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Executive Summary
Little Snake River Supplemental Storage Level II Phase II Study

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Little Snake River Supplemental Storage Level II Phase II Study

October 2017

This document is released under the authority of Victor E. Anderson, P.E. on October 18, 2017.

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1.0 Executive Summary

1.1 INTRODUCTION AND BACKGROUND

In 1979, the legislature enacted WS 41-2-204, which defined the Cheyenne Stage I, II, and III Projects, as well as Little Snake River "in-basin needs". Stage I and II consisted of water collection, storage and transmission facilities to 1) bring water from the headwaters of the Little Snake River drainage into the North Platte River drainage 2) bring water from the headwaters of the Douglas Creek drainage into the Crow Creek drainage and 3) bring water from the North Platte River and Crow Creek drainages into the Cheyenne water system. Stage I was completed in 1966. In 1980, the legislature authorized the Stage II Project and, in the same legislation, instructed the Wyoming Water Development Commission (WWDC) to study the feasibility of constructing storage in the Little Snake River drainage, above the Savery Creek confluence to mitigate depletions resulting from operation of the Stage II project. The legislation called for 50,000 acre-feet of storage to be constructed in the Little Snake Basin as mitigation for the Stage II project.

In 2004, High Savery Dam with a storage capacity of 22,433 acre-feet was constructed to serve as an agricultural and municipal water supply, as well as recreation, environmental enhancement, and mitigation to the Little Snake River Basin for any and all impacts resulting from the Stage I and II transbasin diversion water supply projects. During the preparation of the Environmental Impact Statement for the High Savery Dam project, 26 alternatives were evaluated that included 22 dam and reservoir sites, three groundwater alternatives (alluvial, deep aquifer and aquifer storage and retrieval) and conservation.

In June, 2008, the Wyoming Water Development Commission contracted with the team led by States West Water Resources (now Wenck Associates) to perform the Little Snake River Supplemental Storage Project, Level II Study. The overall purpose of this study was to first review and revise hydrological models of the basin and develop a StateMod hydrologic model to get an accurate measure of the shortage and supply conditions. The second purpose of this study was to identify practical locations within the Savery-Little Snake River Water Conservancy District (District) for a maximum of two reservoirs to augment the irrigation water supply within the District. The recently completed High Savery reservoir has yielded a larger supply of water than had been predicted and, while this reservoir serves a large number of water users, its geographic location and size prevents service to a significant number of other irrigators. Additionally, High Savery does not meet all of the shortages downstream of the facility. The District would like to construct a reservoir that would increase the benefits to these users and others.

While the Little Snake River basin is one of the most widely studied basins, previous studies focused on larger reservoirs such as High Savery. The Level II study focused on smaller reservoirs that were selected based on previous reports as well as conversations with the District.

The major components of the Level II study were: the basin hydrology study; site identification and initial screening; preliminary design and cost estimates for the most feasible site(s); and Haggarty Creek in-stream dissolved copper investigation and fisheries investigation. The West Fork Battle Creek at Haggarty Creek site (West Fork Reservoir) was identified in the Level II study as the preferred site and progressed to the preliminary design stage. The Level II study recommended a reservoir with a capacity of 8,500 acre-feet be constructed. A roller compacted concrete (RCC) dam was recommended with a gated multi-level concrete intake tower, 42-inch concrete-encased outlet pipe and access adit. The spillway would consist of a cast-in-place concrete Ogee crest, a stepped chute integral to the RCC dam steps, and a grouted riprap stilling basin. Preliminary cost estimates were then developed based on the preliminary design.

Upon conclusion of the Level II study, Wenck Associates, Inc. (Wenck) was retained to perform the Little Snake River Supplemental Storage Project, Level II Phase II Study. The results of the Level II Phase II study are briefly summarized here within. Full project results are presented in the report. The Level II Phase II study focused on the West Fork Reservoir site with a capacity of 8,500 acre-feet and 10,000 acre-feet. Three accounts were set in the proposed 8,500 and 10,000 acre-foot capacity reservoir:

1) Irrigation account, capacity: 5,000 and 6,500 acre-feet respectively
2) Minimum bypass account, capacity: 1,500 acre-feet
3) Conservation pool, capacity: 2,000 acre-feet

The major components of the Level II Phase II study include: more detailed water quality analysis; land ownership and right-of-way impacts; hydrology study; environmental impacts; economic analysis; and recommendations.

1.2 WATER QUALITY ANALYSIS

Haggarty Creek is a snowmelt and precipitation generated perennial headwater stream within the Colorado River Basin. It originates near the Continental Divide at an elevation near 10,800 feet above mean sea level (amsl) within the Sierra Madre Range. It flows southwest to the West Fork of Battle Creek (WFBC) before entering Battle Creek and then into the Little Snake River. Legacy mines in the Haggarty Creek headwaters discharge contaminated runoff water causing water quality and ecological impacts downstream. This impacted watershed and ecosystem has been extensively studied over the past 40 years. Today, the stream remains impaired and in need of a mechanism of cleanup.

Along its path, at approximately 9,500 feet amsl, Haggarty Creek passes below the historic Ferris Haggarty copper mine (FHM) and portal. As runoff from legacy mine disturbances and copper laden discharge from the mine portal (Osceola Tunnel) commingle with Haggarty Creek, copper and, by inference, cadmium and silver contaminate the water. As a result, in 1996, the State of Wyoming Department of Environmental Quality, Water Quality Division (WDEQ/WQD) listed the stream as impaired under section 303(d) of the Clean Water Act, and by 2011 established pollution reduction target values (a Total Maximum Daily Load (TMDL)) for three parameters: copper, cadmium, and silver. Haggarty Creek is listed as an impaired waterbody from the Ferris Haggarty Mine to its confluence with the WFBC under chronic aquatic life criteria. Additionally, the WFBC was listed as an impaired water body by WDEQ/WQD in 2000 due to copper contamination from Haggarty Creek (WDEQ/WQD, 2011).

