BLM, which will require extensive permitting and documentation required by the National Environmental Policy Act (NEPA). As part of the Phase 2A work, the RBWCD has initiated conversations with key permitting agencies and stakeholders about initiating a Lean approach to project permitting in an effort to make the NEPA process more efficient while providing adequate documentation that is scientifically sound, credible, defensible, and environmentally responsible.

2.2 Initial Phase (Phase 1 and Phase 2) Scope of Work Summary

The initial planning work towards the development of storage in the White River basin began in 2013, spearheaded by the RBWCD. The RBWCD's mission is to conserve and develop land and water resources for the best use of water within the RBWCD boundaries. In line with that mission, the RBWCD took the initiative to lead this study in an effort to start a process to mitigate a developing water crisis.

Work on the Initial Phase of the White River Storage Feasibility Study (referred to as Phase 1 and Phase 2) occurred from 2013 through March of 2015 and is documented in the White River Storage Feasibility Study Final Report (Wheeler, 2015). The Initial Phase included:

1. The development of the purpose and need for a water project within the White River basin. Harvey Economics (HE) updated previous state-wide water demand

projection information, interviewed potential water users, and updated water demands prepared by others to develop a future water demand estimate for the White River basin. A range of future water needs was identified, which included water needs for municipal and industrial; oil and natural gas; oil shale; recreation; and endangered fish flows. The total range of projected annual water needs was about 16,600 to 90,950 acre-feet by the year 2065. The water storage needs developed in the Initial Phase were used in this Phase 2A Study.

2. An alternatives map study that identified locations within the entire White River basin that could potentially be used as new water storage sites.
3. Coarse screening of alternatives to eliminate reservoir sites that did not meet the long-term storage demands; did not meet desired recreational criteria; were too far downstream to meet upstream water needs efficiently; or had significant environmental impacts, infrastructure impacts, or property impacts. Additionally, the RBWCD elected to proceed with storage alternatives located within the RBWCD boundaries. Based on the coarse screening of alternatives, three primary dam sites were identified.
4. At each of the three primary dam sites (Gillam Draw, Spring Creek, and Wolf Creek) Wheeler developed feasibility-level designs and opinions of probable project cost for two reservoir sizes: a 20,000 acre-foot and a 90,000 acre-foot reservoir. The 20,000 acre-foot and 90,000 acre-foot reservoir sizes were approximately equivalent to the low end and high end of the projected long-term water demands in the White River Basin. The feasibility designs assumed that the reservoirs would be filled with water from the White River using pump stations and pipelines.
5. Wheeler performed an alternatives evaluation considering feasibility-level cost opinions and preliminary environmental and geologic information collected during site visits to the primary dam and reservoir sites. The Wolf Creek Dam, located on Wolf Creek immediately above its confluence with the White River, was found to be the preferred alternative for future planning and permitting assessments. The Wolf Creek Reservoir had the most favorable capital costs and pumping costs; no significant identified environmental or cultural resources impacts; has the flexibility to be expanded to a larger size if future needs require additional water storage; and the reservoir is located in an area that will allow recreation access from both U.S. Highway 40 in Moffat County and State Highway 64 in Rio Blanco County.
6. Harvey Economics assessed the financial element of the Wolf Creek Reservoir which consisted of quantifying the potential financial benefits; assessing the ability and willingness to pay for key stakeholders; and developed a financial roadmap for funding the Wolf Creek Project construction.

7. Seven public workshops and Project update presentations were made, five update presentations were provided to the Yampa/White/Green Roundtable, and more than 50 other key stakeholder meetings were held.
8. Wheeler prepared a draft report of the work, which included a public presentation, and solicited comments. The comments were addressed, if possible, and a final report was prepared. The final report was entitled the White River Storage Feasibility Study Final Report (Wheeler, 2015).

2.3 Wolf Creek Dam Modeling for the Yampa/White/Green Basin Roundtable

The Yampa/White/Green Basin Roundtable (BRT) contracted with Wilson Water Group to complete Modeling Phase 3 work related to the Basin Implementation Plan (BIP). The modeling was summarized in a final report (Wilson Water Group, April 2018). The BIP Phase 3 modeling included the refinement of the previously developed Colorado Decision Support System (CDSS) water rights allocation model, StateMod, for the White River. The White River CDSS model was refined to include more accurate representations of the current water uses, operations, and administrations based on information from water uses in the community and the Basin Roundtable.

As part of the Phase 3 modeling, the BRT elected to model the Wolf Creek Dam as an Identified Project and Process (IPP) to explore the benefits and impacts associated with the project in considering the projected future water demands. Excerpts from the report, as they pertain to the White River and Wolf Creek Dam project are provided in Appendix D.

White River StateMod Model Input Summary

A summary of the key inputs and various model scenarios that were evaluated in the Phase 3 modeling are summarized below:

1. The BRT decided to include three hydrology scenarios within the modeling to examine a range of future hydrologic conditions including:
   a. A baseline condition climate scenario representative of historical hydrologic conditions;
   b. A “hot and dry” climate scenario representative of lower runoff and higher crop irrigation requirements by 2050, which is consistent with the Statewide Water Supply Initiative (SWSI) effort; and
   c. A “between” climate scenario that is between the “baseline” and the “hot and dry” climate scenarios.

2. The 2065 demands in the White River modeling included the following:
   a. ***A total future demand of 45,800 acre-feet per year for energy development on the White River and Piceance Creek.*** The total future

demand volume was from the high end of the projected energy water demands from the Initial Phase of this work (Wheeler, 2015). The BRT considered these demands the most representative data source for future energy development in the White River basin that was available at the time of the modeling. A potential diversion on the White River, located just downstream of Wolf Creek Dam, represented about 75 percent (~35,800 acre-feet) of the total energy water demand in the model. A potential diversion on Piceance Creek represented about 25 percent (~10,000 acre-feet) of the demand in the model. The potential Piceance Creek demand was based on water generally available in Piceance Creek. A 2016 water right was included in the model for the diversion on the White River and a 1975 water right was included in the model for the Piceance Creek diversion, which generally represents the dates of conditional water rights currently held by energy companies in the Piceance Basin.

b. ***Additional future demands for the Town of Rangely, Town of Meeker, and a golf course.*** The demands for the Town of Rangely increased from the current demand of 1,810 acre-feet per year to 3,150 acre-feet per year. The demands for the Rio Blanco County unincorporated municipal and domestic use increased from the current demand of 1,104 acre-feet per year to 1,921 acre-feet per year. The demands for the Town of Meeker increased from the current demand of 338 acre-feet per year to 558 acre-feet per year. A future golf course, assumed to be located just upstream of Meeker, had a demand of 300 acre-feet per year.

c. ***Instream flow target at the Watson Gage of 300 cfs year-round.*** This is a preliminary value that was used in the Phase 3 modeling, which will be updated once the U.S. Fish and Wildlife Service (USFWS) completes the White River Programmatic Biological Opinion (PBO). Based on preliminary information from the PBO team, the target flows will likely vary based on hydrologic year type and the season as opposed to strictly maintaining a constant minimum flow. The PBO work was being performed simultaneously with this Phase 2A Study, allowing the utilization of the base StateMod model to support both the PBO and Phase 3 modeling work efficiently.

3. The Wolf Creek Reservoir and White River Reservoir were included in the model. It was assumed that the Wolf Creek Reservoir would be filled using a pump station from the White River, but the White River Reservoir would be filled by direct river inflows. The conditional water rights associated with the application filed on October 29, 2014 were assigned to the Wolf Creek Reservoir/White River Reservoir in the model.

Modeling for the Wolf Creek Reservoir and White River Reservoir produced similar results, because at the modeled filling flow of 400 cubic feet per second (cfs) was large enough to capture most of the available flows.

White River StateMod Model Results Summary

The model provided documentation that the Wolf Creek Reservoir/White River Reservoir has the ability to provide the additional water to meet the projected long-term future demands through 2065 for energy needs and the municipal and industrial needs for the Town of Rangely. Table No. 2-1 presents the projected water shortages with and without the Wolf Creek Reservoir/White River Reservoir.

Table 2-1 - Percent Volume Shortage to Consumptive Demands in the White River

	Baseline	Future Demands, No IPPs	Wolf Creek Reservoir/ White River Reservoir (90,000 acre-foot)
Rangely	1%	1%	0%
Future Energy Development, White River	-	8%	0%
Future Energy Development, Piceance Basin	-	25%	0%

Information from Table No. 30 in Appendix D.

In addition to modeling the future water demands, the BRT also reviewed how the Wolf Creek Reservoir/White River Reservoir would offset shortages under the modeled future hydrology scenarios. The storage in the 90,000 acre-foot Wolf Creek Reservoir, with the future projected demands in the White River Basin under the three hydrology scenarios, is shown on Figure No. 2-1.

The White River StateMod model conservatively assumes that if water is available in the Piceance Creek or the White River, then the energy demands would be diverted directly from the White River or Piceance Creek and would not pass through the Wolf Creek Reservoir. Water from the Wolf Creek/White River Reservoir would only be released to meet the demands if such requirements cannot be satisfied by their direct diversion from the White River/Piceance Creek. As a result, if an energy company transfers its water rights to the Wolf Creek/White River Reservoir or purchases a share in the reservoir and diverts under the 2014 water right filed by the District, additional water could be stored in the Wolf Creek/White River Reservoir beyond what was shown in the StateMod modeling results.

The BRT reviewed an IPP to enlarge Lake Avery as part of the Phase 3 modeling work. However, the BRT elected to not further investigate an enlargement of Lake Avery after the July 2017 workshop presentation due to the limited value of the enlargement for streamflow enhancement (see Appendix D of Appendix D).

Additional details on the modeling that was performed for the White River without any future reservoirs, the Wolf Creek Reservoir, and the White River Reservoir are included in Appendix D.

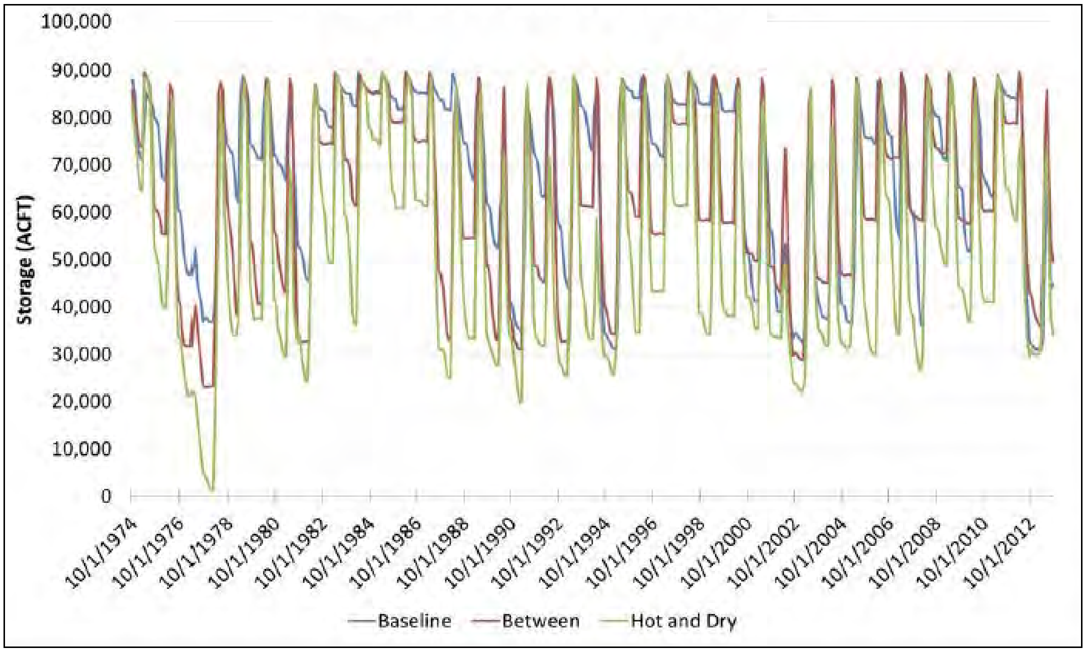

Figure 2-1 – Wolf Creek Dam End of Month Storage in StateMod Modeling Future Demand Depletions with Hydrology Scenarios

Note: This is Figure No. 45 in Appendix D.

2.4 Water Rights

The majority of the senior water rights on the White River are located upstream of the Town of Meeker. Downstream of Meeker, the White River continues to operate under free river conditions throughout most of the year. Depending on the future hydrologic conditions and additional development within the White River, the free river conditions may not continue. Several conditional water rights are in the process of being filed for at the Wolf Creek/White River Dam site(s) or are being considered for transfer to the site(s) including:

- A water right was filed in 2014 by the RBWCD for a 90,000 acre-foot reservoir in either the White River Dam location or Wolf Creek Dam location with a 400 cfs pump filling station (see Section 2.4.1);
- The RBWCD is considering transferring conditional water rights associated with Taylor Draw Dam (Kenney Reservoir) to the site (see Section 2.4.1);
- Terra Carta Energy Resources, LLC has filed an application to change the location of a September 14, 1964, 85,342.4 acre-foot conditional storage water

right to the Wolf Creek Reservoir location (termed South Fork Reservoir No. 1 in the application). It should be noted that the change in location application filed by Terra Carta was not submitted in coordination with the RBWCD, and this volume is not included in the 90,000 acre-foot reservoir energy demand pool. At the time this report was being prepared, the RBWCD was an opposer to Terra Carta's exchange case.

Other water rights are being considered for transfer to the Wolf Creek Reservoir or White River Reservoir site and are undergoing legal review.

2.4.1 2014 RBWCD Water Rights

As a result of the Initial Phase of the White River Storage Feasibility Study, the RBWCD filed for three conditional water rights associated with the Wolf Creek Reservoir on October 29, 2014 including:

- 400 cfs Wolf Creek Reservoir Pump and Pipeline water right for filling the Wolf Creek Reservoir;
- 90,000 acre-foot storage right for the Wolf Creek Dam and Reservoir; and
- An alternative 90,000 acre-foot storage right for the Wolf Creek Mainstem Dam and Reservoir that would be constructed on the mainstem of the White River. This is referred to as the White River Dam in this report.

As listed in the application, the proposed uses of the water right include municipal, industrial, commercial, irrigation, domestic, recreation, piscatorial, augmentation, wildlife habitat, maintenance and recovery of federally listed threatened and endangered species, hydroelectric power generation and all other beneficial uses.

The RBWCD also has conditional water rights associated with Taylor Draw Dam that could be transferred to the preferred reservoir site with minimal impacts expected to other water users. The RBWCD conditional water rights include:

- 13,800 acre-feet (Adjudication date: 11/21/1966)
- 13,800 acre-feet (Adjudication date: 12/31/1982)
- 620 cfs (Adjudication date: 11/21/1966)

3.0 PURPOSE & NEED STORAGE REFINEMENTS

In the Initial Phase of the White River Storage Feasibility Study, Harvey Economics (HE), in cooperation with EIS Solutions (EIS), updated previous state-wide water demand projection information, interviewed potential water users, and updated water demands prepared by others to develop a site-specific future water demand estimate for the RBWCD through the year 2065. The details of this purpose and need evaluation are provided in Wheeler, 2015.

Following the Initial Phase, key stakeholders concluded that three additional pools should be included in the reservoir: (1) a dedicated minimum recreation pool to ensure recreation is always available at the site; (2) a sediment pool to extend the life and usefulness of the reservoir; and (3) an insurance pool for the Wolf Creek Reservoir to maintain operations for a period of time if the fill facilities require significant maintenance and cannot be operated. The details of these storage volumes and refinements are summarized in the following sections.

3.1 Water Storage Summary

A summary of the water demands that were developed in the Initial Phase are provided in Table No. 3-1. These needs are termed the "Working Pool" throughout the report. The range of water demands was rounded to evaluate reservoir storage sites that could accommodate a 20,000 acre-foot working pool to meet the low end of the projected water demands, and a 90,000 acre-foot working pool to meet the high end of the water demands.

A summary of the total storage capacity needed to accommodate the Working Pool, recreation pool, sediment pool, and insurance pool at each dam site is provided in Table No. 3-2. A description of the criteria for these pools is provided in Sections 3.2 through 3.4.

Table 3-1 – Projected Water Storage Needs (Working Pool)

Water Use Sectors	Long-Term (through year 2065) Low End of Range (acre-feet)	High End of Range (acre-feet)
Municipal and Industrial (M&I)	1,600	3,150
Oil and Natural Gas	3,500	3,500 [3]
Oil Shale	8,500	42,300 [3]
Environmental [1]	3,000	42,000
Other [2]	-	-
TOTAL	**16,600**	**90,950**

[1] These environmental storage volumes are based on meeting a year-round target streamflow for endangered fish of 200 cfs or 300 cfs at the Watson, Utah streamflow gage. Flow targets as of 2018 being considered by the U.S. Fish and Wildlife Service, for the Programmatic Biologic Opinion, may result in lower environmental storage requirements, since the flow targets vary depending on annual hydrologic conditions and time of year. Additional modeling for the PBO will provide refined estimates.

[2] Other sectors not refined by Harvey Economics in the Initial Phase could need water in the long-term (see Section 3.6).

[3] Energy demands that were selected by the Yampa/White/Green Basin Roundtable to be used in the Modeling Phase 3 work related to the Basin Implementation Plan (Wilson Water Group, April 2018) (see Section 2.3).

Table 3-2 – Summary of Identified Water Storage Pools Used for Dam Sizing

Reservoir Pools	Wolf Creek Dam (Acre-feet)	Wolf Creek Dam (Acre-feet)	White River Dam (Acre-feet)	White River Dam (Acre-feet)
Working Pool [1]	20,000	90,000	20,000	90,000
Recreation Pool	15,000	15,000	24,000	24,000
Sediment Pool	3,000	3,000	24,000	24,000
Insurance Pool	3,000	22,000	-	-
Total Storage	**41,000**	**130,000**	**68,000**	**138,000**

[1] Rounded values from Table No. 3-1.

3.2 Reservoir Sedimentation Estimates

Reservoir sedimentation was identified to be a key concern by several stakeholders in the Initial Phase of this study, largely because of the siltation that has occurred at Kenney Reservoir since its construction. The siltation at Kenney Reservoir has severely limited the reservoir pool for storage and recreation. Kenney Reservoir is only projected to have about ten more years of functional use for providing any water storage or surface water recreation. However, the run-of-the-river hydropower operations at Kenney Reservoir are expected to continue.

As part of this study, Wheeler researched several methods for estimating the sedimentation within the White River Basin, specific to the Wolf Creek Dam and White River Dam sites. The sediment accumulation volumes were estimated for a 50-year time frame.

In 1993 the USGS performed a site-specific study on the White River that focused on sediment transport data collection over a 14-year period, water years 1975 to 1988, at six sampling sites. The sampling locations are shown on Figure No. 3-1. Two soil sampling sites were located in general proximity to the Wolf Creek Dam and White River Dam sites. One site was located approximately seven miles upstream of the Wolf Creek confluence with the White River (Site 5) and the other site was located approximately three miles downstream of the confluence (Site 6).

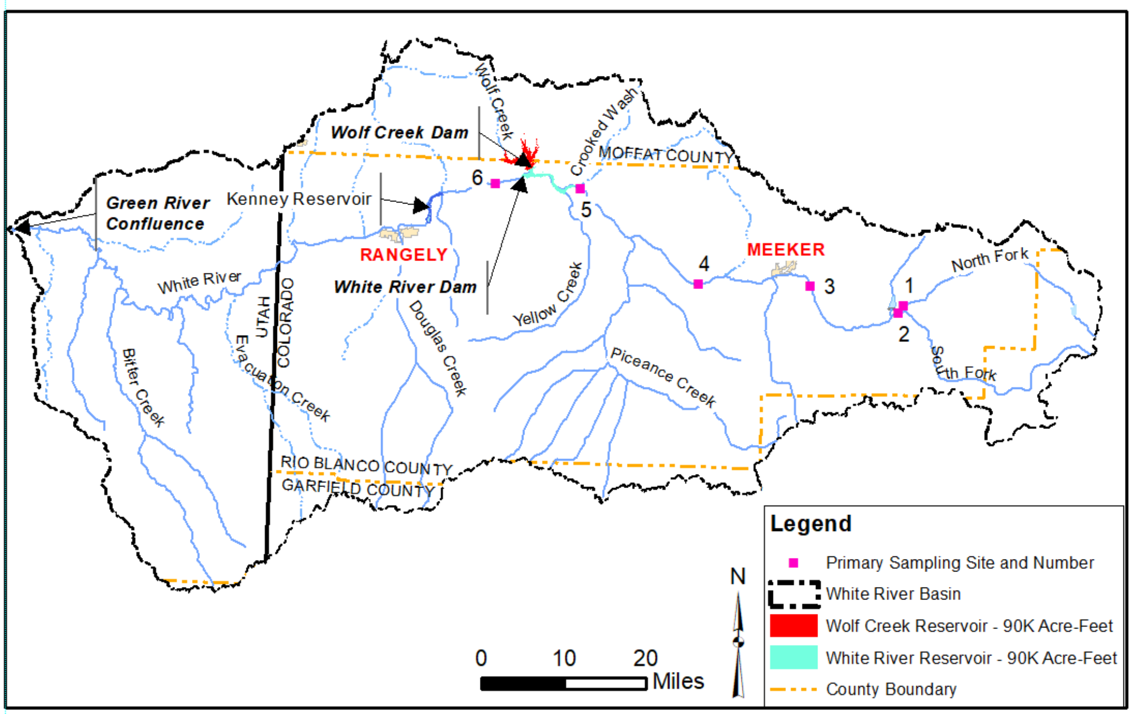

Figure 3-1 – Location of the USGS White River Sediment Sampling Points

Streamflow within the study period was highly variable, resulting in large variations in annual sediment deposits. Annual loads of sediment deposits increase from sites upstream to downstream as the basin size increases. A large increase in sediment loads was documented just upstream of Site 5 potentially due to seasonal inputs from larger perennial streams. The USGS calculated annual sediment loads at each of the six study sites, including Sites 5 and 6. The USGS projected that the sediment retention percentage for a reservoir on the White River that is larger than Kenney Reservoir, which was originally 13,800 acre-feet, could exceed 98 percent based on evidence that the sediment retention in Kenney Reservoir was between 91 and 98 percent. Based on a 98 percent sediment retention rate, the USGS estimated a volume displacement of reservoir storage based on tons of sediment measured at each study site.

The average annual sediment load calculated for the White River Reservoir was 472 acre-feet using the annual sediment load information at Site 6, located approximately two miles downstream from the White River Dam location. Because of variability in flow and corresponding sediment load from year to year, the annual sediment load in the reservoir could range from about 62 acre-feet to 1,307 acre-feet. It should be noted that these values may be conservatively high because the White River Dam is located upstream of Site 6.

The average annual sediment load calculated for the Wolf Creek Reservoir was 57 acre-feet, based on a calculation of the difference in average annual sediment load between Sites 5 and 6 to estimate the amount of sediment that was contributed by tributaries within this reach on the White River. The Wolf Creek Dam drainage area is approximately 203 square miles, which is about 28.6-percent of the drainage area between Sites 5 and 6. The average annual sediment load between Sites 5 and 6 (198 acre-feet) was multiplied by 28.6-percent to obtain the average annual sediment load of 57 acre-feet for the Wolf Creek drainage.

Table 3-3 – Reservoir Sedimentation Results Summary

	Average Annual Calculated Sediment Accumulations (acre-feet)	50-year Sediment Accumulations used for Reservoir Sizing (acre-feet)
White River Dam	472	24,000
Wolf Creek Dam	57	3,000

Wheeler used several other sources to confirm that the sedimentation estimates based on the USGS (1993) study were appropriate. A bathymetric survey was performed of Kenney Reservoir in 1998. Based on the survey, the average annual rate of sediment accumulation at that reservoir was estimated to be about 315 acre-feet (GEI, 1988). The White River Dam is located upstream of Kenney Reservoir, but the projected sedimentation rate for the White River Dam is somewhat higher, for conservative planning purposes. General equations for reservoir sedimentation from the Bureau of Reclamation (USBR, 1988) that are solely a function of drainage area were reviewed; however, this method estimated higher sedimentation loads than the site-specific data. After review, Wheeler considered it appropriate to use the White River site-specific information developed by the USGS in 1993 because that data provides estimates that are applicable to the White River Basin and are in the appropriate range when compared to actual data collected at Kenney Reservoir.

3.3 Recreation Pool Sizing

In the Initial Phase of this study, a demand for additional reservoir recreational opportunities was identified, with details provided in Wheeler, 2015. After conducting several local interviews, Harvey Economics identified reservoir characteristics that would support a number of recreational opportunities. These characteristics include:

- A minimum of 700 to 1,500 acres of surface area;
- An elongated shape;
- Reservoir depth of 50 feet in some areas of the lake;
- Variable bottom shelving;
- Interesting and variable lakeside topography; and
- Good road access for visitors with boats and other equipment.

The Wolf Creek Dam and White River Dam sites have the ability to meet these identified favorable reservoir characteristics for recreation. The recreation pool volumes were calculated based on the recreation design criteria of a minimum surface area of 700 acres and a minimum depth of 50 feet. Table No. 3-4 summarizes the recreation pool criteria for the White River Dam and Wolf Creek Dam. The recreation pool is the same at each site regardless of the reservoir size for the Working Pool, because the same criteria was used for sizing the recreation pool.

Table 3-4 – Recreation Pool Sizing Criteria Summary

	Wolf Creek Reservoir	White River Reservoir
Volume (acre-feet)	15,000	24,000
Minimum Depth (feet)	55	50 [1]
Surface Area (acres)	700 [2]	946

[1] Criteria used to define the minimum recreation pool was based on some areas of the reservoir having a depth of at least 50 feet.

[2] Criteria used to define the minimum recreation pool was based on a minimum surface area of 700 acres.

3.4 Insurance Pool for Wolf Creek Reservoir

An insurance pool for the Wolf Creek Reservoir was included to provide some assurances for the reservoir water users that if the fill facilities (gravity canal, gravity pipeline, or pump station and pipeline) are inoperable for an extended period of time, a pool is available to continue operations while repairs are being made. It was assumed that the insurance pool would be filled by a one-time diversion.

The insurance pool was sized based a continuous flow of the maximum fill rate: 100 cfs for the 20,000 acre-foot Working Pool and 400 cfs for the 90,000 acre-foot Working Pool. The insurance pool for the 20,000 acre-foot Working Pool reservoir was sized using the maximum fill rate for two weeks and the 90,000 acre-foot Working Pool reservoir was sized using the maximum fill rate for four weeks equating to an insurance pool of about

3,000 acre-feet and 22,000 acre-feet, respectively. The 20,000 acre-foot Working Pool insurance pool is smaller, considering that these facilities are smaller in scale and would likely be repaired in a shorter time frame.

3.5 Maximum Reservoir Size

The maximum dam and reservoir size was calculated for the Wolf Creek Dam site and the White River Dam site. When Colorado U.S. Senator Cory Gardner visited the dam sites in the summer of 2017, he asked how large of a reservoir could physically be built in either location. As a result of his inquiry, the development of a maximum size reservoir in either location was included within the scope of the Phase 2A Study. The maximum reservoir size is based on how much water can physically be stored in the reservoir pool, based on topographic constraints. The storage volume was reduced so the Probable Maximum Flood (PMF) could be stored and routed through the reservoir (see Section 4.0 for additional information). The maximum reservoir volume is provided in Table No. 3-5.

Table 3-5 – Maximum Reservoir Volumes

Site	Volume (acre-feet)
Wolf Creek Reservoir	1,490,000
White River Reservoir	2,070,000

It should be noted that this was an evaluation of the maximum storage that can physically be stored and is not reflective of the storage volume that the White River can reliably support. Prior hydrologic evaluations have indicated that the maximum practicable reservoir storage on the White River is about 400,000 acre-feet (USGS, 1984). It should also be noted that it is physically possible to divert water from other adjacent drainage basins for storage in the Wolf Creek Reservoir or White River Reservoir; however, this was not investigated as part of the Phase 2A Study.

3.6 Potential Purpose and Need Refinements

As the Phase 2A Study progressed, additional water demands were discussed with some stakeholders, including agricultural water needs, hydropower water needs, and potential Colorado Compact storage. These needs were identified in the Initial Phase of the White River Storage Feasibility Study; however, at the time the purpose and need evaluation was being developed, these needs were not yet refined or quantified.

The Pre-Permitting Phase is planned following this Phase 2A Study, which includes refining the purpose and need for the reservoir. This effort will include further investigation into these potential additional water storage needs in the basin.

3.6.1 Potential Hydroelectric Water Needs

Hydropower has been a need that was identified early in the planning of the White River Storage Project, especially since Kenney Reservoir already has a functional, profitable hydroelectric plant that has been in operation for about 25 years. The hydroelectric plant at Kenney Reservoir was installed after the construction of Taylor Draw Dam (Kenney Reservoir). If it is considered to be viable, a hydroelectric plant could be considered after the construction of the dam and reservoir is complete.

3.6.2 Potential Compact Insurance Water Needs

Considering the below-average snowpack in the Colorado River Basin over the last several years and the recent population growth that corresponds to increasing water needs in Colorado, stakeholders are investigating the implications that a 1922 Colorado River Compact call could have on the water users within Colorado. A reservoir in the White River Basin could serve as "insurance water" or "drought mitigation" water for northwestern Colorado. If a compact call is exercised, the water from the reservoir could be used to meet the compact obligations and reduce curtailment of other water diversions in the Colorado River basin. Although a much larger reservoir could be constructed at either the Wolf Creek or White River Dam site(s) to provide additional storage for compact insurance, this type of storage has not been included in the initial storage considerations. Others with much larger funding sources, such as the federal government, could be a potential partner in this project to pursue a large Colorado Compact Storage reservoir at either dam site. The project has been identified to potentially be "sized up" to provide water storage for compact needs by other west slope water users, including the Colorado River Water Conservation District (Webb, 2018).

3.6.3 Potential Agricultural Water Needs

The need for additional water to support agriculture has been discussed with several stakeholders within the White River basin. As a result, Wheeler performed research to quantify the area of currently irrigated lands and the land areas that could potentially be suitable farmland, if irrigated, in the White River Basin. The Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) provides information on geology and soil assessments in a portion of the White River basin, which includes farmland classification ratings for various soil types. The portion of the White River Basin where the NRCS soil data is available was researched to quantify the land areas that are considered "Prime Farmland…" or "Farmland of Statewide Importance". The currently irrigated lands were also quantified using data available from the Colorado Decision Support Systems (CDSS, 2015).

Figure No. 3-2 and Table No. 3-6 summarizes the areas of lands that are currently irrigated in the White River Basin and the farmland classification information associated with the areas in the White River Basin where soil information is available.

As shown in Table No. 3-6, of the soils data available by NRCS, about 8.3-percent of the White River Basin is designed by the NRCS as "Prime Farmland" or "Farmland of Statewide Importance" and only 1.2-percent of the White River Basin is currently irrigated, demonstrating the potential for additional water use to irrigate lands for agricultural purposes and development.

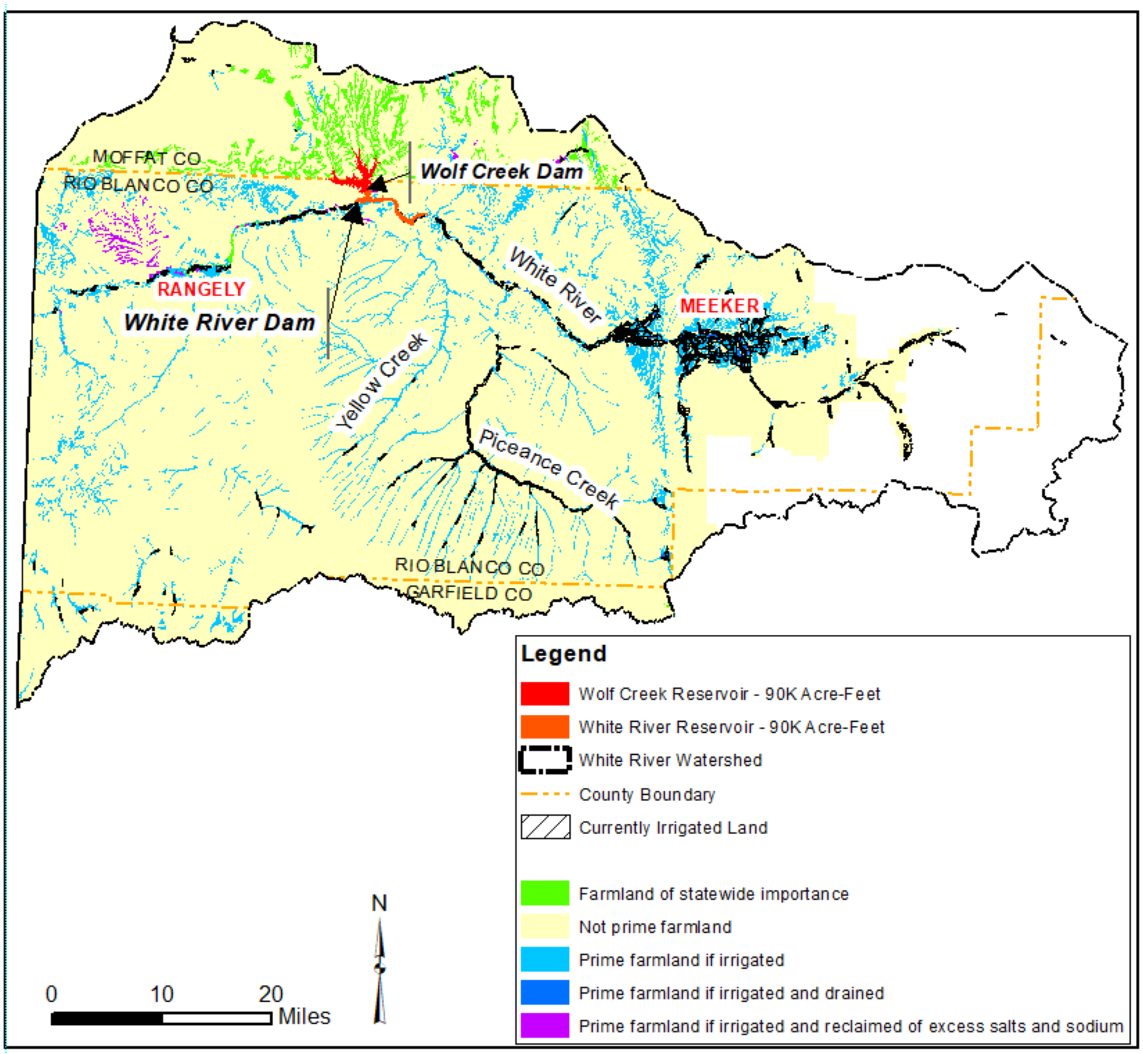

Figure 3-2. White River Basin Farmland Classification Map

Table 3-6 – White River Basin Irrigated Lands and Farmland Classification Summary

White River Drainage Basin Area within Colorado (square miles)	3747	
Currently Irrigated Land Area (square miles) [1]	46	
Currently Irrigated Basin Area (%) [1]	1.2%	
Farmland Classification	**Area (square miles)**	**Percentage (%)**
Farmland of statewide importance [2]	59	1.6
Prime farmland if irrigated [2]	234	6.3
Prime farmland if irrigated and drained [2]	5	0.1
Prime farmland if irrigated and reclaimed of excess salts and sodium [2]	12	0.3
Not prime farmland [2]	2878	76.8
No soil data available [2]	558	14.9
Total of Farmland of Statewide Importance, Prime Farmland if Irrigated, etc. [2]	**310**	**8.3%**

[1] Information from Colorado Decision Support Systems.

[2] Information from NRCS.

4.0 ENGINEERING FEASIBILITY DESIGNS

Wheeler developed feasibility-level designs and opinions of probable project costs for three reservoir sizes at both the Wolf Creek Dam site and White River Dam site, including a 20,000 acre-foot Working Pool, a 90,000 acre-foot Working Pool, and a maximum storage reservoir. Figure No. 4-1 is a site map of the Wolf Creek Reservoir and White River Reservoir for the 90,000 acre-foot working pool to show the extents and locations of the sites relative to each other.

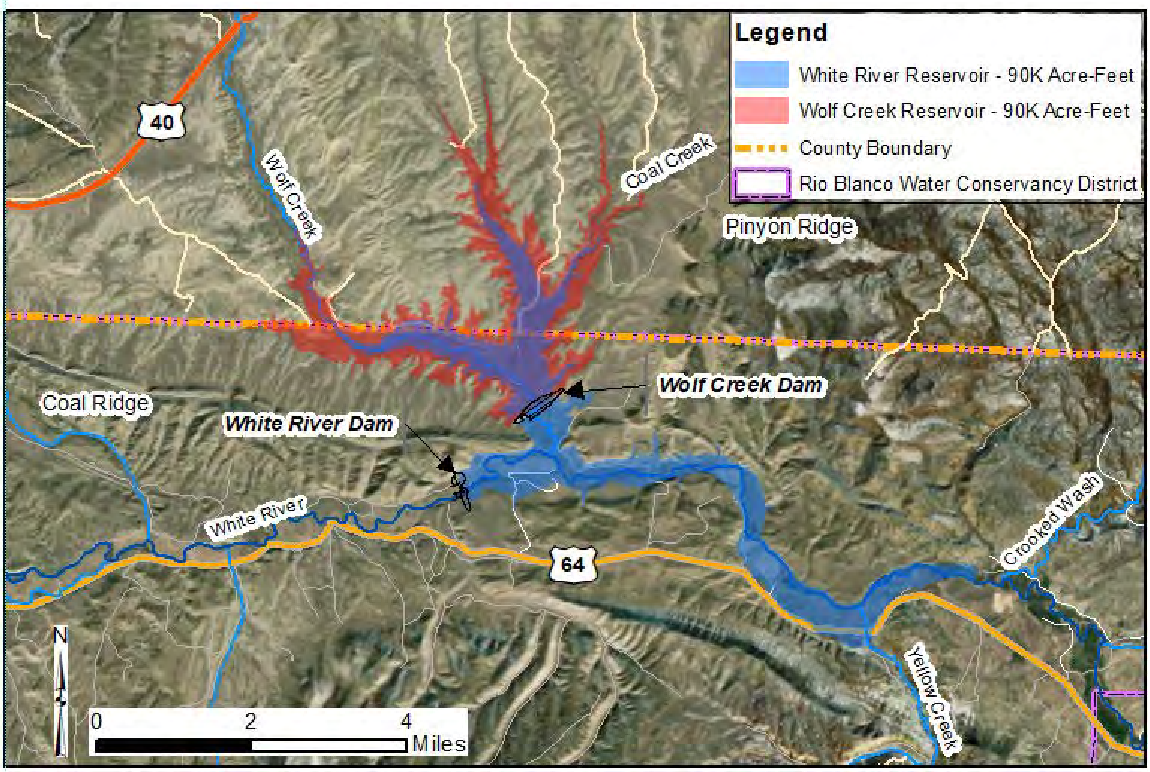

Figure 4-1. Wolf Creek Reservoir and White River Reservoir Aerial Site Map

Feasibility design drawings for the primary dam sites are provided in Appendices A.1 – A.3. Key preliminary dam design criteria are summarized as follows:

4.1 <u>General Dam Feasibility Design Criteria</u>

The dam configurations were generally designed to be consistent with the State of Colorado dam safety regulations (Colorado DWR, 2007) using the criteria related to a high-hazard potential dam. The dams and spillways were designed to route the Probable Maximum Flood (PMF) through the reservoir with at least one-foot of residual freeboard. Each of the dam designs included foundation cleaning, dental concrete, and foundation grouting based on limited information available from the sites. A geologic reconnaissance was conducted in the Initial Phase, but no recent subsurface investigations were conducted at either dam site. Key feasibility design assumptions and characteristics for the Wolf Creek Dam(s) and White River Dam(s) are summarized in Table No. 4-1.

The Wolf Creek Dam included various options for facilities to fill the reservoir, including a gravity-operated pipeline, a gravity-operated canal, and a pump station which was refined from the Initial Phase feasibility design. These fill facilities are further described in Sections 4.2.1 – 4.2.2.

Table 4-1 – General Dam Design Criteria & Descriptions

	Wolf Creek Dam(s)	White River Dam(s)
Hazard Classification	High Hazard-Potential	
Embankment Type for Working Pool Reservoirs	Zoned embankment dam.	Zoned embankment dam with a Roller Compacted Concrete (RCC) spillway section.
Embankment Type for Maximum Reservoirs	Zoned embankment dam.	
Spillway Crest for the Working Pool Reservoirs	Set at elevation of total storage for the Working Pool, recreation pool, sediment pool, and insurance pool.	Set at elevation of total storage for the Working Pool, recreation pool, and sediment pool.
Spillway Crest for the Maximum Reservoirs	Set to elevation based on maximum topographic capacity minus freeboard required to route the PMF.	
Spillway Description	Earth-cut channel with concrete control sill located in the left abutment.	--Working Pool Dams - RCC spillway in the center of the dam. --Maximum Dam - Earth-cut channel with concrete control sill located in the left abutment.

4.2 Wolf Creek Dam Feasibility Design

The Wolf Creek Dam site is located approximately 20 miles northeast of Rangely as shown on Figure No. 1-1. The dam axis for the 20,000 acre-foot Working Pool, 90,000 acre-foot Working Pool, and maximum reservoir pool was selected to be in approximately the same location as shown on Figure No. 4-3. The original feasibility designs for the 20,000 and 90,000 acre-foot Working Pool reservoirs were developed in the Initial Phase. In the Phase 2A Study, these feasibility designs were modified to include additional storage for the recreation pool, sediment pool, and insurance pool. The updated feasibility designs included a multi-level outlet works gate tower to enhance water quality and to control the temperature of reservoir releases. Also, a design option for a gravity fill canal or pipeline was included to offset the annual pumping costs described in Sections 4.2.1 – 4.2.2. Figure No. 4-2 shows the general reservoir extents for the various sizes of the Wolf Creek Dam(s).

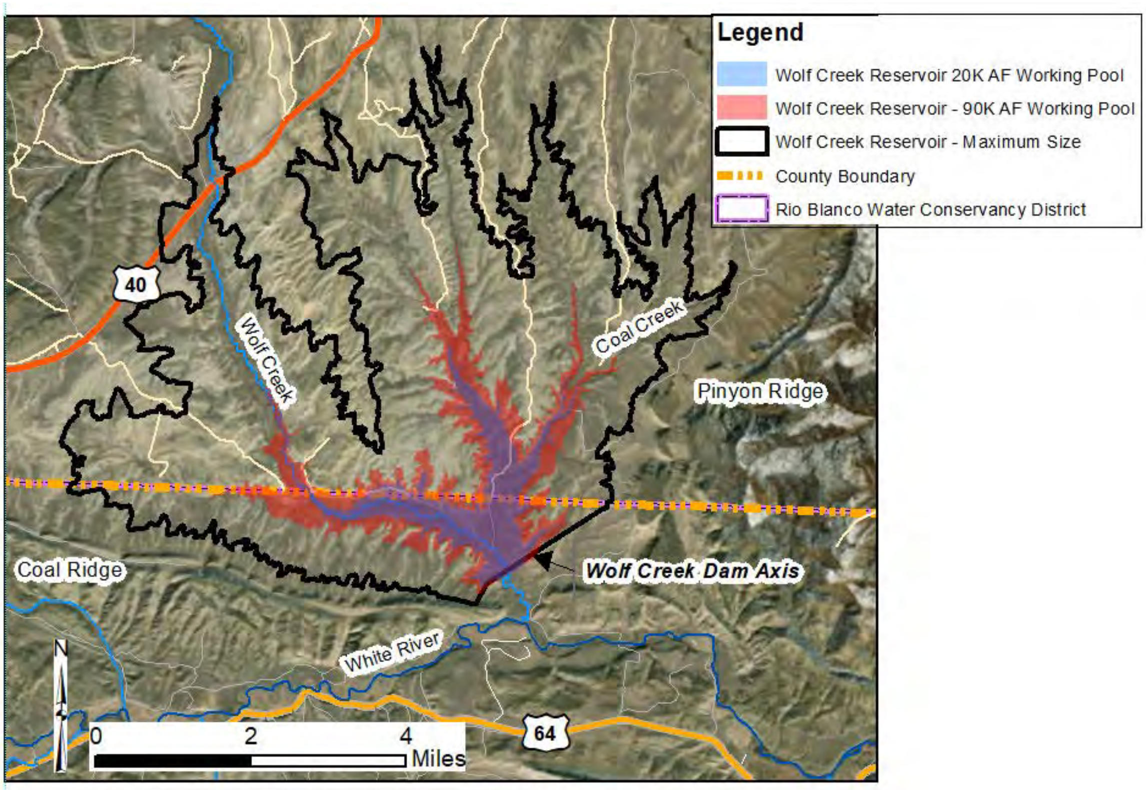

Figure 4-2. Wolf Creek Reservoir Aerial Site Map

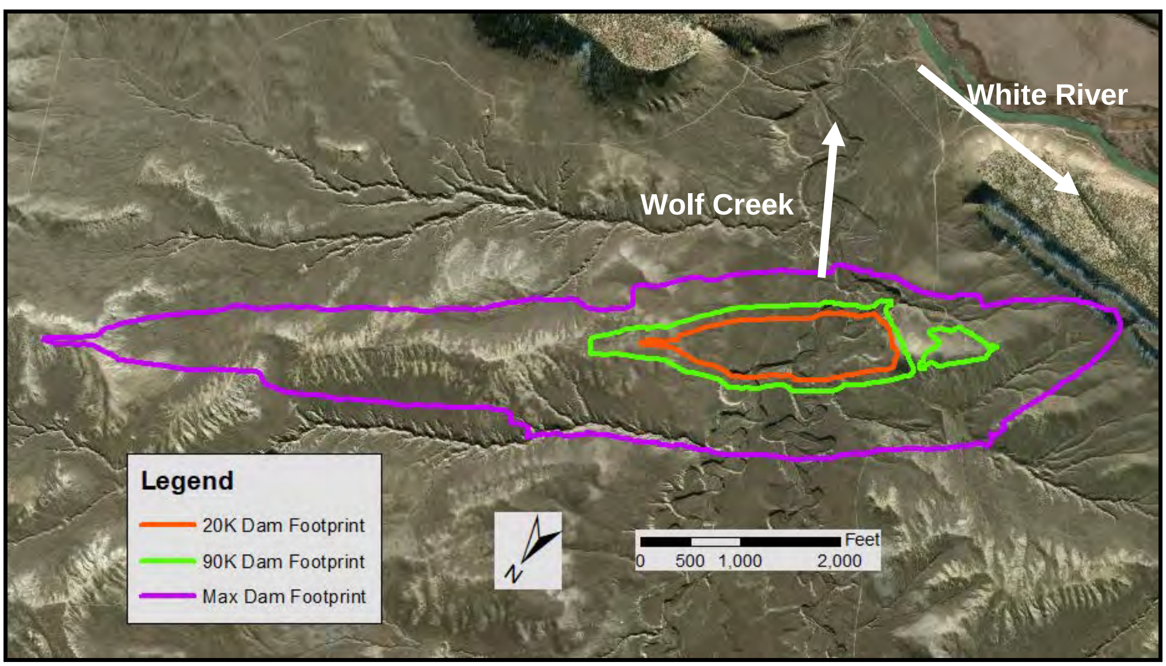

Figure 4-3. Wolf Creek Dam Footprints

The feasibility design for the Wolf Creek Dam for each size includes a zoned earth, embankment dam with a low permeability clay core, a 5-foot-wide downstream chimney drain, and 10-foot-thick blanket drain for seepage control. The embankment was estimated to have an upstream slope of 3H:1V (horizontal: vertical) and a downstream slope of 3.5H:1V, with a 25-foot-wide dam crest. These general dam dimensions were conservatively based on information provided by the U.S. Bureau of Reclamation (USBR, 1988). For the maximum-sized dam, an embankment bench was included in the upstream and downstream embankment to enhance stability due to the larger dam heights. Riprap was assumed to be placed on the upstream slope of the embankment to provide protection against wave action.

The feasibility design for the Wolf Creek Dam spillway for each size includes a 400-foot-wide earth-cut spillway located in the left abutment of the dam. The spillway crest was set at the elevation required to store the Working Pool, recreation pool, insurance pool, and sediment pool (see elevations in Table No. 4-2). The spillway feasibility design includes a concrete control section with concrete and riprap drop structures. The spillway feasibility design also includes earth training berms constructed on either side of the spillway channel.

The outlet works consists of a gate tower located in the reservoir near the toe of the upstream slope with a bridge to provide access from the dam crest. The gate tower was designed to include multiple gates to allow water to be released from various depths in the reservoir. The multi-level intake will help control the temperature and quality of the water released from the reservoir, which was identified to be important to key stakeholders in the Initial Phase of this project for fish habitat. A concrete encased, 8-foot-diameter steel outlet conduit extends from the gate tower to the outlet works stilling basin. A bifurcation of the outlet conduit is shown on the drawings that maybe evaluated and included in the final design to allow for the installation of a powerhouse for generating power with the outlet works discharges. The outlet works was designed to be of sufficient size to meet the State of Colorado dam safety drawdown requirements of the top 5 feet in 5 days, and is also large enough to make releases for downstream water right requirements.

Table 4-2 – Wolf Creek Dam–Dam Characteristics & Reservoir Routing Summary

	20,000 Working Pool	90,000 Working Pool	Maximum Storage
Total Maximum Normal Storage, (acre-feet)	41,000	130,000	1,490,000
Total Maximum Normal Surface Area, (acres)	1,335	3,246	18,400
Total Minimum Normal Recreation Surface Area, (acres)	700	700	700
Maximum Normal Water Surface Elevation at Spillway Crest	5560.0	5599.2	5735.0
Dam Crest Elevation	5573.0	5610.0	5740.0
Normal Freeboard, (feet)	13.0	10.8	5.0
Assumed Foundation Elevation	5470.0	5470.0	5470.0
Structural Dam Height, (feet)	103	140	270
Dam Length (excluding spillway), (feet)	2,400	3,900	10,950
Dam Volume, (cubic yards) [1]	1,983,000	4,115,600	40,684,100
<u>Spillway</u>			
Drainage Area, (square miles)	202	202	202
PMF Volume, (acre-feet)	51,100	51,100	51,100
Peak PMF Inflow, (cfs)	68,400	68,400	68,400
Peak PMF Outflow, (cfs)	43,000	24,800	4,500
Spillway Crest Elevation, (feet)	5560.0	5599.2	5735.0
Spillway Width, (feet)	400	400	400
Maximum Water Surface Elevation, (feet)	5571.4	5607.1	5737.5
Maximum Storage, (acre-feet)	59,700	159,300	1,536,200
Residual Freeboard, (feet)	1.6	2.9	2.5
<u>Outlet Works</u>			
Outlet Works Inlet Elevation, feet	5475.0	5475.0	5475.0
Outlet Works Length, feet	700	900	2,000
Number of Outlet Conduits	1	1	4
Outlet Works Capacity at Maximum Normal Storage (cfs)	2,020	2,460	11,120

[1] Includes Zone 1 material, Zone 3 material, Zone 2 material, riprap, and basecourse.

This site is advantageous in that if a smaller dam is constructed and additional storage is needed in the future, the height of the dam could be increased to gain more reservoir capacity.

The feasibility drawings for the Wolf Creek Dam at the 20,000 acre-feet Working Pool, 90,000 acre-feet Working Pool, and maximum storage reservoir are included in Appendix A.1.

4.2.1 Pump Station Design

The pump station fill capacities were sized based on the flow rate that optimized water storage in the reservoir during most periods, assuming target streamflows in the White River of 200 cfs and 300 cfs to estimate periods of reservoir inflow and releases (Wheeler, 2015). As part of the Programmatic Biological Opinion (PBO), the target streamflows will likely vary based on the water year (wet, dry, etc.) and will include a minimum baseflow for specific periods in each year as well as peak flows and shoulder peak flows for specific periods. Once the target streamflows are developed by the PBO and the pool needed for environmental purposes is refined, the pump station capacities will need to be re-evaluated.

The pump station for the Wolf Creek Dam maximum reservoir size design was assumed to have the same fill capacity as the 90,000 acre-foot Working Pool reservoir. The pump station capacity of the maximum size dam was not further refined because this dam and reservoir size was included for informational purposes only.

Based on the modeling performed for the Wolf Creek Dam for the Yampa/White/Green Basin Roundtable, the design flow for the 20,000 acre-foot Working Pool reservoir was revised to 100 cfs, which was also used in this study. Table No. 4-3 specifies the feasibility design pump station characteristics.

Table 4-3 – Pump Station Characteristics Summary for Wolf Creek Dam

	20,000 acre-foot Working Pool	90,000 acre-foot Working Pool	Maximum Storage Working Pool
Fill Line Capacity, (cfs)	100	400	400
Fill Line Length, (feet)	3,100	3,100	3,100
Fill Line Diameter, (feet)	4	8	8
Total Design Pumping Head, (feet)	200	190	290
Pump Capacity (HP)	3,200	12,200	18,700

4.2.2 Feasibility Design for Gravity Fill Facilities

Due to the estimated annual pumping costs developed in the Initial Phase, feasibility designs for gravity fill facilities for the Wolf Creek Dam were developed in Phase 2A. The gravity fill facilities were designed using fill rates that were consistent with the pump station designs; 100 cfs for the 20,000 acre-foot Working Pool reservoir and 400 cfs for the 90,000 acre-foot Working Pool reservoir and maximum reservoir. Feasibility designs were developed for a gravity canal system to convey the 100 cfs and 400 cfs fill rates. A pipeline system was also evaluated for the 100 cfs fill rate. The gravity fill designs include a diversion dam on the White River to divert water from the White River into the gravity fill facilities, about 36 miles of canal (or pipeline), 15 inverted siphons, and various appurtenant features including transitions structures, road crossings, and access roads for maintenance.   These features are described separately below.

4.2.2.1 Diversion Dam

The diversion dam is located approximately 28 White River miles upstream of the confluence of the White River with Wolf Creek. The slope of the White River is approximately 0.25-percent, which is a relatively flat slope. To divert water into the reservoir at an elevation above the maximum normal reservoir water surface elevation, the water needs to be diverted at a location that is far enough upstream to provide a reasonable positive slope for drainage of the gravity fill line from the White River into the reservoir. The slope of the gravity fill lines for the various storage options are described in Section 4.2.2.2. The general location of the diversion dam was selected because the topography appeared favorable with an existing rock outcrop on the left abutment and what appeared to be a natural diversion site on the right side of the White River based on aerial photography and a site visit.

The feasibility design for the diversion dam includes a 7-foot-high RCC overflow section on the White River to allow diversion into the gravity fill canal (or pipeline) for the maximum diversion flow of 400 cfs. The RCC overflow crest section is 15 feet long with a stepped downstream RCC face designed at a 1H:1V slope. Two 10-foot-wide by 7-foot-high sluice gates were included in the RCC overflow section that can be used to flush sediments in the White River through the diversion dam or to pass flows through the diversion dam when diversions are not occurring.

The right side of the diversion dam includes the diversion gate. The RCC dam at the diversion is 7 feet higher than the RCC overflow crest, which was designed to pass a flow in the White River of 10,000 cfs over the RCC overflow crest. This design overflow rate is in excess of the recorded streamflow based on the upstream and downstream USGS streamflow gages on the White River, without overtopping the right side of the diversion dam (USGS, 2018). A 10-foot-wide by 7-foot-high sluice gate was included in the diversion dam to release water into the gravity fill canal for the 400 cfs diversion flow. A 7-foot-wide by 7-foot-high sluice gate was included in the diversion dam to release water into the gravity fill canal (or pipeline) for the 100 cfs diversion flow.

The RCC cross section was conservatively designed based on Wheeler's experience and judgment. No specific stability or seepage analysis was performed for the feasibility design.

4.2.2.2 Gravity Fill Facilities Design

As described above, the diversion from the White River to the gravity fill line was established in a location that provided a reasonable positive slope for water conveyance from the White River into the reservoir. Precautions were taken in the placement of the gravity fill alignment to avoid impacts to Bureau of Land Management (BLM) areas of critical environmental concern (ACEC) and wilderness study areas. The slope of the gravity fill facilities varies depending on the height of maximum water surface in the Wolf Creek Reservoir. The canal was designed with additional freeboard to account for any additional tributary inflow into the canal or debris that may impact the flow capacity of the canal. Key characteristics of the gravity fill facilities are provided in Table No. 4-4. Drawings of the gravity fill facilities are included in Appendix A.3.

Wheeler used data from the web soil survey from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) to review the available soil data along the length of the gravity fill canal (NRCS, 2017). The design included lining of the canal section with a geomembrane to prevent erosion and water loss due to infiltration in sections that had a very low, low, or medium runoff classification. Canal sections with high or very high runoff classifications were assumed to be earth-lined. The canal section was lined with concrete for 50 feet upstream and downstream of the inverted siphon transition structures.

The design included inverted siphons in locations where it was economically favorable to construct a siphon as opposed to extending the canal around a drainage and in areas where it was topographically difficult to construct creek crossings. The use of siphons reduced the total canal length and also improved the overall canal slope. The general inverted siphon design was based on the U.S. Bureau of Reclamation standard design (USBR, 1983). The excavations and siphon installation included a minimum pipe cover of 4 feet.

The cut and fill associated with construction of the canal and the construction of a 12-foot-wide access road along the entire alignment for canal maintenance was included in the design of the gravity canal facilities.

The pipeline cost for the entire alignment was estimated for the 100 cfs capacity option. The total cost of the pipeline was more than twice that of the canal for the 100 cfs option (see Section 5.2 for more information).

The pipeline option for the 400 cfs fill rate was considered to be infeasible because of high cost.

Table 4-4 – Gravity Fill Canal and Pipeline Characteristics

	20,000 acre-foot Working Pool	90,000 acre-foot Working Pool	Maximum Storage Working Pool
Gravity Fill Line Slope	0.13%	0.11%	0.04%
Flow Capacity, cfs	100	400	400
Total Siphon Length, miles	2.2	2.2	2.2
Canal Length, miles (excluding siphons)	35.8	35.8	35.8
Siphon Diameter, feet	5.0	10.0	10.0
Canal Bottom Width, feet	5	10	10
Canal Side Slopes	3H:1V	3H:1V	3H:1V
Canal Depth, feet	5.0	7.5	7.5
Approx. Canal Freeboard, feet	2.5	3.5	2.5
Pipeline Diameter, feet	5.0	N/A	N/A

4.2.2.3 Other Considerations

In the design of the gravity fill facilities, several design options were considered including extending the canal around drainages as opposed to siphoning the flows underneath drainages, suspended bridges to support a pipeline at creek crossings, and various options for canal lining methods. In general, the most economical option was used in the design.

4.3 White River Dam Feasibility Design

The White River Dam is located approximately 20 miles northeast of Rangely on the White River just downstream of the confluence with Wolf Creek, as shown on Figure No. 1-1. The dam axis and configuration for the 20,000 acre-foot Working Pool and 90,000 acre-foot Working Pool are in approximately the same location and are generally the same design. The dam for the maximum reservoir is located slightly upstream to take advantage of a natural topographic location for the spillway in the left abutment. The reservoir areas for the various sizes of White River Dam(s) are shown on Figure No. 4-4 and the footprints of the dam(s) are shown on Figure No. 4-5.

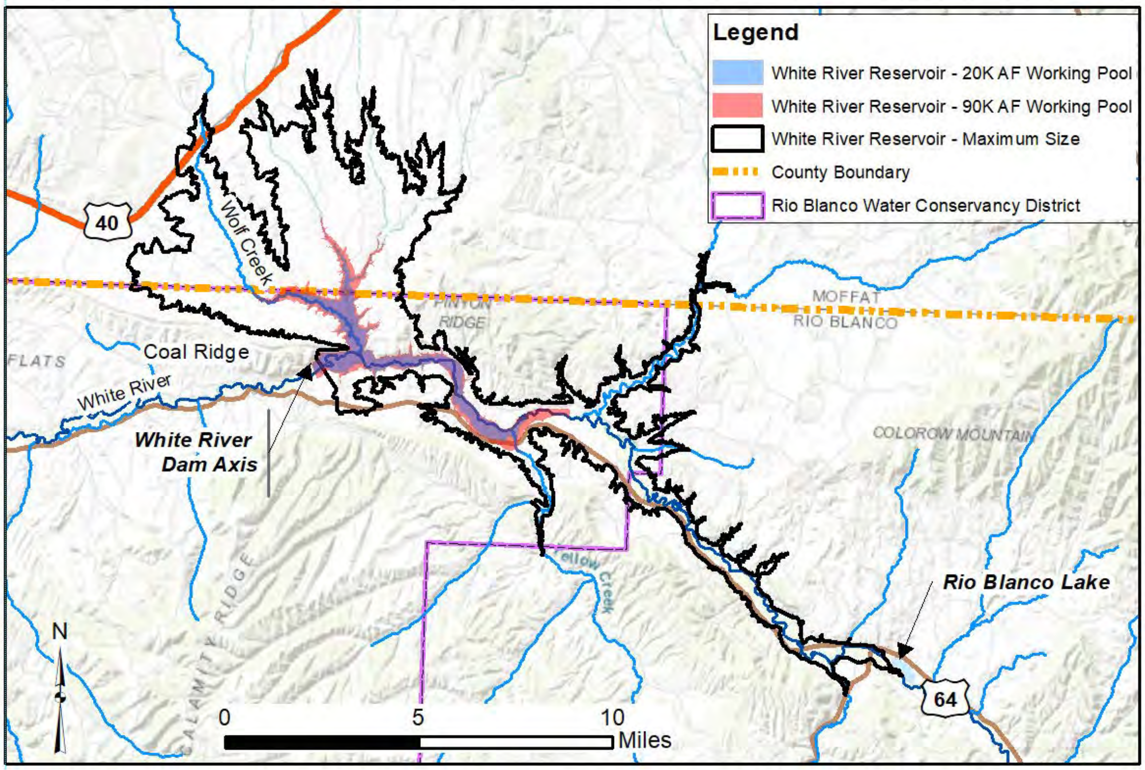

Figure 4-4. White River Reservoir Site Map

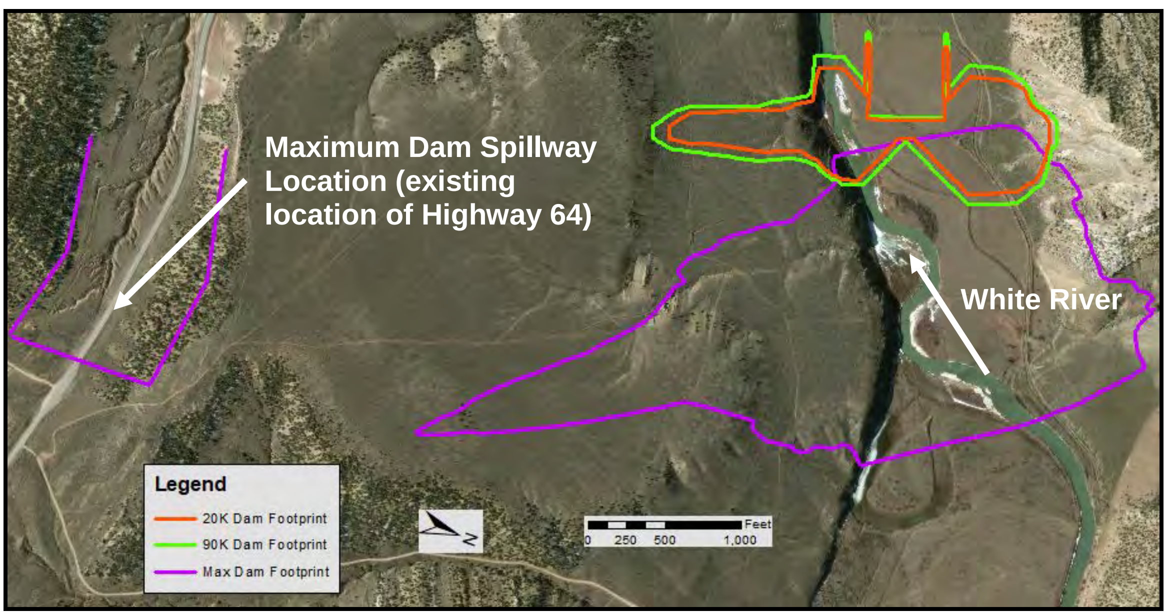

Figure 4-5. White River Dam Footprints

Detailed geologic and geotechnical investigations were performed for the White River Dam by Western Engineers, Inc. for the Colorado River District in 1983 (Western, 1983). The dam axis, which was the focus of the geotechnical field investigations in 1983, was located about 1,500 feet downstream of the White River Dam in the Phase 2A Study. The information from the 1983 investigations was valuable in understanding the subsurface conditions at the White River Dam for the three dam configurations investigated. Based on these investigations, it was determined that the White River channel contains an alluvium layer that is about 20 feet thick and the left abutment has a terrace deposit with a maximum thickness of about 10 feet. These alluvium and terrace deposits will need to be removed prior to placing embankment materials. The 1983 geotechnical investigation was useful for developing information for refinement of the dam materials, excavation quantities, and foundation treatments in the feasibility designs.

Because the White River Dam is located on the mainstem of the White River, significant flows would need to be diverted around the dam site during construction. The peak discharge on the White River is often in excess of 5,000 cfs during several days in the summer according to the gaging stations located on the White River (USGS, 2018). The feasibility design included a bypass tunnel around the dam site that would be used to protect the dam construction site during a multi-year construction project. Wheeler worked with Lithos Engineering to assess the construction feasibility and the opinion of probable construction costs associated with the construction of a diversion tunnel through the left abutment of the dam (Lithos, 2018). For these feasibility designs, the tunnel was evaluated as a 20-foot inside diameter tunnel with a 1-foot-thick reinforced concrete lining, to allow pressurization through the tunnel during peak flows on the White River. Temporary coffer dams would be constructed to isolate the entry and exit portals during dam construction. Following construction of the dam, this tunnel could be repurposed for hydropower generation, with a powerhouse located at the downstream end of the tunnel. However, hydropower was not considered in this phase of the study.

<u>20,000 and 90,000 acre-foot Working Pool Feasibility Designs - White River Dam</u>

The feasibility design for the White River Dam 20,000 acre-foot and 90,000 acre-foot Working Pool included a zoned earth embankment dam with a 500-foot-wide roller compacted concrete (RCC) spillway located in the middle of the dam. Figure No. 4-6 shows a three-dimensional (3D) rendering of the White River Dam for the 90,000 acre-foot Working Pool. The zoned earthfill embankment is consistent with the Wolf Creek Dam designs including a low permeable core, a 5-foot-wide downstream chimney drain, and 10-foot-thick blanket drain for seepage control. The embankment was estimated to have an upstream slope of 3H:1V (horizontal: vertical) and a downstream slope of 3.5H:1V, with a 25-foot-wide dam crest. Riprap slope protection was assumed to be placed on the upstream slope of the embankment.

The feasibility design for the White River Dam spillway included a 500-foot-wide RCC section with the RCC spillway crest set at the elevation required to store the Working Pool, recreation pool and sediment pool. These elevations are provided in Table No. 4-5. The spillway is designed with a concrete ogee control section that discharges to the stepped downstream RCC face that conveys water to the downstream stilling basin before flowing back to the White River. The RCC cross section and spillway stilling basin were designed conservatively based on Wheeler's experience with dam construction and judgment. No stability analysis was performed to size the dam or spillway during the feasibility design. The spillway discharge channel includes RCC training berms on either side to protect the embankment from spillway flows.

The outlet works consists of a gate tower located just left and upstream of the RCC spillway section. The gate tower was designed to include multiple gates to allow water to be released from various depths in the reservoir for temperature and water quality control. The outlet works discharge conduit is an 8-foot-diameter steel pipe encased in concrete through the RCC spillway section that discharges into a stilling well, then into the stilling basin downstream of the spillway. The spillway also includes an access bridge that spans the length of the spillway, providing access to the right side of the embankment and abutment.

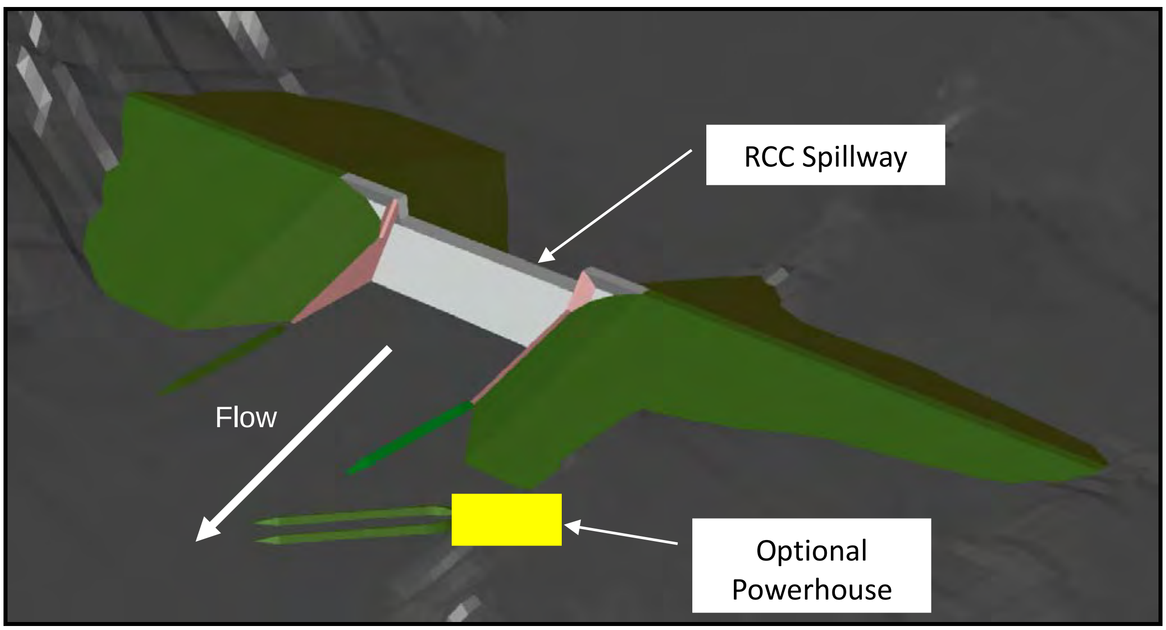

Figure 4-6. White River Dam 90,000 acre-foot Working Pool 3D Rendering

Maximum Reservoir Feasibility Design - White River Dam

The feasibility design for the White River Dam for the maximum reservoir storage included a zoned earth embankment dam with a low permeable core, downstream chimney drain, and blanket drain. The zoned embankment dam characteristics are the same as the Wolf Creek Dam and White River Dam Working Pool configurations previously described; however, the design includes an embankment bench in the upstream and downstream embankment to enhance stability. Due to the large extent of the reservoir area associated with the maximum storage reservoir, inundation of portions of Highway 64 and Highway 40 are anticipated. The feasibility design cost opinion includes the relocation and reconstruction of these highways.

The spillway for the White River maximum storage dam was evaluated as a 950-foot-wide, earth-cut spillway located approximately 1,700 feet left of the left abutment of the dam in a topographically flat area. The spillway crest was set at the maximum elevation topographically possible, while allowing storage and routing capacity for the PMF, see Table No. 4-5. The feasibility design includes an RCC control section with concrete and riprap drop structures installed for about 7,000 feet from the spillway control section to Spring Creek then to the White River. The spillway location is at the current location of Highway 64.

The outlet works consists of a gate tower located in the reservoir at the toe of the upstream slope with a bridge providing access from the dam crest. The gate tower was placed in the reservoir to include multiple gates installed at various elevations. Four concrete encased, 8-foot-diameter steel outlet pipes extend from the gate tower to the outlet works stilling basin. A bifurcation of the outlet conduit is shown on the drawings to allow for the installation of a powerhouse for generating power with the outlet works discharges. The outlet works was designed to be of sufficient size to meet the State of Colorado drawdown requirements of the top 5 feet within 5 days, and large enough to make releases for downstream water rights.

The feasibility drawings for White River Dam at 20,000 acre-feet Working Pool, 90,000 acre-feet Working Pool, and maximum storage reservoir are included in Appendix A.3.

Table 4-5–White River Dam – Dam Characteristics & Reservoir Routing Summary

	20,000 Working Pool	90,000 Working Pool	Maximum Storage
Total Maximum Normal Storage, (acre-feet)	68,000	138,000	2,070,000
Total Maximum Normal Surface Area, (acres)	2,180	3,490	25,100
Total Minimum Normal Recreation Surface Area, (acres)	970	970	970
Maximum Normal Water Surface Elevation at Spillway Crest	5530.0	5555.0	5710.0
Dam Crest Elevation	5570.0	5592.0	5725.0
Normal Freeboard, (feet)	40.0	37.0	15.0
Assumed Foundation Elevation	5415	5415	5415
Structural Dam Height, (feet)	155	177	310
Dam Length (excluding spillway), feet	2,100	2,300	4,600
Embankment Dam Volume, (cubic yards) [1]	2,081,870	3,250,000	21,868,700
RCC Volume, (cubic yards)	320,000	455,000	15,000
Spillway			
Drainage Area, (square miles)	2,498	2,498	2,498
PMF Volume, (acre-feet)	535,800	535, 800	535, 800
Peak PMF Inflow, (cfs)	439,200	439, 200	439, 200
Peak PMF Outflow, (cfs)	345,100	298,000	122,100
Spillway Width, (feet)	500	500	950
Maximum Water Surface Elevation, (feet)	5567.5	5589.1	5722.8
Maximum Storage, (acre-feet)	187,300	302,000	2,409,000
Residual Freeboard, (feet)	2.5	2.9	2.2
Outlet Works			
Outlet Works Inlet Elevation, (feet)	5450	5450	5450
Outlet Works Length, (feet)	530	620	2,060
Number of Outlet Conduits	1	1	5
Outlet Works Capacity at Maximum Normal Storage, (cfs)	2,080	2,410	13,620

[1] Includes Zone 1 material, Zone 3 material, Zone 2 material, riprap, and basecourse.

5.0 OPINION OF PROBABLE COSTS

5.1 Capital Budgeting Approach

Wheeler developed feasibility-level opinions of probable project cost for three reservoir sizes at both the Wolf Creek Dam site and the White River Dam site. Wheeler's opinions of probable cost are considered to be equivalent to a Class 4, feasibility level budget opinion (USSD, 2012). Class 4 cost opinions are generally based on a very limited project definition. Wheeler's cost opinion was developed to be reasonably conservative and is expected to be within 30 percent on the low end of the budget and within 50 percent on the high end of the budget in 2018 dollars. As project planning progresses, significant project requirements and other refinements can develop, which could significantly change the project and the associated project budgets.

Wheeler's approach for developing opinions of probable project costs was to individually develop costs for direct and indirect construction items. Direct construction costs include items directly related to the dam construction, such as embankment and spillway construction. Direct construction items were developed in a bid tab format in 2018 construction dollars. The indirect costs include a budget for non-construction items that are required to develop the project, such as easement/land purchase costs, engineering, and permitting. A summary of the opinion of probable direct construction and indirect project development costs for each dam site is provided in Table No. 5-1, with the total cost summary illustrated on Figure No. 5-1. The detailed bid tabs for Wheeler's feasibility-level opinion of probable project costs for each dam configuration are included in Appendix B. Details of the direct and indirect construction costs are summarized in Sections 5.2 and 5.3.

It is important to note that Wheeler's opinions of probable project costs are based on year 2018 dollars. These cost opinions will increase in subsequent years and are subject to further refinement and revision based on further field investigations, final design modifications, definition of permitting requirements, and inflation.

