Investigations and Analysis Report for the Corn Creek Watershed Plan and Environmental Assessment

Corn Creek Watershed, Millard County, Utah

Table of Contents

List of Tables

List of Figures

Background/Existing Conditions (TM 001)

The Corn Creek watershed is a hydrologically closed basin. Significant flooding occurred in 2011, causing damage to homes and agricultural fields. The Town of Kanosh is at risk of severe flooding and experiences issues related to water shortages and high demand on groundwater resources. There are very limited recreational opportunities in Kanosh. Additionally, the Kanosh Band of Paiutes, located north of Kanosh, experience culinary water shortages due to outdoor water use. Details beyond those included in this report may be found in Technical Memorandum 001 in Appendix E.

Corn Creek Debris Basin

The Corn Creek debris basin, located upstream of Kanosh, was originally constructed in 1955 and reconstructed in 1985 after failing during the 1984 floods. The reconstruction included various enhancements to improve floodwater management and prevent flooding in Kanosh, such as new outlet works, secondary and emergency spillways, embankment improvements, and erosion prevention measures. The basin's capacity as of 2019 was 200 acre-feet at the secondary spillway crest and 468 acre-feet at the embankment crest. However, Utah Dam Safety has identified significant foundation seepage issues with the embankment, rating the dam as high hazard due to its location. Maintenance issues have persisted, including vegetation growth, breaching, burrowing rodents, riprap sloughing, and extensive foundation seepage.

Utah Dam Safety has expressed concerns about the seepage through the embankment foundation and the inadequacy of the toe drain installed in 1985, requiring remediation to prevent internal erosion. Utah Dam Safety has mandated the control be completely open to prevent storage of flood water. This increases the risk of downstream flooding. The basin stores water only briefly during peak runoff periods and is dry for most of the summer; it’s mainly used for animal grazing, ATV recreation, and gravel stockpiling that originates from the debris basin. The gravel stockpiles vary in aggregate size and will likely be used as a source for the proposed debris basin embankment. Without adequate water detention, the peak flows cannot be attenuated, potentially leading to significant flooding in Kanosh.

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Figure 1: Debris Basin and Corn Creek from Above the Outlet Works, July 2021

Primary Outlet and Secondary Spillway

The debris basin's primary outlet and secondary spillway are in good condition. The outlet works' stilling basin shows erosion and algae buildup, with the spillway capable of discharging about 2,300 cfs at the dam crest (5,198 feet). The 60-inch outlet pipe, with capacities of 365 cfs at the secondary spillway crest (5189.62 feet) and 440 cfs at the dam crest, shows corrosion and delaminating tar lining. A conveyance pipeline for Kanosh's secondary irrigation system includes a rarely used 12-inch PVC pipe to the Paiute Tribe, whose leaking headgate allows some water to reach the reservation pond. The Town's secondary system pipeline is also a 12-inch PVC pipe rated at 100 psi. In the past, during high flow events, stop logs have been used in the secondary spillway to get the water level high enough to go out the emergency spillway. Placing stop logs in the secondary spillway increases failure risk during high floods and Utah Dam Safety has prohibited the use of stop logs in the future. The configuration of the existing dam and spillways are listed in Table 6-1: Comparison of Existing Dam Design and Preferred Alternative Design in Chapter 6 Section 2 of the Plan-EA.

Figure 2: Outlet Works Stilling Basin, June 2021

Emergency Spillway and Flood Channel

The emergency spillway culverts, designed to release excess water to a flood channel, consist of four partially obstructed 49-inch corrugated metal pipe (CMP) arch culverts, reducing their discharge capacity and increasing the dam's failure risk due to foundation seepage issues. Currently, water must back up in the debris basin before it can flow through the emergency spillway, leading to all flood water passing through the 60-inch primary outlet works until it overflows the secondary and emergency spillway crests (5189.65 feet and 5,189.5 feet). Clearing the culverts could allow a maximum discharge of approximately 427 cfs to the flood channel when water is at the dam crest. The basin's configuration and filling restriction result in nearly all flood water flowing uncontrolled towards Kanosh, risking debris and sediment blockage of channels and culverts. The emergency spillway channel, with a capacity of about 2,000 cfs, discharges to land east of Kanosh, potentially flooding agricultural fields and Highway 133.

Figure 3: Emergency Spillway and Flood Channel, July 2021

Existing Ditches and Historic Natural Channel

Downstream of the debris basin, Corn Creek is diverted into several channels at two primary locations: the outlet works stilling basin and a splitting structure further downstream. The East Middle Hatton Double Ditch, one of the channels, is concrete-lined but has leakage issues and a design capacity of about 12 cfs, but it can handle no more than 4-5 cfs without overflowing due to settlement of a blockage by failed concrete farther down the channel. The South & West Field Double Ditch transitions to a 24-inch PVC pipe after 100 feet, with a maximum flow rate limited to about 15 cfs due to debris blockage at the pipe inlet.

Figure 4: Leakage from the East Middle Hatton Ditch, Flow Approx. 3 cfs, July 2021

At higher flows, water is discharged to a natural channel from the outlet works stilling basin, with a capacity of approximately 1,300 cfs, though vegetation limits this. The splitting structure, 650 feet downstream from the outlet works, divides the flow into four channels: South Single Ditch, West Single Ditch (natural channel), Main Hatton Single Ditch, and East Field Single Ditch. Each channel has different capacities and limitations, with debris and sediment buildup significantly impacting their effectiveness.

The East Field Single Ditch has an estimated capacity of about 280 cfs but is limited to 50 cfs at certain culverts. The Main Hatton Single Ditch, the largest of the splitting structures, has a capacity of around 630 cfs when free of debris but is currently limited due to sediment and debris buildup. The West Single Ditch historically passed through Kanosh but is now redirected, with a concrete channel portion capable of handling significant storm events, though the capacity drops to 65 cfs in the dirt channel section at the end due to a smaller culvert.

Figure 5: Diversion Structure, July 2021

Overall, the system's flood routing capacity is limited by downstream culverts, channel size reductions, and vegetation and debris. Best-case capacity is approximately 950 cfs for protecting homes and buildings, and 690 cfs for agricultural fields, but actual capacity is much lower due to blockages. The inability to control water flow into individual ditches during prolonged floods, combined with sediment and debris issues, significantly increases the risk of flooding in Kanosh and potential dam failure during severe events.

Water Rights

Corn Creek Irrigation Company (CCIC) and Kanosh Town share Water Right 67-1048, adjudicated in the 1936 Cox Decree, with CCIC entitled to 89 cfs for irrigating 3,550.9 acres and non-irrigation uses, while Kanosh receives 2 cfs for culinary purposes. CCIC also holds Water Right 67-664, established in 1964, granting 15 acre-feet for irrigation, stock, and domestic use over 682 acres. Kanosh additionally holds Water Right 67-1182, with a priority date of 1915, allowing 1.07 cfs or 774.6586 acre-feet for municipal use, sourced from a horizontal collection system. The 2013 Correction Water Deed superseded previous agreements, delineating the respective allocations for CCIC and Kanosh.

Design Criteria & Practice Standards (TM 002)

The USDA-NRCS, in partnership with the Town of Kanosh, CCIC, and Kanosh Band of Paiutes Tribe, is conducting a Watershed Plan-Environmental Assessment (Plan-EA) for the Corn Creek watershed in eastern Millard County. The project aims to address flooding in Kanosh and surrounding agricultural lands and improve water conservation with a piped irrigation system for CCIC. Proposed solutions include reconstructing and enlarging the debris basin/reservoir and installing a piped irrigation system and flood control facilities. Technical Memorandum 002 in Appendix E outlines design criteria for meeting NRCS authorized purposes of flood control, irrigation, and recreation elements, with a summary of applicable design standards provided in that Memo. This document provides a brief summary of each design criteria used.

Millard County Road and Bridge Design Standards

The Millard County Road and Bridge Department requires their roads to meet certain design standards. The proposed project would involve crossing county roads during construction. The road crossings would need to be designed to meet county standards.

NRCS Code 327: Conservation Cover

NRCS Code 327 mandates permanent vegetation cover, which is crucial for the preferred alternative of diverting flood water north of Kanosh, ensuring the infrequently used channel has vegetative cover to prevent erosion.

NRCS Code 342: Critical Area Planting

NRCS Code 342 design criteria applies to highly disturbed areas and would be used in the project where permanent vegetation is needed but cannot be achieved with normal seeding/planting methods.

NRCS Code 362: Diversion

NRCS Code 362 outlines design criteria for constructing channels to divert surface runoff to desired locations, and the project proposes constructing a diversion upstream of the existing debris basin to direct water to a regulating pond for the pressurized irrigation system and using the basin to divert flood water around Kanosh.

NRCS Code 373: Dust Control on Unpaved Roads and Surfaces

NRCS Code 373 provides criteria for controlling particulate emissions from traffic and wind on unpaved surfaces by applying a palliative, which will be necessary for the unpaved roads and surfaces created during construction, including those built using Code 560.

NRCS Code 402: Dam and TR 210-60 Earth Dams and Reservoirs

NRCS Code 402 provides design criteria for dams to reduce flood damage, store water for beneficial uses, and improve wildlife habitats, and the project includes replacing the existing dam for flood control, irrigation, and recreational purposes, using Code 402 alongside Code 436 and Utah Division of Water Rights Dam Safety Rules.

NRCS Code 430: Irrigation Pipeline

NRCS Code 430 outlines the minimum design criteria for water conveyance pipelines, and the project proposes a pressurized irrigation pipeline to replace CCIC's canal system.

NRCS Code 436: Irrigation Reservoir

NRCS Code 436 provides criteria for irrigation water storage structures, and the project includes replacing the current dam structure to store irrigation water and constructing a regulating pond for the pressurized irrigation pipeline, using Code 436 in conjunction with Code 402 and Utah Division of Water Rights Dam Safety Rules.

NRCS Code 472: Access Control

NRCS Code 472 sets requirements for temporary or permanent access control measures, and the project may require these for access roads created under Code 560 to project locations such as the maintenance road for the proposed irrigation pipeline.

NRCS Code 560: Access Road

NRCS Code 560 provides criteria for constructing access roads for equipment and vehicles, which will be designed to allow access to construct and maintain project facilities.

NRCS Code 566: Recreation Land Improvement and Protection

NRCS Code 566 outlines criteria for modifying land surfaces to support recreational use, and proposed recreational facilities will be graded and shaped accordingly.

NRCS Code 570: Stormwater Runoff Control

NRCS Code 570 provides criteria for controlling erosion, sedimentation, and stormwater runoff during and after construction, and these considerations will be applied to any construction activities during the project.

NRCS Code 582: Open Channel

NRCS Code 582 provides criteria for improving, constructing, and restoring open channels, which will be applied to any work on open drainage channels in the project.

NRCS Code 587: Structure for Water Control

NRCS Code 587 provides criteria for water management systems to control water flow, and the project includes culvert replacement and structures for the pressurized irrigation system.

NRCS National Engineering Handbook (NEH)

The NEH provides design criteria for various engineering applications, and only criteria related to irrigation, drainage, flood prevention, and hydrology modeling and design are included in this section.

