APPENDIX D: INVESTIGATION AND ANALYSIS

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D 1. INTRODUCTION

This appendix presents information that supports the formulation, evaluation, and conclusions of the North Fork Elkhorn River Watershed Plan-EA. The outline is organized under major headings that allow the reader who is not familiar with the details of the watershed and the analysis leading to the conclusions to be able to form a conclusion and form an opinion on the adequacy of the Plan. The appendix follows USDA NRCS Watershed Program Manuals and guidance previously referenced in the Plan. The appendix is intended to supplement information contained in the Plan.

The appendix was written by the project consultant in collaboration with the Nebraska NRCS Engineering team and in consultation with other federal, state, and local agencies; property owners, sub-consultants, Lower Elkhorn NRD, and local community representatives. These stakeholders worked together to incrementally analyze a cost-effective alternative that meets social, political, and economic acceptability.

D 2. HYDROLOGIC ANALYSIS

Hydrologic Analysis was completed as part of the WFPO planning process for the North Fork Elkhorn River Watershed. This analysis establishes an existing conditions model to use as a baseline for evaluating alternatives identified in the planning process. The Project Area includes three complete HUC10s (1022000201, 1022000202, and 1022000205), and a small portion of a fourth HUC10 (1022000203) near the City of Pierce. An expanded watershed area was included for hydrologic evaluation and modeling purposes, as shown in Figure 1. There are six communities within the Project Area: Wausa, Magnet, Plainview, Osmond, Foster, and Pierce. The majority of the Project Area is located in Pierce County with portions extending into Knox, Cedar, and Antelope Counties.

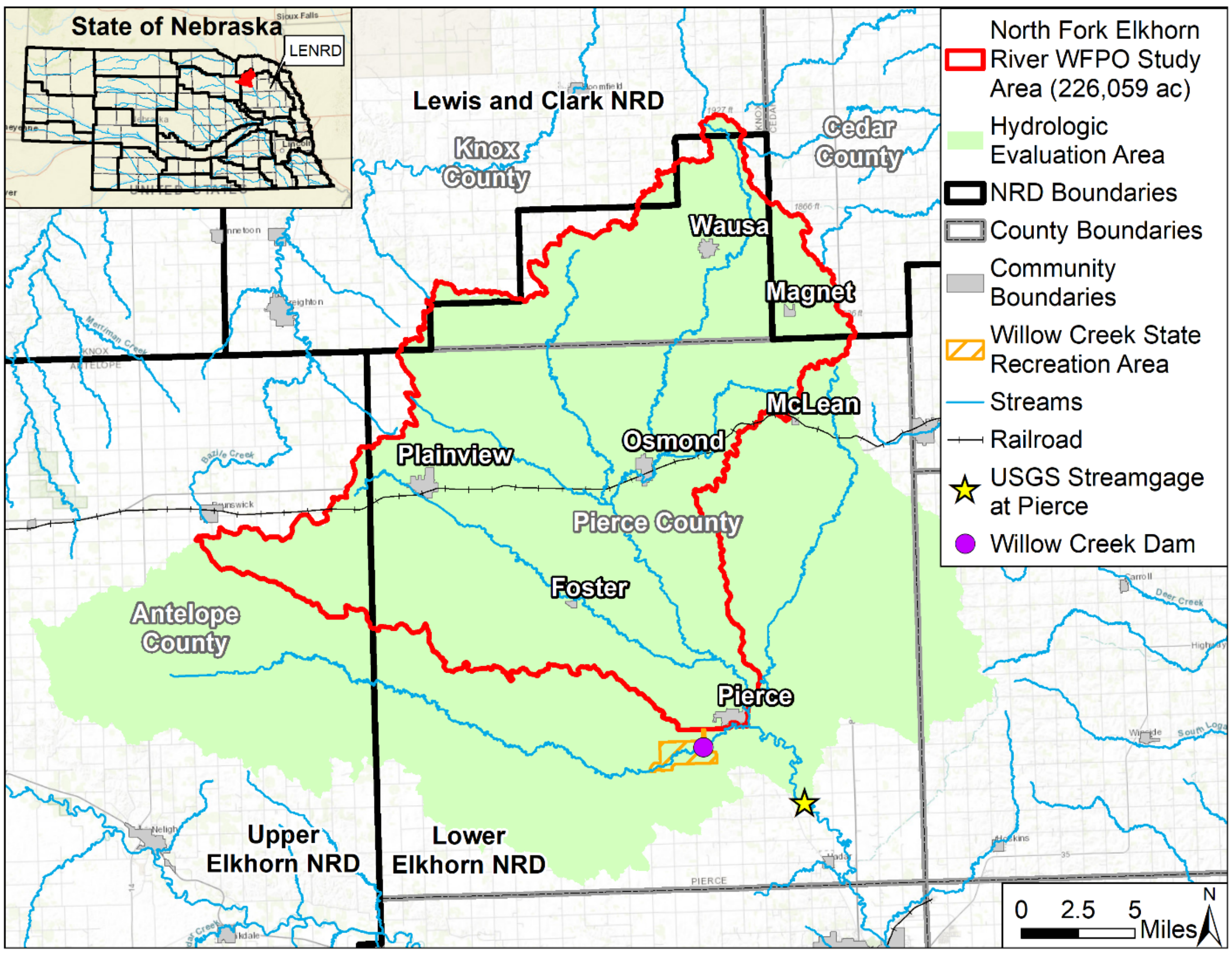


Figure 1: Project Evaluation Area

The following sections outline available background data, data sources, and other methods used in the development of the baseline hydrologic conditions within the study area.

D 2.01 EXISTING STUDIES

PIERCE-NORTH BRANCH ELKHORN RIGHT BANK LEVEE SYSTEM

The Pierce-North Branch Elkhorn Flood Protection Project was authorized in 1950 and constructed between September 1963 and May 1964. According to the National Levee Database, the Levee System manages flood risk for approximately 0.77 square miles of the City of Pierce, and includes 1,253 people, 563 structures and a total estimated property value of $250 million. According to the levee O&M Manual, the Levee System was designed to pass the flows resulting from a 100-year storm with peak discharge of 24,000 cfs upstream of Willow Creek and 30,000 cfs downstream of Willow Creek with three feet of freeboard.

WILLOW CREEK DAM AS-BUILT DATA

Willow Creek Dam is located outside of the project area but is situated upstream of the closest stream gage, as shown in Figure 1. This stream gage was used for model calibration. As such, it was necessary to include the Willow Creek Dam in the hydrologic modeling to accurately represent watershed conditions and ensure proper calibration to observed flows. Construction of the Willow Creek Dam was completed in 1980. Per the as-built plans the contributing drainage area to the dam is 210 square miles. According to the as-builts the 100-Year runoff to the dam was calculated using the SCS method assuming a runoff curve number of 64.5 and a time of concentration of 68.5 hours resulting in a peak flow of 4,490 cfs.

USACE ELKHORN RIVER FLOODPLAIN MANAGEMENT SERVICES (FPMS)

Significant flooding was experienced in the Elkhorn River watershed in June 2010 and again in March 2019. Widespread rainfall over the watershed during June of 2010 caused flooding of the Elkhorn River and its tributaries amounting to millions of dollars in damages to public and private property. In March of 2019 rapid snowmelt combined with a bomb cyclone again resulted in significant flooding across the state of Nebraska including the Elkhorn River Watershed.

The USACE completed a hydrologic analysis of the Elkhorn River Watershed in 2018 and subsequently updated the analysis in 2022 following the March 2019 flood event. The 2018 original study included the creation of an HEC-HMS hydrologic model which was calibrated to two historic events and the results from gage analyses of the stream gages in the watershed. The gage analyses completed as part of the 2018 event were updated following the March 2019 event.

A mixed population peak flow frequency (PFF) analysis was determined to be most applicable to the Elkhorn Basin and its flood record for two primary reasons: the single-population PFF did not represent the infrequent events well at many of the gages and there are two driving runoff mechanisms (snowmelt and rainfall) which produced two very different seasonal PFFs. Bulletin 17C analysis was completed for each of the gages for each season using a weighted skew. A 14-gage seasonal regional skew was developed from the station skews of the gages in the study.

Per the study, the USGS (Soenkson et. Al, 1999) regional skews could not be used because: the Soenksen study is too dated, extraordinary events like the 2010 and 2019 events were not included in the regional skew estimates, and the regional estimate includes a mixture of snowmelt and rainfall events. Further analysis was then completed to establish hydrographs for each stream gage for both the snowmelt and rainfall season.

NEDNR FLOOD RISK AWARENESS AREAS

The Nebraska Department of Natural Resources (NeDNR) completed a hydrologic and hydraulic analysis of the watershed using Nebraska's Flood Assessment Calculation Tool (NFACT). The NFACT tool estimates peak flows for the watershed using the regional regression equations. Base flood elevations are then estimated using LiDAR data and normal depth based hydraulic calculations. This analysis did not explicitly include any gage observations or other calibration data from recent major flood events, nor did it include the USACE hydrology study.

OSMOND DRAINAGE STUDY

Following the historic flooding resulting from the March 2019 event, the City of Osmond contracted JEO Consulting Group to evaluate the existing flood risk to the city and provide recommended actions to reduce the risk. JEO collected a survey of the existing bridge and culvert structures to aid in the development of a 1D/2D HEC-RAS hydraulic model. Analysis was completed to replicate the March 2019 event as well as the estimated 100-Year event based on the USACE 2018 hydrologic model. Alternatives recommended to reduce the existing flood risk included various levees, development of a flood preparedness plan, and nonstructural alternatives.

PIERCE DRAINAGE STUDY

The City of Pierce has a history of flooding behind the levee system due to interior drainage. Following the March 2019 event the city contracted JEO Consulting Group to evaluate the existing interior drainage conditions within the city and to provide recommendations for drainage improvements to reduce flooding risks from interior drainage. The study identified three key areas where flows enter the city based on city staff feedback which were verified by topography. A HEC-RAS rain-on-grid analysis was completed to identify the existing conditions based on 10-Year and 100-Year storm events assuming both open and closed outfall conditions at the levee. Alternatives recommended to reduce the existing flood risk included various culvert improvements and upstream detention.

STREAM GAGES

The USGS Stream Gage 06799100 North Fork Elkhorn River Near Pierce, Nebraska has been active since 1960. The stream gage is located at 850th Road approximately three miles south of the City of Pierce. Daily and annual peak flow data from this gage is available from 1960 to the present. Instantaneous, stage data and a rating curve are available from 1990 to the present. Recorded annual peak flows range from 46 cfs in 1990 to an estimated 79,000 cfs in 2019.

D 2.02 HYDROLOGIC METHODOLOGY

HYDROMETEORLOGICAL CONDITIONS

Runoff within the North Fork Elkhorn River watershed can be due to two different hydrometeorological conditions, rainfall and snowmelt runoff events, which vary seasonally. However, since NRCS designs are based exclusively on rainfall events, this analysis is focused only on runoff events due to rainfall.

SUBBASIN DELINEATIONS

North Fork Elkhorn River subbasins were delineated using HEC-HMS version 4.11. Terrain data was obtained from USGS NE_Northeast_2020 LiDAR collected between March and June 2020. Basins were delineated based on the locations of tributary confluences. In total, 57 subbasins ranging in size from 0.1 to 210 square miles were delineated. The smaller basins represent those basins which contribute to the interior drainage to the Pierce levee system while the largest basin represents the entire portion of the watershed which drains to the Willow Creek Reservoir.

LOSS AND TRANSFORM METHODS

The North Fork Elkhorn River hydrologic model uses the SCS Curve Number loss method. A lookup table was created based on TR-55 runoff curve number tables and similar studies in the area to determine the curve number for each hydrologic soil group and land use combination. The lookup table was cross referenced with the soil and land use data to determine the initial SCS runoff curve numbers for each subbasin. Within ArcGIS, the zonal statistics function was used to determine the composite curve number for each subbasin. The resulting composite curve number for Willow Creek was significantly lower than the value reported in the design plans. The grassland/herbaceous land use curve number value for HSG Group A was therefore increased from 39 to 49. The final curve number lookup table used is shown in Table 1. Figure 2 illustrates an overview of basin delineations and final calculated curve numbers.

Table 1: Curve Number Lookup Table

Land Use Description (NLCD 2019)	Hydrologic Soil Groups (SSURGO)			
	A	B	C	D
Open water	100	100	100	100
Developed, open space	49	69	79	84
Developed, low intensity	51	68	79	84
Developed, medium intensity	77	85	90	92
Developed, high intensity	89	92	94	95
Barren land (rock/sand/clay)	77	86	91	94
Deciduous forest	45	66	77	83
Evergreen forest	30	55	70	77

Mixed Forest land	36	60	73	79
Shrub/Scrub	35	56	70	77
Grassland/Herbaceous	49	61	74	80
Sedge	39	62	74	85
Pasture/Hay	68	79	86	89
Cultivated crops	64	75	82	85
Woody wetlands	36	58	72	78
Emergent Herbaceous wetlands	30	58	71	78

The Time of Concentration for each basin was developed with TR-55 methodology. Depending on the subbasin, a mixture of Sheet Flow, Shallow Concentrated Flow, and Channel Flow was used. The maximum length of sheet flow was assumed to be 100 feet. Channel slopes were determined using stream elevation profiles calculated in ArcGIS. The SCS lag time was then assumed to be 0.6 times the calculated time of concentration. Initial model parameters assumed the standard SCS peaking factor of 484.

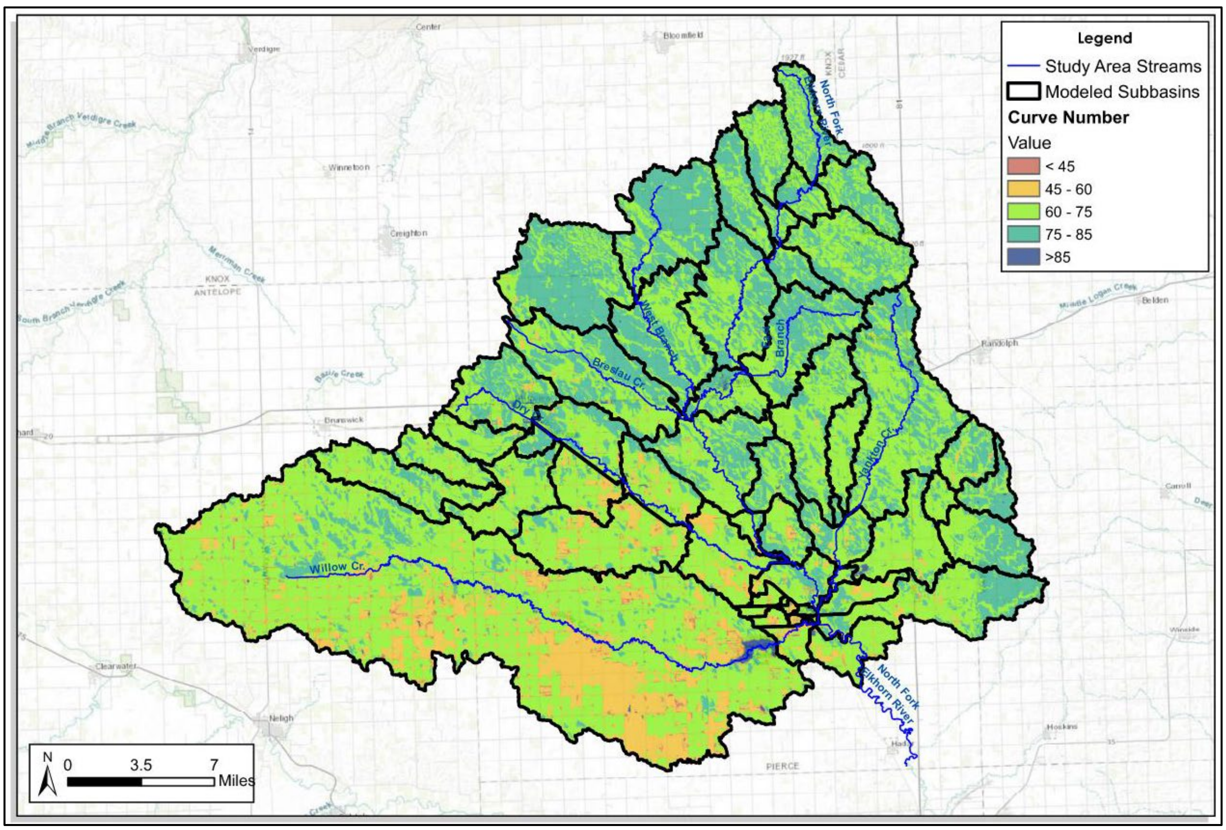


Figure 2: Initial Curve Numbers

ROUTING AND STORAGE – EXISTING CONDITIONS

The Muskingum-Cunge method was used to route flow through the stream reaches. Channel lengths and slopes were determined using HEC-HMS. Channel slopes ranged from 0.0003 ft/ft to 0.0030 ft/ft. Channel cross sections were defined by eight-point cross sections; these cross-sections were determined using the 1-meter DEM and the points filter tool in HEC-RAS. A manning's n-value of 0.03 and 0.04 was assigned for the main channel and overbanks, respectively.

The Willow Creek Dam was modeled using the Elevation-Storage-Discharge method within HEC-HMS. The Elevation-Storage and Elevation-Discharge tables were taken from the USACE 2018 HEC-HMS model.

METEOROLOGICAL MODEL – EXISTING CONDITIONS FREQUENCY STORM

Hypothetical storms created using the frequency storm meteorologic model were used to develop a baseline model for the hypothetical 10- through 500-year storm events. Nested precipitation frequency data, illustrated in Table 2 for the 24-hour rainfall depths only, was obtained from the National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server (PFDS) based on Atlas 14. A 5-minute timestep was used in the model. Full details of the precipitation data are provided in the HMS model. An areal reduction factor was applied based on the watershed area and the TP40 TP 49 area reduction method.

Table 2 – 24 Hour Rainfall Depths

Design Storm	Rainfall Depth (In)
10-year	3.8
25-year	4.5
50-year	5.1
100-year	5.7
500-year	6.3

D 2.03 MODEL CALIBRATION

A Bulletin 17C statistical calibration was completed for this model. The model was run using hypothetical storms and the results were compared with the statistical parameters from the Bulletin 17C analysis.

BULLETIN 17C CALIBRATION

An annual Bulletin 17C analysis of the USGS Stream Gage 06799100 North Fork Elkhorn River Near Pierce was completed using the HEC-SSP software program Version 2.2. Annual analysis was completed in lieu of the USACE seasonal analysis to simplify the modeling to focus on the runoff from rainfall events while still maintaining the integrity of the results. Annual peak discharges reported from the gage ranged from 46-cfs (1990) to 79,000-cfs (2019). The 2019 peak flow was estimated based on stage observations using a rating curve. An annual regional skew was calculated using the same 14 gages analyzed in the USACE seasonal study and the formula reported in the USACE seasonal study –

$$G_R = \frac{\sum_{i=1}^{n} x_i G_i}{\sum_{i=1}^{n} x_i}$$

Where G_R is the regional skew (weighted average skew), x is the number of systematic events in the period of record, G is the seasonal station skew and n is the number of gage stations. The resulting regional calculated skew 0.015 as shown in Table 3. Also reported in Table 3 are the seasonal regional skews reported in the USACE study.

Table 3: Regional Skew Analysis

Gage	Events	Station Skew
Foster	18	-0.359
Madison	15	-0.167
Scribner	15	0.300
Ewing (South Fork)	36	0.155
Nickerson	72	0.033
Atkinson	11	-1.007
Pierce	62	0.827
Pender	28	-0.216
Uehling	82	-0.636
Ewing (Elkhorn)	75	-0.031
Neligh	61	0.210
Norfolk	90	0.067
West Point	79	-0.003
Waterloo	105	0.089
Annual Weighted Average Skew		**0.015**
USACE Snowmelt Average Skew		**0.170**
USACE Rainfall Average Skew		**-0.330**

The Bulletin 17C analysis used a weighted skew of 0.441 which was calculated using a combination of the station and regional skew values. The station skew, determined from the USGS gage, was -0.453. The analysis identified one low outlier resulting in an equivalent record length of 61 years. Results of the analysis compared to the USACE seasonal analysis are shown in Table 4 and Figure 3.

Table 4: Peak Flow Frequency Results (cfs)

Annual Exceedance Probability	USACE Mixed Population Analysis	Updated Annual Analysis
0.2	76,800	51,800
1	27,200	23,100
2	16,600	15,800
4	10,000	10,500
10	5,400	5,700

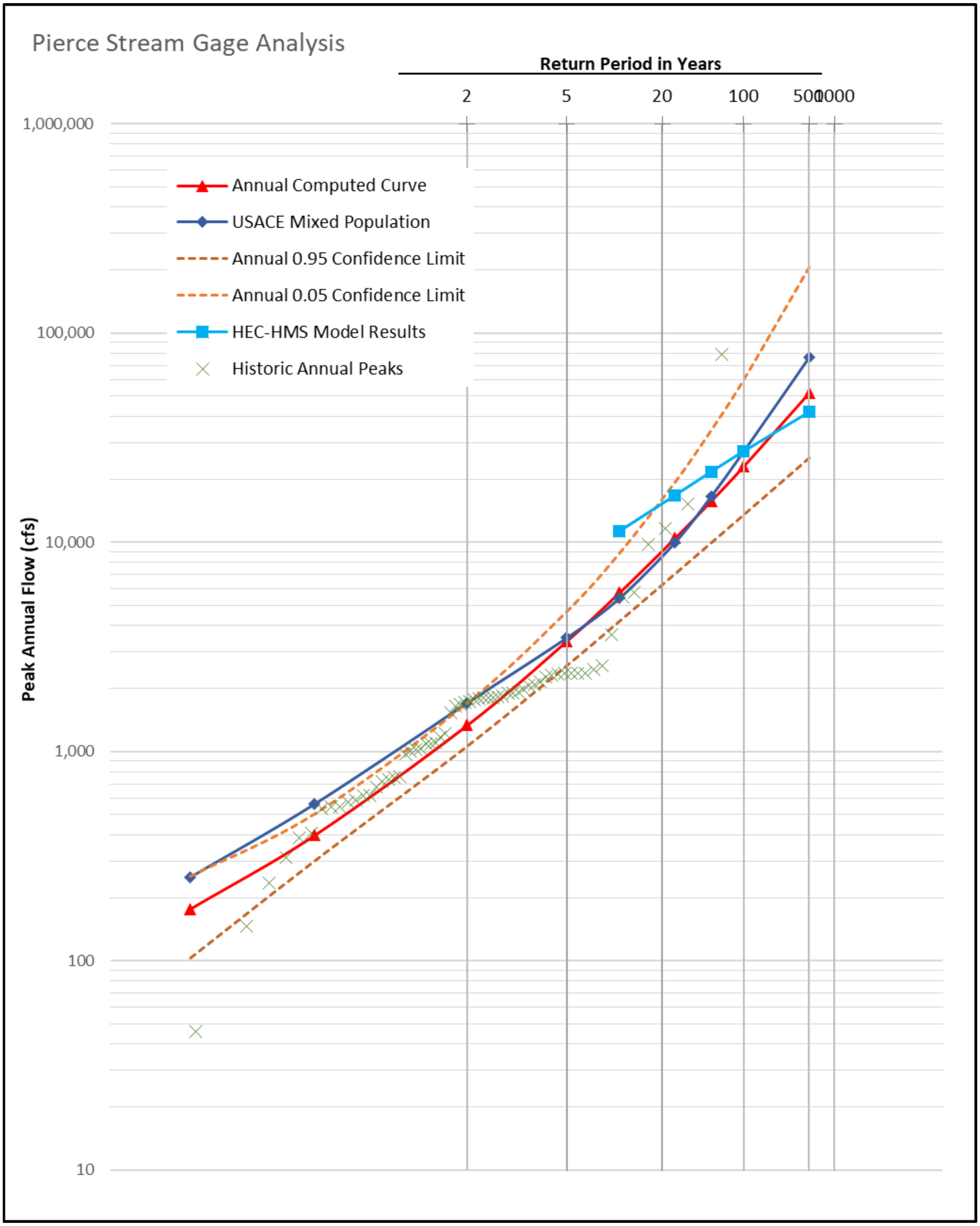


Figure 3: Bulletin 17C Gage Analysis Plots

The uncalibrated HEC-HMS model resulted in peak flows higher than results of the Bulletin 17C Annual Analysis for all events as shown in Table 5.

