HOUSTON ENGINEERING INC.

Fargo, ND | HEI No. 1915-0241
September 30, 2019

# ENGINEER'S DESIGN REPORT – ADDENDUM #1

## Lower Otter Tail River Channel Restoration

BUFFALO-RED RIVER WATERSHED DISTRICT

CLEAN WATER LAND & LEGACY AMENDMENT

# ENGINEER'S DESIGN REPORT

## Addendum #1

## Lower Otter Tail River Channel Restoration

September 30, 2019

Fargo, ND

HOUSTON ENGINEERING INC.

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a <insert Registered Professional Engineer OR duly Licensed Engineer> under the laws of the State of <insert state>.

Erik L. Jones

Erik Jones
License No. 41161

9/30/2019

Date

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# 1 INTRODUCTION

In 2016, the Buffalo-Red River Watershed District (BRRWD) received grant funding for a comprehensive feasibility study to be completed for the Lower Otter Tail River. The principle objectives of the study were

**Objective 1:** Civic Engagement and Outreach
**Objective 2:** Channel Restoration Survey to establish the existing channel conditions
**Objective 3:** Channel Restoration and Sediment Reduction Engineering Design
**Objective 4:** Grant Administration/Reporting

An Engineer's Design Report (HEI, 2019) was completed in early 2019 that included detailed discussion on existing conditions, proposed alternatives for channel restoration, hydraulic modeling and project plans and cost estimates.

As part of the flood protection project certification process for the flood protection works completed in the cities of Breckenridge, MN and Wahpeton, ND, the United States Army Corp of Engineers (USACE) re-evaluated the effective flood insurance study (FIS) flow events and incorporated the additional years from 1971 through 2011, into the period of record. This resulted in larger peak discharges throughout the study reach for each of the recurrence events. After discussions with USACE, it was agreed upon to adopt the updated FIS 10-year peak discharge to analyze the restoration hydraulics.

The purpose of this addendum to the Engineer's Design Report for the Lower Otter Tail River Channel Restoration (HEI, 2019), is to present the updated restoration design and hydraulic modeling after incorporating the larger FIS 10-year peak discharge into the analysis. General background, existing conditions and additional information regarding project alternatives and design components can be found in the original Engineer's Design Report.

# 2 HYDRAULIC MODELING

Section 5 of the original design report discusses the development of the hydraulic models that were used to analyze existing and proposed conditions. Based on discussions with USACE, modifications were made to the 2D HEC-RAS model in order to more accurately represent velocities occurring within the channel. Additionally, the 2D models were updated to the most recent version of HEC-RAS, version 5.0.7.

## 2.1 DESIGN FLOWS

The 1953 USACE project utilized the 10-year event (10-percent annual chance) for project design which equated to a flow of approximately 1,625 cfs. Hydrology has significantly changed since the 1950's which has caused an increase in the 10-year peak discharge. USACE re-evaluated the effective FIS flow events using a period of record from 1942 through 2011. This resulted in a larger peak discharge throughout the study reach for each of the recurrence events as shown in **Table 1**.

*Table 1: Revised FIS Flows*

| Flooding Source and Location | Peak Discharges (cubic feet per second) | | | |
|---|---|---|---|---|
| | 10-Percent-Annual-Chance | 2-Percent-Annual-Chance | 1-Percent-Annual-Chance | 0.2-Percent-Annual-Chance |
| OTTER TAIL RIVER | | | | |
| At Otter Tail/Wilkin County Border | 2,450 | 3,800 | 4,450 | 6,200 |
| Upstream of Otter Tail River Diversion | 3,200 | 5,100 | 6,300 | 8,800 |

The restored meanders are designed to carry at least a bankfull discharge of 1,150 cfs, however in order to maintain flood damage reduction benefits, it was decided to adopt the new 10-year discharge of 2,450 cfs as the design flow for the flood protection. The 100-year event (4,450 cfs) was analyzed for impacts as well.

## 2.2 HYDRAULIC MODEL GEOMETRY

### 2.2.1 EXISTING CONDITIONS

After reviewing the original 2D model, USACE recommended using a smaller 2D mesh cell size within the channel in order to more accurately represent velocities. As mentioned in the original design report, a terrain surface DEM was created to include survey data from 2016 by burning the channel bathymetry into the existing terrain. A smaller cell size is necessary to capture the detail of the underlying channel bathymetry in the terrain. Gary Brunner from the Hydraulic Engineering Center recommends using 3 -10 cells to model river channels (Boyd, personal communication). Based on this guidance, a cell size of 20-ft was used in refinement regions that encompass the straightened reach and the proposed meanders. This led to approximately 5 - 6 cells per channel width depending on location. The perimeter of refinement regions acts as a breakline to prevent water from breaking out of the channel before reaching bankfull. Smaller cell size resulted in slightly higher velocities in the channel and therefore the manning's roughness coefficient (n) was increased to recalibrate the 2D mesh. The manning's n of the existing channel was increased from 0.02 to 0.023. The manning's n of open water (representing areas of water that are not within the existing river channel) was increased from 0.02 to 0.03 to better represent the increase in roughness due to vegetation in the disconnected historic oxbows for existing conditions. **Table 2** displays the manning's n values used for modeling.

*Table 2: Manning's "N" Values by NLCD 2011 Use Category*

| NLCD 2011 Land Use Category | Manning's n Value |
|---|---|
| Existing Channel | **0.023** |
| Proposed Oxbow Channels | **0.025** |
| Pasture/Hay | 0.08 |
| Woody Wetlands | 0.09 |
| Barren Land Rock/Sand/Clay | 0.05 |
| Cultivated Crops | 0.06 |
| Deciduous Forest | 0.1 |
| Developed, Low Intensity | 0.04 |
| Developed, Medium Intensity | 0.04 |
| Developed, Open Space | 0.04 |
| Emergent Herbaceous Wetland | 0.09 |
| Open Water | **0.03** |

The Full Momentum equations in HEC-RAS were chosen to solve for the flow moving over the 2D mesh. The computational time step can be related to cell size and velocity using the Courant number. Because the cell size decreased significantly in the channel, a smaller time step of 7.5 seconds was chosen to get numerically stable and accurate solutions.

There are two locations within the 2D mesh where bridges exist, County Road 169 and County Road 17. Due to limitations in 2D modeling, bridges cannot be modeled like they traditionally are in 1D modeling. The original model utilized large box culverts to represent these crossings. However, with a smaller cell size in the channel, the model could not converge on an accurate solution at these crossings using culverts. The geometry of the bridges at these locations does not cause significant contraction compared to the river channel and the 100-year event does not reach the low chord of the bridges. As seen in the 1D model, the bridges do not cause significant stage increase. The surveyed bridge cross sections from the 1D model were input into the 2D connection at these locations to model the crossings.

### 2.2.2 PROPOSED CONDITIONS

The changes made to the existing model were transferred to the proposed conditions model. Proposed conditions were modeled assuming all 7 of the alternatives would be implemented which includes 23 oxbows and overflow structures as well as setback levees. The manning's n of the proposed oxbow channels was increased from 0.02 to 0.025. The proposed oxbows are expected to have a higher roughness than the straightened reach.

# 3 RESTORATION DESIGN

## 3.1 RESTORATION GOALS

The goal of the project is to create an environment along the Lower Otter Tail River where stable and natural stream conditions can be reached, and natural geomorphic processes will allow the river to adjust to future changes in hydrology. Stable stream conditions are expected to carry benefits for water quality

and aquatic habitat while maintaining the flood damage reduction benefits of the 1953 USACE project (10-year level of protection).

## 3.2 STREAM GEOMETRY

Section 4.2 of the original design report describes in detail the proposed profile, dimension and pattern of the restoration design. Restoration profile and pattern remained unchanged to accommodate the larger 10-year design flow. Based on stream evolution principles and guidance from the Minnesota Department of Natural Resources (MNDNR), rivers are most resilient when they have sufficient cross-sectional area to convey bankfull flow but also have the ability to breakout into the floodplain above bankfull flow. This theory was used to approximate the dimensions of the restored oxbows. Preliminary design plans show a trapezoidal cross section, however final design will use an elliptical shape to emulate natural channel shape. Bankfull width and depth (width/depth ratio) of the elliptical cross section may be altered during final design to achieve stable morphology.

Ideally, water would be allowed to breakout into the floodplain above flows of 1,150 cfs, however in order to maintain 10-year flood reduction benefits and minimize impact to agricultural land, this restoration will provide additional conveyance within the existing straightened channel through the use of overflow structures as discussed in the next section. Overflows are not used until the bankfull discharge of 1,150 cfs is exceeded.

Significant stage increase was seen near alternative 5 as a result of using the revised 10-year hydrology. Cross sectional area modifications were made to oxbows 12-21 in an effort to reduce stage increase. By increasing cross-sectional area at these locations, depth above the USACE design profile was reduced to a maximum of 1ft. Further increase in cross-sectional area would have negative effects on the stability of the restored meanders geomorphology. Proposed bankfull cross-sectional area for each of the oxbows is shown below in **Table 3**.

***Table 3: Restoration Channel Dimension***

| Alternative | Project | Oxbow | Design Riffle Gradeline | Bankfull Area ($ft^2$) |
|---|---|---|---|---|
| 1 | Oxbows 26-27 Restoration | 27 | 0.01% | 501 |
| | | 26 | 0.01% | 501 |
| 2 | Oxbows 22-25 Restoration | 25 | 0.01% | 550 |
| | | 24 | 0.01% | 550 |
| | | 22 | 0.07% | 550 |
| 3 | Oxbows 19-21 Restoration | 21 | 0.02% | 501 |
| | | 20 | 0.04% | 501 |
| | | 19 | 0.06% | 501 |
| 4 | Oxbow 18 Restoration | 18 | 0.06% | 548 |
| 5 | Oxbows 12-17 Restoration | 17 | 0.01% | 677 |
| | | 16 | 0.01% | 677 |
| | | 15 | 0.01% | 677 |
| | | 14 | 0.01% | 677 |
| | | 13 | 0.01% | 677 |
| | | 12 | 0.01% | 677 |
| 6 | Oxbows 8-9 Restoration | 9 | 0.07% | 312 |

| | | | | |
|---|---|---|---|---|
| | | 8 | 0.07% | 312 |
| 7 | Oxbows 1-7 Restoration | 7 | 0.04% | 304 |
| | | 6 | 0.03% | 304 |
| | | 5 | 0.05% | 304 |
| | | 4 | 0.06% | 304 |
| | | 3 | 0.05% | 304 |
| | | 1 | 0.05% | 304 |

## 3.3 OVERFLOW STRUCTURES

Overflow structures are incorporated into the preliminary design downstream of each of the oxbow inlets at the main river channel. These overflow structures serve two purposes. The first is to ensure that the normal run of the river is redirected into the restored oxbow rather than through the straightened reach, even if the restored oxbow is at a higher grade line than the existing channel. The second purpose of the overflow structures is to alleviate upstream stage increases during large flood events. Through bank erosion and channel degradation the existing channel has a much higher carrying capacity than it was designed for in the 1950's. Restoration of the meanders increases the hydraulic profile in each of the alternative regions. At a minimum, bankfull discharge (approximately 1,150 cfs) must be directed through the restored meanders in order for the channel restoration to provide ecological benefits. This will establish stable stream conditions and allow natural geomorphic processes to occur. Therefore, the overflow structure heights were set at the approximate bankfull depth for each of the alternatives.

## 3.4 FLOODPLAIN RESTORATION AND MITIGATION MEASURES

Although the overflow structures provide additional flow capacity within the existing straightened channel, inundation still occurs in low areas during a 10-year flood. Reconnecting the river to its floodplain provides important ecological and water quality benefits. Allowing floodwaters to spill out of the channel banks during high flow will slow velocities and provide floodplain storage which strengthens the resiliency of the stream restoration. Additional mitigation measures such as setback levees and flowage easements were proposed in the original design report for the 100-year flood event and are discussed in Section 4.3.6 of the original report. The functionality of these mitigation measures extends to the 10-year flood. Protection was not considered for flooding that occurs on existing uncropped land such as wooded areas, wetlands, ditches and well-defined swales. By purchasing flowage easements along the river and constructing setback levees in some areas, the river will have access to its floodplain providing ecological benefits while maintaining flood damage reduction benefits.

# 4 RESULTS

## 4.1 CALIBRATION

Exhibit 1 shows the new calibration results of the 2D model compared to the surveyed water surface elevation on the day of surveying (approximated to be a flow of 713 cfs). The calibration profile is consistent with the accuracy of the 1D calibrated profile as well as the previous 2D calibrated profile. It was determined that a manning's roughness coefficient (n) of 0.023 would be used to represent the existing roughness of the straightened channel.

## 4.2 FIS 10-YEAR PEAK FLOW

Modifications to the restoration design were made to accommodate the larger 10-year design flow and maintain the same level of protection as the 1953 USACE project. These modifications are discussed in Section 3 of this report. There is approximately a 50% increase in flow from the original USACE design flow (1,625 cfs) to the current 10-year peak discharge. This causes an increase in flooding even with the modifications to the restoration design. Exhibit 2 compares the USACE 10-year water surface profile with the existing and proposed conditions water surface profiles. Results show that the proposed 10-year water surface profile is above the USACE 10-year water surface profile near alternatives 5 and 7. Exhibit 3 shows the inundation for the proposed 10-year flood compared to the 1950's inundation for a 10-year flood. Due to the drastic changes in dimension and profile of the river over the years, some areas experience worse flooding while others see an improvement from the 1950's.

Significant degradation and widening through erosion of the river channel have led to lower flood levels in this area of the Lower Otter Tail River. Flowage easements are the principal mitigation measure for the 10-year event and will be purchased in areas that experience an increase in flooding due to the restoration project. These flowage easements will help to reestablish a floodplain corridor along the river. Setback levees will be constructed in some areas to reduce inundation beyond the desired floodplain corridor. Although the setback levees are primarily used during a 100-year flood, they provide some functionality during the 10-year event as well. Exhibit 4 shows the proposed setback levee alignments and compares existing conditions 10-year inundation to proposed 10-year inundation.

## 4.3 FIS 100-YEAR PEAK FLOW

The 2017 100-year FIS peak flow was analyzed in the original design report in Section 5.3.2. A total of five setback levee alignments were proposed for the 100-year event to establish a floodplain corridor and prevent breakout flows from leaving the drainage area. The proposed mitigation for the 100-year event is unchanged from the original analysis. Exhibit 5 compares existing conditions 100-year inundation to proposed 100-year inundation for the 2017 FIS peak flows.

# 5 PROJECT PLANS AND COST ESTIMATES

Updated preliminary (feasibility level) restoration plans have been assembled and are included in this report as Appendix A. The plan set includes the restoration of all alternative oxbows (with modifications to oxbows 12-21) as well as the headcut stabilization upstream of the original USACE project. Adjoining cost estimates (less land and potential mitigation) have been broken down by alternative and are included as Exhibits 6-1 to 6-8. A summary of the estimated total project costs is shown in Table 4 below.

**Table 4: Summary of Estimated Alternative Costs**

| Alternative | Project Extent | Restoration Estimated Project Cost |
|---|---|---|
| 1 | Oxbows 26-27 | $ 1,620,489 |
| 2 | Oxbows 22-25 | $ 2,248,159 |
| 3 | Oxbows 19-21 | $ 3,094,771 |
| 4 | Oxbow 18 | $ 1,144,739 |
| 5 | Oxbows 12-17 | $ 5,238,669 |
| 6 | Oxbows 8-9 | $ 2,275,992 |
| 7 | Oxbows 1-7 | $ 4,155,926 |
| 8 | Headcut Stabilization | $ 568,140 |
| ***TOTAL RESTORATION COST:*** | | $ 20,346,884 |

Additional costs will be incurred with the inclusion of land requirements and mitigation measures. The project footprint is approximately 665 acres. Purchasing easements on this land would add an estimated $2.25 million to the Restoration Cost bringing the total to $22.6 million. This land cost is based on current County Estimated Market Value prices for land adjacent to the river. A breakdown of mitigation costs can be found in Exhibit 7. Mitigation costs have the potential to add up to $1.3 million to the Total Restoration Cost which would make a total estimated project cost of $23.9 million. Ultimately, the mitigation required could change or potentially be eliminated depending on design changes that occur during final restoration design. The mitigation easement cost is given as a lump sum cost in the detailed cost estimate but is fundamentally based on the current County Estimated Market Value price of the affected parcels. The final approach for determining the value and cost of acquired land may vary for each alternative based on landowner negotiations.

# 6 RECOMMENDATIONS / NEXT STEPS

The Lower Otter Tail River Restoration aims to reduce channel erosion to help achieve water quality standards and improve aquatic and wildlife habitat along the Otter Tail River. In order to fully implement the project, further work must be done to gather support from landowners and seek funding for construction. Next steps include:

Continue working with USACE to achieve the ecosystem restoration goals of Section 1135.

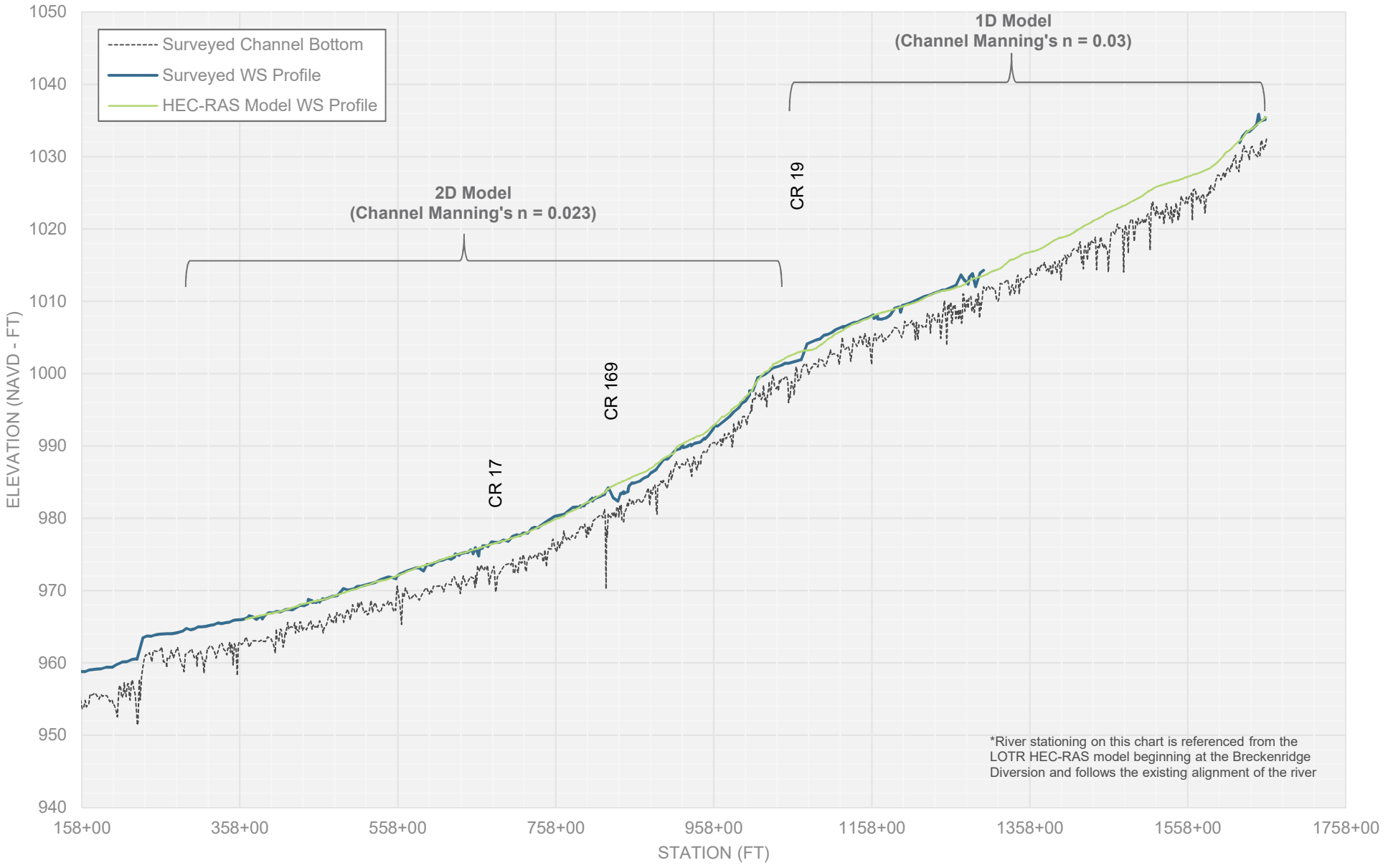
- Work with USACE and MNDNR to evaluate the use of the restoration of the Lower Otter Tail River as a mitigation site for the Fargo-Moorhead Flood Risk Management Project.
- Continue design refinement working with the MN DNR River Ecology Unit and USACE.
- Continue implementation of grade control structures to address tributary gully erosion delivering sediment to the Otter Tail River.
- Begin project Environmental Review and Permitting
- Continue to search for outside funding for implementation and construction. Possible funding sources include:
    - Federal EPA Section 319 Grant
    - MN Clean Water Fund
    - USACE Section 1135 Funding
    - Lessard-Sams Outdoor Heritage Council's Outdoor Heritage Fund Grant Program
- Buffalo-Red River Watershed will need to establish the channel restoration project as a Watershed project under Minnesota Statute Chapter 103D.
- Continue landowner outreach and education and address landowner concerns in final design. Landowner engagement will help to determine successful phasing of the project.

# 7 REFERENCES

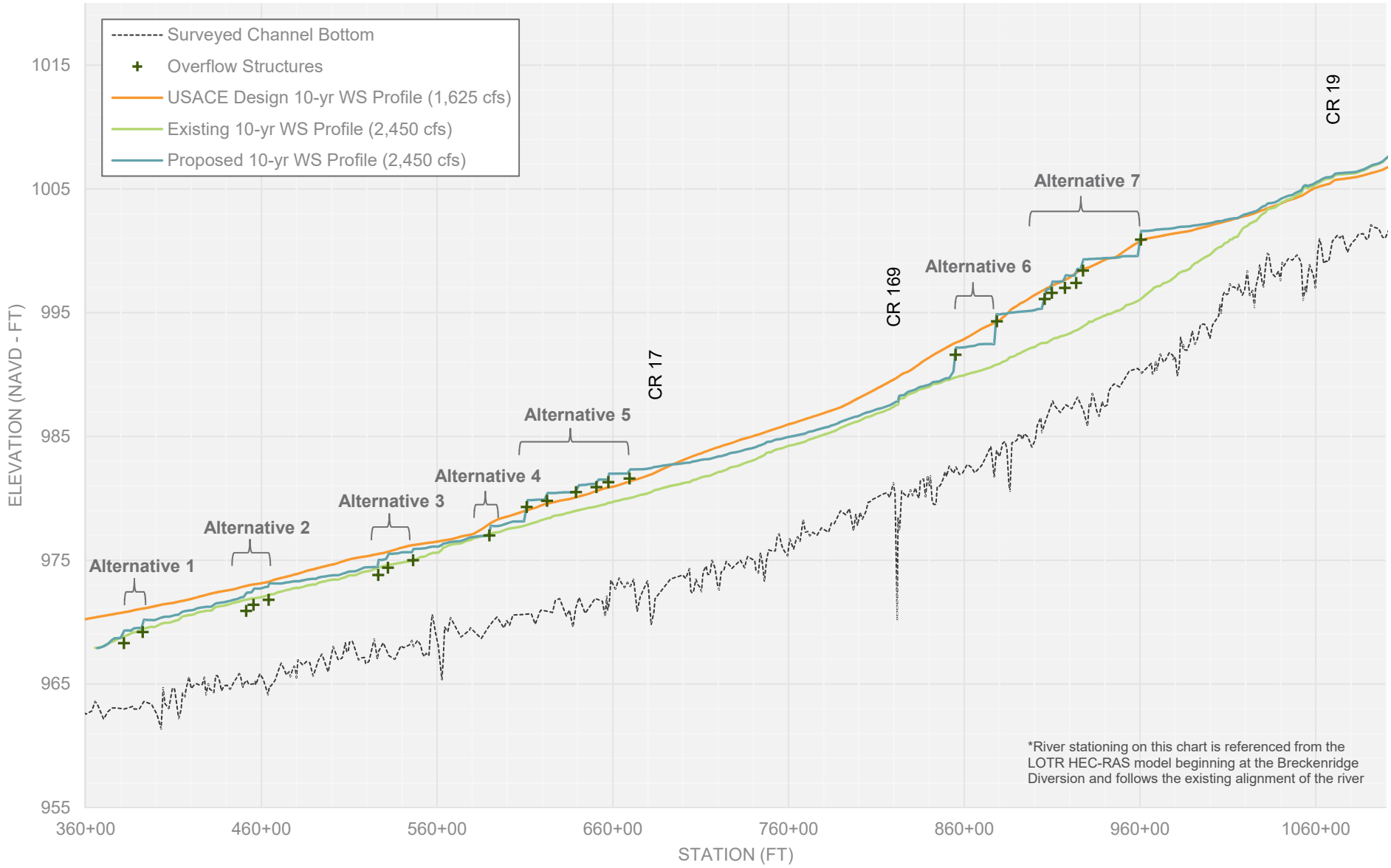
Houston Engineering, Inc. (January 2019). *Engineer's Design Report: Lower Otter Tail River Restoration.* Engineer's Design Report.

# EXHIBITS

# EXHIBIT 1: CALIBRATION PROFILES



# EXHIBIT 2: 10-YEAR DESIGN EVENT PROFILE COMPARISON



# Exhibit 3

# USACE Design Inundation vs. Proposed 10-year Inundation

N

CD 4

CD 2

CD 4A

CD 35-1

CD 35

CD 27

CD 8-A

CD 10-1

SD 17

CO-OP DITCH 1

CO-OP DITCH 1

COUNTY 14 ROAD

COUNTY 169 ROAD

COUNTY 162 ROAD

COUNTY 17 ROAD

COUNTY 160 ROAD

COUNTY 158 ROAD

COUNTY 159 ROAD

COUNTY 169 ROAD

COUNTY 9 ROAD

COUNTY 8 ROAD

Sunnyside Twp.

Foxhome Twp.

Brandrup Twp.

Bradford Twp.

7 8 9 12 13 14 15 16 17 18 19 20 21 22 23 24

25 26 27 28 29 30 31 32 33 34 35 36

1 2 3 4 5 6

County Ditches

Levee Ditch Alignment

Restored Oxbow

Setback Levee Alignment

10yr USACE Inundation

10yr Proposed Inundation

0 1.5 3 Miles

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# Exhibit 4

## Existing Conditions vs. Proposed Conditions 10-year Inundation

N

CD 2

CD 4A

CD 4

CD 35-1

CD 35

CD 27

CD 8-A

CD 10-1

SD 17

CO-OP DITCH 1

CO-OP DITCH 1

COUNTY 14 ROAD

COUNTY 169 ROAD

COUNTY 162 ROAD

COUNTY 17 ROAD

COUNTY 160 ROAD

COUNTY 158 ROAD

COUNTY 159 ROAD

COUNTY 169 ROAD

COUNTY 9 ROAD

COUNTY 8 ROAD

Sunnyside Twp.