NRCS National Engineering Manual (NEM)

The NEM provides design policy for various engineering applications; only policies related to irrigation, drainage, flood prevention, and hydrology modeling and design are included in this section.

UDOT Drainage Regulations

UDOT provides technical guidance for designing drainage structures in its jurisdiction, and relevant criteria will be used for all UDOT drainage structures alongside NRCS and other design standards.

Utah Division of Water Rights Dam Safety Rules

The Utah Division of Water Rights Dam Safety program ensures that plans for new dams and modifications meet design criteria under Utah Code Title 73, Chapter 5a. The project's dam replacement will follow these rules and applicable NRCS standards.

Utah Pollutant Discharge Elimination System (UPDES) General Construction Permit

Utah's Pollutant Discharge Elimination System (UPDES) develops permits for effluent discharges and provides stormwater discharge criteria, which will be followed in the project's Stormwater Pollution Prevention Plan.

Utah Pollutant Discharge Elimination System (UPDES) MS4 Permit

The UPDES MS4 Permit sets criteria for municipal storm sewer systems, and these standards will be applied where applicable in the Town of Kanosh.

Corn Creek Hydrology (TM 003)

To evaluate any alternative associated with the Corn Creek Watershed Plan-EA, it is necessary to determine the amount of water generated by the Corn Creek Watershed for the purposes of evaluating flooding depths and flows at different recurrence events, determining probable maximum flood conditions as defined by TR-60 and the Utah State Code, and estimating annual flows for irrigation. Technical Memorandum 003, located in Appendix E, provides details on the methods used to obtain this data including historical data and hydrologic calculations. This report provides an overview and summary of the findings of these studies.

Corn Creek drains a watershed from the Pavant Mountain Range southeast of Kanosh, Utah, with an area of approximately 88.8 square miles (USGS StreamStats) as measured at the historical USGS gauging station. A map of the Corn Creek Watershed Basin is included below.

The Corn Creek watershed, despite its high elevations, faces arid conditions with low precipitation, especially during the summer months. The watershed relies heavily on snow accumulation from October through April, with snowmelt runoff being essential for irrigation to support agricultural production. Figure 6 illustrates the average precipitation distribution, highlighting the insufficient summer precipitation for meeting crop water demands. The basin's elevation gradient, rising from 5,300 feet to over 10,000 feet with a mean slope of 34%, exacerbates the susceptibility to flooding during extreme rainfall events, particularly in the monsoon season.

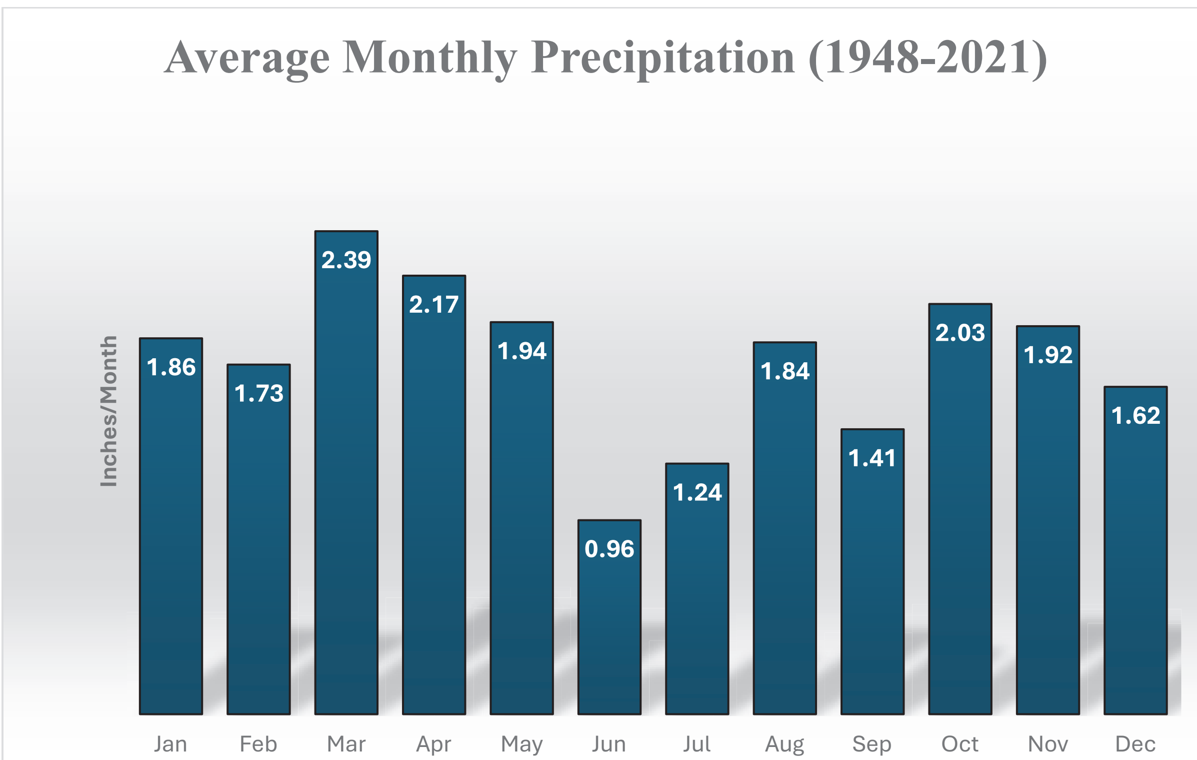

Figure 6: Corn Creek Watershed Average Precipitation (USGS StreamStats)

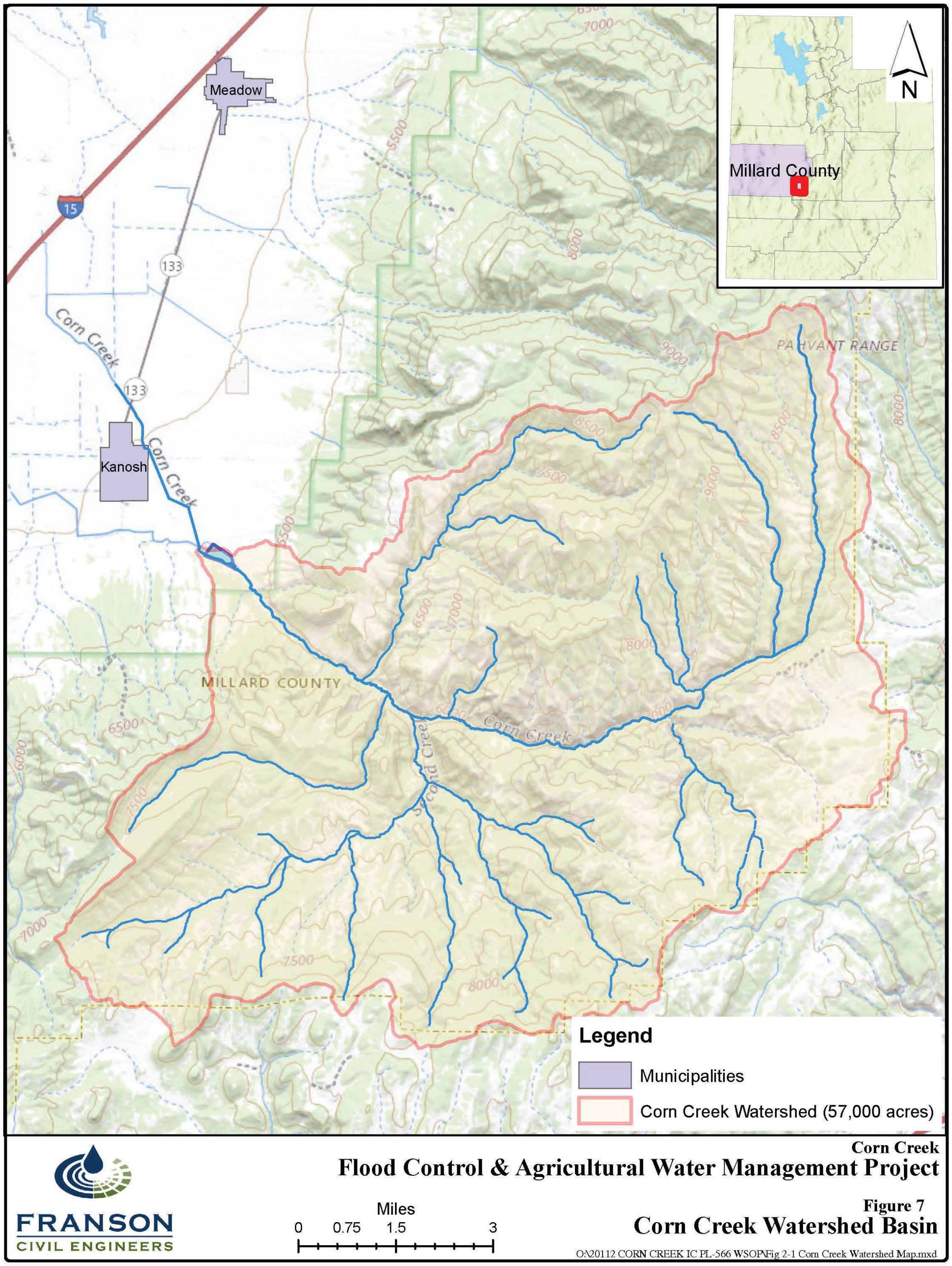

Figure 7: Corn Creek Watershed Basin

Several factors contribute to the watershed's vulnerability to high runoff during summer monsoons. The west-facing basin is prone to orographic effects, where moist air is forced up the mountain face, leading to intense thunderstorms and flooding. Additionally, the region's aridity results in sparse vegetation, reducing absorption and increasing runoff. Utah's status as the second driest state further accentuates these conditions. Lastly, the area experiences exceptionally high temperatures in July and August, fueling monsoon storms and contributing to the shift from snowmelt-dominated runoff to monsoon-driven floods for lower probability storms, such as those occurring 2% of the time or less.

Available Hydrologic Data

To assess the flooding dynamics in Corn Creek, historical records from 1959 to 1975 were reviewed including data from a USGS gauging station and daily water rights reports. These records, though limited to 17 years, confirm the dominance of snowmelt and rain-on-snow events in peak flow occurrences. The data reveals that while most peak flows align with snowmelt events, the most extreme events, including the 1965 peak, and several others, occur from July to September, characteristic of the monsoonal thunderstorm events in the region. Full tabular data may be found in Technical Memorandum 003 in Appendix E.

Soils information was generally taken from the NRCS web soil database where available. However, above the debris basin location, there is no information available. As a result, geology information was downloaded from the Utah Geological Survey (UGS).

The hydrology model for the Corn Creek watershed utilized land cover data from a study conducted by Utah State University's College of Natural Resources RS/GIS Laboratory from 1999 to 2001. This study categorized 125 land classes based on vegetation type, with 26 classes found within the watershed. Each of these 26 land classes was then correlated to a hydrologic soil cover type per the National Engineering Handbook (NEH) Part 630 Chapter 9 to ensure compatibility with the modeling software.

