EXHIBIT MH-3

$250.00 ____ Minnehaha County
____ Sioux Falls Joint
_____ Dell Rapids Joint

CONDITIONAL USE PERMIT APPLICATION

Minnehaha County
Office of Planning and Zoning
Administration Building, 415 N. Dakota Ave.
Sioux Falls, SD 57104
Phone: 605-367-4204
Website: www.minnehahacounty.gov/dept/pl/pl.php

Petition #: _____
Date: _____
Filing Fee: _____
Receipt #: _____

FILING FEE IS NON-REFUNDABLE

I/We, the undersigned, do hereby petition for approval of a conditional use permit on the following described property and authorize representatives of Minnehaha County to enter the property for inspection purposes.

Legal description (please print or type): See information on next page

Parcel Size _____262.24 acres_____

Address or General Location __48231 259TH ST_____

Existing Zoning District ___A1/I1_____

Purpose ___Expansion of existing hard rock quarry_____
_____

Petitioner (Print) Sweetman Construction Co. (dba Knife River)

Signature

Date 6/26/25 Phone (605) 336-5776

Address 1500 N Sweetman PL

Sioux Falls SD 57107

City State Zip

Email colin.chatterton@kniferiver.com

■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■

Owner (Print)

If different than above

Signature

Date Phone

Address

City State Zip

Office use only

Location _____
Checked By _____
Given Signs_____
Site Plan _____
Add'l Reports _____
PC Date _____
PC Action _____
CC Date _____
CC Action _____
Effective Date _____
Purpose

www.kniferiver.com

1500 N Sweetman Place
PO Box 84140
Sioux Falls, SD 57117-4140
(605) 336-5760
(605) 334-6221 FAX

June 26, 2025

Minnehaha County
Office of Planning & Zoning
Administration Building, 415 N. Dakota Ave.
Sioux Falls, SD 57104

RE: Knife River Conditional Use Permit Application, East Corson, Parcels 13848, 13942, 55302, 55303, 55304 and 55305

With this letter, please find the requirements of Additional Use Regulations for Rock, Sand, and Gravel Extraction, Section 12.08 of the Minnehaha County Zoning Ordinance. The following information is being provided to request expansion of a quartzite quarry on Knife River property. This property is adjacent to existing Knife River sand and gravel mining operations.

Knife River proposes the quarry encompass an additional 85.7 acres to the 39.7-acre area previously permitted for total quarry area of 125.4 acres. The legal description of the parcels to be impacted are:

SW1/4 (EX RY & H-1, H-2 & H-3) 14 102 48 BRANDON TOWNSHIP 102-48; PT NW1/4 NW1/4 LYING N OF TOWNSHIP ROAD 23 102 48 BRANDON TOWNSHIP 102-48; LOT 1 KUEHL'S ADDN NW1/4 23 102 48 BRANDON TOWNSHIP 102-48; TRACT 2 HUNTERS ADD NW 1/4 23 102 48 BRANDON TOWNSHIP 102-48; TRACT 3 HUNTERS ADD NW 1/4 23 102 48 BRANDON TOWNSHIP 102-48; ALL THAT PT NW1/4 LYING E OF RR ROW & E OF HY (EX HUNTERS ADD & EX KUEHL'S ADDN) 23 102 48 BRANDON TOWNSHIP 102-48

Operations at the site will see continuation of mining quartzite rock. Quartzite materials will be drilled and blasted. The resulting rock will be crushed and screened on site utilizing permanent infrastructure.

Thank you for your consideration. If you have any questions or require further information, please contact me at (605) 336-5776.

Colin Chatterton, CPESC, CPISM
Environmental Manager

1. **Maps (attached):**
    - Corson Quarry Mining Operations Plan Cover Page
    - Corson Quarry Existing Conditions
    - Corson Quarry Mined Conditions
    - Corson Quarry Restoration

2. **Surface Land Use and Vegetation**

The area subject to this application is currently used for agricultural purposes (grazing or cropland). The subject parcels lie east of County Road 11 and north of 259th Street. The proposed quarry lies on 125 acres of parcels 13848, 13942, 55302, 55303, 55304 and 55305 east of the Burlington Northern (BN) rail line.

The site is located in the US EPA's Ecoregion 47a, Loess Prairies of Iowa and South Dakota, which is part of the Western Corn Belt Plains. This area is described as follows:

> *The high agricultural productivity of the Western Corn Belt Plains ecoregion is due to its fertile soil, temperate climate, and adequate precipitation during the growing season. This ecoregion has a relatively homogeneous topography of level to gently rolling glacial till plains with areas of morainal hills and loess deposits. The original tallgrass prairie vegetation has been converted to intensive row-crop agriculture of corn, soybeans, and feed grains to support livestock production.*
>
> *The Loess Prairies of Iowa and South Dakota surround the perimeter of the Des Moines lobe of the Late Wisconsinan glaciation. Of the two areas in South Dakota, the northern one is distinguished from neighboring regions by its rock-free soil and a paucity of wetlands. The southern area is more highly dissected, with deciduous woodland and brush on the steeper slopes and in the draws.*

There are two intermittent streams that bisect the site from east to west. These streams drain small watersheds with ultimate discharge to the Split Rock Creek. A Wetland Delineation was completed for the site (see Appendix A). Wetlands are found along the edges of the intermittent streams and Knife River is currently working through the individual permit process with the USACE to reroute the tributaries flowing through the future mine site (see Appendix B)

A Level III Cultural Resource Inventory was completed for the site (see Appendix C). The railroad, a railroad bridge and culvert were considered eligible for the National Register of Historic Places. All noted artifacts are outside of the project area and will not be adversely affected. A determination of no adverse effects to historic properties was recommended.

3. Hydrologic Study

The site is in the Split Rock Creek Watershed within the Central Big Sioux River Watershed. Natural drainage makes it way to Split Rock Creek and eventually the Big Sioux River. A Drainage Analysis was completed by Westwood Engineering (see Appendix D). From the hydrologic evaluation, it appears that the proposed Phase I mine development will not negatively impact Split Rock Creek since dewatering needs are expected at levels well below modeled 10-year flows that will travel through the creek diversion. For the floodplain evaluation, there will be no impact on 100-year flood levels based on HEC-RAS modeling that was performed. A floodplain development permit was obtained during this process as well.

A previous study by Barr evaluated potential groundwater inflow rates to the proposed mine pit (see Appendix E). From this study, it is predicted that between 21 and 136 gpm will enter the mine via groundwater flows (given quartzite as the dominant material), but with larger seeps the inflow may be closer to 500 - 800 gpm. As the mine is developed, it will be necessary to dewater the excavation with pumping, along with appropriate treatment. This dewatering discharge will be routed to Split Rock creek via either the tributary to the west or the newly constructed creek diversion.

Groundwater is estimated to be greater than 50 feet below grade in the mining area. No recorded wells (not owned by Sweetman) are identified as being within 300 feet of the area's boundaries. Surficial geology at the site shows 5 to 30 feet of glacial deposits overlay the Sioux Quartzite. Quartzite was present in all boreholes during exploratory drilling

4. Reclamation Plan

See attached maps. The overburden will be reclaimed to maximum slopes of 3:1. The quarry will be reclaimed in part, based on depth, water table, and terrain. Reclamation will not be possible until all mining is completed and may require limited construction of temporary features including ponds, basins, roads, safety, and drainage features. It is anticipated the surrounding land will be returned to agricultural land, likely for grazing, while the quarry area will become a water filled reservoir.

5. Development Criteria

- Buffer Areas

  Buffer areas are shown on the Existing Conditions and Mining Conditions Maps. The are no residences (not owned by Sweetman Const. Co.) that will be in the 1,000-foot buffer area. Mining will stay at least 50 feet from township/county road rights of way. A minimum 10-foot-high berm will be placed along all sides of the new quarry extent and vegetated appropriately.

- Hours of Operation

  Mining operations may occur on Monday through Friday from 7 A.M. to 6 P.M. and Saturday from 8 A.M. to 12 P.M. No operations will be allowed on legal holidays. Maintenance operations not creating off site noise may occur outside of the designated hours of operation.

- Visual Considerations

  Actions to mitigate impacts to neighbors and highway travelers include:
  - Berms will be placed and vegetated as necessary to alleviate visual concerns.
  - Close coordination with Township, County, Municipal, and State agencies to identify and act to prevent problems.

- Blasting

  All blasting will be done in compliance with U.S. Department of the Interior Office of Surface Mining standards. This will include monitoring ground vibration and air blast. An alert system is in place for impacted residents within 1 square mile of the current mine footprint (excluding some that have opted out). This alert is sent 24 hours prior to blasting occurring and will continue to be utilized moving forward.

- Noise

  Noise levels will not exceed an average of 55 decibels recorded over a 10- minute period measured at the nearest residence of concern. Knife River will test and provide a noise survey if complaints arise.

- Air Quality

  At the County's discretion, ambient air monitoring will occur according to State of South Dakota regulations. Impact on air quality will be minimized by following company procedures for controlling fugitive dust from mining and associated operations. Dust from traffic within the operational area will be controlled with water or applications of calcium chloride. Dust from the screening and conveying process is controlled by ensuring moisture is present in the material being processed. If visible dust can be observed leaving the crushing/conveying process, water is added to the aggregate material as it is fed into the process.

- Hydrology, Dewatering, and Drainage

See item 3 above. It is anticipated that dewatering will be required as mining progresses. This will be in accordance with SD DANR NPDES permitting and the site SWPPP. Drainage around the quarry area is routed as shown on the attached maps.

- Haul Roads

  Materials from the quarry area will be conveyed south across land owned by Knife River. Quartzite material mined will be processed (crushed/screened) at the quarry. See attached maps for haul routes and proposed infrastructure. Material will be shipped from the Corson site utilizing existing truck and rail systems, with the addition of one new rail spur off the existing BNSF main line.

- Operator Surety

  Sweetman Construction Co. (dba Knife River) will provide whatever surety is required by Minnehaha County.

- Reclamation

  See item 4 above.

Corson Quarry

MINING OPERATIONS PLAN

COVER PAGE

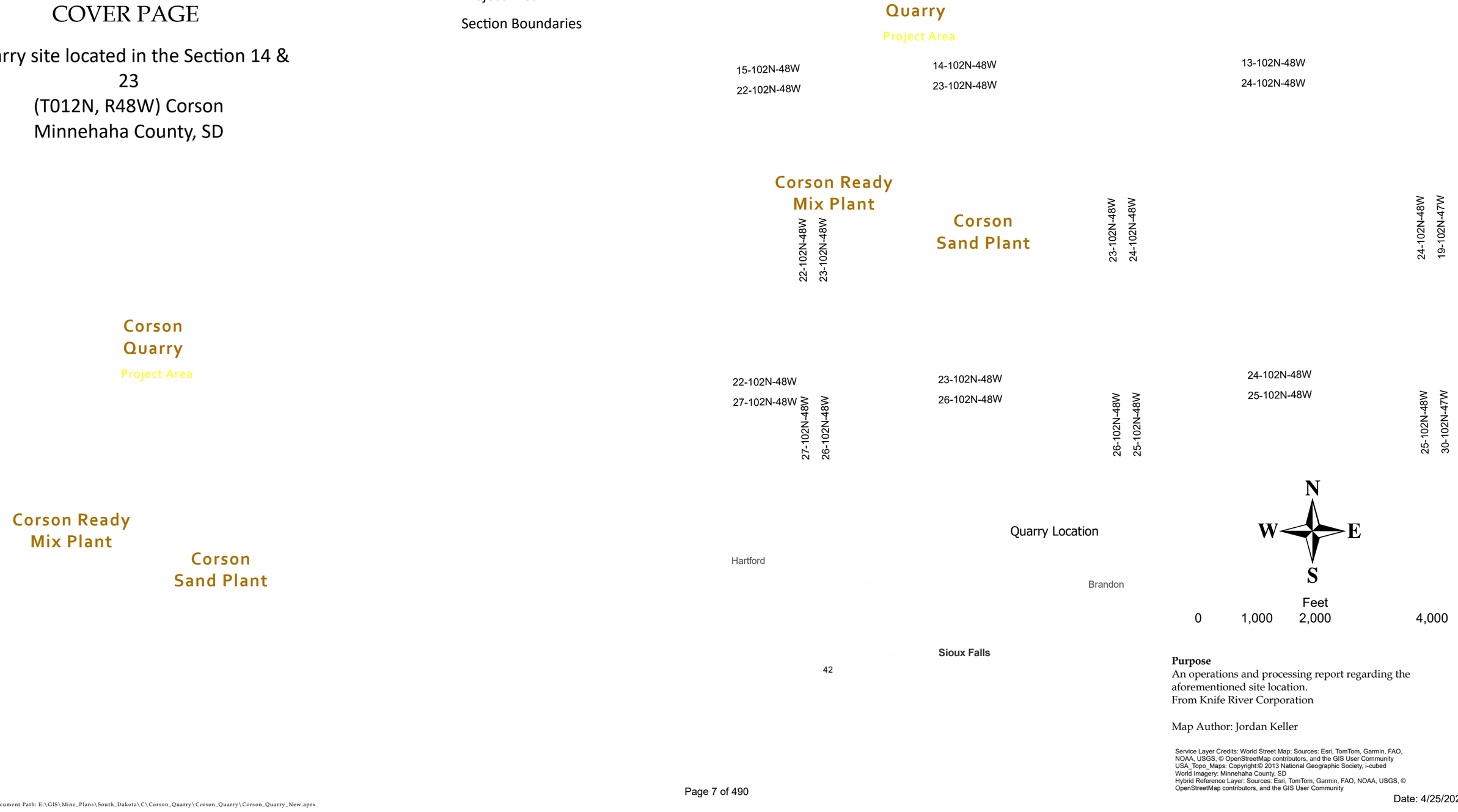
Quarry site located in the Section 14 & 23
(T012N, R48W) Corson
Minnehaha County, SD

Legend

Knife River Property

Project Area

Section Boundaries



Purpose
An operations and processing report regarding the aforementioned site location.
From Knife River Corporation

Map Author: Jordan Keller

Service Layer Credits: World Street Map: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community
USA_Topo_Maps: Copyright:© 2013 National Geographic Society, i-cubed
World Imagery: Minnehaha County, SD
Hybrid Reference Layer: Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Date: 4/25/2025

ArcMap Document Path: E:\GIS\Mine_Plans\South_Dakota\C\Corson_Quarry\Corson_Quarry\Corson_Quarry_New.aprx

North
Quarry Permit Expansion
54.9 Acres

Existing Quarry
Permit Area: 39.7
Acres

South Quarry Permit
Expansion
30.9 Acres

Burlington Northern Railroad

259th St

Corson Quarry

Existing Conditions (August 2024)

Sec 14 & 23
T102N, R48W
Corson SD

Legend

- Existing Quarry Permit Area
- Streams
- Wetland (Sayre Delineation)
- Knife River Property
- Expansion Footprint
- 10' Contour
- 2' Contour

N
W E
S

Feet
0 275 550

KNIFE RIVER

Document Path: E:\GIS\Mine Plans\South Dakota\C\Corson Quarry\Corson Quarry\Corson Quarry New.aprx

Map Author: Jordan Keller

STREAM REROUTE PLANNED IN ACCORDANCE WITH ARMY CORPS OF ENGINEERS APPROVAL PROCESS

Permit Area
125.4 Acres

Burlington Northern Railroad

259th St

Rock Creek

Corson Quarry

Mined Conditions

Sec 14 & 23
T102N, R48W
Corson SD

Legend

- Wetland (Sayre Delineation)
- Expansion Footprint
- Berms
- Streams
- Knife River Property
- 10' Contour
- 2' Contour

N
W E
S

Feet
0 275 550

KNIFE RIVER

Document Path: E:\GIS\Mine Plans\South Dakota\C\Corson Quarry\Corson Quarry New.aprx

Map Author: Jordan Keller

Open water
filling remaining
quarry extent

Burlington Northern Railroad

259th St

Corson Quarry

Restoration

Sec 14 & 23
T102N, R48W
Corson SD

Legend

- Wetland (Sayre Delineation)
- Open Water
- Streams
- Knife River Property
- 10' Contour
- 2' Contour

N
W E
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Feet
0 275 550

KNIFE RIVER

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Map Author: Jordan Keller

MEMORANDUM

Date: November 1, 2021

Re: Corson Property
File 0033065.00

To: USACE Minnehaha County Project Manager

Cc: Ron Klinker, Knife River Corporation

From: Matthew Vollbrecht

With this Memo, Westwood Professional Services, on behalf of Knife River, requests the Omaha District of the US Army Corps of Engineers assign a Project Manager and issue an Official Approved Jurisdictional Determination for the Corson Pit Project.

The Project Site is located in Corson Township, Minnehaha County, South Dakota (**Exhibit 1**). The Site consists of 232.5 acres comprised of seven parcels. (PIN #'s 01-17-23-100-008-000, 01-17-23-100-004-000, 01-17-23-100-005-000, 01-17-23-100-006-000, 01-17-23-100-007-000, 01-17-14-300-001-000, 01-17-23-100-009-000).

The Project Area consists mostly of grazed pasture and cropland, with a quarry operation in the east-central portion of the property and two single-family residences in the southwestern quadrant. The Site is mostly surrounded by agricultural land with the exception of a gravel mining operation to the south. It is bordered to the south by Split Rock Creek and to the west by Highway 11. The Site is bisected east to west by 259th Street and north to south by a railroad easement.

The property was delineated by Westwood Professional Services from September 22 through October 1, 2021. The Delineation Report dated October 18, 2021, is included in this memo.

Westwood Professional Services requests the Omaha District of the US Army Corps of Engineers assign a Project Manager and issue an Official Approved Jurisdictional Determination for the Corson Pit Project. Site photos for the delineated features can be found in the attached Delineation Report. Westwood can also provide the delineated water feature data to the Omaha District in the Corps of Engineers Bulk Upload Spreadsheet or a summary Excel file. Please contact me if you have any questions or need any further information.

PREPARED FOR:

Mr. Ron Klinker
Environmental and Land Development Manager
Knife River
4787 Shadow Wood Drive NE
Sauk Rapids, MN 56379

PREPARED BY:

Wetland Delineation Report

Corson Quarry Project

Prepared for:
Mr. Ron Klinker
Knife River
4787 Shadow Wood Drive NE
Sauk Rapids, MN 56379

Prepared by:
Westwood Professional Services
12701 Whitewater Drive, Suite 300
Minnetonka, MN 55343
(952) 937-5150

Project Number: 0033065.00
Date: 10/18/2021

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Exhibit 5: Delineated Features

APPENDICES

Appendix A: Wetland Delineation Data Forms

Appendix B: Wetland Delineation Photographs

Appendix C: Watercourse Data Forms and Photographs

1.0 PURPOSE

This report with the attached exhibits and appendices constitutes the wetland delineation report for the Corson Quarry Project ("Project" or "Site"), an approximately 232.5-acre area in Corson Township, Minnehaha County, South Dakota (PIN #'s 01-17-23-100-008-000, 01-17-23-100-004-000, 01-17-23-100-005-000, 01-17-23-100-006-000, 01-17-23-100-007-000, 01-17-14-300-001-000, 01-17-23-100-009-000). This report provides the required documentation for wetland boundary determinations in conformance with the United States Army Corps of Engineers (USACE) Wetlands Delineation Manual (Environmental Laboratory, Waterways Experiment Station, 1987) and the Regional Supplement to the USACE Wetland Delineation Manual: Midwest Region (U.S. Army Corps of Engineers, 2010).

2.0 SITE LOCATION AND DESCRIPTION

The Site is located in Sections 14 & 23, T102N, R48W, Corson Township, Minnehaha County, South Dakota (Exhibit 1). It consists mostly of grazed pasture and cropland, with a quarry operation in the east-central portion of the property and two single-family residences in the southwestern quadrant. The Site is mostly surrounded by agricultural land with the exception of a gravel mining operation to the south. It is bordered to the south by Split Rock Creek and to the west by Highway 11. The Site is bisected east to west by 259th Street and north to south by a railroad easement. The landscape slopes gently toward the central and southern portions of the Site, with the lowest elevations occurring near Split Rock Creek and an unnamed, south-flowing, tributary. Elevations range from 1,320 feet to 1,410 feet above mean sea level (msl).

3.0 FIELD DELINEATION METHODOLOGY

3.1 Mapping

Prior to delineating wetland boundaries in the field, the National Wetlands Inventory (NWI) mapping (Exhibit 2), the National Hydrography Dataset (NHD) (Exhibit 2), the Minnesota Department of Natural Resources (MN DNR) Public Waters and Wetlands Inventory (PWI) (Exhibit 2), and the Natural Resource Conservation Service (NRCS) Soil Survey Geographic database (SSURGO2) for Minnehaha County (Exhibit 3) were reviewed. Elevation mapping was completed using LiDAR contours (Exhibit 4).

3.2 Wetland Delineation Methodology

The field delineation was conducted from September 22 through October 1, 2021, by a wetland delineator from Westwood using a level two routine determination method set forth in the USACE Wetland Delineation Manual and the supplemental methods set forth in the Regional Supplement to the USACE Wetland Delineation Manual: Midwest Region. Wetland data forms from the delineation are included in Appendix A. Wetland photographs from the delineation are included in Appendix B. Watercourse data forms and photographs are included in Appendix C.

Wetlands, if present, were classified according to Wetlands of the United States (U.S. Fish and Wildlife Service Circular 39; Shaw and Fredine; 1971) and Wetlands and Deepwater Habitats of the United States (FWS/OBS Publication 79/31; Cowardin et. al. 1979). Common and scientific names for vegetation identified in this report and on the attached data forms generally correspond with the nomenclature used in the 2018 National Wetland Plant List (Lichvar 2018). Wetland boundaries were located using a Trimble GPS unit capable of sub-meter accuracy.

3.3 Watercourse Delineation Methodology

Drainages within the Project were considered non-wetland Waters of the U.S. (WOTUS), as they may not exhibit all parameters required for wetlands (i.e. predominance of hydrophytes, hydric soils, and jurisdictional hydrology). Accordingly, their boundaries were delineated in the field by documenting their Ordinary High-Water Marks (OHWMs), as determined according to the USACE Regulatory Guidance Letter No. 05-05 (U.S. Army Corps of Engineers 2005). USACE regulations set forth at 33 CFR 328.3(e) defines the OHWM for purposes of Clean Water Act lateral jurisdiction which means that line on the shore established by the fluctuations of water and indicated by physical characteristics including:

- Natural line impressed on the bank
- Changes in the character of soil
- Presence of litter and debris
- Vegetation matted down, bent, or absent
- Leaf litter disturbed or washed away
- Deposition
- Bed and banks
- Change in plant community
- Shelving
- Destruction of terrestrial vegetation
- Wracking
- Sediment sorting
- Scour
- Multiple observed flow events
- Water staining

4.0 RESULTS

4.1 Mapping

A total of ten (10) NWI polygons are mapped within the Site; wetlands include freshwater emergent and riverine wetlands (Exhibit 2). A total of five (5) NHD flowlines, Split Rock Creek and four unnamed tributaries, are also mapped on the Site. The NHD and NWI datasets significantly overlap one another.

The NRCS SSURGO2 for Minnehaha County indicates that the soils listed in Table 4.1 are mapped within the Delineation Area (Exhibit 3). Based on the NRCS Web Soil Survey Hydric

Rating, four soil types are classified as predominantly hydric, and the remaining soil types are non-hydric.

Table 4.1. Soil Summary Table

Map Symbol[1]	Map Unit Name[2]	Rating[2]	Percent Hydric Soil[3]
AcB	Alcester silty clay loam, cool, 2 to 6 percent slopes	Non-hydric	0
BcA	Benclare-Corson complex, 0 to 2 percent slopes	Predominantly Non-hydric	5
Bo	Bon loam, 0 to 2 percent slopes, occasionally flooded	Predominantly Non-hydric	9
Ch	Chaska loam, channeled, 0 to 3 percent slopes, frequently flooded	Predominantly Hydric	93
CrD	Crofton-Nora complex, 9 to 15 percent slopes	Predominantly Non-hydric	6
DgD	Delmont-Talmo complex, 9 to 15 percent slopes	Non-hydric	0
FaB	Flandreau loam, 2 to 6 percent slopes	Non-hydric	0
Lb	Lamo silty clay loam, channeled	Predominantly Hydric	87
IrE	Ihlen-Rock outcrop complex, 4 to 35 percent slopes	Non-hydric	0
MnB	Moody-Nora complex, 2 to 6 percent slopes	Predominantly Non-hydric	2
NcC	Nora-Crofton complex, 6 to 9 percent slopes	Predominantly Non-hydric	3
Ob	Obert silty clay loam, 0 to 1 percent slopes	Predominantly Hydric	99
Wk	Whitewood silty clay loam, 0 to 2 percent slopes	Predominantly Hydric	85

[1] – Soils determined using GIS geospatial query clipping the NRCS Soil Survey Geographic (SSURGO2) spatial data by Project boundaries.

[2] – As indicated in the SSURGO2 database

[3] Where percentages are small (e.g. < 15 %) the hydric soil is likely an inclusion that is not recognized in the map unit name. The absence of a value does not necessarily indicate the absence of hydric soils, but that the relative percentages of included minor soils have not been determined.

4.2 Antecedent Precipitation

Antecedent precipitation data was evaluated for the 3 months prior to the site visit using AgACIS WETS Station: Sioux Falls Foss Field, South Dakota. Table 4.2 constitutes the "NRCS Method/3-Month Prior Method" using the Precipitation Documentation Worksheet from the Minnesota Climatology Working Group. Antecedent precipitation was determined to be wet for the three months prior to the field delineation.

Table 4.2. Precipitation Documentation Worksheet (Score using 1981-2010 time period)

values are in inches A 'R' following a monthly total indicates a provisional value derived from radar-based estimates.	first prior month: **September 2020**	second prior month: **August 2020**	third prior month: **July 2020**
estimated precipitation total for this location:	**3.21**	**6.29**	**4.9**
there is a 30% chance this location will have less than:	1.69	1.93	1.73
there is a 30% chance this location will have more than:	3.36	3.67	3.76
type of month: dry **normal** wet	**normal**	**wet**	**wet**
monthly score	**3*2=6**	**2*3=6**	**1*3=3**
multi-month score: 6 to 9 (dry) 10 to 14 (normal) 15 to 18 (wet)		**15 (WET)**	

4.3 On-Site Wetland and Watercourse Delineation Results

From September 22 through October 1, 2021, Westwood delineated eight wetlands, two ponds, and seven watercourses within the Project Area. Summaries of each wetland's characteristics are provided in Table 4.3. Summaries of each watercourse's characteristics are provided in Table 4.4. Exhibit 5 is a map showing delineated wetland and watercourse boundaries. Data forms documenting wetland and upland characteristics are located in Appendix A. Photos of delineated wetlands and non-wetland sample points are located in Appendix B. Watercourse data forms and photographs are located in Appendix C.

Table 4.3. Delineated Wetlands

Wetland Name	Acres	Mapped on NWI	Circular 39	Cowardin Classification
WB-01	2.27	Yes	Type 2	PEM1B
WB-02	2.02	Yes	Type 2	PEM1B
WB-03	0.09	No	Type 2/ Type 5	PEM1B/ PUBx
WB-05	0.16	No	Type 2	PEM1B
WB-06	0.92	Yes	Type 2/ Type 3	PEM1B/ PEM1C
WB-07	0.67	No	Type 2/ Type 3	PEM1B/ PEM1C
WB-08	0.39	No	Type 7	PSS1B
WB-10	8.39	Yes	Type 2/ Type 3/ Type 5	PEM1B/ PEM1C/ PUBx
PO-01	1.58	No	N/A	PUBx
PO-02	0.54	No	N/A	PUBx

Table 4.4. Delineated Watercourses

Watercourse Name	Length (Linear Feet)	Area (acres)	Mapped on NWI	Mapped on NHD	NHD Name	Flow Characteristics
WC-01	886.9	0.02	Yes	Yes	Unnamed tributary	Intermittent
WC-02	3,372.9	0.04	Yes	Yes	Unnamed tributary	Perennial
WC-03	2,217.4	2.48	Yes	Yes	Split Rock Creek	Perennial
WC-04	483.0	0.01	Yes	No	Unnamed tributary	Intermittent
WC-05	423.3	0.03	No	No	Unnamed tributary	Intermittent
WC-06	2,654.5	0.30	Yes	Yes	Unnamed tributary	Intermittent
WC-07	705.8	0.02	No	No	Unnamed tributary	Intermittent

Other Areas

Non-Wetland Sample Point NWB-01 was taken in an excavated basin located in the northeast portion of the Site. The dominant vegetation was smooth brome (*Bromus inermis*, FACU). Neither hydric soil or wetland hydrology indicators were observed.

Non-Wetland Sample Point NWB-02 was taken in a swale feature approximately 150 feet north of WB-02 and is mapped on the NWI dataset as R4SBC. Dominant vegetation was a mix of smooth brome and quackgrass (*Elymus repens*, FACU). Hydric soil may be present, a horizon that would confirm an A12 indicator, if present, was too deep to sample while on-site. No hydrology indicator other than geomorphic position was met. Non-Watercourse Sample Points NWC-01 and NWC-02 (Appendix C) were also taken along this swale and provide further evidence that the area does not meet watercourse OHWM criteria or wetland indicator criteria.

Non-Wetland Sample Point NWB-03 was taken in a concave area in a swale north of WB-05. This area was dominated in quackgrass and did not meet hydrophytic vegetation criteria, however a small amount of sedge and rush species were present in the vicinity. Soils met the redox dark surface indicator. No hydrology other than geomorphic position was observed.

5.0 CONCLUSIONS

Westwood delineated eight wetlands and two ponds totaling 17.03 acres, and seven watercourses totaling 10,743.8 linear feet and 3.44 acres within the Corson Quarry Project. Westwood requests that the USACE review and process this report and provide written concurrence that the extent of potentially jurisdictional water resources have been accurately identified.

6.0 CERTIFICATION

I certify that, to the best of my knowledge and belief, the wetland delineation completed for this Site is consistent with current wetland delineation practices and guidelines. I have the specific qualifications, education, training, and experience to complete wetland delineations and determinations in accordance with federal and state requirements.

Sincerely,
WESTWOOD PROFESSIONAL SERVICES

Audrey McTaggart
Wetland Scientist

Matthew Vollbrecht
Environmental Project Manager
Professional Wetland Scientist (PWS) No. 2115
MN Certified Wetland Delineator No.1101

7.0 LITERATURE CITED

Cowardin, L.M. , V.M. Carter , F.C. Golet , and E.T. LaRoe . 1979. Classification of Wetlands and Deepwater Habitats of the United States. U.S. Fish and Wildlife Service, Biological Services Program, Washington, DC, USA. FWS/OBS-79/31. 103pp.

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Exhibits

Corson Quarry Project

Corson Township, Minnehaha County, South Dakota

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ND

MT

MN

SD

Project

WY

IA

NE

South Dakota

Minnesota

Project

T102 R48

T102 R47

90

90

Brandon

N

0

Feet

2,000

Data Source(s): Westwood (2021); ESRI WMS USA Topo, National Geographic, & World Streets Basemaps (Accessed 2021); Census Bureau (2019).

Legend

Delineation Area Boundary

Municipal Boundary

Major Road

PLS Township Boundary

PLS Section Boundary

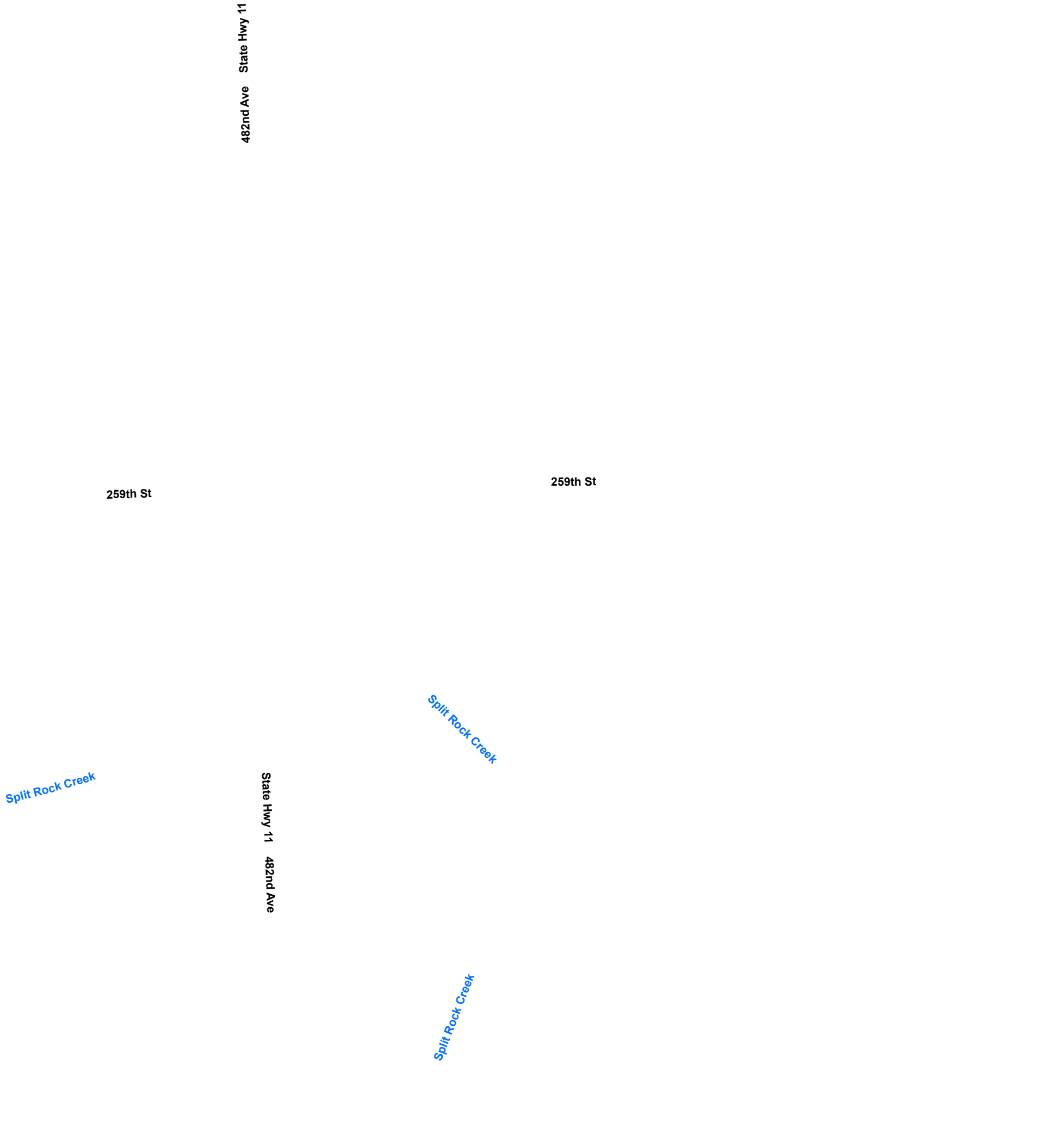
Corson Quarry Project

Minnehaha County, South Dakota

Project Location Map

EXHIBIT 1

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Data Source(s): Westwood (2021); South Dakota NAIP Imagery (2020); Census Bureau (2020); U.S. Fish and Wildlife Service (2020); Ducks Unlimited (2020); USGS NHD Dataset (2015); FEMA (2020).

Legend

- Delineation Area Boundary
- NHD Flowline
- NHD Waterbody
- NWI Wetland
- FEMA Floodplain

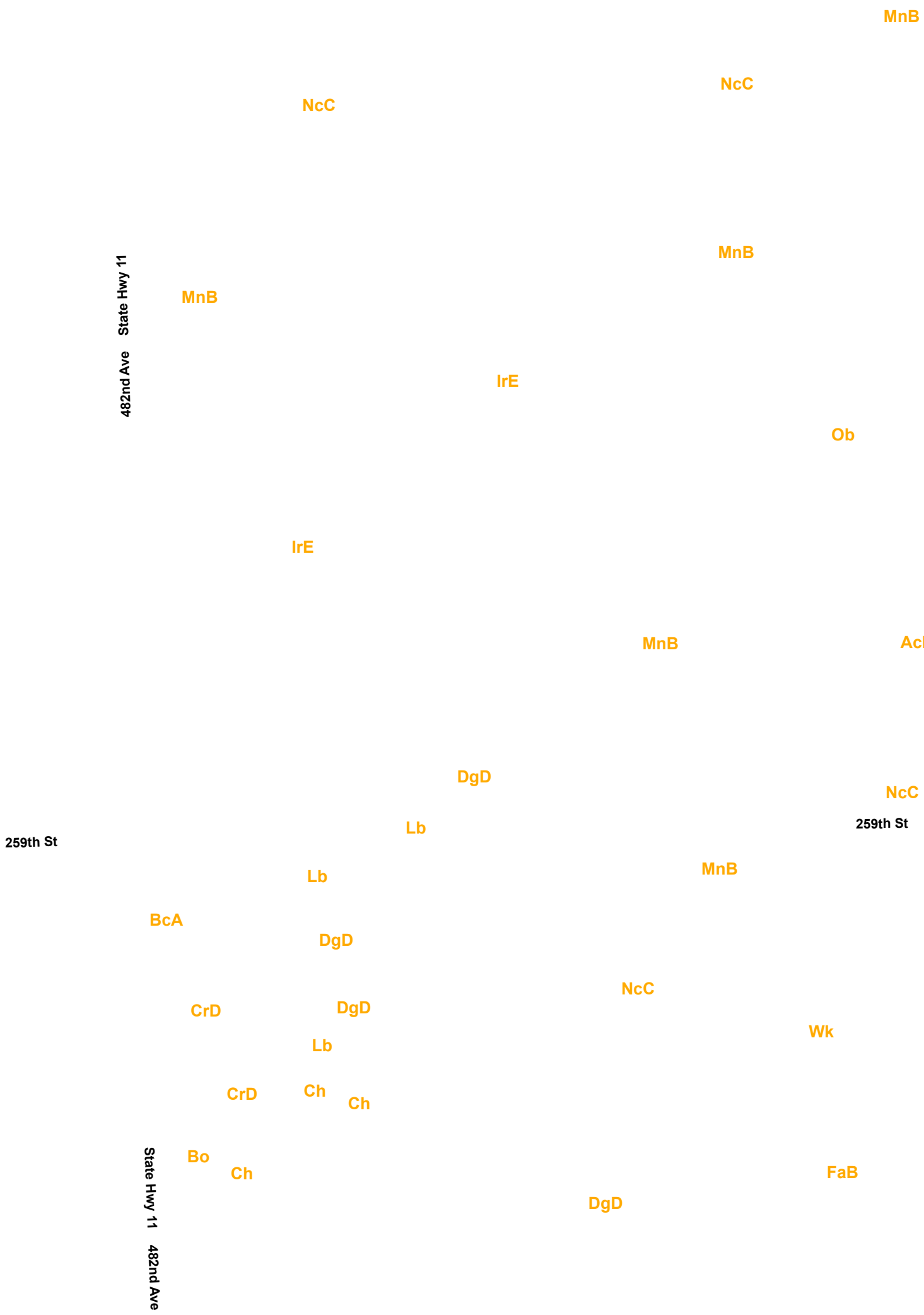
Corson Quarry Project

Minnehaha County, South Dakota

Water Resources Map

EXHIBIT 2

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Map Unit Symbol | Map Unit Name | Hydric Class | % Hydric

AcB | Alcester silty clay loam, cool, 2 to 6 percent slopes | Non-hydric | 0% Hydric
BcA | Benclare-Corson complex, 0 to 2 percent slopes | Predominantly Non-hydric | 5% Hydric
Bo | Bon loam, 0 to 2 percent slopes, occasionally flooded | Predominantly Non-hydric | 9% Hydric
Ch | Chaska loam, channeled, 0 to 3 percent slopes, frequently flooded | Predominantly Hydric | 93% Hydric
CrD | Crofton-Nora complex, 9 to 15 percent slopes | Predominantly Non-hydric | 6% Hydric
DgD | Delmont-Talmo complex, 9 to 15 percent slopes | Non-hydric | 0% Hydric
FaB | Flandreau loam, 2 to 6 percent slopes | Non-hydric | 0% Hydric
IrE | Ihlen-Rock outcrop complex, 4 to 35 percent slopes | Non-hydric | 0% Hydric
Lb | Lamo silty clay loam, channeled | Predominantly Hydric | 87% Hydric
MnB | Moody-Nora complex, 2 to 6 percent slopes | Predominantly Non-hydric | 2% Hydric
NcC | Nora-Crofton complex, 6 to 9 percent slopes | Predominantly Non-hydric | 3% Hydric
Ob | Obert silty clay loam, 0 to 1 percent slopes | Predominantly Hydric | 99% Hydric
Wk | Whitewood silty clay loam, 0 to 2 percent slopes | Predominantly Hydric | 85% Hydric

Data Source(s): Westwood (2021); South Dakota NAIP Imagery (2020); Census Bureau (2020); .S. Department of Agriculture, Natural Resources Conservation Service (2021).

Legend

Delineation Area Boundary

Predominantly Hydric Soil (66%-99%)

Predominantly Non-Hydric (1%-33%) or Non-Hydric (0%) Soil

N

0 400 Feet

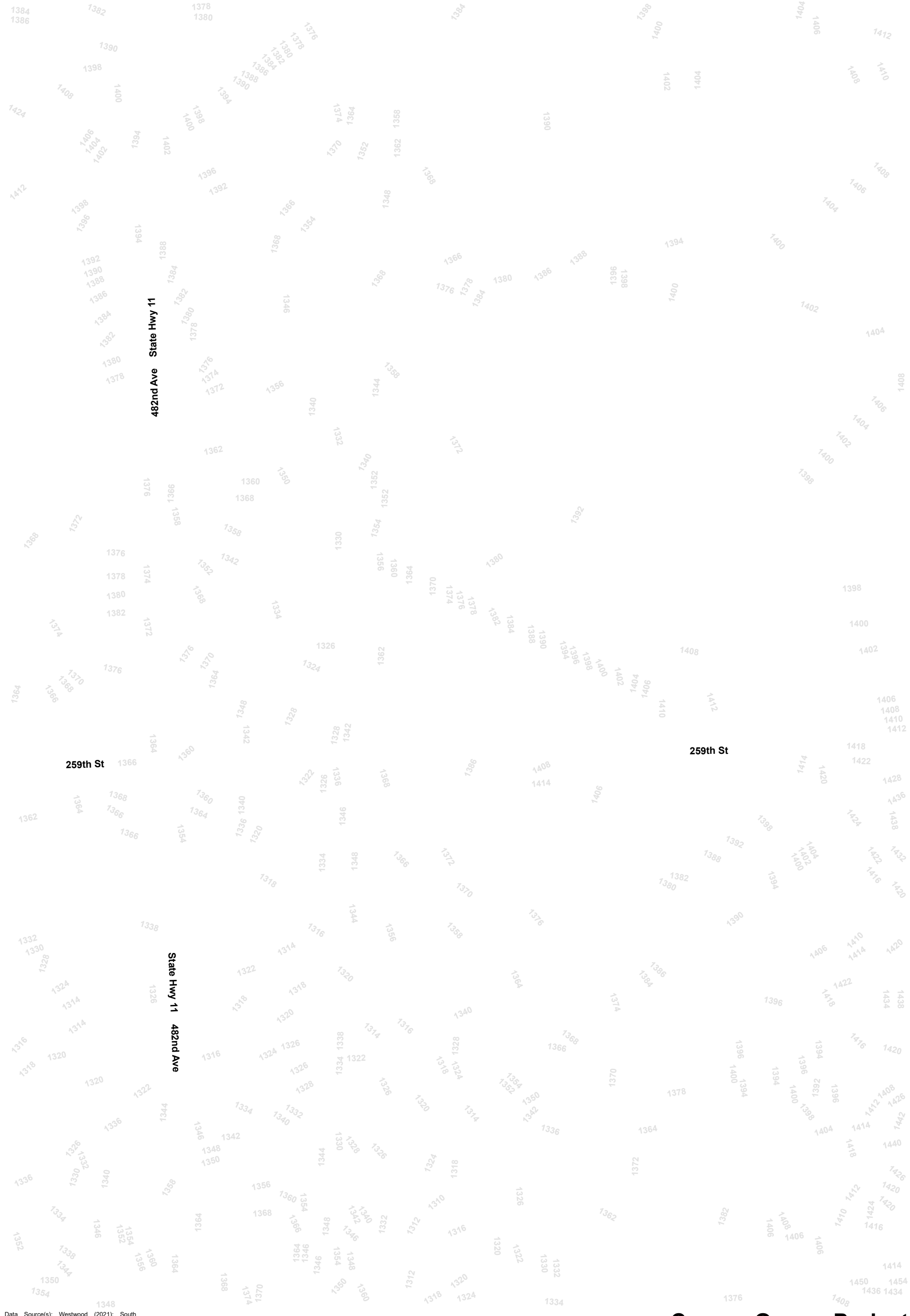
Corson Quarry Project

Minnehaha County, South Dakota

Soils Map

EXHIBIT 3

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Data Source(s): Westwood (2021); South Dakota NAIP Imagery (2020); Census Bureau (2020); USGS NED (2021).

Legend

Delineation Area Boundary

10ft Contour

2ft Contour

N

0

Feet
400

Corson Quarry Project

Minnehaha County, South Dakota

Contours Map

EXHIBIT 4

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NWC-02
WC-01
WB-01
NWC-01
NWB-02
NWB-01
WC-06
WB-10
WC-07
WC-02
WB-03
WB-02
259th St
259th St
WC-02
WC-03
NWB-03
WB-05
WB-06
WC-04
PO-01
WC-03
WB-07
PO-02
WC-05
WC-08
482nd Ave State Hwy 11
State Hwy 11 482nd Ave

N
0
400
Feet

Data Source(s): Westwood (2021); South Dakota NAIP Imagery (2020); Census Bureau (2020).

Legend

- Delineation Area Boundary
- Field Delineated Wetland
- Field Delineated Pond
- Field Delineated Watercourse
- Wetland Sample Point
- Upland Sample Point
- Watercourse Sample Point
- Non-Watercourse Sample Point
- Non-Wetland Sample Point
- Bridge Sample Point
- Culvert Sample Point

Corson Quarry Project

Minnehaha County, South Dakota

Field Delineated Wetlands Map

EXHIBIT 5

Appendix A

Wetland Delineation Data Forms

Corson Quarry Project

Corson Township, Minnehaha County, South Dakota

Corson Quarry		Brandon Township, Minnehaha County	2021-09-27
Knife River		South Dakota	WB-01a-up
A.McTaggart		S14 & 23, T102N, R48	
	Hillslope		Convex
3-6	43.6372834	-96.5627411	WGS 84
	Nora-Crofton complex, 6 to 9 percent slopes		N/A

| | | |

SOIL

Sampling Point: WB-01a-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 5	7.5YR 2.5/1	85	7.5YR 3/4	15	C		Clay	
5 - 20	7.5YR 3/1	90	7.5YR 3/4	10	C	M	Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No hydrology noted

Corson Quarry	Brandon Township, Minnehaha County	2021-09-27
Knife River	South Dakota	WB-01a-wet
A.McTaggart	S14 & 23, T102N, R48	
Swale		Concave
43.6373459	-96.5627625	NAD 83
Nora-Crofton complex, 6 to 9 percent slopes		PEM1A
	✔	
✔		✔
✔		
✔		
✔		✔

wet conditions, on edge of planted soy field.

30 ft r						
					2	
					2	
					100	
15 ft r						
				7	7	
				45	90	
				10	30	
				0	0	
				0	0	
5 ft r				62	127	
Phalaris arundinacea	25	✔	FACW			
Echinochloa crus-galli	20	✔	FACW		2.05	
Setaria pumila	10		FAC			
Persicaria amphibia	5		OBL	✔		
Typha angustifolia	2		OBL	✔		
				✔		
	62%					
30 ft r						
					✔	

Swale mowed, grass S. pumila, P. arundinacea, & E. crusgalli seed heads present but relative % is approximated. Sporadic Typha occurring in soy portion of veg plot. Point located at soy field/grass swale border.

SOIL

Sampling Point: WB-01a-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 24	7.5YR 2.5/1	70	5YR 3/4	30	C	PL / M	Clay	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ✔ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes ✔ No _____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-01b-up
A.McTaggart	S14 & 23, T102N, R48		
	Depression		Concave
0	43.6376497	-96.5681085	WGS 84
	Ihlen-Rock outcrop complex, 4 to 35 percent slopes		N/A

✔

✔ ✔ ✔

✔

✔

✔ ✔

wet conditions. Cattle disturbance is severe, area is trampled & compacted, grasses are cropped closely to ground.

30 ft r

1

3

33.3

15 ft r

0	0		
20	40		
0	0		
62	248		
0	0		
82	288		

5 ft r

Ambrosia psilostachya	25	✔	FACU
Elymus repens	20	✔	FACU
Phalaris arundinacea	20	✔	FACW
Medicago lupulina	10		FACU
Trifolium pratense	5		FACU
Erigeron canadensis	2		FACU

3.51

82%

30 ft r

✔

SOIL

Sampling Point: WB-01b-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 18	10YR 2/1	95	7.5YR 4/4	5	C	M	Clay Loam	Some gravel occurring in lower part of horizon
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

impervious @18in from cattle trampling

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

D2 only hydrology observed

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-01b-wet
A.McTaggart	S14 & 23, T102N, R48		
	Depression	Concave	
0	43.6376043	-96.5679582	WGS 84
	Ihlen-Rock outcrop complex, 4 to 35 percent slopes	PEM1A	

				✔				
✔	✔							✔
		✔						
		✔						
		✔				✔		

wet conditions. Cattle disturbance is severe, basin is trampled & compacted, vegetation in basin is cropped very close to the ground (where it occurs).

	30 ft r					1	
						1	
						100	
	15 ft r						
					0	0	
					65	130	
					0	0	
					15	60	
					0	0	
	5 ft r				80	190	
Phalaris arundinacea		65	✔	FACW			
Ambrosia psilostachya		15		FACU		2.38	
				✔			
				✔			
				✔			
		80%					
	30 ft r						
						✔	

Vegetation severely disturbed. What is left in basin has been cropped close to the ground or trampled.

SOIL

Sampling Point: WB-01b-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 11	10YR 2/1	95	7.5YR 4/4	5	C	M	Clay Loam	Some gravel occurring in horizon
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Unknown-compaction?

Depth (inches): 11

Hydric Soil Present? Yes ✔ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ✔ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ✔ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ___ No ✔ Depth (inches): ___

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ✔ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Basin severely trampled

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-02a-up
A.McTaggart	S14 & 23, T102N, R48		
	Depression	Convex	
0-3	43.6307896	-96.5698538	WGS 84
	Lamo silty clay loam, channeled		N/A
		✔	
			✔
	✔		
	✔		
	✔		✔

wet conditions, some cattle disturbance (compaction, grazing)

30 ft r					
					0
					1
					0
15 ft r					
				0	0
				5	10
				0	0
				95	380
				0	0
5 ft r				100	390
Bromus inermis	95	✔	FACU		
Phalaris arundinacea	5		FACW		3.90
	100%				
30 ft r					
					✔

SOIL

Sampling Point: WB-02a-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 20	10YR 2/1	100					Clay Loam	
20 - 27	10YR 3/1	100					Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes _____ No ✔

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No hydrology other than geomorphic position observed. No water table w/in 2.5 feet of surface

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-02a-wet
A.McTaggart	S14 & 23, T102N, R48		
Depression		Concave	
0	43.6306811	-96.5698708	WGS 84
Lamo silty clay loam, channeled		N/A	
	✔		✔
✔			
✔			
✔		✔	

wet conditions, some cattle disturbance (compaction, grazing)

30 ft r						2
						3
						66.7
15 ft r						
					0	0
					75	150
					0	0
					25	100
					0	0
5 ft r					100	250
Carex sp.	50	✔	FACW			
Bromus inermis	25	✔	FACU			2.50
Phalaris arundinacea	25	✔	FACW			
				✔		
				✔		
	100%					
30 ft r						
					✔	

No reproductive parts on Carex. Can’t tell species. Assumed wet.

SOIL

Sampling Point: WB-02a-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 2	10YR 2/1	100					Clay Loam	
2 - 10	10YR 2/1	85	7.5YR 3/4	15	C	PL / M	Clay Loam	
10 - 24	10YR 2/1	100					Clay Loam	
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ✔ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes ✔ No _____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No presence of water table or saturation w/in upper 24 inches. Soil was moist & not dry/crumbly like in nearby upland data point. Very dry conditions on-site.

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-02b-up
A.McTaggart	S14 & 23, T102N, R48		
	Depression		Concave
0-3	43.6353959	-96.5683488	WGS 84
	Ihlen-Rock outcrop complex, 4 to 35 percent slopes		N/A
		✔	
✔			✔
	✔		
✔			
	✔		✔

wet conditions, some cattle & vehicle compaction. point taken in swale, above erosional headcut where WB-02 ends.

30 ft r

0

2

0

15 ft r

				0	0
				0	0
				0	0
				95	380
				2	10
5 ft r				97	390
Elymus repens	65	✔	FACU		
Bromus inermis	30	✔	FACU		4.02
Verbascum thapsus	2		UPL		
Verbena stricta	2		NI		

99%

30 ft r

✔

SOIL

Sampling Point: WB-02b-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 4	7.5YR 2.5/1	98	7.5YR 3/3	2	C	M	Clay Loam	Some redox, not very distinct
4 - 24	7.5YR 2.5/1	100					Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): 24

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No hydrology other than geomorphic position observed. No water table w/in 2 feet of surface, soils dry.

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-02b-wet
A.McTaggart	S14 & 23, T102N, R48		
Depression		Concave	
0 43.6353865	-96.5684090	WGS 84	
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		N/A	
	✔		
✔		✔	
✔			
✔			
✔		✔	

wet conditions, cattle compaction in wetland

30 ft r						
						1
						1
						100
15 ft r						
					0	0
					102	204
					0	0
					0	0
					0	0
5 ft r					102	204
Phalaris arundinacea	100	✔	FACW			
Urtica dioica	2		FACW			2.00
				✔		
				✔		
				✔		
	102%					
30 ft r						
					✔	

SOIL

Sampling Point: WB-02b-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 12	10YR 2/1	95	7.5YR 4/6	5	C	M	Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Compacted from cattle

Depth (inches): 12

Hydric Soil Present? Yes ✔ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ___ No ✔ Depth (inches): ___

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ✔ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No presence of water table or saturation w/in upper 12 inches. Soil was compacted & could not dig further.

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-03-up
A.McTaggart	S14 & 23, T102N, R48		
Hillslope		Convex	
0-3	43.6324447	-96.5690483	WGS 84
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		N/A	
	✔		
		✔	
	✔		
	✔		
	✔		✔

wet conditions

30 ft r					
				1	
				2	
				50	
15 ft r					
				0	0
				50	100
				0	0
				50	200
				0	0
5 ft r				100	300
Bromus inermis	50	✔	FACU		
Phalaris arundinacea	40	✔	FACW		3.00
Carex sp.	10		FACW		
	100%				
30 ft r					
					✔

SOIL

Sampling Point: WB-03-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 18	10YR 2/1	100					Sandy Clay Loam	
18 - 24	10YR 3/3	100					Sandy Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes _____ No ✔

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

None observed

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-28
Knife River	South Dakota		WB-03-wet
A.McTaggart	S14 & 23, T102N, R48		
Basin		Concave	
0-3	43.6325041	-96.5689863	WGS 84
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		N/A	

✔ ✔

✔ ✔ ✔ ✔

wet conditions, soil severely compacted from cattle

30 ft r

1

1

100

15 ft r

				0	0
				67	134
				20	60
				0	0
				0	0
5 ft r				87	194
Phalaris arundinacea	60	✔	FACW		
Eragrostis pectinacea	10		FAC		2.23
Setaria pumila	10		FAC		
Persicaria maculosa	5		FACW	✔	
Verbena hastata	2		FACW	✔	
				✔	

87%

30 ft r

✔

SOIL

Sampling Point: WB-03-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 10	2.5Y 2.5/1	85	5YR 3/4	15	C	PL / M	Sandy Clay	Hit impermeable layer @10 in
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Clay compaction

Depth (inches): 10

Hydric Soil Present? Yes ✔ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ✔ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ✔ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ✔ No ___ Depth (inches): 10

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ✔ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Surface water observed within 5 ft of data point. No surface water, saturation, or water table observed at soil hole.

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-05-up
A.McTaggart	S14 & 23, T102N, R48		
Swale		Concave	
3-6	43.6280062	-96.5676815	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		N/A	
	✔		
		✔	
	✔		
✔			
	✔		✔

wet conditions

30 ft r					
					1
					3
					33.3
15 ft r					
				0	0
				0	0
				35	105
				90	360
				0	0
5 ft r				125	465
Elymus repens	40	✔	FACU		
Setaria pumila	35	✔	FAC		3.72
Cirsium arvense	30	✔	FACU		
Chenopodium album	20		FACU		

	125%	
30 ft r		
		✔

SOIL

Sampling Point: WB-05-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 24	10YR 2/1	85	7.5YR 3/4	15	C	M	Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

No hydrology other than D2 observed

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-05-wet
A.McTaggart	S14 & 23, T102N, R48		
Swale		Concave	
5-10	43.6279859	-96.5677052	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		N/A	

				✔				✔	
		✔					✔		
		✔							
		✔					✔		

wet conditions. Wet line based on topo break & upland species encroachment.

	30 ft r							1	
								1	
								100	
	15 ft r								
							0	0	
							100	200	
							0	0	
							0	0	
							0	0	
	5 ft r						100	200	
Carex sp.		100	✔	FACW				2.00	
					✔				
					✔				
					✔				
		100%							
	30 ft r								
								✔	

Unknown sedge, no seed head. Assumed wet.

SOIL

Sampling Point: WB-05-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 4	10YR 2/1	98	2.5YR 2.5/3	2	C	M	Clay Loam	
4 - 24	10YR 2/1	98	2.5Y 5/4	2	C	M	Clay Loam	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes ✔ No _____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-06a-up
A.McTaggart	S14 & 23, T102N, R48		
Swale			Concave
0-3	43.6278475	-96.5656471	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes			n/a
		✔	
			✔
	✔		
✔			
	✔		✔

wet conditions

30 ft r					
					0
					2
					0
15 ft r					
				0	0
				15	30
				0	0
				80	320
				0	0
5 ft r				95	350
Bromus inermis	35	✔	FACU		
Cirsium arvense	30	✔	FACU		3.68
Phleum pratense	10		FACU		
Solidago gigantea	10		FACW		
Achillea millefolium	5		FACU		
Echinochloa crus-galli	5		FACW		
	95%				
30 ft r					
					✔

SOIL

Sampling Point: WB-06a-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 6	10YR 2/2	95	7.5YR 2.5/3	5	C	M	Clay Loam	
6 - 24	10YR 2/2	100					Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

Redox is present, not prominent & hard to see

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-06a-wet
A.McTaggart	S14 & 23, T102N, R48		
Swale		Concave	
0-3	43.6278747	-96.5658104	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		n/a	

			✔			
						✔
	✔					
	✔					
	✔				✔	

wet conditions. Wetland seeps along northern topo break.

30 ft r						
						2
						3
						66.7
15 ft r						
					10	10
					67	134
					0	0
					25	100
					0	0
5 ft r					102	244
Phalaris arundinacea	30	✔	FACW			
Solidago gigantea	30	✔	FACW			2.39
Cirsium arvense	25	✔	FACU			
Typha angustifolia	10		OBL			
Scirpus sp.	5		FACW	✔		
Persicaria maculosa	2		FACW	✔		
	102%					
30 ft r						
					✔	

Unknown sedge, no seed head

SOIL

Sampling Point: WB-06a-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 3	10YR 2/1	100					Clay Loam	
3 - 24	10YR 2/1	85	2.5YR 3/6	15	C	M	Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ✔ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ✔ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ✔ No _____ Depth (inches): 1

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes ✔ No _____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Surface water visible w/in 10 ft. No A indicators present @ soil pit/data point

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-06b-up
A.McTaggart	S14 & 23, T102N, R48		
	Hillslope	Convex	
10	43.6268327	-96.5664795	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		n/a	
	✔		
		✔	
	✔		
	✔		
	✔	✔	

wet conditions

30 ft r						
						1
						2
						50
15 ft r						
					0	0
					40	80
					0	0
					70	280
					0	0
5 ft r					110	360
Bromus inermis		70	✔	FACU		
Solidago gigantea		40	✔	FACW		3.27

110%	
30 ft r	
	✔

SOIL

Sampling Point: WB-06b-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 10	10YR 2/2	100					Sandy Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Gravel? Bedrock?

Depth (inches): 10

Hydric Soil Present? Yes _____ No ✔

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

No hydrology

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-06b-wet
A.McTaggart	S14 & 23, T102N, R48		
Hillslope		Concave	
0-3	43.6268874	-96.5664914	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		n/a	

				✔				
							✔	
	✔							
	✔							
	✔				✔			

wet conditions. Seep coming from hillside

30 ft r								
							2	
							2	
							100	
15 ft r								
						40	40	
						80	160	
						0	0	
						0	0	
						0	0	
5 ft r						120	200	
Carex sp.	60	✔	FACW					
Eupatorium perfoliatum	40	✔	OBL				1.67	
Solidago gigantea	20		FACW					
				✔				
				✔				
				✔				
	120%							
30 ft r								
								✔

SOIL

Sampling Point: WB-06b-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 6	10YR 2/2	100					Mucky Loam/Clay	
6 - 20	10YR 2/1	98	7.5YR 3/4	2	C	M	Sandy Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ✔ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ✔ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes ✔ No _____ Depth (inches): 4

Wetland Hydrology Present? Yes ✔ No _____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-07-up
A.McTaggart	S14 & 23, T102N, R48		
Swale		Concave	
5	43.6262706	-96.5656258	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		n/a	
	✔		
✔			✔
	✔		
	✔		
	✔		✔

wet conditions. Area dammed upslope - water treatment pond? pump located downslope at gravel pad

30 ft r					0	
					2	
					0	
15 ft r						
				0	0	
				0	0	
				0	0	
				90	360	
				0	0	
5 ft r				90	360	
Bromus inermis	60	✔	FACU			
Cirsium arvense	30	✔	FACU		4.00	
Bidens sp.	15		NI			
	105%					
30 ft r						
						✔

SOIL

Sampling Point: WB-07-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 22	7.5YR 2.5/1	98	7.5YR 2.5/3	2	C	M	Clay	
22 - 28	7.5YR 2.5/1	90	10YR 3/4	10	C	M	Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes _____ No ✔

Remarks:

Really faint, very sparse redox in upper 22 inches. Don't think it meets redox dark surface prominent/distinct criteria.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-07-wet
A.McTaggart	S14 & 23, T102N, R48		
Swale		Concave	
0-3	43.6262261	-96.5656545	WGS 84
Delmont-Talmo complex, 9 to 15 percent slopes		N/A	
	✔		
✔			✔
✔			
✔			
✔		✔	

wet conditions. Upslope is dammed, downslope has pump (see Wb-07-up remarks)

30 ft r					2
					3
					66.7
15 ft r					
				0	0
				75	150
				0	0
				20	80
				0	0
5 ft r				95	230
Phalaris arundinacea	40	✔	FACW		
Solidago gigantea	35	✔	FACW		2.42
Cirsium arvense	20	✔	FACU		
			✔		
			✔		
	95%				
30 ft r					
				✔	

SOIL

Sampling Point: WB-07-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 6	10YR 3/1	85	7.5YR 3/4	15	C	M	Clay	
6 - 20	10YR 2/1	90	10YR 3/4	10	C	M	Clay	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ✔ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ✔ No _____ Depth (inches): 1

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes ✔ No _____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Surface water w/in 10 ft. No A indicators at soil hole

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-08-up
A.McTaggart	S14 & 23, T102N, R48		
	Hillslope	Convex	
10	43.6258748	-96.5663683	WGS 84
Chaska loam, channeled, 0 to 3 percent slopes, frequently flooded			N/A

✔ ✔ ✔

✔ ✔ ✔ ✔

wet conditions, pump located upslope of datapoint on gravel pad

30 ft r

1

3

33.3

15 ft r

Symphoricarpos occidentalis	30	✔	UPL		
Amorpha fruticosa	25	✔	FACW	0	0
				30	60
				0	0
				85	340
	55%			30	150
5 ft r				145	550
Bromus inermis	80	✔	FACU		
Carex sp.	5		FACW		3.79
Cirsium arvense	5		FACU		

90%

30 ft r

✔

SOIL

Sampling Point: WB-08-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 19	7.5YR 2/1	100					Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Bedrock

Depth (inches): 19

Hydric Soil Present? Yes _____ No ✔

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No hydrology observed

Corson Quarry	Brandon Township, Minnehaha County		2021-09-29
Knife River	South Dakota		WB-08-wet
A.McTaggart	S14 & 23, T102N, R48		
Hillslope		Concave	
5	43.6257841	-96.5663520	WGS 84
Chaska loam, channeled, 0 to 3 percent slopes, frequently flooded		N/a	

✔ ✔ ✔ ✔ ✔ ✔ ✔ ✔

wet conditions, pump located up slope of datapoint

30 ft r					4
					4
					100
15 ft r					
Amorpha fruticosa	30	✔	FACW		
Salix interior	30	✔	FACW	0	0
Fraxinus pennsylvanica	10		FACW	175	350
Symphoricarpos occidentalis	5		UPL	0	0
				0	0
	75%			5	25
5 ft r				180	375
Phalaris arundinacea	60	✔	FACW		
Solidago gigantea	30	✔	FACW		2.08
Carex sp.	15		FACW		

✔ ✔ ✔

105%		
30 ft r		

✔

SOIL

Sampling Point: WB-08-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 7	10YR 2/2	100					Clay Loam	
7 - 18	10YR 2/1	95	7.5YR 3/4	5	C	M	Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Bedrock

Depth (inches): 19

Hydric Soil Present? Yes ✔ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ___ No ✔ Depth (inches): ___

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ✔ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-10-01
Knife River	South Dakota		WB-10a-up
A.McTaggart	S14 & 23, T102N, R48		
	Hillslope	Convex	
0-3	43.6346805	-96.5677141	WGS 84
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		n/a	
	✔		
			✔
✔			
	✔		
	✔		
	✔		✔

wet conditions. Quartz bedrock at/close to surface in this area. Upland island where data point was taken is the only upland with soil & vegetation, other upland islands within mapped WB-10 are raised areas of bedrock that are significantly higher than the surrounding wetland.

30 ft r					
					0
					2
					0
15 ft r					
Juniperus virginiana	5	✔	FACU		
				0	0
				10	20
				0	0
				95	380
	5%			0	0
5 ft r				105	400
Bromus inermis	80	✔	FACU		
Ambrosia psilostachya	10		FACU		3.81
Phalaris arundinacea	10		FACW		
	100%				
30 ft r					
					✔

SOIL

Sampling Point: WB-10a-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 10	7.5YR 2.5/1	100					Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Bedrock

Depth (inches): 10

Hydric Soil Present? Yes _____ No ✔

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County		2021-10-01
Knife River	South Dakota		WB-10a-wet
A.McTaggart	S14 & 23, T102N, R48		
Depression		Concave	
0-3	43.6346501	-96.5677387	WGS 84
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		n/a	

✔ ✔

✔ ✔ ✔ ✔

wet conditions. Quartz bedrock close to/at surface in most of the area

30 ft r

1

1

100

15 ft r

Lonicera sp.	10	✔			0	0
					100	200
					0	0
					10	40
	10%				0	0
5 ft r					110	240
Phalaris arundinacea	90	✔	FACW			
Asclepias syriaca	10		FACU			2.18
Amorpha fruticosa	5		FACW			
Urtica dioica	5		FACW	✔		
				✔		
				✔		

110%

30 ft r

✔

SOIL

Sampling Point: WB-10a-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 6	7.5YR 2.5/1	90	7.5YR 3/3	10	C	M	Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Bedrock

Depth (inches): 6

Hydric Soil Present? Yes ✔ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ✔ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ✔ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ✔ No ___ Depth (inches): .5

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ✔ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Surface water w/in 5 feet of data point observed

Corson Quarry		Brandon Township, Minnehaha County	2021-10-01
Knife River		South Dakota	WB-10b-up
A.McTaggart		S14 & 23, T102N, R48	
	Hillslope		Convex
0-3	43.6347324	-96.5645473	WGS 84
	Ihlen-Rock outcrop complex, 4 to 35 percent slopes		n/a

✔ ✔

✔ ✔

✔ ✔

wet conditions

30 ft r

0

2

0

15 ft r

0	0		
15	30		
0	0		
100	400		
0	0		
115	430		

5 ft r

Elymus repens	60	✔	FACU
Bromus inermis	40	✔	FACU
Carex sp.	10		FACW
Phalaris arundinacea	5		FACW

3.74

115%

30 ft r

✔

SOIL

Sampling Point: WB-10b-up

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 15	7.5YR 2.5/1	95	7.5YR 2.5/3	5	C	M	Clay Loam	
15 - 24	7.5YR 2.5/1	65					Clay Loam	
15 - 24	10YR 4/3	35						
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Bedrock

Depth (inches): 10

Hydric Soil Present? Yes ✔ No ___

Remarks:

Redox in 1st horizon very faint. 2nd horizon w/dual matrix

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ___ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ___ No ✔ Depth (inches): ___

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ___ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry		Brandon Township, Minnehaha County	2021-10-01
Knife River		South Dakota	WB-10b-wet
A.McTaggart		S14 & 23, T102N, R48	
	Hillslope		Concave
0-3	43.6348284	-96.5645575	WGS 84
	Ihlen-Rock outcrop complex, 4 to 35 percent slopes		n/a

		✔	
			✔
✔			
✔			
✔		✔	

wet conditions

30 ft r					
					1
					2
					50
15 ft r					
				0	0
				80	160
				0	0
				25	100
				0	0
5 ft r				105	260
Phalaris arundinacea	60	✔	FACW		
Elymus repens	25	✔	FACU		2.48
Carex sp.	20		FACW		

				✔	
	105%				
30 ft r					
					✔

SOIL

Sampling Point: WB-10b-wet

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 16	7.5YR 2.5/1	85	5YR 3/4	15	C	PL / M	Clay	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Bedrock

Depth (inches): 16

Hydric Soil Present? Yes ✔ No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ✔ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes ___ No ✔ Depth (inches): ___

Water Table Present? Yes ___ No ✔ Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No ✔ Depth (inches): ___

Wetland Hydrology Present? Yes ✔ No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry	Brandon Township, Minnehaha County	2021-09-28
Knife River	South Dakota	NWB-01
A.McTaggart	S14 & 23, T102N, R48	
Basin		Concave
43.6352625	-96.5691502	WGS 84
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		N/A
	✔	
✔		✔
	✔	
	✔	
	✔	✔

wet conditions, Man-made excavated basin

30 ft r					
				0	
				1	
				0	
15 ft r					
				0	0
				2	4
				0	0
				95	380
				1	5
5 ft r				98	389
Bromus inermis	95	✔	FACU		
Verbena hastata	2		FACW		3.97
Verbascum thapsus	1		UPL		
	98%				
30 ft r					
					✔

SOIL

Sampling Point: NWB-01

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 10	10YR 3/2	100					Sandy Clay Loam	
-								
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: Unknown

Depth (inches): 10

Hydric Soil Present? Yes _____ No ✔

Remarks:

Gravel in soil sample, impervious @10 in.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

No observed hydrology other than D2

Corson Quarry	Brandon Township, Minnehaha County	2021-09-28
Knife River	South Dakota	NWB-02
A.McTaggart	S14 & 23, T102N, R48	

Depression		Concave
43.6357558	-96.5681243	WGS 84
Ihlen-Rock outcrop complex, 4 to 35 percent slopes		R4SBC

	✔	
		✔
✔		
✔		
✔		✔

wet conditions, some cattle disturbance.
NWI polygon & NHD flowline mapped through area. No obvious OHWM or wetland criteria observed in the field. See Non-Watercourse points NWC-01 & NWC-02 for additional photos & data.

30 ft r					
					0
					2
					0
15 ft r					
				0	0
				0	0
				0	0
				100	400
				0	0
5 ft r				100	400
Elymus repens	80	✔	FACU		
Bromus inermis	20	✔	FACU		4.00

	100%		
30 ft r			
			✔

SOIL

Sampling Point: NWB-02

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 18	10YR 2/1	100					Clay Loam	
18 - 35	10YR 2/2	100					Clay Loam	
-								
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes _____ No ✔

Remarks:

hydric soil may be present, could not sample past 35 inches.

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Corson Quarry		Brandon Township, Minnehaha County	2021-09-29
Knife River		South Dakota	NWB-03
A.McTaggart		S14 & 23, T102N, R48	
	Swale		Concave
0-3	43.6282716	-96.5675108	WGS 84
	Delmont-Talmo complex, 9 to 15 percent slopes		N/A

✔ ✔

✔ ✔ ✔

Wet conditions.

30 ft r

0

1

0

15 ft r

				0	0
				15	30
				0	0
				90	360
				0	0
5 ft r				105	390
Elymus repens	90	✔	FACU		
Scirpus sp.	10		FACW		3.71
Juncus sp.	5		FACW		

105%

30 ft r

✔

some hydrophytic veg present in small quantities.

SOIL

Sampling Point: NWB-03

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	%	Redox Features Color (moist)	%	Type[1]	Loc[2]	Texture	Remarks
0 - 18	7.5YR 2.5/1	85	7.5YR 4/4	10	C	M	Clay Loam	
0 - 18			5YR 4/6	5	C	M		
18 - 24	7.5YR 2.5/1	95	5YR 3/4	5	C	M	Clay Loam	
-								
-								
-								
-								

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, MS=Masked Sand Grains.

[2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators:

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Stratified Layers (A5)
- ___ 2 cm Muck (A10)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ 5 cm Mucky Peat or Peat (S3)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1)
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ✔ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ Coast Prairie Redox (A16)
- ___ Dark Surface (S7)
- ___ Iron-Manganese Masses (F12)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):

Type: _____

Depth (inches): _____

Hydric Soil Present? Yes ✔ No _____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9)
- ___ Aquatic Fauna (B13)
- ___ True Aquatic Plants (B14)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres on Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Thin Muck Surface (C7)
- ___ Gauge or Well Data (D9)
- ___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

- ___ Surface Soil Cracks (B6)
- ___ Drainage Patterns (B10)
- ___ Dry-Season Water Table (C2)
- ___ Crayfish Burrows (C8)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Stunted or Stressed Plants (D1)
- ✔ Geomorphic Position (D2)
- ___ FAC-Neutral Test (D5)

Field Observations:

Surface Water Present? Yes _____ No ✔ Depth (inches): _____

Water Table Present? Yes _____ No ✔ Depth (inches): _____

Saturation Present? (includes capillary fringe) Yes _____ No ✔ Depth (inches): _____

Wetland Hydrology Present? Yes _____ No ✔

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

no hydrology other than D2 observed

Appendix B

Wetland Delineation Photographs

Corson Quarry Project

Corson Township, Minnehaha County, South Dakota

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Corson Quarry Project
Delineation Site Photograph

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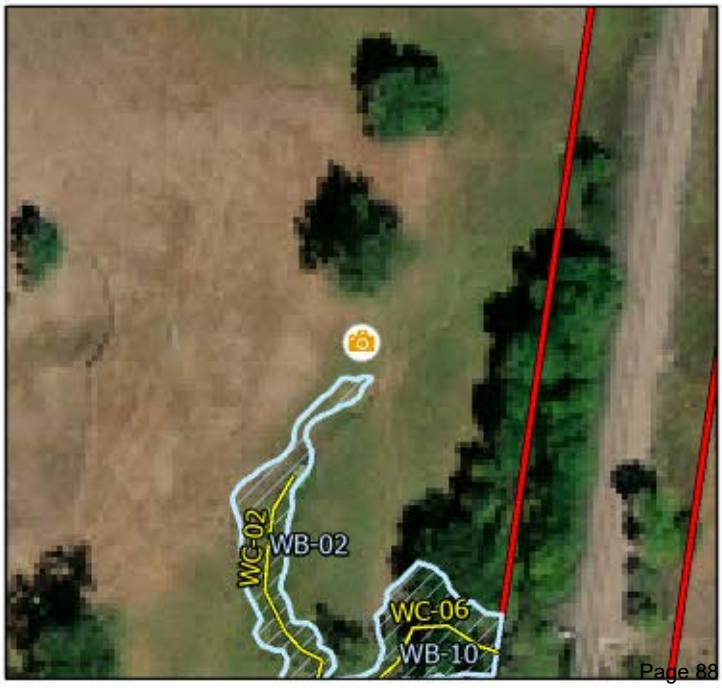


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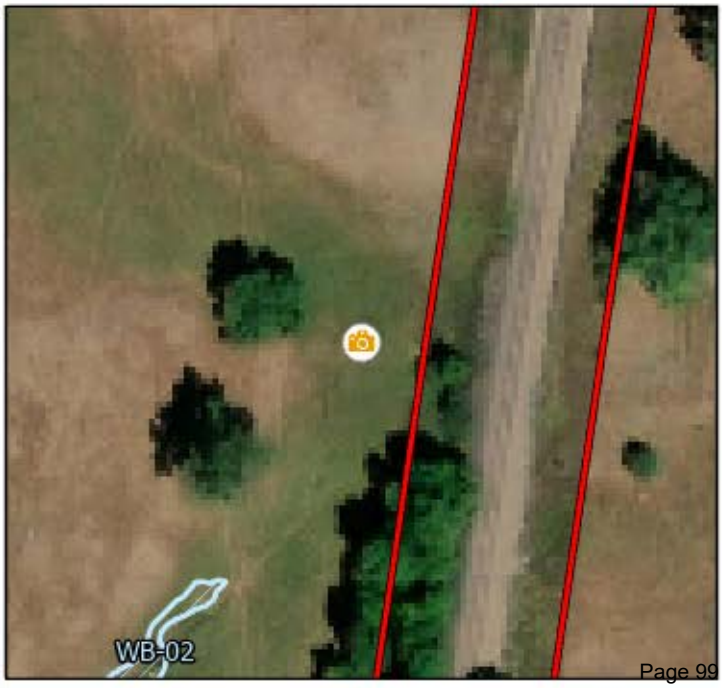


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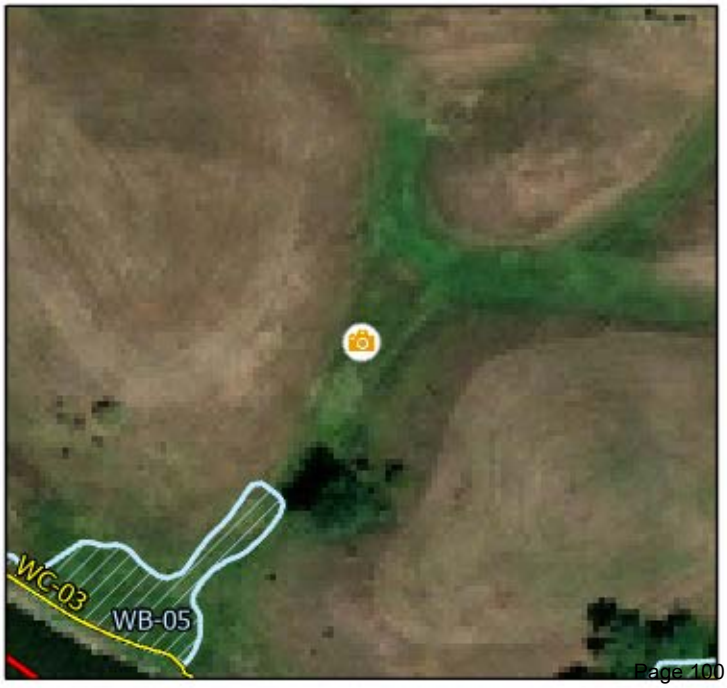


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Appendix C

Watercourse Data Forms and Photographs

Corson Quarry Project

Corson Township, Minnehaha County, South Dakota

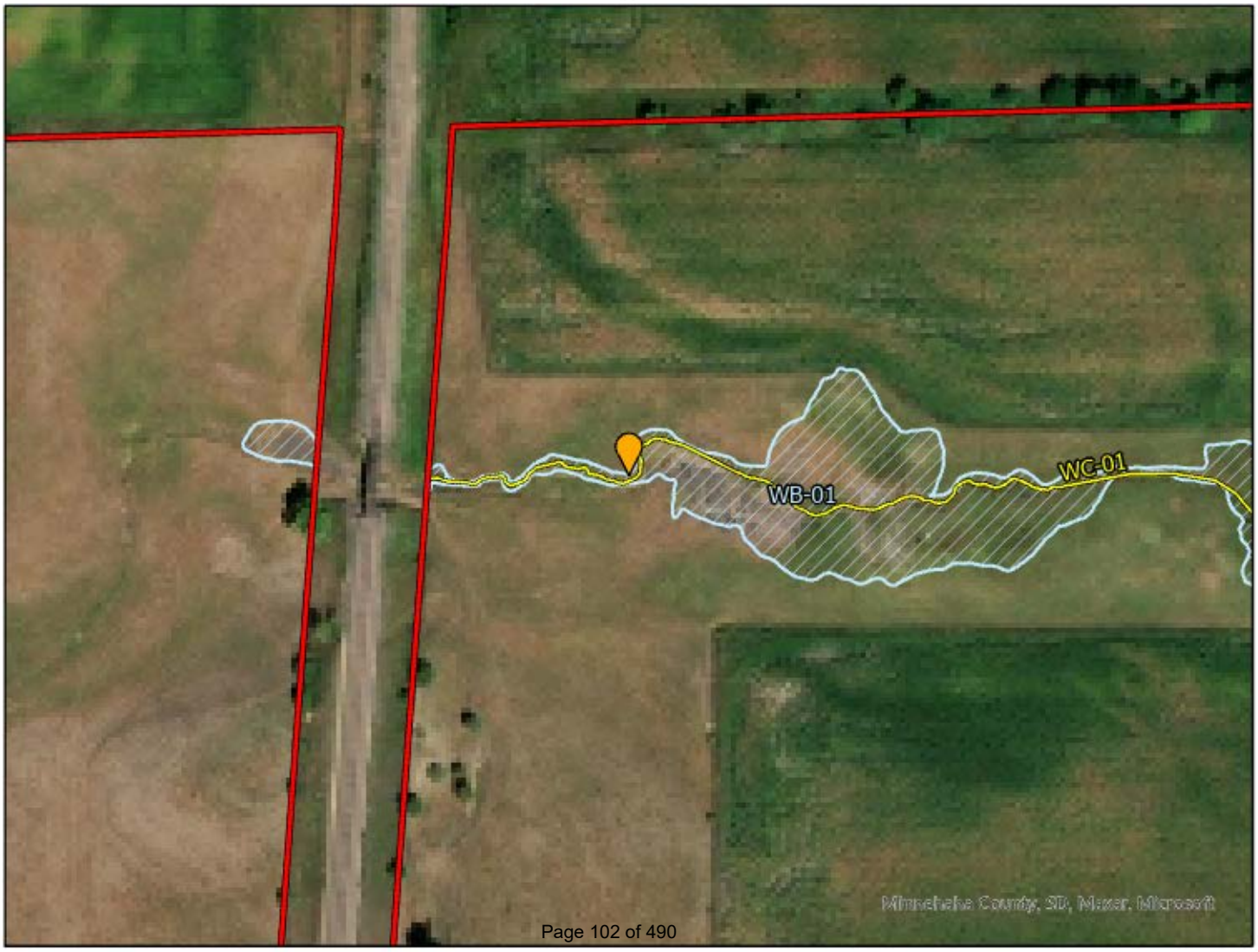
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Corson Quarry Project
Watercourse Data Form

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Attributes

Feature ID	WC-01
Defined Bed & Bank	Yes
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	Intermittent
Direction of the Flow	W
Water Width at Observation Point (ft)	0
Water Depth at Observation Point (ft)	0
Left Bank Height (ft) - Looking Downstream	2
Right Bank Height (ft) - Looking Downstream	2
OHWM Width (ft)	1
OHWM Height (ft from Substrate)	1
Evidence of Scour or Erosion	Yes
OHWM Criteria	bed_bank,plant_community_change,scour
Pools, Riffles, Runs Present?	none
Substrate	Silt

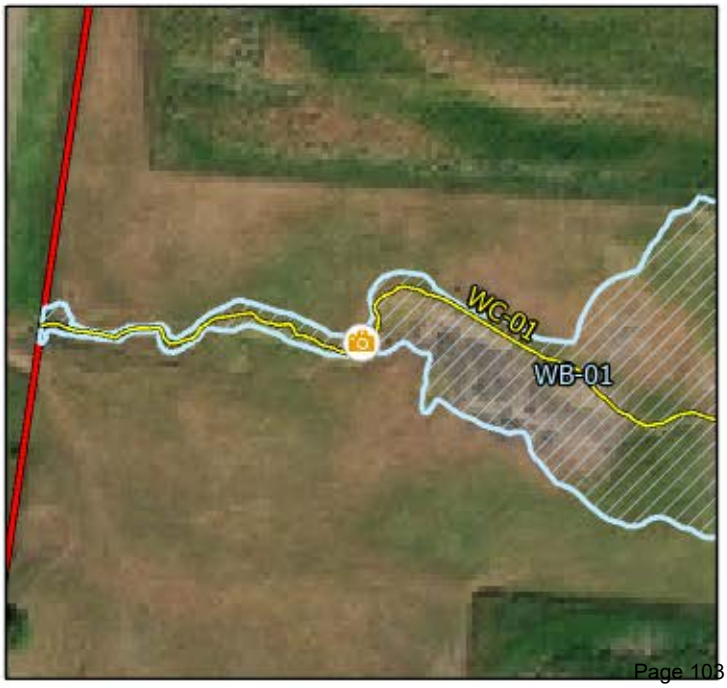


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Attributes

Feature ID	WC-02
Defined Bed & Bank	Yes
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	Perennial
Direction of the Flow	S
Water Width at Observation Point (ft)	5
Water Depth at Observation Point (ft)	2
Left Bank Height (ft) - Looking Downstream	3
Right Bank Height (ft) - Looking Downstream	3
OHWM Width (ft)	5
OHWM Height (ft from Substrate)	3
Evidence of Scour or Erosion	Yes
OHWM Criteria	plant_community_change,scour,shelving,bed_bank
Pools, Riffles, Runs Present?	runs
Substrate	Silt

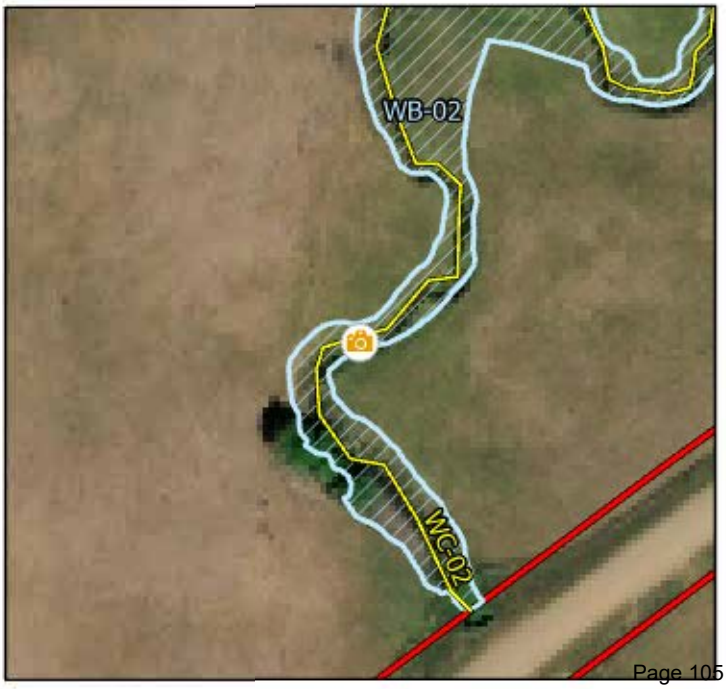


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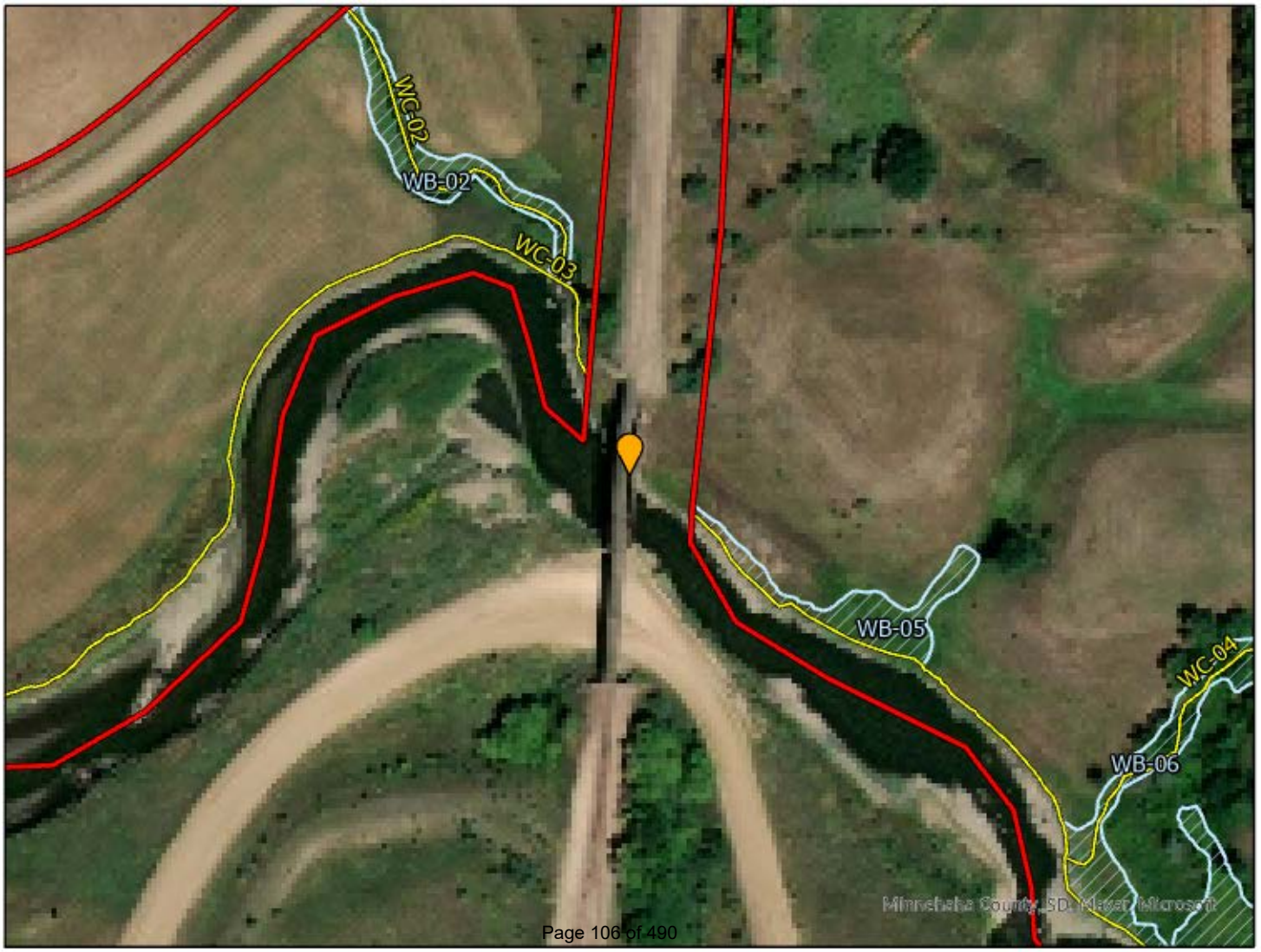
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Attributes

Feature ID	WC-03
Defined Bed & Bank	Yes
Waters of the US	Yes
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	Perennial
Direction of the Flow	W
Water Width at Observation Point (ft)	100
Water Depth at Observation Point (ft)	4
Left Bank Height (ft) - Looking Downstream	5
Right Bank Height (ft) - Looking Downstream	8
OHWM Width (ft)	110
OHWM Height (ft from Substrate)	7
Evidence of Scour or Erosion	Yes
OHWM Criteria	natural_line,bed_bank,scour
Pools, Riffles, Runs Present?	pools,riffles,runs
Substrate	Sand



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Attributes

Feature ID	WC-04
Defined Bed & Bank	Yes
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	Intermittent
Direction of the Flow	SW
Water Width at Observation Point (ft)	1
Water Depth at Observation Point (ft)	0.5
Left Bank Height (ft) - Looking Downstream	4
Right Bank Height (ft) - Looking Downstream	20
OHWM Width (ft)	6
OHWM Height (ft from Substrate)	1
Evidence of Scour or Erosion	No
OHWM Criteria	veg_matted_bent_absent,natural_line,plant_community_change
Pools, Riffles, Runs Present?	runs
Substrate	Sand



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Attributes

Feature ID	WC-05
Defined Bed & Bank	Yes
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	Intermittent
Direction of the Flow	W
Water Width at Observation Point (ft)	1
Water Depth at Observation Point (ft)	0.5
Left Bank Height (ft) - Looking Downstream	2
Right Bank Height (ft) - Looking Downstream	2
OHWM Width (ft)	3
OHWM Height (ft from Substrate)	1
Evidence of Scour or Erosion	Yes
OHWM Criteria	natural_line,plant_community_change,scour
Pools, Riffles, Runs Present?	runs
Substrate	Clay



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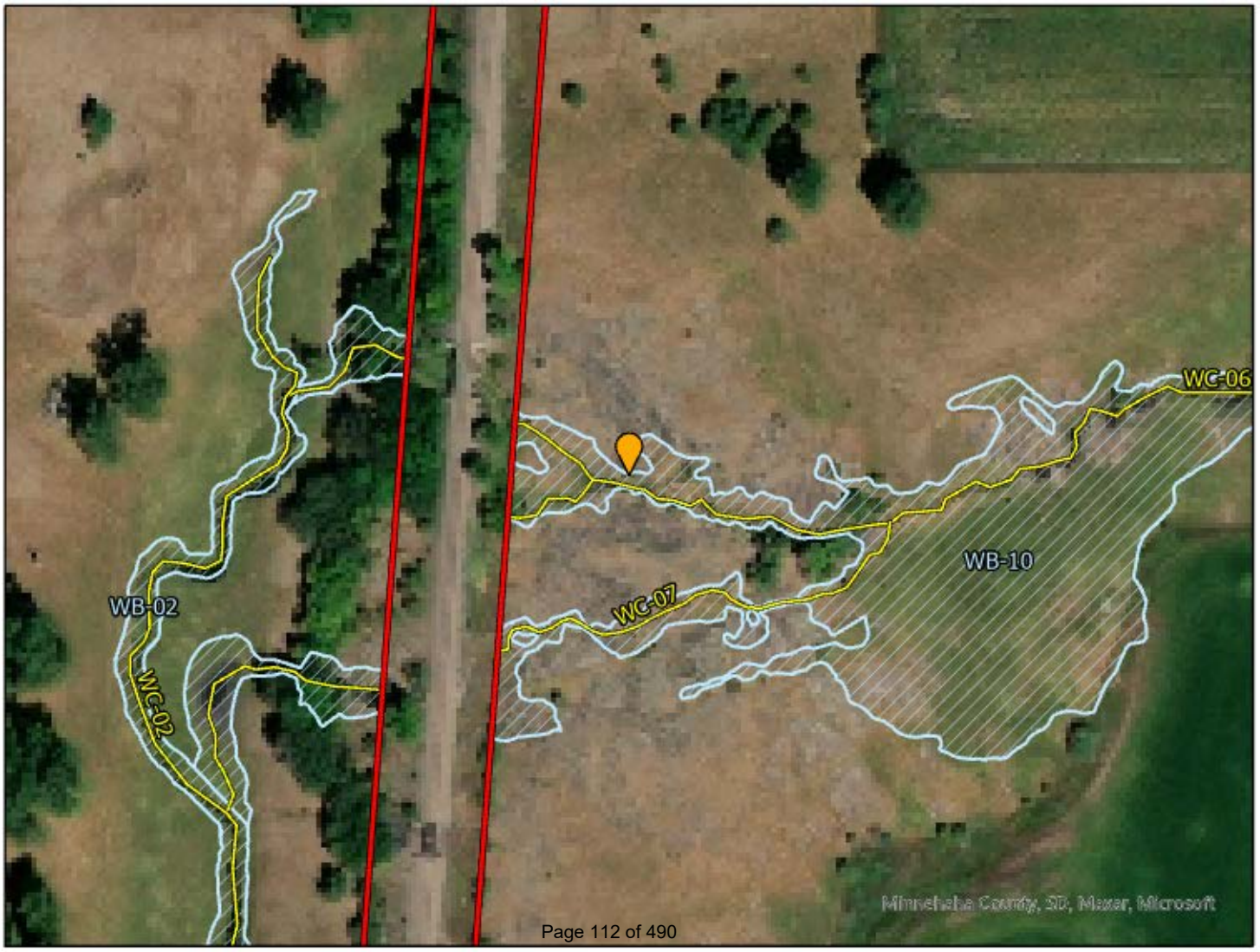
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Attributes

Feature ID	WC-06
Defined Bed & Bank	
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	Intermittent
Direction of the Flow	
Water Width at Observation Point (ft)	2
Water Depth at Observation Point (ft)	0.5
Left Bank Height (ft) - Looking Downstream	2.5
Right Bank Height (ft) - Looking Downstream	2.5
OHWM Width (ft)	6
OHWM Height (ft from Substrate)	1
Evidence of Scour or Erosion	No
OHWM Criteria	plant_community_change,natural_line
Pools, Riffles, Runs Present?	pools,runs
Substrate	Bedrock



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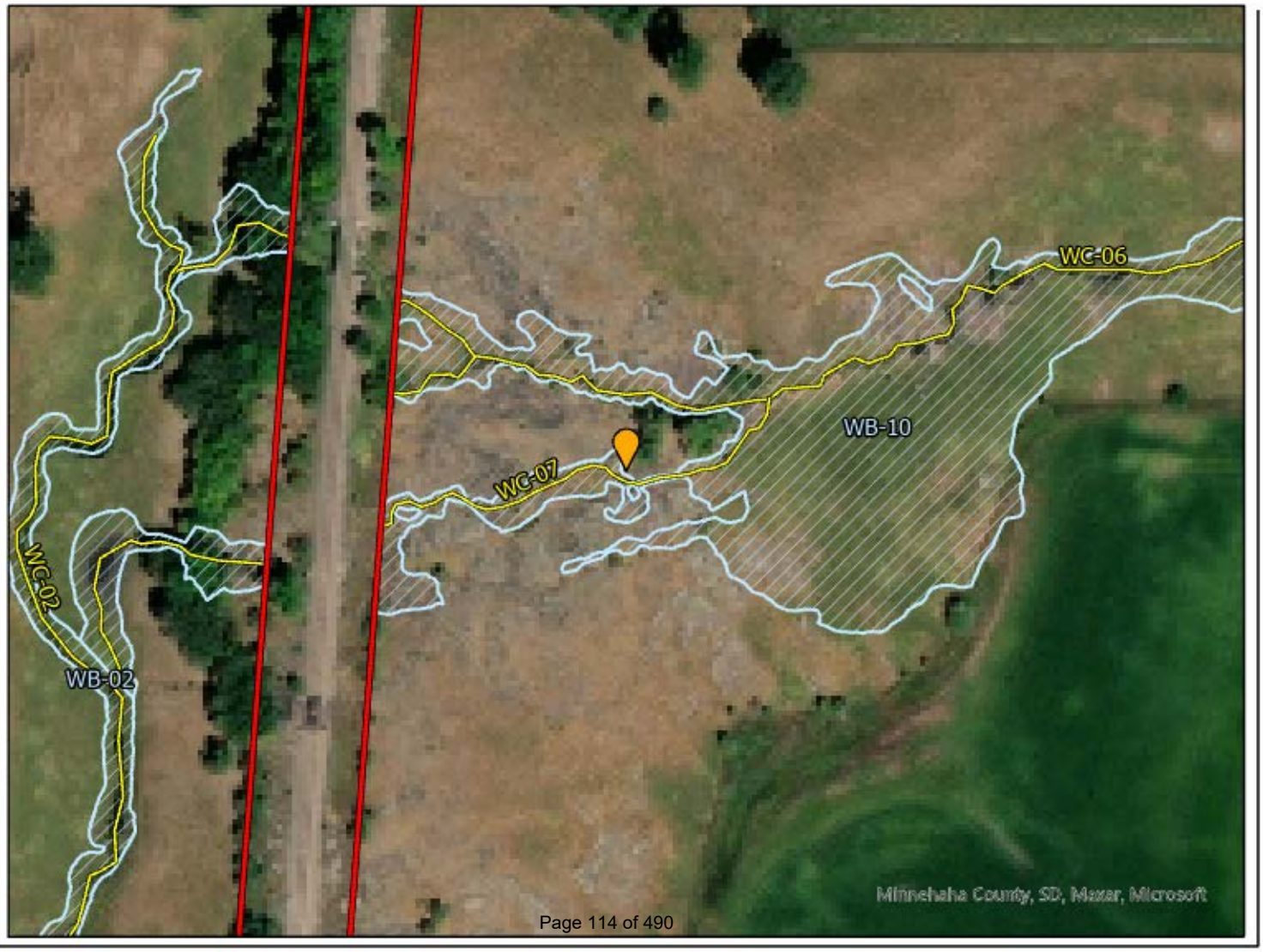
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Attributes

Feature ID	WC-07
Defined Bed & Bank	No
Waters of the US	No
Mapped on NHD	
Mapped on NWI	
Investigator	ALM
Flow Characteristics	Intermittent
Direction of the Flow	W
Water Width at Observation Point (ft)	1
Water Depth at Observation Point (ft)	0.5
Left Bank Height (ft) - Looking Downstream	3
Right Bank Height (ft) - Looking Downstream	1
OHWM Width (ft)	5
OHWM Height (ft from Substrate)	1
Evidence of Scour or Erosion	No
OHWM Criteria	natural_line,plant_community_change
Pools, Riffles, Runs Present?	pools,runs
Substrate	Bedrock



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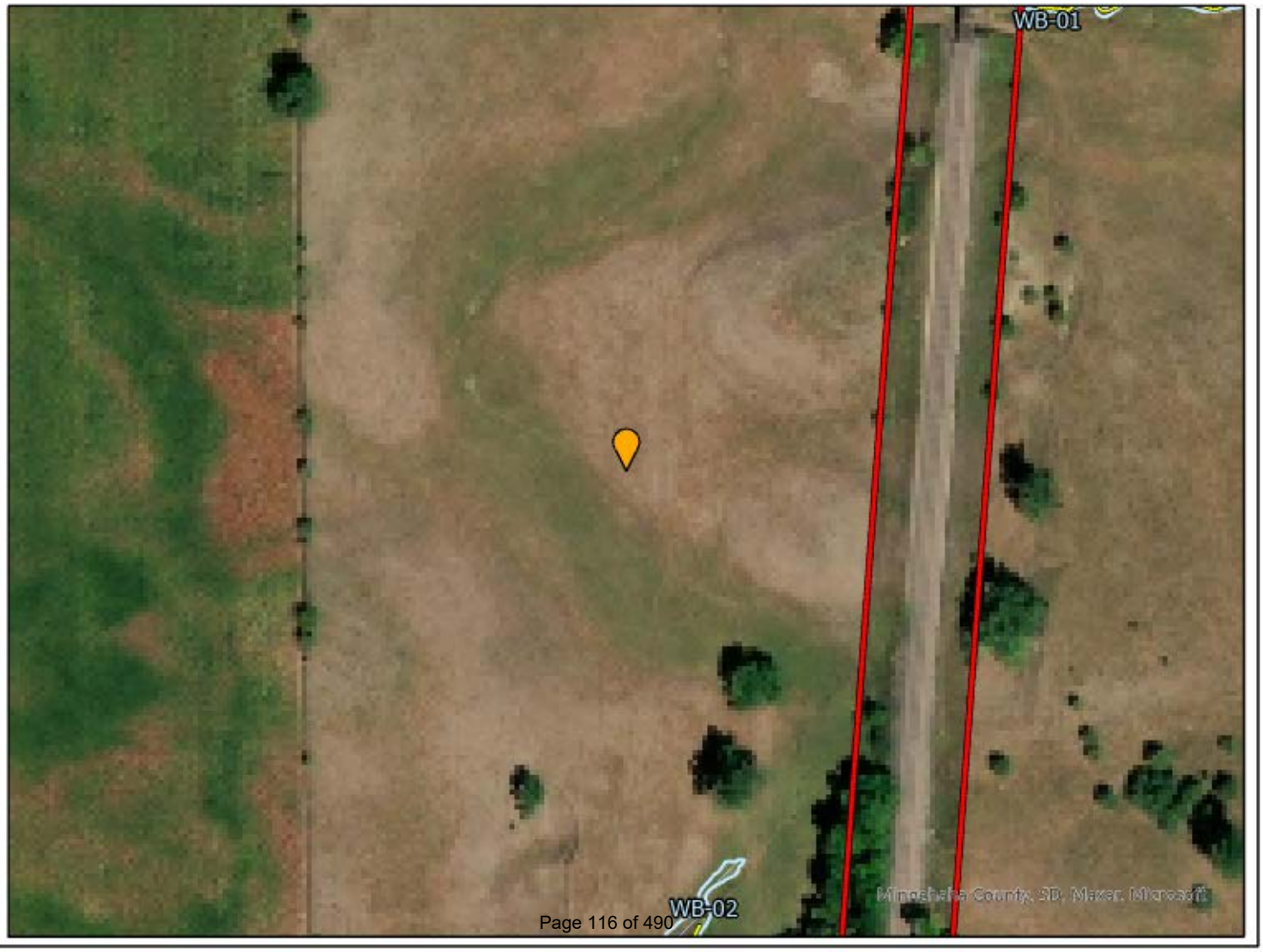
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Watercourse Data Form

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Attributes

Feature ID	NWC-01
Defined Bed & Bank	No
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	
Direction of the Flow	
Water Width at Observation Point (ft)	
Water Depth at Observation Point (ft)	
Left Bank Height (ft) - Looking Downstream	
Right Bank Height (ft) - Looking Downstream	
OHWM Width (ft)	No OHWM or evidence of channel
OHWM Height (ft from Substrate)	
Evidence of Scour or Erosion	
OHWM Criteria	
Pools, Riffles, Runs Present?	
Substrate	



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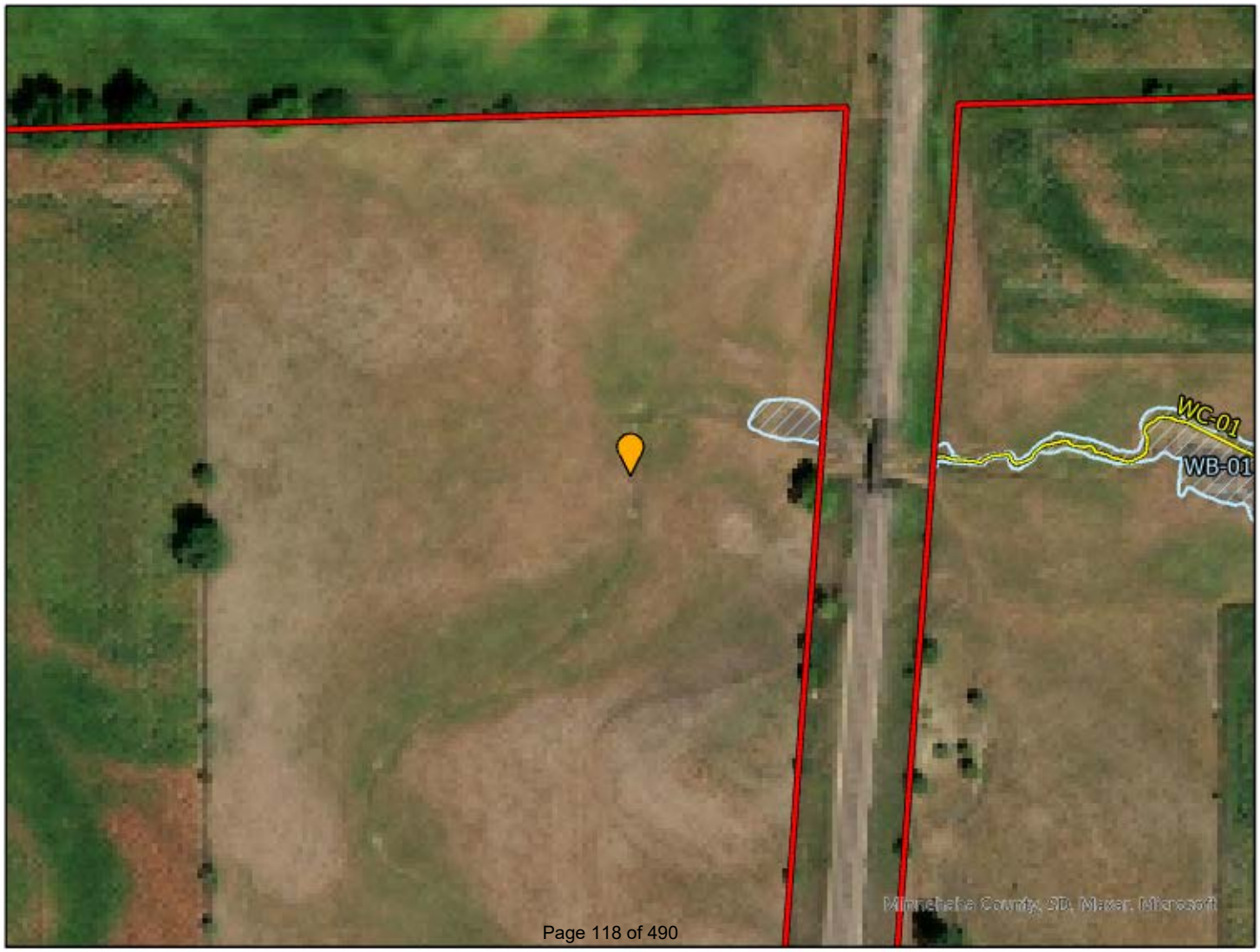
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Attributes

Feature ID	NWC-02
Defined Bed & Bank	No
Waters of the US	No
Mapped on NHD	Yes
Mapped on NWI	Yes
Investigator	ALM
Flow Characteristics	
Direction of the Flow	
Water Width at Observation Point (ft)	
Water Depth at Observation Point (ft)	
Left Bank Height (ft) - Looking Downstream	
Right Bank Height (ft) - Looking Downstream	
OHWM Width (ft)	No OHWM or evidence of channel, point taken at area where cattle use has caused erosion
OHWM Height (ft from Substrate)	
Evidence of Scour or Erosion	
OHWM Criteria	
Pools, Riffles, Runs Present?	
Substrate	

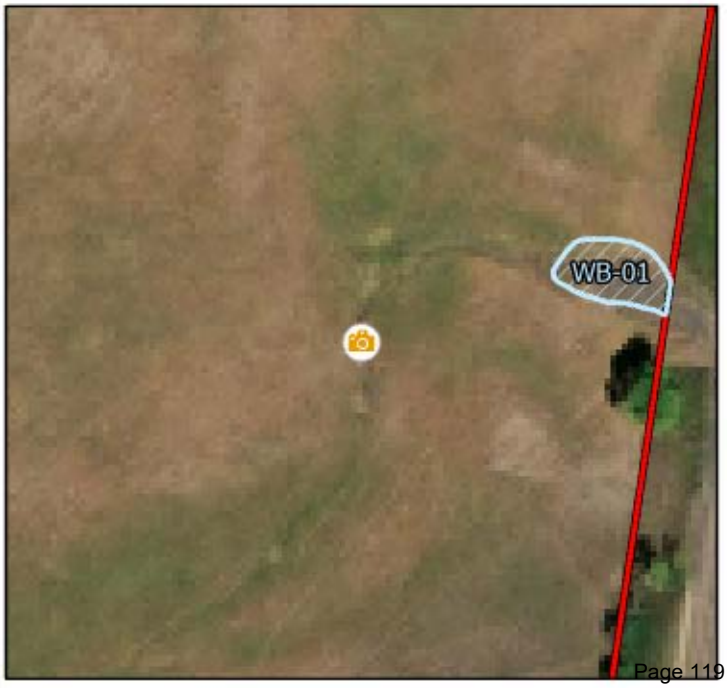


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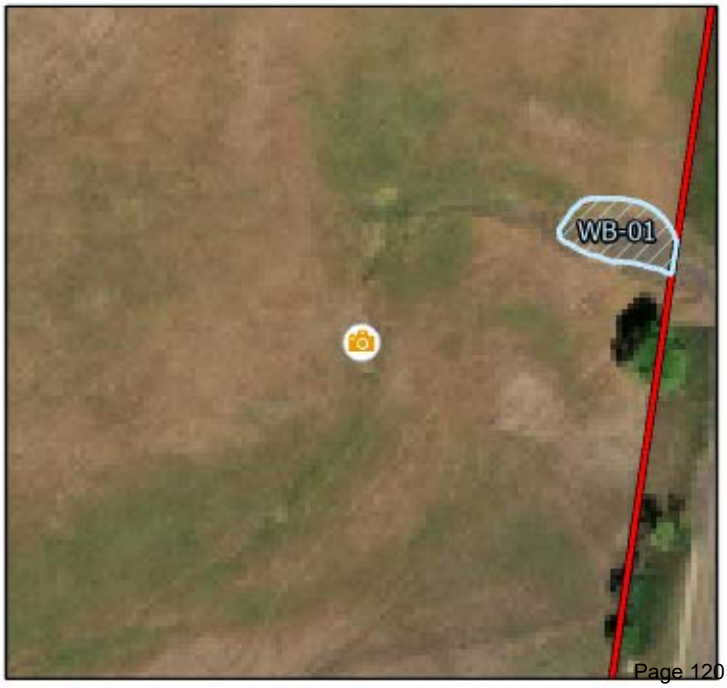


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CONSTRUCTION PLANS

FOR

STREAM REALIGNMENT

FOR

CORSON QUARRY

MINNEHAHA COUNTY, SD

PREPARED FOR:

KNIFE RIVER CORPORATION

4787 SHADOW WOOD DRIVE NE
SAUK RAPIDS, MN, 56379
CONTACT: RON KLINKER
PHONE: 320-291-6876
EMAIL: RON.KLINKER@KNIFERIVER.COM

PREPARED BY:

Phone	(320) 253-9495	1900 Medical Arts Ave S, Suite 100
Fax	(320) 358-2001	Sartell, MN 56377
	(800) 270-9495	

PROJECT NUMBER: 0033065
CONTACT: JOHN S. BLENKER

04/01/2025



Vicinity Map
(NOT TO SCALE)

SHEET INDEX

Sheet Number	Sheet Title
1	COVER
2	EXISTING CONDITIONS
3	OVERALL PLAN
4	JURISDICTIONAL WATERS IMPACTS
5	CHANNEL PLAN & PROFILE
6	CHANNEL PLAN & PROFILE
7	CHANNEL PLAN & PROFILE
8	CHANNEL PLAN & PROFILE
9	ROAD PLAN & PROFILE
10	ROAD PLAN & PROFILE
11	GRADING PLAN
12	INITAIL EROSION CONTROL PLAN
13	INITAIL EROSION CONTROL PLAN
14	INITAIL EROSION CONTROL PLAN
15	FINAL EROSION CONTROL PLAN
16	FINAL EROSION CONTROL PLAN
17	FINAL EROSION CONTROL PLAN
18	DETAILS
19	DETAILS

NO.	DATE	REVISION	SHEETS
1	4/01/25	USACE COMMENTS	ALL

CONSTRUCTION PLANS
FOR
STREAM REALIGNMENT
FOR
CORSON QUARRY
MINNEHAHA COUNTY, SD

INITIAL SUBMITTAL DATE: 4/01/25 SHEET: 1 OF 19

PROJECT NUMBER: 0033065

CORSON QUARRY

N:\0033065.00\DWG\CIVIL\0033065CV01.DWG

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SOUTH DAKOTA ONE CALL:
CALL BEFORE YOU DIG.
811 (IN STATE)
1-800-781-7474 (OUT OF STATE)

DESIGNED: . . .
CHECKED:
DRAWN:
HORIZONTAL SCALE: 1" = 200'
VERTICAL SCALE: 1" = 20'

INITIAL ISSUE: 4/01/25
REVISIONS: 4/01/25 USACE COMMENTS

PREPARED FOR:
KNIFE RIVER CORPORATION
4787 SHADOW WOOD DRIVE NE
SAUK RAPIDS, MN, 56379

04/01/2025



LEGEND

- SANITARY MANHOLE
- SEWER CLEANOUT
- STORM MANHOLE
- BEEHIVE CATCH BASIN
- CATCH BASIN
- FLARED END SECTION
- CULVERT
- CATCH BASIN MANHOLE
- HYDRANT
- GATE VALVE
- WELL
- ELECTRIC BOX
- ELECTRIC MANHOLE
- ELECTRIC TOWER
- STREET LIGHT
- STEEL/WOOD POST
- SIGN
- MAIL BOX
- FLAG POLE
- BUSH/SHRUB
- CONIFEROUS TREE
- DECIDUOUS TREE
- BOUNDARY LINE
- RIGHT-OF-WAY LINE
- LOT LINE
- EASEMENT LINE
- SECTION LINE
- TREE LINE
- CABLE TELEVISION LINE
- GUY WIRE
- POWER POLE
- TELEPHONE BOX
- CABLE TV BOX
- CABLE TV MANHOLE
- UNKNOWN MANHOLE
- CONCRETE SURFACE
- BITUMINOUS SURFACE
- GRAVEL SURFACE
- WETLAND
- WATERCOARSE
- GAS LINE
- POWER OVERHEAD
- POWER UNDERGROUND
- SANITARY SEWER
- STORM SEWER
- TELEPHONE OVERHEAD
- TELEPHONE UNDERGROUND
- WATERMAIN
- FIBER OPTIC
- FENCE LINE

0' 200' 400' 600'

CORSON QUARRY
MINNEHAHA COUNTY, SD

1900 Medical Arts Ave S, Suite 100
Sartell, MN 56377
(320) 253-8495
(320) 358-2001
(800) 270-9495
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Fax

EXISTING CONDITIONS

SHEET NUMBER: 2 OF 19

CONSTRUCTION PLANS

DATE: 4/01/25

PROJECT NUMBER: 0033065

CORSON QUARRY

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GRADING NOTES

1. LOCATIONS AND ELEVATIONS OF EXISTING TOPOGRAPHY AND UTILITIES AS SHOWN ON THIS PLAN ARE APPROXIMATE. CONTRACTOR SHALL FIELD VERIFY SITE CONDITIONS AND UTILITY LOCATIONS PRIOR TO EXCAVATION/CONSTRUCTION. THE ENGINEER SHALL BE NOTIFIED IMMEDIATELY IF ANY DISCREPANCIES ARE FOUND.
2. CONTRACTORS SHALL REFER TO ARCHITECTURAL PLANS FOR EXACT LOCATIONS AND DIMENSIONS OF VESTIBULE, SLOPED PAVEMENT, EXIT PORCHES, RAMPS, TRUCK DOCKS, PRECISE BUILDING DIMENSIONS, EXACT BUILDING UTILITY ENTRANCE LOCATIONS, AND EXACT LOCATIONS AND NUMBER OF DOWNSPOUTS.
3. ALL EXCAVATION SHALL BE IN ACCORDANCE WITH THE CURRENT EDITION OF "STANDARD SPECIFICATIONS FOR TRENCH EXCAVATION AND BACKFILL/SURFACE RESTORATION" AS PREPARED BY THE CITY ENGINEERS ASSOCIATION OF MINNESOTA.
4. ALL DISTURBED UNPAVED AREAS ARE TO RECEIVE SIX INCHES OF TOPSOIL AND SOD OR SEED. THESE AREAS SHALL BE WATERED UNTIL A HEALTHY STAND OF GRASS IS OBTAINED. SEE LANDSCAPE PLAN FOR PLANTING AND TURF ESTABLISHMENT.
5. THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROVIDING AND MAINTAINING TRAFFIC CONTROL DEVICES SUCH AS BARRICADES, WARNING SIGNS, DIRECTIONAL SIGNS, FLAGMEN AND LIGHTS TO CONTROL THE MOVEMENT OF TRAFFIC WHERE NECESSARY. PLACEMENT OF THESE DEVICES SHALL BE APPROVED BY THE ENGINEER PRIOR TO PLACEMENT. TRAFFIC CONTROL DEVICES SHALL CONFORM TO APPROPRIATE MNDOT STANDARDS.
6. ALL SLOPES SHALL BE GRADED TO 3:1 OR FLATTER, UNLESS OTHERWISE INDICATED ON THIS SHEET.
7. CONTRACTOR SHALL UNIFORMLY GRADE AREAS WITHIN LIMITS OF GRADING AND PROVIDE A SMOOTH FINISHED SURFACE WITH UNIFORM SLOPES BETWEEN POINTS WHERE ELEVATIONS ARE SHOWN OR BETWEEN SUCH POINTS AND EXISTING GRADES.
8. **SPOT ELEVATIONS SHOWN INDICATE FINISHED PAVEMENT ELEVATIONS & GUTTER FLOW LINE UNLESS OTHERWISE NOTED. PROPOSED CONTOURS ARE TO FINISHED SURFACE GRADE.**
9. SEE SOILS REPORT FOR PAVEMENT THICKNESSES AND HOLD DOWNS.
10. CONTRACTOR SHALL DISPOSE OF ANY EXCESS SOIL MATERIAL THAT EXISTS AFTER THE SITE GRADING AND UTILITY CONSTRUCTION IS COMPLETED. THE CONTRACTOR SHALL DISPOSE OF ALL EXCESS SOIL MATERIAL IN A MANNER ACCEPTABLE TO THE OWNER AND THE REGULATING AGENCIES.
11. CONTRACTOR SHALL PROVIDE A STRUCTURAL RETAINING WALL DESIGN CERTIFIED BY A LICENSED PROFESSIONAL ENGINEER.
12. ALL CONSTRUCTION SHALL CONFORM TO LOCAL, STATE AND FEDERAL RULES INCLUDING THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT REQUIREMENTS.
13. PRIOR TO PLACEMENT OF ANY STRUCTURE OR PAVEMENT, A PROOF ROLL, AT MINIMUM, WILL BE REQUIRED ON THE SUBGRADE. PROOF ROLLING SHALL BE ACCOMPLISHED BY MAKING MINIMUM OF 2 COMPLETE PASSES WITH FULLY-LOADED TANDEM-AXLE DUMP TRUCK, OR APPROVED EQUAL, IN EACH OF 2 PERPENDICULAR DIRECTIONS WHILE UNDER SUPERVISION AND DIRECTION OF THE INDEPENDENT TESTING LABORATORY. AREAS OF FAILURE SHALL BE EXCAVATED AND RE-COMPACTED AS SPECIFIED HEREIN.
14. EMBANKMENT MATERIAL PLACED BENEATH BUILDINGS AND STREET OR PARKING AREAS SHALL BE COMPACTED IN ACCORDANCE WITH THE SPECIFIED DENSITY METHOD AS OUTLINED IN MNDOT 2105.3F1 AND THE REQUIREMENTS OF THE GEOTECHNICAL ENGINEER.
15. EMBANKMENT MATERIAL NOT PLACED IN THE BUILDING PAD, STREETS OR PARKING AREA, SHALL BE COMPACTED IN ACCORDANCE WITH REQUIREMENTS OF THE ORDINARY COMPACTION METHOD AS OUTLINED IN MNDOT 2105.3F2.
16. ALL SOILS AND MATERIALS TESTING SHALL BE COMPLETED BY AN INDEPENDENT GEOTECHNICAL ENGINEER. EXCAVATION FOR THE PURPOSE OF REMOVING UNSTABLE OR UNSUITABLE SOILS SHALL BE COMPLETED AS REQUIRED BY THE GEOTECHNICAL ENGINEER. THE CONTRACTOR SHALL BE RESPONSIBLE FOR COORDINATING ALL REQUIRED SOILS TESTS AND INSPECTIONS WITH THE GEOTECHNICAL ENGINEER.

GENERAL EROSION CONTROL NOTES

1. THE CONTRACTOR IS SPECIFICALLY CAUTIONED THAT THE LOCATION AND/OR ELEVATION OF EXISTING UTILITIES AS SHOWN ON THESE PLANS ARE BASED ON RECORDS OF THE VARIOUS UTILITY COMPANIES AND LIMITED MEASUREMENTS TAKEN IN THE FIELD. THE INFORMATION SHALL NOT BE RELIED ON AS BEING EXACT OR COMPLETE. THE CONTRACTOR SHALL VERIFY EXISTING CONDITIONS PRIOR TO CONSTRUCTION AND NOTIFY THE OWNER OR ENGINEER OF DISCREPANCIES.
2. ALL SILT FENCE AND OTHER EROSION CONTROL FEATURES SHALL BE IN-PLACE PRIOR TO ANY EXCAVATION/CONSTRUCTION AND SHALL BE MAINTAINED UNTIL VIABLE TURF OR GROUND COVER HAS BEEN ESTABLISHED. EXISTING SILT FENCE ON-SITE SHALL BE MAINTAINED AND OR REMOVED AND SHALL BE CONSIDERED INCIDENTAL TO THE GRADING CONTRACT. IT IS OF EXTREME IMPORTANCE TO BE AWARE OF CURRENT FIELD CONDITIONS WITH RESPECT TO EROSION CONTROL. TEMPORARY PONDING, DIKES, HAYBALES, ETC., REQUIRED BY THE CITY SHALL BE INCIDENTAL TO THE GRADING CONTRACT.
3. EROSION AND SILTATION CONTROL (ESC): THE CONTRACTOR SHALL ASSUME COMPLETE RESPONSIBILITY FOR CONTROLLING ALL SILTATION AND EROSION OF THE PROJECT AREA. THE CONTRACTOR SHALL USE WHATEVER MEANS NECESSARY TO CONTROL THE EROSION AND SILTATION INCLUDING BUT NOT LIMITED TO: CATCH BASIN INSERTS, CONSTRUCTION ENTRANCES, EROSION CONTROL BLANKET, AND SILT FENCE. ESC SHALL COMMENCE WITH GRADING AND CONTINUE THROUGHOUT THE PROJECT UNTIL ACCEPTANCE OF THE WORK BY THE OWNER. THE CONTRACTOR'S RESPONSIBILITY INCLUDES ALL IMPLEMENTATION AS REQUIRED TO PREVENT EROSION AND THE DEPOSITING OF SILT. THE OWNER MAY DIRECT THE CONTRACTOR'S METHODS AS DEEMED FIT TO PROTECT PROPERTY AND IMPROVEMENTS. ANY DEPOSITION OF SILT OR MUD ON NEW OR EXISTING PAVEMENT OR IN EXISTING STORM SEWERS OR SWALES SHALL BE REMOVED AFTER EACH RAIN EVENT. AFFECTED AREAS SHALL BE CLEANED TO THE SATISFACTION OF THE OWNER, ALL AT THE EXPENSE OF THE CONTRACTOR. ALL TEMPORARY EROSION CONTROL SHALL BE REMOVED BY THE CONTRACTOR AFTER THE TURF IS ESTABLISHED.
4. ALL STREETS DISTURBED DURING WORKING HOURS MUST BE CLEANED AT THE END OF EACH WORKING DAY. A CONSTRUCTION ENTRANCE TO THE SITE MUST BE PROVIDED ACCORDING TO DETAILS TO REDUCE TRACKING OF DIRT ONTO PUBLIC STREETS.
5. PROPOSED PONDS SHALL BE EXCAVATED FIRST AND USED AS TEMPORARY PONDING DURING CONSTRUCTION.
6. WHEN INSTALLING END-OF-LINE FLARED END SECTIONS, BRING THE SILT FENCE UP & OVER THE FLARED END SECTIONS & COVER DISTURBED AREAS WITH RIP RAP. THE UPSTREAM FLARED END SECTIONS SHALL HAVE WOOD FIBER BLANKET INSTALLED ON THE DISTURBED SOILS.
7. ALL UNPAVED AREAS ALTERED DUE TO CONSTRUCTION ACTIVITIES MUST BE RESTORED WITH SEED AND MULCH, SOD, EROSION CONTROL BLANKET OR BE HARD SURFACE WITHIN 2 WEEKS OF COMPLETION OF CONSTRUCTION.
8. THE SITE MUST BE STABILIZED PER THE REQUIREMENTS OF THE MPCA, NPDES, MNDOT, AND CITY.
   A. TEMPORARY (GREATER THAN 1-YEAR) SEED SHALL BE MNDOT SEED MIX 22-111 AT 30.5-POUNDS PER ACRE.
   B. TEMPORARY (LESS THAN 1-YEAR) SEED SHALL BE MNDOT SEED MIX 21-112 (FALL) OR 21-111 (SPRING/SUMMER) AT 100-POUNDS PER ACRE
   C. INFILTRATION/FILTRATION BASIN SHALL BE MNDOT SEED MIX 34-262 AT 14.5-POUNDS PER ACRE.
   D. POND SLOPES SHALL BE MNDOT SEED MIX 33-261 AT 35-POUNDS PER ACRE.
   E. GENERAL SEEDING SHALL BE MNDOT SEED MIX 25-151 AT 70-POUNDS PER ACRE.
   F. MULCH SHALL BE MNDOT TYPE 1 APPLIED AT 2-TONS PER ACRE.
9. FOR AREAS WITH SLOPE OF 3:1 OR GREATER, RESTORATION WITH SOD OR EROSION CONTROL BLANKET IS REQUIRED.
10. ALL TEMPORARY STOCKPILES MUST HAVE SILT FENCE INSTALLED AROUND THEM TO TRAP SEDIMENT.
11. ALL PERMANENT PONDS USED AS TEMPORARY SEDIMENT BASINS DURING CONSTRUCTION SHALL BE DREDGED AFTER THE SITE HAS BEEN STABILIZED TO RESTORE THE POND TO THE PROPOSED BOTTOM ELEVATION.
12. ALL CONSTRUCTION SHALL CONFORM TO LOCAL AND STATE RULES INCLUDING THE NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT REQUIREMENTS.
13. THE SITE MUST BE KEPT IN A WELL-DRAINED CONDITION AT ALL TIMES. THE CONTRACTOR SHALL BE RESPONSIBLE FOR TEMPORARY DITCHES, PIPING OR OTHER MEANS REQUIRED TO INSURE PROPER DRAINAGE DURING CONSTRUCTION. LOW POINTS IN ROADWAYS OR BUILDING PADS MUST BE PROVIDED WITH A POSITIVE OUTFLOW.

