D1.0 INTRODUCTION

This appendix provides supporting information for the formulation, evaluation, and conclusions of this Plan-EA. Items of a routine nature are not included; however, citations are included throughout the Plan-EA and this Investigation and Analysis report for appropriate manuals, handbooks, research, and other references. USDA NRCS manuals and handbooks, state guidelines, and other reference documents were utilized to guide the planning of this project. These are referenced in Chapter 8 of the Plan-EA.

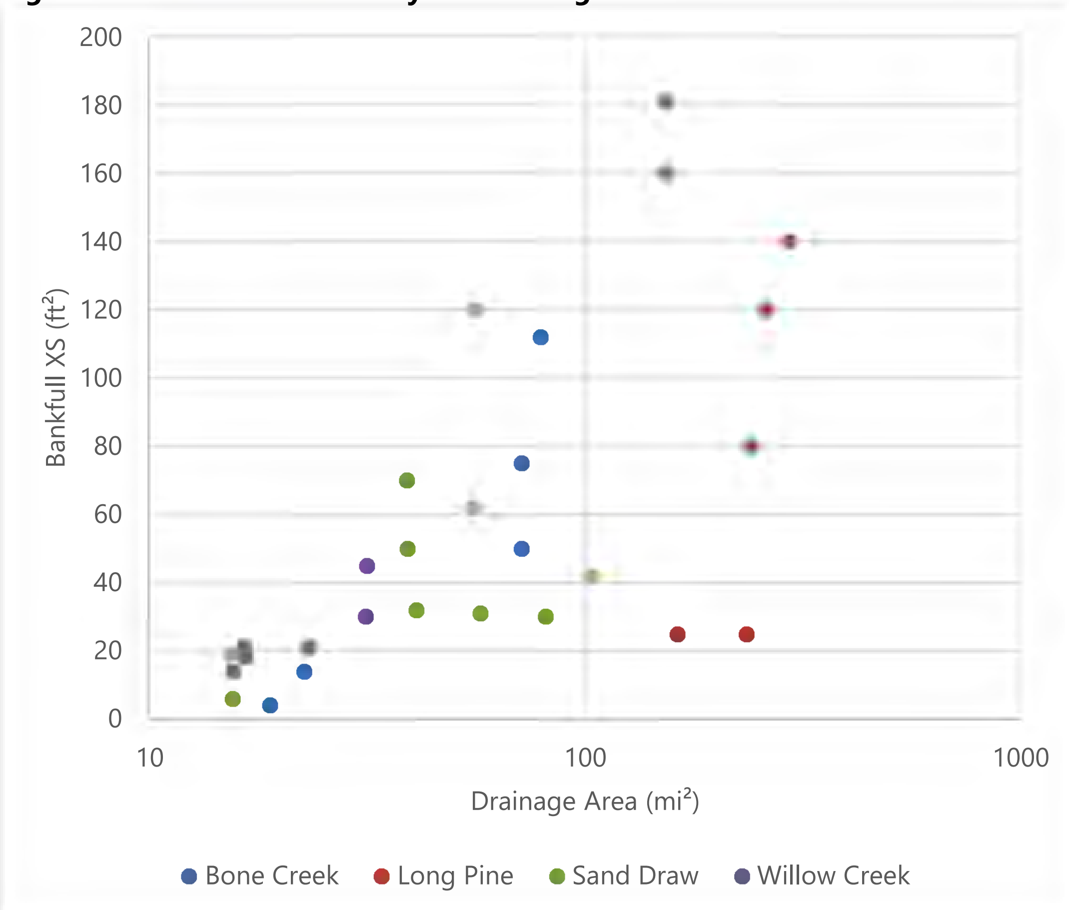
The NRCS staff and hired consultants worked with other federal, state, and local agencies, individual watershed residents, private professional services consultants, the Sponsor, and NRCS State and National staff specialists throughout the planning process. Interdisciplinary teams were utilized in the assessment and evaluation of present, No Action, and Future With-Project conditions. This coordinated planning effort produced a forecasted Without Project condition that allowed for the consideration of several alternatives.

D2.0 WATERSHED ANALYSIS

D2.1 Regression Equations

Regression equations have been developed throughout the country to establish ratios between channel geometry, bankfull discharge, and drainage areas. These relationships help to simplify the application of natural channel design methods. No preexisting regression equations are available that define channel geometry behavior for this watershed. In an attempt to define these relationships, observation data from site visits performed after the 2019 flood events were utilized to establish trends between bankfull cross sectional area (below the OHWM) and drainage area. These trends are noisy due to the damage caused by flooding in 2019. Attempts made to utilize LiDAR from before the flooding was compounded by the inability to discern the bankfull extents accurately and would require the use of a hydraulic bankfull capacity which would not be as useful for natural channel design methods as the streams regularly handle the 10+ year event in this area. Figure D2-1 below shows the relationship between bankfull geometry and drainage area at various locations throughout the watershed.

Figure D2-1. Bankfull Geometry and Drainage Area

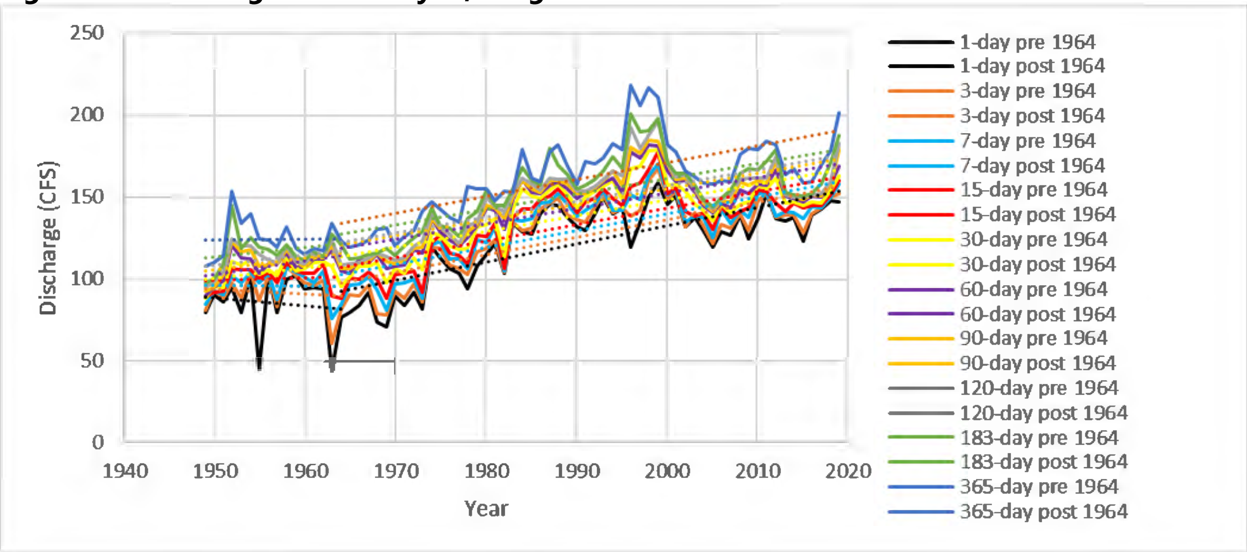


D2.2 Stream Gage and Groundwater Analysis

The main streams (Long Pine Creek, Willow Creek, Sand Creek, and Bone Creek) and associated tributaries have experienced average flow rate increases since the 1960s, leading to significant channel incision and widening through scour and erosion. Throughout the watershed, groundwater levels had also been steadily increasing in the area since widespread irrigation began in the mid-1960s. The increasing groundwater likely led to a significant portion of the increase in average discharge on area streams as groundwater was replenished faster than the area streams could drain it. Analyses of historical rainfall, stream flow, groundwater levels, and meteorological conditions were performed on available data within the basins of interest as well as several locations outside of the watershed to discern trends and establish cause and effect of witnessed stream flow changes and channel degradation. The obvious addition of significant quantity of irrigation water from Merritt Reservoir is of primary concern, but other factors were considered. Of particular interest is the possibility that a climate shift is causing a transition to more significant rainfall or rainfall rates. Data from Long Pine Creek at Riverview and the Niobrara River at Sparks was utilized along with groundwater data from NeDNR and precipitation data from NOAA in this analysis.

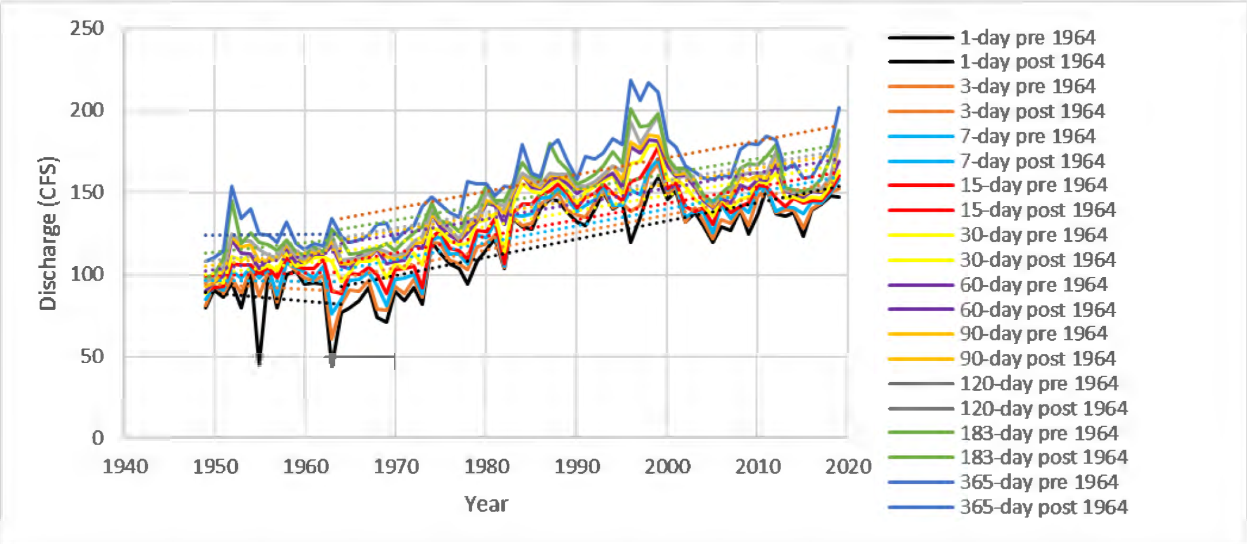
The watershed was analyzed for baseline hydrology using stream gage data from USGS. Trends were analyzed and it was determined that gages Riverview (Station Number 6463500), Plum Creek (Station Number 6462500), and Sparks (Station Number 6461500) all had sufficient amounts of data and could be used for further analysis. See Figures D2-2, D2-3, and D2-4 for the minimum annual discharge for each duration pre- and post-1964 for Riverview, Plum Creek, and Sparks stream gages. Riverview showed a clear increase in flow post-1964. Plum Creek showed an increase in flow both pre- and post-1964. Sparks also showed a change from pre- and post-1964, however this change was due to the construction of Merritt Reservoir which appears to have reduced average discharge in the system. For further analysis, Riverview and Sparks were carried forward for additional study.

