MONTANA
TAYLOR J WINKEL
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LICENSED PROFESSIONAL ENGINEER
08/09/2024

EXECUTIVE SUMMARY – HYDROLOGY & HYDRAULICS ANALYSIS

INTRODUCTION

The Clark Fork River Access and Restoration-Beartracks Bridge to Madison St. Bridge project is within the downtown city limits of Missoula, Montana, situated upstream of Caras Park on portions of the north and south banks of the Clark Fork River. Beartracks Bridge, Toole Park, East River Access, West River Access, and Madison St. Bridge are the five (5) sites that will be improved. Each of the sites are heavily accessed by the public for river recreation purposes, have bank stability issues, and no formal, designated river access. The proposed restoration will remediate these issues and give greater access to the public. The improved access will also help to restore other non-formal access sites to their natural condition by focusing river accessibility to the proposed locations. The installations will include a variation of terraced boulders, grouted stairs, vegetated riprap, and gravel trails to the river's edge. This memorandum provides hydrologic and hydraulic analysis for the project area that was used to assess the potential impacts of proposed designs on the existing floodplain.

HYDROLOGIC ANALYSIS

A hydrologic analysis was completed by Pioneer Technical Services (Pioneer) for the Clark Fork River in July of 2020. Design discharges for various flood return intervals were extracted from the Pioneer report, using the Grant Creek location for peak discharge values. The United States Geological Survey's (USGS) two-site logarithmic interpolation method was used to estimate peak discharges for the 10-, 25-, 50-, 100-, 100-plus-, and the 500- year events, as shown in **Table 1**. Peak discharge values are calibrated to USGS gages 12340500 (Clark Fork above Missoula, MT), and 12353000 (Clark Fork below Missoula, MT).

Table 1. Summary of peak discharges for the Clark Fork River along the river access sites, in cubic feet per second (cfs).

10% annual chance (10-yr event) (cfs)	4% annual chance (25-yr event) (cfs)	2% annual chance (50-yr event) (cfs)	1% annual chance (100-yr event) (cfs)	1%+ annual chance (100-yr plus event) (cfs)	0.2% annual chance (500-yr event) (cfs)
27100	32600	36700	40500	47200	49000

HYDRAULIC ANALYSIS

Allied Engineering Services Inc. (AESI) developed multiple, one dimensional (1D) hydraulic model runs, using HEC-RAS, for regulatory flood mapping purposes along the Clark Fork River. The "CFR_MC_Msla" model, upstream and downstream of Downtown City of Missoula, was selected for use at the Clark Fork River Access and Restoration-Beartracks Bridge to Madison St. Bridge

locations. Due to the reach length, RESPEC shortened the model based on the project extent and location.

To analyze the floodplain impacts of each proposed site, five (5) models were created from the "CFR_MC_Msla" model, regulatory naming convention, for each site to individually assess the impacts of proposed project work in comparison to the existing conditions. The five (5) proposed sites were all located in-between cross-section geometries in the regulatory model. Therefore, cross-sections were added through each access site to obtain a direct comparison of water surface elevations in the existing and proposed conditions. Each site was modeled on an individual basis, (not all in the same model), to show that each site will not have adverse impacts and to show that each site is not reliant on the other sites to create a no-rise scenario. This allows for each site to potentially be built during different funding phases, without impacting the floodplain. The hydraulic analyses were then used to assess the water surface elevations, velocity distributions, riprap sizing, and scour along each structure (**Figure 1**).

In the Beartracks Bridge and Madison St. Bridge models, the bridges' geometries were removed due to the proximity of the proposed structures in these locations (**Figure 1**). To account for the bridges' impact to water surface elevation calculations, a cross-section was added along the centerline of each bridge and blocked obstructions were incorporated where piers were located (**Figure 2 and Figure 6**). Since the bridges were removed, the models with no bridge geometry have discrepancies in water surface elevation and should not be compared between models. The engineering team understands there is a discrepancy in water surface elevation between the separate models. In addition, the other three (3) sites contain bridge geometries from the "CFR_MC_Msla" model, and in general the addition of cross-sections at the various sites creates slightly different water surface elevation results upstream and downstream of the added cross-sections. This course of action was chosen to most accurately depict the changes in grade of proposed and existing structures for water surface elevation comparisons. Aside from the added cross-sections, remaining cross-section extents and geometry were not altered from the "CFR_MC_Msla" model for all hydraulic analyses.