PHASING

PHASE 1
PHASE 2
PHASE 3

GRADING LEGEND

EXISTING	PROPOSED	
980	980	PROPERTY LINE
982	982	INDEX CONTOUR
		INTERVAL CONTOUR
		POND NORMAL WATER LEVEL
		STORM SEWER
		FLARED END SECTION (WITH RIPRAP)

0' 200' 400' 600'

DESIGNED: - - -
CHECKED: - - -
DRAWN: - - -
HORIZONTAL SCALE: 1"=200'
VERTICAL SCALE: 1" = 40' or 20'

INITIAL ISSUE: 4/01/25
REVISIONS: 4/01/25 USACE COMMENTS

PREPARED FOR:
KNIFE RIVER CORPORATION
4787 SHADOW WOOD DRIVE NE
SAUK RAPIDS, MN, 56379

04/01/2025

CORSON QUARRY
MINNEHAHA COUNTY, SD

1900 Medical Arts Ave S, Suite 100
Sartell, MN 56377
(320) 253-9495 Phone
(320) 308-2001 Fax
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OVERALL PLAN

SHEET NUMBER: 3 OF 19

DATE: 4/01/25

CONSTRUCTION PLANS

PROJECT NUMBER: 0033065

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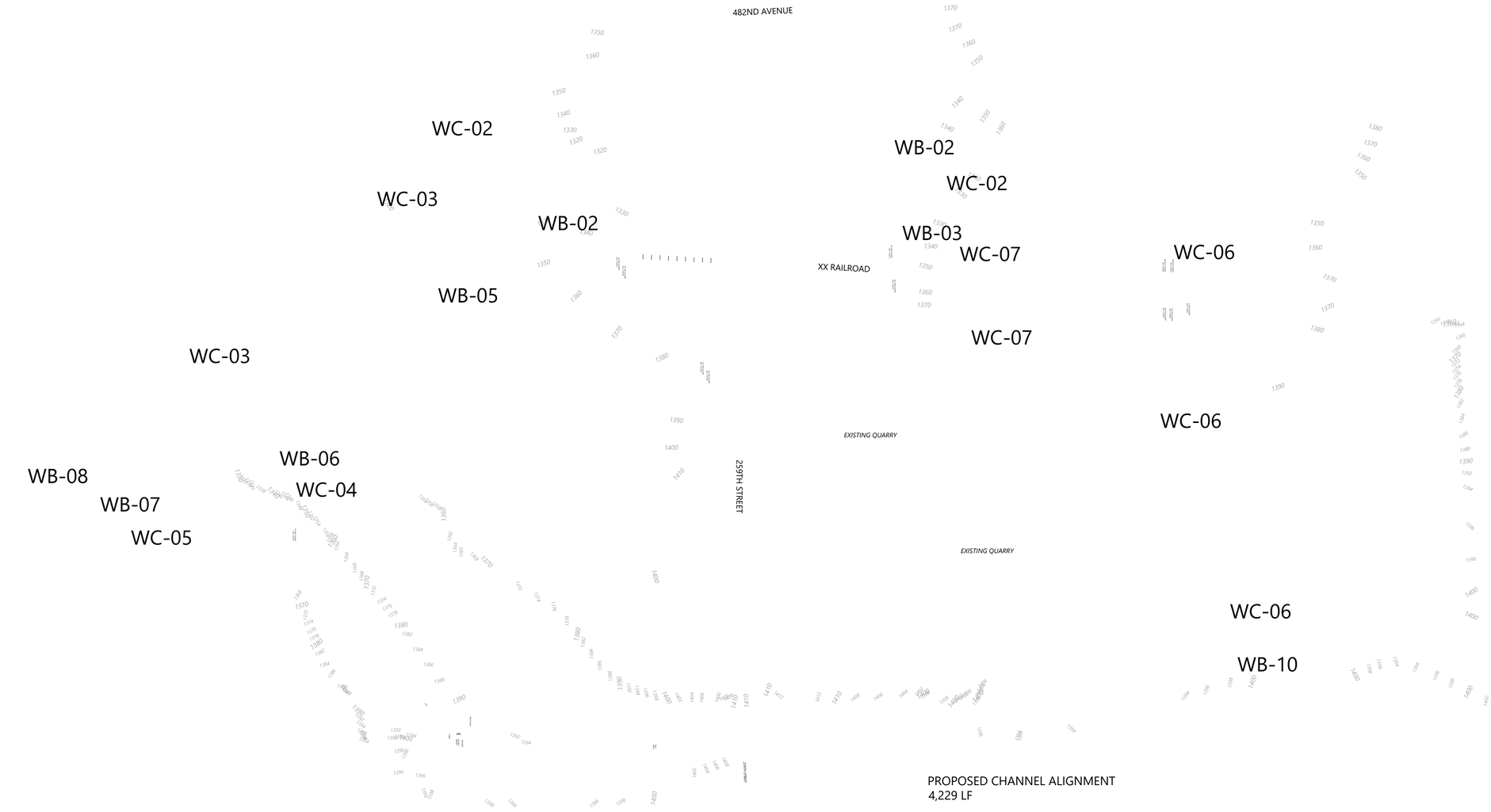
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PROPOSED CHANNEL ALIGNMENT
4,229 LF

NOTE:

REFER TO ENVIRONMENTAL DOCUMENTS COMPLETED BY WESTWOOD PROFESSIONAL SERVICES FOR WETLAND AND WATER COURSE PERMITTING AND DETAILS.

WETLAND DIRECT IMPACTS

DELINEATED WETLAND	ACRES	ACRES IMPACTED
WB-02	2.33	
WB-03	0.09	
WB-05	0.12	
WB-06	0.92	
WB-07	0.67	
WB-08	0.39	
WB-10	8.10	8.10

WETLAND INDIRECT IMPACTS

DELINEATED WETLAND	ACRES	ACRES IMPACTED
WB-02	2.33	2.33
WB-03	0.09	0.09
WB-05	0.12	
WB-06	0.92	
WB-07	0.67	
WB-08	0.39	
WB-10	8.10	

* INDIRECT IMPACT AREAS DUE TO LOSS OF HYDROLOGY

WATERCOURSE DIRECT IMPACTS

DELINEATED WATERCOURSE	LINEAL FEET	LINEAL FEET IMPACTED	ACRES IMPACTED
WC-02	3,431		
WC-03	2,366		
WC-04	482		
WC-05	356		
WC-06	2,645	2,514	0.29
WC-07	702	423	0.01

WATERCOURSE INDIRECT IMPACTS

DELINEATED WATERCOURSE	LINEAL FEET	LINEAL FEET IMPACTED	ACRES IMPACTED
WC-02	3,431	3,431	0.39
WC-03	2,366		
WC-04	482		
WC-05	356		
WC-06	2,645	131	.01
WC-07	702	279	.01

* INDIRECT IMPACT AREAS DUE TO LOSS OF HYDROLOGY

LEGEND

- DELINEATED WETLAND NO IMPACTS
- DELINEATED WATERCOURSE NO IMPACTS
- DELINEATED WETLAND DIRECT IMPACTS
- DELINEATED WATERCOURSE DIRECT IMPACTS
- DELINEATED WETLAND INDIRECT IMPACTS
- DELINEATED WATERCOURSE INDIRECT IMPACTS

0' 200' 400' 600'

PREPARED FOR:
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4787 SHADOW WOOD DRIVE NE
SAUK RAPIDS, MN, 56379

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1900 Medical Arts Ave S, Suite 100
Sartell, MN 56377
(320) 253-8495
(320) 358-2001
(800) 270-9495
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JURISDICTIONAL WATERS IMPACTS

SHEET NUMBER: 4 OF 19

CONSTRUCTION PLANS

DATE: 4/01/25

PROJECT NUMBER: 0033065

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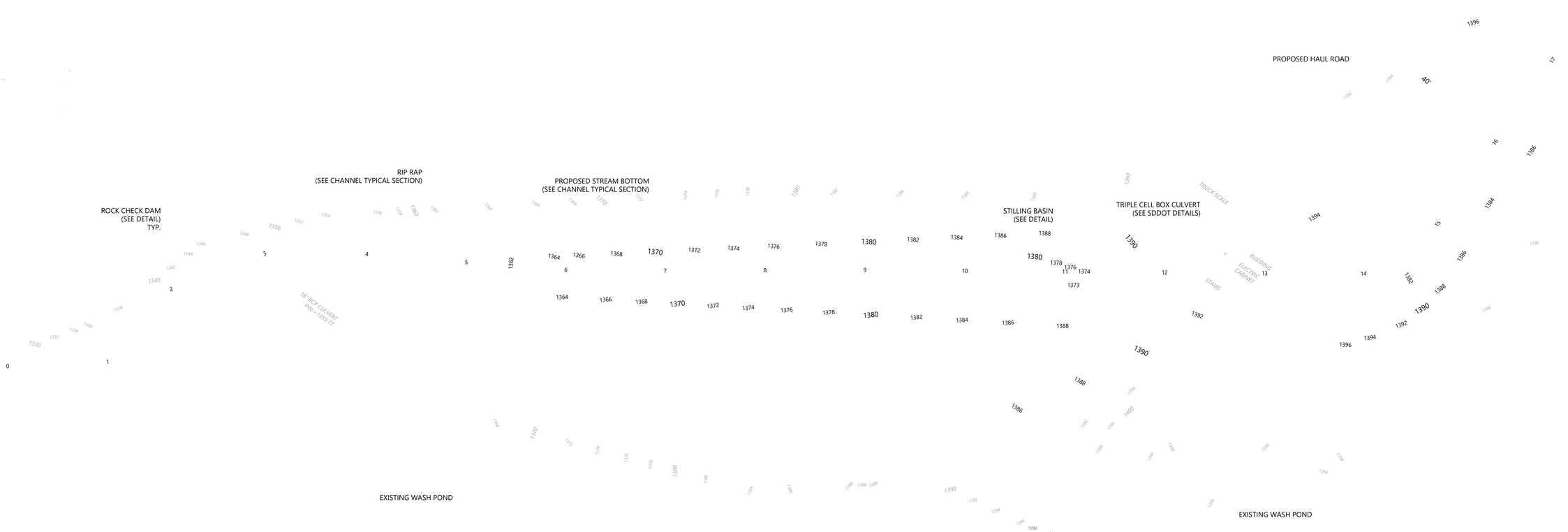
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VERTICAL SCALE10' or 5'

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4/01/25

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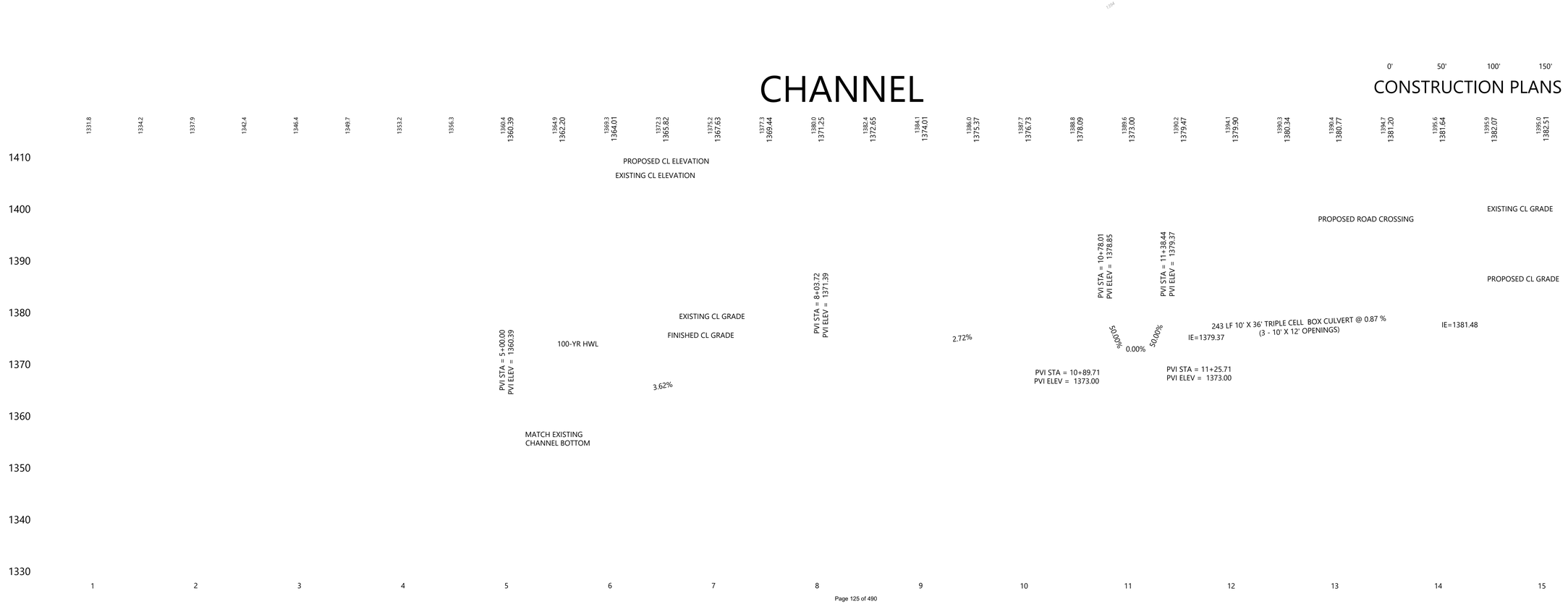
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CHANNEL

0' 50' 100' 150'

CONSTRUCTION PLANS



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(320) 253-8495
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CHANNEL PLAN & PROFILE

SHEET NUMBER:
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OF
19

DATE: 4/01/25

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TRIPLE CELL BOX CULVERT
(SEE SDDOT DETAILS)

EXISTING SCALE TO BE
RELOCATED

PROPOSED HAUL ROAD

RIP RAP
(SEE CHANNEL TYPICAL SECTION)

TRIPLE CELL BOX CULVERT
(SEE SDDOT DETAILS)

PROPOSED CHANNEL BOTTOM
(SEE STREAM TYPICAL SECTION)

259TH STREET

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4787 SHADOW WOOD DRIVE NE
SAUK RAPIDS, MN, 56379

04/01/2025

CHANNEL

0' 50' 100' 150'

CONSTRUCTION PLANS

1379.47 | 1394.1 1379.90 | 1390.3 1380.34 | 1390.4 1380.77 | 1394.7 1381.20 | 1395.6 1381.64 | 1395.9 1382.07 | 1395.0 1382.51 | 1394.0 1382.94 | 1393.5 1383.38 | 1393.3 1383.81 | 1393.5 1384.24 | 1393.3 1384.68 | 1393.4 1385.11 | 1393.9 1385.55 | 1394.7 1385.98 | 1395.7 1386.41 | 1396.5 1386.85 | 1397.8 1387.28 | 1399.2 1387.72 | 1399.8 1388.15 | 1402.5 1388.58 | 1404.4 1389.02 | 1406.3 1389.45 | 1409.1 1389.55 | 1411.6 1389.65 | 1410.7 1389.75 | 1410.8 1389.85 | 1410.4 1389.95 | 1410.6 1390.05 | 1410.0

PROPOSED CL ELEVATION
EXISTING CL ELEVATION

PROPOSED ROAD CROSSING

EXISTING CL GRADE

PROPOSED CL GRADE

100-YR HWL

0.87%

243 LF 10' X 36' TRIPLE CELL BOX CULVERT @ 0.87 %
(3 - 10' X 12' OPENINGS)

IE=1379.37

STA = 11+25.71
ELEV = 1373.00

IE=1381.48

PVI STA = 22+99.93
PVI ELEV = 1389.45

IE=1389.49

172 LF 10' X 36' TRIPLE CELL BOX CULVERT @ 0.20 %
(3 - 10' X 12' OPENINGS)

IE=1389.83

EXISTING ROAD CROSSING

EXISTING CL GRADE

PROPOSED CL GRADE

1430 1420 1410 1400 1390 1380 1370 1360 1350

12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

CORSON QUARRY
MINNEHAHA COUNTY, SD

1900 Medical Arts Ave S, Suite 100
Sartell, MN 56377
(320) 253-8495
(320) 358-2001
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CHANNEL PLAN & PROFILE

SHEET NUMBER: 6 OF 19

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EXISTING OPEN PIT QUARRY

PROPOSED BERM
(SEE BERM SECTION SHEET 11)

TRIPLE CELL BOX CULVERT
(SEE SDDOT DETAILS)

PROPOSED STREAM BOTTOM
(SEE CHANNEL TYPICAL SECTION)

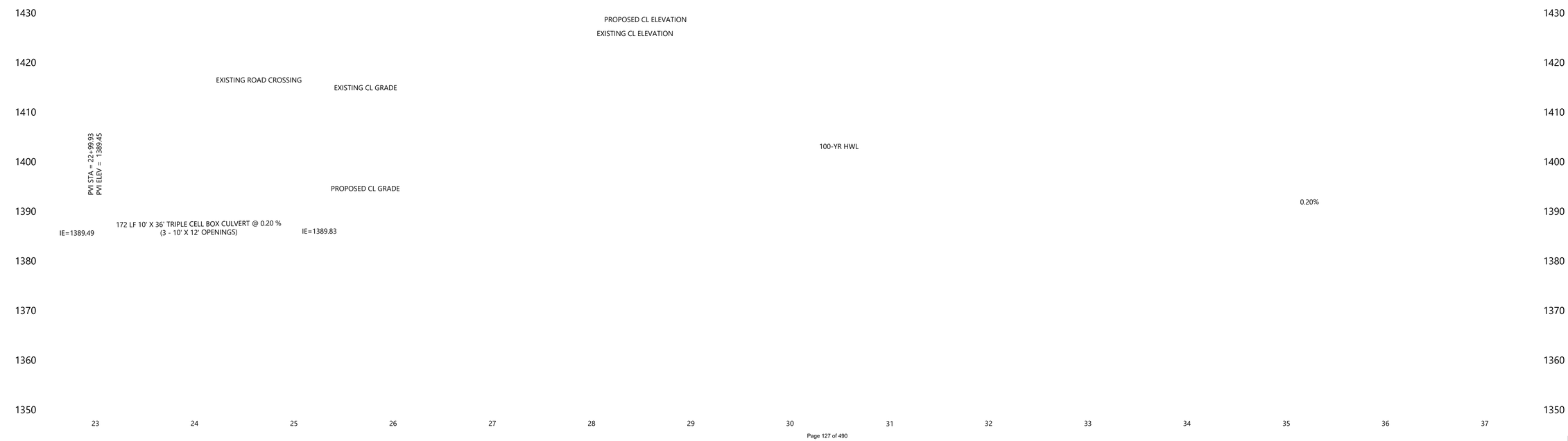
PROPERTY BOUNDARY

RIP RAP
(SEE CHANNEL TYPICAL SECTION)

259TH STREET

CHANNEL

CONSTRUCTION PLANS



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Sartell, MN 56377
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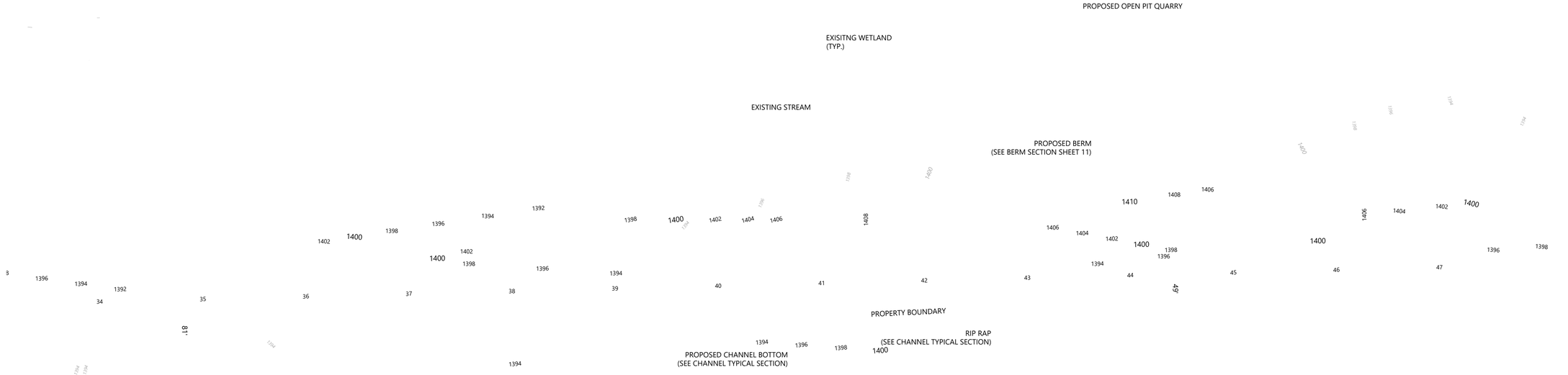
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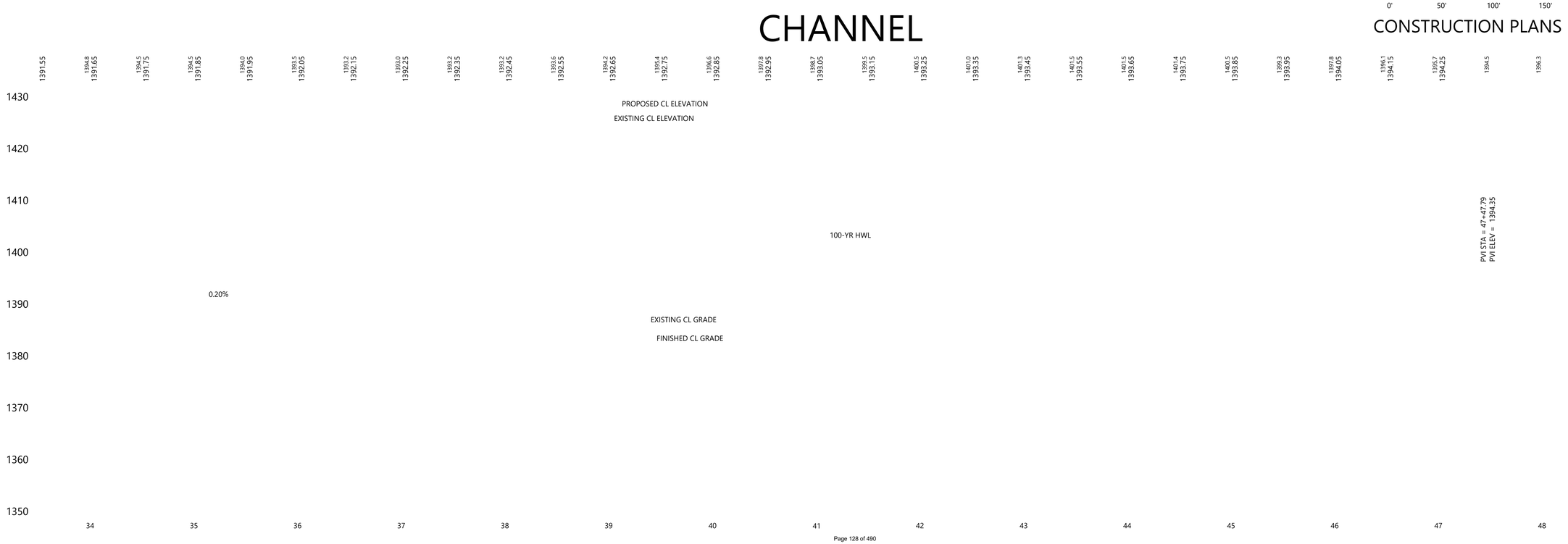
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CHANNEL

CONSTRUCTION PLANS



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VERTICAL SCALE10' or 5'

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MINNEHAHA COUNTY, SD

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Sartell, MN 56377
(320) 253-8495
(320) 358-2001
(800) 270-9495
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CHANNEL PLAN & PROFILE

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TRIPLE CELL BOX CULVERT
(SEE SDDOT DETAILS)

PROPOSED HAUL ROAD

TRIPLE CELL BOX CULVERT
(SEE SDDOT DETAILS)

PROPOSED CHANNEL

259TH STREET

ROAD

0' 50' 100' 150'

CONSTRUCTION PLANS

| | | |

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PREPARED FOR:
KNIFE RIVER CORPORATION
4787 SHADOW WOOD DRIVE NE
SAUK RAPIDS, MN, 56379

04/01/2025

PROPOSED HAUL ROAD

PROPOSED CHANNEL

259TH STREET

ROAD

0' 50' 100' 150'

CONSTRUCTION PLANS

CORSON QUARRY
MINNEHAHA COUNTY, SD

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Sartell, MN 56377
Phone (320) 253-8495
Fax (320) 258-2001
(800) 270-8495

PROPOSED CL ELEVATION
EXISTING CL ELEVATION

PVI STA = 8+50.00
PVI ELEV = 1399.21

PVI STA = 13+91.20
PVI ELEV = 1410.25

PVI STA = 14+15.24
PVI ELEV = 1410.28

PVI STA = 22+24.16
PVI ELEV = 1389.72

2.04%

2.51%

EXISTING ROAD CL

EXISTING CL GRADE

PROPOSED CL GRADE

1398.40	1399.2 1399.21	1399.8 1400.23	1398.0 1401.25	1394.6 1402.27	1395.8 1403.29	1398.6 1404.31	1401.4 1405.33	1403.9 1406.35	1405.2 1407.37	1407.0 1408.39	1404.9 1409.41	1410.6	1407.6 1409.41	1408.9 1408.15	1411.7 1406.90	1412.5 1405.64	1412.3 1404.39	1411.1 1403.13	1410.2 1401.88	1408.9 1400.62	1407.8 1399.37	1406.8 1398.11	1405.4 1396.86	1403.4 1395.60	1401.5 1394.34	1399.4 1393.09	1393.3 1391.83	1390.5 1390.58	1389.2
8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23														

SHEET NUMBER: 10 OF 19

DATE: 4/01/25

PROJECT NUMBER: 0033065

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BERM SECTION

0' 50' 100' 150'

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CORSON QUARRY
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GRADING PLAN

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04/01/2025

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MAINTAIN EXISTING VEGETATION IN CHANNEL UNTIL UPSTREAM IS STABLIZED AND THIS IS READY FOR RIP RAP CONSTRUCTION

FENCE OR TOPSOIL BERM (TYP.)

18" RCP CULVERT INV.=1357.77

DOUBLE ROW/REDUNDANT SILT FENCE OR TOPSOIL BERM 50' FROM WETLAND.

SEE ABOVE

FENCE OR TOPSOIL BERM (TYP.)

SEE BELOW

CONSTRUCTION ENTRANCE

SEE SHEET 13

TRUCK SCALE
BUILDING
ELECTRIC CABINET
STAIRS

259TH STREET

EROSION CONTROL LEGEND

EXISTING	PROPOSED	
		PROPERTY LINE
980	980	INDEX CONTOUR
982	982	INTERVAL CONTOUR
		PERIMETER CONTROL (SILT FENCE OR TOPSOIL BERM
		STORM SEWER
		FLARED END SECTION (WITH RIPRAP)
		EROSION CONTROL BLANKET
		RIP RAP (SEE DETAIL)

0' 50' 100' 150'

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INITAIL EROSION CONTROL PLAN

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DATE: 4/01/25

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CONSTRUCTION PLANS

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SEE SHEET 12

CONSTRUCTION ENTRANCE

259TH STREET

FENCE OR TOPSOIL BERM (TYP.)

SEE BELOW

SEE ABOVE

FENCE OR TOPSOIL BERM (TYP.)

SEE SHEET 14

EROSION CONTROL LEGEND

EXISTING	PROPOSED	
		PROPERTY LINE
980	980	INDEX CONTOUR
982	982	INTERVAL CONTOUR
		PERIMETER CONTROL (SILT FENCE OR TOPSOIL BERM
		STORM SEWER
		FLARED END SECTION (WITH RIPRAP)
		EROSION CONTROL BLANKET
		RIP RAP (SEE DETAIL)

0' 50' 100' 150'

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EROSION CONTROL LEGEND

EXISTING	PROPOSED	
		PROPERTY LINE
980	980	INDEX CONTOUR
982	982	INTERVAL CONTOUR
		PERIMETER CONTROL (SILT FENCE OR TOPSOIL BERM
		STORM SEWER
		FLARED END SECTION (WITH RIPRAP)
		EROSION CONTROL BLANKET
		RIP RAP (SEE DETAIL)

1" = 50'

0' 50' 100' 150'

CONSTRUCTION PLANS

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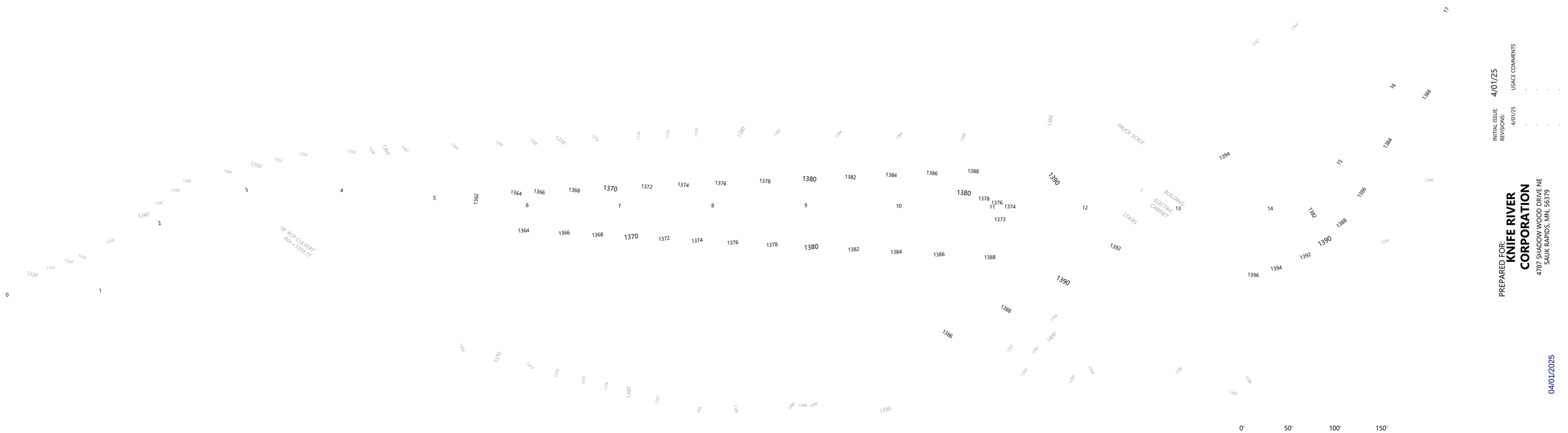
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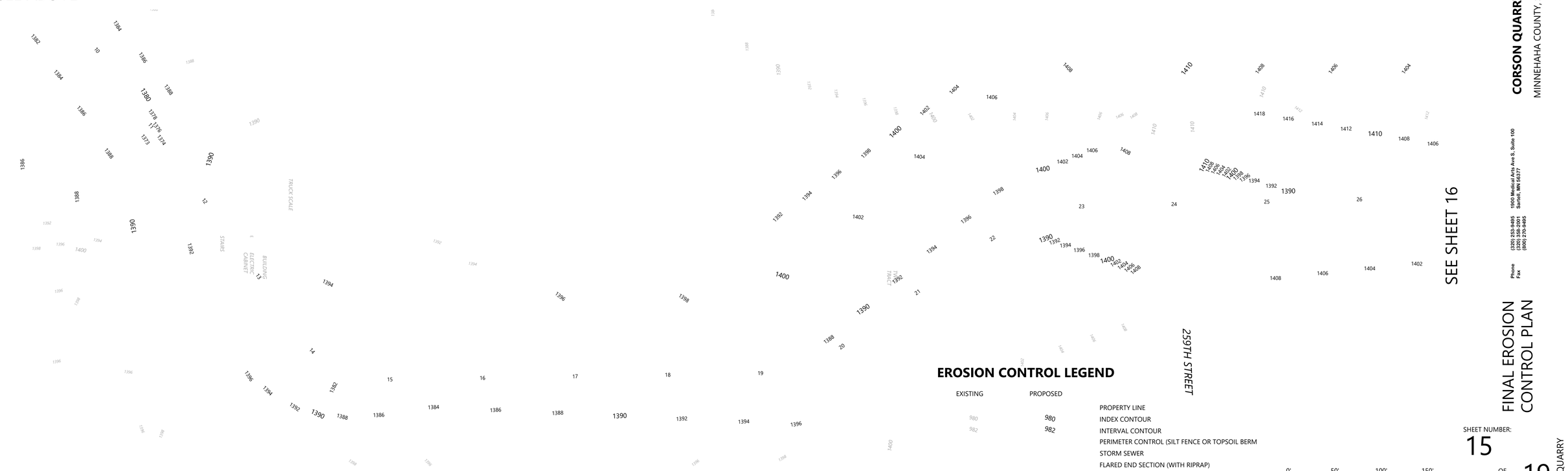
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		PROPERTY LINE
980	980	INDEX CONTOUR
982	982	INTERVAL CONTOUR
		PERIMETER CONTROL (SILT FENCE OR TOPSOIL BERM
		STORM SEWER
		FLARED END SECTION (WITH RIPRAP)
		EROSION CONTROL BLANKET
		RIP RAP (SEE DETAIL)

SEE SHEET 16

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FINAL EROSION CONTROL PLAN

SHEET NUMBER: 15 OF 19

CONSTRUCTION PLANS DATE: 4/01/25

PROJECT NUMBER: 0033065

CORSON QUARRY

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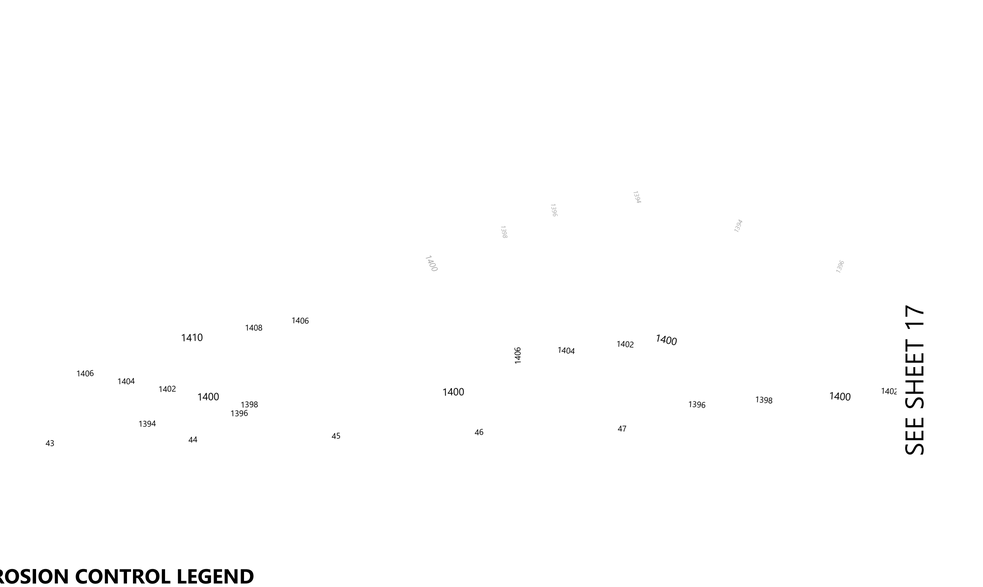
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SEE SHEET 15



SEE SHEET BELOW

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EROSION CONTROL LEGEND

EXISTING	PROPOSED	
		PROPERTY LINE
980	980	INDEX CONTOUR
982	982	INTERVAL CONTOUR
		PERIMETER CONTROL (SILT FENCE OR TOPSOIL BERM
		STORM SEWER
		FLARED END SECTION (WITH RIPRAP)
		EROSION CONTROL BLANKET
		RIP RAP (SEE DETAIL)

0' 50' 100' 150'

CONSTRUCTION PLANS

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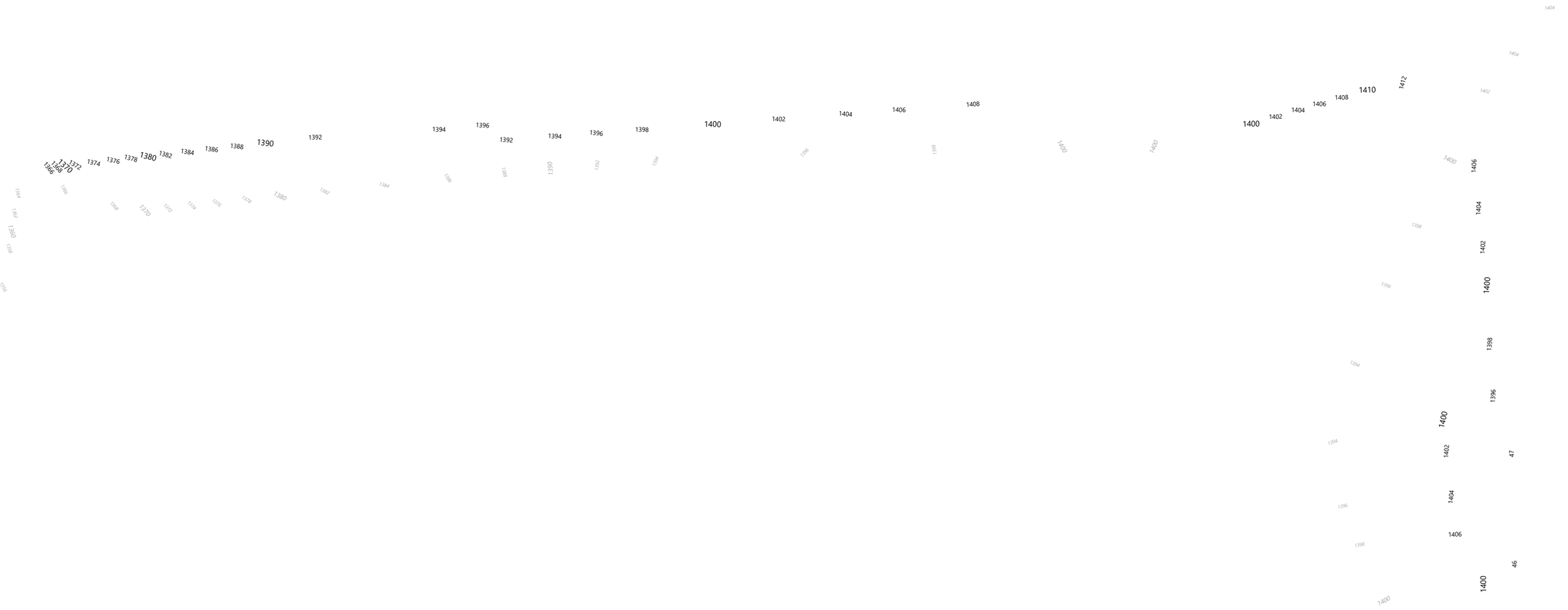
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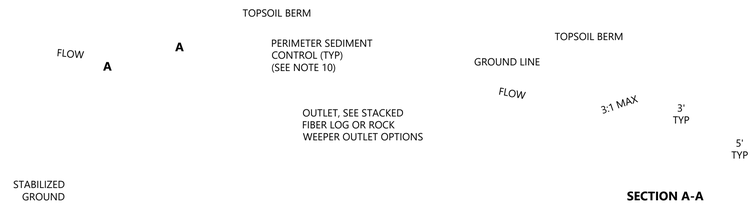
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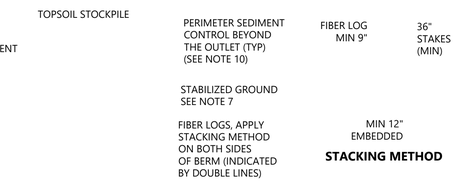
PERSPECTIVE VIEW

SECTION A-A

NOTES:

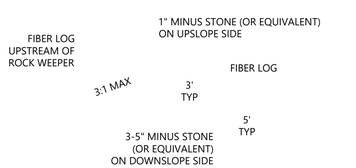
1. REFER TO NPDES PERMIT FOR SPECIFICATIONS OF EROSION AND SEDIMENT CONTROL MEASURES.
2. REDUNDANT PERIMETER SEDIMENT CONTROL IS REQUIRED WITHIN 50' OF WETLANDS AND STREAMS.
3. TERMINAL ENDS OF TOPSOIL BERM SHOULD BE HIGHER IN ELEVATION THAN THE TOP OF BERM.
4. MULTIPLE OUTLETS MAY BE NEEDED, CONTRACTOR TO FIELD FIT AS NECESSARY. OUTLETS ARE OPTIONAL TO MINIMIZE WATER ACCUMULATION ALONG THE TOPSOIL BERM.
5. TEMPORARY STABILIZATION FOR STOCKPILES MAY CONSIST OF HYDROMULCH, SOIL STABILIZER, OR TACKIFIER.
6. PERIMETER SEDIMENT CONTROL MAY CONSIST OF SILT FENCE, FIBER LOGS, OR WOOD MULCH BERMS. REFER TO APPROPRIATE DETAIL FOR INSTALLATION REQUIREMENTS.
7. EROSION CONTROL BEST PRACTICES TO BE APPLIED TO ALL DISTURBED SOILS BETWEEN AND DOWNGRADIENT OF THE STACKED FIBER LOGS. STABILIZE GROUND BETWEEN THE STACKED FIBER LOGS WITH STRAW OR EROSION CONTROL BLANKET FOR STEEPER SLOPES, GREATER THAN OR EQUAL TO 3:1.
8. IF LOCATED NEAR THE TOE OF A STEEP SLOPE, PLACE TOPSOIL BERM ALONG DOWNSTREAM SIDE AT LEAST 5 TO 7 FEET AWAY FROM THE TOE TO IMPOUND STORMWATER RUNOFF. IF LOCATED AT THE TOP OF A RAVINE OR POND AREA, PLACE TOPSOIL BERM ALONG UPSTREAM EDGE AT 3 FEET AWAY FROM GRADE DROP-OFF TO ALLOW FOR SLUMPING OVER TIME.
9. AFTER COMPLETION OF THE MASS GRADING EFFORT, TOPSOIL BERM MAY BE RESPREAD AND UTILIZED IN AREAS DESIGNATED FOR VEGETATIVE GROWTH TO HELP ACHIEVE STABILIZATION.
10. IF TOPSOIL BERM IS IMMEDIATELY STABILIZED, ADDITIONAL PERIMETER SEDIMENT CONTROL MAY NOT BE NEEDED ON DOWNSTREAM SIDE. CONSULT QSP FOR PROJECT.

TOPSOIL BERM - PERIMETER SEDIMENT CONTROL



STACKING METHOD

STACKED FIBER LOG OUTLET (OPTION #1)



ROCK WEEPER OUTLET (OPTION #2)

NOT TO SCALE



STANDARD DETAIL
TRENCH WITH NATIVE BACKFILL

NOTES:

1. INSPECT AND REPAIR FENCE AFTER EACH STORM EVENT AND REMOVE SEDIMENT WHEN ACCUMULATED TO 1/2 THE HEIGHT OF THE FABRIC OR MORE.
2. REMOVED SEDIMENT SHALL BE DEPOSITED TO AN AREA THAT WILL NOT CONTRIBUTE SEDIMENT OFF-SITE AND CAN BE PERMANENTLY STABILIZED.
3. SILT FENCE SHALL BE PLACED ON SLOPE CONTOURS TO MAXIMIZE PONDING EFFICIENCY.
4. ALL ENDS OF THE SILT FENCE SHALL BE WRAPPED UPSLOPE SO THE ELEVATION OF THE BOTTOM OF FABRIC IS HIGHER THAN "PONDING HEIGHT".
5. "HEAVY DUTY" IS SAME AS MACHINE SLICED ONLY HAND INSTALLED.

MACHINE SLICED SILT FENCE
(HEAVY DUTY)

LAST REVISED: 08/15/17
GD03



NOTES:

1. FILTER FABRIC SHALL BE PLACED UNDER ROCK/WOOD CHIPS TO STOP MUD MIGRATION THROUGH ROCK/WOOD CHIPS.
2. WOODCHIPS USED FOR CONSTRUCTION ENTRANCES MUST BE 80% NOT LESS THAN 2-INCHES AND NOT MORE THAN 5-INCHES. NO CHIPPED-UP MANUFACTURED WOOD AND/OR CHEMICALLY TREATED IS ALLOWED.
3. ENTRANCES MUST BE MAINTAINED REGULARLY TO PREVENT SEDIMENTATION ON PUBLIC ROADWAYS. FUGITIVE ROCK OR WOODCHIPS WILL BE REMOVED FROM ADJACENT ROADWAYS DAILY OR MORE FREQUENTLY AS NECESSARY.
4. LENGTH AND WIDTH TO BE ADJUSTED FOR SITE CONDITIONS.

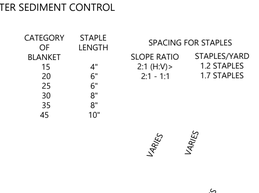
CONSTRUCTION ENTRANCE

LAST REVISED: 08/15/17
GD05

CATEGORY OF BLANKET	STAPLE LENGTH
15	4"
20	6"
25	6"
30	8"
35	8"
45	10"

SPACING FOR STAPLES

SLOPE RATIO	STAPLES/YARD
2:1 (H:V) > 2:1 - 1:1	1.2 STAPLES 1.7 STAPLES



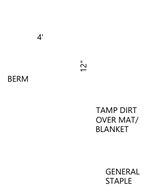
TYPICAL SLOPE SOIL STABILIZATION ISOMETRIC VIEW

NOTES:

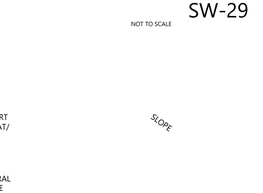
1. MATS/BLANKETS SHOULD BE INSTALLED VERTICALLY DOWNSLOPE.
2. SLOPE SURFACE SHALL BE FREE OF ROCKS, CLODS, STICK AND GRASS.
3. MATS/BLANKETS SHALL HAVE GOOD SOIL CONTACT.
4. LAY BLANKETS LOOSELY AND STAKE OR STAPLE TO MAINTAIN DIRECT CONTACT WITH THE SOIL.
5. DO NOT STRETCH.

TEMPORARY EROSION BLANKETS
TURF REINFORCEMENT MATS FOR SLOPES

LAST REVISED: 04/20/21
GD21



WET SLOPE LINING
NON-WOVEN GEOTEXTILE FILTER FABRIC UNDER TYPICAL TREATMENT



SLOPE TRACKING

TEMPORARY CONTOUR FURROWS

NOTES:

1. GROOVES WILL CATCH SEED, FERTILIZER, MULCH, RAINFALL AND DECREASE RUNOFF RATE.
2. USE SLOPE TRACKING FOR SLOPES 4:1 AND 50 FEET LONG OR STEEPER/LONGER.
3. USE TEMPORARY CONTOUR FURROWS FOR SLOPES 3:1 AND 75 FEET LONG OR STEEPER/LONGER.

SURFACE ROUGHENING FOR ALL SLOPES GREATER THAN 4:1

LAST REVISED: 08/15/17
GD09

HAUL ROAD TYPICAL SECTION



12" GRAVEL SURFACE

COMPACTED SUBGRADE

STREAM TYPICAL SECTION



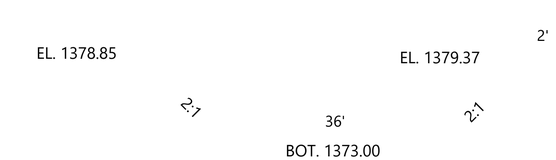
RIP RAP

STATION	RIPRAP
1+00 - 5+00	CLASS C
5+00 - 47+40	CLASS A

8" THICK GRANULAR CUSHION

GEOTEXTILE FABRIC

STILLING BASIN



CLASS A RIP RAP

8" THICK GRANULAR CUSHION

GEOTEXTILE FABRIC

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MINNEHAHA COUNTY, SD

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LEVEL III

CULTURAL RESOURCE INVENTORY

OF THE

CONCRETE MATERIALS COMPANY

CORSON QUARRY EXPANSION

Minnehaha County, South Dakota

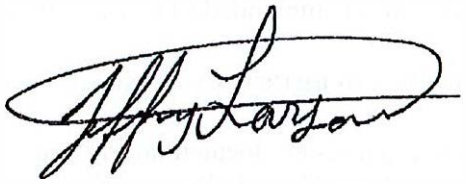
T102N, R48W, Sections 14 & 23

By Jeffrey D. Larson, RPA

Lance Rom, editor

Quality Services, Inc. *Project #SD3916030*

November 25, 2016



Jeffrey D. Larson, RPA
Principal Investigator

Quality Services, Inc.
Archeology, Architectural History, Forestry, Geophysics, History & Paleontology
1621 Sheridan Lake Road, Suite A
Rapid City, SD 57702-3432
Phone 605-388-5309
Fax 605-388-5319
Email: info@qualityservices.us.com
www.qualityservices.us.com

Abstract

October 25 through 27, 2016, ***Quality Services, Inc.*** conducted Level III cultural resource inventory for the Concrete Materials Company Corson Quarry Expansion project in Minnehaha County, South Dakota. Concrete Materials Company proposes to expand mining operations, construct a plant and associated parking and roads, divert and protect streams, possibly realign a road and build bridge over a railroad, and possibly regrade areas near the railroad. A total of 280 acres were pedestrian surveyed covering the proposed project activities.

Cultural resources records search with the South Dakota State Historical Society revealed three known cultural resource sites in the area of potential effects. Road bridges MH00001648 and MH00001649 were considered ***not eligible*** for the National Register of Historic Places (NRHP). They have since been removed and replaced with new structures. .

During the Level III pedestrian inventory seven additional cultural resources were located, recorded, and evaluated for the National Register of Historic Places. Historic period surface artifact scatter 39MH0334 is recommended ***not eligible*** and will not need protective measures. The Great Northern Railroad, 39MH2013, has been previously determined ***eligible*** for the NRHP by the SHPO. Corn crib MH00002386 and railroad masonry culvert MH00002387 are recommended ***not eligible***. Railroad culvert MH00002388 is recommended ***eligible***. Railroad structures MH00002389 and MH00002390 are both recommended ***not eligible***.

Railroad 39MH2013, railroad bridge MH00000902, and railroad culvert MH00002388 are considered ***eligible*** for the NRHP and recommended to be **avoided** by project activities.

A determination of no adverse effect to historic properties is recommended.

In the unlikely event that cultural resources are located during construction activities, it is recommended that the South Dakota State Historic Preservation Office and ***Quality Services, Inc.*** be contacted immediately.

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Introduction & Project Description

Concrete Materials Company proposes to expand an existing quarry approximately 0.8 mi. north of Corson, South Dakota in the Lower Big Sioux archeological region. Activities will occur in four quadrants based on the location of the existing railroad and 259th Street.

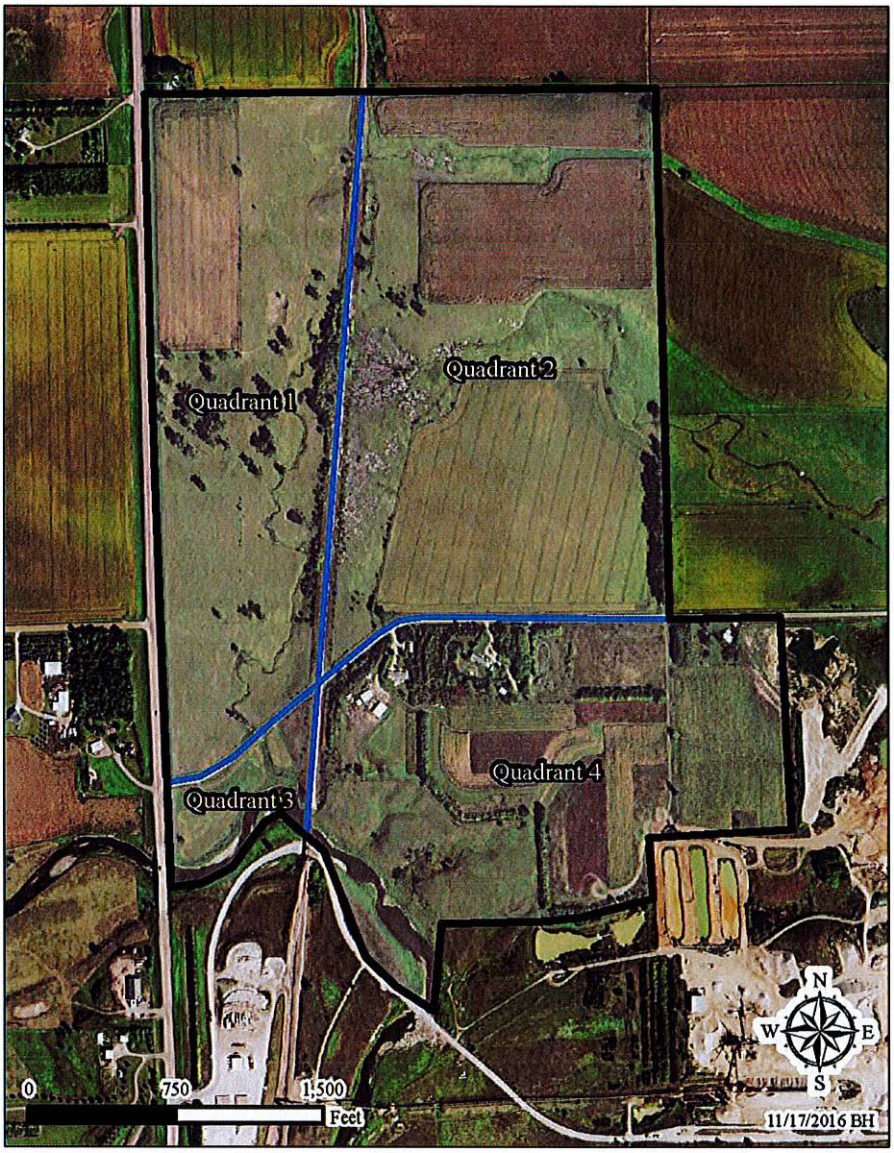


Figure 1. Quadrants for proposed project activities.

Project activities include:

- Quadrant #1: the realignment of 259th Street and minor changes to the drainage.
- Quadrant #2: excavation of all surface area and diversions to the intermittent streams.
- Quadrant #3: minor changes to the drainage and grading along the railroad.
- Quadrant #4: grading and the construction of a plant, railway spur and sidings, roads, parking areas, utilities, and drainageways and basins.

The proposed project's Area of Potential Effect (APE) is considered to be the area directly impacted by mining and construction activities for this project.

Quality Services, Inc. (***QSI***) was contracted to conduct a cultural resource investigation for the project area in order to fulfill the requirements of Section 106 of the National Preservation Act of 1966 (P.L. 89-665) as amended and 36 CFR part 800, which serves to implement the Act. The project research design was to determine if any cultural resources would be impacted by the developments and to provide appropriate date to Federal, State, and Local review agencies. Federal agencies involved include the U.S. Army Corps of Engineers (USACE), the USDA Natural Resources Conservation Service (NRCS), and the U.S. Environmental Protection Agency (EPA). State and Local government involvement include the South Dakota Department of Environmental and Natural Resources (DENR), South Dakota Department of Transportation (DOT), Minnehaha County Planning, Minnehaha County Road Department, Brandon Township Board, and the City of Brandon.

Location & Acres Surveyed

280 acres were Level III inventoried.

Table 1. Legal location of the project area

County	Township	Range	Sections	Meridian
Minnehaha	102N	48W	14 & 23	Fifth

USGS 7.5' Garretson West, South Dakota topographic quadrangle 1962, Photorevised 1976.

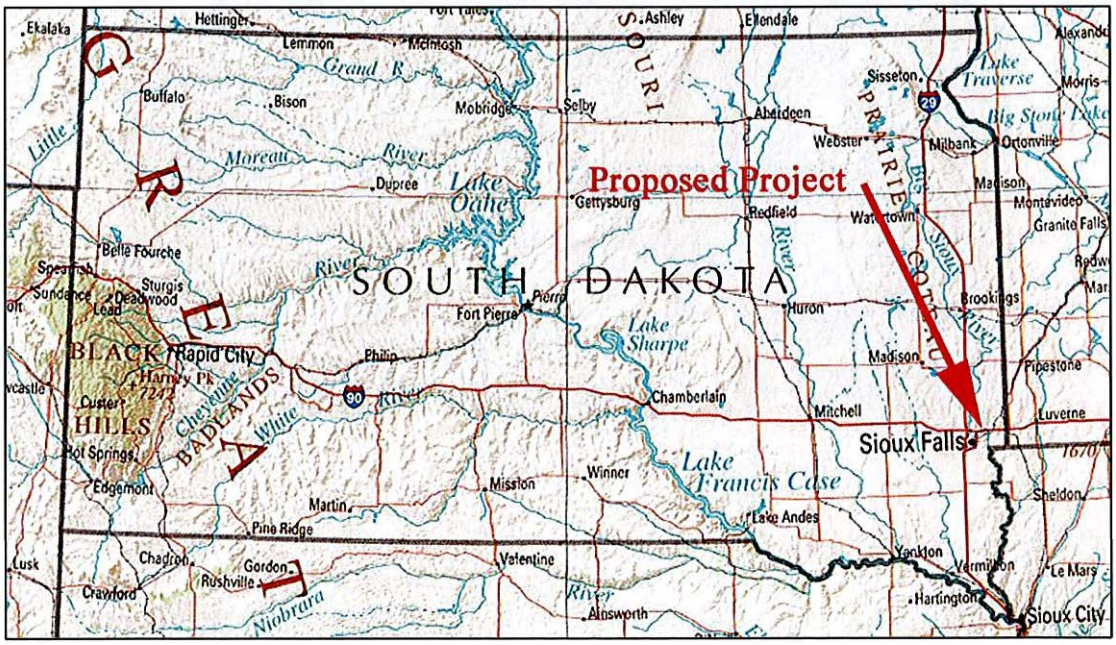


Figure 2. General location of proposed project within South Dakota.

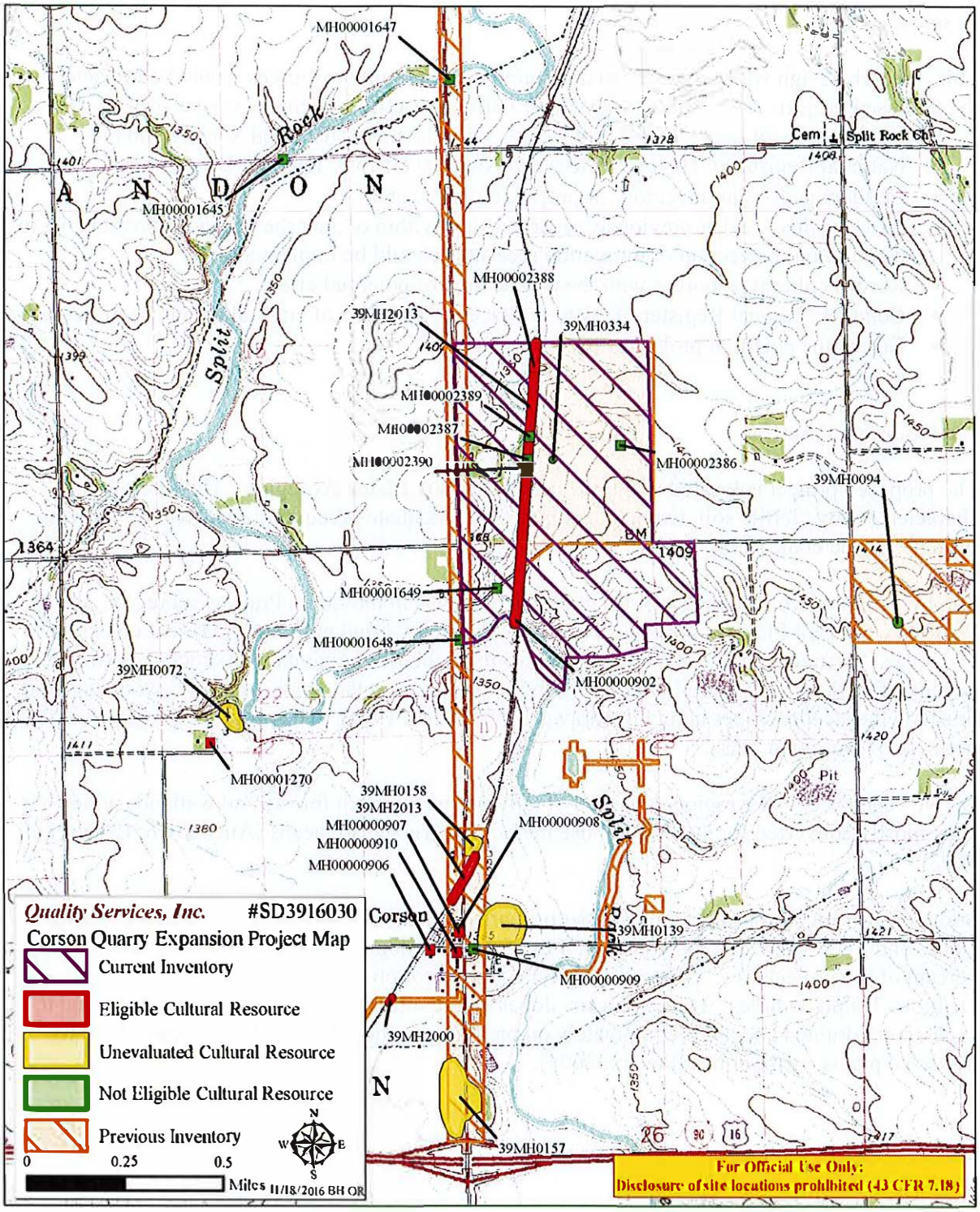


Figure 3. Corson Quarry Expansion Project Map.
T102N, R48W, Sections 14 & 23
USGS 7.5' Garretson West, South Dakota topographic quadrangle 1962, Photorevised 1976

Research Design

This research design was developed to determine if any cultural resources would be impacted by the proposed project. The methodology of the cultural resource inventory was as follows:

- Conduct record search of the project area with the State Historical Society and the National Register of Historic Places and National Historic Landmark databases.
- Conduct pedestrian inventory of proposed project areas.
- As warranted, revisit previously recorded sites within or near the proposed project area to determine if protection or mitigation measures should be implemented.
- Record cultural resources with the project area of potential effect.
- Conduct National Register of Historic Places evaluations of cultural resources, if needed.
- Determine potential project effects.

Environmental Setting

The proposed project is located in the Western Corn Belt Plains ecoregion. This ecoregion is characterized by "fertile soil, temperate climate, and adequate precipitation during the growing season" (Bryce et al. 1998).

Subdivided into two localized regions, the project area is in the Loess Prairies subregion of the Western Corn Belt Plains ecoregion. The Loess Prairies subregion in South Dakota consists of two areas, "the northern one is distinguished from neighboring regions by its rock-free soil and a paucity of wetlands. The southern areas is more highly dissected, with deciduous woodland and brush on the steeper slopes and in the draws" (Bryce et al. 1998). The proposed project is in the northern of these two areas.

Native vegetation in the region consisted of tallgrass prairie with forests and wetlands which has been mostly converted for agricultural use including corn and soybeans (Auch 2016; Bryce et al. 1998).

Soils for the proposed project area consist primarily of Moody-Nora complex, 2 to 6 percent slopes and Ihlen-Rock outcrop complex, 4 to 35 percent slopes making up approximately 50 percent of the project area. Other soils include Nora-Crofton complex, 6 to 9 percent slopes and Delmont-Talmo complex, 9 to 15 percent slopes among others. These soils are well-drained to excessively drained and are predominately on backslopes, shoulders, and footslopes of plains, dissected plains, or moraines (Preston 2004).



Figure 4. Typical mixed grass survey areas facing north.
J. Larson 10/25/2016.



Figure 5. Typical cultivated field in inventory area facing south.
J. Larson 10/25/2016.



Figure 6. Rock outcrop in survey area facing north.
J. Larson 10/27/2016.

Culture History

The lower reaches of the Big Sioux River drainage basin in southeastern South Dakota provide the geographic setting for the Lower Big Sioux Archeological Region #22. Portions of Union, Lincoln, Turner, McCook, and Minnehaha counties are contained in this region (Winham and Hannus 1991). The Big Sioux River valley, bluffs, and adjacent plains comprise the general topography of the area (Winham and Hannus 1991). Out of the plains, the Newton Hills in Lincoln County offer local relief. Precambrian age Sioux quartzite is the bedrock types predominate in this region (Winham and Hannus 1991). Although no pre-ceramic material have been reported in this area, as of May 2005, there are many unconfirmed reports of deeply buried cultural strata eroding out of the cutbanks of the Big Sioux River. Geomorphologic investigations in this region could help develop predictive statements regarding contextual locations of deeply buried pre-ceramic aboriginal sites and locales (Winham and Hannus 1991).

The First Americans c. 15,000 B.P.

Between 25,000 to 11,000 years ago, bitter cold temperatures during the late Wisconsin glaciation caused water to become trapped in advancing ice sheets. The result was a drop in world sea levels that effectively exposed low-lying landmasses, and the original immigrants to the Americas are believed to have arrived by means of an exposed land bridge connecting Siberia with Alaska.

The pathway for further migration south is still under debate. Since the 1950s, conventional understanding was that an "ice-free corridor" existed between the Cordilleran and Laurentide ice sheets as they retreated north when warmer temperatures returned around 15,000 years ago. Without this pathway, many scholars felt that migration into the New World would have been impossible due to the existing glaciers. However, a "growing body of evidence indicates that pathway between the great glaciers of the Last Ice Age was closed – in fact, the way south may have been blocked until the centuries after the dawn of Clovis" (Dixon and Heaton 2000).

Another popular hypothesis is that Early Americans migrated to the New World via a Pacific Ocean coastal route. Work by archeologists and paleontologists has shown that the Northwest coast of North America was not always covered by ice as once thought (Dixon 2000; Dixon and Heaton 2000). In fact, there is evidence that ancient life existed along this coast for tens of thousands of years. Jim Dixon and Tim Heaton's excavation of the coastline has uncovered a continuous record of caribou, fox, and bear bones dating back 50,000 years (Dixon and Heaton 2000). Furthermore, the western coastline was likely more extensive during ice ages. Sea levels were significantly lowered as much of the earth's water was trapped in glacial ice. This, along with the isostatic effects on land masses from the weight of the glaciers, would have exposed substantial tracts of land along coastline providing a route further south.

Archeological sites dating to such antiquity are extremely rare, and only a handful of these sites exist in the Americas. The most notable and intensely investigated site is the Monte Verde site in Chile, South America (Dillehay 1997). This site contained wooden huts, hearths, a wish-bone-shaped structure, and several bone and stone artifacts that date to between 14,050 and 13,600 years ago [cal]. Other sites include the Chesrow Complex in Southeastern Wisconsin (Overstreet 1993, 2000), the La Sena and Jensen site in central Nebraska (Holen 1994, 1995; Holen and May 2002), the Meadowcroft Rockshelter site in southwestern Pennsylvania (Adovasio et al. 1978; Adovasio and Page 2002), sites from the Old Crow Basin in Canada's Yukon Basin (Bonnichsen 1979; Irving et al. 1989), and the Cactus Hill Site in southern Virginia (Dixon 1999; Monastersky 2000; Adovasio and Page 2002).

Although many of these sites have not received complete scientific acceptance, the archeological evidence appears to support regional adaptation underway 12,000 years ago, and the Early Americans emphasized the local environments for subsistence, which included both a variety of floral and faunal resources (Dixon 1999). Furthermore, both genetic and linguistic studies are providing mounting evidence that there were multiple migrations of people, and they were not of a shared, single biological or cultural stock (e.g. Schurr and Wallace 1999; Nichols 1990). In other words, the first Americans were likely made up of several people and cultures that migrated from the Old World, and they adapted to many different environments in several different ways.

Clovis, Folsom, & Paleo-Indian c. 13,400[cal]-7600 B.P.

Towards the end of the Wisconsin glaciation, the Plains environment harbored big-game species such as the mammoth and Ice-age bison adapted to the periglacial environment and the seasonal extremes of the times. During this time a new culture, named Clovis after the early archeological excavations in Clovis, New Mexico, began in the Americas. Based on the lack of any definite

occurrence of the Clovis material culture, such as the Clovis projectile point, north of the ice sheets or in the Artic, Clovis is believed to be the first truly indigenous North American culture.

The Clovis tradition people likely lived in highly mobile small bands of people armed with a shared tool kit that included the diagnostic fluted lanceolate Clovis point, gravers, a variety of end scrapers, and a blade-technology with cutting and scraping tools made out of the blades. The discovery of kill sites in the western United States has tended to emphasize a life-way based on specialized hunting of now extinct Ice-age big-game animals such as mastodons and mammoths. Martin (1967) even argued that the success of Clovis hunters largely contributed to the megafaunal extinction. However, more recent research has convincingly demonstrated that this type of subsistence was not a widespread important role in Clovis subsistence, and the Clovis people appear to have emphasized a variety of flora and fauna (Anderson and Sassaman 1996; Griffin et al. 1988; Bryan 1991).

Archeological manifestations associated with the Clovis time period are rare and usually consist of isolated surface-find projectile points. No Clovis sites have been found in the Lower Big Sioux archeological region as of May 2005. Well known in Plains archeology, the Lange-Ferguson site in Shannon County is the only Clovis site to be investigated in the state as of May 2005 (Hannus 1994). This Clovis site is mammoth kill/butchery locality with direct evidence for the use of mammoth bone tools in the butchering process.

The Younger Dryas cold snap characterized by a worldwide cold interval followed Clovis times and lasted between 11,000 and 9650 B.C. [cal]. As a drier climatic regime resulted in the retreat of spruce forest and the expansion of grassland on the northern plains, many of the Ice-age megafauna died. Bison, however, became well adapted to this environment and the size and mobility of the herds likely increased significantly. Similar to the landscape today, in the Black Hills proper pine forests characterized this area while grasslands surrounded the Hills at the lower elevations.

During this time period, the Folsom complex emerged. This complex is identified by well-made lanceolate points fluted entirely up to their tips, and the people relied heavily on the bison herds and other big game for subsistence. Bamforth (1988) hypothesizes that as bison herds grew in size; this food resource became more predictable. Folsom groups reacted by using regular and preferred locations, engaging in communal hunts, and concentrating into larger social groups. As evidenced by their specialized point production, this may have led to greater social complexity from Clovis to Folsom.

Like Clovis, Folsom archeological remains are rare and are typically surface finds. Within the Lower Big Sioux region no Folsom sites have been reported or recorded as of May 2005.

Following and partly overlapping the Folsom period around 10,500 to 9000 B.P. in addition to a climatic shift more similar to modern times, many regional adaptations appeared in North America. Many Plains archeologists refer to this period as the Middle Paleo-Indian period (see Frison 1991). This period includes the Alberta, Hell Gap, and Agate Basin cultural complexes. These groups continued to emphasize a subsistence based on bison hunting and were involved in massive bison drives that probably required intimate knowledge of the landscape and several people. Beginning at about 9000 B.P. and continuing on to about 8000 B.P., it appears that

Plains groups began to develop a hunting/gathering subsistence mode that was focused on a more generalized resource base. This period is referred to as the Late Paleo-Indian period (9000-8000 B.P.) and several variations of parallel-oblique flaked, unfluted, lanceolate point forms existed including the Jimmy Allen, Frederick Allen, Pryor Stemmed, Lovell Constricted, Angostura, Lusk, and many others. In addition, the Cody complex dates to the Late Paleo-Indian period and consists of finely made stemmed spear points such as the Scottsbluff and Eden types. The use of local stones for tool manufacture and the limited distribution of the projectile point types relative to earlier times may suggest that cultural boundaries also were present to some degree.

Reports of deeply buried strata eroding from the Big Sioux River cutbank indicates that pre-ceramic cultures were occupying the area (Winham and Hannus 1991). Investigations at the Chalk Rock Site 39BK1000 on Big Sioux in Brookings County have uncovered artifacts in association with mammoth bone. Deeper strata also contain the potential for older deposits and this possible multi-component site may offer important information on Paleo-Indian presence in Eastern South Dakota.

Plains Archaic c. 7600 B.P. to 1500 B.P.

The Plains Archaic is defined by a marked subsistence focus on broad based hunting and gathering whereas the preceding Paleo-Indian period is thought to have been focused primarily on big game hunting. A marked increase of groundstone tools such as manos and metates used for processing and grinding food material is evident in the archeological record and reflects a major subsistence shift to a more generalized subsistence base (Frison 1998). While this lifeway existed to some degree in the late Paleo-Indian times, it was not as widespread. Frison (1998) writes that the term 'Archaic,' in one sense of the word, is meant to denote an adaptation dominated by hunting and gathering rather than a cultural time period. In fact, many Plains groups continued the Archaic lifestyle well into historic times, and Archaic temporal periods are defined much more by changes in projectile point styles rather than significant changes in lifeways.

Early Plains Archaic c. 7600 to 5000 B.P.

The Early Plains Archaic coincides with an extremely warm and dry climatic episode known as the Hypsithermal or Altithermal. Though the effects of this episode on plants, animals, and people are still debated, Frison (1998) suggests that severe droughts caused plant communities to shift to higher elevations; and, as a result, many Early Plains Archaic people occupied foothill-mountain areas. Frison (1998) points to the presence of several Early Archaic sites in low elevation intermountane settings in addition to Early Plains Archaic bison kill sites in the Wyoming Black Hills as mounting evidence for this hypothesis on the human response to the Altithermal. In addition, very few Early Archaic sites have been found on the plains proper and bison remains dramatically decrease in Altithermal aged deposits, reflecting the almost desert like conditions that were thought to exist on the plains during the Early Archaic (Frison 1998). Size diminution of bison has been a gradual process throughout the Holocene, and there is some indication of a slight acceleration of this trend through the Altithermal (Frison 1998).

Habitation features, known as pit house features, also first appear during this time (Frison 1991). They date toward the end of the Late Archaic period and extend into the Middle Archaic. These

features "usually appear as deep, circular stains; sometimes with central post molds … others are oval with multiple post molds along the long axis" (Sundstrom 1996). Cache pits, fire pits, and grinding stone are commonly found in the pit houses. Most of these features are found in the intermountain basins of the northern plains. The presence of these fairly significant habitation features may be associated with some level of sedentism.

Relative to the Paleo-Indian times, Early Archaic bison kill sites are typically small consisting of only 10-20 bison. Hunting strategies included the use of arroyo traps and jumps (much later in the period) and probably required small groups or bands to accomplish. However, many sites such as the Spring Creek site in south-central Nebraska and the Coffey site in northern Kansas contain much more small game and plant remains than large herbivores. Certainly this is an indication of the more generalized resource base.

Other than groundstone implements, the Early Archaic also included the arrival of a new type of projectile point. These projectile points are distinctly side-notched although there are many regional variations of this form. The technological innovation of notching offered a much stronger binding to the foreshaft of a spear while reducing the bonding mass at the same time (Howard 1995).

Middle Plains Archaic c. 4900 to 3000 B.P.

The end of the Altithermal and the return to modern climatic condition marks the beginning of the Middle Archaic Period. Bison populations again proliferated (Frison 1998). In addition to a refinement in bison hunting strategies, the Middle Plains Archaic period witnessed an even greater emphasis on plant foods. Reused sandstone plant grinders as well as roasting pits are common at sites dating to this time period. While small bison kill sites are the most typical of the period, Middle Archaic people continued to use bison jumps. One noteworthy innovation by Middle Archaic hunters was the use of bison corrals like that seen at the Scoggin Site in Wyoming. This strategy is very different in that it likely needed much fewer people to operate relative to the other strategies. Overall, Middle Archaic groups developed a carefully planned scheduling of economic activities based on seasonal plants and movements of game.

During this time period, the Plains also witnessed the widespread appearance of stone circles. The features typically measure between 13 and 23 feet in diameter. Although the function of them has been debated, it is generally agreed that most represent a circular anchor "to hold down the cover of a conical (or some other type) lodge" (Frison 1998).

The McKean Complex is the most notable Plains Middle Archaic archeological manifestation, and McKean sites have an extremely wide distribution across the Plains. These site types are most readily recognized by the lanceolate McKean point with an indented base and convex blade edges. However, there are many variations of the McKean point and include side-notched and stemmed forms.

Common Middle Archaic site types are bison kills, open occupations, and cave/rock shelters. Usually, Middle Archaic sites are far more common than preceding periods; however, only three Middle Archaic sites were listed on the South Dakota Archaeological Research Center database within the Lower Big Sioux region (39LN2, 39LN7, and 39LN19). Site 39LN7, is the only site

of the three that has a definite McKean association. The other two sites are typed as general Middle Archaic.

Late Plains Archaic 3000 to 1500 B.P.

The Late Plains Archaic is marked by the appearance of corner-notched points on the Plains. This notching technique produced flared edges with sharp points where the base and edge intersect. In general, Late Archaic people appeared to shift back to a focus on large, upland game (Deaver and Deaver 1988), although other resources were certainly exploited to some extent.

The earliest Late Archaic manifestations are the Pelican Lake and the Yonkee phases (see Frison 1991). However, these archeological complexes are typically found in the northwestern Plains; and within the Lower Big Sioux study unit, no Late Archaic sites have been assigned to the Yonkee complex (Hanenberger et al. 2004).

Problematic in identifying Pelican Lake presence toward eastern South Dakota is the observation that corner-notched points virtually identical to the Pelican Lake point are identified with the more recent early Plains Woodland manifestations throughout eastern South Dakota (Sundstrom 1996). As a result, no sites have been assigned to the Pelican Lake cultural complex within the Lower Big Sioux region as of May 2005.

Six sites have been assigned to the Late Archaic period within the Lower Big Sioux region. Most of these are typed as small artifact scatters.

The Late Prehistoric 1500 B.P. to 16th Century A.D.

The Middle Missouri witnessed significant changes during the Late Prehistoric Period on the Central Plains. The innovation of the bow and arrow as indicated by small delicate projectile points was introduced around this time. Yet, while many essentially continued Archaic-based lifestyles with a strong emphasis on bison hunting aided by the widespread use of the bow and arrow, others around the Missouri River Valley and eastern South Dakota began horticulture in the Dakotas and probably developed more complex societies.

Besant and Avonlea phases are typically associated with the continuation of a general Archaic-based lifestyle. Besant represented a highly sophisticated bison hunting culture. Bison kill sites associated with this phase often consist of complicated, skillfully constructed bison corrals similar to modern cattle corrals. The use of these corrals would have required great knowledge and understanding of stampeding animals (Fagan 2000). At the Ruby site along the Powder River in Wyoming, a structure at the southern end of this bison corral site is interpreted to be a ceremonial structure. If this is true, this could represent the importance of ritual at communal hunts similar to the rituals documented in historical accounts. Ceramics also occasionally appear at Besant sites.

One Besant site has been recorded within the Lower Big Sioux region as of May 2005. Site 39MH69 is listed as an artifact scatter associated with a single Besant projectile point. .

Around A.D. 1, the Avonlea phase began on the Plains and continued well into the Late Prehistoric Period. Avonlea points are typically side-notched points with slightly concave bases. Based on their smaller sizes, it is believed that the Avonlea people were the first to use the bow and arrow on the Plains. Avonlea ceramic styles include net impressed, spiral channeled and smooth surfaces (Dyck 1983).

No Avonlea sites have been recorded within the Lower Big Sioux region as of May 2005.

Nascent horticulture groups are associated with the Woodland Tradition. As the name implies, the introduction of horticulture likely spread from the east. These Woodland groups are characterized by fixed settlements, more complex societies, seed horticulture, pottery/ceramic production, and the construction of burial mounds. The Woodland Tradition is generally sub-divided into Early, Middle, and Late Woodland periods as well as other phases and cultures. These further divisions are mainly identified through ceramic types, geographic locales, and temporal ranges.

The South Dakota Archaeological Research Center database indicated that a total of seven sites in the Lower Big Sioux study unit have been assigned to the Woodland period as of May 2005. Most of the seven sites are recorded as mounds; however, artifact scatters and occupations are also in the database.

The Plains Village period supplanted or continued the Woodland culture in the Middle Missouri around A.D. 900 and extended throughout the eastern Plains. The transition is generally marked by larger villages (sometimes with fortifications) and greater horticulture produce including corn, beans, squash, and sunflowers. This period is typically divided into "sub-traditions" and variants based on dates, ceramics, house types, and other characteristics. This includes, in order of antiquity, the Initial (IMM), Extended (EMM), and Terminal (TMM) Middle Missouri Variants and the Initial (IC), Extended (ExC), Post-Contact (PCC), and Disorganized Coalescent Variants.

The State Historical Society database indicates that the Lower Big Sioux region contains 13 Plains Village sites. Of these sites, eight are listed as Great Oasis, two as Oneota, two as Initial Middle Missouri, and one as a general Plains Village site. In addition, six sites are listed as general Late Prehistoric sites. A total of 27 Late Prehistoric sites have been recorded within the Lower Big Sioux archeological region.

The Protohistoric or Contact Period c.1600-1804

The Protohistoric Period marks the beginning of even greater change on the Plains. The term Protohistoric is associated with the onset of Euro-American presence on the Plains, even though this does not imply there was full-scale or even frequent direct contact with Euro-Americans. Certainly the greatest impact was the arrival of trade goods including horses and firearms. Horses were provided indirectly by the Spanish from the southwest, and firearms came later indirectly from the French, English, and American fur-traders from the northeast. Both trade goods greatly increased the ease of bison hunting and also influenced other once semi-sedentary horticulture groups from the east such as the Cheyenne, Crow, and the Lakota/Dakota to become Plains equestrian nomadic Bison hunters. The Mandan, Hidatsa, and Arikara along the Missouri River also became central providers of firearms to tribes further west.

Many of the Protohistoric Plains groups were highly mobile focusing intensely on bison hunting with only a supplemental emphasis on other resources, although others certainly continued village farming. The need to cover large migration ranges of bison coupled with the influx of other groups competing for the same resource created much competition between tribes. As a result intertribal conflict became more common, and the power of tribes as well as individuals became defined by the accumulation of European trade goods.

Protohistoric sites are recognized by the occurrence of both native artifacts such as stone tools mixed in with European trade goods such as gun parts, trade beads, metal projectile points, and other metal items.

The South Dakota Archaeological Research Center database indicates that there is only one site within the Lower Big Sioux region that can be assigned to the Proto-Historic period as of May 2005. Site 39LN2 is a proto-historic Oneota village.

The Historic Period 1800-1950

Although smaller trading operations under the control of the Missouri Company were present in the Dakotas and the Middle Missouri during the late 18th century, the purchase of the Louisiana Territory in 1803 and arrival of Lewis and Clark in 1804 signaled the beginning of the Historic Period and full-scale interaction between Native American groups and Euro-Americans. Euro-American fur traders and trappers were the first to enter the region after Lewis and Clark, and the Missouri River became an increasingly important trading locale.

In the early half of the 19th century, permanent settlements of forts and trade posts began to be set up along the Missouri River. The first trading fort was set up by the Missouri Company in 1794 and focused on trapping beaver and otter; this industry did not shift focus to buffalo robes until around 1815 (Hanenberger et al. 2004). By 1840, buffalo were the most sought after skins in the fur trading business (Hanenberger et al. 2004).

Certainly, the expansion of America into the west was accomplished at the expense of the Plains tribes. Though tribal boundaries and reorganization had already taken place in protohistoric times, European diseases decimated Native American populations and continued this trend. The Arikara, who once occupied the Middle Missouri in the Dakotas, fell to several outbreaks of smallpox during the mid to late 18th century, greatly diminishing their numbers. By the 19th century, the Dakota "were in clear control of the Missouri River Valley" (Hanenberger et al. 2004).

Conflicts between the tribes and Euro Americans also escalated. Although once considered "Indian Territory," the United States looked to the west for expansion and settlement. During the 1800s, several treaties aimed at acquiring these Indian lands. While lands cessations were small at first, these could not keep up with the influx of migrants to these areas. Hoping to curtail the growing hostilities between the Northwestern tribes and the American frontier, the Fort Laramie Treaty of 1851 was signed between the United States and the Lakota, Arapaho, Cheyenne, Crow, Assiniboine, Mandan, Arikara, and Shoshone.

This "Great Treaty" and others, however, did little to assuage the conflicts since they were often breached or altogether ignored. In the 1860s, several tribes declared war on the Americas. The United States reacted by establishing several forts in the region.

The second "Great Treaty," the Fort Laramie Treaty of 1868, established the Great Sioux reservation in central South Dakota, and all lands east of the Missouri River were ceded and officially opened for settlement. The separate Lower Brule reservation was also established around the White River near present day Oacoma.

Only a few years later, expansion ambitions to the west of the Missouri River again threatened tribal lands. Political attempts focused at breaking up the Great Sioux Reservation. Two key events accomplished this. The General Allotment Act of 1887, or Dawes Act, allotted 160 to 320 acres to tribal families. The tracts of land were intended to "encourage" the Native Americans to take up farming in order to assimilate them into American economy and society. Surplus reservation lands were then available to be sold to non-Indian settlers. Under fear and broken promises, the state of South Dakota also officially divided the Great Reservation in the five present-day reservations of Standing Rock, Lower Brule, Rosebud, Pine Ridge, and Cheyenne River. Following this, these areas to the west were now opened for settlement.

These events deeply impacted the Dakota. The result was a loss of 42 percent of their lands (Hanenberger et al. 2004). The shortsightedness of the Dawes Act had no means of sufficiently providing for the family heirs of the small tracts of lands and the government was slow in providing the promised compensations and rations to the tribes. Understandably angered at their situation, some Dakota again turned to open conflict with the United States. National Historic Landmark Wounded Knee in the White River Badlands is the site of the last armed conflict between Native Americans and United States government troops, fought on December 29, 1890.

Ranchers, Farmers, Miners, and entrepreneurs from all over the U.S. began to settle South Dakota in the late 19th century. Most sites that are assigned to the historic period are associated with ranching, farming, railroad, and/or industrial activities. There are 100+ sites dating to the historic period in the Lower Big Sioux region. These site types include dumps, well/cisterns, depressions, foundations, farmsteads, non-farm ruins, artifact scatters, railroads, cabins, burials, earthworks, industrial sites, and roads.

Cultural Resources Records Review

Nathan A. Barton of Wasteline, Inc. requested records search data for previous inventories, and archeological and historic period architectural resources from the South Dakota State Historical Society on October 7, 2016. Records search was conducted by Jane P. Watts October 11, 2016. ***QSI*** historian and GIS Specialist Brian Huot checked the National Register of Historic Places (NRHP) and National Historic Landmark databases on October 21, 2016. Results are listed in the tables below.

Table 2. Cultural resources within one mile of the project area.

ID#	Name/Type	NRHP	Potential Effect, Relationship to Project, & Recommendations
39MH0072	Native American Artifact Scatter	*Unevaluated*	**No Effect** – Out of APE
39MH0094	Native American Isolated Find	*Not Eligible*	**No Effect** – Out of APE
39MH0139	Native American Artifact Scatter	*Unevaluated*	**No Effect** – Out of APE
39MH0157	Constance Site Native American Artifact Scatter	*Unevaluated*	**No Effect** – Out of APE
39MH0158	Native American Artifact Scatter	*Unevaluated*	**No Effect** – Out of APE
39MH2000	Burlington Northern Railroad	*Eligible*	**No Effect** – Out of APE
39MH2013	Great Northern Railroad	*Eligible*	**No Adverse Effect** – In APE - **Avoid**
MH00000902	Railroad Bridge over Split Rock Creek	*Eligible*	**No Adverse Effect** – In APE - **Avoid**
MH00000906	Forman Ford	*Eligible*	**No Effect** – Out of APE
MH00000907	Ray's Motel	*Eligible*	**No Effect** – Out of APE
MH00000908	Community/Township Hall	*Not Eligible*	**No Effect** – Out of APE Out of APE
MH00000909	Bank House	*Not Eligible*	**No Effect** – Out of APE
MH00000910	Fauske-Christopherson House	*Eligible*	**No Effect** – Out of APE
MH00001270	Thomas Rovang Farm	*Eligible*	**No Effect** – Out of APE
MH00001645	Bridge 50-279-140	*Not Eligible*	**No Effect** – Out of APE
MH00001647	Bridge 50-280-139	*Not Eligible*	**No Effect** – Out of APE
MH00001648	Bridge 50-280-152	*Not Eligible*	**Removed and Replaced**
MH00001649	Bridge 50-281-151	*Not Eligible*	**Removed and Replaced**

Table 3. Previous inventories within one mile of the project area.

Resource#	Author(s)	Year	Title
AMH-0018	Winham, R.	1986	An Intensive Cultural Resource Survey of a Proposed Quarry Area Near Corson, in Minnehaha County, South Dakota
AMH-0031	Haberman, T.	1987	Cultural Resource Survey of a Materials Pit in Section 24, T102N, R48W, Minnehaha County, South Dakota.

Resource#	Author(s)	Year	Title
AMH-0057	Fosha, M.	1990	An Intensive Cultural Resources Survey of the Proposed Material Pit Near the City of Corson, Minnehaha County, South Dakota.
AMH-0108	Braun, K.	1994	An Intensive Cultural Resource Survey on a Highway SD11 from I-90 to the North Side of Corson in Minnehaha County, SD
AMH-0165	Vaillancourt, D.	2003	A Level III Cultural Resource Letter Report for a Surface Pipeline and Cross Fencing Project for Jarrod Johnson, T102N, R48W, Section 23, Minnehaha County, South Dakota.
AMH-0179	Messerli, T.	2003	An Intensive Cultural Resources Survey of SDDOT Small Road Project No. P-PH 0011(05)81, PCEMS 6229, Minnehaha County, South Dakota
AMH-0265	Miller, P.	2009	An Intensive Cultural Resources Survey for SDDOT Emergency Erosion Repair Project PCN 00Z2, for SD Highway 11, Minnehaha County, South Dakota
AMH-0266	Lueck, E.	2009	A Level III Cultural Resources Survey of the Proposed Corson Water Main, T102N, R48W, Section 27, Minnehaha County, South Dakota
ESD-0001	Sigstad, J.	1973	An Archaeological Survey of the Proposed Watertown, South Dakota-Moville, Iowa 345 KV Transmission Line 1973, Brookings, Codington, Deuel, Lincoln, Minnehaha, Moody and Union Counties, South Dakota.
ESD-0154	Gillen, T. et al.	1994	An Intensive Cultural Resources Survey of Proposed Sioux Valley Electric Projects in Eastern South Dakota.

Survey Methods & Results

QSI archeologist and historian Jeffrey D. Larson, archeologist and architectural historian Mark Carpenter, and archeologist Emily Rodgers conducted Level III cultural resources inventory of the project area October 25 through 27, 2016. The average temperature was 55 degrees Fahrenheit and the ground was dry other than in the drainages. The project area was located using a global positioning system (GPS) application, aerial and topographic maps, and project information provided by the client. Field investigation consisted of visual inspection, photography, and subsurface testing.

Pedestrian inventory was conducted in transects less than 30 meters apart covering the 280 acre survey area. Ground cover varied from mixed grasses, recently harvested crops, unharvested corn crops, manicured lawns, and rock outcroppings. Ground surface visibility ranged from 5 to 100 percent, averaging about 15 percent for most of the project area. The majority of the project area was on hillslopes near Split Rock Creek and an unnamed intermittent stream. Topography ranged from level terrain to 40 percent slopes for most of the project area.

Existing disturbance from agricultural activities and construction of railroad, roads, and houses and other structures was evident in the project area. Cultural resources located during the survey

include the railroad, three railroad bridges, one railroad masonry culvert, one corn crib, and one historic artifact scatter. Additionally, a 70 ft. by 50 ft. earthen dam was located; however, this was constructed in 1991 according to records obtained from the South Dakota Department of Environment and Natural Resources (DENR). A washing machine used for target practice, as evidenced by bullet holes, and a wood and metal livestock trough were located during the inventory as well but were not recorded as cultural resources based on input from Jane Watts of the State Historical Society.

Considering the project is by Split Rock Creek and within 5 mi. of several recorded mounds – Split Rock Creek Mounds 39MH0006, East Brandon Burial Mounds 39MH0010, Beaver Creek Mounds 39MH0011, and the Graff Mound 39MH0021, among others near Split Rock Creek – there was potential to locate mounds in the current inventory area. Although no mounds were identified in the records review within one mile of the project area, the area was closely inspected for the presence of intact mounds and mounds which could have been destroyed. However, no evidence of mounds was identified.

One subsurface test was conducted on a bench along Split Rock Creek. Ground surface visibility was below 30 percent in this portion of the survey area. No cultural resources were located on the surface and no subsurface cultural deposits were located in this test.

Table 4. Subsurface Test #1.

Location: UTM Zone 14 E/696073 N/4833520 **Size & Depth**: 54x58x95cm		
Stratigraphy: 0-95cm 7.5YR 3/1, very dark gray, silty clay loam		
Contents: Small rodent bone and piece of shell at 65cm; no cultural materials located		
Screen Sizes: 1/4"	**Liners**: No	**Backfilled**: Yes

Previously Recorded Cultural Resources

Three previously recorded bridges were identified in the project area during the record search. Two ***not eligible*** road bridges MH00001648 and MH00001649 had been removed and replaced with new concrete structures prior to the current inventory.

MH00000902 – Railroad Bridge over Split Rock Creek

This ***eligible*** railroad bridge was recorded in 1995 as a steel Warren truss bridge over Split Rock Creek with piers made of stone on concrete footings. The structure was noted as being constructed around 1910 since Warren trusses were poplar after that date; however, it could have been constructed earlier or later. Considering the railroad was constructed in 1888 and the Warren truss was patented in 1848, it is possible this bridge was constructed before 1910.

In the quadrants where this bridge is located, Concrete Materials proposes to do grading along the railroad and add a spur line and sidings. The addition of a spur line and sidings are not expected to impact this bridge because it is an active railroad and the addition of spur lines and sidings are common on active railroads. There will be **no adverse effect** to this structure.



Figure 7. View of MH00000902 facing west-southwest.
J. Larson 10/27/2016.

39MH0334 – Outcrop Artifact Scatter

Site Description & Contents

This site consisted of several thick clear, cobalt blue, and light green glass fragments, a few fragments of thick white ceramics, as well as a small a cobalt blue Vicks Vaporub bottle and a small clear glass bottle. On the base of the Vaporub bottle is a single triangle with "Vicks Vaporub" embossed around it. Embossed letters were on the base of the small clear glass bottle in two rows with the first row reading "DES" and the second row reading "REG.". A vertical ribbed design is on each of the corners of this bottle. The site was primarily in two concentrated areas 10 ft. apart on bedrock outcroppings with mixed grasses in between.

Evaluation/Collection Methods

The artifact scatter was located during pedestrian inventory spaced less than 30 meters apart. Mixed grasses around the site were closely inspected for additional components of the site; however, no additional resources were located. No cultural resources were collected and no shovel tests were conducted.

Site Interpretation

The single triangle on the base of the Vicks Vaporub bottle indicates it was manufactured between the 1930s and the 1970s. Between 1912 and the 1930s, Vicks Vaporub bottles typically had two triangles in the center and by the 1970s plastic bottles replaced glass ones.



Figure 8. Overview of 39MH0334.
Note site is between the rock outcroppings on bedrock. E. Rodgers 10/27/2016.



Figure 9. View of 39MH0334 concentration one.
E. Rodgers 10/27/2016.

Based on size and design, the clear glass bottle appears to be an Owens-Illinois Glass Company Duo-Ovals Model A-5139 pharmaceutical and proprietary bottle. Unfortunately, the base does not include a maker's mark or other information to help date the bottle, other than "DES REG.". "DES REG." may refer to a Design Registration, a term commonly used in other countries such

as the United Kingdom and Spain instead of the U.S. equivalent Design Patent. Although no information was located to date the bottle definitely, the bottle design appears in a 1933 Owen-Illinois bottle catalog indicating the bottle could have been manufactured around that time (Owens-Illinois Glass Company 1933).



Figure 10. View of 39MH0334 concentration two.
E. Rodgers 10/27/2016.

A previous inventory (AMH-0018) from 1986 in this area identified "historic/recent debris" in the vicinity of the site indicating that the materials were deposited here before that inventory (Winham 1986). No additional information was provided in the inventory report and the site was not recorded by the archeologists who performed that inventory.

It is likely that the materials located were dumped in this location by either a nearby resident or a traveler. With the Great Northern Railway tracks located approximately 330 ft. west of the site, it is possible these materials were deposited by passengers or crew members as trains passed through this area.

National Register of Historic Places Eligibility

This site is recommended ***not eligible*** for the NRHP. It retains five of the seven aspects of integrity, excluding design and association since there is no apparent conscious decision to the way these materials are scattered and they are not known to have been associated with an important individual or event.

The artifact scatter is not associated with a significant person or event making it ***not eligible*** under Criterion A and B. The materials located are commonly found in historic dumps and do not appear to have been made by a master craftsman; therefore, it is considered ***not eligible***

under Criterion C. Considering the site is located on bedrock outcropping and contained common materials, it is not likely to yield information important in history and is, therefore, considered ***not eligible*** under Criterion D.

Management Recommendations

No protection measures are necessary for the site.

39MH2013 – Great Northern Railroad

Environmental Description

The site is located on a downslope with an unnamed intermittent stream crossing underneath the railroad in one location and Split Rock Creek crossing in another location. North of 259th Street, rock outcroppings are located east of the railroad with a few outcroppings to the west. South of 259th Street, a shelterbelt is located east of the railroad and a slope with mixed grasses is to the west. This segment of the railroad is located near the top of a downslope for most of it length. The approximately 15 meter wide railroad grade is covered in ballast fill with the ties and rails on top of the ballast. In the 7.5 meters on each side of the grade that make up the railroad right-of-way, there are mixed grasses, rock outcrops, and occasionally trees, primarily near the drainages.



Figure 11. View of 39MH2013 and MH00002388 facing east-southeast. Photograph taken at north end of site. J. Larson 10/25/2016.

Site Description & Contents

This is an active segment of the Great Northern Railway, now operated by Burlington Northern Santa Fe. This segment runs roughly north-south through the project area and is visible from most of the project area with some areas obscured by topography and vegetation. One ***eligible*** railroad bridge, three previously unrecorded bridges, and a previously unrecorded masonry culvert were located along this segment of railroad. Several large pieces of wood were in the northwest corner where 259th Street crosses the railroad, and are likely used to replace the wood slats at that railroad crossing. No other features or materials were identified from visual inspection of the railroad.

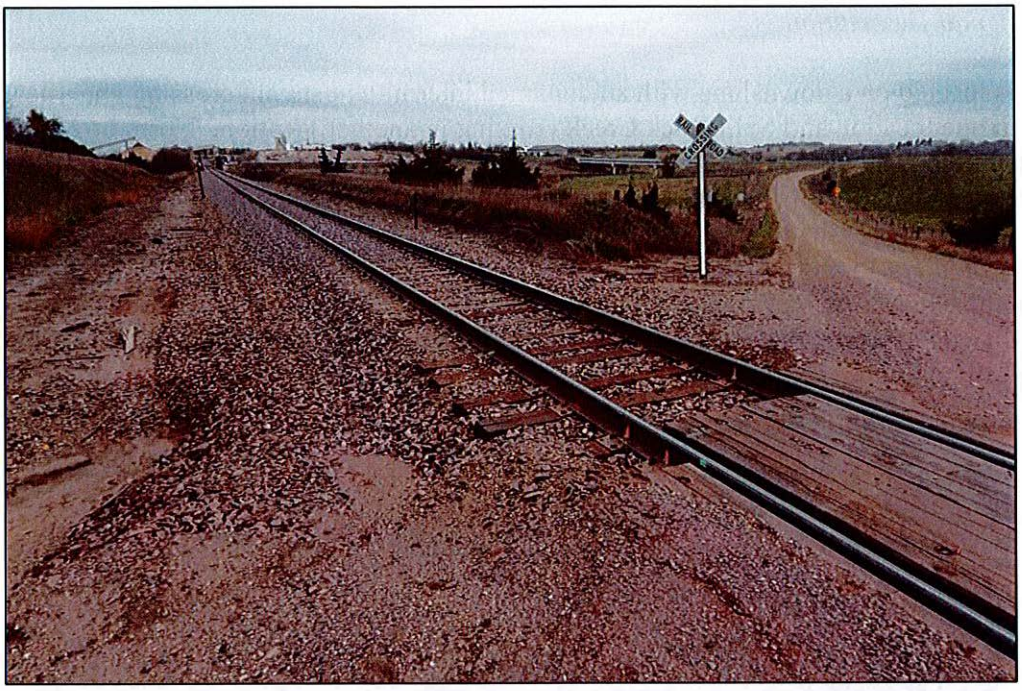


Figure 12. View of 39MH2013 where it crosses 259th Street, facing southwest. Note wood slats used for railroad crossing. Photograph taken at south end of site. J. Larson 10/25/2016.

Evaluation/Collection Methods

The segment of railroad in the proposed project area of potential effect was recorded. It was located on topographic maps, confirmed in the field through visual inspection and photography. No cultural resources were collected and no shovel tests were conducted.

Site Interpretation

Constructed in 1888, this segment of the Great Northern Railroad served as a connection from Sioux Falls, South Dakota to the port city of Duluth, Minnesota. This connection allowed for transportation of goods and people between eastern South Dakota and the Great Lakes Region.

Over the course of its history, the Great Northern Railway expanded into the Midwest and the Pacific Northwest, having begun in the Twin Cities area of Minnesota. The railway operated in ten states from Wisconsin to Oregon and two Canadian provinces. James J. Hill, founder of the Great Northern Railway, understood that if the railroad was going to prosper, the region serviced by the railroad would need to prosper. This understanding guided the Great Northern railroads development throughout its history (Great Northern Railway Company 1958).

Formed in 1889 from several railroads in the region, the Great Northern Railroad expanded westward from Minnesota to provide a northern route from the eastern cities to Seattle, Portland, and other cities in the northwest (Great Northern Railway Company 1958). A rail route through South Dakota was overlooked for routes in neighboring states North Dakota and Nebraska; therefore, the extent of the Great Northern Railway in South Dakota is limited to three routes: to Aberdeen, to Watertown and Huron, and to Sioux Falls and Yankton (Hufstetler and Bedeau 2007). This segment is part of the latter and is still in active use. By 1970, the Great Northern joined Burlington Northern Railroad which in 1995 became the Burlington Northern Santa Fe Railroad (Hufstetler and Bedeau 2007), which still operates this railroad segment today.

National Register of Historic Places Eligibility

The Great Northern Railway, like other railroads in South Dakota, allowed for quicker and safer transportation of freight and passengers in and out of South Dakota and encouraged increased settlement into the area.

This site meets all seven aspects of integrity. The railroad appears to retain its historic design and is in a rural agricultural setting as it would have been during its early operation. However, some changes to the setting have occurred, including mining, road construction, and residences dating mostly to the 1980s. It is also following its historic route and, therefore, retains integrity of location. Wood materials and metal rails, although repaired and replaced over time, are similar to those used during construction and reflect the standard workmanship of railroad construction. Since the site's historical setting is largely intact, it retains integrity of feeling and association.

Considering its significance in state transportation and settlement, the Great Northern Railroad is considered ***eligible*** under Criterion A. It is also considered ***eligible*** under Criterion B due to its association with the founder of the Great Northern Railway James J. Hill. This segment of railroad is considered ***eligible*** under Criterion C due to the original route being maintained and the majority of the materials reflecting those that were used during railroad construction in 1888, excluding one bridge which has been replaced by a concrete bridge. Considering the railroad maintains a standard design for railroads in this time period, it is not likely to yield any significant or unusual subsurface data; therefore, it is considered ***not eligible*** under Criterion D.

Management Recommendations

The proposed project would result in **no adverse effect** to the Great Northern Railroad. While, the current setting will change as a result of the project, the setting has already been altered from its historic 1888 setting. An existing mine south of the project area, a highway and other roads, as well as multiple residences and other structures primarily built in the 1980s are in the vicinity

of the project and have altered the historic setting. Additionally, mining and construction will not destroy or reroute the well-maintained, active railroad. The proposed project will add a spur line and sidings to the existing railroad; however, spur lines and sidings are commonly added to active railroads and will not impact the historicity of the existing railroad. As long as the railroad is not impacted by mining or construction, there will be **no adverse effect**.

MH00002386 – Two Fields Corn Crib

Two Fields Corn Crib consists of a 16 ft. by 16 ft. concrete foundation with a circular metal cage and a metal roof. Tension bolts are present in each corner with braided metal wire attached from the roof to the bolts in two of the corners. Wood plan flooring is used inside the structure with fence materials now stored inside. Text stamped in the roof reads "MODEL 54 GROUP 1 ROOF NO. 2 BDL. 1 BDL. REQ.".

Two Fields Corn Crib is recommended ***not eligible*** for the NRHP due to its typical gazebo style with no indication of association with important persons or events. It is also not the work of a master craftsman nor is it likely to yield subsurface finds. No protection measures are recommended for this structure.



Figure 13. View of MH00002386 facing south.
J. Larson 10/27/2016.

MH00002387 – Railroad Masonry Culvert

This is a masonry culvert in good condition under the railroad. It consists of brick and mortar on the top and sides with ballast, ties, and rails on top. There appears to be a metal platform between the bricks and ballast for support. This culvert is recommended ***not eligible*** for the NRHP with no protection measures.



Figure 14. View of MH00002387 facing west.
J. Larson 10/27/2016.

MH00002388 – Railroad Bridge at Mile Post 134.1

Railroad Bridge at Mile Post 134.1 is a small timber trestle bridge in good condition that is currently active. It has four central supports that allow for a drainage and a narrow cattle passage under the bridge. Pasture is on each side of the bridge with corn crops nearby as well as an active mine to the south.



Figure 15. View of MH00002388 facing southeast.
J. Larson 10/25/2016.

The bridge is recommended ***eligible*** for the NRHP under Criterion A and C for its importance in South Dakota transportation history and because it reflects elements of railroad engineering in the late 19th Century. Although the bridge has received regular maintenance including replacing ties, timber supports, and hardware, the bridge retains integrity of location, setting, design, materials, workmanship, feeling, and association. According to South Dakota's Railroads Historic Context (Hufstetler and Bedeau 2007), original materials do not need to survive to meet design, materials, and workmanship integrity.

Although mining is planned on the east side of the railroad and the stream under the railroad bridge may be diverted, there will be **no adverse effect** if project activities **avoid** impacting the bridge.

MH00002389 – Railroad Bridge at Mile Post 134.26

Railroad Bridge at Mile Post 134.26 is a small concrete bridge in good condition that is currently active. It consists of concrete spans with one concrete leg in the center. Ballast, ties, and rails run on top of the bridge with metal fencing on the west side of the tracks for the length of the bridge. A small waterfall is present beneath the bridge. While there are no markings on the bridge, its location between bridges at Mile Post 134.1 and 134.3 indicates that this bridge is at Mile Post 134.26. Pasture is on each side of the bridge with corn crops nearby as well as an active mine to the south.



Figure 16. View of MH00002389 facing east.
J. Larson 10/25/2016.

When the railroad was constructed in 1888, there was likely a timber truss bridge in this location which has since been replaced with a concrete bridge providing more stability over the intermittent stream. This concrete bridge has undergone regular maintenance such as replacing the ballast, ties, and rails and was likely constructed in the 1980s or 1990s.

The bridge is recommended ***not eligible*** for the NRHP. Although the bridge maintains integrity of location and setting, the concrete bridge did not serve during the historic period of early travel and commerce within South Dakota and does not reflect the historic engineering of the railroad bridge that would have historically been in this location.

MH00002390 – Railroad Bridge at Mile Post 134.3

Railroad Bridge at Mile Post 134.3 is a small timber bridge in good condition that is currently active. It consists of creosote soaked timber supports laid horizontally at each end of the bridge to allow for the drainage to pass under the railroad. Pasture is on each side of the bridge with corn crops nearby as well as an active mine to the south.

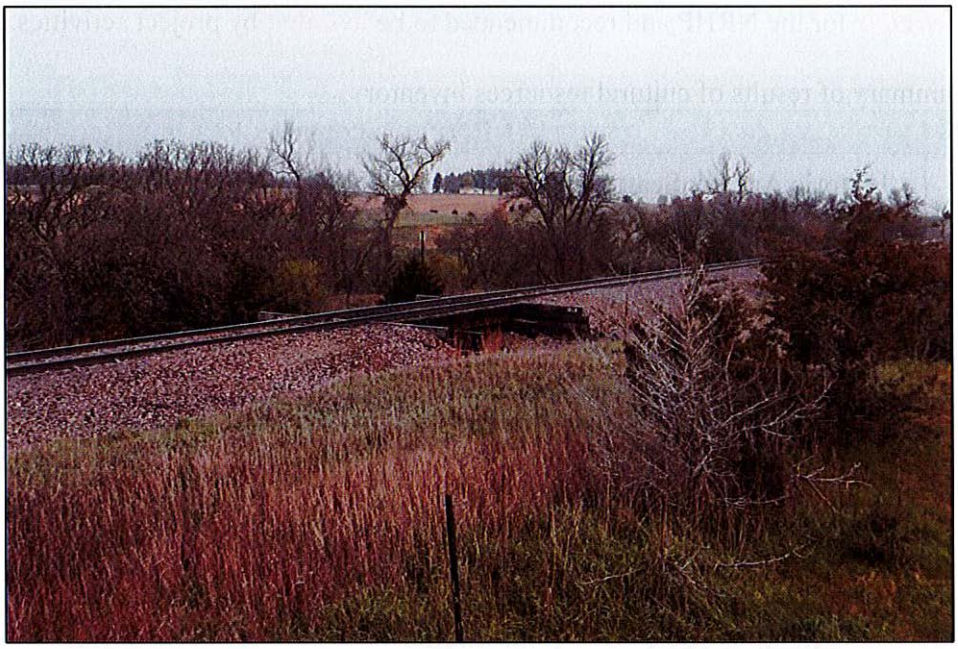


Figure 17. View of MH00002390 facing northwest.
J. Larson 10/27/2016.

The bridge is recommended ***not eligible*** for the NRHP; therefore, no protection measures are recommended.

Management Recommendations & Conclusions

Cultural resources records search with the South Dakota State Historical Society revealed three known cultural resource sites in the area of potential effects. Road bridges MH00001648 and MH00001649 were considered ***not eligible*** for the National Register of Historic Places (NRHP). They have since been removed and replaced with new structures. .

During the Level III pedestrian inventory seven additional cultural resources were located, recorded, and evaluated for the National Register of Historic Places. Historic period surface artifact scatter 39MH0334 is recommended ***not eligible*** and will not need protective measures. The Great Northern Railroad, 39MH2013, has been previously determined ***eligible*** for the NRHP by the SHPO. Corn crib MH00002386 and railroad masonry culvert MH00002387 are recommended ***not eligible***. Railroad culvert MH00002388 is recommended ***eligible***. Railroad structures MH00002389 and MH00002390 are both recommended ***not eligible***.

Railroad 39MH2013, railroad bridge MH00000902, and railroad culvert MH00002388 are considered ***eligible*** for the NRHP and recommended to be **avoided** by project activities.

Table 5. Summary of results of cultural resources inventory.

ID#	Name/Type	NRHP	Potential Effect & Recommendations
39MH0334	Historic Artifact Scatter	***Not Eligible***	**No Effect**
39MH2013	Great Northern Railroad	***Eligible***	**No Adverse Effect – Avoid**
MH00000902	Railroad Bridge	***Eligible***	**No Adverse Effect – Avoid**
MH00002386	Two Fields Corn Crib	***Not Eligible***	**No Effect**
MH00002387	Railroad Masonry Culvert	***Not Eligible***	**No Effect**
MH00002388	Railroad Bridge at Mile Post 134.1	***Eligible***	**No Adverse Effect – Avoid** Do not impact railroad bridge.
MH00002389	Railroad Bridge at Mile Post 134.26	***Not Eligible***	**No Effect**
MH00002390	Railroad Bridge at Mile Post 134.3	***Not Eligible***	**No Effect**

A determination of no adverse effect to historic properties is recommended.

In the unlikely event that cultural resources are located during construction activities, it is recommended that the South Dakota State Historic Preservation Office and ***Quality Services, Inc.*** be contacted immediately.

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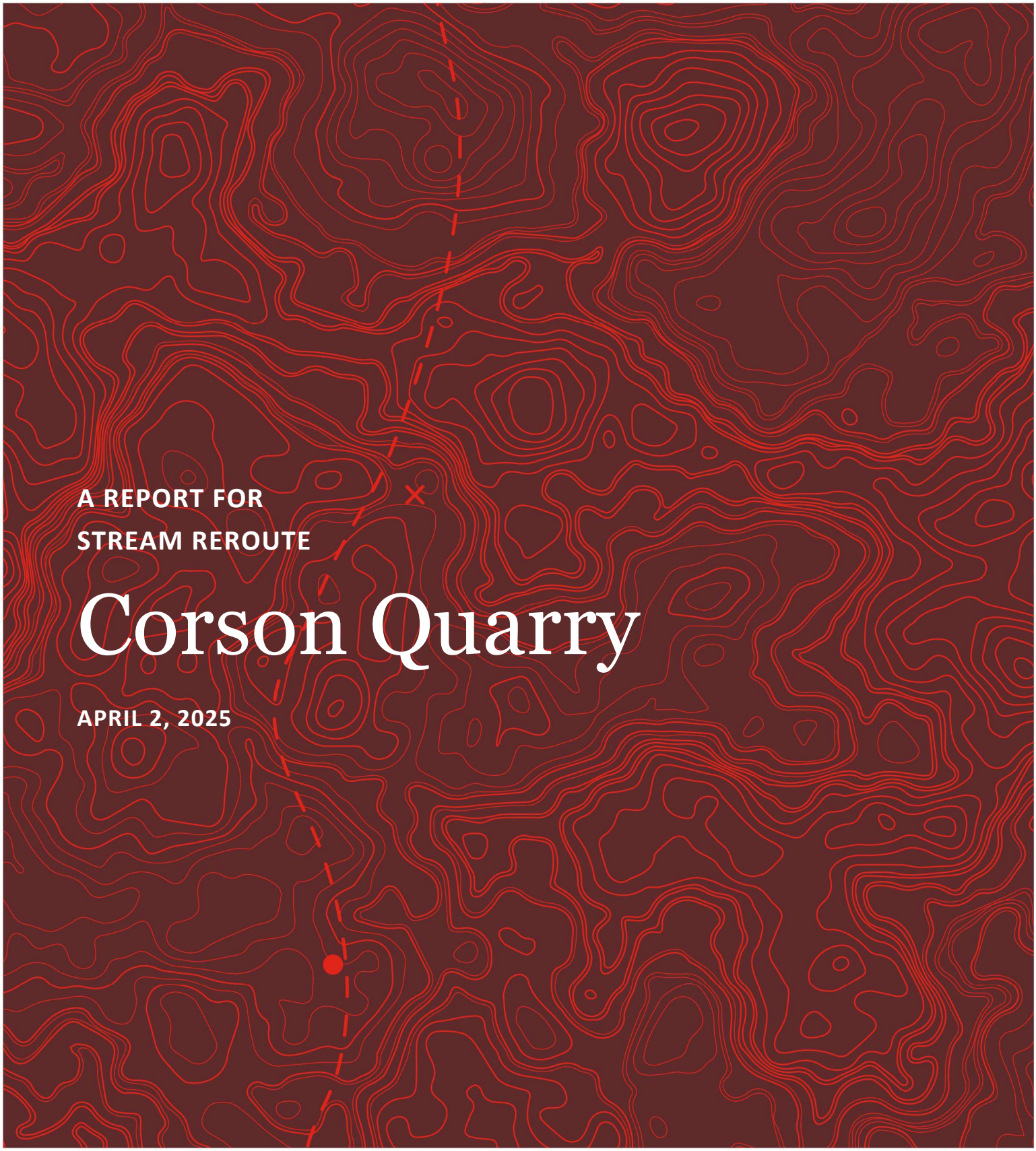
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A REPORT FOR

STREAM REROUTE

Corson Quarry

APRIL 2, 2025

PREPARED FOR:

Knife River

4787 Shadow Wood Drive NE

Sauk Rapids, MN 56379

PREPARED BY: Westwood

Westwood

Stream Reroute Report

Corson Quarry

Town of Brandon, Minnehaha County, SD

Prepared For:

Knife River
4787 Shadow Wood Drive NE
Sauk Rapids, MN 56379

Prepared By:

Westwood Professional Services, Inc.
One Systems Drive
Appleton, WI 54914-1654
(920) 735-6900

Project Number: R0033065.00
Date: April 2, 2025

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Appendix B: Streamstats Reports
Appendix C: Riprap References
Appendix D: HEC-RAS

Westwood

Appendix E: HEC-RAS digital files

Appendix F: Planset

1.0 General Project Information

1.1 Project Description

Knife River is seeking assistance to relocate several streams to make way for a proposed quarry in the Town of Brandon in Minnehaha County in South Dakota. The existing intermittent streams ultimately converge with Split Rock Creek which is a tributary of Big Sioux River. The proposed quarry location is mainly wetlands with intermittent streams carrying little to no flow during dry periods. A Water Source Protection Area is located partially within the project area however the proposed stream realignment will not pose a risk to the water source.

A FEMA Flood Insurance Rate Map exists for Minnehaha County at the project location. The flood zone is defined as Zone A which means no base flood elevations were determined or modeled when the flood zone was originally mapped. As a result of the proposed channel, the floodplain will not be increased on adjacent properties.

A location map of the site denoting tributaries is included in **Appendix A**.

1.2 Computer Modeling Software

The primary computer modeling tools used to analyze the existing tributaries and the proposed realignment was HEC-RAS 6.6.

2.0 Hydrology

Flow rates for the storm events were obtained from Streamstats, an online software created by the United States Geological Survey.

2.1 Streamstats

Streamstats was used to obtain flow rates for all tributaries. The software uses regression equations from "A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055" to estimate the peak flow rates. Table 2.1 shows the results and complete Streamstats reports are found in **Appendix B**.

Table 2.1 – Peak Runoff Flow Rates from Streamstats

Reach	10-year Flow (cfs)	25-year Flow (cfs)	50-year Flow (cfs)	100-year Flow (cfs)
eA/Realignment 1	117	176	223	272
eA1	144	217	275	336
eAB	593	898	1,150	1,430
eB	533	806	1,030	1,280
pAB/Realignment 2*	677	1,023	1,305	1,616
eC	53.5	79.8	101	122
eC1	88.2	132	167	203
pABC*	730.5	1,102.8	1,406	1,738
eD	69.4	104	131	159
pABCD*	799.9	1,206.8	1,537	1,897
SRC/Main Channel	7,460	11,500	15,000	18,900

*Denotes flows rates have been added together due to existing tributary and realignment converging.

3.0 HEC-RAS Hydraulic Analysis

The hydraulic modeling in this report contains cross sections created using a combination of survey data and County LiDAR data to fill in missing information. All cross sections are stationed looking downstream from left to right.

3.1 Existing Hydraulic Model

3.1.1. Reaches

The existing model is split into seven reaches. Table 3.3 below illustrates the bounding cross sections of each reach.

Table 3.1 – Existing HEC RAS Reaches

Reach	Upstream Cross Section	Downstream Cross Section
eA	4200	580
eAB	3070	110
eB	2900	8
eC	100	50
eD	300	100
eSRC-CD	101	50
eSRC-D	0.5	0.1

3.1.2. Boundary Conditions

The flow data was modeled in HEC-RAS as *Steady Flow Data*. The boundary conditions for existing and proposed conditions are shown in Table 3.2 below.

Table 3.2 – Existing HEC RAS Boundary conditions

Reach	Upstream Boundary Condition	Downstream Boundary Condition
eA	Normal Depth S = 0.0087	Junction = J1
eAB	Junction = J1	Junction = 1
eB	Normal Depth S = 0.003	Junction = J1
eC		Junction = 1
eD		Junction = 2
eSRC-CD	Junction = 1	Junction = 2
eSRC-D	Junction = 2	Normal Depth S = 0.0068

3.1.3. Manning's N Values

Manning's N values were established using Table 3-1 from the HEC-RAS Hydraulic Reference Manual. A value of 0.04 was chosen for the channel bottom as it was mainly silty with little excess vegetation. A value of 0.03 was chosen for the overbanks fields as mature row crops were present in aerial photos.

3.1.4. Railroad Bridge and Culvert Crossings

There are two railroad bridges and one culvert crossing under the existing railroad. Structures were surveyed and input into the HEC RAS model.

3.1.5. Ineffective Flow Areas

Ineffective flow areas were established based on the water backing up from the railroad bridges and culvert crossing during the 100-year storm event, using a 1:1 contraction ratio upstream and a 1:2 expansion ratio downstream.

Calculations can be found in **Appendix C**.

3.2 Proposed Hydraulic Model

3.2.1. Reaches

The proposed model is split into seven reaches. Table 3.3 below illustrates the bounding cross sections of each reach.

Table 3.3 – Proposed HEC RAS Reaches

Reach	Upstream Cross Section	Downstream Cross Section
eB	2900	2520
eC	100	50
Main Channel	113	110
Main Channel 1.5	101	100
Main Channel 2	0.5	0.1
Realignment 1	4200	2100
Realignment 2	2000	100

3.2.2. Boundary Conditions

The flow data was modeled in HEC-RAS as *Steady Flow Data*. The boundary conditions for existing and proposed conditions are shown in Table 3.4 below.

Table 3.4 – Proposed HEC RAS Boundary conditions

Tributary Area	Upstream Boundary Condition	Downstream Boundary Condition
eB	Normal Depth S = 0.003	Junction = Junction 1
eC		Junction = 2
Main Channel	Normal Depth S = 0.001	Junction = 2
Main Channel 1.5	Junction = 2	Junction = Convergence
Main Channel 2	Junction = Convergence	Normal Depth S = 0.0068
Realignment 1	Normal Depth S = 0.0087	Junction = 2
Realignment 2	Junction = 2	Junction = Convergence

3.2.3. Channel Design

The proposed realignment is designed to contain the 100-year storm event and not increase the existing Zone A floodplain. A typical section of the realignment has 3:1 side slopes and a varying bottom width.

Complete plans can be found in **Appendix F**.

3.2.4. Culvert Crossings

Two culvert crossings will be constructed; one at the 259th street crossing located at RS 1650 and another along a quarry road located at RS 950. Both culvert crossings will be 10' tall and 36' feet wide and consist of 3-10' x 12' openings.

3.2.5. Riprap and Manning's N Values

Riprap was designed using the guidelines set forth in Chapter 15.7.1 "Riprap Size" from the South Dakota Drainage Manual. For all cross sections, the following parameters were employed using Equation 15.4:

- Safety factor of 1.2
- Stability coefficient of 0.30 for angular rock
- Blanket thickness coefficient of 1.0
- Bank angle of 33°
- Specific gravity of 2.48
- Acceleration due to gravity of 32.2 ft/sec^2
- Characteristic velocity for design for trapezoidal channels
- For any straight sections of channel, the centerline radius of curvature is assumed to be 100,000 such that the ratio of centerline radius of curvature to width of water surface is very large as well. Using a value of 0 for the centerline radius of curvature results in an infinitely large ratio therefore the assumption is valid.

Riprap classes are determined from the SDDOT Standard Specifications for Roads and Bridges Section 830.1. Rock size is based on a specific gravity of 2.65 however riprap gradations were calculated based on a specific gravity of 2.48. This is a more conservative approach as a higher specific gravity led to a smaller riprap gradation. The riprap class table, riprap sizing guidelines and riprap calculations can be found in **Appendix C.**

Manning's n values were established using Equation 6 from the publication "Rock Riprap Design for Protection of Stream Channels Near Highway Structures" Volume 1 published by the USGS in 1986. This equation uses the intermediate diameter of stone and was developed by Anderson and others in 1970 to demonstrate a relationship for estimating Manning's n values from an intermediate particle size (D_{50}). Calculated values range from 0.039 for Class A riprap to 0.044 for Class C riprap.

3.2.6. Stilling Basin Design

A stilling basin is proposed at the downstream end of the culvert crossing 950 to dissipate energy. The design is based off of Chapter 8 from Hydraulic Engineering Circular No. 14, Third Edition. The 100-year flow rate was used to design the stilling basin and will have the following parameters:

- 2' transition downstream of culvert to elevation 1,379.37'

- 2:1 slope down to bottom of basin
- Bottom basin elevation of 1,373.00'
- Basin length of 36'
- 2:1 slope up to tie into channel bottom at elevation 1,376.85'

3.2.7. Rock Check Dam Design

Several rock checks are proposed starting at station 5+00. They are spaced 50' apart and will be permanent. These rock checks will serve as energy dissipaters to prevent erosion at the downstream tie in location. The rock checks are based of off South Dakota Department of Transportation guidance.

3.2.8. Ineffective Flow Areas

Ineffective flow areas were established based on the water backing up from the proposed culvert crossings during the 100-year storm event, using a 1:1 contraction ratio upstream and a 1:2 expansion ratio downstream.

Calculations can be found in **Appendix D**.

4.0 Hydraulic Modeling Results

The HEC RAS modeling demonstrates that the proposed channel alignment will safely convey all storm events up to and including the 100-year storm event without adversely impacting any neighboring properties or the quarry operations.

Complete hydraulic modeling results are found in **Appendix F**. The following attachments are included in **Appendix F**:

- F.1 Existing Water Surface Elevations based on survey and LiDAR data
- F.2 Proposed Water Surface Elevations based on proposed grading and LiDAR outside of grading limits
- F.3 Comparing Existing and Proposed Water Surface Elevations compares the existing cross sections to the proposed to show there is no worsening of the floodplain for the 100-year event on adjacent properties.

