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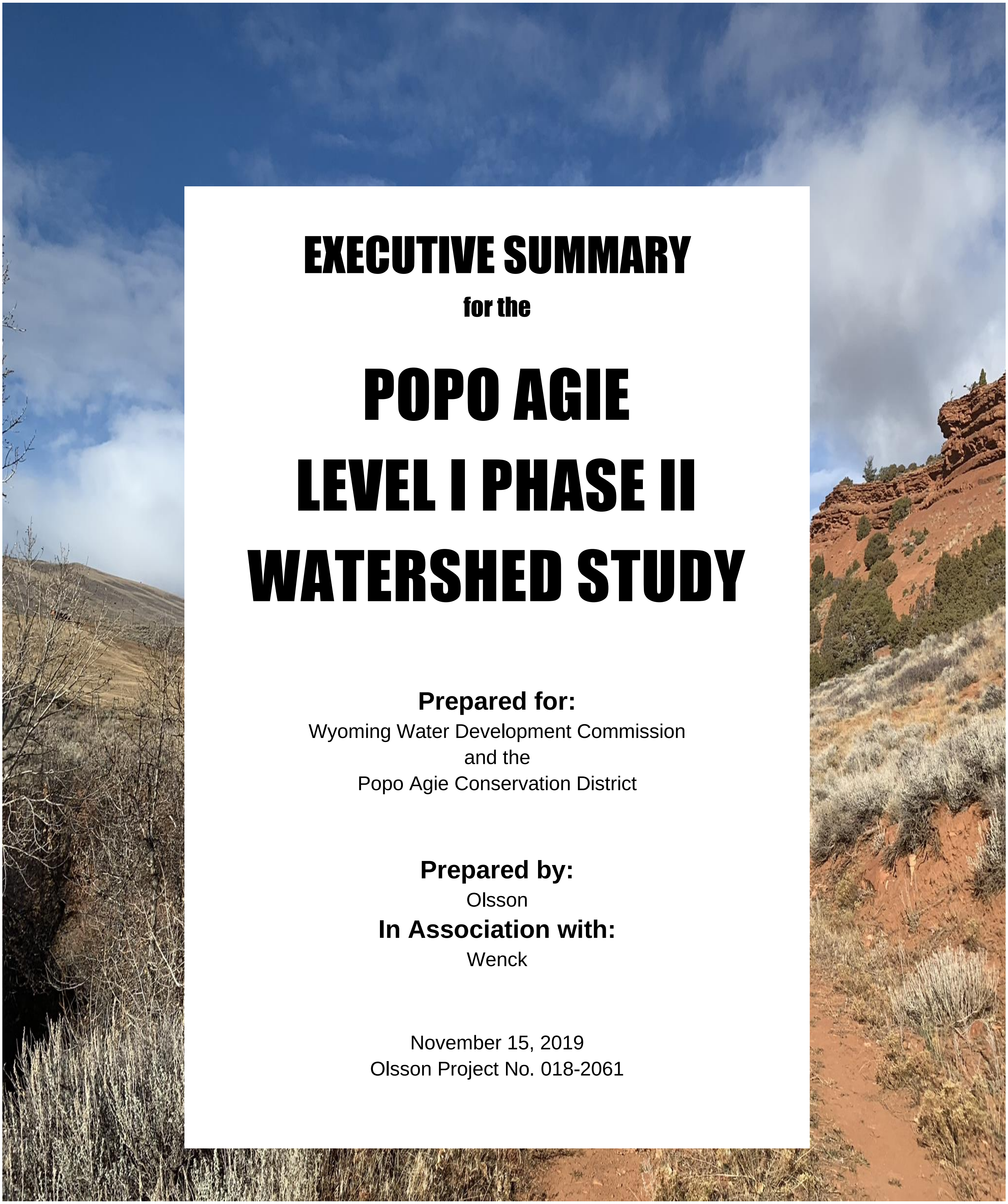

EXECUTIVE SUMMARY

for the

POPO AGIE LEVEL I PHASE II WATERSHED STUDY

Prepared for:

Wyoming Water Development Commission
and the
Popo Agie Conservation District

Prepared by:

Olsson

In Association with:

Wenck

November 15, 2019
Olsson Project No. 018-2061

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for the

Popo Agie
Level I Phase II
Watershed Study

WWDC Contract for Services
Number 05SC0297515
Olsson Project Number 018-2061

November 15, 2019

I hereby certify that this report was prepared by us or under our direct supervision and that we are duly licensed professional geologists and engineers under the laws of the state of Wyoming.