Figure D2-2. Average Flow Analysis, Long Pine Creek at Riverview[1]



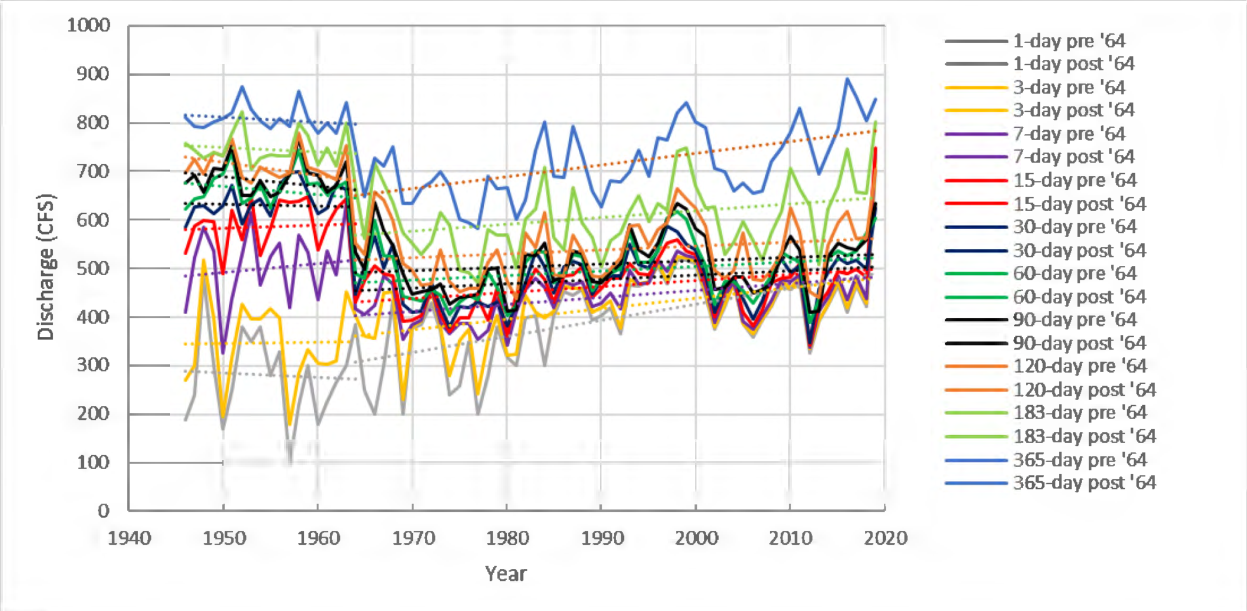
[1]Chart showing average flow analysis for various durations for pre-1964 and post-1964 for Long Pine Creek at Riverview.

Figure D2-3. Average Flow Analysis, Plum Creek at Meadville[1]



[1]Chart showing average flow analysis for various durations for pre-1964 and post-1964 for Plum Creek at Meadville.

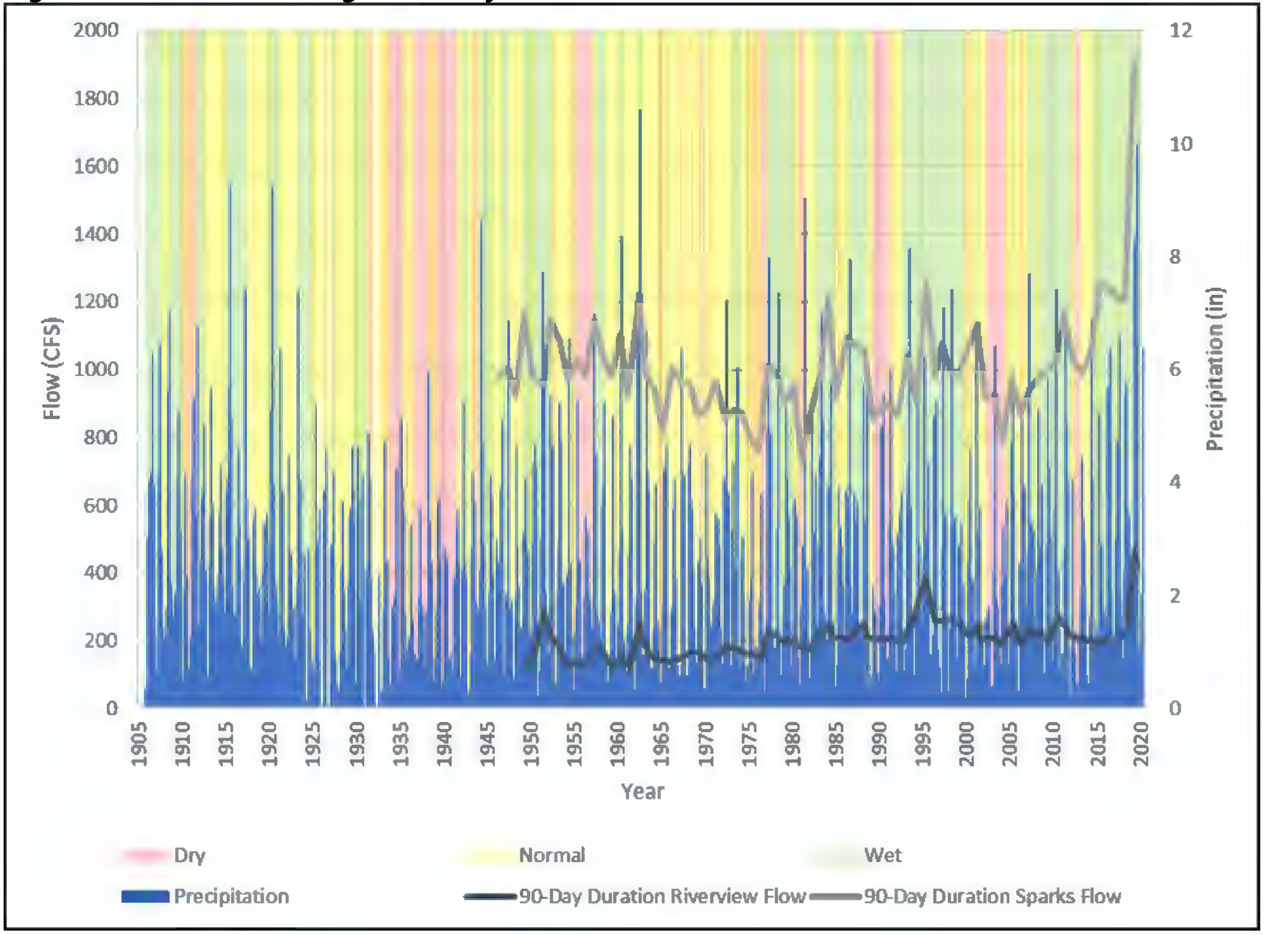
Figure D2-4. Average Flow Analysis, Niobrara River at Sparks[1]



[1]Chart showing average flow analysis for various durations for pre-1964 and post-1964 for Niobrara River at Sparks.

While changes in water quantity are important to understand the degradation that has occurred in the Long Pine Creek Watershed, the reason for those changes is relevant to the alternatives selected. Since 1975, the region has entered into a slightly wetter period than the previous 50 years, more similar to the early 1900s, as indicated by the Palmer Drought Severity Index (PDSI) and seasonal rainfall totals. Climactic conditions vary wildly throughout geologic history, so making long term inferences from relatively short period of record datasets will likely lead to incorrect conclusions if not appropriately vetted. There is insufficient data to provide a high confidence conclusion as to the effect of climate change on watershed runoff characteristics as the advent of high temporal resolution rainfall gages did not exist for the majority of the period of record, making any discussions of changes in rainfall intensity weak. Therefore, in order to remove one variable from the assessment, we elected to normalize the runoff data by using a standard watershed yield calculation. This utilized the average stream discharge (cfs) divided by the inches of precipitation, providing a watershed yield in cfs/in. Rainfall data was taken from a gage location at Ainsworth (USC00250050) which provided rainfall records in varying resolution back to 1905. In principle, more rainfall should result in more runoff, but the ratio of cfs per inch of precipitation shouldn't change over longer time periods without other changes to the system. The watershed yield will vary throughout the year, depending on soil moisture and frozen ground, so annual averages were utilized. This has the effect of buffering extremely intense rainfalls with long duration, soaking events, or snowfall to provide a more holistic view of the behavior of the watershed.