Foxhome Twp.

Brandrup Twp.

Bradford Twp.

7 8 9

18 17 16 15 14 13

19 20 21 22 23 24

30 29 28 27 26 25

31 32 33 34 35 36

6 5 4 3 2 1

18 17 16 15

19 20 21 22

29 28 27

30 31 32 33 34

County Ditches

Levee Ditch Alignment

Restored Oxbow

Setback Levee Alignment

10yr Existing Inundation

10yr Proposed Inundation

0 1.5 3 Miles

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# Exhibit 5

# Existing Conditions vs. Proposed Conditions 100-year Inundation

N

Sunnyside Twp.

Foxhome Twp.

Brandrup Twp.

Bradford Twp.

CD 2

CD 4

CD 4A

CD 27

CD 35-1

CD 35

SD 17

CD 8-A

CD 10-1

CO-OP DITCH 1

COUNTY 14 ROAD

COUNTY 169 ROAD

COUNTY 162 ROAD

COUNTY 17 ROAD

COUNTY 160 ROAD

COUNTY 158 ROAD

COUNTY 159 ROAD

COUNTY 8 ROAD

- County Ditches
- Levee Ditch Alignment
- Restored Oxbow
- Setback Levee Alignment
- 100yr Existing Inundation
- 100yr Proposed Inundation

0 1.5 3 Miles

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**EXHIBIT 6-1 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNATIVE 1**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 92,287 | $ 5.00 | $ 461,437.04 |
| 2 | Embankment | CY | 261 | $ 5.00 | $ 1,305.63 |
| 3 | Toe-Wood Debris | CY | 2,487 | $ 25.00 | $ 62,182.17 |
| 4 | Sod Mat | SY | 1,492 | $ 12.00 | $ 17,908.46 |
| 5 | Random Riprap Class II | CY | 2501 | $ 80.00 | $ 200,088.89 |
| 6 | Random Riprap Class V | CY | 4,169 | $ 100.00 | $ 416,851.85 |
| 7 | Erosion Control | EA | 4 | $ 5,000.00 | $ 20,000.00 |
| 8 | Seeding and Mulching "Riparian Mix" | AC | 8.3 | $ 2,500.00 | $ 20,633.15 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 1,200,407.19 |
| Contingencies (20%) | | | | | $ 240,081.44 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 180,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 1,620,488.63 |

**Exhibit 6-2 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNATIVE 2**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 148,790 | $ 5.00 | $ 743,951.85 |
| 2 | Embankment | CY | 574 | $ 5.00 | $ 2,872.30 |
| 3 | Toe-Wood Debris | CY | 3,182 | $ 25.00 | $ 79,558.18 |
| 4 | Sod Mat | SY | 1,909 | $ 12.00 | $ 22,912.76 |
| 5 | Random Riprap Class II | CY | 3059 | $ 80.00 | $ 244,711.11 |
| 6 | Random Riprap Class V | CY | 5,098 | $ 100.00 | $ 509,814.81 |
| 7 | Erosion Control | EA | 6 | $ 5,000.00 | $ 30,000.00 |
| 8 | Seeding and Mulching "Riparian Mix" | AC | 12.5 | $ 2,500.00 | $ 31,311.29 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 1,665,132.31 |
| Contingencies (20%) | | | | | $ 333,026.46 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 250,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 2,248,158.77 |

**Exhibit 6-3 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNATIVE 3**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 198,487 | $ 5.00 | $ 992,437.04 |
| 2 | Embankment | CY | 1,495 | $ 5.00 | $ 7,474.82 |
| 3 | Toe-Wood Debris | CY | 4,134 | $ 25.00 | $ 103,338.50 |
| 4 | Sod Mat | SY | 2,480 | $ 12.00 | $ 29,761.49 |
| 5 | Random Riprap Class II | CY | 4335 | $ 80.00 | $ 346,800.00 |
| 6 | Random Riprap Class V | CY | 7,225 | $ 100.00 | $ 722,500.00 |
| 7 | Rock Weir (36" to 72" Diameter Boulders) | L.F. | 338 | $ 50.00 | $ 16,900.00 |
| 8 | Erosion Control | EA | 6 | $ 5,000.00 | $ 30,000.00 |
| 9 | Seeding and Mulching "Riparian Mix" | AC | 17.2 | $ 2,500.00 | $ 43,097.11 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 2,292,308.95 |
| Contingencies (20%) | | | | | $ 458,461.79 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 344,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 3,094,770.74 |

**Exhibit 6-4 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNATIVE 4**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 56,700 | $ 5.00 | $ 283,500.00 |
| 2 | Embankment | CY | 974 | $ 5.00 | $ 4,868.34 |
| 3 | Toe-Wood Debris | CY | 1,874 | $ 25.00 | $ 46,854.31 |
| 4 | Sod Mat | SY | 1,125 | $ 12.00 | $ 13,494.04 |
| 5 | Random Riprap Class II | CY | 1856 | $ 80.00 | $ 148,488.89 |
| 6 | Random Riprap Class V | CY | 3,094 | $ 100.00 | $ 309,351.85 |
| 7 | Rock Weir (36" to 72" Diameter Boulders) | L.F. | 338 | $ 50.00 | $ 16,900.00 |
| 8 | Erosion Control | EA | 2 | $ 5,000.00 | $ 10,000.00 |
| 9 | Seeding and Mulching "Riparian Mix" | AC | 5.9 | $ 2,500.00 | $ 14,658.63 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 848,116.06 |
| Contingencies (20%) | | | | | $ 169,623.21 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 127,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 1,144,739.27 |

**EXHIBIT 6-5 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNATIVE 5**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 259,512 | $ 5.00 | $ 1,297,559.26 |
| 2 | Embankment | CY | 5,074 | $ 5.00 | $ 25,372.28 |
| 3 | Toe-Wood Debris | CY | 6,110 | $ 25.00 | $ 152,750.61 |
| 4 | Sod Mat | SY | 3,666 | $ 12.00 | $ 43,992.18 |
| 5 | Random Riprap Class II | CY | 8,843 | $ 80.00 | $ 707,422.22 |
| 6 | Random Riprap Class V | CY | 14,738 | $ 100.00 | $ 1,473,796.30 |
| 7 | Rock Weir (36" to 72" Diameter Boulders) | L.F. | 845 | $ 50.00 | $ 42,250.00 |
| 8 | Erosion Control | EA | 12 | $ 5,000.00 | $ 60,000.00 |
| 9 | Seeding and Mulching "Riparian Mix" | AC | 31.0 | $ 2,500.00 | $ 77,414.60 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 3,880,557.45 |
| Contingencies (20%) | | | | | $ 776,111.49 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 582,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 5,238,668.93 |

**EXHIBIT 6-6 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNATIVE 6**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 19,941 | $ 5.00 | $ 99,707.41 |
| 2 | Embankment | CY | 2,424 | $ 5.00 | $ 12,119.00 |
| 3 | Toe-Wood Debris | CY | 2,114 | $ 25.00 | $ 52,852.35 |
| 4 | Sod Mat | SY | 1,268 | $ 12.00 | $ 15,221.48 |
| 5 | Random Riprap Class II | CY | 5,552 | $ 80.00 | $ 444,133.33 |
| 6 | Random Riprap Class V | CY | 9,253 | $ 100.00 | $ 925,277.78 |
| 7 | Rock Weir (36" to 72" Diameter Boulders) | L.F. | 1,950 | $ 50.00 | $ 97,500.00 |
| 8 | Erosion Control | EA | 4 | $ 5,000.00 | $ 20,000.00 |
| 9 | Seeding and Mulching "Riparian Mix" | AC | 7.6 | $ 2,500.00 | $ 19,015.38 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 1,685,826.72 |
| Contingencies (20%) | | | | | $ 337,165.34 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 253,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 2,275,992.07 |

**EXHIBIT 6-7 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - ALTERNTIVE 7**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 93,377 | $ 5.00 | $ 466,885.19 |
| 2 | Embankment | CY | 6,363 | $ 5.00 | $ 31,812.97 |
| 3 | Toe-Wood Debris | CY | 6,489 | $ 25.00 | $ 162,226.10 |
| 4 | Sod Mat | SY | 3,893 | $ 12.00 | $ 46,721.12 |
| 5 | Random Riprap Class II | CY | 8809 | $ 80.00 | $ 704,755.56 |
| 6 | Random Riprap Class V | CY | 14,682 | $ 100.00 | $ 1,468,240.74 |
| 7 | Rock Weir (36" to 72" Diameter Boulders) | L.F. | 1,482 | $ 50.00 | $ 74,100.00 |
| 8 | Erosion Control | EA | 12 | $ 5,000.00 | $ 60,000.00 |
| 9 | Seeding and Mulching "Riparian Mix" | AC | 25.4 | $ 2,500.00 | $ 63,530.07 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 3,078,271.74 |
| Contingencies (20%) | | | | | $ 615,654.35 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 462,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 4,155,926.08 |

**Exhibit 6-8 PRELIMINARY OPINION OF PROBABLE COST**
**LOWER OTTER TAIL RIVER - GRADE CONTROL STRUCTURE (SEC 27, FOXHOME TWP)**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Excavation | CY | 2,222 | $ 5.00 | $ 11,111.11 |
| 2 | Embankment | CY | 148 | $ 5.00 | $ 742.22 |
| 3 | Riprap Class II | CY | 1,444 | $ 80.00 | $ 115,555.56 |
| 4 | Riprap Class V | CY | 2,407 | $ 100.00 | $ 240,740.74 |
| 5 | Rock Weir (36" to 72" Diameter Boulders) | L.F. | 950 | $ 50.00 | $ 47,500.00 |
| 6 | Erosion Control | LS | 1 | $ 5,000.00 | $ 5,000.00 |
| 7 | Seeding | AC | 0.2 | $ 1,500.00 | $ 300.00 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 420,949.63 |
| Contingencies (20%) | | | | | $ 84,189.93 |
| Engineering (Final Design, Construction Staking and Admin.) | | | | | $ 63,000.00 |
| TOTAL PROJECT COSTS | | | | | $ 568,139.56 |

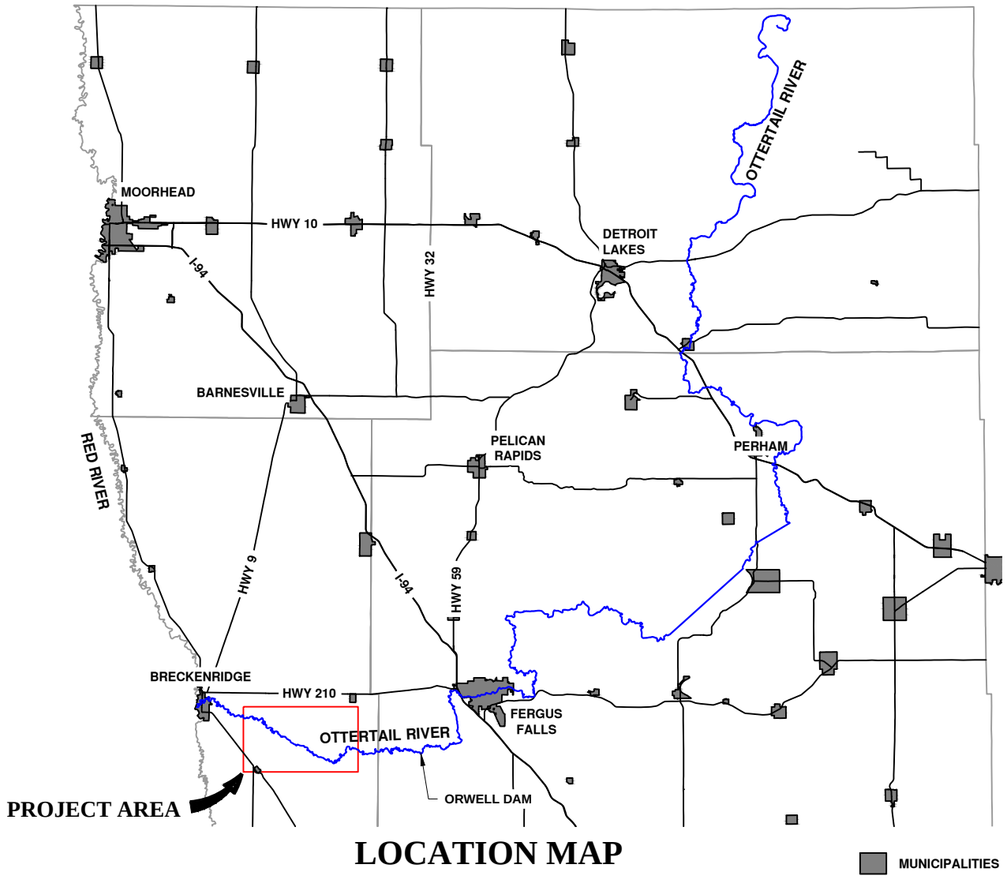
**EXHIBIT 7 PRELIMINARY OPINION OF PROBABLE COST**
**MITIGATION COSTS FOR LOWER OTTER TAIL RIVER RESTORATION**
**Buffalo-Red River Watershed District**
**HEI Proj. No. 1915-241**
**September 25, 2019**

| No. | Item | Unit | Quantity | Unit Price | Total Costs |
|---|---|---|---|---|---|
| 1 | Impervious Fill | CY | 55,438 | $ 5.00 | $ 277,188 |
| 2 | Ditch Earthwork | CY | 2,093 | $ 5.00 | $ 10,466 |
| 3 | Salvage & Replace Base Course Aggregate | CY | 170 | $ 20.00 | $ 3,394 |
| 4 | Base Course Aggregate | CY | 161 | $ 50.00 | $ 8,056 |
| 4 | 24" Corrugated Metal Pipe (CMP) | LF | 160 | $ 55.00 | $ 8,800 |
| 5 | 24" Steel Flap Gate | EA | 4 | $ 480.00 | $ 1,920 |
| 6 | Setback Levee Easement | AC | 32 | $ 5,500.00 | $ 176,000 |
| 7 | Flowage Easement | LS | 1 | $ 490,000.00 | $ 490,000 |
| 8 | Erosion Control | LS | 1 | $ 5,000.00 | $ 5,000 |
| 9 | Seeding and Mulching "Riparian Mix" | AC | 32 | $ 2,500.00 | $ 80,000 |
| TOTAL CONSTRUCTION COSTS | | | | | $ 1,060,824 |
| Contingencies (20%) | | | | | $ 212,165 |
| TOTAL PROJECT COSTS | | | | | $ 1,272,990 |

# APPENDIX A

# FEASIBILITY STUDY PLANS FOR

# LOWER OTTERTAIL RIVER RESTORATION
# BUFFALO - RED RIVER WATERSHED DISTRICT
# WILKIN COUNTY, MINNESOTA
# 2019




## LOCATION MAP

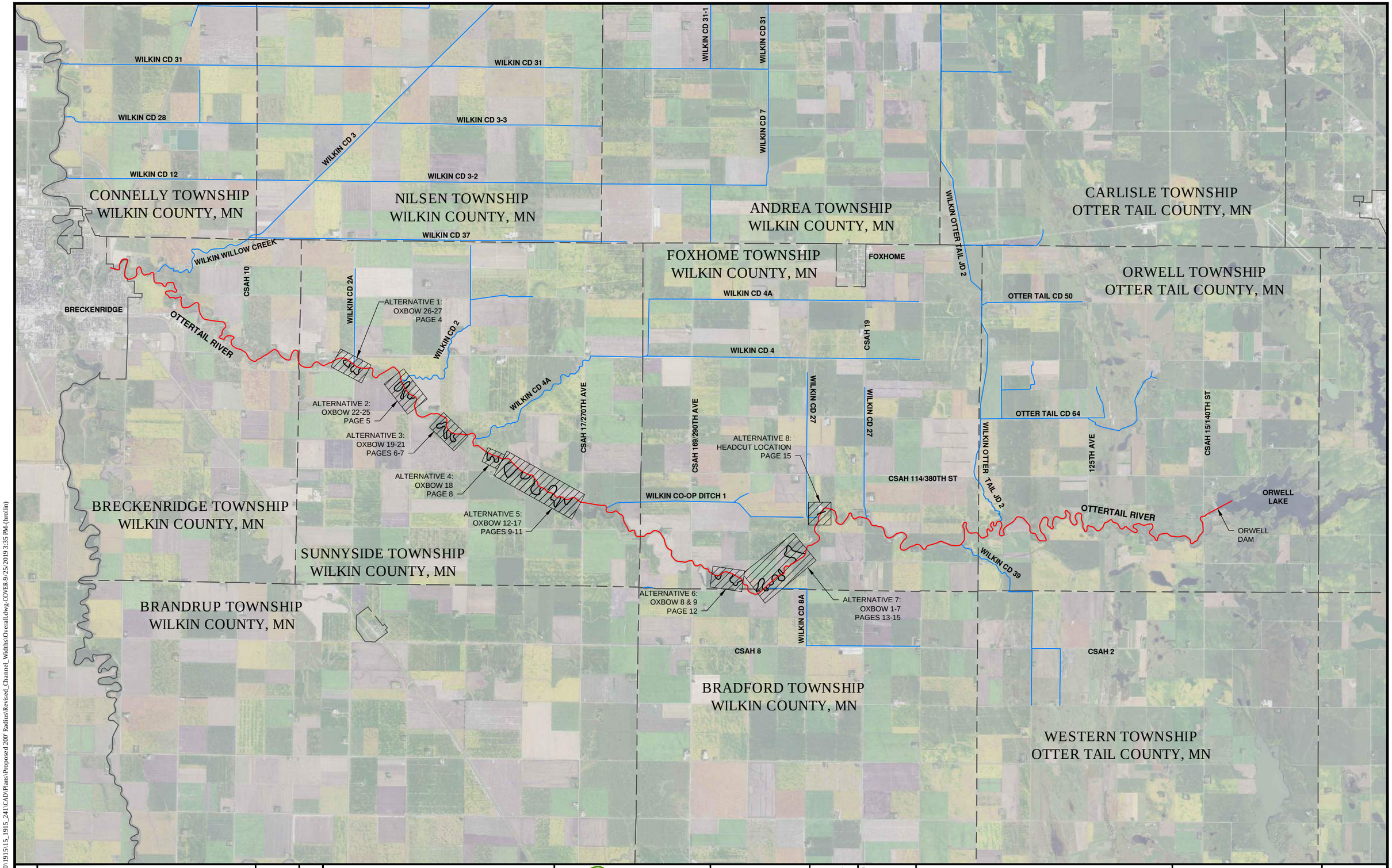

## PROJECT VICINITY MAP

Not to Scale

***SHEET INDEX:***

| SHEET NO | DESCRIPTION |
|---|---|
| 1 | LOCATION AND VICINITY MAPS |
| 2 | INDEX MAP |
| 3 | LEGEND AND NOTES |
| 4 | OXBOWS 26-27 PLAN AND PROFILE |
| 5 | OXBOWS 22-25 PLAN AND PROFILE |
| 6-7 | OXBOWS 19-21 PLAN AND PROFILE |
| 8 | OXBOW 18 PLAN AND PROFILE |
| 9-11 | OXBOWS 12-17 PLAN AND PROFILE |
| 12 | OXBOWS 8-9 PLAN AND PROFILE |
| 13-15 | OXBOWS 1-7 PLAN AND PROFILE |
| 16 | HEADCUT PLAN AND PROFILE |
| 17 | RIFFLE DETAIL |
| 18 | OVERFLOW STRUCTURE DETAIL |
| 19 | GRADE CONTROL STURCUTRE DETAIL |
| 20 | TOE-WOOD DETAIL |
| 21 | OXBOWS 26-27 CROSS SECTIONS |
| 22 | OXBOWS 22-25 CROSS SECTIONS |
| 23-24 | OXBOWS 19-21 CROSS SECTIONS |
| 25 | OXBOW 18 CROSS SECTIONS |
| 26 | OXBOWS 12-17 CROSS SECTIONS |
| 27 | OXBOWS 8-9 CROSS SECTIONS |
| 28-30 | OXBOWS 1-7 CROSS SECTIONS |
| 31 | HEADCUT CROSS SECTIONS |


PREPARED BY: Houston Engineering Inc. FARGO, NORTH DAKOTA

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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

INDEX MAP

PROJECT NO. 1915-241

SHEET
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## GENERAL NOTES:

1. ADD NOTES AS NEEDED.

LEGEND

EXISTING CHANNEL ALIGNMENT

PROPOSED OXBOW ALIGNMENT

EXISTING PROFILE

PROPOSED RESTORATION PROFILE

TOE-WOOD LOCATIONS

SEDIMENT TEST PIT DEPTH

ROCK RIFFLES

OVERFLOW STRUCTURES

GRADE CONTROL BOULDER WEIRS

SETBACK LEVEE ALIGNMENT

SETBACK LEVEE DITCH ALIGNMENT

VERTICAL CONTROL DATUM
NAVD 88

HORIZONTAL CONTROL SYSTEM
MINNESOTA STATE PLANE - NORTH ZONE
NAD 83, US SURVEY FEET

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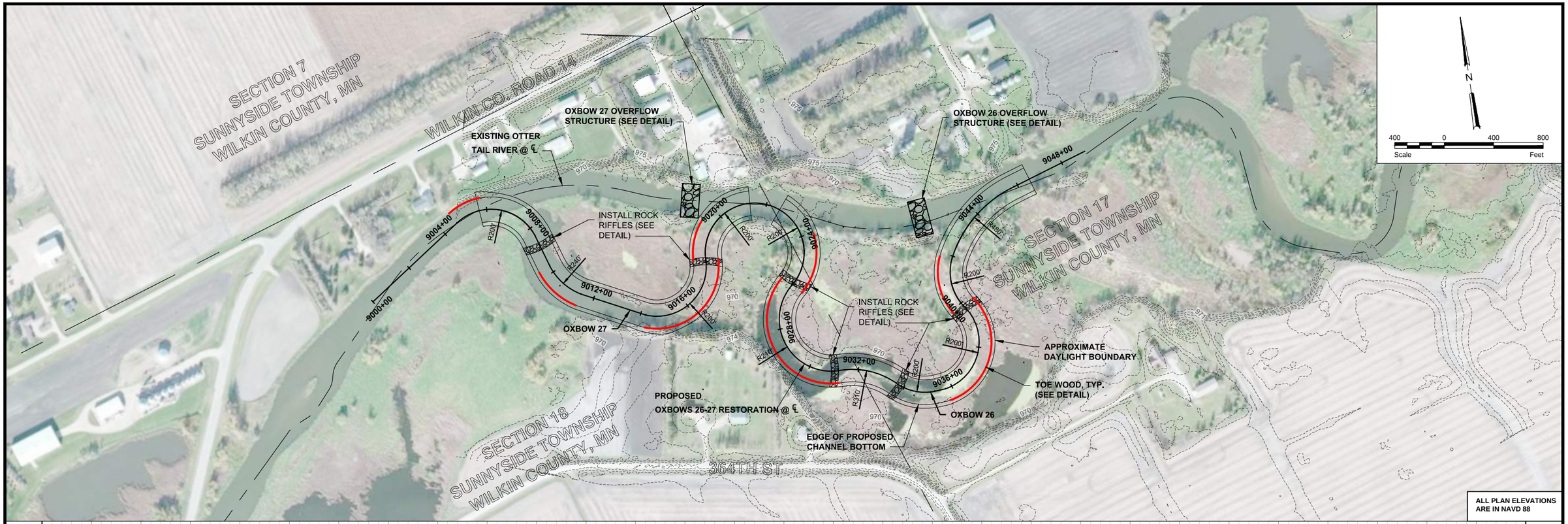
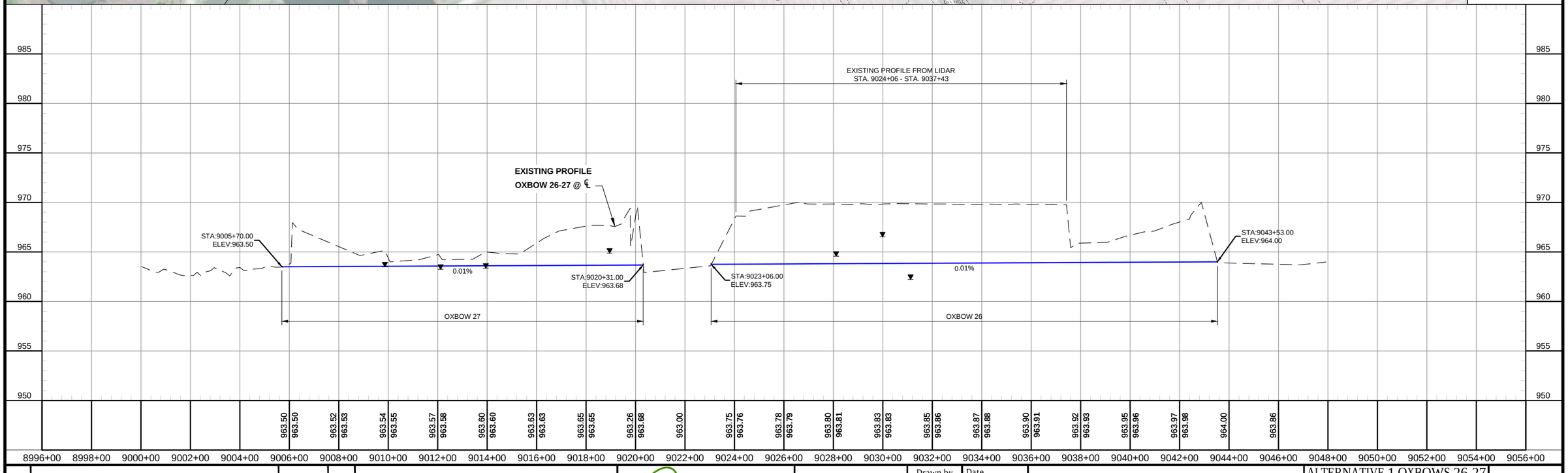
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

LEGEND AND NOTES

PROJECT NO. 1915-241

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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 1 OXBOWS 26-27
PLAN & PROFILE