Precipitation data was determined using the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Precipitation Frequency Data Server.

Google Earth Pro software was used to determine elevations and slopes for hydrologic modeling. These results were comparable to the data from the 10-meter digital elevation model (DEM) data available from the Utah Geological Resource Center (UGRC) and simpler to use for this area.

Aerial photos used in creating maps and figures were downloaded from the UGRC website. These aerials were used in determining vegetation density and curve numbers association with each land cover type.

Maps and figures displaying the available hydrologic data summarized above may be found in Technical Memorandum 003 in Appendix E.

Methodology and Procedures

The study followed NRCS standard procedures outlined in NEH Part 630, which directs the use of TR-60, a method based on TR-55 or the NRCS Curve Number method for rainstorm hyetograph simulations. However, TR-55 is not suitable for rain-on-snow or frozen ground events, and other methods should be used for those cases. Due to limited gauged data (only 17 years) for Corn Creek, a nearby basin's gauging station from the Beaver River watershed was used for comparison. This approach helped evaluate common snowmelt events, while the TR-55 method was used to simulate less frequent monsoonal events due to data constraints.

Nearby Gauged Watershed and Characteristics

The Beaver River, located approximately 33 miles southwest of the Corn Creek watershed, drains an area of about 92.1 square miles. Its watershed, characterized by a mean elevation of 9,230 feet and a highest point at Delano Peak reaching 12,175 feet, features a predominantly forested area covering 82.3% of its land. With a mean annual precipitation of 29.4 inches and a mean basin slope of 29.2%, the Beaver River watershed experiences precipitation patterns similar to those expected in an arid region, with rain-on-snowmelt as the primary runoff factor and occasional extreme monsoonal events during less frequent occurrences.

Historical data from the Beaver River gauge, maintained for over 107 years, provides insights into the watershed's runoff patterns. The largest discharge recorded was during a monsoon rain event in 1936, reaching 1,080 cfs, while the second-largest event in 1984 at 1,060 cfs occurred during a high snowmelt year with rain-on-snow conditions. Analysis of annual peak flows indicates deviations from a log-normal curve, suggesting shifts between snowmelt, rain-on-snow, and monsoonal runoff events, highlighting the complex hydrological dynamics of the Beaver River watershed. More detailed graphical representations of this information are located in technical memorandum 003 in Appendix E.

A comparison of peak flow data between Corn Creek and Beaver River, for the 17 years when data is available for the Corn Creek watershed, reveals that Corn Creek's watershed is significantly drier than Beaver River's, with Corn Creek generating approximately 39% of the peak flow of Beaver River. This analysis, focusing on snowmelt and rain-on-snow events and excluding monsoonal peaks, indicates a clear aridity difference between the two watersheds. While additional data would enhance the evaluation, the observed trend aligns with field observations, suggesting a reasonable correlation between the two watersheds.

Annual Average Flow and Watershed Yield Analysis

The evaluation of the irrigation system size and annual water yield for the Corn Creek watershed involved comparing historical data with the nearby Beaver River watershed. Daily flow data from the Utah Division of Water Rights, spanning from 1965 to 1975, was used to develop a correlation of daily flows and annual basin yields between the two watersheds. Despite limitations, a watershed correlation for average flows and a critical season yield (March through September) of 39% were found, indicating similar annual yields and peak flows between the two basins. Adjustments were made to the hydrographs for modeling purposes, aligning the data for Corn Creek with that of Beaver River. Tabular data and hydrographs may be found in Technical Memorandum 003 located in Appendix E.

Rainfall Event Delineation

The Corn Creek watershed, covering 88.8 square miles, was divided into 17 sub-basins for precise hydrology data analysis as shown in Figure 8. This subdivision was based on elevations and flow routing patterns. Precipitation events were sourced from various studies, including the National

Weather Survey NOAA Atlas 14 and documents by Donald T. Jensen, to understand rainfall patterns. The development of NRCS weighted curve numbers for each sub-basin involved evaluating land cover types and assigning curve numbers based on the USDA SCS curve number method.

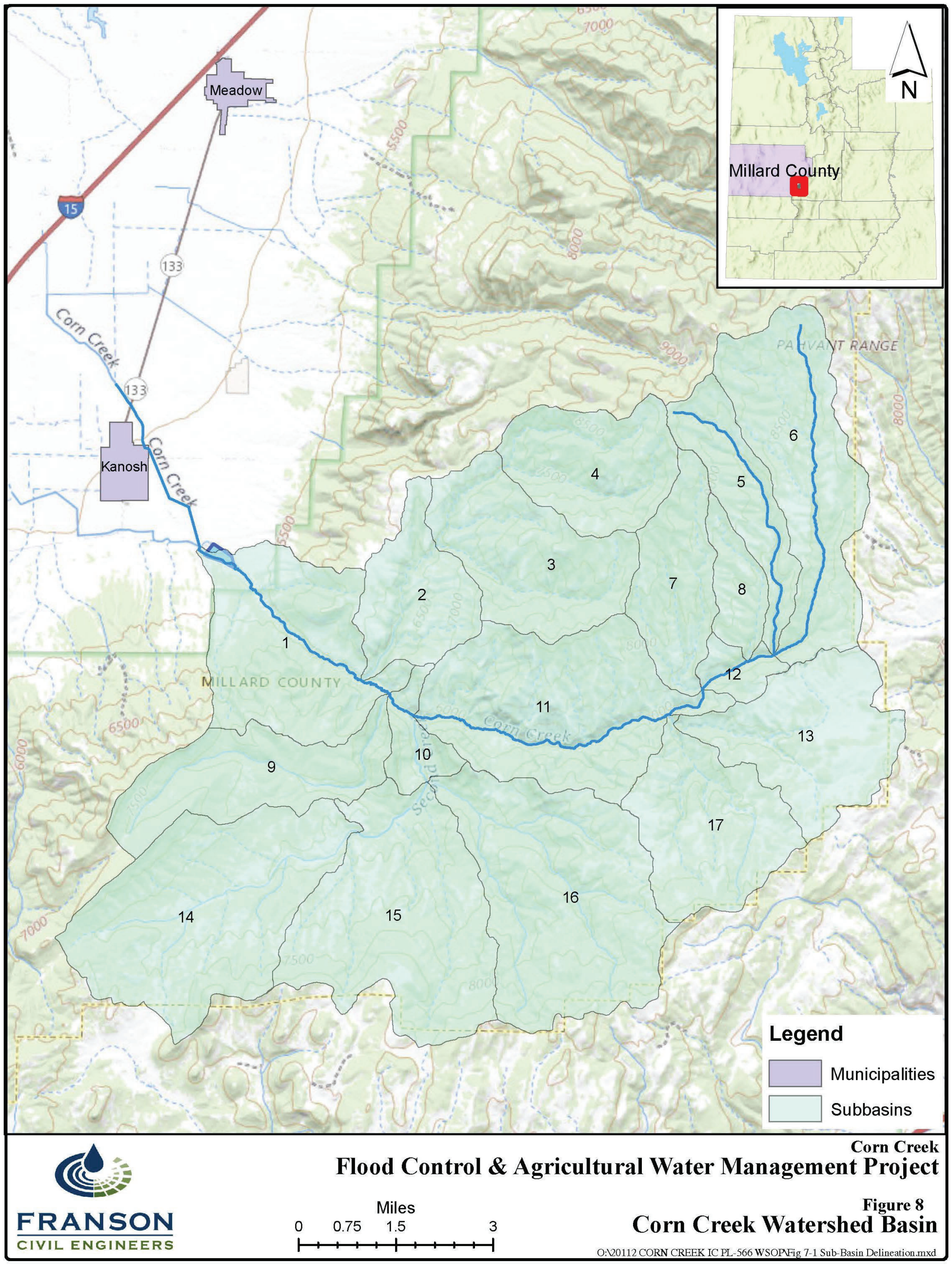

Figure 8: Corn Creek Watershed Sub-Basin Areas

Hydrologic routing through and between sub-basins was done using kinematic wave theory, considering factors like roughness and slopes. The calculated times of concentration for each sub-basin indicated the duration for runoff to travel from the farthest point to the outlet. Design flows for different storm events were developed using rainfall distribution methods like WinTR-20 and NRCS time transformation spreadsheet. These design flows, modeled using the TR-55 methodology, provide insights into peak flood flow rates for various storm scenarios. Tabular data is included in Technical Memorandum 003 in Appendix E.

Accepted Design Storms and Hydrographs & Summary

Figure 9 displays hydrographs from three storms at the debris and detention basin, crucial for design evaluations in the Corn Creek watershed. A base flow of 150 cfs, representing the 100-year April snowmelt, was used for all storm hydrographs. Flood event results indicate a critical season basin water yield of about 8,800 acre-feet at the 50th percentile and 19,400 acre-feet at the 90th percentile. The reliable irrigation peak flow during spring is approximately 100 cfs, primarily in April and May, decreasing to less than 20 cfs by August.

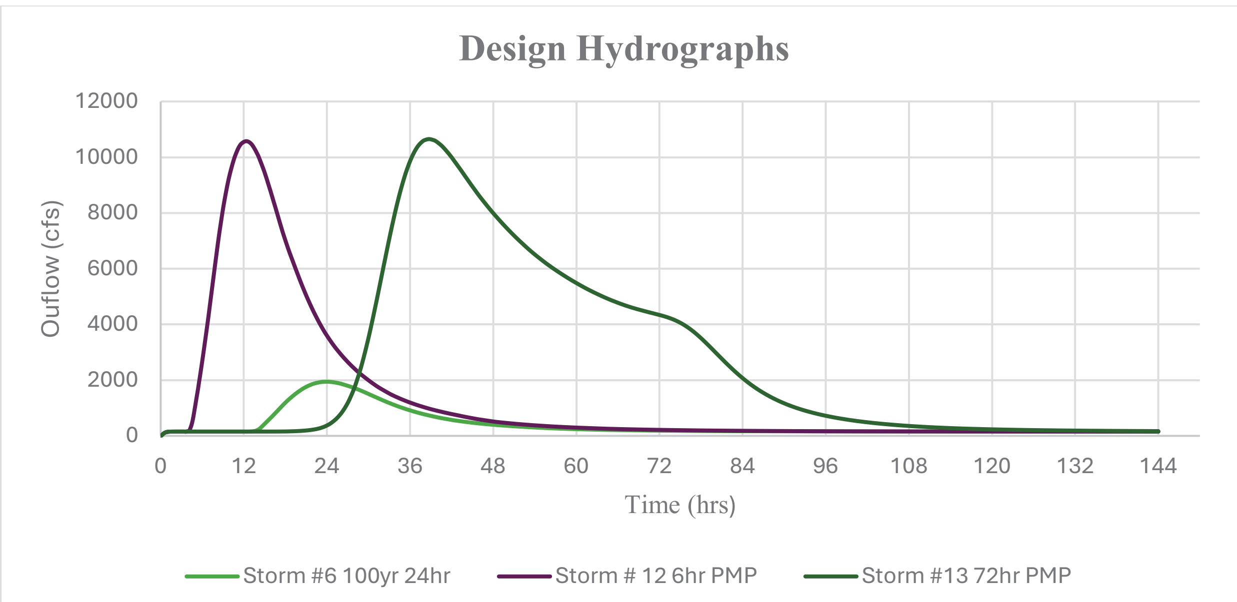

Figure 9: Hydrographs for the 100-year Inundation Design Flow Storm Events

Table 1 shows the estimated design flows for various flood events.

