Appendix E

Other Supporting Information

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Table of Contents

List of Tables

List of Figures

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E.1 Alternatives Analysis: NRCS 9-Step Planning Process Memo

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July 26, 2023

TO: Todd Boldt, ASTC- Water Resources
Natural Resources Conservation Service (NRCS)
Colorado Springs, Colorado
todd.boldt@usda.gov

FROM: Aleta Powers, President of ERO Resources Corporation (ERO)

RE: Lower Gunnison Supplemental Watershed Plan-Environmental Assessment (EA), Delta County Colorado

ERO Resources Corporation is providing this Technical Memorandum to provide the results of the alternatives selection process for the Lower Gunnison Supplemental Watershed Plan-EA (Supplemental Watershed Plan-EA). The NRCS 9-step planning process was applied. The NRCS 9-step conservation planning process (which is a core NRCS business practice) is required in all watershed planning efforts. Using the NRCS National Planning Procedures Handbook, Amendment 9 (USDA NRCS 2021) in conjunction with National Environmental Policy Act (NEPA) compliance provides guidance for alternatives formulation and screening of alternatives using criteria such as Completeness, Effectiveness, Efficiency, and Acceptability, as well as “degree to meeting the Federal Objectives and Guiding Principles” (NWPM 501.12.A/B and USDA DM P&G 1.1.1(e)). Each step in the 9-step process is detailed below. The italicized sections are a direct copy from the NRCS website (U.S. Department of Agriculture (USDA) NRCS 2022).

1. Identify Problems and Opportunities.

Planning can start with a problem, an opportunity, shared concerns, or a perceived threat. Initial opportunities and problems are first identified based on readily available information provided by the customer. There may be information available through local Soil and Water Conservation Districts or through a larger-scale conservation plan.

Problems and opportunities were identified in a collaborative and iterative process described in detail below and in the Lower Gunnison Watershed Project Plan-EA (NRCS, 2018) and draft Supplemental Watershed Plan-EA Section 1.3. In summary, the main problems identified were:

1. Water Quality Degradation: Excessive salts (and selenium) in surface waters and groundwaters;
2. Insufficient Water: Inefficient use of irrigation water;
3. Soil Quality Degradation: Concentration of salts and other chemicals;
4. Inadequate Habitat for Fish and Wildlife: Habitat degradation; and
5. Maintenance and Water Management Costs for Irrigation Water Providers.

Primary opportunities to address the main problems were identified as the following:

1. Piping of open ditches to remedy water and soil quality issues and related habitat degradation as well as inefficient water use;
2. Infrastructure required by piping to allow effective water and sediment management; and
3. Implementation of automated water management and measurement systems to improve water use efficiency and decrease labor costs.

The Supplemental Watershed Plan-EA Project (project) selection for Batch 2 was cooperatively developed over a 9- to 12-month period using a project prioritization and selection process that included input meetings with more than 30 interested partners. A call for projects was sent to CRD stakeholders and submitted projects were considered for inclusion in the Watershed Plan EA. The project development process identified:

1. Areas within the Lower Gunnison River Basin watershed where Regional Conservation Partnership Program Critical Conservation Areas (RCPP CCA) natural resource concerns exist, including water quality degradation (e.g., selenium and salinity), wildlife habitat degradation, and soil health degradation;
2. Willing and able partners that met the statutory definition of an eligible entity to receive P.L. 566 Watershed Authority funding;
3. Highest priority irrigation improvement projects that addressed at least two or more of the CCA natural resource concerns;
4. Highest priority delivery system projects that enabled on-farm irrigation system efficiency improvements that also address natural resource concerns;
5. Highest priority planning and implementation projects that increased the ability of partners to implement system improvements to address agricultural and natural resource improvements in the future; and
6. Ability to leverage RCPP funds with other partner funding sources to expand the scope, size, and benefits of proposed project components.

The North Fork Irrigation Management Plan (JUB Engineers, Inc. 2017) provides additional local planning context, and identifies the following conclusions and recommendations that are relevant to this project:

1. Aging infrastructure associated with irrigation diversions and conveyance infrastructure could benefit from small-scale water control structure grant program; and
2. Support conveyance efficiency improvements that reduce salinity inflows, particularly the North Fork community and piping of open irrigation canals.

In addition, maintenance costs with aging infrastructure and manual measuring devices that require "boots on the ground" to document flows were identified as benefits of Supervisory Control and Data Acquisition (SCADA) projects that are a priority for water management. Piping requires other infrastructure for supply regulation and sediment management, which were considered during the project selection process.

2. Determine Objectives.

During this step, the stakeholders identify their objectives. A conservationist guides the process so that it includes both the stakeholder needs and values, the resource use, and on-site and off-site ecological protection. Objectives may need to be revised and modified as new information is gathered later in the process. Objectives may not be finalized until Step 4 of the planning process

During discussions with stakeholders, they identified their needs for the project as:

1. Address constraints and challenges of infrastructure management and improvement by local ditch companies; and
2. Address aging infrastructure, safety, and water and labor efficiency issues.

Related to conservation and ecological protection, objectives include:

1. Improve habitat conditions in downstream waters to benefit aquatic and riparian species by improving water quality; and
2. Improve habitat conditions with water efficiency, thereby providing opportunities for increasing water quantity.

3. Inventory Resources.

In this step, appropriate natural resource, economic and social information for the planning area is collected. The information will be used to further define the problems and opportunities. It will also be used throughout the process to define alternatives and to evaluate the plan. It is important that as much information as possible can be collected so that the plan will fit both the needs of the landowner and the natural resources. Inventories can range from a farmstead or small watershed to a complete inventory of resources for a state or the entire nation, such as with the NRCS National Resources Inventory or the Soil Survey Program.

A resource inventory was completed for the Lower Gunnison Watershed Plan-EA in 2018. The resource inventory includes a comprehensive data collection and analysis for natural resources, economics, and social information for the entire planning area. In addition, more surveys and data collection efforts were conducted to add to the body of knowledge for watershed areas in the vicinity of potential projects. In addition to the NRCS National Resources Inventory and Soil Survey information, statewide databases for Colorado Parks and Wildlife/wildlife occurrences and important habitat, national databases for wetlands, critical habitat, census data, and other resources were collected. Cultural resource inventories were also conducted.

Because of the importance of water quality in the Lower Gunnison Watershed Plan-EA project area, baseline water quality data in the Lower Gunnison River Basin have been collected as part of the Lower Gunnison River Basin Water Quality Monitoring effort (River District 2015) for more than 30 years due to concerns identified under the Clean Water Act and Endangered Species Act. The Lower Gunnison River Basin Water Quality Monitoring effort collects data at both short-term reconnaissance and long-term trend monitoring sites throughout the basin. This includes tributary sites and those on the mainstem of the Gunnison River, which serves as critical habitat to several federally listed fish species. The long-term trend monitoring site for the Gunnison River is located at Whitewater, Colorado, upstream of where the Gunnison River joins the Colorado River near Grand Junction. This site is also the compliance point for the Gunnison Basin Selenium Management Program (Salinity Control Forum 2020), which is the conservation measure being implemented by Gunnison River Basin water users and the Bureau of Reclamation (Reclamation) under the Aspinall Unit Re-Operations Record of Decision for the benefit of listed fish species. This site will serve as the single evaluation point for the Lower Gunnison project as it integrates the beneficial impacts associated with the upstream project improvements.

4. Analyze Resource Data.

This involves studying the resource data and clearly defining existing conditions for the natural resources, including limitations and potential for the desired use. This step is crucial to developing plans that will work for a landowner and their land. It also provides a clear understanding of the baseline conditions that will help assess how effective a project is after it has been put into place

A resource analysis was completed for the Lower Gunnison Watershed Plan-EA in 2018. An additional comprehensive analysis is included in the Supplemental Watershed Plan-EA, which thoroughly documents the resource impacts from project implementation. After analysis was conducted, it was verified that no significant impacts would result from implementation of any of the alternative projects and elements. Baseline resource conditions are reported in detail in the Supplemental Watershed Plan-EA.

5. Formulate Alternatives.

The purpose here is to achieve the goals for the land, by solving all identified problems, taking advantage of opportunities, and meeting the needs of the planning project. With NRCS conservation planning, we often can help landowners come up with alternatives based on financial assistance programs that help offset the financial expense of implementing conservation practices.

Formulating Alternatives determines all possible measures that could be used to address the problems and meet objectives. Table 1 provides a list of the project measures developed during the prior steps.

Table 1. Potential Project Measures.

Project Considered
7 SCADA sites/gates for Aspen Piping Project
9 SCADA network sites, measurement and controls - including Muddy and Alkali Creek inlet
KREX Tower for SCADA on BLM land
Grandview diversion structure and gate rebuild
Grandview storage regulating pond, sedimentation and clean-out structure on the Grandview Canal
Clipper regulating water pond, piping, and expanded sediment basin
SCADA at three water trade sites (Saddle Mountain, Virginia, and at the "Clear Fork" site where return flows come into the reservoir)
Fire Mountain pipeline extension (about 2.5 miles) between reservoir sites and lower piped section
Fire Mountain regulating reservoir sites (two options—one private and one BOR), and short amount of piping between; and up to 4 SCADA (repeater tower site listed separately); 10 total SCADA options analyzed but 1 selected (see SCADA map)
SCADA repeater tower installation to support Fire Mountain Reservoir

Project Considered
Fire Mountain diversion structure replacement
Paonia Ditch improvements and SCADA - improvements to diversion structure, better spill, keeping water split out
Fire Mountain additional pipeline in Wolf Park area - Wolf Park siphon
Piping Rogers Mesa East (no consensus, under study)
Overland and Highline piping (above Rogers Mesa)
Farmers Ditch - Improvement to manage flows in Hotchkiss (no concept designed)
Farmers Ditch - Safety improvement to diversion
Terror Creek Ditch improvements and SCADA
Bostwick Park East Lateral

6. Evaluate Alternatives.

Next is to evaluate the alternatives to determine their effectiveness in addressing the customer's problems, opportunities and objectives. Attention must be given to those ecological values protected by law or executive order.

The potential project measures identified during the scoping process were evaluated and screened, documenting why the measures should or should not be included in the project or Action Alternative. This evaluation was completed based on each measure's responsiveness to solving identified problems, taking advantage of opportunities, and meeting the intended planning project needs. The following questions were asked to help determine if projects should be included in any of the Action Alternatives or eliminated from detailed consideration in the Supplemental Watershed Plan-EA.

1. Within the 2018 Lower Gunnison Watershed Plan-EA boundary? Those projects outside of the boundary were eliminated because they do not solve identified problems within the geographic context considered for the 2018 effort.
2. Improved water use efficiency and management? Projects that do not directly or indirectly result in water use and management efficiency were considered nonresponsive to the purpose and need for the Supplemental Watershed Plan-EA. Examples of improved water use efficiency and management include providing pressurized systems to support on-farm use and repair of aging or damaged infrastructure.
3. Necessary system components as part of a Reclamation salinity-funded piping project? Projects that take advantage of opportunities provided by other funding sources, including Reclamation salinity funding, were considered to optimize NRCS funding opportunities.
4. Project design status? Projects lacking adequate levels of planning and engineering were considered at risk of not being implemented within the 15-year timeframe required. Conversely, some measures required implementation more quickly than P.L. 566 process could support.
5. Cost to benefit analysis is positive? Projects with excessive cost relative to benefits, when compared to other similar projects, were eliminated from further analysis.
6. Meets Federal Objective identified in the P&G: "The Federal objective of water and related land resources project planning is to contribute to national economic development consistent with protecting the Nation's environment, pursuant to national environmental statutes, applicable executive orders, and other Federal planning requirements." See Table 2.

Chapters 4 and 5 and Appendix D of the Supplemental Watershed Plan-EA contain a thorough analysis of the action alternatives, and the no action and their impacts on resources, including all those resources protected by law or executive order.

Table 2. Potential Project Measures Screening.

Project Considered	Screening decision and Rationale
7 SCADA sites/gates for Aspen Piping Project	Include; directly or indirectly result in water use and management efficiency at reasonable cost
9 SCADA network sites, measurement and controls - including Muddy and Alkali Creek inlet	Include; directly or indirectly result in water use and management efficiency at reasonable cost
KREX Tower for SCADA on BLM land	Include; directly or indirectly result in water use and management efficiency by supporting SCADA for improved water management efficiency at reasonable cost
Grandview diversion structure and gate rebuild	Exclude; the project required completion more quickly than the P.L. 566 process could support. Other funding secured.
Grandview storage regulating pond, sedimentation and clean-out structure on the Grandview Canal	Exclude; the project required completion more quickly than the P.L. 566 process could support. Other funding secured.
Clipper regulating water pond, piping, and expanded sediment basin	Exclude; the project required completion more quickly than the P.L. 566 process could support. Other funding secured.
SCADA at three water trade sites (Saddle Mountain, Virginia, and at the "Clear Fork" site where return flows come into the reservoir)	Exclude; would not directly or indirectly result in water use and management efficiency at reasonable cost because communication between SCADA locations and tower would be problematic topographically.
Fire Mountain pipeline extension (about 2.5 miles) between reservoir sites and lower piped section	Include; directly or indirectly result in water use and management efficiency at reasonable cost and opportunities to complement projects that are already implemented on Fire Mountain
Fire Mountain regulating reservoir sites (two options—one private and one BOR), and short amount of piping between; and up to 4 SCADA (repeater tower site listed separately)	Include; directly or indirectly result in water use and management efficiency at reasonable cost; opportunities to complement projects that are already implemented on Fire Mountain
SCADA repeater tower installation to support Fire Mountain Reservoir	Include; supports improved water management efficiency at reasonable cost
Fire Mountain diversion structure replacement	Exclude; lacking adequate levels of planning and engineering
Paonia Ditch improvements and SCADA - improvements to diversion structure, better spill, keeping water split out	Exclude; lacking adequate levels of planning and engineering and lack of consensus by stakeholders for most effective project
Fire Mountain additional pipeline in Wolf Park area - Wolf Park siphon	Exclude, this section in area with highest salinity; BOR salinity funding more appropriate
Piping Rogers Mesa East (no consensus, under study)	Exclude; lack of consensus by stakeholders for most effective project; additional planning and engineering studies required
Overland and Highline piping (above Rogers Mesa)	Exclude; lacking adequate levels of planning and engineering
Farmers Ditch - Improvement to manage flows in Hotchkiss (no concept designed)	Exclude; additional planning and engineering studies required
Farmers Ditch - Safety improvement to diversion	Exclude; the project required completion more quickly than the P.L. 566 process could support. Other funding secured.
Terror Creek Ditch improvements and SCADA	Exclude; not within planning boundary
Bostwick Park East Lateral	Exclude; additional planning and engineering studies required

7. Make Decisions.

At this point, the landowner chooses which project or plan will work best for their situation. The planner prepares the documentation. In the case of an areawide plan, public review and comment are obtained before a decision is reached.

Chapter 7 of the Supplemental Watershed Plan-EA documents the rationale for selecting the preferred alternative for accomplishing the project purpose. The Watershed Agreement documents the joint NRCS and Sponsor's decision to implement the preferred alternative. -

8. Implement the Plan.

Technical assistance is provided to help with the installation of adequate and properly designed conservation practices. At this point in NRCS conservation planning, our conservation engineers step in and make designs based on our technical standards. Also, assistance is given in obtaining permits, land rights, surveys, final designs, and inspections for structural practices.

The Supplemental Watershed Plan-EA implementation will be conducted at construction, after the supplemental plan has been authorized by the NRCS Chief and Federal and local funds are available, using methods described in the Watershed Agreement. .

9. Evaluate the Plan.

Conservation planning is an ongoing process that continues long after the implementation of a conservation practice. By evaluating the effectiveness of a conservation plan or a practice within a plan, stakeholders can decide whether to continue with other aspects of an overall areawide plan.

The Supplemental Watershed Plan-EA evaluation will be made at a later time, after the Plan-EA has been implemented.

References

JUB Engineers, Inc. (JUB). 2017. North Fork of the Gunnison River Irrigation Management Plan. Prepared for North Fork Water Conservancy District. November.

Colorado River Water Conservation District (River District). 2015. Expanding the modernization of agricultural water management in the Lower Gunnison River Basin: A Producer-led effort to increase water use efficiency while boosting productivity and improving water-quality (LGPE). RCPP Narrative Elements for Full Proposal. Form 1397. *Confidential, contains sensitive financial data.*

Salinity Control Forum. 2020. Review of Water Quality Standards for Salinity. http://coloradoriversalinity.org/docs/2020%20REVIEW%20-%20June%20Draft%20Complete.pdf. October. 97 pp.

U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS). 2014. National Planning Procedures Handbook (NPPH), Edition, 180-600-H, 1st Ed., Amend. 6, Nov 2014. Electronic doc: https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=36483.wba. Accessed 6/13/23U.S. Department of Agriculture Natural Resources Conservation Service (USDA NRCS). 2022. Conservation Planning. https://www.nrcs.usda.gov/getting-assistance/conservation-technical-assistance/conservation-planning#:~:text=NRCS%20uses%20a%20nine-step%20planning%20process%3A%201%201.,8%208.%20Implement%20the%20Plan.%20...%20More%20items. Last accessed November 10, 2022.

Aleta S. Powers

SIGNED:

Aleta Powers, President and Environmental Scientist

E.2 Supporting Information for Water Resources

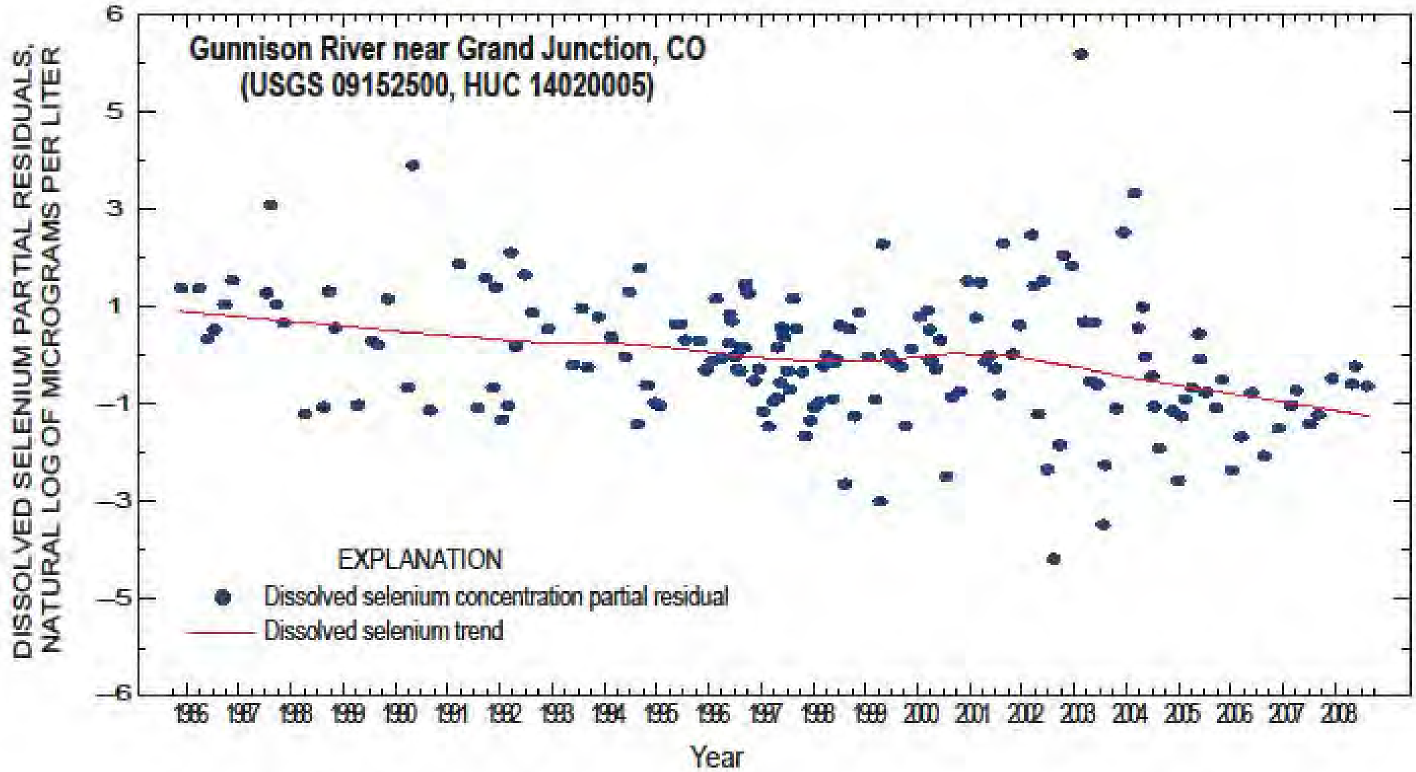

Figure 5.2-1. Dissolved Selenium Concentration Partial Residuals and Trend Line for Gunnison River near Grand Junction, 1986-2008 (from Mayo and Leib 2012).

E.3 Supporting Information for Biological Resources
3.1 Vegetation

3.1.1 Special Status Plant Species

Two Endangered Species Act (ESA)-protected plant species occur in the project area for the 2018 Lower Gunnison Watershed Plan-EA (NRCS 2018): clay-loving wild buckwheat (*Eriogonum pelinophilum*) and Colorado hookless cactus (*Sclerocactus glaucus*).

3.1.1.1 Clay-Loving Wild Buckwheat

Clay-loving wild buckwheat was listed as endangered in 1984 at 49 Federal Register (FR) 28562–28565 (July 13, 2014) due to its extremely limited range and the high risk of habitat loss and fragmentation caused by residential and agricultural development and off-road vehicle travel. The U.S. Fish and Wildlife Service (USFWS) also designated critical habitat for clay-loving wild buckwheat at the same time. No designated critical habitat areas are present in the four subwatersheds of the project area, as shown on Figure 3.4-10 (2018 Plan-EA; NRCS 2018).

Clay-loving wild buckwheat is a small low-growing, densely branched shrub in the buckwheat family, with dark green linear leaves and small white to cream-colored flowers that bloom from late May through early September. Generally, the plants are found in a sharply defined soil microhabitat (whitish calcareous clay soils derived from Mancos Shale, often mapped as Billings Series soils) on mid to lower slopes of adobe hills. Clay-loving wild buckwheat occurs with other xerophytic low shrubs such as shadscale, mat saltbush, and black sagebrush. Field observations have suggested that the species is most abundant where biological soil crust cover is not extensive (USFWS 2017; Colorado Natural Heritage Program [CNHP] 2013).

3.1.1.2 Colorado Hookless Cactus

Colorado hookless cactus was listed as threatened in 1979 at 44 FR 58868-58870 (October 11, 1979) due to habitat threats, unregulated collection, and commercial trade by nurseries and private collectors. No critical habitat has been designated for this species. Colorado hookless cactus is a squat rounded spiny succulent, usually consisting of a single blue-green stem. The plants are inconspicuous except during their bloom (April and May), when pink flowers develop at the top of the stems. Following the blooming period during dry years, smaller plants can be difficult to locate because the stems may shrink below ground level. In the vicinity of the project area, Colorado hookless cactus is found on river terraces and the Mancos Shale formation (adobe hills), often on rocky or gravelly soils. Plant associations include low semi-desert shrubland species such as shadscale, mat saltbush, black sagebrush, and galleta (CNHP 2022).

Two Bureau of Land Management (BLM) Sensitive plant species, Colorado desert parsley and Uncompahgre bladderpod, occur in the project area for the 2018 Lower Gunnison Watershed Plan-EA (NRCS 2018):

3.1.2 Invasive Plant Species

Table E-1 presents the state-listed noxious weeds (Colorado Department of Agriculture 2016) known from and potentially occurring in the project area by county (Colorado State University [CSU] 2017; Delta County 2010; Montrose County 2011, 2017; Ouray County 2011), along with the current management priority for each weed assigned by the counties and BLM's Uncompahgre Field Office (UFO) (BLM 2016).

Table E-1. State- and BLM-Listed Noxious Weeds by County, with Associated Management Priorities.

Common Name	Scientific Name	State Noxious Weed List[1]	Management Priority		
			BLM Land	Delta County	Montrose County
Meadow knapweed	*Centaurea nigrescens*	A	--	--	--
Myrtle spurge	*Euphorbia myrsinites*	A	--	E	--
Orange hawkweed	*Hieracium aurantiacum*	A	--	--	--
Purple loosestrife	*Lythrum salicaria*	A	SC	E	P
Yellow starthistle	*Centaurea solstitialis*	A	SC	E	P
Absinth wormwood	*Artemisia absinthium*	B	--	--	--
Black henbane	*Hyoscyamus niger*	B	--	--	--
Bull thistle	*Cirsium vulgare*	B	SC	x	x
Canada thistle	*Cirsium arvense*	B	SC	CC	x
Chinese clematis	*Clematis orientalis*	B	SC	--	x
Common tansy	*Tanacetum vulgare*	B	--	--	--
Common teasel	*Dipsacus fullonum*	B	--	--	x
Dalmatian toadflax	*Linaria dalmatica*	B	SC	--	--
Dame's rocket	*Hesperis matronalis*	B	--	--	--
Diffuse knapweed	*Centaurea diffusa*	B	SC	E	P
Hoary cress	*Cardaria draba*	B	SC	CC	P
Houndstongue	*Cynoglossum officinale*	B	SC	CC	x
Jointed goatgrass	*Aegilops cylindrica*	B	SC	x	x
Leafy spurge	*Euphorbia esula*	B	SC	E	--
Moth mullein	*Verbascum blattaria*	B	--	--	x
Musk thistle	*Carduus nutans*	B	SC	CC	x
Oxeye daisy	*Leucanthemum vulgare*	B	SC	CC	x
Perennial pepperweed	*Lepidium latifolium*	B	--	--	--
Plumeless thistle	*Carduus acanthoides*	B	SC	--	--
Russian knapweed	*Acroptilon repens*	B	SC	CC	P
Russian olive	*Elaeagnus angustifolia*	B	SC	x	x
Salt cedar	*Tamarix* spp.	B	SC	x	P
Scentless chamomile	*Tripleurospermum perforata*	B	--	--	--
Scotch thistle	*Onopordum* spp.	B	SC	CC	x
Spotted knapweed	*Centaurea stoebe*	B	SC	E	P
Sulfur cinquefoil	*Potentilla recta*	B	SC	--	x
Wild caraway	*Carum carvi*	B	--	--	x
Yellow nutsedge	*Cyperus esculentus*	B	--	--	x
Yellow toadflax	*Linaria vulgaris*	B	SC	E	P
Bulbous bluegrass	*Poa bulbosa*	C	--	x	x
Chicory	*Cichorium intybus*	C	SC	x	x
Common burdock	*Arctium minus*	C	SC	x	x
Common mullein	*Verbascum thapsus*	C	SC	x	x
Downy brome	*Bromus tectorum*	C	--	x	x
Field bindweed	*Convolvulus arvensis*	C	SC	x	x
Halogeton	*Halogeton glomeratus*	C	SC	x	x
Johnsongrass	*Sorghum halepense*	C	--	x	x
Perennial sowthistle	*Sonchus arvensis*	C	--	x	x
Poison hemlock	*Conium maculatum*	C	--	x	x

Common Name	Scientific Name	State Noxious Weed List[1]	Management Priority		
			BLM Land	Delta County	Montrose County
Puncturevine	*Tribulus terrestris*	C	--	CC	x
Quackgrass	*Elymus repens*	C	--	--	x
Redstem filaree	*Erodium cicutarium*	C	--	x	x
Velvetleaf	*Abutilon theophrasti*	C	--	--	x
Wild proso millet	*Panicum miliaceum*	C	--	--	x

"List A" weeds are designated for eradication, and are usually less common or thought to be present at levels at which eradication is possible. "List B" weeds are typically well-established and mandated for control and containment. "List C" weeds are species for which the state supports local government's management on public and private lands, but for which there is no mandate for eradication or control.
SC = BLM weed species of concern; x = present but without assigned priority or management directive; -- = not present; E = eradicate; CC = contain and control; MC = mandated for control; P = priority for management

3.2 Wildlife

3.2.1 Special Status Wildlife

3.2.1.1 Federally Protected Birds and Their Critical Habitats

3.2.1.1.1 Gunnison Sage-Grouse

The Gunnison sage-grouse was listed as threatened and critical habitat was designated on November 20, 2014, at 79 FR 69191–69310 and 79 FR 69311–69363. The Gunnison sage-grouse is a sagebrush obligate endemic to Colorado and Utah south of the Colorado River. Breeding grounds (leks) consist of open areas next to tall sagebrush. For nesting and rearing young, the species requires large contiguous patches of sagebrush (greater than 200 acres) with an abundant and relatively tall herbaceous understory, interspersed with wet swales. Wintering sage-grouse feed exclusively on sagebrush leaves.

Rangewide threats facing Gunnison sage-grouse include habitat destruction, modification, or curtailment of its habitat or range, and predation and disease (79 FR 69191–69310). Localized threats include small population size, lack of habitat protection from permanent loss, risk from noxious and invasive weeds, predation, recreation activities, vehicle collisions, fences and power poles that provide perches for predatory raptors, unmanaged lek-viewing, drought impacts, improper grazing management, encroachment of pinyon-juniper woodlands into sagebrush, insufficient amounts of grass and forbs in the sagebrush understory, and low vegetative class diversity in the area's sagebrush communities (Crawford Area Gunnison Sage-Grouse Working Group [CWG] 1998, 2011).

Seven distinct populations of Gunnison sage-grouse exist in southwest Colorado and southeast Utah (79 FR 69191–69310). The USFWS established critical habitat in the seven population areas, with classifications of "occupied," "potential/unoccupied," and "vacant." Occupied critical habitat was designated in the geographic areas known to be occupied at the time of the species' listing. Areas of potential/unoccupied critical habitat were designated in areas formerly occupied by the species and deemed essential to its conservation. The "potential/unoccupied" critical habitat classification is more specifically "unoccupied habitats that could be suitable for occupation of sage-grouse if practical restoration were applied." "Vacant" critical habitat is defined by 79 FR 69191–69310 as "suitable habitat for sage-grouse that is separated (not contiguous) from occupied habitats that either has not been adequately inventoried, or has not had documentation of sage-grouse presence in the past 10 years.” Figure 3.5-4 for the 2018 Lower Gunnison Watershed Plan-EA (NRCS 2018) shows the locations of occupied and potential/unoccupied Gunnison sage-grouse designated critical habitat in the project area. No vacant critical habitat is mapped in the project area. The North Fork subwatershed lies outside the documented range of Gunnison sage-grouse and outside areas of designated critical habitat. The Crawford subwatershed lies northeast of documented occupied range of the Crawford population of Gunnison sage-grouse, but encompasses an area of potential/unoccupied designated critical habitat. The Gunnison Basin population, the largest and most genetically viable of the seven populations, occurs in the Gunnison Valley in Gunnison County, well outside the project area for the 2018 Lower Gunnison Watershed Plan-EA (NRCS 2018).

3.2.1.1.2 Mexican Spotted Owl

The Mexican spotted owl has not been documented in the two subwatersheds (Table 3.5-3) or near the project area and is therefore dismissed from further analysis in the Supplemental Plan-EA. The USFWS acknowledged that the Mexican spotted owl will receive no consideration. There are no recent or historic Mexican spotted owl records from the project area (BLM 2016). The two subwatersheds lack suitable breeding habitat, which consists of dense old growth conifers on steep canyon or mountain terrain. Numerous spotted owl surveys over the past two decades in the region, including the Dolores and San Miguel watersheds, the Uncompahgre Plateau (BLM 2016), and the Black Canyon of the Gunnison (National Park Service 2014), all returned negative results. USFWS designated critical habitat for Mexican spotted owl on February 1, 2001 at 69 FR 53182–53298 in Mesa Verde National Park in southwest Colorado and in the Wet Mountains and Pikes Peak area in the Front Range. The species is uncommon, nonmigratory, and extremely site-specific in Colorado, with documented nest locations only in designated critical habitat.

3.2.1.1.3 Western Yellow-Billed Cuckoo

The western yellow-billed cuckoo was listed as threatened on October 3, 2014 (79 FR 59992–600038), after several years as a candidate for listing. Critical habitat was proposed for the species on August 15, 2014 at 79 FR 48548–48652 (i.e., the “proposed rule”). The yellow-billed cuckoo is a fairly large and secretive migratory songbird that breeds in the United States and winters in South America. Its preferred breeding habitat is low-elevation old-growth riparian cottonwood forests or woodlands with dense scrubby understories of willows or other riparian shrubs. The riparian areas are in broad open river valleys with a low gradient (less than 3 percent slope) and wide floodplain conditions (greater than 325 feet). Studies in California indicate this species may need extensive stands of riparian forest for nesting success of at least 24 acres in size (Halterman 1991). Patches chosen as nest sites by cuckoos vary in size and shape from large contiguous stands to irregularly shaped mosaics of dense cottonwoods interspersed with open areas (Halterman et al. 2015). The yellow-billed cuckoo has a short nesting season—incubation to fledging can be completed in as little as 14 days. Cuckoos arrive on breeding and nesting grounds in Colorado in late May or early June, and depart by early August through early September.

The decline of the yellow-billed cuckoo throughout the western United States has been attributed to destruction of its preferred riparian habitat due to agricultural conversions, flood control projects, and urbanization. In some parts of its breeding range, pesticide use may have affected the yellow-billed cuckoo’s prey base of pest insects such as tent caterpillars, which tend to occur in cyclic outbreaks.

Although it was probably never common in western Colorado, the yellow-billed cuckoo is now considered an extremely rare summer resident and nearly extirpated (Carter 1998). Only one confirmed nesting occurrence was recorded in western Colorado (the Yampa River near Hayden) during Colorado Breeding Bird Atlas surveys from 1987 through 1994 (Carter 1998). Up until 2003, only one or two unofficial yellow-billed cuckoo observations, and no nesting reports, occurred annually in western Colorado, mostly from the Uncompahgre River and Grand Valleys. Since 2003, cuckoos have been documented nearly annually in the North Fork of the Gunnison River Valley (Beason, pers. comm. 2017). The Colorado Breeding Bird Atlas II surveys did not detect records for cuckoo in the subwatersheds outside of the North Fork between the 2007 to 2012 survey period (Wickersham 2016).

As shown on Figure 3.5-4 Threatened and Endangered Species Habitat for the Lower Gunnison Supplemental Watershed Plan-EA presented in Appendix C on page 18, the North Fork subwatershed includes all of western yellow-billed cuckoo critical habitat unit 56: CO-3 (North Fork Gunnison River, Delta County). Critical habitat is defined in the proposed rule (79 FR 48548–48652) as follows: “(1). The specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the [ESA], on which are found those physical or biological features a) essential to the conservation of the species and b) which may require special management considerations or protection, and (2) Specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination that such areas are essential for the conservation of the species.”

3.2.1.2 Federally Protected Mammals and Their Critical Habitats

3.2.1.2.1 Lynx

The lynx was listed as threatened May 24, 2000 at 65 FR 16051–16086. Although it was never abundant, the lynx historically occurred in appropriate habitat in upper montane and subalpine zones throughout central Colorado, and was assumed extirpated from the state by 1973 (Seidel et al. 1998). Threats to lynx include habitat destruction (timber harvest), snow-based winter recreation, low densities of snowshoe hare (their primary prey), and vehicle collisions (USFWS 2017). Colorado Parks and Wildlife (CPW) initiated a reintroduction program in Colorado in 1999, and in 2010 announced that its benchmarks for reintroduction success had been achieved and breeding subpopulations of lynx were established. In Colorado, persistent lynx populations in the state are thought to be centered around the Collegiate Range and in the San Juan Mountains of the central and southwest parts of the state. Preliminary results of recent monitoring continue to confirm the presence of lynx in the San Juan Mountains (Ivan et al. 2015). Individuals have been tracked in the past on the Gunnison and Grand Mesa National Forests (Theobald and Shenk 2011).

Primary lynx habitat (denning habitat) in Colorado includes coniferous forests of spruce and fir or lodgepole pine. Secondary habitat consists of aspen or Douglas-fir mixed with primary coniferous habitat, between 8,000 and 11,500 feet elevation (Shenk 2009). Lynx typically forage in uneven- aged subalpine forests with shrubs or small trees that provide habitat for snowshoe hares, their primary prey. Small forest openings with low cover enhance foraging habitat, although lynx mostly avoid openings larger than several acres. Closed canopy subalpine forests with significant dead and down trees provide optimum denning habitat. In areas with deep winter snow, foraging habitat must contain shrubs or small trees of sufficient height to extend above snowpack.

The USFWS has not designated critical habitat for lynx in Colorado because the Southern Rocky Mountains in Colorado do not meet the Primary Constituent Elements of critical habitat required by the ruling (lynx habitat and snowshoe hare densities in Colorado are considered patchy and marginal). However, the U.S. Forest Service and other cooperating agencies have developed mapping of lynx potential habitat in Colorado based on geospatial land cover data (CPW 2016).

3.2.1.2.2 Wolverine

The wolverine has not been documented in the two subwatersheds (Table 3.5-3) or near the project area and is therefore dismissed from further analysis in the Supplemental Plan-EA. Deep, persistent, and reliable spring snow cover (April 15 to May 14) is the best overall predictor of wolverine occurrence in the contiguous United States. In the southern portion of the species' range (i.e., in the vicinity of the subwatersheds), the distribution of wolverine would be limited to elevations higher than the subwatersheds (i.e., the alpine zone). Furthermore, there are no documented viable populations of wolverine in western Colorado. Although numerous historical records of wolverines from the Rocky Mountains exist, the species is believed to have been extirpated from Colorado, New Mexico, and Wyoming by the early 1900s (Copeland et al. 2010). Only one individual has been documented in the Southern Rocky Mountains (in north-central Colorado) since 1919 (CPW 2017).

3.2.1.3 Federally Protected Insects

3.2.1.3.1 Monarch Butterfly

The monarch butterfly was listed as a candidate species on December 17, 2020 in 85 FR 81818-81822. North America contains two migratory populations of the monarch butterfly separated by the Rocky Mountains. The largest migratory population breeds across the central and eastern parts of the continent and winters in Mexico. A smaller migratory population breeds in western North America and winters primarily along the California coast south into Baja California, Mexico. Colorado is considered a contact zone between the eastern and western populations with summer breeding areas, but is not included in the two migratory populations (USFWS 2020). Monarch butterfly occurrences are low in southwest Colorado relative to the two migratory populations in North America (Western Monarch Milkweed Mapper 2023). Monarch butterflies occur at elevations from 4,300 to 11,500 feet (rarely above 9,000 feet), mainly in lowlands near larval food plants. Milkweed (*Asclepias* spp.) is an essential feature of quality monarch butterfly habitat. Eggs, larvae, and adults require healthy and abundant milkweed for oviposition and larval consumption (USFWS 2020). Common places where milkweed occurs include shortgrass and tallgrass prairies, livestock pastures, agricultural margins, roadsides, wetland and riparian areas, sandy areas, and gardens; in addition to deserts, open forests, and woodlands. Monarch butterflies migrate in the spring (March to June) and fall (August to October) to breeding and overwintering sites (USFWS 2020). Milkweed is scattered throughout the subwatersheds and blooming forbs provide nectar for adult monarchs; therefore, suitable habitat for the monarch butterfly occurs throughout the subwatersheds.

3.2.1.3.2 Silverspot

The silverspot was proposed for listing as a threatened species on May 4, 2022 in 85 FR 26319-26337. The silverspot range includes southeast Utah, southwest Colorado, and northwest New Mexico from 5,000 to 8,500 feet in elevation (USFWS 2021). The silverspot occurs in permanent spring-fed meadows, seeps, marshes, and boggy streamside meadows with bog violet. Bog violet is the only known larval host plant for the silverspot. Microhabitat for the bog violet is soggy soil and shade often under willows or other shrubs at the edge of the habitat that is mixed with herbaceous vegetation such as sedges, grasses, and forbs. Forbs provide nectar for adult silverspots (USFWS 2021). This species is not known to occur in Delta County, Colorado but it is likely that potential habitat occurs in the subwatersheds.

3.2.1.4 BLM Sensitive Mammals

3.2.1.4.1 White-Tailed Prairie Dog

The white-tailed prairie dog, a BLM sensitive species, occurs in northwestern and west-central Colorado, and has a wide distribution across both watersheds (CPW 2020). It prefers level to gently sloping grasslands and open semi-desert shrublands from 5,000 to 10,000 feet in elevation, although most records are from below 8,500 feet (Armstrong et al. 2011). White-tailed prairie dogs occur in loosely organized colonies and their burrows and mounds may be present in the margins of irrigated lands, and in dams and irrigation ditch banks, adjacent to and near semi-desert shrublands and grasslands. Primary threats to prairie dogs are the sylvatic plague (BLM 2016), recreational shooting, and extermination (to remove them from agricultural lands). BLM’s primary purpose in tracking prairie dog colonies in the region is to monitor potential nesting locations for burrowing owls, another BLM sensitive species (Holsinger, pers. comm.2020). Prairie dog burrows serve as nesting sites for burrowing owl and provide shelter for a variety of rodents and reptiles. Prairie dogs are also a major source of prey for several raptor species in the region.

3.2.1.4.2 Bats

Three species of bats potentially found in appropriate habitat in both subwatersheds are considered sensitive by BLM—the spotted bat, fringed myotis, and Townsend’s big-eared bat (Table 3.5-4). The following information about the three BLM sensitive bat species was synthesized from the Colorado Bat Working Group (CBWG 2010).

Apparently quite rare in Colorado, spotted bats prefer rocky canyons and have been observed or captured in ponderosa pine woodlands, montane forests, pinyon-juniper woodlands, semi-desert shrublands, riparian vegetation, and over open sandbars. Individuals forage alone for moths, grasshoppers, beetles, katydids, and other insects. Lactating females have been captured in Colorado, but nursery and roost sites have not been located. Little is known about hibernation or its migratory movements.

The fringed myotis, thought to occur in scattered populations at moderate elevations in Colorado, feeds on moths, spiders, and beetles over semi-desert shrublands, coniferous woodlands, Gambel oak shrublands, and meadows, especially near water. It uses caves, mines, and buildings as day and night roosts, and seasonal migration is not thought to be extensive. No nursery colonies have been reported in Colorado.

The Townsend's big-eared bat feeds on moths, beetles, flies, and wasps along the edges of semi-desert shrublands, pinyon-juniper woodlands, and open montane forests. It can be found throughout Colorado, but its distribution may be limited to areas near caves and abandoned mines, which it uses for day roosts, nursery colonies, and hibernacula. Day roosts have also been documented in crevices on rock cliffs and abandoned buildings. Like the fringed myotis, Townsend's big-eared bats do not make major seasonal migrations.

Each of these bat species could be expected to forage in appropriate habitats in the subwatersheds and use rock outcrops, caves, or buildings as roosts.

3.2.1.4.3 Rocky Mountain Bighorn Sheep

CPW introduced desert bighorn sheep to the region in the 1980s and populations are closely managed on BLM lands. The desert bighorn inhabits steep, mountainous or hilly terrain with grass, low shrubs, rock cover, and areas near open escape and cliff retreats (BLM 2016). In the North Fork subwatershed, a small amount of overall range on BLM land is mapped near the north-facing steep slopes of Scenic Mesa along the North Fork River, about 1 mile upstream of the Gunnison River confluence. In the Crawford subwatershed, a small amount of overall range (CPW 2020) on BLM lands is mapped in the Smith Fork Canyon near the Gunnison River confluence.

3.2.1.5 BLM Sensitive Birds

3.2.1.5.1 Raptors

Each of the BLM sensitive raptor species in Table 3.5-4 has the potential to occur in appropriate habitat in each subwatershed. Each raptor has documented nest sites in or near at least one of the subwatersheds.

Bald eagles are rare summer residents and fairly common late fall and winter residents in the subwatersheds. CPW (2020a) maps bald eagle winter concentration areas in the North Fork River corridor, and winter feeding grounds and roosts across the valleys (Figure 3.5-3). Bald eagles forage across open pastures and low shrublands in winter for rodents and carrion, and along riverbanks for stranded fish or waterfowl. Nesting is rare in the region, but a few active nest sites have been recently documented (Figure 3.5-3) in or near the subwatersheds. Nests are typically constructed in the crowns of tall trees along forested rivers and lakes. Nesting is initiated as early as January and young are typically fledged before August. Human disturbance is thought to cause stress to nesting bald eagles, although some pairs have successfully nested near golf courses and other areas of high human activity (Kingery 1998).

The golden eagle hunts widely for rabbits and rodents over a variety of habitats in and near the subwatersheds, from low-elevation shrublands to alpine tundra. Nests are constructed on cliffs and steep escarpments in shrublands and grasslands. Mated pairs return to the same nest site or nearby alternate nest sites each year. Nesting building can initiate as early as January, with occupancy usually occurring in mid-April. Young are fledged between May and early August, depending on the year (Kingery 1998).

The peregrine falcon hunts in open country near cliff habitat, often near water such as rivers, lakes, and marshes. It nests on ledges or holes on cliff faces and crags between mid-March and mid- August. CPW (2020a) maps one potential peregrine nesting site in the project area, on Needle Rock on BLM land in the Crawford subwatershed. A recently active peregrine nest on the south side of Needle Rock has been noted by residents of the area.

The ferruginous hawk prefers open rolling and/or rugged terrain in grasslands, shrubsteppe communities, or cultivated fields. It nests on cliffs and rock outcrops. No nesting records exist in the project area (Holsinger, pers. comm.). Wintering birds could be present in appropriate habitat in the subwatersheds, especially open agricultural fields where burrowing rodents are present, but spring and fall migrants are more likely (Holsinger, pers. comm. 2020).

The burrowing owl prefers level to gently sloping grasslands and semi-desert grasslands. Prairie dog colonies are commonly used for shelter and nesting. BLM considers any prairie dog burrows to be potential nest sites for burrowing owl across the subwatersheds. Nesting occurs between April and July.

3.2.1.5.2 Brewer's Sparrow

Brewer's sparrow breeds primarily in sagebrush shrublands, less commonly in tall semi-desert shrublands, and occasionally in open pinyon-juniper woodlands with shrub understories. This species requires relatively large contiguous shrubland patches for nesting. Breeding records exist for southeast Delta County and the Uncompahgre Valley (Kingery 1998; Wickersham 2016). Nest building begins in mid-May, nests are occupied by June, and young are fledged by late July.

Brewer's sparrows select nest sites in open shrublands with relatively tall shrubs on gentle slopes far from habitat edges. Migrants occur in wooded, brushy, and weedy riparian, agricultural, and urban areas, and occasionally in pinyon-juniper woodlands.

3.2.1.6 BLM Sensitive Reptiles

3.2.1.6.1 Midget Faded Rattlesnake

The midget-faded rattlesnake, known only from Mesa, Delta, and Garfield Counties in Colorado (Hammerson 1999) is a BLM sensitive species due to its apparent rarity and small range. A major threat to the species is the long-term persecution by humans killing snakes out of concern for public safety. Taxonomists do not agree on whether this small distinctly colored snake represents a subspecies of the western rattlesnake (*Crotalus viridis* v. *concolor*) or a separate species (Hammerson 1999). The midget-faded rattlesnake reaches about 24 inches in length, with brownish dorsal blotches on a tan, cream, or yellow-brown background color. In older adults the blotches are faded or sometimes absent. The species can occupy a wide range of vegetation communities, but appears to prefer rocky areas, often near riparian corridors, especially with a south aspect. They are active outside their hibernacula from about May to September, and young are produced between late August and early October. The BLM's UFO is currently working with researchers to develop a predictive habitat model for midget faded rattlesnake (Holsinger, pers. comm.). Preliminary modeling predicts that terrain north of Olathe is the most likely area to be occupied by the species near the project area.

3.2.1.7 Federally Protected Fish Species

3.2.1.7.1 Bonytail Chub

The bonytail chub was listed as an endangered species in 1980 and critical habitat was designated in 1994 (USFWS 1994). Bonytail chubs are the rarest fish in the Colorado River Basin and can reach lengths of up to 22 inches and weigh as much as 2.4 pounds (USFWS 1994, 2002a).

Bonytail chub were historically widespread in large rivers of the Colorado River Basin; however, beginning in the 1950s, the species' population and range declined dramatically (USFWS 2002a). The wild population generally consists of low numbers of mature fish and very low to nonexistent recruitment (USFWS 1994). In the Lower Colorado River Basin, the species has been recorded in Lake Mojave and Lake Havasu. In the Upper Colorado River Basin, the species has been documented in the Yampa River in Dinosaur National Monument, the Green River in Desolation and Gray Canyons, and the Colorado River in Black Rocks and Cataract Canyon (USFWS 1994). The species is rarely found in the Green River and Colorado River subbasins (USFWS 2002a).

The bonytail chub inhabits pools and eddies in the warm waters of the Colorado River mainstem and tributaries (USFWS 2002a). Because the species was extirpated from most its historic range prior to extensive surveys, little is known about specific habitat preferences. Spawning takes place in pools and eddies over rocky substrates with silt-boulder mixtures and flooded bottomlands are used for nursery habitat (USFWS 2002a). Ongoing recovery efforts by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) have included a stocking program for bonytail chub; as part of this program, fish have been released into the Yampa, Green, and Colorado Rivers (Upper Colorado River Endangered Fish Recovery Program 2015).

The primary threats to the bonytail chub include streamflow regulation, habitat modification, predation by nonnative fish species, hybridization, and pesticides and pollutants (USFWS 2002a).

3.2.1.7.2 Colorado Pikeminnow

The Colorado pikeminnow was listed as an endangered species in 1967 and critical habitat was designated in 1994 (USFWS 1994). The species is North America's largest minnow species and can reach up to approximately 6 feet in length and weigh as much as 80 pounds (USFWS 2002b).

Colorado pikeminnows prefer fast muddy rivers with quiet backwaters, pools, deep runs, and eddies maintained by high spring flows (USFWS 2002b).

Colorado pikeminnows have historically occurred throughout the Colorado River system in Colorado, Wyoming, Utah, New Mexico, Arizona, Nevada, California, and Mexico. Presently, three wild populations occur in the Green River, Upper Colorado River, and San Juan River subbasins (USFWS 2002b). The decline of the species throughout its range is attributed to extensive habitat loss, modification, and fragmentation and blocked fish passage associated with dam construction and operations. Other threats include competition with and predation by nonnative fish species, and decreased water quality from pesticides and contaminants (specifically selenium and mercury) (USFWS 2002b).

Recovery efforts include development of flow recommendations, mechanical removal of nonnative fishes, modifying or removing instream water diversion structures to provide fish passage, monitoring fish population numbers, and development of backwaters for early life stages (Aspinall Unit Study Plan ad hoc Committee 2011). According to the fiscal year 2016 annual project report, 33 subadult and adult Colorado pikeminnow were captured in the Redlands fish passage during 2016 at the Redlands Diversion Dam on the Gunnison River (Colorado River Recovery Program [CRRP] 2016).

The primary threats to the Colorado pikeminnow include streamflow regulation, habitat modification, competition with and predation by nonnative fish species, and pesticides and pollutants (USFWS 2002b).

3.2.1.7.3 Humpback Chub

The humpback chub was listed as an endangered species in 1967; critical habitat was designated in 1994 (USFWS 1994). Humpback chubs are a medium sized minnow (averaging less than 20 inches in length) endemic to the Colorado River basin (USFWS 1990). The species has a unique body shape that is believed to aid in navigating turbulent, deep-water habitats of the Colorado River system.

Humpback chubs are highly adapted to turbid water conditions with fluctuating hydrology; the species lives and completes its life cycle in the canyon-bound reaches of the Colorado mainstem and larger tributaries (USFWS 2002c). Within the mainstem of the Colorado River, humpback chubs have been recorded in a variety of habitats – including swift currents, deep pools, riffles, shoreline eddies, and rapids (USFWS 1994). Adults and juveniles require eddies and sheltered shoreline habitats (USFWS 2002c). Humpback chubs are reproductive from May to July, depending on the location. Spawning generally occurs over gravel and cobble deposits at or soon after peak flows in spring (USFWS 2002c).

The humpback chub's historic distribution included portions of the mainstem Colorado River and four tributaries: the Green, Yampa, White, and Little Colorado Rivers (USFWS 1994). The species' most recently known distribution includes the Yampa River in Dinosaur National Monument (Colorado); the Green River in Desolation Canyon, Gray Canyon, and Dinosaur National Monument (Utah and Colorado); the Little Colorado River (Arizona); and several stretches of the Colorado River – Marble and Grand Canyons (Arizona), Cataract and Westwater Canyons (Utah), and Black Rocks (Colorado) (USFWS 1990).

The primary threats to the humpback chub include streamflow regulation, habitat modification, predation by nonnative fish species, parasitism, hybridization with other native *Gila* species, and pesticides and pollutants (USFWS 2002c).

3.2.1.7.4 Razorback Sucker

The razorback sucker was listed as an endangered species in 1991 (USFWS 1991) and critical habitat was designated in 1994 (USFWS 1994). The razorback sucker can reach 3 feet in length and weigh up to 13 pounds, qualifying as one of North America's largest suckers (USFWS 2002d). The razorback sucker is found in large rivers with depths ranging from 4 to 10 feet as well as some reservoirs. Habitat for razorback sucker varies seasonally, with deep runs, eddies, backwaters, and flooded off-channels used in spring, runs and shallow pools in summer, and low-velocity runs, pools, and eddies in winter (USFWS 2002d). Turbidity can range from clear to muddy, and substrate can range from mud to sand to gravel. This species may spawn in a variety of river or reservoir habitats, and young require nursery environments with quiet, warm, shallow waters (USFWS 2002d).

Historically, razorback sucker was widespread in warmwater reaches of large rivers in the Colorado River Basin, from Wyoming south to Mexico (USFWS 2002d). The species is currently found in the Green River, Upper Colorado River, and San Juan River subbasins; lower Colorado River between Lake Havasu and Davis Dam; reservoirs of Lakes Mead and Mohave; tributaries of the Gila River subbasin; and in local areas under intensive management such as Cibola High Levee Pond, Achii Hanyo Native Fish Facility, and Parker Strip (USFWS 2002d).

The Recovery Program experimentally stocked razorback suckers in the lower Gunnison River (i.e., downstream of Delta) during the mid-1990s and initiated an integrated stocking plan in 2003 (Bureau of Reclamation [Reclamation] 2008). Successful spawning activity has been documented in the Gunnison River between the Redlands Diversion Dam and Delta (Reclamation 2008). According to the fiscal year 2010 annual project report, 27 razorback suckers ascended the fish passageway at the Redlands Diversion Dam on the Gunnison River (CRRP 2010). One razorback sucker was captured in the Redlands fish passage during 2016 (CRRP 2016).

The primary threats to the razorback sucker include streamflow regulation, habitat modification, predation by nonnative fish species, and pesticides and pollutants (USFWS 2002d).

3.2.1.8 BLM Sensitive Amphibian and Fish Species

3.2.1.8.1 Northern Leopard Frog

The northern leopard frog is known to occur in Delta County (CNHP 2015). Typical habitats include wet meadows, springs, and the banks and shallows of marshes, ponds, glacial kettle ponds, beaver ponds, lakes, reservoirs, streams, and irrigation ditches (NatureServe 2015). The northern leopard frog breeds in shallow quiet areas of permanent bodies of water, in beaver ponds, and in seasonally flooded areas adjacent to or contiguous with permanent pools or streams. They may forage along the water's edge or in nearby meadows or fields. Part of their statewide decline seems to be due to predation by the bullfrog (*Rana catesbiana*), which was native to the eastern United States but introduced in Colorado (Lyon and Williams 1998).

3.2.1.8.2 Canyon Treefrog

Distribution of the canyon treefrog includes Delta County (International Union for Conservation of Nature 2004). The canyon treefrog prefers habit along rocky, intermittent and perennial stream courses in canyons. Its current range includes the canyons of the west-central and southwestern Colorado (NatureServe 2015). The canyon tree frog typically breeds in temporary or permanent pools along intermittently flowing streams, primarily in spring (April-July) and perhaps sometimes after heavy rains in summer. Larvae metamorphose into small frogs as early as late July.

3.2.1.8.3 Colorado River Cutthroat Trout

The Colorado River cutthroat trout is native to Colorado, but is seldom found to be genetically pure due to hybridization with introduced rainbow trout (*Oncorhynchus mykiss*). Historic range was on the West Slope (west of the Continental Divide) and included the Yampa and White Rivers (USFWS 2014). The range has been reduced due to competition with introduced nonnative trout species such as brook trout, hybridization with nonnative trout, disease (i.e., whirling disease), and habitat alteration such as fragmentation and dewatering by water diversions. They typically occur as isolated populations in high-elevation lakes and streams.

The North Fork of the Gunnison River is in the historic range for the Colorado River cutthroat trout (Hirsch et al. 2013). Of the 663 kilometers of historic stream habitat in the North Fork, only 77.3 kilometers are currently occupied by the Colorado River cutthroat trout, representing 11 percent of the historic range (Hirsch et al. 2013). This fish has been documented in the North Fork and Crawford subwatersheds (CNHP 2015; Hirsch et al. 2013).

3.2.1.8.4 Bluehead Sucker

The bluehead sucker is found in only 45 percent of its historic range, but is known to occur in Delta County (Bezzerides and Bestgen 2002; CNHP 2015). The bluehead sucker prefers large rivers and mountain streams and is rarely found in lakes. Occupied habitat is variable, from cold, clear mountain streams to warm, turbid streams. This fish typically prefers moderate to fast flowing water above rubble-rock substrate. Young prefer quiet shallow areas near shoreline. Spawning at higher elevations occurs mid- to late summer.

Dams and reservoirs, water diversions and associated changes in flow, stream channelization, and general deterioration of riparian corridors are major threats to this species (Ptacek et al. 2005).

Hybridization between the nonnative white sucker (*Catostomus commersoni*) and bluehead sucker has been documented, as well as individuals with genetic contributions from the white sucker, bluehead sucker, and native flannelmouth sucker (*Catostomus latipinnis*) (McDonald et al. 2008).

The bluehead sucker is vulnerable to predation from nonnative fish species including northern pike and brown trout (Webber et al. 2012). Development in riparian areas can affect the quality of occupied bluehead sucker habitat.

3.2.1.8.5 Flannelmouth Sucker

The flannelmouth sucker prefers warm moderate- to large-sized rivers. They are seldom captured in small creeks and are typically absent from impoundments (Utah Department of Natural Resources [UDNR] 2006). They prefer pool habitat and deeper runs, often near tributary mouths. They also occupy riffles and backwaters. They generally occupy streams with minimal vegetation, moderate to high turbidities, and high spring flows. Channel depths can range from 1 to 6 feet, with substrates consisting of rocks, gravel, or mud. Young usually occupy shallower water than adults. Seasonal migrations are made in the spring to suitable spawning habitat. Habitat degradation (including changes in substrate, instream habitat complexity, and flow regimes) and interactions with nonnative species have been identified as primary threats to flannelmouth sucker. Obstruction to movement caused by dams or diversions has resulted in the loss of spawning habitat and habitat quality (changes to channel geometry, water chemistry, water temperature, and flow regimes (Rees et al. 2005). Some dams may have a positive impact by creating a barrier to the upstream spawning of nonnative fish species that prey on, hybridize, and compete with flannelmouth sucker for resources (CPW 2016). Therefore, dams and diversions can be part of a conservation strategy to maintain species survival.

3.2.1.8.6 Roundtail Chub

The roundtail chub uses slow-moving deep pools for cover and feeding (UDNR 2006). They occupy medium to large warmwater streams and rivers with rocky runs, rapids, and pools. The historical range for this species included the Colorado River and its tributaries from southwestern Wyoming, Utah, and Colorado southward to the Little Colorado River confluence in Arizona, south of which the species occurred only in primary tributaries of the Colorado River (Carman 2006). The roundtail chub is not known to occur in the Gunnison River drainage or tributaries. It also inhabits large reservoirs in the Upper Colorado River system. They generally prefer cobble-rubble, sand-cobble, or sand-gravel substrates. Adults prefer pools associated with undercut banks and other types of cover, while young fish inhabit shallower water with lower flows. Runs and riffles are used to feed. Spawning begins in June to early July.

Their decline in the Gunnison River has been attributed in part to cold water releases downstream of Curecanti Dam (Woodling 1985).

3.2.1.9 Lists of Species Mentioned in the Supplemental Plan-EA Text or Appendix E

Tables E-2 and E-3 list plant and wildlife species, respectively, mentioned in the Supplemental Plan-EA or this Appendix E.

Table E-2. Common and Scientific Names of Plant Species Mentioned in the Supplemental Plan-EA Text or Appendix E.

Common Name	Scientific Name	Threatened and Endangered Species	BLM Sensitive Species	Nonnative
Antelope bitterbrush	*Purshia tridentata*			
Aspen	*Populus tremuloides*			
Baltic rush	*Juncus arcticus*			
Basin big sagebrush	*Artemisia tridentata* ssp. *tridentata*			
Black sagebrush	*Artemisia nova*			
Blue spruce	*Picea pungens*			
Bottlebrush squirreltail	*Elymus elymoides*			
Boxelder	*Acer negundo*			
Broom snakeweed	*Gutierrezia sarothrae*			
Bud sagebrush	*Picrothamnus desertorum*			
Canada thistle	*Cirsium arvense*			X
Cattail	*Typha* sp.			
Clay-loving wild buckwheat	*Eriogonum pelinophilum*	X		
Colorado desert parsley	*Lomatium concinnum*		X	
Colorado hookless cactus	*Sclerocactus glaucus*	X		
Common cocklebur	*Xanthium strumarium*			X
Coyote willow	*Salix exigua*			
Crandall's rockcress	*Boechera crandallii (Arabis crandallii)*		X	
Crested wheatgrass	*Agropyron cristatum*			X
Dandelion	*Taraxacum officinale*			X
Douglas-fir	*Pseudotsuga menziesii*			
Downy brome (cheatgrass)	*Bromus tectorum*			X
Drummond's willow	*Salix drummondiana*			
Elk sedge	*Carex geyeri*			
Engelmann spruce	*Picea engelmannii*			
Field bindweed	*Convolvulus arvensis*			X
Fourwing saltbush	*Atriplex canescens*			
Fremont cottonwood	*Populus fremontii*			
Gambel oak	*Quercus gambelii*			
Greasewood	*Sacrobatus vermiculatus*			
Giant reed	*Arundo donax*			
Grand Junction milkvetch	*Astragalus linifolius*		X	
Halogeton	*Halogeton glomeratus*			X
Hoary cress (whitetop)	*Cardaria* sp.			X
Houndstongue	*Cynoglossum officinale*			X
Jointed goat grass	*Aegilops cylindrica*			X
Kochia	*Bassia scoparia*			X
Mat saltbush	*Atriplex corrugata*			
Meadow-rue	*Thalictrum* sp.			
Mountain mahogany	*Cercocarpus montanus*			
Mountain big sagebrush	*Artemisia tridentata* ssp. *vaseyana*			
Narrowleaf cottonwood	*Populus angustifolia*			
Naturita milkvetch	*Astragalus naturitensis*		X	

Common Name	Scientific Name	Threatened and Endangered Species	BLM Sensitive Species	Nonnative
Oxeye daisy	*Leucanthemum vulgare*			X
Paradox breadroot	*Pediomelum aromaticum*		X	
Paradox Valley (Payson's) lupine	*Lupinus crassus*		X	
Pinyon pine	*Pinus edulis*			
Ponderosa pine	*Pinus ponderosa*			
Puncturevine	*Tribulus terrestris*			X
Purple loosestrife	*Lythrum salicaria*			X
Redosier dogwood	*Cornus sericea*			
Redstem filaree (stork's bill)	*Erodium cicutarium*			X
Reed canarygrass	*Phalaroides arundinacea*			
Rocky Mountain juniper	*Juniperus scopulorum*			
Russian knapweed	*Acroptilon repens*			X
Russian olive	*Elaeagnus angustifolia*			X
Salt cedar (tamarisk)	*Tamarix* sp.			X
Saltbush	*Atriplex* spp.			
Saltgrass	*Distichlis stricta*			
Sandstone milkvetch	*Astragalus sequiflorus*		X	
San Rafael milkvetch	*Astragalus rafaelensis*		X	
Scentless chamomile	*Tripleurospermum perforata*			X
Shadscale	*Atriplex confertifolia*			
Siberian elm	*Ulmus pumila*			X
Skunkbush sumac	*Rhus trilobata*			
Softstem bulrush	*Schoenoplectus tabernaemontani*			
Spikerush	*Eleocharis palustris*			
Subalpine fir	*Abies lasiocarpa*			
Sweetclover	*Melilotus* spp.			X
Thinleaf alder	*Alnus incana ssp. tenuifolia*			
Three-square bulrush	*Schoenoplectus pungens*			
Tumbleweed (Russian thistle)	*Salsola kali*			X
Uncompahgre bladderpod	*Lesquerella* (aka *Physaria) vicina*		X	
Utah juniper	*Juniperus osteosperma*			
Wyoming big sagebrush	*Artemisia tridentata* ssp. *wyomingensis*			
Yellow toadflax	*Linaria vulgaris*			X

Table E-3. Common and Scientific Names of Wildlife Species Mentioned in the Supplemental Plan-EA Text and in Appendix E.

Common Name	Scientific Name	Mammal	Fish	Reptile	Amphibian	Bird
Allen's (Mexican) big-eared bat	*Idionycteris phyllotis*	X				
American avocet	*Recurvirostra americana*					X
American badger	*Taxidea taxus*	X				
American bittern	*Botaurus letiginosus*					X
American bullfrog	*Lithobates catesbeianus*				X	
American coot	*Fulica americana*					X
American kestrel	*Falco sparverius*					X
American peregrine falcon	*Falco peregrines*					X
American robin	*Turdus migratorius*					X
Bald eagle	*Haliaeetus leucocephalus*					X
Beaver	*Castor canadensis*	X				
Belted kingfisher	*Ceryle alcyon*					X
Black bear	*Ursus americanus*	X				
Black bullhead	*Ameiurus melas*		X			
Black crappie	*Pomoxis nigromaculatus*		X			
Black rosy-finch	*Leucosticte atrata*					X
Black swift	*Cypseloides niger*					X
Black-billed magpie	*Pica pica*					X
Black-chinned hummingbird	*Archilochus alexandri*					X
Bluegill	*Lepomis macrochirus*		X			
Bluehead sucker	*Catostomus discobolus*		X			
Bobcat	*Lynx rufus*	X				
Bonytail chub	*Gila elegans*		X			
Brewer's blackbird	*Euphagus cyanocephalus*					X
Brewer's sparrow	*Spizella breweri*					X
Broad-tailed hummingbird	*Selasphorus platycercus*					X
Brook trout	*Salvelinus fontinalis*		X			
Brown-capped rosy-finch	*Leucosticte australis*					X
Brown trout	*Salmo trutta*		X			
Bufflehead	*Bucephala albeola*					X
Bullfrog	*Lithobates catesbeianus*				X	
Bullsnake	*Pituophis catenifer*			X		
Burrowing owl	*Athene cunicularia*					X
Canada goose	*Branta canadensis*					X
Canyon tree frog	*Hyla arenicolor*				X	
Cassin's finch	*Carpodacus cassinii*					X
Channel catfish	*Ictalurus punctatus*		X			
Chestnut-collared longspur	*Calcarius ornatus*					X
Chipmunk	*Neotamias* spp.	X				
Chipping sparrow	*Spizella passerina*					X
Cinnamon teal	*Anas cyanoptera*					X
Clark's grebe	*Aechomophorus clarkia*					X
Collared lizard	*Crotaphytus collaris*			X		
Colorado pikeminnow	*Ptychocheilus lucius*		X			
Colorado River cutthroat trout	*Oncorhynchus clarki pleuriticus*		X			
Common carp	*Cyprinus carpio*		X			
Common merganser	*Mergus merganser*					X
Common nighthawk	*Chordeiles minor*					X
Common raven	*Corvus corax*					X
Cooper's hawk	*Accipiter cooperii*					X
Coyote	*Canis latrans*	X				
Desert bighorn sheep	*Ovis canadensis nelsoni*	X				
Desert cottontail rabbit	*Sylvilagus audubonii*	X				
Dusky grouse	*Dendragapus obscurus*					X
Elk	*Cervus canadensis*	X				

Common Name	Scientific Name	Mammal	Fish	Reptile	Amphibian	Bird
European starling	*Sturnus vulgaris*					X
Fence lizard	*Sceloporus undulatus*			X		
Ferruginous hawk	*Buteo regalis*					X
Flammulated owl	*Otus flammeolus*					X
Flannelmouth sucker	*Catostomus latipinnis*		X			
Fox sparrow	*Passerilla iliaca*					X
Fringed myotis	*Myotis thysanodes*	X				
Gadwall	*Anas strepera*					X
Gizzard shad	*Dorosoma cepedianum*		X			
Golden eagle	*Aquila chrysaetos*					X
Grace's warbler	*Dendroica graciae*					X
Gray vireo	*Vireo vicinior*					X
Great basin spadefoot toad	*Spea intermontane*				X	
Great blue heron	*Ardea herodias*					X
Greater sandhill crane	*Grus canadensis tabida*					X
Great-horned owl	*Bubo virginianus*					X
Greenback cutthroat trout	*Oncorhynchus clarki stomias*		X			
Green sunfish	*Lepomis cyanellus*		X			
Green-tailed towhee	*Pipilo chlorurus*					X
Green-winged teal	*Anas crecca*					X
Ground squirrel	*Urocitellus* spp.	X				
Gunnison sage-grouse	*Centrocercus minimus*					X
Gunnison's prairie dog	*Cynomys gunnisoni*	X				
Horned lark	*Eremophila alpestris*					X
House sparrow	*Passer domesticus*					X
House wren	*Troglodytes aedon*					X
Humpback chub	*Gila cypha*		X			
Juniper titmouse	*Baeolophus griseus*					X
Killdeer	*Charadrius vociferus*					X
Kit fox	*Vulpes macrotis*	X				
Largemouth bass	*Micropterus salmoides*		X			
Lesser yellowlegs	*Tringa flavipes*					X
Lewis's woodpecker	*Melanerpes lewis*					X
Loggerhead shrike	*Lanius ludovicianus*					X
Long-billed curlew	*Numenius americanus*					X
Long-eared owl	*Asio otus*					X
Longnose dace	*Rhinichthys cataractae*		X			
Longnose leopard lizard	*Gambelia wislizenii*			X		
Lynx	*Lynx canadensis*	X				
Mallard	*Anas platyrhynchos*					X
Mexican spotted owl	*Strix occidentalis lucida*					X
Midget faded rattlesnake	*Crotalus viridis concolor*			X		
Mink	*Neovison vison*	X				
Shira's moose	*Alces alces shirasi*	X				
Mottled sculpin	*Cottus bairdii*		X			
Mountain bluebird	*Sialia currucoides*					X
Mountain chickadee	*Poecile gambeli*					X
Mountain cottontail rabbit	*Sylvilagus nuttallii*	X				
Mountain lion	*Puma concolor*	X				
Mountain plover	*Charadrius montanus*					X
Mouse	*Peromyscus* spp.	X				
Mule deer	*Odocoileus hemionus*	X				
Muskrat	*Ondatra zibethicus*	X				
Northern harrier	*Circus cyaneus*					X
Northern flicker	*Colaptes auratus*					X
Northern goshawk	*Accipiter gentilis*					X
Northern leopard frog	*Rana pipiens*				X	

Common Name	Scientific Name	Mammal	Fish	Reptile	Amphibian	Bird
Northern pike	*Esox lucius*		X			
Northern raccoon	*Procyon lotor*	X				
Olive-sided flycatcher	*Contopus cooperi*					X
Peregrine falcon	*Falco peregrinus*					X
Pied-billed grebe	*Podilymbus podiceps*					X
Pinyon jay	*Gymnorhinus cyanocephalus*					X
Plateau striped whiptail	*Cnemidophorus velox*			X		
Plumbeous vireo	*Vireo plumbeus*					X
Porcupine	*Erethizon dorsatum*	X				
Prairie falcon	*Falco mexicanus*					X
Pygmy nuthatch	*Sitta pygmaea*					X
Rainbow trout	*Oncorhynchus mykiss*		X			
Razorback sucker	*Xyrauchen texanus*		X			
Red fox	*Vulpes vulpes*	X				
Red-tailed hawk	*Buteo jamaicensis*					X
Red-winged blackbird	*Agelaius phoeniceus*					X
Ring-necked pheasant	*Phasianus colchicus*					X
Ringtail cat	*Bassariscus astutus*	X				
River otter	*Lontra canadensis*	X				
Rocky Mountain bighorn sheep	*Ovis canadensis*	X				
Roundtail chub	*Gila robusta*		X			
Ruby-crowned kinglet	*Regulus calendula*					X
Rufous hummingbird	*Selasphorus rufus*					X
Sage thrasher	*Oreoscoptes montanus*					X
Sagebrush lizard	*Sceloporus graciosus*			X		
Short-eared owl	*Asio flammeus*					X
Short-horned lizard	*Phrynosoma hernandesi*			X		
Smallmouth bass	*Micropterus dolomieu*		X			
Smooth green snake	*Liochlorophis vernalis*			X		
Snowy plover	*Chardrius alexandrines*					X
Song sparrow	*Melospiza melodia*					X
Sora	*Porzana carolina*					X
Speckled dace	*Millicoma daces*		X			
Spotted bat	*Euderma maculatum*	X				
Spotted sandpiper	*Actitis macularia*					X
Spotted skunk	*Spilogale* sp.	X				
Spotted towhee	*Pipilo maculatus*					X
Striped skunk	*Mephitis mephitis*	X				
Swainson’s hawk	*Buteo swainsini*					X
Tiger salamander	*Ambystoma tigrinum*				X	
Townsend's big-eared bat	*Corynorhinus townsendii*	X				
Turkey vulture	*Cathartes aura*					X
Veery	*Catharus fuscescens*					X
Vesper sparrow	*Pooecetes gramineus*					X
Virginia's warbler	*Vermivora virginiae*					X
Vole	*Microtus* spp.	X				
Weasel	*Mustela* spp.	X				
Western chorus frog	*Pseudacris triseriata*				X	
Western grebe	*Aechmophorus occidentalis*					X
Western meadowlark	*Sturnella neglecta*					X
Western terrestrial garter snake	*Thamnophis elegans*			X		
Western wood-pewee	*Contopus sordidulus*					X
Western yellow-billed cuckoo	*Coccyzus americanus*					X
White sucker	*Catostomus commersonii*		X			
White-crowned sparrow	*Zonotrichia leucophrys*					X
White-faced ibis	*Plegadis chihi*					X
White-tailed jackrabbit	*Lepus townsendii*	X				

Common Name	Scientific Name	Mammal	Fish	Reptile	Amphibian	Bird
White-tailed prairie dog	*Cynomys leucurus*	X				
Wild turkey	*Meleagris gallopavo*					X
Williamson's sapsucker	*Sphyrapicus thyroideus*					X
Willow flycatcher	*Empidonax traillii*					X
Wilson's phalarope	*Phalaropus tricolor*					X
Wolverine	*Gulo gulo luscus*	X				
Woodhouse’s toad	*Anaxyrus woodhousii*				X	
Woodrat	*Neotoma* spp.	X				
Yellow perch	*Perca flavescens*		X			
Yellow warbler	*Dendroica petechia*					X
Yellow-bellied marmot	*Marmota flaviventris*	X				
Yellow-rumped warbler	*Dendroica coronata*					X

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USFWS 1994	United States Fish and Wildlife Service (USFWS). (1994). Endangered and threatened wildlife and plants; determination of critical habitat for Colorado river endangered fishes: razorback sucker, Colorado squawfish, humpback chub, and bonytail chub. *Federal Register, 59*(54). March 21, 1994.
USFWS 2002a	United States Fish and Wildlife Service (USFWS). (2002a). *Bonytail (Gila elegans) recovery goals: amendment and supplement to the bonytail chub recovery plan*. Denver, CO: U.S. Fish and Wildlife Service.

USFWS 2002b	United States Fish and Wildlife Service (USFWS). (2002b). *Colorado pikeminnow (Ptychocheilus lucius) recovery goals: amendment and supplement to the Colorado squawfish recovery plan.* Denver, CO: U.S. Fish and Wildlife Service.
USFWS 2002c	United States Fish and Wildlife Service (USFWS). (2002c). *Humpback chub (Gila cypha) recovery goals: amendment and supplement to the humpback chub recovery plan.* Denver, CO: U.S. Fish and Wildlife Service.
USFWS 2002d	United States Fish and Wildlife Service (USFWS). (2002d). *Razorback sucker (Xyrauchen texanus) recovery goals: amendment and supplement to the razorback sucker recovery plan.* Denver, CO: U.S. Fish and Wildlife Service.
USFWS 2014	U.S. Fish and Wildlife Service (USFWS). (2014). *Final summary report: greenback cutthroat trout genetics and meristics studies facilitated expert panel workshop*. USFWS Order No. F13PB00113. Golden, CO: AMEC Environment and Infrastructure, Inc. Retrieved from: http://cpw.state.co.us/Documents/Research/Aquatic/ CutthroatTrout/2014GreenbackCutthroatTroutWorkshopSummary.pdf.
USFWS 2017	U.S. Fish and Wildlife Service (USFWS). (2017). *ECOS (Environmental Conservation Online System*). http://ecos.fws.gov/ecp/species-reports.
USFWS 2020	U.S. Fish and Wildlife Service (USFWS). (2020). Monarch (*Danaus plexippus*) Species Status Assessment Report. V2.1 96 pp + appendices.
USFWS 2021	U.S. Fish and Wildlife Service (USFWS). (2021). Species status assessment report for *Speyeria nokomis nokomis.* Grand Junction, Colorado.
Webber et al. 2012	Webber, P. A., Thompson, P. D., and Budy, P. (2012). Status and structure of two populations of bluehead sucker (*Catostomus discobolus*) in the Weber River, Utah. *The Southwestern Naturalist, 57*(3), 267-276.
Western Monarch Milkweed Mapper 2023	Western Monarch Milkweed Mapper. (2023). Western Monarch Milkweed Mapper. https://www.monarchmilkweedmapper.org/app/#/combined/map. .
Wickersham 2016	Wickersham, L. (Ed.). (2016). *Colorado breeding bird atlas* (2nd ed). Denver, CO: Colorado Bird Atlas Partnership & Colorado Division of Wildlife. Online dataset retrieved from http://cobreedingbirdatlasii.org/index.html.
Woodling 1985	Woodling, J. (1985). *Colorado's little fish: a guide to the minnows and other lesser known fishes in the state of Colorado.* Denver, CO: Colorado Division of Wildlife, Department of Natural Resource.

E.4 Supporting Information for Cultural Resources

4.1 Memorandum of Agreement

MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
THE BUREAU OF LAND MANAGEMENT,
AND THE COLORADO STATE HISTORIC PRESERVATION OFFICER
REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

WHEREAS, the Natural Resources Conservation Service (NRCS) as the lead agency is working in partnership with Colorado River Water Conservation District (CRWCD) to improve irrigation systems in Delta County by implementing irrigation system efficiency modernization, including piping, water control facilities, and Supervisory Control and Data Acquisition (SCADA) improvements within the North Fork watershed area and Crawford watershed area (hereafter referred to as the "Project"); and

WHEREAS, the NRCS is providing funding through the Watershed Protection and Flood Prevention Act of 1954 (Public Law [P.L.] 83-566, thereby making the Project an undertaking subject to review under Section 106 of the National Historic Preservation Act (NHPA), 54 USC 306108, and its implementing regulations, 36 CFR Part 800; and

WHEREAS, the NRCS in consultation with the Colorado State Historic Preservation Officer (SHPO) has defined the Projects' Area of Potential Effects (APE) as 89.08 acres, including a 200-foot buffer around each SCADA site and a headgate replacement, a 100-foot buffer along piped areas, and a 50-foot buffer along access roads, the APE is primarily located on private property (69.61 acres), Bureau of Reclamation (BOR; 16.85 acres), and Bureau of Land Management Uncompahgre Field Office (BLM-UFO) (2.1 acres); as indicated in the map included in Appendix A;

WHEREAS, the recorded segments of the Grandview Canal (5DT1780.7 and 5DT1780.8), and a segment of the Fire Mountain Canal (5DT1277.9) have, in consultation with the SHPO, been determined to be supporting segments of resources that are eligible for listing in the National Register of Historic Places under Criterion A, and that the Project will result in an adverse effect to these historic properties; and

WHEREAS, CRWCD, as the proponent for this Project, has participated in the consultation, and has accepted the invitation to participate in the Memorandum of Agreement as a Concurring Party; and

WHEREAS, the NRCS has consulted with the BOR and the BLM UFO regarding the effects of the undertaking on these resources, has invited the BOR and the BLM UFO to sign this Agreement as Signatory Parties and the invitation has been accepted; and

WHEREAS, the NRCS has consulted with the Fire Mountain Canal and Reservoir Company (FMC&RC), operator of the Fire Mountain Canal and the BOR, owner of the Fire Mountain Canal; and the Grand View Canal Irrigation Company (GVIC), operator and owner of the Grandview Canal, via letters sent December 3, 2020 and has invited the FMC&RC and GVIC to sign this Agreement as Concurring Parties and the invitation has been accepted; and

WHEREAS, the NRCS has consulted with the Southern Ute Indian Tribe, the Ute Mountain Ute Tribe, and the Ute Indian Tribe - Uintah & Ouray Reservation, via letters sent December 3, 2020, and as of signing this Agreement, the tribes did not respond; and

WHEREAS, in accordance with 36 CFR 800.6(a)(1), the NRCS has notified the Advisory Council on Historic Preservation (ACHP) of its adverse effect determination providing the specified documentation, and the ACHP has chosen not to participate in the consultation pursuant to 36 CFR 800.6(a)(1)(iii);

NOW, THEREFORE, pursuant to Section 106 of the NHPA, the NRCS, the BOR, the BLM UFO, and the SHPO agree that the Project shall be implemented in accordance with the following stipulations in order to take into account the effect of the Project on historic properties.

STIPULATIONS

The NRCS shall ensure that the following measures are carried out:

I. MITIGATION

A. NRCS shall develop, host, and maintain an interactive website intended to document the history and development of agricultural irrigation in Delta County and other surrounding areas in western Colorado. NRCS shall publish the website and maintain such open and free for the larger public for a period of no less than five (5) years following initial publication of the final, approved website content (see Stipulation I.B below). The website shall initially focus on the Grandview Canal (5DT1780) and the Fire Mountain Canal (5DT1277), but will be designed to allow the incorporation of other irrigation-related resources as part of future potential mitigation projects.

B. NRCS shall develop all content for the website described in Stipulation I.A. NRCS shall make all information, photographs, maps, images, etc. available to SHPO, BOR, BLM, and CRWCD for a review period of no less than thirty (30) calendar days. All parties to this Agreement shall have the opportunity to provide comments and edits, and approve the website's final content. NRCS shall provide draft content in either digital format or as links to the draft website along with an appropriate comment matrix document in .docx (Word) format. All parties shall provide comments to NRCS via email. NRCS shall consider all comments and edits provided by the parties and shall make all efforts to include such in the final website content as deemed appropriate by NRCS. NRCS shall notify all parties when the final, approved website has been published for public access.

C. NRCS shall publish the final, approved website content within no less than twelve (12) months of the execution of this Agreement.

D. The website will be in ArcGIS StoryMap format and will be targeted towards the general public as well as historic researchers. The website will include, at minimum, the following elements:
   a. A history of the Grandview Canal (5DT1780) and Fire Mountain Canal (5DT1277) and their role in the agricultural development in the region.
   b. Historic and modern images and maps of the ditches, including at least Segments (5DT1780.7), (5DT1780.8) and (5DT1277.9).
   c. A brief discussion of the importance of agriculture and irrigation as well as the development of such within the State of Colorado. The focus of such can be primarily of the Western Slope region of Colorado, but the website content should at least briefly discuss all this within the larger national and state trends and developments of agriculture and irrigation in the Western United States.
   d. Links to additional information, source materials, libraries, archives, and/or other websites that provide further context about agriculture and irrigation within the State of Colorado.

E. NRCS will publicize the website in a variety of ways, including, but not limited to the following:
   a. Inclusion in NRCS email newsletters sent to conservation partners across the State.
   b. Posting notices at local NRCS offices and Water Conservation Districts.

c. Informing organizations dedicated to historic research and water use, such as the CCPA and local area museums, specifically the Hotchkiss-Crawford Historical Museum.

F. NRCS shall prepare a report of all final, approved content prepared for the StoryMap for this Agreement. The report will be published in two formats: 1) as a digital PDF file; and 2) printed on archival quality paper. Copies of the report in both digital and paper formats will be provided free of charge to the SHPO and the Hotchkiss-Crawford Historical Museum.

G. All work, research, recording, documentation, etc. intended to fulfill Stipulation I of this Agreement shall be completed by qualified professionals meeting the *Secretary of the Interior's Historic Preservation Professional Qualification Standards* for the applicable field (see 48 FR 44716, September 29, 1983, and 62 FR 33708, June 20, 1997). NRCS may hire a consultant to complete any work, research, or documentation required for this Agreement so long as the consultant meets the aforementioned professional qualification standards.

II. POST-REVIEW DISCOVERIES

If historic properties are discovered or unanticipated effects on historic properties found, the NRCS shall implement the discovery plan included as Appendix B of this Agreement.

III. DISPUTE RESOLUTION

Should any Signatory to this Agreement object at any time to any actions proposed or the manner in which the terms of this Agreement are implemented, the NRCS shall consult with such party to resolve the objection. If the NRCS determines that such objection cannot be resolved, the NRCS will:

A. Forward all documentation relevant to the dispute, including the NRCS's proposed resolution, to the ACHP. The ACHP shall provide the NRCS with its advice on the resolution of the objection within thirty (30) days of receiving adequate documentation. Prior to reaching a final decision on the dispute, the NRCS shall prepare a written response that takes into account any timely advice or comments regarding the dispute from the ACHP and the Signatories, and provide them with a copy of this written response. The NRCS will then proceed according to its final decision.

B. If the ACHP does not provide its advice regarding the dispute within the thirty (30) day time period, the NRCS may make a final decision on the dispute and proceed accordingly. Prior to reaching such a final decision, the NRCS shall prepare a written response that takes into account any timely comments regarding the dispute from the Signatories to this Agreement, and provide them and the ACHP with a copy of such written response.

C. It will be the responsibility of the NRCS to carry out all other actions subject to the terms of this Agreement that are not the subject of the dispute.

IV. AMENDMENTS

This Agreement may be amended when such an amendment is agreed to in writing by all signatories. The amendment will be effective on the date a copy signed by all of the signatories is filed with the ACHP.

V. DURATION AND TERMINATION

A. If the terms of this Agreement have not been implemented within five (5) years from the date of its execution, then this Agreement shall be considered null and void. In such an event, the NRCS shall notify the Signatories to this Agreement and, if it chooses to continue with the Project, then it shall reinitiate review of and consultation on the Project in accordance with 36 CFR 800.3 through 800.7.

B. In the event that the NRCS does not carry out the terms of this Agreement, the Signatories shall consult to seek amendment to this Agreement and proceed in accordance with 36 CFR 800.6(c)(8).

C. Any Signatory to this Agreement may terminate this Agreement by providing thirty (30) days' notice to the other parties, provided that the parties shall consult during the period prior to termination to seek agreement on amendments or other actions that would avoid termination. In the event of termination, the NRCS shall proceed in accordance with 36 CFR 800.6(c)(8), execute a new agreement in accordance with 800.6(c)(1) or request comments of the ACHP under 800.7(a).

VI. USDA Stipulations

A. The NRCS, the BOR, the BLM UFO, and the SHPO and their respective agencies will handle their own activities and utilize their own resources, including the expenditure of their own funds, in pursuing these objectives. Each party will carry out its separate activities in a coordinated and mutually beneficial manner.

B. Any transfer of funds from one party to another shall be done via a separate instrument as appropriate. Specific work projects or activities that involve the transfer of funds, services, or property among the NRCS, the BOR, the BLM UFO, and the SHPO and their respective agencies will require execution of separate agreements and be contingent upon the availability of appropriated funds. Negotiation, execution, and administration of each such agreement must comply with all applicable statutes and regulations.

SIGNATORY PAGE

MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
THE BUREAU OF LAND MANAGEMENT,
AND THE COLORADO STATE HISTORIC PRESERVATION OFFICER
REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

NATURAL RESOURCES CONSERVATION SERVICE

_________________________________ Date: ________________
Bronson Smart, Colorado State Conservationist (Acting)

SIGNATORY PAGE

MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
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REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

BUREAU OF RECLAMATION

LOUIS WARNER
2022.06.21 13:58:00 -06'00'
____ Date: _________________
Ed Warner, Area Manager for Reclamation's Western Colorado Area Office

SIGNATORY PAGE

MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
THE BUREAU OF LAND MANAGEMENT,
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REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

BUREAU OF LAND MANAGEMENT

SUZANNE COPPING Digitally signed by SUZANNE COPPING
Date: 2022.06.13 09:41:11 -06'00'

______________________________________ Date: ____________________
Suzanne Copping, Field Manager for the Uncompahgre Field Office

SIGNATORY PAGE

MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
THE BUREAU OF LAND MANAGEMENT,
AND THE COLORADO STATE HISTORIC PRESERVATION OFFICER
REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

COLORADO STATE HISTORIC PRESERVATION OFFICER

Patrick A. Eidman Digitally signed by Patrick A. Eidman
Date: 2022.06.22 12:55:23 -06'00'

______________________________________ Date: __________________

Dawn DiPrince, Colorado State Historic Preservation Officer

CONCURRING PARTY
MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
THE BUREAU OF LAND MANAGEMENT,
AND THE COLORADO STATE HISTORIC PRESERVATION OFFICER
REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

COLORADO RIVER WATER CONSERVATION DISTRICT

_______________________________ Date: 7/1/22

Andy Mueller, General Manager

CONCURRING PARTY

MEMORANDUM OF AGREEMENT
AMONG
THE NATURAL RESOURCES CONSERVATION SERVICE,
THE BUREAU OF RECLAMATION,
THE BUREAU OF LAND MANAGEMENT,
AND THE COLORADO STATE HISTORIC PRESERVATION OFFICER
REGARDING THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT
LOCATED IN DELTA COUNTY, COLORADO

GRANDVIEW DITCH COMPANY

_________________________________ Date: ______________
Mark LeValley, President

FIRE MOUNTAIN DITCH COMPANY

Dixie Luke - President Date: 6/29/2022
Dixie Luke, President

APPENDIX A

AREA OF POTENTIAL EFFECTS

[MAPS ARE REDACTED FOR PUBLIC]

APPENDIX B

POST-REVIEW DISCOVERY PLAN

PLAN AND PROCEDURES FOR THE UNANTICIPATED DISCOVERY OF CULTURAL RESOURCES

THE LOWER GUNNISON SUPPLEMENTAL WATERSHED PLAN PROJECT LOCATED IN DELTA COUNTY, COLORADO

I. INTRODUCTION

The Colorado River Water Conservation District, in partnership with the Natural Resources Conservation Service (NRCS), plans to improve irrigation systems in Delta County by implementing irrigation system efficiency modernization, including piping, water control facilities, and Supervisory Control and Data Acquisition (SCADA) improvements within the North Fork watershed area and Crawford watershed area. The following Post-Review Discovery Plan outlines procedures to follow, in accordance with state and federal laws, if cultural resource materials are discovered during construction.

II. RECOGNIZING CULTURAL RESOURCES

A cultural resource discovery could be prehistoric or historic. Examples include, but are not limited to:

- An accumulation of shell, burned rocks, or other food related materials
- An area of charcoal or very dark stained soil with artifacts,
- Stone tools or waste flakes (i.e. an arrowhead, or stone chips),
- Clusters of tin cans or bottles, logging or agricultural equipment that appears to be older than 50 years,
- Buried railroad tracks, decking, or other industrial materials.

When in doubt, assume the material is a cultural resource.

III. UNANTICIPATED DISCOVERIES PROCEDURES

A. In the events that previously unidentified cultural resources are identified during project implementation, the following steps shall be taken:

1. Construction will be immediately halted in the area of the discovery, and measures taken to protect the resource until such time that an NRCS Cultural Resources Specialist (CRS) or qualified professional inspects the work site.
2. Notify the NRCS. Contact the Area 1 CRS: Jeremy Omvig, 970-964-3593, jeremy.omvig@usda.gov.
3. The NRCS CRS shall inspect the discovery within 24 hours, if weather permits, and in consultation with the project sponsor, concerned Indian tribes, the Colorado State Historic Preservation Office (SHPO), the NRCS CRS shall establish a protective buffer zone surrounding the discovery.

4. All NRCS contact with media shall occur only under the direction of the NRCS Public Affairs Officer, as appropriate, and the NRCS State Conservationist.
5. Security shall be established to protect the resources/historic properties, workers, and private property. Local law enforcement authorities will be notified in accordance with applicable State law and NRCS policy in order to protect the resources. Construction and/or work may resume outside the buffer only when the State Conservationist determines it is appropriate and safe for the resources and workers.
6. The NRCS CRS shall notify the Colorado SHPO no later than 48 hours after the discovery and describe NRCS' assessment of the National Register eligibility of the property, as feasible and proposed actions to resolve any adverse effects to historic properties. The eligibility determination may require the assessment and advice of concerned Indian tribes, the Colorado SHPO, and technical experts not employed by the NRCS.
7. The Colorado SHPO shall respond within 48 hours from receipt of the notification with any comments on the discovery and proposed actions.
8. NRCS Colorado shall take any comments provided into account and carry out appropriate actions to resolve any adverse effects.
9. NRCS Colorado shall provide a report to the Colorado SHPO of the actions when they are completed.

B. The project is located on both federal and private lands. On federal land the requirements under the Native American Graves Protection and Repatriation Act (NAGPRA) apply (43 CFR Part 10). For all discoveries, the kinds of objects considered and referred to as NAGPRA items as defined in 43 CFR 10.2 (d) include: human remains, funerary objects, sacred objects, and objects of cultural patrimony. The requirements under State Law Colorado Revised Statute (CRS) for the Unmarked Human Graves Colorado Statute (CRS 24-80-1301-1305) applies if the human remains are on private lands. Additionally, the process described in the 2008 guidelines titled "Process for consultation, Transfer, and Reburial of culturally Unidentifiable Native American Human Remains and Associated Funerary Objects Originating from Inadvertent Discoveries on Colorado State and Private Lands" would be followed to ensure appropriate treatment for such discoveries.

The following steps shall be taken if human remains or suspected human remains, funerary objects, sacred objects, or objects of cultural patrimony are discovered in the project area during planning or during implementation.

1. Stop all work in the immediate vicinity of the remains.
2. Immediately notify the NRCS CRS and appropriate project manager.
3. Mark the area in which the remains or objects are located, as well as a minimum buffer area, with a radius of 30 meters (100 feet) surrounding the remains or objects. The buffer area may be larger if more remains or objects in the area are anticipated or, in the case of slopes or cut banks, where work located nearby may impact the site of the remains or objects. It is imperative that the remains or objects are protected from possible impacts while the appropriate parties are contacted to determine next steps.

4. Approaches for protecting the remains or objects from the elements include covering them with a tarp or other material, shoring up cut banks or trench walls so that no further exposure occurs, and making sure that no water will collect on or around the remains.
5. If remains are found that may not be human but are suspected to be, a qualified specialist must be called in for identification. The following contacts will be coordinated with immediately:
   NRCS State Cultural Resource Specialist
   Craig Dengel
   (719) 749-8596

   Delta County Sheriff
   970-874-2000

   Delta County Coroner
   970-874-5918

6. If the coroner determines that the remains are archeological and not of forensic interest, the coroner will notify the Colorado State Archaeologist (Holly Norton, (303) 866-2736/ holly.norton@state.co.us) of the discovery as well as consulting tribes. Notifications can be made by phone or email and should include a details description of the nature and extent of the remains and an accurate and precise legal location.
7. Planning and construction activities at the site can recommence only after the plan for treating the remains as outlined by CRS 24-80-1301 et seq. is complete

E.5 External Documents Used in Analysis

1. Applegate Group, Inc. (2019). Phase II Salinity Improvements, Feasibility Study, Prepared for the Fire Mountain Canal and Reservoir Company. AG File # 17-124. May. 19 pp.
2. Applegate Group, Inc. (2020). Fire Mountain Canal Regulating Reservoir Feasibility Study. AG File # 18-128. August 12. 68 pp.
3. J-U-B Engineers. (2016). North Fork Water Conservancy District: master plan and funding plan. Kaysville, UT: J-U-B Engineers.
4. J-U-B Engineers. (2017). North Fork of the Gunnison River Irrigation Management Plan. Palisade, CO: J-U-B Engineers.
5. Irrigation Training and Research Center. (2017). Integrated Assessment, Comprehensive Implementation Planning and Engineering Review: Fire Mountain Reconfiguration Project. Prepared for: Colorado River Water Conservation District.

Phase II Salinity Improvements
Feasibility Study

May 2019

AG File # 17-124

Fire Mountain Canal
and Reservoir Company

Applegate Group, Inc.
Water Resource Advisors for the West
www.applegategroup.com
303-452-6611

INTRODUCTION

This study was funded through the Delta Conservation District, with funds provided by the Colorado Water Conservation Board to provide technical assistance to ditch companies for planning and applying for federal funds. Fire Mountain Canal was awarded funding from the Colorado River Basin-wide Salinity Control Program for piping the lower end of the Canal identified as Segment 47 following application to the 2015 Funding Opportunity Announcement (FOA). The purpose of this study is to investigate the feasibility of several additional proposed improvements to the Fire Mountain Canal. The Colorado River Basin-wide Salinity Control Program is presumed to be a major source of funding for most of these improvements, though it is anticipated that additional funding would also be required to complete financing of all proposed improvements.

PROPOSED IMPROVEMENTS

The following improvement projects were identified in the 2015 Master Study completed by J-U-B Engineers, and further evaluated in this study:

- Wolf Park Siphon,
- Coal Road to 3300 Road pipeline,
- 3300 Rd to Leroux Creek pipeline,
- Garvin Mesa pipeline.

The feasibility of piping additional reaches of the Fire Mountain Canal was analyzed based on the following assumptions:

- Pressurized pipeline for all sections except Garvin Mesa;
- Preliminary salt loads provided by Andrew Limbach, USBR hydrologist, May 2019;
- Potential funding from USBR administrated Colorado River Basin-wide Salinity Control Program of $65 per ton of salt per year removed;
- Elevation data from published LiDAR data, with on-site level survey to confirm water surface slope on Garvin Mesa.

The distribution of shares and associated design flowrates are shown in the table below.

TABLE 1 DESIGN FLOWS

Garvin Mesa	188	6.85-7.18	1,700	37
Wolf Park Siphon	133	21.93-23.56	8,600	677
Coal Rd to 3300 Rd	124	25.04-25.80	4,000	305
3300 Rd to Leroux Creek	119	25.80-27.92	11,200	804

PIPE MATERIALS

Spirolite, a dual wall high density polyethene bell and spigot pipe, is the presumed piping material for sections that apply for federal funding. This pipe is currently the only plastic pipe available in the large diameter sizes required to pipe the Fire Mountain Canal. The Garvin Mesa reach is not likely to be financed with federal funds, so corrugated steel pipe is a potential option and was considered as an alternate material for piping this canal section. Addition of a liner and shotcrete layer to the existing shotcrete canal was an additional option considered for improving the canal along Garvin Mesa.

ESTIMATED COSTS

Cost estimates were prepared using actual bids from recent projects in this area, or from supplier and contractor estimates. Total project costs and potential funding are included in the report. Details of individual project section cost estimates follow in the Appendix.

PROJECT SECTIONS

GARVIN MESA

Just below Terror Creek, the Fire Mountain Canal traverses the south side of Garvin Mesa. This stretch of ditch has long been a troublesome area, prone to rockfall and slides. A 500-foot section of asphalt-coated corrugated metal pipe was installed in 1991 approximately at ditch mile 6.95 following a slide that washed out this section of the canal.

This study assumes piping 1700 LF of the canal along Garvin Mesa from ditch mile 6.86 to 7.18, including the removal and replacement of the existing pipe. This length of pipe will protect the canal from the two evident slide areas. There is an area of moisture downstream of this proposed pipeline that appears to be the result of seepage from two small ponds directly above the area of increased vegetation. While this area clearly has increased seepage, the slopes and surface appear stable, so it was not included in the planned pipeline. This area could be also be protected by adding approximately 565 LF of pipe.

Several options were considered for improving this section of the canal. Spirolite, a bell and spigot high density polyethylene pipe available in 20-foot sticks is the material of choice that meets Bureau of Reclamation standards. If federal funding is not pursued for this project, corrugated steel pipe is a lower-cost option. For this analysis, a polymer-coated steel pipe, with gasketed bands at pipe joints was also considered.

Shotcrete improvements were also considered. While this stretch of the canal has an existing layer of shotcrete, installation of a polymer-geotextile liner and an additional layer of shotcrete would reduce seepage losses. This approach, however, does not address rock fall and slide protection for the canal from the uphill slopes.

PROJECT COST & FUNDING

It is not recommended that Salinity Program funding be pursued for the Garvin Mesa project, as the increased costs associated with federal funding for NEPA compliance and habitat mitigation ($57,300) exceed the amount of funding anticipated to be received based on the salt load (($53,260). The table below shows total project costs for the improvement options considered, along with a financing scenario based on a 50% grant/50% loan funding package from the Colorado Water Conservation Board. While this funding ratio is representative of recent CWCB awards, the amount of grant funding available and increasing level of competition for these funds may result in reduced grant funding percentages in the future.

TABLE 2 GARVIN MESA COST ESTIMATES

Description	Project Estimated Cost	Cost/ft	50% Grants	50% Loan	Annual Pmt 40 yr@ 2.05%	Pmt per Share
Garvin Mesa, Spirolite (non-fed)	$ 846,038	$ 498	$ 423,019	$ 423,019	$ 15,600	$ 0.07
Garvin Mesa, PolyCoat	$ 597,944	$ 344	$ 298,972	$ 298,972	$ 11,025	$ 0.05
Garvin Mesa, Shotcrete	$ 268,888	$ 158	$ 134,444	$ 134,444	$ 4,958	$ 0.02

WOLF PARK SIPHON

Construction of a siphon across Short Draw Creek at Wolf Park is the project with highest funding potential from the Salinity Control Program. Replacing 8600 linear feet of open canal with a 1050 linear foot pipeline could potentially be fully funded and contribute $200,000 to the construction of another project section.

The proposed inverted siphon across Short Draw is within land managed by the Bureau of Reclamation, so no additional private-owner easements would be needed. A pipe inlet and spillway structure, along with an outlet and energy dissipation structure would be required. To meet the pressure requirements and simplify installation, fused high density polyethylene pipe is the proposed material for this project section.

COAL ROAD TO 3300 ROAD PIPELINE

A pipeline from the "drop" just below Coal Road to 3300 Road would be needed if a regulating reservoir is built at either the Coal Road or 3300 Road sites under consideration. This section is planned for piping with 66-inch diameter Spirolite bell and spigot pipe and includes an inlet structure and two user turnouts. The outlet of this reach of pipeline would either discharge into a reservoir at IX Draw, or tie into the next segment of pipeline.

3300 ROAD TO LEROUX CREEK PIPELINE

Extending the current Segment 47 pipeline project up the canal to a regulating reservoir is an essential element of creating an on-demand water delivery system on Rogers Mesa. Two routes were considered for this reach: one following the existing canal alignment, the other shortening the pipeline by following straight south along 3300 Road for approximately 3000 feet before re-joining the existing canal alignment. The shorter route reduces construction costs, though it would require the approval of Delta County, and new easements with the private property landowners Richard Selbe and Bear Ranch.

PROJECT COST AND FUNDING

Cost estimates are based on current material and construction bids for similar projects in the same geographic area. Final engineering design would refine these initial feasibility level cost estimates. Itemized cost estimates for each section are included in the Appendix. Projects funded through this program typically request funding in the range of $50-$65 per ton of salt removed annually. The Wolf Park Siphon is the only project section that could be fully funded by the Salinity Control Program. As noted previously, the Garvin Mesa pipeline is not recommended to be included in a Salinity Control Program project.

TABLE 3 COST ESTIMATE SUMMARY

Description	Project Estimated Cost	Cost/ft	2019 Salt Load tons/yr	Project $/ton
Wolf Park Siphon	$ 756,581	$ 721	677	$ 47
Coal Rd to 3300 Rd Pipeline *	$ 1,456,497	$ 309	305	$ 199
3300 Rd to Leroux Creek Pipeline	$ 3,955,597	$ 378	804	$ 205
Alternate Route along 3300 Rd	$ 3,439,799	$ 365	804	$ 178
Garvin Mesa Pipeline	$ 903,351	$ 531	37	$ 1,018

FUNDING SCENERIO

The table below shows potential Salinity Program funding scenarios for piping sections of the Fire Mountain Canal. The potential funding from the Colorado River Basin-wide Salinity Control Program is assumed to be $65 per ton, which is on the high end of recently funded projects. Supplemental funding is assumed to come from programs administered by the Colorado Water Conservation Board in the form of a 50% grant, 50% loan package. While this ratio has received funding in the past, the 3300 Road to Leroux Creek pipeline would require a large amount of grant money from the state, and a greater proportion of funding through a loan or other funding source such as NRCS Regional Conservation Partnership Program would likely be needed for this section. Individual funding programs are described in the following sections.

TABLE 4 SALINITY PROJECT FUNDING

Description	USBR Funding @ $65/ton	Other Funding Needed	50% Grants	50% Loan	Annual Pmt 40 yr@ 2.05%	Pmt per Share
Wolf Park Siphon	$ 974,568	$ (217,988)				
Coal Rd to 3300 Rd Pipeline *	$ 439,060	$ 1,017,437	$ 399,725	$ 399,725	$ 14,741	$ 0.07
3300 Rd to Leroux Creek Pipeline	$ 1,157,390	$ 2,798,207	$ 1,399,104	$ 1,399,104	$ 51,595	$ 0.23
Alternate Route along 3300 Rd	$ 1,157,390	$ 2,282,409	$ 1,141,205	$ 1,141,205	$ 42,084	$ 0.19
Garvin Mesa Pipeline	$ 53,263	$ 850,088	$ 425,044	$ 425,044	$ 15,674	$ 0.07

* Coal Rd to 3300 Rd Pipeline includes credit from Wolf Park Siphon applied to the 50% grants funding.

Pursuing the recommended options for all proposed improvements considered would result in project costs summarized in the table below.

TABLE 5 TOTAL PROJECT COSTS

Description	Project Estimated Cost	USBR Funding @ $65/ton	Other Funding Needed	50% Grants	50% Loan	Annual Pmt 40 yr@ 2.05%	Pmt per Share
Wolf Park Siphon	$ 756,581	$ 974,568	$ (217,988)				
Coal Rd to 3300 Rd Pipeline *	$ 1,456,497	$ 439,060	$ 1,017,437	$ 399,725	$ 399,725	$ 14,741	$ 0.07
3300 Rd to Seg 47, alt route	$ 3,439,799	$ 1,157,390	$ 2,282,409	$ 1,141,205	$ 1,141,205	$ 42,084	$ 0.19
Garvin Mesa, PolyCoat	$ 597,944		$ 597,944	$ 298,972	$ 298,972	$ 11,025	$ 0.05
TOTAL	$ 6,250,820	$ 2,571,017	$ 3,679,803	$ 1,839,902	$ 1,839,902	$ 67,850	$ 0.31

FUNDING PROGRAMS

COLORADO RIVER BASIN-WIDE SALINITY CONTROL PROGRAM

Salinity Control in the Colorado River is funded by annual appropriations from the federal budget, with additional funds provided from the Lower Colorado River Basin Development Fund which receives a portion of hydropower revenues from the major dams on the Colorado River. This program provides the most significant source of funding for ditch piping projects in the Upper Colorado River basin. The Lower Gunnison Basin is currently a priority area, as a significant portion of the unaddressed salt contributions to the Colorado River system originate from seepage through the underlying Mancos Shale in this region. This program has provided $30-$40 million in grant funding for irrigation system improvements through a competitive Funding Opportunity Announcement (FOA) typically offered every 3 years. Applications are ranked on a series of factors, though the cost per ton of salt removed is the key ranking. Since 2000, projects awarded funding have averaged $46-$67 per ton, with a general downward trend. In the most recent 2017 FOA, the average cost per ton was $54 for projects awarded funding, with an average project cost of $58 per ton for all applications submitted. It is also important to note the current USBR preference for funding pressurized systems. In the 2017 FOA, USBR ranking criteria strongly favored pressurized systems. It is unclear at this time if that preference will continue into future funding cycles.

If other sources of funding are pursued to reduce the portion of the project cost to be funded through the Salinity Control Program, in effect "buying down" the cost per ton to the Salinity Program, these supplemental funds are required to be committed prior to submitting an application through the FOA process. The next Salinity Control Program FOA is planned for mid to late 2019.

COLORADO WATER CONSERVATION BOARD

WATER SUPPLY RESERVE FUND

Irrigation system improvement projects are good candidates for receiving state funds through this program, administered by our local Gunnison Basin Roundtable. Applications must be submitted to the selection committee for initial screening. If the committee recommends approval, the application is then considered at the following Roundtable meeting, then subject to final approval by the Colorado Water Conservation Board. Applications to the Basin Fund account are considered at any time. The Gunnison Basin Roundtable meets every other month, on the third Monday of the month, at the Holiday Inn Express in Montrose. The CWCB meets every other month at locations rotating around the state. Applications to the WSRF State Account are considered by the board at their September and February meetings, and must be approved by the local roundtable prior to the submission to CWCB staff for consideration by the board. As of April 2019, there is $2.2 million in the State Account and $300,000 in the Gunnison Basin Account. More information is available at http://cwcb.state.co.us.

Colorado Water Plan Grants

In 2019, $7 million in state funds is available to fund projects that further the implementation of the Colorado Water Plan. One million of this funding is designated for agricultural projects. Irrigation modernization projects that leverage this state funding with significant federal funds have been viewed favorably by this program. Applications are accepted twice a year, due February 1 and August 1. See the CWCB website for more information.

Water Project Loans

Low interest long-term loans are offered by the Colorado Water Conservation Board to help fund a variety of water projects. The minimum loan application is $100,000, with total program funding of $50 million available each year. A technical and financial feasibility study is required as part of the loan application process. Details including current rates for 30-year and 40-year loan terms can be found on the Water Project Loan Program page of the CWCB website listed above.

OTHER FUNDING OPTIONS

USBR WaterSMART Program

This federal program offers Water and Energy Efficiency Grants that can help fund irrigation system improvements. Projects incorporating hydropower generation components are an especially good fit for this program. In 2019, the USBR awarded $24 million in Water and Energy Efficiency grants. All WaterSMART grants require a 50% funding match from non-federal sources. Applications were due March 19, 2019; watch USBR.gov WaterSMART website for dates of future funding opportunities.