Table 5: Bulletin 17C Analysis Vs. HEC-HMS Model Results

Annual Exceedance Probability	USACE Mixed Population Computed Curve from SSP (cfs)	Annual Computed Curve Flow from SSP (cfs)	Annual 0.05 Confidence Limit from SSP (cfs)	Annual 0.95 Confidence Limit from SSP (cfs)	HEC-HMS Uncalibrated Results (cfs)	Percent Difference Between Pre-Calibration and Annual 17C Flows	HEC-HMS Calibrated Results (cfs)	Percent Difference Between Calibrated and Annual 17C Flows
0.002	76,800	51,804	206,850	25,449	60,352	14%	42,110	-23%
0.01	27,200	23,067	59,780	13,598	38,946	41%	27,239	15%
0.02	16,600	15,769	34,341	9,996	31,072	49%	21,734	27%
0.04	10,000	10,485	19,421	7,109	24,051	56%	16,774	37%
0.10	5,400	5,747	8,847	4,208	16,134	64%	11,255	49%

Reach manning's n values and the transform peaking factor were reviewed and adjusted for model calibration to better match the annual 17C analysis results. Manning's n values were adjusted to 0.045 and 0.055 for the main channel and overbanks, respectively. Transform peaking factors were set at 300 for the upper northern and eastern basins which have steeper slopes and 250 for the lower and western basins based on guidance from Table 2 of the NOAA Unit Hydrograph Technical Manual as shown in Figure 4.

General Description	Peaking Factor	Limb Ratio (Recession to Rising)
Urban areas; steep slopes	575	1.25
Typical SCS	484	1.67
Misxed urban/rural	400	2.25
Rural, rolling hills	300	3.33
Rural, slight slopes	200	5.5
Rural, very flat	100	12.0

Figure 4: NOAA Unit Hydrograph Technical Manual Table 2

Resulting calibrated peak flows for the 0.10 to 0.002 annual exceedance probability (AEP) events are shown in Table 5. While the model matches well for the 0.01 AEP event based on the USACE seasonal analysis and the updated annual Bulletin 17C analysis, it underpredicts the 0.002 AEP and overpredicts for the more frequent events.

VOLUME FREQUENCY ANALYSIS CALIBRATION

A Volume-Frequency Analysis of the USGS Stream Gage 06799100 North Fork Elkhorn River Near Pierce was completed using the HEC-SSP software program Version 2.2. The Volume Frequency Analysis used Log Transform, analyzed Maximums, the Weibull plotting position, and the station skew. Results of the Volume Frequency Analysis compared to model output are reported in Table 6:

Table 6: Results of Volume Frequency Analysis

Annual Exceedance Probability	HEC-SSP 3-Day Volume (acft)	HEC-HMS Model 3-Day Volume (acft)	Percent Difference Between HEC-HMS Model and HEC-SSP
0.002	126,193	96,500	-0.31
0.01	63,059	62,768	0.00
0.02	45,409	51,209	0.11
0.04	31,869	40,653	0.22
0.10	18,841	28,362	0.34

USACE BALANCED HYDROGRAPH

As previously mentioned, the USACE developed balanced hydrographs based on the USGS Stream Gage 06799100 North Fork Elkhorn River Near Pierce. Per the study:

> *Observed hydrographs were scaled by both peak flow and critical duration volume. Snowmelt and rainfall flow events were identified at each gage and their durations estimated from the hydrographs. Volume frequencies were developed to help estimate volumes for the critical duration and hydrograph patterns were scaled by peak flow and critical volume.*

The USACE calculated peak hydrographs plotted against the resulting 0.01 AEP hydrograph from the calibrated HEC-HMS model is shown in Figure 5.

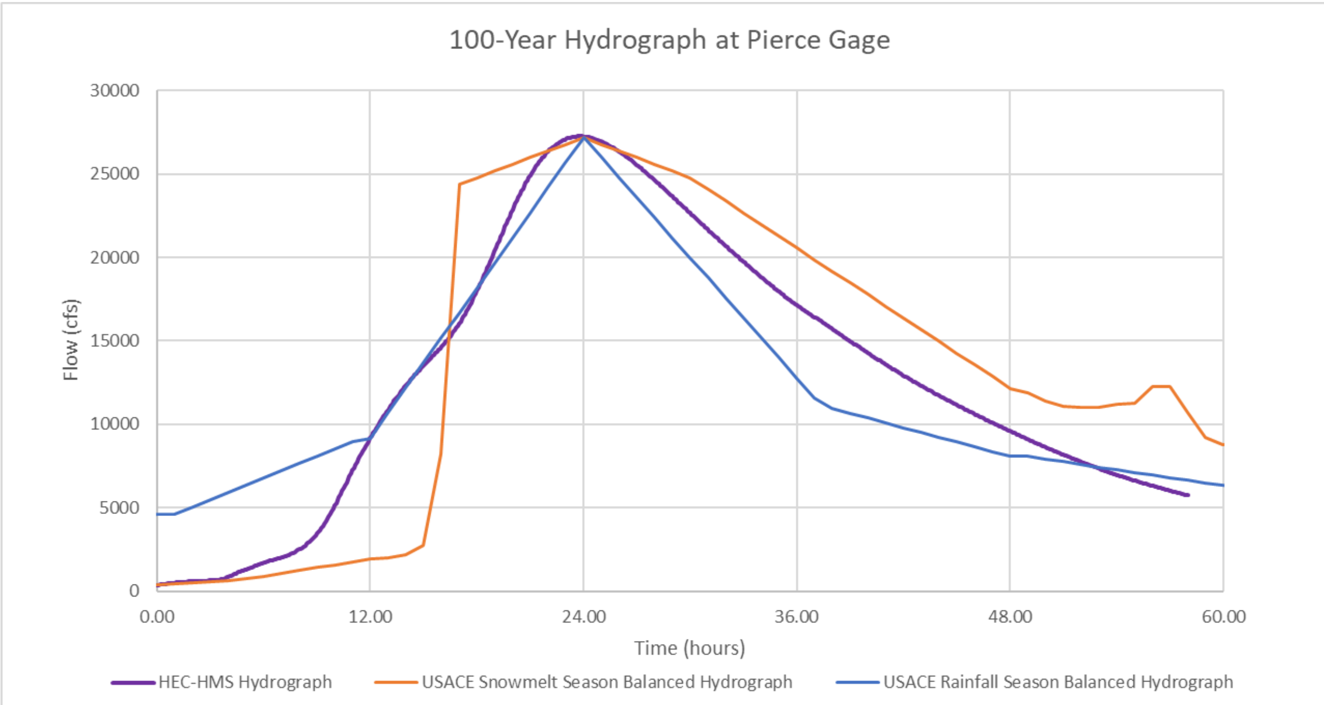


Figure 5: USACE and HEC-HMS Hydrograph at Pierce Gage

REGRESSION EQUATION REVIEW

The NeDNR flood risk awareness analysis of the watershed included peak flow estimates based on regional regression equations. The regression equation estimates for the 0.01 AEP event were compared to the HEC-HMS model results at key locations. Results shown in Table 7 include both the HEC-HMS model results with and without the areal reduction factor based on the watershed drainage area of 706 square miles at the gage site.

Table 7: 100-Year Peak Flows HEC-HMS vs. Regression Equations

Location	Contributing Drainage Area (sqmi)	HEC-HMS (w/o Areal Reduction)	HEC-HMS (with Areal Reduction)	1993 Cordes Regression	2005 Strahm Regression	1999 Soenksen Regression
Osmond	100.2	9,557	9,276	9,580	10,202	14,709
Dry Creek	115.8	6,538	6,330	10,995	6,048	5,898
Yankton Slough	105.9	9,561	9,239	11,971	10,927	14,763
Willow Creek Dam	210.6	5,746	4,738	15,803	10,528	6,949
USGS Stream Gage	706	28,336	27,239	29,358	21,064	35,643

FINAL CALIBRATION

Based on the results of the Bulletin 17C analyses and the Volume Frequency Analysis, the model overpredicts peak flows and flood volumes for more frequent return period events while slightly underpredicting for the 0.002 annual exceedance probability event. However, it does closely match for the 0.01 annual exceedance probability event based on the gage analysis as well as the regression equations and the USACE seasonal study. Overall results are a reasonable representation of rainfall runoff conditions for the purposes of modeling flood stages and conceptual flood risk reduction action effectiveness.

D 2.04 BASELINE HYDRAULIC CONDITIONS

Hydrologic conditions for the calibrated HEC-HMS model were utilized to simulate regional flooding risk using hydraulic modeling. Figure 6 shows the locations where unsteady flows are taken from the HEC-HMS model for the hydraulic modeling of Pierce. Peak flows at these locations as well as the peak flows at Osmond (J5) are shown in Table 8 for each flow event.

Figure 6: Hydraulic Model Inflow Locations

Table 8: HMS Modeled Baseline Peak Flows

HEC-HMS Model Peak Flow (CFS)							
Flow Location	**HEC-RAS Modeled Area**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**	**500-Year**
J5	Osmond	2,979	4,134	5,932	7,523	9,276	13,899
J15	Pierce Riverine	5,068	7,001	10,141	12,890	15,929	23,985
J21	Pierce Riverine	3,064	4,189	5,965	7,518	9,223	13,752
Dry_Creek	Pierce Riverine	1,711	2,502	3,804	4,991	6,330	10,048
Willow_Dam	Pierce Riverine	334	540	689	783	871	3,704
NF41	Pierce Riverine	143	200	291	372	462	705
NF42	Pierce Riverine	41	60	91	119	150	234
NF45	Pierce Riverine	101	145	216	281	353	549
NF46	Pierce Riverine	372	510	725	913	1,120	1,669
NF47	Pierce Riverine	168	250	385	509	649	1,034
NF44_1	Pierce Interior	48	77	126	172	224	371
NF44_2	Pierce Interior	10	16	25	34	45	73
NF44_3	Pierce Interior	45	72	118	161	209	344
NF44_4	Pierce Interior	8	14	23	32	42	70
NF44_5	Pierce Interior	105	135	182	222	265	376
NF44_6	Pierce Interior	53	88	149	208	275	464
NF44_7	Pierce Interior	58	76	107	136	169	261
NF44_8	Pierce Interior	13	17	23	27	33	47
NF44_9	Pierce Interior	38	48	63	76	90	126
NF44_10	Pierce Interior	64	104	172	235	309	517
NF44_11	Pierce Interior	11	21	39	56	77	138

D 3. HYDRAULIC ANALYSIS

The purpose of this section is to outline the hydraulic analysis completed as part of the WFPO planning process for the North Fork Elkhorn River Watershed. This hydraulic model will be used to establish existing conditions and serve as a baseline for evaluating engineering alternatives identified as part of the planning process. The North Fork Elkhorn River has a history of documented flooding events. Prior flood events, studies, and relevant information were taken into consideration with this hydraulic modeling effort and report:

- Pierce-North Branch Elkhorn Right Bank Levee System (1963)
- Willow Creek Dam (1980)
- Elkhorn River Floodplain Management Services (USACE 2022)
- Flood Risk Awareness Analysis (NeDNR)
- March 2019 Flood event
- Osmond Drainage Study (JEO 2020)
- Pierce Drainage Study (JEO 2022)

D 3.01 HYDRAULIC METHODOLOGY

Following discussions with local residents and stakeholders, it was determined there were two primary areas with historical flooding issues which were desired to be focused on: the cities of Pierce and Osmond in Pierce County, Nebraska. The hydraulic analysis was completed in HEC-RAS Version 6.4.1 using a two dimensional (2D) modeling approach. Terrain data for the analysis was obtained from the most recent USGS LiDAR (2020) and supplemented as needed. The LiDAR at Pierce was collected on March 29, 2020. According to the USGS Stream Gage at Pierce flow on the North Fork Elkhorn River ranged between approximately 900 and 1,200 cfs at the time the LiDAR was flown. A pilot trapezoidal baseflow channel was created using the terrain modifications function in HEC-RAS to approximate the bathymetry which would not have been collected by the LiDAR. NDOT as-built bridge plans were used to model the Highway 98 Bridge by Pierce while survey collected in 2020 and as a part of this study was used to model the highway through and adjacent to Osmond. The railroad bridges in Osmond have recently been removed and replaced. A survey of the railroads was therefore collected and included in the model. Additional survey was also collected and incorporated into the model of key culverts around Pierce.

Numerous break lines were incorporated within the model to enforce important topographic features (roadway embankments, berms, channel bottoms, etc.) into the 2D grid to shape the modeled flow of water to natural topographic features. Manning's roughness coefficients of the channel and floodplains were based off land use data obtained from the 2019 NLCD. A channel override value was used to help calibrate flows and better reflect actual channel roughness. A channel manning's n-value of 0.04 was assumed for the portion of the river through and adjacent to Osmond considering the numerous bends throughout this reach. Channel manning's n-value for the section of reach adjacent to Pierce was originally set at 0.03 assuming a fairly straight clean reach and then lowered to 0.025 to better match high water marks taken following the March 2019 flood event and the rating curve of the USGS stream gage south of Pierce. Table 9 shows the different land uses and associated Manning's n values used in the model.

2D HEC-RAS models were created for the North Fork Elkhorn River, focusing on Pierce and Osmond. A grid cell size of 50 ft x 50 ft for Osmond and 100 ft x 100 ft for Pierce was used to provide sufficient resolution of model outputs while also maintaining reasonable computing run times. Break line cell spacing along key features such as 2D area connections was generally set at 50 ft. A visual schematic of the hydraulic model outline is shown in Figure 7 and Figure 8. The outflow boundary condition was assumed to be normal depth with the energy slope estimated from LiDAR, which was 0.00085 ft/ft. Each model has one outflow boundary condition where flow can leave the models, which is the North Fork Elkhorn River southwest of the City of Osmond and southeast of the City of Pierce. There were also numerous inflow boundaries used to model the different hydrographs from each subbasin as modeled in HEC-HMS; see Figure 6. The different boundary conditions were paired with flow hydrographs from the HMS output at various points throughout the model. The model was run for a period sufficient to pass the peak flow completely through each community.

Table 9: Manning's n-values Used in HEC-RAS Model

Land Use	Manning's n-values	Land Use	Manning's n-values
Cultivated Crops	0.03	Mixed Forest	0.08
Grassland-Herbaceous	0.04	Emergent Herbaceous Wetlands	0.06
Developed, Open Space	0.04	Woody Wetlands	0.08
Deciduous Forest	0.08	Open Water	0.03
Developed, Low Intensity	0.06	Pasture-Hay	0.04
Developed, Medium Intensity	0.08	Barren Land Rock-Sand-Clay	0.03
Developed, High Intensity	0.12	Evergreen Forest	0.08

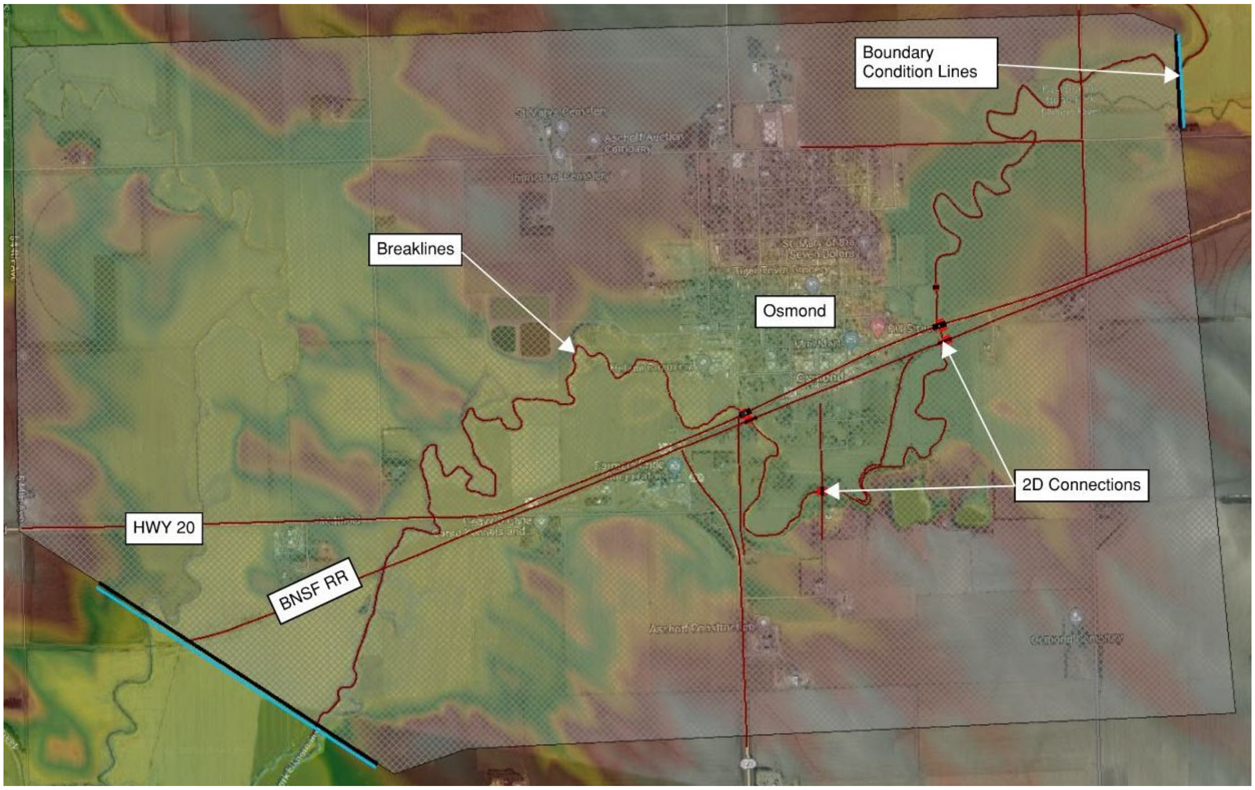


Figure 7: 2D Extents for Hydraulic Modeling at Osmond

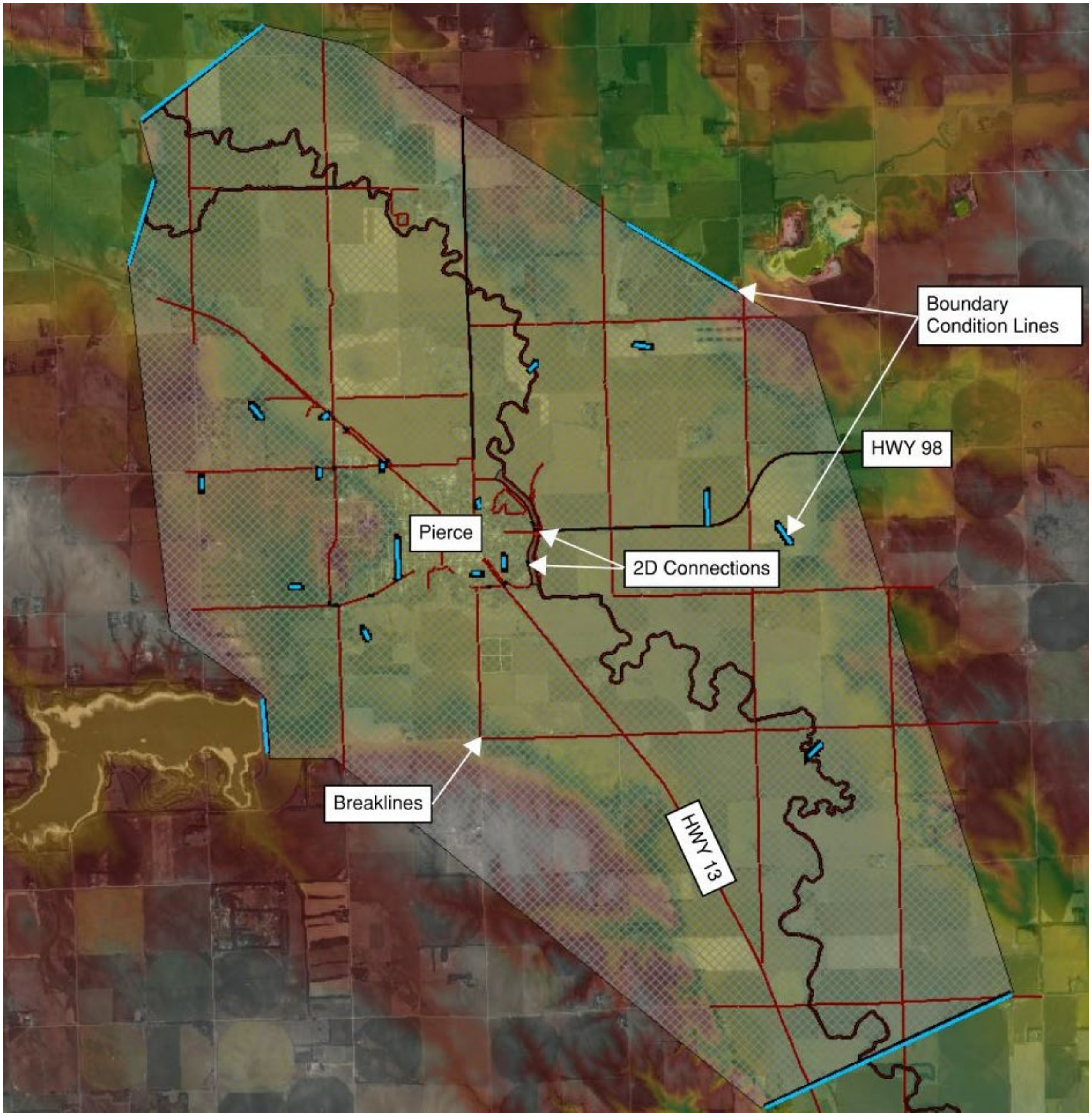
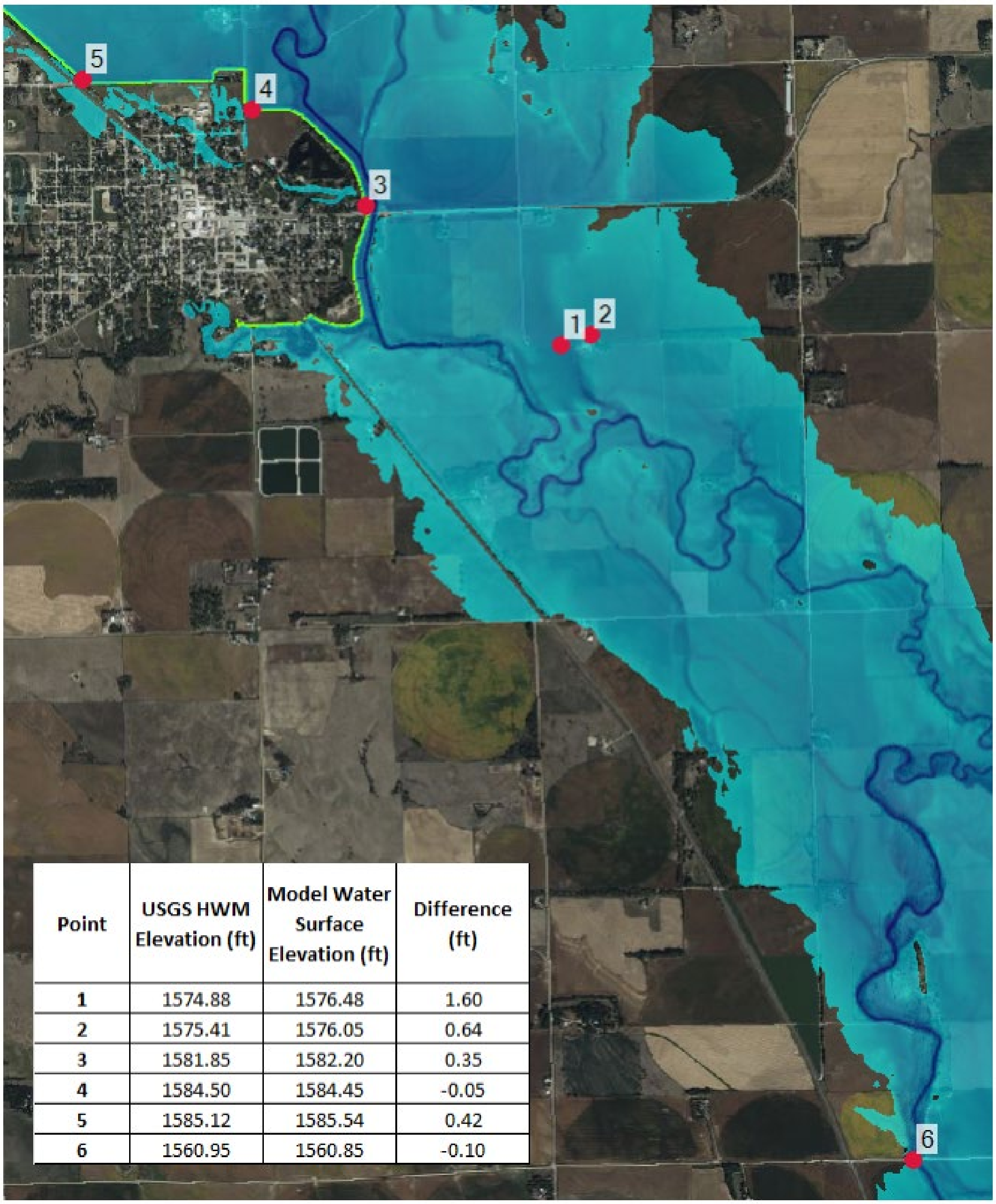


Figure 8: 2D Extents for Hydraulic Modeling at Pierce

D 3.02 MODEL CALIBRATION

Hydraulic model calibration was completed using the measured flow at the USGS Stream Gage at Pierce during the March 2019 flood event. A flow hydrograph with a peak discharge of 65,200 cfs was input into the model at the J15 boundary condition line. Originally the estimated peak flow of 79,000 as reported at the gage was used, but the model results were consistently higher than the USGS-surveyed high water marks (HWM). Given the uncertainty in the flow, the lower USGS field measured value was used for calibration instead. The channel Manning's n-values were lowered to 0.025 in the Pierce model. Additional override regions were also placed and set a 0.015 on the major roads which are significantly overtopped during the infrequent events. The resulting modeled water surface elevation was within +/- 0.5 feet of the surveyed elevation at four of the six high water marks, as shown in Figure 9.