Table 1: Final Summary of Flood Events

Storm #	Storm Event & Duration	Source	Peak Flows (cfs)
1	2-Year 24-Hour	NOAA	255
2	5-Year 24-Hour	NOAA	446
3	10-Year 24-Hour	NOAA	674
4	25-Year 24-Hour	NOAA	1,081

Storm #	Storm Event & Duration	Source	Peak Flows (cfs)
5	50-Year 24-Hour	NOAA	1,480
6	100-Year 24-Hour	NOAA	1,945
7	200-Year 24-Hour	NOAA	2,477
8	500-Year 24-Hour	NOAA	3,457
9	100-Year 6-Hour ARC III	NOAA	3,210
10	100-Year 24-Hour ARC III	NOAA	5,193
11	100 Year 10-Day	NOAA	4,292
12	PMP 6-Hour	Jensen	10,580
13	PMP 72-Hour	Jensen	10,655
14	Local ASH 6-Hour	TR-60	2,624
15	General ASH 72-Hour	TR-60	2,707
16	Local FBH 6-Hour	TR-60	10,580
17	General FBH 72-Hour	TR-60	7,565

Hydraulic Modeling & Flood Inundation (TM 004)

The evaluation of flood management alternatives for the Corn Creek Watershed Plan-EA required assessing the water impacts from the basin draining into Corn Creek. Models were developed for various recurrence flood events under existing and proposed conditions. These models determined the depths and durations of flooding at different locations, such as homes, buildings, roads, and agricultural fields. The comparison between existing conditions and the proposed action aimed to ascertain the economic benefits of the project to the community. While all alternatives from Chapter 4 of the EA were considered, not all were modeled. The methodology and results of this analysis are detailed in the following sections. Further detail and information on the methodology and analysis may be found in Technical Memorandum 004 located in Appendix E.

Methodologies

The flood events in the Corn Creek watershed were modeled using HEC-RAS, a software developed by the US Army Corps of Engineers (USACE) capable of modeling one- and two-dimensional flows, sediment transport, and water quality. Two-dimensional unsteady flow modeling was employed, where the user defines topography, cell positions, cell sizes, and flow inputs. The Navier-Stokes equations and numerical methods calculate water depth and velocity between cells based on user inputs. The model utilized cells with sizes of 50 feet or smaller, with some areas refined to 10 feet for higher precision. The surface elevation data, obtained from the Utah Geospatial Resource Center website, was used to create the model, with modifications made to accurately represent the capacity of the CCIC ditch system.

The National Land Cover Database (NLCD) was used to determine the roughness of various land cover types in the project area, defining the roughness using Manning's coefficients. Culverts in the model were sized based on field data when available, with Google Earth imagery used for estimates when data was lacking. Manning's coefficients and entrance/loss coefficients were assigned to culverts based on material and type. The modeling methodology and results are detailed in subsequent sections, providing insights into flood management alternatives for the Corn Creek watershed.

Existing Floodplains

Kanosh and its surrounding area are situated on an alluvial fan, characterized by sediment accumulation that fans out from a concentrated source, commonly found in arid and semi-arid mountainous regions like Utah. The unique topography of an alluvial fan results in shallow channels that frequently shift locations, posing challenges for flood management. Unlike typical drainages, where floodwater returns to the channel if it exceeds capacity, on an alluvial fan, excess water can create new channels, altering the flood flow direction. Moreover, the presence of irrigation channels exacerbates flooding potential by spreading water over a larger area.

The complex flood routing conditions in the Corn Creek watershed, exacerbated by irrigation ditches and land development, have resulted in the elimination of the Corn Creek channel downstream of Kanosh. Floodwaters are diverted northward when they exceed the capacity of the irrigation ditches, eventually flowing into drainage systems or lava tubes. The existing debris basin secondary spillway predominantly releases floodwater towards the irrigation ditch system.

However, during high water levels, an emergency flood channel redirects water northward, reducing the impact on Kanosh.

Historical flood events, such as those in July 1997, May/June 1983, May 1984, and May/June 2010, have caused significant damage, with the 1984 event being particularly notable for its breach of the debris basin embankment (see Figure 10). The breach led to extensive erosion and damage to infrastructure, necessitating repairs and modifications to mitigate future flood risks. Culverts, berm constructions, and emergency channels were implemented to manage floodwaters and protect critical infrastructure, highlighting the ongoing efforts to address flood hazards in the area. Despite these measures, the absence of comprehensive flooding maps and FEMA studies underscores the reliance on historical records and recent modeling to understand and mitigate flood risks effectively.

Figure 10: Aerial Photo of Kanosh 1984 Flooding

Utah Dam Safety has identified a seepage issue in the foundation of the Corn Creek Dam, leading to a restriction on filling the debris basin and requiring the outlet to remain open. Two potential scenarios exist: one where the debris basin does not fail and another where it fails during a flood similar to the one in 1984. The No-Action Alternative, which involves no structural changes, was determined to be best represented by the scenario where the debris basin breaches. Modeling for both scenarios was conducted, including a 100-year 24-hour storm event, with detailed results in Technical Memorandum 004 in Appendix E.

In the No-Action Alternative, without any interventions, the dam is likely to fail due to a piping failure caused by foundation seepage. Utah Dam Safety inspectors observed cloudy seepage, indicating soil movement and potential piping. This scenario was modeled using HEC-RAS to understand the impact on homes, businesses, roads, and agricultural fields during flood events. The breach model indicated that failure would occur during all modeled storm events except the 2-year storm event, with maximum water levels shown in Table 2.

Table 2: Maximum Water Elevation in Debris Basin for No-Action Alternative

Flood Event	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	500-Year
Maximum Debris Basin Water Elevation (feet)	5178.8	5184.7	5190.8	5194.2	5195.4	5196.6	5197.7

The breach model assumed the failure east of the primary outlet, with a piping failure at 5,180 feet elevation, and included parameters such as a final breach width of 62 feet and a breach formation time of 0.52 hours. Peak flows for different storm events were calculated, with significant outflows during higher flood events. The model results indicated considerable impacts on structures and roadways during these events, with detailed flood inundation maps included in Technical Memorandum 004 in Appendix E.

For the Non-Breach Existing Scenario, the current spillway configuration was modeled, assuming no breach. The model used the primary outlet works and emergency spillway data to generate hydrographs. Although this scenario showed that Kanosh would still experience flooding during a 100-year storm event, the non-breach condition was ultimately not adopted due to the ongoing risk of dam failure and higher water elevations in the debris basin.

The Proposed Action Alternative aimed to modify the dam and its surrounding infrastructure to route the 100-year flood around Kanosh without overtopping Interstate-15. Changes included raising the debris basin embankment, adjusting spillways, constructing berms, and modifying channels to handle storm flows better. These modifications aimed to reduce flood risk while accommodating design updates for freeboard requirements.

The modeling and modifications suggested that while the auxiliary spillway would not be engaged during lower storm events, it would reduce water release toward Kanosh during more severe storms. The proposed changes aimed to minimize flood depths in Kanosh, ensuring better management of peak flows through updated spillway and channel configurations. Detailed flood inundation maps for proposed conditions are included in Technical Memorandum 004 in Appendix E, illustrating the effectiveness of the proposed measures in mitigating flood impacts.

Summary of Results

Hydraulic modeling was performed for the watershed to determine the impact of flooding from a thunderstorm event for the 5-, 10-, 25-, 50-, 100-, 200-, and 500-year storm events.

The analysis results found that there are multiple locations that see significant flooding that threaten structures which coincided with historic observations reported in newspaper articles and local residents. By implementing the proposed flood control improvements during the 100-year storm event, there will be reduced flood risk to homes, commercial structures, roads, and agricultural fields. A detailed benefit cost analysis was performed, and results can be seen in a later section of this report.

Irrigation Pipeline & Accessory Structure Design (TM 005)

This section of the report outlines the assumptions and calculations for improving the irrigation system for the Corn Creek Irrigation Company (CCIC). The section details water supply, demand, and losses under current conditions, and evaluates various proposed actions. The preferred alternative, a gravity flow pipe system, is explained in terms of pipe sizing, design process, and cost analysis. The existing system's conditions and operations are detailed in Appendix E, which is frequently referenced. The gravity flow system will also deliver stock water during the non-irrigation season, eliminating the need for a separate stock water pipeline.

Water Loss Analysis

To assess the potential benefits of piping or lining CCIC's open canal system, a water loss analysis was conducted, focusing on water supply, demand, and the existing irrigation system. The detailed water right description in Technical Memorandum 001 grants CCIC the right to divert 89 cubic feet per second (cfs) from Corn Creek. However, hydrological studies in Technical Memorandum 003, which correlated limited Corn Creek data with Beaver River flow data, indicate that during an average water year, CCIC's water availability is capped at 63 cfs, showing a limitation due to water availability rather than water rights.

The water demand analysis, referencing Utah's Irrigation Duty Map, indicates that the project area requires 4 acre-feet per acre for irrigation, with CCIC's 3,550.9 irrigable acres allowing a maximum diversion of 14,200 acre-feet (AF). However, Corn Creek only provides 7,164 AF in an average year, far below this allowance. The existing irrigation system, detailed in Technical Memorandum 001, comprises a network of low and high flow ditches. The low flow system faces significant capacity issues, particularly in the East Middle Hatton Double Ditch, leading to substantial water losses. High flow conditions involve water being diverted into four single ditches. Soil data from the NRCS's Web Soil Survey, indicating significant seepage losses, highlights the inefficiencies of the current system, while evapotranspiration losses are deemed negligible.

The methodology used to calculate seepage loss in CCIC's irrigation system classifies ditches by width, type (concrete-lined or unlined), and soil type. The widths were measured using Google Earth, and the condition of the concrete linings ranged from poor to fair. Seepage rates were determined based on soil type and ditch lining, with conservative estimates considering the age and condition of the concrete ditches. The seepage flow rates were calculated by multiplying the area of each ditch segment by its seepage rate and adjusting for the time each section delivers water. The analysis included both low flow (double ditch) and high flow (single ditch) operations to account for different flow conditions.

Results show significant water losses in both low and high flow scenarios. The low flow operation, handling up to 27 cfs, results in a 39% water loss, primarily due to the capacity limitations of the East Middle Hatton Double Ditch. High flow operations, handling between 27-89 cfs, experience even higher losses initially, with a calculated seepage loss of 21.41 cfs at a flow of 27 cfs in the unlined ditches, as verified by CCIC. Overall, during an average irrigation season, 44% of the total inflow (3,148 AF of 7,164 AF) is lost to seepage. This analysis highlights the inefficiencies in the current system and supports the potential benefits of updating the canal infrastructure to reduce water loss.