Appendix

Appendix A: Maps

A1. Existing HEC RAS Cross Sections

A2. Proposed HEC RAS Cross Sections

A3. FIRM Existing Zone A Map

A4. Existing and Proposed Floodplain Extents

Appendix B: Streamstats Reports

Appendix C: Riprap References

Appendix D: HEC-RAS

D1. Geometry

D2. Summary Table

D3. Profile

D4. Cross Sections

D5. Ineffective Flow Areas

Appendix E: HEC-RAS digital files

Appendix F: Hydraulic Modeling Results

F1. Existing Water Surface Elevations

F2. Proposed Water Surface Elevations

F3. Comparing Existing and Proposed Water Surface Elevations

Appendix G: Planset

Appendix A

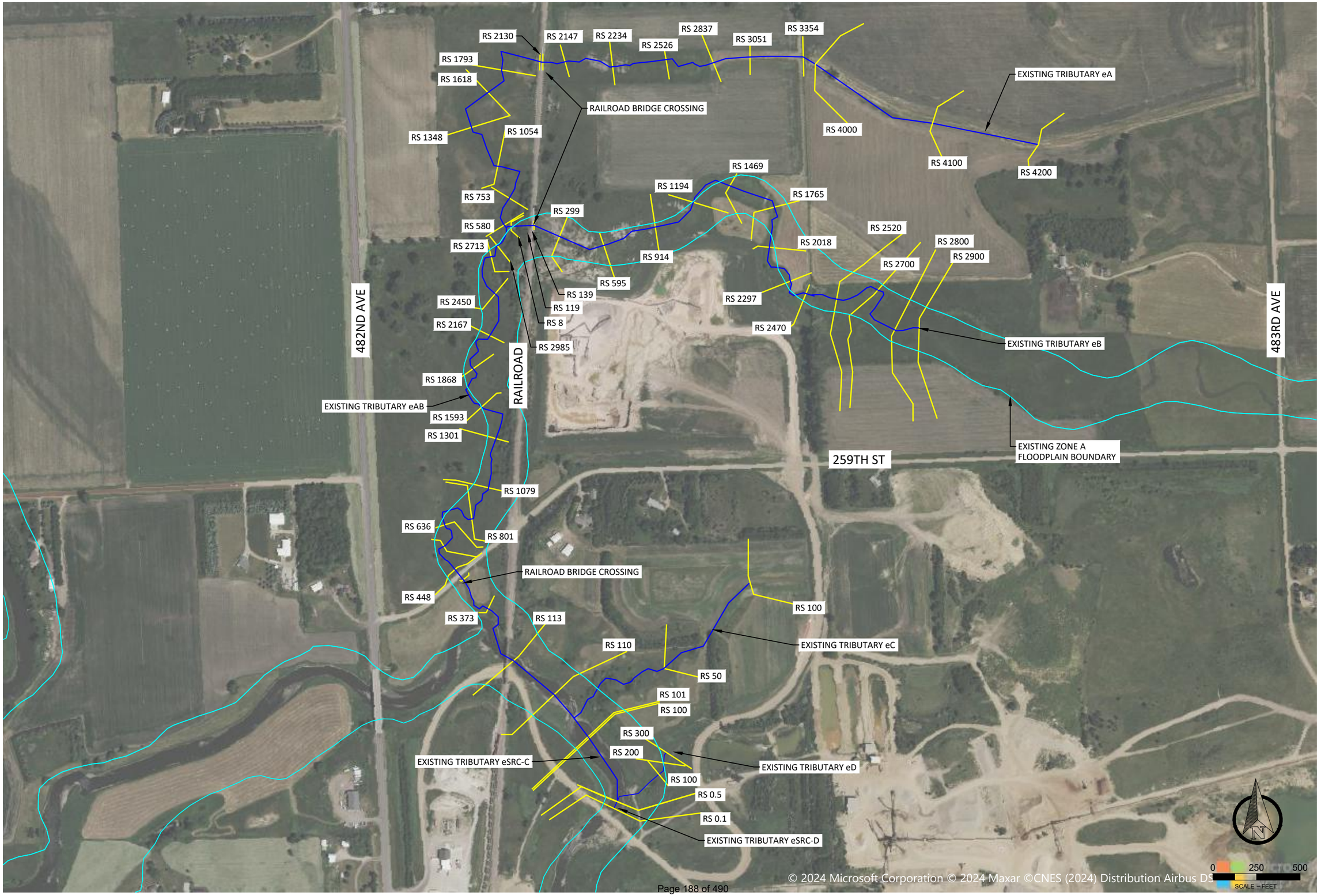
Maps

A1. ***Existing HEC RAS Cross Sections***

A2. ***Proposed HEC RAS Cross Sections***

A3. ***FIRM Existing Zone A Map***

A4. ***Existing and Proposed Floodplain Extents***



Westwood
One Systems Drive
Appleton, WI 54914-1654
westwoodps.com
Phone (920) 735-6900
Fax (920) 830-6100
Toll Free (800) 571-6677
Westwood Infrastructure, Inc.

REV.	DATE	DESCRIPTION

KNIFE RIVER CORSON QUARRY STREAM REALIGNMENT BRANDON, SD

EXISTING CROSS SECTION LOCATIONS

PROJECT MANAGER
JSB

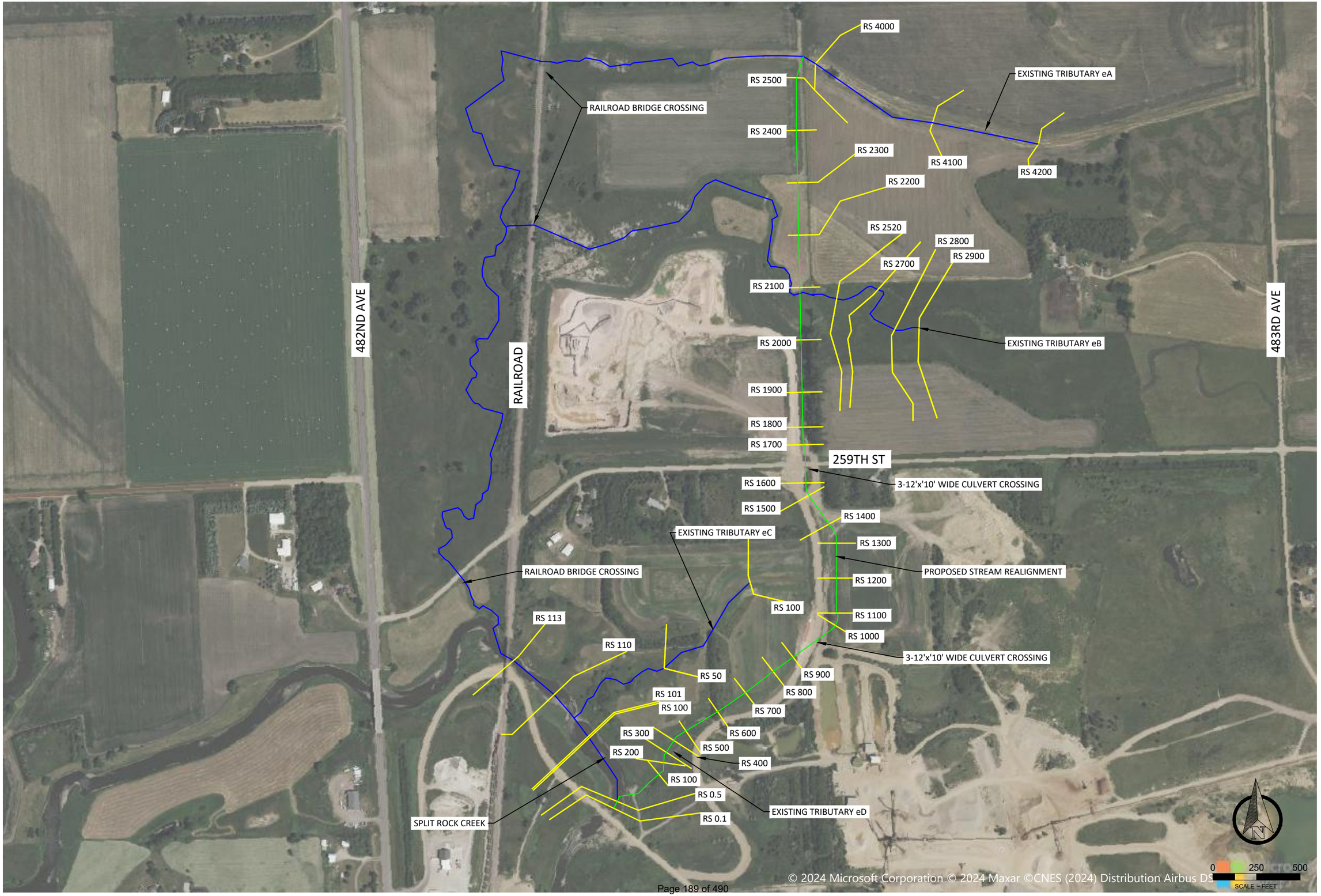
PROJECT NO.
0033065.00

DATE
10/30/2024

SHEET NO.
A1

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File Name: N:\0033065.00\dwg\WR\0033065 Existing Cross sections map.dwg
Plotted By: KASEPPANEN on 10/30/2024 at 08:58 AM



Westwood
Phone (920) 735-6900
Fax (920) 830-6100
Toll Free (800) 571-6677
One Systems Drive
Appleton, WI 54914-1654
westwoodps.com
Westwood Infrastructure, Inc.

REV.	DATE	DESCRIPTION

KNIFE RIVER CORSON QUARRY STREAM REALIGNMENT BRANDON, SD

PROPOSED CROSS SECTION LOCATIONS

PROJECT MANAGER
JSB

PROJECT NO.
0033065.00

DATE
04/03/2025

SHEET NO.
A2

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File Name: N:\0033065.00\dwg\WR\0033065 Proposed Cross sections map.dwg
Plotted By: KASEPPANEN on 04/03/2025 at 08:28 AM

NOTES TO USERS

use in administering the National Flood Insurance Program. It arily identify all areas subject to flooding, particularly from local e of small size. The **community map repository** should be ssible updated or additional flood hazard information.

detailed information in areas where **Base Flood Elevations** oodways have been determined, users are encouraged to consult es and Floodway Data and/or Summary of Stillwater Elevations within the Flood Insurance Study (FIS) report that accompanies rs should be aware that BFEs shown on the FIRM represent ood elevations. These BFEs are intended for flood insurance only and should not be used as the sole source of flood ation. Accordingly, flood elevation data presented in the FIS be utilized in conjunction with the FIRM for purposes of or floodplain management.

Flood Elevations shown on this map apply only landward American Vertical Datum of 1988 (NAVD 88). Users of this aware that coastal flood elevations are also provided in the llwater Elevations table in the Flood Insurance Study report on. Elevations shown in the Summary of Stillwater Elevations used for construction and/or floodplain management purposes igher than the elevations shown on this FIRM.

floodways were computed at cross sections and interpolated ections. The floodways were based on hydraulic considerations quirements of the National Flood Insurance Program. Floodway er pertinent floodway data are provided in the Flood Insurance this jurisdiction.

t in Special Flood Hazard Areas may be protected by **flood es.** Refer to Section 2.4 "Flood Protection Measures" of nce Study report for information on flood control structures n.

used in the preparation of this map was Universal Transverse zone 14. The **horizontal datum** was NAD83, GRS1980 nces in datum, spheroid, projection or UTM zones used in FIRMs for adjacent jurisdictions may result in slight positional ap features across jurisdiction boundaries. These differences accuracy of this FIRM.

on this map are referenced to the North American Vertical . These flood elevations must be compared to structure and s referenced to the same **vertical datum.** For information rsion between the National Geodetic Vertical Datum of 1929 American Vertical Datum of 1988, visit the National Geodetic at http://www.ngs.noaa.gov/ or contact the National Geodetic llowing address:

Services

Survey

Highway
20910-3282

elevation, description, and/or location information for **benchmarks** map, please contact the Information Services Branch of the tic Survey at **(301) 713-3242,** or visit its website at aa.gov/.

ation shown on this FIRM was derived from multiple sources. Base vided in digital format by the State of South Dakota, Minnehaha ity of Sioux Falls GIS departments. This information was compiled s in 2004.

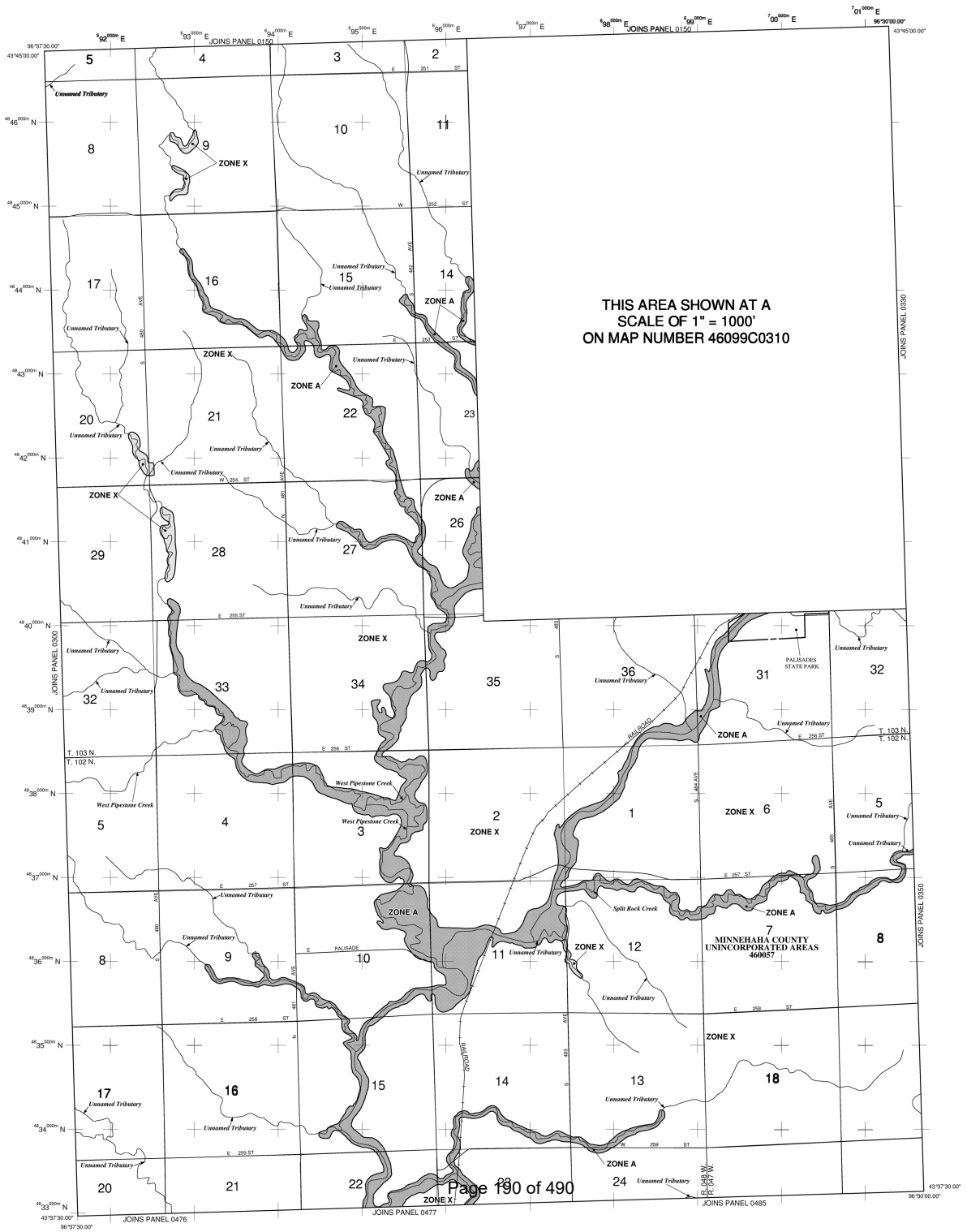
more detailed and up-to-date **stream channel configurations** n on the previous FIRM for this jurisdiction. The floodplains hat were transferred from the previous FIRM may have been nform to these new stream channel configurations. As a d Profiles and Floodway Data tables *in the Flood Insurance* hich contains authoritative hydraulic data) may reflect stream s that differ from what is shown on this map.

s shown on this map are based on the best data available plication. Because changes due to annexations or de-annexations rred after this map was published, map users should contact munity officials to verify current corporate limit locations.

he separately printed **Map Index** for an overview map of the the layout of map panels; community map repository addresses; Communities table containing National Flood Insurance Program community as well as a listing of the panels on which each ated.

MA Map Service Center at 1-800-358-9616 for information on ts associated with this FIRM. Available products may include d Letters of Map Change, a *Flood Insurance Study report*, rsions of this map. The FEMA Map Service Center may also be at 1-800-358-9620 and its website at http://www.msc.fema.gov/.

estions about this map or questions concerning the National Program in general, please call **1-877-FEMA MAP** (1-877-336-2627) A website at http://www.fema.gov/.



LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Special Flood Hazard Area formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- Floodplain boundary
- **Floodway boundary**
- **Zone D boundary**
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

* Referenced to the North American Vertical Datum of 1988 (NAVD 88)

- A — A — Cross section line
- 23 — 23 — Transect line
- 97°07'30", 32°22'30" — **Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)**
- 4275000mN — 1000-meter Universal Transverse Mercator grid ticks, zone 14
- 6000000 M — **5000-foot grid ticks: New York State Plane coordinate system, east zone (FIPSZONE 3101), Transverse Mercator**
- DX5510 — **Bench mark (see explanation in Notes to Users section of this FIRM panel)**
- M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
September 2, 2009
EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 2000'
1000 0 2000 4000 FEET
600 0 600 1200 METERS

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0325D

FIRM
FLOOD INSURANCE RATE MAP
MINNEHAHA COUNTY, SOUTH DAKOTA
AND INCORPORATED AREAS

PANEL 325 OF 650
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

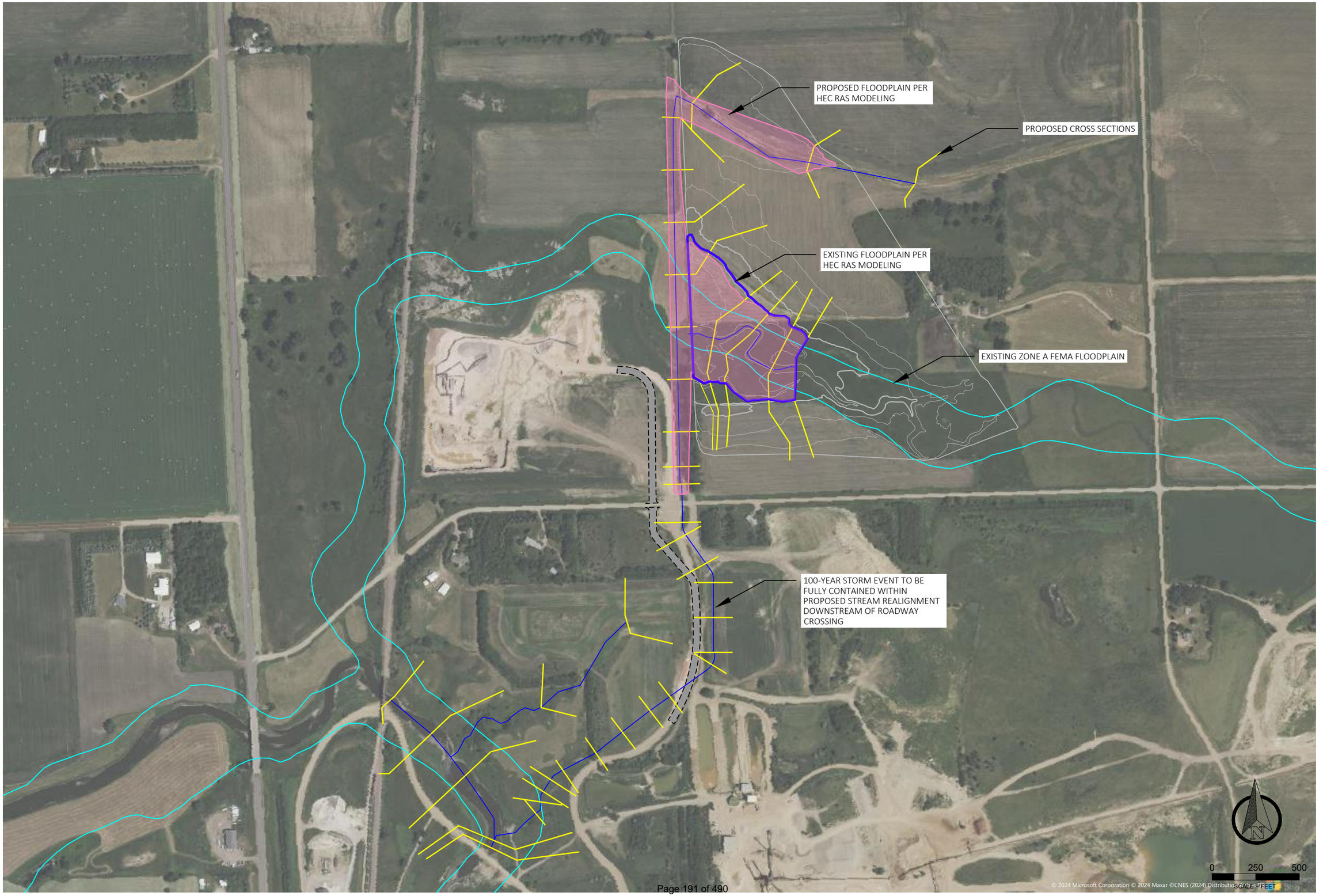
COMMUNITY	NUMBER	PANEL	SUFFIX
MINNEHAHA COUNTY	460057	0325	D

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
46099C0325D

EFFECTIVE DATE
SEPTEMBER 2, 2009

Federal Emergency Management Agency



Westwood
Phone (920) 735-6900
Fax (920) 830-6100
Toll Free (800) 571-6677
One Systems Drive
Appleton, WI 54914-1654
westwoodps.com
Westwood Infrastructure, Inc.

REV.	DATE	DESCRIPTION

KNIFE RIVER CORSON QUARRY STREAM REALIGNMENT BRANDON, SD

EXISTING AND PROPOSED FLOODPLAIN

PROJECT MANAGER
JSB

PROJECT NO.
0033065.00

DATE
12/02/2024

SHEET NO.
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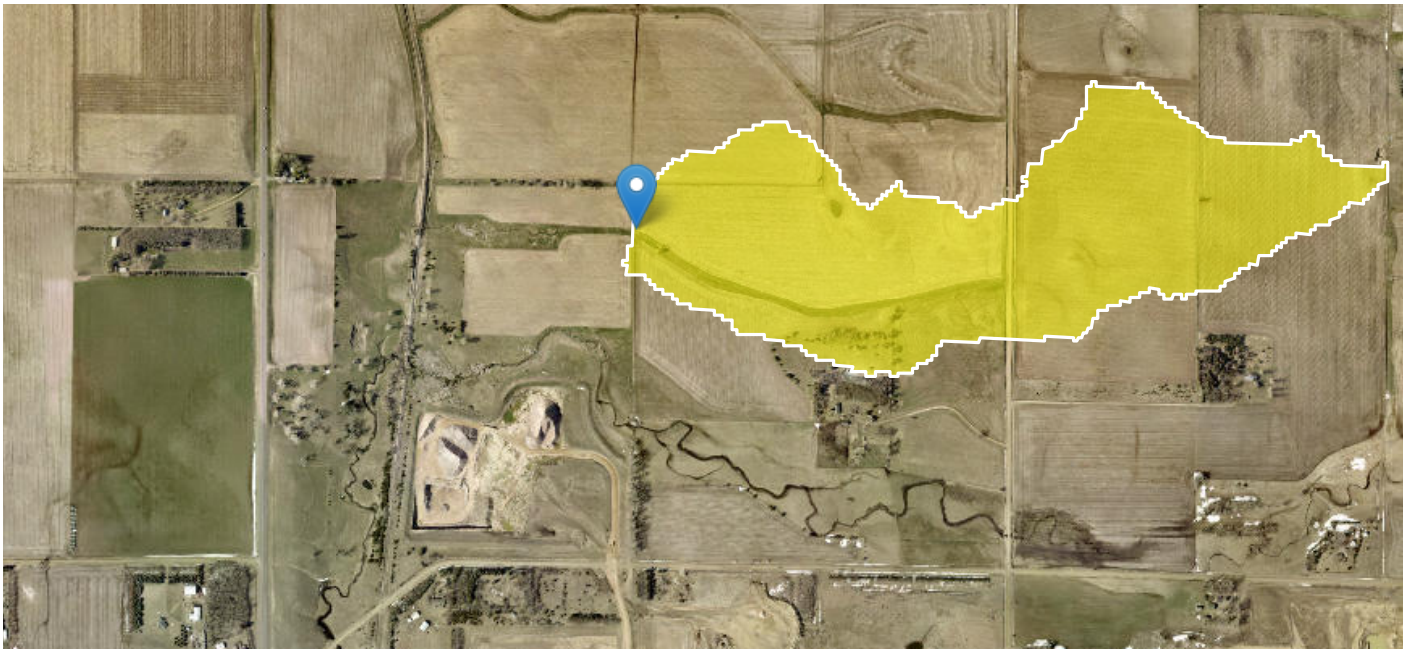
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Plotted By: KASEPPANEN on 12/02/2024 at 10:34 AM

Appendix B

Streamstats Reports

StreamStats Report eA RS 3354

Region ID: SD
Workspace ID: SD20231212134211203000
Clicked Point (Latitude, Longitude): 43.63740, -96.56184
Time: 2023-12-12 07:42:37 -0600



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.21	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	0.21	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Flow Report [Subregion A]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIL	PIU	SE	ASEp	Equiv. Yrs.
50-percent AEP flood	38.3	ft^3/s	15.1	97.4	59	59	4.5
20-percent AEP flood	95.2	ft^3/s	40.2	225	54	54	6.1
10-percent AEP flood	144	ft^3/s	60.7	342	54	54	7.8
4-percent AEP flood	217	ft^3/s	88.7	531	56	56	9.8
2-percent AEP flood	275	ft^3/s	109	695	58	58	11
1-percent AEP flood	336	ft^3/s	128	883	61	61	11.9
0.2-percent AEP flood	485	ft^3/s	167	1410	69	69	13

Peak-Flow Statistics Citations

Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

USGS Data Disclaimer: Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data for other purposes, nor on all computer systems, nor shall the act of distribution constitute any such warranty.

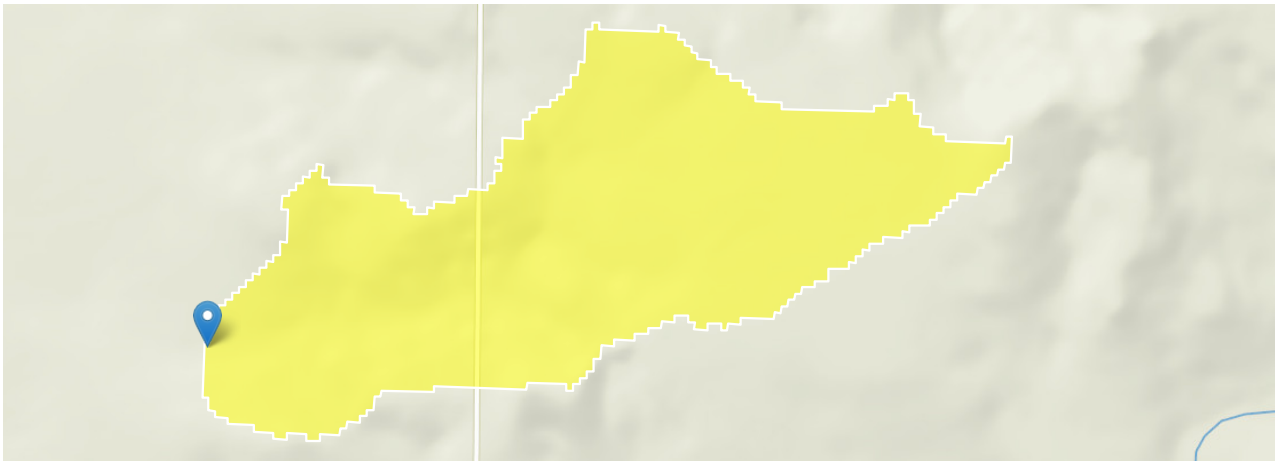
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Application Version: 4.19.2
StreamStats Services Version: 1.2.22
NSS Services Version: 2.3.2

StreamStats Report eA RS 4200

Region ID: SD
Workspace ID: SD20240904114901324000
Clicked Point (Latitude, Longitude): 43.63582, -96.55691
Time: 2024-09-04 06:49:28 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.14	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	0.14	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Flow Report [Subregion A]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct (other -- see report)

Statistic	Value	Unit	PIL	PIU	SE	ASEp	Equiv. Yrs.
50-percent AEP flood	31.1	ft^3/s	12.2	79.5	59	59	4.5
20-percent AEP flood	77.5	ft^3/s	32.6	184	54	54	6.1
10-percent AEP flood	117	ft^3/s	49	279	54	54	7.8
4-percent AEP flood	176	ft^3/s	71.5	433	56	56	9.8
2-percent AEP flood	223	ft^3/s	87.6	568	58	58	11
1-percent AEP flood	272	ft^3/s	103	720	61	61	11.9
0.2-percent AEP flood	391	ft^3/s	134	1140	69	69	13

Peak-Flow Statistics Citations

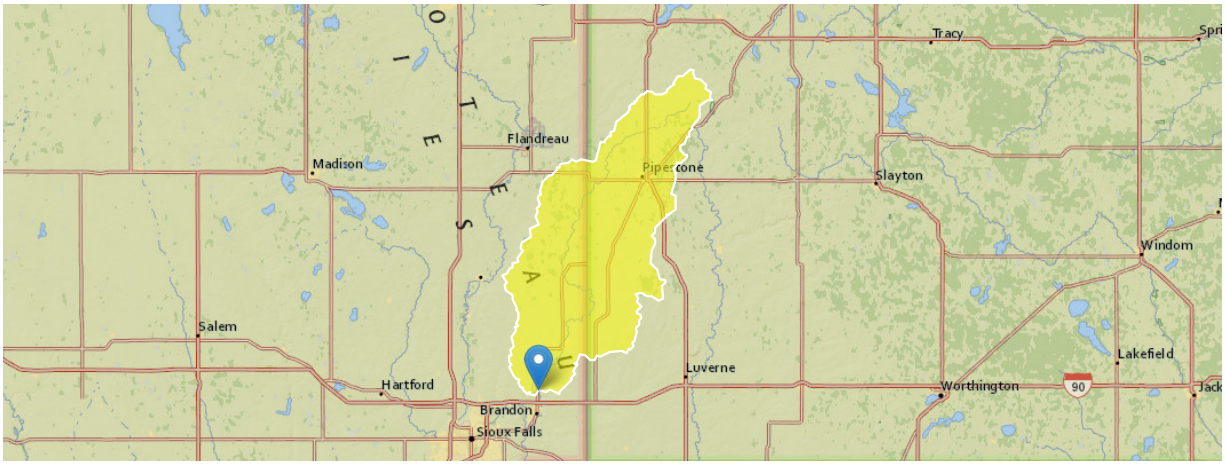
Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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StreamStats Report eAB RS 110

Region ID: SD
Workspace ID: SD20240909131701353000
Clicked Point (Latitude, Longitude): 43.62806, -96.56867
Time: 2024-09-09 08:17:55 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	480.96	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	480.96	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Flow Report [Subregion A]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct (other -- see report)

Statistic	Value	Unit	PIL	PIU	SE	ASEp	Equiv. Yrs.
50-percent AEP flood	2030	ft^3/s	822	5010	59	59	4.5
20-percent AEP flood	4890	ft^3/s	2120	11300	54	54	6.1
10-percent AEP flood	7460	ft^3/s	3240	17200	54	54	7.8
4-percent AEP flood	11500	ft^3/s	4860	27200	56	56	9.8
2-percent AEP flood	15000	ft^3/s	6140	36600	58	58	11
1-percent AEP flood	18900	ft^3/s	7470	47800	61	61	11.9
0.2-percent AEP flood	29500	ft^3/s	10600	82100	69	69	13

Peak-Flow Statistics Citations

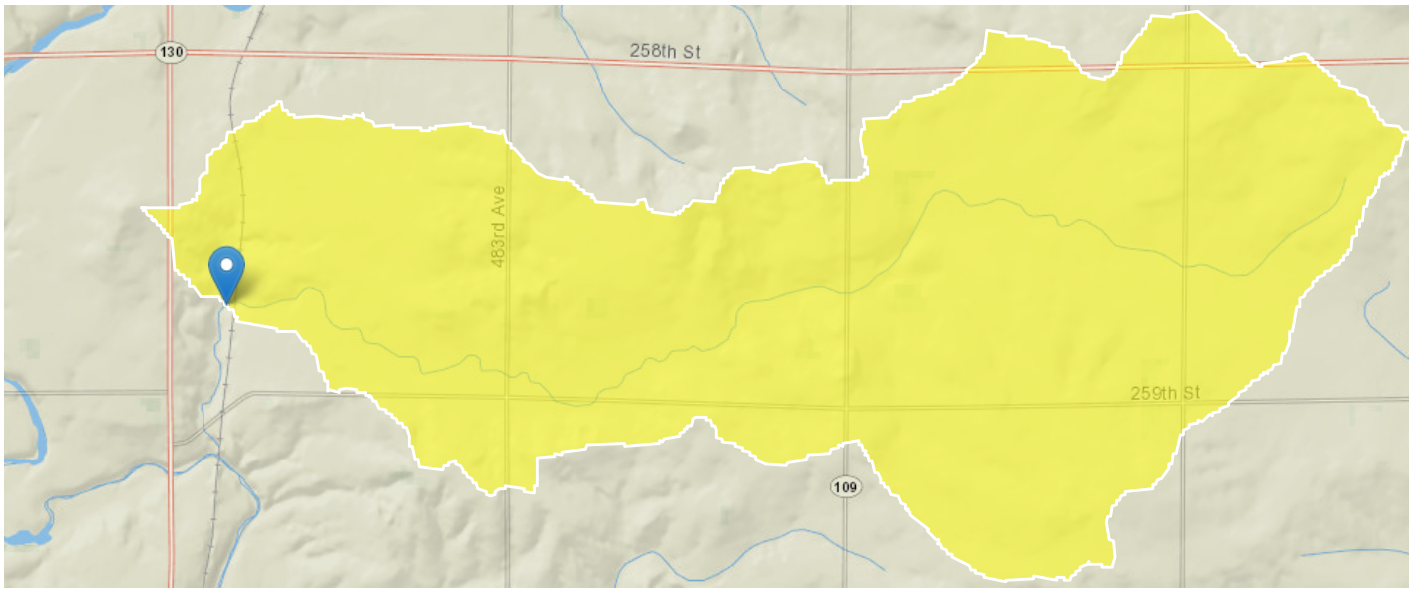
Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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StreamStats Report eAB RS 3070

Region ID: SD
Workspace ID: SD20221214183922634000
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Time: 2022-12-14 12:39:47 -0600



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	3.36	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	3.36	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Flow Report [Subregion A]

PII: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PII	PIu	SE	ASEp	Equiv. Yrs.
50-percent AEP flood	159	ft^3/s	64.4	393	59	59	4.5
20-percent AEP flood	391	ft^3/s	170	900	54	54	6.1

Statistic	Value	Unit	PII	Plu	SE	ASEp	Equiv. Yrs.
10-percent AEP flood	593	ft^3/s	257	1370	54	54	7.8
4-percent AEP flood	898	ft^3/s	379	2130	56	56	9.8
2-percent AEP flood	1150	ft^3/s	471	2810	58	58	11
1-percent AEP flood	1430	ft^3/s	565	3620	61	61	11.9
0.2-percent AEP flood	2120	ft^3/s	762	5900	69	69	13

Peak-Flow Statistics Citations

Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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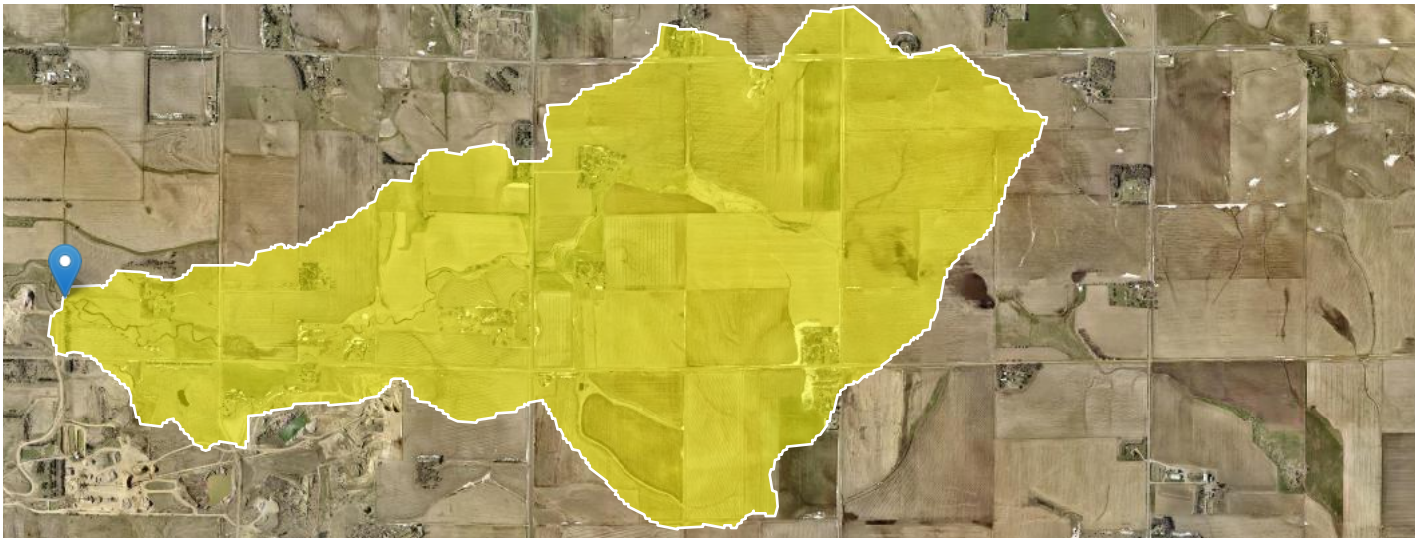
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Application Version: 4.11.1
StreamStats Services Version: 1.2.22
NSS Services Version: 2.2.1

StreamStats Report eB RS 2900

Region ID: SD
Workspace ID: SD20231212134641283000
Clicked Point (Latitude, Longitude): 43.63370, -96.56187
Time: 2023-12-12 07:47:05 -0600



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	2.72	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	2.72	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Flow Report [Subregion A]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	PIL	PIU	SE	ASEp	Equiv. Yrs.
50-percent AEP flood	143	ft^3/s	57.8	354	59	59	4.5
20-percent AEP flood	351	ft^3/s	152	809	54	54	6.1
10-percent AEP flood	533	ft^3/s	231	1230	54	54	7.8
4-percent AEP flood	806	ft^3/s	340	1910	56	56	9.8
2-percent AEP flood	1030	ft^3/s	421	2520	58	58	11
1-percent AEP flood	1280	ft^3/s	505	3250	61	61	11.9
0.2-percent AEP flood	1890	ft^3/s	678	5270	69	69	13

Peak-Flow Statistics Citations

Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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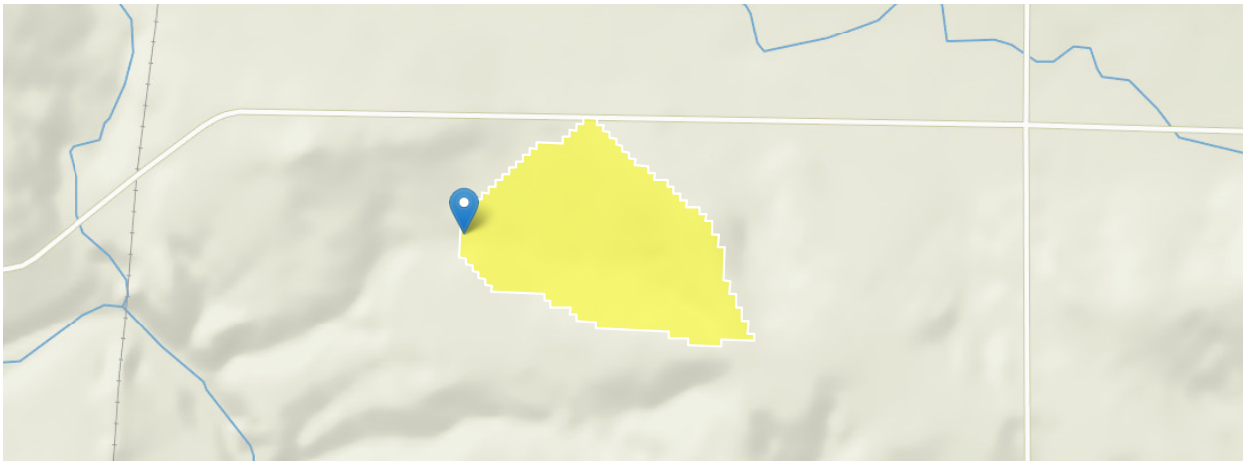
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Application Version: 4.19.2
StreamStats Services Version: 1.2.22
NSS Services Version: 2.3.2

StreamStats Report eC RS 100

Region ID: SD
Workspace ID: SD20240906160339267000
Clicked Point (Latitude, Longitude): 43.62933, -96.56250
Time: 2024-09-06 11:04:14 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.03	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	0.03	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Disclaimers [Subregion A]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [Subregion A]

Statistic	Value	Unit
50-percent AEP flood	14.1	ft^3/s
20-percent AEP flood	35.4	ft^3/s
10-percent AEP flood	53.5	ft^3/s
4-percent AEP flood	79.8	ft^3/s
2-percent AEP flood	101	ft^3/s
1-percent AEP flood	122	ft^3/s
0.2-percent AEP flood	173	ft^3/s

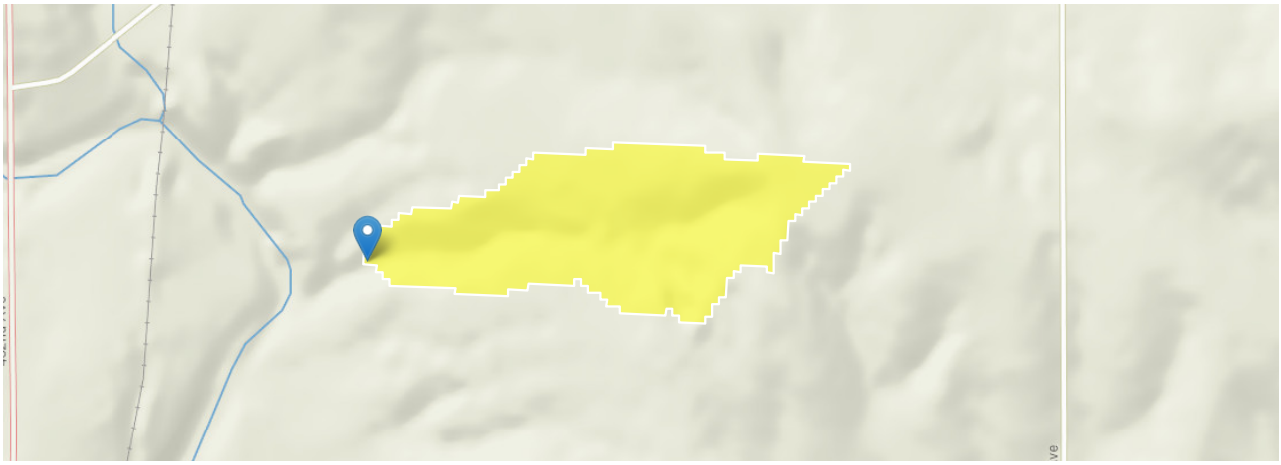
Peak-Flow Statistics Citations

Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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StreamStats Report eD RS 300

Region ID: SD
Workspace ID: SD20240909163032667000
Clicked Point (Latitude, Longitude): 43.62645, -96.56500
Time: 2024-09-09 11:31:00 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	0.05	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	0.05	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Disclaimers [Subregion A]

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors.

Peak-Flow Statistics Flow Report [Subregion A]

Statistic	Value	Unit
50-percent AEP flood	18.4	ft^3/s
20-percent AEP flood	45.9	ft^3/s
10-percent AEP flood	69.4	ft^3/s
4-percent AEP flood	104	ft^3/s
2-percent AEP flood	131	ft^3/s
1-percent AEP flood	159	ft^3/s
0.2-percent AEP flood	227	ft^3/s

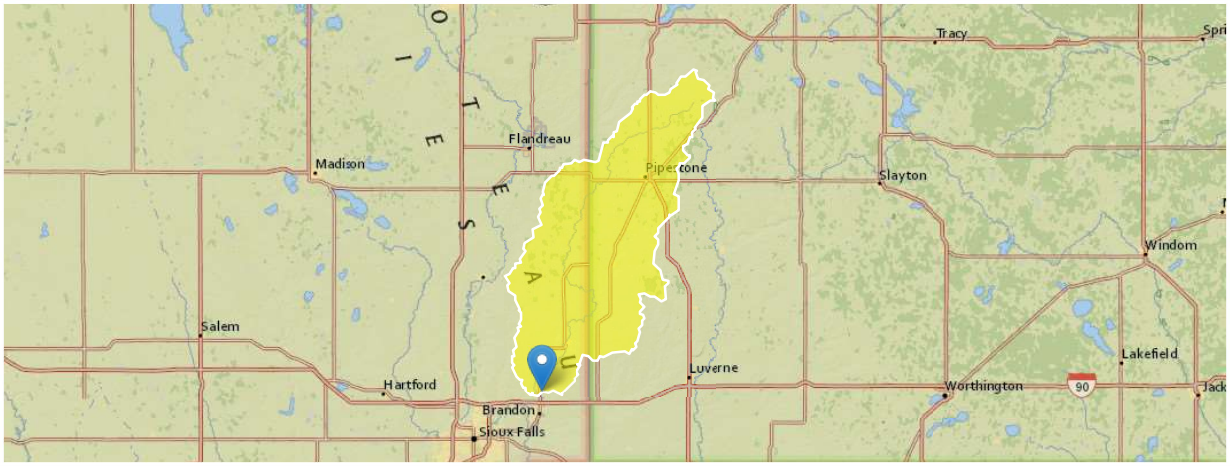
Peak-Flow Statistics Citations

Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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StreamStats Report eSRC-C & eSRC-D

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Workspace ID: SD20241021182330823000
Clicked Point (Latitude, Longitude): 43.62724, -96.56770
Time: 2024-10-21 13:24:05 -0500



Collapse All

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
CONTDA	Area that contributes flow to a point on a stream	481.07	square miles
PII_SD	Maximum 24-hour precipitation that occurs on average once in 2 years minus 1.5 inches	1.18	inches

Peak-Flow Statistics

Peak-Flow Statistics Parameters [Subregion A]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
CONTDA	Contributing Drainage Area	481.07	square miles	0.14	983
PII_SD	S Dakota Precipitation Intensity Index	1.18	inches	0.79	1.3

Peak-Flow Statistics Flow Report [Subregion A]

PIL: Lower 90% Prediction Interval, PIU: Upper 90% Prediction Interval, ASEp: Average Standard Error of Prediction, SE: Standard Error, PC: Percent Correct, RMSE: Root Mean Squared Error, PseudoR^2: Pseudo R Squared (other -- see report)

Statistic	Value	Unit	PIL	PIU	SE	ASEp	Equiv. Yrs.
50-percent AEP flood	2030	ft^3/s	822	5010	59	59	4.5
20-percent AEP flood	4890	ft^3/s	2120	11300	54	54	6.1
10-percent AEP flood	7460	ft^3/s	3240	17200	54	54	7.8
4-percent AEP flood	11500	ft^3/s	4860	27200	56	56	9.8
2-percent AEP flood	15000	ft^3/s	6140	36600	58	58	11
1-percent AEP flood	18900	ft^3/s	7470	47800	61	61	11.9
0.2-percent AEP flood	29500	ft^3/s	10600	82100	69	69	13

Peak-Flow Statistics Citations

Sando, Steven K.,1998, A Method for Estimating Magnitude and Frequency of Floods in South Dakota: U.S. Geological Survey Water-Resources Investigations Report 98-4055, 48 p. (http://pubs.water.usgs.gov/wri98-4055/)

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Appendix C

Riprap References

ROCK RIPRAP DESIGN FOR PROTECTION OF STREAM CHANNELS NEAR HIGHWAY STRUCTURES

VOLUME 1 -- HYDRAULIC CHARACTERISTICS OF OPEN CHANNELS

By J.C. Blodgett

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 86-4127

Prepared in cooperation with

FEDERAL HIGHWAY ADMINISTRATION



8054-01

Sacramento, California
1986

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information,
write to:

District Chief
U.S. Geological Survey
Federal Building, Room W-2234
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LIST OF SYMBOLS

Symbol	Term
a,b,c	Constants
A	Area
B	Channel bottom width
C	Coefficient; Chezy resistance coefficient
d_a	Mean depth
d_A	Subunit area applicable to point velocity
d_c	Critical depth
d_m	Maximum depth
d_s	Depth of scour
$d_{s(max)}$	Estimated maximum depth of scour
$d_{s(mean)}$	Estimated mean depth of scour
D	Diameter of rock particles
D_w	Selected percentile size of stone measured at the intermediate axis
f	Darcy-Weisbach resistance coefficient
F	Froude number
g	Acceleration of gravity
h	Water-surface elevation
k	Equivalent roughness; energy recovery coefficient; constant
K_c	Conveyance of channel at supercritical flow
L	Length of stream channel being considered
n	Manning's roughness coefficient
P	Total wetted perimeter
Q	Total discharge
R	Hydraulic radius
R_d	Mean radius of outside bank of bend
R_o	Mean radius of channel centerline at bend
S_c	Critical slope
S_e	Energy slope
S_f	Friction slope
S_o	Channel bed slope
S_w	Water-surface slope
T	Top width of channel

LIST OF SYMBOLS (continued)

Symbol	Term
v	Point velocity
V	Velocity
V_a	Average velocity in cross section
V_m	Maximum point velocity in cross section
z	Side slope, ratio of horizontal to vertical
α	Velocity-head coefficient, alpha
β	Momentum coefficient, beta
Δ	Internal angle of channel bend, in degrees
ΔA	Subunit area applicable to point velocity
Δh	Change in water-surface elevation between cross sections
Δy	Magnitude of superelevation

CONVERSION FACTORS

For readers who prefer metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
ft (feet)	0.3048	m (meters)
ft (feet)	304.8	mm (millimeters)
ft/s (feet per second)	0.3048	m/s (meters per second)
ft/ft (feet per foot)	0.3048	m/m (meters per meter)
ft^2 (square feet)	0.0929	m^2 (square meters)
ft^3/s (cubic feet per second)	0.0283	m^3/s (cubic meters per second)
inches	25.4	mm (millimeters)
lb/ft^2 (pounds per square foot)	4.882	kg/m^2 (kilograms per square meter)
mi (miles)	1.609	km (kilometers)

ROCK RIPRAP DESIGN FOR PROTECTION OF STREAM CHANNELS NEAR HIGHWAY STRUCTURES

VOLUME 1--HYDRAULIC CHARACTERISTICS OF OPEN CHANNELS

By J.C. Blodgett

ABSTRACT

Volume 1 discusses the hydraulic and channel properties of streams, based on data from several hundred sites. Streamflow and geomorphic data have been collected and developed to indicate the range in hydraulic factors typical of open channels, to assist design, maintenance, and construction engineers in preparing rock riprap bank protection. Typical channels were found to have a maximum-to-mean depth ratio of 1.55 and a ratio of hydraulic radius to mean depth of 0.98, which is independent of width. Most stable channel characteristics for a given discharge are slope, maximum depth, and hydraulic radius.

Volume 2, "Evaluation of Riprap Design Procedures," evaluates seven riprap design procedures now used. A review of field data and design procedures suggests that estimates of hydraulic forces acting on the boundary based on flow velocity rather than shear stress are more reliable. Several adjustments for local conditions, such as channel curvature, superelevation, or boundary roughness, may be unwarranted in view of the difficulty in estimating critical hydraulic forces for which riprap is to be designed. Factors associated with riprap failure include stone size, bank side slope, size gradation, thickness, insufficient toe or endwall, failure of bank material, overtopping, and geomorphic changes in the channel. Success of riprap is related not only to the appropriate procedure for selecting stone size, but also to reliability of estimated hydraulic and channel factors applicable to the site.

Further identification of channel properties and the development of a procedure for estimating stone size are presented in volume 3, "Assessment of Hydraulic Characteristics of Streams at Bank Protection Sites."

INTRODUCTION

There are a variety of procedures available for designing rock riprap to protect streambanks from erosion. Diverse results may be obtained, however, depending on the procedure used and assumptions concerning hydraulic and geomorphic conditions. This diversity indicates a need to better understand the various design concepts, and consequences of application of the selected riprap design procedures. Riprap failures (fig. 1) are usually attributed to excessive hydraulic forces acting on the bank and causing displacement of the stones that comprise the riprap. However, other factors, such as improper gradation or placement, inadequate assessment of probable morphologic changes, or failure of the original bank material may also contribute to the failure.

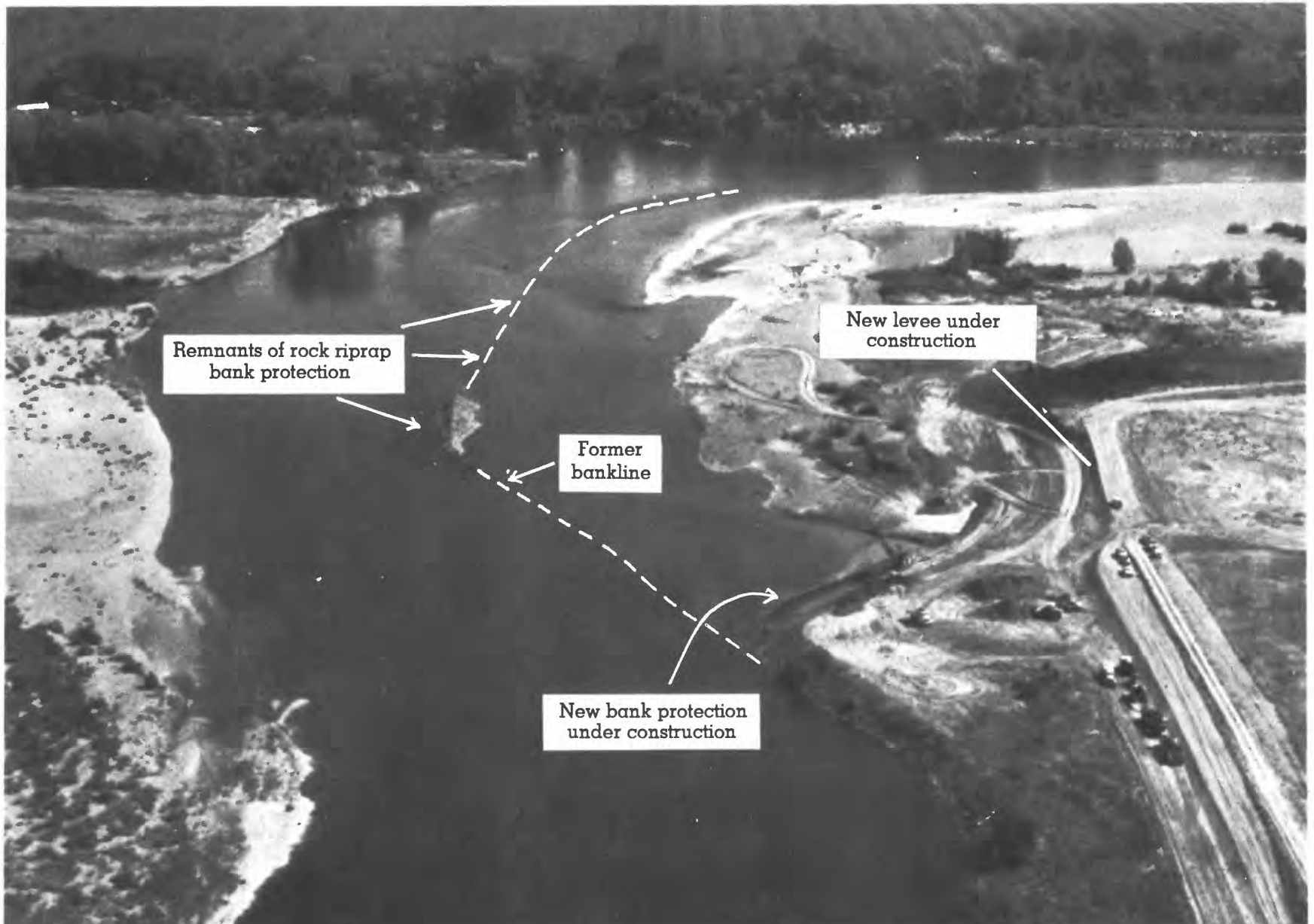


FIGURE 1. Aerial photograph of failed rock riprap intended to prevent lateral erosion on right bank of Sacramento River near Hamilton City, California (September 1984).

Most of the data used in developing existing design procedures (Searcy, 1967; U.S. Army Corps of Engineers, 1970) were based on data collected below dams, in stilling basins, or from laboratory flume studies. In the study reported here, actual streamflow data were used to supplement the existing data that had been used in the previous studies. Stream sites were selected to provide data that would indicate which hydraulic characteristics were important and realistic when applied to the various design procedures.

Several sources of data were used to provide the basis for estimating the magnitude and range of typical hydraulic and morphologic properties of natural streams. The sources of streamflow data include: (1) field surveys made specifically for this project, (2) the ongoing U.S. Geological Survey stream-gaging program, and (3) reports that include detailed tabulations of hydraulic and channel data. Field surveys for this project were made at 26 sites in Washington, Arizona, Oregon, California, and Nevada. Many of the sites, those referred to as pilot study sites, were selected because rock riprap had been installed. Sites that are part of the stream-gaging program may or may not have riprap; they were selected to provide representative flow and channel geometry data.[1] Discharge data for many of these sites are published in annual water resources data publications of the Geological Survey. The third data source is a group of previous studies that include hydraulic and channel data. Some of these studies were published; three especially useful reports are studies of Manning's roughness coefficient by Jarrett (1984) and Limerinos (1970), and a study of the velocity head and momentum factors by Hulsing and others (1966).

GEOMETRIC PROPERTIES OF OPEN CHANNELS

The hydraulic and channel properties that most completely describe an open channel (fig. 2) include discharge (Q), width (T), area (A), wetted perimeter (P), water-surface slope (S_w), maximum depth (d_m), and maximum velocity (V_m). From these, the hydraulic radius (R), Froude number (F), mean depth (d_a), and mean velocity (V_a) may be determined, and various combinations of these properties may be expressed in the form of ratios. The subscript "a" refers to mean (average) values, and the subscript "m" to maximum values. A summary of hydraulic properties and channel geometry determined at more than 700 cross sections of streams is given in tables 1 and 2. The sites were selected to represent a wide range of channel conditions. All sites are on natural open channels not affected by control structures such as bridge openings or jetties. For many sites, statistics such as the median, mean, and standard deviation of certain hydraulic properties are important, but the minimum and maximum values are also presented to indicate the range in data. The data for the different streams are grouped on the basis of slope (table 1) and curvature (table 2).

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[1]The term "channel geometry" generally refers to a description of the shape of a given cross section within a limited reach of a river channel (Bates and Jackson, 1980). For this study, this term has been expanded to include channel shape, size, and slope; these are properties that describe the geometry of a channel used for engineering purposes. The use of this term is intended to provide a precise description for certain channel properties that are described in general by the terms stream morphology or river morphology.

Table 1. Hydraulic properties and channel geometry of streams as a function of channel slope.

Variable	Number of values	Median	Mean	Standard deviation	Minimum value	Maximum value
	Water-surface slope, <0.001					
Discharge, Q (ft^3/s)	76				277	406,000
Width, T (ft)	75				82	1,800
Area, A (ft^2)	75				139	49,600
Wetted perimeter, P (ft)	75				83.3	1,798
Water-surface slope, S_w (ft/ft).	76				-0.00507	0.000911
Maximum depth, d_m (ft)	75				2.5	50.4
Maximum point velocity, V_m (ft/s).	44				2.6	9.77
Average depth, d_a (ft)	75		14.8	11.2	1.58	35.9
Hydraulic radius, R (ft)	75		14.4	10.8	1.57	34.7
Average velocity, V_a (ft/s).	75		3.97	1.51	1.21	8.62
Froude number, F	75		0.222	0.096	0.0935	0.442
d_m/d_a	75	1.47	1.61	0.363	1.029	3.54
V_m/V_a	44	1.46	1.56	0.393	1.055	3.51
T/d_m	75	15.4	19.4	11.02	7.33	60.7
R/d_a	75	0.978	0.979	0.0186	0.916	1.032
	Water-surface slope, >0.001-<0.005					
Discharge, Q (ft^3/s)	101				137	67,100
Width, T (ft)	101				51	978
Area, A (ft^2)	101				60.9	5,589
Wetted perimeter, P (ft)	101				54.0	982
Water-surface slope, S_w (ft/ft).	101				0.00114	0.0048
Maximum depth, d_m (ft)	101				1.73	23.4
Maximum point velocity, V_m (ft/s).	53				2.11	14.8
Average depth, d_a (ft)	101		4.11	2.63	0.716	17.7
Hydraulic radius, R (ft)	101		4.26	2.76	0.69	17
Average velocity, V_a (ft/s).	101		4.94	2.21	1.25	14.1
Froude number, F	101		0.446	0.149	0.160	1.00
d_m/d_a	101	1.59	1.68	0.390	1.14	2.78
V_m/V_a	53	1.50	1.62	0.294	1.25	2.77
T/d_m	101	25.8	27.8	13.1	6.99	83.8
R/d_a	101	0.987	1.03	0.213	0.880	2.43

Table 1. Hydraulic properties and channel geometry of streams as a function of channel slope (continued).

Variable	Number of values	Median	Mean	Standard deviation	Minimum value	Maximum value
			Water-surface slope, >0.005			
Discharge, Q (ft^3/s)	120				14	26,500
Width, T (ft)	120				5.8	475
Area, A (ft^2)	120				2.89	1,986
Wetted perimeter, P (ft)	120				6.42	480
Water-surface slope, S_w (ft/ft).	120				0.00505	0.1013
Maximum depth, d_m (ft)	120				0.93	19.2
Maximum point velocity, V_m (ft/s).	48				1.23	16.7
Average depth, d_a (ft)	120		4.057	3.063	0.490	12.9
Hydraulic radius, R (ft)	120		3.89	2.87	0.45	11.4
Average velocity, V_a (ft/s).	120		7.37	4.42	0.850	23.0
Froude number, F	120		0.681	0.307	0.143	1.71
d_m/d_a	120	1.69	1.73	0.297	1.18	2.91
V_m/V_a	48	1.53	1.71	0.549	1.09	3.45
T/d_m	120	14.0	19.5	17.0	2.58	81.7
R/d_a	120	0.954	0.965	0.122	0.729	1.70
			Water-surface slope, all			
Discharge, Q (ft^3/s)	764				0.026	598,000
Width, T (ft)	764				0.7	2,492
Area, A (ft^2)	763				0.07	86,270
Wetted perimeter, P (ft)	728				6.42	2,493
Water-surface slope, S_w (ft/ft).	297	[1]0.00368	0.00931		-0.00507	0.1013
Maximum depth, d_m (ft)	761	7.1	10.3		0.16	88.3
Maximum point velocity, V_m (ft/s).	578				0.26	16.7
Average depth, d_a (ft)	763	4.6	6.93	7.73	0.1	54.7
Hydraulic radius, R (ft)	728	4.7	7.04	7.59	0.45	52.2
Average velocity, V_a (ft/s).	763	3.8	4.39	2.98	0.232	23.0
Froude number, F	763	0.313	0.356	0.234	0.027	1.71
d_m/d_a	761	1.49	1.55	0.284	1.02	3.54
V_m/V_a	578	1.53	1.61	0.301	1.055	3.51
T/d_m	761	15.8	19.8	13.4	2.58	83.8
R/d_a	728	0.974	0.975	0.102	0.480	2.43

[1]Median water-surface slope for 728 sites.

Table 2. Hydraulic properties and channel geometry of streams as a function of channel curvature.

Variable	Number of values	Median	Mean	Standard deviation	Minimum value	Maximum value
			STRAIGHT			
Maximum depth, d_m (ft)	98		11.7	7.73	1.40	43.8
Maximum velocity, V_m (ft/s).	96		4.73	3.40	1.07	16.7
d_m/d_a	98	1.53	1.61	0.423	0.198	3.54
V_m/V_a	96	1.50	1.60	0.452	1.06	3.51
T/d_m	98	13.4	18.1	11.1	3.09	62.9
R/d_a	97	0.975	0.967	0.104	0.164	1.20
			BEND			
Maximum depth, d_m (ft)	44		16.5	11.8	1.80	48.0
Maximum velocity, V_m (ft/s).	43		4.87	3.46	1.01	15.9
d_m/d_a	44	1.65	1.69	0.226	1.34	2.38
V_m/V_a	43	1.46	1.53	0.286	1.15	2.47
T/d_m	44	9.67	12.0	6.77	6.25	32.4
R/d_a	43	0.956	0.950	0.049	0.737	1.04

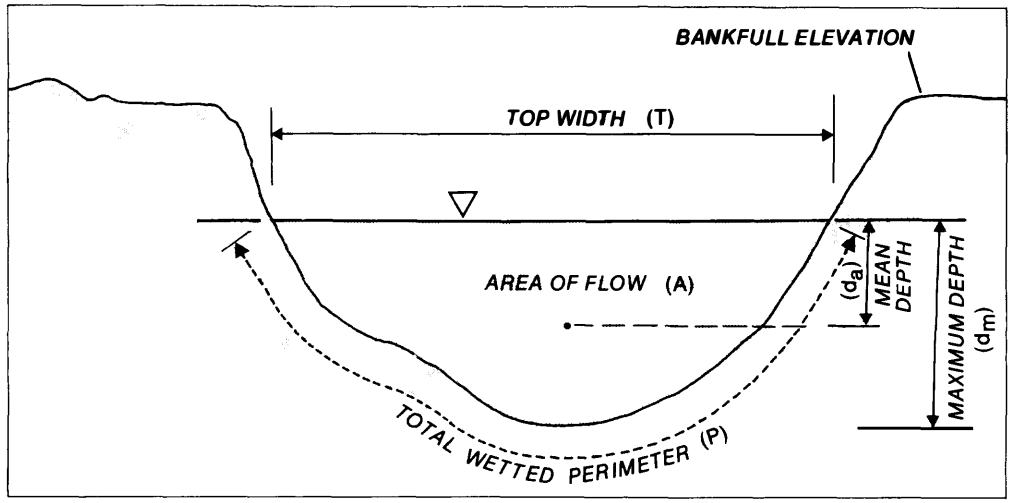


FIGURE 2. Cross-sectional sketch of typical channel.

The sites in table 1 were selected to represent streams in valleys, mountains, coastal areas, and deserts, and include both straight and curved reaches. Most streams are perennial, but some are ephemeral. The magnitude of streamflow was limited to bankfull so that overflow areas that require subdivision of the cross section were omitted from the analysis. The channel slope was not defined for many of the sites in table 1, but other hydraulic and channel data were available. As a result, there are many entries in table 1 for "all water-surface slopes" that are not included in other parts of the table.

The channel slopes given in table 1 generally represent the slope defined over a short reach and reflect localized changes in the channel geometry. A distinction between a short or long reach is dependent on the size of the channel, expressed in terms of discharge or width and the slope. A short reach is considered to vary between 1 and 11 channel widths in length, and a long reach is longer than 11 channel widths. For streams in mountain areas, a short reach may be only one or two channel widths in length, depending on the topography and geology. The value of 11 channel widths was determined on the basis of surveys of 14 streams with slopes up to 0.002, in which the longest continuous water-surface profiles (without a change in slope) were found to have a median value of 11 channel widths. In this analysis, it was assumed all flows were less than bankfull.

In some cases, the mean velocity in table 1 for a group of slopes is greater than the maximum. The mean velocity was determined on the basis of channel surveys, but measured point velocities at sites with high mean velocities were not always available for inclusion in the table. This is indicated by the fact that mean velocities are available for 763 sites, but only 578 sites have measurements of maximum point velocities. Discharges of streams in this sample range from 0.03 to 598,000 ft^3/s (0.00085 to 16,900 m^3/s).

Ratio of Maximum to Mean Depth

Based on mean values for the streams in table 1 for all slopes, the following observations concerning channel and hydraulic properties typical of open channels may be made:

- The ratio of maximum depth to mean depth in a reach is 1.55. This ratio appears to be independent of channel slope.

- The ratio of maximum point velocity in a cross section to mean velocity in a reach of channel is 1.61. This ratio shows a slight increase for channels with a steeper slope.

- The ratio (0.98) of hydraulic radius to mean depth is slightly less than 1.0, and is independent of channel width for most open channels. This result supports the common assumption made in analysis of wide-open channels that the hydraulic radius and mean depth may be considered equal.

A summary of channel and hydraulic properties separated on the basis of straight and curved reaches is listed in table 2. Using mean values, these data indicate:

- The ratio of maximum to mean depth for curved channels (1.7) is slightly greater than the ratio for straight channels (1.6).
- The ratio of maximum to mean velocities in a cross section at bends (1.5) is slightly less than the ratio for straight reaches (1.6).
- The ratio of water-surface width to maximum depth for curved reaches is less than for straight reaches. This suggests the average depth of flow at bends is greater than in straight reaches.
- The ratio of hydraulic radius to mean depth is slightly smaller at bends than in straight reaches, a result comparable to the ratio of water-surface width to maximum depth.

The data in tables 1 and 2 are based on a sample of streams that may not include the complete range of channel and hydraulic properties that occur in natural channels. These data, however, provide reasonable guidelines for estimating properties of natural channels that should be considered in both channel and riprap design.

The flow capacity of a channel is related to the area of flow, to slope, and to boundary roughness. The conveyance and efficiency of a channel cross section increases with an increase in area and a decrease in wetted perimeter. The most efficient channel--one of a maximum conveyance--has the least wetted perimeter for a given cross sectional area, and has been defined by Chow (1959) as the best hydraulic section. The side slope of a trapezoidal channel that gives the least wetted perimeter has a ratio of horizontal distance to vertical distance of $\frac{\sqrt{3}}{3}$:1 or the value of z is equal to 0.577.

Open channels are usually designed with a trapezoidal cross section with side slopes that are about 2 horizontal to 1 vertical as compared with the hydraulically best slope of 0.577:1. Side slopes of at least 1:1 are usually required to reduce the possibility of bank erosion. Chow (1959, p. 158) and Anderson and others (1970, p. 59) present data (table 3) indicating suitable side slopes for various types of bank material. The recommended side slopes for various base materials should be used even though bank protection is planned, to reduce the possibility of bank failure by shear that is related to excess pore pressure in the bank material. The instability of a soil mass from excess pore pressure occurs when the soil is saturated by water from precipitation or is inundated during high flows.

In the design or modification of channels that approximate a trapezoidal shape, the possibility should be considered that, in time, the channel geometry will change from the as-built condition. Most likely changes in the channel are scour, fill, and lateral erosion. For most natural channels, the ratio of maximum to mean depth based on an analysis of 761 cross sections is 1.55, as shown in figure 3. This ratio closely approximates the corresponding ratio of 1.5 for a parabolic shaped channel (Chow, 1959). In comparison, the ratio is 1.33 for the hydraulically best trapezoidal channel. The ratio of maximum to mean depth varies from 1.0 for a rectangular channel to 2.0 for a triangular channel.

As shown in figure 3, hydraulically best channel cross sections are not commonly found in natural channels. Instead, natural channels usually have a cross-sectional shape between a trapezoid and a triangle. The relationship of flow depths for natural channels (fig. 3) indicates that in the design of a trapezoidal channel bed with bank protection, allowances should be made for a 17 percent increase ($\frac{1.55-1.33}{1.33}$ = 17 percent) in maximum depth by erosion.

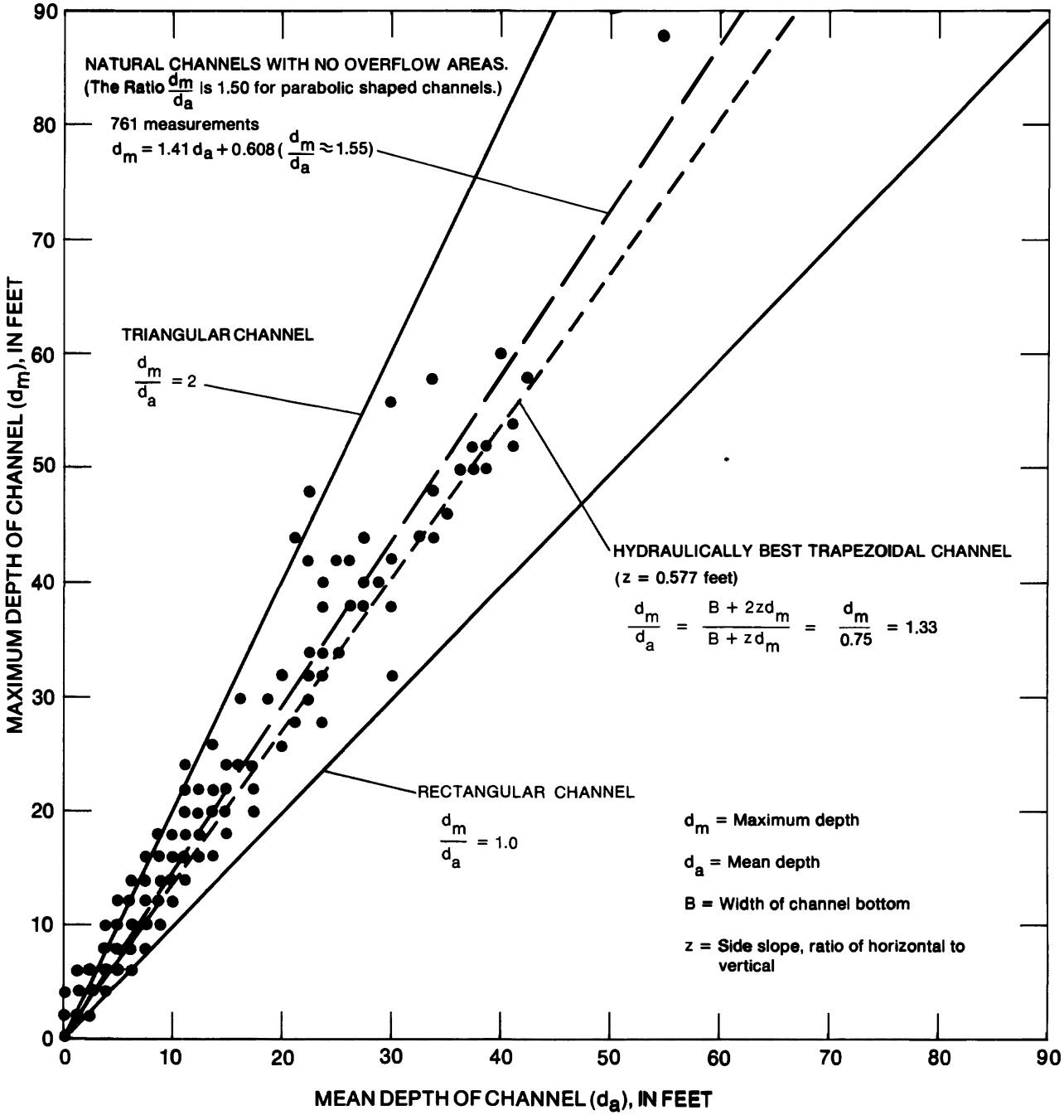


FIGURE 3. Comparison of flow depths for various channel shapes.

Table 3. Suitable side slopes for channels built in various kinds of materials.

[Adapted from Chow, 1959, and Anderson and others, 1970]

Base material	Side slope (horizontal to vertical)
Rock (solid)	Nearly vertical
Rock (crushed)[1]	2½:1
Rock (very angular)[1]	2½:1
Rock (very rounded)[1]	3:1
Muck and peat soils	¼:1
Stiff clay or earth with concrete lining	½:1 to 1:1
Earth with stone lining, or earth for large channels	1:1
Firm clay or earth for small ditches	1½:1
Loose sandy earth	2:1
Sandy loam or porous clay	3:1

[1]From Anderson and others (1970), and assumes rock riprap D_{50} is 0.1 ft. For riprap with D_{50} of 0.5 ft or larger, maximum recommended side slope for all types of rock is 2½:1.

Changes in Channel Shape

Although most constructed channels are designed to have a trapezoidal cross section, the action of bed scour and bank erosion eventually creates a channel shaped as a parabola or trapezoid with rounded corners, as shown in figure 4. Pinole Creek at Pinole, California, is an example of an altered trapezoidal channel which was designed for a flood discharge of 2,500 ft^3/s (71 m^3/s) with a bottom width of 20 ft (6.1 m) for most of a 1,400-ft (427-m) long reach (fig. 5). Channel banks were designed with a 2:1 side slope.

The Manning's roughness coefficient, n, for the 17 cross sections (fig. 5) ranged from 0.027 to 0.048, based on verification studies made after the January 1982 flood. A chute structure was constructed in the vicinity of cross section 0.4, causing rapid flow conditions. At cross section 7, which is on a curve (see fig. 5), the channel bed on the outside of the bend scoured about 2 ft (0.6 m). It is significant that, as originally designed and constructed, the ratio d_m/d_a was 1.55, but after the channel bed scoured, the ratio d_m/d_a was 1.87, with the increase in depth ratio attributed to the presence of the riprap placed on both banks that limited scour to the channel bed.

The original channel alinement and slope for this reach were altered when improvements were constructed in 1966. Minor increases in channel sinuosity were noted in 1982, but lateral migration of the channel is generally restricted by the rock riprap layer. A summary of original, constructed, and present channel conditions is presented in table 4.

Table 4. Summary of channel alinement and slope changes for 1965-82 for Pinole Creek at Pinole, California.

Date	Average slope, S_o	Percent change	Sinuosity	Percent change
1965 (preconstruction)	0.0056	--	1.31	--
1966 (constructed channel)	.00701	+25	1.29	-1.5
1982 (present conditions)	.00696	0	1.29	0

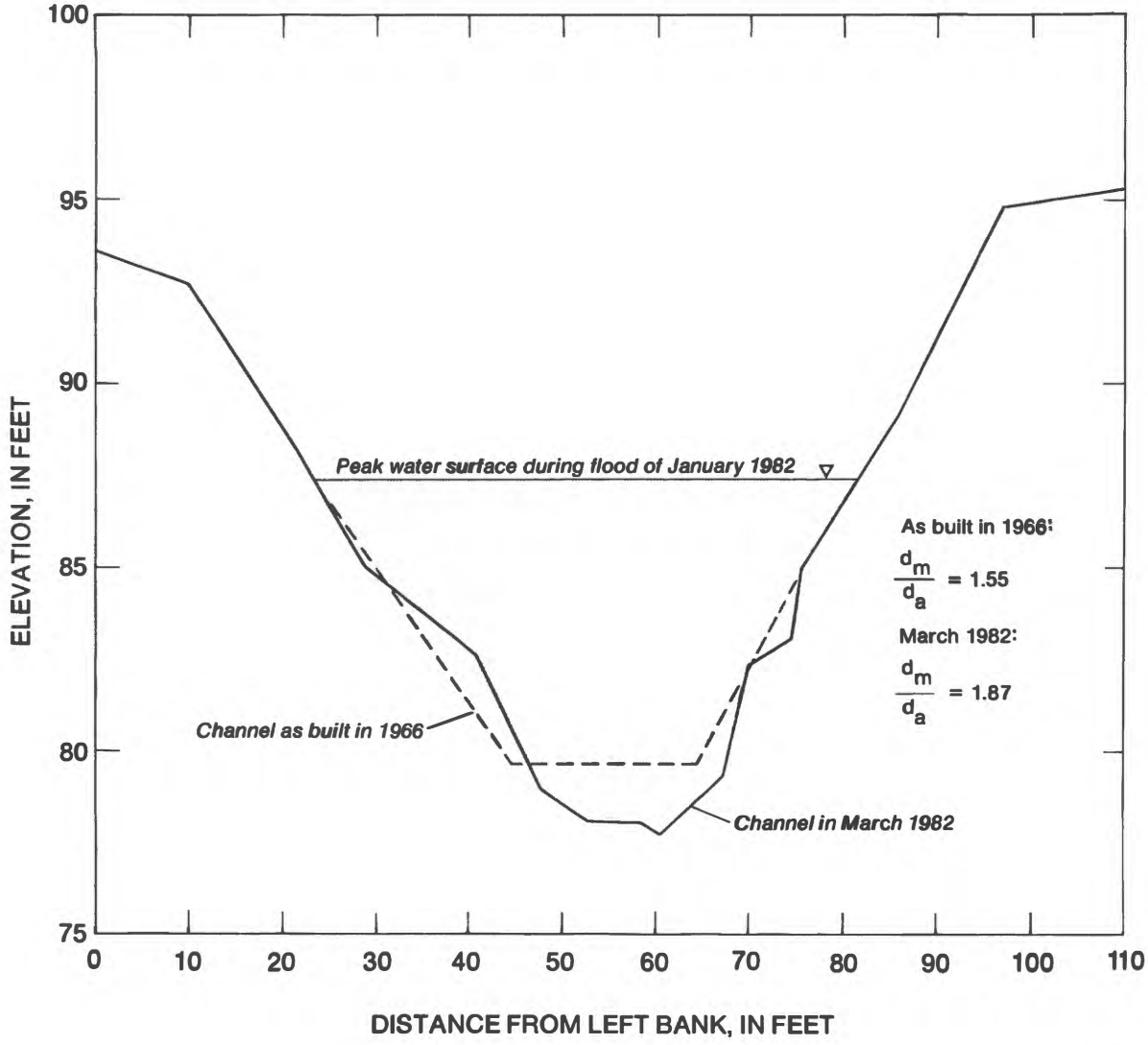


FIGURE 4. Comparison of constructed and present channel geometry at cross section 7, Pinole Creek at Pinole, California.

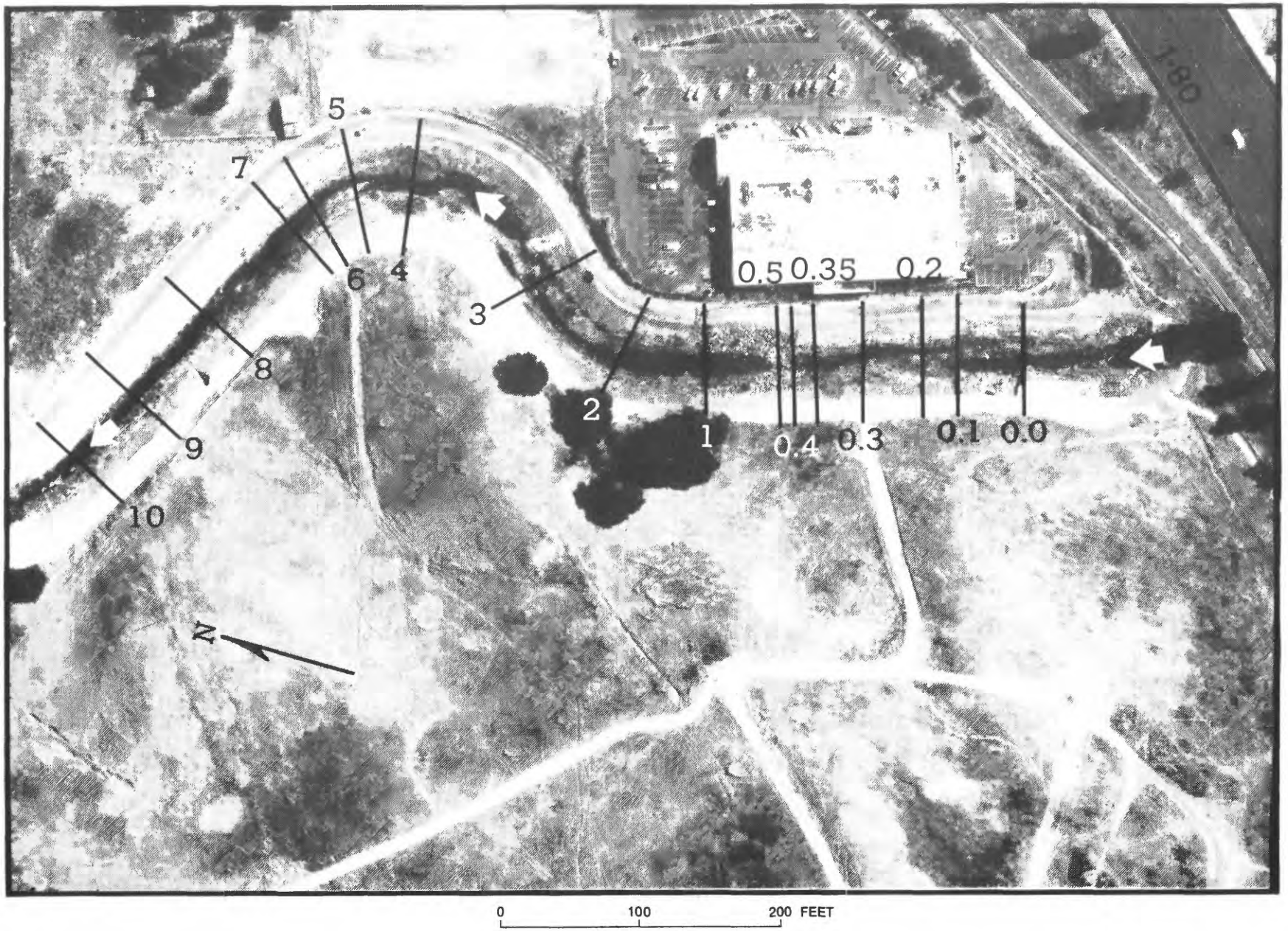


FIGURE 5. Aerial photograph of Pinole Creek at Pinole, California, showing study reach and cross sections (October 1, 1982).

The channel sinuosity is determined as the ratio of the reach length measured along the channel centerline to the reach length measured as a straight (airline) distance between ends of the reach. Channel slopes for pre- and postconstruction conditions were determined from construction plans. The slope for present conditions is based on surveyed water-surface elevations. The data in table 4 indicate that the channel slope has not changed since construction in 1966 even though the slope is steeper than before channel improvements, and flow velocities are higher. Data in table 5 show a comparison of the channel geometry at the time of construction and at the end of the period 1966-82. The comparison is based on the January 1982 flood discharge of 2,250 ft^3/s (63.68 m^3/s), which is 10 percent less than the flow used for channel design.

Referring to table 5, the average area of flow for the 11 cross sections in the straight reach increased by 8 percent and the maximum depth increased from 6.9 to 8.7 ft (2.1 to 2.7 m), or an average of 26 percent. The ratio of maximum to mean depth (d_m/d_a) for the straight and curved parts of the reach increased from about 1.43 to 1.72 (20 percent) and 1.49 to 1.78 (19 percent), respectively. The present ratios of maximum to mean depth (d_m/d_a) for the straight and curved reaches are 1.72 and 1.78, both of which are greater than the ratio of 1.55 for natural channels (table 1). The increase in the depth ratios is attributed to the bank protection, which effectively restricted lateral erosion so that the water-surface width and hydraulic radius changed less than 7 percent during the study period. The lack of significant change in water-surface width throughout the reach indicates that all of the channel scour and bank erosion occurred near the bottom part of each cross section. The stability of the hydraulic radius for all cross sections indicates that the capacity of the channel is relatively constant, regardless of changes in other hydraulic factors.

An unexpected channel change for Pinole Creek is the reduction in flow area (table 5) at five cross sections in the reach. The reduction in area for these cross sections is attributed to erosion of riprap and subsequent deposition downstream on the channel bed (fig. 6).

For comparison, changes in the Sacramento River near Ord Bend channel between 1972 and 1984 have been documented for a discharge of 10,000 ft^3/s (283 m^3/s) (table 6). Based on data collected over this period, the channel thalweg has moved laterally over 100 ft (80.5 m). Unlike Pinole Creek, the channel is not confined and is therefore able to migrate laterally, and a point bar on the right bank is subject to continual scour and fill. For a constant discharge, hydraulic properties such as area, hydraulic radius, water-surface width, and depth, changed up to 87 percent from the mean for the period. The changes noted are related to both low and high flows that occurred during the study period. Because the comparative discharge for the study period is constant but the cross-sectional area shows variations of ±40 percent, the mean velocity must also vary in order to maintain continuity of flow:

$$Q = A_1V_1 = A_2V_2 = \ldots . A_nV_n \qquad (1)$$

The changes in velocity evidently are related to local changes in slope for a short reach near the site. In general, changes in channel slope are localized in terms of length of reach and are for short periods of time. The subject of channel slope stability is discussed in a later section of this report.

Table 5. Comparison of constructed and present (1982) channel geometry for Pinole Creek at Pinole, California.

[Measurements are based on January 1982 flood discharge of 2,250 ft^3/s]

Cross section	Constructed (1966)						Present (March 1982)					
	Water-surface width, T (ft)	Area, A (ft^2)	Maximum depth, d_m (ft)	Hydraulic radius, R (ft)	Elevation of thalweg (ft)	Ratio of maximum to mean depth, d_m/d_a	Water-surface width, T (ft)	Area, A (ft^2)	Maximum depth, d_m (ft)	Hydraulic radius, R (ft)	Elevation of thalweg (ft)	Ratio of maximum to mean depth, d_m/d_a
0.0	53	253	6.9	4.54	86.4	1.45	51	298	9.9	5.02	83.4	1.69
0.1	54	258	6.9	4.59	86.0	1.44	57	326	9.1	5.28	83.8	1.62
0.2	52	251	6.9	4.54	85.6	1.46	53	259	8.3	4.60	84.2	1.70
0.3	56	278	6.6	4.72	85.3	1.33	51	222	8.2	4.09	83.7	1.88
0.35	46	188	5.9	3.82	84.9	1.44	49	212	7.2	4.06	83.6	1.66
0.4	--	Rapid	--	--	--	--	--	Rapid	--	--	--	--
0.5	--	flow	--	--	--	--	--	flow	--	--	--	--
1	58	315	8.0	5.15	80.9	1.47	62	353	8.8	5.33	80.1	1.55
2[1]	63	346	8.2	5.23	80.6	1.52	64	339	9.3	5.01	79.5	1.76
3[1]	56	306	7.5	5.08	80.4	1.37	61	298	7.7	4.62	80.6	1.58
4[1]	58	304	7.6	4.98	80.0	1.45	57	300	10.5	4.85	77.1	2.00
5[1]	59	304	7.4	4.90	79.8	1.46	58	313	8.8	5.00	78.4	1.63
6[1]	55	276	8.0	4.82	79.6	1.57	54	268	9.5	4.62	78.0	1.95
7[1]	56	278	7.7	4.71	79.5	1.55	55	282	9.6	4.73	77.6	1.87
8	56	273	7.0	4.63	79.2	1.44	55	285	8.9	4.77	77.3	1.72
9	53	242	6.7	4.40	78.8	1.44	52	259	8.9	4.59	76.6	1.79
10	52	246	6.8	4.47	78.6	1.44	55	268	8.9	4.62	76.5	1.83
Straight reach:												
Mean		256	6.86	4.54	82.9	1.43		276	8.69	4.71	81.0	1.72
Standard deviation		33.9	0.54	0.35	3.39	0.041		45.6	0.74	0.45	3.39	0.104
Curved reach:												
Mean		302	7.73	4.95	80.0	1.49		299	9.17	4.80	78.5	1.78
Standard deviation		25.3	0.31	0.19	0.44	0.074		24.8	1.07	0.19	1.30	0.196

[1]Cross sections in reach with curve.

Table 6. Changes in channel geometry of Sacramento River at cross section 6 near Ord Bend, California, 1972-84, for a discharge of 10,000 ft^3/s.

[Winter peak discharge is annual peak discharge for winter preceding survey. Thalweg movement is from initial point, based on location in 1972]

Survey date	Winter peak discharge, Q (ft^3/s)	Lateral movement of thalweg (ft)	Cross sectional area, A (ft^2)	Hydraulic radius, R (ft)	Width at water surface, T (ft)	Mean depth, d_a (ft)	Maximum depth, d_m (ft)	Ratio, d_m/d_a
10-17-72	95,800	0	3,278	11.7	273	12.0	19.7	1.64
8-20-73	98,500	21	3,071	8.2	372	8.3	14.6	1.77
9-17-74	136,000	77	2,015	8.3	602	3.3	11.5	3.44
8-24-76	27,300	73	2,294	3.9	585	3.9	11.1	2.83
6-27-78	121,000	83	3,319	4.4	757	4.4	12.1	2.76
8-16-79	58,000	84	3,327	4.5	733	4.5	12.2	2.69
10-10-80	124,000	111	2,927	6.1	475	6.2	17.6	2.86
9-3-81	67,000	91	2,711	6.1	445	6.1	14.8	2.43
8-5-82	102,000	95	4,565	9.9	452	10.1	18.4	1.82
8-10-83	157,000	107	4,106	6.1	670	6.1	18.7	3.05
8-07-84	129,000	100	3,742	5.5	667	5.6	18.5	3.30
Mean			3,214	6.34	548	6.41	15.4	2.60
Standard deviation			746	2.61	156	2.70	3.30	0.62
Range in data as a percentage of the mean[1]			+42.0	+84.5	+38.1	+87.2	+27.9	+33.8
			-37.3	-47.9	-50.2	-48.5	-27.9	-36.9

[1]The means of the percentage range in data for the six hydraulic factors (A, R, T, d_a, d_m, and d_m/d_a) are +52.3 and -41.5 percent.



FIGURE 6. Pinole Creek at Pinole, California, showing displaced rock in channel bottom following flood of January 4, 1982 (photographed March 1982).

The data in table 6 suggest the hydraulic properties that define the capacity of the channel are constantly changing from year to year in response to various flow conditions. The various hydraulic properties in table 6 may range from the long-term mean by an average of plus 52 and minus 41 percent, with the maximum depth showing the least variation from year to year. These data suggest that hydraulic data surveyed at a site during a given year may vary as much as ±50 percent from the long-term mean. Further, the net change in cross-sectional area between 1972 and 1984 is about +14 percent.

An evaluation of the flow capacity of a channel and the extent of bank protection needed is dependent on the timing of the site survey. Therefore, allowances need to be made for probable changes in time of the hydraulic properties that will affect the channel size and shape and associated riprap design. For example, a design for Sacramento River at Ord Bend that was based on surveys in 1972 would be much different from a design based on surveys in 1976. Likewise, mean velocity and boundary stresses based on cross sections surveyed in 1976 would differ from those based on surveys made in 1982.

The data for Pinole Creek and the Sacramento River suggest that certain channel properties may reflect short-term changes but, on the average, remain relatively constant. Thus, selected channel properties, based on average conditions with an allowance for short-term deviation from the mean, should be used for estimating the channel capacity as part of the bed or bank protection design.

Definition of a Wide-Open Channel

A wide-open channel is a channel in which the lateral distribution of velocity in the central part of the cross section is similar to that of a rectangular channel of infinite width. Velocities in the central part of a cross section are unaffected by the boundary only when the width is about 10 times greater than the depth of flow. Channels with these dimensions are considered to be wide-open, as defined by Chow (1959). The definition of a wide-open channel includes the assumption that the hydraulic radius and mean depth are equal in order to simplify hydraulic analyses.

The ratios of water-surface width to maximum depth (T/d_m) given in table 1 range from 2.58 to 83.8 for 761 cross sections, with a mean value of 19.8. Although table 1 shows a larger T/d_m for slopes between 0.001 and 0.005, the difference was not found to be statistically significant, and the ratio is considered to be independent of the slope. This suggests that channels of streams on steep mountainous slopes, in terms of the width and depth ratio, are similar to streams in the lowlands. For channels with slopes flatter than 0.001, the ratio of T/d_m for all cross sections exceeds 7.3. The ratio of water-surface width to depth exceeds 10 for 80 percent of the cross sections in table 1, indicating that most channels may be considered as wide-open channels.

Estimation of Probable Channel Geometry

The properties that define the channel geometry of a natural stream for a selected discharge and that are least likely to be affected in the long term (5 or more years) are the cross-sectional area, slope for a long reach, and hydraulic radius. Only if the channel is constricted, the alinement straightened, chute cutoffs occur, or drop structures are installed, will the slope be altered. If the channel is realined or modified, the properties most likely to change are the cross-sectional area, short-reach slope, roughness, width, and depth. The boundary roughness generally decreases because the bed and banks will be smoother and straighter after channel realinement. However, if large size riprap is placed on the channel banks, the boundary roughness may increase. The required channel size that will convey the design discharge in a channel being considered for realinement, bank protection, or alteration in size or shape, may be estimated as follows:

Utilizing the Manning equation,

$$Q = \frac{1.486}{n} AR^{2/3} S_e^{1/2} \tag{2}$$

where Q = the design discharge
n = Manning's roughness coefficient
A = cross-sectional area
R = hydraulic radius
S_e = energy slope, and may be approximated by the water-surface slope (S_w)

Rearranging terms in equation 2 gives:

$$AR^{2/3} = \frac{Qn}{1.486\ S_w^{1/2}} \tag{3}$$

Because the mean depth and hydraulic radius are approximately equal (table 1), and the area is equal to top width times the mean depth, equation 3 may be modified to

$$d_a = \left(\frac{Qn}{1.486\ TS_w^{1/2}}\right)^{3/5} \tag{4}$$

where T = width of water surface
d_a = mean depth

Equation 4 may be used to estimate a design channel that is hydraulically equivalent to the original channel.

Application of equation 4 is illustrated by the following example. Assume the channel properties of an existing stream are to be altered by straightening and then protecting the new banks with rock riprap. A tabulation of the properties to be evaluated at the site are listed in table 7, followed by calculations for the new channel.

Table 7. Comparison of hydraulic properties and channel geometry for an existing and proposed new channel.

Hydraulic and channel geometry properties	Old channel	Proposed new channel
Discharge, Q	2,250 ft^3/s	2,250 ft^3/s
Slope (water-surface slope, S_w, is assumed to equal energy slope, S_e).	0.0056	0.00696
Sinuosity ratio	1.31	1.29
Manning's n	0.030	0.045
Width of water surface, T	52 ft	52 ft
Cross-sectional area, A	227 ft^2	271 ft^2
Mean depth, d_a	4.37 ft	5.21 ft
Average velocity, V_a	9.91 ft/s	8.30 ft/s
Channel side slope, z	variable	2:1
Median stone size of riprap, D_{50}	none	1.1 ft

The average depth of the old channel at design discharge is:

$$d_a = \left(\frac{Qn}{1.486\ TS_w^{1/2}}\right)^{3/5} = \left(\frac{2250 \times 0.030}{1.486 \times 52(0.0056)^{1/2}}\right)^{3/5} = 4.37 \text{ ft } (1.33 \text{ m})$$

For the new channel, the slope increases because the channel is straightened, the roughness coefficient increases due to the addition of rock riprap, and assuming T remains constant at 52 ft (15.9 m), then:

$$d_a = \left(\frac{Qn}{1.486\ TS_w^{1/2}}\right)^{3/5} = \left(\frac{2250 \times 0.045}{1.486 \times 52(0.00696)^{1/2}}\right)^{3/5} = 5.2 \text{ ft } (1.6 \text{ m})$$

This increase in average depth from 4.4 to 5.2 ft (1.3 to 1.6 m) represents an 18 percent increase in average channel depth in order to maintain a similar hydraulic capacity between the old and new channels.

Determination of Manning's Roughness Coefficient

As part of the design or evaluation of channels, it is necessary to estimate the flow capacity of the channel. All formulas based on continuity of flow that relate the discharge capacity of a channel to its geometry include an estimate of friction losses. The three equations in general use for estimating friction losses are referred to as the Chezy, Manning, and Darcy-Weisbach equations, each of which has a resistance coefficient (designated, respectively, as C, n, and f). Each roughness coefficient is a function of the size of the bed and bank material and of other flow obstructions. The coefficients are related as follows:

$$\frac{C}{1.486} = \frac{R^{1/6}}{n} = \frac{10.8}{f^{1/2}} \tag{5}$$

Each particle in a streambed has a minimum, intermediate, and maximum axis (diameter). A particle at rest on the bed generally has its minimum diameter in the vertical position. The intermediate diameter is the one most easily measurable by either sieve analysis or other methods and is the diameter most commonly used as a measure of roughness. The particle size referred to in the following equations is the intermediate diameter. Anderson and others (1970) present a relationship for estimating Manning's n from median particle size (D_{50}) of the bed material:

$$n = 0.0395\ (D_{50})^{1/6} \tag{6}$$

This equation was first proposed by Strickler (1923) for estimating Manning's n for streambeds. The relationship has been utilized in studies of roughness coefficients and channel design by a number of other investigators including Normann (1975, p. 9) and Maynord (1978, p. 62).

Another procedure for deriving Manning's roughness coefficient in natural channels is based on a study by Limerinos (1970) of hydraulic and channel properties for 11 sites on California streams. In this study, Manning's n values ranged from 0.020 to 0.107. A roughness factor, $n/R^{1/6}$, was derived which relates the roughness to the characteristic size of streambed particles and hydraulic radius of the channel. The relationship between roughness factor and particle size using the intermediate diameter and 84 percentile size particle (D_{84}) was found to give better results than using the 50 percentile size particle (D_{50}).

The equation for relating the roughness factor ($n/R^{1/6}$) to relative smoothness R/D_w, is:

$$\frac{n}{R^{1/6}} = 0.0926\sqrt{f} = \frac{0.0926}{a+b \log R/D_w} \quad (7)$$

where f = resistance factor derived by Darcy-Weisbach = $\left(\frac{1}{a+b \log R/D_w}\right)^2$

n = Manning's roughness coefficient

R = hydraulic radius

D_w = selected percentile size of bed material measured at the intermediate axis

a and b = constants

In riprap design procedures, the 50 percentile size of stones is more commonly used as an indicator of bed and bank material size than is the 84 percentile size. A relationship of the roughness factor and relative roughness of the bed, using the intermediate diameter of stone (D_{50}) as developed by Limerinos (1970), is described by the equation:

$$\frac{n}{R^{1/6}} = \frac{0.0926}{0.35 + 2.0 \log R/D_{50}} \quad (8)$$

The coefficients a and b in equation 7 are 1.16 and 2.0 if the D_{84} size rather than D_{50} size is used. The 1.8 percent loss in accuracy that results when using D_{50} instead of D_{84} is not considered significant for channel design purposes.

Equation 8 is not directly comparable to roughness relationships presented in the National Cooperative Highway Research Program (NCHRP) Report 108 by Anderson and others (1970) or to those in Figure C-4 of Hydrologic Engineering Circular-15 by Normann (1975). In order to make the equations comparable, the equation was modified by substituting mean depth for hydraulic radius and adding the gravitational acceleration.

Since R and d_a are nearly equivalent, and the constant 0.0926 includes the gravitational acceleration (g), equation 8 can be modified to:

$$\frac{n\sqrt{g}}{d_a^{1/6}} = \frac{0.5254}{0.35 + 2.0 \log d_a/D_{50}} \quad (9)$$

Rearranging terms gives the following equation for n:

$$n = \frac{0.0926\ d_a^{0.167}}{0.35 + 2.0 \log d_a/D_{50}} \quad (10)$$

The roughness factor $n\sqrt{g}/d_a^{1/6}$ in equation 9 has been used as the basis for comparing the roughness relationship derived by Anderson and others (1970) with bed roughness values obtained during field surveys for Manning's n verification. The variation of Manning's n with the relative roughness of the channel bed was analyzed using hydraulic data for boulder, cobble, gravel, and sand bed channels, assembled by Culbertson and Dawdy (1964), Barnes (1967), Limerinos (1970), and Jarrett (1984), and from various site surveys made during this project. These data are summarized in table 8. An important criterion in selecting sites for this study was that they be relatively free from velocity-retarding influences such as bed and bank forms so that the effect of stone size on the channel bed would be measured. A comparison of relationships between the roughness factor and corresponding bed particle size derived from laboratory flume and natural channel data is shown in figure 7.

The scatter of data points in figure 7 is attributed to one or a combination of the following factors:

- Errors in measuring hydraulic properties, such as discharge, slope, cross section, and area, that are used in determining Manning's n.
- Effects of bank shape irregularities, changes in channel alinement, and occasional large boulders or bedrock outcrops that create high local energy losses.
- The size of bed and bank material, expressed as D_{50}, may vary throughout the reach but is usually based on data obtained at one cross section.

To simplify the evaluation of data presented in figure 7, roughness factors for gravel bed channels were separated from sand bed channels. This distinction was made by selecting the bed material size (D_{50}) for sand bed channels to be 0.00328 ft or 1 mm, which is the maximum size of coarse sand given by Guy (1969). The range in Manning's roughness coefficient, n, for the data in figure 7 for gravel, cobble, and boulder bed channels is 0.020 to 0.159, and for sand bed channels, the range in Manning's n is 0.013 to 0.046.

Referring to figure 7, curve A is an enveloping curve for upper limits of roughness factor data for gravel bed channels. The median bed material size (D_{50}) is larger than 0.00328 ft (1 mm). This curve is arbitrarily truncated at a relative roughness value (D_a/D_{50}) of 35, although the largest ratio measured for gravel or cobble beds was about 185.

Curve B is an enveloping curve for sand bed channels. This curve has been arbitrarily extended into the zone of smaller size gravel bed channels in order to intersect curve A. The variation in roughness factor data for sand channels represents the effect of various bed forms (dune, antidune) as well as variations in bed material size.

Curve C is a least squares fit of roughness factor data for gravel and cobble bed channels using procedures similar to those described by Limerinos (1970). Curve D is a least squares fit of roughness factor data for sand bed channels. Curve E is a lower limit curve for gravel, cobble, and boulder bed channels based on laboratory data and published by Anderson and others (1970) and Normann (1975).

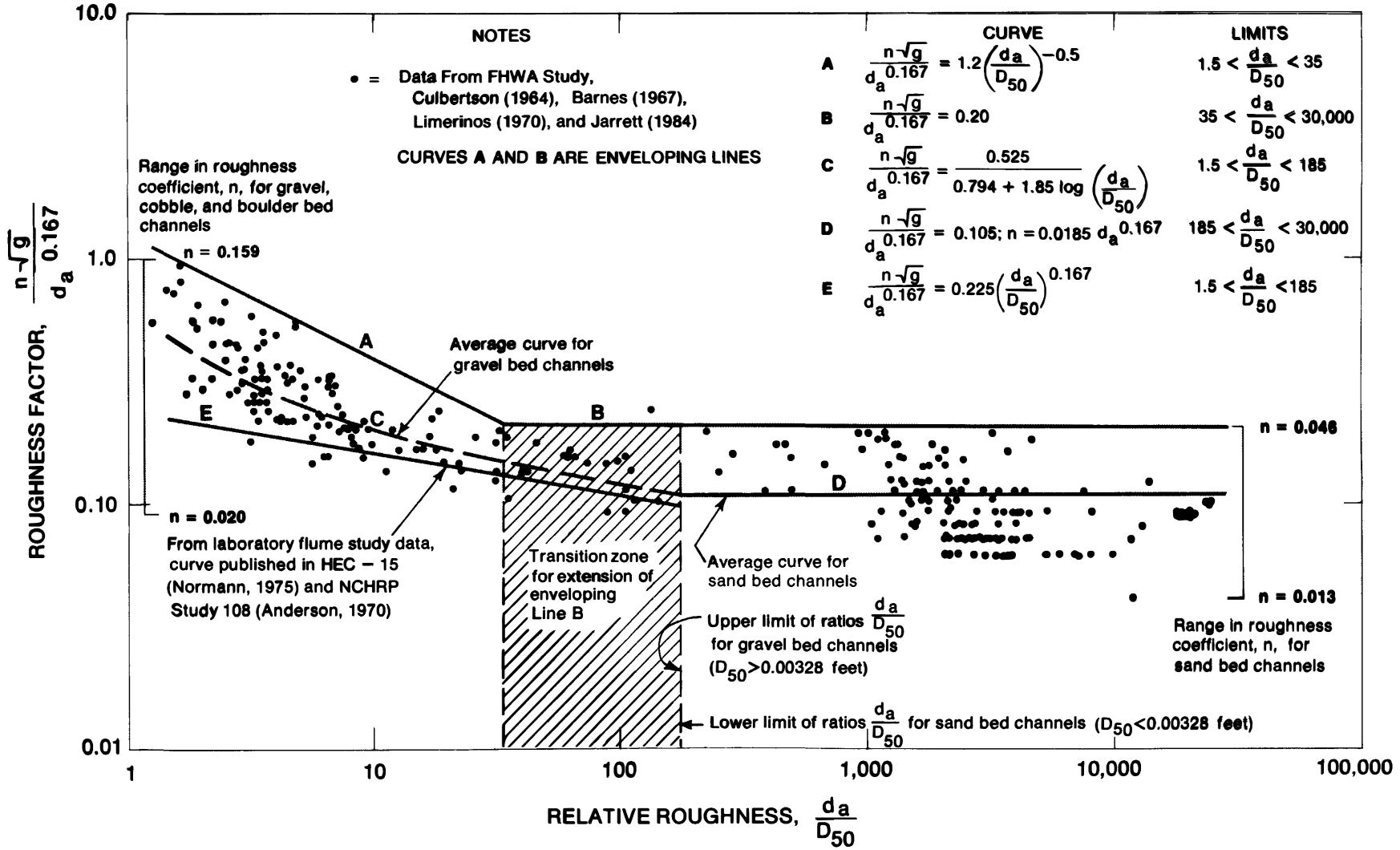


FIGURE 7. Comparison of Manning's roughness coefficient, n, derived from laboratory and natural channel data.

Table 8. Hydraulic data for estimating Manning's roughness coefficient, n.

[Sources: 1, Barnes, 1967; 2, Culbertson and Dawdy, 1964; 3, Limerinos, 1970; 4, site surveys made for this project; and 5, Jarrett, 1984. D_{50} is median bed material size]

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Arkansas River at Pine Creek School above Buena Vista, CO	925	1.40	0.026	3.6	0.142	5
	1,450	1.40	.022	4.7	.132	
	2,120	1.40	.020	5.2	.112	
	2,760	1.40	.024	5.8	.110	
	4,530	1.40	.023	6.6	.086	
Austin Creek near Cazadero, CA	672	.056	.003	1.9	.038	3
	853	.056	.003	2.0	.036	
	1,370	.056	.002	2.6	.036	
	4,300	.056	.002	5.2	.032	
	5,050	.056	.002	6.2	.036	
	6,150	.056	.003	7.8	.060	
Blackfoot River near Ovando, MT	8,200	.509	.002	6.1	.036	1
Boaring Fork River at Glenwood Springs, CO	571	.500	.003	1.7	.044	5
	650	.500	.003	1.7	.041	
	1,170	.500	.003	2.3	.043	
	3,260	.500	.004	3.3	.032	
Boundary Creek near Porthill, ID	2,530	.689	.018	4.4	.073	1
Buckeye Creek near Cool, CA	14.0	.035	.032	.5	.016	4
Cache Creek at Yolo, CA	277	.024	.001	1.3	.023	3
	944	.024	.001	2.6	.022	
	2,180	.024	.001	4.4	.020	
Clark Fork above Missoula, MT	31,500	.574	.001	12.8	.030	1
Clark Fork at St. Regis, ID	68,900	.443	.001	16.4	.028	1
Clear Creek near Lawson, CO	53.0	.600	.015	1.0	.138	5
	214	.600	.017	1.5	.084	
	360	.600	.018	2.1	.084	
	765	.600	.020	2.7	.067	
Coeur D'Alene River near Prichard, ID	11,300	.338	.008	7.9	.032	1
Cottonwood Creek below Hot Springs near Buena Vista, CO	31.0	.500	.030	.9	.159	5
	115	.500	.034	1.2	.097	
	281	.500	.039	1.4	.052	
Crystal River above Avalanche Creek near Redstone, CO	83.0	.400	.003	.73	.045	5
	272	.400	.005	1.3	.046	
	530	.400	.005	1.7	.041	
	1,220	.400	.006	2.3	.028	
Eagle River below Gypsum, CO	204	.400	.003	1.2	.054	5
	224	.400	.004	1.4	.051	
	233	.400	.002	1.4	.052	
	577	.400	.044	2.0	.050	
	2,300	.400	.004	3.5	.041	
	3,710	.400	.005	4.1	.037	

Table 8. Hydraulic data for estimating Manning's roughness coefficient, n (continued).

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Elk River at Clark, CO	39.0	0.700	0.003	0.66	0.058	5
	254	.700	.004	1.5	.052	
	1,050	.700	.005	2.3	.034	
	1,410	.700	.005	3.0	.044	
Galisteo Creek at Domingo, NM	5.9	.001	.004	.3	.028	2
	20.5	.001	.004	.4	.025	
	30.8	.001	.004	.4	.019	
	75.0	.001	.004	.6	.017	
	119	.001	.004	.7	.025	
	448	.001	.004	.7	.018	
	1,730	.001	.004	2.1	.020	
	11,700	.001	.004	4.9	.025	
Grande Ronde River at La Grande, OR	4,620	.305	.004	5.4	.043	1
Half Moon Creek near Malta, CO	12.0	.300	.011	.5	.109	5
	94.0	.300	.016	1.1	.062	
	242	.300	.015	1.3	.042	
Hermosa Creek near Hermosa, CO	493	.800	.019	2.3	.087	5
	1,380	.800	.014	2.9	.052	
	1,580	.800	.014	3.1	.054	
	1,800	.800	.014	3.1	.049	
Kaweah River at Three Rivers, CA	405	.520	.008	1.4	.083	3
	869	.520	.007	1.9	.067	
	1,050	.520	.008	2.1	.071	
Kings River below North Fork near Trimmer, CA	2,440	.530	.004	3.3	.066	3
	3,200	.530	.005	3.6	.064	
	3,660	.530	.005	3.7	.059	
	3,690	.530	.005	3.8	.064	
Lake Creek above Twin Lakes Reservoir, CO	148	1.00	.019	1.3	.098	5
	830	1.00	.023	2.3	.062	
	1,360	1.00	.024	2.7	.056	
Mad Creek near Steamboat Springs, CO	48.0	.400	.026	.6	.117	5
	92.0	.400	.026	.8	.108	
	331	.400	.027	1.5	.082	
	409	.400	.023	2.0	.105	
Mainbar Canyon Creek near Greenwood, CA	276	.310	.054	1.7	.042	4
Merced River at Clarks Bridge near Yosemite, CA	622	.400	.002	2.7	.064	3
	666	.400	.003	2.8	.068	
	983	.400	.002	3.1	.052	
	1,170	.400	.003	2.9	.050	
	1,340	.400	.002	3.6	.044	
	1,650	.400	.002	3.4	.036	
	1,840	.400	.002	3.6	.035	

Table 8. - Hydraulic data for estimating Manning's roughness coefficient, n (continued).

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Merced River at Happy Isles Bridge near Yosemite, CA	211	0.830	0.008	1.5	0.100	3
	622	.830	.009	2.1	.074	
	666	.830	.011	2.4	.087	
	983	.830	.010	2.6	.070	
	1,170	.830	.010	2.8	.066	
	1,340	.830	.010	3.0	.065	
	1,650	.830	.011	3.0	.058	
	1,840	.830	.011	3.2	.060	
	1,950	.830	.021	4.3	.065	
	1,950	.830	.021	4.5	.060	
	1,950	.830	.021	4.0	.068	
	1,990	.830	.021	3.8	.067	
MF Eel River below Black Butte River near Covelo, CA	1,350	.078	.006	1.5	.043	4
	9,000	.078	.002	4.9	.035	
MF Flathead River near Essex, MT	14,500	.466	.004	8.8	.041	1
MF Smith River at Gasquet, CA	1,570	.510	.004	3.1	.047	3
	1,950	.510	.004	3.5	.044	
	3,000	.510	.001	4.0	.042	
	3,000	.510	.004	4.1	.042	
MF Eel River below Black Butte River, CA	1,350	.078	.006	1.6	.043	3
	9,000	.078	.002	5.0	.038	
Outlet Creek near Longvale, CA	348	.100	.002	2.7	.038	3
	542	.100	.000	3.3	.036	
	1,130	.100	.001	3.3	.025	
	1,200	.100	.001	4.2	.029	
	1,210	.100	.000	4.1	.028	
	1,610	.100	.002	3.3	.028	
	4,420	.100	.001	7.8	.036	
	5,640	.100	.034	6.2	.035	
	15,200	.100	.001	11.5	.034	
Piedra River at Piedra, CO	2,920	.400	.004	3.8	.034	5
	3,170	.400	.005	4.1	.037	
Rio Grande at Angostrua HD near Algodones, NM	902	.001	.001	1.8	.032	2
	946	.001	.001	1.8	.033	
	1,200	.001	.001	2.0	.029	
Rio Grande at Cochiti, NM	347	.001	.001	1.5	.033	2
	667	.001	.001	1.7	.040	
	709	.003	.001	1.2	.031	
	2,040	.002	.001	2.2	.028	
	4,990	.002	.001	3.6	.026	
	5,060	.002	.001	4.0	.031	
	7,960	.001	.001	3.9	.020	
	8,680	.001	.001	4.8	.024	
	8,900	.001	.001	4.1	.020	
	8,920	.001	.001	4.3	.021	

Table 8. - Hydraulic data for estimating Manning's roughness coefficient, n (continued).

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Rio Grande at Otowi Bridge near San Ildefonso, NM	309	0.002	0.002	1.0	0.030	2
	1,130	.002	.002	1.4	.026	
	5,000	.002	.002	7.2	.046	
	7,320	.002	.002	8.1	.040	
	9,340	.002	.002	10.2	.046	
	10,100	.002	.002	10.2	.046	
Rio Grande at San Antonio, NM	378	.001	.001	1.2	.025	2
	739	.001	.001	1.7	.015	
	1,420	.001	.001	1.6	.010	
	4,090	.001	.001	3.3	.014	
	6,180	.001	.001	3.9	.013	
	6,940	.001	.001	4.3	.014	
	8,500	.001	.001	5.0	.014	
Rio Grande at San Felipe, NM	360	.001	.001	1.2	.035	2
	414	.001	.001	1.4	.035	
	755	.001	.001	1.5	.034	
	762	.001	.001	1.6	.036	
	2,200	.002	.001	2.7	.026	
	5,010	.001	.001	4.5	.025	
	7,520	.002	.001	4.5	.026	
	8,200	.003	.001	5.6	.025	
	8,590	.001	.001	6.0	.027	
	9,140	.001	.001	5.9	.025	
	9,720	.003	.001	6.2	.026	
Rio Grande at Wagonwheel Gap, CO	151	.300	.004	.9	.058	5
	2,060	.300	.004	3.0	.041	
	4,040	.300	.004	4.0	.035	
Rio Grande Floodway at San Marcial, NM	3,810	.000	.004	3.6	.013	2
	4,570	.000	.004	4.1	.013	
	6,420	.000	.004	5.0	.013	
	7,710	.000	.004	6.2	.016	
Rio Grande near Belen, Casa Colorada Reach, NM	833	.001	.001	1.8	.019	2
	930	.001	.001	2.7	.041	
	1,200	.001	.001	1.7	.029	
	1,830	.001	.001	2.3	.016	
	2,610	.001	.001	1.8	.017	
	2,760	.001	.001	1.8	.018	
	3,060	.001	.001	2.2	.017	
	3,230	.001	.001	2.0	.014	
	3,410	.001	.001	1.8	.013	
	3,580	.001	.001	2.3	.014	
	3,600	.001	.001	2.2	.016	
	3,600	.001	.001	1.8	.012	
	3,690	.001	.001	2.0	.014	
	3,730	.001	.001	2.3	.014	
	3,800	.001	.001	2.4	.015	

Table 8. - Hydraulic data for estimating Manning's roughness coefficient, n (continued).

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Rio Grande near Belen, Casa Colorada Reach, NM--Continued	4,150	0.001	0.001	2.5	0.015	2
	4,160	.001	.001	4.6	.022	
	4,440	.001	.001	2.3	.014	
	5,760	.001	.001	2.5	.014	
	5,800	.001	.001	2.3	.013	
	6,020	.001	.001	2.9	.014	
	6,150	.001	.001	2.4	.013	
	6,510	.001	.001	3.3	.016	
	6,580	.001	.001	2.7	.014	
	7,160	.001	.001	2.7	.015	
	7,310	.001	.001	2.8	.015	
	7,310	.001	.001	3.5	.014	
	7,370	.001	.001	3.1	.015	
	7,440	.001	.001	2.9	.014	
	8,270	.001	.001	3.8	.015	
Rio Grande near Bernalillo, NM	425	.001	.001	1.0	.028	2
	1,270	.001	.001	1.8	.022	
	1,320	.001	.001	1.7	.024	
	1,340	.001	.001	2.1	.033	
	1,410	.001	.001	1.5	.022	
	1,430	.001	.001	2.0	.033	
	1,430	.001	.001	2.0	.023	
	1,430	.001	.001	1.6	.019	
	1,450	.001	.001	1.3	.022	
	1,540	.001	.001	2.2	.029	
	1,570	.001	.001	1.8	.023	
	2,060	.001	.001	2.7	.031	
	2,400	.001	.001	1.4	.021	
	2,570	.001	.001	2.7	.025	
	2,730	.001	.001	2.5	.021	
	2,910	.001	.001	1.2	.013	
	4,000	.001	.001	3.0	.019	
	4,300	.001	.001	2.8	.016	
	4,720	.001	.001	2.4	.015	
	4,830	.001	.001	3.5	.021	
	5,440	.001	.001	2.1	.016	
	6,040	.001	.001	3.4	.016	
	6,100	.001	.001	2.2	.014	
	6,490	.001	.001	3.6	.017	
	6,730	.001	.001	2.2	.014	
	7,360	.001	.001	3.7	.015	
	8,160	.001	.001	4.3	.018	
	8,200	.001	.001	4.0	.015	
	8,310	.001	.001	2.6	.014	
	8,680	.001	.001	4.1	.015	
	9,810	.001	.001	4.4	.021	
	9,970	.001	.001	2.6	.015	

Table 8. - Hydraulic data for estimating Manning's roughness coefficient, n (continued).

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Rio Grande near Secorro Reach, NM	697	0.001	0.001	1.0	0.014	2
	697	.001	.001	.7	.013	
	697	.001	.001	1.5	.021	
	874	.001	.001	1.1	.017	
	891	.001	.001	1.2	.018	
	3,600	.001	.001	2.3	.012	
Rio Puerco near Bernardo, NM	159	.001	.001	1.0	.015	
	197	.001	.001	1.2	.017	
	259	.001	.001	1.4	.018	
	283	.001	.001	1.4	.016	
	301	.001	.001	1.2	.012	
	313	.001	.001	1.3	.015	
	343	.001	.001	1.5	.016	
	595	.001	.001	1.9	.012	
	603	.001	.001	2.0	.016	
	775	.001	.001	2.2	.013	
	790	.001	.001	2.0	.012	
	1,410	.001	.001	2.6	.014	
	1,470	.001	.001	2.9	.014	
	1,600	.001	.001	2.6	.014	
	1,900	.001	.001	3.2	.014	
	2,010	.001	.001	2.6	.012	
	3,440	.001	.001	3.2	.014	
	4,340	.001	.001	3.5	.019	
	5,440	.001	.001	3.9	.020	
	6,620	.001	.001	7.0	.023	
Rock Creek near Darby, MT	1,500	.722	.043	3.7	.075	1
Rock Creek Canal near Darby, MT	138	.689	.021	1.3	.060	1
Sacramento River at E-10 near Chico, CA	5,900	.072	.001	7.4	.047	4
	9,590	.072	.000	7.9	.022	
	21,000	.072	.001	8.6	.025	
	27,700	.072	.001	10.3	.026	
Sacramento River at Freeport, CA	40,000	.001	.000	26.5	.028	4
	40,700	.001	.000	26.8	.029	
	41,900	.001	.000	26.6	.029	
	43,600	.001	.000	27.0	.029	
	50,100	.001	.000	28.1	.029	
	50,200	.001	.000	28.0	.028	
	50,400	.001	.000	28.6	.028	
	51,200	.001	.000	28.6	.029	
	59,600	.001	.000	29.7	.029	
	60,100	.001	.000	30.1	.029	
	61,600	.001	.000	30.3	.029	
	62,400	.001	.000	30.6	.029	
	80,000	.001	.000	33.9	.031	
	80,200	.001	.000	34.1	.031	
	90,100	.001	.000	35.9	.032	

Table 8. - Hydraulic data for estimating Manning's roughness coefficient, n (continued).

Station name	Discharge, Q (ft^3/s)	D_{50} (ft)	Water-surface slope, S_w	Mean depth, d_a, (ft)	Manning's roughness coefficient, n	Source
Sacramento River at Peterson Ranch near Hamilton City, CA	10,500	0.120	0.001	5.1	0.030	4
	25,700	.120	.002	8.1	.037	
	56,000	.120	.000	11.1	.025	
Sacramento River near Colusa, CA	12,354	.002	.000	15.3	.017	4
	35,300	.002	.000	26.3	.036	
	40,600	.002	.000	24.2	.023	
	41,400	.002	.000	22.3	.013	
San Juan River at Pagosa Springs, CO	2,700	.400	.008	3.3	.042	5
	3,175	.400	.007	3.4	.038	
South Fork Clearwater River near Grangeville, ID	12,600	.820	.006	7.7	.051	1
South Fork of Rio Grande at South Fork, CO	70.0	.500	.009	1.0	.087	5
	800	.500	.006	2.4	.043	
Spokane River at Spokane, WA	39,600	.640	.002	14.6	.038	1
Trout Creek near Oak Creek, CO	13.0	.200	.016	1.0	.089	5
	29.0	.200	.018	.6	.065	
	57.0	.200	.016	.8	.053	
	164	.200	.015	1.2	.033	
Van Duzen River near Bridgeville, CA	1,840	.370	.001	2.8	.039	3
Walton Creek near Steamboat Springs, CO	234	.700	.027	1.6	.103	5
	590	.700	.034	2.2	.074	
Wenatchee River at Plain, WA	22,700	.532	.002	10.7	.037	1
West Fork Bitterroot River near Conner, MT	3,880	.564	.005	4.8	.036	1
White River above Coal Creek, NM	358	.200	.002	2.5	.039	5
	1,350	.200	.003	3.1	.034	
	1,740	.200	.004	3.3	.035	
Wildcat Canyon near Cool, CA	41.2	.110	.056	.7	.039	4
Yampa River at Steamboat Springs, CO	86.0	.400	.006	.9	.074	5
	335	.400	.006	1.4	.047	
	1,170	.400	.005	2.4	.041	
	1,870	.400	.006	2.7	.032	

A least squares analysis of the data in table 8 gives the following equation for estimating the roughness coefficient expressed by curve C in figure 7:

$$\frac{n\sqrt{g}}{d_a^{1/6}} = \frac{0.5254}{0.794 + 1.85 \log d_a/D_{50}} \tag{11}$$

Rearranging and combining terms gives the equation for n:

$$n = \frac{0.0926 d_a^{0.167}}{0.794 + 1.85 \log d_a/D_{50}} \quad \text{for } 1.5 < d_a/D_{50} < 185 \tag{12}$$

The difference between equations 9 and 11 is an increase in the constant "a" from 0.35 to 0.794 and a decrease in the constant "b" from 2.0 to 1.85. Both of the new constants are based on a sample of 142 Manning's n verification measurements. The change in constants "a" and "b" has the effect of slightly reducing the roughness coefficient $n\sqrt{g}/d_a^{1/6}$ for a given relative roughness (d_a/D_{50}). The reliability of equation 11 is indicated by a procedure described by Limerinos (1970) in which the standard deviation of the percentage differences between actual and estimated values of Manning's roughness, n, are computed. The standard deviation of the percentage differences for the sample of 142 measurements with bed material sizes larger than sand (curve C in fig. 7) was ±13.4 percent, for a range of n values between 0.020 and 0.159. For comparison, Limerinos (1970) reported a standard deviation of the percentage differences of ±22.4 percent in n for a sample of 50 measurements, and based on the median (D_{50}) size of bed material, for a slightly smaller range in n values from 0.020 to 0.107.

A comparison (fig. 7) of the relationship used in Hydraulic Engineering Circular-15 (HEC-15, Normann, 1975), curve E, and the regression derived for this study (curve C, equation 12) suggests that use of the relationship in HEC-15 will indicate a more hydraulically efficient channel than actually occurs. For a given discharge, the water-surface elevation is lower, the cross section smaller, and the depth of flow less than actually occurs.