Point	USGS HWM Elevation (ft)	Model Water Surface Elevation (ft)	Difference (ft)
1	1574.88	1576.48	1.60
2	1575.41	1576.05	0.64
3	1581.85	1582.20	0.35
4	1584.50	1584.45	-0.05
5	1585.12	1585.54	0.42
6	1560.95	1560.85	-0.10

Figure 9: March 2019 Hydraulic Calibration

The USGS stream gage rating curve was also compared to the model results and found to be within +/- 0.5 feet for the modeled events as shown in Table 10. Generally, the model appears to overpredict the less frequent event water surface elevations, while underpredicting the more frequent events.

Table 10: USGS Rating Curve vs. Model Results

Event	Peak Flow at Outlet (cfs)	Water Surface Elevation (NAVD88 ft)		Difference (ft)
		Rating Curve	Model	
500-Year	43828	1560.124	1560.24	-0.116
100-Year	28061	1559.764	1559.61	0.154
50-Year	21845	1559.564	1559.3	0.264
25-Year	16743	1559.354	1559.05	0.304
10-Year	10545	1558.994	1558.6	0.394

D 3.03 BASELINE HYDRAULIC RESULTS

OSMOND AREA FLOODING RESULTS

Significant flooding occurs in Osmond caused by riverine flooding of the North Fork Elkhorn River as shown in Figure 10. The peak flow rate from the 100-year event just upstream of Osmond is 9,276 cfs with a three-day volume accumulation of 14,980 acre-ft. The max flooding depth at the flowline of the North Fork Elkhorn River is approximately 15 ft. Once water escapes the main channel bank, flooding depths range from two to eight feet. The modeled floodplain widths range from 1,200 ft to 2,600 ft.

During a 100-year flood event, there is significant overtopping of both the highway and railroad bridges on the east and west sides of town. The backwater effects from the east structures create a secondary flow path along 4th Street, which continues through downtown Osmond before rejoining the North Fork Elkhorn River floodplain west of the city. The area south of the railroad tracks lies mostly within the natural floodplain and has historically experienced severe flooding. There are limited properties in this area partially due to regulations and proactive city policies, including property acquisition offers following the March 2019 flood. Additionally, a newer subdivision in the northeast part of the city is affected by the backwater from the bridges, with homes in this area reporting basement flooding up to depths of approximately seven feet during the March 2019 event.

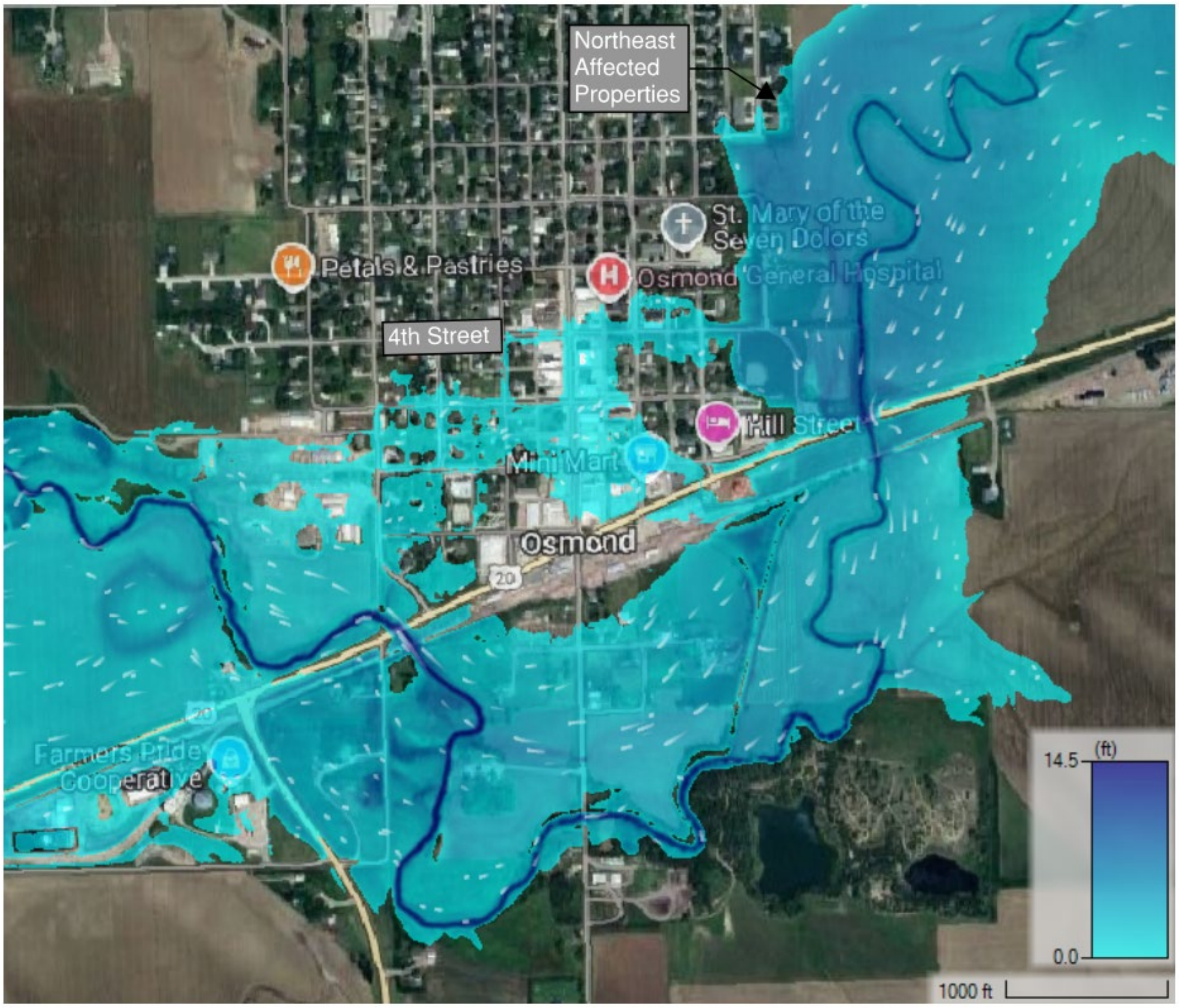


Figure 10: Existing 100-Year Maximum Flooding Depths at Osmond

PIERCE AREA FLOODING RESULTS

During the March 2019 flood event the City of Pierce was protected from flooding of the North Fork Elkhorn River by the Pierce-North Branch Elkhorn Flood Protection Project which was constructed between September 1963 and May 1964. While the levee served its purpose to reduce impacts from riverine flooding, the city has a history of flooding landside of the levee system due to interior drainage. During high flow events in the river, gate closures on the gravity pipes through the levee system are utilized to prevent backflow of flood waters from the river to the city. When these gates are closed, interior drainage within the city cannot drain by gravity through the levee to the river, resulting in ponding within the city. This occurred in the March 2019 flood event, when several homes and businesses experienced flood damage.

Pierce is therefore impacted by flooding from two sources within the North Fork Elkhorn River Watershed herein identified as Riverine and Interior Drainage. Each was modeled separately using the National Cooperative Highway Research Program NCHRP Report 15-36 technique for estimating joint probabilities of coincident flows developed by the AASHTO Model Drainage Manual. The drainage area ratios of the interior drainage basins and the drainage basins contributing flow to the North Fork Elkhorn River at Pierce were used to determine the flood flow frequency used in the model for the North Fork Elkhorn River corresponding to the size of event modeled for the interior drainage basins and vice versa. Table 11 below shows the coincident events with the North Fork Elkhorn River.

Table 11: Joint Probability of Coincident Flood Events

Stream	Frequency for Coincidental Occurrence (years)				
Joint Return Period	**10**	**25**	**50**	**100**	**500**
Interior Drainage	10	25	50	100	500
North Fork Elkhorn River	2	2	2	2	5
North Fork Elkhorn River Flow Rate (cfs)	4,719	4,719	4,719	4,719	7,792

INTERIOR FLOODING RESULTS

Flooding results during a 100-Year interior rainfall event are shown in Figure 11. Three key locations were identified which ultimately resulted in ponding landside of the existing levee. These locations are identified as the Southwest Area, Northwest Area and Urban Drainage area.

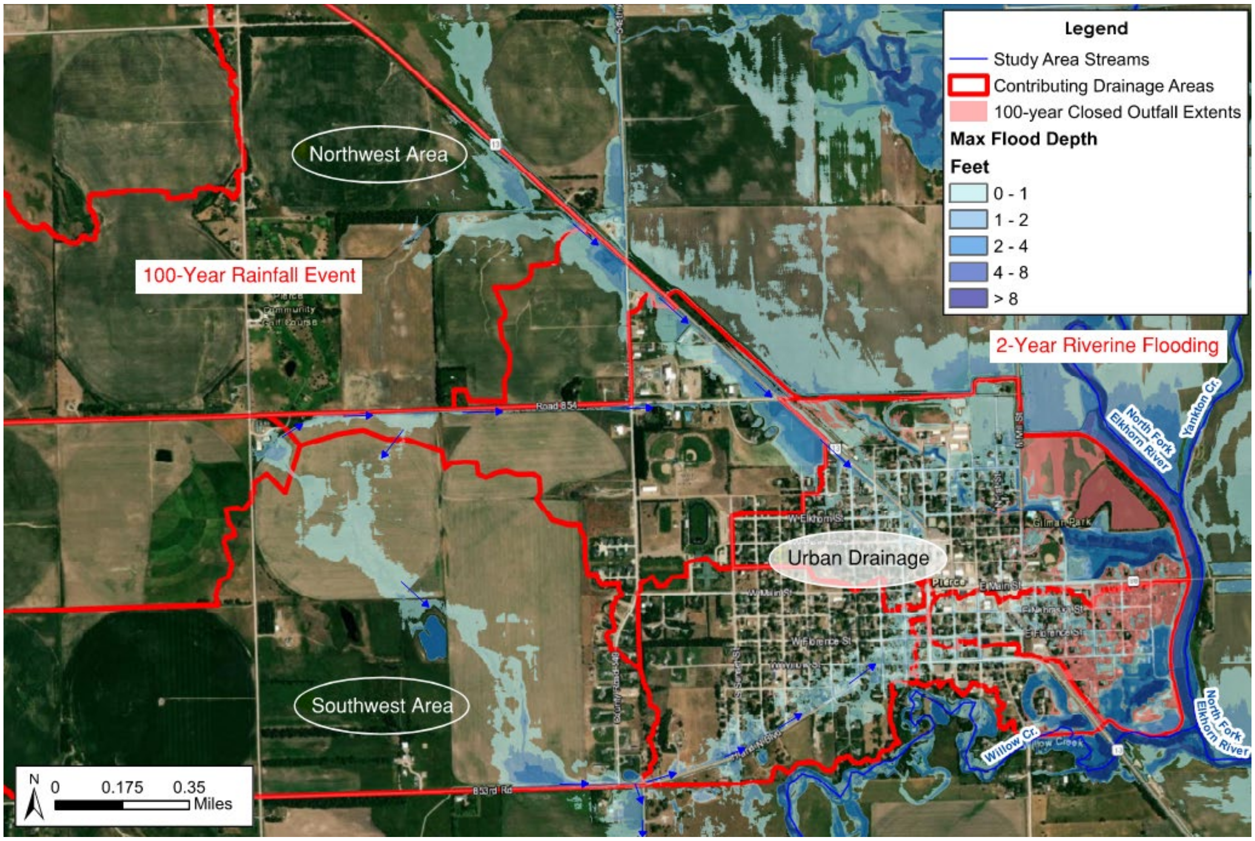


Figure 11: Existing Pierce 100-Year Interior Flooding

The southwest area includes runoff which flows towards the intersection of 853rd Road and 549th Avenue. During small storm events, drainage from the west is conveyed by a 36" CMP culvert under 853rd Road south and ultimately to Willow Creek. However, during heavy rainfall runoff ultimately overtops the intersection resulting in approximately 49 acre-feet and a peak flow of 120 cfs flowing along the north side of H and N Boulevard during the 100-Year storm event towards the landside of the levee, as shown in Figure 12.

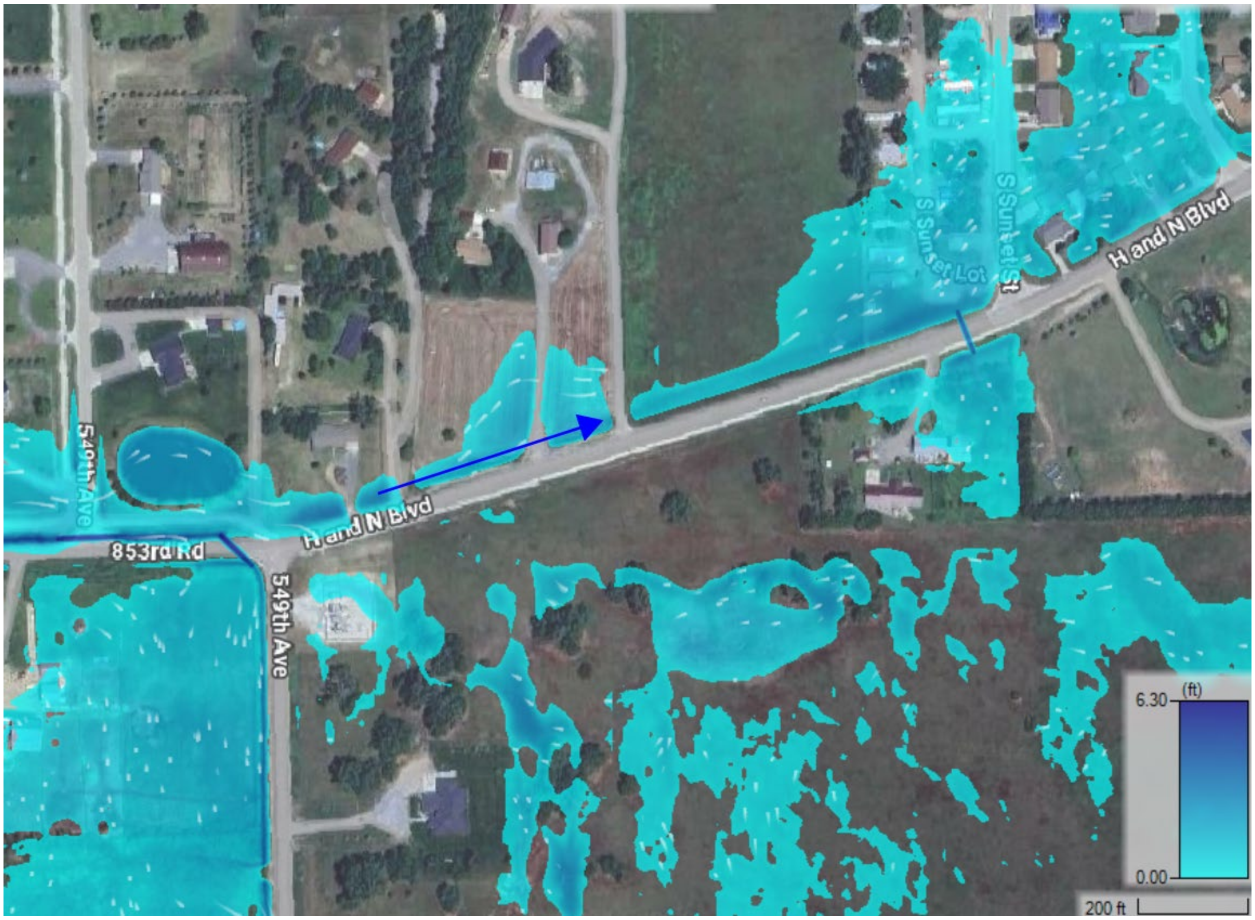


Figure 12: Existing Pierce Southwest Area 100-Year Flow

The northwest area includes runoff which flows towards the intersection of 854th Road and 549th Avenue. While some flows overtop 854th Road during heavy rainfall events, most runoff is conveyed toward the east on the south side of 854th Road via a 24” CMP and roadway overtopping. During the 100-Year storm event, this results in approximately 24 acre-feet and a peak flow of 37 cfs flowing along the south side of 854th Road towards the landside of the levee, as shown in Figure 13.

Figure 13: Existing Pierce Northwest Area 100-Year Flow

The urban drainage area includes the runoff produced by rainfall directly on the city. This runoff is collected by the city storm sewer system or overland flows towards the levee drainage structures and ultimately discharges to the North Fork Elkhorn River or Willow Creek. Per the levee Operation and Maintenance Manual there are a total of five drainage culverts through the levee. Culvert details and locations are shown in Table 12 and Figure 14. Each of these was included in the model with the “No-Negative-Flow Flaps” option to prevent backflow. During the 100-Year flood event runoff is conveyed through drainage structures at levee stations 5+70, 116+70 and 122+65 due to a positive head differential. Runoff is not conveyed through the drainage structures at levee stations 80+80 and 97+10 due to a negative head differential resulting from the North Fork Elkhorn River water surface elevations.

Table 12: Pierce Levee Drainage Structures

O&M Manual Station	O&M Manual Structure Type	O&M Manual Dimensions (inches)	Number of Structures	Backwater Prevention
5+70	CMP	48	1	Flap
80+80	RCB	60x60	1	Flap and Slide
97+10	CMP	48	1	Flap and Slide
116+70	CMP	42	1	Flap
122+65	CMP	30	1	Flap

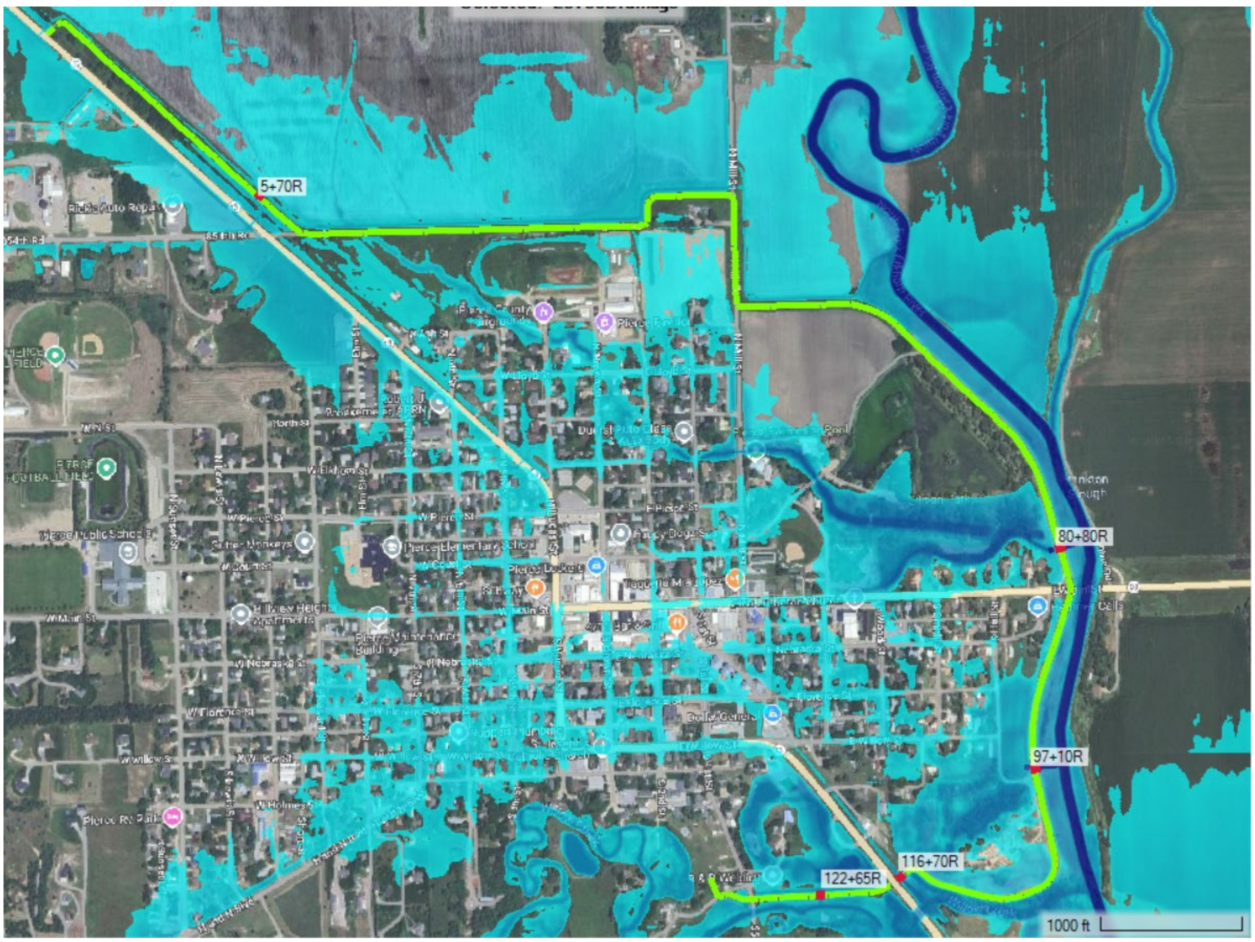


Figure 14: Existing Pierce Levee Drainage Structure Locations

RIVERINE FLOODING RESULTS

The Pierce-North Branch Elkhorn River Levee system was evaluated based upon current regulatory agency guidance and found to be deficient as shown in Table 13.

Table 13: Pierce Levee Regulatory Deficiencies

Pierce Levee								
Classification	**Material**	**Design Max High-Water Height (ft)**	**Minimum Storm Design Frequency (yr)**	**Minimum Freeboard in feet (2')**	**Minimum Top Width in feet (10')**	**Minimum Side Slope Ratio (H:V)**	**Seepage and Stability**	**Pipe Closures**
Class I	Mineral Soils	9.2	100	2.25	10*	3:1	0 to 50' Seepage Berm	Slide Gates on 2/5 Structures
Meets NRCS Criteria				Yes	Yes	Unknown**	Unknown**	No
Meets FEMA Criteria				No	Yes	Yes	Unknown**	No
Meets USACE Criteria				NA	Yes	Yes	Unknown**	No

** Based on as-built*
*** Geotechnical analysis needed to verify*

Given the levee deficiencies the hydraulic model of Pierce was also modeled using FEMA Natural Valley procedures. This method operates on the assumption that the levee has no effect on floodwaters, resulting in a more moderate estimate of potential damages. A levee breach, depending on the location, may result in far greater potential damages as floodwaters would flow into the protected area and become confined there. Flooding results during a 100-Year riverine event without the existing levee are shown in Figure 15. As can be seen this results in significant flooding with most of the area east of Highway 13 inundated.