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1.0 INTRODUCTION

This Level I, Phase II watershed study was prepared under contract to the Wyoming Water Development Commission (WWDC). The Popo Agie Conservation District (PACD) in Lander, Wyoming, is the project sponsor, and the plan was prepared on behalf of the landowners, land managers, stewards, and visitors of the Popo Agie Watershed. The scientists and engineers of Olsson completed the study in collaboration with Wenck.

Photo 1. The Sinks at the Sinks and Rise State Park in the Popo Agie Watershed.

1.1. Purpose and Scope of the Study

In 2003, Anderson Consulting Engineers prepared a comprehensive Level I watershed study for the Popo Agie Watershed (ACE 2003). Previous reports had presented information that the watershed's water supply was not capable of fully satisfying the requirements of all water users, especially those in the Middle Popo Agie River. The Level I watershed study confirmed this. In the Level I watershed study, specific recommendations were made to proactively address the water issues the community was facing.

Since 2003, most of the proposed projects listed in the Level I watershed study (ACE 2003) have been completed. Unfortunately, the impact has not been sufficient to address the low-flow conditions in the Middle Popo Agie River in the late summer. For this reason, the project sponsors requested a Level I, Phase II watershed study be completed.

Since this Level I, Phase II watershed study is a follow-up to the Level I study completed in 2003 (ACE 2003), the scope is narrowly focused on the three areas identified by the project sponsor, that will provide the needed updates based on new technologies and updated datasets. The three focus areas for this Level I, Phase II watershed study as defined in the scope of work included:

- Water Budget Investigation and Irrigation Infrastructure Assessment
- Microstorage Facilities Investigation
- Aquifer Storage and Recovery (ASR)

The primary goals of each topic were as follows:

- Update the water budget with recent water monitoring data and use the new water budget to describe the hydrology of the Popo Agie River watershed including quantification of significant natural and anthropogenic inputs to, and outputs from, the system.
- Use the water budget to identify where and when there are water surpluses and deficits in the Popo Agie Watershed and to prioritize both future implementation projects to address water quantity issues and identify future study needs.
- Identify potential irrigation improvements that will deliver the greatest increases in efficiency and provide the water to address the deficits identified in the updated water budget.
- Identify potential locations for microstorage facilities off main river channels that will enable irrigators to hold water in the system for use later in the irrigation season.
- Assess the potential for capturing surface water at certain times of the year to store underground, to recharge the groundwater resource, and to enhance late-season water availability.

Each of these topics was identified to help address the water issues, which range from too much water in some areas to too little in others. But that is not all. The project is not only a technical challenge that involves understanding the interconnections between groundwater and surface water, but it also requires a deep understanding of the interconnections of the people, plants, and animals that live and thrive in this watershed.

For this reason, project meetings were held to engage the public in the process and solicit input on proposed solutions. A formal scoping meeting was held in June 2018, and two project meetings open to the public were held in the fall of 2018. Throughout the winter, conference calls were conducted with the PACD and stakeholders to discuss progress on the project and to provide a forum for discussion and project refinement. Two more well attended project meetings were held in Lander in the spring and fall of 2019. Draft findings of the study were presented to the public at the 2019 meetings.

2.0 RESULTS AND RECOMMENDATIONS

2.1. Water Budget Investigation Results

One of the first items the stakeholder group wanted to better understand was, "Does our watershed have excess water that could be used to address the seasonal water shortages facing irrigators and other water users across the Popo Agie Watershed?" For this reason, the first part of the study focused on updating the water budget model presented in the Phase I Level I watershed study (ACE 2003).