In the proceeding sections, the existing and proposed conditions of each site are compared detailing a range of Manning's n values used (**Table 7**), water surface elevations, velocities, riprap sizing, and scour along each structure.

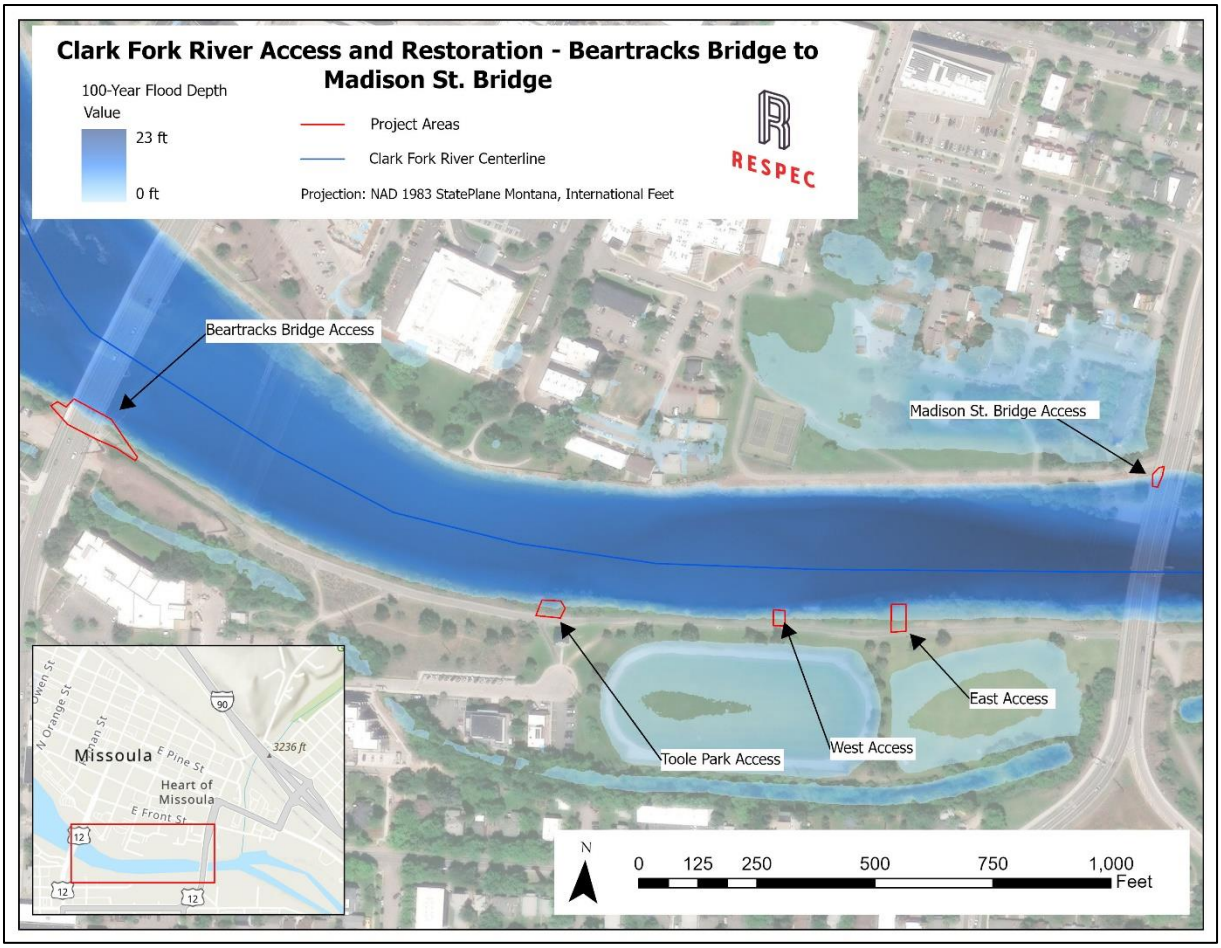


Figure 1. Site locator map of Beartracks Bridge to Madsion St. Bridge for structures used in hydraulic analyses.