Evaluation of Alternatives

To address water loss due to seepage, CCIC evaluated various piping alternatives, considering both gravity flow and pressurized systems. Shared assumptions for all alternatives included CCIC's water right of 89 cfs, with allowances for the Kanosh Town secondary system to take up to 4 cfs and the Kanosh Band of the Paiute Tribe to take up to 1 cfs. Demand calculations were based on existing splitting structures and ditch capacities. For gravity flow alternatives, HDPE piping was used, designed with Manning's equation assuming a roughness factor of 0.012. Minimum flow design ensured 8 cfs could be delivered to every turnout, with pipe inlets designed to maintain open channel flow and prevent surge pressures, allowing for sediment buildup and incorrect operation scenarios without exceeding the pipe's pressure rating.

For pressurized alternatives, the system included a regulating pond downstream of the debris basin and utilized HDPE or PIP materials based on required pressure ratings. Bentley WaterCAD was used for hydraulic modeling, ensuring flow velocity remained below 5 feet per second and working pressure at 72% of the pipe's rating. Multiple pressurized configurations were evaluated, including systems designed to deliver flows of 10 cfs and 5 cfs, as well as a true pressurized irrigation system delivering flow evenly across all served acres. The alternatives were assessed with and without pressure-reducing valves (PRVs) to manage high pressures at system endpoints, ensuring robust and efficient water delivery.

Proposed Agricultural Management Alternative

A gravity flow system with a 40 cfs capacity was chosen as the Preferred Alternative due to cost and operational efficiency. Larger capacity alternatives, which could handle the full water right of 85 cfs, were found to be significantly more expensive without effectively increasing the water supply due to the limited water availability mentioned above. The selection was informed by a study from Utah State University Extension, which showed that the maximum water demand for alfalfa in the Fillmore area is 7.35 inches per month, translating to 36 cfs if all 3,500 acres were planted in alfalfa. The current crop mix, mainly alfalfa, makes a 40 cfs capacity sufficient to meet crop demands, with the flexibility to use existing dirt ditches for additional water conveyance if needed.

Pressurized systems were more costly and required the expense of a full-time water master to ensure equitable operation. Additionally, gravity flow systems offered greater flexibility in modifying or eliminating laterals to reduce costs if necessary. The preferred design also included measures to prevent flooding by replacing existing ditches with pipes, enhancing public safety, and reducing road maintenance costs. Key design features included the use of a main pipeline to deliver water to various ditches, strategic placement of splitting structures to ensure equitable water distribution, and the incorporation of energy dissipation mechanisms in splitter boxes to maintain accurate flow splits. The proposed gravity flow irrigation system can be seen in Figure 11.

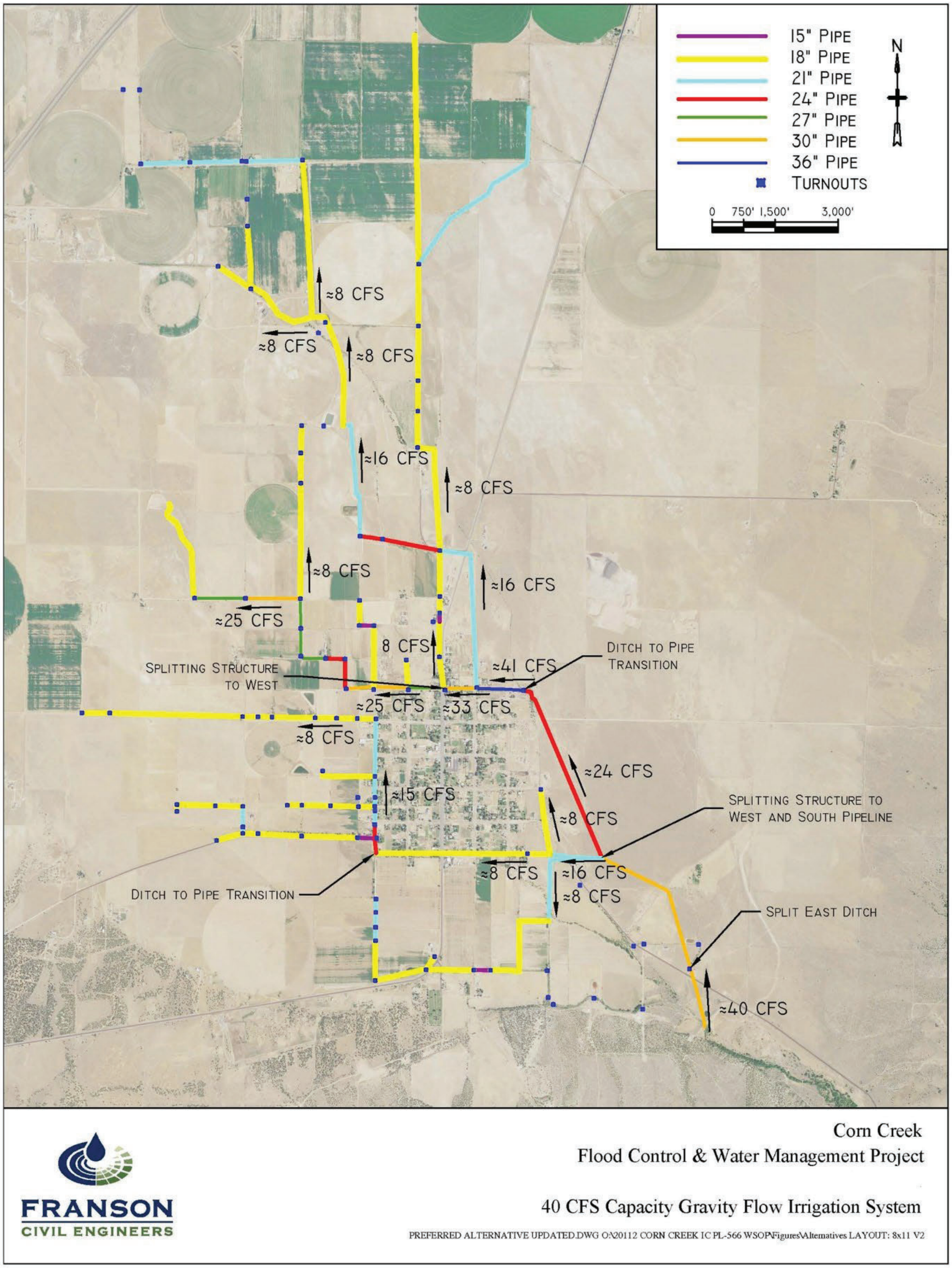

Figure 11: 40 cfs Capacity Gravity Flow Irrigation System

Cost Estimate

The gravity flow system with a capacity of 40 cfs was identified as the most effective agricultural management design to meet the crop demands of CCIC shareholders and the operational preferences of the irrigation company while being cost efficient. This system allows for accurate measurement of water at the inlet and splitting structures, enhancing water management and maximizing crop production. The use of splitting structures minimizes conflicts through visual verification of operations. Notably, this design increases the water supply by at least 44%, significantly improving resource availability.

The estimated total cost for constructing this irrigation system is $14,300,000, with an additional $2,650,000 for design engineering, construction management, administration, and easement acquisition, bringing the total to $16,950,000. The cost breakdown includes expenses for mobilization, various pipe installations, headgates, diversion boxes, splitting structures, excavation, and associated contingencies. However, it is important to note that these estimates are based on current costs, which may fluctuate due to volatile material and labor prices. A more detailed cost estimate for the irrigation pipeline may be found in Appendix E.

Secondary Water System for Kanosh Band of Paiutes Tribe & Kanosh Town Regulating Pond Replacement (TM 006)

The Corn Creek Watershed Project aims to improve irrigation systems for the Kanosh Band of Paiute Indian Tribe by adding a secondary system to the existing pipeline between the debris basin and the community. This project will replace the existing regulating pond for Kanosh Town, which will be eliminated due to dam reconstruction. The new regulating pond will be at a higher elevation that will allow it to service both the Town and Kanosh Band. The secondary system for the Kanosh Band will reduce the demand on existing culinary water systems. Water will be diverted from Corn Creek before it reaches the debris basin, stored in a new regulating pond with a partition to separate the Tribe's water from the Town's water.

The Tribe's current pipeline, installed in 2005, has not been effectively used, leading to flooding and underutilization of water shares. The new system will allow better management of tribal water rights, providing up to 400 gpm to supply 17 developed lots, though actual flow in Corn Creek will determine the amount of water available. The Town of Kanosh, with rights to 10% of CCIC's water, will also benefit from the new system, which includes relocating their pond to a higher elevation to ensure adequate pressure. The project includes designing diversion and splitting structures, a regulating pond, and pipelines to optimize water distribution and minimize seepage, thereby supporting both the Tribe's and the Town's irrigation needs.

Figure 12 on the following page shows the layout of the secondary water system project components.