USDA-NRCS/Regional Conservation Partnership Program

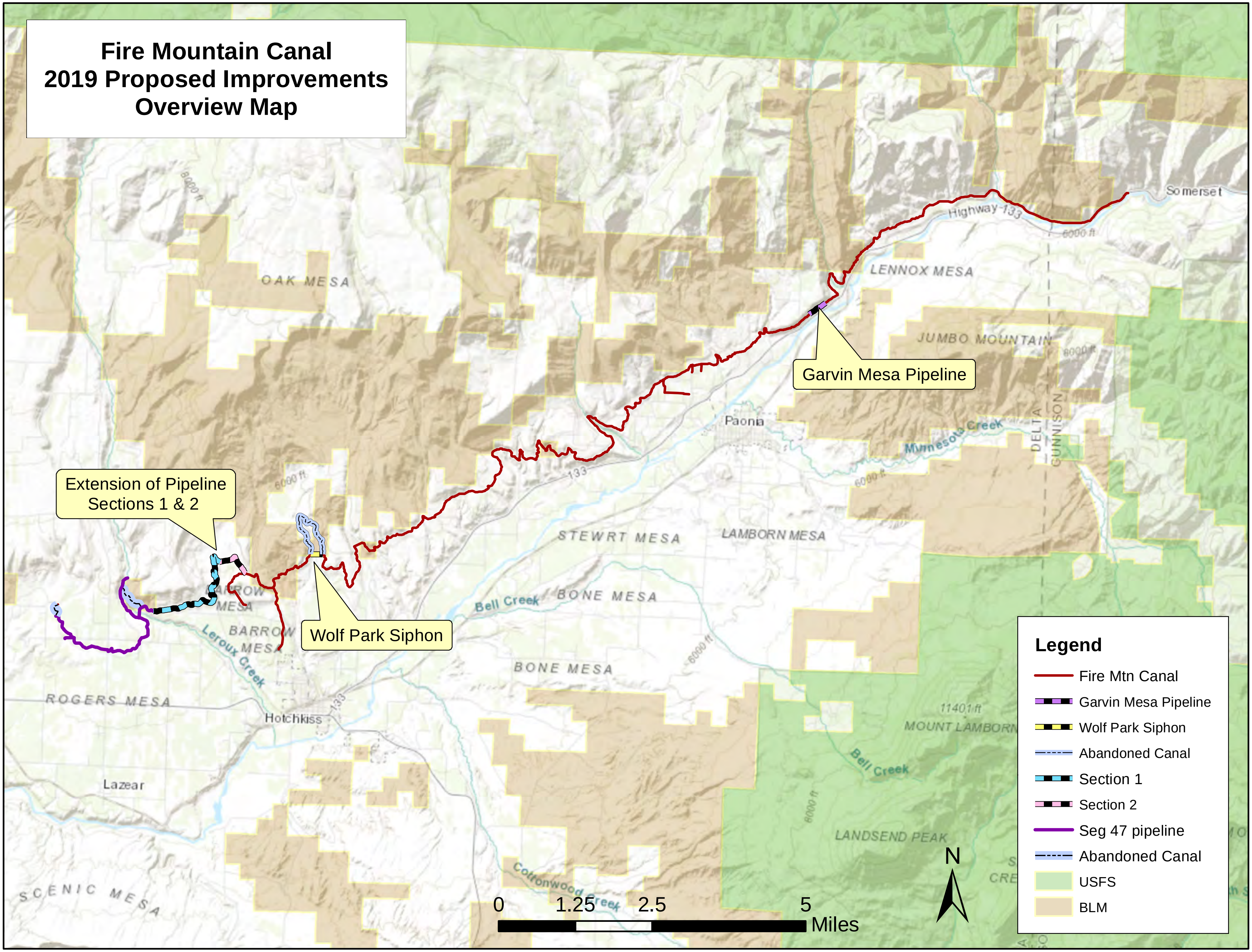
The Fire Mountain Canal is a partner in the Lower Gunnison Regional Conservation Partnership Program (RCPP) project area, a collection of irrigation improvement projects administered by the Colorado River Water Conservation District and received RCPP funding for the current Segment 47 piping project. If future applications for RCPP funding of the Lower Gunnison Project are successful, the Fire Mountain Canal is well placed to receive support for these planned improvements.

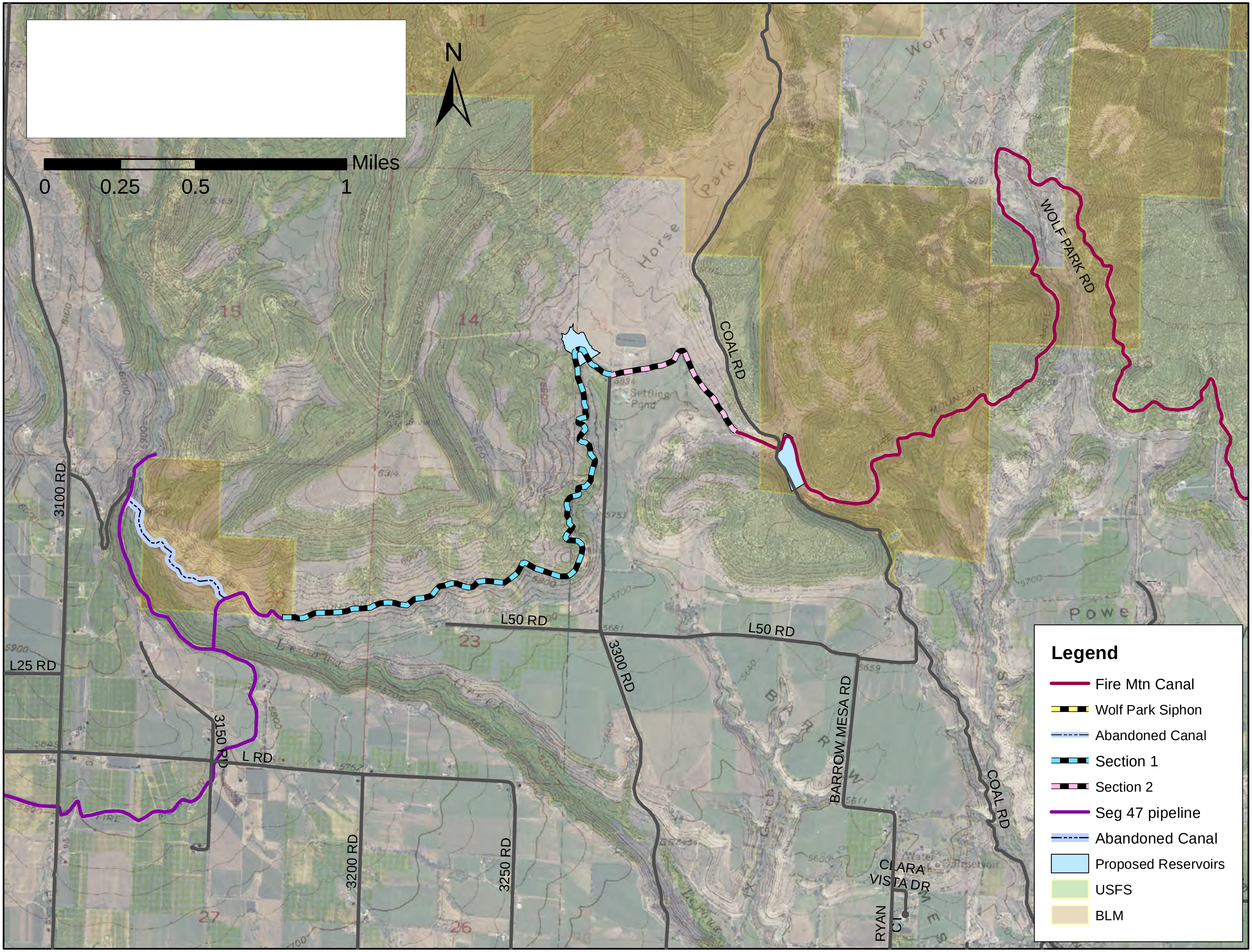
CONCLUSIONS

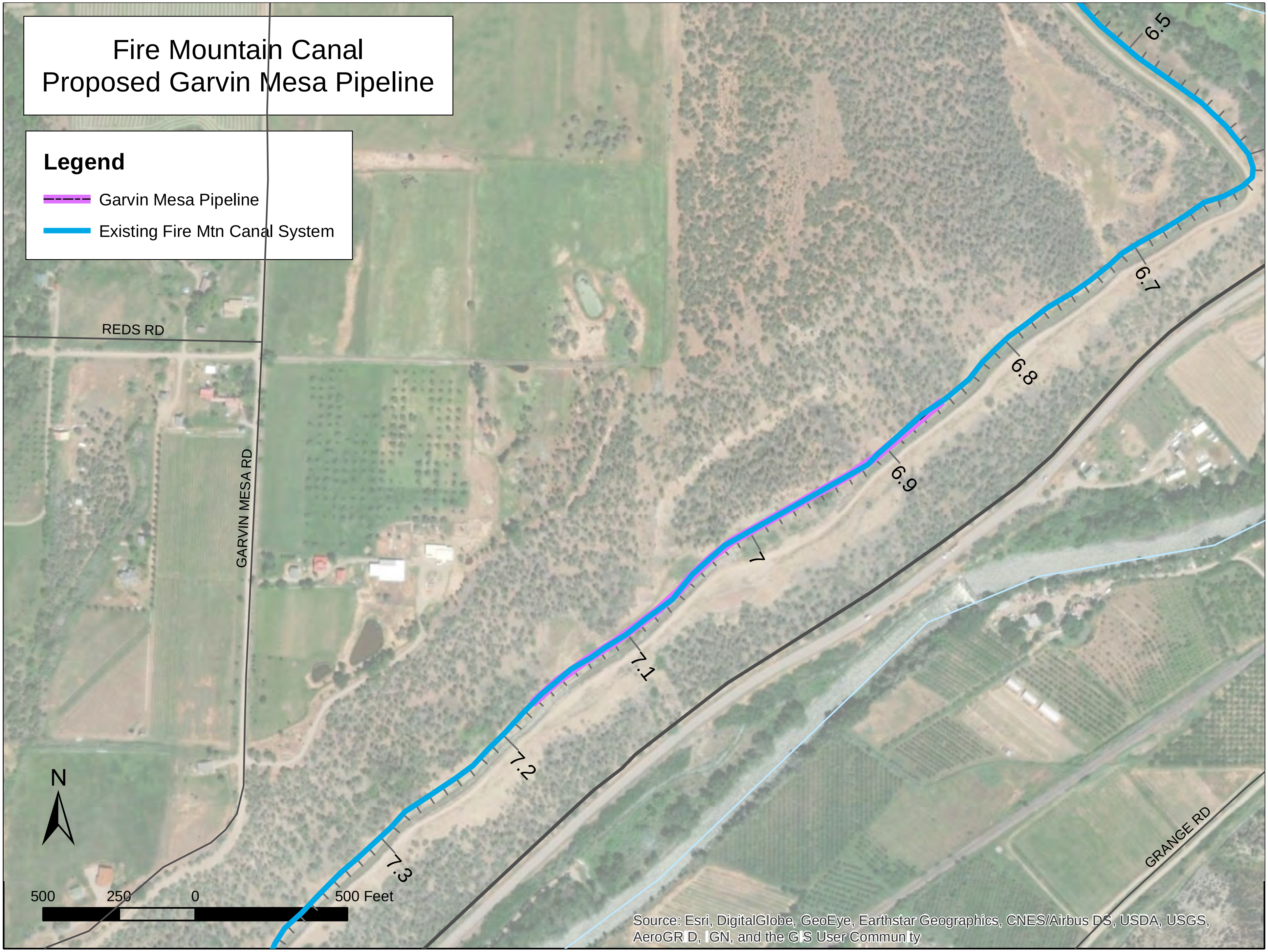
The Wolf Park siphon is the only section of the Fire Mountain Canal considered for improvement that could be fully funded by the Colorado River Basinwide Salinity Control Program. While the salt load savings of the Wolf Park siphon could contribute to the feasibility of funding other sections, significant additional funding is necessary to pursue any other canal improvements. An estimated $3.68 million is needed in addition to Salinity Program funds to complete the proposed piping of these four canal segments.

APPENDIX

1. FMC Improvements Overview Map
2. Garvin Mesa Piping Project Map
3. Barrow Mesa Area Improvements Map
4. Ditch Section Cost Estimates


Fire Mountain Canal
2019 Proposed Improvements
Overview Map
Garvin Mesa Pipeline
Extension of Pipeline
Sections 1 & 2
Wolf Park Siphon
Legend
Fire Mtn Canal
Garvin Mesa Pipeline
Wolf Park Siphon
Abandoned Canal
Section 1
Section 2
Seg 47 pipeline
Abandoned Canal
USFS
BLM
0
1.25
2.5
5
Miles
N
Somerset
Highway 133
133
LENNOX MESA
JUMBO MOUNTAIN
OAK MESA
Paonia
Minnesota Creek
DELTA
GUNNISON
STEWRT MESA
LAMBORN MESA
BONE MESA
BONE MESA
Bell Creek
BARROW MESA
Leroux Creek
ROGERS MESA
Hotchkiss
Lazear
SCENIC MESA
11401 ft
MOUNT LAMBORN
Bell Creek
LANDSEND PEAK
Cottonwood Creek
6000 ft
8000 ft


N
Miles
0
0.25
0.5
1
Legend
Fire Mtn Canal
Wolf Park Siphon
Abandoned Canal
Section 1
Section 2
Seg 47 pipeline
Abandoned Canal
Proposed Reservoirs
USFS
BLM
WOLF PARK RD
COAL RD
3100 RD
L25 RD
L50 RD
3300 RD
3150 RD
L RD
3200 RD
3250 RD
BARROW MESA RD
CLARA VISTA DR
RYAN CT
Horse
Wolf
Park
Settling Pond
Powe



Fire Mountain Canal
Proposed Garvin Mesa Pipeline
Legend
Garvin Mesa Pipeline
Existing Fire Mtn Canal System
REDS RD
GARVIN MESA RD
GRANGE RD
6.5
6.7
6.8
6.9
7
7.1
7.2
7.3
N
500
250
0
500 Feet
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Engineers Opinion of Probable Construction Cost

Applegate Group, Inc.
www.applegategroup.com
AG JOB NO.: 15-147
BY: BAK/CMU

Fire Mountain Canal
Pipeline Section 1 - 3300 Rd to Leroux Creek

Date: 12/4/2019
Client: NDIC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization	%	-	6%	$ 195,290
1.02	Engineering Design & Survey	%	-	6%	$ 195,290
1.03	Construction Management	%	-	4%	$ 130,193
1.04	NEPA	%	-	3%	$ 97,645
1.05	Habitat Mitigation	%	-	5%	$ 162,741
2	Earthwork				
2.01	Prep existing canal	LF	10,460	$ 4.00	$ 41,840
2.02	Turnout structure removal	EA	7.00	$ 1,400	$ 9,800
2.03	Reclamation & seeding	Ac	12	$ 6,880	$ 82,604
3	Pipe				
3.01	72" Spirolite	LF	10,460	$ 215.41	$ 2,253,189
3.02	72" Pipe fittings	EA	33.00	$ 8,948	$ 295,284
3.03	72" pipe installation	LF	10,460	$ 60	$ 627,600
4	Structures & Appertances				
4.01	Pipe Inlet Structure	CY	10	$ 1,600	$ 16,000
4.02	Air Vents/Valves	EA	9	$ 3,850	$ 34,650
4.03	Turnouts	EA	7	$ 4,015	$ 28,105
					$ -
Construction Subtotal					**$ 3,450,117**
Bonding (Performance and Warranty)		%		2%	$ 66,000
Contingency/Missing Items		%		15%	$ 518,000
Project Total					$ 4,034,117
Project Total cost per foot		$/LF			$ 386

Engineers Opinion of Probable Construction Cost

Applegate Group, Inc.
www.applegategroup.com

AG JOB NO.: 15-147
BY: BAK/CMU

Fire Mountain Canal
Pipeline Section 2 - Coal Rd to 3300 Rd

Date: 12/4/2019
Client: NDIC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization	%	-	6%	$ 70,982
1.02	Engineering Design & Survey	%	-	6%	$ 70,982
1.03	Construction Management	%	-	4%	$ 47,321
1.04	NEPA	%	-	3%	$ 35,491
1.05	Habitat Mitigation	%	-	5%	$ 59,151
2	Earthwork				
2.01	Prep existing canal	LF	4,719	$ 4.00	$ 18,876
2.02	Turnout structure removal	EA	2.00	$ 1,400	$ 2,800
2.03	Reclamation & seeding	LF	4,719	$ 3	$ 12,788
3	Pipe				
3.01	66" Spirolite	LF	4,719	$ 182.35	$ 860,495
3.02	66" Pipe fittings	EA	6.00	$ 5,628	$ 33,766
3.03	66" pipe installation	LF	4,719	$ 56	$ 264,736
4	Structures & Appertances				
4.01	Pipe Inlet Structure	CY	10	$ 1,600	$ 16,000
4.02	Air Vents/Valves	EA	3		$ -
4.03	User Turnouts	EA	2	$ 4,015	$ 8,030
					$ -
Construction Subtotal					$ 1,254,009
Bonding (Performance and Warranty)		%		2%	$ 24,000
Contingency/Missing Items		%		5%	$ 63,000
Project Total					$ 1,341,009
Project Total cost per foot		$/LF			$ 284

Engineers Opinion of Probable Construction Cost

Applegate Group, Inc.

www.applegategroup.com

AG JOB NO.: 17-124

BY: BAK/CMU

Fire Mtn Canal

Wolf Park Siphon

Date: 12/4/2019

Client: FMC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization & Bonding	%	-	10%	$ 61,427
1.02	Engineering Design	%	-	6%	$ 36,856
1.03	Construction Management	%	-	4%	$ 24,571
1.04	NEPA	%	-	3%	$ 18,428
1.05	Habitat Mitigation	%	-	5%	$ 30,714
1.06	Cultural Resources	%	-	3%	$ 18,428
2	Earthwork				
2.01	Clear & Grub siphon alignment	LF	1,050	$ 12.00	$ 12,600
2.02	Abandon old canal	LF	8,659	$ 9.90	$ 85,724
2.03	Reclamation & seeding	LF	9,709	$ 4.28	$ 41,555
2.04	Structure removal	EA	1	$ 2,475.00	$ 2,475
3	Pipe				
3.01	54" HDPE DR 26	LF	624	$ 238.32	$ 148,712
3.02	54" HDPE DR 41	LF	406	$ 153	$ 62,309
3.03	36" HDPE DR 41 - spillway pipe	LF	560	$ 68.21	$ 38,198
3.04	54" HDPE installation	LF	1,050	$ 70.00	$ 73,500
3.05	36" HDPE installation	LF	560	$ 55.00	$ 30,800
4	Appurtanances				
4.01	Intake & Spillway structure	CY	30	$ 1,780	$ 53,400
4.02	Pipe Outlet	CY	8	$ 1,780	$ 14,240
4.03	Energy Dissipation structure	CY	27.0	$ 1,880	$ 50,760
4.04					
Construction Subtotal					$ 786,268
Single Audit		LS	1	$ 2,800.00	$ 2,800
Contingency/Missing Items		%			$ -
Project Total					$ 789,068
Project Total cost per foot		$/LF			$ 751

Engineers Opinion of Probable Construction Cost

Applegate Group, Inc.

www.applegategroup.com

AG JOB NO.: 17-124

BY: BAK/CMU

Fire Mountain Canal
Garvin Mesa
Spirolite Pipeline - Federal Funding

Date: 12/4/2019

Client: FMC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization	%	-	6%	$ 42,985
1.02	Engineering Design	%	-	6%	$ 42,985
1.03	Construction Management	%	-	4%	$ 28,656
1.04	NEPA	%	-	3%	$ 21,492
1.05	Habitat Mitigation	%	-	5%	$ 35,821
1.06	Cultural Resources	%	-	3%	$ 21,492
2	Earthwork				
2.01	Prep existing canal	LF	1,700	$ 4.00	$ 6,800
2.02	Reclamation & seeding	LF	1,700	$ 3	$ 4,607
3	Pipe				
3.01	72" Spirolite	LF	0	$ 215.41	$ -
3.02	72" Spirolite fittings, elbows <45°	EA	0	$ 8,948	$ -
3.03	84" Spirolite	LF	1,700	$ 283.86	$ 482,562
3.04	84"" Spirolite fittings, elbows <45°	EA	5	$ 10,637	$ 53,183
3.04	72" Spirolite installation	LF	0	$ 60.00	$ -
3.05	84" Spirolite installation	LF	1,700	$ 81.00	$ 137,700
4	Appurtanances				
4.01	Pipe Inlet & screen	LS	1	$ 15,750	$ 15,750
4.02	Pipe Outlet	LS	1	$ 6,000	$ 6,000
4.03	Access/transition box	CY	8.2	$ 1,200	$ 9,810
4.04					
Construction Subtotal					$ **888,351**
Bonding (Performance and Warranty)		%		2%	$ 15,000
Contingency/Missing Items		%			$ -
Project Total					$ 903,351
Project Total cost per foot		$/LF			$ 531

Engineers Opinion of Probable Construction Cost

Applegate Group, Inc.

www.applegategroup.com

AG JOB NO.: 17-124

BY: BAK/CMU

Fire Mtn Canal
Garvin Mesa Pipeline
Spirolite - Local Funding

Date: 12/4/2019

Client: FMC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization	%	-	6%	$ 42,985
1.02	Engineering Design	%	-	6%	$ 42,985
1.03	Construction Management	%	-	4%	$ 28,656
2	Earthwork				
2.01	Prep existing canal	LF	1,700	$ 4.00	$ 6,800
2.02	Reclamation & seeding	LF	1,700	$ 3	$ 4,607
3	Pipe				
3.01	72" Spirolite	LF	0	$ 215.41	$ -
3.02	72" Spirolite fittings, elbows <45°	EA	0	$ 8,948	$ -
3.03	84" Spirolite	LF	1,700	$ 283.86	$ 482,562
3.04	84"" Spirolite fittings, elbows <45°	EA	5	$ 10,637	$ 53,183
3.04	72" Spirolite installation	LF	0	$ 60.00	$ -
3.05	84" Spirolite installation	LF	1,700	$ 81.00	$ 137,700
4	Appurtanances				
4.01	Pipe Inlet & screen	LS	1	$ 15,750	$ 15,750
4.02	Pipe Outlet	LS	1	$ 6,000	$ 6,000
4.03	Access/transition box	CY	8.2	$ 1,200	$ 9,810
4.04					
Construction Subtotal					$ 831,038
Bonding (Performance and Warranty)		%		2%	$ 15,000
Contingency/Missing Items		%			$ -
Project Total					$ 846,038
Project Total cost per foot		$/LF			$ 498

Engineers Opinion of Probable Construction Cost

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AG JOB NO.: 17-124
BY: BAK/CMU

Fire Mtn Canal
Garvin Mesa Pipeline
Corrugated Steel Pipe

Date: 12/4/2019

Client: FMC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization	%	-	6%	$ 30,359
1.02	Engineering Design	%	-	6%	$ 30,359
1.03	Construction Management	%	-	4%	$ 20,239
2	Earthwork				
2.01	Prep existing canal	LF	1,700	$ 4.00	$ 6,800
2.02	Reclamation & seeding	LF	1,700	$ 3	$ 4,607
3	Pipe				
3.01	84" PolyCoat Ultra Flo, corrugated steel	LF	1,700	$ 134.56	$ 228,752
3.02	84" PolyCoat fittings, elbows <45°	EA	5	$ 3,179	$ 15,897
3.03	Hugger Bands Galvanized w/gasket	EA	70	$ 475	$ 33,171
3.04	Shipping	truck	38	$ 1,250	$ 47,500
3.05	84" pipe installation	LF	1,700	$ 81.00	$ 137,700
4	Appurtanances				
4.01	Pipe Inlet & screen	LS	1	$ 15,750	$ 15,750
4.02	Pipe Outlet	LS	1	$ 6,000	$ 6,000
4.03	Access/transition box	CY	8.2	$ 1,200	$ 9,810
4.04					
Construction Subtotal					$ 586,944
Bonding (Performance and Warranty)		%		2%	$ 11,000
Contingency/Missing Items		%			$ -
Project Total					$ 597,944
Project Total cost per foot		$/LF			$ 344

Engineers Opinion of Probable Construction Cost

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AG JOB NO.: 17-124

BY: BAK/CMU

Fire Mtn Canal
Garvin Mesa Pipeline
Local Funding

Date: 12/4/2019

Client: FMC

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	Pre-Construction Activities				
1.01	Mobilization	%	-	6%	$ 12,408
1.02	Engineering Design	%	-	6%	$ 12,408
1.03	Construction Management	%	-	4%	$ 8,272
2	Earthwork				
2.01	Prep existing canal	LF	1,700	$ 4.00	$ 6,800
3	Shotcrete				
3.01	Liner & shotcrete, materials & installation	sqft	40,000	$ 5.00	$ 200,000
Construction Subtotal					$ 239,888
Bonding (Performance and Warranty)		%		2%	$ 5,000
Contingency/Missing Items		%		10%	$ 24,000
Project Total					$ 268,888
Project Total cost per foot		$/LF			$ 158

August 12, 2020
AG File # 18-128

Prepared for:
Fire Mountain Canal and Reservoir Company
and

COLORADO
Colorado Water Conservation Board
Department of Natural Resources

Applegate Group, Inc.
Water Resource Advisors for the West
www.applegategroup.com
303-452-6611

CONTENTS

INTRODUCTION

The Board of the Fire Mountain Canal and Reservoir Company (FMC) has been actively working to modernize this irrigation system to enhance the efficiency of the limited water resources available. After years of planning, piping of the canal across Rogers Mesa, where over 60% of the water is delivered, was recently completed in April 2020. As part of this planning process, a master plan of improvements was compiled by J-U-B Engineers, and an optimization study was completed by Irrigation Training and Research Center at Cal-Poly (ITRC). These studies of the Fire Mountain Canal system have highlighted the potential benefits of creating a regulating reservoir somewhere along the lower section of the canal.

PURPOSE AND NEED

The FMC system is primarily composed of the main canal extending from near Somerset, Colorado to Rogers Mesa near Hotchkiss, Colorado and the Paonia Reservoir approximately 7 miles above Somerset. Figure 1 provides an overview of the system. Irrigation water is physically supplied to approximately 9,000 acres of land under the system. The FMC derives its water supply primarily from the North Fork of the Gunnison River with some additional spring runoff diverted from Leroux Creek. The FMC has a relatively junior water right which results in lack of sufficient water supply during the late summer and early fall period. As snowmelt comes to an end in early summer, flows in the North Fork of the Gunnison decrease and water is released from Paonia Reservoir to maintain flows in the FMC. Paonia Reservoir stores approximately 15,000 acre-feet of water which is used nearly every year in its entirety. Even with this supplemental water, the system is still short of water during average or dry years. The FMC typically supplies water through mid-September, however, during droughts such as 1977, 2002, 2012, and 2018 the canal has been out of water as early as the first week of August.

The distance from the river diversion to Rogers Mesa is nearly 30 miles along the canal, making it difficult to balance demand on Rogers Mesa with diversions from the river. Water diverted from the river takes nearly 1.5 days to reach Rogers Mesa, during which time the actual demand varies. To avoid shortages in the system, a relatively steady flow is always supplied. Later in the season, when the canal is primarily relying on releases from Paonia Reservoir nearly 7 miles above the river diversion, it becomes even more challenging to balance supply and demand. Once water is released from Paonia Reservoir it is destined to flow through the system regardless of whether it gets used or not.

The function of a regulating reservoir is to provide enough storage capacity to moderate day to day fluctuations in either the supply or demand until adjustments can be made at the river diversion or reservoir outlet. The purpose of this reservoir does not include storing spring runoff water for use in the fall as Paonia Reservoir currently serves that need. Better management below the regulating reservoir will generally allow the releases from Paonia Reservoir to be periodically decreased which would thereby lengthen the overall irrigation season for the entire system, providing a benefit for all shareholders not just those below the reservoir. The lengthening of the irrigation season would not only allow the season to be extended but may also allow additional crops to be grown under the system that are not currently possible with the potential for a lack of water in August and September.

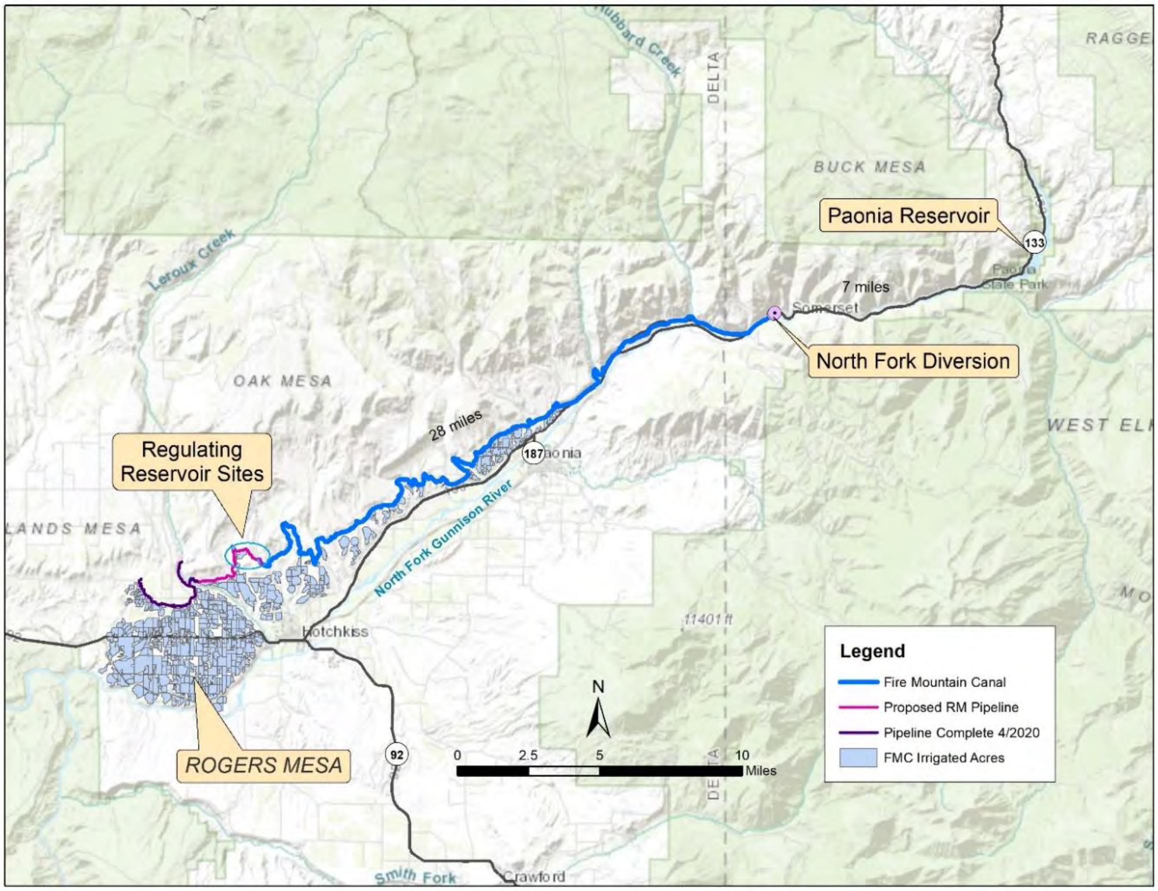


FIGURE 1 FIRE MOUNTAIN CANAL SYSTEM OVERVIEW

Other potential system improvements such as a pipeline system downstream of a proposed reservoir, and pressurization of the East Lateral on Rogers Mesa could further improve the water management in the system and extend the irrigation season even further.

ITRC REPORT (2016)

As part of the Lower Gunnison Project administered by the Colorado River District and funded by the NRCS Regional Conservation Partnership Program, the ITRC was engaged to do an assessment for the Fire Mountain Canal. This assessment reviewed criteria and assumptions for the recently completed Rogers Mesa pipeline project, as well as associated system improvements including automated controls and construction of a regulating reservoir somewhere along the lower reach of the canal. The analysis by ITRC concluded that construction of a regulating reservoir with piped connection to Rogers Mesa would provide the best option for improved system control incorporating demand management. In order to achieve increased efficiency and flexibility in water delivery, they recommended the following sequence of improvements:

1. Completion of the Fire Mountain Canal pipeline across Rogers Mesa; Completed Spring 2020;
2. Construction of a regulating reservoir near the end of the system above Rogers Mesa;
3. Construction of closed pipeline laterals to supply users on Rogers Mesa with pressurized, on-demand service;
4. Construction of a pipeline connecting the regulating reservoir to the Fire Mountain Canal pipeline.

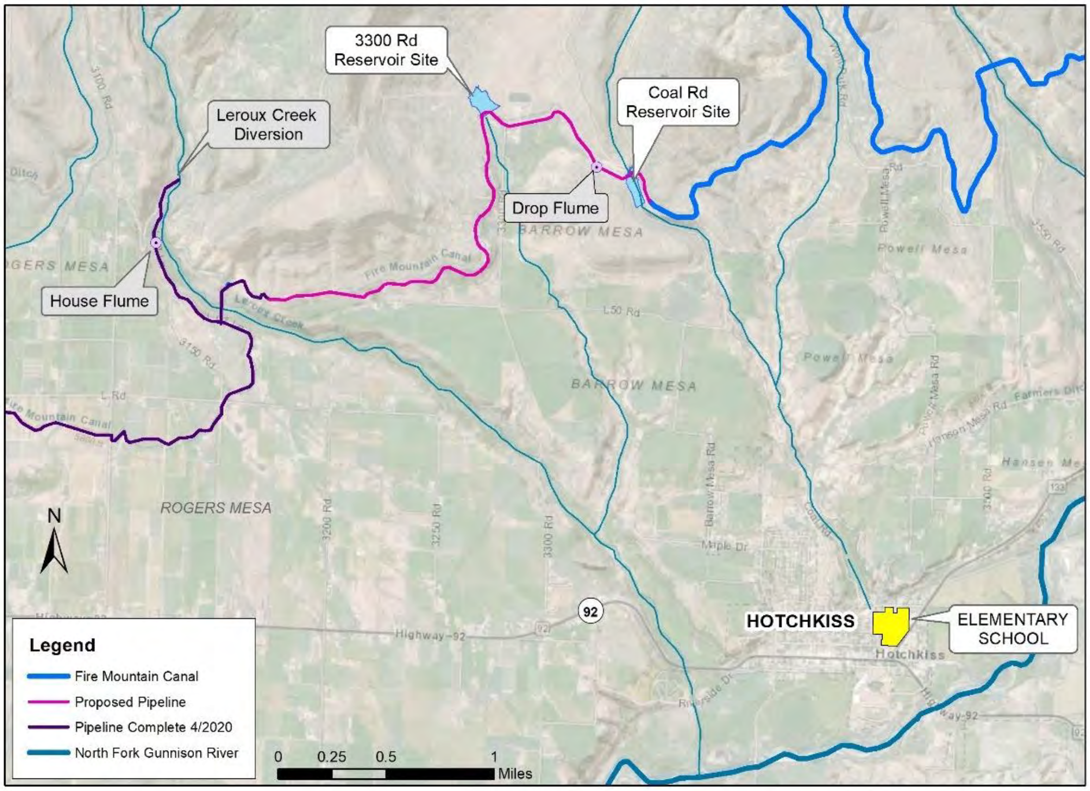


FIGURE 2 VICINITY MAP

Construction of a low-pressure pipeline to replace the open canal across Rogers Mesa began in December 2018 and was completed in April 2020. This report summarizes analysis of options for construction of a regulating reservoir east of Leroux Creek, as recommended above in item 2. The addition of a regulating reservoir will reduce the operational spill at the Leroux Creek siphon inlet, slightly increase the pressure in the system, and provide a buffer giving operators time to make adjustments to flow diversions at the canal head-gate when storm events provide inflow to the canal, or water users increase or decrease delivery demand. All elements of an improved irrigation water delivery system are essential to convert from the current supply managed system where water is delivered at a constant rate throughout the irrigation season, to a demand managed system where water is conserved and stored in the system when users are not irrigating.

FIRE MOUNTAIN CANAL-FLOW DATA

Daily canal flows at measurement locations along the canal are recorded in the journals of the ditch riders. The Colorado River District digitized and analyzed this data for 2013. Additional ditch rider logs were digitized as part of this study for 2016, 2017 and 2018. These data are compiled in Appendix A. These data show a typical canal flow rate of around 110 cfs at the "Drop" flume near the Coal Road canal drop and 100-125 cfs at the Rogers Mesa House Flume. The difference between these two peaks can be attributed to inflows diverted from Leroux Creek in 2016 and 2017. Drought conditions in 2018 precluded any significant diversions from Leroux Creek.

The charts show that the existing canal flow rate changes little day to day under the existing supply management system. A steady flowrate is maintained right up until the canal is shut off. Day to day fluctuations at the drop flume are approximately 5 cfs, or about 5 percent of the total flow. Fluctuations at the House Flume were widely varied during spring runoff primarily due to changes in Leroux Creek resulting from cold periods reducing the snowmelt for a few days. During the summer months, fluctuations at the house flume were similar or less than those at the Drop Flume. The slightly more stable flows at the House Flume during the summer season is attributed to the automated gate controlling diversions from Leroux Creek in order to maintain a steady flow at the House Flume.

Assuming that any adjustments made at the reservoir or river diversion took 1.5 days to balance out on Rogers Mesa, the required storage volume would be approximately 15 acre-feet. However, the reservoir would be operated with a target water level in the middle of the active storage pool in order to be able to either accept excess inflows or release water to boost canal flows. Therefore, the total active storage would ideally be a minimum of 30 acre-feet. According to the ITRC report, if the system management was switched from supply to demand management the daily fluctuations would likely increase and additional storage could be required, but no estimate of the amount of increase was stated.

SITE EVALUATION

SITE DESCRIPTION

Two sites for a potential regulating reservoir were considered. Both sites are located along the canal approximately 2 to 3 miles upstream of Leroux Creek, see Figure 2. This general location provides the ability to regulate canal flows upstream of the deliveries to Rogers Mesa. Constructing a reservoir along the canal in this vicinity also allows the elevation drop in the canal near Coal Road to be utilized for gravity inflow and outflow, thereby avoiding the cost, power and maintenance requirements of a pumped system. Adding a pumped system may allow additional storage volume to be utilized at each site and is discussed later in this report.

COAL ROAD

The Coal Road site is located just below where Coal Road crosses the Fire Mountain Canal, approximately 2.4 miles upstream of Hotchkiss. This area is a relatively narrow drainage along Coal Creek, providing a good site for creating storage with a relatively short dam crest length. The property at this site is managed by the Bureau of Reclamation (USBR) providing a distinct advantage to this site. A small amount of BLM property, however, could be impacted by the reservoir inundation area or required canal improvements.

Construction of a reservoir at this site would inundate a section of Coal Road, a non-maintained seasonal four-wheel drive road. which would necessitate the construction of a new road alignment. Two potential road alignments are shown in Appendix B. One of these alignments would require a switchback but would stay on USBR property while the other re-route would be primarily on BLM lands with a short section potentially crossing private land. The private land in question is in a dedicated conservation easement which means coordination with the easement holder would be required.

3300 ROAD

The alternate site considered is at the north end of 3300 Road, near the top of the IX Draw drainage. This site is privately owned by Raymond Selbe of Steamboat Springs, who has indicated a willingness to discuss the potential for a reservoir on this property with the Fire Mountain Canal. The topography of this site would require a longer, but lower height dam to provide the desired functional storage capacity. Depending on the final configuration of a dam embankment, there are several existing structures near the left dam abutment that could be impacted, however, these do not appear to be well kept habitable structures. There is an existing raw water supply pipeline for the Town of Hotchkiss located north of the proposed reservoir, outside of the proposed inundation area.

To maximize the efficiency of this site, it was assumed that all materials necessary for the dam embankment would be excavated from the reservoir basin. Furthermore, additional storage within the active pool could be generated by moving material from the active storage pool to completely fill the dead pool. This approach would also have a positive effect on the hazard classification discussed later in this report as it would lower the breach height of the structure and thereby reduce the resulting breach flood.

Figures depicting each site are located in Appendix B. Table 3, near the end of this report, provides a comparison of the two reservoirs assuming that they are constructed to utilize the existing elevation drop in the canal with no pumping. It was also assumed that the material needed for construction of the embankment would be excavated from the reservoir area within the active pool zone in order to maximize active storage at each site.

ENVIRONMENTAL ISSUES

A Natural Resource Assessment of the two sites was completed by ERO Resources in 2019. The purpose of the study was to identify any environmental factors that could impact the development of a reservoir at each site and estimate the costs of addressing any issues. A summary excerpt from that report is shown below, additional information and detail is provided in the ERO report.

TABLE 1 PERMITTING COMPARISON

NEPA	NEPA for three federal agencies is assumed; one federal agency for funding, and the BOR and BLM (landowners); this would result increased cost and time for EA, relative to Site B. EA would likely be \$30K-\$45K.	NEPA for one agency, assuming federal funding nexus through USDA or other (Rural Development funding or NRCS). Based on prior ERO experience and limited potential resource issues at Site B, this would likely be a simple EA; cost is estimated at \$15K.
Clean Water Act	If wetlands are present along the canal or impacts below the OHWM are expected, the project could be permitted under NWP 18 (3 months, and \$4,000); additional costs for preparing a technical memo regarding the regulated nature of the wetland area is estimated to be \$4,000. If wetlands are regulated, an Individual Permit would be required (12 months and approximately \$12K) and a mitigation plan due to extent of wetland impacts.	Presence of wetlands likely less than 0.1 of an acre. If no wetlands are present, the project would likely be exempt. If wetlands are present, the project could be permitted under NWP 18 (3 months, and \$4,000)
Environmental survey requirements	Wetland delineation, cultural resources, surveys may be required by the BOR for BLM-sensitive species. Pre-construction nest surveys if clearing during MB nesting season. Potentially \$2K-\$4K extra survey requirements.	Possible wetland delineation (simplified-less acreage), cultural resources (assuming federal nexus). Preconstruction nest surveys if clearing during MB nesting season.,

Other requirements	Delta County authorization would be required. ERO assumes the project would not qualify for salinity-related funding, and habitat replacement procedures (required under the Salinity Control Act) would not be required.	Delta County authorization
Key differences in timeframe, cost	Total federal clearance costs up to $61K, plus mitigation costs, and take 12 to 15 months. BOR Authorization, wetland impacts and individual permit required with mitigation.	Total federal clearance costs might be: $19K and take 3 to 8 months.

COAL ROAD

The ERO report mentions that the site will slightly impact BLM lands and would require agency approval. The report also mentions that the wetlands associated with the Coal Road Site may be considered "leaky ditch wetlands" and therefore exempt from permitting under the Clean Water Act. Further documentation of these wetlands would be required for an official determination to be made. The costs mentioned in the table above assume that an individual permit and mitigation would be required.

3300 ROAD

This site lies entirely on private lands and therefore permitting would be limited to any federal agency providing funding for the project. Very little, if any, wetlands are suspected to exist at this site, further simplifying the overall permitting process.

HAZARD CLASSIFICATION

The Division of Water Resources assigns dams a hazard classification based on the potential damage that would be caused by a 'sunny day' failure of the dam. The hazard classification determines specific criteria required for design and construction of the dam. Hydraulic modeling is used to predict the areas of inundation that could occur from failure of a planned dam site, which is used to determine the degree of potential damage. High Hazard dams are associated with a significant risk of loss of human life in the event of failure. Significant Hazard dams could cause damage to structures where people generally live, work or recreate, though no loss of life would be anticipated. Failure of a Low Hazard dam would not cause a significant threat of damage to existing buildings or infrastructure.

COAL ROAD

Below the dam site, Coal Creek is a well-defined, steep drainage. The drainage emerges at the edge of Hotchkiss where it becomes less defined and a dam breach flood would likely spread horizontally across the area. The drainage passes directly through the town of Hotchkiss and immediately adjacent to the Hotchkiss K-8 school. A failure of the proposed dam would likely impact several existing houses and structures including the school and therefore this dam would likely be classified as High Hazard. The scope of this project did not include a detailed hydraulic model for this site. Further study would be required to verify the High Hazard classification of this site.

3300 ROAD

IX draw below the dam site is relatively wide and heads due south to join Leroux Creek on the north side of Highway 92. There are few existing structures near IX draw between the dam and the highway. A dam breach hydraulic model was prepared for the drainage below this site to estimate impacts to structures and the highway and thereby determine the hazard classification of the dam. Our analysis indicates that there is minimal risk of property damage from this site. Portions of some existing agricultural structures could be partially inundated if a dam at this location breached, however, a loss of life would not be expected. This would result in the dam being classified as Low Hazard. Mapping of the estimated inundation area is included in Appendix C.

FLOOD HYDROLOGY & SPILLWAY

Current Dam Safety Rules and Regulations dictate the magnitude of flood event that dams are required to safely pass. The higher the dam hazard, the larger the flood event that must be safely conveyed through the dam and reservoir. A preliminary hydrologic analysis was prepared for the two sites in order to estimate the spillway size and thereby the construction cost. The Dam Safety Division updated the Hydrology design criteria for dams within the State of Colorado in January 2020 and the new guidance and rules were used in this analysis.

The analysis of each site included an evaluation of the existing soils based on data from Soil Conservation Service mapping to estimate the infiltration rates for the basins. Both basins are primarily composed of loam and sandy loam soils with relatively high infiltration rates. A spreadsheet program produced by the Colorado Dam Safety Branch was utilized to estimate key infiltration parameters based on this data. The small drainage basins and high infiltration rates resulted in the high intensity/low duration thunderstorm type events controlling the design of the spillway at both sites. Low intensity 48-hour type events produced very little runoff due to the high infiltration rates. This information was then input into a HEC-HMS hydrology model to estimate the runoff from various storm events.

COAL ROAD

As discussed in the section above, this site would likely be classified as a High Hazard Dam. Within this Hazard Classification there are two sub-classes for hydrology, High and Extreme.

- High hydrologic hazard means that a dam breach will result in a loss of life of less than one;
- Extreme hydrologic hazard is defined as a loss of life greater than one.

Determining which of the two classes that this structure may fall under is beyond the scope of this study, so it was assumed that this site would be classified as Extreme in order to be conservative. The drainage basin at this site is extremely small as shown on the figure in Appendix D. For purposes of this analysis it was assumed that the spillway would be composed of a rectangular ogee crested spillway. The total freeboard on the dam was assumed to be 5 feet. The spillway width was determined by assuming that the flood passing through the reservoir would result in a maximum water level one foot below the dam crest as required by the rules and regulations.

3300 ROAD

This site would be classified as a low hazard dam and therefore would only be required to pass the equivalent of a 100-yr (1% Annual Exceedance Probability) event. The required spillway size was determined in the same manner as the Coal Road site. An overview of the results is shown in the table below:

TABLE 2 HYDROLOGY SUMMARY

Parameter	Coal Road		3300 Road		
	2-hour	6-hour	2-hour	4-hour	6-hour
Max Inflow (cfs)	1023	787	760	206	551
Max Outflow (cfs)	852	686	470	79	295
Max Water Surface Elev.	5854.0	5853.5	5851.0	5848.2	5849.9
Spillway Width (ft)	25		15		

GEOTECHNICAL INVESTIGATION

The subsurface conditions of each site were investigated using a combination of augured test holes, test pits and laboratory testing and classification of representative samples. Test holes were completed using a tracked drill rig and 4-inch hollow-stem augers. Split-spoon samples and standard penetrations tests were taken at 5-foot intervals. Laboratory testing was performed on representative samples of the various materials encountered. Tests performed included gradation down to a #200 sieve and Atterberg Limits testing to estimate the plasticity of the soils and suitability for a dam embankment. All data and test results are included in Appendix E.

COAL ROAD

Three test holes were completed along the dam alignment and a fourth was completed in the vicinity of the proposed primary outlet conduit. One test pit was excavated to 10 feet in a potential borrow area, see Appendix E for location map. The soils along the proposed dam embankment were relatively consistent throughout the length of each hole and consisted of lean and heavy clays. The existing soils are very stiff to hard at relatively shallow depths. Borrow materials appear to primarily consist of lean-to heavy clays with no significant amount of gravels or rocks.

3300 ROAD

Two test holes were completed along the existing canal bank on either side of the proposed dam and a third was performed in the center of the draw along the canal. Two test pits were also excavated to examine the soil profile. The top 10-15 feet of soils at this site differ significantly from the Coal Road site. A large amount of sand, gravel, and cobbles were encountered in Test Pit 1. At a depth of 15 feet the material transitioned to very stiff to hard clays like those found at the Coal Road site.

The presence of these materials may lend this site to the construction of a zoned embankment. Sandy and gravelly soils near the surface could be used for the outer shell of the embankment while the deeper clays could be utilized for the embankment core. This method of construction would allow steeper slopes to be used for the upstream and downstream slopes of the embankment. According to guidance listed in the USBR Design of Small Dams a 3:1 upstream slope and 2:1 downstream slope would likely be suitable for a zoned structure at this site. One downside to this site is that it would require a 10-15-foot-deep keyway under the embankment core in order to address the sands and gravels under the dam.

DAM EMBANKMENT

Preliminary design including embankment slopes, foundation design, storage volume, internal drainage system, and erosion protection was completed for each site. Both sites were assumed to be subjected to rapid drawdown as the water level could change drastically over a 24-hour period during regular operations.

Coal Road

Based on the existing information this site is best suited for a homogenous clay embankment. Based on preliminary soil tests the embankment would require upstream and downstream slopes of 3.5H:1V and 2.5H:1V respectively. The dam height would require a crest width of 18 feet to meet state standards. As mentioned previously the dam would incorporate 5 feet of freeboard and a 25-foot-wide spillway would be required. Due to topographical constraints, it is likely that the spillway would need to pass directly over the dam thereby requiring a concrete spillway channel to the base of the dam. Material for the embankment would be excavated from the active storage pool of the reservoir to increase the associated volume. Due to the high hazard rating and the homogenous structure of this dam, it is assumed that a chimney filter and blanket drain system would be required.

Another issue that would need to be addressed at this site is the operation of the canal which passes through the reservoir. To separate flood flows from the canal, the preliminary design assumes that the canal would be piped through the reservoir area. A small saddle dam would be required at the northwest corner of the reservoir to contain flood flows within the basin and prevent them from exiting out the canal. The existing canal bank within the reservoir is very steep and would require some regrading to remain stable during operation of the reservoir. The existing slopes would need to be flattened to a minimum of 2.5:1 which will require an additional amount of earthwork.

3300 Road

As mentioned above, a wider variety of materials seems to be available at this site which may lend itself to the construction of a zoned embankment. The foundation will likely require a 10 to 15-foot-deep keyway trench to tie into the relatively impermeable clay below. While this is an expensive feature, it is necessary to provide a seepage cutoff under the dam for water efficiency and dam embankment stability reasons. Using a zoned embankment at this site would allow the upstream and downstream faces to be 3:1 and 2:1 respectively. Material for the embankment would be excavated from the active storage pool zone. Due to the low hazard rating, low water storage depth (13 feet), and the zoned embankment design it is assumed that a chimney filter and blanket drain system would not be required. This assumption would be verified during final design.

INLET AND OUTLET INFRASTRUCTURE

As previously mentioned, both sites are located near an existing drop structure in the canal. This allows the elevation drop to be used to drain and fill a regulating reservoir by gravity. Another option for either site would include using a pump system to either fill the reservoir or withdraw water from storage and utilize the elevation drop to provide an additional pressure of about 5 psi to the pipeline. The pump would only be required to move the amount of excess or shortage within the system to and from the reservoir. The full canal flowrate of 110 cfs would not need to be pumped in and out of the reservoir.

The addition of a pump system would add some complexity to the system with both construction and maintenance costs associated with this additional infrastructure. While the elevation lift needed would be small due to the site locations being near the canal, a pump station would still come with an associated cost of electricity every year and be susceptible to power outages and equipment downtime. The actual annual cost of power would depend on maximum pumping rates and the amount of water that was pumped every year. Assuming that a 40-horsepower pump station was operated periodically for 5 months such that the reservoir drains and refills 50% of its capacity every 2 days, the annual cost of electricity would be approximately $3,800 at 2020 electricity rates. Furthermore, if this option was pursued, the Leroux Creek

Inlet would need to either be relocated further upstream or a pump would need to be installed to force water into the system at this location due to the increased system pressure.

The remainder of this report assumes that the proposed reservoirs would operate with gravity inlets and outlets and no pump stations would be required. Each site can achieve a reasonable level of storage volume by utilizing gravity outlets and the FMC board has specified that their preference would be to construct a gravity system if acceptable levels of storage could be attained. Therefore, the remainder of this study assumes that pump stations would not be included in the preliminary reservoir designs.

COAL ROAD

Maximizing the storage at this site would be complicated by the fact that the canal would essentially run through the dam and reservoir area, but water would not exit the site through the dam. The primary outlet would exit through a pipeline to the existing ditch, but a low-level outlet through the dam would be required by the State Engineers Office to allow the reservoir to be fully drained. The reservoir would typically operate at a level lower than the historical canal level, however during a large flood event the canal could be inundated and water would back up in the canal and overtop on the downstream side of the canal. In order to avoid this canal overflow condition, we have assumed that the canal would need to be piped through the site and separated from the reservoir. This pipe would end at the northwest side of the reservoir where it would discharge into the open canal. Piping the canal through the site would also allow construction or maintenance to be performed on the dam and reservoir while the canal is in service.

After exiting the pipe through the reservoir, water would pass through the existing canal cut to near the drop chute where it would enter a new drop pipeline. The inlet to this pipeline would incorporate a measuring flume and a slide gate for the existing Turnout #66 at the top of the drop. The pipe would then drop approximately 12 feet in elevation and then enter the bottom of the outlet control tower. This structure would consist of a rectangular concrete tower with a divider wall in the middle. Slide gates mounted to the divider wall would control deliveries to the canal below. Another short pipeline would exit this structure below the slide gates and connect to outlet control tower to the open canal. Deliveries to and from the reservoir would occur through a 36” siphon pipe installed between the reservoir and the upstream side of the outlet control tower. This siphon pipe could be buried just below the invert of the existing open canal. Installing this pipe at the bottom of the regulating pool of the regulating reservoir would require a large amount of excavation due to the depth of excavation required and the fact that the open canal is already excavated through a large cut in this location.

Using a siphon pipe would save a significant amount of excavation work and reduce the seepage potential along the conduit from the reservoir to the outlet control tower. The siphon could be primed with water provided from the open canal above. Once primed, the water level upstream of the divider wall in the outlet control tower would essentially track up and down with the level in the reservoir. When the canal flow exceeded the system demand below, the gates would close which would force the water level to rise on the upstream side of the divider wall and water would then flow back into the reservoir. If the demand began to exceed the supply the control gates would open and lower the water level in the control tower and water would then flow from the reservoir to the control tower to maintain the desired flow.

3300 ROAD

Water would be supplied to this site through a 72-inch pipeline that would convey water from the top of the existing drop chute to an outlet control tower located below the dam. The inlet to this pipeline would incorporate a new measuring flume, a coarse trash rack and a new diversion for Turnout #66. The outlet control tower would be like the Coal Road site with a divider wall in the middle. A 30-inch pipeline would connect the outlet control tower to the reservoir and serve as the low-level outlet for the dam. Like the 36" siphon pipe at the Coal Road site, this pipe would flow either direction depending on the imbalance between supply and demand below the reservoir.

Spring Debris Flushing

During spring startup of the Fire Mountain Canal, the operators begin by flushing all the debris out of the canal that has accumulated over the winter months. Typically, they begin diversions from the river on the first day and dump all the water and debris back to the canal at Roatcap Creek. On the following day, they send the water down the canal to Leroux Creek where it passes down the recently installed spillway pipe at the entrance to the existing pipeline. Following construction of either reservoir, the proposed infrastructure should allow the canal to be flushed through the outlet control tower and down the open canal to the recently installed Leroux Creek spillway where it would be dumped to Leroux Creek per historical practices.

Canal Pipeline – regulating Reservoir to Rogers Mesa Pipeline

To obtain the maximum level of water conservation in the system, the existing open canal would need to be piped from the regulating reservoir to the recently installed pipeline across Rogers Mesa. This pipeline would be designed to flow completely full and function as a low-pressure pipeline. Such conditions would allow the system below this point to function as an on-demand system, if desired, where users could turn off their water when it is not needed. The intake to this pipeline would be located approximately 500 feet from the outlet control tower. A leveling pool would be graded along the existing canal alignment between the outlet control tower and the pipe intake. This pool will allow a constant pressure to be maintained on the low-pressure pipeline below this point. The SCADA system would monitor the level of this pool and operate the control valves in the outlet tower to maintain a steady operating level.

The installation of this pipeline would also require modifications to the existing Leroux Creek Spillway and Screen structure that was recently installed. The automated screen would be relocated to a new concrete inlet structure at the downstream end of the leveling pool. This structure would need to incorporate a spillway to allow spring flushing flows to bypass the screen and continue down the pipeline to the Leroux Creek spillway where it would be dumped to Leroux Creek. Additional modifications would be required at the Leroux Creek spillway structure including extending the 54" pipe about 40 feet to bypass the portion of this structure that was required to accommodate the automated screen. The existing 54" gate would also need to be relocated to the new entrance. The walls of the remaining structure would need to be raised at least 5 feet to allow the development of additional head pressure at this location and prevent unintended spills from occurring to Leroux Creek. A 48" gate would also be required to dump spring flushing flows down to Leroux Creek.

CONSTRUCTION COST

An engineer's opinion of probable cost was prepared to compare the two sites from an economical perspective. Detailed cost estimates are in Appendix F, and a summary is shown in Table 3. This opinion of probable cost includes a 20% contingency to account for smaller items and some uncertainty in the final design. Overall, the two reservoir sites will likely have a similar cost if just the reservoir was considered. Considerable cost savings become apparent, however, when considering the pipeline from the reservoir to the existing Rogers Mesa Pipeline as the 3300 Road site is significantly closer.

SUMMARY

The table below provides a side by side comparison of the two sites analyzed in this report. Based on our analysis, either site will be suitable for the intended purpose of a regulating reservoir. However, the 3300 Road site would be significantly more cost effective due to the reduced pipeline costs to tie into the existing Rogers Mesa Pipeline.

TABLE 3 SITE COMPARRISON

Factor	Coal Road	3300 Road
Land Ownership	Bureau of Reclamation	Private
Total Storage (acre-ft)	60	44
Active Storage (acre-ft)	49	44
Embankment Height (ft)	40	30
Environmental Constraints	May involve jurisdictional wetlands	None of Significance
Geotechnical	Relatively uniform clay materials. Minimal Keyway needed, Homogenous dam embankment	Wide range of materials available. May allow for zoned embankment construction. Keyway will need to intercept gravel layer in foundation
Hazard Classification	High	Low
Upstream Embankment Slope	3.5:1	3:1
Downstream Embankment Slope	2.5:1	2:1
Infrastructure	Two outlets required – one at the Dam and the main siphon inlet/outlet. Canal piped through reservoir area Concrete chute spillway required down dam embankment	Requires piped inlet from existing canal drop to reservoir. Only one dam outlet required. Riprap lined spillway channel around dam
Estimated Reservoir Cost (million $)	$1.93	$1.52
Estimate Pipeline Cost (million $)	$5.67	$4.08
Total Estimated Project Cost (million $)	$7.60	$5.60

NEXT STEPS

The next most logical step in this process would be to meet with the landowner at the 3300 Road site and determine if any agreement could be reached that would allow the construction and operation of the reservoir at that site. If the owner is willing to allow a permanent easement or land purchase for approximately 19 acres, then this would be the site recommended for final design. If the landowner is unwilling to work with FMC, then the Coal Road site is the only option. Once this issue has been settled, then funding sources should be investigated to determine how and when the project could be funded.

Appendix A – Flow Data

FMC Rogers Mesa DROP FLUME READINGS

6' Parshall Flume

Q = 24*h^1.59 — missing data

	2016				2017				2018			
	h	Q	Storage	2day V	h	Q	Storage	2day V	h	Q	Storage	2day V
MAX	**2.68**	**115.1**	**41.2**	**20.7**	**2.7**	**116.4**	**56.0**	**56.4**	**2.84**	**126.2**	**389.9**	**68.6**
9-Apr												
10-Apr									2.48	101.7	0.0	
11-Apr									2.48	101.7	0.0	
12-Apr									2.58	108.3	0.0	26.4
13-Apr									2.66	113.7	3.4	47.9
14-Apr									2.6	109.7	0.0	5.4
15-Apr									2.4	96.5	0.0	68.6
16-Apr									2.4	96.5	0.0	52.4
17-Apr									2.36	94.0	0.0	10.2
18-Apr									2.38	95.3	0.0	5.1
19-Apr					2.3	90.2	0.0		2.26	87.7	0.0	25.0
20-Apr					2.32	91.5	0.0		2.3	90.2	0.0	20.2
21-Apr					2.52	104.3	0.0	56.4	2.3	90.2	0.0	9.9
22-Apr	2.45	99.8	0.0		2.46	100.4	0.0	35.7	2.38	95.3	0.0	20.2
23-Apr	2.37	94.6	0.0		2.56	107.0	0.0	10.6	2.4	96.5	0.0	25.3
24-Apr	2.37	94.6	0.0	20.5	2.6	109.7	0.0	37.0	2.5	103.0	0.0	31.0
25-Apr	2.38	95.3	0.0	2.5	2.62	111.0	0.0	16.1	2.61	110.3	0.0	55.1
26-Apr	2.40	96.5	0.0	7.6	2.61	110.3	0.0	2.7	2.64	112.3	0.7	37.3
27-Apr	2.44	99.1	0.0	15.4	2.62	111.0	0.0	0.0	2.68	115.1	6.8	19.0
28-Apr	2.48	101.7	0.0	20.7	2.58	108.3	0.0	8.0	2.68	115.1	13.0	10.9
29-Apr	2.48	101.7	0.0	10.4	2.6	109.7	0.0	5.4	2.7	116.4	21.8	5.5
30-Apr	2.52	104.3	0.0	10.5	2.58	108.3	0.0	0.0	2.67	114.4	26.6	2.7
1-May	2.50	103.0	0.0	5.2	2.58	108.3	0.0	5.4	2.67	114.4	31.4	8.2
2-May	2.50	103.0	0.0	5.3	2.6	109.7	0.0	5.4	2.68	115.1	37.5	2.7
3-May	2.50	103.0	0.0	0.0	2.6	109.7	0.0	5.4	2.67	114.4	42.3	0.0
4-May	2.51	103.7	0.0	2.6	2.6	109.7	0.0	0.0	2.66	113.7	45.7	5.4
5-May	2.50	103.0	0.0	0.0	2.61	110.3	0.0	2.7	2.66	113.7	49.1	2.7
6-May	2.50	103.0	0.0	2.6	2.6	109.7	0.0	0.0	2.66	113.7	52.5	0.0
7-May	2.50	103.0	0.0	0.0	2.6	109.7	0.0	2.7	2.62	111.0	50.5	10.8
8-May	2.50	103.0	0.0	0.0	2.58	108.3	0.0	5.4	2.67	114.4	55.2	2.7
9-May	2.50	103.02	0.0	0.0	2.6	109.7	0.0	0.0	2.66	113.7	58.6	10.8
10-May	2.50	103.02	0.0	0.0	2.6	109.7	0.0	5.4	2.68	115.1	64.8	2.7
11-May	2.57	107.6	0.0	18.5	2.63	111.7	0.0	8.1	2.68	115.1	70.9	5.4
12-May	2.50	103.0	0.0	0.0	2.63	111.7	0.0	8.1	2.68	115.1	77.0	0.0
13-May	2.50	103.02	0.0	18.5	2.63	111.7	0.0	0.0	2.69	115.7	84.5	2.7
14-May	2.54	105.7	0.0	10.5	2.6	109.7	0.0	8.1	2.67	114.4	89.3	2.7
15-May	2.52	104.3	0.0	5.3	2.6	109.7	0.0	8.1	2.67	114.4	94.1	5.5
16-May	2.52	104.3	0.0	5.3	2.6	109.7	0.0	0.0	2.67	114.4	98.8	0.0
17-May	2.54	105.7	0.0	5.3	2.58	108.3	0.0	5.4	2.68	115.1	105.0	2.7
18-May	2.51	103.7	0.0	2.6	2.58	108.3	0.0	5.4	2.66	113.7	108.4	2.7
19-May	2.52	104.3	0.0	5.3	2.58	108.3	0.0	0.0	2.66	113.7	111.8	5.4
20-May	2.51	103.7	0.0	0.0	2.6	109.7	0.0	5.4	2.65	113.0	113.8	2.7
21-May	2.53	105.0	0.0	2.6	2.58	108.3	0.0	0.0	2.65	113.0	115.9	2.7
22-May	2.54	105.7	0.0	7.9	2.62	111.0	0.0	5.4	2.66	113.7	119.3	2.7
23-May	2.51	103.7	0.0	5.3	2.6	109.7	0.0	5.4	2.66	113.7	122.7	2.7
24-May	2.54	105.7	0.0	0.0	2.54	105.7	0.0	21.4	2.65	113.0	124.7	2.7
25-May	2.54	105.7	0.0	7.9	2.56	107.0	0.0	10.7	2.66	113.7	128.1	0.0
26-May	2.55	106.3	0.0	2.6	2.57	107.6	0.0	8.0	2.68	115.1	134.3	8.2
27-May	2.55	106.3	0.0	2.6	2.59	109.0	0.0	8.0	2.65	113.0	136.3	2.7
28-May	2.55	106.3	0.0	0.0	2.57	107.6	0.0	0.0	2.66	113.7	139.7	5.4
29-May	2.55	106.3	0.0	0.0	2.57	107.6	0.0	5.3	2.67	114.4	144.5	5.4
30-May	2.53	105.0	0.0	5.3	2.57	107.6	0.0	0.0	2.67	114.4	149.3	2.7
31-May	2.52	104.3	0.0	7.9	2.57	107.6	0.0	0.0	2.68	115.1	155.4	2.7
1-Jun	2.53	105.0	0.0	0.0	2.6	109.7	0.0	8.0	2.68	115.1	161.5	2.7

FMC Rogers Mesa DROP FLUME READINGS
6' Parshall Flume
Q = 24*h^1.59

missing data

	2016				2017				2018			
	h	Q	Storage	2day V	h	Q	Storage	2day V	h	Q	Storage	2day V
MAX	**2.68**	**115.1**	**41.2**	**20.7**	**2.7**	**116.4**	**56.0**	**56.4**	**2.84**	**126.2**	**389.9**	**68.6**
2-Jun	2.54	105.7	0.0	5.3	2.6	109.7	0.0	8.0	2.67	114.4	166.3	2.7
3-Jun	2.55	106.3	0.0	5.3	2.6	109.7	0.0	0.0	2.68	115.1	172.4	0.0
4-Jun	2.55	106.3	0.0	2.6	2.61	110.3	0.0	2.7	2.68	115.1	178.6	2.7
5-Jun	2.55	106.3	0.0	0.0	2.62	111.0	0.0	5.4	2.69	115.7	186.1	2.7
6-Jun	2.56	107.0	0.0	2.7	2.66	113.7	3.4	13.5	2.68	115.1	192.2	0.0
7-Jun	2.57	107.6	0.0	5.3	2.65	113.0	5.5	8.1	2.67	114.4	197.0	5.5
8-Jun	2.57	107.6	0.0	2.7	2.67	114.4	10.2	2.7	2.68	115.1	203.1	0.0
9-Jun	2.57	107.6	0.0	0.0	2.65	113.0	12.3	0.0	2.67	114.4	207.9	0.0
10-Jun	2.58	108.3	0.0	2.7	2.66	113.7	15.7	2.7	2.67	114.4	212.6	2.7
11-Jun	2.57	107.6	0.0	0.0	2.66	113.7	19.1	2.7	2.64	112.3	213.3	8.1
12-Jun	2.58	108.3	0.0	0.0	2.66	113.7	22.5	0.0	2.64	112.3	214.0	8.1
13-Jun	2.60	109.7	0.0	8.0	2.66	113.7	25.9	0.0	2.64	112.3	214.7	0.0
14-Jun	2.62	111.0	0.0	10.7	2.66	113.7	29.3	0.0	2.66	113.7	218.1	5.4
15-Jun	2.60	109.7	0.0	0.0	2.66	113.7	32.7	0.0	2.67	114.4	222.9	8.1
16-Jun	2.62	111.0	0.0	0.0	2.66	113.7	36.1	0.0	2.66	113.7	226.3	0.0
17-Jun	2.62	111.0	0.0	5.4	2.65	113.0	38.2	2.7	2.68	115.1	232.4	2.7
18-Jun	2.61	110.3	0.0	2.7	2.65	113.0	40.2	2.7	2.68	115.1	238.6	5.4
19-Jun	2.60	109.7	0.0	5.4	2.64	112.3	40.9	2.7	2.68	115.1	244.7	0.0
20-Jun	2.60	109.7	0.0	2.7	2.64	112.3	41.6	2.7	2.68	115.1	250.8	0.0
21-Jun	2.60	109.7	0.0	0.0	2.64	112.3	42.3	0.0	2.67	114.4	255.6	2.7
22-Jun	2.63	111.7	0.0	8.1	2.64	112.3	43.0	0.0	2.67	114.4	260.3	2.7
23-Jun	2.63	111.7	0.0	8.1	2.65	113.0	45.0	2.7	2.67	114.4	265.1	0.0
24-Jun	2.61	110.3	0.0	5.4	2.65	113.0	47.1	2.7	2.67	114.4	269.9	0.0
25-Jun	2.61	110.3	0.0	5.4	2.63	111.7	46.4	5.4	2.67	114.4	274.7	0.0
26-Jun	2.62	111.0	0.0	2.7	2.63	111.7	45.8	5.4	2.68	115.1	280.8	2.7
27-Jun	2.61	110.3	0.0	0.0	2.65	113.0	47.8	5.4	2.67	114.4	285.5	0.0
28-Jun	2.60	109.7	0.0	5.4	2.65	113.0	49.9	5.4	2.67	114.4	290.3	2.7
29-Jun	2.63	111.7	0.0	5.4	2.64	112.3	50.6	2.7	2.67	114.4	295.1	0.0
30-Jun	2.64	112.3	0.7	10.8	2.65	113.0	52.6	0.0	2.66	113.7	298.5	2.7
1-Jul	2.64	112.3	1.4	2.7	2.66	113.7	56.0	5.4	2.66	113.7	301.9	2.7
2-Jul	2.64	112.3	2.1	0.0	2.6	109.7	51.3	13.5	2.66	113.7	305.3	0.0
3-Jul	2.64	112.3	2.8	0.0	2.6	109.7	46.6	16.2	2.66	113.7	308.7	0.0
4-Jul	2.64	112.3	3.5	0.0	2.6	109.7	41.9	0.0	2.66	113.7	312.1	0.0
5-Jul	2.64	112.3	4.2	0.0	2.6	109.7	37.2	0.0	2.66	113.7	315.5	0.0
6-Jul	2.65	113.0	6.2	2.7	2.6	109.7	32.5	0.0	2.66	113.7	318.9	0.0
7-Jul	2.65	113.0	8.3	2.7	2.6	109.7	27.9	0.0	2.68	115.1	325.1	5.4
8-Jul	2.65	113.0	10.3	0.0	2.62	111.0	25.8	5.4	2.7	116.4	333.9	10.9
9-Jul	2.66	113.7	13.7	2.7	2.61	110.3	22.5	2.7	2.84	126.2	362.3	44.5
10-Jul	2.66	113.7	17.1	2.7	2.63	111.7	21.8	2.7	2.65	113.0	364.3	13.6
11-Jul	2.64	112.3	17.8	5.4	2.65	113.0	23.9	10.8	2.64	112.3	365.0	55.3
12-Jul	2.62	111.0	15.8	10.8	2.65	113.0	25.9	5.4	2.65	113.0	367.1	0.0
13-Jul	2.64	112.3	16.5	0.0	2.68	115.1	32.1	8.2	2.62	111.0	365.1	5.4
14-Jul	2.67	114.4	21.3	13.5	2.66	113.7	35.5	2.7	2.61	110.3	361.7	10.8
15-Jul	2.67	114.4	26.0	8.1	2.67	114.4	40.2	2.7	2.65	113.0	363.8	8.1
16-Jul	2.67	114.4	30.8	0.0	2.66	113.7	43.6	0.0	2.65	113.0	365.8	10.8
17-Jul	2.68	115.1	36.9	2.7	2.69	115.7	51.1	5.5	2.66	113.7	369.2	2.7
18-Jul	2.62	111.0	34.9	13.5	2.63	111.7	50.5	8.1	2.64	112.3	369.9	2.7
19-Jul	2.66	113.7	38.3	5.4	2.64	112.3	51.2	13.6	2.66	113.7	373.3	0.0
20-Jul	2.64	112.3	39.0	5.4	2.62	111.0	49.2	2.7	2.65	113.0	375.4	2.7
21-Jul	2.64	112.3	39.7	5.4	2.62	111.0	47.2	5.4	2.62	111.0	373.4	10.8
22-Jul	2.64	112.3	40.4	0.0	2.63	111.7	46.5	2.7	2.62	111.0	371.4	8.1
23-Jul	2.63	111.7	39.8	2.7	2.65	113.0	48.6	8.1	2.64	112.3	372.1	5.4
24-Jul	2.64	112.3	40.5	0.0	2.64	112.3	49.3	2.7	2.64	112.3	372.7	5.4
25-Jul	2.64	112.3	41.2	2.7	2.64	112.3	49.9	2.7	2.66	113.7	376.2	5.4

FMC Rogers Mesa DROP FLUME READINGS
6' Parshall Flume
Q = 24*h^1.59

missing data

	2016				2017				2018			
	h	Q	Storage	2day V	h	Q	Storage	2day V	h	Q	Storage	2day V
MAX	**2.68**	**115.1**	**41.2**	**20.7**	**2.7**	**116.4**	**56.0**	**56.4**	**2.84**	**126.2**	**389.9**	**68.6**
26-Jul	2.63	111.7	40.5	2.7	2.64	112.3	50.6	0.0	2.65	113.0	378.2	2.7
27-Jul	2.62	111.0	38.5	5.4	2.64	112.3	51.3	0.0	2.64	112.3	378.9	5.4
28-Jul	2.62	111.0	36.5	2.7	2.64	112.3	52.0	0.0	2.64	112.3	379.6	2.7
29-Jul	2.62	111.0	34.5	0.0	2.64	112.3	52.7	0.0	2.64	112.3	380.3	0.0
30-Jul	2.62	111.0	32.5	0.0	2.64	112.3	53.4	0.0	2.65	113.0	382.3	2.7
31-Jul	2.62	111.0	30.5	0.0	2.63	111.7	52.8	2.7	2.65	113.0	384.4	2.7
1-Aug	2.61	110.3	27.1	2.7	2.62	111.0	50.8	5.4	2.65	113.0	386.4	0.0
2-Aug	2.6	109.7	22.4	5.4	2.62	111.0	48.7	2.7	2.65	113.0	388.5	0.0
3-Aug	2.62	111.0	20.4	2.7	2.62	111.0	46.7	0.0	2.64	112.3	389.2	2.7
4-Aug	2.62	111.0	18.4	5.4	2.61	110.3	43.4	2.7	2.64	112.3	389.9	2.7
5-Aug	2.62	111.0	16.4	0.0	2.63	111.7	42.7	2.7				
6-Aug	2.62	111.0	14.4	0.0	2.7	116.4	51.6	24.4				
7-Aug	2.61	110.3	11.0	2.7	2.65	113.0	53.6	5.4				
8-Aug	2.61	110.3	7.7	2.7	2.6	109.7	48.9	27.1				
9-Aug	2.61	110.3	4.3	0.0	2.61	110.3	45.6	10.8				
10-Aug	2.6	109.7	0.0	2.7	2.62	111.0	43.6	5.4				
11-Aug	2.61	110.3	0.0	0.0	2.61	110.3	40.2	0.0				
12-Aug	2.61	110.3	0.0	2.7	2.64	112.3	40.9	5.4				
13-Aug	2.62	111.0	0.0	2.7	2.64	112.3	41.6	8.1				
14-Aug	2.62	111.0	0.0	2.7	2.68	115.1	47.8	10.9				
15-Aug	2.62	111.0	0.0	0.0	2.62	111.0	45.8	5.4				
16-Aug	2.64	112.3	0.7	5.4	2.61	110.3	42.4	19.0				
17-Aug	2.63	111.7	0.0	2.7	2.58	108.3	35.0	10.7				
18-Aug	2.63	111.7	0.0	2.7	2.63	111.7	34.4	5.4				
19-Aug	2.61	110.3	0.0	5.4	2.63	111.7	33.7	13.4				
20-Aug	2.61	110.3	0.0	5.4	2.63	111.7	33.1	0.0				
21-Aug	2.61	110.3	0.0	0.0	2.63	111.7	32.4	0.0				
22-Aug	2.6	109.7	0.0	2.7	2.58	108.3	25.0	13.4				
23-Aug	2.63	111.7	0.0	5.4	2.58	108.3	17.7	13.4				
24-Aug	2.62	111.0	0.0	5.4	2.58	108.3	10.3	0.0				
25-Aug	2.62	111.0	0.0	2.7	2.61	110.3	6.9	8.0				
26-Aug	2.63	111.7	0.0	2.7	2.61	110.3	3.6	8.0				
27-Aug	2.64	112.3	0.7	5.4	2.61	110.3	0.2	0.0				
28-Aug	2.64	112.3	1.4	2.7	2.65	113.0	2.3	10.8				
29-Aug	2.64	112.3	2.1	0.0	2.65	113.0	4.3	10.8				
30-Aug	2.65	113.0	4.1	2.7	2.63	111.7	3.7	5.4				
31-Aug	2.61	110.3	0.8	8.1	2.6	109.7	0.0	13.5				
1-Sep	2.61	110.3	0.0	10.8	2.62	111.0	0.0	2.7				
2-Sep	2.62	111.0	0.0	2.7	2.62	111.0	0.0	5.4				
3-Sep	2.62	111.0	0.0	2.7	2.62	111.0	0.0	0.0				
4-Sep	2.63	111.7	0.0	2.7	2.62	111.0	0.0	0.0				
5-Sep	2.63	111.7	0.0	2.7	2.62	111.0	0.0	0.0				
6-Sep	2.62	111.0	0.0	2.7	2.61	110.3	0.0	2.7				
7-Sep	2.62	111.0	0.0	2.7	2.6	109.7	0.0	5.4				
8-Sep	2.62	111.0	0.0	0.0	2.58	108.3	0.0	8.0				
9-Sep	2.6	109.7	0.0	5.4	2.58	108.3	0.0	5.4				
10-Sep	2.59	109.0	0.0	8.1	2.6	109.7	0.0	5.4				
11-Sep	2.61	110.3	0.0	2.7	2.6	109.7	0.0	5.4				
12-Sep	2.61	110.3	0.0	5.4	2.63	111.7	0.0	8.1				
13-Sep	2.61	110.3	0.0	0.0	2.63	111.7	0.0	8.1				
14-Sep	2.62	111.0	0.0	2.7	2.63	111.7	0.0	0.0				
15-Sep	2.62	111.0	0.0	2.7								
16-Sep	2.62	111.0	0.0	0.0								
17-Sep	2.03	74.0	0.0									

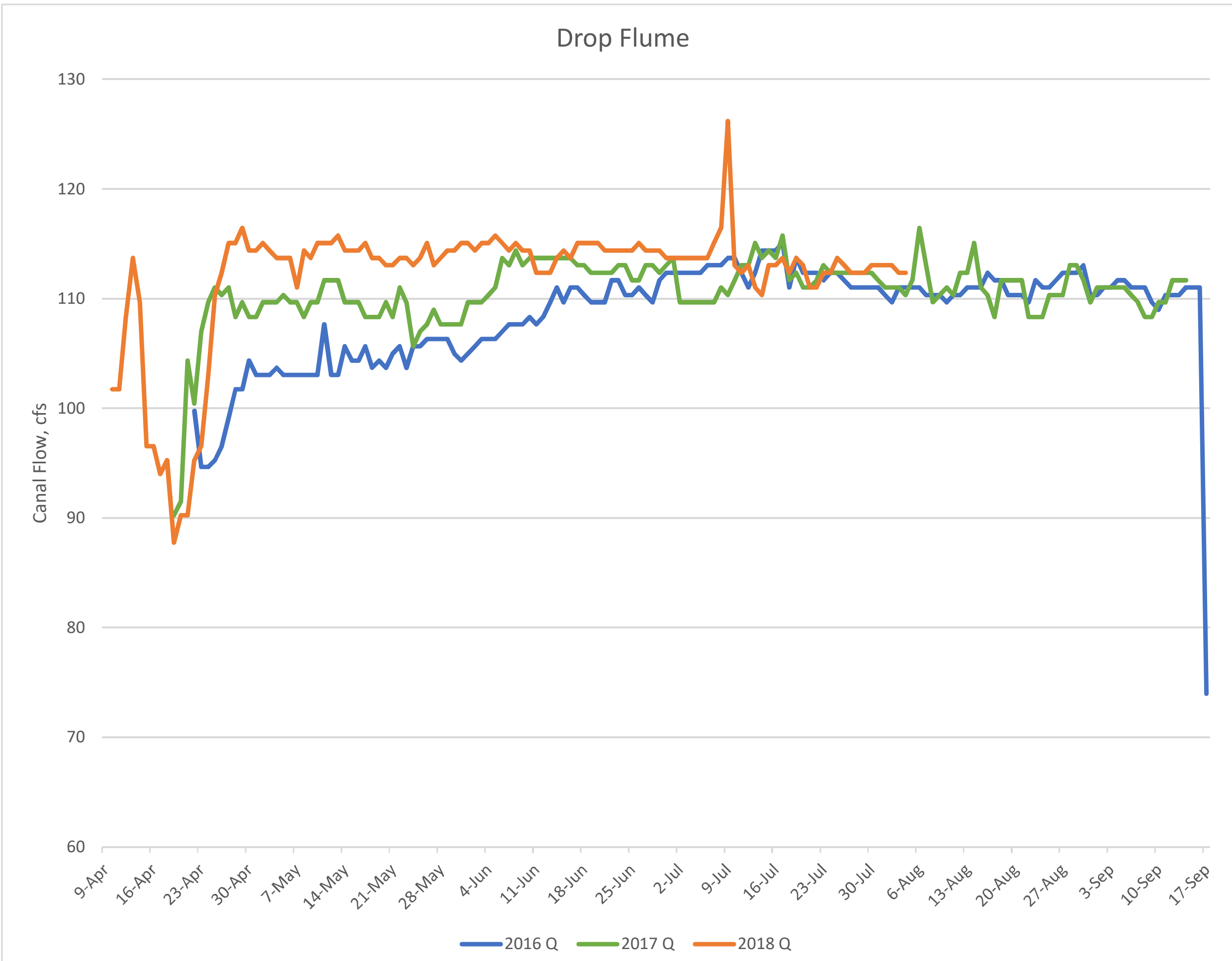
FMC Rogers Mesa DROP FLUME READINGS

6' Parshall Flume

Q = 24*h^1.59

missing data

	2016				2017				2018			
	h	Q	Storage	2day V	h	Q	Storage	2day V	h	Q	Storage	2day V
MAX	**2.68**	**115.1**	**41.2**	**20.7**	**2.7**	**116.4**	**56.0**	**56.4**	**2.84**	**126.2**	**389.9**	**68.6**



FMC Rogers Mesa HOUSE FLUME READINGS
8' Parshall Flume
Q = 32*h^1.61

	2016			2017			2018		
	h	Q	cfs	h	Q	cfs	h	Q	cfs
MAX	2.27	119.8	112	2.33	124.9	122.8	2.12	107.3	106
9-Apr							1.8	82.44	82.2
10-Apr							1.88	88.42	89
11-Apr							1.96	94.55	94
12-Apr							1.96	94.55	94
13-Apr									
14-Apr							1.79	81.70	
15-Apr							1.8	82.44	
16-Apr			38				1.78	80.97	
17-Apr			38	1.82	83.92	83.7	1.77	80.24	80
18-Apr	1.50	61.47		1.83	84.66	83	1.78	80.97	81
19-Apr	1.52	62.79		2.21	114.72	114	1.67	73.07	73
20-Apr	1.56	65.48	64	2.28	120.62	120	1.71	75.91	75.6
21-Apr	1.84	85.41	85	2.28	120.62		1.87	87.66	87.4
22-Apr	1.89	89.18		2.28	120.62		1.78	80.97	81
23-Apr	1.90	89.94		2.28	120.62		1.78	80.97	80.5
24-Apr	1.90	89.94		2.28	120.62		1.9	89.94	90
25-Apr	1.90	89.94		2.3	122.33		1.96	94.55	94.5
26-Apr	1.90	89.94		2.15	109.74		2.11	106.47	106
27-Apr	1.88	88.42		1.99	96.90	96.6	2.05	101.64	101
28-Apr	1.94	93.01		1.93	92.24	92	2.05	101.64	101
29-Apr	1.88	88.42		1.95	93.78	93.5	2	97.68	97.5
30-Apr	1.89	89.18		1.93	92.24	92	2.02	99.26	99
1-May	1.86	86.91		1.94	93.01		2	97.68	97.5
2-May	1.88	88.42		1.95	93.78	94.5	2	97.68	
3-May	1.92	91.47		1.93	92.24	92	1.98	96.11	95.8
4-May	1.97	95.33		2.23	116.39		1.97	95.33	95.1
5-May	2.05	101.64		2.23	116.39	120.5			
6-May	2.05	101.64		2.31	123.19	122.8			
7-May	2.05	101.64		2.33	124.91		1.92	91.47	91.2
8-May	2.05	101.64		2.31	123.19	122.8	1.96	94.55	94.5
9-May	2.13	108.10		2.31	123.19		2.03	100.05	99
10-May	2.11	106.47		2.31	123.19		1.99	96.90	96.6
11-May	2.12	107.29		2.31	123.19		2.07	103.24	103
12-May	2.11	106.47		2.31	123.19		2.01	98.47	98
13-May	2.18	112.22		2.3	122.33		2.03	100.05	99.8
14-May	2.20	113.88		2.31	123.19		1.97	95.33	95.1
15-May	2.19	113.05		2.3	122.33		1.97	95.33	95
16-May	2.18	112.22		2.29	121.47		1.95	93.78	93.5
17-May	2.23	116.39		2.28	120.62		1.97	95.33	95.1
18-May	2.21	114.72		2.28	120.62		1.97	95.33	95.1

FMC Rogers Mesa HOUSE FLUME READINGS

8' Parshall Flume

Q = 32*h^1.61

	2016			2017			2018		
	h	Q	cfs	h	Q	cfs	h	Q	cfs
MAX	2.27	119.8	112	2.33	124.9	122.8	2.12	107.3	106
19-May	2.22	115.55		2.26	118.92		1.96	94.55	94.3
20-May	2.23	116.39		2.07	103.24		1.94	93.01	92.7
21-May	2.26	118.92		2.08	104.05		1.93	92.24	92
22-May	2.27	119.77		2.08	104.05		1.94	93.01	92.7
23-May	2.25	118.08		2.22	115.55	115	1.94	93.01	92.7
24-May	2.26	118.92		2.26	118.92		1.93	92.24	92.02
25-May	2.26	118.92		2.26	118.92		1.94	93.01	
26-May	2.27	119.77		2.27	119.77		1.96	94.55	94.3
27-May	2.27	119.77		2.27	119.77		1.93	92.24	92
28-May	2.27	119.77		2.27	119.77		1.94	93.01	92.7
29-May	2.27	119.77		2.27	119.77	118	1.95	93.78	
30-May	2.27	119.77		2.27	119.77		1.95	93.78	
31-May	2.26	118.92		2.28	120.62		1.96	94.55	
1-Jun	2.27	119.77		2.28	120.62	120	1.96	94.55	
2-Jun	2.27	119.77		2.29	121.47		1.95	93.78	
3-Jun	2.27	119.77		2.27	119.77		1.95	93.78	
4-Jun	2.26	118.92		2.28	120.62		1.96	94.55	
5-Jun	2.26	118.92		2.28	120.62		1.97	95.33	
6-Jun	2.27	119.77		2.28	120.62		1.96	94.55	
7-Jun	2.27	119.77		2.28	120.62		1.96	94.55	
8-Jun	2.27	119.77		2.27	119.77		1.95	93.78	
9-Jun	2.27	119.77		2.27	119.77		1.94	93.01	
10-Jun	2.27	119.77		2.28	120.62		1.94	93.01	
11-Jun	2.26	118.92		2.28	120.62		1.91	90.70	90.5
12-Jun	2.26	118.92		2.27	119.77		1.92	91.47	
13-Jun	2.19	113.05	112	2.18	112.22	112	1.91	90.70	
14-Jun	2.18	112.22	112			94	1.95	93.78	
15-Jun	1.93	92.24	92.5				1.95	93.78	
16-Jun	1.95	93.78	93.5	2.12	107.29	107	1.94	93.01	92.7
17-Jun	2.05	101.64	102	2.24	117.23	117	1.97	95.33	
18-Jun		98.00	98	2.24	117.23		1.98	96.11	95.8
19-Jun	1.93	92.24	92	2.12	107.29	107	1.98	96.11	
20-Jun	1.96	94.55	94	2.07	103.24	103	1.96	94.55	
21-Jun	1.96	94.55	94	1.99	96.90	96	1.96	94.55	
22-Jun	1.95	93.78	93	1.98	96.11	96	1.96	94.55	
23-Jun	1.98	96.11	95	1.97	95.33	95	1.97	95.33	
24-Jun	1.93	92.24	92	2	97.68	97.5	1.97	95.33	
25-Jun	1.93	92.24	92	1.94	93.01	92.7	1.97	95.33	
26-Jun	1.94	93.01	92.5	1.93	92.24		1.97	95.33	
27-Jun	1.93	92.24	92	1.96	94.55	94	1.97	95.33	

FMC Rogers Mesa HOUSE FLUME READINGS

8' Parshall Flume

Q = 32*h^1.61

	2016			2017			2018		
	h	Q	cfs	h	Q	cfs	h	Q	cfs
MAX	2.27	119.8	112	2.33	124.9	122.8	2.12	107.3	106
28-Jun	1.92	91.47		1.92	91.47	91.7	1.96	94.55	
29-Jun	1.94	93.01		1.92	91.47		1.94	93.01	
30-Jun	1.96	94.55		1.95	93.78		1.93	92.24	
1-Jul	1.96	94.55		1.96	94.55	94	1.95	93.78	
2-Jul	1.95	93.78							
3-Jul									
4-Jul									
5-Jul									
6-Jul	1.75	78.78							
7-Jul	1.95	93.78		1.9	89.94	90	1.96	94.55	
8-Jul	1.94	93.01		1.92	91.47	92	2	97.68	
9-Jul	1.97	95.33		1.91	90.70		2.12	107.29	
10-Jul	1.97	95.33		1.94	93.01	92.7	1.96	94.55	
11-Jul	1.95	93.78		1.96	94.55	94	1.94	93.01	
12-Jul	1.93	92.24		1.96	94.55		1.95	93.78	
13-Jul	1.95	93.78		1.98	96.11		1.92	91.47	
14-Jul	1.96	94.55		1.95	93.78		1.92	91.47	
15-Jul	1.95	93.78		1.96	94.55		1.96	94.55	
16-Jul	1.95	93.78		1.95	93.78		1.95	93.78	
17-Jul	1.97	95.33		2.01	98.47		1.96	94.55	
18-Jul	1.93	92.24	92	1.95	93.78	93.5	1.94	93.01	
19-Jul	1.96	94.55		1.96	94.55	94.3	1.96	94.55	
20-Jul	1.96	94.55		1.95	93.78	93.5	1.95	93.78	
21-Jul	1.95	93.78		1.95	93.78		1.94	93.01	
22-Jul	1.95	93.78		1.96	94.55		1.95	93.78	
23-Jul	1.95	93.78		1.97	95.33		1.94	93.01	
24-Jul	1.96	94.55		1.96	94.55		1.94	93.01	
25-Jul	1.96	94.55	94.3	1.95	93.78		1.96	94.55	
26-Jul	1.95	93.78	93.5	1.96	94.55		1.95	93.78	
27-Jul	1.94	93.01		1.97	95.33	95	1.65	71.66	
28-Jul	1.94	93.01		1.96	94.55	94.5	1.95	93.78	
29-Jul	1.94	93.01		1.97	95.33		1.95	93.78	
30-Jul	1.94	93.01		1.98	96.11		1.96	94.55	
31-Jul	1.94	93.01		1.97	95.33	95	1.95	93.78	
1-Aug	1.93	92.24		1.95	93.78	93.5	1.95	93.78	
2-Aug	1.93	92.24		1.96	94.55	94.3	1.96	94.55	
3-Aug	1.93	92.24	92	1.96	94.55		1.94	93.01	
4-Aug	1.93	92.24		1.96	94.55		1.94	93.01	
5-Aug	1.97	95.33	95	1.97	95.33				
6-Aug	1.95	93.78	93.5	2.04	100.85				

FMC Rogers Mesa HOUSE FLUME READINGS

8' Parshall Flume

Q = 32*h^1.61

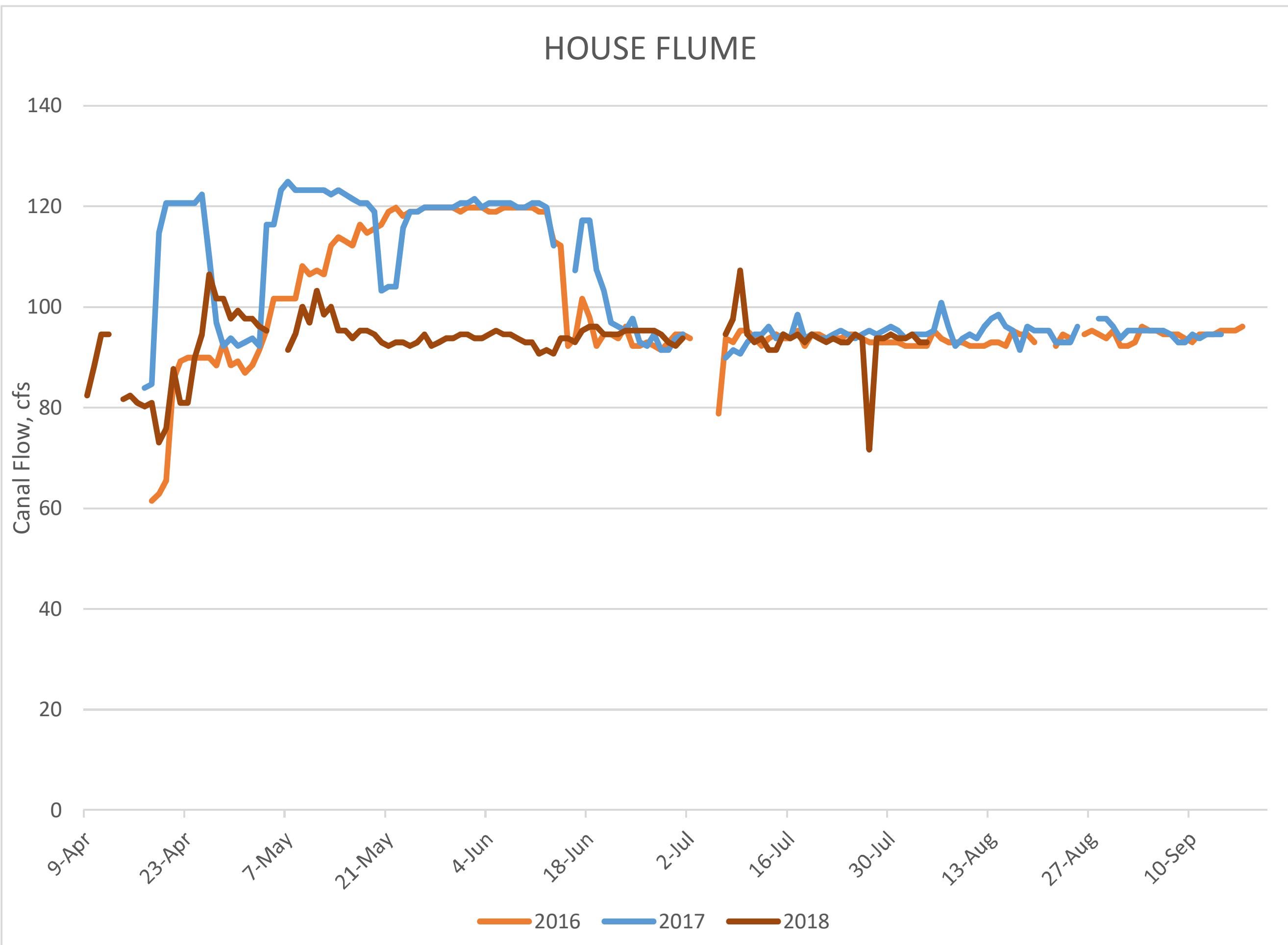
	2016			2017			2018		
	h	Q	cfs	h	Q	cfs	h	Q	cfs
MAX	2.27	119.8	112	2.33	124.9	122.8	2.12	107.3	106
7-Aug	1.94	93.01		1.98	96.11				
8-Aug	1.94	93.01		1.93	92.24	92			
9-Aug	1.94	93.01		1.95	93.78				
10-Aug	1.93	92.24	92	1.96	94.55	94.1			
11-Aug	1.93	92.24		1.95	93.78				
12-Aug	1.93	92.24		1.98	96.11	95.6			
13-Aug	1.94	93.01		2	97.68	97.5			
14-Aug	1.94	93.01		2.01	98.47	98.3			
15-Aug	1.93	92.24		1.98	96.11	95.9			
16-Aug	1.97	95.33		1.97	95.33	95.1			
17-Aug	1.96	94.55		1.92	91.47	91.2			
18-Aug	1.96	94.55		1.98	96.11	95.9			
19-Aug	1.94	93.01		1.97	95.33	95.1			
20-Aug				1.97	95.33				
21-Aug				1.97	95.33				
22-Aug	1.93	92.24	92	1.94	93.01	92.7			
23-Aug	1.96	94.55		1.94	93.01				
24-Aug	1.95	93.78		1.94	93.01				
25-Aug				1.98	96.11				
26-Aug	1.96	94.55							
27-Aug	1.97	95.33							
28-Aug	1.96	94.55		2	97.68	97.5			
29-Aug	1.95	93.78		2	97.68	97.5			
30-Aug	1.97	95.33		1.98	96.11				
31-Aug	1.93	92.24		1.95	93.78				
1-Sep	1.93	92.24	92	1.97	95.33				
2-Sep	1.94	93.01		1.97	95.33				
3-Sep	1.98	96.11		1.97	95.33				
4-Sep	1.97	95.33		1.97	95.33				
5-Sep	1.97	95.33		1.97	95.33				
6-Sep	1.96	94.55		1.97	95.33				
7-Sep	1.96	94.55		1.96	94.55				
8-Sep	1.96	94.55		1.94	93.01				
9-Sep	1.95	93.78		1.94	93.01				
10-Sep	1.94	93.01		1.96	94.55				
11-Sep	1.96	94.55		1.95	93.78				
12-Sep	1.96	94.55		1.96	94.55				
13-Sep	1.96	94.55		1.96	94.55				
14-Sep	1.97	95.33		1.96	94.55				
15-Sep	1.97	95.33							

FMC Rogers Mesa HOUSE FLUME READINGS

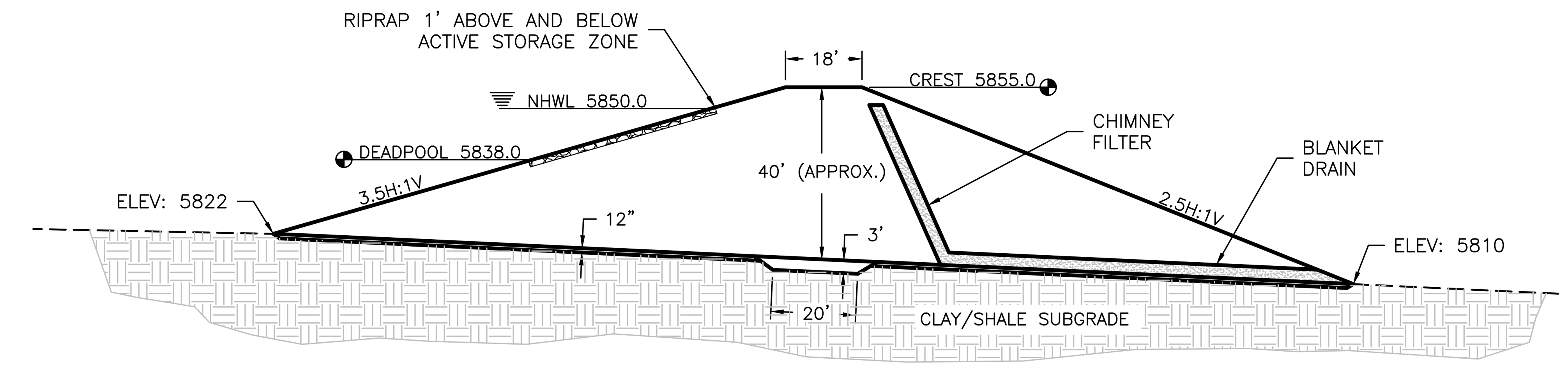
8' Parshall Flume

Q = 32*h^1.61

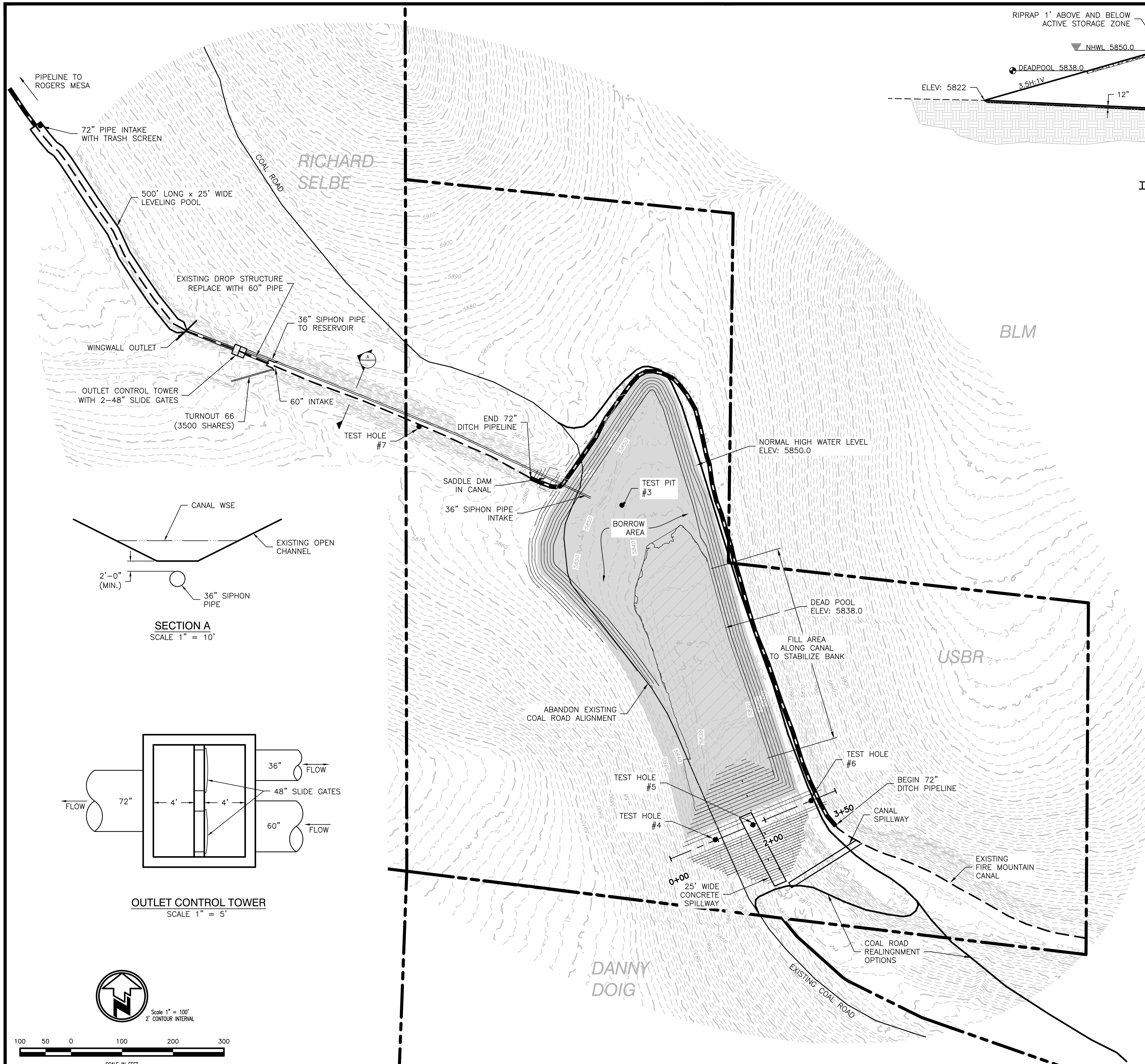
	2016			2017			2018		
	h	Q	cfs	h	Q	cfs	h	Q	cfs
MAX	2.27	119.8	112	2.33	124.9	122.8	2.12	107.3	106
16-Sep	1.97	95.33							
17-Sep	1.98	96.11							
18-Sep									
19-Sep									
20-Sep									



Appendix B – Preliminary Dam Layouts



TYPICAL DAM SECTION
SCALE 1" = 30'



OVERALL GRADING VOLUME
FILL: 26,565 CY
CUT: 25,503 CY

NET: 1,062 CY (FILL)

Elevation ft	Area ac	Storage ac-ft	
5823	0.05	-	
5824	0.11	0.08	
5825	0.14	0.20	
5826	0.17	0.36	
5827	0.20	0.54	
5828	0.41	0.84	
5829	0.51	1.30	
5830	0.61	1.86	
5831	0.72	2.52	
5832	0.84	3.31	
5833	0.98	4.21	
5834	1.13	5.27	
5835	1.28	6.47	
5836	1.44	7.83	
5837	1.60	9.34	
5838	1.76	11.02	Dead Pool
5839	3.41	13.56	
5840	3.56	17.05	
5841	3.70	20.68	
5842	3.85	24.45	
5843	4.00	28.38	
5844	4.16	32.46	
5845	4.31	36.70	
5846	4.47	41.09	
5847	4.62	45.64	
5848	4.77	50.34	
5849	4.93	55.19	
5850	5.10	60.21	Normal High Water
5851	5.72	65.62	
5852	6.16	71.56	
5853	6.45	77.86	
5854	6.71	84.45	
5855	7.01	91.31	Dam Crest

ACTIVE STORAGE = 49.19 ac-ft

1490 West 121st Ave., Suite 100
Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

NO	DATE	BY	CHK'D	DESCRIPTION

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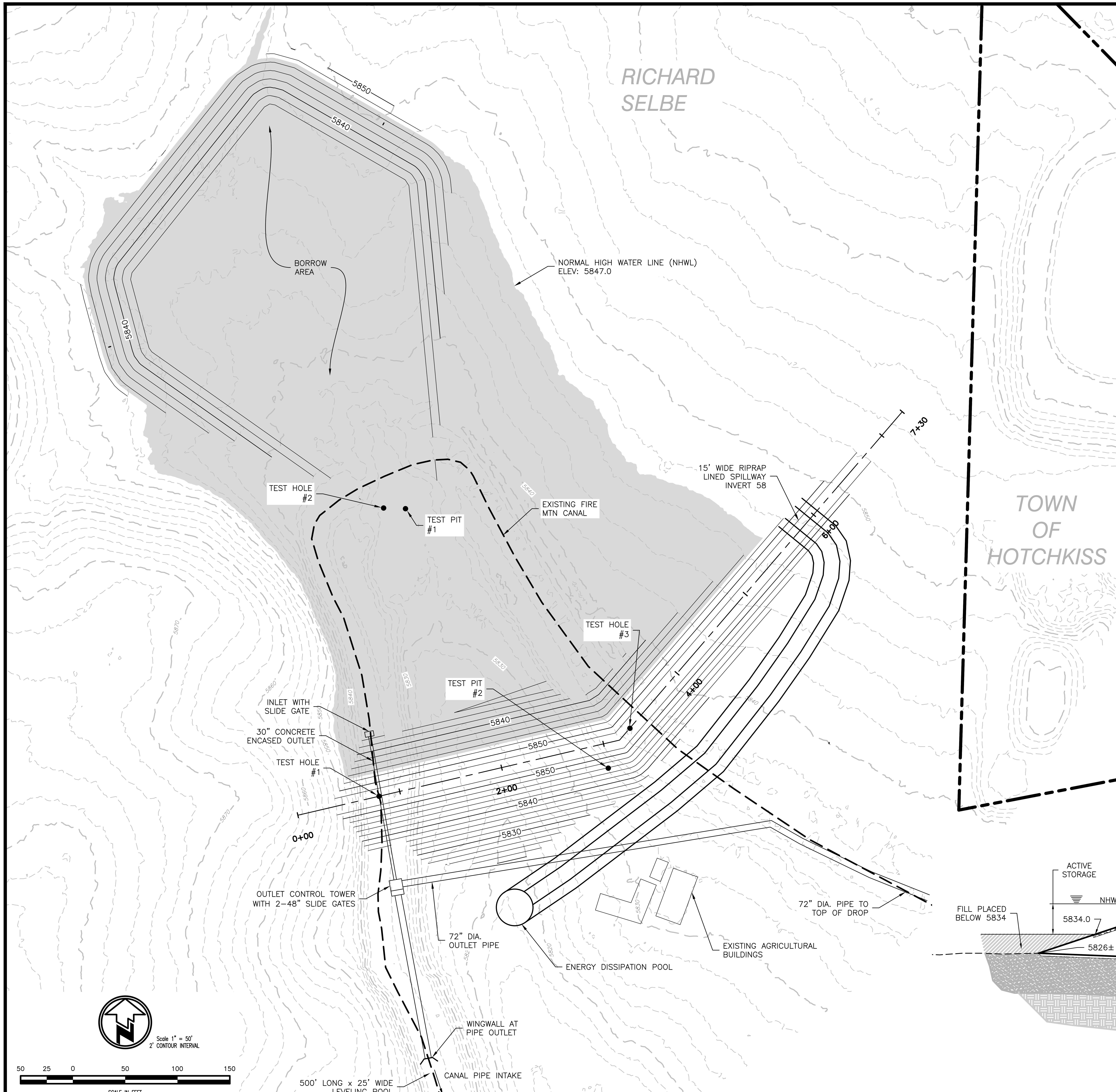
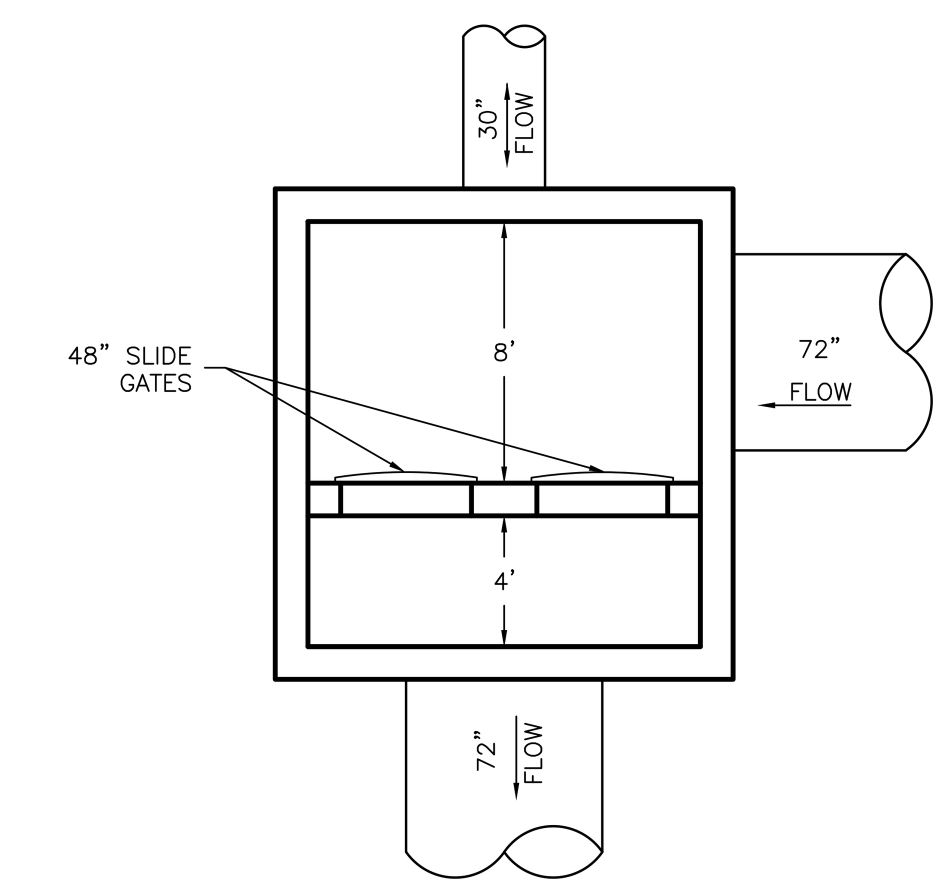


Elevation ft	Area ac	Storage ac-ft	Note
5834	0.01	-	
5835	0.81	0.30	
5836	2.35	1.81	
5837	2.63	4.30	
5838	2.90	7.07	
5839	3.15	10.09	
5840	3.48	13.41	
5841	3.70	17.00	
5842	3.95	20.82	
5843	4.19	24.89	
5844	4.46	29.22	
5845	4.75	33.82	
5846	5.05	38.72	
5847	5.39	43.94	Normal High Water
5848	5.84	49.55	
5849	6.35	55.65	
5850	6.86	62.25	
5851	7.43	69.39	
5852	8.05	77.13	Dam Crest

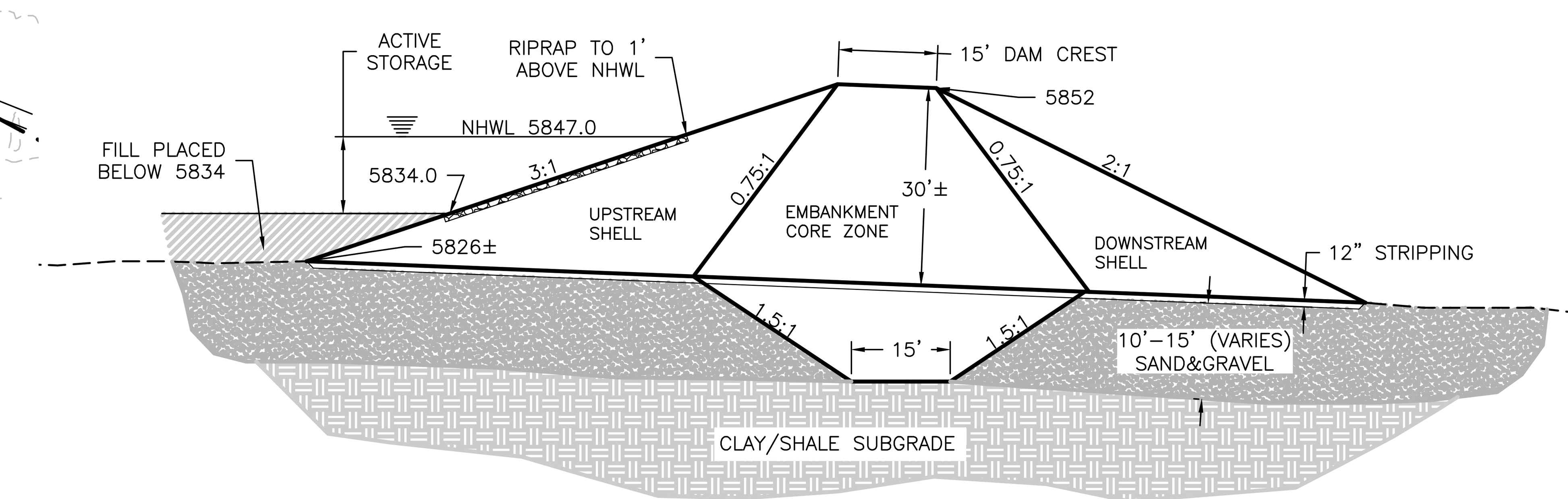
ACTIVE STORAGE = 43.94 ac–ft

GRADING VOLUMES:
CUT: 25,172 CY
FILL: 24,111 CY

NET: 1.062 CY



OUTLET CONTROL TOWER
SCALE 1" = 5'



TYPICAL DAM SECTION
SCALE 1" = 20'

1490 West 121st Ave., Suite 100
Denver, CO 80234
(303) 452-6611
Fax: (303) 452-2759
email: info@applegategroup.com Website: www.applegategroup.com

NO	DATE	BY	CHK'D	DESCRIPTION

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Appendix C – Hazard Classification

BREACH PARAMETER ESTIMATION
MACDONALD & LANGRIDGE-MONOPOLIS (1984)
FAILURE TIMES ESTIMATED BY WASHINGTON STATE (2007)

DAM NAME:	3300 Rd Dam
DAMID:	N/A
DATE:	Oct-18

BREACH INPUT DATA:

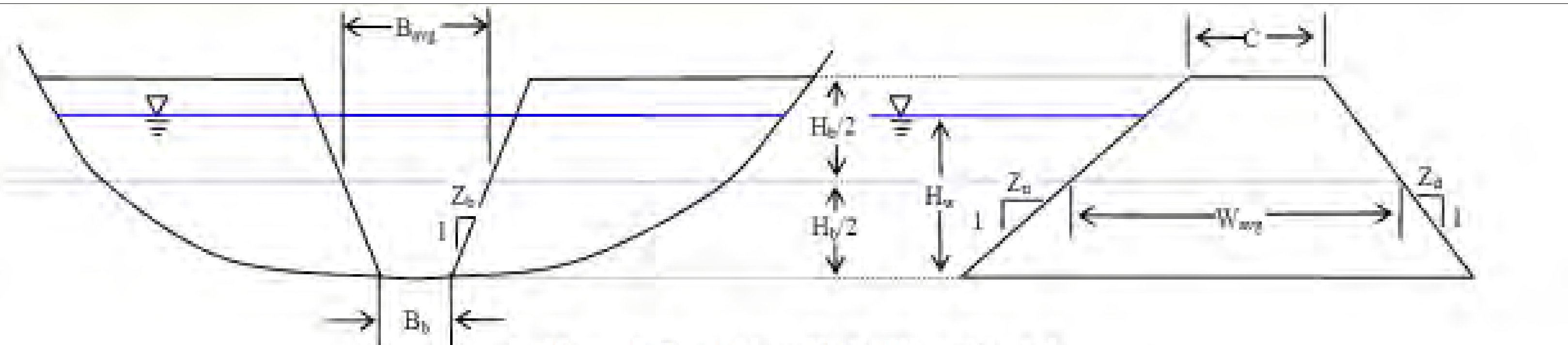


Figure 1- Breach Variable Definition Sketch

Select Embankment Type From Drop-Down Menu:	EARTHEN (COHESIVE)	
Maximum depth of water stored behind the breach (H_w) =	13.0	Feet
Reservoir volume stored at Hw (V_w) =	44.0	Acre-Feet
Reservoir Surface Area at Hw (A_s) =	5.4	Acres
Crest width of dam (C) =	15.0	Feet
and breach invert (Hb) =	18.0	Feet
Slope of upstream dam face (Z_u) =	3.0	Zu(H):1(V)
Slope of downstream dam face (Z_d) =	2.0	Zd(H):1(V)
Breach side-slope ratio (Z_b) =	0.5	Zb(H):1(V)
Piping Orifice Coefficient (C_p) =	0.70	Used To Calculate Peak Discharge Through Piping Hole
Dam Size Class:	Minor	Assumes Full Reservoir At Time of Breach

CALCULATED BREACH PARAMETERS:

Breach Formation Factor (BFF) =	572	
Embankment Volume Eroded (V_{er}) =	433.5	Cubic Yards
Average Dam Width (W_{avg}) =	60.0	Feet (In Direction of Flow)
Average Breach Width (B_{avg}) =	10.8	Feet
Bottom Width of Breach (B_b) =	1.8	Feet
Breach Formation Time (T_f) =	0.32	Hours
Storage Intensity (SI) =	3.4	Acre Feet/Foot

MAXIMUM BREACH OUTFLOW (SMPDBK, Wetmore and Fread, 1984)

Instantaneous Flow Reduction Factor (C) =	11.7
Predicted Peak Flow (Q_p) =	1,186.1

RESULTS CHECK:

Average Breach Width Divided by Height of Breach (Bavg/Hb) =	0.6	If (Bavg/Hb) > 0.6, Full Breach Development is Anticipated
Erosion Rate (ER), Calculated as (Bavg/Tf) =	33.8	
Erosion Rate Divided by Height of Water Over Base of Breach (ER/Hw) =	2.6	If 1.6 < (ER/Hw) < 21, Erosion Rate is Assumed Reasonable

PIPING HOLE (CALCULATED ONLY IF Bavg/Hb < 0.6) :

Full Breach Development Will Likely Occur

BREACH PARAMETER ESTIMATION, FROEHLICH (2008)

DAM NAME: 3300 Rd Dam
DAMID: N/A
DATE: Oct-18
BREACH INPUT DATA:

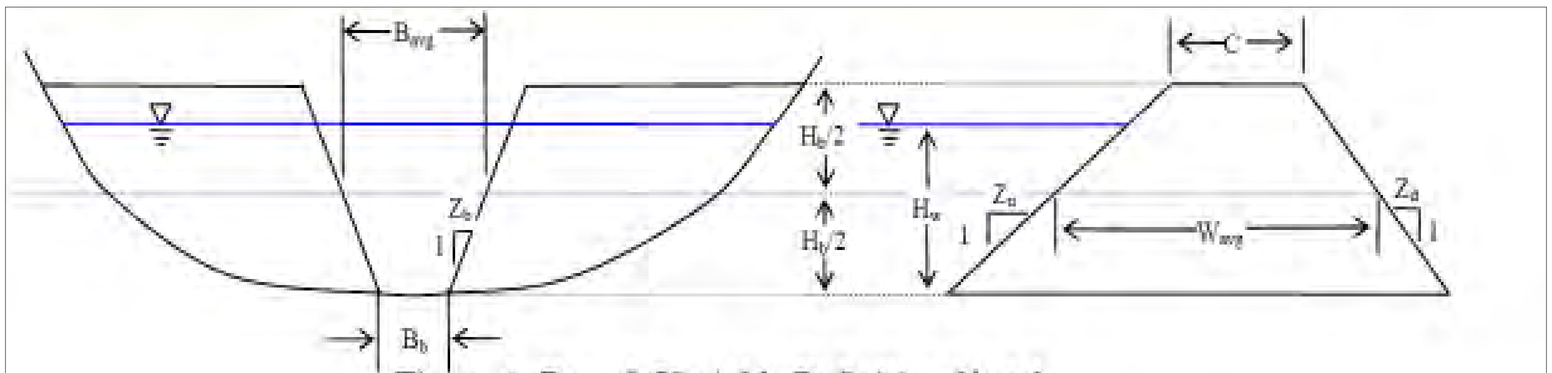


Figure 1- Breach Variable Definition Sketch

Select Failure Mode From Drop-Down Menu:	PIPING	
Maximum depth of water stored behind the breach (H_w) =	13.0	Feet
Reservoir volume stored at Hw (V_w) =	44.0	Acre-Feet
Reservoir Surface Area at Hw (A_s) =	5.4	Acres
Height of breach; vertical distance between dam crest and breach invert (H_b) =	18.0	Feet
Failure Mode Factor (K_o) =	1	
Breach Side-Slope Ratio (Z_b) =	0.7	Zb(H):1(V)
Dam Size Class:	Minor	Assumes Full Reservoir At Time of Breach.