Table 5-1 - Summary of Opinion of Probable Project Costs

Reservoir Size	Dam Configuration	Direct Construction Costs	Indirect Project Costs	Total Project Costs
20K Acre-Foot Working Pool	Wolf Creek Dam-Gravity Canal Fill	$126M	$69M	$195M
	Wolf Creek Dam-Gravity Pipeline Fill	$227M	$102M	$329M
	Wolf Creek Dam-Pump Station Fill	$74M	$45M	$119M
	White River Dam	$166M	$109M	$275M
90K Acre-Foot Working Pool	Wolf Creek Dam-Gravity Canal Fill	$211M	$107M	$318M
	Wolf Creek Dam-Pump Station Fill	$123M	$68M	$191M
	White River Dam	$224M	$136M	$360M
Maximum Storage Reservoir	Wolf Creek Dam-Gravity Canal Fill	$726M	$482M	$1,208M
	Wolf Creek Dam-Pump Station Fill	$648M	$431M	$1,079M
	White River Dam	$576M	$481M	$1,057M

$M denotes millions of dollars

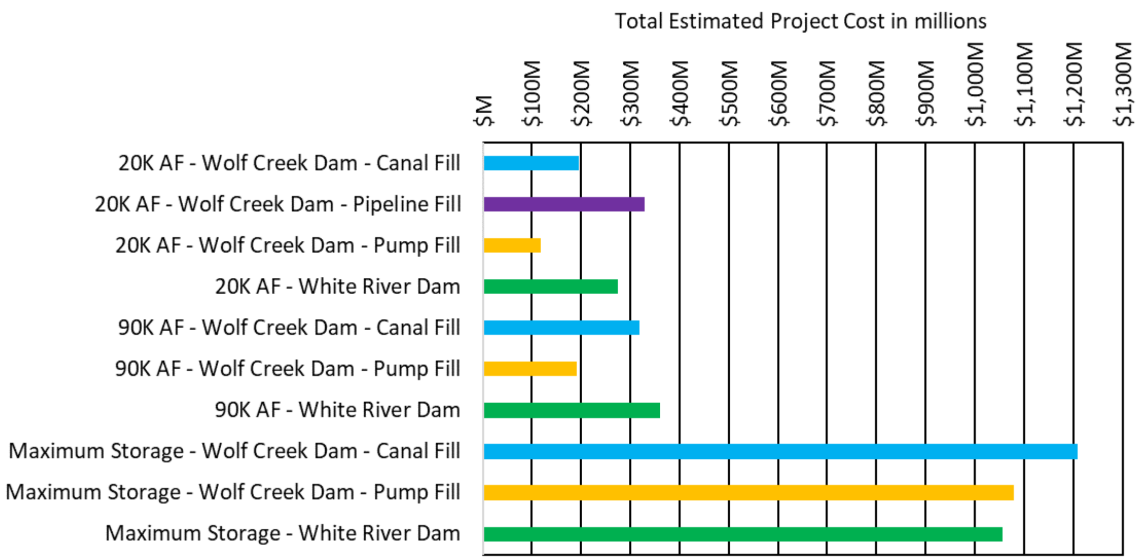

Figure 5-1 – Total Project Cost Summary

5.2 Direct Construction Costs

The breakdown of the direct construction opinions of probable costs are summarized in Figure Nos. 5-2, 5-3, and 5-4 for the 20K acre-foot Working Pool reservoirs, 90K acre-foot Working Pool reservoirs, and the maximum reservoir, respectively. These are the expected costs for construction of key elements of the dams. The costs were estimated based on the preliminary designs. The construction material quantities were based the embankment designs that utilized topography from 1/3rd arc-second Digital Elevation Models (DEM) (USGS, 2013). Unit costs associated with material, labor, and equipment were estimated referencing RSMeans for Heavy Construction Costs (RSMeans, 2018), information from local suppliers, and bid information from other dam construction projects that Wheeler staff has been involved in.

The cost opinion includes a line item for Unlisted Items, which is meant to account for work items that cannot be defined at this stage of project development that will be added to the design as the project develops. The Unlisted Items were estimated as 20-percent of the total of listed items. The contractor mobilization, bonds, and insurance were estimated at 10 percent of the listed items, which was considered appropriate for projects of this size.

It should be noted that the Wolf Creek Dam configurations include the same design options for the dam, and only vary in the design associated with the fill facilities. The initial construction cost of the fill facilities for the gravity fill options pipeline and canal are 2.5 to 10 times greater than the initial construction costs for the pump station (see Figure Nos. 5-2 through 5-4). These higher direct costs for the fill facilities propagate into the percentage-based estimates including the mobilization and unlisted item direct cost line items and the indirect construction items.

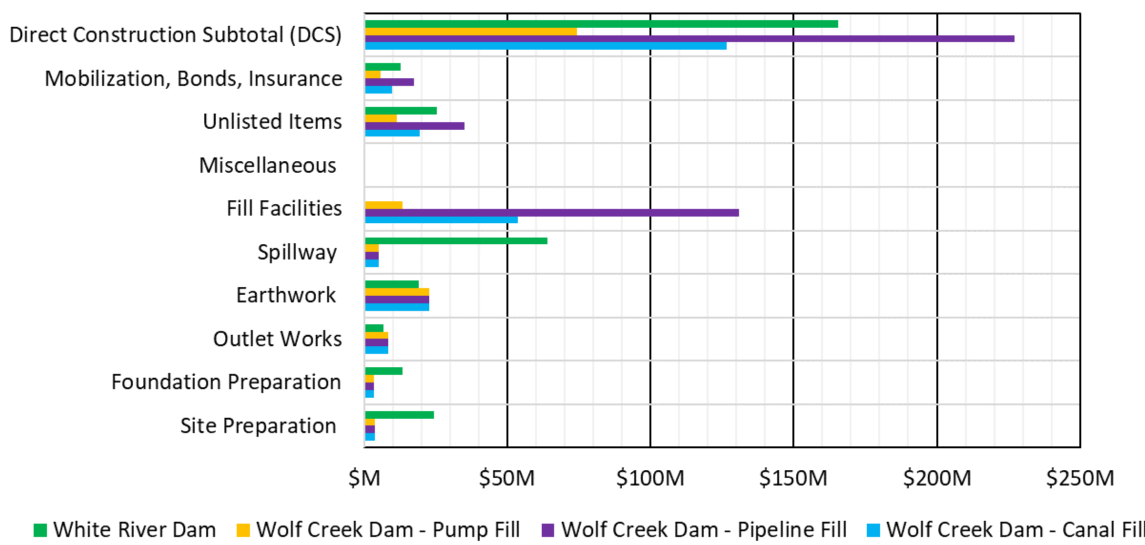

Figure 5-2 – Direct Construction Cost Summary – 20,000 acre-foot Working Pool

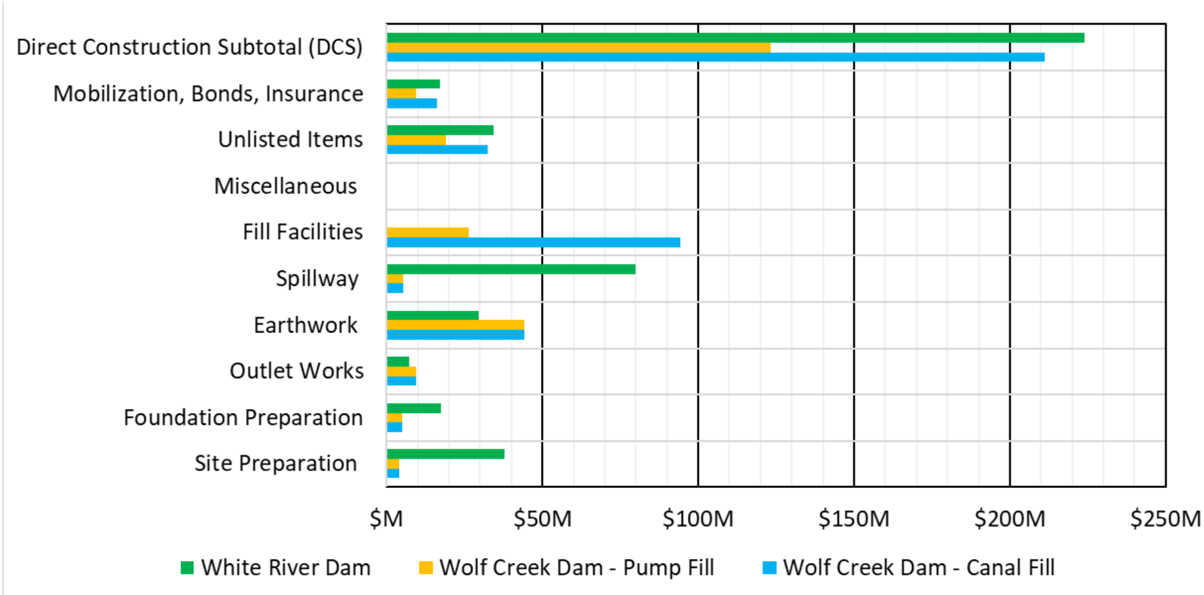

Figure 5-3 – Direct Construction Cost Summary – 90,000 acre-foot Working Pool

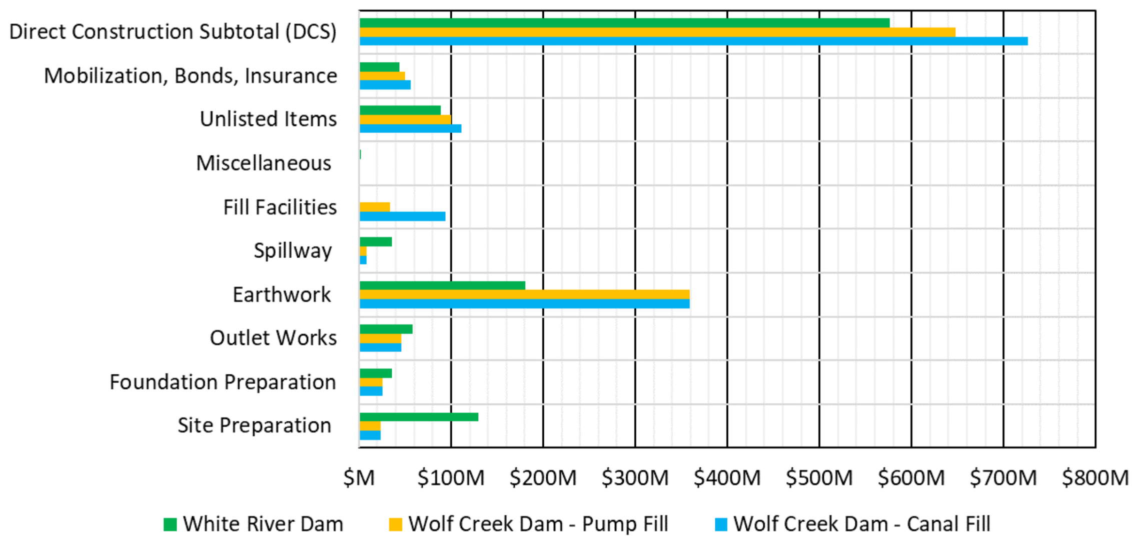

Figure 5-4 – Direct Construction Cost Summary – Maximum Reservoir

5.3 Indirect Costs

The opinions of probable costs include the non-construction program items that will be required to permit, design, and construct a dam and reservoir. A summary of the development of the indirect project cost elements is provided on the following pages. The breakdown of the indirect construction opinions of probable costs are summarized in Figure Nos. 5-5, 5-6, and 5-7 for the 20K acre-foot Working Pool reservoirs, 90K acre-foot Working Pool reservoirs, and the maximum reservoir, respectively.

1. ***Construction Change Order Contingency:***
   A change order contingency equivalent to 25 percent of the Base Construction Subtotal plus Mobilization is shown on the work sheets in Appendix B. This contingency is included to address changes to construction quantities or changes that normally occur during a large heavy civil construction project. A large part of this contingency is related to unanticipated changes in foundation conditions that cannot be completely identified until the foundation is excavated during construction. The change order contingency can be significantly reduced after geotechnical investigations are completed that would identify the depth and condition of bedrock in the foundation at any particular dam site.

2. ***Final Design Engineering:***
   The final design engineering was assumed to be ten percent of the direct construction opinion of probable cost total. This would include final design mapping and field investigations, detailed construction drawings, construction specifications, a reservoir application and filing fee, a detailed design report that documents the hydraulic design of the spillway and outlet works, structural design of the spillway and outlet works, stability analysis, design of seepage and settlement control features, and design of other project features such as access roads and dam instrumentation systems. Detailed design drawings, specifications, and analysis reports will require approval by the Colorado Office of the State Engineer before initiating construction.

3. ***Permitting and Mitigation:***
   The permitting budget was assumed to be a total of $10 million in each of the feasibility level options. The permitting and mitigation budget assumed a cost of $2 million each year for five years. As part of the Phase 2A work, the RBWCD has begun the meetings and conversations with permitting agencies and stakeholders to begin a Lean permitting approach in an effort to make the NEPA process more efficient.

   Environmental permitting and mitigation costs are typically in the range of five to ten percent of the line item costs, which can exceed $35 million dollars for the 90K acre-foot Working Pool alternatives. It should be noted that if the Lean permitting process is not successful, the permitting costs included within the opinions of probable costs can increase significantly.

4. ***Public Outreach:***
   The public outreach budget was assumed to be 0.5 percent of the direct construction cost total.

5. ***Easement/Land Purchases:***
   Before constructing the project, the RBWCD would need to either own the property or have easements for the property that would be impacted by the dam,

reservoir, and reservoir fill facilities. At the feasibility level, Wheeler assumed that the lands that are impacted by the dam and reservoir construction and operation would be purchased. Legal fees associated with the negotiations and purchases of these lands were also included in the line item. The assumed value of the private land was dependent on the area in which the land was located, with lands near the White River being higher in value. Based on information from 2016 – 2018 land sales in the area, land acquisition was estimated to range from about $1,000 to $10,000 per acre, excluding legal fees.

The cost opinions assumed an easement acquisition of the lands impacted by the gravity fill facilities, including a 150-foot-wide area across the property assuming the cost per acre for the easement at about $1,000 per acre, excluding legal fees.

The costs assumed for land/easement purchase are considered preliminary and will be further refined as landowner negotiations and discussions continue for the selected reservoir site and size. It should be noted that the land/easement purchases are more than five times the cost for the White River Dam compared to the Wolf Creek Dam largely due to the significant amount of private irrigated land that is impacted near the White River by the White River Dam and reservoir.

6. ***Legal and Administrative Costs:***
   The legal and administrative costs were assumed to be two percent of the direct construction cost total. This would include legal fees, payments for RBWCD staff, and other administrative fees required to complete the Project.

7. ***Construction Administration and Engineering:***
   The construction administration engineering costs were assumed to be ten percent of the direct construction cost total. Based on experience with the Colorado Dam Safety Branch Rules, the following construction administration activities will be required and are included in this cost:

   a) Full-time resident engineering.
   b) Materials testing.
   c) Progress reports with photos and lab test results.
   d) Review and approval of contractor's monthly payment requests.
   e) Construction engineering and administration of change orders.
   f) Responses to contractor Requests for Information (RFI).
   g) Preparation of a Final Construction Report.
   h) Preparation of Record Drawings after construction is complete.

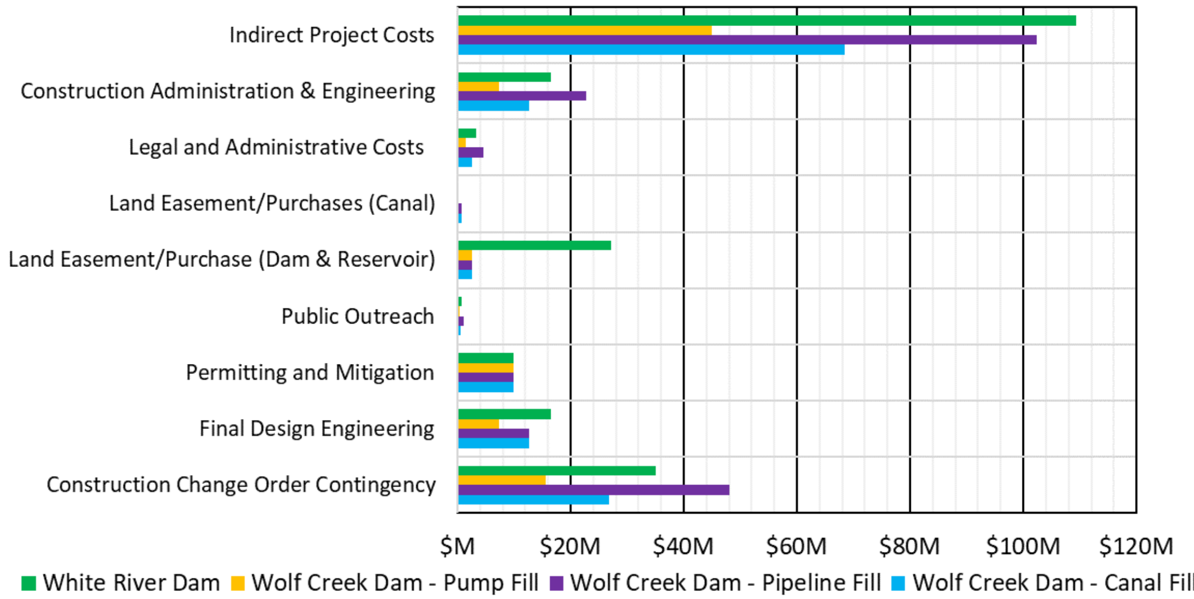

Figure 5-5 – Indirect Construction Cost Summary – 20,000 acre-foot Working Pool

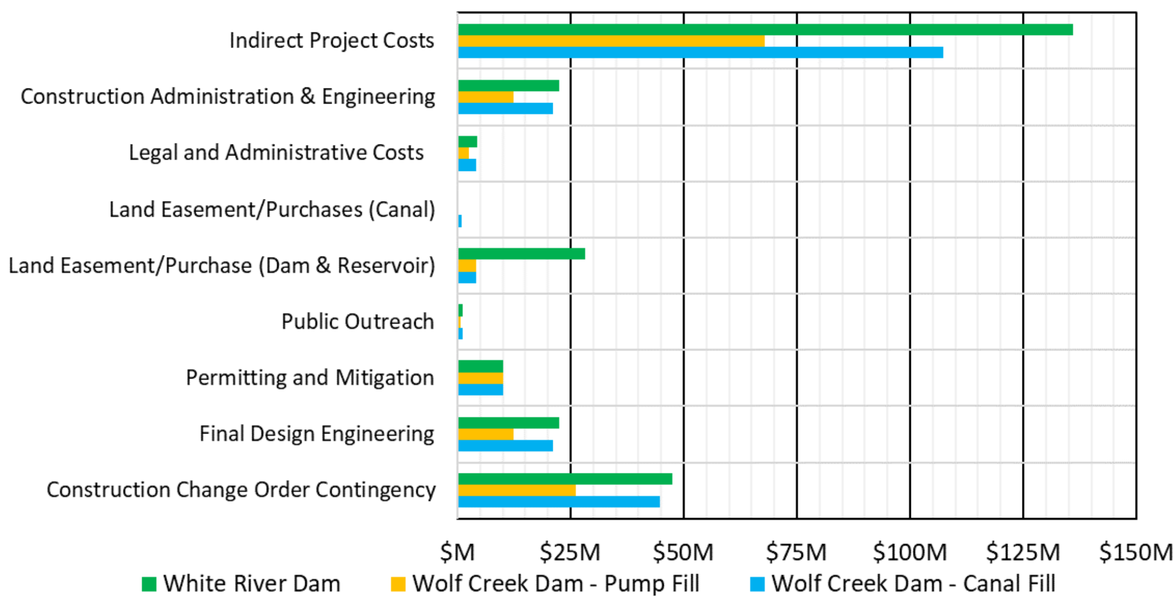

Figure 5-6 – Indirect Construction Cost Summary – 90,000 acre-foot Working Pool

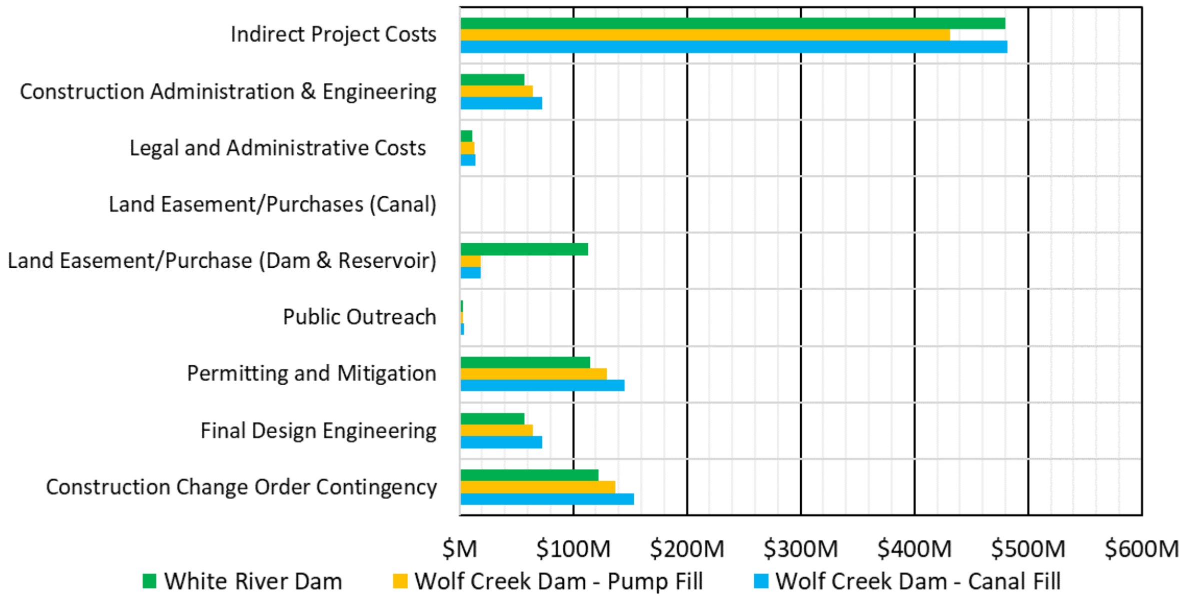

Figure 5-7 – Indirect Construction Cost Summary – Maximum Storage Reservoir

5.4 Operations & Maintenance Costs

Annual operation and maintenance (O&M) costs vary depending on the alternative. For both the White River Dam and Wolf Creek Dam it is anticipated that the RBWCD will need an additional employee and an additional vehicle to perform diligent monitoring and operation of the dam, which was assumed to be about $100,000 annually. Recreation management was assumed to be provided by others. Additional O&M is necessary for the Wolf Creek Dam site to maintain the gravity fill facilities and operate the pump facilities. A summary of the average annual O&M costs assumed for each facility is summarized in Table No. 5-2. The details of these costs are further described in Sections 5.4.1 and 5.4.2.

Table 5-2 - Summary of Average Annual Estimated O&M Costs

Reservoir Size	Dam Configuration	Average Annual Estimated O&M Costs
20K Acre-Foot Working Pool	Wolf Creek Dam - Gravity Canal Fill	$300,000
	Wolf Creek Dam - Gravity Pipeline Fill	$100,000
	Wolf Creek Dam - Pump Station Fill	$263,000
	White River Dam	$100,000
90K Acre-Foot Working Pool	Wolf Creek Dam - Gravity Canal Fill	$300,000
	Wolf Creek Dam - Pump Station Fill	$638,000
	White River Dam	$100,000
Maximum Storage Reservoir	Wolf Creek Dam - Gravity Canal Fill	$300,000
	Wolf Creek Dam - Pump Station Fill	$765,000
	White River Dam	$100,000

5.4.1 Gravity Fill Facilities Operation & Maintenance

Maintenance associated with an open-channel canal fill facility within Rio Blanco County will present some challenges with the winter temperatures and remote access to the canal site.

The following typical work is expected for maintenance of an open-channel canal:

- Removing excess aquatic vegetation, debris in the canal impeding water flow, or ice jams;
- Maintaining year-round access to the canal in its entirety to perform maintenance, as needed; and
- Maintaining and operating a telemetry-operated monitoring system that provides flow information along various portions of canal to identify and locate operational issues.

The pipeline gravity fill option would eliminate some of the maintenance effort; however, it is still expected that a telemetry-operated monitoring system will be needed for operations.

For the gravity fill canal facilities, the assumed O&M costs include two additional employees and equipment at $200,000 per year to maintain the canal system. This cost is in addition to the $100,000 per year already anticipated for the additional employee to maintain the dam. The gravity fill pipeline was not assumed to need additional employees beyond the single additional employee to maintain the dam because the pipeline is buried and not anticipated to need as much maintenance.

5.4.2 Pumping Operation Costs

The O&M cost estimation procedure used for the Wolf Creek Dam pump fill facilities was not substantially modified in Phase 2A from the Initial Phase of the White River Storage Feasibility Study (Wheeler, 2015). In the 2015 development of the O&M costs, Wheeler took into account the amount of water that was able to be pumped to the reservoir or released from the reservoir on a daily basis to meet a year-round minimum streamflow in the White River of 200 and 300 cfs for the 20K and 90K acre-foot Working Pool storage reservoirs, respectively. Additional information is available in Section 7.4 of Wheeler, 2015. The Programmatic Biological Opinion (PBO) work, which was developed concurrently with this study, would likely refine the target streamflows. As a result, any work to refine the pumping O&M costs would not be useful until the PBO work is complete and target streamflows are identified and finalized. However, the pumping costs are considered to be within the expected order of magnitude of what is expected after the PBO target streamflows are developed. A summary of the pumping operations costs is provided in Table No. 5-3.

Table 5-3 – Pump Station Annual Operation Cost Summary [1,2]

	20K Working Pool with 100 cfs Pump Station [3]	90K Working Pool with 400 cfs Pump Station	Maximum Reservoir with Releases for 90K Demands and 400 cfs Pump Station
Average	$163,000	$538,000	$665,000
Range	$84,000 - $368,000	$53,000 - $1,000,000	$53,000 - $1,547,000

[1] Costs based on electric costs of $0.04 per Kilowatt-hour (KWH) based on information provided by White River Electric Association assuming flexibility of the pump station to pump available water that is less than the maximum diversion flow rate.

[2] Costs include annual electric pumping costs only and do not include O&M described in Section 5.4.1.

[3] Refined in Phase 2A to include a maximum pump rate of 100 cfs (see Section 4.2.2).

Other alternatives were discussed as potential ways to reduce some of the operations costs associated with pumping that include the following:

- Using solar power or wind power to operate the pump station.
- Designing the pump station to be operated using natural gas as opposed to electric power.
- Including hydropower within the project to generate revenue to offset some of the costs associated with operating the pump station.

These pumping alternatives were not evaluated in this study, but could be analyzed in future project phases.

5.5 Cost Evaluation Summary

5.5.1 Capital Cost Per Acre-Foot

To evaluate the dam and reservoir costs for the White River Dam(s) and the Wolf Creek Dam(s), Wheeler reviewed the unit cost data by calculating the capital cost per acre-foot of water storage, which is a typical way to compare the reservoir storage project costs with other reservoir sites. The unit cost data was reviewed in two different ways; by calculating the cost per acre-foot using the Working Pool storage, which results in a larger cost per acre-foot, and calculating the cost per acre-foot using the total storage including the applicable recreation pool(s), sediment pool(s), and insurance pool(s). Table No. 5-4 provides information for the cost per acre-foot for the various dam configurations.

Table 5-4 – Capital Cost Per Acre-Foot Summary [1]

Dam Configuration		Total Project Cost ($)	Working Pool Storage Cost ($/acre-foot)	Total Reservoir Storage Cost ($/acre-foot)
20K acre-foot Working Pool	Wolf Creek Dam Gravity Canal Fill	$195M	$9,800/AF	$4,800/AF
	Wolf Creek Dam Gravity Pipeline Fill	$329M	$16,500/AF	$8,000/AF
	Wolf Creek Dam Pump Fill	$119M	$6,000/AF	$2,900/AF
	White River Dam	$275M	$13,700/AF	$4,000/AF
90K acre-foot Working Pool	Wolf Creek Dam Gravity Canal Fill	$318M	$3,500/AF	$2,400/AF
	Wolf Creek Dam Pump Fill	$191M	$2,100/AF	$1,500/AF
	White River Dam	$360M	$4,000/AF	$2,600/AF
Maximum Storage Reservoir	Wolf Creek Dam Gravity Canal Fill	$1,208M	-	$760/AF
	Wolf Creek Dam Pump Fill	$1,079M	-	$680/AF
	White River Dam	$1,057M	-	$510/AF

[1] Total Project Costs include the Direct Construction Costs and Indirect Construction Costs. O&M costs are not included in this table.

In general, the cost per acre-foot decreases as the storage in the reservoir increases and varies considerably based on the dam features and associated water rights. For comparison, the cost to purchase shares of Colorado-Big Thompson Project water in 2015 were about $37,000 per acre-foot (WestWater, 2016).

6.0 ALTERNATIVE EVALUATION

6.1 Initial Phase Alternative Screening Summary

The White River basin currently does not have adequate storage to meet the current water needs during drought conditions or to provide reliable water supply for additional future water needs within the basin. As a result, the RBWCD has been proactive in its efforts to develop a multi-use water storage reservoir to provide water reliability for its constituents as well as develop a project that has the ability to diversify the economy in northwestern Colorado and generate revenue for local businesses and tax revenues for local and state governmental entities.

In the Initial Phase, a wide range of storage alternatives were evaluated and screened to produce the primary alternatives. A summary of the new storage site alternatives explored in the Initial Phase are summarized in Table No. 6-1. Additional information is provided in the Phase 1 and 2 Report (Wheeler, 2015).

In addition to new storage sites, other alternatives were also considered, but eliminated from consideration based on the following reasons:

- Enlargement of Taylor Draw Dam
  Eliminated from consideration because of the current reservoir siltation issues and infrastructure impacts. Further explained in Section 4.2 (Wheeler, 2015).
- Dredging of Kenney Reservoir
  Eliminated from consideration due to the substantial costs of dredging and unidentified location for disposal of the reservoir sediments (Wheeler, 2015). The cost of the dredging effort at Strontia Springs near Denver, Colorado was reviewed and costs were about $75,000 per acre-foot for sediment removed from the reservoir with a nearby disposal area available. A disposal area has not been identified for the sediments from Kenney Reservoir and to regain the original Kenney Reservoir capacity of 13,800 acre-feet, costs are expected to be in excess of $700 million. Also, it would be anticipated to have the same sediment accumulation issues in the future resulting in a similar dredging effort in about 30 years. There would also be significant impacts to the wetlands that have formed in the upstream portion of Kenney Reservoir.

The No Action alternative has not been evaluated in detail as the RBWCD does not consider this a viable option considering the implications, which are presented in further detail in Section 6.3.

Table 6-1 – Summary of White River Storage Potential Dam Site Alternatives

Potential Dam Sites	Eliminated in Initial Phase **Preliminary Screening** Reason for Screening: Storage	Recreation	Location	Eliminated in Initial Phase **Secondary Screening** Reason for Screening: Environmental Impacts	Infrastructure Impacts	Sites not within RBWCD
Chase Draw Reservoir	X	X				
Cottonwood Creek Reservoir			X			
Crooked Wash Reservoir				X		
Douglas Creek Reservoir					X	
Gillam Draw Reservoir [1]						
Hall Draw Reservoir	X	X				
Hammond Draw Reservoir	X	X				
Hay Gulch Reservoir						X
Kellog Gulch Reservoir	X	X				
Kenney #2 Reservoir	X	X				
Little Spring Creek Reservoir	X	X				
McAndrews Gulch Reservoir	X	X				
School Gulch Reservoir	X	X				
Scullion Gulch Reservoir		X				
Smith Gulch Reservoir				X		X
Spring Creek Reservoir [2]						
Sulphur Creek Reservoir						X
Taylor Draw Reservoir		X				
Tom Little Gulch Reservoir	X	X				
Wolf Creek Reservoir						
White River Reservoir (referred to as Wolf Creek Reservoir – Mainstem in Initial Phase) [3]				X		
Wray Gulch Reservoir	X	X				
Yellow Creek Reservoir				X		

[1] Feasibility-level designs were developed for Gillam Draw Dam in the Initial Phase; however, it was eliminated from consideration based on a fault system located within the dam axis.

[2] Feasibility-level designs were developed for Spring Creek Dam in the Initial Phase; however, it was eliminated from consideration in Phase 2A because the site did not have the additional storage capacity for the recreation pool, insurance pool, and sediment pool.

[3] The White River Dam was originally screened due to the significant wetland impacts along the White River. However, the RBWCD requested that the White River Dam site be included as another preferred alternative because it could be the most practicable alternative when considering the pumping operations costs of other alternatives.

6.2 Summary of Preferred Alternatives and Evaluations

Based on the work performed in the Initial Phase, the Wolf Creek Dam was considered to be the preferred alternative for a storage site on the White River after considering feasibility-level cost opinions and preliminary environmental and geologic information collected during site visits. However, the RBWCD requested that the White River Dam be included as another primary alternative that would have significantly lower operations costs because it would not require any pumping to fill the reservoir.

Table No. 6-2 was developed to generally present the costs, impacts, and various decision considerations associated with the White River Dam and the Wolf Creek Dam with a pump fill facility or gravity fill facility. Appendix E includes some general impact maps that are based on available GIS shapefiles from the BLM, U.S. Fish and Wildlife Service, and property information data.

Table 6-2 – Alternative Comparison and Impact Summary

Size:	20,000 acre-foot Working Pool				90,000 acre-foot Working Pool		
Dam Site:	**Wolf Creek Dam**			**White River Dam**	**Wolf Creek Dam**		**White River Dam**
Fill Method:	**Canal Fill**	**Pipeline Fill**	**Pump Fill**	**Direct**	**Canal Fill**	**Pump Fill**	**Direct**
Construction Cost (2018 dollars)	$195M	$329M	$119M	$275M	$318M	$191M	$360M
Cost per AF based on Construction Costs & Total Reservoir Storage	$4,800/AF	$8,000/AF	$2,900/AF	$4,000/AF	$2,400/AF	$1,500/AF	$2,600/AF
Average Annual O&M Costs [2]	$300,000	$100,000	$263,000	$100,000	$300,000	$638,000	$100,000
Average Annual Potential Hydropower Revenue [1]	$31,000	$31,000	$31,000	$468,000	$153,000	$153,000	$468,000
Average Annual Storage loss from Sediment (acre-feet)	57	57	57	472	57	57	472
Anticipated Relative Environmental Impacts	Moderate	Lower	Lower	Higher	Moderate	Lower	Higher
Long-term Private Land Impacts	Moderate	Less	Less	More	Moderate	Less	More
Major Highway Impacts	Yes, Highway 64 at Diversion	Yes, Highway 64 at Diversion	No	No	Yes, Highway 64 at Diversion	No	Yes, Highway 64 reservoir inundation
BLM Lands Impacted	Yes	Yes	Yes	Yes	Yes	Yes	Yes
BLM Areas of Critical Environmental Concern Impacted	No	No	No	Yes	No	No	Yes
BLM Wilderness Study Areas Impacted	No	No	No	No	No	No	No

Green shading denotes more favorable compared to other alternatives.

[1] The Wolf Creek Dam annual average hydropower revenue was calculated based on outlet works releases for consumptive demands assuming the assumed future demands are routed through the reservoir. The White River Dam annual hydropower revenue was calculated based on the average annual kilowatt hour (KWH) generated from Kenney Reservoir/Taylor Draw Hydroelectric Plant, assuming similar operations. Electric costs of $0.04 per KWH were used based on information provided by White River Electric.

[2] Includes additional employees, equipment, and annual pumping electric costs.

6.3 No Action Alternative Implications

The only significant storage within the White River Basin consist of Kenney Reservoir, Rio Blanco Lake, and Lake Avery. As of 2018, the storage capacity in Kenney Reservoir was estimated to be 3,400 acre-feet. Based on the average sedimentation accumulation rate, it is estimated that Kenney Reservoir will provide water storage or limited flat water recreation for only about ten more years. The other reservoirs in the area, Lake Avery (7,658 acre-feet) and Rio Blanco Lake (1,036 acre-feet) are owned and operated by Colorado Parks and Wildlife (CPW) with designated uses for wildlife and limited recreation, not water supply.

If a new water supply reservoir is not constructed within the White River basin, the following are considered to be inevitable outcomes:

- Within the next ten years, Kenney Reservoir will no longer provide any water storage benefits. The Town of Rangely gets its water supply directly from the White River. If the flows in the White River are lower than the intake during a drought, the Town will not be able to divert water for the Town's water supply. During a severe drought, this could occur for an extended period of time.
- The Planning Team working on the Programmatic Biological Opinion (PBO) is in the process of developing preliminary endangered fish flow targets for the White River and testing those against future demand scenarios. If the PBO predicts that under future development scenarios the flow targets are not met, there could be adverse impacts to the endangered fish populations if storage does not become available to supplement the White River flows when needed, and other conservation measures are not sufficient to offset anticipated effects on the endangered fish.
- The Rangely Oil Field is the largest oil-producing field in the Rocky Mountain Region. When prices are favorable, it is anticipated that significant energy development would occur in the area. About 640,000 acre-feet of conditional water rights are currently on the White River. If even a small fraction of these are developed and used for energy development, it is expected that less water will be available in the White River for other uses including the Town of Rangely and endangered fish flows. As shown in the modeling performed by the Yampa/White/Green Basin Roundtable, significant shortages in water for energy development are expected if a water storage reservoir is not developed.

7.0 PROJECT PERMITTING

7.1 Key Approvals

Based on the stakeholder meetings that have been held at the time this report was prepared and the initial Lean Permitting workshop with the BLM on August 9, 2018, the key permits and approvals required to construct the preferred alternative are summarized in Table No. 7-1.

Table 7-1 – Summary of Key Permits and Approvals

Permit or Approval	Agency
Right-of-Way Approval	BLM
National Environmental Policy Act (NEPA) Compliance Document	BLM
Section 7 of the Endangered Species Act (ESA) Clearance	U.S. Fish & Wildlife Service
Section 106 of the National Historic Preservation Act (NHPA) Clearances	State Historic Preservation Officer
404 Dredge and Fill Permit	U.S. Army Corps of Engineers
401 Water Quality Certification	Colorado Department of Public Health and Environment
County 1041 Documentation	Not Applicable in Rio Blanco or Moffat Counties
Floodplain Permit	Rio Blanco County
Dam Construction Approval	Colorado Division of Water Resources

7.2 Key Issues

At the time that this report was prepared, the Project impacts to the following resources are expected to be documented in the NEPA compliance document:

- Cultural resources
- Wetlands
- Migratory Birds
- Sage Grouse Habitat
- Big Game Habitat
- BLM grazing lands
- BLM oil and gas leases
- Endangered animals and plants
- Recreation facilities
- Water Quality
- Water Rights
- Socioeconomic Impacts
- Transportation facilities

Impacts to other resources could also be identified in the scoping process.

8.0 STAKEHOLDER MEETINGS

8.1 Key Meetings

Several public workshops were conducted to provide the public with information on the progress of the feasibility study and to gather public input. A public Phase 2A Study kick off meeting was held in Rangely on August 22, 2017; an update was provided to the White River Basin Forum on April 4, 2018 in Rangely; and a draft report public meeting was held in Rangely, CO on August 28, 2018.

The RBWCD is a key participant in the Planning Team associated with the White River Management Plan and Programmatic Biological Opinion Development. The Planning Team is guiding the process for developing preliminary endangered fish flow targets for the White River and testing those against future demand scenarios developed by the Yampa/Green/White Basin Roundtable. The Planning Team consists of representatives of the U.S. Fish and Wildlife Service, Colorado Water Conservation Board, Utah Division of Water Resources, The Nature Conservancy, and the RBWCD. Wilson Water Group has provided modeling support to the Planning Team. The Planning Team met several times per year from 2016 through 2018.

The RBWCD also provided a tour of its facilities and gave a presentation on the project to the Colorado River Water Conservation District in April 2018.

A meeting was held with the Bureau of Land Management (BLM) Meeker Office in August 2018. Since a majority of the lands impacted by the reservoir are owned by the BLM, the BLM will likely assume the lead role in preparing the NEPA documentation and will be the agency responsible for issuance of the Right-of-Way approval. As a result, the BLM requested a meeting to discuss the Lean approach to permitting that will hopefully result in efficiencies in the NEPA process.

8.2 YWG Meetings & Participation

EIS Solutions and Wheeler also provided update presentations to the Yampa/White/Green Basin Water Roundtable (BRT) as part of the feasibility study in November 2017, May 2018, and September 2018.

The RBWCD, Wheeler, and EIS Solutions also participated in the Basin Implementation Plan (BIP) Modeling Phase 3 work by Wilson Water Group. The RBWCD, Wheeler, and EIS Solutions attended modeling workshops and provided key input to Wilson Water Group on the inclusion of the Wolf Creek Reservoir and White River Reservoir within the modeling at the request of the BRT.

8.3 Other Stakeholder Meetings

The following is a list of some of the key stakeholders that were involved in the Stakeholder outreach process.

1. Meeker Town Trustees
2. US Congressman Ken Buck's Area Representative, Dusty Johnson
3. Western CO Regional Director for Senator Cory Gardner, Betsy Bair
4. Rio Blanco County Commissioner, Si Woodruff
5. State of Colorado, Division 6 Engineer, Erin Light
6. White River BLM office in Meeker
7. Moffat County Land Use Board & Citizens Advisory Group
8. White River Electric Association
9. 3 Springs Ranch Manager, Joel Tuck
10. Director of the Meeker Chamber of Commerce, Stephanie Kobald
11. Executive Director for Club 20, Christian Reece
12. CO State House District 55 Representative, Dan Thurlow
13. CO State House District 54 candidate, Matt Soper
14. Colorado Senate District 7, Senator Ray Scott
15. CO State House District 57 Representative, Bob Rankin
16. Colorado Senate District 8, Senator Randy Baumgardner
17. Associated Governments of Northern Colorado (AGNC) Executive Director, Bonnie Petersen
18. Colorado River District, General Manager, Andy Mueller
19. Colorado River District, Director of Community Affairs, Jim Pokrandt
20. Colorado River District, External Affairs Manager, Chris Treese
21. Regional Director for Congressman Scott Tipton, Brian Meinhart
22. Town of Rangely Trustees
23. Rio Blanco County Commissioners
24. Rangely Area Chamber of Commerce, Konnie Billgren
25. State of the White River Basin Forum
26. Douglas Creek Conservation District
27. Senator Michael Bennet's State Policy Director, Noah Koerper
28. Senator Michael Bennet's Regional Representative, Shannon Wadas
29. Senator Cory Gardener toured the site prior to the Phase 2A study
30. 4M Ranch Owner, Craig MacNab
31. Colorado Water Conservation Board, Anna Mauss
32. Colorado Water Conservation Board, Jojo La
33. Colorado Water Conservation Board, Michelle Garrison
34. Deputy Secretary of the Interior, David Bernhardt

9.0 SUMMARY OF RESULTS AND CONCLUSIONS

Based on the results of this study and the previous studies documented in this report, Wheeler offers the following summary of results and conclusions:

1. A pending water crisis is developing on the White River that can be alleviated by constructing storage in the lower White River basin.

2. The water storage project could provide significant benefits to northwestern Colorado including providing recreation for the local community and tourism; tax revenue associated with uses of the reservoir; water supply to support the endangered species on the White River; and water supply for municipal, industrial, and energy development.

3. The work completed to date has not identified a viable alternative method for alleviating the pending water crisis on the White River. Based on the work performed to date on the White River Storage Feasibility Project, the only identified feasible storage locations within the RBWCD's boundaries that can meet the projected future water needs in the White River Basin include the Wolf Creek Reservoir site or the White River Reservoir site.

4. The Spring Creek Reservoir site is no longer considered to be a viable option because it cannot support the insurance pool, recreation pool, and sediment pool to provide an adequate working pool. Recreation access to the reservoir is also considered to be very poor.

5. The unit cost per acre-foot of reservoir storage at either the Wolf Creek Dam or the White River Dam was considered to be very economical in comparison with other regional water projects.

6. The average annual estimated storage loss at the White River Reservoir due to sedimentation is much more than at the Wolf Creek Reservoir.

7. The Wolf Creek Dam, with a pump station fill facility, has the most economical construction costs.

8. A gravity fill canal or pipeline for the Wolf Creek Reservoir is not considered to be economical when considering the additional construction costs and additional annual operation and maintenance costs.

9. If hydropower is considered after this project is constructed, the White River Dam may provide the opportunity to generate more revenue compared to the Wolf Creek Dam.

10. The BLM will likely be the lead federal agency to complete documentation under the National Environmental Policy Act for the project.

11. The RBWCD is prepared to initiate a Lean state and federal permitting process by the end of calendar year 2019 after the Pre-Permitting Phase is complete.

12. The RBWCD’s preferred alternative for providing additional storage in the RBWCD is the Wolf Creek Dam site with a pump station for filling the reservoir. The secondary alternative is the White River Dam.

13. Based on modeling of the Wolf Creek Reservoir and White River Reservoir performed independently of this Phase 2A Study by Wilson Water Group working with the Yampa/White/Green Basin Roundtable, the reservoir(s) can be reliably filled with water from the White River. Either reservoir has the ability to provide additional water to meet the projected long-term future water demands through year 2065 for municipal and industrial for the Town of Rangely and energy. Both reservoirs have the ability to offset shortages resulting from future hydrologic conditions that could be drier than current conditions while assuming that some of the energy water rights in the basin were senior to the reservoir’s water right.

14. A Cultural Resources Inventory Assessment and an on-site geological assessment, biological habitat assessment, and wetland assessment were performed for the Wolf Creek Dam and reservoir site in May 2014 resulting in no identified significant environmental, cultural resources, or geologic hazards.

15. Based on the Initial Phase and Phase 2A work, several key comments from stakeholders have been incorporated into the Pre-Permitting Phase tasks, which is the next phase of this project. The goal of the Pre-Permitting Phase is to define the site disturbance area and establish the reservoir size that will be included in the permit applications. Another key goal of the Pre-Permitting Phase is to confirm the financial plan that documents how much each key partnering organization will commit to the Project. The Pre-Permitting Phase tasks were developed to make the Permitting Phase as efficient as possible and consistent with the recent Department of the Interior directives for preparing Environmental Impact Statements.

10.0 NEXT STEPS

10.1 General Next Steps

Following the Phase 2A Study, the Project is scheduled to develop in the following phases:

- Pre-Permitting Phase;
- Permitting Phase;
- Final Design Phase; and
- Construction Phase.

The project development schedule is summarized on Figure No. 10-1 and each of the planned phases are generally described in Sections 10.2 through 10.4.

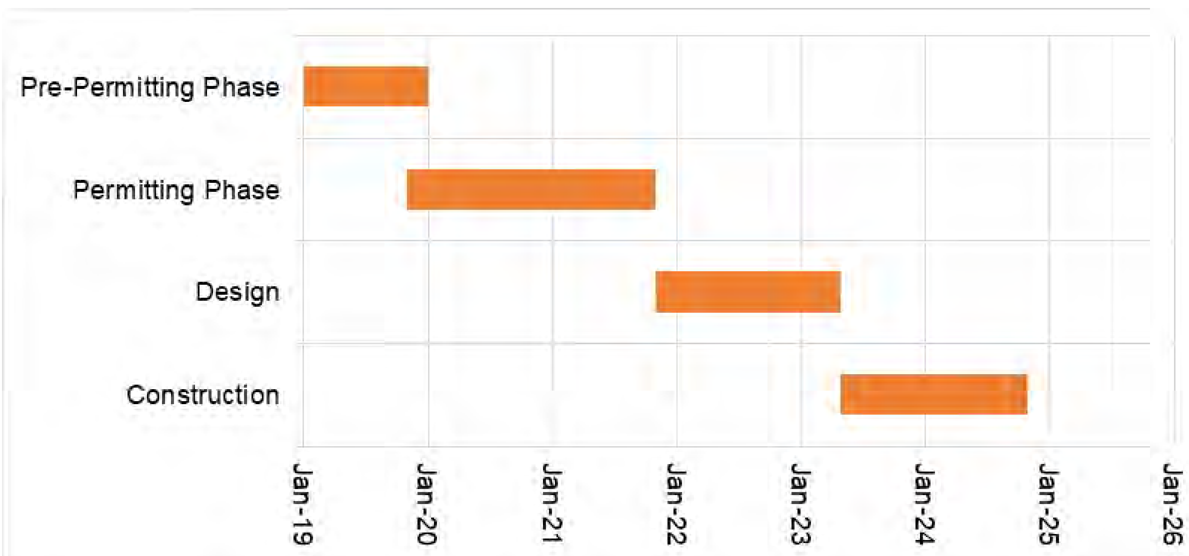

Figure 10-1 – Preliminary Project Schedule through Construction

10.2 Pre-Permitting Phase

The objective of the Pre-Permitting Phase of the Project development is to finalize the preferred reservoir size and appurtenant facilities and firm-up financial commitments of key Project partners so that applications for federal permits can be filed by the end of 2019. The Pre-Permitting Phase work also includes preliminary work that will be needed in the Permitting Phase to streamline the Permitting Phase work. The following tasks are planned in the Pre-Permitting Phase:

- Project Management, Outreach and Public Meetings;
- Continued coordination with the Programmatic Biological Opinion (PBO) and White River Management Plan developments;

- Continued meetings with key permitting agencies to frame the groundwork to implement a Lean permitting process;
- Development of a preliminary recreation plan to identify recreation disturbance areas for future permitting;
- Refinement of the purpose and need to enter into the Permitting Phase with a preferred reservoir location and size;
- Development of a Financing Plan for the preferred reservoir; and
- Preparation of a report documenting the Pre-Permitting Phase work.

10.3 Permitting Phase

The detailed plan for permitting will be developed as part of the Pre-Permitting Phase Scope of Work. The Colorado Water Conservation Board has focused recently on improving efficiency and coordination to streamline an otherwise lengthy water supply permitting process, by developing a general framework for a Lean permitting process.

Deputy Secretary of the Interior, David Bernhardt, has also emphasized the benefits of a shorter, streamlined permitting process for water projects.

10.4 Financing, Design, and Construction

After the permitting phase, the project will be financed, designed in accordance with the Colorado Division of Water Resources Rules and Regulations, and constructed.

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APPENDIX A
FEASIBILITY-LEVEL DESIGNS

APPENDIX A.1 – WOLF CREEK DAM FIGURES

APPENDIX A.2 – GRAVITY FILL FACILITY FIGURES FOR WOLF CREEK DAM

APPENDIX A.3 – WHITE RIVER DAM FIGURES

APPENDIX A.1 – WOLF CREEK DAM FIGURES

Figure A.1-1-1 – Wolf Creek Dam – 20,000 Acre-Foot – Overall Map

Figure A.1-1-2 - Wolf Creek Dam – 20,000 Acre-Foot – Dam Plan View

Figure A.1-1-3 - Wolf Creek Dam – 20,000 Acre-Foot – Dam Section

Figure A.1-2-1 – Wolf Creek Dam – 90,000 Acre-Foot – Overall Map

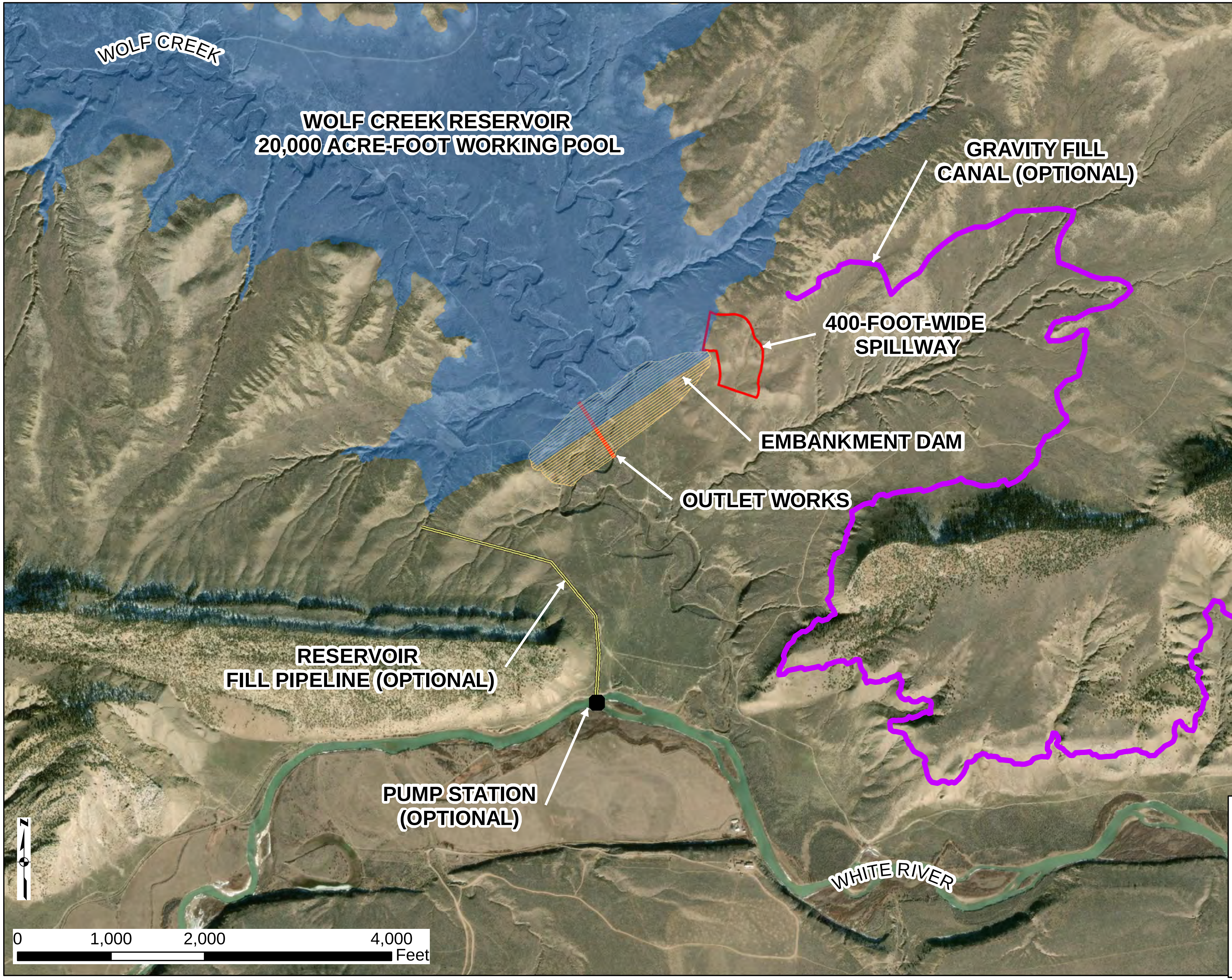
Figure A.1-2-2 - Wolf Creek Dam – 90,000 Acre-Foot – Dam Plan View

Figure A.1-2-3 - Wolf Creek Dam – 90,000 Acre-Foot – Dam Section

Figure A.1-3-1 – Wolf Creek Dam – Maximum Storage – Overall Map

Figure A.1-3-2 - Wolf Creek Dam – Maximum Storage – Dam Plan View

Figure A.1-3-3 - Wolf Creek Dam – Maximum Storage – Dam Section



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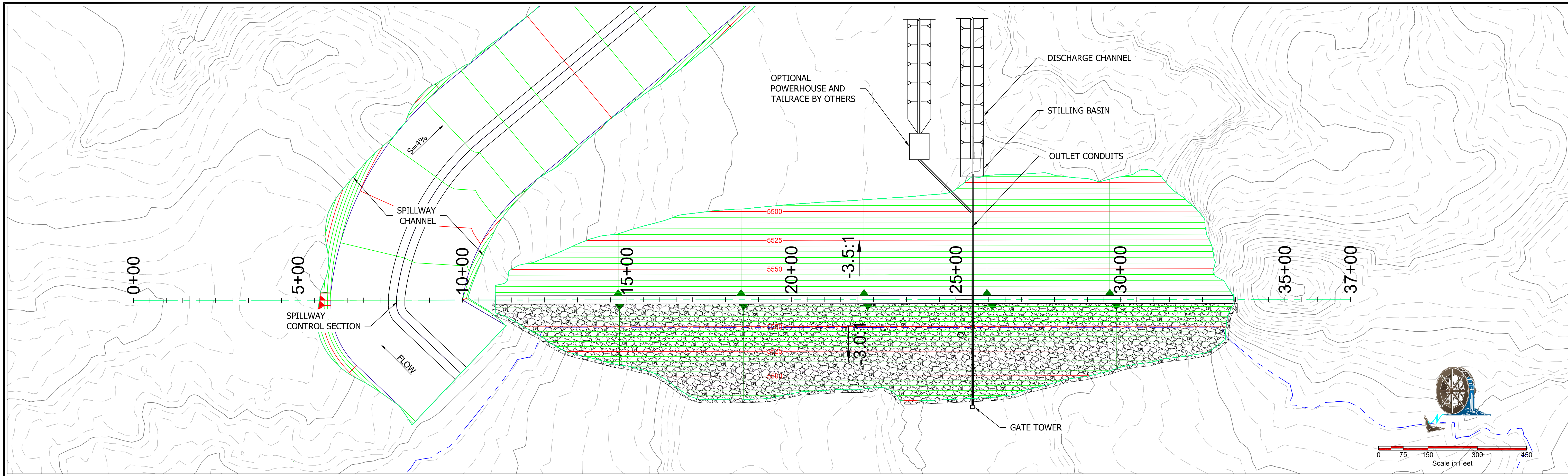
AUGUST 2018

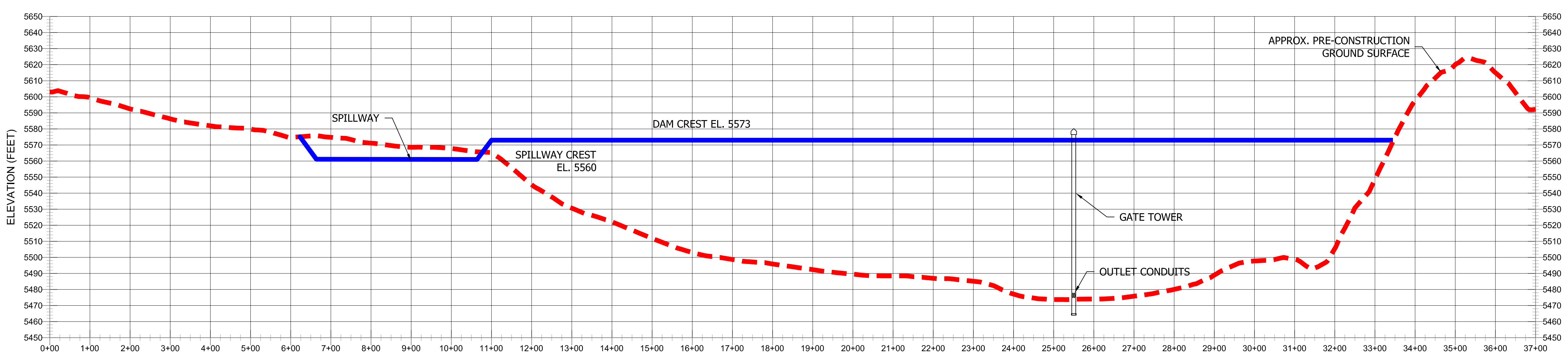
W. W. WHEELER & ASSOCIATES, INC.
Water Resources Engineers

White River Storage Feasibility Study - Phase 2A
Wolf Creek Dam - 20,000 Acre-Foot Overall Map

Job No. 1656.07.01

FIGURE A.1-1-1





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REVISIONS No.	Date	Made	Checked	Remarks
1	3/4/15	DRT	SLJ	PRELIMINARY DESIGN

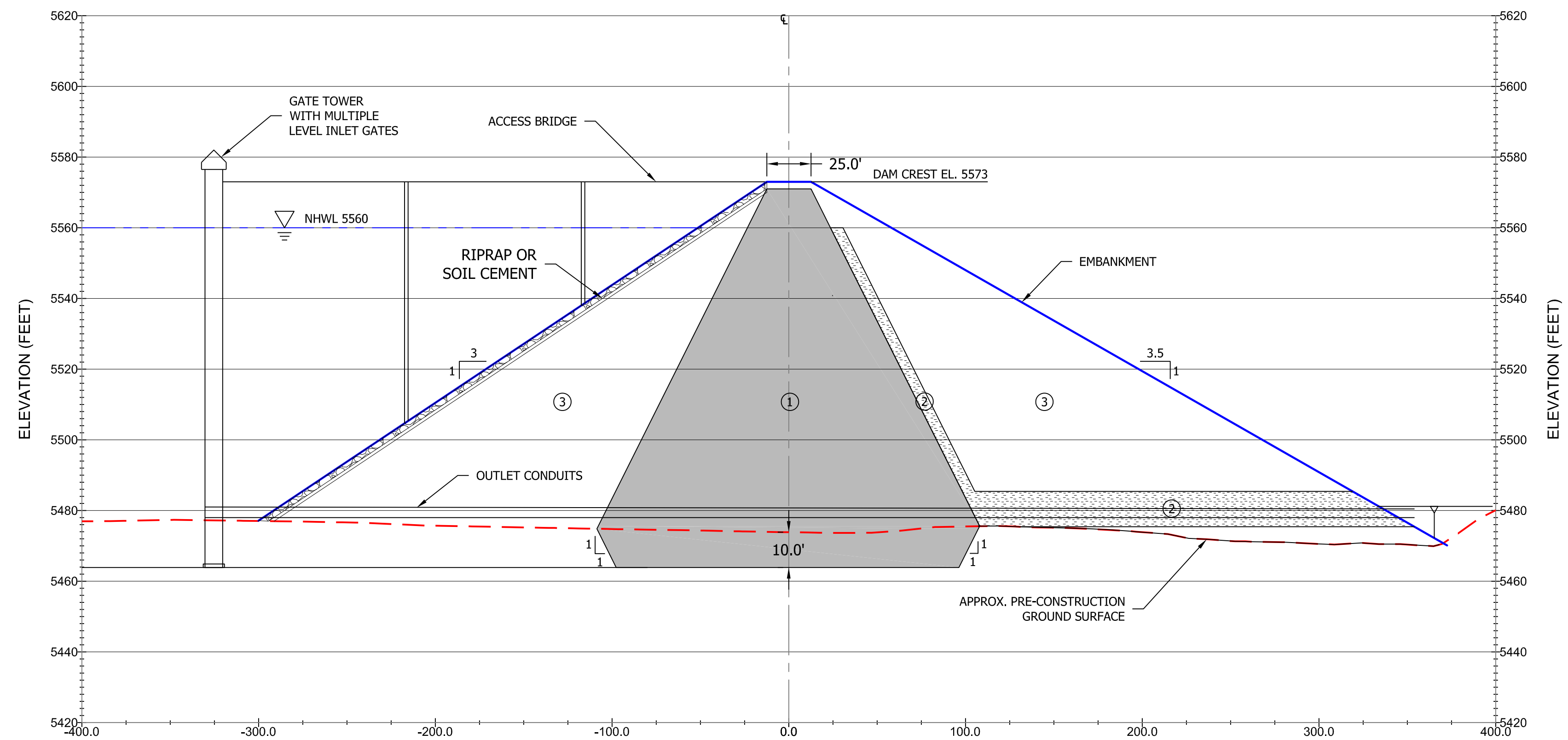
REFERENCE Sheet No.	Drawing No.	Title

PRELIMINARY ONLY
NOT FOR CONSTRUCTION

W. W. WHEELER & ASSOCIATES, INC
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | Fax 303-761-2802

WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 20,000 ACRE-FOOT
DAM PLAN VIEW

Client	RBWCD		
Design	DTH	01/18	Wheeler No. 1656.07
Drawn	AWT	01/18	Sheet No. 2 of 3
Check	SLJ	01/18	
Plot Date 08/02/2018		1	Drawing No. A.1-1-2



MAXIMUM SECTION AT OUTLET WORKS
STA. 25+50

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REFERENCE

Sheet No.	Drawing No.	Title

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& ASSOCIATES, INC
Water Resources Engineers
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303-761-4130 | fax 303-761-2802

WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 20,000 ACRE-FOOT
DAM SECTIONS AND DETAILS

Client: RBWCD			
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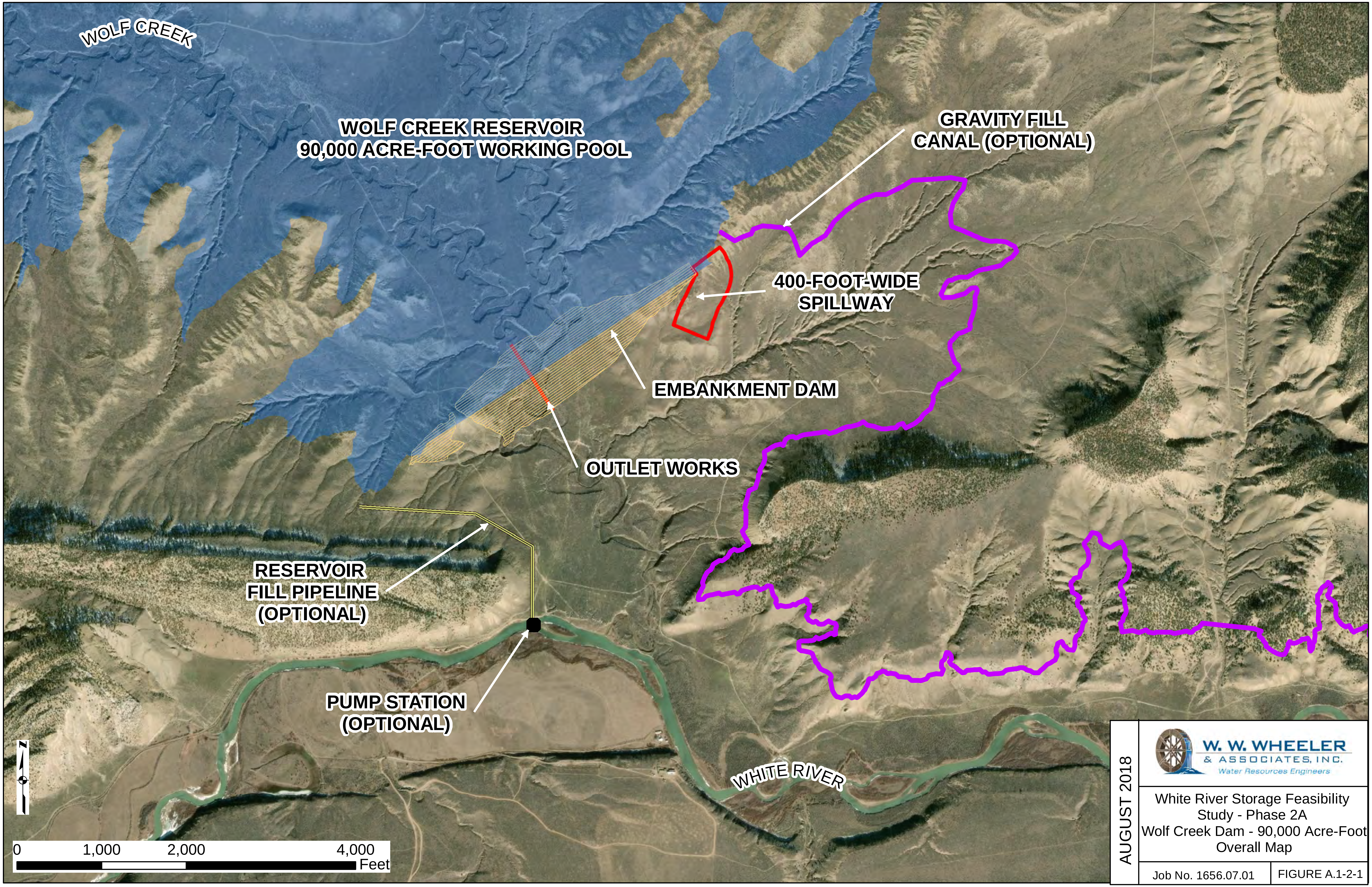
Check	SLJ	01/18	
Plot Date 07/31/2018		1	Drawing No. A.1-1-3



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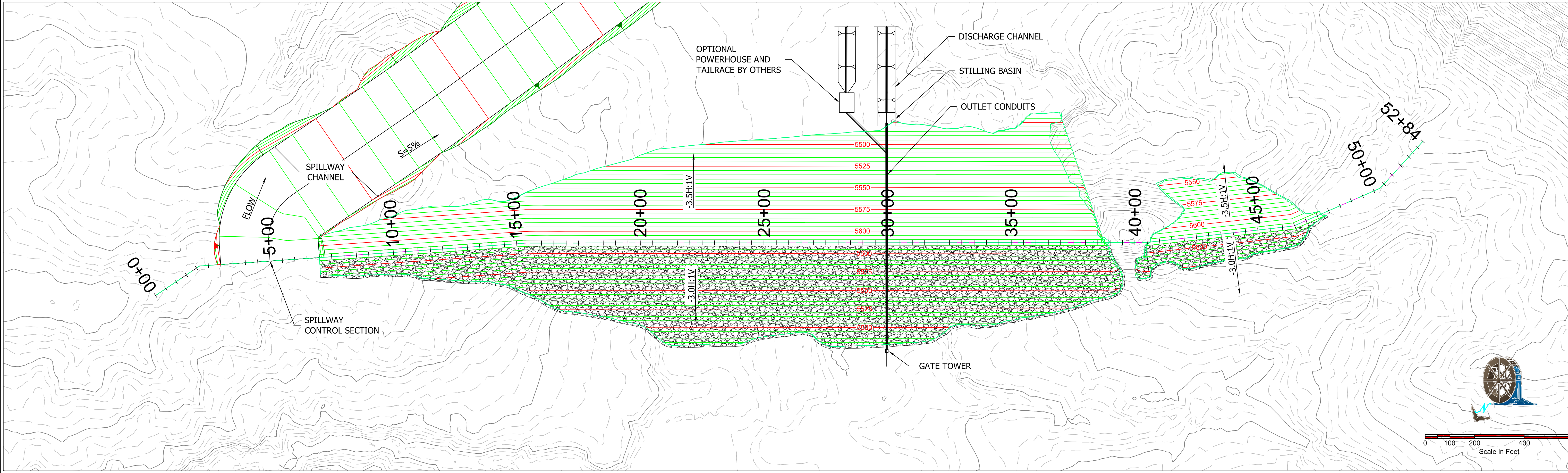

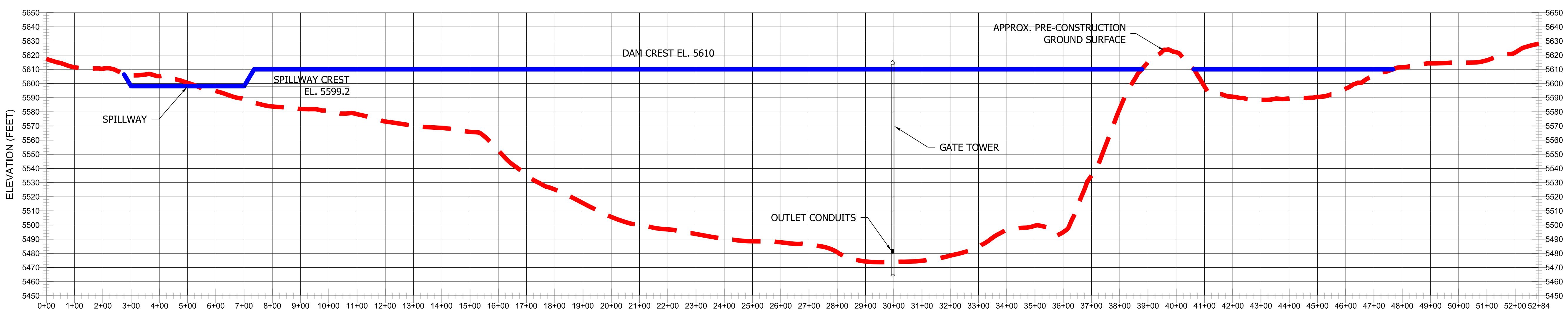

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REVISIONS

No.	Date	Made	Checked	Remarks
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REFERENCE

Sheet No.	Drawing No.	Title

PRELIMINARY ONLY
NOT FOR CONSTRUCTION

W. W. WHEELER & ASSOCIATES, INC
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | Fax 303-761-2802

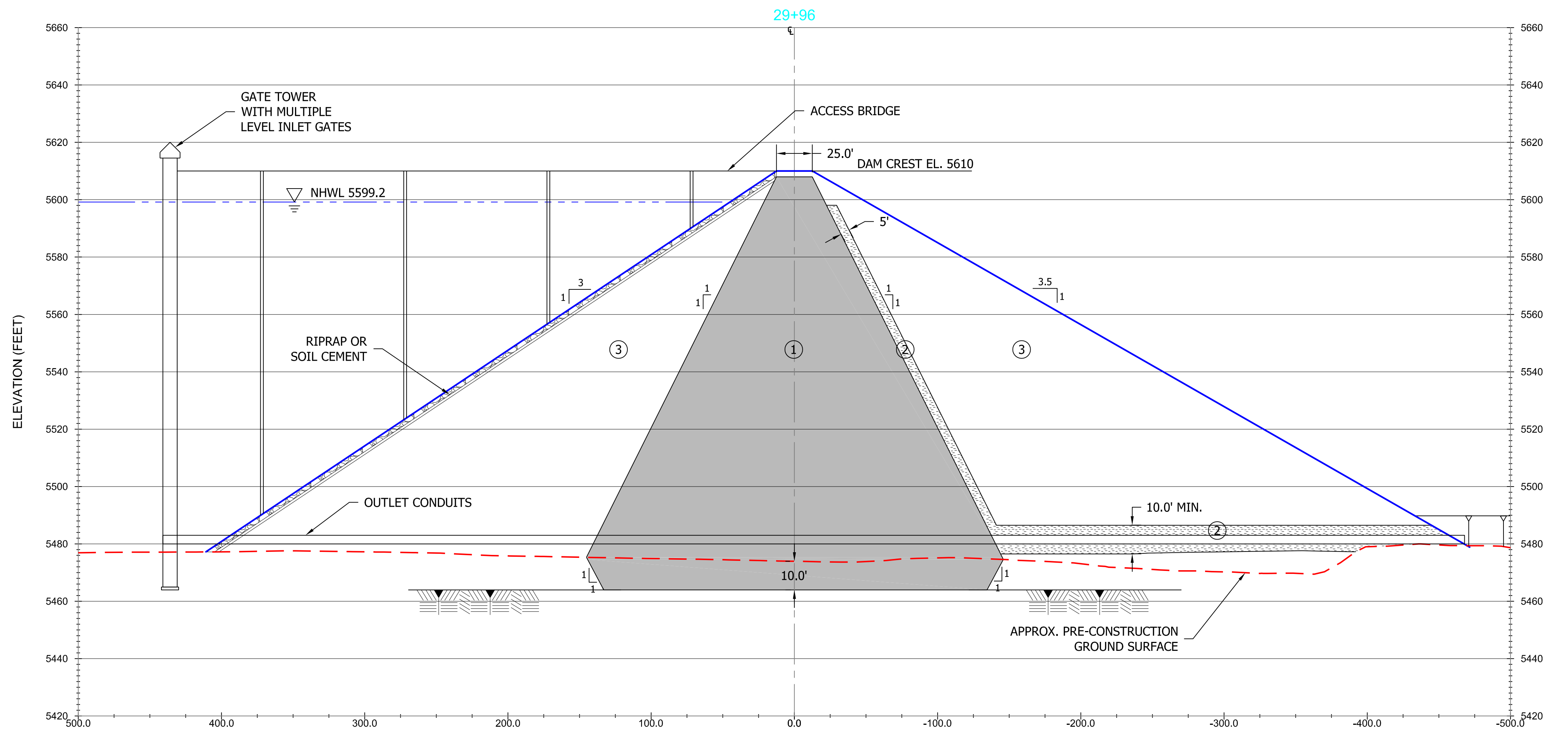
WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 90,000 ACRE-FOOT
DAM PLAN AND PROFILE

Client: RBWCD

Design	DTH	08/18
Drawn	AWT	08/18
Check	SLJ	08/18

Plot Date: 07/31/2018 — Revision 1

Wheeler No.: 1656.07
Sheet No.: 2 of 3
Drawing No.: A.1-2-2



MAXIMUM SECTION AT OUTLET WORKS

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REVISIONS

NO.	DATE	MADE	CHECKED	REMARKS
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REFERENCE