For this Level I, Phase II Study, ACE's Model was refined with the incorporation of new information to better assess current water availability within the Popo Agie Watershed. Model results were used to assist in the microstorage reservoir evaluation and location selection as well as the ASR portion of this watershed study. The results of the water budget model analysis indicate that even during a dry year, 46 percent of stream flows are not consumed by diversions, and during a wet year, only 22 percent of total in-stream flows are diverted. Examination of the watershed on an annual basis shows that water is available for storage. Of course, consideration must be given to downstream water right appropriations of the Little Wind River. Therefore, subtracting downstream water rights, 68 percent of the annual flow (230,535 acre-feet) is available for storage during a normal year.

To determine when flow is available for storage, the Model was examined on a monthly basis. The Model summarizes monthly outflows by node and reach in acre-feet. On a by-reach basis for normal years, 67,214 acre-feet is available in the North Popo Agie, 116,630 in the Middle Popo Agie, and 71,338 in the Little Popo Agie. As is expected, Model results show low flow volumes during the winter months (December, January, and February) and high flow volumes as snowmelt occurs (April, May, and June). Finally, as the late irrigation season is reached, flow volumes decrease significantly, especially close to Lander. This is partly caused by the high density of diversions near and upstream of Lander.

Another aspect of the water budget analysis was an assessment of conveyance and application losses associated with the current irrigation delivery system infrastructure and on-farm irrigation application systems. Conveyance and application losses were estimated using the Model and while it is not feasible to recover all losses, improvements to conveyance and application can help decrease losses and increase flow and water availability. The following section presents improvement projects that could help conserve water and alleviate low flows during the late irrigation season to improve the ecological health of the watershed.

To illustrate the results of the water budget investigation for the public meeting held in October 2019, Figure 1 was developed using the results from the model. Figure 1 presents the water availability in June and August of a normal year. The figure highlights the low flow conditions in Lander at model node 2.3.38.

2.2. Irrigation Improvement Recommendations

The objective of the proposed irrigation system improvements was to recommend projects that will result in conservation of water for the Popo Agie Watershed and/or reduce losses that occur. The Olsson/Wenck project team recommended the following irrigation improvements after review of the water budget analysis, field visits with landowners, and feedback from PACD and HRI.

2.2.1. Cemetery Ditch and Dutch Flat / Taylor Ditch

The Cemetery Ditch and the Dutch Flat / Taylor Ditch are in proximity to each other, and operational issues affect the ditches. Consolidating the ditches would eliminate these issues. The upper section of the Cemetery Ditch would still be used to provide irrigation water to lands near the diversion. The middle section of the ditch that flows through the City of Lander could be abandoned.

2.2.2. Nicol and Table Mountain Ditch and Baldwin Peralta Ditch

The Nicol and Table Mountain Ditch and Baldwin Peralta Ditch are also located close to each other. The Baldwin Peralta Ditch includes a small area of irrigated lands near the diversion structure and then a long ditch length to the area where most of the irrigated lands are located. It would be beneficial to consolidate the two ditches so that the lower portion of the Baldwin Peralta Ditch could be served by the Nicol and Table Mountain Ditch.The Baldwin Peralta Ditch would still be used to irrigate lands in the upper section of the ditch; however, the middle section could be abandoned.

2.2.3. Enterprise Ditch

The Enterprise Ditch includes various features that could be upgraded and/or improved to increase the conveyance efficiency of the ditch. Recommended improvements for the ditch include relining ditch sections where the existing liner has deteriorated and replacing a dilapidated headgate lateral and drop structure. Previous reports have also suggested stabilizing the steep ditch section located at the Cascade Drop in the Sawmill Creek reach. These improvement projects can help reduce conveyance losses that occur along the Enterprise Ditch.