CALCULATED BREACH PARAMETERS:

Average Breach Width (B_{avg}) =	31.0	Feet
Bottom Width of Breach (B_b) =	18.4	Feet
Breach Development Time (T_f) =	0.24	Hours
Storage Intensity (SI) =	3.4	Acre Feet/Foot

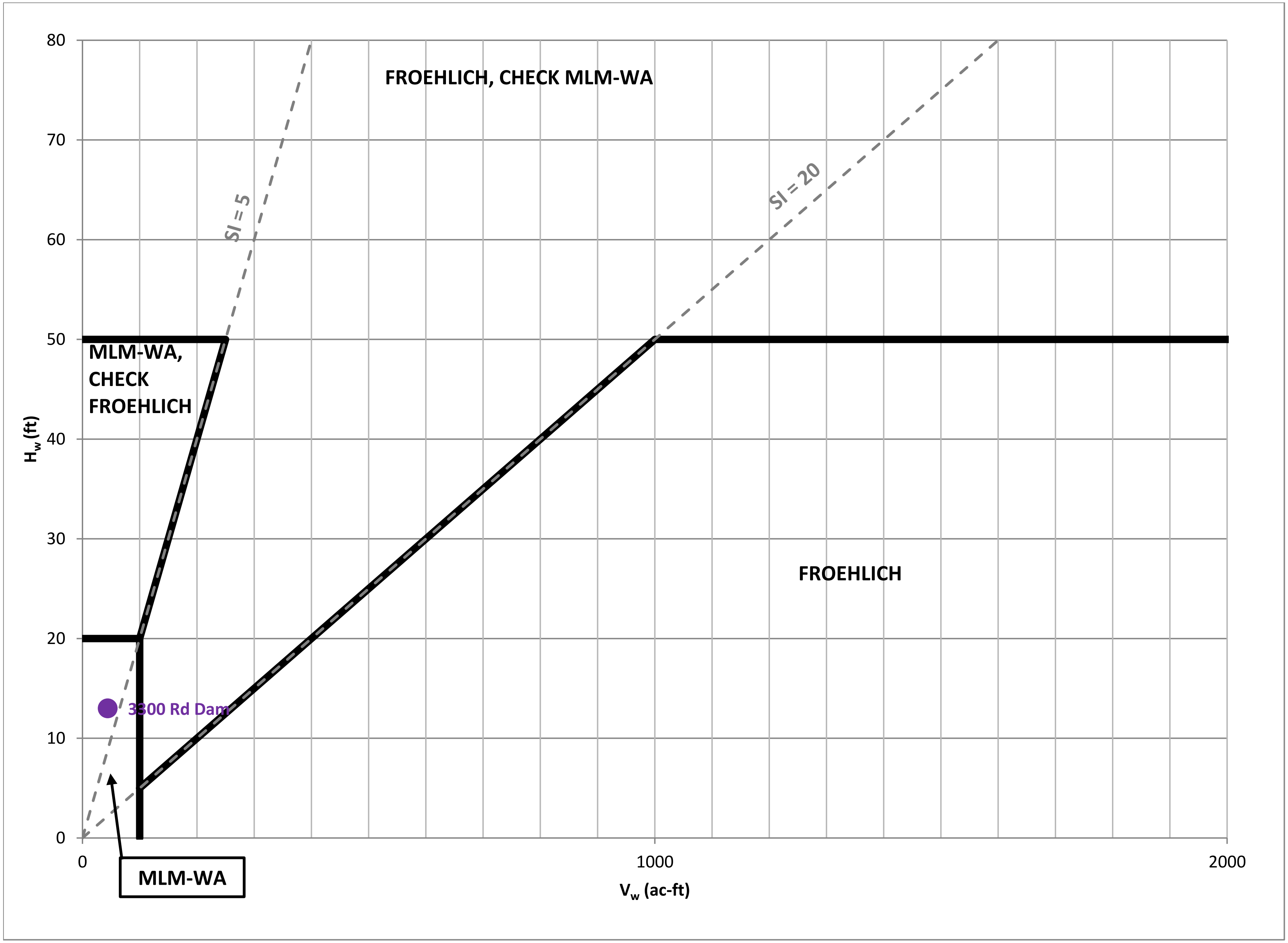
MAXIMUM BREACH OUTFLOW (SMPDBK, Wetmore and Fread, 1984):

Instantaneous Flow Reduction Factor (C) =	4.1	
Predicted Peak Flow (Q_p) =	2541	Cubic Feet per Second

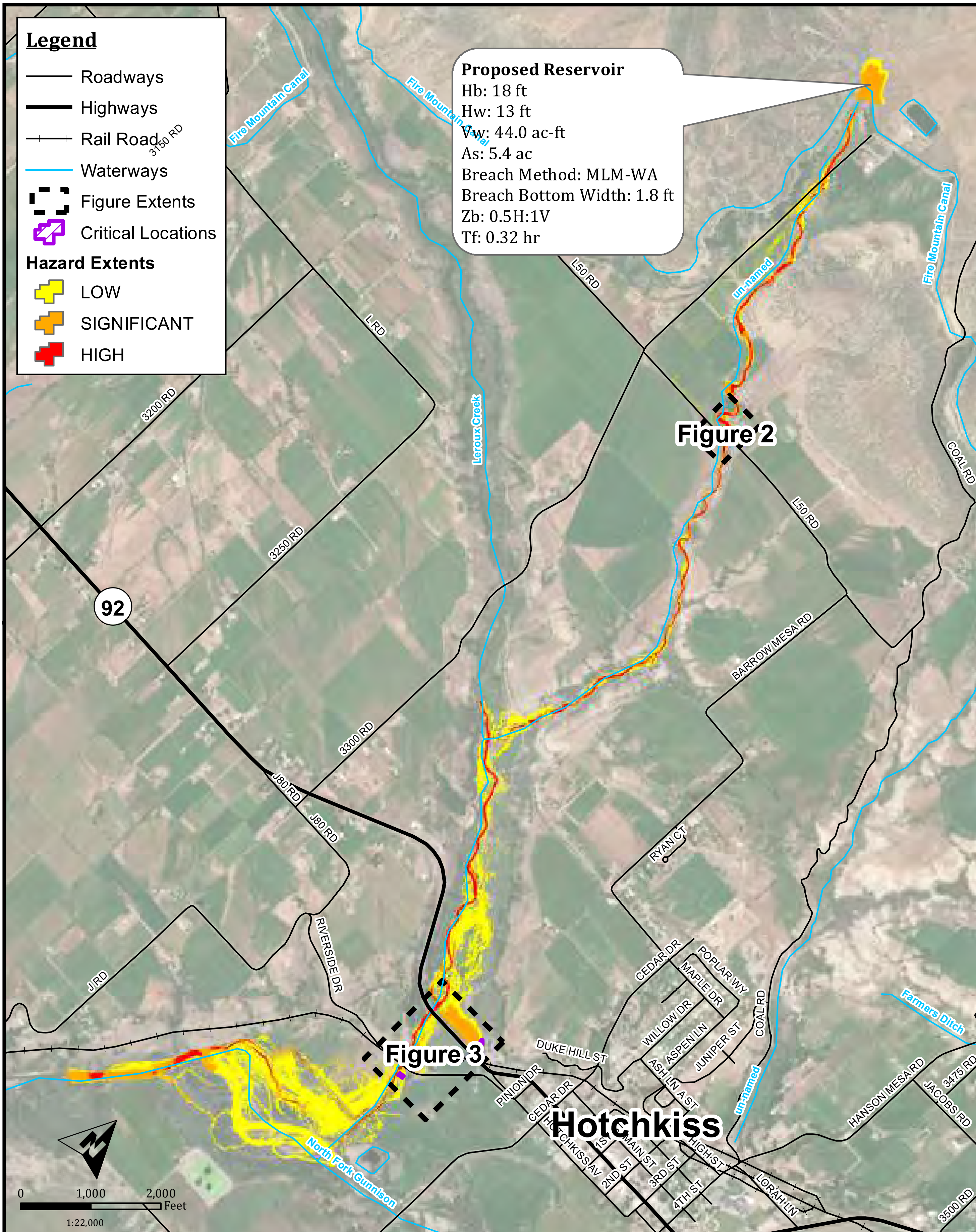
RESULTS CHECK:

Average Breach Width Divided by Height of Breach (B_{avg}/H_b) =	1.7	If (B_{avg}/H_b) > 0.6, Full Breach Devlopment is Anticipated
Erosion Rate (ER), Calculated as (B_{avg}/T_f) =	130.5	
Erosion Rate Divided by Height of Water Over Base of Breach (ER/H_w) =	10.0	If 1.6 < (ER/H_w) < 21, Erosion Rate is Assumed Reasonable

Full breach devlopment will likely occur. Froehlich method is applicable.
Storage volume of reservoir is outside data set used to develop emprical equations for Froehlich (2008)



FROEHLICH, CHECK MLM-WA
MLM-WA, CHECK FROEHLICH
SI = 5
SI = 20
FROEHLICH
3300 Rd Dam
MLM-WA
H_w (ft)
V_w (ac-ft)
0
10
20
30
40
50
60
70
80
0
1000
2000



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Applegate Group, Inc.
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1490 West 121st Ave., Ste 100
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e-mail: info@applegategroup.com

Prelim Hazard Class Study

Overview Map

Date: 13 AUG 2020

Job #: 18-128

Drawn By: TJD

Figure: 1

Of: 3

Date Saved: 8/13/2020 12:46:57 PM
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Applegate Group, Inc.
Water Resource Advisors for the West
1490 West 121st Ave., Ste 100
Denver, CO 80234-2728
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Prelim Hazard Class Study

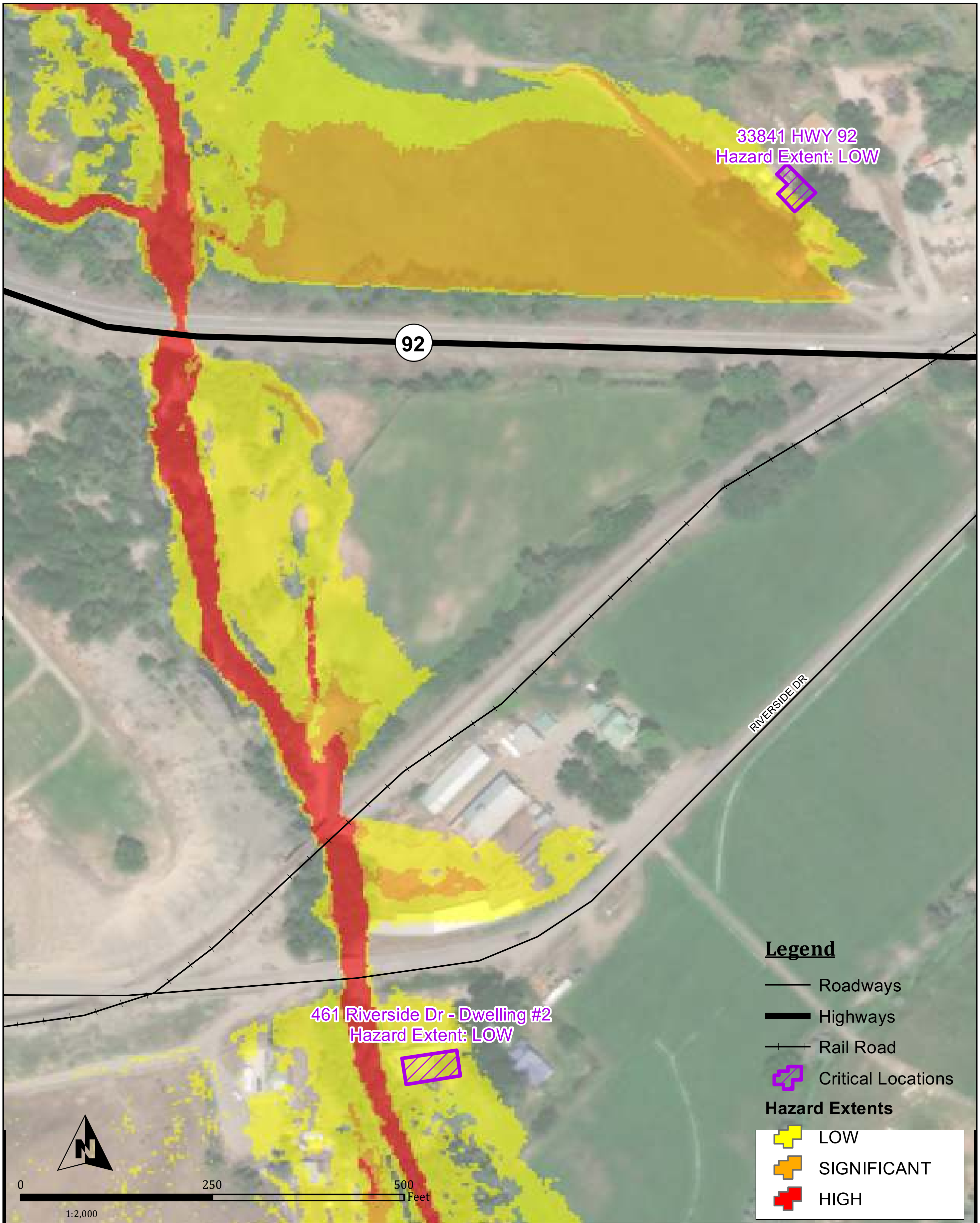
Figure 2

Date: 15 OCT 2018

Job #: 18-128

Drawn By: TJD

Figure: 2 Of: 3



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Prelim Hazard Class Study

Figure 3

Date: 13 AUG 2020

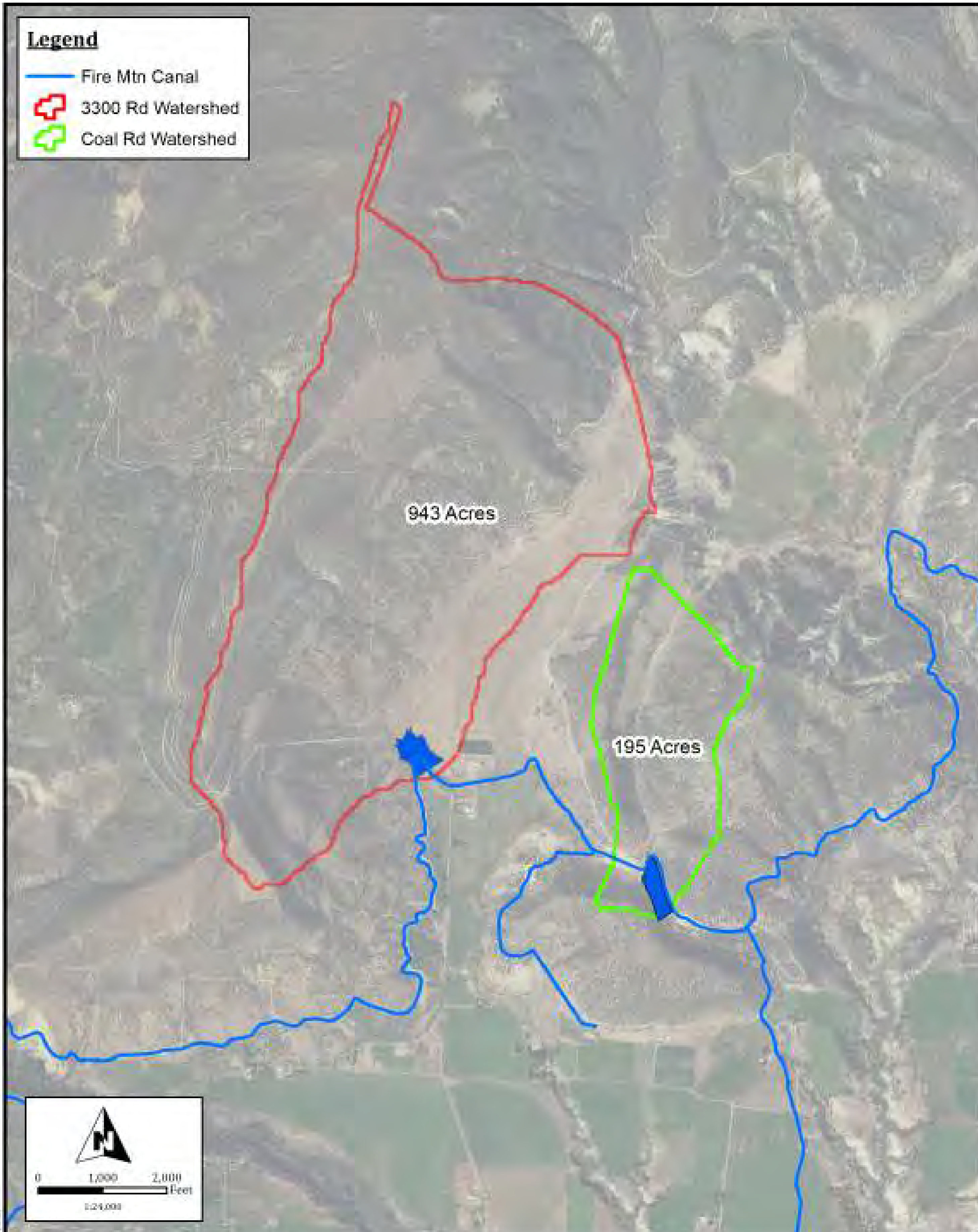
Job #: 18-128

Drawn By: TJD

Figure: **3**

Of: 3

Appendix D – Hydrology Analysis



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Fire Mtn Regulating Res. Study

Watershed Map

Date: 8-12-20

Job #: 18-128

Drawn By: CU

Figure: 1

Of: 1

RAINFALL LOSSES SOIL PROPERTIES TABLE:

Project: 3300 Rd Site - FMC Re-Reg Reservoir

By: BAK

Date: 9/13/2018

Design Storm: Frequency Storm (Extreme Storm/PMP, Frequency Storm)

Soil Depth: 6" (Analyze 18" soil depth for Extreme Storm/PMP; 6" depth for 100-YR and more frequent storm)

blue text = User Entry

red text = Excel calculation

DATA SOURCE:	Soil Survey	ArcMap	Map Unit (MU) Description Report	Engineering Properties Report	Component Legend Report	Table 10 (Sabol 2008), VLOOKUP	Engineering Properties Report	Component Legend Report	Table 10 (Sabol 2008), VLOOKUP	Engineering Properties Report	Component Legend Report	Table 10 (Sabol 2008), VLOOKUP	ArcMap	=[E]+[H]+[K]	Eq. 2, Sabol 2008 =10^{([E]*Log10[F]+[H]Log10[I]+[K]Log10[L])/[N]}	=[M]LOG10[O]	Aerial photo, Land Use Map, Site Visit	Weights Sand and Loamy Sand as 10% Vegetation Cover	=[R]*[M]	Engineering Properties Report or Aerial photo	=[T]*[M]	
	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]
	Soil Survey ID	Map Unit (MU)	Landform Description	Component 1 Infiltration-Limiting Soil Texture	% of MU	Ksat1 (in/hr)	Component 2 Infiltration-Limiting Soil Texture	% of MU	Ksat2 (in/hr)	Component 3 Infiltration-Limiting Soil Texture	% of MU	Ksat3 (in/hr)	MU Area (m^2)	Sum % MU	MU Avg. Ksat (in/hr)	MU Area* Log10(MU Avg. Ksat)	% Vegetative Cover	% Veg. Cover Adjusted for Sand & Loamy Sand[1]	%Veg Cover *MU Area	% Impervious	% Imp *MU Area	Ground Cover Notes
	CO679	4	Agua Fria stony loam 12-25% slopes	loam	85	0.25	silty clay loam		0.04				944,132	85	0.25	-568424	75%	75%	708099	0%	0	Decomp. Plant material
	CO679	68	Saraton gravelly loam, 3-12% slopes	sandy loam	85	0.4	loamy sand		1.2				20,234	85	0.40	-8052	75%	75%	15176	0%	0	
	CO679	69	Saraton stony loam 3-20% slopes	sandy loam	40	0.4	loamy sand		1.2				22,662	40	0.40	-9018	75%	75%	16997	0%	0	Decomp. Plant material
	CO679	70	Saraton-Agua Fria complex 20-50% slopes	loam	40	0.25	sandy loam		0.4				2,825,113	40	0.25	-1700887	75%	75%	2118835	0%	0	Decomp. Plant material

NOTE 1: No Vegetation Cover Adjustment allowed to bare ground Ksat for Sand & Loamy Sand. Therefore % Vegetation Cover must be adjusted to10% cover for Sand and Loamy Sand MU Components (Reference Figure 8, Sabol 2008).

Table 10 (Sabol 2008)

Soil Texture	Ksat (in/hr)
sand	1.2
loamy sand	1.2
sandy loam	0.4
loam	0.25
silty loam	0.15
silt	0.1
sandy clay loam	0.06
clay loam	0.04
silty clay loam	0.04
sandy clay	0.02
silty clay	0.02
clay	0.01

SUB-BASIN RAINFALL LOSSES SUMMARY TABLE:		DATA SOURCE:
Total MU/Sub-basin area (m^2)	3,812,142	[AA]=Sum[M]
Sub-basin Weighted Avg Bare Ground Ksat, (in/hr)	0.25	[BB]=10^(Sum[P]/[AA]), Eq. 2 Sabol 2008
Sub-basin Weighted Avg % Vegetation Cover	75%	[CC]=Sum[S]/[AA], Eq. 1 Sabol 2008
Average Sub-basin slope	21%	[DD] From ArcMap, USGS Stream Stats, etc.
Antecedent Moisture Condition	Normal	[EE], Use engineering judgment. Dry=WP, Normal=FC, OR Saturated
Sub-basin Initial Abstraction (IA), (inches)	0.3	[FF], Table 8, Sabol 2008
G&A Suction head at capillary front, PSIF, (inches)	7	[GG], Figure 4, Sabol 2008
G&A soil moisture deficit, DTHETA (vol/vol)	0.15	[HH], Figure 4, Sabol 2008
Vegetation Cover Factor	1.72	[JJ]=(%Veg Cover-10)/90 + 1. Figure 8, Sabol 2008
Sub-basin Adjusted Ksat, XKSAT, (in/hr)	0.43	[KK]=[BB]*[JJ]
Sub-basin Weighted Avg. % Impervious (RTIMP)	0%	[LL]=Sum[U]/[AA], Eq. 1 Sabol 2008

= HMS parameter

ROCKY MOUNTAIN (THUNDERSTORM) UNIT HYDROGRAPH 12-Aug-20

FMC-3300 Road

DAMID: 000000 INITIALS

Sub-Basin 1

Drainage Area =	1.47	sq. miles	Lg+D/2 =	0.81	Hours
Basin Slope =	653.9	ft./mile	Basin Factor =	0.08	
L =	2.77	mi., Length of Watercourse	V' =	39.53	cfs/Day
Lca =	0.706	mi., Distance to Centroid	Qs =	49.0	* q, cfs
Kn =	0.065	-, Ave. Weighted Manning's n			

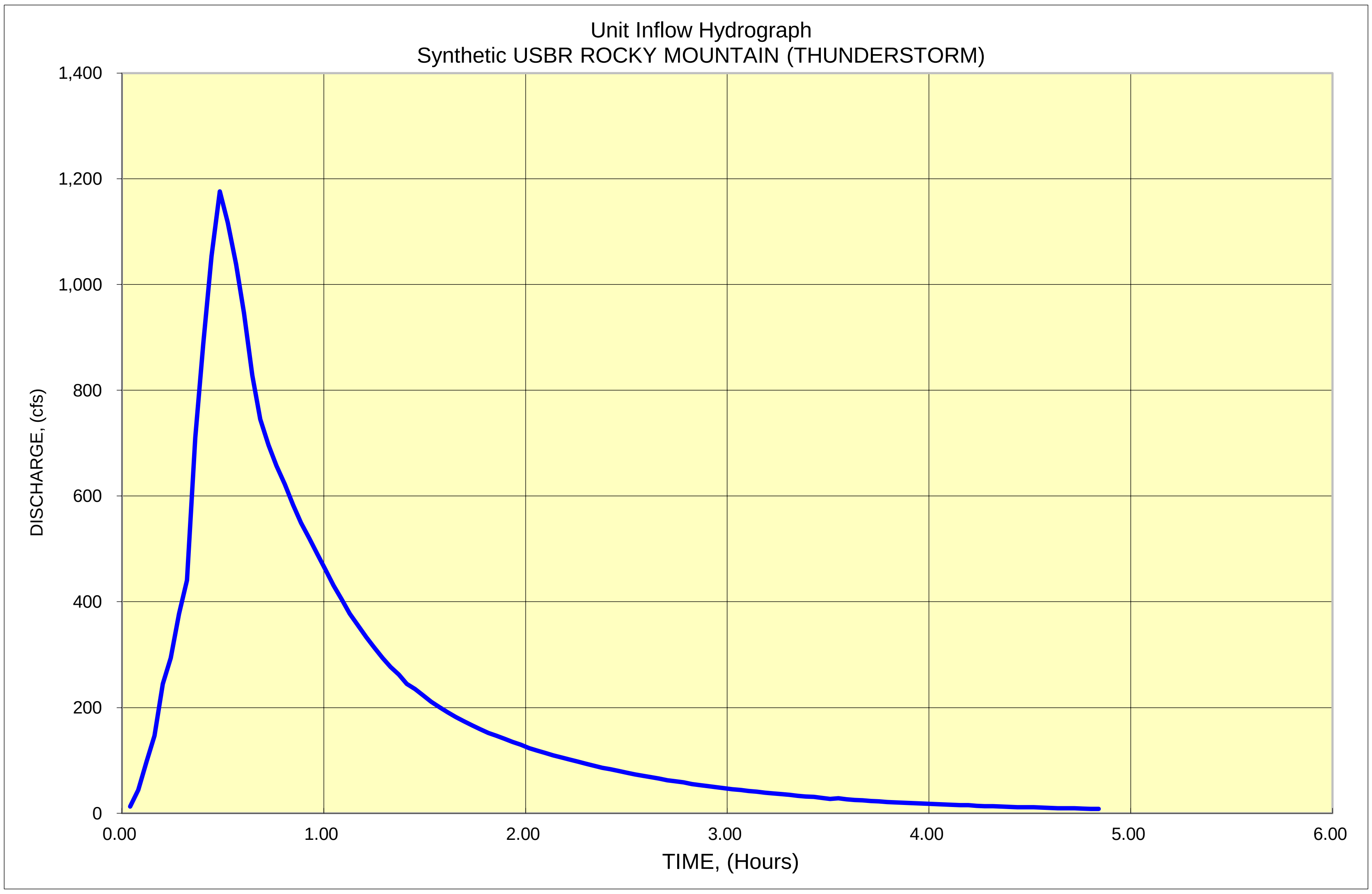
PARAMETERS:

Calculated: Lag Time, Lg = 0.72 Hours Unit Duration, D = 7.89 minutes

Calculated Timestep = 2.42 minutes

Data to be used in Analysis Unit Duration, D = 10 minutes, round down to nearest of 5, 10, 15, 30, 60, 120, 180, or 360

Selected Timestep = 3 minutes, integer value evenly divisible into 60



UI Record - Unit Graph 3 **minute interval**

UI	8	13	22	40	100	240	386	526	668	818
UI	972	1126	1279	1358	1247	1128	1011	892	775	652
UI	539	452	389	338	294	262	234	213	192	174
UI	159	147	136	127	117	109	101	95	89	84
UI	80	76	72	68	64	61	58	55	52	49
UI	47	44	42	40	37	36	34	32	30	29
UI	27	26	24	23	22	21	20	18	17	16
UI	16	15	14	13	13	12	12	11	10	10
UI	9	9	8	8	8	7	7	7	6	6
UI	6	5	5	5	5	4	3			
UI										

UI

USBR calculated unitgraph peak = 1389 Interpolated Peak = 1358

Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs	Time t, % of Lg+D/2	Hours	Min.	q	Qs cfs
5.0	0.04	2.4	0.14	7	305.0	2.46	147.7	1.05	51
10.0	0.08	4.8	0.21	10	310.0	2.50	150.1	1.00	49
15.0	0.12	7.3	0.33	16	315.0	2.54	152.5	0.96	47
20.0	0.16	9.7	0.51	25	320.0	2.58	154.9	0.92	45
25.0	0.20	12.1	0.84	41	325.0	2.62	157.3	0.88	43
30.0	0.24	14.5	1.62	79	330.0	2.66	159.8	0.84	41
35.0	0.28	16.9	3.74	183	335.0	2.70	162.2	0.81	40
40.0	0.32	19.4	6.38	313	340.0	2.74	164.6	0.77	38
45.0	0.36	21.8	8.61	422	345.0	2.78	167.0	0.74	36
50.0	0.40	24.2	10.94	536	350.0	2.82	169.4	0.71	35
55.0	0.44	26.6	13.26	650	355.0	2.86	171.9	0.68	33
60.0	0.48	29.0	15.70	769	360.0	2.90	174.3	0.65	32
65.0	0.52	31.5	18.23	893	365.0	2.95	176.7	0.62	30
70.0	0.56	33.9	20.76	1,017	370.0	2.99	179.1	0.59	29
75.0	0.61	36.3	23.30	1,141	375.0	3.03	181.5	0.57	28
80.0	0.65	38.7	25.83	1,265	380.0	3.07	184.0	0.55	27
85.0	0.69	41.1	28.36	1,389	385.0	3.11	186.4	0.52	25
90.0	0.73	43.6	26.53	1,300	390.0	3.15	188.8	0.50	24
95.0	0.77	46.0	24.71	1,211	395.0	3.19	191.2	0.48	24
100.0	0.81	48.4	22.68	1,111	400.0	3.23	193.6	0.46	23
105.0	0.85	50.8	20.76	1,017	405.0	3.27	196.1	0.43	21
110.0	0.89	53.3	18.84	923	410.0	3.31	198.5	0.42	21
115.0	0.93	55.7	16.81	824	415.0	3.35	200.9	0.40	20
120.0	0.97	58.1	14.99	734	420.0	3.39	203.3	0.38	19
125.0	1.01	60.5	12.86	630	425.0	3.43	205.7	0.36	18
130.0	1.05	62.9	11.04	541	430.0	3.47	208.2	0.35	17
135.0	1.09	65.4	9.52	466	435.0	3.51	210.6	0.33	16
140.0	1.13	67.8	8.41	412	440.0	3.55	213.0	0.32	16
145.0	1.17	70.2	7.50	367	445.0	3.59	215.4	0.31	15
150.0	1.21	72.6	6.69	328	450.0	3.63	217.9	0.29	14
155.0	1.25	75.0	5.98	293	455.0	3.67	220.3	0.28	14
160.0	1.29	77.5	5.47	268	460.0	3.71	222.7	0.27	13
165.0	1.33	79.9	4.97	243	465.0	3.75	225.1	0.26	13
170.0	1.37	82.3	4.55	223	470.0	3.79	227.5	0.25	12
175.0	1.41	84.7	4.25	208	475.0	3.83	230.0	0.24	12
180.0	1.45	87.1	3.89	191	480.0	3.87	232.4	0.23	11
185.0	1.49	89.6	3.59	176	485.0	3.91	234.8	0.22	11
190.0	1.53	92.0	3.34	164	490.0	3.95	237.2	0.21	10
195.0	1.57	94.4	3.13	153	495.0	3.99	239.6	0.20	10
200.0	1.61	96.8	2.93	144	500.0	4.03	242.1	0.19	9
205.0	1.65	99.2	2.75	135	505.0	4.07	244.5	0.18	9
210.0	1.69	101.7	2.61	128	510.0	4.11	246.9	0.17	8
215.0	1.73	104.1	2.44	120	515.0	4.16	249.3	0.17	8
220.0	1.78	106.5	2.31	113	520.0	4.20	251.7	0.16	8
225.0	1.82	108.9	2.17	106	525.0	4.24	254.2	0.16	8
230.0	1.86	111.3	2.04	100	530.0	4.28	256.6	0.15	7
235.0	1.90	113.8	1.95	96	535.0	4.32	259.0	0.15	7
240.0	1.94	116.2	1.84	90	540.0	4.36	261.4	0.14	7
245.0	1.98	118.6	1.76	86	545.0	4.40	263.8	0.14	7
250.0	2.02	121.0	1.69	83	550.0	4.44	266.3	0.13	6
255.0	2.06	123.4	1.62	79	555.0	4.48	268.7	0.13	6
260.0	2.10	125.9	1.55	76	560.0	4.52	271.1	0.12	6
265.0	2.14	128.3	1.49	73	565.0	4.56	273.5	0.12	6
270.0	2.18	130.7	1.42	70	570.0	4.60	275.9	0.11	5
275.0	2.22	133.1	1.36	67	575.0	4.64	278.4	0.11	5
280.0	2.26	135.6	1.30	64	580.0	4.68	280.8	0.10	5
285.0	2.30	138.0	1.24	61	585.0	4.72	283.2	0.10	5
290.0	2.34	140.4	1.19	58	590.0	4.76	285.6	0.09	4
295.0	2.38	142.8	1.14	56	595.0	4.80	288.0	0.09	4
300.0	2.42	145.2	1.09	53	600.0	4.84	290.5	0.08	4

NOTES :
1. Methodology used Dimensionless Unit Hydrograph.
2. For values of q use Table 4-11 from Flood Hydrology Manual

UH volume = 78.36 AF
Total runoff = 78.40 AF
Ratio = 1.00

RAINFALL LOSSES SOIL PROPERTIES TABLE:

Project: Coal Rd Site - FMC Re-reg Reservoir

By: BAK

Date: 9/13/2018

Design Storm: EPAT Local Storm (Extreme Storm/PMP, Frequency Storm)

Soil Depth: 18" (Analyze 18" soil depth for Extreme Storm/PMP; 6" depth for 100-YR and more frequent storm)

blue text = User Entry

red text = Excel calculation

DATA SOURCE:	Soil Survey	ArcMap	Map Unit (MU) Description Report	Engineering Properties Report	Component Legend Report	Table 10 (Sabol 2008), VLOOKUP	Engineering Properties Report	Component Legend Report	Table 10 (Sabol 2008), VLOOKUP	Engineering Properties Report	Component Legend Report	Table 10 (Sabol 2008), VLOOKUP	ArcMap	=[E]+[H]+[K]	Eq. 2, Sabol 2008 =10^{([E]*Log10[F]+[H]Log10[I]+[K]Log10[L])/[N]}	=[M]LOG10[O]	Aerial photo, Land Use Map, Site Visit	Weights Sand and Loamy Sand as 10% Vegetation Cover	=[R]*[M]	Engineering Properties Report or Aerial photo	=[T]*[M]	
	[A] Soil Survey ID	[B] Map Unit (MU)	[C] Landform Description	[D] Component 1 Infiltration-Limiting Soil Texture	[E] % of MU	[F] Ksat1 (in/hr)	[G] Component 2 Infiltration-Limiting Soil Texture	[H] % of MU	[I] Ksat2 (in/hr)	[J] Component 3 Infiltration-Limiting Soil Texture	[K] % of MU	[L] Ksat3 (in/hr)	[M] MU Area (m^2)	[N] Sum % MU	[O] MU Avg. Ksat (in/hr)	[P] MU Area* Log10(MU Avg. Ksat)	[Q] % Vegetative Cover	[R] % Veg. Cover Adjusted for Sand & Loamy Sand[1]	[S] %Veg Cover *MU Area	[T] % Impervious	[U] % Imp *MU Area	[V] Ground Cover Notes
	CO679	27	Colona silty clay loam, 6-12% slopes	silty clay loam	85	0.04							29,137	85	0.04	-40732	75%	75%	21853	0%	0	Decomp. Plant material
	CO679	68	Saraton gravelly loam, 3-12% slopes	sandy loam	85	0.4							38,445	85	0.40	-15299	75%	75%	28834	0%	0	
	CO679	69	Saraton stony loam 3-20% slopes	sandy loam	85	0.4							20,639	85	0.40	-8213	75%	75%	15479	0%	0	Decomp. Plant material
	CO679	70	Saraton-Agua Fria complex 20-50% slopes	loam	40	0.25	sandy loam	40	0.4				663,685	80	0.32	-331843	75%	75%	497764	0%	0	Decomp. Plant material

NOTE 1: No Vegetation Cover Adjustment allowed to bare ground Ksat for Sand & Loamy Sand. Therefore % Vegetation Cover must be adjusted to10% cover for Sand and Loamy Sand MU Components (Reference Figure 8, Sabol 2008).

Table 10 (Sabol 2008)

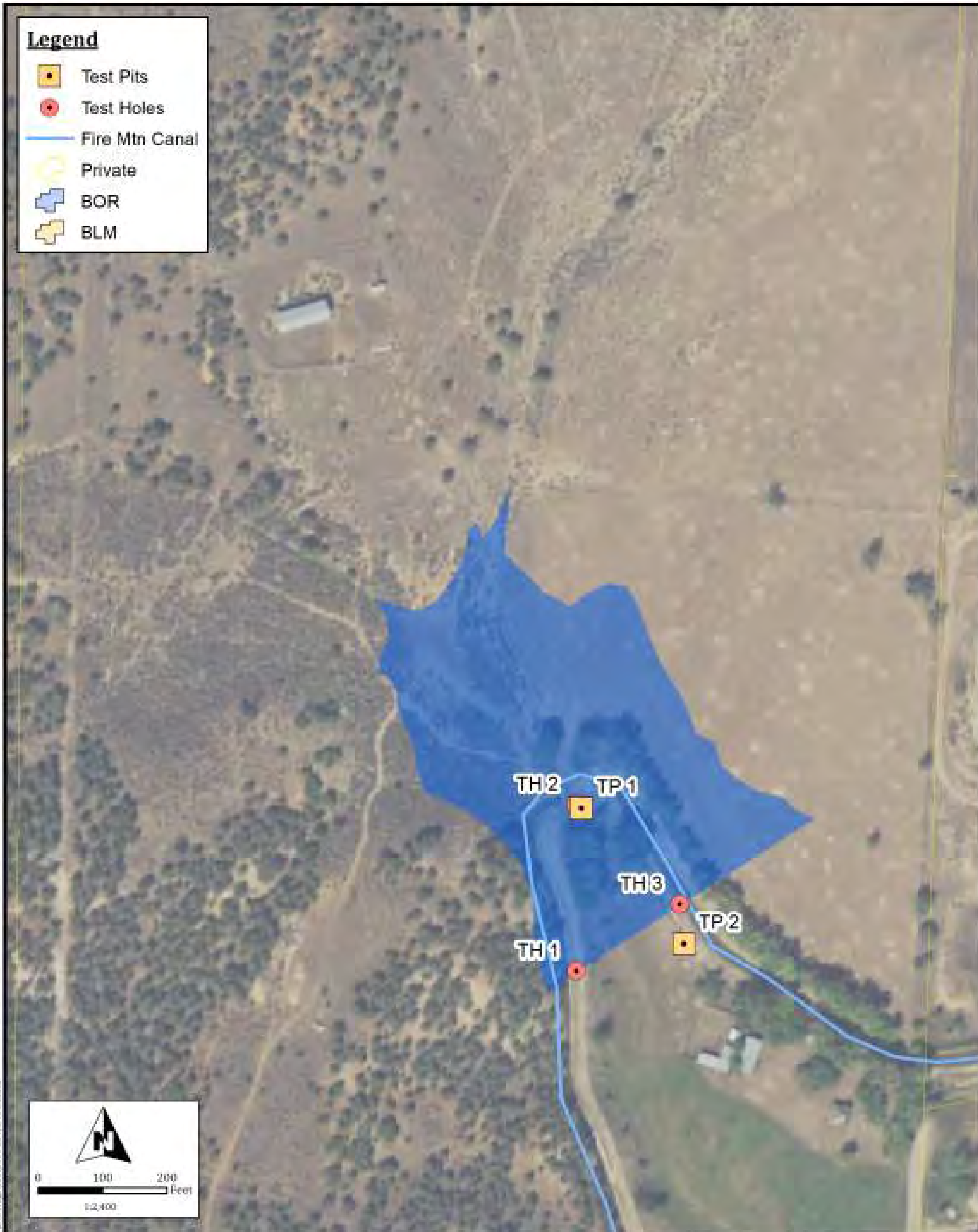
Soil Texture	Ksat (in/hr)
sand	1.2
loamy sand	1.2
sandy loam	0.4
loam	0.25
silty loam	0.15
silt	0.1
sandy clay loam	0.06
clay loam	0.04
silty clay loam	0.04
sandy clay	0.02
silty clay	0.02
clay	0.01

SUB-BASIN RAINFALL LOSSES SUMMARY TABLE:		DATA SOURCE:
Total MU/Sub-basin area (m^2)	751,906	[AA]=Sum[M]
Sub-basin Weighted Avg Bare Ground Ksat, (in/hr)	0.30	[BB]=10^(Sum[P]/[AA]), Eq. 2 Sabol 2008
Sub-basin Weighted Avg % Vegetation Cover	75%	[CC]=Sum[S]/[AA], Eq. 1 Sabol 2008
Average Sub-basin slope	25%	[DD] From ArcMap, USGS Stream Stats, etc.
Antecedent Moisture Condition	Normal	[EE], Use engineering judgment. Dry=WP, Normal=FC, OR Saturated
Sub-basin Initial Abstraction (IA), (inches)	0.3	[FF], Table 8, Sabol 2008
G&A Suction head at capillary front, PSIF, (inches)	7	[GG], Figure 4, Sabol 2008
G&A soil moisture deficit, DTHETA (vol/vol)	0.15	[HH], Figure 4, Sabol 2008
Vegetation Cover Factor	1.72	[JJ]=(%Veg Cover-10)/90 + 1. Figure 8, Sabol 2008
Sub-basin Adjusted Ksat, XKSAT, (in/hr)	0.51	[KK]=[BB]*[JJ]
Sub-basin Weighted Avg. % Impervious (RTIMP)	0%	[LL]=Sum[U]/[AA], Eq. 1 Sabol 2008

= HMS parameter

Appendix E – Geotechnical Data/Testing

Applegate Group, Inc. Water Resource Advisors for the West 1490 West 121st Ave., Ste 100 Denver, CO 80234-2728 www.ApplegateGroup.com Phone: (303) 452-6611 Fax: (303) 452-2759 e-mail: info@applegategroup.com	**Coal Road Site** Borehole and Test Pits	Date: 8-12-20 Job #: 18-128 Drawn By: CU	Figure: **1** Of: 2



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e-mail: info@applegategroup.com

3300 Road Site

Borehole and Test Pits

Date: 8-12-20

Job #: 18-128

Drawn By: CU

Figure: 2

Of: 2

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 1
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date:11/27/2018 — Started: 8:30 AM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 9:45 AM	Groundwater Depth: none	Elevation:
	Backfilled:		Total Depth of Boring: 25

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
			5,5,12		• tan, dry, silty clay (splitspoon sample)			
					• intermitent rocks and gravels from 5' to 10'			
					• tan, dry, silty clay			
					• material sloughing into hole			
			rock in spoon					
			9,16,31		• tan, moist, very stiff silty clay w/ rocks/gravel (splitspoon sample)			
			14,25,42		• brown, moist, hard, silty clay w/ red porous rocks (splitspoon sample)			
			19,25,30		• brown, moist, very stiff, silty clay w/ gravels; layer of gray, moist, stiff, sticky clay (splitspoon sample)			

Boring Log: Sheet 1 of 7

- Standard Penetration Slit Spoon Sampler (SPT)
- California Sampler
- CPP Sampler
- Shelby Tube
- Bulk/ Bag Sample
- StabIlized Ground water
- Groundwater At time of Drilling

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 2
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date: 11/27/2018 — Started: 10:00 AM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 10:45 AM	Groundwater Depth: none	Elevation:
	Backfilled:		Total Depth of Boring: 20

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
					• tan, dry to slightly moist, silty clay w/ gravels			
5	SPT		10,11,16		• tan, dry to slightly moist, stiff silty clay w/ rocks/gravels (splitspoon sample)			
					• significant amounts of rock/gravel layers encountered			
					• light brown, moist, silty clay w/ rocks/gravels			
10	SPT		14,8,43		• grayish brown, moist, hard clay w/ rock/gravels; pocket of yellow clay w/ fine gravel (splitspoon sample)			
					• auger out of gravels and drilled smooth after 13'			
15	SPT		21,41, 50/4"		• brown, moist, hard, clay, breaks apart in flat layers (splitspoon sample)			
					• drilled smooth from 15' to 20'			
20	SPT		28,54		• brown and gray clay, moist, hard, clay w/ white deposits, breaks apart in flat layers (splitspoon sample)			
25								
30								

Boring Log: Sheet 2 of 7

Standard Penetration Slit Spoon Sampler (SPT)

California Sampler

CPP Sampler

Stabllized Ground water

Shelby Tube

Bulk/ Bag Sample

Groundwater At time of Drilling

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 3
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date: 11/27/2018 — Started: 11:00 AM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 12:15 PM	Groundwater Depth: none	Elevation:
	Backfilled:		Total Depth of Boring: 25

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description: Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
0–1					• light tan, dry, silty clay			
5	SPT		5,7,9		• tanish brown, dry to slightly moist, clay w/ gravels (splitspoon samples)			
10	SPT		19,25,23		• brown, dry to slightly moist, clay w/ gray and red lava-like rock; layer of gray clay w/ similar characteristcs to brown clay (splitspoon sampe)			
11					• rock/gravel layers encountered at 11' to 13.5'			
15	SPT		9,12,12		• brown, moist, firm, clay (splitspoon sample but forgot photo)			
17					• encountered significant amount of rock(s)/gravel(s) at about 17' then smooth to 20'			
20	SPT		7,11,14		• tanish yellow, moist, firm, clay			
22					• tanish yellow, moist, soft clay appeared in slag			
25	SPT		15,30,49		• tanish yellow, moist, hard, clay, breaks apart in flat layers (splitspoon sample)			
30								

Boring Log: Sheet 3 of 7

Standard Penetration Slit Spoon Sampler (SPT)

California Sampler | CPP Sampler | Stablllized Ground water

Shelby Tube | Bulk/ Bag Sample | Groundwater At time of Drilling

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 4
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date: 11/27/2018 — Started: 1:00 PM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 2:45 PM	Groundwater Depth: 23'	Elevation:
	Backfilled:		Total Depth of Boring: 30'

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description: Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
					• brown, dry, clay w/ rocks likely from road construction			
5			8,18,15		• redish brown, slightly moist, hard, clay w/ rocks/gravels (splitspoon sample)			
10			7,7,14		• reddish brown, dry to moist, firm, clay w/ rocks/gravels (splitspoon sample)			
					• rocks/gravels encountered at about 12' to 14'			
15			11,14,17		• reddish brown, moist, clay w/ gravelss, stiff; specs of yellow and white, soft, clay; gray rocks throughout sample (splitspoon sample)			
					• brown, moist, soft, clay w/ gravels appeared in slag			
20			22,17,22		• grayish brown w/ specs of yellow, moist, stiff clay w/ black and red rocks/gravels at tip of sample; small gravels throughout sample (splitspoon sample)			
					• rock/gravel layer encountered at about 20' to 23'			
					• smooth gravels appeared in slag			
25			10,31,19		• brown, saturated, firm, clay w/ gravels; gravel at tip of sampler (splitspoon sample)			
					• rocks/gravel encountered at about 25' to 28'			
			18,36, 50/4.5"		• brown, saturated, clay; brown, moist, hard, clay at tip of sampler (splitspoon sample)			

Boring Log: Sheet 4 of 7

Standard Penetration Slit Spoon Sampler (SPT)

California Sampler

CPP Sampler

Stablllized Ground water

Shelby Tube

Bulk/ Bag Sample

Groundwater At time of Drilling

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 5
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date: 11/27/2018 — Started: 3:00 PM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 3:30 PM	Groundwater Depth: 4'	Elevation:
	Backfilled:		Total Depth of Boring: 20'

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description: Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
					• some rocks/gravels but mostly smooth drilling			
					• brown, wet, clay slag			
						▽		
5	SPT		4,7,8		• blueish white/ gray clay, wet, firm clay w/ small gravel layer(could be slough) (splitspoon sample)			
					• smooth drilling through clay from 5' to 10'			
10	SPT		8,14,19		• brown, moist, stiff clay w/ gray deposits and veins (splitspoon sample)			
					• smooth drilling from 10' to 15'			
15	SPT		13,15,18		• brown, moist, very stiff clay w/ white and gray crystal like flakey deposits and veins (splitspoon sample)			
20	SPT		18,35, 50/5"		• brown, moist, hard, clay w/ white and gray crystal like flakey deposits and veins (splitspoon sample)			
25								
30								

Boring Log: Sheet 5 of 7

Standard Penetration Slit Spoon Sampler (SPT)

California Sampler

CPP Sampler

Stablllized Ground water

Shelby Tube

Bulk/ Bag Sample

Groundwater At time of Drilling

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 6
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date: 11/28/2018 — Started: 9:30 AM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 11:00 AM	Groundwater Depth: none	Elevation:
	Backfilled:		Total Depth of Boring: 30'

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
					• tan, dry, clay			
					• intermitant gravels encountered			
5	SPT		10,11,13		• nothing in splitspoon sample, probably hit rock			
10	SPT		6,5,6		• tan, moist, firm clay (splitspoon sample)			
15	SPT		6,7,9		• tanish brown, moist, firm clay (splitspoon sample)			
					• material stiffened up at about 16.5'			
20	SPT		12,15,22		• brown, moist, very stiff, clay, breaks apart in flat layers (splitspoon sample)			
25	SPT		9,15,16		• brown, moist, very stiff, clay w/ white deposits; breaks apart in flat layers (splitspoon sample)			
30	SPT		13,17,26		• brown, moist, very stiff, clay w/ white deposits; breaks apart in flat layers (splitspoon sample)			

Boring Log: Sheet 6 of 7

Standard Penetration Slit Spoon Sampler (SPT)
California Sampler
CPP Sampler
Shelby Tube
Bulk/ Bag Sample
StabIlized Ground water
Groundwater At time of Drilling

Project: Fr Mtn Reg Res Feas Study	Project Number: 18-128	Client: Fire Mountain Canal	Boring No. 7
Address, City, State: Fr Mtn Canal N. of Hotchkiss		Drilling Contractor: HRL	Drill Rig Type: CME 55
Logged By: Tyler Desiderio	Date: 11/28/2018 — Started: 11:30 AM	Bit Type: Solid Stem Auger	Diameter: 4"
Drill Crew: Jose and Mike	Completed: 12:00 PM	Groundwater Depth: none	Elevation:
	Backfilled:		Total Depth of Boring: 15'

Depth (feet)	Sample Type	Sample Number	Blow Counts (blows/foot)	Graphic Log	Description Composition (Gravel, Sand, Clay, Shale, Sandstone, etc) Moisture Level (Dry, Moist, Saturated) Consistency (Very Soft, Soft, Firm, Hard, Very Hard) Color	Water Level	Piezometer Pipe	Piez. Backfill
					• shale fragments on surface			
					• moist, tanish brown clay close to surface			
5	SPT		25,46, 50/4"		• brown, moist, hard clay w/ white deposits and veins throughout sample, breaks aparts in layers (splitspoon sample)			
10	SPT		22,45, 50/4"		• brown, moist, hard clay w/ white deposits and veins throughout sample, breaks aparts in layers (splitspoon sample)			
15	SPT		25,50		• brown, moist, hard clay w/ white and gray deposits and veins throughout sample, breaks aparts in layers (splitspoon sample)			
20								
25								
30								

Boring Log: Sheet __of ___

Standard Penetration Slit Spoon Sampler (SPT)

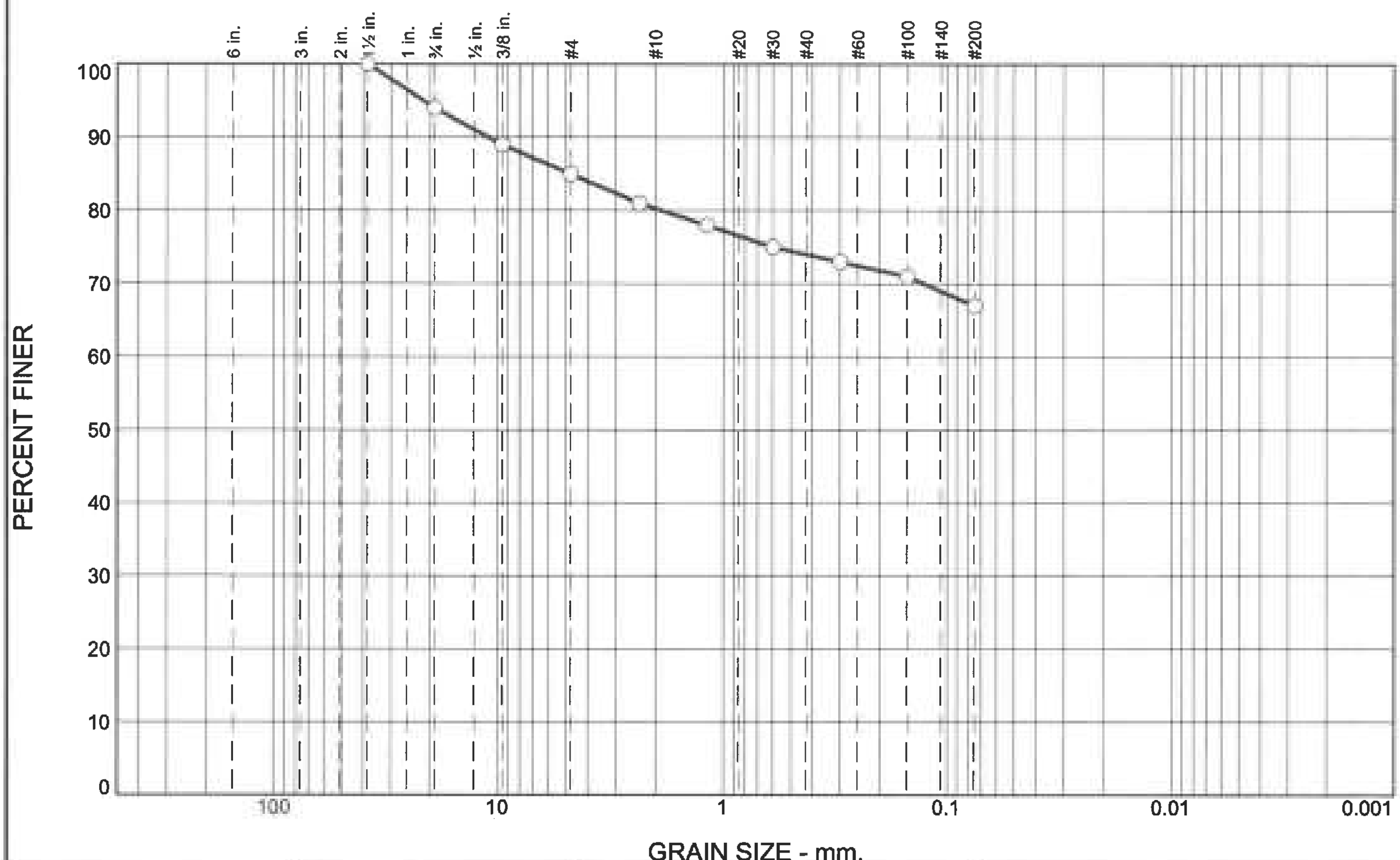
California Sampler — CPP Sampler — StabIlized Ground water

Shelby Tube — Bulk/ Bag Sample — Groundwater At time of Drilling

FIRE MOUNTAIN CANAL - Regulating Reservoir Study
Geotechnical Analysis Summary

Test Hole No.	Depth ft	% Fines	% Sand	% Gravel	Plastic Limit	Liquid Limit	Plasticity Index	USCS Classification
1	5	67	18	15	20	35	15	CL
1	15	36	18	46	19	39	21	GC
2	4	23	63	14	23	33	11	SC
2	8	45	52	3	17	24	6	SC-SM
2	10	35	41	24	20	34	15	SC
2	15	86	7	7	20	42	22	CL
3	4-5	83	16	1	15	27	13	CL
3	20	89	9	5	19	0	21	CL
5	5	95	5	0	21	50	29	CH
6	10	83	14	3	20	39	19	CL

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	6	9	5	6	7	67	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100		
3/4"	94		
3/8"	89		
#4	85		
#8	81		
#16	78		
#30	75		
#50	73		
#100	71		
#200	67		

* (no specification provided)

Soil Description

Sandy Clay with Gravel

Atterberg Limits

PL= 20 LL= 35 PI= 15

Coefficients

D_{90}= 10.9414 D_{85}= 4.7500 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-6(8)

Remarks

Location: TH-1
Depth: 5'

Date: 11/28/18

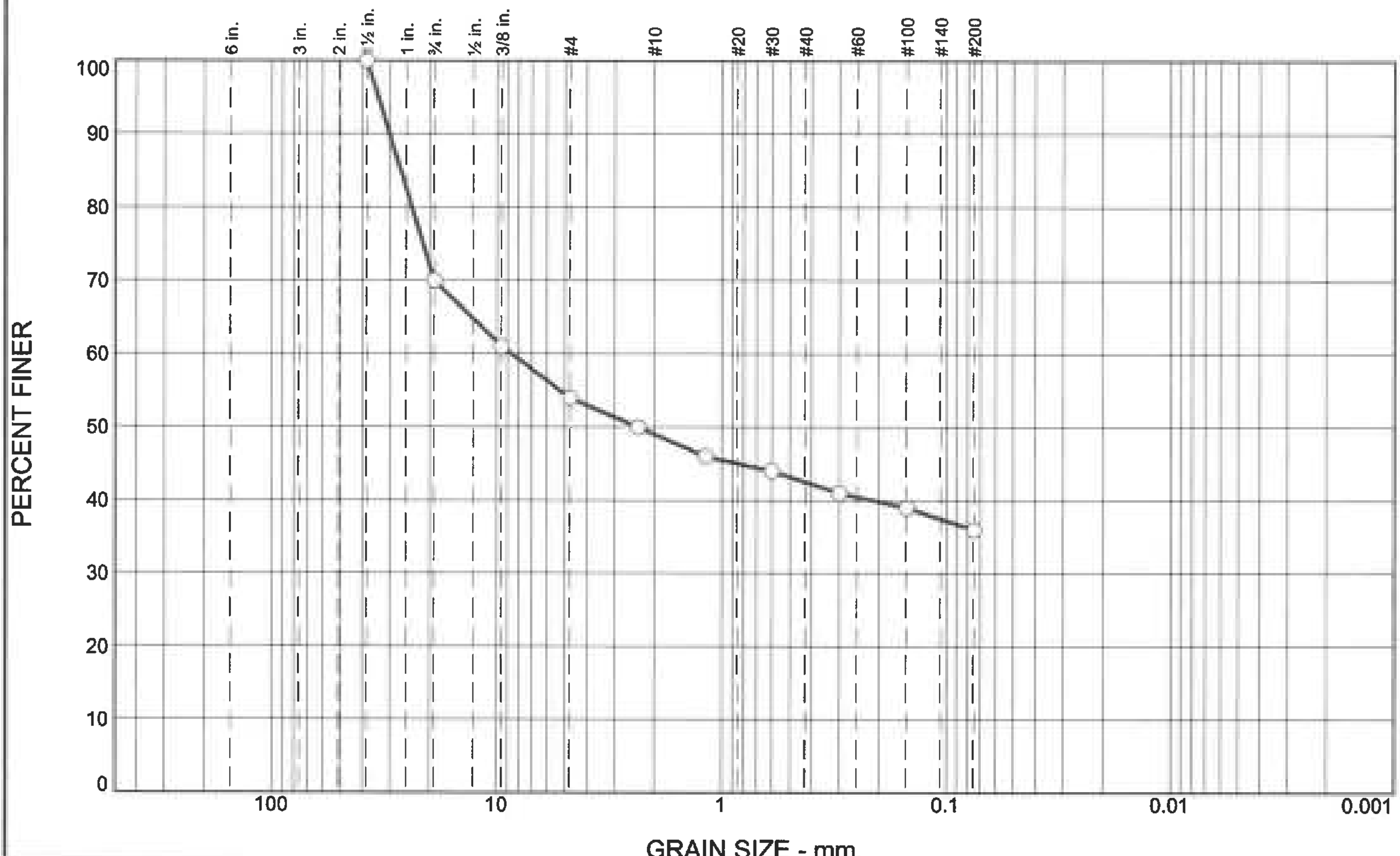
Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 1

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	30	16	5	6	7	36	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100		
3/4"	70		
3/8"	61		
#4	54		
#8	50		
#16	46		
#30	44		
#50	41		
#100	39		
#200	36		

* (no specification provided)

Soil Description

Clayey Gravel with Sand

Atterberg Limits

PL= 19 LL= 39 PI= 21

Coefficients

D_{90}= 30.2400 D_{85}= 26.9408 D_{60}= 8.6238
D_{50}= 2.3600 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= GC AASHTO= A-6(2)

Remarks

Location: TH-1
Depth: 15'

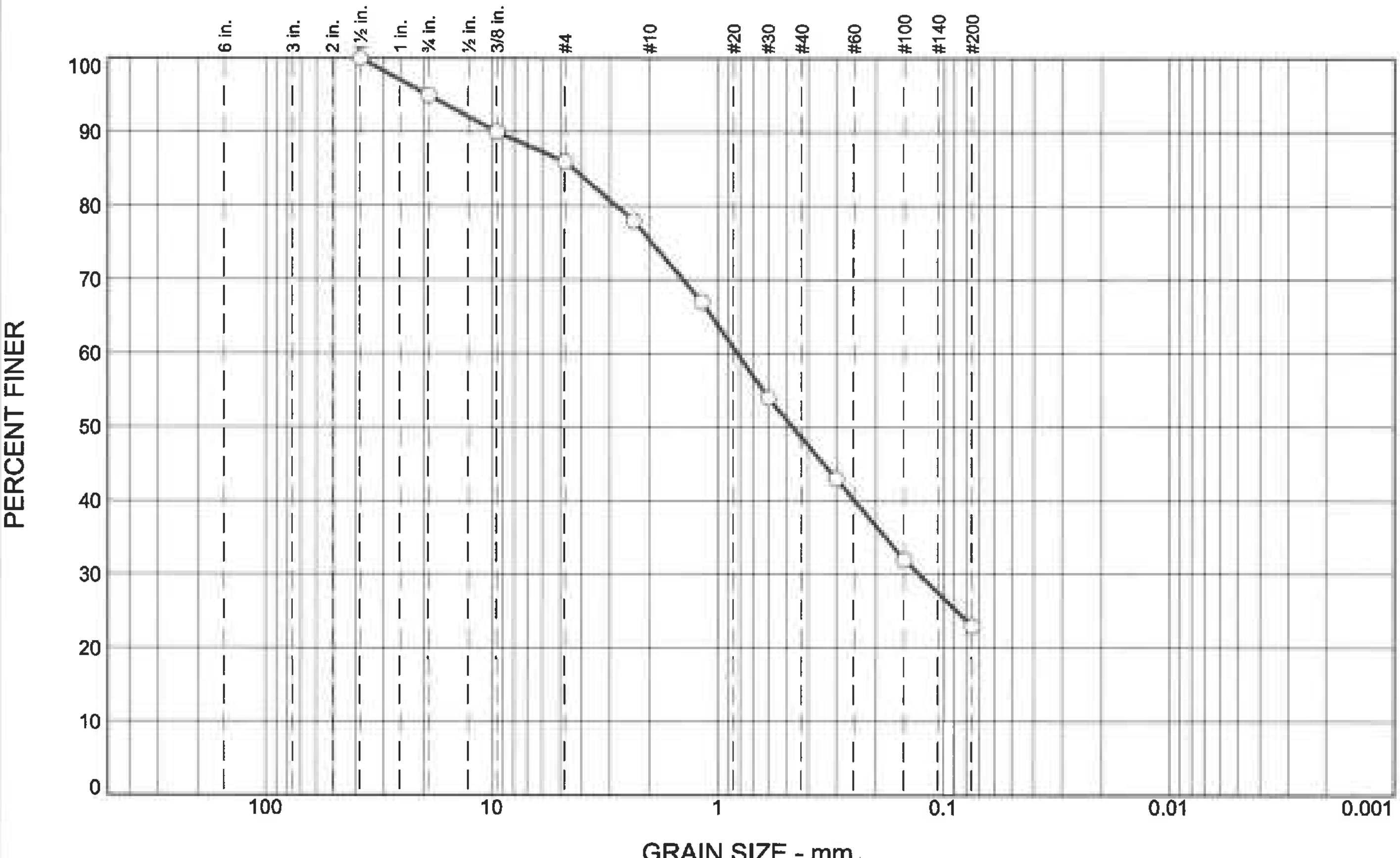
Date: 11/28/2018

Kumar & Associates, Inc.
Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 2

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	5	9	11	26	26	23	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100		
3/4"	95		
3/8"	90		
#4	86		
#8	78		
#16	67		
#30	54		
#50	43		
#100	32		
#200	23		

* (no specification provided)

Soil Description

Clayey Sand with Gravel

Atterberg Limits

PL= 23 LL= 33 PI= 11

Coefficients

D_{90}= 9.5250 D_{85}= 4.3523 D_{60}= 0.8198
D_{50}= 0.4663 D_{30}= 0.1286 D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SC AASHTO= A-2-4(0)

Remarks

Location: TH-2
Depth: 4'

Date: 1/11/2019

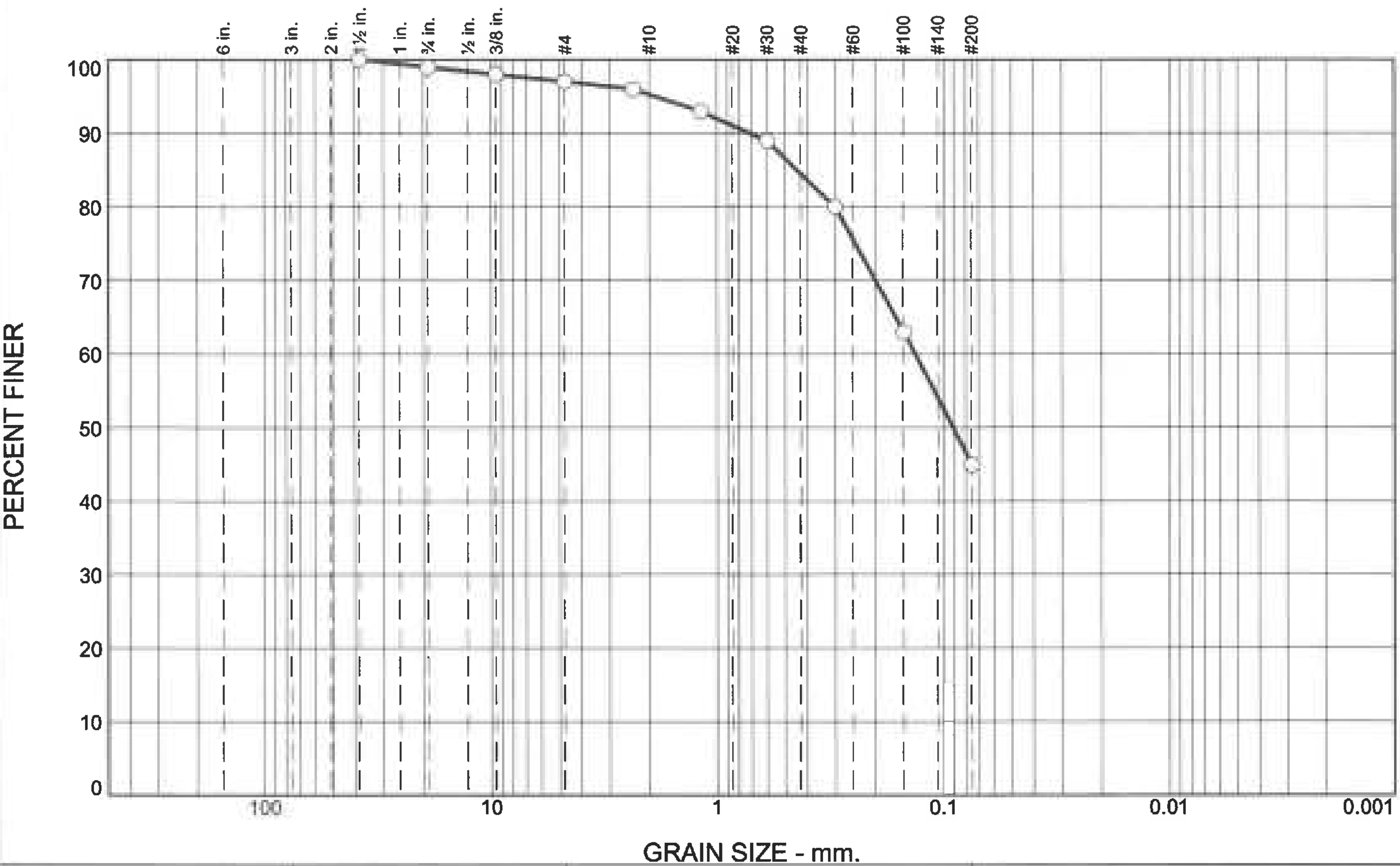
Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 8

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	1	2	2	10	40	45	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100		
3/4"	99		
3/8"	98		
#4	97		
#8	96		
#16	93		
#30	89		
#50	80		
#100	63		
#200	45		

* (no specification provided)

Soil Description

Silty Clayey Sand

Atterberg Limits

PL= 17 LL= 24 PI= 6

Coefficients

D_{90}= 0.7105 D_{85}= 0.4409 D_{60}= 0.1336
D_{50}= 0.0909 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SC-SM AASHTO= A-4(0)

Remarks

Location: TH-2
Depth: 8'

Date: 1/11/2019

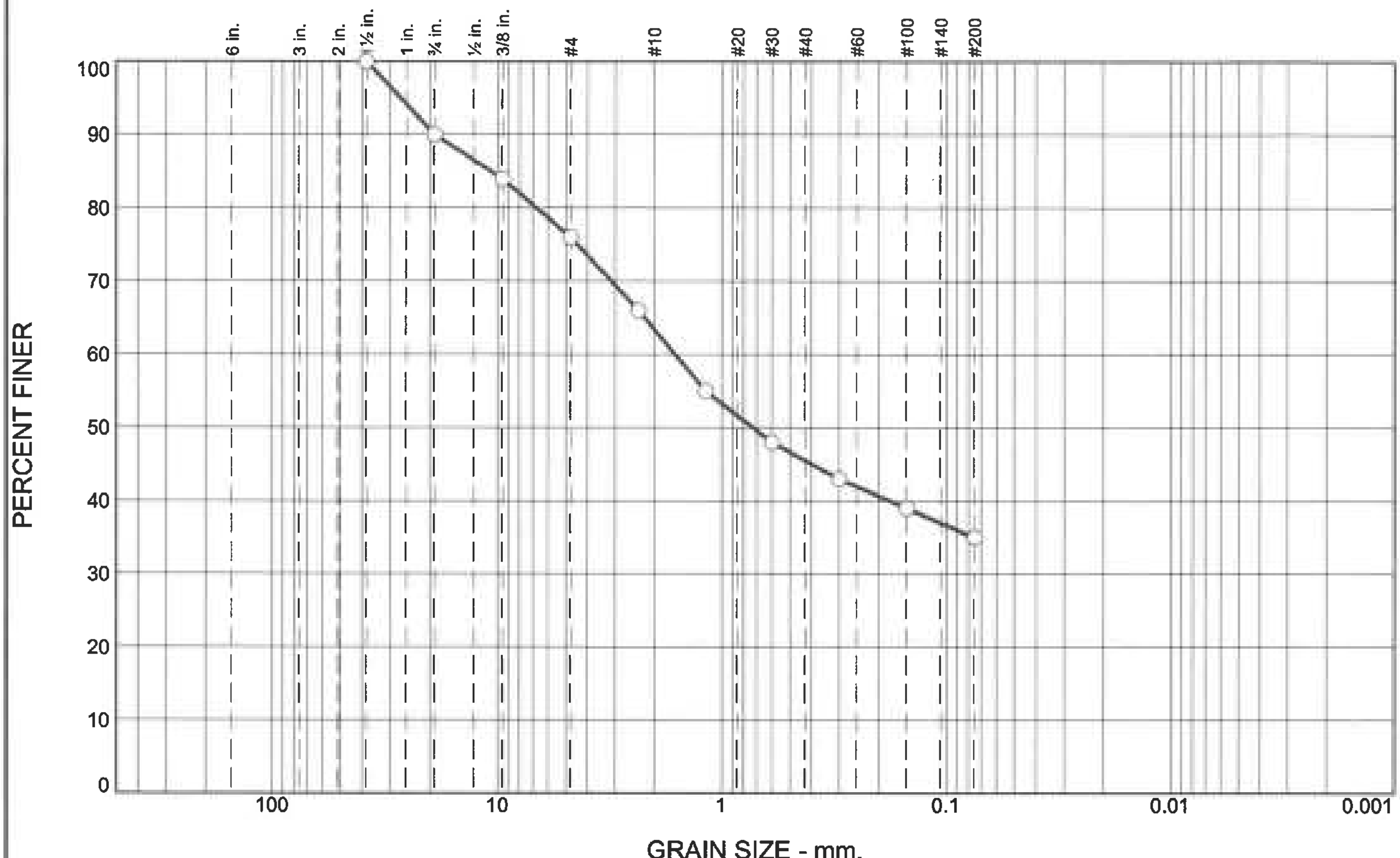
Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 9

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	10	14	13	17	11	35	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
1.5	100		
3/4"	90		
3/8"	84		
#4	76		
#8	66		
#16	55		
#30	48		
#50	43		
#100	39		
#200	35		

* (no specification provided)

Soil Description

Clayey Sand with Gravel

Atterberg Limits

PL= 20 LL= 34 PI= 15

Coefficients

D_{90}= 19.0500 D_{85}= 10.6915 D_{60}= 1.6170
D_{50}= 0.7279 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= SC AASHTO= A-2-6(1)

Remarks

Location: TH-2
Depth: 10'

Date: 11/28/2018

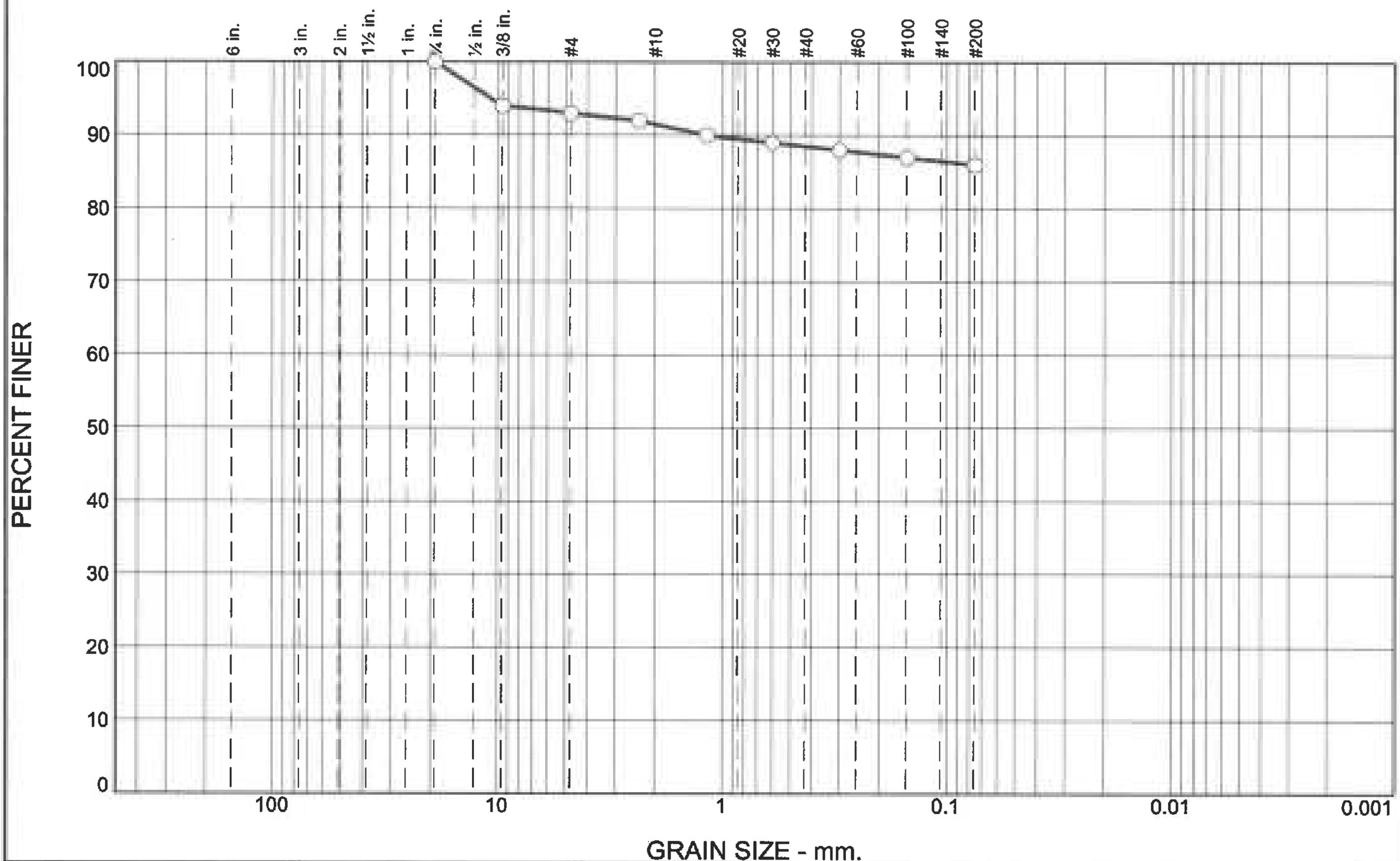
Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 3

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	7	1	3	3	86	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100		
3/8"	94		
#4	93		
#8	92		
#16	90		
#30	89		
#50	88		
#100	87		
#200	86		

* (no specification provided)

Soil Description

Clay

Atterberg Limits

PL= 20 LL= 42 PI= 22

Coefficients

D_{90}= 1.1800 D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-7-6(19)

Remarks

Location: TH-2
Depth: 15'

Date: 11/28/2018

Kumar & Associates, Inc.

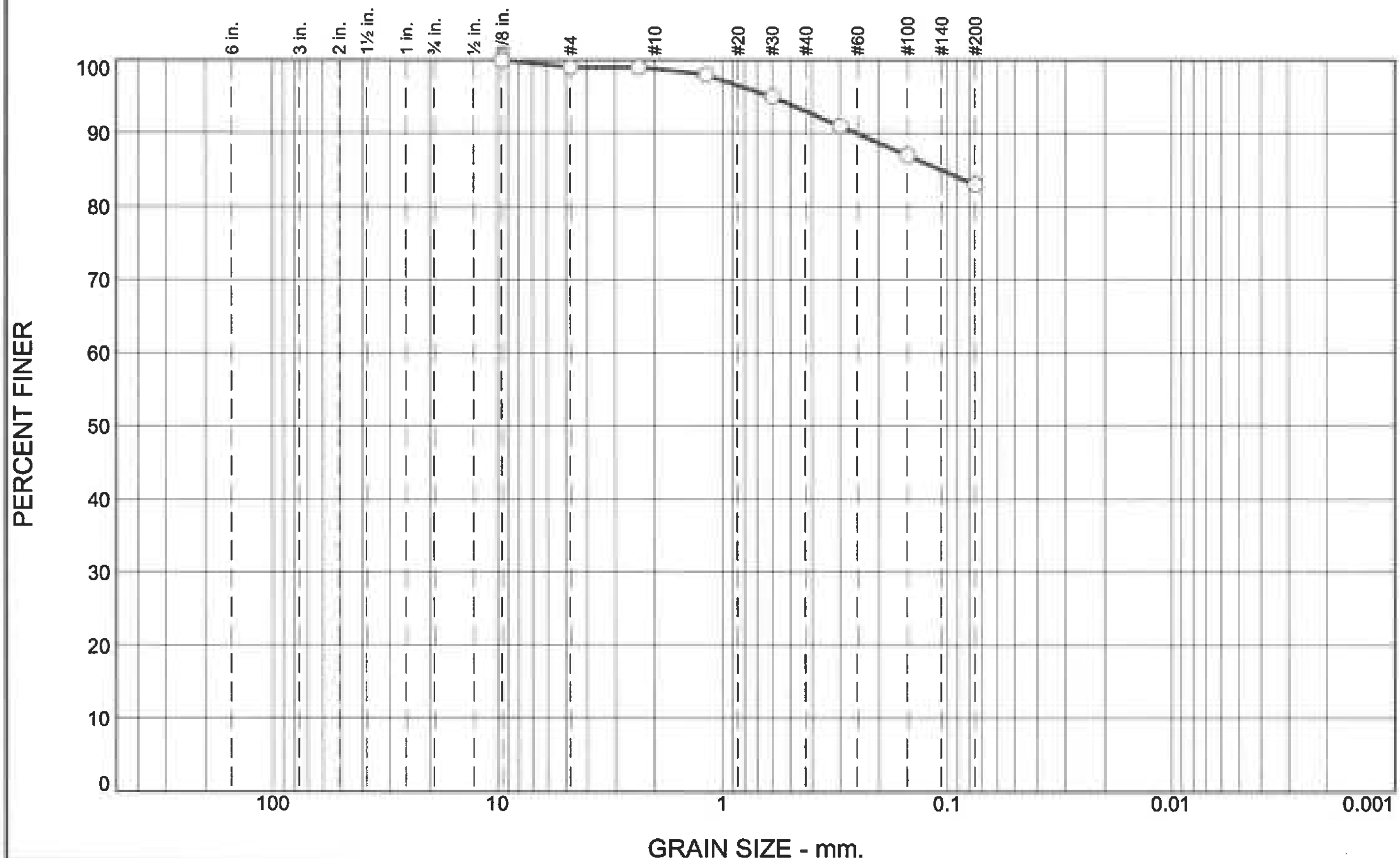
Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study

Project No: 18-7-716 **Figure** 4

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	1	0	6	10	83	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/8"	100		
#4	99		
#8	99		
#16	98		
#30	95		
#50	91		
#100	87		
#200	83		

* (no specification provided)

Soil Description

Clay with Sand

Atterberg Limits

PL= 15 LL= 27 PI= 13

Coefficients

D_{90}= 0.2523 D_{85}= 0.1061 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-6(8)

Remarks

Location: TH-3
Depth: 4'-5'

Date: 1/11/2019

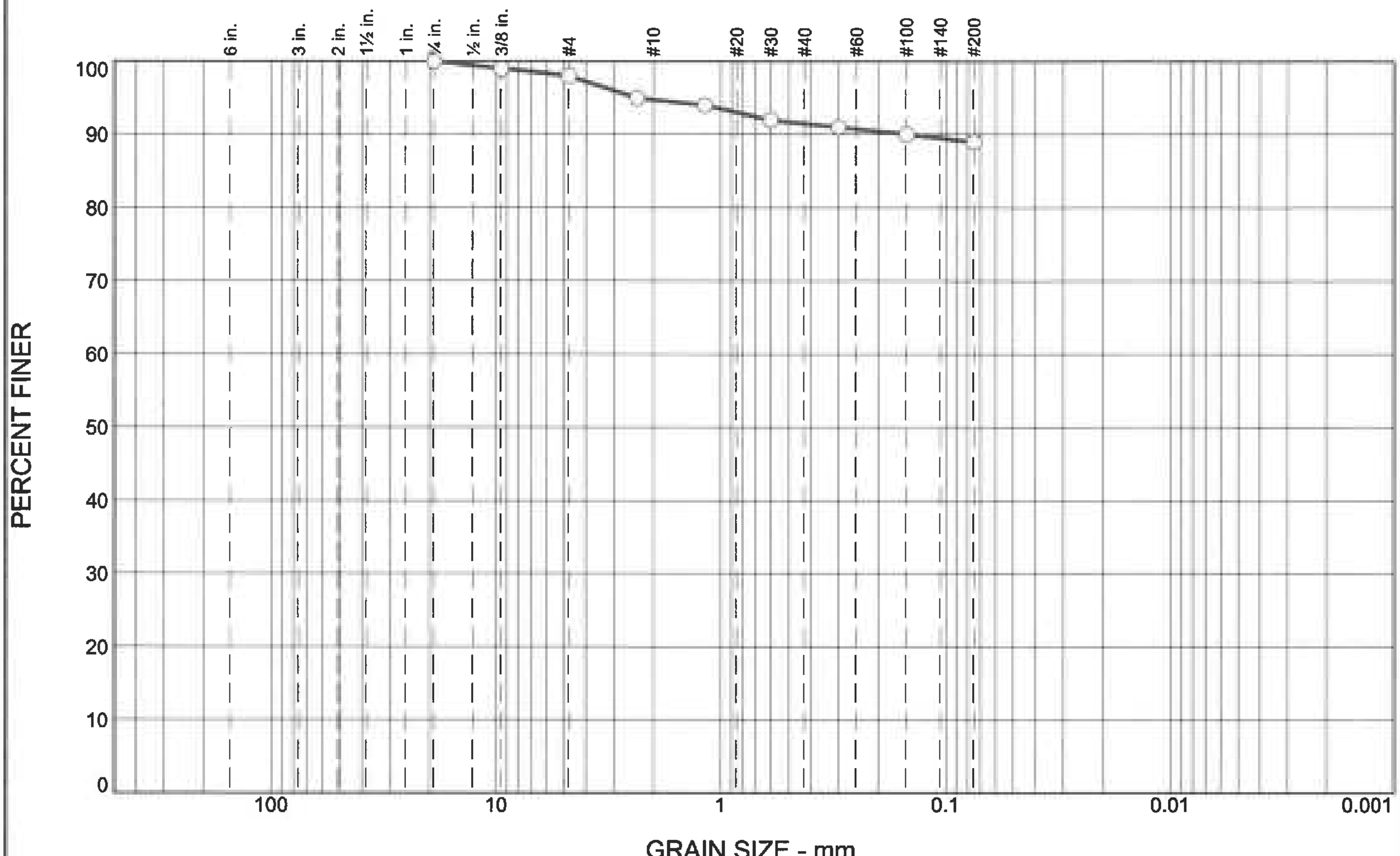
Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 10

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	2	3	3	3	89	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100		
3/8"	99		
#4	98		
#8	95		
#16	94		
#30	92		
#50	91		
#100	90		
#200	89		

* (no specification provided)

Soil Description

Clay

Atterberg Limits

PL= 19 LL= 40 PI= 21

Coefficients

D_{90}= 0.1500 D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-6(19)

Remarks

Location: TH-3
Depth: 20'

Date: 11/28/2018

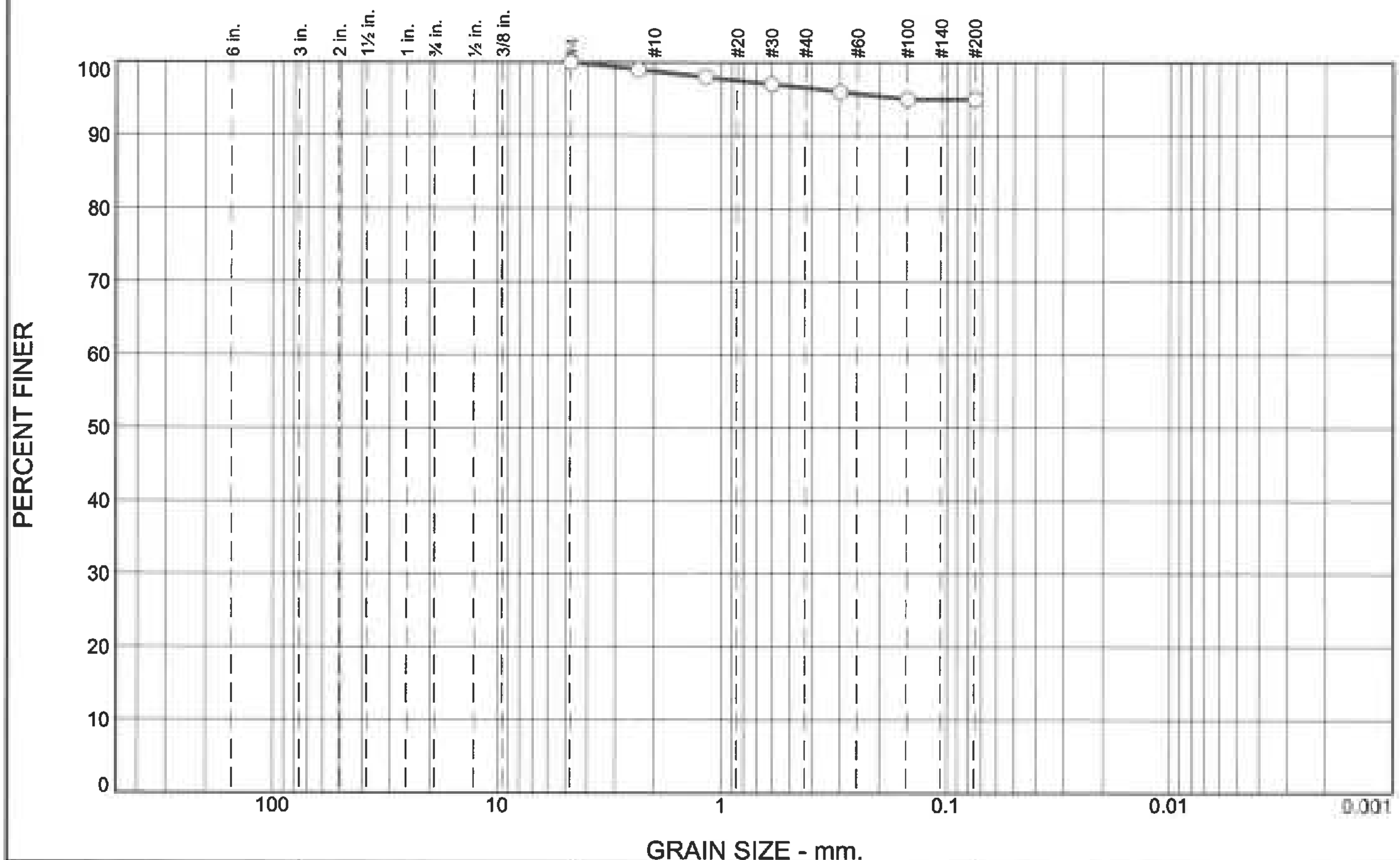
Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 5

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	1	2	2	95	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
#4	100		
#8	99		
#16	98		
#30	97		
#50	96		
#100	95		
#200	95		

* (no specification provided)

Soil Description

Clay

Atterberg Limits

PL= 21 LL= 50 PI= 29

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CH AASHTO= A-7-6(30)

Remarks

Location: TH-5
Depth: 5'

Date: 11/28/2018

Kumar & Associates, Inc.

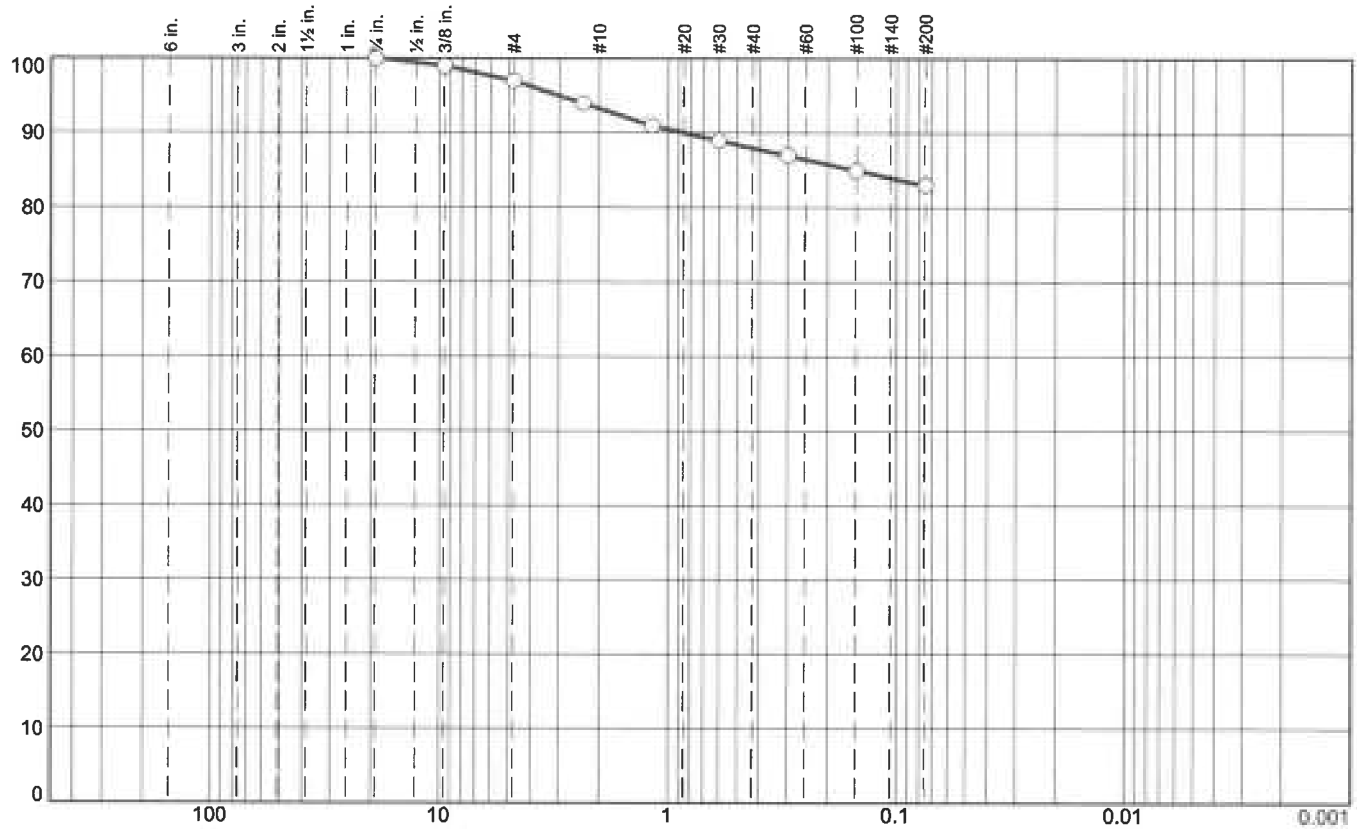
Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study

Project No: 18-7-716 **Figure** 6

Tested By: JC **Checked By:** TJW

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	3	4	5	5	83	

SIEVE SIZE	PERCENT FINER	SPEC.* PERCENT	PASS? (X=NO)
3/4"	100		
3/8"	99		
#4	97		
#8	94		
#16	91		
#30	89		
#50	87		
#100	85		
#200	83		

* (no specification provided)

Soil Description

Slightly Sandy Clay

Atterberg Limits

PL= 20 LL= 39 PI= 19

Coefficients

D_{90}= 0.8414 D_{85}= 0.1500 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Classification

USCS= CL AASHTO= A-6(15)

Remarks

Location: TH-6
Depth: 10'

Date: 11/28/2018

Kumar & Associates, Inc.

Glenwood Springs, Colorado

Client: Applegate Group
Project: Fire Mountain Canal Regulating Reservoir Feasibility Study
Project No: 18-7-716 **Figure** 7

Tested By: JC **Checked By:** TJW

Applegate Group, Inc.

Daily Construction Report

General Project Site Information

Date: *12-14-2018*	***Job Name: Fire Mtn Canal – Re-Regulating Reservoir Feas. Study***	***Report No. 1***
AG P#:18-128	***Client: Fire Mountain Canal Co.***	***Inspector: Craig Ullmann***
Weather: 20-30 deg		***Time on Site: 10 AM – 1 PM***

Construction Observation

Principals on Site: ***Craig Ullmann (AG)*** ***Steve Fletcher (FMC)*** ***Bill Moore (FMC)***	***Equipment Data (observed in operation):*** Backhoe

Work Performed:

Dug three test pits at proposed reservoir sites to evaluate subsurface soils and borrow site potential.