WATER SURFACE ELEVATIONS

For the proposed and existing hydraulic models, the 100-year event was simulated using peak discharge values from **Table 1**. **Table 2** through **Table 6** show the modeled water surface elevations for existing conditions and proposed (post-construction) conditions of the restoration sites from Beartracks Bridge to Madison St. Bridge.

BEARTRACKS BRIDGE

The project site is located under Beartracks Bridge and upstream and downstream of the bridge's extent (**Figure 2**). Frequent river access has caused bank erosion and a need for designated walkways to the river's edge. Terrace boulders, boulder stairs, and a gravel trail have been incorporated into the proposed design with an emphasis on matching the existing grade.

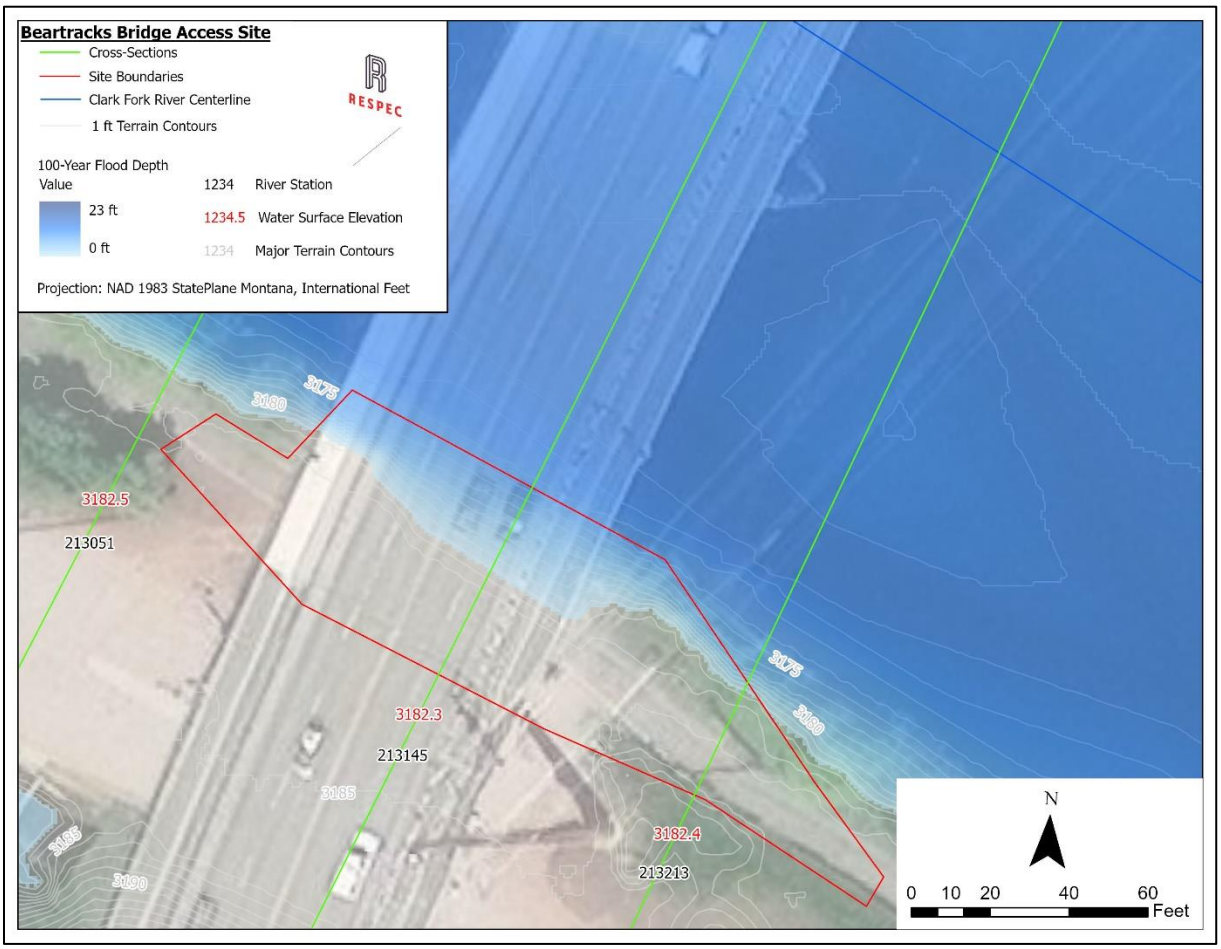


Figure 2. Cross-sections along the **Beartracks Bridge** structure for existing and proposed water surface elevation, velocity, riprap, and scour analyses.

