APPENDIX D – INVESTIGATION AND ANALYSIS

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D1.0 INTRODUCTION

This appendix provides supporting information for the formulation, evaluation, and conclusions of this Draft Supplemental Plan-EA. Items of a routine nature are not included; however, citations are included throughout the Draft Supplemental 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 8.0 of the Draft Supplemental Plan-EA.

The NRCS planning 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, Future Without Federal Investment, 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 PREFERRED ALTERNATIVE DESIGN DETAILS

D2.1 Loose Rock Structures

Loose rock structures were designed for the purpose of grade stabilization. The locations of each loose rock structure were selected based on the existing head cuts, estimated future change in grade, and minimization of impacts. Observed stream characteristics from aerials, LiDAR, and field reconnaissance were used to analyze existing stream conditions. Field reconnaissance was performed at each site in June 2019 and included verifications of headcuts, knickpoints, measurement and characterization of stream geometries, identification of utilities, bed material, and rapid assessment of stream function. Existing grade control structures (most often in the form of culverts and other protected road crossings) were identified to determine potential stream bed loss. Previous analyses within the watershed have determined an estimated stable stream slope grade of 0.0016 feet/feet (0.16%). Potential future stream profiles were developed using the following assumptions:

- Streams will degrade through headcut progression, with the downstream slope driving the elevations
- The future 'stable' stream profile is 0.16 percent
- Existing grade control structures are assumed to remain intact and therefore the elevations upstream of these structures would remain constant from present-day to future conditions
- Culverts are assumed to act as grade control structures
- Maximum future degradation height of 4-feet

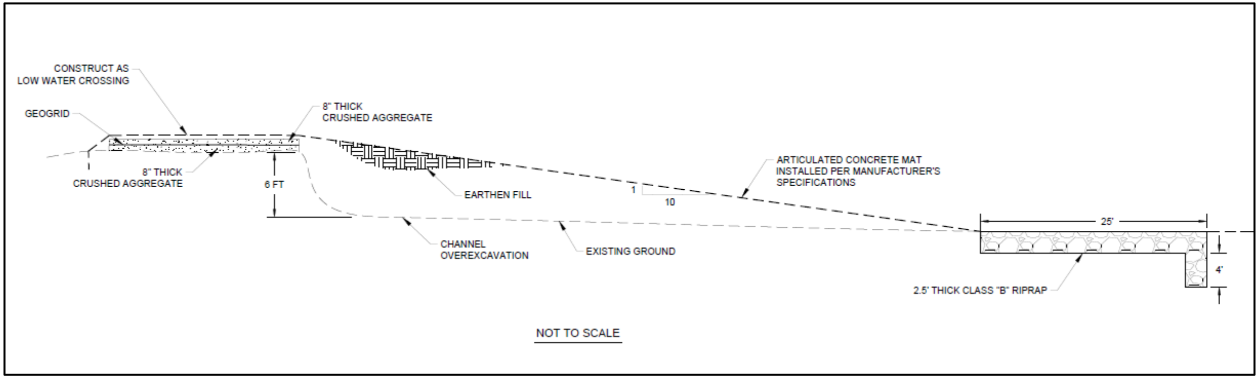
Using these assumptions, loose rock structures were positioned to 'catch' future headcuts and maintain future drops of not more than 4-feet. Impacts to wetlands, tributary confluences, existing infrastructure, and existing gullies were all considered and structures were placed to minimize wetland impacts and maximize protection benefits where applicable. The stream setback areas of the existing and future channels were calculated using a 3H:1V channel bank side slopes and a 50-foot wide buffer from the top of the 3H:1V channel banks. Stream widths were determined from a mix of field reconnaissance recorded values and LiDAR data. 2010 LiDAR data was used for the channel bottom elevation for the existing condition set back areas and the future setback areas were calculated 0.16 percent channel slopes. A preliminary cost to benefit analysis was performed and it was determined that costs begin to outweigh monetary land savings benefits when land protection from future degradation and widening is less than approximately 1-acre. This threshold was used to determine the number of structures at each location.

The loose rock structure is designed for long term stability, low maintenance, and resilience of future infrequent runoff events. The structure includes Nebraska Department of Transportation (NDOT) Type C gradation rock riprap that will be placed along the stream channel bottom and partially up the banks to a bank elevation of the 100-year flood event or top of bank, whichever is lower. The structures are approximately 46-feet long and excavation along channel banks will occur for approximately 40-feet to achieve a 3H:1V channel bank slope above the 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. Please see Appendix C for a plan and profile view of the stream stabilization structure design.

D2.2 D-2 Rigid Drop Structure

An headcut, approximately six feet tall, exists within the channel at Site D-2. The land directly upstream of the drop is currently being used as a crossing for farm equipment. Due to the drop exceeding the 4-foot vertical elevation difference that the loose rock structures are designed to withstand, a rigid drop structure is being proposed at the location of the existing drop. The location of the rigid drop structure is shown in the figure provided in Appendix C. The structure will provide a reinforced crossing for farm equipment and will stop the headcut from progressing further, thus protecting the upstream Hwy 133 embankment from damage. The preliminary design includes crushed aggregate and a geogrid over the existing crossing with an articulated concrete mat over the crushed aggregate and at a 10H:1V slope into the channel. Earthen fill will be placed underneath the articulated concrete mat and 25-feet of riprap will be placed at the downstream end of the drop structure. The articulated concrete mat is 5-feet wide. The channel side slopes will be graded at a 3H:1V slope and the concrete mat will extent on both sides into the channel for a vertical height of 2-feet. Headcut progression and proximity to Hwy 133 will need to be accounted for in final design to ensure proper placement and compliance with NRCS grade stabilization structure (code 410) conservation practice standards. Please see Figure D2-1 for a profile view of the rigid drop structure at Site D-2.

Figure D2-1. Site D-2 Rigid Drop Structure Profile View



D2.3 S-15 Rigid Drop Structure

An existing drop, approximately 10-feet tall, exists within the northern tributary at Site S-15. Due to the drop exceeding the 4-foot vertical elevation difference that the loose rock structures are designed to withstand, a rigid drop structure is being proposed at the location of the drop instead of a loose rock structure. The location of the rigid drop structure is shown in Appendix C. The proposed design follows NRCS grade stabilization structure (code 410) conservation practice standards and includes placing earthen fill in the 10-foot deep hole to create a 10H:1V slope to existing ground and use an articulated concrete mat on top of the fill to accommodate the high velocities at this location. The articulated concrete mat will be 15-feet wide. The channel banks will be graded out to a 3H:1V slope on both sides of the concrete mat and the concrete mat will extend 5-feet vertically on both side slopes. Riprap and sheet pile will be placed at the downstream end of the structure to provide grade control and maintain stability at the structure. The plan and profile view of the rigid drop structure at Site S-15 are shown below in Figures D2-2 – D2-3.

Figure D2-2. Site S-15 Rigid Drop Structure Plan View

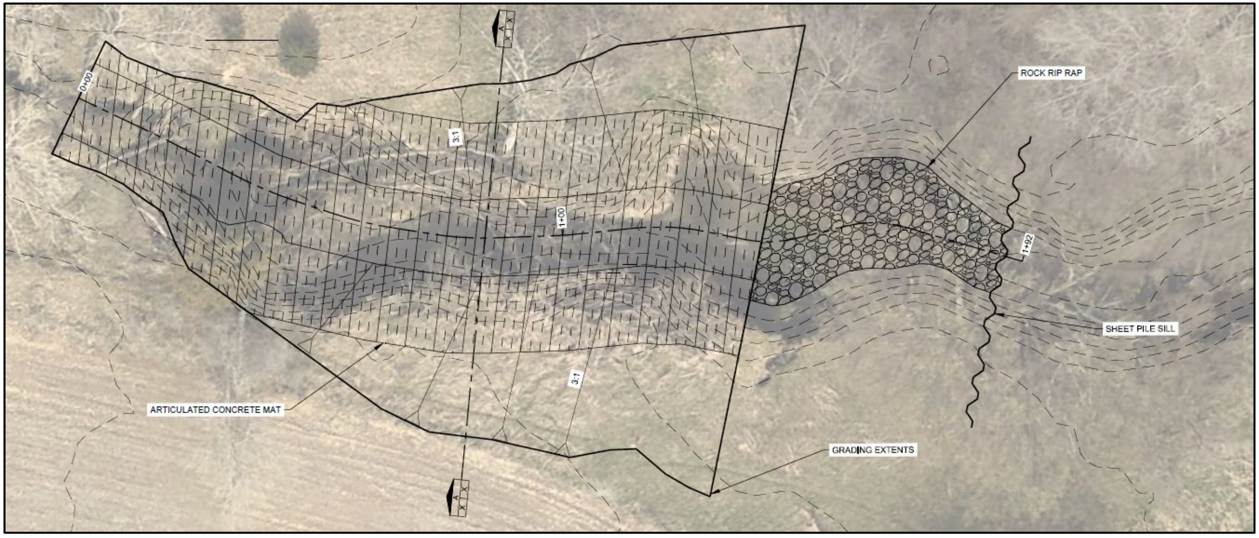
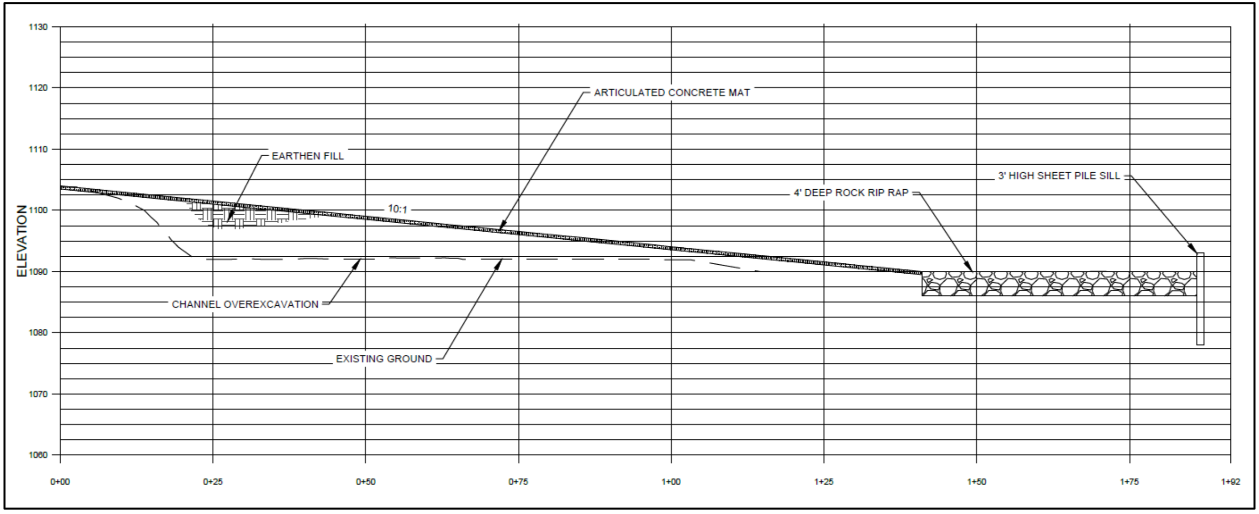