Water quality analyses were conducted to address water-quality conditions of the proposed West Fork Reservoir.

1.2.1 Summary of Reservoir Water Quality Analysis

A reservoir with 8,500 acre-feet capacity has been proposed for West Fork Battle Creek, located in the headwaters of the upper Little Snake River Basin, Wyoming, tributary to the Green and Colorado Rivers. Watershed characterization studies indicate that contributing drainage to the proposed reservoir would yield about 18,800 acre-feet per year, with more than 60 percent of the yield coming from snowmelt runoff. The Southwest Hydro-Logic study investigated the effects of reservoir mixing on water quality and dissolved metal concentrations, and the effects that different reservoir outlet works—upper level versus bottom gate—would have on water quality conditions in the proposed reservoir.

Water quality of the proposed reservoir will be affected by geologic setting and forested cover of the upper watershed. The geology consists mainly of quartz rocks, and quartz does not dissolve easily in water; therefore, water quality of streams in the study area consists of low concentrations of total dissolved solids (TDS). In water samples collected during snowmelt runoff, TDS concentrations were extremely low indicating very low concentrations of dissolved constituents. Since the reservoir will be filled during snowmelt runoff, it is likely that reservoir water quality will have low TDS concentrations. With mainly quartz as bedrock, dissolved silicate, which is generally unreactive in nature, is among the primary constituents. Calcium and magnesium concentrations are low, with hardness concentrations as low as 7 mg/L as calcium carbonate. Dissolved organic carbon concentrations in streams draining the forested watershed range from 1.2 to 5.6 mg/L, and comprise a large percentage of the TDS; therefore, the sequestering actions of organic carbon play an important role in the fate, transport, and aquatic toxicity of dissolved metals.

Water quality of the proposed reservoir also may be affected by discharge from the historical mine that contributes copper to the headwaters of Haggarty Creek. Historical water-quality data indicate that elevated copper concentrations in water from the mine are seasonal with higher flows and loading occurring during the snowmelt period. Water directly entering the upper workings through snowmelt can be reduced by continued efforts to seal mine openings as well as institution of hydrological controls such that surface "run-in" can be diverted around the footprint of the upper mine workings. Mine mapping has been used to identify the spatial distribution of the underground mine workings. Surface geophysics would allow further documentation of where mine tunnel openings have not been reported. Other mitigation efforts could include, but are not limited to surface grouting, construction of diversion ditches and berms, use of expansive foams, continued mitigation of subsidence features, existing mine shafts, in-situ and outside of the tunnel mine water treatment.

For the proposed reservoir, water-quality and reservoir modeling was done using the U.S. Army Corps of Engineers CE-QUAL-W2 program, where daily average data were used as inputs to the model, including tributary discharges, water quality inflow concentrations, and meteorological conditions from a nearby weather station. The reservoir model describes daily changes in typical lake parameters such as water temperature and dissolved oxygen. Results show that for upper level outlet works, the reservoir would become stratified, with low dissolved-oxygen concentrations at the bottom of the reservoir, and warm water temperatures at the lake surface during summer. By releasing from upper level outlet works, water quality within the reservoir would potentially stratify. For bottom gate outlet works, irrigation releases during summer could provide mixing action for the reservoir and stratification of the reservoir would be subdued or would not develop at all. Efforts to reduce and eliminate stratification and ultimately lake turnover are important considerations when considering dissolved metals within the reservoir. In the case of the bottom releases water quality downstream from the dam would be similar to or improved above baseline stream conditions.

The CE-QUAL-W2 reservoir model does not calculate dissolved trace-metal concentrations such as copper; therefore, geochemical modeling was done using the U.S. Geological Survey's PHREEQC model to simulate mixing of different proportions of tributary waters within the reservoir according to month of year. Because higher copper concentrations are correlated with snowmelt runoff events, copper concentrations within the reservoir may be highest during the inflow period.

Reservoir geochemical modeling indicates that for average monthly conditions, dissolved copper concentrations are comprised of many different copper species; some copper species are not toxic to aquatic life. The model predicts that total dissolved copper concentrations might range from 12 to 42 micrograms per liter (μg/L), and dissolved cupric copper (Cu^{+2}) concentrations, the most toxic to aquatic life, might range from 1.1 to 4.3 μg/L in the proposed reservoir.

In order to estimate acute and chronic copper levels as they may affect aquatic life in the reservoir, monthly geochemical modeling results were used as input for the Environmental Protection Agency's Biotic Ligand Model (EPA-BLM). The EPA-BLM accounts for the effects of dissolved organic carbon and other dissolved constituents in order to determine toxicity limits for aquatic life. For total dissolved copper, monthly chronic limits for rainbow trout would range from 6.6 to 11.7 μg/L, with an annual average of 8.6 μg/L, and monthly acute limits for rainbow trout would range from 21.5 to 37.7 μg/L, with an annual average of 27.8 μg/L. Data collection from the Belvidere Ditch, where juvenile cutthroat trout are present found that total dissolved copper levels ranged from 10-40 μg/L with an average of 21μg/L.

With watershed yield being almost twice the reservoir capacity (and almost three times the active pool), the reservoir would be operated as a flow-through system, especially during snowmelt runoff. With the bottom gate outlet structure, velocities through the reservoir and along the reservoir bottom would transport metals and suspended sediments through the system; therefore, metals would not accumulate in reservoir sediments, and the reservoir would not act as a sink for metals. The lower outlet works will enhance the quality of the reservoir by eliminating stratification of the waters within the reservoir. Downstream from the dam, sedimentary rocks occur in the geologic strata, which provides buffering capacity and hardness, further reducing toxicity of dissolved metals. For management of metals in the proposed reservoir, recommendations include: (1) Design and construction of bottom gate outlet works; (2) Removal of all trees and organic matter from the reservoir basin prior to filling; (3) Shaping and contouring of the reservoir basin to facilitate flow of density currents though the system. If required or desired, improvements in the water quality of the stream system and reservoir can be achieved by the following: (1) Decreasing copper concentrations in mine discharge using hydrological controls upgradient from the mine; (2) Continuous flow-through operations to flush metals through the system; (3) Attenuation of copper through natural water treatment as discussed in subsequent sections (constructed wetlands, stream restoration, and habitat enhancement structures using limestone and zeolite as construction and treatment media).