In cases where a conservative estimate of Manning's roughness coefficient, n, is desired for the design or modification of gravel and cobble bed channels, an enveloping curve for values of relative roughness between 1.5 and 35 has been defined in figure 7. The equation for curve A is:

$$\frac{n\sqrt{g}}{d_a^{0.167}} = 1.2\left(\frac{d_a}{D_{50}}\right)^{-0.5} \quad \text{for } 1.5 < d_a/D_{50} < 35 \tag{13}$$

The location of this relationship in figure 7 is very near the upper 95 percent confidence limit of regression described by equation 11. The corresponding equation for Manning's roughness coefficient is:

$$n = \frac{0.211\ D_{50}^{0.50}}{d_a^{0.333}} \quad \text{for } 1.5 < d_a/D_{50} < 35 \tag{14}$$

Sand-bed channels are defined as those in which the median grain size (D_{50}) is equal to 0.00328 ft (1.0 mm) or smaller. The boundary roughness of sand bed channels is related to bed form and depth of flow as well as to grain size. Because the bed form is dependent on the flow and viscosity, its effect on Manning's roughness cannot be predicted. Therefore, curve B has been drawn as an enveloping curve in figure 7 for values of d_a/D_{50} between 35 and 30,000. The enveloping curve for estimating the roughness coefficient of sand bed channels is:

$$\frac{n\sqrt{g}}{d_a^{0.167}} = 0.20 \quad \text{for } 35 < d_a/D_{50} < 30{,}000 \tag{15}$$

The equation for estimating the upper limiting value of Manning's roughness coefficient, n, for sand channels with mobile beds is then:

$$n = 0.0352\ d_a^{0.167} \quad \text{for } 35 < d_a/D_{50} < 30{,}000 \tag{16}$$

This equation will generally give conservative estimates of n for channels with variable roughness due to changes in bed form.

For average roughness conditions in channels with sand beds, the equation for estimating Manning's coefficient, n, is defined by curve D in figure 7 as:

$$n = 0.0185\ d_a^{0.167} \quad \text{for } 185 < d_a/D_{50} < 30{,}000 \tag{17}$$

The enveloping curve (curve B) for sand bed channels (fig. 7) was extended to intersect curve A at d_a/D_{50} of 35.

A comparison of Manning's roughness coefficient, n, estimated by methods described in Hydraulic Engineering Circular-15 (Normann, 1975), in Limerinos (1970), and in procedures derived in this study, is given in table 9. The comparison is based on an assumed hydraulic radius, R, of 4.7 that represents a relatively small channel with a water-surface width, T, of 54 ft (16.4 m); area, A, of 275 ft^2 (25.6 m^2); discharge, Q, of 2,250 ft^3/s (63.68 m^3/s); average depth, d_a, of 5.09 ft (1.56 m); and maximum depth, d_m, of 8.3 ft (2.5 m).

Table 9. Comparison of methods to compute Manning's roughness coefficient, n, based on selected channel conditions.

[Mean depth, d_a = 5.09 ft]

D_{50} (ft)	Bed material	Manning's roughness coefficient, n				
		HEC-15 (Equation 6)[1]	Limerinos (Equation 11)[1]	Blodgett (Equation 12)[1]	Enveloping curve (Equation 13)[2]	Enveloping curve (Equation 15)[3]
0.003	Coarse sand	[4]0.015	[4]0.018	[4]0.018	--	0.046
0.01	Very fine gravel	[4].018	[4].021	[4].021	--	.046
0.1	Coarse gravel	[4].027	[4].032	[4].031	--	.046
0.25	Small cobble	.031	.041	.038	0.061	--
0.50	Large cobble	.035	.052	.046	.087	--
0.80	Large cobble	.038	.064	.053	.110	--
1.0	Boulders	.040	.071	.058	.123	--
1.5	Boulders	.042	.086	.069	.150	--
2.0	Boulders	.044	.105	.079	.174	--

Equations applicable for median size (D_{50}) of bed material:

[1]Limits: $1.5 < d_a/D_{50} < 185$.

[2]Limits: $1.5 < d_a/D_{50} < 35$.

[3]Limits: $35 < d_a/D_{50} < 30{,}000$.

[4]For comparison of equations.

To simplify the application of the various equations for estimating Manning's coefficient, n, table 10 has been prepared. This table presents values of Manning's n for selected mean depths and median bed material size. The table is based on curve C in figure 7 (eq. 12) for gravel and cobble bed channels with roughness coefficient values between 1.5 and 185. For sand bed channels with larger values of the coefficient, ($185 < d_a/D_{50} < 30{,}000$), the curve D (eq. 17) has been used. Because three variables are involved in application of these equations, the table has been arranged using arbitrary values of mean depth and median size of bed material. Application of data for site conditions not included in the table may be interpolated. For the full range of relative roughness (d_a/D_{50} in fig. 7), bank and alinement conditions as well as bed material size at the site should be considered in selecting Manning's n.

Table 10. Manning's roughness coefficient, n, for selected values of mean depth and median bed material size.

Mean depth, d_a (ft)	Median diameter of bed material, D_{50}, in feet													
	Fine sand	Medium sand	Coarse sand	Fine gravel			Medium gravel	Coarse gravel	Small cobble	Medium cobble	Large cobble	Boulders		
	0.0005	0.001	0.005	0.010	0.015	0.020	0.10	0.20	0.30	0.40	0.50	1.0	1.25	1.50
1	0.019	0.019	0.019	0.021	0.022	0.024	0.035	0.044	0.053	0.061	0.068	0.117	0.151	0.198
2	.021	.021	.021	.021	.022	.023	.032	.039	.045	.050	.054	.077	.089	.101
3	.022	.022	.022	.022	.022	.023	.032	.038	.042	.046	.050	.066	.074	.082
4	.023	.023	.023	.023	.023	.023	.031	.036	.041	.044	.047	.061	.068	.074
5	.024	.024	.024	.024	.024	.024	.031	.036	.040	.043	.046	.058	.064	.069
6	.025	.025	.025	.025	.025	.025	.031	.035	.039	.042	.045	.056	.061	.066
7	.026	.026	.026	.026	.026	.026	.030	.035	.038	.041	.044	.054	.059	.063
8	.026	.026	.026	.026	.026	.026	.030	.035	.038	.041	.053	.053	.057	.061
9	.027	.027	.027	.027	.027	.027	.030	.035	.038	.041	.043	.052	.056	.060
10	.027	.027	.027	.027	.027	.027	.030	.035	.038	.040	.042	.051	.055	.059
12	.028	.028	.028	.028	.028	.028	.030	.034	.037	.040	.042	.050	.054	.057
14	.029	.029	.029	.029	.029	.029	.030	.034	.037	.039	.042	.049	.053	.056
15	.029	.029	.029	.029	.029	.029	.030	.034	.037	.039	.041	.049	.052	.055
20	.031	.031	.031	.031	.031	.031	.031	.034	.037	.039	.041	.048	.050	.053
25	.032	.032	.032	.032	.032	.032	.032	.034	.036	.039	.040	.047	.050	.052
30	.033	.033	.033	.033	.033	.033	.033	.034	.036	.038	.040	.046	.049	.051
35	.033	.033	.033	.033	.033	.033	.033	.034	.036	.038	.040	.046	.048	.050
40	.034	.034	.034	.034	.034	.034	.034	.034	.036	.038	.040	.046	.048	.050

Relationships used in preparing table:

Equation 12 $$n = \frac{0.0926\, d_a^{0.167}}{0.794+1.85 \log d_a/D_{50}} \quad \text{for } 1.5 < d_a/D_{50} < 185$$

Equation 17 $$n = 0.0185 d_a^{0.167} \quad \text{for } 185 < d_a/D_{50} < 30{,}000$$

The procedures by Strickler (1923) and Limerinos (1970) and the relationships shown in figure 7 require streambed particle-size information. Jarrett (1984) suggests that a relationship exists between resistance, expressed as Manning's n, and channel slope, and that there is an interrelationship between channel slope and particle size of the bed material in gravel, cobble, and boulder streams. With steeper slopes, and predominantly coarse bed material and limited amounts of sand, the finer particles are removed, leaving larger particles, which in turn provide greater resistance to movement and an increased friction slope. Using a sample of 21 sites on Colorado streams, Jarrett (1984) derived a relationship between bed roughness, friction slope, and size of channel as:

$$n = 0.395\ S_f^{0.38}\ R^{-0.16} \qquad (18)$$

where n = Manning's roughness coefficient, n

S_f = friction slope

R = hydraulic radius

By substituting water-surface slope (S_w) for S_f and mean depth (d_a) for R, equation 18 may then be modified to:

$$n = 0.395\ S_w^{0.38}\ d_a^{-0.16} \qquad (19)$$

The standard deviation of the percentage differences using equation 18 was 31 percent, compared with 23 percent for the Limerinos approach and 13 percent based on the 142 measurements in this study.

The method suggested by Jarrett (1984) is based on bed material sizes (D_{50}) larger than 0.2 ft, which is very coarse gravel or cobble (Guy, 1969). Equation 19 is considered applicable to natural channels without overbank flow and with stable beds of gravels, cobble, and boulders, and slopes between 0.002 and 0.034. The hydraulic radius (R) or mean depth (d_a) may vary between 0.5 and 7 ft. Results of Jarrett's study indicate that values of n do not vary significantly for hydraulic radius (R) or mean depths (d_a) greater than 7 ft, suggesting equation 19 can be extended to larger flows or $d_a/D_{50} \cong 185$, provided the channel bed remains stable; the procedure is not recommended, however, for d_a/D_{50} values greater than 35.

Table 11 has been prepared to simplify the estimation of Manning's n values for different flow depths and channel slopes. Because the relationship given by equation 19 is not applicable to sand bed channels, values of n less than 0.028 are not given. The procedure for estimating n based on channel slope is not recommended for use in channels with unstable sand beds. In addition, values of n for mean depths greater than 7 ft are based on an extension of the relationship given by equation 19, and may not be reliable.

Table 11. Manning's roughness coefficient, n, for selected values of channel slope.

[Adapted from Jarrett, 1984. Equation given by Jarrett is $n=0.395S_f^{0.38} R^{-0.16}$. Because R is approximately equal to d_a, and S_f is approximately equal to S_w, the equation has been modified to $n = 0.395S_w^{0.38} d_a^{-0.16}$. Values of n for mean depths greater than 7 ft are based on an extension of the relationship given by equation 19 and may not be reliable]

Mean depth, d_a (ft)	Channel slope (ft/ft)				
	0.001	0.003	0.005	0.007	0.100
1	0.028	0.043	0.052	0.059	0.163
2		.038	.047	.053	.146
3		.036	.044	.050	.136
4		.034	.042	.047	.130
5		.033	.040	.046	.126
6		.033	.039	.044	.122
7		.031	.038	.043	.119
8		.031	.037	.042	.117
9		.030	.037	.042	.114
10		.030	.036	.041	.112
12		.029	.035	.040	.109
14		.028	.034	.039	.107
15		.028	.034	.038	.105
20			.032	.037	.101
25			.031	.036	.097
30			.030	.034	.094
35			.029	.034	.092
40			.029	.033	.090

Velocity-Head Coefficient

Channel bank and bed irregularities, variation in roughness, channel curvature, and obstructions cause the velocity of a stream to vary nonuniformly in a cross section. The variation may be in both the vertical and horizontal planes, and may cause the value of velocity head or kinetic energy, as computed from the expression $V^2/2g$, to be lower than actually occurs in the cross section. The actual velocity head may be expressed as $\alpha V^2/2g$ where alpha is the velocity-(energy-)head coefficient. The derivation of the velocity-head coefficient α (Chow, 1959) is given by the equation:

$$\alpha = \frac{\int v^3 d_A}{V_a{}^3 A} \cong \frac{\Sigma(v^3 \Delta A)}{V_a{}^3 A} \qquad (20)$$

where v = point velocity

d_A = subunit area applicable to the point velocity

ΔA = approximate subunit area applicable to the point velocity

V_a = average velocity in cross section

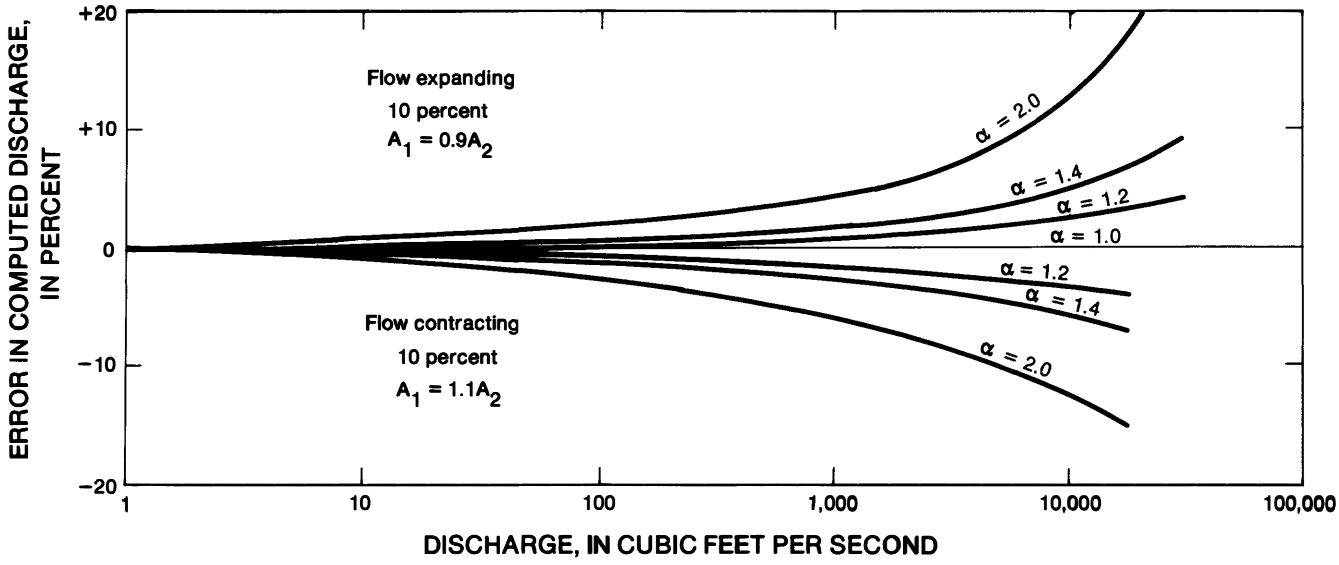
A = area of cross section

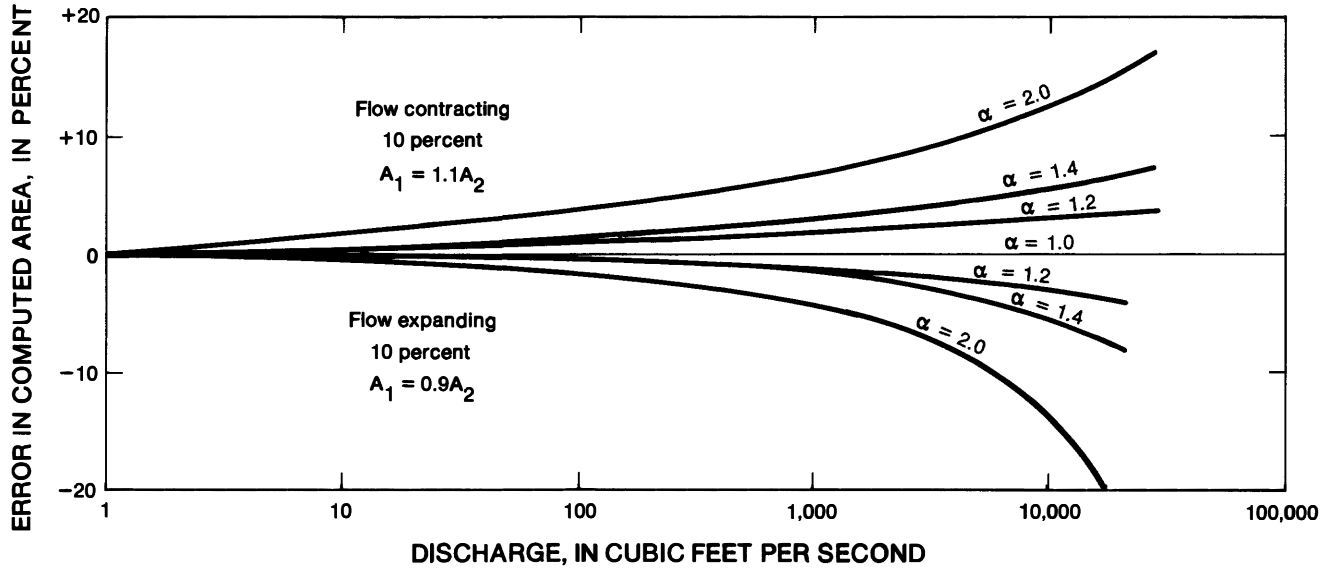
The coefficient is generally assumed to be 1.0 for unit channels. Hulsing and others (1966) show that this is seldom the case, because velocity is not distributed uniformly within a cross section. Factors that cause nonuniform distribution of velocity are size and arrangement of bed material, vegetation, channel geometry, bends, and obstructions. A summary of the coefficients computed by Hulsing and others for 645 discharge measurements in natural channels and canals is given in table 12, which shows median values of 1.40 where the flow was confined to the main channel and 1.46 where overbank flow occurred. Figure 8 shows the error that can result for different values of the true alpha if alpha is assumed to be 1.0. For example, a discharge that was computed to be 10,000 ft^3/s for an alpha of 1.0 in a reach that contracts 10 percent in area would be 6 percent larger than if an alpha of 1.4 had been used. If the reach were expanding by 10 percent, the computed discharge would be 6 percent smaller than if an alpha of 1.4 had been used.

Table 12. Summary of alpha coefficients for various types of cross sections.

[Modified from report by Hulsing and others, 1966]

Type of cross section	Number of measurements	Alpha coefficient (α)		
		Minimum	Maximum	Median
Natural channel without overbank flow.	402	1.09	2.90	1.40
Canal or manmade channel	73	1.03	1.76	1.10
Natural channel with overbank flow.	170	1.18	2.99	1.46





A_1 IS UPSTREAM CROSS SECTION
A_2 IS DOWNSTREAM CROSS SECTION

FIGURE 8. Magnitude of errors in computed discharge and cross-sectional areas for various velocity-head coefficients (alpha) if the value is assumed to be 1.0.

The channel and flow conditions assumed in preparation of figure 8 were based on the following equation, which assumes a constant channel width and length of reach:

$$Q = \frac{1.486A_2^{5/3}}{n_2 T_2^{2/3}} \left[\frac{\Delta h}{\frac{A_2^{5/3}}{A_1^{5/3}} + \frac{0.0343A_2^{4/3}}{n_2^2 T_2^{4/3}} [-\alpha_1(A_2/A_1)^2(1-k)+\alpha_2(1-k)]} \right]^{\frac{1}{2}} \quad (21)$$

in which Q = discharge
A_2 = area of downstream cross section
A_1 = area of upstream cross section
n_2 = Manning's roughness coefficient for downstream cross section
T_2 = width of channel at water surface for downstream cross section
α_1 = velocity-head coefficient at upstream cross section
α_2 = velocity-head coefficient at downstream cross section
k = 0 for contracting reach $A_1 \geq A_2$ and 0.5 for expanding reach $A_1 < A_2$
Δh = change in water-surface elevation between cross sections

Since the purpose of the analysis of velocity-head coefficients is to evaluate the effect of variable alpha (α) for different combinations of A_1 and A_2, the other terms (n_2 and Δh) in equation 21 were held constant.

In the determination of channel size for a site with a specified design discharge and channel slope, the magnitude of error in computing the needed flow area is also affected by the selected value of the velocity-head coefficient (α). As indicated in figure 8, the error in computing the cross-sectional area may be ±7 percent for a design discharge of 1,000 ft^3/s (283 m^3/s), depending on the value of alpha and whether or not the reach is expanding or contracting.

Flow Expansion and Reverse Flow

Application of riprap design procedures based on estimates of shear stress requires accurate estimates of the kinetic energy or water-surface slope. Estimates of slope determined from surveys of the channel bed may provide misleading data if the channel bed has pools and riffles or is subject to scour and fill. Sinuous streams with point bars or expanding reaches generally have pools at bends and riffles in straight reaches. Flows in pools and areas where the channel is expanding may be in reverse to the normal downstream direction. The conversion of velocity to static head in pools and other areas of flow expansion creates turbulence and localized areas of negative water-surface slope.

The data in table 13 indicate that negative slope (and associated reverse flow) in localized reaches of a channel may be greater than the overall slope for the study reach. Upstream velocities as high as 5.0 ft/s (1.5 m/s) have been measured in areas of reverse flow. Shear stresses in the areas of reverse slope may create greater potential for bank erosion than stresses defined on the basis of overall reach slope. Present procedures for calculating shear stresses on the boundary do not consider local reverse flow conditions that may be critical in estimating boundary stability.

Table 13. Comparison of water-surface slopes in channels with areas of flow expansion.

Site	Date	Discharge (ft^3/s)	Water-surface slope		Length of reach (ft)	
			Overall reach of channel	Negative slope in area of expansion (next to boundary)	Overall channel	Area of expansion (next to boundary)
Sacramento River at cross section 5.3 near Chico, CA.	2-18-82	76,000	0.000758	-0.00125	1,055	398
Aptos Creek near Aptos, CA.	1-4-82	3,930	.002728	-.00147	843	326
Sacramento River at Scotty's Landing near Chico, CA.	2-17-82	78,800	.000863	-.000496	834	564
	3-4-82	33,700	.000648	-.000909	445	304
Cosumnes River at site 2 near Dillard Road Bridge near Sloughhouse, CA.	3-31-83	3,970	.000604	-.00202	440	54
Sacramento River at Hamilton City, CA.	2-20-80	73,900	.000422	-.000417	1,350	96

Failure of rock riprap in areas of flow expansion has been documented at three sites. At these sites (Sacramento River at Scotty's Landing, Pinole Creek at Pinole, and Cosumnes River at site 2 near Dillard Road Bridge), flows were not impinging on the bank in the vicinity of the failure. The riprap at these locations probably failed due to undermining of the toe of the riprap. The failures at these and other sites indicate that bank riprap design criteria based only on the shear stress, with adjustments for radius and degree of channel curvature, may not take into account the significant hydraulic conditions that create stresses on the boundary.

Superelevation at Bends

Superelevation of the water surface at bends is caused by the centrifugal force acting on the flow. With superelevated conditions, the water surface on the outer bank is higher than on the inside bank. Associated with flow at bends is an irregular distribution of velocity across the channel that gives values of velocity coefficient alpha (α) and momentum coefficient beta (β) (Chow, 1959) greater than unity.

According to Chow (1959), flow characteristics associated with superelevation for subcritical flow are a smooth water surface and a spiral flow pattern in the vicinity of the bend. The spiral flow pattern represents the movement of water particles in a helical path in the general direction of flow. Associated with spiral flow is the component of transverse velocity that creates a secondary flow movement normal to the direction of the channel. The spiral flow represents a friction phenomenon whose magnitude is associated with the Reynolds number. When flows are supercritical and the water surface is rough, there are strong patterns of cross wave disturbances and a large amount of superelevation. The cross waves represent the effect of gravity on the water surface, and an analysis of supercritical flow conditions is based on the Froude number. For simplicity, the amount of superelevation in curved channels may be estimated, assuming that the water surface across a section is a straight line, and that all incremental velocities in the cross section are equal to the mean velocity.

The magnitude of superelevation at a channel bend may be estimated for subcritical flow by the simplified equation:

$$\Delta y = C \frac{V_a^2 T}{g R_o} \tag{22}$$

where Δy = superelevation of water surface
C = coefficient that relates free vortex motion to velocity streamlines for unequal radius of curvature
V_a = mean velocity
T = water-surface width of channel
g = gravitational acceleration
R_o = mean radius of channel centerline at bend; R_d is mean radius of outside bank of bend = $(R_o + T/2)$

The value of the coefficient C has been determined for 28 flow events (table 14) at channel bends whose radius of curvature ranged from 190 to 4,280 ft (58 to 1,305 m). For these events, the superelevation ranged from 0 to 0.7 ft (0.2 m) and is independent of the angle of the bend. Larger amounts of superelevation are probable. The mean coefficient C, derived from the data in table 14 for equation 22, is 1.5. The values of superelevation observed at the study sites are affected by channel gradient, bed and bank roughness, and by perturbations along the channel bank.

An allowance for channel freeboard is needed to prevent overtopping of the riprap material. Freeboard is measured as the vertical distance above design water surface to the top of the channel bank. The allowance for freeboard should include the effect of superelevation at channel bends.

Table 14. Superelevation of water surface at channel bends.

[Coefficient, C, relates free vortex motion to velocity streamlines for unequal radius of curvature]

Station	Date	Discharge, Q (ft^3/s)	Froude number, F	Width, T (ft)	Average velocity, V_a (ft/s)[a]	Radius, R_o (ft)	Angle of bend Δ	Superelevation of water surface (ft)		Coefficient, C
								Measured	Computed	
East Fork Carson River near	90382	215	0.415	35	3.28	367	76.0	0.12	0.032	3.77
Markleeville, CA	63082	730	.834	49	7.56	379	75.0	.44	.229	1.92
Donner Creek near Truckee, CA	61582	211	.402	30	3.22	215	63.0	.29	.045	6.45
Hoh River near Forks, WA, site 1	110482	5,060	.423	121	6.22	991	80.5	.08	.147	.55
	110382	2,170	.258	94	3.67	991	80.5	.11	.040	2.77
Hoh River near Forks, WA, site 2	110282	2,140	.284	127	3.52	748	53.5	.13	.065	1.94
Sacramento River at Peterson	11383	10,500	.379	450	4.73	1,224	25.0	.09	.255	.352
Ranch near Hamilton City, CA	41482	56,000	.309	863	5.83	1,224	25.0	.16	.744	.215
	121681	25,700	.337	482	5.82	1,224	25.0	.42	.414	1.01
Sacramento River near Chico, CA	121581	27,700	.349	448	6.42	4,280	11.0	.09	.134	.672
	120181	21,000	.337	388	5.85	4,280	11.0	.09	.096	.934
Sacramento River at Princeton, CA	21783	71,200	.182	425	5.61	2,030	45.0	.41	.205	2.00
	11183	12,300	.170	275	2.71	2,030	45.0	.03	.031	.97
Sacramento River near Colusa, CA	31083	41,400	.142	470	3.83	981	51.0	.20	.218	.916
	11083	12,400	.115	274	2.69	964	51.0	.03	.064	.470
	112581	35,300	.127	330	3.91	964	51.0	.27	.163	1.66
Truckee River at Reno, NV	62982	2,800	.568	90	6.83	608	22.0	.17	.214	.793
Truckee River at Sparks, NV	52782	3,740	.314	108	5.22	646	18.0	.27	.141	1.91
W. Walker River nr Coleville, CA:										
Site 2	61182	1,450	1.051	45	9.93	760	24.0	.26	.181	1.43
Site 4	61082	1,280	.949	42	9.14	634	28.0	.24	.172	1.40
Cosumnes River at Dillard Road near Sloughhouse, CA:										
Site 1	113082	9,110	.172	358	2.90	587	100.0	.07	.159	.439
Site 1	12783	14,100	.173	508	3.04	585	102.0	.28	.249	1.12
Site 2	33183	3,970	.239	293	2.92	671	47.0	.07	.116	.605
Site 3	60783	1,743	.272	112	3.33	458	99.0	.25	.084	2.97
Site 4	41583	1,330	.267	155	2.70	999	41.0	.08	.035	2.28
Russian River near Cloverdale, CA	112081	917	.419	147	3.28	852	44.0	.07	.058	1.21
Pinole Creek at Pinole, CA	10382	2,250	.602	57	7.72	190	93.5	.72	.556	1.29
Santiam River at Albany, OR	102782	7,440	.178	191	3.41	3,220	16.0	.00	.021	.00
									MEAN	1.50

The difficulties in estimating the freeboard needed at a site are related to the need to assess the following hydraulic factors:

- o Design discharge.
- o Water-surface elevation for the corresponding design discharge.
- o Effect of channel bed and bank perturbations (irregularities in bank alinement) and roughness.
- o Effect of channel curvature.
- o Height of wind- or boat-generated waves.

For small drainage channels with a prismatic cross section, about 1 ft (0.3 m) of freeboard, as recommended by Normann (1975), should be adequate. Large channels may require more freeboard, especially natural channels that are not prismatic and have perturbations on the bank that cause localized changes in water-surface elevation. The U.S. Army Corps of Engineers (EM-1913, 1978) requires a freeboard of 2 ft (0.6 m) for levees in agricultural areas and 3 ft (0.9 m) for levees in urban areas. These guidelines are increased by 0.5 to 1.0 ft (0.15 m to 0.3 m) at locations near the upstream end of protective riprap, in the vicinity of structures on the levee or bank, near bridges, and in situations in which wave action caused by boat traffic or wind is likely.

Supercritical Flow

The occurrence of supercritical flow in open channels is usually associated with steep gradient streams. However, supercritical flow may occur at flow control or drop structures in channels with low slopes. Several hydraulic conditions that characterize supercritical flow are as follows:

- o The specific energy is a minimum for a given discharge.
- o The velocity head is half the mean depth.
- o Bed slope is equal to or greater than critical slope, $S_o \geq S_c$.
- o The Froude number is approximately 1.0.
- o The flow is uniform and critical when the depth of flow = d_c.

The Froude number is a measure of the effect of gravity on the flow, and is determined as the ratio of inertia to gravity forces:

$$F = \frac{V_a}{\sqrt{g d_a}} \tag{23}$$

where V_a = mean velocity in the cross section

g = acceleration of gravity

d_a = mean depth

When flow conditions approach the critical state ($F \cong 1.0$), relatively large changes in flow depth will occur in a short distance. Flows are in a state of transition, in which inertia and gravity forces are unbalanced, and excessive wave action, hydraulic jumps, localized changes in water-surface slope (known as drawdown or pileup), and flow turbulence occur. All of these actions create stresses on the boundary that are difficult to assess quantitatively.

Experiments by the U.S. Army Corps of Engineers (EM-1601, 1970) on a rectangular channel were made to establish the borderline channel and flow conditions when critical flow may occur. Results of their analysis are as follows:

Subcritical (tranquil) flow: $d_a > 1.1\ d_c$ or $F < 0.86$

Supercritical (rapid) flow: $d_a < 0.9\ d_c$ or $F > 1.13$

where d_a = mean depth
d_c = critical depth
F = Froude number

These results suggest that analyses for rectangular channels should assume that critical flow conditions may occur whenever the Froude number exceeds 0.86. The Froude number at which critical conditions may occur in natural channels is difficult to determine, but is assumed to be 0.95. Use of the Froude number of 0.95 rather than 0.86 gives greater flow depths for a given discharge, and indicates the maximum channel size needed for the design discharge.

The hydraulic analysis or design of a channel for subcritical flow should provide for the following two conditions:

- The Froude number should be less than about 0.95.
- The maximum depth of flow in a channel will be greater than the mean depth (d_m/d_a) by a ratio of about 1.5, similar to the ratio given in table 1 for natural channels.

Application of these properties of flow for average open channel conditions results in the following equation that relates mean depth to average velocity for subcritical flow:

$$V_a = 0.95\sqrt{gd_a} \tag{24}$$

Combining constants, equation 24 is simplified to:

$$d_a = 0.03441\ V_a^2 \tag{25}$$

in which the depth of flow is a function of average velocity and may be expressed graphically as shown in figure 9. This graph provides a method of determining whether or not a channel will convey the design discharge under subcritical flow conditions. If supercritical flow conditions are anticipated, the channel may need to be redesigned or special procedures needed to protect the boundaries.

Another channel characteristic to consider when evaluating the flow condition is that the bed slope (S_o) must be equal to or less than critical slope (S_c) or ($S_o \leq S_c$) for subcritical flow. For supercritical flow conditions to occur, the bed slope is greater than the critical slope ($S_o > S_c$). As an aid in defining the hydraulics of a channel for classifying the type of flow prior to design of the riprap, the following equations have been developed.

The bed slope (S_o) of a channel may be approximated by the water-surface slope using the equation:

$$S_o = \frac{h_2 - h_1}{L} \tag{26}$$

where h_2 = water-surface elevation at the upstream site
h_1 = water-surface elevation at the downstream site
L = channel length between sites

This estimate of bed slope is usually more reliable than using channel bed elevations, which are subject to abrupt changes such as between pools and riffles.

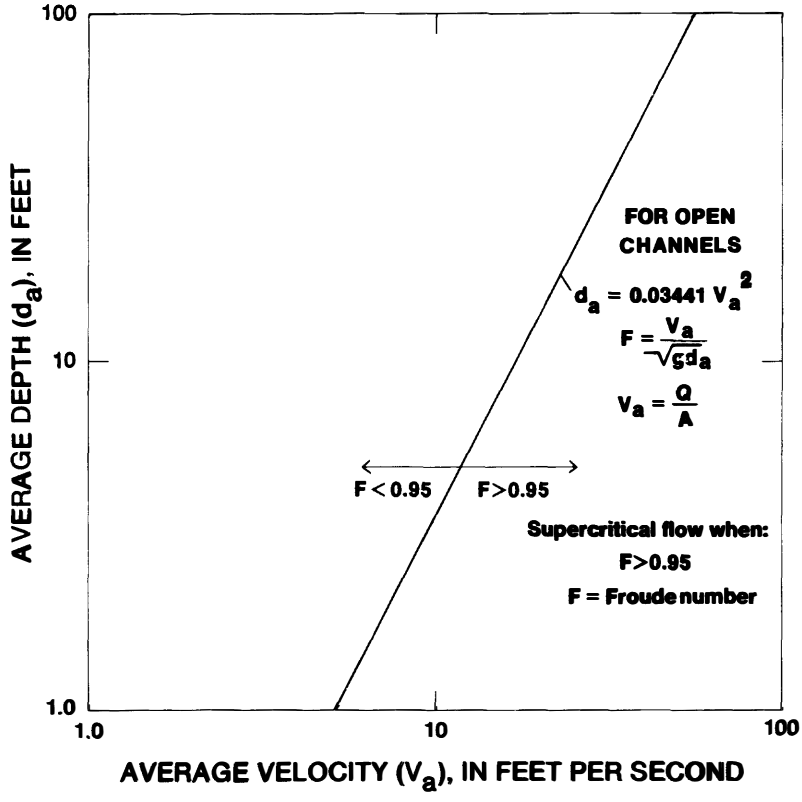


FIGURE 9. Relationship of average velocity and depth for supercritical flow conditions.

The minimum slope at which supercritical flow in a channel of any shape may occur is defined as:

$$S_c = (Q/K_c)^2 \tag{27}$$

Substituting $K_c = \frac{1.486}{n} AR^{2/3}$, gives:

$$S_c = \left(\frac{Qn}{1.486\ AR^{2/3}}\right)^2 \tag{28}$$

where Q = design discharge

K_c = minimum channel conveyance at which supercritical flow will occur

n = Manning's n

A = cross-sectional area

R = hydraulic radius

Equation 28 can be modified to include the factor of mean depth (d_a) because d_a and R are nearly equivalent (table 1), as follows:

$$S_c = \frac{0.453\ Q^2 n^2}{A^2 d_a^{4/3}} \tag{29}$$

Because Q/A equals velocity (V_a), equation 29 may be expressed in terms of velocity as:

$$S_c = \frac{0.453 n^2 V_a^2}{d_a^{4/3}} \tag{30}$$

In this case, the water-surface slope $S_w \cong S_e \cong S_o$.

Because the mean depth (d_a) and velocity of flow (V_a) for open channels are related as shown in figure 9, the critical slope (S_c) at which supercritical flow will occur in a channel without overbank flow may be approximated by combining equations 25 and 30 and simplifying, which gives:

$$S_c = \frac{13.1\ n^2}{d_a^{1/3}} \tag{31}$$

Equations 28-31 may be used to estimate the critical slope for proposed channel geometry and design discharge. Results that indicate critical slope may require an increase in size of boundary material to increase Manning's n, which also reduces the potential for erosion, or a change in channel size. As an aid to estimating critical channel slopes for given depths and channel roughness, the family of curves in figure 10 has been prepared, based on supercritical flow occurring whenever the Froude number exceeds 0.95. Combinations of slope and mean depth that fall to the right of the appropriate roughness curve indicate supercritical flow conditions, and values to the left indicate subcritical flow. The curves in figure 10 indicate supercritical flow for a selected depth can be prevented by either reducing the slope or increasing the boundary roughness. If critical flows are assumed to occur with a Froude number of 0.86, based on U.S. Army Corps of Engineers data given in EM-1601 (1970), the equation relating mean depth (d_a), critical slope (S_c), and Manning's roughness, n, is:

$$S_c = \frac{10.8\ n^2}{d_a^{1/3}} \tag{32}$$

This equation represents a 17 percent decrease in slope from equation 31, which is based on a Froude number of 0.95.

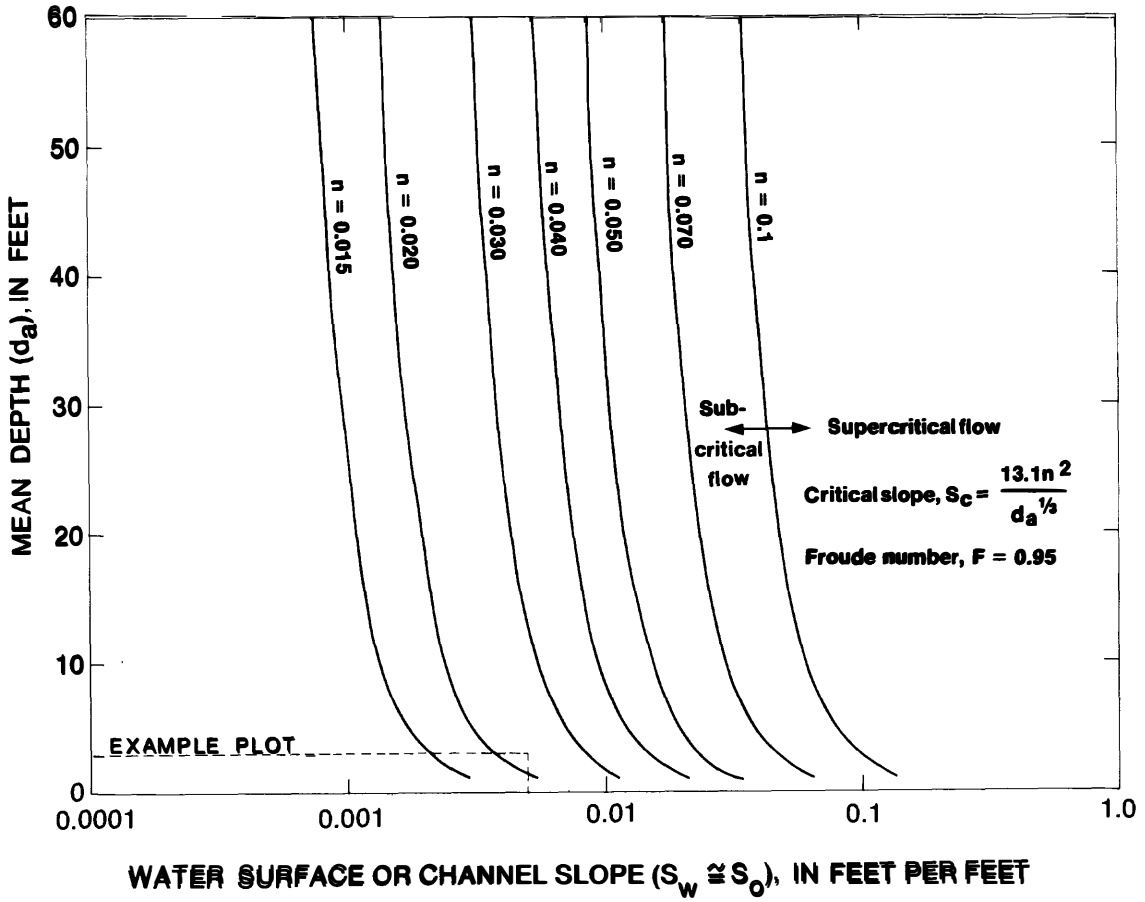


FIGURE 10. Relationship of flow depth, boundary roughness, and slope required for supercritical flow.

As an example of the use of the family of curves in figure 10, the following flow and channel design has been assumed:

$Q = 1{,}000\ ft^3/s\ (28.3\ m^3/s)$,

$S_o \cong S_w = 0.005\ ft/ft\ (1.5\ mm/mm)$,

$n = 0.030$, and

$d_a = 3\ ft\ (0.9\ m)$.

The plotting location in figure 10 for these hydraulic conditions is to the left of the roughness curve (n=0.030) and indicates that the flow will be subcritical. The critical channel slope in this case is about 0.0082 ft/ft (2.5 mm/mm).

SELECTED MORPHOLOGIC CHARACTERISTICS OF OPEN CHANNELS

Both natural and manmade channels may require the use of riprap on the bed or banks to maintain a stable geometry, prevent scour, or prevent changes in alinement. As discussed by Brice and Blodgett (1978), natural channels are at some degree of equilibrium, and a pronounced change in the discharge, sediment transport, alinement, or channel geometry will lead to scour or fill at some location in the reach. When manmade channels are constructed without adequate regard for hydraulic and morphologic characteristics of the stream under consideration, channel instability in terms of scour, fill, or lateral erosion may then occur until the channel reaches a state of equilibrium.

For a given average discharge, there is a certain combination of width, depth, and velocity of flow that is unique to a site. Channel modifications, such as riprap that restricts the width or depth of flow at a site, will result in a corresponding increase in velocity. In general, the most stable channel characteristic is the overall slope based on a reach length that includes several meander bends. This also assumes no occurrence of degradation or aggradation due to significant but untypical events (such as volcanic activity and gravel mining). The slope along a meandering channel is always less than the valley slope, and the degree of sinuosity is a function of the sediment grain size, ratio of bedload to total load, and discharge of the stream (Bloom, 1978). With the condition of a fixed slope, the channel area and sediment discharge at a site will vary according to stream discharge. Studies by Leopold and Maddock (1953) show that the width, depth, and velocity increase as a power function of discharge, as shown in the following equations:

$$T = aQ^b,\ d_a = cQ^f,\ \text{and}\ V_a = kQ^m \qquad (33A,B,C)$$

where T = water-surface width

d_a = mean depth of water

V_a = mean velocity of flow

Q = flow equal to or less than bankfull discharge

For the streams included in table 1, the approximate value of a is 3.9, c is 0.28, and k is 1.3. The exponents for equations 33A-C are 0.46, 0.38, and 0.16, respectively. These constants should be considered approximations and used only to provide guidelines for the analysis of streams in the project area.

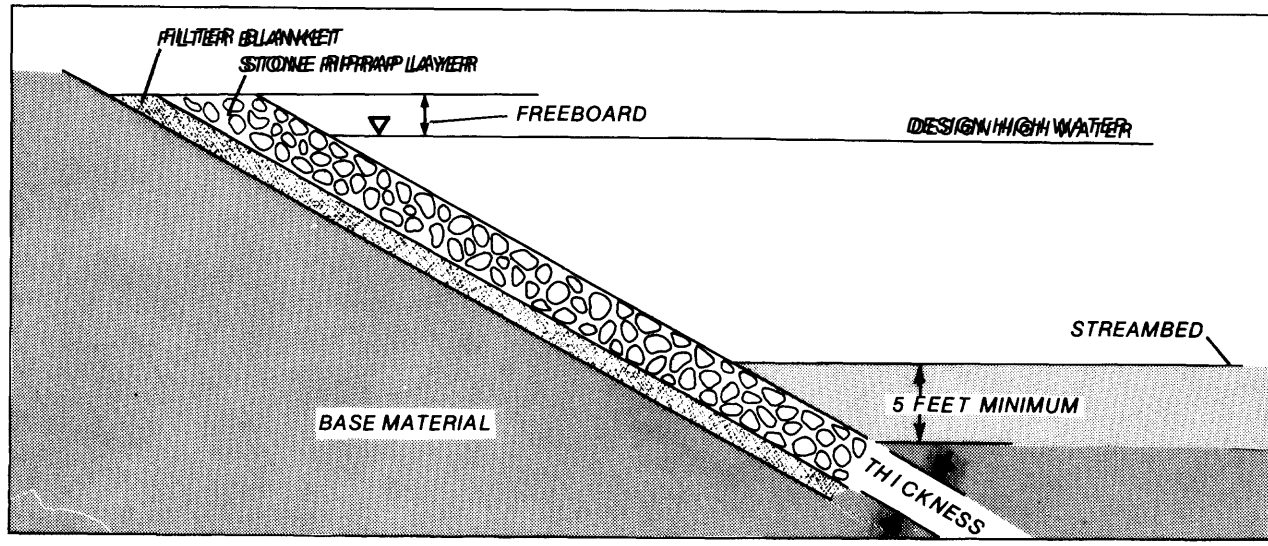
The mean depth of a stream is inversely proportional to the width and mean velocity. The design and placement of bank protection should, therefore, attempt to minimize the reduction in channel width or area so that increases in flow depth or velocity, and consequent potential for scour, will be minimized. If the channel width must be decreased, it may be necessary to add riprap to the channel bed or to lower the toe of the bank protection to prevent damage by the action of scour as flows respond to the new channel conditions.

Depth of Scour in Alluvial Channels

The depth of scour in a channel bed is a function of the amount of suspended sediment, size and placement of bed material, and magnitude of erosion stresses exerted by the stream. In the design of bank protection, estimates of the depth of scour are needed so that the protective layer is placed sufficiently low in the streambed to prevent undermining. Design procedures in Hydraulic Engineering Circular-11 (Searcy, 1967) recommend that the riprap layer extend a minimum vertical distance of 5 ft (1.5 m) below the streambed, and on a continuous slope with the embankment (fig. 11). The recommendation may not be adequate for reasons described in this report.

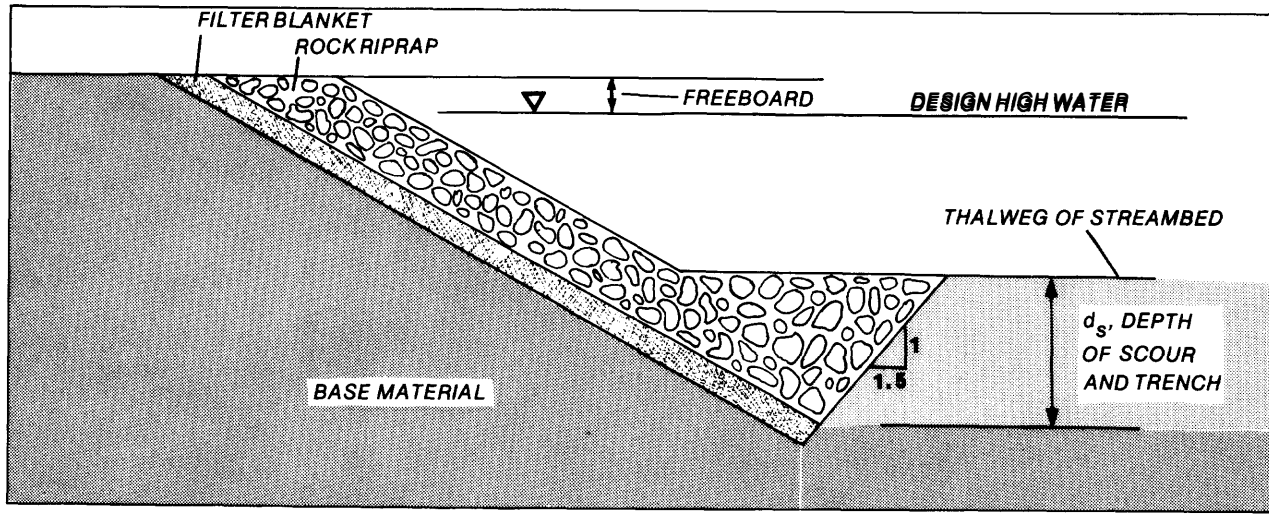
For typical channels that are not affected by degradation or aggradation (caused by mining, landslides, or changes in flow regime), scour and fill of the channel boundary is a continuing and natural phenomenon. Changes in channel shape and size are related, in part, to discharge and suspended-sediment load, as shown by Leopold and Maddock (1953). Their studies indicate that scour and fill of a riverbed during a flood is directly related to changes in suspended-sediment concentration.

Scour and fill of the channel boundary results in fluctuations about a mean elevation or position as part of a continuing process in natural streams. Therefore, there is some limit in the magnitude of the channel changes unless the stream is aggrading or degrading. Studies of streambed scour at 21 sites were made to determine typical depths of scour for various sizes of bed material and flow conditions. Depths of scour (table 15) were measured at sites on streams with sand, gravel, and cobble beds. Sites were selected that were unaffected by bridge piers or other cultural features, were generally in straight reaches, and were without features such as bedrock or large boulders that may cause localized scour. Measurements of the channel bed elevation were made systematically (either annually or monthly) by soundings or depth fathometer at the same location from a boat, cableway structure, or by wading.



A – STONE LAYER (BLANKET) AND TOE TRENCH DETAIL

(adapted from Figure 3, HEC – 11, Searcy, 1967)



B – MODIFIED STONE LAYER (BLANKET) AND TOE TRENCH DETAIL

FIGURE 11. Riprap layer (blanket) and toe foundation detail.

Table 15. Depth of scour for selected sand, gravel, and cobble bed streams.

[Maximum scour is determined as difference in thalweg elevation from reference elevation; reference elevation is maximum thalweg elevation for period of sample. Standard deviation of scour was computed only if sample size was 10 or more]

Stream	Period of record (water years)	Number of channel measurements	Median size of bed material D_{50} (ft)	Channel bed scour (ft)		
				Maximum, $d_{s(max)}$	Mean, d_s	Standard deviation
Sacramento River near Butte City, CA:[1]						
Cross-section 1	1972-83	10	0.074	8.8	7.0	1.82
Cross-section 2	1972-83	10	.074	6.6	3.7	2.60
Cross-section 3	1972-83	10	.059	4.2	2.5	1.25
Cross-section 4	1972-83	10	.057	6.3	2.5	1.94
Cross-section 5	1972-83	10	.042	8.0	3.6	2.19
Cross-section 6	1972-83	9	.033	8.8	4.7	
Cross-section 7	1972-80	4	.025	1.6	.7	
Sacramento River at E-10, at Chico Landing, CA.	1981-83	7	.076	7.0	2.7	
Sacramento River at Princeton, CA:						
Cross section 2	1981-83	3	.0072	5.1	4.5	
Cross section 3	1981-83	6	.0072	5.4	1.6	
Sacramento River near Colusa, CA.	1981-83	7	.0017	13.0	8.8	
Rio Grande near Bernalillo, NM[2]	1948	3	.001063	4.1	2.4	
San Juan River near Bluff, UT[2]	1941	4	.000912	10.6	6.3	
Colorado River at Grand Canyon, AZ[2].	1941	4	.000427	[3]7.4	6.8	
Hassayampa River at Box Canyon Damsite near Wickenburg, AZ.	1964-75	73	[4].002	4.4	1.4	.85
Santa Maria River near Bagdad, AZ.	1976-82	26	.00269	4.8	.8	.94
Santa Cruz River near Nogales, AZ.	1980-83	43	.00164	1.6	.7	.33
Klamath River near Siead Valley, CA.	1951-83	302	.403	3.3	1.0	.61
Sacramento River above Bend Bridge near Red Bluff, CA.	1968-83	173	.335	3.7	.9	.39
Sacramento River near Red Bluff, CA.	1931-63	215	.235	1.8	.7	.36
Hoh River at Highway 101 near Forks, WA.	1983-84	8	[5].076	1.4	1.0	

[1]Data prior to 1978 adapted from study of flood hydrology of Butte Basin, CA, by Simpson (1978).

[2]Adapted from study of hydraulic geometry of stream channels by Leopold and Maddock (1953).

[3]For discharges greater than about 90,000 ft^3/s, the sand bed material goes into suspension, exposing a bedrock channel bed.

[4]Estimated from sand sizes for Santa Maria River near Bagdad, AZ, and Santa Cruz River near Nogales, AZ.

[5]Estimated.

Determination of the depth of scour at these sites required the definition of the reference plane. The reference plane was selected as the highest thalweg elevation found at the cross section during the period over which a given site was studied (fig. 12). The depth of scour at any given time is defined as the distance between the reference plane and the lowest point in the cross section at the time of the survey.

The data in table 15 indicate that the mean depth of scour for the sample of 21 sites is about 3.1 ft (0.95 m). The relationship of mean depth of scour to size of bed material (fig. 13) for 21 sites indicates that mean scour depths range from about 4 ft (1.2 m) for sand beds to about 2 ft (0.6 m) for gravel and cobble bed channels. In addition to sampling errors, this relationship is influenced by many of the factors that affect the amount of bed scour at a site, such as size of bed material, size distribution (which may cause armoring of the surface material), channel curvature, changes in channel size, variation in suspended-sediment concentrations, bedrock or presence of hardpan, the effects of debris and channel bed irregularities, and shear stress.

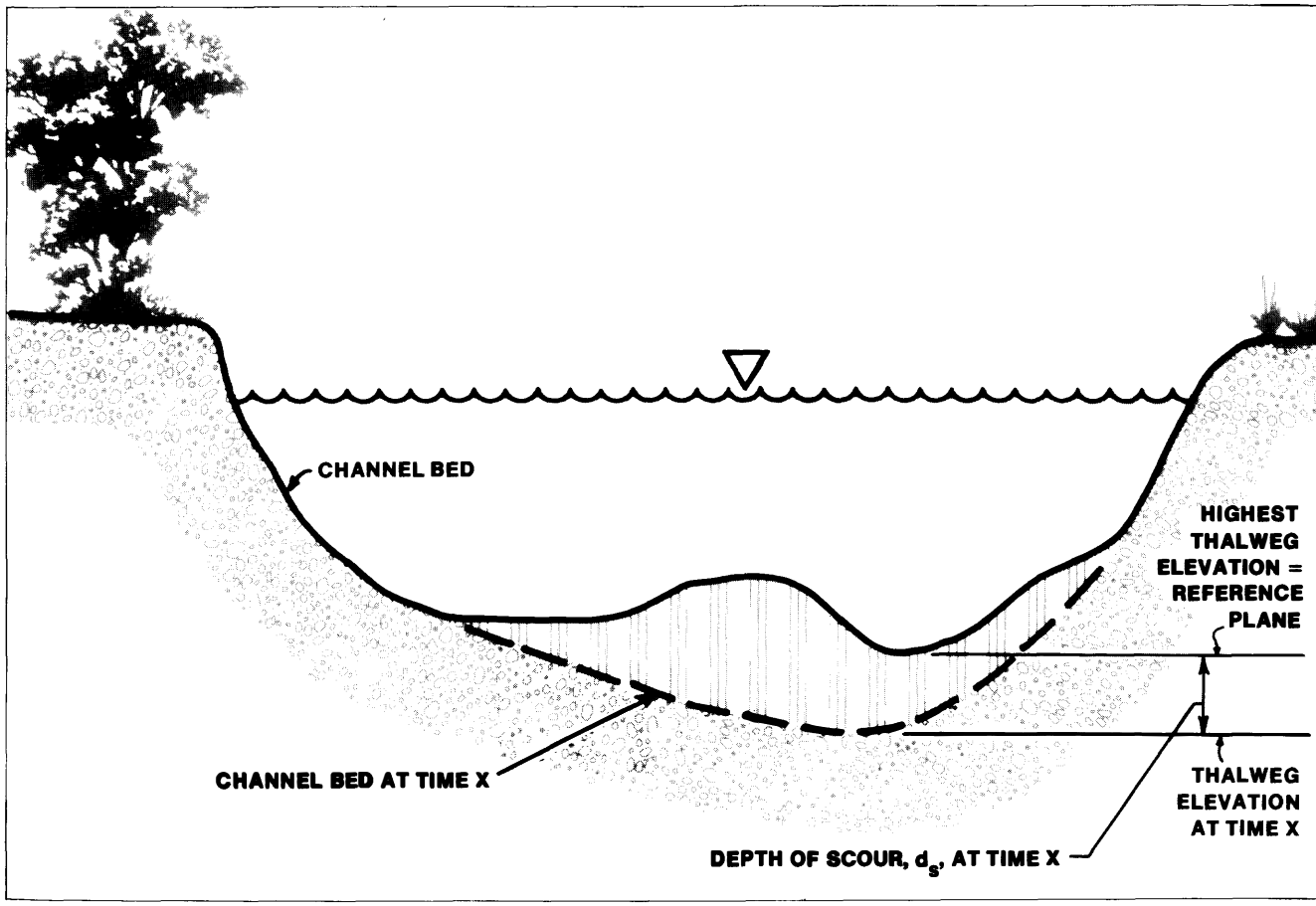


FIGURE 12. Definition sketch of channel bed scour.

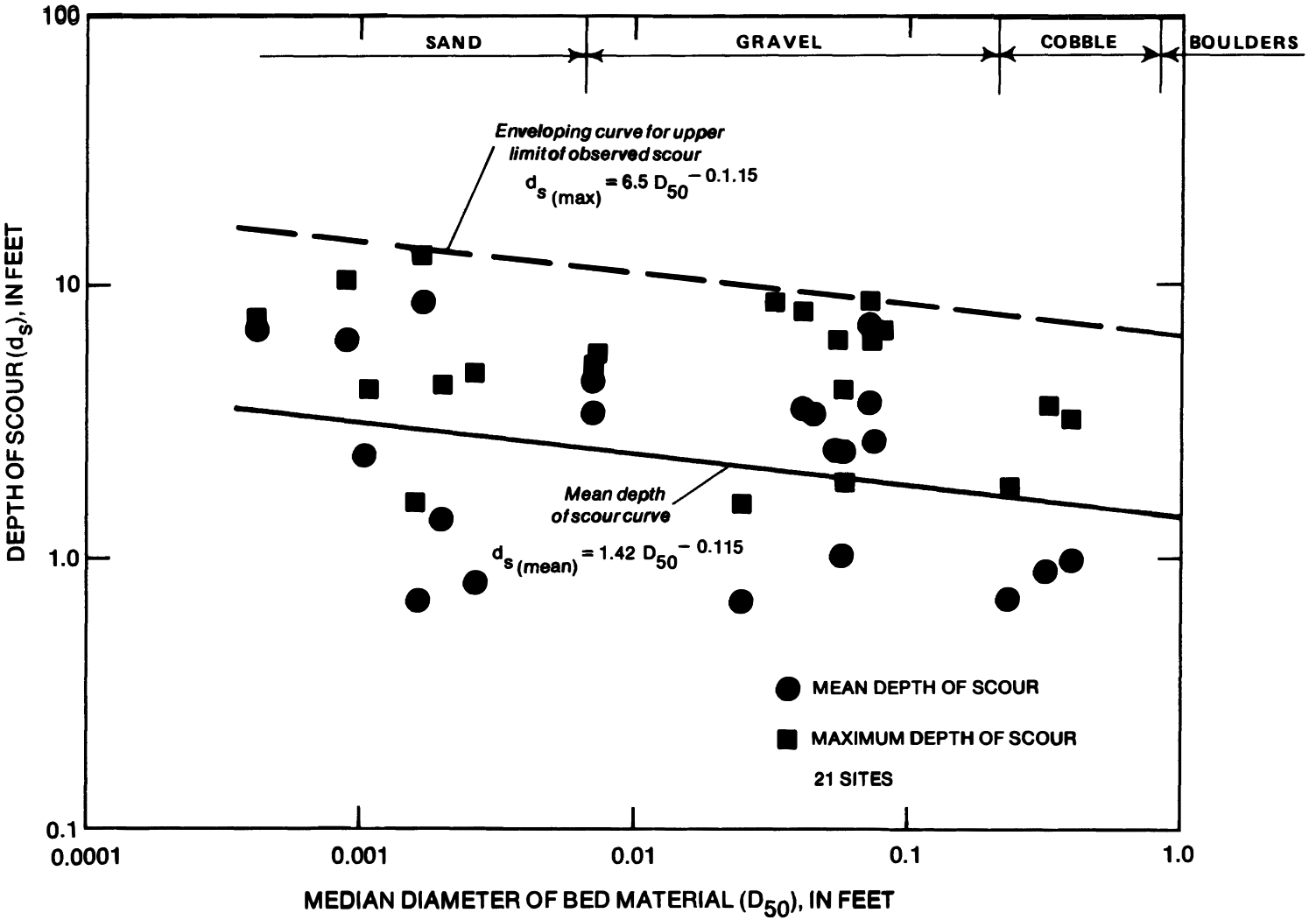


FIGURE 13. Relationship of scour depth to median size of bed material in channel.

The enveloping curve in figure 13 indicates a provisional upper limit of scour that occurred at the sample sites. The slope of the enveloping curve has arbitrarily been drawn parallel to the curve for mean depth of scour. Scour depths greater than those indicated by the enveloping curve may occur during floods larger than those occurring during the sample period or in the vicinity of contracting reaches or sites with bridge piers or at local obstructions such as bedrock formations or large boulders.

To estimate the depth of the toe trench needed to prevent undermining of the riprap (d_s, figs. 11 and 12), the following relationship, based on the enveloping curve in figure 13, has been developed:

$$d_{s(max)} = 6.5\ D_{50}^{-0.115} \tag{34}$$

where $d_{s(max)}$ = estimated maximum depth of scour for alluvial bed channels
D_{50} = median diameter of bed material

The maximum depth of scour for construction of the toe trench as estimated by this relationship is greater than the previously recommended value (5 ft or 1.5 m, fig. 11) for all sizes of bed material. In application, the maximum depth of scour, $d_{s(max)}$, determined from equation 34, should be measured from the reference plane to define the lowest elevation in the cross section, and the toe trench constructed and filled as shown in figure 11. Because the elevation of the surveyed channel bed in relation to the reference plane is not known, the following relationship for estimating mean depth of scour may be used:

$$d_{s(mean)} = 1.42\ D_{50}^{-0.115} \tag{35}$$

The location of the low point may shift from bank to bank, and the design procedure should assume that the low point in the cross section may eventually move adjacent to the riprap.

Permissible Nonscour Velocity

A determination of the maximum permissible velocity that will not cause erosion of a channel has been the subject of investigation for years. Chow (1959) presents a table of permissible velocities (table 16) for different materials. This table lists allowable velocities and unit tractive forces for a channel conveying clear water or suspended sediment. Some suspended sediment will be transported in all natural channels, and the relationship of velocity to material size, as derived from table 16 and shown in figure 14, is for water transporting colloidal material. For comparison, data on nonscour velocities for canals in various soil types have been adapted from a study by Keown and others (1977) and from a study by Mamak (1964) and further simplified for this study (table 17), and are also shown in figure 14 for mean depths of 1.3 and 9.8 ft (0.40 m and 3.0 m). The velocities in table 17, modified from Keown and others (1977), take into account the effect of depth and give the highest permissible nonscour velocities.

Table 16. Maximum permissible velocities recommended by Fortier and Scobey and the corresponding unit-tractive-force values converted by the U.S. Bureau of Reclamation.

[Adapted from Chow, 1959. For straight channels of small slope, after aging. The Fortier and Scobey values were recommended for use in 1926 by the Special Committee on Irrigation Research of the American Society of Civil Engineers]

Material	n	Clear water		Water transporting colloidal silts	
		Velocity (ft/s)	Unit tractive force (lb/ft^2)	Velocity (ft/s)	Unit tractive force (lb/ft^2)
Fine sand, colloidal	0.020	1.50	0.027	2.50	0.075
Sandy loam, noncolloidal	.020	1.75	.037	2.50	.075
Silt loam, noncolloidal	.020	2.00	.048	3.00	.11
Alluvial silts, noncolloidal	.020	2.00	.048	3.50	.15
Ordinary firm loam	.020	2.50	.075	3.50	.15
Volcanic ash	.020	2.50	.075	3.50	.15
Stiff clay, very colloidal	.025	3.75	.26	5.00	.46
Alluvial silts, colloidal	.025	3.75	.26	5.00	.46
Shales and hardpans	.025	6.00	.67	6.00	.67
Fine gravel	.020	2.50	.075	5.00	.32
Graded loam to cobbles when noncolloidal.	.030	3.75	.38	5.00	.66
Graded silts to cobbles when colloidal.	.030	4.00	.43	5.50	.80
Coarse gravel, noncolloidal	.025	4.00	.30	6.00	.67
Cobbles and shingles	.035	5.00	.91	5.50	1.10

Table 17. Nonscour velocities for soils.

[Modified from a report by Keown and others, 1977]

Kind of soil	Grain dimensions		Approximate nonscour velocities (feet per second) Mean depth			
	Millimeters	Feet	1.3 ft	3.3 ft	6.6 ft	9.8 ft
			For noncohesive soils			
Boulders	>256	>0.840	15.1	16.7	19.0	20.3
Large cobbles	256-128	0.840-0.420	11.8	13.4	15.4	16.4
Small cobbles	128-64	0.420-0.210	7.5	8.9	10.2	11.2
Very coarse gravel	64-32	0.210-0.105	5.2	6.2	7.2	8.2
Coarse gravel	32-16	0.105-0.0525	4.1	4.7	5.4	6.1
Medium gravel	16-8.0	0.0525-0.0262	3.3	3.7	4.1	4.6
Fine gravel	8.0-4.0	0.0262-0.0131	2.6	3.0	3.3	3.8
Very fine gravel	4.0-2.0	0.0131-0.00656	2.2	2.5	2.8	3.1
Very coarse sand	2.0-1.0	0.00656-0.00328	1.8	2.1	2.4	2.7
Coarse sand	1.0-0.50	0.00328-0.00164	1.5	1.8	2.1	2.3
Medium sand	0.50-0.25	0.00164-0.000820	1.2	1.5	1.8	2.0
Fine sand	0.25-0.125	0.000820-0.000410	.98	1.3	1.6	1.8
			For compact cohesive soils			
Sandy loam (heavy)			3.3	3.9	4.6	4.9
Sandy loam (light)			3.1	3.9	4.6	4.9
Loess soils in the conditions of finished settlement			2.6	3.3	3.9	4.3

Effect of Alinement Changes on Channel Slope

Alluvial streams develop meanders that are confined in lateral movement by nonerosive rock or other material at the valley boundary or by levees constructed to prevent flooding. The degree of stream meandering is indicated by channel sinuosity, which is determined as the ratio of a reach length measured along the channel centerline to the reach length measured as a straight line between ends of the reach. A characteristic of all sinuous channels is the migration of the meanders over a period of time. Eventually, the neck of the meander loop may become so small in relation to the width of the channel that a cutoff (referred to as a chute or neck cutoff) between meander loops occurs. Associated with the cutoff is an increase in channel slope, and lateral erosion of the banks at adjacent bends, with the length of reach affected by the cutoff a function of the channel size.

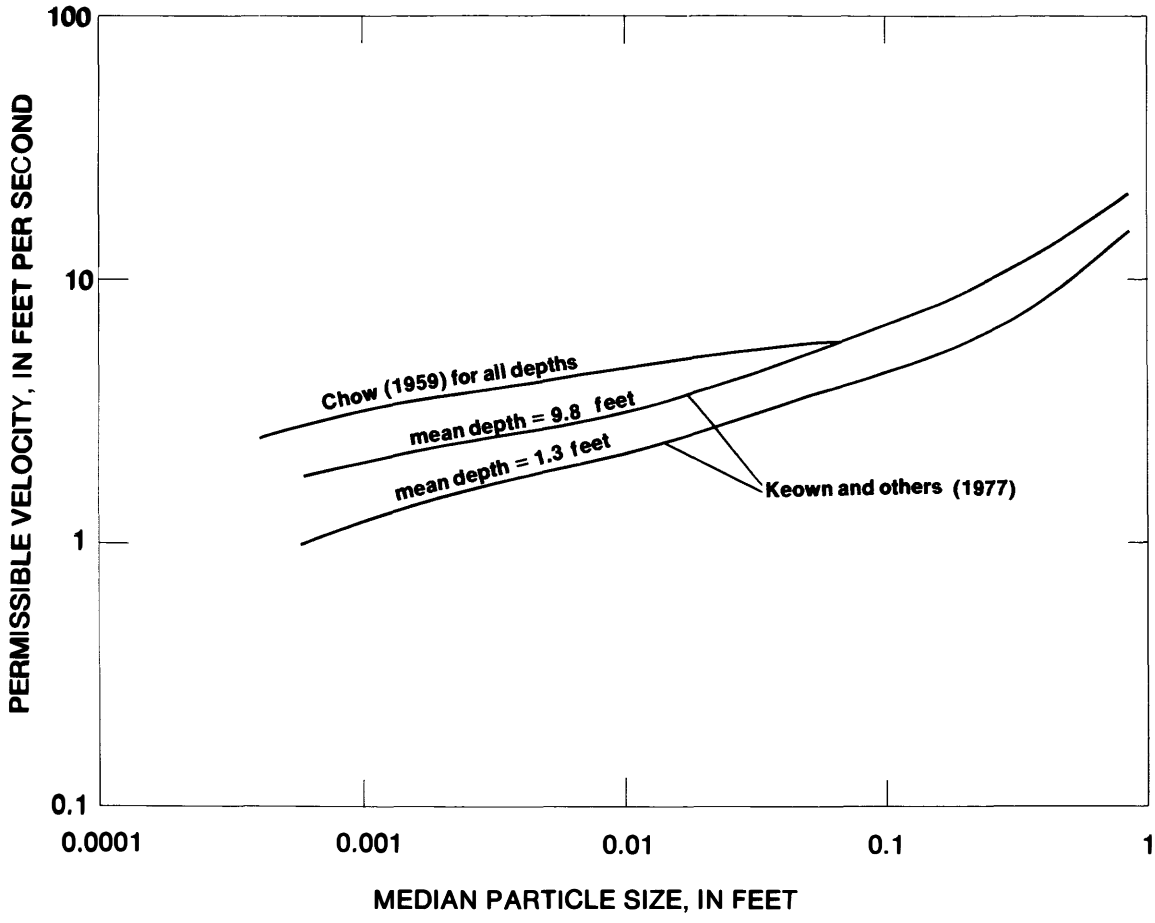


FIGURE 14. Comparison of permissible velocities from Chow (1959) and Keown and others (1977).

Meander properties of the Sacramento River between Chico Landing and Woodson Bridge, California, were studied by Blodgett (1981). Data summarized in table 18 indicate that changes in the centerline length and sinuosity of the channel caused by chute cutoffs, meander migration, and other alinement changes in a 24-mi (38.6-km) reach caused changes in slope of the river for reaches between 5 and 12 mi (8.0 and 19.3 km) long up to 23 percent over a 7-year period. The downstream extent of changes in slope is related to the degree of channel straightening and stream size. However, for reaches sufficiently long to include at least three meander loops, and over the long-term period of 35 years (1946-80), the level of sinuosity and channel slope did not change significantly, and the channel appears to be in a state of equilibrium. The channel slope for the 24-mi (38.6-km) reach during a 31-year period (1950-80) changed only 0.7 percent, with the possibility that this apparent change is due to inaccuracy in the data. If short-term changes in sinuosity and slope for short reaches of the Sacramento River are typical of most rivers, then the overall channel slope may be considered constant. Because channel migration is a continuing process, bank protection activities near highway structures will be needed on a continual basis to restrict lateral erosion. It is also apparent that riprap placed at a point of active stress on a meander loop may in time be isolated from the active channel if alinement changes and chute cutoffs occur (see fig. 1).

Table 18. Morphologic and hydraulic properties of Sacramento River between Chico Landing (site E-10) and Woodson Bridge, California.

[Modified from report by Blodgett, 1981]

Reach description	River miles[1]	Number of meander loops		Valley length (feet)	Sinuosity of channel			
		Per reach	Per mile		April 11, 1946[2]	March 4, 1972[2]	June 21-July 25, 1980[2]	April 2, 1979[2]
Chico Landing Gianella Bridge	194 to 199	2	2.5	19,520	1.28	1.39	1.13	1.20
Gianella Bridge Freer/Barchett	199 to 206	3	2.3	24,210	1.04	1.07	1.12	1.14
Freer/Barchett Woodson Bridge	206 to 218	7	1.7	40,660	1.50	1.54	1.32	1.46
TOTAL				84,390	1.31	1.37	1.22	1.31

Reach description	Valley slope[3] (feet per 1,000 ft)	Water-surface slope[4] (feet per 1,000 ft) for selected floods				
		Dec. 15, 1950[5]	Dec. 23, 1964[5]	Jan. 24, 1970[6]	Jan. 17, 1978[7]	Feb. 20, 1980[8]
Chico Landing to Gianella Bridge	0.523	0.409	0.394	0.390	0.372	0.443
Gianella Bridge to Freer/Barchett	.587	.564	.579	.543	--	.507
Freer/Barchett to Woodson Bridge	.635	.424	.441	.428	--	.437
MEAN	.595	.453	.462	.444	.487	.456

[1]After U.S. Army Corps of Engineers, 1976.

[2]Date of aerial photography.

[3]Determined from distances derived from USGS 7.5-minute topographic maps, Foster Island, Hamilton City, Ord Ferry, Nord, and Woodson, and elevations of water surface during flood of December 15, 1950.

[4]Date of photography used in defining channel length and slope:

[5]1946.

[6]1972.

[7]1979.

[8]1980.

SUMMARY

- Guidelines suggested here for hydraulic and morphologic analyses of stream channels are based on field data collected at over 700 sites throughout the United States. A thorough understanding of the characteristics of natural streams and manmade channels is essential to design adequate rock riprap to stabilize the channel and control bank erosion.

- Analyses of natural open channels indicate that hydraulic and morphologic properties that define the flow and channel shape usually exhibit consistently similar quantitative values, such as ratio of maximum velocity to mean velocity of 1.61, and ratio of hydraulic radius to mean depth of 0.98.

- Channels at curves exhibit a slightly greater ratio of maximum to mean depth (1.7) compared with the ratio of 1.6 for straight reaches.

- Suitable side slopes of channels in all types of material other than solid rock or clay, or lined with material such as concrete, should be flatter than 1.5:1 (table 3).

- For a selected discharge, hydraulic properties that define the geometry of a channel, such as area, hydraulic radius, width, and depth, may change in any given year ±50 percent from the long-term mean, depending on flow conditions at the site. Because hydraulic analysis of a channel assumes the field data are representative of average conditions at a site, these changes suggest that site surveys may indicate channel conditions that are much different than those needed for adequate design purposes.

- Based on data for 60 sites, Manning's roughness coefficients for gravel, cobble, and boulder bed channels range from 0.020 to 0.159. For 113 measurements of sand bed channels, Manning's roughness coefficients varied between 0.013 to 0.046, depending on the bed configuration. Equations for estimating Manning's roughness coefficient have been developed based on average depth, channel slope, and median bed material size.

- The median velocity-head coefficient (α) for over 400 channels without overbank flow is 1.40, and if overbank flow occurs, the median value of alpha increases to 1.46. Errors in hydraulic computations assuming an alpha of 1.0 can be significant.

- Localized parts of a channel may be subject to reverse flow as a result of flow expansions or eddies. Sites have been documented in which negative velocities up to 5 ft/s (1.5 m/s) and reverse slopes up to 0.002 ft/ft (0.6 mm/mm) for a distance over 400 ft (120 m) occurred.

- Superelevation of the water surface at bends up to 0.7 ft (0.2 m) has been measured at the study sites. Larger values are probable. Field data indicate the amount of superelevation is independent of bend angle, but is related to the channel gradient, bed and bank roughness, and irregular shape of bank.

- Supercritical flow in natural channels may occur when the Froude number exceeds 0.86. Supercritical flow conditions may be prevented by increasing the depth of flow, reducing the slope, or increasing the boundary roughness by using larger size riprap.

- The depth of scour in natural alluvial channels is related to the size of bed material and armoring. Maximum observed depths of scour at 21 sites unaffected by piers or other obstructions is 13 ft (4.0 m).

- Permissible nonscour velocities are a function of type of bank and bed material and depth of flow. Typical velocities for a flow depth of 10 ft (3.1 m) range from about 2 ft/s (0.6 m/s) for fine sand to 11 ft/s (3.4 m/s) for small cobbles.

- Changes in channel centerline length and sinuosity that occur as a result of natural meander migration or chute cutoff may cause sudden local increases in channel slope. The downstream extent of changes in slope is related to the degree of channel straightening and stream size. For reaches sufficiently long to include at least three meander loops, and over a long-term period (generally several decades), the level of sinuosity and channel slope remain nearly constant.

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830.1 REQUIREMENTS

A. Riprap: Stone for riprap shall be hard and durable and shall have a minimum weight of 155 pounds per cubic foot. Riprap may be ledge rock or field stone. If field stone is utilized for Class C or larger, the stone shall have a minimum of 2 crushed faces as defined under SD 211. Stone shall be free from overburden, spoil, shale, and organic material. The riprap stone shall meet the following gradation requirements:

Riprap Class	Rock Size*[1] in feet	Rock Size in pounds	Percent of Riprap Smaller Than
A	1.30 0.95 0.40	200 75 5	100 50 15
B	1.80 1.30 0.40	500 200 5	100 50 15
C	2.25 1.80 0.95	1000 500 75	100 50 15
D	2.85 2.25 1.80	2000 1000 500	100 50 15
E	3.60 2.85 2.25	4000 2000 1000	100 50 15
F	4.50 3.60 2.85	8000 4000 2000	100 50 15

*[1] Based on a specific gravity of 2.65 and spherical shape.

The riprap class is the median particle weight with 50% of the material smaller and 50% of the material larger.

Each load of riprap shall be well graded from the smallest to the maximum size specified.

B. Testing:

Specific Gravity ..... SD 210

RS	y (ft)	sf	k1	Cs	Rc	W	Rc/W	Cv	Ct	Vavg (ft/s)	Vdes (ft/s)	Sg	g (ft2/sec)	min ch El	WS elev	D30 (ft)	D50 (ft)	Riprap Class	Class D50 (ft)	Thickness (ft)	n value
2500	3.45	1.2	1.306184	0.3	100,000	199.06	502.36	1	1	1.1	0.902	2.48	32.2	1394.09	1397.54	0.0012	0.0014	A	0.95	1.43	0.039
2400	3.99	1.2	1.306184	0.3	100,000	96.55	1,035.73	1	1	1.09	0.894	2.48	32.2	1393.49	1397.48	0.0011	0.0013	A	0.95	1.43	0.039
2300	4.57	1.2	1.306184	0.3	100,000	94.67	1,056.30	1	1	0.79	0.648	2.48	32.2	1392.89	1397.46	0.0005	0.0006	A	0.95	1.43	0.039
2200	5.17	1.2	1.306184	0.3	100,000	332.62	300.64	1	1	0.41	0.336	2.48	32.2	1392.29	1397.46	0.0001	0.0001	A	0.95	1.43	0.039
2100	5.77	1.2	1.306184	0.3	100,000	489.52	204.28	1	1	0.26	0.213	2.48	32.2	1391.69	1397.46	0.0000	0.0000	A	0.95	1.43	0.039
2000	6.19	1.2	1.306184	0.3	100,000	111.78	894.61	1	1	3.17	2.599	2.48	32.2	1391.09	1397.28	0.0142	0.0171	A	0.95	1.43	0.039
1900	6.48	1.2	1.306184	0.3	100,000	97.6	1,024.59	1	1	3.62	2.968	2.48	32.2	1390.49	1396.97	0.0196	0.0235	A	0.95	1.43	0.039
1800	6.48	1.2	1.306184	0.3	100,000	85.05	1,175.78	1	1	3.95	3.239	2.48	32.2	1390.09	1396.57	0.0244	0.0292	A	0.95	1.43	0.039
1700	6.49	1.2	1.306184	0.3	100,000	79.07	1,264.70	1	1	4.25	3.485	2.48	32.2	1389.89	1396.38	0.0292	0.0351	A	0.95	1.43	0.039
1600	4.34	1.2	1.306184	0.3	100	69.07	1.45	1	1	7.45	11.806	2.48	32.2	1389.48	1393.82	0.6831	0.8197	A	0.95	1.43	0.039
1500	4.11	1.2	1.306184	0.3	100	69.51	1.44	1	1	8.27	13.123	2.48	32.2	1388.78	1392.89	0.9021	1.0825	A	0.95	1.43	0.039
1400	4.65	1.2	1.306184	0.3	100	70.81	1.41	1.25	1	6.49	10.339	2.48	32.2	1387.04	1391.69	0.6039	0.7246	A	0.95	1.43	0.039
1300	4.57	1.2	1.306184	0.3	100	69.83	1.43	1.25	1	7.59	12.056	2.48	32.2	1386	1390.57	0.8896	1.0675	A	0.95	1.43	0.039
1200	4.84	1.2	1.306184	0.3	100,000	69.89	1,430.82	0.65	1	7.38	6.052	2.48	32.2	1384.26	1389.1	0.0815	0.0978	A	0.95	1.43	0.039
1100	6.04	1.2	1.306184	0.3	100	73.83	1.35	1.26	1	5.28	8.486	2.48	32.2	1382.52	1388.56	0.3462	0.4155	A	0.95	1.43	0.039
1000	6.55	1.2	1.306184	0.3	100	77.03	1.30	1.26	1	4.62	7.492	2.48	32.2	1381.89	1388.44	0.2492	0.2990	A	0.95	1.43	0.039
900	3.76	1.2	1.306184	0.3	100,000	60.28	1,658.93	0.64	1	9.82	8.052	2.48	32.2	1379.25	1383.01	0.1739	0.2086	A	0.95	1.43	0.039
800	3.68	1.2	1.306184	0.3	100,000	58.9	1,697.79	0.64	1	9.74	7.987	2.48	32.2	1376.05	1379.73	0.1707	0.2049	A	0.95	1.43	0.039
700	3.65	1.2	1.306184	0.3	100,000	58.91	1,697.50	0.64	1	9.81	8.044	2.48	32.2	1370.7	1374.35	0.1742	0.2090	A	0.95	1.43	0.039
600	3.79	1.2	1.306184	0.3	100,000	115.15	868.43	0.70	1	8.49	6.962	2.48	32.2	1363.7	1367.49	0.1312	0.1574	A	0.95	1.43	0.039
500	3.17	1.2	1.306184	0.3	265	82.48	3.21	1.18	1	8.76	11.516	2.48	32.2	1352.06	1355.23	0.8206	0.9847	C	1.8	2.70	0.044
400	3.62	1.2	1.306184	0.3	265	76.05	3.48	1.17	1	9	11.584	2.48	32.2	1345.59	1349.21	0.8008	0.9609	C	1.8	2.70	0.044
300	4.19	1.2	1.306184	0.3	265	81.19	3.26	1.18	1	8.95	11.718	2.48	32.2	1338.63	1342.82	0.7984	0.9581	C	1.8	2.70	0.044
200	4.22	1.2	1.306184	0.3	265	74.02	3.58	1.17	1	9.26	11.834	2.48	32.2	1333.77	1337.99	0.8112	0.9735	C	1.8	2.70	0.044
100	5.76	1.2	1.306184	0.3	265	69.82	3.80	1.17	1	9.5	11.953	2.48	32.2	1326.54	1332.3	0.7662	0.9194	C	1.8	2.70	0.044

Appendix D

HEC RAS

D1. ***Geometry***

D2. ***Summary Table***

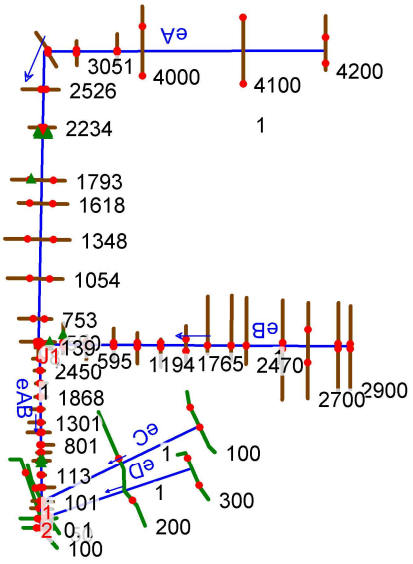
D3. ***Profile***

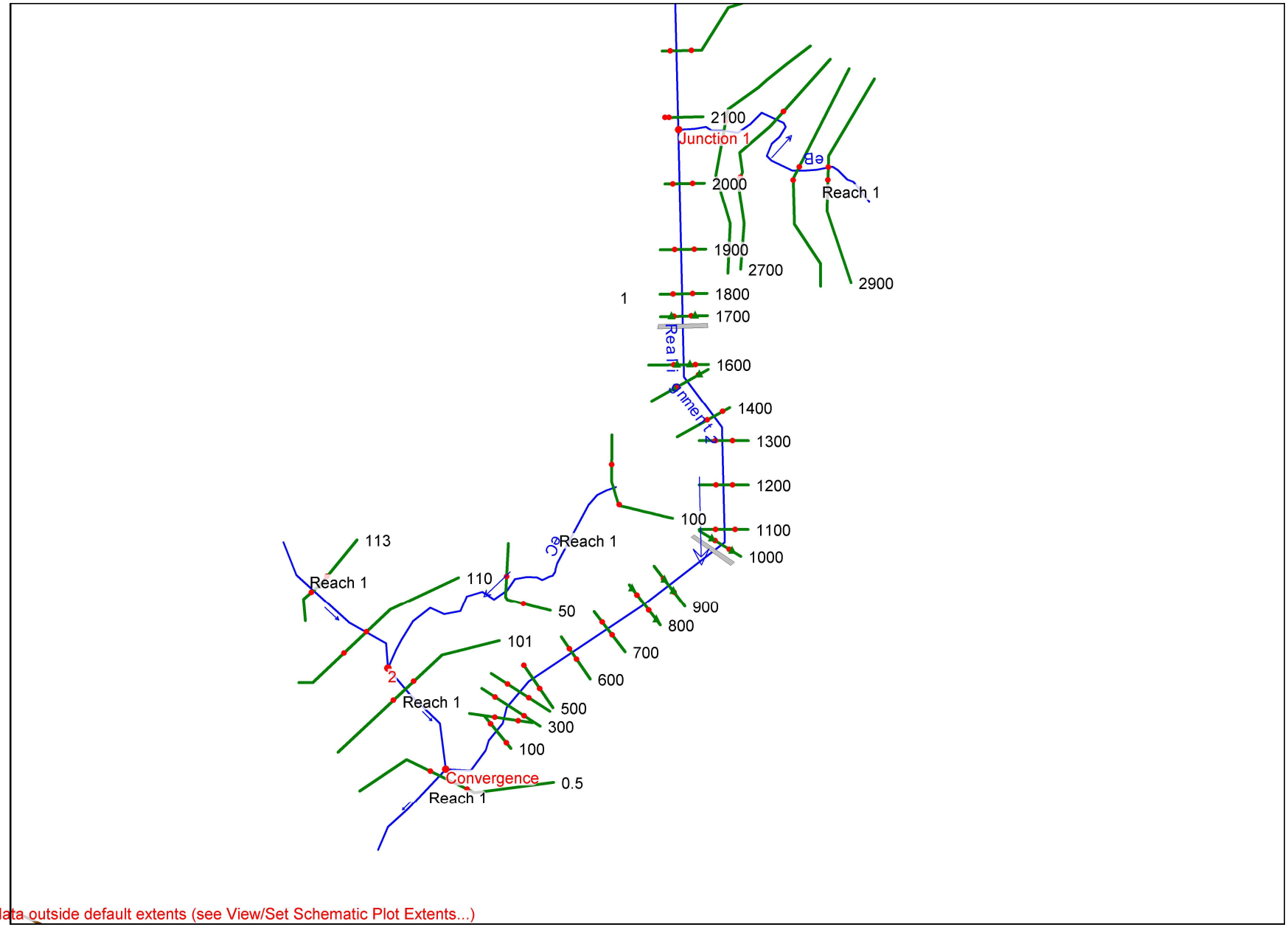
D4. ***Cross Sections***

D5. ***Existing HEC RAS Report***

D6. ***Proposed HEC RAS Report***

D7. ***Ineffective Flow Areas***


eA
3051
4000
4100
4200
2526
2234
1
1793
1618
1348
1054
753
eB
139
595
1194
1765
2470
2700
2900
2450
1868
1301
801
113
101
100
eC
eD
1
100
300
200
0.1



Some schematic data outside default extents (see View/Set Schematic Plot Extents...)

HEC-RAS Plan: exbridge

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eSRC-D	1	0.5	10 yr	7460.00	1310.99	1318.13	1317.14	1319.62	0.003820	9.89	810.19	199.71	0.72
eSRC-D	1	0.5	100 yr	18900.00	1310.99	1323.19	1321.09	1324.97	0.002294	11.57	2121.36	345.95	0.62
eSRC-D	1	0.5	25-year	11500.00	1310.99	1320.35	1318.96	1321.87	0.002723	10.32	1301.51	237.32	0.64
eSRC-D	1	0.5	50-year	15000.00	1310.99	1321.89	1320.02	1323.51	0.002374	10.82	1706.77	297.74	0.61
eSRC-D	1	0.1	10 yr	7460.00	1310.98	1317.18	1317.01	1319.35	0.006807	11.84	642.70	149.13	0.93
eSRC-D	1	0.1	100 yr	18900.00	1310.98	1321.46	1321.46	1324.70	0.004783	14.98	1505.89	286.59	0.87
eSRC-D	1	0.1	25-year	11500.00	1310.98	1318.73	1318.73	1321.57	0.006330	13.67	894.33	174.37	0.94
eSRC-D	1	0.1	50-year	15000.00	1310.98	1319.94	1319.94	1323.20	0.005899	14.77	1125.13	213.81	0.93
eSRC-CD	1	101	10 yr	7460.00	1312.87	1319.77	1319.77	1322.17	0.007782	12.44	603.98	138.37	0.99
eSRC-CD	1	101	100 yr	18900.00	1312.87	1324.31	1324.31	1327.03	0.004173	14.11	1707.02	321.59	0.81
eSRC-CD	1	101	25-year	11500.00	1312.87	1321.82	1321.82	1324.35	0.005336	13.01	993.84	241.04	0.87
eSRC-CD	1	101	50-year	15000.00	1312.87	1322.79	1322.76	1325.75	0.005436	14.32	1238.84	265.51	0.90
eSRC-CD	1	50	10 yr	7460.00	1311.37	1320.00		1320.69	0.001579	6.70	1112.69	173.17	0.47
eSRC-CD	1	50	100 yr	18900.00	1311.37	1324.38		1325.84	0.001707	9.80	2039.62	238.28	0.53
eSRC-CD	1	50	25-year	11500.00	1311.37	1321.81		1322.81	0.001640	8.00	1462.63	211.28	0.49
eSRC-CD	1	50	50-year	15000.00	1311.37	1323.17		1324.38	0.001636	8.86	1759.67	225.58	0.51
eD	1	300	10 yr	69.40	1338.63	1339.40	1339.40	1339.69	0.028526	4.33	16.04	27.91	1.01
eD	1	300	100 yr	159.00	1338.63	1339.85	1339.85	1340.28	0.025011	5.25	30.26	35.63	1.01
eD	1	300	25-year	104.00	1338.63	1339.59	1339.59	1339.95	0.026723	4.77	21.83	31.28	1.01
eD	1	300	50-year	131.00	1338.63	1339.73	1339.73	1340.12	0.025807	5.03	26.05	33.52	1.01
eD	1	200	10 yr	69.40	1333.77	1334.53	1334.53	1334.81	0.029375	4.20	16.53	30.79	1.01
eD	1	200	100 yr	159.00	1333.77	1334.95	1334.95	1335.37	0.025275	5.22	30.45	36.47	1.01
eD	1	200	25-year	104.00	1333.77	1334.71	1334.71	1335.05	0.027035	4.67	22.29	33.26	1.00
eD	1	200	50-year	131.00	1333.77	1334.83	1334.83	1335.22	0.026142	4.97	26.37	34.90	1.01
eD	1	100	10 yr	69.40	1326.54	1328.74	1328.74	1329.14	0.029601	5.02	13.82	18.36	1.02
eD	1	100	100 yr	159.00	1326.54	1329.35	1329.35	1329.86	0.025617	5.70	27.89	27.75	1.00
eD	1	100	25-year	104.00	1326.54	1329.02	1329.02	1329.46	0.027723	5.34	19.49	22.62	1.01
eD	1	100	50-year	131.00	1326.54	1329.20	1329.20	1329.67	0.026490	5.52	23.72	25.33	1.01
eC	1	100	10 yr	53.50	1376.83	1377.64	1377.64	1377.84	0.032891	3.61	14.84	37.85	1.02
eC	1	100	100 yr	122.00	1376.83	1377.95	1377.95	1378.22	0.029537	4.11	29.65	57.28	1.01
eC	1	100	25-year	79.80	1376.83	1377.77	1377.77	1378.01	0.031290	3.90	20.47	44.76	1.02
eC	1	100	50-year	101.00	1376.83	1377.87	1377.87	1378.12	0.030290	4.03	25.09	51.04	1.01
eC	1	50	10 yr	53.50	1350.72	1351.65	1351.65	1351.85	0.033349	3.56	15.01	39.35	1.02
eC	1	50	100 yr	122.00	1350.72	1351.94	1351.94	1352.23	0.029424	4.32	28.21	50.38	1.02

HEC-RAS Plan: exbridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eC	1	50	25-year	79.80	1350.72	1351.79	1351.79	1352.01	0.030697	3.80	20.98	46.87	1.00
eC	1	50	50-year	101.00	1350.72	1351.86	1351.86	1352.12	0.030805	4.12	24.49	48.61	1.02
eB	1	2900	10 yr	533.00	1396.85	1399.08		1399.14	0.003507	2.44	294.58	313.71	0.34
eB	1	2900	100 yr	1280.00	1396.85	1399.72		1399.83	0.004221	3.33	511.85	368.21	0.39
eB	1	2900	25-year	806.00	1396.85	1399.35		1399.43	0.003834	2.82	382.34	337.14	0.36
eB	1	2900	50-year	1030.00	1396.85	1399.54		1399.63	0.004016	3.07	447.22	353.64	0.37
eB	1	2800	10 yr	533.00	1396.00	1398.50	1398.19	1398.57	0.004846	2.64	286.21	387.79	0.39
eB	1	2800	100 yr	1280.00	1396.00	1399.15		1399.24	0.004083	3.10	557.20	443.05	0.38
eB	1	2800	25-year	806.00	1396.00	1398.78		1398.85	0.004418	2.83	397.01	417.08	0.38
eB	1	2800	50-year	1030.00	1396.00	1398.96		1399.05	0.004207	2.96	476.28	429.40	0.38
eB	1	2700	10 yr	533.00	1395.70	1397.50		1397.53	0.001911	1.34	400.12	398.31	0.23
eB	1	2700	100 yr	1280.00	1395.70	1398.20		1398.25	0.001944	1.88	708.89	510.97	0.25
eB	1	2700	25-year	806.00	1395.70	1397.79		1397.83	0.001944	1.57	520.40	425.24	0.24
eB	1	2700	50-year	1030.00	1395.70	1398.00		1398.04	0.001950	1.73	609.23	456.46	0.25
eB	1	2520	10 yr	533.00	1395.00	1397.02		1397.04	0.001449	1.47	475.28	504.80	0.21
eB	1	2520	100 yr	1280.00	1395.00	1397.71		1397.75	0.001445	1.90	848.14	563.19	0.23
eB	1	2520	25-year	806.00	1395.00	1397.31		1397.34	0.001428	1.64	627.15	529.79	0.22
eB	1	2520	50-year	1030.00	1395.00	1397.51		1397.55	0.001430	1.77	736.97	546.81	0.22
eB	1	2470	10 yr	533.00	1392.63	1395.90		1395.97	0.005014	3.38	268.62	305.65	0.39
eB	1	2470	100 yr	1280.00	1392.63	1396.54		1396.66	0.005296	4.10	495.86	393.55	0.42
eB	1	2470	25-year	806.00	1392.63	1396.17		1396.25	0.005285	3.74	356.53	345.20	0.41
eB	1	2470	50-year	1030.00	1392.63	1396.35		1396.45	0.005316	3.93	423.79	369.34	0.42
eB	1	2297	10 yr	533.00	1391.80	1395.03		1395.13	0.006987	3.71	225.70	269.06	0.46
eB	1	2297	100 yr	1280.00	1391.80	1395.79		1395.92	0.005508	4.06	459.10	346.64	0.43
eB	1	2297	25-year	806.00	1391.80	1395.36		1395.47	0.006079	3.82	318.26	302.26	0.44
eB	1	2297	50-year	1030.00	1391.80	1395.57		1395.70	0.005734	3.93	387.19	324.74	0.43
eB	1	2018	10 yr	533.00	1390.71	1394.11		1394.16	0.003137	2.68	292.30	255.71	0.28
eB	1	2018	100 yr	1280.00	1390.71	1394.81		1394.92	0.004278	3.63	492.64	321.78	0.34
eB	1	2018	25-year	806.00	1390.71	1394.40		1394.47	0.003724	3.11	369.38	280.86	0.31
eB	1	2018	50-year	1030.00	1390.71	1394.61		1394.70	0.004021	3.38	429.63	301.24	0.33
eB	1	1765	10 yr	533.00	1391.01	1391.93	1391.93	1392.22	0.037961	4.54	128.71	228.15	0.96
eB	1	1765	100 yr	1280.00	1391.01	1392.57		1392.91	0.019091	4.97	286.94	267.29	0.76
eB	1	1765	25-year	806.00	1391.01	1392.21	1392.12	1392.50	0.024885	4.59	193.65	244.71	0.82
eB	1	1765	50-year	1030.00	1391.01	1392.39	1392.26	1392.70	0.021285	4.76	239.56	255.77	0.78

HEC-RAS Plan: exbridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eB	1	1469	10 yr	533.00	1385.47	1389.47		1389.61	0.003950	3.34	200.49	148.47	0.38
eB	1	1469	100 yr	1280.00	1385.47	1390.43	1389.53	1390.64	0.004836	4.41	390.13	232.43	0.44
eB	1	1469	25-year	806.00	1385.47	1389.92		1390.10	0.004446	3.84	280.60	204.32	0.41
eB	1	1469	50-year	1030.00	1385.47	1390.18	1389.25	1390.37	0.004689	4.11	334.90	218.06	0.43
eB	1	1194	10 yr	533.00	1384.04	1387.12	1387.12	1387.67	0.020709	6.13	99.28	102.40	0.82
eB	1	1194	100 yr	1280.00	1384.04	1388.01	1388.01	1388.72	0.019567	7.54	213.86	157.41	0.85
eB	1	1194	25-year	806.00	1384.04	1387.53	1387.53	1388.13	0.020226	6.68	145.81	126.70	0.83
eB	1	1194	50-year	1030.00	1384.04	1387.78	1387.78	1388.43	0.019623	7.09	180.07	144.03	0.84
eB	1	914	10 yr	533.00	1379.43	1381.78	1381.78	1382.09	0.017938	5.23	142.66	222.47	0.75
eB	1	914	100 yr	1280.00	1379.43	1382.28	1382.28	1382.75	0.020524	6.78	268.44	270.77	0.84
eB	1	914	25-year	806.00	1379.43	1381.99	1381.99	1382.37	0.019374	5.93	191.60	244.18	0.80
eB	1	914	50-year	1030.00	1379.43	1382.15	1382.15	1382.55	0.019235	6.27	232.01	265.96	0.81
eB	1	595	10 yr	533.00	1369.31	1372.07	1372.07	1372.72	0.030253	6.54	83.69	68.61	0.96
eB	1	595	100 yr	1280.00	1369.31	1373.11	1373.11	1374.00	0.026785	7.82	174.41	102.34	0.96
eB	1	595	25-year	806.00	1369.31	1372.56	1372.56	1373.28	0.026948	6.97	122.31	86.95	0.94
eB	1	595	50-year	1030.00	1369.31	1372.85	1372.85	1373.64	0.026452	7.34	149.09	94.48	0.94
eB	1	299	10 yr	533.00	1356.50	1357.86	1357.86	1358.23	0.033763	5.33	111.84	165.22	0.96
eB	1	299	100 yr	1280.00	1356.50	1358.41	1358.41	1358.99	0.029592	6.74	216.69	186.72	0.97
eB	1	299	25-year	806.00	1356.50	1358.10	1358.10	1358.59	0.033203	6.10	146.48	173.94	0.98
eB	1	299	50-year	1030.00	1356.50	1358.28	1358.28	1358.75	0.027254	6.08	192.35	180.23	0.91
eB	1	139	10 yr	533.00	1347.51	1351.10	1350.25	1351.55	0.008311	5.47	102.44	40.39	0.57
eB	1	139	100 yr	1280.00	1347.51	1353.03	1351.78	1353.84	0.007877	7.49	183.02	43.53	0.60
eB	1	139	25-year	806.00	1347.51	1351.88	1350.88	1352.47	0.008173	6.36	134.31	41.49	0.58
eB	1	139	50-year	1030.00	1347.51	1352.45	1351.35	1353.15	0.008027	6.94	158.14	42.35	0.59
eB	1	125		Bridge									
eB	1	119	10 yr	533.00	1347.51	1350.26	1350.26	1351.21	0.028254	8.39	69.67	37.39	1.00
eB	1	119	100 yr	1280.00	1347.51	1351.78	1351.78	1353.36	0.023552	10.88	130.32	41.35	0.99
eB	1	119	25-year	806.00	1347.51	1350.88	1350.88	1352.09	0.026254	9.54	93.46	39.59	1.00
eB	1	119	50-year	1030.00	1347.51	1351.35	1351.35	1352.72	0.024238	10.16	112.42	40.75	0.99
eB	1	8	10 yr	533.00	1330.41	1332.59		1332.80	0.003454	4.52	166.31	123.03	0.57
eB	1	8	100 yr	1280.00	1330.41	1333.71		1334.04	0.003142	5.82	316.69	144.94	0.58
eB	1	8	25-year	806.00	1330.41	1333.15		1333.39	0.002780	4.80	239.42	134.74	0.53
eB	1	8	50-year	1030.00	1330.41	1333.44		1333.72	0.002916	5.29	279.31	140.10	0.55

HEC-RAS Plan: exbridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eAB	1	3070	10 yr	593.00	1326.35	1331.96	1331.96	1332.75	0.004548	7.66	113.24	98.16	0.70
eAB	1	3070	100 yr	1430.00	1326.35	1333.21	1333.21	1333.99	0.004350	9.08	294.71	166.50	0.71
eAB	1	3070	25-year	898.00	1326.35	1332.70	1332.70	1333.35	0.003586	7.67	212.81	154.93	0.64
eAB	1	3070	50-year	1150.00	1326.35	1332.95	1332.95	1333.68	0.004098	8.49	250.80	160.40	0.69
eAB	1	2985	10 yr	593.00	1325.92	1331.15	1330.37	1331.59	0.003269	6.54	177.93	167.05	0.59
eAB	1	2985	100 yr	1430.00	1325.92	1332.14		1332.61	0.003591	8.00	370.30	222.09	0.65
eAB	1	2985	25-year	898.00	1325.92	1331.52	1331.39	1332.03	0.003829	7.53	242.74	187.36	0.65
eAB	1	2985	50-year	1150.00	1325.92	1331.88		1332.34	0.003478	7.59	314.73	212.41	0.63
eAB	1	2713	10 yr	593.00	1324.58	1329.54	1329.39	1330.45	0.006774	8.26	91.02	51.40	0.83
eAB	1	2713	100 yr	1430.00	1324.58	1331.08	1330.91	1331.71	0.004033	8.35	311.51	172.14	0.69
eAB	1	2713	25-year	898.00	1324.58	1330.38	1330.38	1331.05	0.004394	7.82	197.36	158.49	0.70
eAB	1	2713	50-year	1150.00	1324.58	1330.65	1330.65	1331.38	0.004725	8.48	240.67	163.01	0.73
eAB	1	2450	10 yr	593.00	1323.34	1328.50		1329.05	0.004059	6.67	127.73	84.13	0.65
eAB	1	2450	100 yr	1430.00	1323.34	1329.51	1329.51	1330.55	0.006208	9.88	226.48	109.98	0.84
eAB	1	2450	25-year	898.00	1323.34	1328.92	1328.80	1329.68	0.005147	8.14	165.40	95.29	0.75
eAB	1	2450	50-year	1150.00	1323.34	1329.20	1329.16	1330.12	0.005905	9.15	192.62	102.19	0.81
eAB	1	2167	10 yr	593.00	1321.99	1327.21	1327.21	1327.89	0.004252	7.01	122.50	128.03	0.68
eAB	1	2167	100 yr	1430.00	1321.99	1328.91		1329.27	0.002021	6.35	421.43	214.38	0.50
eAB	1	2167	25-year	898.00	1321.99	1327.76	1327.76	1328.43	0.004055	7.57	202.06	163.30	0.68
eAB	1	2167	50-year	1150.00	1321.99	1328.08	1328.08	1328.76	0.004072	8.00	257.15	181.05	0.69
eAB	1	1868	10 yr	593.00	1320.55	1326.00	1325.29	1326.43	0.002631	5.71	144.18	97.63	0.53
eAB	1	1868	100 yr	1430.00	1320.55	1328.75		1328.92	0.000718	4.37	549.08	174.58	0.31
eAB	1	1868	25-year	898.00	1320.55	1327.15		1327.45	0.001520	5.23	284.90	155.65	0.43
eAB	1	1868	50-year	1150.00	1320.55	1327.87		1328.10	0.001075	4.84	400.27	163.86	0.37
eAB	1	1593	10 yr	593.00	1319.24	1324.38	1324.38	1325.34	0.006384	8.83	96.49	57.44	0.82
eAB	1	1593	100 yr	1430.00	1319.24	1328.62		1328.76	0.000553	4.35	634.40	198.95	0.27
eAB	1	1593	25-year	898.00	1319.24	1326.89		1327.11	0.001023	5.02	328.09	145.97	0.36
eAB	1	1593	50-year	1150.00	1319.24	1327.67		1327.86	0.000812	4.84	453.25	174.82	0.32
eAB	1	1301	10 yr	593.00	1317.84	1324.04		1324.31	0.001536	4.99	197.37	113.45	0.42
eAB	1	1301	100 yr	1430.00	1317.84	1328.65		1328.67	0.000095	1.99	1297.21	276.59	0.12
eAB	1	1301	25-year	898.00	1317.84	1326.94		1326.97	0.000132	2.04	842.66	256.41	0.13
eAB	1	1301	50-year	1150.00	1317.84	1327.71		1327.74	0.000117	2.05	1043.05	266.10	0.13
eAB	1	1079	10 yr	593.00	1316.77	1324.11		1324.15	0.000180	1.66	604.24	403.81	0.14

HEC-RAS Plan: exbridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eAB	1	1079	100 yr	1430.00	1316.77	1328.65		1328.66	0.000018	0.86	2667.38	485.42	0.05
eAB	1	1079	25-year	898.00	1316.77	1326.95		1326.96	0.000021	0.80	1857.73	465.26	0.05
eAB	1	1079	50-year	1150.00	1316.77	1327.72		1327.72	0.000020	0.84	2217.84	474.54	0.05
eAB	1	801	10 yr	593.00	1315.44	1324.09		1324.12	0.000092	1.55	675.69	256.85	0.11
eAB	1	801	100 yr	1430.00	1315.44	1328.64		1328.66	0.000026	1.20	2011.84	327.29	0.06
eAB	1	801	25-year	898.00	1315.44	1326.94		1326.95	0.000025	1.05	1474.81	303.94	0.06
eAB	1	801	50-year	1150.00	1315.44	1327.71		1327.72	0.000027	1.14	1711.46	314.44	0.06
eAB	1	636	10 yr	593.00	1314.65	1324.09		1324.10	0.000059	1.35	744.75	201.43	0.09
eAB	1	636	100 yr	1430.00	1314.65	1328.64		1328.65	0.000028	1.29	1919.48	295.98	0.07
eAB	1	636	25-year	898.00	1314.65	1326.94		1326.95	0.000025	1.11	1428.70	273.81	0.06
eAB	1	636	50-year	1150.00	1314.65	1327.70		1327.72	0.000028	1.23	1644.32	290.16	0.07
eAB	1	448	10 yr	593.00	1314.03	1324.05	1317.42	1324.09	0.000065	1.54	393.79	155.88	0.10
eAB	1	448	100 yr	1430.00	1314.03	1328.63	1319.25	1328.65	0.000027	1.33	1762.53	337.08	0.07
eAB	1	448	25-year	898.00	1314.03	1326.93	1318.40	1326.94	0.000022	1.09	1253.52	267.36	0.06
eAB	1	448	50-year	1150.00	1314.03	1327.69	1318.82	1327.71	0.000026	1.23	1467.74	293.67	0.07
eAB	1	400		Culvert									
eAB	1	373	10 yr	593.00	1313.81	1323.45	1318.04	1323.77	0.000439	4.58	141.03	63.13	0.27
eAB	1	373	100 yr	1430.00	1313.81	1328.42	1321.21	1328.60	0.000218	4.29	590.39	81.59	0.20
eAB	1	373	25-year	898.00	1313.81	1325.49	1319.27	1325.97	0.000508	5.62	178.76	81.59	0.29
eAB	1	373	50-year	1150.00	1313.81	1327.13	1320.20	1327.31	0.000233	4.17	484.87	81.59	0.20
eAB	1	113	10 yr	593.00	1313.38	1323.58		1323.60	0.000048	1.35	645.04	146.75	0.08
eAB	1	113	100 yr	1430.00	1313.38	1328.49		1328.51	0.000032	1.51	1391.23	152.86	0.07
eAB	1	113	25-year	898.00	1313.38	1325.70		1325.72	0.000037	1.38	964.91	152.86	0.08
eAB	1	113	50-year	1150.00	1313.38	1327.19		1327.21	0.000033	1.42	1193.66	152.86	0.07
eAB	1	110	10 yr	7460.00	1313.04	1322.41		1323.25	0.001608	8.29	1211.99	213.38	0.49
eAB	1	110	100 yr	18900.00	1313.04	1326.31		1328.03	0.002218	12.41	2087.23	235.68	0.61
eAB	1	110	25-year	11500.00	1313.04	1324.26		1325.34	0.001704	9.68	1616.19	223.86	0.52
eAB	1	110	50-year	15000.00	1313.04	1325.49		1326.81	0.001840	10.82	1895.33	230.81	0.55
eA	1	4200	10 yr	117.00	1410.00	1411.14	1410.81	1411.19	0.005189	1.84	63.58	111.46	0.43
eA	1	4200	100 yr	272.00	1410.00	1411.54	1411.13	1411.62	0.005726	2.36	115.36	150.13	0.47
eA	1	4200	25-year	176.00	1410.00	1411.32	1410.95	1411.39	0.005406	2.07	85.04	128.90	0.45
eA	1	4200	50-year	223.00	1410.00	1411.44	1411.05	1411.51	0.005543	2.22	100.61	140.21	0.46
eA	1	4100	10 yr	117.00	1404.00	1404.26	1404.26	1404.39	0.037110	2.81	41.68	169.62	1.00

HEC-RAS Plan: exbridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eA	1	4100	100 yr	272.00	1404.00	1404.45	1404.45	1404.66	0.031476	3.61	75.41	186.24	1.00
eA	1	4100	25-year	176.00	1404.00	1404.34	1404.34	1404.50	0.034660	3.19	55.22	176.48	1.00
eA	1	4100	50-year	223.00	1404.00	1404.40	1404.40	1404.58	0.033447	3.43	65.02	181.29	1.01
eA	1	4000	10 yr	117.00	1396.00	1397.41		1397.43	0.001919	1.29	91.00	129.54	0.27
eA	1	4000	100 yr	272.00	1396.00	1397.99		1398.02	0.001641	1.50	181.68	183.04	0.26
eA	1	4000	25-year	176.00	1396.00	1397.66		1397.69	0.001769	1.38	127.42	153.29	0.27
eA	1	4000	50-year	223.00	1396.00	1397.83		1397.86	0.001698	1.44	154.55	168.83	0.27
eA	1	3354	10 yr	144.00	1394.58	1396.24	1396.14	1396.51	0.011838	4.60	34.92	46.19	0.73
eA	1	3354	100 yr	336.00	1394.58	1396.83	1396.66	1397.19	0.012190	6.05	79.89	131.04	0.79
eA	1	3354	25-year	217.00	1394.58	1396.50	1396.39	1396.83	0.011821	5.21	48.03	56.78	0.75
eA	1	3354	50-year	275.00	1394.58	1396.66	1396.61	1397.03	0.012125	5.65	58.59	91.99	0.77
eA	1	3051	10 yr	144.00	1392.10	1393.34		1393.49	0.008281	3.43	48.13	79.84	0.60
eA	1	3051	100 yr	336.00	1392.10	1393.76	1393.60	1394.01	0.008998	4.49	86.49	104.59	0.66
eA	1	3051	25-year	217.00	1392.10	1393.52	1393.37	1393.72	0.008779	3.94	63.49	90.56	0.63
eA	1	3051	50-year	275.00	1392.10	1393.65	1393.49	1393.87	0.008793	4.21	75.39	98.07	0.64
eA	1	2837	10 yr	144.00	1389.26	1390.56	1390.56	1390.86	0.020010	4.60	33.26	57.86	0.89
eA	1	2837	100 yr	336.00	1389.26	1391.02	1391.02	1391.46	0.016238	5.59	64.22	74.56	0.87
eA	1	2837	25-year	217.00	1389.26	1390.76	1390.76	1391.12	0.017795	5.03	45.88	65.18	0.88
eA	1	2837	50-year	275.00	1389.26	1390.89	1390.89	1391.30	0.017255	5.36	54.66	69.83	0.88
eA	1	2526	10 yr	144.00	1367.69	1369.04	1369.04	1369.24	0.017259	3.93	41.05	90.24	0.81
eA	1	2526	100 yr	336.00	1367.69	1369.35	1369.35	1369.71	0.018127	5.12	71.41	103.23	0.89
eA	1	2526	25-year	217.00	1367.69	1369.16	1369.16	1369.44	0.018854	4.57	52.57	95.38	0.87
eA	1	2526	50-year	275.00	1367.69	1369.25	1369.25	1369.58	0.018887	4.90	61.59	99.22	0.89
eA	1	2234	10 yr	144.00	1350.00	1351.72	1351.72	1352.28	0.023597	5.98	24.09	22.10	1.01
eA	1	2234	100 yr	336.00	1350.00	1352.59	1352.59	1353.40	0.020813	7.21	46.65	29.64	1.01
eA	1	2234	25-year	217.00	1350.00	1352.11	1352.11	1352.77	0.022253	6.52	33.28	25.63	1.01
eA	1	2234	50-year	275.00	1350.00	1352.37	1352.37	1353.09	0.021281	6.82	40.30	28.03	1.00
eA	1	2147	10 yr	144.00	1349.24	1351.26	1350.82	1351.51	0.008579	4.02	35.79	26.76	0.61
eA	1	2147	100 yr	336.00	1349.24	1352.22	1351.66	1352.65	0.008415	5.26	63.89	31.35	0.65
eA	1	2147	25-year	217.00	1349.24	1351.70	1351.18	1352.01	0.008229	4.50	48.19	29.49	0.62
eA	1	2147	50-year	275.00	1349.24	1351.96	1351.43	1352.34	0.008318	4.90	56.13	30.44	0.64
eA	1	2140		Bridge									
eA	1	2130	10 yr	144.00	1348.64	1351.11	1350.28	1351.30	0.004877	3.48	41.44	25.61	0.48

HEC-RAS Plan: exbridge (Continued)

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
eA	1	2130	100 yr	336.00	1348.64	1352.01	1351.27	1352.40	0.006721	5.05	66.52	29.60	0.59
eA	1	2130	25-year	217.00	1348.64	1351.53	1350.71	1351.79	0.005526	4.11	52.86	27.86	0.53
eA	1	2130	50-year	275.00	1348.64	1351.78	1351.00	1352.11	0.006136	4.59	59.88	28.76	0.56
eA	1	1793	10 yr	144.00	1347.00	1347.79	1347.79	1347.99	0.029299	3.50	41.14	100.75	0.97
eA	1	1793	100 yr	336.00	1347.00	1348.13	1348.11	1348.40	0.025116	4.15	80.88	136.43	0.95
eA	1	1793	25-year	217.00	1347.00	1347.93	1347.93	1348.17	0.029315	3.91	55.45	114.88	0.99
eA	1	1793	50-year	275.00	1347.00	1348.03	1348.02	1348.29	0.027049	4.05	67.93	125.91	0.97
eA	1	1618	10 yr	144.00	1345.01	1345.88		1345.95	0.005796	2.17	66.24	98.23	0.47
eA	1	1618	100 yr	336.00	1345.01	1346.36		1346.48	0.005870	2.84	118.30	118.60	0.50
eA	1	1618	25-year	217.00	1345.01	1346.09		1346.18	0.005772	2.47	87.82	107.15	0.48
eA	1	1618	50-year	275.00	1345.01	1346.23		1346.34	0.005823	2.67	103.16	113.05	0.49
eA	1	1348	10 yr	144.00	1343.10	1344.23		1344.30	0.006381	2.22	64.81	99.98	0.49
eA	1	1348	100 yr	336.00	1343.10	1344.70		1344.83	0.006399	2.81	119.46	129.69	0.52
eA	1	1348	25-year	217.00	1343.10	1344.43		1344.53	0.006506	2.51	86.44	112.68	0.51
eA	1	1348	50-year	275.00	1343.10	1344.57		1344.68	0.006461	2.67	102.89	121.45	0.51
eA	1	1054	10 yr	144.00	1340.65	1341.58	1341.45	1341.68	0.013259	2.62	55.02	114.89	0.67
eA	1	1054	100 yr	336.00	1340.65	1341.89	1341.75	1342.09	0.014499	3.62	92.79	128.51	0.75
eA	1	1054	25-year	217.00	1340.65	1341.72	1341.57	1341.86	0.013547	3.04	71.35	120.88	0.70
eA	1	1054	50-year	275.00	1340.65	1341.80	1341.66	1341.98	0.014084	3.34	82.25	124.76	0.73
eA	1	753	10 yr	144.00	1335.07	1335.87	1335.87	1336.08	0.029335	3.63	39.25	92.20	0.97
eA	1	753	100 yr	336.00	1335.07	1336.19	1336.19	1336.56	0.025111	4.85	69.20	96.46	0.99
eA	1	753	25-year	217.00	1335.07	1336.00	1336.00	1336.28	0.028121	4.22	51.08	93.90	1.00
eA	1	753	50-year	275.00	1335.07	1336.09	1336.09	1336.42	0.026295	4.54	60.31	95.21	0.99
eA	1	580	10 yr	144.00	1328.27	1332.83		1332.84	0.000084	0.76	218.62	132.65	0.07
eA	1	580	100 yr	336.00	1328.27	1334.07		1334.09	0.000086	0.94	403.18	165.83	0.08
eA	1	580	25-year	217.00	1328.27	1333.41		1333.42	0.000080	0.82	299.95	146.98	0.07
eA	1	580	50-year	275.00	1328.27	1333.75		1333.76	0.000084	0.89	351.38	156.67	0.08

HEC-RAS Plan: proposed realignment

River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Realignment 2	1	2000	10 yr	677.00	1391.09	1394.72		1394.82	0.001075	2.55	266.75	94.08	0.26
Realignment 2	1	2000	25-year	1023.00	1391.09	1395.71		1395.84	0.000913	2.86	363.53	100.06	0.25
Realignment 2	1	2000	50-year	1305.00	1391.09	1396.47		1396.62	0.000810	3.03	441.54	104.64	0.25
Realignment 2	1	2000	100-year	1616.00	1391.09	1397.28		1397.43	0.000719	3.17	528.61	120.63	0.24
Realignment 2	1	1900	10 yr	677.00	1390.49	1394.28		1394.42	0.001586	3.05	222.05	78.58	0.32
Realignment 2	1	1900	25-year	1023.00	1390.49	1395.33		1395.51	0.001320	3.35	308.24	84.91	0.30
Realignment 2	1	1900	50-year	1305.00	1390.49	1396.13		1396.32	0.001163	3.50	378.07	89.99	0.29
Realignment 2	1	1900	100-year	1616.00	1390.49	1396.97		1397.17	0.001030	3.62	455.38	95.40	0.28
Realignment 2	1	1800	10 yr	677.00	1390.09	1393.70		1393.89	0.001993	3.47	195.04	65.90	0.36
Realignment 2	1	1800	25-year	1023.00	1390.09	1394.84		1395.06	0.001678	3.73	274.11	72.75	0.34
Realignment 2	1	1800	50-year	1305.00	1390.09	1395.69		1395.92	0.001488	3.86	338.22	77.85	0.33
Realignment 2	1	1800	100-year	1616.00	1390.09	1396.57		1396.82	0.001325	3.95	409.01	83.13	0.31
Realignment 2	1	1700	10 yr	677.00	1389.89	1393.41	1391.91	1393.65	0.002584	3.88	174.62	60.58	0.40
Realignment 2	1	1700	25-year	1023.00	1389.89	1394.60	1392.50	1394.86	0.002060	4.08	250.71	67.70	0.37
Realignment 2	1	1700	50-year	1305.00	1389.89	1395.48	1392.92	1395.75	0.001784	4.18	312.42	72.96	0.36
Realignment 2	1	1700	100-year	1616.00	1389.89	1396.38	1393.34	1396.66	0.001531	4.25	380.71	78.38	0.34
Realignment 2	1	1650		Culvert									
Realignment 2	1	1600	10 yr	677.00	1389.48	1392.25	1391.53	1392.69	0.006290	5.29	128.02	54.78	0.61
Realignment 2	1	1600	25-year	1023.00	1389.48	1392.92	1392.12	1393.52	0.006463	6.19	165.14	58.79	0.64
Realignment 2	1	1600	50-year	1305.00	1389.48	1393.38	1392.53	1394.10	0.006637	6.81	191.51	61.57	0.66
Realignment 2	1	1600	100-year	1616.00	1389.48	1393.82	1392.95	1394.68	0.006755	7.45	216.97	64.20	0.68
Realignment 2	1	1500	10 yr	677.00	1388.78	1391.49	1391.04	1392.05	0.009308	5.98	113.27	53.98	0.73
Realignment 2	1	1500	25-year	1023.00	1388.78	1392.12	1391.65	1392.86	0.009544	6.89	148.56	58.19	0.76
Realignment 2	1	1500	50-year	1305.00	1388.78	1392.52	1392.07	1393.41	0.010034	7.58	172.23	60.59	0.79
Realignment 2	1	1500	100-year	1616.00	1388.78	1392.89	1392.46	1393.96	0.010614	8.27	195.48	62.86	0.83
Realignment 2	1	1400	10 yr	677.00	1387.04	1389.84		1390.34	0.007597	5.66	120.57	60.12	0.66
Realignment 2	1	1400	25-year	1023.00	1387.04	1390.60		1391.18	0.006904	6.18	173.26	79.02	0.65
Realignment 2	1	1400	50-year	1305.00	1387.04	1391.14		1391.75	0.006269	6.37	219.77	92.39	0.64
Realignment 2	1	1400	100-year	1616.00	1387.04	1391.69		1392.30	0.005660	6.49	273.71	107.91	0.61
Realignment 2	1	1300	10 yr	677.00	1386.00	1388.94		1389.44	0.007279	5.65	119.73	51.40	0.65
Realignment 2	1	1300	25-year	1023.00	1386.00	1389.67		1390.31	0.007371	6.43	159.04	56.69	0.68
Realignment 2	1	1300	50-year	1305.00	1386.00	1390.12		1390.89	0.007758	7.04	185.48	59.98	0.71
Realignment 2	1	1300	100-year	1616.00	1386.00	1390.57		1391.46	0.008056	7.59	213.01	63.23	0.73

HEC-RAS Plan: proposed realignment (Continued)

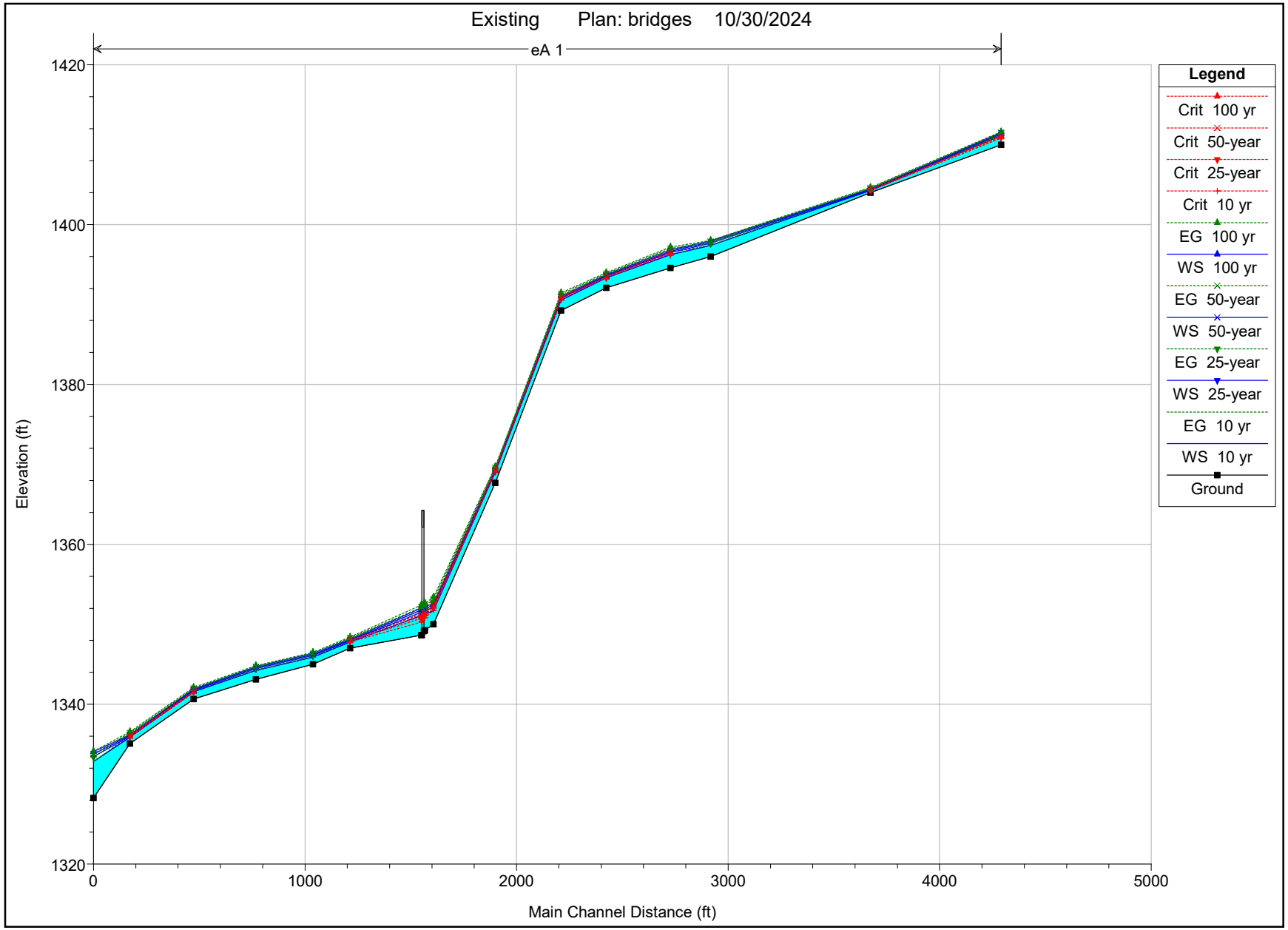
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Realignment 2	1	1200	10 yr	730.50	1384.26	1386.99		1387.66	0.010742	6.57	111.22	51.14	0.79
Realignment 2	1	1200	25-year	1102.80	1384.26	1387.71		1388.55	0.010332	7.34	150.16	56.60	0.79
Realignment 2	1	1200	50-year	1406.00	1384.26	1388.35		1389.22	0.008849	7.47	188.20	61.47	0.75
Realignment 2	1	1200	100-year	1738.00	1384.26	1389.10		1389.94	0.007096	7.38	235.65	66.36	0.69
Realignment 2	1	1100	10 yr	730.50	1382.52	1385.55		1386.00	0.006138	5.39	135.46	54.93	0.61
Realignment 2	1	1100	25-year	1102.80	1382.52	1386.73		1387.18	0.004197	5.39	204.73	62.28	0.52
Realignment 2	1	1100	50-year	1406.00	1382.52	1387.63		1388.07	0.003315	5.34	263.41	67.88	0.48
Realignment 2	1	1100	100-year	1738.00	1382.52	1388.56		1388.99	0.002696	5.28	329.11	73.65	0.44
Realignment 2	1	1000	10 yr	730.50	1381.89	1385.25	1384.02	1385.57	0.003751	4.54	160.80	58.15	0.48
Realignment 2	1	1000	25-year	1102.80	1381.89	1386.54	1384.66	1386.87	0.002647	4.58	240.66	65.87	0.42
Realignment 2	1	1000	50-year	1406.00	1381.89	1387.48	1385.11	1387.81	0.002175	4.60	305.53	71.54	0.39
Realignment 2	1	1000	100-year	1738.00	1381.89	1388.44	1385.53	1388.78	0.001788	4.62	376.94	77.29	0.36
Realignment 2	1	950		Culvert									
Realignment 2	1	900	10 yr	730.50	1373.00	1379.70	1377.13	1379.99	0.002098	4.27	171.03	42.12	0.37
Realignment 2	1	900	25-year	1102.80	1373.00	1380.59	1378.08	1381.01	0.002764	5.25	210.16	46.68	0.44
Realignment 2	1	900	50-year	1406.00	1373.00	1381.17	1378.73	1381.71	0.003234	5.90	238.30	49.95	0.48
Realignment 2	1	900	100-year	1738.00	1373.00	1381.72	1379.34	1382.38	0.003679	6.52	266.71	53.05	0.51
Realignment 2	1	800	10 yr	730.50	1376.05	1378.22	1378.22	1379.14	0.018093	7.70	94.91	50.94	0.99
Realignment 2	1	800	25-year	1102.80	1376.05	1378.83	1378.83	1380.00	0.017208	8.69	126.96	54.59	1.00
Realignment 2	1	800	50-year	1406.00	1376.05	1379.28	1379.28	1380.61	0.016340	9.24	152.21	57.30	1.00
Realignment 2	1	800	100-year	1738.00	1376.05	1379.73	1379.73	1381.20	0.015635	9.74	178.52	59.99	0.99
Realignment 2	1	700	10 yr	730.50	1370.70	1372.85	1372.85	1373.79	0.018591	7.76	94.08	50.85	1.01
Realignment 2	1	700	25-year	1102.80	1370.70	1373.47	1373.47	1374.65	0.017290	8.70	126.77	54.57	1.01
Realignment 2	1	700	50-year	1406.00	1370.70	1373.91	1373.91	1375.25	0.016608	9.29	151.39	57.21	1.01
Realignment 2	1	700	100-year	1738.00	1370.70	1374.35	1374.35	1375.85	0.016001	9.81	177.13	59.85	1.01
Realignment 2	1	600	10 yr	730.50	1363.70	1366.05	1366.05	1366.98	0.017837	7.71	95.35	58.69	0.99
Realignment 2	1	600	25-year	1102.80	1363.70	1366.84	1366.84	1367.66	0.011529	7.54	164.73	105.46	0.84
Realignment 2	1	600	50-year	1406.00	1363.70	1367.17	1367.17	1368.08	0.011479	8.04	200.96	111.72	0.85
Realignment 2	1	600	100-year	1738.00	1363.70	1367.49	1367.49	1368.47	0.011395	8.49	237.66	117.35	0.86
Realignment 2	1	500	10 yr	730.50	1352.06	1354.02	1354.02	1354.77	0.025088	6.97	104.85	70.28	1.01
Realignment 2	1	500	25-year	1102.80	1352.06	1354.52	1354.52	1355.46	0.023334	7.79	141.53	75.90	1.01
Realignment 2	1	500	50-year	1406.00	1352.06	1354.88	1354.88	1355.95	0.022254	8.29	169.60	79.94	1.00
Realignment 2	1	500	100-year	1738.00	1352.06	1355.23	1355.23	1356.42	0.021512	8.76	198.40	83.88	1.00