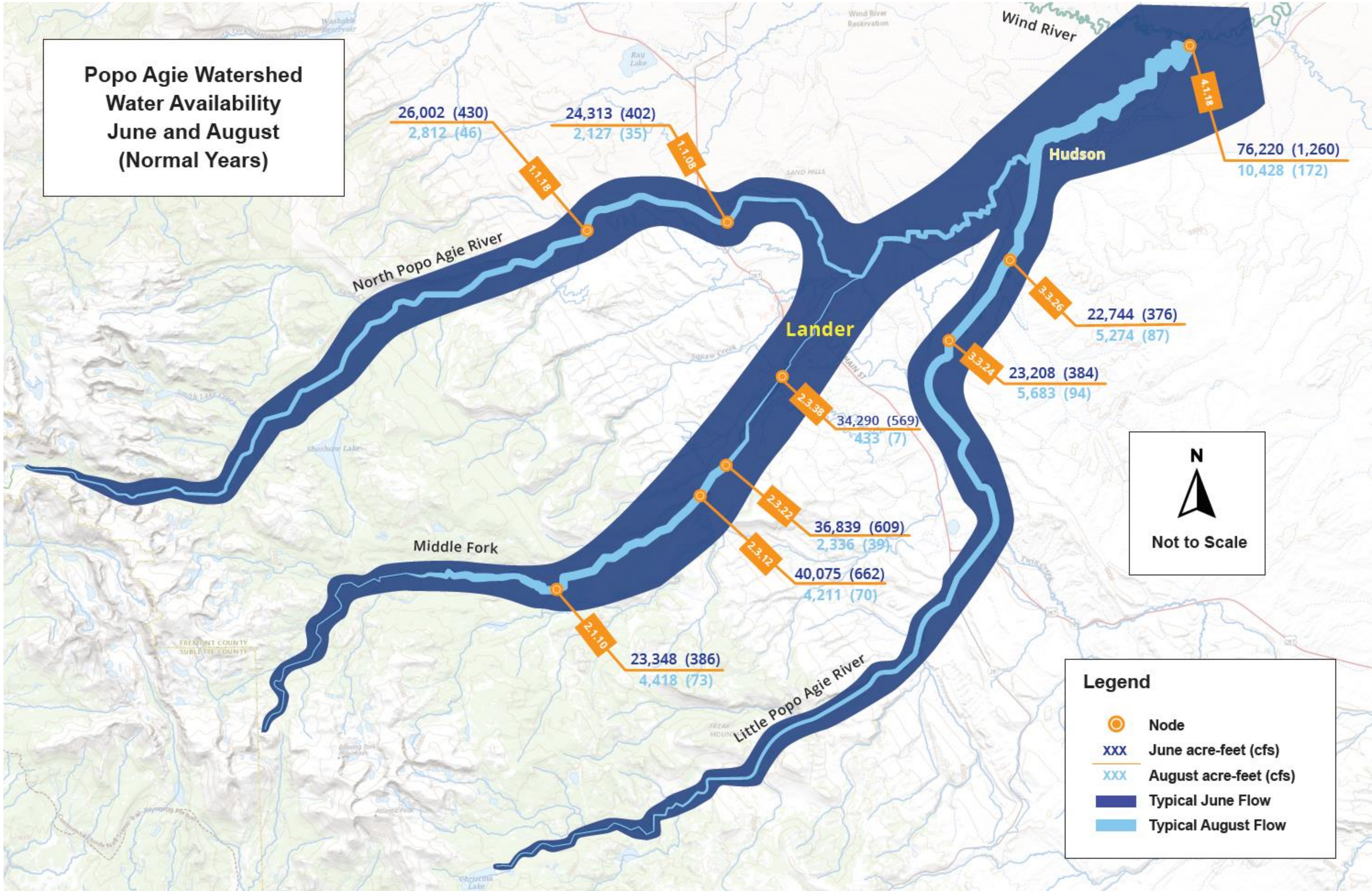

Figure 1 Popo Agie Watershed Water Availability June and August (Normal Years). In acre-feet and cubic feet per second (cfs).