Test Pit No. 1 – along ditch access road at drainage crossing

- 0-1' Rocky topsoil
- 1-6' Dry, about 50% rock varying from 1-12" in diam., rock is infilled with sands, gravels and some fines.
- 6-8' Larger rocks encountered, digging difficult with backhoe, test pit abandoned

Test Pit No. 2 – Left Abutment of 3300 Road site near Test Hole 3

- 0-18" Rocky topsoil
- 18"-5' Dry, light tan, fine grained with occasional rocks
- 5-7' Dry, very rocky
- 7'-9'6" Fine to medium Sand, relatively clean, little to no rocks, non plastic
- 9'6"-10' Sand with some rocks, little clay, non plastic

Test Pit No. 3 – Potential Borrow Area for Coal Road Site

- 0-18" Topsoil, relatively clean
- 18"-10' Clay, multicolored with calcite deposits, roots down to 36", very few rocks

Work Performed (continued):

Test Pit 1

Test Pit 2


Test Pit 3


Test Pit 3 sample with calcite


Test Pit 3 sample with calcite

Appendix F – Opinion of Probable Cost

Engineers Opinion of Probable Cost

Applegate Group, Inc.
www.applegategroup.com

AG JOB NO.: 18-128
BY: CU/bak

FIRE MOUNTAIN CANAL RE-REGULATING RESERVOIR FEASIBILITY STUDY
Coal Road Site - Siphon Outlet

Date: 8/12/2020
Client: Fire Mtn Canal & Reservoir Company

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	**Reservoir Project**				
1.01	Mobilization	%		6%	$ 99,476
1.02	Bonding and Insurance	%		2%	$ 33,159
1.03	Coal Road re-route	LS	1	$ 25,000	$ 25,000
1.04	Homogenous Embankment	CY	25,200	$ 9	$ 226,800
1.05	Keyway Construction	CY	700	$ 12	$ 8,400
1.06	Chimney and Blanket Drain	CY	1,300	$ 110	$ 143,000
1.07	Riprap on Upstream Dam Face	CY	620	$ 100	$ 62,000
1.08	Grade Beam with Staff Gage, Gate Stem, and Air Vent	LF	57	$ 320	$ 18,240
1.09	Concrete Spillway, Reservoir	CY	165	$ 1,600	$ 264,000
1.10	Pipe Spillway for Canal	LS	1	$ 87,500	$ 87,500
1.11	72" Canal Pipe within reservoir	LF	1,200	$ 265	$ 318,000
1.12	36" Outlet Siphon Pipe	LF	900	$ 125	$ 112,500
1.13	60" Pipe for Drop Structure	LF	100	$ 225	$ 22,500
1.14	Outlet Control Structure with gates	LS	1	$ 196,000	$ 196,000
1.15	12" Low Level Dam Outlet, Concrete Encased	LF	240	$ 600	$ 144,000
1.16	Reclamation	AC	10	$ 3,000	$ 30,000
				Reservoir Construction Subtotal	$ 1,285,575
1.17	Engineering Design & Dam Safety Permitting	%		12%	$ 154,269
1.18	NEPA, Permitting and Planning	LS	1	$ 61,000	$ 61,000
1.19	Engineering Oversight During Construction	%		8%	$ 102,846
1.20	Survey and QA/QC	%		5%	$ 64,279
1.21	Contingency/Missing Items	%		20%	$ 257,115
				Reservoir Project Subtotal	**$ 1,925,084**
2	**Pipeline Project**				
2.01	Mobilization	%		6%	$ 236,283
2.02	Bonding and Insurance	%		2%	$ 78,761
2.03	Regulating Pool Cut/Fill Grading	CY	500	$ 20	$ 10,000
2.04	72" Pipeline Screen Intake Structure (relocated screen)	CY	50	$ 1,500	$ 75,000
2.05	Canal Prep Grading	LF	13,800	$ 5	$ 69,000
2.06	72" Canal Pipe Below Drop	LF	13,800	$ 265	$ 3,657,000
2.07	User Turouts	EA	10	$ 7,000	$ 70,000
2.08	Modifications to Existing Screen Structure	LS	1	$ 50	$ 50
2.09	Reclamation	AC	19	$ 3,000	$ 57,000
				Pipeline Constructure Subtotal	$ 4,253,094
2.10	Engineering Design & Dam Safety Permitting	%		5%	$ 212,655
2.11	NEPA, Permitting and Planning	LS	1	$ 15,000	$ 15,000
2.12	Engineering Oversight During Construction	%		6%	$ 255,186
2.13	Survey and QA/QC	%		2%	$ 85,062
2.14	Contingency/Missing Items	%		20%	$ 850,619
				Pipeline Project Total	**$ 5,671,615**
				Total Project Cost	**$ 7,596,699**

Engineers Opinion of Probable Cost

Applegate Group, Inc.
www.applegategroup.com

AG JOB NO.: 18-128
BY: BAK/CMU

FIRE MOUNTAIN CANAL RE-REGULATING RESERVOIR FEASIBILITY STUDY
3300 Road Site

Date: 8/12/2020
Client: Fire Mtn Canal & Reservoir Company

Item No.	Description	Units	Quantity	Unit Cost	Total Cost
1	**Reservoir Project**				
1.01	Mobilization	%		6%	$ 53,144
1.02	Bonding & Insurance	%		2%	$ 17,715
1.03	Zoned Embankment	CY	24,000	$ 9	$ 216,000
1.05	Keyway Construction	CY	8,000	$ 12	$ 96,000
1.06	Riprap Lined Spillway	CY	925	$ 100	$ 92,500
1.07	Riprap on Upstream Dam Face	CY	980	$ 100	$ 98,000
1.08	30" Concrete Encased Dam outlet w/ Upstream slide gate	LS	1	$ 153,000	$ 153,000
1.09	Reservoir Inlet structure	CY	15	$ 1,600	$ 24,000
1.1	Grade Beam with Staff Gage, Gate Stem, and Air Vent	LF	57	$ 320	$ 18,240
1.11	Outlet Control Structure w gates	LS	1	$ 158,000	$ 158,000
1.12	Reclamation	AC	10	$ 3,000.00	$ 30,000.00
				Reservoir Construction Subtotal	$ 956,599
1.13	Engineering Design & Dam Safety Permitting	%		10%	$ 95,660
1.14	NEPA & Permitting	LS	1	$ 19,000	$ 19,000
1.15	Land purchase incl. subdivision	Acre	19	$ 6,000	$ 114,000
1.16	Engineering Oversight	%		10%	$ 95,660
1.17	Survey and QA/QC testing	%		5%	$ 47,830
1.18	Contingency	%		20%	$ 191,320
				Reservoir Project Subtotal	**$ 1,520,069**

2	**Pipeline Project**				
2.01	Mobilization	%		6%	$ 172,500
2.02	Bonding and Insurance	%		2%	$ 57,500
2.03	Regulating Pool Cut/Fill Grading	CY	500	$ 20	$ 10,000
2.04	72" Pipeline Screen Intake Structure (relocated screen)	CY	50	$ 1,500	$ 75,000
2.05	Canal Prep Grading	LF	9,800	$ 5	$ 49,000
2.06	72" Canal Pipe Below Drop	LF	9,800	$ 265	$ 2,597,000
2.07	User Turouts	EA	7	$ 7,000	$ 49,000
2.08	Modifications to Existing Screen Structure	LS	1	$ 50,000	$ 50,000
2.09	Reclamation	AC	15	$ 3,000	$ 45,000
				Pipeline Constructure Subtotal	$ 3,105,000
2.10	Engineering Design & Dam Safety Permitting	%		5%	$ 155,250
2.11	NEPA, Permitting and Planning	LS	1	$ 15,000	$ 15,000
2.12	Engineering Oversight During Construction	%		6%	$ 172,500
2.13	Survey and QA/QC	%		2%	$ 57,500
2.14	Contingency/Missing Items	%		20%	$ 575,000
				Pipeline Project Total	**$ 4,080,250**

Total Project Cost $ 5,600,319

NORTH FORK WATER CONSERVANCY DISTRICT

Master Plan & Funding Plan

June 30, 2016

Prepared by:

J·U·B ENGINEERS, INC.

466 North 900 West
Kaysville, Utah 84037
801 547 0393

Table of Contents

NORTH FORK CONSERVANCY DISTRICT
WATER MASTER PLAN AND FUNDING PLAN

June 30, 2016

1 - INTRODUCTION

The Paonia Project, which provides irrigation water to 15,300 acres in the North Fork of the Gunnison River Valley, was completed by the U.S. Bureau of Reclamation (USBR) in 1962 as part of the Colorado River Storage Project. On June 1, 1962, the North Fork Water Conservancy District (NFWCD) assumed responsibility for the operation, maintenance and safety of the Paonia Dam and associated structures. In that same year, NFWCD entered into an agreement with the Fire Mountain Canal and Reservoir Company (FMCRC) through which FMCRC assumed responsibility for the operation and maintenance of the Fire Mountain Canal, a water-delivery facility which provides irrigation water to about 8,200 acres of farms and ranches near Paonia and Hotchkiss, Colorado.

A Water Management Plan for NFWCD was completed in July 2001. A copy of the 2001 Water Management Plan is in Appendix I. Chapter 3 of the 2001 Water Management Plan was updated in 2009. A copy of the 2009 update of Chapter 3 in in Appendix J. The 2001 management plan provides an excellent history of the NFWCD.

This Master Plan will focus on two areas:

1. The Fire Mountain Canal which is 33.275 miles long and delivers water to approximately 90 turnouts and approximately 480 water users.

2. The Paonia Reservoir which was constructed with an initial capacity of 18,150 acre-feet.

The purpose of this Master Plan is to supplement the Water Management Plan and to provide guidance for future improvement projects on the canal. The goals of selected improvement projects will include one or more of the following outcomes:

- Improve water quantity (seepage loss and inefficient delivery)
- Improve canal safety through canal enclosures in geologically sensitive areas
- Improve water quality (salinity and selenium reduction)
- Improve system efficiency through remote monitoring and data acquisition and remote control (SCADA system)
- Improve on-farm efficiency (provide pressurized irrigation alternatives)

The Master Plan is a "living" document, meaning that it is constantly subject to change based upon factors such as funding opportunities, operation and maintenance concerns, safety issues, etc. which may change the project priorities or project approaches. An annual review and update of the Master Plan is recommended so that it will remain valuable as a decision-making and informational tool.

2 - SYSTEM EVALUATION

2-1 Existing Canal

The 33 miles of the Fire Mountain Canal was mapped using GIS to create canal inventory maps for the NFWCD. USBR surveyed the existing facilities on the canal and provided that survey information for the preparation of the GIS maps. The locations for the turnouts, overshots, undershots, check structures, wasteways, and locations of existing concrete liner or canal enclosures have been shown on the sixteen Fire Mountain Canal Maps included in Appendix A of this Plan. This information will be provided to NFWCD in a GIS format to become the starting point of a future District GIS system.

As a result of several on-site meetings with the NFWCD manager, critical areas of concern have been identified and reviewed in detail. In some cases, USBR had previously proposed repairs to the facilities. Those recommendations have been incorporated into the project priorities lists that are part of the Master Plan.

2-2 Water Rights

The 2001 Water Management Plan provides an excellent history on the water rights and flow rates of the Fire Mountain Canal and Paonia Reservoir. A brief summary of the water rights are as follows:

- 208.0 CFS for Irrigation from the North Fork of the Gunnison River
- 70.0 CFS for irrigation from Terror Creek
- 40.0 CFS for irrigation from Roatcap Creek
- 30 CFS for domestic and stock use during the non-irrigation season diverted cumulative from the North Fork and Terror Creek

2-3 Flow Rates

The flow rates used in this Master Plan are shown in Table 1 on the following page. These flow rates correspond with the design criteria from the original USBR design and are found on drawings provided by USBR.

Table 1: Flow Rates

Starting Station	Ending Station	Length (ft)	100% Flow Rate (cfs)	135% Flow (cfs)
2+03	108+73	10,670	180	243
108+73	655+94	54,721	165	223
655+94	1043+00	38,706	145	196
1043+00	1537+70	49,470	135	182
1537+70	1758+95	22,125	100	135

The Fire Mountain Canal currently has capacity which approximates the 135% flow in Table 1. Pipelines and siphons have been sized accordingly.

2-4 Largest Turnouts

The Fire Mountain Canal delivers the majority of its water to 4 ditch companies near the end of the canal. Those ditch companies are the Jesse Ditch and the Rogers Mesa Water Distribution Association's East, Slack and Patterson Lateral. Table 2 below provides more detail regarding the water delivered at these four turnouts. There are many turnouts along the canal, but they are small in comparison.

Table 2: Summary of Largest Turnouts

Ditch Company Turnout	Station	2015 Flow Rate (cfs)
Jesse Ditch	1537+70	4.8
RMWDA East Lateral	1635+50	36.7
RMWDA Slack Lateral	1664+10	14.7
RMWDA Patterson Lateral	1667+20	29.9

*2015 Flow Rate is based on 1450 shares = 1 cfs

2-5 Existing Canal Segments

The 175,692 feet or 33.275 miles of canal have been broken into 48 specific segments to help identify potential improvement projects along the canal. Canal stationing has been added to the GIS mapping in order to provide correlation between the maps and the master planned projects. Initially, the segments were based on approximate 5,000-foot reaches of the canal. These segments were subsequently adjusted to begin or end at existing siphons, previously identified projects, or other features as necessary. The 48 segment locations are identified on the Fire Mountain Canal maps in Appendix A and are shown on the Canal Projects Table in Appendix B.

The vast majority of the total canal reach follows along hillsides and roadways with only minor variations over long distances. For that reason, a description of each of the 48 segments would be redundant and is not necessary for planning purposes. The only difference between several of the segments is the length. For that reason, rather than describe each segment individually, the Canal Projects Table in Appendix B gives the necessary detail for the different segments.

The priority segments that are recommended as projects are described in detail in the Section 3 of the Master Plan.

2-6 Salt Loadings

Salt loadings along the canal were also obtained from USBR. These loadings are shown with the segments in the Canal Projects Table. According to USBR estimates, the Fire Mountain Canal contributes a total of 6,135 ton of salt annually to the Colorado River Drainage. FMCRC has been selected to receive a grant from the USBR Colorado River Basin Salinity Control Program to pipe a portion of the Fire Mountain canal based upon an estimate of 2,365 tons of salt annually, or 38.5% of the total. That project, described later in the Master Plan, goes from the Jesse Turnout by Leroux Creek to the end of the Fire Mountain Canal, a distance of just over 4 miles. The remaining 3,770 tons of salt, or 62.5%, are distributed along 29 miles of the canal, resulting in a much lower water quality impact to the irrigation system.

2-7 Existing Siphons

There are 10 siphons on the canal that cover a total length of 2,678 feet. According to the NFWCD Manager, the siphons are in good condition and are functioning property. He has stated that the siphons are inspected annually by the NFWCD and every 5 years by USBR. Based on the manager's observations, the siphons still have significant life left in them. He does not anticipate the siphons needing to be replaced for at least 20 years. Given that the siphons have at least a 20-year life remaining, replacement costs for the siphons are not included in this Master Plan. However, maintenance costs of the siphons are included as a means of estimating anticipated expenses to keep the siphons functioning property over their remaining life. Table 3 below provides a list of the siphons along with their location, lengths, sizes, and flow rates.

Table 3: Existing Siphons

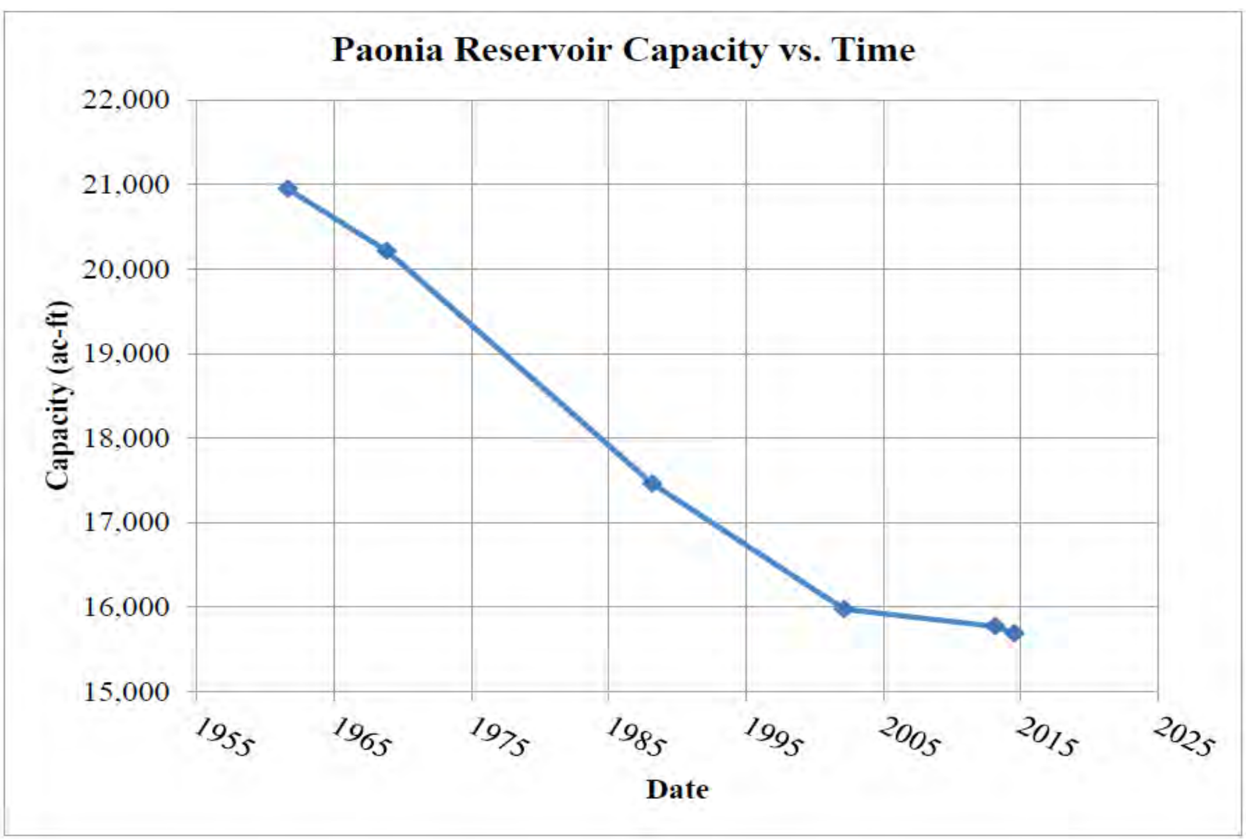
Segment	Name	Starting Station	Ending Station	Length (ft)	Size	100% Flow Rate (cfs)
3	Bear Creek	39+30	40+34	104	6'-0"	180
5	Unnamed	97+23	98+73	150	6'-0"	180
8	Hubbard Creek	130+03	137+53	750	6'-0"	165
13	Terror Creek	332+10	333+30	120	6'-0"	165
19	Stevens Gulch	493+78	495+11	133		165
23	Roatcap Creek	655+94	657+06	112		145
33	Jay Creek	1065+46	1073+08	762	4'-6"	135
38	Wolf Park	1240+84	1242+41	157	4'-6"	135
43	Horse Park	1420+00	1420+81	81	4'-6"	135
48	Leroux Creek	1579+51	1582+60	309	4'-0"	100

2-8 Water Losses

As part of the 2001 Water Management Plan, a water loss study was completed. Based on the flow measurements of this study, the Fire Mountain Canal is losing 0.95 cfs per mile of canal. This water is being lost to evaporation, seepage, and root uptake. The NFWCD manager has recently taken separate measurements and has independently concluded that the canal is still losing an average1 cfs per mile. A canal loss of 1 cfs per mile equates to 33 cfs for the entire canal resulting in a 66 acre-feet per day water loss for the canal. Over a 180-day irrigation season, this results in a loss of 11,880 acre-feet of water for the year. No new seepage loss study was done as part of this Master Plan.

2-9 Paonia Reservoir

Paonia Dam is located on Muddy Creek approximately 1 mile upstream of its confluence with Anthracite Creek, which in turns forms the North Fork of the Gunnison River. The dam is an earthfilled structure containing 1,302,000 cubic yards of embankment fill. Paonia Reservoir has a surface area of 334 acres. The North Fork Water Conservancy District has a storage right of 21,000 acre-feet in Paonia Reservoir, see the 2001 Water Management Plan for more information on the storage rights. Sedimentation over the years have decreased the active storage capacity. The estimated active storage capacity published in the 2001 Water Management Plan was 15,237 acre-feet. The following chart shows the decrease in active reservoir capacity over time.



3 – PROPOSED CANAL PROJECTS

3-1 Generation of Improvement Alternatives

The mater-planned canal projects were analyzed using several methods. The project currently awaiting a grant from the Colorado River Basin Salinity Control Program Project was modelled using the modeling software Innovyze's InfoWater running in ArcGIS. Any proposed improvements for segments using open liner sections were based on the current canal widths and capacities. Natural Resource Conservation Service (NRCS) and USBR Design Standards were considered in the evaluation and costs of the improvement alternatives.

Initial project alternatives have been further evaluated in conjunction with the NFWCD manager. Following that evaluation, the alternatives were then reviewed with the NFWCD and the FMCRC. The purpose of these various evaluation and reviews was to look for ways that the alternatives might be modified to be more efficient and still serve the needs of the NFWCD and FMCRC shareholders.

Cost estimates were generated for each segment of the canal based on either piping or open canal liner alternatives. The cost estimates are based on pricing data from recent projects, material suppliers, local contractors, and USBR requirements. Cost estimates within this Plan are presented in present day dollars.

The list of all the projects is shown in the Canal Projects Table in Appendix B. From this list, the project segments have been prioritized based on several key factors including, but in no special order, availability of funding, safety concerns, water loss, operation and maintenance challenges, salt loading, visual inspections, current conditions, and NFWCD recommendations. The priority projects are summarized in the High Priority Project list included in Appendix C. The Engineer's Opinions of Probable Cost for all of the projects are included in Appendix D.

As stated above, the High Priority Project list consists of projects that are considered to be possible safety concerns, indicate high losses of water, or difficult to operate or maintain, among other reasons. The order of the high priorities list should be reviewed at least annually. Projects may move up the list in importance based on adjacent development along the canal, maintenance of vegetation, ability to clean, better conservation, prevention of water seepage, protection of the environment, and other factors.

The stationing for the canal projects and segment numbers are shown on the Fire Mountain Canal Maps in Appendix A. If new alignments have been proposed for certain segment, maps for those area have been created and included in Appendix A as well.

The cost of rehabilitation for all the 33 miles of the Fire Mountain Canal is significant! In order to keep these costs as low as possible, construction of a new canal liners has been chosen as the best alternative for a majority of the canal segments. This new liner would contain a PVC membrane and a shotcrete cover on the membrane per USBR standards. In areas where concrete liner already exists, the liner is not being recommended for replacement.

Piping of the entire canal, although a desirable alternative for several reasons, is expensive due to the required design flows and the nature of readily available pipe materials to carry those flows. The lower end of the canal can be piped with a 63-inch diameter HDPE pipe or smaller. The remainder of the canal would require two side-by-side HDPE pipes or a single pipe 72 inches in diameter or larger. The most readily available and cost-effective pipe material in a 72-inch diameter is corrugated metal pipe (CMP). Due to sediment load in the water and concerns for abrasion in the pipe, NFWCD prefers not to use CMP on the canal.

A comparison of the cost of two 63-inch HDPE pipes to the open canal liner was done. For most of the segments identified, side-by-side 63-inch HDPE pipes or larger would be required to carry the design flow at the velocities typical for USBR and NRCS projects. When all the costs of the project are included over a 5,000-foot length of canal, the cost of the new liner is approximately $410 per foot of liner. This cost obviously decreases for segments that already have sections of exiting concrete liner. The average cost of side-by-side 63-inch diameter HDPE pipes to replace the open canal is about $850 per linear foot, over twice the cost of the new canal liner. As a "pipeline alternative" to any of the segments shown with new canal liner, should that be preferred sometime in the future, simply double the liner costs listed as a starting point for estimating piping costs.

3-2 High Priority Projects List

The High Priority Projects List has been generated from two sources. The first source is the projects identified by USBR as part of the Colorado River Storage Project Act – Memorandum of Agreement (MOA) Planning Report. A full list of these projects is provided in Section 3-3 of this Plan and a copy of the USBR report is included in Appendix G. The second source of priority projects came from discussions, field observations and identified funding opportunities that were associated with this master planning effort. Table 4 below provides a snapshot of the High Priority Projects. A more-detailed table is provided in Appendix C.

Table 4 – High Priority Project Summary

Year	Project	Funding Source	Funding Amount	Notes
2016	Paonia Reservoir Dam Outlet	MOA	$ 7,800,000	USBR Design and Construction Administration
2016	Paonia Reservoir Dam Elevator Repairs	MOA	$ 101,000	USBR Design and Construction Administration
2016	Segment 47: Leroux Creek to End of Canal	FOA/RCPP	$ 4,465,500	2015 RCPP and FOA Funding approved
2017	Segment 6: Canal Enclosure at Railroad Tracks	RCPP or MOA	$ 934,600	2017 RCPP Application or MOA
2017	Wolf Park Siphon	RCPP	$ 911,800	2017 RCPP Application
2018	Segment 40 (portion): Wolf Park Siphon with Segment 40	FOA	$ 503,000	2018 FOA Application if Wolf Park is funded with RCPP
2018	Segment 15: Garvin Mesa Piping	RCPP or MOA	$ 1,967,400	2018 RCPP Application or MOA
2019	Segment 1: Fire Mountain Canal Diversion Structure	RCPP or MOA	$ 1,929,000	2019 RCPP Application or MOA
2018	SCADA System	RCPP or MOA or WaterSMART	$ 585,000	Incorporated with 2017-2020 RCPP applications
2022	Start Canal Projects from Leroux Creek to River Diversion	WaterSMART / CWCB	$ 2,000,000 per project	Apply for WaterSMART application with 50% from CWCB

The following pages include descriptions of several high priority projects identified by the NFWCD and the FMCRC through the master planning process. Descriptions of the USBR MOA projects are found in Appendix D. Note that there is "cross-over" between the two categories of projects based upon the timing and availability of funding. This is described in Section 4-2, Funding Strategies.

3-2-1 Segment 47: Leroux Creek to End of Canal – Station 1537+70 to 1758+95

This project consists of piping the canal from the Jesse Turnout on the east side of Leroux Creek to the end of the canal. 19,222 feet of solid wall fusion welded HDPE pipe ranging from 63" to 14" diameter will be installed. A new siphon across Leroux Creek will be constructed at a new location in order to eliminate approximately 1.3 miles of canal. The canal through Leroux Creek has many seeps and is difficult to maintain. This project will also remove 2,365 tons of salt annually that are contributed to the Colorado River Drainage.

By piping the canal from the Jesse Turnout to the end, a low-head pressurized system will be created. This will allow this section act like an on-demand system. Water not needed by users will be diverted into Leroux Creek. This will be extremely beneficial in times of heavy rains that collect on the hillsides above the canal and flow directly into the canal. The flows from these rain storms will now be able to be safely sent to the river without over topping the canal or affecting the downstream users.

This project has been selected to received funding from the 2015 FOA from the USBR Colorado River Basin Salinity Control Program and from the NRCS RCPP program. Local fund from NFWCD and FMCRC have also been committed to the project.

The Project is estimated at $4,465,500. Contracts for the work on this project are pending at this time. Construction of this project should take place between 2016 and 2018. A map of this project is shown in Appendix E. The construction cost estimate is included with the other cost estimates in Appendix D.

3-2-2 Segment 37 to 39: Wolf Park Siphon – Station 1183+00 to 1281+30

The Wolf Park Siphon is an alternative project to repairing the canal in its existing location and would replace the Segments 37, 38, and 39 in the Canal Project List. This project would require the construction of a new siphon across Wolf Park and would eliminate 9,830 feet of canal currently experiencing seepage issues. The siphon would be about 1,400 feet long and would be constructed on land that is owned by USBR. The siphon is sized for a 54-inch HDPE pipeline which matches the flow capacity of the existing siphon. The approximate location of the siphon is shown on Sheet 12 of the maps in Appendix A.

This project will remove approximately 320 tons of salt annually that are contributed to the Colorado River Drainage. The 320 tons of salt are not sufficient to provide a cost-effective project that would not include additional funding sources besides the Colorado River Basin Salinity Control Program. If this project can be funded in its entirety with a funding source besides salinity funds, the 320 tons of salt could be used construct a small liner project downstream of the siphon described in Section 3-2-3 below, which is also a priority.

If segments 37 and 39 are constructed, the total cost is $3,254,000. If the Wolf Park siphon is constructed in lieu of 37, 38, and 39, the project is estimated at $911,800.

3-2-3 Segment 40 (portion): Wolf Park Siphon with Segment 40 – Station 1281+30 to 1293+30

With the construction of the Wolf Park Siphon, approximately 320 tons of salt are removed annually. This salt savings could be applied to a small canal lining project using the Colorado River Basin Salinity Control funds to improve water quality and eliminate canal seepage in this area. The funding strategies discussed later in this Plan describe cost effectiveness in the Salinity program and use $60/ton of salt reduction as a target for Salinity projects. 320 tons of salt reduction would allow approximately this level of cost effectiveness. This project would only be viable with the installation of the Wolf Park Siphon from another funding source, such as RCPP funding.

The estimated cost of this project is $503,000. This would only cover the cost of 1,200 feet of new liner in Segment 40.

3-2-4 Segment 15: Garvin Mesa Piping – Station 367+00 to 390+00

The hillside above the canal on Garvin Mesa has been sliding for many years. Landslides in the past have necessitated to piping of 500 feet of the canal in this area using two 60-inch corrugated metal pipes. The hillside above these two pipes continues to move and is damaging the pipes. Geotechnical engineers from USBR have visited the site with the NFWCD manager and have recommend that the pipes be replaced and placed deeper to a location below the landslide. This would create a siphon on the canal. There are two visible landslides in this area. It is currently not known if there are more areas that may begin to slide.

The entire length of the canal through the Garvin Mesa area is approximately 6,500 feet. It has been determined that 2,300 feet should be placed in a siphon. This will clear both of the visible landslides. A detailed geotechnical study should still be completed in this area in order to determine the specific area that needs to be piped, the depth of the pipeline, and how to address the landslide. This Mater Plan report only considers the cost of placing two 63-inch diameter HDPE pipes through this area. The costs to address the hillside will need to be included after a geotechnical investigation is complete. This project will remove 57 tons of salt annually that are contributed to the Colorado River Drainage.

The estimated cost of piping on Garvin Mesa is $1,967,400.

3-2-5 Segment 6: Canal Enclosure at Railroad Tracks – Station 98+73 to 108+73

When the railroad was installed, the natural drainage channel was cut off. This forces all of the runoff from storm events off of the hillside above the canal to flow directly into the canal. As a result, the canal has overtopped several times in this location and has threatened to wash out the roadway and the railroad tracks.

This project will connect onto the existing 6-ft x 6-ft box culvert underneath the railroad tracks and run 1,000 feet of new box culvert to the Hubbard Creek wasteway. A swale will be installed on top of the box culvert to allow storm water to follow along the box culvert to the wasteway. The storm water will then safely be discharged through the wasteway into Hubbard Creek. This project will remove 25 tons of salt annually that are contributed to the Colorado River Drainage.

The estimated cost of this project is $934,600.

3-2-6 Segment 1: Fire Mountain Canal Diversion Structure – Station 2+03

The Fire Mountain Canal diversion structure is in need of modifications. The current configuration of the structure in the river results in extreme amounts of debris accumulation on the trash rack and sediment from the river being diverted into the canal. By modifying the inlet angle on the structure, the debris and sediment can be left in the river. The check structure in the river is also a hazard to those who use the river for recreation.

In 2013, Trout Unlimited hired a river consultant to provide a concept design and cost estimates for improving the diversion structure. This report is included in Appendix F. The construction costs from the report were used to generate the cost estimate for the modification of the diversion structure.

Modifying the diversion structure is estimated to cost $1,929,000.

3-2-7 Supervisory Control and Data Acquisition

This project includes Supervisory Control and Data Acquisition (SCADA) to be installed on major turnouts, wasteways, and flumes. There will be a master monitoring and control station housed at a central location to be determined by NFWCD.

Remote site components include a panel, site enclosure, solar power, and telemetry equipment. Automation of wasteway gate and turnouts could also be done.

SCADA capability will be installed at the following remote sites throughout NFWCD:

- 7 wasteway gates
- Jesse Turnout
- RMWDA East Lateral
- RMWDA Slack Lateral
- RMWDA Patterson Lateral
- 3 Flumes

The estimated cost for this project is $585,000.

3-2-8 Re-Regulating Reservoir – Station 1365+00

With the Fire Mountain Canal being over 33 miles long, it can be difficult to control flows on the lower end. The currently-funded 2015 Salinity project will create a low-head, on-demand system from Leroux Creek to the end of the canal. To make the most from this new on-demand system, a re-regulating reservoir is needed. Currently, if water is not being diverted by the turnouts, it is returned to the river and lost to the canal system. If a re-regulating reservoir were to be constructed, this water could be stored during low demand times and delivered to users during peak demand periods.

A conceptual layout of a re-regulating reservoir is shown near Station 1365+00 on a map included in Appendix H. This location is also shown on Sheet 13 of the Fire Mountain Canal Maps in Appendix A. The property at this site is currently owned by USBR. It is surrounded on three sides by hills, and there currently exists an 11-foot drop in the canal at about Station 1377+00.

For this site to be a re-regulating reservoir, an embankment dam will need to be constructed across the site and the 11-foot drop piped about 500 feet to the reservoir location. This 11-foot drop will allow the outlet of the reservoir to be 11-feet deeper than the inlet and give the reservoir an average depth of 11 feet. Based on a concept layout, the reservoir could hold up to 50 acre-feet of storage.

Most of the users from the reservoir site to the Leroux Creek project have already installed sprinkler irrigation systems and would benefit from this reservoir. This would also make it so that all of the large users on Roger's Mesa that will have water delivered with the new Leroux Creek salinity project could easily transition to a pressurized irrigation system.

There are, however, several issues that would need to be evaluated in further detail that are beyond the scope of this Master Plan in order to determine if a re-regulating reservoir is feasible. Some of these issues are:

- Geotechnical evaluation of the site
- Approval from USBR to use the property
- The feasibility of installing the 500 feet of pipe from the 11-drop to the reservoir site (the canal in this area is already cut about 20 feet through the hillside)
- Connecting the Leroux Creek water rights into the new system. Pressurizing from the proposed reservoir would make it more difficult to place Leroux Creek water in the system
- The cost and pipe size to run the 17,000 feet from the reservoir site to the Leroux Creek salinity project.

It is estimated that the cost of the piping mentioned above would be approximately $8,000,000, in addition to the cost of constructing the reservoir. These piping costs are based on a single 63-inch HDPE pipeline. The flows in this area are approaching the design capacity of a single pipe and may require that two pipes be installed. This cannot be determined until the configuration and elevation of the reservoir are determined in more detail.

The rough-order-of-magnitude cost estimate for the re-regulation reservoir described is $1,500,000. The reservoir is not included in the project priority list at this time. However, it should continue to be studied in order to determine if it is feasible and whether funding would be available to design and construct the project.

3-2-9 Hydroelectric Considerations

Determining hydroelectric power generation along the Fire Mountain Canal is beyond the scope of this Master Plan. However, it is clear that hydropower production is possible and additional feasibility studies are recommended. For example, one potential site to be considered would be the Hubbard Creek wasteway located near Station 108+00.

Hubbard Creek is about 2 miles downstream from the canal diversion structure. The canal from the diversion structure to Hubbard Creek has extra capacity. The wasteway is approximately 50 feet above the river. Water could be diverted into the canal and through the wasteway to potentially generate power and then returned to the river. Detailed investigation into potential hydropower production and a cost pro forma need be done in order to determine if this site is a viable hydroelectric site.

3-3 Colorado River Storage Project Act – Memorandum of Agreement (MOA) Project Priorities

USBR provided a list of projects that have been identified as priorities on the MOA. Verification of the cost and scope of the MOA projects is beyond the scope of this Master Plan. The MOA sections relating to the NFWCD are in Appendix G and are summarized here.

MOA Priority	Item	Contract Cost Estimate	Total Cost Estimate
1	Dam Elevator Repairs	$78,000	$101,000
2	Dam Outlet Works Modification and Inlet Repairs	$6,000,000	$7,800,000
3	Fire Mountain Canal Safety Improvements	$3,214,000	$4,178,000
4	Replace Fire Mountain Canal Diversion Structure	$2,210,000	$2,873,000
5	Planning Study on Long-term Delivery System Improvements	$100,000	$110,000
6	Implementation of Delivery System Optimization Components from Long Term Study (SCADA)	$450,000	$585,000
	Cost Estimate Totals	$11,602,000	$15,062,000

Detailed descriptions of the MOA priority projects are listed in the MOA report in Appendix G.

Priorities 1 and 2 are at the Paonia Reservoir. Due to the current sediment issues at Paonia Reservoir, MOA priority #2 is the top priority for NFWCD for the MOA funding. It is unlikely that funds will be available for other MOA projects until the outlet works at the reservoir are addressed.

Priority 3 is for work along Garvin Mesa. This corresponds to Segment 15 of the Master Plan. The NFWCD manager also stated that the work in Segment 6 at the railroad crossing was also included in the MOA project. No cost estimate or detailed description of work was given for the MOA project so a direct comparison between the MOA project and the projects at Segments 6 and 15 cannot be done.

Priority 4 is for the Fire Mountain Canal diversion structure. This corresponds to Segment 1. No cost estimate or detailed description of work was given for the MOA project so a direct comparison between the MOA project and the project at Segments 1cannot be done.

Priority 5 is for a master plan of projects for the canal. This Master Plan could be used to meet those objectives.

Priority 6 is for the implementation of a SCADA system. This corresponds to Segment SCADA. No cost estimate or detailed description of work was given for the MOA project so a direct comparison cannot be done.

4 – FUNDING PLAN

4-1 Potential Funding Sources

There are both grant and loan opportunities available for consideration as potential funding sources. Those sources include:

- Colorado River Basin Salinity Control Program (Salinity)
- Colorado River Storage Project Act – Memorandum of Agreement (MOA)
- Natural Resource Conservation Service (NRCS) Regional Conservation Partnership Program (RCPP)
- US Bureau of Reclamation WaterSMART
- Colorado Water Conservation Board Grants & Loans

The cost estimates prepared for project improvements in this report included costs for NEPA as it was assumed that most of these funding sources would require that level of environmental clearances. If there are other potential costs associated with a particular funding source, those are mentioned in the description of the funding sources.

4-1-1 Colorado River Basin Salinity Control Program

The Bureau of Reclamation solicits, ranks, and selects Salinity Control Projects based on a competitive process open to the entities within the Upper Colorado River Drainage. Typically, the most critical factor in ranking projects is the cost effectiveness of the project expressed in terms of the annual cost per ton of salt reduction resulting from the project implementation. The USBR will evaluate and provide the estimated annual salt load reduction for a given project. Cooperative agreements are awarded with selected applicants. Projects have typically involved converting unlined canals and ditches to pipelines to reduce seepage that picks up salt and carries it into the Colorado River system.

Although there is no specified cycle for this funding, historically it has been about every 3 years. The most recent cycle closed in July 2015. A funding cycle is referred to as a Funding Opportunity Announcement or "FOA". So the most recent funding cycle is typically referred to as the "2015 FOA". The average cost effectiveness in the most recent FOA was approximately $56 per ton of salt reduction. This is an important factor in creating funding strategies for future projects. $60 per ton or less was the target used as a funding strategy for this report.

The cost effectiveness can be "bought down" by using non-USBR funds on the project. When this happens, the annual cost per ton of salt reduction is calculated only on the Salinity Control Program funding.

This funding requires that habitat replacement be part of any project. Typically, 5% of estimated construction costs is required to be assumed for habitat replacement. Those costs will be added into any project considered for this funding.

4-1-2 Colorado River Storage Project Act – Memorandum of Agreement

Under the CRSP-MOA, hydropower revenues generated from CRSP projects can be used by the State of Colorado to further the purposes of the CRSP Act (1956) by implementing improvements to CRSP facilities as recommended by the State. These improvements can them be approved and implemented by the USBR. Within the NFWCD, the Fire Mountain Canal and the Paonia Reservoir are CRSP projects and could qualify for this funding.

4-1-3 Natural Resource Conservation Service Regional Conservation Partnership Program

RCPP promotes coordination between NRCS and its partners to deliver conservation assistance to producers and landowners. Through RCPP, NRCS and its partners help producers install and maintain conservation activities in selected project areas. Partners leverage RCPP funding in project areas and report on the benefits achieved. The application is made annually and is a 2-part process.

NFWCD is a partner in the Lower Gunnison Project (LGP) which applied for and received $8 Million through RCPP in FY 2015. Approximately $1,000,000 is available for projects within the NFWCD. The LGP will also make application in FY 2017.

4-1-4 US Bureau of Reclamation WaterSMART

USBR established the WaterSMART program in February 2010. WaterSMART allows USBR to work with States, Tribes, local governments, and non-governmental organizations to pursue a sustainable water supply for the Nation by establishing a framework to provide federal leadership and assistance on the efficient use of water, integrating water and energy policies to support the sustainable use of all natural resources, and coordinating the water conservation activities of the various Interior offices.

Water SMART grant opportunities are available through an application process on an annual basis. Typically projects which can show significant water and energy conservation receive higher rankings. Grants received are a cost share by USBR of up to 50% with a total award of no more than $1M.

4-1-5 Colorado Water Conservation Board (CWCB) Water Supply Reserve Account (WRSA) Grant

The WSRA Program provides grants and loans to assist Colorado water users in addressing their critical water supply issues and interests. The funds help eligible entities complete water activities, which may include competitive grants for structural water projects or activities. Requests for funds from the Account must be included in the Basin Implementation Plan and must be approved by the Gunnison Basin Roundtable. The Roundtable meets monthly. The request is then forwarded to the CWCB to evaluate and make final funding decisions.

Other loan and grant opportunities exist with CWCB.

4-2 Funding Strategies and Project Priorities

The following factors come into play when creating the Project Funding and Implementation Schedule:

- NFWCD and FMCRC opinions
- NFWCD and FMCRC willingness to implement proposed project(s)
- Matching appropriate funding source(s) with proposed project
- Timing of funding sources associated with proposed project
- Strategic combination of funding sources to maximize funding opportunities
- Likelihood of successfully funding a proposed project

Neither the NFWCD and FMCRC have expressed a desire to take on debt for implementation of projects. CWCB Loans have been considered, but not as the first option in creating funding strategies.

Where projects have been identified by USBR as MOA projects, the preference by NFWCD is to use those funds to complete the projects. However, the exact timing of many of those projects is unknown. It may be necessary to seek other grant opportunities such as NRCS-RCPP in order to complete these projects in the time frames identified in this Plan.

Project priorities were established after consideration of two main factors:

1. NFWCD and FMCRC input
2. Highest potential for receiving grant funding

With the low amount of salt available on the majority of the canal for Salinity funding, there are no projects that can currently standalone for Salinity funding without the addition of funding from another source. This is based on the $60/ton of salt for project costs. The Wolf Park area is the only area that can generate enough salt reduction to combine the proposed RCPP siphon funding with a reasonable amount of new canal liner funded as a salinity project. The other projects save a minimal amount of salt and could be investigated at the time they are funded to determine if a there is an advantage to a salinity funding application.

Several of the projects identified in the project priority list can be funded by both RCPP or MOA funding. The MOA funding for the NFWCD is currently tied up in repairing the outlet structure at the reservoir. It is unknown when there will be MOA funding available for other projects listed. RCPP funding is based on competitive grant applications and is therefore not guaranteed.

The projects identified in the High Priority Project list are needed now and so the NFWCD will take whichever funding is available first to complete the project. It is estimated that it may take 10 years to complete those projects listed. When those projects are completed the master planned projects will be re-evaluated.

4-3 Project Funding & Implementation Schedule

The funding plan for the Fire Mountain Canal is as follows:

4-3-1 Paonia Reservoir Dam Outlet

This project is currently being worked on by USBR and is the top project for MOA funding for NFWCD. The design has not yet been completed.

4-3-2 Segment 47: Leroux Creek to End of Canal – Station 1537+70 to 1758+95

This project has been selected to receive funding from the 2015 Colorado River Basin Salinity Control Program and from 2015 NRCS-RCPP funding. In addition, NRWCD and FMCRC have committed local funding to assist in the project. The project is estimated to cost $4,465,460.

4-3-3 Segment 37 to 39: Wolf Park Siphon – Station 1183+00 to 1281+30

The recommendation is to pursue the $911,800 for the Wolf Park Siphon in the 2017 RCPP application.

4-3-4 Segment 6: Canal Enclosure at Railroad Tracks – Station 98+73 to 108+73

The recommendation is to apply for 2017 RCPP funding along with the Wolf Park siphon. It is also recommended to continue to pursue MOA and to construct the $934,600 project with whichever funding is available first.

4-3-5 Segment 40 (portion): Wolf Park Siphon with Segment 40 – Station 1281+30 to 1293+30

If the Wolf Park Siphon is funded in the 2017 RCPP application, we recommend applying for a $503,000 salinity project to construct canal liner downstream of the siphon. Combining this project with the siphon gives a $60/ton of salt removed based on 350 tons of salt.

4-3-6 Segment 15: Garvin Mesa Piping – Station 367+00 to 390+00

The recommendation for this project is to apply for RCPP funding in 2018 after the Wolf Park siphon is funded. It is also recommended to continue to pursue MOA and to construct the $1,967,000 with whichever funding is available first.

4-3-7 Segment 1: Fire Mountain Canal Diversion Structure – Station 2+03

The recommendation for this project is to apply for RCPP funding in 2019 after the other RCPP projects have been funded. It is also recommended to continue to pursue MOA funds and to construct the $1,929,000 diversion structure with MOA funds if the timing works for those funds.

4-3-8 Supervisory Control and Data Acquisition

It is recommended to add the SCADA system components to future RCPP applications as deemed feasible. SCADA can also be funded with USBR's WaterSMART Field Services program which has a 50% match requirement.

4-3-9 Dam Elevator Repairs

It is recommended that the funding for the elevator repairs be through the MOA program.

4-3-10 CWCB Loans and USBR WaterSMART Grants

As stated before, much of the Fire Mountain Canal will be very difficult to fund with 100% grants. The cost effectiveness is very high for consideration in the Salinity Reduction Program in the foreseeable future and it is difficult to compete for funding in the RCPP program. All of the canal projects will fit into the USBR WaterSMART program. This program requires a minimum of a 50% match. Loans, and potentially grants, from the CWCB would need to be obtained to match the 50% WaterSMART grant. The funding package for a $2 million canal segment might resemble the following:

$1,000,000 WaterSMART Grant
$500,000 CWCB Grant
$500,000 CWCB Loan Match
$2,000,000 Total Project

It is recommended that this funding strategy be implemented as soon as possible for projects that do not meet MOA, salinity, or RCPP funding parameters. It is also recommended that NFWCD begin with projects at the lower end of the canal where the canal is elevated and has seepage issues and then work toward the river diversion structure in $2,000,000 funding segments.

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

APPENDIX F

APPENDIX G

APPENDIX H

APPENDIX I

APPENDIX J

North Fork of the Gunnison River Irrigation Management Plan

Prepared for:

North Fork Water Conservancy District

November 2017

Prepared by: J U B ENGINEERS, Inc.

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Table of Contents

List of Appendices

List of Tables

List of Figures

1.0 EXECUTIVE SUMMARY

The North Fork of the Gunnison River (North Fork) is a major tributary to the Gunnison River in Western Colorado. It is a river of roughly 35.5 miles in length, beginning at the confluence of Muddy Creek and Anthracite Creek, both of whose origins begin in the West Elk Mountains of Colorado. The North Fork ends roughly 8 miles southwest of Hotchkiss, CO at its confluence with the Gunnison River. The surrounding terrain is highly variable with a combination of river corridor lowlands and fertile mesas. The North Fork traverses the valley such that irrigation and crop cultivation occur on both sides of the river. The terrain and river location within the valley require multiple diversions to serve all of the irrigable lands. As such, there are approximately 12 agricultural river diversions along the North Fork, each of varying scale and varying impact to the overall river system.

The North Fork Valley (the Valley or Valley) contains fertile soils, and experiences a climate conducive to widely varying agricultural production. Agriculture would not be practical in the Valley without irrigation. Farming and ranching provide a major economic driver to the region, and are important to the local and regional culture and economy. As the primary beneficial consumptive users of water from the North Fork, it is important that agricultural irrigators continue their work to improve the river system as a whole while protecting their historic water rights through beneficial consumptive use. Agriculture will remain an important part of the Valley for generations to come.

The purpose of this irrigation management plan is twofold. The primary objective is to identify the near river infrastructure needs of agricultural users who divert water directly from the North Fork and provide recommendations for moving forward with improvements within the river corridor that have multiple benefits. Secondarily, this plan seeks to educate the agricultural water users of their strong position on the river, and to bring them into the process of stream management planning and emphasize the following ideas:

- Non-consumptive beneficial uses may also be realized without damage to existing agricultural water rights
- Beneficial and meaningful infrastructure improvements may be achieved by working with non-consumptive water use interests on the river.
- Infrastructure improvements are a means of protecting agricultural water rights.

Irrigator needs were identified in two ways: through interviews with ditch board members and water users and through a brief river infrastructure assessment focused primarily on the diversion infrastructure. Interviews have provided a wealth of local knowledge and experience to help promote or reject potential improvement opportunities. The interview process also allowed for one on one conversations regarding river infrastructure improvements and the "big picture" issues associated with the North Fork and its place in the larger Colorado River basin. The river infrastructure assessment contributed ideas for improvements regarding infrastructure, beginning in-stream and ending near the measuring device utilized by the Colorado Division of Water Resources (CDWR) division 4 staff for diversion measurement.

Preliminary cost estimates were provided for potential improvements to provide a sense of scale and to help identify which projects may be fundable. Once practical potential improvements were identified, they were ranked with a relative priority scale.

This report presents some of the findings (water rights, river system interaction, etc.). However, this report does not seek to report on actual river administration. Administration of water rights along the North Fork is the responsibility of the CDWR Division 4. This report is intended to assist decision makers in moving forward with agricultural water resources projects in the Valley.

2.0 EXISTING CONDITIONS ASSESSMENT

This existing conditions assessment was developed through a combination of agricultural user interviews and a river infrastructure assessment, both conducted by J-U-B Engineers, Inc. The intent of the assessment was to analyze the infrastructure and needs of the agricultural diversions between the confluence of Muddy Creek and Anthracite Creek to the confluence with the Gunnison River.

To assist in long-term planning and to assist with further projects associated with stream management planning we have established a series of reaches along the river. These reaches are based on locations of larger diversions. These may be used when examining infrastructure needs, looking at environmental concerns on the river, discussions of river health, etc. Table 2.0.1 summarizes the locations of the established reaches. Note that stationing was established with 0+00 at the confluence of Muddy Creek and Anthracite Creek. Appendix A contains a mapbook showing diversion locations, reach divisions, and river stationing.

Table 2.0.1. Summary of Established Reaches

Reach	Description	Starting Sta.	Ending Sta.	Length (mi.)	Diversions within Reach
1	Upper North Fork	0+00	376+35	7.13	N/A
2	Fire Mountain to Stewart	376+35	608+87	4.40	Fire Mountain Canal, Carrol Ditch, Lennox Ditch Pump
3	Stewart to N.F. Farmer's	608+87	719+59	2.10	Stewart Ditch
4	N.F. Farmer's to Paonia	719+59	813+33	1.78	North Fork Farmer's Ditch, Feldman Ditch
5	Paonia to Short	813+33	1060+76	4.69	Paonia Ditch, Monitor Ditch, Shepherd and Wilmott Ditch
6	Short to Vandeford	1060+76	1296+73	4.47	Short Ditch
7	Vandeford to Smith and McKnight	1296+73	1385+65	1.68	Vandeford
8	Lower North Fork	1385+65	1873+55	9.24	Smith and McKnight

The Fire Mountain Canal in Reach 2 is the largest diversion (by total volume diverted) in the North Fork, with an average annual diversion of over 45,000 ac-ft. This diversion, however, is largely supplemented by Paonia Reservoir. The other North Fork diversions do not have access to reservoir water. However, they benefit significantly from increased natural flow made available for diversion in the North Fork because of Paonia Reservoir. Figure 2.0.1 summarizes the agricultural diversion volumes within each reach along the North Fork. This figure displays the average annual diversion from the years 2007 to 2016 according to the

Colorado Department of Natural Resources (DNR). Note that data for the Carrol Ditch was only available for 2015 to 2016.

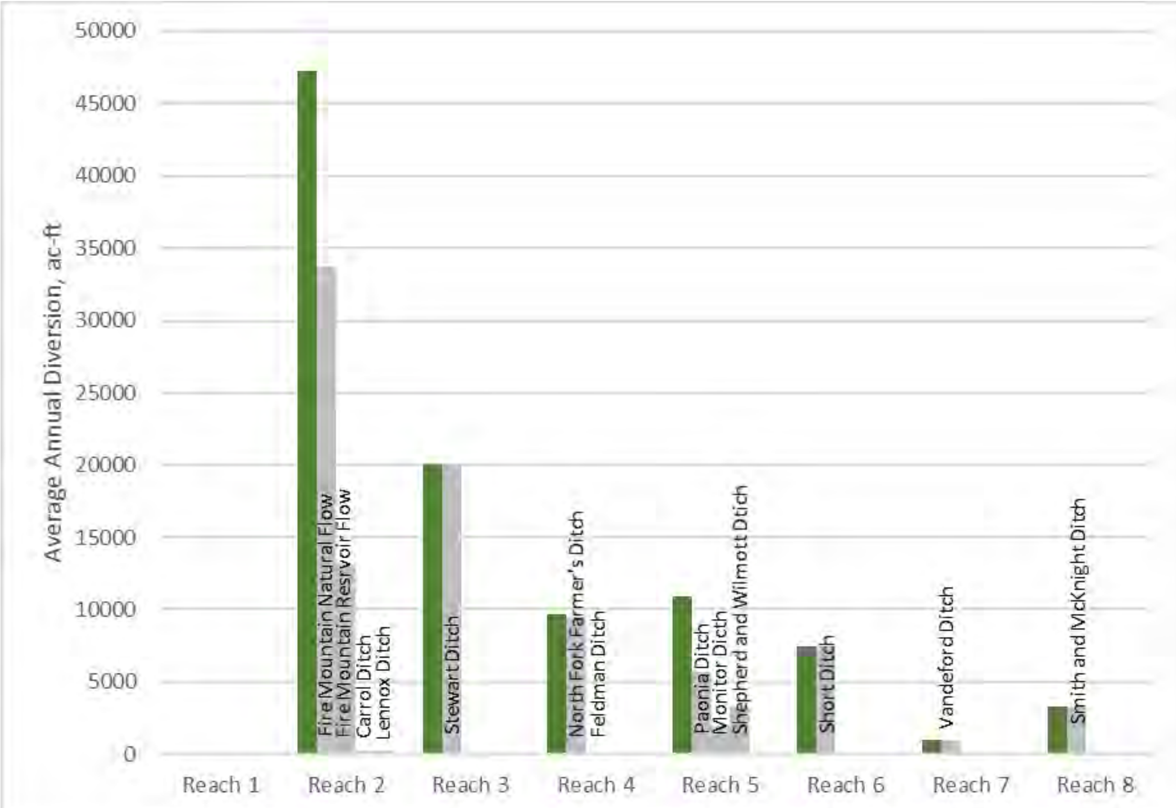

Figure 2.0.1. 2007 to 2016 Average Annual Diversion Volumes by reach Along the North Fork

The efficiency of an irrigation diversion (system efficiency) is the measure of diverted water consumptively used for crops as a percentage of the total water diverted for irrigation. Ideally, efficiency would be 100%, but a variety of factors prevents this from happening even in the most efficient systems. System efficiency is a product of both conveyance efficiency and application efficiency, however, with the data available it is difficult to distinguish where the inefficiencies lie within the total system.

Data for crop consumptive use for the irrigated lands was borrowed from the "Jessie Ditch Irrigation Demand Study" completed by Olsson Associates in May 2016. Using the ASCE Standardized Penman-Monteith Method, the study found the historical consumptive use for Alfalfa to be 34.7 in/ac while the consumptive use for grass pasture is 33.1 in/ac. The spatial proximity and climactic similarity of the Jessie Ditch service area makes this data suitable for use within this report. Consumptive use by other crops was not explored in the Jessie Ditch Irrigation Demand Study, so the grass pasture consumptive use requirement was assumed for all irrigable acreage on each diversion. This should serve as a conservative estimate as corn, small grains, and orchards often require less water than grass pasture.

By utilizing data on irrigated acreage and annual diversion amounts acquired from the Colorado Division Support System (CDSS) with the crop consumptive use data, system efficiencies were determined for each diversion. An overview of system efficiency is provided with each ditch overview in the ensuing sections. It is important to emphasize that low system efficiency is not inherently an indicator of negative management. The diversions along the North Fork have been managed in conjunction with each other for decades in a manner that decreases conflict amongst users and provides sufficient water throughout the irrigation season. Aged infrastructure often requires higher diversion in order to deliver sufficient water to each field.

2.1 Reach 1 Overview

Reach 1, known as the Upper North Fork begins at the confluence of Muddy Creek and Anthracite Creek and travels 7.13 miles to immediately before the Fire Mountain Canal Diversion. While there are no diversions in this reach, flows are largely impacted by the releases from Paonia Reservoir to the Fire Mt. Canal diversion. For this reason, relatively higher flows are often maintained in Reach 1 late into the irrigation season.

2.2 Reach 2 Overview

Reach 2 begins with the Fire Mountain Canal Diversion and ends immediately prior to the Stewart Ditch Diversion. Within this 4.4 mile stretch there are two other small diverters (the Carrol Ditch and the Lennox Ditch Pump). The Fire Mountain Canal is the largest diverter on the North Fork, and thus Reach 2 has substantially less flow than Reach 1 during the irrigation season. Figure 2.2.1 summarizes the average annual diversions from 2007 to 2016 for all reaches, with a focus on the diversions from Reach 2.

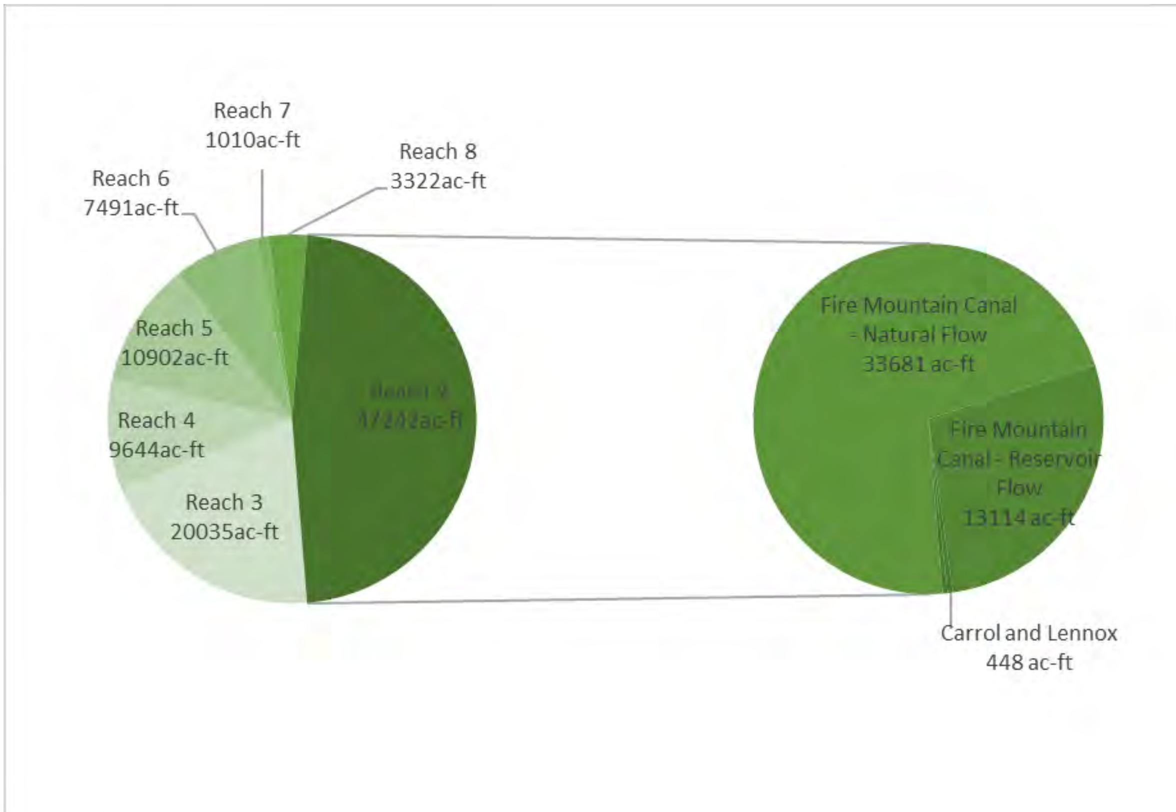

Figure 2.2.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 2

2.2.1 Fire Mountain Canal

Canal Overview –

The Fire Mountain Canal Diversion is located in Reach 2 at 376+35, just below the Town of Somerset, CO. The ditch traverses the Northern edge of the Valley irrigating multiple areas along the way. The bulk of the Fire Mountain Canal's water is used to supply irrigators on Rogers Mesa. On its way to Rogers Mesa, the Fire Mountain Canal receives inflows from multiple water sources including Terror Creek and Leroux Creek. Figure 2.2.1.1 provides the 2007 to 2016 average diversion statistics for the Fire Mountain Canal. A large portion of this water, particularly in mid-to-late irrigation season, is reservoir water from Paonia Reservoir.

It is important to note that the 10-year average diversions for the Fire Mt. canal during the months of May, June and July are relatively uniform. The month of August shows a slightly decreased average diversion, however the decrease of average diversion in August can be almost entirely accounted for by August of 2012 in which only 1,045 ac-ft was diverted. The relatively constant diversion throughout the season represents a constant demand across the irrigation season and does not represent a demand curve that is a function of crop demand.

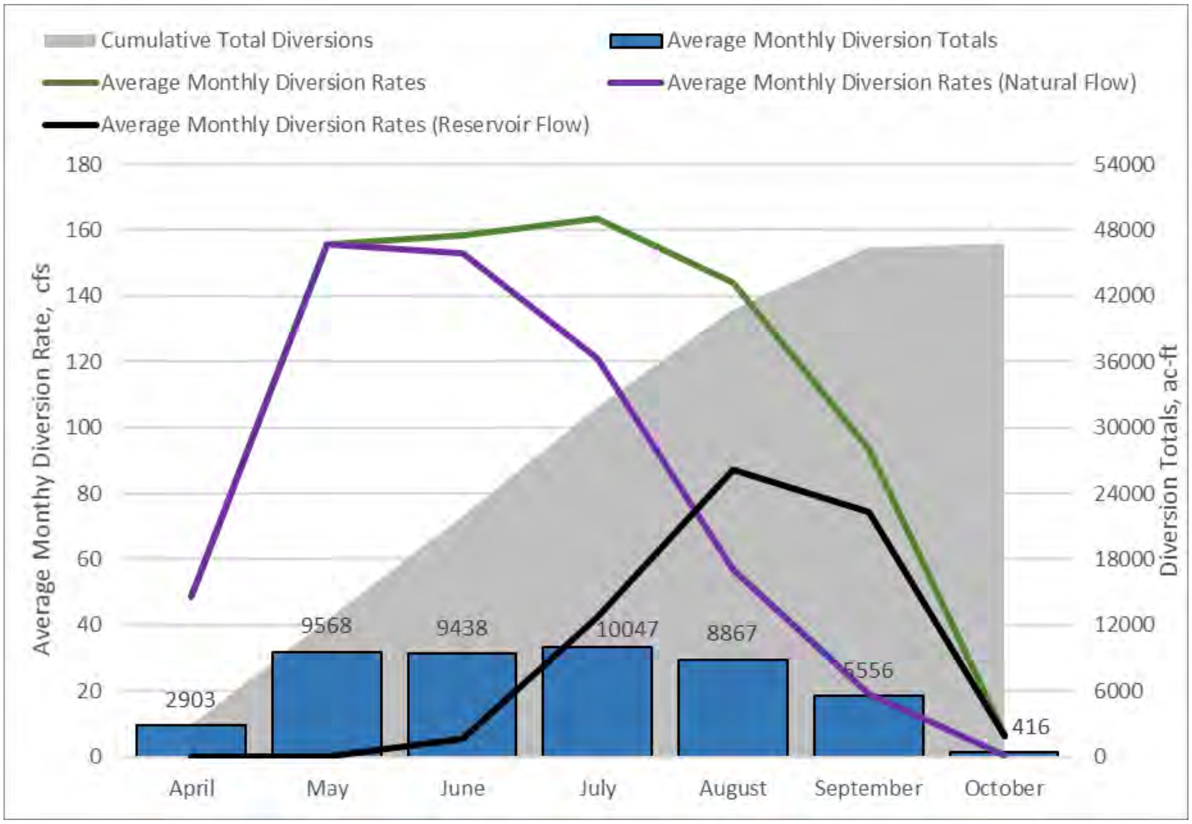

Figure 2.2.1.1. 2007 to 2016 Average Diversion Statistics for Fire Mountain Canal from the North Fork

CDSS reports that the Fire Mountain Canal provides irrigation water to 5,632 acres. Approximately 72% of the irrigated land is used to cultivate grass pasture, with substantial acreage used for alfalfa, and fruit orchards. Small grains and corn are also cultivated within the service area. Using the methods described in Section 2.0, the efficiency was calculated as 24%. Note that this figure does not account for water diverted from other water sources (such as Terror and Leroux Creek). Accounting for these additional sources would decrease overall efficiency. Figure 2.2.1.2 provides a visual breakdown for the calculated efficiency of the Fire Mountain Canal.

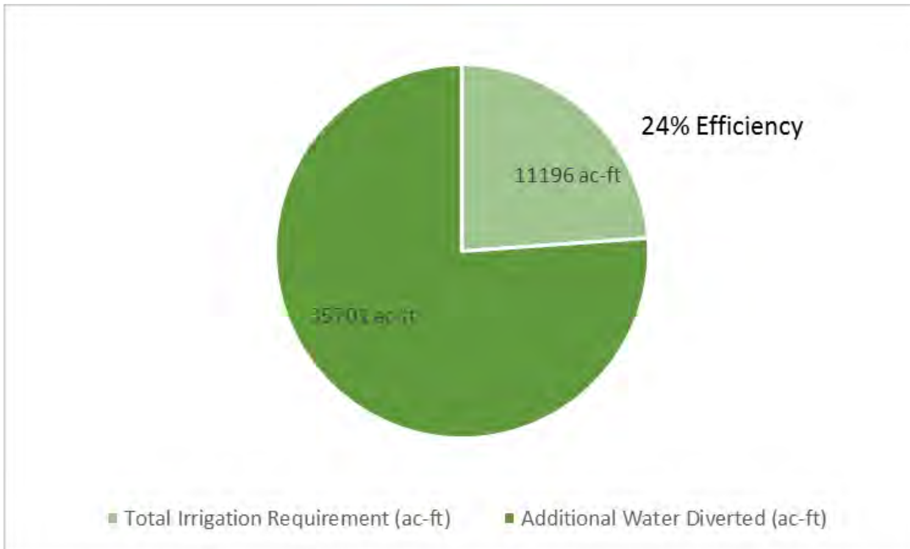

Figure 2.2.1.2. Calculated System Efficiency for the Fire Mountain Canal, excluding Terror and Leroux Creek Inflows

Brief Diversion Description –

The Fire Mountain Canal Diversion consists of a concrete wall that spans the entire width of the North Fork. The downstream side of the wall is backfilled with large boulders that gradually slope to the natural river bottom. Figure 2.2.1.3 shows a portion of the concrete wall with the boulder back-fill.

Figure 2.2.1.3. Portion of Concrete Wall with Boulder Backfill

There is a large concrete intake structure on the North side of the river. Flow into the canal is managed by a large radial gate. Once through the radial gate, water enters a stilling pool and then is immediately siphoned under the highway into the Fire Mountain Canal. The front of the intake structure consists of a concrete headwall and large trash rack of vertical steel bars. Recently, a skimming boom was placed upstream of the headwall to redirect large debris away from the structure and prevent it from clogging the trash rack. Figure 2.2.1.4 shows the front of the intake structure, including the trash rack and skimming boom. Figure 2.2.1.5 shows the radial gate along with a steel plate which can be used to prevent water entry into the canal.

Figure 2.2.1.4. Fire Mountain Canal Intake Structure

Figure 2.2.1.5. Radial Gate and Steel Stop Plate within Fire Mountain Canal Intake Structure

Structural Integrity and Diversion Functionality –

The Fire Mountain Canal diversion appears to be both structurally sound and functional. The concrete diversion wall is in good repair and is well supported by the boulder backfill. The river channel in the immediate vicinity of the diversion is well established and unlikely to meander. There appears to be minimal risk of flanking around the diversion wall, allowing the continual supply of water to the intake structure. The intake structure appears to be in good repair. The recent addition of the skimming boom will likely decrease maintenance requirements at the diversion during the irrigation season.

Ability to Divert Appropriate Range of Flows –

The diversion is able to divert a wide range of flows, as evidenced by both diversion records and physical inspection. The concrete diversion wall maintains a sufficient water surface elevation in the river such that water may always be supplied to the intake structure. The intake itself is adequately sized to take the full water right.

Diversion Issues that Affect River Function –

The diversion segregates the waters upstream of the concrete wall with those downstream of the wall. This likely makes fish passage more difficult; however, the boulder backfill may act as somewhat of a fish ladder. The boulder backfill helps dissipate the energy of the river to help maintain channel integrity. River energy is kept parallel to the banks by the diversion, assisting in maintaining channel integrity.

Diversion Issues that Affect Recreational Users –

At low flows the diversion blocks river passage for recreational users, as seen in Figure 2.2.1.3. At high flows, the diversion likely creates rapids while allowing boat passage. The skimming boom has likely provided safety to recreationalists, as it assists in keeping watercraft within the river channel. The banks in the vicinity of the diversion are steep and likely make it difficult to remove water craft from the river. Boat passage through or around the diversion may make recreation in the area easier.

Recommendations –

1. <u>Boat Passage</u>: With augmented flows during the latter portion of the irrigation season, the river upstream of the Fire Mountain Canal diversion is likely heavily used for watercraft. Adding boat passage through the diversion or a semi-maintained overland passage around the diversion may improve safety for recreationalists.

Preliminary Cost Estimates –

1. <u>Boat Passage</u> - $25,000 to $50,000

2.2.2 Carrol Ditch

Ditch Overview –

The Carrol Ditch Diversion is located in Reach 2 at 429+38, roughly one mile downstream of the Fire Mountain Canal Diversion. The ditch irrigates the river bottom in the immediate vicinity where a single landowner cultivates hay. The infrastructure is minimally disruptive to the river due to the small diversion rate and water right. Figure 2.2.2.1 provides the 2015 to 2016 average diversion statistics for the Carrol Ditch.

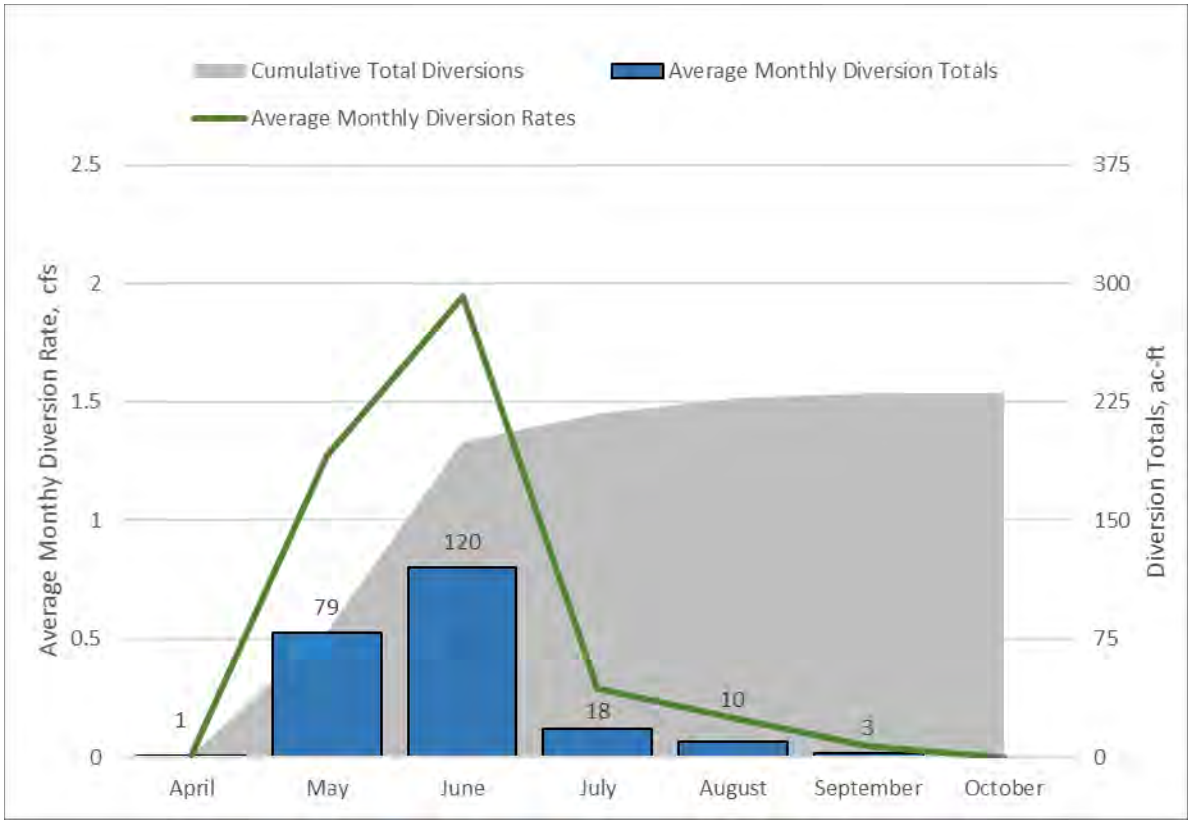

Figure 2.2.2.1. 2015 to 2016 Average Diversion Statistics for the Carrol Ditch

CDSS did not provide an estimate for irrigated lands served by the Carrol Ditch, so an efficiency was not calculated. The amount of water diverted by the Carrol Ditch is small relative to most diversions on the North Fork, so any efficiency improvements will likely represent a small impact on the overall river system.

Brief Diversion Description –

The Carrol Ditch Diversion consists of a small diversion channel adjacent to the principal river channel of the North Fork. Approximately 180 feet from the start of the diversion channel is a small headgate utilized to administer water into the Carrol Ditch. The diversion channel reconnects with the principal river approximately 200 feet downstream of the original diversion.

The Carrol Ditch diversion is entirely dependent on river level for its diversion as no artificial structure is in place to raise the level of the river. This is reflected in the data as well. Figure 2.2.2.2 displays the entrance to the diversion channel from the principal river channel. Figure 2.2.2.3 shows the ditch headgate from the entrance of the diversion channel.

Figure 2.2.2.2. Entrance to Diversion Channel from Principal River Channel

Figure 2.2.2.3. Ditch Headgate from Entrance of Diversion Channel

Structural Integrity and Diversion Functionality –

From a structural standpoint, there is minimal concern with the Carrol Ditch inlet. As a simple headgate, regular maintenance and occasional replacement may be required.

Diversion functionality is likely a seasonal issue. With no structure in the river to raise water levels, there are likely times when the river cannot access the diversion channel, meaning no water can be supplied to the Carrol Ditch. Additionally, the low-velocity flow through the channel makes it ideal for sediment deposition. Semi-regular dredging of the diversion channel is necessary to maintain use of the water right.

Ability to Divert Appropriate Range of Flows –

The simple design of the Carrol Ditch inlet structure easily provides the ditch its water right (0.625 cfs). This is, however predicated on the ability of the diversion channel to take water from the North Fork. The Carrol Ditch currently has no ability to maintain water surface elevation in the river at the point of diversion, so the ability to divert water year-round is limited during low flows.

Diversion Issues that Affect River Function –

The current configuration of the Carrol Ditch diversion has a minimal impact on river function. The diversion amount is small relative to the other irrigators, and excess diversions are re-introduced to the river soon after the initial water diversion.

Diversion Issues that Affect Recreational Users –

The current Carrol Ditch layout creates no river impedance for recreational users and should cause minimal or no issues. In fact most recreational users would likely pass by without noticing that the Carrol Ditch existed.

Recommendations –

1. <u>Grouted Boulder U-Weir</u>: An in-stream grouted boulder U-weir would ensure that there is adequate water surface elevation for the Carrol Ditch to be able to divert flows throughout the season. This type of infrastructure would likely also need to create significant recreation, environmental or other benefit to justify the costs of creating an in-stream structure for such a small water right. It should be noted that the single user of the Carrol Ditch at this time finds the infrastructure adequate for the needs of the irrigation taking place. However, if significant non-consumptive benefit could be realized by in-stream work at this location, incorporating the diversion would be necessary and may aid in permitting.

Preliminary Cost Estimates –

1. <u>Grouted Boulder U-Weir</u> – N/A, costs far exceed benefits at this time.

2.2.3 Lennox Ditch Pump

Ditch Overview –

The Lennox Diversion is located in Reach 2 at 495+12. This is approximately 1.25 miles downstream of the Fire Mountain Canal. Historically there was a physical ditch; however, the diversion now supplies water to a pool immediately adjacent to the river channel where a pump is utilized to divert water. The Lennox supplies a single landowner who grows Alfalfa for a ranching operation. Figure 2.2.3.1 provides the 2007 to 2016 average diversion statistics for the Lennox Ditch.

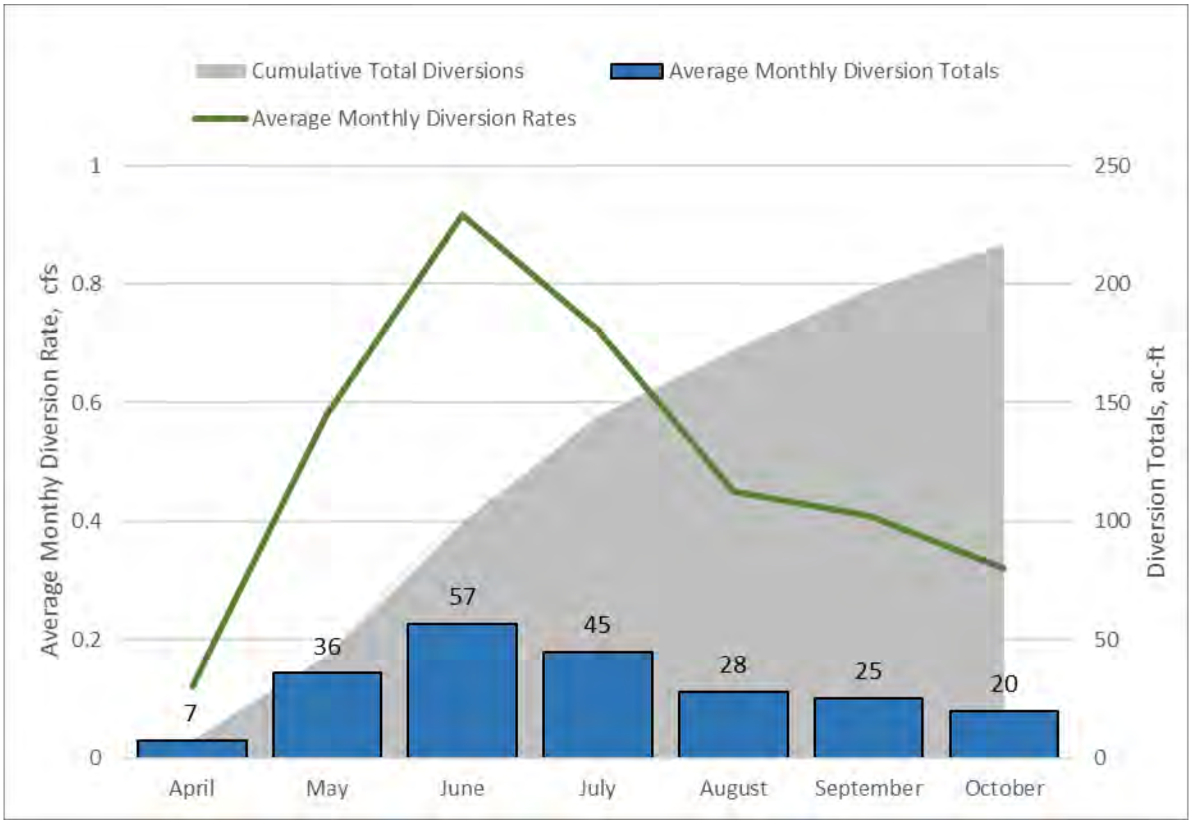

Figure 2.2.3.1. 2007 to 2016 Average Diversion Statistics for the Lennox Ditch

As would be expected with sprinkler irrigation and no conveyance losses, the system efficiency of the Lennox diversion is substantially higher than all other diversions on the North Fork. CDSS reports that a total acreage of 49.13 acres is served by the Lennox, and reports the acreage as grass pasture. With this in mind, system efficiency for the Lennox is calculated as 62%. Figure 2.2.3.2 illustrates the system efficiency of the Lennox Ditch.

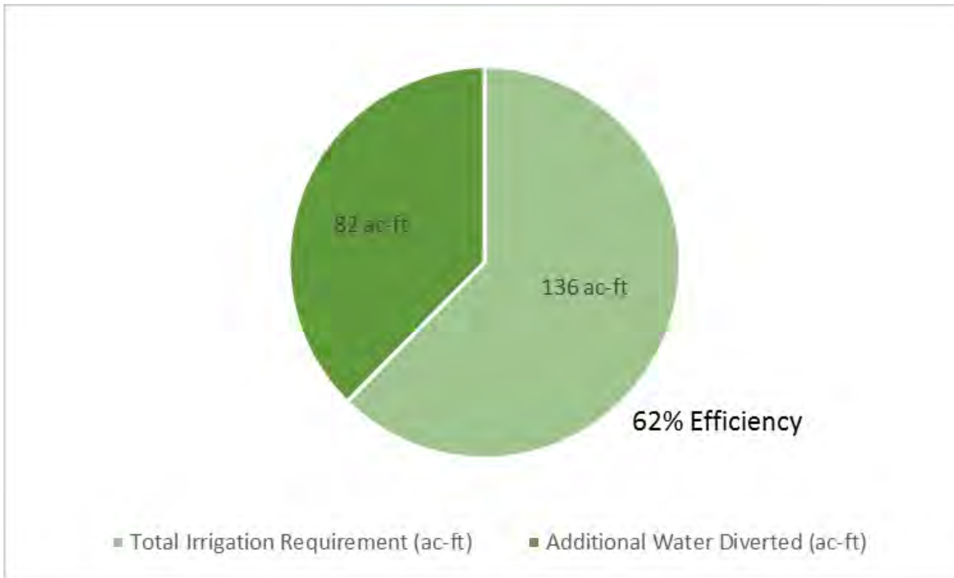

Figure 2.2.3.2. Calculated System Efficiency for the Lennox Ditch

Brief Diversion Description –

The Lennox "Ditch" provides irrigation water to a single landowner with multiple parcels both near the river and on the neighboring mesa via pressurized sprinkler irrigation. The diversion consists of a submerged boulder weir to maintain water surface elevation in a small pool adjacent to the river channel. The pump system suction hose is placed in the pool to extract water from the river. Figure 2.2.3.3 shows the river diversion with the manmade pool. Figure 2.2.3.4 displays the pump system that is used to convey the irrigation water.

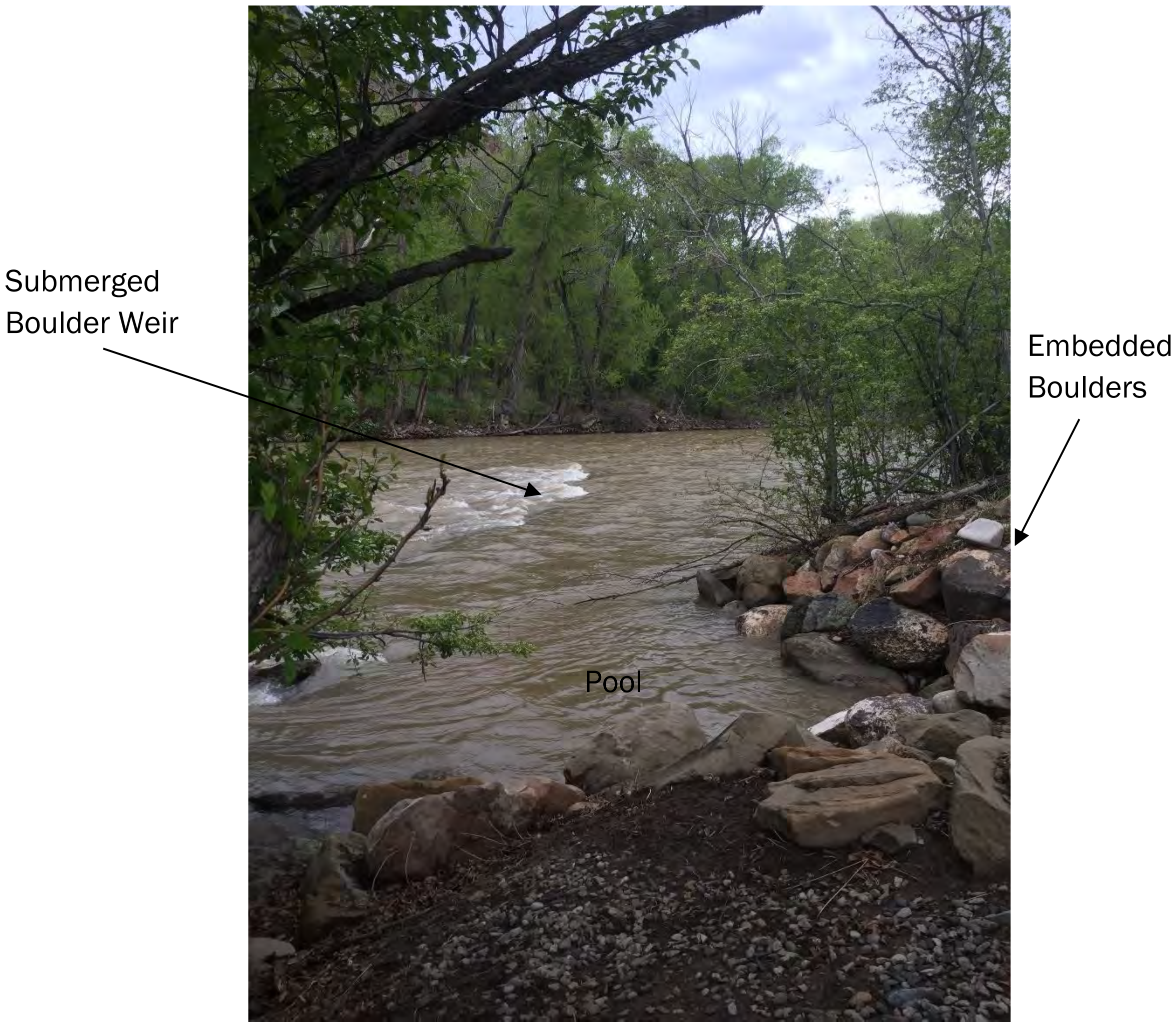

Figure 2.2.3.3. Lennox River Diversion with Pool

Figure 2.2.3.4 Lennox Ditch Pump System to Convey Irrigation Water

Structural Integrity and Diversion Functionality –

The pool structure is maintained by boulders embedded into the river bank, and is out of alignment with the primary flow path. The submerged boulder weir appears to be successfully directing the energy of the flow back toward the center of the river channel, making erosion of the pool unlikely during normal river conditions.

The diversion remains functional as long as there is adequate depth in the pool to fully submerge the pump suction hose and filter. Agricultural interviews revealed that there is an annual history of sediment build up that must be manually cleared.

Ability to Divert Appropriate Range of Flows –

The submerged boulder weir appears to keep to the water an appropriate level so that the pool remains full year round. This allows for the pumps to take the appropriate quantity of water at any time.

Diversion Issues that Affect River Function –

All in-stream diversions slightly effect the water surface profile of the river; however, the size of this diversion provides a minimal and highly localized effect. The weir does not span the entirety of the river channel, which helps maintain river function.

Diversion Issues that Affect Recreational Users –

Riffles are created by the submerged boulder weir; however, since it does not span the width of the entire river, passage through this segment of river is likely unimpaired for recreational users.

Recommendations –

There appear to be no major issues with this diversion or the river in the immediate vicinity. Time will tell if the submerged weir is structurally sound and will continue to perform its function. No recommendations are made at this time.

Preliminary Cost Estimate –

N/A

2.3 Reach 3 Overview

Reach 3 begins with the Stewart Ditch Diversion and ends just before the North Fork Farmer's Ditch. Reach 3 totals 2.1 miles in length and is located downstream of Bowie, CO but before Paonia, CO. The Stewart Ditch, which is the second largest diverter on the North Fork, is the sole diverter in Reach 3. Figure 2.3.1 below shows the average annual diversions for each reach on the North Fork, with focus given to Reach 3.

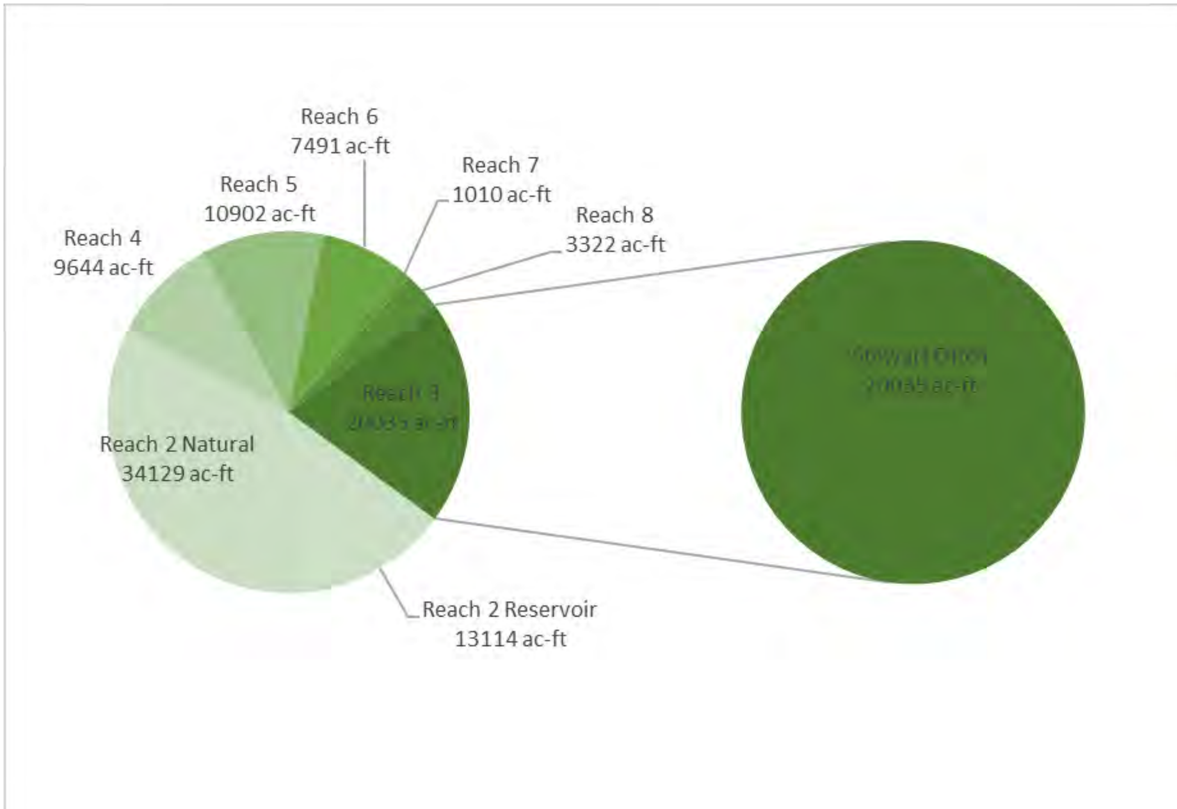

Figure 2.3.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 3

2.3.1 Stewart Ditch

Ditch Overview –

The Stewart Ditch Diversion is located in Reach 3 at 608+87, just downstream of Bowie, CO. The ditch supplies water to the south of the river to river-bottom fields upstream of Paonia, CO and elevated mesas between Hochkiss, CO and Paonia, CO. Figure 2.3.1.1 illustrates the average diversion statistics from 2007 to 2016 for the Stewart Ditch.

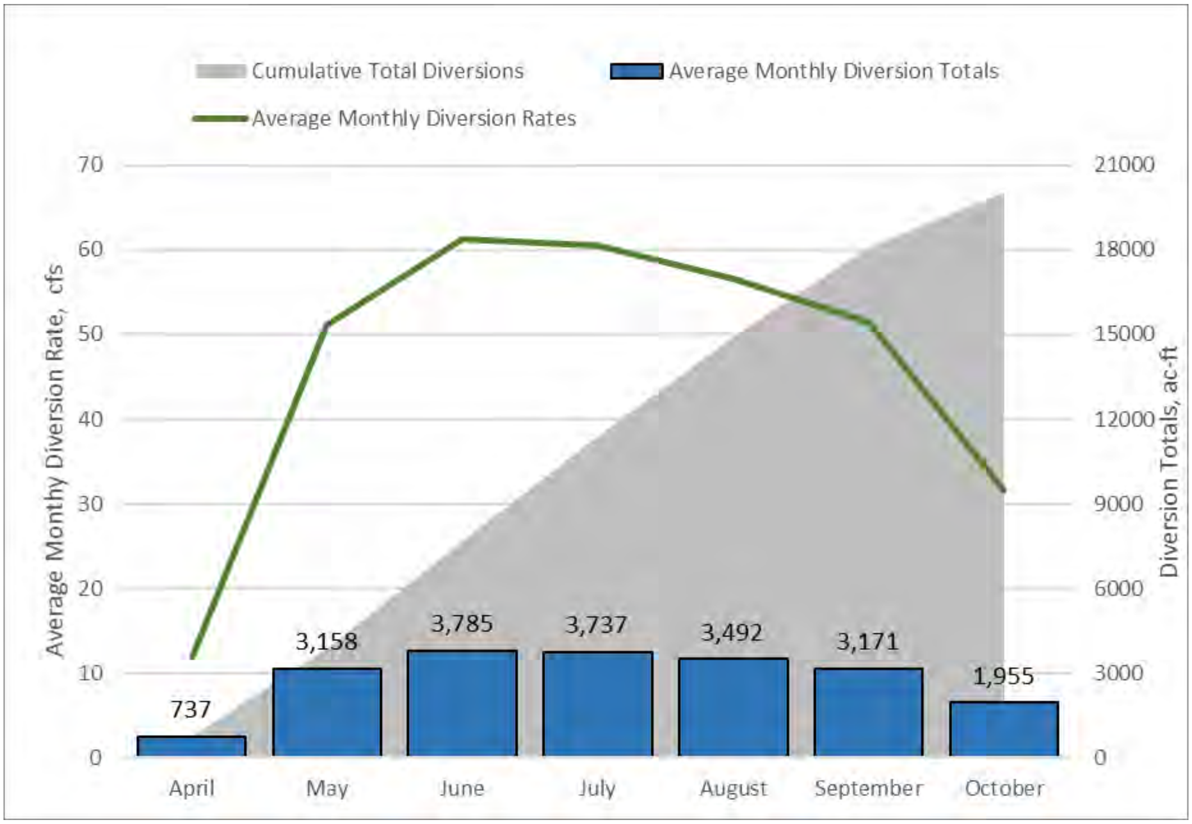

Figure 2.3.1.1. 2007 to 2016 Average Diversion Statistics for the Stewart Ditch

State records show that the Stewart Ditch provides irrigation water to 2743.8 acres. The records indicate that nearly 95% of the acreage is used to cultivate grass pasture, with the remaining acreage growing alfalfa and fruit orchards. The annual water requirement for consumptive use for the Stewart Ditch was calculated to be 7172.2 ac-ft, placing the system efficiency at 36%. Figure 2.3.1.2 provides the calculated system efficiency for the Stewart Ditch.

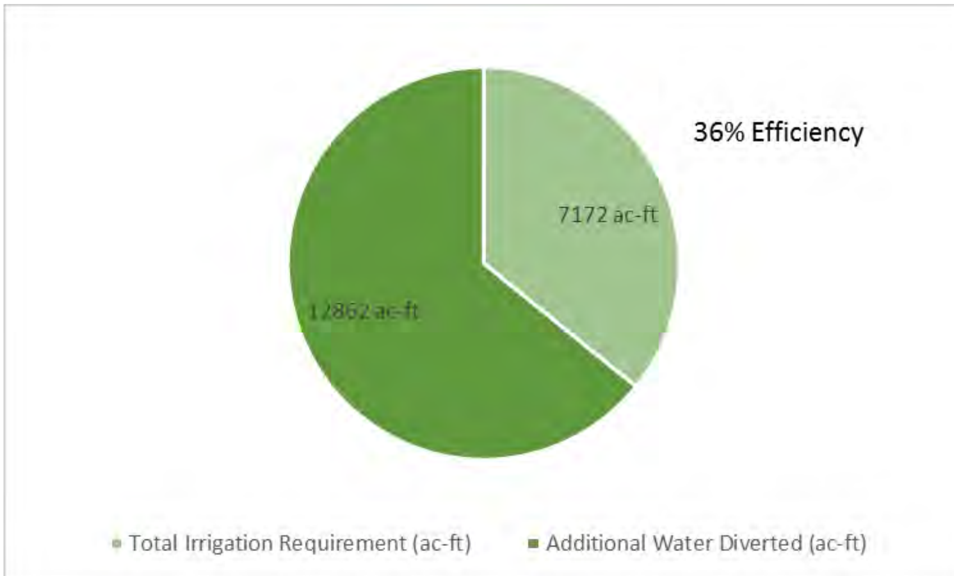

Figure 2.3.1.2. Calculated System Efficiency for the Stewart Ditch

Brief Diversion Description –

The Stewart Ditch diversion utilizes a small island in the North Fork to segregate a diversion channel from the principal river channel. There does not appear to be any structure in place at the upstream end of the island to control flow separation between the diversion channel and the river, but the diversion channel appears to be of similar scale to the adjacent river, and most likely is the dominant flow channel during the latter parts of irrigation season. Once in the diversion channel, water travels approximately 0.2 miles to the Stewart Ditch headgate. Adjacent to the headgate a large boulder weir supports the diversion channel bed above the natural riverbed. Figure 2.3.1.3 shows the headgate with the diversion channel in the foreground and river channel in the background. The function of the boulder weir is to maintain water surface elevation at the headgate. Any excess water in the diversion channel flows over the boulder weir and back into the river channel, as shown in Figure 2.3.1.4. The headgate consists of a radial gate on a small concrete headwall. The headwall is not of sufficient height to keep water from overtopping into the ditch at high flows, and thus sandbags are often used to aid in headwall function. Figure 2.3.1.5 shows the radial headgate with sandbags used to prevent overtopping.

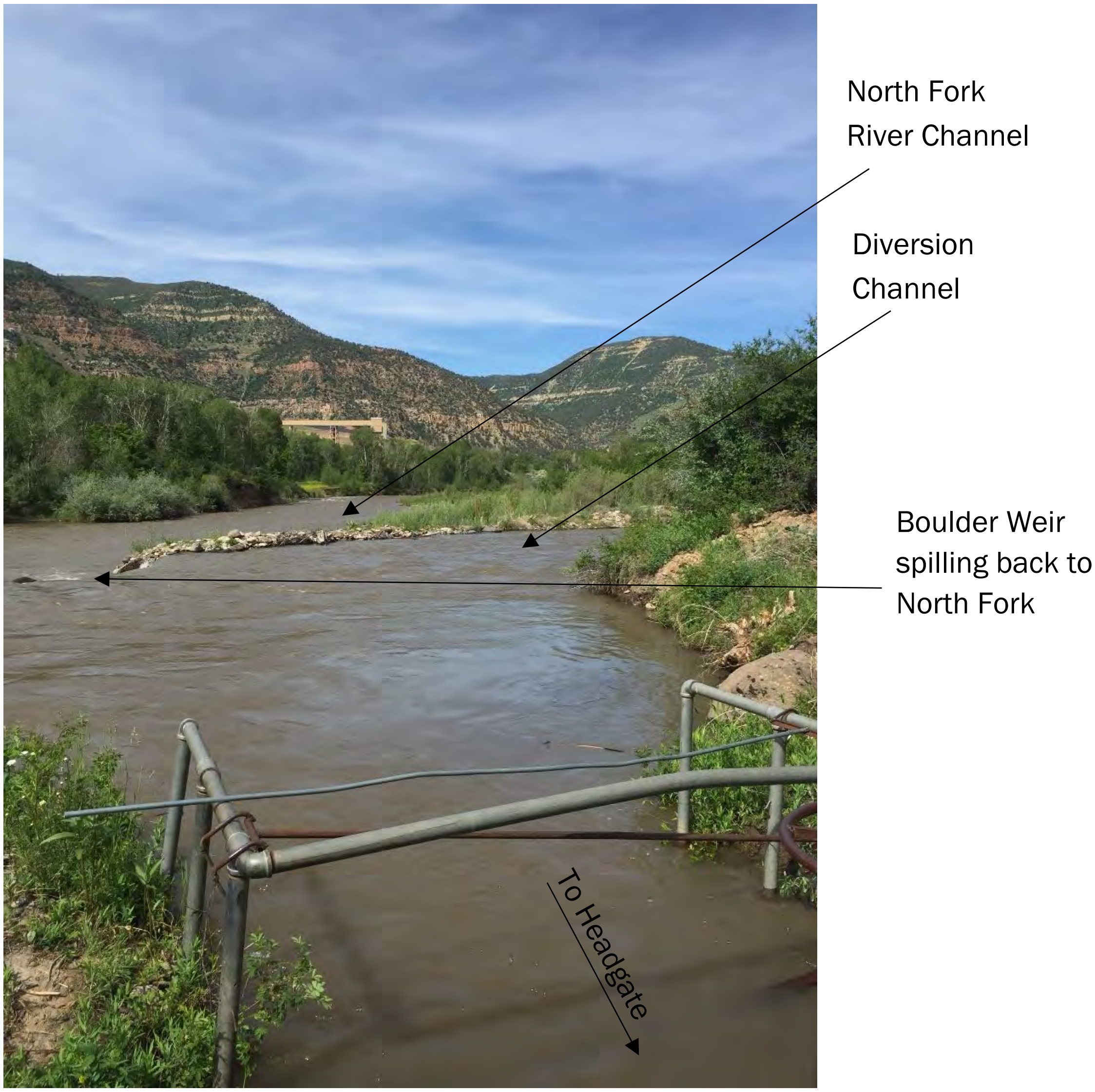

Figure 2.3.1.3. View of Stewart Ditch Diversion Channel from Headgate

Figure 2.3.1.4. Spill over Boulder Weir

Figure 2.3.1.5. Stewart Ditch Headgate

Structural Integrity and Diversion Functionality –

The boulder weir at the end of the diversion channel provides adequate, year-round water surface elevation to supply water to the Stewart Ditch. However, the ability of the boulder weir to withstand flood conditions is unknown, and likely will become an issue eventually. Also, the area where the two channels diverge upstream of the headgate is likely to be adversely affected by high flow events.

The top elevation of the headwall at the headgate is too low and results in uncontrolled over diversion at times during high flows. The over diversion is not a problem from a water rights standpoint and does not appear to threaten the integrity of the ditch. However, it appears to be a nuisance at high flows. Inability to control intake into the diversion channel may inhibit functionality at some future date. Natural river channel migration may require that the Stewart Ditch enter the river with heavy equipment to re-form the top end of the diversion channel. This could become an annual maintenance operation at some future date.

The river island separating the diversion channel from the river channel is an important feature for the Stewart ditch diversion. If the island loses the ability to fully segregate the channels during a flood event, the Stewart Ditch could potentially need to complete extensive river work to replace it.

Ability to Divert Appropriate Range of Flows –

The boulder weir and headgate allow for the regulation of flows into the ditch. The inability to control flow into the diversion channel could make diversion of decreed volumes difficult under certain river conditions. Examination of historical diversion records do not indicate that this is a problem. However, a single high flow event could do significant damage to the Stewart Ditch’s ability to divert their water right.

Diversion Issues that Affect River Function –

There is currently no mechanism to control flow into the diversion channel other than building a “push up” dam in the river channel. For this reason, the diversion channel often acts as the main river channel. This potentially creates a fish passage issue during certain, relatively short times of the year.

Diversion Issues that Affect Recreational Users –

Since the diversion channel is of similar size to the main river channel, recreationalists have inadvertently traveled down the diversion channel rather than the river channel. The boulder weir is an impassable obstruction for boaters, which results in frustration for recreational users that inadvertently travel down the diversion channel.

Recommendations –

1. River Signs: Signs on the river visible to recreationalists on the approach to the division between the diversion channel and the principal river channel to provide warning and avoid confusion.
2. Island Stabilization: Stabilization of island that segregates river channel and diversion channel – embedded boulders on upstream end with geostabilization along entire island banks.
3. Upstream Headwall: Headwall with sluice at upstream end of diversion channel to regulate flow into diversion channel.
4. Diversion Relocation/Complete Rebuild: Relocation of diversion upstream, construction of new diversion structure and 1,200 feet of large diameter conveyance pipeline.

Preliminary Cost Estimates –

1. River Signs – $1,000
2. Island Stabilization - $20,000 to $50,000
3. Upstream Headwall - $100,000 to $300,000
4. Diversion Relocation/Complete Rebuild - $1M - $3M

2.4 Reach 4 Overview

Reach 4 spans the area between the North Fork Farmer's Ditch and the Paonia Ditch. The smaller Feldman Ditch is just upstream of the Paonia Ditch and thus falls within the Reach. Reach 4 is 1.78 miles in length and ends just upstream of the Town of Paonia, CO. Figure 2.4.1 illustrates the average annual diversion rates from Reach 4 from 2007 to 2016 in comparison to the other reaches of the North Fork. The large majority of the diversion rate from Reach 4 comes from the North Fork Farmer's Ditch.

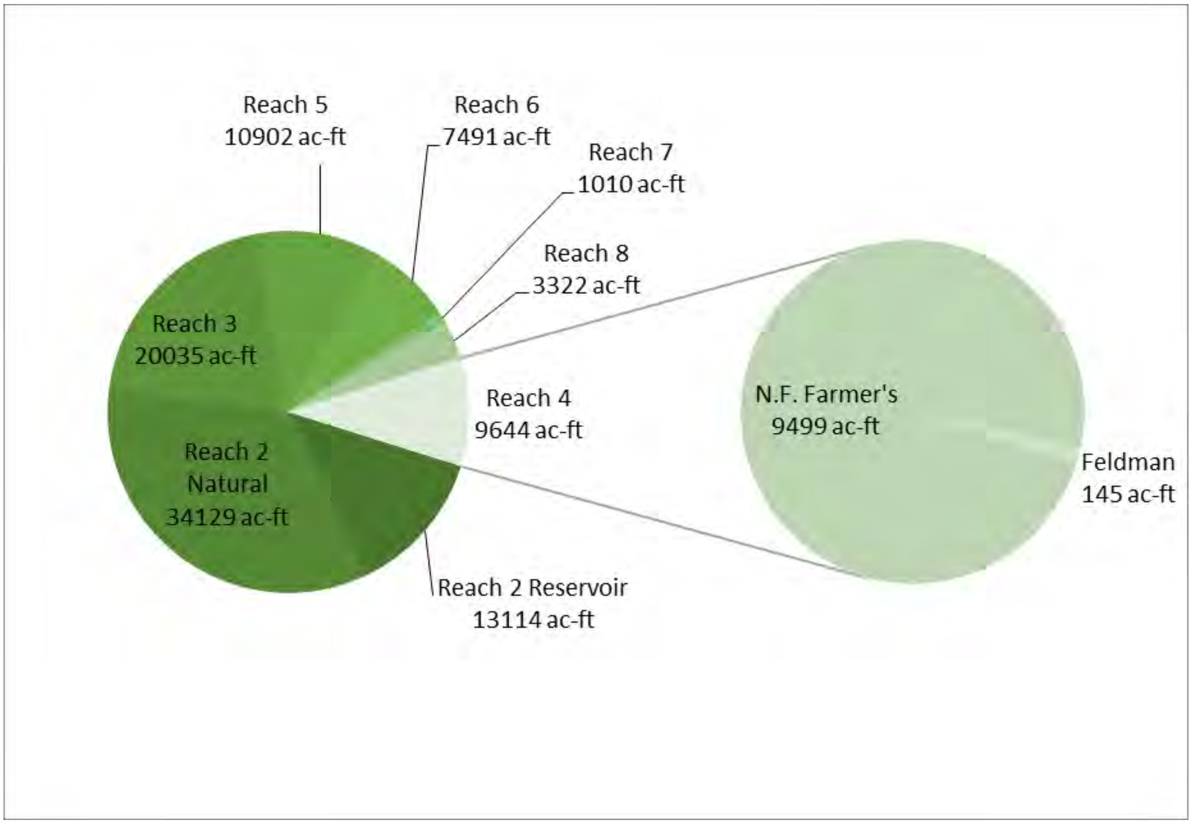

Figure 2.4.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 4

2.4.1 North Fork Farmer's Ditch

Ditch Overview –

The North Fork Farmer's Ditch Diversion is located in Reach 4 at 719+59, approximately 2.1 miles downstream of the Stewart Ditch Diversion. The ditch supplies irrigation water to river lowlands on the north side of the North Fork and to the Hansen Mesa area just Northeast of Hotchkiss, CO. The upper end (in the river lowlands) is governed by a separate board than the lower end (Hansen Mesa area). The governing body for the lower end is known as the North Fork Farmer's Ditch Extension. Grass pasture, corn, and small grains are common along the entire ditch while some vineyards and fruit are grown on the Extension. Figure 2.4.1.1 illustrates the average diversion statistics from 2007 to 2016 for the North Fork Farmer's Ditch.

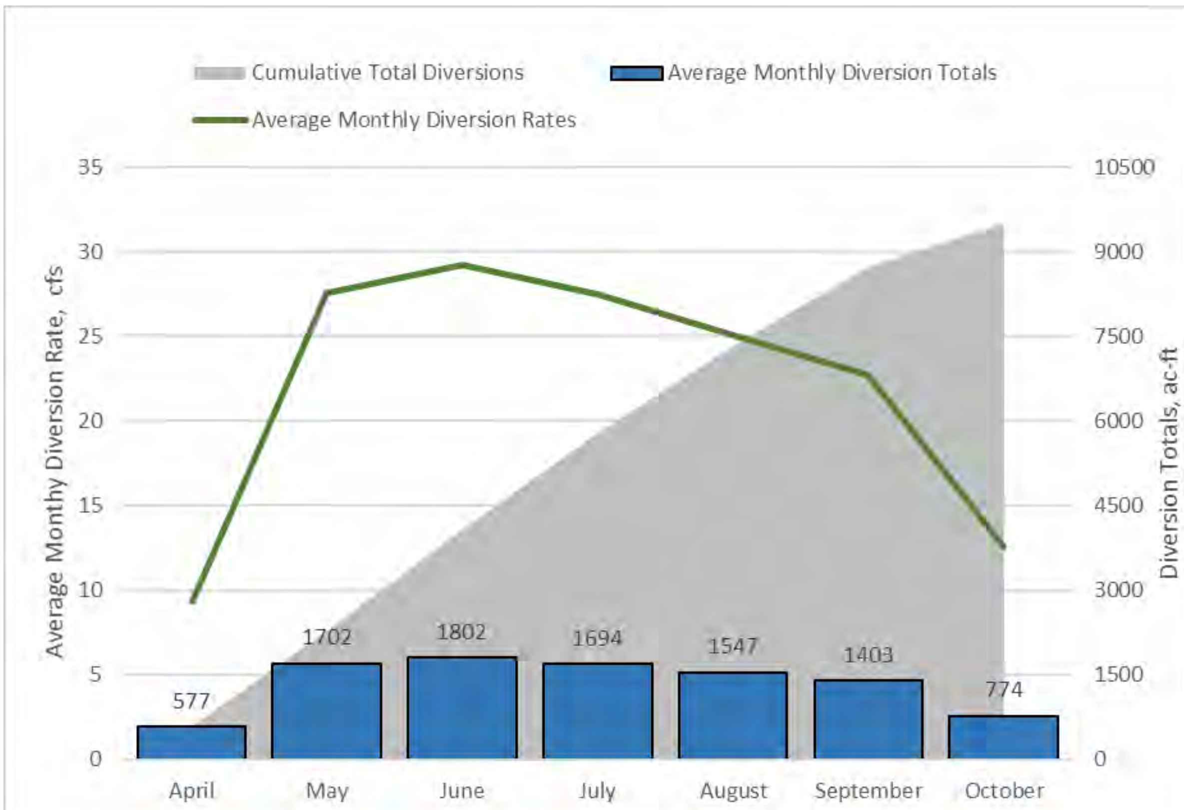

Figure 2.4.1.1. 2007 to 2016 Average Diversion Statistics for the North Fork Farmer's Ditch

According to CDSS 965.87 acres are irrigated using water from the North Fork Farmer's Ditch, with a reported 87% of the irrigated acres cultivating either grass pasture or alfalfa. A 28% system efficiency was calculated for the North Fork Farmer's Ditch. Figure 2.4.1.2 provides a breakdown of water provided to fulfill the total irrigation requirement versus the total water diverted.