Figure D2-3. Site S-15 Rigid Drop Structure Profile View



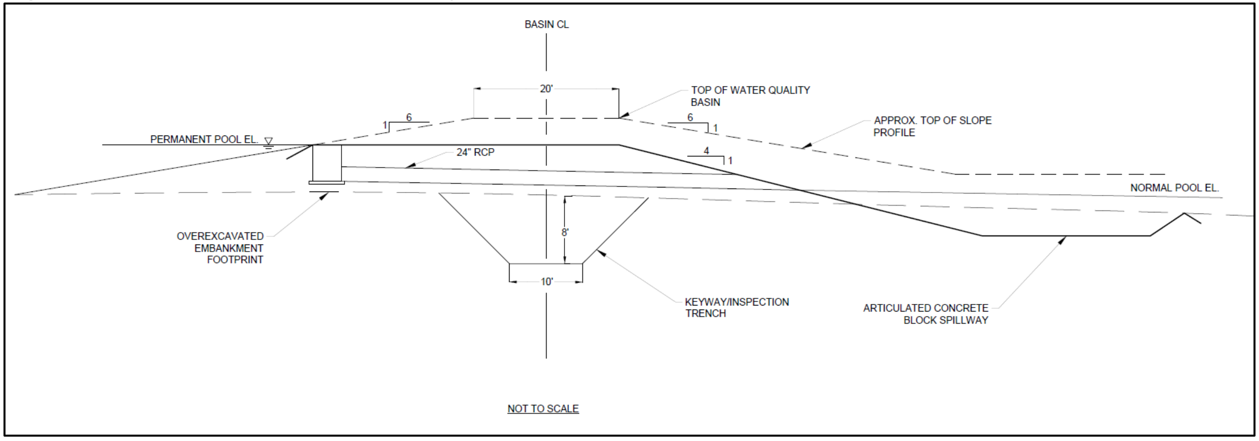
D2.4 S-1 Water Quality Basin

A water quality basin is being proposed at Site S-1, shown in Appendix C. The water quality basin was based on a previously planned water quality basin (WQB) by the Sponsor, known as the Dam Site 19 North Water Quality Basin (DS19 NWQB). The DS19 NWQB is a proposed water quality basin that was preliminarily designed in 2018 and is located upstream of the Sponsor-planned high hazard potential DS-19 regional detention structure. Both are part of the Papillion Creek Watershed Management Plan, developed by the Papillion Creek Watershed Partnership (2009, 2014). The location of this alternative's WQB was selected based on previous studies, the alternatives analysis provided in this document, and to minimize wetland impacts. 2016 LiDAR was used to find the stage storage volumes and the permanent pool volume was set based on previous studies and the DS-19 design. NRCS sediment basin (code 350) conservation practice standards were followed for the preliminary design.

A HEC-HMS model was developed to run the hydrologic storms and set the top of the water quality basin elevation. The drainage area was divided into two subbasins in HEC-HMS to more accurately represent basin runoff volumes and timing. Curve numbers were computed in accordance to the methodology in the NRCS TR-55 Urban Hydrology for Small Watersheds. Land uses were determined based on aerial imagery and future conditions were accounted for by assuming a future build-out that would result in 30 percent impervious area. A broad-crested auxiliary spillway was used and its elevation was set at the permanent pool elevation. This water quality basin was designed without flood storage to reduce the amount of required land acquisition. The top of the water quality basin elevation was set at the 500-year, 24-hour storm event using an Atlas 14, 24-hours 90 percent 4th Quartile temporal distribution.

Previous studies calculated the maximum discharge through the downstream box culvert underneath South 204th Street using an HY-8 analysis (HDR, 2018). The peak breach discharge for the S-1 WQB was calculated in accordance with the peak breach discharge criteria in TR 210-60 Earth Dams and Reservoirs for varying top of dam elevations. These peak breach discharges were compared against the maximum discharge through the downstream culvert. An auxiliary spillway width of 150-feet wide was selected to ensure a peak breach discharge below the maximum discharge through the downstream culvert and, therefore, ensure that the downstream road would not be overtopped in the case of a sudden breach. This alternative would be built in conjunction with the Sponsor-planned DS-19 regional detention structure, leveraging Federal, state, and local funds and contributing to the overall goals of the watershed. Please see Figure D2-4 for a profile view of the water quality basin at Site S-1.

Figure D2-4. Site S-1 Water Quality Basin Profile View



It was assumed that land will be purchased for the embankment and top of dam extents. Additionally, the assumption was made for the cost determination that when the land purchase area encompasses over ¾ of the parcel, the whole parcel will be purchased. Unit costs are proved in Section D5.1and total costs, including land acquisition, permitting, mitigation, and construction observation are provided in Table 4-3a in the Supplemental Plan-EA.

D2.5 WP-1 Regional Detention Site, Wet Dam

The WP-1 regional detention basin site is located on Whispering Ridge Creek, a left bank tributary to West Papillion Creek, in Section 5, Township 15 North, Range 11 East, in Douglas County, Nebraska (Figure 1, Appendix B). The creek flows southerly through the project site, which is bordered by Fort Street to the north, North 180th Street to the east, West Maple Street (Nebraska Highway 64) to the south, and agricultural fields to the west. The contributing drainage area at the proposed impoundment is approximately 1.3-square miles (852-acres). The WP-1 regional detention basin is located in the upper reaches of the Papillion Creek Watershed.

The drainage area of WP-1 is entirely confined to the North Branch West Papillion Creek-West Papillion Creek HUC 12 (102300060101). The drainage area of WP-1 is primarily agricultural land with expanding residential development. The soil consists of silt loam to silty clay loam. The topography of the WP-1 drainage area is typical of the upland areas within the watershed, with moderate to steeply sloping hills and deep, incised valleys with relatively steep valley slopes. Whispering Ridge Creek, located upstream of WP-1, is a narrow bottom channel with wooded banks and stream gradient averaging 65-feet per mile, similar to other tributaries within small watersheds in the region.

The dam structure consists of an earthen embankment approximately 900-feet in length. The top of dam (TOD) elevation is set at the 1,194-foot elevation, which is approximately 40-feet above the channel bottom. The structure would require an estimated 130,000 cubic yards (cy) of compacted earthen fill material.

The principal spillway consists of a 4-foot by 12-foot concrete riser and a 48-inch reinforced concrete pressure pipe. An impact basin is proposed at the principal spillway outlet. The elevation of the principal outlet is 1,178 ft. The earth cut, vegetated auxiliary spillway is located at the dam's left abutment with a crest elevation of 1,189-feet. The auxiliary spillway would have a 200-foot wide bottom, 50-foot long crest, 3H:1V side slopes, a 1.0 percent approach slope, and a 4.5 percent downstream slope.

The WP-1 reservoir would impound a permanent pool at an elevation of 1,178-feet based on a reservoir sustainability ratio of 2.5 percent (the percentage of lake surface area to drainage area). The permanent pool would have a surface area of approximately 21-acres and provide approximately 785 acre-feet (ac-ft) of storage. The mean permanent pool depth would be approximately 6-feet, with depths up to 23-feet within the submerged channel alignment. The WP-1 reservoir would provide a total of 1,164 acre-feet of storage volume and a maximum flood pool area of 80-acres at the TOD elevation.

A sediment basin structure consisting of a berm and culvert is located upstream of the dam structure and downstream of Fort Street and was designed to extend the life of the downstream reservoir. The sediment basin will provide an area of shallow inundation for the purposes of improving water quality and decreasing sediment transfer to the main reservoir. The sediment basin would impound a permanent pool of approximately two acres in surface area at an elevation of 1,180-feet and would store approximately 3 acre-feet of sediment. The sediment basin would store approximately 28 acre-feet of water between the top of the sediment basin and permanent pool (elevations 1,180-feet and 1,184-feet respectively).

At the proposed normal pool elevation, the WP-1 reservoir would provide the following:

- Reduction of the 100-year peak discharge (for 2040 land use conditions) from approximately 2,035 cfs to 245 cfs at the principal spillway outflow.
- Reduction in the 500-year peak discharge (for 2040 land use conditions) from approximately 2,866 cfs to 265 cfs at the principal spillway outflow.

- Sediment storage capacity of 98 acre-feet below the principal spillway riser, which exceeds NRCS sediment-storage design criteria (USDA 2008a) and is adopted by the Nebraska Department of Natural Resources (NDNR).
- Permanent storage capacity of approximately 785 acre-feet; Flood control effects and water quality benefits downstream through West Papillion Creek.
- Improved water quality by mitigating stormwater discharge effects through reducing sediment and pollutant loads in downstream receiving waters.

WP-1 is classified as a high hazard dam according to the NeDNR Classification of Dams (NeDNR, 2013) and design specifications described in NRCS Technical Release 210-60 (TR 210-60). 12-hour rainfall depths and distributions for the 10-year, 100-year, and 500-year events were developed by AWA (Applied Weather Associates) for the P-MRNRD and used in the design of the principal and auxiliary spillway. The AWA rainfall data does create higher peak discharges and runoff volumes when compared to the NOAA Atlas 14 values and Type 2 distribution, which establishes a conservative design approach. The 6-hour Nebraska Statewide Probable Maximum Precipitation (PMP) was used to determine the freeboard hydrograph.

Storm recurrence intervals provide a basis for design calculations. Recurrence intervals quantify the rainfall depth necessary to reach the maximum carrying capacity of a facility or the rainfall depth required when flooding begins in a location. Storm classification is then based upon a scale of 100. For example, a rainfall depth that has a 100 percent chance of occurring every year is a 1-year storm event and a rainfall depth with a 50 percent chance of occurring in a given year is a 2-year storm. This is a consistent relationship for the 20 percent (5-year), 10 percent (10-year), 4 percent (25-year), 2 percent (50-year), 1 percent (100-year), 0.5 percent (200-year), up to the 0.2 percent (500-year). Some design examples would be that surface features such as trails may be become inundated or city streets may be designed to only convey more frequent storms such as a 10-year while flood protection structures are regularly required to meet 100-year or 500-year protection levels.

When designing a flood control dam there are several hydrographs that are developed to help guide design decisions. The principal spillway hydrograph (PSH) is a tool used to help determine the size of the principal spillway. All precipitation events equal to or less than the PSH will flow through the principal spillway without any flow through the auxiliary spillway. The stability design hydrograph (SDH) is used to build hydraulic models to analyze the erodibility of earthen auxiliary spillways, such as the one used at site WP-1. In the case of a Dam such as WP-1 there are rainfall values related to dam safety which are the probable maximum precipitation (PMP) storm events that are used to develop the freeboard hydrograph (FBH), which is used for calculating the top of dam elevation and necessary for public safety.

The United States Army Corps of Engineers (USACE) HEC-HMS program was used to perform the reservoir routing. The NRCS Water Resources Site Analysis (SITES) program was used to provide a check for the reservoir routing as well as perform auxiliary spillway stability calculations. Times of concentration and lag times for the site were computed in accordance with the methodology presented in the National Engineering Handbook Part 630 - Hydrology, Chapter 15 - Time of Concentration within the National Engineering Handbook. Curve numbers (CNs) were determined from land use and hydrologic soil group according to the procedure set forth in TR-55. Existing land use was identified using the 2011 National

Land Cover data. Proposed land use was estimated based upon the City of Omaha future land used map dated August 26, 2015.

D2.6 Dam Breach Analysis

A dam breach analysis was performed for dam hazard class protection according to the procedures outlined in the NRCS Technical Release 66 (TR-66) and TR 210-60. The breach hydrograph was developed by first computing a breach peak outflow using TR-60 equations with dam embankment and reservoir storage information as inputs. The hydrograph was then created by using the TR-66 attenuation-kinematic (Att-Kin) curvilinear routing equations. The hydrographs were run through a HEC-RAS 1-D, unsteady hydraulic model with the Little Papillion Creek serving as the downstream boundary condition. The breach analysis was performed to a level of detail to sufficiently confirm the hazard classification and restrict development downstream. WP-1 was assigned a high hazard classification based on the criteria contained in the Classification of Dams by the NeDNR. The breach inundation map, included in Appendix C, shows sunny day dam breach flows.