PROJECT NO. 1915-241

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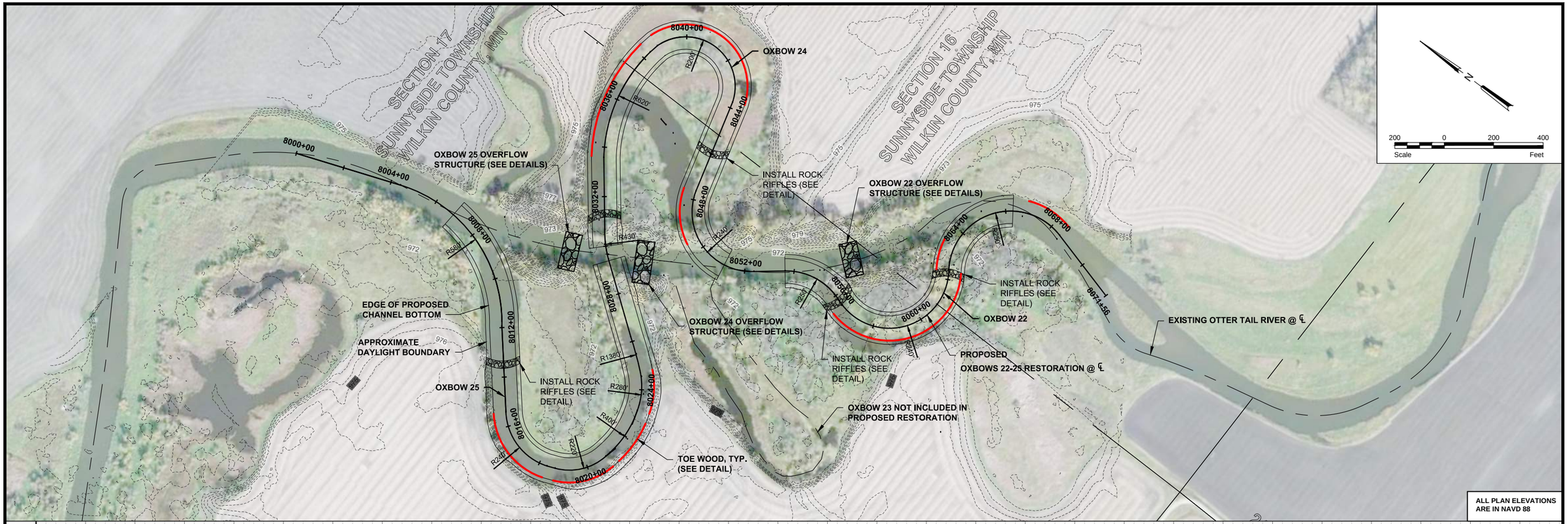


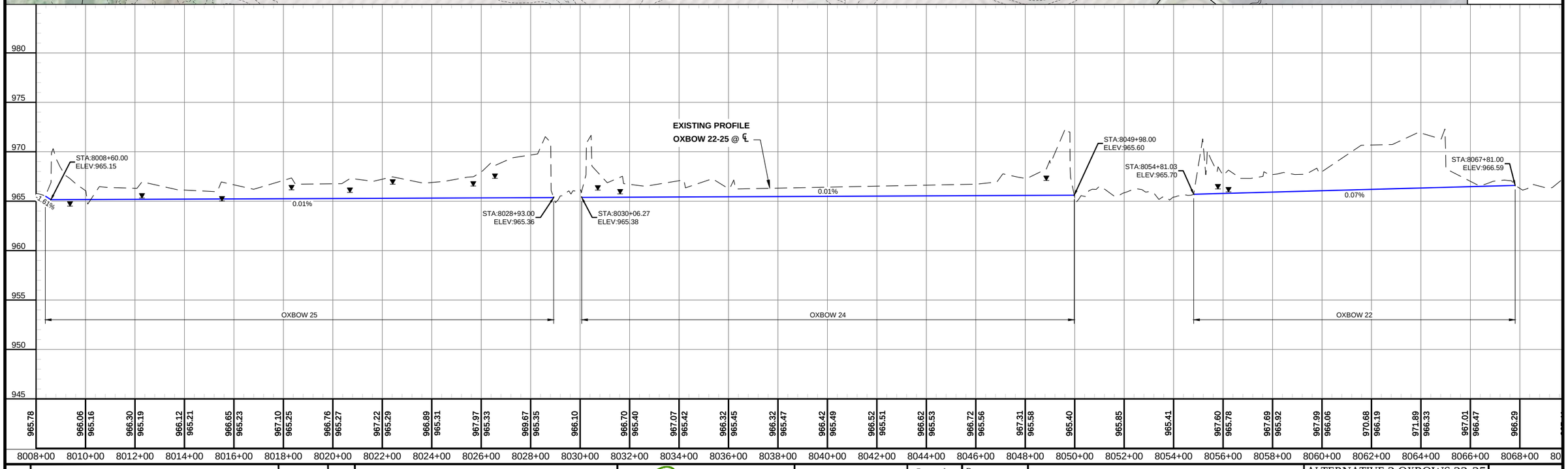


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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 2 OXBOWS 22-25
PLAN & PROFILE

PROJECT NO. 1915-241

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SECTION 16
SUNNYSIDE TOWNSHIP
WILKIN COUNTY, MN

SECTION 21
SUNNYSIDE TOWNSHIP
WILKIN COUNTY, MN

7000+00
7004+00
EXISTING OTTER TAIL RIVER @ ℄
R200'
INSTALL ROCK RIFFLES (SEE DETAIL)
R300'
7008+00
R230'
APPROXIMATE DAYLIGHT BOUNDARY
7012+00
EDGE OF PROPOSED CHANNEL BOTTOM
R310'
7016+00
R200'
R280'
7020+00
7024+00
R145'
7028+00
R190'
7032+00
R380'
INSTALL ROCK RIFFLES (SEE DETAIL)
OXBOW 21
7036+00
R145'
7040+00
7044+00
OXBOW 20 OVERFLOW STRUCTURE (SEE DETAILS)
OXBOW 21 OVERFLOW STRUCTURE (SEE DETAILS)
7048+00
R200'
R310'
R270'
7052+00
R570'
7056+00
R660'
7060+00
R220'
INSTALL ROCK RIFFLES (SEE DETAIL)
7064+00
R140'
OXBOW 20
TOE WOOD, TYP. (SEE DETAIL)
7068+00
R160'
7072+00
OXBOW 19 GRADE CONTROL
INSTALL ROCK RIFFLES (SEE DETAIL)
PROPOSED OXBOWS 19-21 RESTORATION @ ℄
OXBOW 19
7076+00
R250'
R200'
7080+00
R200'
7084+00
R300'
INSTALL ROCK RIFFLES (SEE DETAIL)
OXBOW 19 OVERFLOW STRUCTURE (SEE DETAILS)
R200'

N

200 0 200 400
Scale Feet

ALL PLAN ELEVATIONS ARE IN NAVD 88

EXISTING PROFILE FROM LIDAR
STA. 7038+45 - STA. 7042+40

EXISTING PROFILE FROM LIDAR
STA. 7042+77 - STA. 7046+49

EXISTING PROFILE
OXBOW 19-21 @ ℄

STA:7003+52.00
ELEV:967.30

0.02%

STA:7046+62.00
ELEV:968.00

STA:7048+97.25
ELEV:968.22

0.04%

0.05%

OXBOW 21

OXBOW 20

985 980 975 970 965 960 955 950

| 7000+00 | 7002+00 | 7004+00 | 7006+00 | 7008+00 | 7010+00 | 7012+00 | 7014+00 | 7016+00 | 7018+00 | 7020+00 | 7022+00 | 7024+00 | 7026+00 | 7028+00 | 7030+00 | 7032+00 | 7034+00 | 7036+00 | 7038+00 | 7040+00 | 7042+00 | 7044+00 | 7046+00 | 7048+00 | 7050+00 | 7052+00 | 7054+00 | 7056+00 | 7058+00 | 7060+00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 3 OXBOWS 19-21
PLAN & PROFILE

PROJECT NO. 1915-241

SHEET
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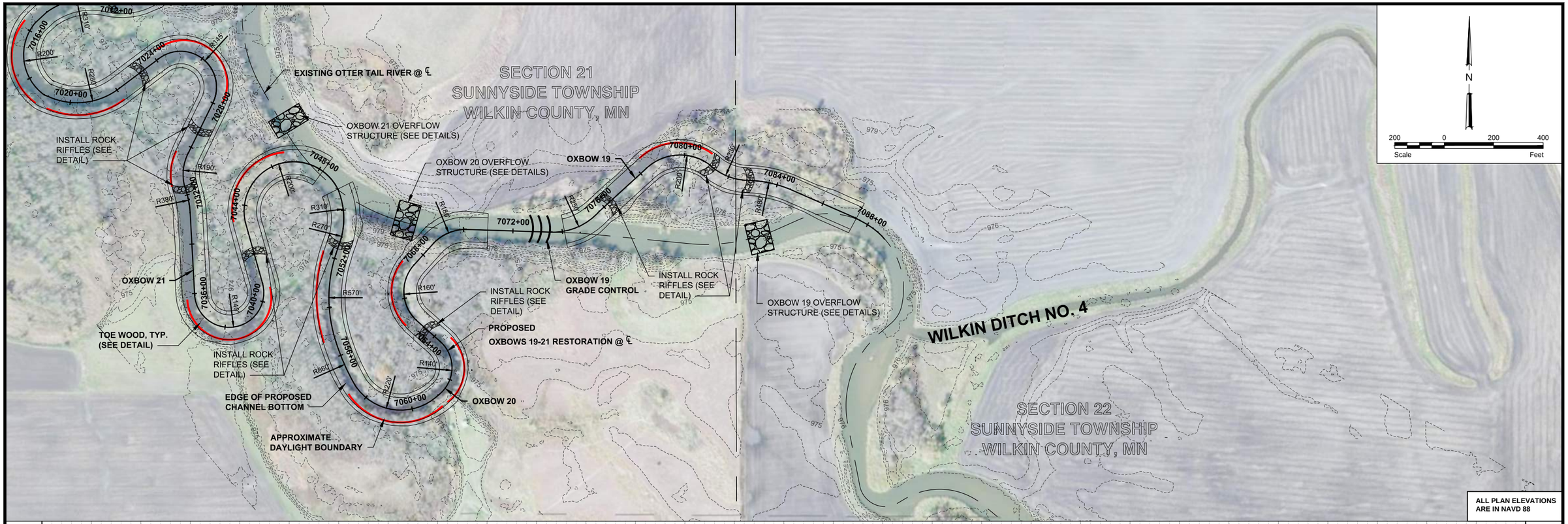


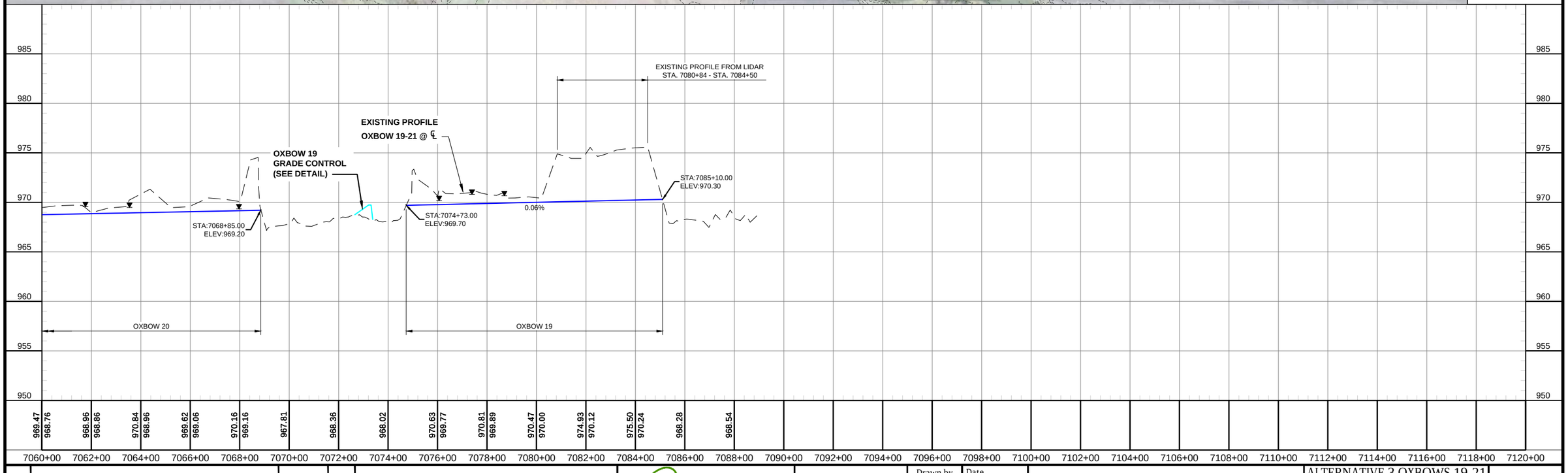


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BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 3 OXBOWS 19-21
PLAN & PROFILE

PROJECT NO. 1915-241

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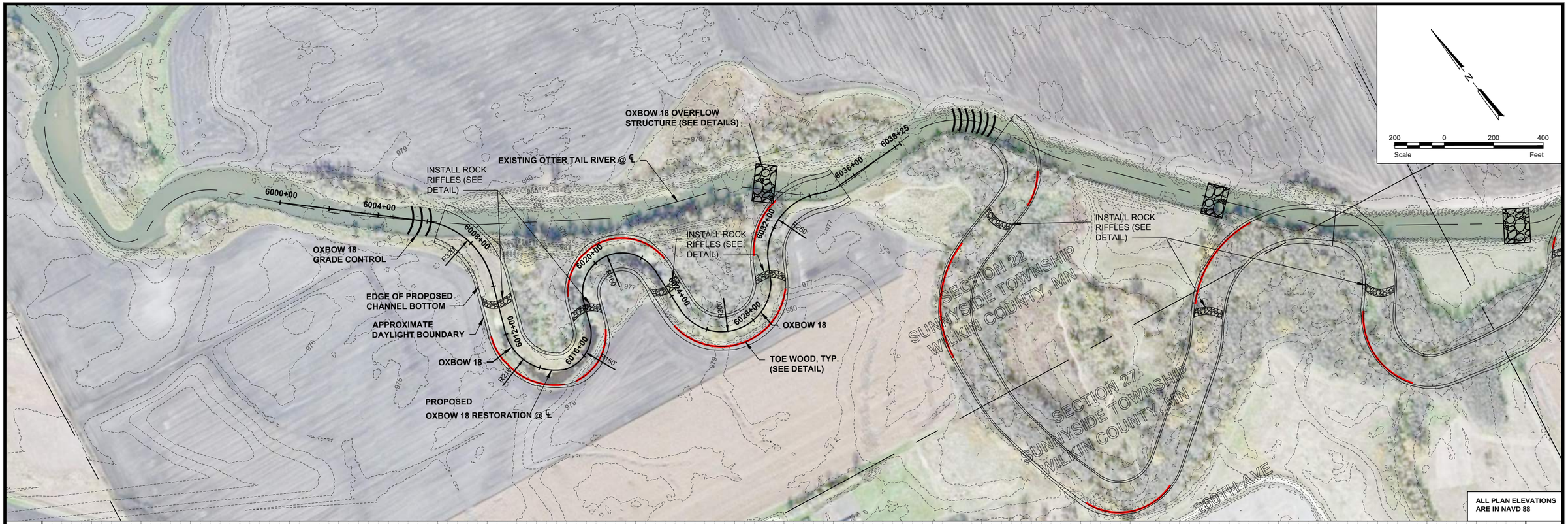


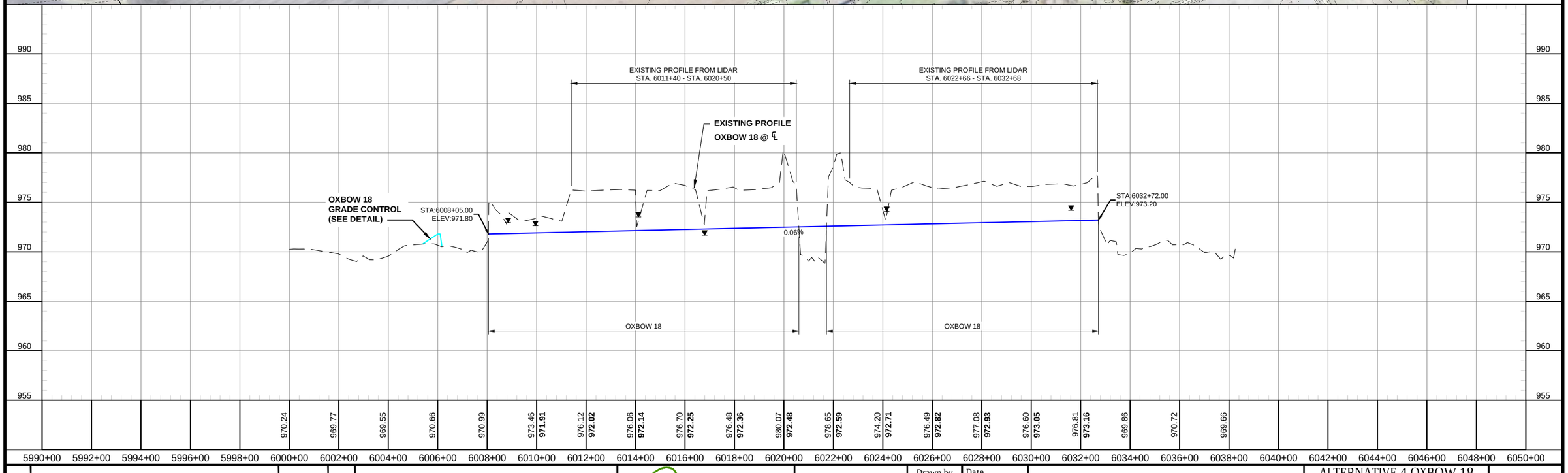


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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 4 OXBOW 18
PLAN & PROFILE

PROJECT NO. 1915-241

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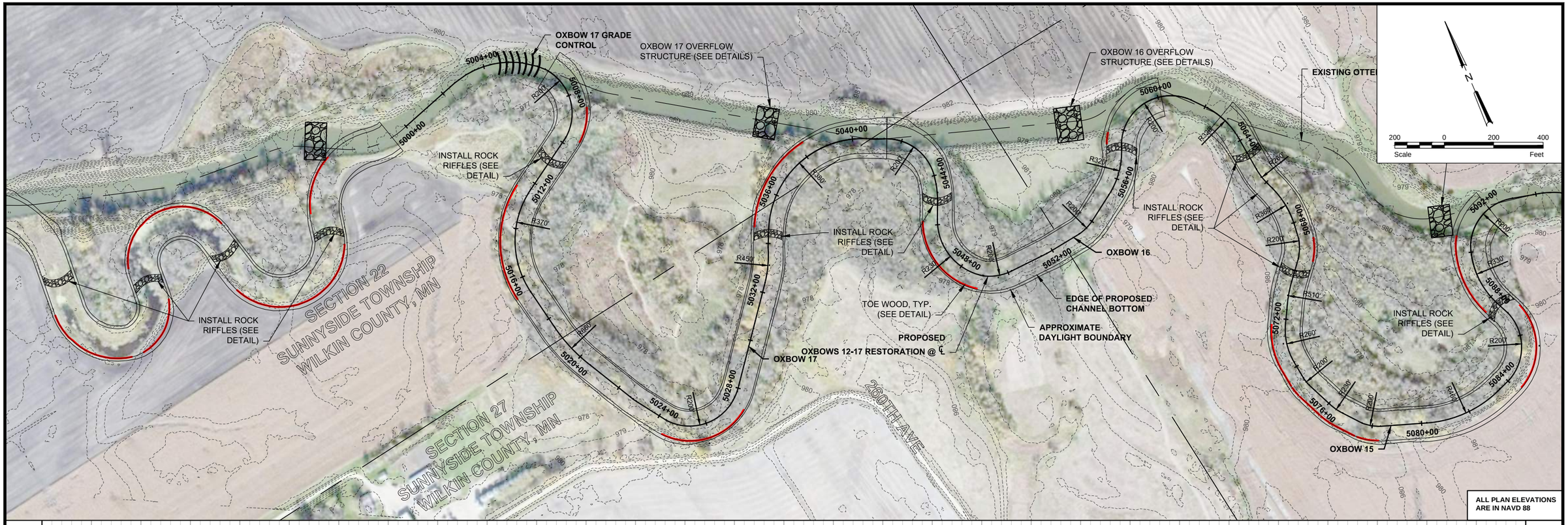


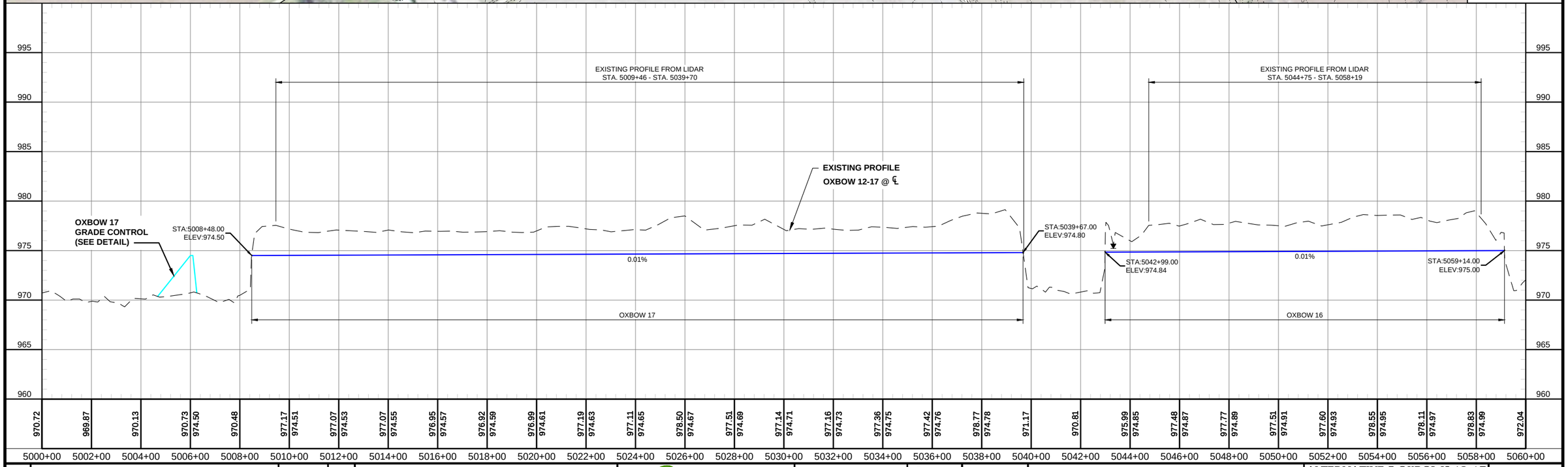


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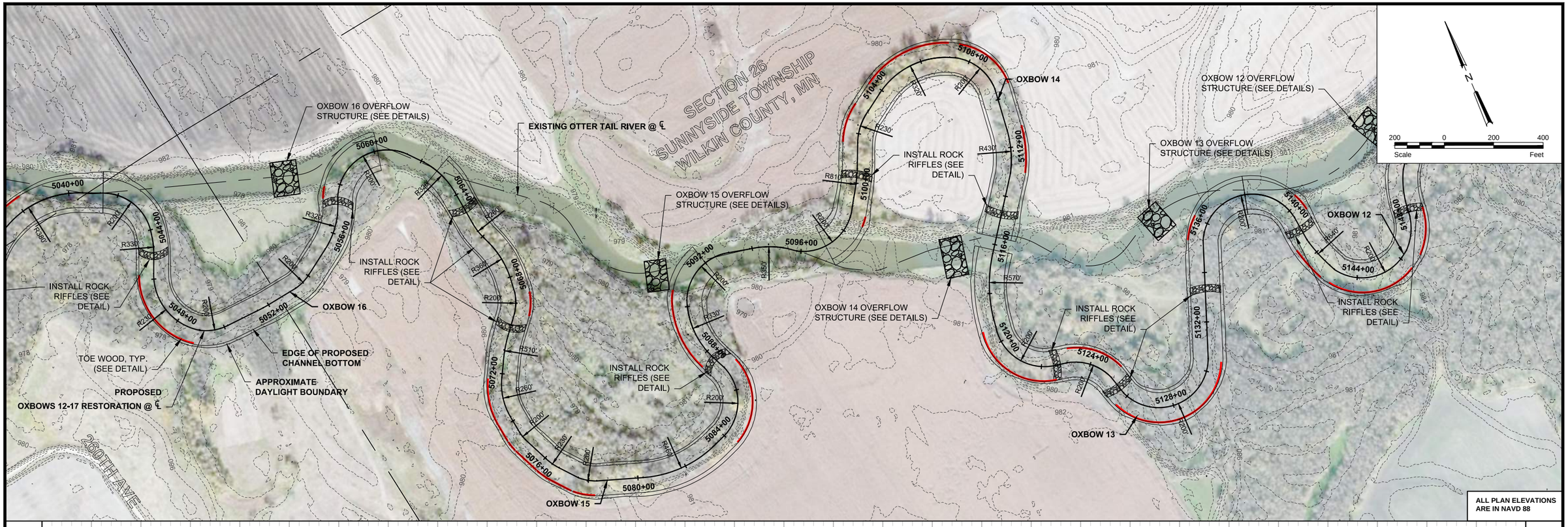
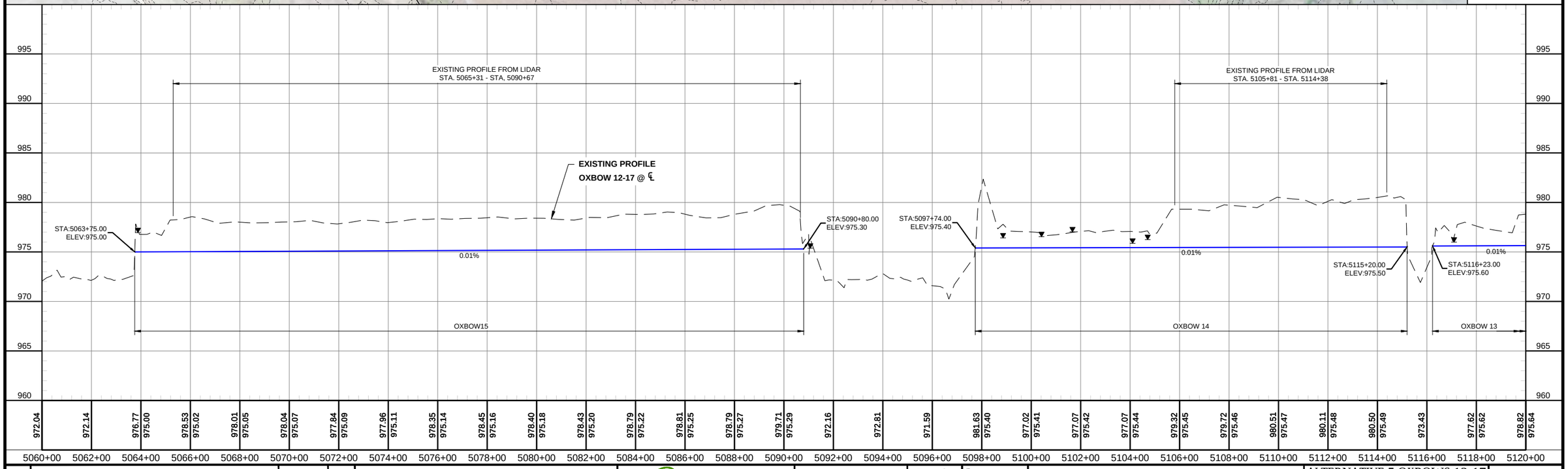
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 5 OXBOWS 12-17
PLAN & PROFILE

PROJECT NO. 1915-241

SHEET 9 of 33

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BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 5 OXBOWS 12-17
PLAN & PROFILE