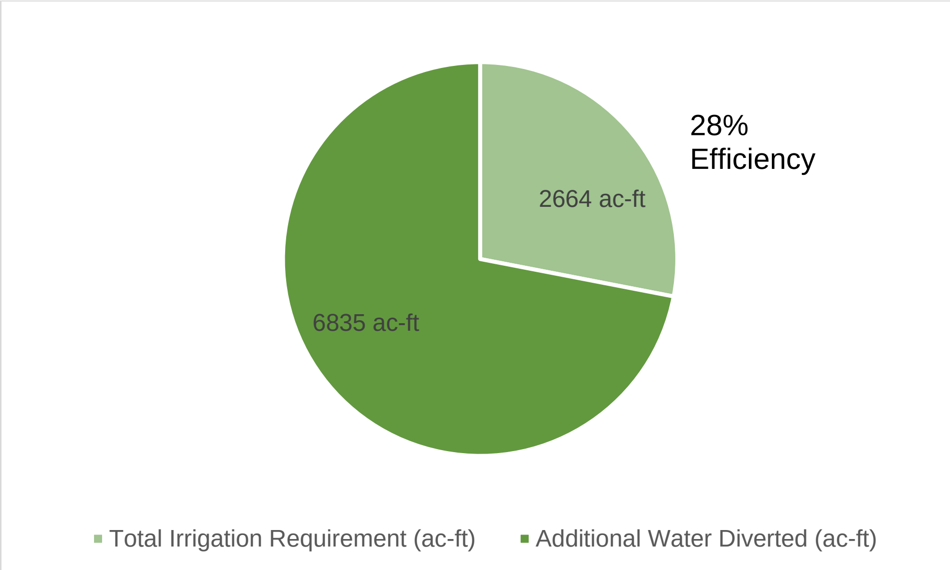

Figure 2.4.1.2. Calculated System Efficiency for the North Fork Farmer's Ditch

Brief Diversion Description –

The North Fork Farmer's Ditch diversion consists of a concrete and timber structure that spans the entire width of the North Fork River. There is a small concrete intake structure on the northwest bank of the river with a custom sluice gate to allow flow into the North Fork Farmer's Ditch. The downstream side of the diversion is supported by boulders, which gradually grade the diversion back to the natural river bottom. The upstream side of the diversion appears to be supported by a metal cribbing structure, which protrudes above the timbers, likely to allow for more timbers to be added to the diversion. The ditch headgate and turnback to the river are approximately 0.3 miles downstream of the diversion. Figure 2.4.1.3 shows the North Fork Farmer's Ditch diversion and intake structure. Figure 2.4.1.4 shows the southeast side of the diversion.

Figure 2.4.1.3. North Fork Farmer's Ditch Diversion and Intake Structure

Figure 2.4.1.4. North Fork Farmer's Ditch Diversion

Structural Integrity and Diversion Functionality –

As one of the older active diversions in the North Fork, the North Farmer's Ditch diversion is stable in its current condition. The downstream boulders and upstream metal cribbing have kept the timbers in place. The river channel in the vicinity appears stable and unlikely to meander away from the diversion. Because the diversion is perpendicular to the flow of the river, the energy is kept within the corridor, thereby minimizing bank erosion. From an irrigation standpoint, the diversion serves its function.

Ability to Divert Appropriate Range of Flows –

The North Fork Farmer's Ditch diversion is able to divert its full diversion as evidenced by the State's diversion records. At low flows, the diversion is able to "sweep the river", as seen in the above figures.

Diversion Issues that Affect River Function –

During low flows, the North Fork Farmer's Ditch diversion is detrimental to overall river function. Since the structure is able to, and often does, sweep the river, it creates a major impasse for the passage of aquatic species. During low flows, it adversely affects the river for approximately 0.3 miles until the headgate and spillback reintroduce water back to the river. Figure 2.4.1.5 shows the North Fork Farmer's Ditch and North Fork River side-by-side immediately after the diversion. Note: the picture used for Figure 2.4.1.5 was taken in early September, 2017.

Figure 2.4.1.5. North Fork Farmer's Ditch and North Fork River Immediately Downstream of Diversion

Diversion Issues that Affect Recreational Users –

The North Fork Farmer's Ditch negatively impacts recreation along the North Fork River corridor. During low flows, the river is dry for 0.3 miles, inhibiting recreation in that stretch. The metal cribbing on the front of the diversion also represents a hazard to recreationalists. There is a history of a contentious relationship between the irrigators on the North Fork Farmer's Ditch and recreationalists.

Recommendations –

1. <u>Improved Diversion</u>: Provide modification to the diversion structure that would allow minimum flows, those typically returned 0.3 miles downstream, to remain in this reach of the river. This could be simply accomplished with a sectioned portion of the weir that accommodates removable check boards. Additionally, removal of exposed cribbing iron that poses a risk to recreationalists should be prioritized. A boat passage could also be incorporated on the south bank of the river.

Preliminary Cost Estimates –

1. <u>Improved Diversion</u> – $75,000 to $100,000

2.4.2 Feldman Ditch

Ditch Overview –

The Feldman Ditch diversion is located immediately upstream of the Paonia Ditch Diversion at stationing 803+63. An irrigator or board member could not be located or contacted for the Feldman Ditch so an interview and infrastructure assessment were not conducted. Division of Natural Resources data shows minor, but active, diversion at the Feldman Ditch. Figure 2.4.2.1 provides some average diversion data for the Feldman Ditch from 2007 to 2016.

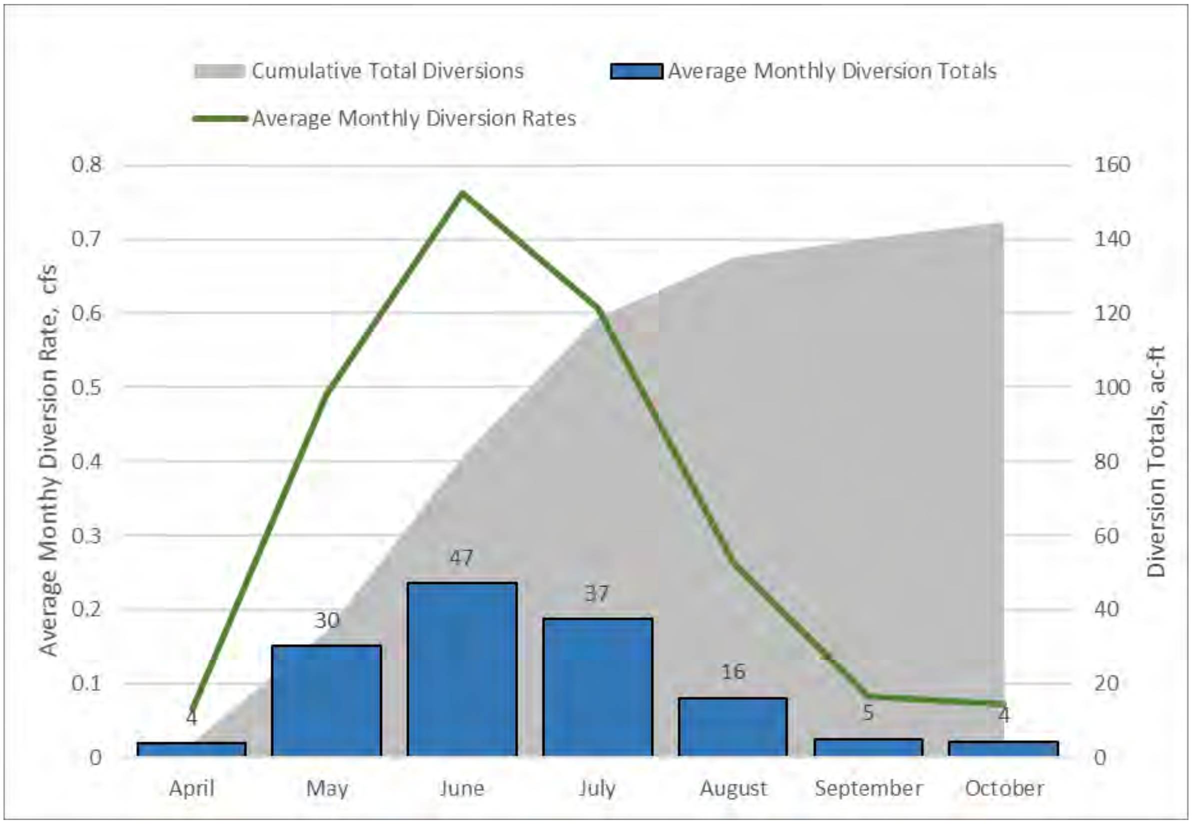

Figure 2.4.2.1. 2007 to 2016 Average Diversion Statistics for the Feldman Ditch

CDSS does not have any record of irrigated lands for the Feldman Ditch. Without acreage or crop data, system efficiency was not calculated.

2.5 Reach 5 Overview

Reach 5 begins with the Paonia Ditch and ends immediately prior to the Short Ditch. The 4.69 mile reach begins immediately prior to the Town of Paonia and ends well downstream of the town. The Monitor Ditch and Shepherd and Wilmott Ditch divert within Reach 5. The Paonia Ditch diverts the most water within the reach; however, diversion amounts are well distributed between the three ditches. Figure 2.5.1 compares the average annual diversion amounts from 2007 to 2016 for the reaches on the North Fork with special emphasis given to Reach 5.

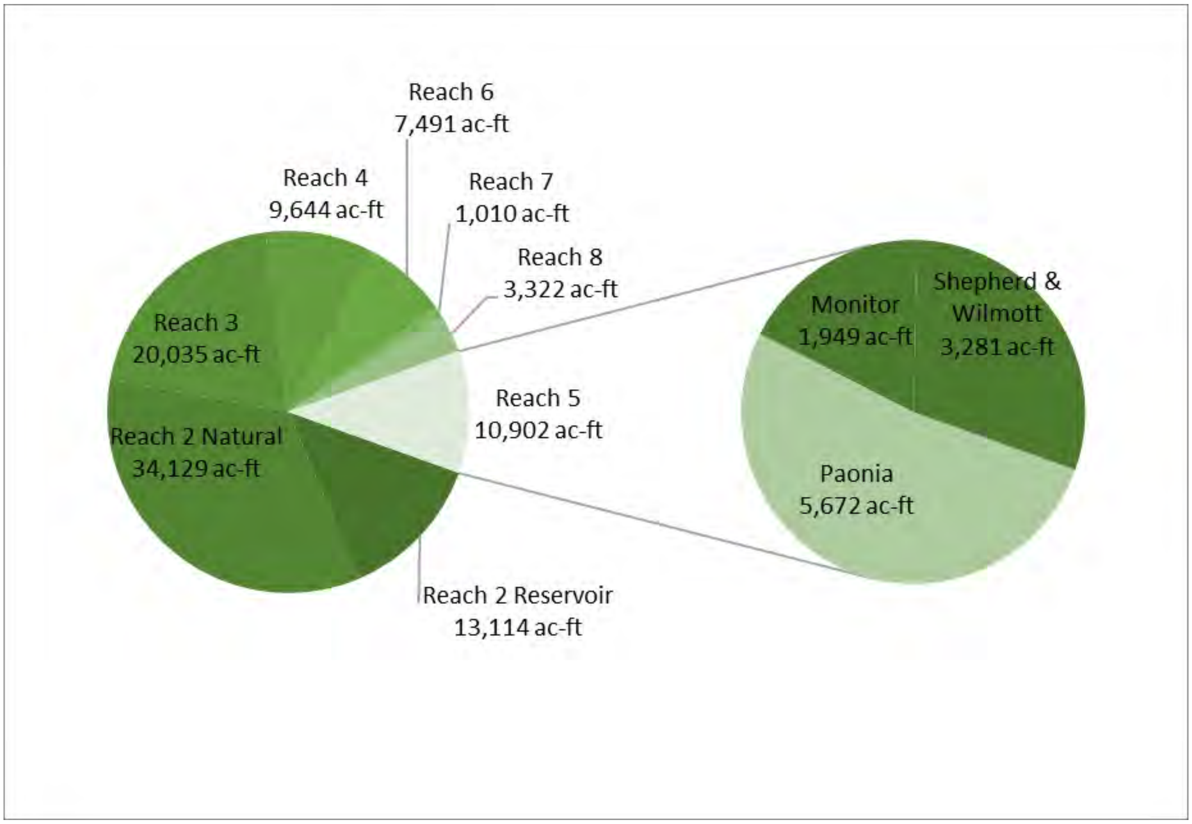

Figure 2.5.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 5

2.5.1 Paonia Ditch Diversion

Ditch Overview –

The Paonia Ditch Diversion is located in Reach 5 at 813+33, just upstream of the Town of Paonia. The Paonia Ditch Diversion supplies irrigation water to both the Paonia Ditch and the Wade and Hightower Ditch. Wade and Hightower water shares the first 0.75 miles of the Paonia Ditch (after the headgate), where it is then divided via proportional split sent into the Wade and Hightower Ditch.

The Paonia Ditch supplies irrigation water to lands primarily to the Southeast of Paonia where a variety of crops are grown including: fruit, alfalfa, small grains, and pasture. Irrigators in this area seem to be trending to more fruits, hops, and farm-to-table crops. Figure 2.5.1.1 illustrates some average diversion statistics from 2007 to 2016 for the Paonia Ditch.

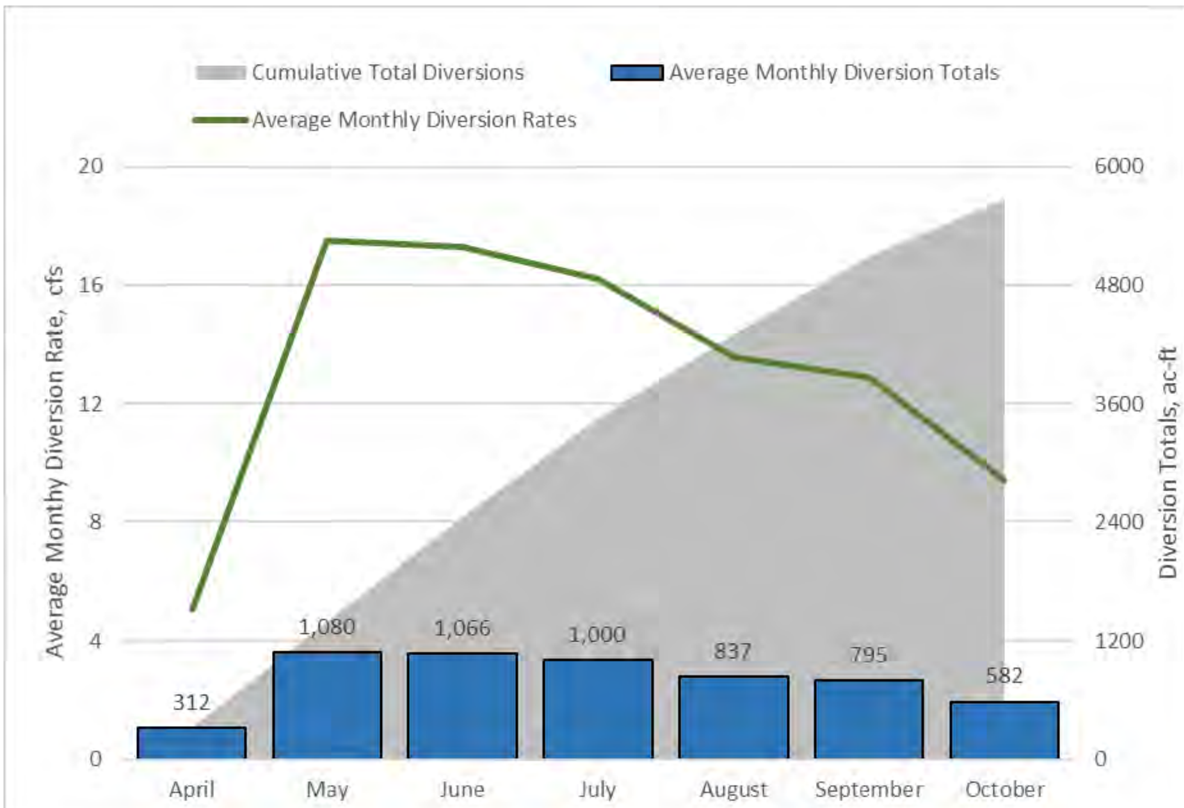

Figure 2.5.1.1. 2007 to 2016 Average Diversion Statistics for the Paonia Ditch

According to CDSS, the Paonia Ditch serves 304.86 acres. Approximately 157 acres are used to cultivate grass and alfalfa, while roughly 148 acres have fruit orchards. This total does not include the irrigated lands of the Wade and Hightower Ditch, which is likely decreasing the calculated efficiency of the system. Based on the CDSS data, the Paonia Ditch has a 15% system efficiency, though it is likely more efficient given the supply to Wade and Hightower. Figure 2.5.1.2 shows the calculated efficiency of the Paonia Ditch.

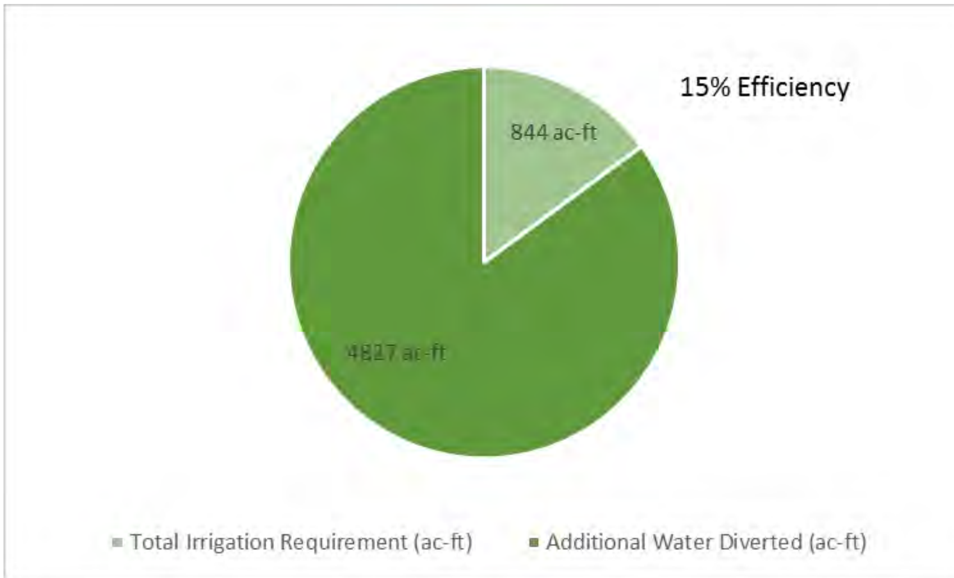

Figure 2.5.1.2. Calculated System Efficiency of the Paonia Ditch

Brief Diversion Description –

The Paonia Ditch diversion consists of a boulder weir with a core of interlocking concrete blocks that crosses diagonally across the river. There is a concrete headwall with an intake at the downstream end of the diversion structure with a canal gate to potentially isolate the ditch from the river (a canal gate is needed here because of the shared channel with Minnesota Creek). Figures 2.5.1.3 and 2.5.1.4 show the river diversion and concrete intake structure for the Paonia Ditch. Approximately 0.25 miles downstream of the intake structure, the diverted water combines with Minnesota Creek. The two water sources share a channel for roughly 0.17 miles until the Paonia Ditch headgate, pictured in Figure 2.5.1.5. Minnesota Creek branches away toward the North Fork of the Gunnison River and serves as a spillway in case of over diversion from the North Fork. Measurement occurs via a 4 foot Parshall flume downstream of the headgate.

The Town of Paonia has expanded around the Paonia Ditch, with the alignment of the ditch crossing through residential and commercial areas. To lower the risk of flooding the town during storm events, the Paonia Ditch utilizes its original headgate location as a secondary spill location. The secondary spill location is pictured in Figure 2.5.1.6.

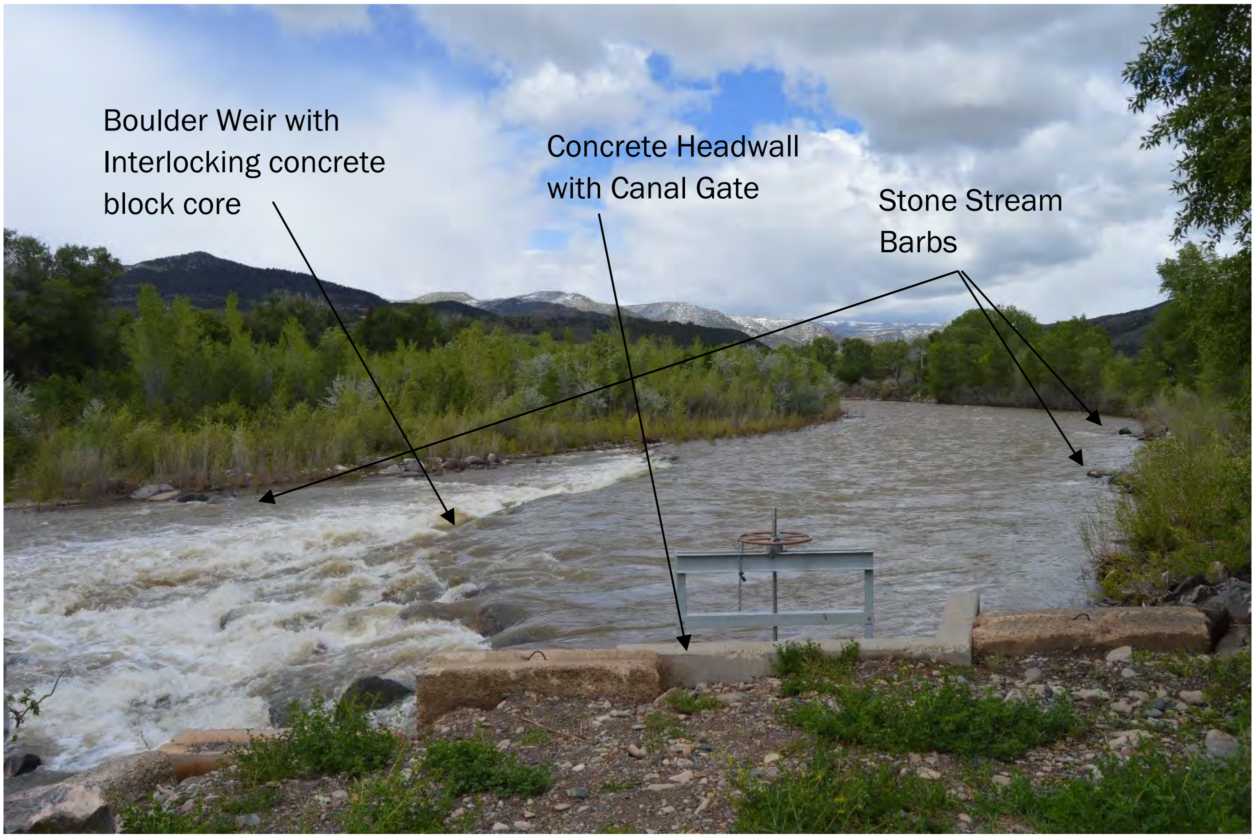

Figure 2.5.1.3. Boulder Weir and Concrete Intake Structure for Paonia Ditch

Figure 2.5.2.4. Concrete Headwall with High Flow Channel at Paonia Ditch Intake Structure

Shared Channel with Minnesota Creek

Creek Channel and Overflow to River

Headgate to Paonia Ditch

Figure 2.5.1.5. Paonia Ditch Headgate with Spill (Minnesota Creek) to River

Secondary Spillway

Secondary Headgate at edge of Town of Paonia

Figure 2.5.1.6. Paonia Ditch Secondary Spill and Headgate

Structural Integrity and Diversion Functionality –

In the recent past, the Paonia Ditch Diversion has been reconstructed twice. Using NFRIA funding a U-weir of grouted bounders was constructed, along with the current headwall intake structure. After approximately 3 months, the diversion failed and a reconstruction effort followed. This resulted in the current diversion, which at its core, is comprised of large interlocking concrete barrier blocks tied together by steel cable. The blocks are surrounded by large boulders. The diversion has not sustained any major damage since its reconstruction and appears to be stable.

Ability to Divert Appropriate Range of Flows –

The current diversion intake is able to divert its full range of flows, as long as the water within the river is at a suitable elevation. During times of low flow in the river, check boards are used to raise water at the intake. However, often times this is not sufficient, so sand bags and other temporary obstructions are utilized to raise the water surface elevation.

Diversion Issues that Affect River Function –

The addition of sandbags and other obstructions later in the irrigation season potentially negatively impacts the river ecosystem. Unlike a U-weir diversion, the current shape of the diversion does not direct the energy of the river away from the banks. While this normally raises the potential for bank erosion, improvements made by the Paonia Ditch in the form of rock stream barbs that extend both upstream and downstream of the diversion help maintain channel integrity. There is additional boulder stabilization upstream of the diversion, on the intake side of the river to prevent flanking.

Diversion Issues that Affect Recreational Users –

The Paonia Ditch Board states that upon putting in the latest diversion, there have been no issues with recreational users.

Recommendations –

1. <u>Improved Headgate Structure</u>: In sharing a channel with Minnesota Creek, silt and trash build-up are more common at the Paonia Ditch headgate. An improved headgate that removes debris and excess silt would benefit users of the ditch, particularly those with high efficiency systems requiring filtration.
2. <u>Bank Stabilization</u>: Stabilization of the bank downstream of the diversion could benefit the longevity of the diversion as erosion is of concern with the current diversion configuration. Imbedded boulders could provide erosion control.
3. <u>Secondary Spill Channel Improvements</u>: The secondary spill channel is overgrown and prevents proper use of the spill channel. This channel provides an extra layer of safety just as the ditch enters the Town of Paonia.

Preliminary Cost Estimates –

1. Improved Headgate Structure – $30,000 to $50,000
2. Bank Stabilization - $10,000 to $20,000
3. Secondary Spill Channel Improvements– $5,000

2.5.2 Monitor Ditch

Ditch Overview –

The Monitor Ditch Diversion is located in Reach 5 at 938+45, approximately 2.4 miles downstream from the Paonia Ditch Diversion and 2.0 miles upstream of the Shepherd and Wilmott Diversion. The Monitor Ditch supplies irrigation water to a section of river lowlands to the North side of the North Fork where hay pasture is the predominant crop. The diversion is new and has recently been replaced through NFRIA funding. Figure 2.5.2.1 presents some average diversion statistics from 2007 to 2016 for the Monitor Ditch.

Figure 2.5.2.1. 2007 to 2016 Average Diversion Statistics for the Monitor Ditch

CDSS reports that the Monitor Ditch provides irrigation water to 204.14 acres of primarily grass pasture. The total irrigation requirement for the Monitor Ditch was found to be approximately 564 acre-ft. With a reported annual average diversion, this puts the system efficiency at 29%. Figure 2.5.2.2 provides the system efficiency breakdown for the Monitor Ditch.

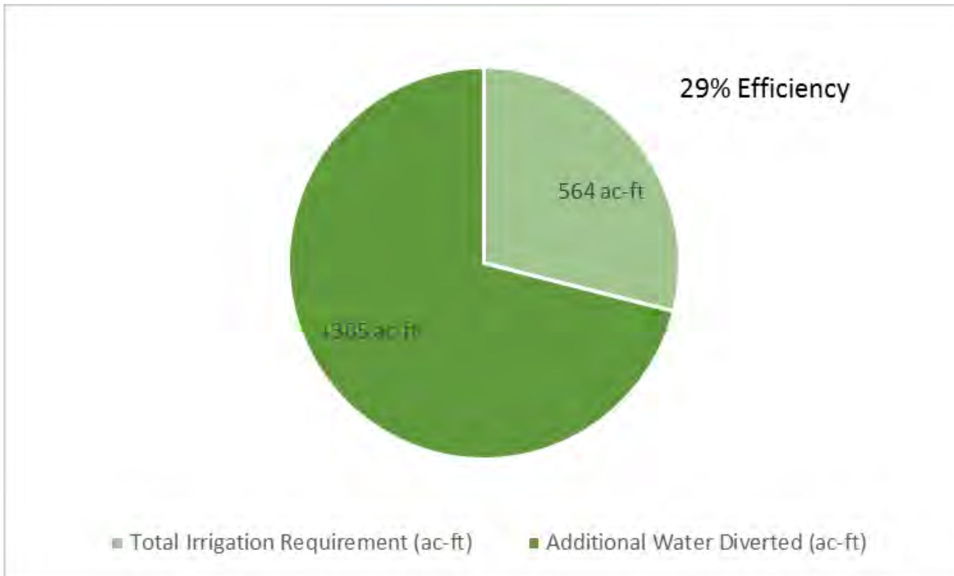

Figure 2.5.2.2. Calculated System Efficiency of the Monitor Ditch

Brief Diversion Description –

The Monitor Ditch Diversion consists of an asymmetric U-weir of grouted and loose boulders within the river. The boulders are grouted on the ditch side of the river, and loose on the far side. Figure 2.5.2.3 shows the rapids created by the boulder weir, along with the resultant high water created by the diversion. On the ditch side bank, a large concrete headwall separates the river from the diversion channel. The headwall contains an opening to allow water to enter the diversion channel, as shown in Figure 2.5.2.4. Within the diversion channel is a steel head gate, used to regulate flow into the Monitor Ditch. There is a 24-inch steel Parshall flume downstream of the headgate to measure flow into the ditch. Water from the diversion channel that is not taken into the Monitor Ditch is returned to the river. Figure 2.5.2.5 illustrates the movement of water at the headgate, and Figure 2.5.2.6 shows the headgate for the Monitor Ditch.

The river banks immediately upstream and downstream of the diversion appear stable, as does the river island that segregates the diversion channel from the main river channel.

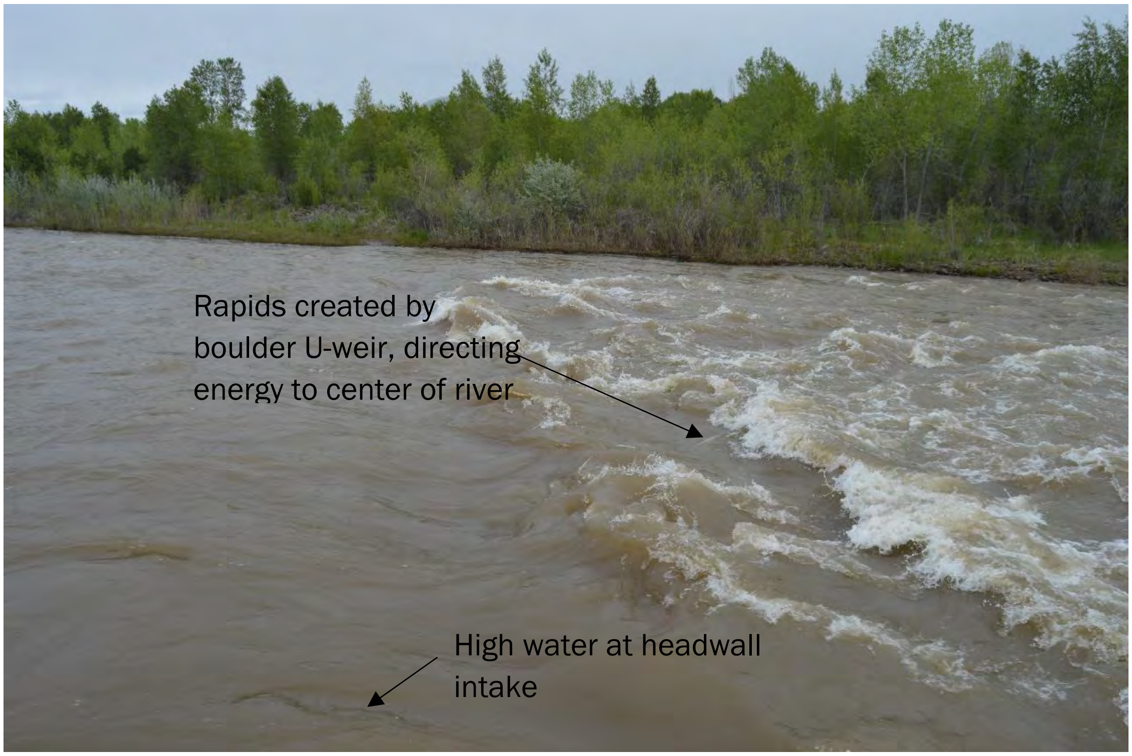

Figure 2.5.2.3. Resultant Water Profile from Monitor Ditch Diversion

Figure 2.5.2.4. Concrete Headwall for Monitor Ditch at River Diversion

Figure 2.5.2.5. Flow of Water in Diversion Channel for Monitor Ditch

Figure 2.5.2.6. Monitor Ditch Headgate

Structural Integrity and Diversion Functionality –

The diversion does an acceptable job of raising water levels at the headwall intake into the diversion channel, while directing the energy of the flow toward the center of the river. The water at the headwall intake can become still in certain flow regimes resulting in the collection of branches and trash at the intake, causing occasional clogging.

The river banks immediately upstream and downstream of the diversion appear stable, as does the river island that segregates the diversion channel from the main river channel. All concrete structures involved in the diversion appear to be in good condition.

Ability to Divert Appropriate Range of Flows –

With the exception of occasional intake clogging, the headwall intake maintains an acceptable water surface elevation in the diversion channel during most river flow regimes. The headgate is able to effectively regulate flow into the ditch from the diversion channel. With the occasional curtailment of the Monitor's junior-most water rights, effective regulation is critical. During exceptionally high flows, however, water will sometimes overtop the headgate, as seen in Figure 2.5.2.5.

Diversion Issues that Affect River Function –

The diversion does not appear to negatively affect river function, as the shape of the weir directs energy away from the banks and prevents erosion.

Diversion Issues that Affect Recreational Users –

Since the installation of the in-stream U-weir, the Monitor Ditch has not had notable issues with the river recreation community.

Recommendations –

1. <u>Increase Headwall Height</u>: To prevent overtopping, it is recommended to add approximately 24" of concrete to the top of the headgate headwall. This will require replacement of the sluice gate.
2. <u>Trash Rack</u>: A trash rack would prevent clogging of the headgate and would act as a safety barrier for river users.

Preliminary Cost Estimates –

1. <u>Increase Headwall Height</u> – $1,000
2. <u>Trash Rack</u> – $10,000

2.5.3 Shepherd and Wilmott Ditch

Ditch Overview –

The Shepherd and Wilmott Ditch Diversion is located at 1045+22 in Reach 5 of the North Fork, roughly 1500 feet upstream of the Short Ditch Diversion. It provides irrigation and stock water to river lowlands immediately downstream of the diversion. Typical crops are pasture, alfalfa, corn, and small grains with no trends to other crop types. The diversion was recently replaced via NFRIA funding. Figure 2.5.3.1 shows average diversion statistics for 2007 to 2016 for the Shepherd and Wilmott Ditch.

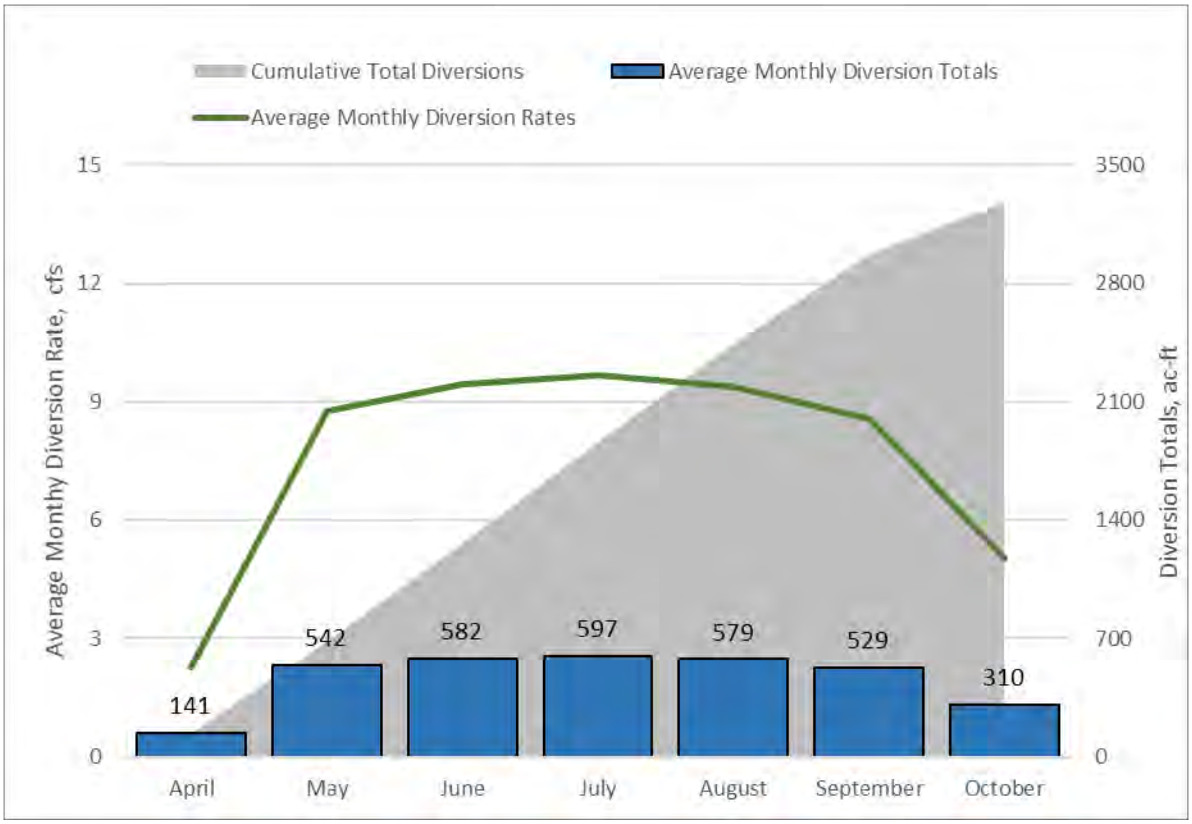

Figure 2.5.3.1. 2007 to 2016 Average Diversion Statistics for the Shepherd and Wilmott Ditch

The Shepherd and Wilmott Ditch reportedly serves 284.26 acres with irrigation water. Roughly 256 of these acres are used for grass pasture cultivation with the remaining acreage used for corn. The total irrigation requirement calculated for the Shepherd and Wilmott is 707 ac-ft annually. With a total reported annual average diversion of 3281.1 ac-ft, the calculated system efficiency of the Shepherd and Wilmott Ditch is 22%.

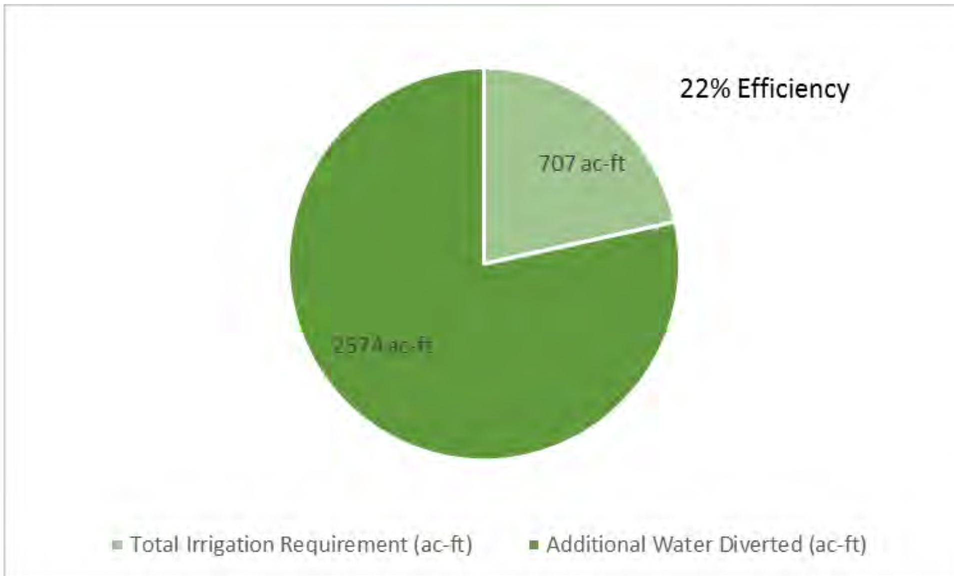

Figure 2.5.3.2. Calculated System Efficiency of the Shepherd and Wilmott Ditch

Brief Diversion Description –

The Shepherd and Wilmott Ditch Diversion consists of an asymmetric U-weir of grouted boulders in the river. The weir creates a still, high water condition on the ditch side bank of the river. There is a concrete headwall separating a diversion channel from the main river channel. Figure 2.5.3.3 shows the concrete headwall and the still high-water created from the diversion. The channel has an intake that directs water from the river into the diversion channel. During many times of the year, there is a substantial drop in water surface elevation from the river into the diversion channel. Figure 2.5.3.4 illustrates the difference in head created by the concrete headwall and intake structure.

To maintain water elevation in the diversion channel there are two concrete spillways that spill back into the river directly in front of the Shepherd and Wilmott headgate. Figure 2.5.3.5 shows the spillway just upstream of the headgate, while Figure 2.5.3.6 shows the entire headgate/spillway infrastructure on the diversion channel. Downstream of the headgate is a 24-inch steel flume to measure flow into the ditch.

The river has had a history of meandering near the Shepherd and Wilmott Diversion. Historically, the diversion intake has had to be relocated to account for the changing river alignment. The stretch near this diversion is a wide and flat floodplain, which can experience erosion and channelizing with annual high-water.

Figure 2.5.3.3. Concrete Headwall and Intake Structure for the Shepherd and Wilmott Diversion

Figure 2.5.3.4. Concrete Headwall and Intake Structure from Diversion Channel

Figure 2.5.3.5. Diversion Channel and Spillway to River from Shepherd and Wilmott Headgate

Figure 2.5.3.6. Shepherd and Wilmott Headgate and Spillways from Diversion Channel

Structural Integrity and Diversion Functionality –

The boulder weir for the Shepherd and Wilmott diversion is grouted and has maintained its structural integrity since it was replaced with NFRIA funding. At certain times of the year, the concrete headwall and intake structure creates substantial suction from the river into the diversion channel. Small 2x4 boards are used to prevent suction of debris. All excess water taken by the intake structure is returned to the river just prior to the headgate to the Shepherd and Wilmott. Functionally, the diversion meets the needs to the Shepherd and Wilmott Ditch.

Ability to Divert Appropriate Range of Flows –

The concrete intake structure allows sufficient water to enter the diversion channel at all flow rates within the river. Flow into the ditch is regulated by the headgate. As such, the diversion can handle all necessary flow rates for the ditch. There are plans to install a custom sluice gate on the intake structure to allow further water regulation.

Diversion Issues that Affect River Function –

The boulder weir appears to be a minor obstruction that does not impede river function during most of the year. The still water created by the diversion results in the build-up of debris, however, this is more of a hassle for the ditch company than an issue affecting river function.

Diversion Issues that Affect Recreational Users –

The boulder weir may result in a minor obstruction to recreational boaters and rafters, however, there does not appear to have been disputes between the ditch company and recreational users since the new NFRIA funded diversion. The suction created by the headwall and intake structure may pose a safety hazard to people.

Recommendations –

1. Trash Rack: Because of the high suction potential at the headgate, a trash rack would help keep debris from entering the diversion channel. Secondarily, the trash rack would protect recreational users from potential suction hazards.
2. Bank Stabilization: Stabilization of the bank downstream of the diversion could benefit the longevity of the diversion as the stream has a tendency to meander in this section of the reach. Geostabilization would likely be an appropriate option.

Preliminary Cost Estimates –

1. Trash Rack – $10,000 to $50,000
2. Bank Stabilization - $20,000 to $50,000

2.6 Reach 6 Overview

Reach 6 begins with and includes the Short Ditch, and ends just before the Vandeford Ditch. It is a total of 4.5 miles in length and does not pass through any towns. The Short Ditch is the last of the major diverters on the North Fork. Figure 2.6.1 compares the average annual diversion totals from 2007 to 2016 for all diverters on the North Fork, focusing on Reach 6.

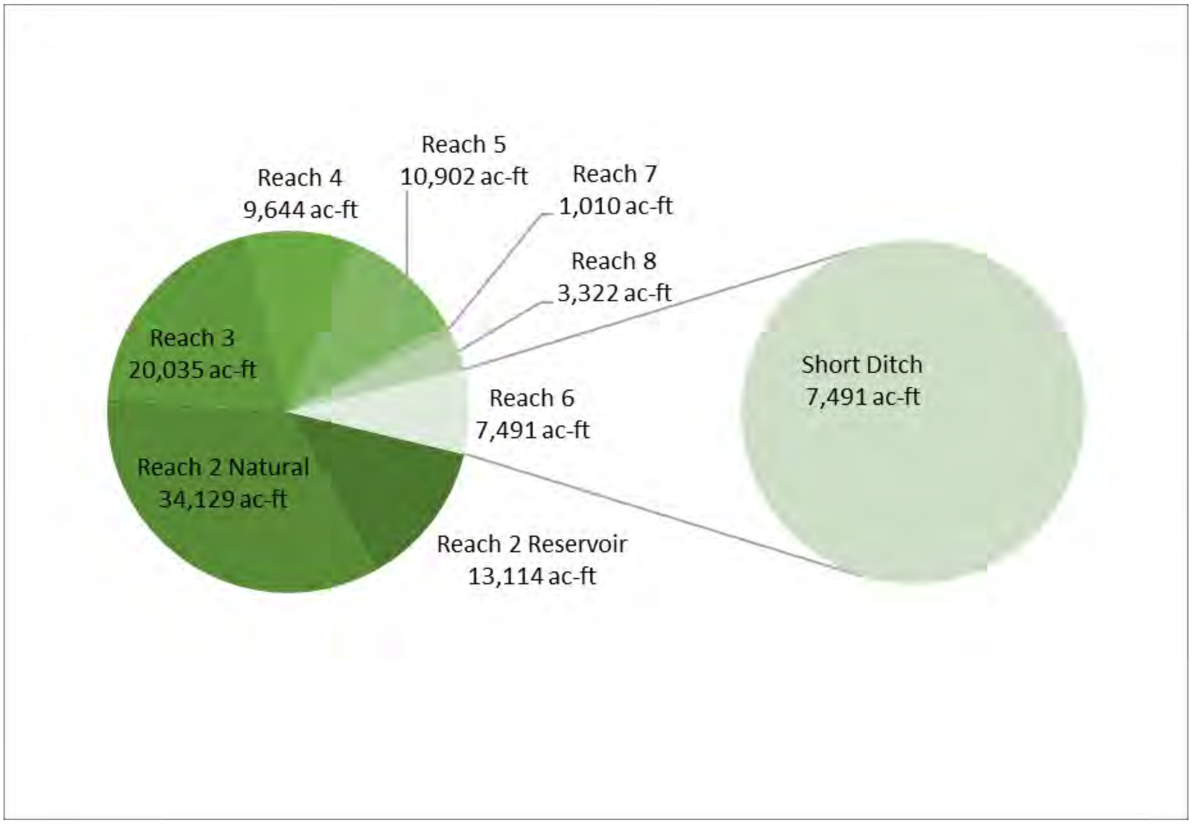

Figure 2.6.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 6

2.6.1 Short Ditch

Ditch Overview –

The Short Ditch is located in Reach 6 of the North Fork at 1060+76, approximately 1500 feet downstream of the Shepherd and Wilmott Diversion. The ditch travels along the South side of the North Fork where irrigation and stockwater are supplied to many of the areas directly to the East of Hotchkiss, CO. Typical crops are pasture, hay, and row crops. The diversion was recently replaced through NFRIA funding. Figure 2.6.1.1 provides average diversion statistics for the Short Ditch for the period from 2007 to 2016.

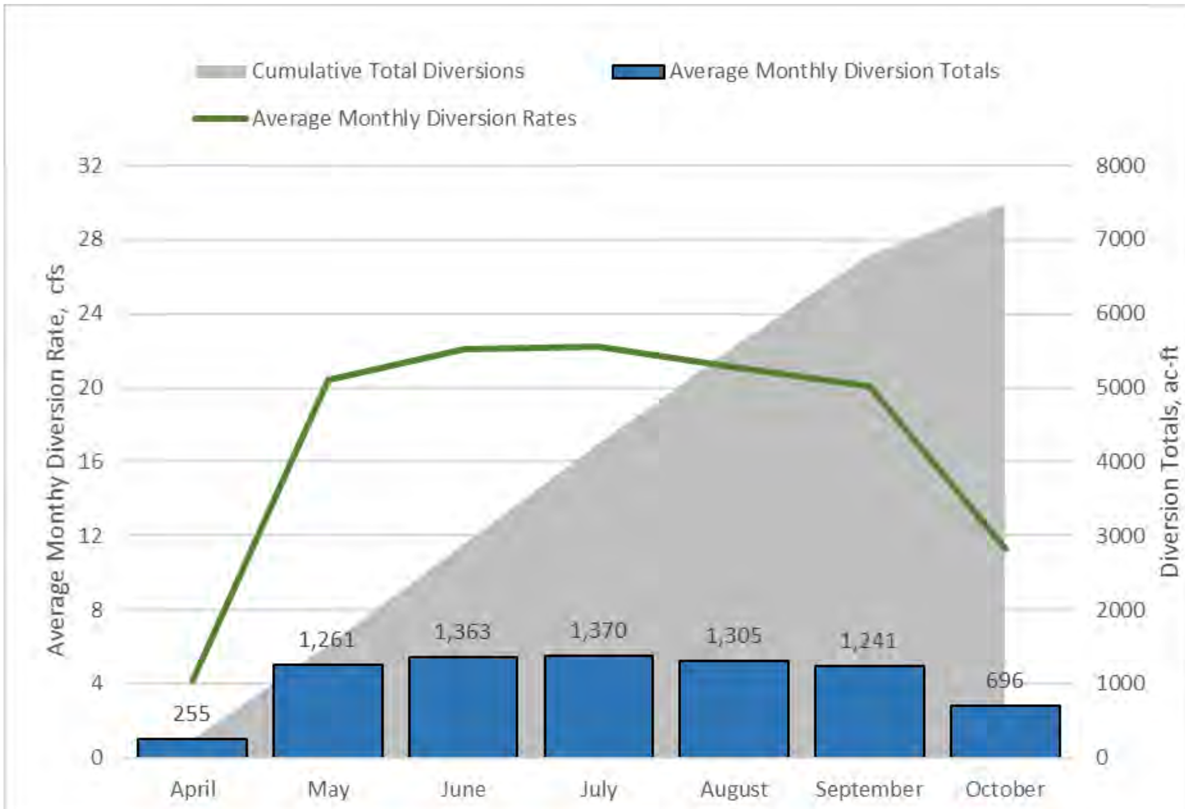

Figure 2.6.1.1. 2007 to 2016 Average Diversion Statistics for the Short Ditch

A total irrigation requirement of 1477 ac-ft/yr was calculated for the Short Ditch. This figure is based on the 535.5 acres receiving irrigation water as reported by CDSS. According to CDSS 100% of the irrigated lands are grass pasture. With this in mind, the overall system efficiency of the Short Ditch is 20%. Figure 2.6.1.2, below, shows the total annual irrigation requirement in relation to the average annual diversion for the Short Ditch.

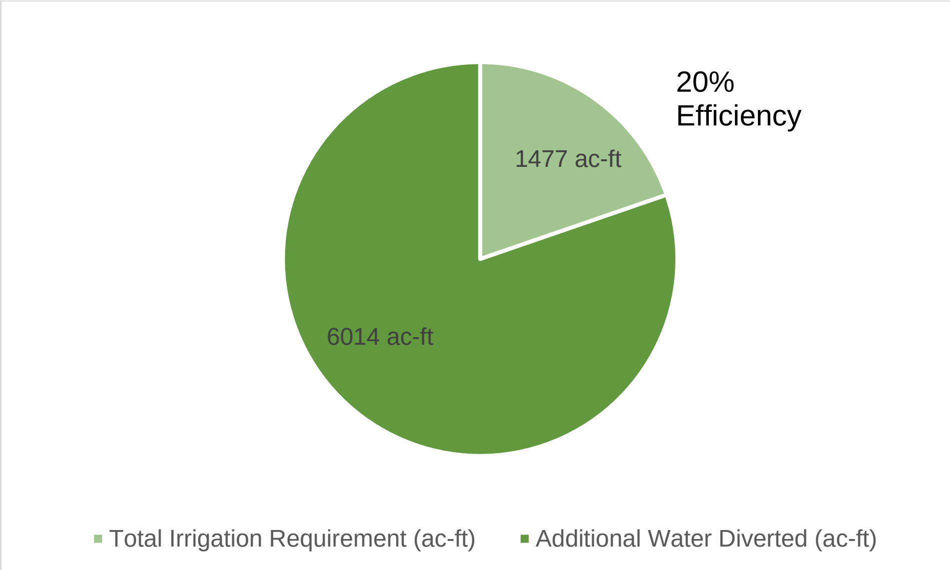

Figure 2.6.1.2. Calculated System Efficiency of the Short Ditch

Brief Diversion Description –

The Short Ditch Diversion consists of an in-stream boulder weir, a concrete headwall with an intake gate, an approximately 0.65 mile long diversion channel with a ditch headgate and a spillback to the river. Water in the diversion channel is regulated by a large canal gate on the concrete headwall. The headwall has a small water surface control channel adjacent to the intake gate that assists in water level management during high flows and allows for more effective capture of water during low flows with the utilization of check boards. Figure 2.6.1.3 shows the boulder weir during a low flow condition in the North Fork. Figure 2.6.1.4 shows the concrete headwall and intake gate.

Figure 2.6.1.3. Short Ditch Boulder Weir Diversion

Figure 2.6.1.4. Short Ditch Diversion Headwall and Intake

Structural Integrity and Diversion Functionality –

The headwall and intake for the Short Ditch are on the southern bank of the North Fork at a point where the river channel is split by a small river island. The boulder weir diversion is positioned between the headwall and the river island; the channel on the far side of the island is significantly smaller than the principal channel on the near side. The weir experiences continual erosion resulting in the dispersion of rocks and boulders down the river channel, as shown in Figure 2.6.1.3. This requires regular maintenance from the Ditch Company through the frequent rebuilding of the weir so the diversion will continue to function.

The continual dispersion of rocks and boulders from the weir threatens to create a river condition where the small channel to the North of the river island is hydraulically favored, causing the stream to predominantly flow to the far side of the island. This could potentially strand the point of diversion during low flows, resulting in the need for a secondary or new diversion.

The headwall/intake is structurally sound. There is concern, however, that the river may flank the sides of the intake structure and wash out the upstream bank, or overtop the headwall during high-flow conditions. Bank stabilization and in-stream energy dissipation may help maintain the integrity of the upstream bank. Expanding the water surface control channel in front of the gate may help to prevent overtopping of the headwall.

Ability to Divert Appropriate Range of Flows –

Prior to erosion and dispersion, the rock and boulder weir is able to divert the appropriate range of flows for the Short Ditch. The concrete channel in front of the headgate allows for sufficient head to be built up during low-flow conditions through the use of checkboards. During high-flow conditions, the checkboards can be removed to decrease the stress on the boulder weir to help prevent erosion.

Unfortunately, over the course of a typical irrigation season, the weir is eroded and dispersed in the river. In order to continue to divert their allotted flow rates, the Ditch Company must often use heavy equipment to rebuild the weir mid-season.

Diversion Issues that Affect River Function –

Continual dispersion of rocks and boulders from the weir appears to have an adverse impact on stream connectivity near the diversion during times of low flow. This is likely most noticeable during the late irrigation season (August through October). Discontinuity in the stream may inhibit fish passage through the reach.

Diversion Issues that Affect Recreational Users –

As with river function, stream discontinuity negatively impacts recreational users. River passage is likely difficult near the Short Ditch diversion. With limited nearby infrastructure, takeout of recreational watercraft is more difficult near the Short Ditch.

Recommendations –

1. Diversion Improvement: Create a more stable and permanent diversion in the river to prevent the erosion/rebuild cycle of the current boulder weir. A grouted boulder weir with a poured concrete core may provide necessary stability.
2. Expand Water Control Channel: Expand the water control channel on the headgate to help displace more water during flood and high-flow conditions.
3. Bank Stabilization: Stabilize the river bank upstream of the headwall to prevent a wash-out and bypass of the headwall. Difficulty of access with heavy equipment will be likely increase cost.

Preliminary Cost Estimates –

1. Diversion Improvement – $100,000+ (possibly very high costs for complete re-build)
2. Expand Water Control Channel - $10,000 to $25,000
3. Bank Stabilization - $50,000 to $100,000

2.7 Reach 7 Overview

Reach 7 begins with the Vandeford ditch and ends just before the Smith and McKnight Diversion. This segment is 1.7 miles in length and travels around the outskirts of Hotchkiss, CO. Figure 2.7.1 puts the diversion totals from this reach in comparison with those from other reaches, calculated as averages from 2007 to 2016.

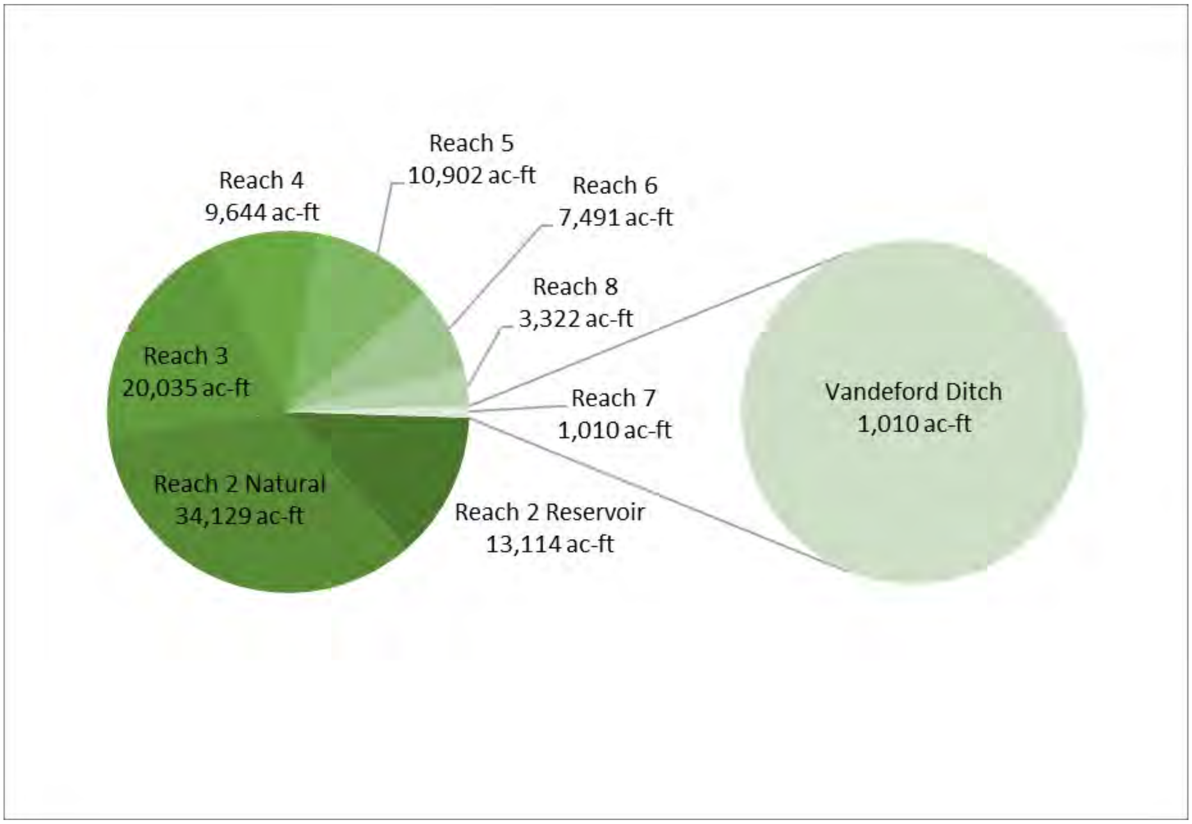

Figure 2.7.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 7

2.7.1 Vandeford Ditch

Ditch Overview –

The Vandeford ditch marks the start of Reach 7 and is located at 1296+73, nearly 4.5 miles downstream of the Short Ditch diversion, and just upstream of Hotchkiss. It supplies irrigation and stock water to a section of lowlands south of Hanson Mesa and North of the river. Common crops are triticale, alfalfa, oats, grass, and corn, with no trends to new crops. No engineering has been completed on the Vandeford Ditch; however, there are some issues that could benefit from engineering assistance. Figure 2.7.1.1 provides average diversion statistics from the period 2007 to 2016 for the Vandeford Ditch.

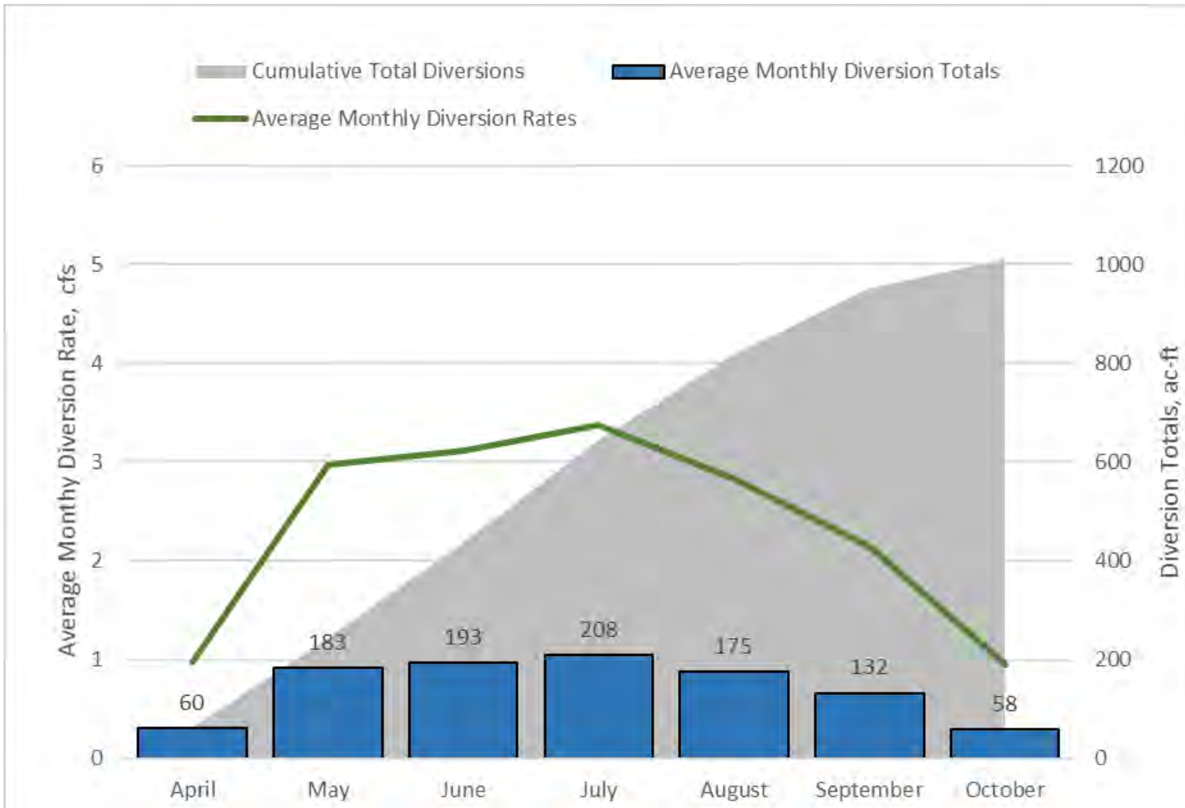

Figure 2.7.1.1. 2007 to 2016 Average Diversion Statistics for the Vandeford Ditch

CDSS reports that 89.2 acres are irrigated by water from the Vandeford Ditch. Cultivation of this acreage is well distributed amongst grass pasture, alfalfa, and corn. Based on the reported acreage and crop distribution, the total irrigation requirement for the Vandeford Ditch is 250 ac-ft or approximately 25% system efficiency. Figure 2.7.1.2 provides the calculated system efficiency of the Vandeford Ditch.

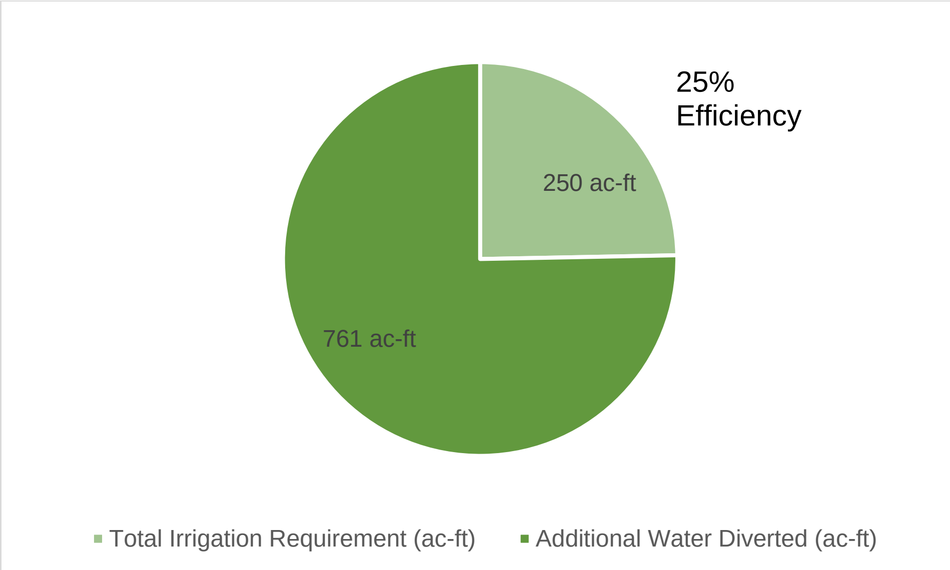

Figure 2.7.1.2. Calculated System Efficiency of the Vandeford Ditch

Brief Diversion Description –

The Vandeford Ditch diversion consists of an in-stream boulder weir that spans approximately one-half of the North Fork. This allows for passage around the diversion, while allowing sufficient flow diversion for the Vandeford's water rights. Just upstream of the diversion on the Northwest bank of the river there is a headgate mounted on the front of a small concrete headwall. Figure 2.7.1.3 shows the headgate and boulder weir of the Vandeford diversion. After water passes through the headgate, it travels through river-bottom wetlands for approximately 0.25 miles to another small headgate, shown in Figure 2.7.1.4. There is a turn-back spill immediately in front of the headgate, sending excess flow back to the river. The Parshall flume used to measure flows on the ditch is another 0.25 miles downstream of the second headgate. In the first half-mile span of the ditch (river diversion to flume), there are significant inflows from irrigation occurring on the surrounding higher ground. Figure 2.7.1.5 provides an example of inflows coming from irrigation on nearby high ground. This directly influences the amount of water the Vandeford must divert from the North Fork, and allows for substantially reduced diversions from the North Fork under certain conditions.

Figure 2.7.1.3. Vandeford Ditch Diversion

Figure 2.7.1.4. Spill Back to River

Figure 2.7.1.5. Example Inflows into Vandeford Ditch

Structural Integrity and Diversion Functionality –

The boulder weir appears to be structurally sound and is able to provide high water at the headgate. The weir often raises the water level above the headwall; however, this does not create any long-term structural or functional issues. The turn-back spill is earthen, so structural integrity is a concern. There have been historical issues with sediment in the Vandeford Ditch.

Ability to Divert Appropriate Range of Flows –

The current configuration of the diversion and headgate is able to divert the appropriate range of flows. The headgate on the ditch, near the turn-back spill, allows for rate adjustments.

Diversion Issues that Affect River Function –

Since the boulder weir does not span the entire river cross-section, there is adequate passage around the diversion for fish and recreational users. The current configuration of the boulder weir tends to create rapids very near the bank of the river. This could cause erosion over time.

Diversion Issues that Affect Recreational Users –

The diversion itself has not caused issues for recreational users. Rafters and kayakers are able to float the river and simply go around the diversion. The rapids created by the boulder weir are attractive to fly fishermen which has caused some conflict with the Vandeford Ditch.

Recommendations –

1. <u>Engineered Spill</u>: The current turn-back spill is earthen and subject to erosion over time. A concrete spill structure with a sluice gate in front of the ditch headgate would be a more permanent structure and would allow for sluicing out material and sediment, which have caused issues for the ditch.

Preliminary Cost Estimates –

1. <u>Engineered Spill</u> – $30,000 to $50,000

2.8 Reach 8 Overview

The Smith and McKnight Ditch Diversion marks the starting point of Reach 8, which concludes at the confluence with the Gunnison River. This reach has a total length of 9.24 miles. It begins in the Town of Hotchkiss and forms the southern boundary of the area known as Roger's Mesa. Figure 2.8.1 compares the diversions from Reach 8 with the other reaches on the river, with special emphasis on Reach 8.

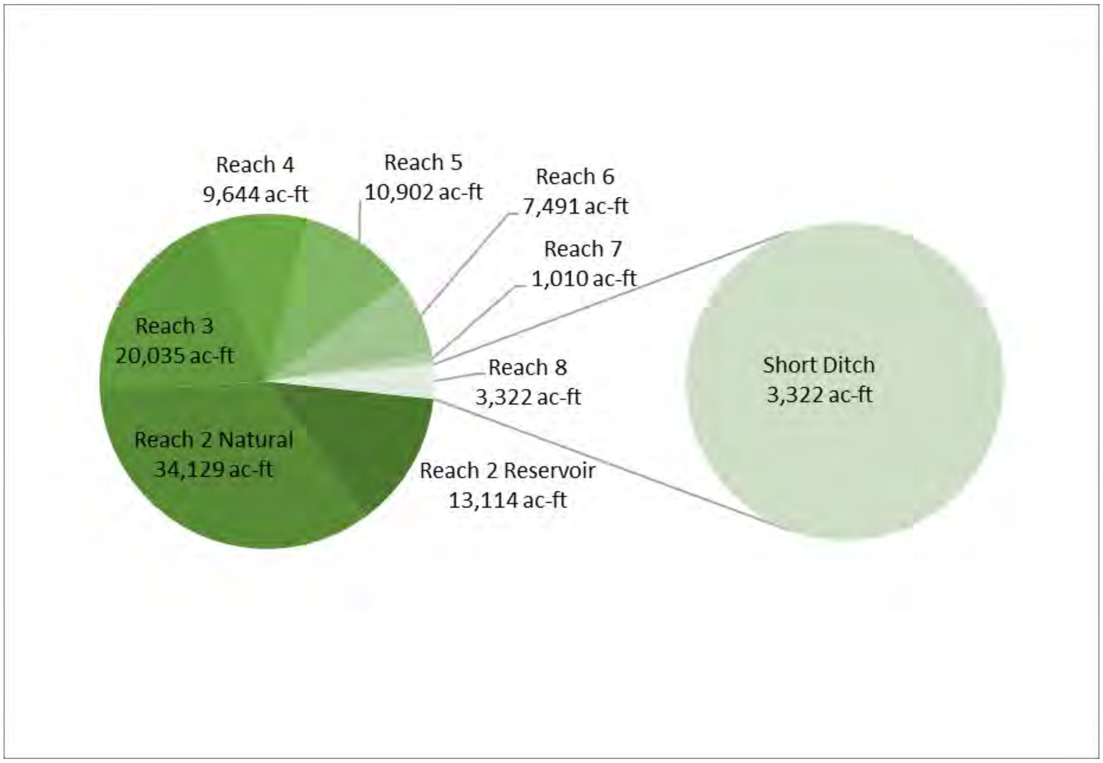

Figure 2.8.1. 2007 to 2016 Average Annual Diversion Rates for Reaches with Focus on Reach 8

2.8.1 Smith and McKnight Ditch

Ditch Overview –

The Smith and McKnight is the final irrigation diversion on the North Fork of the Gunnison and is located at 1385+65, immediately to the Southeast of downtown Hotchkiss, CO. It provides irrigation water to lands to the Southwest of Hotchkiss, in an area bounded by the North Fork to the North and West and arid bluffs to the South and East. Irrigators on the ditch typically cultivate corn, alfalfa, and dry beans. Figure 2.8.1.1 gives some average statistics for diversion amounts for a period from 2007 to 2016 for the Smith and McKnight Ditch.

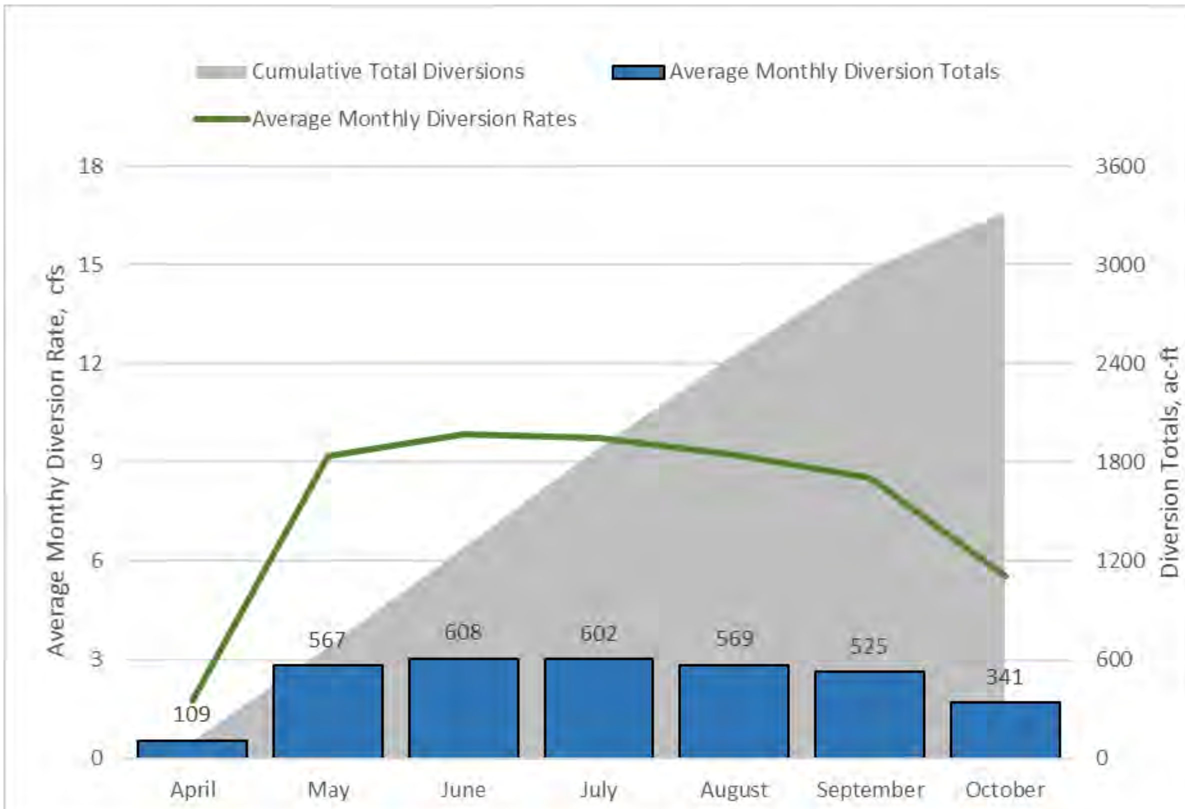

Figure 2.8.1.1. 2007 to 2016 Average Diversion Statistics for the Smith and McKnight Ditch

The Smith and McKnight reportedly diverts an average of 3322 ac-ft per year for 375.66 acres of irrigable land. Crop selection is dominated by grass and alfalfa, though dry beans are also reported on CDSS. Based on this data, 1048 ac-ft is required to properly irrigate the crops. The total system efficiency is 32%, which is depicted in Figure 2.8.1.2.

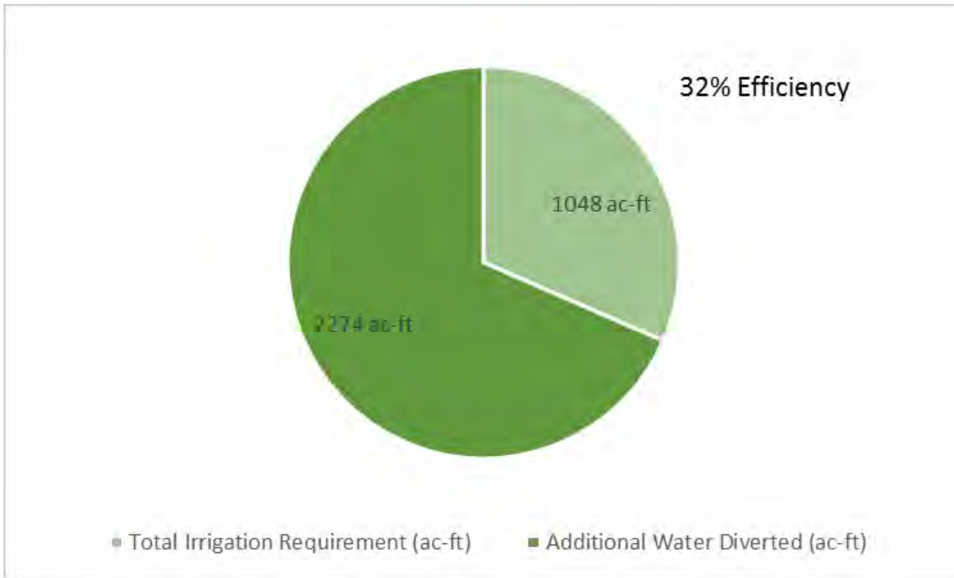

Figure 2.8.1.2. Calculated System Efficiency of the Smith and McKnight Ditch

Brief Diversion Description –

The Smith and McKnight Ditch Diversion occurs on the upstream side of the CO-92 highway bridge over the North Fork. It consists of an in-stream partially submerged boulder weir and a canal gate mounted to a concrete headwall, as shown in Figure 2.8.1.3. Behind the canal gate there is a pipe that brings water under the highway and into the Smith and McKnight Ditch. The concrete headwall is designed to prevent erosion of the bank, and also provides a point on which a safety fence is mounted on the front of the canal gate, which is shown in detail in Figure 2.8.1.4.

Figure 2.8.1.3. Smith and McKnight Diversion

Figure 2.8.1.4. Canal Headgate with Safety Fence

Structural Integrity and Diversion Functionality –

The ditch inlet structure (concrete headwall, gate, and safety fence) appears to be in good repair and is functional and appropriate for the ditch. The partially submerged boulder weir does not appear to have an engineered form, and seems to be an accumulation of stacked boulders over the course of many years. While the boulders are effective in diverting the river, during low flows they create a major river obstruction.

Ability to Divert Appropriate Range of Flows –

The canal gate allows for adjustments of flow rates to the Smith and McKnight Ditch. The size of the boulder weir allows for the water right to be diverted even in times of low flow.

Diversion Issues that Affect River Function –

It has been noted that often times during the late summer the Smith and McKnight Diversion tends to drawdown the river to levels that make recreational use of the river difficult immediately below the diversion.

Diversion Issues that Affect Recreational Users –

During times of low river flow, the Smith and McKnight Diversion creates a major obstruction in the North Fork of the Gunnison. The safety fence has been effective in helping recreational users safely navigate the section of the river.

Recommendations –

1. <u>Diversion Improvement</u>: Creating a more efficient and low profile weir with an engineered low-flow bypass may help alleviate issues of river function. The canal gate could potentially be lowered further into the stream with the inlet pipe extended further down the Smith and McKnight alignment to make the low profile weir functional during low flow conditions.
2. <u>Boat Passage</u>: Boat passage through the diversion or an overland passage around the diversion may assist with recreational issues at diversion.

Preliminary Cost Estimate –

1. <u>Diversion Improvement</u> - $50,000 to $100,000
2. <u>Boat Passage</u> - $25,000 to $50,000

3.0 IMPROVEMENT PRIORITIZATION

Potential river infrastructure improvements have been broadly categorized into three major categories, “Low”, “Medium”, and “High”. Category definitions are defined below:

Low – The “Low” category is for improvement projects that provide minor improvements to diversion efficiency or river function or are unlikely to receive grant funding.

Medium – The “Medium” category is for improvement projects that correct minor to medium safety deficits in river infrastructure and for improvements that can provide medium to high diversion efficiency or river function.

High – Improvements fall into the “High” category when there is a safety deficit in current river infrastructure that an improvement can immediately remedy. Other improvements in the “High” category are those which can greatly improve diversion efficiency or river function in a cost-effective and fundable manner.

Table 3.0.1, below, lists potential river corridor improvements with their associated priority category.

Table 3.0.1. Potential North Fork River Corridor Infrastructure Improvements

Reach	Applicable Ditch Company	Project Description	Desc. Of Benefits	Estimated Cost*	Relative Priority
2	Fire Mountain Canal	Boat Passage	Improved safety for recreationalists	$25,000 to $50,000	Medium
2	Carrol Ditch	Grouted Boulder U-Weir	Would allow for a longer irrigation season	N/A	Low
3	Stewart Ditch	River Signs	Improved safety for recreationalists	$1,000	Medium
3	Stewart Ditch	Island Stabilization	Improved long term river and diversion function	$20,000 to $50,000	High
3	Stewart Ditch	Upstream Headwall	Improved river function, improved safety for recreationalists	$100,000 to $300,000	Medium
3	Stewart Ditch	Diversion Relocation / Complete Rebuild	Improved long-term river function, improved diversion for ditch, improved recreational use	$1M to $3M	Low - Unlikely to be funded
4	North Fork Farmer's Ditch	Improved Diversion	Improved long term river function, improved safety for recreationalists	$75,000 to $100,000	High
5	Paonia Ditch	Secondary Spill Channel Improvements	Improved safety	$5,000	High
5	Paonia Ditch	Improved Headgate Structure	Reduction in silt for users on Paonia Ditch	$30,000 to $50,000	Medium
5	Paonia Ditch	Bank Stabilization	Improved long-term diversion function	$10,000 to $20,000	Medium
5	Monitor Ditch	Increase Headwall Height	Improved diversion functionality	$1,000	High
5	Monitor Ditch	Trash Rack	Improved safety for recreationalists, improved diversion functionality	$10,000	Medium
5	Shepherd and Wilmott Ditch	Trash Rack	Improved safety for river users, improved diversion functionality	$10,000 to $50,000	High
5	Shepherd and Wilmott Ditch	Bank Stabilization	Improved long-term river and diversion function	$20,000 to $50,000	High
6	Short Ditch	Diversion Improvement	Improved long-term diversion functionality, improved river function, improved recreational use	$100,000+	High
6	Short Ditch	Expand Water Control Channel	Improved diversion functionality	$10,000 to $25,000	High
6	Short Ditch	Bank Stabilization	Improved diversion functionality	$50,000 to $100,000	High
7	Vandeford Ditch	Engineered Spill	Improved diversion functionality	$30,000 to $50,000	Low
8	Smith and McKnight Ditch	Diversion Improvement	Improved diversion functionality, improved river function, improved reacreational use	$50,000 to $100,000	High
8	Smith and McKnight Ditch	Boat Passage	Improved recreational safety and use	$25,000 to $50,000	High

*Cost Estimates indicate potential conceptual project scale. Specific projects will require further feasibility and cost exploration

The proposed projects in Table 3.0.1 involve ditch infrastructure improvements that predominantly provide benefits that can be realized by both irrigators and non-consumptive users. The proposed projects do not, however, address many of the inherent irrigation inefficiencies within the Valley. Upgraded conveyance infrastructure (piping or lining) on many ditches could assist in improving conveyance efficiency while providing environmental benefit. For certain ditches, such as the Short Ditch and Smith and McKnight Ditch, combination projects to increase efficiency and reduce river infrastructure warrant exploration. Consideration for such projects must include verification that ditch combination will not upset current river administration, as described in Section 4.

4.0 AGRICULTURE'S POSITION ON THE NORTH FORK

4.1 Big Picture Issues for Agriculture

Agriculture has historical, cultural and economic significance in the North Fork Valley. The water rights and the irrigable land use reflect this. The users on the North Fork have historically done a great job protecting their rights by continuing to use their decreed water for beneficial uses. It is in the best interest of irrigators and the larger community to ensure that any infrastructure improvements do not endanger these water rights.

The biggest factor in determining beneficial use in irrigation is irrigated acreage. Irrigating agricultural land proves that water is used beneficially, which will preserve existing water rights. Permanent reduction of agricultural land use in the North Fork Valley could endanger the water rights. The extent of irrigated acreage in the North Fork is shown in Appendix B, which contains maps that show the irrigated lands for each diversion. This data was collected from the HydroBase Data Viewer from the Colorado Department of Natural Resources. These maps are intended to be used as a visual guide to show general areas served by each ditch and may not reflect the most current data. While beneficial use does account for system inefficiencies (conveyance and application), efficiency improvements will not endanger absolute water rights but should instead serve to benefit irrigators and secure the volume of the water right.

Avoiding a loss of decreed water is a top priority of both the agricultural community and those that enjoy the wooded and riparian areas created within the North Fork Valley. Better utilizing the water of the North Fork for multiple purposes should not, and will not, endanger the water rights of the irrigators.

4.2 Water Rights and Administration Concerns

Administration of water rights on the North Fork is complex. Water rights range in administration numbers from 14413.11840 (the Senior Most Right of the Stewart Ditch, appropriated in 1882) to flood decrees with very junior administration numbers and appropriation dates of as recent as 2015. Many ditches have multiple water rights with ranging seniorities. This results in the frequent total or partial discontinuance of junior rights throughout the valley and thus complex administration during mid to late irrigation season on many of the ditches. Table 4.1.1 provides a ranking of water rights by administration numbers. According to the agricultural interviews (compiled in Appendix C), it is historically rare that any ditch on the North Fork has been completely curtailed to satisfy a more senior diverter due to the portfolio of water rights possessed by many of the ditches.

Table 4.1.1. North Fork Water Rights by Administration Number

Adminstration Number	Diverter	Appropriation Date	Rate Amount (cfs)
14413.11840	STEWART DITCH	1882-06-01	1.3
14413.12054	VANDEFORD DITCH	1883-01-01	2.7
14413.12054	VANDEFORD DITCH	1883-01-01	0.6
14413.12100	MONITOR DITCH	1883-02-16	6.5
14413.12114	PAONIA DITCH	1883-03-02	9.5
14413.12483	SHEPHERD & WILMOTT DITCH	1884-03-05	8.2
14413.13185	VANDEFORD DITCH	1886-02-05	10.0
14413.14062	VANDEFORD DITCH	1888-07-01	1.8
14427.00000	PAONIA DITCH	1889-07-01	2.3
14567.00000	SHORT DITCH	1889-11-18	10.5
14766.00000	NORTH FORK FARMERS DITCH	1890-06-05	22.8
15702.00000	STEWART DITCH	1892-12-27	4.7
15873.00000	PAONIA DITCH	1893-06-16	0.6
16528.00000	PAONIA DITCH	1895-04-02	1.3
16882.00000	NORTH FORK FARMERS DITCH	1896-03-21	2.0
16954.00000	SMITH AND MCKNIGHT DITCH	1896-06-01	4.1
19415.12996	MONITOR DITCH	1885-07-31	1.8
19415.13938	CARROL DITCH	1888-02-28	0.6
19415.14567	SHORT DITCH	1889-11-18	2.2
19415.16770	STEWART DITCH	1895-11-30	50.8
19415.16954	SMITH AND MCKNIGHT DITCH	1896-06-01	0.9
19415.16998	SHEPHERD & WILMOTT DITCH	1896-07-15	0.4
19415.17059	FIRE MOUNTAIN CANAL	1896-09-14	50.0
19415.18353	SHEPHERD & WILMOTT DITCH	1900-04-01	2.9
19415.18718	STEWART DITCH	1901-04-01	1.1
19415.18718	SHEPHERD & WILMOTT DITCH	1901-04-01	0.2
19415.18718	SHORT DITCH	1901-04-01	6.5
19415.18718	SMITH AND MCKNIGHT DITCH	1901-04-01	0.6
19415.19083	SHEPHERD & WILMOTT DITCH	1902-04-01	0.5
19415.19083	SHORT DITCH	1902-04-01	4.5
19415.19083	SMITH AND MCKNIGHT DITCH	1902-04-01	0.3
19448.00000	SHEPHERD & WILMOTT DITCH	1903-04-01	0.4
19448.00000	SHORT DITCH	1903-04-01	2.5
19448.00000	SMITH AND MCKNIGHT DITCH	1903-04-01	1.8
21263.18353	FELDMAN DITCH	1900-04-01	1.9
21701.00000	FIRE MOUNTAIN CANAL	1909-06-01	44.5
25807.17623	NORTH FORK FARMERS DITCH	1898-04-01	7.3
25807.19783	SHORT DITCH	1904-03-01	17.3
25807.22261	STEWART DITCH	1910-12-13	19.3
25807.23550	FIRE MOUNTAIN CANAL	1914-06-24	7.5
29260.18730	PAONIA DITCH	1901-04-13	21.4
30771.00000	SMITH AND MCKNIGHT DITCH	1934-04-01	2.7
31924.12100	MONITOR DITCH	1883-02-16	2.0
31924.12483	SHEPHERD & WILMOTT DITCH	1884-03-05	3.5
31924.17059	FIRE MOUNTAIN CANAL	1896-09-14	30.0
31924.31197	FIRE MOUNTAIN CANAL	1935-06-01	90.0
31924.31197	FIRE MOUNTAIN CANAL	1935-06-01	16.0
46020.18353	FELDMAN DITCH	1900-04-01	1.9
52595.25932	STEWART DITCH	1920-12-31	5.0
60306.00000	FIRE MOUNTAIN CANAL	2015-02-10	100.0
60630.13118	STEWART DITCH	1885-11-30	5.0
Total:			591.8

Like many other river systems in western Colorado, but perhaps to a greater extent, administration of rights on the North Fork is a function of both priority and location. Beginning at the Fire Mountain Canal diversion and ending at the Smith and McKnight diversion, there are twelve diversions within an approximately 19.1 mile long reach. Within this same 19.1 miles, there are countless arroyos and washes, and numerous tributaries including Terror Creek, Minnesota Creek, Jay Creek, and Roatcap Creek. Nearly all of the ditches begin and end within this 19.1 mile segment, meaning that there are return flows from certain ditches before other ditches have diverted flow. Appendix D contains the North Fork of the Gunnison River Straight-Line Diagram from "North Fork Study", prepared by Clear Water Solutions in July 2014. This diagram illustrates the approximate locations of many of the large inflows and outflows along the river. It does not, however, illustrate ditch tailwater returns and subsurface flow from up-gradient irrigation, which have significant contribution to total streamflow at the down-river diversions.

Downstream of the Paonia Ditch, river flows are increased by incoming tributary flows from Minnesota Creek, Stevens Gulch, and Roatcap Creek all before the next irrigation diversion (Monitor Ditch). The incoming flow is often sufficient to satisfy many rights downstream of the Paonia Ditch, while allowing the Paonia Ditch to divert the entire available natural stream flow. In many ways, this allows water rights on the North Fork to be administered as if there are two separate, unconnected rivers divided by the Paonia Ditch. This often allows for upstream Juniors to continue diverting later in the season.

While there are countless scenarios for how water is administered on the North Fork, acknowledgement that both priority and location are critical components of administration is vital. Changes in efficiency could have a direct impact on individual irrigators. Significant projects to increase efficiency may provide recreational and/or environmental benefit. However, water administration impact studies may be a prudent exercise before any major projects are undertaken.

4.3 Cooperation with Other Water Users

There are several non-agricultural communities that have an interest in agricultural use of water on the river. These communities include both recreationalists and environmentalists, and their interests can benefit from many of the infrastructure improvements provided in this report. Many of the proposed river corridor improvement projects increase safety and river function, while providing a functional benefit to the irrigators by ensuring operable infrastructure. Multiple beneficiaries to single projects can allow ditch companies and irrigators to leverage the benefits for partial or total funding of projects.

5.0 CONCLUSION & RECOMMENDATIONS

The North Fork of the Gunnison River is a complex system with many beneficial uses competing for a renewable, but at times scarce resource. The agricultural uses of water benefit from their position as senior appropriators of the natural flow of water, and have a stake in protecting their right to beneficial use of the water. The diversions for irrigation purposes support significant riparian habitat along the river corridor as well as maintain the North Fork Valley as an important agricultural region within Colorado.

Increased value is being recognized within the surrounding community of the benefits of non-consumptive uses of the water. Recreationalists are increasingly placing value in the river as an important place for boating and fishing. River health continues to be emphasized by interested groups, some with a significant local presence. Late season flows are often viewed as a proxy for river health. Historically late season river flows were likely less than seen today. Return flows from irrigation coupled with stored water released from Paonia Reservoir and other smaller storage facilities on the Grand Mesa that are tributary to the North Fork likely increase late season river flows on the North Fork.

Historically the river has been managed primarily as a means of supplying irrigation water to the surrounding community. This report does not intend to suggest any change to this use of the river corridor. However, there is significant opportunity to manage the river in a way that maintains the historic use of the river as a means for irrigation delivery while recognizing non-consumptive uses and at times utilizing the infrastructure and seniority of the agricultural rights to increase the beneficial use of the resource in the Valley.

Our recommendations for action within the river corridor are as follows:

1. **Create a small-scale water control structure grant program**.

   There is a significant amount of aging infrastructure associated with irrigation diversions and conveyance infrastructure. A grant program could be set up, potentially with seed money from a local non-consumptive use group, and potentially augmented with state funds. The program would likely be best administered by the Delta Conservation District or the North Fork Water Conservancy District. A very simple application could be generated. Irrigators could apply for funds for small-scale repair of water control structures within the valley.

   A grant program like this was successfully executed in the Plateau Valley (on the North side of the Grand Mesa) for a number of years. Simple ranking criteria, such as that used in our project prioritization, could be developed in order to guide the projects towards solutions that create multiple benefits. Emphasis should be placed on structures that decrease the use of proportional splits and provide opportunity to increase on-farm efficiency.

2. **Develop a conservation program allowing for irrigators to monetize "foregone diversion".**

   This is likely a complex idea and would require significant administration to develop. However, a conservation program of this type may be feasible for at least a portion of the

North Fork. There are also potentially interested non-consumptive use groups who may "lease" foregone diversion from irrigators for environmental purposes. State law allows conservation practices of this nature with no risk to future water rights transactions if the program is sponsored by and approved by a water conservation district such as the NFWCD of the CRWCD. A water conservation program of this type may also serve as the basis for future "demand management" associated with drought resiliency and already identified in the Colorado River Basin Drought Contingency Plan.

3. **Begin (and continue in some cases) to educate irrigators and community members that the basis for any value associated with the beneficial use of irrigation water is dominated, not by the diversion, but by the irrigated acreage.**

   It appears in the data that many diversions from the North Fork are far above crop demand during the spring and early summer. A significant portion of the increased diversion is likely a product of insufficient and/or inefficient infrastructure, and therefore necessary and beneficial. However, some of the excessive diversion can likely be attributed to a misunderstanding of the "use it or lose it" nature of Colorado water law. Leaving this water in the river has no effect on the value of a water right.

4. **Emphasize and support a funding plan for improvements to the following large diversions:**

   a. A feasibility study on combining the diversion and conveyance infrastructure of the Short and Smith-McKnight Ditches, or reconstruction of existing Smith-McKnight diversion to allow for bypass flows when appropriate and boat passage and possibly incorporated boater access.

   b. Stewart Ditch, construction of a new diversion or rehabilitation of the existing facilities with incorporated riparian bioengineering and geo-stabilization on the "island" created between the diversion channel and the North Fork.

   c. Fire Mt Canal, rehabilitation of existing facilities, including continued support for reservoir rehabilitation and efficiency projects. Specific emphasis should be placed on eliminating proportional splits of irrigation water within the lateral system on Roger's Mesa.

   d. North Fork Farmer's Ditch, rehabilitation of existing diversion structure. Specifically removing exposed iron (see Figure 2.4.1.3).

   e. Shepherd and Wilmott Ditch, placement of rock rip-rap and in stream low profile rock weir to stabilize river movement.

5. **Emphasize and support projects that remove proportional splits from conveyance infrastructure.**

   It remains very common in the North Fork Valley for shares of water to be split amongst users utilizing proportional splits of available water. This is the single biggest limitation to flexible water management in the Valley. Under current conditions, each ditch must remain as full as possible in order to deliver the maximum demand to any single user. The ability of an irrigation system to deliver large quantities of water to each user is an important function, and in an on-demand system, is an important part of an efficient irrigation system. The largest impact may be felt by converting the shareholders in the Fire Mountain from proportional splits to an on-demand system. This could, if managed properly, free up natural flow for the other users that in turn frees up natural flow for the river system itself.

6. **Support the rehabilitation of Paonia Reservoir and encourage increased management**.

   Paonia Reservoir currently has a huge positive effect on the river system and has the potential through increased management of the water resource to have an even greater effect on the overall health of the river for all users.

7. **Continue to support Colorado River Salinity Reduction projects with local and state funds.**

   Conveyance efficiency improvements will benefit not only the irrigators but also the environmental and recreational community. The United States Bureau of Reclamation (USBR) provides funding to projects that reduce salinity inflows into the Colorado River and its tributaries. The North Fork community should continue to utilize these federal funds to pipe open irrigation canals. State grant and loan funds are available to increase the cost effectiveness of the projects and local and state decision makers should continue to emphasize the opportunities available to the irrigators.