RESPEC

Table 2. Water surface elevation comparison for the Beartracks Bridge structure.

Current Study RS (CE)	Existing Conditions (EC)	Proposed Conditions (PC)	Difference, PC-EC (ft)
	1% annual chance WSE (ft)	1% annual chance WSE (ft)	
215903	3189.2	3189.2	0.0
215510	3188.9	3188.9	0.0
215345 FA	3188.2	3188.2	0.0
215028	3187.9	3187.9	0.0
214721	3187.4	3187.4	0.0
214360 EZ	3185.5	3185.5	0.0
213928	3183.0	3183.0	0.0
213559	3183.0	3183.0	0.0
213213 EY	3182.5	3182.5	0.0
213145	3182.3	3182.3	0.0
213051	3182.5	3182.5	0.0
212761	3182.4	3182.4	0.0
212437 EX	3182.3	3182.3	0.0
212073	3182.2	3182.2	0.0
211719	3181.6	3181.6	0.0
211523 EW	3181.1	3181.1	0.0
211368	3180.3	3180.3	0.0
211060	3179.3	3179.3	0.0
210689 EV	3178.4	3178.4	0.0
210417	3176.9	3176.9	0.0
210120	3177.3	3177.3	0.0
209856 EU	3176.8	3176.8	0.0
209768	3176.1	3176.1	0.0
209592	3176.0	3176.0	0.0
209242 ET	3176.1	3176.1	0.0

TOOLE PARK

Toole Park is located upstream of Beartracks Bridge, and additionally its bank has been eroded due to frequent access from the trail, on top of the river bank, down to the water's edge. Toole Park also provides a shaded beach area that is frequently used as a resting spot (**Figure 3**). To restore and stabilize the bank, boulder stairs and terraced boulder seating have been incorporated into the proposed design formalizing the river access site as well as providing a hardened area that still allows recreationalists to use the beach as a resting spot.