1.2.2 Water Quality Data

The initial studies of Haggarty Creek water quality began in the 1960's. Haggarty Creek has been listed as an impaired water body since 1996, a direct result of the abandoned Ferris Haggarty Mine in its headwaters. The location and siting of an irrigation reservoir not only addresses the watershed yield but considers water quality. The WWDC through their consultants have collected data on influent water quality and the processes which influence copper loading and copper release. Fate and transport of dissolved copper will likely be addressed further in the environmental review process.

Water quality sampling for over 20 years by numerous individuals and agencies have established that the copper concentrations are attenuated downstream from the Ferris Haggarty Mine. The compiled water quality data at the Highway 70 crossing (over 60+

samples) suggest a range in water quality over time with the majority of pH readings above 7.0 and total dissolved copper concentration averaging 32.1 µg/L. Data at the Battle Creek Campground, downstream of the proposed reservoir site found total dissolved copper concentrations of 10 µg/L with pH of 7.5.

Because of the importance of pH in the geochemistry of copper, Lidstone and Associates (LA) installed a continuous pH probe (Troll 9500) near the Highway 70 crossing of Haggarty Creek. Data from this probe were collected from March 11 through June 30, 2015 and are summarized in the report contained in Appendix A of the report. The probe was used to collect pH and temperature measurements at intervals ranging from 1 to 4 hours. The data indicate that the pH measurements through the first five or six days appear to be consistent with a natural pattern of slight variability and diurnal fluctuations with pH's above 7.0 and likely falling within the pH range from 7.25 to 7.5. However, a pH probe operating in such low conductivity water requires calibration on a weekly or more frequent basis. Water temperature fluctuations during this same period ranged from 0 degrees Celsius in mid-March to a high of 12 degrees Celsius near the end of June. Diurnal temperature changes likely associated with snowmelt typically ranged from 3 to 5 degrees.

The data investigation concludes that continued efforts to control snowmelt recharge (inflow) to the Ferris Haggarty Mine underground workings will result in reduction in copper load to Haggarty Creek. The water quality investigation also included the collection of sediment data throughout the Haggarty Creek system. Copper concentrations in the sediment decrease downstream from the mine suggesting complexation, adsorption and precipitation of copper to finer grained sediment and organic matter are natural processes within the watershed. These processes can be reproduced through a natural water treatment program (see Section 1.2.3) which reconnects the stream to its bed, bank and floodplain sediments and vegetation. Total copper in sediment at one location (Haggarty Creek immediately upstream of the Belvidere Ditch) ranged from 551 to 723 mg/kg. Extractable copper at this same location ranged from 83 to 198 mg/kg respectively. This suggests that once the copper is taken out of dissolved load of the stream, the majority will remain "tied up" in the sediment and will not be toxic to aquatic life. The extractable copper reflects that portion of the copper which might return to the water column during a subsequent runoff or site inundation event. The difference between total copper and extractable copper provides a qualitative look at how much copper will remain permanently "tied up" in sediment or organic matter. This is an important concept both in natural water treatment and when considering the behavior of sediment in a reservoir. In-channel and off channel treatment using natural wetland methods will further aid in the effort to restore the Haggarty Creek fishery and improve water quality for the downstream reservoir, if necessary.

During the initial investigation phase for this project, acidic runoff from snowmelt, transport of dissolved metals and their accumulation in a lacustrine environment was identified as a concern. To address this concern, LA sampled two alpine lakes within the Sierra Madre Mountain Range and within 10 miles of the proposed West Fork Reservoir. Water samples were collected near the surface and at depth and a pH and dissolved oxygen probe was lowered from the boat and were continuously monitored from the surface to the bottom of each lake. Neither pH nor metal concentrations were problematical at either reservoir. In fact copper, cadmium and silver concentrations were below analytical detection limits. The pH values were generally near or above neutral (7.0 s.u).

1.2.3 Natural Water Treatment

As stated above, geochemical modeling found that the West Fork of Battle Creek Reservoir with the construction of lower outlet works and an operational program that changes the water over frequently and passes a significant portion of the spring runoff downstream will meet water quality goals of the project. Any efforts to reduce dissolved copper levels in the influent waters will improve not only the reservoir and downstream from the reservoir, but also existing Haggarty Creek water quality. Attenuation and complexation of copper in Haggarty Creek using constructed wetlands, stream restoration projects, and habitat enhancement structures using native and imported natural materials as construction and treatment media was analyzed and conceptual design and costs estimates were prepared.

Lidstone and Associates, Inc. (LA), as a subcontractor to Wenck Associates, prepared two reports: Conceptual Plan: Natural Wetland Treatment of Haggarty Creek Upstream of Wyoming Highway 70 and Water Quality Data Collection and Interpretation: Haggarty Creek and West Fork of Battle Creek Reservoir. These reports incorporated over 30 years of water quality and streamflow data, fluvial geomorphic data, and benthic macroinvertebrate study, and sediment data to identify feasible alternatives for improving Haggarty Creek water quality, benthic macroinvertebrate populations, and fish habitat. Of the alternatives explored by LA to reduce dissolved copper concentrations in Haggarty Creek, the option of Natural Water Treatment (NWT), which allows natural in-channel and off-channel processes to form the basis of treatment, was determined to be economically feasible. Implementation of the NWT approach allows a perpetually sustainable set of processes with minimal impact to the landscape and other stakeholders along Haggarty Creek.