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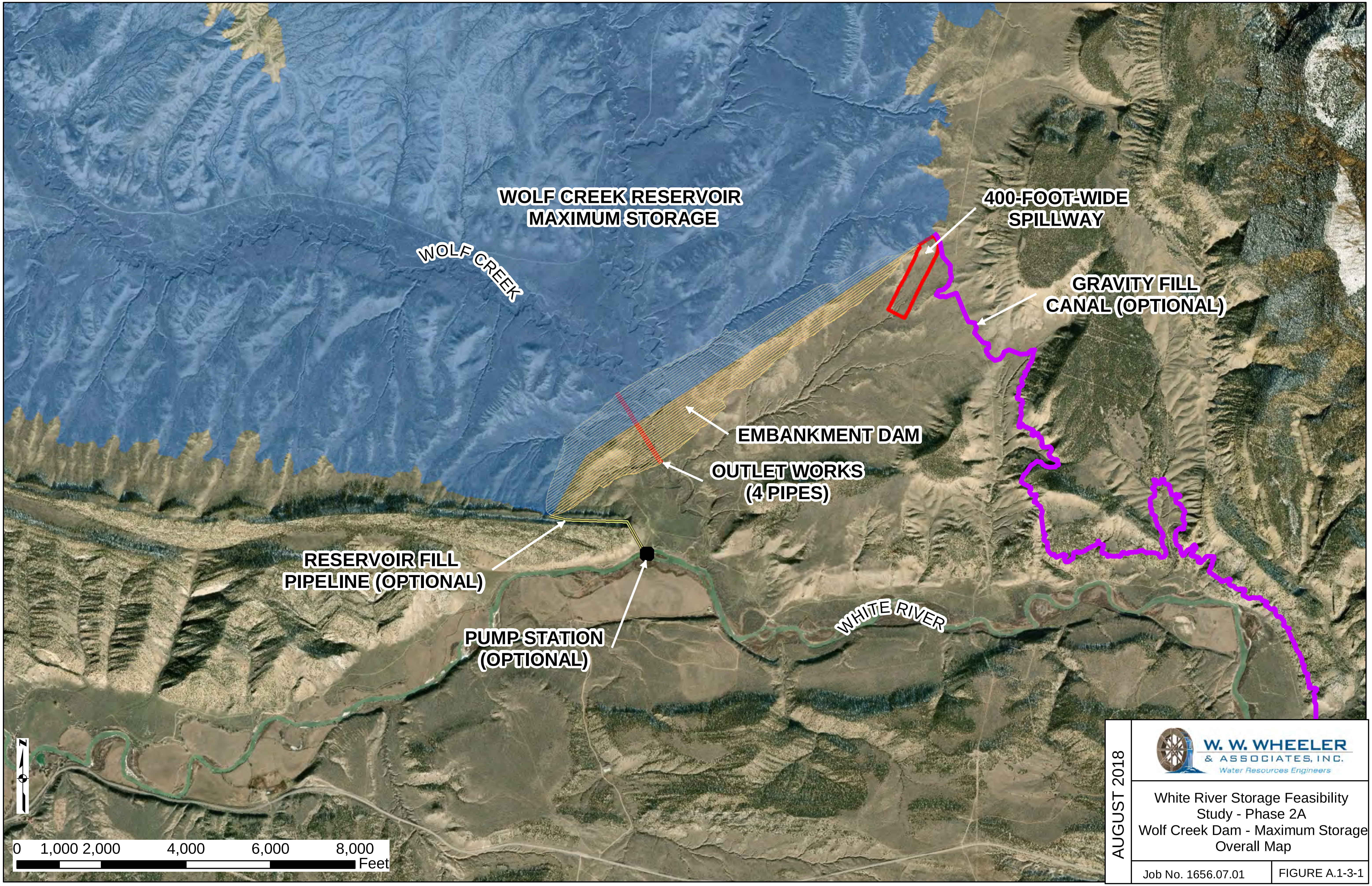
WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 90,000 ACRE-FOOT
DAM SECTIONS AND DETAILS

CLIENT	RBWCD		
DESIGN	DTH	08/18	WHEELER NO. 1656.07
DRAWN	AWT	08/18	SHEET NO. 3 of 3
CHECK	SLJ	08/18	
PLOT DATE	07/31/2018	1	DRAWING NO. A.1-2-3



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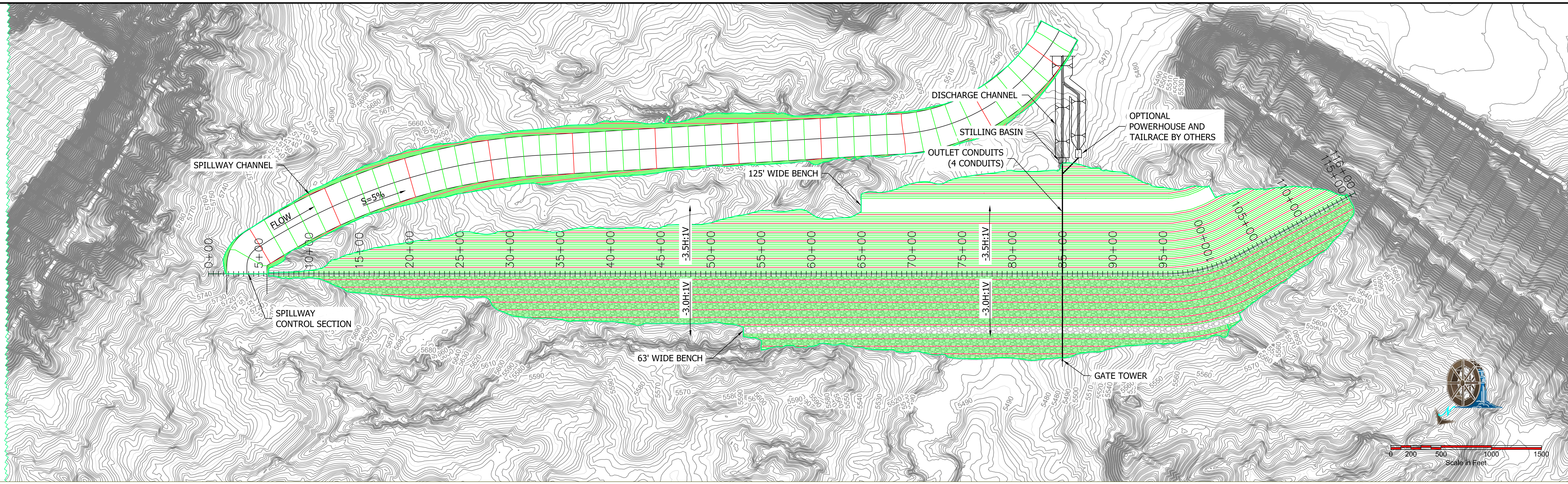
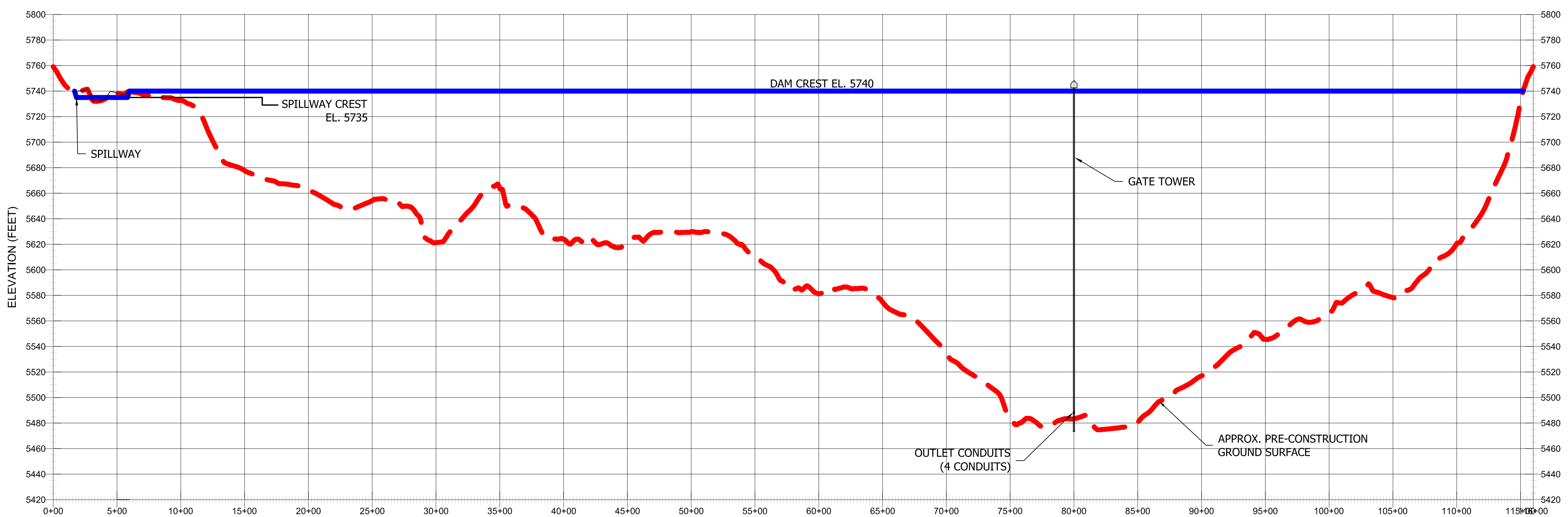
White River Storage Feasibility Study - Phase 2A
Wolf Creek Dam - Maximum Storage
Overall Map

Job No. 1656.07.01

FIGURE A.1-3-1





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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - MAXIMUM STORAGE
DAM PLAN AND PROFILE

Client	RBWCD		
Design	DTH	08/18	Wheeler No. 1656.07.01
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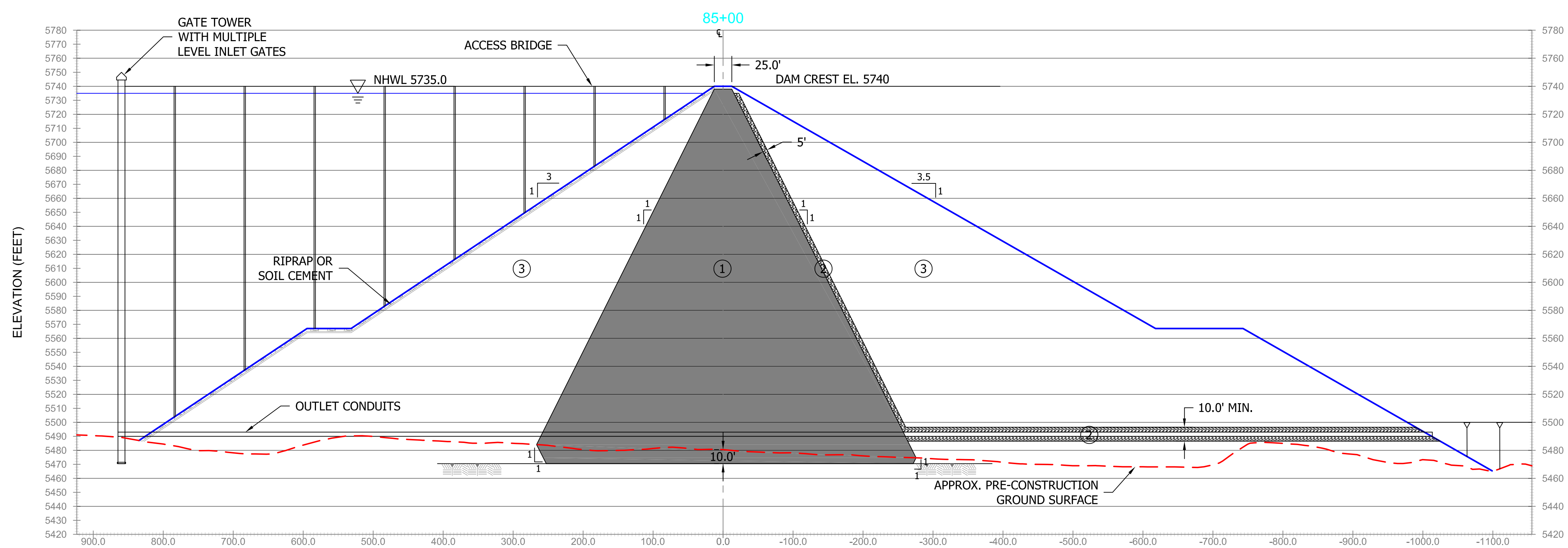
Plot Date	07/31/2018	X	Drawing No. A.1-3-2



MAXIMUM SECTION AT OUTLET WORKS
STA. 85+00

REVISIONS No.	Date	Made	Checked	Remarks
1	8/1/2018	DTH	SLJ	PRELIMINARY DESIGN

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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - MAXIMUM STORAGE
DAM SECTION AND DETAILS

Client: RBWCD			
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Drawn	AWT	08/18	Sheet No. 3 of 3
Check	SLJ	08/18	
Plot Date 07/31/2018	X		Drawing No. A.1-3-3

APPENDIX A.2 – GRAVITY FILL FACILITY FIGURES FOR WOLF CREEK DAM

Figure A.2-1-1 – Wolf Creek Dam – 90,000 Acre-Foot – Gravity Fill Canal – Canal Plan and Profile

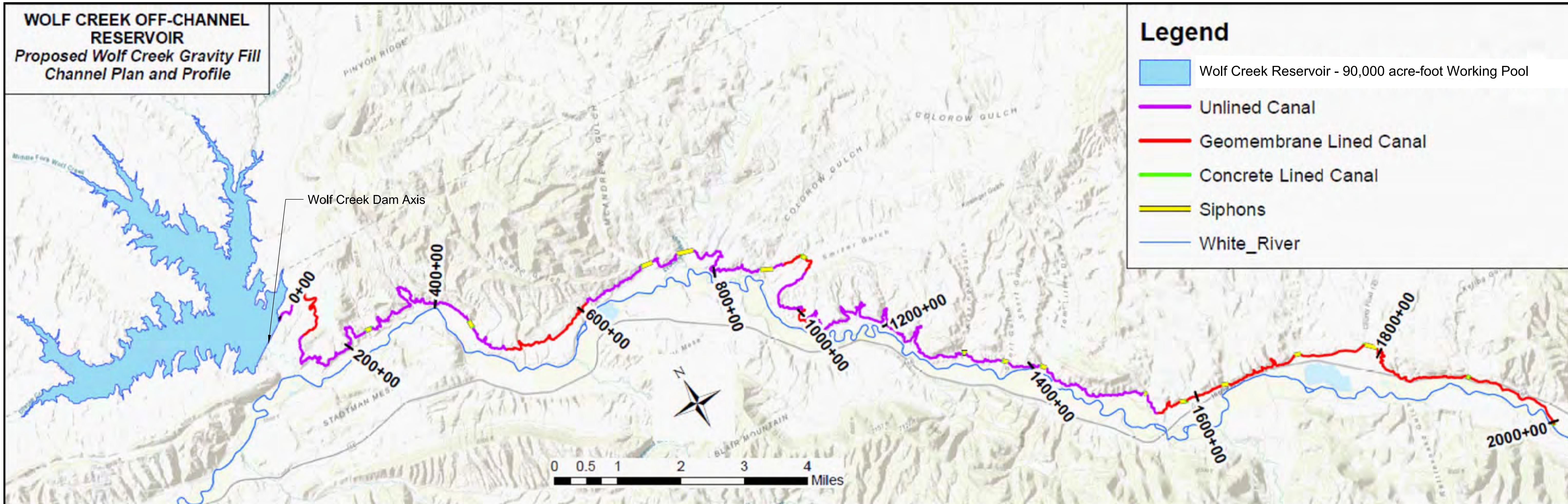
Figure A.2-1-2 - Wolf Creek Dam –Gravity Fill Canal – Typical Canal Sections for 400 CFS Flow Rate

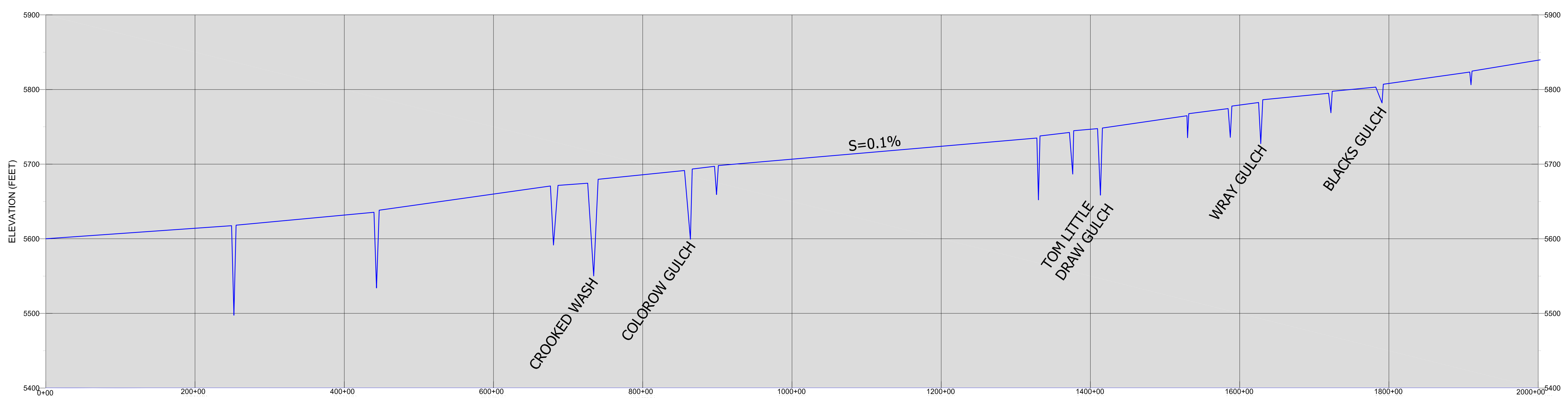
Figure A.2-1-3 - Wolf Creek Dam –Gravity Fill Canal – Typical Siphon Plan and Profile for 400 CFS Flow Rate

Figure A.2-1-4 - Wolf Creek Dam –Gravity Fill Canal – Typical Siphon Details for 400 CFS Flow Rate

Figure A.2-1-5 - Wolf Creek Dam –Gravity Fill Canal – Diversion Dam Plan and Profile for 400 CFS Flow Rate

Figure A.2-2-1 - Wolf Creek Dam –Gravity Fill Canal & Pipeline – Typical Canal & Pipeline Sections for 100 CFS Flow Rate





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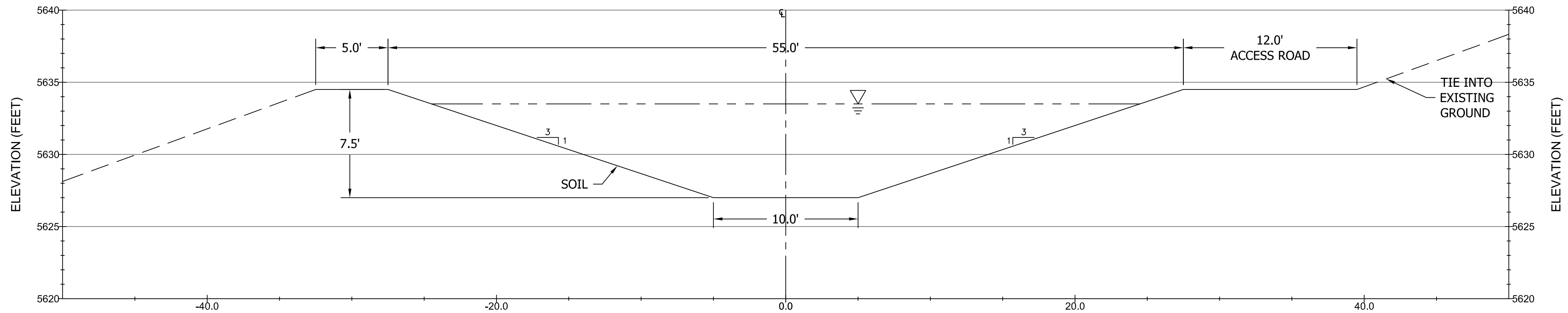
WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 90,000 ACRE-FOOT
GRAVITY FILL CANAL
CANAL PLAN AND PROFILE

Client	RIO BLANCO WATER CONSERVANCY DISTRICT		
Design	AWT	08/18	Wheeler No. 1656.07.01
Drawn	AWT	08/18	Sheet No. 1 of 5
Check	DTH	08/18	
Plot Date 08/01/2018	△A		Drawing No. A.2-1-1



UNLINED CANAL
TYPICAL SECTION (1)

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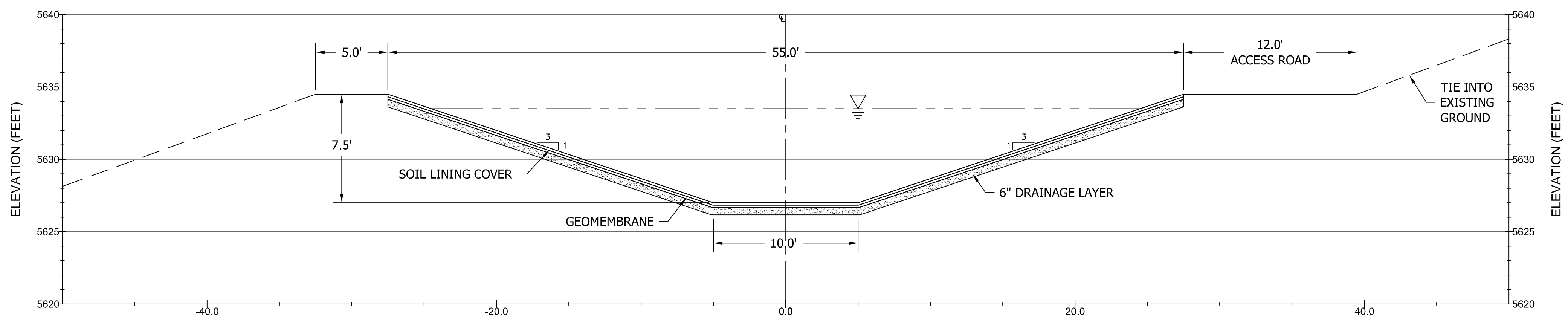
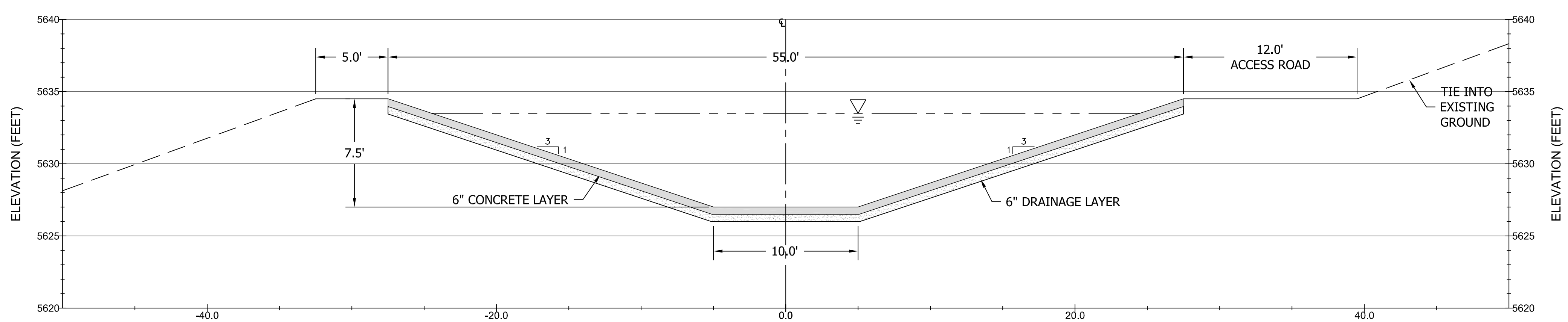
Scale in Feet



GEOMEMBRANE LINED CANAL
TYPICAL SECTION (2)

0 2 5 10 15
Scale in Feet



CONCRETE LINED CANAL
TYPICAL SECTION (3)

0 2 5 10 15
Scale in Feet

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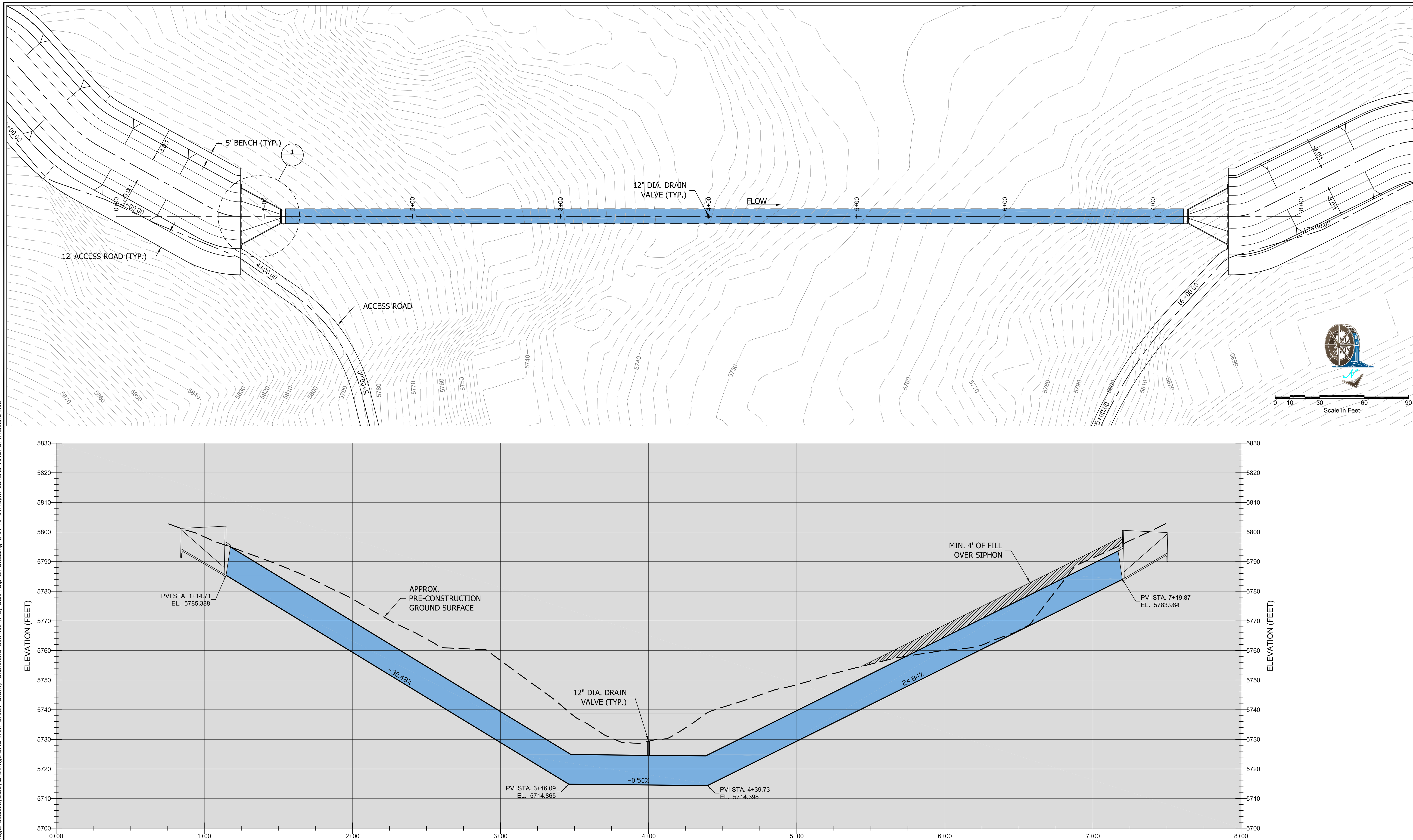
WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 400 CFS CANAL
GRAVITY FILL CANAL
TYPICAL CANAL SECTIONS FOR 400 CFS FLOW RATE

Client	RBWCD	
Design	AWT	02/18
Drawn	AWT	02/18
Check	DTH	02/18
Plot Date	08/01/2018	△A

Wheeler No.	1656.07.01
Sheet No.	2 of 5
Drawing No.	A.2-1-2



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REVISIONS: No.	Date	Made	Checked	Remarks

REFERENCE: Sheet No.	Drawing No.	Title

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WHITE RIVER STORAGE FEASIBILITY STUDY

PHASE 2A
WOLF CREEK DAM - 400 CFS CANAL
GRAVITY FILL CANAL
TYPICAL SIPHON PLAN AND PROFILE

Client	RIO BLANCO WATER CONSERVANCY DISTRICT		
Design	AWT	Wheeler No.	1656.07.01
Drawn	SAA	Sheet No.	3 of 5
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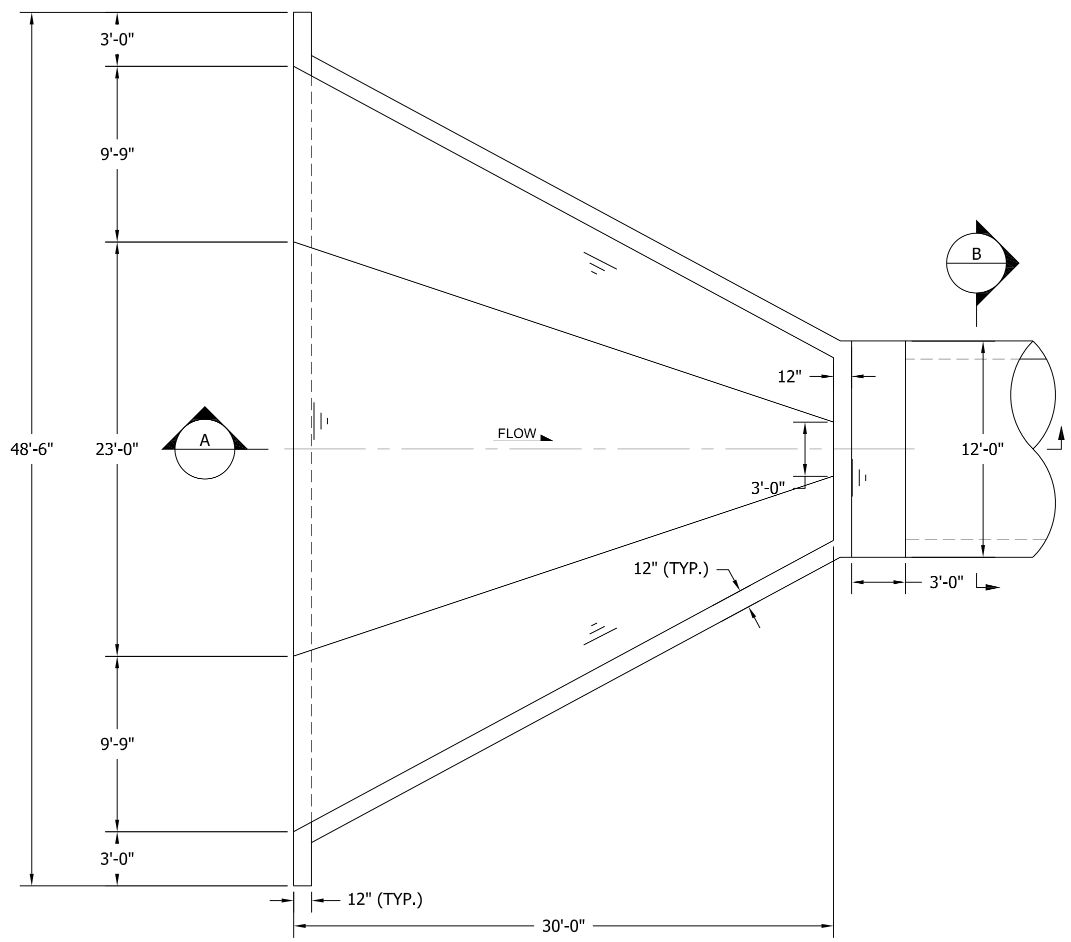
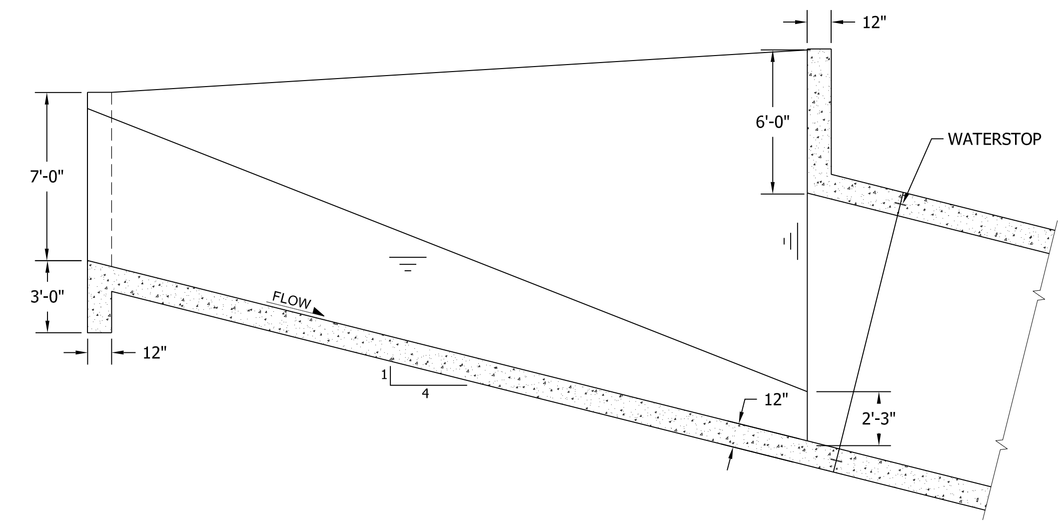
Plot Date	08/01/2018	Drawing No.	A.2-1-3



1 CANAL TRANSITION
PLAN VIEW

0 4 8 12 16
Scale in Feet



CANAL TRANSITION (A)
SECTION

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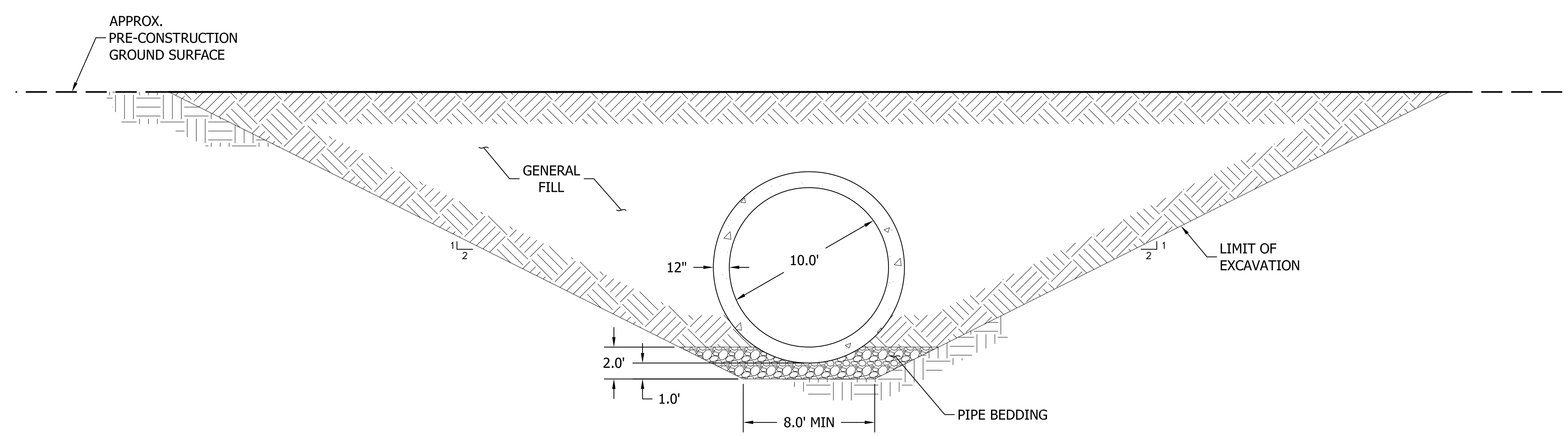
Scale in Feet



PIPE TRENCH (B)
TYPICAL SECTION

0 5 10 20 30
Scale in Feet

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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 400 CFS CANAL
GRAVITY FILL CANAL
SIPHON DETAILS

Client: RBWCD			
Design	AWT	08/18	Wheeler No. 1656.07.01
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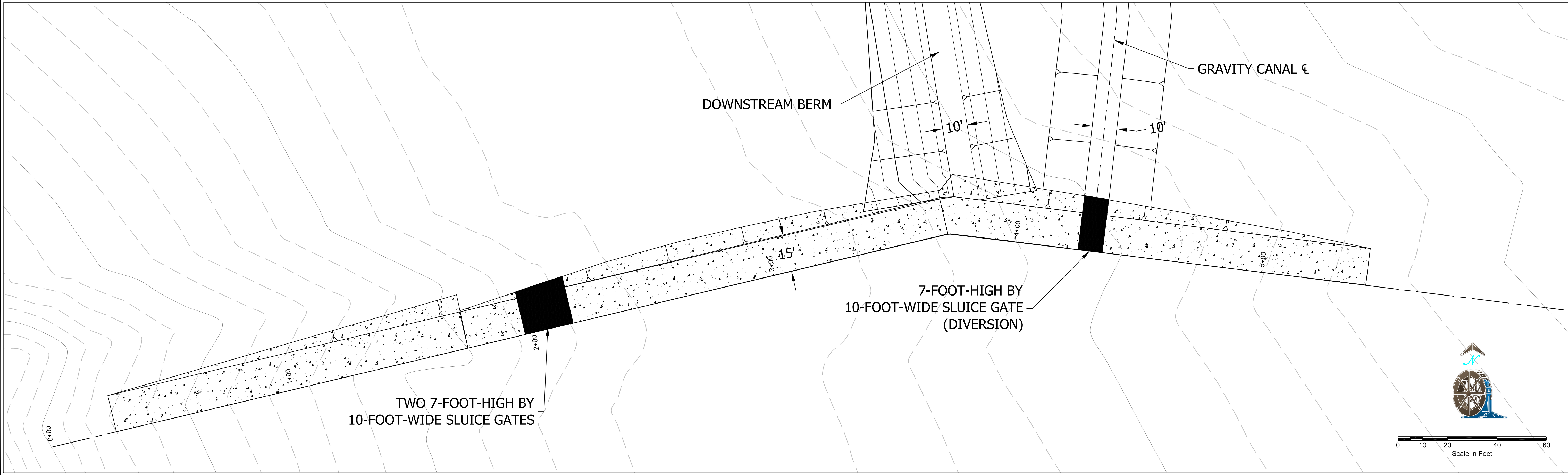
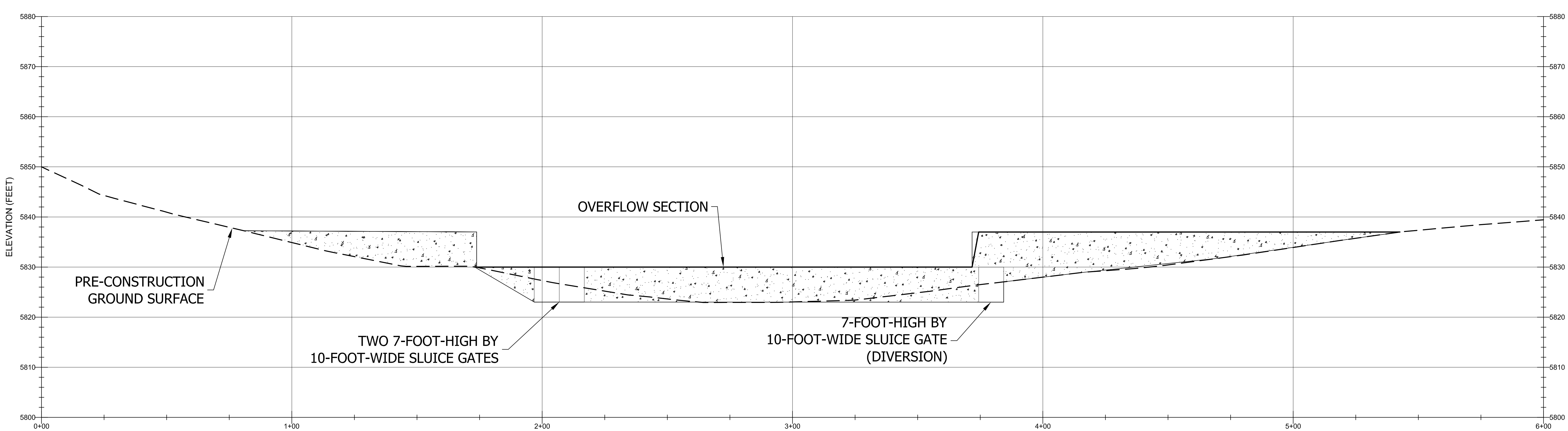
Check	DTH	08/18	Sheet No. 4 of 5
Plot Date 08/01/2018	△A		Drawing No. A.2-1-4





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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 400 CFS CANAL
GRAVITY FILL CANAL
DIVERSION DAM PLAN AND PROFILE

Client	RBWCD		
Design	AWT	08/18	Wheeler No. 1656.07.01
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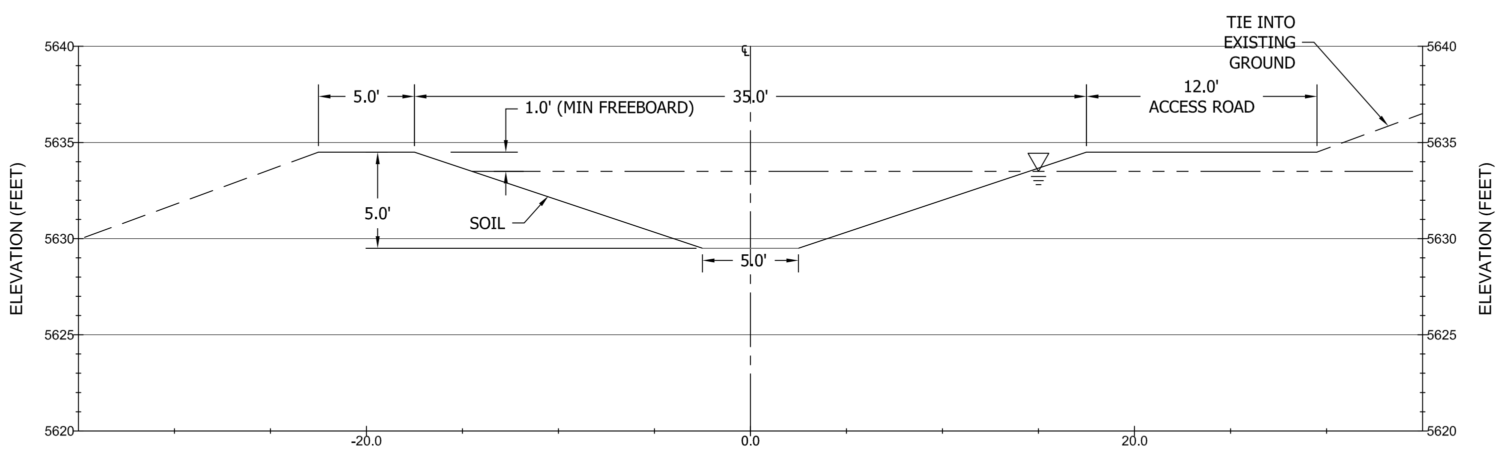
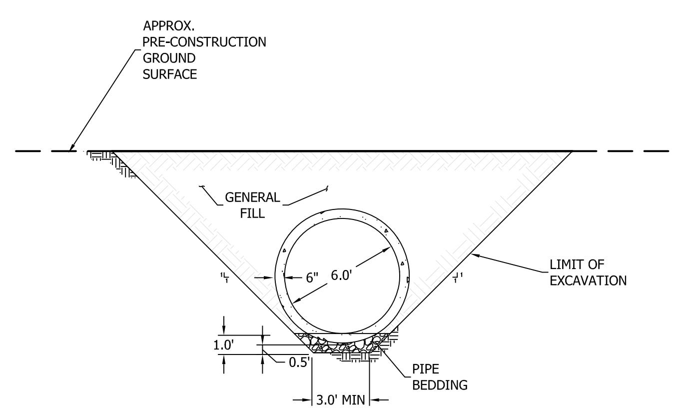
Check	DTH	08/18	
Plot Date 08/01/2018	△		Drawing No. A.2-1-5



UNLINED CANAL (1)
TYPICAL SECTION

LINED CANAL SECTIONS ARE SIMILAR IN DIMENSION, WITH DETAILS SHOWN ON DRAWING A.2-1-2.



PIPE TRENCH (B)
TYPICAL SECTION

0 2 5 10 15
Scale in Feet

DETAILS FOR THE CANAL ALIGNMENT, DIVERSION DAM, AND SIPHON ARE SIMILAR TO THE 400 CFS FLOW RATE FOR THE 100 CFS FLOW RATE (SEE DRAWINGS A.2-1-1 THROUGH A.2-1-5. DIFFERENCES IN DIMENSIONS ARE PROVIDED IN SECTION 4.2.2.

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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WOLF CREEK DAM - 100 CFS CANAL
GRAVITY FILL CANAL & PIPELINE
TYPICAL CANAL & PIPELINE SECTIONS FOR 100 CFS FLOW RATE

CLIENT	RBWCD	
DESIGN	AWT	08/18
DRAWN	AWT	08/18
CHECK	DTH	08/18
PLOT DATE	08/01/2018	

WHEELER No. 1656.07.01
SHEET No. 1 of 1
DRAWING No. A.2-2.1

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APPENDIX A.3 – WHITE RIVER DAM FIGURES

Figure A.3-1-1 – White River Dam – 20,000 Acre-Foot – Overall Map

Figure A.3-1-2 - White River Dam – 20,000 Acre-Foot – Dam Plan View

Figure A.3-1-3 - White River Dam – 20,000 Acre-Foot – Dam Profile

Figure A.3-1-4 - White River Dam – 20,000 Acre-Foot – Dam Section

Figure A.3-2-1 – White River Dam – 90,000 Acre-Foot – Overall Map

Figure A.3-2-2 - White River Dam – 90,000 Acre-Foot – Dam Plan View

Figure A.3-2-3 - White River Dam – 90,000 Acre-Foot – Dam Profile

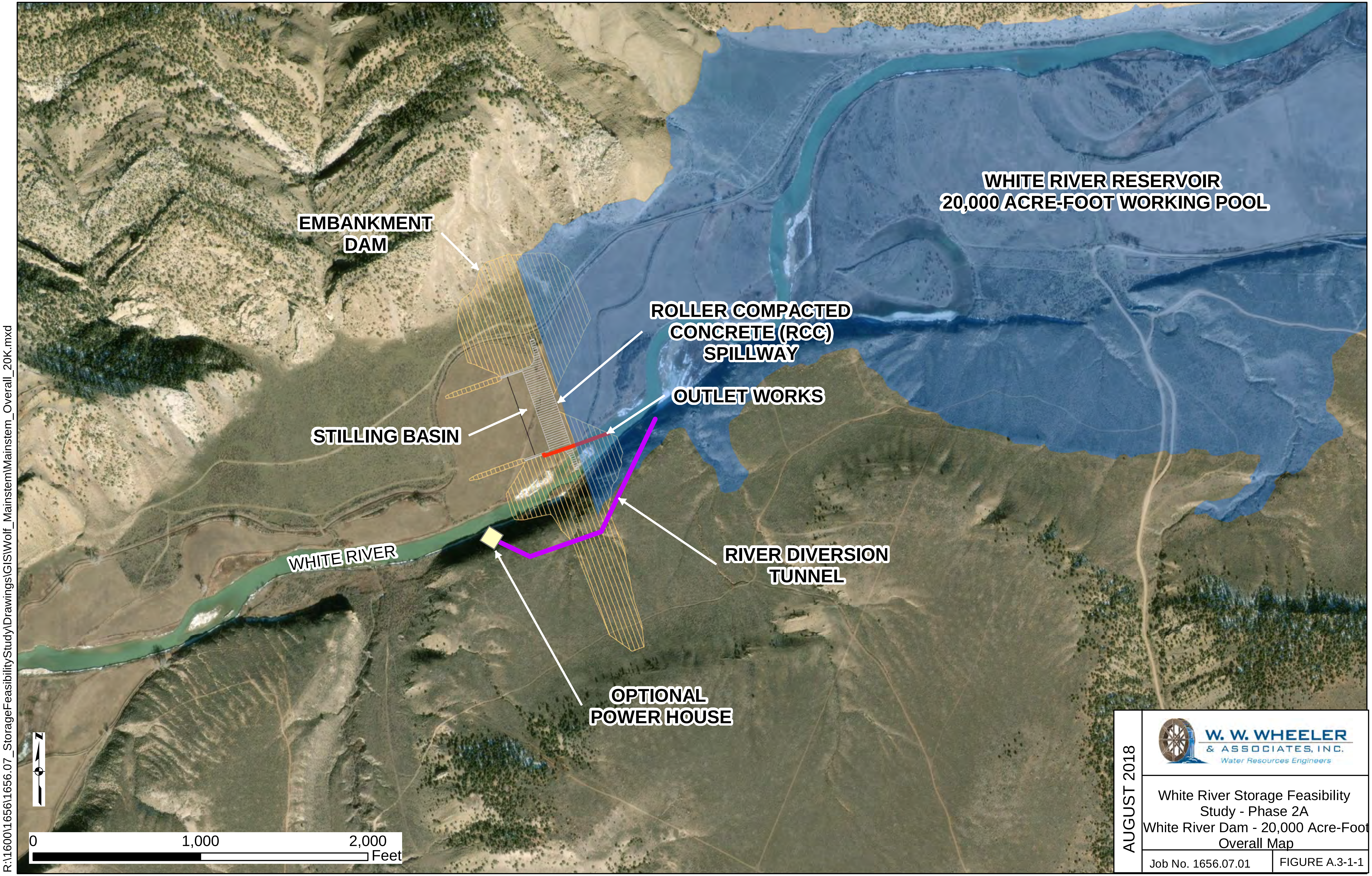
Figure A.3-2-4 - White River Dam – 90,000 Acre-Foot – Dam Section

Figure A.3-3-1 – White River Dam – Maximum Storage – Overall Map

Figure A.3-3-2 - White River Dam – Maximum Storage – Dam Plan View

Figure A.3-3-3 - White River Dam – Maximum Storage – Dam Profile

Figure A.3-3-4 - White River Dam – Maximum Storage – Dam Section


WHITE RIVER RESERVOIR
20,000 ACRE-FOOT WORKING POOL
EMBANKMENT DAM
ROLLER COMPACTED CONCRETE (RCC) SPILLWAY
OUTLET WORKS
STILLING BASIN
RIVER DIVERSION TUNNEL
WHITE RIVER
OPTIONAL POWER HOUSE
0
1,000
2,000
Feet
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AUGUST 2018
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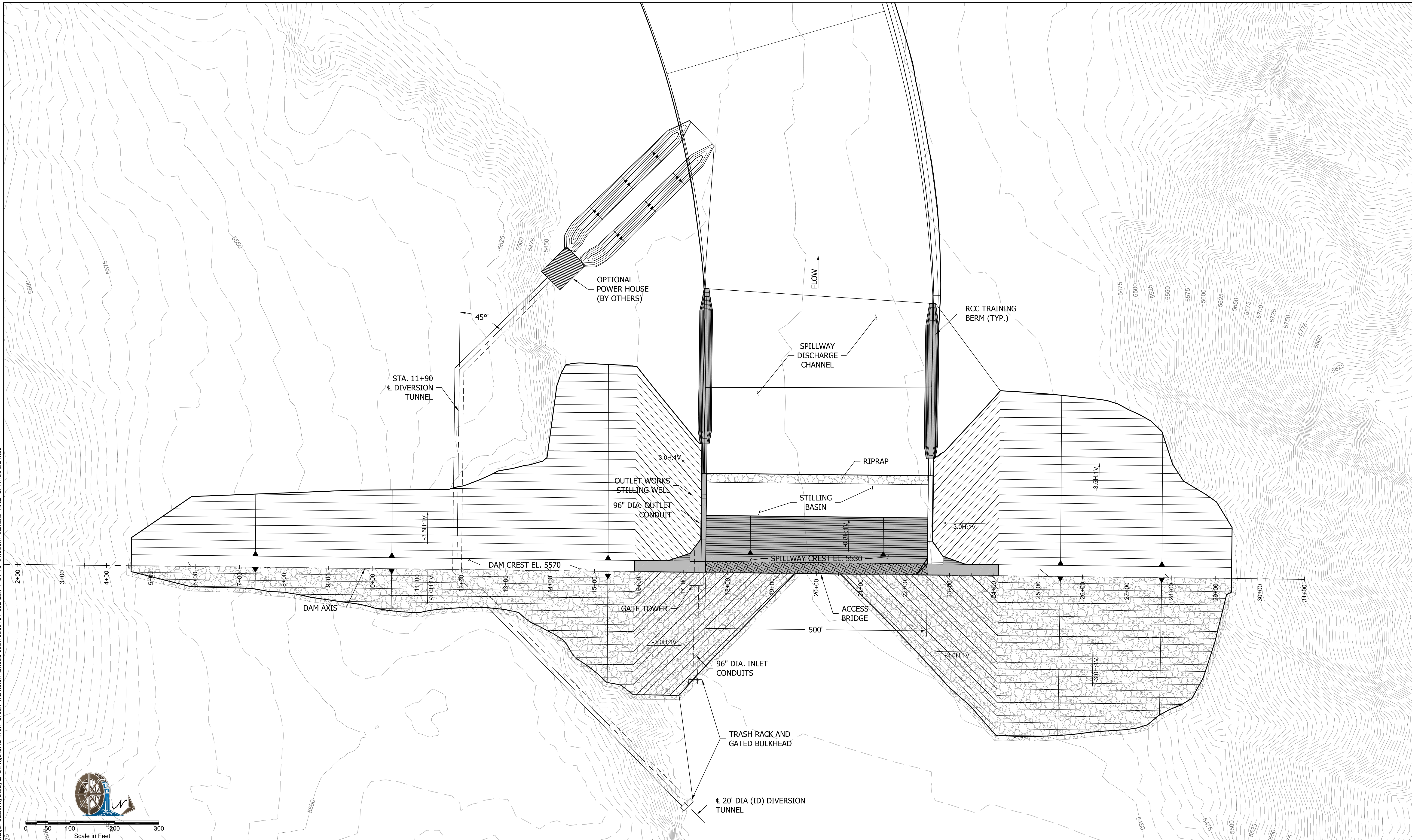
Water Resources Engineers
White River Storage Feasibility Study - Phase 2A
White River Dam - 20,000 Acre-Foot
Overall Map
Job No. 1656.07.01
FIGURE A.3-1-1



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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - 20,000 ACRE-FOOT
DAM PLAN VIEW

Client	RIO BLANCO WATER CONSERVANCY DISTRICT	
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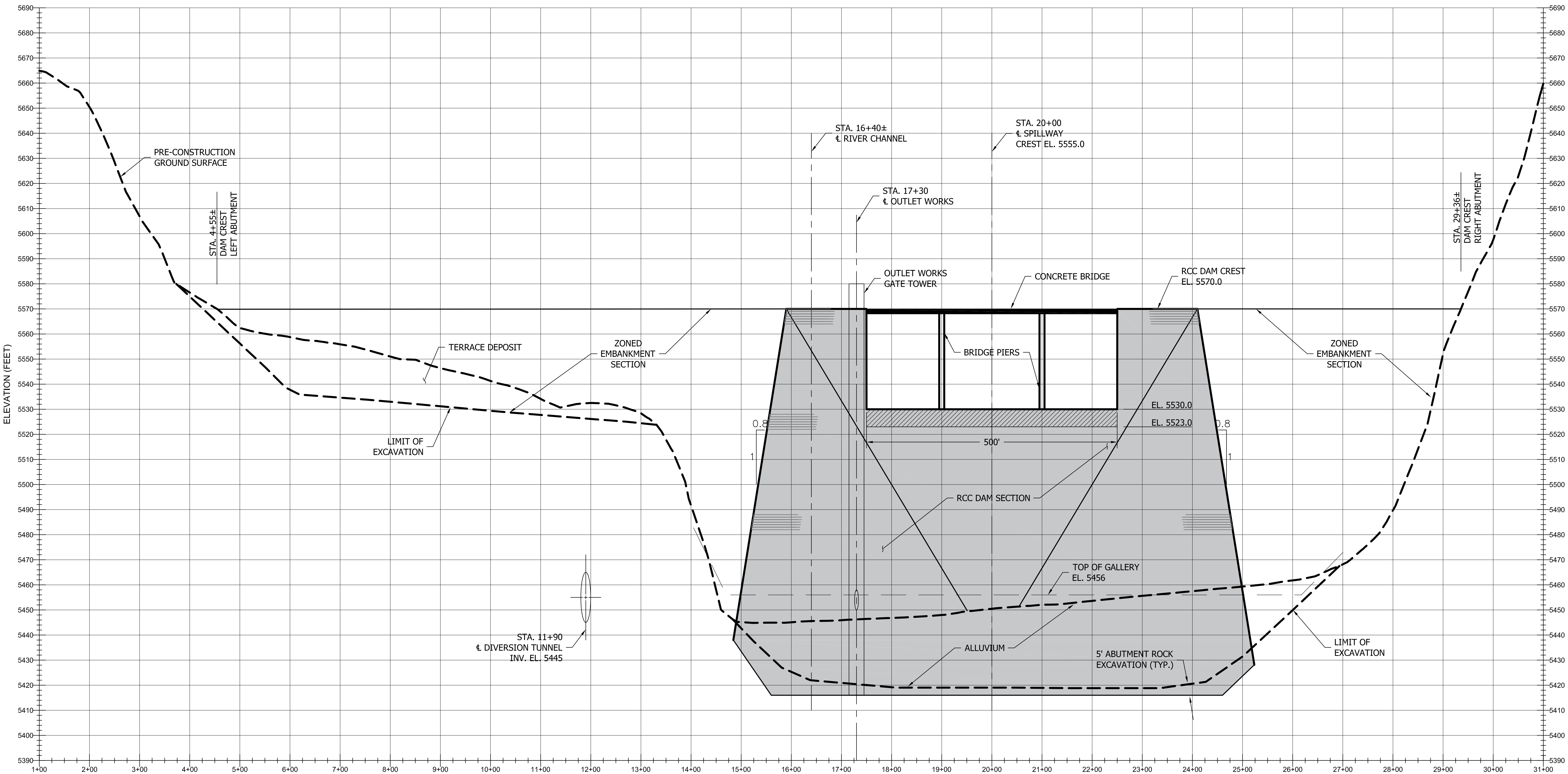
Check	DTH	
Plot Date 07/31/2018	A	Drawing No. A.3-1-2



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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - 20,000 ACRE-FOOT
DAM PROFILE

CLIENT: RIO BLANCO WATER CONSERVANCY DISTRICT

DESIGN	YKC	WHEELER NO.	1656.07.01
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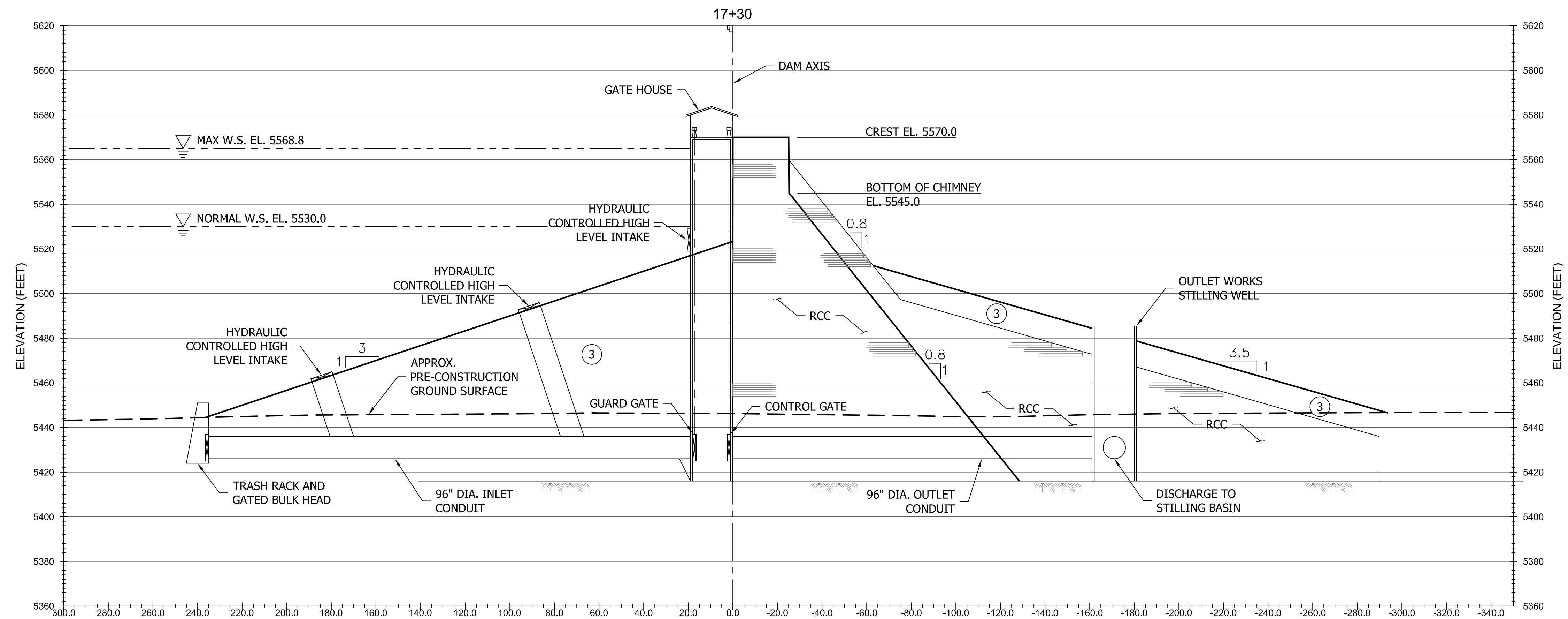
PLOT DATE	07/31/2018	DRAWING NO.	A.3-1-3



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REFERENCE Sheet No.	Drawing No.	Title

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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - 20,000 ACRE-FOOT
DAM SECTION

Client	RIO BLANCO WATER CONSERVANCY DISTRICT	
Design	YKC	Wheeler No. 1656.07.01
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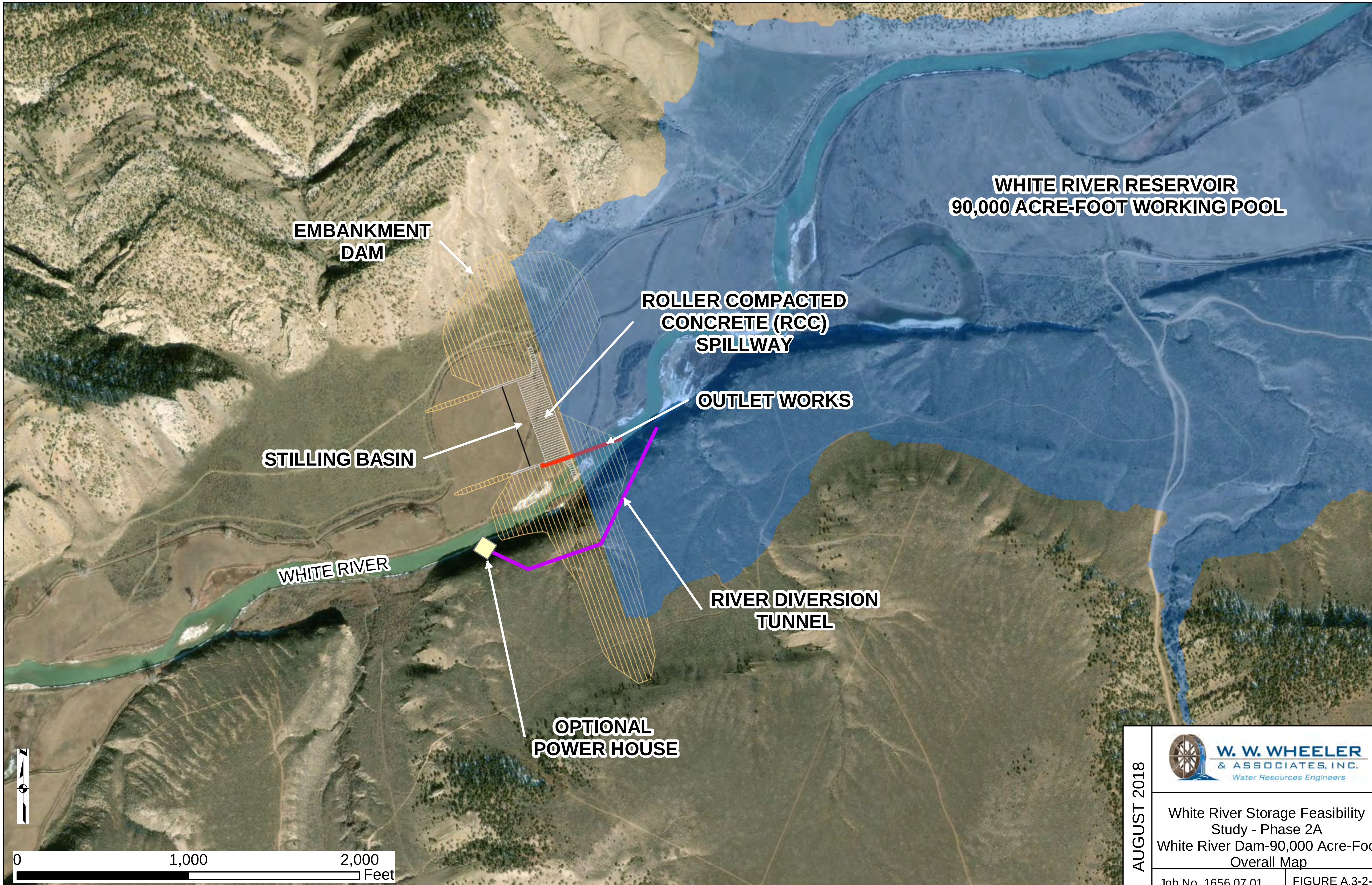
Plot Date 07/31/2018	A	Drawing No. A.3-1-4



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White River Storage Feasibility Study - Phase 2A
White River Dam-90,000 Acre-Foot Overall Map

Job No. 1656.07.01

FIGURE A.3-2-1

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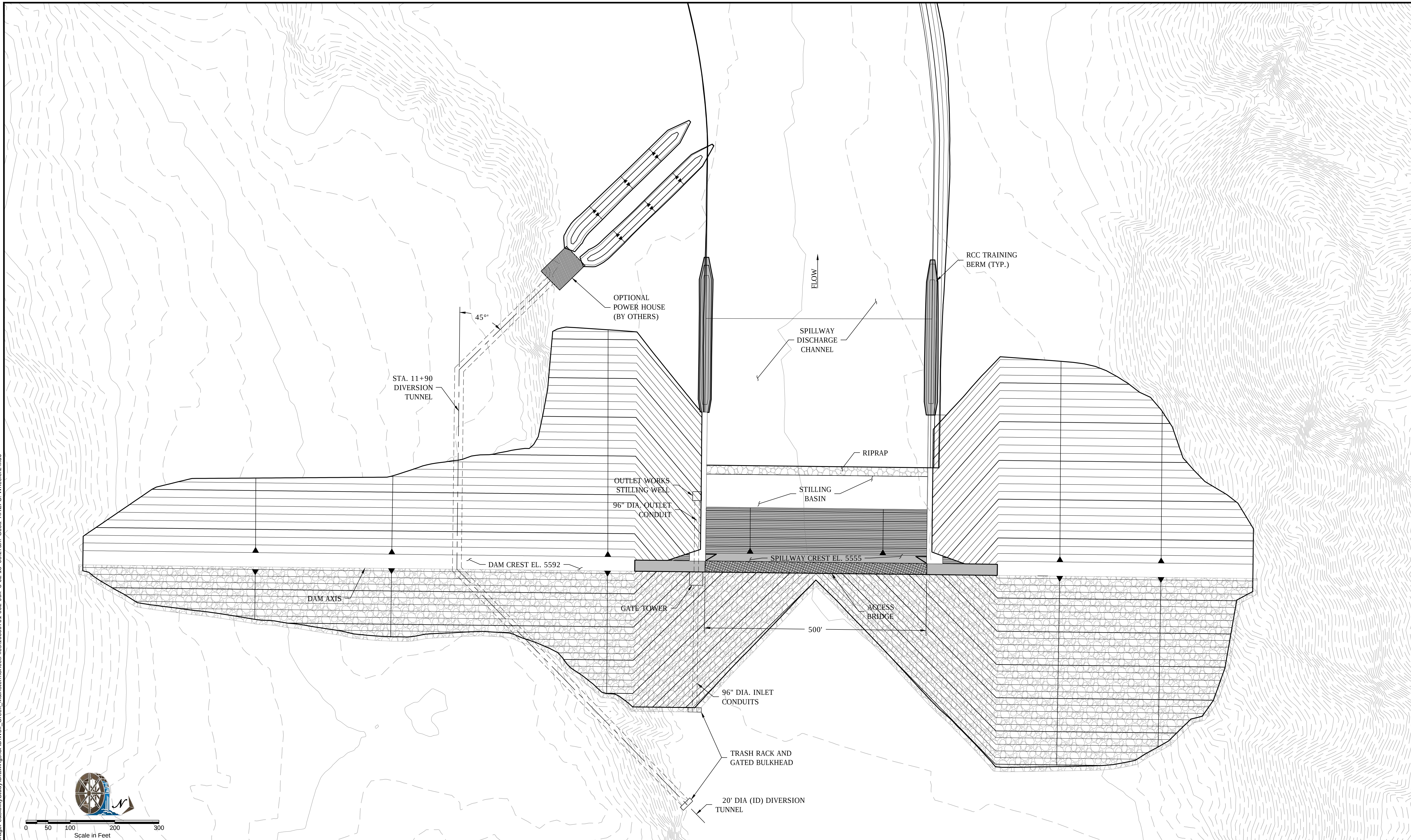

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WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - 90,000 ACRE-FOOT
DAM PLAN VIEW

Client	RIO BLANCO WATER CONSERVANCY DISTRICT		
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Drawn	SAA	Sheet No.	2 of 4
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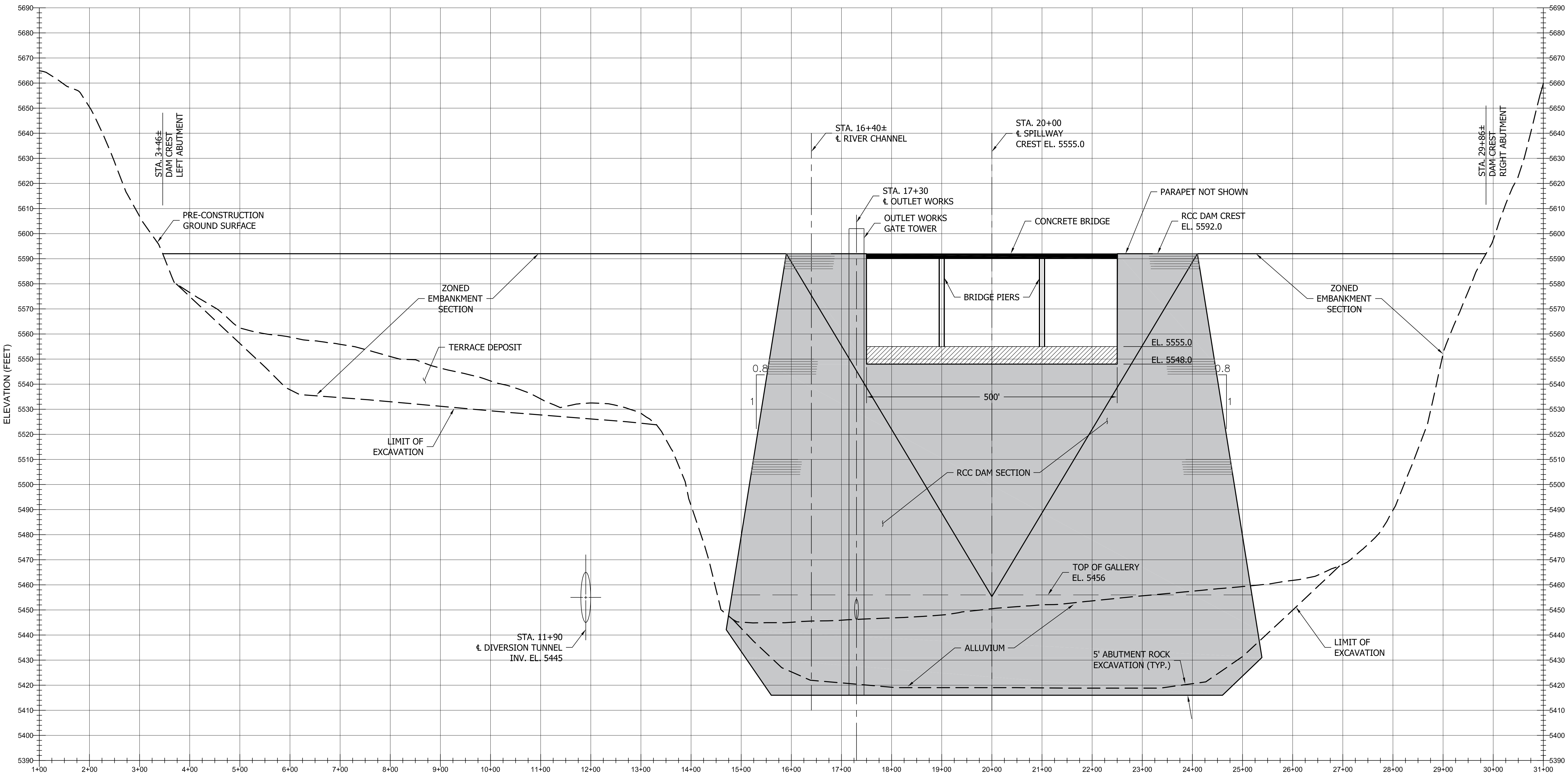

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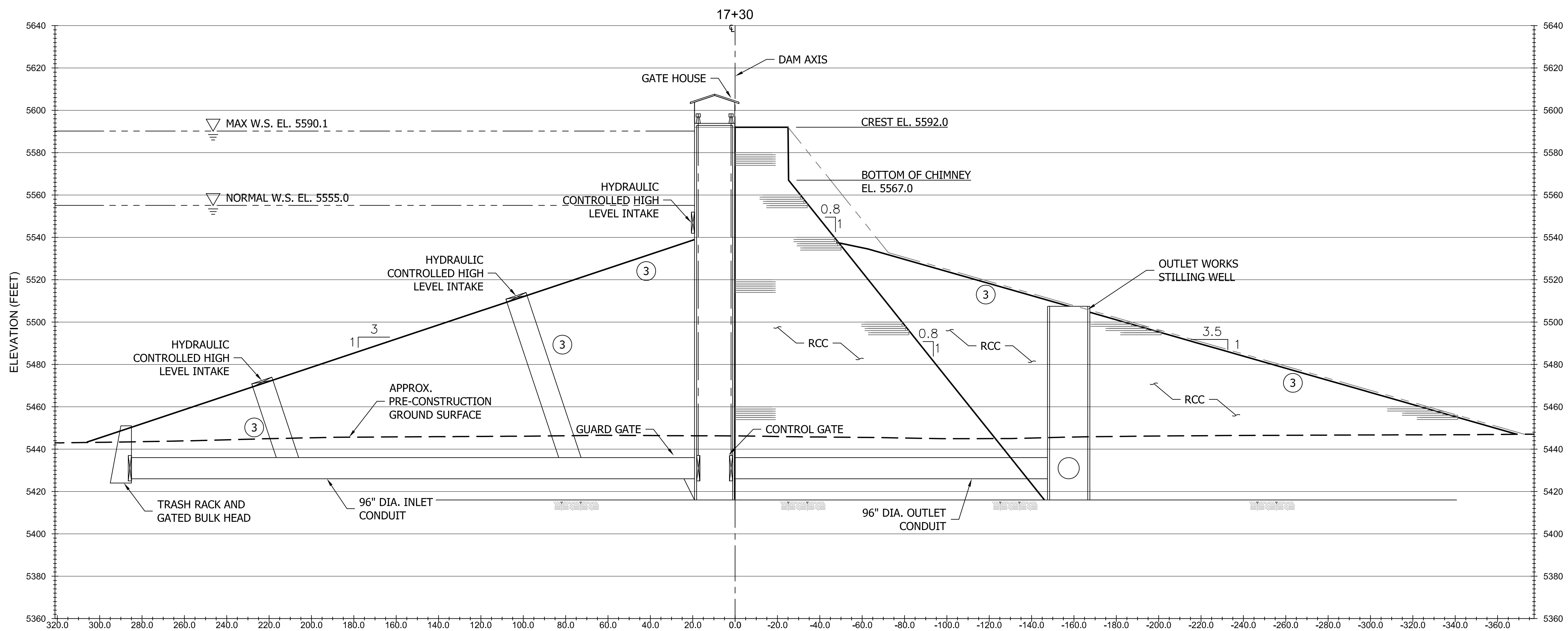
WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - 90,000 ACRE-FOOT
DAM PROFILE

Client	RIO BLANCO WATER CONSERVANCY DISTRICT	
Design	YKC	Wheeler No. 1656.07.01
Drawn	SAA	Sheet No. 3 of 4
Check	DTH	
Plot Date 07/31/2018	A	Drawing No. A.3-2-3