PROJECT NO. 1915-241

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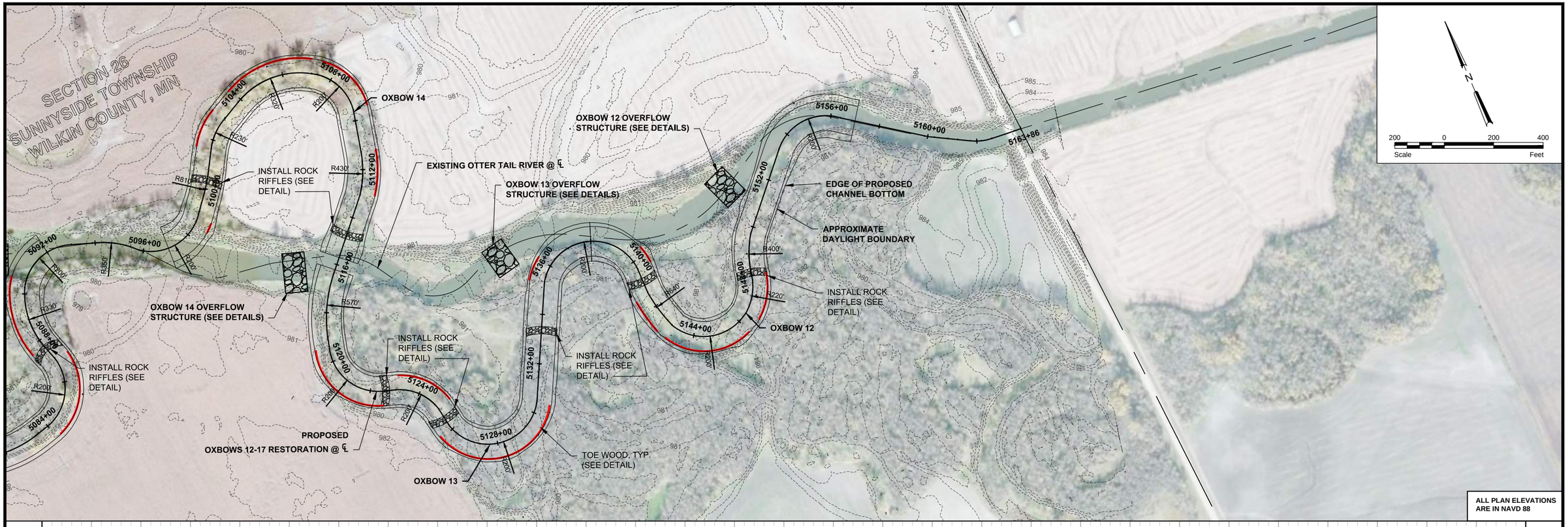


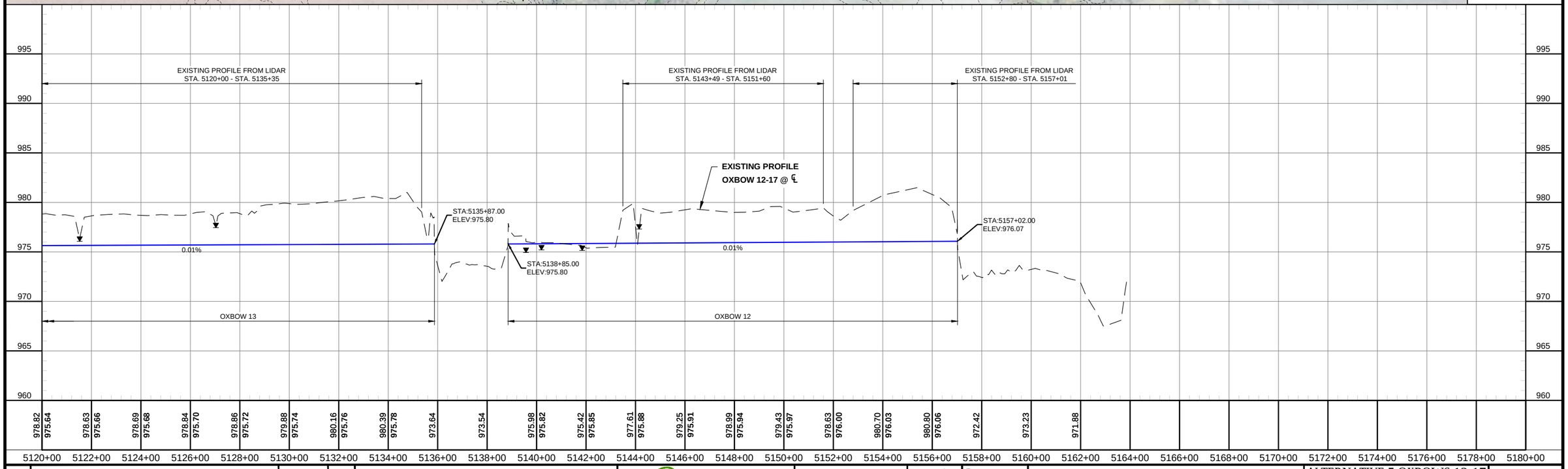


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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 5 OXBOWS 12-17
PLAN & PROFILE

PROJECT NO. 1915-241

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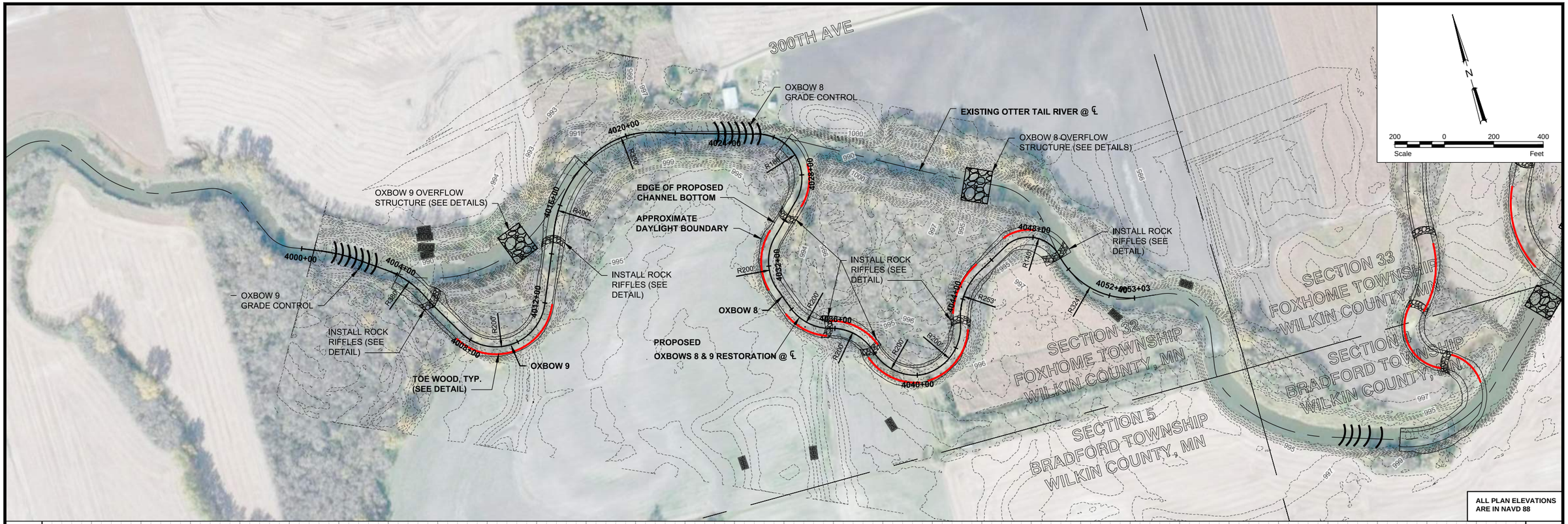


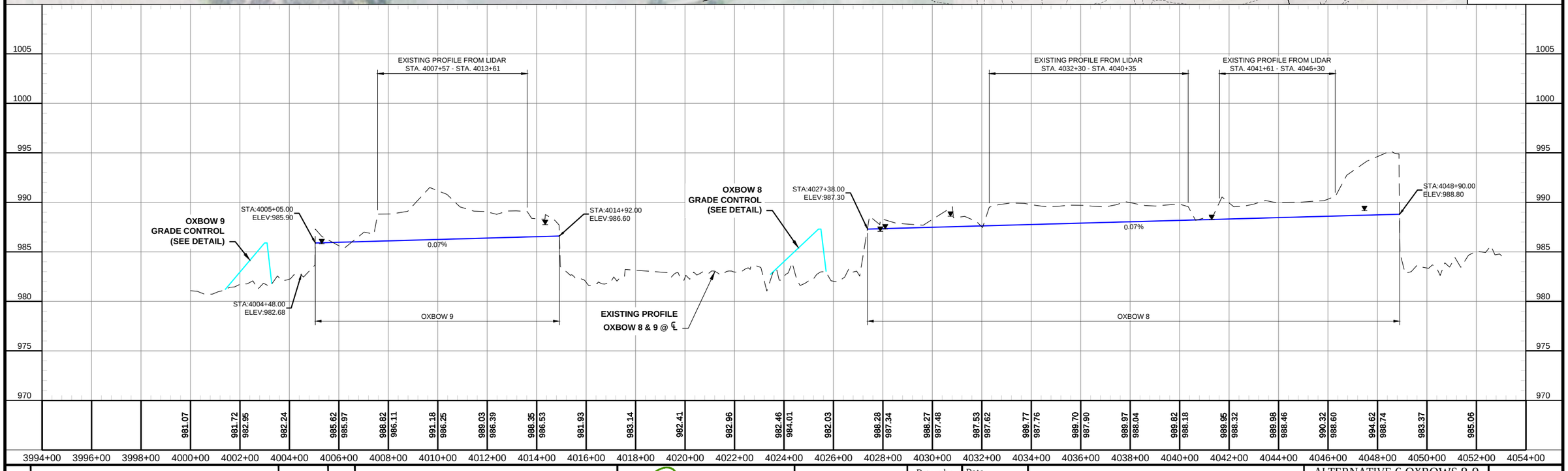


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BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 6 OXBOWS 8-9
PLAN & PROFILE

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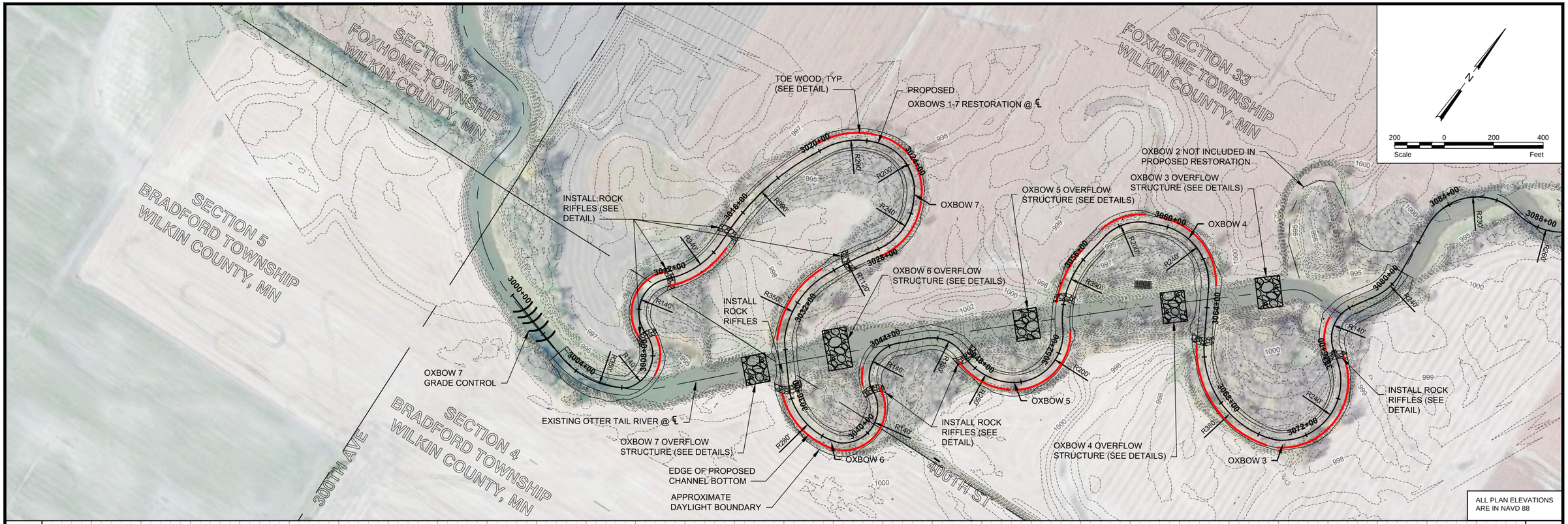


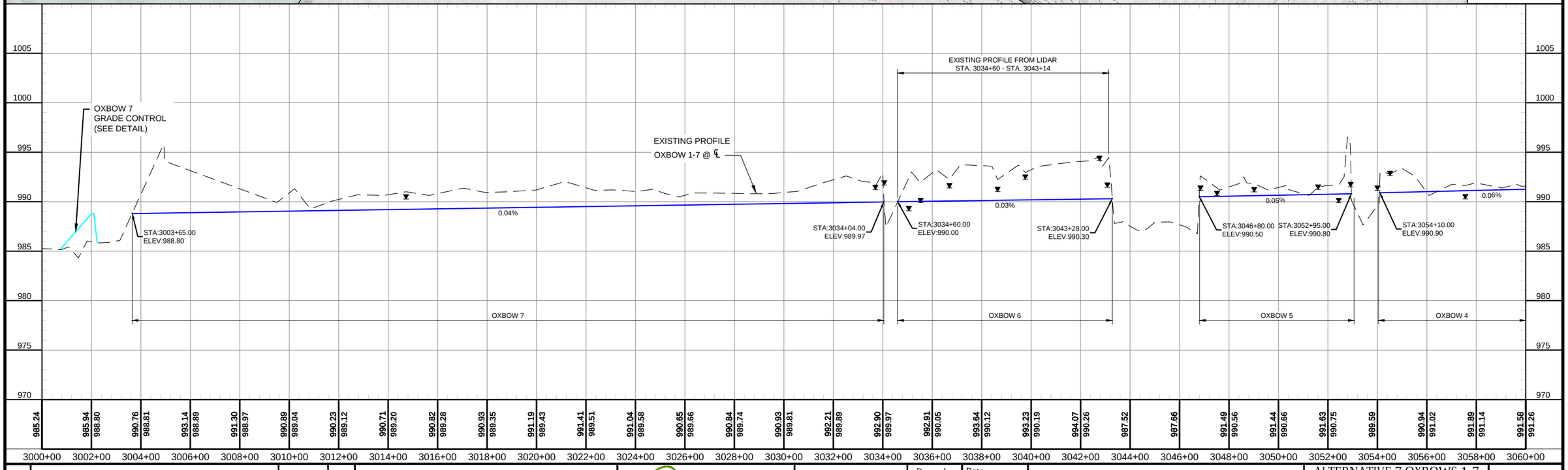


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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 7 OXBOWS 1-7
PLAN & PROFILE

PROJECT NO. 1915-241

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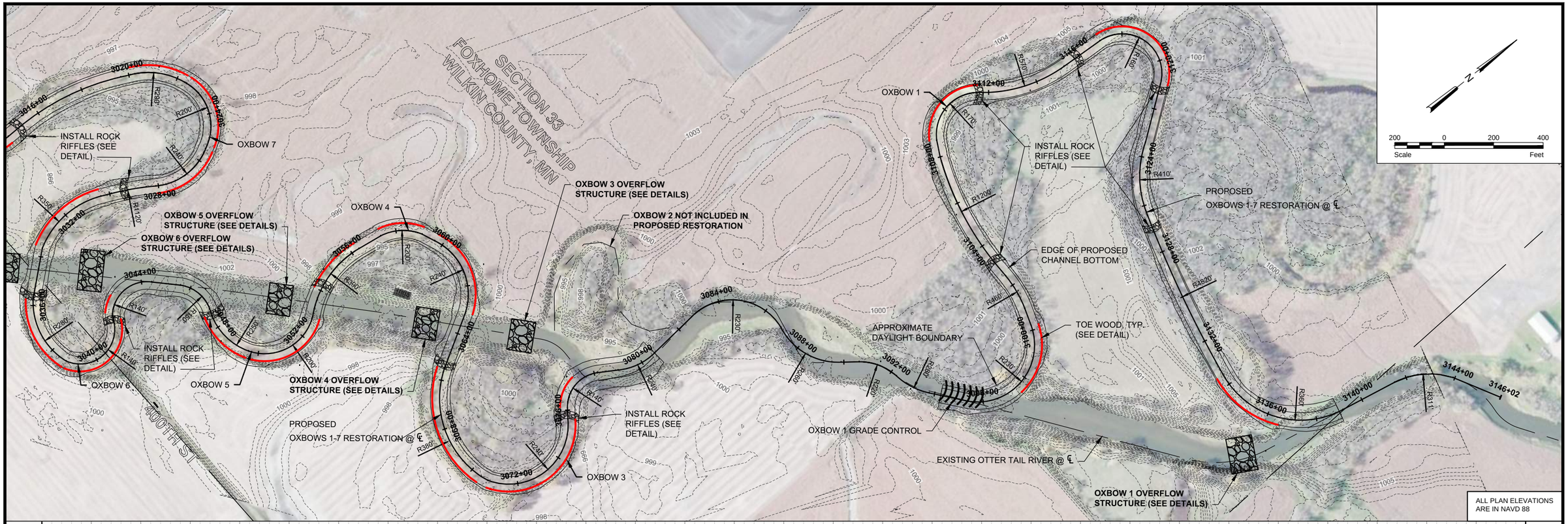
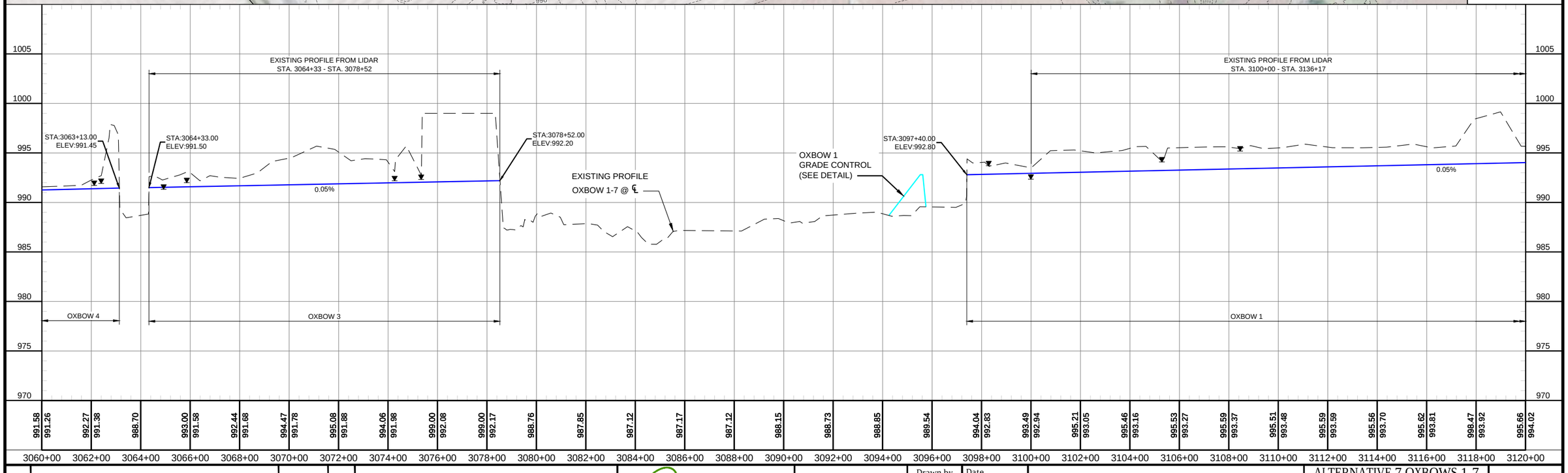
13 of 33

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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 7 OXBOWS 1-7
PLAN & PROFILE

PROJECT NO. 1915-241

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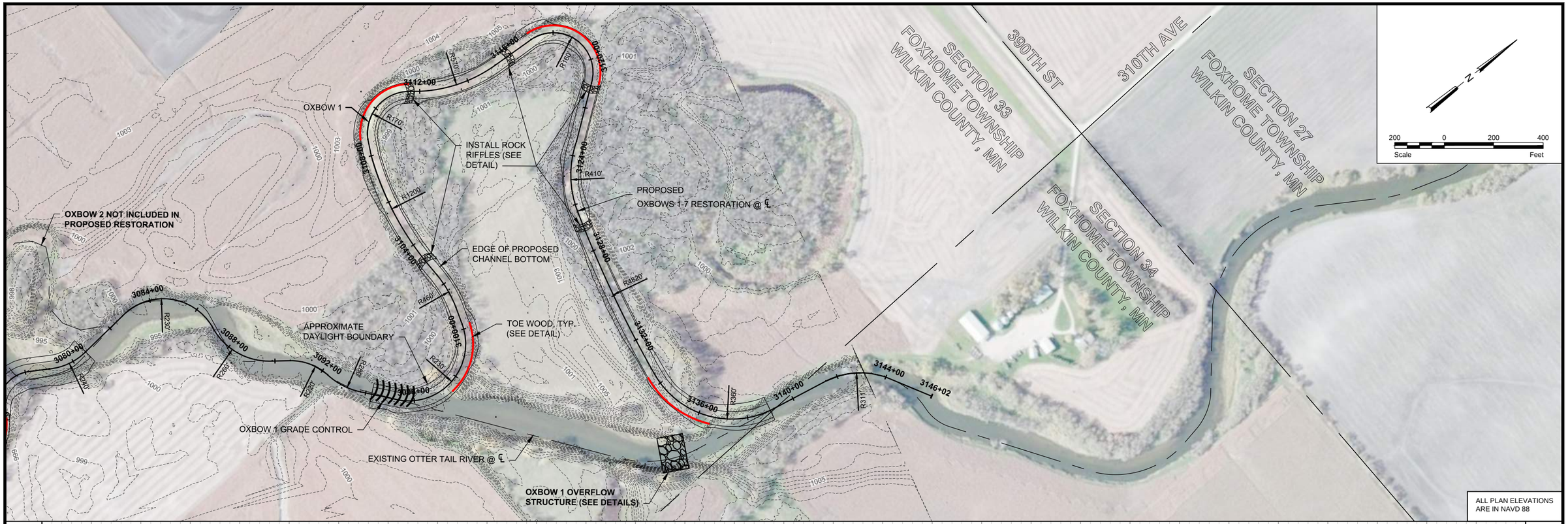


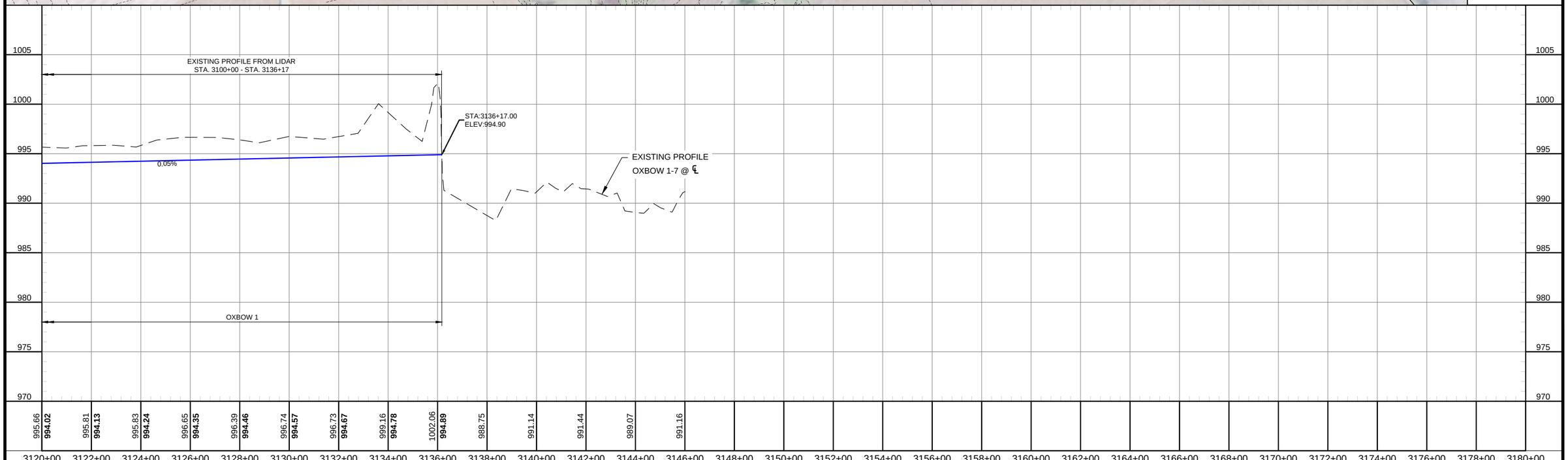


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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 7 OXBOWS 1-7
PLAN & PROFILE

PROJECT NO. 1915-241

SHEET 15 of 33

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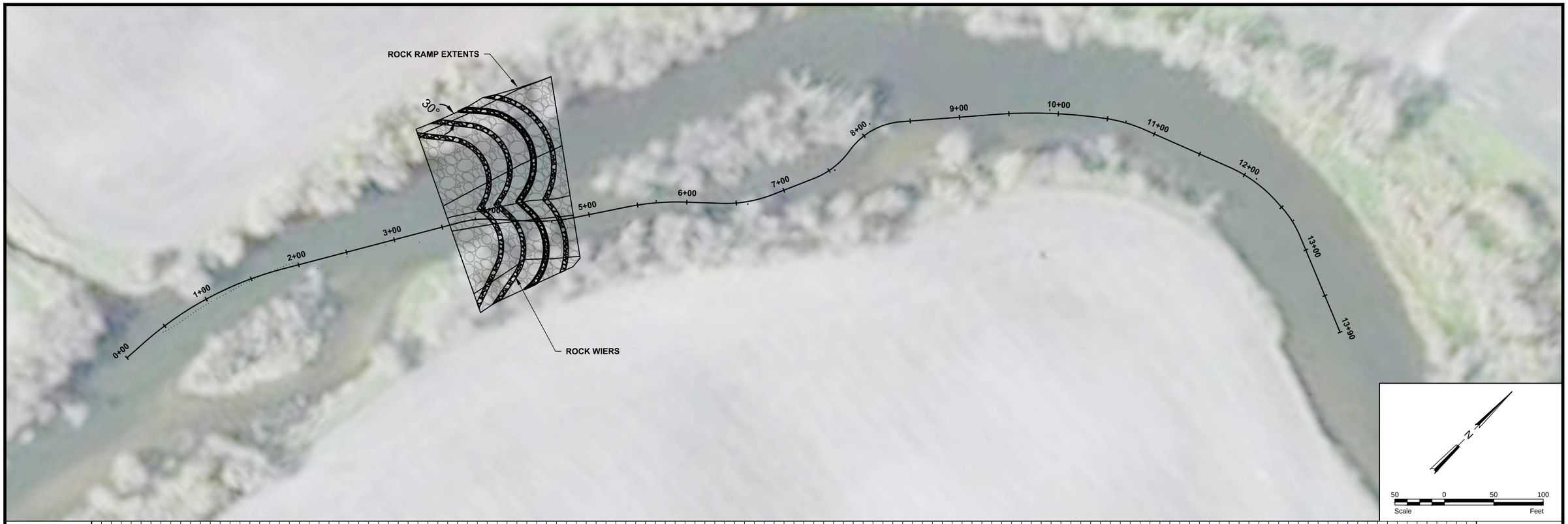