The natural water treatment approach or NWT includes the placement of in-channel stream structures to enhance stream oxidation, adsorption and chelation processes and increased interaction of the copper-contaminated flow with the channel floodplain and overbank areas (mid-level and upper terraces). Flow could be taken out of Haggarty Creek, diverted onto the floodplain and upland areas and come in to contact with native soils and vegetation before it is returned back to the mainstem. Plantings and soil enhancements will be added to these floodplain and upland areas to increase plant uptake and soil chelation and absorption of the dissolved phase of copper. The exposure to this interaction on a more frequent and opportunistic basis will result in a net decrease in dissolved metals within the stream channel. During high flow, this system might not achieve full capacity, but could be naturally self-sustaining during low flow.

Past efforts by the Wyoming Abandoned Mine Land Program (AML) and the Department of Environmental Quality Water Quality Division (DEQ) have proposed active water treatment at the Ferris Haggarty Mine. Based on concerns with maintenance, operational feasibility, disposal costs of EPA-regulated hazardous waste (copper slimes) and high annual costs, coupled with the fact that landowner consent could not be achieved, the construction of an active water treatment program was determined to not be feasible. The above described natural water treatment approach is less intrusive, significantly less costly and does not require perpetual maintenance. Landowner consent and local support is more likely achievable. A secondary benefit will be the construction of in-channel structures. Such structures will serve to improve channel aesthetics. Fish and macro invertebrate habitat are generally seen as favorable by landowners. Implementation of natural water treatment could provide project benefits including environmental mitigation for the construction of the reservoir.

Project conceptual costs are estimated at $1,062,000. Additional conceptual level costs associated with the NWT approach that are not included are pilot studies, monitoring, additional water quality and quantity measurements, and expenses associated with easements and permitting.

1.3 PROPERTY AND RIGHT-OF-WAY

The proposed West Fork Reservoir would impact both private property owned by American Milling Company and U.S. Forest Service (USFS) lands.

1.3.1 Private Property Impacts

The representative of American Milling Company has indicated interest in selling the land for the reservoir. They do not want to sell the entire holding but would consider selling additional land to eliminate isolated parcels and facilitate potential land exchanges with the USFS. The company also has other holdings in the area and would consider selling portions of those parcels.

1.3.2 United States Forest Service Land Impacts

The USFS lands directly impacted by the dam and reservoir would need to be acquired. The reservoir area would need to be acquired up to the maximum reservoir water level. The dam site would require additional land for construction purposes including access roads. The total estimated acreage of USFS land needed would be 100 acres.

The existing access road terminates in the proposed construction area. This road is quite primitive and would need to be upgraded for construction traffic. The improved road could be used for permanent access to the dam and reservoir.

1.4 HYDROLOGY

A historic consumptive use analysis and a surface water allocation model representation of the Little Snake River watershed was developed by subconsultant Leonard Rice Engineers in the Little Snake River Supplemental Storage Level II Study[1] completed in 2012. Wenck Associates (Wenck) refined and updated this model through 2014. The modeling platform used for the consumptive use analysis was StateCU and the water allocation model used was StateMod. The historic consumptive use analysis defines the crop demand and irrigation water requirement. The surface water allocation model identifies available flow, estimates shortages, and simulates proposed 'what if' scenarios and proposed water development projects in the watershed.

The following sections briefly summarize the modifications and results of the modeling effort. Additional information on approach, methodology, assumptions, procedure, and results are in **Appendix B** of the report.

1.4.1 Overview of Model Refinements and Updates

In 2016, Wenck reviewed data inputs and modeling procedures and methods used in the Leonard Rice Engineers 2012 StateMod model (LRE 2012). It was believed that the hydrology of West Fork Battle Creek (also called Haggarty Creek) was not well represented in the LRE 2012 model due to a lack of streamflow data. Subsequent to the development of

[1] Report to Wyoming Water Development Commission for the Little Snake River Supplemental Storage Level II Study, States West Water Resources Corporation, December 2012.

the LRE 2012 model, additional temporary gauge streamflow data has been collected. This information provided the basis and the reason to update the model.

The main updates and refinements to the models included the following:

- Incorporation and direct use of temporary gauge streamflow data
- Consumptive use estimates calculated using ASCE Standardized Penman-Monteith method
- Incorporation of all available historic diversion records
- Extension of the modeling period: 1971 through 2014 (previously through 2006)

Water right, structure information and irrigated acreage data were not changed.

1.4.2 Temporary Stream Gauging

Temporary streamflow gauges were installed at key data-short locations to assist in hydrology model development and future refinement. Temporary streamflow gauges were deployed and have been maintained since 2009 by the Little Snake River Conservation District (LSRCD) in the following locations.

- Haggarty Creek at Highway 70
- Lost Creek at Highway 70
- Belvidere Ditch Headgate

1.4.3 Hydrologic Modeling Results

Three scenarios of the Little Snake River StateMod model were developed to identify shortages, water availability and what-if scenarios in the watershed. The following scenarios were simulated:

1. Baseline Scenario: represents current conditions (currently irrigated acreage) and operations in the watershed and determines water shortages and availability based on current conditions.

2. Permitted Baseline Scenario: represents irrigation of all Wyoming permitted acreage in the watershed and determines water shortages and availability.

3. Proposed West Fork Reservoir: represents construction of the proposed West Fork Reservoir for agricultural use.

The scenarios were simulated over the 1971 to 2014 period. Unless otherwise noted, irrigation demands were set to the maximum of irrigation water requirement and historic diversion based on Hydrographer records. Irrigation demands set in the model are the requested diversion amounts and are subject to regulation in accordance with water law. Summarized results can be found in the following sections.