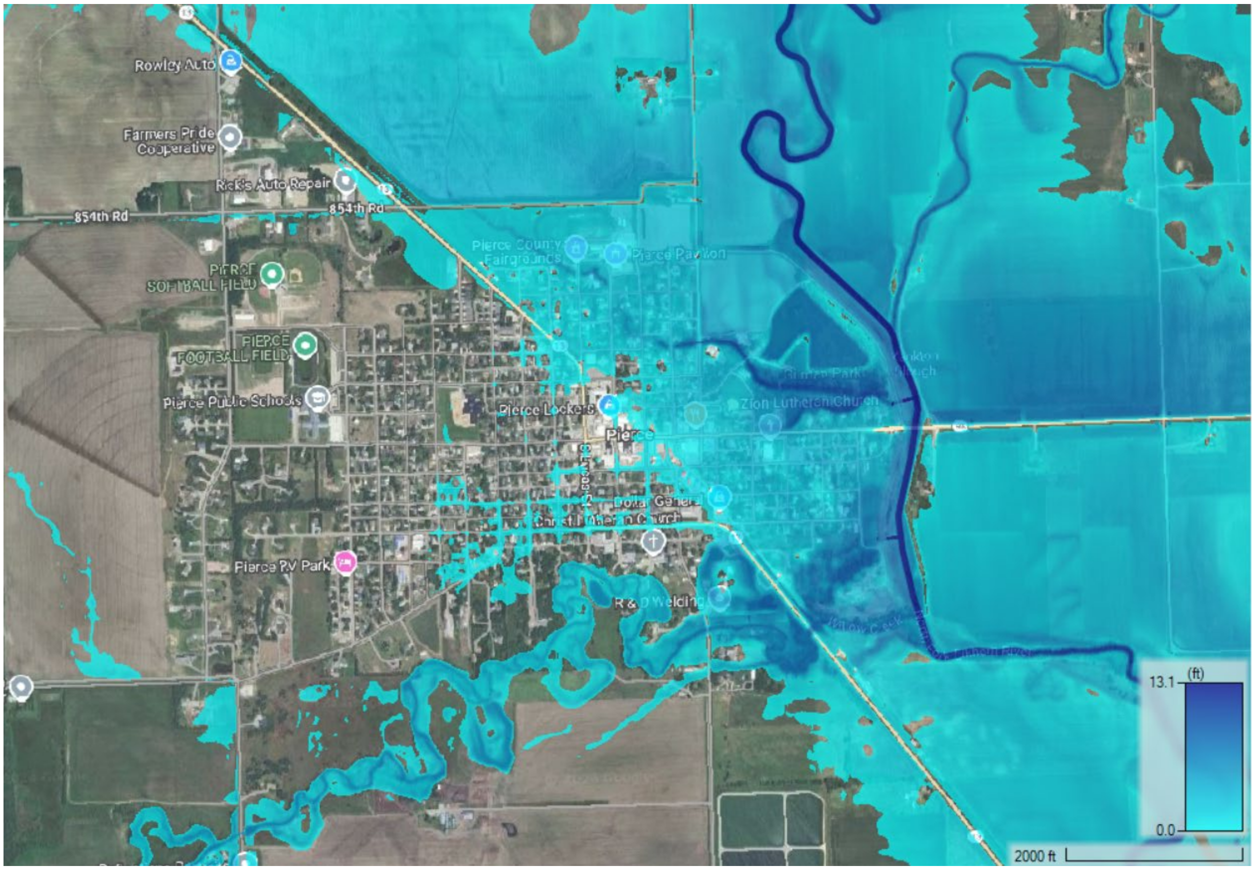


Figure 15: Existing Pierce 100-Year Riverine Flood Extents (No Levee/Natural Valley)

D 4. PREFERRED ALTERNATIVE ANALYSIS AND DESIGN

The results of the baseline hydraulic analysis and risk assessment were utilized as an evaluation tool to compare the effectiveness of alternatives in reducing flooding damages in the watershed. A variety of potential alternatives were considered, evaluated, and documented within the watershed plan. Through this alternative evaluation process, a combination of a road raise, berm, and nonstructural retrofitting were identified for Osmond, and two diversion channels, stormwater pumping stations, and levee improvements were identified for Pierce. The preferred alternatives will achieve the purpose and need of the Plan-EA.

Results from the preliminary geotechnical investigation were used in planning this project and a summary is included further below. The full report is attached in Appendix E.

D 4.01 SITE IDENTIFICATION

Potential project sites were identified and analyzed using several factors including aerial imagery, publicly available GIS data, topographic data, field investigation, previous studies, and information gained through stakeholder and public involvement. Locations of existing infrastructure were taken into consideration to avoid and minimize as many impacts as possible. The preferred alternatives for Pierce and Osmond are combinations of individual alternatives. Sites selected for individual alternatives served as a starting point for the final preferred alternatives.

Existing sensitive resources were also considered when choosing potential site locations. Stream and woodland corridors and potential wetlands were identified and used in conjunction with the other data collected.

D 4.02 SITE PRIORITIZATION

PIERCE LEVEE IMPROVEMENTS L1-20

L1-20 is centered on improving the existing levee between Pierce and the North Fork Elkhorn River. Consequently, the only effective location for this individual alternative is the location in the preferred alternative along the existing levee alignment.

PIERCE SOUTHWEST DRAINAGE IMPROVEMENTS C1-30

To aid with Pierce's localized interior drainage issues, C1-30 was identified as a diversion channel to reroute flows coming from the west that would otherwise end up in Pierce, to the south. The location of the improvements needed to connect the drainage area north of 853rd Road and west of 549th Ave to the nearest tributary to the North Fork Elkhorn River which is Willow Creek. The location selected for C1-30 was ideal as it has fewer utility impacts, following property lines and existing ROW. The chosen location for C1-30 allows flows to continue along the basin's natural drainage path without being redirected east by 853rd Road into Pierce.

PIERCE NORTHWEST DRAINAGE IMPROVEMENTS C1-10

In conjunction with C1-30, C1-10 acts as a diversion channel along 854th Road and 549th Ave to reduce flows entering Pierce from the northwest. The alignment was ideal for following the existing drainage system and reducing utility and driveway crossing impacts.

PIERCE STORMWATER PUMPING STATIONS

In addition to C1-30 and C1-10, the two pumping stations were sited in Pierce to reduce the flood risk due to localized interior drainage issues. Site locations were limited, as the pump stations have maximum effectiveness when placed at sump locations. Two sumps on the landward side of the levee were identified, north and south of Highway 98, and the pumps were sited at these sump locations.

OSMOND 4TH STREET FLOOD REDUCTION F1-1

F1-1 was determined to be the most cost-effective site for flood reduction improvements due to its smaller footprint. It was identified that most of the flooding in eastern/downtown Osmond was due to the elimination of an old high point in the topography at 4th and Hill St. Structures further east, closer to the North Fork Elkhorn River, were considered, but F1-1 was the ideal site as it restores natural topography rather than disrupting the floodplain to the east.

OSMOND NORTHEAST FLOOD REDUCTION F1-2

The site for F1-2 was chosen to mitigate the effects of increased water surface elevations at N Park Street homes in northeast Osmond from F1-1. F1-2's grading extents were sited to minimize agricultural disruption to the east while also minimizing homeowner impacts to the west. The site for F1-2 had few alternative locations due to the topography's limited high ground tie-in options.

OSMOND NONSTRUCTURAL

South Osmond experiences flooding due to proximity to the North Fork Elkhorn River south of Highway 20. However, in this region of the community, there are a limited number of buildings. This combined with moderate to high flood depths indicated that structural alternatives are not economically feasible. Therefore, nonstructural alternatives such as retrofitting through elevation, flood vent installation in crawl spaces, localized berms, and backflow prevention are recommended. These will significantly reduce flood risk by modifying each individual at-risk building.

D 4.03 SITE SPECIFIC DESIGN INFORMATION

PIERCE LEVEE IMPROVEMENTS L1-20

As mentioned above, the existing levee is situated directly between the North Fork Elkhorn River and the community of Pierce. The improvements intend to support the original intent of the levee: to reduce the risk of riverine flooding in Pierce from the North Fork Elkhorn River. Levee improvements were based on the 100-year modeled water surface elevation, plus 3.5 feet freeboard (minimum). Top of levee elevation and geotechnical seepage mitigation requirements heavily influenced the extent of improvements along the existing levee. Figure 16 shows the proposed levee alignment with grading extents of improvements. The improvements concentrate earth fill to the landward side of the existing levee with a 4:1 (H:V) landward slope and maximum top of levee elevation raises of approximately two feet.

For seepage mitigation, seepage berms and toe trench trains were implemented into the design. A four-foot tall, 150-foot-wide seepage berm was preferred where space permitted. The toe trench drains were implemented where other existing infrastructure conflicted with the space requirements of a seepage berm. The levee necessitates one drainage structure extension, two drainage structure removals, and five drainage structure removals and replacements. Replacements require ancillary items including flap gates, gatewell structures, headwalls etc. Structural details are included in the Structural Tables in Chapter 7 of the Plan-EA and supporting drawings are included in Appendix C. The levee is designed per FEMA and USACE as well as the following NRCS Conservation Practice Codes:

- CPS 342: Critical area planting
- CPS 356: Dike and levee (Class 1)
- CPS 620: Underground outlet

Note that improvements made to the levee upstream of the confluence of the North Fork Elkhorn River and Yankton Slough are eligible for PL 83-566 funding. Improvements made downstream of the confluence are not eligible for PL 83-566 funding, but could be funded through other federal funding programs. This division of funding is included in the estimated costs used throughout this plan.

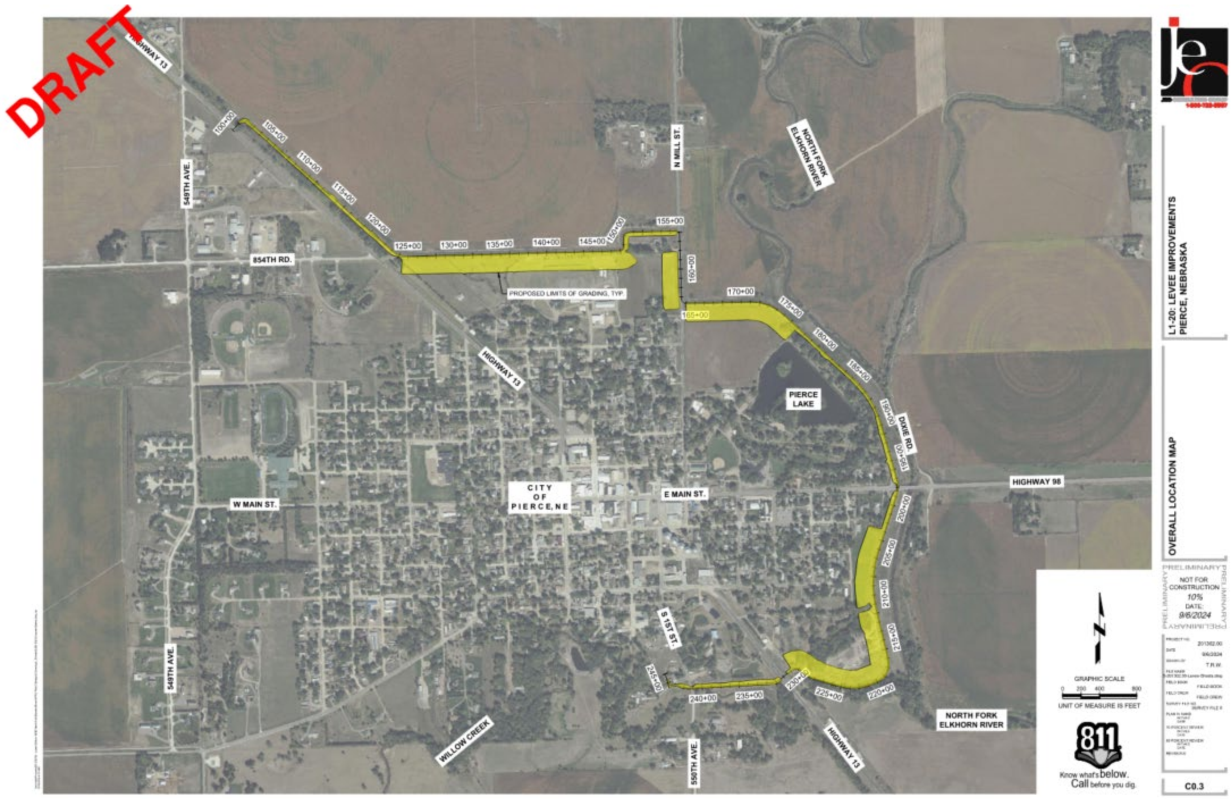


Figure 16: Proposed Levee Improvements L1-20 Alignment

PIERCE SOUTHWEST DRAINAGE IMPROVEMENTS C1-30

C1-30 works in conjunction with C1-10 and the Stormwater Pumping Stations to help with localized interior drainage within Pierce on the landward side of the levee. As for C1-30 improvements, the diversion channel bottom is diverted under 853rd Road. The roadside channel slope is 4:1 (H:V) while the opposing slope is 3:1. The bottom width is 14 feet. Improvements include structure improvements/upsizing at road crossings and a short pedestrian bridge along the north pedestrian trail to reduce backwater at embankment crossing locations. C1-30 also includes stream stabilization improvements at the downstream end of the improvements near the Willow Creek outfall to mitigate larger flows and higher velocities due to the improvements. Figure 17 illustrates the drainage improvements alignment. Structural details are included in the Structural Tables in Chapter 7 of the Plan-EA and supporting drawings are included in Appendix C. The drainage improvements are designed under the following CPS codes:

- CPS 342: Critical area planting
- CPS 410: Grade stabilization structure
- CPS 500: Obstruction Removal
- CPS 572: Spoil disposal
- CPS 582: Open channel

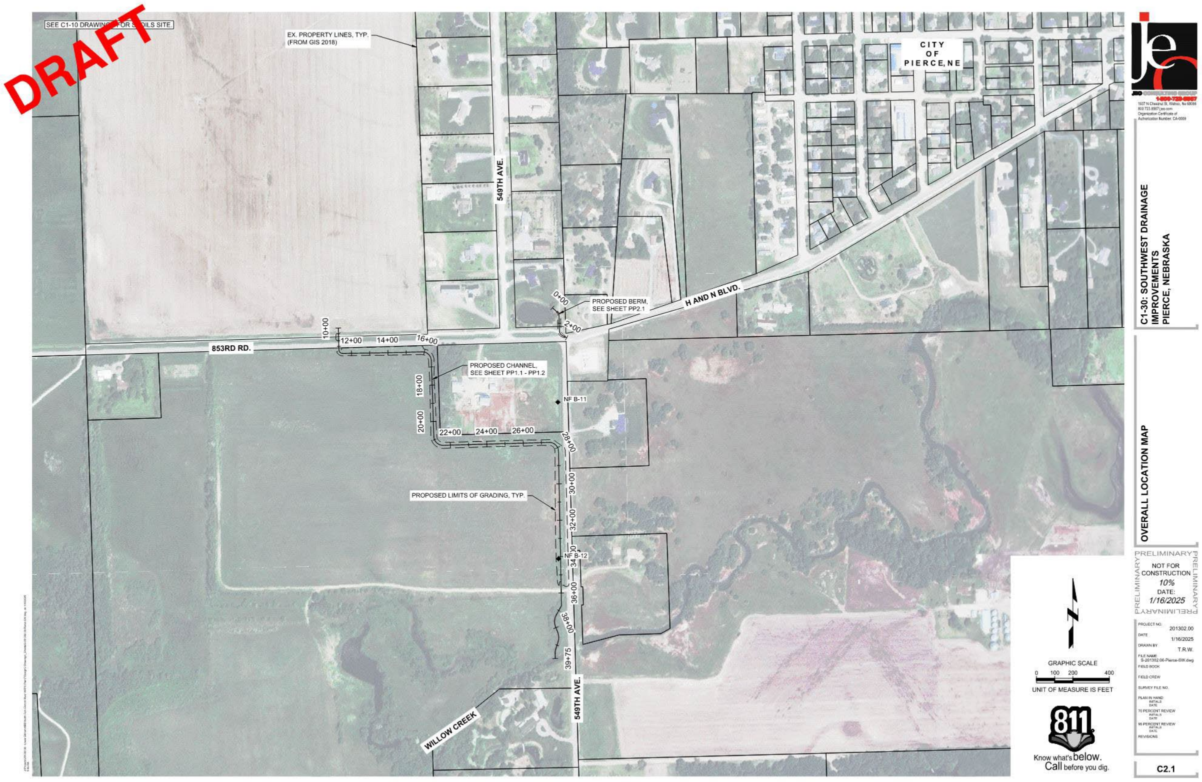


Figure 17: Southwest Drainage Improvements C1-30 Alternative Location

PIERCE NORTHWEST DRAINAGE IMPROVEMENTS C1-10

As mentioned above, C1-10 improvements are intended to work interdependently with C1-30 and the Stormwater Pumping Stations to reduce damages from localized interior drainage in Pierce on the landward side of the levee. As for C1-10 improvements, the roadside channel slope is 4:1 (H:V) while the opposing slope is 3:1. South of 845th Road, the bottom width is 10 feet. Once the improvements alignment turns north at the 549th Ave crossing, the bottom width increases to 12 feet to accommodate larger downstream flows. Figure 18 illustrates the drainage improvements alignment. Structural details are included in the Structural Tables in Chapter 7 of the Plan-EA and supporting drawings are included in Appendix C. The drainage improvements are designed under the following CPS codes:

- CPS 342: Critical area planting
- CPS 500: Obstruction removal
- CPS 572: Spoil disposal
- CPS 580: Streambank and shoreline protection
- CPS 582: Open Channel

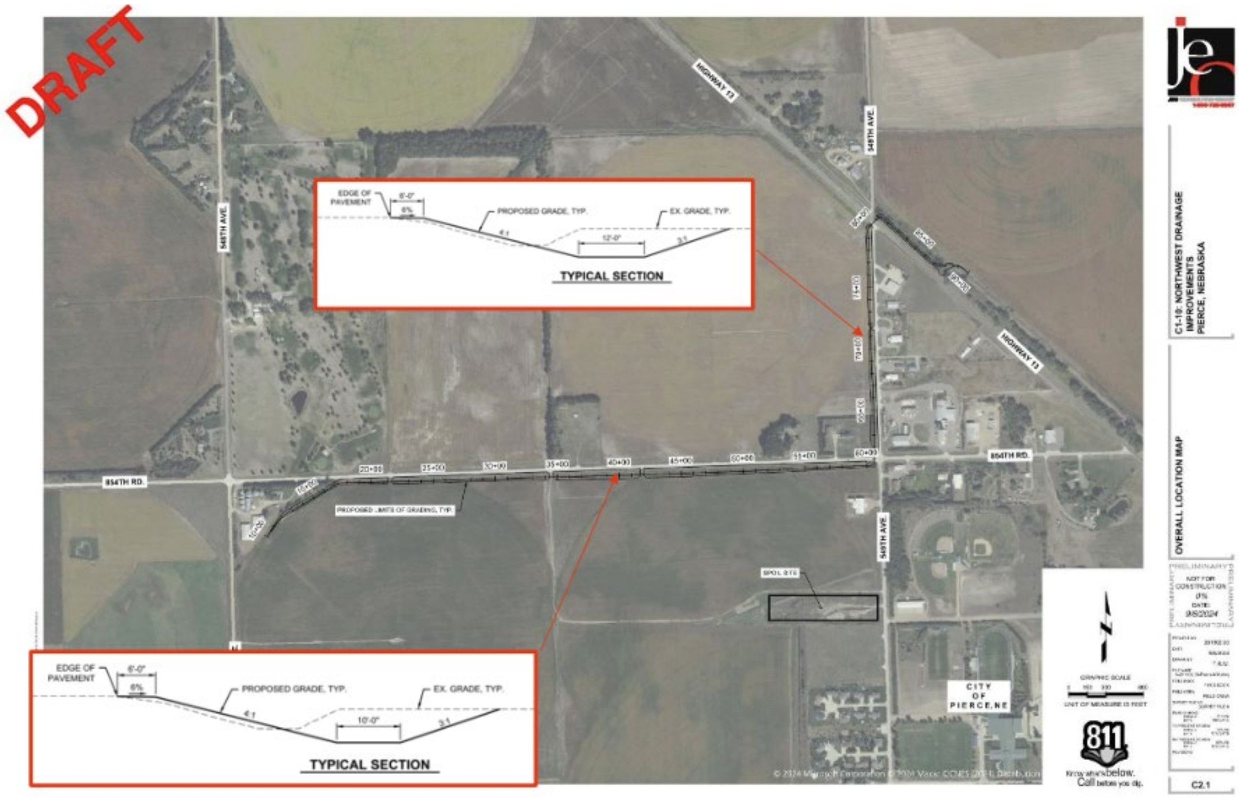


Figure 18: Northwest Drainage Improvements C1-10 Alternative Location

PIERCE STORMWATER PUMPING STATIONS

Two stormwater pumping stations are included in the drawings for L1-20. However, it's important to restate that the purpose of the pump stations is to mitigate flood risk due to localized interior drainage (along with C1-10 and C1-30) while the purpose of the levee improvements is to reduce flood risk due to riverine flooding. The preferred alternative design includes the location of the pump, controls, and generator while final design would consider the specifics of electrical, piping, and site layout. Figure 19 shows the locations of the two pump stations. Structural details are included in the Structural Tables in Chapter 7 of the Plan-EA and supporting drawings are included in Appendix C. The drainage improvements are designed under the following CPS codes:

- CPS 472: Access Control
- CPS 533: Pumping Plant
- CPS 572: Spoil disposal

Figure 19: Stormwater Pumping Stations Alternative Location

OSMOND 4TH STREET FLOOD REDUCTION F1-1

In Osmond, the 4th Street F1-1 project restores high ground along the 4th Street corridor. The regrading of this street and surrounding ballfield area allows for protection against riverine flooding backing up through this gap in the high ground and flooding downtown Osmond. The project was designed for the 100-Year riverine flooding event plus two feet of freeboard. The freeboard is shown to protect up to the 500-Year event and the record observed flooding of March 2019. To minimize grading impacts to homeowners and avoid disrupting the ballfield's level grade, a retaining wall with a maximum height of six feet was utilized on the eastern perimeter of the flood reduction improvements. The ballfield concessions stand and bathrooms are raised to proposed grade, above flood elevations. The existing swale to the north of 4th street is converted to underground pipe flow, connecting to the existing storm system. An automatic flap gate is utilized at the outfall to prevent backflow in the stormwater system and a manual slide gate is utilized for redundancy. Figure 20 shows the grading extents and site layout of the project. Structural details are included in the Structural Tables in Chapter 7 of the Plan-EA and supporting drawings are included in Appendix C. The drainage improvements are designed under the following CPS codes:

- CPS 500: Obstruction removal

- CPS 560: Access road
- CPS 620: Underground outlet

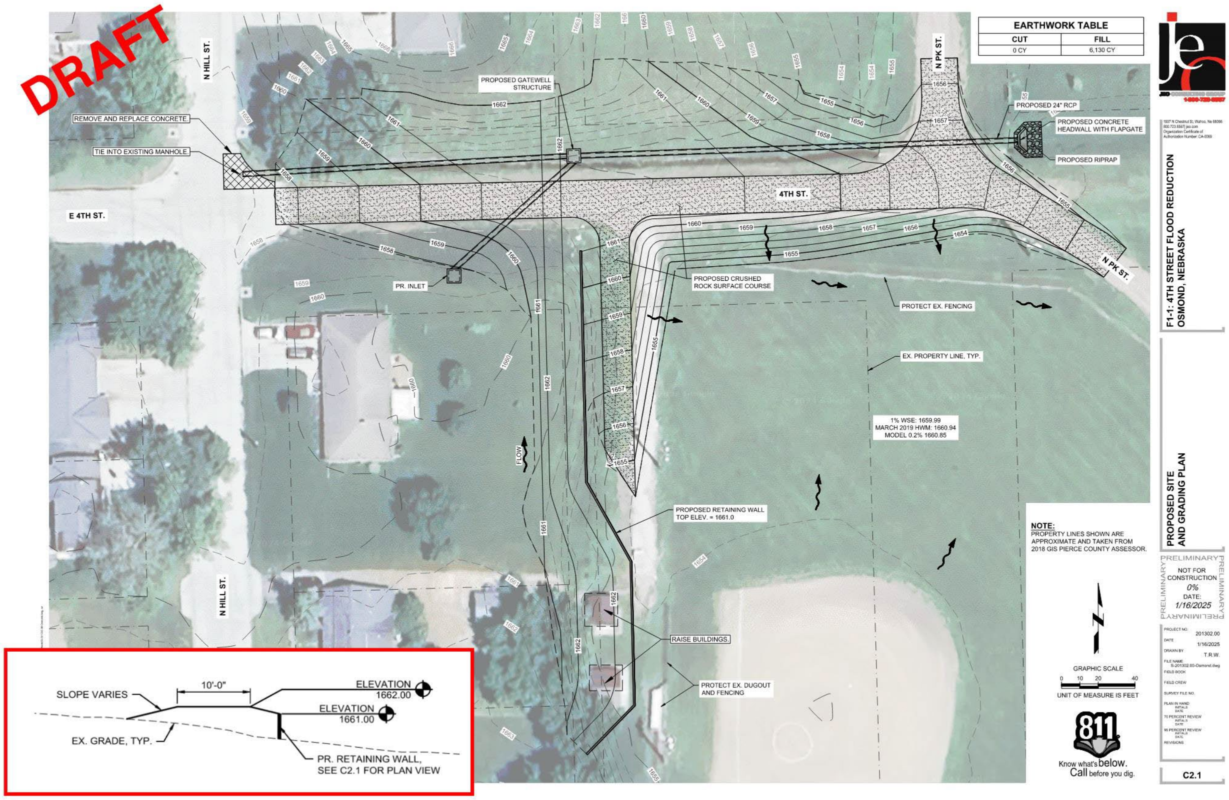


Figure 20: 4th Street Flood Reduction F1-1 Alternative Location

OSMOND NORTHEAST FLOOD REDUCTION F1-2

F1-2 works interdependently with F1-1, as F1-2 protects northeast Osmond homes from slight rises in the water surface elevation caused by F1-1. This berm ties into the north and the south with a top width of 10 feet, a maximum height of 7.6 feet, and 3:1 side slopes. The design also includes a pipe and flap gate system to allow interior drainage to flow east while preventing any riverine backwater. Figure 21 shows the grading extents and site layout of the project. The crest elevation of F1-2 is designed up to the 100-year water surface elevation with one foot of freeboard. The freeboard is shown to protect up to the 500-Year event and the record observed flooding of March 2019.Structural details are included in the Structural Tables in Chapter 7 of the Plan-EA and supporting drawings are included in Appendix C. The drainage improvements are designed under the following CPS codes:

- CPS 342: Critical area planting
- CPS 620: Underground Outlet

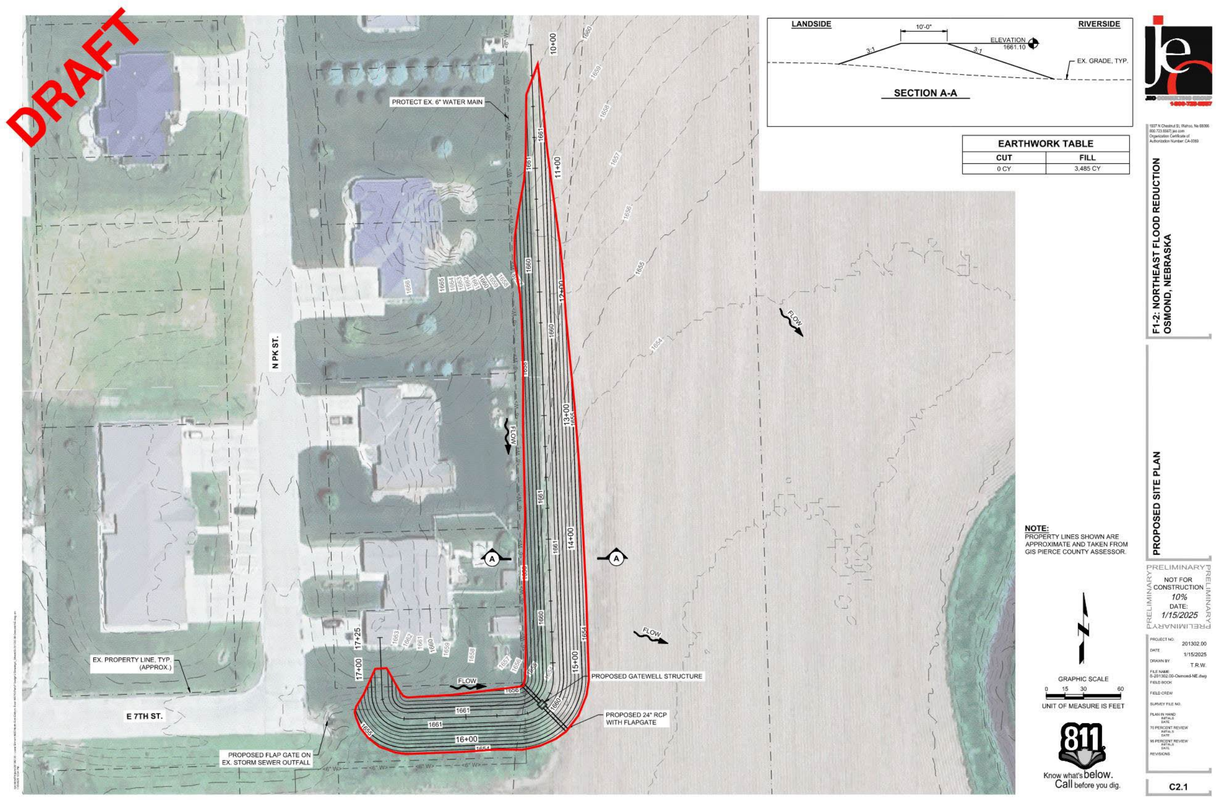


Figure 21: Northeast Flood Reduction F1-2 Alternative Location

OSMOND NONSTRUCTURAL

This alternative includes building modifications through retrofitting for twelve buildings in South Osmond. For eight buildings, elevation is recommended. Elevation requires site specific assessment for each building by a contractor who will determine the best process to physically separate the building from the foundation, extend the foundation, and raise the building to be placed on the modified foundation. Most of the identified buildings do not have basements; in the event a building has a basement it is filled in as part of the elevation process. For two buildings, flood vents are recommended. For these sites, any basements or crawlspaces are filled in at least until the interior grade matches the exterior grade. Flood vents are added to the perimeter of the resulting stem wall foundation to allow floodwaters to automatically enter and exit. For one building, a berm is recommended due to construction type. The berm would surround the building to a defined elevation with the purpose of excluding floodwaters. Finally, for all buildings backflow preventers are recommended. These will function to prevent sewage backflow during a flood event. For more information on the location of the buildings recommended for nonstructural retrofitting as well as the recommended actions see Figure 22 and Table 14.

Figure 22: Locations of Potential Nonstructural Measures

Table 14: Proposed Nonstructural Measures

Address	Proposed Action
209 S State St	Elevation
107 E Market St	Flood Vents
307 E Market St	Elevation
208 S Logan Street	Elevation
202 E Market St	Elevation
302 S Main St	Berm
103 S State St	Backflow Prevention
102 E Market St	Elevation
300 S Main St	Elevation
201/203 S Main St	Flood Vents
204 S Maple St	Elevation
312 S State St	Elevation

D 4.04 PROPOSED CONDITIONS HYDRAULICS

PIERCE PROPOSED CONDITIONS

The proposed levee, northwest and southwest drainage channels, and pumping stations can be used in combination to mitigate flooding within Pierce and diminish any residual flooding. The levee was designed to prevent flooding within Pierce and have three to four feet of freeboard during a 100-Year riverine flooding event. Results of 100-Year riverine flooding with the coincident 2-Year interior rainfall runoff, with the proposed levee (shown in green), are shown in Figure 23.

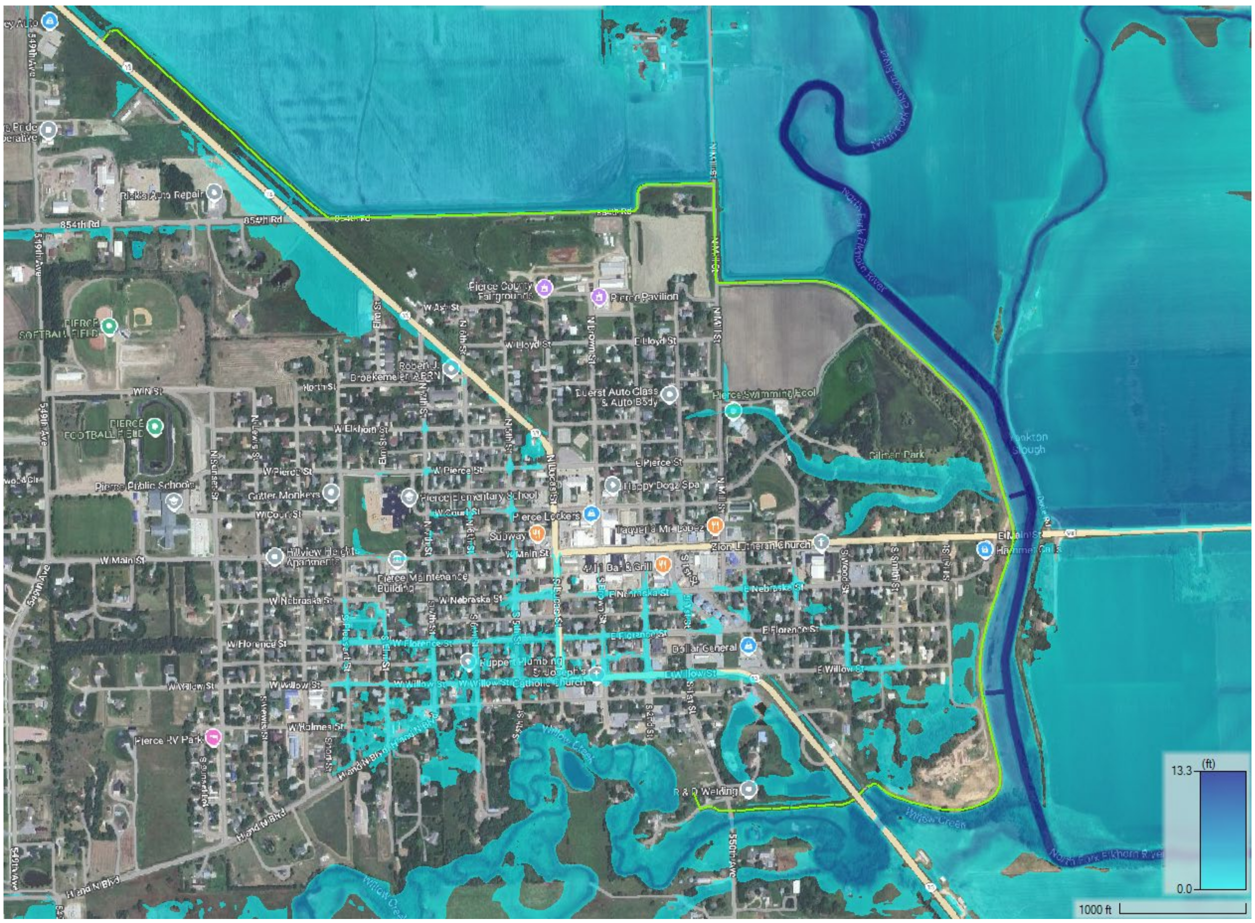


Figure 23: Proposed 100-Year Riverine with 2-Year Interior Rainfall Runoff Hydraulic Results

The levee is simulated to successfully reduce flooding in Pierce from the North Fork Elkhorn River, but would also result in interior ponding landside of the levee during an interior drainage rainfall event. The Southwest and Northwest Drainage Improvements and the pump stations were designed based on the 100-Year interior rainfall event with a coincident 2-Year riverine flooding event. Results during 100-Year interior with 2-Year riverine flooding with the proposed alternatives are shown in Figure 24.

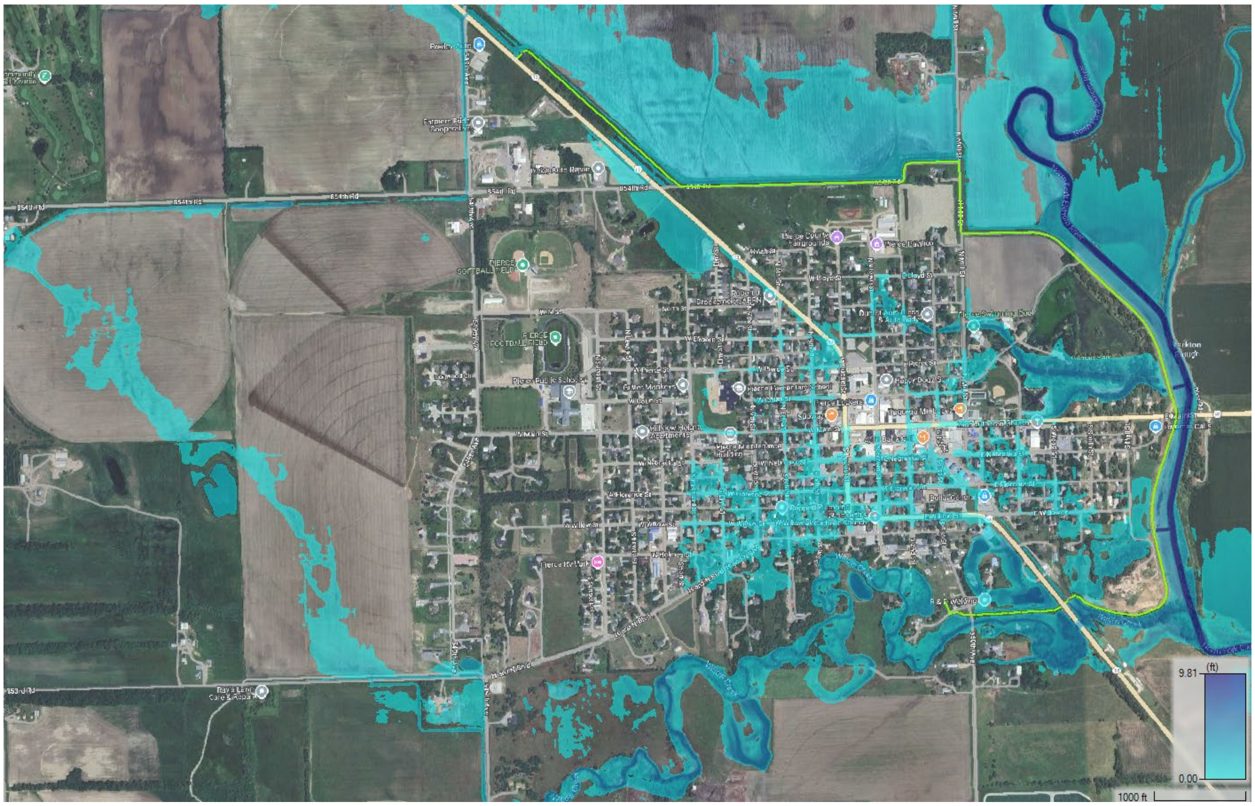


Figure 24: Proposed 100-Year Interior Rainfall with 2-Year Riverine Hydraulic Conditions

OSMOND PROPOSED CONDITIONS

The Osmond 4th Street Flood Reduction Project will minimize flooding in downtown Osmond by eliminating the secondary flow path down 4th Street for the 100-Year flood event plus additional freeboard. Results of the 100-Year flood event with the proposed improvements are shown in Figure 25.

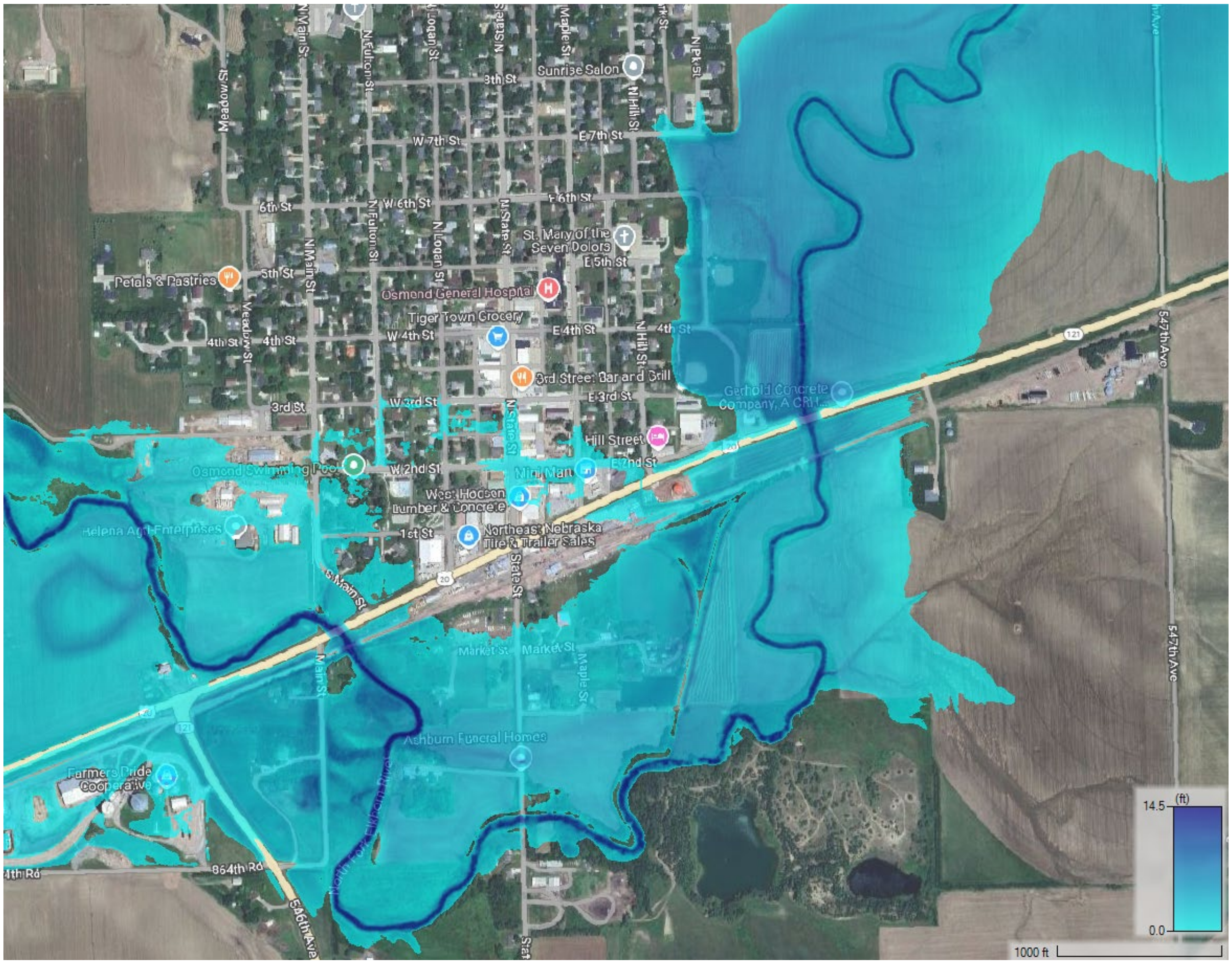


Figure 25: Osmond 100-Year Proposed Hydraulic Conditions

PIERCE RESIDUAL RISK

Though significant improvement exists for all design storms, there is still residual risk from the improvements. The analysis at Pierce used the best available current literature to estimate the joint probabilities of coincident flows which assumed a 5-Year interior rainfall event would coincide with a 500-Year riverine flood event. During the March 2019 event this area was significantly impacted. While the exact runoff event for the interior drainage is not readily known due to it being from rainfall and snowmelt on frozen ground, it is very possible the runoff was greater than the amount which would be produced from a 5-Year rainfall event. At the same time the riverine flooding was estimated to be about the 500-Year event based on the stream gage downstream. Should this event recur, there would possibly be minor impacts to some structures adjacent to the levee. Due to the relatively infrequent nature of this event occurring, this residual risk was considered acceptable. It is also clear from the proposed results there will still be street and some minor structural flooding during a 100-Year interior rainfall event. This is considered typical urban flooding. A full analysis of the urban pipe network was not completed to fully understand the actual residual risk; rather this analysis focused on the overland flow assuming no storm sewer systems. Further mitigation of this urban flooding is beyond the scope of this effort. Under anticipated proposed conditions, there is no residual risk of loss of life during a 100-year flooding event.

OSMOND RESIDUAL RISK

Though significant improvement exists for all design storms, there is still residual risk from the improvements. The Osmond 4th Street Flood Reduction Project was designed for a 100-Year flood event plus two feet of freeboard. The freeboard resulted in a protection equal to approximately the 500-year event. A less frequent event would likely overtop the improvements. Additionally, there is a drainage ditch north of Highway 20 that backflows during the 100-Year event resulting in minor street flooding, although no structures are shown to be impacted, and addressing this issue was not economically efficient. The area south of the railroad tracks is also shown to be frequently impacted by flood events. Various structural alternatives were evaluated but none were found to be cost beneficial. Therefore, nonstructural improvements were recommended for those buildings located south of the railroad. Residual risk of flood damages would remain for any buildings that do not implement the recommended nonstructural improvements. Under anticipated proposed conditions, there is no residual risk of loss of life during a 100-year flooding event.

PIERCE AVOIDANCE OF DOWNSTREAM IMPACTS

The levee at Pierce will reduce the conveyance area of the North Fork Elkhorn River, leading to an increase in water surface elevation on the riverside of the levee. Figure 26 provides a review of this elevation increase caused by the levee. Eliminating flow conveyance through the city results in an increase of less than one foot on the riverside, which is considered acceptable given the levee is already in place. While the impacts are mostly to farmland, an aerial review identified seven farmsteads which may be impacted. Additionally, the levee causes interior ponding from rainfall runoff, however this will be managed by other proposed projects.