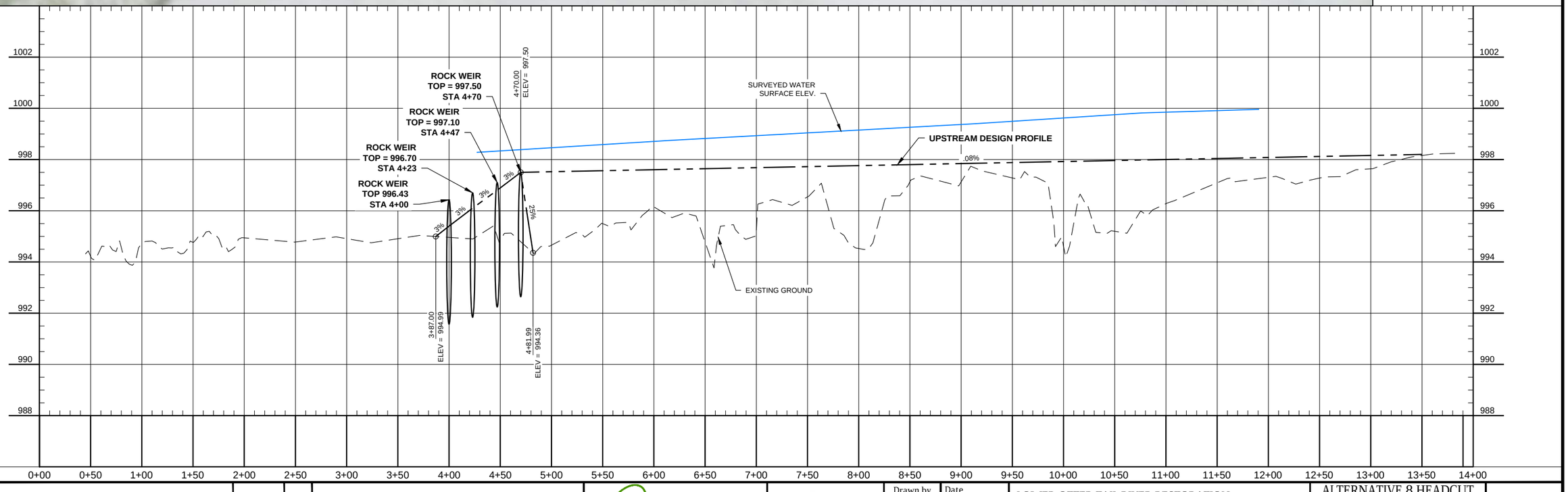


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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 8 HEADCUT
PLAN & PROFILE

PROJECT NO. 1915-241

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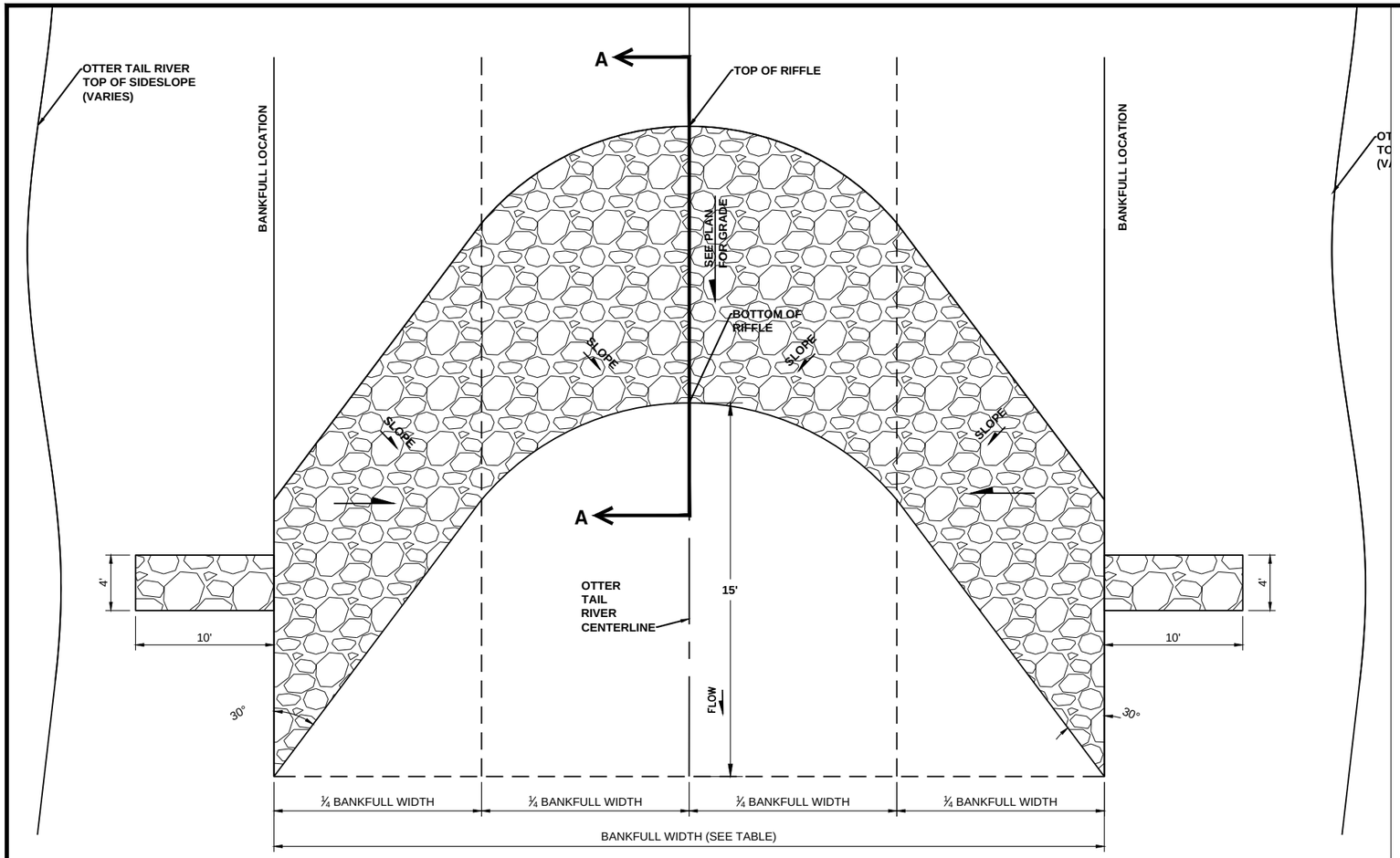
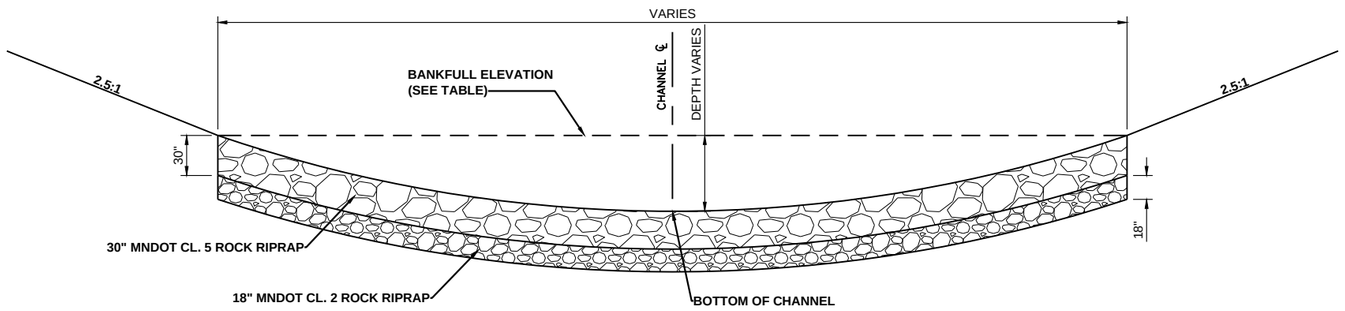



## OTTER TAIL RIVER CHANNEL RIFFLE PLAN VIEW

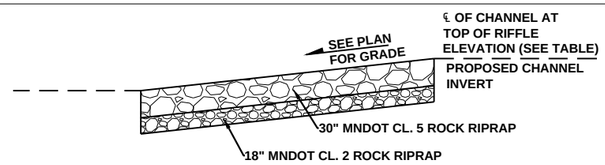
NOT TO SCALE




## OTTER TAIL RIVER CHANNEL RIFFLE CROSS SECTION VIEW

NOT TO SCALE

| Riffle Structures | | | | | | |
|---|---|---|---|---|---|---|
| Alternative | Oxbow | From Station | To Station | Channel Elevation at Top of Riffle | Bankfull Elevation | Bankfull Width |
| Alternative 1 | 27 | 9008+98 | 9008+68 | 963.54 | 968.04 | 122.5 |
| | 27 | 9018+18 | 9017+88 | 963.65 | 968.15 | 122.5 |
| | 26 | 9026+08 | 9025+78 | 963.79 | 968.29 | 122.5 |
| | 26 | 9031+19 | 9030+89 | 963.85 | 968.35 | 122.5 |
| | 26 | 9033+96 | 9033+66 | 963.88 | 968.38 | 122.5 |
| | 26 | 9039+89 | 9039+59 | 963.96 | 968.46 | 122.5 |
| Alternative 2 | 25 | 8013+65 | 8013+35 | 965.2 | 970.1 | 124.5 |
| | 24 | 8046+14 | 8045+84 | 965.56 | 970.46 | 124.5 |
| | 22 | 8056+42 | 8056+12 | 965.81 | 970.71 | 124.5 |
| | 22 | 8062+43 | 8062+13 | 966.22 | 971.12 | 124.5 |
| Alternative 3 | 21 | 7007+95 | 7007+65 | 967.37 | 971.87 | 122.5 |
| | 21 | 7010+38 | 7010+08 | 967.41 | 971.91 | 122.5 |
| | 21 | 7012+35 | 7012+05 | 967.44 | 971.94 | 122.5 |
| | 21 | 7023+40 | 7023+10 | 967.62 | 972.12 | 122.5 |
| | 21 | 7029+43 | 7029+13 | 967.72 | 972.22 | 122.5 |
| | 21 | 7031+92 | 7031+62 | 967.76 | 972.26 | 122.5 |
| | 21 | 7042+25 | 7041+95 | 967.93 | 972.43 | 122.5 |
| | 20 | 7051+59 | 7051+29 | 968.33 | 972.83 | 122.5 |
| | 20 | 7064+59 | 7064+29 | 968.97 | 973.47 | 122.5 |
| | 19 | 7076+47 | 7076+17 | 969.8 | 974.3 | 122.5 |
| | 19 | 7081+40 | 7081+10 | 970.09 | 974.59 | 122.5 |
| | 19 | 7083+06 | 7082+76 | 970.18 | 974.68 | 122.5 |
| Alternative 4 | 18 | 6010+90 | 6010+60 | 971.97 | 976.17 | 141 |
| | 18 | 6018+16 | 6017+86 | 972.36 | 976.56 | 141 |
| | 18 | 6023+82 | 6023+52 | 972.68 | 976.88 | 141 |
| | 18 | 6030+23 | 6029+93 | 973.06 | 977.26 | 141 |
| Alternative 5 | 17 | 5011+07 | 5010+77 | 974.53 | 979.63 | 145.5 |
| | 17 | 5034+57 | 5034+27 | 974.75 | 979.85 | 145.5 |
| | 16 | 5045+22 | 5044+92 | 974.86 | 979.96 | 145.5 |
| | 16 | 5057+48 | 5057+18 | 974.98 | 980.08 | 145.5 |
| | 15 | 5064+83 | 5064+53 | 975 | 980.1 | 145.5 |
| | 15 | 5066+38 | 5066+08 | 975.03 | 980.13 | 145.5 |
| | 15 | 5070+27 | 5069+97 | 975.07 | 980.17 | 145.5 |
| | 15 | 5087+74 | 5087+44 | 975.27 | 980.37 | 145.5 |
| | 14 | 5100+51 | 5100+21 | 975.42 | 980.52 | 145.5 |
| | 14 | 5114+90 | 5114+60 | 975.5 | 980.6 | 145.5 |
| | 13 | 5122+79 | 5122+49 | 975.67 | 980.77 | 145.5 |
| | 13 | 5125+66 | 5125+36 | 975.7 | 980.8 | 145.5 |
| | 13 | 5133+51 | 5133+21 | 975.78 | 980.88 | 145.5 |
| | 12 | 5141+05 | 5140+75 | 975.83 | 980.93 | 145.5 |
| | 12 | 5148+29 | 5147+99 | 975.94 | 981.04 | 145.5 |
| Alternative 6 | 9 | 4005+99 | 4005+69 | 985.97 | 990.37 | 82 |
| | 9 | 4014+75 | 4014+45 | 986.59 | 990.99 | 82 |
| | 8 | 4030+03 | 4029+73 | 987.48 | 991.88 | 82 |
| | 8 | 4035+91 | 4035+61 | 987.89 | 992.29 | 82 |
| | 8 | 4037+96 | 4037+66 | 988.04 | 992.44 | 82 |
| | 8 | 4043+33 | 4043+03 | 988.41 | 992.81 | 82 |
| | 8 | 4049+45 | 4049+15 | 988.8 | 993.2 | 82 |
| Alternative 7 | 7 | 3009+06 | 3008+76 | 989.01 | 993.31 | 81.5 |
| | 7 | 3012+10 | 3011+80 | 989.13 | 993.43 | 81.5 |
| | 7 | 3015+22 | 3014+92 | 989.25 | 993.55 | 81.5 |
| | 7 | 3029+56 | 3029+26 | 989.8 | 994.1 | 81.5 |
| | 6 | 3036+00 | 3035+70 | 990.05 | 994.35 | 81.5 |
| | 6 | 3042+06 | 3041+76 | 990.26 | 994.56 | 81.5 |
| | 5 | 3047+60 | 3047+30 | 990.54 | 994.84 | 81.5 |
| | 5 | 3052+70 | 3052+40 | 990.79 | 995.09 | 81.5 |
| | 3 | 3065+00 | 3064+70 | 991.53 | 995.83 | 81.5 |
| | 3 | 3075+96 | 3075+66 | 992.07 | 996.37 | 81.5 |
| | 1 | 3103+42 | 3103+12 | 993.13 | 997.43 | 81.5 |
| | 1 | 3111+79 | 3111+49 | 993.58 | 997.88 | 81.5 |
| | 1 | 3116+09 | 3115+79 | 993.81 | 998.11 | 81.5 |
| | 1 | 3121+37 | 3121+07 | 994.1 | 998.4 | 81.5 |
| | 1 | 3127+14 | 3126+84 | 994.41 | 998.71 | 81.5 |




## SECTION A - A

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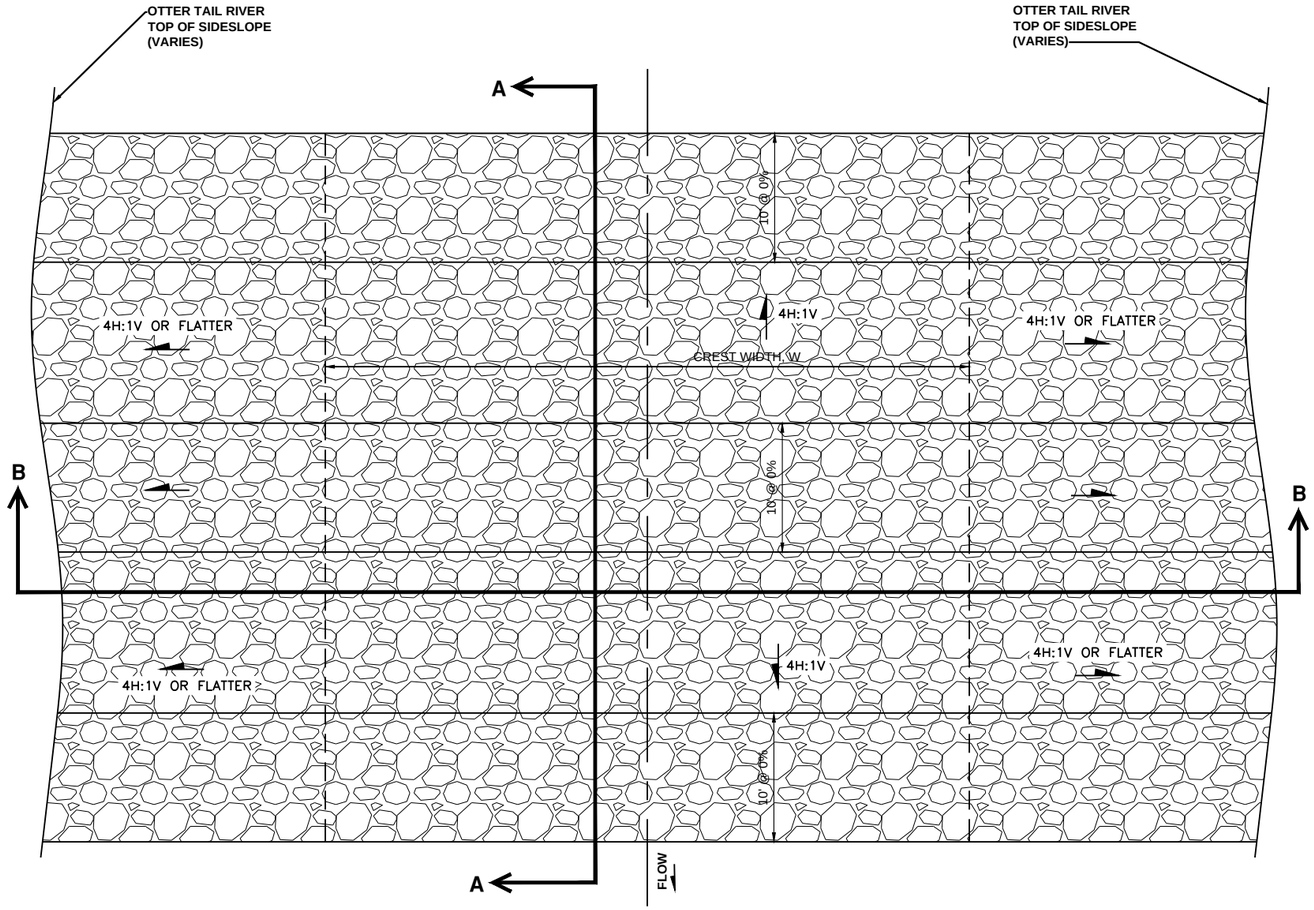
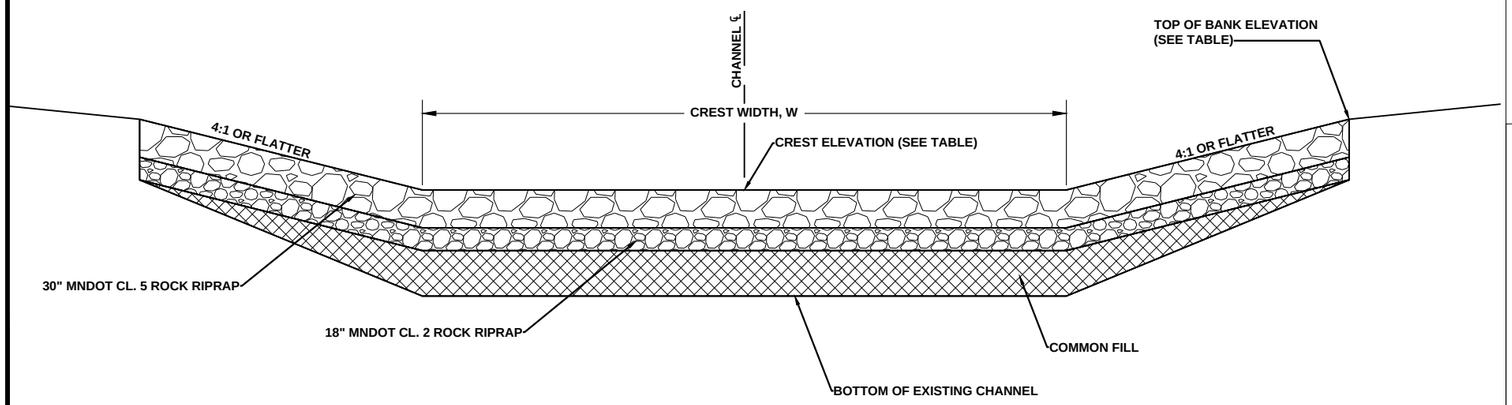
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

RIFFLES DETAIL

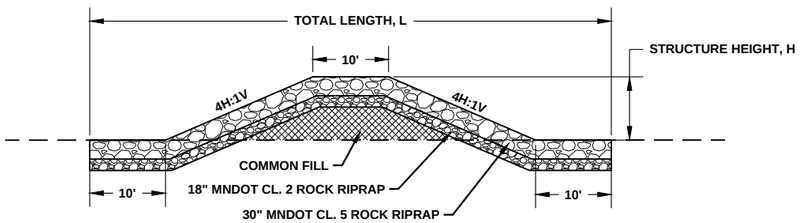
PROJECT NO. 1915-241




## SECTION B - B
NOT TO SCALE

| Overflow Structures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Alternative | Oxbow | Begin Station | End Station | Total Length L | Crest Width W | Crest Elevation | Structure Height H | Top of Bank Elevation |
| 1 | 27 | 491+37 | 490+65 | 72 | 140 | 968.3 | 5.3 | 972.8 |
| | 26 | 500+85 | 500+09 | 76 | 150 | 969.2 | 5.7 | 973.3 |
| 2 | 25 | 561+68 | 560+94 | 74 | 150 | 970.9 | 5.5 | 982.2 |
| | 24 | 565+10 | 564+32 | 78 | 170 | 971.4 | 6 | 978.1 |
| | 22 | 573+18 | 572+38 | 80 | 140 | 971.8 | 6.2 | 977.5 |
| 3 | 21 | 635+80 | 635+02 | 78 | 150 | 973.8 | 6 | 976.6 |
| | 20 | 642+40 | 641+56 | 84 | 150 | 974.4 | 6.8 | 979.5 |
| | 19 | 656+80 | 655+92 | 88 | 140 | 975 | 7.3 | 976.4 |
| 4 | 18 | 701+06 | 700+22 | 84 | 150 | 977 | 6.7 | 979 |
| 5 | 17 | 720+75 | 719+80 | 95 | 130 | 979.3 | 8.1 | 982.3 |
| | 16 | 733+15 | 731+99 | 116 | 140 | 979.8 | 10.7 | 982.7 |
| | 15 | 750+05 | 749+07 | 98 | 130 | 980.5 | 8.5 | 981.3 |
| | 14 | 762+50 | 761+46 | 104 | 160 | 980.9 | 9.3 | 982.3 |
| | 13 | 771+80 | 770+72 | 108 | 130 | 981.3 | 9.7 | 982.6 |
| | 12 | 781+90 | 780+88 | 102 | 140 | 981.6 | 9 | 986.2 |
| 6 | 9 | 967+85 | 966+74 | 111 | 140 | 991.6 | 10.1 | 998.8 |
| | 8 | 988+50 | 987+34 | 116 | 140 | 994.3 | 10.8 | 1000.8 |
| 7 | 7 | 1019+50 | 1018+46 | 104 | 120 | 996.1 | 9.3 | 999.7 |
| | 6 | 1022+90 | 1021+82 | 108 | 170 | 996.6 | 9.8 | 1001.3 |
| | 5 | 1030+60 | 1029+54 | 106 | 130 | 997 | 9.5 | 1002.7 |
| | 4 | 1036+60 | 1035+51 | 109 | 130 | 997.4 | 9.9 | 1005.5 |
| | 3 | 1040+50 | 1039+33 | 117 | 130 | 998.4 | 10.9 | 1003.4 |
| | 1 | 1073+40 | 1072+23 | 117 | 140 | 1000.9 | 10.9 | 1007.4 |




## SECTION A - A
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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

OVERFLOW STRUCTURE DETAIL

PROJECT NO. 1915-241

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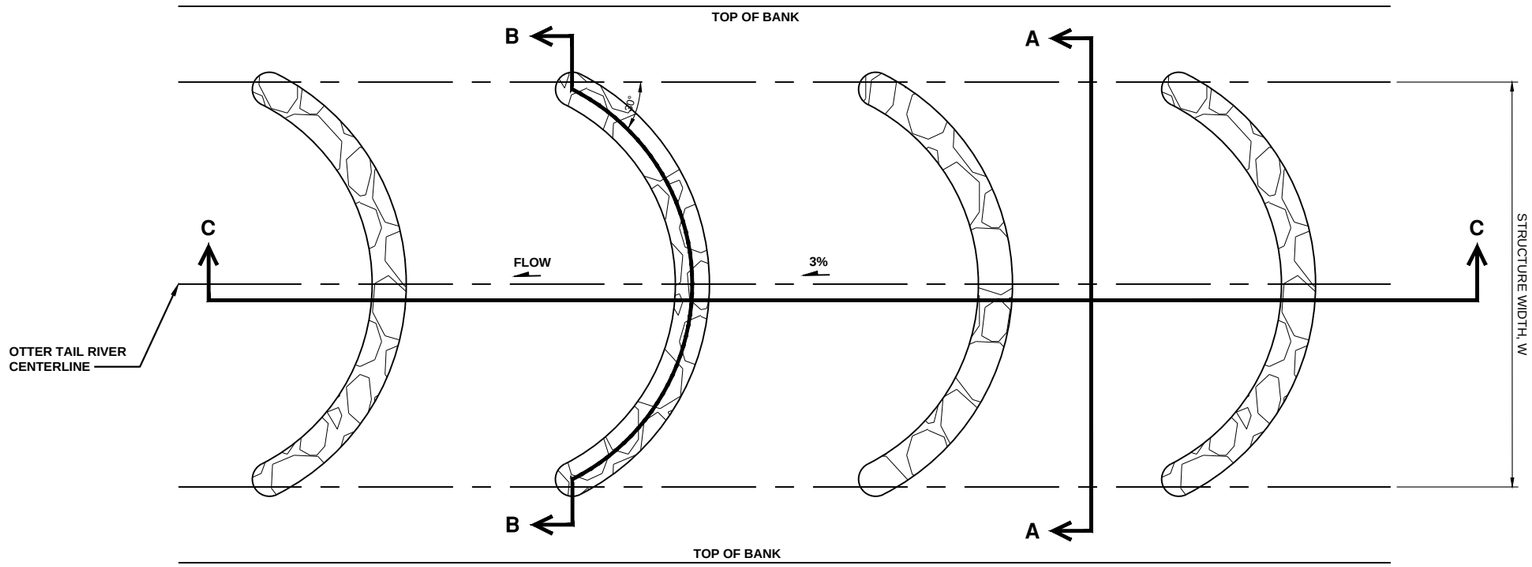
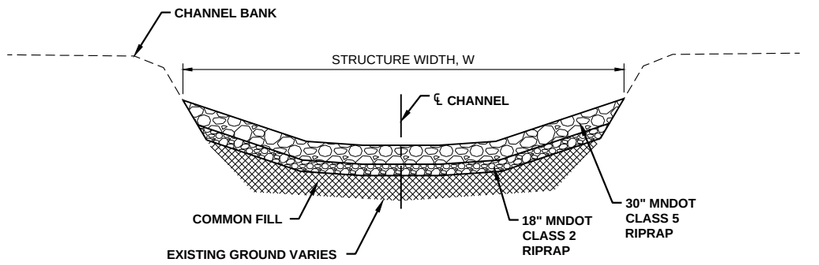
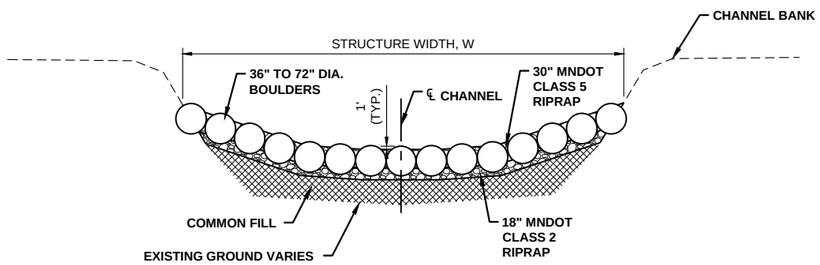