1.4.3.1 Baseline Scenario

Shortage

The basin operates as a water-short system, therefore the model simulation develops information on shortages seen at the diversion structures due to a lack of physically or legally available flow in the creeks. For the Baseline Scenario, which is based on current conditions (i.e. currently irrigated acreage), annual shortage for the ditches in the service area of West Fork Reservoir are as shown in **Figure 1.4-1**. Average annual shortage in the

West Fork Reservoir service area is 3,600 acre-feet. Shortages are much higher in some years as the figures indicate. The West Fork Reservoir service area includes the following reaches:

- Battle Creek
- Little Snake River from Battle Creek confluence to below Baggs, WY
- Savery Creek below High Savery Reservoir (by coordination of High Savery Reservoir and West Fork Reservoir)

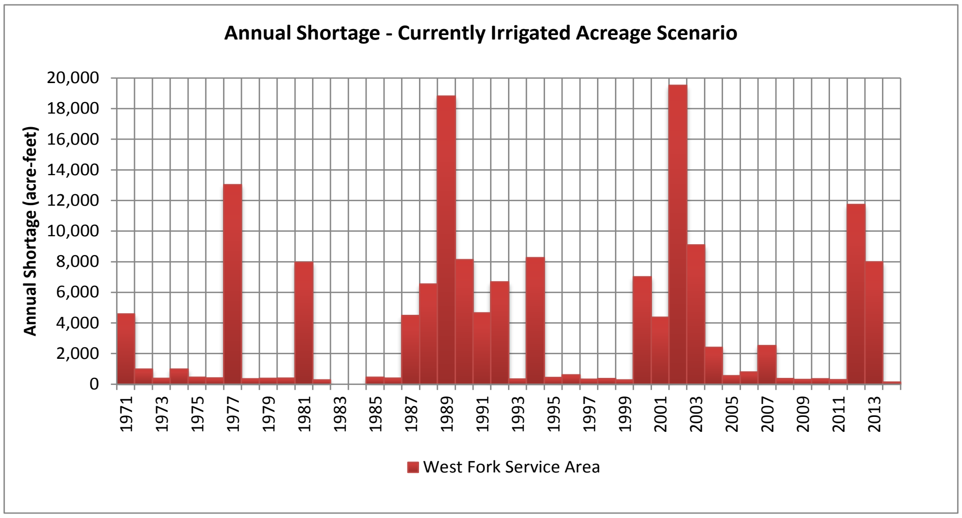

Figure 1.4-1: Baseline Scenario – West Fork Reservoir Service Area - Average Annual Shortage

Available Flow

Available flow at the proposed West Fork Reservoir was evaluated. Available flow is determined as the lesser of physically present flow and legally available flow. The potential minimum recommended bypass flows at West Fork Reservoir that were developed in the Level II study were set in the model as shown in **Table 1.4-1**. Current condition average annual available flow at West Fork Reservoir is 10,900 acre-feet.

Table 1.4-1: Modeled Monthly Minimum Recommended Flows

Modeled Monthly Minimum Recommended Flows (cfs)												
Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Haggarty Creek @ West Fork Reservoir Site	5.6	5.6	5.6	8	30	30	12	12	12	5.6	5.6	5.6

1.4.3.2 Permitted Baseline Scenario

Shortage

In contrast to the preceding baseline scenario, the Permitted Baseline Scenario determines shortages based on permitted acreage rather than currently irrigated land. This represents a theoretical maximum demand in the event that, with additional water available, irrigators will bring permitted but currently not irrigated land into production. The permitted acreage scenario was developed in the previous model build. The Wyoming permitted acreage was developed from water right appropriations (i.e. one cfs per 70 acres). The currently irrigated acreage was used for the Colorado structures in this scenario.

Annual shortage for the ditches in the West Fork Reservoir service area are as shown in **Figure 1.4-2**. For the Permitted Baseline Scenario, average annual shortage in the West Fork Reservoir service area is 10,900 acre-feet.

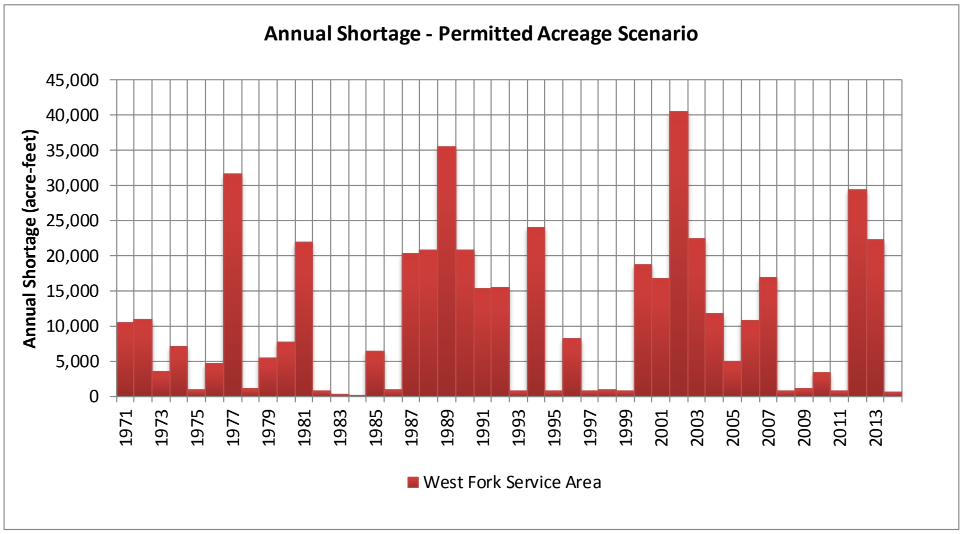

Figure 1.4-2: Permitted Baseline Scenario – West Fork Reservoir Service Area – Average Annual Shortage

Available Flow

Permitted acreage scenario average annual available flow at West Fork Reservoir is 10,900 acre-feet.