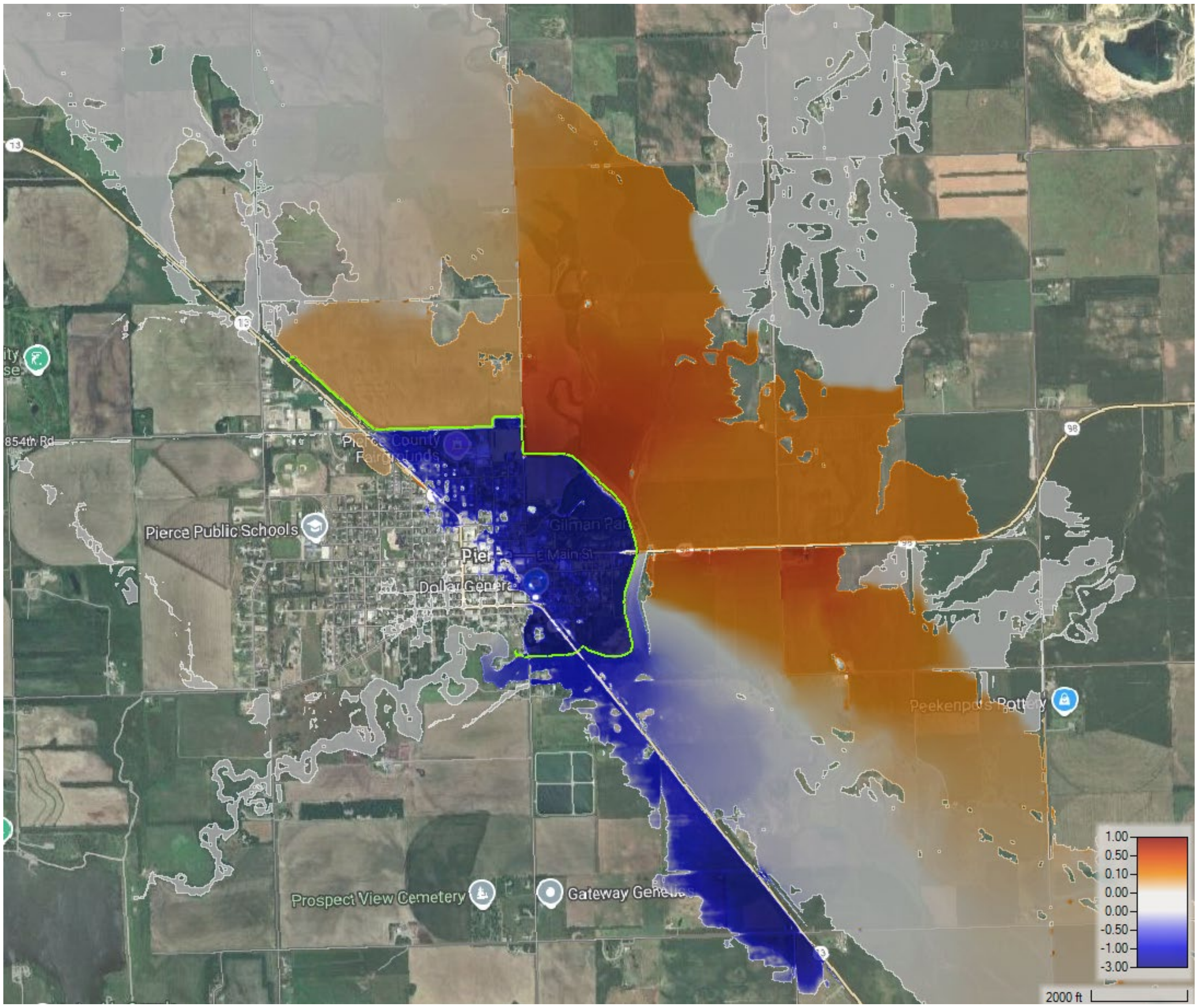


Figure 26: Pierce 100-Year Riverine Water Surface Elevation Difference (Proposed - No Levee)

The proposed channel improvements and pump stations in Pierce results in some increases in water surface elevation as shown in Figure 27. The Northwest Channel improvements result in a maximum water surface elevation increase of 0.6 feet in the agricultural land northeast of the proposed levee. The increase in water surface elevation was partially mitigated by replacing the existing culvert at 550th Avenue with a concrete box culvert. Increases south of the levee system are minimal and confined primarily to Willow Creek and therefore were deemed acceptable. An aerial review of the impacts found no buildings or structures will be impacted.

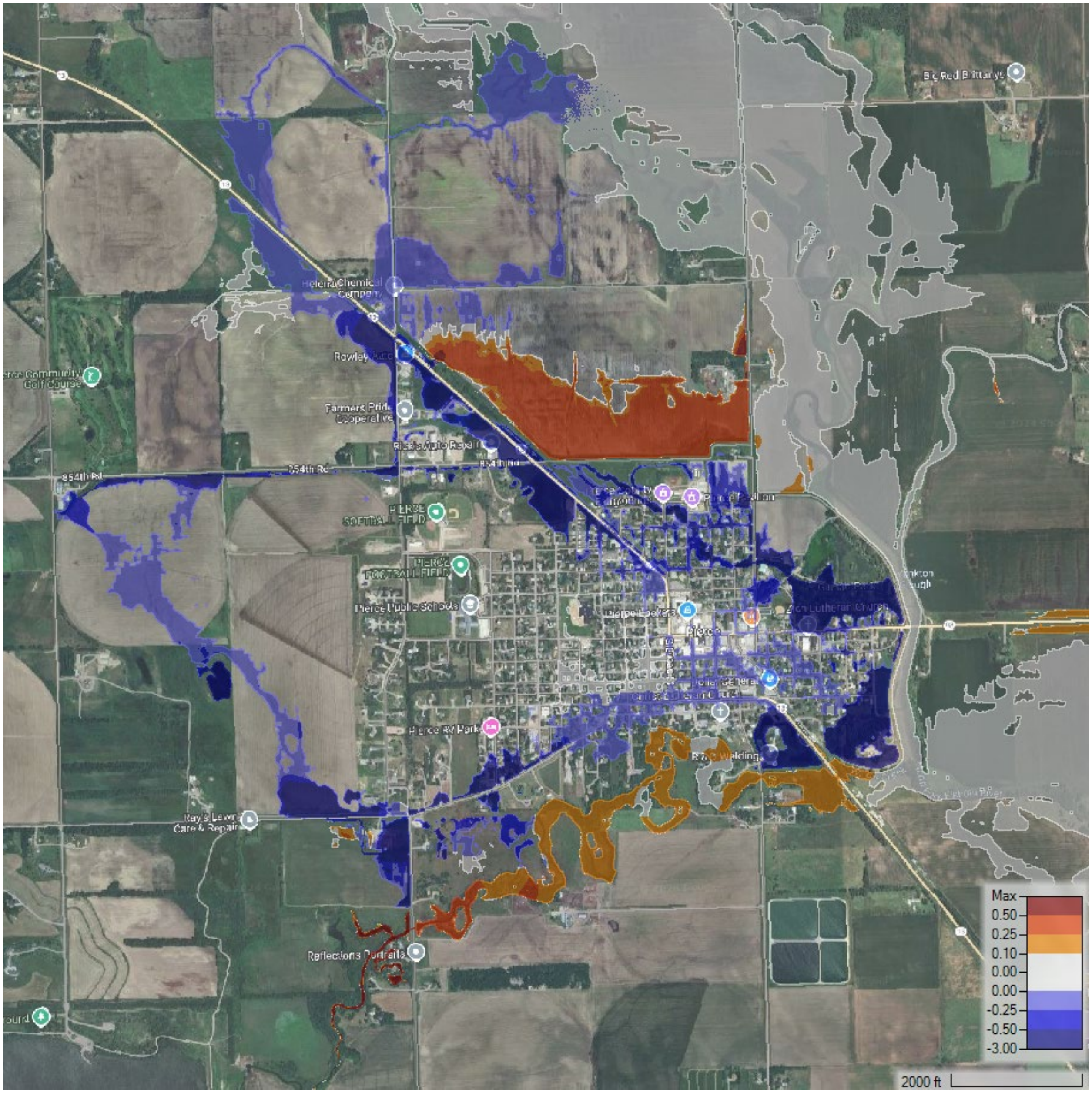


Figure 27: Pierce 100-Year Interior Rainfall Water Surface Elevation Difference (Proposed - With Levee)

OSMOND AVOIDANCE OF IMPACTS

The proposed Osmond 4th Street Flood Reduction Project will eliminate the secondary flow path along 4th Street, leading to an increase in water surface elevation upstream and downstream of the proposed project. Figure 28 provides a review of this elevation increase caused by the project. The northeast berm is designed to mitigate the induced damages from the 4th Street project while the nonstructural alternatives are designed to mitigate the induced damages downstream of the proposed project.

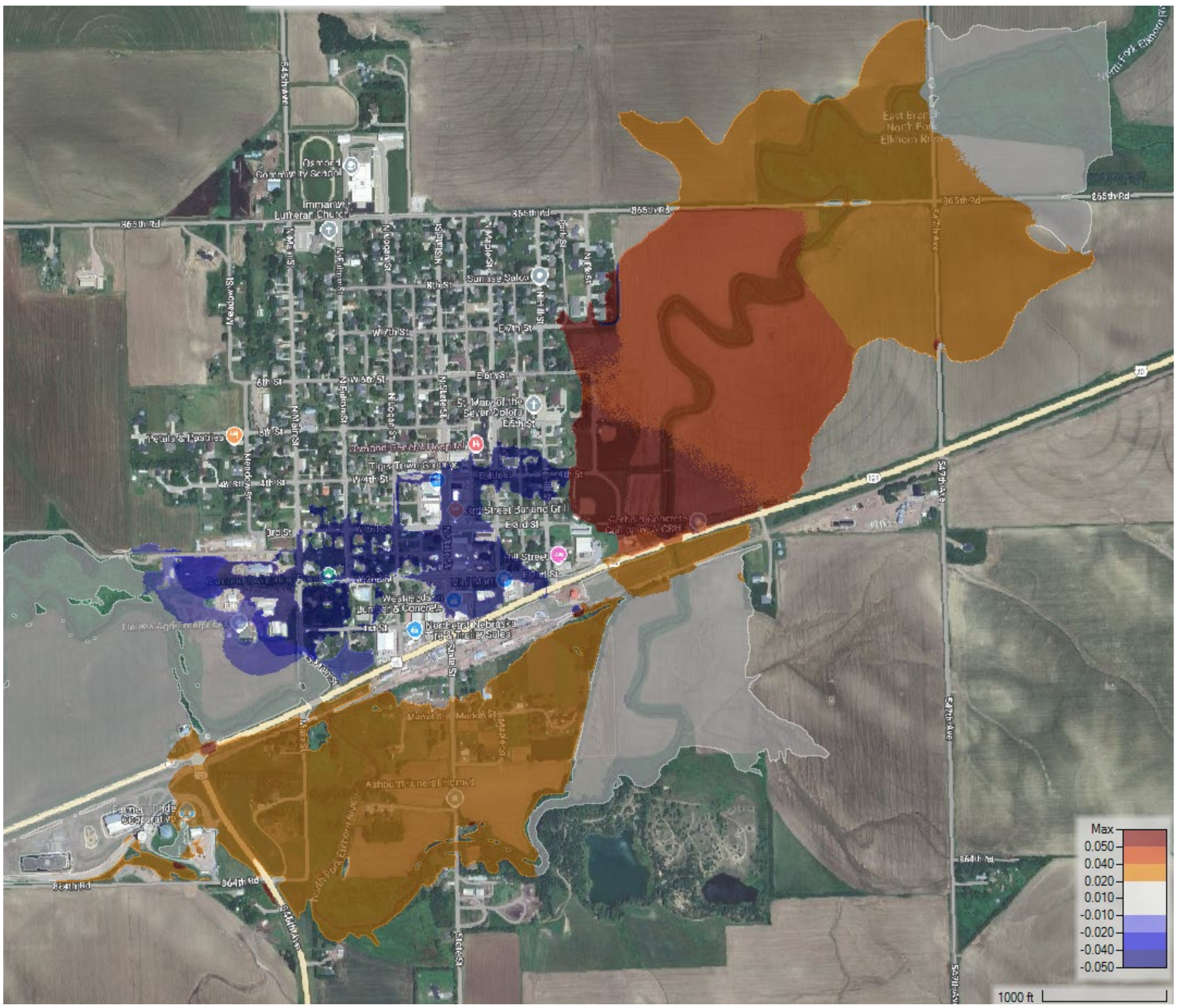


Figure 28: Osmond 100-Year Event Water Surface Elevation Difference (Proposed - Existing)

D 5. GEOLOGY

GEOLOGICAL INVESTIGATION

A preliminary level geological investigation, including subsurface sampling, was performed to support the design of the preferred alternative and characterize potential borrow material. The purpose was to identify any geologic conditions or hazards to address in the design, construction, or operation of the preferred alternative. Field investigations were completed by Thiele Geotech, Inc. between July 24 – 26, 2024. A summary is included below. The full report is attached in Appendix E. A detailed geological investigation will be completed during the design phase and has been included in the project costs.

Soil borings were conducted at 14 sites: 12 in Pierce and two in Osmond. The soils encountered primarily consisted of alluvial deposits, ranging in moisture contents, consistency, and plasticity. These soil conditions appear generally suitable for support of the proposed alternative. However, some site preparation considerations may be necessary depending on the final design considerations. There are several potential geotechnical engineering concerns, including: high moisture contents of excavated materials, consolidation of the alluvial soils that could occur under induced stresses of fill placement, relatively shallow groundwater, and moderately low strength alluvial deposits. Careful consideration should be given to these items during site preparation. Dewatering may be required to facilitate construction of the pump stations.

SEISMIC HAZARD EVALUATION

Preliminary seismic hazard evaluation for the preferred alternative was performed by locating the region as denoted within the 2018 USGS Long-term National Seismic Hazard Map. As seen within the map, the project area is located within a low hazard region. Additionally, the project area is not located over any active faults, as confirmed by the USGS Quaternary Fault Database. A full seismic evaluation as determined necessary by NRCS guidelines will be performed within the design phase of the project.

D 6. ECONOMICS

D 6.01 INTRODUCTION

The North Fork of the Elkhorn River Watershed is located in northeastern Nebraska and covers an area of approximately 242,600 acres over portions of five counties. The watershed is also located within the Lower Elkhorn Natural Resources District (LENRD). The watershed contains seven incorporated communities, including the cities of Osmond and Pierce, which have experienced severe flooding events in the past. The most recent flood event in 2019 was extensive and damaged homes, businesses, farmland, and transportation infrastructure, resulting in millions of dollars of damage.

The project is needed because of the watershed's long history of repetitive flood damage. Flooding impacts the local economy, makes travel difficult or impossible, threatens lives, and damages structures and property. As a result, the primary objective of the watershed plan is to reduce flood damage within and near the cities of Osmond and Pierce, where some of the most extensive flood damage has occurred in the past. The two cities also account for a majority of the watershed's population of 4,631 people.

The objective of this report is to estimate the benefits and costs of the action alternatives considered as part of the North Fork Elkhorn River Watershed Plan and Environmental Assessment (EA). The proposed measures are evaluated in conformance with the Principles, Requirements, and Guidelines for federal investments in water resource projects (DM 9500-13). Specifically, this report uses an ecosystem services framework to consider the benefits and costs of the action alternatives. Those benefits and costs are compared against a baseline of no action, which is also referred to as the Future Without Federal Investment (FWOFI).

This report is structured into the following sections:

- Federal Guidelines of National Economic Efficiency Analysis of Watershed Improvement Measures
- Alternatives and Ecosystem Services Evaluated
- Benefit-Cost Analysis Data and Methodology
- Current Economic Costs
- Economic and Structural Tables

D 6.02 FEDERAL GUIDELINES OF NATIONAL ECONOMIC EFFICIENCY ANALYSIS OF WATERSHED IMPROVEMENT MEASURES

The benefit-cost analysis (BCA) conducted as part of this report uses federal water resource project and National Resources Conservation Service (NRCS) guidelines for the evaluation of benefits and costs of the No Action and action alternatives, relying primarily on the Principles, Requirements and Guidelines (PR&G)(DM 9500-013), the Water Resources Handbook for Economics (Part 611), and the National Watershed Program Manual (Title 390-NWPM, Part 500).

With the passage of the 2007 Water Resources Development Act, Congress directed the federal government to update and consolidate its past guidance on evaluating the costs and benefits of federal investments. The original Principles and Guidelines (P&G) was replaced by Principles, Requirements and Guidelines (PR&G). The PR&G allow for:

> *…maximizing public benefits (of all types) relative to costs, the use of quantified and unquantified information in the tradeoff analysis, flexibility in decision making to promote localized solutions, ability to rely on the best available science and objectivity, and advance transparency for Federal investments in water resources (CEQ 2014).*

The PR&G further state:

> *Federal investments in water resources as a whole should strive to maximize public benefits, with appropriate consideration of costs. Public benefits encompass environmental, economic and social goals; include monetary and non-monetary effects; and allow for the consideration of both quantified and unquantified measures (CEQ 2014).*

The PR&G requires benefits and costs to be evaluated in an ecosystem service framework. An ecosystem is a natural unit of living and non-living things that function together to create goods and services valued by people (Olander et al., 2016). "Ecosystem services" is a broad term used to describe the benefits humanity receives from ecosystems as a byproduct of their functioning.

By putting nature at the center, ecosystem services frameworks give economic, social, and environmental costs and benefits equal standing in decision-making processes and therefore help to accomplish the federal objective of maximizing national economic efficiency, ensuring federal investments protect and restore ecosystem functions and values and avoid irreversible impacts. Economic efficiency requires that resources are used in their highest valued use. Projects that create more benefits than costs utilize resources more efficiently than baseline conditions and therefore increase national economic efficiency.

The four-category ecosystem framework adopted in the PR&G, and utilized in this report, is shown in Table 15.

Table 15: Ecosystem Services Framework Used to Evaluate Benefits and Costs

Service Type	Examples
Provisioning	The supply of food, fuel, fiber, water, timber, and genetic resources
Regulating	The regulation of air, climate, natural hazards, water quality, pests, and disease
Cultural	Services that enhance cultural values, like aesthetics, recreation, tourism, and spiritual or religious values
Supporting	Nutrient cycling, soil formation, and primary production

Source: USDA 2017

GUIDING PRINCIPLES[1]

In addition to requiring projects to be evaluated using an ecosystem service framework, the PR&G also seeks to promote projects that fulfill guiding principles related to federal investments in water resources. These principles include:

- Healthy and Resilient Ecosystems – Federal investments in water resources should protect and restore functions of ecosystems and mitigate any unavoidable damage to these natural systems.
- Sustainable Economic Development – Federal investments in water resources should encourage sustainable economic development that improve the economic well-being of the Nation for present and future generations through the sustainable use and management of water resources.
- Floodplains – Federal investments in water resources should avoid the unwise use of flood-prone areas and avoid and minimize adverse impacts and vulnerabilities in any case in which a flood-prone area must be used. Federal investments should seek to reduce the Nation’s vulnerability to floods and storms.
- Public Safety – Federal investments in water resources should avoid, reduce, or mitigate risks to people, including both loss of life and injury, from natural events.
- Environmental Justice – Federal investments in water resources should ensure that disproportionately high and adverse public safety, human health, or environmental burdens of projects on tribal, minority, or low-income populations are identified, mitigated, or eliminated.
- Watershed Approach - Federal investments in water resources should use a watershed approach that properly frames a problem by evaluating it on a systems level that identifies root causes and interconnectedness of watershed problems that enables the design of solutions that consider the benefits of water resources for a wide range of stakeholders within and around the watershed.

The Watershed Plan and Environmental Assessment for the Project considered these principles in the characterization of flood mitigation challenges and shortages of recreation opportunities faced by stakeholders in the watershed and the formulation of solutions as defined in the action alternatives.

[1] DM 9500-013

D 6.03 ALTERNATIVES AND ECOSYSTEM SERVICES EVALUATED

To reduce flood damage in the North Fork of the Elkhorn River watershed, two action alternatives were carried forward for additional analysis. The Osmond alternative would raise a road, install a berm, and make non-structural improvements to a dozen residential structures to reduce flood damage in the City of Osmond. Under the Pierce alternative, a set of interdependent works of improvement would be installed. Two diversion channels and two pump stations would be constructed to reduce interior flooding that occurs behind the existing levee. In addition, levee improvements would be installed to prevent floodwaters outside the levee from entering the city. Together, the action alternatives meet the project's purpose and need and achieve the project's objectives of reducing flood damage in the watershed.

The No Action Alternative, also known as the Future Without Federal Investment (FWOFI), describes the most likely future if no federal investment is made in the watershed. Under the FWOFI, flooding would continue to cause damage in the watershed across all flood frequencies.

The economic analysis analyzed the costs and benefits of all three alternatives.

TYPES OF SERVICES IMPACTED

Section 3.07 of the watershed plan-EA shows the causal chain describing how the action alternatives would create social benefits and costs in the North Fork of the Elkhorn River Watershed. The change in watershed structure would improve the regulation of flood damage, leading to reduced flood damage to buildings and business and personal income.

ABILITY TO CHARACTERIZE, QUANTIFY, AND MONETIZE SERVICES

The ecosystem services can be characterized, quantified, and monetized to varying degrees. Modeling impacts from mitigating flood risk to buildings and businesses require a large amount of data and sophisticated geospatial models depicting hydrologic conditions in the watershed under different climate and weather conditions. While these barriers are high, publicly available models, such as U.S. Federal Emergency Management Authority's (FEMA) HAZUS model, are commonly used to quantify and value flood damages to the buildings and businesses.

HAZUS estimates involve several sources of uncertainty, primarily related to input data quality, modeling assumptions, and the inherent variability of flood events. Data inputs such as building inventory, elevation, and land use may be incomplete, outdated, or generalized, particularly in smaller or rural communities. Model assumptions, like depth-damage curves and economic loss functions, are based on national averages that may not fully capture local construction practices, topography, or economic conditions. These issues can introduce potential bias, leading to either over- or underestimation of damages.

Despite these uncertainties, HAZUS remains a valuable and reliable tool for planning and risk assessment. It provides a consistent, standardized methodology that allows for reasonable comparison across locations and scenarios, and it incorporates scientifically vetted relationships between hazard intensity and damage. When combined with local data, expert review, and engineering judgment, HAZUS results offer credible, actionable insights to support mitigation planning, funding applications, and communication of flood risk to stakeholders.

METRICS TO EVALUATE SERVICES

This section describes metrics used to measure changes to ecosystem services that are quantified and valued as part of this analysis. Damages to buildings, including contents and inventories, are quantified in terms of the number of buildings and the overall square footage of building space damaged by flooding. Lost personal and business income is also measured in terms of square feet of building space damaged, as discussed in more detail, below.

PRIORITIZING SERVICES

Services were prioritized based on their expected contribution to the project's primary objectives of reducing flood damage in the North Fork of the Elkhorn River watershed. As a result, the analysis prioritized the regulating services impacted by the flood control measures proposed to be installed in the watershed.

SUMMARY AND COMPARISON OF ECOSYSTEM SERVICE CHANGES

A summary of each action alternative's impact on ecosystem services in the North Fork of the Elkhorn River Watershed and fulfillment of federal investment principles in water resources is shown in Section 5 of the watershed plan.

In terms of benefits and costs, the action alternative's combined investment in the watershed would generate economic returns in excess of the upfront installation and ongoing management costs as compared to the FWOFI. The action alternatives would invest an average annualized amount of $915,000 in built infrastructure to reduce flood damage in the North Fork of the Elkhorn River watershed while the discounted annualized value of the enhanced regulating service benefits generated by the project amounts to about $1.6 million, outweighing the action alternative's expense.

D 6.04 NATIONAL ECONOMIC EFFICIENCY BENEFIT-COST ANALYSIS DATA AND METHODOLOGY

Benefits and costs were calculated based on the expected effects of the action alternatives on regulating ecosystem services as compared against the FWOFI. Effects of the action alternatives were evaluated over a 100-year evaluation period, Construction costs were brought forward using the interest during construction (IDC) approach, which accounts for the opportunity cost of capital by adding interest to installation expenses incurred during the construction period. This represents the cost of financing or holding funds before the project becomes operational. The pump stations proposed as part of the Pierce alternative have a 50-year useful life and will be replaced within the 100-year evaluation period.

Projected benefits and costs are based on a full employment economy and assume no change in relative prices during the period of analysis. Benefits and costs are discounted using the discount rate for Federal projects of 2.75 percent for 2024 (USACE, 2023). Results are reported in current-year values and average annual values in 2024 dollars.

To assess the economic benefits and costs of the action alternatives, appropriate methods were used to quantify and value the impacts of the action alternatives as compared to the FWOFI. Flood damage to buildings, businesses, and employees under the FWOFI and action alternatives was estimated using the H&H analysis in conjunction with GIS-based models as discussed in more detail below. In all of the analyses discussed below, the unit of analysis is the system of projects combined under each action alternative.

REDUCED BUILDING-RELATED DAMAGE (PIERCE AND OSMOND STRUCTURAL ALTERNATIVES)

Reduced building-related damages were estimated with the HAZUS model. The HAZUS model, endorsed by the NRCS for watershed planning and developed by FEMA, serves as a robust tool for estimating flood damage across various scenarios. The model's primary strength lies in its ability to quickly produce estimates using user-defined H&H modeling and pre-packaged building data, making it well-suited for widespread and integrated flood risk assessments. However, this convenience comes with a tradeoff in precision; HAZUS may not provide the same level of detail for building-specific flood depth damages as models like HEC-FDA. On the other hand, models like HEC-FDA are specifically designed for detailed flood risk analysis but demand more time, specialized expertise, and detailed data, which can limit their accessibility for large flood inundation areas with diverse building inventories.

Still, peer-reviewed comparisons that applied the HAZUS and HEC-FDA models to several different study areas, found the outputs from HAZUS are similar and consistent with those from HEC-FDA, while requiring a fraction of the time and effort to produce.[2] Based on these reviews and to best utilize the limited resources available in preparing the watershed plan, the project team chose to utilize HAZUS to estimate building-related flood damage reductions.