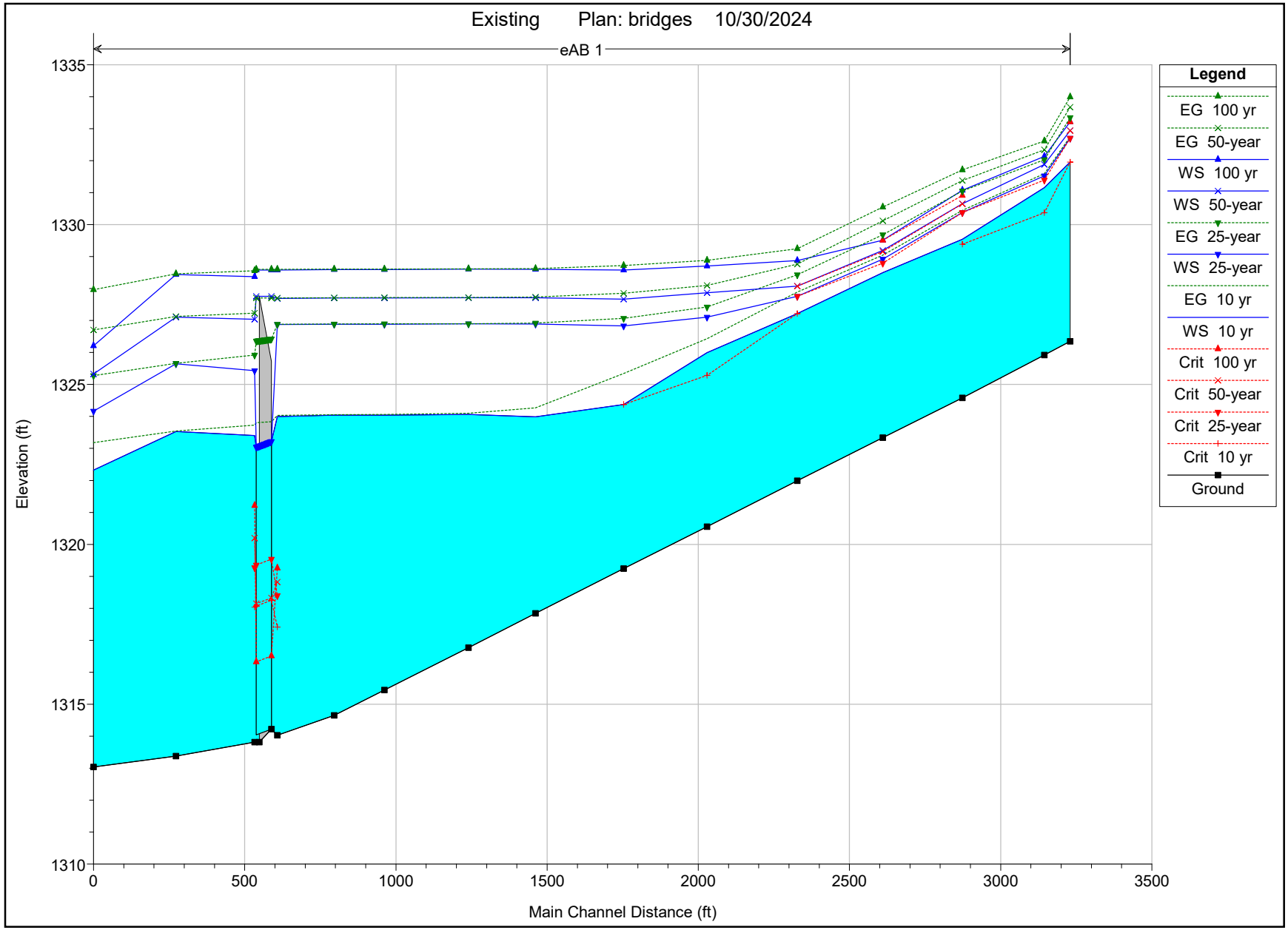
HEC-RAS Plan: proposed realignment (Continued)

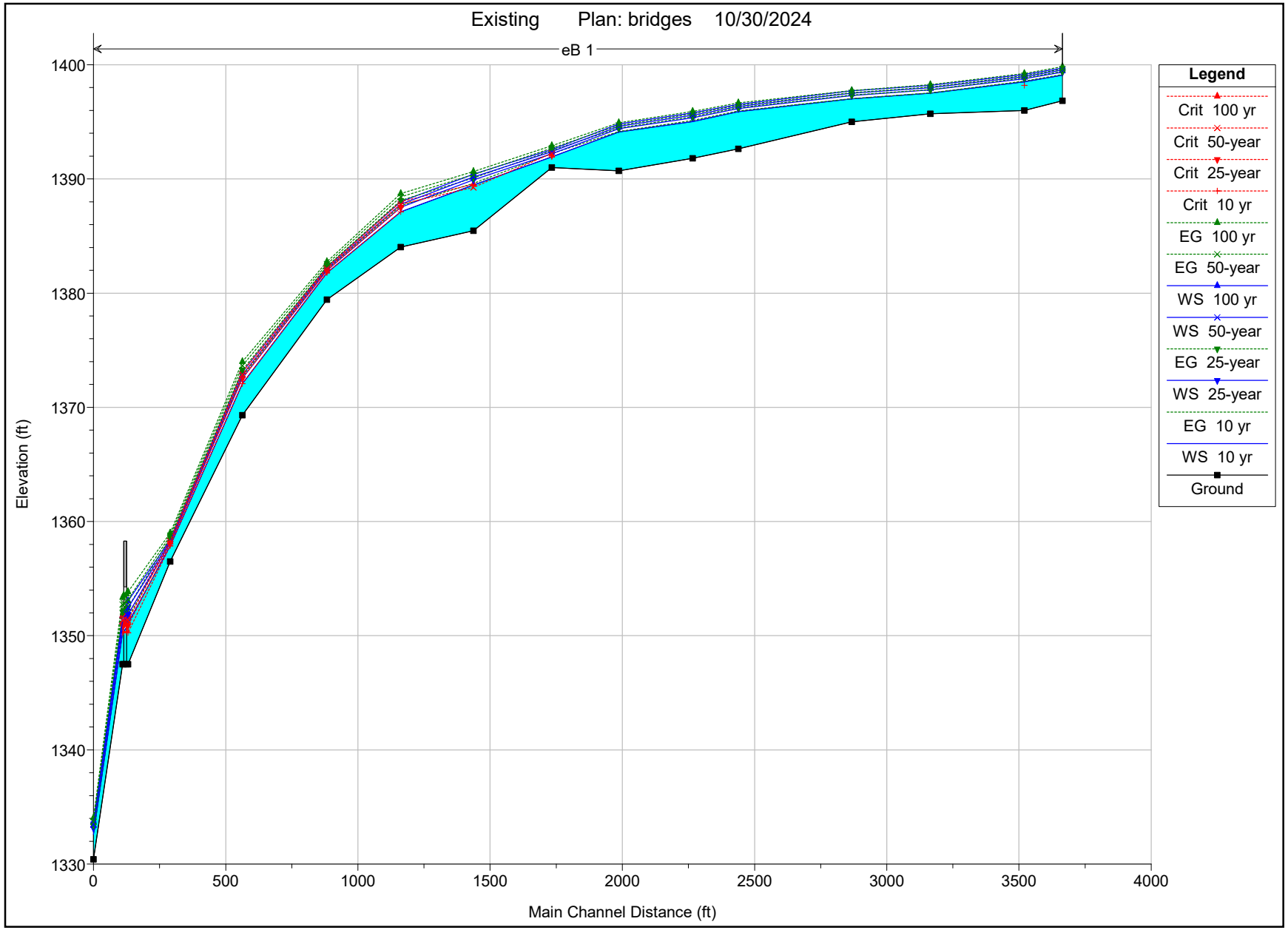
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Realignment 2	1	400	10 yr	730.50	1345.59	1347.85	1347.85	1348.69	0.024332	7.36	99.20	59.68	1.01
Realignment 2	1	400	25-year	1102.80	1345.59	1348.42	1348.42	1349.45	0.022842	8.11	135.93	67.41	1.01
Realignment 2	1	400	50-year	1406.00	1345.59	1348.82	1348.82	1349.97	0.022067	8.58	163.83	72.73	1.01
Realignment 2	1	400	100-year	1738.00	1345.59	1349.21	1349.21	1350.47	0.021327	9.00	193.17	77.85	1.01
Realignment 2	1	300	10 yr	799.90	1338.63	1341.45	1341.41	1342.28	0.022572	7.29	109.75	63.37	0.98
Realignment 2	1	300	25-year	1206.80	1338.63	1342.01	1342.01	1343.05	0.022865	8.16	147.88	72.76	1.01
Realignment 2	1	300	50-year	1537.00	1338.63	1342.43	1342.43	1343.57	0.021977	8.57	179.41	79.66	1.01
Realignment 2	1	300	100-year	1897.00	1338.63	1342.82	1342.82	1344.06	0.021313	8.95	212.06	86.22	1.01
Realignment 2	1	200	10 yr	799.90	1333.77	1336.51	1336.51	1337.43	0.023831	7.68	104.19	57.89	1.01
Realignment 2	1	200	25-year	1206.80	1333.77	1337.16	1337.16	1338.24	0.022028	8.35	144.59	66.78	1.00
Realignment 2	1	200	50-year	1537.00	1333.77	1337.59	1337.59	1338.79	0.021291	8.80	174.75	72.71	1.00
Realignment 2	1	200	100-year	1897.00	1333.77	1337.99	1337.99	1339.32	0.021046	9.26	204.83	78.18	1.01
Realignment 2	1	100	10 yr	799.90	1326.54	1330.92	1330.92	1331.79	0.025115	7.49	106.85	62.00	1.01
Realignment 2	1	100	25-year	1206.80	1326.54	1331.47	1331.47	1332.59	0.023825	8.47	142.46	66.03	1.02
Realignment 2	1	100	50-year	1537.00	1326.54	1331.91	1331.91	1333.15	0.022035	8.95	171.76	69.16	1.00
Realignment 2	1	100	100-year	1897.00	1326.54	1332.30	1332.30	1333.71	0.021410	9.50	199.78	72.03	1.01
Realignment 1	1	4200	10 yr	117.00	1410.00	1410.81	1410.81	1411.02	0.032227	3.65	32.05	79.14	1.01
Realignment 1	1	4200	25-year	176.00	1410.00	1410.95	1410.95	1411.20	0.030610	3.97	44.39	93.13	1.01
Realignment 1	1	4200	50-year	223.00	1410.00	1411.05	1411.05	1411.32	0.029760	4.16	53.57	102.31	1.01
Realignment 1	1	4200	100-year	272.00	1410.00	1411.41	1411.13	1411.53	0.009124	2.81	96.87	137.57	0.59
Realignment 1	1	4100	10 yr	117.00	1404.00	1404.48		1404.52	0.004712	1.45	80.79	188.76	0.39
Realignment 1	1	4100	25-year	176.00	1404.00	1404.61		1404.65	0.004785	1.67	105.09	199.73	0.41
Realignment 1	1	4100	50-year	223.00	1404.00	1404.69		1404.75	0.004828	1.82	122.61	207.27	0.42
Realignment 1	1	4100	100-year	272.00	1404.00	1404.58		1404.69	0.013669	2.75	99.06	197.06	0.68
Realignment 1	1	4000	10 yr	117.00	1396.00	1396.83	1396.83	1397.04	0.032214	3.70	31.60	76.34	1.01
Realignment 1	1	4000	25-year	176.00	1396.00	1396.98	1396.98	1397.23	0.030330	4.01	43.90	89.98	1.01
Realignment 1	1	4000	50-year	223.00	1396.00	1397.07	1397.07	1397.35	0.029153	4.19	53.21	99.06	1.01
Realignment 1	1	4000	100-year	272.00	1396.00	1397.52		1397.62	0.006806	2.55	106.57	140.19	0.52
Realignment 1	1	2500	10 yr	117.00	1394.09	1395.32		1395.35	0.001229	1.47	79.81	69.06	0.24
Realignment 1	1	2500	25-year	176.00	1394.09	1396.08		1396.10	0.000542	1.31	133.90	73.61	0.17
Realignment 1	1	2500	50-year	223.00	1394.09	1396.77		1396.79	0.000312	1.20	186.38	77.77	0.14
Realignment 1	1	2500	100-year	272.00	1394.09	1397.54		1397.55	0.000194	1.10	254.74	179.57	0.11
Realignment 1	1	2400	10 yr	117.00	1393.49	1394.99		1395.03	0.000942	1.44	81.15	58.82	0.22
Realignment 1	1	2400	25-year	176.00	1393.49	1395.94		1395.96	0.000399	1.26	139.52	65.65	0.15

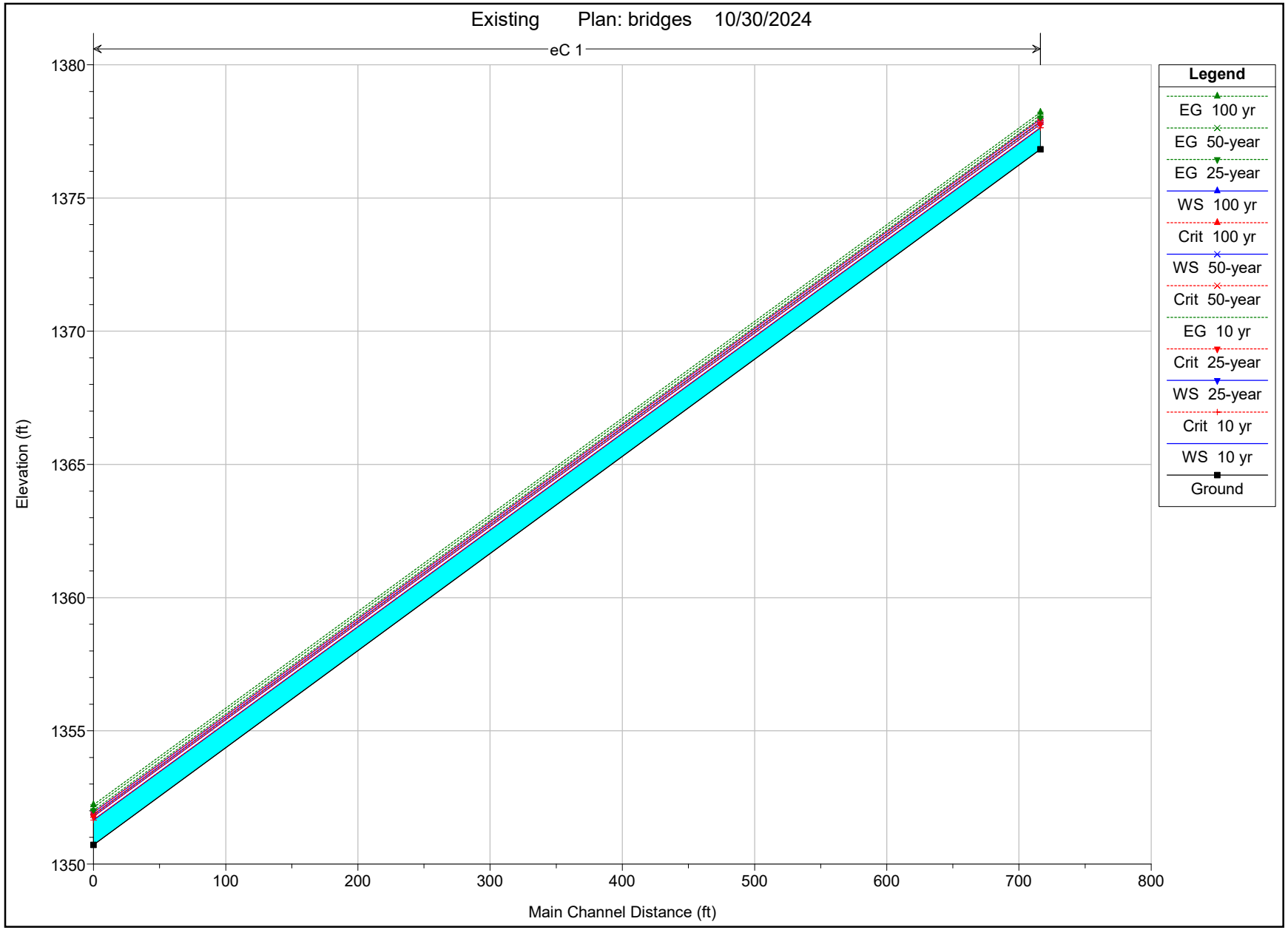
HEC-RAS Plan: proposed realignment (Continued)

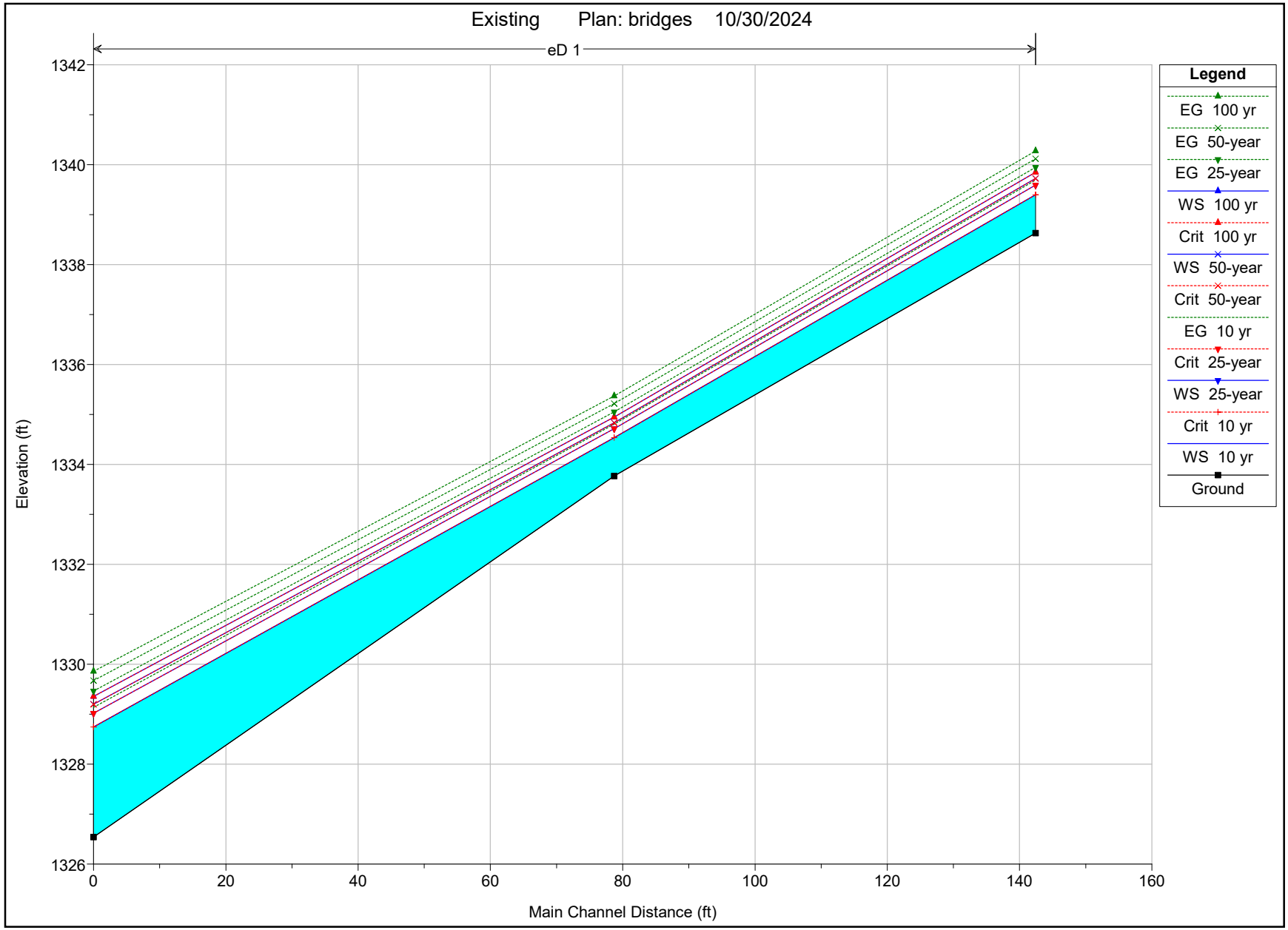
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Realignment 1	1	2400	50-year	223.00	1393.49	1396.69		1396.71	0.000243	1.17	193.08	77.27	0.12
Realignment 1	1	2400	100-year	272.00	1393.49	1397.48		1397.50	0.000158	1.09	259.53	89.61	0.10
Realignment 1	1	2300	10 yr	117.00	1392.89	1394.89		1394.90	0.000218	0.85	138.56	76.55	0.11
Realignment 1	1	2300	25-year	176.00	1392.89	1395.89		1395.90	0.000120	0.82	217.95	82.54	0.09
Realignment 1	1	2300	50-year	223.00	1392.89	1396.65		1396.66	0.000087	0.80	282.99	87.14	0.08
Realignment 1	1	2300	100-year	272.00	1392.89	1397.46		1397.47	0.000064	0.79	355.24	91.98	0.07
Realignment 1	1	2200	10 yr	117.00	1392.29	1394.87		1394.87	0.000056	0.50	250.52	150.45	0.06
Realignment 1	1	2200	25-year	176.00	1392.29	1395.88		1395.88	0.000031	0.48	433.23	211.01	0.05
Realignment 1	1	2200	50-year	223.00	1392.29	1396.65		1396.65	0.000021	0.45	613.95	257.25	0.04
Realignment 1	1	2200	100-year	272.00	1392.29	1397.46		1397.46	0.000014	0.41	842.02	305.78	0.03
Realignment 1	1	2100	10 yr	117.00	1391.69	1394.86		1394.86	0.000016	0.32	466.23	275.60	0.03
Realignment 1	1	2100	25-year	176.00	1391.69	1395.87		1395.87	0.000009	0.30	786.10	352.51	0.03
Realignment 1	1	2100	50-year	223.00	1391.69	1396.65		1396.65	0.000007	0.28	1079.11	405.64	0.02
Realignment 1	1	2100	100-year	272.00	1391.69	1397.46		1397.46	0.000005	0.26	1430.65	461.39	0.02
Main Channel 2	Reach 1	0.5	10 yr	7460.00	1311.37	1320.02		1320.71	0.001565	6.68	1116.23	173.38	0.46
Main Channel 2	Reach 1	0.5	25-year	11500.00	1311.37	1321.98		1322.93	0.001533	7.84	1497.13	212.99	0.48
Main Channel 2	Reach 1	0.5	50-year	15000.00	1311.37	1323.40		1324.54	0.001509	8.64	1810.02	227.92	0.49
Main Channel 2	Reach 1	0.5	100-year	18900.00	1311.37	1324.57		1325.97	0.001606	9.61	2084.30	240.25	0.51
Main Channel 2	Reach 1	0.1	10 yr	7460.00	1310.98	1317.18	1317.01	1319.35	0.006807	11.84	642.70	149.13	0.93
Main Channel 2	Reach 1	0.1	25-year	11500.00	1310.98	1318.73	1318.73	1321.57	0.006333	13.67	894.20	174.36	0.94
Main Channel 2	Reach 1	0.1	50-year	15000.00	1310.98	1319.94	1319.94	1323.20	0.005900	14.77	1125.00	213.78	0.93
Main Channel 2	Reach 1	0.1	100-year	18900.00	1310.98	1321.46	1321.46	1324.70	0.004784	14.98	1505.75	286.57	0.87
Main Channel 1.5	Reach 1	101	10 yr	7460.00	1312.87	1320.54	1319.77	1322.30	0.004697	10.66	726.73	173.46	0.79
Main Channel 1.5	Reach 1	101	25-year	11500.00	1312.87	1322.57	1321.82	1324.46	0.003561	11.38	1183.09	260.56	0.72
Main Channel 1.5	Reach 1	101	50-year	15000.00	1312.87	1323.82	1322.79	1325.88	0.003327	12.16	1548.91	319.14	0.72
Main Channel 1.5	Reach 1	101	100-year	18900.00	1312.87	1324.96	1324.32	1327.12	0.003118	12.75	1916.89	325.19	0.71
Main Channel 1.5	Reach 1	100	10 yr	7460.00	1312.87	1319.76	1319.76	1322.17	0.007828	12.46	602.82	137.97	0.99
Main Channel 1.5	Reach 1	100	25-year	11500.00	1312.87	1321.82	1321.82	1324.35	0.005343	13.02	993.28	240.97	0.87
Main Channel 1.5	Reach 1	100	50-year	15000.00	1312.87	1322.79	1322.79	1325.75	0.005424	14.31	1240.01	265.71	0.90
Main Channel 1.5	Reach 1	100	100-year	18900.00	1312.87	1324.32	1324.32	1327.03	0.004155	14.09	1710.16	321.63	0.81
Main Channel	Reach 1	113	10 yr	7460.00	1313.38	1324.17	1324.17	1326.58	0.005463	15.05	732.73	149.33	0.90
Main Channel	Reach 1	113	25-year	11500.00	1313.38	1325.89	1325.89	1328.85	0.005590	17.17	994.96	152.86	0.94
Main Channel	Reach 1	113	50-year	15000.00	1313.38	1327.05	1327.05	1330.55	0.005900	18.91	1171.44	152.86	0.98
Main Channel	Reach 1	113	100-year	18900.00	1313.38	1328.23	1328.23	1332.30	0.006118	20.54	1351.93	152.86	1.01

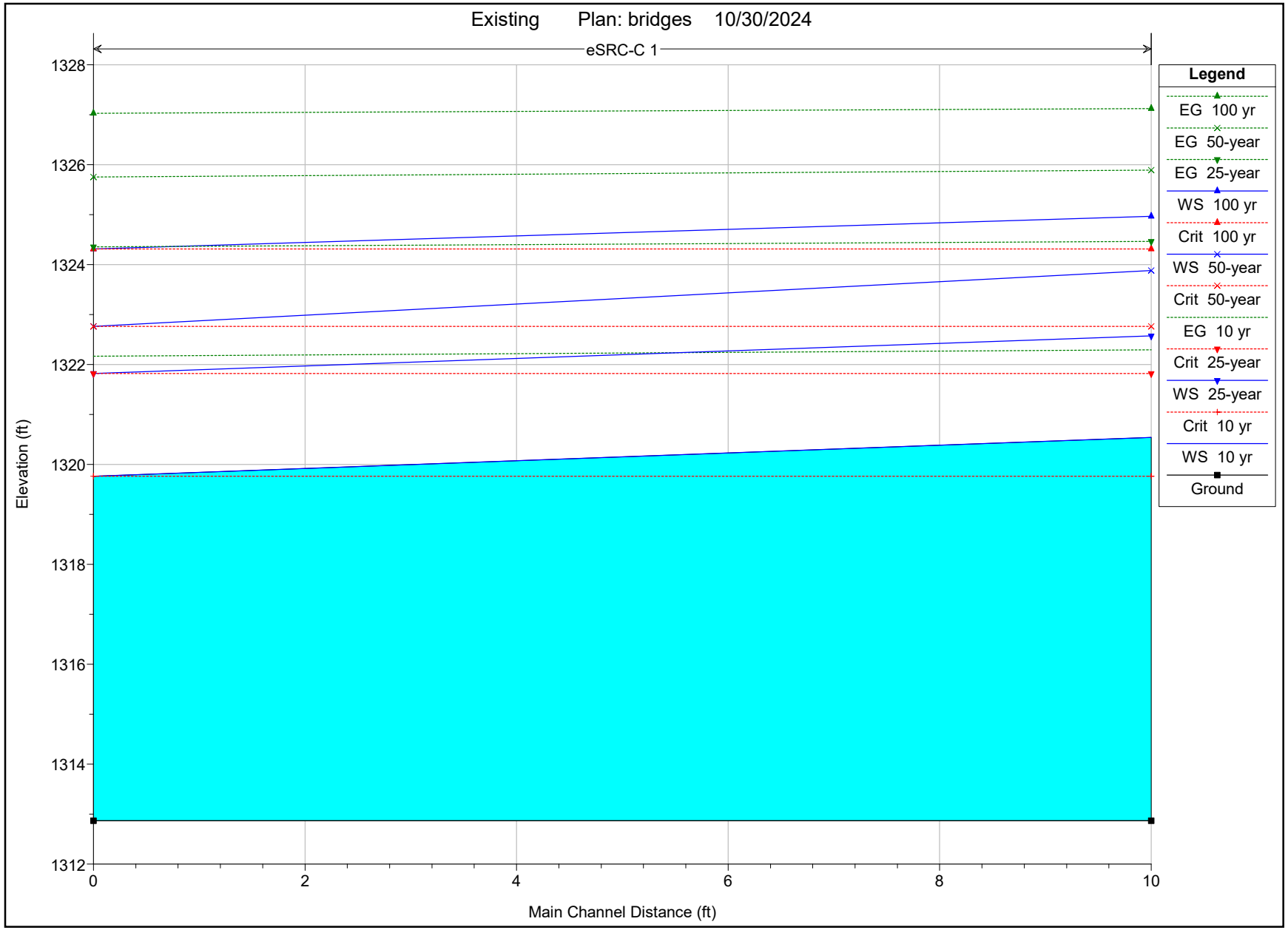

Existing Plan: bridges 10/30/2024
eA 1
1420
1400
1380
1360
1340
1320
Elevation (ft)
0
1000
2000
3000
4000
5000
Main Channel Distance (ft)
Legend
Crit 100 yr
Crit 50-year
Crit 25-year
Crit 10 yr
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground

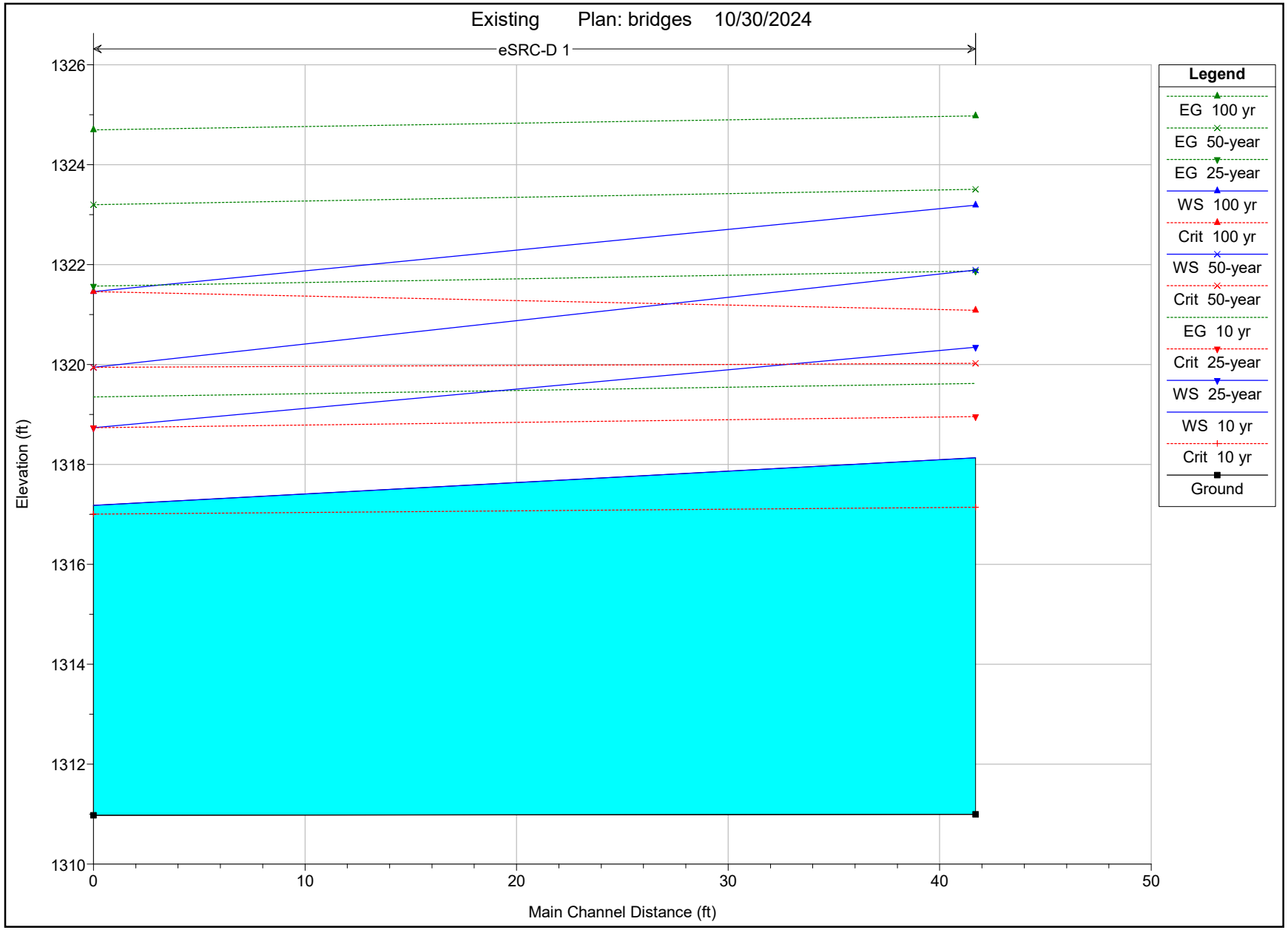

Existing Plan: bridges 10/30/2024
eAB 1
Elevation (ft)
1335
1330
1325
1320
1315
1310
0
500
1000
1500
2000
2500
3000
3500
Main Channel Distance (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 100 yr
Crit 50-year
Crit 25-year
Crit 10 yr
Ground

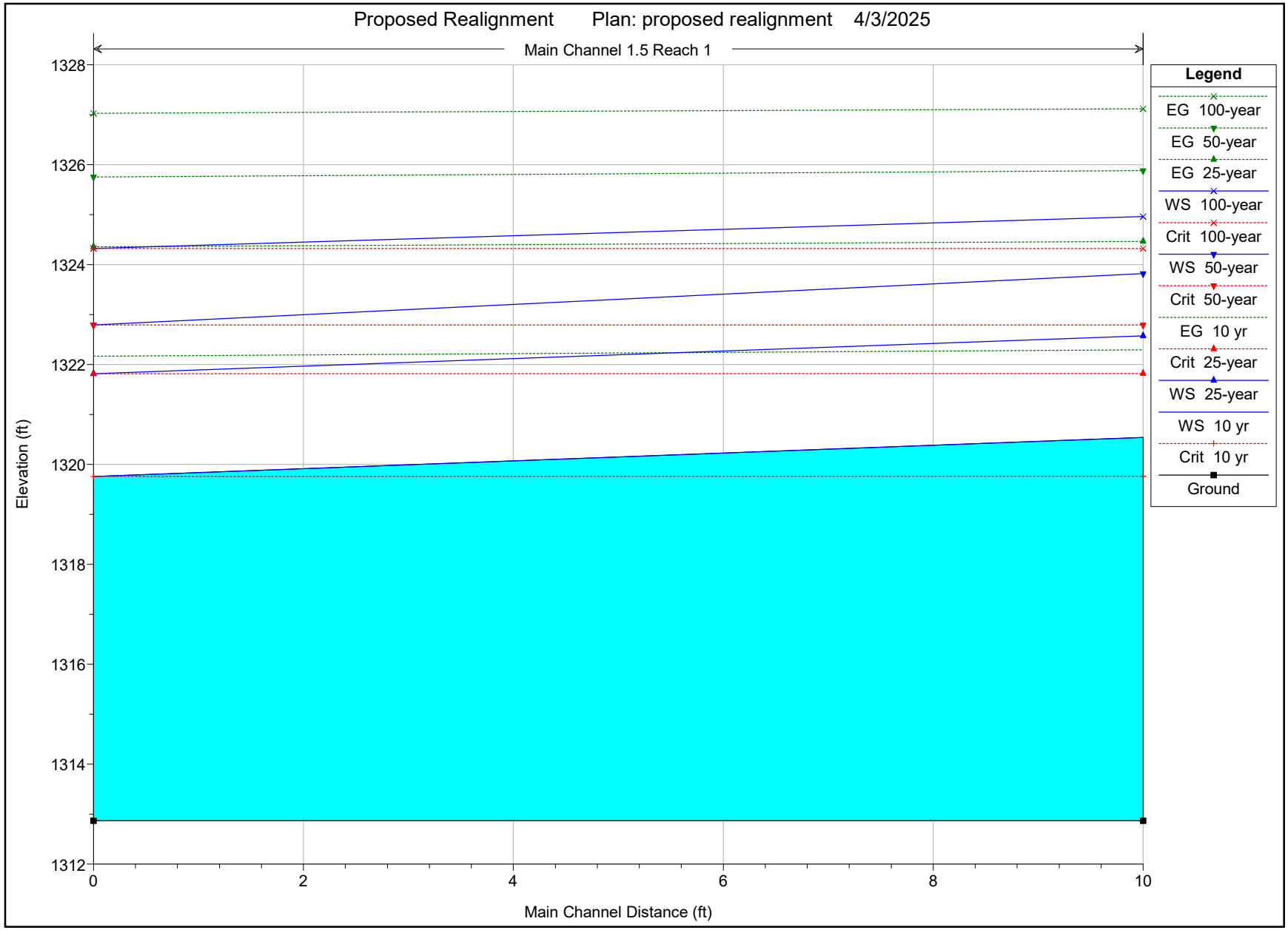

Existing Plan: bridges 10/30/2024
eB 1
Elevation (ft)
1400
1390
1380
1370
1360
1350
1340
1330
0
500
1000
1500
2000
2500
3000
3500
4000
Main Channel Distance (ft)
Legend
Crit 100 yr
Crit 50-year
Crit 25-year
Crit 10 yr
EG 100 yr
EG 50-year
WS 100 yr
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground

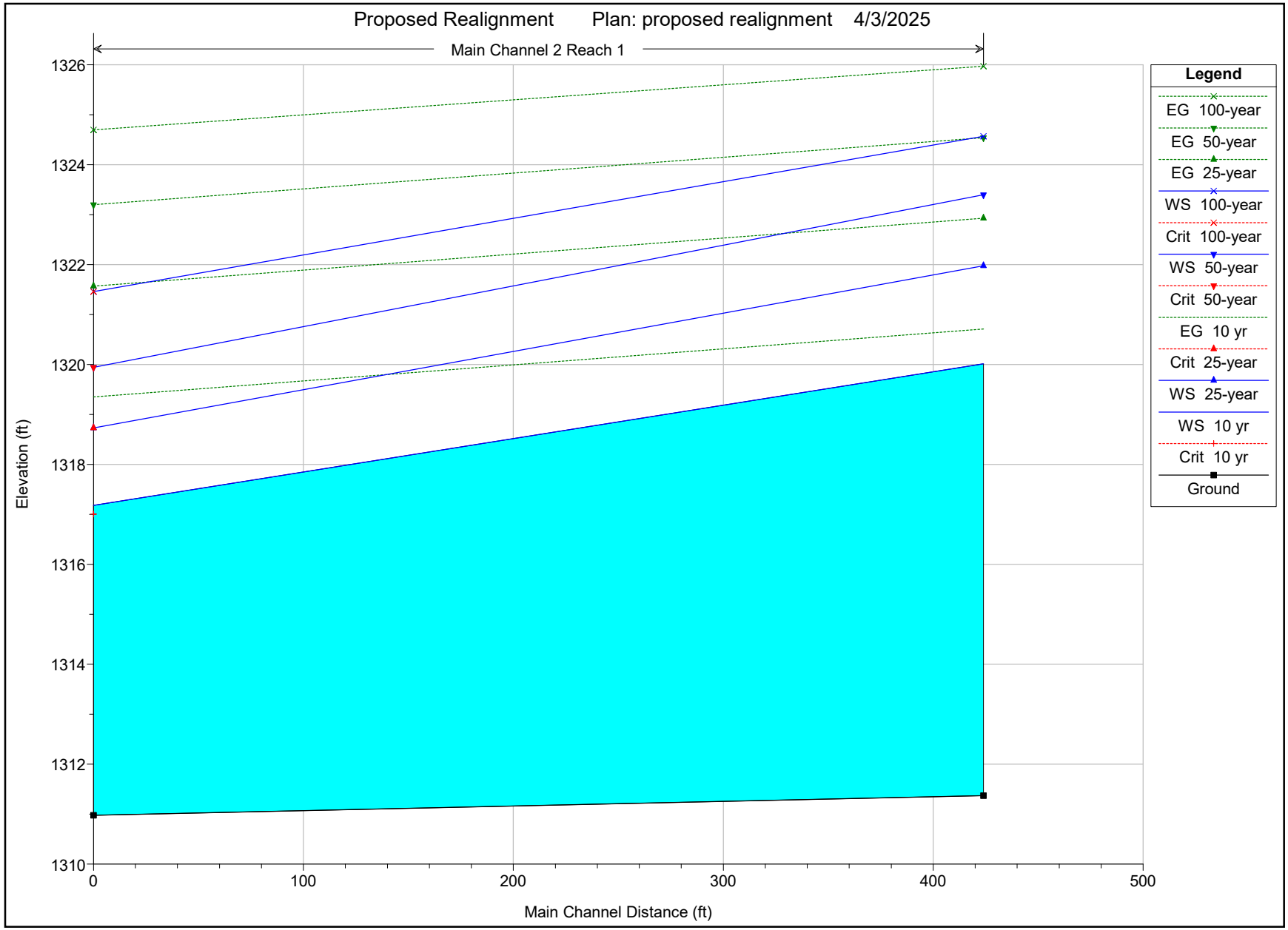

Existing Plan: bridges 10/30/2024
eC 1
Elevation (ft)
1380
1375
1370
1365
1360
1355
1350
0
100
200
300
400
500
600
700
800
Main Channel Distance (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground

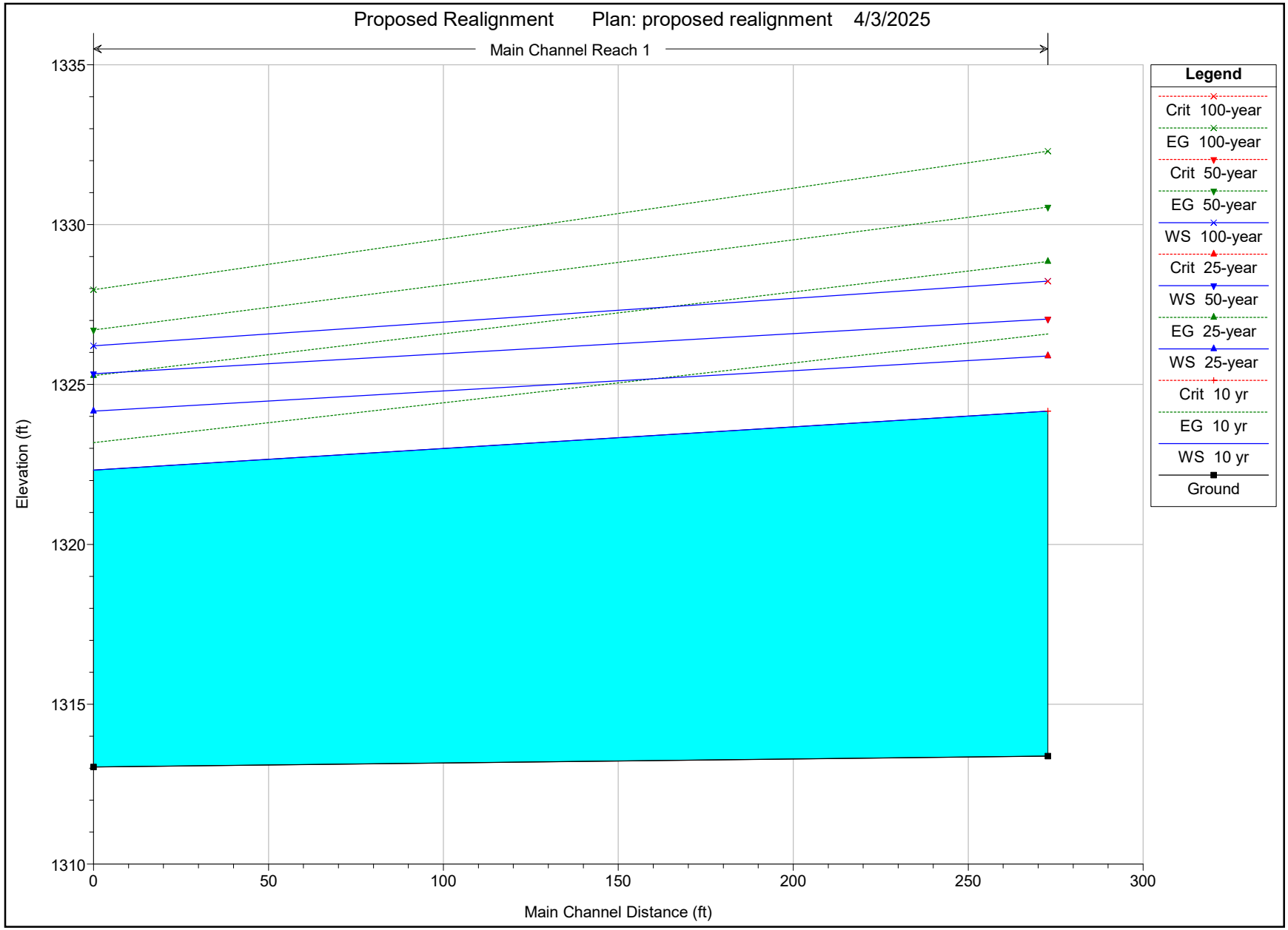

Existing Plan: bridges 10/30/2024
eD 1
Elevation (ft)
1342
1340
1338
1336
1334
1332
1330
1328
1326
0
20
40
60
80
100
120
140
160
Main Channel Distance (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground

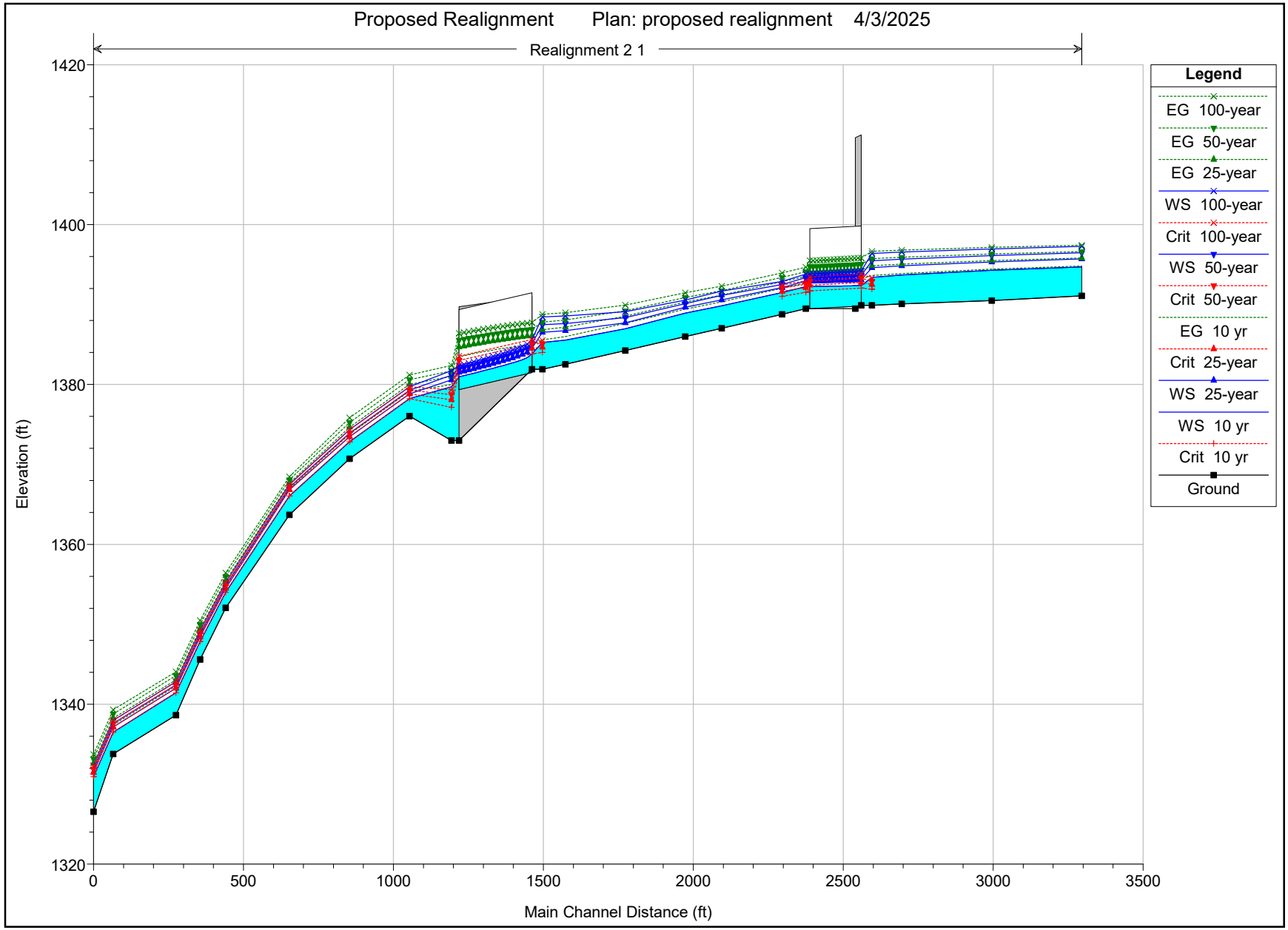

Existing Plan: bridges 10/30/2024
eSRC-C 1
Elevation (ft)
1328
1326
1324
1322
1320
1318
1316
1314
1312
0
2
4
6
8
10
Main Channel Distance (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground

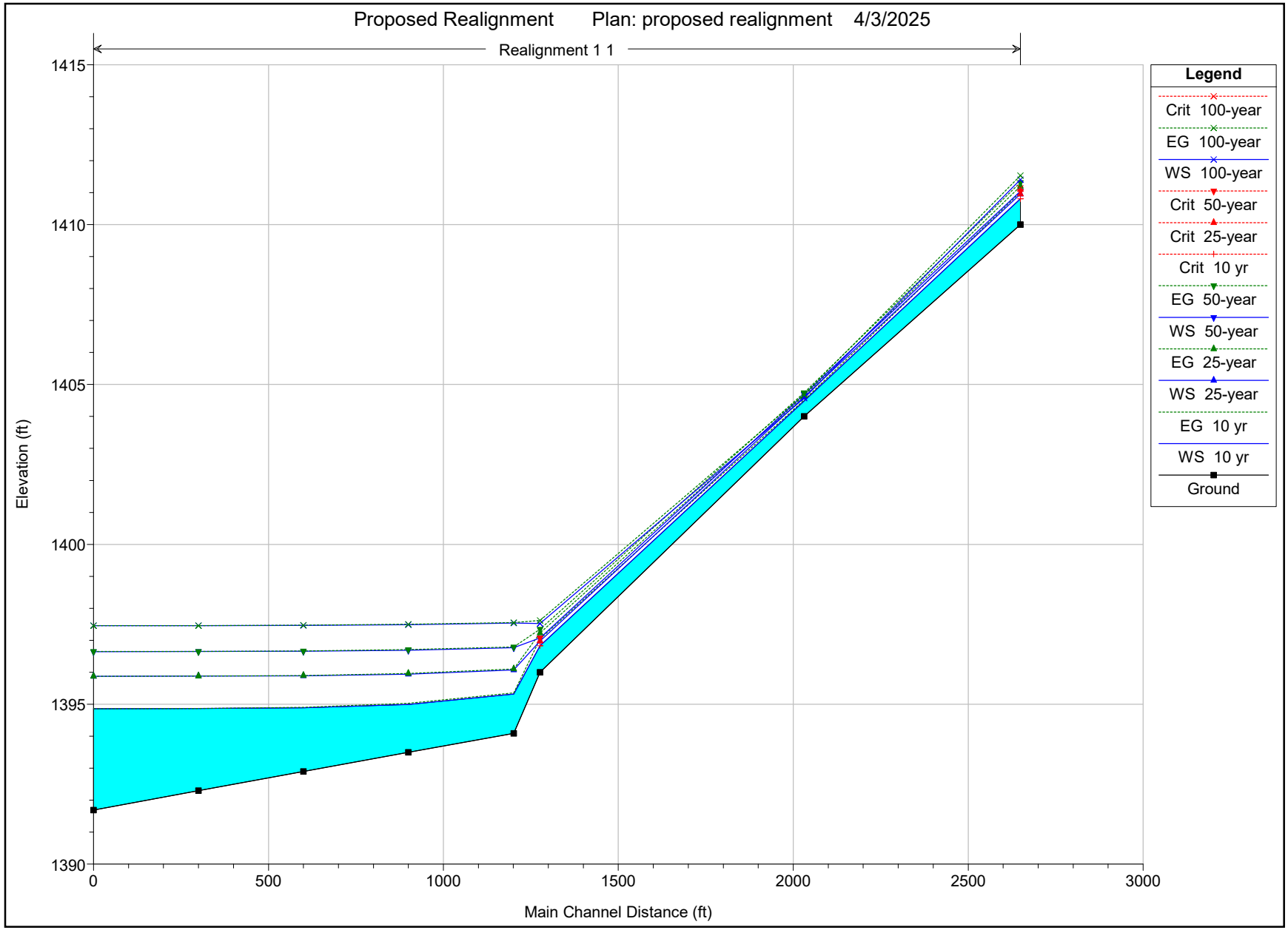

Existing Plan: bridges 10/30/2024
eSRC-D 1
Elevation (ft)
Main Channel Distance (ft)
1326
1324
1322
1320
1318
1316
1314
1312
1310
0
10
20
30
40
50
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground

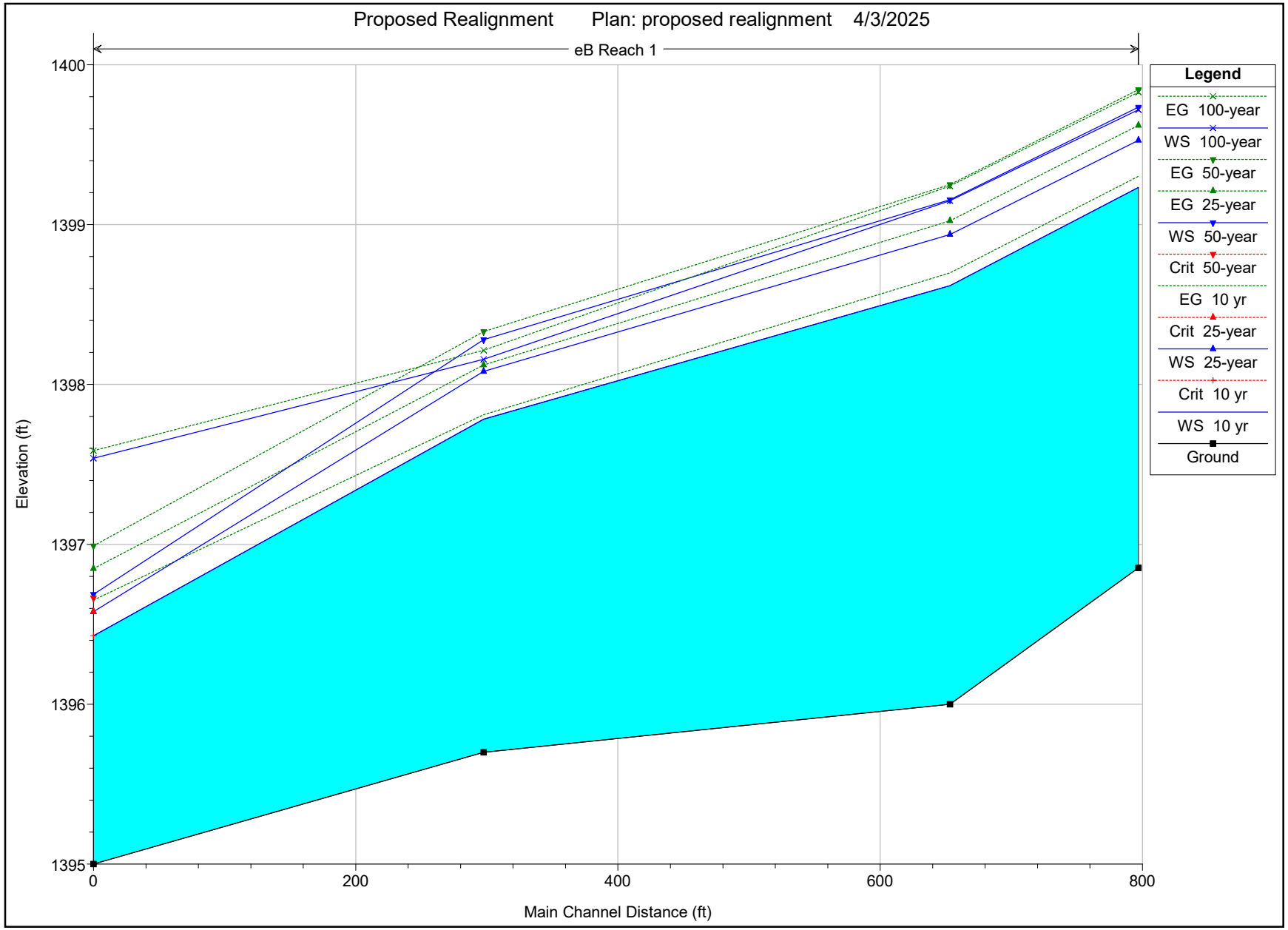

Proposed Realignment Plan: proposed realignment 4/3/2025
Main Channel 1.5 Reach 1
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Elevation (ft)
1328
1326
1324
1322
1320
1318
1316
1314
1312
0
2
4
6
8
10
Main Channel Distance (ft)

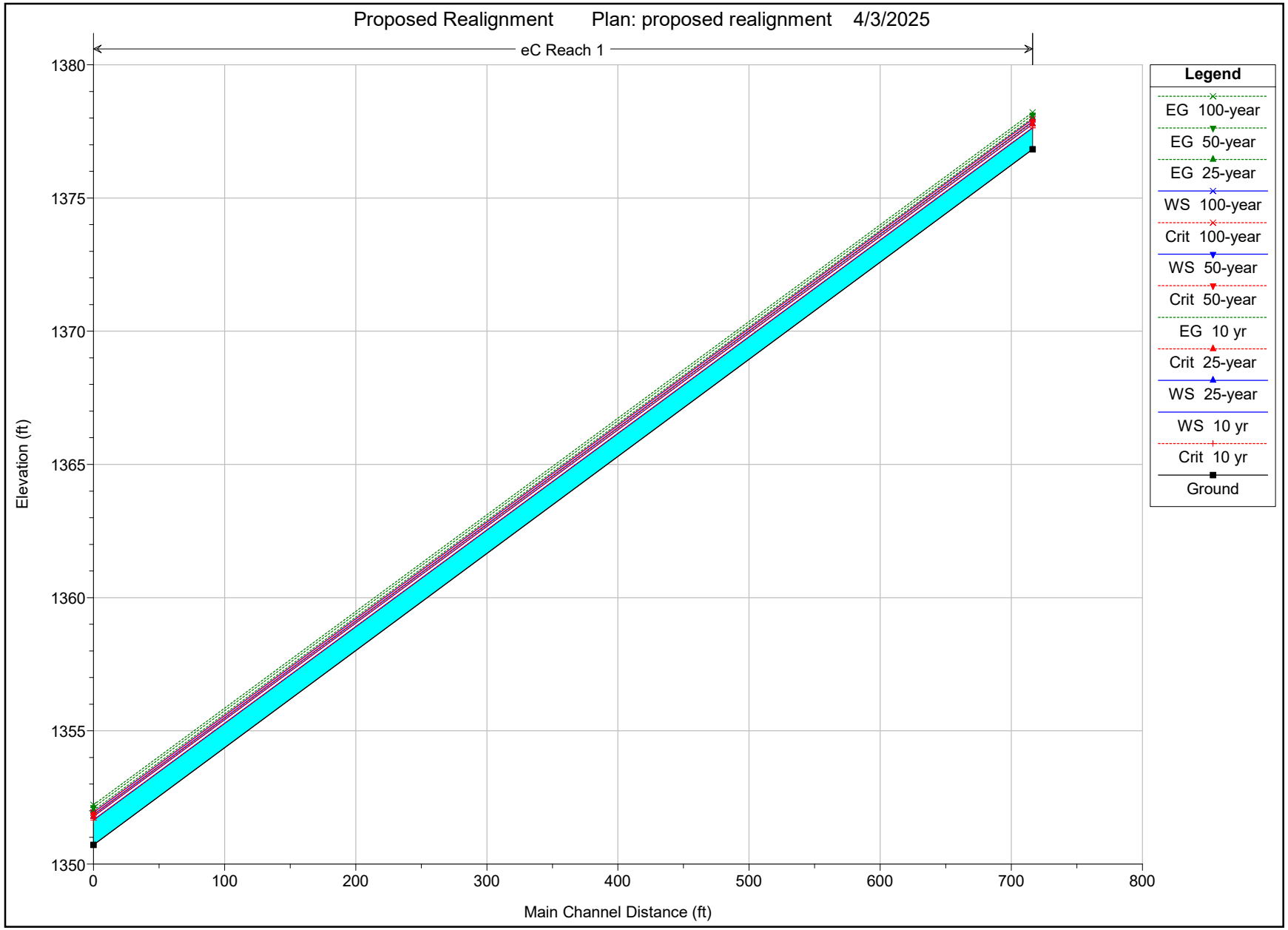

Proposed Realignment Plan: proposed realignment 4/3/2025
Main Channel 2 Reach 1
Elevation (ft)
1326
1324
1322
1320
1318
1316
1314
1312
1310
0
100
200
300
400
500
Main Channel Distance (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground


Proposed Realignment Plan: proposed realignment 4/3/2025
Main Channel Reach 1
Elevation (ft)
1335
1330
1325
1320
1315
1310
0
50
100
150
200
250
300
Main Channel Distance (ft)
Legend
Crit 100-year
EG 100-year
Crit 50-year
EG 50-year
WS 100-year
Crit 25-year
WS 50-year
EG 25-year
WS 25-year
Crit 10 yr
EG 10 yr
WS 10 yr
Ground


Proposed Realignment Plan: proposed realignment 4/3/2025
Realignment 2 1
Elevation (ft)
1420
1400
1380
1360
1340
1320
0
500
1000
1500
2000
2500
3000
3500
Main Channel Distance (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground

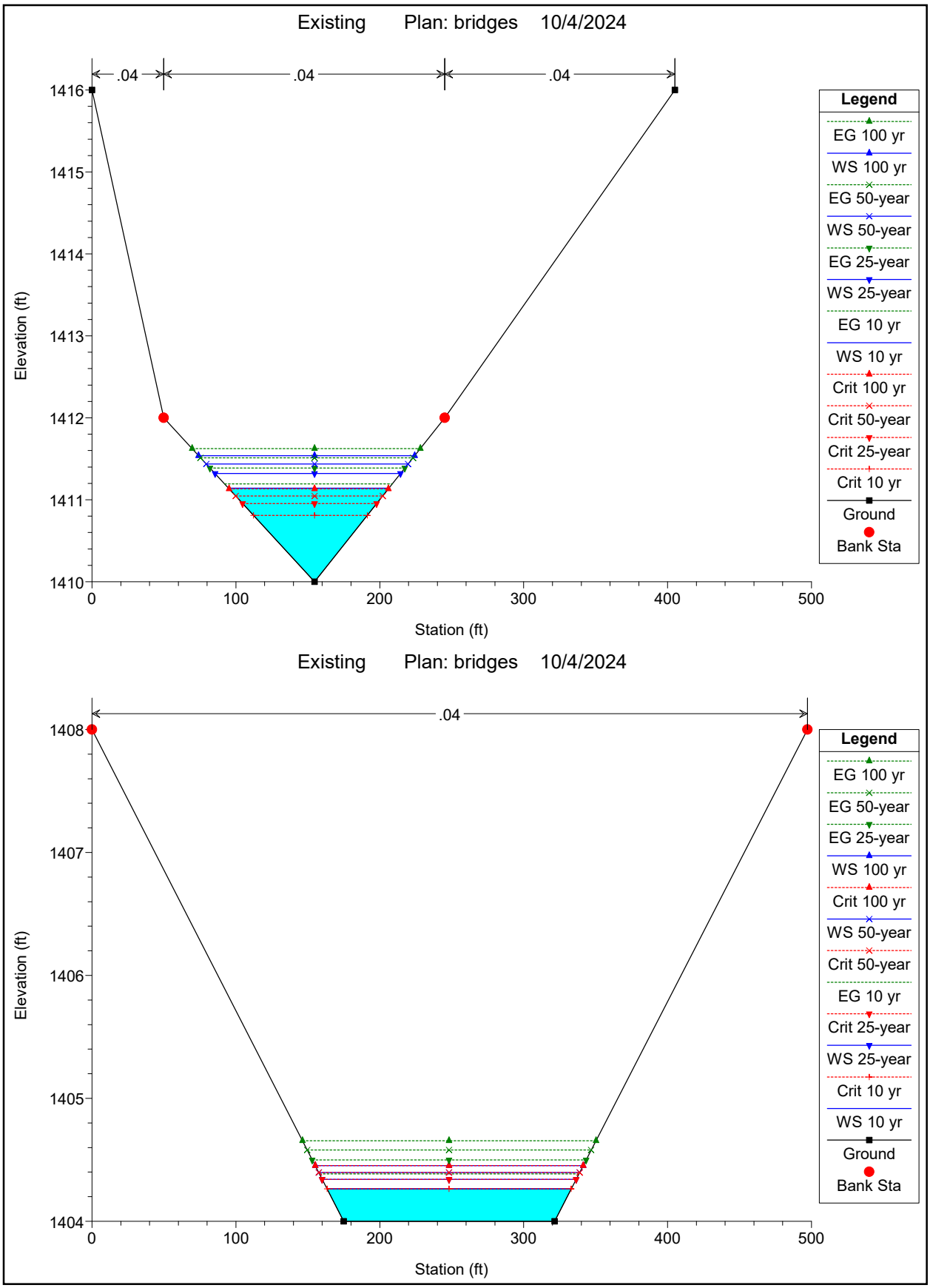

Proposed Realignment Plan: proposed realignment 4/3/2025
Realignment 1 1
Elevation (ft)
1415
1410
1405
1400
1395
1390
0
500
1000
1500
2000
2500
3000
Main Channel Distance (ft)
Legend
Crit 100-year
EG 100-year
WS 100-year
Crit 50-year
Crit 25-year
Crit 10 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground

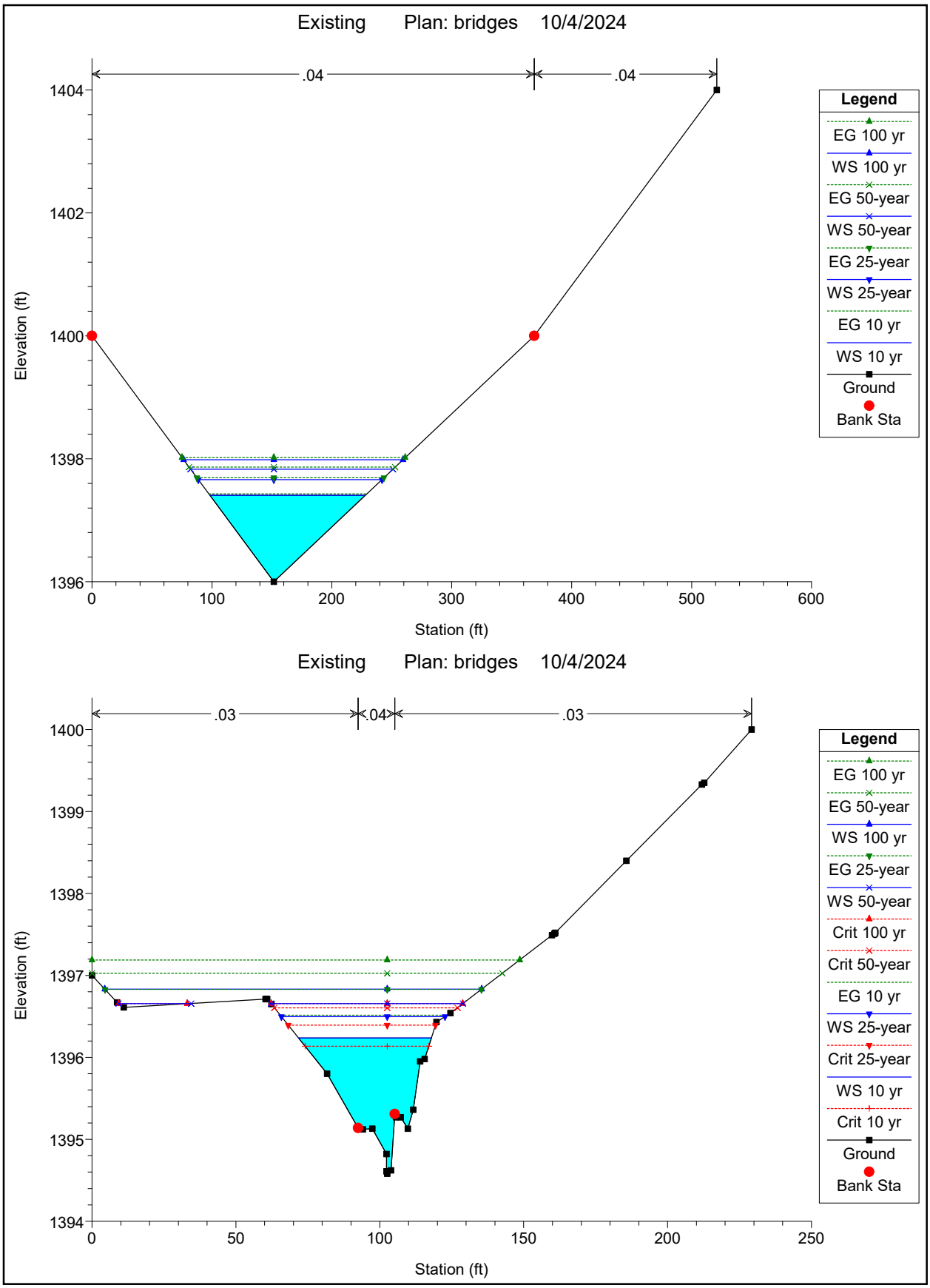

Proposed Realignment Plan: proposed realignment 4/3/2025
eB Reach 1
1400
1399
1398
1397
1396
1395
Elevation (ft)
0
200
400
600
800
Main Channel Distance (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
EG 25-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground

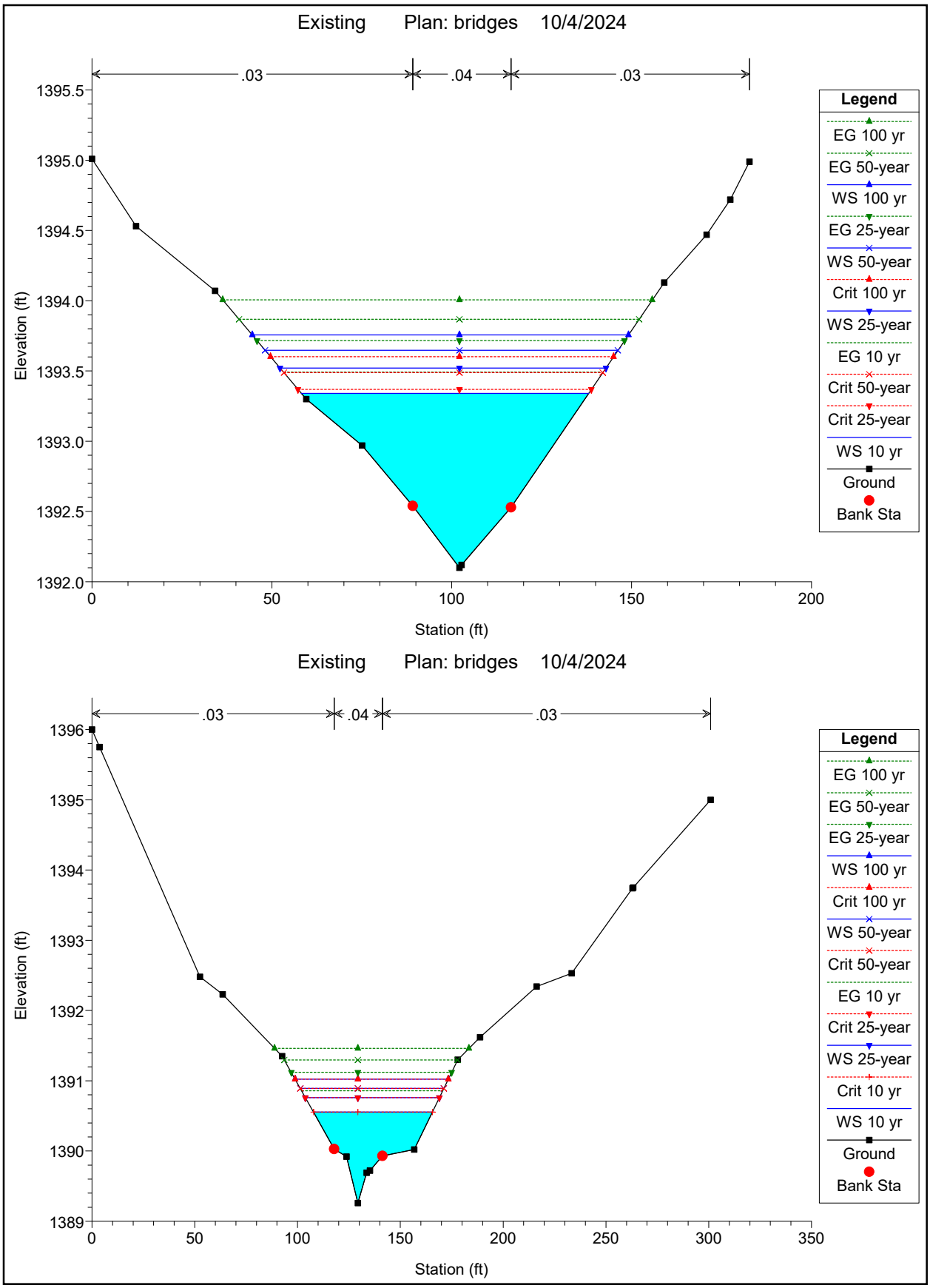

Proposed Realignment Plan: proposed realignment 4/3/2025
eC Reach 1
Elevation (ft)
1380
1375
1370
1365
1360
1355
1350
0
100
200
300
400
500
600
700
800
Main Channel Distance (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground

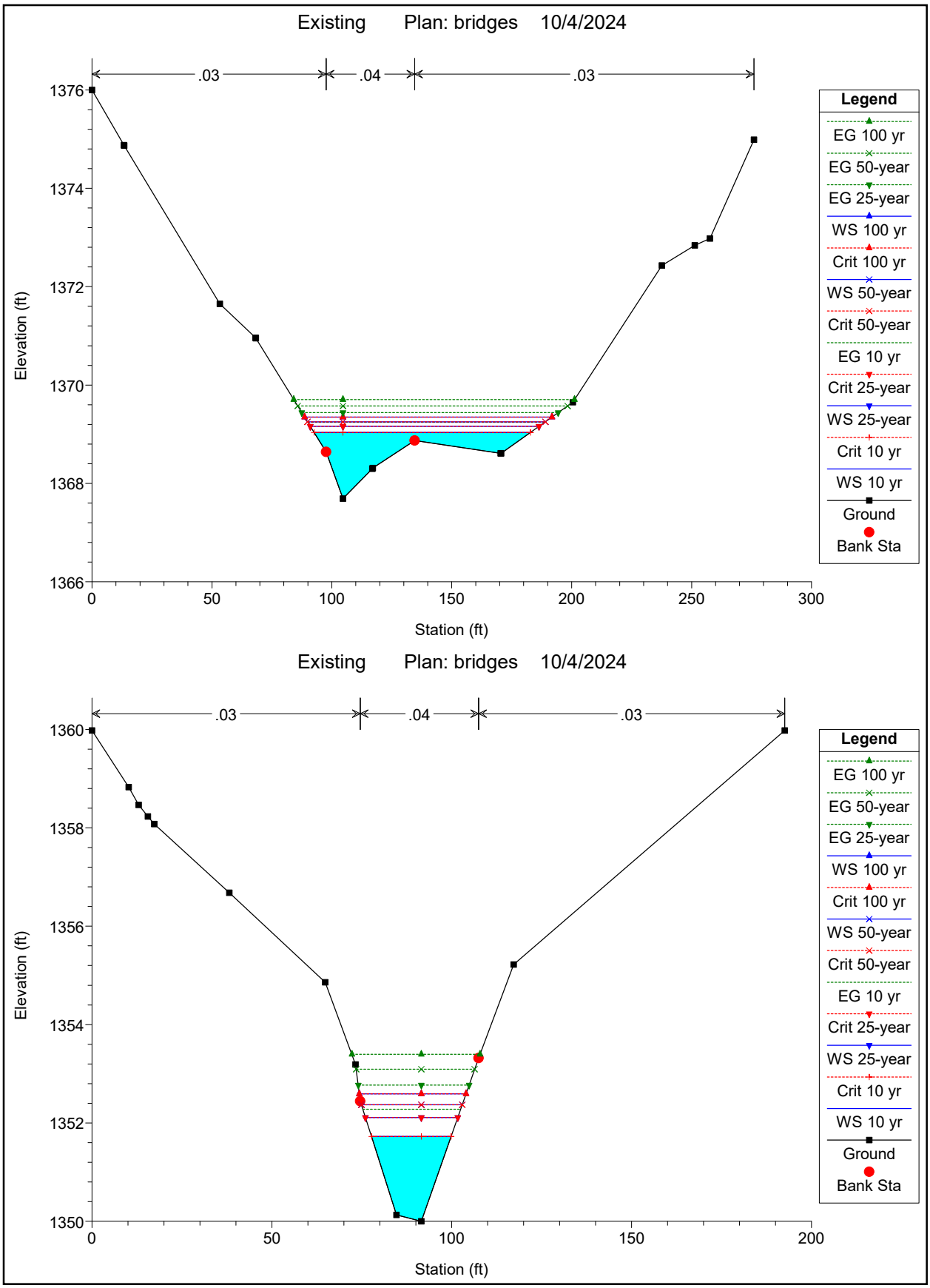
HEC-RAS Plan: proposed realignment (Continued)

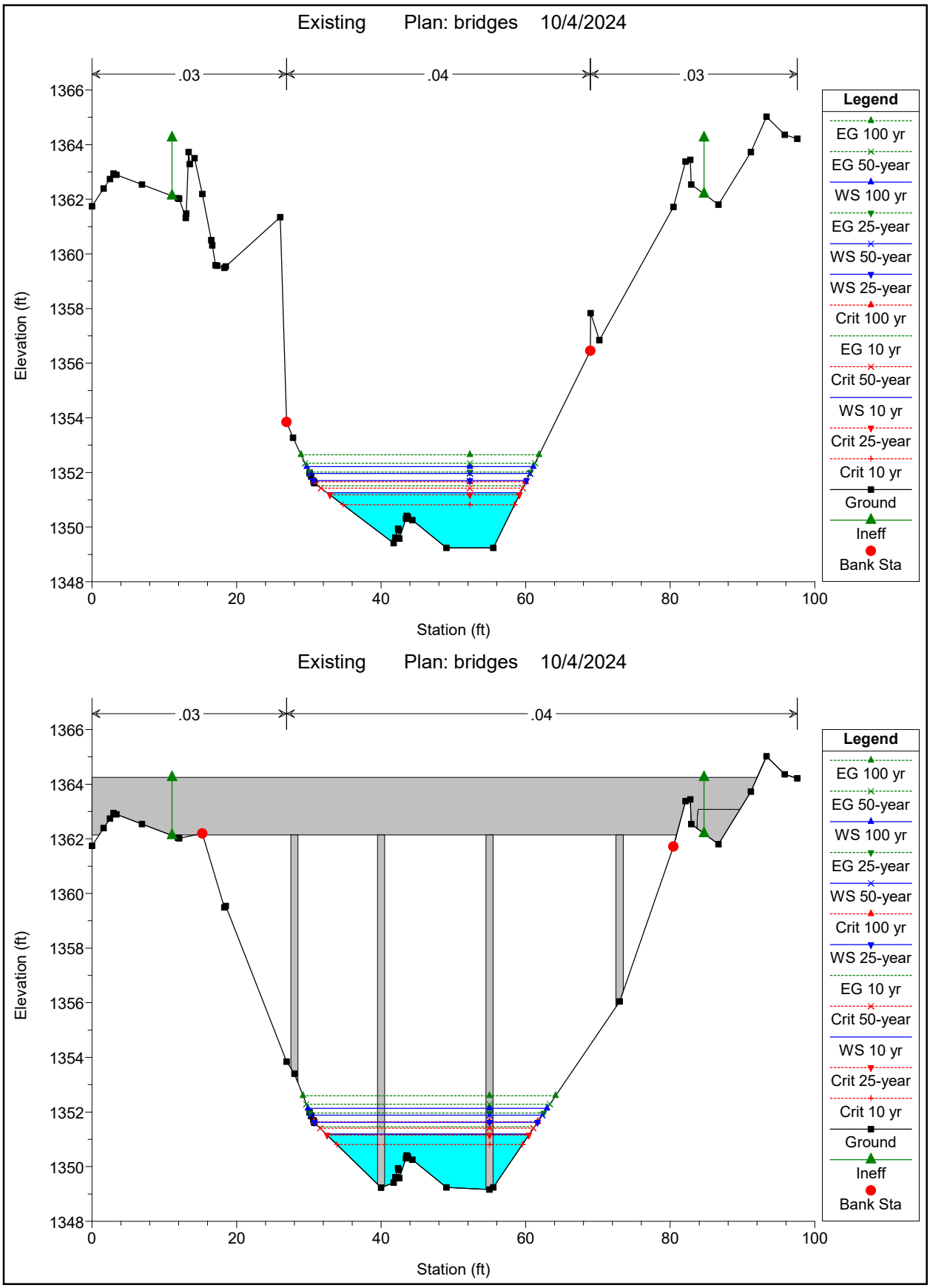
River	Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
				(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Main Channel	Reach 1	110	10 yr	7460.00	1313.04	1322.32		1323.18	0.001682	8.43	1192.40	212.86	0.50
Main Channel	Reach 1	110	25-year	11500.00	1313.04	1324.17		1325.28	0.001769	9.81	1595.12	223.32	0.53
Main Channel	Reach 1	110	50-year	15000.00	1313.04	1325.33		1326.71	0.001945	11.02	1859.22	229.92	0.57
Main Channel	Reach 1	110	100-year	18900.00	1313.04	1326.21		1327.97	0.002293	12.55	2062.93	235.02	0.62
eC	Reach 1	100	10 yr	53.50	1376.83	1377.64	1377.64	1377.84	0.032891	3.61	14.84	37.85	1.02
eC	Reach 1	100	25-year	79.80	1376.83	1377.77	1377.77	1378.01	0.031290	3.90	20.47	44.76	1.02
eC	Reach 1	100	50-year	101.00	1376.83	1377.87	1377.87	1378.12	0.030290	4.03	25.09	51.04	1.01
eC	Reach 1	100	100-year	122.00	1376.83	1377.95	1377.95	1378.22	0.029537	4.11	29.65	57.28	1.01
eC	Reach 1	50	10 yr	53.50	1350.72	1351.65	1351.65	1351.85	0.033456	3.57	14.99	39.32	1.02
eC	Reach 1	50	25-year	79.80	1350.72	1351.79	1351.79	1352.01	0.030952	3.81	20.92	46.85	1.01
eC	Reach 1	50	50-year	101.00	1350.72	1351.86	1351.86	1352.12	0.030805	4.12	24.49	48.61	1.02
eC	Reach 1	50	100-year	122.00	1350.72	1351.94	1351.94	1352.23	0.029424	4.32	28.21	50.38	1.02
eB	Reach 1	2900	10 yr	677.00	1396.85	1399.23		1399.30	0.003656	2.64	343.86	327.33	0.35
eB	Reach 1	2900	25-year	1023.00	1396.85	1399.53		1399.62	0.004042	3.08	444.07	352.90	0.38
eB	Reach 1	2900	50-year	1305.00	1396.85	1399.74		1399.85	0.004217	3.35	519.02	369.78	0.39
eB	Reach 1	2900	100-year	1280.00	1396.85	1399.72		1399.83	0.004190	3.32	513.16	368.50	0.39
eB	Reach 1	2800	10 yr	677.00	1396.00	1398.62		1398.70	0.005204	2.87	332.72	403.93	0.41
eB	Reach 1	2800	25-year	1023.00	1396.00	1398.94		1399.02	0.004436	3.00	465.98	427.85	0.39
eB	Reach 1	2800	50-year	1305.00	1396.00	1399.16		1399.25	0.004155	3.12	561.32	443.54	0.38
eB	Reach 1	2800	100-year	1280.00	1396.00	1399.15		1399.24	0.004060	3.08	558.45	443.20	0.38
eB	Reach 1	2700	10 yr	677.00	1395.70	1397.78		1397.81	0.001409	1.33	515.95	424.19	0.21
eB	Reach 1	2700	25-year	1023.00	1395.70	1398.08		1398.12	0.001587	1.62	650.94	493.72	0.23
eB	Reach 1	2700	50-year	1305.00	1395.70	1398.28		1398.33	0.001708	1.82	751.69	523.35	0.24
eB	Reach 1	2700	100-year	1280.00	1395.70	1398.16		1398.21	0.002115	1.93	688.36	504.93	0.26
eB	Reach 1	2520	10 yr	677.00	1395.00	1396.43	1396.43	1396.65	0.029757	4.74	200.59	427.34	0.89
eB	Reach 1	2520	25-year	1023.00	1395.00	1396.58	1396.58	1396.85	0.029587	5.25	266.68	448.01	0.91
eB	Reach 1	2520	50-year	1305.00	1395.00	1396.69	1396.66	1396.99	0.029155	5.57	316.10	462.86	0.92
eB	Reach 1	2520	100-year	1280.00	1395.00	1397.54		1397.59	0.002086	2.16	751.08	548.90	0.27

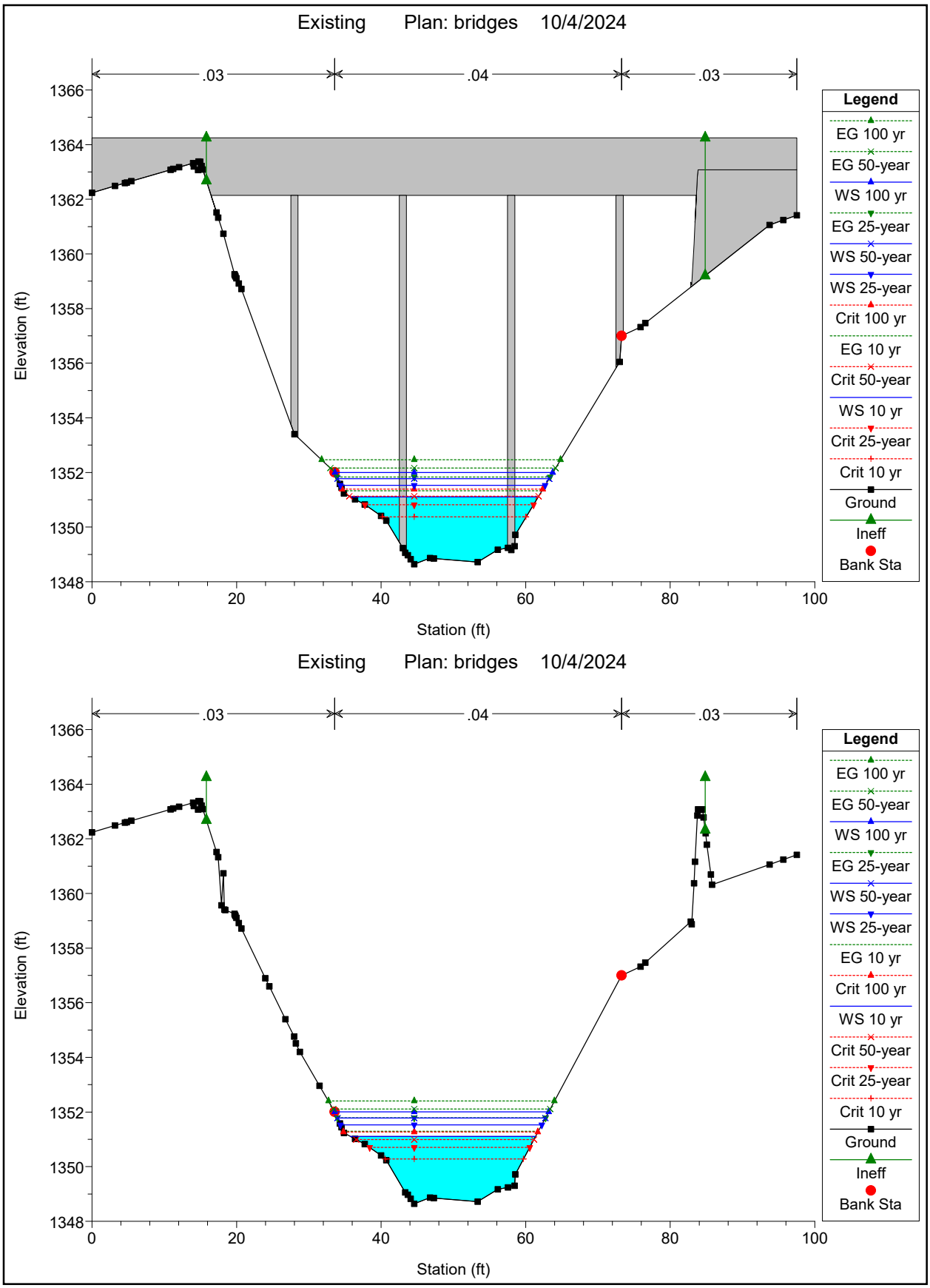

Existing Plan: bridges 10/4/2024
.04
.04
.04
1416
1415
1414
1413
1412
1411
1410
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 100 yr
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
1408
1407
1406
1405
1404
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

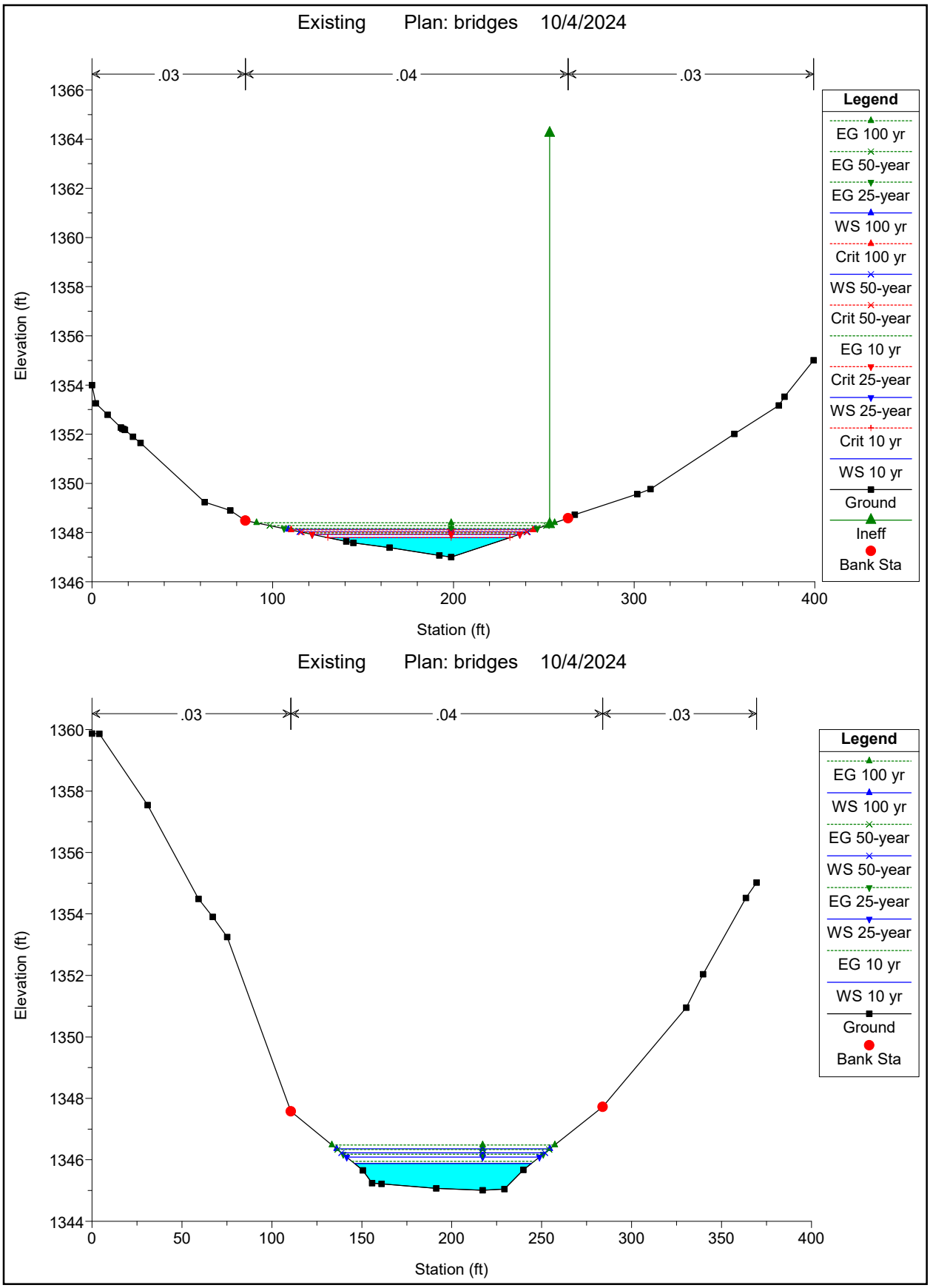

Existing Plan: bridges 10/4/2024
.04
.04
1404
1402
1400
1398
1396
Elevation (ft)
0
100
200
300
400
500
600
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.03
.04
.03
1400
1399
1398
1397
1396
1395
1394
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
Crit 100 yr
Crit 50-year
EG 10 yr
WS 25-year
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

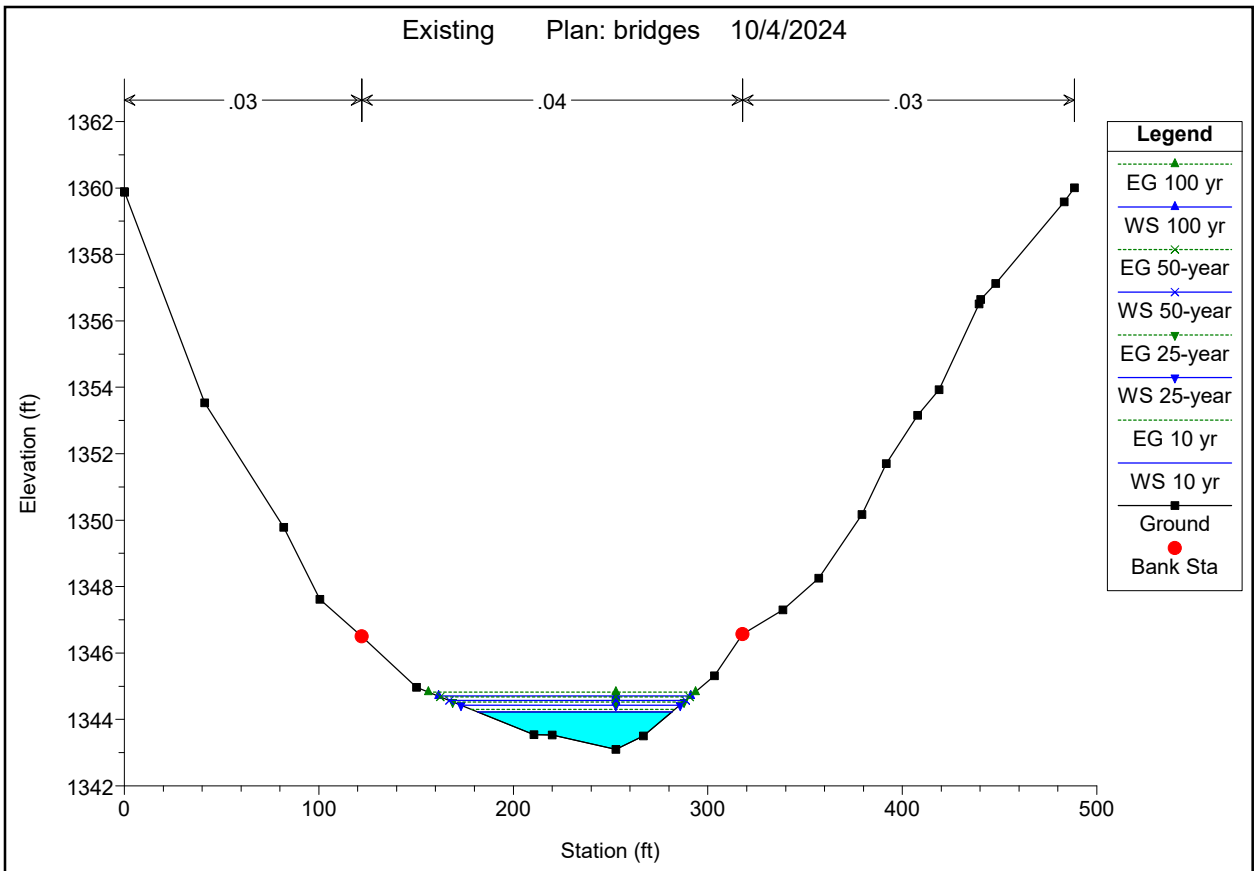

Existing Plan: bridges 10/4/2024
.03
.04
.03
1395.5
1395.0
1394.5
1394.0
1393.5
1393.0
1392.5
1392.0
Elevation (ft)
0
50
100
150
200
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
Crit 100 yr
WS 25-year
EG 10 yr
Crit 50-year
Crit 25-year
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.03
.04
.03
1396
1395
1394
1393
1392
1391
1390
1389
Elevation (ft)
0
50
100
150
200
250
300
350
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

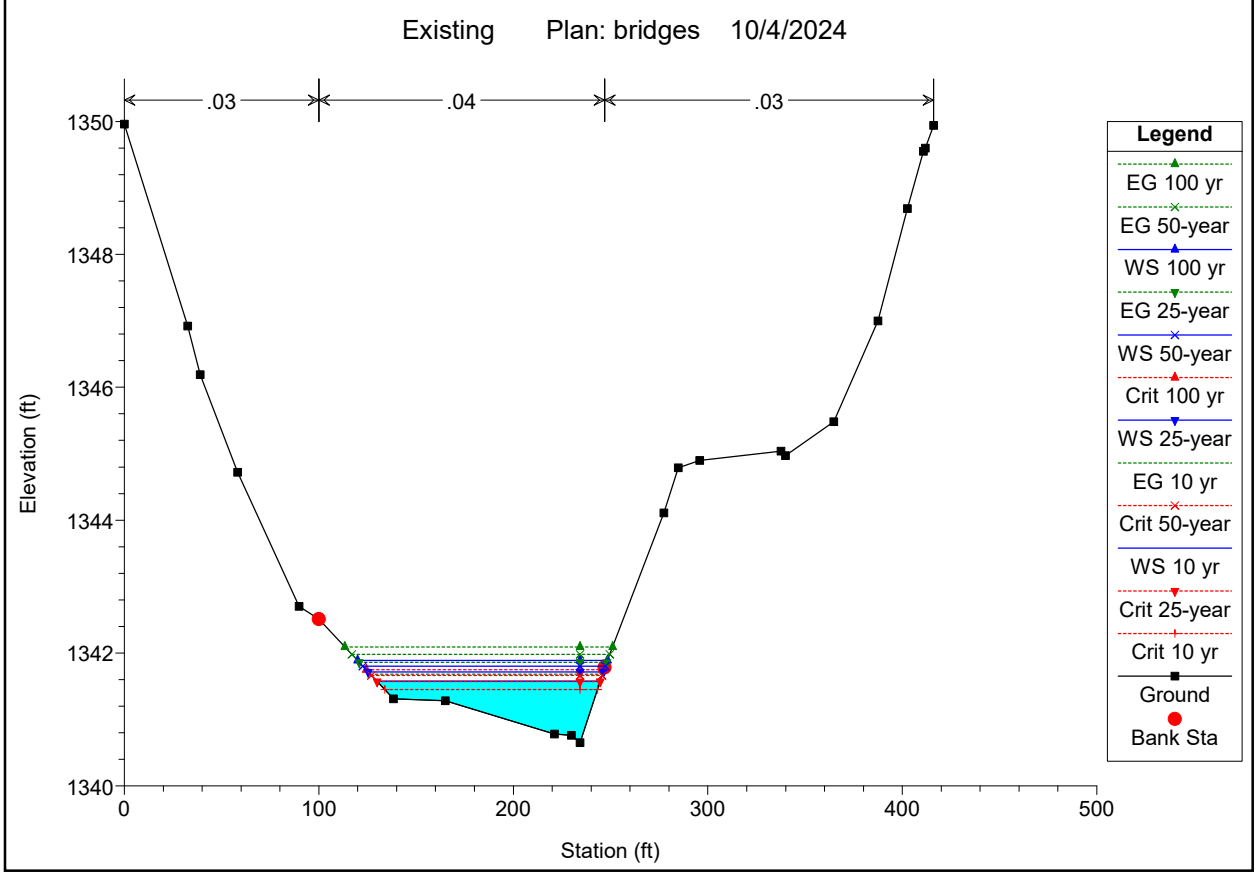

Existing Plan: bridges 10/4/2024
.03
.04
.03
1376
1374
1372
1370
1368
1366
Elevation (ft)
0
50
100
150
200
250
300
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.03
.04
.03
1360
1358
1356
1354
1352
1350
Elevation (ft)
0
50
100
150
200
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

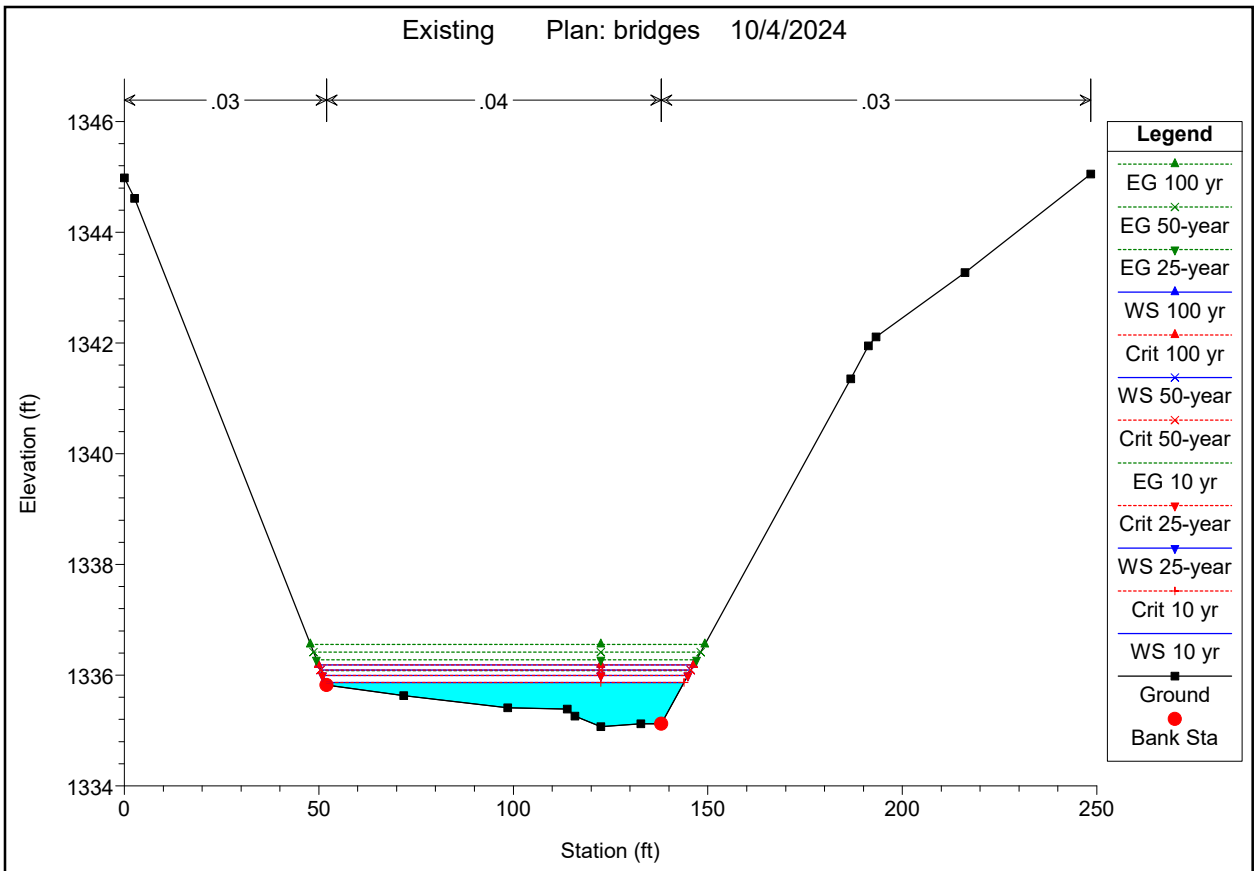

Existing Plan: bridges 10/4/2024
.03
.04
.03
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
WS 25-year
Crit 100 yr
EG 10 yr
Crit 50-year
WS 10 yr
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta
Existing Plan: bridges 10/4/2024
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
Crit 100 yr
WS 25-year
EG 10 yr
Crit 50-year
WS 10 yr
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

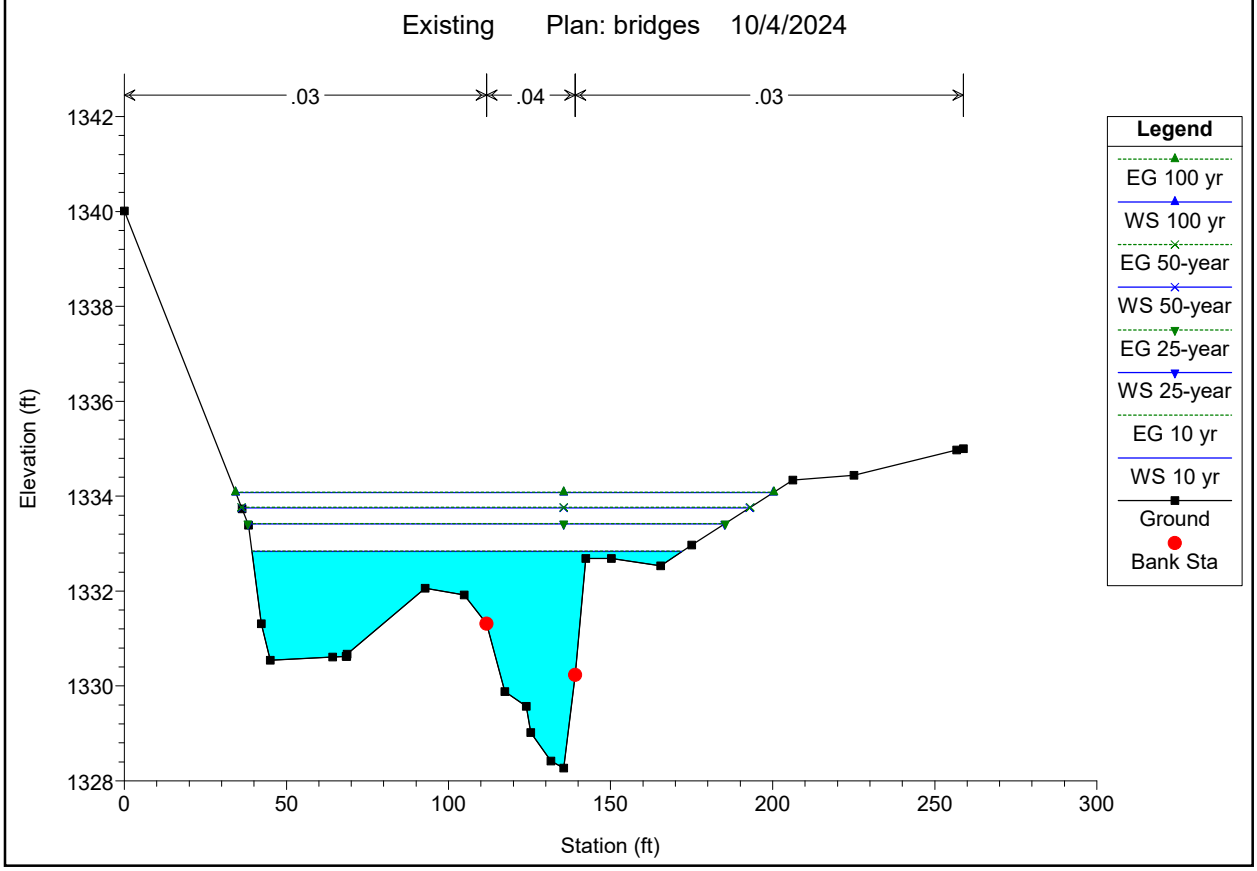

Existing Plan: bridges 10/4/2024
.03
.04
.03
1366
1364
1362
1360
1358
1356
1354
1352
1350
1348
Elevation (ft)
0
20
40
60
80
100
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
WS 25-year
Crit 100 yr
EG 10 yr
Crit 50-year
WS 10 yr
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta
Existing Plan: bridges 10/4/2024
.03
.04
.03
1366
1364
1362
1360
1358
1356
1354
1352
1350
1348
Elevation (ft)
0
20
40
60
80
100
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
WS 25-year
EG 10 yr
Crit 100 yr
WS 10 yr
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

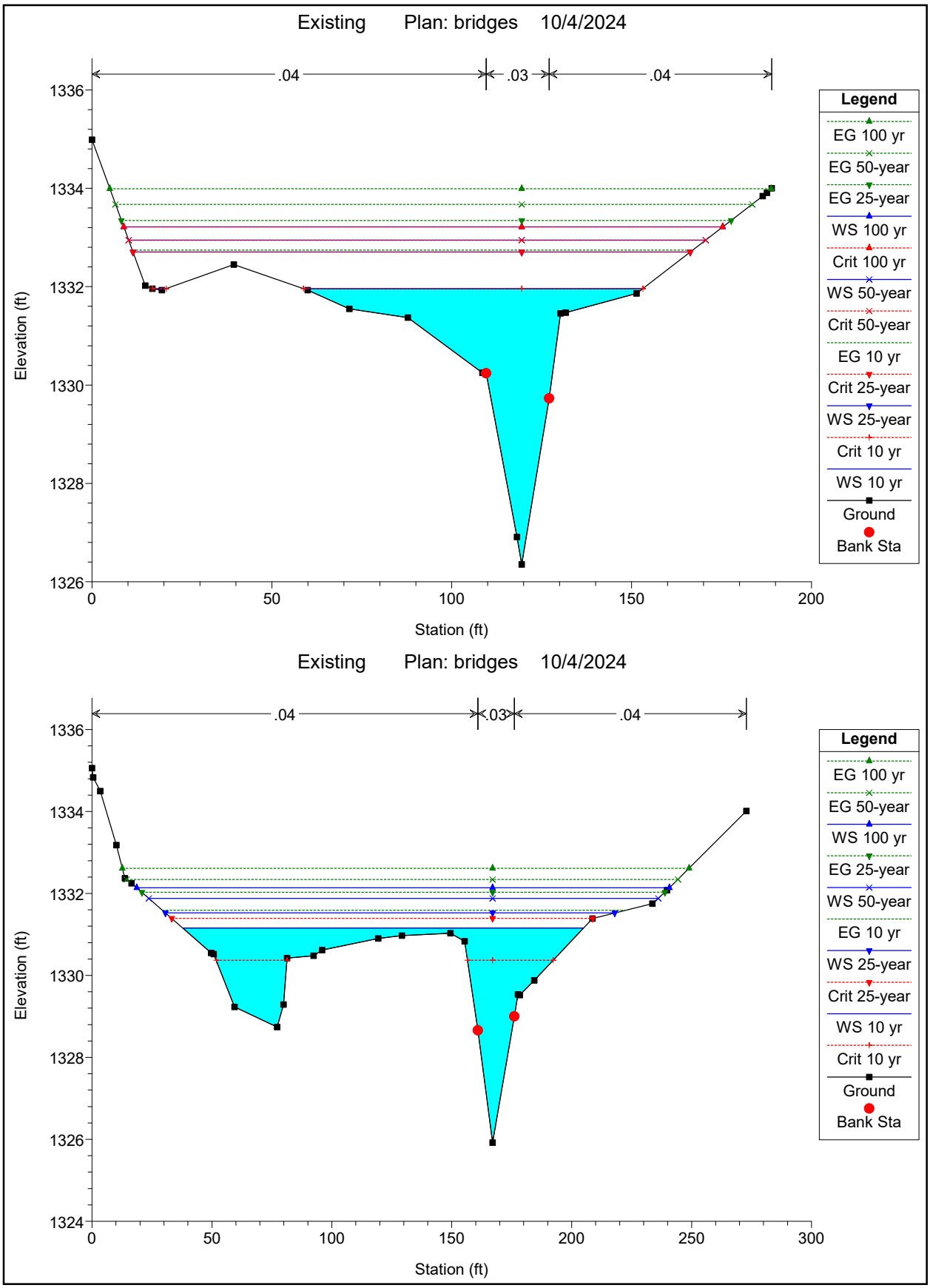

Existing Plan: bridges 10/4/2024
.03
.04
.03
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Ineff
Bank Sta
Existing Plan: bridges 10/4/2024
.03
.04
.03
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

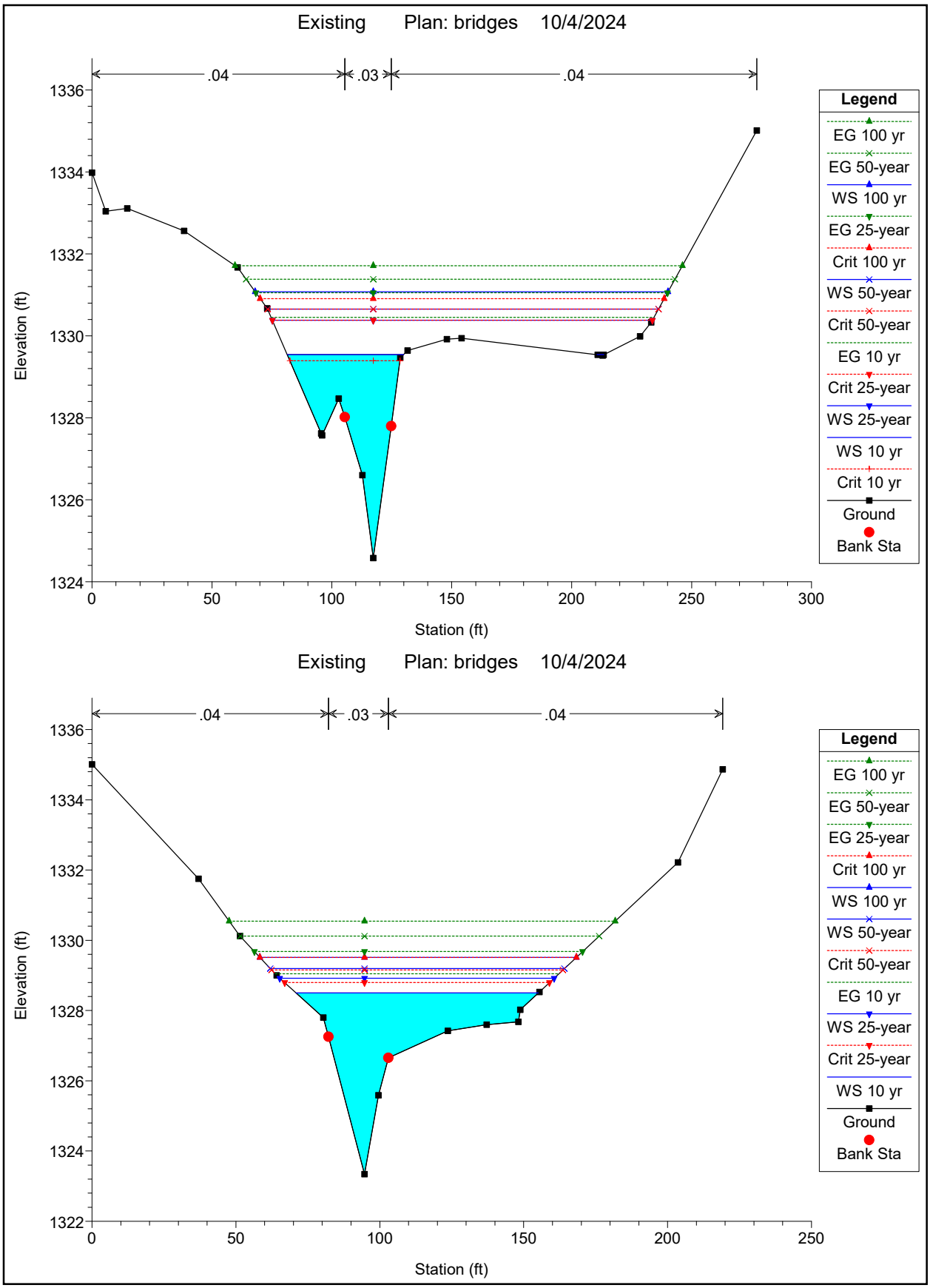

Existing Plan: bridges 10/4/2024
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1350
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1344
1342
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

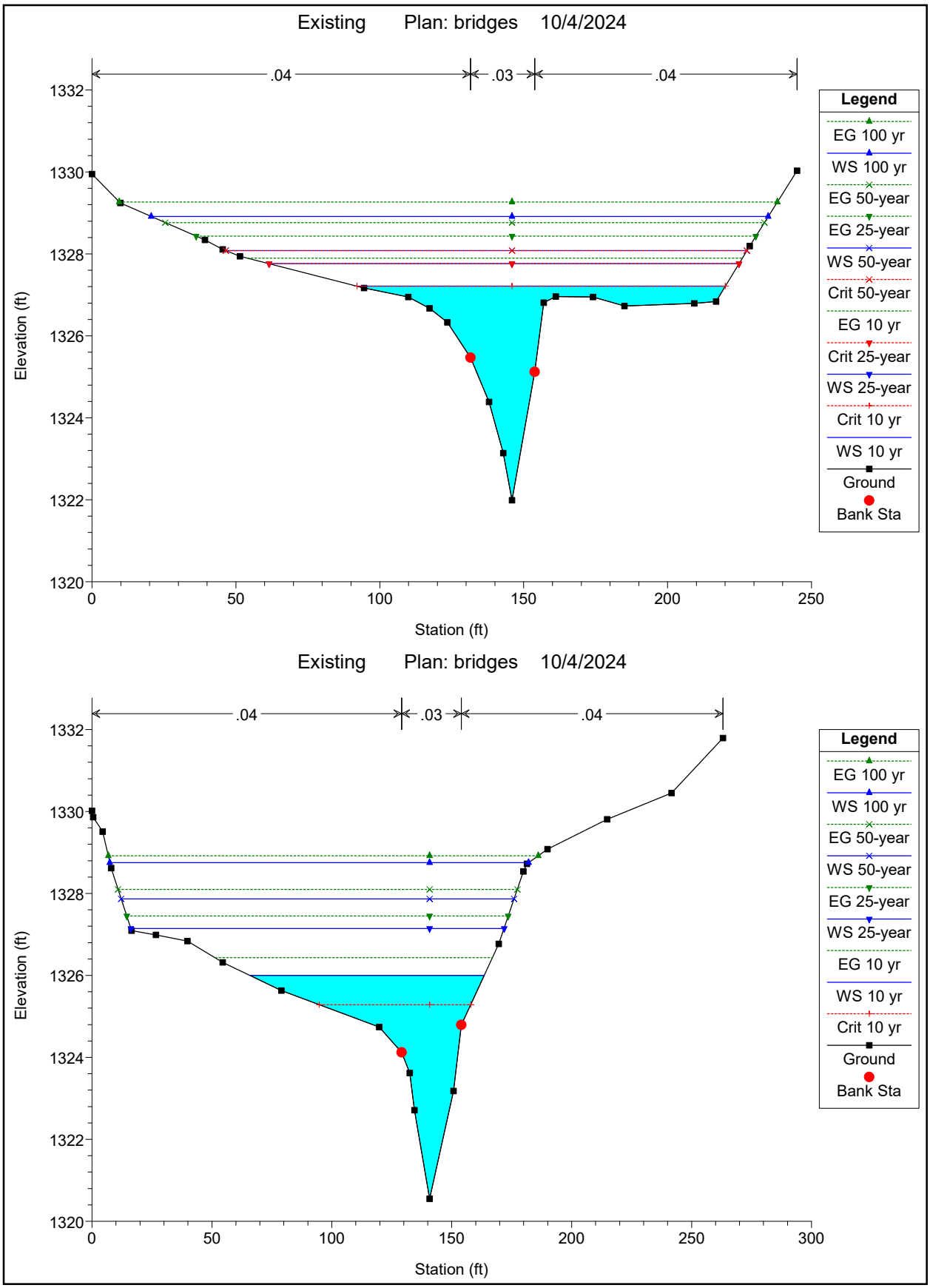

Existing Plan: bridges 10/4/2024
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1344
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1340
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
Crit 100 yr
WS 25-year
EG 10 yr
Crit 50-year
WS 10 yr
Crit 25-year
Crit 10 yr
Ground
Bank Sta

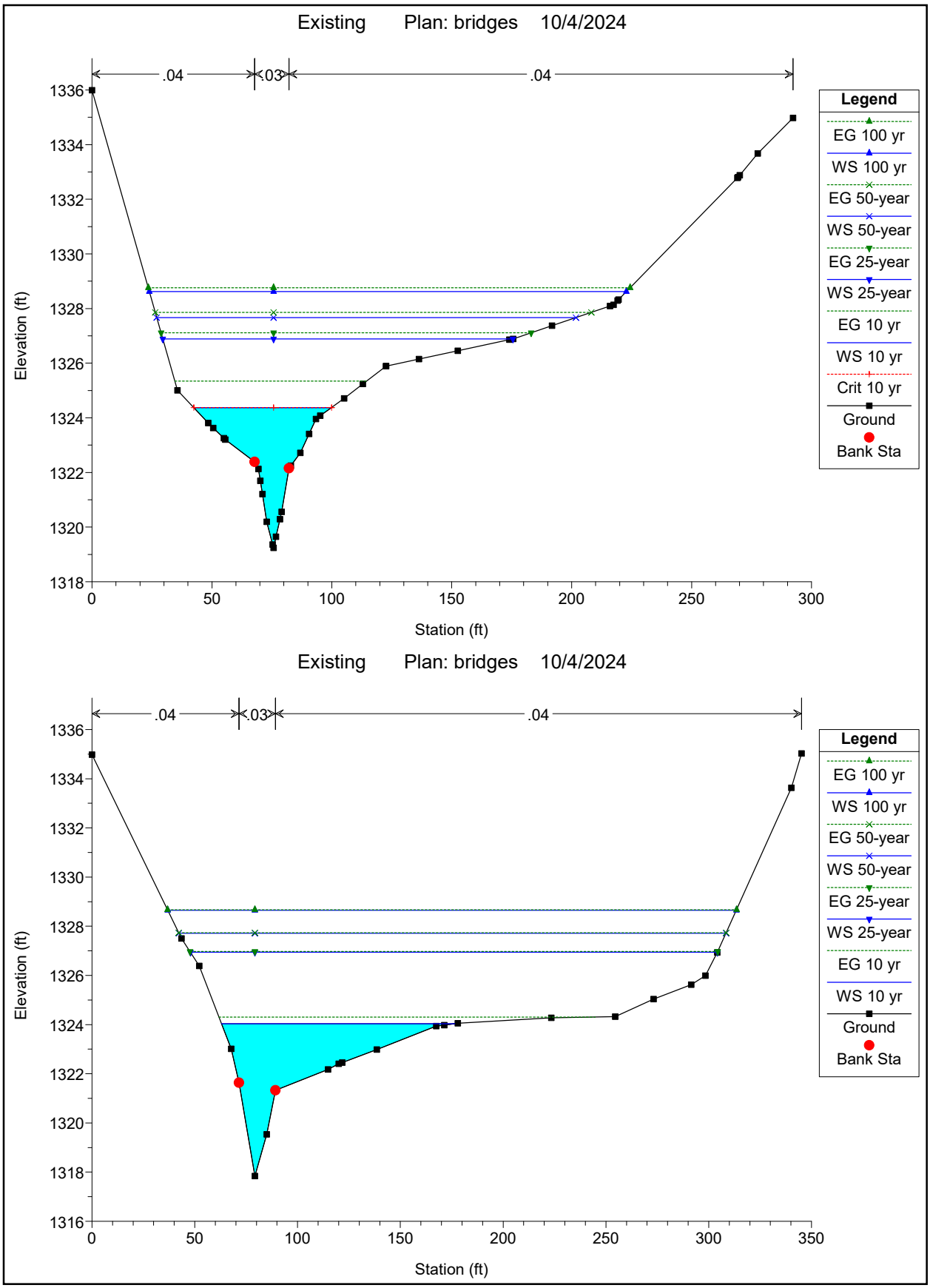

Existing Plan: bridges 10/4/2024
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1346
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1334
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