2.2.4. Lyons Ditch

A section of the Lyons Ditch overflows where it crosses the northwest side of the Lyons Valley Road. A gated wasteway should be installed at this location for spilling excess flows. Additionally, the ditch capacity should be increased upstream of the culvert crossing so that the ditch does not overtop. Cleaning the ditch and elevating the bank (~2,000 LF) should eliminate the overtopping problem.

2.3. Microstorage Recommendations

Another of the key objectives of this Level I, Phase II watershed study was to identify potential locations for microstorage facilities off the main river channels that will enable irrigators to hold water in the system for use later in the irrigation season. The updated water budget showed that at least 1,000 acre-feet of water would be available in May and June in each of the Little Popo Agie, Middle Popo Agie, and North Popo Agie subwatersheds and that this water could be stored and used later in the irrigation season. For this reason, all three subwatersheds were evaluated for potential microstorage sites.

2.3.1. Microstorage Capacity and Location Recommendations

A target capacity was developed to evaluate the sites. The target volume of desirable water was based on an example calculation. The goal was to irrigate a 100-acre alfalfa field in August when surface water supplies are low. Considering all aspects of the water budget and the need to compensate for evaporation, seepage and transmission losses, and adding volume for flexibility, a volume of 300 acre-feet was used as the target volume for the microstorage sites. It should be noted that if a site is selected for construction, the actual storage volume could be larger or smaller but for evaluation purposes, using the same volume at each potential site yielded a like comparison. Thirty-six sites were identified across the entire watershed using the following primary selection parameters for potential microstorage site location:

- Sites would be located outside of wilderness areas.
- Sites would not be located on the mainstem of the three river branches.
- Existing reservoirs were generally not evaluated, with Worthen Meadows Reservoir and Pete's Lake as exceptions.

2.3.2. Microstorage Site Ranking

With 36 potential microstorage sites to be compared, criteria were developed so that the sites could be ranked. Eight criteria categories were developed and scored from 1 (lowest) to 3 (highest). Water availability, versatility of benefit, and cost were considered the most important criteria and were given twice the weight of the other categories. **Table 1** shows the scores and rankings for each site sorted into approximate thirds by color, with green being the most favorable third, yellow the middle third, and red the least favorable third. Along with the microstorage site ranking, input from residents and stakeholders in the watershed is invaluable in helping determine the sites with the best potential for advancement and where additional water would prove to be most beneficial. For this reason, information regarding the 36 sites was submitted to the PACD and distributed to the HRI. A small group of HRI members reviewed the sites and provided input. The input consists of pros, cons, and general comments regarding 24 of the sites, and it raises location suitability questions in some instances. The feedback does not necessarily provide endorsement of one site versus another, but it should be taken into consideration along with the information presented in this report.