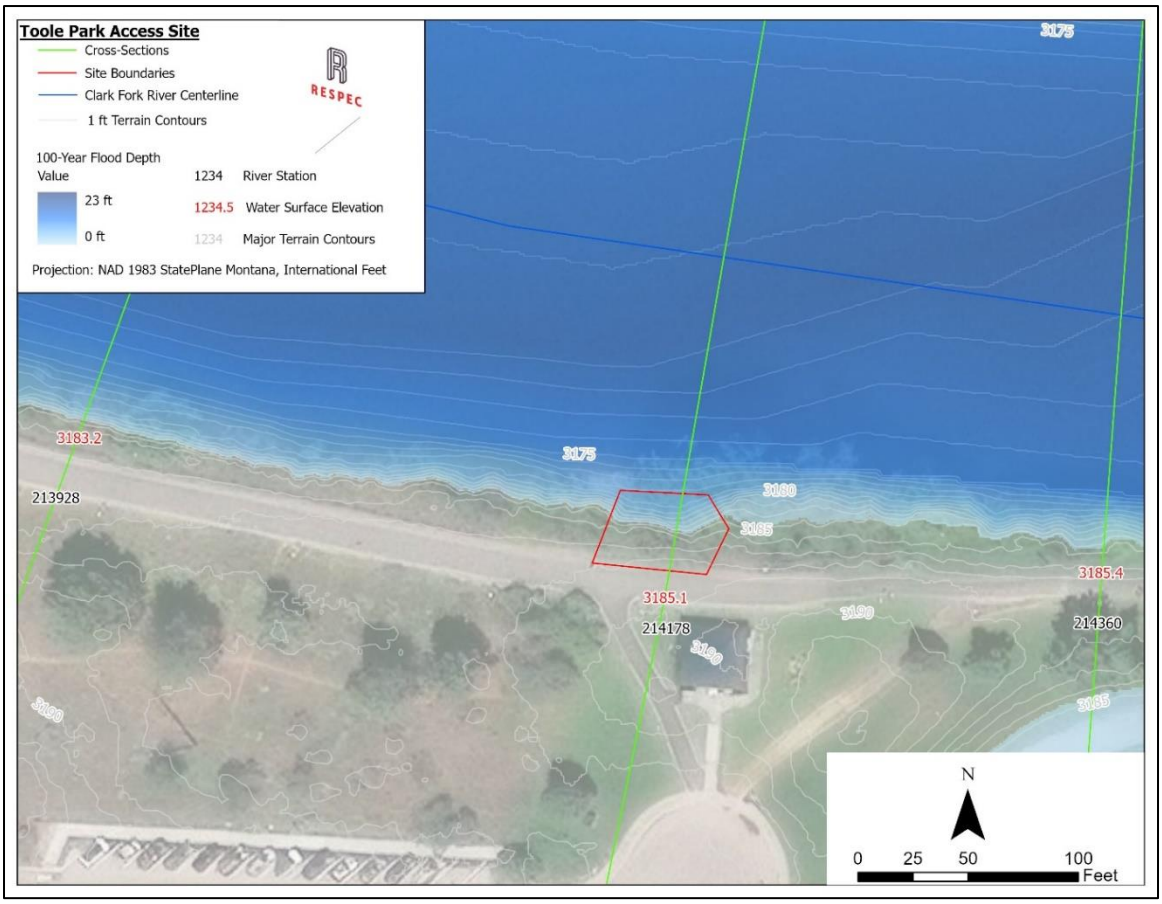


Figure 3. Cross-sections along the **Toole Park** structure for existing and proposed water surface elevation, velocity, riprap, and scour analyses.

Table 3. Water surface elevation comparison for the Toole Park structure.

Current Study RS (CE)	Existing Conditions (EC)	Proposed Conditions (PC)	Difference, PC-EC (ft)
	1% annual chance WSE (ft)	1% annual chance WSE (ft)	
215903	3189.2	3189.2	0.0
215510	3188.8	3188.8	0.0
215345 FA	3188.2	3188.2	0.0
215028	3187.9	3187.9	0.0
214721	3187.4	3187.4	0.0
214360 EZ	3185.4	3185.4	0.0
214178	3185.1	3185.1	0.0
213928	3183.2	3183.2	0.0
213559	3183.2	3183.2	0.0
213213 EY	3182.7	3182.7	0.0
213051	3182.5	3182.5	0.0
212761	3182.4	3182.4	0.0
212437 EX	3182.3	3182.3	0.0
212073	3182.2	3182.2	0.0
211719	3181.6	3181.6	0.0
211523 EW	3181.1	3181.1	0.0
211368	3180.3	3180.3	0.0
211060	3179.3	3179.3	0.0
210689 EV	3178.4	3178.4	0.0
210417	3176.9	3176.9	0.0
210120	3177.3	3177.3	0.0
209856 EU	3176.8	3176.8	0.0
209768	3176.1	3176.1	0.0
209592	3176.0	3176.0	0.0
209242 ET	3176.1	3176.1	0.0

WEST RIVER ACCESS

West River Access along the Clark Fork River is located upstream of Toole Park (**Figure 4**). Boulder stairs have been incorporated into the design to remediate the scoured bank and restore it to its natural grade and create designated river access.