APPENDIX A – MAPBOOK

North Fork of the Gunnison

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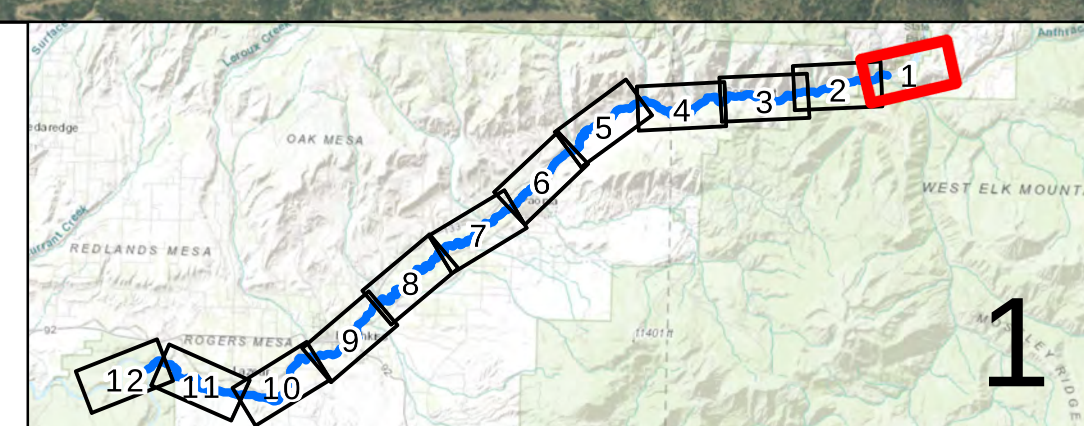

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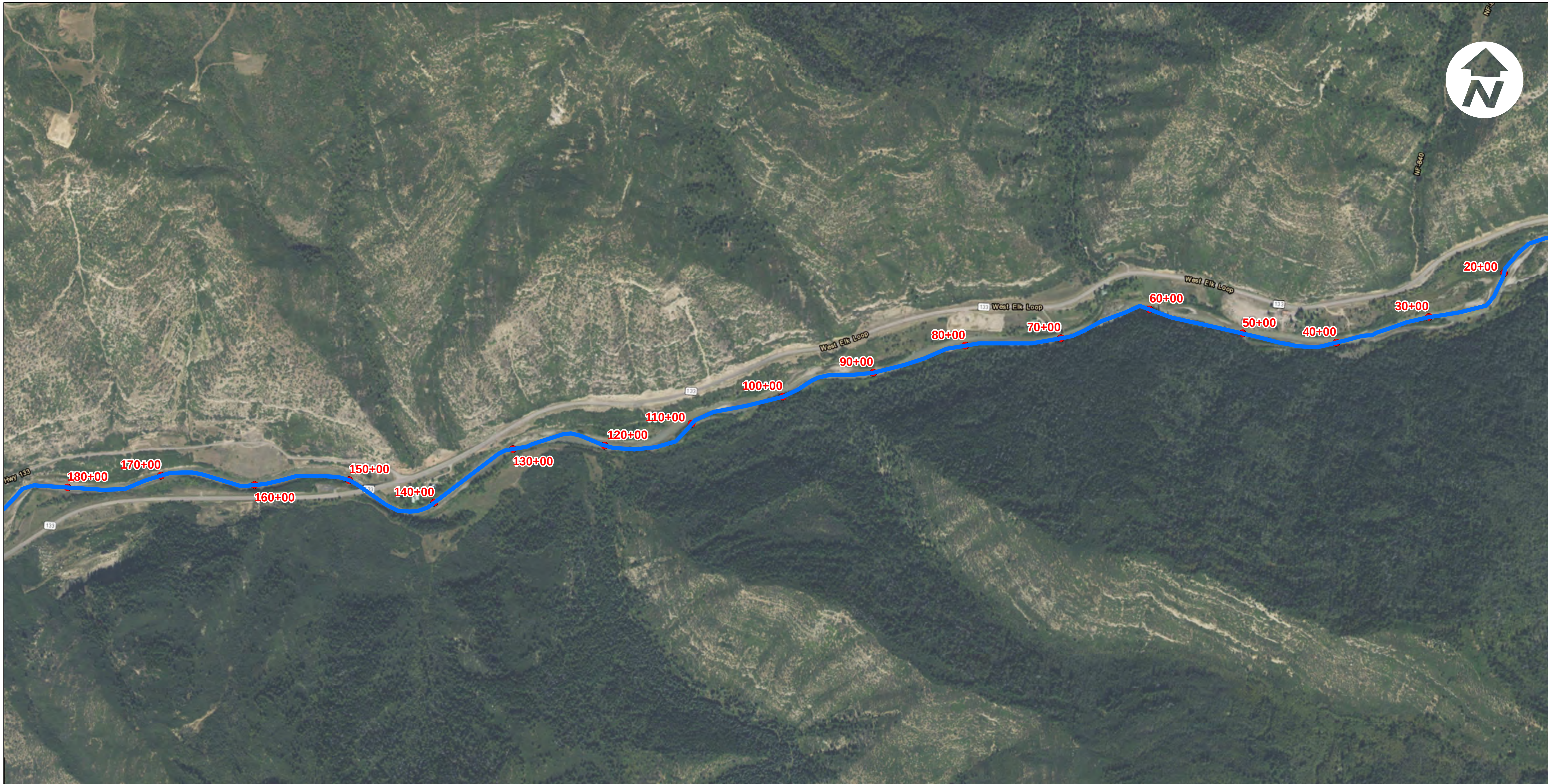

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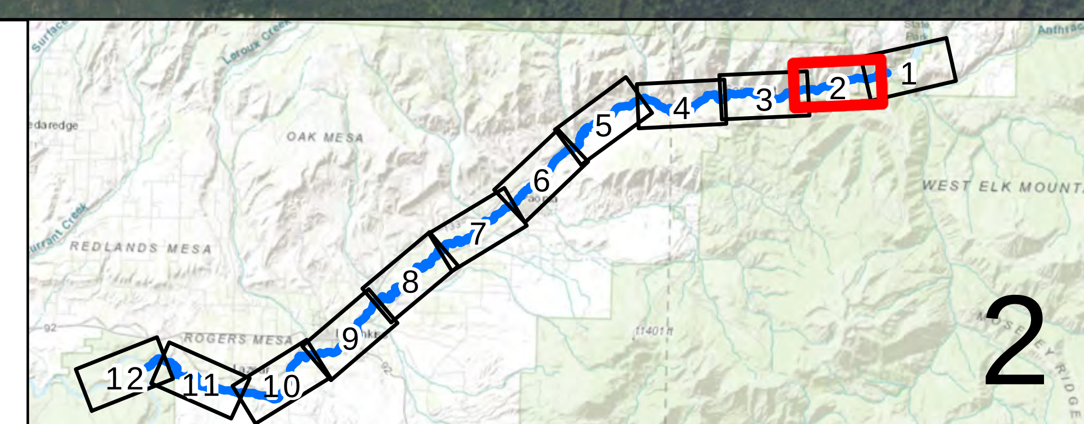

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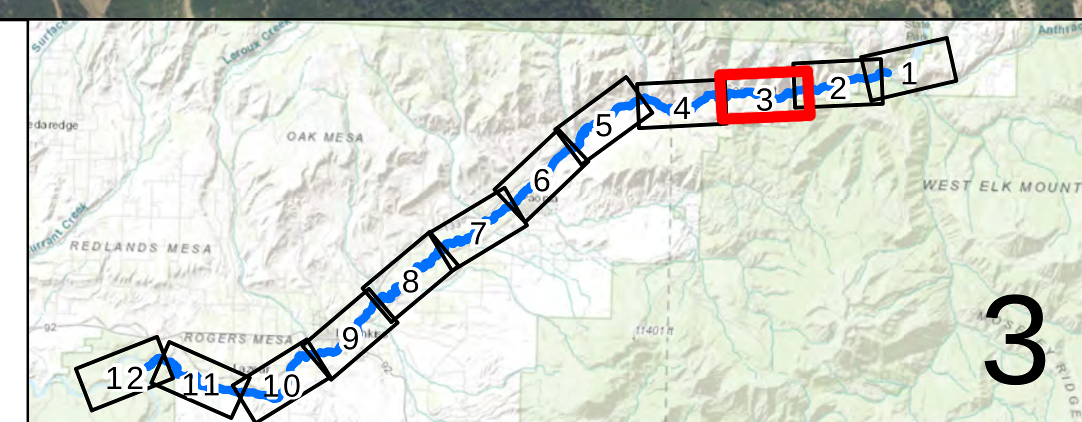

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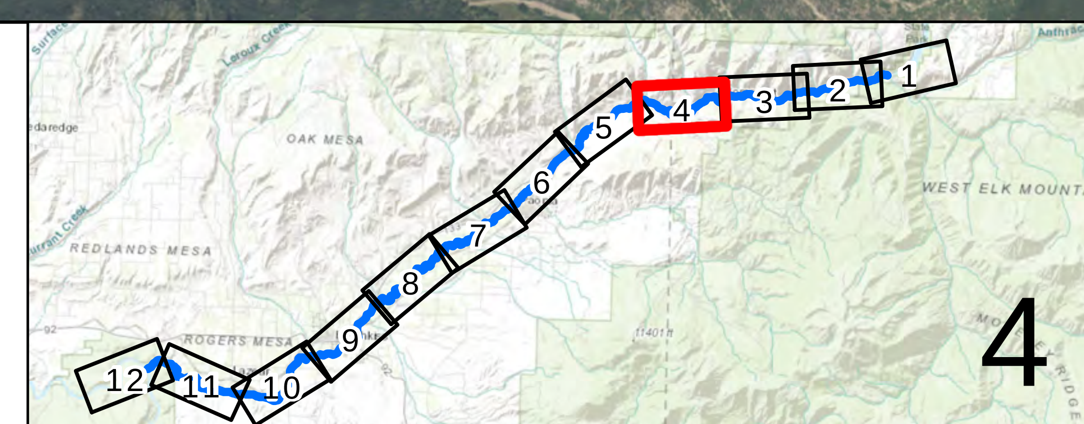

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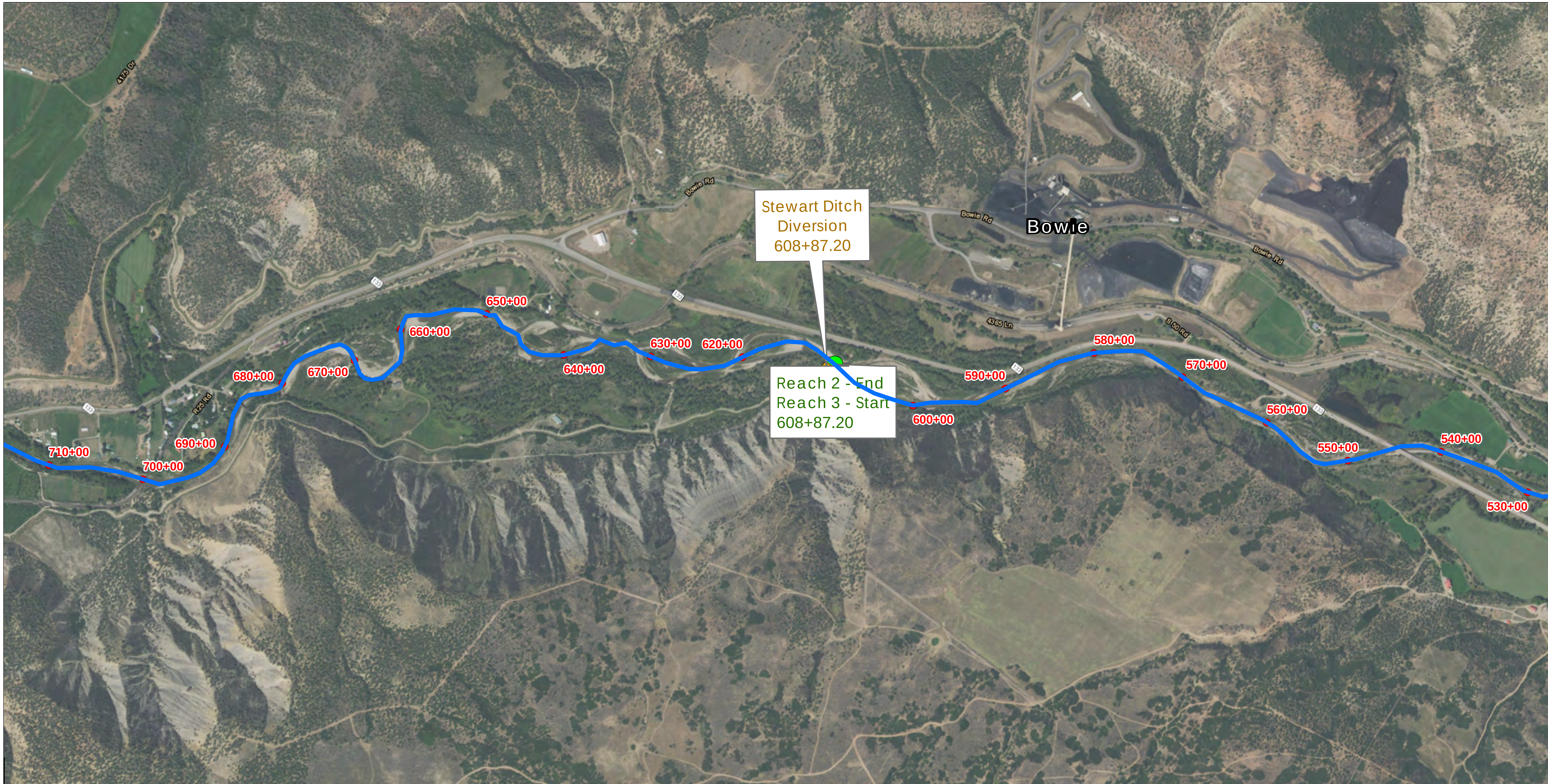

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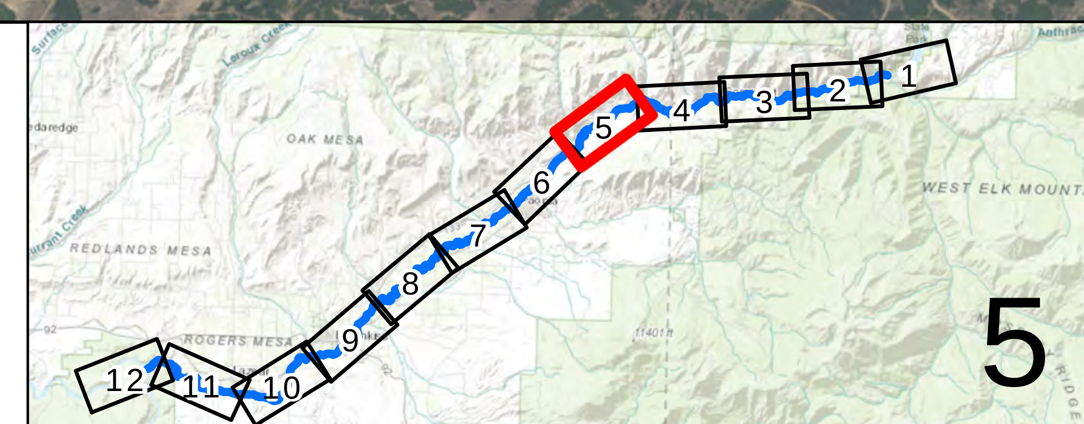

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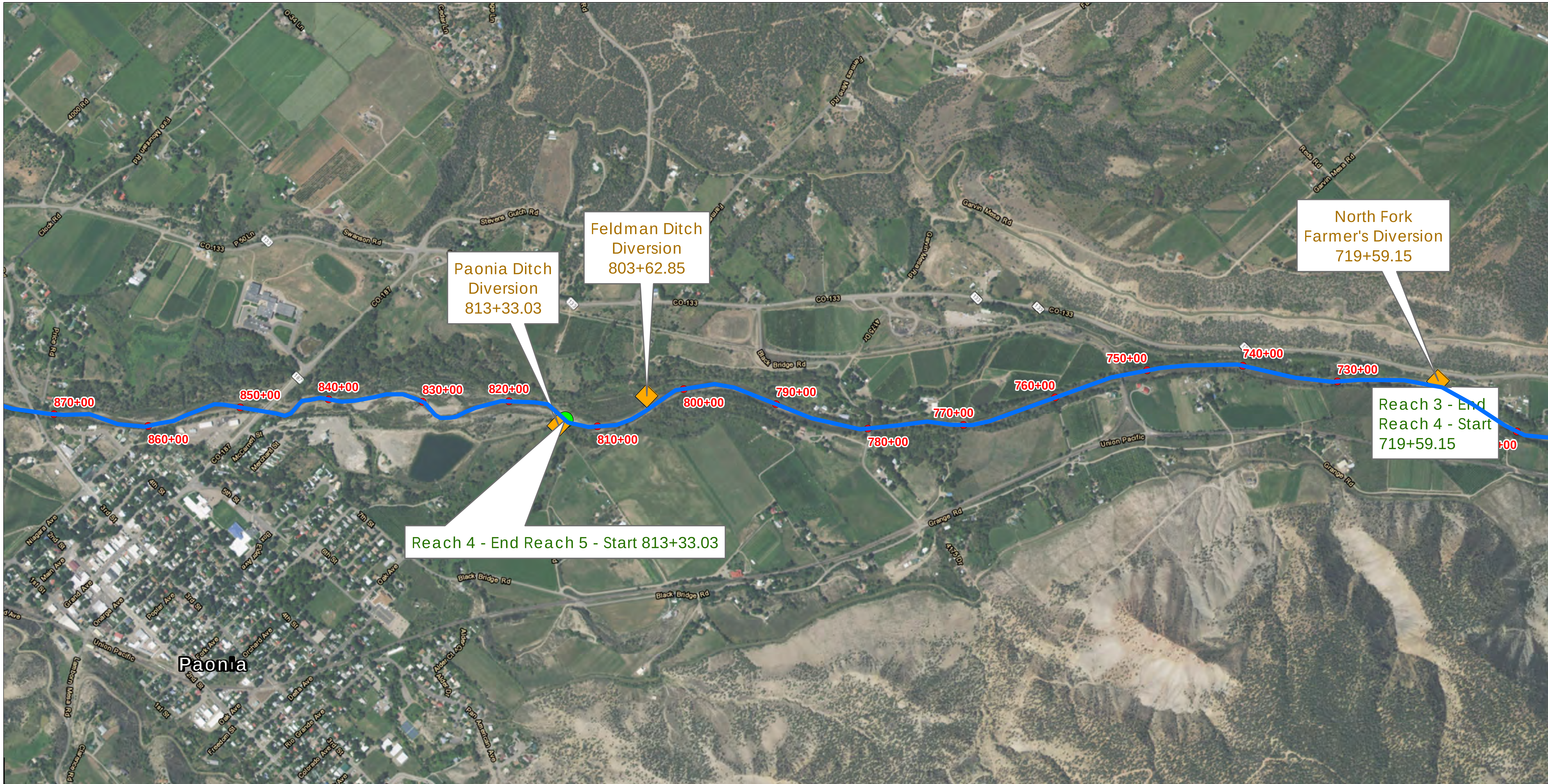

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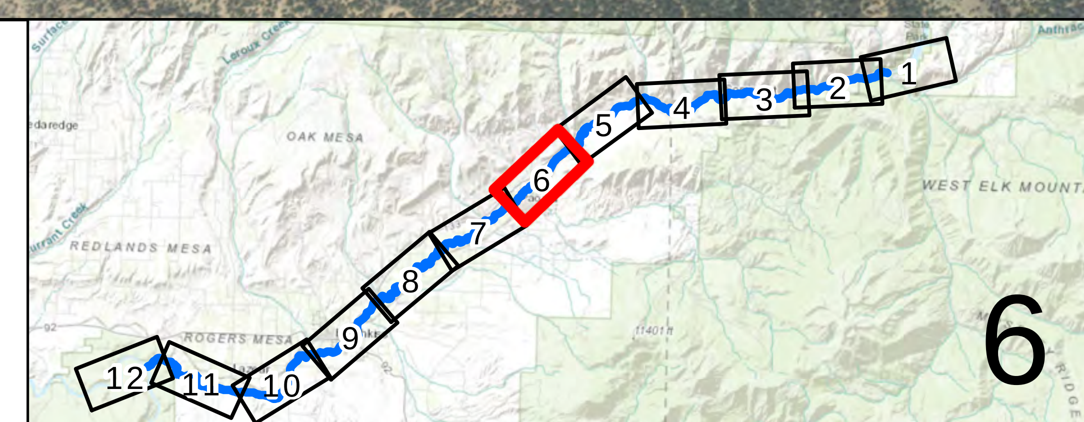

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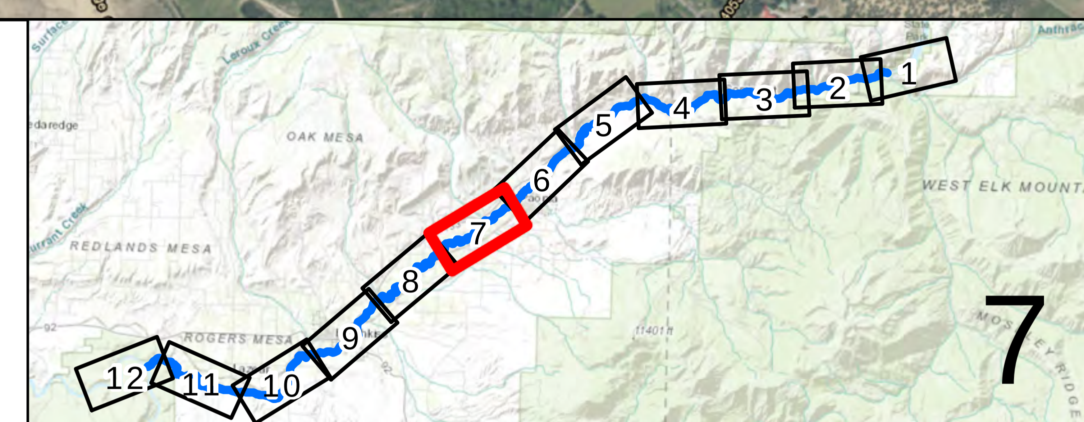

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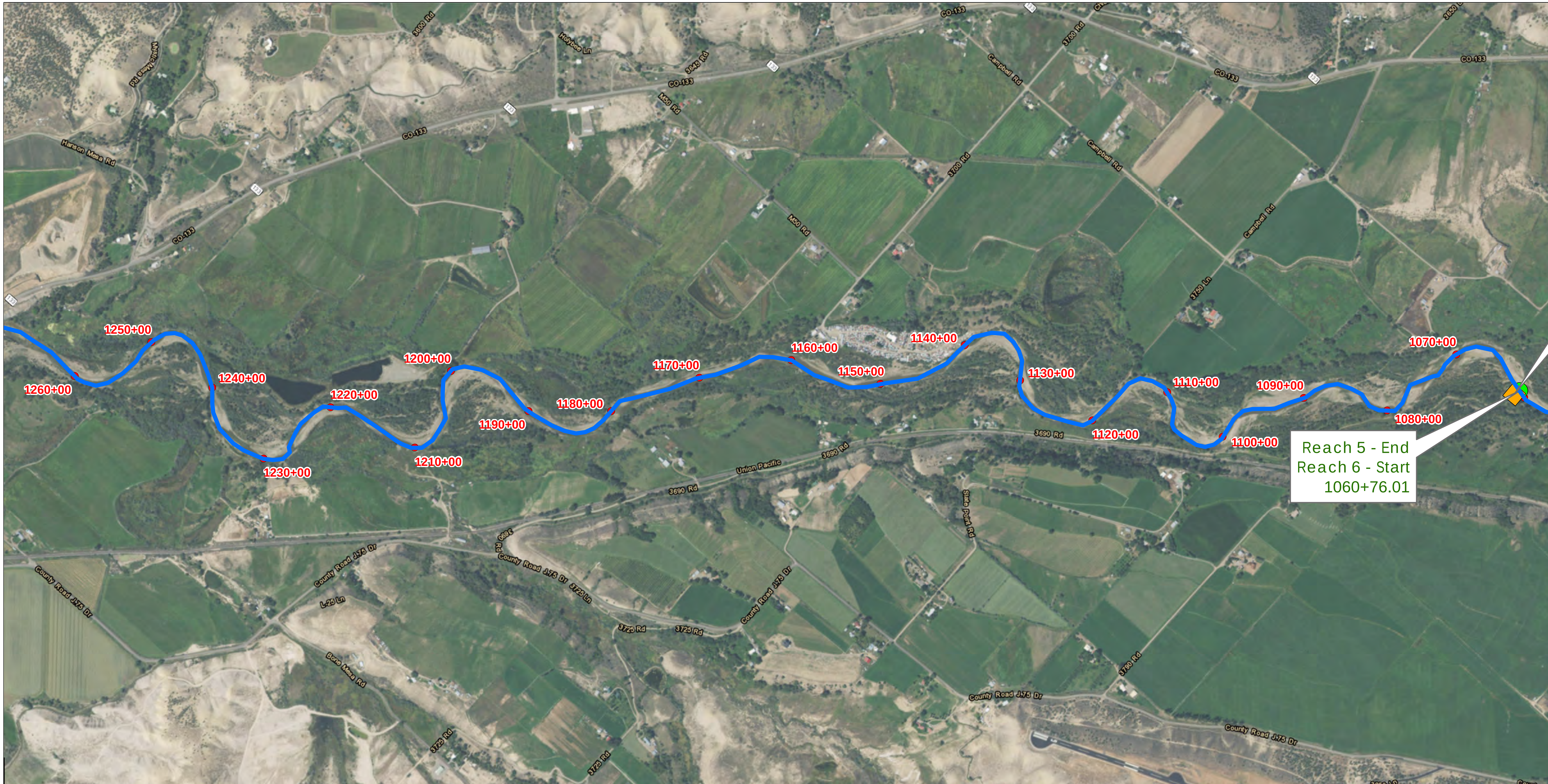

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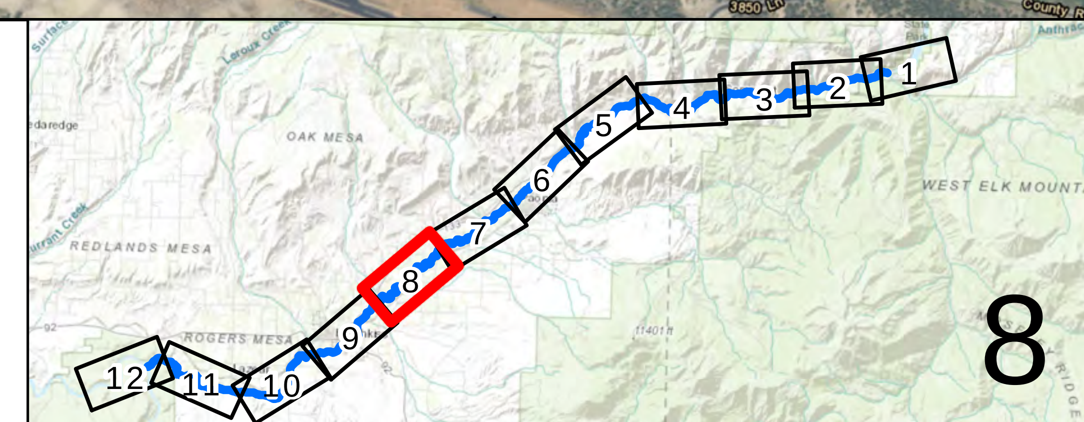

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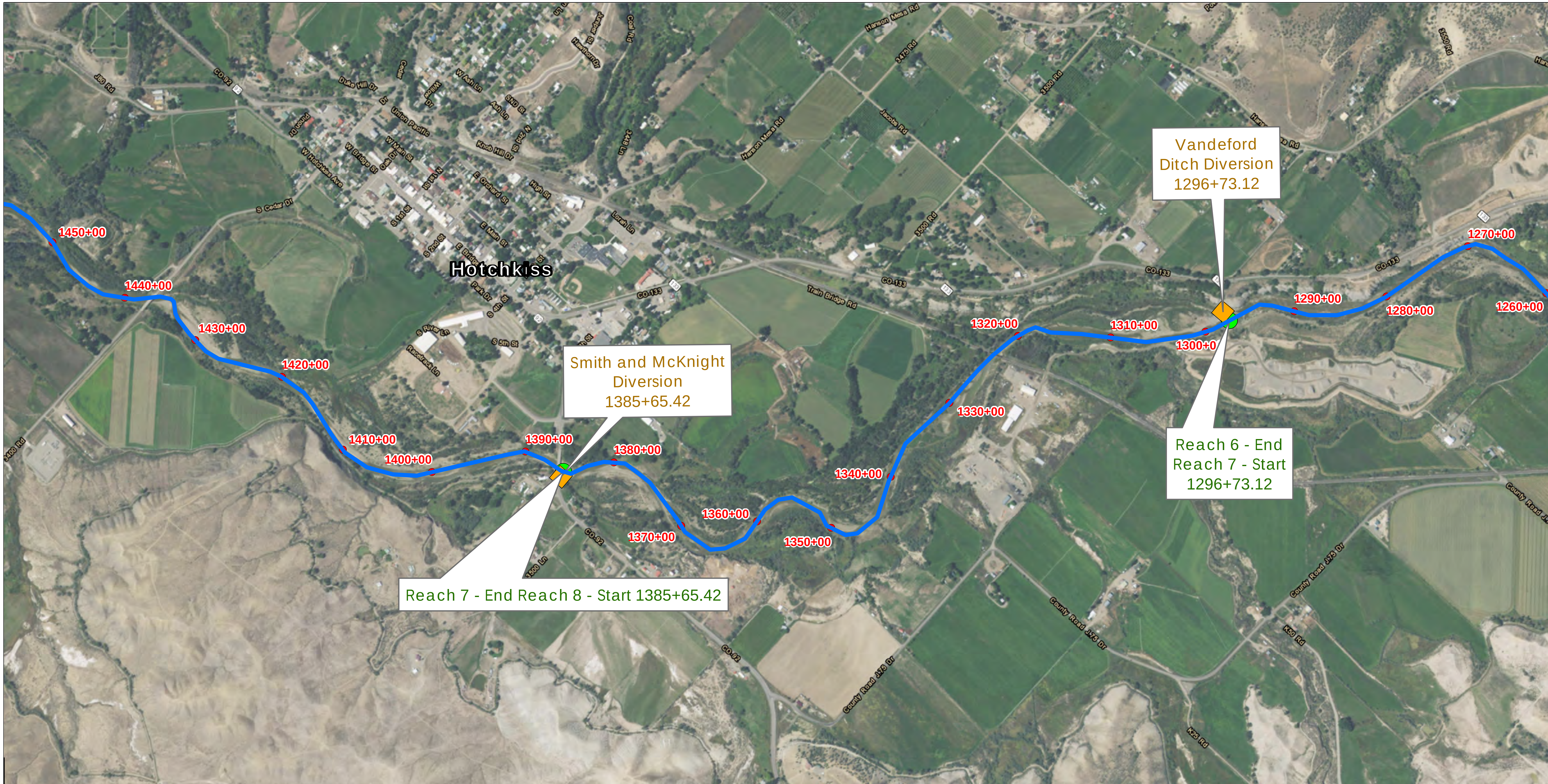

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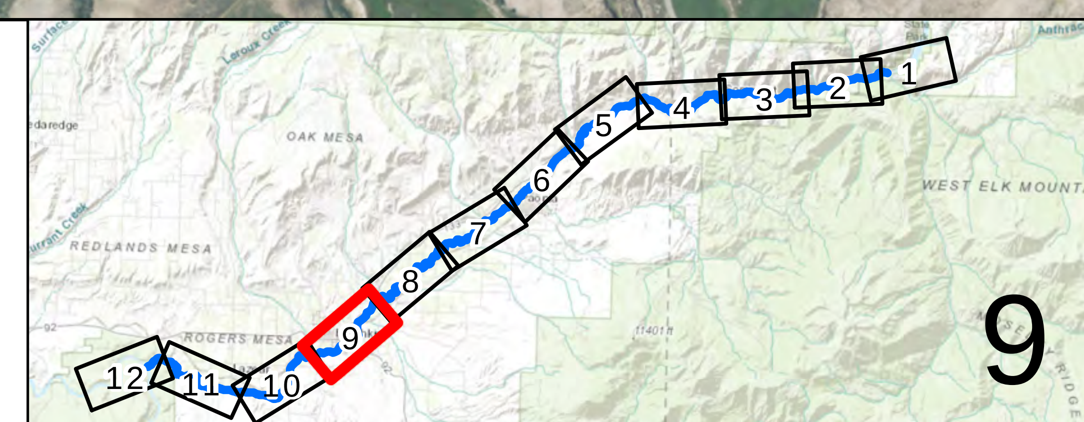

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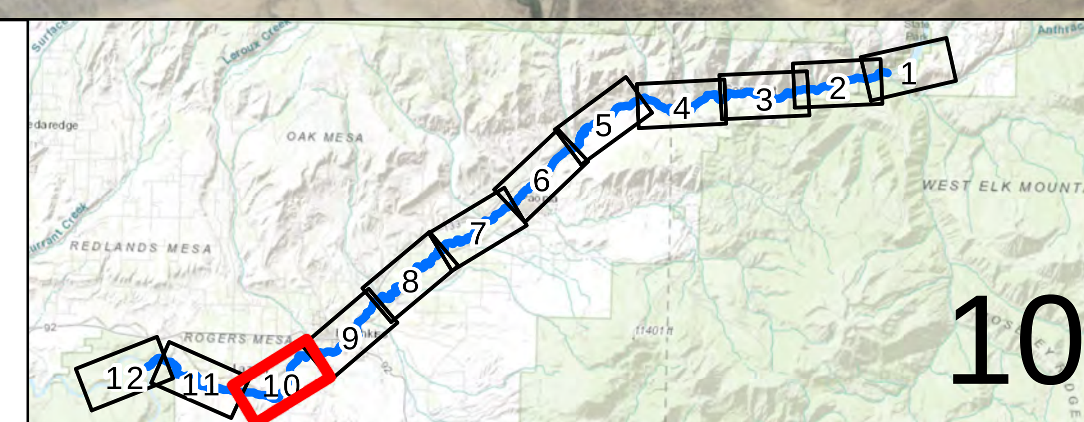

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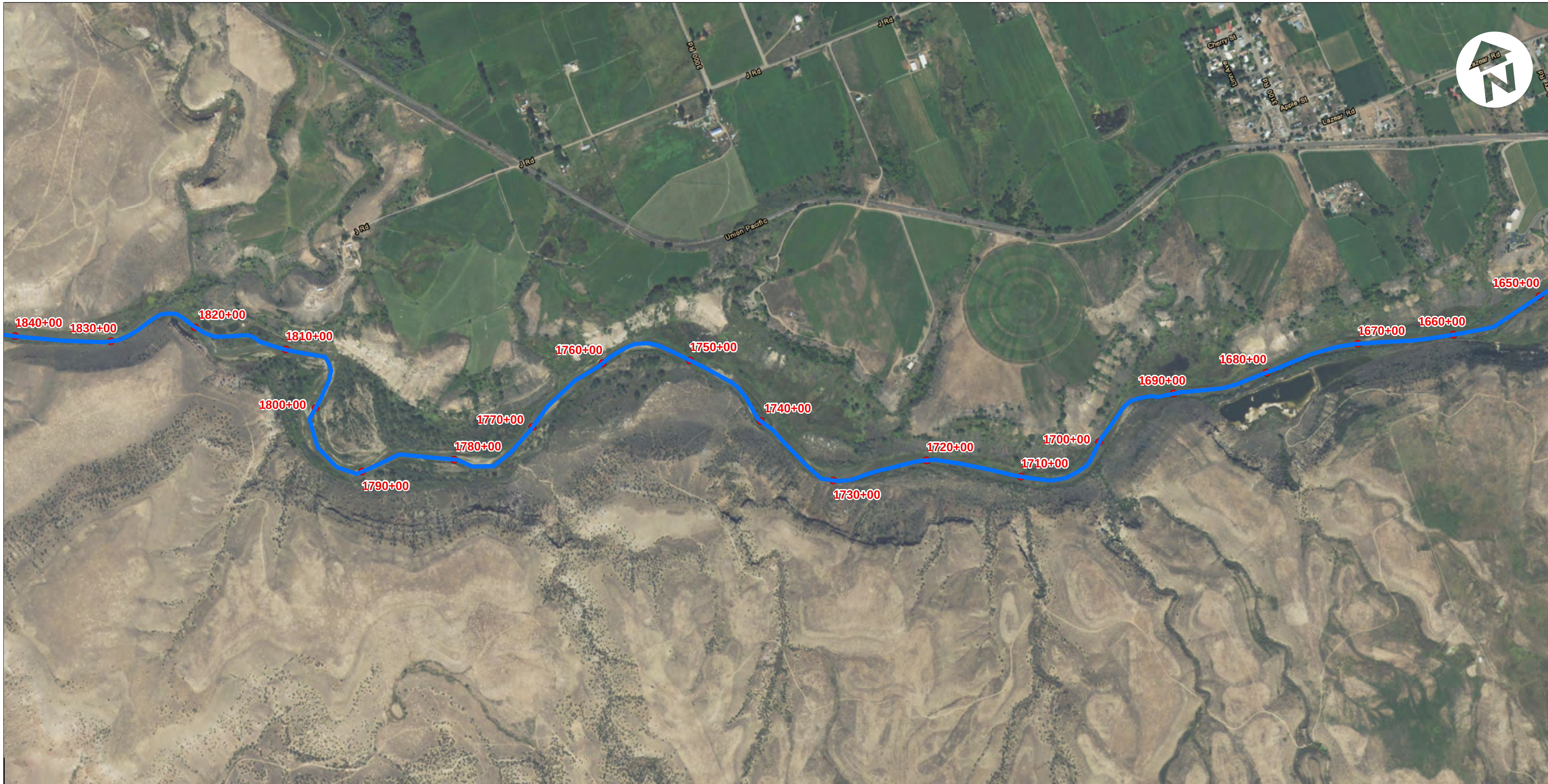

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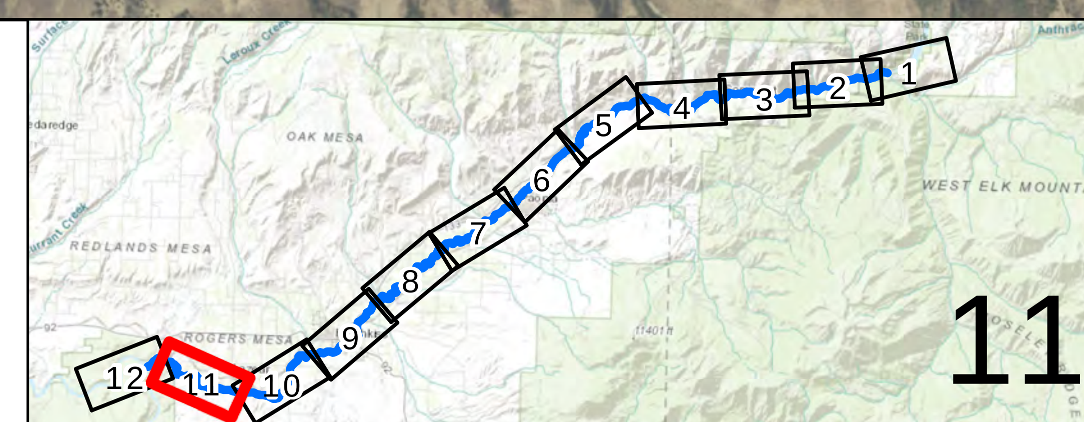

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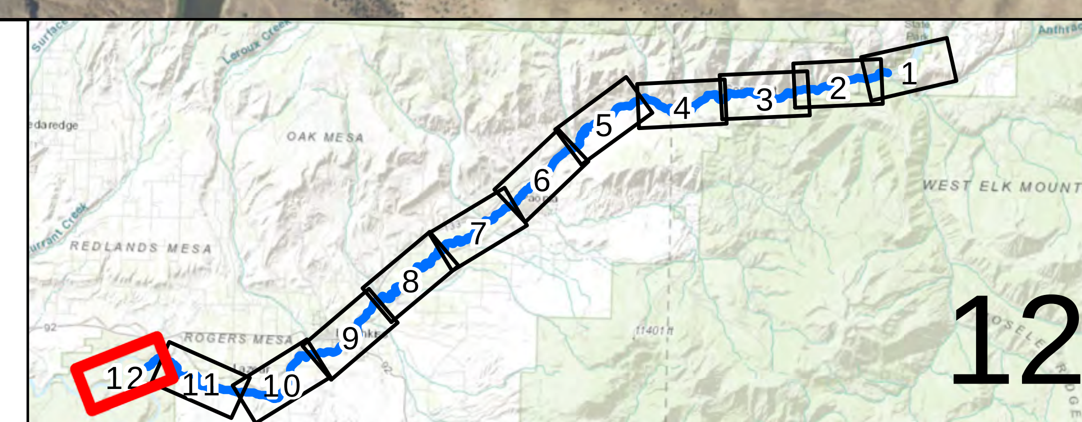
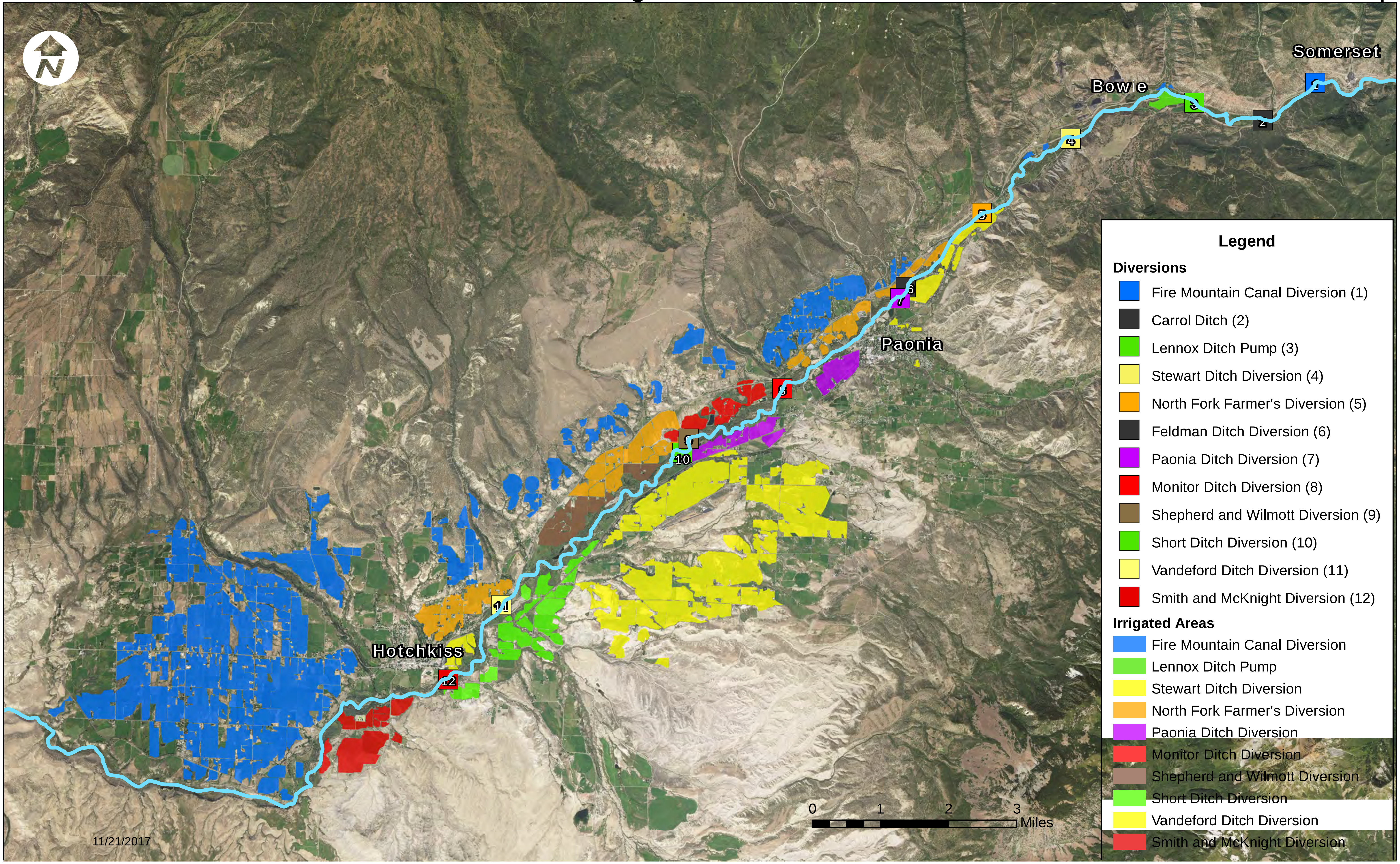


APPENDIX B – MAPS OF IRRIGATED LANDS

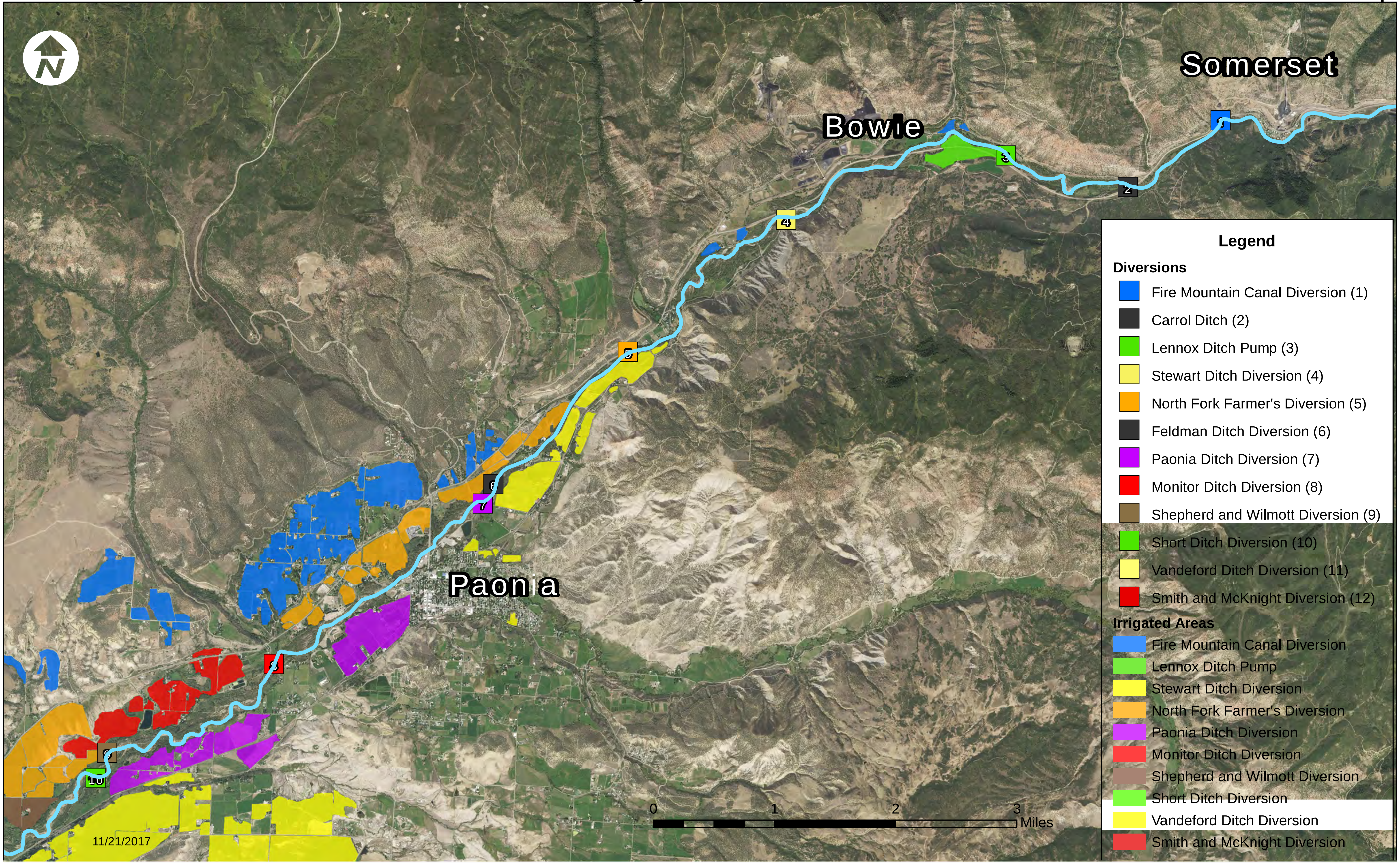
North Fork of the Gunnison: Diversions and Irrigated Lands

Overview Map



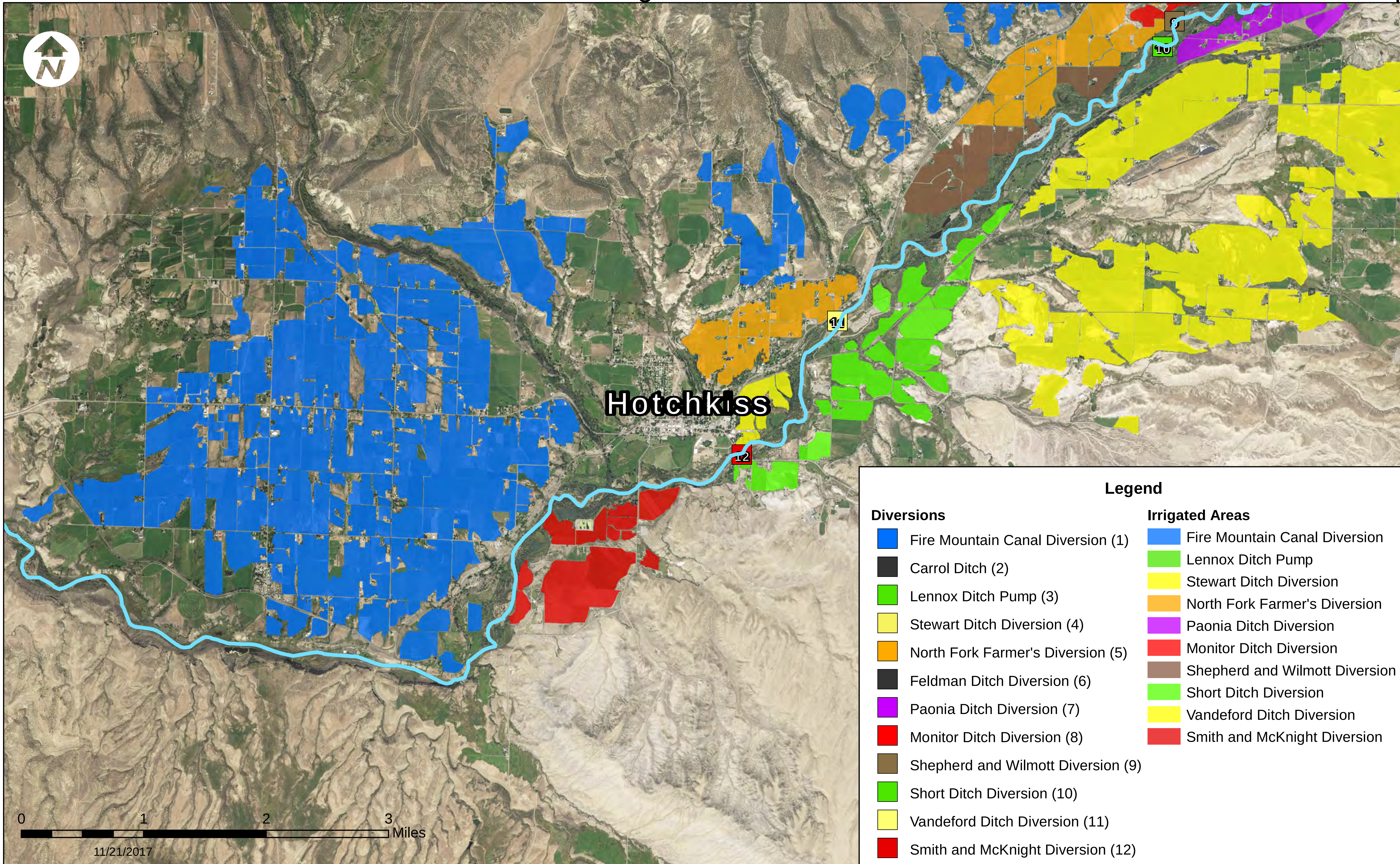
North Fork of the Gunnison: Diversions and Irrigated Lands

Overview Map



North Fork of the Gunnison: Diversions and Irrigated Lands

Overview Map



APPENDIX C – RESPONSES TO AGRICULTURAL INTERVIEWS

Fire Mountain Canal

Interviewee: [redacted]

J·U·B ENGINEERS, INC.

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**Multiple decrees, exchange agreements, very complicated. Div 4 ([redacted]) knows best how it is administered and when and why. Clearwater report should contain water rights data.**
a. How often do you get called out?	**Often, but there is Paonia res water for the project**
• Who is calling you out?	**“Assumed” call by Paonia ditch, other DS mainstem diversions**
b. Is there any stored water released to your diversion?	**Yes**
• How much?	**15,300 ac-ft**
• When?	**Throughout season, fruit growers would like later water**
2. Is there any record of the acres served by the diversion?	**Yes. Not sure where, shares are tied to acres, but can be sold**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	**Yes**
b. Have you been successful in securing funding?	**Yes, salinity funding, other Reclamation grants**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**A few boaters use the river near diversion, fishermen use it too**

5. What about your diversion would you change if funds were available?	Automate emergency canal gates (see Mcloughlin report), change orientation of intakes, need better sluice channel, big gravel bar gives them trouble in front of diversion.
6. How are orders for water placed within the system?	No orders placed, 130% of shares early, 100% shares until res is exhausted
7. What are typical turn in/turn out dates?	Turn in – Mid-April Turn out – September
8. Is there any stockwater decreed and/or used on the system?	Some water enters FM Canal at Leroux Creek and is utilized for stock – unsure of water right of exchange
9. What type of crops are grown?	Forage/fruit/some row crops/some vineyards
a. Are there any trends towards other crops?	Did not ask
10. Have USDA-NRCS programs had an impact on the overall system?	Yes
11. Who are your current Board members?	FM Canal board and NFWCD board (I did not get this information at the time of interview)

a. Do you have any staff? Please describe.	**4 people**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**Yes, [redacted]'s email**
	Yes

Additional notes:

This conversation took place on Aug. 4, 2016; [redacted] is current manager. [redacted] has a lot of experience, but was still quite new to his position as manager of the FM Canal. Therefore, he did not have as much information as he would like, but he will quickly be coming up to speed. [redacted] is a very knowledgeable manager, and has been through the process of infrastructure improvements with other water users and canals. [redacted] definitely expressed that he sees the opportunity to extend the usefulness of the storage in Paonia Reservoir.

Interview done with [redacted] and [redacted]

Carrol Ditch

Interviewee: [redacted]

J·U·B ENGINEERS, INC.

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**Take as much as possible until call comes on**
a. How often do you get called out?	**Has never been called out**
• Who is calling you out?	**N/A**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**No, used to be entire river bottom previously. Lots of it is currently overgrown.**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☐ N☒**
a. Can I get a copy of what exists?	**N/A**
b. Have you been successful in securing funding?	**N/A**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**N/A**
5. What about your diversion would you change if funds were available?	**Nothing currently. Would see what (if anything) was offered and evaluate any suggestions.**

Interview Questions and Responses

6. How are orders for water placed within the system?	**None. Only one irrigator**
7. What are typical turn in/turn out dates?	**Turn in – April 1st** **Turn out – End of October**
8. Is there any stockwater decreed and/or used on the system?	**Yes**
9. What type of crops are grown?	**Hay**
a. Are there any trends towards other crops?	**No**
10. Have USDA-NRCS programs had an impact on the overall system?	**No**
11. Who are your current Board members?	[redacted] **(owner)**
a. Do you have any staff? Please describe.	**No**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	[redacted]
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**No, he prefers flood irrigation**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**No, everything is in good shape now**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**No**

Additional notes:

Lennox Ditch

Interviewee: [redacted]

J·U·B ENGINEERS, INC.

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**Multiple Decrees totaling 348 gpm, and high water decrees.**
a. How often do you get called out?	**Usually annually. It was August in 2016**
• Who is calling you out?	**Fire Mountain Canal**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**Unsure, but there are approximately 60 acres**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	**N/A, all work is completed**
b. Have you been successful in securing funding?	**Work was privately funded with NRCS Engineering Help**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**N/A**
5. What about your diversion would you change if funds were available?	**Nothing**

6. How are orders for water placed within the system?	**N/A, only one user on "ditch"**
7. What are typical turn in/turn out dates?	**Turn in – late May or June** **Turn out - October**
8. Is there any stockwater decreed and/or used on the system?	**No**
9. What type of crops are grown?	**All Alfalfa**
a. Are there any trends towards other crops?	**No**
10. Have USDA-NRCS programs had an impact on the overall system?	**Yes, they designed the sprinkler system**
11. Who are your current Board members?	**None**
a. Do you have any staff? Please describe.	**None**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	[redacted] **Office #:** [redacted]
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**No, entire system is already pressurized, in pipe, and in sprinklers**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**No, it is all piped.**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**No, pivots and sprinklers work great.**

Additional notes:

The Lennox Ditch serves one water user. Water is taken from the stream via an NRCS designed pump system.

Stewart Ditch

Interviewee: [redacted]

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**59 cfs, 19 cfs out of Minnesota (separate from our plan)**
a. How often do you get called out?	**It happens almost yearly – none in 2016**
• Who is calling you out?	**Probably the Short Ditch**
b. Is there any stored water released to your diversion?	**Lost Lakes slough water**
• How much?	**Not much**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**Yes, they have some record – around 2500 acres**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	**Salinity FOA 2017 and 2012/2013**
b. Have you been successful in securing funding?	**Yes – first; yes, for 2017 (except salinity)**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**N/A**
5. What about your diversion would you change if funds were available?	**Diversion changes necessary. During high water a sluice for first section; headgate repair.**

6. How are orders for water placed within the system?	**Traditionally proportional split with new flexibility or current changes adjusting to pipeline**
7. What are typical turn in/turn out dates?	**Turn in – April 15th** **Turn out – October 15th**
8. Is there any stockwater decreed and/or used on the system?	**Yes – year-round**
9. What type of crops are grown?	**Some small grains, corn, hay, orchard, pasture**
a. Are there any trends towards other crops?	**Hops, hemp**
10. Have USDA-NRCS programs had an impact on the overall system?	**Yes**
11. Who are your current Board members?	[redacted]
a. Do you have any staff? Please describe.	**Yes – DR hired**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	[redacted]
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**They could have an impact**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**Yes - piping**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Some individuals are interested in on-farm efficiency improvements**

Additional notes:

North Fork Farmer's Ditch

Interviewee: [redacted]

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**32 cfs at flood, 26 cfs on decree**
a. How often do you get called out?	**No call. Sometimes work with Paonia and Short Ditch to find solutions**
• Who is calling you out?	**N/A**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	[redacted] **believes that the NRCS did a study, however, he does not believe this is in a decree.**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	[redacted] **(secretary/treasurer –** [redacted] **has the info. Harward did FOA application, Applegate did survey)**
b. Have you been successful in securing funding?	**No, salinity numbers were too low**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☒ N☐**
a. If yes, can you elaborate?	**A few complaints, nothing major**
5. What about your diversion would you change if funds were available?	**Probably not much. The diversion works great. Might consider improvements to help with recreational issues.**

Interview Questions and Responses

6. How are orders for water placed within the system?	**No orders. Proportional split used to measure. It is satisfactory though some control would help**
7. What are typical turn in/turn out dates?	**Turn in – April 5th** **Turn out – October 15th**
8. Is there any stockwater decreed and/or used on the system?	**No decree, there is stockwater in summer**
9. What type of crops are grown?	**Pasture, corn, small grains (extension has some vineyards and fruit)**
a. Are there any trends towards other crops?	**Consistent, but vineyards becoming a little more common**
10. Have USDA-NRCS programs had an impact on the overall system?	**No,**
11. Who are your current Board members?	[redacted]
a. Do you have any staff? Please describe.	**No official staff**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**No, phone calls to individuals is typical form of contact**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**Efficiency improvements could be help**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**Spillway above Bowie loadout could help.**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Yes, a few people have expressed desire**

Additional notes:

North Fork Farmer's has an extension company which manages irrigators on upper end. There are 215.7 shares total, and buying/selling shares is allowed. Some eroding hillsides along canal length.

Paonia Ditch

Interviewees: [redacted]

J·U·B ENGINEERS, INC.

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**Roughly 35 cfs split over 4 decrees (also carry water for Wade and Hightower Ditch)**
a. How often do you get called out?	**Flood decree gets called out annually, usually in mid-June. Lowest they ever get called to is about 12 cfs**
• Who is calling you out?	**Short Ditch**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**770 Acres**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	**NFRIA planned diversion structure, which lasted 3 months. Nothing for conveyance infrastructure**
b. Have you been successful in securing funding?	**Yes**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**Originally, but with latest diversion there is no issue**
5. What about your diversion would you change if funds were available?	**Something to take out sediment (most of the sediment is coming from Minnesota Creek rather than North Fork).**

Interview Questions and Responses

6. How are orders for water placed within the system?	**N/A, proportional split**
7. What are typical turn in/turn out dates?	**Turn in – April 15th** **Turn out – October 15th**
8. Is there any stockwater decreed and/or used on the system?	**No**
9. What type of crops are grown?	**Fruit, alfalfa, small grains, pasture**
a. Are there any trends towards other crops?	**Renewed interest in fruit, hops, farm-to-table**
10. Have USDA-NRCS programs had an impact on the overall system?	**No (however, proportional split to Wade and Hightower was designed by NRCS)**
11. Who are your current Board members?	[redacted] **– President** [redacted] **– Treasurer/Ditch Rider** [redacted] **- Secretary**
a. Do you have any staff? Please describe.	[redacted] **– Ditch Rider (part time)**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**Mailing list (paper)**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**Yes – potential longer season, but they are pinched in by river to ever expand acreage**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**Sediment Control for users using pressurized irrigation, diversion boxes could increase efficiency.**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Some users are utilizing NRCS funding for on-farm efficiency improvements. But responsibility of ditch company ends at shareholder's point of diversion**

Additional notes:

Currently, there is substantial sections of open ditch through the town of Paonia. For both safety and efficiency concerns, piping could be beneficial.

Monitor Ditch

Interviewee: [redacted]

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**10.25 cfs**
a. How often do you get called out?	**Once per year, sometimes twice. Often in mid-July, but it is not a major issue.**
• Who is calling you out?	**Would need to talk to water commissioner, probably Short Ditch.**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**Yes, CDSS. Overview Map provided by JUB looks consistent with reality.**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	**NFRIA planned diversion structure (this is extent of what is available, and all the engineering that has happened)**
b. Have you been successful in securing funding?	**Yes, through NFRIA**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**N/A**
5. What about your diversion would you change if funds were available?	**Could grout the entirety of the rock weir in river. Would like to add height to headgate. Would like a self-cleaning trash-rack.**

6. How are orders for water placed within the system?	**No orders are placed. Shares are restricted and tied to land.**
7. What are typical turn in/turn out dates?	**Turn in – April 10th (avg)** **Turn out – late October**
8. Is there any stockwater decreed and/or used on the system?	**Yes, and it is used all winter**
9. What type of crops are grown?	**Mainly hay pasture**
a. Are there any trends towards other crops?	**No, everything is consistent**
10. Have USDA-NRCS programs had an impact on the overall system?	**No**
11. Who are your current Board members?	[redacted]
a. Do you have any staff? Please describe.	**Not officially, [redacted] and [redacted] act as ditch riders.**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**Through the secretary ([redacted])**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**No**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**Nothing serious, though ditch could be higher to more effectively irrigate some acreage that borders the ditch.**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**No**

Additional notes:

Shepherd and Wilmott Ditch

Interviewee: [redacted]

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	[redacted] **has paperwork, unsure at time of interview**
a. How often do you get called out?	**Never**
• Who is calling you out?	**N/A**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**Property Deeds contain records (shares are tied to land in deed)**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☐ N☒**
a. Can I get a copy of what exists?	**N/A**
b. Have you been successful in securing funding?	**N/A**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**N/A (NFRI helped with new diversion)**
5. What about your diversion would you change if funds were available?	**Nothing**

6. How are orders for water placed within the system?	**No orders. Proportional split boards currently in use to manage water**
7. What are typical turn in/turn out dates?	**Turn in – April 5th** **Turn out – October 15th**
8. Is there any stockwater decreed and/or used on the system?	**Yes (and it is utilized)**
9. What type of crops are grown?	**Pasture, alfalfa, corn, small grains**
a. Are there any trends towards other crops?	**No, crop types are consistent year to year**
10. Have USDA-NRCS programs had an impact on the overall system?	**No, but they have helped with a few divide boxes**
11. Who are your current Board members?	[redacted]
a. Do you have any staff? Please describe.	**No official, [redacted] functions as ditch rider**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**No, phone calls to individuals is typical form of contact**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**No**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**No, [redacted] does not believe there is adequate elevation to pressurize the system**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Not really**

Additional notes:

[redacted] has a list of shareholders that he can provide. Shares cannot be exchanged between parcels, water is entirely tied to land.

Short Ditch

Interviewee: [redacted]

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**24 cfs and flood decree**
a. How often do you get called out?	**Not too often, Short down to 13 on highest priority**
• Who is calling you out?	**Just to river**
b. Is there any stored water released to your diversion?	**No**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**CDSS numbers appear to reflect actual acreage fairly well**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☒ N☐**
a. Can I get a copy of what exists?	**FOA by JUB**
b. Have you been successful in securing funding?	**No; exception of NFRIA on diversion. Diversion works well now, but might be left in river if there is another big year**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☐ N☒**
a. If yes, can you elaborate?	**N/A**
5. What about your diversion would you change if funds were available?	**Move it back to bank to avoid disaster at high water, or from the river moving away**

Interview Questions and Responses

6. How are orders for water placed within the system?	**None, proportional splits**
7. What are typical turn in/turn out dates?	**Turn in – April 15th** **Turn out – middle of November or freeze**
8. Is there any stockwater decreed and/or used on the system?	**No stockwater is decreed, but tail water is used during winter in some places**
9. What type of crops are grown?	**Hay, +[redacted]'s row crops, pasture**
a. Are there any trends towards other crops?	**No**
10. Have USDA-NRCS programs had an impact on the overall system?	**[redacted] pivots, [redacted] put in sprinklers**
11. Who are your current Board members?	[redacted]
a. Do you have any staff? Please describe.	**Yes – [redacted] on upper end is DR and Superintendent, [redacted] on lower end**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**No**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**Possibly, but only if pumps were implemented**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**Yes – leaks through bank are marked on map near [redacted] residence**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Yes**

Additional notes:

Vandeford Ditch

Interviewee: [redacted]

J·U·B ENGINEERS, INC.

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**14 cfs, up to 16 cfs in come cases**
a. How often do you get called out?	**Only [redacted] (within the ditch), no call from [redacted] (CDWR)**
• Who is calling you out?	**N/A**
b. Is there any stored water released to your diversion?	**N/A**
• How much?	**N/A**
• When?	**N/A**
2. Is there any record of the acres served by the diversion?	**128 acres [redacted] , 6 (or more) acres, 22 acres of riverbottom lands**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☐ N☒**
a. Can I get a copy of what exists?	**N/A**
b. Have you been successful in securing funding?	**N/A**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☒ N☐**
a. If yes, can you elaborate?	**People want to fish on diversion**
5. What about your diversion would you change if funds were available?	**The whole thing. Sediment in ditch is a big problem, new headgate in river is shoddy. River elevation dropped when gravel was harvested from river, Vandeford owners put big rock in river, which helps.**

6. How are orders for water placed within the system?	**Self**
7. What are typical turn in/turn out dates?	**Turn in – April 15th** **Turn out – October 15th**
8. Is there any stockwater decreed and/or used on the system?	**Yes – both decreed and used**
9. What type of crops are grown?	**Triticale, alfalfa, oats, grass, corn**
a. Are there any trends towards other crops?	**No – users rotate above crops**
10. Have USDA-NRCS programs had an impact on the overall system?	**Yes, a long time ago – users went from flood irrigation to gated pipe**
11. Who are your current Board members?	[redacted]**, other Board members currently being selected**
a. Do you have any staff? Please describe.	**No. Ditch rider is** [redacted]
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**Cell phone**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**Yes, pivot would help, sprinklers due to high water table, river bottom could be developed a further 45 acres**

13. Are there any infrastructure improvements within the conveyance system that are needed?	**Piped to the first headgate would be beneficial – 1.5 miles, or all the way to the canals**
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Pivots, sprinklers, benefits to using pipe on fields**

Additional notes:

Smith and McKnight Ditch

Interviewee: [redacted]

J·U·B ENGINEERS, INC.

NORTH FORK OF THE GUNNISON AGRICULTURAL DIVERSION

Interview Questions and Responses

1. What is the diversion right(s) (cfs) associated with your diversion?	**Senior, 10.303 cfs**
a. How often do you get called out?	**Never**
• Who is calling you out?	**N/A (do not get called out)**
b. Is there any stored water released to your diversion?	**No**
• How much?	**Unsure**
• When?	**Unsure**
2. Is there any record of the acres served by the diversion?	**Not that [redacted] is aware of**
3. Has any engineering and/or planning taken place for the areas served by this diversion?	**Y☐ N☒**
a. Can I get a copy of what exists?	**Very Preliminary Engineering Done by Tracy Allen at J-U-B**
b. Have you been successful in securing funding?	**No**
4. Have you had any conflicts with recreational river users at your diversion?	**Y☒ N☐**
a. If yes, can you elaborate?	**They try to mess with the headgate (attempt to close it).**
5. What about your diversion would you change if funds were available?	**Would like to change the headgate**

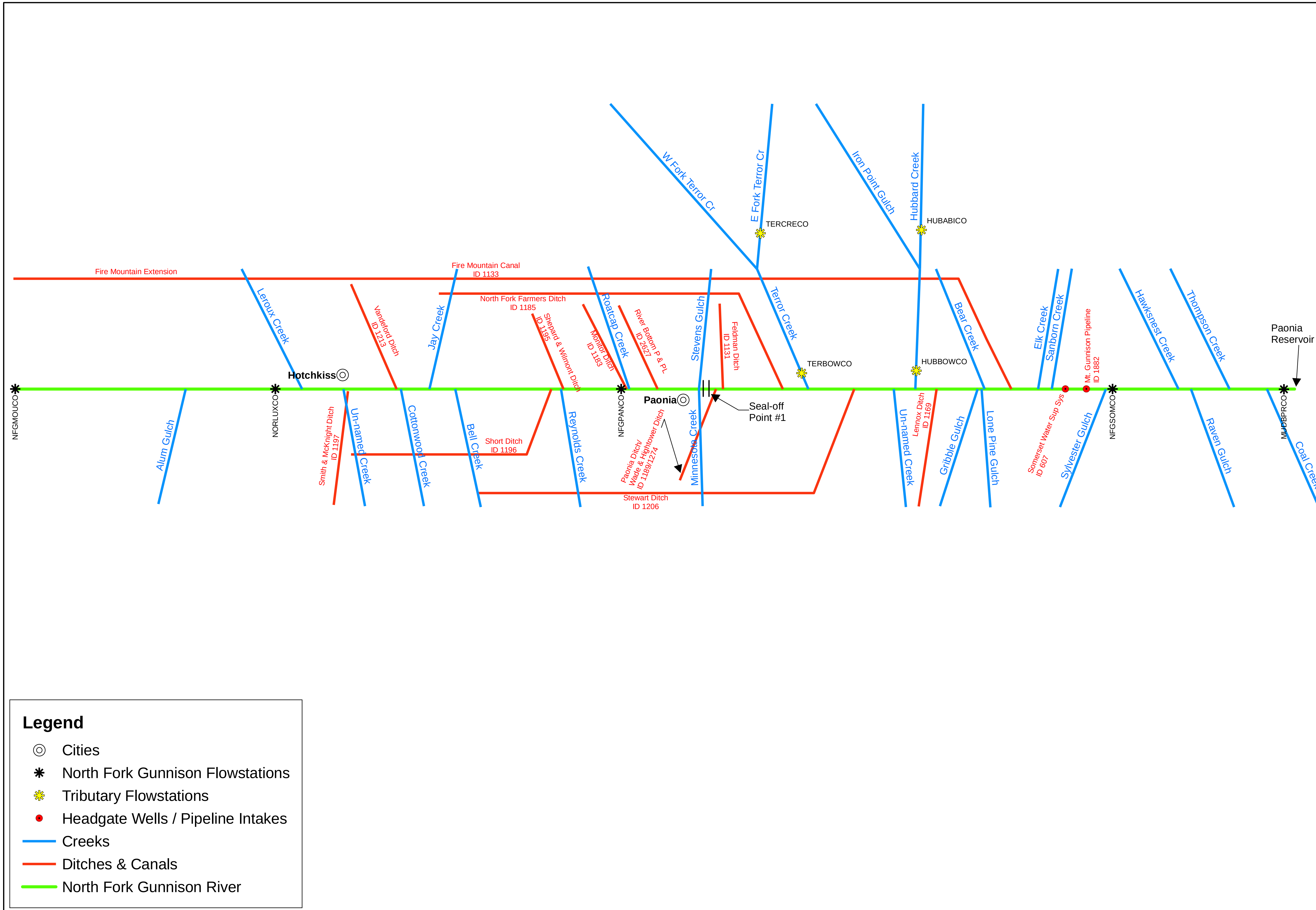
6. How are orders for water placed within the system?	**N/A**
7. What are typical turn in/turn out dates?	**Turn in – April 1** **Turn out – November 1**
8. Is there any stockwater decreed and/or used on the system?	**Yes**
9. What type of crops are grown?	**Corn, alfalfa, dry beans**
a. Are there any trends towards other crops?	**Possibly, but unsure**
10. Have USDA-NRCS programs had an impact on the overall system?	**Not that [redacted] is aware of**
11. Who are your current Board members?	**[redacted] President** **[redacted], Vice President** **[redacted] Secretary and Treasurer**
a. Do you have any staff? Please describe.	**No**
b. Is there a centralized way to contact your group (email, accountant, attorney)?	**Yes, members have email accounts.**
12. Would system (efficiency) improvements within your delivery and on-farm system increase the ability for beneficial irrigation use (expansion of acreage, longer season) under your ditch?	**Yes**

	Yes
14. Are there on-farm efficiency improvements amongst the water users on the ditch that are necessary or desired?	**Yes**

Additional notes:

[redacted] at the Smith and McKnight Ditch is interested in pursuing USBR Salinity funding to help fund a piped system. Plans on getting some more engineering work done.

APPENDIX D – STRAIGHT LINE DIAGRAM OF NORTH FORK (CLEAR WATER SOLUTIONS, 2014)



clearWATERsolutions
water rights • planning • engineering
8010 S. County Road 5, Ste. 105 - Windsor, CO - 80528 - 970.223.3706

Figure 1
North Fork of the Gunnison River
Straight-Line Diagram

North Fork Study

Date: 5-15-2013
Drawn By: RVP
Scale: 1 in = 2 miles
Job No: 13-120

moving water in new directions

IRRIGATION TRAINING & RESEARCH CENTER

Integrated Assessment, Comprehensive Implementation Planning and Engineering Review: *Fire Mountain Canal Reconfiguration Project*

and

Optimization of Water Delivery System: *A Rapid Assessment*

Colorado River Water Conservation District

September 2017

IRRIGATION
TRAINING &
RESEARCH
CENTER

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Irrigation Training & Research Center
September 2017

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- Steve Fletcher, Manager of the Fire Mountain Canal and Res. Co.
- Beth Karberg, Salinity Field Coordinator, Lower Gunnison Basin
- Bill Moore, Operator for the Fire Mountain Canal and Res. Co.
- Dixie Luke, President of the Fire Mountain Canal and Res. Co.
- Sonja Chavez, Colorado River District

EXECUTIVE SUMMARY

Rogers Mesa Pipeline

The primary focus of the rapid assessment was to review assumptions and criteria for the planned Rogers Mesa pipeline. The Rogers Mesa canal is scheduled to be pipelined with a $4.5 million grant intended to reduce salinity loading. A variety of options were examined, and are summarized in Table 1. They are further discussed within the report. The $4.5 million budget may have under-estimated the actual cost required.

Table 1. Options examined for Rogers Mesa pipeline

Feature A	Feature B	Feature C	Feature D	Option #	Explanation for not using combination of features
Flow Rates Through the Siphon		J-U-B flow rates through siphon and into Rogers Mesa		1	Flow rates are too low for eventual flexibility needed by farmers. The "share" concept was meant for old irrigation techniques with steady flows and was intended for early design from equitable distribution. Modern design converts the "share" concept into volumes provided as needed to maximize efficiency and production.
		"Demand" flow rates determined by ITRC		2	**RECOMMENDED FOR THE FIRST PHASE**
Flow Rates From Leroux Creek		Rogers Mesa, only		3	This option was needed to establish the base cost, without including any Jesse options. The final decision included summer Jesse flows through the siphon.
		Rogers Mesa plus Jesse spring flows		4	The extra capacity needed for the Spring flows required a larger pipe from the Leroux Creek to the East Ditch turnout, and between the FMC and the Jesse service area. The price was higher than what the Jesse farmers thought they could afford. They may eventually pipe the old Jesse canal for spring flows. But the summer flows via pipeline provided better service and security for the majority of the irrigation season.
		Rogers Mesa plus Jesse summer flow		5	**RECOMMENDED FOR THE FIRST PHASE**
Control Strategies	No Reservoir	All fluctuations pass through new pipeline and discharge into Patterson Lateral		6	FMC staff preferred to have stable flows into Patterson Lateral and to put the variations into Leroux Creek. Currently, fluctuations go into the Patterson Lateral
		All excess flows spill into Leroux Creek at inlet to the siphon		7	**RECOMMENDED FOR THE FIRST PHASE**
	Reservoir on Rogers Mesa	Limited spills at entrance to the siphon		8	The only available site was unsuitable because of the terrain, complexity, and small volume of storage that could be obtained. The control would have also been complicated.
	Reservoir at Horse Park Spill	Open canal connection between reservoir and siphon. Releases from reservoir could be scheduled, but there would always be spill at the entrance to the siphon.		9	**THE SECOND PHASE ONLY INCLUDES THE CONSTRUCTION OF THE RESERVOIR**
		Improved connection between the reservoir and the siphon	Automated control of the reservoir outlet with downstream control	10	Simulation of the automated downstream control with sophisticated PIF logic showed that the control could be unstable to provide "on demand" service to the siphon. The canal section is too steep and has insufficient storage to provide stable and rapid control, and the PLCs, communication, and sensors require complex maintenance.
			Closed pipeline connection between reservoir and siphon	11	**THE THIRD PHASE PROVIDES A DIRECT PIPED CONNECTION BETWEEN THE RESERVOIR AND THE SIPHON, PROVIDING VERY SIMPLE, RELIABLE, AND FLEXIBLE CONTROL.**

The key points for the Rogers Mesa pipeline are:

1. The pipeline is an essential first step toward eventual improvement of on-farm irrigation within Rogers Mesa. It will also provide lower maintenance costs to FMC.
2. The pipeline, by itself, will <u>not</u> provide perceived benefits such as:
    a. A “demand” delivery of irrigation water to fields.
    b. A “demand” delivery to the heads of the laterals.
    c. Water conservation or improved on-farm irrigation that is associated with improved water service to agricultural customers.
3. The decision on how to appropriately incorporate the Jesse water into the new design was made after considerable discussion. In April 2017 it was tentatively decided to deliver the summer Jesse water through the new siphon, with a turnout for a future connecting pipeline installed near the East Ditch turnout.
4. The pipeline must be designed to carry sufficient flow rates to provide flexible deliveries. Recommendations are given.
5. Excellent water delivery service (consisting of both a high degree of flexibility and efficiency) to Rogers Mesa fields will only be possible after all of the following are completed, in is sequence:
    a. The Rogers Mesa pipeline is installed.
    b. A regulating reservoir is installed at Horse Park.
    c. The majority of field turnouts within Rogers Mesa are supplied by closed pipelines that are directly connected to the Rogers Mesa pipeline. This will require modifications of existing pipelines, and the addition of pipelines where none exist.
    d. The regulating reservoir outlet is directly connected to the siphon pipe, using a closed pipeline.
6. The Rogers Mesa extension pipeline can provide a convenient platform for trials of new incentives and delivery schedules, to anticipate how the future pipeline lateral connections might operate.

Safety Issues along the Fire Mountain Canal (FMC)

Two pressing safety issues are addressed:

1. There is a need for automated spills to remove sudden storm flows. A standardized design is recommended for locally constructed ITRC Flap Gates, while allowing for flushing of spring cleanout water with a parallel gate. FMC has been provided with shop drawings for the standardized flap gate.
2. A number of sections of the canal are located on steep ridges, with a potential for landslides from above filling the canal, or from seepage-induced bank failures on the downhill side. The Gavin Mesa site, in particular, appears to merit immediate attention. ITRC concurs with an earlier J-U-B report that this section should be piped. This report also indicates several other canal sections that can be considered.

SCADA (Telemetry)

The FMC already has some rudimentary components for remote monitoring and control. There is one automated site (the Bear Mountain spillway). Supervisory Control and Data Acquisition (SCADA) systems can provide early warning of problems, improve the accuracy and efficiency of water control, and reduce labor/travel. Because “the devil is in the details” with SCADA systems, a fairly detailed chapter is provided, including specific recommendations for various sites.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1. Scope and General Background

This Rapid Assessment project was performed under two contracts (phases) with the Colorado River District.

First Phase. The first contract focused on providing comments regarding a pipeline design provided by J-U-B Engineers in their North Fork Water Conservancy District Master Plan and Funding Plan (dated June 2016). The J-U-B report states that a new pipeline to serve the Rogers Mesa area of the Fire Mountain Canal (FMC) would reduce the salt loading to the Colorado River Drainage by 2,365 tons/yr. A grant of about $4.5 million has been received by the Fire Mountain Canal and Reservoir Company (FMCRC) to construct this pipeline.

As such, this first phase focused on tasks such as:

- Organizing information on surveys, flow rates, etc.
- Examining the hydraulics of the pipeline proposed by J-U-B
- Several visits and meetings with stakeholders to understand concerns and objectives
- Examining the design assumptions for the pipeline
- Providing very preliminary estimates of alternatives and costs

The over-riding uncertainty in the first phase was how to account for flows that might be provided to the Jesse Lateral service area, which currently receives water from its own diversion on Leroux Creek. That uncertainty was not resolved in the first phase, but the flow rates to Jesse (during spring and summer) needed to be determined to properly define Rogers Mesa pipeline sizes and capacities. The farmers along the Jesse Lateral were not yet comfortable with entering into any agreement with the FMCRC.

Second Phase. The second phase, approved in February 2017, involved the following:

- Helping the stakeholders make a decision on the deliveries to the Jesse Lateral service area
- Re-examining pipeline sizes and control with the final flow rates
- Examining options for control of flows, including simulation of automation of a reservoir outlet
- Providing recommendations or details for:
    - improved safety at spill points between the head of the FMC and Rogers Mesa
    - improved safety along some stretches of the FMC
    - improved flow measurement and control at the head of the FMC
    - a preliminary SCADA plan
    - very approximate estimates of water conservation, and explanations of these estimates
- Writing a final report and meeting with stakeholders

Fire Mountain Canal (FMC)

The Fire Mountain Canal is part of the Paonia Project, which serves 15,300 acres (perhaps 11,000 acres of which receive water) in the North Fork of the Gunnison River Valley. The North Fork Water Conservancy District has the responsibility for the operation and maintenance of the Paonia Dam, diversion structure, and the Fire Mountain Canal (FMC). The Fire Mountain Canal is owned by the private Fire Mountain Canal and Reservoir Company, which holds the water rights for about 8,780 acres of agricultural land near Paonia and Hotchkiss, Colorado.

The river diversion structure is located near Somerset, CO in Gunnison County. It has a low diversion dam constructed on loose boulders and timbers and a concrete weir that raises the water level enough to enter the headworks of the canal. The headworks consists of single radial gate. Key characteristics of the FMC specified in previous reports are:

- 33.3 miles long
- Flow rates into the FMC (after a spill point near the diversion) are about 170-180 CFS.
- Maximum decreed flow rate into the canal is 238 CFS.
- Water rights are based on flow rates; however, this is tempered by the fact that there is limited storage in the reservoir.
- Mostly unlined
- 90 turnouts
- 480 water users
- Seepage losses are about 1 CFS/mile.

Further details are in the J-U-B Engineering report (June 2016) and are not repeated here.

Figure 1. Location of the FMC. Map segments correspond to USBR mapping sections referenced in the J-U-B report (2016)

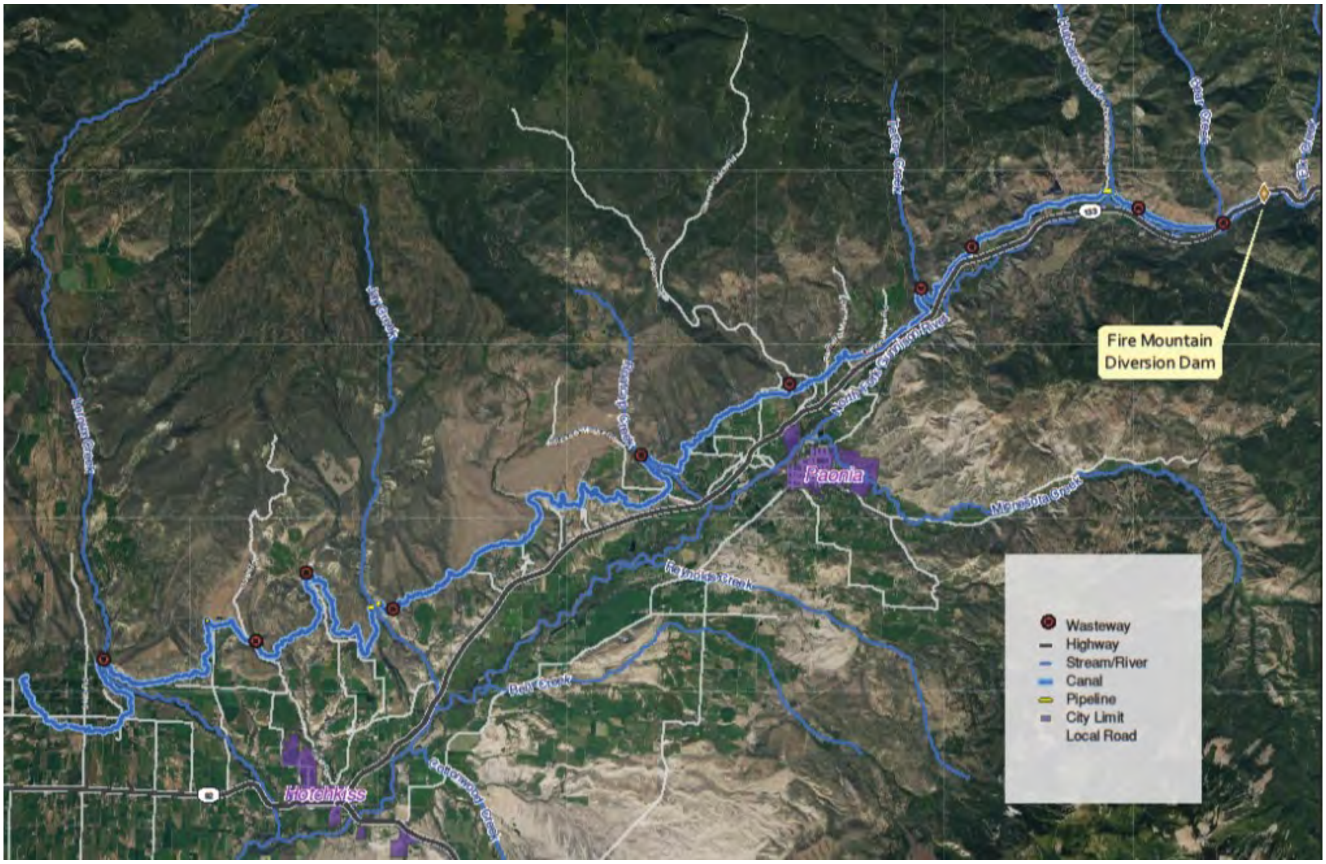


Figure 2. FMC map (courtesy of USBR). Rogers Mesa is downstream of Leroux Creek on the lower left.

Other notes are:

- A substantial portion of the canal length (about 3.5 miles) is located along very steep hills. The canal can fill with rocks/soil sliding down from above. Usually these sections also have a steep downhill side, with a potential for a damaging canal break.
- In the Rogers Mesa area (at the downstream end of the FMC), most of the deliveries are made to ditch companies rather than to individual farmers.
- About 60% of the FMC water rights are in the Rogers Mesa area.
- Two ditchriders and one manager are responsible for the operation of the canal.
- During high spring flows, water from Leroux Creek is also captured and farmers on Rogers Mesa receive about 135% of their entitlements for a few weeks.
- About 80% of storage releases from Paonia dam occur in August and September.
- Table 2 shows river diversions into the FMC, and the water shares along the FMC are shown in Table 3.

Table 2. Diversion into FMC below Bear Creek (Clear Water Solutions, 2014)

Year	Ditch Start Date	Direct Flow Stop Date	Reservoir Start Date	Reservoir Stop Date	Total Reservoir Diverted (ac-ft)	Total Water Diverted (ac-ft)	Total Days Ditch Run	Total Days of Reservoir Release
2001	4/18	9/22	7/6	9/22	15,912	51,510	158	79
2002	4/12	7/17	6/12	8/5	13,012	36,088	116	55
2003	4/7	9/2	7/9	9/2	15,939	49,312	149	56
2004	4/13	8/24	7/6	9/1	13,075	45,126	138	58
2005	4/14	10/4	8/12	10/4	9,661	54,394	174	54
2006	4/15	9/14	7/15	9/14	12,979	51,754	153	62
2007	4/15	9/9	7/5	9/9	12,055	47,535	148	67
2008	4/23	9/28	7/30	9/28	10,455	47,771	148	48
2009	4/29	8/24	7/19	9/15	14,354	40,596	128	59
2010	4/17	9/23	7/10	9/23	15,016	50,846	159	74

Table 3. Water shares of the FMC

Turnout #	Total Shares for T.O.	Total Acres Service by T.O.	# of users on T.O.	WMD Size	100% Flow (CFS)	Setting (Gate?) at 100% Flow
1	0.0	0.0	1	6	0.00	0
1a	16.0	0.6	1	pump	0.01	
2	114.0	4.6	1	6	0.08	0.13
3	300.0	12.0	1	6	0.21	0.24
4	600.0	24.0	1	6	0.43	0.37
5	182.0	7.3	1	6	0.13	0.17
6	923.0	36.9	1	6	0.66	0.49
7	386.0	15.4	1	6	0.28	0.28
8	300.0	12.0	1	6	0.21	0.24
9	100.0	4.0	1	6	0.07	0.12
10	100.0	4.0	1	6	0.07	0.12
11	150.0	6.0	1	6	0.11	0.15
12	150.0	6.0	1	6	0.11	0.15
13	100.0	4.0	1	6	0.07	0.12
13a	181.0	7.2	1	pump	0.13	
14	283.4	11.3	1	6	0.20	0.23
15	283.3	11.3	1	6	0.20	0.23
16	433.3	17.3	2	9	0.31	0.22
17	413.0	16.5	1	6	0.30	0.29
Terror Creek	74.0	3.0	4		0.05	
18	200.0	8.0	1	6	0.14	0.18
19	200.0	8.0	1	6	0.14	0.18
20a	1,008.0	40.3	4	9	0.72	0.39
20b	450.0	18.0	3	6	0.32	0.23
21a	75.0	3.0	1	6	0.05	0.1
21b	1,168.8	46.8	4	6	0.83	0.56
21c	70.0	2.8	1	6	0.05	0.1
22	50.0	2.0	1	6	0.04	0.08
23	473.0	18.9	2	6	0.34	0.32
24a	985.0	39.4	2	6	0.70	0.51
24b	225.0	9.0	1	6	0.16	0.2
25	300.0	12.0	3	6	0.21	0.24
26	137.4	5.5	1	6	0.10	0.15
27	1,761.0	70.4	1	6	1.26	0.73
28a	100.0	4.0	1	9	0.07	0.09
28b	25.0	1.0	1	6	0.02	0.05
29	1,101.6	44.1	6	9	0.79	0.41
30a	666.0	26.6	1	9	0.48	0.3
30b	1,230.0	49.2	3	9	0.88	0.44
31a	700.0	28.0	3	9	0.50	0.31
31b	670.4	26.8	4	9	0.48	0.3
32	800.0	32.0	1	9	0.57	0.33
33a	708.6	28.3	2	9	0.51	0.31
33b	3,129.1	125.2	23	12	2.24	0.68
34a	548.8	22.0	1	9	0.39	0.26
34b	2,430.6	97.2	13	12	1.74	0.58
34c	725.6	29.0	1	6	0.52	0.42
35a	275.0	11.0	3	3	0.20	0.35
35b	225.0	9.0	1	6	0.16	0.2
36a	2,081.6	83.3	6	9	1.49	0.62
36b	350.0	14.0	1	9	0.25	0.19
37a	360.0	14.4	1	9	0.26	0.2
37b	1,608.2	64.3	5	12	1.15	0.44
38	1,000.0	40.0	1	6	0.71	0.51
40	100.0	4.0	1	6	0.07	0.12
41	50.0	2.0	1	6	0.04	0.08
42	450.0	18.0	3	6	0.32	0.31
43	324.0	13.0	1	6	0.23	0.25
44	614.0	24.6	2	6	0.44	0.38
45	390.0	15.6	2	6	0.28	0.28
46	700.8	28.0	1	9	0.50	0.31
47	700.0	28.0	2	6	0.50	0.41
48a	800.0	32.0	4	9	0.57	0.33
48b	285.0	11.4	1	6	0.20	0.23
49	250.0	10.0	1	6	0.18	0.21
50	785.0	31.4	3	6	0.56	0.44
51	400.0	16.0	1	6	0.29	0.29
52	538.0	21.5	2	6	0.38	0.35
53a	1,308.0	52.3	1	9	0.93	0.46
53b	682.0	27.3	4	6	0.49	0.4
54	1,393.0	55.7	5	6	1.00	0.63
55	885.0	35.4	1	6	0.63	0.47
56	1,885.0	75.4	1	6	1.35	0.76
58	400.0	16.0	3	6	0.29	0.29
59	335.0	13.4	1	6	0.24	0.26
60	335.0	13.4	1	6	0.24	0.26
61a	7,098.0	283.9	12	12	5.07	1.17
61b	1,250.0	50.0	2	9	0.89	0.45
62	1,203.0	48.1	3	9	0.86	0.44
63	5,755.2	230.2	6	12	4.11	1.02
64a	1,115.0	44.6	2	9	0.80	0.41
64b	2,135.0	85.4	3	12	1.53	0.53
65	7,009.0	280.4	18	12	5.01	1.16
67	2,562.0	102.5	4	9	1.83	0.71
68	601.4	24.1	1	6	0.43	0.37
69	601.3	24.1	1	9	0.43	0.28
70	601.3	24.1	1	6	0.43	0.37
71	2,842.0	113.7	2	12	2.03	0.64
72	2,000.0	80.0	2	9	1.43	0.61
73	3,567.0	142.7	3	9	2.55	0.89
74	272.0	10.9	2	6	0.19	0.22
75	0.0	0.0	1	9	0.00	0
76	470.0	18.8	1	6	0.34	0.32
77	470.0	18.8	1	6	0.34	0.32
79	7,458.0	298.3	16	24	5.33	0.77
80	38.0	1.5	1	6	0.03	0.06
81	500.0	20.0	1	6	0.36	0.33
82	935.0	37.4	3	6	0.67	0.49
East	53,704.3	2,148.2	118	48	38.36	1.74
83a	2,175.0	87.0	1	12	1.55	0.54
83b	1,008.0	40.3	1	6	0.72	0.51
84	0.0	0.0	1	9	0.00	0
Slack	18,613.0	744.5	42	36	13.30	1.07
85	1,908.0	76.3	1	9	1.36	0.59
Patterson	40,315.8	1,612.6	44	48	28.80	1.45
Extension	8,803.0	352.1	15	24	6.29	0.86
Totals	**219,548**	**8,782**	**479.0**	**--**	**156.87**	**--**

Motivation for Change

There are several motivations for change, including that climate change and increased competition for water (both as instream flows and consumption) have the potential to require more demand-based management of diversions in the future. This would reduce gross diversions from the river. At the present time, the flow rates into the Fire Mountain Canal remain fairly constant throughout the delivery season. The graphs in Figure **3** were generated in a 2014 report by Clearwater Solutions on behalf of Trout Unlimited. They represent just two years of data, but they clearly illustrate the point of fairly constant diversions.

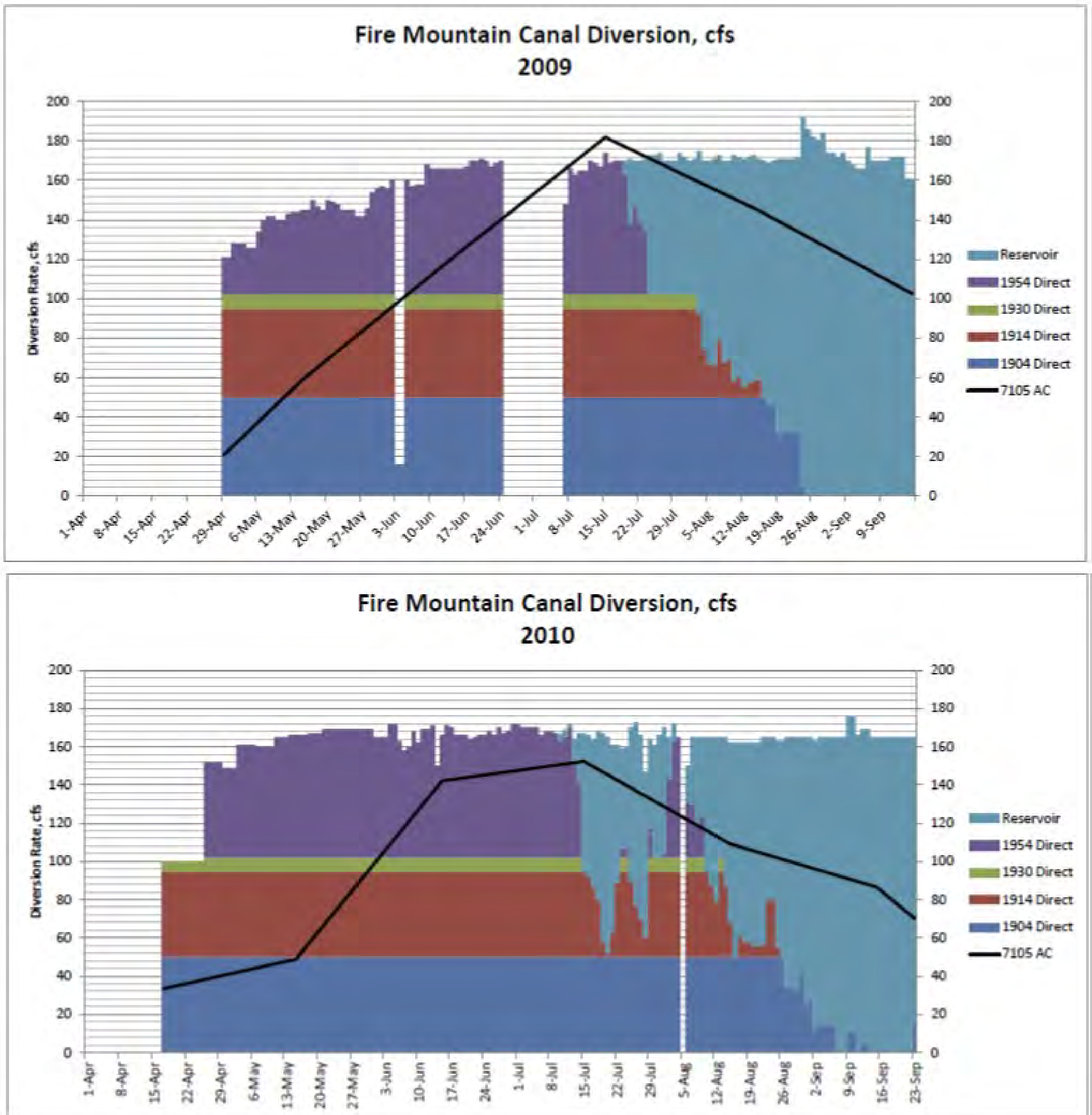


Figure 3. Historical FMC diversions. From 2014 North Fork Study by Clearwater Solutions for Trout Unlimited.

Chapter 2. LIKELY WATER CONSERVATION BENEFITS FROM PROPOSED ACTIONS

Overview

The accuracy of water conservation estimates for the FMC system suffer from typical problems such as uncertainties/accuracies of actual flows, limited actual seepage tests, unmeasured spills, and so on. For example, the Parshall flume that measures the inflow to the FMC does not have the instrumentation to measure flows accurately in all conditions. During the development of this report, there were significant variations in flow rate estimates provided for Leroux Creek inflows and Jesse Ditch flows.

Independent estimates are often made regarding various flows and volumes, which may not be compared within the bigger form of a water balance. This Rapid Assessment was just that: a rapid assessment. It was not funded to verify and cross-check the many numbers that have been reported.

A more complete water balance study would be required to have a high degree of confidence in the numbers. Likely, it is better at this stage to just begin construction work and in the process obtain better flow rate values that could be used to fine-tune future estimates.

The Bigger Picture

The question of "water conservation" goes beyond the issue of accuracy. Water conservation for the FMC does not necessarily translate into water conservation for the basin. This is an old story. In spite of "water conservation" efforts, aquifers continue to decline because the return flows (and therefore the recharge) decrease. In this specific area of the Colorado River basin, there are of course substantial reductions in salt loading with reduced seepage and deep percolation.

The discussion of flow rate requirements recognizes that with better irrigation management and improved agronomic practices, it is typical that annual irrigation water consumption (in the form of evapotranspiration) actually increases. This is because there is more uniform, unstressed growth throughout fields. Furthermore, a very large potential advantage for the Rogers Mesa farmers could be that with "water conservation" during the summer, the "conserved water" could be stored in Paonia Reservoir and then used for an extended irrigation season. Hence, no actual water conservation.

Therefore, Table 4 provides two categories of "conserved water". Seepage reduction will likely result in reduced river diversions, and no impact on local water consumption. Therefore, it is classified as "permanent". Some of the other "conserved water" could result in less annual diversions immediately, but might also result in a prolonged irrigation season with better crop yields and better crop uniformity and vigor, and have no reduction in annual water diversions.

Table 4. Possible water conservation

Action	Action Description	Pre-requisite Action	Sub-Category	Perm. Reduced Diversion from Seepage (AF/yr.)	Short-term Reduced Diversion (AF/yr.)		Salt Load Reduction (Tons/yr.)
					Spill	On-Farm	
1	Rogers Mesa Pipeline	n/a	Reduced seepage in FMC	1500			2365
		Pipeline from FMC to Jesse area is installed	Reduced seepage in Jesse Ditch during summer	480			380
2	Improved spill control along FMC	n/a			240		
3	Reservoir at Horse Park, equipped with SCADA and proper in/out control	1			1400		
4	Pipeline between Reservoir and siphon	3			980		1680
5	Closed pipelines on Patterson, East, and Slack	4				4700	
6	Dangerous FMC sections are piped	n/a		360 AF/mile			560/mile

A – Improved Operation with the Newly Piped Rogers Mesa Canal

No water conservation benefits due to improved operation are envisioned with the Rogers Mesa pipeline. This is because there is a physical "disconnect" between the supply and the demand.

The turnouts from the new pipeline will discharge into the air, and will not provide pressurized water (with the possible exception of the new Jesse connection of about 6.5 CFS) to farmers. Therefore, there will be no impact on on-farm water conservation due to the new pipeline. Whatever happens downstream of the new Rogers Mesa pipeline turnouts will never be noticed by the Rogers Mesa pipeline. Furthermore, if any excess water from the FMC arrives at the head of the pipeline, it will spill into the Leroux Creek. The water cannot be "forced" into the new pipeline.

B – Reduced Seepage

Rogers Mesa Pipeline. The pipelining of the Rogers Mesa portion of the FMC is anticipated to save water due to reduced seepage. Approximately 22,125 feet (4.2 miles) of canal will be piped, with an estimated (by others) seepage reduction of 1 CFS/mile, or 4.2 CFS. Assuming 180 days of operation/year, this provides 1,500 Acre-feet of reduced seepage. The total salt load reduction is estimated by others to be 2,365 tons/year.

Jesse Ditch. During the summer months (for about 160 days), water to the Jesse Lateral service area will no longer flow through the old stretch of Jesse ditch between the river and the service area. There are no seepage numbers available, but in this report it is assumed that with the sandy soil, there is a seepage loss of about 1.5 CFS in the 5400' of ditch length (see the condition of this ditch in Figure 4). This represents about 480 Acre-feet of water saved per year. There is also likely to be some salt load reduction, but evidently the salinity load reduction program only allows credit if a canal is completely removed/piped.

Figure 4. View of Jesse Ditch

C – Reduced Spills along the FMC

The volumes of spills under the current operation are not known. It can be seen from the diversion records that the diversion flow rates remain relatively constant during the delivery season. When rains occur, releases from the dam and diversions into the FMC might be able to be reduced if the remote monitoring and control capabilities were improved. Without further physical infrastructure additions, such as a regulating reservoir, there will likely be minor savings. As a rough estimate, a 0.25% savings of the total diversion is assigned. This equates to approximately 120 Acre-fee per year. The primary benefit of the improved spills is one of safety.

D – Balancing Reservoir with a Canal between the Reservoir and the Leroux Creek Siphon

The balancing reservoir will allow the FMC operators to conserve some rainfall runoff that would otherwise occur, and also enable them to re-adjust the canal flows into the Rogers Mesa area with much more ease than at present.

Rainfall spill values are not known, but as a rough estimate, a value of 3% of the total FMC inflow is assumed to be conservable. This represents about 1400 AF. Whether it will represent a true reduction in diversion, or eventually be used on Rogers Mesa for increased consumption, or to compensate for a warming climate pattern, is of course unknown. It has been assigned to the "permanent" category.

E – Balancing Reservoir with a Pipeline between the Reservoir and the Leroux Creek Siphon

The pipeline will reduce spill at the Leroux Creek entrance to the siphon, perhaps by as much as 5% of the siphon flow (980 AF/yr.). This will likely be a temporary savings.

The pipeline will also eliminate seepage, which should result in less salinity leaching. The piping of the last 22,125' of the FMC is estimated to reduce salt loading by 2365 tons/yr. Applying the same factor to this pipeline connection of about 15,725 feet, this would reduce salt loading by an additional 1680 tons/yr.

F – Balancing Reservoir/Pipeline with New User-owned Pressurized Pipelines Directly Connected to the Rogers Mesa Pipeline.

This is where the major benefit to the irrigators will occur. It might reduce the applied water by as much as 20%, but likely it will be closer to 10%. The primary advantage will be increased efficiency; that is, there will be a higher consumption (and crop growth) with the same or less water applied.

This 10% (4700 AF/yr.) is assigned to "temporary" as discussed earlier.

Recap

In short, the Rogers Mesa pipeline is just a first step toward water conservation that will be attributed to improved water management. Before such water conservation occurs, a regulating reservoir must be constructed upstream of the Rogers Mesa pipeline. The next steps are to complete the pressurized pipeline connections on both ends of the new Rogers Mesa pipeline, as follows:

1. A pipeline should connect the reservoir to the Leroux Creek siphon (the beginning of the new Rogers Mesa pipeline).
2. Ditch companies on Rogers Mesa that currently use proportional division of flow on pipelines and/or ditches need to have a pressurized connection to the new Rogers Mesa Pipeline, with standard turnouts and flow measurement devices at individual fields or groups of fields.

Chapter 3. CONVEYANCE PORTION OF THE FIRE MOUNTAIN CANAL (FMC)

Background

This chapter focuses on the portion of the Fire Mountain Canal (FMC) between the diversion dam and the potential re-regulating reservoir at Horse Park, located about 26 miles downstream. Approximately 60% of all deliveries are located downstream of this point.

Present Daily Operation

There are three locations of flow control into the FMC:

1. *At the diversion dam on the North Fork of the Gunnison River*. The radial gate is adjusted to always deliver more water than needed by the FMC. The flow rate is not measured at this point. The flow rate is changed almost daily, by an operator manually adjusting the radial gate on site. The adjustment is based on the amount of spill downstream into Bear Creek.
2. *At Bear Creek*. Bear Creek is located about 4000' downstream of the diversion dam. An automated side spill gate on the FMC discharges water back to the river, to maintain a target flow rate through a Parshall flume in the FMC, downstream of the Bear Creek spill. The target flow is stated to be adjusted about four times each week. The diversion records show almost constant flow rates for fairly long periods of time.
3. *At Leroux Creek*. The flow rate into the FMC where it crosses Leroux Creek can be controlled.

The time for a flow rate change to appear at the end of the canal is about 13 hours during high flow rates.

No Need for Automation of the FMC

There is absolutely no need to install numerous automated check structures along the FMC at this time. The recommendation to automate the FMC was seen in some reports, and should not be followed. Such automation would create huge on-going maintenance concerns and costs, cost a significant amount up front, and provide little or no benefit. This type of canal is not suitable for any automation routine such as can be promoted by various canal gate manufacturers. ITRC has a vast theoretical and practical experience and success in dozens of irrigation district modernization/automation programs. If a recommendation for automation was needed, it would be provided in this report. ITRC is very pro-automation where it is needed.

The only automation that is needed is very simple, consisting of:

1. Improvement of the control and measurement at the Parshall flume near the Bear Creek spill.
2. Automation of the inlet radial gate at the diversion dam, or remote manual control – to avoid the need for traveling all the way up to it every day.
3. The in/out control of the proposed regulating reservoir.
4. Spills, which will be automated with hydraulic ITRC Flap Gates that require no computers or sensors.

In about 20 years, if the basic problems have been solved, and the FMC is flush with capital, the question of automated check structures (which do not currently exist) in the FMC can be discussed. It would be a waste of time to consider it now.

As a related topic of interest, it was noted that the Rubicon gate installed at Leroux Creek has not worked properly since installation.

Primary Concerns for the FMC Conveyance Section

There are <u>two primary concerns that need immediate attention</u>:

1. Risk of canal damage in steep areas
2. Ability to quickly and automatically control spills from the FMC when rainfall runoff enters the canal

There is <u>one primary concern for the future operation</u>. This is the lack of any facilities down in the system, near Rogers Mesa, to allow the whole system to be operated with a high degree of flexibility plus a high efficiency (i.e., little or no spill). Specifically, a regulating reservoir is needed with proper in/out controls, at the proper location, and with proper linkage to the future Rogers Mesa pipeline.

<u>Canal Damage/Failure</u>

The J-U-B Engineering (2016) report recommends that a 2300' section near Garvin Mesa (367+00 to 390+00) be piped with two 63-inch diameter HDPE pipes at an estimated cost of about $2 million.

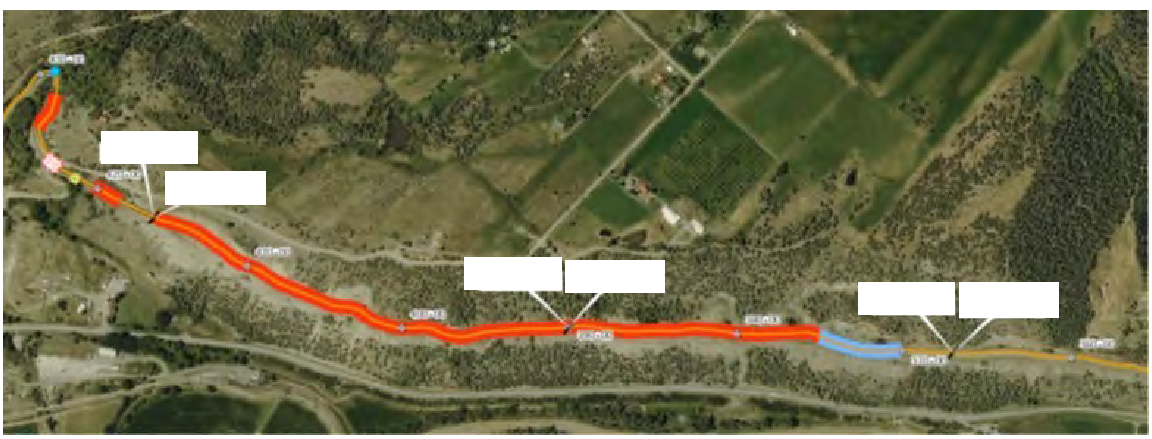


Figure 5. Section of FMC discussed in J-U-B report for piping

Specific wording from the J-U-B report is:

> *The hillside above the canal on Garvin Mesa has been sliding for many years. Landslides in the past have necessitated the piping of 500 feet of the canal in this area using two 60-inch corrugated metal pipes. The hillside above these two pipes continues to move and is damaging the pipes. Geotechnical engineers from USBR have visited the site with the NFWCD manager and have recommend that the pipes be replaced and placed deeper to a location below the landslide. This would create a siphon*

on the canal. There are two visible landslides in this area. It is currently not known if there are more areas that may begin to slide.

The entire length of the canal through the Garvin Mesa area is approximately 6,500 feet. It has been determined that 2,300 feet should be placed in a siphon. This will clear both of the visible landslides. A detailed geotechnical study should still be completed in this area in order to determine the specific area that needs to be piped, the depth of the pipeline, and how to address the landslide.

This report agrees with the conclusion of J-U-B Engineering that this is a dangerous section of canal. If a landside from above fills the canal, the canal will overflow and cause severe damage to the canal, plus cause flooding damage to downstream areas. If the canal section fails by itself in the form of a canal break, the same thing will happen. Pipelines are the logical answer.

The question is not if pipelines are needed; the question is what types of pipelines are needed. Welded HDPE pipe has definite advantages in terms of strength, and the ability to withstand prolonged pressures. The J-U-B recommendation of a siphon implies that the pipelines would be full in at least part of their sections. Some other alternatives, such as DuroMaxx pipe, should also be explored.

In addition to this specific section of canal, several other sections appear to be at risk. These are shown in the following figures. Segment 3 refers to the Garvin Mesa site that was just discussed.

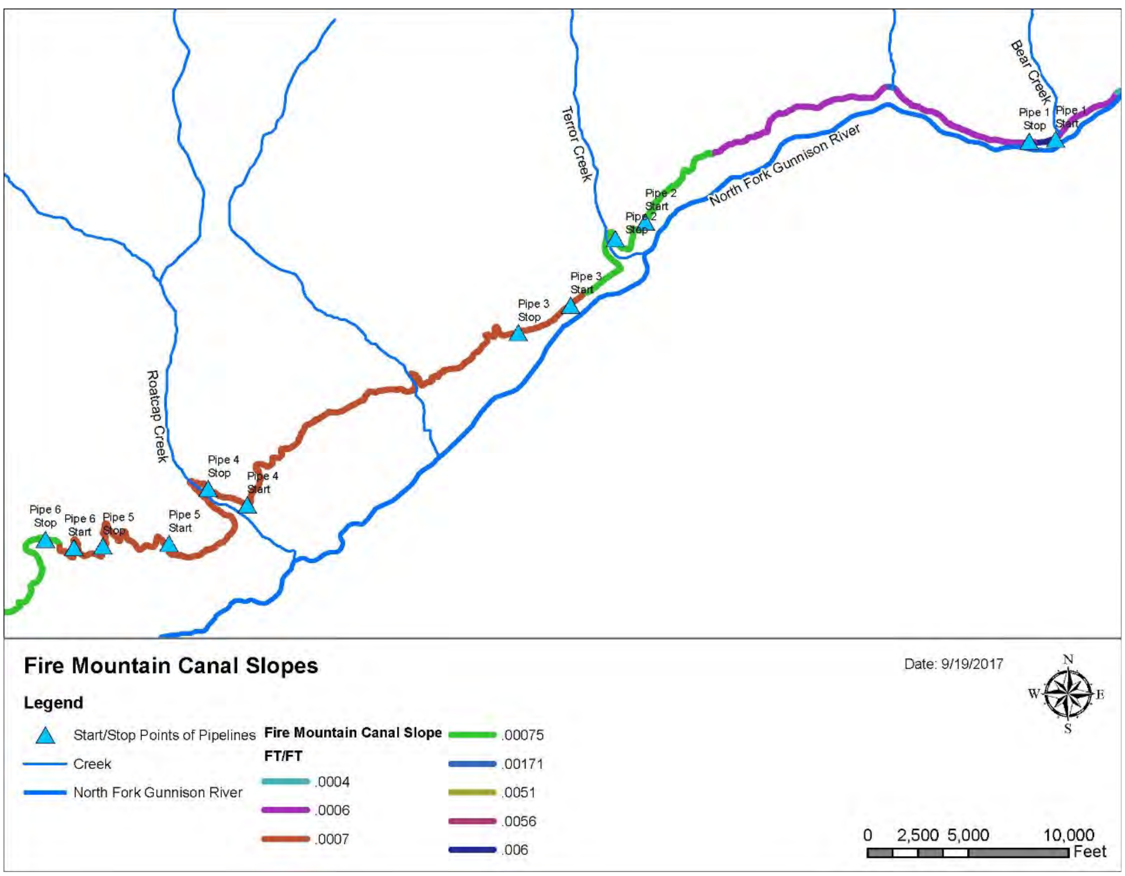


Figure 6. Approximate canal slopes for the first 16 miles of the Fire Mountain Canal

Section	L, ft
1	1,300

	Lat	long
Pipe Start:	38.920559	-107.489279
Pipe Stop:	38.920175	-107.493923

Canal Slope = 0.006 ft/ft
Canal Drop = 7.8 ft

Figure 7. Segment 1 map and approximate canal slope

Section	L, ft
2	3,000

	Lat	long
Pipe Start:	38.908003	-107.56065
Pipe Stop:	38.905607	-107.565845

Canal Slope = 0.00075 ft/ft
Canal Drop = 2.3 ft

Figure 8. Segment 2 map and approximate canal slope

Section	L, ft
3	3,200

	Lat	long
Pipe Start:	38.896383	-107.573359
Pipe Stop:	38.892479	-107.582466

Canal Slope = 0.0007 ft/ft
Canal Drop = 2.2 ft

Figure 9. Segment 3 map and approximate canal slope

Section	L, ft
4	2,300

	Lat	long
Pipe Start:	38.868088	-107.629032
Pipe Stop:	38.870156	-107.635987

Canal Slope =	0.0007	ft/ft
Canal Drop =	1.6	ft

Figure 10. Segment 4 map and approximate canal slope

Section	L, ft
5	6,250

	Lat	long
Pipe Start:	38.862546	-107.64259
Pipe Stop:	38.861988	-107.654087

Canal Slope =	0.0007	ft/ft
Canal Drop =	4.4	ft

Figure 11. Segment 5 map and approximate canal slope

Section	L, ft
6	2,570

	Lat	long
Pipe Start:	38.861671	-107.659123
Pipe Stop:	38.86271	-107.664165

Canal Slope =	0.00075	ft/ft
Canal Drop =	1.9	ft

Figure 12. Segment 6 map and approximate canal

For a good analysis of the piping requirements, there should be a better definition of the maximum flow rates through each section. Two 63" welded HDPE pipes appear to be the best selection for segment 3 (Garvin Mesa), but other segments have different slopes and flow rates.

Another alternative that could be less expensive would be to use double walled, smooth internal wall, corrugated PE pipe, such as the ADS N-1® WT IB. This pipe, if properly bedded (surrounded with excellent compacted soil or sand), has great strength against external loads (such as from rockslides). A primary disadvantage is that the joints tend to leak if they are exposed to some pressure for more than about 30 days. If the pressure is relieved for even a day, the deformation of the joints is removed and the pipeline functions well for another 30 days or so. With the FMC, the water cannot be shut off every 30 days. Therefore, the only way this type of corrugated pipe could be used is if it flowed partially full all the time. Another drawback is that the maximum diameter of the ADS pipe is 60", so it would likely only be useful downstream of segment 3 where the flows are less.

Emergency Spills

The Fire Mountain Canal (FMC) has 7 major spillways upstream of Leroux Creek, which are described in Table 5.

Table 5. Major spillways upstream of Leroux Creek on the FMC

Spill Name	Latitude	Longitude	MP from Diversion (approx.)	Comments
Bear Creek	38.921089	-107.488496	4000	Automatic spill to maintain target water level over 8' Parshall supplying FMC
Terror Creek	38.906459	-107.566754	33,200	On the side of the siphon structure
Stevens	38.886377	-107.600506	44,500	Upstream of siphon
Roatcap Creek	38.871184	-107.638650	65,600	On the side of the siphon structure
Jay Creek	38.83871	-107.702178	106,500	Significantly upstream of siphon; just u/s of a check.
Wolf Park	38.845673	-107.724953	123,800	Upstream of siphon
Horse Park	38.8315	-107.7376	136,600	Adjacent to possible regulating reservoir site.

The following map of the spill locations was prepared by USBR.

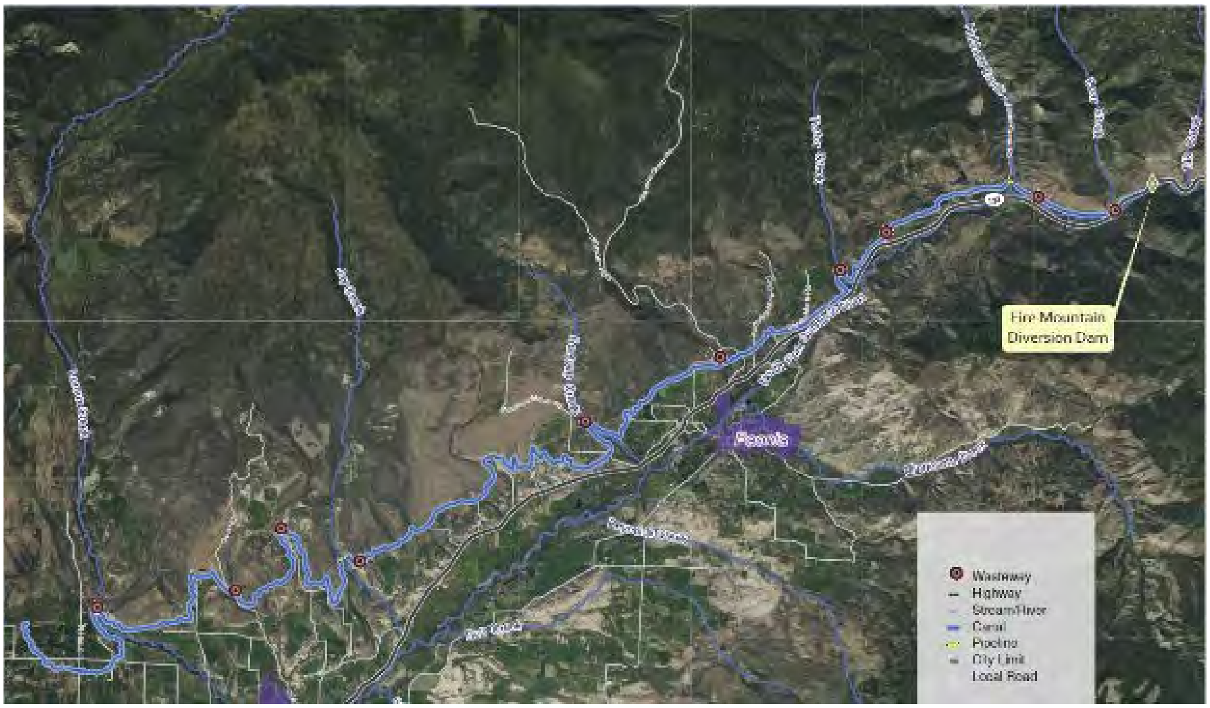


Figure 13. USBR map of spill locations

The simplest and most cost-effective means of providing automatic spills is to use ITRC Flap Gates. These can be constructed locally, using shop drawing provided by ITRC. ITRC has already supplied a drawing and instructions for the Terror Creek spill. The general recommendations are:

1. Make all of the gates the same:
   a. Fit in 5' wide opening
   b. 34 CFS capacity
   c. One flap gate per spill site
2. Remove one spill gate (or set of boards). Leave the other sluice gate in place for flushing of trash during the spring start-up.
3. The flashboard slots are too close to the spill structure walls at 4 of the sites; the flap gate frame would not fit, and the flap gate would not be able to rotate. Therefore, modifications are needed at four sites:
   a. Terror
   b. Stevens
   c. Roatcap
   d. Jay Creek
4. At each of the four sites listed above, modify the entrance to the removed sluice gate by constructing walls sticking out upstream of the existing sluice gate.
5. The modification will require the construction of two walls that extend upstream and out for a distance of 3.5', into the canal.
   a. The Stevens wall opening will converge, moving away from the existing sluice gate, from 5.75' to 5'.
   b. The Roatcap wall opening will diverge, moving away from the existing sluice gate, from 4' to 5'.

6. All the wall inlets will have a 5' wide opening where the flap gate can be installed.
7. The spill structures at Wolf Park and Horse Park have wooden walkways that can be removed (in part) so there can be enough room to drop an ITRC Flap Gate into the existing flashboard slots, leaving enough room to rotate.