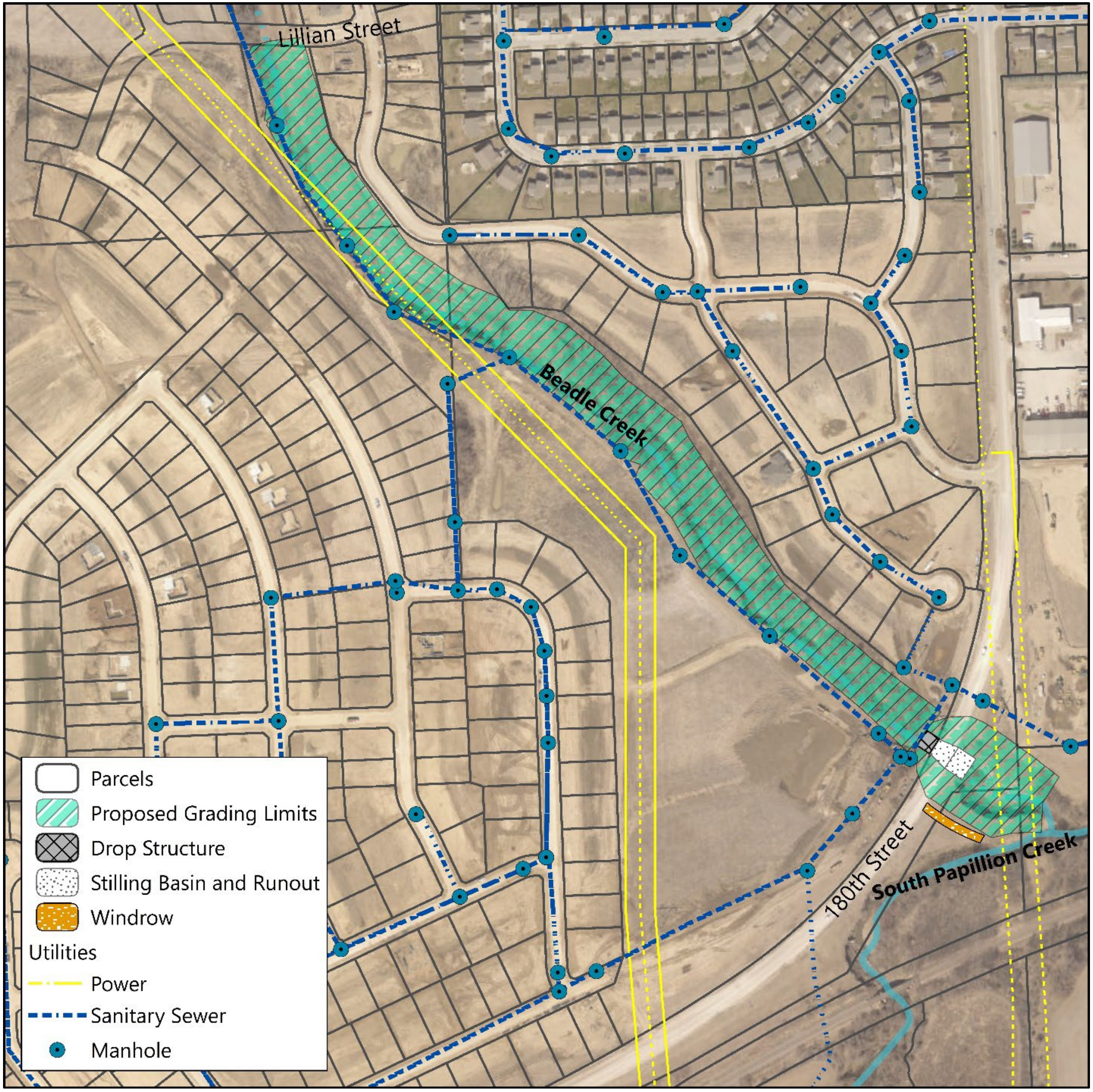
D2.7 S-5 Stream Restoration Alternative

The Site S-5 project extents include Beadle Creek from the Lillian Street crossing downstream to the confluence of South Branch Papillion Creek. Beadle Creek represents a nearly fully degraded channel throughout these extents, with the creek depth exceeding 20-feet. The area for channel work is limited on both banks by developed properties and valuable infrastructure including residential lots, an interceptor sanitary sewer, and power transmission lines, which leave a maximum allowable channel width of approximately 120-feet at the narrowest point. A culvert crossing at South 180th Street is providing protection from an additional 8- to 10-feet of impending headcut which must continue to provide protection until a permanent solution can be installed. The culvert at South 180th Street is a controlling structure consisting of a 10-foot diameter corrugated metal pipe (CMP) which causes substantial backwater during high flow events. Improving the conveyance capacity of this structure will improve flooding concerns upstream. Sarpy County plans to realign South 180th Street to cross South Branch Papillion Creek and the existing railroad and install a bridge downstream of the existing culvert. Design is underway for both the roadway realignment and bridge and construction is expected to begin in 2021.

The design process for S-5 was an iterative approach that balanced the available land rights, infrastructure proximity, flooding impacts, stream stability, public safety, and stream habitat and quality. Photograph D2-1 shows existing conditions along Beadle Creek and Figure D2-5 shows the existing infrastructure and property lines.

Photograph D2-1. Existing Conditions at S-5

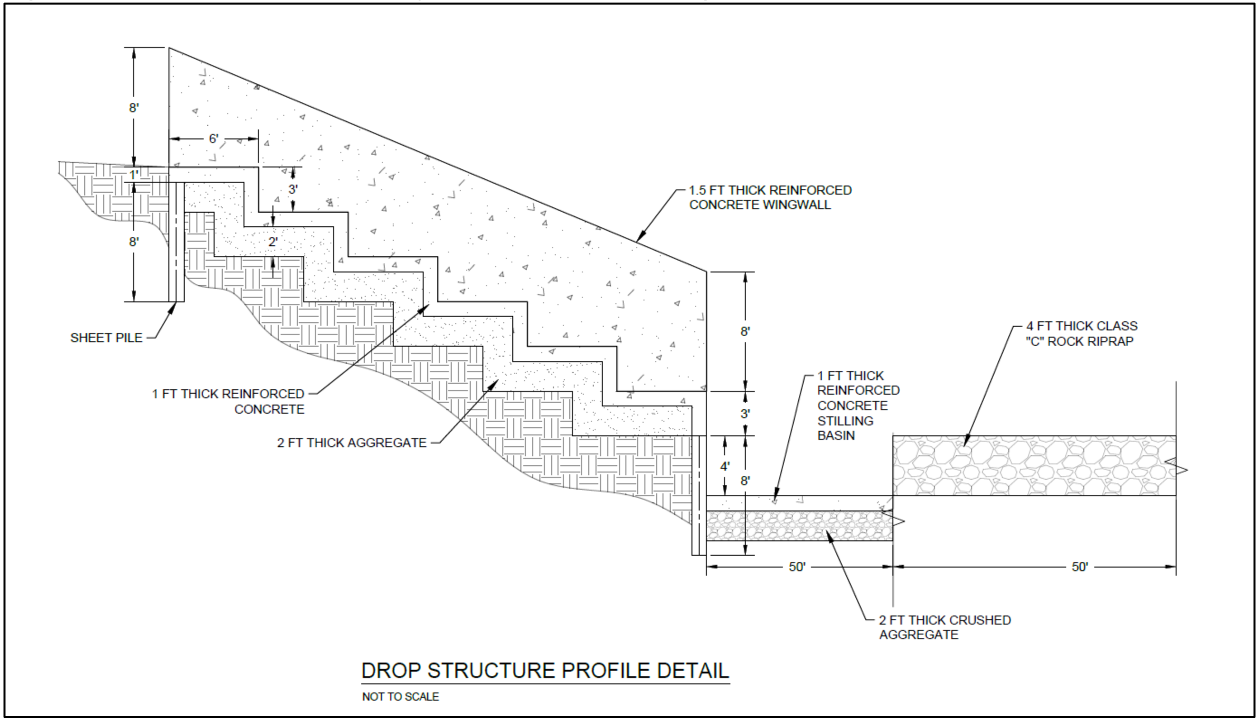
Figure D2-5. Site S-5 Existing Infrastructure and Project Limits



Removing the South 180th Street culvert and replacing it with an armored drop structure was considered the only feasible option due to its proximity to the confluence of South Papillion Creek, the existing headcut at the downstream end, and very high unit discharge of over 100 cubic feet per second per linear foot (cfs/lf). This armored drop structure would protect the upstream channel from the approximately 10-foot headcut at the existing culvert and allow for significant energy dissipation within a controlled footprint. While several NRCS structure types are available, the high unit discharge drove the design alternative toward a reinforced-concrete stepped spillway. USBR PAP-0951 and HL-2015-06 were utilized as a basis for an approximate stepped spillway design (shown in Figure D2-6 below) and the exact design will be optimized during final design. As flow characteristics tend toward a smooth spillway as step sizes decrease (thereby minimizing energy dissipation), each step should consist of a 2- or 3-foot drop with a 4- or 6-foot wide step

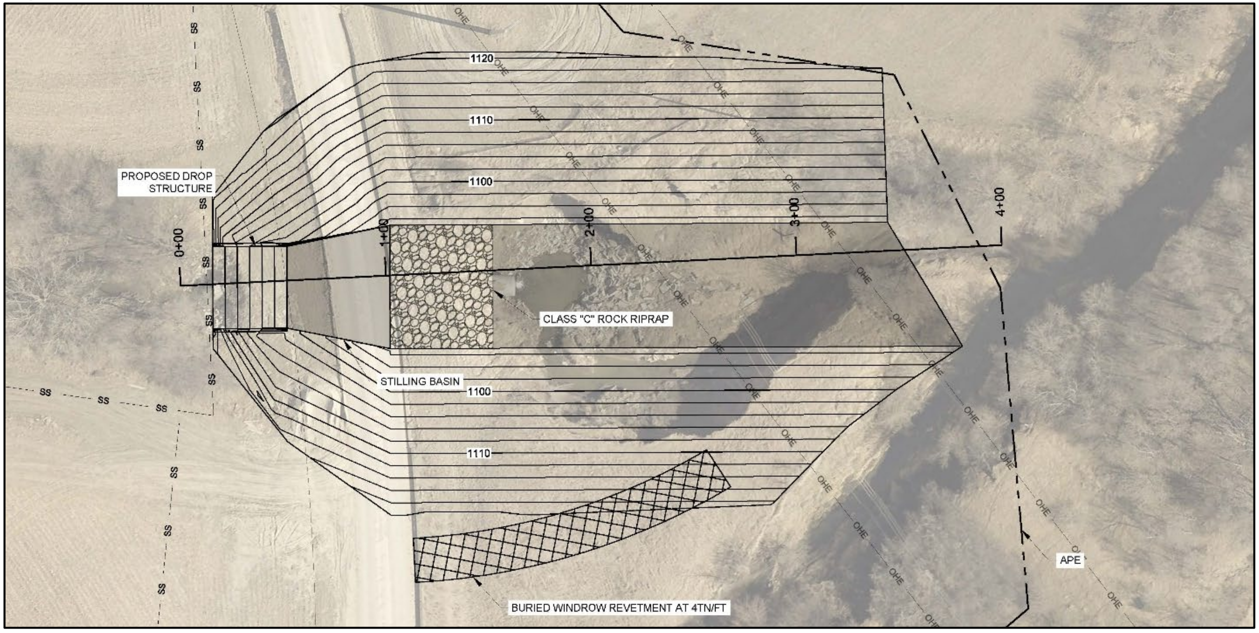
(1:2) to ensure adequate interception of the nappe for the vast majority of event discharges with transition to skimming flow occurring during more significant events. The exact transition and energy dissipation will be calculated during final design when step width to height ratio is decided. For this planning effort, this ratio is assumed to be 1:2. Flow is anticipated to be between 6- and 8-feet deep during a 500-year event with a 40-foot wide base width over the stepped spillway. The sidewalls within the reinforced-concrete section will consist of reinforced-concrete to a height of 8- to 10-feet to contain the 500-year event and earthen side slopes will be graded at a 3:1 to natural ground above this concrete wall. The steps, while high at 3-feet, are the upper limit of what is considered safe should the public gain access to the site while also maximizing energy dissipation.