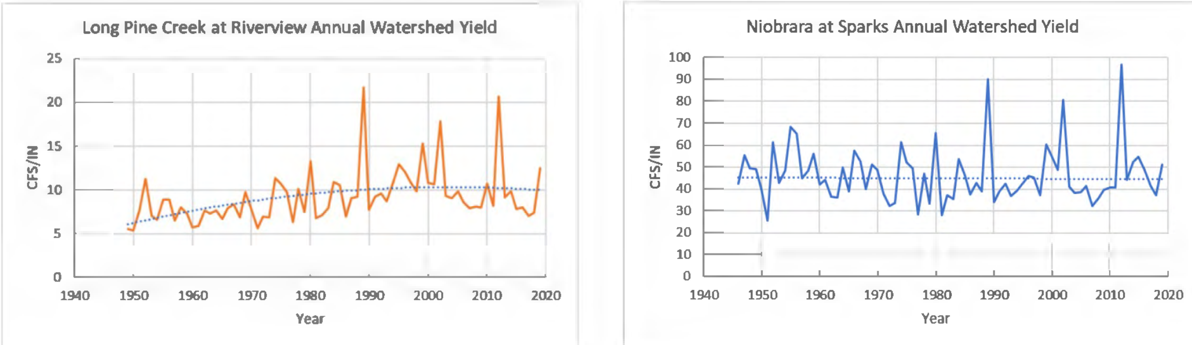
Figure D2-5. Palmer Drought Severity Index[1]



[1]Chart depicting Palmer Drought Severity Index as wet/normal/dry, Precipitation in inches and average discharge in the Niobrara River (at Sparks) and Long Pine Creek (at Riverview)

Given the shift to a wetter period, we would expect to see an increase in average discharge on the area streams, which we do at both Niobrara at Sparks and Long Pine at Riverview. However, the cfs increase on the Niobrara behaves proportionally to the increase in rainfall whereas Long Pine Creek's behavior is nonproportional. Inspection of the watershed yield shows an increase only in the regions that have been utilizing supplemental irrigation water. This implies that the rate of runoff per inch of rainfall (as calculated by cfs of runoff per inch of rainfall) hasn't changed outside of the regions that have supplemented with additional irrigation water. The watershed yield appears to have peaked in the late 1990's and is starting to decrease; however, the data is noisy and only general trends can be assessed. Watershed yield at Long Pine Creek and Niobrara River are shown in Figure D2-6 below.

Figure D2-6. Annual Watershed Yield at Long Pine Creek and Niobrara River[1]



[1]Charts showing the annual watershed yield in CFS/inch at both Long Pine Creek (Riverview) and Niobrara River (Sparks). Trends (while noisy) suggest a steady yield at Niobrara with an increasing to stabilizing trend at Long Pine.

Assessment of groundwater trends shows a steady increase from the 1960s to the early 2000s. However, the trend over the last 20 years has been slightly to moderately downward, depending on location. As groundwater levels increase, we would expect baseflow in streams to increase as well. The groundwater level increases are due to a combination of irrigation using groundwater and Merritt Reservoir sources, as well as increased precipitation evident in the climate record (as compared to the 1970s). However, it is important to note that precipitation increases do not appear to be out of line with historical records and consequently we would expect these basins to have experienced wet periods like this previously. Based on site visits, we have been able to observe geomorphological evidence of multiple degradation and aggradation phases within the Long Pine Creek and Bone Creek waterways. These previous degradational phases were likely caused by wet periods as well, and/or periods with little sediment transport in the system. As we put these observations together, we are left to conclude that the application of significant quantities of irrigation water, possibly combined with a wetter than average precipitation pattern since the 1970s, over the watershed has added substantial potential energy to the system through increased groundwater levels. This energy is expended within the channel through increased baseflow. Increased discharges within the system, combined with significant flooding events, lead to channel degradation and streambank steepening. Because the stream has now cut further into the saturated ground, baseflow is increased further, and the cycle repeats. This change has shifted several streams in the watershed from ephemeral and intermittent to perennial flow patterns. Figures D2-7a through D3-7d presented below for each of the streams show the change in groundwater elevation over time for a few selected groundwater wells. While not definitive, the trends in groundwater elevations considering the observed stream degradation do support the conclusions presented here.