## GRADE CONTROL - TYPICAL PLAN VIEW
NOT TO SCALE

| Grade Control Structures | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Alternative | Oxbow | From Station | To Station | Total Length L | Structure Width W | Crest Elevation | Structure Height H | Number of Boulder Weirs |
| 3 | 19 | 7073+38 | 7072+64 | 74 | 130 | 969.7 | 1.5 | 2 |
| 4 | 18 | 6006+17 | 6005+40 | 77 | 130 | 971.8 | 1.3 | 2 |
| 5 | 17 | 5006+26 | 5004+67 | 159 | 130 | 974.5 | 3.8 | 5 |
| 6 | 9 | 4003+29 | 4001+40 | 189 | 130 | 985.9 | 4.2 | 6 |
| | 8 | 4025+71 | 4023+44 | 227 | 120 | 987.3 | 4.3 | 6 |
| 7 | 7 | 3095+75 | 3094+25 | 150 | 90 | 992.8 | 4.1 | 6 |
| | 1 | 3002+23 | 3000+73 | 150 | 120 | 998.8 | 3.7 | 5 |



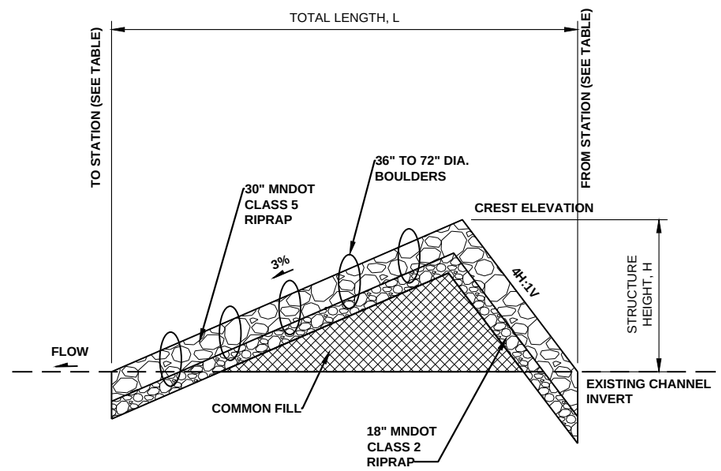

## TYPICAL SECTION A -A
NOT TO SCALE




## ROCK WEIR SECTION B - B
NOT TO SCALE

NOTES:

1. NUMBER OF BOULDERS FOR EACH ROCK-ARCH IS DEPENDENT ON SIZE AND SPACING OF BOULDERS.
2. 36" - 72" BOULDERS SHALL BE SET 1' ABOVE MNDOT CL. 5 ROCK RIPRAP TO RESULT IN WEIRS SPACED AT APPROXIMATELY 23'-4"" INTERVALS.
3. BOULDERS ARE TO BE FILLED WITH SMALLER STONE (MNDOT CL. 2 AND CL. 1 ROCK RIPRAP) TO REDUCE LEAKAGE AND CREATE POOLS.
4. ADDITIONAL BOULDERS WILL BE ADDED RANDOMLY TO ADD TO AESTHETICS AS DIRECTED BY THE ENGINEER OR REPRESENTATIVE IN THE FIELD.
5. THE WEIRS FUNCTION TO PROVIDE ADDED STABILITY TO THE RAPIDS, RESTING AREA FOR THE MIGRATION OF FISH, DIRECTING FLOW TOWARDS MID-CHANNEL (REDUCING STRESS ON BANKS) AND INCREASING SAFETY BY CREATING LOW VELOCITIES NEAR BANKS.
6. WEIRS ARE TO BE INTEGRATED INTO THE CONSTRUCTED BANKS, THE GAPS BETWEEN BOULDERS SHALL TYPICALLY RANGE FROM 0 TO 6 INCHES.
7. ALL FILL MATERIAL UNDER RIPRAP RAMP TO BE EITHER EXCAVATED CHANNEL MATERIAL OR SELECT GRANULAR.




## SECTION C - C
NOT TO SCALE

**NOTE:**
**1) PLACE ADDITIONAL ROCK BEDDING MATERIAL AS NECESSARY TO RAISE EXISTING GROUND TO REQUIRED GRADE.**

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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

GRADE CONTROL STRUCTURE DETAIL

PROJECT NO. 1915-241

| Toe-Wood Locations | | | | |
|---|---|---|---|---|
| | From Station | To Station | Length - feet (along Toe-Wood CL) | Bankfull Elevation |
| Alternative 1 | 9004+65 | 9005+84 | 149 | 968.00 |
| | 9009+71 | 9011+45 | 209 | 968.05 |
| | 9014+21 | 9018+08 | 485 | 968.11 |
| | 9018+08 | 9019+48 | 177 | 968.15 |
| | 9024+02 | 9026+10 | 262 | 968.26 |
| | 9026+11 | 9031+18 | 630 | 968.29 |
| | 9035+72 | 9039+84 | 517 | 968.40 |
| | 9039+84 | 9041+91 | 256 | 968.45 |
| Alternative 2 | 8015+41 | 8018+33 | 351 | 970.12 |
| | 8018+67 | 8020+86 | 268 | 970.15 |
| | 8021+09 | 8022+84 | 193 | 970.18 |
| | 8023+14 | 8024+75 | 188 | 970.20 |
| | 8033+58 | 8038+35 | 513 | 970.32 |
| | 8038+73 | 8043+76 | 630 | 970.38 |
| | 8047+63 | 8049+65 | 244 | 970.47 |
| | 8056+48 | 8062+31 | 707 | 970.72 |
| | 8062+37 | 8063+48 | 140 | 971.12 |
| | 8066+80 | 8068+48 | 202 | 971.42 |
| Alternative 3 | 7007+13 | 7007+96 | 96 | 971.86 |
| | 7012+44 | 7014+97 | 278 | 971.94 |
| | 7015+60 | 7018+91 | 384 | 972.00 |
| | 7019+08 | 7022+12 | 337 | 972.05 |
| | 7024+08 | 7028+05 | 484 | 972.14 |
| | 7030+28 | 7031+57 | 161 | 972.23 |
| | 7036+02 | 7040+74 | 579 | 972.33 |
| | 7043+29 | 7046+73 | 400 | 972.45 |
| | 7051+82 | 7055+44 | 381 | 972.84 |
| | 7057+32 | 7061+19 | 443 | 973.12 |
| | 7061+19 | 7063+66 | 303 | 973.31 |
| | 7064+97 | 7067+43 | 294 | 973.51 |
| | 7078+30 | 7081+11 | 325 | 974.41 |

| Toe-Wood Locations | | | | |
|---|---|---|---|---|
| | From Station | To Station | Length - feet (along Toe-Wood CL) | Bankfull Elevation |
| Alternative 4 | 6011+73 | 6015+08 | 385 | 676.21 |
| | 6015+08 | 6017+22 | 259 | 976.4 |
| | 6018+33 | 6022+82 | 538 | 976.59 |
| | 6024+67 | 6029+75 | 589 | 976.94 |
| | 6030+71 | 6032+75 | 253 | 977.29 |
| Alternative 5 | 5008+54 | 5009+74 | 152 | 979.6 |
| | 5012+32 | 5016+70 | 496 | 979.64 |
| | 5024+33 | 5027+46 | 390 | 979.75 |
| | 5034+58 | 5038+24 | 416 | 979.85 |
| | 5045+78 | 5048+95 | 385 | 979.97 |
| | 5057+40 | 5057+80 | 51 | 980.08 |
| | 5068+68 | 5069+51 | 102 | 980.15 |
| | 5072+15 | 5073+80 | 196 | 980.19 |
| | 5073+80 | 5074+56 | 76 | 980.21 |
| | 5074+56 | 5074+92 | 44 | 980.22 |
| | 5074+92 | 5076+06 | 114 | 980.22 |
| | 5076+06 | 5076+70 | 75 | 980.24 |
| | 5076+70 | 5077+57 | 87 | 980.24 |
| | 5077+57 | 5078+33 | 93 | 980.25 |
| | 5084+07 | 5087+04 | 373 | 980.33 |
| | 5087+62 | 5090+60 | 298 | 980.36 |
| | 5098+42 | 5098+77 | 44 | 980.5 |
| | 5101+62 | 5103+02 | 168 | 980.52 |
| | 5103+86 | 5107+19 | 383 | 980.53 |
| | 5107+42 | 5109+56 | 268 | 980.56 |
| | 5111+27 | 5113+05 | 195 | 980.58 |
| | 5119+37 | 5122+56 | 400 | 980.73 |
| | 5123+06 | 5125+02 | 245 | 980.77 |
| | 5125+82 | 5130+51 | 588 | 980.8 |
| | 5135+31 | 5136+15 | 107 | 980.9 |
| | 5139+72 | 5140+32 | 76 | 980.91 |
| | 5141+37 | 5142+76 | 146 | 980.94 |
| | 5143+02 | 5146+06 | 380 | 980.96 |
| | 5146+41 | 5148+05 | 200 | 981.01 |

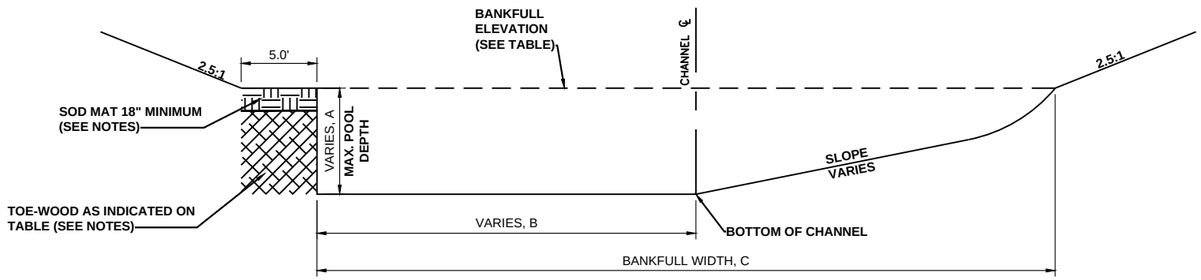
| Toe-Wood Locations | | | | |
|---|---|---|---|---|
| | From Station | To Station | Length - feet (along Toe-Wood CL) | Bankfull Elevation |
| Alternative 6 | 4007+55 | 4011+99 | 514 | 990.48 |
| | 4027+63 | 4029+19 | 184 | 991.72 |
| | 4030+64 | 4032+89 | 259 | 991.93 |
| | 4033+99 | 4035+71 | 198 | 992.16 |
| | 4035+77 | 4037+78 | 231 | 992.29 |
| | 4037+96 | 4040+10 | 247 | 992.43 |
| | 4040+33 | 4042+80 | 286 | 992.6 |
| | 4043+39 | 4045+45 | 231 | 992.82 |
| | 4046+92 | 4048+00 | 134 | 993.06 |
| Alternative 7 | 3007+31 | 3008+71 | 205 | 993.24 |
| | 3009+02 | 3011+82 | 349 | 993.31 |
| | 3011+82 | 3014+47 | 287 | 993.41 |
| | 3020+06 | 3022+35 | 253 | 993.73 |
| | 3022+43 | 3025+31 | 333 | 993.82 |
| | 3025+46 | 3028+10 | 298 | 993.94 |
| | 3030+37 | 3033+65 | 356 | 994.13 |
| | 3035+71 | 3038+72 | 334 | 994.34 |
| | 3038+72 | 3041+88 | 386 | 994.44 |
| | 3042+13 | 3042+79 | 82 | 994.56 |
| | 3047+39 | 3049+60 | 247 | 994.83 |
| | 3049+72 | 3052+88 | 366 | 994.94 |
| | 3054+01 | 3056+31 | 249 | 995.2 |
| | 3057+35 | 3059+08 | 199 | 995.4 |
| | 3059+66 | 3063+11 | 390 | 995.54 |
| | 3065+50 | 3070+47 | 537 | 995.86 |
| | 3070+77 | 3075+63 | 549 | 995.92 |
| | 3076+09 | 3077+24 | 142 | 996.38 |
| | 3097+48 | 3100+18 | 308 | 997.1 |
| | 3108+67 | 3111+58 | 343 | 997.71 |
| | 3117+05 | 3120+98 | 472 | 998.16 |
| | 3133+55 | 3136+52 | 324 | 999.06 |

ESTIMATED BENCH QUANTITIES

1. COMPACTED WOOD DEBRIS = 26,390 C.Y.
2. 18" MIN THICKNESS SOD MATERIAL = 15,834 S.Y.

NOTES:

1. TOE-WOOD TO BE INSTALLED ON OUTSIDE BANK OF MEANDER. TOE-WOOD IS TO BE INSTALLED 5 FT WIDE VARY IN DEPTH BELOW BANKFULL ELEVATION. SEE TABLE FOR VARIED DIMENSIONS. SEE PLAN FOR LOCATIONS.
2. TOE-WOOD DEBRIS SHALL CONSIST OF TREE ROOT SYSTEMS WITH A MINIMUM 10FT PORTION OF THE TRUNK STILL ATTACHED. THE ROOT SYSTEMS SHALL BE PLACED A MAXIMUM OF 20FT APART WHEN MEASURED FROM CENTER TO CENTER.
3. ADDITIONAL WOOD DEBRIS REQUIRED TO RAISE BENCH TO SPECIFIED ELEVATION. ACCEPTABLE DEBRIS CONSISTS OF ANY WOOD MATERIAL THAT HAS SUFFICIENT LIMBS TO LINK TO TREE ROOTS/OTHER DEBRIS.
4. ACCEPTABLE WOOD DEBRIS SHALL BE DETERMINED BY THE ENGINEER OR FIELD REPRESENTATIVE.
5. COMPACTION OF WOOD DEBRIS IS REQUIRED. SUFFICIENT COMPACTION SHALL BE DETERMINED BY THE ENGINEER OR FIELD REPRESENTATIVE.
6. SOD MATERIAL SHALL CONSIST OF SUFFICIENT PLANT GROWTH TO BIND THE SOD MAT TOGETHER. SOD MATS CONTAINING WILLOWS AND/OR DENSE STANDS OF GRASSES ARE CONSIDERED IDEAL. ACCEPTABLE SOD MATERIAL SHALL BE DETERMINED BY ENGINEER OR FIELD REPRESENTATIVE.




## TOE-WOOD TYPICAL SECTION

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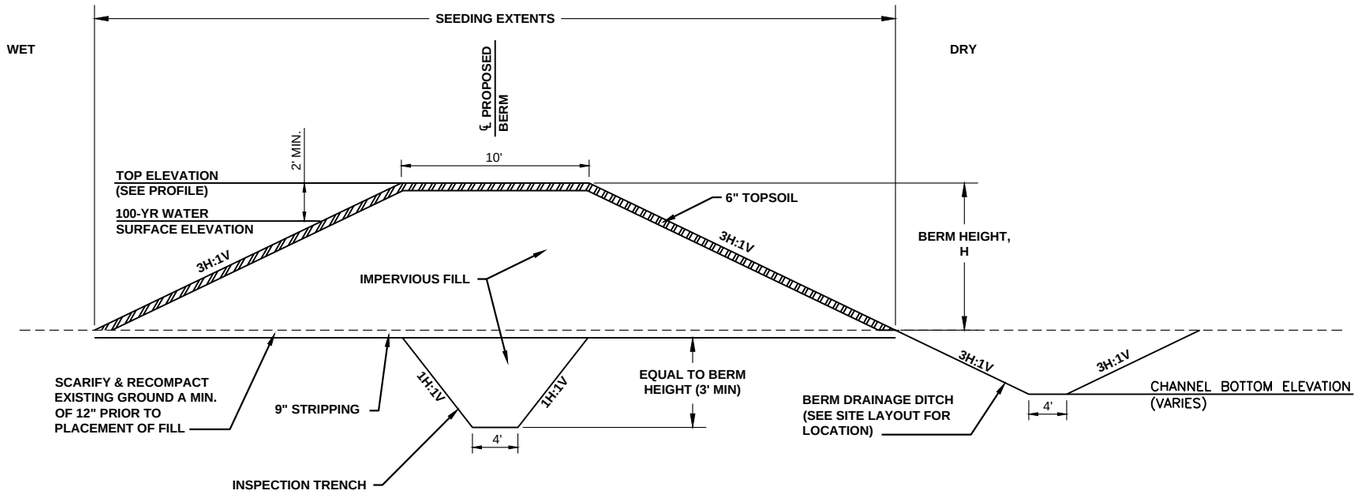
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

TOE-WOOD DETAIL

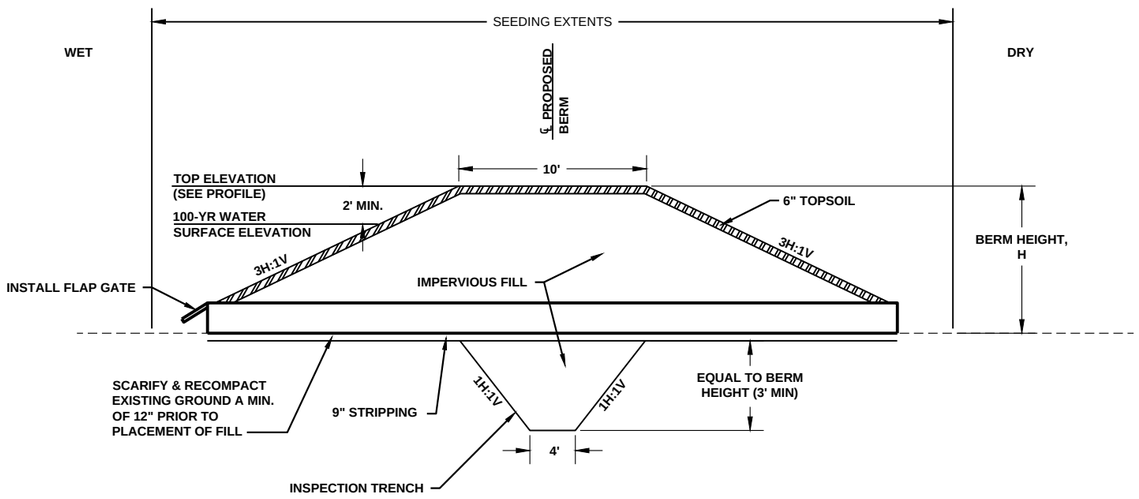
PROJECT NO. 1915-241




## SETBACK LEVEE TYPICAL SECTION

NOT TO SCALE

| Setback Levees | | | | | | |
|---|---|---|---|---|---|---|
| Alternative | Levee Alignment | Length | Beginning Elevation (Upstream) | End Elevation (Downstream) | Maximum Levee Height | Length of Levee Ditch |
| 5 | 1 | 2,440 | 981.50 | 981.2 | 4 | 1,720 |
| 5 | 2 | 3,830 | 984.70 | 982.5 | 5 | 4,480 |
| 5 | 3 | 7,840 | 983.60 | 983.6 | 5 | 3,260 |
| 1-7 | 4 | 6,650 | 993.90 | 990.8 | 5 | 1,250 |
| 1-7 | 5 | 7,710 | 997.60 | 995.4 | 6.5 | 4,590 |




## SETBACK LEVEE TYPICAL SECTION WITH CULVERT

NOT TO SCALE

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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

SETBACK LEVEE TYPICAL SECTION

PROJECT NO. 1915-241

WILKIN CD 4A

ALIGNMENT 2
(ALTERNATIVE 5)

ALIGNMENT 1
(ALTERNATIVE 5)

INSTALL CULVERT
WITH FLAP GATE

ALIGNMENT 3
(ALTERNATIVE 5)

INSTALL CULVERT
WITH FLAP GATE

INSTALL FLAP
GATE ON EXISTING
CULVERT

CSAH 17/270TH AVE

290TH AVE

COUNTY ROAD 169

WILKIN C O-OP DITCH 1

FOXHOME TOWNSHIP
WILKIN COUNTY, MN

SUNNYSIDE TOWNSHIP
WILKIN COUNTY, MN

BRANDRUP TOWNSHIP
WILKIN COUNTY, MN

BRADFORD TOWNSHIP
WILKIN COUNTY, MN

RAISE ROAD FOR
APPROX. 500'
(ALTERNATIVES 1 - 7)

INSTALL CULVERT
WITH FLAP GATE

ALIGNMENT 4
(ALTERNATIVES 1 - 7)

INSTALL CULVERT
WITH FLAP GATE

ALIGNMENT 5
(ALTERNATIVES 1 - 7)

LEGEND

- EXISTING CHANNEL ALIGNMENT
- PROPOSED OXBOW ALIGNMENT
- SETBACK LEVEE ALIGNMENT
- SETBACK LEVEE DITCH ALIGNMENT

| No. | Revision | Date | By |
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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

SETBACK LEVEE SITE LAYOUT

PROJECT NO. 1915-241

SHEET
22 of 33

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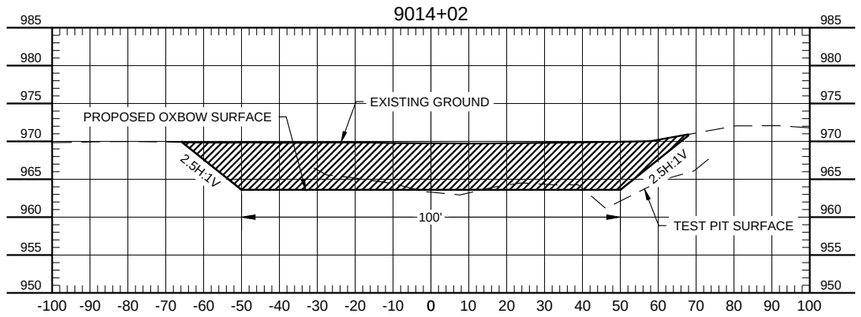


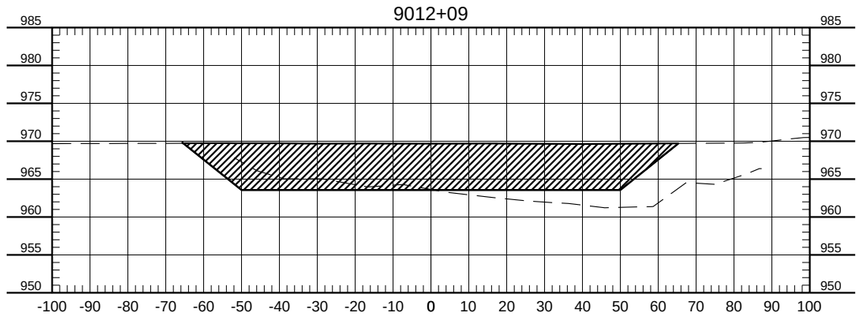


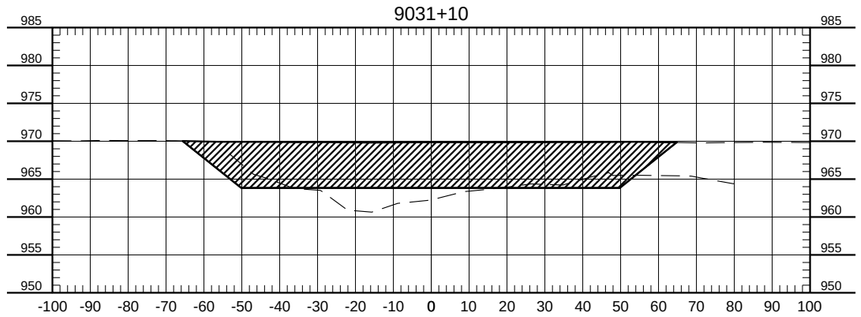


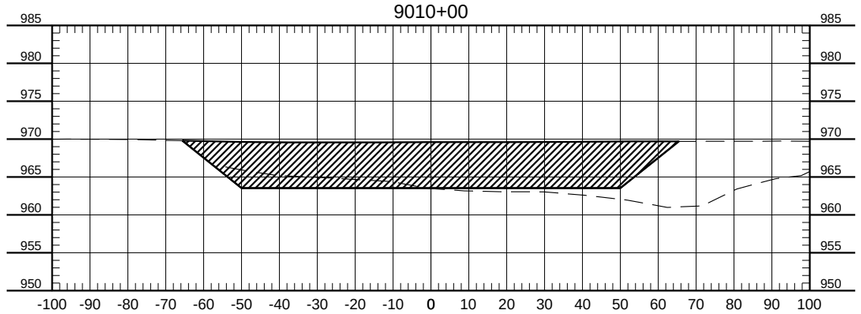


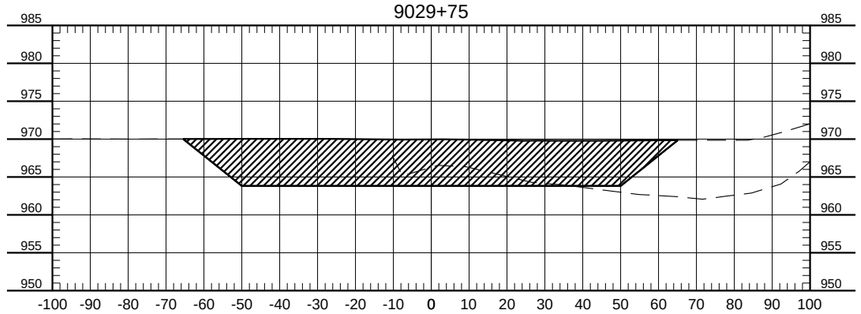


NOTES:
FINAL DESIGN TO HAVE A
PARABOLIC/ROUNDED BOTTOM

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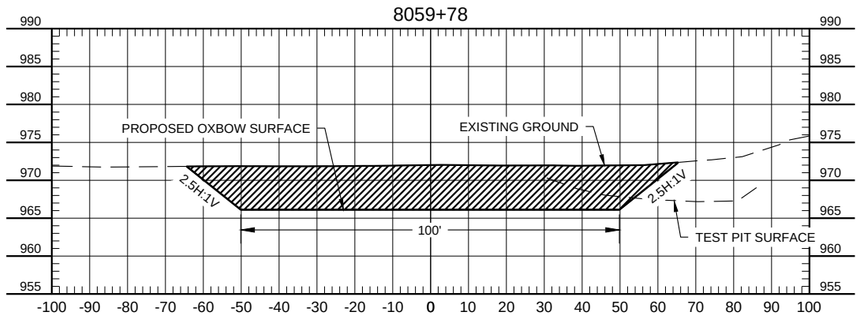
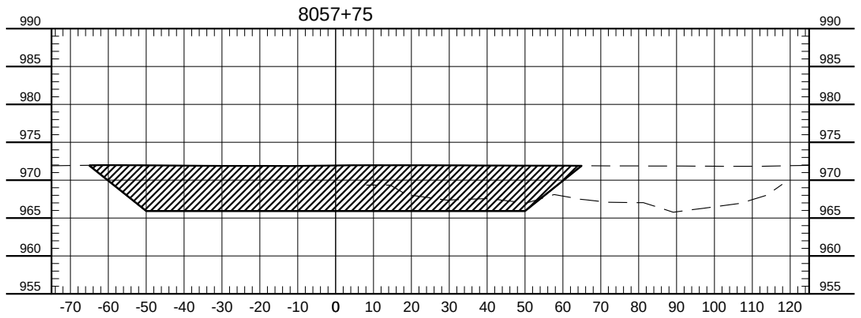
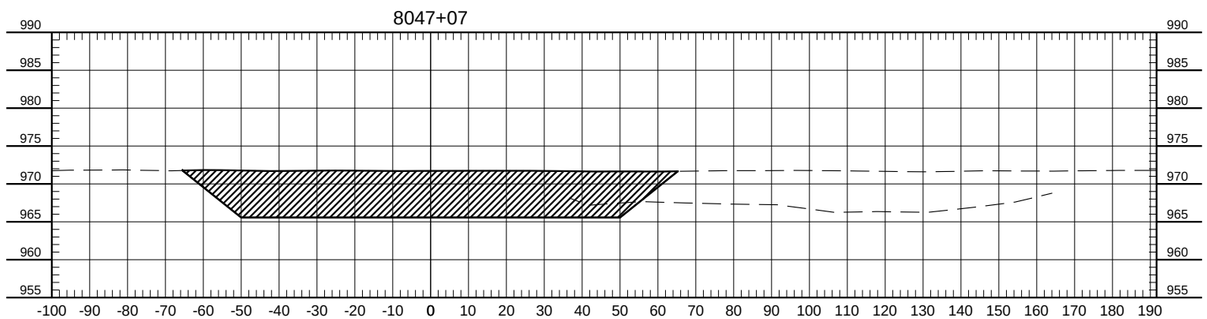
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 1 OXBOWS 26-27
CROSS SECTIONS
PROJECT NO. 1915-241