1.4.3.3 West Fork Reservoir

This scenario represents construction of the proposed West Fork Reservoir with the primary use of supplemental irrigation water. The potential minimum recommended bypass flows were set in the model. Minimal water is available during the winter months (October through March) with the minimum bypass conditions. In addition to the potential minimum bypass, the reservoir was set to not store available flow from October through March. This is a conservative approach done in part due to uncertainty of winter Belvidere Ditch stock water diversions.

Belvidere Ditch demands and water rights were modeled in accordance with Wyoming water law. Belvidere Ditch was not regulated by the proposed West Fork Reservoir under any of the scenarios presented below. The timing of reservoir filling occurs in April, May and June in these scenarios, and Belvidere Ditch historic demand as indicated by temporary gauge data remains low until June. As a result, the reservoir either filled prior to increasing Belvidere Ditch demand or went out of priority and no regulation of Belvidere Ditch occurred. Actual reservoir operation and future Belvidere Ditch demand may vary and regulation of Belvidere Ditch may occur in accordance with Wyoming water law under some conditions.

High Savery Reservoir shareholders on the Little Snake River mainstem ditches may be able to trade or sell their shares to Savery Creek ditches and acquire West Fork Reservoir shares, which could allow coordination between the two reservoirs. Therefore, coordination with High Savery Reservoir was anticipated and modeled accordingly.

Shortage Reduction

Irrigation shortages for the ditches in the West Fork Reservoir service area were estimated for both the baseline condition and 'with project' condition. In this analysis, the watershed is simulated on a monthly time step and available water is stored in the proposed reservoir and set to release to irrigation demands of the ditches in the reservoir service area. Two reservoir capacities were analyzed (8,500 and 10,000 acre-feet) and the corresponding shortage reductions are provided in **Table 1.4-2** and **Table 1.4-3**.

Table 1.4-2: West Fork Reservoir Service Area Shortage Reduction Summary – 8,500 acre-feet

Currently Irrigated Acreage Scenario		
	All Modeled Years	Dry Period
Baseline - Average Annual Shortage (acre-feet)	3,600	5,800
Baseline - Average Annual Shortage (%)	2.7%	4.3%
w/ West Fork Reservoir – Average Annual Shortage (acre-feet)	1,650	2,960
w/ West Fork Reservoir – Average Annual Shortage (%)	1.2%	2.2%
Reduction in Average Annual Shortage (acre-feet)	1,960	2,830
Reduction in Average Annual Shortage (%)	54%	49%

Permitted Acreage Scenario		
	All Modeled Years	Dry Period
Baseline - Average Annual Shortage (acre-feet)	10,900	17,900
Baseline - Average Annual Shortage (%)	6.6%	10.5%
w/ West Fork Reservoir – Average Annual Shortage (acre-feet)	7,500	13,100
w/ West Fork Reservoir – Average Annual Shortage (%)	4.5%	7.7%
Reduction in Average Annual Shortage (acre-feet)	3,400	4,800
Reduction in Average Annual Shortage (%)	31%	27%

(Dry Period = 2000-2007)

The number of years with annual shortage >2 percent are as follows:

- Baseline: 17 years (39 percent of years)
- w/ West Fork Reservoir: 9 years (20 percent of years)
- Permitted Baseline: 29 years (66 percent of years)
- Permitted w/ West Fork Reservoir: 23 years (52 percent of years)

Table 1.4-3: West Fork Reservoir Service Area Shortage Reduction Summary – 10,000 acre-feet

Currently Irrigated Acreage Scenario		
	All Modeled Years	Dry Period
Baseline - Average Annual Shortage (acre-feet)	3,600	5,800
Baseline - Average Annual Shortage (%)	2.7%	4.3%
w/ West Fork Reservoir – Average Annual Shortage (acre-feet)	1,450	2,750
w/ West Fork Reservoir – Average Annual Shortage (%)	1.1%	2.0%
Reduction in Average Annual Shortage (acre-feet)	2,160	3,040
Reduction in Average Annual Shortage (%)	60%	52%

Permitted Acreage Scenario		
	All Modeled Years	Dry Period
Baseline - Average Annual Shortage (acre-feet)	10,900	17,900
Baseline - Average Annual Shortage (%)	6.6%	10.5%
w/ West Fork Reservoir – Average Annual Shortage (acre-feet)	6,900	12,300
w/ West Fork Reservoir – Average Annual Shortage (%)	4.1%	7.2%
Reduction in Average Annual Shortage (acre-feet)	4,000	5,600
Reduction in Average Annual Shortage (%)	37%	31%

(Dry Period = 2000-2007)

The number of years with annual shortage >2 percent are as follows:

- Baseline: 17 years (39 percent of years)
- w/ West Fork Reservoir: 6 years (14 percent of years)
- Permitted Baseline: 29 years (66 percent of years)
- Permitted w/ West Fork Reservoir: 22 years (50 percent of years)

8 out of 10 Year Firm Yield

The 8,500 acre-foot West Fork Reservoir could provide an 8 out of 10 year firm yield of 4,300 acre-feet from the 5,000 acre-feet irrigation account. The 10,000 acre-foot West Fork Reservoir could provide an 8 out of 10 year firm yield of 5,120 acre-feet from the 6,500 acre-feet irrigation account. The 8 out of 10 year firm yield of the reservoir is the same under both the currently irrigated acreage and permitted acreage scenarios.

Average Yield

The average yield of the 5,000 and 6,500 acre-feet West Fork reservoir irrigation account if it were filled and released every year is 4,300 and 5,400 acre-feet respectively. The average yield of the reservoir is the same under both the currently irrigated acreage and permitted acreage scenarios.