OUTLET WORKS
SECTION
B
A.2-5

Revisions No.	Date	Made	Checked	Remarks
A	04/18	DTH	SLJ	DRAFT REPORT

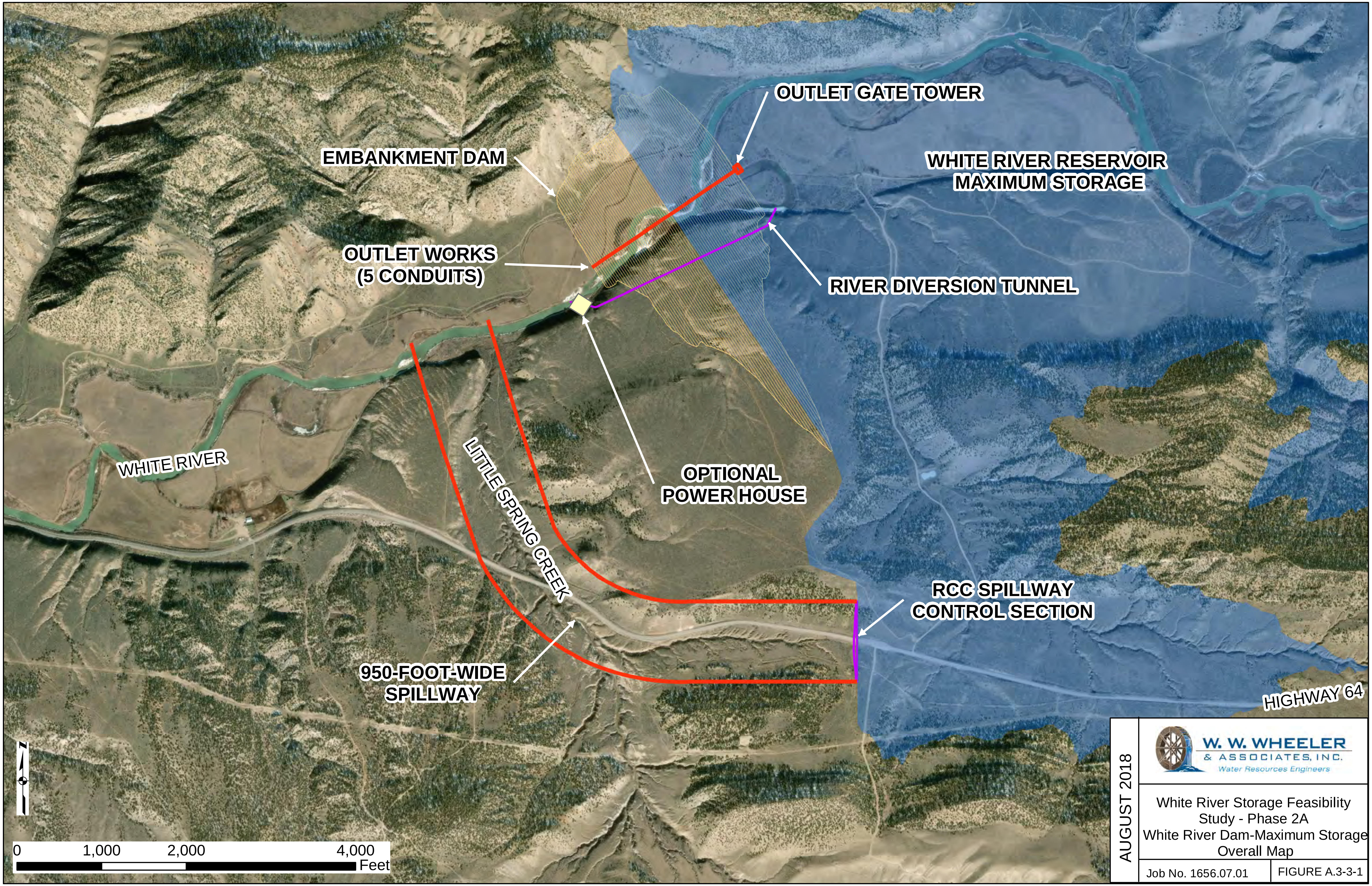
Reference Sheet No.	Drawing No.	Title

PRELIMINARY ONLY
NOT FOR CONSTRUCTION

W. W. WHEELER & ASSOCIATES, INC
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | fax 303-761-2802

WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - 90,000 ACRE-FOOT
DAM SECTION

Client	RIO BLANCO WATER CONSERVANCY DISTRICT	
Design	YKC	Wheeler No. 1656.07.01
Drawn	SAA	Sheet No. 4 of 4
Check	DTH	
Plot Date	07/31/2018	A	Drawing No. A.3-2-4



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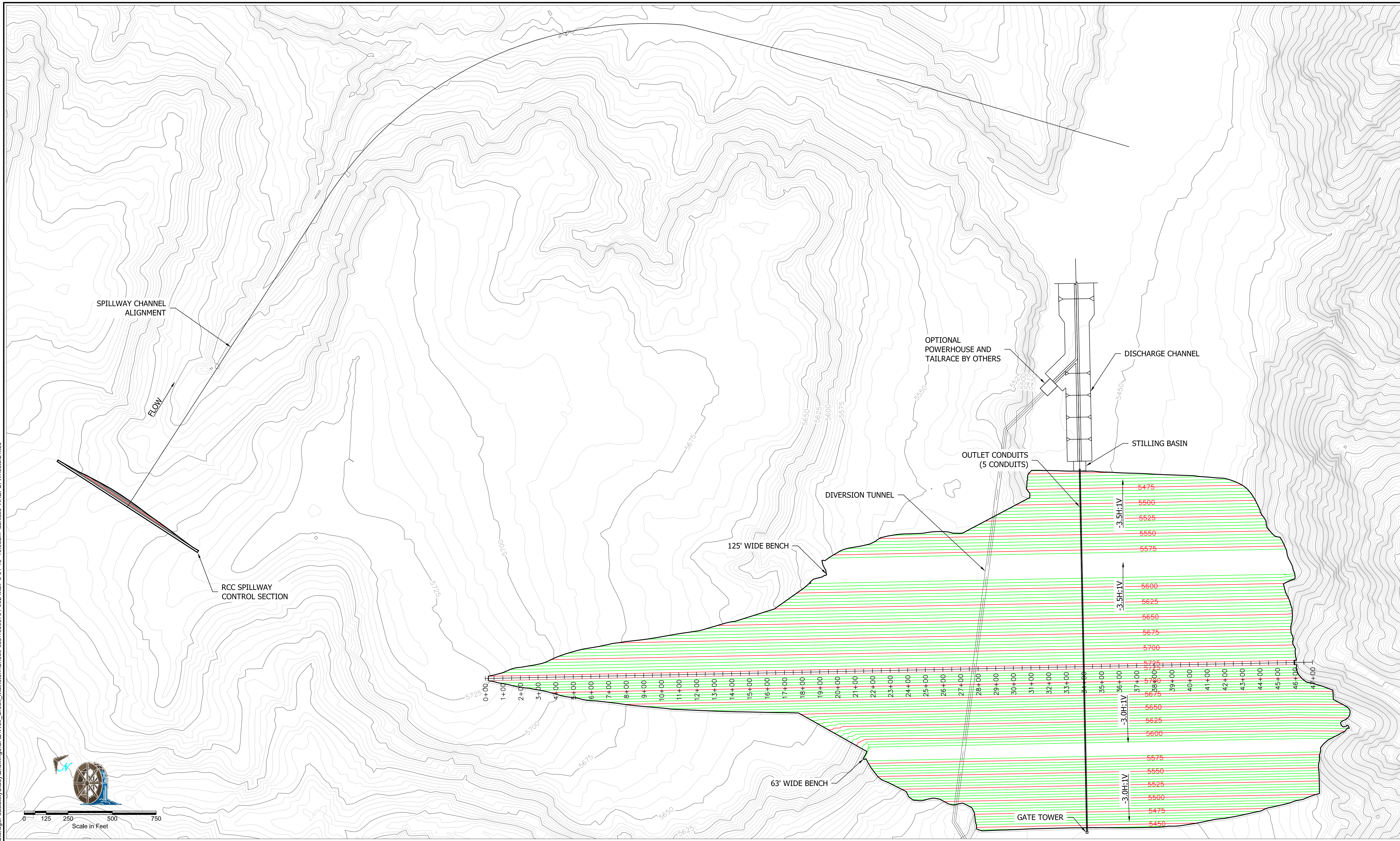
AUGUST 2018

W. W. WHEELER & ASSOCIATES, INC.
Water Resources Engineers

White River Storage Feasibility Study - Phase 2A
White River Dam-Maximum Storage Overall Map

Job No. 1656.07.01

FIGURE A.3-3-1



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REVISIONS

No.	Date	Made	Checked	Remarks
A	04/18	DTH	SLJ	DRAFT REPORT

REFERENCE

Sheet No.	Drawing No.	Title

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Water Resources Engineers
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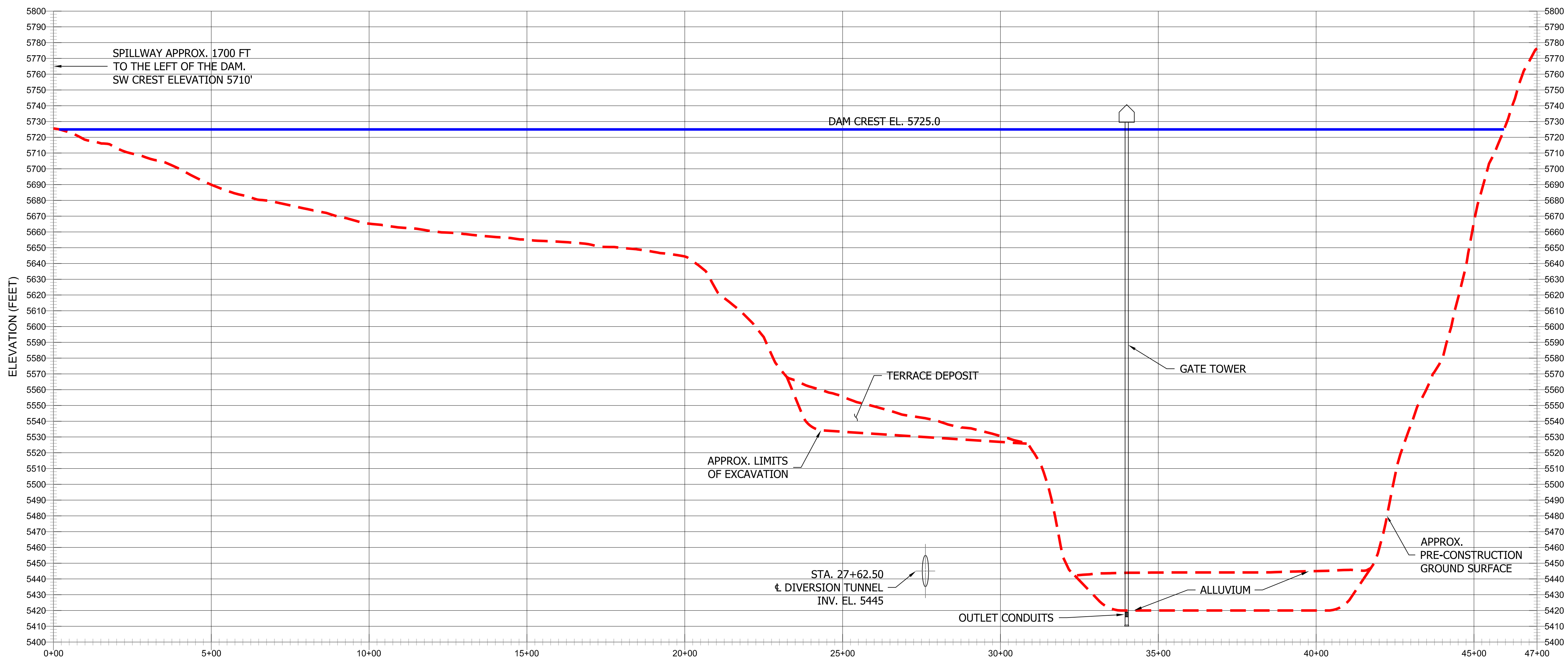
303-761-4130 | fax 303-761-2802

WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - MAXIMUM STORAGE
DAM PLAN VIEW

Client	RIO BLANCO WATER CONSERVANCY DISTRICT		
Design	DTH	Wheeler No.	1656.07.01
Drawn	AWT	Sheet No.	2 of 4
Check	SLJ		
Plot Date	08/01/2018	Drawing No.	A.3-3.2



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REVISIONS

No.	Date	Made	Checked	Remarks
A	04/18	DTH	SLJ	DRAFT REPORT

REFERENCE

Sheet No.	Drawing No.	Title

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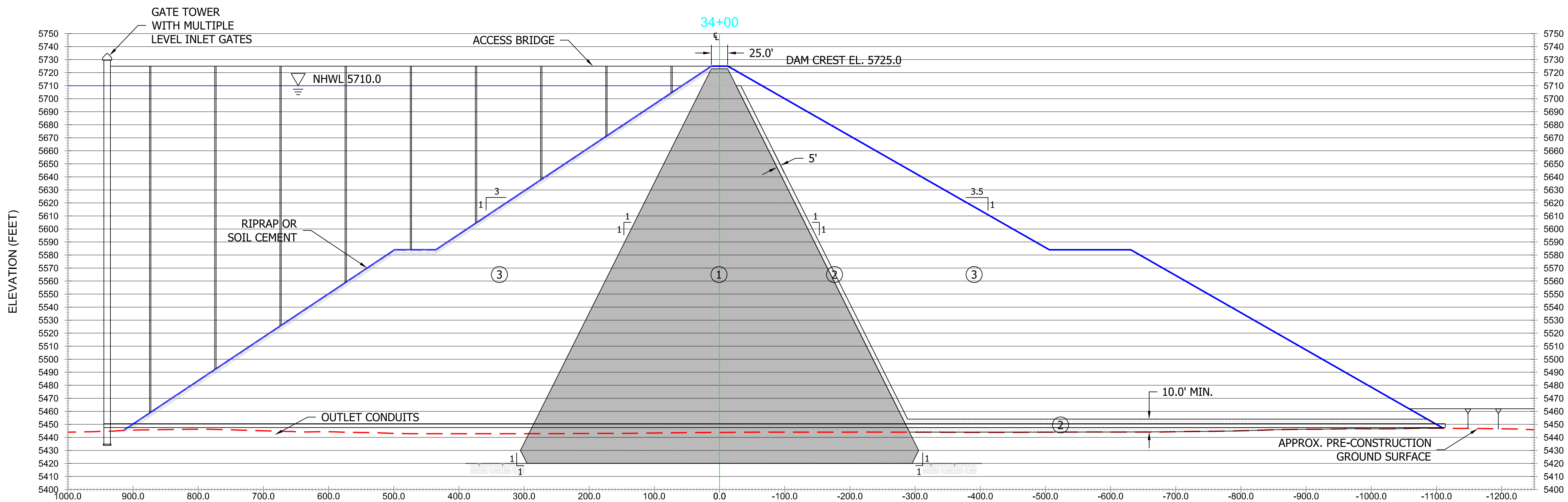
Water Resources Engineers
3700 S. Inca Street | Englewood, CO 80110-3405
303-761-4130 | fax 303-761-2802

WHITE RIVER STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - MAXIMUM STORAGE
DAM PROFILE

Client: RIO BLANCO WATER CONSERVANCY DISTRICT
Design: YKC
Drawn: SAA
Check: DTH
Plot Date: 08/01/2018
Revision: A
Wheeler No.: 1656.07.01
Sheet No.: 3 of 4
Drawing No.: A.3-3-3



MAXIMUM SECTION AT OUTLET WORKS
STA. 34+00

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REVISIONS

No.	Date	Made	Checked	Remarks
A	04/18	DTH	SLJ	DRAFT REPORT

REFERENCE

Sheet No.	Drawing No.	Title

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& ASSOCIATES, INC
Water Resources Engineers
3700 S. INCA STREET | ENGLEWOOD, CO 80110-3405
303-761-4130 | FAX 303-761-2802

PHASE 2A STORAGE FEASIBILITY STUDY
PHASE 2A
WHITE RIVER DAM - MAXIMUM STORAGE
DAM SECTIONS

CLIENT	RIO BLANCO WATER CONSERVANCY DISTRICT		
DESIGN	DTH	WHEELER NO.	1656.07.01
DRAWN	AWT	SHEET NO.	4 of 4
CHECK	SLJ		
PLOT DATE	08/01/2018	A	DRAWING NO. A.3-3-4

APPENDIX B
FEASIBILITY-LEVEL COST OPINIONS

Page B1 - Wolf Creek Dam – 20,000 Acre-Foot

Page B2 - Wolf Creek Dam – 90,000 Acre-Foot

Page B3 - Wolf Creek Dam – Maximum Storage

Page B4 – White River Dam – 20,000 Acre-Foot

Page B5 - White River Dam – 90,000 Acre-Foot

Page B6 - White River Dam – Maximum Storage

2018 FEASIBILITY-LEVEL OPINION OF PROBABLE PROJECT INVESTMENT
WOLF CREEK DAM 20,000 AF WORKING POOL
RIO BLANCO WATER CONSERVANCY DISTRICT

Item No.	Description	Quantity	Unit	Unit Price	Amount		
					Canal Fill	Pipeline Fill	Pump Fill
1	Site Access Roads	1	LS	$ 3,206,000.00		$3,206,000	
2	Creek Diversion	1	LS	$ 461,000.00		$461,000	
3	Clearing & Grubbing	26	acres	$ 7,000.00		$182,000	
	Site Preparation Subtotal					**$3,849,000**	
4	Foundation Dewatering	1	LS	$ 550,000.00		$550,000	
5	Foundation Treatment (Cleaning & Dental Concrete)	1	LS	$ 2,226,000.00		$2,226,000	
6	Foundation Grouting	1	LS	$ 667,000.00		$667,000	
	Foundation Preparation					**$3,443,000**	
7	Service Spillway/Outlet Conduit	700	LF	$ 4,225.00		$2,958,000	
8	Outlet Tower	675	CY	$ 1,500.00		$1,013,000	
9	Outlet Bridge	1	LS	$ 544,000.00		$544,000	
10	Outlet Gates & Trashrack	1	LS	$ 2,618,000.00		$2,618,000	
11	Terminal Structure	1	LS	$ 556,000.00		$556,000	
12	Discharge Channel to White River	1	LS	$ 634,000.00		$634,000	
	Outlet Subtotal					**$8,323,000**	
13	Stripping & Stockpiling Topsoil	14,200	CY	$ 6.00		$85,000	
14	Excavation	80,800	CY	$ 5.00		$404,000	
15	Furnishing & Placing Zone 1 Fill	740,000	CY	$ 7.00		$5,180,000	
16	Furnishing & Placing Zone 3 Fill	1,016,000	CY	$ 5.00		$5,080,000	
17	Furnishing & Placing Filter/Drain Sand (Zone 2)	165,000	CY	$ 45.00		$7,425,000	
18	Furnishing & Placing Toe Drain	2,250	LF	$ 68.00		$153,000	
19	Furnishing & Placing Slope Protection	61,000	CY	$ 70.00		$4,270,000	
20	Furnishing and Placing Basecourse	1,050	CY	$ 92.00		$97,000	
21	Placing Topsoil	10,700	CY	$ 10.00		$107,000	
	Earthwork Subtotal					**$22,801,000**	
22	Spillway Soil Excavation	43,700	CY	$ 5.00		$219,000	
23	Spillway Rock Excavation	84,400	CY	$ 31.00		$2,616,000	
24	Concrete Control Sections	400	LF	$ 300.00		$120,000	
25	Spillway Chute Berms	82,500	CY	$ 5.00		$413,000	
26	Spillway Erosion Protection	1	LS	$ 1,785,000.00		$1,785,000	
	Spillway Subtotal					**$5,153,000**	
27	Siphons	11,400	LF	$ 1,450.00	$ 16,530,000		
28	Concrete Lined Canal	1,600	LF	$ 950.00	$ 1,520,000		
29	Membrane Lined Canal	65,700	LF	$ 220.00	$ 14,454,000		
30	Non-Lined Canal	122,000	LF	$ 150.00	$ 18,300,000		
31	Diversion Dam	1	LS	$ 890,000.00	$ 890,000		
32	Road Crossings (Paved)	1	EA	$ 362,000.00	$ 362,000		
33	Road Crossings (Gravel)	50	EA	$ 30,000.00	$ 1,500,000		
A1	Siphons	11,400	LF	$ 1,450.00		$ 16,530,000	
A2	Pipeline	189,200	LF	$ 600.00		$ 113,520,000	
A3	Diversion Dam	1	LS	$ 890,000.00		$ 890,000	
B1	Construct Power Facilities to Site for Pumping	2	miles	$ 100,000.00			$ 150,000
B2	Pump Station	1	LS	$ 11,056,000.00			$ 11,056,000
B3	Pipeline from Pump Station to Reservoir	3,100	LF	$ 680.00			$ 2,108,000
	Fill Facilities Subtotal				**$53,556,000**	**$130,940,000**	**$13,314,000**
34	Reseeding	53	acres	$ 1,300.00		$69,000	
35	Instrumentation	1	LS	$ 100,000.00		$100,000	
	Miscellaneous Items Subtotal					**$169,000**	
	Listed Items Subtotal				**$97,294,000**	**$174,678,000**	**$57,052,000**
Base Construction Subtotal (BCS)					**$97,294,000**	**$174,678,000**	**$57,052,000**
---	Unlisted Items (20% of subtotal of listed items)				$19,459,000	$34,936,000	$11,410,000
	Mobilization, Bonds, Insurance (10% of BCS)				$9,730,000	$17,470,000	$5,710,000
Direct Construction Subtotal (DCS)					**$126,483,000**	**$227,084,000**	**$74,172,000**
	Construction Change Order Contingency (25% of BCS & Mobilization …)				$26,760,000	$48,040,000	$15,690,000
	Final Design Engineering (10% of DCS)				$12,650,000	$12,650,000	$7,420,000
	Permitting and Mitigation (assumed lean permitting)				$10,000,000	$10,000,000	$10,000,000
	Public Outreach (0.5% of DCS)				$630,000	$1,140,000	$370,000
	Land Easement/Purchases (Dam & Reservoir)				$2,500,000	$2,500,000	$2,500,000
	Land Easement/Purchases (Canal)				$800,000	$800,000	$0
	Legal and Administrative Costs (2% of DCS)				$2,530,000	$4,540,000	$1,480,000
	Construction Administration and Engineering (10% of DCS)				$12,650,000	$22,710,000	$7,420,000
TOTAL ESTIMATED PROJECT COST					**$195,003,000**	**$329,464,000**	**$119,052,000**

	Canal Fill	Pipeline Fill	Pump Fill
Cost per AF (20K AF Working Pool)	$9,750.00	$16,473.00	$5,953.00
Cost per AF (41K AF Total Pool)	$4,756.00	$8,036.00	$2,904.00
Low Range	***$ 136,500,000***	***$ 230,620,000***	***$ 83,340,000***
High Range	***$ 292,500,000***	***$ 494,200,000***	***$ 178,580,000***

Note: Cost opinion is based on 2018 dollars and will increase due to inflation each year.

2018 FEASIBILITY-LEVEL OPINION OF PROBABLE PROJECT INVESTMENT
WOLF CREEK DAM 90,000 AF WORKING POOL
RIO BLANCO WATER CONSERVANCY DISTRICT

Item No.	Description	Quantity	Unit	Unit Price	Amount Canal Fill	Amount Pump Fill
1	Site Access Roads	1	LS	$ 3,206,000	$3,206,000	
2	Creek Diversion	1	LS	$ 472,000	$472,000	
3	Clearing & Grubbing	50	acres	$ 7,000.00	$350,000	
	Site Preparation Subtotal				**$4,028,000**	
4	Foundation Dewatering	1	LS	$ 550,000.00	$550,000	
5	Foundation Treatment (Cleaning & Dental Concrete)	1	LS	$ 3,392,000.00	$3,392,000	
6	Foundation Grouting	1	LS	$ 1,140,000.00	$1,140,000	
	Foundation Preparation				**$5,082,000**	
7	Service Spillway/Outlet Conduit	900	LF	$ 4,225.00	$3,803,000	
8	Outlet Tower	820	CY	$ 1,500.00	$1,230,000	
9	Outlet Bridge	1	LS	$ 771,000.00	$771,000	
10	Outlet Gates & Trashrack	1	LS	$ 2,618,000.00	$2,618,000	
11	Terminal Structure	1	LS	$ 641,000.00	$641,000	
12	Discharge Channel to White River	1	LS	$ 521,000.00	$521,000	
	Outlet Subtotal				**$9,584,000**	
13	Stripping & Stockpiling Topsoil	26,000	CY	$ 6.00	$156,000	
14	Excavation	124,000	CY	$ 5.00	$620,000	
15	Furnishing & Placing Zone 1 Fill	1,443,000	CY	$ 7.00	$10,101,000	
16	Furnishing & Placing Zone 3 Fill	2,262,000	CY	$ 5.00	$11,310,000	
17	Furnishing & Placing Filter/Drain Sand (Zone 2)	292,000	CY	$ 45.00	$13,140,000	
18	Furnishing & Placing Toe Drain	3,900	LF	$ 68.00	$265,000	
19	Furnishing & Placing Slope Protection	115,000	CY	$ 70.00	$8,050,000	
20	Furnishing and Placing Basecourse	3,600	CY	$ 92.00	$331,000	
21	Placing Topsoil	19,000	CY	$ 10.00	$190,000	
	Earthwork Subtotal				**$44,163,000**	
22	Spillway Soil Excavation	47,000	CY	$ 5.00	$235,000	
23	Spillway Rock Excavation	64,000	CY	$ 31.00	$1,984,000	
24	Concrete Control Section	400	LF	$ 300.00	$120,000	
25	Spillway Chute Berms	77,400	CY	$ 5.00	$387,000	
26	Spillway Erosion Protection	1	LS	$ 2,432,000.00	$2,432,000	
	Spillway Subtotal				**$5,158,000**	
27	Siphons	11,400	LF	$ 3,100.00	$35,340,000	
28	Concrete Lined Canal	1,600	LF	$ 1,500.00	$2,400,000	
29	Membrane Lined Canal	65,700	LF	$ 350.00	$22,995,000	
30	Non-Lined Canal	122,000	LF	$ 240.00	$29,280,000	
31	Diversion Dam	1	LS	$ 1,090,000.00	$1,090,000	
32	Road Crossings (Paved)	1	LS	$ 570,000.00	$570,000	
33	Road Crossings (Gravel)	50	EA	$ 50,000.00	$2,500,000	
B1	Construct Power Facilities to Site for Pumping	1.5	miles	$ 100,000.00		$150,000
B2	Pump Station	1	LS	$ 22,000,000.00		$22,000,000
B3	Pipeline from Pump Station to Reservoir	3,100	LF	$ 1,400.00		$4,340,000
	Fill Facilities Subtotal				**$94,175,000**	**$26,490,000**
34	Reseeding	100	acres	$ 1,300.00	$130,000	
35	Instrumentation	1	LS	$ 100,000.00	$100,000	
	Miscellaneous Items Subtotal				**$230,000**	
	Listed Items Subtotal				**$162,420,000**	**$94,735,000**
Base Construction Subtotal (BCS)					**$162,420,000**	**$94,735,000**
---	Unlisted Items (20% of subtotal of listed items)				$32,484,000	$18,947,000
	Mobilization, Bonds, Insurance (10% of BCS)				$16,240,000	$9,470,000
Direct Construction Subtotal (DCS)					**$211,144,000**	**$123,152,000**
	Construction Change Order Contingency (25% of BCS & Mobilization …)				$44,670,000	$26,050,000
	Final Design Engineering (10% of DCS)				$21,110,000	$12,320,000
	Permitting and Mitigation (assumed lean permitting)				$10,000,000	$10,000,000
	Public Outreach (0.5% of DCS)				$1,060,000	$620,000
	Land Easement/Purchases (Dam & Reservoir)				$4,130,000	$4,130,000
	Land Easement/Purchases (Canal)				$1,030,000	$0
	Legal and Administrative Costs (2% of DCS)				$4,220,000	$2,460,000
	Construction Administration and Engineering (10% of DCS)				$21,110,000	$12,320,000
TOTAL ESTIMATED PROJECT COST					**$318,474,000**	**$191,052,000**

	Canal Fill	Pump Fill
Cost per AF (90K AF Working Pool)	$3,539.00	$2,123.00
Cost per AF (130K AF Total Pool)	$2,450.00	$1,470.00
Low Range	***$ 222,930,000***	***$ 133,740,000***
High Range	***$ 477,710,000***	***$ 286,580,000***

Note: Cost opinion is based on 2018 dollars and will increase due to inflation each year.

2018 FEASIBILITY-LEVEL OPINION OF PROBABLE PROJECT INVESTMENT
WOLF CREEK MAX AF
RIO BLANCO WATER CONSERVANCY DISTRICT

Item No.	Description	Quantity	Unit	Unit Price	Amount	
					Canal Fill	Pump Fill
1	Site Access Roads (site & pump facility)	1	LS	$ 3,206,000.00	$ 3,206,000.00	
2	Creek Diversion	1	LS	$ 529,000.00	$ 529,000.00	
3	Clearing & Grubbing	280	acres	$ 7,000.00	$ 1,960,000.00	
3.5	Highway 40 Impacts	1	LS	$ 17,930,000.00	$ 17,930,000.00	
	Site Preparation Subtotal				$ 23,625,000.00	
4	Foundation Dewatering	1	LS	$ 1,000,000.00	$ 1,000,000.00	
5	Foundation Treatment (Cleaning & Dental Concrete)	1	LS	$ 19,871,000.00	$ 19,871,000.00	
6	Foundation Grouting	1	LS	$ 4,980,000.00	$ 4,980,000.00	
	Foundation Preparation				$ 25,851,000.00	
7	Service Spillway/Outlet Conduit	8,000	LF	$ 4,225.00	$ 33,800,000.00	
8	Outlet Tower	3,650	CY	$ 1,500.00	$ 5,475,000.00	
9	Outlet Bridge	1	LS	$ 1,543,000.00	$ 1,543,000.00	
10	Outlet Gates & Trashrack	1	LS	$ 3,491,000.00	$ 3,491,000.00	
11	Terminal Structure	1	LS	$ 817,000.00	$ 817,000.00	
12	Discharge Channel to White River	1	LS	$ 521,000.00	$ 521,000.00	
	Outlet Subtotal				$ 45,647,000.00	
13	Stripping & Stockpiling Topsoil	149,000	CY	$ 6.00	$ 894,000.00	
14	Excavation	721,000	CY	$ 5.00	$ 3,605,000.00	
15	Furnishing & Placing Zone 1 Fill	12,814,000	CY	$ 7.00	$ 89,698,000.00	
16	Furnishing & Placing Zone 3 Fill	25,198,000	CY	$ 5.00	$ 125,990,000.00	
17	Furnishing & Placing Filter/Drain Sand (Zone 2)	1,991,000	CY	$ 45.00	$ 89,595,000.00	
18	Furnishing & Placing Toe Drain	10,900	LF	$ 68.00	$ 741,200.00	
19	Furnishing & Placing Slope Protection	676,000	CY	$ 70.00	$ 47,320,000.00	
20	Furnishing and Placing Basecourse	5,100	CY	$ 92.00	$ 469,200.00	
21	Placing Topsoil	112,000	CY	$ 10.00	$ 1,120,000.00	
	Earthwork Subtotal				$ 359,432,400.00	
22	Spillway Soil Excavation	157,200	CY	$ 5.00	$ 786,000.00	
23	Spillway Rock Excavation	99,900	CY	$ 31.00	$ 3,096,900.00	
24	Concrete Control Sections	400	LF	$ 300.00	$ 120,000.00	
25	Spillway Chute Berms	87,300	CY	$ 5.00	$ 436,500.00	
26	Spillway Erosion Protection	1	LS	$ 4,371,000.00	$ 4,371,000.00	
	Spillway Subtotal				$ 8,810,400.00	
27	Siphons	11,400	LF	$ 3,100.00	$ 35,340,000.00	
28	Concrete Lined Canal	1,600	LF	$ 1,500.00	$ 2,400,000.00	
29	Membrane Lined Canal	65,700	LF	$ 350.00	$ 22,995,000.00	
30	Non-Lined Canal	122,000	LF	$ 240.00	$ 29,280,000.00	
31	Diversion Dam	1	LS	$ 1,090,000.00	$ 1,090,000.00	
32	Road Crossings (Paved)	1	EA	$ 570,000.00	$ 570,000.00	
33	Road Crossings (Gravel)	50	EA	$ 50,000.00	$ 2,500,000.00	
B1	Construct Power Facilities to Site for Pumping	1.5	MI	$ 100,000.00		$ 150,000.00
B2	Pump Station	1	LS	$ 29,500,000.00		$ 29,500,000.00
B3	Pipeline from Pump Station to Reservoir	3,100	LF	$ 1,400.00		$ 4,340,000.00
	Gravity Fill Line Subtotal				$ 94,175,000.00	$ 33,990,000.00
34	Reseeding	560	acres	$ 1,300.00	$ 728,000.00	
35	Instrumentation	1	LS	$ 200,000.00	$ 200,000.00	
	Miscellaneous Items Subtotal				$ 928,000.00	
	Listed Items Subtotal				$ 558,468,800.00	$ 498,283,800.00
Base Construction Subtotal (BCS)					**$558,469,000**	**$498,284,000**
---	Unlisted Items (20% of subtotal of listed items)				$111,694,000	$99,657,000
	Mobilization, Bonds, Insurance (10% of BCS)				$55,850,000	$49,830,000
Direct Construction Subtotal (DCS)					**$726,013,000**	**$647,771,000**
	Construction Change Order Contingency (25% of BCS & Mobilization …)				$153,580,000	$137,030,000
	Final Design Engineering (10% of DCS)				$72,600,000	$64,780,000
	Permitting and Mitigation (assumed 20% for maximum dam)				$145,200,000	$129,550,000
	Public Outreach (0.5% of DCS)				$3,630,000	$3,240,000
	Land Easement/Purchases (Dam & Reservoir)				$18,800,000	$18,800,000
	Land Easement/Purchases (Canal)				$1,030,000	$0
	Legal and Administrative Costs (2% of DCS)				$14,520,000	$12,960,000
	Construction Administration and Engineering (10% of DCS)				$72,600,000	$64,780,000
TOTAL ESTIMATED PROJECT COST					**$1,207,973,000**	**$1,078,911,000**

	Canal Fill	Pump Fill
Cost per AF (1.58M AF Total Pool)	$764.00	$682.00
Low Range	***$ 845,580,000***	***$ 755,240,000***
High Range	***$ 1,811,960,000***	***$ 1,618,370,000***

Note: Cost opinion is based on 2018 dollars and will increase due to inflation each year.

2018 FEASIBILITY-LEVEL OPINION OF PROBABLE PROJECT INVESTMENT
WHITE RIVER DAM AT WOLF CREEK 20,000 AF WORKING POOL
RIO BLANCO WATER CONSERVANCY DISTRICT

Item No.	Description	Quantity	Unit	Unit Price	Amount
1	Site Access Roads	1	LS	3,206,000.00	$ 3,206,000
2	Highway 64 Reconstruction	1	LS	0.00	$ -
3	Stream Diversion Tunnel	1	LS	20,200,000.00	$ 20,200,000
4	Cofferdams for Stream Diversion	1	LS	382,000.00	$ 382,000
5	Clearing and Grubbing	73	acres	7,000.00	$ 511,000
	Site Preparation Subtotal				**$24,299,000**
6	Foundation Rock Excavation	44,700	CY	27.00	$ 1,207,000
7	Unclassified Soil Excavation	755,000	CY	8.00	$ 6,040,000
8	Foundation Dewatering	1	LS	2,000,000.00	$ 2,000,000
9	Foundation Grouting	1	LS	1,003,000.00	$ 1,003,000
10	Foundation Treatment (Cleaning & Dental Concrete)	1	LS	2,126,000.00	$ 2,126,000
11	Foundation Drain Holes	4,200	LF	15.00	$ 63,000
12	Random Fill	158,000	CY	5.00	$ 790,000
	Foundation Preparation				**$13,229,000**
13	Outlet Works Gate Tower	930	CY	1,500.00	$ 1,395,000
14	Outlet Works Pipe (including encasement)	530	LF	4,250.00	$ 2,253,000
15	Stilling Well	290	CY	1,500.00	$ 435,000
16	Sluice Gates, Operators, and Trashracks	1	LS	2,618,000.00	$ 2,618,000
	Outlet Subtotal				**$6,701,000**
17	RCC Test Section	1	LS	100,000.00	$ 100,000
18	Furnishing and Placing RCC	320,000	CY	75.00	$ 24,000,000
19	Furnishing Cement for RCC	1,200	tons	172.00	$ 206,000
20	Furnishing Fly Ash for RCC	1,200	tons	87.00	$ 104,000
21	Unreinforced Facing Concrete	15,800	CY	925.00	$ 14,615,000
22	Reinforced Facing Concrete	6,000	CY	1,500.00	$ 9,000,000
23	Leveling Concrete	11,400	CY	400.00	$ 4,560,000
24	Dam Contraction Joints	650	LF	10.00	$ 7,000
25	Dam Drain Holes	3,500	LF	90.00	$ 315,000
26	Anchor Bars	630	EA	1,000.00	$ 630,000
27	Concrete Parapet Walls	90	CY	1,000.00	$ 90,000
28	Spillway Concrete Ogee and Slab	3,000	CY	1,000.00	$ 3,000,000
29	Spillway Concrete Stilling Basin Floor	6,230	CY	1,000.00	$ 6,230,000
30	Spillway Bridge and Piers	1	LS	908,000.00	$ 908,000
31	Spillway Erosion Protection	1,120	CY	71.00	$ 80,000
	Spillway Subtotal				**$63,845,000**
32	Stripping & Stockpiling Topsoil	11,500	CY	6.00	$ 69,000
33	Excavation	15,200	CY	5.00	$ 76,000
34	Furnishing & Placing Zone 1 Fill	453,700	CY	7.00	$ 3,176,000
35	Furnishing & Placing Zone 3 Fill	1,476,500	CY	5.00	$ 7,383,000
36	Furnishing & Placing Filter/Drain Sand (Zone 2)	100,700	CY	45.00	$ 4,532,000
37	Furnishing & Placing Toe Drain	1,960	LF	68.00	$ 133,000
38	Furnishing & Placing Slope Protection	50,200	CY	70.00	$ 3,514,000
39	Furnishing and Placing Basecourse	770	CY	92.00	$ 71,000
40	Placing Topsoil	9,300	CY	10.00	$ 93,000
	Earthwork Subtotal				**$19,047,000**
41	Dam Instrumentation	1	LS	100,000.00	$ 100,000
42	Reclamation	73	acres	1,300.00	$ 95,000
	Miscellaneous Items Subtotal				**$195,000**
	Listed Items Subtotal				**$127,316,000**
Base Construction Subtotal (BCS)					**$127,316,000**
---	Unlisted Items (20% of subtotal of listed items)				$25,463,000
	Mobilization, Bonds, Insurance (10% of BCS)				$12,730,000
Direct Construction Subtotal (DCS)					**$165,509,000**
	Construction Change Order Contingency (25% of BCS & Mobilization …)				$35,010,000
	Final Design Engineering (10% of DCS)				$16,550,000
	Permitting and Mitigation (assumed lean permitting)				$10,000,000
	Public Outreach (0.5% of DCS)				$830,000
	Land Easement/Purchases (Dam & Reservoir)				$27,158,000
	Legal and Administrative Costs (2% of DCS)				$3,310,000
	Construction Administration and Engineering (10% of DCS)				$16,550,000
TOTAL ESTIMATED PROJECT COST					**$274,917,000**

Cost per AF (20K AF Working Pool) $13,746.00
Cost per AF (68K AF Total Pool) $4,043.00

Low Range ***$ 192,440,000***
High Range ***$ 412,380,000***

Note: Cost opinion is based on 2018 dollars and will increase due to inflation each year.

2018 FEASIBILITY-LEVEL OPINION OF PROBABLE PROJECT INVESTMENT
WHITE RIVER DAM AT WOLF CREEK 90,000 AF WORKING POOL
RIO BLANCO WATER CONSERVANCY DISTRICT

Item No.	Description	Quantity	Unit	Unit Price	Amount
1	Site Access Roads	1	LS	3,206,000.00	$ 3,206,000
2	Highway 64 Reconstruction	1	LS	13,572,000.00	$ 13,572,000
3	Stream Diversion Tunnel	1	LS	20,200,000.00	$ 20,200,000
4	Cofferdams for Stream Diversion	1	LS	382,000.00	$ 382,000
5	Clearing and Grubbing	85	acres	7,000.00	$ 595,000
	Site Preparation Subtotal				**$37,955,000**
6	Foundation Rock Excavation	53,500	CY	27.00	$ 1,445,000
7	Unclassified Soil Excavation in White River	1,019,000	CY	8.00	$ 8,152,000
8	Foundation Dewatering	1	LS	2,500,000.00	$ 2,500,000
9	Foundation Grouting	1	LS	1,151,000.00	$ 1,151,000
10	Foundation Treatment (Cleaning & Dental Concrete)	1	LS	2,490,000.00	$ 2,490,000
11	Foundation Drain Holes	4,400	LF	15.00	$ 66,000
12	Random Fill	292,000	CY	5.00	$ 1,460,000
	Foundation Preparation				**$17,264,000**
13	Outlet Works Gate Tower	1,010	CY	1,500.00	$ 1,515,000
14	Outlet Works Pipe (including encasement)	620	LF	4,250.00	$ 2,635,000
15	Stilling Well	380	CY	1,500.00	$ 570,000
16	Sluice Gates, Operators, and Trashracks	1	LS	2,618,000.00	$ 2,618,000
	Outlet Subtotal				**$7,338,000**
17	RCC Test Section	1	LS	100,000.00	$ 100,000
18	Furnishing and Placing RCC	455,000	CY	75.00	$ 34,125,000
19	Furnishing Cement for RCC	1,700	tons	172.00	$ 292,000
20	Furnishing Fly Ash for RCC	1,700	tons	87.00	$ 148,000
21	Unreinforced Facing Concrete	19,000	CY	925.00	$ 17,575,000
22	Reinforced Facing Concrete	7,400	CY	1,500.00	$ 11,100,000
23	Leveling Concrete	13,100	CY	400.00	$ 5,240,000
24	Dam Contraction Joints	750	LF	10.00	$ 8,000
25	Dam Drain Holes	4,500	LF	90.00	$ 405,000
26	Anchor Bars	640	EA	1,000.00	$ 640,000
27	Concrete Parapet Walls	90	CY	1,000.00	$ 90,000
28	Spillway Concrete Ogee and Slab	3,000	CY	1,000.00	$ 3,000,000
29	Spillway Concrete Stilling Basin Floor	6,230	CY	1,000.00	$ 6,230,000
30	Spillway Bridge and Piers	1	LS	908,000.00	$ 908,000
31	Spillway Erosion Protection	1,120	CY	71.00	$ 80,000
	Spillway Subtotal				**$79,941,000**
32	Stripping & Stockpiling Topsoil	14,400	CY	6.00	$ 86,000
33	Excavation	17,300	CY	5.00	$ 87,000
34	Furnishing & Placing Zone 1 Fill	729,700	CY	7.00	$ 5,108,000
35	Furnishing & Placing Zone 3 Fill	2,277,300	CY	5.00	$ 11,387,000
36	Furnishing & Placing Filter/Drain Sand (Zone 2)	172,800	CY	45.00	$ 7,776,000
37	Furnishing & Placing Toe Drain	2,120	LF	68.00	$ 144,000
38	Furnishing & Placing Slope Protection	69,400	CY	70.00	$ 4,858,000
39	Furnishing and Placing Basecourse	850	CY	92.00	$ 78,000
40	Placing Topsoil	11,100	CY	10.00	$ 111,000
	Earthwork Subtotal				**$29,635,000**
41	Dam Instrumentation	1	LS	100,000.00	$ 100,000
42	Reclamation	85	acres	1,300.00	$ 111,000
	Miscellaneous Items Subtotal				**$211,000**
	Listed Items Subtotal				**$172,344,000**
Base Construction Subtotal (BCS)					**$172,344,000**
---	Unlisted Items (20% of subtotal of listed items)				$34,469,000
	Mobilization, Bonds, Insurance (10% of BCS)				$17,230,000
Direct Construction Subtotal (DCS)					**$224,043,000**
	Construction Change Order Contingency (25% of BCS & Mobilization …)				$47,390,000
	Final Design Engineering (10% of DCS)				$22,400,000
	Permitting and Mitigation (assumed lean permitting)				$10,000,000
	Public Outreach (0.5% of DCS)				$1,120,000
	Land Easement/Purchases (Dam & Reservoir)				$28,158,000
	Legal and Administrative Costs (2% of DCS)				$4,480,000
	Construction Administration and Engineering (10% of DCS)				$22,400,000
TOTAL ESTIMATED PROJECT COST					**$359,991,000**

Cost per AF (90K AF Working Pool)	$4,000.00
Cost per AF (138K AF Total Pool)	$2,609.00
Low Range	***$ 251,990,000***
High Range	***$ 539,990,000***

Note: Cost opinion is based on 2018 dollars and will increase due to inflation each year.

2018 FEASIBILITY-LEVEL OPINION OF PROBABLE PROJECT INVESTMENT
WHITE RIVER DAM - MAXIMUM STORAGE
RIO BLANCO WATER CONSERVANCY DISTRICT

Item No.	Description	Quantity	Unit	Unit Price	Amount
1	Site Access Roads (site & pump facility)	1	LS	$ 3,206,000.00	$ 3,206,000
2	Highway 64 & Highway 40 Reconstruction	1	LS	$ 86,300,000.00	$ 86,300,000
3	Stream Diversion Tunnel	1	LS	$ 38,075,000.00	$ 38,075,000
4	Cofferdams for Stream Diversion	1	LS	$ 383,000.00	$ 383,000
5	Clearing & Grubbing	290	acres	$ 7,000.00	$ 2,030,000
	Site Preparation Subtotal				**$129,994,000**
6	Foundation Soil (Alluvium) Excavation in the White River	2,965,000	CY	$ 8.00	$ 23,720,000
7	Foundation Dewatering	1	LS	$ 2,500,000.00	$ 2,500,000
8	Foundation Treatment (Cleaning & Dental Concrete)	1	LS	$ 7,720,000.00	$ 7,720,000
9	Foundation Grouting	1	LS	$ 2,220,000.00	$ 2,220,000
	Foundation Preparation				**$36,160,000**
10	Service Spillway/Outlet Conduit	10,300	LF	$ 4,225.00	$ 43,517,500
11	Outlet Tower	5,200	CY	$ 1,500.00	$ 7,800,000
12	Outlet Bridge	1	LS	$ 1,724,000.00	$ 1,724,000
13	Outlet Gates & Trashrack	1	LS	$ 3,927,000.00	$ 3,927,000
14	Terminal Structure	1	LS	$ 905,000.00	$ 905,000
	Outlet Subtotal				**$57,873,500**
15	Stripping & Stockpiling Topsoil	67,800	CY	$ 6.00	$ 406,800
16	Excavation	93,400	CY	$ 5.00	$ 467,000
17	Furnishing & Placing Zone 1 Fill	6,227,800	CY	$ 7.00	$ 43,594,600
18	Furnishing & Placing Zone 3 Fill	14,393,400	CY	$ 5.00	$ 71,967,000
19	Furnishing & Placing Filter/Drain Sand (Zone 2)	940,300	CY	$ 45.00	$ 42,313,500
20	Furnishing & Placing Toe Drain	4,600	LF	$ 68.00	$ 312,800
21	Furnishing & Placing Slope Protection	305,000	CY	$ 70.00	$ 21,350,000
22	Furnishing and Placing Basecourse	2,200	CY	$ 92.00	$ 202,400
23	Placing Topsoil	50,900	CY	$ 10.00	$ 509,000
	Earthwork Subtotal				**$181,123,100**
24	Spillway Soil Excavation	3,325,000	CY	$ 5.00	$ 16,625,000
25	RCC Control Section	15,000	CY	$ 300.00	$ 4,500,000
26	Spillway Erosion Protection	1	LS	$ 14,760,000.00	$ 14,760,000
	Spillway Subtotal				**$35,885,000**
27	Reseeding	260	acres	$ 1,300.00	$ 338,000
28	Instrumentation	1	LS	$ 2,000,000.00	$ 2,000,000
	Miscellaneous Items Subtotal				**$2,338,000**
	Listed Items Subtotal				**$443,373,600**
Base Construction Subtotal (BCS)					**$443,374,000**
---	Unlisted Items (20% of subtotal of listed items)				$88,675,000
	Mobilization, Bonds, Insurance (10% of BCS)				$44,340,000
Direct Construction Subtotal (DCS)					**$576,389,000**
	Construction Change Order Contingency (25% of BCS & Mobilization …)				$121,930,000
	Final Design Engineering (10% of DCS)				$57,640,000
	Permitting and Mitigation (assumed 20% for maximum dam)				$115,277,800
	Public Outreach (0.5% of DCS)				$2,880,000
	Land Easement/Purchases (Dam & Reservoir)				$113,535,000
	Legal and Administrative Costs (2% of DCS)				$11,530,000
	Construction Administration and Engineering (10% of DCS)				$57,640,000
TOTAL ESTIMATED PROJECT COST					**$1,056,821,800**

Cost per AF (2.1M AF Total Pool)	$511.00
Low Range	***$ 739,780,000***
High Range	***$ 1,585,230,000***

Note: Cost opinion is based on 2018 dollars and will increase due to inflation each year.

APPENDIX C
PHASE 2A FEASIBILITY STUDY
STATEMENT OF WORK

EXHIBIT A – White River Storage Project – Phase 2A Study Statement of Work

STUDY OBJECTIVE

In March of 2015, the Rio Blanco Water Conservancy District completed an initial feasibility study to identify potential water storage sites in the White River Basin. The study evaluated 25 potential storage sites along the White River and concluded that a new reservoir, located near the confluence of the White River and Wolf Creek, would provide a very efficient, cost effective, multipurpose water project for northwestern Colorado. The purpose of additional White River water storage is to conserve and put to beneficial use some of the approximately 500,000 acre-feet of unused water that flows out of Colorado from the White River each year. The Rio Blanco Water Conservancy District continues to face a serious water crisis because it's Kenney Reservoir, which originally provided 13,800 acre-feet of storage, is silting in at an average rate of more than 300 acre-feet per year. The annual loss of water storage in Kenney Reservoir reduces recreation use in the reservoir each year and significantly increases the risk to the Town of Rangely's water supply in times of droughts. Storing a portion of the water that flows out of Colorado from the White River each year will provide significant benefits to endangered fish; provide additional water for municipal, agricultural, and industrial; provide water quality benefits; and meet future demands for a variety of recreation activities in northwest Colorado. The Phase 1 study also documented that that a new Wolf Creek Reservoir would produce additional annual tax revenues of nearly $1.4 million to local economies and the State of Colorado.

The Rio Blanco Water Conservancy District has filed water rights for the Wolf Creek Reservoir site, which would be either an off-channel dam located on Wolf Creek immediately upstream of the confluence with the White River or an on-channel dam constructed on the main stem of the White River, immediately downstream of the White River/Wolf Creek confluence. See Figure 1 for the location of the dam sites. The objective of this second study phase is to continue work to refine the primary alternatives to meet the many important water conservation needs within the Rio Blanco Water Conservancy District so that the project permitting phase may begin in 2018.

PROJECT ROLES

The Rio Blanco Water Conservancy District would continue to engage EIS Solutions and W. W. Wheeler and Associates, Inc. (Wheeler) to complete the second phase of the study. EIS Solutions will be responsible for managing the project, facilitating project communications, and conducting stakeholder meetings and Wheeler would perform technical evaluations and prepare a Phase 2A Study Report.

BUDGET and SCHEDULE

The study would be completed concurrently with the White River Modeling and Management Plan during 2017 and 2018. A description of the key study tasks are provided on the next page. Key Milestone schedules and budgets for the study are summarized in Table 1 on the next page. A summary of key project study partner funding is provided in Table 2.

Table 1 – Summary of Key Phase 2A Study Task Budgets and Schedules

Task No.	Task	Tentative Task Start Date	Tentative Task End Date	Task Budget
1	Project Management, Outreach and Public Meetings	6-21-17	9-30-18	$175,000
2	Primary Alternatives Refinement	6-21-17	9-30-18	$55,000
2a	Maximum Reservoir Evaluation	6-21-17	9-30-18	$25,000
3	Preliminary Reservoir Sedimentation Studies	6-21-17	9-30-18	$20,000
4	Modeling Coordination	6-21-17	9-30-18	$30,000
5	Phase 2A Report	6-21-17	9-30-18	$45,000
	Phase 2A Subtotal			**$350,000**

Table 2 – White River Storage Project Partnership Funding Summary

Study Partner	Contribution	Contribution Percentage
CWCB WSRA Grant	$82,888	24%
Yampa/White/Green Roundtable	$85,000	24%
Rio Blanco Water Conservancy District	$75,000	21%
Town of Rangely	$50,000	14%
Town of Meeker	$10,000	3%
Rio Blanco County	$47,112	13%
Phase 2A Study Total	**$350,000**	

STUDY TASK DESCRIPTIONS:

Task 1 – Project Management, Outreach and Public Meetings: This task includes the following:

- Task 1a – Project Management and Coordination
- Task 1b – Continued Stakeholder Outreach
- Task 1c – Public Meetings

The subtasks are described below.

Task 1a – Project Management and Coordination: Includes project management, coordination of key study criteria, methods, results and meeting coordination.

Deliverables: Brief progress reports will be prepared for each Yampa/White/Green Roundtable meeting.

Task 1b - Continued Key Stakeholder Outreach and Meetings: EIS will continue to meet with key potential stakeholders, interested community groups and Yampa/White/Green Basin Roundtable members to further refine the primary alternatives for the project. The continued outreach and stakeholder meetings are included as part of the Phase 2A Scope of Work to further refine the Project so that the National Environmental Policy Act (NEPA) documentation and project permitting can begin following the conclusion of the Phase 2A study. Some of the key stakeholder update meetings that are anticipated include meetings with the following organizations:

- The BLM
- White River Electric Association
- The Colorado River District
- The U.S. Fish & Wildlife Service
- Colorado Parks and Wildlife
- The Yampa/White/Green Basin Roundtable
- Colorado Water Conservation Board
- Moon Lake Electric Association
- Rio Blanco County
- Moffat County
- Town of Rangely
- Town of Meeker
- City of Craig
- Upper Colorado River Endangered Fish Recovery Program (Implementation Committee)
- Yellow Jack Water Conservancy District
- Bureau of Reclamation
- Western Area Power Administration
- State legislators
- Colorado Department of Natural Resources and the Governor's office
- Congressional delegation
- Colorado Water Congress members
- Colorado River Water Users Association members
- Club 20
- AGNC (Associated Governments of Northern Colorado)
- Mesa and Garfield Counties
- Media and Editorial boards (Daily Sentinel, Denver Post)
- NW Colorado newspaper and radio reporters
- Area Chambers of Commerce and Economic Development organizations
- Various environmental organizations
- Other identified stakeholders
- Additional civic groups
- Additional energy development partners

Deliverables: Meeting summaries of key stakeholder meetings.

Task 1c – Public Meetings: This task includes holding up to a minimum of three public meetings throughout the study. The public meetings are anticipated as follows:

- An initial meeting at the beginning of the Study to explain the Phase 2A Study Scope and solicit additional public input;

- A progress meeting to provide an update during the Study;
- A draft report meeting to review the results of the draft report and solicit public comments before the Phase 2A report is finalized.

Each of the public meetings are tentatively scheduled to be held in Rangely, Colorado. Each meeting will include both an open house and public presentation format that that will occur over several hours to maximize the exchange of information with interested stakeholders. The meetings may also be scheduled to coincide with other key water related meetings in the basin. We have also included up to three meetings with the Yampa/White/Green Roundtable and one meeting with the Rio Blanco Water Conservation District Board to update these key stakeholders on the progress of key work tasks.

Deliverables: A summary of each public meeting including a listing of meeting attendees will be prepared and included in an appendix of the Phase 2A report.

Task 2 - Primary Alternatives Refinement: After the initial meetings in 2017 with some of the key stakeholders, Wheeler will refine the 2015 feasibility designs and cost opinions so that the off-channel and on-channel reservoirs and associated drain and fill facilities are developed to a comparable level of detail. The feasibility designs for the on-channel reservoir were not fully developed during the 2015 feasibility study. The feasibility designs will include the development of preliminary drawings, construction quantities, and cost opinions for the on-channel dam, spillway, and outlet works. Wheeler will also re-evaluate the drain and fill facilities for the off-channel reservoir to determine if the off-channel reservoir could be filled by less expensive gravity flow ditches or a combination of gravity flow ditches and smaller booster stations from diversion points located higher in the basin such as Wray Gulch and Strawberry Creek. The feasibility of using other more senior water rights from other potential partners such, as the Colorado River District, will be evaluated as part of this task.

Task 2a - Maximum Reservoir Evaluation: Based on recent comments from some stakeholders, it may be beneficial to build the largest possible reservoir at Wolf Creek. As part of this task, Wheeler will develop feasibility designs and cost opinions for the maximum size reservoir that could be constructed at both the off-channel or on-channel reservoir near the confluence of the White River and Wolf Creek. No additional water modeling will be performed for these larger reservoirs. If larger reservoirs are considered to be viable, additional information such as reservoir yield and key resource impacts would need to be developed by others as part of future development or permitting work. The objective of this maximum reservoir work would be to develop an approximate cost for a much larger reservoir that could have additional benefits to the State of Colorado.

Deliverables: The Phase 2A report will document the following Task 2 work:

- Update feasibility drawings, construction quantities and cost opinions for the off-channel and on-channel reservoirs;
- Updated feasibility designs for off-channel drain and fill facilities;
- Updated comparison of key adverse impacts expected from both the reservoirs to key resources such as wetlands, wildlife, private properties, and sensitive BLM lands; and
- Include information from the Maximum Reservoir Evaluation.

Task 3 – Preliminary Reservoir Sedimentation Studies: Wheeler will use available soils data from the Natural Resources Conservation Service (NRCS) and BLM to develop preliminary estimates of the rate of sedimentation for both the off-channel and on-channel Wolf Creek reservoirs. These estimates will be used to refine the extent of the sediment pools in each alternative reservoir site. This task will also document some of the sedimentation pond construction work that has already been cooperatively completed by the BLM and the Rio Blanco Water Conservatively District in the last twenty years and the effectiveness of these facilities to minimize sediment runoff into the proposed reservoirs.

Deliverables: The Phase 2A report will document the watershed sedimentation data collected as well as the key sedimentation assumptions, methods, and results of the sedimentation estimates and potential sedimentation mitigation measures for both the off-channel or on-channel Wolf Creek reservoirs.

Task 4 – Modeling Coordination: This task would include continued Wheeler involvement in coordination meetings associated with the White River Modeling and Management Plan, which is scheduled to be completed concurrently with the proposed Phase 2A study.

Deliverables: The Phase 2A report will include a chapter on yields expected for both the off-channel and on-channel Wolf Creek Reservoirs based on the modeling that is scheduled to be completed concurrently with the Phase 2A study.

Task 5 - Phase 2A Report: Wheeler will prepare a draft report that summarizes the Phase 2A work. The draft report is tentatively scheduled to be available for public review by June 1, 2018. After a public review period and the draft report meeting, a final report will be issued that addresses public comments received.

Deliverables: A draft and final report will be prepared and provided to interested stakeholders.

APPENDIX D

BASIN IMPLEMENTATION PLAN MODEL PHASE 3 FINAL REPORT EXTRACTS

(WILSON WATER GROUP, 2018)

Yampa/White/Green Basin Roundtable

Basin Implementation Plan Modeling Phase 3 Final Report

Prepared by
Wilson Water Group

April 2018

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Executive Summary

The Yampa/White/Green Basin Roundtable (BRT) chose to take full advantage of the momentum generated from the development of their Basin Implementation Plan and continue making progress on their basin goals. This project was the third phase of modeling efforts undertaken by the BRT. This phase further developed and allowed the BRT to gain confidence in models of the Yampa and White river basins and used those models to move forward with cooperative integrated planning. The models were used to explore the potential benefits and impacts of Identified Projects and Processes (IPPs), illuminate the effects of water rights administration, and support the White River Programmatic Biological Opinion (PBO) process. This project was exploratory, not prescriptive; meaning the BRT wanted to investigate a variety of “what-if” scenarios, without subscribing to specific projects or operations.

One unique aspect of this project was the collaborative process between the modeling experts (Wilson Water Group) and the basin experts (members of the Basin Roundtable). Working in close communication and with frequent in-person meetings and workshops, Wilson Water Group and the Basin Roundtable created a useful model that provides meaningful results and a better understanding of the interrelationships of current and proposed projects.

The primary goals of the project were to:

- Refine the baseline CDSS Yampa and White river models to accurately represent current uses, operations and administration – with input from basin users,
- Build confidence in the use of the model by clearly explaining how it operates and represents actual basin uses,
- Convert the Yampa and White river models to a daily time step to provide results that are useful for non-consumptive needs assessment,
- Work closely with the BRT to define and incorporate possible future uses,
- Work closely with IPP proponents to implement their projects faithfully in the models,
- Provide meaningful results in workshops and a final report, and
- Deliver a modeling tool that can be used in the future integrated water resource planning.

These goals have been accomplished over the course of the project. Specific project accomplishments include the following:

- BRT members participated in workshops with WWG to learn about the capabilities of the StateMod modeling platform. Participants learned how StateMod represents Colorado water rights and represents more complex system operations, such as reservoirs and municipal water supply infrastructure. Through this educational process, the BRT was able to confirm that StateMod is the best tool for this project.

- WWG worked with basin water uses and water suppliers to better understand current operations in order to capture those operations accurately in the models. WWG demonstrated to the BRT that current uses, water rights, and reservoir operations are correctly represented in the Yampa and White models. The BRT gained confidence in the models for use in this project.
- The BRT and WWG worked collaboratively to determine the appropriate future demands, hydrology scenarios, and IPPs to represent in the model. The results from this process are clearly and transparently documented in this report and in the workshop presentations. Although specific details regarding contracts, regulatory constraints, or operational policies of modeled entities were represented in a simplified manner, this effort provided the BRT with a meaningful set of model scenarios to investigate.
- Through the workshop presentations and discussions, the BRT was able to explore the impacts of IPPs on the river system. Scenarios were developed that examine each IPP individually, and in various combinations with other IPPs. The explorative process increased the BRT's understanding of the river system, shortages to consumptive and non-consumptive demands, opportunities for synergy between IPPs, and examples of competition between future demands and IPPs.
- Because of the close communication between the Basin Experts and the Model Experts, WWG was able to respond to feedback from the BRT in order to explore new ideas in an iterative manner. This allowed the BRT to understand and direct model revisions throughout the project.
- The BRT now has Yampa and White models they are confident appropriately represent the basins current and potential future operations under water right administration. These models can be used to continue to investigate integrated planning options to accomplish the BRT basin goals.

The future demands, IPPs, and climate projected hydrologic analyses developed and investigated through the workshop process resulted in the following general conclusions:

- The Yampa River basin future demands are generally not for new sectors; they are increased demands for existing water users.
- The Yampa River basin future consumptive demands that increase existing water uses are often met with current water rights portfolios and existing reservoir storage; however, Stagecoach Reservoir is unable to refill in some scenarios and the City of Steamboat's projected growth on the west side requires additional urban infrastructure and a new supply.
- The White River basin future demands include new demands for the oil and gas sector.

- The climate projected scenarios show a shift to earlier runoff and a significant decrease in late season flows.
- The climate projected scenarios show droughts that are more severe in terms of magnitude than current hydrology and paleohydrology contains droughts that are more severe in terms of duration than the climate scenarios.
- The Yampa and White river basins' future consumptive demands with present day (junior) water rights cannot be fully met from historical natural streamflow; and shortages increase under climate projected hydrology.
- The Yampa and White basin existing agricultural users are not impacted by increases in future demands under historical hydrologic conditions because their water rights are senior to the new demands. However, the model shows existing agriculture users experience additional shortages under climate projections because the projected higher temperatures both increase crop demands, and decrease natural streamflow during the late irrigation season.
- The Yampa and White basins have distinct snowmelt runoff hydrographs. The majority of the streamflow occurs during the spring and early summer. Under the IPP scenarios that considered new storage, the models showed reservoir releases during the late season could meet future consumptive demand shortages. Even under the climate projected hydrology, the models showed water available for storage during the runoff that could be released during the low flow season to help alleviate shortages.
- Non-consumptive demands for fisheries and water quality issues focus on the low flow periods. The model shows that IPPs that use supplemental supply from existing reservoirs can help meet these flow targets in drier years. Additional supplies from IPP reservoirs can fully satisfy the low flow demands in the Yampa River basin; however IPP reservoirs in the White River basin cannot fully satisfy a 300 cfs year-round flow target.
- Non-consumptive demands for boating focus on the high flow periods. In the Yampa, the increase in storage investigated has a limited impact on boatable days. In the White, the large increase in storage investigated has a more pronounced impact on boatable days.

Introduction

The Yampa/White/Green Basin Roundtable (BRT) completed their Basin Implementation Plan (BIP) in 2015. The BRT chose to take full advantage of the momentum generated from the development of their BIP and continue making progress on their basin goal. The BRT determined that the first step was a modeling project that would allow the BRT to build confidence in the basin representation and use of the current model, understand the potential benefits and impacts of the Identified Projects and Processes (IPPs), illuminate the effects of water rights administration, and support the White River Programmatic Biological Opinion (PBO) process. The modeling project was exploratory, not prescriptive; meaning the BRT wanted to gain confidence and a better understanding of the model capabilities while testing a variety of "what-if" scenarios, without subscribing to specific projects or operations.

Wilson Water Group (WWG) was selected as the contractor for the project with clear direction: WWG's role was to be the model expert and the BRT's role was to be the basin expert. Working in close communication and with frequent in-person meetings and workshops, WWG and the BRT created a useful model that provides meaningful results.

The goals of the project were to:

- Refine the baseline CDSS Yampa and White river models to accurately represent current uses, operations and administration – with input from basin users,
- Build confidence in the use of the model by clearly explaining how it operates and represents actual basin uses,
- Convert the Yampa and White river models to a daily time step to provide results that are useful for non-consumptive needs assessment,
- Work closely with the BRT to define and incorporate possible future uses,
- Work closely with IPP proponents to implement their projects faithfully in the models,
- Provide meaningful results in workshops and a final report, and
- Deliver a modeling tool that can be used in the future integrated water resource planning.

This document is the final report for the project. The results presented in the body of the report focus on a sub-set of the model scenarios that compare and contrast different approaches to meeting the future consumptive and non-consumptive needs in the Yampa and White river basins. These scenarios outlined are examples of the types of scenarios that were considered and highlight interesting aspects of the river basins. The selection of these scenarios does not imply endorsement of any project or operation.

Significant emphasis was placed on opportunities for the basin experts to review the model experts' representation of IPP model scenarios and interpretation of results. To that end, eight modeling workshops were held in the basin to present information and provide interactive discussion on IPP representation and results. The appendices to the report present slides and/or handouts from each interactive workshop; where the configuration and results of the full slate of scenarios considered as part of the exploratory process were presented and discussed. Table 1 provides the dates and general topics of each interactive workshop and meetings with basin water users and providers. In accomplishing the goals defined above, it is important to emphasis that the majority of WWG's effort was in preparing for and leading the interactive workshops to assure that the BRT understands - and has faith in - their basin model.

Table 1: Interactive Workshops

Workshop Date	Primary Topic	Location
December 9, 2015	StateMod 101 to understand model platform, including basic water rights and reservoir operations	Appendix A
July 13, 2016	Kickoff Meeting to discuss approach	Appendix B
Summer/Fall 2016	Meeting with water users and providers. Conversion of models to daily time step	Table 2
March 8, 2017 **March 20, 2017**	Discussion of future demands, IPP Factsheets, and including Colorado's Water Plan climate scenarios	Framework for Modeling Future Conditions Section/Appendix C
July 12, 2017	Present and discuss results for the future demands and IPPs in the White basin and the upper portion of the Yampa basin with historical hydrology	Appendix D
August 24, 2017	Present and discuss results for the future demands and IPPs in the lower portion of the Yampa basin. Compare paleohydrology and climate projected hydrology	Appendix E
October 19, 2017	Present and discuss results for the Yampa and White basins with climate projected hydrology	Appendix F
November 8, 2017	Present and discuss updated results based on feedback from the October 19, 2017 workshop. Review the report outline	Appendix G
January 10, 2018	Presentation of project results to full Basin Roundtable	Appendix H

Project Process

The following process diagram shown in Figure 1 defines the project process and the roles and responsibilities of the Basin Experts and the Model Experts necessary for the successful completion of this modeling effort.

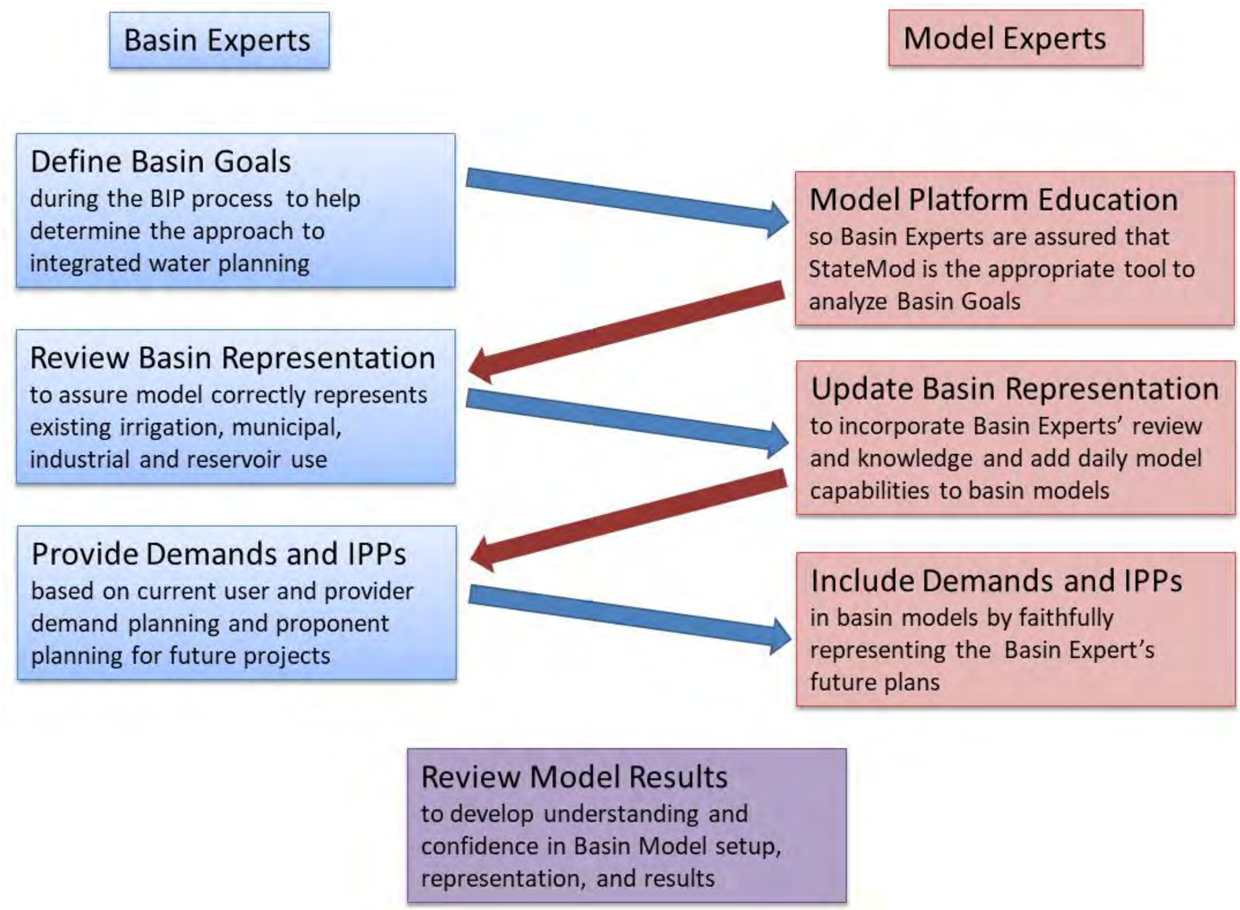
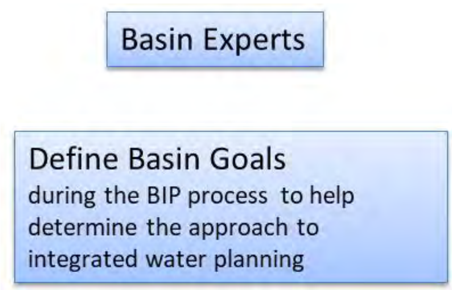


Figure 1: Project Process Diagram

Basin Goals

During the Yampa/White/Green (YWG) BIP process, the BRT set eight goals to meet the needs of the basin. This section discusses how this project addressed and worked to achieve the basin goals. Note that the order in which the basin goals are presented does not imply a relative priority or importance.



- *Protect the YWG Basin from compact curtailment of existing decreed water uses and some increment of future uses.*
    - The refined daily time step Yampa and White models developed for this project are ideal for investigating impacts of curtailment administration scenarios and answering questions regarding different operations to protect against curtailment. As part of this project, the model refinements were vetted by basin experts; providing confidence that the models accurately represent existing water rights and basin operations.
- *Protect and encourage agriculture uses of water in the YWG Basin within the context of private property rights.*
    - The modeling platform simulates allocation of water based on prior appropriation. The demands in the model are assigned their respective water rights, thereby protecting the private property rights of agricultural users.
- *Improve agricultural water supplies to increase irrigated land and reduce shortages. The agricultural needs study of the YWG BRT identified an additional 14,805 acres of potential new agricultural production in the future.*
    - The model uses full agricultural consumptive demand based on current irrigated acreage, allowing hydrologic conditions and water rights to determine available water for diversions. Existing agricultural shortages under both current conditions and alternate climate hydrology are identified in the modeling project. Several of the IPPs investigated include additional storage supplies to meet existing agricultural demand shortages.
    - Future development of additional irrigated acreage is considered. The BRT chose to investigate an additional 500 acres that represents a first increment of potential new irrigated acreage.
- *Identify and address municipal and industrial (M&I) water shortages.*

- Future demand projections for Steamboat/Mt. Werner Water District, Craig, Meeker, Rangely, and unincorporated domestic water users are included in the model in order to identify municipal and industrial water shortages.
    - Future increases to self-supplying industrial demands, including for Hayden Station; Craig Station; coal mining; and energy development, are included in the model to identify shortages.
    - IPPs to address M&I water shortages are explored.
- *Quantify and protect environmental and recreational water uses at locations identified in the non-consumptive needs study of the YWG BRT.*
    - The Yampa and White models were converted to a daily time step in order to accurately assess non-consumptive needs.
    - Impacts on streamflow at the Preferred Flow Target (located at the Steamboat wastewater treatment plant outfall) are examined.
    - Results for streamflow at the Maybell Fish Flow Reach are examined in detail and compared to a range of flow targets.
    - This modeling project proceeded in tandem with the on-going White River PBO process to quantify the streamflow needs of endangered species in the White River basin.
    - For recreational uses, the impact on Boatable Days throughout the basins is considered.
- *Maintain and consider the existing natural range of water quality that is necessary for current and anticipated water uses.*
    - Although this goal was not specifically addressed in this study, the daily models can be used in the future to assist with understanding impacts and enhancements to flow-based water quality issues.
- *Restore, maintain, and modernize water storage and distribution infrastructure.*
    - Although this goal was not specifically addressed in this study, the models can be used to investigate improvements in storage and distribution infrastructure in terms of reduction in shortages associated with increased capacity to divert or deliver water.
- *Develop an integrated system of water use, storage, administration and delivery to reduce water shortages and meet environmental and recreational needs.*
    - This project is a significant step toward accomplishing this goal, because it examined how the IPPs and future demands interact with each other and their overall impact on the river system. The models are the ideal tools to move forward with continued options for integrated water management.

Basin Characteristics

Figure 3 provides an overview of the major tributaries of Yampa and White basins and the locations of key gages used to present flow-based model results. The existing reservoirs that were investigated for operational IPPs are also shown, including Stagecoach Reservoir, Steamboat Lake, Elkhead Reservoir, and Lake Avery.

The streamflow in the Yampa is highly variable depending on snowpack. Figure 2 shows daily flow for the recent representative period 2007 through 2013 for three gages in the basin. The runoff pattern is similar for these three locations, and for most tributaries to the Yampa. The peak runoff can occur in May or June, depending both on winter snowpack and temperatures during April and May. The period shown includes one of the wettest years on record, 2011, followed by one of the driest years on record, 2012. The difference in annual stream flow for the two years is more than 2.6 MAF – the streamflow in 2012 was less than 20 percent of the 2011 streamflow. As shown in the results section, this variability allows new storage to provide a significant benefit to meet the stress placed on the basin by future increased demands and more flow variability associated with future climate projections.