Figure D2-7a. Bone Creek Groundwater

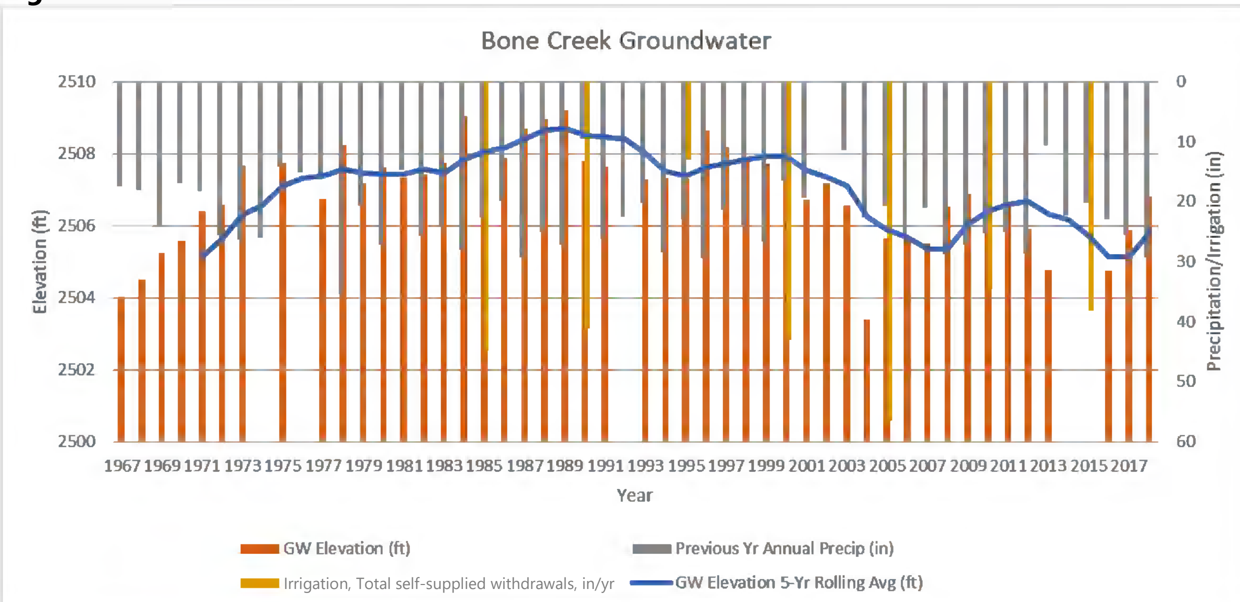


Figure D2-7b. Sand Draw Creek Groundwater

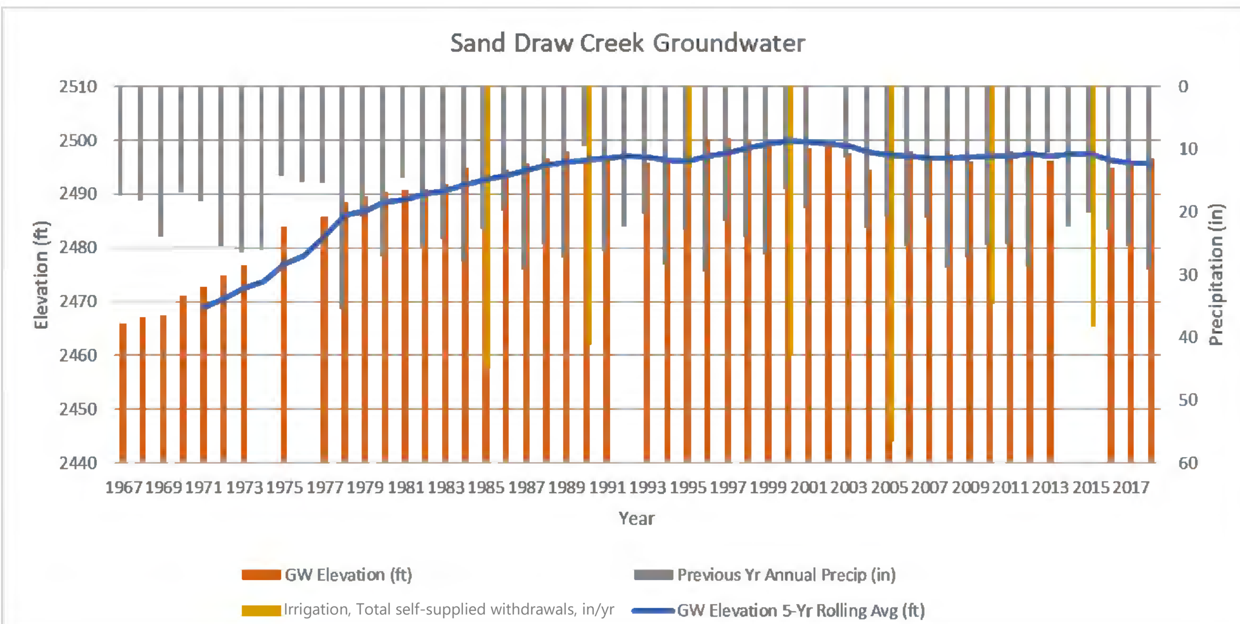


Figure D2-7c. Willow Creek Groundwater

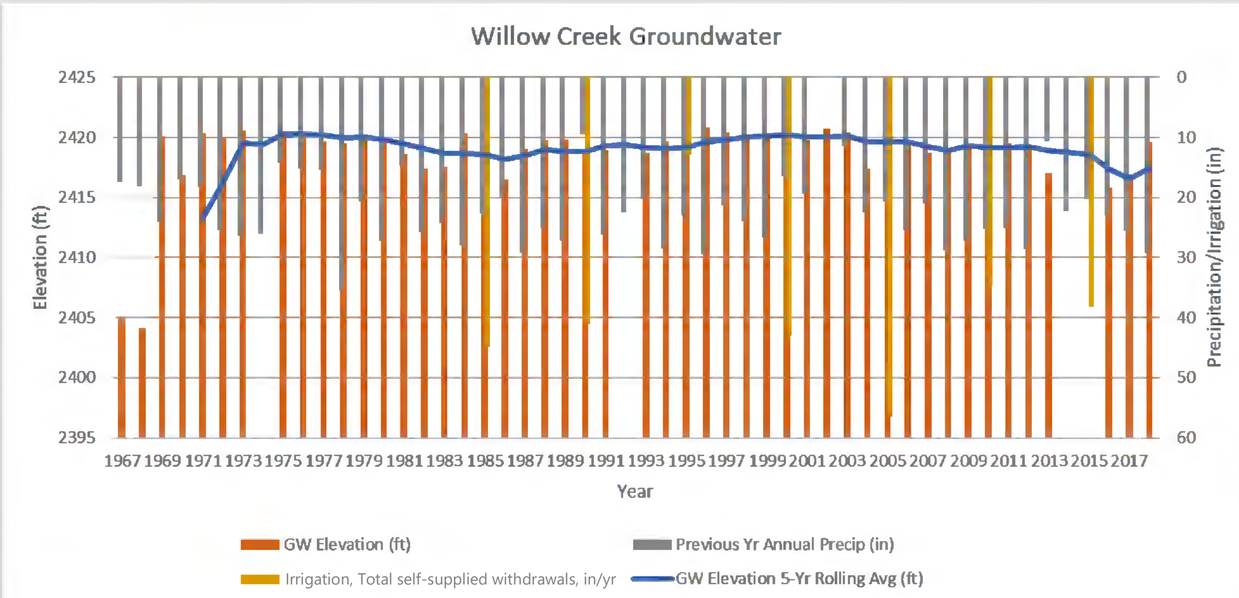
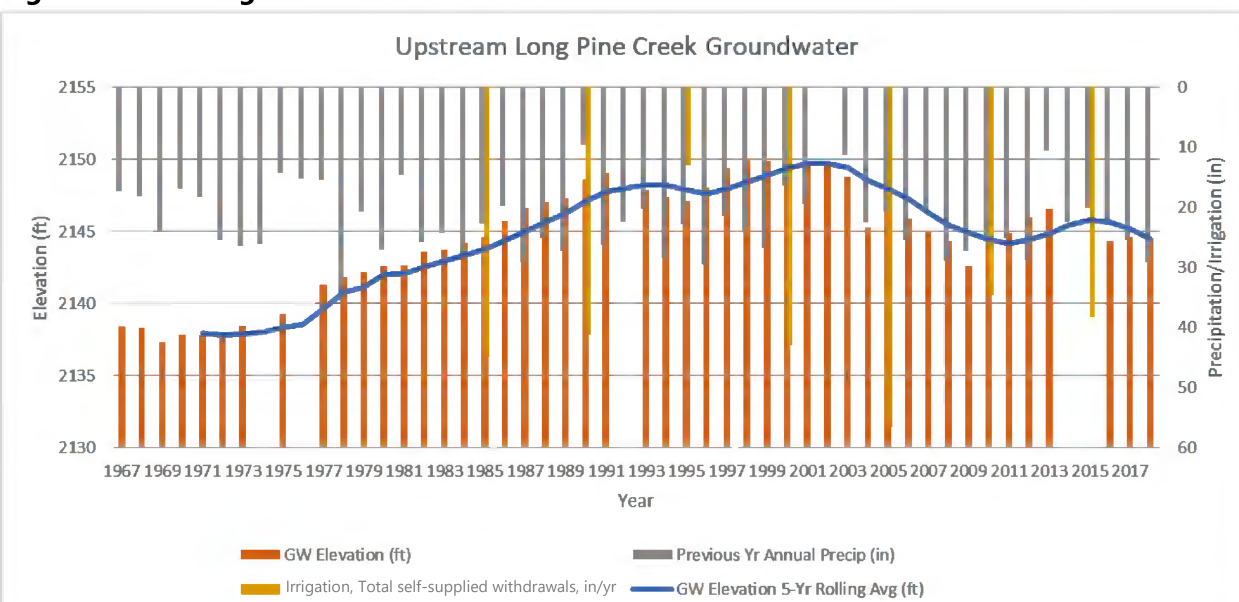


Figure D2-7d. Long Pine Creek Groundwater



Figures D2-7a through D2-7d: Further complicating the watershed yield is that the increase in yield within Long Pine Creek has multiple sources. Excess water could come in part from precipitation and from agricultural irrigation. It is difficult to discern which of the two is playing a more significant role.

In the long term, the additional energy available to the system from irrigation water, precipitation, and groundwater levels will eventually equilibrate with channel capacity as the systems continue to degrade and widen. Unless irrigation usage decreases or channels are restored by elevating their thalweg, the baseflow will remain at elevated flowrates versus the historical averages due to the additional surface water application, but the channel will begin to stabilize to the increase in energy that is available to the system. Based on the available data, it appears that the larger streams (most downstream) started recovering as early as 2000 where we see groundwater levels and watershed yield values both beginning to decline. This is not to say that the streams are done recalibrating to the excess water, but the process is well underway and may have already passed its peak throughout the lower portions of the watershed. It is expected that additional degradation and widening will occur throughout the system in the future, especially in the mid to upper reaches of the watershed.

D3.0 PREFERRED ALTERNATIVE DESIGN DETAILS (TIER 1)

The following sections describe details about the design components proposed within this Plan-EA. Due to the highly erosive and quickly evolving nature of streams within the watershed, all proposed designs will require survey during final design to account for current stream conditions.

D3.1 Design Discharge

Flood frequency distributions were calculated at two USGS Stream Gages using HEC-SSP V2.2: Long Pine Creek near Riverview, Nebr. (Site number: 06463500) and Long Pine Creek near Long Pine, NE (Site number: 06463080). Results from the Riverview Station yielded slightly more conservative results and were used as a base frequency distribution for the entire watershed. The Square Root Transform (SRT) method was used to transfer the flood frequency distribution to other parts of the watershed to approximate discharges for the purpose of preliminary design. The drainage areas for the Long Pine near Riverview site and each project site were determined using 2016 LiDAR in combination with the delineated watershed boundaries from the watershed boundary dataset.

D3.2 Restoration Structures

The restoration structures consist of grade control and channel defining structures included in the NRCS National Engineering Handbook (NEH) Part 654 Stream Restoration Design, NRCS Technical Supplements 14G, 14N, and 14H and the Iowa Department of Natural resources (IDNR) River Restoration Toolbox (IRRT). The IRRT Tool Box Data Collection and Data analysis spreadsheet was used to identify potential structures and evaluate feasibility of structures within each reach. Data inputs for the IRRT spreadsheet were recorded during the October 2020 stream assessment along with other stream characteristics (see Stream Assessment section, this Appendix). NRCS design standards, IRRT practice guides, recorded field conditions, and 2016 LiDAR were used to guide structure design and size. The following sections describe the specific restoration techniques included in this Plan-EA. See Appendix C for typical design details and proposed locations of these structures. The locations and size of each structure will be re-evaluated during final design based on survey due to rapidly changing stream conditions.

D3.2.1 Cross-Vane, Structures G2-41-1, G2-41-2, G2-3-1, G2-3-2, G2-3-4, G2-3-5, and G2-3-6

The cross-vane is an in-stream structure that offers grade control and redirects flows towards the center of the channel, reducing erosion along streambanks. It additionally improves aquatic habitat by reducing energies with smoother drops and providing pools. The cross-vane is designed to use SDDOT Class E riprap to withstand flow as single stones without upstream and downstream protection. Class A riprap is to be used just upstream of the boulders as backfill material and as chinking material. The width of the structure varies based on the top of bank widths at each site. Flanking protection is proposed to protect from future meanders and will need to be adjusted in final design based on more detailed analysis of the probability of future stream meanders.

D3.2.2 W-Weir, Structures G2-41-3 and G2-3-3

The w-weir is an in-stream structure that offers grade control and redirects flows towards the center of the channel, reducing erosion along streambanks. It additionally improves aquatic habitat by reducing energies with smoother drops and providing pools to increase depth diversity. The w-weir is ideal for widened stretches of stream. It is designed to use SDDOT Class E riprap to withstand flows as single stones without upstream and downstream protection. Class A riprap is to be used just upstream of the boulders as backfill material and as chinking material. The width of the structure varies based on the top of bank widths at each site. Flanking protection is proposed to protect from future meanders and will need to be adjusted in final design based on more detailed analysis of the probability of future stream meanders.

D3.2.3 Bendway Weir, Structures BS2-6-1, BS2-6-2, BS2-6-3

The bendway weir is a channel defining structure used to redirect water from a bankline and improve aquatic habitat. Multiple bendway weirs are typically placed together along a bend to protect the shoreline from further erosion. The structures consist of submerged SDDOT Class B riprap angled upstream to divert energy from a bank. It may be necessary to increase the riprap size to Class C in some cases to increase stability. The bendway weirs are angled 60 to 80 degrees from the bank and will be adjusted based on field survey. The bendway weirs are to be spaced approximately 1/3 to 1/2 of the top of bank width but may be adjusted based on the field determined channel gradient. The bendway weirs are proposed to be four feet high at ARA 7 (structures BS2-6-1, BS2-6-2, and BS2-6-3) to remain above the approximate baseflow water level while accounting for probable future burying of riprap into the existing streambed. The required flanking protection into the channel bank may be adjusted in final design.

D3.3 Zeedyke Structures

Zeedyke structures are smaller hand-built structures designed to manage gully erosion and channel incision. These are smaller structures that consist largely of natural material such as trees and rocks and are designed in accordance with the USDA Range Technical Note No. 40: Hand-Built Structures for Restoring Degrading Meadows in Sagebrush Rangelands. Two types of Zeedyke structures are proposed in the preferred alternative, described below.

D3.3.1 Log and Fabric, Structure G2-44

The log and fabric structure consists of stacked, trimmed logs tied together with wire and fencing staples. The logs are stacked at the edge of a gully headcut to provide grade stabilization and protect from further degradation. The log and fabric Zeedyke structure is proposed at the end of a gully with a 3-foot drop and 12-foot width recorded during the October 2020 field visit (structure G2-44). A typical cross-section of the log and fabric Zeedyke structure is included in Appendix D.

D3.3.2 Rock Rundown, Structure G2-2-1

The rock rundown Zeedyke structure involves grading an existing headcut to a 3H:1V slope and placing biodegradable geotextile mesh and Class "B" Riprap over the 3H:1V slope to stabilize the headcut. The rock rundown structure is proposed at the end of an existing gully with a 1.5-foot drop and 3-foot width recorded during the October field visit 2020 (structure G2-2-1) and will help to prevent further degradation draining of the existing wet meadow. A typical cross-section of the rock rundown structure is included in Appendix D.