Minimum Recommended Bypass Flows

The minimum bypass account in West Fork reservoir was set to release water to maintain the minimum recommended flows when reservoir bypasses and irrigation releases were not sufficient to meet the minimum recommended flows. Baseline annual average minimum recommended flow shortage is 530 acre-feet. Releases from the West Fork reservoir minimum bypass account reduce minimum recommended flow shortages to zero in all years.

The water released to maintain the minimum recommended flow in West Fork Battle Creek (Haggarty Creek) becomes available water beyond the confluence with Battle Creek in this model build. It could remain in the creek for additional stream use benefits for a distance below the confluence with Battle Creek or could be used for another purpose. Most of the water released solely to maintain the minimum recommended flow occurs during the non-irrigation season months.

1.5 ENVIRONMENTAL AND PERMITTING EVALUATION

Western EcoSystems Technology, Inc. (WEST) conducted an aquatic resources inventory of the proposed West Fork Dam site in August and September 2014, and included area up to the high water elevation of the proposed 10,000 acre-feet reservoir. The report prepared by WEST is presented in **Appendix C** of the report. The findings of the WEST report are summarized below. The West Fork Reservoir site was selected during the process of completing the Little Snake River Supplemental Storage Level II Study (December 2012)[1] because of the minimal environmental impacts and hydrologic and engineering considerations at that location.

1.5.1 Potentially Affected Aquatic Resources

Streams

Approximately two (2) miles of the West Fork Battle Creek and Haggerty Creek will be inundated by the proposed reservoir. An unnamed tributary to West Fork Battle Creek with a small stock pond occurs at the western end of the project site. In the opinion of WEST, the stock pond meets the definition of a palustrine emergent wetland. However, this feature and the other wetlands have not been verified by the U.S. Army Corps of Engineers Cheyenne regulatory staff and the actual acreage of wetlands may be greater or less than reported by WEST.

The Little Snake River Supplemental Storage Level II Study (December 2012)[1] completed an analysis of fishery resources in Haggarty Creek, West Battle Creek, and Battle Creek in areas with potential impacts from the proposed reservoir. The Habitat Retention Method was used to assist with determining base flows from which mitigation flows could be established, Physical Habitat Simulation System (PHABSIM) was used to determine fish flows during runoff, and natural flows were recommended during winter months from October through March. The resulting recommended flow rates are listed in **Table 1.4-1**. The recommended flows are intended to mitigate impacts for the inundated stream segments and will enhance stream fisheries below the proposed reservoir.

Wetlands

Twenty wetlands were delineated in the project area. There are sufficient areas to mitigate wetland impacts. Wetland mitigation opportunities are numerous in the project area. Depending on the final configuration and size of the reservoir, impacted wetland acreage may be less than 2.21 acres.

1.5.2 Environmental And Recreation Benefits

The West Fork Battle Creek Dam project will provide the following secondary environmental and recreation benefits:

- Flat water recreation
- Fishery Flows
- Fish Passage
- Water Quality

1.5.3 Permitting Evaluation

A description of the required permits and process is contained in the report. The required permitting agencies include the following:

- U.S. Forest Service
- U.S. Army Corps of Engineers
- Wyoming Department of Environmental Quality, Water Quality Division
- Wyoming State Engineer's Office

1.6 ECONOMIC ANALYSIS

The proposed West Fork Reservoir site, at a size of 8,500 and 10,000 acre-feet, was used to analyze project costs, project benefits, project benefit-cost ratio, and project financing including the estimated agricultural ability to pay.

1.6.1 Cost Estimates

Three cost estimate components were developed for this project: the initial capital cost, operation and maintenance, and mechanical component end-of-life replacement. The estimated capital cost of the project totals $73 million for an 8,500 acre-feet reservoir and $80 million for a 10,000 acre-feet reservoir. The annual operation and maintaining cost to hire a dam tender and contribute to a routine maintenance sinking fund totals $45,500. To fund like kind replacement of mechanical components at the end of their design life, an annual investment of $34,400 is required.

1.6.2 Project Benefits

A summary and comparison of the total benefits and total costs of each enlargement alternative is summarized in **Table 1.6-1**. Total project costs include capital costs only and do not include annual operation and maintenance costs. Annual operation, maintenance and replacement costs were estimated to be $79,900. Irrigation benefits include the direct annual net revenue to irrigators in the watershed over a 50-year period plus the indirect benefit to the local economy. Recreation benefits include flat water reservoir recreation, camping and hiking recreation, and stream fishery recreation and habitat flow benefits. The construction benefit includes only the Wyoming portion of total construction benefits. Total benefits include direct and indirect irrigation benefits, recreational, and Wyoming construction benefits.

Table 1.6-1: Project Benefits and Costs Summary

Site	Irrigation Benefits $Mil	Recreation Benefits $Mil	Habitat Flow Benefits $Mil	Wyoming Construction Benefits $Mil	Total Benefits $Mil	Project Cost $Mil	B/C Ratio
8,500 AF West Fork Reservoir	$42.8M	$4.0M	$35M	$5.4M	$87.2M	$73.0M	1.19
10,000 AF West Fork Reservoir	$51.0M	$4.3M	$35M	$6.0M	$96.3M	$80.0M	1.20

Note: (1) All costs and benefits were discounted back to 2016 using a discount rate of 4 percent

1.6.3 Project Financing & Agricultural Ability to Pay

WWDC funding criteria permits the WWDC to recommend a project funding package based on the sponsor's ability to pay. Funding packages typically consist of a 67% grant and 33% loan at 4% interest and a payment period of up to 50 years not to exceed the life of the project. In the case of severe financial hardship, the maximum grant can be increased to 75%. However, for projects that meet the Dam and Reservoir Program Criteria, the WWDC may recommend a loan/grant mix based on the sponsor's ability to pay a portion of the project capital costs and all of the operation, maintenance, and replacement costs. Grant funding under the Dam and Reservoir Program Criteria cannot exceed the public benefit of the project. Public benefits of West Fork Reservoir include indirect irrigation benefits ($26.5M), recreational benefits ($4M), habitat flow benefits to publicly accessible reaches ($26.8M), the indirect benefit of private enterprise fishing ($5M) and Wyoming construction benefits ($5.4M) which total $67.7 million and $73.7 million for the 8,500 and 10,000 acre-foot reservoir respectively. Capital costs total $73 million and $80 million for the 8,500 and 10,000 acre-foot West Fork Reservoir respectively, therefore the public benefit of the project exceeds the 92 percent grant funding amount.