Figure D2-6. Site S-5 Preliminary Drop Structure Design



A reinforced concrete stilling basin with a 4 to 6-foot tall, slotted end sill is planned at the base of the steps. This is to encourage a hydraulic jump to occur under specific flow conditions, particularly during skimming flow events where unit discharges exceed 50 cfs/lf. The slotted end sill will fill with water during significant events but will not hold water under baseflow conditions. Downstream of the sill is a transition zone to allow flow expansion (via channel width increase) to occur over Class C riprap. This expansion is a potentially turbulent zone necessary to decrease velocities to sub-erosive conditions under most flow events prior to entering South Papillion Creek. Figure D2-7 shows a plan view of the preliminary drop structure and runout. Substantial damage has already occurred downstream of the existing CMP culvert that will be corrected as part of this project. This structure appears to be an ideal hydraulic choice as it minimizes all hydraulic and floodplain impacts upstream and provides the best chance to maximize channel restoration potential within Beadle Creek by elevating channel grade.

Figure D2-7. Site S-5 Preliminary Drop Structure Plan View

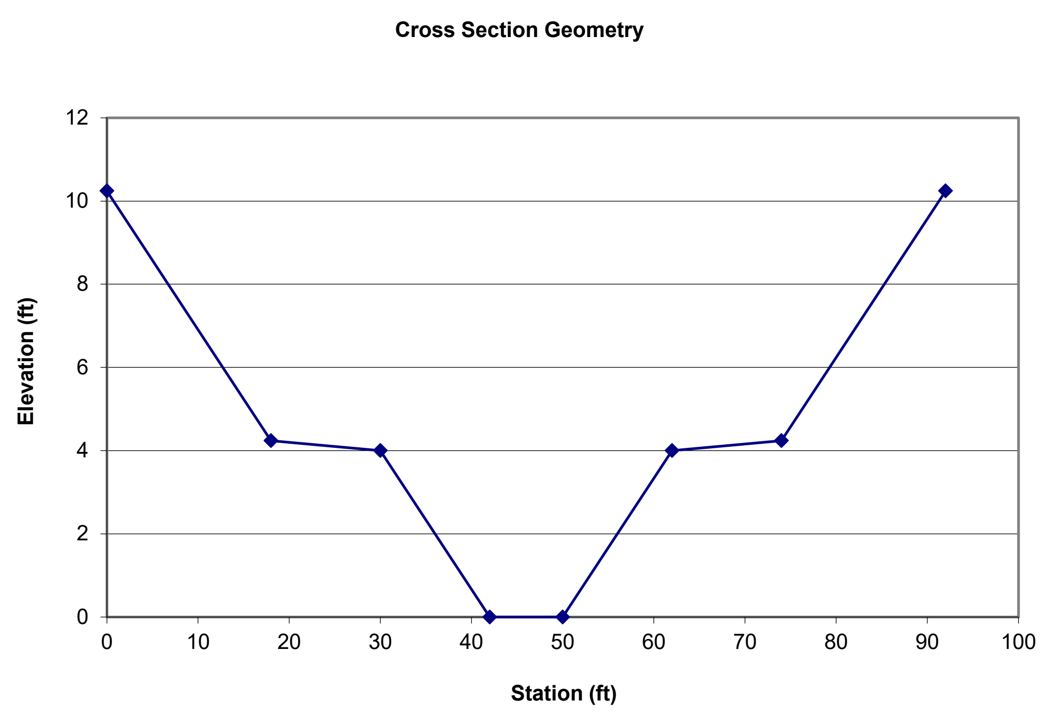


Preliminary design of the channel upstream of the drop structure began with analyzing the interim Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) regulatory model (HEC RASS V 5.0.7), which is in the process of mapping with FEMA. The HEC RAS model was ran using the 100-year and 500-year future conditions discharges to provide a flood profile baseline for impact comparison of the design conditions. No design that showed an increase in risk from flood elevations during either the 100- or 500-year events was pursued due to the close proximity of residences.

There are several constraints along the length of Beadle Creek, including power transmission lines and an interceptor sanitary sewer that has been relocated twice previously due to degradation of the Beadle Creek. Combining these infrastructure constraints with the minimal land rights available leads to a constrained footprint for grade stabilization efforts and limits the channel width to less than 120-feet. An optimized cross section was found through iterations within HEC-RAS of cross-sectional shape, area, and slope to maximize flood conveyance while minimizing the potential for erosive conditions. Unfortunately, to provide a no-rise condition for the 500-year event and maintain 500-year flow within the channel, the channel slope is higher than the ideal slope of 0.0008 ft/ft for these soil types (Loess silt, non-cohesive, plasticity index less than15) and is therefore erosive during high flow events. The channel geometry consists of a low flow channel with an 8-foot base width, 3:1 side slopes, and depth of 4-feet (see Figure D2-8) that carries the 5-year discharge. The channel contains two benches approximately 12-feet wide on either side with a 2 percent cross slope allowing another 6-feet of flow depth. The general cross-section utilizes 3:1 side slopes which are inherently stable using area soils and therefore provide significantly increased safety for the public. This yields a top width of approximately 92-feet, which can fully contain the 500-year future discharge.

Average channel velocity of low flow events (5-year) should be less than 4 ft/s. The maximum capacity of the channel (500-year) will have an average velocity of less than 7 ft/s, but velocities may reach 10-12 ft/s at the channel base. An armored solution in the low-flow channel is required due to this high velocity potential. A Pyramax or GreenArmor permanent turf reinforcement mat (TRM) is an ideal product with low cost and the added benefit of anchoring vegetation while withstanding velocities in excess of 10 ft/s. Although flow conditions during a flood event will have velocity exceeding 10 ft/s, the improved side slopes, decreased channel depth, and significantly increased channel stability will provide a significant increase in human safety.

Figure D2-8. Site S-5 Channel Geometry



It is anticipated that additional degradation will occur upstream from this location prior to construction. This may expand the region for restoration or alter the design of the box culverts. A project is currently under construction at Lillian Street to install a double box culvert which will stop further headcuts from progressing upstream; however, no restoration is being completed as part of this project. The elevation of the Lillian Street crossing is approximately 8-feet too low to allow for a stable channel cross section to be constructed within the 120-foot allowable right of way. There is not a safe way to utilize this culvert and therefore the Lillian Street crossing will need to be reconstructed as part of this project and has been included in the cost estimate. The culverts will be increased from a double to a triple box culvert to allow for the same capacity at a lower hydraulic head, but will provide a smoother flow transition downstream to minimize local scour potential.

D3.0 HIGH HAZARD DAM ALTERNATIVES

A high hazard potential wet dam was considered at Sites W-5, D-78, D-2, and S-15, but was not carried forward for detailed analysis. A rainfall/runoff model using National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation values was used with the storm frequencies for the Principal Spillway Hydrographs (PSH), Auxiliary Spillway Hydrographs (SDH), and Freeboard Hydrographs (FBH) set in accordance with the high-hazard specifications described in TR-210-60. The 90th percentile, 4th quartile Atlas 14 temporal distribution was used due to its conservative routings with Atlas 14 precipitation data.

A 2.5 percent sustainability factor, which corresponds to a 40:1 drainage area to lake surface area ratio, was used to set the permanent pool elevation. This is a commonly accepted method in the area to ensure storage capacity for the 50-year lifespan and to prevent conditions conducive to frequent algal growth as the structure ages. The NRCS Water Resources Site Analysis Program (SITES) program was used to set structure elevations. To run the Atlas 14 distribution, a HEC-HMS model was developed to provide the inflow hydrograph to input into the SITES program for each run. Times of concentration and lag times for each drainage area were computed in accordance with the methodology in the NRCS TR-55 Urban Hydrology for Small Watersheds (TR-55) document. Curve numbers (CNs) were determined from land use and hydrologic soil group according to the procedure set forth in TR-55. A Muskingum-Cunge reach routing was used using a trapezoidal cross section input to model existing streams when applicable. Land uses were determined based on aerial imagery and future conditions were accounted for by assuming that the future build-out would result in 30 percent impervious area. The 1-day/10-day storm distribution was modeled in SITES using precipitation data from NOAA's Technical Paper No. 40 and Technical Paper No. 49. Elevations for the auxiliary spillway crest and top of dam were rounded up to the nearest half-foot for slightly conservative elevations. A 100-foot wide auxiliary spillway was used to set the top of dam elevation.

Figures that show the locations and extents of each high hazard dam alternative that was analyzed are included below. Due to property constraints caused by existing and platted development there is no plausible location at Site S-5 and therefore it is not included in a figure.