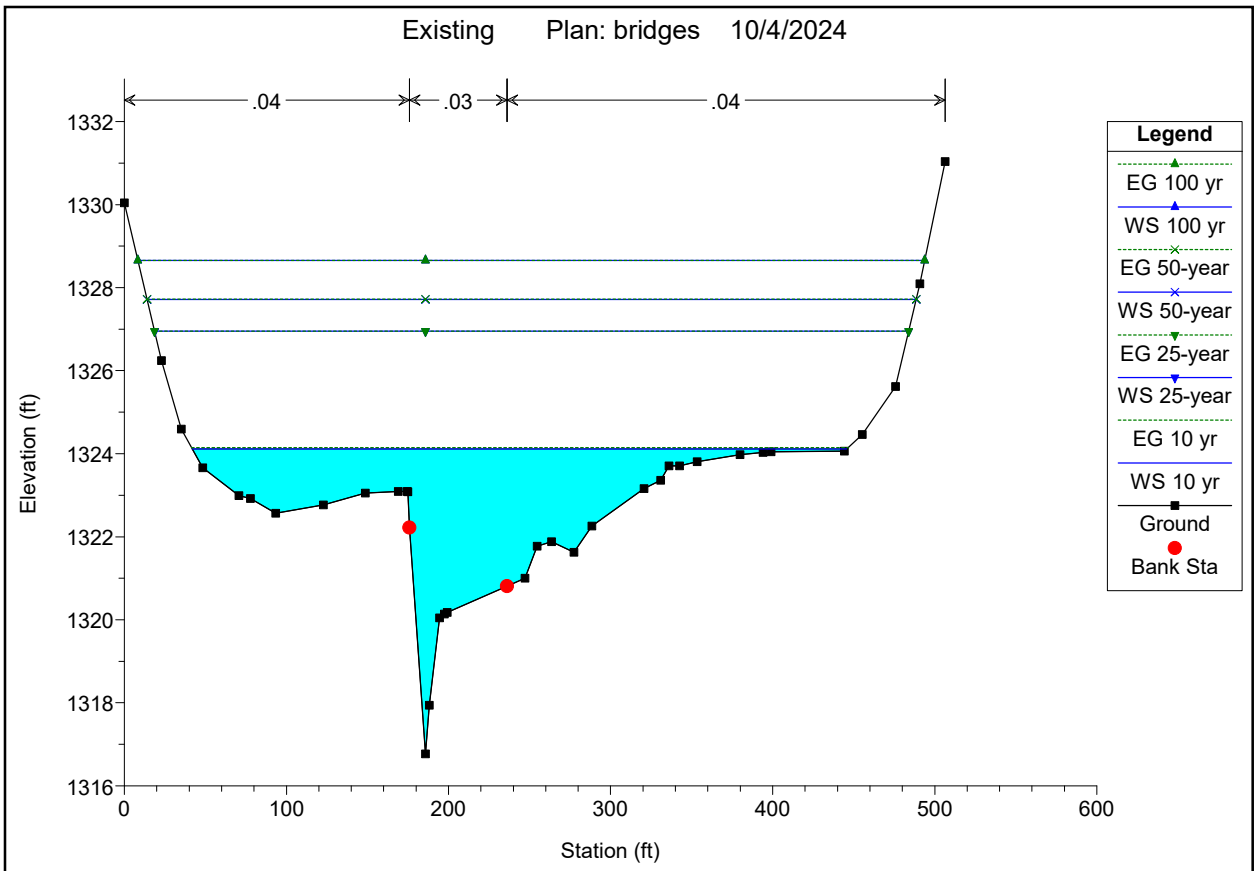

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1328
Elevation (ft)
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50
100
150
200
250
300
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

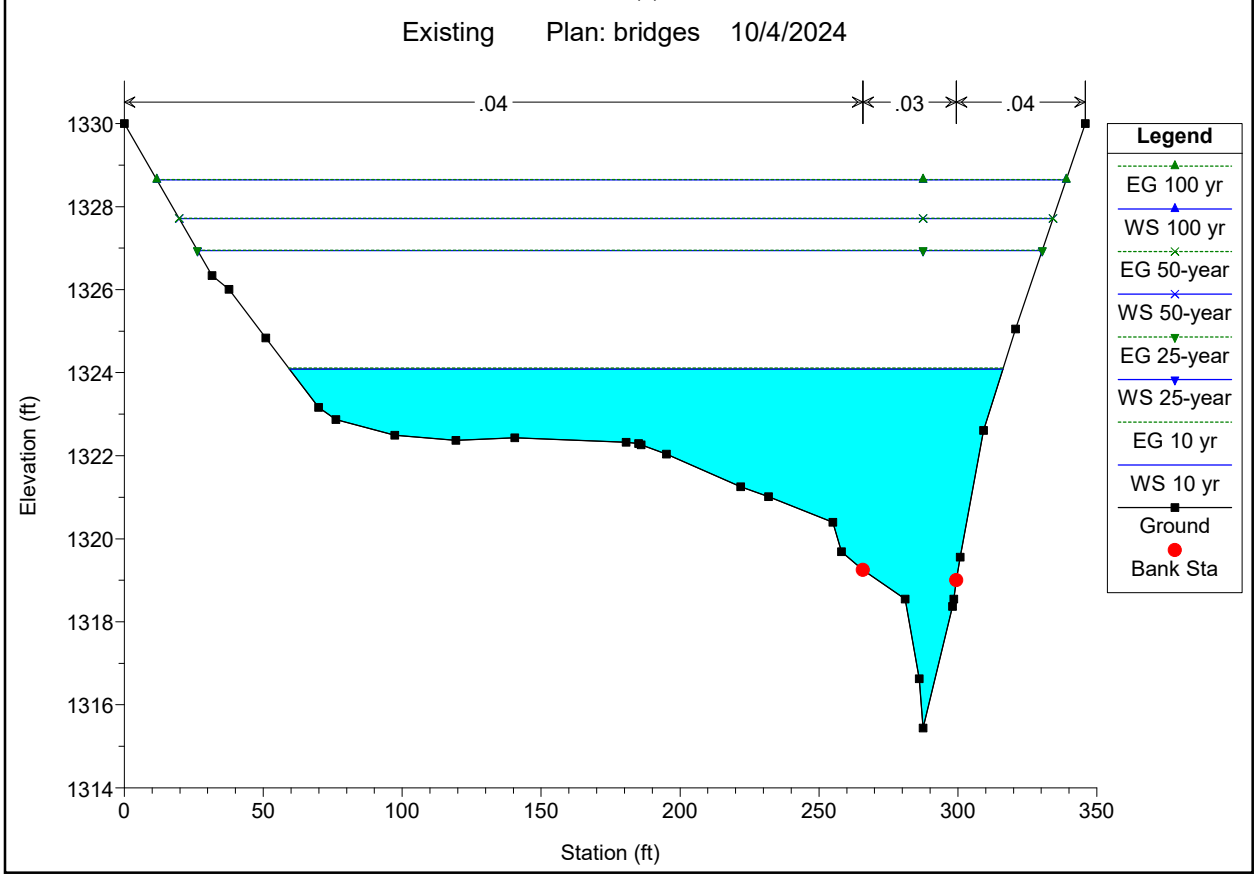

Existing Plan: bridges 10/4/2024
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1326
Elevation (ft)
0
50
100
150
200
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
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1324
Elevation (ft)
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100
150
200
250
300
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
EG 10 yr
WS 25-year
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

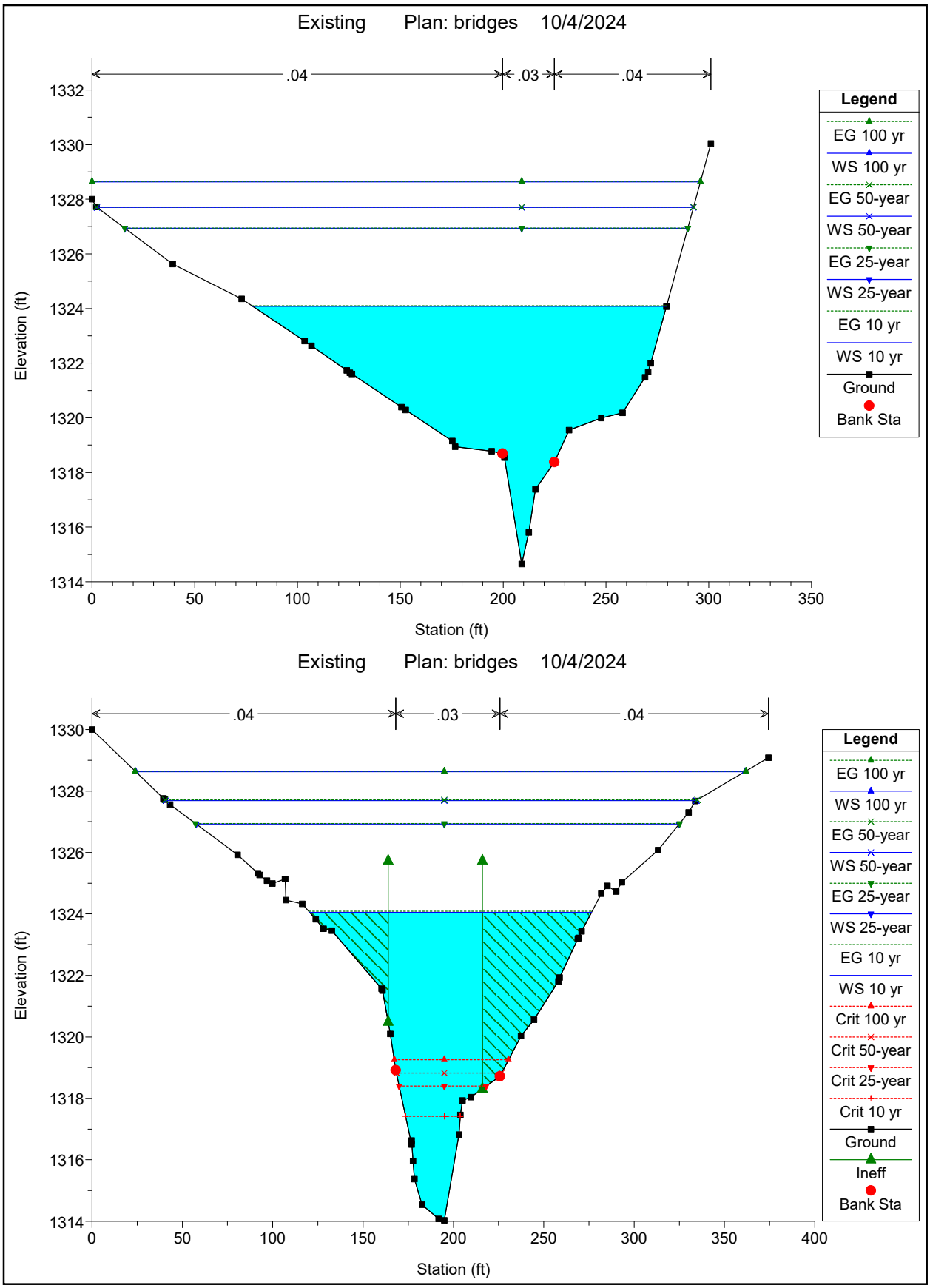

Existing Plan: bridges 10/4/2024
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1324
Elevation (ft)
0
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100
150
200
250
300
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
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1336
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1324
1322
Elevation (ft)
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100
150
200
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Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
Crit 100 yr
WS 100 yr
WS 50-year
Crit 50-year
EG 10 yr
WS 25-year
Crit 25-year
WS 10 yr
Ground
Bank Sta

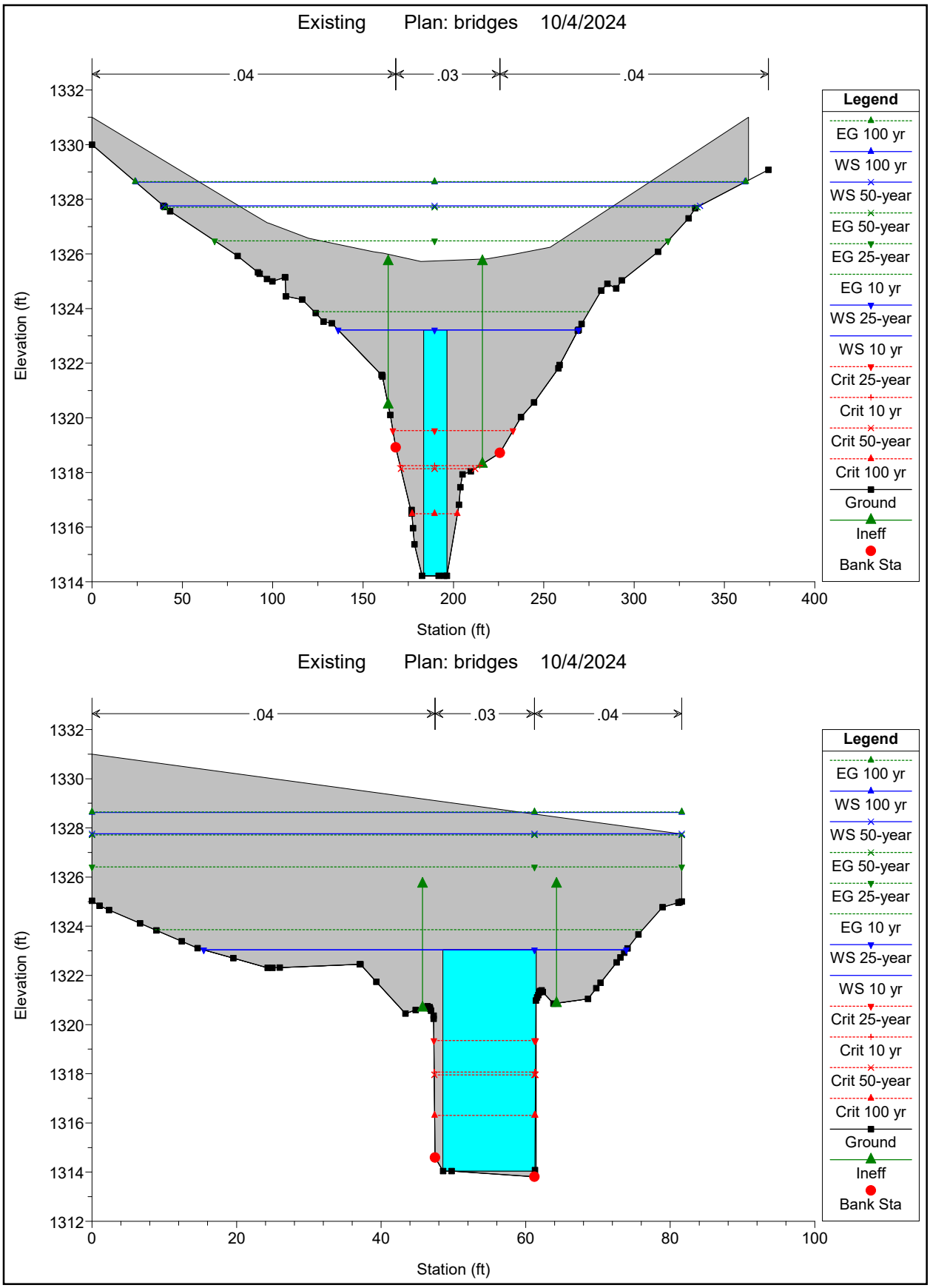

Existing Plan: bridges 10/4/2024
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1320
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
EG 25-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
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1332
1330
1328
1326
1324
1322
1320
Elevation (ft)
0
50
100
150
200
250
300
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 10 yr
Ground
Bank Sta

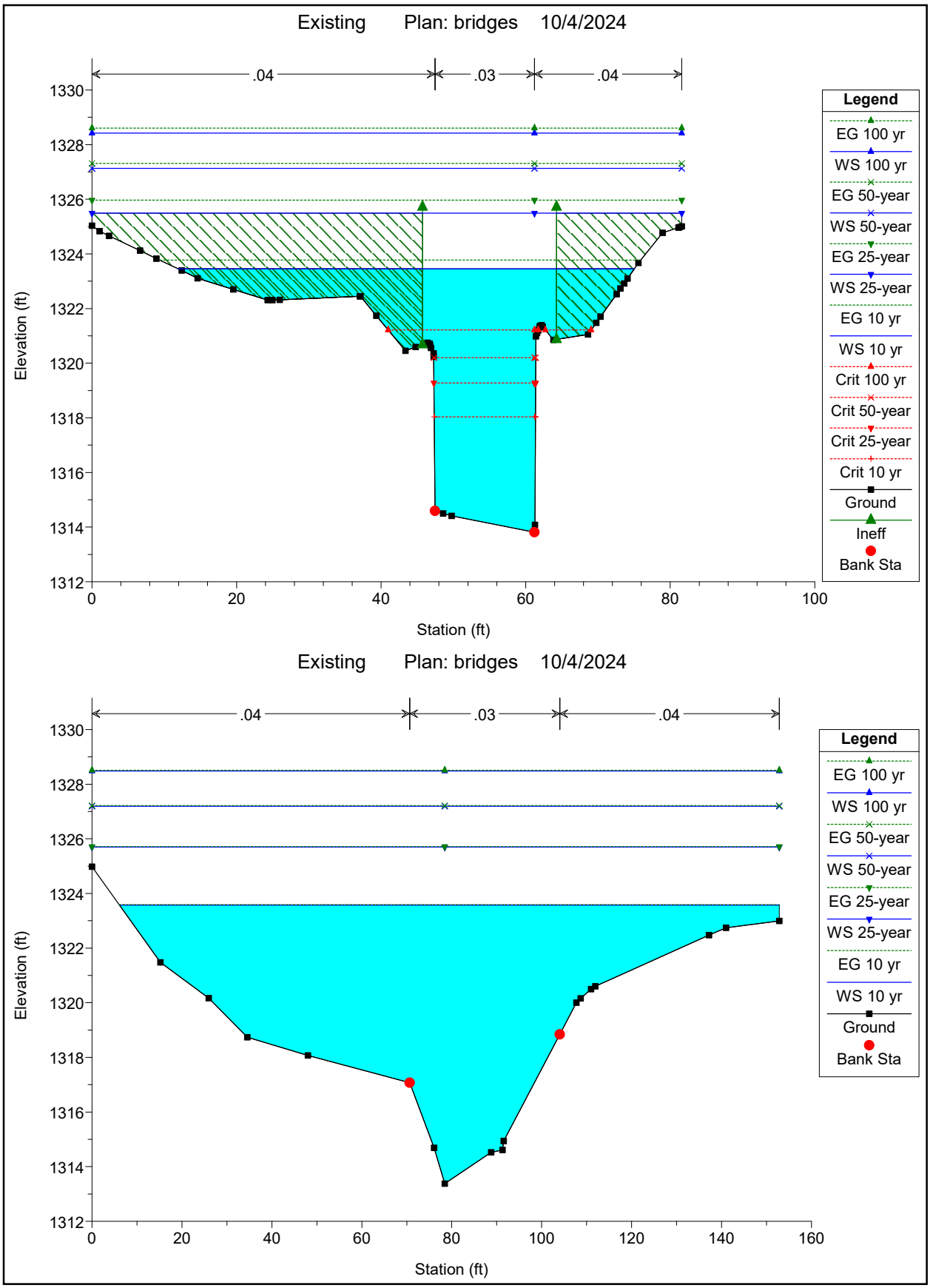

Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

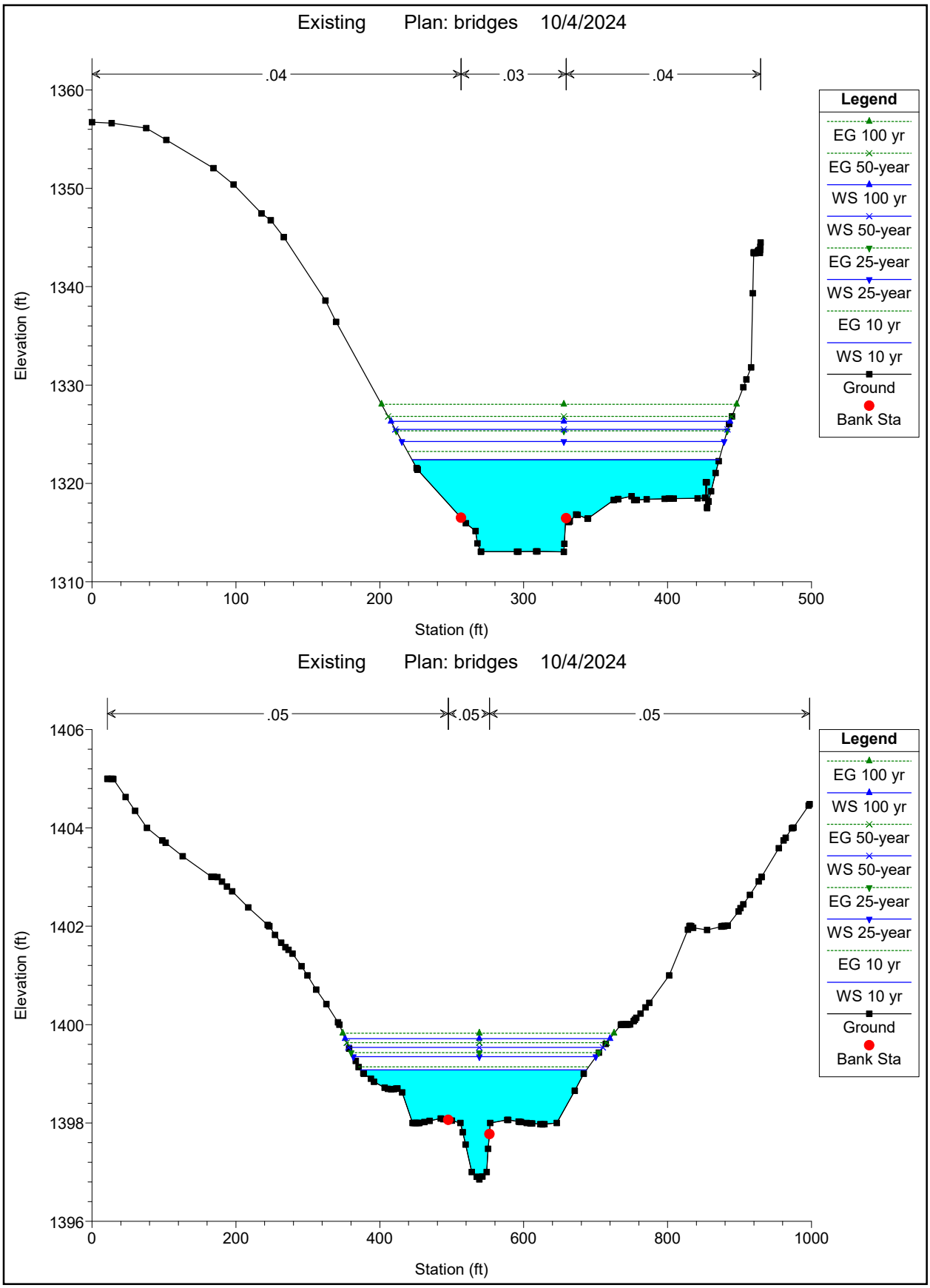

Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

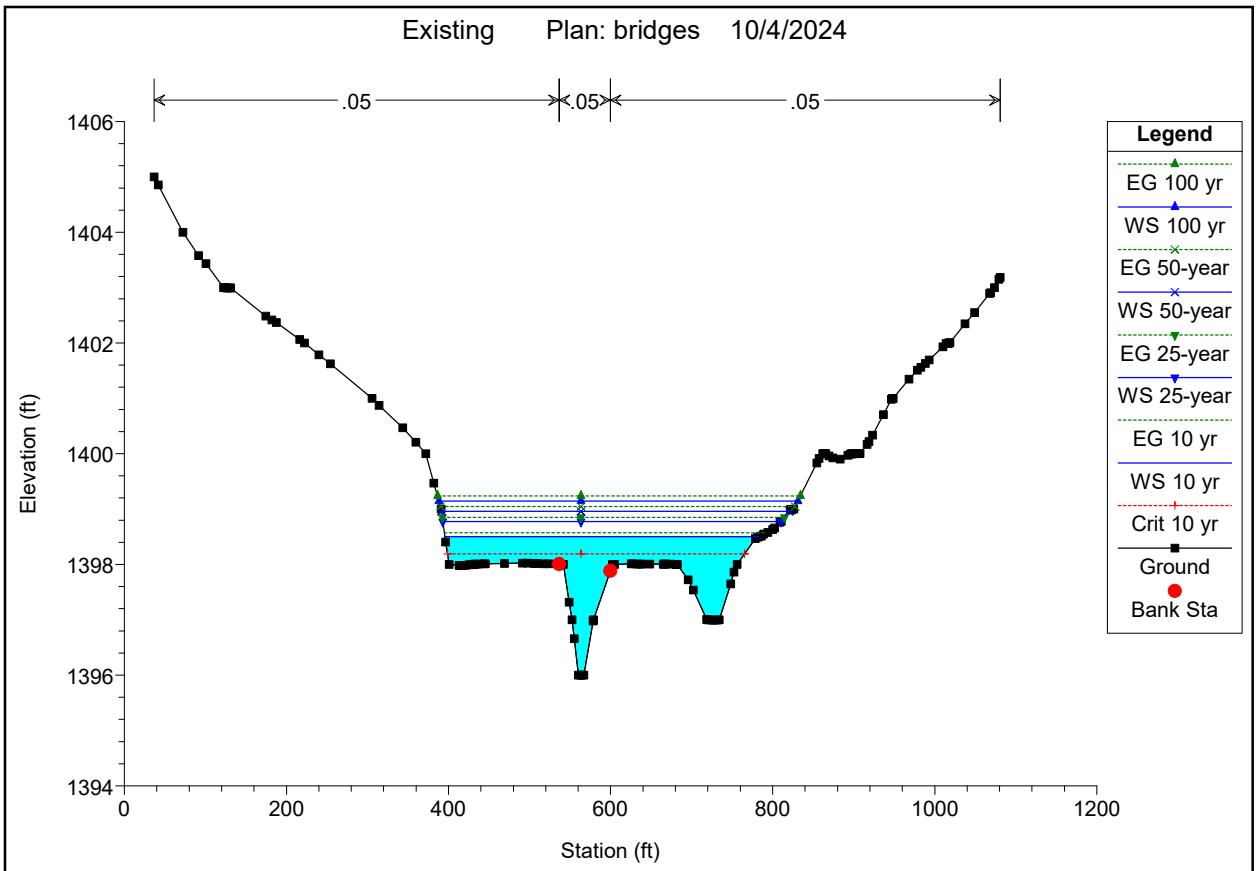

Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

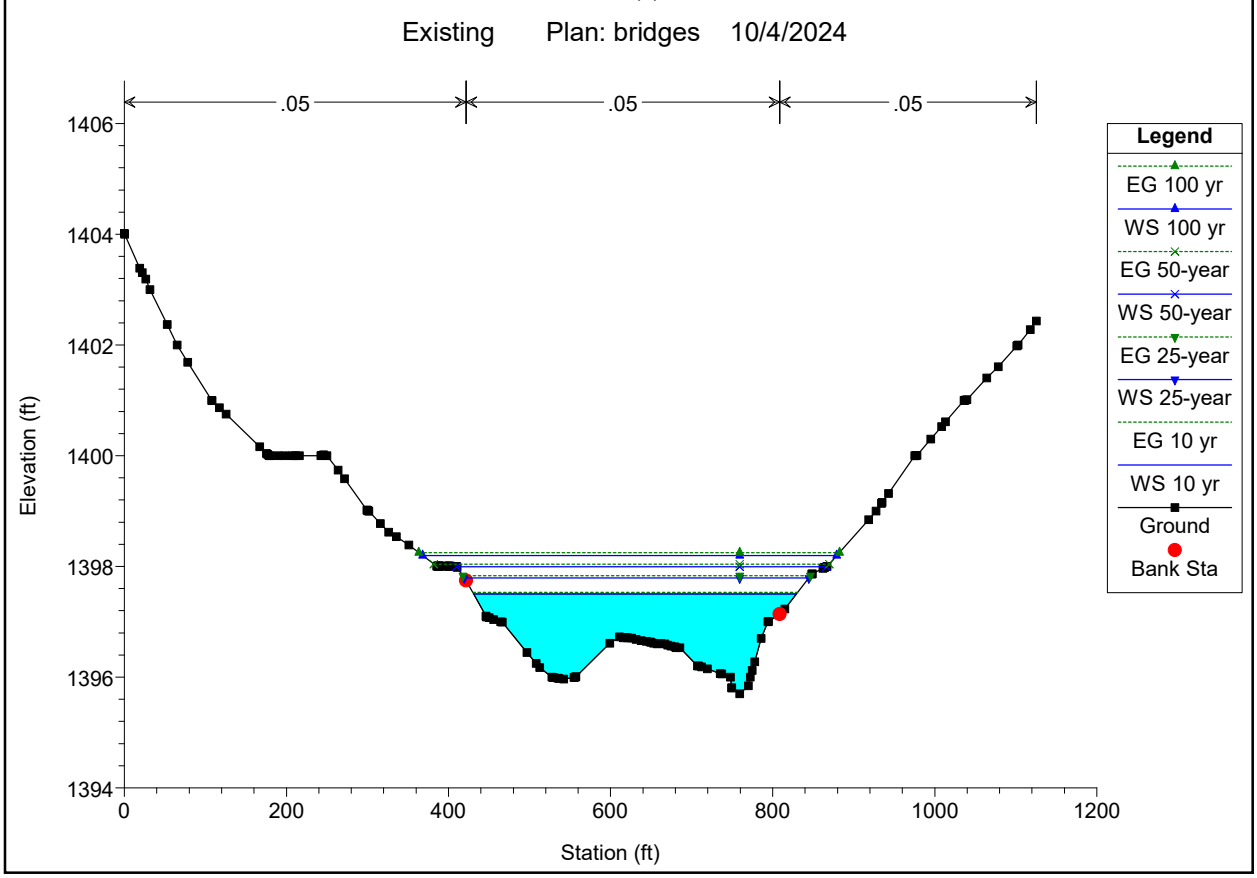

Existing Plan: bridges 10/4/2024
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.03
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1320
1318
1316
1314
Elevation (ft)
0
50
100
150
200
250
300
350
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.03
.04
1330
1328
1326
1324
1322
1320
1318
1316
1314
Elevation (ft)
0
50
100
150
200
250
300
350
400
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 100 yr
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

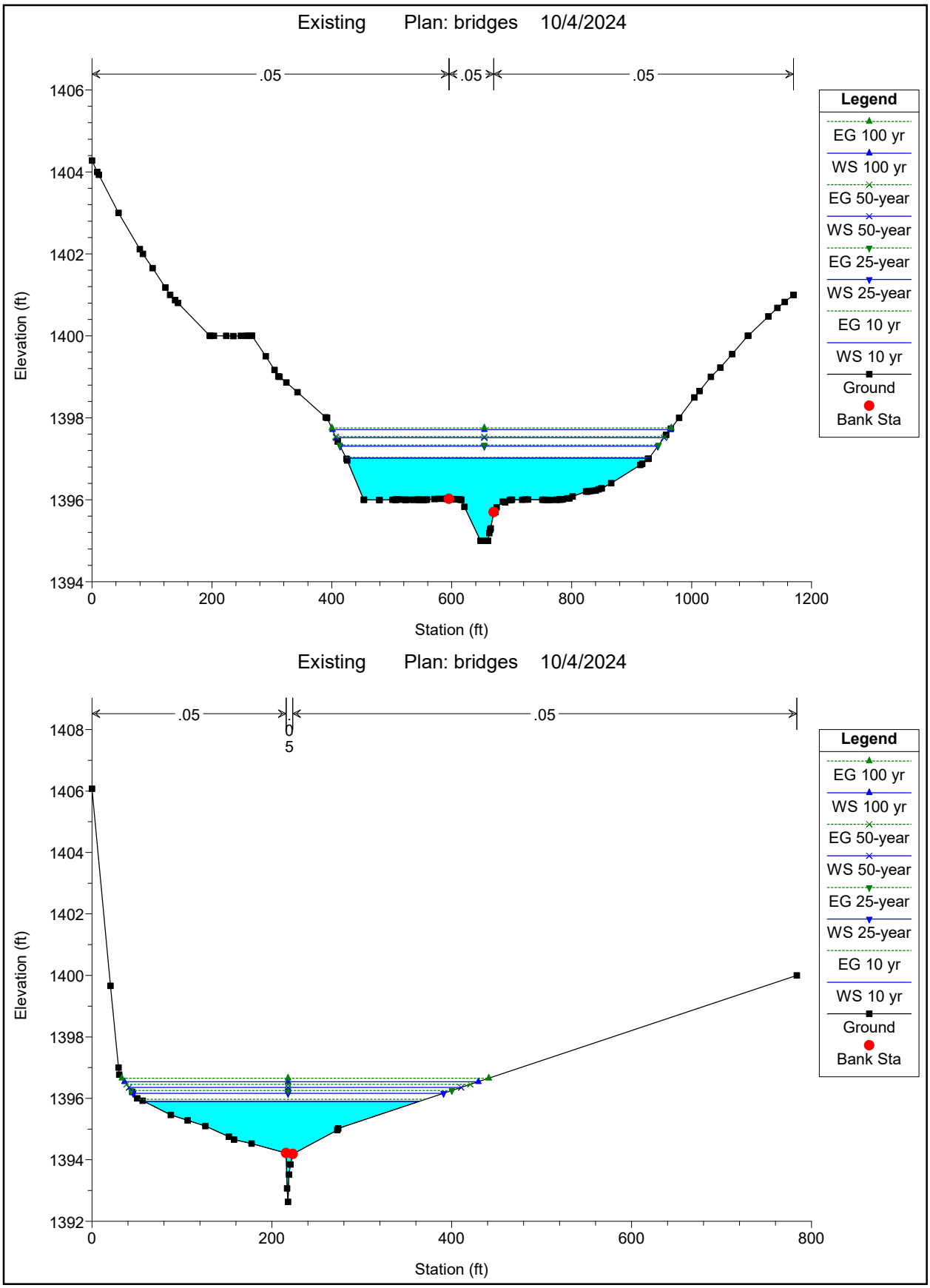

Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
WS 50-year
EG 50-year
EG 25-year
EG 10 yr
WS 25-year
WS 10 yr
Crit 25-year
Crit 10 yr
Crit 50-year
Crit 100 yr
Ground
Ineff
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
WS 50-year
EG 50-year
EG 25-year
EG 10 yr
WS 25-year
WS 10 yr
Crit 25-year
Crit 10 yr
Crit 50-year
Crit 100 yr
Ground
Ineff
Bank Sta

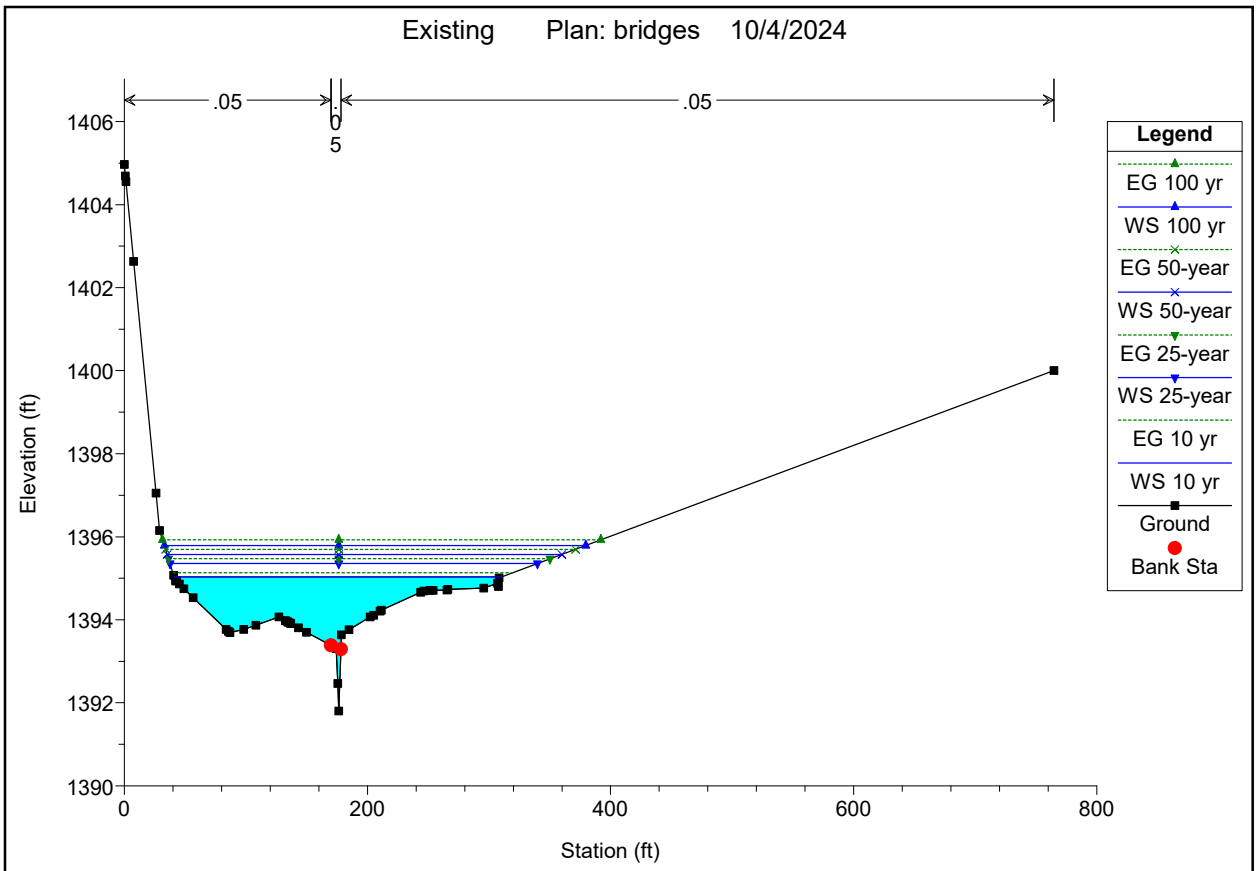

Existing Plan: bridges 10/4/2024
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.03
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1328
1326
1324
1322
1320
1318
1316
1314
1312
Elevation (ft)
0
20
40
60
80
100
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 100 yr
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.03
.04
1330
1328
1326
1324
1322
1320
1318
1316
1314
1312
Elevation (ft)
0
20
40
60
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100
120
140
160
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

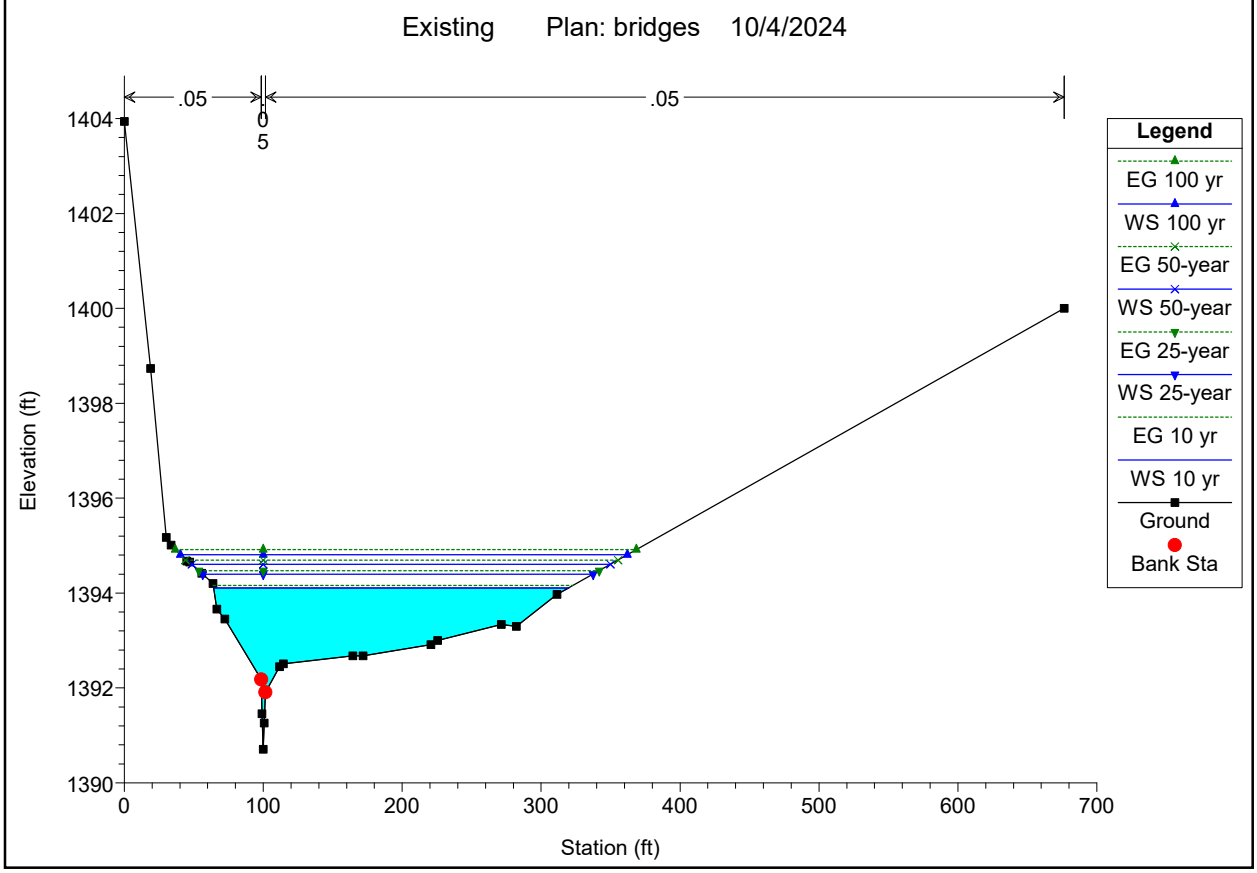

Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.05
.05
.05
Elevation (ft)
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

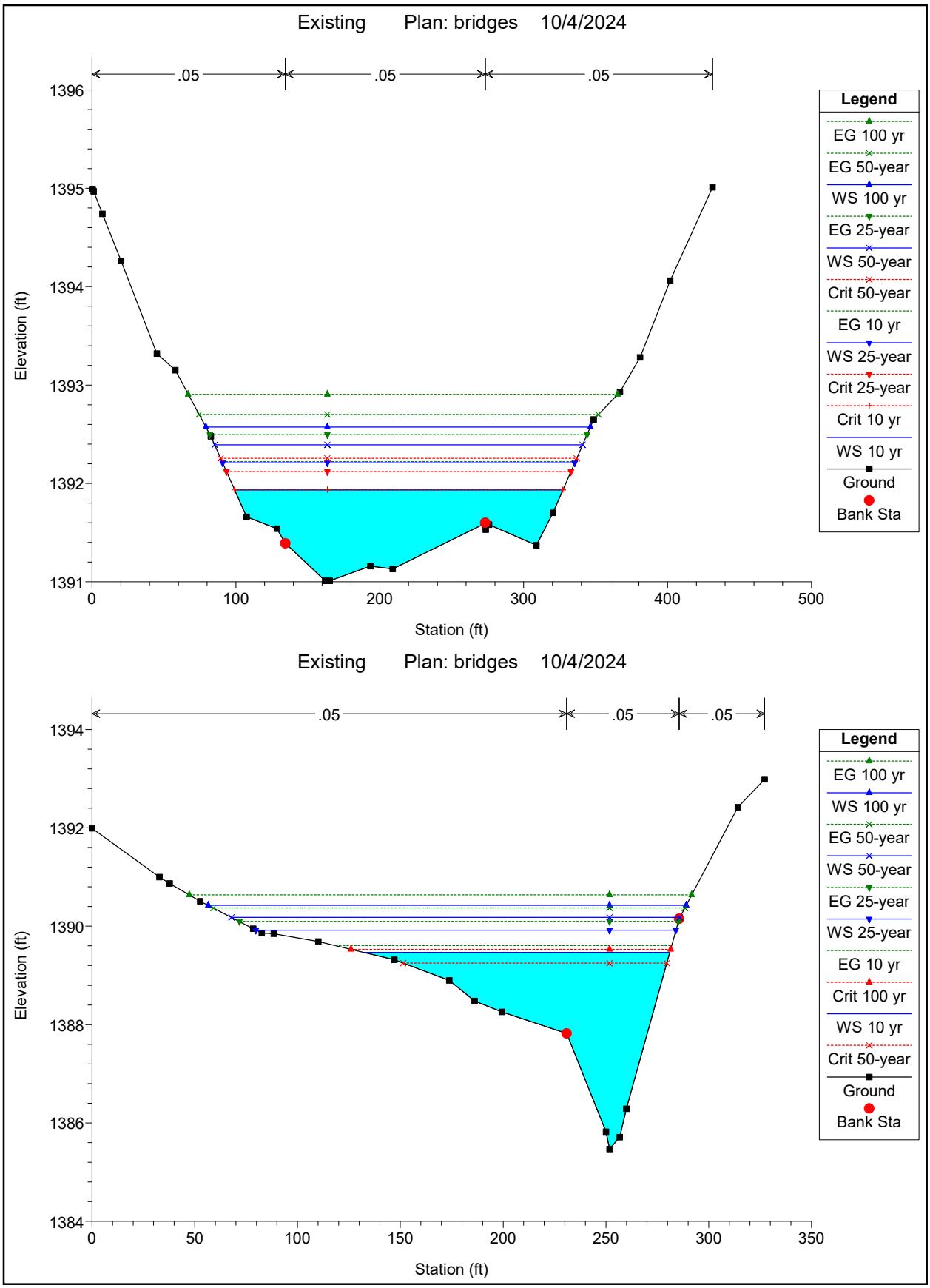

Existing Plan: bridges 10/4/2024
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.05
.05
1406
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1402
1400
1398
1396
1394
Elevation (ft)
0
200
400
600
800
1000
1200
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 10 yr
Ground
Bank Sta

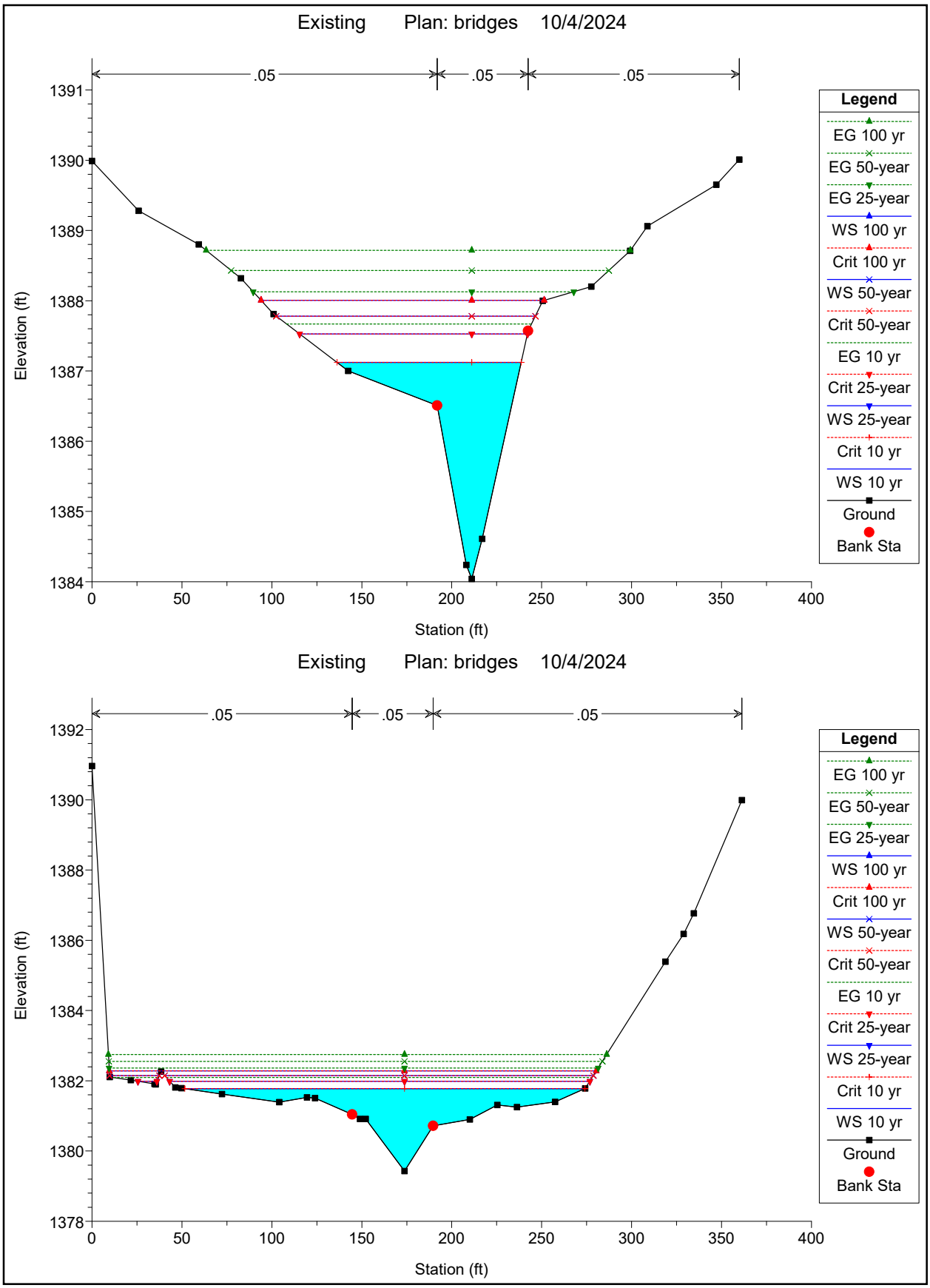

Existing Plan: bridges 10/4/2024
.05
.05
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1406
1404
1402
1400
1398
1396
1394
Elevation (ft)
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600
800
1000
1200
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

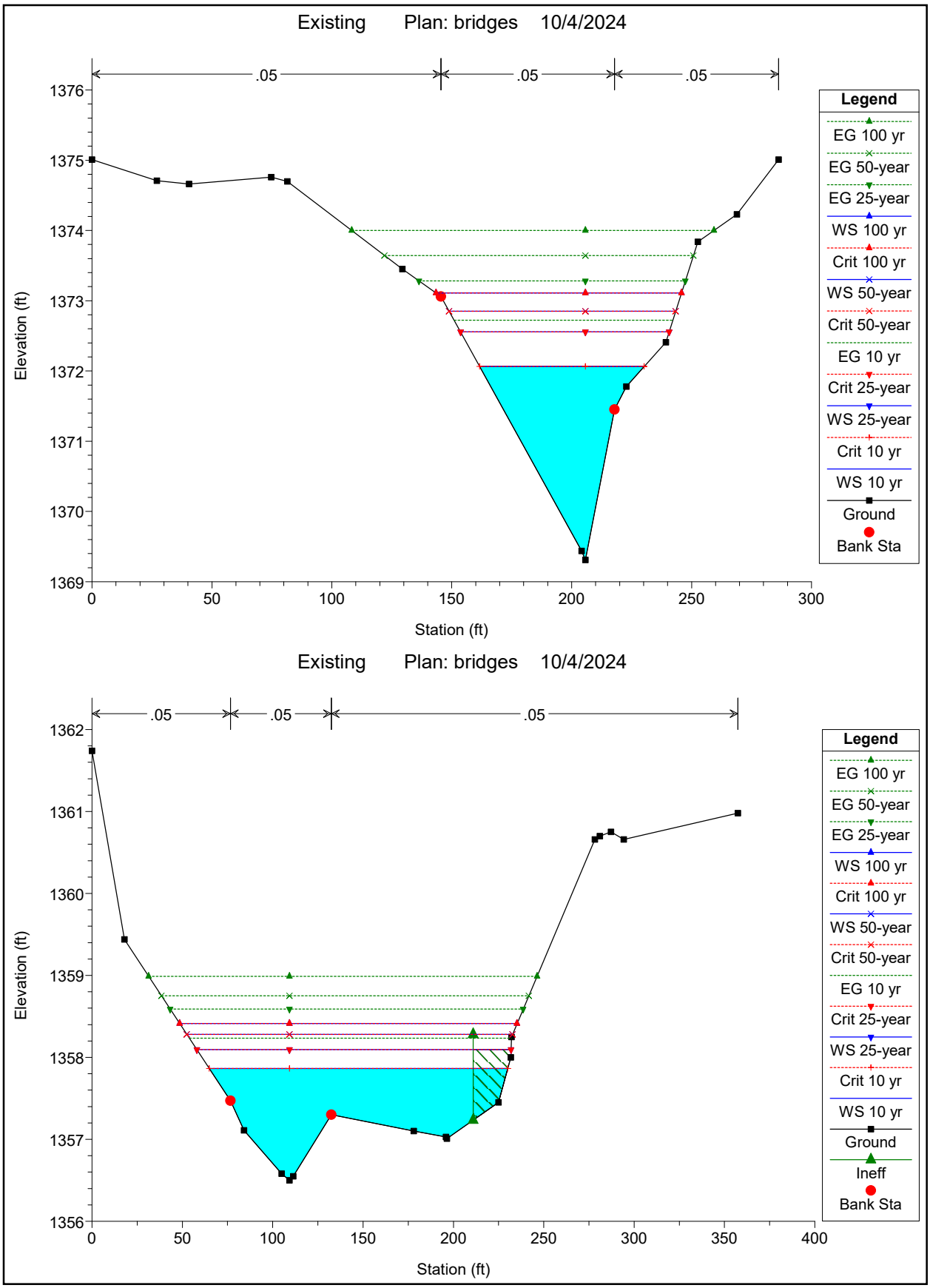

Existing Plan: bridges 10/4/2024
.05
.05
.05
1406
1404
1402
1400
1398
1396
1394
Elevation (ft)
0
200
400
600
800
1000
1200
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.05
.05
1408
1406
1404
1402
1400
1398
1396
1394
1392
Elevation (ft)
0
200
400
600
800
Station (ft)
Legend
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WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

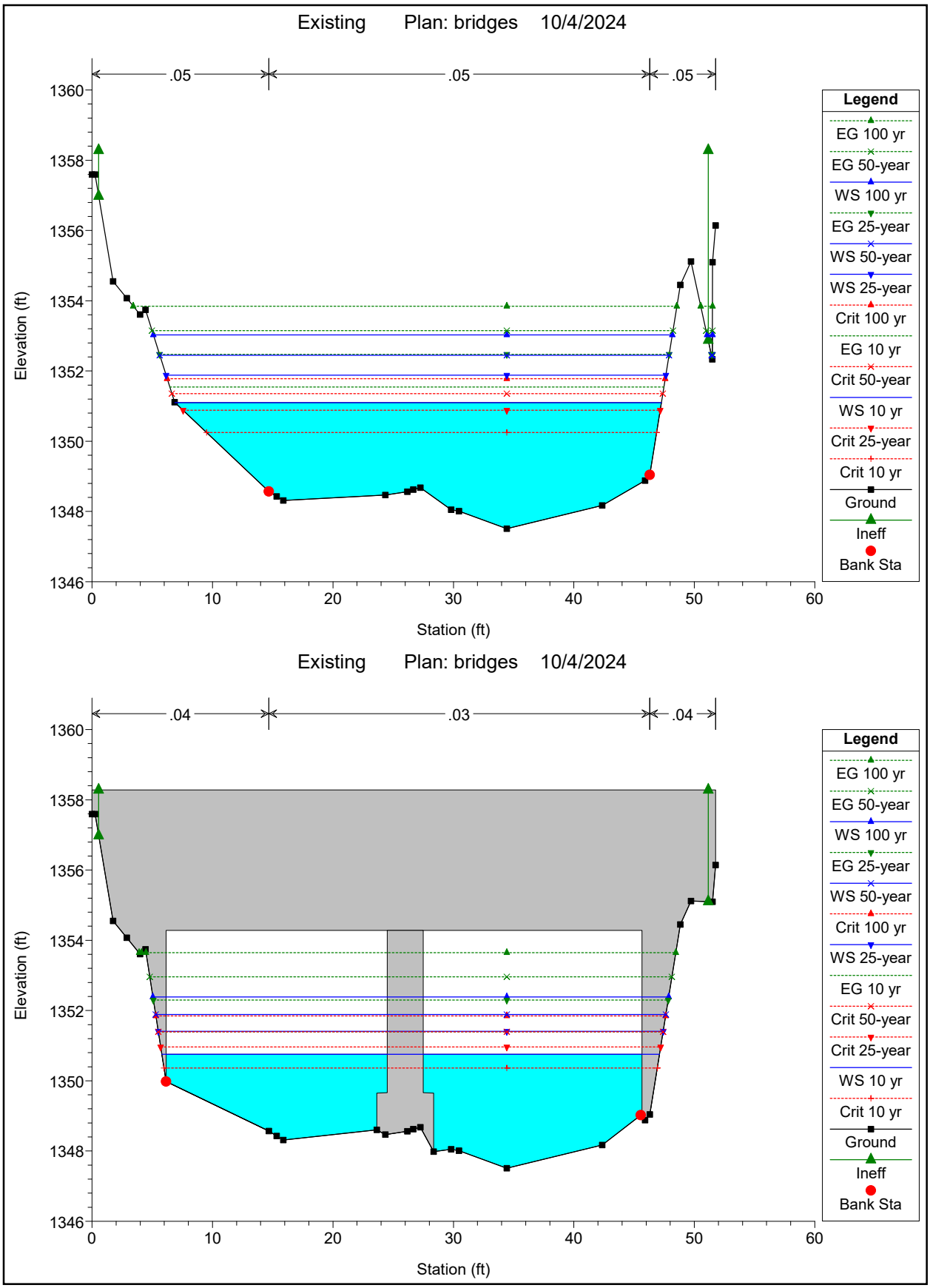

Existing Plan: bridges 10/4/2024
.05
.05
1406
1404
1402
1400
1398
1396
1394
1392
1390
Elevation (ft)
0
200
400
600
800
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

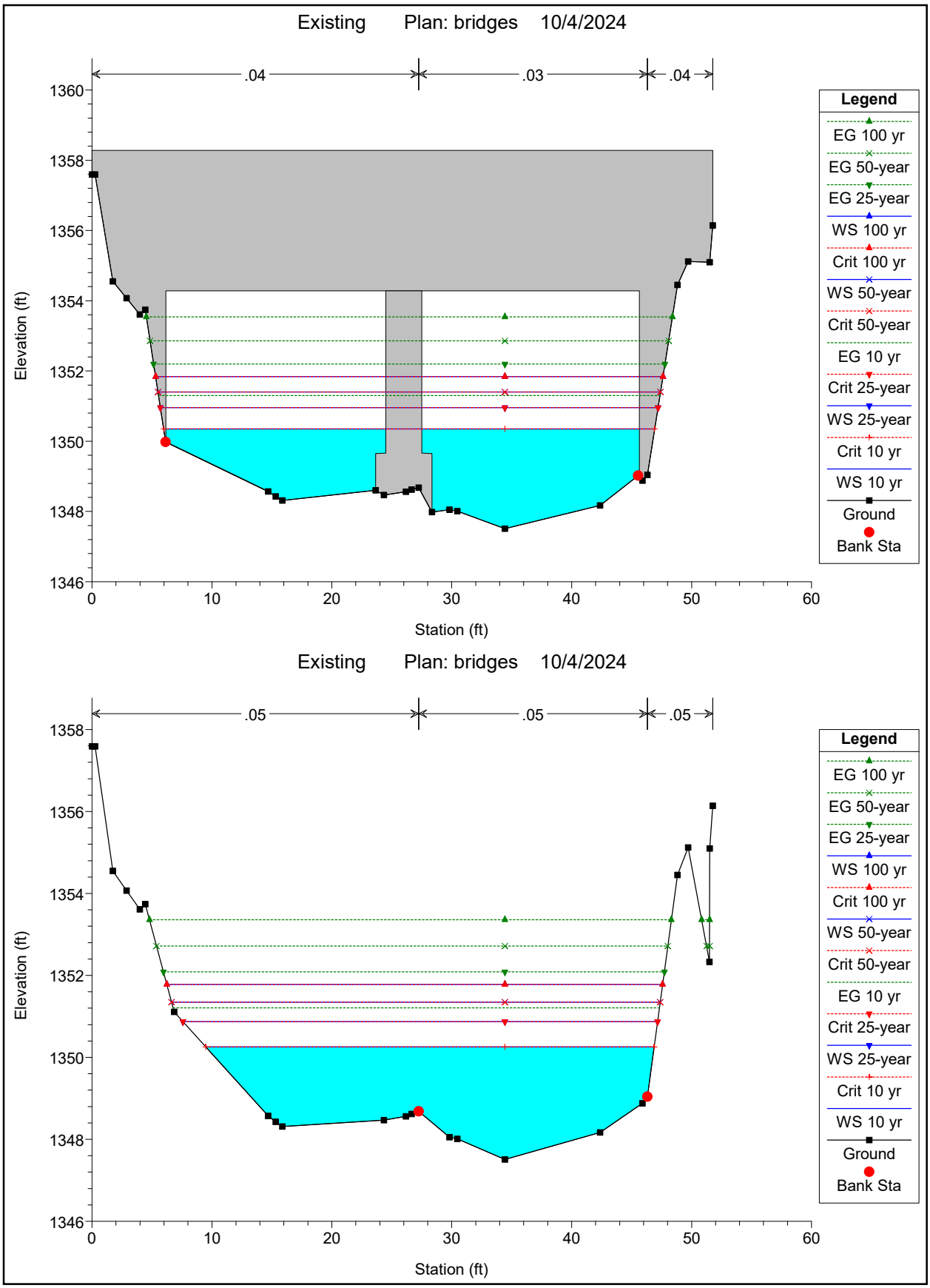

Existing Plan: bridges 10/4/2024
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.05
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1402
1400
1398
1396
1394
1392
1390
Elevation (ft)
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100
200
300
400
500
600
700
Station (ft)
Legend
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WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

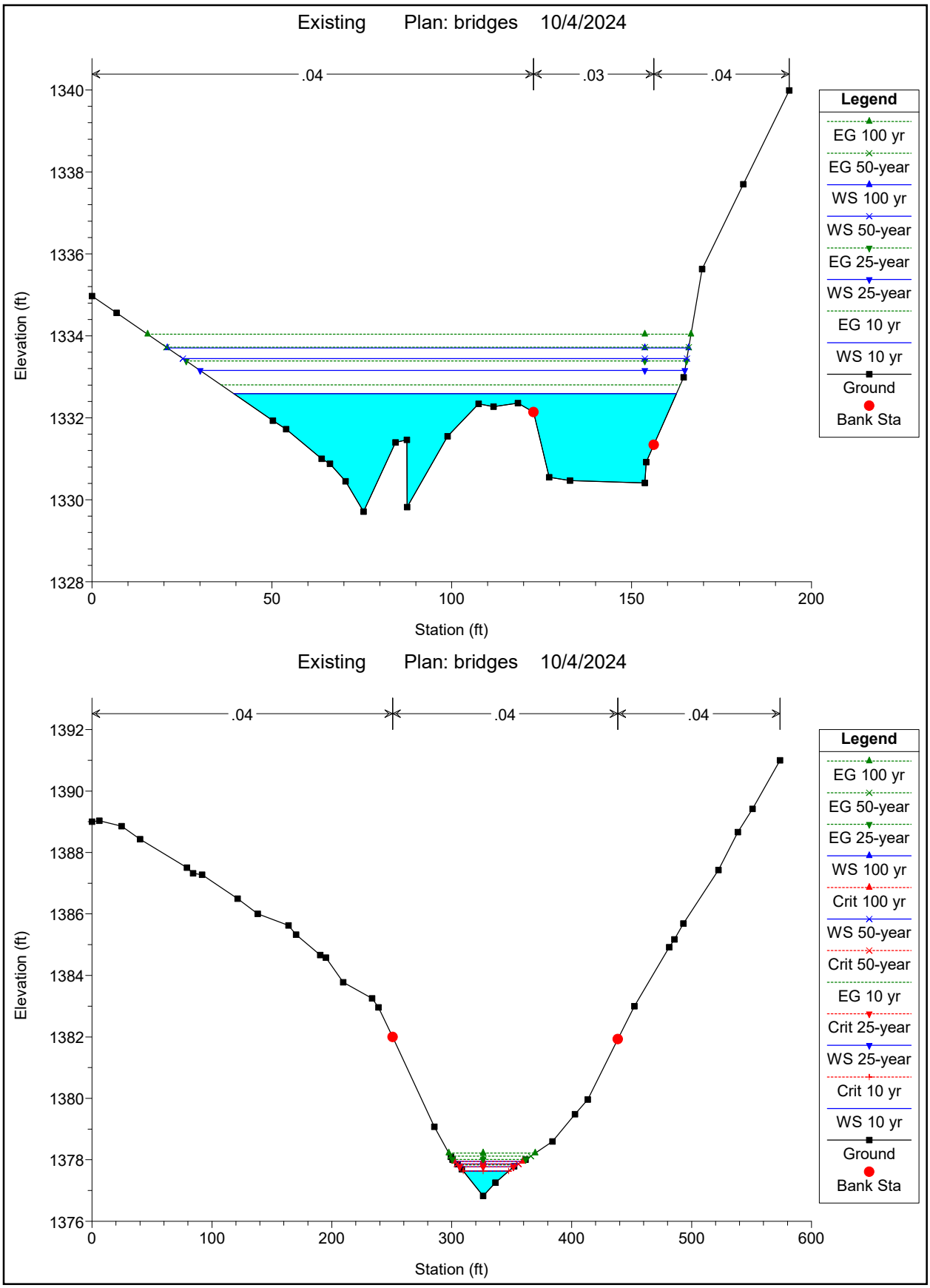

Existing Plan: bridges 10/4/2024
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.05
.05
1396
1395
1394
1393
1392
1391
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
Crit 50-year
EG 10 yr
WS 25-year
Crit 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.05
.05
.05
1394
1392
1390
1388
1386
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Elevation (ft)
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50
100
150
200
250
300
350
Station (ft)
Legend
EG 100 yr
WS 100 yr
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
Crit 100 yr
WS 10 yr
Crit 50-year
Ground
Bank Sta

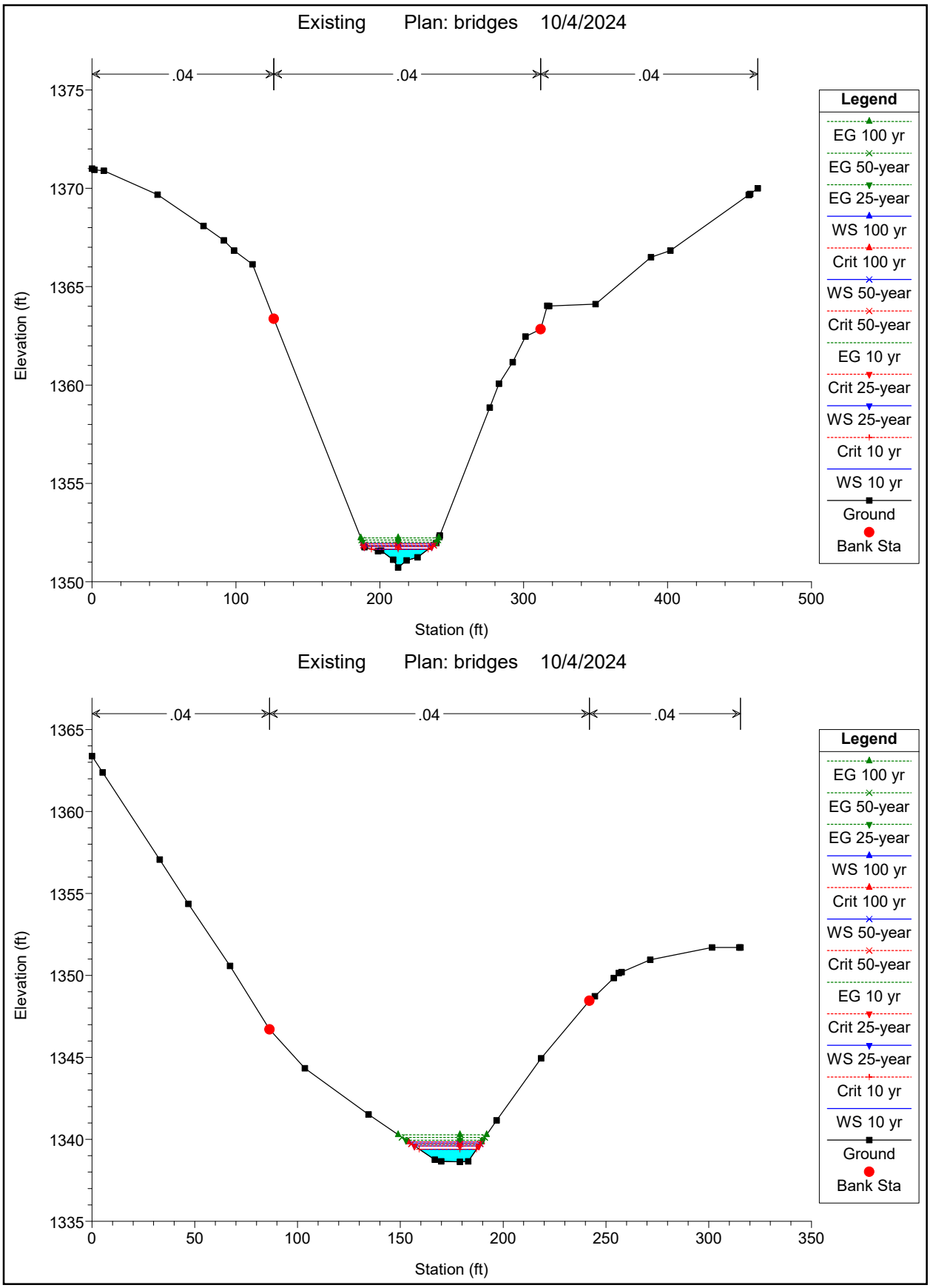

Existing Plan: bridges 10/4/2024
.05
.05
.05
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.05
.05
.05
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

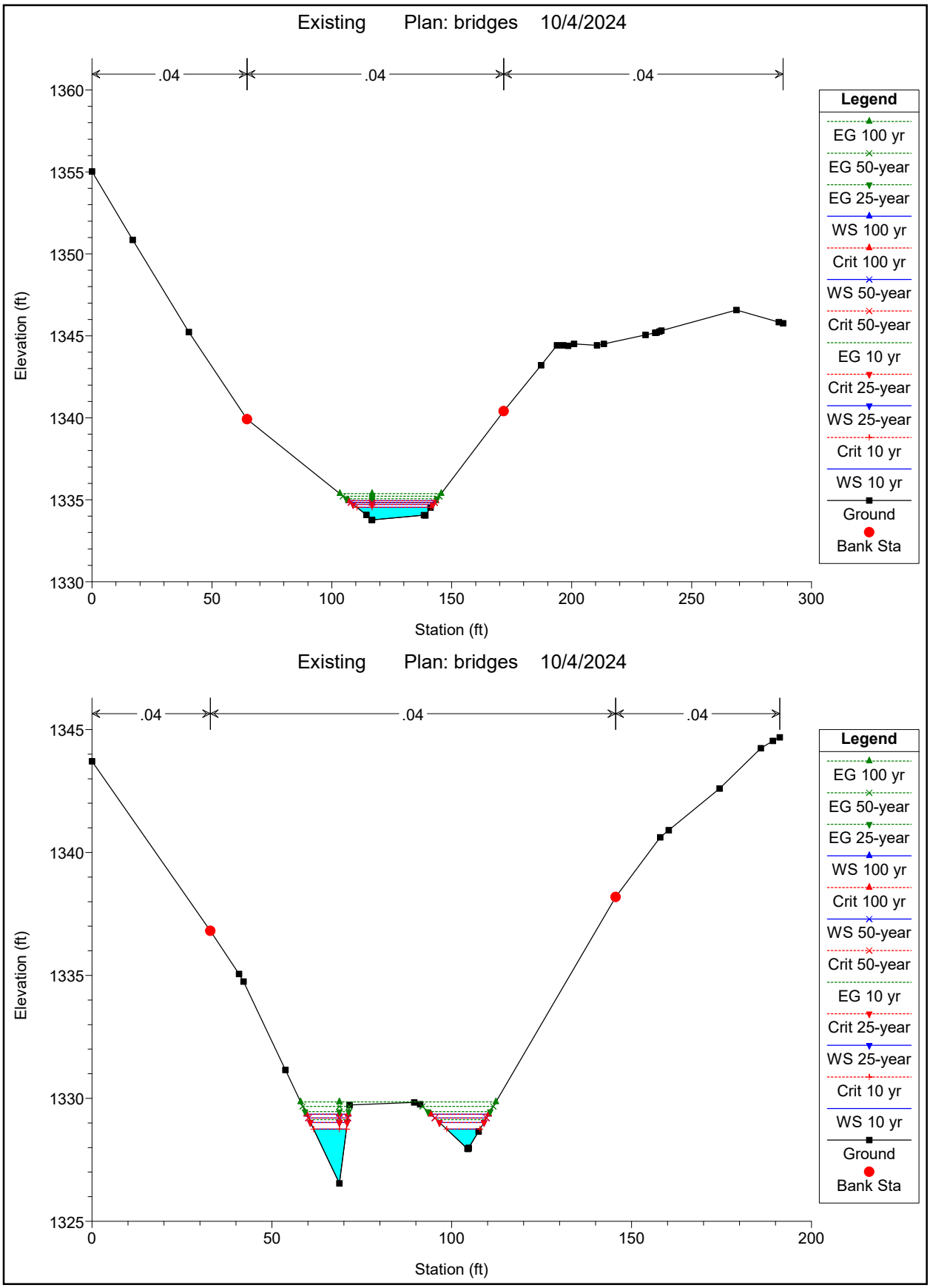

Existing Plan: bridges 10/4/2024
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.05
.05
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1370
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Elevation (ft)
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50
100
150
200
250
300
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.05
.05
.05
1362
1361
1360
1359
1358
1357
1356
Elevation (ft)
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50
100
150
200
250
300
350
400
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Ineff
Bank Sta

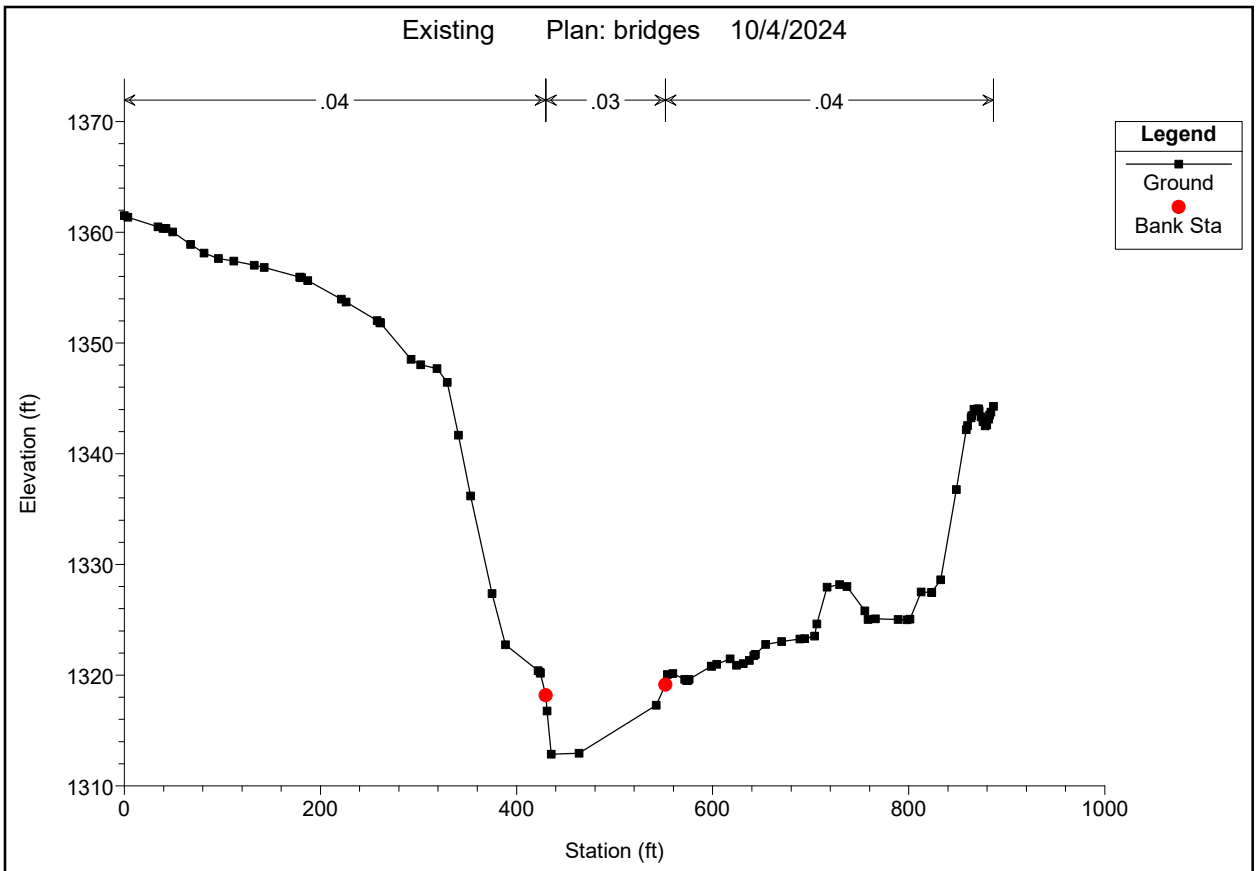

Existing Plan: bridges 10/4/2024
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.05
.05
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
WS 25-year
Crit 100 yr
EG 10 yr
Crit 50-year
WS 10 yr
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
EG 25-year
WS 50-year
Crit 100 yr
WS 25-year
EG 10 yr
Crit 50-year
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Ineff
Bank Sta

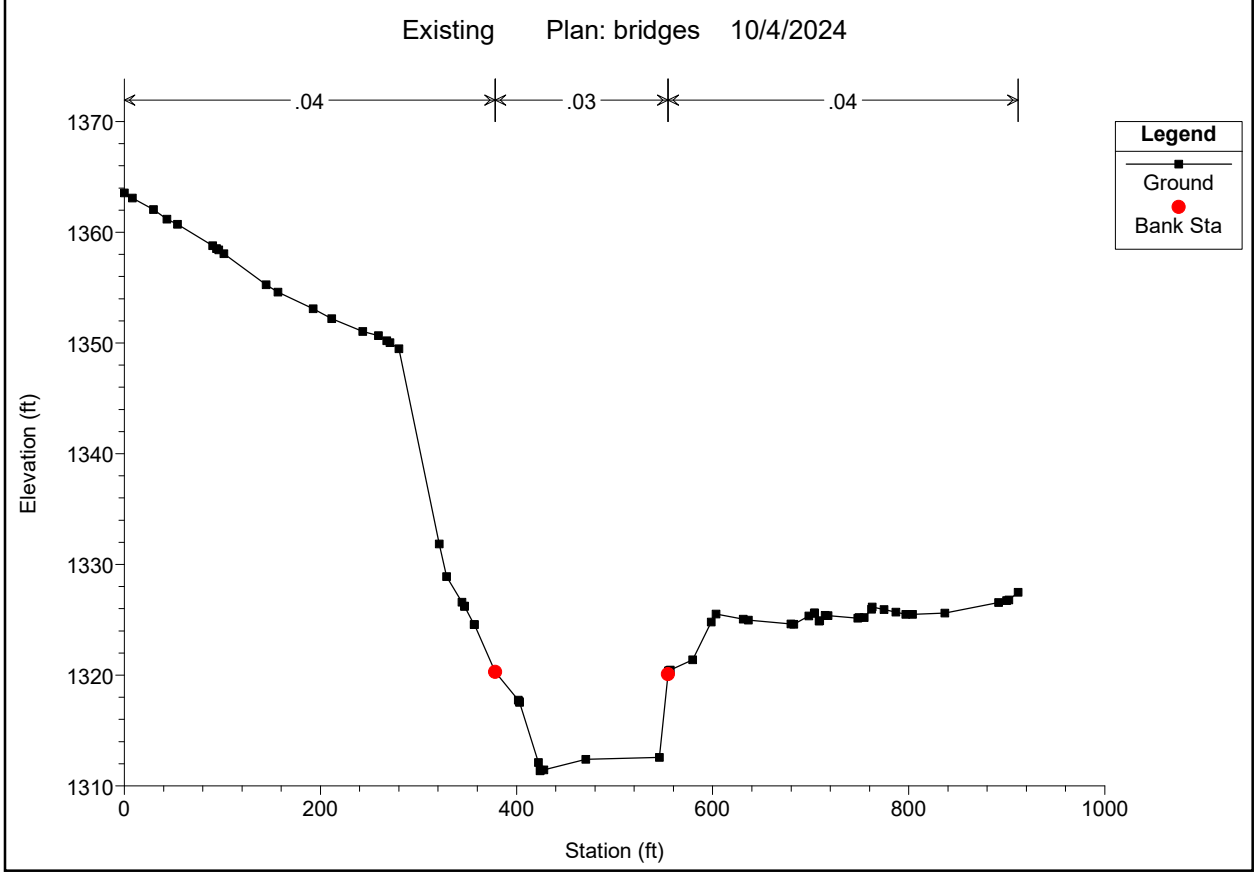

Existing Plan: bridges 10/4/2024
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.05
.05
.05
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

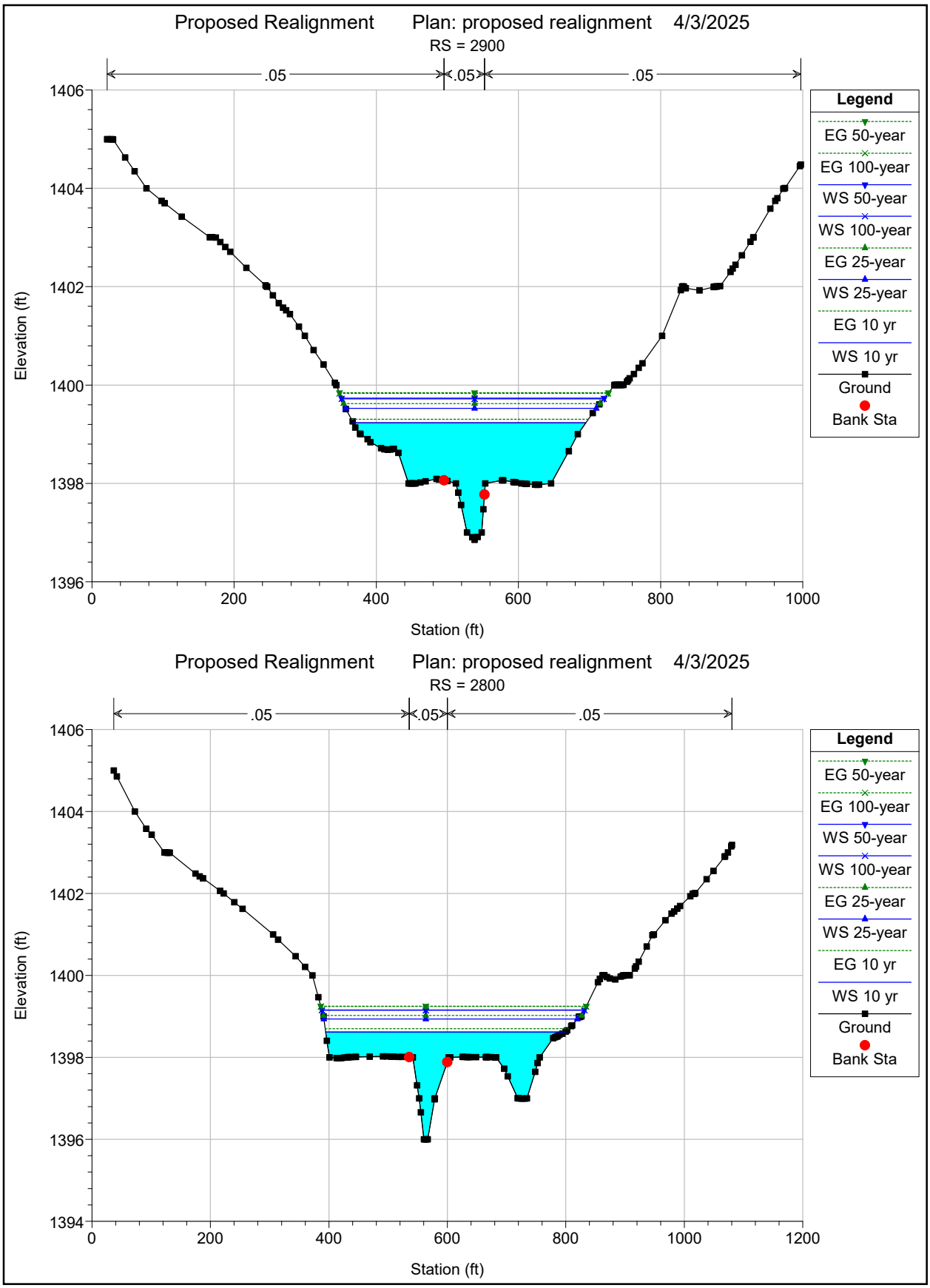

Existing Plan: bridges 10/4/2024
.04
.03
.04
1340
1338
1336
1334
1332
1330
1328
Elevation (ft)
0
50
100
150
200
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.04
.04
1392
1390
1388
1386
1384
1382
1380
1378
1376
Elevation (ft)
0
100
200
300
400
500
600
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

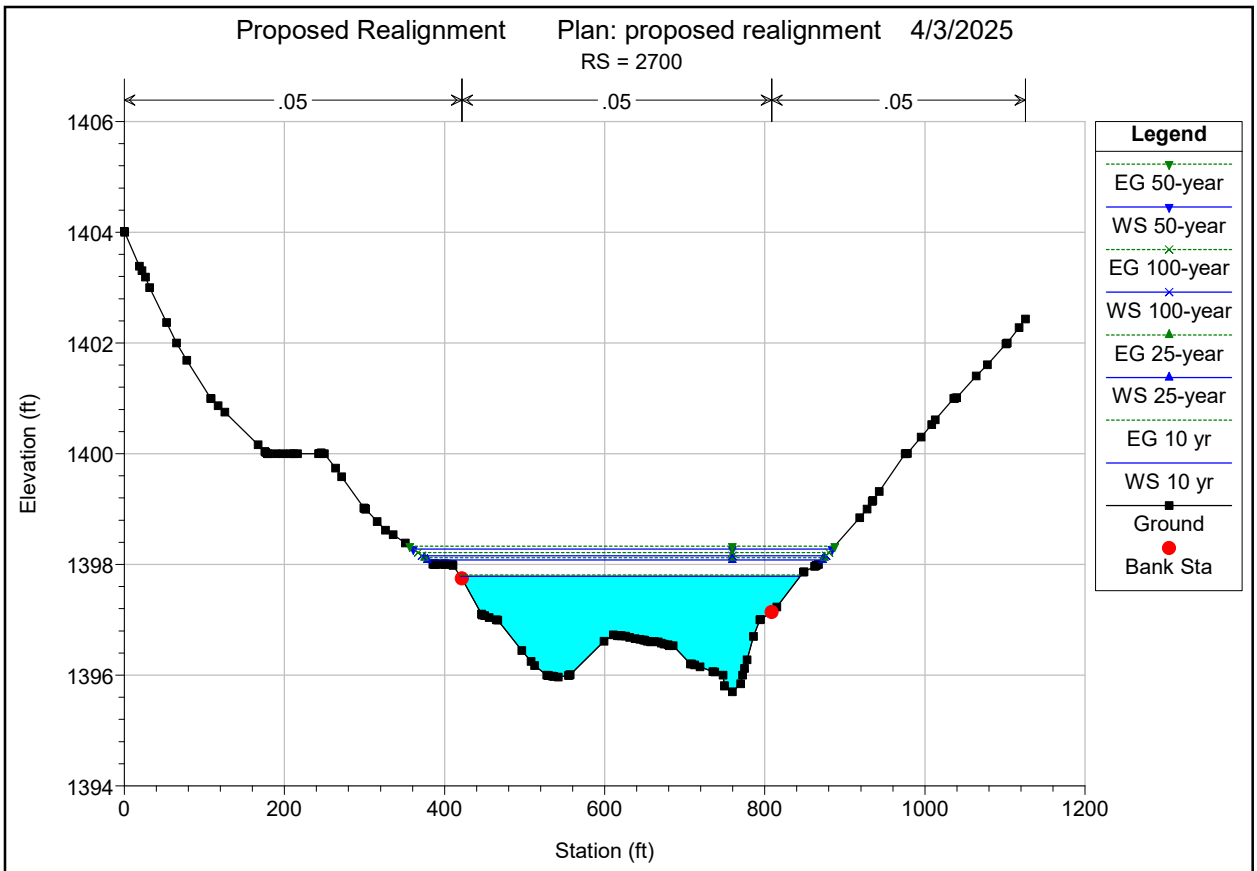

Existing Plan: bridges 10/4/2024
.04
.04
.04
1375
1370
1365
1360
1355
1350
Elevation (ft)
0
100
200
300
400
500
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.04
.04
1365
1360
1355
1350
1345
1340
1335
Elevation (ft)
0
50
100
150
200
250
300
350
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

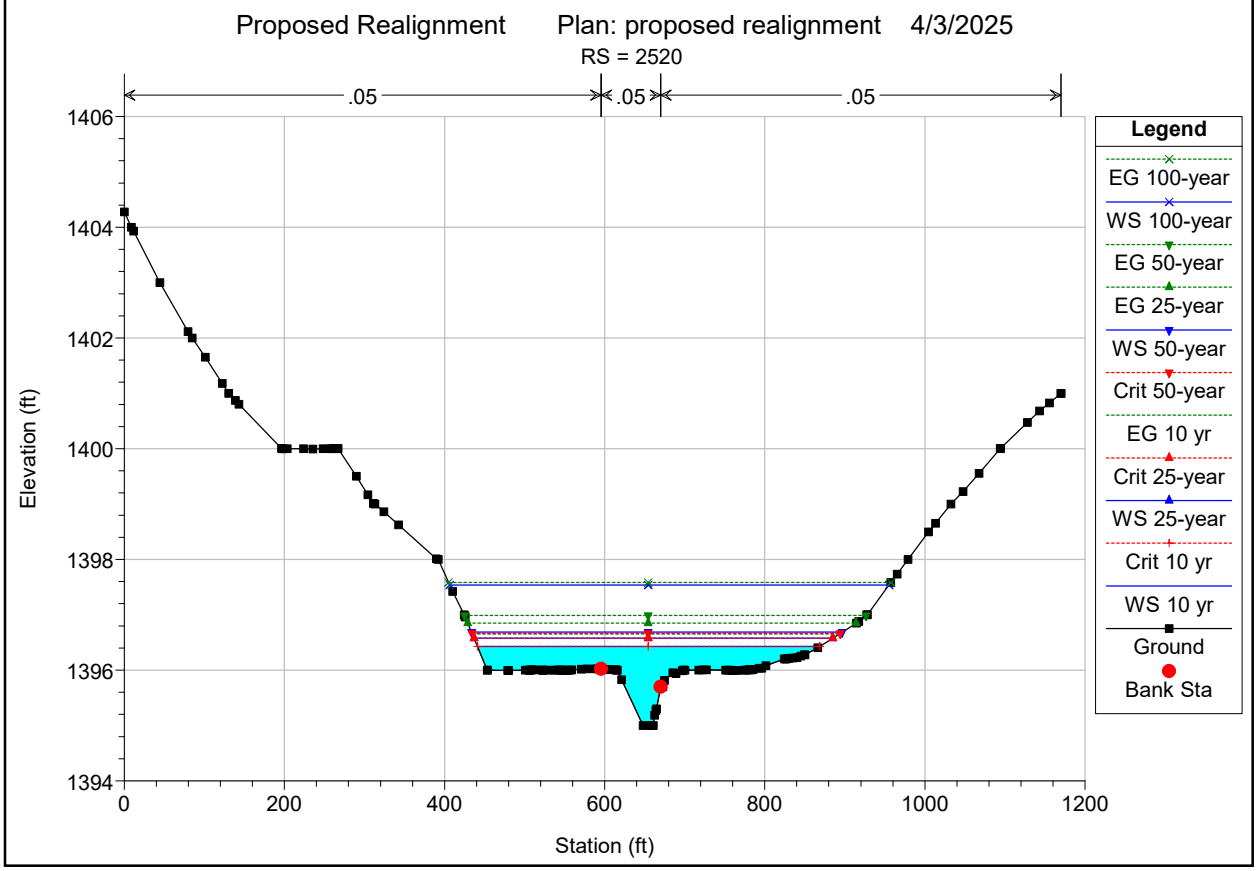

Existing Plan: bridges 10/4/2024
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Existing Plan: bridges 10/4/2024
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

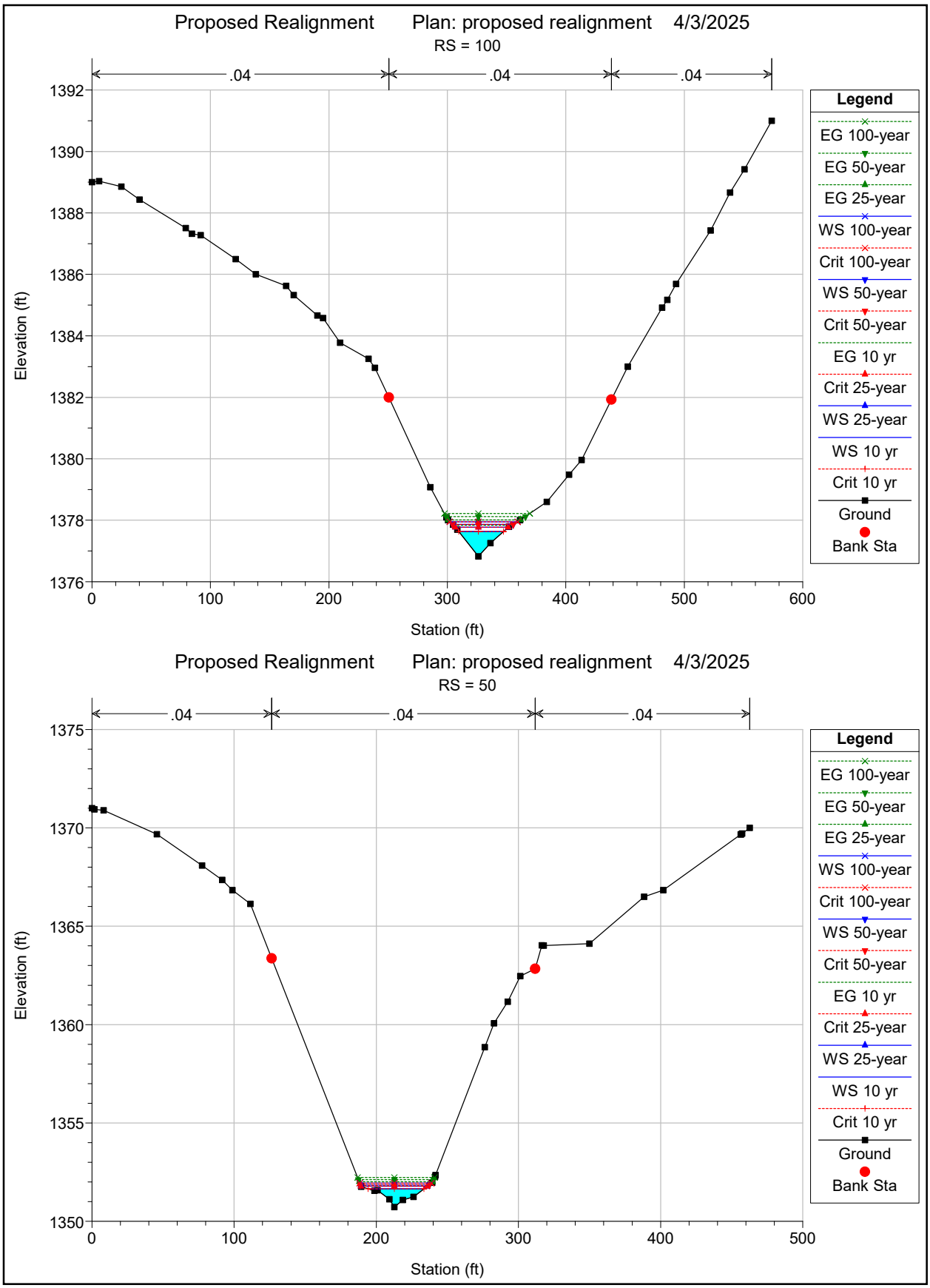

Existing Plan: bridges 10/4/2024
.04
.03
.04
Legend
Ground
Bank Sta
Elevation (ft)
Station (ft)
1370
1360
1350
1340
1330
1320
1310
0
200
400
600
800
1000

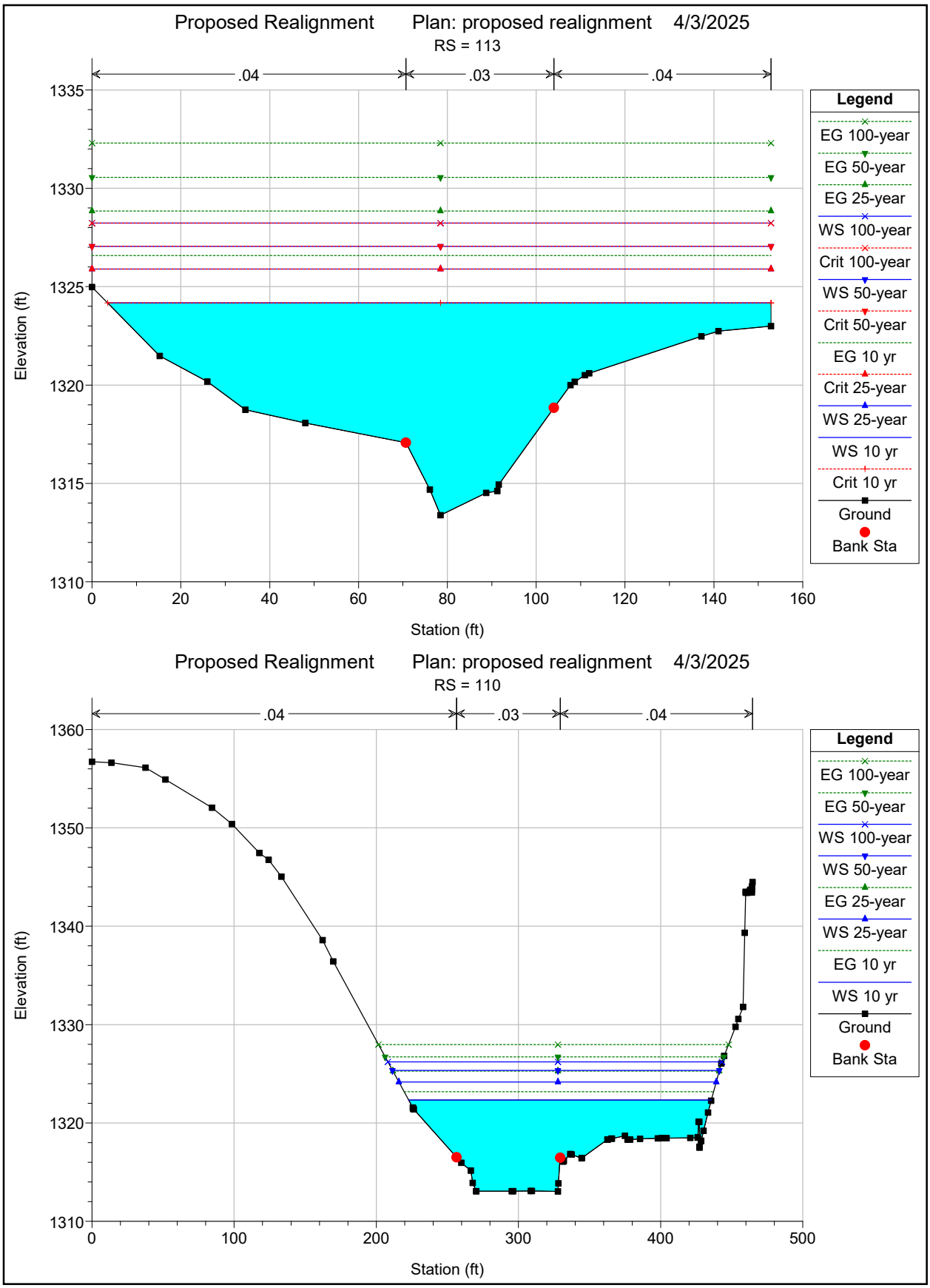

Existing Plan: bridges 10/4/2024
.04
.03
.04
Legend
Ground
Bank Sta
Elevation (ft)
Station (ft)
1370
1360
1350
1340
1330
1320
1310
0
200
400
600
800
1000

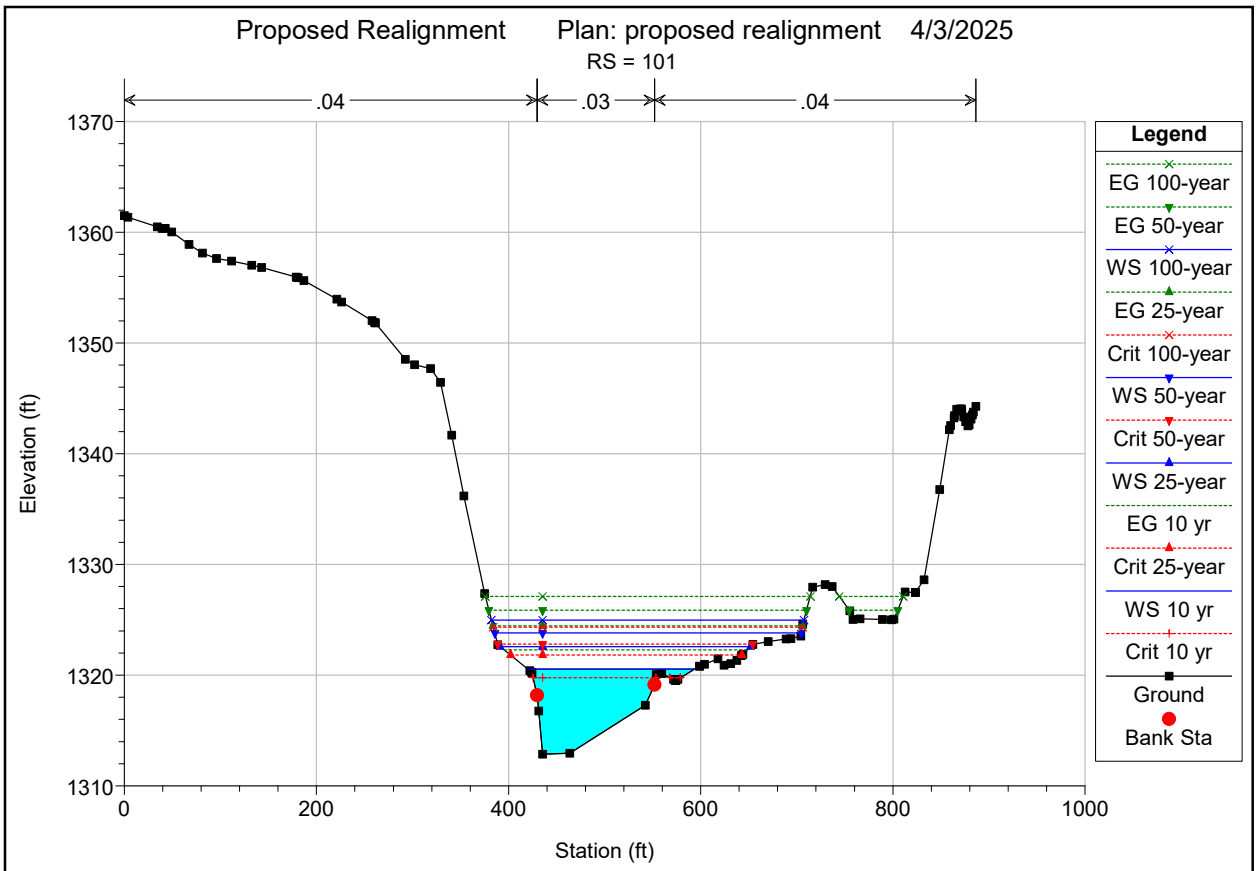

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2900
.05
.05
.05
Elevation (ft)
1406
1404
1402
1400
1398
1396
0
200
400
600
800
1000
Station (ft)
Legend
EG 50-year
EG 100-year
WS 50-year
WS 100-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2800
.05
.05
.05
Elevation (ft)
1406
1404
1402
1400
1398
1396
1394
0
200
400
600
800
1000
1200
Station (ft)
Legend
EG 50-year
EG 100-year
WS 50-year
WS 100-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

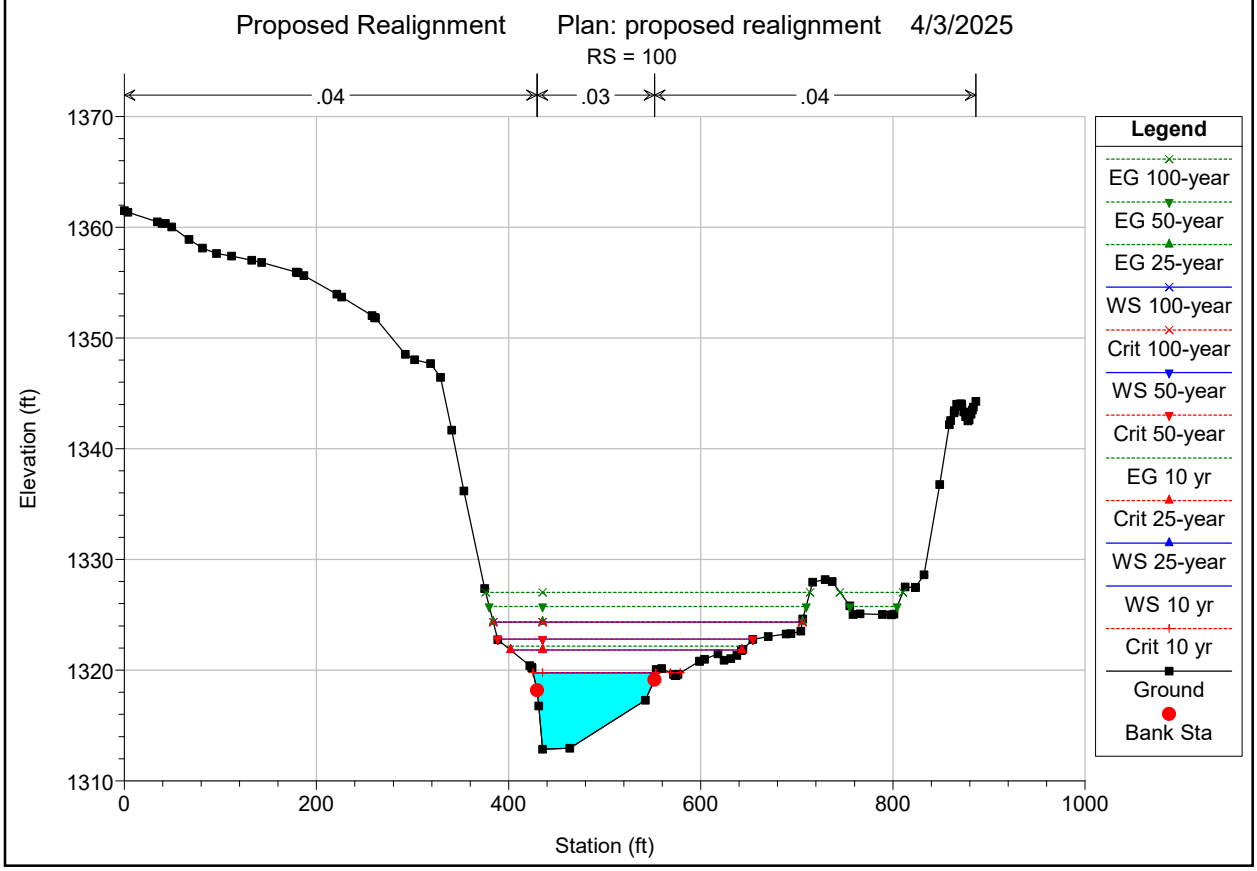

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2700
.05
.05
.05
Elevation (ft)
1406
1404
1402
1400
1398
1396
1394
0
200
400
600
800
1000
1200
Station (ft)
Legend
EG 50-year
WS 50-year
EG 100-year
WS 100-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

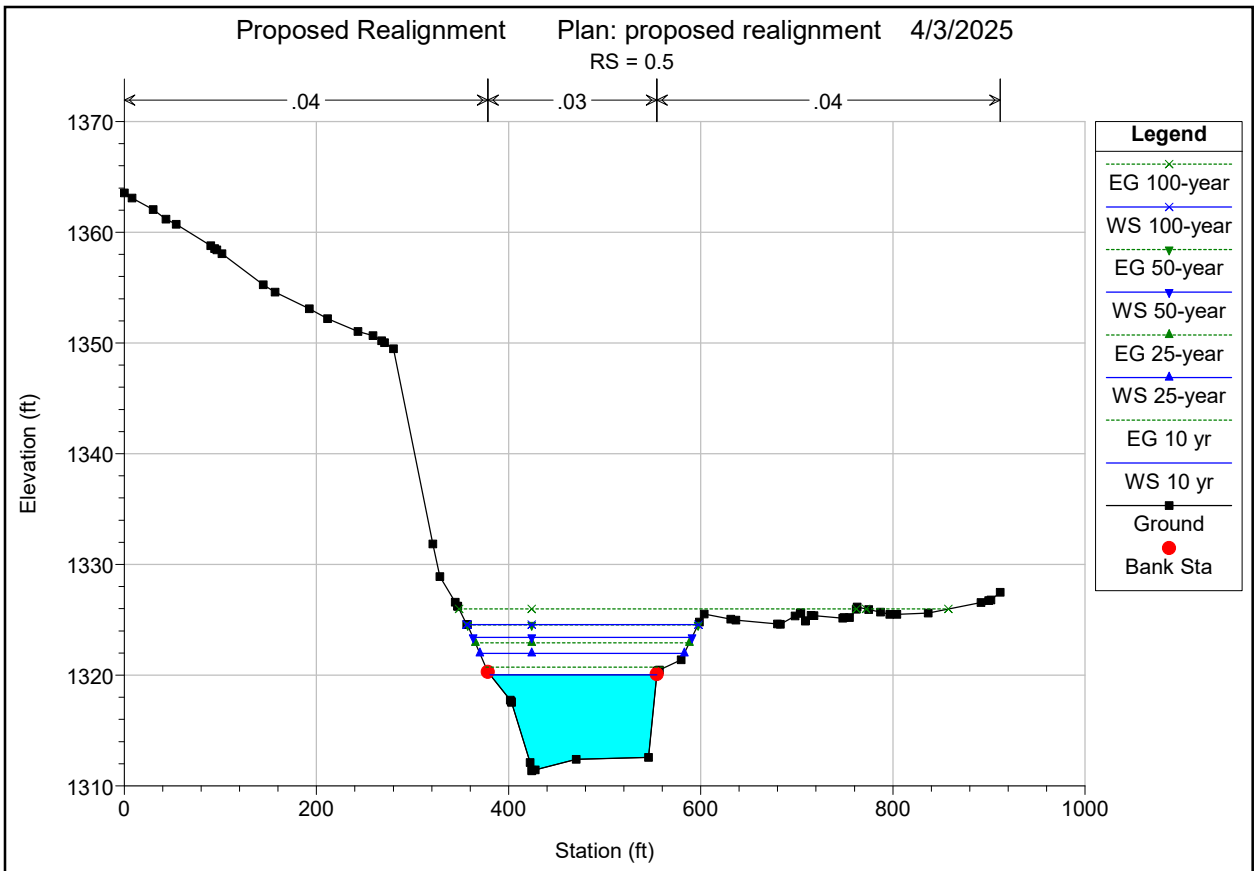

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2520
.05
.05
.05
Elevation (ft)
1406
1404
1402
1400
1398
1396
1394
0
200
400
600
800
1000
1200
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
EG 25-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta

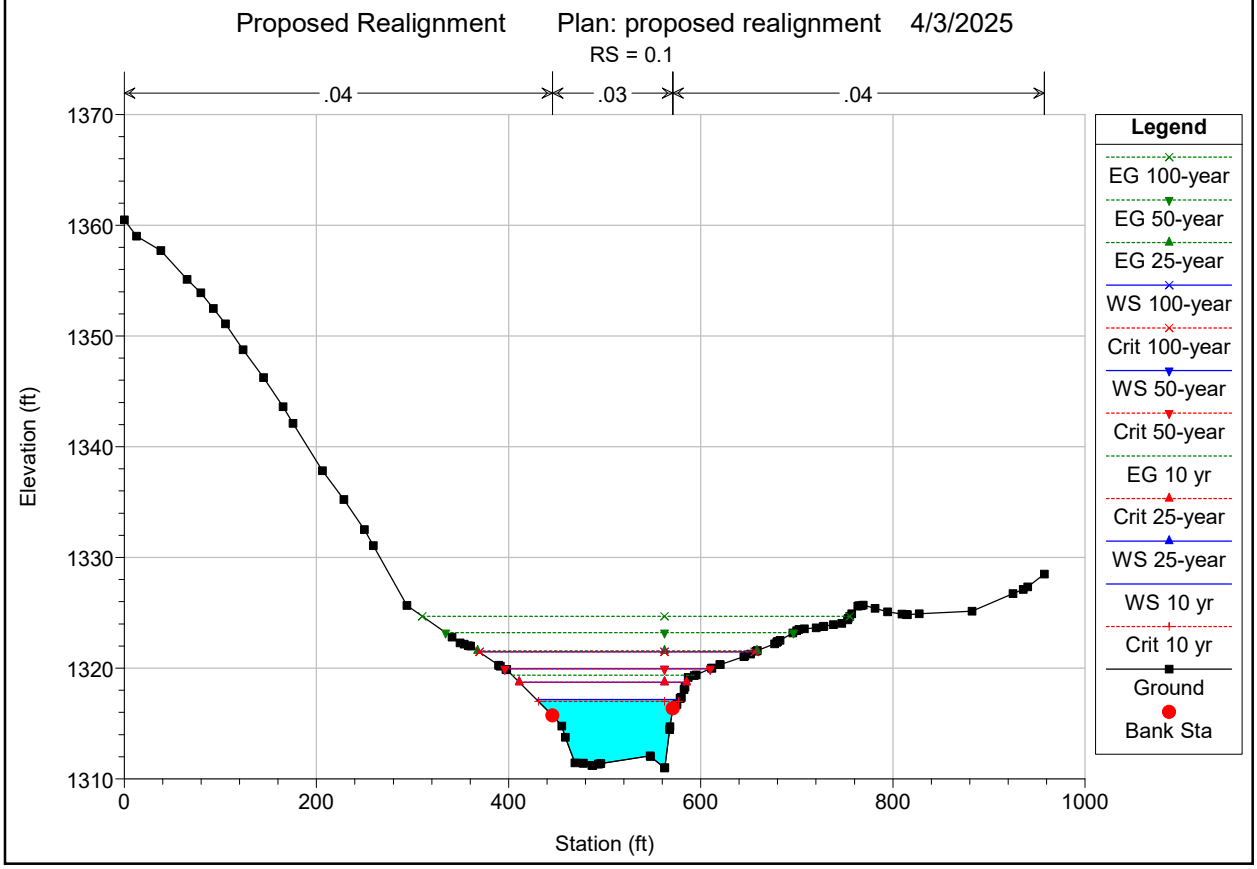

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 100
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 50
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

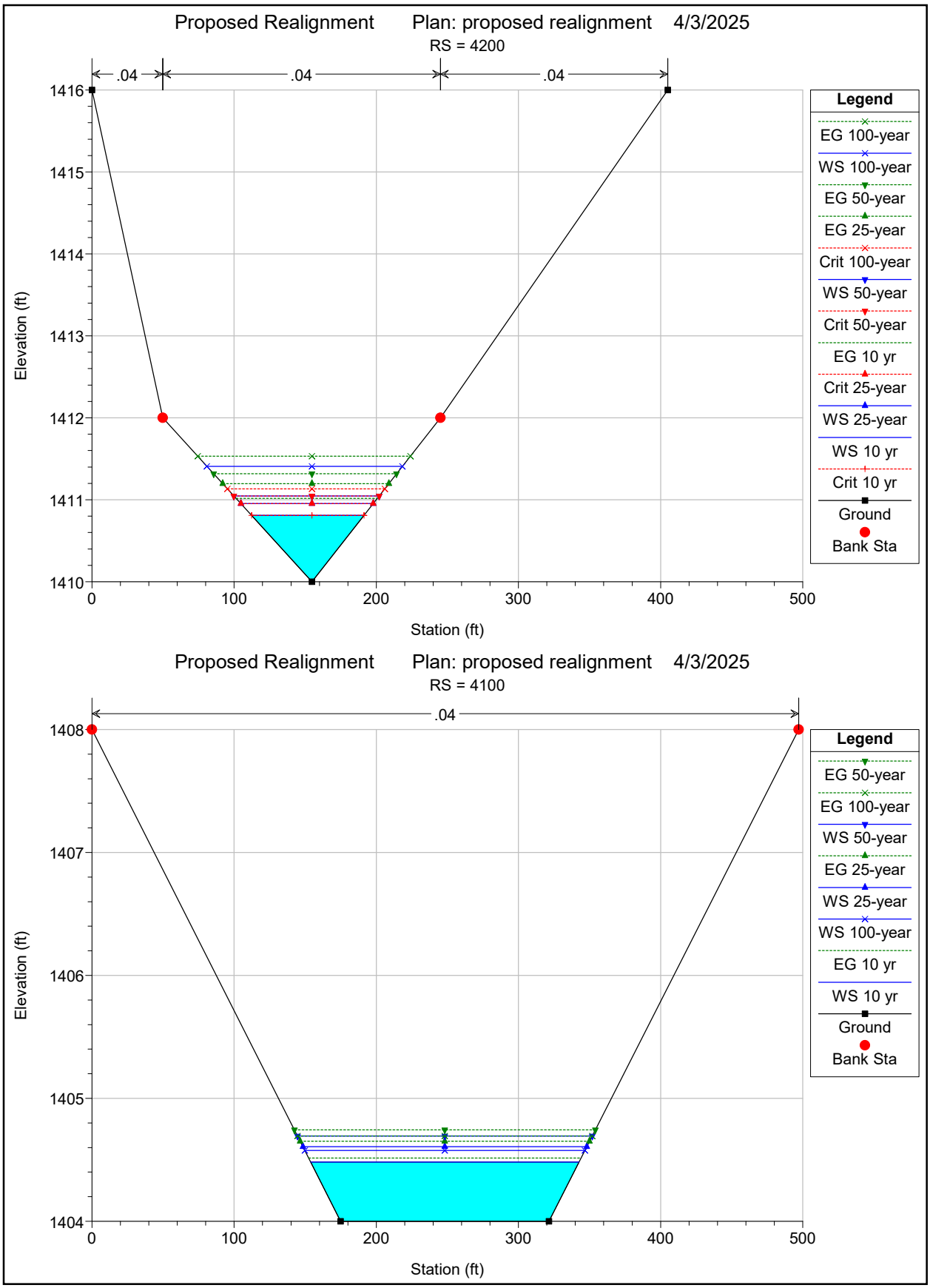

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 113
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 110
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

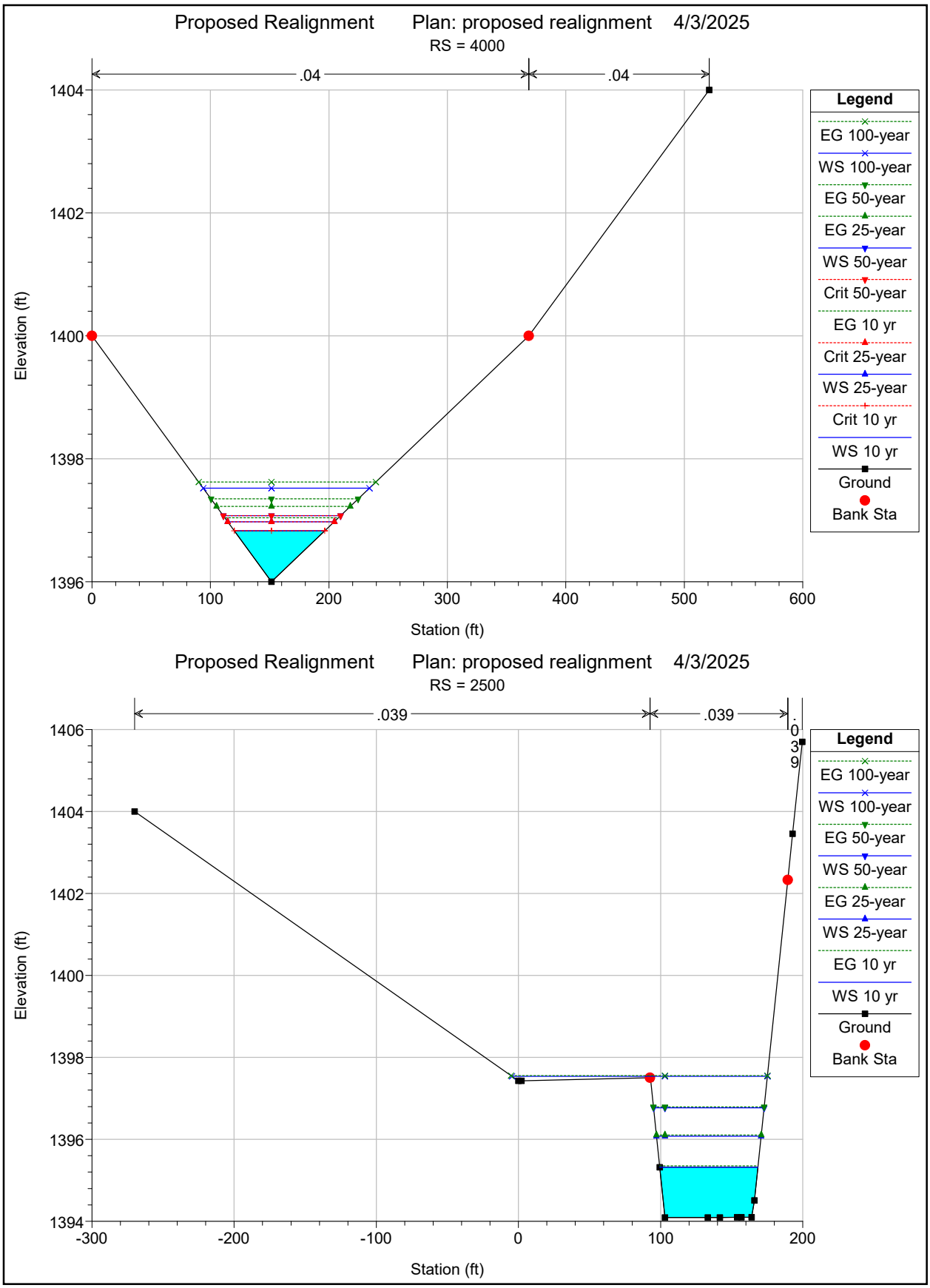

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 101
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
EG 25-year
Crit 100-year
WS 50-year
Crit 50-year
WS 25-year
EG 10 yr
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

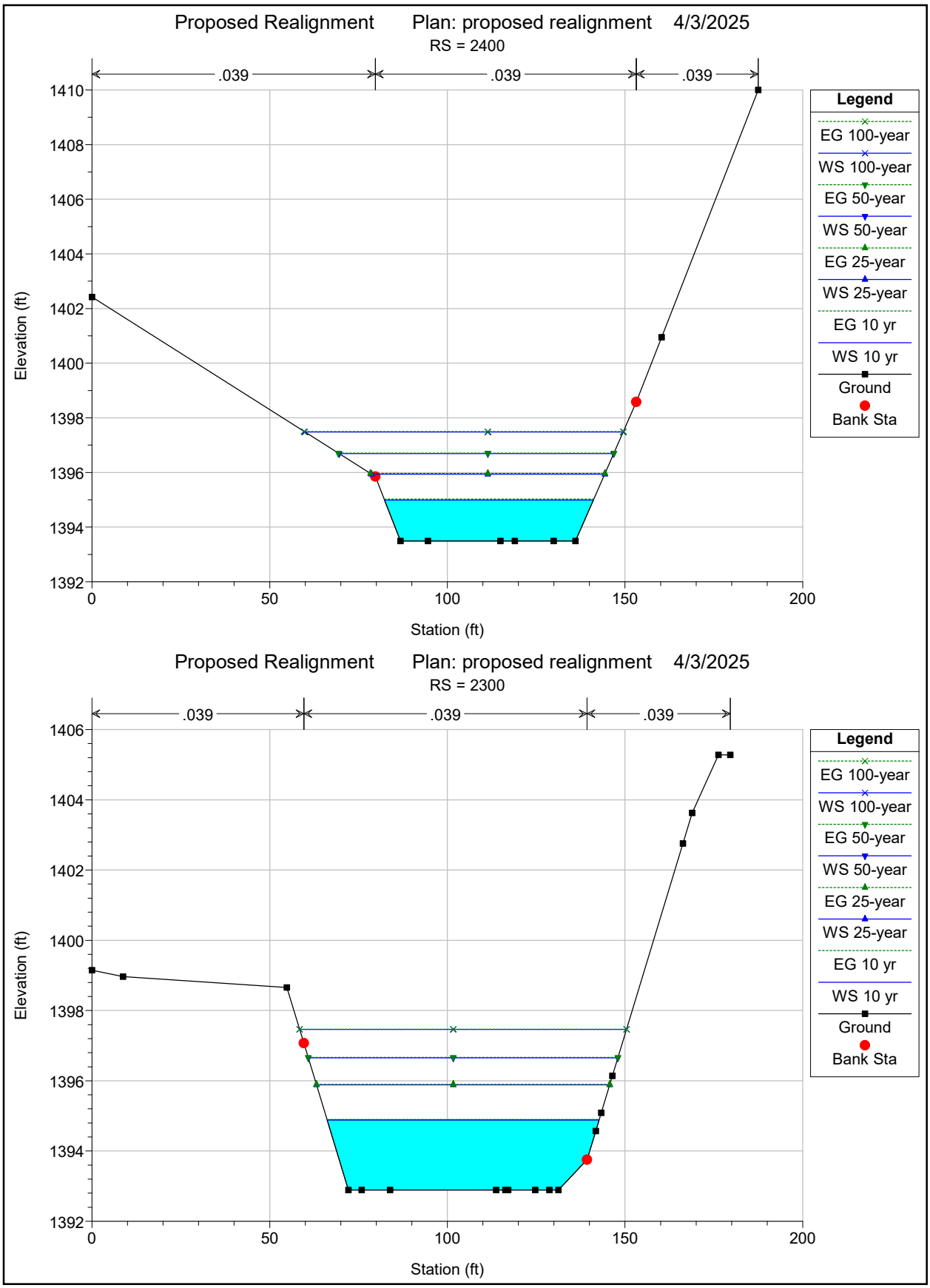

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 100
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