Table 6. Spill structures

	CFS	Walls needed?	Wall opening at u/s, ft.	Wall opening at existing	Expanding wall sides, going u/s?	Converging wall sides, going u/s?
Terror	34	Yes	5	5		
Stevens	34	Yes	5	5.75		Y
Roatcap	34	Yes	5	4	Y	
Jay Creek	34	Yes	5	5		
Wolf Park	34	No	5	5		
Horse Park	34	No	5	5		

8. The walls must be tied together well enough that they will not deflect. They could be designed to have about 3.5' long flashboards on the sides, which could be removed to help flush water in the spring. Figure 14 does not exactly match the configuration, because it was a long-crested weir, but the nature of the construction might provide some ideas. The long-crested weir shown in Figure 14 has three bays on each side; the FMC structures would only need 1 bay on each side. The flap gate would be installed at the end.
9. Flashboard slots need to have sufficient depth to hold the static frame of the flap gate. "Channel" configurations (3" × 3") can be constructed by using one piece of 3" angle steel, with a 3" wide flat plate welded on one side.

Figure 14. Example of a simple structure with slots for flashboards

The following figures show the design program for the ITRC Flap Gate, for the FMC spills. As mentioned earlier, the detailed shop drawings for construction were sent to the project earlier.

This program is produced as an educational aid. Any use of the information provided by this program is made by the user at his / her c
No w arranty or guarantee is stated or implied by ITRC or Cal Poly. Users assume full responsibility for any usage of this material.

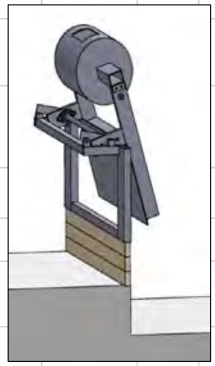
Value is lower than expected
Value is higher than expected

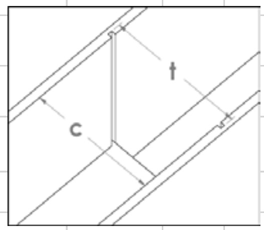
Cal Poly ITRC Flap Gate Program - FMC Spills

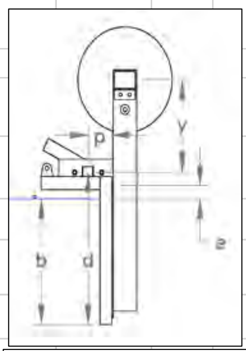
Red fonts indicate user input values | Orange cells indicate important results | Grey cells indicate design checks

Version 2016-02-05

	Inputs	Calculated		Design Variable (see sketches)	Calculated Variable (not in sketches)
Dynamic Gate Dimensions					
1. Enter the desired upstream water height above the bottom of the static support frame:	28.00		inches	b	
If there is no bottom frame, this is the water height above the bottom of the structure flow path. In either case, the total change in water level across the structure is equal to the MAX value you should input here.					
2. Enter the height of the pivot point above the bottom of the static frame:	34.00		inches	d	
This needs to be 4 to 6 inches larger than Variable (b).					
Distance (in.) from the u/s water surface to the pivot point. This *should be 4" or more, but typically doesn't need to be more than 8".* This is to keep the static frame support and bearings out of the water.		6.00			a
Distance (in.) from the bottom of the static frame lower support member to the top of the static horizontal pivot lever arm support.		33.00			
3. Enter the width of the structure opening (the flow path):	60.00		inches	c	
4. Enter the total width including the depth of both board slots:	64.50		inches	t	
This is the width of the flow path plus the depth of each board slot. If the walls are not plumb, be sure to use the smallest value.					
Depth (in.) of each board slot. Two inches is the recommended minimum.		2.25			
Total width (in.) of flashboard static frame.		63.50			
5. Enter the desired vertical distance from the top of the upstream water level to the top of the faceplate:	2.00		inches	e	
Two inches works well and is recommended.					
6. Enter the pivot lever arm length from the pivot point to the upstream side of the faceplate:	5.50		inches	p	
This should be a minimum of 4" in order to leave room for the 2-bolt flange bearings and provide leverage to minimize the counterweight. Typical values range between 4 and 8 inches.					
Water depth (in.) above the top of bottom static support frame.		24.00			h
Width (in.) of flow path between vertical static frame supports. This is used to estimate the maximum flow rate through the gate.		51.50			
7. Enter the faceplate overlap of the static frame:	0.50		inches		
ITRC recommends 0.5" if the static tubing wall thickness is 0.35" or less; if the wall thickness is greater than 0.35" use 0.75".					
Width (in.) of faceplate including overlap.		52.50			
8. Enter the faceplate thickness:	0.250		inches		
This should be 0.25" or more to prevent the plate from bending if it were to slam shut. It can also be increased to help with the closing moment, if necessary. ***This is also the thickness of the counterweight end caps and brackets.***					
9. Enter the weight per foot of the steel tubing used to make the dynamic frame as well as the tubing dimensions:	8.78		lbs / foot		
Tubing depth	2.00		inches	l	
Tubing width	4.00		inches	m	
Tubing wall thickness	0.250		inches		
This is the vertical tubing that supports both the counterweight and the faceplate, plus the horizontal faceplate supports.					







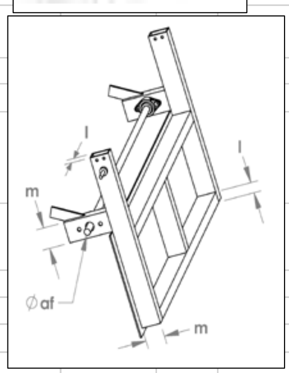


Figure 15. First page of the ITRC Flap Gate design program input

Counterweight Dimensions							
12. Enter the density of the material used to fill the counterweight:	145	lbs / cubic foot					
Counterweight material	Quikrete Concrete						
13. Select the counterweight (CW) support tubing dimensions:							**Design Checks**
CW support height	4.00	inches	x				OK
CW support width	4.00	inches	aa				
CW support wall thickness	0.250	inches					OK
Weight of CW support material	12.18	lbs / foot					
14. Enter the diameter and the length of the pipe/cylinder that causes the closing moment to equal the opening moment:				Adjust dimensions until the opening and closing moments below are equal			OK
Pipe diameter (actual OD, if possible)	24.00	inches	ac	Opening moment:	1020	ft-lbs.	
Pipe wall thickness	0.250	inches		Closing moment:	1019	ft-lbs.	
CW pipe length	28.80	inches	ae				OK
Counterweight end cap thickness (in.)		0.250					OK
15. Select the rebar size to adjusting the counterweight:	4			Try to obtain a value between 5 and 15%	6.3%		OK
Approximate weight (lbs) of the rebar to add during initial start-up.		86					OK
Approximate length (ft) of rebar required to achieve that weight.		129		Try to obtain a value less than 4 while maintaining the ratios below:	0.8		
16. Enter the vertical distance from the pivot to center of the counterweight:	14.00	inches	y				OK
Keep the orange value on the right less than 4 while keeping the ratios in Step 17 within range.							
17. Check on various ratios, and adjust inputs as needed:							OK
Angle from pivot to center of gravity			deg	Should be between 48 and 53 deg.	50.5		
Pivot to water level / upstream water depth			a / h	Should be 0.5 or less	0.25		OK
Lever arm length / pivot height			p / (h+a)	Should be 0.25 or less	0.18		OK
Pivot Shaft Dimensions							
18. Select the pivot shaft diameter:	2.00	inches	af	Minimum shaft diameter without strip(s) (inches)	1.54		OK

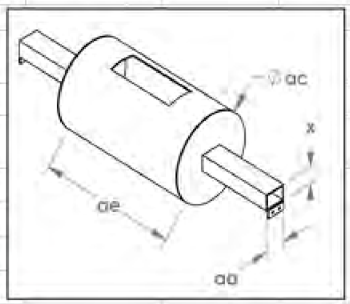


Figure 16. Second page of the ITRC Flap Gate program's input

Individual Site Descriptions for Flap Gates

Brief descriptions of each site are provided in the following sections. The details are not too important, because the same size Flap Gate is recommended for all sites.

Bear Creek is not included because it will not be equipped with an emergency automatic spill.

<u>Terror Creek</u>

- In the photo in Figure 17 (taken from upstream), the left two sluice gates and flashboard bay are for the main canal. The FMC siphons under the creek.
- The right two sluice gates and flashboard bay spill to the creek.
- There is an old diversion structure upstream in the creek that goes to a feeder canal that eventually discharges back to the FMC downstream of the siphon.
- The FMC has junior 1930 rights of 70 CFS to Terror Creek.
    - Other ditches have more senior rights so it is unlikely that the FMC could get the full amount.
    - In reality, there may be about 10 CFS available during some springs.
    - There may be no water available during summer time when creek runoff is low.
    - The creek water is clean.
- The first priority should be to install automatic spill gates into the creek.
- After several summers with good flow measurement in the creek, it might be decided to bring the water right flows into the canal. The decision on how to reconstruct the feeder canal, or to use a pipeline rather than the old feeder canal, can be made then.

Figure 17. Terror Creek structure. The right hand two sluice gates control the spill.

Figure 18. **Flow path to Terror Creek from spill gates**

Figure 19. **Head of feeder canal on Terror Creek. Abandoned canal starts at lower left.**

Figure 20. **Gate near head of abandoned feeder canal from Terror Creek**

Figure 21. Terror Creek upstream of the old diversion, showing significant elevation drop

Figure 22. Aerial view of Terror Creek

Recommendations for Terror Creek

1. Keep the right-hand sluice gate in place for flushing the canal during the spring.
2. Use one flap gate with a capacity of about 34 CFS. The static frame bottom horizontal tubing is sufficiently large. All thicknesses of steel must be carefully checked during fabrication.
3. Parallel side walls need to be built out to the front of the far right-hand side spill sluice gate, a distance of 3.5’ from the concrete walls. The walls should maintain the 5’ width (inside wall-to-inside wall)
4. At the upstream end of each side wall, install a vertical fabricated “C” channel, constructed of a 3” angle with a 3” flat stock steel welded to make a “C”. These channels, flush with the insides of the new side walls, will hold the static frame of the flap gate. Each steel channel will have about a 3” inside depth ×2.5” inside width to hold the static frame of the flap gate.

<u>Stevens Spill</u>

- The side spill is located upstream of the check structure, on the left-hand side of the canal.
- Flap gates will not fit into the existing flashboard slots because of concrete bulkhead walls behind the existing sluice gates.
- For easy silt removal, it is best to install the flap gate upstream of the existing sluice gates rather than downstream of the road crossing.

Figure 23. Inlet view of Stevens Spill

Figure 24. Discharge of Stevens Spill

Figure 25. View into the discharge structure of Stevens Spill

Figure 26. Location of Stevens Spill

Recommendations for Stevens Spill

1. Build parallel side walls of steel or concrete or flashboards extending to the front of one of the spill gates. These walls should maintain the 69" opening (inside wall-to-inside wall). The walls should extend 3.5' to the front of one of the existing openings.
2. At the upstream end of each side wall, install a vertical fabricated "C" channel, constructed of a 3" angle with a 3" flat stock steel welded to make a "C". These channels, flush with the new side walls, will hold the static frame of the flap gate. Each channel will have about a 3" inside depth ×2.5" inside width to hold the static frame of the flap gate.

<u>Roatcap Creek Spill</u>

The structure is similar to the Terror Creek spill, but the spill gates are have 4' width, instead of 5'. Figure 27 shows the layout of the existing structure at Roatcap Creek.

- The left two gates and flashboard bay lead to the siphon under the creek for the FMC.
- The right two gates and flashboard bay spill to the creek.
- The FMC may have some very junior rights to Roatcap Creek.

Figure 27. View from upstream of the Roatcap Creek spill

Figure 28. Google image of the Roatcap spill location

Recommendation for Roatcap Spill

1. Build **<u>expanding</u>** (diverging) side walls of steel or concrete or flashboards extending to the front of the right-hand side spill gate. These walls should expand the opening (inside wall-to-inside wall) from 4' at the bridge, to 5' on their upstream end. The walls should extend 3.5' to the front of one of the existing openings.

2. At the upstream end of each side wall, install a vertical fabricated "C" channel, constructed of a 3" angle with a 3" flat stock steel welded to make a "C". These channels, flush with the new side walls, will hold the static frame of the flap gate. Each channel will have about a 3" inside depth ×2.5" inside width to hold the static frame of the flap gate.
3. The gate will be the same as the Terror Creek gate. Flow rate capacity will be about 34 CFS.

Jay Creek Spill

Jay Creek spill is shown in Figure 29 and Figure 30.

Figure 29. Entrance to the Jay Creek spill

Figure 30. Google image of the Jay Creek spill location

Recommendation for Jay Creek Spill

1. The basic configuration will be the same as for the Stevens Spill, but the Jay Creek spill only has a 5' width per flashboard bay (the same as Terror Creek), rather than the 69" of Stevens Creek.
2. Build parallel side walls of steel or concrete or flashboards extending to the front of one of the spill gates. These walls should maintain the 69" opening (inside wall-to-inside wall). The walls should extend 3.5' to the front of one of the existing openings.
3. At the upstream end of each side wall, install a vertical fabricated "C" channel, constructed of a 3" angle with a 3" flat stock steel welded to make a "C". These channels, flush with the new side walls, will hold the static frame of the flap gate. Each channel will have about a 3" inside depth ×2.5" inside width to hold the static frame of the flap gate.
4. Use the same gate design as for the Terror Creek spill

Wolf Park Spill

The spill is on the left-hand side of the canal, a few hundred feet upstream of a siphon. Each flashboard section has a 5' opening width. This particular structure has a wood walkway on top, which is not used as a road crossing. This means the flashboard slots can be used to hold the flap gate static frame.

Figure 31. Front (inlet) view of Wolf Park Spill

Figure 32. Google image of the Wolf Park Spill

Recommendations for the Wolf Park spill are similar to those of the Jay Creek spill.

Horse Park Spill

This is the site for the future re-regulating reservoir. Although an ITRC Flap Gate would provide good spill protection now, a different structure (with less head loss) would be needed in the future for the reservoir inlet. Therefore, if it appears that funding will be available in a few years for the reservoir, it may be judicious to leave this as the last structure to automate.

The spill structure has two bays, each with a 5' width, and the following characteristics:

- The spill is located on the left hand side of the canal, about 100' u/s of a check structure.
- There is no road across the structure; boards can be removed to place the flap gate frame into the board slots without any upper restriction.
- There is a bridge crossing on a corner downstream that is possibly providing a restriction. Downstream of the bridge is the large canal drop.
- The road immediately downstream of the spill structure will need to be lowered so that it does not cause back pressure on the flap gates.

Figure 33. View of inlet of Horse Park Spill

Figure 34. Location of Horse Park Spill

Recommendation for Horse Park Spill
If flap gates are installed, they would be similar to the Terror Creek installation. However, the proposed reservoir site is in the swale/ravine adjacent to the bend in the canal at this point. A different spill structure will be needed for the eventual reservoir.

Chapter 4. FLOW RATE REQUIREMENTS FOR FLEXIBLE DELIVERIES ON ROGERS MESA

Background

The existing physical configuration of the Rogers Mesa canal is shown in Figure 35. The major turnouts are the East, Slack, and Patterson service areas, along with the "Extension," which begins just downstream of the Patterson turnout. Presently, the Jesse service area is supplied from the FMC with about 6 CFS at a drop structure to the river. That 6 CFS, plus early larger stream flows, are picked up at a downstream diversion in Leroux Creek and put into a separate small canal.

Figure 35. Existing configuration of Rogers Mesa canal

The preliminary report (June 2016) by J-U-B engineers provided recommendations for flow rate capacities along the proposed Rogers Mesa pipeline, as seen in Figure 36.

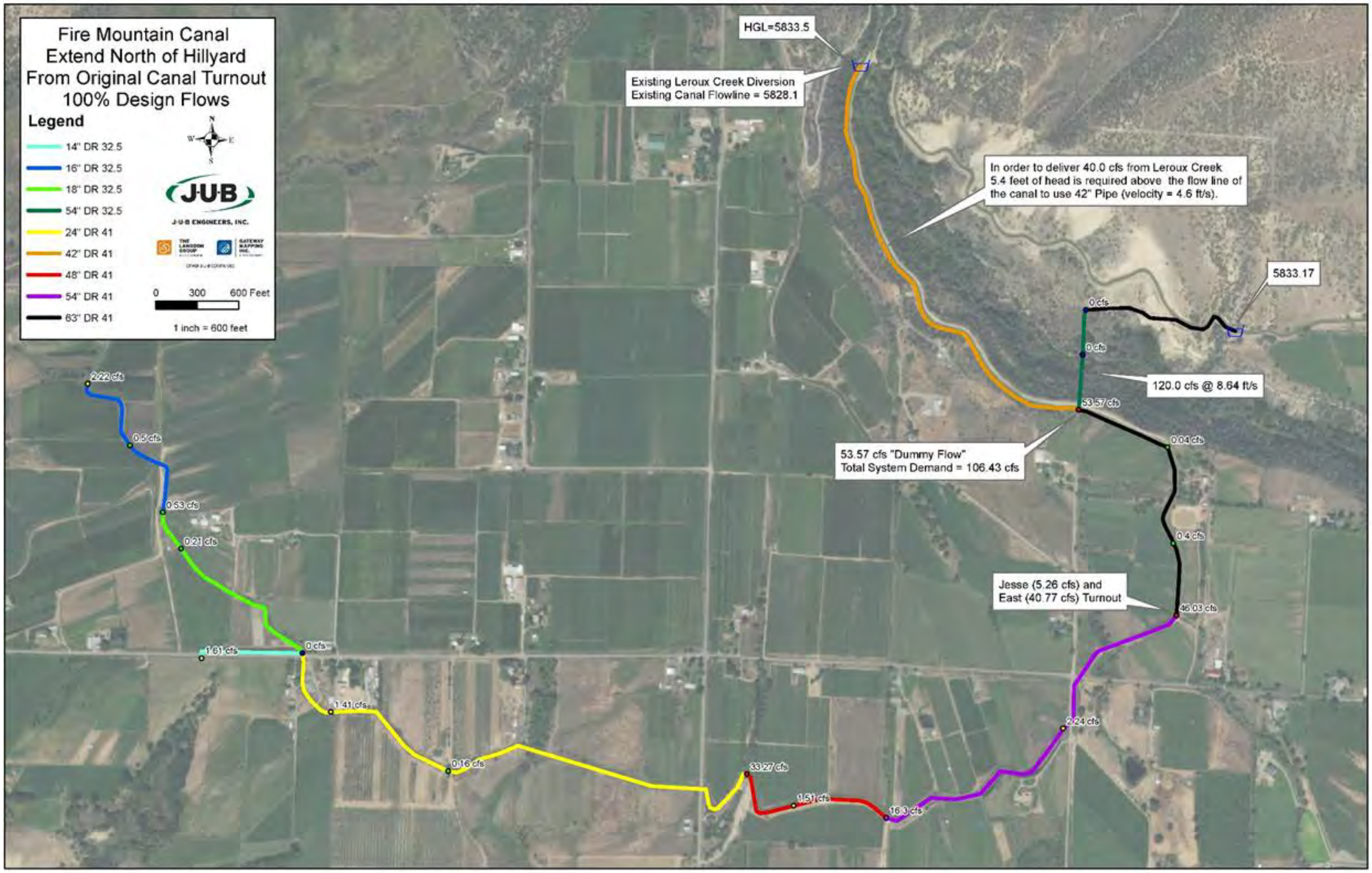


Figure 36. Preliminary flow rate estimates from J-U-B (June 2106)

Various elevations and initial pipe size recommendations from J-U-B are shown in Figure 37.

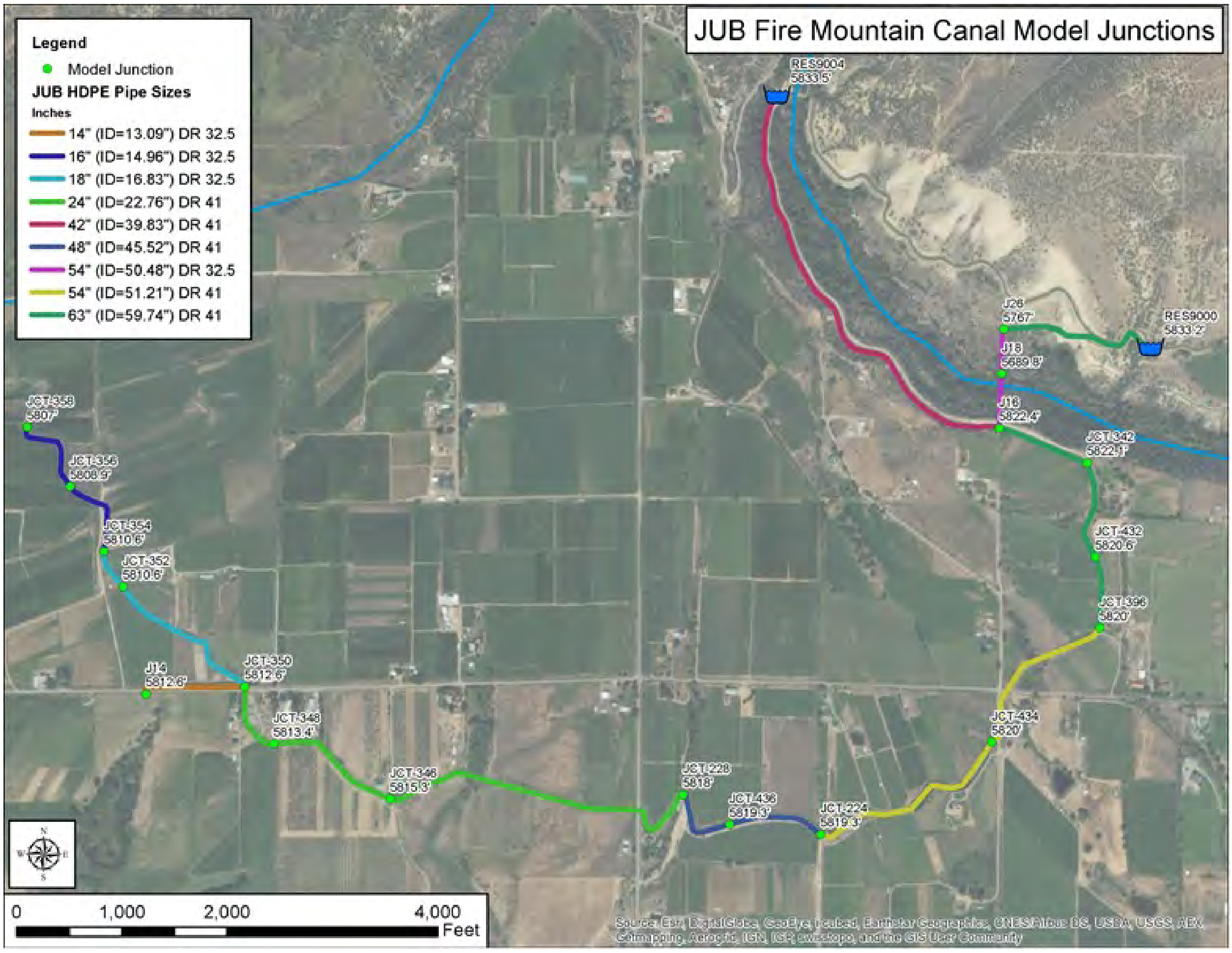


Figure 37. Preliminary pipe sizes selected by J-U-B (June, 2016)

Considerations

One of the questions that ITRC was asked to address was the flow rate capacities of the pipeline segments. For proper examination, typical needs such as "shares" and "historical flow rates" must be considered. The more challenging aspect is to estimate future behavior by farmers if they are eventually supplied by pressurized pipelines that are connected to the Rogers Mesa pipeline. New pipelines must be designed with sufficient capacity for today's needs, as well as future needs. The definition of "needs" can vary. A designer might assume that the "needs" should be based upon a "reasonable" level of conveyance and on-farm irrigation efficiency.

Furthermore, designs must generally provide at least the flow rates that they are receiving today. Farmers will be upset if they are not provided tomorrow with the same level of service, or better, than they receive today. That level of service may have little or no relationship to perceived (by others) reasonableness of water use.

The Current Situation

Shares

Fields have possession of water "shares". There are 25 shares/acre, with 0.325 GPM/share (0.000725 CFS/share). This translates to a right to a 24/7 flow rate of 8.13 GPM/acre.

However, farmers and the Fire Mountain Canal employees sometimes refer to a "130% Share" entitlement. This translates to a 24/7 flow rate of 10.6 GPM/acre.

The number of shares on Rogers Mesa is reported to be equivalent to 5197 acres. This translates to a 24/7 flow rate entitlement of:

94.1 CFS @ 100%
122.4 CFS @ 130%

Historical Maximum Flow Rates

There are a variety of estimates of the maximum flow rates that actually enter the Rogers Mesa service area of the FMC (which is not the same as *design* values). It should be noted that it is difficult to have a flow rate measurement accuracy of better than 5-10% in the field. Therefore, a "measured" flow rate of 120 CFS might actually be as high as 132 CFS or so, or as low as 110 CFS. These flows do not include possible future Jesse flow rates of about 6 CFS.

The maximum actual flow rate into the head/diversion of the FMC has been estimated at somewhere between 150-180 CFS (Appendix F from J-U-B 2016 report - Fire Mt. Canal Diversion structure.pdf, which is a copy of a memo of April 17, 2013 from McLaughlin Whitewater). Graphs of some historical diversions are shown in earlier pages of this report. There are various losses and diversions between the diversion point and the Rogers Mesa. In addition there can be inflows, such as from Leroux Creek.

David Kanzer provided the preliminary graph seen in Figure 38 from 2013 data. The gray and blue lines near the top are of the most interest. The gray "House" line represents the flow in the FMC at Leroux Creek. The blue "Drop" line represents the flow in the FMC several miles upstream of Leroux Creek, at a large drop in the canal. The maximum flow on the gray line occurs in May, and is about **122 CFS**. It represents the FMC canal flow, plus some additional flow from Leroux Creek, the combination of which goes to Rogers Mesa.

Various other reported maximum actual flow rates into Rogers Mesa were in the **120-125 CFS** range. In other words, they were fairly consistent.

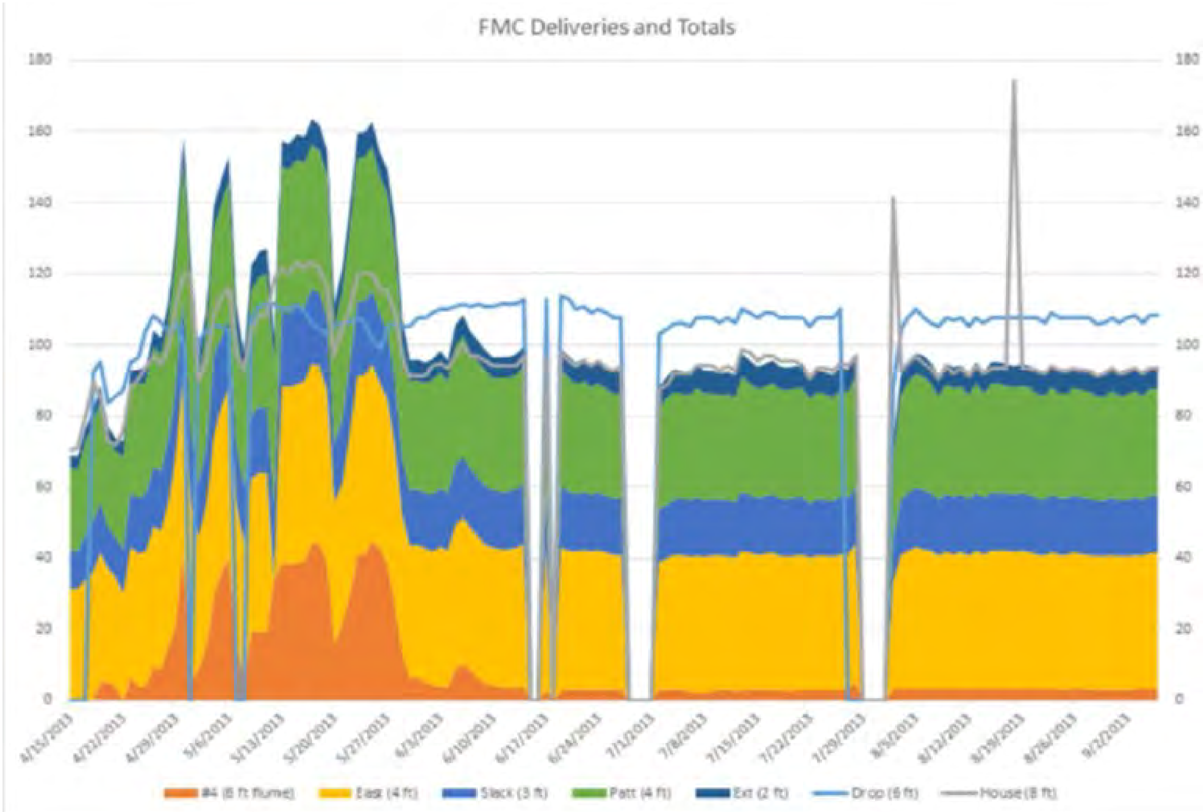


Figure 38. 2013 Flow rates (preliminary) to Rogers Mesa. Provided by David Kanzer

Weather Data and ET_o Computations

As part of the computation of water requirements for Rogers Mesa, the crop water use was estimated. Net crop water use is also known as "evapotranspiration", or "ET". The computation of crop ET values, on a daily, monthly, or annual basis can be done with a variety of formulas and weather station inputs. Old studies did not have the benefit of modern automated weather stations, and the "Blaney-Criddle" formula was often used in the western US to estimate crop ET. This formula was used in the Trout Unlimited study by Clear Water Solutions (2104), and provided reasonable results. Now, with the availability of good weather data, it is more common to use the ET_o approach and formulas described in this section because it provides more consistent high quality estimates of evapotranspiration.

The evapotranspiration rate from a reference crop, not short of water, is called the reference crop evapotranspiration (ET_o) (Allen et al, 1998). When multiplied by a crop coefficient (K_c), ET_o is used to determine the crop evapotranspiration rate (ET) for a particular time period. The equation for computing ET is:

$$ETcrop = K_C \times ET_o$$

For the study of Rogers Mesa water requirements, the ET_o was estimated for a grass reference crop with specific characteristics of no stress and a dry soil surface. The concept of ET_o was introduced to study the evaporative demand of the atmosphere independently of crop type, crop development, and management practices. ET_o is a climatic parameter and can be computed from meteorological weather data such as solar radiation, air temperature, air humidity, and wind speed data.

Weather Data Source

The crop water use rates of interest were in the summer, when the weather is the hottest. Therefore, daily weather data was used to compute daily ET_o for June, July, and August from 1998 to 2016. The weather data was provided by the Colorado Agricultural Meteorological Network (CoAgMet) weather station located in the Rogers Mesa area just south of the Fire Mountain Canal System. Figure 39 shows the approximate location.

Figure 39. Approximate location of agricultural weather station in Rogers Mesa area

Characteristics of the weather station in the area of interest are as follows:

- Station ID: HOT01
- Station Name: CSU Rogers Mesa Expt Station
- Location: 4 mi W Hotchkiss
- Elevation: 5,547'
- Latitude: 38.7917
- Longitude: -107.792
- Recording start date: 5/21/1998
- Surrounding area: Partially irrigated

Figure 40 shows an example photo of a CoAgMet weather station.

Figure 40. Example photo of a CoAgMet weather station

Weather Data Quality Control

The historical weather data was analyzed for quality control. The quality control methods include:

- For any missing average daily data, an estimate was made by averaging the weather component values of the previous day and the following day.
- The relative humidity was not allowed to exceed 100%.
- Average daily wind speed was not available for download. Therefore, hourly wind speed measurements were averaged to compute the average daily wind speed used in the calculations for ET_o.

Computation of ET_o

Daily ET_o values were computed using the FAO Irrigation and Drainage Paper No. 56 (FAO 56) Penman Monteith process (Allen et. al, 1998). Average daily weather data of air temperature, solar radiation, relative humidity, and wind speed were run through a series of equations that produce an estimated daily ET_o value in inches per day.

Historical ET_o values for Rogers Mesa

The historical daily ET_o values for Rogers Mesa are shown in Figure 41.

Figure 41. Historical daily ET_o values for Rogers Mesa

Figure 10 (continued). Historical daily ET_o values for Rogers Mesa

Converting from ET_o to Crop ET

As noted earlier, the conversion from ET_o to crop ET is accomplished by multiplying the ET_o by a "crop coefficient" (Kc). The Kc depends upon the crop, health of the plant, level of stress, stage of growth and other factors. The most common crops in the area are corn silage, pasture, and alfalfa. All have peak Kc values of about 1.0, if one considers that alfalfa will be cut once during July. Another major crop is orchards, which can have a peak Kc as high as 1.2 if there is a very healthy cover crop. Countering these values is the likelihood that reported acreages are likely gross, and not net acreages.

In fact, most crop coefficients are in the ballpark of 1.0. Tremendous amounts of research have been done to fine-tune the crop coefficient values In fact, the final value of gross irrigation water required are more dependent upon estimates of irrigation efficiency than it is on the precision of the Kc estimates. While Kc estimates may be off by 5%, estimates of irrigation efficiency can easily be off by 20%.

The Clear Water Solutions (2014) report provided the following values of cropped acreage in Rogers Mesa:

84% alfalfa and pasture grass
4% silage and grains
12% orchards

The important factor regarding crop ET is that the vast majority of the crops have fairly constant leaf cover over the soil during the irrigation season, and typical crop coefficients for these crops are about 1.0. The result is that during the irrigation season, the crop ET can be assumed to approximately equal ET_o. For planning and estimation purposes, such as for this report, further analysis is not merited.

Net Volumes of Irrigation Water Needed for Rogers Mesa

The "net" irrigation requirement is usually estimated as:

Net irrigation requirement = ET – effective precipitation

When looking at annual volumes, the annual effective precipitation is typically considered, which must account for non-beneficial evaporation and deep percolation of that water. Leaching requirement for salt control should also be factored in.

For this report, there was no attempt to make detailed annual computations of effective precipitation and leaching requirement. The new volume of irrigation water needed is only used to make approximate values of potential water conservation based on future investments.

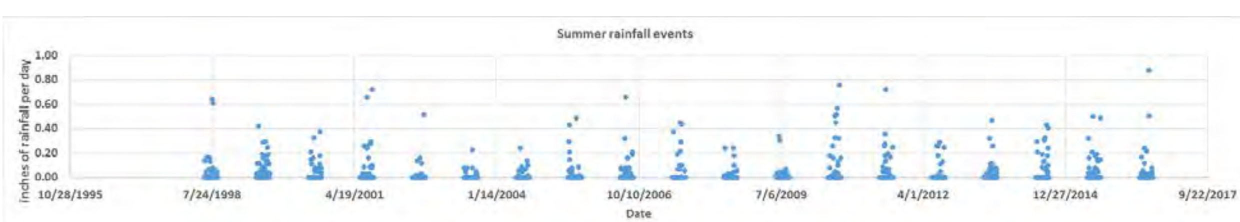


Figure 42. Distribution of individual precipitation events, June-August

Table 7. Historical summer (June – August) precipitation

Summer	Precipitation, inches
1998	2.39
1999	3.45
2000	2.11
2001	3.37
2002	1.06
2003	0.72
2004	0.82
2005	2.06
2006	2.48
2007	2.68
2008	1.05
2009	1.05
2010	4.74
2011	3.11
2012	2.78
2013	1.98
2014	3.31
2015	3.24
2016	2.53
average	2.36
minimum	0.72
maximum	4.74

The precipitation events are typically small. The effect would primarily be to raise the ET for several days per rain event, above ITRC's computed ET. Therefore, for the estimates in this report, summer ET was ignored in computing gross summer irrigation requirements.

Because the gross irrigation water requirements in this report focus on diversions from the river, the extra water to fill the root zones in early spring irrigations is also ignored. In large part, this is because during early spring large flows are available from Leroux Creek for this purpose, and are not required from the river.

The average 3-month crop ET during June, July, and August over the past 19 years is about 1.6 AF/acre. The maximum crop ET during the same 3 months is about 1.9 AF/acre, and the minimum is 1.4 AF/acre. An approximate average crop ET during the ±150 days of irrigation water delivery from the river is 2.3 AF/acre. Assuming 7105 irrigated acres, this represents a <u>net</u> irrigation water requirement from the river of about 16,300 AF/yr. Given all the uncertainties involved in such computations, it is likely correct within ±20%.

Assuming 5197 acres (which matches the shares on Rogers Mesa), this represents about 11,900 AF/yr. ITRC did not attempt to determine why the Clear Water Solutions (2014) acreage of 7105 irrigated acres differs from the 5197 acres with shares.

Demand Theory for Determining Pipe Flow Rates

Flow rate capacities for new projects are sometimes determined using "demand theory". Demand theory originated in the 1960's in France and has been used and verified by ITRC in a variety of western US irrigation projects. For clarification, this discussion applies to the procedure to determine pipeline flow rate capacities – not annual volumes of water used.

The condensed computation process is:

1. Estimate the net continuous irrigation requirement (GPM/acre). This requires that the local weather data be obtained, and estimates of crop type made.
2. Convert that net continuous requirement into a gross value by assuming irrigation efficiencies.
3. Estimate if the irrigation water usage will be continuous, or if it might be less or more during certain days of the week (such as on weekends), or during certain hours of the day (for example, if farmers enter into a time-of-use electrical rate with utilities and do not pump between noon and 6 p.m.).
4. Determine the relative turnout size at delivery points. For example, if a gross irrigation demand is 8 GPM/acre, and the turnout size is such that it can only deliver 8 GPM/acre, there will be very little flexibility during periods of peak ET. However, if the turnout is capable of delivering 3 times that flow rate, a turnout might be operated only one-third of the time.
5. Assign a reasonable acceptable value of "congestion". That is, one might assume that having enough flow rate capacity for everyone to take water when desired 97% of the time is sufficient (3% congestion), as opposed to 100% of the time, which would require much higher flow capacities for rare occasions.

Judgment is required in assigning almost all the values. Nevertheless, this process has been shown to be robust, and provides a good estimate of required flow rates under future scenarios – as opposed to simply using historical records.

The following values were used to compute flow rates for future scheduled irrigations:

1. Continuous (net) irrigation requirement = 4.3 GPM

   The peak monthly ET_o was computing using weather data from the CSU Rogers Mesa Experiment Station approximately 4 miles west of Hotchkiss. Monthly summaries, based on daily computations for 19 years (1998-2016) are shown in Table 8. A maximum ET_o value of 7.5 in/mo. was used, based on the average of the highest July values from four years.

   For computations, an average <u>Kc of 1.0</u> was selected, which results in a maximum design **<u>crop ET of 7.5 in/mo., which is equivalent to 4.6 GPM/acre continuous net flow rate.</u>**

   Daily peak ET values were not used, because the soil provides a buffering water holding capacity. Computations for the irrigation requirement assumed that there would be negligible effective rainfall during this period, because during some years the precipitation is only about one-third of an inch during July.

Table 8. Peak monthly ET_o summary – metric units

Year	Monthly Sum of ETo (mm/month)		
	June	**July**	**August**
1998	195	201	180
1999	181	170	147
2000	192	195	176
2001	176	163	156
2002	179	165	163
2003	180	160	146
2004	176	177	160
2005	163	191	144
2006	176	167	140
2007	166	171	142
2008	167	169	146
2009	135	163	140
2010	169	171	140
2011	175	167	153
2012	188	167	144
2013	177	168	135
2014	169	166	132
2015	164	149	139
2016	167	166	133
Average:	173	171	148
Maximum:	195	201	180
Average 4 highest:	189	191	170

Table 9. Peak monthly ET_o values in English units

	ETo, in/mo.		
	June	**July**	**Aug**
Average	6.8	6.7	5.8
Maximum	7.7	7.9	7.1

2. The computation of the gross continuous future irrigation requirement from the FMC in the Rogers Mesa area assumed a 100% conveyance efficiency because of the likelihood of pipelines that will distribute water to fields. The field irrigation efficiency was assumed to be 60%, which is likely the highest attainable with small fields until some future date when more sophisticated irrigation systems and management are used.
3. Computations assumed that there is a likelihood that in the future, farmers will do the majority of their irrigation in 6 days out of 7.
4. It was estimated that in the future, the average field size will be 5 acres. The smaller fields will likely have irrigation systems that are pressurized and not over-sized by much. However, there will likely still be some surface (flood) irrigated fields that require occasional high flow rates. Therefore, the average field turnout was assumed to have three times the capacity that would be needed for continuous irrigation.

Recommended FMC Turnout Capacities

Table 10 provides a comparison of two estimates of turnout flow rate requirements:

1. Values obtained using "demand theory" as described above
2. 130% of today's shares

The preliminary recommended design would be the greater of the two values. This is just the first step.

Table 10. Comparison of turnout flow rate requirement estimates – first step

Rogers Mesa Turnout	MP	Flow Requirements for Rogers Mesa Turnouts, CFS		
		Flexibility for the future	130% of today's shares	Recommended FMC design
#80	28.455	0.9	0.04	0.9
#81	28.556	0.9	0.5	0.9
#82	28.716	1.4	0.9	1.4
East	28.722	47.2	50.6	50.6
#83a	29.144	2.7	2.0	2.7
#83b	29.144	1.5	0.9	1.5
Slack	29.308	17.5	17.5	17.5
#84	29.482	2.4	1.8	2.4
Patterson	29.556	36.0	38.0	38.0
#85	29.596	2.4	1.8	2.4
Extension	29.67	8.9	8.3	8.9
Pump		0.9	0.01	0.9
		122.5	122	128

It is pure coincidence that the flow rate needed for flexibility in the future ("demand" scheduling) is almost identical to the 130% values. The 130% flows have been sufficient for traditional irrigation, which includes substantial on-farm and conveyance inefficiencies after water leaves the FMC.

In the future, the efficiencies will be higher, but occasional larger flow rate capacities will be needed to provide the flexibility demanded by future farmers, especially by small operators who want to just flip a switch and turn on their irrigation. This coincidence – that the historical flow rate requirements are almost identical to the future flow rate requirements – is a fairly unusual situation.

It is essential to understand that high turnout <u>flow rate capacities</u> in the future will be used as one tool to reduce <u>seasonal volume requirements</u>. In many irrigation projects throughout the western US, it is understood that if farmers have the flexibility to use water when it is needed, and if they can also shut off when needed, they will use less total volume (acre-feet) during the year. This also assumes that there are flow meters on individual turnouts that register in both flow rate and volume – a typical situation with piped irrigation deliveries.

That switch will not happen immediately on the Rogers Mesa. Significant investment will be needed to provide flexible pipelines from the FMC to farmer fields. Farmers will gradually shift to more efficient on-farm irrigation methods. The existing pipelines do not provide this capability. A first there will be a complete disconnect (in the form of an air gap) between the new Rogers Mesa pipeline and the existing distribution pipelines in two of the turnouts.

Comparison of Turnout Flow Rate Values to be used for Design

Table 11 provides a comparison of the new recommended turnout flow rates, against very preliminary estimates by J-U-B. The J-U-B estimates for the East Ditch of 46.03 CFS were composed of 5.26 CFS for the Jesse, plus 40.77 CFS for the East Ditch. The values are also different because ITRC included the availability of flows from Leroux Creek in the spring. Note that some of the ITRC recommended turnout flow rates are higher than previously mentioned. This is an adjustment that accounts for field sizes and irrigation system requirements.

Table 11. Comparison of new recommended turnout flow rate values with J-U-B estimates (Jesse not included)

Rogers Mesa Turnout	MP	Flow Rates (CFS)		
		ITRC Recommended FMC Design	J-U-B from Original Canal Turnout 100% Design Flow Map	J-U-B Model Hydraulic Characteristics
#80	28.455	1.3	0.04	0.04
#81	28.556	0.8	0.4	0.4
#82	28.716	1.3		
East	28.722	50.6	46.03	46.03
#83a	29.144	2.5	2.24	2.24
#83b		1.4		
Slack	29.308	17.5	16.3	16.3
#84	29.482	2.3		
Patterson	29.556	38	33.27	33.27
#85	29.596	2.3	1.51	1.51
Extension	29.67	8.3	6.37	6.7
Pump		0.8	0	0
Totals		127.1	106.2	106.5

References

Allen, R.G., L.S. Pereira, D. Raes, and M. Smith. 1998. *Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements*. FAO Irrigation and Drainage Paper 56. Food and Agriculture Organization. Rome, Italy, 1998.

Clear Water Solutions, Inc. 2014. North Fork Study. Prepared for Trout Unlimited.

Chapter 5. JESSE LATERAL

Existing Conditions

The Jesse Lateral services approximately 300 acres along the eastern part of Rogers Mesa. Figure 43 shows the existing alignment and characteristics of the Jesse Lateral.

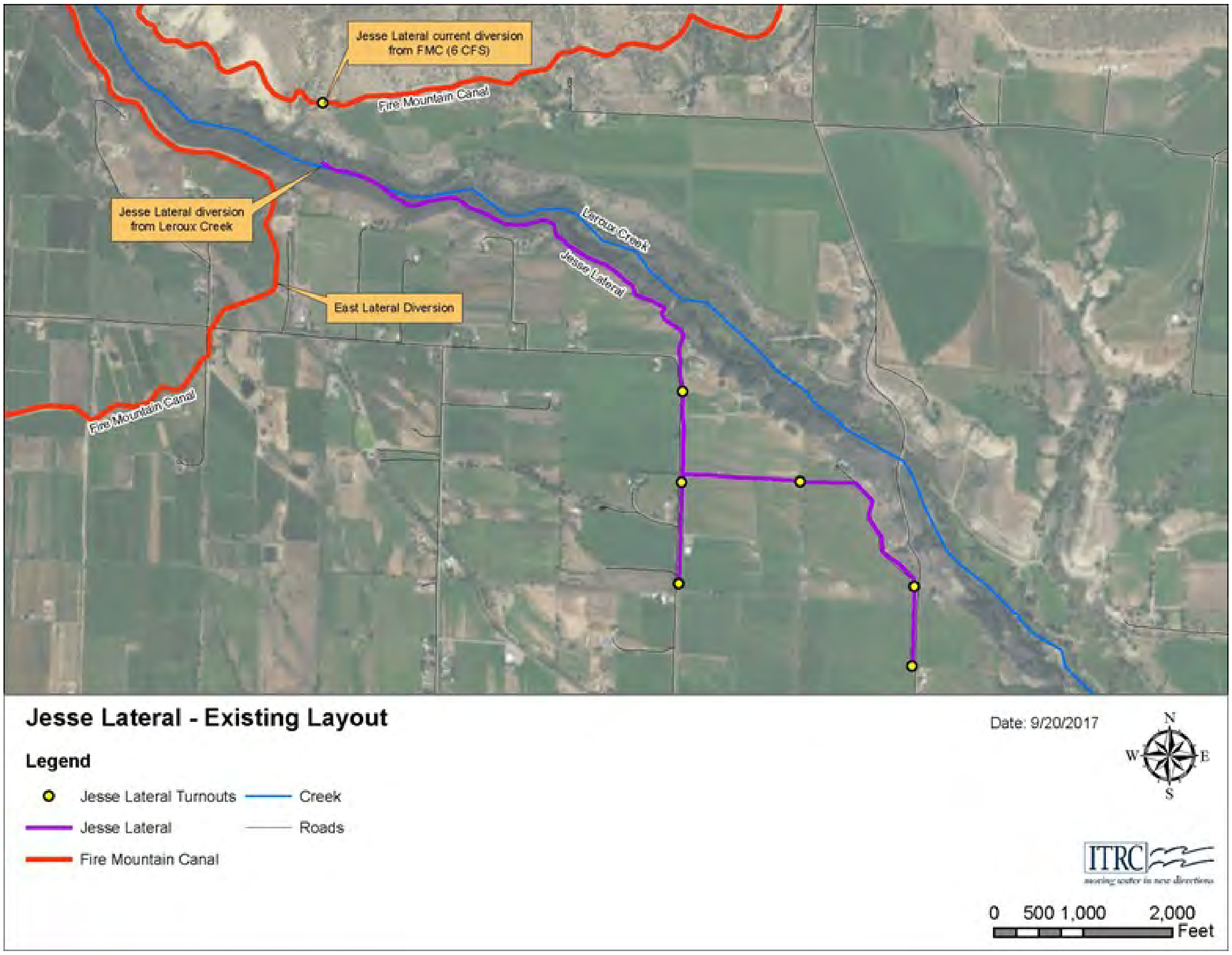


Figure 43. Existing alignment of the Jesse Lateral

The existing control is as follows:

- Approximately 6 CFS is diverted from the FMC for the Jesse Lateral at the top of the canyon. The water meanders down the canyon and eventually discharges into Leroux Creek just upstream of the Jesse Lateral diversion.
- A gate directly in Leroux Creek (see Figure 44) diverts water into a short feeder section of the Jesse Lateral.

Figure 44. Diversion gate on Leroux Creek

- Approximately 275 ft downstream from the creek diversion gate, a wooden flow control sluice gate is used to set the target flow rate into the Jesse Lateral. A small weir in the left canal bank (if moving downstream) is used to provide upstream water level control.
  - During the spring when runoff is high, approximately 21 CFS is diverted into the Jesse Lateral. The flows rate from the two water sources is broken down as follows:
    - Approximately 15 CFS from Leroux Creek. This flow typically only last two weeks.
    - Approximately 6 CFS from the FMC.
  - Any excess flows not diverted through the flow control gate spills over a small weir and returns to the creek.

Figure 45. Flow control gate to set the target flow rate into the Jesse Lateral

- The flow rate diverted into the Lateral is measured using the 3 ft wide Parshall flume (see Figure 46).

Figure 46. Three-foot Parshall flume just downstream of the flow control gate

- At the bifurcation point of the Jesse Lateral, a proportional splitter (see Figure 47) is used to divide the flow into the two lateral segments.

Figure 47. Proportional splitter at the bifurcation of the Jesse Lateral

- There are six individual turnout locations. Figure 48 shows an example of a turnout structure on the Jesse Lateral located just downstream of the bifurcation point.

Figure 48. Example turnouts on the Jesse Lateral

Options Discussed

The key issue surrounding the Jesse Lateral was whether or not the water rights should be included in the new Rogers Mesa Pipeline. With thorough discussion between various groups, three possible outcomes were identified for handling the Jesse Lateral:

Option 1: Do not include any of the Jesse Lateral water rights in the new Rogers Mesa Pipeline. The Jesse Lateral would continue to operate as-is by diverting their Leroux Creek spring and FMC shares through Leroux Creek via their existing canal.

Option 2: Include only the Jesse Lateral's FMC shares in the new Rogers Mesa Pipeline.

- The Rogers Mesa Pipeline would be sized to convey only the Jesse Lateral's FMC shares (approximately 6.5 CFS) to its future location next to the East Lateral diversion (refer to Figure 43) at no expense to the Jesse water users.
- A new pipeline would eventually be constructed to convey the Jesse Lateral's FMC water rights down the hillside until it would eventually connect to their service area. From there it could discharge directly into their lateral.
    - The new pipeline would be at the expense of the Jesse water users.
    - Part of the pipeline could possibly be paid for with grants from NRCS.
    - Until the pipeline connecting the Jesse service area is constructed, the Jesse Lateral's FMC share will continue to be serviced from its current location.
- During the spring, the Jesse Lateral's water right of 15 CFS would continue to be diverted from Leroux Creek and conveyed using their existing canal.

Option 3: Include the Jesse Lateral's spring and FMC shares (approximately 21.5 CFS) in the new Rogers Mesa Pipeline.

- This option would require the new pipeline section from Leroux Creek to have a large capacity to convey the additional 15 CFS for the Jesse spring flows. The Jesse water users would have to pay for the additional cost for increasing the pipe size of the Leroux Creek pipeline.

- A larger pipeline would also be needed to convey all of the Jesse Lateral water rights to the service area from the Rogers Mesa Pipeline. Again, this pipeline would be financed by the Jesse water users with possible NRCS grants.
- The diversion on Leroux Creek would be abandoned.

The pros and cons for the three options are presented in Table 12.

Table 12. Pros and cons for three Jesse Lateral options

Option	Pros	Cons
1	- Operation continue as-is - No cost to the Jesse water users	- The first 0.9 miles of the canal is at risk of failure along the steep hillside - If the canal fails, Jesse water users will be without water for an unknown amount of time
2	- More reliable delivery of the FMC water shares - If the Jesse Lateral fails, it would only affect the spring water rights from Leroux Creek, not the FMC shares that are used throughout the irrigation season	- Cost to the Jesse water users to construct the new service pipeline from the future diversion point on the Rogers Mesa Pipeline
3	- More reliable delivery of the FMC and Leroux Creek water shares - No risk of canal failure that would cut off all flow to the Jesse service area	- Higher cost to Jesse water users to pay for additional pipe sizing required for the Leroux Creek segment pipeline and the new pipeline to the Jesse service area

Decision

A meeting of representatives from the Jesse water users, JUB, Applegate, Colorado Department of Agriculture, Fire Mountain Canal & Reservoir Company, Colorado River District, and ITRC was held on April 11th, 2017. The goal of the meeting was to make a final decision on whether or not to include the Jesse Lateral water rights in the Rogers Mesa Pipeline so that the design process for the pipeline could continue forward.

After much discussion, it was decided that the Rogers Mesa Pipeline would be sized to include the Jesse Lateral's FMC shares to its future location near the East Lateral diversion. The Jesse Lateral's Leroux Creek spring water rights will remain in the creek and be diverted as-is. Until the Jesse water users are ready to construct a new pipeline to connect the new diversion point on the Rogers Mesa Pipeline to their service area, the Jesse Lateral will continue to operate as-is through the diversion on Leroux Creek.

Chapter 6. ROGERS MESA PIPELINE

Design Stages

Three individual design stages are proposed for the Rogers Mesa Pipeline.

Stage 1: Construct a single pipeline supplied primarily by the FMC but also supplemented by Leroux Creek to service the Rogers Mesa Area. Create a new spill system near the Jesse Lateral diversion.

Stage 2: Construct a 50 AF regulating reservoir approximately three miles upstream of the proposed FMC Pipeline.

Stage 3: Pipe the remaining three miles of the FMC from the regulating reservoir to the FMC Pipeline siphon inlet.

The following report sections describe the three individual design stages.

Stage 1

The main question that drives the Stage 1 design of the Rogers Mesa Pipeline is whether to include the Jesse Lateral water rights in the pipeline. If the rights are included, the most hydraulically beneficial location must be determined for the new Jesse diversion.

The Jesse Lateral water rights are as follows:

- Spring conditions are approximately 21.5 CFS, made up of:
    - Approximately 6.5 CFS from the FMC
    - Approximately 15 CFS from Leroux Creek.
- Normal irrigation season conditions are approximately 6.5 CFS from the FMC.

Four different options were considered for Stage 1 design:

A. Convey up to 21.5 CFS of Jesse Lateral water in the FMC Pipeline to be diverted at the East Lateral diversion.
B. Convey the 21.5 CFS of Jesse water to be diverted at the #81 Turnout diversion.
C. Convey the 21.5 CFS of Jesse water to be diverted at the #80 Turnout diversion.
D. Convey NO Jesse Lateral flows in the FMC pipeline with the exception of 6.5 CFS of Jesse's FMC shares. This 6 CFS would be released from the bottom of the FMC Pipeline Siphon to Leroux Creek.

Ultimately is was decided to only convey the Jesse Lateral's FMC shares to the East Lateral diversion. Information about the A-D designs and an overflow structure that were explored as options but decided against can be found at the end of this chapter in the *Options Considered but Not Used* section.

Stage 1 – Recommended Design

Figure 49 shows the recommended spring and normal flows for Stage 1. Only the Jesse Lateral's FMC shares will be conveyed by the Rogers Mesa Pipeline. The new Jesse Lateral diversion will be next to the East Lateral diversion.

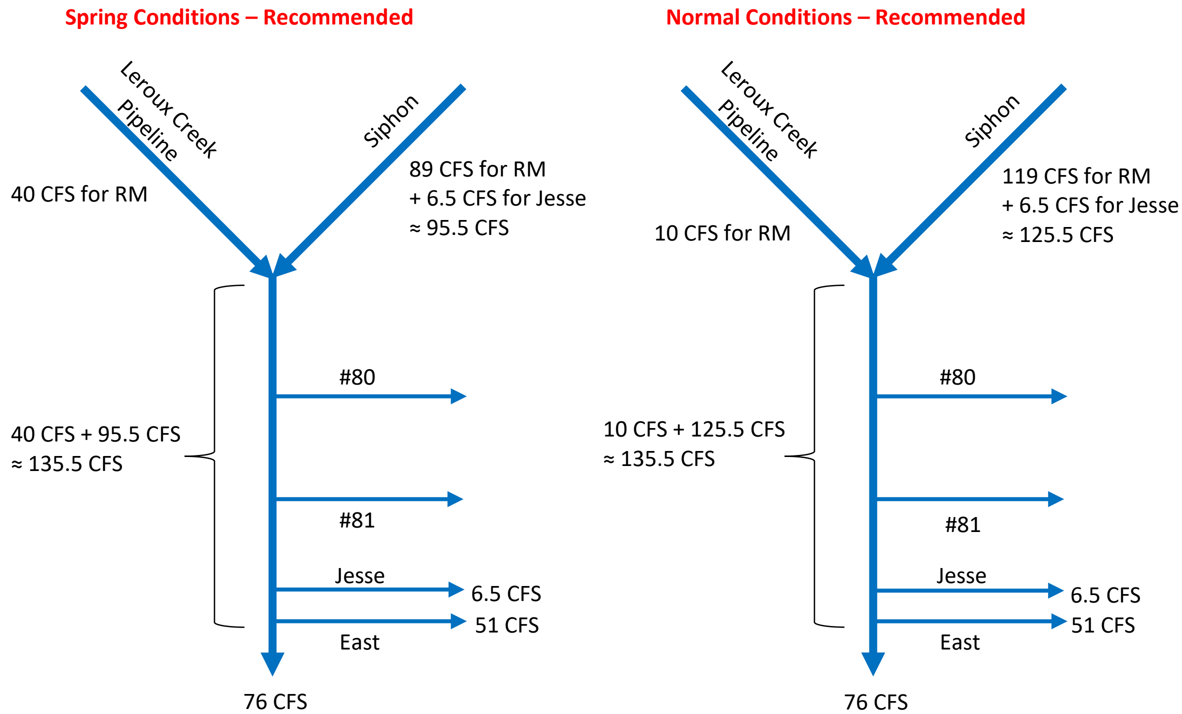


Figure 49. Recommended spring and normal flows for Stage 1 design

Table 13 contains the recommended individual turnout and segments flows for the Stage 1 Rogers Mesa Pipeline.

Table 13. Individual turnout and pipe segment flows for recommended Stage 1 design

Recommended Turnout and Pipe Segment Flows for the Rogers Mesa Pipeline				
T.O.	**U/S Spring T.O. Flow (CFS)**	**U/S Spring Segment Flow (CFS)**	**U/S Normal T.O. Flow (CFS)**	**U/S Normal Segment Flow (CFS)**
U/S of Siphon Inlet	0.0	95.5	0.0	125.5
Siphon Inlet	0.0	95.5	0.0	125.5
Siphon Bottom	0.0	95.5	0.0	125.5
Siphon Outlet	40.0	95.5	10.0	125.5
#80	0.5	135.5	0.5	135.5
#81	0.5	135.0	0.5	135.0
#82	1.0	134.5	1.0	134.5
East/Jesse	57.5	133.5	57.5	133.5
#83a	2.0	76.0	2.0	76.0
#83b	2.0	74.0	2.0	74.0
Slack	17.0	72.0	17.0	72.0
#84	2.0	55.0	2.0	55.0
Patterson	40.0	53.0	40.0	53.0
#85	1.0	13.0	1.0	13.0
Extension HG	0.3	12.0	0.3	12.0
Ext. #1	2.9	11.7	2.9	11.7
Ext. #2	2.5	8.8	2.5	8.8
Ext. #3	2.9	6.3	2.9	6.3
Ext. #4	0.5	3.4	0.5	3.4
Ext. #5	1.2	2.9	1.2	2.9
Ext. #6	0.5	1.7	0.5	1.7
Ext. #7	1.2	1.2	1.2	1.2
Leroux Creek Inlet	40.0	40.0	10.0	10.0

Figure 50 shows the pipe characteristics for the Stage 1 recommended Rogers Mesa Pipeline design. Table 14 and Table 15 contain the summary of individual pipe lengths and the feasibility cost summary for the Stage 1 recommended pipeline design, respectively.

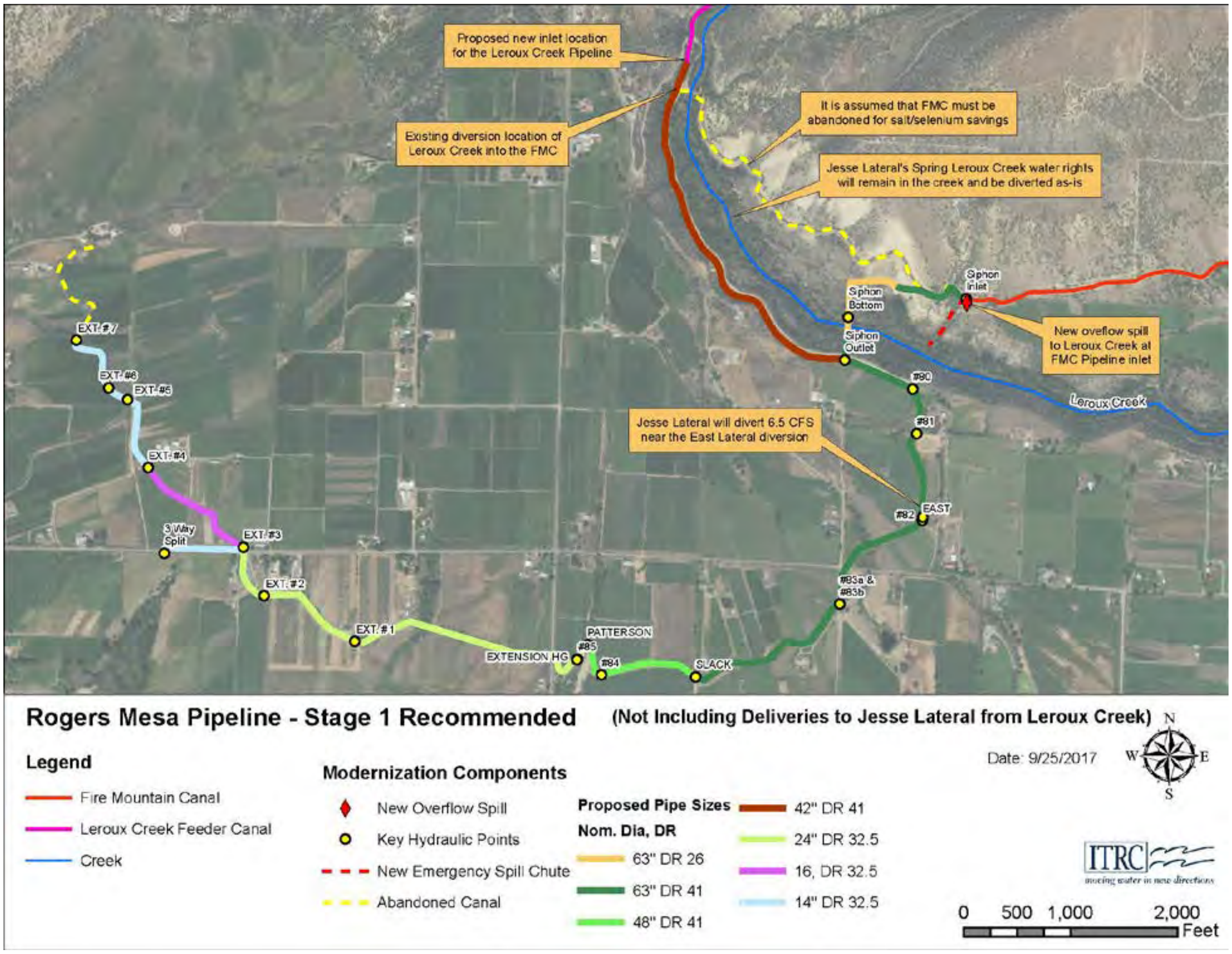


Figure 50. ITRC's Stage 1 recommended Rogers Mesa pipeline design

Table 14. Stage 1 recommended pipe size and length summary

Option 2 Pipeline Sizes	
Pipe Size & Dimension Ratio (DR)	**Total Length (ft.)**
63" HDPE DR 41 PIPE	6,755
63" HDPE DR 26 Pipe	565
48" HDPE DR 41 PIPE	1,275
42" HDPE DR 41 PIPE	4,050
24" HDPE DR 32.5 PIPE	4,080
16" HDPE DR 32.5 PIPE	1,220
14" HDPE DR 32.5 PIPE	2,405
Total	**20,350**

Table 15. Stage 1 recommended design feasibility cost summary

Stage 1 Recommended Rogers Mesa Pipeline Feasibility Cost Estimates

(Does Not Include Jesse Lateral Spring Flows - Jesse Lateral's FMC Shared Diverted at East Lateral)

Construction Costs

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
a	63" HDPE DR 41 PIPE (Material + Installation)	6,755	LF	$238.75	$1,612,756
b	63" HDPE DR 26 Pipe (Material + Installation)	565	LF	$267.13	$150,928
c	48" HDPE DR 41 PIPE (Material + Installation)	1,275	LF	$146.11	$186,290
d	42" HDPE DR 41 PIPE (Material + Installation)	4,050	LF	$114.96	$465,588
e	24" HDPE DR 32.5 PIPE (Material + Installation)	4,080	LF	$64.21	$261,977
f	16" HDPE DR 32.5 PIPE (Material + Installation)	1,220	LF	$41.59	$50,740
g	14" HDPE DR 32.5 PIPE (Material + Installation)	2,405	LF	$34.31	$82,516
h	Fire Mountain Canal Spill upstream of Siphon Inlet to Leroux Creek	1	LS	$200,000	$200,000
i	New Leroux Creek Inlet Structure & Spill	1	LS	$200,000	$200,000
j	Automatic Trash Screen at Siphon Inlet	1	EA	$150,000	$150,000
k	Automatic Trash Screen at Leroux Creek Pipe Inlet	1	EA	$75,000	$75,000
l	Patterson Overflow Weir Structure	1	LS	$100,000	$100,000
m	Pipe Fittings (5% of all pipe costs)	1	LS	$141,000	$141,000
n	Air Vents	12	LS	$5,000	$60,000
o	Turnouts, large (includes valves, flow meter, etc)	4	EA	$40,000	$160,000
p	Turnouts, small (includes valves, flow meter, etc)	15	ea	$12,000	$180,000
q	Siphon Drain (Valve and Fittings)	1	EA	$5,000	$5,000
r	Siphon Easement	1	AC	$5,000	$5,000
s	Fill Ditch	16,725	LF	$2	$33,450
t	Clear Vegetation	16,725	LF	$2	$33,450
u	Imported Fill	5,575	CY	$10	$55,750
v	Road Crossing Surface Restoration	1	LS	$50,000	$50,000
w	Total Field Costs				$4,260,000
x	Contingency				$426,000
y	Sub-Total				$4,686,000
a	Engineering and Project Management				$426,000
aa	Mobilization				$171,000
bb	Owner administration				$30,000
cc	Habitat replacement				$180,000
dd	NEPA compliance and cultural resources				$128,900
ee	A-133 Audit				$6,000
ff	**Total Option 2 Implementation Cost[5]**				**$5,628,000**
gg	**Acres Serviced**				**5,300**
hh	**Cost/Acre**				**$1,062**

Notes:

1) Unit Notation:

LF = Linear Feet LM = Linear Miles LS = Lump Sum EA = Each SF = Square Foot SY = Square Yard CY = Cubic Yard

2) Contingencies based on a percentage of the construction costs (parts, installation, structures)

contingencies % of project costs 10%

3) Engineering & Project Management based on a percentage of the construction costs (parts, installation, structures)

eng. & proj. mgmt. % of construction parts 10%

4) Mobilization based on a percentage of the construction costs (parts, installation, structures)

mobilization % of projects costs 4%

5) Rounded up to nearest thousand dollars

New Fire Mountain Canal Spill

Figure 51 and Figure 52 show the existing conditions of the FMC system near the Jesse Lateral diversion and the proposed takeoff point for the new Rogers Mesa Pipeline.

Figure 51. Existing conditions of FMC near Leroux Creek and the Jesse Lateral diversion

Figure 52. FMC at the existing Jesse Lateral diversion where the new Rogers Mesa siphon inlet will be constructed

Modernization Changes

Figure 53 shows the modernization changes near the Jesse Lateral diversion.

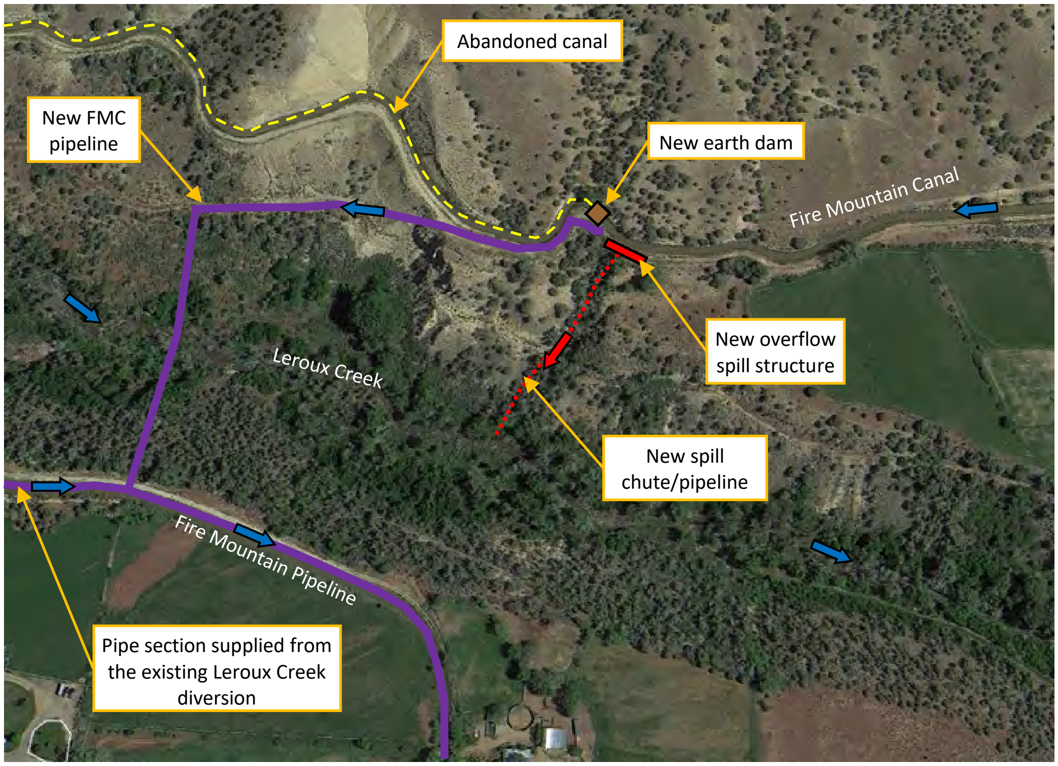


Figure 53. Existing conditions of FMC near Leroux Creek and the Jesse Lateral diversion

The modernization changes include:

1. The new FMC pipeline will divert water from the FMC near the existing Jesse Lateral diversion to supply the Rogers Mesa service area.
    a. An automatic trash screen will need to be installed just upstream of the pipeline entrance. Figure 54 shows examples of a side-sweeping screen and trash rack cleaner manufactured by Aqua Systems 2000 Inc.

Figure 54. Self-sweeping screen and trash rack cleaner manufactured by Aqua Systems 2000 Inc.

   a. On/off gate/gates will be installed at the entrance of the pipeline.
   b. A series of air vents (vacuum relief and continuous acting) will be installed along the first hundred feet of the pipeline to remove any air that may have entered the pipeline.
2. A short distance downstream of the new pipeline entrance, an earth dam will be constructed to block off the remaining portion of the FMC.
3. The portion of the FMC from the new earth dam to the Leroux Creek diversion (approximately 0.75 miles) will be abandoned and filled in. It is assumed that this portion of the canal must be abandoned to receive the salt and selenium savings credits.
4. Immediately upstream of the pipeline entrance, a new overflow spill structure will be constructed in the left bank of the FMC.
   a. As part of improving flexibility to turnouts along the pipeline, there should always be a small amount of flow (approximately 5 CFS) spilling at the overflow structure The new overflow structure will:
      i. Provide fairly constant water level at the pipeline entrance as well as several turnouts located upstream on the canal.
      ii. Automatically pass all excess flow variations and emergency flows down to Leroux Creek.
      iii. Pass winter flows in the canal to Leroux Creek during the non-irrigation season.
   b. The new structure will be composed of the following control components:
      i. Two identical ITRC flap gates designed to pass 50 CFS each (total 100 CFS).
      ii. A 20 ft long-crested weir (LCW) to serve as redundancy emergency spill for the flap gates.
      iii. A single 5 ft wide manual sluice gates to opened only during:
         1. in the spring at the beginning of the irrigation season to flush the dirty water down the spill as the canal fills up
         2. non-irrigation season to pass any winter flows in the canal
         3. canal flows during required pipeline maintenance
         4. emergency flows
      iv. The flap gates will be set to open once the water in the canal reaches the crest of the LCW. During an emergency situation, if the emergency flow was to exceed 100 CFS, water would then pass over the crest of the LCW.
5. Water that spills at the new overflow structure will be conveyed down to Leroux Creek via a new spill chute/pipeline constructed down the mountain side. The approximate elevation change from the canal to the creek is 150 ft.

Figure 55 shows a sketch of the proposed control.

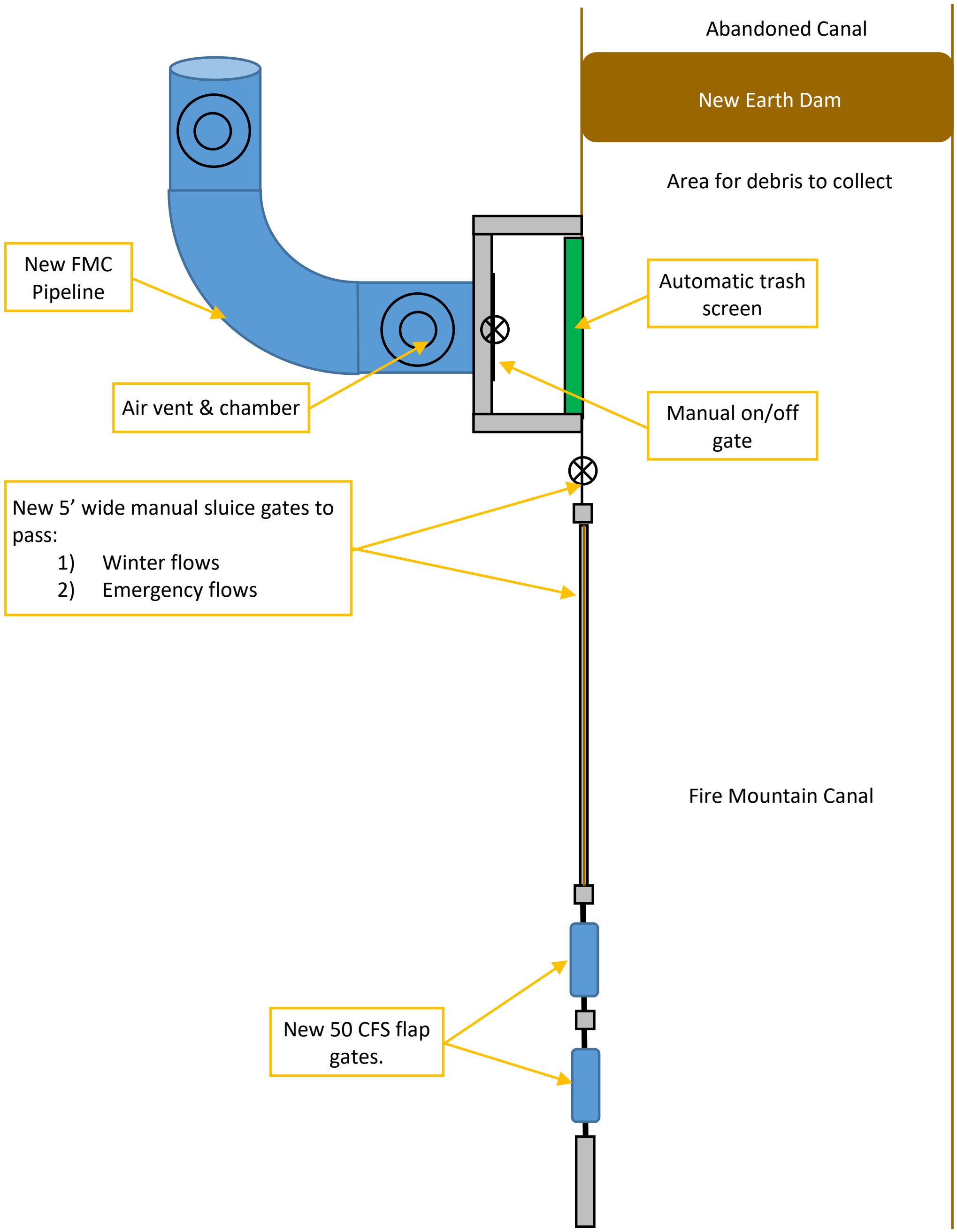


Figure 55. Conceptual control at the inlet to the Rogers Mesa Pipeline (not to scale)

Stage 2

The Stage 2 design will include the construction of a 50 AF regulating reservoir approximately three miles upstream of the siphon inlet to the Rogers Mesa Pipeline (refer to Figure 56).

The control scheme of Stage 2 will be as follows:

- The regulating reservoir will help absorb the flow rate variations in the FMC.
- The reservoir will automatically maintain a target water level elevation in a new level pool adjacent to the reservoir.
    - If the water level in the level pool exceeds the target water level elevation, the excess flow will automatically spill into the reservoir via gravity.
    - When the water surface in the level pool drops below the target water level elevation (indicating a deficient flow in the FMC), multiple reservoir variable-frequency drive (VFD) pumps will discharge water in the reservoir back into the level pool.
    - An emergency spill will be built into the reservoir to automatically pass emergency flows when the reservoir is full.
- A new flow control gate installed at the downstream end of the level pool (at the top of the large canal drop located approximately 1,000 ft downstream of the reservoir site), will "restart" the flow rate to the downstream portion of the FMC.
    - The flow rate can be changed at any time in order to more closely meet the flow demand of the downstream water users along the canal and FMC Pipeline.
    - The flow control gate will be remotely controlled via SCADA.
- A new flow measurement flume will be installed downstream of the large canal drop to:
    - Allow operators to remotely monitor the flow rate heading to the Rogers Mesa area.
    - Be used in the automation control of the new flow control "restart" gate.
- The operation and management of the Rogers Mesa Pipeline will be the same as in the Stage 1 Design.

Details about a proposed reservoir location that was examined but decided against can be found at the end of this chapter in the *Options Considered but Not Used* section.

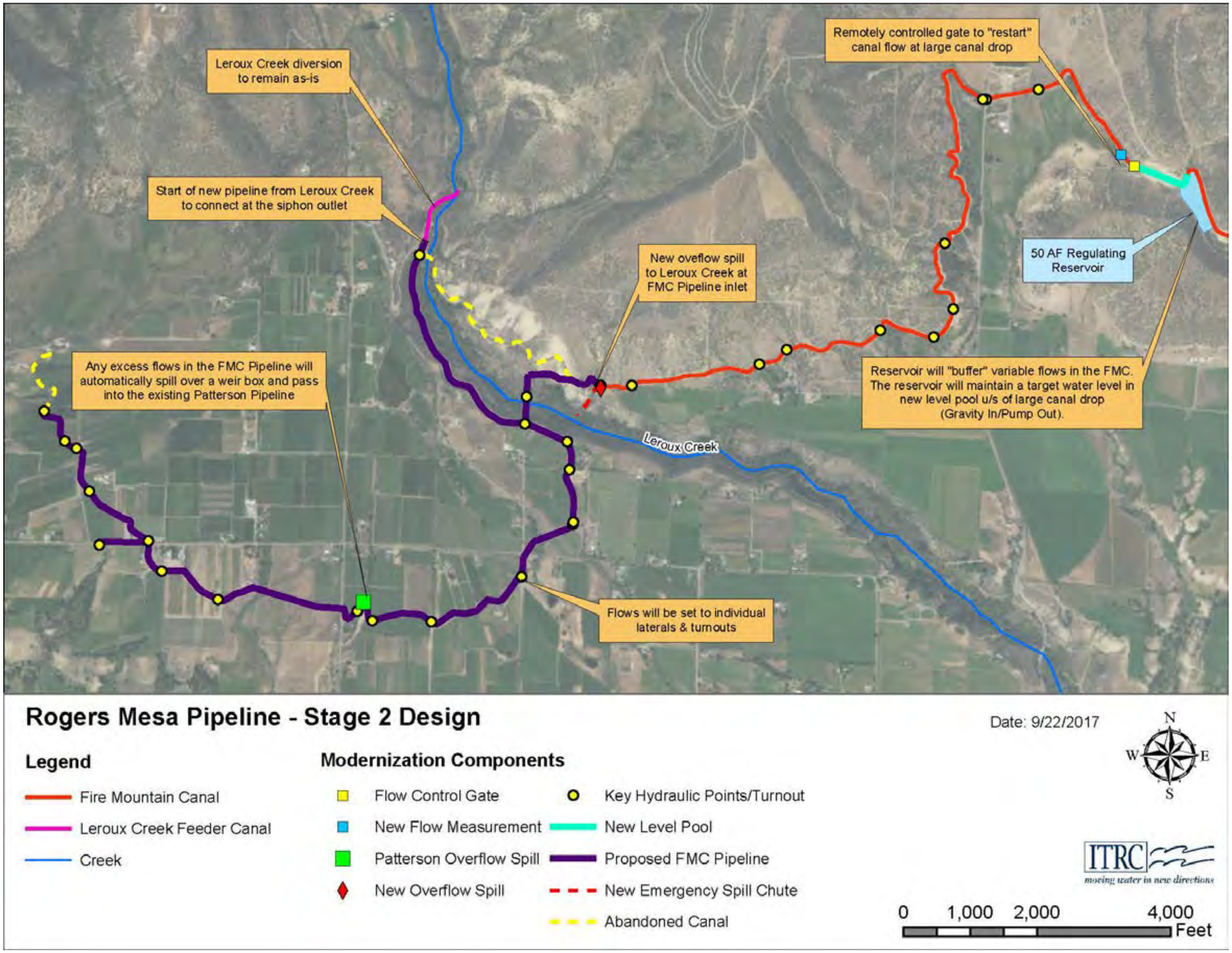


Figure 56. Conceptual Stage 2 design for the FMC Pipeline system

<u>Regulating Reservoir System</u>

With the construction of the Rogers Mesa Pipeline, it will be nearly impossible to match the demands of the pipeline with the supply of the canal. This is especially true if a fairly flexible water delivery schedule matching flow requirements is desired.

In order to meet the flow demands of the pipeline, water will need to continually spill at the inlet(s). With the pipeline, there will be no conservation of water with the exception of seepage reduction. The only way the Rogers Mesa Pipeline will truly conserve water is if a regulating reservoir is constructed to “buffer” the variable flows of the pipeline demand and the canal supply.

Horse Park Reservoir Site

The Horse Park Reservoir site was identified in the 2016 *North Fork Water Conservancy District Master Plan & Funding Plan* developed by JUB. The approximately 4 acre reservoir site is owned by the BOR. JUB estimated that the reservoir would have a possible storage capacity of 50 AF. Figure 57 shows the conceptual design of the reservoir by JUB.

Figure 57. Conceptual design of the Horse Park regulating reservoir by JUB

Figure 58 shows the existing conditions and Figure 59 shows a photo of the proposed reservoir site.

Figure 58. Existing conditions near the proposed Horse Park reservoir site

Figure 59. Horse Creek reservoir site. Photo was taken at the FMC spill into the reservoir site

The existing control is as follows:

- An emergency spill (see Figure 60) in the left canal bank (if moving downstream) is used to:
  - Pass dirty water when the canal is being filled in the early spring
  - Pass storm flows during rain events
- A check structure in the FMC just downstream of the Horse Park (see Figure 61) spill is used to provide water level control.

Figure 60. Existing Horse Park spill

Figure 61. Existing check structure in the FMC at the Horse Park Reservoir site

- A vehicle bridge is located at the sharp bend in the FMC. The bridge slightly protrudes into the canal, creating a flow restriction along with the bend.
- Farther downstream on the FMC is a large canal drop.

The Horse Park site appears to be the only feasible location for a regulating reservoir needed to help with operational control and water conservation of the Rogers Mesa Pipeline. The benefits to the reservoir include:

- Increased turnout flexibility both upstream on the FMC and downstream on the Rogers Mesa Pipeline.
- A “buffer” for variable flows between the FMC and the Rogers Mesa Pipeline.
- Allow for the flow rate in the FMC to be “restarted” at any time.
- Reduction of operational spill.
- Ease of management for the FMC operators.

Figure 62 shows the conceptual control components of the Horse Park Reservoir System for the Stage 2 Design.

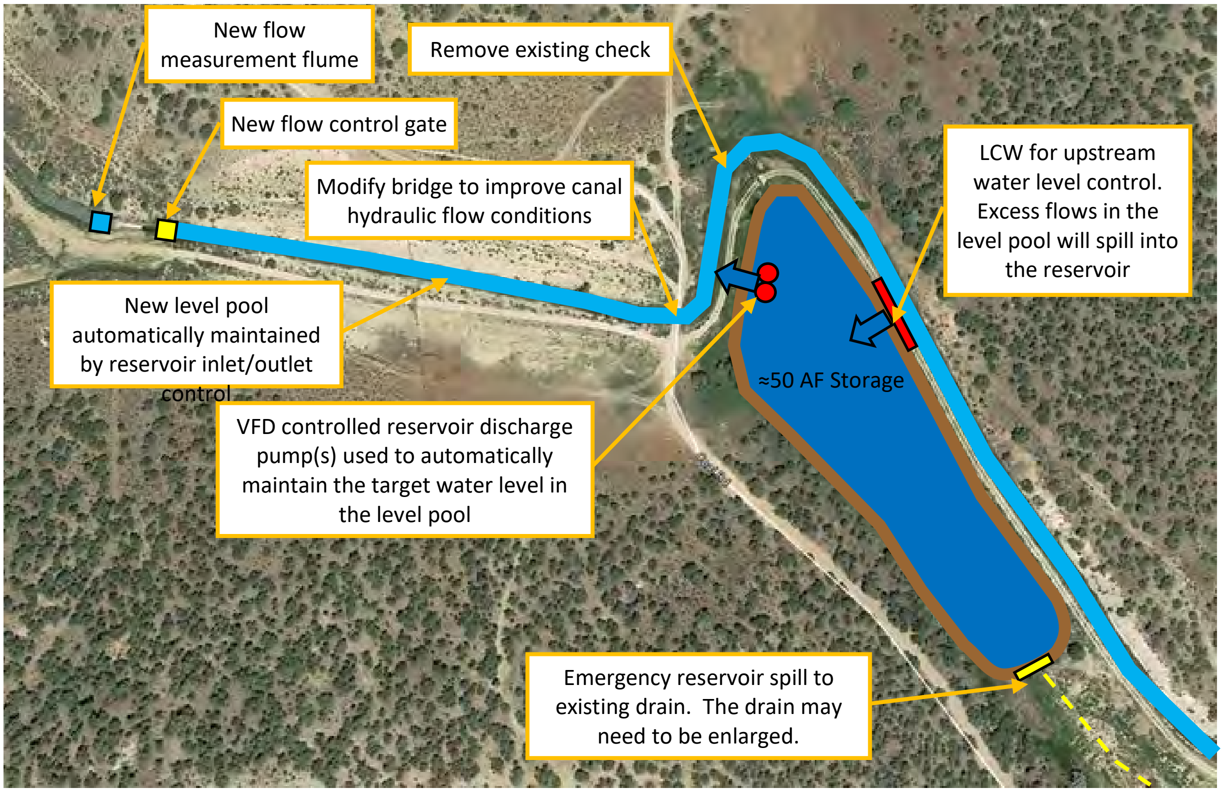


Figure 62. Conceptual control components of the Horse Park Reservoir

The conceptual control components include the following:

1. A new flow control gate will be installed in the FMC at the top of the existing canal drop. The flow control gate will be adjusted to set a target flow rate to the downstream canal system to better match the flow demand of the Rogers Mesa Pipeline while spilling as little water as possible at the siphon inlet.
2. A new flow measurement flume will be constructed at the bottom of the canal drop to allow operators to properly set the target flow rate at the upstream flow control gate.
3. The segment of the FMC upstream of the new flow control gate will operate as a level pool that will be automatically maintained by the reservoir.
4. The reservoir inlet and outlet control will automatically maintain a target water level in the pool. The control will be as follows:
    a. A long-crested weir (LCW) will be installed in the left bank of the FMC (moving downstream on the canal). If the water level in the level pool rises above the target water level elevation (indicating excess flow in the canal), the excess flow will spill over the LCW and into the reservoir.
    b. If the water level in the level pool falls below the target water level elevation (indicating deficit flow in the canal) VFD controlled pump(s) in the reservoir will automatically turn on and discharge water back into the canal. The pump(s) will remain on until the target water level is achieved.
5. An emergency spill will need to be constructed in the southeast portion of the reservoir to automatically spill water to an existing drain if the reservoir exceeds its maximum capacity. The capacity of the existing drain will need to be checked. It may need to be enlarged to handle the possible emergency flow capacities.

6. Other items:
   a. The existing check structure in the FMC will need to be removed.
   b. The existing bridge that crosses at the bend in the FMC will need to be modified in order to improve hydraulic flow conditions of the canal.
   c. Power will need to be brought to the site from approximately 0.5 miles away.

The reservoir could have a gravity flow discharge pipeline that would daylight just downstream of the drop. This is not recommended because when the FMC pipeline connecting the Rogers Mesa Pipeline and reservoir is constructed, the hydraulic conditions in the pipeline would suffer when the reservoir is at a low storage level. With the recommended reservoir control, there would very little changes once the FMC pipeline is constructed. The pipeline would connect right to the level pool and the flow control gate would be used for on/off control. The hydraulic conditions would remain constant at the pipeline inlet no matter the storage level in the reservoir.

Stage 3

The Horse Park Reservoir alone will improve water conservation by reducing operational spill at the siphon inlet of the Rogers Mesa Pipeline, but it will not maximize the potential water conservation. The reservoir only buys time for the FMC operators to make flow adjustments based on the demand of the pipeline, supply of the canal, and storage level in the reservoir.

In order to achieve the maximum water conservation potential, a pipeline between the reservoir and the siphon inlet will need to be constructed. The Rogers Mesa Pipeline will have the ability to operate as a flexible water delivery system. If a flow rate change is made at any turnout on the pipeline, the reservoir will automatically accommodate for the flow rate change. For example, if a turnout was to:

- Stop taking water, the excess flow no longer being diverted would immediately spill into the reservoir to be used at a later time.
- Start taking water, the reservoir would automatically make up the difference in flow in order to meet the new pipeline demand.

The Stage 3 design for the Rogers Mesa Pipeline will include the following changes (Figure 63):

1. The three-mile section of the FMC from the regulating reservoir to the siphon inlet will be piped. The new pipeline will be connected directly to the level pool automatically maintained by the Horse Park Reservoir.
2. The flow control gate introduced in Stage 2 at the reservoir will be used for on/off control of the entire Rogers Mesa Pipeline.
3. An automated trash screen will be installed at the inlet of the pipeline.
4. The emergency spill at the inlet to the siphon will be abandoned.
5. New VFD pump(s) will be installed at the inlet of the Leroux Creek Pipeline in order to divert Leroux Creek water into the Rogers Mesa Pipeline. The pump(s) is needed to overcome the increased pressure in the pipeline by moving the inlet up to Horse Park Reservoir.

The control operation of the Horse Park Reservoir will remain the same as is presented in Stage 2. The option of using automated downstream control with sophisticated PIF logic was explored but rejected because the control would not be stable enough. Details on the control simulations can be found at the end of this chapter in the *Options Considered but Not Used* section.

Additionally, flow rate changes at the head of the canal may become more frequent depending on the storage level of the reservoir. If the reservoir storage level starts to run low, additional flow should be diverted at the river and the control gate at Bear Creek. When the reservoir nears capacity, the flow rate at the head of the canal will be decreased. This same operation is true for the flow releases at Paonia Reservoir.

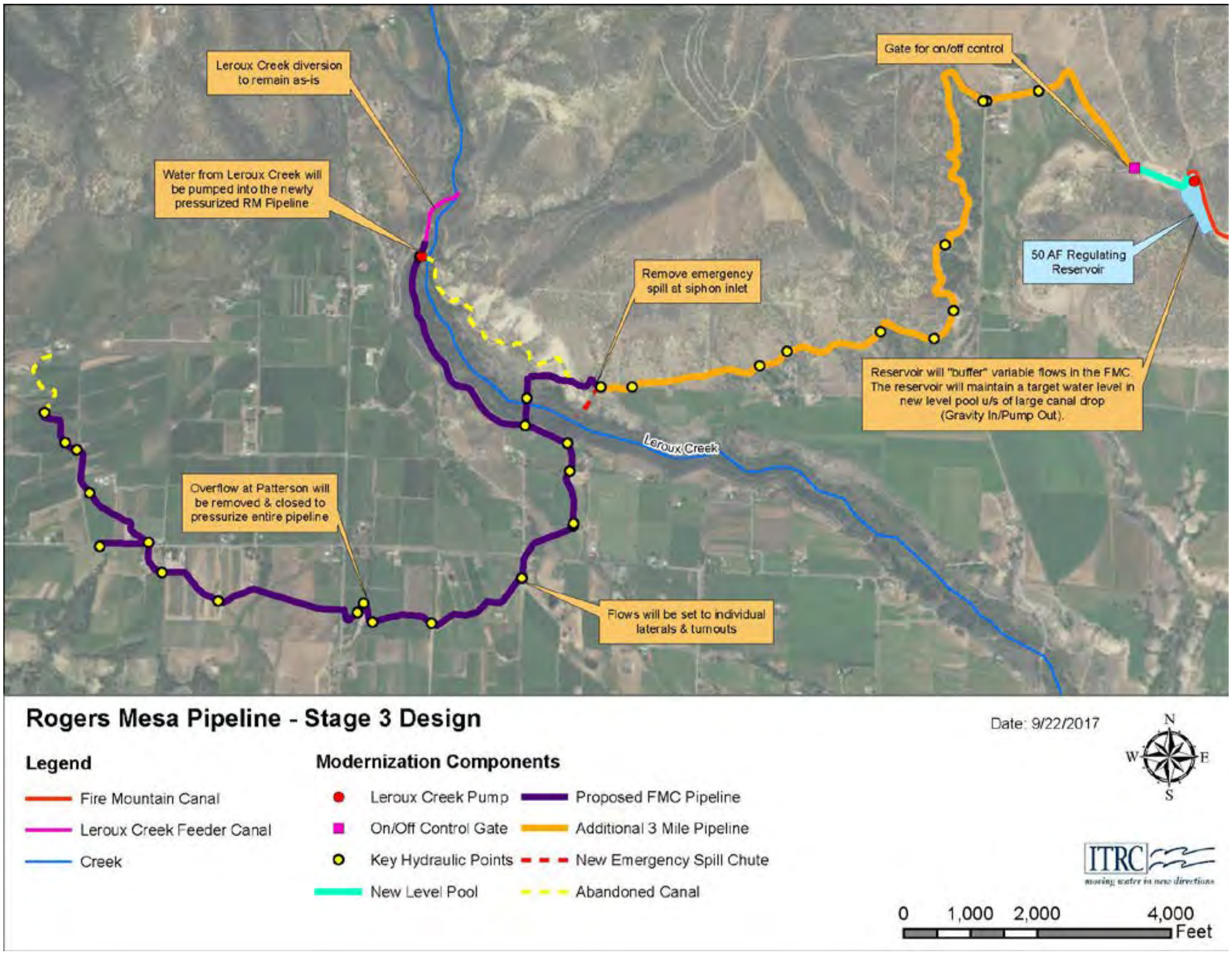


Figure 63. Stage 3 design for the FMC Pipeline system

Options Considered but Not Used

<u>Stage 1 Options Considered</u>

Stage 1A – Jesse Diversion at East Lateral Diversion

Figure 64 shows the spring and normal flows for Stage 1A, which include conveying all of the Jesse Lateral water shares to the East Lateral diversion.

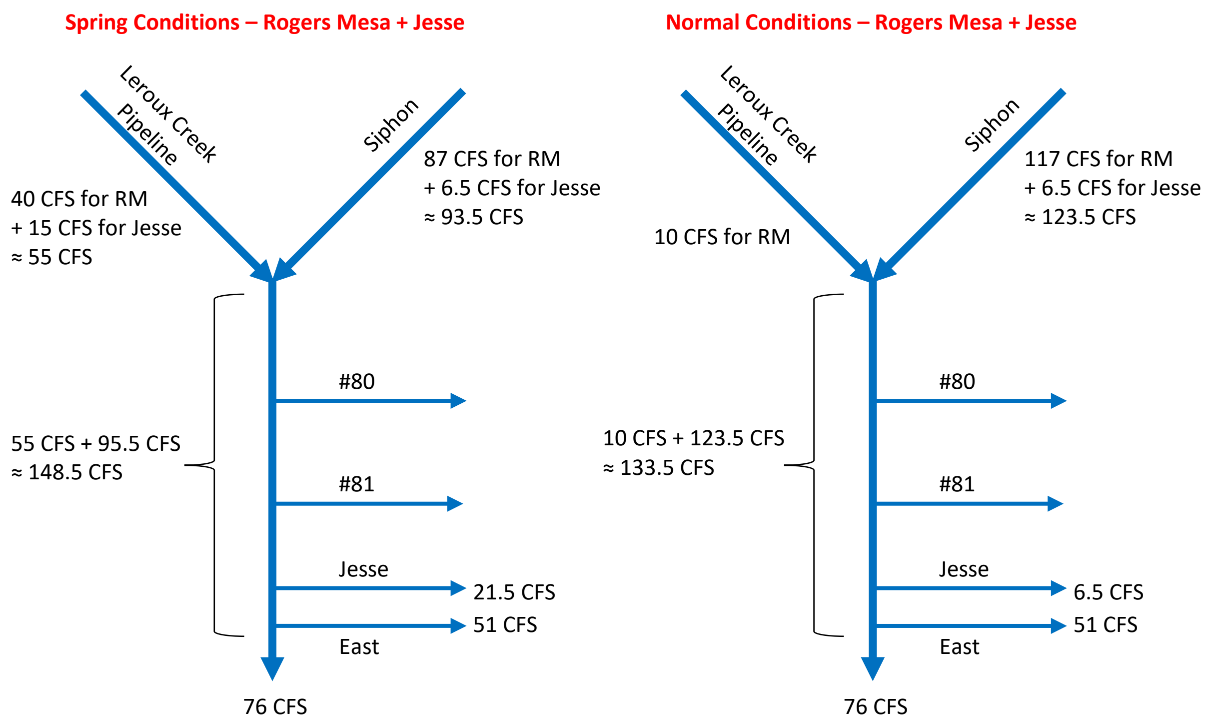


Figure 64. Spring and normal flows for Stage 1A design – discarded option

Figure 65 shows the pipe characteristics for the Stage 1A pipeline design. Table 16 and Table 17 summarize individual pipe lengths and feasibility costs for the Stage 1A Pipeline design, respectively.

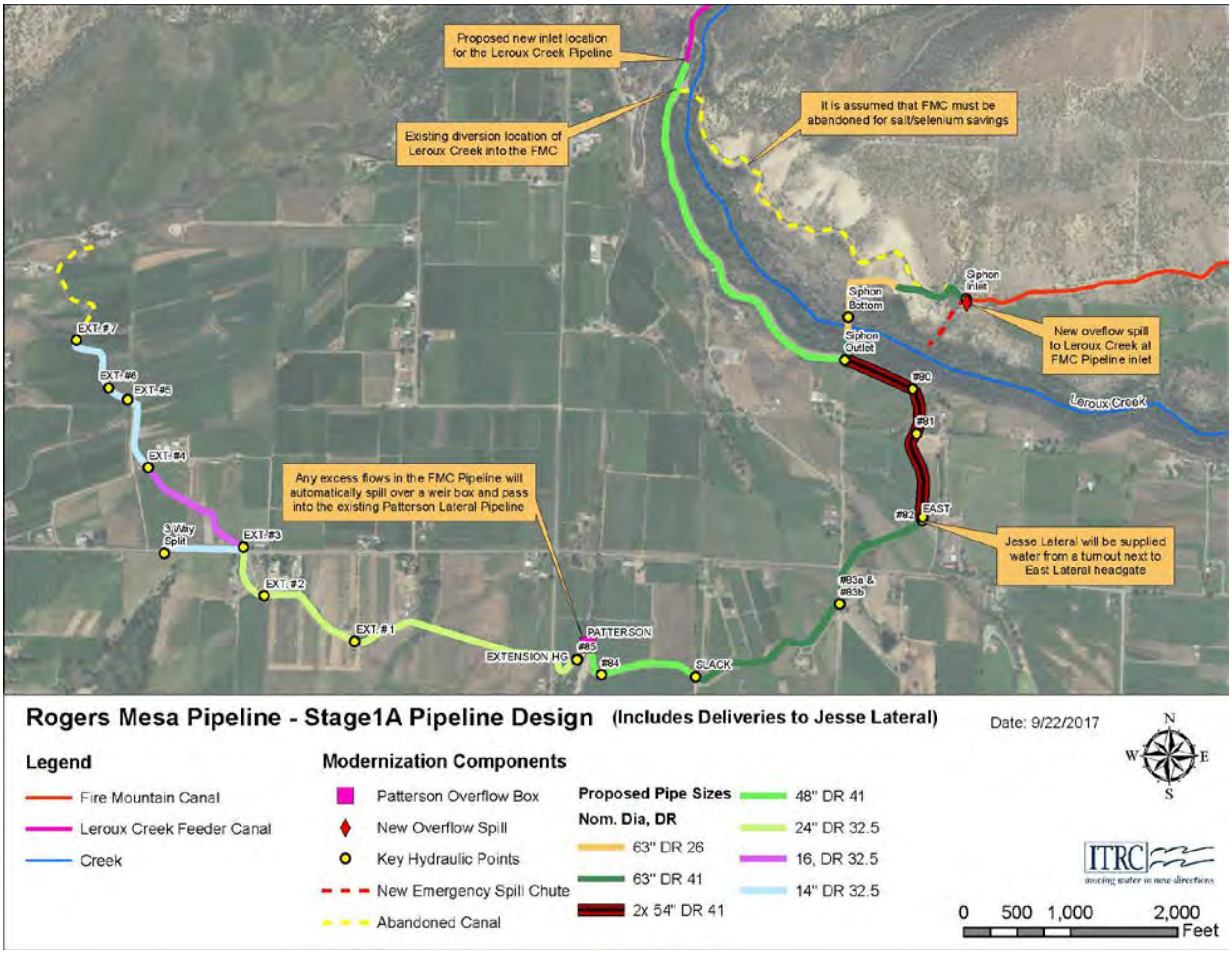


Figure 65. ITRC Stage 1A Roger Mesa pipeline design to include service to Rogers Mesa and the Jesse Lateral – discarded option

Table 16. Stage 1A pipe size and length summary – discarded option

Stage 1A Pipeline Sizes	
Pipe Size & Dimension Ratio (DR)	**Total Length (ft.)**
63" HDPE DR 41 PIPE	4,315
63" HDPE DR 26 Pipe	565
54" HDPE DR 41 PIPE	4,880
48" HDPE DR 41 PIPE	5,325
24" HDPE DR 32.5 PIPE	4,080
16" HDPE DR 32.5 PIPE	1,220
14" HDPE DR 32.5 PIPE	2,405
Total	**22,790**

Table 17. Stage 1A design feasibility cost estimate – discarded option

Stage 1A Rogers Mesa Pipeline Feasibility Cost Estimates

(Includes Jesse Lateral Diversion at East Lateral Diversion)

Construction Costs

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
a	63" HDPE DR 41 PIPE (Material + Installation)	4,315	LF	$238.75	$1,030,206
b	63" HDPE DR 26 Pipe (Material + Installation)	565	LF	$267.13	$150,928
c	54" HDPE DR 41 PIPE (Material + Installation)	4,880	LF	$189.48	$924,662
d	48" HDPE DR 41 PIPE (Material + Installation)	5,325	LF	$146.11	$778,036
e	24" HDPE DR 32.5 PIPE (Material + Installation)	4,080	LF	$64.21	$261,977
f	16" HDPE DR 32.5 PIPE (Material + Installation)	1,220	LF	$41.59	$50,740
g	14" HDPE DR 32.5 PIPE (Material + Installation)	2,405	LF	$34.31	$82,516
h	Fire Mountain Canal Spill upstream of Siphon Inlet to Leroux Creek	1	LS	$200,000	$200,000
i	New Leroux Creek Inlet Structure & Spill	1	LS	$200,000	$200,000
j	Automatic Trash Screen at Siphon Inlet	1	EA	$150,000	$150,000
k	Automatic Trash Screen at Leroux Creek Pipe Inlet	1	EA	$75,000	$75,000
l	Patterson Overflow Weir Structure	1	LS	$100,000	$100,000
m	Pipe Fittings (5% of all pipe costs)	1	LS	$164,000	$164,000
n	Air Vents	12	LS	$5,000	$60,000
o	Turnouts, large (includes valves, flow meter, etc)	5	EA	$40,000	$200,000
p	Turnouts, small (includes valves, flow meter, etc)	15	ea	$12,000	$180,000
q	Siphon Drain (Valve and Fittings)	1	EA	$5,000	$5,000
r	Siphon Easement	1	AC	$5,000	$5,000
s	Fill Ditch	19,165	LF	$2	$38,330
t	Clear Vegetation	19,165	LF	$2	$38,330
u	Imported Fill	6,388	CY	$10	$63,883
v	Road Crossing Surface Restoration	1	LS	$50,000	$50,000
w	Total Field Costs				$4,809,000
x	Contingency				$481,000
z	Sub-Total				$5,290,000
aa	Engineering and Project Management				$481,000
bb	Mobilization				$193,000
cc	Owner administration				$30,000
dd	Habitat replacement				$180,000
ee	NEPA compliance and cultural resources				$128,900
ff	A-133 Audit				$6,000
gg	**Total Option 1 Implementation Cost[5]**				**$6,309,000**
hh	**Acres Serviced**				**5,300**
ii	**Cost/Acre**				**$1,190**

Notes:

1) Unit Notation:

LF = Linear Feet LM = Linear Miles LS = Lump Sum EA = Each SF = Square Foot SY = Square Yard CY = Cubic Yard

2) Contingencies based on a percentage of the construction costs (parts, installation, structures)

contingencies % of project costs 10%

3) Engineering & Project Management based on a percentage of the construction costs (parts, installation, structures)

eng. & proj. mgmt. % of construction parts 10%

4) Mobilization based on a percentage of the construction costs (parts, installation, structures)

mobilization % of projects costs 4%

5) Rounded up to nearest thousand dollars

Stage 1B – Jesse Diversion at Turnout #81 Diversion

Figure 66 shows the spring and normal flows for Stage 1B. This included conveying all of the Jesse Lateral water shares to the Turnout #81 diversion. The hydraulic analysis and cost estimate for Stage 1B were very similar to those found in Table 16 and Table 17.

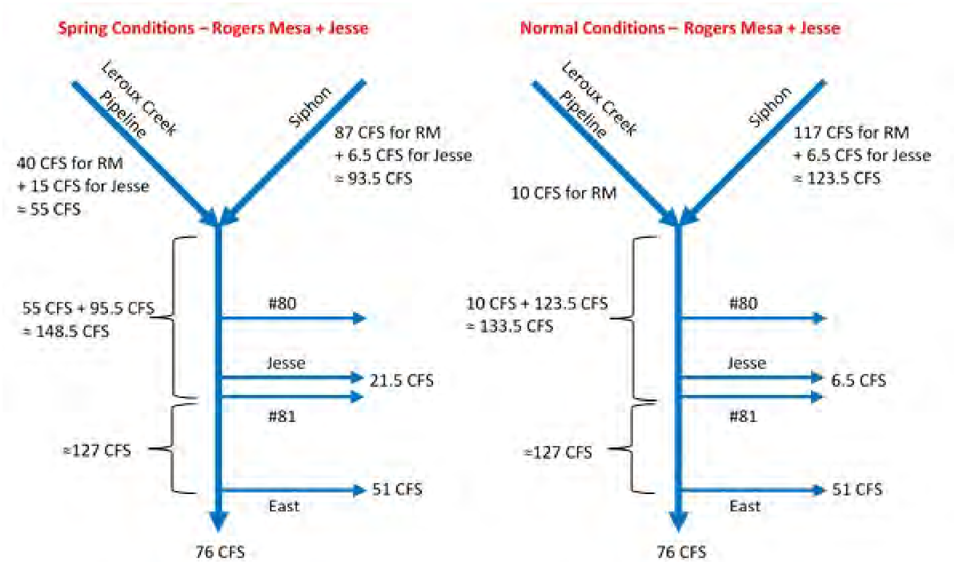


Figure 66. Spring and normal flows for Stage 1B design – discarded option

Stage 1C – Jesse Diversion at Turnout #80 Diversion

Figure 67 shows the spring and normal flows for Stage 1C. This included conveying all of the Jesse Lateral water shares to the Turnout #80 diversion. The hydraulic analysis and cost estimate for Stage 1C were very similar to those found in Table 16 and Table 17.

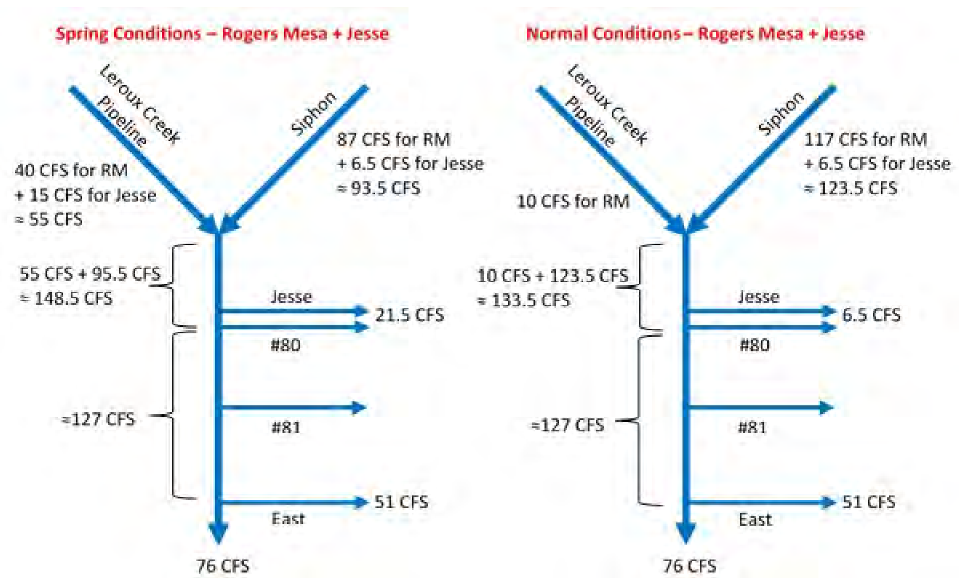


Figure 67. Spring and normal flows for Stage 1C design – discarded option

Stage 1D – No Conveyance of Jesse Lateral Water

Figure 68 shows the spring and normal flows for Stage 1D. The Rogers Mesa pipeline will only convey the Jesse Laterals FMC to the bottom of the siphon where it will discharge to Leroux Creek and be diverted through the existing canal. The Jesse Lateral's spring flows will remain in Leroux Creek. The hydraulic analysis and cost estimate for Stage 1D were very similar to the recommended design discussed previously in this chapter.