Figure D3-1. Site W-5 Wet Dam Alternative

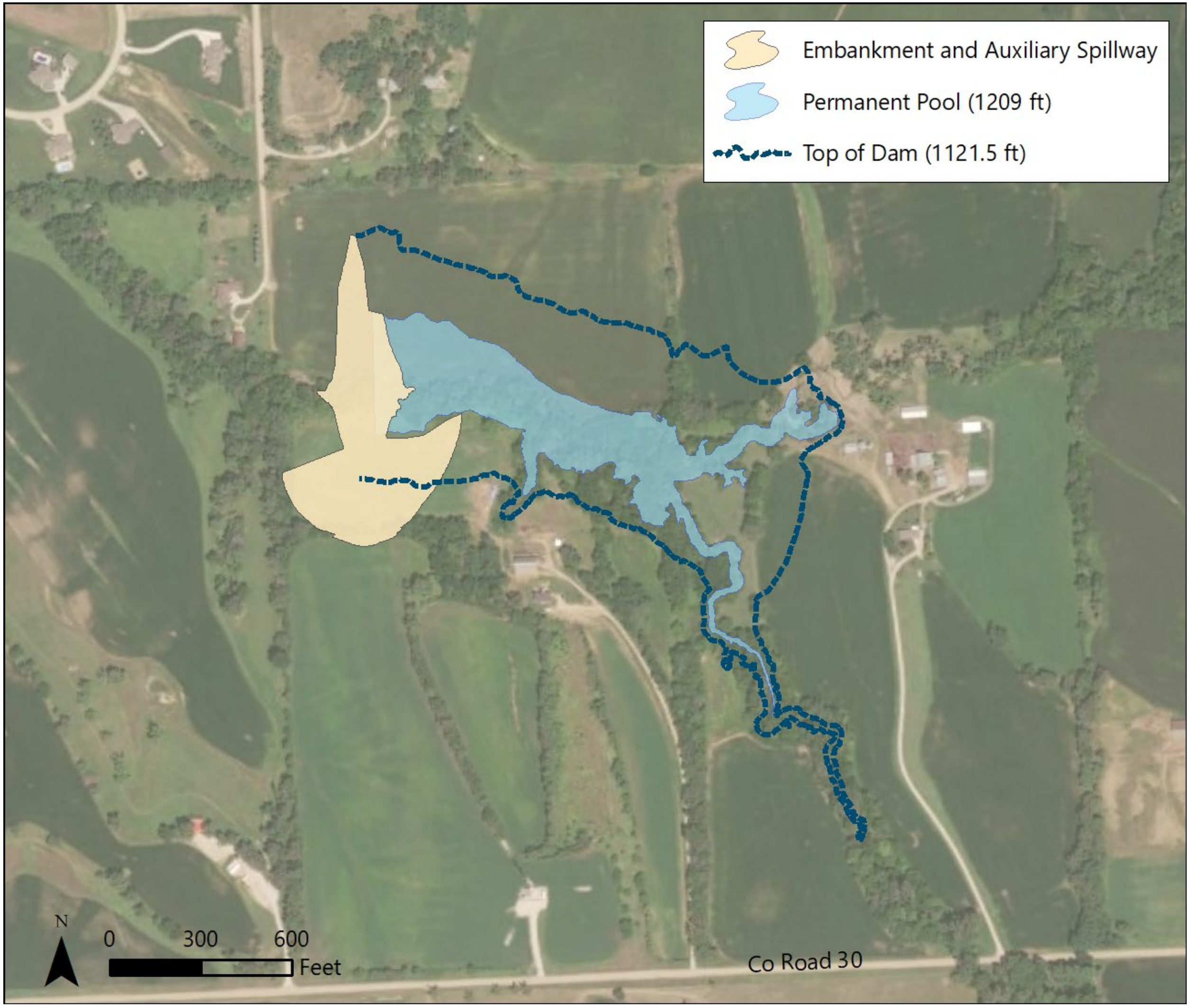


Figure D3-2. Site D-78 Wet Dam Alternative

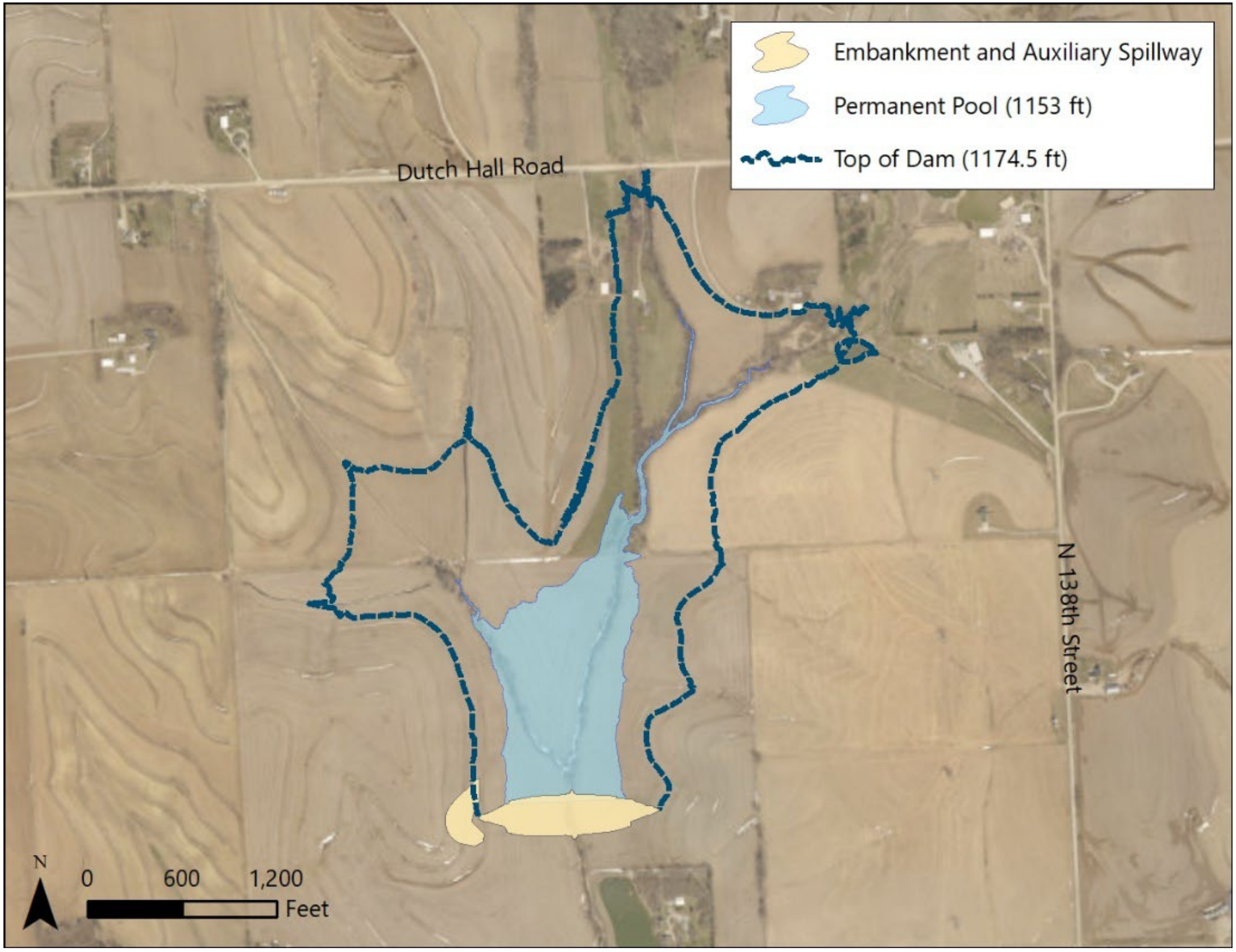


Figure D3-3. Site D-2 Wet Dam Alternative

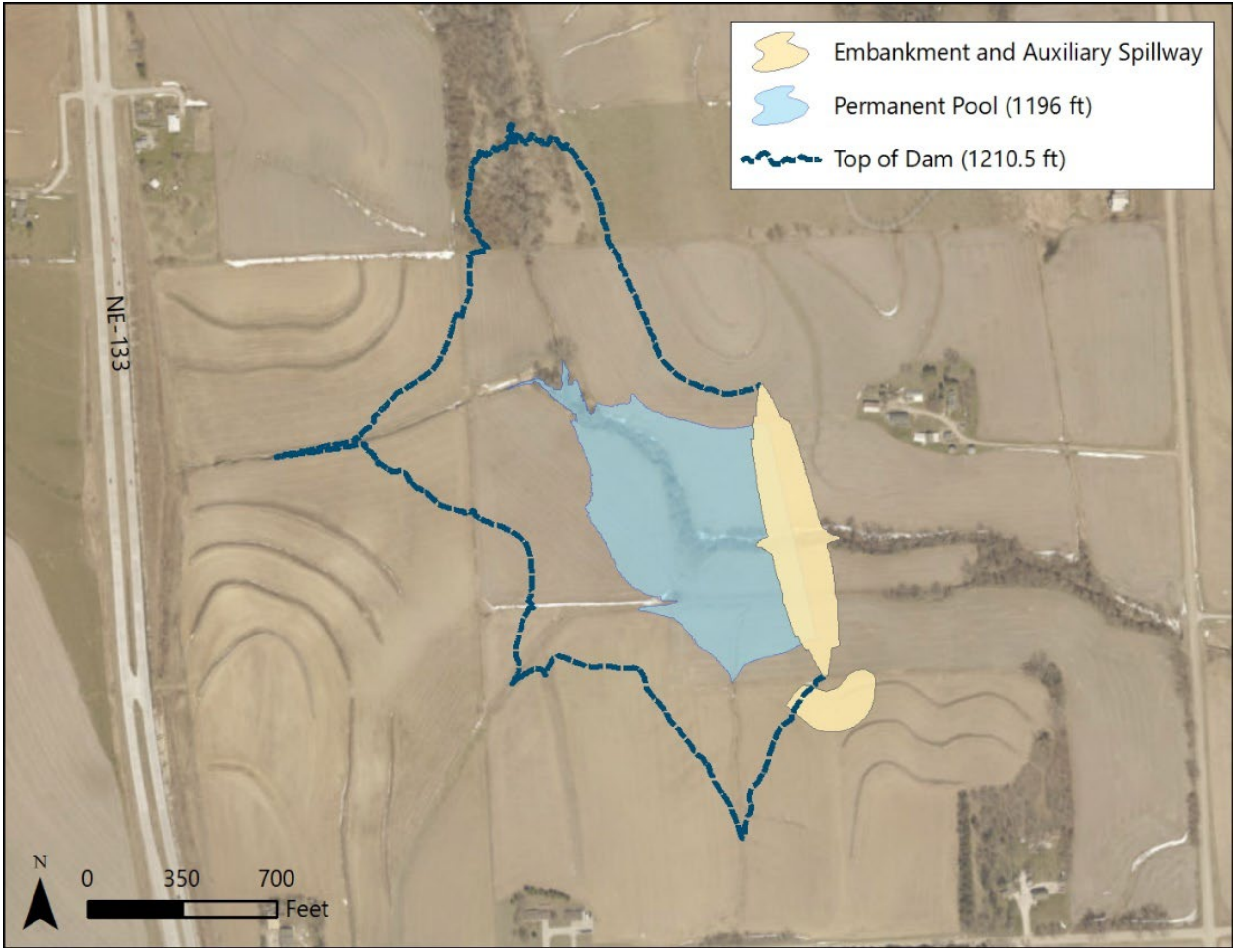
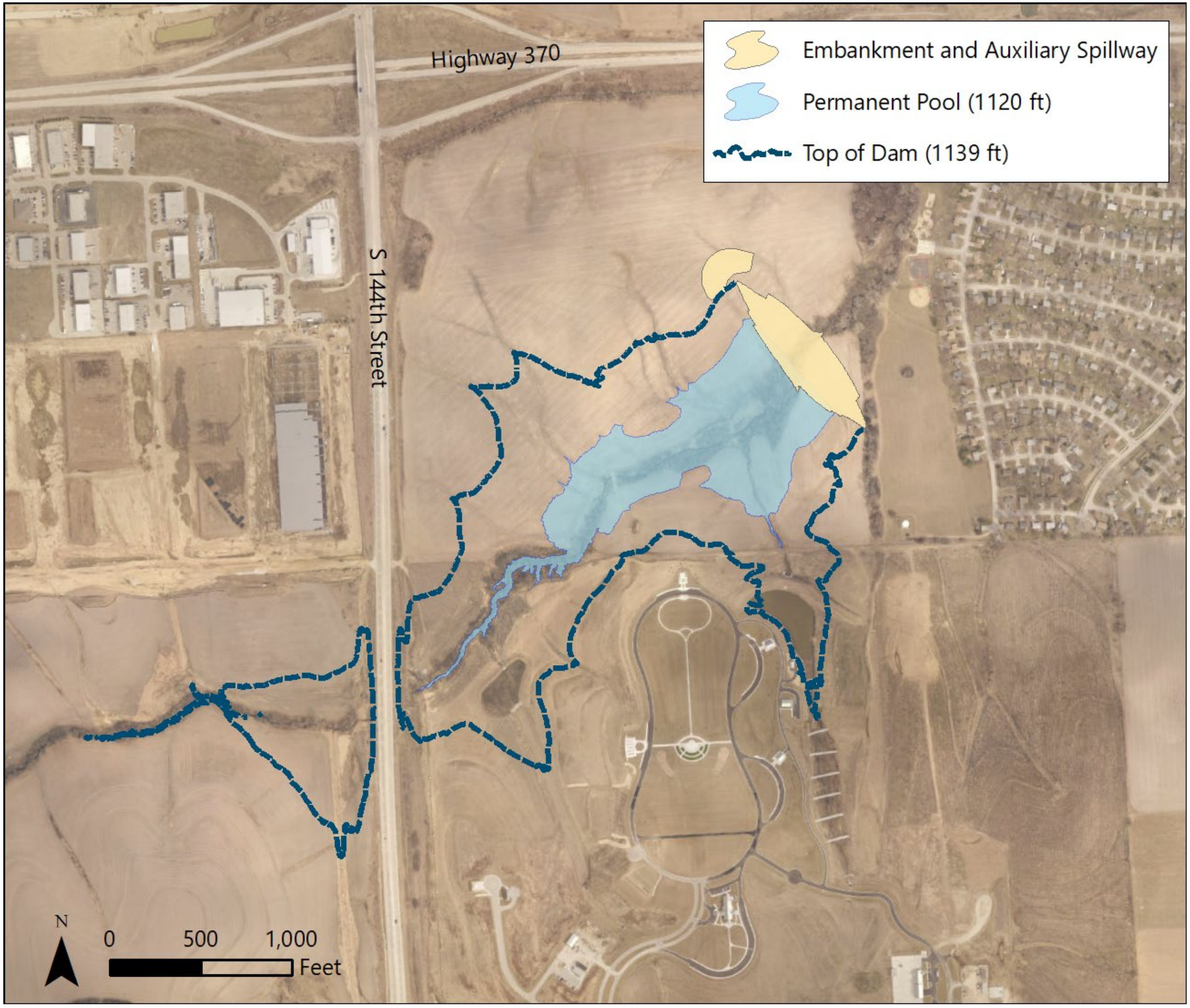


Figure 3-4. Site S-15 Wet Dam Alternative



D4.0 PR&G GUIDING PRINCIPLES

A checkmark (✓) is included in Table 4-6 for the alternative that best supports the guiding principle. Information is included below to support that decision.