D3.4 Tied Concrete Block Mat Crossing, Structure SC2-1

This alternative involves implementation of a vegetated tied concrete block mat (Flexamat or approved alternative) crossing on Sand Draw Creek. The grade change across the crossing was based on the observed 2.5-foot progressing headcut at the downstream end that was observed during the October 2020 field investigations. The velocity and shear stress through the proposed crossing at full flow conditions were calculated using Manning's equation. Side slopes of 4H:1V or flatter are proposed to allow for vehicle traffic. The length of the proposed structure was adjusted to ensure that the velocity, shear stress, and slope were below the maximum recommended from the NRCS Design Guidance for Sand Hills Grade Control Structures (2014), which are listed below. Plan and profile views are included in Appendix C.

- Maximum tractive shear stress not to exceed 7.5 lb/ft^2
- Maximum permissible velocity not to exceed 8.0 ft/s
- Maximum permissible slope not to be steeper than 5:1 in channel
- Manning's n = 0.05

D3.5 Sill with Fish Passage, Structure G2-2-2

A sill with fish passage is proposed to provide grade stabilization benefits, provide an upstream pool as requested by the landowner, and provide passage for aquatic organisms. The permanent pool is set at 2506-feet above mean sea level (MSL) to create an approximately 6-acre permanent pool with a minimum pool depth of 2-feet. A spillway is set at the permanent pool elevation and designed with a 25-foot-wide base width and 3H:1V side slopes. The spillway will be designed to flow at the permanent pool elevation to provide fish passage around the sill's embankment. The center of the spillway will contain a 5-foot-wide channel lined with Class "B" riprap. The channel was designed in accordance with the NRCS Conservation Practice Standard Code 396, Aquatic Organisms Passage and should have a grade of two percent or lower to maintain a maximum velocity of 2-feet per second for fish passage at baseflow conditions (approximately 5 cfs). The fish passage channel bed material may be adjusted to promote better fish habitat and decrease velocity. A profile of the spillway is included in Appendix C. The top of the sill elevation was set at 2510-feet MSL to provide a 4-foot-tall embankment. The embankment has a 3H:1V upstream slope and 10H:1V downstream slope. There will be no pipe or riser structure and the spillway is present to accommodate fish passage. The sill will have a 13-foot-wide top width to allow for vehicle crossings. Vehicle traffic will include landowner ATV and UTV usage and will not be open to the public. Material for the embankment will be obtained first from the excavated material from the auxiliary spillway and then from the permanent pool to increase the pool depth. A turf reinforcement matting (TRM) will be placed across the embankment surface to ensure that a 100-year storm can safely pass over the embankment without creating erosion. The 100-year peak flow is approximately 1,900 cfs and overtops the embankment by approximately 2.5 feet. The TRM will need to handle flow velocities of 17 ft/s to provide protection against the 100-year event. See Appendix C for a plan, profile, and cross-section views of the proposed structure.

D3.6 Pond, Structure P2-4

The proposed pond is located on a gully located upstream of Sand Draw Creek to protect the gully from further degradation and was designed in accordance with the NRCS Conservation Practice Standard (CPS) Code 378 procedures. 2016 LiDAR with 1-meter accuracy was used to calculate the stage storage areas and volumes. The permanent pool was set approximately 4-feet above the low point in the channel to store approximately 50-years of sediment based on the sedimentation rates from the 2016 Water Quality Management Plan. Curve numbers and times of concentration were computed for the drainage area in accordance with the methodology in the NRCS TR-55 Urban Hydrology for Small Watersheds. Land uses for the curve number calculations were determined based on aerial imagery.

A SITES model was developed to run the hydrologic storms and set the auxiliary spillway and top of dam elevation. The auxiliary spillway was set using the 10-year, 24-hour storm. The top of dam was set to detain a 50-year, 24-hour storm and the minimum elevation requirements as detailed in the NRCS CPS Code 378 procedures. Precipitation values were obtained from the NOAA, Precipitation Frequency Data Server at the location of Structure P2-4. The auxiliary spillway width was set at 20-feet to set the top of dam elevation.

The embankment consists of a vegetated earthen embankment that is a maximum of 10-feet tall along the centerline. There will be a 24-inch high-density polyethylene (HDPE) riser and 12" HDPE principal spillway. The top width is 12-feet wide to allow for vehicle crossings and a 10H:1V backslope was provided to reduce potential for erosion and therefore minimize maintenance. See Appendix C for a plan, profile, and cross-section views of the proposed pond.

D3.7 Water and Sediment Control Basin, Structure G2-5

A sediment basin is proposed on a gully located upstream of Sand Draw Creek to provide grade stabilization and water quality benefits. The sediment basin was designed in accordance with the NRCS Conservation Practice Standard (CPS) Code 638 procedures. 2016 LiDAR with 1-meter accuracy was used to calculate the stage storage areas and volumes. The storage pool elevation was set at to detain approximately 20-years of sediment using the soil loss from the 2016 Water Quality Management Plan and dry density from web soil survey. The average curve number for the watershed was calculated in accordance with the methodology in the NRCS TR-55 Urban Hydrology for Small Watersheds. Land uses for the curve number calculations were determined based on aerial imagery.

The capacity of the sediment basin was calculated in accordance with National Engineering Handbook, Chapter 8. The volume of runoff was calculated using the NRCS SCS Runoff Curve method for a 25-year, 24-hour storm event. Precipitation values were obtained from the NOAA, Precipitation Frequency Data Server at the location of the sediment basin. The top of basin elevation was set to detain the 25-year, 24-hour storm event by rounding up the required volume of runoff to the nearest 0.5-foot elevation. The sediment basin does not have an auxiliary spillway. A 6" PVC spillway is proposed with a slotted riser to have a dry basin and not hold water in the permanent pool. The design capacity of the pipe was determined using the NRCS CPS Code 606 procedures by applying the Manning's equation and assuming full flow at design flow (25-year, 24-hour storm). The velocity through the pipe at these conditions was calculated to ensure that the velocity is below the maximum allowed flow velocity for the sand and sandy loam soil texture. See Appendix C for a plan, profile, and cross-section views of the proposed sediment basin.

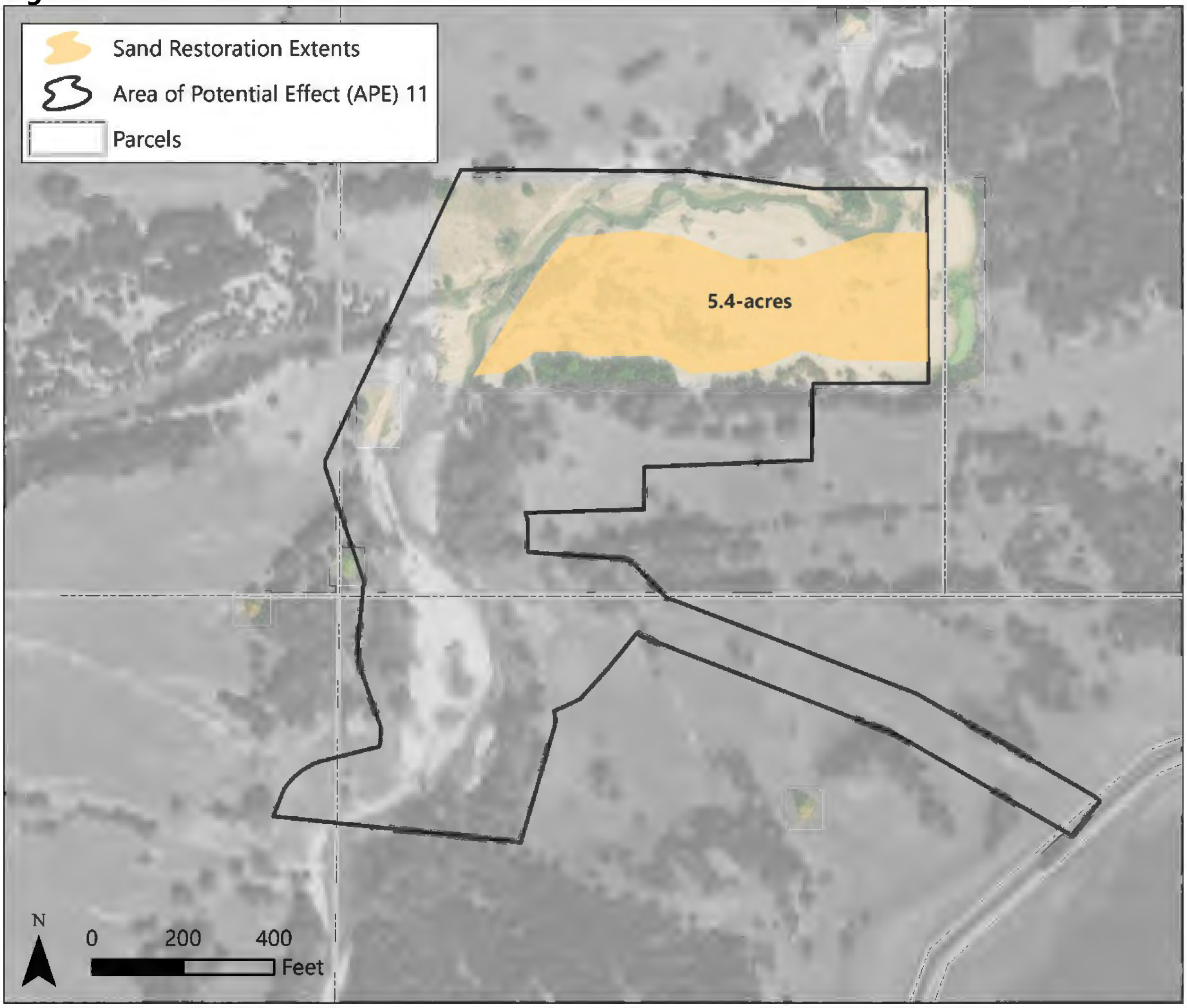
D3.8 Rock Chute, Structures G2-32

The rock chute was designed using the NRCS Rock Chute Design Data spreadsheet, based on the Design of Rock Chutes by Robinson, Rice, Kadavy, ASAE, 1998 to provide grade control and protection from an impending headcut. The spreadsheet was used with an applied factor of safety of 1.3. The design discharge used to size the structure is the discharge of the 100-year flood event or top of bank, whichever is lower. Excavation along channel banks will occur throughout the structure to achieve 3H:1V channel bank slopes and riprap will be placed up to the design discharge elevation. The rock chute is designed to control an existing 4-foot deep headcut and to also account for additional degradation due to the steep existing channel grade. Dimensions were adjusted to meet acceptable stability conditions for SDDOT Class C riprap. Channel banks will be graded back at a 3:1 ratio upstream of the rock structure to allow stream flow to naturally expand without hitting the channel banks and transitioned back towards the existing channel downstream of the structures at a 1:1 ratio based on stream flow's typical contraction ratio. To protect against future stream meanders, the structures are toed-in on the upstream side with rock that is buried 25-feet perpendicular to the bank on each side. The length of these will need to be adjusted in final design according to more detailed analysis of the probability of future stream meanders. See Appendix C for a cross-sectional and plan and profile view of the rock chute design.