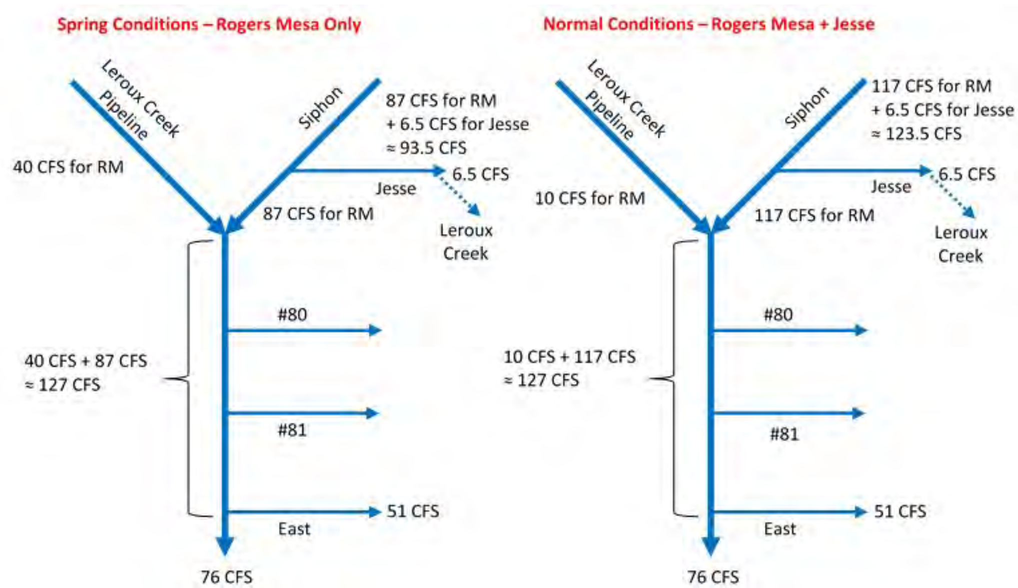


Figure 68. Spring and normal flows for Stage 1D design – discarded option

<u>Patterson Overflow Structure</u>

This section describes the features for an overflow control structure at the Patterson Lateral originally proposed for the Rogers Mesa Pipeline (Figure 69 and Figure 70). Currently all the flow rate variations on Rogers Mesa flow pass directly into the Patterson Lateral pipeline. It was intended to keep the same operations even with the Rogers Mesa Pipeline constructed.

FMC staff preferred to have stable flows into Patterson Lateral and to put the variations into Leroux Creek. The following information is presented as an option that was considered.

The control features of the Patterson overflow weir include:

- The Patterson Lateral Pipeline will absorb all fluctuations when there is excess flow in the pipeline. At the Patterson Lateral there will be (refer to Figure 70):
    - A standard turnout valve to deliver the demand flow to the downstream water users on the existing Patterson Pipeline.
    - A manually controlled overshot gate would be adjusted to control the available pressure in the main pipeline.
    - A flow meter installed just upstream of the first diversion box on the existing pipeline (in order to ensure a full pipe), since the Patterson Lateral is an open pipeline.
    - With the overflow, the Rogers Mesa pipeline would operate as an upstream control system.

- Flows would be set into all turnouts along the pipeline, including those along the Extension.
- The Extension would have no flow control at the head.
    - The Extension would always be under some pressure from the Patterson overflow structure.
    - A valve would be installed at the head for on/off control along with a flow meter.
    - A flow meter would be installed at the head of each turnout along the Extension.
- Flow meters will be installed at the heads of the East, Slack, and Jesse Laterals. The Patterson flume would still be used.

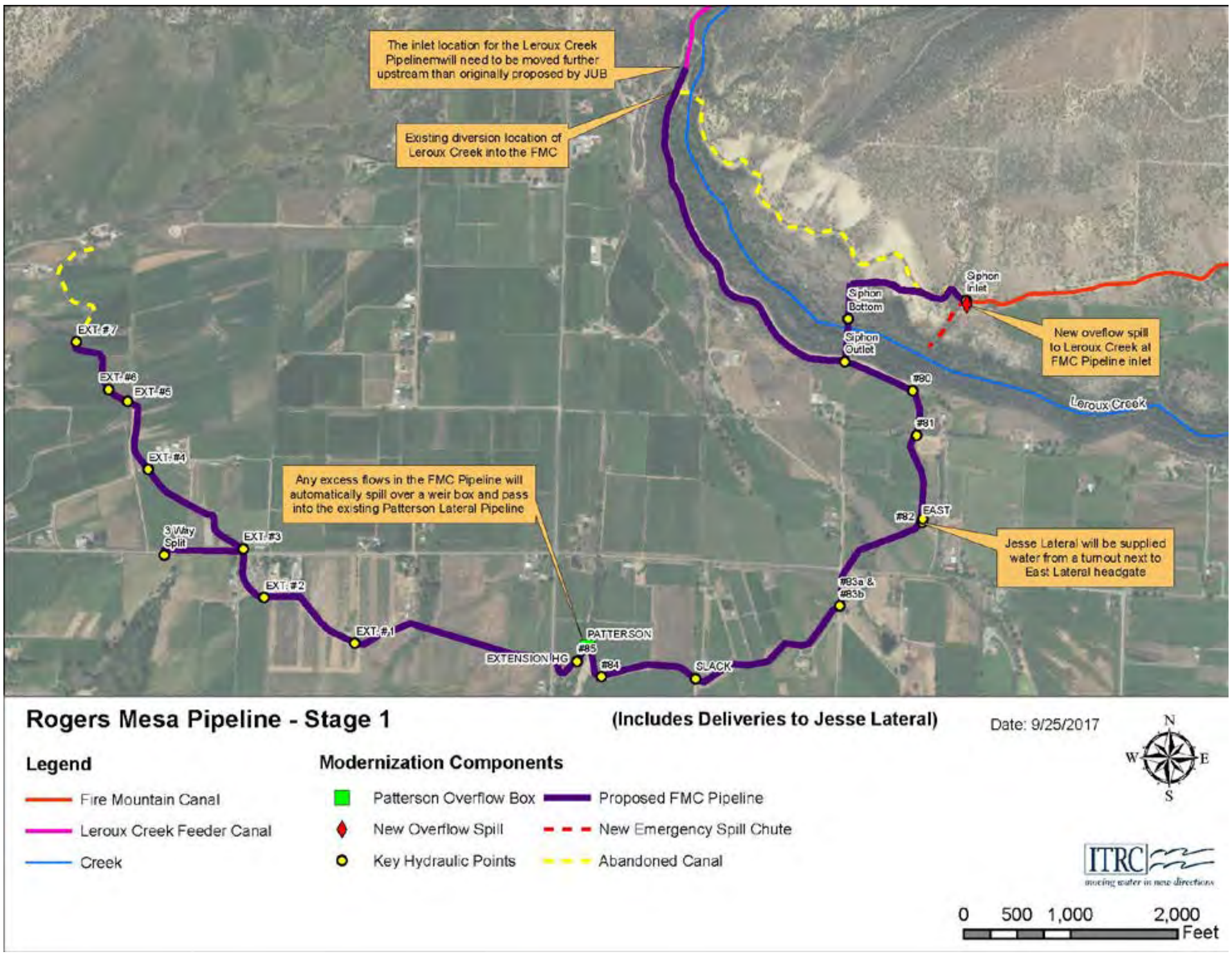


Figure 69. Map showing the location of the originally proposed Patterson Overflow Weir – discarded option

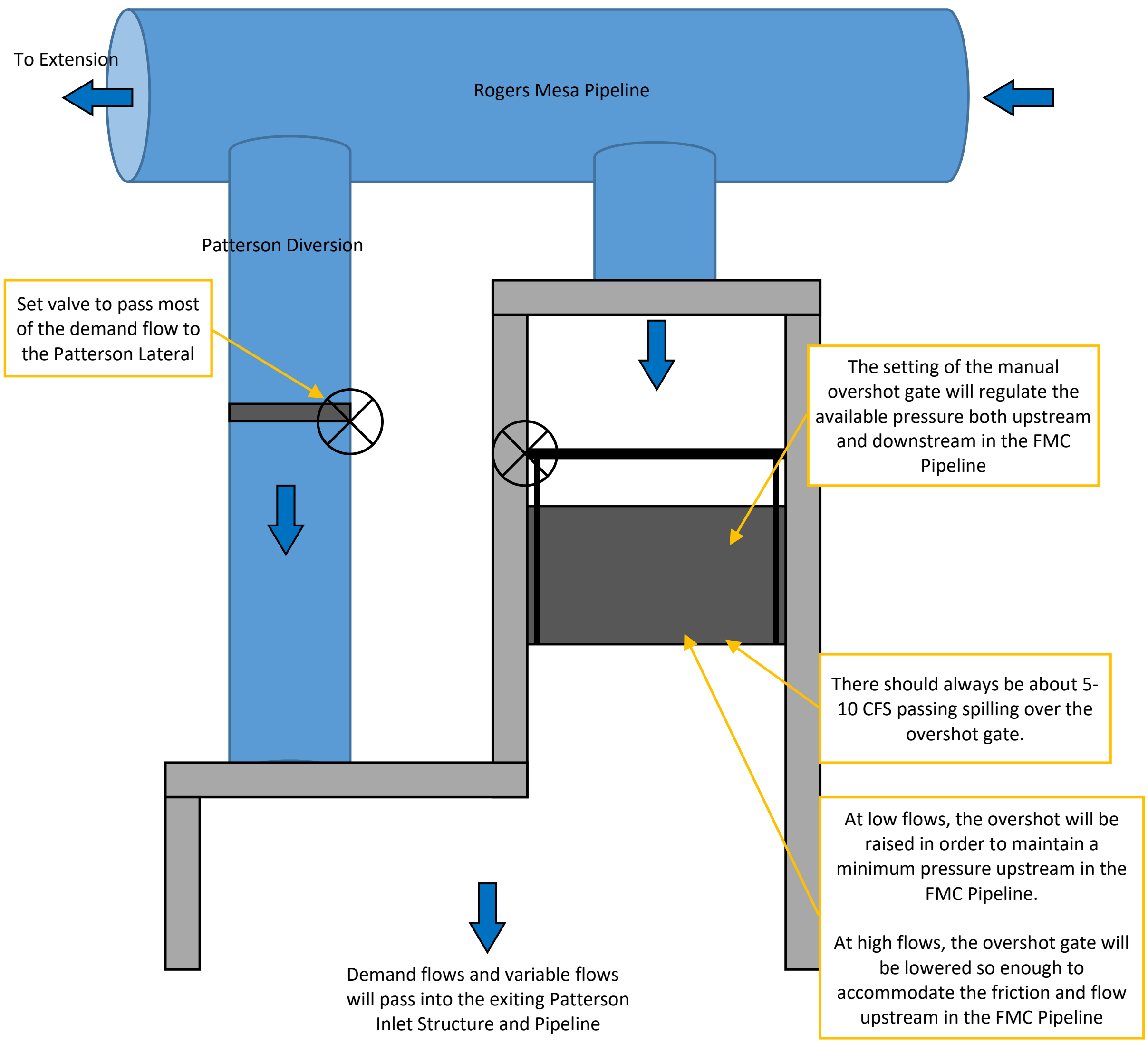


Figure 70. Conceptual design of the Patterson overflow weir (not to scale) – discarded option

Stage 3 Options Considered

Rogers Mesa Reservoir Site (Abandoned)

Early design phases for the Rogers Mesa Pipeline included construction a regulating reservoir approximately 1,000 ft downstream of the East Lateral to help “buffer” flow variations in the FMC as well as the pipeline itself (see Figure 71).

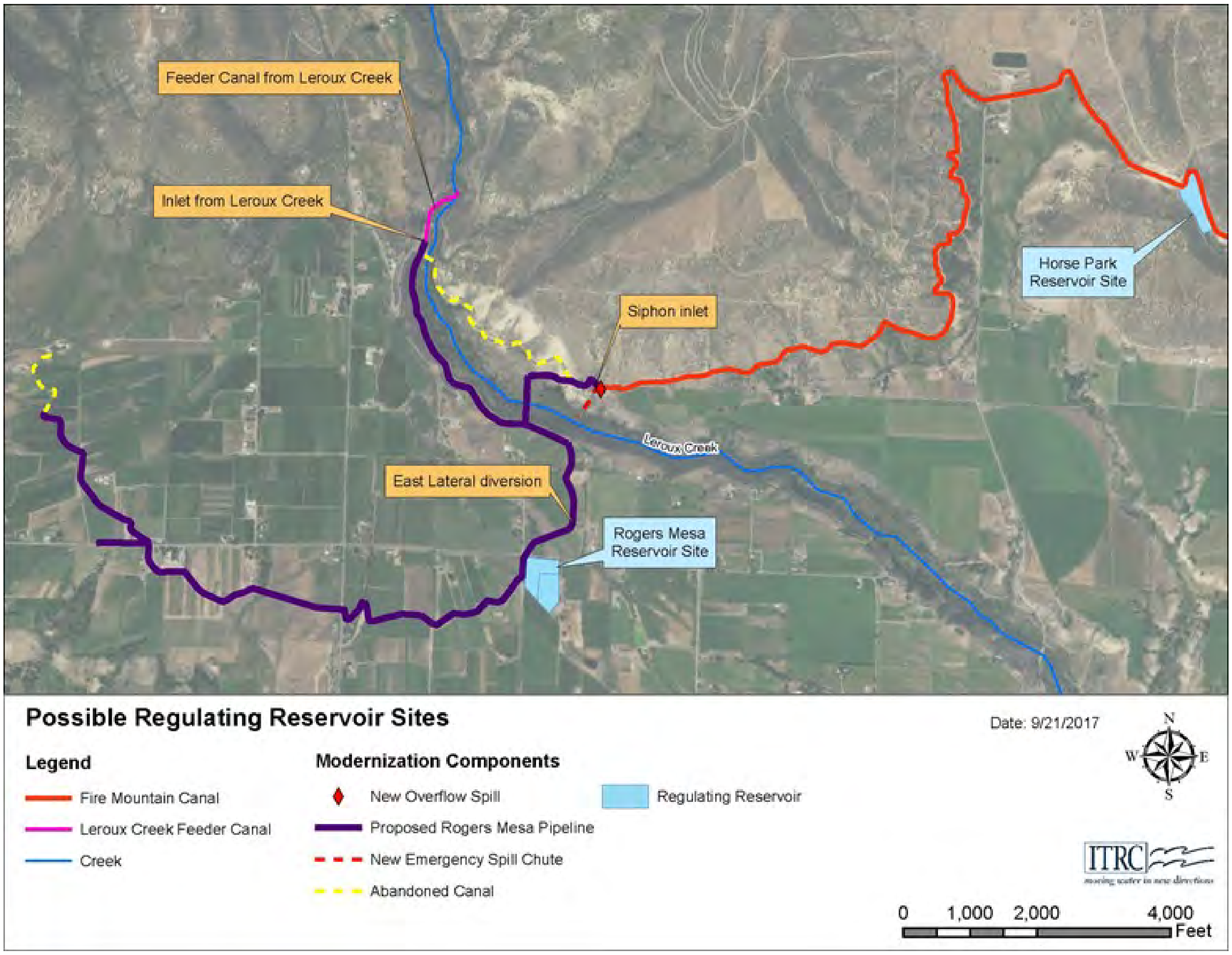


Figure 71. Possible regulating reservoir site on Rogers Mesa – discarded option

Figure 72 shows an aerial view of the proposed Rogers Mesa regulating reservoir site on a piece of undeveloped land. The site was approximately 7 acres in size and had approximately 20 ft of elevation change. The approximate 10 ft elevation contours shown in Figure 72 were produced from the National Elevation Dataset (NED) provided by the United States Geological Survey (USGS). The contours can be vertically inaccurate by several feet.

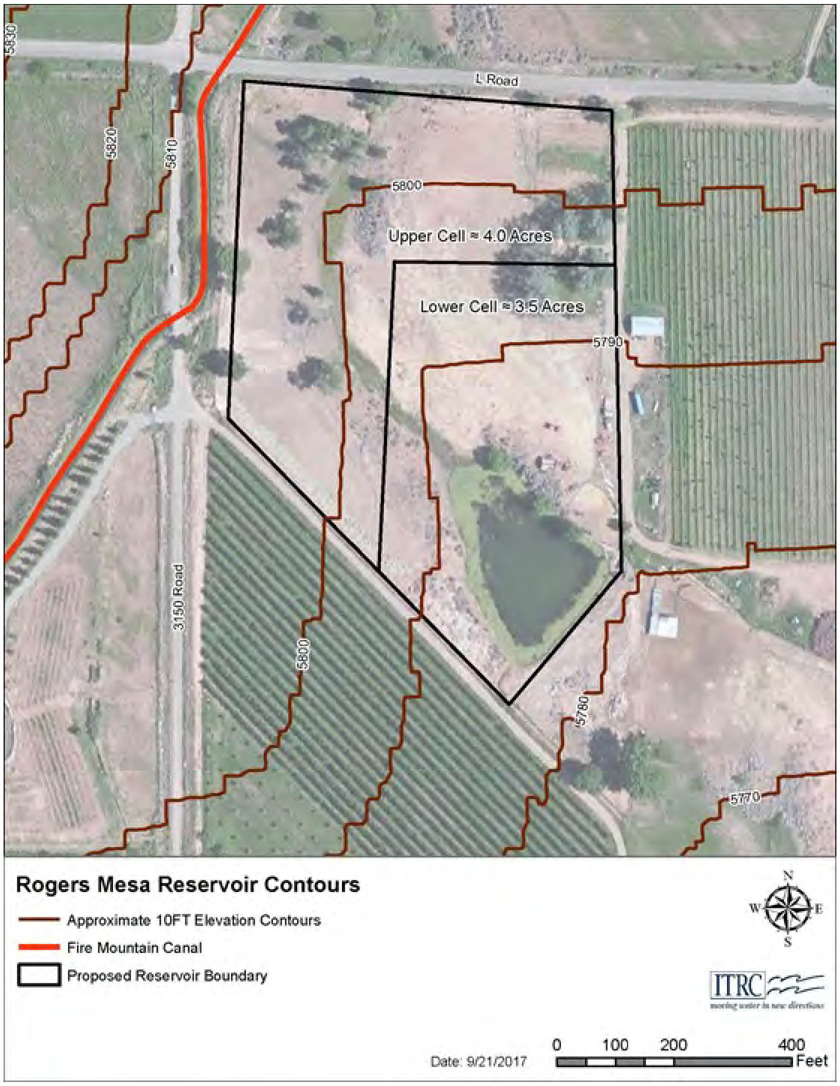


Figure 72. Aerial view of proposed Rogers Mesa reservoir site. Elevation contours were produced from the NED provided by the USGS. Discarded option.

After much thought and consideration, it was decided to abandon the reservoir at this location due to:

1. Limited storage size of the reservoir due to field availability as well as existing topography. The reservoir would at most only have a total storage of 30 AF (15 AF of live storage).
2. The reservoir inlet and outlet control of the reservoir was going to be very complicated because of the interaction with the FMC Pipeline.
3. The overall cost was going to be very high for a relatively small amount of benefit.

Fire Mountain Canal Downstream Control Simulations

One of the proposed improvement projects for the FMC included:

- A new downstream flow control gate (~ STN 1380+00) designed to automatically maintain a relatively contstant target water depth at the inlet to a new pipeline (~ STN 1537+25)
- Raising the banks for some distance upstream of the pipe inlet to increase pool storage
- A new flap gate spill structure just upstream of the new pipeline inlet

Simulation of the automated downstream control with sophisticated PIF logic were conducted using CanalCAD on the segment of the FMC between the Rogers Mesa siphon inlet and the proposed reservoir at Horse Park. The purpose of the simulations were to see if it would be possible to operate the FMC under downstream control in order to:

1. provide “on-demand” service to the siphon
2. reduce operational spill

Based on the simulation results, it was determined that logic was too unstable to provide “on-demand” service. The canal section is too steep and has insufficient storage to provide stable and rapid control. Plus, the PLCs, communication, and sensors require complex maintenance. There was too much lag time for the system to stabilize after a flow rate change at the inlet of the pipeline.

Table 18 lists the parameters and values used in all three simulations.

Table 18. Parameters and values used in all three simulations

Description	Value
Max pipe flow demand	125 CFS
KP	-1.31
KI	-0.22
FC	0
Control Time Step	40 minutes
Water level averaging	3 second sampling interval over the minute just prior to each control opportunity
Target Water Depth	4.86 feet
Spill Level	5.36 feet
Heuristic control adjustment(s)	When there is spill use the following adjustments → KP_{new} = 5 * KP & KI_{new} = 2 * KI

Control Simulation Results

The tables and graphs on the next few pages contain information about and results for each of the three control simulations.

Table 19. Simulation 1 overview

Description	Value
Steady state flow @ start	125 CFS
Change in flow	- 40 CFS
Time of flow change	1 hour
Flow change ramp time	2 minutes

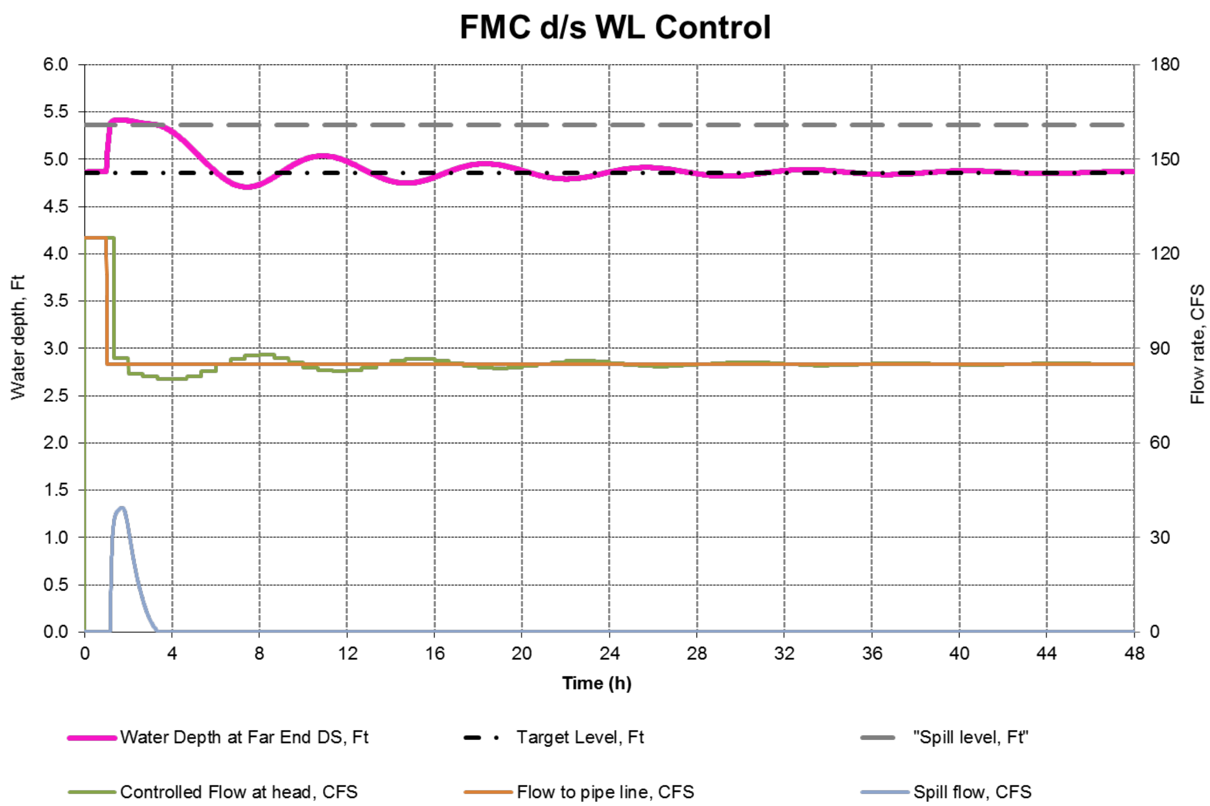


Figure 73. Simulation 1 results

Table 20. Simulation 2 overview

Description	Value
Steady state flow @ start	125 CFS
Change in flow	- 20 CFS
Time of flow change	1 hour
Flow change ramp time	2 minutes

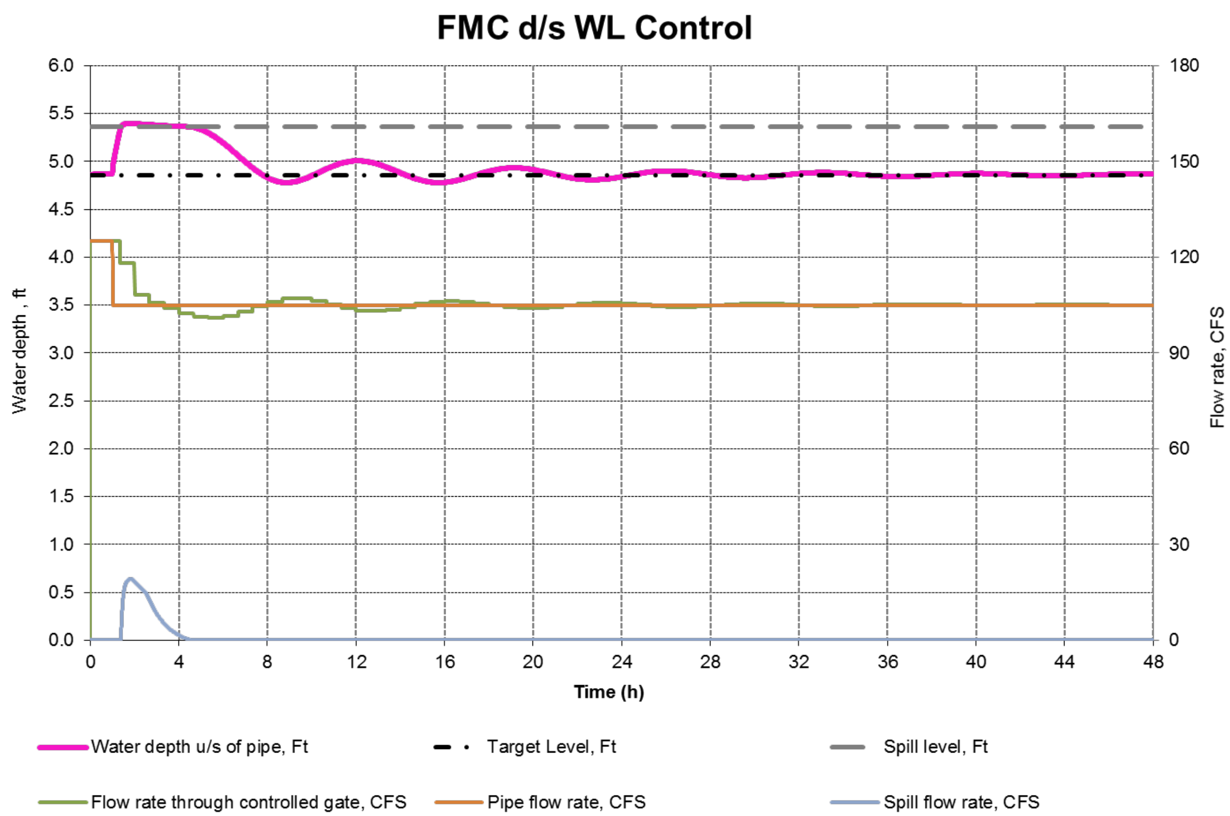


Figure 74. Simulation 2 results

Table 21. Simulation 3 overview

Description	Value
Steady state flow @ start	125 CFS
First change in flow	- 40 CFS
Time of first flow change	1 hour
First flow change ramp time	2 minutes
Second change in flow	+10 CFS
Time of second flow change	12 hours
Second flow change ramp time	5 minutes

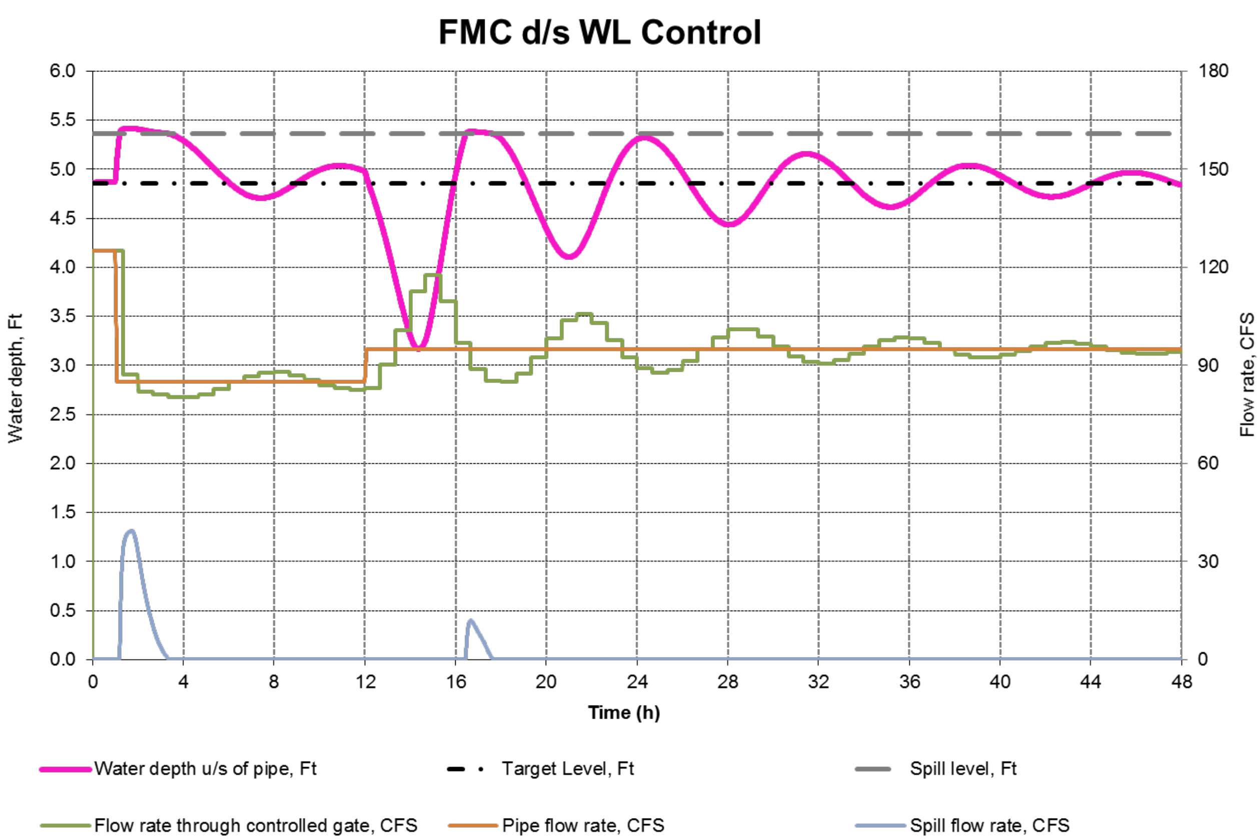


Figure 75. Simulation 3 results

Chapter 7. IMPROVEMENT OF FIELD DELIVERIES WITHIN ROGERS MESA

"Demand" Pipelines

At least one report mentions that the new Rogers Mesa pipeline will be an "on-demand" system. This terminology of "on-demand" is inconsistent with the standard definition of a "demand" system. Technically, a "demand" irrigation system is one that provides unlimited flexibility in frequency, rate, and duration of water deliveries to turnouts. While it is possible to provide unlimited flexibility in frequency and duration (such as in domestic water systems), there is always some limitation on the maximum flow rate at any turnout, and within the distribution system network. Therefore, for irrigation districts it is often desirable to strive for a "limited-rate demand" system design that provides excellent flexibility of frequency and duration, but some limitation on the flow rates.

But the characterization of the initial Rogers Mesa pipeline as a "limited-rate demand" system would still be incorrect for two reasons:

1. The preliminary J-U-B flow rate capacities are about 14% lower than those recommended by ITRC. The ITRC flow rate capacities (described in the chapter on Flow Rate Requirements) account for demand theory and how water might be used downstream of the Rogers Mesa pipeline, if pressurized pipelines are ever installed to service the farmers.
2. The Rogers Mesa pipeline will allow the canal operators to shut off the water at the turnouts, but the unused water will simply spill into Leroux Creek at the entrance to the Rogers Mesa pipeline siphon. This is acknowledged by the J-U-B (2016) report. However, this is only one side of a "demand" operation. The other side is that such an operation must also be able to provide, <u>without advance notice</u>, additional flows when needed. The new Rogers Mesa pipeline will not be able to provide this type of water delivery service, without constantly spilling excess water into Leroux Creek.

It is common that during a discussion of a "demand" or "limited-rate demand" or "on-demand" irrigation system, people assume that this level of service will reduce water diversions. It must be clear that this will not be the case with the new Rogers Mesa pipeline, until additional features such as a regulating reservoir are constructed, and pressurized pipelines are installed within the Rogers Mesa area.

Existing Irrigation Water Distribution Downstream of the FMC

At the present time, both the Slack and Patterson laterals are piped. However, the pipe design is fairly unusual and does not provide the flexibility that will be required in the future.
Some of the attributes of these piped laterals are:

1. The pipes are classified as "open" pipelines. That is, there are division boxes that break up the pressure at various intervals. Any water that is not used at upstream turnouts continues down the pipeline. This design functions very similar to a typical "upstream controlled" canal. In such pipelines and canals, an operator determines what flow rate should be delivered into the head of the pipeline. Regardless of whether that flow rate is more or less

than is actually used at the turnouts, this is the flow rate that must somehow leave the pipe. If it does not exit the turnouts, it spills at the tail (downstream) end.

2. The division boxes are designed for "proportional" control. Proportional control is very ancient and based solely upon the principle of providing equity to all users. It focuses on splitting flows at al diversion points – not delivering volumes of water as needed. For example, half of the acreage might be served by a turnout and half the acreage is below the turnout. The division structure is designed to split the incoming flow "proportionally". That is, regardless of what the flow rate is, half will go in one direction and half will go in another direction. Proportional control is used primarily with small primitive irrigations systems that rely upon "run-of-the-river" water supplies. That is, the flow rate into the small project varies almost continually, and there is a need for "automatic" equitable proportional division of that flow rate.

   Proportional control is incompatible with modern concepts of irrigation scheduling. Modern irrigation scheduling is based on the concept of delivering water only part of the time, in a flow rate that matches the field irrigation system requirement, for a duration that is required to fill up the root zone. Furthermore, modern irrigation scheduling and reservoir management typically focus more on efficient, equitable, and flexible allocation of limited volumes of water throughout a season. A key aspect of modern irrigation scheduling is that the farmer makes the decision on when and how much to irrigate, rather than having the irrigation supply system dictate those decisions.

   An additional problem with some of the Rogers Mesa pipelines was that the division boxes were too small, which prevented equitable proportioning of water.

   The next few photos illustrate examples of proportional control devices.

Figure 76. A simple but effective proportional control structure to equitably divide a stream flow in which the flow rate constantly varies.

Figure 77. Proportional distributor near Beni Amir, Morocco. One large flow is split into two smaller flows (one on each side), and one big flow in the middle.

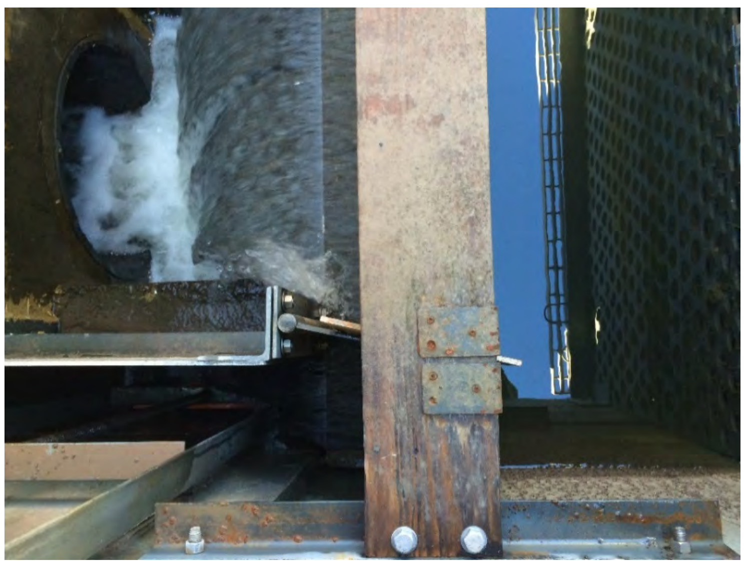


Figure 78. View from above, down into a division box on the Patterson Lateral. An adjustable arm allows an operator to proportion the incoming flow into two directions as the flow passes over a weir.

Future Conditions – Farming and Pipelines

The Rogers Mesa area has small fields. It is also a highly desirable location for people to relocate to. The trend will likely be toward a more "urbanized" rural setting, with many more homes built on small parcels, or occupying parts of existing parcels.

Evidently, the average age of the farmers is increasing. This will likely only accelerate the sales of agricultural lands.

When this type of "urbanization" occurs, it is very difficult to properly manage water. New residents know very little about traditional agricultural customs, and are accustomed to irrigating their gardens the way they did it in the cities. If they have "surface" or "flood" irrigation (i.e., furrows), they will typically have very low irrigation efficiencies. For these customers, pressurized irrigation with a water supply that can be turned on or off, more or less at will, is the preferred situation.

Pipelines are designed in many different ways. Some, such as the Patterson Lateral, are designed as "open" systems. If any turnout stops taking water, the water simply continues downstream. It is not conserved.

Other pipelines, such as many of those in the Uncompaghre Valley and in Grand Valley, are "closed" pipelines that are directly connected to the supply canal. If water is not used, it simply does not enter the closed pipeline. The pipeline is always full, but the flow rate into it depends upon the number of open turnouts.

It is envisioned that eventually all the turnouts in the Rogers Mesa area will be closed pipelines that will be connected directly to the new Rogers Mesa FMC pipeline. The operators of FMC will not control the flows into the lateral pipelines; those flows will depend upon the open turnouts downstream. However, the FMC operators will need to monitor the flows, and will need to work out arrangements with the smaller laterals to avoid overdrafting the supply. Physically, the whole system will require a reservoir at the head of the Rogers Mesa FMC pipeline. That reservoir will absorb variations in flow that arrive from upstream of it, and variations in demand downstream of it.

Potential for Reduced Volumes of Water Delivered

Clear Water Solutions (2014) estimated that the actual volume of annual crop ET on Rogers Mesa over about 10 years averaged about 15,000 AF/yr. Assuming 7105 irrigated acres, they translated this to 2.1 AF/acre. ITRC estimated a slightly higher value of 16,300 AF/yr. (2.3 AF/acre) that needs to be supplied from the river diversions, with a confidence interval of ±15%. These values will likely increase in the future as better irrigation management produces less crop stress and more uniform, healthy crop growth in fields.

This report estimates an average ET requirement of about 2.5 AF/acre for the future. Assuming an eventual 70% on-farm irrigation efficiency, and no conveyance losses (due to pipelines), this translates to a gross irrigation requirement of 3.6 AF/acre if the crops are irrigated to have no/little stress.

The actual average deliveries to Rogers Mesa are in the neighborhood of 4.6 AF/acre. In concept, this indicates that there is future potential of saving about 1.0 AF/acre.

This savings has two benefits for the farmers on Rogers Mesa:

1. During drought years, they can make limited water supplies stretch throughout most or all of the season. In this case, there will be no water conservation for the basin, as the farmers will use all of the water allocated to them.
2. During regular years, the improved irrigation efficiency during the months of April – July should allow them to keep more water in storage in Paonia Reservoir, which should allow them to extend the irrigation season.

For the Colorado River as a whole, the increased crop vigor will result in higher total consumption of irrigation water. However, this will be offset by less leaching of salts and fertilizers below the root zone and eventually into the river.

Solutions for the Existing Pipelines (Slack and Patterson)

Assuming that the pipelines have sufficient pressure ratings, the division boxes can be completely bypassed. This will create a pressurized pipe instead of an open pipeline. Special fittings can be used to put risers into/onto the pipelines. Each riser would contain:

1. Two butterfly valves: one for on/off, and a second one to limit the maximum flow rate
2. A flow meter
3. Sufficiently large air vents of two types continuous air release and combination air relief/vacuum relief

Rogers Mesa FMC Extension

The Rogers Mesa Extension of the FMC will be piped. This could serve as an excellent trial of providing water in a more flexible manner. Specifically, a trial could include all of the following:

- Each turnout should have a flow meter that measures both flow rate and volumetric deliveries.
- Farmers would be rewarded if they only used less than a specific volume of water before some date such as Sept. 1.
- The reward would consist of an additional irrigation at the end of the season

This trial could serve to determine if farmers have any interest in such a program. If there is interest, it could serve as stimulus for the farmers in other Rogers Mesa areas to install pressurized pipes that are connected to the new FMC.

This trial itself will not conserve any water, because the idea is that farmers will shut off their turnouts earlier than usual for each irrigation. The potentially conserved water will spill at the entrance to the new pipeline, into Leroux Creek.

Chapter 8. SCADA MASTER PLAN

SCADA Master Plan Executive Summary

This *SCADA Master Plan* outlines the transition of the existing remote monitoring/control system to a an eventual Supervisory Control and Data Acquisition (SCADA) system that will include new sites and new capabilities. The purpose of the SCADA transition is to achieve the goals in Table 22. Approximate total cost estimates are also provided.

Please note that the three "phases" for the SCADA Plan are not the same as the three "stages" recommended for the Rogers Mesa pipeline in Chapter 6. As shown in the "priority" column of Table 22, the second and third phases of the SCADA Plan are expected to be implemented concurrent with or following the first and second stages of the Rogers Mesa pipeline project.

Table 22. Immediate projects if dismantling remote control at Paonia Dam

Project Type	Site(s)	Survey level cost SCADA estimate**	Benefits	Incremental annual project maintenance costs	Priority
Immediate and minor	• Bear Creek • Office • Paonia Dam	$25,000	• Automatic alarm notifications • Improved diversion flow measurement • Improve cybersecurity	$2,000	1
Phase 1	• Diversion • New Canal Monitoring Stations	$90,000	• Streamline daily water operations via more remote monitoring and control sites • Improve emergency notification systems in canal failure and blockage scenarios • Improve the level of service to growers and other downstream users	$10,000	2
Phase 2	• New Pipeline Entrances (FMC and Leroux Creek) • Pipeline Turnouts	$250,000		$25,000	Conncurrent with or following Rogers Mesa Pipeline project
Phase 3	• Reservoir	$80,000		$8,000	Conncurrent with or following FMC buffer reservoir project
Eventual system upgrades	• All SCADA sites including Office	$430,000	• Prepare for future regulatory reporting requirements • Implement an independent, in-house, communications system	$43,000	As needed
Rounded totals		**$900,000**		**$90,000**	

A conceptual illustration of the eventual SCADA system is provided in Figure 79.

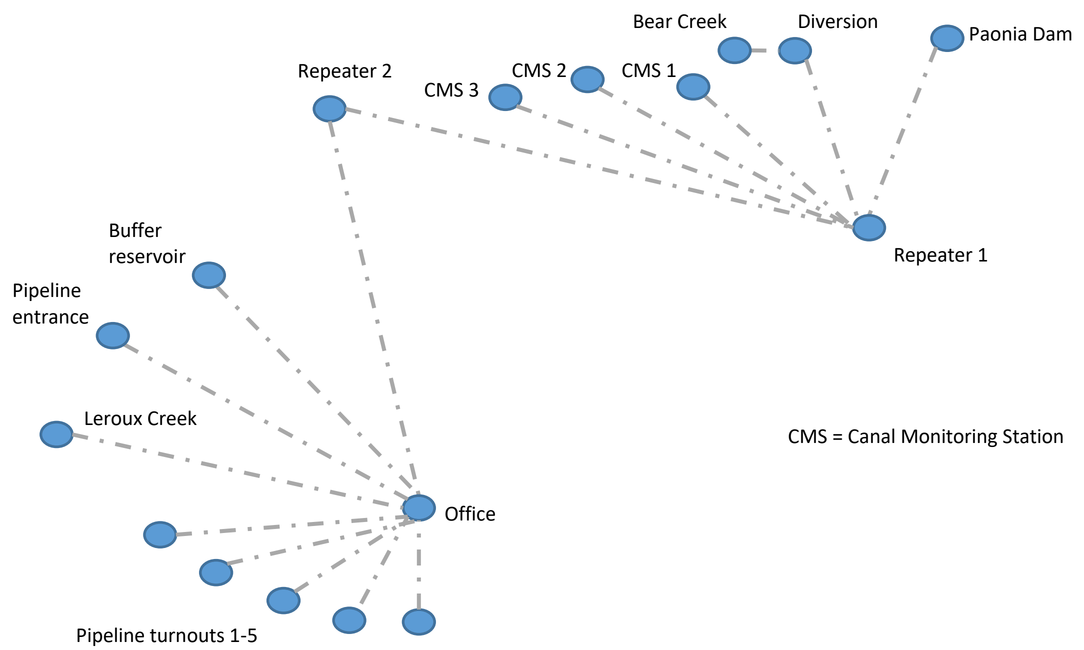


Figure 79. Conceptual FMCRC SCADA network, with radio links (not to scale)

Project Prioritization

Some of the project categories can be implemented now or at any time, as they are not dependent on large civil projects:

- Immediate and minor
- Phase 1
- Eventual system upgrades

The remainder of the SCADA projects will be implemented concurrently, or following large civil works, such as the new Rogers Mesa pipeline and the Fire Mountain Canal (FMC) buffer reservoir.

Total Costs

The total estimated cost for the SCADA system as recommended within this document is **$900,000 for 15 SCADA sites** including the base station. This document also provides less expensive and incremental implementation alternatives. In other words, it is not envisioned that all the recommendations would need to be, or would be, implemented at one time. In fact, it is recommended that FMCRC implement the recommendations in phases.

The estimated cost does not include large civil construction components (reservoir, gates or pumps), but does include radio infrastructure (tower) construction, SCADA planning, and implementation.

Background

The Fire Mountain Canal and Reservoir Company (FMCRC) primarily manages water infrastructure through a strategy of frequent field visists to key system locations for local hydraulic monitoring and control purposes. While this management strategy is common for most irrigation districts, it has inherent disadvantages. Canal management via local monitoring and control is labor-intensive and prone to delayed reactions. However, the characteristics of FMCRC amplify these disadvantages because:

1. Key system locations are remote and dispersed throughout the FMCRC service area.
2. Site access is limited.

FMCRC has recently experimented with local gate automation and a limited SCADA system to provide remote monitoring and control capabilities for FMCRC staff. Based on staff feedback:

- The experimental project was successful in enhancing local water management.
- It is anticipated that the existing SCADA system will be expanded in the future to include new sites and provide new capabilities.

To maximize the value and utilization of future automation and SCADA projects, it is important to properly define a strategy for planning and implementing projects that is tailored to local conditions.

The local conditions within FMCRC justify a unique approach to SCADA and automation because:

1. FMCRC's small service area is reflected in relatively small operational budgets, staffing levels, and administrative infrastucture.
2. FMCRC has access to external funding from entities such as the Colorado River Water Conservation District and other sources for project planning and implementation. However, FMCRC will need to fund the continued operations and maintenance costs with smaller, internal budgets.
3. The terrrain is extreme, making traditional line-of-sight wireless communications difficult for large portions of the service area.
4. FMCRC leases shared office space for its administrative staff; therefore, it is prudent to minimize new office infrastructure.

The points above guided the development of this report.

Existing Remote Monitoring System

As part of a district-wide *Modernization Plan*, it is envisioned that Fire Mountain Canal and Reservoir Company (FMCRC) will expand an existing remote monitoring and remote control system.

The existing remote monitoring/control system is described in Table 23.

Table 23. Existing SCADA sites and capabilities

Site No.	Location	Devices Or Structures	Automatic Control	Remote Manual Control	Remote Monitoring
1	Paonia Reservoir	One gate and downstream rated section	X	X	X
2	Bear Creek	One gate and Parshall flume			

The existing system communicates over analog telephone lines. Using a computer in the office, district staff are able to connect to each site using a dial-up modem. The remote connections allow district staff to remotely:

- adjust automatic control target set poitns
- manually adjust gate positions
- monitor water levels and flow rates in near real-time

The existing remote monitoring and control system uses analog telephone lines for communications. Using a computer in the office, district staff are able to remotely connect to each field site equipment (PLC and touchscreen) site using a dial-up modem. The remote connections allow district staff to remotely:

- adjust automatic control target set poitns
- manually adjust gate positions
- monitor water levels and flow rates in near real-time

The communications system, and system architecture, are well suited for initial and smaller scale projects. For example, the telephone system is:

- relatively inexpensive, to connect new sites and maintain
- already installed adjacent and parallel to a large portion of the FMC

However, there are also disadvantages with the telephone system and the existing monitoring and control network architecture:

1. It is unlikely that the existing security protocols meet the requirements for large dams (as defined by USBR) because:
    a. There is nothing in place to detect, monitor, or stop a threat from repeated connection attempts in an effort to gain remote control of a site.
    b. With any dial-up connection, a threat only needs the following items to gain access, all of which could be easily determined with sufficient time and motivation:
        i. dial-up phone number
        ii. IP address of the touch screen
        iii. one or more passwords
2. District staff must dial in (connect) to each site indiviudally for monitoring. As more sites are added to the network, monitoring the entire system may become time-consuming.
3. Dail-up technology and components will eventually become obsolete. It will soon be harder to find available, good-quality products.
4. The existing communications system is incompatible with a centralized data collection system that may be needed to comply with immediate projects

It is therefore anticipated that FMCRC may continue to expand the existing remote control and monitoring network with new sites. It is also anticipated that FMRC will eventually outgrow the existing system architecture and transition to an industrial HMI system.

Before the transition to an industrial HMI system, FMCRC should consider more fully utilizing the existing system architecture. More specifically, the existing remote monitoring and control system has the following potential capabilities, which could be implemented with minor wiring and field programming changes:

1. *Automatic alarm dail-out notification to cell phones*. District staff could be notified of alarm conditions (high water level/flow, gate failure to move, etc.) with some additional wiring and programming.
2. *Local data logging*. Although saving historical data is not a priority for the district at this time, it will likely be valuable in the future. Adding a USB drive to each touchscreen and additional programming may provide sufficient local data logging.

Recommendations and further discussion are provided in later sections.

Immediate Projects

Recommended minor projects that can be implemented immediately are listed in Table 24.

Table 24. Immediate project summary

Description	Estimated expenses	Priority
Wire and configure automatic alarm dial-out system at existing monitoring and control sites (2 sites total)	$5,000	1
Flow measurement improvements at Bear Creek	$15,000	2
Install/configure firewalls and other security equipment at all existing and future network nodes facing public networks (3 total) and dismantle remote control at Paonia Dam	$5,000	3

Automatic Alarming

The Bear Creek site is fitted with a Viking auto-dialer that is capable of accepting two unique digital inputs from a Programmable Logic Controller (PLC) that trigger the device to automatically dial one or multiple phone numbers to announce alarm conditions. However, it is the authors' understanding that the Viking units have not been fully wired and programmed for this capability.

It is also unknown if the Paonia Reservoir site has a similar Viking device. Regardless, it is recommended that these devices be utilized to automatically inform FMCRC staff of alarm conditions such as high water level(s) or high flow rates. Implementing this recommendation will require minor programming changes to:

1. The PLC, so that digital output signals represent alarms
2. The Viking (or equivalent) dialer (phone numbers, alarm messages)

Minor wiring changes will also be required.

Flow Measurement Improvements at Bear Creek

Recommendations and discussion of flow measurement improvements at Bear Creek are provided in **Attachment 3**.

Security Upgrades

Irrigation facility remote control systems are susceptible to cybersecurity breaches, potentially resulting in unauthorized access to gate control. In order to minimize exposure to cyber-based threats, most remote control systems will use multi-leveled security controls. In practice, the level of security controls used in irrigation district SCADA systems can be characterized by one or more of the following categories:

1. Security is assumed to be provided and properly configured by the Integrator installing the system. No questions are usually asked, and nothing is verified by the district or third parties. Therefore, the actual security level is unknown, and will vary based on individual Integrator practices.
2. Industry standard or well-accepted "best practices" are specified before a project has start, and the results are verified by district or third party personnel.
3. Security controls are mandated by regulatory agencies that require regular reporting and improvement.

It is important to note that the authors have an incomplete understanding of the security controls currently installed and configured for the FMCRC remote monitoring and control system. Therefore, specific recommendations cannot be provided. However, the following basic "industry-standard" security measures should be considered and employed:

1. A properly configured firewall or equivalent hardware appliance is installed between control/monitoring sites and public-facing network connections. Basic firewall rulesets for simple systems include:
    a. Internet Protocol (IP) and Media Access Control (MAC) address filtering. Only connections from valid addresses are allowed. All others are blocked.
    b. Only required communication protocols are allowed; all others are blocked.
    c. Only the required number of concurrent connections are allowed.
    d. All connections time out after a reasonable duration set point (e.g., 0.5 hours).
2. All packets sent over public networks are encrypted end-to-end via Virtual Private Network (VPN) or equivalent protocols.
3. New passwords are configured to replace default passwords for all devices.

These basic cybersecurity controls are typical for most remote control systems but are, by themselves, inadequate to meet the requirements that are required for federal networks – or those that may be required for networks remotely controlling dam gates.

Cybersecurity for Dams

FMCRC operates a dam owned by US Bureau of Reclamation for the purposes of storing and releasing water for agricultural irrigation. As detailed in **Attachment 2**, it is anticipated that significant investments are, or will soon be, required to meet federal information security requirements that are triggered by the existing remote control capabilities at Paonia Dam. As such, it is anticipated that FMCC will need to decide between two choices:

1. Maintain remote control capabilities at Paonia Dam and allocate sufficient budget to comply with existing security regulations. A rough estimate of costs for the development and implementation of a security plan is about $100,000, assuming some hardware and software improvements will be needed. Additional annual expenses of about $20,000 should also be budgeted for maintaining compliance and continuous security improvements.
2. **Recommended alternative**: Dismantle the remote control capabilities and instead, proceed with only remote monitoring at Paonia Dam. However, remote control capabilities of other canal facilities could be maintained and expanded. A rough estimate of costs to implement this recommendation is about $2,000.

Phase 1 Projects

Phase 1 includes:

1. New remote control capabilities at the FMC Diversion
2. New remote monitoring sites along FMC for high/low water level warning stations

The sites and capabilities are outlined in Table 25.

Table 25. Recommended Phase 1 sites and capabilities

Site No.	Location	Devices Or Structures	Project Description	Automatic Control	Remote Manual Control	Remote Monitoring	Estimated SCADA costs	Priority
3	River diversion gate	Existing radial gate with new actuator	**Remote manual gate adjustments to maintain a rough spill target at Bear Creek**		**X**	**X**	**$40,000**	**3**
4-6	FMC Monitoring Sites (3 total)	None – water level monitoring stations only	**Automatic notification of high/low water level alarm**			**X**	**$50,000**	**4**

Phase 1 can be implemented at any time at existing sites. The projects do not need to follow sustantial civil works, which is the case for subesequent phases.

River Diversion Gate

Water is diverted from the river into the Fire Mountain Canal (FMC) at the Diversion site. As shown in Figure 80, an existing radial gate has an AC powered electronic actuator that is manually adjusted to maintain the target flow rate into FMC plus a manageable spill flow rate downstream at Bear Creek.

There is no existing instrumentation or remote monitoring/control equipment at the diversion site. However, the Bear Creek site has been fitted with an RTU to provide automatic upstream water level control via a spill gate. FMCRC operators currently need to visit the Diversion site regularly to monitor the river water level and to make any necessary gate adjustments so that sufficient, but not excessive, flow is diverted to the Bear Creek site.

Figure 80. Existing diversion gate and electronic actuator, looking upstream at river

Recommended Modifications

The following modifications are recommended at the Diversion site:

1. Verify the functionality and availability of parts for the existing actuator, gate limit switches, and actuator brake. If any of these parts are unavailable or difficult to repair, install two new AC-powered actuators with internal gate position sensors.
2. Install one upstream and one downstream water level sensor.
3. Install permanent staff gauges upstream and downstream of the Diversion gate.
4. Install an RTU with an Ethernet connection to the office.
5. Program the RTU to provide remote manual control of the Diversion gate position.
6. Include an automatic dial-out alarm system to notify FMCRC operators of the following alarm conditions:
    a. Gate failure to move
    b. High or low upstream water level

A summary of the new capabilities at the Diversion site are listed in Table 26.

Table 26. New remote monitoring and control capabilities at the Diversion site

Item	Capabilities Provided
Remote monitoring capabilities	• Upstream water level • Downstream water level • Both gate positions
Remote control capabilities	• Manual adjustment to both Diversion gate position
Alarm outputs	• High and/or Low upstream water level • High and/or Low upstream water level

Diversion Gate Operation after Modifications

After the recommended modifications, FMCRC will continue to operate the Diversion site in conjunction with the local automatic control at the Bear Creek site. More specifically:

1. The Bear Creek site would continue to be operated primarily under automatic control.
2. Operators will periodically remotely monitor the Bear Creek spill gate position and river water level.
3. Operators will remotely adjust the diversion gate position as described in Table 27.

Table 27. New operating strategy for Bear Creek and FMC Diversion after the recommended modifications are implemented

Scenario	Diversion Gate Position	Bear Creek Spill Gate Position	Task for FMCRC Operators	Result
Beginning of season	Fully closed	Fully closed	• Manually open the FMC gate at Bear Creek to provide the required flow rate into the FMC • Configure the Bear Creek spill gate into automatic control • Incrementally open both Diversion gates equally until the Bear Creek spill gate flow rate is as desired	The Bear Creek spill gate will automatically open as needed to maintain a relatively constant upstream water level
Through-out irrigation season	Not fully closed or open	75% open or greater	Partially close the Diversion gates	The Bear Creek spill gate will automatically close slightly to maintain a relatively constant upstream water level
		Less than 25% open	Partially open the Diversion gates	The Bear Creek spill gate will automatically open slightly to maintain a relatively constant upstream water level

A simple rating table for the Diversion gates may be helpful for operators to determine the correct amount of Diversion gate adjustment.

Canal Level Monitoring Stations

The Fire Mountain Canal is relatively long, and in many areas is located on the side of a steep cliff. The steep slopes on both sides of the canal make it susceptible to:

- Rocks, trees, debris and landslides from the up-facing slopes
- Canal bank failures on the down-facing slopes

It is recommended that FMCRC install simple canal water level monitoring stations (at least three) in these steep areas.

Locations

Three canal monitoring station locations were selected based on the steep slope criteria outlined above as well as good potential line-of-sight with a future radio repeater site (see **Attachment 1** for radio repeater details).

The proposed canal monitoring locations are listed in Table 28.

Table 28. Proposed canal monitoring locations

Site ID	Latitude	Longitude
1	38°55'28.94"N	107°30'51.28"W
2	38°54'57.03"N	107°33'7.98"W
3	38°54'21.88"N	107°33'45.81"W

Details

Each proposed canal monitoring station would be fitted with:

1. simple RTU
2. single ultrasonic water level sensor in a vented and insulated vandalism enclosure
3. permanent staff gauge
4. alarm dial-out device and telephone connection

The RTU would be programmed to measure the canal water level and output alarm signals to the dial-out device in the event that the canal water level exceeds the high/low set point. The dial-out device will automatically dial one or a series of pre-configured phone numbers to inform FMCRC staff of emergency canal conditions.

Example ultrasonic water level measurement stations are shown in Figure 81 and Figure 82.

Figure 81. Example ultrasonic water level measurement with retractable (swinging) bracket and staff gauge at Imperial Irrigation District. The RTU is not shown.

Figure 82. Another example of a simple ultrasonic water level measurement – this bracket does not appear to have enough overhang to eliminate obstructions of the cone-shaped sound path. Note the white, vented enclosure for temperature control.

Phase 2 Projects

A new gravity pipeline project, the Rogers Mesa Pipeline, has been proposed at the tail end of the existing FMC alignment. As shown in Error! Reference source not found., The pipeline will be supplied by two sources (FMC and Leroux Creek) and deliver water to a number of turnouts. More information about the reservoir can be found in Chapter 6.

Once the proposed gravity pipeline is completed, new remote monitoring capabilities can be implemented to aid in pipeline operations as part of **Phase 2**. See Table 29 for a summary of SCADA projects.

Table 29. Recommended Phase 2 sites and capabilities

Site No.	Location (Name)	Devices Or Structures	Project Description	Automatic Control	Remote Manual Control	Remote Monitoring	Estimated SCADA cost
7	FMC Pipeline inlet and siphon	• Spill gate • Pipe inflow meter • Trash rack	**Remote monitoring of pipe inlet conditions**			**X**	**$50,000**
8-12	Pipeline laterals (5 total)	Turnout with existing flow measurement device (e.g., flume) and new actuated valve	**Remote monitoring of turnout delivery flow rates**			**X**	**$150,000**
13	Leroux Creek pipeline inlet	New diversion gate and flow meter device; new actuator	**Remote monitoring and manual control of diversion and pipe inlet conditions**		**X**	**X**	**$50,000**

<u>FMC Pipeline Entrance</u>

The existing FMC channel will end at a new pipeline entrance. The FMC pipe entrance will be fitted with:

1. An automatic, self-cleaning traveling screen just upstream of the pipe inlet
2. A flow meter, some distance downstream of the traveling screen
3. A water level measurement upstream of the traveling screen
4. A weir or flap gate configured to automatically divert excess FMC flows back to the river or Leroux Creek

Until the proposed reservoir is constructed, operators will adjust FMC inflows to maintain a relatively constant spill flow rate upstream of the FMC pipe inlet.

Leroux Creek

In order for the pipeline hydraulics to work with two independently controlled inflows, the Leroux Creek inlet to the proposed FMC pipeline will need to be located upstream of the existing diversion. While the design details have not yet been determined, the site will likely be fitted with the following equipment:

1. A new Leroux Creek diversion gate to direct water into the pipeline, with a gate position sensor and electronic actuator. An automatic spill structure (weir or ITRC flap gate) will also be installed to divert excess water back to Leroux Creek.
2. A water level measurement upstream of the diversion gate
3. An automatic, self-cleaning traveling screen just upstream of the pipe inlet
4. A flow meter, some distance downstream of the traveling screen

Operators would remotely monitor the spill flow rate upstream of the pipe inlet and adjust the diversion gate as necessary to maintain a reasonable spill flow rate.

Pipeline Turnouts

The pipeline will supply a number of turnouts. Some of the turnouts will continue downstream as pipes. Other turnouts will have open discharges into existing canals, where existing flow measurement devices will be reused. A summary of the inflow and outflow structures and instrumentation is provided in Table 30.

Table 30. Overview of proposed pipeline connections and instrumentation

Site Name	Pipeline Connection Type	Reuse existing flow measurement?	New flow measurement	New instrumentation other than magnetic meters	New RTU?
FMC end	Inflow	No	• Mag meter into siphon • Weir or similar to measure spill flow rate	• Upstream FMC water level to estimate spill flow rate • Automated trash rack on/off status	Yes, at each site
Leroux Creek Feeder		No, a new diversion may need to be constructed further upstream on Leroux Creek	Mag meter or similar	• Gate position • Upstream water level • Trash rack on/off status	
East Ditch	Outflow	Yes, flume/weir		Water level sensor upstream of flume/weir	
New Jesse Pipe			Mag meter		
Slack Ditch		Yes, flume/weir		Water level sensor upstream of flume	
Patterson Ditch		Yes, flume/weir		Water level sensor upstream of flume	
Extension Pipe			Mag meter		

The instrumentation and new RTUs will provide the capabilities listed in Table 31.

Table 31. Proposed remote monitoring and control capabilities at each pipeline connection

Site Name	Remote monitoring capabilities	Remote control capabilities	Alarm outputs
FMC end	• Flow rate into siphon • Spill flow rate • Traveling screen on/off	None	High and low spill flow rate
Leroux Creek Feeder	• Flow rate into pipeline • Gate position • Traveling screen on/off	Remote manual control of Leroux Creek Feeder gate position	• Gate fail • High flow into pipe
East Ditch	Flow rate	None	High/low flow rate
New Jesse Pipe			
Slack Ditch			
Patterson Ditch			
Extension Pipe			

Phase 3 Projects

<u>Buffer Reservoir</u>

A ~50 acre-foot buffer reservoir is proposed approximately 1 mile upstream of the FMC siphon. The buffer reservoir will be utilized to:

1. Capture excess FMC flow rates
2. Supplement FMC deficit flow rates

Because the design is preliminary, as discussed in Chapter 6, the exact in/outflow control devices are unknown at this time. Regardless, the design will most likely feature one of the control combinations listed in Table 32.

Table 32. Potential combinations of reservoir inflow and outflow control devices

Inflow control	Outflow control
Gate(s)	Gate(s)
Pump(s)	Gate(s)
Gate(s)	Pump(s)
Pump(s)	Pump(s)

The buffer reservoir will be automated to maintain a relatively constant FMC water level just upstream of the future FMC pipe inlet (location to be determined). Redundant control-related instrumentation is recommended as follows:

1. FMC water level
2. Reservoir water level
3. Gate position(s)
4. Pump speed(s)

The instrumentation and logic that will be provided at the proposed buffer reservoir are expected to provide the capabilities listed in Table 33.

Table 33. Recommended remote monitoring and control capabilities at the new buffer reservoir

Item	Capabilities Provided
Remote monitoring capabilities	• FMC water level • Reservoir water level • All gate positions • All pump speeds • Calculated time to fill/empty based on instantaneous net flow rate in/out of the reservoir
Remote control capabilities	• Manual adjustment of gate positions/pump speeds
Alarm outputs	• High and/or Low FMC and reservoir water levels • Gate/pump fail

Eventual Upgrades

It is anticipated that FMCRC will eventually outgrow the existing system of singular telephone connections to remote touchscreens. Eventually, FMCRC will need to:

1. Upgrade both the communications system, and
2. Transition to a Human Machine Interface (HMI) software package at the Office Base Station (Site 15) that provides enhanced remote control and monitoring capabilities.

The benefits and costs are summarized in Table 34.

Table 34. Benefits and costs for various eventual, major system upgrades

Upgrade Item	Benefits or Capabilities Provided	Estimated up-front cost for implementation	Recurring costs (maintenance, licenses, data etc.)	Various options
Industrial Human Machine Interface (HMI)	A single, unified platform providing remote control and monitoring for all sites simultaneously	\$50,000 to \$120,000 depending on the number of sites and options	\$3,000 to \$15,000	• Basic system: desktop server in office • Industrial rack server with multiple office workstations • Mobile smartphone/tablet access • Historical data archiving and report generation • Automatic email/text/voice alarming (unlimited) with adjustable scheduling and call lists
VHF radio network (recomm-ended)	• Communication independence • Able to communicate to sites without considering proximity to telephone lines • Moving away from potential telephone service/hardware obsolescence	\$300,000	\$20,000	Other communication options that are less expensive up-front are presented later in the document

Office Base Station

An existing office computer and dial-up modem provide FMCRC staff with individual connections to remote sites for monitoring and control. It is anticipated that the existing system will eventually become insufficient as many new sites are added to the network.

At that point FMCRC will install a server to enable multiple concurrent remote site connections. It is recommended that an industrial HMI package is installed. The HMI package would provide the following new benefits:

1. A single unified interface providing operators with the opportunity to view each measured value and adjust the system in near-real time
2. Enable the collection and archiving of historic data to:
    a. Evaluate and benchmark control performance
    b. Help troubleshoot automatic control sites when necessary
    c. Preemptively prepare for enhanced environmental reporting regulations
3. Provide a way to conveniently produce historical reports
4. View and manage all system alarms

An industrial HMI package will provide a stable, and robust platform for further growth. HMI packages are also custom assembled with numerous options that will affect the cost of the system.

It is recommended that FMCRC staff discuss the various options and cost premiums prior to making firm decisions. For example, the most basic HMI system will cost about $50,000 to assemble with about $5,000 of annual maintenance and license costs.

On the other hand, an HMI system with common add-ons (alarm notification, report generation, and mobile phone/table access) can cost up to $150,000 to implement – with about $15,000 of annual licensing and maintenance costs.

Examples of various irrigation district HMI screens are provided in Figure 83 and Figure 84.

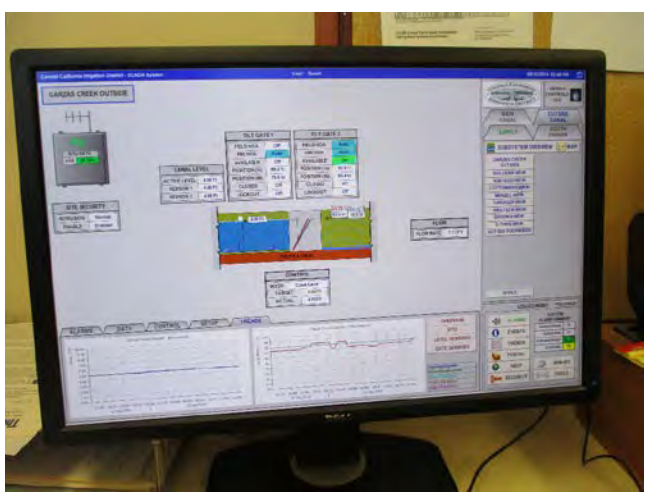


Figure 83. Relatively advanced HMI screens at Central California Irrigation District with numerical displays, control capabilities and trend lines

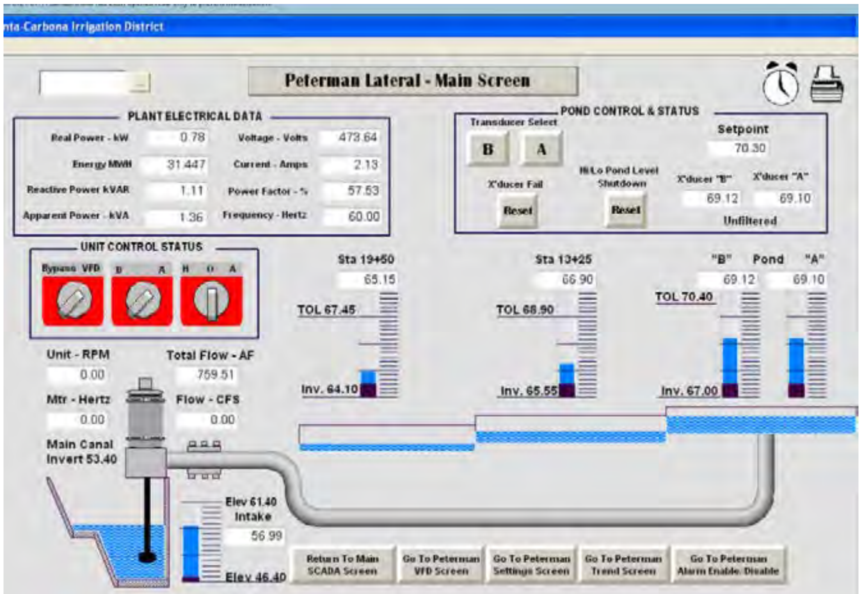


Figure 84. Alternative HMI screen design at Banta Carbona Irrigation District in California

Wireless Communications

As mentioned previously in this report, it is anticipated that FMCRC will eventually outgrow or otherwise choose to transition away from the existing dial-up telephone network.

Various triggers may indicate the need to transition to other communication platforms:

1. A telephone connection is unavailable or in poor condition in the area, or prohibitively expensive to extend where needed.
2. Telephone connections are insufficient for FMCRC in terms of reliability and data throughput, or are incapable of supporting a sufficient number of concurrent connections with remote sites.

There are a number of alternative options available for wide area, irrigation district communications:

1. Hardline cabled networks, private or public
    a. Cable/DSL networks
    b. T1 or leased lines
2. Licensed and unlicensed radios
3. Cellular and satellite radios

It is recommended that FMCRC eventually install a licensed, narrowband VHF (150 or 220 MHz bands) radio network for the following reasons:

1. It is unlikely that hardline public networks will be available where needed (up to each remote site), or financially viable to construct as a private network.
2. Unlicensed radios are risky in both urban and rural environments due to the proliferation of unlicensed radio transmitters in all sectors, which shows little signs of slowing down.

3. Cellular and satellite networks, while sometimes convenient and less expensive up front, require:
    a. Recurring data payments ($30 to $300 per site per month, depending on usage)
    b. Reliance on multiple entities (and contracts between them) for functioning communications
4. Depending on the whole SCADA network architecture, a private network can minimize a SCADA owner's exposure to cyber threats and require a smaller security foot print (hardware, software and labor) for equivalent protection to public facing networks.

Proposed VHF radio links, including repeater sites and initial antenna heights, are provided in **Attachment 1**. This information is preliminary and should be used as a starting point for a field radio survey using actual radio equipment to measure expected performance and verify antenna details.

If the system described in **Attachment 1** is not feasible initially, a less expensive and intermediate alternative is a hybrid approach: a combination of cellular (or satellite if cell coverage is not available) and VHF radios as listed in Table 35.

Table 35. Alternative and/or intermediate hybrid wireless communications system

Site Name	Cellular/Satellite radio	VHF radio
Paonia Dam	X	
Diversion	X	
Bear Creek	X	
Canal Monitoring Stations 1-3	X	
Buffer Reservoir		X
FMC Spill		X
Leroux Creek Feeder		X
Pipeline Turnouts 1-5		X
Office Base Station		X

Three options were evaluated and a total cost of ownership was estimated for each:
1. All VHF radios, requiring two additional radio repeater sites (see **Attachment 1**)
2. A mix of cellular and VHF sites
3. A mix of satellite and VHF sites

A summary comparison between these options is provided in Table 36 using assumptions of data usage and data plans available online.

Table 36. Cost comparison of radio options

	Option 1 - All VHF	Option 2 - Cell / VHF	Option 3 - Sat / VHF
Up-front costs including planning, materials and installation	$300,000	$180,000	$190,000
Annual data costs	$0.00	$1,620	$9,876
Annual maintenance costs	$6,000	$5,000	$5,000
Year	**Total cost of ownership**		
0	$300,000	$180,000	$190,000
1	$306,000.00	$186,620	$204,876
2	$312,000.00	$193,240	$219,752
3	$318,000.00	$199,860	$234,628
4	$324,000.00	$206,480	$249,504
5	$330,000.00	$213,100	$264,380
6	$336,000.00	$219,720	$279,256
7	$342,000.00	$226,340	$294,132
8	$348,000.00	$232,960	$309,008
9	$354,000.00	$239,580	$323,884
10	$360,000.00	$246,200	$338,760
11	$366,000.00	$252,820	$353,636
12	$372,000.00	$259,440	$368,512
13	$378,000.00	$266,060	$383,388
14	$384,000.00	$272,680	$398,264
15	$390,000.00	$279,300	$413,140
16	$396,000.00	$285,920	$428,016
17	$402,000.00	$292,540	$442,892
18	$408,000.00	$299,160	$457,768
19	$414,000.00	$305,780	$472,644
20	$420,000.00	$312,400	$487,520
21	$426,000.00	$319,020	$502,396
22	$432,000.00	$325,640	$517,272
23	$438,000.00	$332,260	$532,148
24	$444,000.00	$338,880	$547,024
25	$450,000.00	$345,500	$561,900

The data presented in Table 36 is plotted in Figure 85.

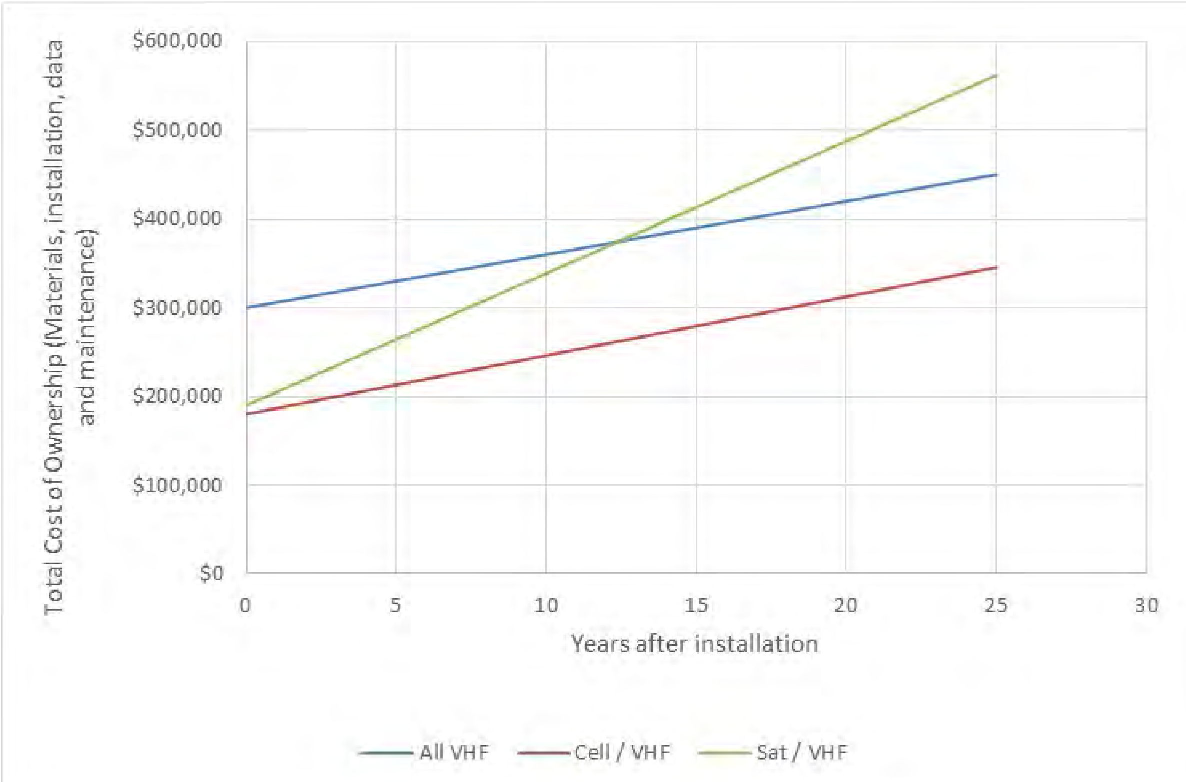


Figure 85. Total cost of ownership comparison (planning, materials, installation, data costs and maintenance) for three different communication networks

ATTACHMENT 1
Proposed VHF Radio Network

Attachment 1
Proposed VHF Radio Network

A licensed Very High Frequency (VHF), Ethernet-based radio system is proposed to connect all of the FMCRC SCADA sites over a private and secure wireless network. It is envisioned that the information provided in this attachment would be used as the starting point for a field radio survey to verify radio performance, antenna heights, and other details prior to construction.

Overview

An overview map of the FMCRC SCADA sites is provided in Figure 1-1.

Figure 1-1. Overview of FMCRC radio sites. Pipeline turnout sites not shown

A cursory, remote analysis indicates that at least two repeater towers will be needed to reach the SCADA sites east of Hotchkiss, CO. The two repeater sites are shown in Figure 1-1, and listed with all other SCADA radio sites in Table 1-1.

Table 1-1. Proposed VHF radio sites, locations and initial tower heights

Site Name	Latitude (DMS)	Longitude (DMS)	Preliminary Tower Height (ft)
Paonia Dam	38°56'33.97"N	107°21'7.95"W	30
Repeater 1	38°54'59.03"N	107°27'56.33"W	100
Diversion	38°55'38.26"N	107°28'41.28"W	40
Canal Level Monitoring Station 1	38°55'28.94"N	107°30'51.28"W	40
Canal Level Monitoring Station 2	38°54'57.03"N	107°33'7.98"W	40
Canal Level Monitoring Station 3	38°54'21.88"N	107°33'45.81"W	40
Bear Creek	38°55'28.94"N	107°30'51.28"W	40
Repeater 2	38°54'4.61"N	107°38'5.34"W	100
Reservoir	38°49'40.63"N	107°43'55.93"W	50
Pipe inlet	38°49'23.99"N	107°46'19.44"W	50
Leroux Creek	38°49'38.14"N	107°46'41.07"W	50
Pipe TO 1-5	?	?	40
Office	38°47'57.86"N	107°43'28.68"	100

Radio Link Network

The individual radio links are illustrated in Figure 1-2.

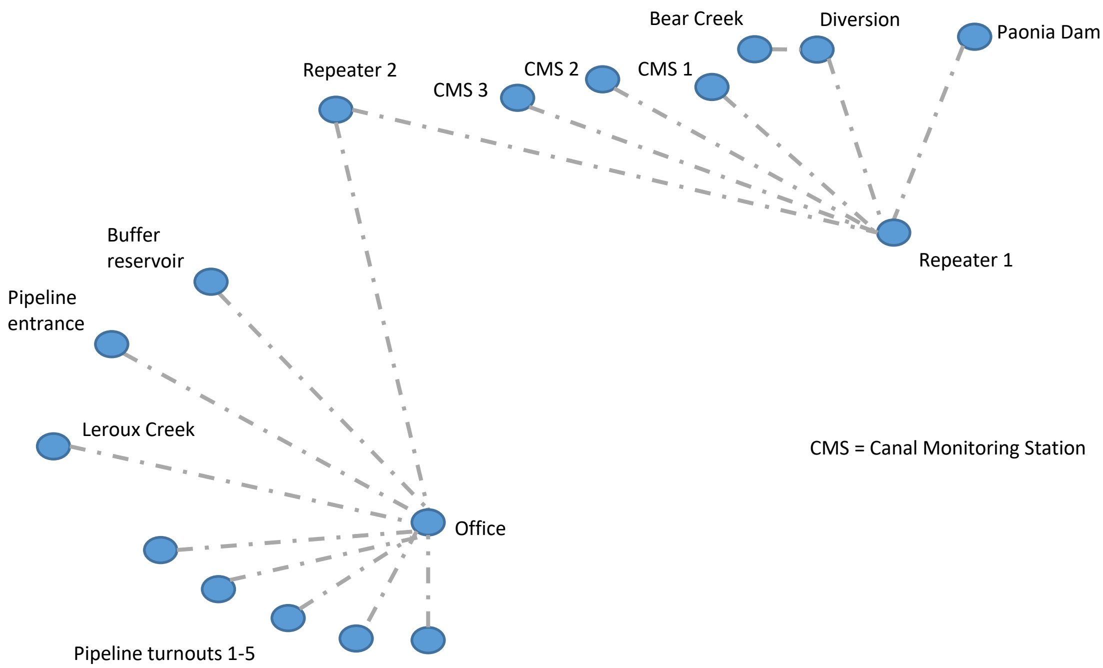


Figure 1-2. Conceptual VHF radio network diagram (not to scale)

Radio Link Details

The remainder of this attachment provides individual radio link details and profiles extracted from Google Earth. Details and profiles for the pipeline turnouts were not provided because their exact location is unknown and they are all relatively close to the office in Hotchkiss, CO.

Repeater 1 to Paonia Dam

Table 1-2. Paonia Dam to Repeater 1 link information

Site Name	Latitude (DMS)	Longitude (DMS)	Preliminary Tower Height (ft)	Link Distance (miles)	Notes
Paonia Dam	38°56'33.97"N	107°21'7.95"W	30	6.41	Line of sight looks feasible.
Repeater 1	38°54'59.03"N	107°27'56.33"W	100		No major obstructions

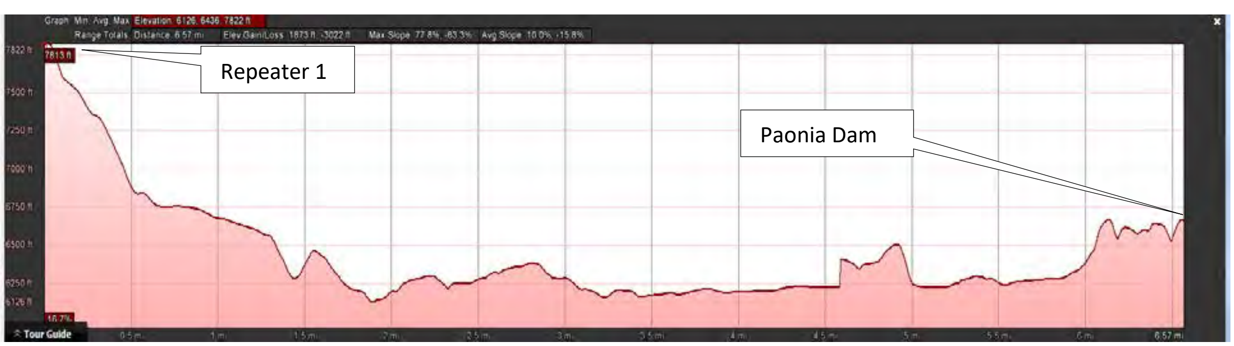


Table 1-3. Paonia Dam to Repeater 1 ground profile

Additional Links to Repeater 1

Table 1-3. Information for additional sites linked to Repeater 1

Site Name	Latitude (DMS)	Longitude (DMS)	Preliminary Tower Height (ft)	Link Distance (miles)
Repeater 1	38°54'59.03"N	107°27'56.33"W	100	
Diversion	38°55'38.26"N	107°28'41.28"W	40	1
Canal Level Monitoring Station 1	38°55'28.94"N	107°30'51.28"W	40	2.7
Canal Level Monitoring Station 2	38°54'57.03"N	107°33'7.98"W	40	4.7
Canal Level Monitoring Station 3	38°54'21.88"N	107°33'45.81"W	40	5.3

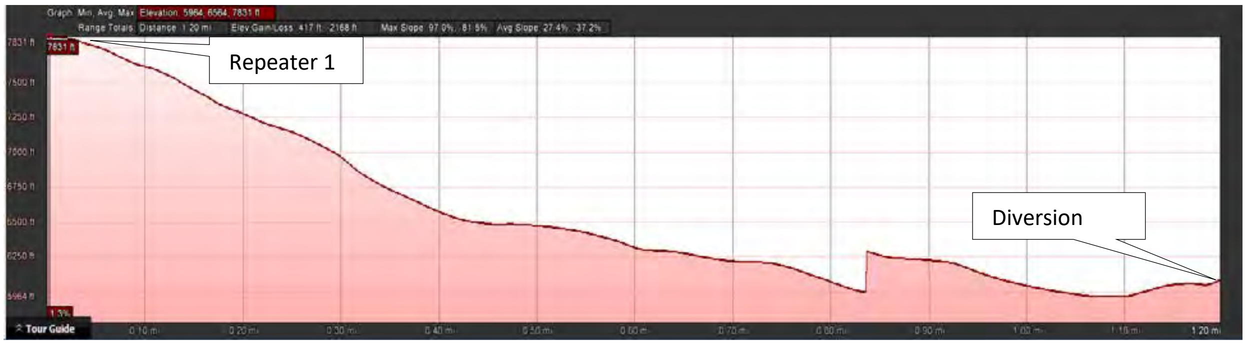


Figure 1-4. Repeater 1 to diversion ground profile

Figure 1-5. Repeater 1 to Canal Level Monitoring Station 1 Link Profile

Figure 1-6. Repeater 1 to Canal Level Monitoring Station 2 Link Profile

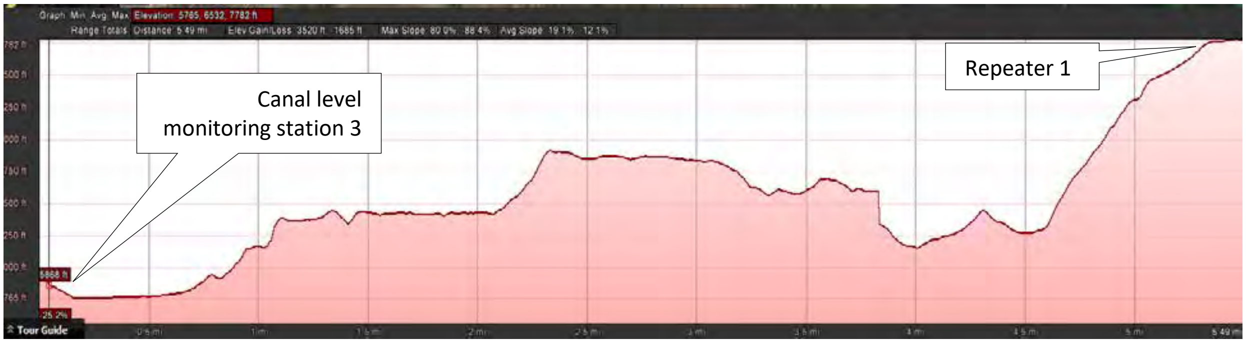


Figure 1-7. Repeater 1 to Canal Level Monitoring Station 3 Link Profile

Bear Creek to Diversion Link

Table 1-4. Link information for Bear Creek to Diversion

Site Name	Latitude (DMS)	Longitude (DMS)	Preliminary Tower Height (ft)	Link Distance (miles)	Notes
Diversion	38°55'38.26"N	107°28'41.28"W	40	0.8	It is recommended to move the Diversion tower ~ 200 feet east of diversion structure for better line of sight
Bear Creek	38°55'28.94"N	107°30'51.28"W	40		

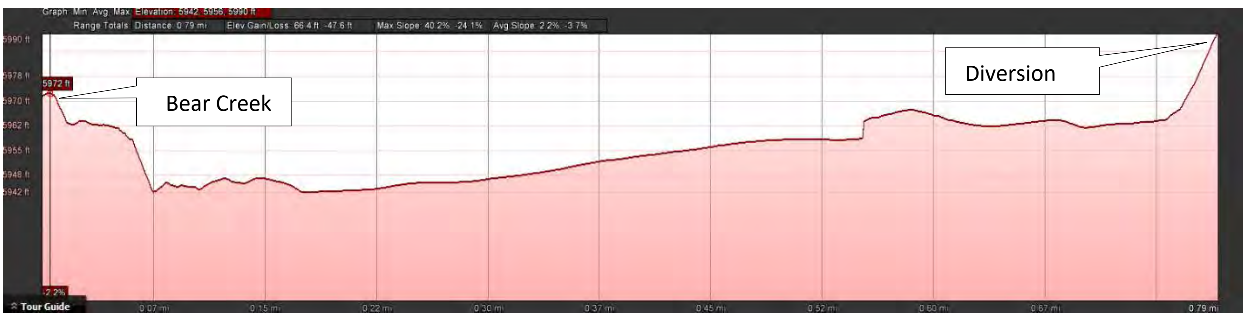


Figure 1-8. Bear Creek to Diversion link profile

Veiwshed from Repeater 1

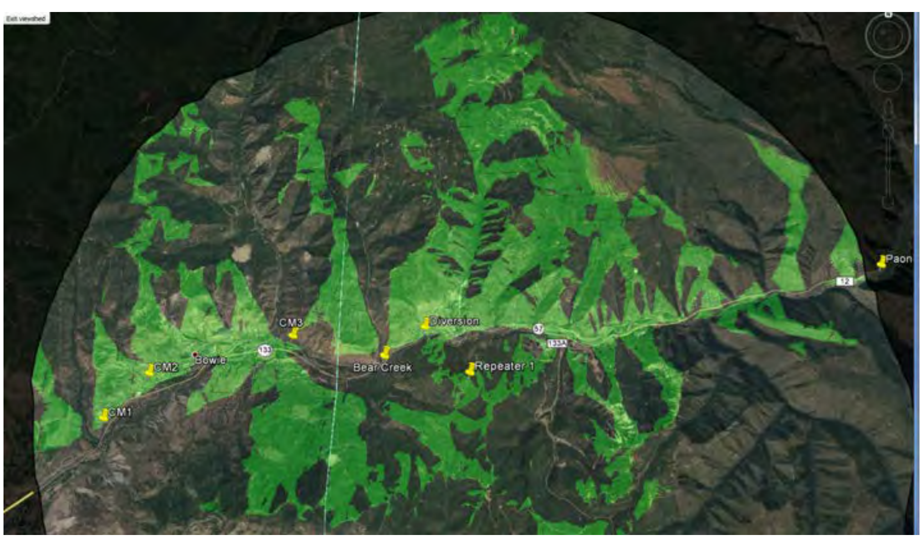


Figure 1-9. Viewshed from 100' above ground surface at Repeater 1

Repeater 1 to Repeater 2

Table 1-5. Link information for Repeater 1 to Repeater 2

Site Name	Latitude (DMS)	Longitude (DMS)	Preliminary Tower Height (ft)	Link Distance (miles)
Repeater 1	38°54'59.03"N	107°27'56.33"W	100	9.2
Repeater 2	38°54'4.61"N	107°38'5.34"W	100	

Figure 1-10. Repeater 1 to Repeater 2 link profile

Direct Links to Hotchkiss Office

Table 1-6. Link information for connections to base station office in Hotchkiss, CO

Site Name	Latitude (DMS)	Longitude (DMS)	Preliminary Tower Height (ft)	Link Distance (miles)	Notes
Office	38°47'57.86"N	107°43'28.68"	100		
Repeater 2	38°54'4.61"N	107°38'5.34"W	100	8.5	
Reservoir	38°49'40.63"N	107°43'55.93"W	50	2	
Pipe inlet	38°49'23.99"N	107°46'19.44"W	50	3	
Leroux Creek	38°49'38.14"N	107°46'41.07"W	50	3.5	Leroux Creek Tower needs to be installed about 300 ft south of site for line of site

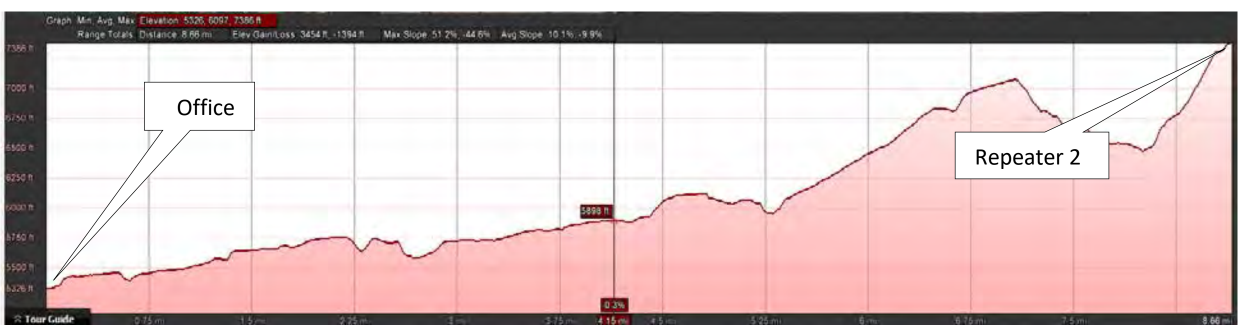


Figure 1-11. Office to Repeater 2 link profile

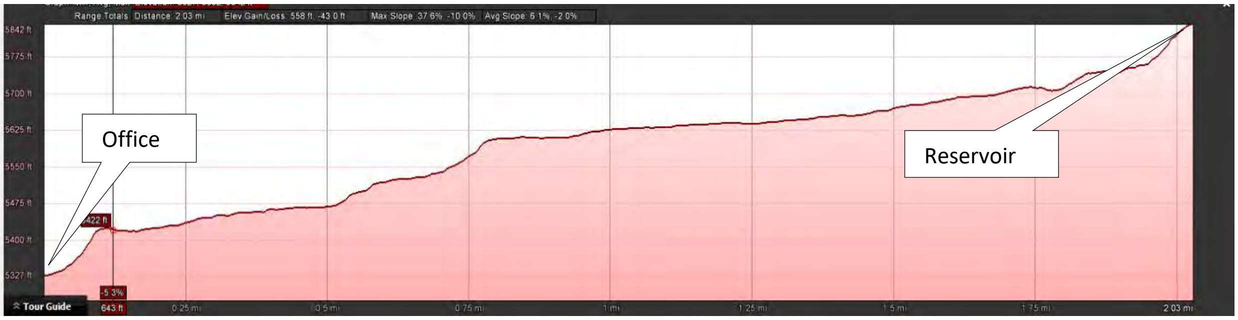


Figure 1-12. Office to Reservoir link profile

Figure 1-13. Office to Pipe Inlet link profile

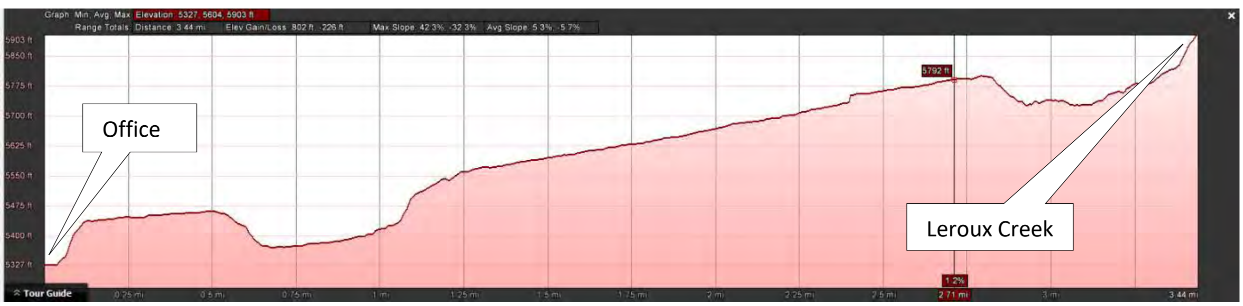


Figure 1-14. Office to Leroux Creek link profile

ATTACHMENT 2
Federal Cybersecurity Overview

Attachment 2
Federal Cybersecurity Overview

The information security regulatory landscape is relatively stringent for federal facilities (presumably including Paonia Dam, a USBR facility). Federal facilities are self-regulated, and are required to develop and implement an *information security plan* that outlines the physical and cyber controls, policies and procedures implemented by the federal facility operator in compliance with NIST SP 800-53 Revision 4 and SP 800-82 standards under the Federal Information Management Act (FISMA), enacted as Title III of the E-Government Act of 2002.

Compliance costs significantly increase when remote control systems are installed due to the increased risk of unauthorized access and the potential for damage to life and property. Therefore, it is anticipated that the existing remote control capabilities utilized by FMCRC at Paonia Dam will require compliance with the federal standards. In the event that the federal standards listed above do not apply to FMCRC and its operations at Paonia Dam, it is likely that equivalent requirements will be mandated in future legislation for remote dam control applications. In either case, FMCRC would be obligated to complete the following:

1. Contract with a Critical Infrastructure Protection consultant to develop an *Information Security Plan*
2. Implement the plan prior to submission
3. Continually revisit, evaluate and update the plan over time

Brief Overview of Federal Security Planning

FIPS Publication 200 outlines the *Minimum Security Requirements*, or categories of policies, for hardware and software implementations for all federal organizations. Similar requirements are applicable for all hydro-power dam operators (private and public).

The FIPS 2000 *minimum security requirement* categories are:

1. Physical and cyber access controls
2. Staff awareness and training
3. Auditing and accountability
4. Certification, accreditation and security assessments
5. Configuration management
6. Contingency planning
7. Identification and authentication
8. Incident response
9. Maintenance
10. Media protection
11. Physical and environmental protection
12. Planning
13. Personnel security
14. Risk assessment
15. System and services acquisition
16. System and communication protection
17. System and information integrity

The specific implementation and planning requirements for each security category are determined in a two-step process:

1. Determine the *impact category* (low, medium or high) using FIPS Publication 199.
2. Determine the *baseline security control category* (low, medium or high) using:
   a. FIPS Publication 200
   b. NIST SP 800-53 and 800-82, which are also used to determine specific requirements listed under each *baseline security control category*, as well as the amount of allowable exceptions/adjustments to the requirements (known as tailoring).

In summary, the federal information security standards are rather complicated and in-depth.

Estimated Compliance Costs

It is estimated that continued remote <u>control</u> operations at Paonia Dam will eventually require about $100,000 in compliance-related costs (in staff time, as well as hardware, software and consultant costs) to develop and implement and likely about $20,000 per year in compliance maintenance.

Alternatives and Recommendations

<u>Alternatively, FMCRC may be able to avoid these eventual costs by:</u>

1. <u>Dismantling the existing remote control capabilities at Paonia Dam in favor of dam monitoring only AND</u>
2. <u>Implementing industry-standard best practices. Approximate costs for industry-standard best practices are included in cost estimates provided in this document.</u>

Other Common Regulatory Bodies

If dam owners are not producing power (which would fall under NERC/FERC regulations and licensing requirements), dam owners are also regulated by their respective State Safety of Dams agencies, which may have additional or equivalent requirements.

References

DHS (2010). Dams Sector Roadmap to Secure Control Systems. Department of Homeland Security – Office of Infrastructure Protection. Pg. 12. Available online at: https://damsafety.org/sites/default/files/files/DamsSectorRoadmapToSecureControlSystems.pdf

NIST (2013). Security and Privacy Controls for Federal Information Systems and Organizations. NIST Special Publication 800-53 – Revision 4. Joint Task Force Transformation Initiative. April 2013. Available online at: http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r4.pdf

NIST and US Dept. of Commerce (2006). Minimum Security Requirements for Federal Information and Information Systems. Computer Security Division. Available online at: http://nvlpubs.nist.gov/nistpubs/FIPS/NIST.FIPS.200.pdf

ATTACHMENT 3
Flow Measurement Improvements at Bear Creek

Attachment 2
Flow Measurement Improvements at Bear Creek

The Parshall Flume that is located at the head of the Fire Mountain Canal has an 8' throat width. Under high flow rate conditions, it is "submerged" and the proper calculation of flow rate requires two measurements. Only the upstream level is used right now. Figure 3-1 shows the two measurement sites (for "Ha" and "Hb") that are required for submerged conditions. Field measurements showed that the stilling well access tubes for these two sites are properly located.

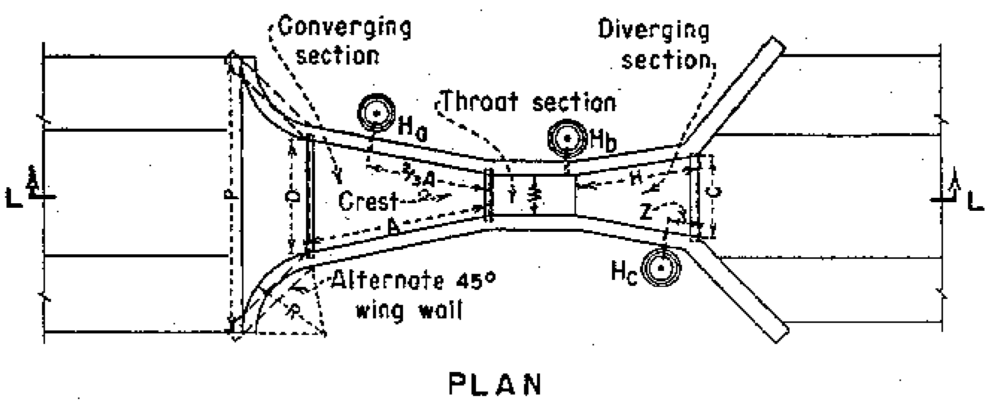


Figure 3-1. Two measurement sites required for submerged conditions.

Both "Ha" and "Hb" water depths are measured with a zero value on the floor of the converging section.

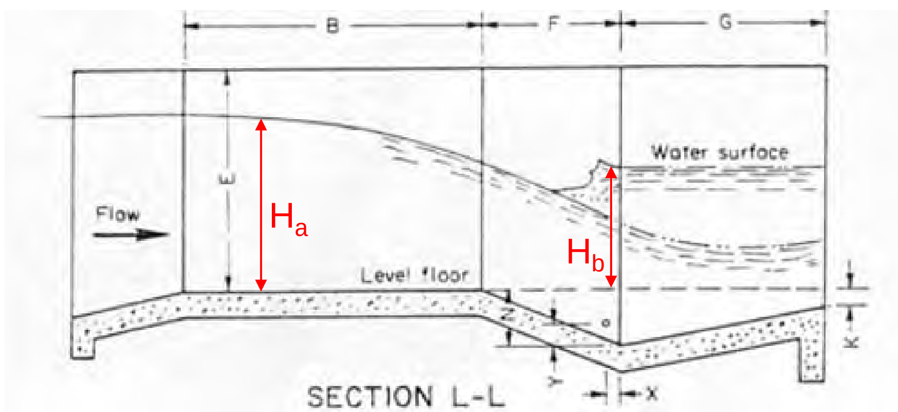


Figure 3-2. Ha and Hb water depth measurements

The USBR Water Measurement Manual provides the following information:

1. For an 8' flume, when Hb/Ha is LESS than 0.70, the flume is NOT submerged, and the flow rate should be computed only using the Ha (upstream) water depth. The flow rate is computed as:

   $CFS = 32 \times Ha^{1.61}$
   For example, if Ha = 1.2 feet,
   $CFS = 32 \times 1.2^{1.61} = 42.9$ CFS

2. If Hb/Ha is GREATER THAN OR EQUAL TO 0.70, the flume is considered to be submerged. The flow rate computation requires both the Hb and Ha measurements. The USBR Water Measurement Manual provides a graph that shows correction factors for various degrees of submergence, and different Ha values. Figure 3-3 is obviously of poor quality, but included here to point out that using it requires a manual examination of the graph, and subsequent manual computations.

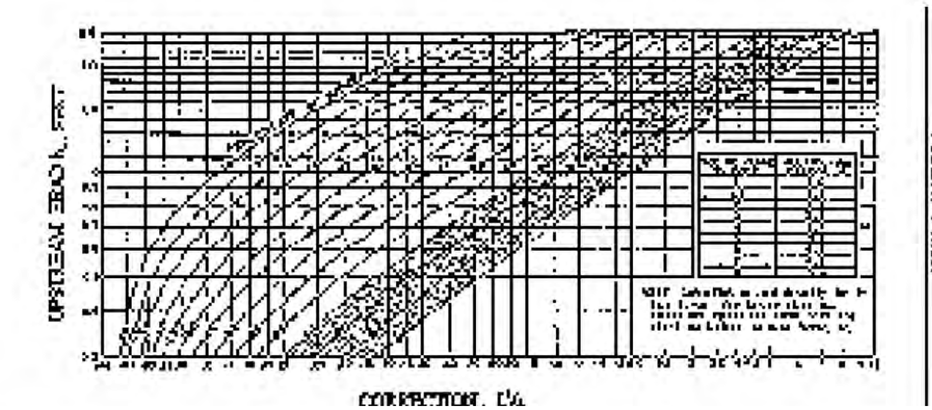


Figure 3-3. Figure 8-16 of the USBR Water Measurement Manual

ITRC took information from Figure 8-16 of the USBR Water Measurement Manual, and used the software program Table Curve 3D to develop a best fit equation of the correction factor for an 8' Parshall flume. The results are shown in Figure 3-4. This equation was selected because it does not use any (log) or (ln) or (exponential) functions, and can likely be entered into the small PLC that is found at the site.

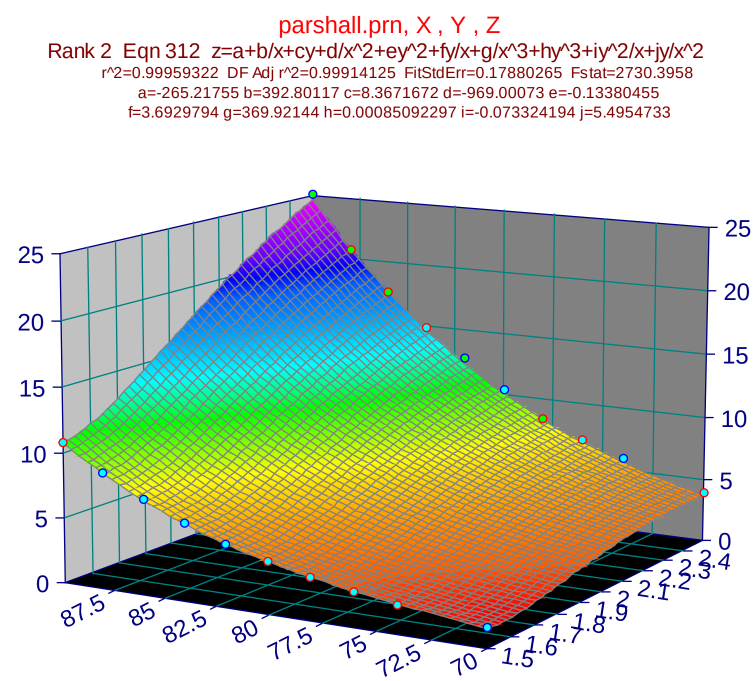


Figure 3-4. Results of Table Curve 3D program

The interpretation of the graph above is as follows:

1. The equation shows an almost perfect fit to the data (r^2 = .9996). Likely the error is due to imprecise extraction of data from the USBR graph.
2. For the equation above, Z = Correction, X = Ha, and Y = % Submergence
3. The inputs, using terminology from the data collection, are:

    CFS Correction = the CFS that need to be <u>subtracted</u> from the free flow solution
    Ha = Upstream water level, feet
    S = Percentage of Submergence (Hb/Ha × 100)

4. The correction equation is:

$$CFS\ Correction = -265.22 + \frac{392.8}{Ha} + 8.367\,S - \frac{969}{Ha^2} - 0.1338\,S^2 + 3.693\frac{S}{Ha} + \frac{369.92}{Ha^3} + 0.000851S^3 - 0.0733\frac{S^2}{Ha} + 5.4955\frac{S}{Ha^2}$$

5. The final equation is:

    CFS = 32($Ha^{1.61}$) – (CFS Correction)

To properly implement this final equation, the following need to be done:

1. The access tubes (the tubes between the water and the stilling well) should be cored out to have a 4" diameter. Currently, they are about ¾"-1" diameter. The larger diameter will provide a quicker response in the stilling well yet still avoid waves in the stilling wells.
2. An additional water level sensor needs to be installed – in the downstream stilling well – to measure Hb.
3. Both water level sensors should be attached to a long strip of stainless steel suspended from a hook on the wall of the stilling well. When the transducers are attached (usually with plastic quick-ties), there should be some line on the stainless steel strip that corresponds to the joint between the transducer and its cap, so that everyone knows if it is installed properly. Care must be taken to not tighten the quick-ties too much, which can cut off the air vent tube. The purpose of doing this is so that the sensor can be removed for inspection and cleaning, and then be lowered into the exact original position, minimizing the need for recalibration.
4. During the field visit, desiccant containers were not observed (maybe they were on the ends of the transducer vent tube, but just not observed). Special desiccant should be used – in an extra-large container (about 4 times bigger than usually sold) – so that it doesn't need to be changed often.
5. Both water level sensors need to be zeroed to exactly the same reference elevation: the floor of the converging section.
6. The PLC needs to be programmed to:
    a. Utilize the new formula
    b. Make the values of Ha and Hb available via the cell phone
    c. Make the gate opening (of the spill gate) available via the cell phone