The HAZUS model runs on standard GIS software and addresses damage associated with almost all parts of the built environment. The model can estimate the value of a wide range of different types of flood loss. The model contains different loss modules, which the user has the option of

[2] Ding, A., White, J. F., Ullman, P. W., & Fashokun, A. O. (2008). "Evaluation of hazus-mh flood model with local data and other program." Nat. Hazards Rev., 10.1061/(ASCE)1527-6988(2008)9:1(20), 1527-6996.

including in their total damage calculation. The modules for reduced property loss, which are time-independent, include:

- Building repair and replacement cost;
- Building content loss; and
- Building inventory loss.

The sum of these losses constitutes building-related losses in the benefit-cost analysis.

To estimate building-related damage, the model works in a two-step process, which includes a flood risk projection step and a flood loss estimation step. In the flood risk projection step, the user defines flood risk in terms of parameters like flood frequency, discharge, and ground elevation in the study area. In the second step, damages are calculated based on the flood risk projections developed in the first step and using default functions relating depth to damage (depth-damage functions) from the U.S. Army Corps of Engineers (USACE) and building inventory and valuation data from the U.S. Census (FEMA, 2022). The model combines this information to produce spatial and tabular data describing flood losses in monetary terms.

An important part of estimating reduced flood damage is identifying the number, value, type, and other characteristics of at-risk building stock. The HAZUS model's General Building Stock data (GBS) includes information on residential, commercial, industrial, agricultural, religious, government, and education buildings for each Census block in the study area. For modeling simplicity, HAZUS assumes building inventory is evenly distributed across a census block, such that building damage estimates represent averages across their respective block. Each building type is associated with a corresponding occupancy classification, of which there are seven categories in the HAZUS model:

- Residential
- Commercial
- Industrial
- Agricultural
- Religion
- Government
- Education

Table 16 and Table 17, below, show the square footage of building types damaged by flooding under each storm event frequency in the North Fork of the Elkhorn River watershed for both action alternatives.

Table 16: Damaged Sq. Ftg. ('000s) of Buildings by Occupancy Type Under FWOFI and Osmond Alternative

Occupancy Type	500-Year		100-Year		50-Year		25-Year		10-Year	
	FWOFI	Osmond	FWOFI	Osmond	FWOFI	Osmond	FWOFI	Osmond	FWOFI	Osmond
Residential	76.62	44.31	59.23	36.68	40.73	30.55	27.89	27.09	23.29	22.90
Commercial	20.61	10.06	13.69	7.65	7.79	5.64	3.67	3.66	1.89	1.88
Industrial	32.94	6.70	18.43	4.13	3.91	1.76	0.54	0.54	0.12	0.12
Agricultural	8.37	8.41	5.99	6.13	4.48	4.50	1.66	1.66	0.37	0.00
Religious	0.07	0.06	0.04	0.04	0.03	0.03	0.02	0.02	0.01	0.01
Government	0.41	0.03	0.12	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Education	0.91	0.33	0.31	0.22	0.16	0.16	0.10	0.10	0.05	0.05
Total	**139.92**	**69.90**	**97.81**	**54.87**	**57.14**	**42.64**	**33.89**	**33.08**	**25.73**	**24.96**

Source: HAZUS v5.1.

Table 17: Damaged Sq. Ftg. ('000s) of Buildings by Occupancy Type Under FWOFI and Pierce Alternative

Occupancy Type	500-Year		100-Year		50-Year		25-Year		10-Year	
	FWOFI	Pierce	FWOFI	Pierce	FWOFI	Pierce	FWOFI	Pierce	FWOFI	Pierce
Residential	220.23	167.69	197.65	129.95	170.33	112.61	142.76	96.99	101.88	76.31
Commercial	15.21	12.40	11.59	8.59	9.52	6.73	7.52	5.08	4.26	3.04
Industrial	1.06	0.86	1.22	0.74	1.03	0.55	0.81	0.40	0.47	0.31
Agricultural	0.42	0.25	0.30	0.15	0.23	0.09	0.14	0.06	0.06	0.04
Religious	0.84	0.84	0.46	0.48	0.36	0.39	0.30	0.32	0.23	0.23
Government	0.22	0.22	0.15	0.14	0.13	0.10	0.08	0.05	0.01	0.01
Education	0.03	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Total	**238.01**	**182.29**	**211.39**	**140.05**	**181.61**	**120.47**	**151.63**	**102.91**	**106.90**	**79.93**

Source: HAZUS v5.1.

As the existing conditions data shows, flooding poses significant risks to a variety of building types in the cities of Osmond and Pierce. For single-family dwellings, manufactured housing, and multifamily units, floodwaters can severely damage foundations, electrical systems, and personal property. Manufactured homes, in particular, are more vulnerable due to their lightweight construction.

Nursing homes are also particularly vulnerable due to the need for emergency evacuations and care for vulnerable populations. During the 2019 spring floods in Pierce, the Premier Estates nursing and critical care facility preemptively evacuated 42 residents before the facility was inundated and significantly damaged by rising flood waters. Emergency responders were able to move all 42 residents to a facility in a nearby community, but the residents were ultimately displaced from Pierce for more than four months while the facility was repaired.[3] The Premier Estates nursing and critical care facility would be a primary beneficiary of the Pierce action alternative.

Other structures, like retail and wholesale businesses, are at risk of losing inventory and having their operations disrupted, while professional/technical services, banks, and medical offices/clinics may face service interruptions and loss of essential records. Flooding also impacts industrial sectors like agricultural processing and light industry, leading to potential contamination risks and operational shutdowns.

To assess damages to structures under the FWOFI and Preferred Alternative, the model combined the general building stock data from Tables 2 and 3 with the H&H data and building-specific depth-damage curves to estimate the building-related losses for the study area's general building stock under the FOWFI and action alternatives. Flood extent and depth data was input into the HAZUS model using depth grids from five return periods (10%, 4%, 2%, 1%, and 0.2% annual chance floods, or 10-, 25-, 50-, 100-, and 500-year return periods) developed as outputs from the H&H for the FWOFI or existing conditions. The HAZUS model's methods for calculating building-related losses are discussed below.

Depreciated Building Replacement Costs

Damage to buildings under the FWOFI and action alternatives were calculated by estimating the cost to repair or replace flood-damaged structures and their contents. Building repair and replacement cost estimates are based on the full replacement cost less depreciation model, whereby losses from flood-damaged buildings are calculated assuming the full value of damages, less depreciation, are restored.

[3] Siouxland Proud. (2019, October 29). Pierce community welcomes back oldest members. Available at: https://www.siouxlandproud.com/news/local-news/pierce-community-welcome-back-oldest-members/

Replacement cost data is stored in the HAZUS model at the Census Block level for each building type. The replacement cost values used by the HAZUS model were depreciated by the study team based on the median age and assumptions regarding the typical condition of structures in the watershed. According to the U.S. Census American Community Survey, the average home in Osmond and Pierce is about 65 years old.[4] A visual survey of residential neighborhoods in the two cities conducted via Google Earth and Zillow showed that homes are generally maintained in average to above-average condition.

This information was cross-referenced with the Swift Estimator, which provides a depreciation curve for structures of various ages.[5] Based on the median age and assumed condition of buildings in the North Fork of the Elkhorn River watershed, the Swift Estimator recommended using a depreciation rate of 15 percent, which was applied to the replacement cost values provided by HAZUS as shown in Table 18.

Table 18: Replacement Cost Values for Buildings (2024 $)

Occupancy Type	HAZUS Replacement Cost per Sq. Ft.	Depreciation Factor	Depreciated Replacement Cost per Sq. Ft. Used in the BCA
Residential	$194.63	15%	$165.43
Commercial	$202.11	15%	$171.80
Industrial	$134.90	15%	$114.67
Agricultural	$228.64	15%	$194.34
Religion/Non-profit	$305.08	15%	$259.31
Government	$144.00	15%	$122.40
Education	$241.96	15%	$205.66

Note: Replacement costs are reported in costs per square foot for multiple occupancy type sub-categories based on the weighted average of values used in the analysis of building damages in the North Fork of the Elkhorn River watershed, NE.
Source: HAZUS v.5.1.

[4] U.S. Census Bureau. "Selected Housing Characteristics." American Community Survey, ACS 5-Year Estimates Data Profiles, Table DP04, 2022, https://data.census.gov/table/ACSDP5Y2022.DP04?q=Osmond&t=Housing Units:Year Structure Built. Accessed on October 1, 2024; U.S. Census Bureau. "Selected Housing Characteristics." American Community Survey, ACS 5-Year Estimates Data Profiles, Table DP04, 2022, https://data.census.gov/table/ACSDP5Y2022.DP04?q=Pierce&t=Housing Units:Year Structure Built. Accessed on October 1, 2024.
[5] SwiftEstimator. (2020). Swift Estimator User Guide. Retrieved from https://www.swiftestimator.com/UserGuide.

Building Content Losses

The HAZUS model estimates damages to building contents as a percentage of the structure replacement value as shown in Table 19. Contents in the model include furniture, equipment, computers, appliances, clothing, and personal possessions. Contents do not include items such as light fixtures, ceiling lamps, or other mechanical or electronic components that are integral to the structure of a building.

Table 19: Building Content Loss as a Percent of Building Replacement Value

Occupancy Type	Content Value as Percent of Building Replacement Value
Residential	50%
Commercial	105%
Industrial	140%
Agricultural	100%
Religious	-
Government	125%
Education	125%

Source: HAZUS v.5.1.

Business Inventory Damages

Many building occupancy types have more than one inventory-depth-damage curve associated with them. In these cases, the HAZUS model averages the relevant depth-damage functions to form a single average function for the entire building occupancy class. The HAZUS model uses this information along with information on total damaged floor area, annual gross sales per square foot, and business inventory as a percent of annual gross sales, to calculate the total inventory damage for each building type. The gross revenue per square foot and business inventory as a percentage of gross revenue are shown in Table 20.

Table 20: Business Inventory Losses as a Percent of Gross Sales per Square Foot

Occupancy Type	Gross Revenue per Sq. Ft.	Business Inventory as Percent of Gross Revenue
Commercial	$68	12%
Industrial	$613	4%
Agricultural	$156	8%

Source: HAZUS v.5.1.

REDUCED BUSINESS INCOME AND WAGE LOSS

The HAZUS model calculates business interruption costs, including proprietor income loss and employee wage loss by building type. In the model, business income and wage losses depend on the amount of time it takes to restore the building where the business resides in addition to restocking its inventory. Restoration time accounts for physical restoration, clean-up, inspections, permits, and contractor availability. Restoration times increase with flood depth and also vary based on building type. Restoration times range from a low of a few months for structures with minimal flooding to a high of several years. For many commercial businesses, restoring lost inventory and equipment accounts for the largest portion of restoration time.

The equations below show how HAZUS calculates business income and wage losses following flood events:

- **Income Loss$_i$** = $\sum$ (1-IRF$_i$) x FA$_{i,j}$ x Inc$_j$ x RT$_{i,j}$
- **Wage Loss$_i$** = $\sum$ (1-WRF$_i$) x FA$_{i,j}$ x WA$_j$ x RT$_{i,j}$

The parameters of the above equations are defined as:

- i is the building type of the impact structure
- IRF$_i$ is the income recapture factor for building type i
- WRF$_i$ is the wage recapture factor for building type i
- FA$_i$ is the income per day (per sq. ft.) for building type i
- INC$_i$ is the business income per day (per sq. ft.) for building type i
- WA$_i$ is the wage per day (per sq. ft.) for building type i
- RT$_{i,j}$ is the restoration time, measured in days, for building type i and flood depth j.

The equations represent income and wage loss as a function of the length of time needed to restore business operations as well as the ability of businesses and employees to recapture their respective incomes and wages. For example, according to the wage loss equation, employees who are able to recover their full wage following a flood event would have a recapture rate of one, which would mean they would not lose any wages as a result of the flood. Lower recapture rates would lead to high damages, all else equal. The income and wage recapture rates used by the HAZUS model ensure that estimates of income and wage loss only include actual losses rather than deferred economic activity. The equations also reflect the productivity of the business as measured by income generated per square foot.

The parameters used to calculate reduced business income and wage losses under the action alternatives and FWOFI are shown in Table 21. The restoration times shown in the table are based on expert opinion and account for various factors like physical restoration, clean-up, inspections, permits, approval processes, and delays due to contractor availability. Table 21 also displays the income recapture rates, annual business income generation rates, and daily wage rates per square foot used in the analysis.

Table 21: Parameters Used to Calculate Business Income Loss and Wage Loss

Occupancy Type	Restoration Time (Days)	Income Recapture Rate	Daily Business Income per Sq. Ft. per Year	Daily Wage per Sq. Ft.
Residential	180 – 720	0%	$0	$0
Commercial	180 – 900	68%	$0.20	$0.48

Industrial	0 – 900	80%	$0.10	$0.42
Agricultural	0 -210	67%	$0.05	$0.17
Religious	180 – 900	80%	$0.16	$2.46
Government	360 – 900	80%	$0.10	$0.14
Education	360 - 900	83%	$0.10	$0.67

Source: HAZUS v.5.1

NREH Part 611.0403 states that the benefit of reducing business income losses from flood risk reduction can be included as part of the benefit-cost ratio when interview data are collected to verify that losses are not compensated for by postponement of an activity or transfer of the economic activity to other establishments.

To validate the nature of business income and wage related losses estimated by HAZUS, a survey of business owners was conducted as part of a separate WFPO project, but similar in nature to this one. As part of the Mud Creek WFPO Watershed Plan-EA, the Lower Loup Natural Resource District (LLNRD) estimated the impact of a 100-year flood event on business revenue and employee wages. LLNRD approached a sample of businesses to participate in the interviews utilizing NRCS Form ECN-003 (NREH Part 611, Appendix 4A, Form NRCS-ECN-003). The LLNRD engaged in structured dialogues with each business to ensure uniformity in questioning and responses. Confidentiality was assured to encourage participation and information sharing. In total, 11 businesses completed the questionnaires.

The responding businesses spanned various sectors, including retail trade, professional and business services, financial services, and information services. They employed between one and 15 people, averaging about 4 employees per enterprise. Considering the types of businesses and limited commercial development in rural watersheds, it's unlikely that a large amount of commercial activity impacted by flooding would shift to other businesses since most businesses in rural areas face little to no direct competition. Flooding would also affect their customers, so even if there were direct business competitors, the demand for goods and services by impacted residents would be greatly reduced during the post-flood recovery period.

For many rural retail businesses, lost sales are unlikely to be recovered. For instance, restaurant patrons will not order additional meals to compensate for missed purchases during flood-induced closures, and gas station customers cannot fill their tanks twice to make up for unpurchased fuel. These flood-related losses in transactions cannot be recovered and reflect real and lasting losses in business income and employee wages.

The comparison of income losses estimated with the survey results and the HAZUS model showed that HAZUS produced conservative estimates. On this basis, the HAZUS estimates of income losses are carried forward as national effects in the benefit-cost analysis following guidance in NREH Part 611.0403.

REDUCED BUILDING-RELATED DAMAGE (OSMOND NON-STRUCTURAL ALTERNATIVE)

Avoided property-related damages for the non-structural works of the Osmond Alternative were evaluated with a spreadsheet-based analysis of impacted structures, contents, and vehicles. Data from the County Assessors' office was combined with Hydrology and Hydraulic (H&H) modeling to identify changes in flood depth to participating properties by different depths of flooding for 10-, 25-, 50-, 100-, and 500-year flood events for the FWOFI and the non-structural portion of the Osmond Alternative.

The County Assessor's data contained information about each impacted structure, including its market value, built square footage, and primary use. The County Assessor's data and a review on Google Earth indicated that most structures in Osmond are single-story homes. Table 22 shows the number of residential, commercial, and other structures impacted by flooding under the FWOFI and the Osmond Alternative at different flood depths.

Table 22: Structure, Type, Size, Value, and Flood Depth Under Different Flood Frequencies for Existing and Proposed Conditions for the Osmond Alternative Non-Structural Works of Improvement

Occupancy Type	Structure Sq. Ft.	Structure Value	Osmond Alternative					FWOFI				
			500-year	100-year	50-year	25-year	10-year	500-year	100-year	50-year	25-year	10-year
Trailer home with addition	1,188	$8,455	0 ft	0 ft	0 ft	0 ft	0 ft	2-3 ft	2-3 ft	1-2 ft	1-2 ft	0-1 ft
Home	1,048	$23,505	3-4 ft	2-3 ft	2-3 ft	1-2 ft	1-2 ft	3-4 ft	2-3 ft	2-3 ft	1-2 ft	1-2 ft
Home	1,281	$22,165	0 ft	0 ft	0 ft	0 ft	0 ft	1-2 ft	1-2 ft	0-1 ft	0-1 ft	0 ft
Trailer home with addition	912	$8,815	0 ft	0 ft	0 ft	0 ft	0 ft	2-3 ft	2-3 ft	1-2 ft	1-2 ft	1-2 ft
Home	1,483	$107,655	0 ft	0 ft	0 ft	0 ft	0 ft	1-2 ft	0-1 ft	0-1 ft	0-1 ft	0 ft
Home	1,845	$194,455	0 ft	0 ft	0 ft	0 ft	0 ft	1-2 ft	1-2 ft	0-1 ft	0-1 ft	0 ft
Home	1,374	$67,725	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft
Home	1,588	$114,980	0 ft	0 ft	0 ft	0 ft	0 ft	1-2 ft	0-1 ft	0-1 ft	0 ft	0ft
Home	1,042	$29,645	0 ft	0 ft	0 ft	0 ft	0 ft	2-3 ft	1-2 ft	1-2 ft	0-1 ft	0-1 ft
Home	1,734	$124,985	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft	0 ft
Home	676	$43,550	0 ft	0 ft	0 ft	0 ft	0 ft	1-2 ft	0-1 ft	0-1 ft	0-1 ft	0-1 ft
Home	5,188	$290,340	0 ft	0 ft	0 ft	0 ft	0 ft	2-3 ft	1-2 ft	1-2 ft	1-2 ft	0-1 ft

Source: JEO Consulting Group

The information in Table 22 was used to calculate building damages and content loss under the FWOFI and Action Alternative using depth to damage functions from the U.S. Army Corps of Engineers (USACE) and parameters from the Federal Emergency Management Agency's HAZUS model.

Building and content damages under the FWOFI and Action Alternative were derived using depth damage functions from the U.S. Army Corps of Engineers (USACE) as shown in Table 23. The depth damage functions relate flooding depth to a corresponding percentage reduction in building and content value. The analysis assumed that building contents represent 75 percent of building value for residential structures and 100 percent of building value for commercial and other structures, following assumptions used in the Federal Emergency Management Agency's HAZUS model.

Table 23: Building and Contents Depth Damage Functions Used in the Benefit-Cost Analysis of the Osmond Alternative Non-Structural Works of Improvement

Flood Depth	Percent Reduction in Building Value	Percent Reduction in Content Value
0-1 ft	26%	12%
1-2 ft	32%	20%
2-3 ft	39%	28%
3-4 ft	46%	34%
4-5 ft	52%	42%
5-6 ft	59%	46%
6-7 ft	65%	47%
7-8 ft	70%	47%

Source: USACE EGM 01-03 (Buildings); USACE 1992 (Contents).

Contents included in the estimate include furniture, equipment, computers, appliances, clothing, and personal possessions. Contents do not include items like light fixtures, ceiling lamps, or mechanical or electronic components that are integral to the structure of a building. As the table shows, content value is assumed to be equal to 75 percent of building value for residential structures.

The analysis also accounted for damage to vehicles at the residential properties. The analysis assumes each household has two vehicles worth with an average depreciated value of $10,500, for a combined total of $21,000. Flood damages to vehicles located at damaged properties were estimated using building flood depths and depth-damage functions for vehicles from the U.S. Army Corps of Engineers as shown in Table 24.

Table 24: Depth-Damage Function for Vehicles Used in the Benefit-Cost Analysis of the Osmond Alternative Non-Structural Works of Improvement

Flood Depth (Feet)	Damage as a Percent of Total Value
0-1	18%
1-2	37%
2-3	54%
3-4	69%
4-5	82%
6-7	100%

Source: Department of the Army. 2009. Economic Guidance Memorandum, 09-04, Generic Depth-Damage Relationships for Vehicles

COSTS

Preliminary engineering work on design, permitting, construction, and operation and maintenance requirements for the structures included as part of the action alternatives was completed. The cost estimates were allocated to cost categories which included:

- Land acquisitions
- Design and engineering
- Project administration
- Permitting
- Construction
- Professional services

Costs were estimated using a bottom-up approach. This method breaks projects and structures into lower-level components and then costs those components for their direct costs, including labor, materials, and professional services. In addition, installation cost estimates include cost contingencies of 20 percent for construction.

Table 25 through Table 31 show the estimated installation costs for all of the structures included in the action alternatives.