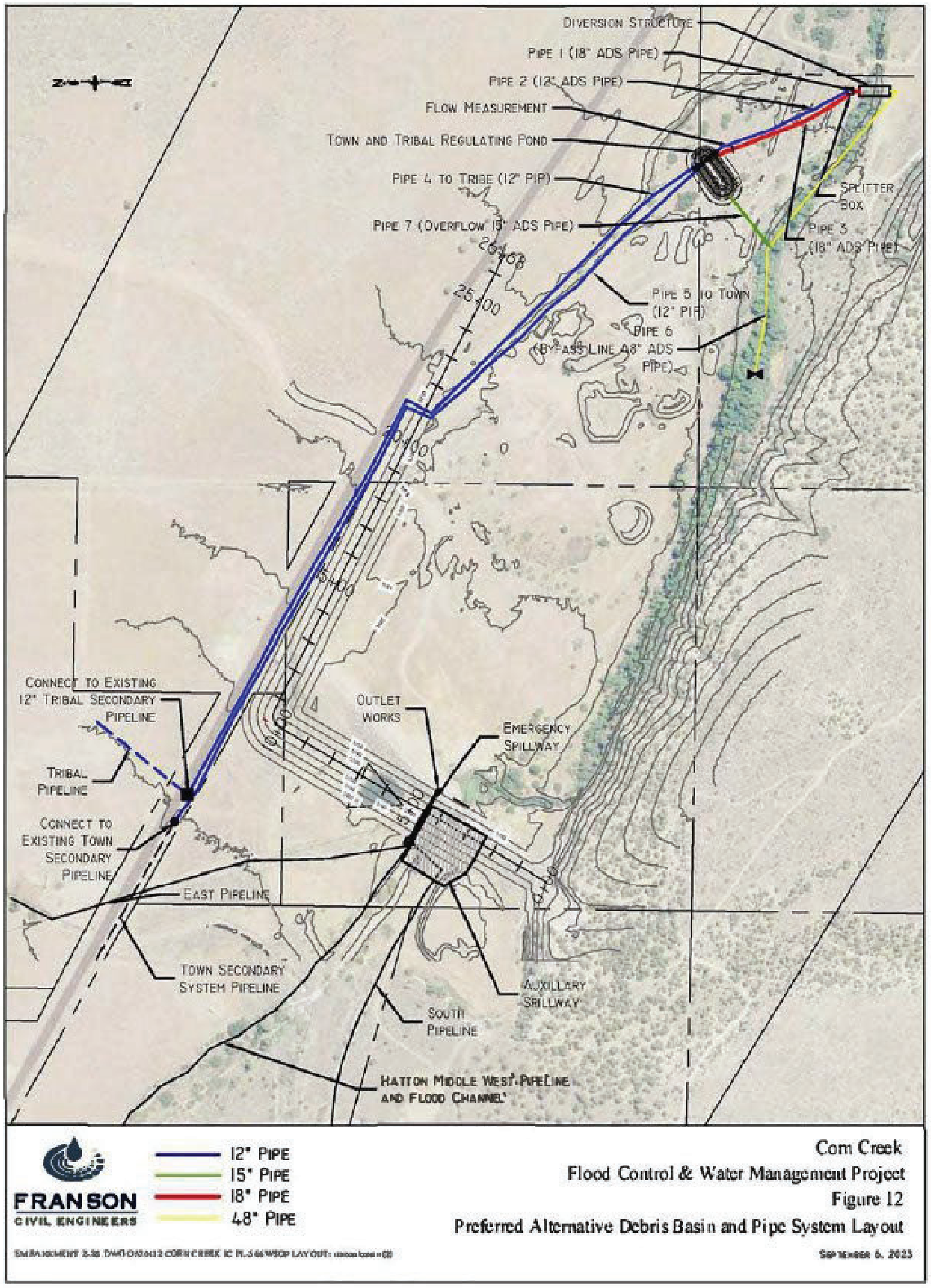

Figure 12: Layout of Secondary Water System Project Components

Diversion Structure

The diversion structure upstream of the debris basin is designed to allocate Corn Creek's flow among various end-users, screen debris, and measure flow. It will divide the flow into three parts: a portion for the Tribe and Town’s secondary water systems, a portion for the CCIC's system, and a bypass channel to reduce seepage losses. If the flow in Corn Creek exceeds the demand of the three water users, the water will continue into the debris basin. The structure's location was chosen for its well-defined, narrower channel, making construction more economical. It features a 40-foot rectangular weir, with a steel plate splitting 11% of the flow for the Tribe and Town and a Coanda screen to filter debris.

The diversion structure, designed to accommodate CCIC's 89 cfs water right, includes custom-designed Coanda screens to handle a flow of 10 cfs for the Tribe and Town. The remaining flow will pass through a bar screen to remove large debris before continuing downstream. The structure includes an 18-inch pipe for the Tribe and Town's water and a 48-inch pipe for the bypass channel. With wingwalls extending 3 feet above the weir crest at an elevation of 5,210 feet, the structure can manage the channel's full capacity of approximately 692 cfs. More details may be found in Appendix E.

Splitting Structure

A splitting structure will be built approximately 5 feet from the diversion structure, serving to divide the diverted flow between the Tribe and the Town. Designed as a pre-cast concrete box, it features a weir and a steel plate that allocates 10% of the flow to the Tribe and 90% to the Town.

Regulating Pond

The proposed regulating pond, located upstream of the debris basin, is designed to serve both the Tribe's and Kanosh Town's secondary water systems. This combined pond solution addresses the elimination of the Town's pond due to dam reconstruction and the need for increased water pressure in some areas. The pond will be situated downstream of the splitting structure, at an elevation ensuring adequate irrigation pressure for both systems. With a design volume of 4,550 cubic yards, it will have a concrete wall separating the Tribe's 10% water storage from the Town's 90%. Water flow from the pond will be measured for accountability, and an overflow pipe will direct excess water to CCIC’s bypass channel.

Pipelines

The pipeline design for the project includes seven pipes of varying sizes and purposes. Pipes 1, 4, and 5 are designed to flow full, with a maximum velocity of 5 feet per second (fps) or less to minimize friction losses and water hammer. Pipes 2, 3, 6, and 7 are assumed to operate under open channel flow conditions, with 80% full capacity to accommodate debris accumulation and maintain open channel hydraulic flow conditions. Manning's equation is used for these pipes, with a Manning's n value of 0.012 for all open channel flow pipes. The design of each pipe is tailored to its specific function and flow requirements, with diameters ranging from 12 to 48 inches and slopes varying from 0.1% to 1.46%.

Pipe 1 conveys water from the diversion structure to the splitting structure, designed to handle approximately 10 cfs flow. Pipes 2 and 3 carry water from the splitting structure to the regulating pond for the Tribe and Town, respectively, with capacities of 0.89 cfs for the Tribe and 8.9 cfs for the Town. Pipes 4 and 5 transport water from the pond to the existing Tribal and Town pipelines, each with a capacity of 0.89 cfs for the Tribe and 4 cfs for the Town. Pipe 6 diverts water from the diversion structure to the CCIC bypass line, designed to convey approximately 50 cfs. Pipe 7 serves as an overflow pipe from the regulating pond to the bypass channel, designed to handle approximately 5 cfs flow.

Tribal Secondary Water Residential Connections

A new pipeline network has been designed for the Kanosh Band of Paiute Indian Tribe to connect their existing 12-inch PVC pipeline to residential homes and fields, allowing them to utilize water from the pond located upstream of the debris basin. This design aims to provide pressure in their irrigation systems, ensuring a more reliable outdoor water supply and reducing the demand on their culinary water system. The new system includes a valve for potential future agricultural connections and provides a 1-inch connection to each lot, whether developed or undeveloped, with additional connections for the park and community buildings. This design enables multiple lots to water simultaneously, assuming each connection uses 15 gpm or less.

Project Costs

The total installation cost for the pond relocation and Kanosh Band secondary connections is projected to be $1,849,000. The costs include mobilization, surveying, concrete installation, Coanda and bar screens, headgates, the splitting structure, regulating pond, divider wall, and various HDPE pipes of different sizes. The construction subtotal is $1,423,000, with additional costs for construction contingency, engineering, construction management, and administration.

The cost estimate for the Kanosh Band residential secondary connections totals $166,000. This includes costs for mobilization, construction survey, and the installation of 1-inch, 2-inch, 4-inch, 6-inch, and 12-inch Schedule 40 PVC pipes. The construction subtotal is $127,000, with additional costs for construction contingency, engineering, construction management, and administration.

More detailed versions of these cost estimates may be found in Appendix E.

Debris Basin Dam & Flood Routing Structures (TM 007)

The existing debris basin dam is facing significant issues that necessitate substantial repairs, full replacement, or complete removal. These issues include foundation and embankment seepage, inadequate spillway capacity, and sections of the embankment not meeting current stability standards. The repair and upgrade of the existing dam would require removal and replacement of the outlet works and spillway, correction of seepage issues, installation of a new drain system, and possible modification or replacement of the core. However, this option is considered less feasible than replacing the dam due to the need to remove a majority of the existing dam for repairs.

Replacing the existing dam is deemed more feasible than repairing it, as it would allow for the construction of a new dam in an area that increases the debris basin's capacity. This option involves removing the existing dam and constructing a new one that meets current Dam Safety standards. Additionally, the removal of the existing dam greatly reduces potential flooding damage caused by a failed dam during a flood event. The new dam's left abutment would be placed in the same location as the current left abutment, but the dam's alignment would shift downstream to increase the debris basin's capacity.

The removal of the debris basin, along with direct connections to existing channels and/or flood channels, is not a feasible option as it increases flooding potential in all cases other than the worst-case scenario. Without the debris basin, culverts are likely to be blocked by debris, increasing flooding potential even at lower flow rates. Therefore, the repair or replacement of the debris basin is considered a critical component of the project to protect Kanosh from flooding. Ultimately, due to the extensive issues with the current debris basin dam, it is more economically feasible to replace it with a new dam.

Proposed Dam and Debris Basin

The proposed debris basin and flood routing structures are designed to minimize the potential for significant damage to the Town of Kanosh and loss of life in the event of a dam failure and/or large flood event. The design criteria are based on Utah Dam Safety Standards and NRCS Technical Release (TR) 210-60 Earth Dams and Reservoirs.

The embankment design considers the failure of the previous dam in 1985, which was attributed to saturation of the embankment and seepage issues. To address this, the new dam is designed as a water storage facility rather than just a flood control structure. The foundation of the dam will be excavated down to the very dense Lower Alluvium to mitigate seepage risks, and a cutoff wall is recommended between the core of the dam and bedrock.

Seismic and geological analyses were conducted to assess site conditions and risks. The project area is located on late Holocene alluvial deposits with two alluvium layers overlying bedrock. The foundation of the dam will be excavated to lower more dense alluvium layer to address seepage risks.

The design includes a two-stage filter chimney and blanket drain to protect against internal erosion. The hydrologic analysis determined the Inflow Design Flood (IDF) to be the 72-hour Probable Maximum Precipitation (PMP) event at 10,655 cfs. The dam is designed to pass this flood event without overtopping. The spillways, including the primary spillway/low-level outlet, secondary spillway, emergency spillway, and auxiliary spillway, are designed to safely route floodwater and prevent overtopping of the dam. The emergency spillway will route excess floodwater around the Town of Kanosh.

Overall, the design of the debris basin and flood routing structures incorporates various safety measures and considerations to mitigate risks associated with the existing dam and to ensure the safety of the Town of Kanosh and surrounding areas during flood events.

For a more detailed description of the proposed dam and debris basin, see the Debris Basin Dam and Flood Routing Structures Technical Memorandum in Appendix E.

Other Flood Routing Actions

To prevent flooding in Kanosh, modifications were made to the East/Middle and Hatton Ditches' splitting structures, ensuring water diversion based on ditch capacity rather than water share distribution. The East/Middle Ditch can safely handle up to 20 cfs, with excess flowing into the Hatton Ditch. The Hatton Ditch can handle up to 200 cfs, with overflow directed to the West Ditch (natural channel). To manage excess water that may be diverted into a ditch, a flow limiting diversion structure and bypass ditch will be implemented to prevent flood water from exceeding the channel capacity. Controlling the amount of water that could be diverted into a ditch will greatly reduce the flooding potential.

Terrain adjustments were crucial to redirect floodwaters around Kanosh and prevent I-15 overtopping. Modeling showed that discharging water farther north led to I-15 overtopping, so modifications were made to maximize the use of existing culverts under I-15. A large berm north of a 10-foot by 6-foot concrete box culvert will divert water through the culvert. Shortening an emergency channel by 600 feet and raising an 800-foot dirt road by 1 foot will divert water west sooner, reducing northward flow. Additionally, the West Ditch's capacity downstream of Main Street will be increased to 450 cfs through various modifications—including clearing shrubs, installing a concrete-lined channel, and replacing culverts with bridges—which will safely route flood waters past Kanosh.

Cost Analysis

The cost estimation for the construction of an embankment with a crest elevation of 5,208.75 feet, including various spillways and structures is included in this subsection. The primary outlet works feature a 42-inch conduit encased in concrete, while the secondary spillway is constructed as a standpipe with a corrugated metal pipe conduit encased in concrete. The emergency spillway is a concrete weir wall that discharges to a flood channel that takes water beyond Kanosh before it sheet flows across undeveloped land. The auxiliary spillway goes over the dam and is armored to prevent erosion.