D3.9 Sand Restoration, CP2-34

The sand restoration alternative includes restoring approximately 5.3-acres of the streambank where sand and large woody debris were deposited during the 2019 large flood events. This alternative includes amending the soil with approximately 6-inch depth of suitable material along the sandy area to facilitate plant growth in sandy soils. Suitable material could be obtained from excavated material from other nearby proposed projects, either included within the Plan-EA or from other funding sources. This alternative also includes removal of debris within the planting area and seeding over the suitable material. See Figure D3-1 for the approximate sand restoration area extents.

Figure D3-1. Sand Restoration Area Extents



D3.10 Sill, Structures G2-42, G2-9-1, G2-9-2, G2-9-3, and G2-33

Sills were designed to reclaim lost streambed grade and provide grade stabilization benefits. The sill height at each site is based on desired grade reclamation while balancing the need for potential upstream flooding. The sill has an upstream slope of 3H:1V, 15-foot top width, 15H:1V backslope, and 3-foot thick class "C" riprap over the surface of the structure. Class "C" riprap is proposed to provide sufficient protection and long-term stability while remaining manageable for construction to reduce construction costs. The sill's side slopes, depth of side slope riprap protection, and back slope were determined based on riprap stability calculations to ensure stable slopes for class "C" riprap. The discharge of the 100-year flood event or top of bank, whichever is the lower, is used for the riprap stability analysis. Channel banks are to be graded back at a 3:1 ratio upstream of the rock structure to allow stream flow to naturally expand without hitting the channel banks and transitioned back towards the existing channel downstream of the structures at a 1:1 ratio based on stream flow's typical contraction ratio.

D3.11 Rock Ramp

D3.11.1 Typical Rock Ramp, Structures G2-43, BS2-31, G2-46, G2-8-1, and G2-8-2

The typical rock ramp structure is designed for long term stability, low maintenance, and resilience of future infrequent runoff events and designed to 'catch' future headcuts and maintain future drops up to 4-feet deep. The structure includes class "C" rock riprap that will be placed along the stream channel bed and partially up the banks to a height of half the top of bank elevation for the upstream portion of the structure. The width of the structure was set to ensure a stable slope with Class "C" riprap with the discharge of the 100-year flood event or top of bank, whichever is the lower. Riprap will be placed up to the top of bank at the downstream sill. The structures vary in length and excavation along channel banks will occur throughout the structure to achieve a 2H:1V channel bank slope. Channel banks will be graded back at a 3:1 ratio upstream of the rock structure to allow stream flow to naturally expand and transitioned back towards the existing channel downstream of the structures at a 1:1 ratio based on stream flow's typical contraction ratio. A plan and profile view of the typical rock ramp is shown in Figure C4.1 in Appendix C.

D3.11.2 Rock Ramp with Grouted Crossing, Structure G2-7

This structure is designed similar to the typical rock ramp, described in D3.11.1. In addition, it also includes a crossing on the upstream end of the ramp to allow vehicles to cross the stream. The upstream 10-feet of the ramp will be grouted between the riprap to create a flat surface to allow for the stream crossing. Plan and profile views are shown in Figure C4.14.in Appendix C.

D3.11.3 Modified Rock Ramp, Structure G2-70

This structure is designed for long term stability, low maintenance, and resilience of future infrequent runoff events and designed to 'catch' future headcuts and maintain future drops up to 6-feet deep. The structure includes class "C" rock riprap that will be placed along the stream channel bed and up the banks to the 100-year flood elevation. The structure is 100-feet long along the channel and excavation along channel banks will occur to achieve a 4H:1V channel bank slope. A plan and a profile view of the structure is shown in Figure C4.21 in Appendix C.

D3.12 Streambank Protection

D3.12.1 Streambank Protection Near Home, Structure BS2-71

This structure includes the placement of a small embankment along an existing channel bank to protect the bankline from further degradation and loss of land. The embankment consists of earthen fill and Class "C" Riprap protection, designed to deform into the existing land after large storm events. The structure is five feet high on the bankline side and eight feet tall from the bottom of the stream channel, designed to be two feet higher than the right bank. It is approximately 1,000-feet long to protect the length of the eroded left channel bank and extends past the southern bend to protect the channel bank from migrating at the bend. The structure is offset from the existing bank to push the stream flow further from the existing streambank. No material is placed between the structure and shoreline to reduce required material during construction while also allowing for material to be placed behind the structure post-construction if desired to provide additional protection. The plan and profile view of the streambank protection is shown in Figure C4.21 in Appendix C.

D3.12.2 Streambank Protection Near Bridge, Structure BS2-72

This structure includes a 100-foot long buried flank protection designed to protect an adjacent bridge from damage from future stream migration. This structure consists of class "C" riprap buried into existing ground and positioned at a 45 degree angle off of the bridge. The structure includes a 10-foot wide bottom width and 2H:1V side slopes buried 4-feet into the ground. A plan and profile view of the structure is shown in Figure C4.21 in Appendix C.

D3.12.3 Toe Protection Near Home, Structure BS2-45

This structure includes class "C" riprap buried into the streambank along the streambank toe. The toe protection is located along a stretch of home that is located near the edge of the top of the channel bank that would be threatened by channel degradation. The toe protection is designed to offer additional protection to protect the channel banks from degradation. The toe protection includes 2.5-foot thick riprap beginning at the ordinary high water mark elevation and at a depth of half of the channel bank height. A plan and profile view of the structure is shown in Figure C4.22 in Appendix C.

D3.13 Costs

The costs for the preferred alternative were determined by engineer estimates for project implementation based on recent, local experience and engineering judgement. The unit costs and total cost estimates for each structure within the preferred alternative are detailed below in Tables D3-1a – D3-1d. All estimated costs are subject to change due to local, regional, or world economics. The estimated cost for each proposed structure includes a 20 percent contingency to account for unforeseeable costs.

Table D3-1a. ARAs 1, 3, 5, and 6 Preferred Alternative Unit Costs

		ARA1		ARA 3	ARA 5	ARA 6
Engineer's Estimate (with 20% Contingency)		$79,070	$94,470	$121,240	$48,940	$74,660
Item	Unit	G2 42	G2 41-1 3	G2 43	SC-2	G2-2 2
Mobilization	LS	10% Cost	10% Cost	10% Cost	10% Cost	10% Cost
Strip & Remove Topsoil	CY					$4
Class "A" Riprap	TN		$90			
Class "B" Riprap	TN				$90	$90
Class "C" Riprap	TN	$90		$90		
Class "E" Riprap	TN		$100			
#3 Stone	TN				$90	
Aggregate	CY				$90	
Earthen Excavation	CY	$4	$4	$4		
Earthen/Sand Fill	CY	$4				$4
Seeding	AC					$2,000
Filter Fabric	SY		$3		$3	
Sheet Pile	SF			$32		
Flexamat	SY				$70	
Geogrid	SF				$3	
TRM	SY					$6

Table D3-1b. ARAs 7, 8, and 9 Preferred Alternative Unit Costs

		ARA 7				ARA 8	ARA 9
Engineer's Estimate (with 20% Contingency)		$30,880	$6,830	$192,120	$86,960	$385,180	$946,540
Item	Unit	P2-4	G2-5	G2 3 1 6, BS2 6 1 3	G2-7	G2-8 1-2	G2-9 1-3
Mobilization	LS	10% Cost	10% Cost	10% Cost	10% Cost	10% Cost	10% Cost
Strip & Remove Topsoil	CY	$4	$4				
Class "A" Riprap	TN		$90	$90			
Class "B" Riprap	TN	$90		$90			
Class "C" Riprap	TN				$90	$90	$90
Class "E" Riprap	TN			$100			
Gravel	TN						$30
Earthen Excavation	CY	$4		$4	$4	$4	$4
Earthen/Sand Fill	CY	$4	$4				$4
12" HDPE	LF	$118					
24" HDPE Riser	EA	$2,000					
6" PVC	LF		$12				
8" Slotted Riser	LF		$500				
Seeding	AC	$2,000	$2,000				$2,000

		ARA 7				ARA 8	ARA 9
Engineer's Estimate (with 20% Contingency)		$30,880	$6,830	$192,120	$86,960	$385,180	$946,540
Item	Unit	P2-4	G2-5	G2 3 1 6, BS2 6 1 3	G2-7	G2-8 1-2	G2-9 1-3
Filter Fabric	SY			$3			
Tree Clearing	AC						$3,500
Sheet Pile	SF				$32		
Bedding	SY						$11
Grout	CY				$300		

Table D3-1c. ARAs 10 and 11 Preferred Alternative Unit Costs

		ARA 10		ARA 11		
Engineer's Estimate (with 20% Contingency)		$86,070	$21,120	$91,650	$98,080	$233,430
Item	Unit	BS2 31	BS2 30	G2 33	CP2 34	G2 32
Mobilization	LS	10% Cost	10% Cost	10% Cost	10% Cost	10% Cost
Class "C" Riprap	TN	$90		$90		$90
Earthen Excavation	CY	$4		$4		$4
Earthen/Sand Fill	CY			$4	$6	
Seeding	AC				$2,000	
Filter Fabric	SY					$3
Tree	EA		$200			
Sheet Pile	SF	$32				
Obstruction Removal	AC				$2,200	
Duck Bill Anchor	EA		$150			
Steel Cable	LF		$2			

Table D3-1d. ARAs 12 and 13 Preferred Alternative Unit Costs

		ARA 12			ARA 13	
Engineer's Estimate (with 20% Contingency)		$336,000	$343,100	$30,990	$25,600	$183,710
Item	Unit	BS2 71	G2 70	BS 72	GS2 45	G2 46
Mobilization	LS	10% Cost	10% Cost	10% Cost	10% Cost	10% Cost
Class "C" Riprap	TN	$90	$90	$90	$90	$90
Earthen Excavation	CY	$4	$4	$4	$4	$4
Seeding	AC			$2,000		

D3.14 Sedimentation

Sediment will be trapped behind certain types of structures within the Preferred Alternative, Tier 1 sites. The proposed pond and sediment basin within ARA 7 are designed with permanent pools that will detain approximately 0.22- and 0.03-acre-feet of sediment, respectively at the end of their design life. The sills at ARA 1, 6, 9, and 11 include embankments that will additionally capture sediment over time. Due to the objectives at ARA 6 and land constraints, costs are included to dredge behind the sill at year 10 of the design life. See Table D3-2 for a summary of the volumes of sediment storage available behind the pond, sediment basin, and sill structures, and the associated sediment that will be captured over the design life.