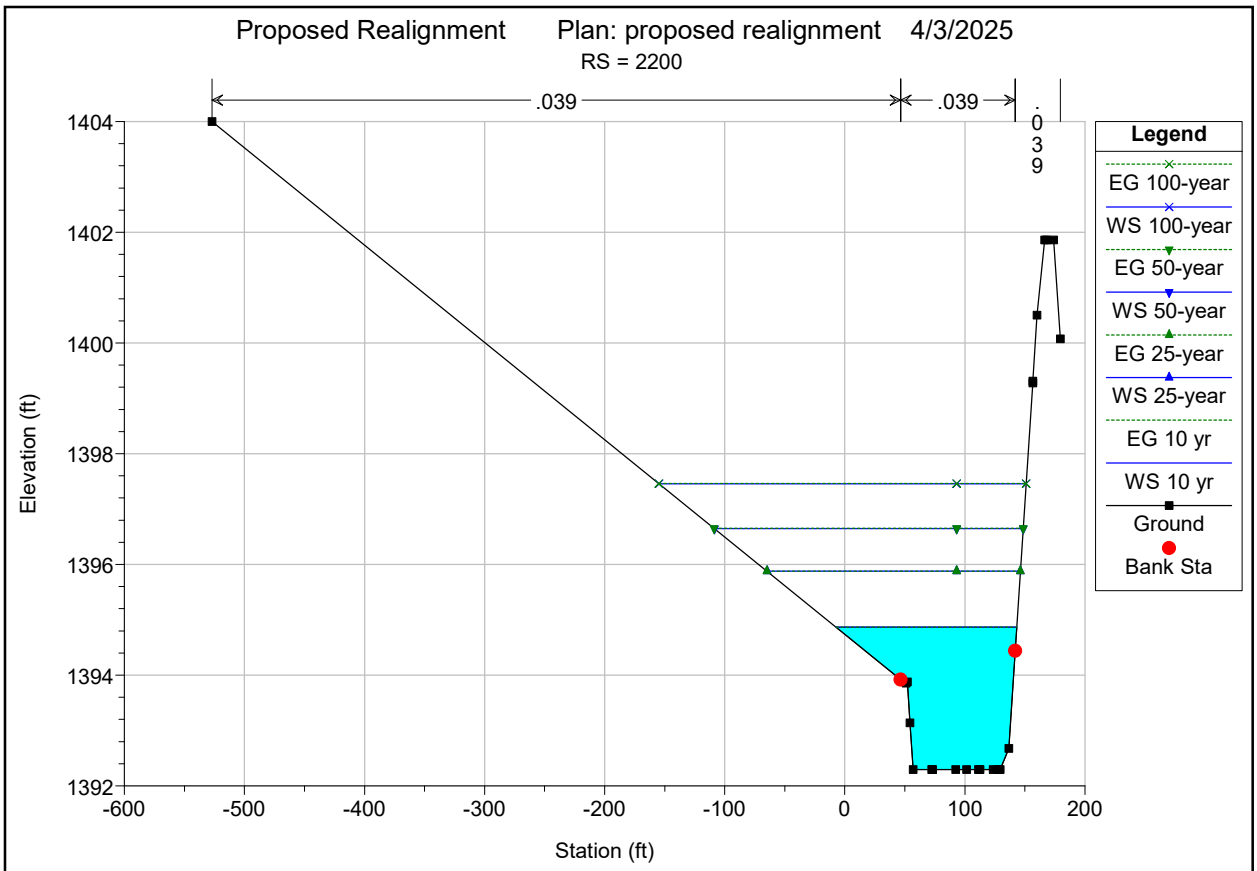

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 0.5
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

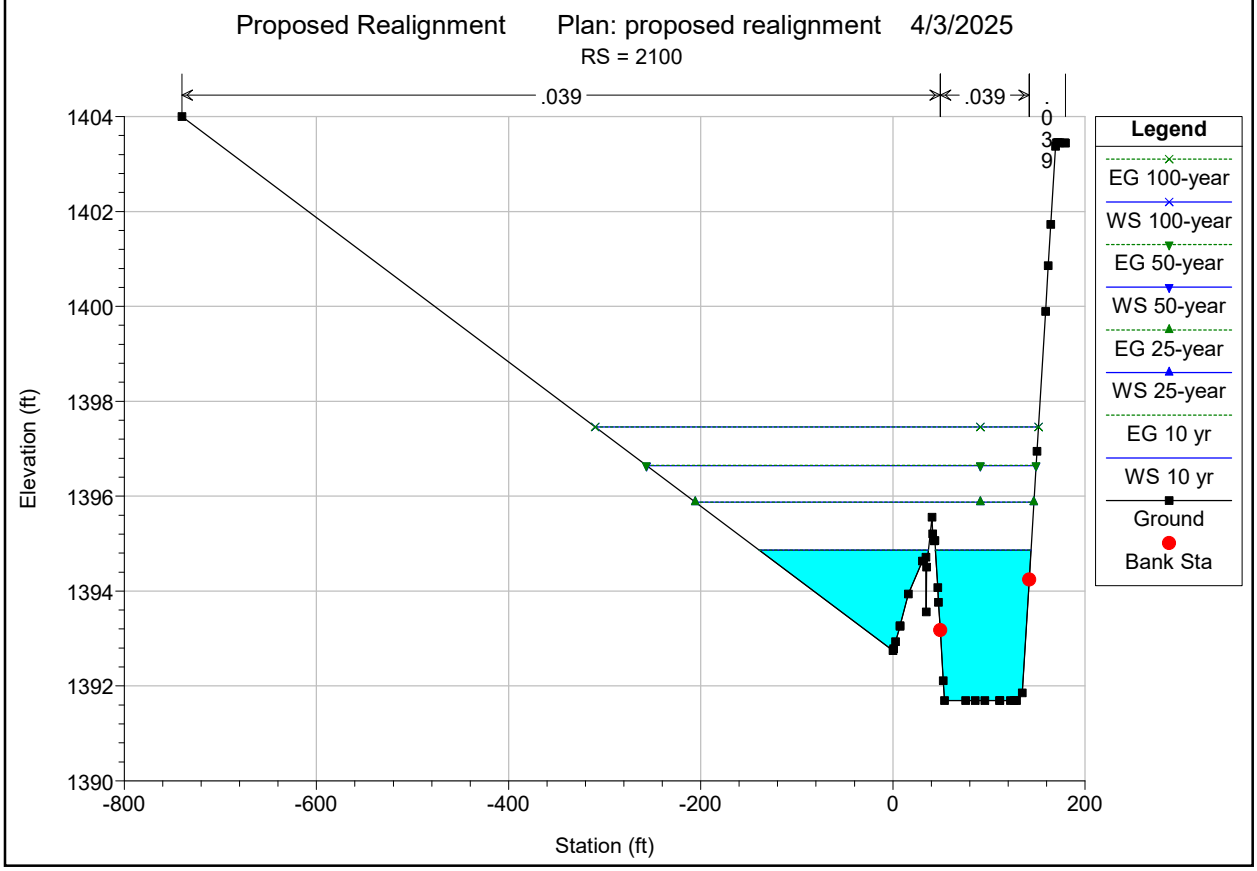

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 0.1
.04
.03
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

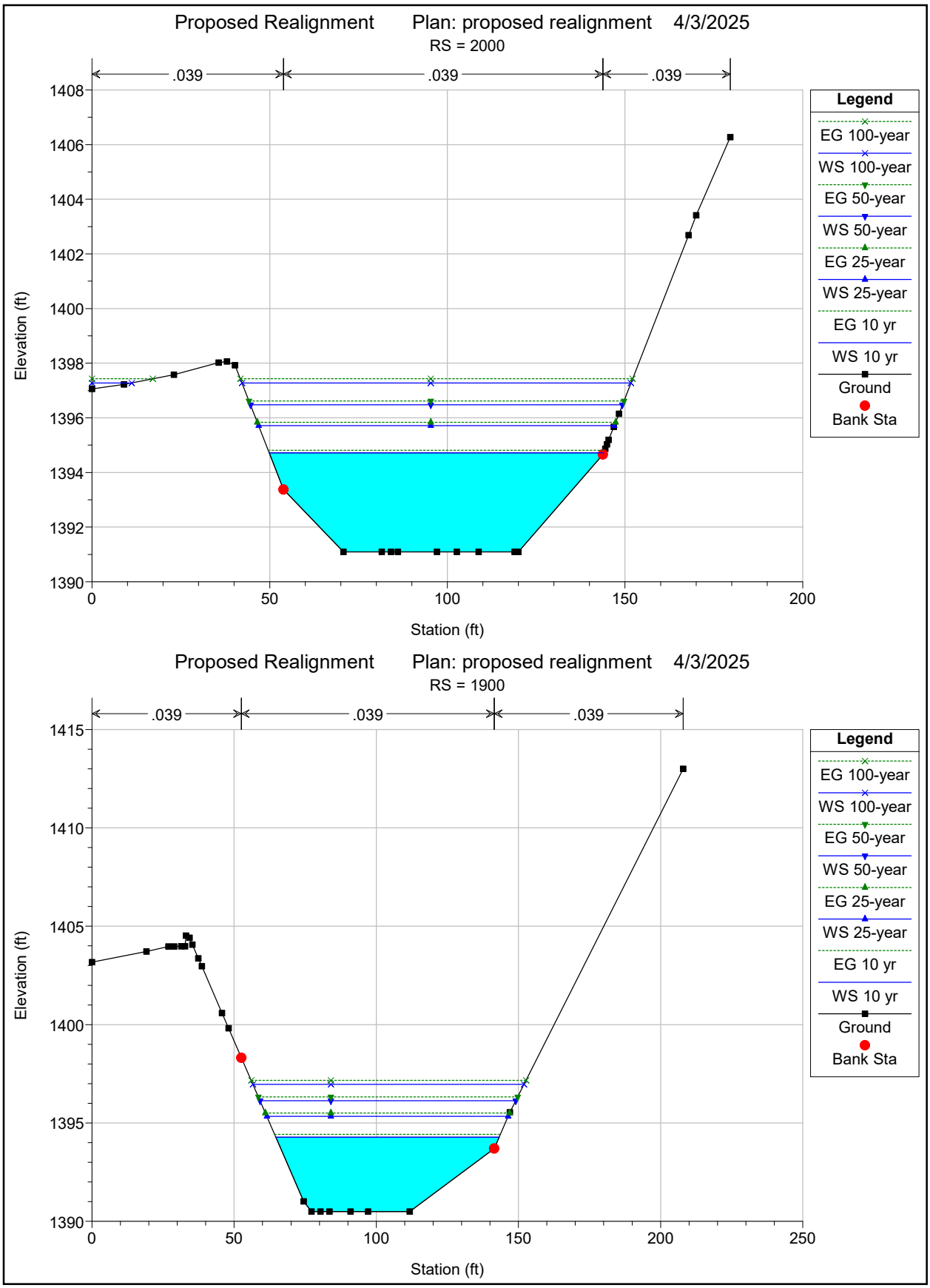

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 4200
.04
.04
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
EG 25-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 4100
.04
Elevation (ft)
Station (ft)
Legend
EG 50-year
EG 100-year
WS 50-year
EG 25-year
WS 25-year
WS 100-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

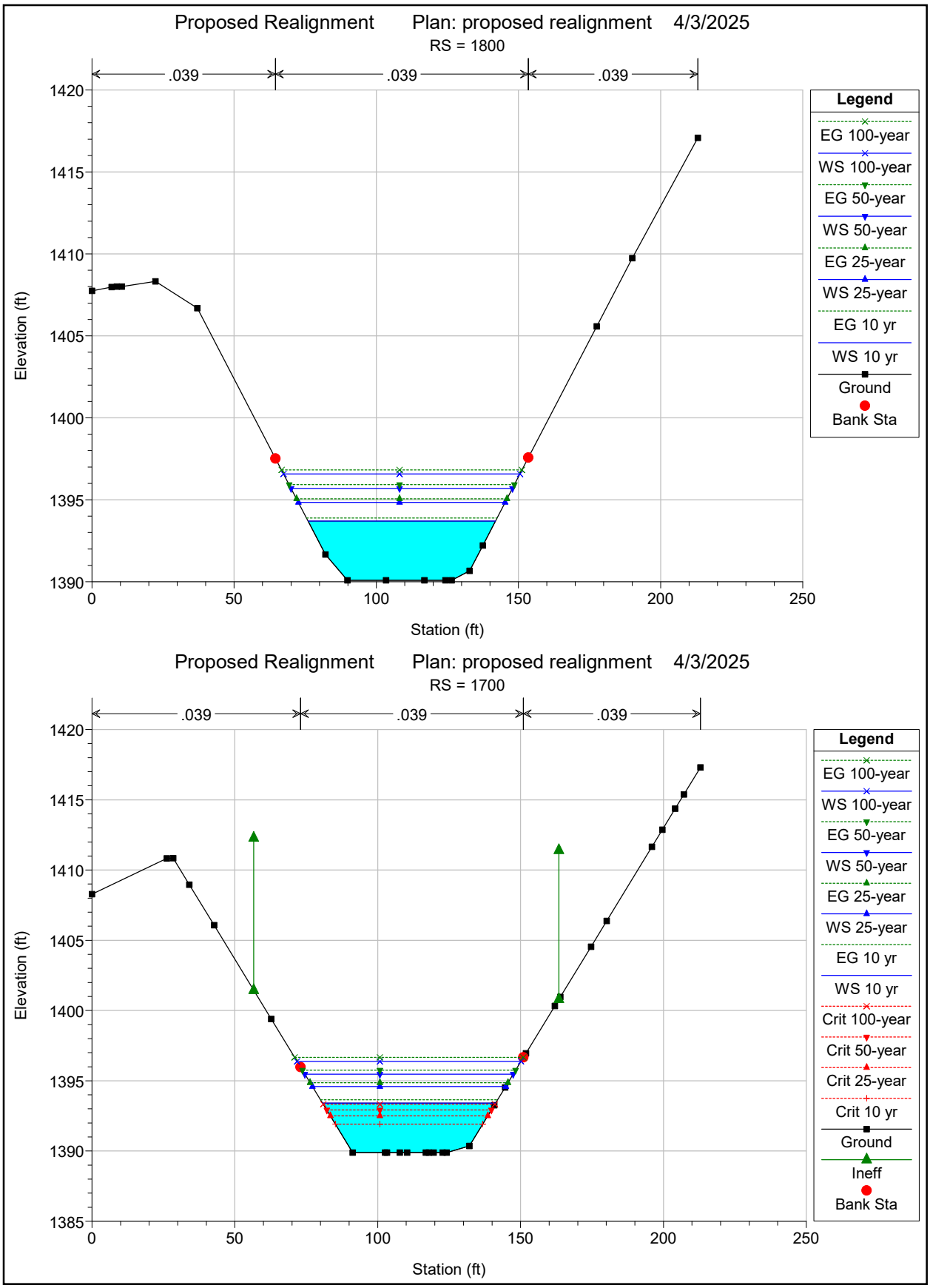

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 4000
.04
.04
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
EG 25-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
Crit 10 yr
WS 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2500
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

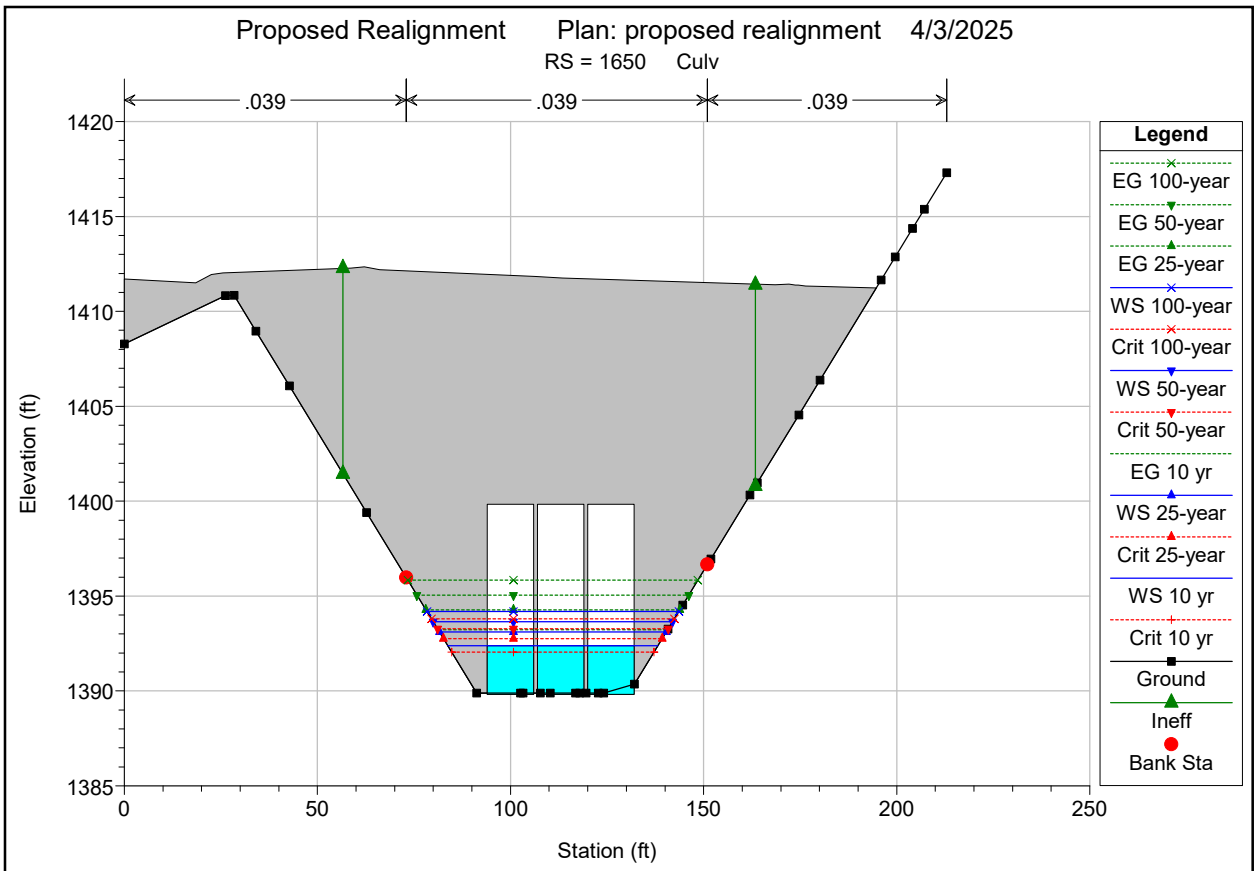

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2400
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2300
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

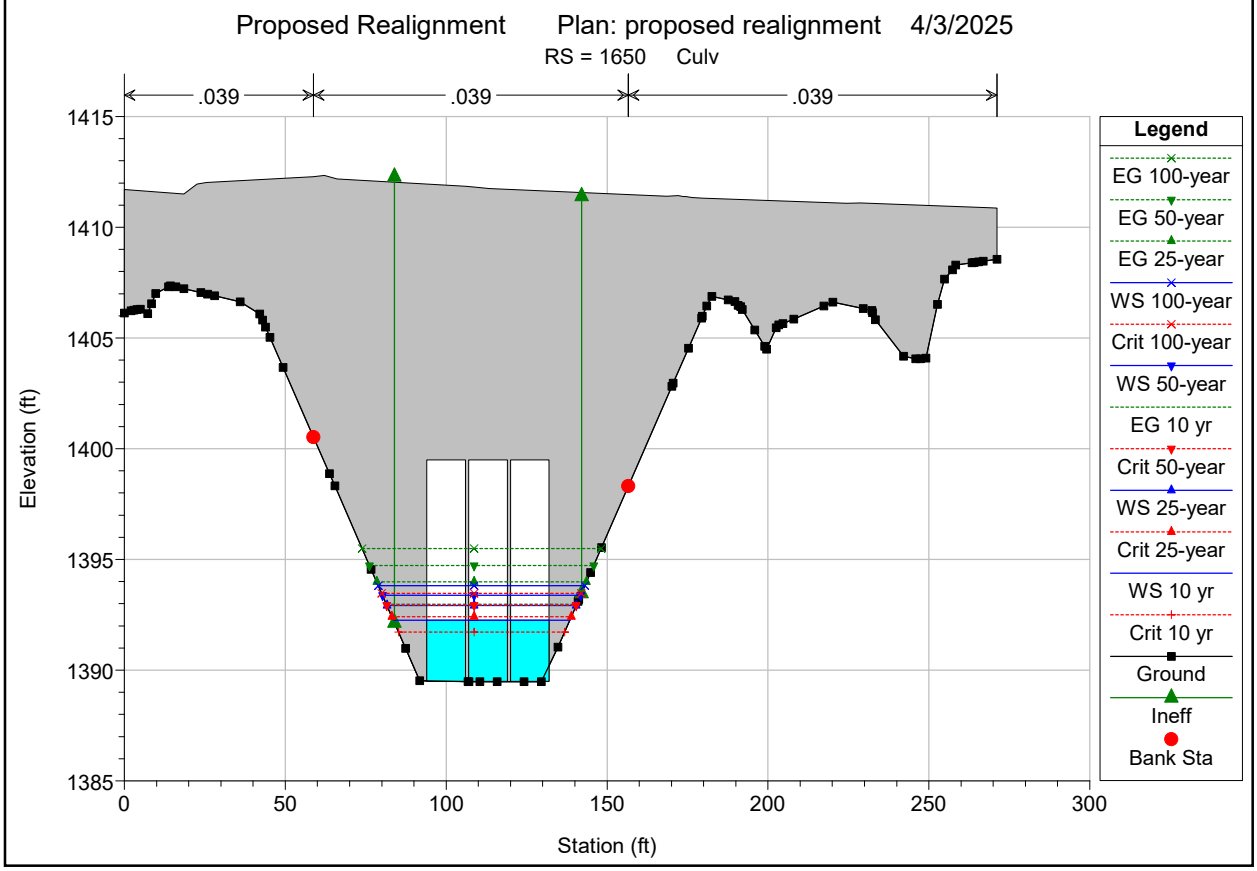

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2200
.039
.039
.039
Elevation (ft)
Station (ft)
1404
1402
1400
1398
1396
1394
1392
-600
-500
-400
-300
-200
-100
0
100
200
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

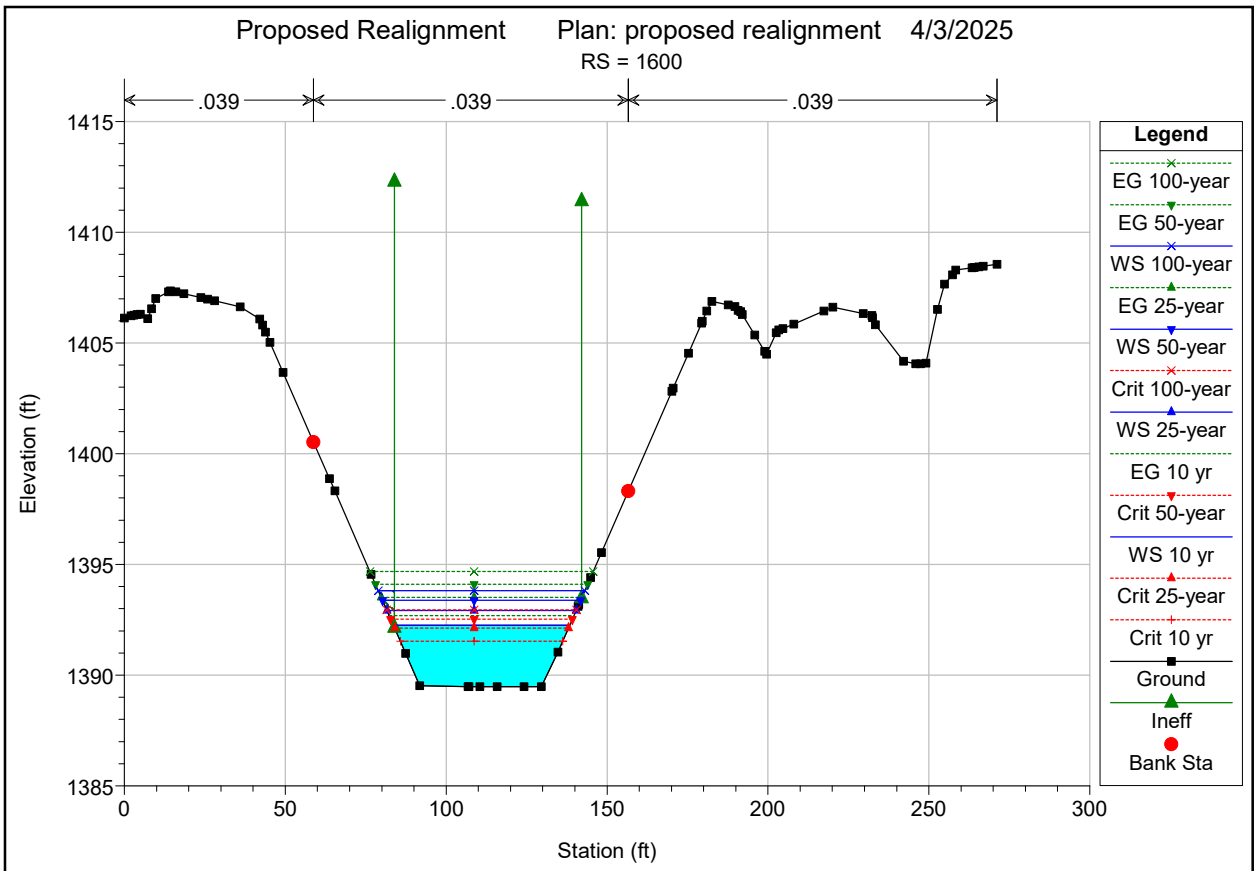

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2100
.039
.039
.039
Elevation (ft)
Station (ft)
1404
1402
1400
1398
1396
1394
1392
1390
-800
-600
-400
-200
0
200
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

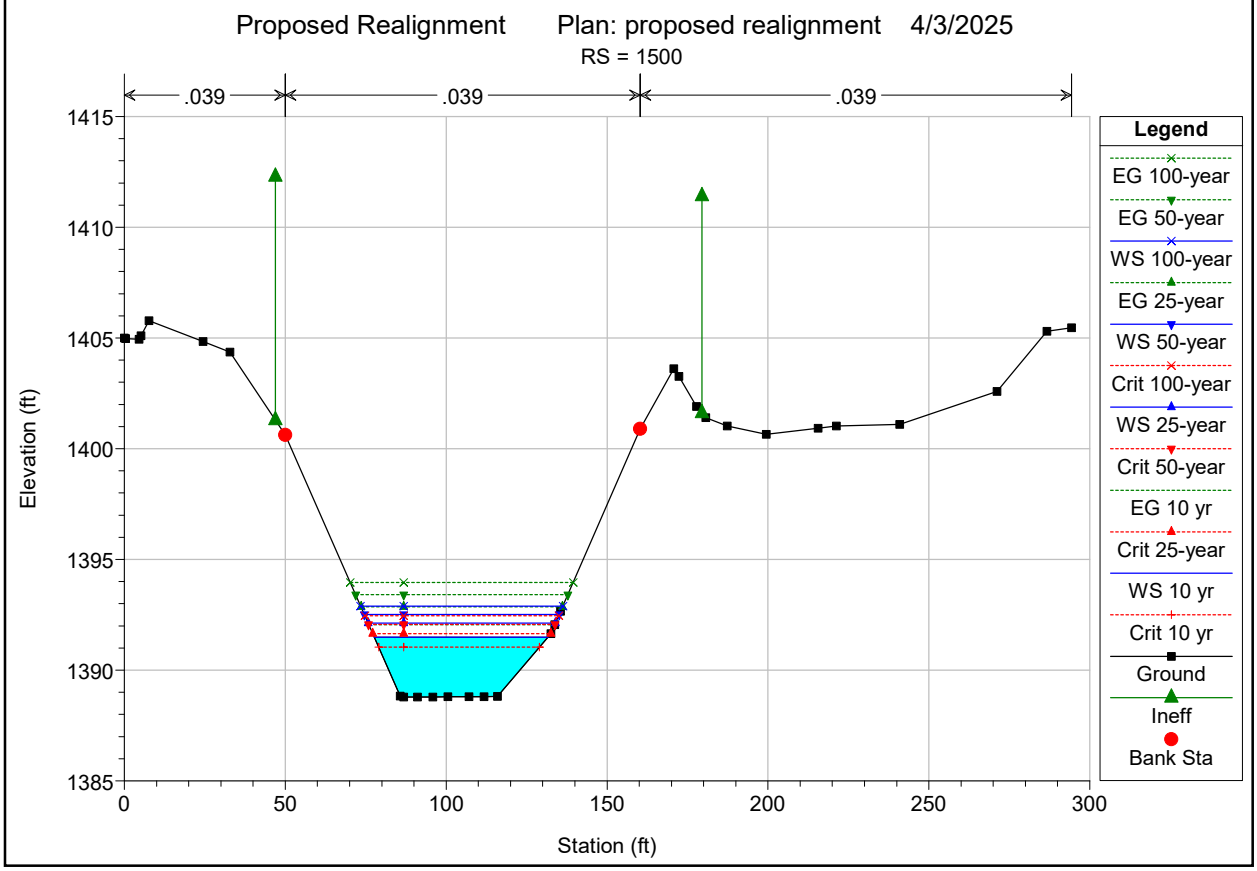

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 2000
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1900
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

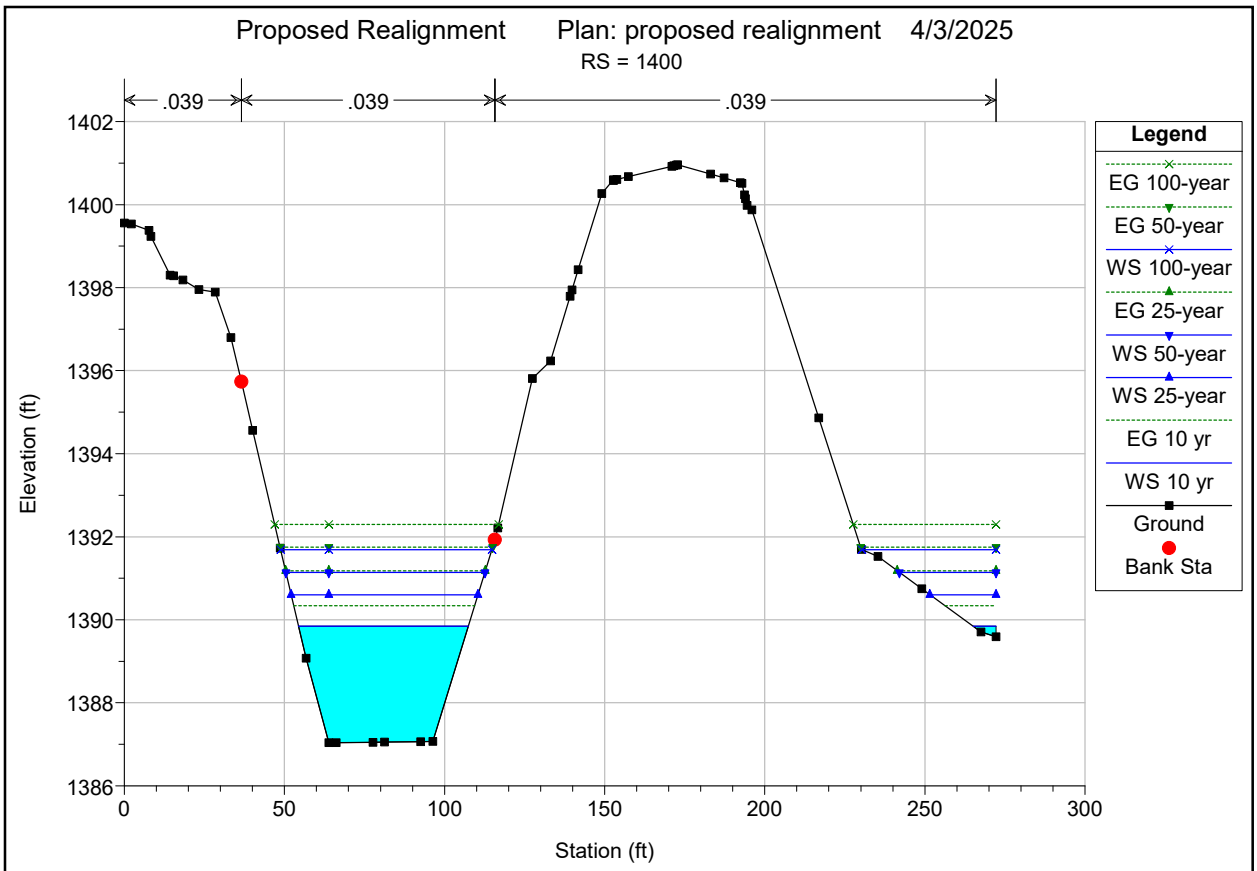

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1800
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1700
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 100-year
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

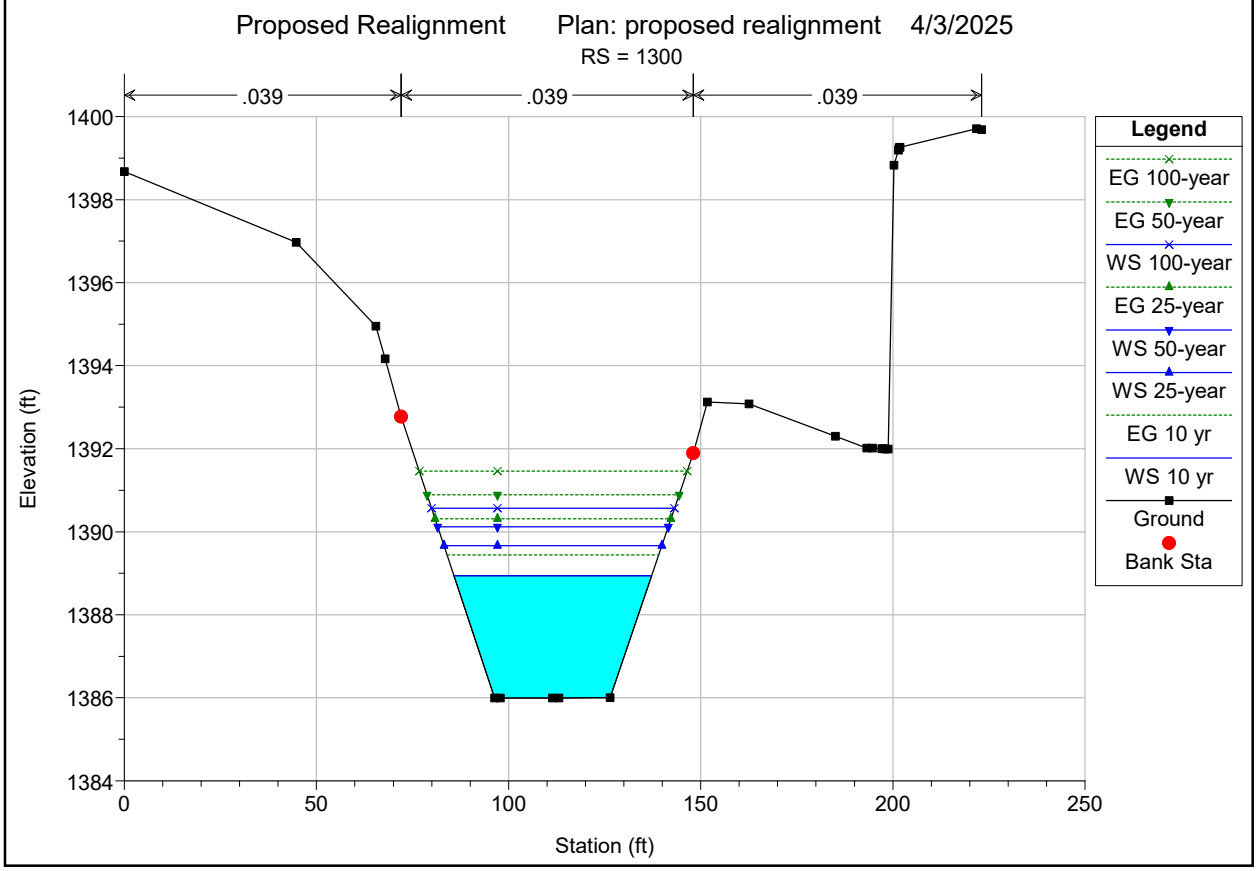

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1650 Culv
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
WS 25-year
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Ineff
Bank Sta

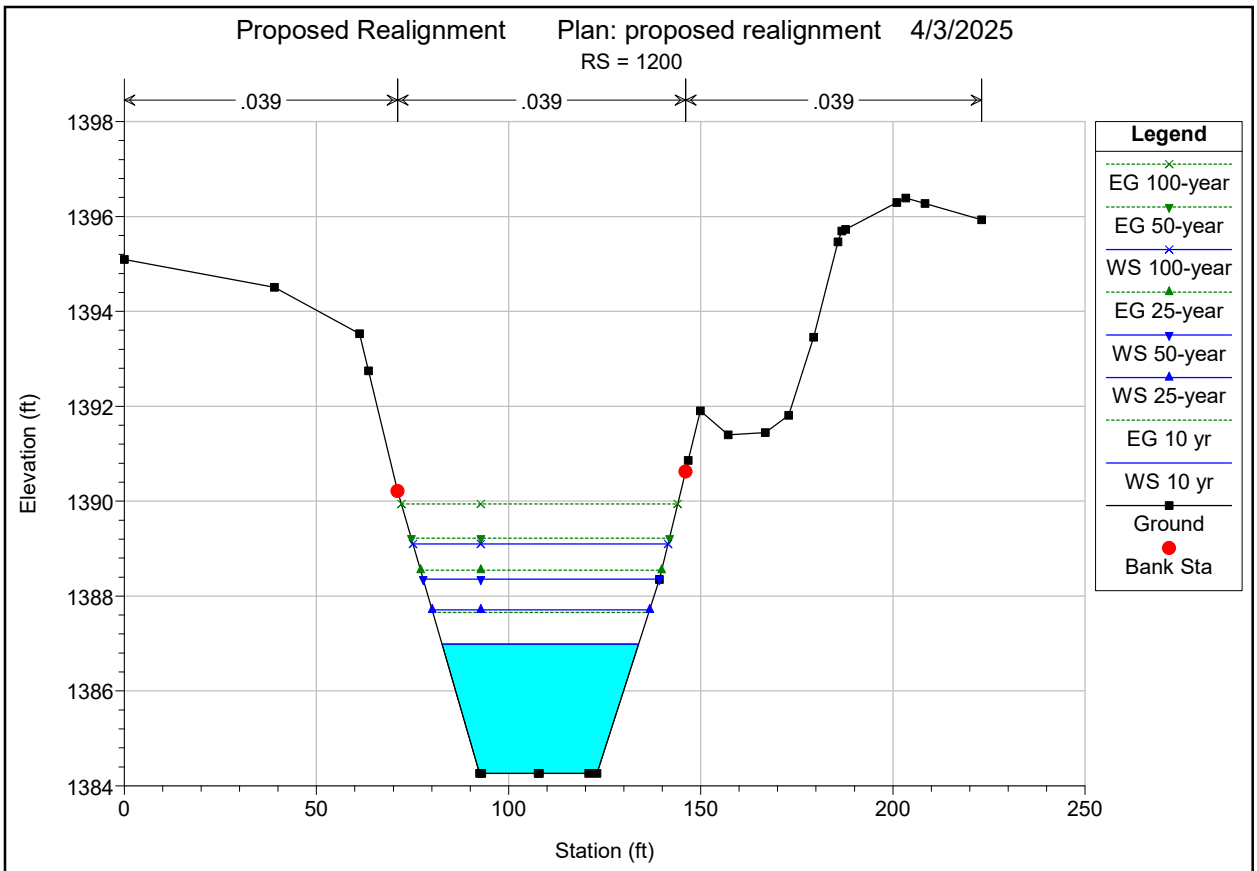

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1650 Culv
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
EG 10 yr
Crit 50-year
WS 25-year
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Ineff
Bank Sta

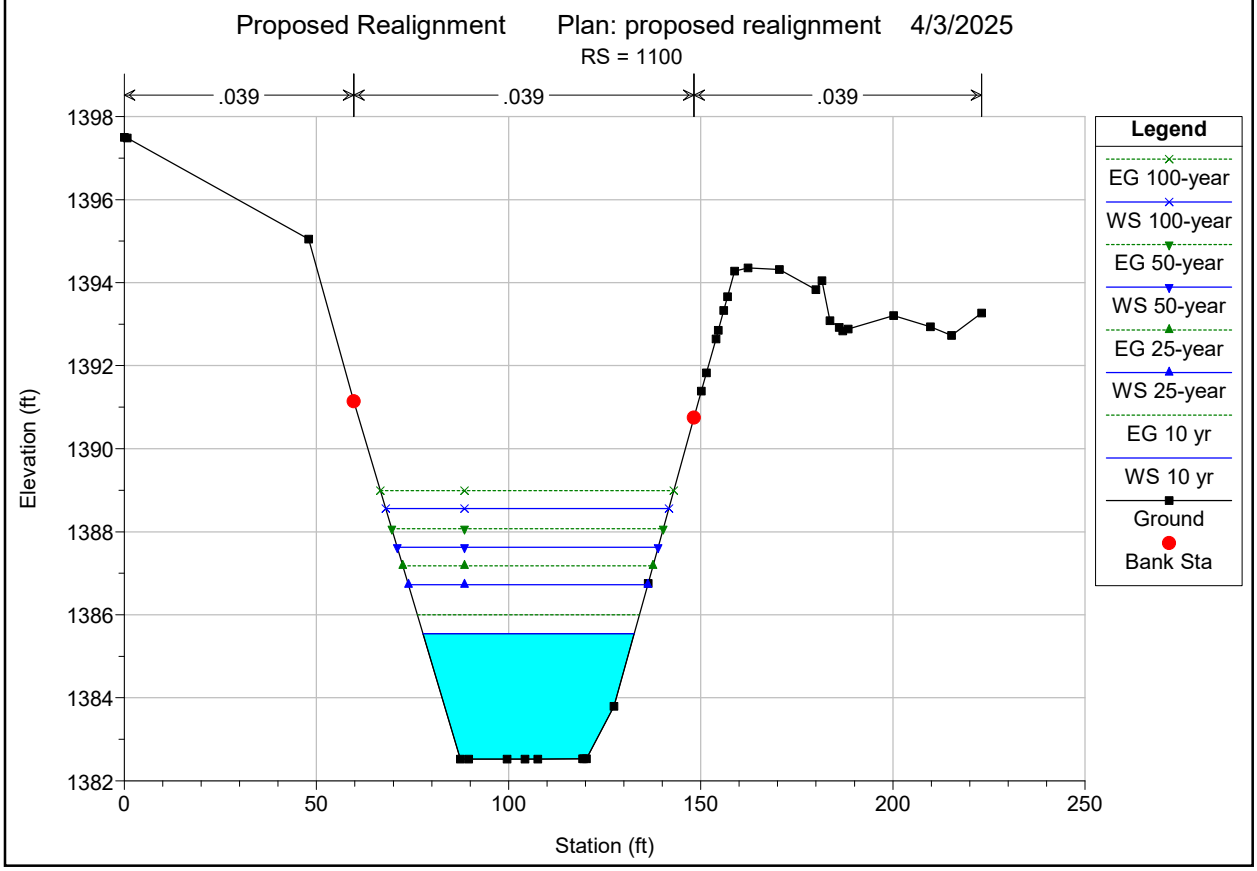

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 1600
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
EG 25-year
WS 50-year
Crit 100-year
WS 25-year
EG 10 yr
Crit 50-year
WS 10 yr
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

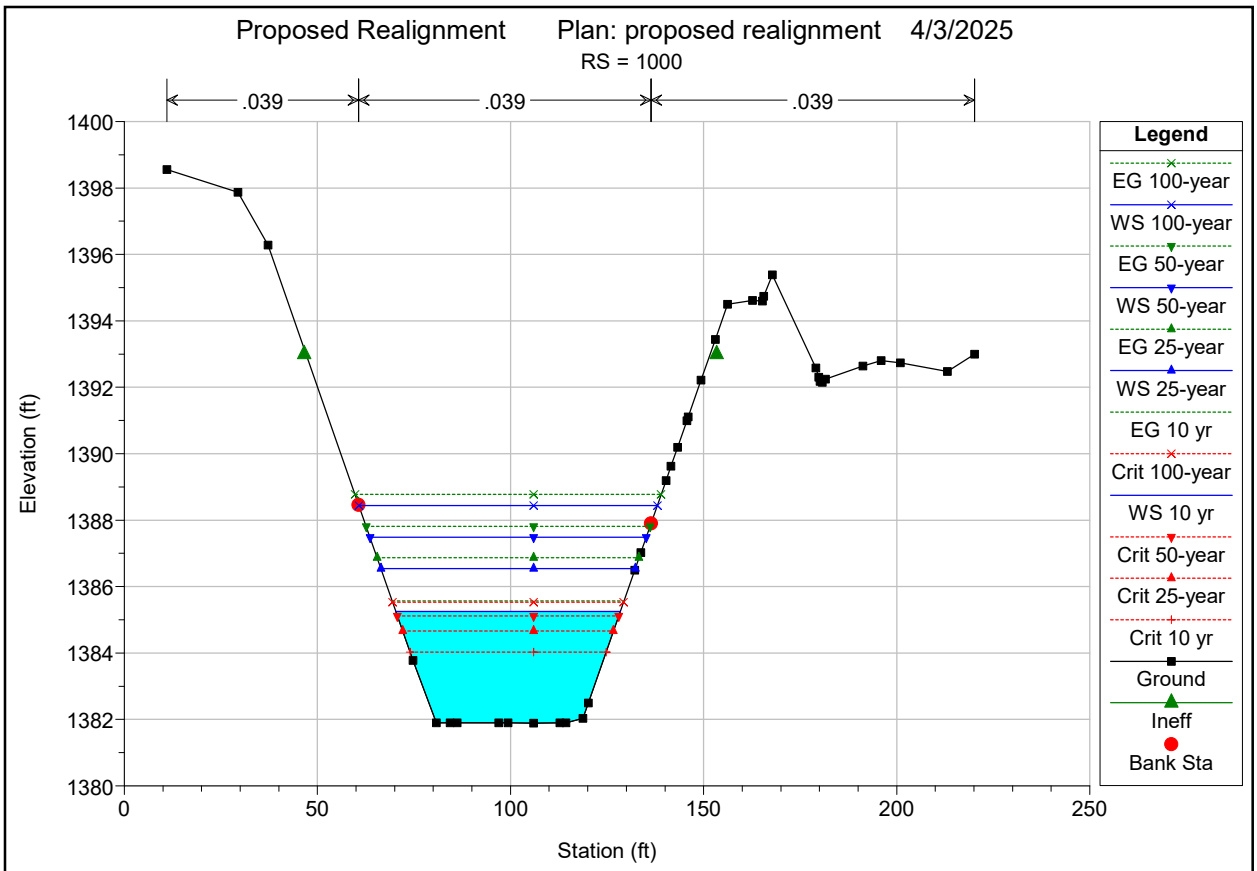

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 1500
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
EG 25-year
WS 50-year
Crit 100-year
WS 25-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Ineff
Bank Sta

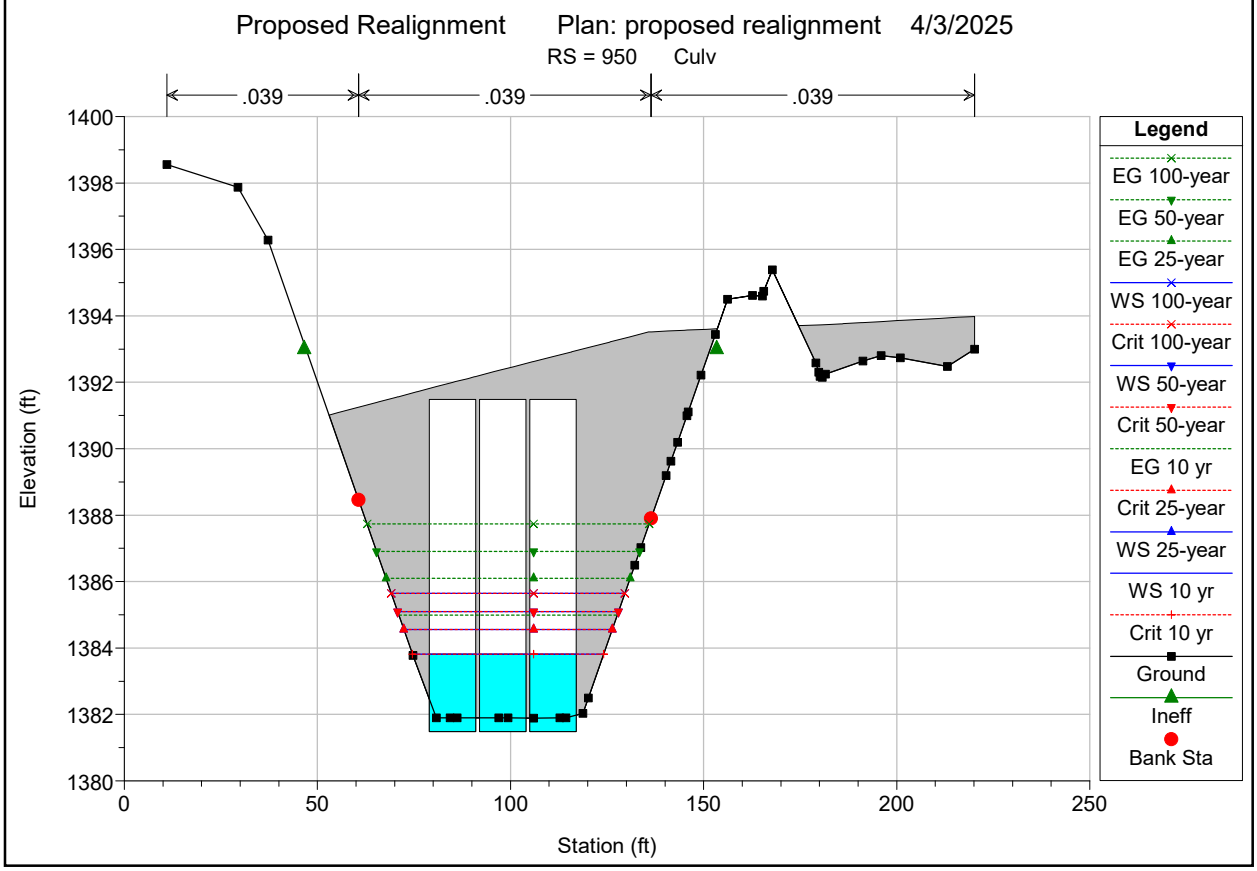

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1400
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
EG 25-year
WS 50-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

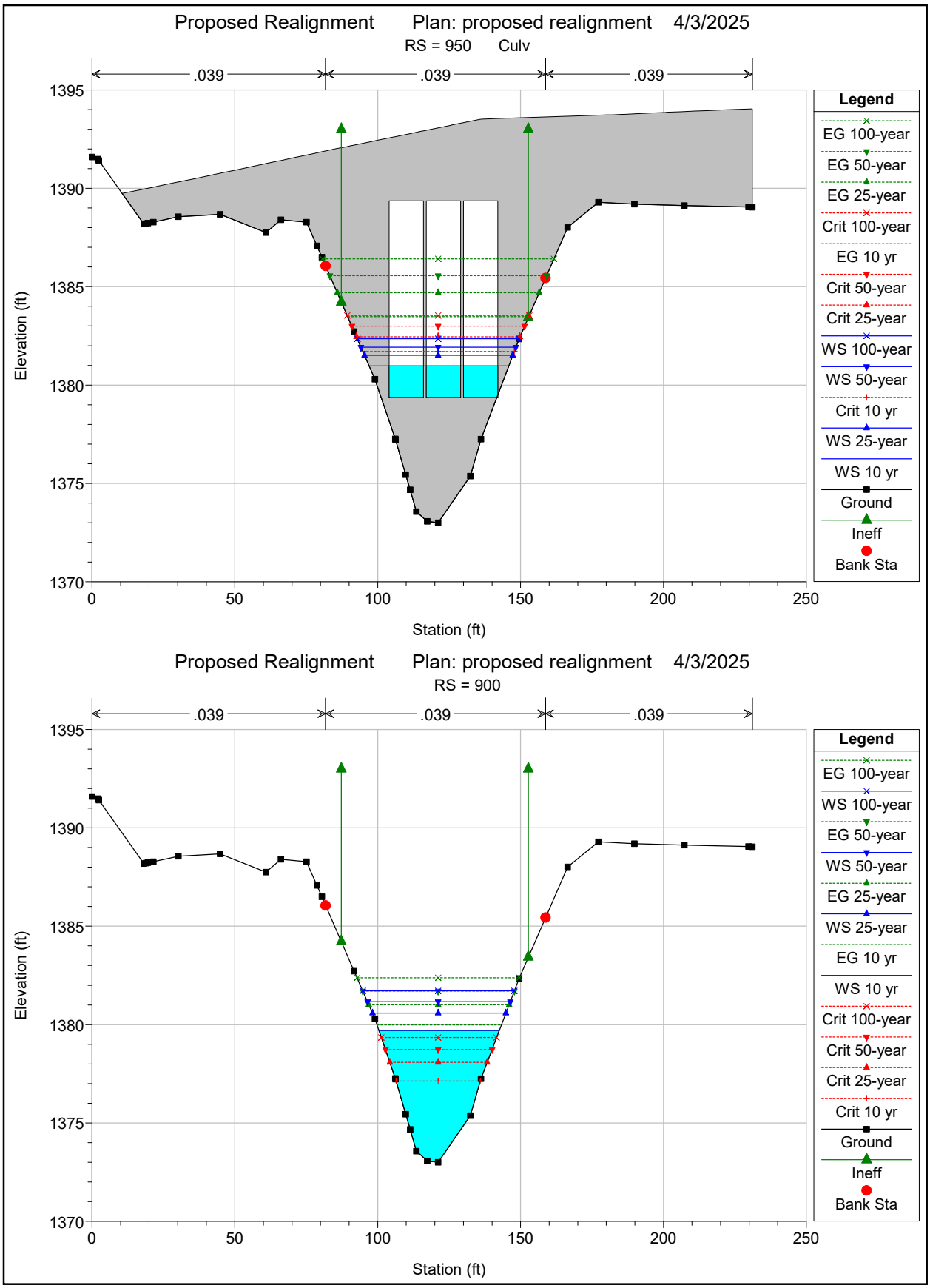

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1300
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
EG 25-year
WS 50-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

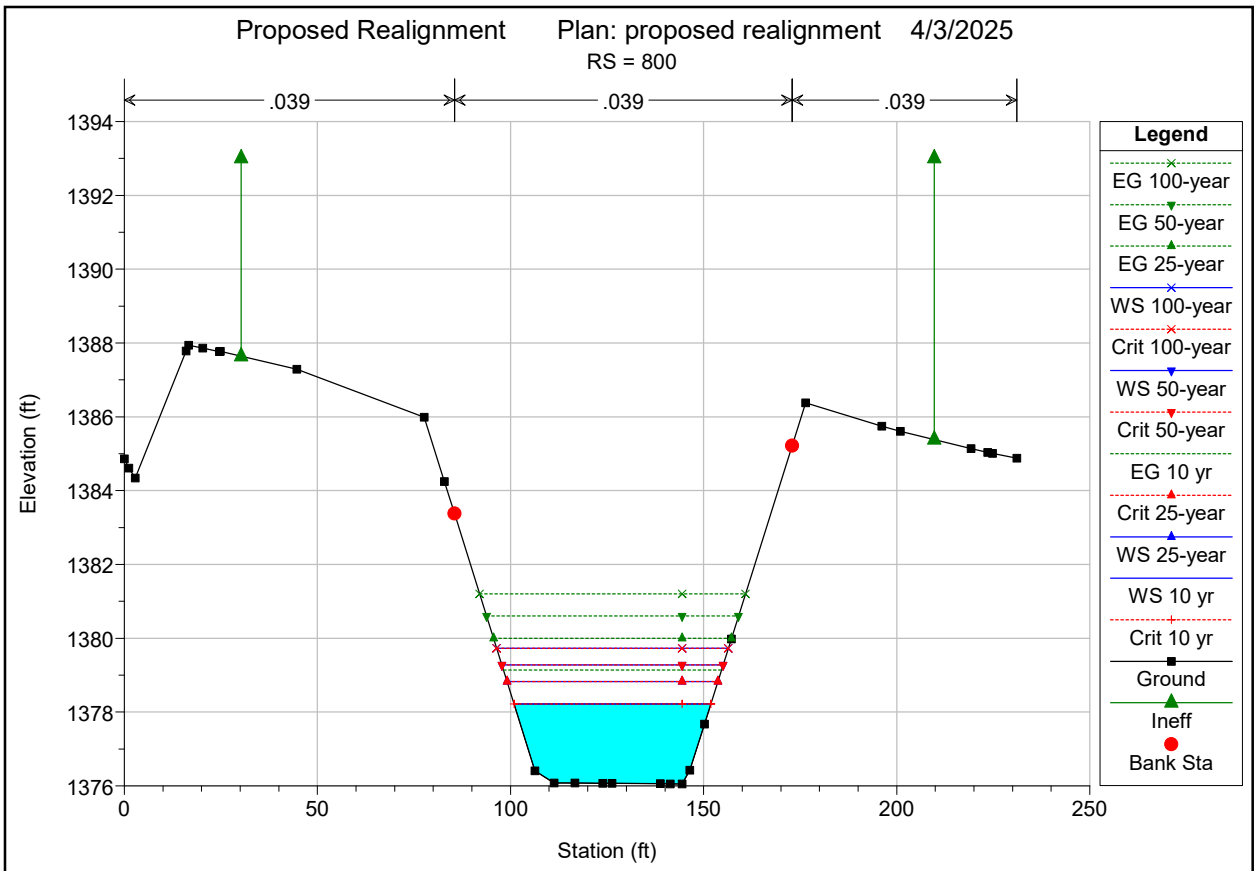

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1200
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
WS 100-year
EG 25-year
WS 50-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

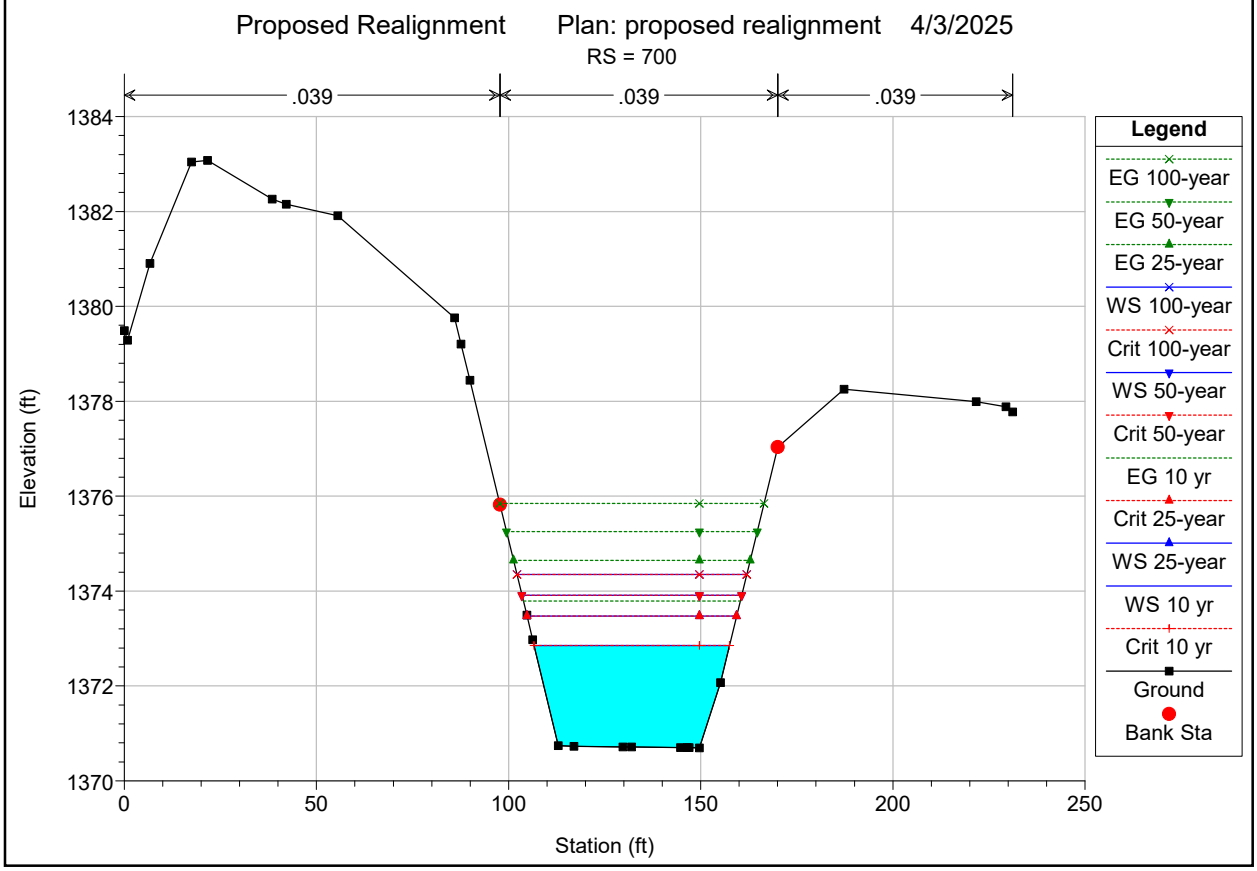

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 1100
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Ground
Bank Sta

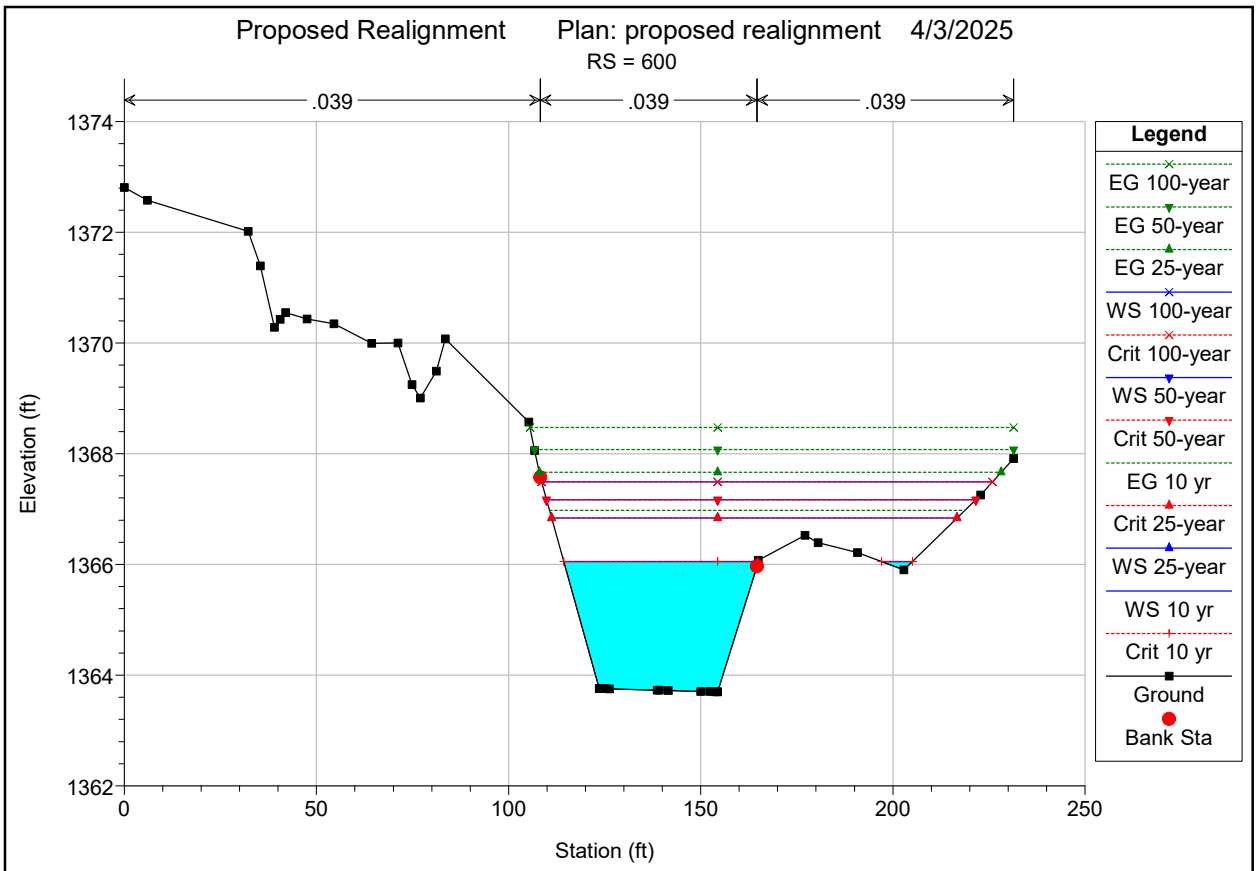

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 1000
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
Crit 100-year
WS 10 yr
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

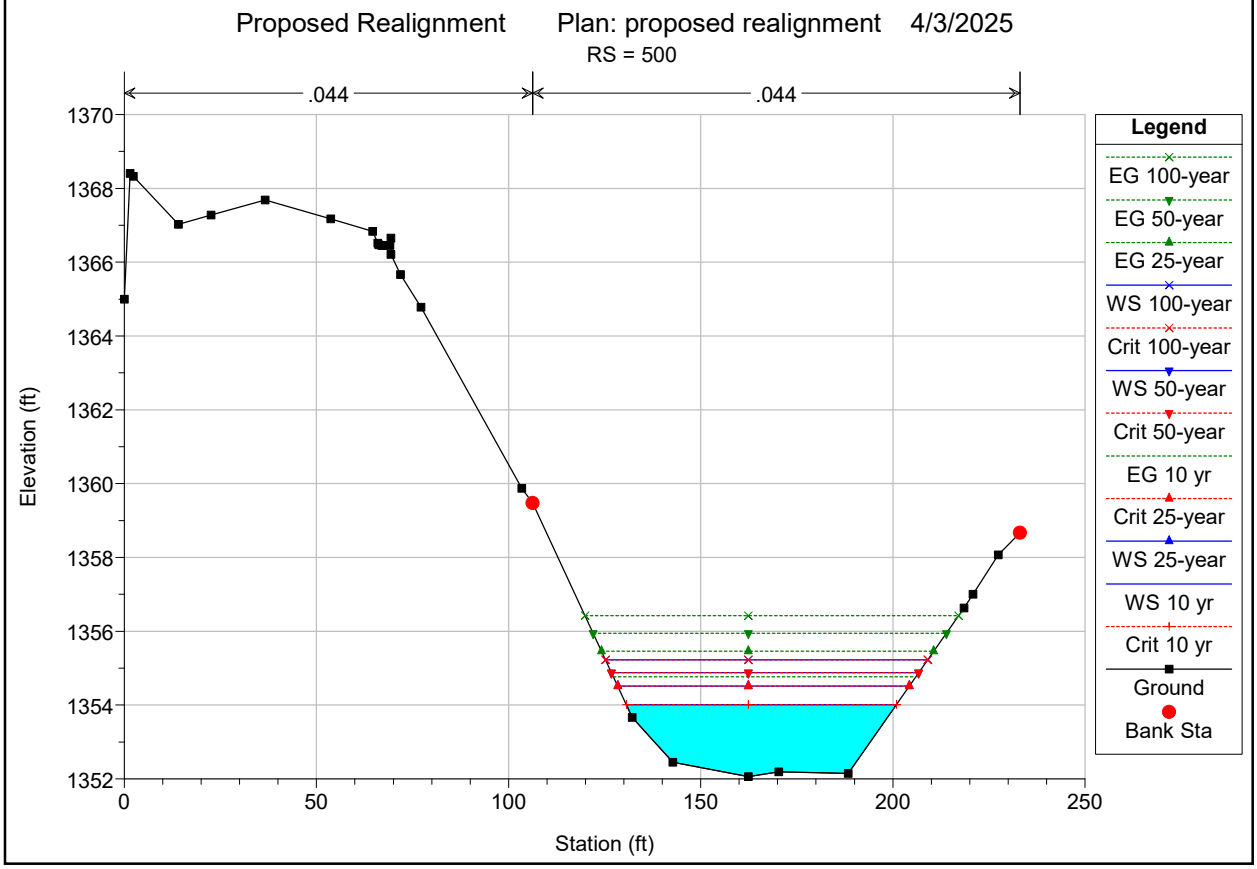

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 950
Culv
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Ineff
Bank Sta

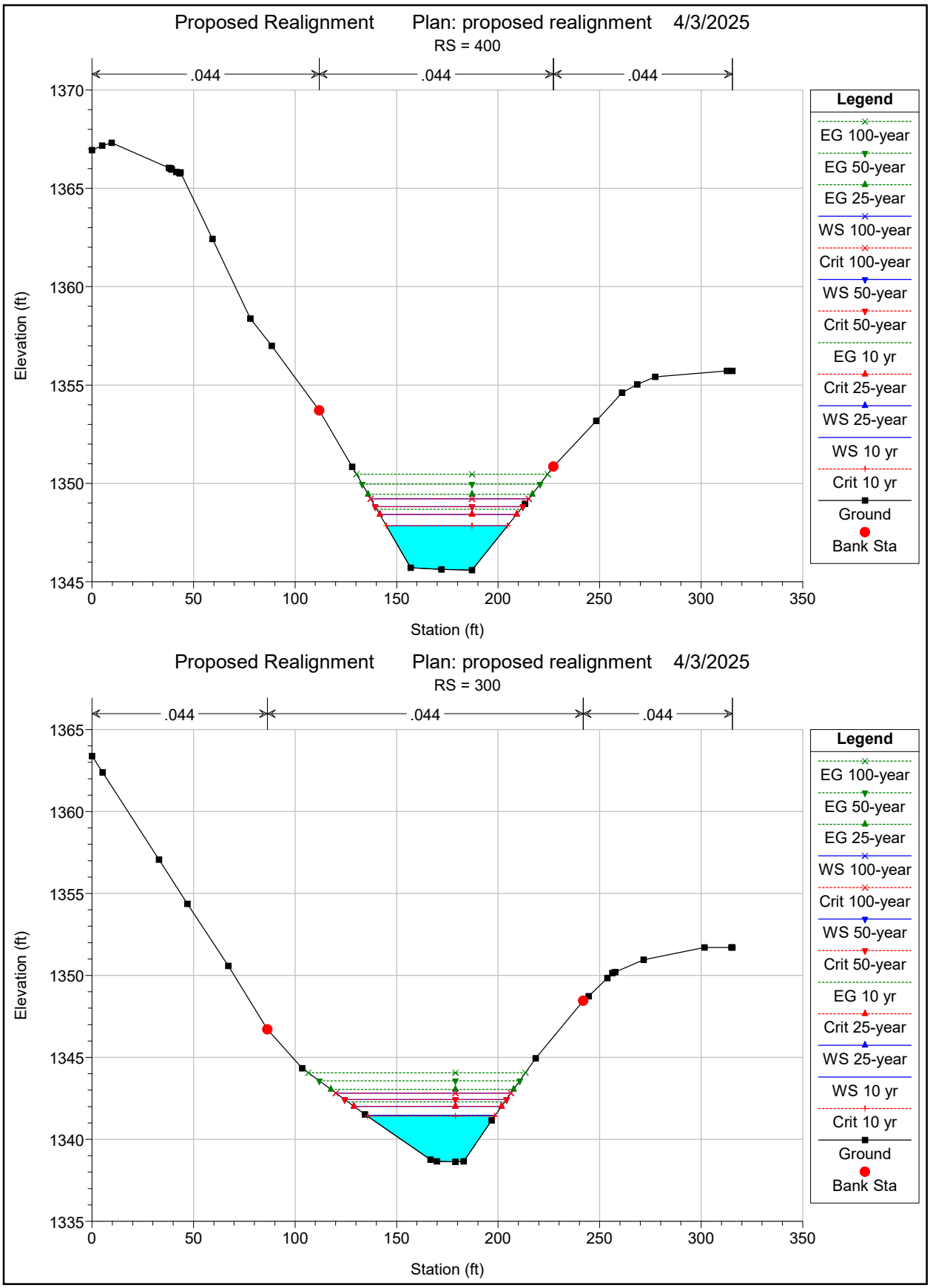

Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 950 Culv
.039
.039
.039
1395
1390
1385
1380
1375
1370
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
Crit 100-year
EG 10 yr
Crit 50-year
Crit 25-year
WS 100-year
WS 50-year
Crit 10 yr
WS 25-year
WS 10 yr
Ground
Ineff
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 900
.039
.039
.039
1395
1390
1385
1380
1375
1370
Elevation (ft)
0
50
100
150
200
250
Station (ft)
Legend
EG 100-year
WS 100-year
EG 50-year
WS 50-year
EG 25-year
WS 25-year
EG 10 yr
WS 10 yr
Crit 100-year
Crit 50-year
Crit 25-year
Crit 10 yr
Ground
Ineff
Bank Sta

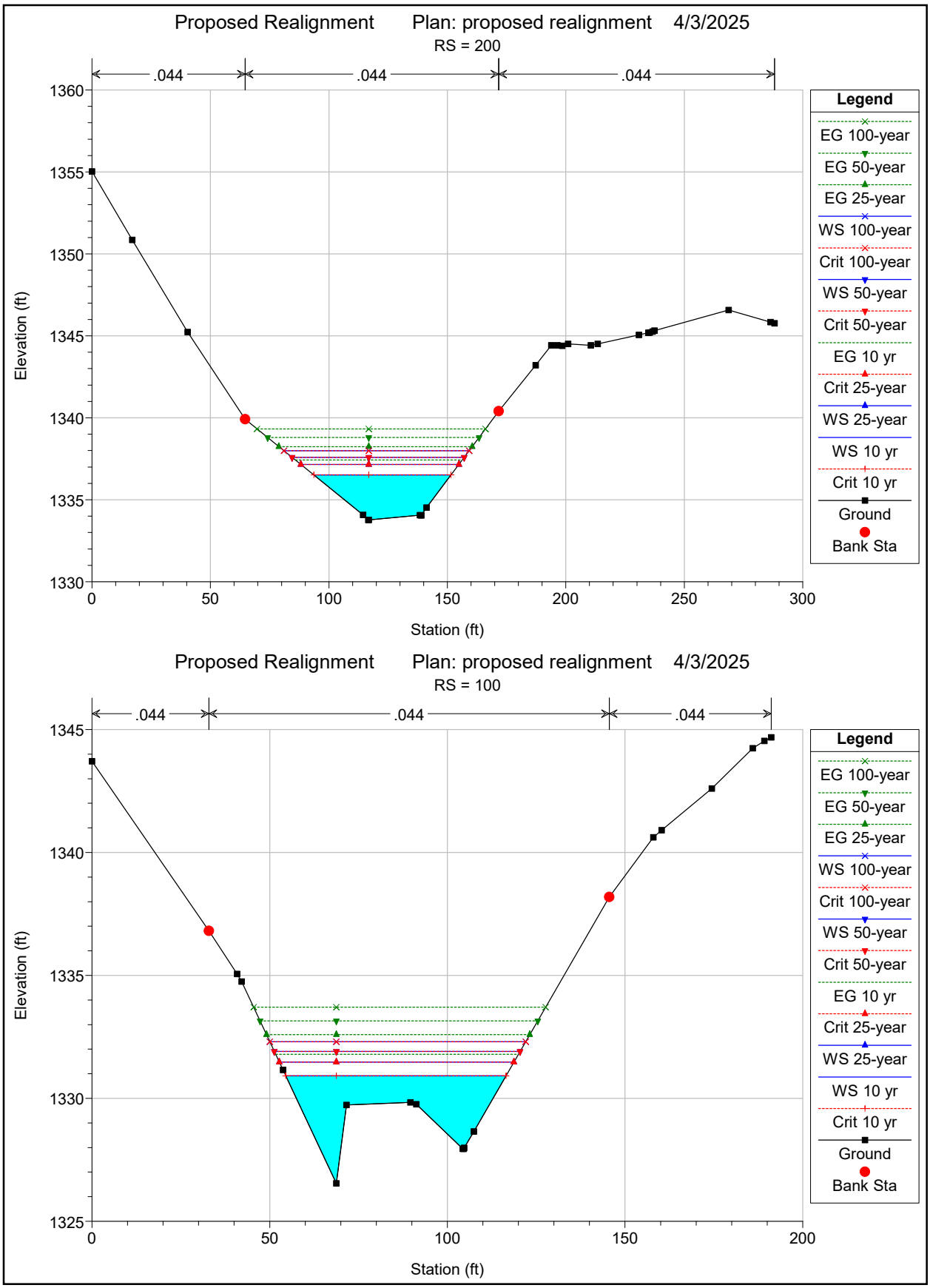

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 800
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Ineff
Bank Sta

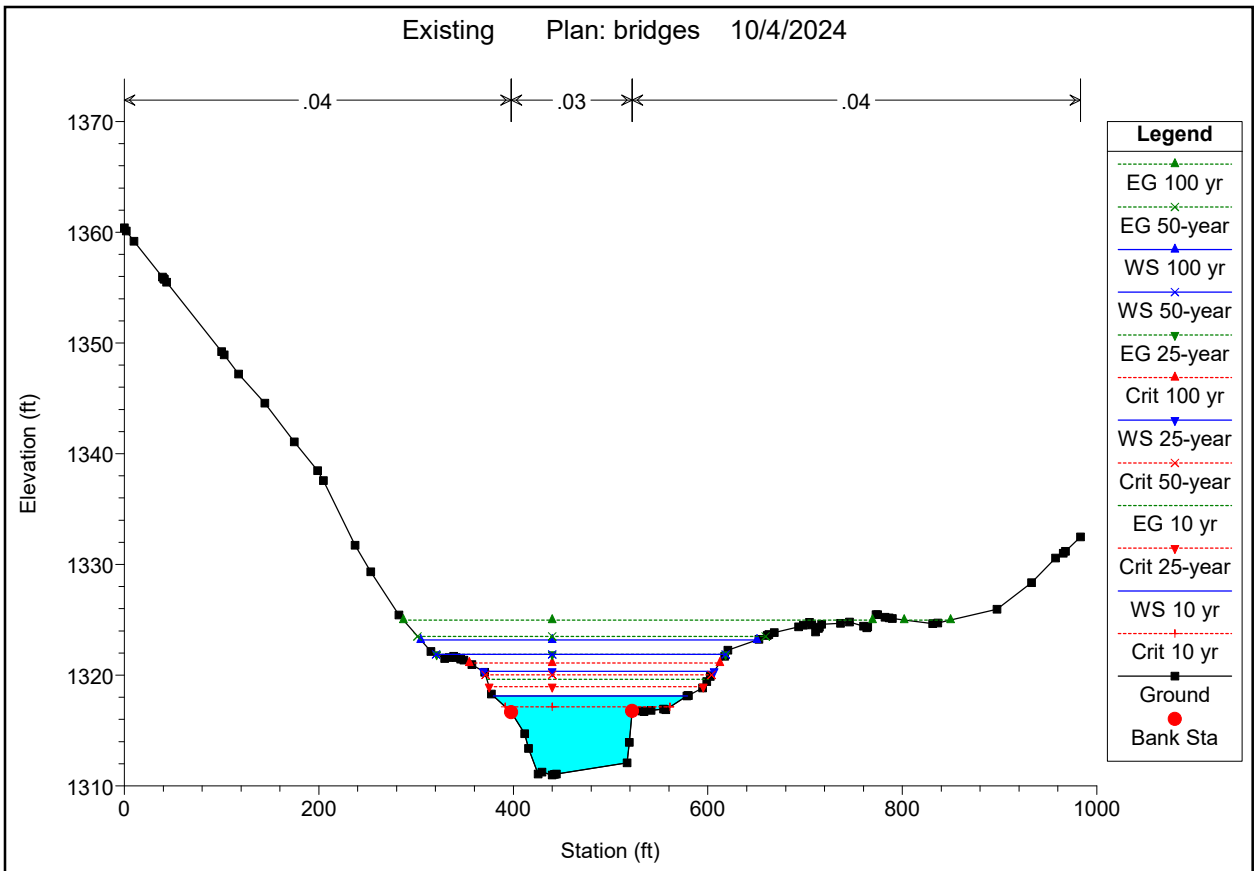

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 700
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

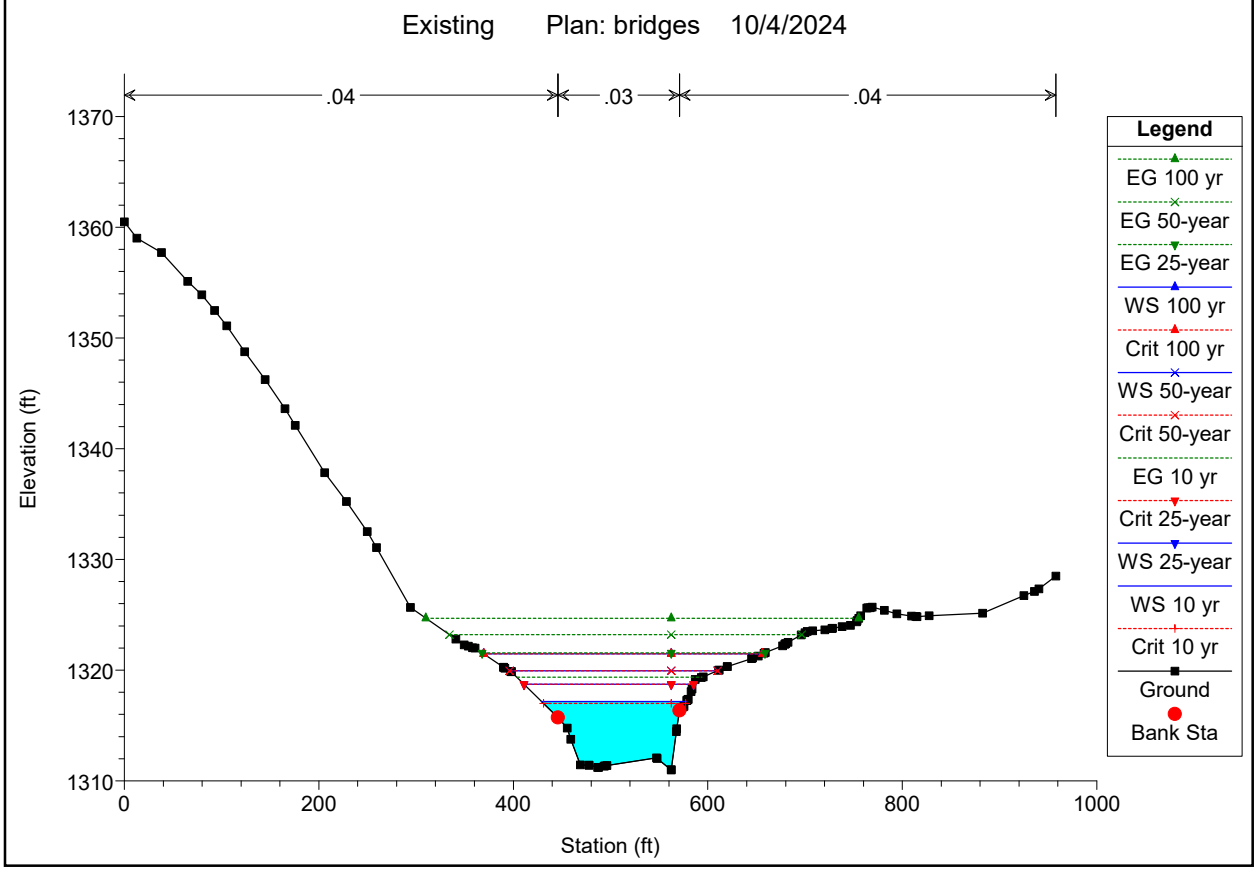

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 600
.039
.039
.039
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta


Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 500
.044
.044
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

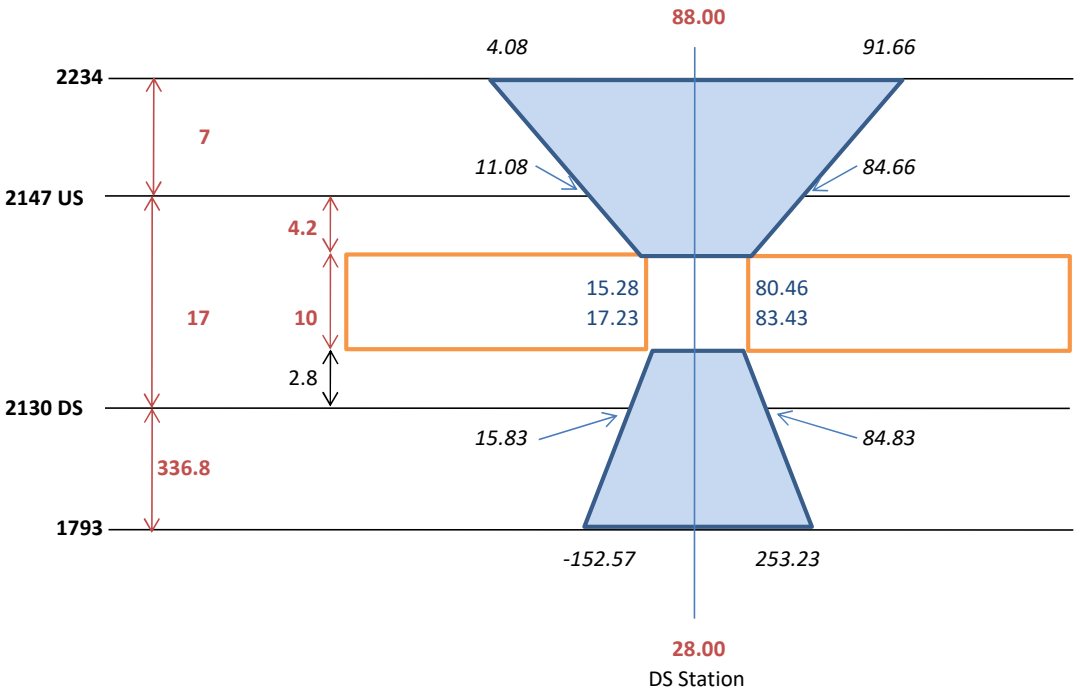

Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 400
.044
.044
.044
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Proposed Realignment
Plan: proposed realignment
4/3/2025
RS = 300
.044
.044
.044
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta


Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 200
.044
.044
.044
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta
Proposed Realignment Plan: proposed realignment 4/3/2025
RS = 100
.044
.044
.044
Elevation (ft)
Station (ft)
Legend
EG 100-year
EG 50-year
EG 25-year
WS 100-year
Crit 100-year
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta


Existing Plan: bridges 10/4/2024
.04
.03
.04
1370
1360
1350
1340
1330
1320
1310
Elevation (ft)
0
200
400
600
800
1000
Station (ft)
Legend
EG 100 yr
EG 50-year
WS 100 yr
WS 50-year
EG 25-year
Crit 100 yr
WS 25-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta


Existing Plan: bridges 10/4/2024
.04
.03
.04
1370
1360
1350
1340
1330
1320
1310
Elevation (ft)
0
200
400
600
800
1000
Station (ft)
Legend
EG 100 yr
EG 50-year
EG 25-year
WS 100 yr
Crit 100 yr
WS 50-year
Crit 50-year
EG 10 yr
Crit 25-year
WS 25-year
WS 10 yr
Crit 10 yr
Ground
Bank Sta

Ineffective Flow Areas 83.92 US Station 3.66 stream centerline 1332.53

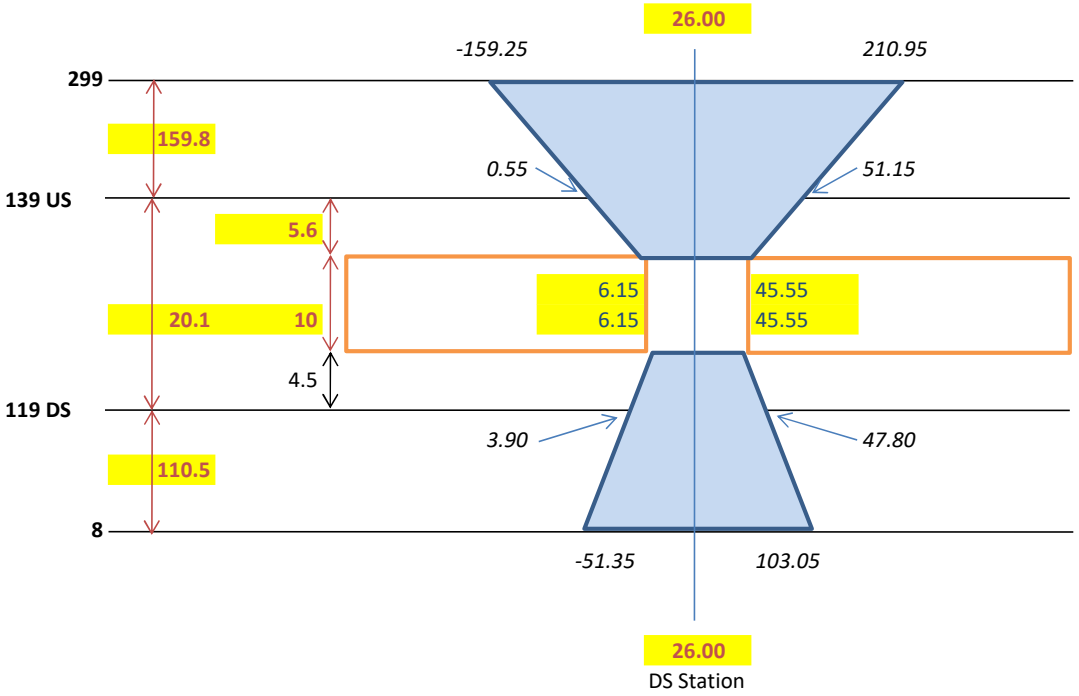


Contraction Ratio: 1 :1

Expansion Ratio: 0.5 :1

Railroad Bridge Crossing over Tributary eA at RS 2140
Minnehaha County
Existing Condition

Ineffective Flow Areas 185.25 US Station 184.95 stream centerline 1332.53



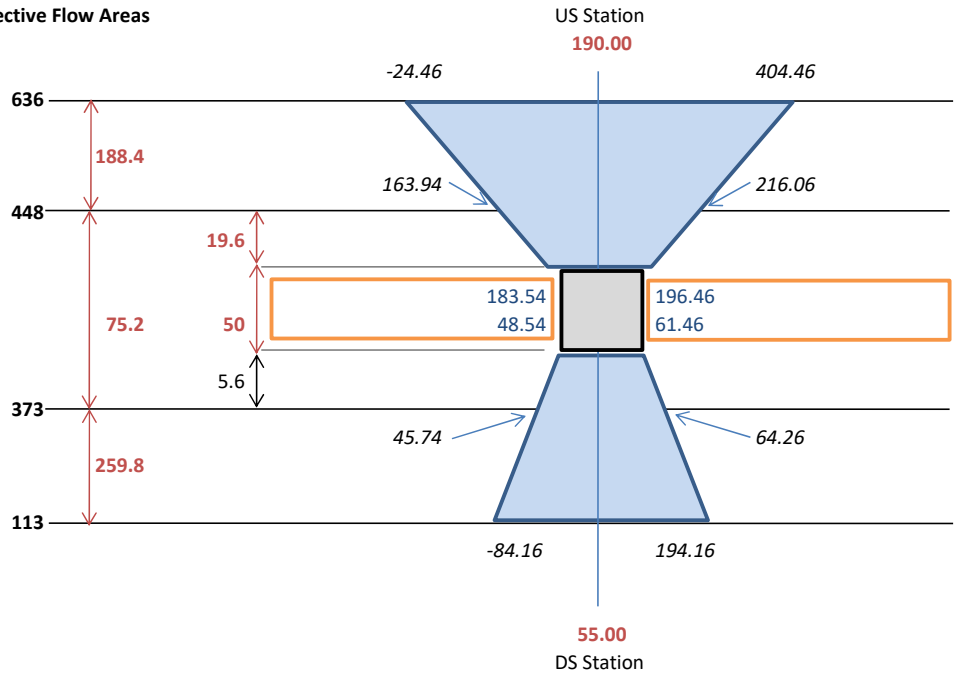
39.40 span
39.40 span

Contraction Ratio: 1 :1

Expansion Ratio: 0.5 :1

Railroad Bridge Crossing over Tributary eB at RS 125
Minnehaha County
Existing Condition

Ineffective Flow Areas



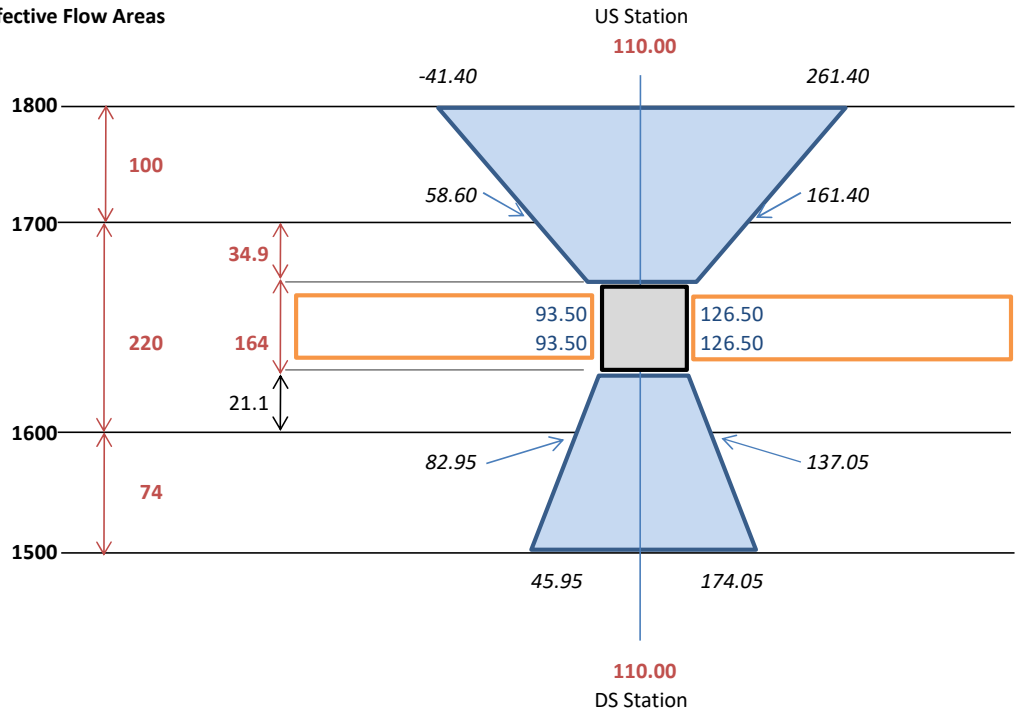
Contraction Ratio: 1 :1

Culvert width: 12.92

Expansion Ratio: 0.5 :1

Railroad Culvert Crossing over Tributary eAB at RS 400
Minnehaha County
Existing Condition

Ineffective Flow Areas



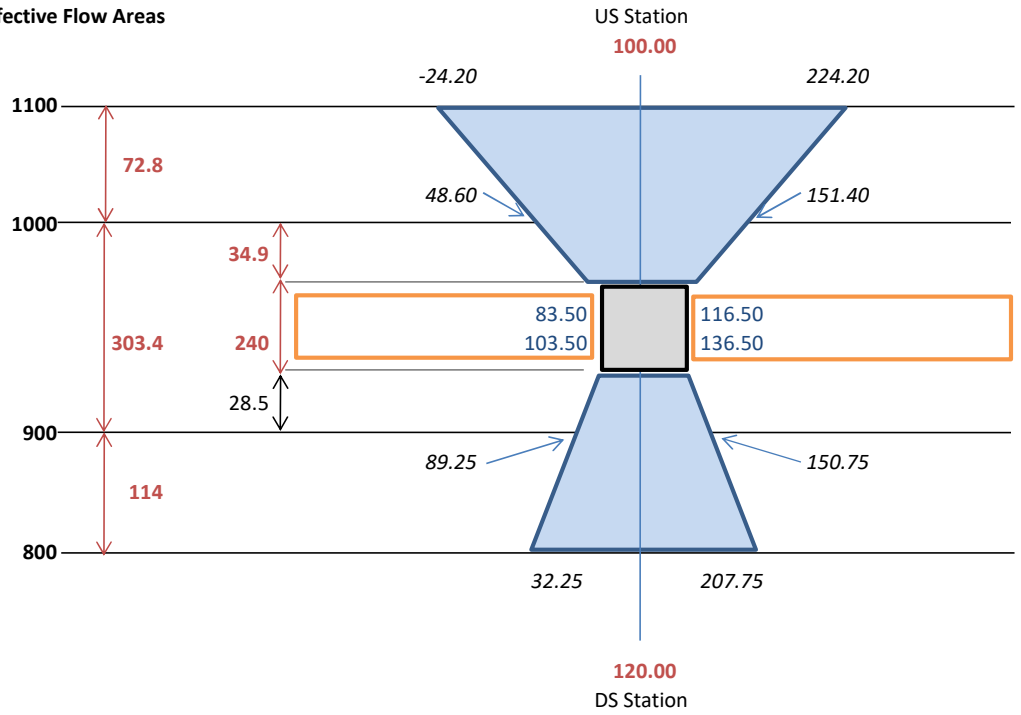
Contraction Ratio: 1 :1

Culvert width: 33

Expansion Ratio: 0.5 :1

Culvert Crossing over realignment at RS 1650
Minnehaha County
Proposed Condition

Ineffective Flow Areas



Contraction Ratio: 1 :1

Culvert width: 33

Expansion Ratio: 0.5 :1

Culvert Crossing over realignment at RS 950
Minnehaha County
Proposed Condition

HEC-RAS HEC-RAS 6.6 September 2024

U.S. Army Corps of Engineers

Hydrologic Engineering Center

609 Second Street

Davis, California

PROJECT DATA

Project Title: Existing

Project File : Existing.prj

Run Date and Time: 10/30/2024 8:36:29 AM

Project in English units

PLAN DATA

Plan Title: bridges

Plan File : n:\0033065.00\source\Floodplain\HEC RAS\Existing\Existing.p05

Geometry Title: ex cross sections_bridges

Geometry File : n:\0033065.00\source\Floodplain\HEC RAS\Existing\Existing.g04

Flow Title : flows

Flow File : n:\0033065.00\source\Floodplain\HEC RAS\Existing\Existing.f01

Plan Summary Information:

Number of: Cross Sections = 56 Multiple Openings = 0

Culverts = 1 Inline Structures = 0

Bridges = 2 Lateral Structures = 0

Computational Information

Water surface calculation tolerance = 0.01

Critical depth calculation tolerance = 0.01

Maximum number of iterations = 20

Maximum difference tolerance = 0.3

Flow tolerance factor = 0.001

Computation Options

Critical depth computed only where necessary

Conveyance Calculation Method: At breaks in n values only

Friction Slope Method: Average Conveyance

Computational Flow Regime: Subcritical Flow

FLOW DATA

Flow Title: flows

Flow File : n:\0033065.00\source\Floodplain\HEC RAS\Existing\Existing.f01

Flow Data (cfs)

River	Reach	RS	10 yr	100 yr	25-year	50-year
Branch C	1	100	53.5	122	79.8	101
Branch Ca	1	101	7460	18900	11500	15000
Branch D	1	300	69.4	159	104	131
Branch Da	1	0.5	7460	18900	11500	15000
north branch	1	4200	117	272	176	223
north branch	1	3354	144	336	217	275
south	1	3070	593	1430	898	1150
south	1	110	7460	18900	11500	15000
south branch	1	2900	533	1280	806	1030
eA	1	4200	117	272	176	223
eA	1	3354	144	336	217	275
eB	1	2900	533	1280	806	1030

eAB	1	3070	593	1430	898	1150
eAB	1	110	7460	18900	11500	15000
eC	1	100	53.5	122	79.8	101
eD	1	300	69.4	159	104	131
eSRC-CD	1	101	7460	18900	11500	15000
eSRC-D	1	0.5	7460	18900	11500	15000
eSRC-C	1	101	7460	18900	11500	15000

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
eA	1	10 yr	Normal S = 0.0087	
eA	1	100 yr	Normal S = 0.0087	
eB	1	10 yr	Normal S = 0.003	
eB	1	100 yr	Normal S = 0.003	
eSRC-D	1	10 yr		Normal S = 0.0068
eSRC-D	1	100 yr		Normal S = 0.0068

GEOMETRY DATA

Geometry Title: ex cross sections_bridges

Geometry File : n:\0033065.00\source\Floodplain\HEC RAS\Existing\Existing.g04

Reach Connection Table

River	Reach	Upstream Boundary	Downstream Boundary
eA	1		J1
eAB	1	J1	1
eB	1		J1
eC	1		1
eD	1		2
eSRC-C	1	1	2
eSRC-D	1		2

JUNCTION INFORMATION

Name: J1

Description:

Energy computation Method

Length across Junction			Tributary			
River	Reach		River	Reach	Length	Angle
eB	1	to	eAB	1	0	
eA	1	to	eAB	1	18	

Name: 1

Description:

Energy computation Method

Length across Junction			Tributary			
River	Reach		River	Reach	Length	Angle
eAB	1	to	eSRC-C	1	303.4	0
eC	1	to	eSRC-C	1	0	0

Name: 2

Description:

Energy computation Method

Length across Junction			Tributary			
River	Reach		River	Reach	Length	Angle
eSRC-C	1	to	eSRC-D	1	423.9	0
eD	1	to	eSRC-D	1	0	0

CROSS SECTION

RIVER: eA

REACH: 1 RS: 4200

INPUT

Description:

Station Elevation Data num= 5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1416	49.82	1412	154.68	1410	245.21	1412	405.06	1416

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	49.82	.04	245.21	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
49.82	245.21	618	618	618	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 4100

INPUT

Description:

Station Elevation Data num= 4

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1408	174.92	1404	321.43	1404	497.17	1408

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	0	.04	497.17	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
0	497.17	813	755	689	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 4000

INPUT

Description:

Station Elevation Data num= 4

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1400	151.57	1396	368.83	1400	520.97	1404

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	0	.04	368.83	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
0	368.83	107	190	409	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 3354

INPUT

Description:

Station Elevation Data num= 31

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1397	8.72	1396.67	11	1396.61	60.33	1396.71	60.56	1396.71
60.86	1396.71	62.35	1396.65	81.71	1395.8	92.46	1395.14	94.1	1395.12
97.39	1395.13	102.35	1394.82	102.36	1394.61	102.58	1394.58	103.88	1394.62
105.22	1395.31	105.6	1395.27	107.25	1395.27	109.73	1395.13	111.67	1395.36
113.98	1395.95	115.62	1395.98	119.68	1396.43	124.56	1396.54	159.84	1397.49
160.67	1397.51	160.99	1397.52	185.63	1398.4	211.95	1399.33	212.77	1399.35
229.22	1400								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	92.46	.04	105.22	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
92.46	105.22	303.56	303.56	303.56	.1		.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 3051

INPUT

Description:

Station Elevation Data num= 13

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1395.01	12.21	1394.53	34.23	1394.07	59.55	1393.3	75.11	1392.97
89.19	1392.54	102.12	1392.1	102.7	1392.12	116.48	1392.53	159.04	1394.13
170.87	1394.47	177.4	1394.72	182.73	1394.99				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	89.19	.04	116.48	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
89.19	116.48	213.73	213.73	213.73	.1		.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 2837

INPUT

Description:

Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1396	3.64	1395.75	52.47	1392.48	63.57	1392.23	92.51	1391.35
117.87	1390.03	123.75	1389.92	129.37	1389.26	133.61	1389.69	135.17	1389.72
141.34	1389.93	156.78	1390.02	177.9	1391.3	188.75	1391.62	216.27	1392.34
233.3	1392.53	262.96	1393.74	263.22	1393.75	300.97	1395		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	117.87	.04	141.34	.03

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
117.87	141.34	311	311	311	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 2526

INPUT

Description:

Station Elevation Data num= 20

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1376	13.33	1374.88	13.42	1374.87	53.26	1371.65	68.2	1370.96
68.35	1370.95	97.59	1368.64	97.66	1368.64	104.6	1367.69	116.86	1368.3
117.04	1368.31	134.52	1368.87	134.61	1368.87	170.39	1368.61	170.58	1368.61
200.46	1369.65	237.61	1372.43	251.29	1372.84	257.66	1372.98	276.03	1374.99

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	97.59	.04	134.52	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

97.59 134.52 272 292 277 .1 .3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 2234

INPUT

Description:

Station Elevation Data num= 14

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1359.98 10.2 1358.83 12.95 1358.47 15.52 1358.23 17.33 1358.08

38.18 1356.68 64.8 1354.86 73.28 1353.19 74.58 1352.44 84.65 1350.13

91.54 1350 107.46 1353.32 117.21 1355.22 192.55 1359.98

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .03 74.58 .04 107.46 .03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

74.58 107.46 40.7 40.7 40.7 .3 .5

CROSS SECTION

RIVER: eA

REACH: 1 RS: 2147

INPUT

Description:

Station Elevation Data num= 51

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1361.74 1.62 1362.39 2.49 1362.74 2.98 1362.94 3.38 1362.9

6.91 1362.54 11.89 1362.04 12.06 1362.02 12.96 1361.32 13.02 1361.47

13.35 1363.73 13.53 1363.29 14.17 1363.5 15.28 1362.19 16.5 1360.5
16.63 1360.31 17.11 1359.58 17.34 1359.57 18.32 1359.49 18.5 1359.54
26.03 1361.34 26.94 1353.84 27.82 1353.27 30.1 1351.99 30.34 1351.85
30.62 1351.69 30.71 1351.64 30.77 1351.61 41.73 1349.41 41.97 1349.61
42.34 1349.94 42.41 1349.89 42.53 1349.58 43.42 1350.31 43.54 1350.41
43.69 1350.38 44.32 1350.25 49.04 1349.24 55.51 1349.24 68.94 1356.45
68.97 1357.83 70.19 1356.84 80.46 1361.72 82.13 1363.38 82.76 1363.44
82.89 1362.54 86.68 1361.8 91.14 1363.73 93.33 1365.02 95.85 1364.36
97.58 1364.21

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	26.94	.04	68.94	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

26.94	68.94	17	17	17	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	11.08	1364.25	F
84.66	97.58	1364.25	F

BRIDGE

RIVER: eA

REACH: 1 RS: 2140

INPUT

Description:

Distance from Upstream XS = 4.2

Deck/Roadway Width = 10

Weir Coefficient = 2.6

Upstream Deck/Roadway Coordinates

num= 2

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

0 1364.25 1362.14 100 1364.25 1362.14

Upstream Bridge Cross Section Data

Station Elevation Data num= 41

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1361.74 1.62 1362.39 2.49 1362.74 2.98 1362.94 3.38 1362.9

6.91 1362.54 11.89 1362.04 12.06 1362.02 15.28 1362.19 18.32 1359.49

18.5 1359.54 26.94 1353.84 28 1353.4 30.1 1351.99 30.34 1351.85

30.62 1351.69 30.71 1351.64 30.77 1351.61 40 1349.23 41.73 1349.41

41.97 1349.61 42.34 1349.94 42.41 1349.89 42.53 1349.58 43.42 1350.31

43.54 1350.41 43.69 1350.38 44.32 1350.25 49.04 1349.24 55 1349.16

55.51 1349.24 73 1356.05 80.46 1361.72 82.13 1363.38 82.76 1363.44

82.89 1362.54 86.68 1361.8 91.14 1363.73 93.33 1365.02 95.85 1364.36

97.58 1364.21

Manning's n Values num= 2

Sta n Val Sta n Val

0 .03 26.94 .04

Bank Sta: Left Right Coeff Contr. Expan.

15.28 80.46 .3 .5

Ineffective Flow num= 2

Sta L Sta R Elev Permanent

0 11.08 1364.25 F

84.66 97.58 1364.25 F

Downstream Deck/Roadway Coordinates

num= 2

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

0 1364.25 1362.14 100 1364.25 1362.14

Downstream Bridge Cross Section Data

Station Elevation Data num= 53

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1362.24 3.19 1362.49 4.55 1362.59 4.81 1362.61 5.43 1362.66

10.89 1363.08 11.24 1363.11 12.06 1363.17 14 1363.32 14.08 1363.2

14.67 1363.07 14.73 1363.38 14.97 1363.37 15.16 1363.22 15.33 1363.09

17.23 1361.52 17.47 1361.33 18.17 1360.74 19.72 1359.25 19.78 1359.21

19.84 1359.18 19.98 1359.11 20.32 1358.92 20.68 1358.72 28 1353.4

33.58 1352.01 34.28 1351.58 34.51 1351.44 34.85 1351.23 36.39 1351.02

37.74 1350.83 39.99 1350.41 40.71 1350.24 43 1349.23 43.33 1349.06

43.7 1348.97 44.1 1348.82 44.59 1348.64 46.76 1348.87 47.31 1348.85

53.37 1348.72 56.14 1349.17 57.56 1349.24 58 1349.16 58.46 1349.3

58.56 1349.72 73 1356.05 73.28 1357 75.9 1357.32 76.55 1357.47

93.75 1361.06 95.65 1361.24 97.5 1361.41

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .03 33.58 .04 73.28 .03

Bank Sta: Left Right Coeff Contr. Expan.

33.58 73.28 .3 .5

Ineffective Flow num= 2

Sta L Sta R Elev Permanent

0 15.83 1364.25 F

84.83 97.5 1364.25 F

Upstream Embankment side slope = 0 horiz. to 1.0 vertical

Downstream Embankment side slope = 0 horiz. to 1.0 vertical

Maximum allowable submergence for weir flow = .98

Elevation at which weir flow begins =

Energy head used in spillway design =

Spillway height used in design =

Weir crest shape = Broad Crested

Number of Abutments = 1

Abutment Data

Upstream num= 7

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
82.84	1358.97	82.98	1358.87	83.28	1360.37	83.43	1361.16	83.77	1362.85
83.86	1363.08	100	1363.08						

Downstream num= 7

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
82.84	1358.97	82.98	1358.87	83.28	1360.37	83.43	1361.16	83.77	1362.85
83.86	1363.08	100	1363.08						

Number of Piers = 4

Pier Data

Pier Station Upstream= 28 Downstream= 28

Upstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Downstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Pier Data

Pier Station Upstream= 40 Downstream= 43

Upstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Downstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Pier Data

Pier Station Upstream= 55 Downstream= 58

Upstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Downstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Pier Data

Pier Station Upstream= 73 Downstream= 73

Upstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Downstream num= 2

Width	Elev	Width	Elev
1	1340	1	1363

Number of Bridge Coefficient Sets = 1

Low Flow Methods and Data

Energy

Selected Low Flow Methods = Highest Energy Answer

High Flow Method

Energy Only

Additional Bridge Parameters

Add Friction component to Momentum

Do not add Weight component to Momentum

Class B flow critical depth computations use critical depth

inside the bridge at the upstream end

Criteria to check for pressure flow = Upstream energy grade line

CROSS SECTION

RIVER: eA

REACH: 1 RS: 2130

INPUT

Description:

Station Elevation Data num= 73

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1362.24	3.19	1362.49	4.55	1362.59	4.81	1362.61	5.43	1362.66
10.89	1363.08	11.24	1363.11	12.06	1363.17	14	1363.32	14.08	1363.2
14.67	1363.07	14.73	1363.38	14.97	1363.37	15.16	1363.22	15.33	1363.09
17.23	1361.52	17.47	1361.33	17.92	1359.57	18.17	1360.74	18.32	1359.41
18.45	1359.39	19.72	1359.25	19.78	1359.21	19.84	1359.18	19.98	1359.11
20.32	1358.92	20.68	1358.72	23.99	1356.9	24.52	1356.6	26.77	1355.4
27.97	1354.76	28.2	1354.51	28.75	1354.2	31.48	1352.96	33.58	1352.01
34.28	1351.58	34.51	1351.44	34.85	1351.23	36.39	1351.02	37.74	1350.83
39.99	1350.41	40.71	1350.24	43.33	1349.06	43.7	1348.97	44.1	1348.82

44.59 1348.64 46.76 1348.87 47.31 1348.85 53.37 1348.72 56.14 1349.17
57.56 1349.24 58.46 1349.3 58.56 1349.72 73.28 1357 75.9 1357.32
76.55 1357.47 82.84 1358.97 82.98 1358.87 83.28 1360.37 83.43 1361.16
83.77 1362.85 83.86 1363.08 84.11 1363.07 84.31 1363.06 84.47 1363.08
84.61 1362.78 84.89 1362.2 85.08 1361.79 85.61 1360.69 85.78 1360.32
93.75 1361.06 95.65 1361.24 97.5 1361.41

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	33.58	.04	73.28	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

33.58	73.28	137	336.8	326	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	15.83	1364.25	F
84.83	97.5	1364.25	F

CROSS SECTION

RIVER: eA

REACH: 1 RS: 1793

INPUT

Description:

Station Elevation Data num= 25

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1354	2.09	1353.25	8.63	1352.79	16.01	1352.27	16.71	1352.22
17.57	1352.2	18.16	1352.18	22.73	1351.9	26.89	1351.65	62.31	1349.24
76.54	1348.9	84.96	1348.49	140.68	1347.64	144.67	1347.58	164.69	1347.39
192.26	1347.07	198.78	1347	263.46	1348.58	267.09	1348.73	301.74	1349.56
309.11	1349.77	355.5	1352.01	380.12	1353.17	383.26	1353.52	399.34	1355.01

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	84.96	.04	263.46	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
84.96	263.46	220	174.8	100		.1	.3

Ineffective Flow num= 1

Sta L	Sta R	Elev	Permanent
253.23	399.34	1364.25	F

CROSS SECTION

RIVER: eA

REACH: 1 RS: 1618

INPUT

Description:

Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1359.87	4.02	1359.86	30.94	1357.54	59.23	1354.49	67.08	1353.9
75.2	1353.25	110.51	1347.58	150.6	1345.66	155.73	1345.24	160.91	1345.22
191.4	1345.07	217.22	1345.01	229.35	1345.05	239.79	1345.67	283.91	1347.72
330.37	1350.95	339.78	1352.04	363.54	1354.52	369.44	1355.02		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	110.51	.04	283.91	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
110.51	283.91	130	269.8	333		.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 1348

INPUT

Description:

Station Elevation Data num= 24

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1359.89	.19	1359.87	41.36	1353.53	81.99	1349.78	100.57	1347.62
122.06	1346.5	150.24	1344.97	210.61	1343.54	219.9	1343.53	252.74	1343.1
266.91	1343.5	303.47	1345.31	317.9	1346.57	338.53	1347.3	356.98	1348.25
379.3	1350.17	391.77	1351.7	407.82	1353.16	418.92	1353.93	439.41	1356.51
440.3	1356.64	447.96	1357.13	483.21	1359.58	488.53	1360.01		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	122.06	.04	317.9	.03

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff Contr.	Expan.
122.06	317.9	173.4	294.4	372.7	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 1054

INPUT

Description:

Station Elevation Data num= 23

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1349.96	32.5	1346.92	39.02	1346.19	58.3	1344.72	89.88	1342.7
100.01	1342.51	138.35	1341.31	165.02	1341.28	221.13	1340.78	229.82	1340.76
234.25	1340.65	247.03	1341.78	277.47	1344.11	284.79	1344.79	295.81	1344.9

337.59 1345.04 339.87 1344.97 364.78 1345.48 387.43 1347 402.54 1348.69
410.9 1349.55 411.75 1349.6 416.12 1349.94

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	100.01	.04	247.03	.03

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
100.01	247.03	350.7	301.1	113.4	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 753

INPUT

Description:

Station Elevation Data num= 15

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1344.98	2.61	1344.61	51.95	1335.82	71.84	1335.63	98.59	1335.41
113.84	1335.39	115.83	1335.26	122.52	1335.07	132.74	1335.12	138.01	1335.12
186.7	1341.35	191.27	1341.95	193.24	1342.11	216.11	1343.27	248.47	1345.05

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	51.95	.04	138.01	.03

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
51.95	138.01	92	172.6	213.1	.1	.3

CROSS SECTION

RIVER: eA

REACH: 1 RS: 580

INPUT

Description:

Station Elevation Data num= 26

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1340.01	36.33	1333.73	38.33	1333.39	42.28	1331.31	45.03	1330.54
64.31	1330.61	68.43	1330.62	68.59	1330.62	68.72	1330.67	92.75	1332.06
104.79	1331.92	111.73	1331.31	117.38	1329.88	124.03	1329.57	125.39	1329.02
131.63	1328.42	135.52	1328.27	139.13	1330.23	142.32	1332.69	150.28	1332.69
165.41	1332.53	175.06	1332.97	206.21	1334.34	225.09	1334.44	256.75	1334.97
258.84	1335								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.03	111.73	.04	139.13	.03

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
111.73	139.13	18.3	18.3	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 3070

INPUT

Description:

Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1334.99	14.79	1332.02	16.78	1331.96	19.44	1331.93	39.43	1332.45
59.96	1331.93	71.51	1331.55	87.76	1331.37	108.5	1330.25	109.59	1330.24

118.13 1326.91 119.42 1326.35 127.1 1329.73 130.24 1331.46 131.67 1331.47
151.34 1331.86 186.46 1333.84 187.63 1333.91 188.94 1334

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	109.59	.03	127.1	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
109.59	127.1	82.3	85	54.7	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 2985

INPUT

Description:

Station Elevation Data num= 28

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1335.06	.5	1334.83	3.5	1334.5	10.14	1333.18	13.72	1332.37
16.47	1332.25	49.63	1330.55	50.78	1330.52	59.39	1329.23	77.2	1328.74
79.83	1329.29	81.38	1330.42	92.43	1330.48	95.91	1330.62	119.35	1330.9
129.22	1330.97	149.47	1331.03	155.39	1330.83	160.92	1328.66	167.01	1325.92
176.09	1329	177.58	1329.54	178.36	1329.52	184.37	1329.88	208.73	1331.39
233.66	1331.75	239.82	1332.08	272.9	1334.01				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	160.92	.03	176.09	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
160.92	176.09	120.4	271.7	327	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 2713

INPUT

Description:

Station Elevation Data num= 23

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1333.98	5.73	1333.04	14.75	1333.11	38.4	1332.56	60.67	1331.67
73.08	1330.67	95.59	1327.62	95.91	1327.57	102.83	1328.47	105.47	1328.02
112.76	1326.6	117.31	1324.58	124.77	1327.8	128.55	1329.46	131.62	1329.64
147.97	1329.92	154.07	1329.94	210.88	1329.54	212.91	1329.52	213.34	1329.54
228.48	1329.99	233.2	1330.33	277.16	1335.01				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	105.47	.03	124.77	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff Contr.	Expan.
105.47	124.77	297.4	262.7	139.6	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 2450

INPUT

Description:

Station Elevation Data num= 16

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1335.01	36.99	1331.75	51.44	1330.12	64.18	1329	80.41	1327.8
82.2	1327.25	94.72	1323.34	99.5	1325.59	102.98	1326.65	123.63	1327.42
137.1	1327.6	148.18	1327.68	148.8	1328.02	155.48	1328.53	203.6	1332.22
219.18	1334.87								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	82.2	.03	102.98	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
82.2	102.98	164.8	282.6	251.6	.1		.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 2167

INPUT

Description:

Station Elevation Data num= 22

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1329.95	9.84	1329.24	39.24	1328.34	45.37	1328.11	51.43	1327.94
94.52	1327.17	109.91	1326.95	117.34	1326.67	123.51	1326.33	131.53	1325.47
137.97	1324.39	142.91	1323.14	145.93	1321.99	153.87	1325.12	156.93	1326.81
161.19	1326.96	174.1	1326.95	185.03	1326.73	209.26	1326.79	216.87	1326.84
228.5	1328.19	244.98	1330.03						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	131.53	.03	153.87	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
131.53	153.87	212.6	299	237	.1		.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 1868

INPUT

Description:

Station Elevation Data num= 23

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1330.02	.47	1329.86	4.4	1329.51	7.97	1328.62	16.48	1327.09
26.64	1326.99	39.82	1326.84	54.54	1326.32	78.96	1325.63	119.77	1324.74
129.13	1324.12	132.43	1323.62	134.45	1322.71	140.8	1320.55	150.74	1323.18
153.99	1324.79	169.64	1326.77	179.91	1328.54	181.34	1328.72	189.91	1329.08
214.8	1329.81	241.64	1330.45	263.04	1331.79				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	129.13	.03	153.99	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
129.13	153.99	253.2	275.4	143.9	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 1593

INPUT

Description:

Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1335.99	35.62	1325.01	48.48	1323.81	50.56	1323.63	55.03	1323.25
55.55	1323.2	67.86	1322.39	69.39	1322.13	70.18	1321.69	71.03	1321.21
72.85	1320.19	75.31	1319.36	75.67	1319.24	76.74	1319.65	78.39	1320.29
79.07	1320.56	82.09	1322.15	82.94	1322.25	86.86	1322.72	90.5	1323.41
93.39	1323.96	95.19	1324.08	105.18	1324.71	112.98	1325.24	122.6	1325.89

122.65 1325.89 136.29 1326.15 152.56 1326.45 174.01 1326.86 175.61 1326.89
191.81 1327.37 215.99 1328.09 217.5 1328.14 219.14 1328.29 219.58 1328.33
269.08 1332.78 269.4 1332.81 270.07 1332.88 277.63 1333.68 292.32 1334.98

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	67.86	.03	82.09	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
67.86	82.09	281.5	291.6	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 1301

INPUT

Description:

Station Elevation Data num= 23

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1334.98	43.52	1327.5	52.2	1326.39	67.76	1323.01	71.57	1321.64
79.2	1317.84	84.97	1319.54	89.31	1321.33	114.84	1322.18	119.99	1322.41
121.74	1322.45	138.52	1322.98	167.45	1323.94	171.33	1323.98	177.9	1324.05
223.44	1324.28	254.49	1324.32	273.19	1325.04	291.52	1325.62	298.35	1325.99
304.2	1326.93	340.23	1333.63	345.21	1335.03				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	71.57	.03	89.31	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
71.57	89.31	132.2	222	264.1	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 1079

INPUT

Description:

Station Elevation Data num= 37

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1330.04	22.95	1326.24	35.05	1324.59	48.42	1323.66	70.72	1322.99
77.77	1322.92	93.32	1322.57	122.77	1322.77	148.69	1323.05	168.98	1323.09
174.52	1323.09	174.94	1323.08	175.93	1322.22	185.7	1316.77	188.18	1317.94
194.39	1320.05	197.4	1320.14	199.21	1320.18	236.13	1320.81	247.22	1321
254.69	1321.77	263.58	1321.88	277.44	1321.63	288.53	1322.26	320.56	1323.16
330.87	1323.36	336.1	1323.71	342.55	1323.71	353.43	1323.81	379.85	1323.98
394.12	1324.03	398.99	1324.05	444.2	1324.06	455.37	1324.46	475.84	1325.62
490.84	1328.09	506.35	1331.04						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	175.93	.03	236.13	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
175.93	236.13	156.5	278.1	50	.1	.3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 801

INPUT

Description:

Station Elevation Data num= 28

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1330 31.59 1326.34 37.65 1326.01 50.93 1324.84 69.87 1323.16

76.1 1322.87 97.36 1322.49 119.31 1322.37 140.51 1322.43 180.59 1322.32

185.09 1322.29 186 1322.26 195.05 1322.04 221.82 1321.25 231.88 1321.01

254.99 1320.4 258.05 1319.69 265.78 1319.25 280.97 1318.55 286.13 1316.63

287.42 1315.44 298.05 1318.37 298.47 1318.55 299.42 1319 300.81 1319.56

309.27 1322.61 320.7 1325.05 345.89 1330

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .04 265.78 .03 299.42 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

265.78 299.42 83.7 165.4 147.4 .1 .3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 636

INPUT

Description:

Station Elevation Data num= 31

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1328 2.12 1327.72 2.14 1327.72 39.24 1325.63 72.83 1324.35

103.46 1322.81 106.71 1322.64 123.9 1321.73 125.47 1321.65 126.41 1321.6

150.56 1320.39 152.56 1320.29 175.31 1319.15 176.66 1318.94 194.38 1318.78

199.66 1318.69 200.11 1318.68 200.35 1318.67 200.59 1318.54 209.06 1314.65

212.46 1315.8 215.66 1317.38 224.91 1318.38 232.05 1319.55 247.69 1319.99

258.04 1320.18 269.04 1321.48 270.56 1321.68 271.76 1321.99 279.41 1324.07

301.06 1330.04

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	199.66	.03	224.91	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

199.66 224.91 86.6 188.4 233.8 .3 .5

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 448

INPUT

Description:

Station Elevation Data num= 51

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1330	39.51	1327.76	39.61	1327.75	40.28	1327.72	43.29	1327.56
80.53	1325.92	91.79	1325.32	92.77	1325.27	96.82	1325.08	99.84	1324.99
106.76	1325.14	106.85	1325.14	107.35	1324.45	116.38	1324.33	123.79	1323.83
128.1	1323.52	132.69	1323.46	160.29	1321.57	160.6	1321.55	160.72	1321.51
165.13	1320.1	168.08	1318.92	176.82	1316.5	176.94	1316.63	177.66	1315.96
178.39	1315.37	182.59	1314.54	191.76	1314.08	194.95	1314.03	203.03	1316.82
203.84	1317.46	205.01	1317.93	209.69	1318.04	225.73	1318.72	225.99	1318.75
237.39	1320.03	244.64	1320.56	258.17	1321.81	258.8	1321.93	268.89	1323.19
269.2	1323.22	269.27	1323.22	270.94	1323.43	281.81	1324.66	285.29	1324.91
290.01	1324.73	293.21	1325.03	313.28	1326.08	330.11	1327.3	333.88	1327.67
374.36	1329.08								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	168.08	.03	225.73	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

168.08 225.73 75.2 75.2 75.2 .3 .5

Ineffective Flow num= 2

Sta L Sta R Elev Permanent

0 163.94 1325.72 F

216.06 374.36 1325.72 F

CULVERT

RIVER: eAB

REACH: 1 RS: 400

INPUT

Description:

Distance from Upstream XS = 19.6

Deck/Roadway Width = 40

Weir Coefficient = 2.6

Upstream Deck/Roadway Coordinates

num= 15

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

0 1331 87.07 1327.53 97.07 1327.14

97.78 1327.13 119.85 1326.57 125.55 1326.49

155.79 1326.08 161.22 1326.03 182.02 1325.72

205.77 1325.78 218.49 1325.82 233.17 1325.98

253.49 1326.24 263.59 1326.68 363.31 1331

Upstream Bridge Cross Section Data

Station Elevation Data num= 52

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1330 39.51 1327.76 39.61 1327.75 40.28 1327.72 43.29 1327.56

80.53 1325.92 91.79 1325.32 92.77 1325.27 96.82 1325.08 99.84 1324.99

106.76 1325.14 106.85 1325.14 107.35 1324.45 116.38 1324.33 123.79 1323.83

128.1 1323.52 132.69 1323.46 160.29 1321.57 160.6 1321.55 160.72 1321.51
165.13 1320.1 168.08 1318.92 176.82 1316.5 176.94 1316.63 177.66 1315.96
178.39 1315.37 182.59 1314.22 191.76 1314.22 194.95 1314.22 196.46 1314.22
203.03 1316.82 203.84 1317.46 205.01 1317.93 209.69 1318.04 225.73 1318.72
225.99 1318.75 237.39 1320.03 244.64 1320.56 258.17 1321.81 258.8 1321.93
268.89 1323.19 269.2 1323.22 269.27 1323.22 270.94 1323.43 281.81 1324.66
285.29 1324.91 290.01 1324.73 293.21 1325.03 313.28 1326.08 330.11 1327.3
333.88 1327.67 374.36 1329.08

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	168.08	.03	225.73	.04

Bank Sta: Left Right Coeff Contr. Expan.