D4.1 Healthy and Resilient Ecosystems

According to PR&G, Federal investments in water resources should protect and restore the functions of ecosystems and mitigate any unavoidable damage to these natural systems and a resilient ecosystem has the capacity to respond to changes. These changes can include processes like the natural evolution of stream functions, climate change, and anthropogenic changes brought on by situations like increased development. Healthy ecosystems enhance both the natural environment and contribute to the economic vitality of the Nation (PR&G, 2013). The following was considered to determine which alternative best supports this principle.

- Does the alternative protect, restore, or improve ecosystem functions?
- Does the alternative improve ecosystem resiliency?
- Does the alternative create a negative impact on the ecosystem?
    - Is the impact temporary? What is the recovery time?
    - Are damages avoided as much as possible?
    - Are damages minimized as much as possible?
    - Are any unavoidable damages mitigated for?

When considering these questions, Alternative 2 best supports this principle due to the protection and stabilization of actively incising streams, enhancement of the natural environment in the form of open water and lacustrine systems, and functional improvements to poorly functioning streams. Alternative 2 also improves ecosystem resiliency, specifically from changes due to impending development, and will both protect the natural environment and improve the economic vitality of the area.

D4.2 Sustainable Economic Development

As stated in PR&G:

> Federal investments in water resources should encourage sustainable economic development. Alternative solutions for resolving water resources problems should improve the economic well-being of the Nation for present and future generations through the sustainable use and management of water resources ensuring both water supply and water quality. Sustainable in this context means the creation and maintenance of conditions under which humans and nature can coexist in the present and into future. Federal investments in sustainable economic development activities contribute to the Nation's resiliency.

When considering this guiding principle, it is important to look at environmental, social, and economic factors individually and as a symbiotic system. For example, we must analyze how a proposed solution impacts the existing and potential economic conditions (employment, income, etc.) of an individual or business outright, how that solution impacts the environment on items like pollutant load and habitat changes, and also how each economic and environmental impact can influence each other. The same can be said for social interests like public safety, unemployment, and poverty rates. If one factor is thriving and the others are waning, the solution would not meet the guiding principle. Alternative 4 offers less environmental, social, and economic opportunities than the other alternatives (besides FWOFA) because there would be no permanent pool for recreation, habitat improvements and stream function, and added safety. Alternative 3 has less of a negative impact than Alternative 4 but does not have the added benefit of increased land values, improved habitat and water quality, and improved safety that come with Alternative 2. Therefore, Alternative 2 best meets this principle when considering these factors.

D4.3 Floodplains

Federal investments should avoid the unwise use of floodplains and flood-prone areas and minimize adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used (PR&G). This principle should be looked at from the lens of regulations like EO 11988 and 7CFR650.25 and also how this may cause an unintended displacement of flood risk. Alternative 1 does not improve flood risk. Flood risk reduction for Alternatives 2, 3, and 4 are all the same downstream of the structures. Alternative 4 adds a safety risk for rapid inundation of the dry basin in an urbanizing area and therefore does not best support this principle. Alternatives 2 and 3 both best meet this principle.

D4.4 Public Safety

Public safety includes threats to people (both loss of life and injury) from natural events (PR&G). The only nonstructural alternative that was brought forward for detailed analysis was Alternative 1, which does nothing to avoid, reduce, or mitigate risks from flooding or from stream degradation. Alternatives 2, 3, and 4 reduce flood risk downstream of the structures and greatly improve safety at each site by providing grade and bank stabilization. Alternative 4 adds an inherent risk of rapid inundation at a dry dam location located in an are that is rapidly urbanizing and therefore does not best meet this principle. Measures must also be included in solutions that manage and communicate residual risks (PR&G). WP-1 and S-1 will have Emergency Action Plans in place for all Alternatives to address potential risks due to a sudden breach. Alternatives 2 and 3 both best meet this principle.

D4.5 Environmental Justice

None of the alternatives disproportionately adversely impact public safety, human health, or environmental burdens on minorities, Tribal communities, or low-income populations.

D4.6 Watershed Approach

Taking a watershed approach to alternative identification, analysis, and decision making is more likely to identify the best solutions to achieve multiple goals over the entire watershed. Using a watershed approach broadens the lens from site-specific issues to more system-wide problems and interconnected solutions. This approach can lead to benefiting a wider range of stakeholders and can also lead to a wider breadth of potential environmental benefits. At a minimum, the indirect and cumulative impacts of certain solutions can be evaluated more thoroughly by taking into account a wider range of various environmental, social, and economic problems and solutions. The following was considered to determine which alternative best supports this principle.

- How does the alternative work together with other past and current watershed plans and studies?
    - Does the alternative have the potential to impede other watershed stakeholder goals?
    - Does the alternative help to reach other watershed stakeholder goals?
    - Can the alternative be used in conjunction with another watershed plan solutions to meet the same goals and objectives?
- Does the alternative effect communities or resources within and outside of the watershed?
- Does the alternative work to provide solutions to enduring (both in the past and looking into the future) environmental concerns?
- How does the alternative effect current and future habitats, stream functionality, and safety upstream and downstream of the proposed action?

There have been many studies within the Papillion Creek Watershed to evaluate potential solutions for flood risk reduction, stream stability, and improved water quality (see Section 3.4 in the Plan-EA). Alternative 2 best supports the watershed approach principle because of the interconnectedness with other watershed plans at Sites WP-1 and S-1 as well as the overall improved habitat and stream function that the alternative brings upstream and downstream of each site.

D5.0 ECONOMICS

D5.1 Costs

Costs were based on local knowledge and site-specific criteria, including quantities and ease of construction. Unit costs are included in Table D5-1 below.

Table D5-1. Unit Costs

Item	Unit	**Loose Rock Structures** (Sites W-5, D-78, D-2, S-15)	**Ramp Structures** (Sites W-5, D-2, S-1, S-15)	**Dredging of DS-19** (Site S-1)	**Stream Restoration** (Site S-5)	**Water Quality Basin** (Site S-1)	**High Hazard Dam**[1] (Sites W-5, D-78, D-2, S-1, S-15)	**Stream Restoration Alternative**[1] (Sites W-5, D-78, D-2, S-1, S-15)
Mobilization	LS	50% of Construction Cost	50% of Construction Cost	35% of total cost	10% of total cost	10% of total cost	10% of total cost	50% of Construction Cost
Clearing and Grubbing	LS			--	$15,000	$15,000	$127,700	
Handling of Water	LS			--	$15,000	$15,000	$28,400	
SWPPP	LS			--	$10,000	$10,000	$29,800	
Seeding	AC			--	$950	$950	$950	
Contingency	LS			20% of total cost	20% of total cost	20% of total cost	20% of total cost	
Earthen Fill	CY	--	$12	--	$12	$5.50	$5.50	--
Earthen Excavation	CY	$16	$16	--	$12	$3.30	$3.30	$16
Rock Riprap - Class "C"	TN	$90	$90	--	$90	$90	$90	$90
Rock Riprap - Class "B"	TN	$65	$65	--	--	--	--	--
Sheet Pile	SF	$60	$60	--	$60	--	--	--
Flexamat	SY	--	$70	--	--	--	--	--
Turf Reinforcement Matting (Pyramat or Approved Equivalent)	SY	--	--	--	$12	--	--	--
Formed Concrete	CY	--	--	--	$1,200	--	$1,000	--
RCCP Pipe - 24" Dia.	LF	--	--	--	--	$370	--	--
Crushed Aggregate	CY	--	--	--	$50	$30	$40	--

Item	Unit	**Loose Rock Structures** (Sites W-5, D-78, D-2, S-15)	**Ramp Structures** (Sites W-5, D-2, S-1, S-15)	**Dredging of DS-19** (Site S-1)	**Stream Restoration** (Site S-5)	**Water Quality Basin** (Site S-1)	**High Hazard Dam**[1] (Sites W-5, D-78, D-2, S-1, S-15)	**Stream Restoration Alternative**[1] (Sites W-5, D-78, D-2, S-1, S-15)
Articulated Concrete Blocks	SF	--	--	--	--	$32	--	--
Geoweb	SF	--	$3	--		$3	--	--
RCCP Pipe - 48" Dia.	LF	--	--	--	--	--	$640	--
PVC Pipe - 6" Dia.	LF	--	--	--	--	$10	$10	--
Metal fabrication (Dam Riser)	LS	--	--	--	--	--	$15,400	--
Knife/Slide gates (Dam Riser)	EA	--	--	--	--	--	$16,000	--
Instrumentation	LS			--	--	--	$36,000	--
Trash Rack	LS	--	--	--	--	$5,000	$5,000	--
Dredging	CY	--	--	$15	--	--	--	--
Approach Grading	LS			--	$70,000	--	--	--
Lillian Street Culvert	LS			--	$400,000	--	--	--
Land Acquisition	AC	$60,000	$60,000	$60,000	$60,000	$60,000	$60,000	--
Access Easements	AC	$30,000	$30,000	--	$30,000	--	--	--
Easement for Structure Footprint	AC	$45,000	$45,000	--	--	--	--	--
Project Administration	LS	7% of Construction Cost						
Construction Observation	LS	10% of Construction Cost						
Design	LS	15% of Construction Cost						
Permitting	LS	5% of Construction Cost		3% of Construction Cost			5% of Construction Cost	
Mitigation	LS	5% of Construction Cost		2% of Construction Cost	$35,000	5% of Construction Cost		

[1] *Not brought forward for detailed analysis*

A detailed construction cost estimate is included for Site WP-1 in Table D5-2 below.