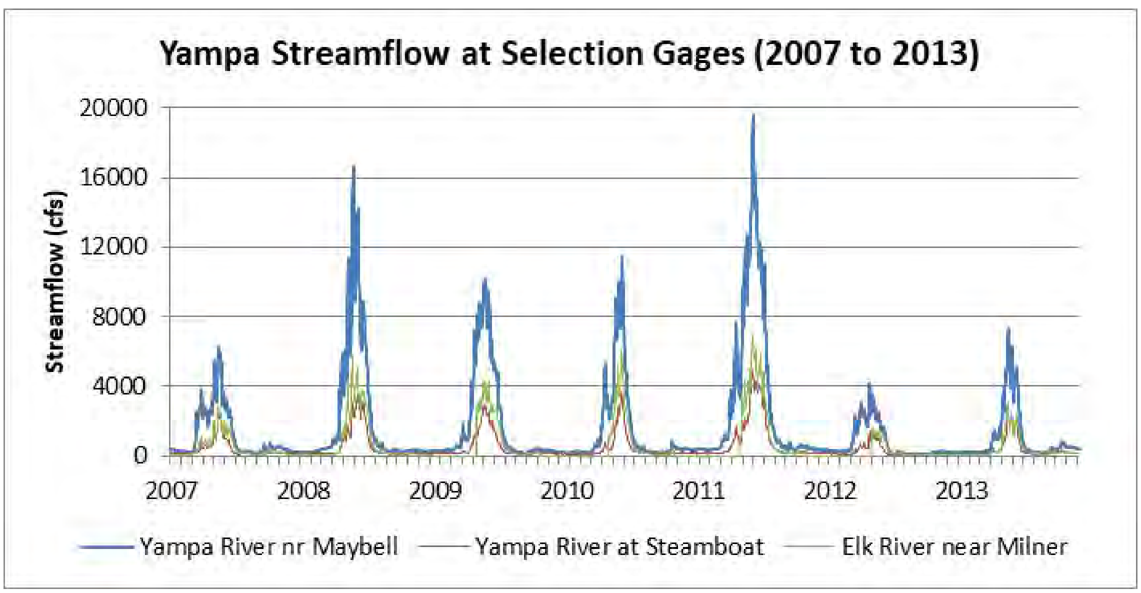


Figure 2: Yampa Basin Streamflow 2007 to 2013

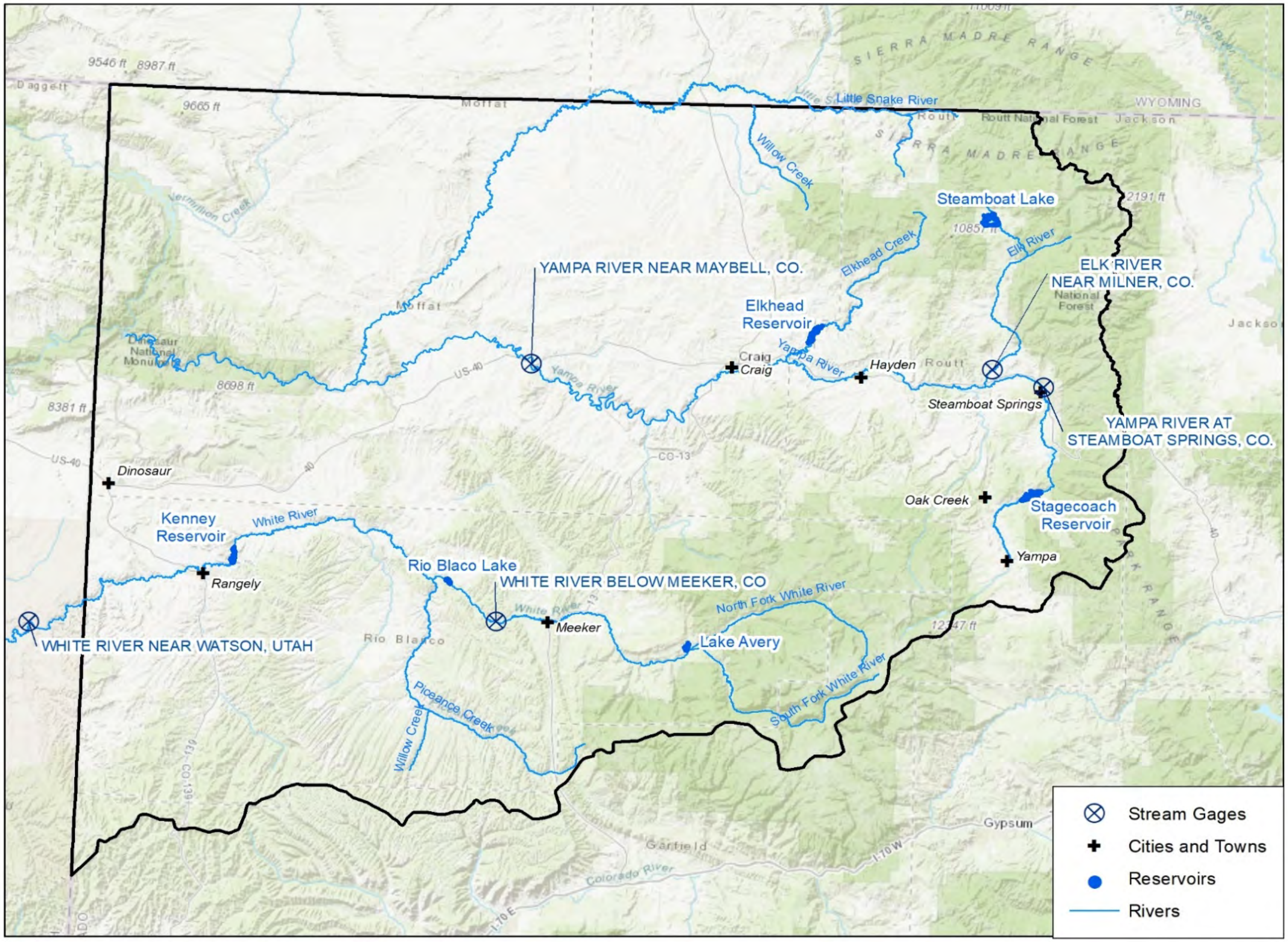


Figure 3: Overview Map of Yampa and White Basins

Figure 4 shows the average monthly natural flow at the Yampa River at Deerlodge gage compared to historical average monthly flow for the 1997 through 2013 analysis period. On average only about 14 percent of the basin natural flow is depleted during that period, about 205,000 acft per year. This again highlights the significant benefit new storage can provide in meeting future needs.

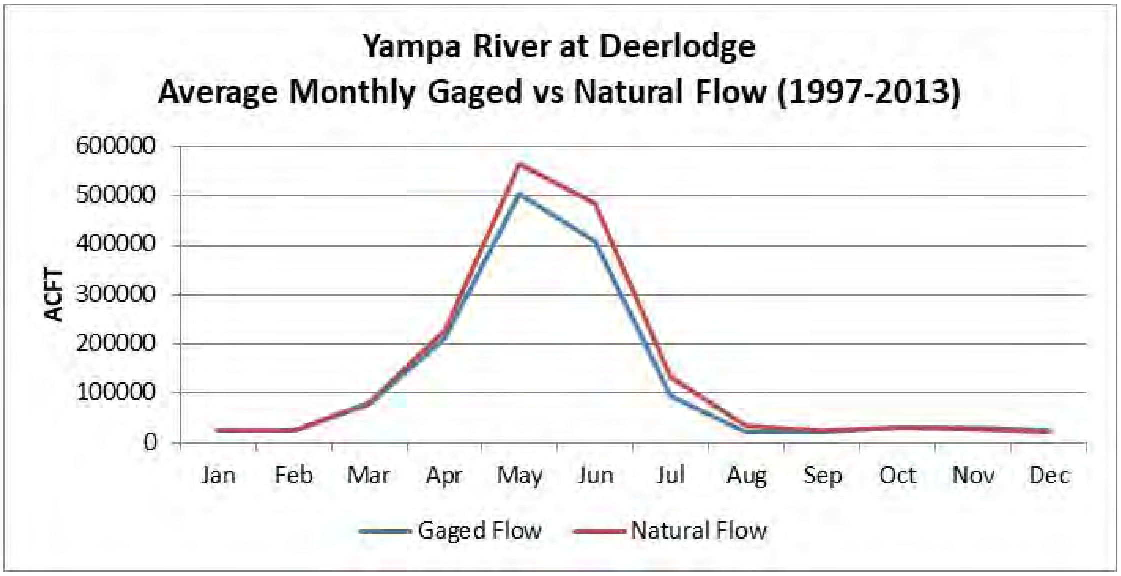


Figure 4: Yampa River at Deerlodge Average Monthly Gaged versus Natural Flow

As shown in Figure 5, the White River also experiences a wide range in high and low flow years, as demonstrated by the flow at the White River at Watson, Utah just downstream of the state line. As in the Yampa, 2011 was one of the highest runoff years on record, followed by one of the lowest runoff years, 2012. The difference in annual stream flow for the two years is more than 475,000 acft – the streamflow in 2012 was only 31 percent of the 2011 streamflow.

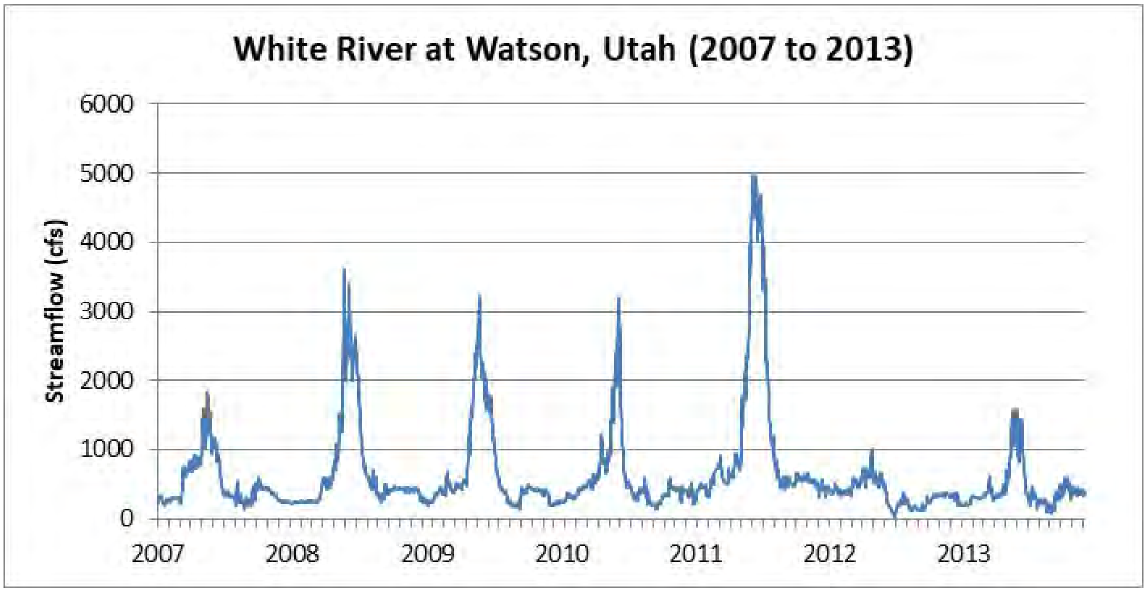


Figure 5: White River at Watson, Utah Streamflow 2007 to 2013

Figure 6 shows the average monthly natural flow at the White River at Watson, Utah gage compared to historical average monthly flow for the 1997 through 2013 analysis period. On average 22 percent of the basin natural flow is depleted during that period, around 106,000 acft per year.

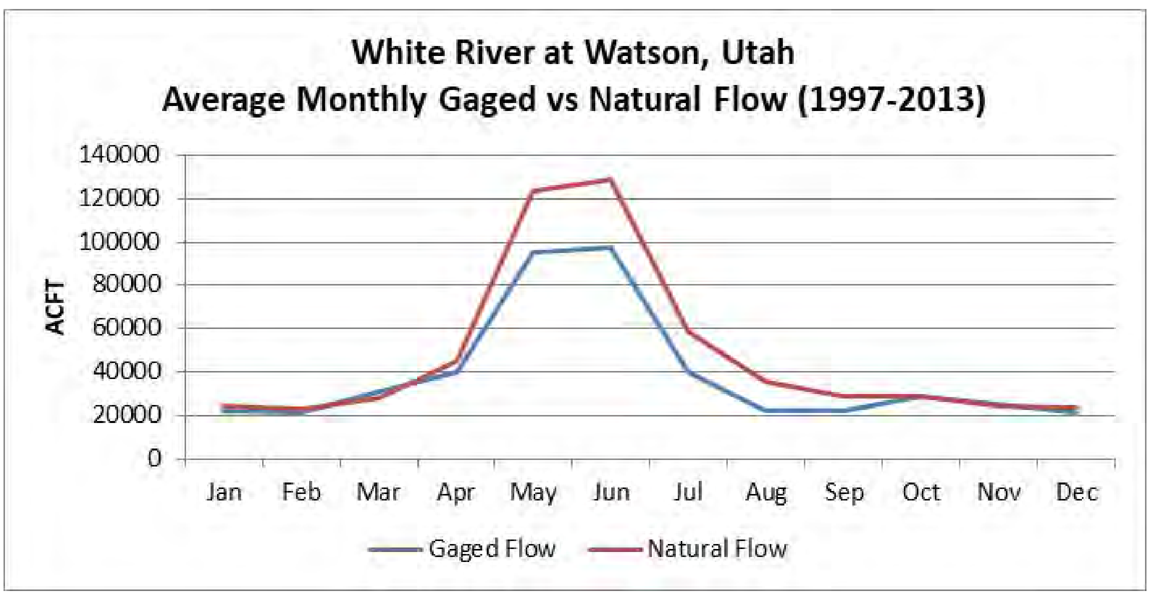


Figure 6: White River at Watson Average Monthly Gaged versus Natural Flow

CDSS Model Overview and Refinements

Over the past 25 years, the Colorado Water Conservation Board (CWCB) and the Colorado Division of Water Resources have developed and updated the Colorado Decision Support System (CDSS) to aid in water resources planning. The CDSS starts with the State Engineer's database of hydrologic and administrative information known as HydroBase. Data from HydroBase are extracted and provided to the CDSS consumptive use model, StateCU, to allow an understanding of demands, historical uses, and shortages associated with irrigated crops. The crop demands estimated from StateCU, plus additional data from HydroBase, are included as inputs to the CDSS water rights allocation model, StateMod. CDSS monthly models were available representing the Yampa Basin and the White Basin with periods of record from 1909 through 2013. For more information on the CDSS models, refer to the 2015 Yampa River Basin Water Resources Planning Model User's Manual and the 2015 White River Basin Water Resources Planning Model User's Manual, available at *cdss.state.co.us*.

StateMod Introduction

StateMod is a water rights allocation planning model developed by the State of Colorado as part of the CDSS effort. At its core, StateMod assigns available water to demands based on the prior appropriation water rights system. This makes it the right tool for long-term water resources planning because it correctly represents the interactions between hydrology, demands, and water rights in Colorado. StateMod can be adapted to any river basin through unique data sets; this report focuses on the Yampa and White river basin applications. This first step of this project was educational: it was critical that BRT understood how StateMod allocated water and represented basin operations so they had confidence in using the model platform moving forward. This first workshop included a "StateMod 101" session to walk through basic model operations and clearly demonstrate that the model is not a "black-box" and, in fact, operates based on Colorado water rights administration. Appendix A includes the presentation that facilitated the StateMod platform discussion in the first workshop.

Model Refinements

The Yampa and White StateMod models were first developed in 1994. The models were updated in the late 1990s and most recently in 2015. Both models have a Historical Calibration scenario and a Baseline scenario. The Historical Calibration scenario represents changing conditions through time and throughout the basin as accurately as possible. This scenario is used to calibrate the model, with an emphasis on matching simulated and observed streamflow, diversions, and reservoir storage. The original monthly calibration for the Yampa and White models is considered good and was improved with the updates made as part of this project, as discussed below.

The Baseline scenario is designed to be the starting point for planning analysis. The Baseline scenario represents current consumptive demands, current instream flow and recreational in-channel diversions (RICDs), existing infrastructure, and current reservoir operations. This current information is then superimposed on historical variable climate and hydrology. For the Yampa and White models, the Baseline scenario uses the 2010 irrigated acreage assessment to represent current levels of agricultural demands. Although historical diversions may have been limited by physical supplies, legal (water rights) availability, or irrigation practices (such as user-decisions not to irrigate after haying); baseline agricultural demands represent full crop irrigation use. This allows the model to determine if there are physical or legal water limitations, providing an actual estimate of agricultural shortages.

One of the goals of the project was to refine the Baseline CDSS Yampa and White river models to accurately represent current uses, operations and administration with input from basin users. To accomplish this goal, WWG set up meetings with water users that have specific knowledge of the more complicated water operations in the basins early in the project. Note that many of these water users are also IPP proponents and both topics were discussed during the meetings. Table 2 summarizes the meetings and attendees.

Table 2: Summary of Water User Meetings

Project or Operation Name	Owner (entity)	Meeting Attendance
Stillwater Reservoir	Bear River Reservoir Company	Andy Schaffner (Water District 58 Commissioner)
Allen Basin Reservoir	Allen Basin Reservoir Company	Mark Rossi and other family members
Stagecoach Reservoir and Yamcolo Reservoir	UYWCD	Kevin McBride, Joe Messina
Lake Catamount	Catamount Metro District	Joel Anderson
City of Steamboat Springs and Mt. Werner Water District	City of Steamboat Springs and Mt. Werner Water District	Kelly Romero-Heaney , Jon Snyder, Frank Alfone
Steamboat Lake and Lester Creek Reservoir (aka Pearl Lake)	Colorado Parks and Wildlife	David Graf and Julie Arington
Hayden Power Station	Xcel	Lauren Nance, Rich Belt, Amy Whillhite
Elkhead Reservoir	CRWCD	Don Meyers
Craig Power Station	Tri-State	Mike Sorensen, Kelly Beal, Jackie Brown
Yampa River PBO	Non-Consumptive Group	Geoff Blakeslee, Meg White, Kevin McBride, Joe Messina, Jackie Brown, Kent Vertress, Nathan Fey
Yampa and White River PBOs	TNC and USFWS	Robert Wigington, Meg White, Geoff Blakeslee, Jana Mohrman, Tom Econopouly
Yampa River PBO administration	Division 6 staff	Erin Light and Kathy Bowers
USGS streamflow gages	USGS staff	Bryan Moore
Big Beaver Creek Reservoir/Lake Avery and Jimmy Johnson Reservoir/Rio Blanco Lake	Colorado Parks and Wildlife	David Graf and Bill Devergie
Town of Meeker	Town of Meeker	Scott Meszaros
Piceance Creek Oil and Gas Operations	Division 6 staff	Brett Watson
Kenney Reservoir	Rio Blanco Water Conservancy District	Alden Vanden Brink and staff
Town of Rangely	Town of Rangely	Don Reed

Based on the user input and a critical examination of the model calibration, the following changes were made to the models.

Yampa Model

- Added winter icing operations to Stillwater Reservoir.
- Corrected winter icing operation for Lake Catamount.
- Updated the representation of the City of Steamboat/Mt. Werner Water District. The municipal demand is now represented at a single node that is met by the various supplies operated by the City and the District.
- Updated the representation of Fish Creek Reservoir to reflect the water rights portfolio of the City and the District.
- Added a typical operational bypass to Fish Creek Reservoir.
- Improved the historical calibration by adding infiltration gallery data provided by Mt. Werner Water District.
- Corrected the location of the future Elk River Diversion IPP structure.
- Corrected Steamboat Lake water rights.
- Updated the representation of Yamcolo Reservoir and Stagecoach Reservoir accounts and operations.
- Set the Stagecoach Reservoir Hydroelectric Plant demand to zero, reflecting the generation of hydroelectric power based on releases for other uses.
- Added representation of Colowyo Pumping Pipeline and Wilson Reservoir.
- Updated City of Craig efficiency values.
- Updated Craig Station to represent alternate and changed points of diversion water rights.
- Update Elkhead Reservoir to reflect recent changes in account ownership.
- Modified the streamflow estimates on Milk Creek to more closely calibrate with a short term streamflow gage.
- Added representation of Deception Creek Ditch, Michaels Ditch, and Barren Field Pivot Pump to use return flows from the Maybell Canal. Correspondingly, updated the Maybell Canal return flow locations.
- Corrected representation of the Five Pines pump and Roberts Ditch.
- Added the following ditches and pumps that operate near Maybell:
    - Myers Ditch No 2
    - Pearce Ditch
    - Haskins Pump Diversion
    - Chew Pump
    - Silver Water Pump
    - Richardson Ditch

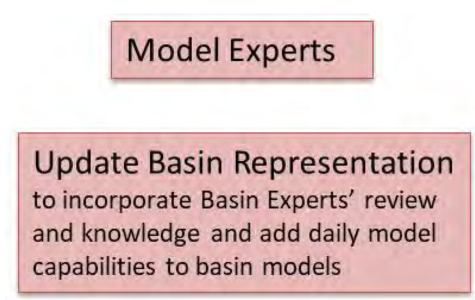
- Cross Mountain Pump No 2
- Lily Park Ditch No 1
- Lily Park Pump Ditch Pump Station No 2

- Updated diversion demands for First Mesa Ditch and Westside Canal (ditches with headgates in Wyoming on the Little Snake River).
- Modified the CDSS approach for extending the available Yampa River at Deerlodge (09260050) streamflow data.

White Model

- Updated baseline headgate demands to use a wet/average/dry year type efficiency patterns for agriculture.
- Updated Rangely demands.
- Added the USGS gage Piceance Creek below Rio Blanco (09306007) to improve calibration on Piceance Creek.
- Extended the model to USGS gage White River near Watson, Utah (09306500). Filled missing data with USGS gage White River near Colorado State Line, Utah (09306395).
- Extend the simulation period from water year 2013 through 2015.

Daily Time Step



One of the most significant changes to the CDSS models was the conversion from a monthly time step to a daily time step. Most IPPs are appropriate to investigate on a monthly time step; therefore the CDSS modeling focuses on development and updates to monthly models. For this project, daily information is needed for assessing impacts on non-consumptive needs. Note that the daily model routine in StateMod does not include streamflow routing. Therefore, water that is released from a reservoir is instantaneously available at the destination. While this is not appropriate for an operational model, it is appropriate for a planning model.

To convert from a monthly time step to a daily time step, the monthly naturalized streamflow is distributed to daily based on pattern gages. This preserves the volume of the monthly naturalized streamflow. The daily pattern gages are selected based on their similarity to the streamgage. Ideally, the pattern gage would represent an undisturbed signature. However, undisturbed gages that represent the correct runoff signature for the mainstem of the Yampa and the White are generally unavailable. The daily pattern gage requires complete data for the length of the model simulation period. Care was taken to find suitable pattern gages that resulted in good calibration. Daily pattern assignments are clearly documented within the StateMod input files, Appendix I and Appendix J.

To convert the monthly diversion demands to daily, the monthly diversion demands were distributed based on a linear interpolation between the monthly mid-points. This option also allows the continued use of monthly irrigation water requirements from the StateCU model. Similar to monthly diversion demands, monthly reservoir storage targets were distributed to daily based on a linear interpolation between the end-of-month targets. Finally, daily instream flow demands used the average monthly demand. Appendix I describes the process used to generate the daily model input files for the Yampa River basin, including the procedure for selection of daily pattern gages. Appendix J describes the process for the White River basin daily mode.

In general, the monthly model calibration follows through to a daily model. The primary effort used to assure calibration of the daily model was the selection of daily pattern gages. Figure 7 through Figure 10 present the daily calibration at key streamflow gages for the Yampa River basin. Figure 11 and Figure 12 present the daily calibration at key streamflow gages for the White River basin. As shown, the calibration is good and the daily models are appropriate to use for comparing scenarios as part of this effort.

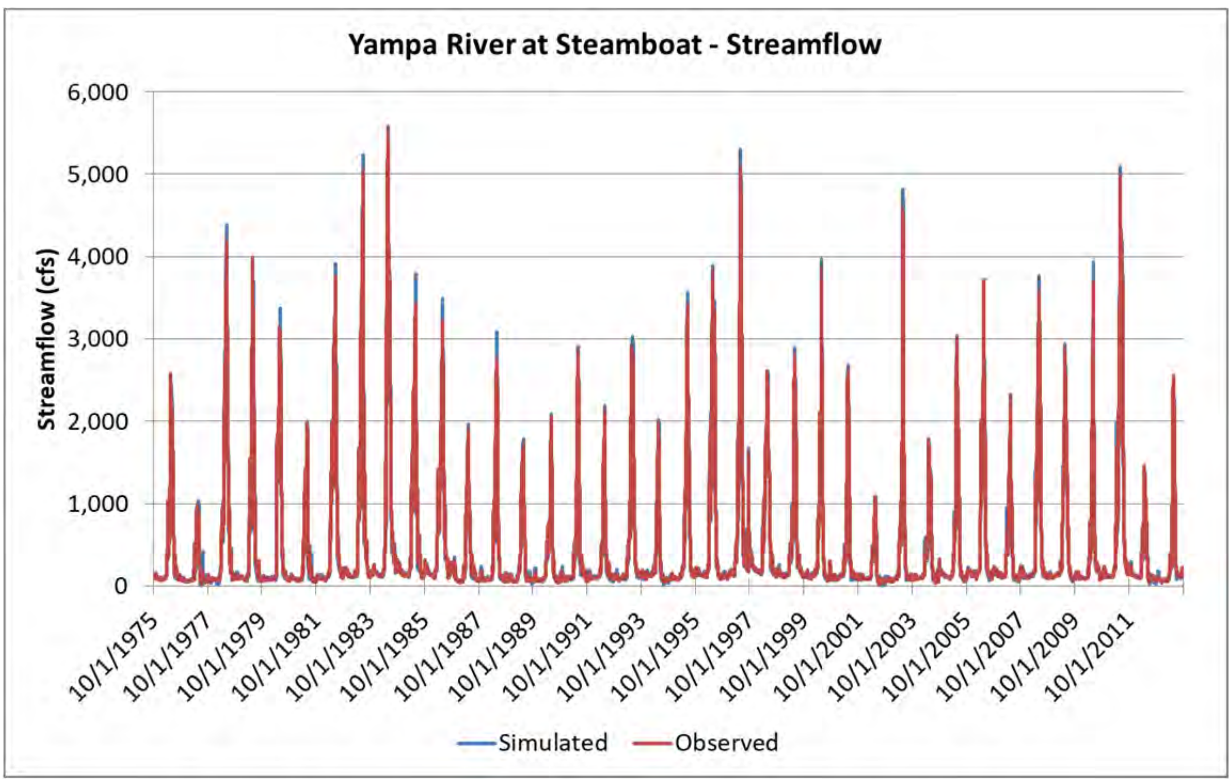


Figure 7: Daily Calibration Time Series for the Yampa River at Steamboat Streamflow

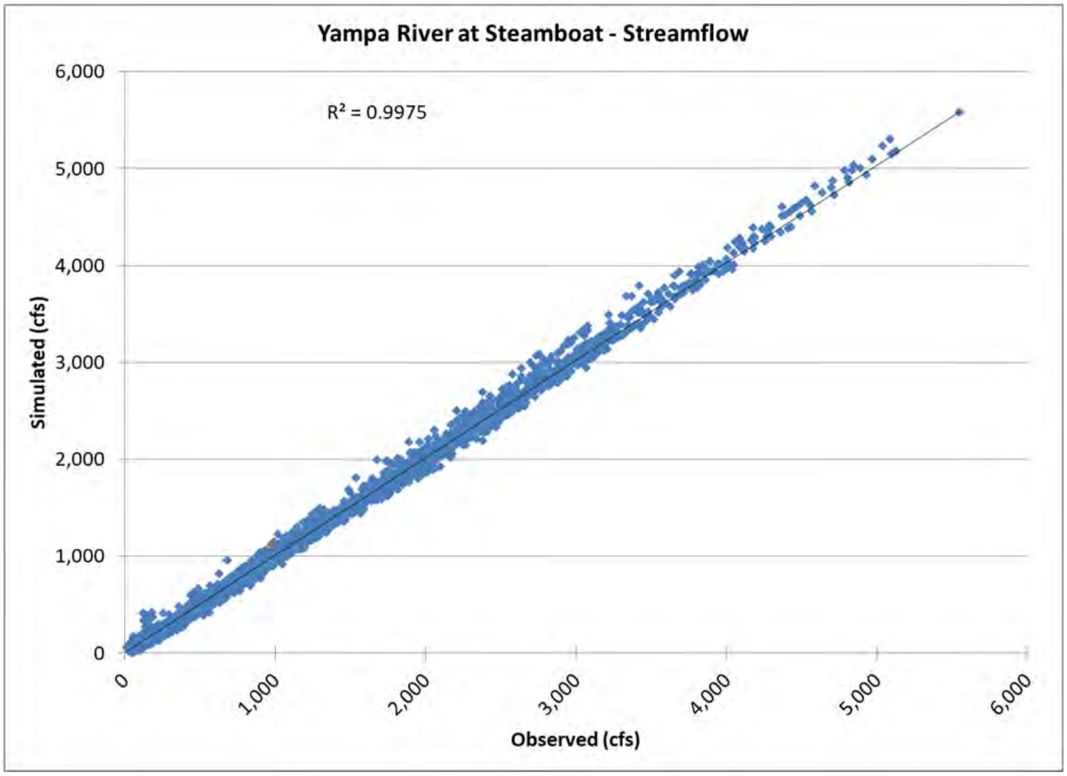


Figure 8: Daily Calibration Scatter Plot for the Yampa River at Steamboat Streamflow

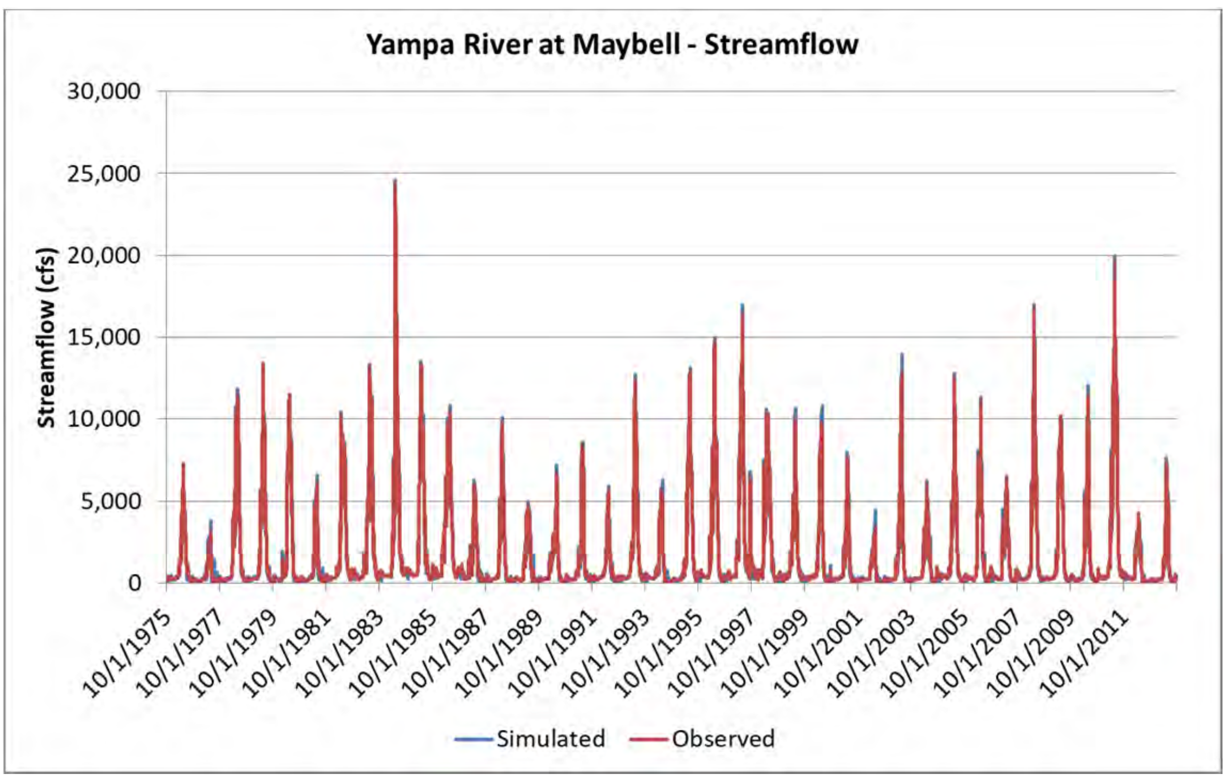


Figure 9: Daily Calibration Time Series for the Yampa River at Maybell Streamflow

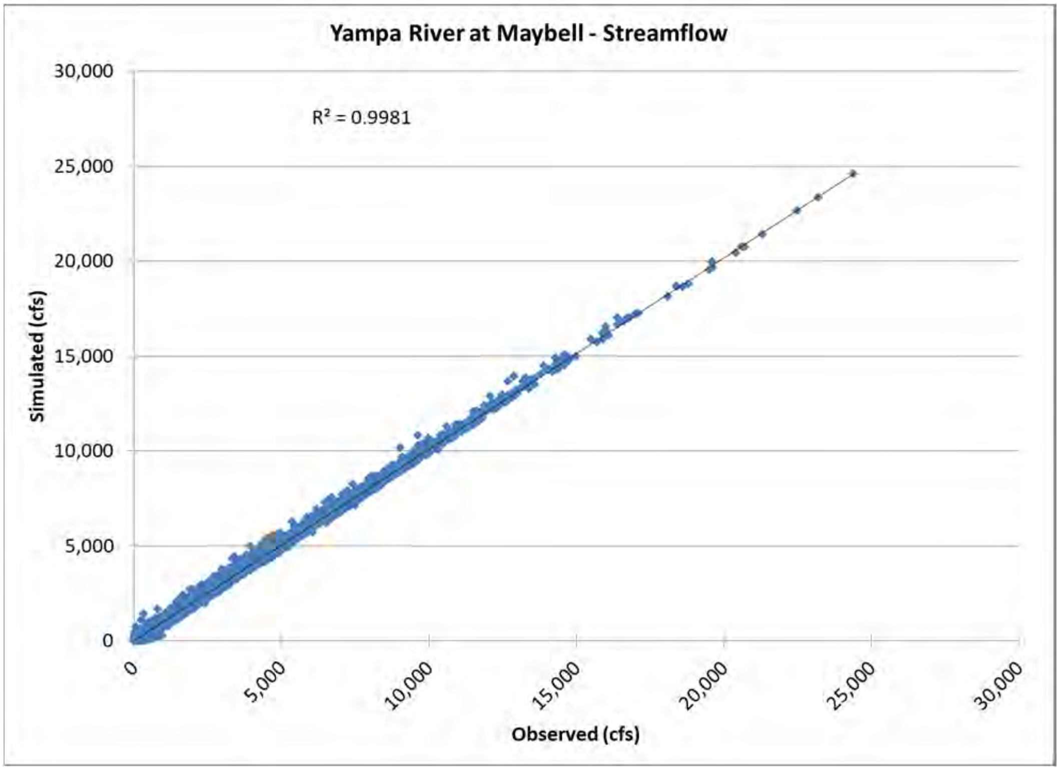


Figure 10: Daily Calibration Scatter Plot for the Yampa River at Maybell Streamflow

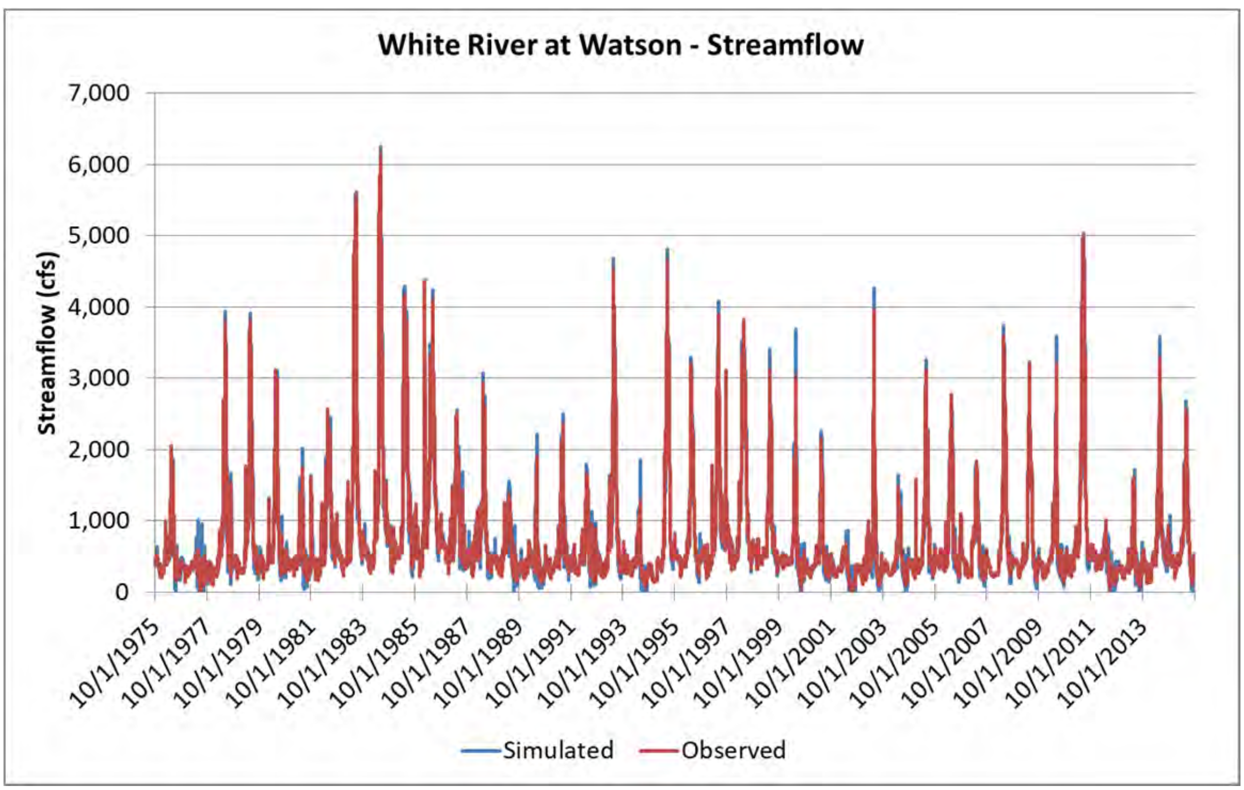


Figure 11: Daily Calibration Time Series for the White River at Watson Streamflow

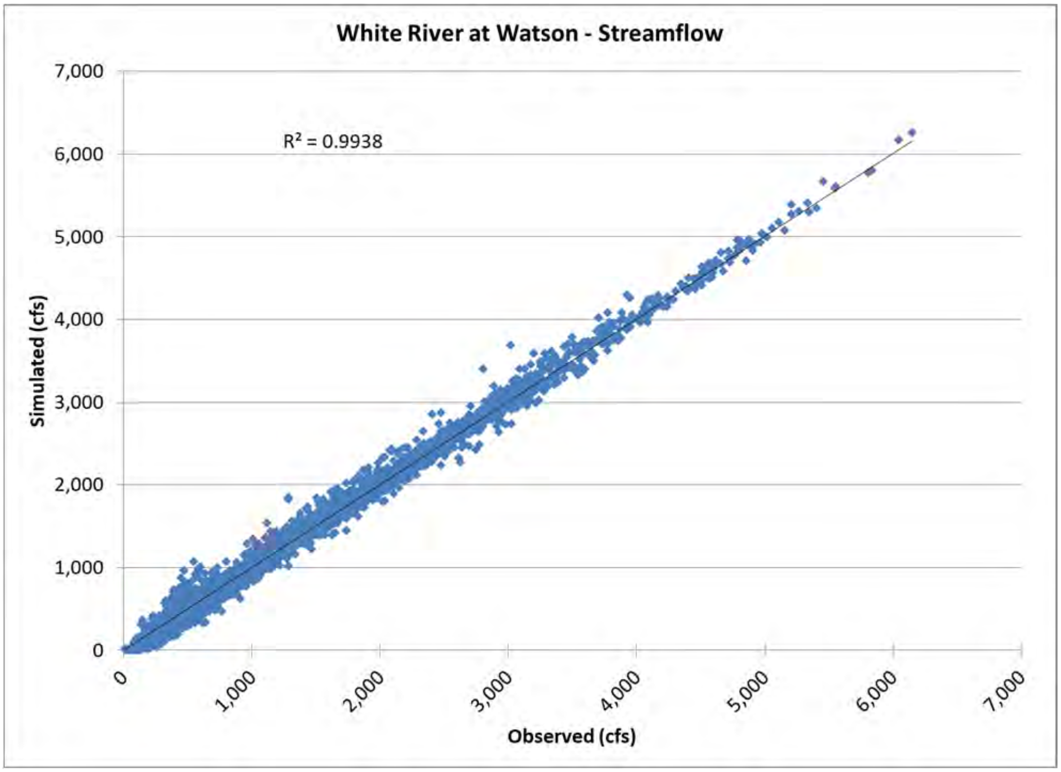


Figure 12: Daily Calibration Scatter Plot for the White River at Watson Streamflow

IPP Meetings

In addition to the water user meetings shown in Table 2, Wilson Water Group organized and attended one additional meeting to discuss a proposed IPP reservoir on Milk Creek. The reservoir is referenced as the Juniper Creek Water Conservancy District reservoir. As shown in Table 3, this was the only IPP-specific meeting held, as the other IPP proponents are existing water users and their proposed projects were discuss in previous meetings.

Table 3: IPP-Specific Project Meeting

Project Name	Proponent	Meeting Attendance
Juniper Creek Water Conservancy District Reservoir	Juniper Creek Water Conservancy District	Jackie Brown, Mike Camblin, Jeff Comstock, T. Wright Dickinson, Tom Gray, and Douglas Wellman

Framework for Modeling Future Conditions

For this project, the BRT considered two primary drivers:

- Hydrology
- Future demands

Layered on top of the hydrology and future demand scenarios are the IPPs from proponents that volunteered to participate in this project. This section discusses the hydrology, future demands, and IPPs.

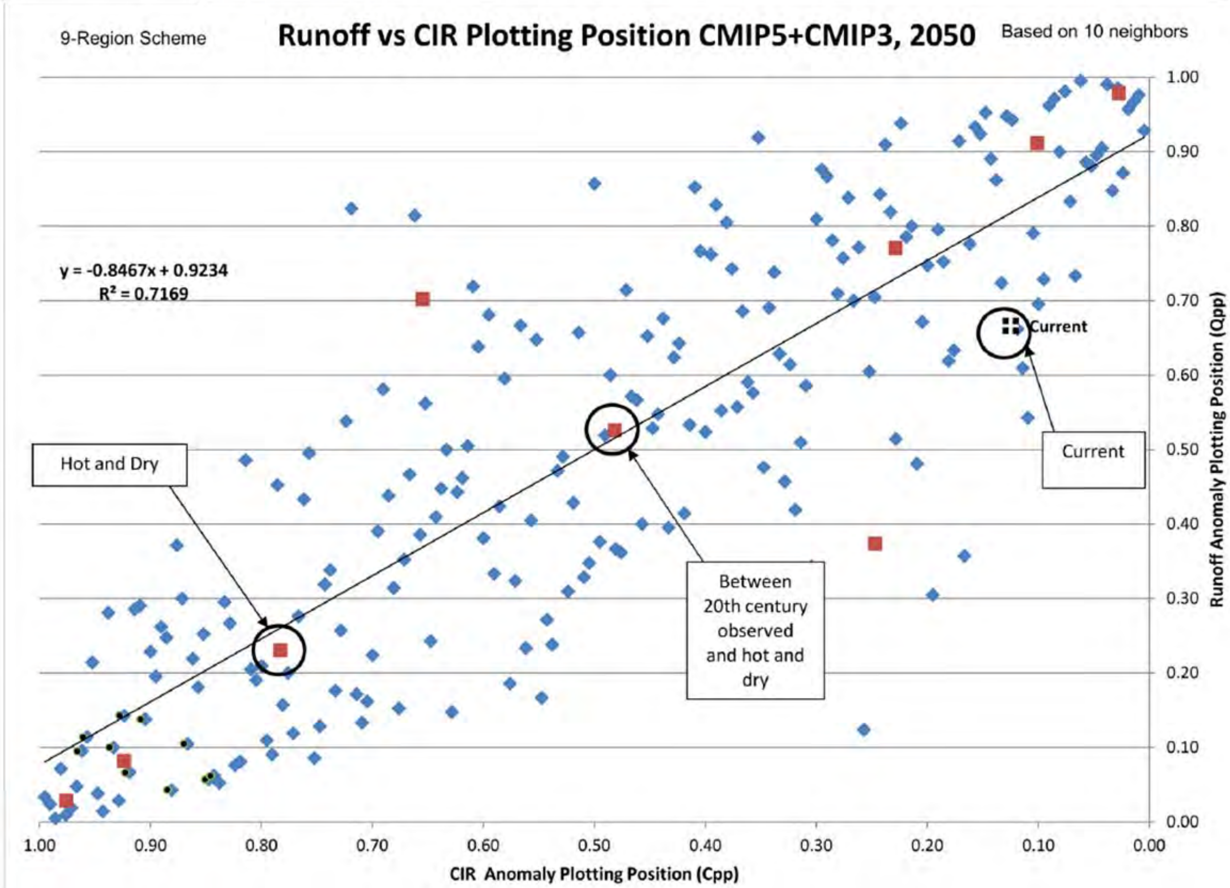
Hydrology

Hydrology is the primary driver of conditions in the Yampa and White basins. Therefore, examining a range of possible future hydrology is prudent. The BRT selected three hydrology scenarios to compare:

- Historical natural streamflow (Current) - represents conditions if history were to repeat itself. The modeling process starts by generating historical natural streamflow by removing the influence of man from the observed flow. StateMod generates natural flow by taking the observed streamflow at each gage in the model, adding the upstream diversions, subtracting the upstream return flows, and adding or subtracting changes in reservoir storage. Natural streamflow is available from water year 1908 through 2013 for the Yampa and through 2015 for the White.
- “Hot and Dry” climate scenario - climate scenario representing one potential climate projected outcome by 2050. The scenario combines lower runoff and higher crop irrigation requirements. This scenario was selected for use in the current Statewide Water Supply Initiative (SWSI) effort supporting Colorado’s Water Plan.
- “Between” climate scenario - climate scenario that is between 20th century observed climate conditions and the Hot and Dry climate scenario. This scenario was also selected for use in the current Statewide Water Supply Initiative (SWSI) effort.

The following Figure 4-9 from Colorado’s Water Plan shows the relative position of the selected climate scenarios compared to the available down-scaled climate projects developed by the U.S. Bureau of Reclamation.

FIGURE 4-9 PLOT OF RUNOFF CROP IRRIGATION REQUIREMENTS USING THE BUREAU OF RECLAMATION ARCHIVE



The climate scenarios represent temperature and precipitation conditions projected for the year 2050. To develop the natural flow hydrology required for StateMod input, climate projected temperature and precipitation was used as input to a rainfall-runoff model that estimated natural hydrology. The natural hydrology was superimposed on a 64 year trace designed to replicate observed variability from 1950 through 2013. WWG used crop consumptive demands prepared for the SWIS effort reflecting the higher temperature signature for the Hot and Dry and Between selected climate models. More detail on the process is included in several technical documents developed to support the SWSI effort, including “CRWAS Phase II Climate, Task 1, Approach for Constructing Climate Scenarios” and the “CRWAS Phase II Supplemental Report” available on the CWCB website.

The climate projected hydrology is only available on a monthly time step; therefore it cannot be distributed to daily using the pattern gage method because the runoff signature is significantly different than what has been observed. Scenarios investigated using climate projected hydrology were simulated on a monthly time step.

As a point of comparison, the Yampa River also has a paleohydrology streamflow sequence available for use (*Millennial-Length Records of Streamflow from Three Major Upper Colorado River Tributaries* by Stephen T. Gray, Jeffrey J. Lukas, and Connie Woodhouse, 2011). Paleohydrology is a reconstruction of annual streamflow based on a statistical relationship with tree-ring widths. Annual flow volumes based on tree-ring reconstruction have been developed for the USGS Yampa River near Maybell, CO (09251000) from year 1000 to 2013 (1,014 year period). The annual flow was disaggregated to other gages throughout the Yampa basin and disaggregated to a monthly time step using the K-Nearest Neighbor resampling technique (*Upper Yampa River Basin Master Plan Modeling Study Task 1 Summary Report: Development of Basin Hydrology*, prepared by AMEC for Upper Yampa Water Conservancy District, January 2, 2013). The graphs and tables below compare the Current, Between, Hot and Dry, and Paleo hydrology options. Overall, the climate projected scenarios show droughts that are more severe in terms of magnitude than current hydrology. However, the paleohydrology contains droughts that are more severe in terms of duration than either of the climate scenarios.

Figure 13 through Figure 15 show the average monthly natural flow for the hydrology scenarios, used as input to the Yampa and White models. Note that the White River graph (Figure 15) only has Current, Between, and Hot and Dry scenarios because there is no paleohydrology available for the White River basin.

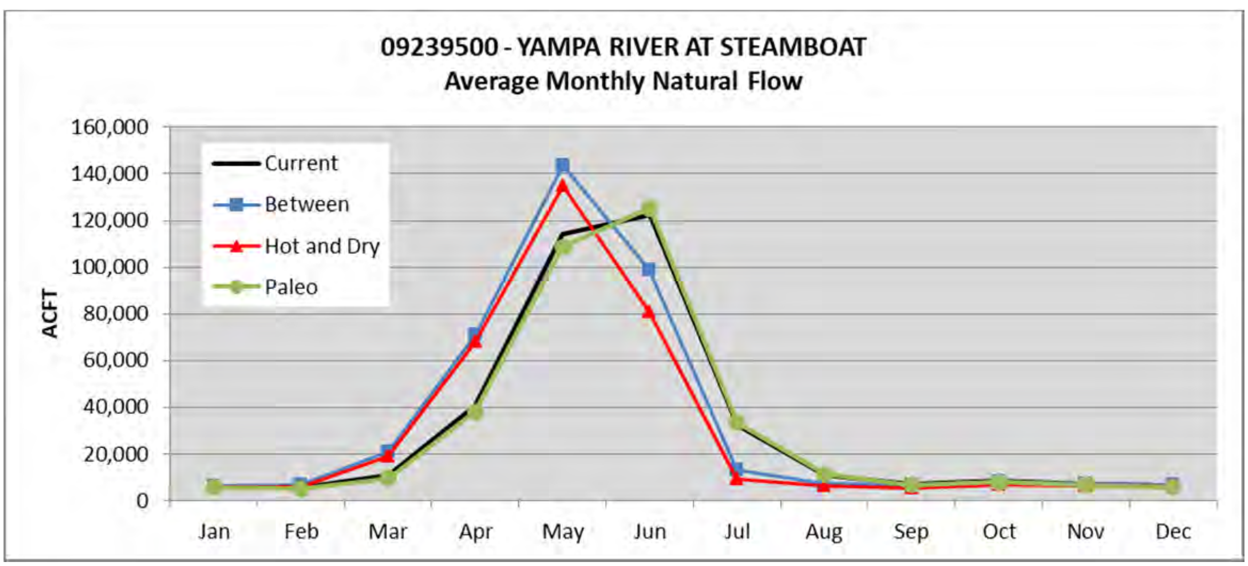


Figure 13: Hydrology Comparison (Yampa River at Steamboat)

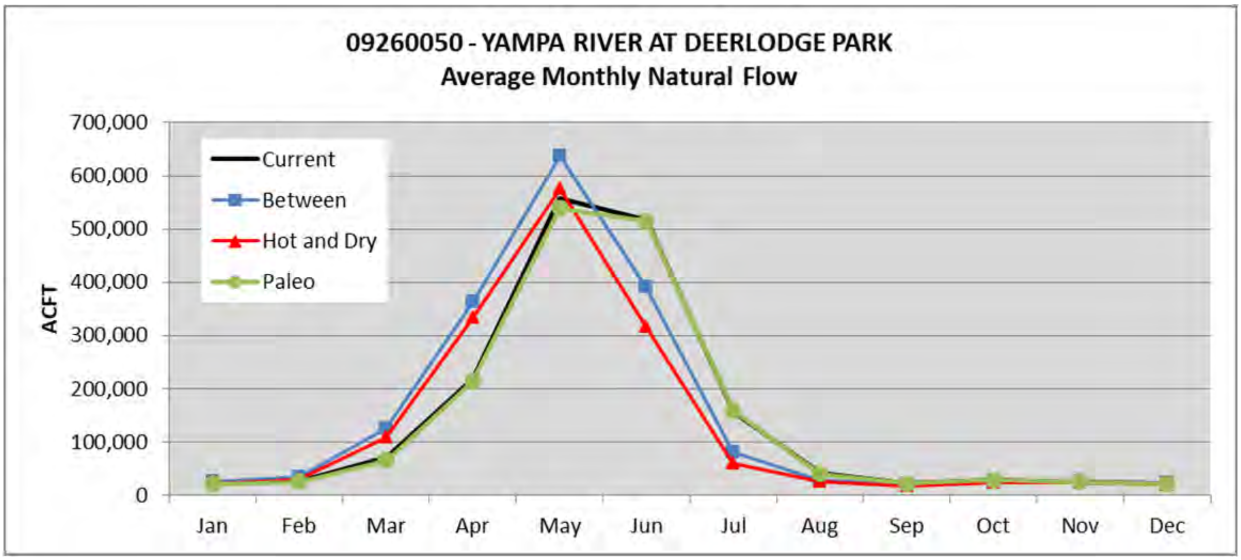


Figure 14: Hydrology Comparison (Yampa River at Deerlodge Park)

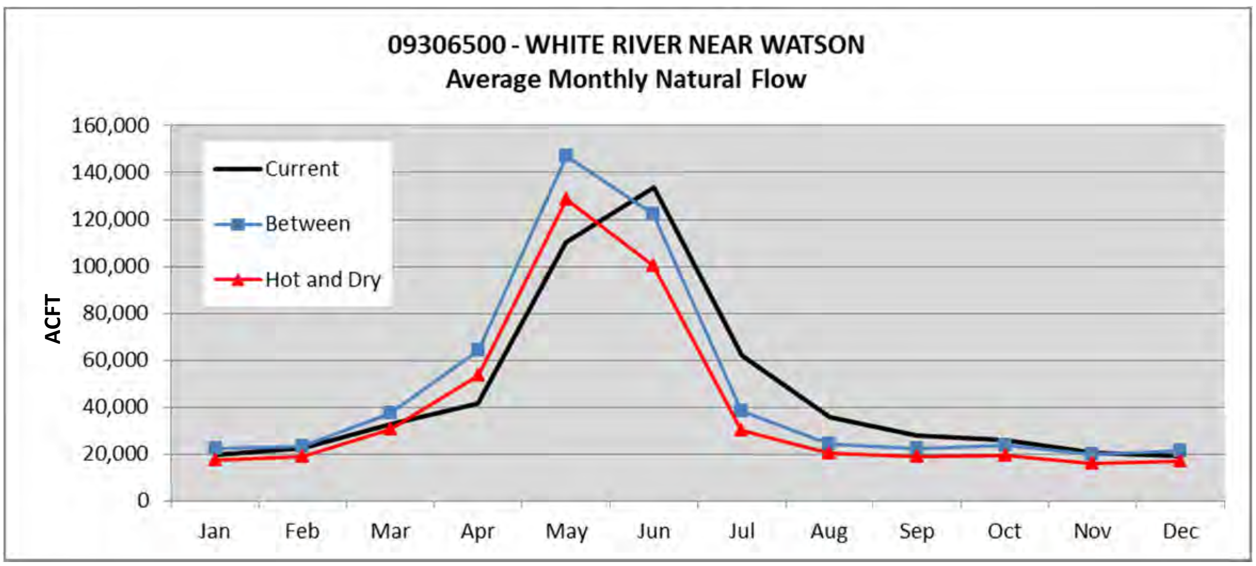


Figure 15: Hydrology Comparison (White River near Watson)

The following are key observations based on the average monthly hydrology comparisons:

- The paleohydrology replicates the current average monthly mean and results in a similar runoff pattern as seen in the observed hydrology.
- The climate projections show a shift to earlier runoff.
- The climate projected peak runoff volume is slightly higher than the current peak runoff volume; and late summer flows are significantly lower.

Table 4 through Table 6 shows the range of annual values for the hydrology scenarios.

Table 4: Annual Natural Flow Comparison (Yampa River at Steamboat)

	Current (ACFT)	Between Climate Projection (ACFT)	Hot and Dry Climate Projection (ACFT)	Paleohydrology (ACFT)
Annual Max	660,189	822,181	758,707	660,090
Annual Mean	371,541	395,782	353,619	363,006
Annual Min	150,954	122,977	100,385	70,403

Table 5: Annual Natural Flow Comparison (Yampa River at Deerlodge Park)

	Current (ACFT)	Between Climate Projection (ACFT)	Hot and Dry Climate Projection (ACFT)	Paleohydrology (ACFT)
Annual Max	3,430,698	4,009,191	3,637,865	3,426,405
Annual Mean	1,747,274	1,783,625	1,552,177	1,651,932
Annual Min	635,799	575,839	487,978	296,111

Table 6: Annual Natural Flow Comparison (White River near Watson)

	Current (ACFT)	Between Climate Projection (ACFT)	Hot and Dry Climate Projection (ACFT)
Annual Max	1,020,023	954,995	803,870
Annual Mean	553,413	566,234	471,327
Annual Min	266,483	249,947	201,803

The following are key observations based on the annual statistics:

- For both of the Yampa River gages, the Between climate projection scenario shows higher annual flow for the maximum year and the overall mean than the Historical. However, the minimum year annual flow is lower. This scenario will highlight conditions that include both higher and lower annual flows than what was been experienced historically.
- For the White River gage, the Between climate scenario has higher overall mean annual flow than the Historical, but the maximum and minimum year flow is lower than Historical. This scenario will highlight conditions with higher flows on average, but lower extreme flows.

- For the Yampa River and White River gages, the Hot and Dry climate scenario shows lower average flow and a lower flow for the minimum year. For the Yampa, the maximum year flow is greater than Historical; however the maximum year flow for the White is less than Historical. This scenario will show more severe conditions than have been experienced historically.
- In the Yampa Basin, the Paleohydrology maximum year flows are very similar to Historical. The mean flows are lower than Historical flows, but higher than the Hot and Dry climate. The minimum year flow is significantly less than Historical (about half) and less than the Hot and Dry climate.

The most significant difference in the Paleohydrology scenario is the length and magnitude of droughts. WWG defined drought as consecutive years below the current annual average volume. For comparison between the shorter climate projected scenarios and the longer paleohydrology scenario, the climate projected time series were repeated to match the length of the paleohydrology. Figure 16 and Figure 17 show the frequency of drought length in the Yampa for the Between, Hot and Dry, and paleohydrology natural flows.

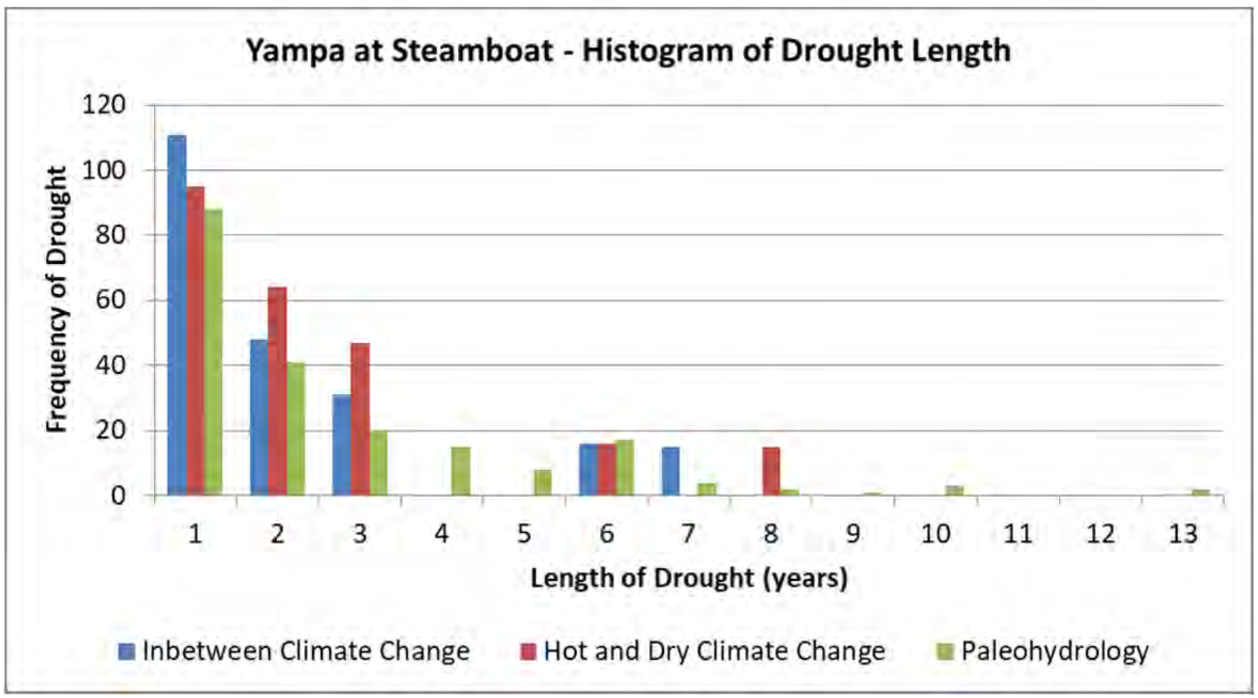


Figure 16: Histogram of Drought Length (Yampa River at Steamboat) Based on the 1000 to 2013 Paleohydrology Period.

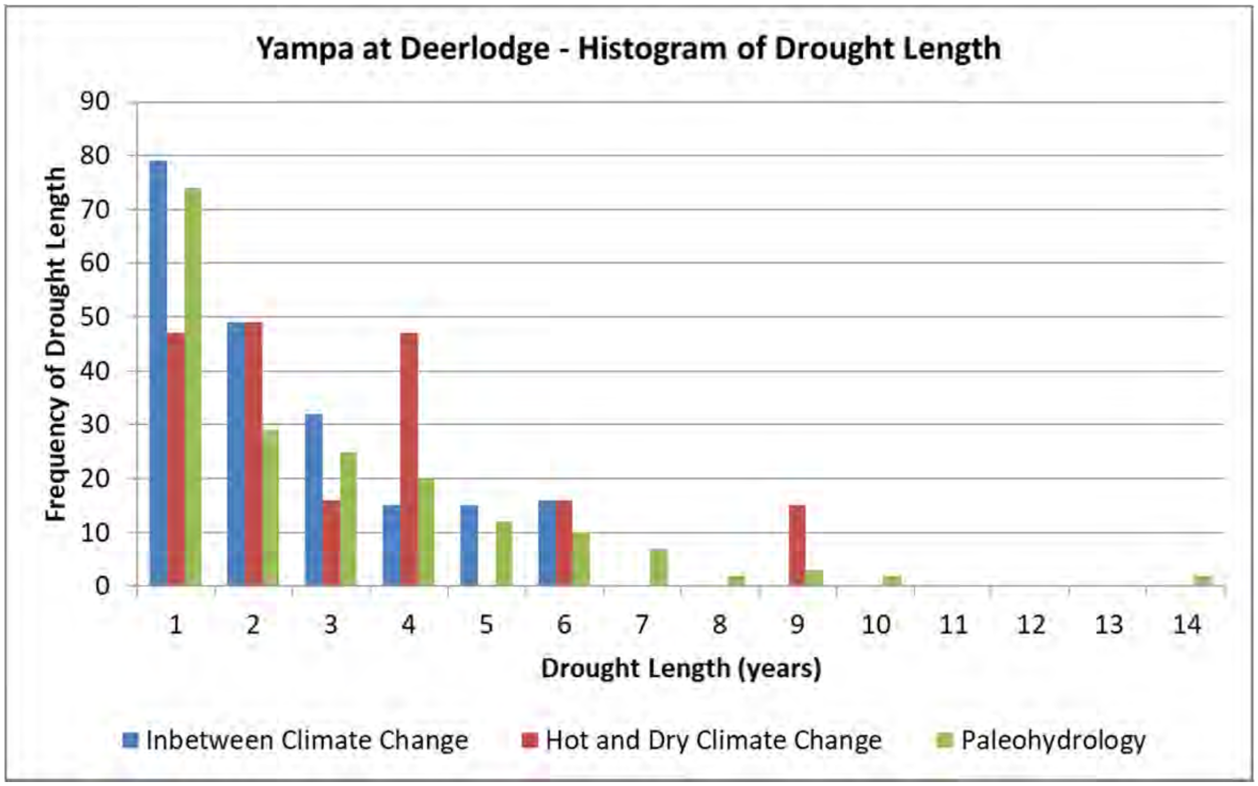


Figure 17: Histogram of Drought Length (Yampa River at Deerlodge Park) Based on the 1000 to 2013 Paleohydrology Period.

The following are key observations based on the histograms of drought length:

- The longest drought seen in the paleohydrology at the Steamboat gage is 13 years; this prolonged drought occurs twice in the record. For the Hot and Dry climate, the longest drought is 8 years and it occurs 15 times in the record. For the Between climate, the longest drought is 7 years and it occurs 15 times in the record.
- The longest drought seen in the paleohydrology at the Deerlodge gage is 14 years; this prolonged drought occurs twice in the record. For the Hot and Dry climate, the longest drought is 9 years and it occurs 15 times in the record. For the Between climate, the longest drought is 6 years and it occurs 16 times in the record.

Table 7 and Table 8 show drought magnitude, determined as the "deficit" streamflow volume. The streamflow deficit is calculated as the difference between annual streamflow volume and the current average annual streamflow volume. The annual streamflow deficit is summed for the length of the drought. The ten droughts with the largest magnitudes are shown for each hydrology. Note that, as discussed above, the climate projected hydrology is superimposed on the 1950 through 2013 variability so, although the projections represent future hydrology, they have been "tied" to observed years.

Table 7: Top 10 Severe Droughts (Yampa River at Steamboat)

Current			Between Climate			Hot and Dry Climate			Paleohydrology		
Drought Start	Drought Length	Drought Magnitude (ACFT)	Drought Start	Drought Length	Drought Magnitude (ACFT)	Drought Start	Drought Length	Drought Magnitude (ACFT)	Drought Start	Drought Length	Drought Magnitude (ACFT)
1987	6	-567,919	1987	6	-549,613	1987	6	-761,737	1146	13	-1,242,920
1999	7	-515,092	1999	7	-436,628	1998	8	-725,682	1499	10	-1,021,942
1939	8	-345,317	1976	2	-278,940	1976	2	-336,055	1656	13	-856,647
1953	4	-343,666	1953	3	-241,413	1953	3	-329,307	1877	7	-739,595
1934	2	-295,138	2012	2	-217,960	1966	2	-288,209	1276	6	-608,020
1976	2	-287,137	1966	2	-206,872	2012	2	-279,171	1590	6	-597,100
2012	2	-251,156	1981	1	-173,036	1963	2	-232,791	1845	4	-594,573
1963	2	-210,557	1963	2	-169,454	1981	1	-207,075	1452	5	-571,211
1966	2	-203,585	1994	1	-126,102	1994	2	-201,083	1987	6	-568,359
1959	3	-158,729	1961	1	-75,476	1959	3	-158,947	1471	10	-560,661

Table 8: Top 10 Severe Droughts (Yampa River at Deerlodge Park)

Current			Between Climate			Hot and Dry Climate			Paleohydrology		
Drought Start	Drought Length	Drought Magnitude (ACFT)	Drought Start	Drought Length	Drought Magnitude (ACFT)	Drought Start	Drought Length	Drought Magnitude (ACFT)	Drought Start	Drought Length	Drought Magnitude (ACFT)
1987	6	-3,333,687	2002	6	-3,008,370	1999	9	-4,600,892	1146	14	-7,710,008
2000	5	-2,837,947	1988	5	-2,565,280	1987	6	-4,017,532	1583	10	-5,708,756
1948	4	-1,936,366	1948	4	-1,850,406	1948	4	-2,464,082	1176	14	-5,082,576
1952	4	-1,663,972	1954	3	-1,611,172	1953	4	-2,101,151	1880	7	-4,548,973
1976	2	-1,578,623	1960	2	-1,563,524	1959	3	-1,850,254	1256	9	-4,314,061
1959	3	-1,522,435	1975	3	-1,205,044	1976	2	-1,817,796	1280	6	-3,550,303
1963	2	-1,439,413	1968	2	-1,060,766	1966	4	-1,745,876	1038	10	-3,524,777
1966	2	-1,072,669	1963	2	-1,023,008	1963	2	-1,355,657	1062	9	-3,440,282
1979	3	-926,339	1981	1	-951,355	1981	1	-1,105,764	1848	4	-3,406,315
1993	2	-826,107	1995	1	-658,310	1994	2	-944,648	1991	6	-3,382,804

The tables of the largest magnitude droughts in the Yampa highlights that the basin has seen longer and more extreme droughts based on the Paleohydrology record than in observed history or projected from the two climate scenarios.

The BRT determined that while the Hot and Dry climate scenario is not as severe as the Paleohydrology, it still shows a significant decrease in streamflow on average and has droughts that are longer and larger than those based on historical hydrology. Therefore, partly to be consistent with Colorado's Water Plan, historical hydrology, Between hydrology, and Hot and Dry hydrology were selected for use in investigating future demands and IPPs in the Yampa and White basins.

Future Demands

The BRT directed WWG to examine future conditions for the Yampa and White basins. A planning horizon of 2050 was selected for future demand levels, to correspond with the planning horizon chosen for Colorado's Water Plan. The BRT determined that high demand projections were appropriate to examine; then solicited water user input on their future demands. Some users recommended that the BRT use values from the State of Colorado's SWSI 2010 report for the 2050 high level demands and others provided updated demand projections for this project. The future consumptive demand values are presented in Table 9, organized by sector and county. The table shows current demands for reference.

Table 9: Future Consumptive Demands for the Yampa and White River Basins

County	Model Node	Node Description	Current Demand (ACFT/Y)	Future Demand (ACFT/Y)
M&I				
Moffat	44_AMY001	Unincorporated domestic in District 44	742	742
	44_FutMun	Future unincorporated domestic District 44	0	1,415
	55_AMY003	Unincorporated domestic in District 55	13	13
	55_FutMun	Future unincorporated domestic District 55 represented on the Little Snake River	0	25
	4400581	City of Craig	2,169	6,305
Routt	57_AMY001	Unincorporated domestic in District 57	484	484
	57_FutMun	Future unincorporated domestic District 57	0	796
	58_AMY001	Unincorporated domestic in District 58	1,342	1,342
	58_FutMun	Future unincorporated domestic District 58	0	2,178
	58_StmbtMW	Combined Steamboat/Mt Werner	4,332	11,200
		OR	**OR**	**OR**
	58_StmbtMW 58_FutElk	Combined Steamboat/Mt Werner Elk River Diversion for Steamboat	4,332 0	9,345 1,855
Rio Blanco	43_AMW001	Unincorporated domestic in District 43	1,104	1,104
	43_FutMun	Future unincorporated domestic District 43	0	816
	4300889_D	Town of Rangely	1,810	3,150
	4306045	Town of Meeker	338	588
Golf Courses				
Moffat	57_FutGC2	Golf Courses in Water District 57	0	2,190
Routt	58_FutGC1	Golf Courses in Water District 58	0	3,410
Rio Blanco	43_FutGlf	Golf Course in Water District 43		300
Snowmaking				
Routt	5802374	Steamboat Resort	355	570
Thermoelectric Power Generation				
Moffat	4400522	Craig Station (Tri-State)	12,483	21,000
Routt	5700512	Hayden Station (Xcel)	5,414	8,000
Energy Development				
Rio Blanco	43_GasOil	Future development on White River mainstem	0	35,800
	43_OilShl	Future development on Piceance Creek	0	10,000
Future Agriculture				
Moffat	44_Oxbow	New irrigated acreage	0	~ 1,469

Municipal demand for Moffat County was supplied by the City of Craig. The estimate for total Moffat County demand was divided into unincorporated domestic demands and the City of Craig demands assuming that the City of Craig would continue to serve approximately 74 percent of Moffat County demands. The City of Craig's future demands and unincorporated demands are modeled with their current water rights portfolios.

Municipal demand for Routt County was from the SWSI 2010 effort. The estimate for total Routt County was divided into unincorporated domestic demand and the City of Steamboat/Mt. Werner Water District demand assuming that the Steamboat/Mt Werner would continue to serve approximately 70 percent of Routt County demands. The City of Steamboat provided the demand numbers for the Elk River Diversion IPP. As shown in Table 9, when the Elk River Diversion is included as an IPP, a portion of the Steamboat/Mt. Werner future demand is represented at a future Elk River diversion structure. The Steamboat/Mt. Werner demands are modeled with their current water rights portfolio. When the Elk River Diversion IPP is active, it is assigned its conditional water right. The future unincorporated demand is provided a junior water right.

The future golf courses have monthly irrigation demands based on turf grass consumptive use, represented as river diversions sprinkler irrigation efficiency estimates. The future golf course in Rio Blanco County represents a single new golf course. The future golf course in Moffat and Routt counties represent multiple new golf courses. Golf course demands are modeled with junior (current day) water rights. Increased snowmaking for Steamboat Ski Area is modeled with the existing snowmaking water rights.

Demands for water to generate thermoelectric power were provided by Tri-State and Xcel, and are modeled with the power companies' current water right portfolios. The BRT selected the long-term high end of the projected water demands from the "White River Storage Feasibility Study" (2015) as the most representative data source for future energy development in the White River basin. The total demand was divided between a diversion on the mainstem of the White River representing 75 percent of the demand and a diversion on Piceance Creek representing 25 percent of the demand, roughly based on water available on Piceance Creek. The White River diversion is provided a present day (2016) water right. The Piceance Creek diversion is modeled with a 1975 water right, which generally represents the dates of conditional water rights currently held by energy companies in the Piceance Basin.

The YWG Agriculture Needs Assessment and the subsequent BIP identified 14,805 acres that could support new agriculture in Moffat County. The diversion is located at the oxbow of the Yampa River for planning purposes. For this effort, the BRT chose to include 500 acres of new agricultural development as a first increment. The 44_Oxbow node assumes that the new acreage would be developed in a similar fashion as existing acreage in the lower Yampa River basin. Therefore, the 500 acres is 7 percent alfalfa and 93 percent grass pasture. It is 81 percent with flood irrigated and 19 percent sprinkler irrigated. The crop irrigation water requirements are based on yearly historical climate conditions. The diversion demand is provided with a junior (current day) water right.

Under the climate projected scenarios, agricultural demands increase because of warmer temperatures. The increased agricultural demands developed for the current (2018) SWSI update were used with the corresponding climate projected hydrology.

Figure 18 shows the modeled location of the future demands.

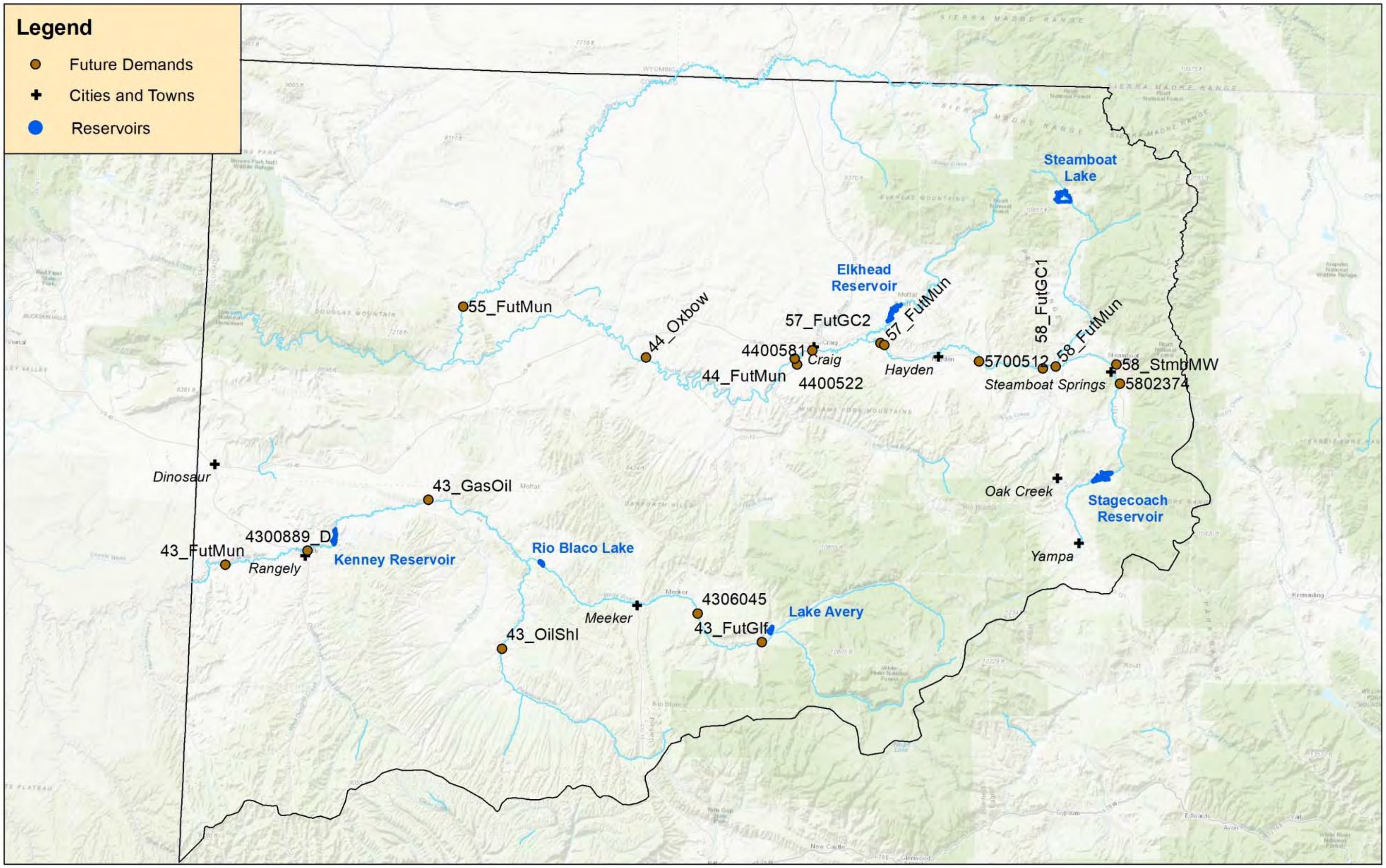


Figure 18: New and Increased Future Demand Locations in the Yampa and White Basins

Figure 19 through Figure 22 show the future monthly demand distribution of select nodes in each sector. Note that oil and gas energy demands are expected to be the same each month.