Assuming that the 5,000 acre-feet of capacity in the irrigation account for a reservoir size of 8,500 acre-feet could be sold at $10 per acre-foot means that local revenues to repay project costs would average $50,000 annually. The same can be said for the proposed 10,000 acre-feet reservoir with an irrigation account of 6,500 acre-feet meaning local revenues to repay project costs would average $65,000 annually. At $10 per acre-foot, local revenues to repay project costs would likely not be enough to cover annual operation, maintenance and replacement costs. Under current WWDC guidelines (67% grant and 33% loan), the sponsor's share of annual project costs, including operation, maintenance and replacement costs, for an 8,500 acre-feet and 10,000 acre-feet reservoir would be approximately $1,202,500 and $1,310,100 respectfully. Realistically, project construction would require the State to assume a larger portion of project costs than specified by current WWDC guidelines. The total annual costs and the annual cost per assessed acres at various grant/loan mixes including operation, maintenance and replacement costs are summarized in **Table 1.6-2** below. The total annual cost per acre-foot of capacity in the irrigation account is shown in the table below since project costs may be spread out over the active irrigation pool. Alternatively, considering the management opportunity with High Savery Reservoir and benefits to the basin, to meet WWDC criteria of grant funding not exceeding public benefit and for the project to be affordable, total annual costs may need to be spread out over the West Fork Reservoir service area of 19,046 acres. In this scenario, the 5,000 acre-foot and 6,500 acre-foot irrigation pools could be allocated at 0.26 acre-feet per acre and 0.34 acre-feet per acre, respectfully.

Table 1.6-2: Expected Annual Costs at Various Grant/Loan Mixes

Grant/Loan Mix	Annual Debt Service	Annual O&M Costs	Total Annual Costs	Total Annual Cost per Assessed Acre	Total Annual Cost per Acre-Foot of Irrigation Account Capacity
8,500 AF					
67/33	$1,122,600	$79,900	$1,202,500	$63.14	$240.50
80/20	$680,400	$79,900	$760,300	$39.92	$152.05
90/10	$340,200	$79,900	$420,100	$22.06	$84.02
92/8	$272,100	$79,900	$352,000	$18.48	$70.40
95/5	$170,100	$79,900	$250,000	$13.13	$50.00
100/0	--	$79,900	$79,900	$4.20	$15.98
10,000 AF					
67/33	$1,230,200	$79,900	$1,310,100	$68.79	$201.56
80/20	$745,600	$79,900	$825,500	$43.34	$127.00
90/10	$372,800	$79,900	$452,700	$23.77	$69.65
92/8	$298,200	$79,900	$378,100	$19.85	$58.17
95/5	$186,400	$79,900	$266,300	$13.98	$40.97
100/0	--	$79,900	$79,900	$4.20	$12.29

Note: (1) Annual costs are based on a 50 year loan at a 4% interest rate
(2) Assumes 19,046 acres, the current actively irrigated land benefited by West Fork Reservoir

Based on a willingness to pay of $10 per acre-foot, West Fork Reservoir does not cash flow. Revenue from the sale of water at $10 per acre-foot is not sufficient to pay for the operation, maintenance, and end of life replacement costs essential to the operation of the reservoir over its life span. A capacity assessment of $15.98 per acre-foot is required to cash flow the operation, maintenance and replacement costs for the 8,500 acre-feet reservoir alternative. A capacity assessment of $12.29 per acre-foot is required to cover the operation, maintenance and replacement costs for the 10,000 acre-feet reservoir alternative.

A per acre assessment of the West Fork Reservoir service area (19,046 acres) of $18.48 and $19.85 per acre is required to cover the annual debt service at 92 percent grant funding and operation, maintenance and replacement costs for the 8,500 acre-feet and 10,000 acre-feet reservoir alternative respectively.

The economic analysis indicates the West Fork Reservoir project has a benefit-cost ratio greater than one for all sizes analyzed. The standard WWDC grant-loan ratio (67% grant and 33% loan) is not economically feasible for the District. A $10 per acre-foot assessment on the active irrigation pool is not sufficient to support operation, maintenance and replacement costs. Considering the management opportunity with High Savery Reservoir and benefits to the basin, to meet WWDC criteria of grant funding not exceeding public benefit, and for the project to be affordable, the assessment of West Fork Reservoir's service area of 19,046 acres could be feasible. As stated, willingness to pay for West Fork Reservoir will have to be discussed further with the District. Ultimately, any financing plan will need to be approved by the WWDC and ultimately the Legislature.

1.7 RECOMMENDATIONS

Based upon the results of this Phase II work the proposed project is technically feasible, therefore it is recommended to progress to land acquisition, permitting and final design phases. Continued discussion with the State of Colorado as a potential funding partner is recommended.

Permitting tasks included in the recommended work include:

- NEPA Liaison and Coordination
- USFS Coordination and Appropriate Level of NEPA Review
- Preparation of USACE Section 404 Permit Application
- Preparation of Mitigation and Monitoring Plan
- USFWS Coordination
- NHPA Section 106 Coordination
- WDEQ Section 401 Permitting
- Wyoming State Engineer’s Office Permitting

Final Design task would include:

- Geotechnical investigations including borings and test pits to characterize subsurface characteristics;
- Preparation of final designs; and
- Preparation of construction contract documents, including drawings and specifications.

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