Table D5-2. WP-1 Regional Detention Basin (Wet Dam), Construction Cost Estimate

Item	Quantity	Unit	Unit Cost	Total Cost
Mobilization	1	LS	$150,000	$150,000
Construction staking	1	LS	$10,000	$10,000
Construction entrance	1	LS	$2,500	$2,500
Tree removal for habitat use	2	AC	$5,000	$10,000
General clearing and grubbing	1	LS	$20,000	$20,000
Strip and salvage top soil	1	LS	$30,000	$30,000
Earthwork cut and spoil	15,900	CY	$8	$127,200
Earthwork measured as embankment	202,200	CY	$5	$909,900
NDOT 47B fine aggregate	530	TON	$65	$34,450
1.5" crushed aggregate	577	TON	$65	$37,505
NDOT type-B riprap	12,865	TON	$65	$836,225
NDOT type-A riprap	55	TON	$65	$3,575
Toe drain	765	LF	$10	$7,650
48" reinforced concrete cylinder pipe	168	LF	$700	$117,600
24" reinforced concrete draw down pipe	30	LF	$50	$1,500
Concrete baffle riser	1	EA	$140,900	$140,900
Concrete impact basin	1	EA	$102,500	$102,500
Boat Ramp	1	EA	$25,000	$25,000
Picnic shelter	1	EA	$20,000	$20,000
Trail (concrete)	7,890	SY	$65	$512,850
Fishery improvements	1	LS	$750,000	$750,000
Water quality drawdown structure	1	EA	$35,000	$35,000
Restroom	1	EA	$50,000	$50,000
Seeding and mulching	94	AC	$3,000	$282,000
Sediment control (SWPPP)	1	LS	$8,000	$8,000
Powerline relocate	1	LS	$750,000	$750,000
Fencing	16692	LF	$6	$91,806
Site paving	4120	SY	$112	$461,440
Lighting	1	LS	$10,000	$10,000
Subtotal				**$5,537,601**
Contingency (25%)				**$1,384,400**
Total Construction				**$6,922,000**

Opinion of Costs provided by Olsson

D5.2 Benefits

The economic benefits in the approved 1966 Watershed Plan were attributable to the prevented land damage and depreciation of agricultural and urban lands as well as the reduction to infrastructure damages, sediment damages, and other secondary benefits created by the 52 proposed grade control structures. This Supplemental Plan-EA includes grade control structures and introduces the additional purpose of flood damage reduction. Indexing of previous grade control benefits was not applicable in this Supplement due to the changes in land use, practices, and infrastructure since the 1960s and therefore these were calculated using current information at the identified sites. The sections below detail project benefits.

D5.2.1 Flood Damage Reduction

It is important to scale the economic analysis to be commensurate with the proposed action's cost, magnitude and significance of potential environmental and human impacts, stakeholder concerns, risks and uncertainties, and other factors as discussed in PR&G and DM 9500-13. Flood damages and flood damage reduction benefits attributable to reservoirs have been extensively studied within the Papillion Creek Watershed within the last five years. Two recent funding applications were submitted to the Nebraska Water Sustainability Fund (WSF) for flood reduction dams within the Papillion Creek Watershed. These applications were reviewed by the Nebraska Department of Natural Resources (NDNR) and included detailed economic analysis of flood damage reduction benefits. Both applications were reviewed and approved and received the highly competitive funding.

The first application was submitted for Regional Detention Sites WP-6 and WP-7 in 2016 and was prepared using a site-specific flood damage reduction analysis using pre- and post-project hydrology, hydraulics, and water surface elevations (FYRA 2016). To assess the flood damage reductions due to the construction of WP-6 and WP-7, the net impact on hydrology and hydraulics was required. Utilizing the effective FEMA DFIRM model, modifications were made to the hydrologic model (HEC-HMS) to reflect the presence of the detention structures and recurrence events were simulated. HEC-RAS, HEC-HMS, and current LiDAR were utilized to develop inundation mapping and pre- and post-project flood damages.

After the WP-6 and WP-7 applications were approved, the second application was prepared for Site WP-1 in 2018 (FYRA 2018), which is included as part of the preferred alternative in this Supplemental Plan-EA. That application used the detailed economics work contained within the WP-6 and WP-7 applications. The benefits were then transposed using the compared drainage areas of the sites as they are all in sub-watersheds with similar land use and topography within the same Papillion Creek Watershed. The annualized flood damage reduction benefits were then indexed to current day values using the appropriate indices.

Analysis of conditions, scale, and scope of this project led to the decision to use these previously calculated flood reduction benefits within this Supplemental Plan-EA. The 2018 flood reduction benefits were indexed to 2019 values and yield $97,290 of annual flood reduction benefits attributable to Site WP-1.

D5.2.2 Recreation Benefits

The preferred alternative at Site WP-1 is a flood risk reduction dam with a permanent pool. Recreation is not a stated purpose of the project, but non-Federal funds will add recreation components to the site which will provide incidental benefits to individuals benefitting from activities at the reservoir that are outside of the project intent of flood risk reduction (indirect beneficiaries). Recreation benefits at reservoirs in the Papillion Creek Watershed have been recently analyzed through various studies. There have been multiple accepted methodologies for calculating recreation benefits in Nebraska (and the Papillion Creek Watershed specifically). Two of these include following the Nebraska Resource Development Fund Guidelines and utilizing USACE guidelines for evaluating the effects of project recreation as outlined in the Planning Guidance Notebook, Appendix E (ER 1105-2-100) and Economic Guidance Memorandum, Unit Day Values for Recreation for Fiscal Year 2019 (EG 19-03). USACE guidance was chosen due to the availability of more recent and applicable data, recent Federal use and acceptance in the watershed, and applicability to the scale and type of project at Site WP-1. The USACE Unit Day Value (UDV) method involves assigning points (scored values) for the study area based on five criteria for either 'general' or 'specialized' recreation. Recreation at WP-1 fits into the general recreation category, meaning it is attractive to the majority of outdoor users and does not require a high degree of specialized skill or knowledge. The points for each criterion are then summed and that value is converted to a dollars per visit value (which is the UDV) based on dollar amounts published in the EG 19-03 (2019 values). The UDV is used in conjunction with an estimate of the number of annual visits to determine the annual recreation value. Visitation is estimated based on reservoirs in the region with similar resource and use characteristics, pool size, and previous studies within the watershed. Table D5-3 below shows how the points were determined for Site WP-1. With an estimated annual visitation of 21,668 and a UDV value of $8.49 (see table), the annual recreation value is estimated at $183,982.

Table D5-3. WP-1 Regional Detention Basin (Wet Dam), Unit Day Method

Criteria	Maximum Points Possible	WP-1 Points	Judgement Factor/Point Rationale	
Recreation Experience	30	6	Several general good quality activities (picnicking, bicycling, walking/running/hiking, fishing, canoeing/kayaking)	
Availability of Opportunity	18	3	Sites within 30 minutes. High recreation demand as shown in SCORP, rapidly growing counties surrounding site	
Carrying Capacity	14	8	Adequate facilities, deterioration of resource/experience not expected	
Accessibility	18	15	Good access, major roads (Maple St, 180th St, Fort St) to site. Good access (both roads and ADA) within site.	
Environmental Quality	20	15	High aesthetic quality (water and vegetation)	
Total Points:	**100**	**47**	**Unit Day Value:**	**$ 8.49**

D5.2.3 Land Value Increase

One-time land value increases occur upstream when a reservoir is built due to the proximity to the water, improved views, associated recreation facilities, and others. A recent study of land value increases upstream of a reservoir in the Papillion Creek Watershed analyzed the difference in appraised value of lake lots with the assessed value of developed lots (FYRA 2016). The study shows that this increase is approximately $12,000 per acre for tracts of land upstream of dam limits. This is an average increase as lot values will increase as you move closer to the lake. Sites WP-1 and S-1 will have a one-time land value increase resulting from the reservoirs being built. The tracts of land expected to show in increase in land values are shown in Figures D5-1 and D5-2 below. The one-time benefit is $8,528,400 for Site WP-1 and $2,263,320 for Site S-1. It is assumed that the WP-1 benefit occurs in year 3 and the S-1 benefit occurs in year 4 based on the projected implementation schedule.

Figure D5-1. Expected Tracts with Land Value Increases at Site WP-1

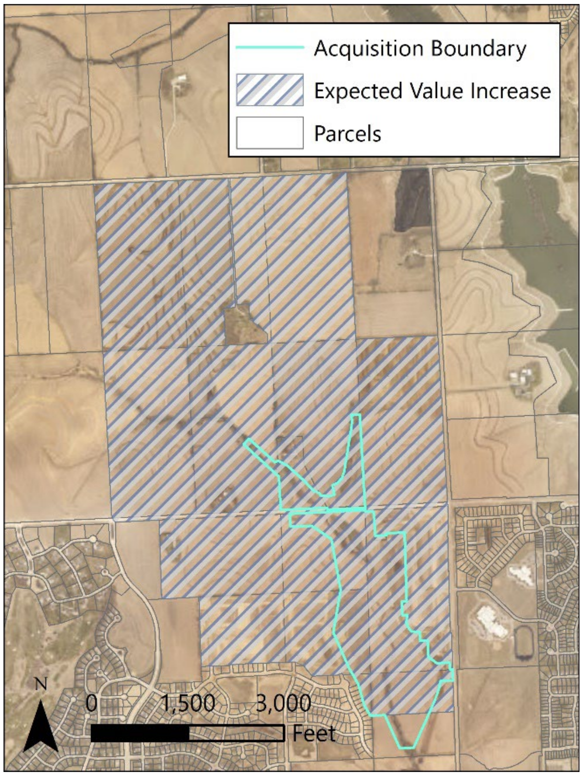
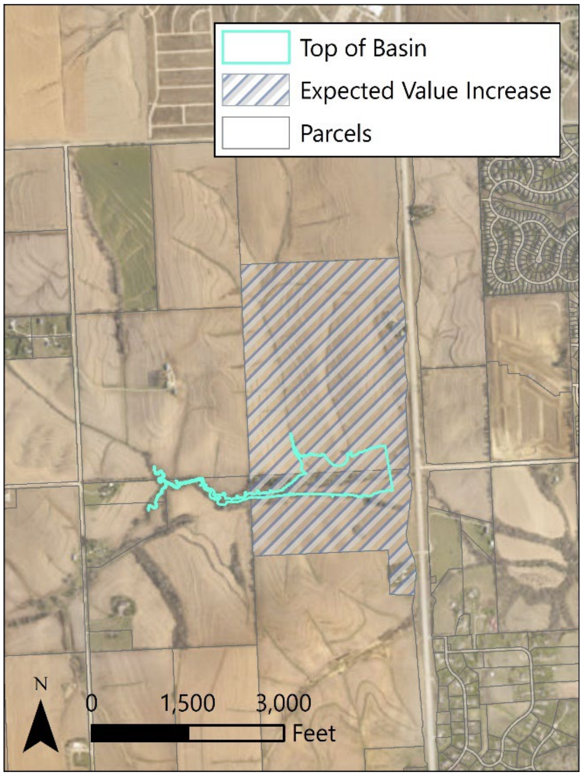


Figure D5-2. Expected Tracts with Land Value Increases at Site S-1



D5.2.4 Infrastructure

As discussed throughout the Supplemental Plan-EA, stream degradation in the watershed has led to and will continue to cause damage to major infrastructure including state highways, county roads, residential roads, sanitary sewers, and power transmission lines. Residential properties and homes near Sites S-5 and W-5 will also be susceptible to encroachment and damage. Repairs to infrastructure and costly attempts to protect residential properties are common within the watershed.

Benefits attributable to future cost avoidances were included with the benefits in the cash flow stream in the economic analysis. These benefits are related to work that will not have to be completed in the future that would have likely been caused by continued degradation of the streams and the impacts on local infrastructure related to continued stream degradation. The year the benefits were applied is a function of assessing the current stability status of the stream segments and a professional judgement on when continued degradation is likely to reach the particular infrastructure component analyzed. Because degradation is primarily event-based and large, unpredictable runoff events can cause more damage than "average annual" impacts on the stream, aerial imagery and other recorded information and personal accounts were used to predict how much time might pass before stream degradation would impact individual infrastructure components. Cost avoidance benefits assume that some level of damage occurs before any preventative maintenance can occur, but repairs would be implemented before replacement would be necessary. For instance, it is assumed that entire highway cross sections would not be destroyed, but rather only a portion of the embankment and the associated utilities would require repair. Costs to buy out residential homes within the projected stream widening footprint were also considered as one-time benefits.