Table D3-2. Sediment Storage

ARA	Structure	Sediment Storage (acre feet)
1	Sill	0.238
6	Sill with Fish Passage	9.96
7	Pond	0.218
	Sediment Basin	0.035
9	Sills (3)	4.868
11	Sill	0.145
	Total	**15.464**

D3.15 Site Selection

Sites were initially identified during the landowner and agency scoping meetings, held on February 18, 2020, described in Section 6.1. Posters of the areas within the watershed were provided for the public and agency representatives to physically mark the locations with pins that they would like to see addressed within the Plan-EA. Photos of two examples of pinned locations of interest from the scoping meeting are shown in Photographs D3-1a and D3-1b. Additional phone calls were held with landowners and agencies to identify and discuss locations with existing stream or habitat degradation and improvement locations. Interested landowners were identified through the scoping meeting and public meetings and from landowners who had previously shown interest in implementing measures on their land through other means, such as Environmental Quality Incentives Program (EQIP), the Sandhills Taskforce, USFWS, and others. Correspondence with NGPC also took place during the planning phase and NGPC provided several areas of interest for potential stream protection and restoration projects, which were included as Tier 1 and Tier 2 sites and are described in Section D5.2.1.

The identified sites were evaluated during the field visits that took place in June and October 2020 to determine site needs and the potential for different project measures. Sites were either designated as either high priority (Tier 1), low priority (Tier 2), or eliminated due to existing site conditions and feasibility of potential project measures. The priority of the site was determined due to a variety of factors such as urgency and need for proposed measures and practicability of implementing proposed measures. The sites determined to be suitable as higher priority projects were designated as Tier 1 and brought forward for analysis within the preferred alternative. Additional information is provided in Section D5.2.

Photograph D3-1a. Pinned Locations of Interest

Figure D3-1b. Pinned Locations of Interest

D4.0 STREAM ASSESSMENTS

In-field stream assessments were performed in October 2020 for streams within each Affected Resource Area (ARA). Information on the stream assessment procedure and results are detailed below.

D4.1 Nebraska Stream Condition Assessment Procedure

The October stream assessments were conducted according to the methodologies and procedures outlined in the U.S. Army Corps of Engineers (USACE) October 2016 Nebraska Stream Condition Assessment Procedure (NeSCAP). The NeSCAP scores for each reach are included in the NeSCAP calculation spreadsheet in Appendix E. NeSCAP scores V1 – V4 were determined during the in-field stream assessments. The V5 and V6 scores were based on aerial photography and observed site conditions during the field assessment.

D4.2 Stream Visual Assessment Protocol Version 2

The October stream assessments were additionally conducted in accordance with the Natural Resource Conservation Service (NRCS) Stream Visual Assessment Protocol Version 2 (SVAPV2). The SVAPV scores for each reach and the associated condition ratings are shown in Appendix E. Element 2–Hydrologic Alteration scores did not vary by evaluated reach and were therefore excluded from the SVAPV scores. The following SAPV2 Elements were determined to be irrelevant to the stream assessment and were therefore not recorded during the stream assessment:

- Element 13–Aquatic Invertebrate Habitat
- Element 14–Aquatic Invertebrate Community
- Element 16–Salinity

D4.3 Additional Stream Data

The Iowa DNR's Iowa River Restoration Toolbox (IRRT) is a tool that provides a series of best management practices to assist designers in stream stabilization and restoration projects. The IRRT requires inputs of existing stream condition. Additional stream condition parameters required for the IRRT that were not already included for the NeSCAP and SVAPV2, such as depositional patterns and bankfull areas, were recorded for each reach. The Bank Erosion Hazard Index (BEHI) components were recorded during the stream assessments and includes a combination of qualitative and quantitative values.

D5.0 NEBRASKA GAME AND PARKS COMMISSION (NGPC) CORRESPONDENCE

Correspondence took place between the Sponsor and the Nebraska Game and Parks Commission (NGPC) that guided the planning process and development of the proposed alternative. A summary of the information received from NGPC is detailed below.

D5.1 Project Background Information

The NGPC provided relevant background information on the watershed. NGPC explained that past watershed Plans typically do not offer concrete solutions to problems but rather describe existing problems and provide general recommendations for watershed improvement projects. NGPC provided context for a past project implemented in the Pine Glen WMA. The project was successful overall with only minor bank failures despite high flow conditions and no bank vegetation. The Class "D" Rock Riprap did not stay in place and were either carried downstream or buried in sediment. Cedar tree clearing along the floodplain was successful at the Pine Glen WMA project by allowing the channel banks to widen and therefore reduce shear stress and stream power.

An in-stream flow right was granted for Long Pine Creek on December 14, 1989 with an effective priority date of April 29, 1988. This water right was approved for the purpose of sustaining naturally reproducing Rainbow and Brown Trout in Long Pine Creek between the Highway 20 bridge to the confluence of Bone and Long Pine Creeks. Appropriation A-16642A is for 50 cubic feet per second (cfs) and appropriation A-16642B is for 60 cfs. An approved aquatic habitat plan was also developed for Long Pine Creek, which was used to facilitate habitat related projects and improve angler access. The aquatic habitat plan is generally only to be used on public lands.

NGPC shared photographs taken from the Keller Park SRA walking bridge that depict the entrenchment and widening occurring, typical of streams across the watershed. These photos are shown in the photographs below.

Photograph D5-1a. Keller Park SRA, 2015

Photograph D5-1b. Keller Park SRA, 2016

Photograph D5-1c. Keller Park SRA, Spring 2019

Photograph D5-1d. Keller Park SRA, Fall 2019

Photograph D5-1e. Keller Park SRA, 2020 Fall

D.5.2 Preliminary Design and Scoping Input

D5.2.1 Areas of Interest

NGPC provided areas of interest for potential stream protection and restoration projects, described below. When feasible, these areas were identified for Tier 1 or Priority 1 or 2 Tier 2 locations, as indicated below in italics. Tier 1 locations are shown in Chapter 4 of the Plan-EA and Tier 2 locations are shown in Section D5.0 of this Appendix. Tier 1 and Tier 2 are defined in Chapter 4, Section 4.0.

- Headwaters of Sand Draw and Bone Creek, the lower confluence of Long Pine Creek – these areas are known to inhabit threatened and endangered species and the *Fundulus sciadicus* (Plains Topminnow). *ARA 5, ARA 6, and various Tier 2 locations (see Section D5.0) address this area.*

- Sport Fishing Areas – NGPC has a high interest in protecting areas which either provide or are adjacent to public access for sport fishing opportunities. *Multiple Tier 2 locations focus on these areas.*
- Long Pine Creek – Long Pine Creek supports one of the best trout populations of rainbow and brown trout in the state and is a popular kayaking and tubing destination. NGPC has already spent a considerable amount of money along Long Pine Creek through specific habitat restoration, stocking, and in-stream flow protections to maintain the fishery. *Multiple Tier 2 locations focus on these areas.*
- Bone Creek: Keller Park State Recreational Area to Niobrara River – Bone Creek, between the Keller SRA and the Niobrara River, is a popular kayaking spot due to the turbulent water. This area has been heavily impacted by recent floods, altered flows, and sedimentation, which have eliminated some of the white water habitat features. FEMA funds have been used to address some concerns in this area. *ARA 12 and reach Tier2-G2-80 include this area.*
- NGPC Owned Properties – The Keller Park SRA, Long Pine SRA, Long Pine Wildlife Management Area (WMA) and the Pine Glen WMA are all owned by the NGPC. Proposed projects on NGPC lands can be used to demonstrate the projects to landowners for future development. Recent projects have been completed at the Long Pine SRA and Pine Glen WMA and on private land between them. *Tier2-H2-52 is within NGPG owned properties.*
- Sand Draw – The landowner had applied for Wetland Reserve Easement (WRE) but will likely not be funded. Interest in a smaller Flexamat structure with the objective of maintaining hydrology and cleaning out of invasive species. *Tier2-G2-1 and Tier2-H2-2 include this area.*
- Hidden Paradise on Long Pine Creek – Experiencing bank erosion from high precipitation events. Continued erosion could affect the downstream trout population on Long Pine Creek. *Tier2-BS2-51 is just upstream of Hidden Paradise. Hidden Paradise is a unique community in a deep valley with residences directly along the creek and therefore options are limited in this area. During the planning process, residents of this community expressed continued concerns about water quality and guidance was given when possible.*

D5.2.2 Preferred Practices

NGPC provided input on preferred potential practices and solutions based on their experience within the watershed and species of interest. Their highest priority recommendation, for Sand Draw Creek in particular, was coordination with the Ainsworth Irrigation District (AID) or other irrigation management practices to identify and support potential solutions for reducing excess water. The Iowa River Restoration Toolbox (IRRT) was recommended as a reference for stream restoration resources and references. Additional practices NGPC promoted are listed below.