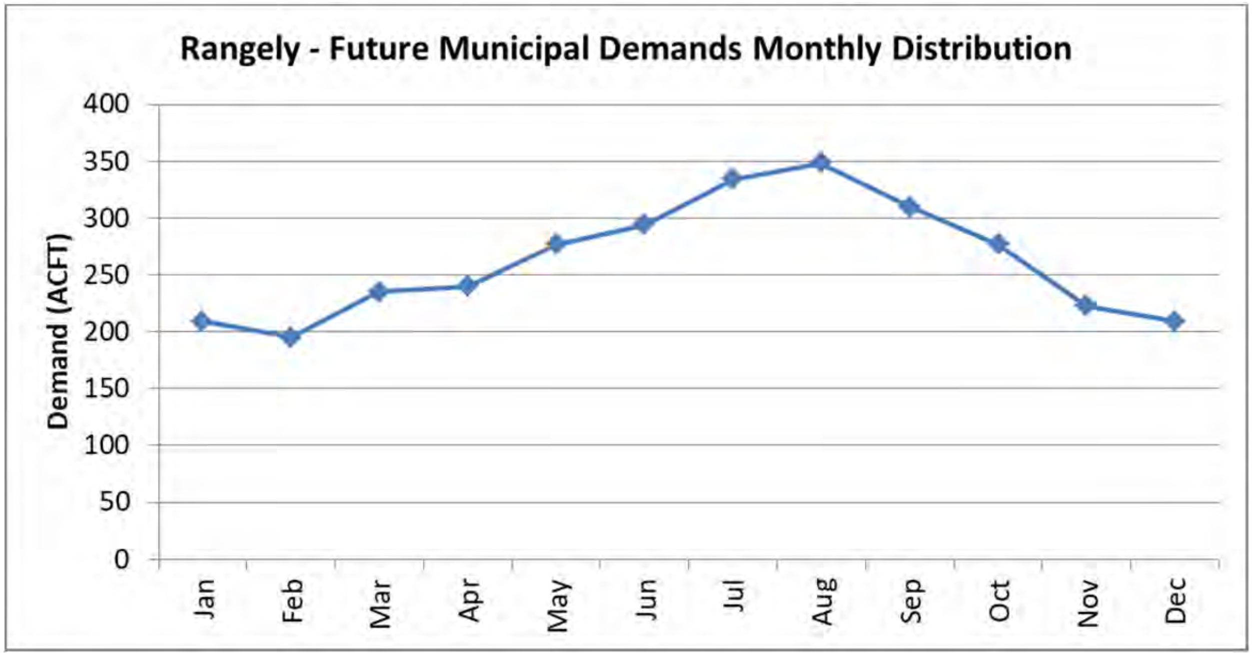


Figure 19: Rangely Future Demand, Example of Municipal Monthly Demand Distribution

Figure 20: 43_FutGlf Future Demand, Example of Golf Course Monthly Demand Distribution

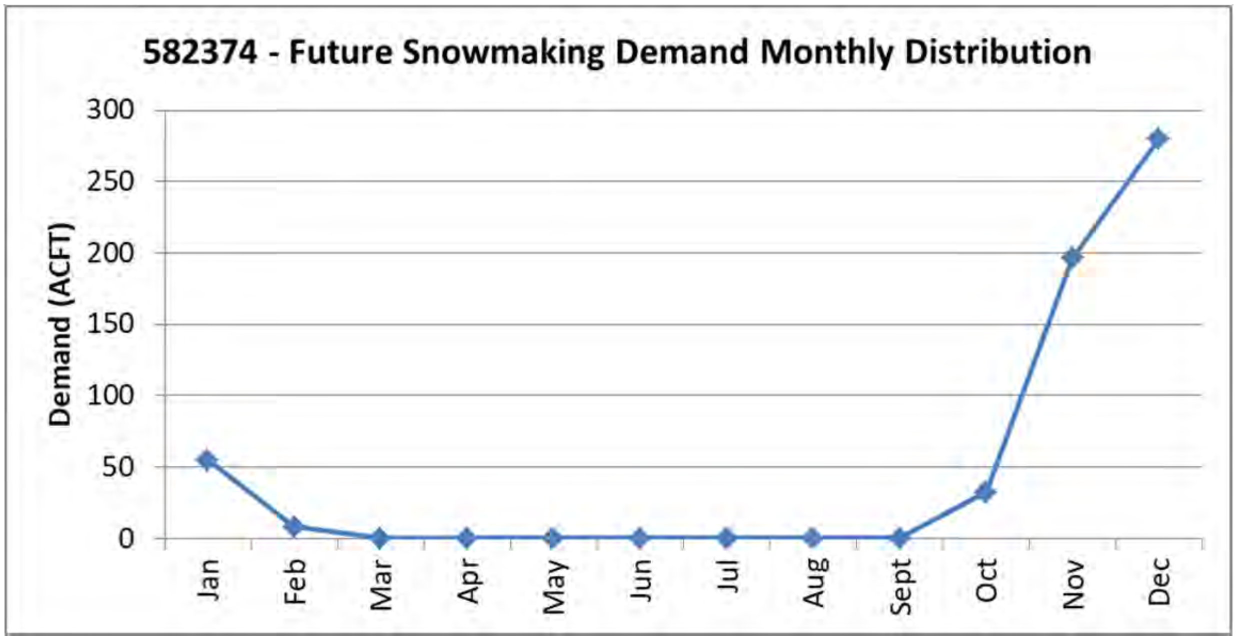


Figure 21: Future Snowmaking Monthly Demand Distribution

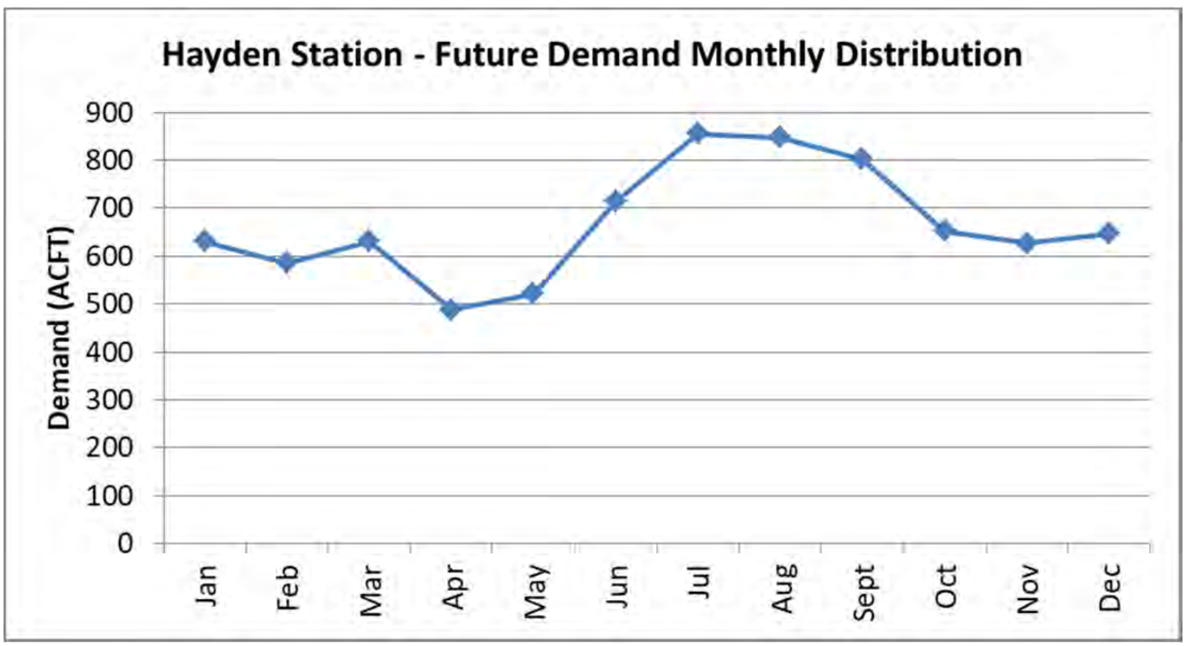
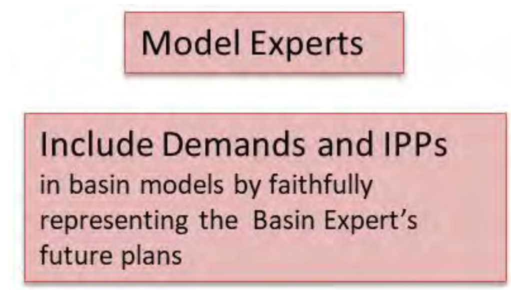


Figure 22: Hayden Station Future Demand, Example of Thermoelectric Monthly Demand Distribution

IPP Fact Sheets



The IPPs included in this project were volunteered by project proponents. WWG met with project proponents and documented how their projects would be represented in the model using fact sheets. The fact sheets were presented and explained to the BRT representatives during the March 8 and March 20, 2017 workshop, providing another opportunity to build confidence in the use of the model by clearly explaining operations, demands, and IPP representation. Table 10 summarizes the IPPs and associated fact sheet, in alphabetical order. The numbers corresponding to the fact sheets indicate the section below in which the fact sheets are presented in their entirety. Note that select IPP alternatives are presented in the Modeling Results section; all of the IPP alternatives investigates were presented at BRT workshops and documented in the appendices. Figure 23 is a map showing the location of the IPPs.

Table 10: IPP Description and Proponents

No.	IPP Fact Sheet	IPP Proponent
1	Approach to the White River PBO	USFWS, State of Colorado, State of Utah, Upper Basin Water Users, TNC, Rio Blanco Water Conservancy District
2	Approach to the Yampa River PBO	USFWS, State of Colorado, State of Wyoming, Upper Basin Water Users, TNC, Colorado River Water Conservation District
3	Elkhead Reservoir Alternative Operations	Colorado River Water Conservation District
4	Elk River Diversion	City of Steamboat Springs
5	Juniper Water Conservancy District Reservoir Alternatives and Operations	Juniper Water Conservancy District
6	Lake Avery Reservoir Enlargement	Yellow Jacket Water Conservancy District, Colorado Parks and Wildlife
7	Little Morrison Diversion	Upper Yampa Water Conservancy District
8	Morrison Creek Reservoir	Upper Yampa Water Conservancy District
9	Preferred Flow Target	City of Steamboat Springs
10	Stagecoach Reservoir Alternative Operations	Upper Yampa Water Conservancy District
11	Steamboat Lake Reservoir Alternative Operations	City of Steamboat Springs, Colorado Parks and Wildlife
12	Wolf Creek Reservoir	Rio Blanco Water Conservancy District
13	Yampa Well Expansion	Mt. Werner Water District

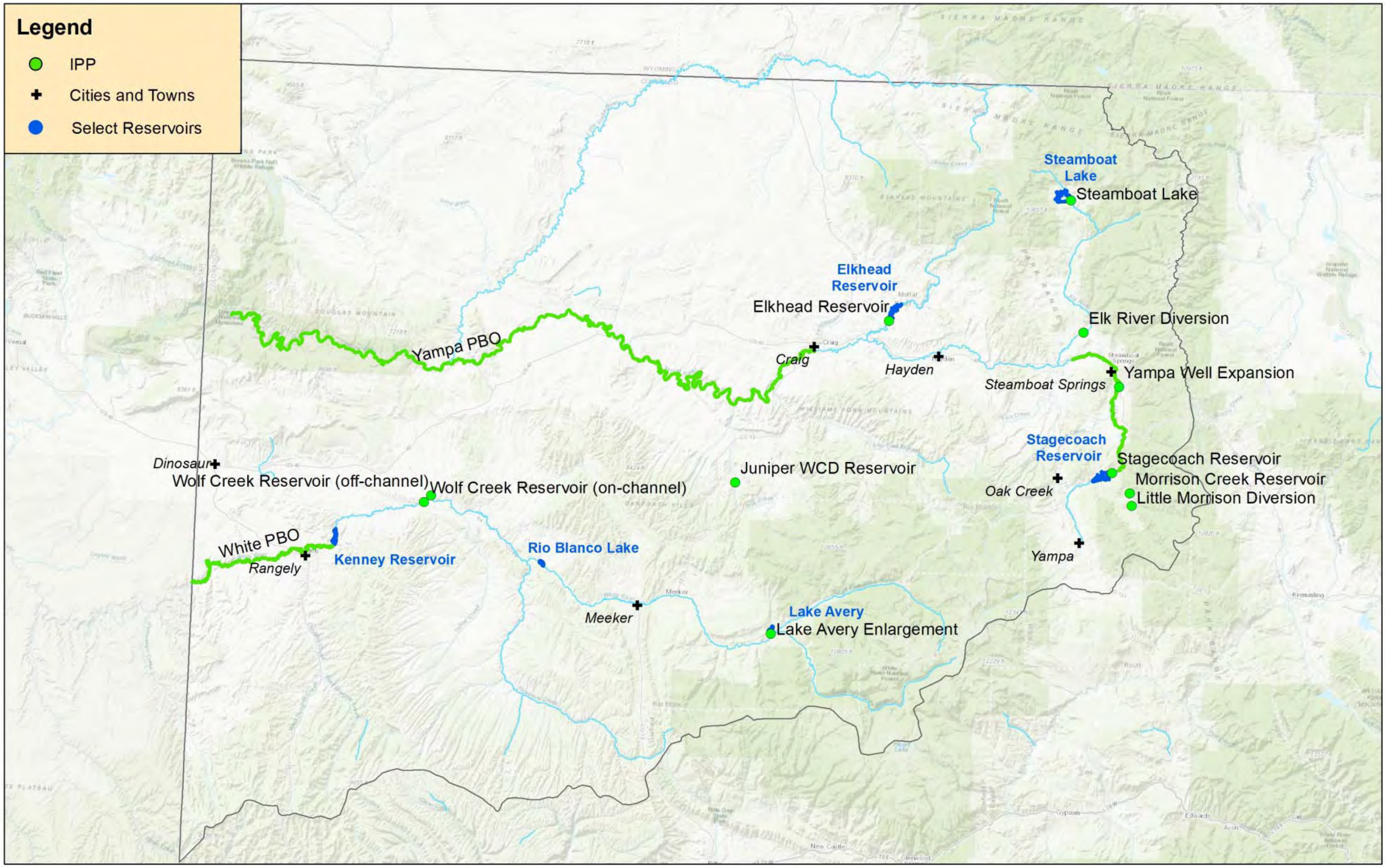


Figure 23: Map of IPP Locations

1. Approach to the White River PBO

Project Description: The U.S. Fish and Wildlife Service (USFWS) is working to develop the Programmatic Biological Opinion (PBO) for endangered fish species in the White River. It is anticipated that the PBO will protect future development while setting streamflow targets to maintain a healthy fishery. The target flows are expected to be measured at USGS gage 0965000 White River at Watson. The USFWS will work with Colorado and Utah state representatives, environmental representatives, and water users to finalize the flow targets and future development "covered" under the PBO. The BRT has the opportunity to investigate future uses in this modeling effort to both inform and recommend anticipated future development opportunities that should be covered under the PBO.

The flow targets **have not been finalized**; however the USFWS has developed potential targets options based on historical flow statistics and biological recommendations. Similar to other fish maintenance and recovery flows, both spring high flows and non-runoff baseflows are being considered and vary depending on hydrologic year-type; the flow "request" is greater during wetter years. These initial flow targets will be used to understand the potential opportunities and impacts from both increased demands and IPPs in the White River basin.

Modeling Information: To represent the target flows, an instream flow node will be used in StateMod. The node will be assigned model ID 43_USFWS. It will be located downstream of the Watson gage.

Instream Flow Demand: The 43_ USFWS instream flow reach is set to 300 cfs year-round. This is a very preliminary value and the BRT expects that the final White River PBO flow targets will be different.

Instream Water Right: 43_ USFWS was assigned the most junior right in the model, which means it cannot call out any of the upstream diverters, but it can call out diversions that are made under free-river conditions. Consumptive IPPs investigated in the White River will be given water rights senior to the Watson target flows.

Potential Interactions: Future demands and consumptive IPPs investigated in the White River will be given water rights senior to the Watson target flows. Reductions in streamflow will be identified and additional opportunities to change the timing of IPP depletions and/or use IPP storage to meet Watson target flows will be investigated.

2. Approach to the Yampa River PBO

Project Description: The US Fish and Wildlife Service (USFWS) released the Programmatic Biological Opinion (PBO) on the *Management Plan for Endangered Fishes in the Yampa River* in

Structure Water Right: The reservoir is filled using a new conditional water right. The water right has a current day priority. Note that previous modeling efforts have used a conditional water right held by Tri-State, which is decreed in a different location for different purposes. Tri-State is not participating in this IPP, so their conditional water right is not considered.

Reservoir Capacity: The reservoir capacity is 20,000 acre-feet.

Structure Demand: Two alternative configurations of the JWCD Reservoir were considered. In Alternative 1, the reservoir releases water to existing late season irrigation shortages and future agricultural development (44_Oxbow). In Alternative 2, the reservoir releases water to the same agricultural demands, plus to the Yampa River PBO. These releases supplement the streamflow at the Maybell gage for the Recovery Program.

Reservoir Accounts: Two alternative configurations of the JWCD Reservoir were considered. In Alternative 1, the reservoir has one account (20,000 acft for agriculture). In Alternative 2, the reservoir has two accounts (10,000 acft for agriculture and 10,000 acft for the Yampa River PBO.

Reservoir Operations: As described above, two alternatives for reservoir operations will be considered. First, the reservoir will release to existing and future agricultural demands. Second, the reservoir will release to existing and future agricultural demands, plus release water to support flows at the Maybell gage for the Yampa River PBO.

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6. Lake Avery Reservoir Enlargement

Project Description: Yellow Jacket Water Conservancy District (YJWCD) is proposing enlarging Lake Avery. The pool created by enlarging the reservoir would be available to meet downstream demands. The reservoir would be expanded by raising the crest of the spillway. Lake Avery is currently owned and operated by Colorado Parks and Wildlife as a State Wildlife Area. The primary purposes of wildlife and recreation would be maintained, with only the enlargement pool available to meet downstream demands.

Model Structure Information: The state has assigned WDID (4303633) to Lake Avery and will be used and the model node identifier. The enlargement will occur in the same location as the current Lake Avery.

Structure Water Right: YJWCD has a conditional storage water right originally decreed for Sawmill Mountain Reservoir, located upstream of Lake Avery on Big Beaver Creek. This conditional storage right would be used to fill the enlargement pool. The storage right is for 10,000 acre-feet and has an Adjudication Date of December 31, 1975. The current water rights will continue to fill the existing Lake Avery pool.

Reservoir Capacity: YJWCD is interested in looking at two enlargement reservoir sizes:

- 1,261 acre feet – this corresponds to raising the spillway by 5 feet.
- 2,644 acre feet – this corresponds to raising the spillway by 10 feet and is the maximum amount the reservoir could be expanded without inundating the upstream Livingston Ranch

Structure Demand: The enlargement pool releases to help maintain flow in the White River for environmental purposes, specifically to help meet the CWCB instream flow right measured at the USGS White River Below Meeker gage. The enlargement pool is also available to meet future demands for a proposed golf course near Sleepy Cat Ranch (43_FutGlf) and Meeker municipal demand. The proponents are also considering providing augmentation water for domestic wells, but this is not represented in StateMod.

Reservoir Accounts: The reservoir is modeled with two accounts. The "Active Storage" account represents the current active storage of the reservoir (7,658 acre feet). It is filled with the current water rights for the reservoir. The "Enlargement" account represents the enlarged storage pool (either 1,261 or 2,644 acre-feet, depending on the enlargement scenario). It is filled with the YJWCD Sawmill Mountain conditional right.

Reservoir Operations: The "Active Storage" will not be released to meet downstream demands. The "Enlargement" account will meet downstream demands. CPW has an operational practice to bypass 2 cfs when filling the reservoir, which will continue to be represented in the model.

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7. Little Morrison Diversion

Project Description: The Upper Yampa Water Conservancy District (UYWCD) is planning for a new diversion point on Morrison Creek. Two alterative infrastructure projects will be considered. The first alternative is the Little Morrison Diversion IPP. The second alternative is the Morrison Creek Reservoir IPP (described below). The Little Morrison Diversion IPP carries water via a pipeline to Stagecoach Reservoir (5804213). Stagecoach Reservoir will serve existing and future UYWCD contractees, which include multiple agricultural users, the City of Steamboat Springs, Mt. Werner Water District, and Tri-State's Craig Station. Additionally, UYWCD can provide short term leases of stored water for the RICD in Steamboat Springs.

Model Structure Information: The state has assigned a WDID (5801869) to the water right and will be used as the model node identifier. It will be located in the model on Morrison Creek between the confluence with Beaver Creek and the proposed Morrison Creek Reservoir location. The model node will be a natural inflow node. It will be assigned an upstream area of 40 square miles and an average annual precipitation of 28.13 inches. The model will determine

Table 13: Steamboat Lake Accounts

Account	Storage Amount (ACFT)
Hayden Station	5,000
Conservation	18,209
Instream Flow Pool	3,155
Total	26,364

Reservoir Operations: This IPP will look at two alternative Reservoir Operations.

- *Hayden Pool Supplements* **-** 1,200 ACFT from the 5,000 acre-foot Hayden Station Pool is available to supplement the Elk River Diversion IPP demand. The 1,200 acre-feet would be filled using the conditional Juniper Reservoir rights. These rights include Steamboat Lake as an alternative point of diversion and are only available when in-priority at the original contemplated point of diversion.
- *CPW Pool Supplements* **-** 1,200 ACFT from CPW pool is available to supplement the future Elk River Diversion IPP demands.

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12. Wolf Creek Reservoir

Project Description: Rio Blanco Water Conservancy District (RBWCD) is proposing a new reservoir in the White River Basin. Information in this modeling fact sheet was provided by W.W. Wheeler and Associates on behalf of RBWCD. The operational scenarios of the reservoir are considered preliminary and will be further refined as project partnerships are confirmed and the needs of project partners are further refined. The operational scenarios are based on the information that was documented in the White River Storage Feasibility Study Final Report dated March 4, 2015.

In summary, the preliminary operational scenarios listed Table 14 in will be considered:

Table 14: Wolf Creek Reservoir IPP Operational Scenarios

<table>
<tr><th></th><th>Off-Channel Dam</th><th>Mainstem Dam</th></tr>
<tr><td rowspan="2">90K ACFT Reservoir

Reservoir Accounts:
42K Environmental (Fish needs)

48K Other needs (M&I, Energy)</td><td>***Scenario 1 –***
• Pump Station Capacity 400 cfs (location defined below)
• Diversions to the reservoir are only made when the target of 300 cfs is met at the Watson Gage</td><td>***Scenario 1a –***
• Water is stored in the reservoir when the flows on the White River are in excess of the target 300 cfs at the Watson Gage.</td></tr>
<tr><td colspan="2">• Releases are made to meet future demands from the 48K account.
• Releases from the 42K account provide supplemental flow to Watson Gage 300 cfs target.</td></tr>
<tr><td rowspan="2">48,000 AF Reservoir

Reservoir Accounts:
48K Other needs (M&I, Energy)

No Environmental Storage</td><td>***Scenario 2 –***
• Pump Station Capacity Estimate – 100 cfs
• Diversions to the reservoir are made whenever the reservoir is in priority ***(Streamflows at Watson are not accounted for.)***</td><td>***Scenario 2a –***
• Water is stored in the reservoir when the reservoir is in priority ***(Streamflows at Watson are not accounted for.)***</td></tr>
<tr><td colspan="2">• Releases are made to meet future demands from the 48K account</td></tr>
</table>

Model Structure Information: In StateMod, two location scenarios will be considered.

For the off-channel scenario, the reservoir will be located on Wolf Creek. It will be assigned model ID 43_WolfOC, short for Wolf Creek Reservoir off-channel immediately upstream of the confluence with the White River. The reservoir will be filled from pumps diverting from the White River. For this modeling effort, the pump station will be located at longitude -108.4828, latitude 40.2004 decimal degrees, or as described water rights application: *The diversion point from the White River for the Wolf Creek Off-Channel Dam is located in the NE quarter of the SE quarter of Section 27, Township 3N, Range 99W, 480 feet west of the east section line of Section 27 and 2620 feet north of the south Section Line of Section 27.* In the model, this is located just downstream of the confluence of Wolf Creek and White River. The pump station will be assigned model ID 43_WolfPS, short for Wolf Creek Reservoir pump station.

For the mainstem scenario, the reservoir will be located on the White River between Stadtman Ditch (4300949) and Lawrence Ditch (4301003). It will be assigned model ID 43_WolfMS, short for Wolf Creek Reservoir Mainstem.

Both project locations include outlet works that are capable of releasing approximately 1,280 cfs – 1,470 cfs from the normal high water line. The flows are assumed to be released into the

White River for downstream diversion and use by Rangely and the Future Energy Demands on the White River. Stored water is released via a pipeline to meet the Future Energy Demands in the Piceance Basin.

Structure Water Rights: The conditional water rights were assigned to Wolf Creek Reservoir in the model. The Rio Blanco Water Conservancy District filed for three conditional water rights associated with the Wolf Creek Reservoir on October 29, 2014. The first right is the Wolf Creek Reservoir Pump and Pipeline, which will be used to fill the Wolf Creek Off-Channel Reservoir. The second right is the Wolf Creek Off-Channel Dam and Reservoir. The third right is for an alternative Wolf Creek Mainstem Dam and Reservoir that would be constructed on the mainstem of the White River. The water right filed is for municipal, industrial, commercial, irrigation, domestic, recreation, piscatorial, augmentation, wildlife habitat, maintenance and recovery of federally listed threatened and endangered species, hydroelectric power generation and all other beneficial uses.

Structure Demands: The reservoir will release to meet Municipal and Industrial needs, Oil and Natural Gas development, Oil Shale development, and Environmental needs (depending on the scenario) that cannot be met directly from the river.

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13. Yampa Well Expansion

Project Description: Mt. Werner Water District and the City of Steamboat Springs are planning on expanding their well field by purchasing additional land and adding a new infiltration gallery. Their goal is to increase their capacity up to 3.5 MGD.

Model Structure Information: The expanded capacity will be represented at the Mt. Werner Yampa Diversion point WDID 5805066, which is currently in the StateMod model. The additional capacity will be 5.25 cfs. The well infiltration gallery are modeled as headgate wells, meaning that their depletions impact the river immediately.

Structure Water Right: The structure will use existing water rights held by Mt. Werner and the City of Steamboat.

Structure Demand: The wells are part of the supply portfolio available to meet the combined City of Steamboat Springs/ Mt Werner Water District future demands. The combined annual demand is 11,200 acft or 9,345 acft when the Elk River IPP is active. The wells work in combination with the other municipal water supplies to satisfy the demands.

Demand Efficiency: The efficiency of water use pattern currently used to represent the City's municipal diversions will be used for this structure to estimate return flow quantity and timing.

White River Results

The modeling results from the White River are presented in this section. The section is sub-divided into results from the Current Hydrology Scenario and results from the climate change projections.

White River - Current Hydrology

The following section provides results for the White River modeling effort using the natural historical hydrology for the 1975 through 2015 period on a daily time-step. The results focus on a comparison of the following scenarios:

Review Model Results
to develop understanding and confidence in Basin Model setup, representation, and results

- **Baseline Scenario** - represents current consumptive demands, current instream flow and recreational in-channel diversions (RICDs), existing infrastructure, and current reservoir operations superimposed on historical climate and hydrology. The 2010 irrigated acreage assessment defines current levels of agricultural demands.
- **Future Demands, No IPPs Scenario** - Future demands are set, as described in the "Future Demands" section above. The baseline demands are used for all other structures.
- **Reservoirs IPP Scenario** - This scenario was built to look at future demands considering interactions between reservoir-related IPPs. In the White River, two reservoir IPPs were initially considered (Wolf Creek Reservoir and Lake Avery Enlargement). After the July 12, 2017 workshop, the Lake Avery Enlargement IPP proponent suggested that further investigation was not warranted. The BRT decided to proceed with the following Wolf Creek Reservoir IPP.
    - Wolf Creek Reservoir IPP Scenario 1.
        - 90,000 AF reservoir, located off-channel.
        - Consumptive demands pool is 48,000 AF.
        - Non-consumptive demands pool is 42,000 AF.
        - Pump station is located just downstream of the confluence of Wolf Creek and White River and has a capacity of 400 cfs.
        - Diversions to reservoir storage can only be made when the flows in the White River meet or exceed 300 cfs.
        - The reservoir releases water from the consumptive demands pool to meet future energy development demands on the mainstem White River and the Town of Rangely demands that cannot be met directly from the river.

    - The reservoir releases water via a pipeline from the consumptive demands pool to meet future energy development demands in the Piceance Basin that cannot be met directly from the river.
    - The reservoir releases to supplement the flow target at the Watson gage from the non-consumptive pool.
  - Approach to the White River PBO – flow demands represented as an instream flow junior to current and future uses in the basin of 300 cfs year-round. This is a very preliminary value for this investigation only - the BRT expects the final White River PBO flow targets to vary by season and year type.

Changes in Shortages

Similar to the Yampa River, the White River has a distinct snowmelt runoff hydrograph. The basin generally has enough physical water supply to satisfy demands during the peak runoff, but there are shortages under current conditions in the late irrigation season. Flows in the river are naturally low and the demand from agriculture is high. Currently, many irrigators chose not to irrigate in September, as they will face low flows in the river and shortages to their supply. The BRT was interested in understanding how the increase in future demands interacts with the current demands. The percent of unmet demand volume for the White River are shown in Table 30.

Current agricultural users have the same demands in the three model scenarios. For the purposes of quantifying agricultural storages, the basin has been divided into regions.

- Upper White Agriculture - irrigation structures located in the North Fork and South Fork of the White River watersheds and diverting from the mainstem of the White River upstream of the confluence with Big Beaver Creek
- Middle White Agriculture - irrigation structures located below the White River confluence with Big Beaver Creek and above the confluence with Piceance Creek
- Piceance Basin Agriculture - irrigation structures located in the Piceance Creek watershed
- Lower White Agriculture - irrigation structures located downstream of the confluence with Piceance Creek

Table 30: Percent Shortage to Consumptive Demands in the White River

Name	WDID	Baseline	Future Demands, No IPPs	Reservoir IPP
Meeker	4306045	0%	0%	0%
Rangely	4300889_D	1%	1%	0%
WD 43 Future Golf Course	43_FutGlf	-	24%	34%
Future Energy Development - White River Mainstem	43_GasOil	-	8%	0%
Future Energy Development - Piceance Basin	43_OilShl	-	25%	0%
Piceance Agriculture	Multiple	22%	22%	22%
Upper White Agriculture	Multiple	13%	11%	11%
Middle White Agriculture	Multiple	13%	11%	11%
Lower White Agriculture	Multiple	2%	2%	2%

Key observations from Table 30 are:

- The future increased demand for municipal water at Meeker and Rangely are met by their existing water rights portfolios. Meeker's demands are fully satisfied; the minor shortages to Rangely's demands in the Future Demands, No IPPs scenario are eliminated by releases from Wolf Creek Reservoir in the Reservoir IPP scenario.
- Shortages to agriculture remain very similar in the three scenarios.
- Future demands, including the future golf course (43_FutGlf) and future energy demands (43_GasOil, 43_OilShl) experience large shortages in the Future Demands, No IPPs scenario. Golf course and energy development demands on the White River mainstem are given current day (January 2016) water rights in the model, which are frequently out of priority. For the future golf course, the river near Meeker supports a large number of agricultural diversions and frequently does not have unallocated water.
- The future energy development in the Piceance Basin (43_OilShl) is modeled with a 1975 water right, but still experiences significant shortages in the Future Demands, No IPPs scenario. The 1975 priority date is a "representative" date for the large number of conditional water rights held by oil and gas companies in the Piceance Basin, and is relatively junior to other diversions in the Piceance Basin. In addition to the legal limitation due to the junior right, Piceance Creek is often limited by the physical availability of water.
- The Reservoir IPP scenario eliminates the shortages to Rangely and both future energy development demands. Stored water in Wolf Creek Reservoir is released to meet these demands when there is insufficient supply in the river.

- The future golf course is modeled with a water right that is junior to Wolf Creek Reservoir. It is not supplied by the reservoir. Therefore, it is "called out" by Wolf Creek Reservoir and experiences additional shortages in the Reservoir IPP scenario.

Change in Water Source to Meet Demands

The source of water at the Watson gage is of particular interest in the development of a White River PBO. It was important to understand if the target streamflow values were being met from unappropriated streamflow, from releases from Wolf Creek Reservoir, or shorted. The graphs below display how the conditions in the river change with the Wolf Creek Reservoir IPP. Figure 37 illustrates the variability in streamflow over the model period from 1974 through 2015. The low flow periods are the most critical, as lower flows can stress the endangered fish. Figure 38 through Figure 40 show "zoomed in" graphics highlighting the source of water at the Watson gage during the 2000 through 2004 water year (October through September) dry period to highlight how the conditions in the river change in the different scenarios. Note that the bar graphs are a monthly summary of daily information. Therefore, the total monthly volume may be above the target volume if the month has high flows at the beginning, but low flows at the end of the month requiring reservoir releases.

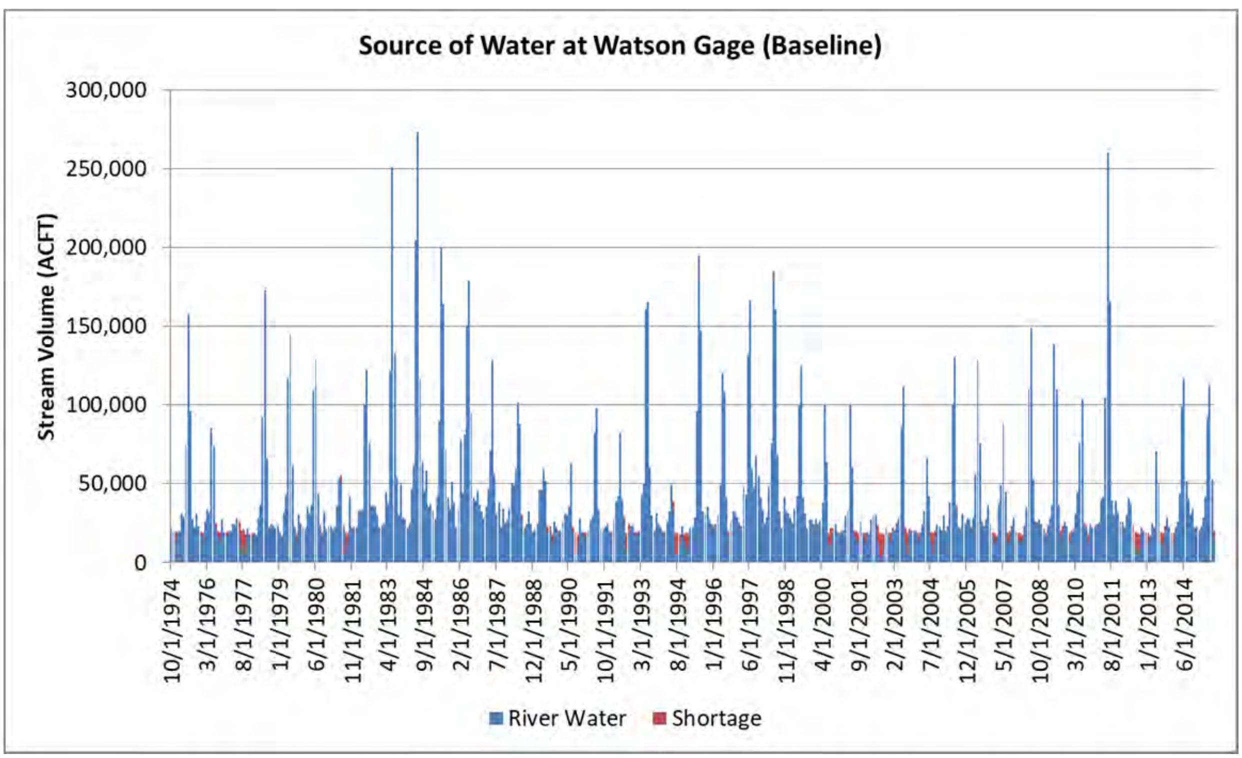


Figure 37: Sources of Water at Watson Gage (Baseline)

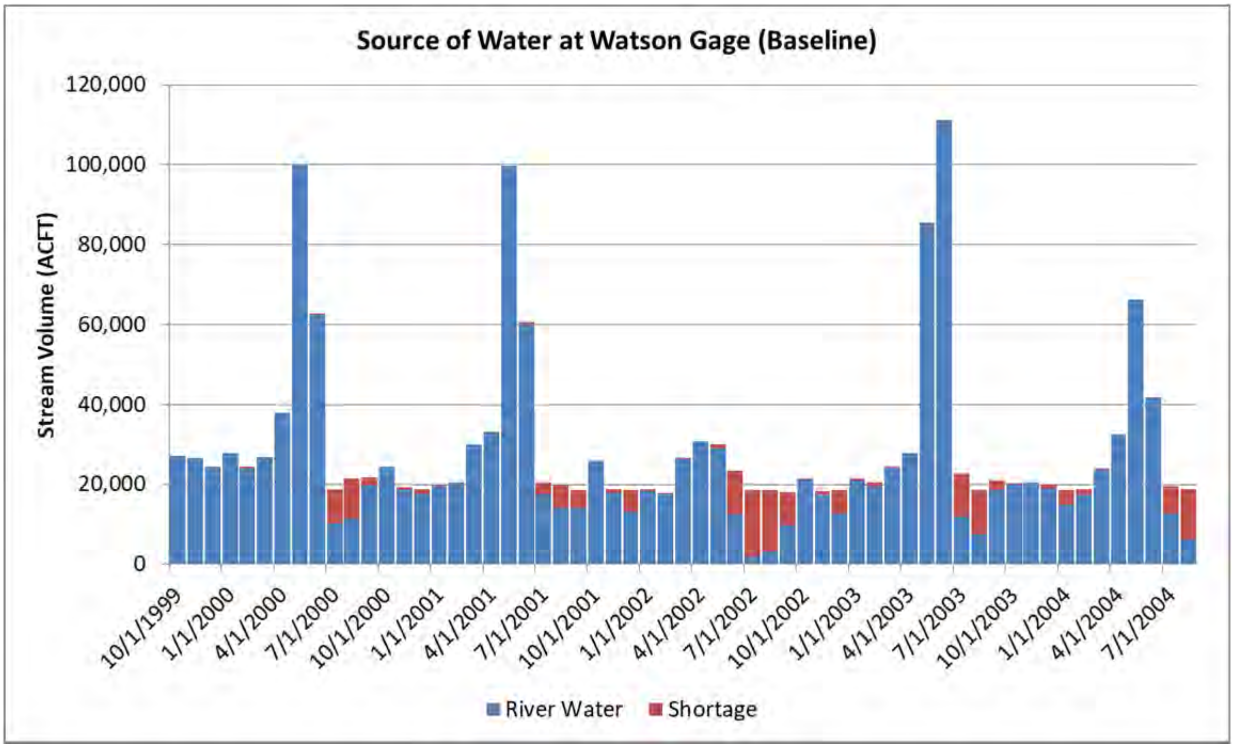


Figure 38: Sources of Water at Watson Gage (Baseline) for Water Year 2000 through 2004

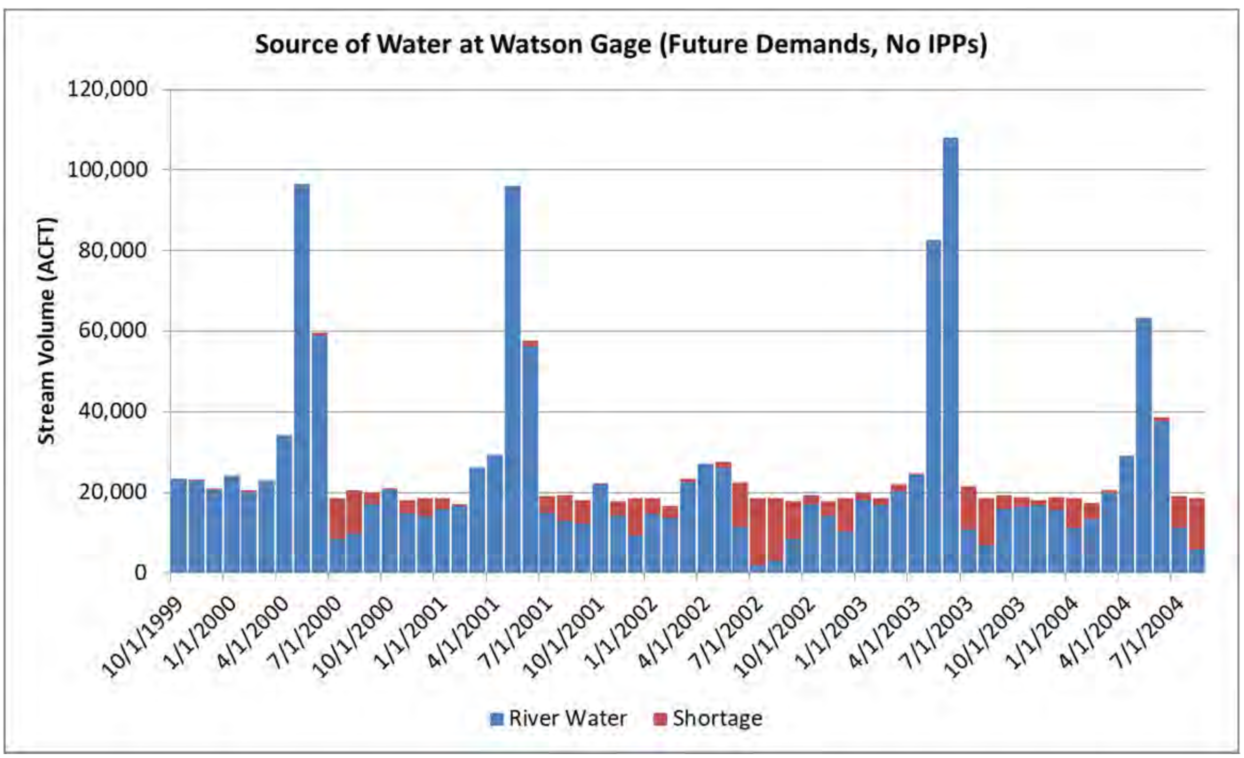


Figure 39: Sources of Water at the Watson Gage (Future Demands No IPPs)

The Watson gage target flow is set to 300 cfs year round (approximately 18,000 acft/month), regardless of season or year type. It is anticipated that the White River PBO process will refine the target flow to vary be season and by year type, however, flow targets were not available for the project. Both the Baseline and the Future Demands No IPPs scenarios show are large shortages to the Watson target flow, with increased shortages in the Future Demands No IPPs scenario compared to the Baseline, as the large future demands for energy development divert water from the river.

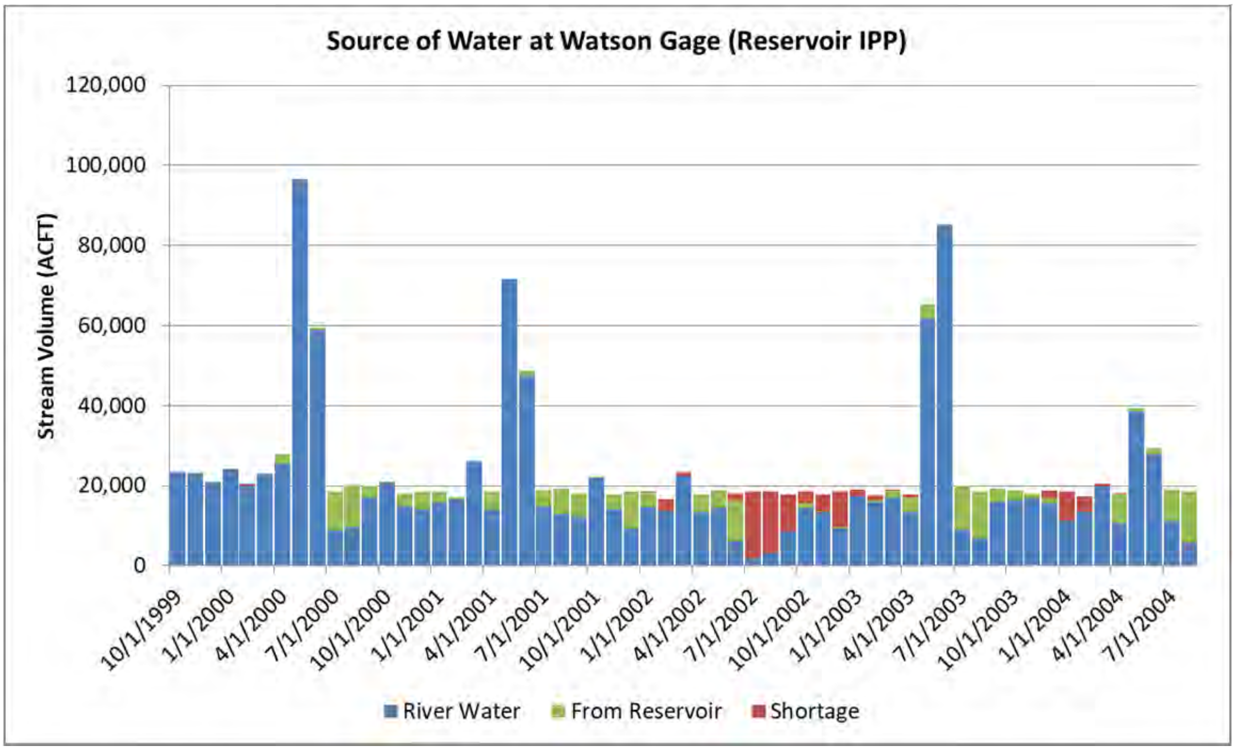


Figure 40: Sources of Water at Watson Gage (Reservoir IPP).

Wolf Creek Reservoir releases to supplement the target flow at Watson are shown in green in Figure 40. The reservoir is able to eliminate shortages in 2000 and 2001. It is able to reduce shortages during the early months of 2002, but the reservoir pool for non-consumptive demands is emptied of water by July 2002. The reservoir is able to start refilling during the 2003 spring runoff and provide water to reduce the shortages during the irrigation season. This graph highlights the need to have the target flow vary with the season and the year type. For example, if the reservoir only released to the streamflow target during the late summer, it would have had enough water in storage to provide supplemental flows during the most critical period. Instead, the Reservoir IPP scenario shows the reservoir providing water early in the year and running out of storage by the late season. Additionally, a year-round flow target causes the reservoir to release supplemental flow during the winter months, which may not be required with a lower winter PBO target.

Changes in Reservoir Storage

Storage in the White River is very limited. The current reservoirs (Lake Avery and Kenney Reservoir) primarily serve as "run-of-the-river" facilities, meaning that they rarely release from storage to meet downstream demands. Lake Avery's primary purpose is to provide habitat for the State wildlife area. Kenney Reservoir provides hydropower and flat water recreation. It can also serve as an emergency water supply for the town of Rangely. In contrast, the Wolf Creek Reservoir IPP would store water during the runoff in order to release water to increased municipal and future energy demands throughout the year. Figure 41 below shows the time series of Wolf Creek Reservoir end of month contents, showing the frequency of reservoir filling and releasing. The figure shows the total reservoir storage and the storage for each pool in the reservoir. In the Reservoir IPP scenario, the reservoir releases more to supplement flow to the Watson flow target than for future consumptive demands. Note that this result may change depending on the final White River PBO flow targets. If they are less than 300 cfs year-round, a smaller non-consumptive pool may meet the flow targets.

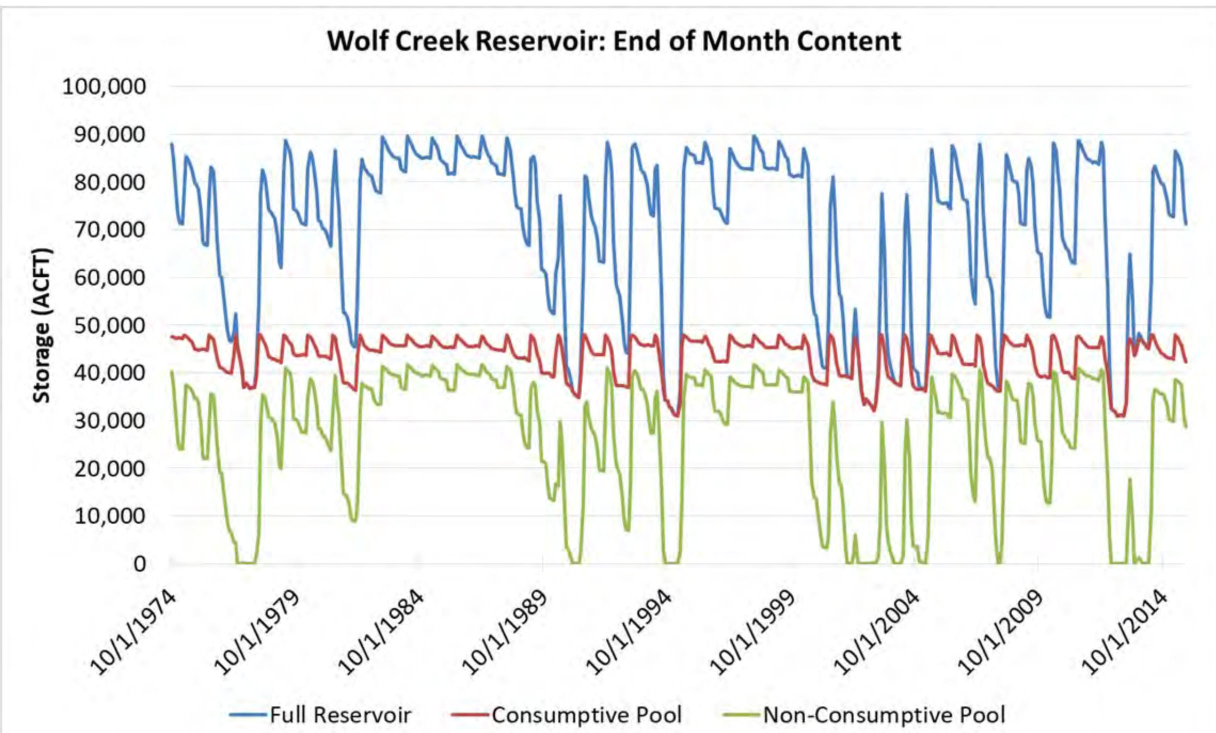


Figure 41: Wolf Creek Reservoir and Account Storage (Reservoir IPP).

As shown in Figure 41, Wolf Creek Reservoir is able to fill to capacity 85 percent of years in the analysis period. Note that for analysis purposes, the reservoir was considered full if storage reaches 90 percent of the reservoir capacity to account for evaporation.

Changes in Streamflow

As discussed for the Yampa River, streamflow throughout the Yampa and White basins supports a variety of non-consumptive uses. Many were identified and mapped as part of the Non-Consumptive Needs Assessment (NCNA). Figure 30 above shows the reaches defined in the NCNA for the White River basin.

For the modeling effort, the focus was on reaches that could be impacted by IPP operations. This section highlights changes to streamflow in the Watson flow target reach. The Watson gage experiences changes in streamflow due to increased future demands and supplemental releases from Wolf Creek Reservoir. Table 30 shows the percent of days in each month that the target flow is met or exceeded.

Table 31: Percent of Days Watson Flow Target is Met or Exceeded

	Baseline	Future Demands, No IPPs	Reservoir IPPs
Jan	62%	39%	84%
Feb	83%	59%	84%
Mar	97%	86%	93%
Apr	100%	97%	95%
May	98%	97%	100%
Jun	89%	87%	100%
Jul	70%	63%	95%
Aug	55%	45%	95%
Sep	58%	46%	90%
Oct	99%	85%	92%
Nov	89%	63%	90%
Dec	60%	41%	85%

As shown, the Watson flow target has consistently lower streamflow in the Future Demands, No IPPs scenario than either the Baseline or Reservoir IPPs scenario. The large future demands for energy development have a significant impact on streamflow at the Watson gage. The addition of Wolf Creek Reservoir can supplement the streamflow to meet the 300 cfs target more frequently than the Baseline scenario.

Changes in Boatable days

As shown in Figure 30 above, there are several reaches throughout the White basin that are popular for boating. Figure 42 shows the Baseline scenario boatable days, based on the flow categories defined in the NCNA, through the Rangely to Bonanza Run. Figure 43 shows the boatable days for the Rangely to Bonanza Run for the Future Demands, No IPPs scenario, and Figure 44 shows the boatable days for the Reservoir IPPs scenario.

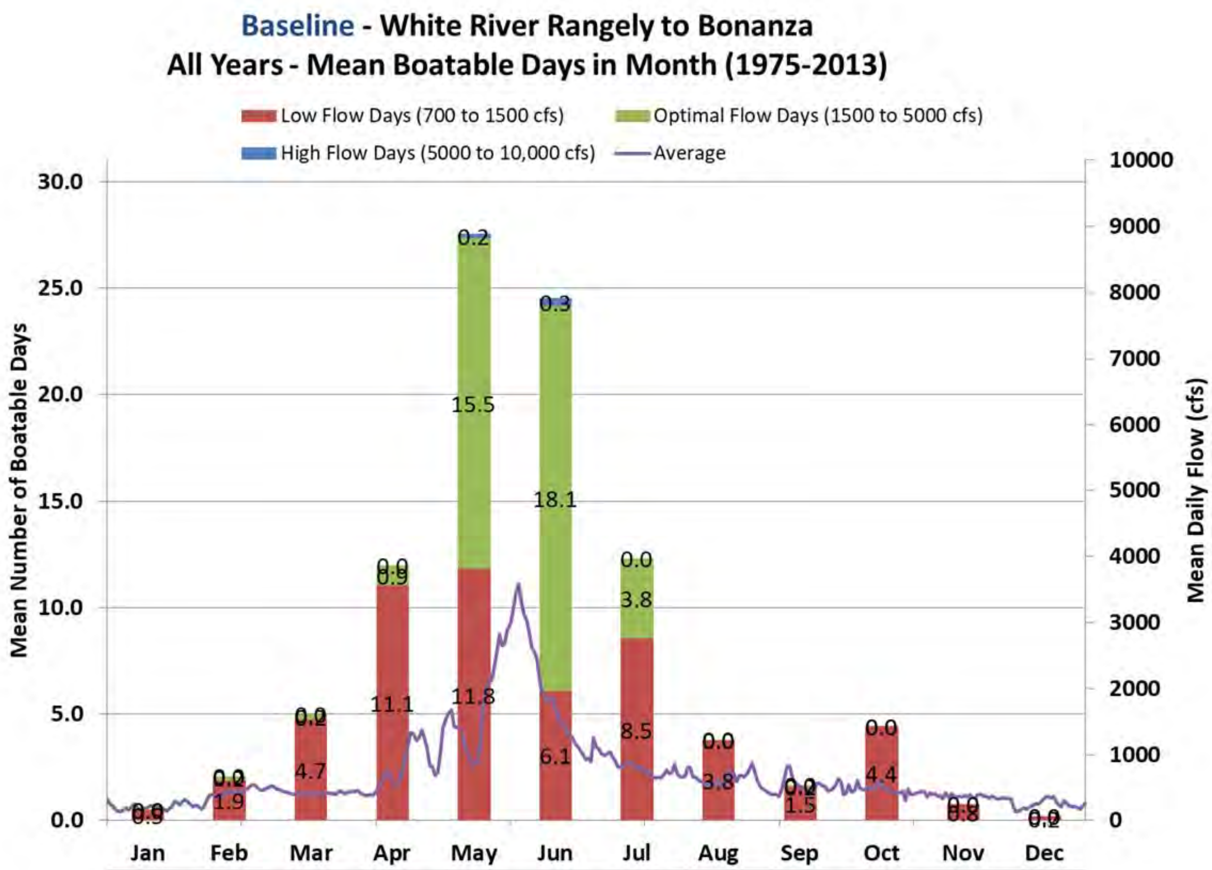


Figure 42: Rangely to Bonanza Run Boatable Days for the Baseline Scenario

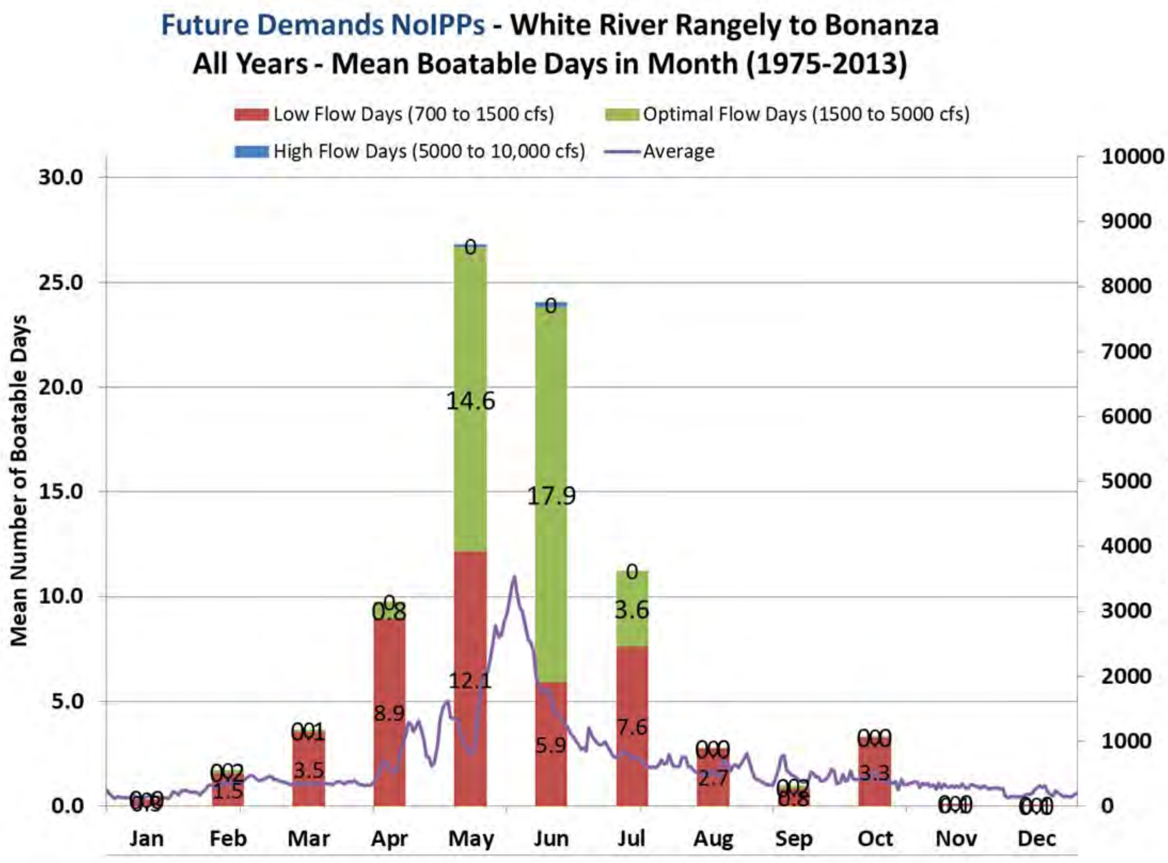


Figure 43: Rangely to Bonanza Run Boatable Days for the Future Demands No IPPs Scenario

A comparison of the boatable days graph for the Baseline scenario and the Future Demands, No IPPs scenario shows a decrease in the mean number of boatable days in all months. The biggest changes are in the shoulder months. April loses an average of two boatable days and July through October loses one boatable day each month. While there are very few days when the streamflows are over 5,000 cfs in the baseline scenario, there are even less in the Future Demands, No IPPs scenario and the mean number of High Flow days drops to zero.

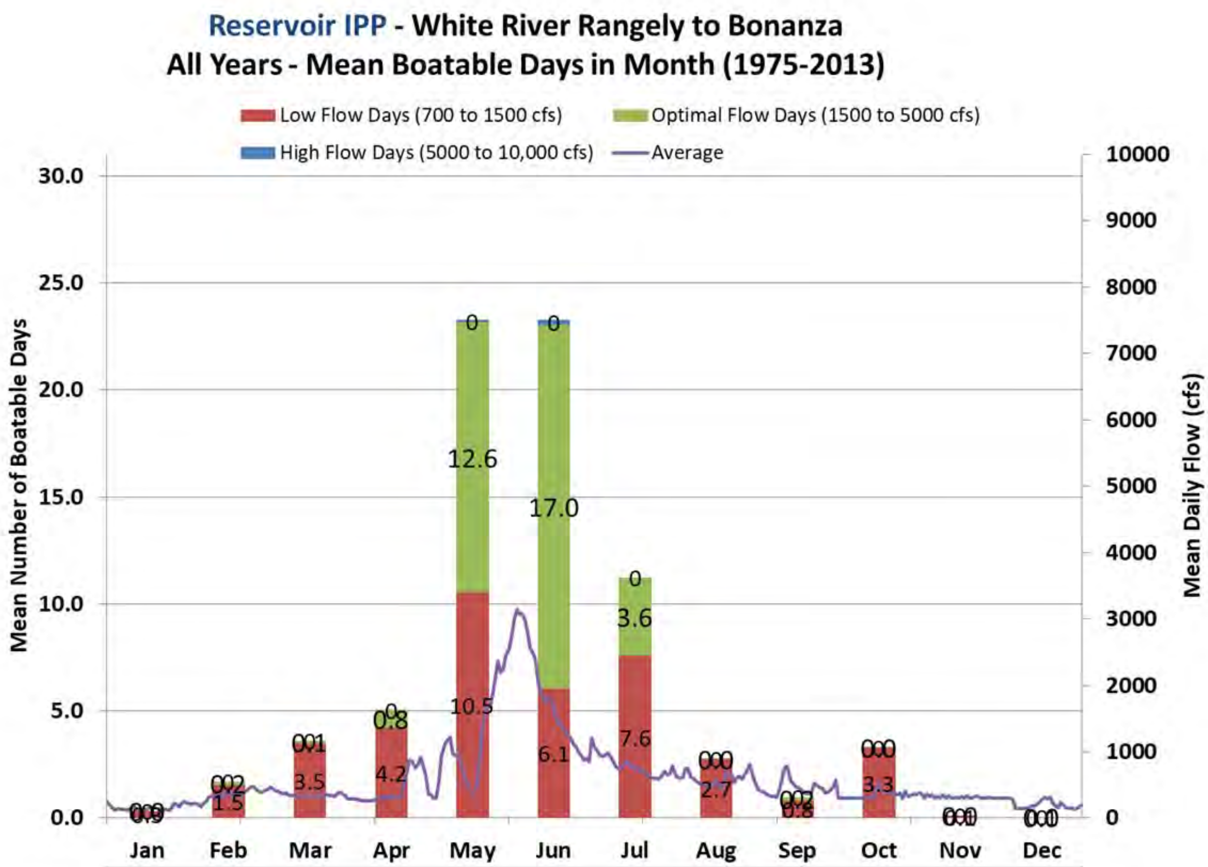


Figure 44: Rangely to Bonanza Run Boatable Days for the Reservoir IPP Scenario

A comparison of the boatable days graph for the Reservoir IPP scenario shows additional decrease in the mean number of boatable days in all months. The biggest changes are in April, which loses an average of seven boatable days, and May, which loses an average of four boatable days. This is because Wolf Creek Reservoir primarily fills during the beginning of spring run-off. Even though the reservoir releases to supplement flows later in the season, the flow target is only 300 cfs; whereas the boatable days flow cutoff is 700 cfs.

Climate Projected Hydrology and Demands in the White Basin

Climate projections impact both the natural flows and agricultural demands. As discussed in the hydrology comparison section, the Between climate projected hydrology is very similar to historical hydrology, but the demands for agricultural are higher due to warmer temperatures during the historical growing period and a longer growing season. Simulation with the Between projected hydrology provides insight into a future with warmer temperatures, but with average annual streamflow similar to historical streamflow. The Hot and Dry climate projected hydrology shows both decreased streamflow and higher demands for agriculture throughout the basin. This scenario stresses the White Basin system and provides additional information on how the IPPs respond.

The results presented in this section reflect a model simulation period from 1975 through 2015 using a monthly time step. As noted above, climate change hydrology and impacts to irrigation demands are currently available on a monthly time step.

Changes in Shortages with Climate Projections

Table 32 highlights the average monthly shortages for the future energy demands on the White River Mainstem for the Future Demands, No IPPs simulated with the Current Hydrology, Between Hydrology, and Hot and Dry Hydrology. Shortages increase dramatically with climate projected hydrology. As expected, the lower streamflow in the late irrigation season (July through September) significantly increase the shortages. One interesting result to note is that the projected streamflow in the Hot and Dry Hydrology shows declines in October through February, which cause increased shortages during a period when relatively few structures are diverting.

Table 32: Average Monthly Shortages to Future Energy Development on the Mainstem in the Future Demands No IPPs Scenario

	Current Hydrology	Between Hydrology	Hot and Dry Hydrology
Jan	4%	2%	22%
Feb	4%	0%	7%
Mar	1%	0%	0%
Apr	0%	0%	0%
May	0%	0%	0%
Jun	8%	8%	13%
Jul	21%	56%	73%
Aug	32%	84%	97%
Sep	26%	56%	80%
Oct	0%	0%	6%
Nov	2%	0%	14%
Dec	4%	1%	25%

Table 33 shows the shortages to future energy development on the Piceance. The shortages are pervasive throughout the year, including the spring run-off. Future water development to support energy demands on the Piceance will require additional sources of water supply.

Table 33: Average Monthly Shortages Future Energy Development on the Piceance in the Future Demands No IPPs Scenario

	Current Hydrology	Between Hydrology	Hot and Dry Hydrology
Jan	9%	9%	20%
Feb	6%	2%	5%
Mar	1%	0%	0%
Apr	9%	4%	9%
May	37%	47%	61%
Jun	54%	63%	77%
Jul	56%	70%	88%
Aug	46%	85%	97%
Sep	49%	74%	88%
Oct	10%	9%	18%
Nov	7%	7%	14%
Dec	9%	8%	16%

In the Reservoir IPP Scenario, the future energy demands on both the White and the Piceance are able to be fully satisfied under both climate change projections because of storage in Wolf Creek Reservoir.

Changes in Reservoir Storage with Climate Projections

Similar to consumptive use demands, the reservoir storage is impacted by the lower flows and higher demands. The results below focus on Wolf Creek Reservoir. As expected, the reduction in streamflow and increase in demands placed on the reservoir are significant. However, Wolf Creek Reservoir is able to fully satisfy the future energy demands. In Figure 45, the Between Hydrology and Hot and Dry Hydrology both show increased draw on the reservoir storage. The reservoir is almost completely emptied in 1977 in the Hot and Dry Hydrology Scenario. 1977 is the driest year in the White River.

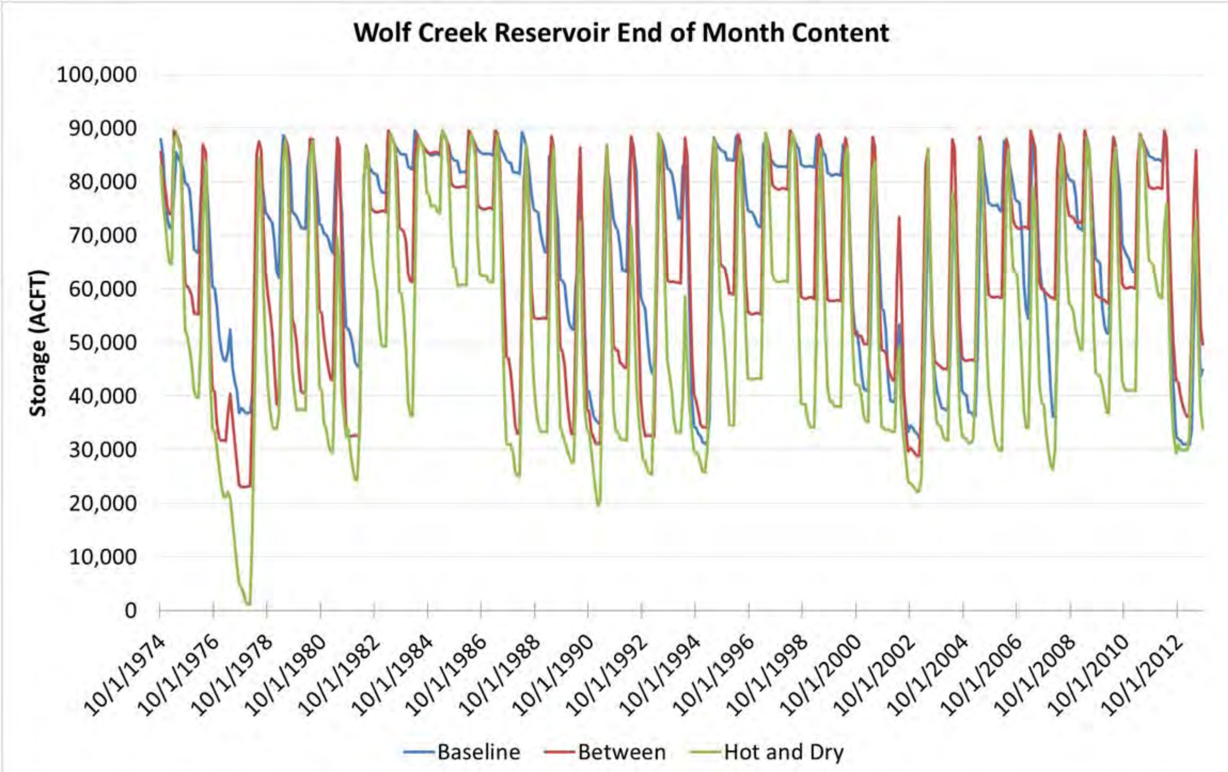


Figure 45: Wolf Creek Reservoir End of Month Contents for the Three Hydrology Scenarios

Changes in Streamflow with Climate Projections

As noted above, the climate projected hydrology is not available on a daily time step. Therefore, the following information is presented for the monthly time step. While this information is not as detailed as the daily model simulations, it provides insight into the significant changes to streamflow.

Table 34 and Table 35 compare the percent of months during the analysis period where streamflow meets or exceeds the Watson flow target under the varying climate projections for the Future Demands No IPPs and Reservoir IPP scenarios.

Table 34: Percent of Months that Meet or Exceed the Watson Flow Target - Future Demands No IPPs Scenario

Month	Current Hydrology	Between Hydrology	Hot and Dry Hydrology
Jan	38%	44%	15%
Feb	64%	69%	28%
Mar	92%	100%	87%
Apr	100%	100%	97%
May	100%	100%	97%
Jun	92%	87%	77%
Jul	67%	28%	13%
Aug	44%	3%	0%
Sep	41%	18%	5%
Oct	87%	77%	38%
Nov	62%	54%	18%
Dec	36%	46%	15%

In the Future Demands No IPPs scenario, the Between Hydrology results in streamflow at the Watson gage that is slightly higher during the winter and early spring that the Current Hydrology. However, the streamflows are lower during the irrigation season due to the combination of higher agricultural demands and lower streamflow during those months. Recall that the Between Hydrology and Hot and Dry Hydrology have streamflow hydrographs that are shifted earlier in the year. This causes the runoff hydrograph to start declining earlier in the year and reduces the streamflow in June and July. In the Hot and Dry Hydrology Scenario, streamflows at the Watson gage are lower year-round due to both higher agricultural demands, lower streamflow, and the shift in the hydrograph.

Table 35: Percent of Months that Meet or Exceed the Preferred Flow Target - Reservoir IPPs Scenario

Month	Current Hydrology	Between Hydrology	Hot and Dry Hydrology
Jan	82%	82%	46%
Feb	79%	87%	51%
Mar	95%	100%	85%
Apr	92%	100%	97%
May	100%	97%	97%
Jun	97%	97%	95%
Jul	95%	97%	92%
Aug	92%	95%	77%
Sep	87%	92%	72%
Oct	92%	95%	74%
Nov	90%	87%	62%
Dec	85%	85%	51%

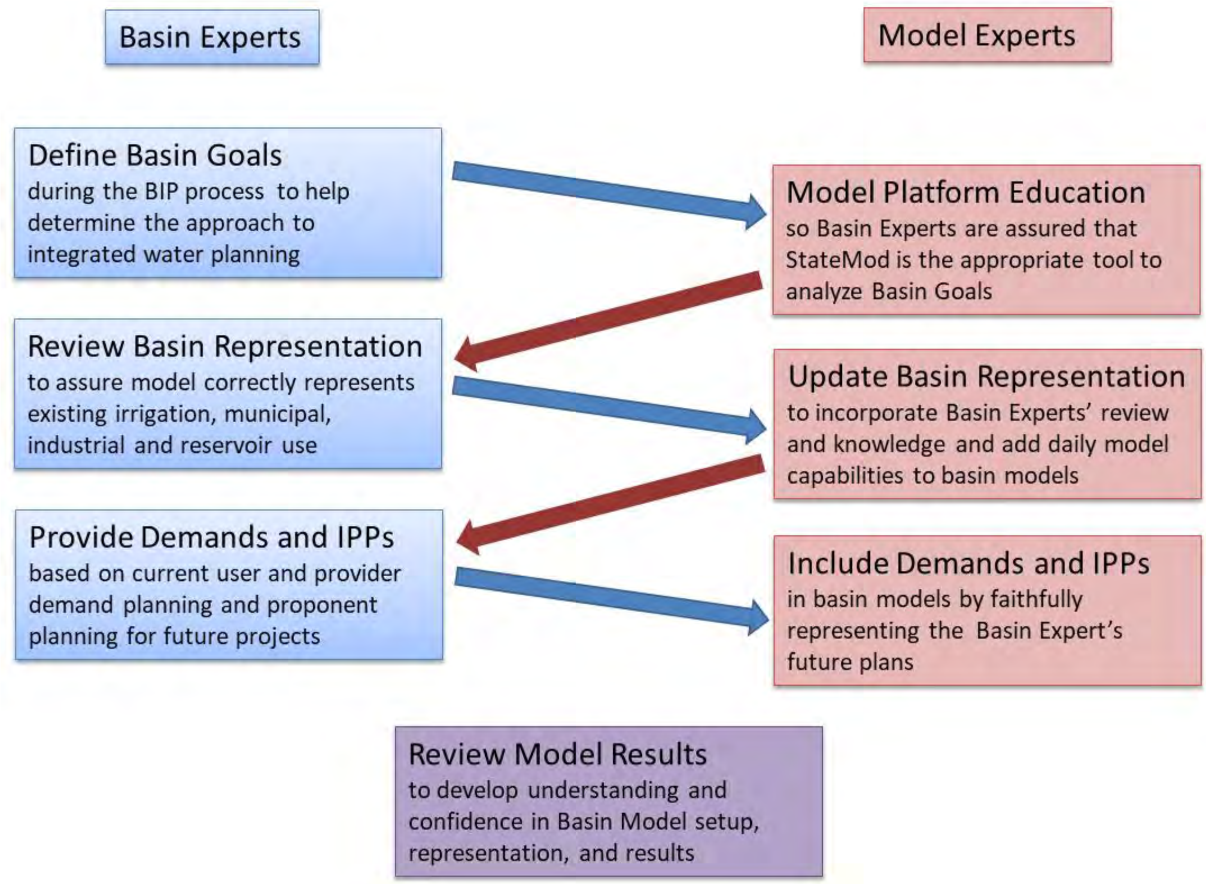
The addition of Wolf Creek Reservoir in the Reservoir IPP scenario provides significant supplemental water to the Watson gage, as seen by the more days that meet or exceed 300 cfs. The biggest changes are in dry months of July, August, and September. With the additional supply from Wolf Creek Reservoir, these months are able to meet the streamflow target at Watson on 92%, 77%, and 72% of the days in the month (respectively) with Hot and Dry Hydrology, as compared to 15%, 0%, and 5% of the days in the month without Wolf Creek Reservoir.