Combined utility protection is expected to be $42,000 annually for the 50-year lifespan of the grade control structures at S-5 and S-15 based on feedback from communities on existing utility repairs throughout the watershed and the location of utilities along stream corridors. All other benefits are included as one-time cost savings of transmission lines, embankments, and residential homes.

D5.2.5 Dredging

One-time benefits for Site S-1 are based on cost savings related to future dredging avoidance of the DS-19 Reservoir. The dredging alternative involves allowing the sediment to enter DS-19 and subsequently dredging the reservoir to remove 44 acre-feet of sediment. Dredging costs were assigned utilizing local knowledge of recent dredging and other water resources projects. Total costs for dredging are approximately $3,041,700 in 2019 dollars. To estimate the assumed implementation year for dredging, sediment erosion rates based on existing and future land use, sediment storage deposition, and trapping efficiency were all analyzed. Based on this information, it is assumed that implementation would occur in year 16 of the project life and benefits are calculated based on this assumption.

D5.2.6 Land Preservation

Stream degradation and widening not only cause damage to infrastructure and stream ecology. They also cause the loss of vital riparian and agricultural land. Using aerial imagery and a stable slope analysis, the potential riparian land lost, what would be saved by proposed improvement projects in this Supplemental Plan-EA, and timing of potential loss were assessed and valuated. Land preservation benefits were included in the analysis as a one-time benefit at years 5, 6, 15, 20, and 25 based on existing and projected future conditions and expected development timelines. Table D5-4 below details shows the assumed acres preserved and associated project year used for the one-time benefit.

Table D5-4. Land Preservation

Site	Acres Preserved	Project Year for Benefit Analysis
S-1	2.8	5
S-5	10.0	5
W-5	20.0	25
D-78	35.7	20
D-2	12.9	15
S-15	20.8	6

Where agricultural production currently exists, losses in crop production related to riparian land lost to degradation and widening were quantified and valuated as a benefit. The value of the crops assumed average annual yield and income per acre for unirrigated fields based on years 2016-2018 and a yearly rotation of corn and soybeans ($537.55/acre). The rate at which acres are lost from production is based on a linear loss of land throughout the design life of the structures. For example, structures at Site W-5 are expected to save 14-acres of agricultural land over the 50-year project life. At year 50, the 14-acres would produce approximately $7,530 annually (2019 dollars). Therefore, year 1 after project implementation would see 1/50 of the 14-acres saved yielding a benefit of $150, year 2 would see a benefit of $300, and so on for the life of the project. Table D5-5 below shows the amount of farm acres expected to be saved over the life of the project.

Table D5-5. Farmland Preservation

Site	Farm Acres Preserved
WP-1	0
S-1	3
S-5	0
W-5	14
D-78	36
D-2	13
S-15	14

D5.2.7 Project Life

All grade stabilization structures were designed to accommodate up to 100-year flow depths and velocities and a design life of 50-years was assumed for all project sites and components except Site WP-1. Maintenance after high flow events will likely be necessary and this was considered in the determination of yearly operations and maintenance costs. Project life of Site WP-1 is 100-years due to the high hazard potential dam facility and use of materials that are consistent with a 100-year design life. The period of analysis is 102 years and includes the installation period of WP-1.

D5.2.8 Annual Equivalents

All benefits and costs were discounted from the year they were planned to incur to the beginning of the period of analysis by converting them to present value equivalents. When the present values were determined, they were amortized over the 102-year period of analysis to establish average annual equivalents. Average annual equivalent costs are $844,400, including $95,900 in annual equivalent O&M

expenditures. The average annual equivalent benefits are $934,130, resulting in a benefit to cost ratio of 1.11 for the project. Agriculture-related benefits, including rural benefits as defined by the NWPM, account for 90 percent of the total project benefits. Economic tables, as outlined in the NWPM, are included in Chapter 7.0.

D6.0 AFFECTED ENVIRONMENT

D6.1 Sheet and Rill Erosion

Sheet and Rill erosion was calculated based on land capability class and land use using the Environmental Protection Agency's (EPA) Spreadsheet Tool for Estimating Pollutant Loads (STEPL). Land capability classes were determined from the web soil survey data for Washington, Douglas, and Sarpy Counties. The 2011 United States Geological Survey (USGS) National Land Cover Dataset, and CALMIT and UNL irrigation data was used to find the watershed land use values. Land use values and land capability classes were combined using ESRI ArcGIS 10.7 and clipped to the watershed boundary. Each land capability class was assigned a subwatershed in STEPL to find erosion rates. The sheet and rill erosion rates were developed using STEPL and the Universal Soil Loss Equation (USLE). The land uses, land capability classes, and sheet and rill erosion rates are shown in Table D6-1.

Assumptions and other notes for the USLE calculations are included below.

1. A and R values based on Douglas County.
2. K factors were calculated by weighing soil type K factors in each land capability class category using factors from EC88-116.
3. LS factors based on slopes of soils in each land capability class and a length of 100 feet.
4. Default C factors for Douglas County used.
5. Default P values for Douglas County used.

Table D6-1. Sheet and Rill Erosion within Papillion Creek Watershed

Land Capability Class		Cropland		Pastureland	Forest	Urban	Water/ Other	Total
		Non-Irrigated	Irrigated					
1	AC	1,542	132	272	13	302	1	**2,262**
	Ton/Year	2,407		91	0	30	2	**2,530**
	Tons/AC	1.44		0.34	0.02	0.10	1.85	**1.12**
2e	AC	38,452	127	5,208	1,265	7,430	53	**52,535**
	Ton/Year	118,858		3,750	68	727	173	**123,575**
	Tons/AC	3.08		0.72	0.05	0.10	3.25	**2.35**
2w	AC	14,282	373	2,071	1,183	4,083	13	**22,006**
	Ton/Year	24,080		795	34	319	23	**25,252**
	Tons/AC	1.64		0.38	0.03	0.08	1.74	**1.15**
3e	AC	29,326	184	4,404	591	12,129	58	**46,692**
	Ton/Year	240,022		8,371	84	1,186	499	**250,162**
	Tons/AC	8.13		1.90	0.14	0.10	8.59	**5.36**
4e	AC	24,388	218	4,857	499	3,349	46	**33,358**
	Ton/Year	375,252		17,312	134	262	742	**393,702**
	Tons/AC	15.25		3.56	0.27	0.08	16.00	**11.80**
5w	AC	334	0	22	67	0	0	**424**
	Ton/Year	550		8	2	0	0	**560**

Land Capability Class		**Cropland**		**Pastureland**	**Forest**	**Urban**	**Water/ Other**	**Total**
		Non-Irrigated	**Irrigated**					
	Tons/AC	1.64		0.39	0.03	0.00	0.00	**1.32**
6e	AC	673	0	342	100	445	1	**1,560**
	Ton/Year	26,084		3,092	68	35	25	**29,303**
	Tons/AC	38.78		9.05	0.68	0.08	39.67	**18.79**
**	AC	851	87	1,529	176	82,880	1,259	**86,782**
	Ton/Year	9,251		3,519	30	6,474	13,113	**32,388**
	Tons/AC	9.86		2.30	0.17	0.08	10.41	**0.37**
TOTAL	AC	109,848	1,121	18,705	3,896	110,617	1,432	**245,619**
	Ton/Year	796,504		36,940	421	9,032	14,576	**857,473**

Notes:
***Other land capability class categories and miscellaneous areas*
e *Erosion and runoff*
w *Excess water*

Sheet and Rill erosion was calculated for each subwatershed by clipping the combined land use values and land capability class shapefile to get unique acreages. The erosion rates calculated in the table above were then used to calculate the tonnage of rill and sheet erosion per subwatershed, shown in Table D6-2.

Table D6-2. Sheet and Rill Erosion by Subwatershed

Subwatershed	**Drainage Area (sq. mile)**	**Total Rill/Sheet Erosion**
D2	0.7	3,735
D78	1.8	8,070
WP-1	1.3	5,443
S5	2.4	1,768
S15	1.5	3,472
S1	2.7	9,020
W5	0.9	4,523
Structure Totals	11.3	36,031
Entire Watershed	**383.8**	**857,473**

D6.2 Streambank and Gully Erosion

Visual observations of LiDAR and aerial imagery using ESRI ArcGIS were the primary basis of streambank and gully erosion estimates. Current aerial photos and LiDAR topographic data/maps were used to trace current streambank limits in ArcGIS. Historical streambank limits were derived in the same manner with historical aerial imagery from 1993. The change in area determined from this evaluation was used with observed stream shape and average stream depths to calculate an estimated streambank erosion volume. This volume was converted to weight using a typical clay soil unit weight. Factoring this volume of soil loss over the time between the historical and current aerials generated an annual streambank erosion rate.

Gullies were accounted for by assuming an annual depth of erosion in visually observable ephemeral gullies. This accounts for small gullies that are in tilled fields which could be filled in each year through tillage operations then reformed as ephemeral gullies during storm events annually. Gullies were observed in historically imagery and then compared to current aerial imagery. The change in length of the gullies from the historic to current imagery was calculated along with an estimated gully geometry to develop a yearly erosion rate for ephemeral gullies. The gully lengths were adjusted to exclude historic gullies that were located in currently developed areas.

The streambank and gully erosion rates are shown below in Table D6-3.

Table D6-3. Stream and Gully Erosion by Subwatershed

Structures	Drainage Area (sq. mile)	Annual Erosion Totals (Ton/Yr)	
		Streambank	Gully*
D2	0.7	41	2
D78	1.8	145	6
S1	1.3	126	45
S5	2.4	386	8
S15	1.5	218	50
WP-1	2.7	73	9
W5	0.9	121	3
Structure Totals	11.3	1,109	123
Entire Watershed	**383.8**	**37,589**	**1,879**

**Only scaled to agricultural acres of watershed.*

D6.3 Sediment Delivery

Erosion quantities were combined with appropriate delivery ratios and knowledge of local materials, terrains, and conditions to generate sediment yields. Sheet and rill erosion have a low sediment delivery efficiency because overland runoff leaves much material behind as depositions on fields, at field boundaries, in road ditches, and other obstacles. An estimated 25 percent of sheet and rill erosion produced annually moves through the stream system. Ephemeral gully erosion is somewhat more efficient at sediment delivery, due to the close proximity to flow channels with an estimated 65 percent delivery rate. Streambank erosion is much more efficiently delivered, due to the greater carrying capacity of channelized flow with an estimated 90 percent delivery rate.

The streambank and gully sedimentation rates are shown below in Table D6-4.

Table D6-4. Streambank and Gully Sedimentation Estimates

Structures	Drainage Area (sq. mile)	Annual Sedimentation Totals (Ton/Yr)			
		Streambank	Gully*	Sheet/Rill	Total
D2	0.7	37	1	934	972
D78	1.8	131	4	2,018	2,153
S1	1.3	113	29	1,361	1,503
S5	2.4	347	5	442	794
S15	1.5	196	33	868	1097
WP-1	2.7	66	6	2,255	2,327
W5	0.9	109	2	1,131	1,242
Structure Totals	11.3	998	80	9,008	10,086
Entire Watershed	**383.8**	**33,830**	**1,221**	**214,368**	**249,419**

**Only scaled to agricultural acres of watershed.*

D7.0 REPRESENTATIVE PHOTOGRAPHS

Representative photographs for each site reach are included below.

Photograph D7-1. Site W-5

Photograph D7-2. Site D-78

Photograph D7-3. Site D-2

Photograph D7-4. Site S-15

Photograph D7-5. Site S-5

Photograph D7-6. Site S-1

Photograph D7-7. Site WP-1

Source: Olsson Associates. Wetland Delineation Report. February 2018.