- In-stream habitat improvements where species are present (ex: rock and log habitat structures that could be also be used to redirect flow)
- Headcut preventions
- Beaver dam analogues
- Riparian management (ex: Cedar removal)

- Livestock control such as off-stream water development for livestock, fencing, prescribed grazing
- Stream fish/aquatic organism passage structure: good Wildlife Initiative (WIN) application through the Environmental Quality Incentives Program (EQIP)
- Flexamat structures
- Zeedyk structures
- Cedar revetments
- Stream crossings
- Headwaters excavation where narrowleaf cattail have taken over former open water habitats
- Old oxbow/floodplain wetland restoration

Natural channel design and Priority 2 stream restoration were additional recommended practices to be used in upstream reaches. Downstream reaches with extreme degradation and widening should be avoided due to the exorbitant and higher risk of failure from ongoing migration of major headcuts and other destabilizing forces. Priority 2 stream restoration is included as a programmatic alternative.

D5.2.3 Additional Information

Additional information provided by NGPC staff is included below.

- Species locations
    - Old Highway 7 is the approximate cut-off point for at-risk species along Sand Draw and Bone Creek, despite the culvert at Old Highway 7 having recently blown out and the headcut that has moved upstream.
- Funding from NGPC is most readily available for headwater species.
- The Plains Topminnow is currently listed as a Tier 1 species under the Nebraska Natural Legacy Program but is being considered for federal listing. NGPC has a special interest in protecting the Plains Topminnow to protect it from becoming federally listed.
- Site-specific species of concern within ARA 5 (see Figure 4-4) are headwater species. These species congregate and thrive in low velocity pool habitats.
    - Plains Topminnow
    - Pearl Dace
    - Northern Redbelly Dace
    - Finescale Dace
    - Blacknose Dace

D6.0 FRAMEWORK FOR NHPA COMPLIANCE FOR TIERED ALTERNATIVES

A Programmatic Agreement is being drafted in coordination with SHPO and USACE to define commitments to NHPA Section 106 for the Tier 2 projects. It will formalize that a professional archeologist will complete a cultural resources survey of the ARA for each Tier 2 location, and NRCS will consult with SHPO and the Tribes on each Tier 2 project. During the EE process, Step 3 on the Cultural Resources guide sheet of the NRCS-CPA-52 will always be checked "Yes" because all the practices proposed for Tier 2 are undertakings that will require consultation. Step 4 of the guide sheet will be filled in by the Nebraska Cultural Resource Specialist or Archaeologist after Section 106 consultation is complete. The Programmatic Agreement will be finalized and included in Appendix E.

D7.0 PREVIOUS STUDIES

Previous studies have taken place for the watershed and areas within the watershed. These studies were referenced during the development of the Plan-EA and are detailed below.

- Nebraska Long Pine Creek, Rural Clean Water Program; Ten-Year Report (1991) – In 1981, the watershed was selected for the experimental Rural Clean Water Program (RCWP), which is a federally-sponsored program designed to control agricultural nonpoint source pollution to improve water quality. The implemented BMPs and results of the implemented BMPs are detailed in the ten-year report. Cedar revetments were one of the most innovative and successful practices implemented under the RCWP by providing streambank stabilization and a variety of habitat benefits to trout and other aquatic life. Several other BMPs were implemented through the RCWP, some of the most successful being irrigation tailwater recovery systems to manage irrigation runoff, establishment of permanent vegetative cover, sediment retention, erosion, or water control structures, and grazing land protection systems.
- Long Pine Creek Watershed Water Quality Management Plan (2016) – This plan was prepared to develop and implement future projects to improve water quality and aquatic resources in the Long Pine Creek Watershed. The plan prioritized subwatersheds to focus management practices towards special priority areas such as Hidden Paradise, Long Pine Creek Corridor, Bone Creek Corridor, and Wellhead Protection Areas. The plan recommends a variety of BMPs such as detention basins, stream restoration projects, riparian fencing and waste control, alternative livestock water, irrigation management, cover crops, and filter strips.
- The Extent and Value of Agricultural, Municipal, and Industrial Water Use in the Niobrara Basin (2010) – The research project provides information on the current and potential extent and value of out-of-stream ground/surface water resources across the Niobrara Basin.
- Annual Operating Plans; Niobrara, Lower Platte, and Kansas River Basins (2018/2019) – Summary of 2018 actual operations and 2019 annual operating plans in the Niobrara, Lower Platte, and Kansas River Basins.
- The Nebraska Center-Pivot Inventory: An Example of Operational Satellite Remote Sensing on a Long-Term Basis (1989) – Summarizes the history, procedures, and results of a long-term program of inventorying center-pivot irrigation systems in Nebraska.
- Nebraska Statewide Groundwater – Level Monitoring Report (2013) – Statewide synthesis of groundwater level monitoring programs in Nebraska.
- Simulation of Groundwater Flow, 1895 – 2010, and Effects and Additional Groundwater Withdrawals on Future Stream Base Flow in the Elkhorn and Loup River Basins, Central Nebraska – Phase Three (2018) – Study focused constructed regional groundwater-flow models to evaluate the effects of groundwater withdrawal on stream base flow in the Elkhorn and Loup River Basins, Nebraska.
- Estimating the mechanical effects of riparian vegetation on stream bank stability using a fiber bundle model (2005) – Study that assesses the impact of the differences between root models on stream bank factor of safety values.

- Stability Thresholds for Stream Restoration Materials (2001) – Study that provides empirical data for shear thresholds for soils and erosion control materials.
- Mechanisms of vegetation uprooting by flow in alluvial non-cohesive sediment (2011) – Study evaluates the establishment and uprooting of riparian vegetation and evaluating how flow-induced uprooting depends on vegetation stages.
- Water Quality and Chemical Evolution of Ground Water in the Long Pine Creek Area, Brown and Rock Counties, Nebraska (1993-94) – Study of water-level and water-quality data from twenty-one groundwater observation wells in the Long Pine Creek Drainage Basin.
- 2017 Nebraska Water Monitoring Programs Report (2018) – Summary of the Nebraska Department of Environmental Quality (NDEQ) monitoring programs set up to manage Nebraska's water resource to protect high quality water and improve poor water quality.
- Middle Niobrara NRD Ground Water Management Plan (1995) – Plan that evaluates the status of the district's groundwater and develops a procedure for protecting it in the future.
- Ground-Water Resources of the Ainsworth Unit; Cherry and Brown Counties, Nebraska (1956) – Study to determine the potential annual yield of groundwater from the aquifer underlying the Ainsworth tableland, the quality of the groundwater throughout the Ainsworth unit, and the effect of the proposed canal on the position of the water table and quality of the water in the sandhills part of the area.
- Hydraulic and Bituminous Studies of Ainsworth Canal Dune Sand, Missouri River Basin Project, Nebraska (1954) – Studies on the Ainsworth Canal and allowable tractive forces and the effects of a high groundwater table.
- Apparent Resistivity and Estimated Interaction Potential of Surface Water and Groundwater along Selected Canals and Streams in the Elkhorn-Loup Model Study Area, North-Central Nebraska (2006-07) – Study that investigates the surface-water and groundwater interaction in north-central Nebraska.
- Merritt Dam; Technical Record of Design and Construction (1968) – Provides a record of the design, construction, and initial operation of the Merritt Dam.
- The Ainsworth Unit; Sandhills Division Pick-Sloan Missouri Basin Program (1999) – Provides a history of the Ainsworth Unit.
- Cool Water Stream Management Plan (2016 – 2020) – The plan used to identify goals for stewardship of cool water stream resources in Nebraska and to develop measurable means to achieve the goals.
- Middle Niobrara NRD Master Plan (2012) – Provides a history of the Middle Niobrara NRD and past projects.
- Public Niobrara Basin-wide Planning Survey Summary (2015) – Details the Niobrara Basin-wide plan between the Nebraska Department of Natural Resources (NDNR) and five Natural Resources Districts to sustain a balance between water uses and water supplies.

D8.0 COST-EFFECTIVENESS ANALYSIS

Non-water resource projects do not require the development and identification of national economic benefits (NWPM, 2015) but they must be formulated in accordance with PR&G economic procedures. An economic and cost effectiveness analysis was prepared for each Tier 1 reach/location utilizing the NRCS Water Resource Handbook for Economics and the least costly socially and environmentally acceptable measure that could meet the determined level of resource protection was selected as part of the preferred alternative. In accordance with 611.0301(f) of the NRCS Water Resource Handbook for Economics, a cost effectiveness analysis was completed utilizing an interdisciplinary team and the outlined four step procedure. Consideration was given to all resources, including the human consideration. This analysis is included for all Tier 1 measures in Appendix E.

Care was taken to follow the outlined procedure for each reach/location. Step 1 included determining the nature and scope of the problem, including identifying the thresholds for analysis. For example, in a location where there is a need to prevent the migration of a 4-foot impending headcut to protect infrastructure and preserve the CEM of upstream sites, the threshold would be the 4 feet of grade stabilization. Steps 2a included identifying all potential alternatives that could address the problem and identifying if it was technically feasible. Some examples of removing measures due to technical feasibility include inducing adverse impacts such as flooding and aggradation, the measure not being practical on the size of stream, or impacts to infrastructure. Step 2b analyzed each measure that moved on from Step 2a to determine if the conservation practice selected for installation could satisfy the requirement that it not be more costly than any reasonable alternative means of accomplishing the same specified objective (NREH 611.0301(f)). These alternatives were analyzed with engineering judgement to determine if they should be brought forward for a more thorough cost estimate. Examples of measures not being brought forward include measures requiring extensive excavation or large footprints, measures requiring specialized modifications to ensure fish passage or to accommodate farm equipment, or exorbitant amounts of riprap. For measures that passed the analysis of Steps 1 – 2b, a common base for cost effectiveness was identified and measures were compared. The common base was determined utilizing the threshold and scope of the problem identified in Step 1. A cost estimate for each measure brought forward to Step 3 was determined using unit costs shown in Section D3.13. These costs per measure were used in conjunction with the identified thresholds and common base (for example, cost per foot of grade maintained upstream). The least costly alternative was then chosen for inclusion as the preferred alternative for that location/reach.