SHEET
23 of 33




NOTES:
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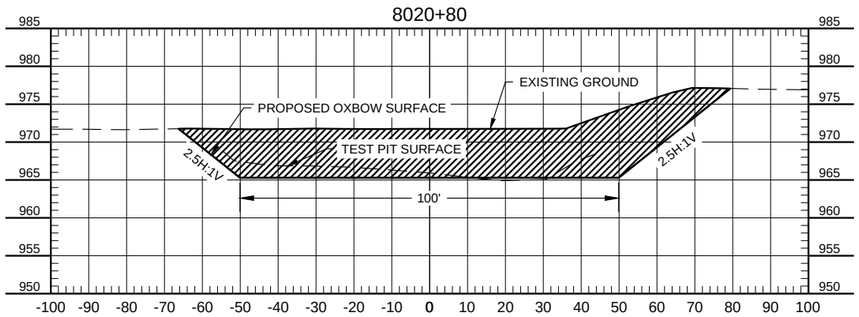
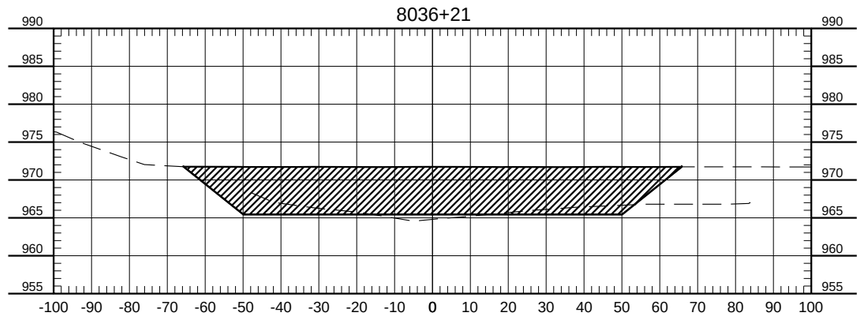
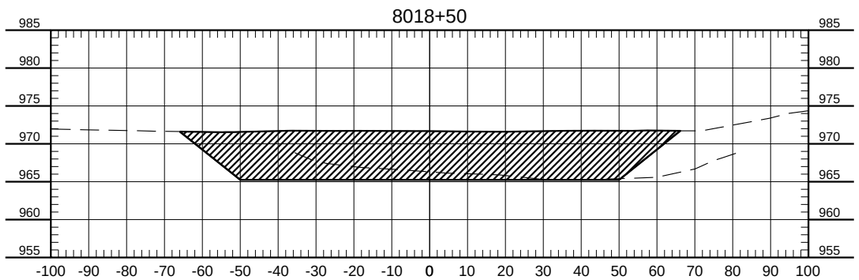
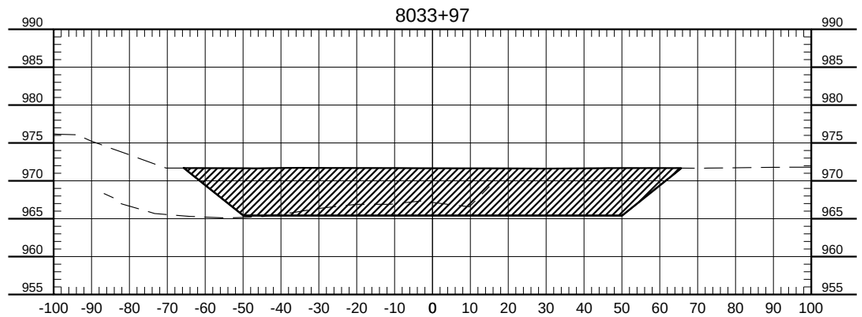
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

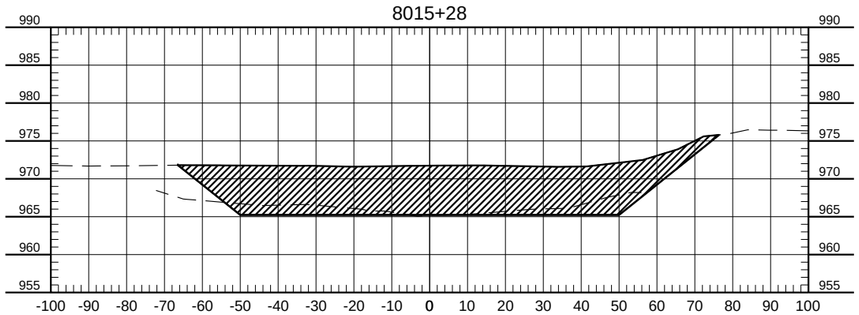
ALTERNATIVE 2 OXBOWS 22-25
CROSS SECTIONS
PROJECT NO. 1915-241

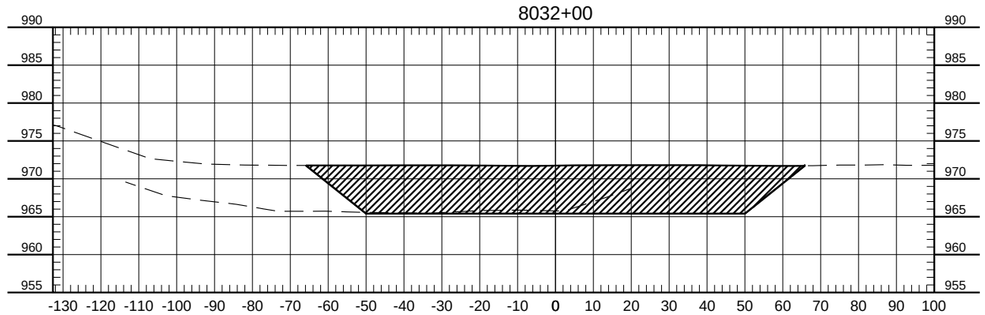


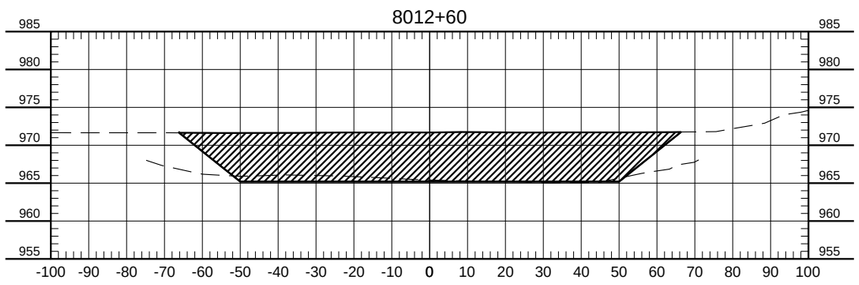



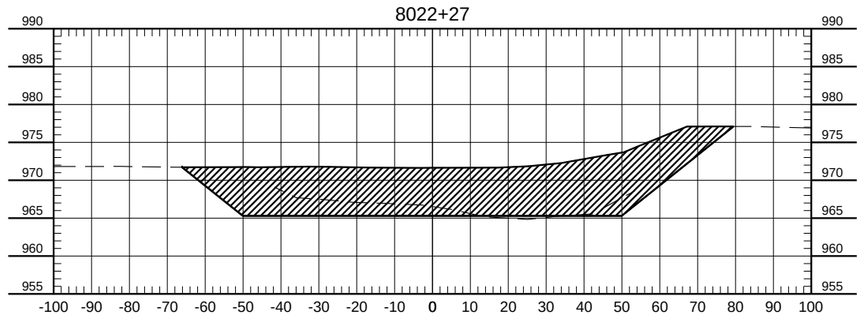




NOTES:
FINAL DESIGN TO HAVE A PARABOLIC/ROUNDED BOTTOM

| No. | Revision | Date | By |
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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 3 OXBOWS 19-21
CROSS SECTIONS
PROJECT NO. 1915-241

SHEET
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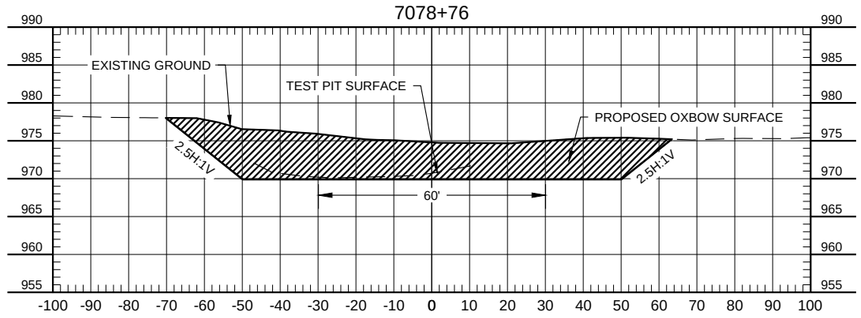


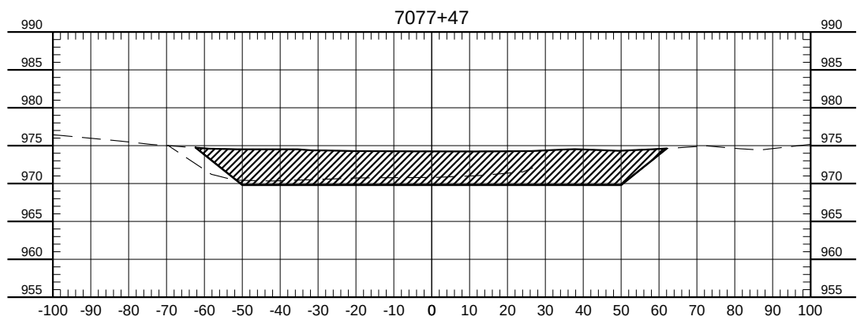


NOTES:
FINAL DESIGN TO HAVE A PARABOLIC/ROUNDED BOTTOM

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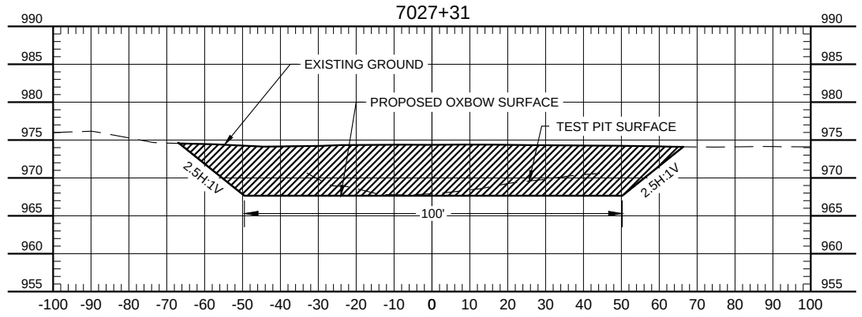
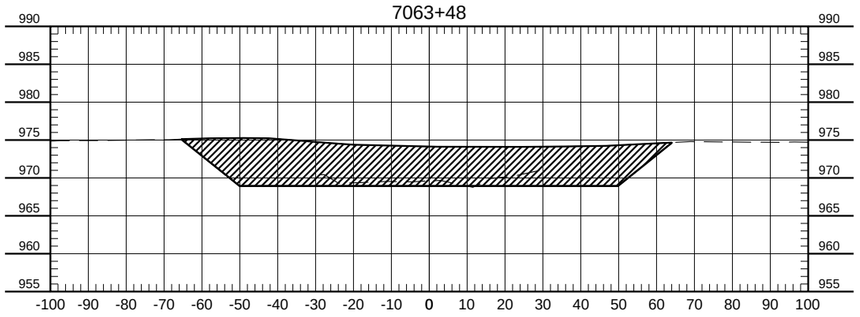
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

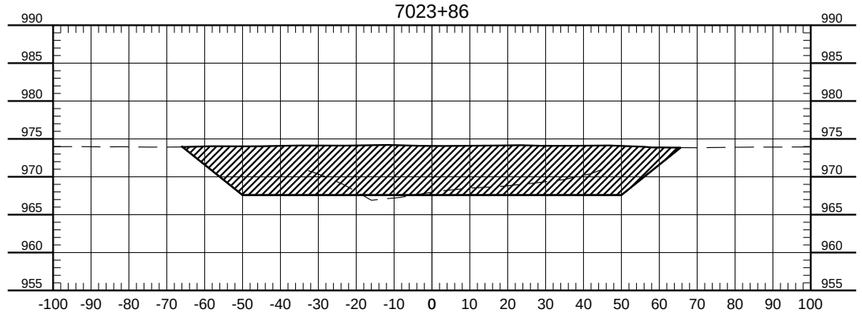
ALTERNATIVE 3 OXBOWS 19-21
CROSS SECTIONS

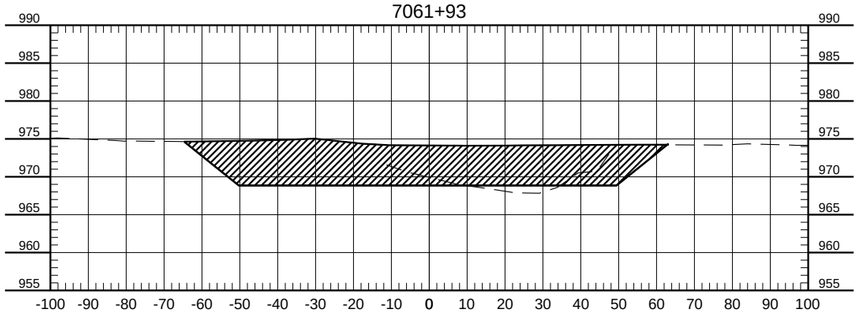
PROJECT NO. 1915-241

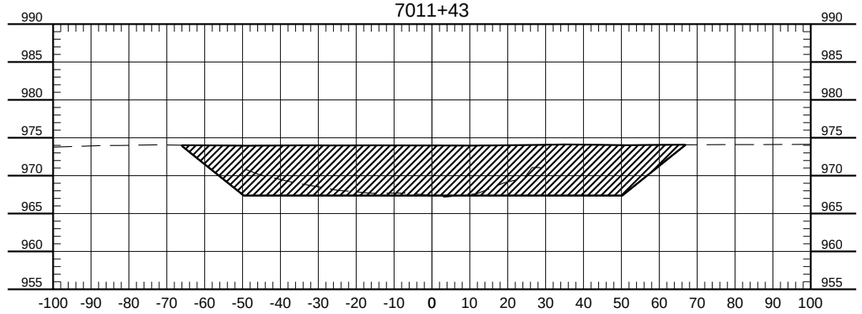
SHEET
26 of 33

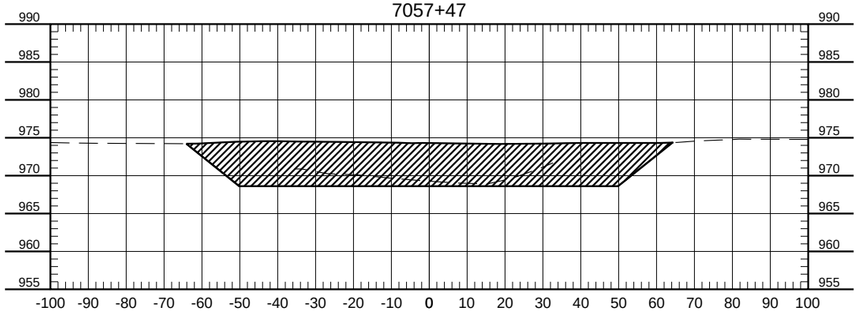


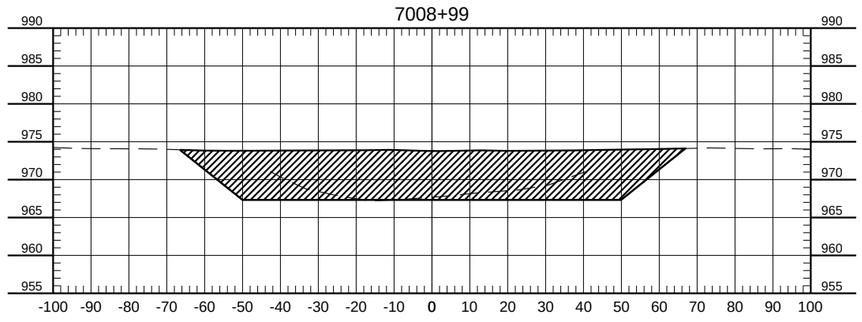



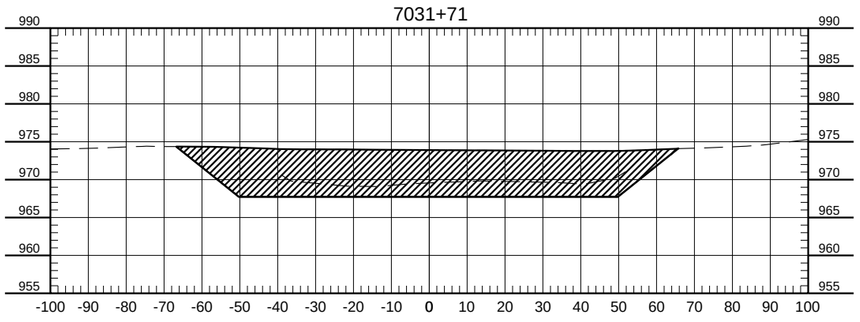

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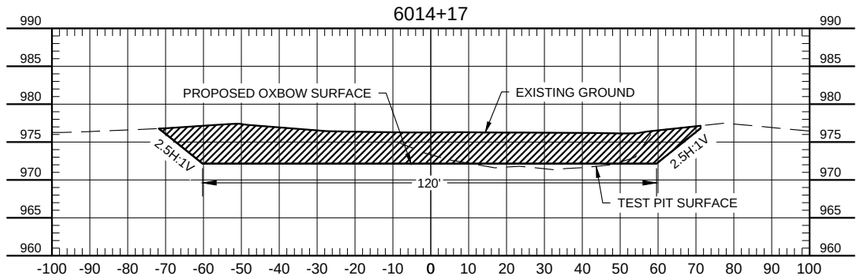
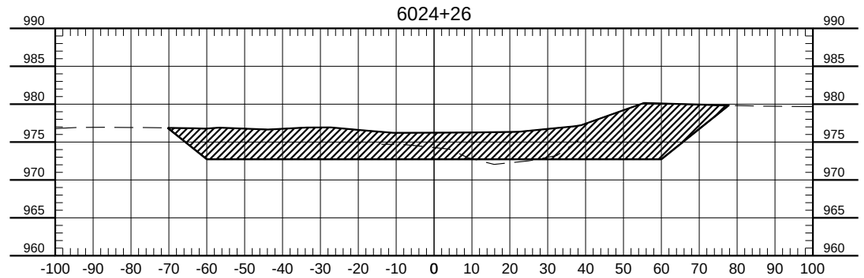
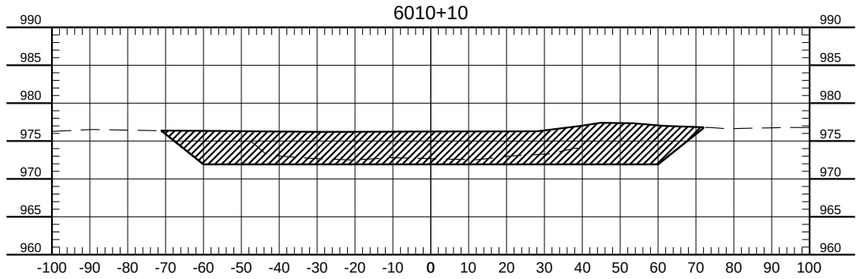
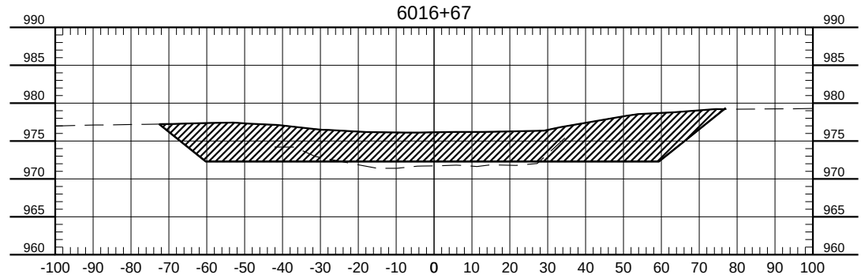
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 4 OXBOW 18
CROSS SECTIONS
PROJECT NO. 1915-241

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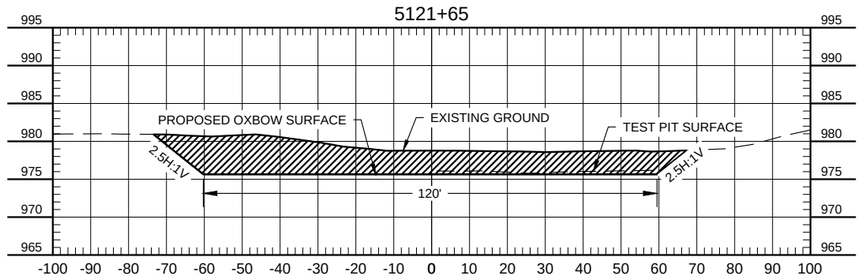
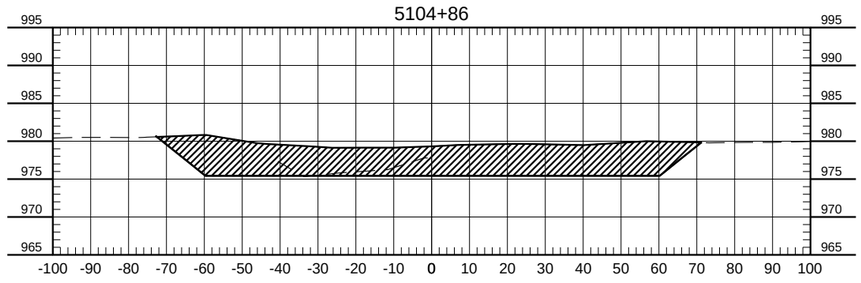
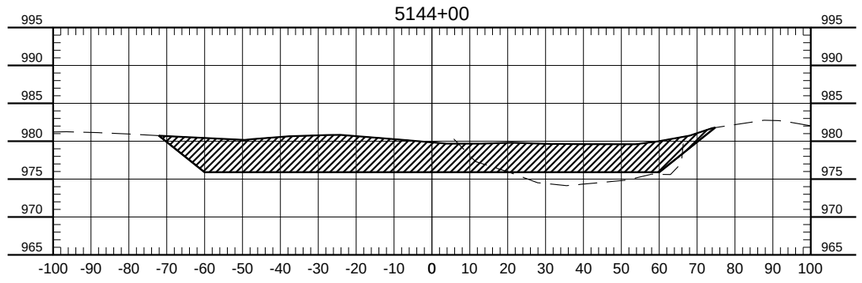
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

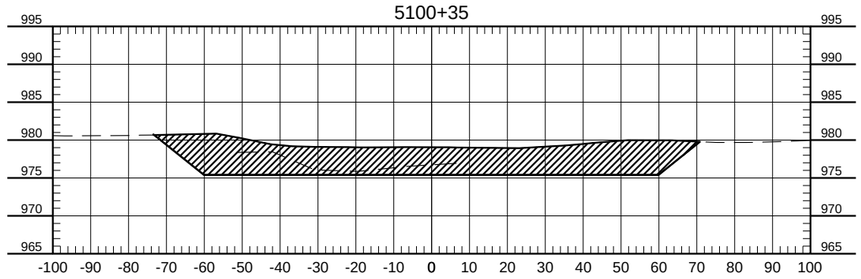
ALTERNATIVE 5 OXBOWS 12-17
CROSS SECTIONS
PROJECT NO. 1915-241

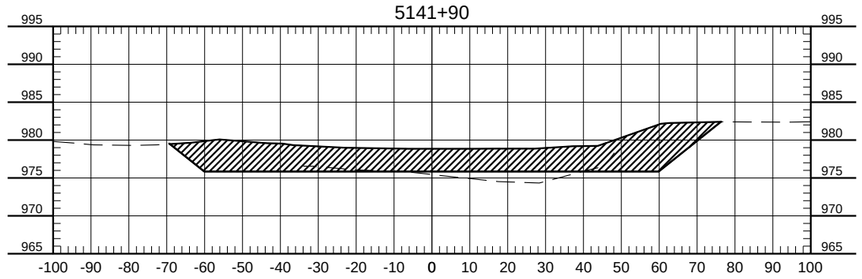
SHEET
28 of 33

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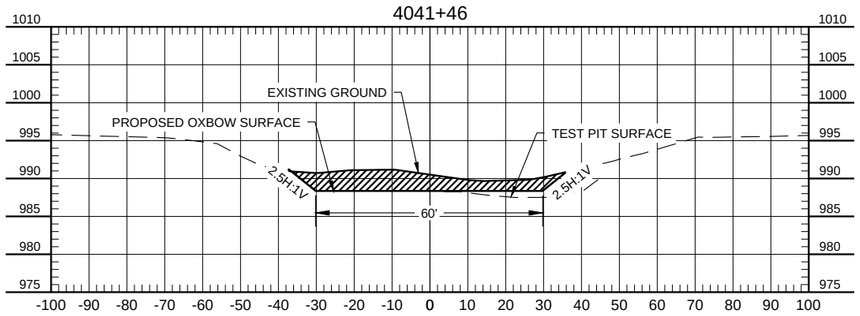
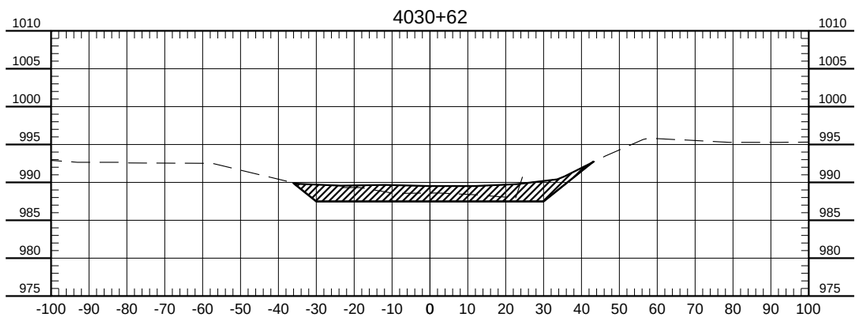
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 6 OXBOWS 8-9
CROSS SECTIONS