The cost breakdown includes labor and material for removing existing embankments, constructing new ones, and building primary, secondary, emergency, and auxiliary spillways. For instance, the cost summary for the debris basin embankment includes foundation excavation, soil bentonite seepage cutoff walls, and various embankment zones. The primary spillway/outlet works involve installing a 42-inch conduit and guard gate. The emergency spillway requires removing existing culverts, constructing a concrete weir spillway, and road modifications. The total construction cost for these structures is estimated at $11,147,000, with additional costs for engineering, construction management, and administration, bringing the installation total to $13,564,000.

Additionally, the cost estimation for flood routing structures and modifications necessary to prevent flooding and overtopping of I-15 includes constructing berms, channel improvements, and raising roads. The West Channel modifications involve constructing bridges, clearing trees and shrubs, and constructing a concrete channel. The total construction cost for these structures is estimated at $639,000, with additional costs for engineering, construction management, and administration, bringing the installation total to $754,000.

A more detailed version of these cost estimates may be found in Appendix E.

Operation & Maintenance Cost Evaluation of Existing & Future Conditions (TM 008)

CCIC provides water to approximately 3,400 acres through a distribution system composed of open channel ditches and diversion structures. CCIC also operates a secondary system in Kanosh. This distribution system begins at the Corn Creek dam and debris basin that CCIC also operates. This section details the annual costs associated with the operations and maintenance of the irrigation and flood control systems. This information is based on CCIC's current budgets. These details are split into two categories: Flood Control and Agricultural Water. In each category, the current and future anticipated operations and maintenance costs for CCIC are described.

Flood Control Operations & Maintenance

CCIC is tasked with operating and maintaining the Corn Creek dam, debris basin, and channels used for flood control and irrigation. Costs for these activities are split, with 50% allocated to flood control and 50% to agricultural water expenses. Annual inspections by Utah Dam Safety representatives ensure compliance with maintenance directives, including vegetation removal from the embankment, keeping recreational vehicles off the dam, clearing waterways of obstructions, and repairing damage from rodent burrows. CCIC's current average costs are based on their operational budget, and it is expected that the proposed dam operations will be managed similarly, with comparable costs.

The proposed dam's operations are expected to incur similar annual costs for CCIC, with no significant changes anticipated. These costs include debris basin maintenance, flood channel upkeep, labor, vegetation control, and equipment rental. The expected annual costs for these activities are $18,500 compared to $15,500 for the Existing (No Action) Alternative.

Agricultural Water Operations & Maintenance

The operations and maintenance costs for agricultural water delivery in the project area, as well as the anticipated expenses for the proposed alternative, are shared with flood management due to the dual use of many ditches. Annual maintenance for earthen and concrete channels includes repairs for freeze-thaw damage, rodent activity, vegetative encroachment, and sediment clearing from culverts, with spot repairs occurring throughout the operating season. The existing average annual costs are based on CCIC's current budget.

Maintenance costs for irrigation ditches were halved because 29,000 feet of concrete-lined double ditches will be replaced with pipes, requiring less maintenance. The current practice of piping sections in disrepair will no longer be necessary. The proposed pipelines will need annual maintenance and occasional cleanouts for optimal performance. While initial maintenance costs for pipelines will be lower, long-term maintenance will include canal gate replacements and sediment removal, justifying consistent maintenance costs. Annual operations during summer require managing system deliveries and diversions, with no change in staffing or equipment resources anticipated for CCIC. The expected annual costs for these activities are $10,000 compared to $10,500 for the Existing (No Action) Alternative.

Estimated Annual O&M Costs

The previous section subtotals are summed in the table below for the estimated annual O&M costs in the project area for the No Action and Proposed Action Alternatives. A more detailed breakdown of these cost estimates may be found in the Operation and Maintenance Cost Evaluation Technical Memorandum in Appendix E.

Table 3: Estimated Annual O&M Costs

Category	Subcategory	Existing (No Action) Average Annual Cost	Estimated Proposed Project Annual Cost
Flood Control	Debris Basin	$5,000.00	$5,000.00
	Flood Channels	$5,000.00	$8,000.00
	Labor	$1,500.00	$1,500.00
	Vegetation Control	$2,500.00	$2,500.00
	Equipment Rental	$1,500.00	$1,500.00
Agricultural Water Management	Irrigation Ditches	$5,000.00	$2,000.00
	Irrigation Pipes	$0.00	$5,000.00
	Labor	$1,500.00	$1,500.00
	Vegetation Control	$2,500.00	$0.00
	Equipment Rental	$1,500.00	$1,500.00
Total		**$26,000.00**	**$28,500.00**

Benefits & Cost Analysis of the Proposed Alternative (TM 009)

The economic analysis for the project was guided by the NRCS National Watershed Program Manual (NWPM) and three additional documents that provide frameworks and guidelines for economic evaluations in water resource projects. These documents include:

- National Resource Economics Handbook;
- Principles and Guidelines for Water and Land Related Resources Implementation Studies (P&G); and
- Guidance for Conducting Analyses Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water Resource Investments (PR&G).

The PR&G emphasizes maximizing public benefits, both monetary and non-monetary, relative to costs, without hierarchical distinctions among economic, social, or environmental goals. It allows for social effect goals, such as threat to human life and quality factors, to outweigh purely economic considerations when appropriate, recognizing the challenges in monetizing subjective values like life and quality of life. The Federal Objective from the Water Resources Development Act of 2007 highlights the priorities of maximizing sustainable economic development, minimizing the unwise use of floodplains and flood-prone areas, and protecting and restoring the functions of natural systems in Federal water resources investments.

The PR&G principles guide federal investments in water resources by promoting healthy and resilient ecosystems, sustainable economic development, avoidance of unwise use of floodplains, and public safety. Additionally, the principles emphasize environmental justice and the fair treatment of all populations in the development, implementation, and enforcement of environmental laws and policies. The watershed approach is encouraged for analysis and decision-making, as it allows for the evaluation of a complete range of potential solutions and is more likely to identify the best means to achieve multiple goals over the entire watershed.

Economic Analysis Assumptions

The baseline for the economic assumptions for the life of the project is defined in the table below.

Table 4: Economic Analysis Assumptions

Project Life	50 Years
Expected Construction Period	2 Years[1]
Expected Design Period	1.5 Years
Discount Rate	2.5%
Basis of Present Worth Dollars (Current Year)	2023
Construction Costs[2]	Recent Bids and Independent Contractor Cost Estimate

Project Benefits[3]	Five-year Averages from Published Market Prices and Local Documentation as Referenced

1. Two years for main construction with a third year for final cleanup and punch list items
2. Due to rapid inflation over the last two years, a five-year average was considered unreliable
3. To be conservative and to not over-inflate benefits, a five-year average was used

Period of Analysis, Economic Analysis, and Documentation

The economic analysis for the project considered a 52-year Period of Analysis, including 2 years for design and construction. Floods from various storm events were analyzed to estimate average annual flood-related damages, and a net present value analysis was conducted to compare costs of project alternatives, all based on 2023 prices. The National Economic Efficiency (NEE) alternative with a 52-year period of analysis yielded the highest net benefits, using a mandated 2.5% discount rate for all federal water resource projects for FY23. An Excel Workbook was used to detail the economic analysis, incorporating FEMA depth-damage curves and locally obtained data to estimate average annual damages for each project alternative and storm event. The workbook also included cost estimates for the preferred alternative, with economic data and results linked to create the required PR&G tables for the final project report.

Preferred Alternative

The watershed plan's primary goal is to reduce average annual flood damage and enhance irrigation water management, with quantified benefits for these aspects and qualitative considerations for other benefits. Floodwater dissipates into farmland and grazing areas after passing I-15, with no further flood damage reported. Alternatives were evaluated based on their economic, social, and environmental impacts, with nonstructural options eliminated due to high costs relative to benefits. The NEE alternative, emphasizing flood control structures, was developed in accordance with PR&G guidelines, with a project life of 50 years, designed to withstand a 100-year flood event, and considering impacts across various flood scenarios.

The preferred alternative includes reconstructing the debris basin and dam embankment, relocating the Town's secondary pond, and constructing spillways and channels to manage floodwaters. It also focuses on agricultural water management, including constructing a gravity pipe system to reduce losses and improve water management. The economic analysis of the NEE alternative showed benefits outweighing costs, with a benefit-cost ratio of 4.07 to 1.0 and net benefits of $3,781,551. The project's implementation is planned over two years, including design and construction, with a period of analysis of 52 years.

The NEE alternative will protect downstream property and infrastructure, minimize threats to human life, and have minimal adverse environmental impacts. The economic analysis considered both monetary and non-monetary benefits, allowing for subjective judgments in cases where the value of life cannot be easily monetized. Overall, the project aligns with federal objectives for water resource investments, promoting sustainable economic development while protecting the environment, and public safety. The preferred alternative will also provide benefits in terms of reduced seepage and evaporation losses in agricultural water management, improving public safety by replacing open ditches with a gravity pipe system.

Environmental and Social Benefits

Environmental and social benefits of the studied alternatives were not monetized but are detailed in the Environmental Consequences section of the Plan-EA. Construction impacts will be minimized, with negligible long-term adverse effects expected in the arid region with sparse tree cover along intermittent streams. Socially, the alternatives will reduce the threat to life and property by lowering flood depths at buildings and roads, including I-15, a major route. The project area also includes about 25 miles of county roads. While the structural alternatives may enhance wildlife and scenery, incidental recreation is expected to continue, with impoundments potentially attracting wildlife without significantly increasing hunting, fishing, or outdoor activity near the dams, which are not designed for recreational use.

Rural Community and Agricultural Damages

The analysis of monetary benefits for the project alternatives was conducted using average annual equivalent terms, which involved calculating the difference between the No Action Alternative and each proposed project alternative. This approach allows for a comprehensive assessment of the expected benefits over time. The expected average annual damages for each alternative were estimated using an equation that considered flood event damages and probabilities. This detailed analysis provides a nuanced understanding of the potential impacts of each alternative on structures, contents, vehicles, roads, crops, erosion, and sedimentation. More details on this analysis may be found in the Benefit Cost Analysis Technical Memorandum in Appendix E.

For instance, the damage to structures, contents, and vehicles were estimated based on factors such as flood depths, property values, and the types of buildings affected. The analysis took into account the varying degrees of damage that could occur at different flood depths, with higher depths leading to more significant damage. Road damage was also assessed, considering the location, flood depth, and surface area impacted by floodwater. The cost of repairing or replacing roads was estimated based on the extent of the damage, with deeper flood depths resulting in higher repair costs.

Additionally, the analysis considered the impacts on agricultural land, particularly in terms of crop damage. The assessment included an evaluation of the flooded area, flood depths, and the types of crops affected. The damages were estimated based on factors such as crop yield data, crop prices, and flood depths. The analysis also accounted for improvements in agricultural water management, such as the installation of an irrigation water pipeline, which was expected to improve irrigation efficiency and increase crop yields.