Table 1 Microstorage Site Scoring and Ranking

Site Name	Branch	Water Availability*	Beneficial Uses*	Cost*	Bedrock Geology and Soils	Proximity to Irrigation	Proximity to Structures	Wetlands	Property Ownership (Original)	Total
Willow Creek No. 2	L	3	2	3	3	3	2	3	3	22
Willow Creek Lower	L	3	3	2	2	3	3	1	3	20
Crooked Creek - Meyer Basin	M	3	3	2	3	1	3	3	1	19
Hornecker - Borner (MPA diversion)	M	3	3	2	1	3	1	3	3	19
Sawmill Creek - Fossil Hill	M	3	3	3	3	1	3	2	1	19
Twin Creek	L	3	2	3	1	3	1	3	3	19
Cottonwood Creek	L	2	1	3	2	3	1	3	3	18
Cottonwood Creek East Fork	L	3	1	3	2	3	2	2	2	18
Hornecker - Borner (tributaries)	M	2	3	2	1	3	1	3	3	18
Little Popo Agie - Louis Lake	L	3	3	3	3	1	3	1	1	18
Sawmill at Loop Road	M	3	2	3	3	1	3	2	1	18
Deep Creek	L	2	1	1	3	3	2	3	2	17
Madison Creek	L	2	2	3	1	2	1	3	3	17
Onion Flats - from Devils Creek	L	1	2	3	3	3	1	3	1	17
Sawmill at Townsend 1	M	3	2	2	3	1	3	2	1	17
Sawmill at Townsend 2	M	3	2	1	3	1	3	3	1	17
Sawmill Creek 1	M	3	3	2	1	1	3	3	1	17
Sawmill Creek 2	M	3	3	1	2	2	1	3	2	17
Smith Creek	M	1	2	3	3	3	2	1	2	17
Surrel Creek No. 1	N	3	3	2	1	3	1	3	1	17
Beason Creek	L	1	3	1	1	3	2	3	2	16
Canyon Creek 1	L	2	1	2	3	1	3	3	1	16
Crooked Creek - Elderberry	M	2	3	2	1	1	3	3	1	16
liams Creek	L	1	3	1	3	3	1	2	2	16
Sheep Creek	M	1	3	1	3	2	1	3	2	16
Surrel Creek No 3	N	1	3	1	3	1	3	3	1	16
Surrel Creek No. 2	N	3	3	2	1	2	1	3	1	16
Willow Creek Upper	L	1	2	2	3	3	1	3	1	16
Baldwin - Farlow	M	2	2	2	3	1	1	3	1	15
Cherry Creek	L	2	1	2	3	1	3	1	2	15
Little Popo Agie - Onion Flats	L	1	2	3	1	3	1	3	1	15
No Name Draw	M	1	2	1	1	3	1	3	3	15
Pete's Lake	M	1	1	3	3	1	3	1	1	14
Canyon Creek	L	1	1	2	3	1	3	1	1	13
Baldwin/Squaw	M	2	2	1	1	1	1	3	1	12
Weiser Creek	L	1	1	2	1	3	1	2	1	12

Notes:
*Category is weighted twice
1 = Poor score, 3 = High score

2.3.3. Recommendations Regarding Worthen Meadows Reservoir

Worthen Meadows Reservoir is included in this report as a potential, and very promising water storage site, but was not evaluated in the same way as the other sites. A study of the City of Lander's water supply is documented in the draft technical memorandum *Water Supply Evaluation and Groundwater Development Alternatives, Lander Test Well Level II Study* dated April 2019 by Wyoming Groundwater LLC. As part of the study, "the management and reliability of the Worthen Meadows Reservoir in providing a late-season water supply was evaluated using a basic reservoir operations model" (Wyoming Groundwater 2019). Two conclusions of the draft reliability evaluation are discussed in the draft Level II study and are particularly relevant to this Popo Agie Level I Phase II study. They are:

- "Short of reservoir failure, there is little reason to expect the reservoir cannot continue to meet the historical levels of demand into the foreseeable future."
- "Under the assumptions of this relatively simple model, Worthen Meadows Reservoir could release quantities approximately twice those experienced historically and still not completely empty the reservoir in any model year."

Increasing the storage capacity or operational manual of Worthen Meadows Reservoir could be considered to mitigate for late-season low flow conditions in the Middle Fork of the Popo Agie River during a Level II feasibility study.

2.4. Aquifer Storage and Recovery

The goal of the ASR analysis was to assess the feasibility of using ASR to retime the water supply in the Popo Agie Watershed to increase late-season river flow. Several selection criteria, including regulatory, operational, hydrogeologic, and cost, were considered and used to evaluate potential ASR technologies, locations, and storage aquifers. The focus of the ASR analysis was on the Middle Fork of the Popo Agie based on the water budget analysis and the need to address the late-season low flow conditions within the sub-watershed. The four ASR technologies considered in this analysis included: 1) injection/recovery wells; 2) injection with passive recovery; 3) infiltration basins; and 4) enhanced ditch infiltration.