Project Accomplishments

As noted above, the goals of the project were to:

- Refine the baseline CDSS Yampa and White river models to accurately represent current uses, operations and administration – with input from basin users,
- Build confidence in the use of the model by clearly explaining how it operates and represents actual basin uses,
- Convert the Yampa and White river models to a daily time step to provide results that are useful for non-consumptive needs assessment,
- Work closely with the BRT to define and incorporate possible future uses,
- Work closely with IPP proponents to implement their projects faithfully in the models,
- Provide meaningful results in workshops and a final report, and
- Deliver a modeling tool that can be used in the future integrated water resource planning.

WWG and the BRT worked together accomplish the project goals through the following collaborative process.



Specific project accomplishments include the following:

- BRT members participated in workshops with WWG to learn about the capabilities of the StateMod modeling platform. Participants learned how StateMod represents Colorado water rights and represents more complex system operations, such as reservoirs and municipal water supply infrastructure. Through this educational process, the BRT was able to confirm that StateMod is the best tool to for the modeling project.
- WWG worked with basin water uses and water suppliers to better understand current operations in order to capture those operations accurately in the models. WWG demonstrated to the BRT that current uses, water rights, and reservoir operations are correctly represented in the Yampa and White models. The BRT gained confidence in the models for use in the modeling project.
- The BRT and WWG worked collaboratively to determine the appropriate future demands, hydrology scenarios, and IPPs to represent in the model. The results from this process are clearly and transparently documented in this report and in the workshop presentations. Although specific details regarding contracts, regulatory constraints, or operational policies of modeled entities were represented in a simplified manner, this effort provided the BRT with a meaningful set of model scenarios to investigate.

- Through the workshop presentations and discussions, the BRT was able to explore the impacts of IPPs on the river system. Scenarios were developed that examine each IPP individually, and in various combinations with other IPPs. The explorative process increased the BRT's understanding of the river system, shortages to consumptive and non-consumptive demands, opportunities for synergy between IPPs, and examples of competition between future demands and IPPs.
- Because of the close communication between the Basin Experts and the Model Experts, WWG was able to respond to feedback from the BRT in order to explore new ideas in an iterative manner. This allowed the BRT to understand and direct model revisions throughout the project.
- The BRT now has Yampa and White models they are confident appropriately represent the basins current and potential future operations under water right administration. These models can be used to continue to investigate integrated planning options to accomplish the BRT basin goals.

Model Scenario Conclusions

The following summarizes the general conclusions from the model scenarios:

- The Yampa River basin future demands are generally not for new sectors; they are increased demands for existing water users.
- The Yampa River basin future consumptive demands that increase existing water uses are generally met with current water rights portfolios and existing reservoir storage; however the City of Steamboat's projected growth on the west side requires additional infrastructure and a new supply.
- The White River basin future demands include new demands for the oil and gas sector.
- The climate projection show a shift to earlier runoff and a significant decrease in late season flows.
- The Yampa and White river basins' future consumptive demands with present day (junior) water rights cannot be fully met from historical natural streamflow; and shortages increase under climate projected hydrology.
- The Yampa and White basin existing agricultural users are not impacted by increases in future demands under historical hydrologic conditions because their water rights are senior to the new demands. However, the model shows existing agriculture users experience additional shortages under climate projections because the projected higher temperatures both increase crop demands, and decrease natural streamflow during the late irrigation season.

- The Yampa and White basins have distinct snowmelt runoff hydrographs. The majority of the streamflow occurs during the spring and early summer. Under the IPP scenarios that considered new storage, the models showed reservoir releases during the late season could meet future consumptive demand shortages. Even under the climate projected hydrology, the models showed water available for storage during the runoff that could be released during the low flow season to help alleviate shortages.
- Non-consumptive demands for fisheries and water quality issues focus on the low flow periods. The model shows that IPPs that use supplemental supply from existing reservoirs can help meet these flow targets in drier years. Additional supplies from IPP reservoirs can fully satisfy the low flow demands in the Yampa River basin; however IPP reservoirs in the White River basin cannot fully satisfy a 300 cfs year-round flow target.
- Non-consumptive demands for boating focus on the high flow periods. In the Yampa, the increase in storage investigated has a limited impact on boatable days. In the White, the large increase in storage investigated indicates a more pronounced impact on boatable days.

This document contains the appendix to the Yampa/White/Green Basin Roundtable Basin Implementation Plan Modeling Phase 3 Final Report, prepared by Wilson Water Group.

Appendix	Workshop Date	Primary Topic
Appendix A	December 9, 2015	StateMod Overview
Appendix B	July 13, 2016	Kickoff Meeting to discuss approach
Appendix C	March 8, 2017 March 20, 2017	Discussion of future demands, IPP Factsheets, and including Colorado's Water Plan climate scenarios
Appendix D	July 12, 2017	Present and discuss results for the future demands and IPPs in the White basin and the upper portion of the Yampa basin with historical hydrology
Appendix E	August 24, 2017	Present and discuss results for the future demands and IPPs in the lower portion of the Yampa basin. Compare paleohydrology and climate scenario hydrology
Appendix F	October 19, 2017	Present and discuss results for the Yampa and White basins with climate scenarios hydrology
Appendix G	November 8, 2017	Present and discuss updated results based on feedback from the October 19, 2017 workshop. Review the report outline
Appendix H	January 10, 2018	Presentation of project results to full Basin Roundtable
Appendix I	-	Describes the process used to generate the daily model input files for the Yampa River basin, including the procedure for selection of daily pattern gages
Appendix J	-	Describes the process used to generate the daily model input files for the White River basin, including the procedure for selection of daily pattern gages
Appendix K	-	Elkhead Maybell Target Release Limited to 50 cfs and 100 cfs Comparison

Appendix D - July 12, 2017 White River Basin Results and Upper Portion of Yampa River Basin Results

This appendix condenses the results from the "on-the-fly" July 12, 2017 workshop into a single document. The focus of the all-day workshop was on the White River Basin and the upper portion of the Yampa River Basin. The lower portion of the Yampa River Basin was not considered due to time constraints at the workshop.

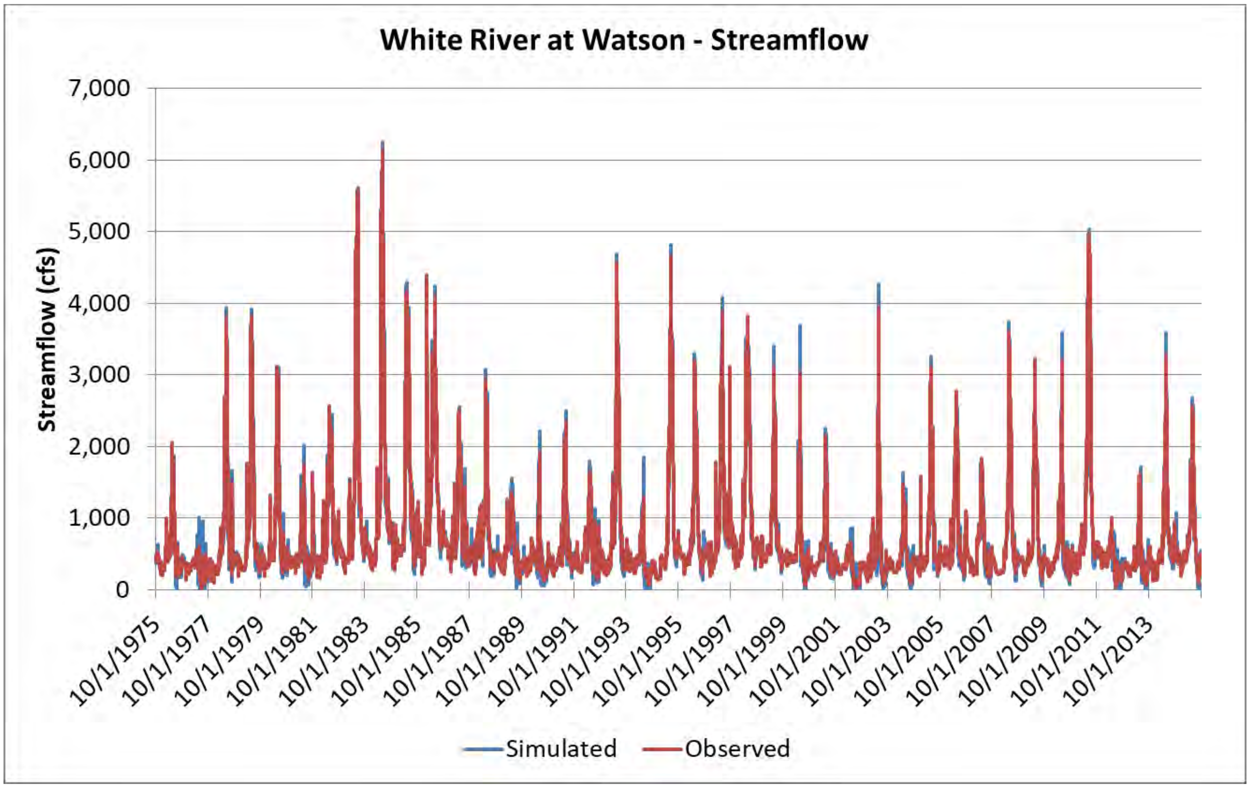
Model results have been updated since the July 12, 2017 workshop to address discrepancies in the future demands. This specifically applies to the Preferred Flow Target in Steamboat and the future Steamboat demand at the Elk River.

- Originally, the Preferred Flow Target was set from May through October to 100 cfs in all year types. This has been updated to be 75 cfs in dry years and 100 cfs in average and wet years. Year categories were determined by the observed total annual flow volume at USGS gage 09239500 - YAMPA RIVER AT STEAMBOAT SPRINGS, CO, with the thresholds at 30% and 70%.
- Originally, the Elk River demands for the City of Steamboat were set to 2,800 acre-feet per year. This value was reviewed and updated to 1,855 acre-feet per year, based on the City of Steamboat's projections.

Overview of Yampa and White daily time step calibration

In general, the daily model calibration closely matches the daily observed streamflow. It appears that the model has a slight tendency to over-simulates the maximum peak flow and under-simulates the minimum low flow. This is most likely due to the method of distributing naturalized streamflow. In StateMod, the monthly natural streamflow is distributed to daily based on a pattern gage. The pattern gages are set by the user and are intended to represent an unaltered flow regime. However, the streamgages with long-term records available in the Yampa and the White basins generally have some level of alteration, which causes the highs and lows to be over-emphasized in the daily model.

The figures below show the daily calibration. The calibration is judged based on how well the model replicates the observed gaged streamflow record.


White River at Watson - Streamflow
Streamflow (cfs)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
10/1/1975
10/1/1977
10/1/1979
10/1/1981
10/1/1983
10/1/1985
10/1/1987
10/1/1989
10/1/1991
10/1/1993
10/1/1995
10/1/1997
10/1/1999
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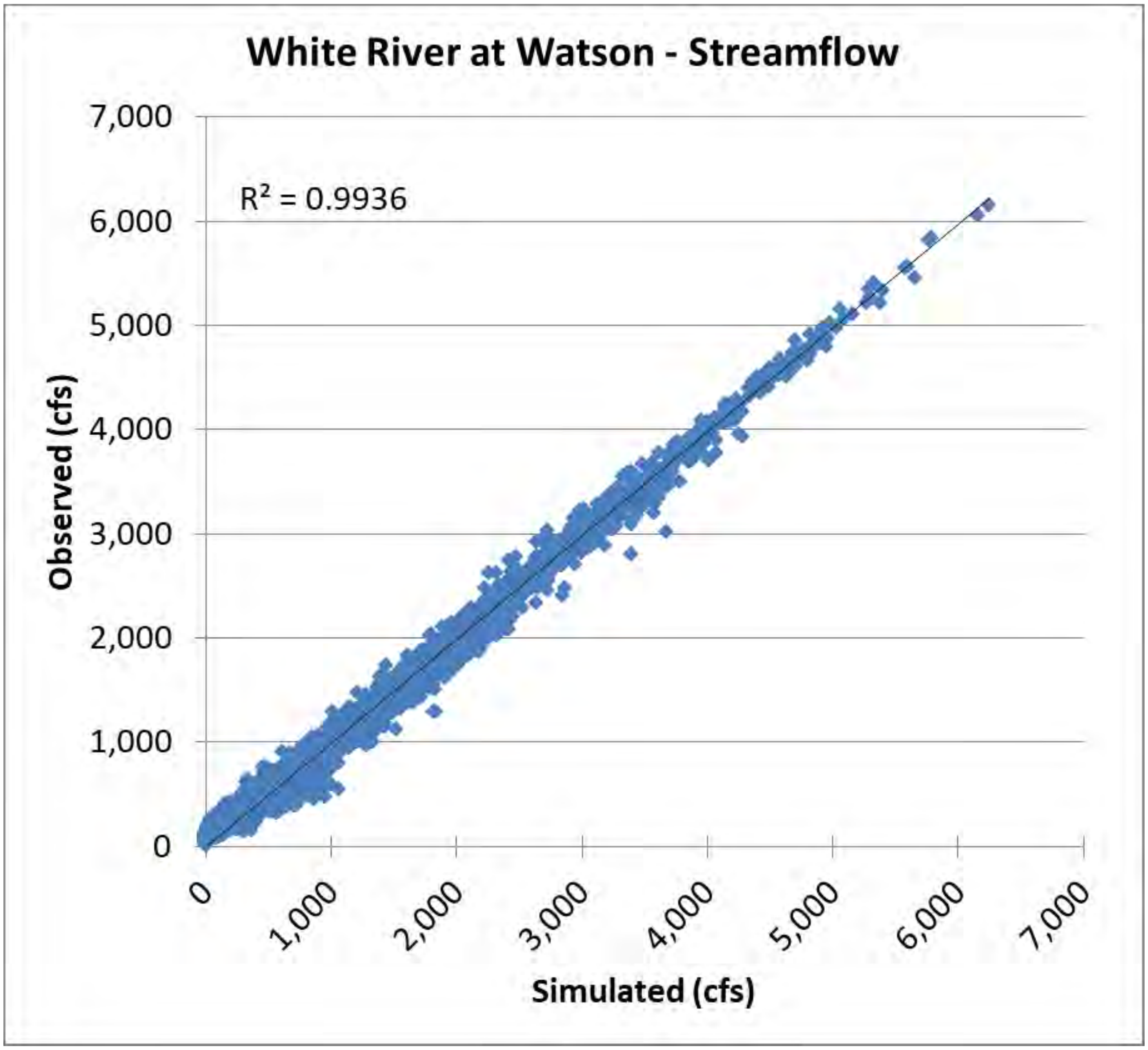
10/1/2013
Simulated
Observed



Future Demands

The table below shows the future demands that were selected by the Yampa/White/Green Subcommittee for the model. The orange rows show the combined demand for the City of Steamboat/Mt Werner split into two portions: The primary demand that can be met by existing supplies (58_ StmbtMW) and the projected future demands that will be met by a new diversion on Elk River (58_FutElk).

Type	County	Name (ID)	Current (acft/year)	Future (acft/year)
M&I	Moffat	City of Craig (4400581)	2,169	6,305
M&I	Moffat	Future domestic (44_FutMun)	742	2,157
M&I	Moffat	Future domestic (55_FutMun)	13	38
M&I	Routt	Future domestic (57_FutMun)	484	1,280
M&I	Routt	Future domestic (58_FutMun)	1,342	3,520
M&I	Routt	Steamboat/Mt Werner (58_StmbtMW) No Elk Diversion	4,332	11,200
M&I	Routt	Steamboat/Mt Werner (58_StmbtMW) W/ Elk Diversion	4,332	9,345
M&I	Routt	Elk Diversion (58_FutElk)	0	1,855
Thermo	Moffat	Craig Station (4400522)	12,483	21,000
Thermo	Routt	Hayden Station (5700512)	5,414	8,000
SSI	Routt	Steamboat Ski Snow Pipeline (5802374)	355	571
SSI	Routt	Future SSI (57_FutGC2)	0	2,190
SSI	Routt	Future SSI (58_FutGC1)	0	3,410
Ag	Moffat	New agriculture (44_Oxbow)	0	1,487
M&I	Rio Blanco	Unincorporated municipal (43_FutMun)	1,104	1,921

Type	County	Name (ID)	Current (acft/year)	Future (acft/year)
M&I	Rio Blanco	Rangely (4300889_D)	1,801	3,150
M&I	Rio Blanco	Meeker (4306045)	338	588
SSI	Rio Blanco	Future Golf Course near Meeker	0	300
Energy	Rio Blanco	Gas and Oil Shale (43_GasOil)	0	35,800
Energy	Rio Blanco	Oil Shale in Piceance (43_OilShl)	0	10,000

- Overview of IPPs - see IPP fact sheets

White River

Two main IPPs were investigated for the White River basin, both of which have options for how they could be constructed. The first IPP is an enlargement of Lake Avery (aka Big Beaver Reservoir). This IPP is considering either a small enlargement of 1,261 acre-feet, or a large enlargement of 2,664 acre-feet. The second IPP is Wolf Creek Reservoir. The BRT investigated both a 90,000 acre-foot and 48,000 acre-foot Wolf Creek Reservoir. The differences between an on-channel and off-channel reservoir site were also considered.

The IPPs were looked at individually and in combination. The scenarios are listed below.

- **Baseline**
    - Historical hydrology
    - Current level demands through time
- **Future Demands No IPPs**

- Future Demands are implemented as described in the future demands table above
  - The Gas and Oil Shale future demand (43_GasOil) is located on the mainstem of the White River and is assigned a current day water right.
  - The Oil Shale in Piceance future demand (43_OilShl) is located on the Piceance River and is assigned a 1970 water right, which is intended to represent the average of the conditional water rights held by energy companies in the area.
- No IPPs are active
- Current projects (Kenney Reservoir and Lake Avery) operate under current rules

- **90,000 AF Wolf Creek Reservoir, off-channel**
  - Wolf Creek Reservoir is represented as a 90,000 AF reservoir and located off-channel. The pump station capacity is 400 cfs. The reservoir has two pools:
    - 48,000 AF for future consumptive demands
    - 42,000 AF for Watson target fish flows
  - The Watson target fish flow is set to 300 cfs year round.
  - Wolf Creek Reservoir makes releases to meet future consumptive demands
  - Wolf Creek Reservoir makes supplemental releases to Watson target fish flow
- **90,000 AF Wolf Creek Reservoir, on-channel**
  - Wolf Creek Reservoir is represented as a 90,000 AF reservoir and located on-channel. The reservoir has two pools:
    - 48,000 AF for future consumptive demands
    - 42,000 AF for Watson target fish flows
  - The Watson target fish flow is set to 300 cfs year round.
  - Wolf Creek Reservoir makes releases to meet future consumptive demands
  - Wolf Creek Reservoir makes supplemental releases to Watson target fish flow
- **48,000 AF Wolf Creek Reservoir, off-channel**

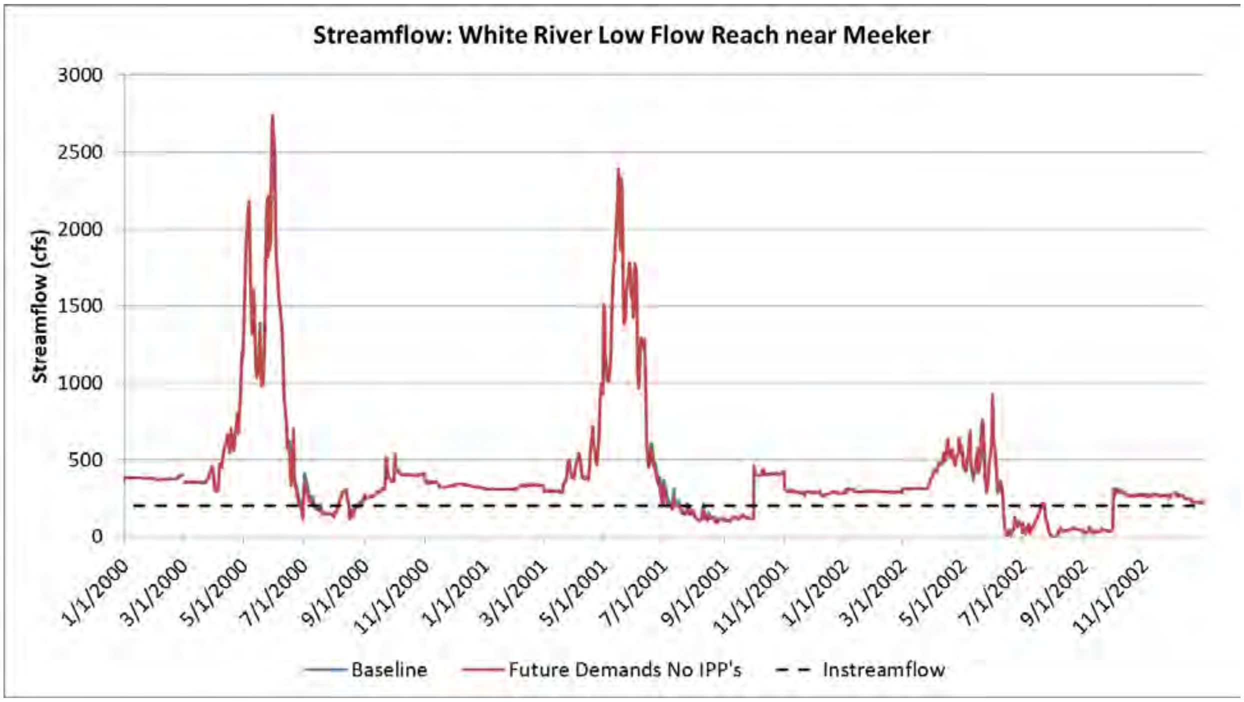
- Wolf Creek Reservoir is represented as a 48,000 AF reservoir and located off-channel. The pump station capacity is 100 cfs. The reservoir has one pool:
  - 48,000 AF for future consumptive demands
- There is no Watson target fish flow
- Wolf Creek Reservoir makes releases to meet future consumptive demands

- **Small Lake Avery enlargement**
  - Lake Avery capacity is increased by 1,261 acre-feet
  - The additional capacity releases to the instream flow target through Meeker and the future golf course demands
- **Large Lake Avery enlargement**
  - Lake Avery capacity is increased by 2,664 acre-feet
  - The additional capacity releases to the instream flow target through Meeker and the future golf course demands
- **90,000 AF Wolf Creek Reservoir, off-channel, Large Lake Avery**
  - Wolf Creek Reservoir is represented as a 90,000 AF reservoir and located off-channel. The pump station capacity is 400 cfs. The reservoir has two pools:
    - 48,000 AF for future consumptive demands
    - 42,000 AF for Watson target fish flows
  - The Watson target fish flow is set to 300 cfs year round.
  - Wolf Creek Reservoir makes releases to meet future consumptive demands
  - Wolf Creek Reservoir makes supplemental releases to Watson target fish flow
  - Lake Avery capacity is increased by 2,664 acre-feet
  - The additional capacity releases to the instream flow target through Meeker and the future golf course demands

Scenario Combination Comparisons

- [**Baseline, Future Demands No IPPs**]
  - The Future Demands increase the draw on the river. Therefore, streamflow decreases compared to Baseline.

- The figure below show the White River streamflow near Meeker. The majority of the future demands are downstream of Meeker (with the exception of the future golf course and the increase demands at Meeker itself), so the streamflow changes are small.

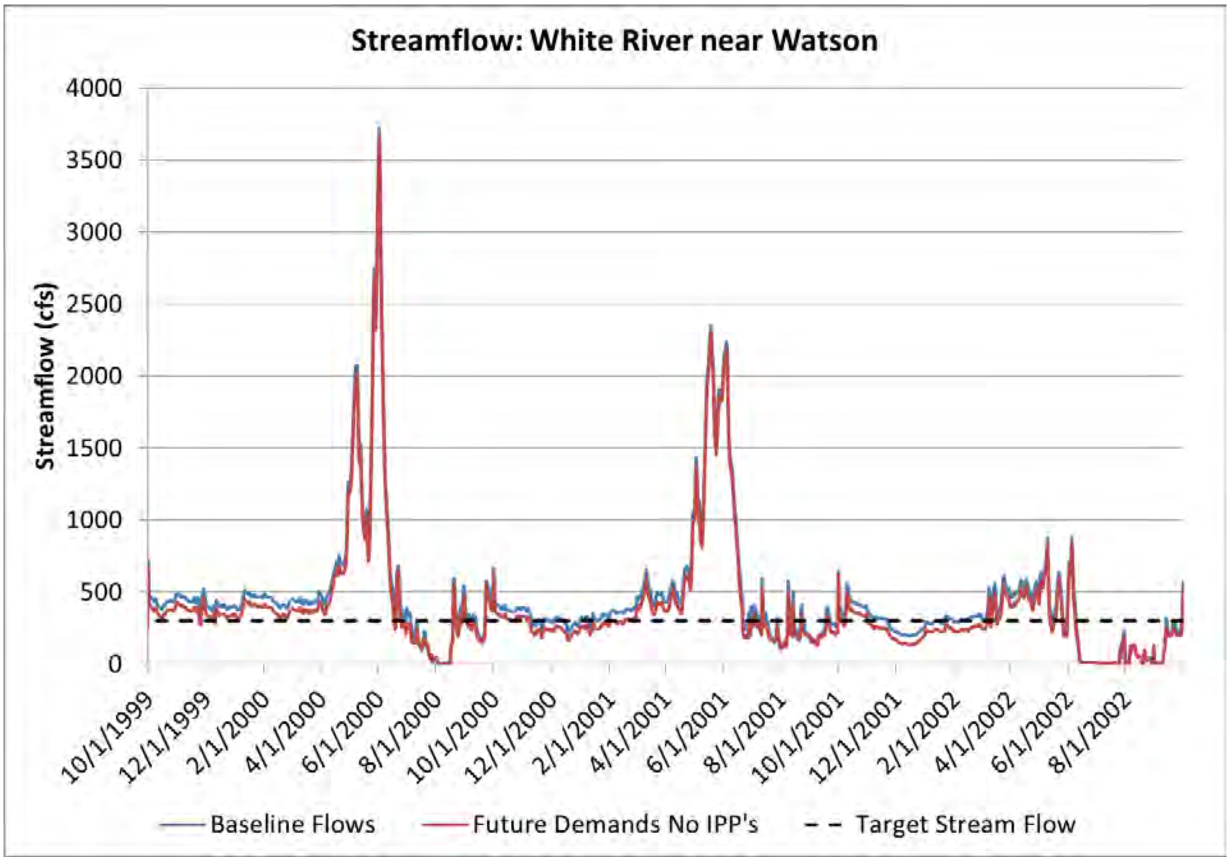


- The table below compares the instream flow target of 200 cfs for the White River near Meeker to the simulated streamflow. The table below shows the percent of days that meet or exceed the target. Because most of the future demands are downstream of Meeker, the instream flow is minimally impacted.

Percent of days in the month that meet or exceed the instream flow (200 cfs) near Meeker		
Month	Baseline	Future Demands, No IPPs
January	99%	99%
February	98%	98%
March	100%	100%
April	100%	100%
May	100%	100%
June	91%	90%
July	72%	73%

August	55%	54%
September	54%	55%
October	100%	100%
November	100%	100%
December	99%	99%

- The figure below shows the streamflow near Watson. All of the future demands are upstream of Watson, and the streamflow shows decreased flow throughout the year.



- For the White River near Watson, a preliminary streamflow target of 300 cfs is considered. Note that the streamflow targets for Watson are currently under development as part of the White River Programmatic Biological Opinion (PBO) process. The table below shows the percent of days that meet or exceed the target.

Percent of days in the month that meet or exceed the preliminary target (300 cfs) near Watson		
Month	Baseline	Future Demands, No IPPs
January	62%	39%
February	83%	59%
March	97%	86%
April	100%	97%
May	98%	97%
June	89%	87%
July	70%	63%
August	55%	45%
September	58%	46%
October	99%	85%
November	89%	63%
December	60%	41%

- The table below shows how frequently the reservoirs in the White River are able to fill to their current capacities. Note that the Wolf Creek Reservoir is not active in these runs.

Percent of years that the reservoir fills (1975 - 2015)		
	Baseline	Future Demands, No IPPs
Lake Avery	100%	100%
Kenney Reservoir	100%	100%

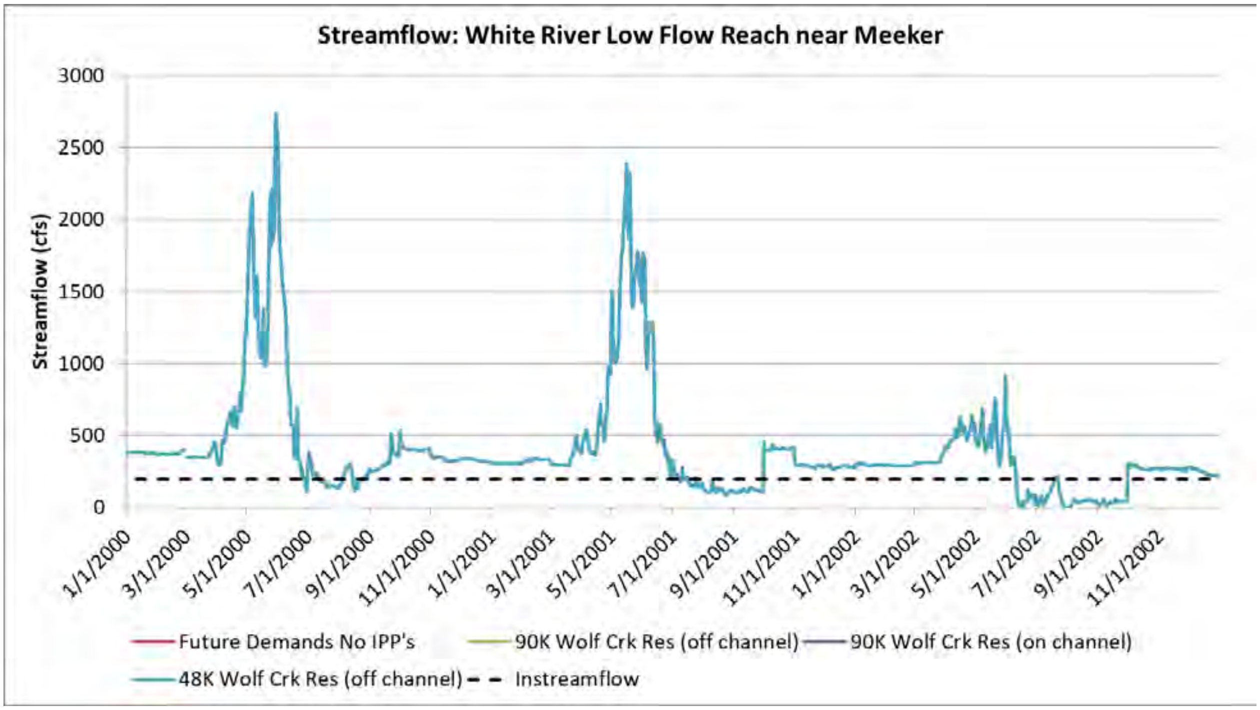
- The tables below show the consumptive use shortages throughout the basin. For agricultural shortages, the basin was divided into upper agriculture (North Fork and South Fork of the White River and down to the confluence with Big Beaver Creek), middle agriculture (below the confluence with Big Beaver Creek and above the confluence with Piceance Creek), Piceance Basin agriculture, and lower agriculture (downstream of the confluence with Piceance Creek).

o

Percent Short from 1975 through 2015			
Name	WDID	Baseline	Future Demands, No IPPs
Meeker	4306045	0%	0%
Rangely	4300889_D	1%	1%
WD 43 Future Golf Course	43_FutGlf	-	24%
Future Energy Development - White River Mainstem	43_GasOil	-	8%
Future Energy Development - Piceance Basin	43_OilShl	-	25%
Piceance Agriculture	Multiple	22%	22%
Upper White Agriculture	Multiple	11%	11%
Middle White Agriculture	Multiple	11%	11%
Lower White Agriculture	Multiple	2%	2%

Percent of unmet demands by month for the Future Demands, No IPPs scenario			
	WD 43 Future Golf Course	Future Energy Development - White River Mainstem	Future Energy Development - Piceance Basin
January	-	4%	9%
February	-	4%	6%
March	-	1%	1%
April	0%	0%	10%
May	1%	0%	38%
June	11%	8%	57%
July	32%	21%	58%
August	49%	32%	47%
September	40%	21%	44%
October	0%	0%	10%
November	-	2%	7%
December	-	4%	10%
Total	**24%**	**8%**	**25%**

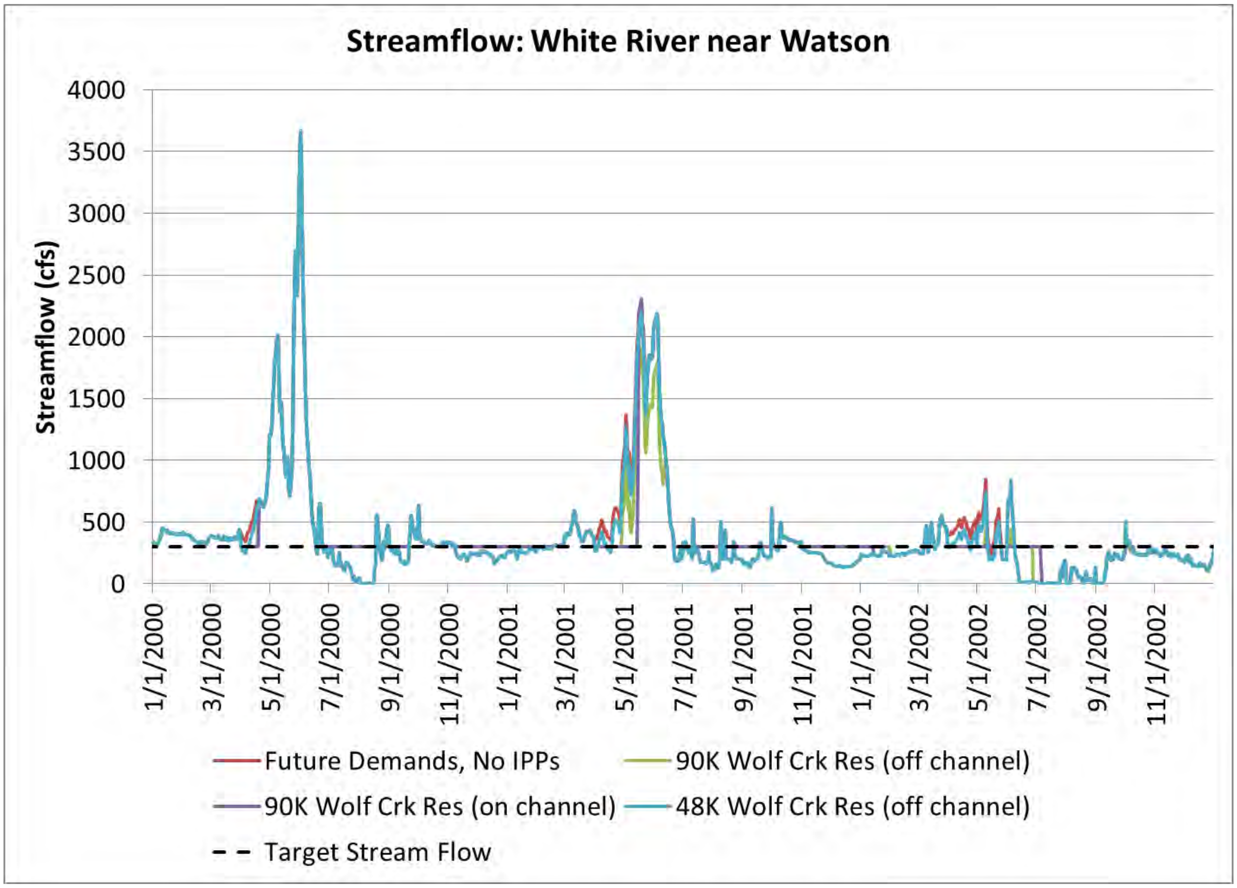
- [**Future Demands No IPPs, 90,000 AF Wolf Creek Reservoir, off-channel, 90,000 AF Wolf Creek Reservoir, on-channel, 48,000 AF Wolf Creek Reservoir, off-channel**]
    - Wolf Creek Reservoir impacts the streamflow below the reservoir, but has no significant impact on streamflow in the Meeker area. The streamflow graph below shows that the flows for the four simulations are essentially the same.



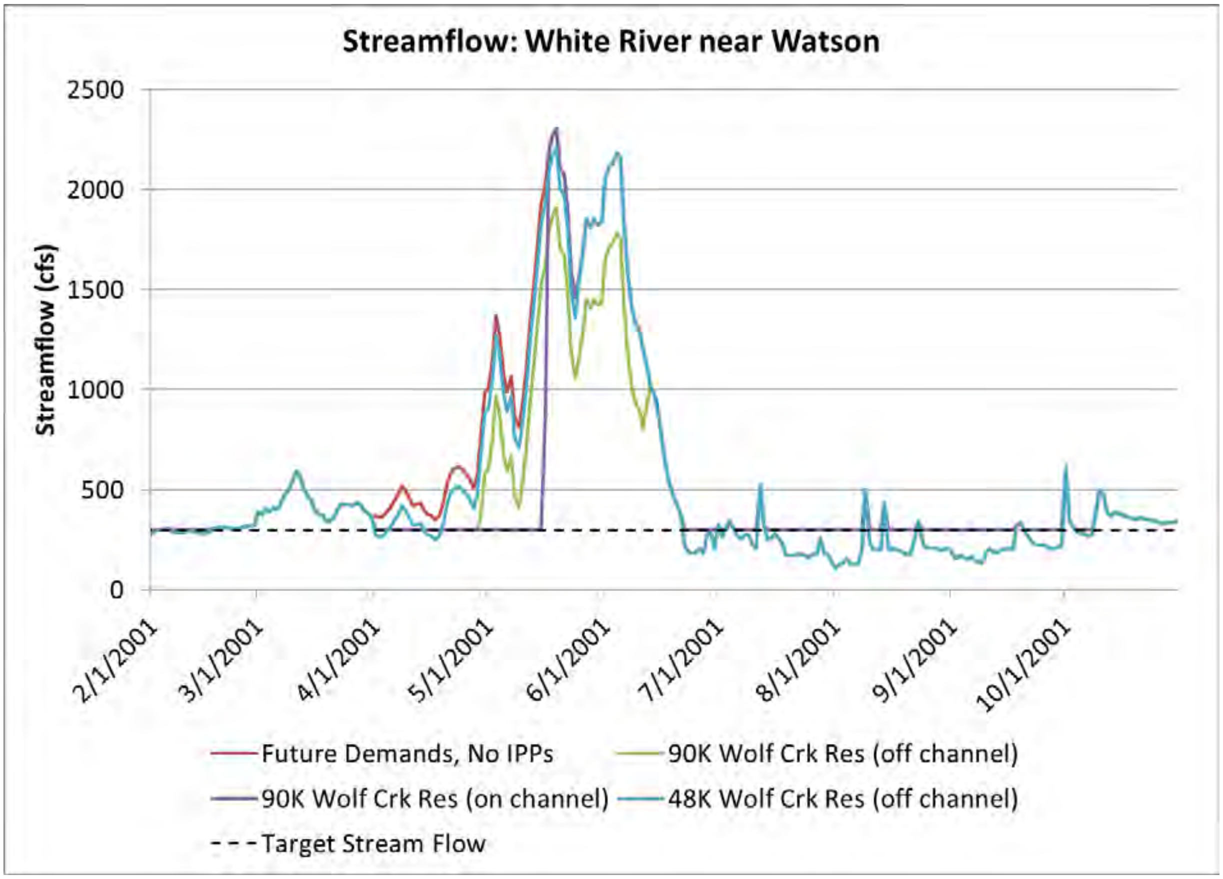
    - The table below compares the simulated streamflow to the instream flow (200 cfs). The results are the same.

Percent of days in the month that meet or exceed the instream flow (200 cfs) near Meeker				
	Future Demands, No IPPs	90K Wolf Crk Res (off channel)	90K Wolf Crk Res (on channel)	48K Wolf Crk Res (off channel)
Jan	99%	99%	99%	99%
Feb	98%	98%	98%	98%
Mar	100%	100%	100%	100%
Apr	100%	100%	100%	100%
May	100%	100%	100%	100%
Jun	90%	90%	90%	90%
Jul	73%	72%	72%	72%
Aug	54%	53%	53%	53%
Sep	55%	55%	55%	55%
Oct	100%	100%	100%	100%
Nov	100%	100%	100%	100%
Dec	99%	99%	99%	99%

- As shown in the figure below, the streamflow at Watson has significant differences because of Wolf Creek Reservoir. The figure below and the zoom-in on 2001 highlights the following impacts:
  - Filling Wolf Creek Reservoir takes water out of the stream during the early run-off. The on-channel Wolf Creek Reservoir does not have a restriction on how quickly it fills. Therefore, it stores almost the entire river (bypassing 300 cfs) from April through mid-May. In contrast, the off-channel reservoirs are limited by the pump station capacity. They take longer to fill, but do not have the same dramatic impact on the river. The 48K off-channel Wolf Creek generally fills by early June and the 90K on-channel Wolf Creek generally fills by late June.
  - Releases from the 90K off-channel and 90K on-channel Wolf Creek Reservoir help supplement the streamflow during low-flow periods. The reservoirs are able to maintain the 300 cfs target in 2000 and 2001. The reservoirs help maintain the 300 cfs target in 2002 through early July, but run out of water in the Fish Pool after that point.
  - The 48K off-channel Wolf Creek Reservoir does not have a Fish Pool and does not help maintain the streamflow.



Streamflow: White River near Watson
Streamflow (cfs)
4000
3500
3000
2500
2000
1500
1000
500
0
1/1/2000
3/1/2000
5/1/2000
7/1/2000
9/1/2000
11/1/2000
1/1/2001
3/1/2001
5/1/2001
7/1/2001
9/1/2001
11/1/2001
1/1/2002
3/1/2002
5/1/2002
7/1/2002
9/1/2002
11/1/2002
Future Demands, No IPPs
90K Wolf Crk Res (off channel)
90K Wolf Crk Res (on channel)
48K Wolf Crk Res (off channel)
Target Stream Flow



- The table below compares the simulated streamflow to the preliminary flow target (300 cfs). Both the off-channel and on-channel 90K Wolf Creek Reservoir significantly increase the streamflow during low flow months.

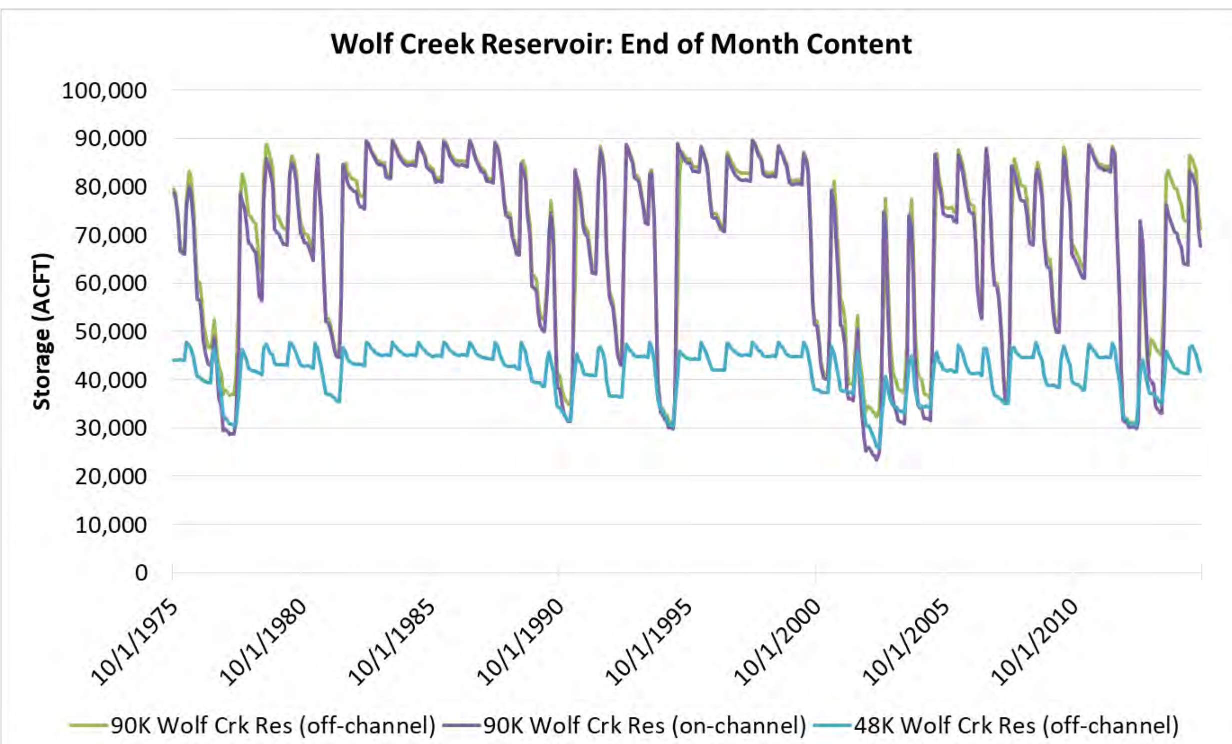
Percent of days in a month that meet or exceed the preliminary target (300 cfs) near Watson				
	Future Demands, No IPPs	90K Wolf Crk Res (off channel)	90K Wolf Crk Res (on channel)	48K Wolf Crk Res (off channel)
Jan	39%	84%	82%	39%
Feb	59%	84%	84%	59%
Mar	86%	93%	93%	86%
Apr	97%	95%	98%	81%
May	97%	100%	100%	95%
Jun	87%	100%	100%	87%
Jul	63%	95%	97%	63%
Aug	45%	95%	96%	45%
Sep	46%	90%	92%	46%
Oct	85%	92%	93%	85%
Nov	63%	90%	90%	63%

Dec	41%	85%	87%	41%

- The table below shows the percent of years in the simulation that the reservoirs are able to fill.

Percent of years that the reservoir fills (1975 - 2015)				
	Future Demands, No IPPs	90K Wolf Crk Res (off-channel)	90K Wolf Crk Res (on-channel)	48K Wolf Crk Res (off-channel)
Lake Avery	100%	100%	100%	100%
Kenney Reservoir	100%	100%	100%	100%
Wolf Creek Res.	-	85%	75%	98%

- The figure below shows the end of month contents for Wolf Creek Reservoir. The off-channel and on-channel reservoirs have slightly different filling signatures. The significant difference between the two 90K reservoirs and the 48K reservoir is the Fish Pool.

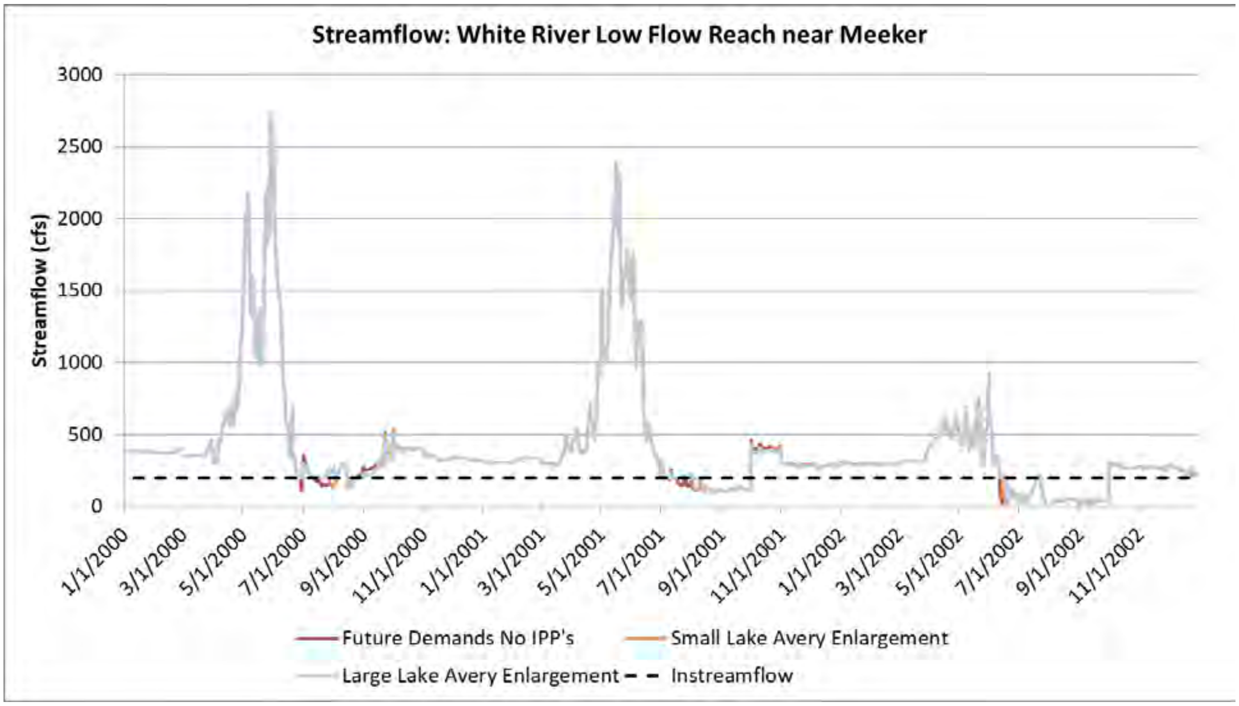


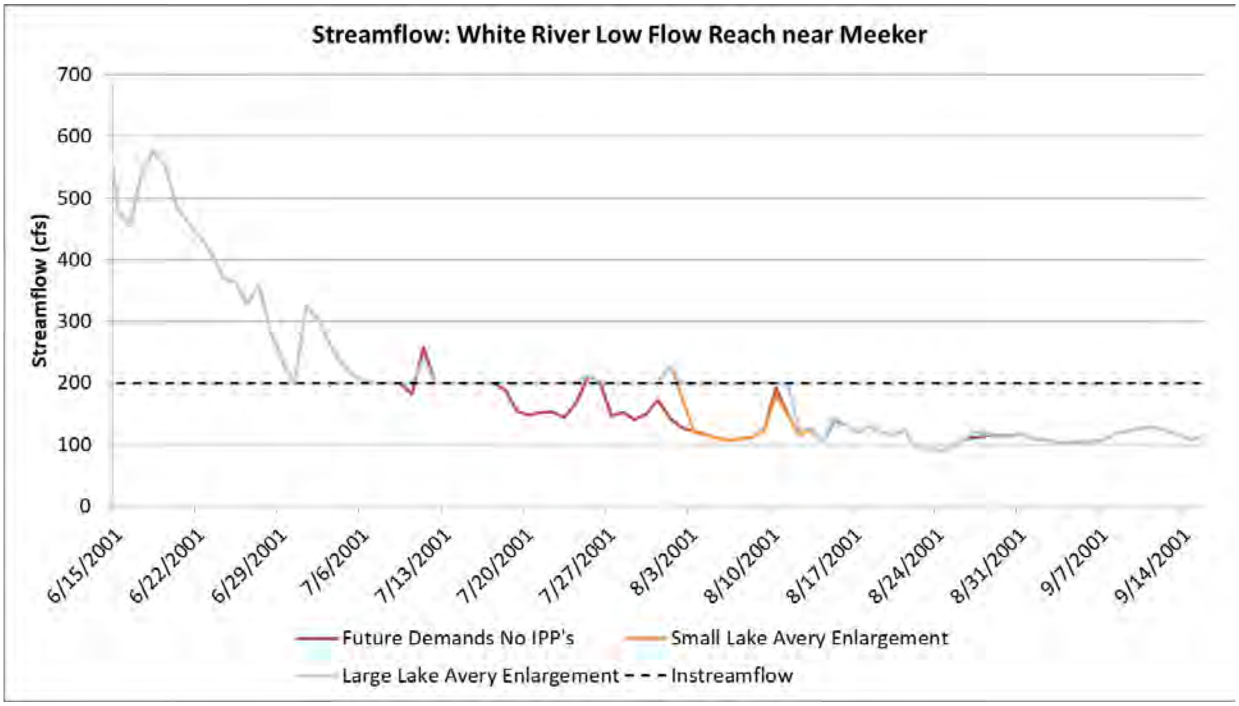
- The table below shows the consumptive use shortages throughout the basin. The addition of Wolf Creek Reservoir eliminates shortages to Rangely and the future energy development. Note that the future golf course is shorted more when Wolf Creek Reservoir is included. Wolf Creek Reservoir is filling under their conditional water right, which is senior to the "current day" water right modeled for the future golf course.

Percent Short from 1975 through 2015					
Name	WDID	Future Demands, No IPPs	90K Wolf Crk Res (off-channel)	90K Wolf Crk Res (on-channel)	48K Wolf Crk Res (off-channel)
Meeker	4306045	0%	0%	0%	0%
Rangely	4300889_D	1%	0%	0%	0%
WD 43 Future Golf Course	43_FutGlf	24%	34%	39%	24%
Future Energy Development - White River Mainstem	43_GasOil	8%	0%	0%	0%
Future Energy Development - Piceance Basin	43_OilShl	25%	0%	0%	0%
Piceance Agriculture	Multiple	22%	22%	22%	22%
Upper White Agriculture	Multiple	11%	11%	11%	11%
Middle White Agriculture	Multiple	11%	11%	11%	11%
Lower White Agriculture	Multiple	2%	2%	2%	2%

- [**Future Demands No IPPs, Small Lake Avery Enlargement, Large Lake Avery Enlargement**]
  - The Lake Avery enlargement primarily supplements streamflow near Meeker. The increase in lake storage helps boost streamflow during low flow periods, but is not able to fully satisfy the instream flow. The figures below focus on the dry period in the early 2000s. The second figure zooms in on the low flow period in 2001. In the Future Demands, No IPPs run, the streamflow drops below 200 cfs around July 17 and stays below 200 cfs. The Small

Lake Avery Enlargement is able to supplement the streamflow until August 1, at which point, the pool runs out of water. The Large Lake Avery Enlargement is able to supplement the streamflow through August 11, at which point, the pool runs out of water. In 2002, the enlargement pools are not able to refill and only provide a few days of supplemental releases.

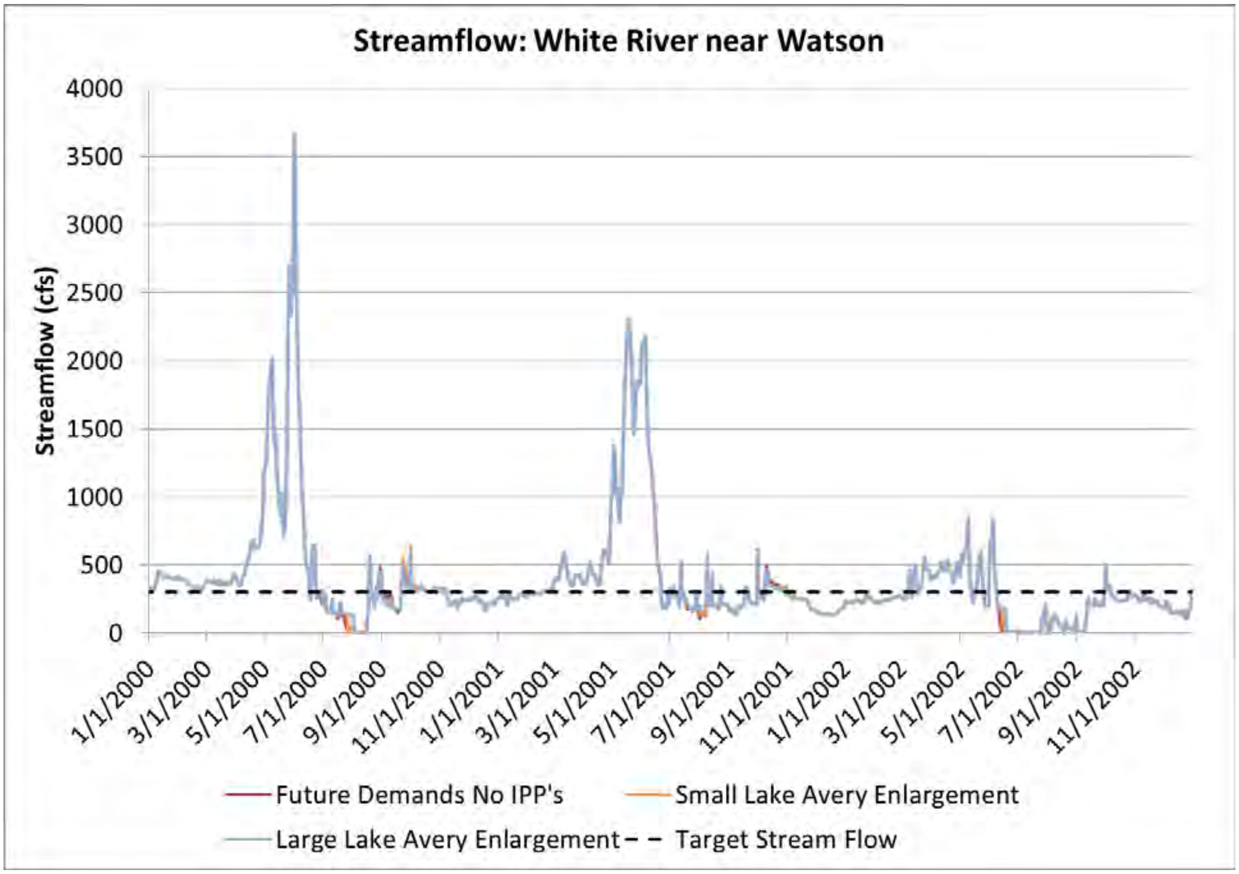




- The table below compares the simulated streamflow to the instream flow (200 cfs) and presents the percent of days in each month that meet or exceed the instream flow. While the enlarged Lake Avery improves the conditions, it does not recover the stream reach.

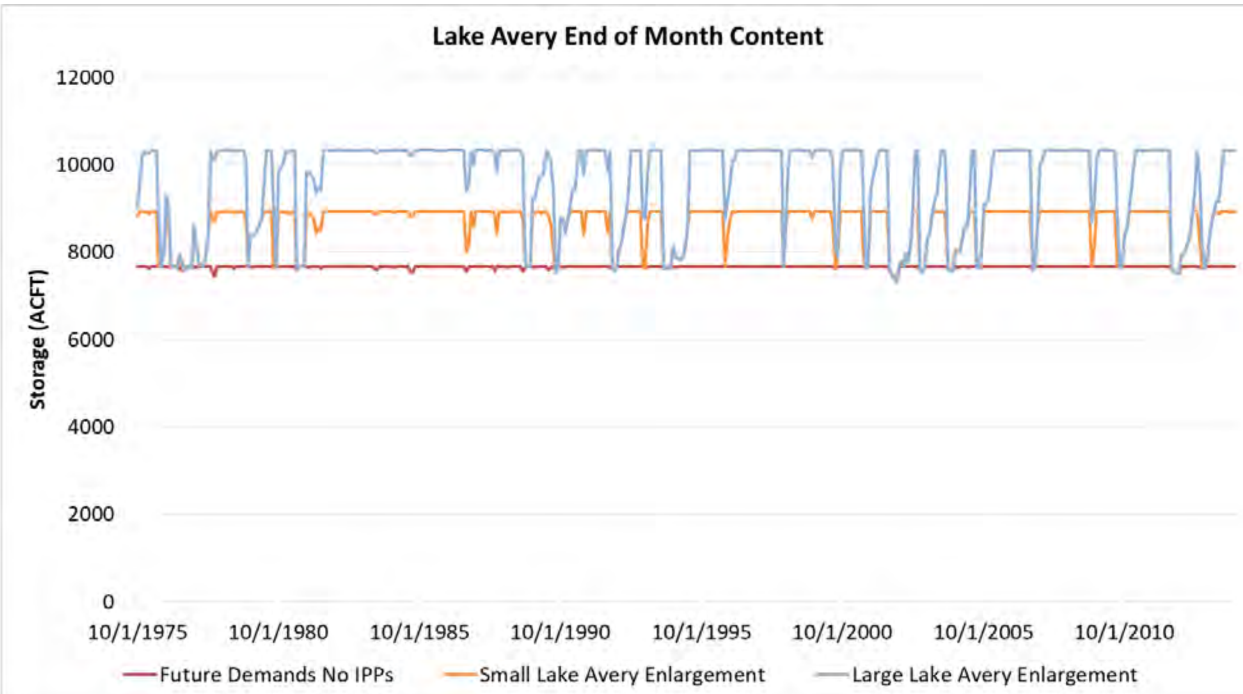
Percent of days in the month that meet or exceed the instream flow (200 cfs) near Meeker			
	Future Demands, No IPPs	Small Lake Avery Enlargement	Large Lake Avery Enlargement
Jan	99%	99%	99%
Feb	98%	99%	99%
Mar	100%	100%	100%
Apr	100%	100%	100%
May	100%	100%	100%
Jun	90%	95%	96%
Jul	73%	83%	87%
Aug	54%	62%	67%
Sep	55%	62%	65%
Oct	100%	100%	100%
Nov	100%	100%	100%
Dec	99%	100%	100%

- The changes to Lake Avery and the streamflow through Meeker have a limited impact on streamflow at Watson, but minor changes can be seen in the figure and table below.



Percent of days in a month that meet or exceed the preliminary target (300 cfs) near Watson			
	Future Demands, No IPPs	Small Lake Avery Enlargement	Large Lake Avery Enlargement
Jan	39%	39%	39%
Feb	59%	59%	58%
Mar	86%	86%	86%
Apr	97%	97%	96%
May	97%	97%	97%
Jun	87%	87%	87%
Jul	63%	64%	64%
Aug	45%	45%	46%
Sep	46%	47%	47%
Oct	85%	82%	82%
Nov	63%	62%	62%
Dec	41%	40%	40%

- The figures below show the Lake Avery end of month storage. The reservoir is only releasing from the enlargement pool to downstream demands. The existing reservoir capacity maintains the lake levels and is only subject to evaporation.



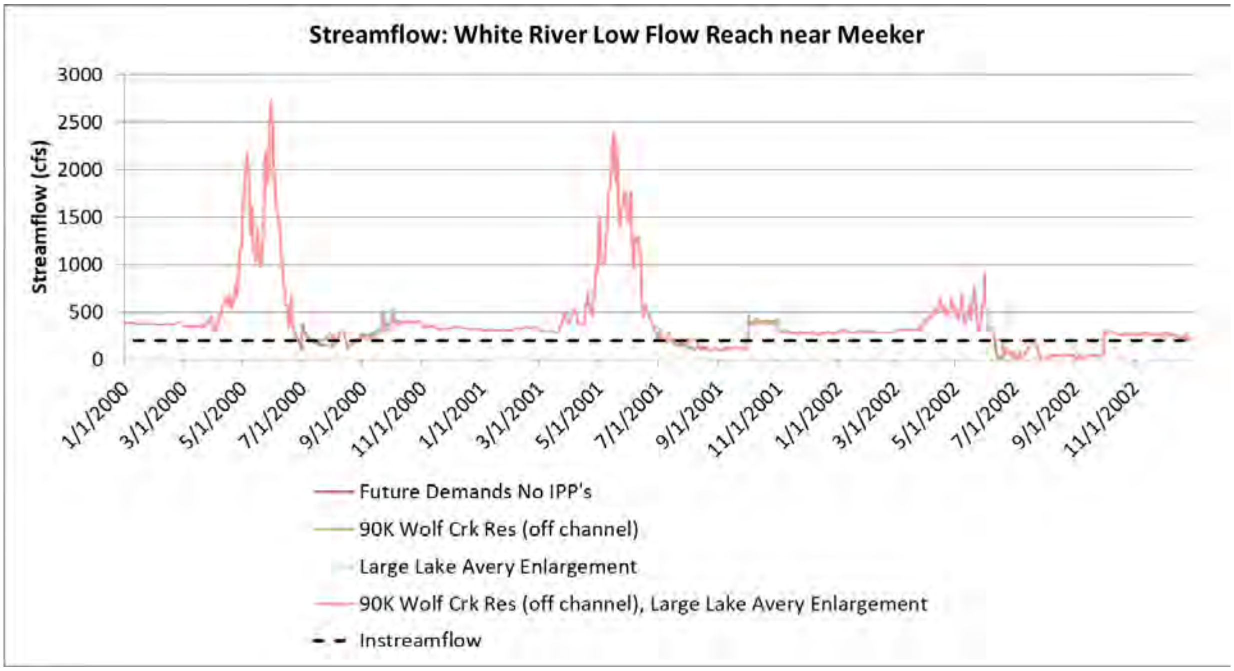
- The table below shows the number of years in the simulation that Lake Avery is able to fill. Note that Wolf Creek Reservoir was not active in these runs. The only year in which Lake Avery is not able to fill is 1977.

Percent of years that the reservoir fills (1975 - 2015)			
	Future Demands, No IPPs	Small Lake Avery Enlargement	Large Lake Avery Enlargement
Lake Avery	100%	98%	98%
Kenney Reservoir	100%	100%	100%

- The tables below show the consumptive use shortages throughout the basin. Note that the Lake Avery enlargement also releases to the Future Golf Course.

Percent Short from 1975 through 2015				
Name	WDID	Future Demands, No IPPs	Small Lake Avery Enlargement	Large Lake Avery Enlargement
Meeker	4306045	0%	0%	0%
Rangely	4300889_D	1%	1%	1%
WD 43 Future Golf Course	43_FutGlf	24%	17%	14%
Future Energy Development - White River Mainstem	43_GasOil	8%	8%	8%
Future Energy Development - Piceance Basin	43_OilShl	25%	25%	25%
Piceance Agriculture	Multiple	22%	22%	22%
Upper White Agriculture	Multiple	11%	11%	11%
Middle White Agriculture	Multiple	11%	11%	11%
Lower White Agriculture	Multiple	2%	2%	2%

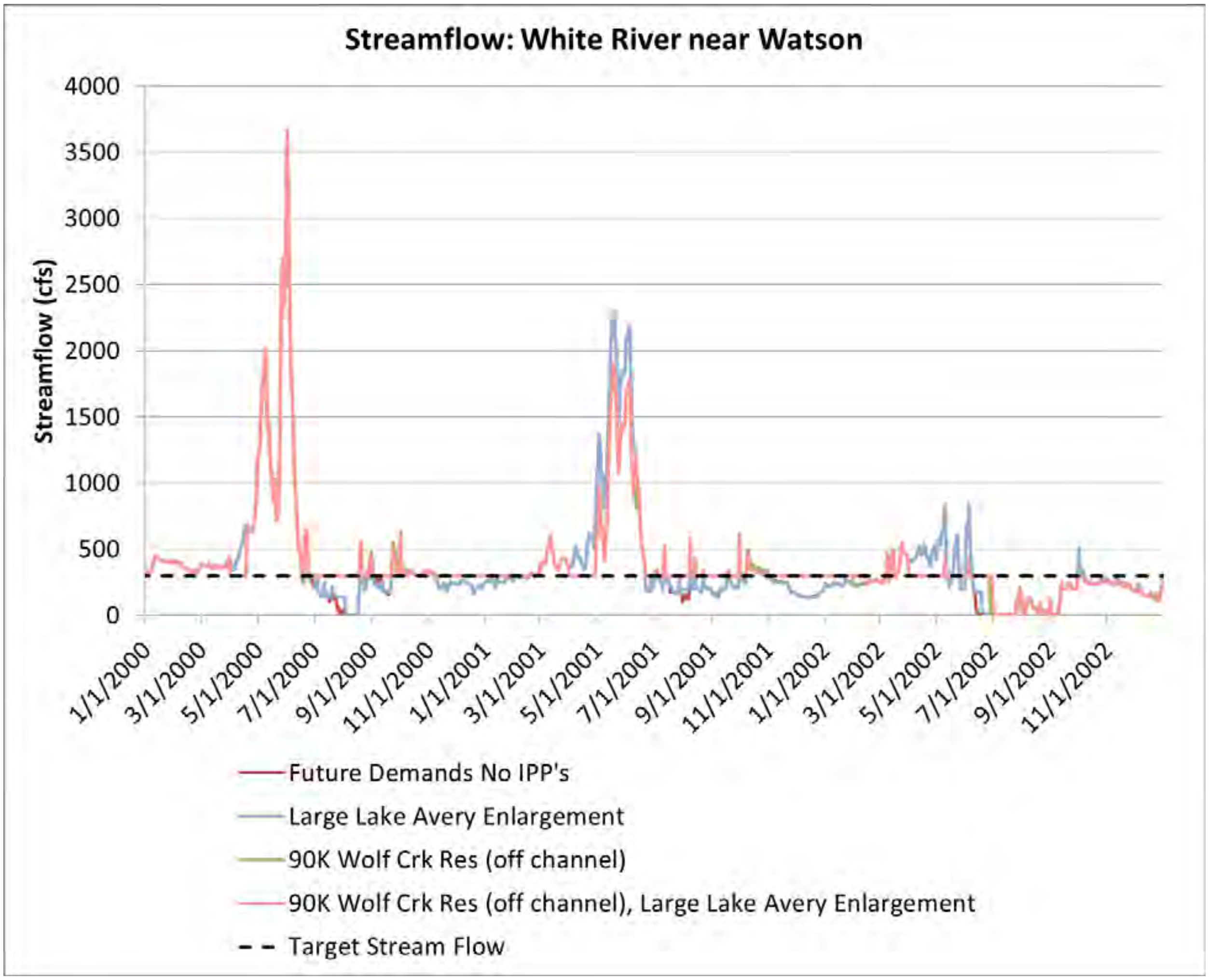
- [**Future Demands No IPPs, 90,000 AF Wolf Creek Reservoir, off-channel, Large Lake Avery enlargement, 90,000 AF Wolf Creek Reservoir, off-channel and Large Lake Avery**]
    - This grouping of runs checks for competition between Wolf Creek Reservoir and Lake Avery Enlargement.
    - The streamflow through Meeker does not reflect competition between the two reservoirs.



- The table below shows the percent of days that meet or exceed the instream flow (200 cfs) through Meeker. There is no change between the Large Lake Avery Enlargement run and the 90K Wolf Crk Res (off-channel) plus Large Lake Avery Enlargement run.

Percent of days in the month that meet or exceed the instream flow (200 cfs) near Meeker				
	Future Demands, No IPPs	90K Wolf Crk Res (off channel)	Large Lake Avery Enlargement	90K Wolf Crk Res (off channel), Large Lake Avery Enlargement
Jan	99%	99%	99%	99%
Feb	98%	98%	99%	99%
Mar	100%	100%	100%	100%
Apr	100%	100%	100%	100%
May	100%	100%	100%	100%
Jun	90%	90%	96%	96%
Jul	73%	72%	87%	87%
Aug	54%	53%	67%	67%
Sep	55%	55%	65%	65%
Oct	100%	100%	100%	100%
Nov	100%	100%	100%	100%
Dec	99%	99%	100%	100%

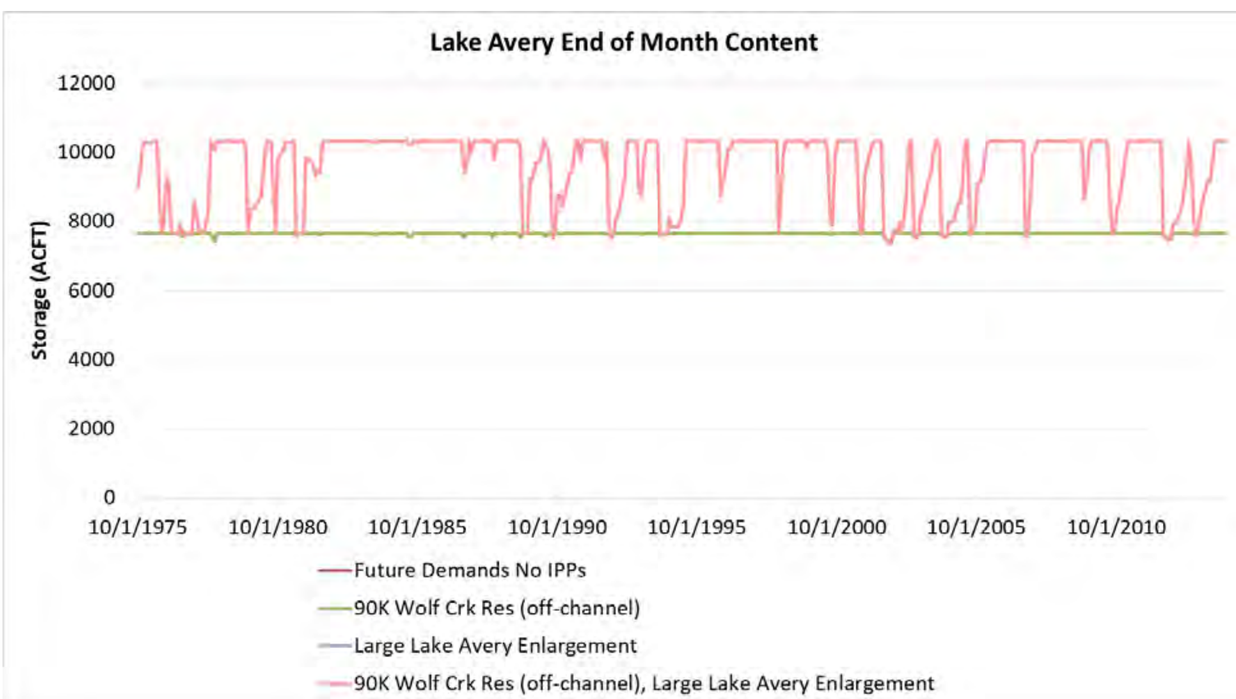
- The streamflow at Watson sees very minor differences between the run with 90K Wolf Crk Res (off-channel) run and the 90K Wolf Crk Res (off-channel) plus Large Lake Avery Enlargement.



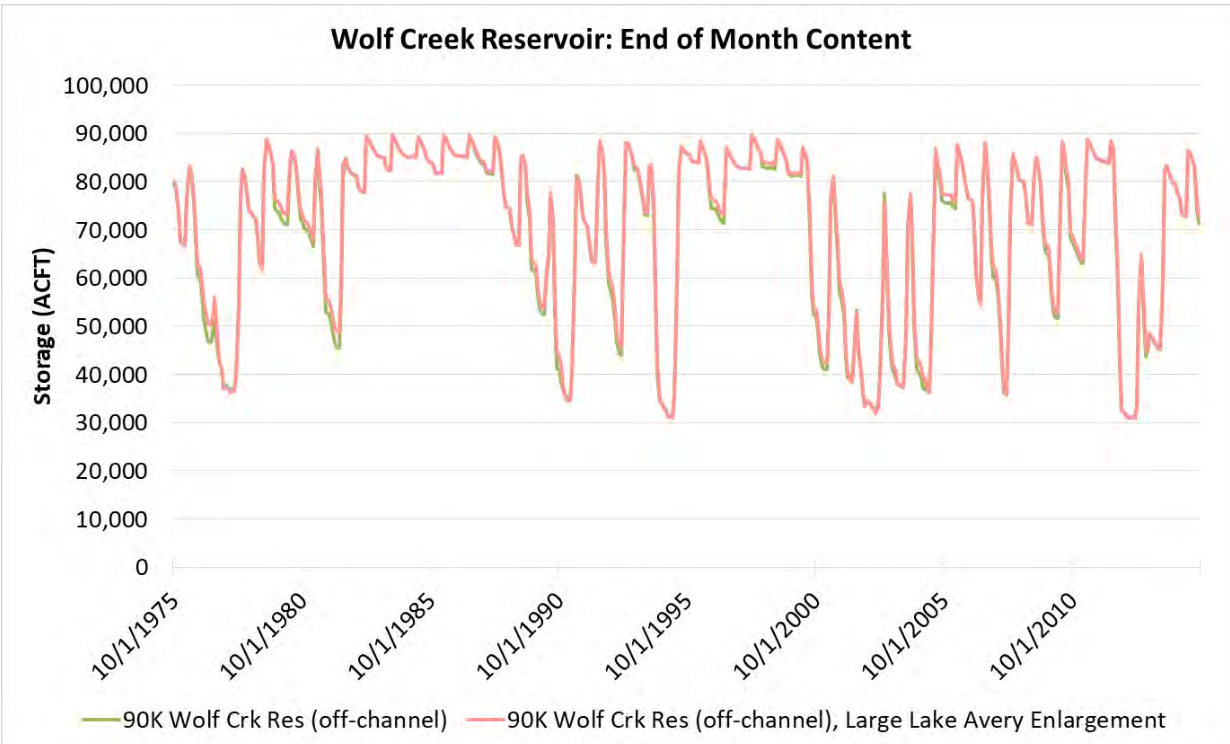
- The table below shows the percent of days per month that meet or exceed the preliminary flow target (300 cfs) at Watson. The flows see minor increases during the drier months.