The analysis further assessed the impacts on recreational activities in the area. While there was limited data on the exact extent of recreational use, the project area was known to be used for activities such as fishing, hunting, and hiking. The analysis considered the potential impacts of the project on these activities, particularly in terms of enhancing wildlife habitat and scenic improvement. Overall, the detailed analysis of monetary benefits provided valuable insights into the potential economic impacts of the project alternatives, helping to inform decision-making regarding the preferred alternative.

Project Benefits Summary

The planning policy guiding this project emphasizes maximizing public benefits from federal investments in water resources, considering both costs and positive ecosystem services. The preferred alternative aims to reduce flood damage and the potential for loss of life, aligning with this policy by maximizing public benefits. A detailed analysis of expected damages and benefits was conducted for each alternative, providing insights into the economic, environmental, and social impacts.

The analysis revealed that without the project (No Action Alternative), current average annual flood damages amount to $3,534,841. In contrast, with the project's implementation, estimated damages would significantly decrease to $198,452, showcasing the substantial impact of the proposed flood control structures. Additionally, downstream properties would benefit from about $5,014,151 in average annual benefits, further highlighting the positive effects of the preferred alternative.

Furthermore, the preferred alternative would protect over 690 people in the inundation zone, reduce the threat of loss of life, and safeguard numerous residences, commercial structures, public properties, and roadways. It would also protect downstream properties and property owners' access and emergency services, providing flood protection for 50 years. The project costs, including installation, operation, and maintenance, were carefully estimated and allocated according to federal guidelines, ensuring a comprehensive financial analysis.

In conclusion, the preferred alternative demonstrates a high benefit-cost ratio of 4.07 to 1.00, indicating that for every dollar invested, there is an expected return of $4.07 in benefits. This analysis underscores the effectiveness of the preferred alternative in maximizing public benefits, reducing flood damages, and enhancing the overall safety and well-being of the affected communities.

Final economic tables may be found in the Benefit Cost Analysis Technical Memorandum located in Appendix E.

Crop Water Use & Crop Yields (TM 010)

The potential benefits of increased crop yield are highlighted as a significant contributor to project benefits. For any proposed project to succeed, it must be economically sustainable in both the short and long term, as per the guiding principle. Understanding and quantifying the impacts of project alternatives on crop yield, due to improved water supply, is crucial. This section outlines the methodology for analyzing and quantifying crop yield impacts, including developing yield curves that correlate water use with yield quantity. These curves help estimate potential yield increases or decreases from project alternatives, providing insights into the project's effects on crop production. Temporal aspects of crop-water demand are also considered, offering further understanding of project benefits and anticipated impacts.

Primary Crops in the Project Area

CCIC primarily grows alfalfa, mixed hay, grass pasture, winter wheat, and corn silage. Other crops grown in the area include triticale, oats, sorghum, barley, and some fruit tree crops. Alfalfa covers approximately 78% of the project area, followed by mixed hay (12%), grass pasture (4%), winter wheat (2%), and corn silage (2%). These cropping patterns are based on historical data and reflect the average distribution of crops in the CCIC service area.

Crop Yields in the Project Area

Based on agricultural statistics and the USDA Web Soil Survey, crop yield conditions were analyzed for the region. The data includes "Non-Irrigated" yields, sourced from the Web Soil Survey and verified by a local farmer indicating dry farming is not feasible in the area. "Irrigated, Low" yields represent current CCIC user yields without additional supplemental irrigation water, while "Irrigated, High" and "Maximum" yields reflect reported values for "Better than Average Range" and "Near Perfect Conditions" for Millard County, respectively. Crop yields for alfalfa, mixed hay, grass pasture, winter wheat, and corn silage are detailed in the table below, providing a range of potential yields under different water supply scenarios.

Table 5: Millard County Agricultural Yield Data for Various Water Supplies

Crop	Non-Irrigated	Irrigated, Low	Irrigated, High	Maximum
Alfalfa (tons/acre)	0.1	3.5	7.4	8.6
Mixed Hay (tons/acre)	0.0	3.5	4.6	5.4
Grass Pasture (AUM/acre)	0.3	3.7	4.9	5.7
Winter Wheat (bushels/acre)	20.0	60.0	93.0	108.1
Corn Silage (tons/acre)	3.0	12.0	22.2	32.0

Expected Consumptive Use

Consumptive use, representing the water plants use through evapotranspiration (ET), varies among crops. For alfalfa, it takes 5 to 7.4 inches of ET to produce 1 ton, with an equation developed for Utah estimating the ET needed to produce 1 ton of alfalfa per acre. Using the Fillmore, Utah weather station's data (elevation: 5,120 feet, latitude: 38.95 degrees), the ET per ton of alfalfa per acre is calculated at 4.7 inches. The detailed calculations may be found in the Crop Yields Technical Memorandum in Appendix E. This value, along with similar calculations for other crops, informs the consumptive use values summarized in the table below, which includes "Non-Irrigated," "Irrigated, Low," "Irrigated, High," and "Maximum" scenarios for crops like alfalfa, mixed hay, grass pasture, winter wheat, and corn silage. These values are crucial for understanding water demand and irrigation needs in the project area.

Table 6: Annual Average Consumptive Use Associated with Crop Yields (inches)

Crop	Non-Irrigated	Irrigated, Low	Irrigated, High	Maximum
Alfalfa	7.5	19.0	35.3	40.6
Mixed Hay	7.5	22.4	27.9	32.1
Grass Pasture	7.5	22.4	28.4	32.7
Winter Wheat	7.5	10.5	15.0	20.0
Corn Silage	7.5	11.0	16.0	23.2

Resulting Yield Curves

A standard plot of the consumptive use and corresponding crop yield for each crop is defined as a crop yield curve or a crop production curve. For both primary crops grown in the project area, the corresponding crop production curves are provided as a basis for estimating the expected yields under the various water conservation options. With an estimate for water conservation, the potential increase in consumptive use available can be directly correlated to the potential increase in yield for the primary crops and the associated economic benefit. It should be noted that crop yield curves extend beyond the maximum consumptive use, and yield decreases with overwatering. For the scope of this project, these curves were not extended to include this data due to a limited water supply. Yield curve graphs are located in the Crop Yields Technical Memorandum located in Appendix E.

Crop-Water Demand Characteristics and Crop Shifting

Yield curves represent the relationship between annual consumptive water use and crop yield but overlook the timing of crop water demand, which varies among crops and affects their suitability for the Corn Creek area due to limited water availability later in the irrigation season. This temporal constraint influences crop selection, favoring crops like silage corn and alfalfa, which have later peaking consumptive water use, over crops like wheat and barley with earlier peaks. Conserving water could increase the availability of water for later-peaking crops, potentially increasing economic benefits as these crops are generally higher in value. Despite this, alfalfa remains the primary crop in the area, as its single cutting is more reliable with the current water availability compared to the risk of a failed crop of wheat or barley, which typically peak after Corn Creek's flow has diminished. Improved water supply could enable farmers to plant more wheat or barley confidently, but due to water supply variability, alfalfa is likely to remain the dominant crop with limited to no crop shifting. This is mainly due to the irrigation company having no water rights for storage to provide reliable late season water.

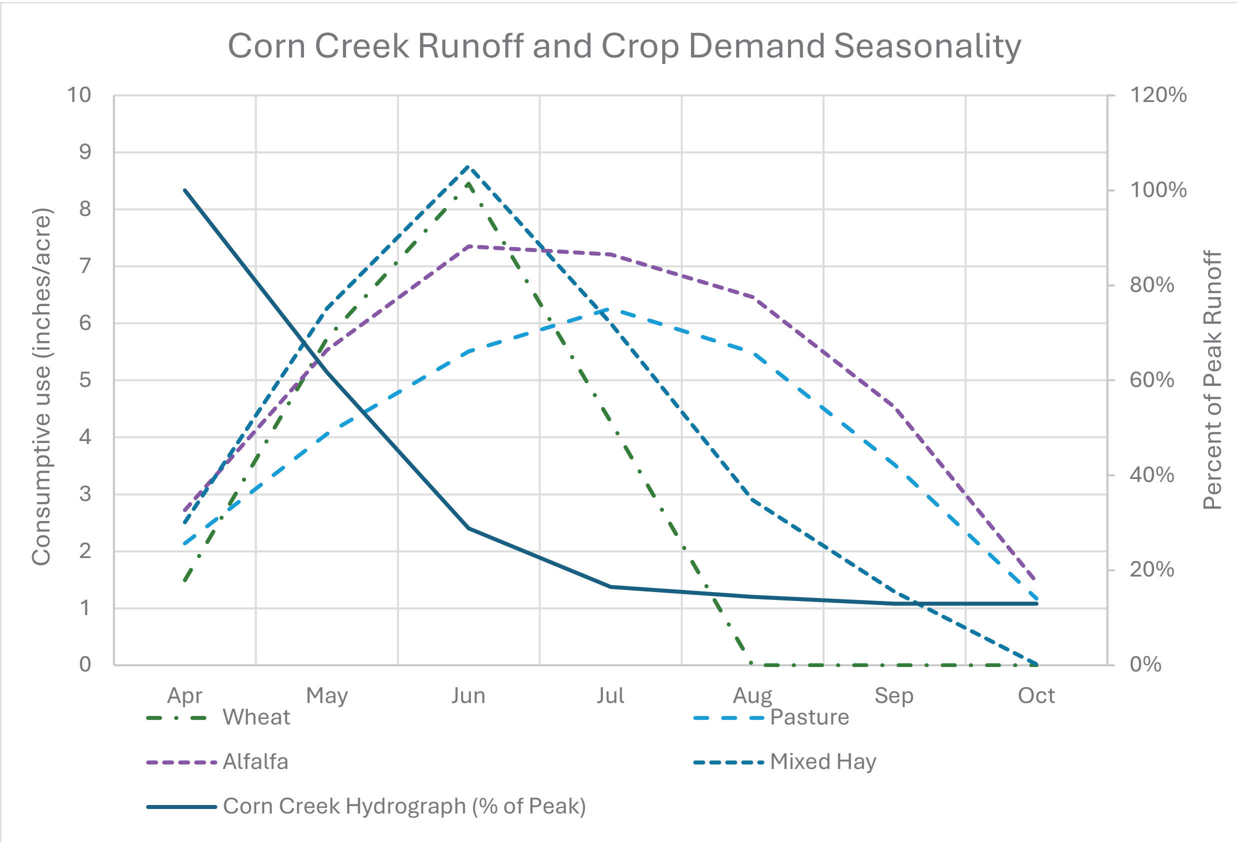

Figure 13: Crop Consumptive Use Compared to Corn Creek Runoff

Conclusion

From available data, correlations between consumptive use and crop yield, as well as consumptive use timing for the project area, were developed. Crop yield increase is the primary regional economic driving factor for agricultural water management.

While a shifting in crop pattern may also be expected, it is unpredictable and unreliable. This is due to the fact that there is no reliable methodology to estimate the amount of crop-shifting that will occur due to project alternatives. However, understanding the expected crop-shifting instills confidence that economic benefits due to water conservation are conservative, and that additional economic benefits are likely, further ensuring the economic sustainability of the proposed projects.

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