2.4.1. Aquifer Storage and Recovery (ASR) Results

Results of the ASR analysis indicate that ASR could be a potential storage option for retiming water supply and increasing late-season flow along the Middle Fork of the Popo Agie River. Analysis of the available data indicates that an ASR facility could contribute up to 1.1 cfs of water if the facility is located strategically within the basin and operated during periods that take advantage of the storage space available within the alluvial aquifer. Storage in the deeper aquifers such as those was not considered a viable option because of the price. To achieve a higher contribution to late-season flow, multiple ASR facilities could be constructed, or ASR could be used in conjunction with other storage options, such as microstorage reservoirs.

2.4.2. Aquifer Storage and Recovery (ASR) Recommendations

Should the Sponsor choose to pursue ASR as part of a Level II study, the data used here would need to be updated and used to refine the analysis of ASR suitability and location. The presented results are highly dependent upon the hydrogeologic characteristics of the alluvial aquifer, including the transmissivity, seasonal groundwater levels, and groundwater gradient. Transmissivity data from the 1999 testing (Lidstone and Associates 1999) was conducted in two locations, and these results were extrapolated along the rest of the Middle Fork. If locations are selected for further study of ASR, each aquifer site should be retested to obtain representative transmissivity values. The available transmissivity data for the two testing locations was also much lower than expected, which had a substantial impact on the selection process for ASR locations. If updated transmissivity values are higher, which would fit more closely with expectations, then ASR facilities should be moved farther from the river. This could open potential locations for enhanced ditch infiltration or could place ASR facilities closer to the water treatment plant, where they can more easily be used for dual purposes.

The operation of ASR facilities is also highly dependent upon water level data, which should be used to ensure water is being stored not just when it is plentiful, but also when there is room available in the aquifer. To proceed with an ASR investigation, seasonal groundwater data should be collected in multiple locations to help better define the water table and the local groundwater gradient.

3.0 CONCLUSIONS

At the end of this study, the primary question posed by the project sponsor was, “What project should we implement first?” And truthfully, the answer is, it depends. As presented earlier, there are several criteria that can be used to prioritize project implementation but, in the end, several factors will come into play. Important factors like what landowner, irrigation district, or agency is interested in completing a project and what funding source is available? However, the answer to this question may have already been answered because currently, an application for Level III funding is pending approval by the WWDC.

In 2008, the upper Sawmill reach of the Enterprise Ditch was identified as having significant seepage approximately three times higher than leakage on other areas of the irrigation system (Aqua Engineering 2008). This seepage represents approximately 50 percent of the total seepage loss on the entire system. Lining or piping this section was recommended to reduce losses. What has changed since the study was completed is that now, there is an opportunity to partner with the Popo Agie Conservation District and NRCS to provide technical assistance and funding to help contribute to this project. For a comparison of the different projects presented in this study, the following information is offered:

- For an estimated cost ranging from $44,000 to $900,000, the irrigation system conveyance system improvements presented in this report could facilitate water conservation, due to water conveyance efficiency, ranging from 0.3 to 3.5 cfs (**Table 2**).
- For an estimated cost ranging from $50,000 to $14 million, the microstorage sites presented in this report could provide additional water storage for use during late season low-flow conditions. The cost per acre foot for the stored water ranged from $630 to $50,800 for the first year of operation (**Table 1**).
- For an estimated cost ranging from $25,000 to $500,000, an estimated 1.1 cfs of water could be returned to the river during late season low-flow conditions.

Table 2 Proposed Irrigation System Improvement and Estimated Water Savings

Proposed Irrigation System Improvement	Estimated Water Savings (cfs)
Enterprise: Ditch lining Sawmill Creek Reach	3.5 cfs
Cemetery & Dutch Flat / Taylor Ditch Consolidation	2.0 cfs
Enterprise: Beason Creek: Thompson Headgate	0.3 cfs
Lyons: Ditch Capacity upgrade and Wasteway	0.3 cfs
Nicol and Table Mountain / Baldwin & Paralta: Ditch Consolidation	0.5 cfs
Enterprise: Cascade Reach-Pipe Drop	1.5 cfs