Table 25: Estimated Installation Costs of Structure F1-1 (2024$)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Mobilization	LS	1	$94,000	$94,000
2.	Bonding and Insurance	LS	1	$32,000	$32,000
3.	Clearing and Grubbing	LS	1	$8,500	$8,500
4.	Remove Tree, >24" Dia.	EA	5	$2,500	$12,500
5.	Earthwork Measured in Embankment (Fill)	CY	6,130	$30	$183,900
6.	Modular Block Wall	SF	1,500	$93	$139,500
7.	24" RCP, Class III	LF	500	$250	$125,000
8.	Area Inlet	EA	1	$11,000	$11,000
9.	24" RCP Headwall	EA	1	$8,500	$8,500
10.	24" Flap Gate	EA	1	$10,000	$10,000
11.	24" Gatewell	EA	1	$97,000	$97,000
12.	Riprap	TONS	48	$120	$5,760
13.	Silt Fence, Low Porosity	LF	2,390	$4	$9,560
14.	Seeding, Fertilizer and Mulch	ACRE	1.4	$10,000	$14,000
15.	Stabilized Construction Entrance	EA	1	$5,000	$5,000
16.	Raise/Relocate Concession Stand	LS	1	$240,000	$240,000
17.	Raise/Relocate Bathhouse	LS	1	$300,000	$300,000
18.	Temporary Traffic Control Measures	LS	1	$10,000	$10,000
			Construction Subtotal		$1,306,300
			Contingency	20%	$261,300
			Total Opinion of Construction Cost		**$1,567,600**
CONSTRUCTION - LOCAL SHARE					
1.	Crushed Rock Surface Course	TONS	240	$60	$14,385
2.	Remove Pavement	SY	222	$30	$6,667
3.	8" Concrete Pavement	SY	222	$80	$17,778
4.	Utility Conflicts	LS	1	$25,000	$25,000
			Construction Subtotal		$63,900
			Contingency	20%	$12,800
			Total Opinion of Construction Cost		**$76,700**
ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
PROPERTY RIGHTS					
1.	Permanent Land	ACRE	0.5	$15,000	$7,500
			Land Acquisition Subtotal		$7,500

	Legal Fees & Land Appraisals			30%	$2,250
	Total Opinion of Property Rights Cost				**$9,750**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$263,100	$263,100
2.	Permitting	LS	1	$65,800	$65,800
3.	Construction Observation	LS	1	$164,500	$164,500
4.	Project Administration (Sponsor)	LS	1	$41,200	$41,200
5.	Project Administration (NRCS)	LS	1	$41,200	$41,200
	Total Opinion of Professional Services Cost				**$575,800**
SUMMARY					
	CONSTRUCTION - FEDERAL SHARE				**$1,567,600**
	CONSTRUCTION - LOCAL SHARE				**$76,700**
	PROPERTY RIGHTS				**$9,750**
	PROFESSIONAL SERVICES				**$569,300**
	TOTAL OPINION OF PROJECT COST				**$2,229,850**

Table 26: Estimated Installation Costs of Structure F1-2 (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Mobilization	LS	1	$21,000	$21,000
2.	Bonding and Insurance	LS	1	$7,000	$7,000
3.	Clearing and Grubbing	LS	1	$6,500	$6,500
4.	Earthwork Measured in Embankment (Fill)	CY	3,485	$30	$104,550
5.	Silt Fence, Low Porosity	LF	1,530	$4	$6,120
6.	Seeding, Fertilizer and Mulch	ACRE	1.3	$10,000	$13,000
7.	Stabilized Construction Entrance	EA	1	$5,000	$5,000
8.	24" RCP, Class III	LF	52	$200	$10,400
9.	24" RCP Headwall	EA	1	$10,000	$10,000
10.	24" RCP Flared End Section	EA	1	$2,500	$2,500
11.	24" Flap Gate	EA	1	$10,000	$10,000
12.	24" Gatewell	EA	1	$97,000	$97,000
13.	Riprap	TONS	40	$120	$4,800
	Construction Subtotal				$297,900
	Contingency			20%	$59,600
	Total Opinion of Construction Cost				**$357,500**
CONSTRUCTION - LOCAL SHARE					
1.	Flap Gate	EA	1	$10,000	$10,000
	Land Acquisition Subtotal				$16,534
	Legal Fees & Land Appraisals			30%	$4,961
	Total Opinion of Construction Cost				**$21,495**
PROPERTY RIGHTS					
1.	Permanent Land	ACRE	1.10	$15,000	$16,533
	Land Acquisition Subtotal				$16,534
	Legal Fees & Land Appraisals			30%	$4,961
	Total Opinion of Property Rights Cost				**$21,495**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$59,200	$59,200
2.	Permitting	LS	1	$14,800	$14,800
3.	Construction Observation	LS	1	$37,000	$37,000
4.	Project Administration (Sponsor)	LS	1	$9,300	$9,300
5.	Project Administration (NRCS)	LS	1	$9,300	$9,300
	Total Opinion of Professional Services Cost				**$129,600**
SUMMARY					
	CONSTRUCTION - FEDERAL SHARE				**$357,500**
	CONSTRUCTION - LOCAL SHARE				**$12,000**
	PROPERTY RIGHTS				**$21,495**
	PROFESSIONAL SERVICES				**$129,600**

TOTAL OPINION OF PROJECT COST	**$520,595**

Table 27: Estimated Installation Costs of Nonstructural Improvements to Residential Homes in Osmond (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Elevation of home at 209 S State St	SF	1,188	$68	$81,022
2.	Elevation of home at 307 E Market St	SF	1,281	$68	$87,364
3.	Elevation of home at 208 S Logan St	SF	912	$68	$62,198
4.	Elevation of home at 202 E Market St	SF	1,483	$68	$101,141
5.	Flood Vents in home at 107 E Market St	LS	1	$5,000	$5,000
6.	Flood Vents in home at 201/203 S Main St	LS	1	$5,000	$5,000
7.	Elevation of home at 312 S State St	SF	1,849	$68	$126,102
8.	Elevation of home at 204 S Maple St	SF	676	$68	$46,103
9.	Elevation of home at 102 E Market St	SF	1,588	$68	$108,302
10.	Elevation of home at 300 S Main St	SF	1,042	$68	$71,064
11.	Elevation of home at 103 S State St	SF	1,374	$68	$93,707
12.	Construction of Berm around home at 302 S Main St	LS	1	$84,040	$84,040
13.	Sewerline Backflow Prevention for home at 103 S State St	EA	1	$3,575	$3,575
14.	Sewerline Backflow Prevention for all other homes (excluding 103 S State St)	EA	12	$3,575	$42,900
15.	Ancillary Items (Including Replacement of Comparable Facilities or Features) for all elevated homes and berm at 302 S Main St	EA	10	$10,000	$100,000
			Construction Subtotal		$1,017,600
			Contingency	20%	$203,600
			Total Opinion of Construction Cost		**$1,221,200**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$195,400	$195,400
2.	Permitting	LS	1	$48,900	$48,900
3.	Construction Observation	LS	1	$122,200	$122,200
4.	Project Administration (Sponsor)	LS	1	$30,600	$30,600
5.	Project Administration (NRCS)	LS	1	$30,600	$30,600
			Total Opinion of Professional Services Cost		**$427,700**
SUMMARY					
	CONSTRUCTION - FEDERAL SHARE				**$1,221,200**
	CONSTRUCTION - LOCAL SHARE				**$0**
	PROPERTY RIGHTS				**$0**
	PROFESSIONAL SERVICES				**$427,700**

TOTAL OPINION OF PROJECT COST	**$1,648,900**

Table 28: Estimated Installation Costs of Structure C1-30 (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Mobilization	LS	1	$83,000	$83,000
2.	Bonding and Insurance	LS	1	$28,000	$28,000
3.	Clearing and Grubbing	LS	1	$75,000	$75,000
4.	Remove Tree, >24" Dia.	EA	9	$2,500	$21,429
5.	Earthwork Measured in Embankment (Cut)	CY	7,110	$20	$142,200
6.	Earthwork Measured in Embankment (Fill)	CY	976	$30	$29,280
7.	Rock Riprap	TONS	320	$120	$38,400
8.	Silt Fence, Low Porosity	LF	6,850	$4	$27,400
9.	Seeding, Fertilizer and Mulch	ACRE	15	$5,000	$75,000
10.	Stabilized Construction Entrance	EA	2	$5,000	$10,000
11.	Grade Control Structure	LS	1	$224,000	$224,000
12.	Trail Bridge	SF	240	$250	$60,000
13.	Crushed Rock Surface Course	TONS	245	$60	$14,700
14.	Temporary Traffic Control Measures	LS	1	$10,000	$10,000
			Construction Subtotal		$838,500
			Contingency	20%	$167,700
			Total Opinion of Construction Cost		**$1,006,200**
CONSTRUCTION - LOCAL SHARE					
1.	Remove Existing Pipe	LF	115	$50	$5,750
2.	Concrete for Box Culvert	CY	201	$1,000	$201,207
3.	Reinforcing Steel for Box Culvert	LBS	21,900	$5	$109,500
4.	Crushed Rock Base Course	TONS	132	$60	$7,938
5.	Crushed Rock Surface Course	TONS	53	$60	$3,150
6.	Remove Asphalt	SY	278	$30	$8,333
7.	Asphalt Concrete	TONS	121	$60	$7,250
8.	Utility Confilcts	LS	1	$30,000	$30,000
1.	Remove Existing Pipe	LF	115	$50	$5,750
			Construction Subtotal		$373,200
			Contingency	20%	$74,700
			Total Opinion of Construction Cost		**$447,900**

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
PROPERTY RIGHTS					
1.	Permanent Land	ACRE	8	$15,000	$120,000
	Land Acquisition Subtotal				$120,000
	Legal Fees & Land Appraisals			30%	$36,000
	Total Opinion of Property Rights Cost				**$156,000**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$232,700	$232,700
2.	Permitting	LS	1	$58,200	$58,200
3.	Construction Observation	LS	1	$145,500	$145,500
4.	Project Administration (Sponsor)	LS	1	$36,400	$36,400
5.	Project Administration (NRCS)	LS	1	$36,400	$36,400
	Total Opinion of Professional Services Cost				**$509,200**
SUMMARY					
	CONSTRUCTION - FEDERAL SHARE				**$1,006,200**
	CONSTRUCTION - LOCAL SHARE				**$447,900**
	PROPERTY RIGHTS				**$156,000**
	PROFESSIONAL SERVICES				**$509,200**
	TOTAL OPINION OF PROJECT COST				**$2,119,300**

Table 29: Estimated Installation Costs of Structure C1-10 (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Mobilization	LS	1	$144,000	$144,000
2.	Bonding and Insurance	LS	1	$48,000	$48,000
3.	Clearing and Grubbing	LS	1	$95,000	$95,000
4.	Remove Tree, >24" Dia.	EA	16	$2,500	$40,000
5.	Earthwork Measured in Embankment (Cut)	CY	27,210	$20	$544,200
6.	Earthwork Measured in Embankment (Fill)	CY	1,045	$30	$31,350
7.	Rock Riprap	TONS	2,170	$120	$260,400
8.	Silt Fence, Low Porosity	LF	18,000	$4	$72,000
9.	Seeding, Fertilizer and Mulch	ACRE	23	$5,000	$115,661
10.	Stabilized Construction Entrance	EA	3	$5,000	$15,000
11.	Temporary Traffic Control Measures	LS	1	$40,000	$40,000
	Construction Subtotal				$1,405,700
	Contingency			20%	$281,200
	Total Opinion of Construction Cost				**$1,686,900**
CONSTRUCTION - LOCAL SHARE					
1.	Remove Existing Pipe	LF	230	$50	$11,500
2.	48" RCP Class III	LF	139	$400	$55,600
3.	48" RCP Flared End Section	EA	4	$3,500	$14,000
4.	Concrete for Box Culvert	CY	274	$1,000	$273,946
5.	Reinforcing Steel for Box Culvert	LBS	29,201	$5	$146,007
6.	Crushed Rock Base Course	TON	174	$60	$10,433
7.	Remove Pavement	SY	933	$30	$28,000
8.	8" Concrete Pavement	SY	933	$80	$74,667
9.	Crushed Rock Surface Course	TONS	53	$60	$3,150
10.	Utility Conflicts	LS	1	$82,500	$82,500
	Construction Subtotal				$699,900
	Contingency			20%	$140,000
	Total Opinion of Construction Cost				**$839,900**
ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
PROPERTY RIGHTS					
1.	Permanent Land	ACRE	19	$15,000	$285,000
	Land Acquisition Subtotal				$285,000

	Legal Fees & Land Appraisals			30%	$85,500
	Total Opinion of Property Rights Cost				**$370,500**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$404,300	$404,300
2.	Permitting	LS	1	$101,100	$101,100
3.	Construction Observation	LS	1	$252,700	$252,700
4.	Project Administration (Sponsor)	LS	1	$63,200	$63,200
5.	Project Administration (NRCS)	LS	1	$63,200	$63,200
	Total Opinion of Professional Services Cost				**$844,500**
SUMMARY					
	CONSTRUCTION - FEDERAL SHARE				**$1,686,900**
	CONSTRUCTION - LOCAL SHARE				**$839,900**
	PROPERTY RIGHTS				**$370,500**
	PROFESSIONAL SERVICES				**$884,500**
	TOTAL OPINION OF PROJECT COST				**$3,781,800**

Table 30: Estimated Installation Costs of Structure L1-20 (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Mobilization	LS	1	$559,000	$559,000
2.	Bonding and Insurance	LS	1	$187,000	$187,000
3.	Clearing and Grubbing	LS	1	$150,000	$150,000
4.	Earthwork Measured in Embankment (Fill)	CY	65,900	$20	$1,318,000
5.	Remove Tree, >24"	EA	17	$2,500	$42,500
6.	Silt Fence, Low Porosity	LF	17,800	$4	$71,200
7.	Seeding, Fertilizer and Mulch	ACRE	30	$3,000	$90,000
8.	Stabilized Construction Entrance	EA	2	$5,000	$10,000
9.	Crushed Rock Surface Course	TONS	2,500	$60	$150,000
10.	Toe Drain Pipe, 10" PVC Perforated	LF	4,390	$200	$878,000
11.	Remove Existing Levee Drainage Structures	LF	40	$80	$3,200
12.	48" RCP Class III	LF	40	$400	$16,000
13.	48" RCP Flared End Section	EA	1	$3,500	$3,500
14.	48" RCP Headwall	EA	1	$20,000	$20,000
15.	48" Flap Gate	EA	1	$20,000	$20,000
16.	48" Gatewell Structure	EA	1	$97,000	$97,000
17.	Landside Seepage Filter	EA	1	$5,000	$5,000
18.	Rock Riprap	TONS	160	$120	$19,200
19.	Temporary Traffic Control Measures	LS	1	$50,000	$50,000
			Construction Subtotal		$3,689,600
			Contingency	20%	$738,000
			Total Opinion of Construction Cost		**$4,427,600**
ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - LOCAL SHARE					
1.	Clearing and Grubbing	LS	1	$105,000	$105,000
2.	Earthwork Measured in Embankment (Fill)	CY	122,670	$20	$2,453,400
3.	Remove Tree, >24"	EA	6	$2,500	$15,000
4.	Silt Fence, Low Porosity	LF	11,200	$4	$44,800
5.	Seeding, Fertilizer and Mulch	ACRE	21	$3,000	$63,000
6.	Stabilized Construction Entrance	EA	2	$5,000	$10,000
7.	Crushed Rock Surface Course	TONS	1,600	$60	$96,000
8.	Toe Drain Pipe, 10" PVC Perforated	LF	2,310	$200	$462,000

9.	Remove Existing Levee Drainage Structures	LF	387	$80	$30,960
10.	Remove Existing Culvert	LF	60	$70	$4,200
11.	48" RCP Class III	LF	185	$400	$74,000
12.	48" RCP Flared End Section	EA	3	$3,500	$10,500
13.	48" RCP Headwall	EA	3	$20,000	$60,000
14.	48" Flap Gate	EA	3	$20,000	$60,000
15.	48" Gatewell Structure	EA	3	$97,000	$291,000
16.	5'x5' Gatewell Structure Modifications	EA	1	$60,000	$60,000
17.	Concrete for Box Culvert	CY	158	$1,000	$158,000
18.	Reinforcing Steel for Box Culvert	LBS	17,100	$5	$85,500
19.	Crushed Rock Base Course	TONS	55	$60	$3,276
20.	Landside Seepage Filter	EA	4	$5,000	$20,000
21.	Rock Riprap	TONS	800	$120	$96,000
22.	Closure Structure	EA	1	$100,000	$100,000
23.	Modify Existing Closure Structure	EA	1	$50,000	$50,000
24.	Remove Asphalt	SY	1,422	$30	$42,667
25.	Asphalt Concrete	SY	1,422	$60	$85,333
26.	Utility Conflicts	LS	1	$25,000	$25,000
			Construction Subtotal		$4,505,700
			Contingency	20%	$901,200
				Total Opinion of Construction Cost	**$5,406,900**
PROPERTY RIGHTS					
1.	Permanent Land	ACRE	17	$15,000	$255,000
			Land Acquisition Subtotal		$255,000
			Legal Fees & Land Appraisals	30%	$76,500
				Total Opinion of Property Rights Cost	**$331,500**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$1,573,600	$1,573,600
2.	Permitting	LS	1	$393,400	$393,400
3.	Construction Observation	LS	1	$983,500	$983,500
4.	Project Administration (Sponsor)	LS	1	$245,900	$245,900
5.	Project Administration (NRCS)	LS	1	$245,900	$245,900
				Total Opinion of Professional Services Cost	**$3,442,300**
SUMMARY					
				CONSTRUCTION - FEDERAL SHARE	**$4,427,600**
				CONSTRUCTION - LOCAL SHARE	**$5,406,900**
				PROPERTY RIGHTS	**$331,500**
				PROFESSIONAL SERVICES	**$3,442,300**
				TOTAL OPINION OF PROJECT COST	**$13,608,300**

Table 31: Estimated Installation Costs of Pierce Pump Stations (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
CONSTRUCTION - FEDERAL SHARE					
1.	Mobilization	LS	1	$199,000	$199,000
2.	Bonding and Insurance	LS	1	$67,000	$67,000
3.	Demolition	LS	2	$5,000	$10,000
4.	Excavation & Backfill	LS	400	$75	$30,000
5.	Concrete	CY	100	$2,500	$250,000
6.	Pump and Controls	LS	2	$750,000	$1,500,000
7.	Electrical	LS	2	$350,000	$700,000
8.	Seeding	LS	2	$15,000	$30,000
9.	Piping	LF	200	$350	$70,000
10.	Slide Gate	LS	2	$25,000	$50,000
11.	Misc Metal	LS	2	$5,000	$10,000
			Construction Subtotal		$2,916,000
			Contingency	20%	$583,200
			Total Opinion of Construction Cost		**$3,499,200**
PROPERTY RIGHTS					
1.	Permanent Land	ACRE	8	$15,000	$120,000
			Land Acquisition Subtotal		$120,000
			Legal Fees & Land Appraisals	30%	$36,000
			Total Opinion of Property Rights Cost		**$156,000**
ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
PROFESSIONAL SERVICES					
1.	Engineering (Including Geology)	LS	1	$559,900	$559,900
2.	Permitting	LS	1	$140,000	$140,000
3.	Construction Observation	LS	1	$350,000	$350,000
4.	Project Administration (Sponsor)	LS	1	$87,500	$87,500
5.	Project Administration (NRCS)	LS	1	$87,500	$87,500
			Total Opinion of Professional Services Cost		**$1,224,900**
SUMMARY					
	CONSTRUCTION - FEDERAL SHARE				**$3,499,200**
	LOCAL SHARE				**$0**
	PROPERTY RIGHTS				**$156,000**
	PROFESSIONAL SERVICES				**$1,224,900**
	TOTAL OPINION OF PROJECT COST				**$4,880,100**

OTHER DIRECT COSTS AND ADVERSE EFFECTS

According to the PR&G:

Other direct costs and adverse effects include uncompensated losses caused by the installation, operation, maintenance, and replacement of a project or group of projects. These other direct costs and adverse impacts can include costs caused by downstream flood damages cause by channel modifications, levees, dikes, and other structures, erosion of land along streambanks created by dams that prevent sediment export downstream, and through lost use value of the land where flood mitigation structures are cited (NRCS, 2014).

The action alternatives have two categories of other direct costs. The nature of and methods used to calculate these other direct costs are discussed in more detail below.

Operations and Maintenance

Once the structures are built, overheads for operations and maintenance will be required for the structures to continue generating benefits. Operations and maintenance costs were estimated by JEO using a bottom-up approach and are shown in Table 32 below.

Table 32: Estimated Annual Operations and Maintenance Costs (2024 $)

Alternative	Structure ID	Annual O&M Costs
Osmond	F1-1	$10,300
Osmond	F1-2	$2,300
Osmond	Non-structural	$7,600
Pierce	C1-10	$15,800
Pierce	L1-20	$61,500
Pierce	C1-30	$9,100
Pierce	Pump Stations	$26,200
Total: Osmond		**$20,200**
Total: Pierce		**$96,800**

Replacement Costs

While most of the structures included in the action alternatives have design lives of 100-years, the pump stations proposed as part of the Pierce Alternative have design lives of 50-years, meaning they must be replaced about halfway through the 100-year evaluation period. The replacement costs of the pump station were accounted for by assuming the pumps and controls, electrical, piping, and slide gates would have to be replaced after 50 years of use at a total cost of $2,320,000 in 2024 dollars (Table 33). In the benefit-cost analysis, the replacement costs were discounted and annualized using a 2.75 percent discount rate assuming replacement would occur at year 55 of the 100-year evaluation period.

Table 33: Estimated Replacement Costs of the Pierce Pump Stations (2024 $)

ESTIMATE OF QUANTITIES					
Item #	**Description**	**Unit**	**Quantity**	**Unit Price**	**Total**
Replacement Cost Components					
1.	Pump and Controls	LS	2	$750,000	$1,500,000
2.	Electrical	LS	2	$350,000	$700,000
3.	Piping	LF	200	$350	$70,000
4.	Slide Gate	LS	2	$25,000	$50,000
				Total Replacement Cost	**$2,320,000**

LAGS OF BENEFITS AND COSTS

The benefits and costs of the action alternatives occur at different points in time. The installation of improvements is anticipated to occur over a five-year period, with the exception of the pump stations, which will be replaced at year 50. After installation, the benefits of improvements are anticipated to accrue over the following 100 years. To account for the difference in timing of benefits and costs, lagging techniques were used to calculate benefits and costs in comparable terms.

The annualized values of installation costs were calculated by dividing the installation costs evenly over five years and discounting the annual values using a discount rate of 2.75 percent. The sum of the discounted installation costs equals their present value. The present value was divided by the present value of an annuity of one over a 100-year period.

Operations and maintenance (O&M) costs were assumed to begin following the five-year installation period. The annual value of O&M costs was discounted at a rate of 2.75 percent, projected over a 100-year period and summed. The sum of the discounted stream of O&M costs was divided by the present value of an annuity based on the 100-year period and a discount rate of 2.75 percent. Building-related damage reductions were assumed to begin after the five-year installation period to be as conservative as possible.

D 6.05 CURRENT ECONOMIC DAMAGES

Average annualized flood damages under the FWOFI were estimated to serve as a benchmark of comparison with the action alternatives (NWPM 501.36). Table 34 and Table 35 summarize average annualized flood damages for Osmond and Pierce under existing conditions, expressed in 2024 dollars and discounted over 100 years at a 2.75% rate. Damages are broken down by recurrence interval and include building-related losses as well as business income and wage losses.

In Osmond, total annualized damages amount to approximately $289,200, increasing from just under $1 million in a 10-year flood to more than $11 million in a 500-year event (Table 34).

Building-related losses and income disruptions grow sharply with flood severity, particularly between the 25- and 100-year events.

Pierce, by comparison, faces significantly higher flood-related damages, with annualized losses nearing $2.93 million (Table 35). Even in a 10-year event, damages exceed $18 million, rising to over $50 million in a 500-year flood. The data highlight Pierce's much greater exposure to flood risk across all categories of damage and recurrence intervals.

In total, average annualized national flood losses under the FWOFI are approximately $3.2 million per year (Table 36).

Table 34: Average Annualized Flood Damages Under Existing Conditions in Osmond by Flood Recurrence Interval (2024$)

Flood Recurrence Interval	Agriculture-related		Average Annual National Damages
	Building - related Losses	Business Income and Wage Losses	
10	$589,500	$326,400	$915,900
25	$927,000	$582,000	$1,509,000
50	$1,400,500	$2,932,800	$4,333,300
100	$2,313,700	$5,414,400	$7,728,100
500	$4,186,900	$6,944,400	$11,131,300
Annualized	**$121,700**	**$167,500**	**$289,200**

Notes: Totals may not sum due to rounding. Building losses include losses to structures as well as structure contents and business inventories. Prepared: October 2024. Price base: 2024 dollars, amortized over 100 years at a discount rate of 2.75 percent.

Table 35: Average Annualized Flood Damages Under Existing Conditions in Pierce by Flood Recurrence Interval (2024$)

Flood Recurrence Interval	Agriculture-related		Average Annual National Damages
	Building - related Losses	Business Income and Wage Losses	
10	$8,412,100	$9,904,800	$18,316,900
25	$14,333,800	$14,612,400	$28,946,200
50	$18,179,200	$17,960,400	$36,139,600
100	$20,841,700	$20,750,400	$41,592,100
500	$25,369,200	$24,849,600	$50,218,800
Annualized	**$1,438,200**	**$1,486,900**	**$2,925,100**

Notes: Totals may not sum due to rounding. Building losses include losses to structures as well as structure contents and business inventories. Prepared: October 2024. Price base: 2024 dollars, amortized over 100 years at a discount rate of 2.75 percent.

Table 36: Average Annualized Flood Damages Under Existing Conditions (2024$)

Alternative	Agriculture-related		Average Annual National Damages
	Building - related Losses	Business Income and Wage Losses	
Osmond FWOFI	$121,700	$167,500	**$289,200**
Pierce FWOFI	$1,438,200	$1,486,900	**$2,925,100**
Total Damages	**$1,559,900**	**$1,654,400**	**$3,214,300**

Notes: Totals may not sum due to rounding. Building losses include losses to structures as well as structure contents and business inventories. Prepared: October 2024. Price base: 2024 dollars, amortized over 100 years at a discount rate of 2.75 percent.

D 6.06 ECONOMIC TABLES

Economic tables are included in Chapter 7 of the Plan-EA.

D 6.07 ECONOMIC REFERENCES

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D 7. CULTURAL RESOURCES

D 7.01 SITE INVESTIGATION

The presence of historic properties and cultural resources with the Area of Potential Effect (APE) at each project site was investigated by professional archeologists and an architectural historian who meet the Secretary of Interior's Standards for Archeology and Historic Preservation. Field investigations were completed by Buried Past Consulting, LLC between July and August 2024. Approximately 198 acres of the APE needs additional cultural resource investigation prior to project construction. The uninvestigated portion of the APE includes three borrow areas near Pierce totaling 90 acres, 26 acres in Pierce where landowners denied access to the cultural resource investigation, and 83 acres in Osmond where houses will be modified to reduce flood damage to the structures. NRCS has executed a Programmatic Agreement to allow for phased identification of historic properties within the uninvestigated portions of the APE. A copy of the programmatic agreement in included in Appendix E.

The full cultural resources inventory report is available on request from History Nebraska. A redacted version is provided in Appendix E. Archaeological site and historic building location information has been removed from the report per Section 304 of the National Historic Preservation Act and Nebraska Revised Statute 84-712.05 ([14] and [15]).