PROJECT NO. 1915-241

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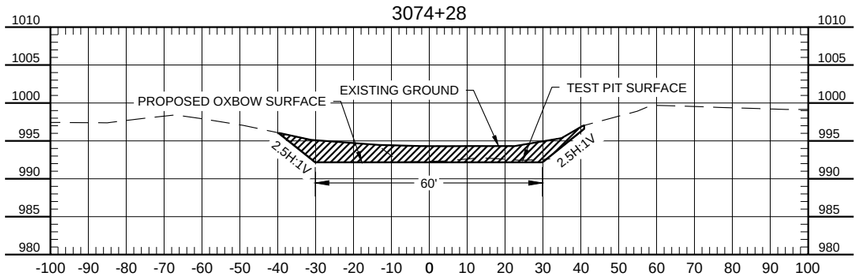
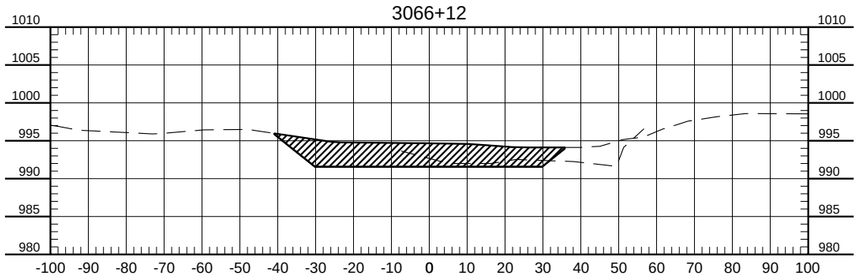
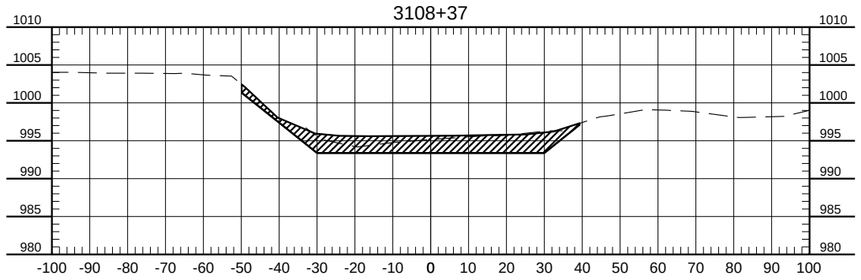
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

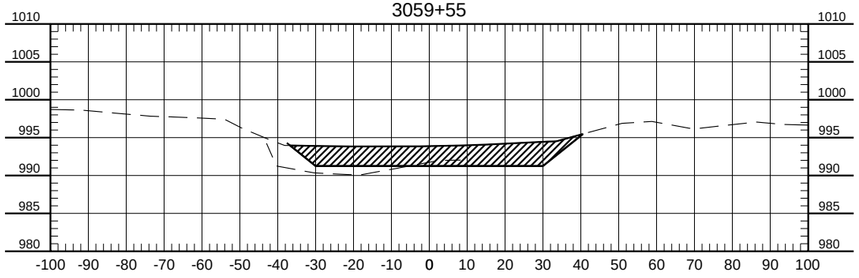
ALTERNATIVE 7 OXBOWS 1-7
CROSS SECTIONS

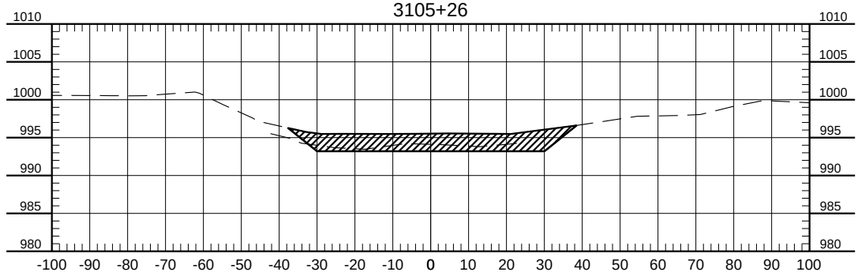
PROJECT NO. 1915-241

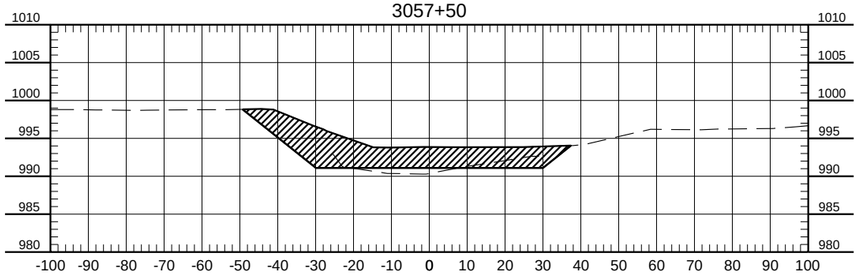


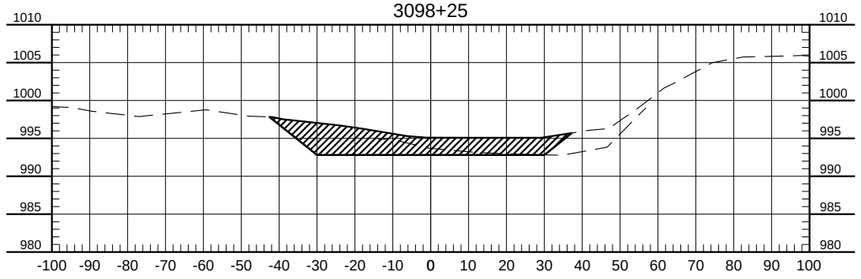

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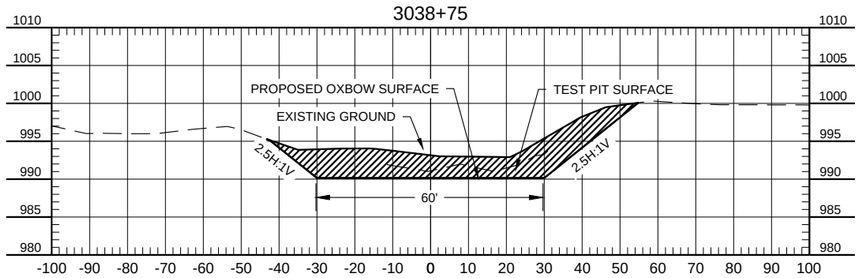
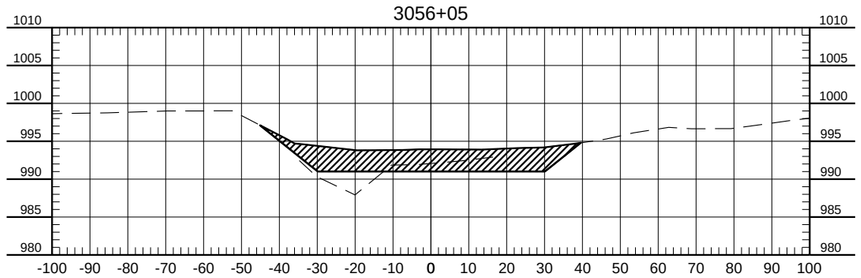
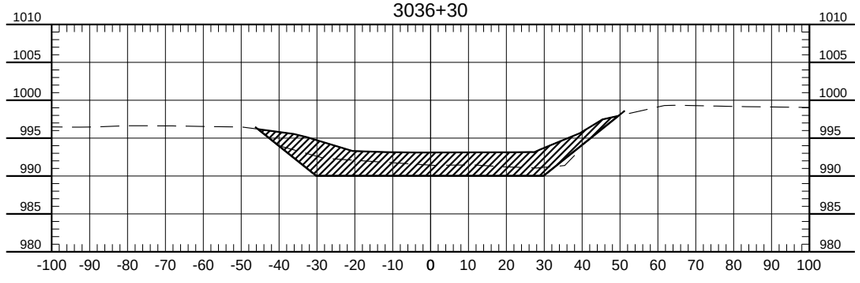
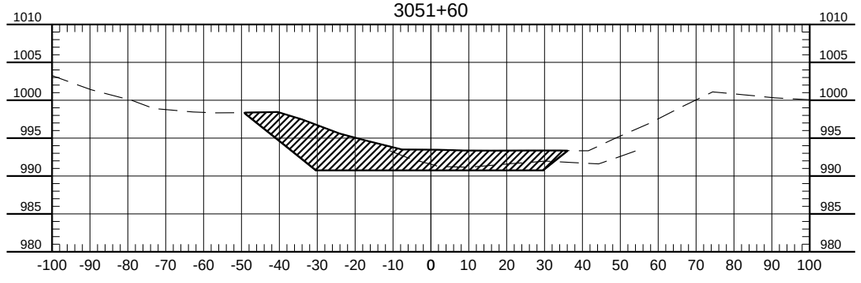
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

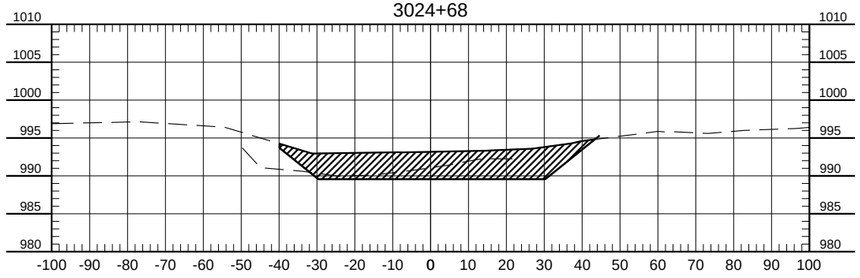
ALTERNATIVE 7 OXBOWS 1-7
CROSS SECTIONS
PROJECT NO. 1915-241

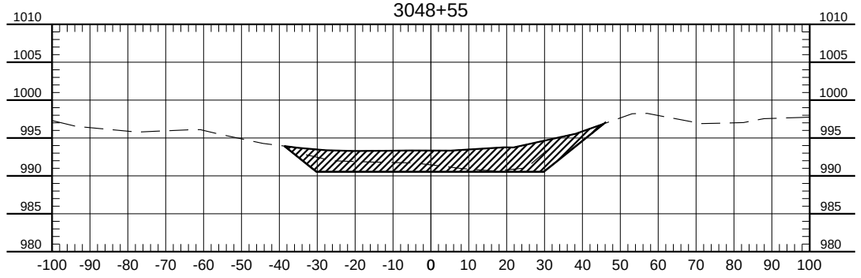


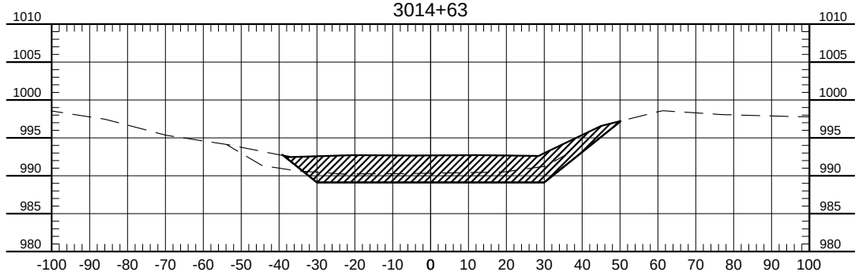



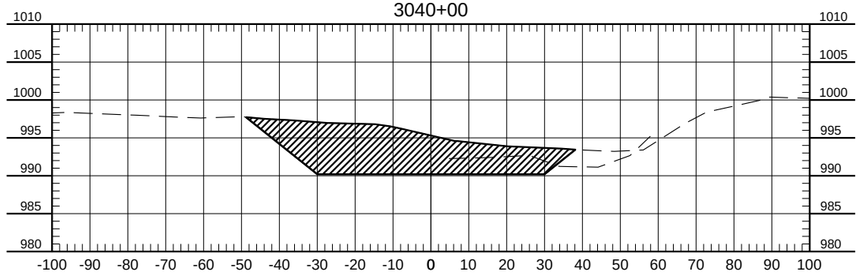

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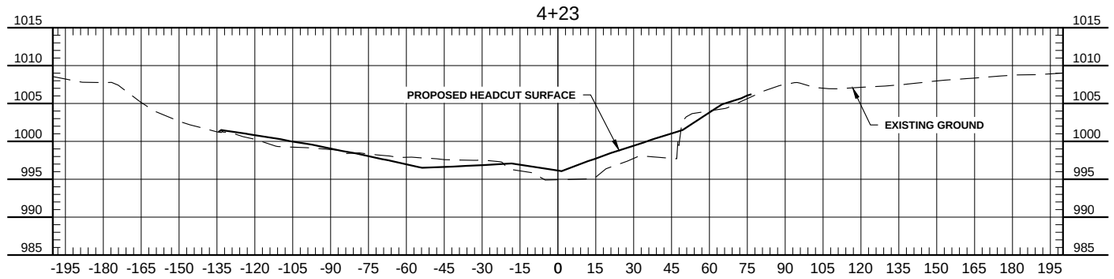
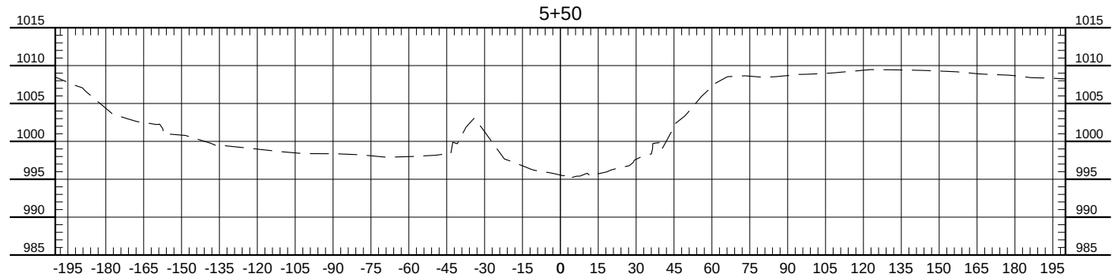
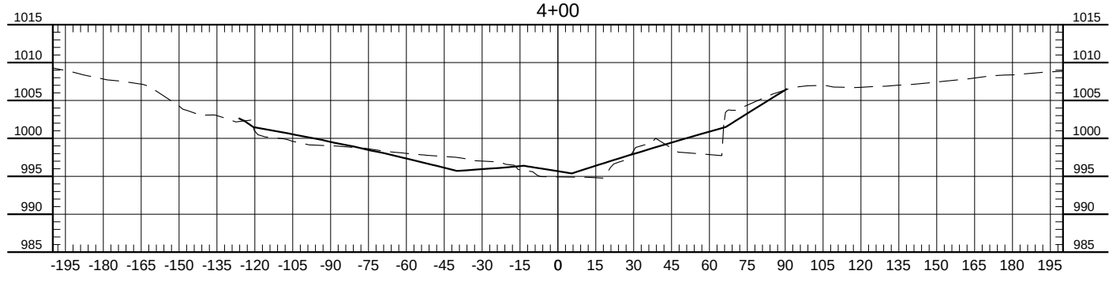
LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

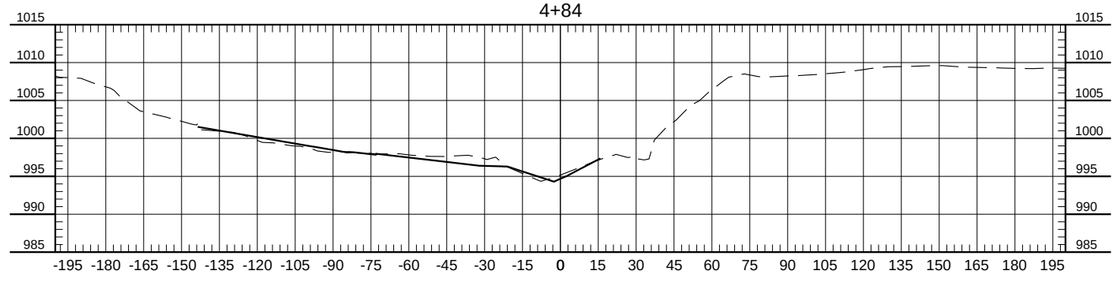
ALTERNATIVE 7 OXBOWS 1-7
CROSS SECTIONS

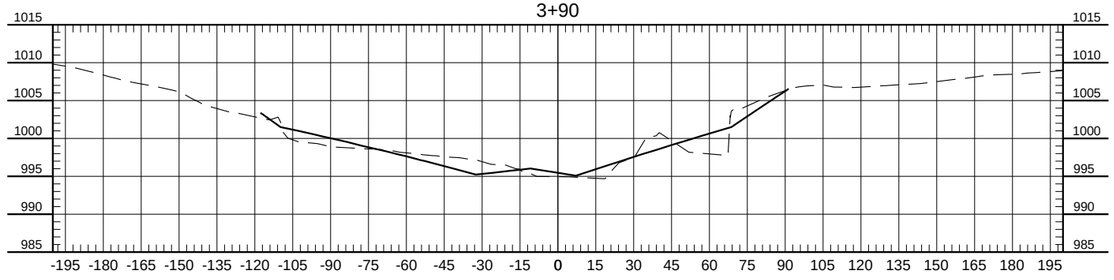
PROJECT NO. 1915-241

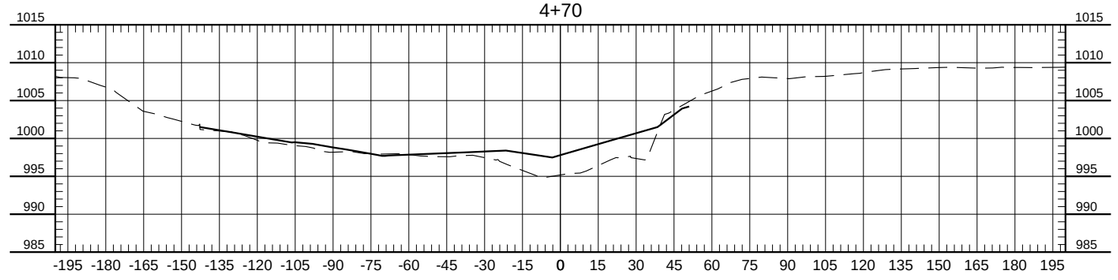


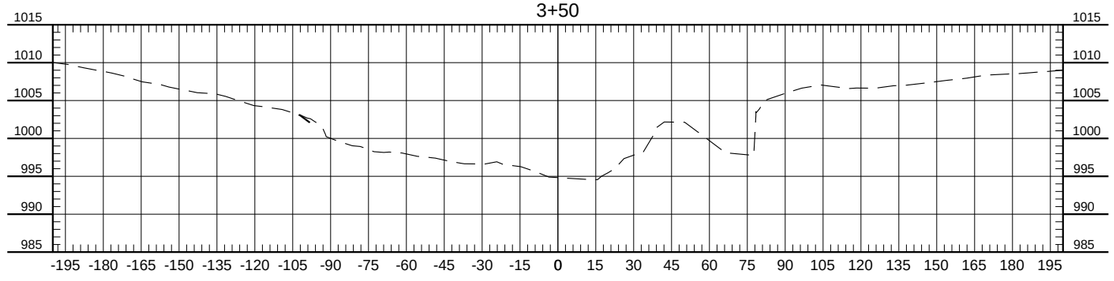



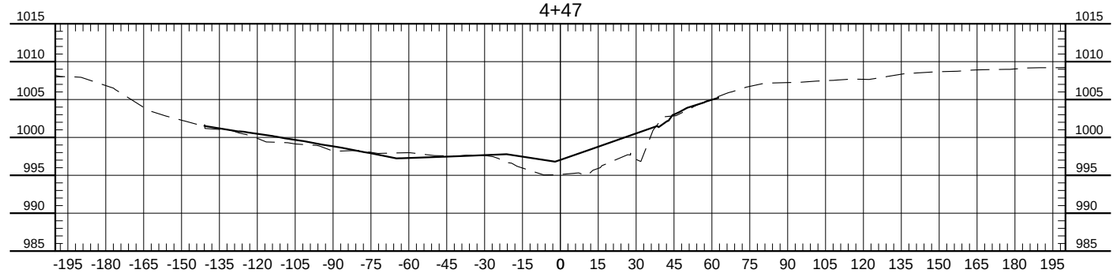



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LOWER OTTER TAIL RIVER RESTORATION
BUFFALO - RED RIVER WATERSHED DISTRICT
WILKIN COUNTY

ALTERNATIVE 8 HEADCUT CROSS SECTIONS

PROJECT NO. 1915-241

# APPENDIX B

Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155-4194

# Final Report
**Section 319 Project**

*Doc Type: Reporting/Final Report*

## Grant project summary

Project title: Lower Otter Tail River Restoration

Organization (Grantee): Buffalo-Red River Watershed District

Project start date: 4/1/2016 Project end date: 09/30/2019 Report submittal date: 9/30/2019

Grantee contact name: Bruce E. Albright Title: Administrator

Address: 1303 4th Avenue NE, PO Box 341

City: Barnesville State: MN Zip: 56514

Phone number: (218) 354-7710 Fax: (218) 354-2503 Email: balbright@brrwd.org

Basin (Red, Minnesota, St. Croix, etc.) /Watershed & 8 digit HUC:: 09020103 County: Wilkin and Otter Tail

**Project type** (check one):

- ☐ Clean Water Partnership
- ☐ Total Maximum Daily Load (TMDL)/Watershed Restoration or Protection Strategy (WRAPS) Development
- ☒ 319 Implementation
- ☐ 319 Demonstration, Education, Research
- ☐ TMDL/WRAPS Implementation

## Grant funding

Final grant amount: $240,675.86 Final total project costs: $442,617.47

Matching funds: Final cash: $201,941.61 Final in-kind: $0 Final Loan: $0

MPCA project manager: **Scott Schroeder**

## Executive summary of project (300 words or less)

This summary will help us prepare the Watershed Achievements Report to the Environmental Protection Agency. (Include any specific project history, purpose, and timeline.)

### Problem

The Minnesota Pollution Control Agency (MPCA) has listed the Lower Otter Tail River (LOTR) reach as impaired for exceeding the turbidity standard for aquatic life. A TMDL study for this reach of the river was completed in 2006. The upstream boundary of the 48-mile LOTR reach is the dam of Orwell Reservoir and the downstream boundary of the LOTR is the confluence with the Bois de Sioux River at Breckenridge. An 18 mile long reach of the LOTR was channelized into 11 miles in the 1950s as part of a US Army Corps of Engineers flood control project and this channelization induced headcutting which has been a major contributor to channel instability and bank failure resulting in excessive sediment loading since that time. Sediment loading to the river increases significantly through the LOTR study area. This is the only reach of the Otter Tail River impaired for turbidity. Based on the results of the TMDL study, the sediment load impairment is a result of stream instability, wind erosion, lack of crop cover during storm events and overland flows. The first implementation strategy discussed in the TMDL were BMPs to hold the water back in contributing drainage systems and release it slower into the LOTR. The second implementation strategy identified in the TMDL was channel restoration practices to stabilize streambank erosion and to speed up the development of an in-channel flood plain, increase sinuosity, restore stability, and help to return the river to a more natural form. Current stream instability and bank erosion is largely a result of channel straightening completed by the Corps of Engineers in the 1950s. Bank instability is a significant contributing factor to the turbidity impairment in the LOTR. The restoration design created through the 319 project addresses the stream instability in the Lower Otter Tail River

### Waterbody improved

The Lower reach of the Otter Tail River was the target of the restoration design work. While the River restoration will take more

time to implement, implementation of sediment controls have begun along the river. The terrain analysis completed as part of this 319 project was used to identify the twenty worst gully locations, and the Wilkin SWCD in cooperation with the Buffalo-Red River Watershed District is in the process of implementing a number of grade stabilizations along the river. Stabilizing the 20 worst gullies are estimated to reduce sediment delivery to the Otter Tail River by 850 tons per year. This work is being funded through a Clean Water Fund grant obtained by the Wilkin SWCD with technical assistance from the BRRWD. In addition, the BRRWD in cooperation with Otter Tail County (through a separate Clean Water Fund Grant) is implementing a grade stabilization project along the outlet of Judicial Ditch No. 2 which is expected to reduce sediment loading to the Otter Tail River by 800 tons per year. This project is expected to be completed by November 2019. The BRRWD is also going to complete the retrofit of Wilkin County Ditch No. 27 in 2020 which will address sediment entering the Otter Tail River in this targeted reach. While all of these efforts will improve water quality on the Otter Tail River, restoration of the river will be necessary to meet State Water quality standards.

### Project highlights

The project has a number of objectives. The first objective is to engage the public through public meetings and outreach. This was accomplished by holding a series of meetings with landowners: project kick-off to make them aware of the project, project preliminary design meeting to disseminate what was learned from the survey work, and a final restoration design meeting to disseminate the recommended restoration design. Additional outreach was completed by the BRRWD though mailings and individual landowner phone calls and meetings, and by the Wilkin SWCD through individual landowner meetings to promote sediment BMP adoption. The second objective was to determine the existing conditions of the channel which involved collecting existing channel information. The third project objective was to complete a restoration design to address channel instability in the Lower Otter Tail River.

### Results

The results of the project included providing education to the public and the development of the engineered implementation roadmap critically needed to reduce channel erosion and help achieve water quality standards along the Otter Tail River. The engineering report, detailed plans, and specifications will be used to direct future management, construction work, and conservation practices that will result in long-term water quality benefits to the Otter Tail River.

### Partnerships (Name all partners and indicate relationship to project)

Wilkin County/Soil and Water Conservation District – The Wilkin County Environmental office helped to coordinate meetings with the project team (MN DNR, Wilkin SWCD, and BRRWD) early in project development. The Wilkin SWCD was instrumental in applying and receiving a Clean Water Fund grant (which is providing much of the project cash match) through the MN Board of Water & Soil Resources. The Wilkin SWCD has also been meeting with landowners individually on installation of sediment best management practices on their properties. Acquisition of land for the river restoration will likely involve using conservation programs (such as Conservation Reserve Enhancement program and Reinvest in Minnesota) to acquire easements. It is anticipated that the Wilkin SWCD will be involved in this acquisition.

### Pictures

**Photo 1 - River Elevation Survey**