Percent of days in a month that meet or exceed the preliminary target (300 cfs) near Watson				
	Future Demands, No IPPs	90K Wolf Crk Res (off channel)	Large Lake Avery Enlargement	90K Wolf Crk Res (off channel), Large Lake Avery Enlargement
Jan	39%	84%	39%	84%
Feb	59%	84%	58%	87%
Mar	86%	93%	86%	93%
Apr	97%	95%	96%	95%
May	97%	100%	97%	100%
Jun	87%	100%	87%	100%
Jul	63%	95%	64%	96%
Aug	45%	95%	46%	96%
Sep	46%	90%	47%	92%
Oct	85%	92%	82%	92%
Nov	63%	90%	62%	90%
Dec	41%	85%	40%	87%

- The figure below shows the Lake Avery end of month storage. The addition of Wolf Creek Reservoir does not change the ability of Lake Avery to fill the enlargement.



- The figure below shows the Wolf Creek Reservoir storage. The results are very similar, with slightly higher storage in some years.



- The table below shows the percent of years in the simulation that reservoirs are able to fill.

Percent of years that the reservoir fills (1975 - 2015)				
	Future Demands, No IPPs	90K Wolf Crk Res (off-channel)	Large Lake Avery Enlargement	90K Wolf Crk Res (off-channel), Large Lake Avery Enlargement
Lake Avery	100%	100%	98%	98%
Wolf Creek	-	85%	-	83%
Kenney Reservoir	100%	100%	100%	100%

- The table below shows the shortages throughout the basin.

Percent Short from 1975 through 2015					
Name	WDID	Future Demands, No IPPs	90K Wolf Crk Res (off-channel)	Large Lake Avery Enlargement	90K Wolf Crk Res (off-channel), Large Lake Avery Enlargement
Meeker	4306045	0%	0%	0%	0%
Rangely	4300889_D	1%	0%	1%	0%
WD 43 Future Golf Course	43_FutGlf	24%	34%	14%	14%
Future Energy Development - White River Mainstem	43_GasOil	8%	0%	8%	0%
Future Energy Development - Piceance Basin	43_OilShl	25%	0%	25%	0%
Piceance Agriculture	Multiple	22%	22%	22%	22%
Upper White Agriculture	Multiple	11%	11%	11%	11%
Middle White Agriculture	Multiple	11%	11%	11%	11%
Lower White Agriculture	Multiple	2%	2%	2%	2%

Yampa River – Upper

The Yampa River has been divided into two main sections: The Upper Yampa (watershed upstream of Craig Station) and the Lower Yampa (downstream of Craig Station). This divide corresponds with the Upper Yampa Water Conservancy District boundary on the mainstem of the Yampa and the focus of IPPs.

Due to time constraints, results for IPPs located in the Lower Yampa were not explored at the July workshop. They were presented in subsequent workshops.

Appendix F - October 19, 2017 Yampa and White Climate Scenario Results

This appendix is the presentation given by Wilson Water Group at the October 19, 2017 workshop held at Carpenter Ranch (outside of Hayden, Colorado).

Agenda

October 19, 2017 at Carpenter Ranch

Yampa/White/Green BRT BIP Phase III Workshop with WWG

- Key Findings and Results
- Description of Hydrologies (Historical, In Between climate change, and Hot & Dry climate change)
- White River StateMod Results
  - Reservoir storage and shortages
  - Consumptive shortages
  - Non-consumptive shortages
  - Boatable Days
- Yampa River StateMod Results
  - Reservoir storage and shortages
  - Consumptive shortages
  - Non-consumptive shortages
  - Boatable Days
- Streamflow Management Planning Process Update

Key Findings and Results

White River Basin

What combination of IPPs best meets future consumptive and non-consumptive demands based on historical hydrology?

- 90,000 acre-feet Wolf Creek Reservoir

Does the IPP meet full demands?

- Future municipal and industrial consumptive demands are met
- 300 cfs flows at Watson are met more than 90 percent of days year-round
- There is a minor decrease in boatable days in June due to reservoir filling

How resilient is the IPP under future climate conditions?

- Future municipal and industrial consumptive demands are met
- Shortages to 300 cfs flows at Watson under Hot and Dry climate conditions are similar to historical hydrology shortages without IPP
- Boatable days may be similar, but shift to earlier in the year

How much additional storage is necessary to fully meet consumptive demands?

- 30,000 af additional storage to meet demands every year except 1977 (driest year in study period)
- 47,000 af additional storage to meet full demand in 1977

Key Findings – Yampa River Basin

What combination of IPPs best meets future consumptive and non-consumptive demands based on historical hydrology?

- Mt. Werner infiltration gallery well expansion
- Stagecoach reoperation to release to Steamboat Preferred Flow Targets
- Elk River Diversion with 1,200 af lease from Steamboat Reservoir
- Elkhead Reservoir reoperation release to meet low-level Maybell Fish Flows from CWCB Pool, Lease Pool, River District Pool, and City of Craig Pool
- 20,000 acre-foot Juniper Reservoir (10,000 af Ag Pool, 10,000 af Fish Pool)

Does the combination meet full demands?

- Future municipal and industrial consumptive demands are met
- Steamboat Preferred Target flows are met
- Maybell low-flow Fish Target flows are met
- There is minimal change to Boating Day Targets
- Juniper Reservoir required to meet Maybell Fish Flows and Oxbow Ag

How resilient is the combination of IPPs under future climate conditions?

- Future municipal and industrial consumptive demands are met
- Ag demands in Upper Yampa, specifically demands that do not receive water from reservoirs, are shorted more under future climate conditions
- Fish targets are not fully met; shortages under Hot and Dry climate conditions are similar to historical hydrology shortages without IPPs
- Boatable days may be similar, but shift to earlier in the year

How much additional storage is necessary to fully meet low-level Maybell Fish targets (assuming Elkhead Reoperation)?

- 10,500 acre-feet additional storage

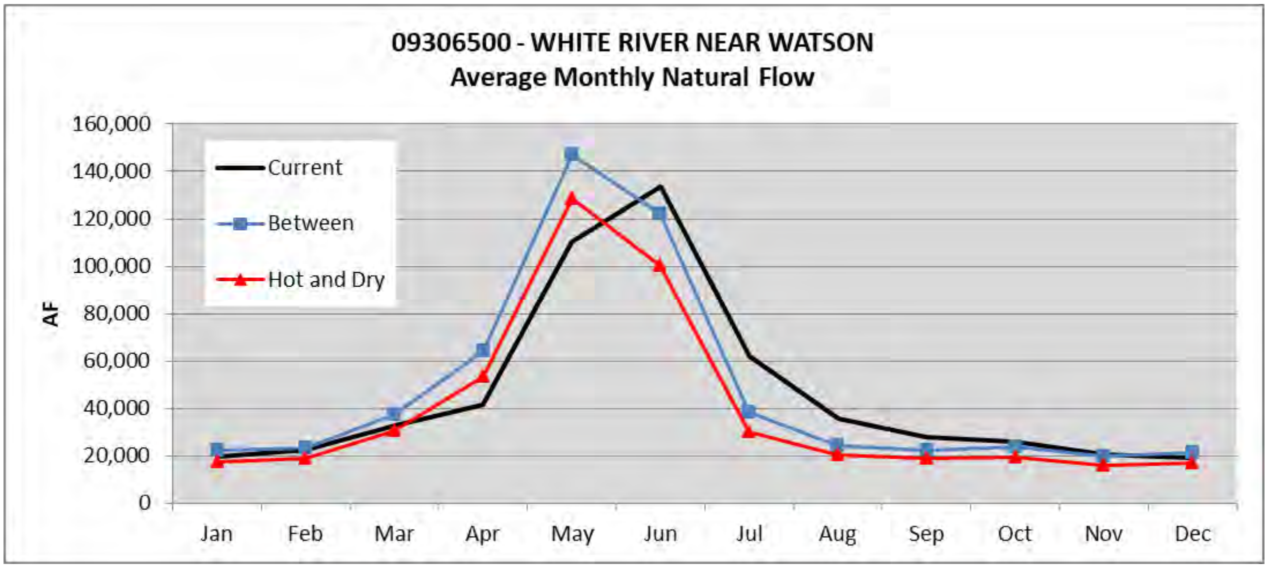
How much storage is necessary to fully meet high-level Maybell Fish targets (assuming Elkhead Reoperation)?

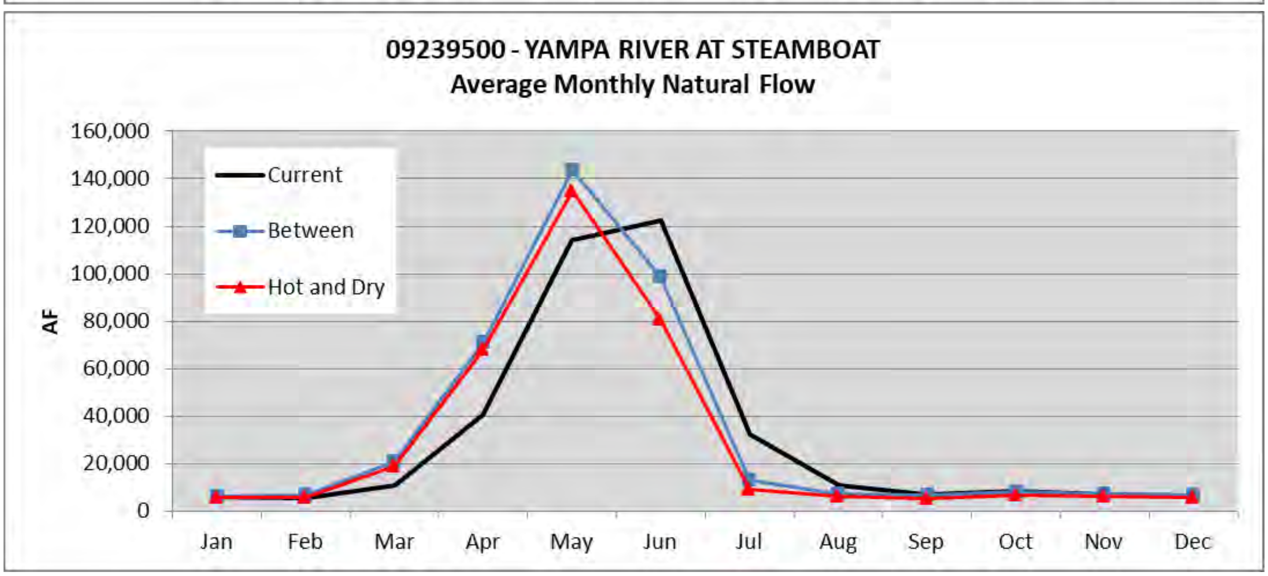
- 15,000 acre-feet additional storage

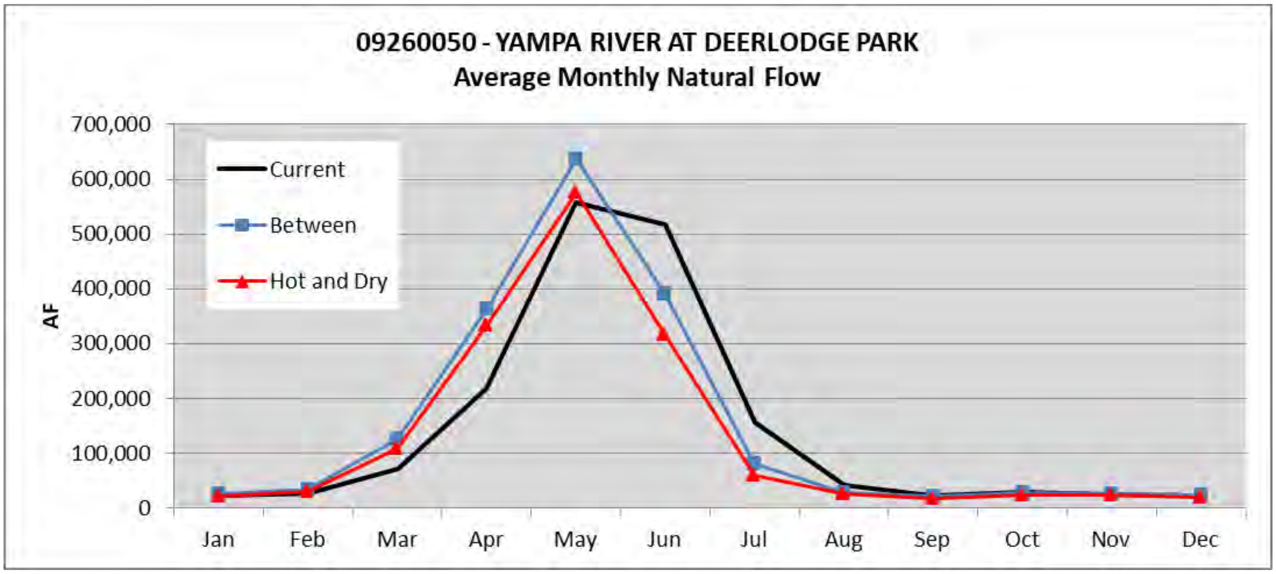
Hydrology

- Historical hydrology is the observed (gaged) streamflow record from 1975 through 2013.
    - In StateMod, the modeling process starts by generating natural flow. The natural flow time series has the influence of man removed from the observed flow. To remove the influence of man on streamflow, StateMod starts with the observed streamflow at each gage in the model, adds the upstream diversions, subtracts the upstream return flows, and adds or subtracts changes in reservoir storage.
- Climate change hydrology has been developed by the State of Colorado as part of the SWSI process representing change as of 2050. The State is looking at two scenarios "Hot and Dry" and "In between" Current and Hot and Dry.
    - Natural flows are revised using a rainfall-runoff model with climate change projected temperature and precipitation.
- Climate change natural flows are only available on a monthly time step.
- The climate change time series is 64 years long. Historical variability has been replicated in the time series. (For this effort, only used 1975 through 2013, same period as the historical daily hydrology).

- The graphs below compare the monthly average flows for the current day natural hydrology and climate change.
- Notice how the climate change hydrology has generally shifted the peak flow earlier in the year.







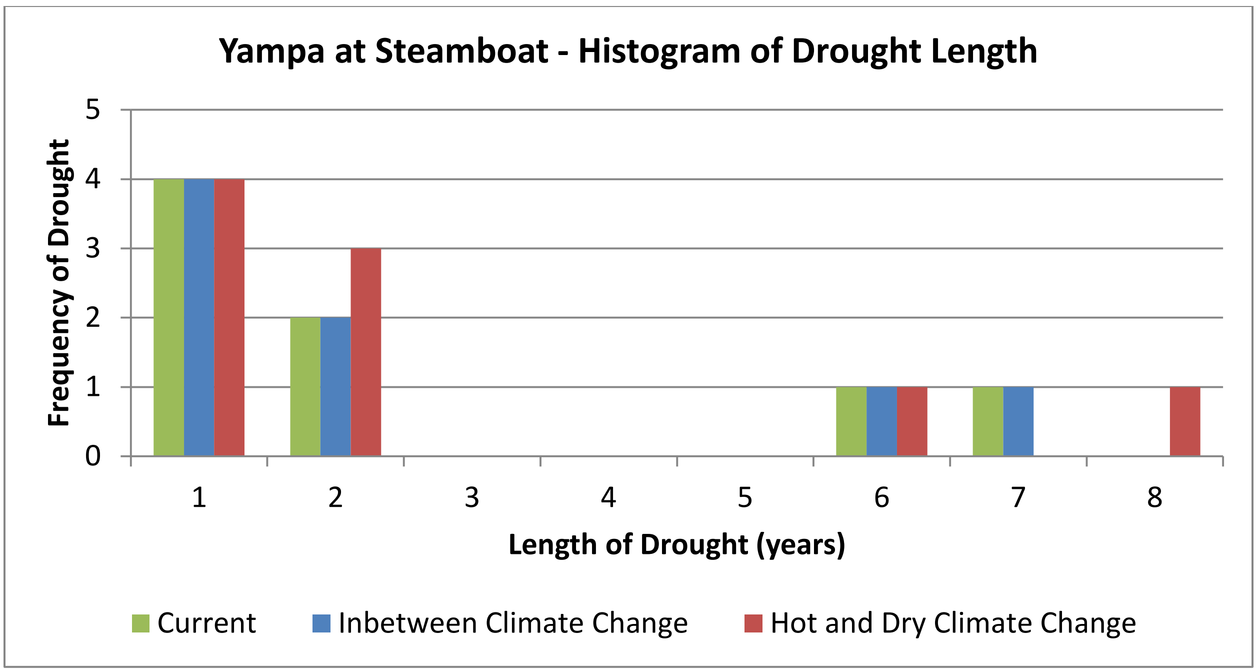
- The table below shows the annual statistics for White River near Watson, Yampa River at the Steamboat gage, and Yampa River near Deerlodge gage.

White River near Watson (09306500)			
	Historical (ACFT)	In between Climate Change (ACFT)	Hot and Dry Climate Change (ACFT)
Year Max	1,020,023	954,995	803,870
Year Mean	553,413	566,234	471,327
Year Min	266,483	249,947	201,803

Yampa River at Steamboat (09239500)			
	Historical (ACFT)	In between Climate Change (ACFT)	Hot and Dry Climate Change (ACFT)
Year Max	660,189	822,181	758,707
Year Mean	371,541	395,782	353,619
Year Min	150,954	122,977	100,385

Yampa River at Deerlodge (09260050)			
	Historical (ACFT)	In between Climate Change (ACFT)	Hot and Dry Climate Change (ACFT)
Year Max	3,430,698	4,009,191	3,637,865
Year Mean	1,747,274	1,783,625	1,552,177
Year Min	635,799	575,839	487,978

- The figures below compare the longest periods of drought.
    - Periods of drought are measured as consecutive years of streamflow volume below the current average annual streamflow volume (count the number of years when the flow is low).



- The tables below compare the largest magnitude of drought.
    - Magnitude of drought is the cumulative volume of water for consecutive years that is less than the average annual streamflow volume.

Yampa River at Steamboat (09239500)					
In between Drought Magnitude (ACFT)	Length of associated drought (years)	Hot and Dry Drought Magnitude (ACFT)	Length of associated drought (years)	Current Drought Magnitude (ACFT)	Length of associated drought (years)
-549,613	6	-761,737	6	-567,919	6
-436,628	7	-725,682	8	-515,092	7
-286,329	2	-377,279	2	-287,137	2
-217,960	2	-279,171	2	-251,156	2
-173,036	1	-207,075	1	-152,663	1
-126,102	1	-201,083	2	-131,299	1
-64,651	1	-105,970	1	-91,801	1
-56,986	1	-103,975	1	-51,186	1
-7,389	1	-41,224	1		
		-1,008	1		

White River

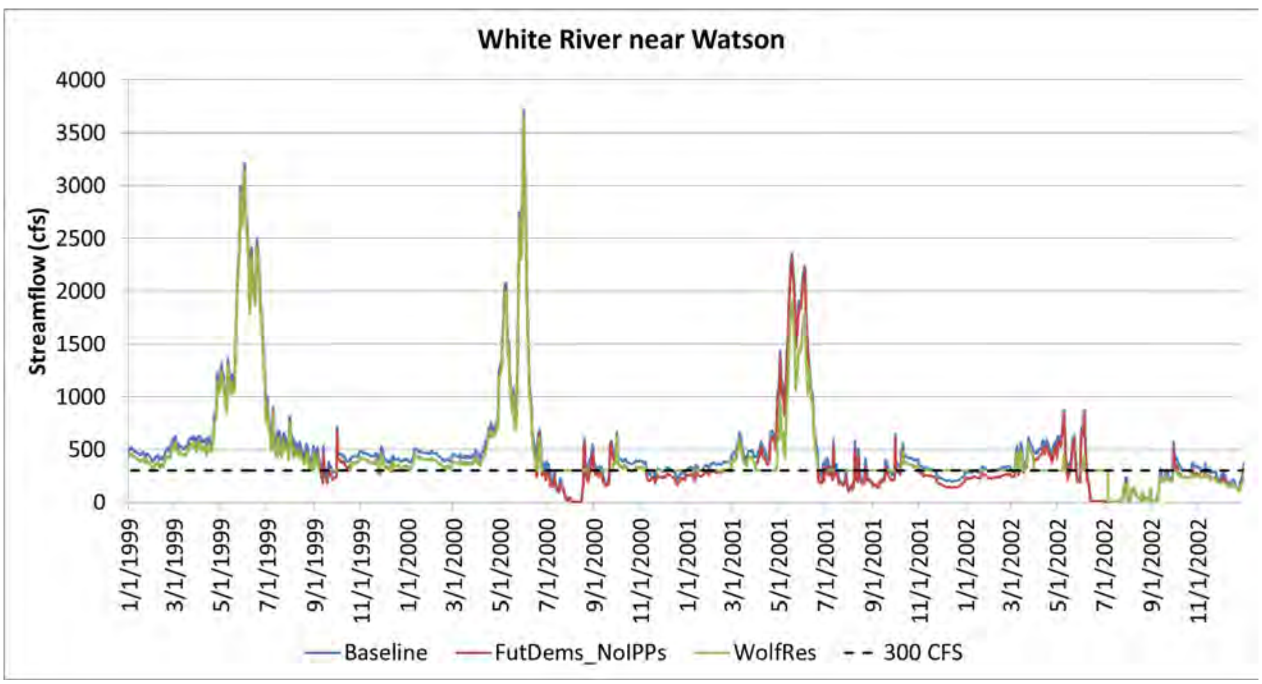
- **Baseline**
    - Historical Hydrology
    - Present day demands
    - No IPPs
    - No fish flow targets at Watson
- **FutDems_NoIPPS**
    - Historical Hydrology
    - Future demands
    - No IPPs
- **In Between FutDems_NoIPPS**
    - In Between climate change hydrology
    - Future demands
    - Increased agricultural demands in response to In Between climate conditions
    - No IPPs
- **Hot and Dry FutDems_NoIPPs**
    - Hot and Dry climate change hydrology
    - Future demands

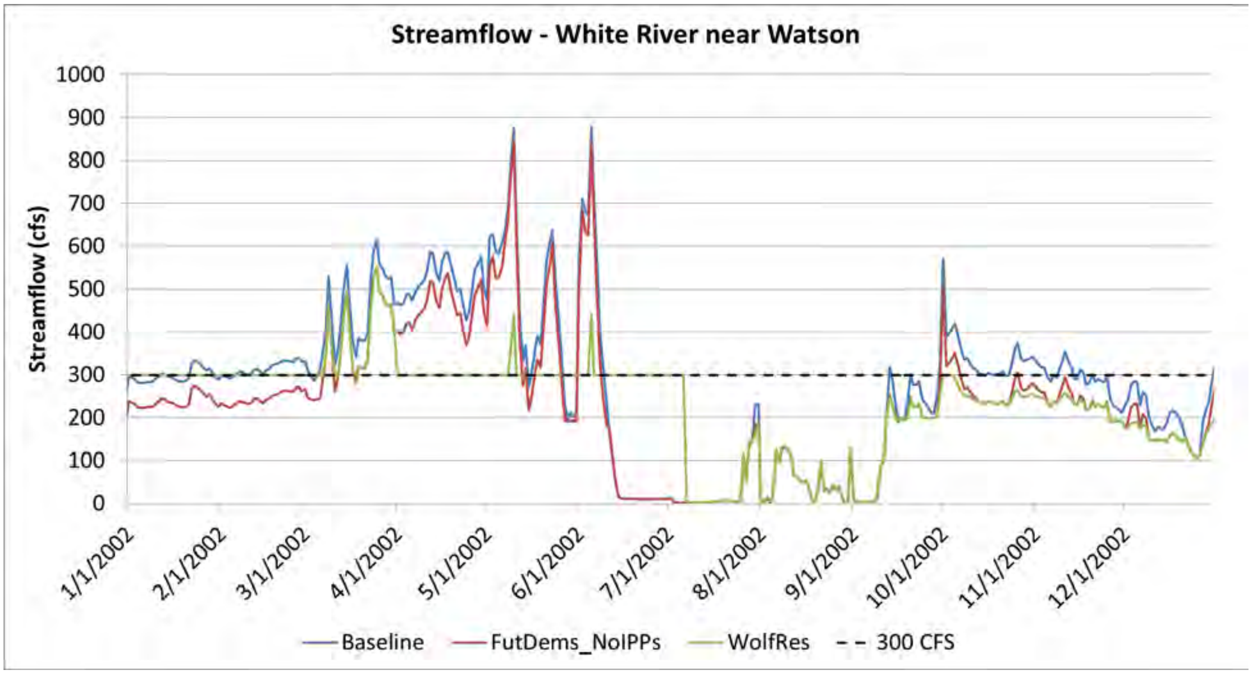
    - Increased agricultural demands in response to Hot and Dry climate conditions
    - No IPPs
- **WolfRes**
    - Historical Hydrology
    - Future Demands
    - Wolf Creek Reservoir is off-channel and 90,000 acre-feet
    - Wolf Creek Reservoir can only store in excess of 300 cfs bypassing the reservoir pump station and 300 cfs at the Watson gage.
    - Wolf Creek Reservoir releases to:
        - Oil and Gas demand nodes
        - Town of Rangley
        - 300 cfs flow target at the Watson gage.
- **In Between WolfRes**
    - In Between climate change hydrology
    - Increased agricultural demands in response to In Between climate conditions
    - Same Wolf Creek Reservoir configuration as WolfRes.
- **Hot and Dry WolfRes**
    - Hot and Dry climate change hydrology
    - Increased agricultural demands in response to Hot and Dry climate conditions
    - Same Wolf Creek Reservoir configuration as WolfRes.
- **Note that the White PBO is independent of this BRT analysis and a target flow has not been identified.**

White River Scenario Combinations

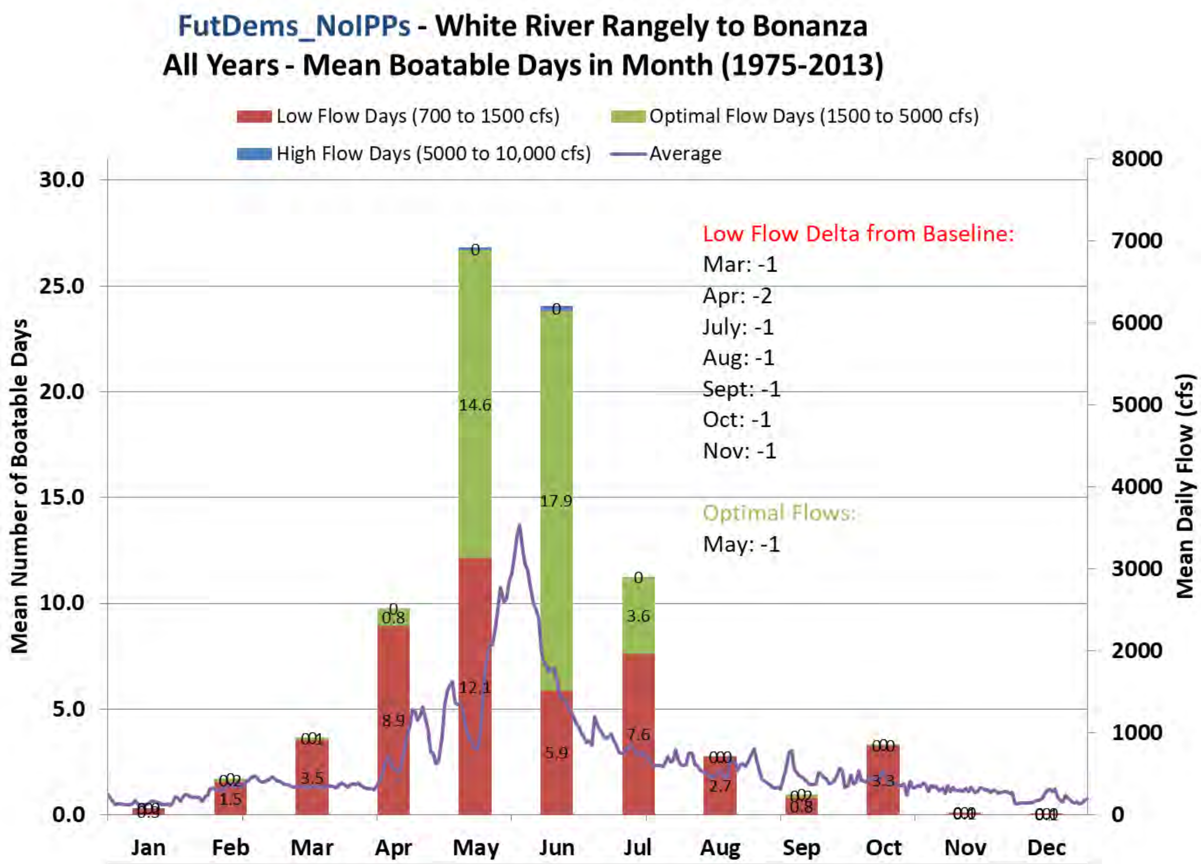
- Baseline vs FutDems_NoIPPS vs WolfRes
    - The future demands cause a decrease in the streamflow at the Watson gage and the river reaches the 300 cfs target on a fewer number of days.
    - Releases from Wolf Creek Reservoir to the Watson gage reduce the number of days when the 300 cfs target cannot be reached.

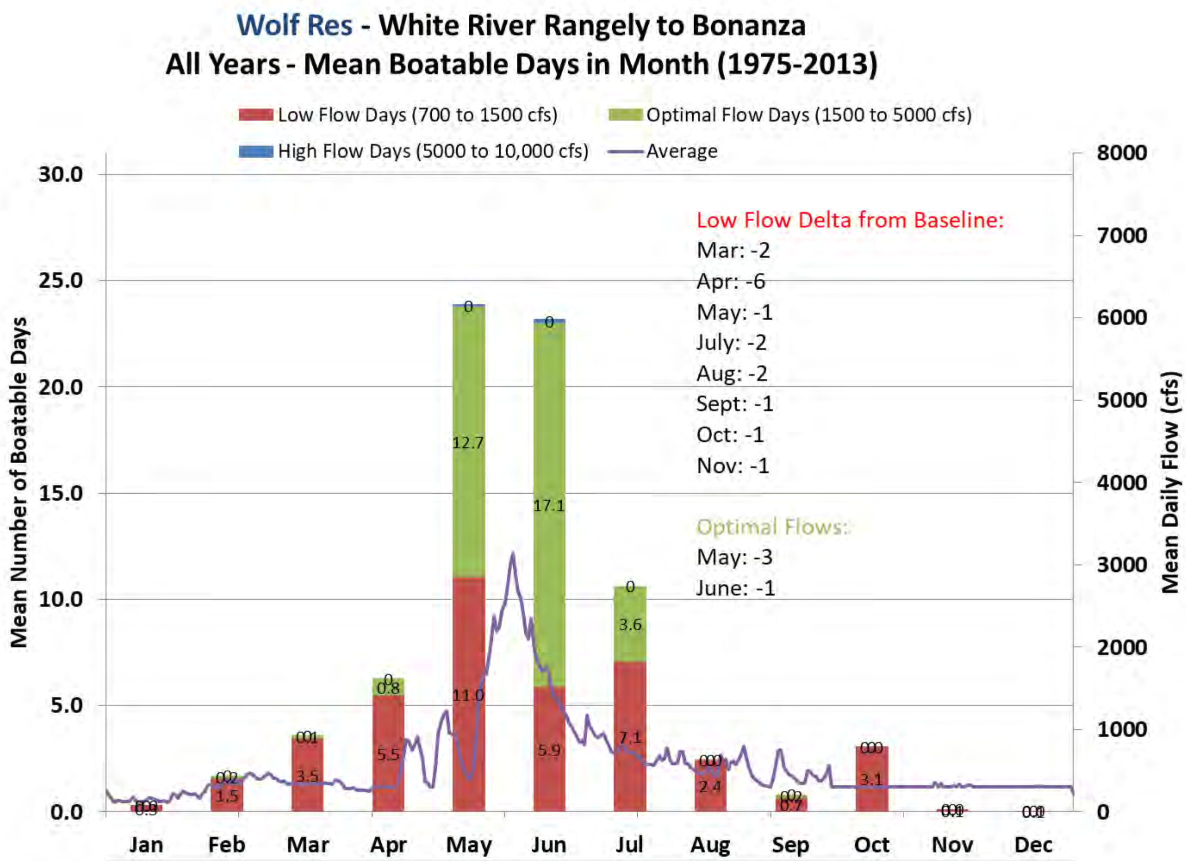
Percent of days in the month that reach or exceed the 300 cfs target at the Watson Gage (09306500).			
	Baseline	FutDems_NoIPPs	WolfRes
January	63%	40%	88%
February	84%	57%	92%
March	97%	86%	96%
April	100%	97%	96%
May	98%	96%	100%
June	89%	86%	100%
July	69%	62%	97%
August	56%	45%	95%
September	57%	45%	94%
October	99%	82%	91%
November	89%	61%	88%
December	59%	40%	88%



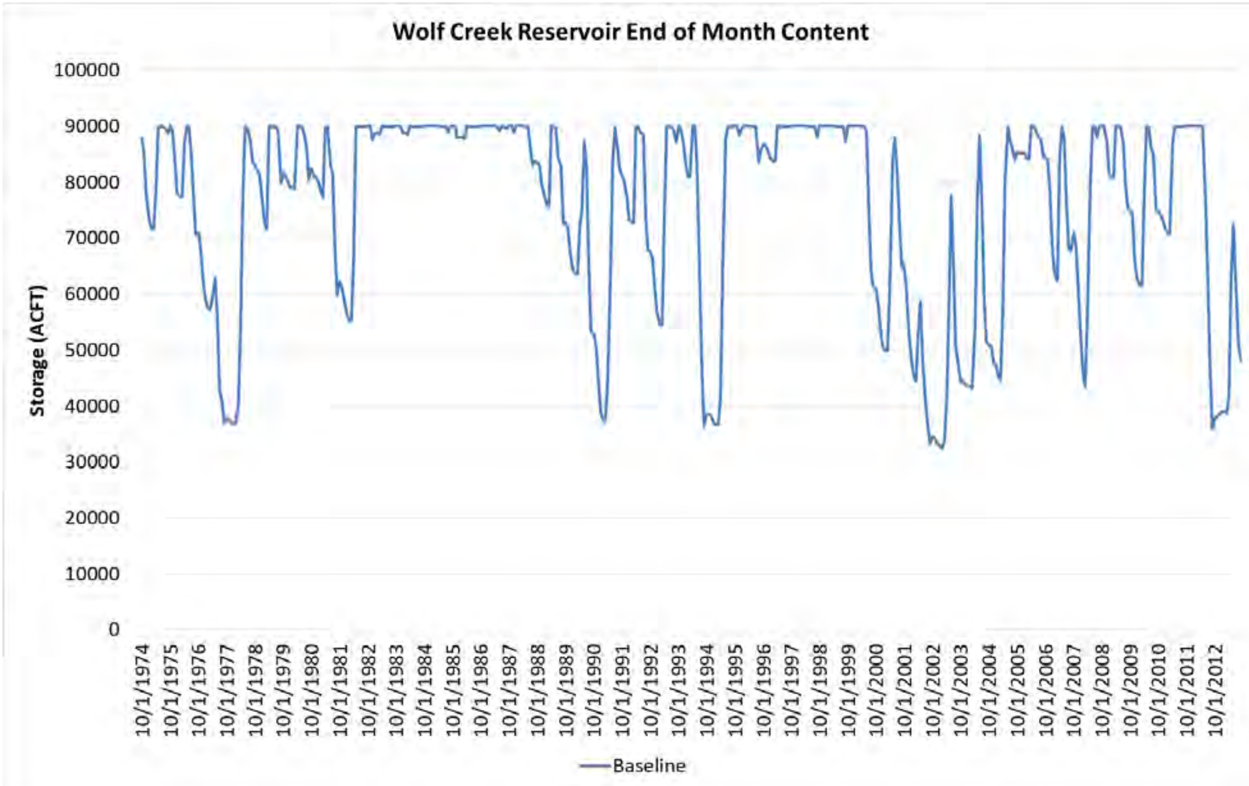


- Even with the large reservoir, the 300 cfs target for this analysis is not reached on all days.
- In order to supply a large amount of water during the low flow periods, the peak flows are impacted. The reservoir pump station has a modeled capacity of 400 cfs to supply the off-channel reservoir. The impact is seen on the number of boatable days for the White River.


FutDems_NoIPPs - White River Rangely to Bonanza
All Years - Mean Boatable Days in Month (1975-2013)
Low Flow Days (700 to 1500 cfs)
Optimal Flow Days (1500 to 5000 cfs)
High Flow Days (5000 to 10,000 cfs)
Average
Low Flow Delta from Baseline:
Mar: -1
Apr: -2
July: -1
Aug: -1
Sept: -1
Oct: -1
Nov: -1
Optimal Flows:
May: -1
Mean Number of Boatable Days
Mean Daily Flow (cfs)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec



- Graph of Wolf Creek Reservoir end-of-month content highlights storage and release operations.



- Without Wolf Creek Reservoir, the future energy demand nodes consistently experience shortage (demand is unmet).
- With Wolf Creek Reservoir, the future energy demand shortages are eliminated.

Percent of Demand Unmet at the future energy demand nodes	
	Historical
FutDems_NoIPPs	12%
WolfRes	0%

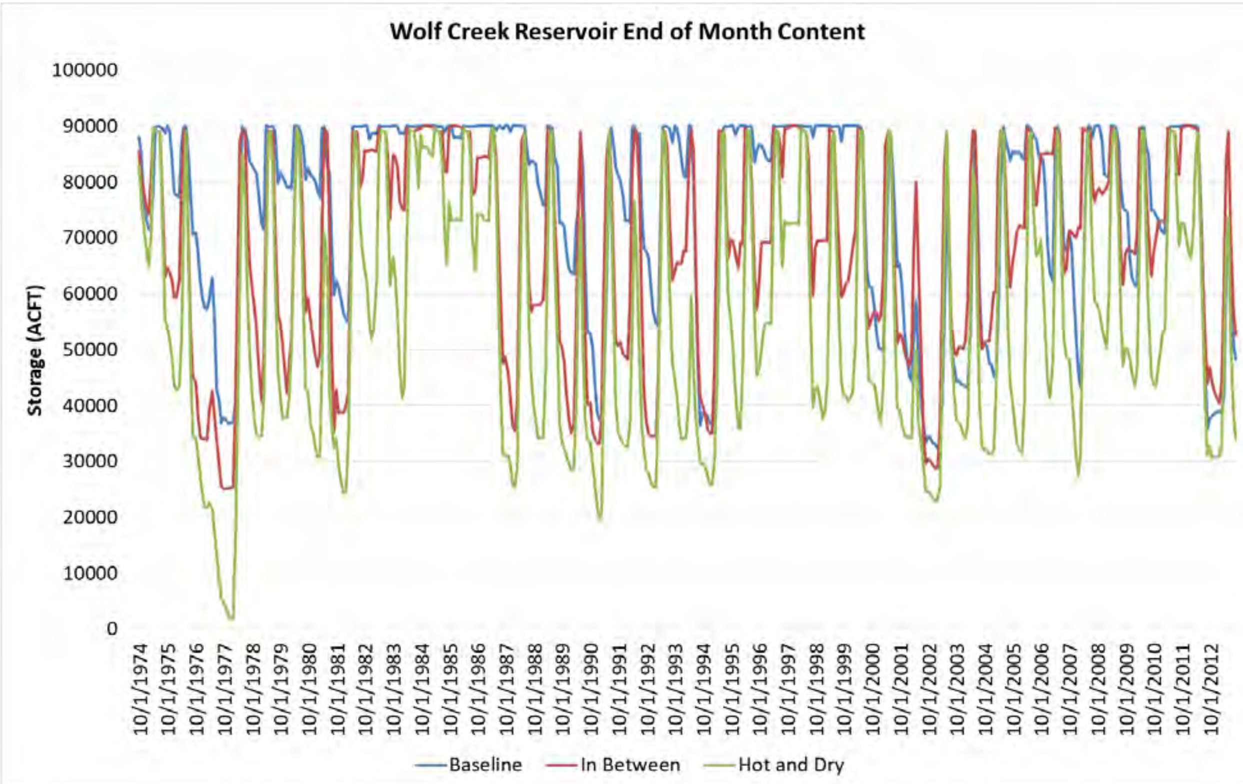
- Historical vs In Between Climate Change vs Hot and Dry Climate Change
  - Reminder: climate scenarios are simulated on a monthly time-step.
  - The In between climate change scenario provides approximately the same annual amount of water to the White River, but with a different shaped hydrograph. The run-off comes earlier in the year. Therefore, late summer and fall low flows are extended.

- The Hot and Dry climate change scenario decreases the amount of water in the White River and also has an earlier run-off.
- The table below summarizes the monthly flow volume at the Watson gage and the percent of months that meet or exceed the target flow volume. (Note that that historical hydrology daily statistics above are slightly different than monthly statistics shown here)

Percent of months in the simulation that meet or exceed the flow target volume at Watson (09306500)				
	Baseline	Historical FutDems_NoIPPs	In Between FutDems_NoIPPs	Hot and Dry FutDems_NoIPPs
Jan	67%	38%	44%	15%
Feb	90%	64%	69%	28%
Mar	100%	92%	100%	87%
Apr	100%	100%	100%	97%
May	100%	100%	100%	97%
Jun	92%	92%	87%	77%
Jul	74%	67%	28%	13%
Aug	59%	44%	3%	0%
Sep	67%	41%	18%	5%
Oct	100%	87%	77%	38%
Nov	92%	62%	54%	18%
Dec	62%	36%	46%	15%

Percent of months in the simulation that meet or exceed the flow target volume at Watson (09306500)				
	Baseline	Historical WolfRes	In Between WolfRes	Hot and Dry WolfRes
Jan	67%	87%	82%	49%
Feb	90%	90%	90%	54%
Mar	100%	97%	97%	85%
Apr	100%	92%	100%	97%
May	100%	100%	97%	97%
Jun	92%	100%	97%	95%
Jul	74%	95%	97%	92%
Aug	59%	95%	97%	82%
Sep	67%	90%	95%	74%
Oct	100%	90%	95%	77%
Nov	92%	87%	92%	67%
Dec	62%	87%	85%	54%

- The climate change hydrology has a large impact. Wolf Creek Reservoir helps to reduce the impact, but still cannot reach the target under the hot and dry climate change hydrology.
- The Wolf Creek EOM graph shows the impact of climate change on the reservoir storage.



- Without Wolf Creek Reservoir, the energy demands have larger shortages under climate change.

Percent of unmet demand for future energy development			
	Historical	In Between	Hot and Dry
FutDems_NoIPPs	12%	20%	31%
WolfRes	0%	0%	0%

- Even with the lower reservoir levels, the future energy demands are able to be met.

Yampa River

- **Baseline**
    - Historical Hydrology
    - Present day demands
    - No IPPs
    - Elkhead releases (based on current operations) from
        - CWCB and Lease pools

Appendix J - White River Model Monthly to Daily Conversion

Introduction

As part of the Phase 3 Modeling effort, the monthly White River StateMod model was enhanced to better represent current operations based on review and input from basin experts. The modeling effort included analyzing IPPs based on non-consumptive flow metrics that are only meaningful when considered on a daily basis. Therefore, the enhanced monthly model as converted to a daily time step.

The daily approach selected is the Daily Pattern method. This approach was recommended and outlined in the *CDSS Daily Yampa Model - Task 4 Recommendation for Full Basin Model memorandum,* 2002, available on the CDSS website. (http://cdss.state.co.us/). Although the recommendations were specific to the Yampa River basin, the same general approach was followed for the White River basin.

Creation of the Daily Model Data Set

The files required to run the White Daily Model are listed in Table 1. All input files are listed; however, only new files or revised files for the daily modeling efforts are discussed in subsequent sections. The steps used to modify the input files are described in these sections. The command files used to generate input files and the input files themselves can be found in the data set delivered for the Yampa Phase 3 Modeling.

Response File (wm2015B_Daily.rsp)

The response file contains the names of all other data files required to run the model. Several of the input files "flags" required for daily modeling were set when the monthly model was developed. The flags set in those files are discussed even though those files were not developed specifically for daily modeling. New file names have been used for the files that have been updated and files related to daily modeling have been added. See the list of files in Table 1. The file is changed by hand-editing.

Table 1. Daily White Input Files for Baseline Scenario

File Description	File Name	New, Revised, or Flag Set in Monthly
Response File	wm2015B_Daily.rsp	Revised
Control File	wm2015_Daily.ctl	Revised
River Network File	wm2015_WolfOC.rin	
Reservoir Station File	wm2015B.res	Flag Set in Monthly
Direct Diversion Station File	wm2015_Int.dds	Flag Set in Monthly
River Station File	wm2015.ris	Revised
Instream Flow Station File	wm2015.ifs	Flag Set in Monthly
Instream Flow Rights File	wm2015.ifr	
Reservoir Rights File	wm2015B.rer	
Direct Diversion Rights File	wm2015.ddr	
Operational Rights File	wm2015B.opr	
Evaporation	wm2015.eva	
Baseflow Data - Monthly	wm2015x.xbm	
Direct Diversion Demand - Monthly	wm2015B_WDA.ddm	
Instream flow Demand - Annual	wm2015.ifa	
Delay Table	wm2015.dly	
Reservoir target	wm2015B.tar	
Reservoir End of month contents	wm2015.eom	
Baseflow Parameter	wm2015.dum	
Historical Streamflow - Monthly	wm2015.rih	
Historical Diversions - Monthly	ym2015.ddh	
Daily Streamflow	wm2015.rid	New
Daily Delay Table	cm2015.dld	New

Control File (wm2015_Daily.ctl)

The control file, which is created and maintained by editing manually, contains information that controls the model simulation. The only difference between the monthly and daily control file is the *iday* switch is used in this analysis. This variable was set to "1" to direct the model to operate on a daily time step.

Reservoir Station File (wm2015B.res)

The "SetReservoirStation" command was used in the **StateDMI** command file *Bres.commands.StateDMI* to set the daily flag variable (*DailyID)* equal to "5" for all reservoirs during the development of the monthly model. This flag tells StateMod, while in simulation mode, to develop daily targets by linearly "connecting" monthly reservoir targets found in the *wm2015B.tar* file. Execution of the **StateDMI** command file *Bres.commands.StateDMI* created the reservoir station file (*wm2015B.res*) used in both the monthly and daily simulation.

Diversion Station File (wm2015_Int.dds)

A global "SetDiversionStation" command was used in the **StateDMI** command file *dds.commands.StateDMI* to set the daily flag variable (*DailyID)* equal to "4" for all diversion stations during the development of the monthly model. This flag tells StateMod, while in simulation mode, to disaggregate the monthly diversion demands found in the *wm2015B_WDA.ddm* file by interpolating the midpoints of the monthly data. Execution of the **StateDMI** command file *dds.commands.StateDMI,* followed by execution of the *Bddm.commands.StateDMI* created the final direct diversion station file (*wm2015_Int.dds*) used in both the monthly and daily simulation.

River Station File (wm2015.ris)

Multiple *"*SetStreamGageStation*"* commands were added to the **StateDMI** command file (*ris.commands.StateDMI*) to set the daily flag variable (*DailyID*) in the river station file defining natural flow nodes to the gages specified in Table 2. The *DailyID* variable tells StateMod to calculate each day's baseflow by disaggregating the monthly baseflow (*wm2015x.xbm*) using a pattern supplied by the corresponding daily gage flow in the daily gage flow file (*wm2015.rid*). Selection of the appropriate "pattern gage" was an important step in the development of the calibrated daily model.

Instream Flow Station File (wm2015.ifs)

A global "SetInstreamFlowStation" command was added to the StateDMI command file *ifs.commands.StateDMI* to set the daily flag variable (*DailyID*) equal to "0" for all instream flow stations during the development of the monthly model. This flag tells StateMod to disaggregate the monthly instream flow demand found in the *wm2015.ifa* file to daily values by setting them to the average daily value. Execution of the StateDMI command file *ifs.commands.StateDMI* created the instream flow station file (*wm2015.ifs*) used in both the monthly and daily analysis.

Daily Delay File (cm2015.dld)

The daily delay table file contains coefficients to lag return flows. Estimation of the lag terms is discussed in detail in the CRDSS Daily Yampa Model Subtask 1 – Equivalent Daily Return Flow Factors memorandum, available on the CDSS website. The daily delay table file created for initial use in the Yampa Basin was used directly to represent daily returns for the White Basin model. The file was created using a text editor.

Table 2. Daily Pattern Gages for White River Sub-basins

Sub-basin/Tributary Area	Daily Pattern Gage
Upper White Basin to the White River near Meeker gage	09304115 White River below North Elk Creek near Buford
Piceance Creek Basin	09306222 Piceance Creek at White River
Lower White Basin downstream of Meeker except Piceance Creek Basin	09306500 White River near Watson, Utah

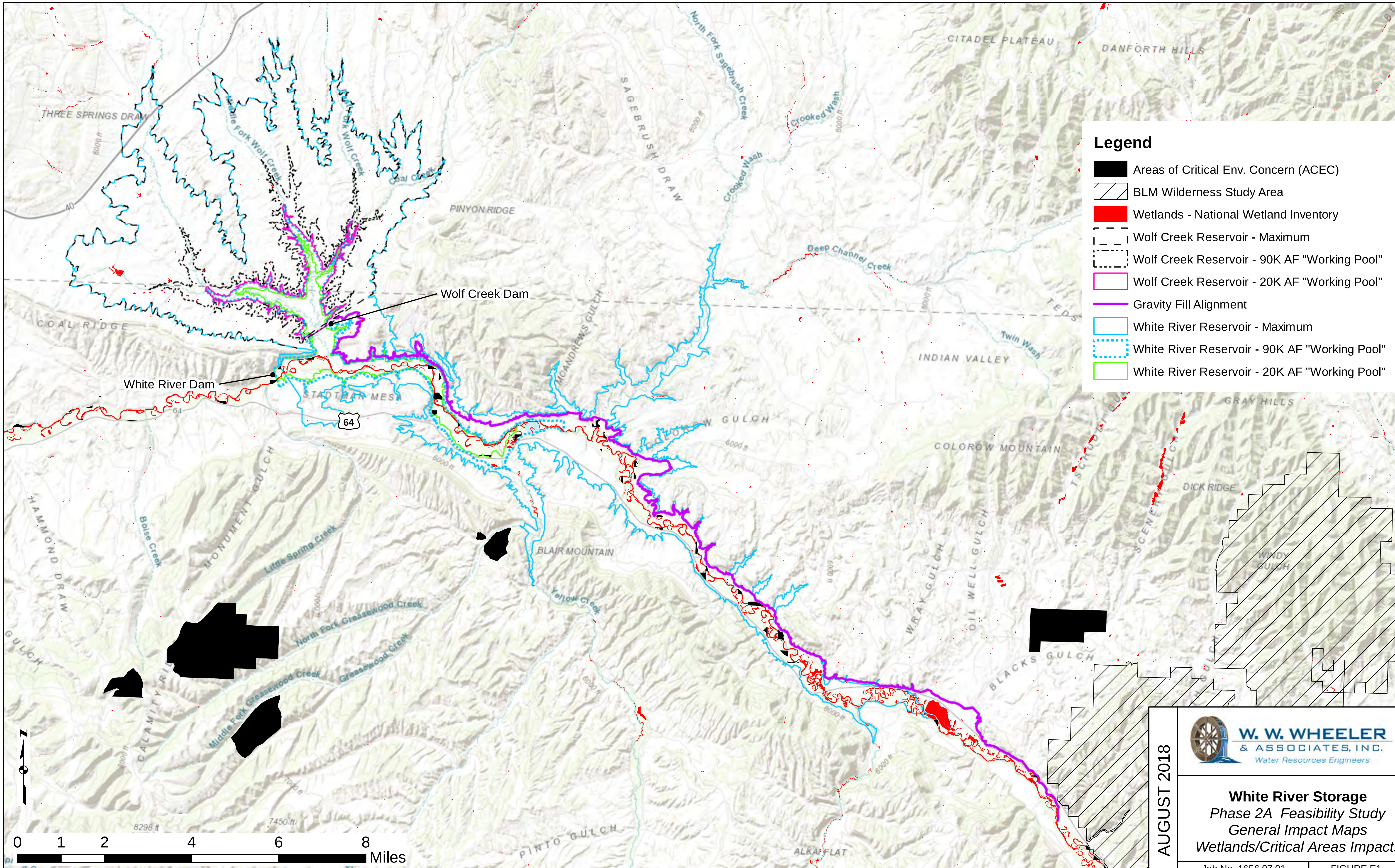
Daily Streamflow File (wm2015.rid)

A new TSTool command file (*rid.commands.TSTool*) was created to generate a file containing the daily streamflow values to be used in disaggregating the monthly baseflow values. The selected gages required some data-filling for the 1975 through 2013 analysis period as shown in Table 3.

Table 3. Daily Pattern Gage Filling

Daily Pattern Gage	Gage Filling Approach
09304115 White River below North Elk Creek near Buford	There are several gages with partial periods of record in the upper White River basin. They have been combined and the remaining minor missing periods have been filled as follows: • Add North Fork White River at Buford (0930300) period 1975 – 2001 and South Fork White River at Buford (09304000) period 1975 - 1999 • Combine with White River bl Elk Creek near Buford (09304115) period 2003 – 2009; 2013 – 2017 • Regress with gage with similar patterns from the Yampa to fill remaining missing years: Fish Creek at Upper Station (09238900)
09306222 Piceance Creek at White River	Gage has complete daily records, no filling required
09306500 White River near Watson, Utah	The gage is missing data from 1980 through 1985. The gage was combined with the White River near Colorado State Line (09306395) gage. There are no intervening diversions between the gage and overlapping data from 1977 to 1980 are nearly identical.

APPENDIX E
GENERAL IMPACT MAPS



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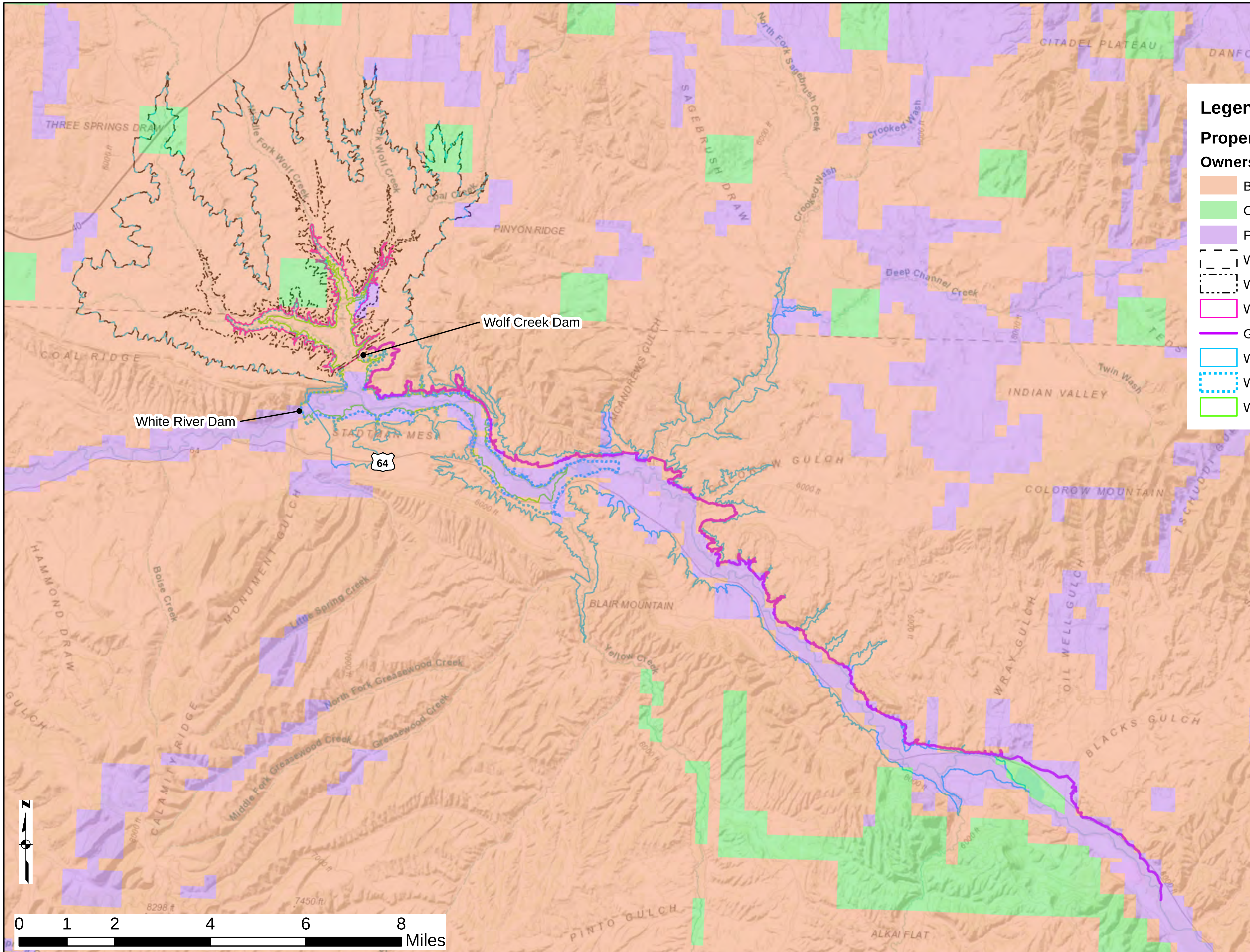

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White River Storage
Phase 2A Feasibility Study
General Impact Maps
Properties

Job No. 1656.07.01 | FIGURE E2

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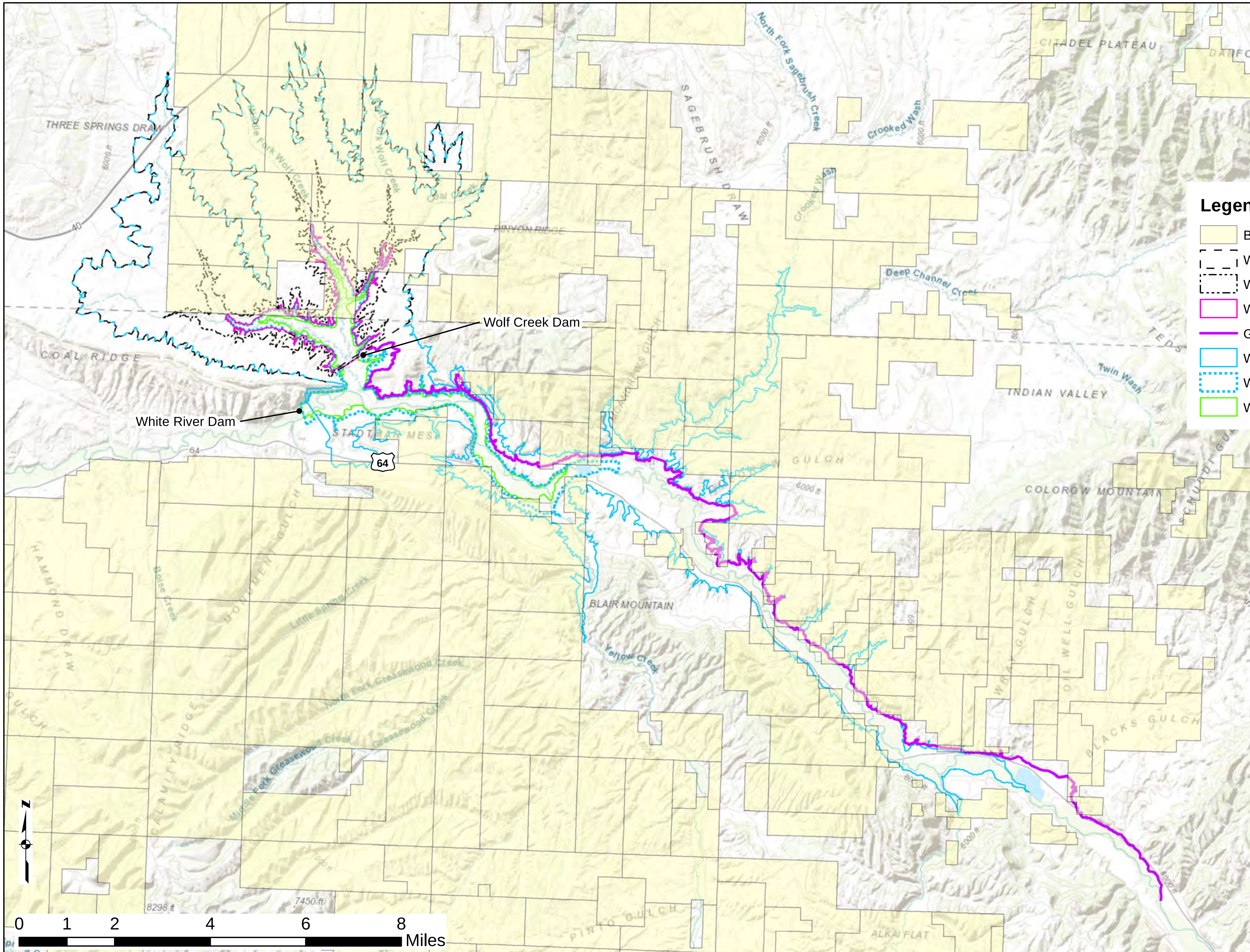

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White River Storage
Phase 2A Feasibility Study
General Impact Maps
Oil and Gas Lease

Job No. 1656.07.01 | FIGURE E3

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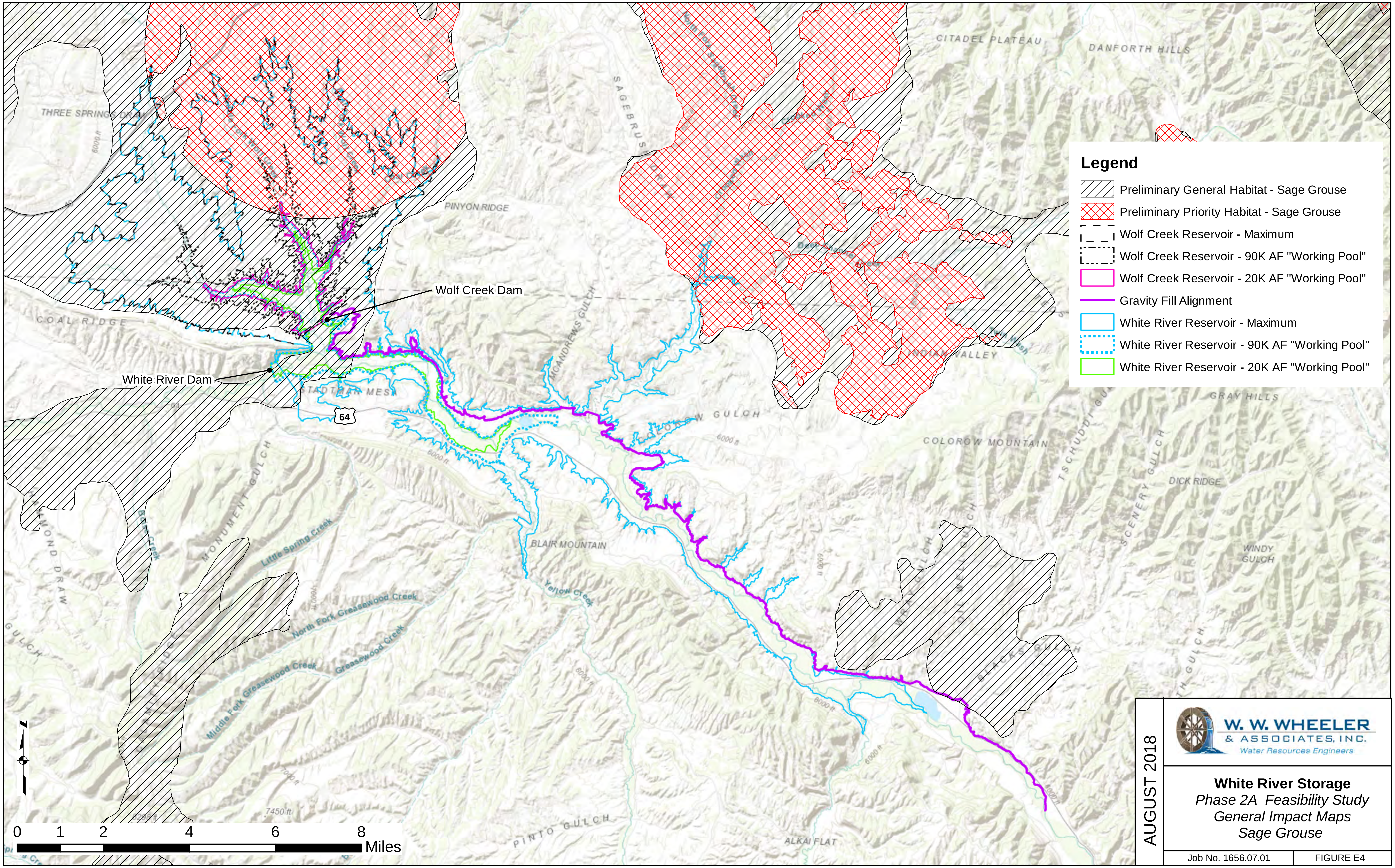

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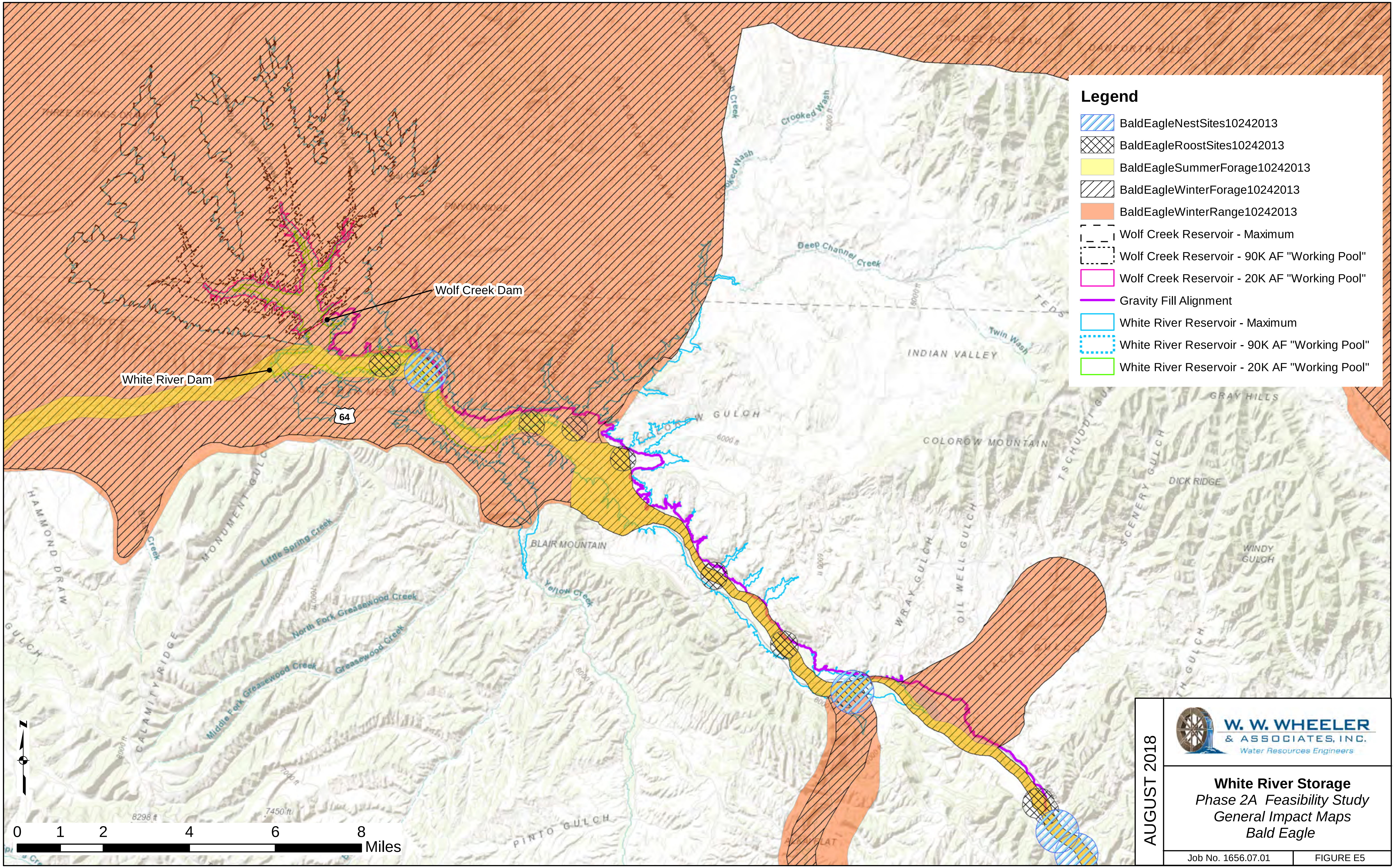

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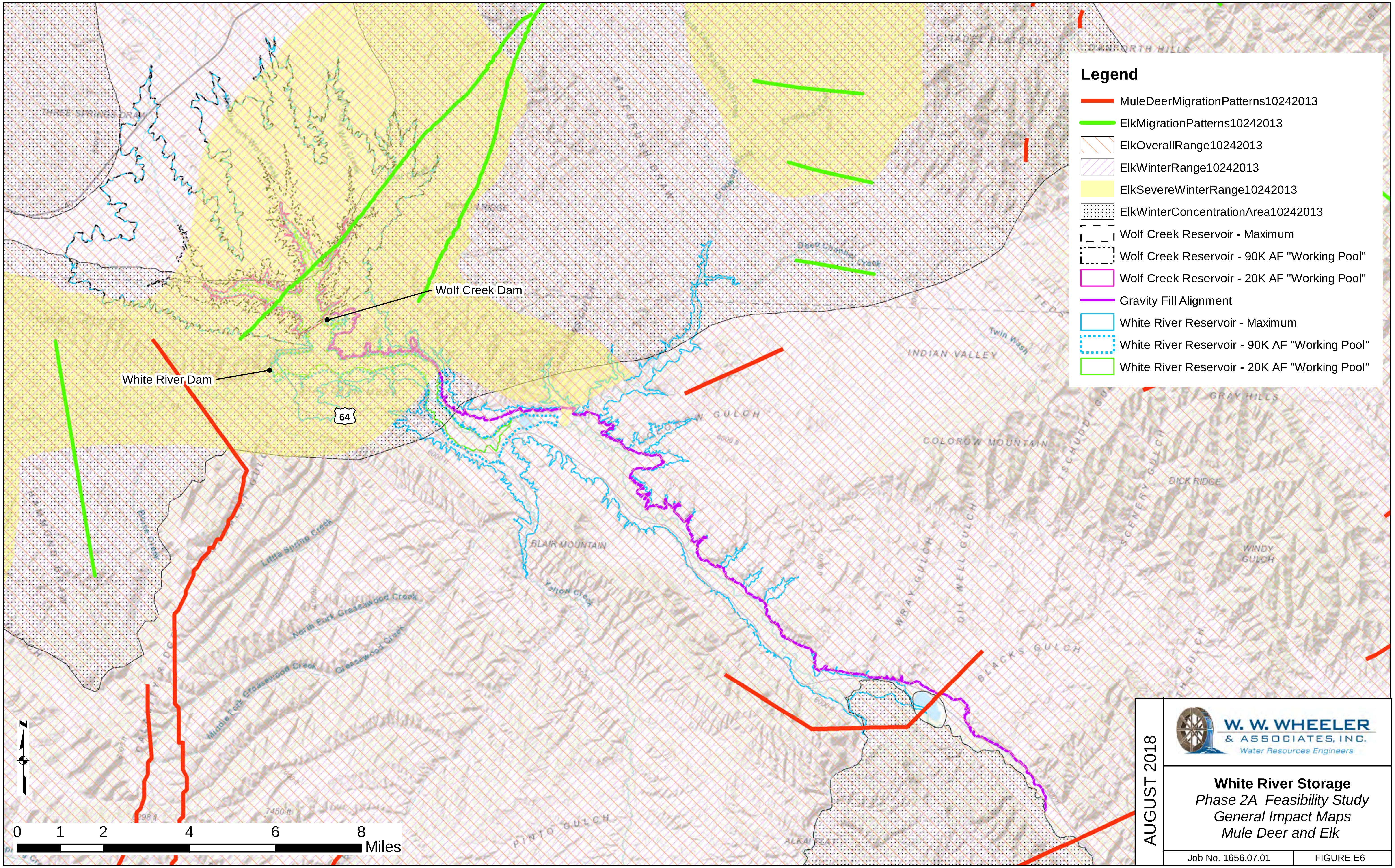

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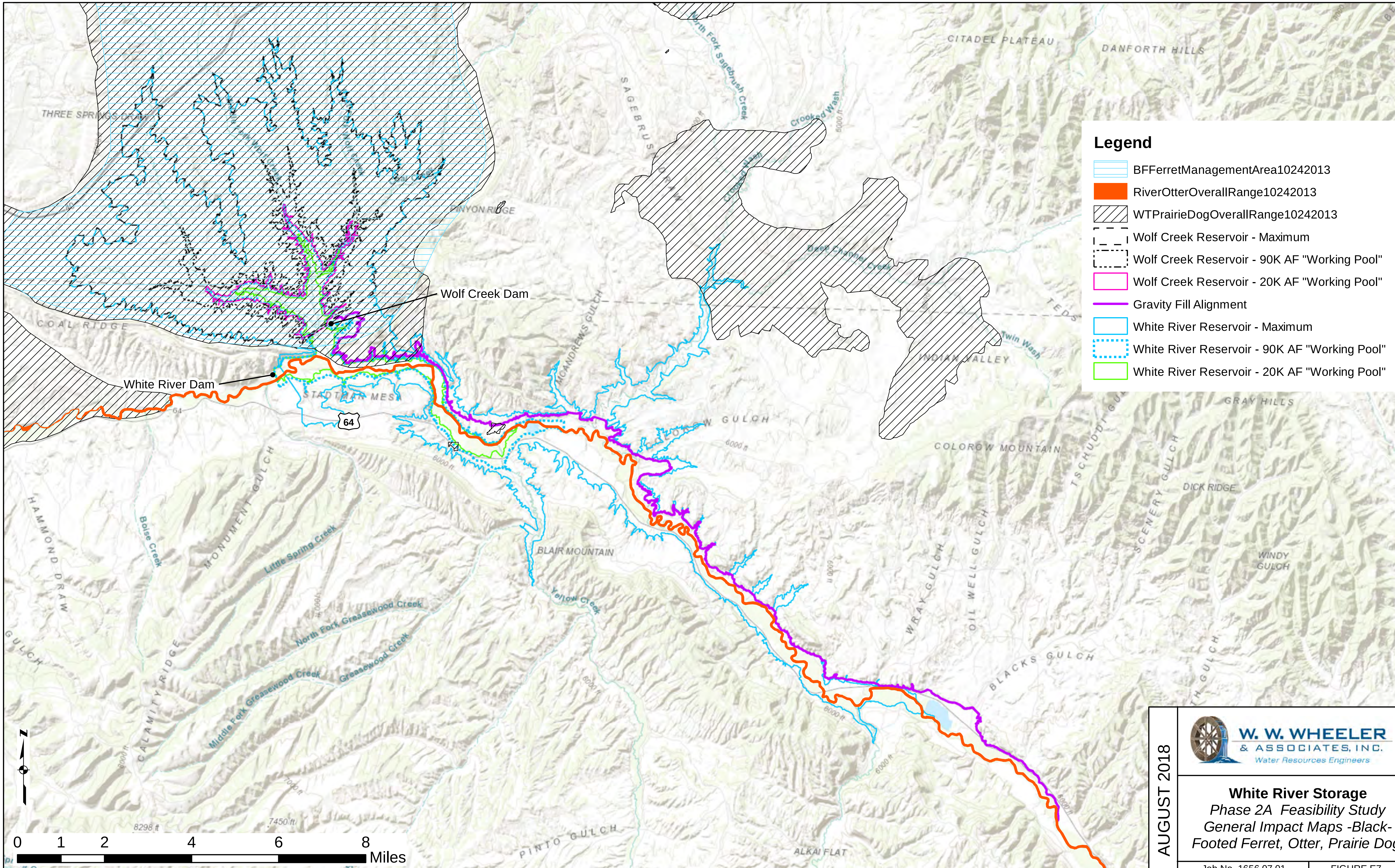
AUGUST 2018

White River Storage
Phase 2A Feasibility Study
General Impact Maps
Mule Deer and Elk

Job No. 1656.07.01 | FIGURE E6



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