Left	Right	Coeff Contr.	Expan.
168.08	225.73	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	163.94	1325.72	F
216.06	374.36	1325.72	F

Downstream Deck/Roadway Coordinates

num= 15

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	1331		87.07	1327.53		97.07	1327.14	
97.78	1327.13		119.85	1326.57		125.55	1326.49	
155.79	1326.08		161.22	1326.03		182.02	1325.72	
205.77	1325.78		218.49	1325.82		233.17	1325.98	
253.49	1326.24		263.59	1326.68		363.31	1331	

Downstream Bridge Cross Section Data

Station Elevation Data num= 47

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1325.03	1.05	1324.83	2.36	1324.66	6.65	1324.12	8.91	1323.83
12.4	1323.39	14.61	1323.11	19.57	1322.7	24.29	1322.31	24.95	1322.31
25.99	1322.32	37.05	1322.45	37.13	1322.45	39.35	1321.74	43.37	1320.45
44.79	1320.59	46.42	1320.75	46.71	1320.71	46.76	1320.65	46.92	1320.56
47.27	1320.36	47.28	1320.24	47.47	1314.59	48.57	1314.04	49.74	1314.04
61.22	1313.81	61.28	1314.08	61.4	1320.98	61.58	1321.1	61.73	1321.2
61.91	1321.31	61.97	1321.36	62.19	1321.39	62.38	1321.33	63.85	1320.85
68.62	1321.05	69.78	1321.48	70.35	1321.7	72.59	1322.53	73.1	1322.73
73.62	1322.92	74.1	1323.1	75.6	1323.67	78.95	1324.77	81.13	1324.96
81.31	1324.98	81.59	1325.01						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	47.47	.03	61.22	.04

Bank Sta: Left	Right	Coeff Contr.	Expan.
47.47	61.22	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	45.74	1325.72	F
64.26	81.59	1325.72	F

Upstream Embankment side slope = 0 horiz. to 1.0 vertical

Downstream Embankment side slope = 0 horiz. to 1.0 vertical

Maximum allowable submergence for weir flow = .98

Elevation at which weir flow begins =

Energy head used in spillway design =

Spillway height used in design =

Weir crest shape = Broad Crested

Number of Culverts = 1

Culvert Name Shape Rise Span

Culvert #1 Box 9 12.92

FHWA Chart # 10- 90 degree headwall; Chamfered or beveled inlet

FHWA Scale # 2 - Inlet edges beveled 1/2 inch at 45 degrees (1:1)

Solution Criteria = Highest U.S. EG

Culvert	Upstrm Dist	Length	Top n	Bottom n	Depth Blocked	Entrance Loss Coef	Exit Loss Coef
	19.6	50	.013	.013	0	.5	1

Upstream Elevation = 1314.22

Centerline Station = 190

Downstream Elevation = 1314.04

Centerline Station = 55

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 373

INPUT

Description:

Station Elevation Data num= 47

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1325.03	1.05	1324.83	2.36	1324.66	6.65	1324.12	8.91	1323.83
12.4	1323.39	14.61	1323.11	19.57	1322.7	24.29	1322.31	24.95	1322.31
25.99	1322.32	37.05	1322.45	37.13	1322.45	39.35	1321.74	43.37	1320.45
44.79	1320.59	46.42	1320.75	46.71	1320.71	46.76	1320.65	46.92	1320.56
47.27	1320.36	47.28	1320.24	47.47	1314.59	48.57	1314.5	49.74	1314.41
61.22	1313.81	61.28	1314.08	61.4	1320.98	61.58	1321.1	61.73	1321.2

61.91 1321.31 61.97 1321.36 62.19 1321.39 62.38 1321.33 63.85 1320.85
68.62 1321.05 69.78 1321.48 70.35 1321.7 72.59 1322.53 73.1 1322.73
73.62 1322.92 74.1 1323.1 75.6 1323.67 78.95 1324.77 81.13 1324.96
81.31 1324.98 81.59 1325.01

Manning's n Values num= 3
Sta n Val Sta n Val Sta n Val
0 .04 47.47 .03 61.22 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.
47.47 61.22 203.6 259.8 225.3 .3 .5
Ineffective Flow num= 2
Sta L Sta R Elev Permanent
0 45.74 1325.72 F
64.26 81.59 1325.72 F

CROSS SECTION
RIVER: eAB
REACH: 1 RS: 113
INPUT
Description:
Station Elevation Data num= 19
Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev
0 1324.98 15.23 1321.48 25.94 1320.17 34.53 1318.74 48.01 1318.07
70.66 1317.07 76.07 1314.69 78.45 1313.38 88.75 1314.52 91.27 1314.61
91.58 1314.94 104.01 1318.84 107.7 1320 108.69 1320.16 110.97 1320.5
111.91 1320.6 137.2 1322.47 141.01 1322.74 152.86 1322.99
Manning's n Values num= 3
Sta n Val Sta n Val Sta n Val
0 .04 70.66 .03 104.01 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

70.66 104.01 410.7 272.8 384.7 .1 .3

CROSS SECTION

RIVER: eAB

REACH: 1 RS: 110

INPUT

Description:

Station Elevation Data num= 78

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01356.731 13.661356.626 37.721356.123 51.641354.917 84.43 1352.06

98.46 1350.39 117.81347.463 124.281346.743 133.26 1345.04 162.281338.595

169.651336.429 225.611321.564 226.09 1321.44 226.161321.425 226.271321.402

256.471316.513 259.791315.953 266.461315.166 267.881313.893 270.31313.059

270.361313.059 295.341313.057 296.381313.057 308.71313.077 309.431313.078

327.841313.038 328.161313.864 329.211316.503 329.491316.446 331.431316.065

331.941316.145 336.39 1316.85 337.431316.794 344.421316.417 344.611316.436

362.641318.313 362.71318.315 365.491318.399 365.721318.406 374.981318.685

376.711318.317 377.151318.317 378.561318.316 385.541318.373 398.031318.431

400.731318.449 401.281318.447 401.841318.449 404.311318.453 420.871318.482

425.991318.491 426.291318.541 426.681320.122 427.121320.114 427.181320.112

427.371317.596 427.381317.499 428.411318.135 428.51318.189 430.251319.206

433.411321.048 435.5 1322.26 442.68 1326.04 444.741326.811 452.621329.764

454.741330.557 458.031331.793 459.241339.336 459.891343.416 459.921343.492

461.161343.408 462.851343.633 463.261343.717 4641343.526 464.111343.438

464.251343.736 464.411344.059 464.67 1344.5

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .04 256.47 .03 329.49 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

256.47 329.49 303.4 303.4 303.4 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2900

INPUT

Description:

Station Elevation Data num= 140

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

21.36 1405 21.78 1405 26.93 1405 28.94 1405 29.591404.994

46.761404.625 601404.349 76.46 1404 97.841403.744 102.351403.696

126.11403.425 166.041403.003 166.261403.003 166.561403.003 168.031403.003

168.841403.002 169.371403.002 174.24 1403 180.711402.907 187.571402.808

194.68 1402.71 217.071402.382 244.181402.027 245.971402.003 246.62 1402

254.421401.824 262.911401.667 268.811401.573 273.061401.522 278.581401.445

291.071401.186 299.38 1401 311.781400.713 325.731400.419 341.851400.048

343.83 1400 357.21399.511 366.591399.259 370.571399.138 377.211399.011

377.9 1399 387.711398.901 391.791398.836 406.731398.716 411.431398.693

415.931398.684 419.751398.686 422.511398.696 424.591398.702 431.121398.618

445.47 1398 447.521397.999 449.641397.999 451.171397.998 453.641397.999

455.01 1398 462.111398.017 469.261398.041 484.711398.089 488.421398.078

495.241398.063 500.111398.046 512.1 1398 515.281397.813 519.311397.563

527.77 1397 534.841396.906 538.431396.853 542.61396.912 548.46 1397

550.591397.472 552.441397.774 553.31 1398 5771398.061 578.561398.063

593.031398.028 594.231398.025 596.33 1398.02 604.13 1398 609.531397.991

611.81397.989 623.121397.976 626.171397.972 628.821397.976 646.01 1398

670.91398.656 683.52 1399 704.421399.432 7141399.607 735.07 1400

735.16 1400 735.61400.001 737.091400.002 737.671400.002 739.291400.002

742.231400.001 742.671400.001 742.911400.001 744.241400.002 745.691400.001

745.791400.001 747.961400.003 752.861400.071 754.451400.098 756.411400.137
762.561400.225 769.21400.348 774.451400.442 802.17 1401 828.291401.932
830.44 1402 830.53 1402 830.96 1402 831.38 1402 831.67 1402
832.69 1402 835.361401.966 854.751401.924 874.63 1401.99 875.221401.999
875.62 1402 877.151402.004 878.691402.004 879.351402.007 883.641402.012
898.551402.301 901.381402.366 905.381402.443 914.351402.636 926.51 1402.91
930.43 1403 930.561403.002 954.531403.589 961.251403.744 964.221403.798
972.851403.989 973.97 1404 974.881404.004 995.941404.455 997.251404.483

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
21.36	.05	495.24	.05	552.44	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
495.24	552.44	159	143.6	127	.1		.3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2800

INPUT

Description:

Station Elevation Data num= 157

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
36.6	1405	41.911404.855		72.27	1404	91.651403.576		100.551403.432	
122.32	1403	124.281402.998		126.021402.996		127.531402.996		130.571402.993	
131.211402.993		174.531402.487		181.851402.419		187.41 1402.37		216.241402.066	
222.21	1402	240.091401.786		254.151401.627		305.8	1401	314.381400.871	
343.64 1400.47		359.861400.208		372.15	1400	381.991399.471		390.95	1399
396.521398.404		400.91	1398	413.081397.982		415.991397.978		420.771397.985	
425.311397.992		4291397.997		431.211398.001		431.711398.001		432.951398.004	

433.341398.004 437.141398.006 444.021398.014 445.551398.014 4691398.017
491.171398.022 497.691398.024 505.481398.018 509.161398.016 517.831398.012
523.59 1398.01 536.651398.005 541.77 1398 548.731397.316 552.33 1397
555.34 1396.66 560.42 1396 563.291395.999 563.71395.999 566.91 1396
578.371396.975 578.521396.986 578.72 1397 599.961397.884 602.21 1398
602.83 1398 604.851398.001 625.39 1398.01 627.521398.009 632.591398.008
636.171398.007 638.681398.007 648.561398.007 665.071398.008 665.311398.008
665.971398.008 667.941398.008 674.041398.005 680.781398.001 680.991398.001
682.52 1398 695.751397.725 701.971397.537 718.81397.004 719.211397.003
719.77 1397 720.861396.999 724.611396.996 727.241396.994 731.121396.996
734.21 1397 748.21 1397.65 752.391397.862 756.08 1398 778.631398.466
781.761398.491 784.641398.508 786.021398.516 789.091398.548 794.11 1398.58
799.91398.631 802.29 1398.66 809.061398.762 810.761398.782 821.981398.985
822.071398.987 822.171398.987 823.221398.989 823.41398.989 823.69 1398.99
826.24 1399 854.431399.834 857.261399.912 861.98 1400 862.191400.001
863.51400.001 864.461400.002 865.05 1400 865.211399.999 869.51399.958
874.311399.924 883.351399.904 892.621399.969 896.131399.997 896.941399.997
897.451399.998 900.8 1400 901.321400.001 902.81400.002 904.591400.005
906.431400.004 906.951400.005 907.531400.006 907.941400.006 916.481400.165
918.671400.218 923.151400.337 936.641400.708 946.361400.985 948.04 1401
948.391401.001 948.621401.001 968.181401.346 978.521401.511 982.911401.562
988.311401.629 993.021401.693 1009.941401.928 1013.961401.989 1014.731401.992
1015.631401.996 1016.371401.997 1017.371401.998 1017.79 1402 1018.71402.003
1037.511402.344 1049.241402.548 1067.91402.896 1068.72 1402.91 1073.75 1403
1079.111403.149 1080.581403.187

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
36.6	.05	536.65	.05	599.96	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

536.65 599.96 382.9 355.7 352.6 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2700

INPUT

Description:

Station Elevation Data num= 147

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01404.015 .33 1404 18.871403.387 22.081403.306 26.331403.189

31.51 1403 52.771402.369 64.99 1402 78.051401.686 107.9 1401

108.341400.997 117.141400.868 125.63 1400.75 166.991400.161 175.371400.041

176.721400.023 178.51 1400 179.49 1400 189.5 1400 198.14 1400

207.381399.999 211.331399.999 216.091399.999 242.49 1400 243.311400.003

245.281400.009 245.77 1400.01 246.261400.009 249.92 1400 263.68 1399.74

271.581399.585 299.421399.015 299.531399.015 300.061399.011 301.35 1399

301.511398.999 315.881398.774 326.25 1398.62 335.81398.536 351.13 1398.39

385.261398.005 386.221398.004 386.631398.004 387.351398.003 387.591398.003

387.881398.003 388.181398.003 388.871398.003 389.111398.003 395.261398.004

396.331398.004 400.011398.005 400.121398.004 401.071398.004 401.121398.004

402.821398.003 409.83 1398 410.481397.985 421.661397.748 446.051397.105

446.751397.088 449.991397.073 455.781397.041 464.33 1397 466.521396.992

496.61396.446 508.081396.249 512.571396.175 527.69 1396 529.21395.997

529.61395.996 534.51395.985 536.381395.979 542.211395.965 554.81395.997

555.79 1396 556.581396.003 556.961396.003 599.051396.614 610.951396.726

615.791396.709 617.351396.715 620.031396.712 621.281396.712 626.031396.703

631.251396.683 637.871396.659 644.121396.645 648.381396.638 650 1396.63

6531396.615 657.311396.602 662.091396.609 666.831396.604 670.681396.579

674.251396.559 679.071396.547 680.91396.533 685.61 1396.53 707.191396.203

708.651396.205 712.281396.185 719.321396.148 735.071396.063 737.341396.057
747.87 1396 749.311395.808 749.561395.802 759.51395.699 769.991395.846
772.36 1396 774.721396.121 777.91 1396.28 785.731396.701 793.97 1397
794.871397.005 808.651397.141 814.99 1397.23 848.341397.862 849.111397.867
862.051397.967 863.741397.978 864.091397.983 867.13 1398 918.441398.842
927.71 1399 934.251399.141 935.011399.156 942.841399.317 975.481399.998
976.361399.998 976.61 1400 978.11400.004 995.25 1400.3 1008.351400.528
1013.11400.612 1036.24 1401 1037.021401.002 1037.641401.004 1039.531401.009
1064.291401.404 1078.281401.609 1101.211401.982 1101.491401.986 1102.78 1402
1117.831402.279 1125.51402.435

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	421.66	.05	808.65	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

421.66 808.65 297.6 297.6 297.6 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2520

INPUT

Description:

Station Elevation Data num= 144

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1404.28	8.77	1404	11.491403.929		44.25	1403	79.571402.113	
84.73	1402	101.141401.652		122.27	1401.18	130.18	1401	138.591400.871	
143.171400.802		196.311400.004		197.33	1400	197.41	1400	197.77	1400
203.311399.999		223.971399.998		235.541399.996		248.421399.999		257.34	1400
260.35	1400	261.481400.004		263.561400.008		265.741400.004		266.351400.003	

266.9 1400 289.731399.503 304.311399.169 310.851399.012 312.9 1399
324.171398.859 342.751398.622 389.79 1398.01 392.19 1398 409.991397.422
424.64 1397 425.26 1396.98 425.81396.962 453.39 1396 453.55 1396
478.851395.995 479.931395.995 501.041395.999 505.34 1396 506.53 1396
506.59 1396 508.951396.005 509.651396.004 513.421396.008 522.11396.002
522.941396.001 523.061396.001 523.471396.002 530.22 1396 536.071395.999
540.04 1396 543.371396.003 545.751396.002 545.871396.002 546.45 1396
549.471395.998 550.741395.998 553.011395.997 554.511395.998 557.48 1396
558.81396.003 570.791396.018 578.21396.021 588.231396.024 591.61396.026
595.451396.021 597.261396.019 604.961396.011 605.641396.011 612.381396.007
614.081396.003 615.44 1396 615.73 1396 621.221395.828 648.06 1395
657.48 1395 660.57 1395 662.411395.183 664.021395.269 664.811395.302
670.151395.698 672.821395.702 674.91395.815 685.241395.956 689.151395.938
696.681395.991 698.361395.999 698.45 1396 700.39 1396 717.341396.002
722.871396.003 727.31396.003 750.96 1396 753.76 1396 756.991395.999
760.011395.997 764.641395.996 774.84 1396 775.381396.001 779.81396.008
780.441396.008 780.941396.009 782.131396.008 783.281396.007 784.011396.009
785.51396.011 792.931396.033 796.251396.036 801.571396.081 824.261396.203
825.91396.203 826.791396.204 829.391396.216 830.841396.212 835.421396.218
840.311396.226 845.081396.254 849.521396.279 850.18 1396.28 866.091396.405
914.451396.852 917.561396.876 927.291396.998 928.16 1397 957.511397.582
965.311397.734 979.13 1398 1004.651398.495 1013.231398.651 1032.33 1399
1047.871399.227 1067.711399.555 1093.96 1400 1094.531400.003 1128.221400.476
1143.321400.681 1155.471400.824 1170.08 1401 1170.16 1401

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	595.45	.05	670.15	.05

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
595.45	670.15	442.5	428.4	431.5	.1	.3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2470

INPUT

Description:

Station Elevation Data num= 22

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1406.07	20.57	1399.66	29.47	1397	30.28	1396.77	44.67	1396.21
50.19	1396	56.25	1395.92	87.71	1395.46	106.44	1395.28	126.21	1395.1
152.27	1394.75	157.86	1394.66	177.34	1394.53	215.87	1394.22	217.02	1393.07
217.91	1392.63	219.11	1393.52	220.54	1393.85	223.24	1394.19	272.63	1394.97
273.71	1395.02	783.71	1400						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	215.87	.05	223.24	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
215.87	223.24	164.2	173.2	81.5	.1		.3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2297

INPUT

Description:

Station Elevation Data num= 50

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1404.97	.92	1404.69	1.39	1404.55	7.71	1402.63	26.11	1397.05
29	1396.15	40.6	1395.07	42.15	1394.95	42.43	1394.93	42.88	1394.94
45.36	1394.86	48.95	1394.75	56.63	1394.53	83.64	1393.77	85.6	1393.72

86.87 1393.69 98.21 1393.77 108.21 1393.87 127.11 1394.07 132.49 1393.98
132.66 1393.98 134.03 1393.96 134.87 1393.94 136.61 1393.92 136.85 1393.91
143.19 1393.81 149.7 1393.7 169.97 1393.38 174.01 1393.32 174.17 1393.31
175.55 1392.47 176.38 1391.8 178.12 1393.29 178.37 1393.64 184.69 1393.76
202.24 1394.07 204.94 1394.11 210.24 1394.21 211.48 1394.23 243.76 1394.66
246.45 1394.69 251.73 1394.71 254.12 1394.71 265.39 1394.72 266.22 1394.73
295.63 1394.76 306.91 1394.88 307.73 1394.8 308.28 1395.01 764.78 1400

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	169.97	.05	178.12	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

169.97 178.12 260.4 279 169.8 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 2018

INPUT

Description:

Station Elevation Data num= 25

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1403.94	18.85	1398.73	30.1	1395.17	33.53	1395.01	44.95	1394.67
46.95	1394.65	55.71	1394.42	63.71	1394.2	66.58	1393.66	72.35	1393.45
98.61	1392.18	99.15	1391.46	99.95	1390.71	100.74	1391.26	101.53	1391.91
111.82	1392.45	114.59	1392.51	164.55	1392.68	171.94	1392.68	220.57	1392.91
225.56	1393	271.3	1393.34	282.06	1393.3	311.41	1393.97	676.41	1400

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	98.61	.05	101.53	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

98.61 101.53 200.3 253.5 263.3 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 1765

INPUT

Description:

Station Elevation Data num= 26

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1394.99 .43 1394.99 1.16 1394.97 7.32 1394.74 20.26 1394.26

45.16 1393.32 57.85 1393.15 82.52 1392.48 107.45 1391.66 128.57 1391.54

134.4 1391.39 161.98 1391.01 165.22 1391.01 193.43 1391.16 209.02 1391.13

272.76 1391.59 273.29 1391.6 273.56 1391.53 275.9 1391.58 308.77 1391.37

320.27 1391.7 348.65 1392.65 366.85 1392.93 380.82 1393.28 401.83 1394.06

431.21 1395.01

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .05 134.4 .05 273.29 .05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

134.4 273.29 150 296.3 314.3 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 1469

INPUT

Description:

Station Elevation Data num= 20

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1391.99 32.84 1391 37.77 1390.87 52.68 1390.51 78.44 1389.95

82.63 1389.86 88.45 1389.85 110.09 1389.69 147.02 1389.32 173.75 1388.9

186.13 1388.48 199.33 1388.26 230.93 1387.82 250.04 1385.82 251.73 1385.47

256.72 1385.71 259.9 1386.29 285.57 1390.15 314.18 1392.42 327.24 1392.99

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .05 230.93 .05 285.57 .05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

230.93 285.57 106 274.5 338 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 1194

INPUT

Description:

Station Elevation Data num= 17

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1389.99 25.97 1389.28 59.36 1388.8 82.8 1388.32 101 1387.81

142.46 1387 191.87 1386.51 208.15 1384.24 211.06 1384.04 216.93 1384.61

242.49 1387.57 250.63 1388 277.58 1388.2 299.17 1388.71 308.72 1389.06

347.13 1389.65 359.84 1390.01

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .05 191.87 .05 242.49 .05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

191.87 242.49 357.8 279.5 182.5 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 914

INPUT

Description:

Station Elevation Data num= 26

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1390.96	9.82	1382.11	21.58	1382.02	34.78	1381.91	35.39	1381.9
38.38	1382.26	46.28	1381.81	49.76	1381.79	72.25	1381.62	104.11	1381.39
119.48	1381.53	123.96	1381.51	144.71	1381.04	148.94	1380.91	152.18	1380.91
173.72	1379.43	189.67	1380.72	210.06	1380.9	225.3	1381.31	236.27	1381.25
257.5	1381.4	274.22	1381.78	318.83	1385.39	328.98	1386.18	334.57	1386.77
361.25	1389.99								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	144.71	.05	189.67	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff Contr.	Expan.
144.71	189.67	306.4	319.4	328.1	.1	.3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 595

INPUT

Description:

Station Elevation Data num= 15

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1375.01	27.03	1374.71	40.51	1374.66	74.73	1374.76	81.49	1374.7
129.38	1373.45	145.53	1373.06	204.14	1369.44	205.68	1369.31	217.82	1371.45

222.79 1371.78 239.27 1372.41 252.6 1373.84 268.9 1374.23 286.26 1375.01

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	145.53	.05	217.82	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

145.53 217.82 332.5 272.9 230 .1 .3

CROSS SECTION

RIVER: eB

REACH: 1 RS: 299

INPUT

Description:

Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1361.74	17.9	1359.44	76.6	1357.47	84.13	1357.11	104.98	1356.58
109.23	1356.5	111.41	1356.55	132.51	1357.3	178.02	1357.1	195.93	1357.03
196.43	1357.01	224.98	1357.45	231.8	1358	232.11	1358.25	278.25	1360.66
281.01	1360.7	287.2	1360.75	294.27	1360.66	357.43	1360.98		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	76.6	.05	132.51	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

76.6 132.51 176 159.8 172 .3 .5

Ineffective Flow num= 1

Sta L	Sta R	Elev	Permanent
210.95	357.43	1358.28	F

CROSS SECTION

RIVER: eB

REACH: 1 RS: 139

INPUT

Description:

Station Elevation Data num= 25

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1357.59	.25	1357.59	1.74	1354.55	2.88	1354.07	3.99	1353.61
4.44	1353.74	6.85	1351.11	14.69	1348.57	15.33	1348.43	15.88	1348.31
24.35	1348.47	26.18	1348.56	26.66	1348.62	27.25	1348.68	29.81	1348.05
30.47	1348.01	34.43	1347.51	42.36	1348.17	45.9	1348.88	46.31	1349.04
48.83	1354.45	49.72	1355.12	51.5	1352.33	51.51	1355.1	51.77	1356.14

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	14.69	.05	46.31	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

14.69	46.31	20.1	20.1	20.1	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	.55	1358.28	F
51.15	51.77	1358.28	F

BRIDGE

RIVER: eB

REACH: 1 RS: 125

INPUT

Description:

Distance from Upstream XS = 5.6

Deck/Roadway Width = 10

Weir Coefficient = 2.6

Upstream Deck/Roadway Coordinates

num= 6

Sta Hi Cord	Lo Cord	Sta Hi Cord	Lo Cord	Sta Hi Cord	Lo Cord
0	1358.28	6.15	1358.28	1340	6.16 1358.28 1354.28
45.65	1358.28	1354.28	45.66	1358.28	1340 100 1358.28

Upstream Bridge Cross Section Data

Station Elevation Data num= 27

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1357.59	.25	1357.59	1.74	1354.55	2.88	1354.07	3.99	1353.61
4.44	1353.74	6.15	1349.98	14.69	1348.57	15.33	1348.43	15.88	1348.31
23.65	1348.6	24.35	1348.47	26.18	1348.56	26.66	1348.62	27.25	1348.68
28.35	1347.98	29.81	1348.05	30.47	1348.01	34.43	1347.51	42.36	1348.17
45.55	1349.02	45.9	1348.88	46.31	1349.04	48.83	1354.45	49.72	1355.12
51.51	1355.1	51.77	1356.14						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	14.69	.03	46.31	.04

Bank Sta: Left	Right	Coeff	Contr.	Expan.
6.15	45.55		.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	.55	1358.28	F
51.15	51.77	1358.28	F

Downstream Deck/Roadway Coordinates

num= 6

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

0 1358.28 6.15 1358.28 1340 6.16 1358.28 1354.28

45.65 1358.28 1354.28 45.66 1358.28 1340 100 1358.28

Downstream Bridge Cross Section Data

Station Elevation Data num= 27

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1357.59 .25 1357.59 1.74 1354.55 2.88 1354.07 3.99 1353.61

4.44 1353.74 6.15 1349.98 14.69 1348.57 15.33 1348.43 15.88 1348.31

23.65 1348.6 24.35 1348.47 26.18 1348.56 26.66 1348.62 27.25 1348.68

28.35 1347.98 29.81 1348.05 30.47 1348.01 34.43 1347.51 42.36 1348.17

45.55 1349.02 45.9 1348.88 46.31 1349.04 48.83 1354.45 49.72 1355.12

51.51 1355.1 51.77 1356.14

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .04 27.25 .03 46.31 .04

Bank Sta: Left Right Coeff Contr. Expan.

6.15 45.55 .3 .5

Upstream Embankment side slope = 0 horiz. to 1.0 vertical

Downstream Embankment side slope = 0 horiz. to 1.0 vertical

Maximum allowable submergence for weir flow = .98

Elevation at which weir flow begins =

Energy head used in spillway design =

Spillway height used in design =

Weir crest shape = Broad Crested

Number of Piers = 1

Pier Data

Pier Station Upstream= 26 Downstream= 26

Upstream num= 4

Width	Elev	Width	Elev	Width	Elev	Width	Elev
4.7	1340	4.7	1349.65	3	1349.66	3	1358

Downstream num= 4

Width	Elev	Width	Elev	Width	Elev	Width	Elev
4.7	1340	4.7	1349.65	3	1349.66	3	1358

Number of Bridge Coefficient Sets = 1

Low Flow Methods and Data

Energy

Selected Low Flow Methods = Energy

High Flow Method

Energy Only

Additional Bridge Parameters

Add Friction component to Momentum

Do not add Weight component to Momentum

Class B flow critical depth computations use critical depth

inside the bridge at the upstream end

Criteria to check for pressure flow = Upstream energy grade line

CROSS SECTION

RIVER: eB

REACH: 1 RS: 119

INPUT

Description:

Station Elevation Data num= 25

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1357.59	.25	1357.59	1.74	1354.55	2.88	1354.07	3.99	1353.61
4.44	1353.74	6.85	1351.11	14.69	1348.57	15.33	1348.43	15.88	1348.31
24.35	1348.47	26.18	1348.56	26.66	1348.62	27.25	1348.68	29.81	1348.05
30.47	1348.01	34.43	1347.51	42.36	1348.17	45.9	1348.88	46.31	1349.04
48.83	1354.45	49.72	1355.12	51.5	1352.33	51.51	1355.1	51.77	1356.14

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	27.25	.05	46.31	.05

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
27.25	46.31	100	110.5	80	.3	.5

CROSS SECTION

RIVER: eB

REACH: 1 RS: 8

INPUT

Description:

Station Elevation Data num= 25

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1334.97	6.83	1334.56	50.29	1331.93	53.95	1331.72	63.83	1331
66.15	1330.88	70.47	1330.45	75.48	1329.71	84.34	1331.4	87.52	1331.46
87.58	1329.82	98.86	1331.55	107.5	1332.34	111.63	1332.27	118.37	1332.36

122.73 1332.14 127.1 1330.55 132.86 1330.47 153.69 1330.41 154.08 1330.92
156.19 1331.34 164.49 1332.99 169.6 1335.63 181.07 1337.7 193.81 1339.99

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	122.73	.03	156.19	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
122.73	156.19	30.6	30.6	30.6	.1		.3

CROSS SECTION

RIVER: eC

REACH: 1 RS: 100

INPUT

Description:

Station Elevation Data num= 38

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1389	6.09	1389.03	1	24.77	1388.85	2	40.13	1388.43
5	79.18	1387.5	84.33	1387.32	91.72	1387.27	121.33	1386.5	
138.31	1386.01	163.81	1385.63	170.23	1385.32	3	190.31	1384.66	
3	195.09	1384.58	209.46	1383.78	233.51	1383.25	2	238.93	1382.96
250.66	1382	285.57	1379.08	299.29	1378.09	3	300.61	1378.00	
2	304.75	1377.86	308.35	1377.69	3	326.21	1376.83	336.33	1377.26
351.93	1377.79	361.44	1378	383.92	1378.60	2	402.72	1379.48	
4	413.35	1379.96	438.43	1381.93	2	452.31	1382.99	6	481.36
1384.92	485.68	1385.17	493.15	1385.69	2	522.31	1387.43	2	538.57
1388.66	550.77	1389.42	573.81	1391					

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	250.66	.04	438.43	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

250.66 438.43 711.4 716.2 656.2 .1 .3

CROSS SECTION

RIVER: eC

REACH: 1 RS: 50

INPUT

Description:

Station Elevation Data num= 33

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1371 1.61370.937 8.15 1370.89 45.561369.681 77.531368.083

91.611367.352 98.711366.836 111.491366.136 126.411363.371 189.351351.755

198.71351.552 200.931351.572 209.261351.122 212.68 1350.72 218.641351.089

226.221351.244 239.31351.965 241.321352.263 241.71352.351 276.351358.851

282.821360.068 292.41361.162 301.331362.467 311.721362.841 316.441364.026

317.771364.012 349.94 1364.11 388.381366.494 401.89 1366.84 456.421369.667

456.77 1369.68 457.441369.713 462.62 1370

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .04 126.41 .04 311.72 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

126.41 311.72 697.1 678.1 691.2 .1 .3

CROSS SECTION

RIVER: eD

REACH: 1 RS: 300

INPUT

Description:

Station Elevation Data num= 23

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1363.378	5.24	1362.38	32.99	1357.073	46.93	1354.366	67.15	1350.572
86.36	1346.7	103.5	1344.34	134.47	1341.512	166.76	1338.751	169.88	1338.656
178.93	1338.63	183	1338.661	196.85	1341.159	218.51	1344.941	241.97	1348.45
244.58	1348.73	253.84	1349.838	256.23	1350.145	257.69	1350.207	271.6	1350.956
301.64	1351.703	314.92	1351.703	315.41	1351.702				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	86.36	.04	241.97	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
86.36	241.97	48.1	63.7	86.9	.1	.3	

CROSS SECTION

RIVER: eD

REACH: 1 RS: 200

INPUT

Description:

Station Elevation Data num= 26

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1355.024	16.99	1350.855	40.33	1345.237	64.64	1339.911	114.42	1334.069
116.6	1333.778	116.78	1333.769	138.36	1334.066	138.98	1334.051	141.16	1334.517
171.71	1340.403	187.31	1343.21	193.87	1344.429	196.42	1344.415	198.47	1344.399
200.99	1344.514	210.57	1344.429	213.44	1344.505	230.84	1345.065	234.85	1345.182
235.42	1345.206	236.6	1345.262	237.45	1345.311	268.68	1346.58	286.36	1345.832
288.11	1345.766								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	64.64	.04	171.71	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

64.64 171.71 108.2 78.7 30.1 .1 .3

CROSS SECTION

RIVER: eD

REACH: 1 RS: 100

INPUT

Description:

Station Elevation Data num= 20

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1343.706	32.89	1336.815	40.84	1335.055	42.11	1334.751	53.74	1331.159
68.77	1326.538	71.59	1329.733	89.58	1329.833	91.24	1329.76	104.36	1327.952
104.61	1327.95	104.72	1327.982	107.47	1328.647	145.55	1338.192	157.93	1340.62
160.29	1340.903	174.44	1342.605	185.92	1344.236	189.24	1344.535	191.17	1344.686

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	32.89	.04	145.55	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

32.89 145.55 247.9 303.5 349 .1 .3

CROSS SECTION

RIVER: eSRC-C

REACH: 1 RS: 101

INPUT

Description:

Station Elevation Data num= 90

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1361.514	3.55	1361.367	34.42	1360.497	39.33	1360.34	42.53	1360.338
49.37	1360.039	67.45	1358.89	81.19	1358.133	95.87	1357.619	111.73	1357.392
132.44	1357.017	142.77	1356.825	178.79	1355.95	179.65	1355.915	180.78	1355.883
186.9	1355.629	221.25	1353.968	226.27	1353.699	257.96	1352.015	260.33	1351.862
261.01	1351.83	261.16	1351.82	292.54	1348.513	302.1	1348.029	318.86	1347.702
329.15	1346.449	340.88	1341.679	353.29	1336.172	375.06	1327.362	388.79	1322.742
422.16	1320.398	423.99	1320.264	424.22	1320.176	429.68	1318.177	431.22	1316.757
435.33	1312.869	463.67	1312.938	542.35	1317.296	551.91	1319.146	553.75	1320.052
559.46	1320.131	571.48	1319.622	573.39	1319.503	574.27	1319.496	576.16	1319.634
598.51	1320.8	598.78	1320.804	604.04	1320.989	617.89	1321.476	624.36	1320.909
631.24	1321.044	637.56	1321.33	642.1	1321.758	643.75	1321.874	654.19	1322.787
670.34	1323.032	688.88	1323.261	693.93	1323.283	704.14	1323.518	706.31	1324.614
716.66	1327.938	729.45	1328.171	736.81	1327.998	755.07	1325.809	758.33	1325.03
765.85	1325.083	789.22	1325.025	798.39	1325.001	801.21	1325.048	812.82	1327.519
823.35	1327.464	823.48	1327.475	832.5	1328.609	848.71	1336.756	858.83	1342.162
860.15	1342.554	863.61	1343.234	864.22	1343.449	866.45	1344.029	870.19	1344.048
871.43	1344.052	871.81	1343.837	873.74	1343.323	875.59	1342.891	877.95	1342.509
879.43	1342.613	881.57	1343.109	882.63	1343.497	883.87	1343.763	886.26	1344.279

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	429.68	.03	551.91	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
429.68	551.91	10	10	10	.1	.3

CROSS SECTION

RIVER: eSRC-C

REACH: 1 RS: 100

INPUT

Description:

Station Elevation Data num= 90

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1361.51	4	1361.36	7	1360.49	7	1360.3	4	1360.33
8	1360.03	9	1358.8	1	1358.13	3	1357.61	9	1357.39
2	1357.01	7	1356.82	5	1355.9	5	1355.91	5	1355.88
3	1355.62	9	1353.96	8	1353.69	9	1352.01	5	1351.86
1	1351.83	1	1351.82	2	1348.51	3	1348.02	9	1347.70
2	1346.44	9	1341.67	9	1336.17	2	1327.36	2	1322.74
2	1320.39	8	1320.26	4	1320.17	6	1318.17	7	1316.75
9	1312.86	3	1312.93	8	1317.29	1	1319.14	2	1320.05
1	1320.13	1	1319.62	3	1319.50	4	1319.49	6	1319.63
5	1320.8	8	1320.80	4	1320.98	7	1321.47	4	1320.90
1	1321.04	6	1321.33	2	1321.75	3	1321.87	7	1322.78
0	1323.03	8	1323.26	3	1323.28	4	1323.51	6	1324.61
6	1327.93	9	1328.17	8	1327.99	5	1325.80	8	1325.03
5	1325.08	1	1325.02	1	1325.04	8	1327.51	3	1327.46
4	1327.47	1	1328.60	8	1336.75	6	1342.16	1	1342.55
4	1343.23	4	1343.44	9	1344.02	8	1344.04	2	1344.05
1	1343.83	3	1343.32	4	1342.89	1	1342.50	3	1342.61
1	1343.10	4	1343.49	7	1343.87	6	1344.27	9	

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	429.68	.03	551.91	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

429.68 551.91 200.3 132.8 54.6 .1 .3

CROSS SECTION

RIVER: eSRC-D

REACH: 1 RS: 0.5

INPUT

Description:

Station Elevation Data num= 81

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01360.411 2.11360.112 9.881359.198 39.161355.958 40.631355.801

41.04 1355.75 43.511355.486 99.931349.217 102.541348.919 117.61347.187

144.41 1344.56 174.811341.073 198.651338.471 204.531337.578 237.361331.743

253.211329.345 282.291325.441 315.311322.128 329.241321.508 334.11321.604

338.541321.692 341.361321.602 345.82 1321.45 349.021321.353 357.421320.949

370.491320.274 377.291318.292 397.821316.652 411.551314.705 415.741313.394

425.481311.064 429.491311.236 439.871310.994 442.21311.041 444.11 1311.07

517.021312.076 519.131313.945 522.281316.758 532.081316.762 534.31316.706

541.53 1316.81 554.531316.925 556.681316.892 578.47 1318.12 579.661318.151

579.781318.157 594.611318.851 5991319.425 602.62 1319.87 617.31321.716

620.581322.264 652.481323.245 661.171323.574 662.721323.657 668.21323.843

693.171324.357 698.42 1324.5 704.55 1324.77 706.851324.548 710.871323.899

713.821324.224 714.811324.339 717.04 1324.6 736.41324.689 745.81324.799

760.061324.409 763.511324.283 764.521324.372 773.041325.453 774.531325.467

782.121325.245 786.451325.169 789.681325.105 831.231324.666 836.431324.707

897.261325.946 932.951328.345 957.51330.576 965.361330.999 967.71331.178

983.24 1332.5

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .04 397.82 .03 522.28 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

397.82 522.28 41.7 41.7 41.7 .1 .3

CROSS SECTION

RIVER: eSRC-D

REACH: 1 RS: 0.1

INPUT

Description:

Station Elevation Data num= 101

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1360.5 12.721359.029 38.041357.731 65.211355.107 79.631353.895

92.691352.488 105.371351.106 123.581348.758 144.85 1346.25 165.331343.603

175.571342.115 206.131337.845 228.51335.241 249.691332.522 259.221331.058

294.121325.676 341.051322.793 349.581322.292 353.751322.165 358.011322.037

360.51 1322 389.791320.268 389.861320.263 391.371320.179 397.411319.879

397.561319.877 397.811319.873 397.96 1319.86 445.861315.715 446.27 1315.68

455.51314.772 458.881313.754 468.91311.459 477.631311.417 477.731311.416

486.661311.207 487.61311.226 493.33 1311.34 494.31 1311.35 496.11311.375

547.141312.078 547.741312.035 562.431310.976 562.5 1311.02 567.621314.458

568.041314.697 570.9 1316.35 571.041316.433 574.521316.664 575.41316.723

578.491317.258 578.61317.276 579.621317.336 579.76 1317.37 582.771318.065

583.721318.309 586.991319.153 593.271319.327 595.211319.381 611.111319.987

611.651320.007 619.851320.306 620.091320.313 644.851321.052 645.951321.084

651.961321.259 657.81321.537 659.02 1321.58 676.95 1322.21 679.221322.352

679.621322.378 6801322.401 682.381322.516 696.011323.172 699.81323.368

702.33 1323.5 707.911323.548 720.141323.653 727.571323.764 728.211323.774

738.021323.923 746.751324.055 752.861324.365 753.651324.484 755.321324.696

757.07 1324.92 763.361325.598 764.791325.641 767.141325.627 769.13 1325.68

781.591325.393 794.321325.099 809.58 1324.89 813.851324.868 815.21324.817

827.551324.917 882.521325.132 924.961326.747 935.731327.115 940.31 1327.35

957.75 1328.5

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	445.86	.03	570.9	.04

Bank Sta: Left Right Coeff Contr. Expan.

Left	Right	Coeff	Contr.	Expan.
445.86	570.9		.1	.3

SUMMARY OF MANNING'S N VALUES

River:eA

Reach	River Sta.	n1	n2	n3
1	4200	.04	.04	.04
1	4100	.04	.04	.04
1	4000	.04	.04	.04
1	3354	.03	.04	.03
1	3051	.03	.04	.03
1	2837	.03	.04	.03
1	2526	.03	.04	.03
1	2234	.03	.04	.03
1	2147	.03	.04	.03
1	2140	Bridge		
1	2130	.03	.04	.03
1	1793	.03	.04	.03
1	1618	.03	.04	.03
1	1348	.03	.04	.03
1	1054	.03	.04	.03
1	753	.03	.04	.03
1	580	.03	.04	.03

River:eAB

Reach	River Sta.	n1	n2	n3
1	3070	.04	.03	.04
1	2985	.04	.03	.04
1	2713	.04	.03	.04
1	2450	.04	.03	.04
1	2167	.04	.03	.04
1	1868	.04	.03	.04
1	1593	.04	.03	.04
1	1301	.04	.03	.04
1	1079	.04	.03	.04
1	801	.04	.03	.04
1	636	.04	.03	.04
1	448	.04	.03	.04
1	400	Culvert		
1	373	.04	.03	.04
1	113	.04	.03	.04
1	110	.04	.03	.04

River:eB

Reach	River Sta.	n1	n2	n3
1	2900	.05	.05	.05
1	2800	.05	.05	.05
1	2700	.05	.05	.05
1	2520	.05	.05	.05
1	2470	.05	.05	.05
1	2297	.05	.05	.05
1	2018	.05	.05	.05
1	1765	.05	.05	.05
1	1469	.05	.05	.05

1	1194	.05	.05	.05
1	914	.05	.05	.05
1	595	.05	.05	.05
1	299	.05	.05	.05
1	139	.05	.05	.05
1	125	Bridge		
1	119	.05	.05	.05
1	8	.04	.03	.04

River:eC

Reach	River Sta.	n1	n2	n3
1	100	.04	.04	.04
1	50	.04	.04	.04

River:eD

Reach	River Sta.	n1	n2	n3
1	300	.04	.04	.04
1	200	.04	.04	.04
1	100	.04	.04	.04

River:eSRC-C

Reach	River Sta.	n1	n2	n3
1	101	.04	.03	.04
1	100	.04	.03	.04

River:eSRC-D

Reach	River Sta.	n1	n2	n3
1	0.5	.04	.03	.04
1	0.1	.04	.03	.04

SUMMARY OF REACH LENGTHS

River: eA

Reach	River Sta.	Left	Channel	Right
1	4200	618	618	618
1	4100	813	755	689
1	4000	107	190	409
1	3354	303.56	303.56	303.56
1	3051	213.73	213.73	213.73
1	2837	311	311	311
1	2526	272	292	277
1	2234	40.7	40.7	40.7
1	2147	17	17	17
1	2140	Bridge		
1	2130	137	336.8	326
1	1793	220	174.8	100
1	1618	130	269.8	333
1	1348	173.4	294.4	372.7
1	1054	350.7	301.1	113.4
1	753	92	172.6	213.1
1	580	18.3	18.3	18.3

River: eAB

Reach	River Sta.	Left	Channel	Right
1	3070	82.3	85	54.7
1	2985	120.4	271.7	327
1	2713	297.4	262.7	139.6
1	2450	164.8	282.6	251.6
1	2167	212.6	299	237
1	1868	253.2	275.4	143.9
1	1593	281.5	291.6	285.6

1	1301	132.2	222	264.1
1	1079	156.5	278.1	50
1	801	83.7	165.4	147.4
1	636	86.6	188.4	233.8
1	448	75.2	75.2	75.2
1	400	Culvert		
1	373	203.6	259.8	225.3
1	113	410.7	272.8	384.7
1	110	303.4	303.4	303.4

River: eB

Reach	River Sta.	Left	Channel	Right
1	2900	159	143.6	127
1	2800	382.9	355.7	352.6
1	2700	297.6	297.6	297.6
1	2520	442.5	428.4	431.5
1	2470	164.2	173.2	81.5
1	2297	260.4	279	169.8
1	2018	200.3	253.5	263.3
1	1765	150	296.3	314.3
1	1469	106	274.5	338
1	1194	357.8	279.5	182.5
1	914	306.4	319.4	328.1
1	595	332.5	272.9	230
1	299	176	159.8	172
1	139	20.1	20.1	20.1
1	125	Bridge		
1	119	100	110.5	80
1	8	30.6	30.6	30.6

River: eC

Reach	River Sta.	Left	Channel	Right
1	100	711.4	716.2	656.2
1	50	697.1	678.1	691.2

River: eD

Reach	River Sta.	Left	Channel	Right
1	300	48.1	63.7	86.9
1	200	108.2	78.7	30.1
1	100	247.9	303.5	349

River: eSRC-C

Reach	River Sta.	Left	Channel	Right
1	101	10	10	10
1	100	200.3	132.8	54.6

River: eSRC-D

Reach	River Sta.	Left	Channel	Right
1	0.5	41.7	41.7	41.7
1	0.1			

SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS

River: eA

Reach	River Sta.	Contr.	Expan.
1	4200	.1	.3
1	4100	.1	.3
1	4000	.1	.3
1	3354	.1	.3
1	3051	.1	.3
1	2837	.1	.3

1	2526	.1	.3
1	2234	.3	.5
1	2147	.3	.5
1	2140	Bridge	
1	2130	.3	.5
1	1793	.1	.3
1	1618	.1	.3
1	1348	.1	.3
1	1054	.1	.3
1	753	.1	.3
1	580	.1	.3

River: eAB

Reach	River Sta.	Contr.	Expan.
1	3070	.1	.3
1	2985	.1	.3
1	2713	.1	.3
1	2450	.1	.3
1	2167	.1	.3
1	1868	.1	.3
1	1593	.1	.3
1	1301	.1	.3
1	1079	.1	.3
1	801	.1	.3
1	636	.3	.5
1	448	.3	.5
1	400	Culvert	
1	373	.3	.5
1	113	.1	.3
1	110	.1	.3

River: eB

Reach	River Sta.	Contr.	Expan.
1	2900	.1	.3
1	2800	.1	.3
1	2700	.1	.3
1	2520	.1	.3
1	2470	.1	.3
1	2297	.1	.3
1	2018	.1	.3
1	1765	.1	.3
1	1469	.1	.3
1	1194	.1	.3
1	914	.1	.3
1	595	.1	.3
1	299	.3	.5
1	139	.3	.5
1	125	Bridge	
1	119	.3	.5
1	8	.1	.3

River: eC

Reach	River Sta.	Contr.	Expan.
1	100	.1	.3
1	50	.1	.3

River: eD

Reach	River Sta.	Contr.	Expan.
1	300	.1	.3
1	200	.1	.3
1	100	.1	.3

River: eSRC-C

Reach	River Sta.	Contr.	Expan.
1	101	.1	.3
1	100	.1	.3

River: eSRC-D

Reach	River Sta.	Contr.	Expan.
1	0.5	.1	.3
1	0.1	.1	.3

HEC-RAS HEC-RAS 6.6 September 2024

U.S. Army Corps of Engineers

Hydrologic Engineering Center

609 Second Street

Davis, California

PROJECT DATA

Project Title: Proposed Realignment

Project File : Existing.prj

Run Date and Time: 4/3/2025 8:37:51 AM

Project in English units

PLAN DATA

Plan Title: proposed realignment

Plan File : n:\0033065.00\source\Floodplain\HEC RAS\Proposed Oops\Existing.p06

Geometry Title: proposed alignment

Geometry File : n:\0033065.00\source\Floodplain\HEC RAS\Proposed Oops\Existing.g01

Flow Title : proposed flows

Flow File : n:\0033065.00\source\Floodplain\HEC RAS\Proposed Oops\Existing.f02

Plan Summary Information:

Number of: Cross Sections = 40 Multiple Openings = 0

Culverts = 2 Inline Structures = 0

Bridges = 0 Lateral Structures = 0

Computational Information

Water surface calculation tolerance = 0.01

Critical depth calculation tolerance = 0.01

Maximum number of iterations = 20

Maximum difference tolerance = 0.3

Flow tolerance factor = 0.001

Computation Options

Critical depth computed only where necessary

Conveyance Calculation Method: At breaks in n values only

Friction Slope Method: Average Conveyance

Computational Flow Regime: Subcritical Flow

FLOW DATA

Flow Title: proposed flows

Flow File : n:\0033065.00\source\Floodplain\HEC RAS\Proposed Oops\Existing.f02

Flow Data (cfs)

River	Reach	RS	10 yr	25-year	50-year	100-year
eB	Reach 1	2900	677	1023	1305	1280
eC	Reach 1	100	53.5	79.8	101	122
Main Channel	Reach 1	113	7460	11500	15000	18900
Main Channel	Reach 1	110	7460	11500	15000	18900
Main Channel 1.5	Reach 1	101	7460	11500	15000	18900
Main Channel 1.5	Reach 1	100	7460	11500	15000	18900
Main Channel 2	Reach 1	0.5	7460	11500	15000	18900
Realignment 1	1	4200	117	176	223	272
Realignment 2	1	2000	677	1023	1305	1616
Realignment 2	1	1200	730.5	1102.8	1406	1738
Realignment 2	1	300	799.9	1206.8	1537	1897

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
eB	Reach 1	10 yr	Normal S = 0.003	
eB	Reach 1	25-year	Normal S = 0.003	
eB	Reach 1	50-year	Normal S = 0.003	
eB	Reach 1	100-year	Normal S = 0.003	
Main Channel	Reach 1	10 yr	Normal S = 0.001	
Main Channel	Reach 1	25-year	Normal S = 0.001	
Main Channel	Reach 1	50-year	Normal S = 0.001	
Main Channel	Reach 1	100-year	Normal S = 0.001	
Main Channel 2	Reach 1	10 yr	Normal S = 0.0068	
Main Channel 2	Reach 1	25-year	Normal S = 0.0068	
Main Channel 2	Reach 1	50-year	Normal S = 0.0068	
Main Channel 2	Reach 1	100-year	Normal S = 0.0068	
Realignment 1	1	10 yr	Normal S = 0.0087	
Realignment 1	1	25-year	Normal S = 0.0087	
Realignment 1	1	50-year	Normal S = 0.0087	
Realignment 1	1	100-year	Normal S = 0.0087	

GEOMETRY DATA

Geometry Title: proposed alignment

Geometry File : n:\0033065.00\source\Floodplain\HEC RAS\Proposed Oops\Existing.g01

Reach Connection Table

River	Reach	Upstream Boundary	Downstream Boundary
eB	Reach 1	Junction 1	
eC	Reach 1	2	
Main Channel	Reach 1	2	
Main Channel 1.5	Reach 1	2	Convergence
Main Channel 2	Reach 1	Convergence	
Realignment 1	1	Junction 1	

Realignment 2 1 Junction 1 Convergence

JUNCTION INFORMATION

Name: Junction 1

Description:

Energy computation Method

	Length across Junction		Tributary		
River	Reach	River	Reach	Length	Angle
eB	Reach 1	to Realignment 2	1	136.7	0
Realignment 1	1	to Realignment 2	1	134	0

Name: 2

Description:

Energy computation Method

	Length across Junction		Tributary		
River	Reach	River	Reach	Length	Angle
eC	Reach 1	to Main Channel 1.5	Reach 1	0	0
Main Channel	Reach 1	to Main Channel 1.5	Reach 1	303.4	0

Name: Convergence

Description:

Energy computation Method

	Length across Junction		Tributary		
River	Reach	River	Reach	Length	Angle
Main Channel 1.5	Reach 1	to Main Channel 2	Reach 1	142.8	0
Realignment 2	1	to Main Channel 2	Reach 1	0	0

CROSS SECTION

RIVER: eB

REACH: Reach 1 RS: 2900

INPUT

Description:

Station Elevation Data num= 140

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

21.36 1405 21.78 1405 26.93 1405 28.94 1405 29.591404.994

46.761404.625 601404.349 76.46 1404 97.841403.744 102.351403.696

126.11403.425 166.041403.003 166.261403.003 166.561403.003 168.031403.003

168.841403.002 169.371403.002 174.24 1403 180.711402.907 187.571402.808

194.68 1402.71 217.071402.382 244.181402.027 245.971402.003 246.62 1402

254.421401.824 262.911401.667 268.811401.573 273.061401.522 278.581401.445

291.071401.186 299.38 1401 311.781400.713 325.731400.419 341.851400.048

343.83 1400 357.21399.511 366.591399.259 370.571399.138 377.211399.011

377.9 1399 387.711398.901 391.791398.836 406.731398.716 411.431398.693

415.931398.684 419.751398.686 422.511398.696 424.591398.702 431.121398.618

445.47 1398 447.521397.999 449.641397.999 451.171397.998 453.641397.999

455.01 1398 462.111398.017 469.261398.041 484.711398.089 488.421398.078

495.241398.063 500.111398.046 512.1 1398 515.281397.813 519.311397.563

527.77 1397 534.841396.906 538.431396.853 542.61396.912 548.46 1397

550.591397.472 552.441397.774 553.31 1398 5771398.061 578.561398.063

593.031398.028 594.231398.025 596.33 1398.02 604.13 1398 609.531397.991

611.81397.989 623.121397.976 626.171397.972 628.821397.976 646.01 1398

670.91398.656 683.52 1399 704.421399.432 7141399.607 735.07 1400

735.16 1400 735.61400.001 737.091400.002 737.671400.002 739.291400.002

742.231400.001 742.671400.001 742.911400.001 744.241400.002 745.691400.001

745.791400.001 747.961400.003 752.861400.071 754.451400.098 756.411400.137

762.561400.225 769.21400.348 774.451400.442 802.17 1401 828.291401.932

830.44 1402 830.53 1402 830.96 1402 831.38 1402 831.67 1402

832.69 1402 835.361401.966 854.751401.924 874.63 1401.99 875.221401.999

875.62 1402 877.151402.004 878.691402.004 879.351402.007 883.641402.012

898.551402.301 901.381402.366 905.381402.443 914.351402.636 926.51 1402.91

930.43 1403 930.561403.002 954.531403.589 961.251403.744 964.221403.798

972.851403.989 973.97 1404 974.881404.004 995.941404.455 997.251404.483

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
21.36	.05	495.24	.05	552.44	.05

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
495.24	552.44	159	143.6	127	.1	.3

CROSS SECTION

RIVER: eB

REACH: Reach 1 RS: 2800

INPUT

Description:

Station Elevation Data num= 158

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
36.6	1405	41.911404.855		72.27	1404	91.651403.576		100.551403.432	
122.32	1403	124.281402.998		126.021402.996		127.531402.996		130.571402.993	
131.211402.993		174.531402.487		181.851402.419		187.41 1402.37		216.241402.066	
222.21	1402	240.091401.786		254.151401.627		305.8	1401	314.381400.871	
343.64 1400.47		359.861400.208		372.15	1400	381.991399.471		390.95	1399
396.521398.404		400.91	1398	413.081397.982		415.991397.978		420.771397.985	
425.311397.992		4291397.997		431.211398.001		431.711398.001		432.951398.004	
433.341398.004		437.141398.006		444.021398.014		445.551398.014		4691398.017	
491.171398.022		497.691398.024		505.481398.018		509.161398.016		517.831398.012	
523.59 1398.01		535.651398.005		536.651398.005		541.77	1398	548.731397.316	

552.33 1397 555.34 1396.66 560.42 1396 563.291395.999 563.71395.999
566.91 1396 578.371396.975 578.521396.986 578.72 1397 599.961397.884
602.21 1398 602.83 1398 604.851398.001 625.39 1398.01 627.521398.009
632.591398.008 636.171398.007 638.681398.007 648.561398.007 665.071398.008
665.311398.008 665.971398.008 667.941398.008 674.041398.005 680.781398.001
680.991398.001 682.52 1398 695.751397.725 701.971397.537 718.81397.004
719.211397.003 719.77 1397 720.861396.999 724.611396.996 727.241396.994
731.121396.996 734.21 1397 748.21 1397.65 752.391397.862 756.08 1398
778.631398.466 781.761398.491 784.641398.508 786.021398.516 789.091398.548
794.11 1398.58 799.91398.631 802.29 1398.66 809.061398.762 810.761398.782
821.981398.985 822.071398.987 822.171398.987 823.221398.989 823.41398.989
823.69 1398.99 826.24 1399 854.431399.834 857.261399.912 861.98 1400
862.191400.001 863.51400.001 864.461400.002 865.05 1400 865.211399.999
869.51399.958 874.311399.924 883.351399.904 892.621399.969 896.131399.997
896.941399.997 897.451399.998 900.8 1400 901.321400.001 902.81400.002
904.591400.005 906.431400.004 906.951400.005 907.531400.006 907.941400.006
916.481400.165 918.671400.218 923.151400.337 936.641400.708 946.361400.985
948.04 1401 948.391401.001 948.621401.001 968.181401.346 978.521401.511
982.911401.562 988.311401.629 993.021401.693 1009.941401.928 1013.961401.989
1014.731401.992 1015.631401.996 1016.371401.997 1017.371401.998 1017.79 1402
1018.71402.003 1037.511402.344 1049.241402.548 1067.91402.896 1068.72 1402.91
1073.75 1403 1079.111403.149 1080.581403.187

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
36.6	.05	535.65	.05	599.96	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Contr.	Expan.
535.65	599.96	382.9	355.7	352.6	.1	.3

CROSS SECTION

RIVER: eB

REACH: Reach 1 RS: 2700

INPUT

Description:

Station Elevation Data num= 147

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01404.015 .33 1404 18.871403.387 22.081403.306 26.331403.189

31.51 1403 52.771402.369 64.99 1402 78.051401.686 107.9 1401

108.341400.997 117.141400.868 125.63 1400.75 166.991400.161 175.371400.041

176.721400.023 178.51 1400 179.49 1400 189.5 1400 198.14 1400

207.381399.999 211.331399.999 216.091399.999 242.49 1400 243.311400.003

245.281400.009 245.77 1400.01 246.261400.009 249.92 1400 263.68 1399.74

271.581399.585 299.421399.015 299.531399.015 300.061399.011 301.35 1399

301.511398.999 315.881398.774 326.25 1398.62 335.81398.536 351.13 1398.39

385.261398.005 386.221398.004 386.631398.004 387.351398.003 387.591398.003

387.881398.003 388.181398.003 388.871398.003 389.111398.003 395.261398.004

396.331398.004 400.011398.005 400.121398.004 401.071398.004 401.121398.004

402.821398.003 409.83 1398 410.481397.985 421.661397.748 446.051397.105

446.751397.088 449.991397.073 455.781397.041 464.33 1397 466.521396.992

496.61396.446 508.081396.249 512.571396.175 527.69 1396 529.21395.997

529.61395.996 534.51395.985 536.381395.979 542.211395.965 554.81395.997

555.79 1396 556.581396.003 556.961396.003 599.051396.614 610.951396.726

615.791396.709 617.351396.715 620.031396.712 621.281396.712 626.031396.703

631.251396.683 637.871396.659 644.121396.645 648.381396.638 650 1396.63

6531396.615 657.311396.602 662.091396.609 666.831396.604 670.681396.579

674.251396.559 679.071396.547 680.91396.533 685.61 1396.53 707.191396.203

708.651396.205 712.281396.185 719.321396.148 735.071396.063 737.341396.057

747.87 1396 749.311395.808 749.561395.802 759.51395.699 769.991395.846

772.36 1396 774.721396.121 777.91 1396.28 785.731396.701 793.97 1397

794.871397.005 808.651397.141 814.99 1397.23 848.341397.862 849.111397.867
862.051397.967 863.741397.978 864.091397.983 867.13 1398 918.441398.842
927.71 1399 934.251399.141 935.011399.156 942.841399.317 975.481399.998
976.361399.998 976.61 1400 978.11400.004 995.25 1400.3 1008.351400.528
1013.11400.612 1036.24 1401 1037.021401.002 1037.641401.004 1039.531401.009
1064.291401.404 1078.281401.609 1101.211401.982 1101.491401.986 1102.78 1402
1117.831402.279 1125.51402.435

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	421.66	.05	808.65	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
421.66	808.65	297.6	297.6	297.6	.1		.3

CROSS SECTION

RIVER: eB

REACH: Reach 1 RS: 2520

INPUT

Description:

Station Elevation Data num= 144

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1404.28	8.77	1404	11.491403.929		44.25	1403	79.571402.113	
84.73	1402	101.141401.652		122.27 1401.18		130.18	1401	138.591400.871	
143.171400.802		196.311400.004		197.33	1400	197.41	1400	197.77	1400
203.311399.999		223.971399.998		235.541399.996		248.421399.999		257.34	1400
260.35	1400	261.481400.004		263.561400.008		265.741400.004		266.351400.003	
266.9	1400	289.731399.503		304.311399.169		310.851399.012		312.9	1399
324.171398.859		342.751398.622		389.79 1398.01		392.19	1398	409.991397.422	
424.64	1397	425.26 1396.98		425.81396.962		453.39	1396	453.55	1396

478.851395.995 479.931395.995 501.041395.999 505.34 1396 506.53 1396
506.59 1396 508.951396.005 509.651396.004 513.421396.008 522.11396.002
522.941396.001 523.061396.001 523.471396.002 530.22 1396 536.071395.999
540.04 1396 543.371396.003 545.751396.002 545.871396.002 546.45 1396
549.471395.998 550.741395.998 553.011395.997 554.511395.998 557.48 1396
558.81396.003 570.791396.018 578.21396.021 588.231396.024 591.61396.026
595.451396.021 597.261396.019 604.961396.011 605.641396.011 612.381396.007
614.081396.003 615.44 1396 615.73 1396 621.221395.828 648.06 1395
657.48 1395 660.57 1395 662.411395.183 664.021395.269 664.811395.302
670.151395.698 672.821395.702 674.91395.815 685.241395.956 689.151395.938
696.681395.991 698.361395.999 698.45 1396 700.39 1396 717.341396.002
722.871396.003 727.31396.003 750.96 1396 753.76 1396 756.991395.999
760.011395.997 764.641395.996 774.84 1396 775.381396.001 779.81396.008
780.441396.008 780.941396.009 782.131396.008 783.281396.007 784.011396.009
785.51396.011 792.931396.033 796.251396.036 801.571396.081 824.261396.203
825.91396.203 826.791396.204 829.391396.216 830.841396.212 835.421396.218
840.311396.226 845.081396.254 849.521396.279 850.18 1396.28 866.091396.405
914.451396.852 917.561396.876 927.291396.998 928.16 1397 957.511397.582
965.311397.734 979.13 1398 1004.651398.495 1013.231398.651 1032.33 1399
1047.871399.227 1067.711399.555 1093.96 1400 1094.531400.003 1128.221400.476
1143.321400.681 1155.471400.824 1170.08 1401 1170.16 1401

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.05	595.45	.05	670.15	.05

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
595.45	670.15		442.5	428.4	431.5	.1	.3

CROSS SECTION

RIVER: eC

REACH: Reach 1 RS: 100

INPUT

Description:

Station Elevation Data num= 38

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1389	6.09	1389.03	1	24.77	1388.85	2	40.13	1388.43
5	79.18	1387.5	84.33	1387.32	91.72	1387.27	121.33	1386.49	
6	138.31	1386.00	3	163.81	1385.63	170.23	1385.32	3	190.31
1384.66	3	195.09	1384.57	8	209.46	1383.77	8	233.51	1383.25
2	238.93	1382.95	9	250.66	1382	285.57	1379.07	5	299.29
1378.09	3	300.61	1378.00	2	304.75	1377.85	8	308.35	1377.69
3	326.21	1376.82	6	336.33	1377.25	8	351.93	1377.79	
361.44	1378	383.92	1378.59	9	402.72	1379.48	4	413.35	1379.96
3	438.43	1381.92	8	452.31	1382.99	6	481.36	1384.91	6
485.68	1385.17	2	493.15	1385.68	9	522.31	1387.42	6	538.57
1388.66	3	550.77	1389.41	6	573.81	1391			

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	250.66	.04	438.43	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

250.66	438.43	711.4	716.2	656.2	.1	.3

CROSS SECTION

RIVER: eC

REACH: Reach 1 RS: 50

INPUT

Description:

Station Elevation Data num= 33

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev

0 1371 1.61370.937 8.15 1370.89 45.561369.681 77.531368.083
91.611367.352 98.711366.836 111.491366.136 126.411363.371 189.351351.755
198.71351.552 200.931351.572 209.261351.122 212.68 1350.72 218.641351.089
226.221351.244 239.31351.965 241.321352.263 241.71352.351 276.351358.851
282.821360.068 292.41361.162 301.331362.467 311.721362.841 316.441364.026
317.771364.012 349.94 1364.11 388.381366.494 401.89 1366.84 456.421369.667
456.77 1369.68 457.441369.713 462.62 1370

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	126.41	.04	311.72	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

126.41 311.72 697.1 678.1 691.2 .1 .3

CROSS SECTION

RIVER: Main Channel

REACH: Reach 1 RS: 113

INPUT

Description:

Station Elevation Data num= 19

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1324.98	15.23	1321.48	25.94	1320.17	34.53	1318.74	48.01	1318.07
70.66	1317.07	76.07	1314.69	78.45	1313.38	88.75	1314.52	91.27	1314.61
91.58	1314.94	104.01	1318.84	107.7	1320	108.69	1320.16	110.97	1320.5
111.91	1320.6	137.2	1322.47	141.01	1322.74	152.86	1322.99		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	70.66	.03	104.01	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

70.66 104.01 410.7 272.8 384.7 .1 .3

CROSS SECTION

RIVER: Main Channel

REACH: Reach 1 RS: 110

INPUT

Description:

Station Elevation Data num= 78

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01356.731 13.661356.626 37.721356.123 51.641354.917 84.43 1352.06

98.46 1350.39 117.81347.463 124.281346.743 133.26 1345.04 162.281338.595

169.651336.429 225.611321.564 226.09 1321.44 226.161321.425 226.271321.402

256.471316.513 259.791315.953 266.461315.166 267.881313.893 270.31313.059

270.361313.059 295.341313.057 296.381313.057 308.71313.077 309.431313.078

327.841313.038 328.161313.864 329.211316.503 329.491316.446 331.431316.065

331.941316.145 336.39 1316.85 337.431316.794 344.421316.417 344.611316.436

362.641318.313 362.71318.315 365.491318.399 365.721318.406 374.981318.685

376.711318.317 377.151318.317 378.561318.316 385.541318.373 398.031318.431

400.731318.449 401.281318.447 401.841318.449 404.311318.453 420.871318.482

425.991318.491 426.291318.541 426.681320.122 427.121320.114 427.181320.112

427.371317.596 427.381317.499 428.411318.135 428.51318.189 430.251319.206

433.411321.048 435.5 1322.26 442.68 1326.04 444.741326.811 452.621329.764

454.741330.557 458.031331.793 459.241339.336 459.891343.416 459.921343.492

461.161343.408 462.851343.633 463.261343.717 4641343.526 464.111343.438

464.251343.736 464.411344.059 464.67 1344.5

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .04 256.47 .03 329.49 .04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

256.47 329.49 303.4 303.4 303.4 .1 .3

CROSS SECTION

RIVER: Main Channel 1.5

REACH: Reach 1 RS: 101

INPUT

Description:

Station Elevation Data num= 90

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01361.514 3.551361.367 34.421360.497 39.33 1360.34 42.531360.338

49.371360.039 67.45 1358.89 81.191358.133 95.871357.619 111.731357.392

132.441357.017 142.771356.825 178.79 1355.95 179.651355.915 180.781355.883

186.91355.629 221.251353.968 226.271353.699 257.961352.015 260.331351.862

261.01 1351.83 261.16 1351.82 292.541348.513 302.11348.029 318.861347.702

329.151346.449 340.881341.679 353.291336.172 375.061327.362 388.791322.742

422.161320.398 423.991320.264 424.221320.176 429.681318.177 431.221316.757

435.331312.869 463.671312.938 542.351317.296 551.911319.146 553.751320.052

559.461320.131 571.481319.622 573.391319.503 574.271319.496 576.161319.634

598.51 1320.8 598.781320.804 604.041320.989 617.891321.476 624.361320.909

631.241321.044 637.56 1321.33 642.11321.758 643.751321.874 654.191322.787

670.341323.032 688.881323.261 693.931323.283 704.141323.518 706.311324.614

716.661327.938 729.451328.171 736.811327.998 755.071325.809 758.33 1325.03

765.851325.083 789.221325.025 798.391325.001 801.211325.048 812.821327.519

823.351327.464 823.481327.475 832.51328.609 848.711336.756 858.831342.162

860.151342.554 863.611343.234 864.221343.449 866.451344.029 870.191344.048

871.431344.052 871.811343.837 873.741343.323 875.591342.891 877.951342.509

879.431342.613 881.571343.109 882.631343.497 883.871343.763 886.261344.279

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	429.68	.03	551.91	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
429.68	551.91		10	10	10	.1	.3

CROSS SECTION

RIVER: Main Channel 1.5

REACH: Reach 1 RS: 100

INPUT

Description:

Station Elevation Data num= 90

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1361.514	3.55	1361.367	34.42	1360.497	39.33	1360.34	42.53	1360.338
49.37	1360.039	67.45	1358.89	81.19	1358.133	95.87	1357.619	111.73	1357.392
132.44	1357.017	142.77	1356.825	178.79	1355.95	179.65	1355.915	180.78	1355.883
186.91	1355.629	221.25	1353.968	226.27	1353.699	257.96	1352.015	260.33	1351.862
261.01	1351.83	261.16	1351.82	292.54	1348.513	302.11	1348.029	318.86	1347.702
329.15	1346.449	340.88	1341.679	353.29	1336.172	375.06	1327.362	388.79	1322.742
422.16	1320.398	423.99	1320.264	424.22	1320.176	429.68	1318.177	431.22	1316.757
435.33	1312.869	463.67	1312.938	542.35	1317.296	551.91	1319.146	553.75	1320.052
559.46	1320.131	571.48	1319.622	573.39	1319.503	574.27	1319.496	576.16	1319.634
598.51	1320.8	598.78	1320.804	604.04	1320.989	617.89	1321.476	624.36	1320.909
631.24	1321.044	637.56	1321.33	642.1	1321.758	643.75	1321.874	654.19	1322.787
670.34	1323.032	688.88	1323.261	693.93	1323.283	704.14	1323.518	706.31	1324.614
716.66	1327.938	729.45	1328.171	736.81	1327.998	755.07	1325.809	758.33	1325.03
765.85	1325.083	789.22	1325.025	798.39	1325.001	801.21	1325.048	812.82	1327.519
823.35	1327.464	823.48	1327.475	832.5	1328.609	848.71	1336.756	858.83	1342.162
860.15	1342.554	863.61	1343.234	864.22	1343.449	866.45	1344.029	870.19	1344.048

871.431344.052 871.811343.837 873.741343.323 875.591342.891 877.951342.509
879.431342.613 881.571343.109 882.631343.497 883.871343.763 886.261344.279

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	429.68	.03	551.91	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
429.68	551.91	200.3	132.8	54.6	.1	.3

CROSS SECTION

RIVER: Main Channel 2

REACH: Reach 1 RS: 0.5

INPUT

Description:

Station Elevation Data num= 68

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1363.548	8.1	1363.105	29.86	1362.055	43.42	1361.197	54.08	1360.725
90.06	1358.781	94.1	1358.54	96.34	1358.406	101.56	1358.076	144.58	1355.246
156.76	1354.59	192.69	1353.096	211.4	1352.19	243.14	1351.035	258.98	1350.654
267.72	1350.2	270.86	1350.036	280.05	1349.491	321	1331.86	328.51	1328.903
344.45	1326.588	346.84	1326.243	347.07	1326.2	356.57	1324.568	357.15	1324.578
378.33	1320.297	401.71	1317.748	402.77	1317.638	403.22	1317.548	422.36	1312.12
424.11	1311.372	424.34	1311.409	427.87	1311.451	470.49	1312.391	545.53	1312.568
554.39	1320.098	554.71	1320.389	555.64	1320.414	556.92	1320.457	579.76	1321.394
598.69	1324.792	603.45	1325.511	631.28	1325.061	636.52	1324.985	679.79	1324.617
682.91	1324.596	698.14	1325.336	703.54	1325.598	703.91	1325.617	704.05	1325.6
708.71	1324.87	709.17	1324.912	714.79	1325.398	717.77	1325.376	747.91	1325.155
749.33	1325.19	754.71	1325.213	761.99	1325.961	762.89	1326.158	774.7	1325.918
787.01	1325.688	796.86	1325.484	803.99	1325.502	836.77	1325.597	891.69	1326.575
899.82	1326.743	902.23	1326.79	911.6	1327.479				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	378.33	.03	554.39	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
378.33	554.39	535.4	423.9	306.2	.1	.3	

CROSS SECTION

RIVER: Main Channel 2

REACH: Reach 1 RS: 0.1

INPUT

Description:

Station Elevation Data num= 101

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1360.5	12.721	359.029	38.041	357.731	65.211	355.107	79.631	353.895
92.691	352.488	105.371	351.106	123.581	348.758	144.85	1346.25	165.331	343.603
175.571	342.115	206.131	337.845	228.51	335.241	249.691	332.522	259.221	331.058
294.121	325.676	341.051	322.793	349.581	322.292	353.751	322.165	358.011	322.037
360.51	1322	389.791	320.268	389.861	320.263	391.371	320.179	397.411	319.879
397.561	319.877	397.811	319.873	397.96	1319.86	445.861	315.715	446.27	1315.68
455.51	314.772	458.881	313.754	468.91	311.459	477.631	311.417	477.731	311.416
486.661	311.207	487.61	311.226	493.33	1311.34	494.31	1311.35	496.11	311.375
547.141	312.078	547.741	312.035	562.431	310.976	562.5	1311.02	567.621	314.458
568.041	314.697	570.9	1316.35	571.041	316.433	574.521	316.664	575.41	316.723
578.491	317.258	578.61	317.276	579.621	317.336	579.76	1317.37	582.771	318.065
583.721	318.309	586.991	319.153	593.271	319.327	595.211	319.381	611.111	319.987
611.651	320.007	619.851	320.306	620.091	320.313	644.851	321.052	645.951	321.084
651.961	321.259	657.81	321.537	659.02	1321.58	676.95	1322.21	679.221	322.352
679.621	322.378	680	1322.401	682.381	322.516	696.011	323.172	699.81	323.368
702.33	1323.5	707.911	323.548	720.141	323.653	727.571	323.764	728.211	323.774

738.021323.923 746.751324.055 752.861324.365 753.651324.484 755.321324.696
757.07 1324.92 763.361325.598 764.791325.641 767.141325.627 769.13 1325.68
781.591325.393 794.321325.099 809.58 1324.89 813.851324.868 815.21324.817
827.551324.917 882.521325.132 924.961326.747 935.731327.115 940.31 1327.35
957.75 1328.5

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	445.86	.03	570.9	.04

Bank Sta: Left Right Coeff Contr. Expan.

Left	Right	Coeff	Contr.	Expan.
445.86	570.9		.1	.3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 4200

INPUT

Description:

Station Elevation Data num= 5

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1416	49.82	1412	154.68	1410	245.21	1412	405.06	1416

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	49.82	.04	245.21	.04

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
49.82	245.21	618	618	618		.1	.3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 4100

INPUT

Description:

Station Elevation Data num= 4

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1408	174.92	1404	321.43	1404	497.17	1408

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	0	.04	497.17	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
0	497.17	813	755	689	.1	.3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 4000

INPUT

Description:

Station Elevation Data num= 4

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1400	151.57	1396	368.83	1400	520.97	1404

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.04	0	.04	368.83	.04

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
0	368.83	107	75.3	409	.1	.3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 2500

INPUT

Description:

Station Elevation Data num= 16

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

-270 1404 01397.427 2.21397.427 92.57 1397.5 92.91397.487

99.41395.317 103.061394.091 133.191394.094 141.771394.095 153.871394.096

156.791394.096 163.981394.097 166.031394.508 189.521402.332 192.91403.456

199.631405.697

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

-270 .039 92.57 .039 189.52 .039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

92.57 189.52 229.66 300.85 303.81 .1 .3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 2400

INPUT

Description:

Station Elevation Data num= 11

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

0 1402.42 79.721395.847 86.781393.492 94.541393.492 114.921393.492

118.961393.492 129.921393.492 136.031393.492 153.191398.582 160.281400.945

187.45 1410

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	79.72	.039	153.19	.039

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
79.72	153.19	300	300	300	.1 .3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 2300

INPUT

Description:

Station Elevation Data num= 21

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1399.148	8.721	398.964	54.851	398.657	59.61	397.074	72.151	392.892
75.861	392.892	83.851	392.892	113.711	392.892	116.341	392.892	117.141	392.892
124.691	392.892	128.711	392.892	131.241	392.892	139.31	393.756	141.75	1394.57
143.31	395.088	146.451	396.139	166.311	402.757	168.921	403.628	176.31	1405.28
179.59	1405.28								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	59.6	.039	139.3	.039

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
59.6	139.3	300	300	300	.1 .3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 2200

INPUT

Description:

Station Elevation Data num= 24

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-527	1404	46.55	1393.92	50.96	1393.854	52.07	1393.877	54.3	1393.139
56.84	1392.292	72.32	1392.292	73.26	1392.292	92.47	1392.292	101.47	1392.292
111.26	1392.292	112.51	1392.292	123.48	1392.292	127.51	1392.292	129.47	1392.292
136.66	1392.676	141.95	1394.439	156.48	1399.28	156.57	1399.313	160.15	1400.504
166.48	1401.864	168.08	1401.864	173.83	1401.864	179.59	1400.078		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
-527	.039	46.55	.039	141.95	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
46.55	141.95	300	300	300	.1		.3

CROSS SECTION

RIVER: Realignment 1

REACH: 1 RS: 2100

INPUT

Description:

Station Elevation Data num= 42

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
-740	1404	0	1392.745	.66	1392.785	2.9	1392.936	7.3	1393.257
7.49	1393.273	16.02	1393.941	30.74	1394.632	34.37	1394.714	34.92	1393.56
35.19	1394.504	40.74	1395.558	41.28	1395.207	43.2	1395.055	43.64	1395.062

46.63 1394.07 47.561393.761 49.311393.178 52.51392.112 53.771391.692
75.821391.692 85.761391.692 95.621391.692 110.931391.692 111.31391.692
122.281391.692 126.31391.692 128.561391.692 134.81391.856 141.961394.243
150.071396.947 158.911399.892 161.81400.856 164.411401.728 169.351403.375
170.421403.446 171.31403.446 171.81403.446 172.461403.446 173.941403.446
179.091403.446 179.591403.441

Manning's n Values num= 3
Sta n Val Sta n Val Sta n Val
-740 .039 49.31 .039 141.96 .039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.
49.31 141.96 300 300 300 .1 .3

CROSS SECTION
RIVER: Realignment 2
REACH: 1 RS: 2000
INPUT
Description:
Station Elevation Data num= 25
Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev
01397.057 8.981397.219 23.04 1397.58 35.611398.017 381398.067
40.251397.928 53.921393.372 70.741391.092 81.521391.092 84.121391.092
86.051391.092 97.051391.092 102.661391.092 108.771391.092 118.911391.092
119.981391.092 143.781394.652 144.411394.861 144.91395.027 145.41395.191
146.831395.668 148.271396.148 167.891402.689 170.05 1403.41 179.591406.277

Manning's n Values num= 3
Sta n Val Sta n Val Sta n Val
0 .039 53.92 .039 143.78 .039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

53.92 143.78 300 300 300 .1 .3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1900

INPUT

Description:

Station Elevation Data num= 24

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01403.172 19.141403.719 26.871403.967 28.911403.967 31.431403.984

32.721403.982 33.021404.524 34.281404.414 35.321404.066 37.431403.364

38.631402.965 45.75 1400.59 48.09 1399.81 52.581398.311 74.461391.015

77.191390.492 80.41390.492 83.561390.492 90.941390.492 97.111390.493

111.781390.493 141.491393.692 147.021395.535 207.93 1413

Manning's n Values num= 3

Sta n Val Sta n Val Sta n Val

0 .039 52.58 .039 141.49 .039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

52.58 141.49 300 300 300 .1 .3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1800

INPUT

Description:

Station Elevation Data num= 19

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01407.746 6.921407.977 8.74 1408 10.481408.013 22.341408.324
37.061406.687 64.561397.518 82.141391.658 89.821390.093 103.451390.093
116.941390.093 124.331390.093 126.461390.093 132.821390.669 137.471392.218
153.52 1397.57 177.541405.574 190.021409.733 213.11417.079

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	64.56	.039	153.52	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

64.56 153.52 100 100 100 .3 .5

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1700

INPUT

Description:

Station Elevation Data num= 31

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1408.275	26.19	1410.836	28.4	1410.837	34.05	1408.959	42.72	1406.067
62.74	1399.395	73	1395.974	91.25	1389.891	102.6	1389.891	103.28	1389.891
107.69	1389.891	110.31	1389.891	116.84	1389.892	117.94	1389.892	119.6	1389.892
122.69	1389.892	124.11	1389.892	132.11	1390.364	140.78	1393.255	144.58	1394.522
151.01	1396.664	151.87	1396.951	161.97	1400.319	163.89	1400.958	174.65	1404.543
180.15	1406.377	195.97	1411.649	199.63	1412.871	204.12	1414.366	207.15	1415.376
212.94	1417.307								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	73	.039	151.01	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

73 151.01 220 220 220 .3 .5

Ineffective Flow num= 2

Sta L Sta R Elev Permanent

0 56.6 1412.28 F

163.4 212.94 1411.4 F

CULVERT

RIVER: Realignment 2

REACH: 1 RS: 1650

INPUT

Description:

Distance from Upstream XS = 35

Deck/Roadway Width = 20

Weir Coefficient = 2.6

Upstream Deck/Roadway Coordinates

num= 22

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

01411.702 18.51411.505 22.571411.944

25.521412.026 58.671412.282 62.161412.338

66.111412.186 106.291411.844 113.411411.751

168.581411.396 172.081411.431 173.741411.389

174.521411.389 176.4 1411.34 179.711411.318

224.431411.077 228.771411.095 266.291410.892

268.891410.886 311.721410.576 320.71410.467

356.881410.106

Upstream Bridge Cross Section Data

Station Elevation Data num= 31

Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev

01408.275 26.191410.836 28.41410.837 34.051408.959 42.721406.067
62.741399.395 731395.974 91.251389.891 102.61389.891 103.281389.891
107.691389.891 110.311389.891 116.841389.892 117.941389.892 119.61389.892
122.691389.892 124.111389.892 132.111390.364 140.781393.255 144.581394.522
151.011396.664 151.871396.951 161.971400.319 163.891400.958 174.651404.543
180.151406.377 195.971411.649 199.631412.871 204.121414.366 207.151415.376
212.941417.307

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	73	.039	151.01	.039

Bank Sta: Left Right Coeff Contr. Expan.

Left	Right	Coeff	Contr.	Expan.
73	151.01		.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	56.6	1412.28	F
163.4	212.94	1411.4	F

Downstream Deck/Roadway Coordinates

num= 22

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	1411.702		18.51	1411.505		22.57	1411.944	
25.52	1412.026		58.67	1412.282		62.16	1412.338	
66.11	1412.186		106.29	1411.844		113.41	1411.751	
168.58	1411.396		172.08	1411.431		173.74	1411.389	
174.52	1411.389		176.4	1411.34		179.71	1411.318	
224.43	1411.077		228.77	1411.095		266.29	1410.892	
268.89	1410.886		311.72	1410.576		320.7	1410.467	
356.88	1410.106							

Downstream Bridge Cross Section Data

Station Elevation Data num= 77

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1406.123	2.13	1406.222	3.03	1406.255	4.02	1406.28	4.96	1406.305
7.22	1406.102	8.47	1406.542	9.73	1407.004	13.73	1407.317	14.31	1407.362
15.97	1407.318	18.49	1407.232	23.74	1407.052	25.87	1406.979	28.04	1406.905
35.99	1406.634	42.11	1406.085	42.93	1405.811	43.89	1405.493	45.27	1405.03
49.36	1403.668	58.79	1400.523	63.73	1398.879	65.42	1398.317	76.71	1394.554
87.41	1390.989	91.78	1389.53	106.78	1389.477	107.08	1389.477	110.5	1389.477
115.86	1389.478	124.18	1389.479	129.59	1389.48	134.76	1391.036	140.97	1393.108
141.24	1393.196	144.86	1394.403	148.27	1395.539	156.59	1398.314	170.09	1402.811
170.55	1402.967	175.28	1404.543	179.35	1405.9	179.58	1405.976	181.01	1406.451
182.59	1406.875	187.65	1406.713	189.72	1406.647	190.76	1406.481	191.54	1406.413
192.04	1406.291	195.92	1405.355	198.96	1404.623	199.56	1404.491	202.57	1405.466
203.33	1405.595	204.67	1405.646	208.06	1405.859	217.32	1406.442	220.17	1406.621
229.6	1406.331	232.3	1406.248	232.53	1406.145	233.42	1405.824	242.1	1404.179
245.89	1404.064	247.42	1404.066	249.1	1404.094	252.64	1406.521	254.82	1407.659
257.33	1408.084	258.33	1408.298	263.41	1408.399	264.06	1408.412	265.48	1408.44
266.85	1408.468	271.19	1408.554						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	58.79	.039	156.59	.039

Bank Sta: Left Right Coeff Contr. Expan.

Left	Right	Coeff Contr.	Expan.
58.79	156.59	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	83.95	1412.28	F

142.05 271.19 1411.4 F

Upstream Embankment side slope = 0 horiz. to 1.0 vertical

Downstream Embankment side slope = 0 horiz. to 1.0 vertical

Maximum allowable submergence for weir flow = .98

Elevation at which weir flow begins =

Energy head used in spillway design =

Spillway height used in design =

Weir crest shape = Broad Crested

Number of Culverts = 1

Culvert Name	Shape	Rise	Span
Culvert #1	Box	10	12

FHWA Chart # 8 - Flared wingwalls

FHWA Scale # 1 - Wingwall flared 30 to 75 deg.

Solution Criteria = Highest U.S. EG

Culvert	Upstrm Dist	Length	Top n	Bottom n	Depth Blocked	Entrance Loss Coef	Exit Loss Coef
	34.9	172	.012	.012	0	.5	1

Number of Barrels = 3

Upstream Elevation = 1389.83

Centerline Stations

Sta.	Sta.	Sta.
100	113	126

Downstream Elevation = 1389.49

Centerline Stations

Sta.	Sta.	Sta.
100	113	126

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1600

INPUT

Description:

Station Elevation Data num= 77

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1406.123	2.13	1406.222	3.03	1406.255	4.02	1406.28	4.96	1406.305
7.22	1406.102	8.47	1406.542	9.73	1407.004	13.73	1407.317	14.31	1407.362
15.97	1407.318	18.49	1407.232	23.74	1407.052	25.87	1406.979	28.04	1406.905
35.99	1406.634	42.11	1406.085	42.93	1405.811	43.89	1405.493	45.27	1405.03
49.36	1403.668	58.79	1400.523	63.73	1398.879	65.42	1398.317	76.71	1394.554
87.4	1390.989	91.78	1389.53	106.78	1389.477	107.08	1389.477	110.5	1389.477
115.86	1389.478	124.18	1389.479	129.59	1389.48	134.76	1391.036	140.97	1393.108
141.24	1393.196	144.86	1394.403	148.27	1395.539	156.59	1398.314	170.09	1402.811
170.55	1402.967	175.28	1404.543	179.35	1405.9	179.58	1405.976	181.01	1406.451
182.59	1406.875	187.65	1406.713	189.72	1406.647	190.76	1406.481	191.54	1406.413
192.04	1406.291	195.92	1405.355	198.96	1404.623	199.56	1404.491	202.57	1405.466
203.33	1405.595	204.67	1405.646	208.06	1405.859	217.32	1406.442	220.17	1406.621
229.6	1406.331	232.3	1406.248	232.53	1406.145	233.42	1405.824	242.1	1404.179
245.89	1404.064	247.42	1404.066	249.1	1404.094	252.64	1406.521	254.82	1407.659
257.33	1408.084	258.33	1408.298	263.41	1408.399	264.06	1408.412	265.48	1408.44
266.85	1408.468	271.19	1408.554						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	58.79	.039	156.59	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
58.79	156.59	22.6	79.4	164	.3	.5	

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	83.95	1412.28	F
142.05	271.19	1411.4	F

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1500

INPUT

Description:

Station Elevation Data num= 32

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1405	.411	404.967	4.611	404.945	5.131	405.097	7.621	405.779
24.49	1404.84	32.781	404.357	50.041	400.619	85.721	388.832	86.811	388.782
91.081	388.786	95.821	388.791	100.521	388.795	107.061	388.801	111.761	388.805
115.971	388.809	132.541	391.645	133.741	392.046	135.561	392.654	160.331	400.898
170.741	403.615	172.371	403.264	177.831	401.906	180.641	401.401	187.361	401.022
199.49	1400.65	215.571	400.921	221.211	401.028	240.981	401.096	271.181	402.586
286.651	405.308	294.381	405.468						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	50.04	.039	160.33	.039

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
50.04	160.33	200	201.4	199.8	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	46.95	1412.28	F
179.5	294.38	1411.4	F

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1400

INPUT

Description:

Station Elevation Data num= 51

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1399.559	2.19	1399.534	7.68	1399.383	8.34	1399.236	14.33	1398.297
15.39	1398.286	18.25	1398.187	23.24	1397.955	28.43	1397.891	33.32	1396.801
36.56	1395.732	40.11	1394.564	48.69	1391.73	56.73	1389.076	63.87	1387.038
66.13	1387.04	77.65	1387.052	81.21	1387.055	92.5	1387.066	96.29	1387.07
115.77	1391.93	116.63	1392.213	127.45	1395.809	133.16	1396.233	139.22	1397.792
139.82	1397.943	141.7	1398.432	149.09	1400.268	152.7	1400.596	152.74	1400.583
152.89	1400.586	153.75	1400.603	157.42	1400.675	170.97	1400.924	171.59	1400.935
172.38	1400.95	172.77	1400.957	183.1	1400.735	187.24	1400.646	192.34	1400.525
192.9	1400.512	193.72	1400.238	193.99	1400.146	194.48	1399.983	195.99	1399.869
216.88	1394.867	230.14	1391.692	235.33	1391.526	249	1390.744	267.55	1389.709
272.25	1389.595								

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	36.56	.039	115.77	.039

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
36.56	115.77	173.6	121.4	102.4	.1	.3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1300

INPUT

Description:

Station Elevation Data num= 26

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1398.67	3	44.69	1396.97	65.49	1394.954	67.85	1394.169	72.04
1392.772	96.39	1385.997	97.88	1385.997	111.39	1385.999	113.07	1385.999	126.39
1386.001	148.05	1391.889	151.75	1393.123	162.53	1393.076	185.06	1392.303	193.17
1392.014	194.71	1392.012	197.14	1392.002	197.46	1392	198	1391.995	198.75
1391.994	200.32	1398.826	201.43	1399.192	201.61	1399.253	201.83	1399.258	221.8
1399.705	223.09	1399.683							

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	72.04	.039	148.05	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
72.04	148.05	200	200	200	.1	.3	

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1200

INPUT

Description:

Station Elevation Data num= 26

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1395.09	4	39.07	1394.509	61.17	1393.53	63.52	1392.746	71.12
1390.214	92.46	1384.26	93	1384.26	107.66	1384.263	108	1384.263	120.84
1384.264	123	1384.265	139.25	1388.349	146.06	1390.619	146.77	1390.857	149.92
1391.905	157.11	1391.397	166.77	1391.442	172.9	1391.808	179.41	1393.454	185.68
1395.464	186.75	1395.693	187.72	1395.729	201.04	1396.292	203.4	1396.386	208.37
1396.272	223.09	1395.929							

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	71.12	.039	146.06	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

71.12	146.06	200	200	200	.1	.3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1100

INPUT

Description:

Station Elevation Data num= 34

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1397.501	.73	1397.483	48	1395.051	59.74	1391.141	87.45	1382.524
89.61	1382.524	99.57	1382.525	104.28	1382.526	107.6	1382.526	119.24	1382.528
119.61	1382.528	120.29	1382.528	127.4	1383.793	136.29	1386.755	148.27	1390.749
150.18	1391.385	151.49	1391.825	153.95	1392.645	154.56	1392.848	156	1393.328
157	1393.661	158.85	1394.277	162.31	1394.355	170.48	1394.318	179.96	1393.834
181.54	1394.044	183.64	1393.081	186.08	1392.923	186.99	1392.838	188.39	1392.884
200.19	1393.206	209.8	1392.937	215.3	1392.729	223.09	1393.266		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	59.74	.039	148.27	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

59.74	148.27	127.6	76.1	6.9	.3	.5

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 1000

INPUT

Description:

Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
11.021	398.556	29.381	397.875	37.21	396.282	60.681	388.458	74.721	383.776
80.761	381.895	84.361	381.894	86.171	381.894	96.921	381.894	99.361	381.894
105.971	381.893	112.81	381.894	114.361	381.894	118.771	382.031	120.161	382.493
132.171	386.496	133.741	387.019	136.371	387.897	140.251	389.191	141.551	389.624
143.261	390.192	145.65	1390.99	146	1391.108	149.311	392.211	153.011	393.444
156.181	394.498	162.691	394.617	165.21	394.597	165.591	394.744	167.81	395.381
179.081	392.585	179.851	392.298	180.151	392.176	180.691	392.152	181.581	392.242
191.291	392.644	195.981	392.807	200.981	392.736	213.11	392.478	220.14	1393

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
11.02	.039	60.68	.039	136.37	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
60.68	136.37	303.4	303.4	303.4	.3	.5	

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
11.02	46.6	1393	F
153.4	220.14	1393	F

CULVERT

RIVER: Realignment 2

REACH: 1 RS: 950

INPUT

Description:

Distance from Upstream XS = 34.9

Deck/Roadway Width = 243

Weir Coefficient = 2.6

Upstream Deck/Roadway Coordinates

num= 98

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

01389.427 .811389.451 1.161389.461

5.811389.597 10.41389.733 10.81389.745

15.37 1389.88 15.791389.893 16.221389.906

20.781390.041 21.221390.055 25.77 1390.19

30.321390.326 30.76 1390.34 35.321390.477

35.75 1390.49 40.321390.628 40.841390.644

41.91390.676 42.221390.686 45.731390.792

50.351390.932 50.731390.944 55.381391.086

55.721391.096 60.42 1391.24 60.721391.249

65.461391.395 65.711391.403 70.521391.551

70.711391.557 70.911391.563 75.721391.711

75.851391.716 80.721391.867 84.951391.998

85.73 1392.02 89.031392.114 90.691392.165

90.741392.167 90.791392.168 95.741392.319

97.721392.379 100.751392.468 105.751392.616

105.791392.617 110.741392.764 115.671392.911

115.741392.913 115.821392.915 120.741393.062

125.671393.209 125.741393.212 125.811393.214

130.741393.362 135.71393.512 135.741393.512

136.61393.518 140.741393.542 145.031393.568
145.741393.572 150.741393.596 155.66 1393.62
155.84 1393.62 160.751393.644 165.561393.665
165.761393.666 165.971393.667 170.771393.689
175.451393.709 180.39 1393.73 182.231393.737
185.441393.759 185.831393.762 186.211393.764
190.841393.795 191.151393.797 195.861393.828
200.69 1393.86 200.871393.861 201.041393.862
205.881393.893 2061393.893 210.881393.924
210.961393.924 215.881393.955 220.891393.985
221.181393.986 225.89 1394.01 230.891394.036
235.831394.063 235.941394.063 240.89 1394.09
245.831394.117 245.881394.118 245.941394.118
250.881394.146 253.651394.162

Upstream Bridge Cross Section Data

Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
11.02	1398.556	29.38	1397.875	37.2	1396.282	60.68	1388.458	74.72	1383.776
80.76	1381.895	84.36	1381.894	86.17	1381.894	96.92	1381.894	99.36	1381.894
105.97	1381.893	112.8	1381.894	114.36	1381.894	118.77	1382.031	120.16	1382.493
132.17	1386.496	133.74	1387.019	136.37	1387.897	140.25	1389.191	141.55	1389.624
143.26	1390.192	145.65	1390.99	146	1391.108	149.31	1392.211	153.01	1393.444
156.18	1394.498	162.69	1394.617	165.2	1394.597	165.59	1394.744	167.8	1395.381
179.08	1392.585	179.85	1392.298	180.15	1392.176	180.69	1392.152	181.58	1392.242
191.29	1392.644	195.98	1392.807	200.98	1392.736	213.1	1392.478	220.14	1393

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
11.02	.039	60.68	.039	136.37	.039

Bank Sta: Left Right Coeff Contr. Expan.

60.68 136.37 .3 .5

Ineffective Flow num= 2

Sta L Sta R Elev Permanent

11.02 46.6 1393 F

153.4 220.14 1393 F

Downstream Deck/Roadway Coordinates

num= 98

Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord Sta Hi Cord Lo Cord

01389.427 .811389.451 1.161389.461

5.811389.597 10.41389.733 10.81389.745

15.37 1389.88 15.791389.893 16.221389.906

20.781390.041 21.221390.055 25.77 1390.19

30.321390.326 30.76 1390.34 35.321390.477

35.75 1390.49 40.321390.628 40.841390.644

41.91390.676 42.221390.686 45.731390.792

50.351390.932 50.731390.944 55.381391.086

55.721391.096 60.42 1391.24 60.721391.249

65.461391.395 65.711391.403 70.521391.551

70.711391.557 70.911391.563 75.721391.711

75.851391.716 80.721391.867 84.951391.998

85.73 1392.02 89.031392.114 90.691392.165

90.741392.167 90.791392.168 95.741392.319

97.721392.379 100.751392.468 105.751392.616

105.791392.617 110.741392.764 115.671392.911

115.741392.913 115.821392.915 120.741393.062

125.671393.209 125.741393.212 125.811393.214

130.741393.362 135.71393.512 135.741393.512

136.61393.518 140.741393.542 145.031393.568
145.741393.572 150.741393.596 155.66 1393.62
155.84 1393.62 160.751393.644 165.561393.665
165.761393.666 165.971393.667 170.771393.689
175.451393.709 180.39 1393.73 182.231393.737
185.441393.759 185.831393.762 186.211393.764
190.841393.795 191.151393.797 195.861393.828
200.69 1393.86 200.871393.861 201.041393.862
205.881393.893 2061393.893 210.881393.924
210.961393.924 215.881393.955 220.891393.985
221.181393.986 225.89 1394.01 230.891394.036
235.831394.063 235.941394.063 240.89 1394.09
245.831394.117 245.881394.118 245.941394.118
250.881394.146 253.651394.162

Downstream Bridge Cross Section Data

Station Elevation Data num= 35

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1391.588	2.05	1391.48	2.15	1391.474	2.38	1391.408	18.14	1388.185
18.89	1388.207	19.57	1388.228	21.46	1388.285	30.25	1388.554	44.87	1388.676
60.93	1387.756	66.13	1388.395	75.11	1388.276	78.7	1387.077	80.42	1386.504
81.76	1386.057	91.77	1382.72	99.05	1380.294	106.14	1377.262	106.21	1377.23
109.77	1375.448	111.33	1374.667	113.54	1373.563	117.3	1373.065	121.15	1372.999
132.39	1375.37	136.16	1377.253	149.45	1382.342	158.76	1385.44	166.48	1388.012
177.27	1389.29	189.85	1389.201	207.33	1389.126	229.74	1389.047	231.14	1389.042

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	81.76	.039	158.76	.039

Bank Sta: Left Right Coeff Contr. Expan.

81.76 158.76 .3 .5

Ineffective Flow num= 2

Sta L Sta R Elev Permanent

0 87.25 1393 F

152.75 231.14 1393 F

Upstream Embankment side slope = 0 horiz. to 1.0 vertical

Downstream Embankment side slope = 0 horiz. to 1.0 vertical

Maximum allowable submergence for weir flow = .98

Elevation at which weir flow begins =

Energy head used in spillway design =

Spillway height used in design =

Weir crest shape = Broad Crested

Number of Culverts = 1

Culvert Name Shape Rise Span

Culvert #1 Box 10 12

FHWA Chart # 8 - Flared wingwalls

FHWA Scale # 1 - Wingwall flared 30 to 75 deg.

Solution Criteria = Highest U.S. EG

Culvert Upstrm Dist Length Top n Bottom n Depth Blocked Entrance Loss Coef Exit Loss Coef

34.9 243 .012 .012 0 .5 1

Number of Barrels = 3

Upstream Elevation = 1381.48

Centerline Stations

Sta. Sta. Sta.

85 98 111

Downstream Elevation = 1379.37

Centerline Stations

Sta.	Sta.	Sta.
110	123	136

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 900

INPUT

Description:

Station Elevation Data num= 35

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1391.588	2.05	1391.48	2.15	1391.474	2.38	1391.408	18.14	1388.185
18.89	1388.207	19.57	1388.228	21.46	1388.285	30.25	1388.554	44.87	1388.676
60.93	1387.756	66.13	1388.395	75.11	1388.276	78.7	1387.077	80.42	1386.504
81.76	1386.057	91.77	1382.72	99.05	1380.294	106.14	1377.262	106.21	1377.23
109.77	1375.448	111.33	1374.667	113.54	1373.563	117.3	1373.065	121.15	1372.999
132.39	1375.37	136.16	1377.253	149.45	1382.342	158.76	1385.44	166.48	1388.012
177.27	1389.29	189.85	1389.201	207.33	1389.126	229.74	1389.047	231.14	1389.042

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	81.76	.039	158.76	.039

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
81.76	158.76	140	140	140	.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	87.25	1393	F
152.75	231.14	1393	F

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 800

INPUT

Description:

Station Elevation Data num= 31

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1384.86	3	1.13	1384.61	3	2.81	1384.34	2	16.01
1387.78	2	16.67	1387.93	8	20.29	1387.86	2	24.57	1387.76
2	24.83	1387.77	2	44.65	1387.28	9	77.65	1385.99	1
82.88	1384.24	3	85.48	1383.37	5	106.35	1376.40	4	111.31
1376.08	2	116.65	1376.07	7	123.86	1376.07		126.32	1376.06
9	138.78	1376.05	7	141.33	1376.05	5	144.44	1376.05	3
146.45	1376.42	4	150.21	1377.67	5	157.16	1379.98	3	172.91
1385.21	4	176.41	1386.37	8	196.16	1385.74	3	200.96	1385.60
5	219.29	1385.14	2	223.53	1385.03	3	224.84	1385.00	5
231.14	1384.88	1							

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	85.48	.039	172.91	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

85.48	172.91	200	200	200	.1	.3

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
0	30.25	1393	F
209.75	231.14	1393	F

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 700

INPUT

Description:

Station Elevation Data num= 28

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1379.487	.8	1379.289	6.65	1380.903	17.45	1383.045	21.65	1383.074
38.46	1382.258	42.15	1382.149	55.52	1381.908	85.96	1379.761	87.63	1379.202
89.91	1378.44	97.76	1375.818	104.73	1373.49	106.27	1372.974	112.96	1370.741
116.99	1370.726	129.77	1370.715	132	1370.713	144.72	1370.702	146.49	1370.7
147	1370.7	149.66	1370.697	155.14	1372.073	170.08	1377.037	187.29	1378.256
221.71	1377.993	229.44	1377.884	231.14	1377.774				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	97.76	.039	170.08	.039

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
97.76	170.08	200	200	200	.1	.3	

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 600

INPUT

Description:

Station Elevation Data num= 40

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1372.808	5.98	1372.579	32.27	1372.019	35.41	1371.395	39.06	1370.286
40.56	1370.429	41.98	1370.55	47.55	1370.436	54.58	1370.348	64.36	1369.997
71.19	1370.001	74.86	1369.25	77	1369.004	81.17	1369.491	83.51	1370.073
105.26	1368.574	106.8	1368.058	108.25	1367.573	123.56	1363.759	123.63	1363.759
124.03	1363.758	124.15	1363.758	125.06	1363.756	126.22	1363.754	138.65	1363.73
139.24	1363.729	141.55	1363.724	149.96	1363.708	152.3	1363.704	153.71	1363.701

154.33 1363.7 154.41 1363.7 164.661365.967 1651366.078 177.171366.526
180.541366.391 190.751366.212 202.91365.902 222.871367.256 231.471367.912

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.039	108.25	.039	164.66	.039

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
108.25	164.66	213	213	213	.1	.3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 500

INPUT

Description:

Station Elevation Data num= 28

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1365	1.531368.402		2.371368.324		14.071367.028		22.541367.274	
36.641367.689		53.71367.175		64.631366.836		65.971366.512		66.24 1366.47	
66.991366.456		67.441366.454		69.121366.453		69.351366.652		69.391366.209	
71.861365.661		77.211364.782		103.41359.869		106.241359.474		132.191353.667	
142.731352.454		162.381352.058		170.341352.193		188.35 1352.15		218.511356.627	
220.881357.001		227.431358.073		233.061358.664					

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.044	106.24	.044	233.06	.044

Bank Sta: Left	Right	Lengths: Left Channel	Right	Coeff Contr.	Expan.
106.24	233.06	85	85	85	.1	.3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 400

INPUT

Description:

Station Elevation Data num= 28

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1366.943	5.05	1367.169	9.65	1367.315	37.88	1366.044	38.62	1366.014
38.68	1366.018	38.92	1365.992	39.33	1365.951	41.56	1365.83	42.85	1365.792
43.25	1365.764	43.59	1365.813	59.35	1362.426	78	1358.374	88.51	1356.993
111.91	1353.709	128.08	1350.845	156.97	1345.716	172.08	1345.625	187.16	1345.585
213.28	1348.96	227.21	1350.849	248.39	1353.179	261	1354.605	268.51	1355.028
277.37	1355.415	312.73	1355.723	315.41	1355.717				

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.044	111.9	.044	227.21	.044

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
111.9	227.21	80.7	80.7	80.7		.1	.3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 300

INPUT

Description:

Station Elevation Data num= 23

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1363.378	5.24	1362.38	32.99	1357.073	46.93	1354.366	67.15	1350.572
86.36	1346.7	103.5	1344.34	134.47	1341.512	166.76	1338.751	169.88	1338.656

178.93 1338.63 1831338.661 196.851341.159 218.51344.941 241.97 1348.45
244.58 1348.73 253.841349.838 256.231350.145 257.691350.207 271.61350.956
301.641351.703 314.921351.703 315.411351.702

Manning's n Values num= 3
Sta n Val Sta n Val Sta n Val
0 .044 86.36 .044 241.97 .044

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.
86.36 241.97 157.8 209 285.1 .1 .3

CROSS SECTION
RIVER: Realignment 2
REACH: 1 RS: 200
INPUT
Description:
Station Elevation Data num= 26
Sta Elev Sta Elev Sta Elev Sta Elev Sta Elev
01355.024 16.991350.855 40.331345.237 64.641339.911 114.421334.069
116.61333.778 116.781333.769 138.361334.066 138.981334.051 141.161334.517
171.711340.403 187.31 1343.21 193.871344.429 196.421344.415 198.471344.399
200.991344.514 210.571344.429 213.441344.505 230.841345.065 234.851345.182
235.421345.206 236.61345.262 237.451345.311 268.68 1346.58 286.361345.832
288.111345.766

Manning's n Values num= 3
Sta n Val Sta n Val Sta n Val
0 .044 64.64 .044 171.71 .044
Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.
64.64 171.71 152.6 65.9 71.9 .1 .3

CROSS SECTION

RIVER: Realignment 2

REACH: 1 RS: 100

INPUT

Description:

Station Elevation Data num= 20

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	1343.706	32.89	1336.815	40.84	1335.055	42.11	1334.751	53.74	1331.159
68.77	1326.538	71.59	1329.733	89.58	1329.833	91.24	1329.76	104.36	1327.952
104.61	1327.95	104.72	1327.982	107.47	1328.647	145.55	1338.192	157.93	1340.62
160.29	1340.903	174.44	1342.605	185.92	1344.236	189.24	1344.535	191.17	1344.686

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.044	32.89	.044	145.55	.044

Bank Sta: Left Right Lengths: Left Channel Right Coeff Contr. Expan.

Left	Right	Left	Channel	Right	Coeff	Contr.	Expan.
32.89	145.55	247.9	303.5	349	.1		.3

SUMMARY OF MANNING'S N VALUES

River:eB

Reach	River Sta.	n1	n2	n3
Reach 1	2900	.05	.05	.05
Reach 1	2800	.05	.05	.05
Reach 1	2700	.05	.05	.05
Reach 1	2520	.05	.05	.05

River:eC

Reach	River Sta.	n1	n2	n3
Reach 1	100	.04	.04	.04
Reach 1	50	.04	.04	.04

River:Main Channel

Reach	River Sta.	n1	n2	n3
Reach 1	113	.04	.03	.04
Reach 1	110	.04	.03	.04

River:Main Channel 1.5

Reach	River Sta.	n1	n2	n3
Reach 1	101	.04	.03	.04
Reach 1	100	.04	.03	.04

River:Main Channel 2

Reach	River Sta.	n1	n2	n3
Reach 1	0.5	.04	.03	.04
Reach 1	0.1	.04	.03	.04

River:Realignment 1

Reach	River Sta.	n1	n2	n3
1	4200	.04	.04	.04
1	4100	.04	.04	.04
1	4000	.04	.04	.04
1	2500	.039	.039	.039
1	2400	.039	.039	.039
1	2300	.039	.039	.039
1	2200	.039	.039	.039
1	2100	.039	.039	.039

River:Realignment 2

Reach	River Sta.	n1	n2	n3
1	2000	.039	.039	.039
1	1900	.039	.039	.039
1	1800	.039	.039	.039
1	1700	.039	.039	.039
1	1650	Culvert		
1	1600	.039	.039	.039
1	1500	.039	.039	.039
1	1400	.039	.039	.039
1	1300	.039	.039	.039
1	1200	.039	.039	.039
1	1100	.039	.039	.039
1	1000	.039	.039	.039
1	950	Culvert		
1	900	.039	.039	.039
1	800	.039	.039	.039
1	700	.039	.039	.039
1	600	.039	.039	.039
1	500	.044	.044	.044
1	400	.044	.044	.044
1	300	.044	.044	.044
1	200	.044	.044	.044
1	100	.044	.044	.044

SUMMARY OF REACH LENGTHS

River: eB

Reach	River Sta.	Left	Channel	Right
Reach 1	2900	159	143.6	127
Reach 1	2800	382.9	355.7	352.6
Reach 1	2700	297.6	297.6	297.6
Reach 1	2520	442.5	428.4	431.5

River: eC

Reach	River Sta.	Left	Channel	Right
Reach 1	100	711.4	716.2	656.2
Reach 1	50	697.1	678.1	691.2

River: Main Channel

Reach	River Sta.	Left	Channel	Right
Reach 1	113	410.7	272.8	384.7
Reach 1	110	303.4	303.4	303.4

River: Main Channel 1.5

Reach	River Sta.	Left	Channel	Right
Reach 1	101	10	10	10
Reach 1	100	200.3	132.8	54.6

River: Main Channel 2

Reach	River Sta.	Left	Channel	Right
Reach 1	0.5	535.4	423.9	306.2
Reach 1	0.1			

River: Realignment 1

Reach	River Sta.	Left	Channel	Right
1	4200	618	618	618
1	4100	813	755	689
1	4000	107	75.3	409
1	2500	229.66	300.85	303.81
1	2400	300	300	300
1	2300	300	300	300
1	2200	300	300	300
1	2100	300	300	300

River: Realignment 2

Reach	River Sta.	Left	Channel	Right
1	2000	300	300	300
1	1900	300	300	300
1	1800	100	100	100
1	1700	220	220	220
1	1650	Culvert		
1	1600	22.6	79.4	164
1	1500	200	201.4	199.8
1	1400	173.6	121.4	102.4
1	1300	200	200	200
1	1200	200	200	200
1	1100	127.6	76.1	6.9
1	1000	303.4	303.4	303.4
1	950	Culvert		
1	900	140	140	140
1	800	200	200	200
1	700	200	200	200
1	600	213	213	213

1	500	85	85	85
1	400	80.7	80.7	80.7
1	300	157.8	209	285.1
1	200	152.6	65.9	71.9
1	100	247.9	303.5	349

SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS

River: eB

Reach	River Sta.	Contr.	Expan.
Reach 1	2900	.1	.3
Reach 1	2800	.1	.3
Reach 1	2700	.1	.3
Reach 1	2520	.1	.3

River: eC

Reach	River Sta.	Contr.	Expan.
Reach 1	100	.1	.3
Reach 1	50	.1	.3

River: Main Channel

Reach	River Sta.	Contr.	Expan.
Reach 1	113	.1	.3
Reach 1	110	.1	.3

River: Main Channel 1.5

Reach	River Sta.	Contr.	Expan.
Reach 1	101	.1	.3
Reach 1	100	.1	.3

River: Main Channel 2

Reach	River Sta.	Contr.	Expan.
Reach 1	0.5	.1	.3
Reach 1	0.1	.1	.3

River: Realignment 1

Reach	River Sta.	Contr.	Expan.
1	4200	.1	.3
1	4100	.1	.3
1	4000	.1	.3
1	2500	.1	.3
1	2400	.1	.3
1	2300	.1	.3
1	2200	.1	.3
1	2100	.1	.3

River: Realignment 2

Reach	River Sta.	Contr.	Expan.
1	2000	.1	.3
1	1900	.1	.3
1	1800	.3	.5
1	1700	.3	.5
1	1650	Culvert	
1	1600	.3	.5
1	1500	.1	.3
1	1400	.1	.3
1	1300	.1	.3
1	1200	.1	.3
1	1100	.3	.5
1	1000	.3	.5

1	950	Culvert	
1	900	.3	.5
1	800	.1	.3
1	700	.1	.3
1	600	.1	.3
1	500	.1	.3
1	400	.1	.3
1	300	.1	.3
1	200	.1	.3
1	100	.1	.3

Appendix E

HEC RAS Digital Files

Appendix F

Hydraulic Modeling Results

F1. ***Existing Water Surface Elevations***

F2. ***Proposed Water Surface Elevations***

F3. ***Comparing Existing and Proposed Water Surface Elevations***

Appendix G

Planset

resourceful. naturally.
engineering and environmental consultants

BARR

Technical Memorandum

To: Billy Pollema, Concrete Materials
From: Ray Wuolo
Subject: Results of Corson Quarry Screening-Level Groundwater Inflow Modeling
Date: January 11, 2017
Project: 42491007.00
C: Brian Anderson, Barr Engineering Co.

Introduction

This Technical Memorandum summarizes the methods and finding of groundwater-flow modeling of the proposed Corson Quarry near Sioux Falls SD. The purpose of the model is to develop initial estimates of groundwater inflows into the quarry at various proposed mining depths, using estimated ranges of hydraulic conductivity of the Sioux Quartzite, which is the proposed mined material. This model and the results of the modeling, are at a "screening level", using available data and employing assumptions to expedite estimates of inflows. It uses ranges of hydraulic conductivity, as interpreted from the South Pit mine area and it does not employ vertical or lateral homogeneity. If more precise estimates are required, the model would need modifications and site-specific data would need to be collected. However, for planning-level purposes, the model results are reliable because they employ likely ranges of hydraulic conductivity, use the planned mine depths and extent, and incorporate regional surface-water features.

Methodology

A single-layer, two-dimensional groundwater flow model was constructed using the USGS's MODFLOW-2000 code in the graphical user interface Groundwater Vistas. The areal extent of the model is shown on Figure 1.

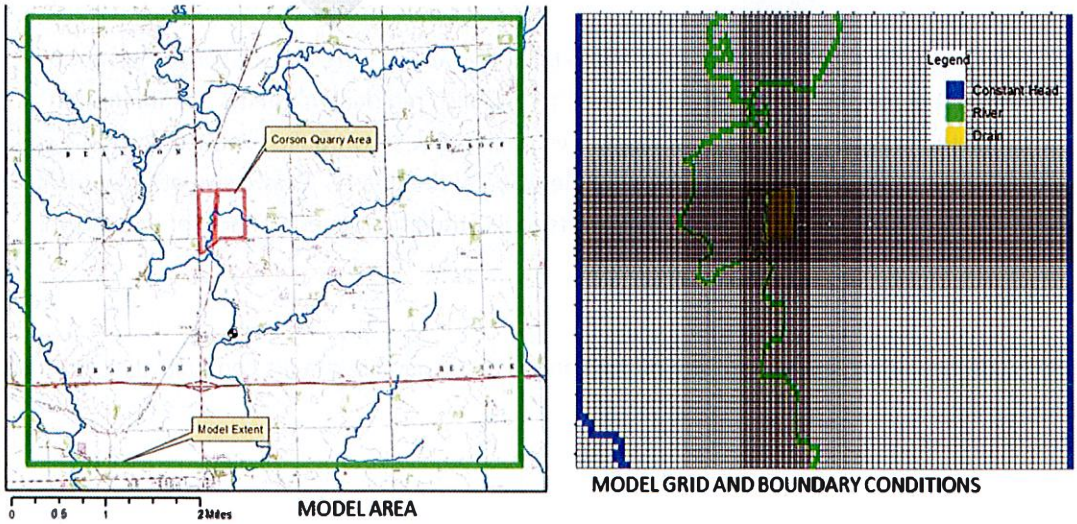


Figure 1 Model Location, Grid, and Boundary Conditions

The model employs a finite-difference grid over the model domain, with grid cells equal to 100 x 100 meters in the far-field and 25 x 25 meters in the vicinity of the proposed quarry. For purposes of this screening-level evaluation, the model's base elevation was set at 1,138 feet MSL (mean sea level), which is approximately 20 feet below the proposed maximum depth of the quarry. The model's top elevation was set above regional ground surface to ensure unconfined conditions in the model simulations. Constant-head cells were used to define the model's boundary conditions to the east and west using estimates of groundwater elevation and to induce a general northeast to southwest flow gradient, as described in Lindgren and Niehus (1991) for the Sioux Quartzite in Minnehaha County, SD. These boundaries were located approximately 2.5 miles away from the quarry to minimize boundary condition artifacts on the model results. These constant-head boundaries are surrogates for regional flow and the effects of infiltrating precipitation (as recharge). Split Rock Creek and a portion of the Big Sioux River were represented as River Package cells in the model and were the primary discharge zones. Secondary streams are primarily ephemeral and were not explicitly modeled.

A base condition was established for the model by simulating groundwater flow and water-table elevation over the model domain without the presence of a quarry. The quarry was sequentially added into the model to represent proposed mine phases and years of mining using the Drain Package in MODFLOW. The modeled elevations range from 1,365 feet MSL to a minimum elevation of 1,160 feet, MSL. Elevation changes were modeled in approximately 50-foot increments, accounting for expansions of the quarry footprint as proposed for the various years of operations.

Hydraulic conductivity is the primary variable controlling inflows into the quarry. All other conditions being unchanged, greater rates of groundwater inflow would be expected with higher values of hydraulic conductivity (i.e. permeability). Because values of hydraulic conductivity can be quite variable, a range of two orders of magnitude was evaluated. Based on previous modeling work at the South Pit, a mean value of 0.3 feet/day was assumed for the bulk hydraulic conductivity of the Sioux Quartzite. Values of 0.03 feet/day and 3.0 feet/day were used to evaluate sensitivity and to provide an approximate range of expected inflows.

In addition to quarry inflow rates, estimates of water-table drawdown were also obtained. Given the structure of the model (i.e. the use of constant heads to establish regional gradients and infiltration effects, the predicted drawdown is relatively insensitive to changes in hydraulic conductivity in the model. Drawdown, however, is sensitive to the dewatering elevation in the quarry. Drawdown at three locations from the quarry were extracted from the model results to illustrate the general effects of drawdown.

Model Results

The predicted groundwater inflows into the pit for various depths and hydraulic conductivity values are shown on Figure 2.

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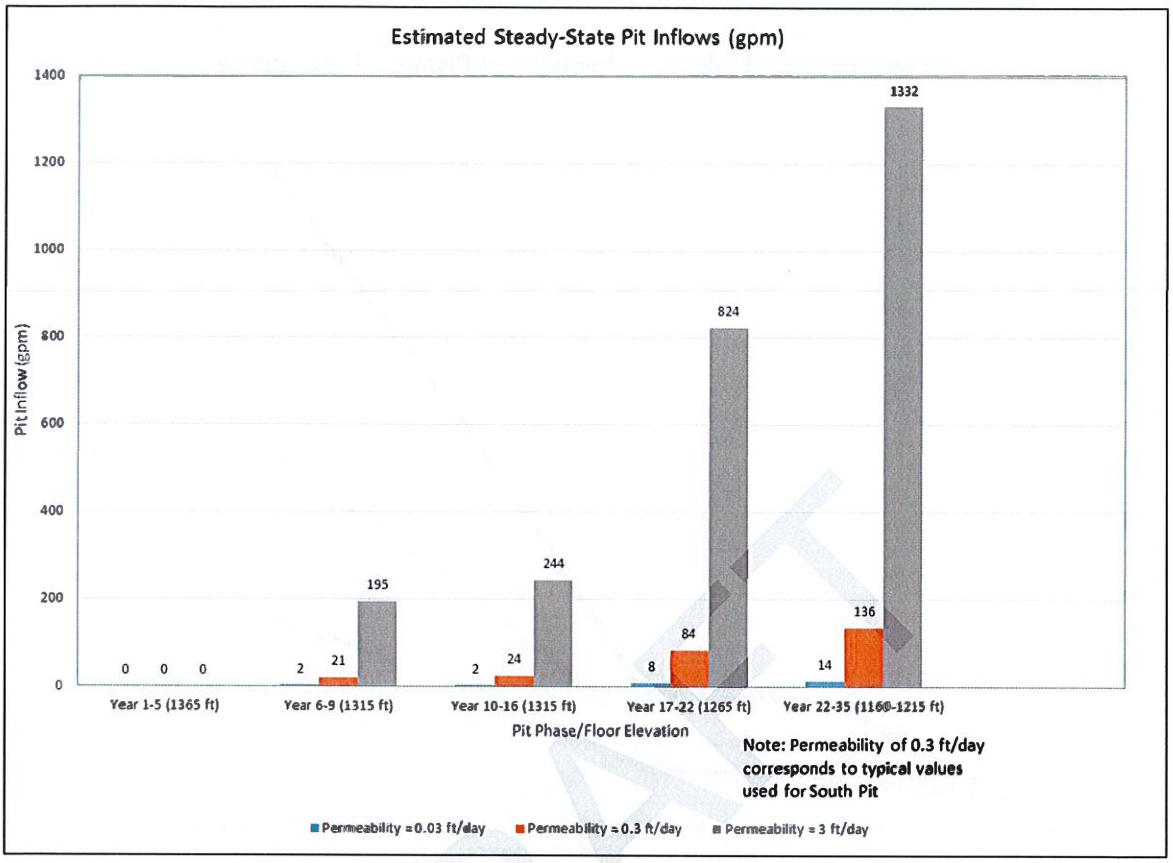


Figure 2 Predicted Inflows into Quarry for Various Phases, Elevations, and Hydraulic Conductivity Values

Inflows into the quarry will likely be more representative of the higher permeability (hydraulic conductivity) values for shallow floor depths and more representative of the lower values as the quarry deepens. This is because secondary porosity features, such as fractures and weathering in the quartzite, are more prevalent and interconnected at shallow depths and tend to become less frequent, smaller, and less connected with depth. The model results should be used to bracket the range in water-handling needs for the quarry operations.

Dewatering of the quarry will result in the lowering of the water table in the vicinity of the quarry. As the quarry deepens, the extent and magnitude of water-table lowering (i.e. "drawdown") will likely increase. The model was used to predict the approximate amount and extent of drawdown of the water table at three distances from the quarry. These are shown on Figure 3. Drawdown may not be uniform in all directions, due to aquifer heterogeneity and the seepage effects of rivers.

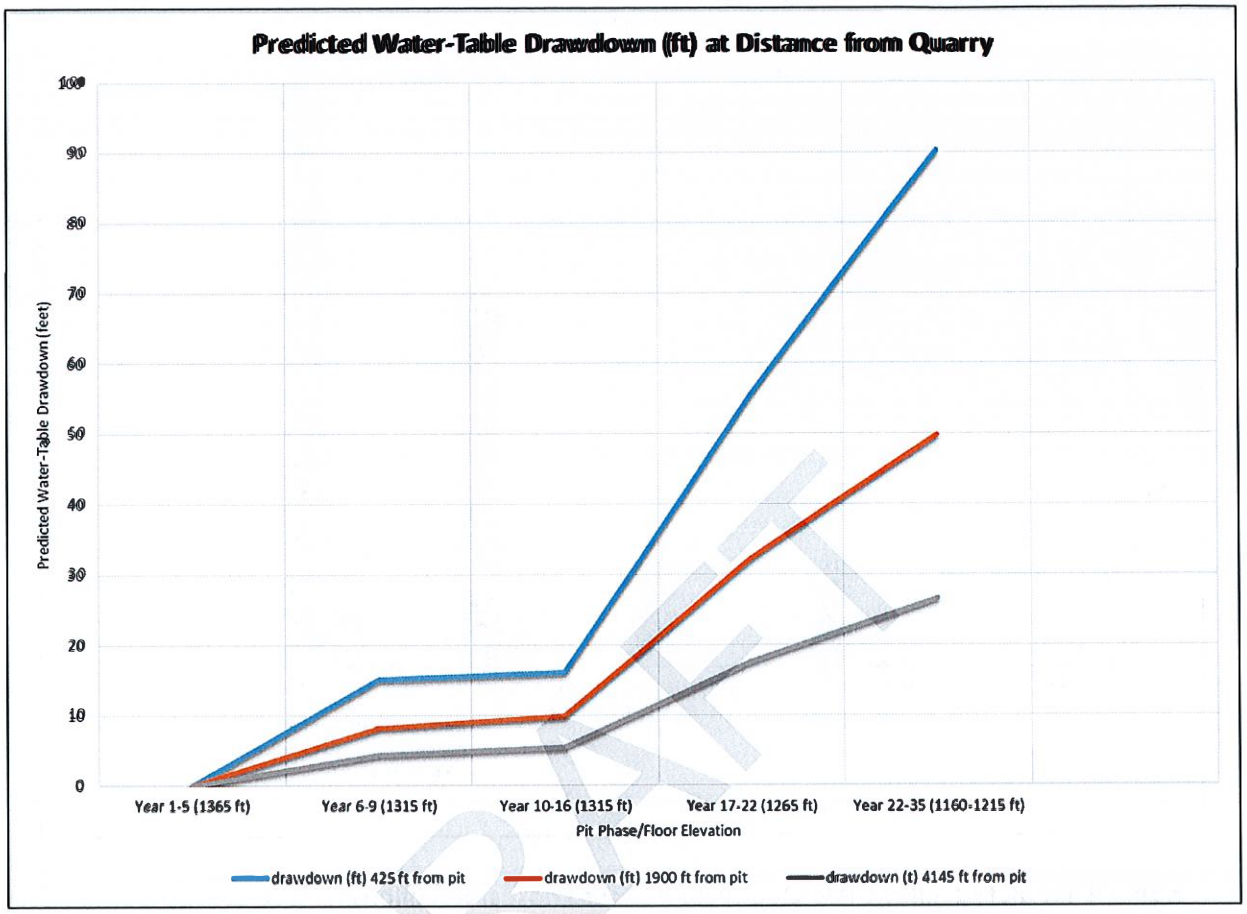


Figure 3 Predicted Water-Table Drawdown at Distance form Quarry

Summary

A groundwater-flow model was used as a screening-level tool to obtain estimates of groundwater inflows into the proposed Corson Quarry and the approximate amount of drawdown of the water table at various distances from the quarry. These results may be used for planning purposes in assessing the water handling needs of the quarry and the potential for water-table drawdown. Inflows into the quarry are dependent upon the water-transmitting characteristics of the Sioux Quartzite, as represented by hydraulic conductivity. For purposes of this screening-level evaluation, the value of hydraulic conductivity was varied by two orders of magnitude. Drawdown is less dependent on hydraulic conductivity, given the structure of the model.

If more precise and accurate estimates of the hydrologic effects of quarrying are required, it is likely that a more detailed and comprehensive model would be necessary, as well as site specific hydrologic data.

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Much of the necessary data to develop a better estimate for both inflows and drawdown can be collected once mining commences and monitoring of the effects of dewatering can be performed.

References

Lindgren, R.J. and C.A. Niehus, 1991. Water Resources of Minnehaha County, South Dakota, USGS Water Resources Investigation Report, 9-4101, 80 p.

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