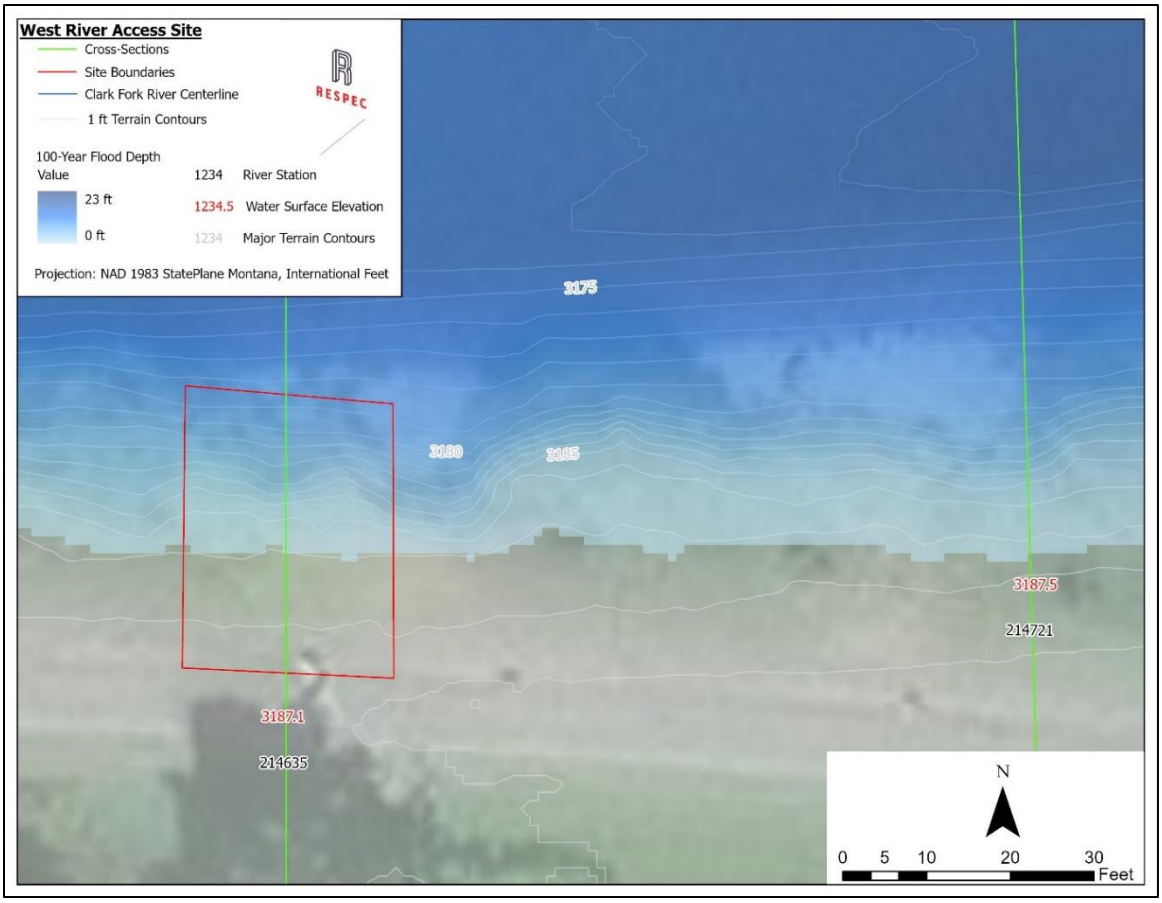


Figure 4. Cross-sections along the **West River Access** structure for existing and proposed water surface elevation, velocity, riprap, and scour analyses.

Table 4. Water surface elevation comparison for the West River Access structure.

Current Study RS (CE)	Existing Conditions (EC)	Proposed Conditions (PC)	Difference, PC-EC (ft)
	1% annual chance WSE (ft)	1% annual chance WSE (ft)	
215903	3189.3	3189.3	0.0
215510	3188.9	3188.9	0.0
215345 FA	3188.3	3188.3	0.0
215028	3188.0	3188.0	0.0
214721	3187.5	3187.5	0.0
214635	3187.1	3187.1	0.0
214360 EZ	3185.5	3185.5	0.0
213928	3183.2	3183.2	0.0
213559	3183.2	3183.2	0.0
213213 EY	3182.7	3182.7	0.0
213051	3182.5	3182.5	0.0
212761	3182.4	3182.4	0.0
212437 EX	3182.3	3182.3	0.0
212073	3182.2	3182.2	0.0
211719	3181.6	3181.6	0.0
211523 EW	3181.1	3181.1	0.0
211368	3180.3	3180.3	0.0
211060	3179.3	3179.3	0.0
210689 EV	3178.4	3178.4	0.0
210417	3176.9	3176.9	0.0
210120	3177.3	3177.3	0.0
209856 EU	3176.8	3176.8	0.0
209768	3176.1	3176.1	0.0
209592	3176.0	3176.0	0.0
209242 ET	3176.1	3176.1	0.0

EAST RIVER ACCESS

The East River Access structure along the Clark Fork River is located upstream of the West River Access site (**Figure 5**). Similarly to the West River Access site, boulder stairs have been incorporated into the proposed design to stabilize the river bank.

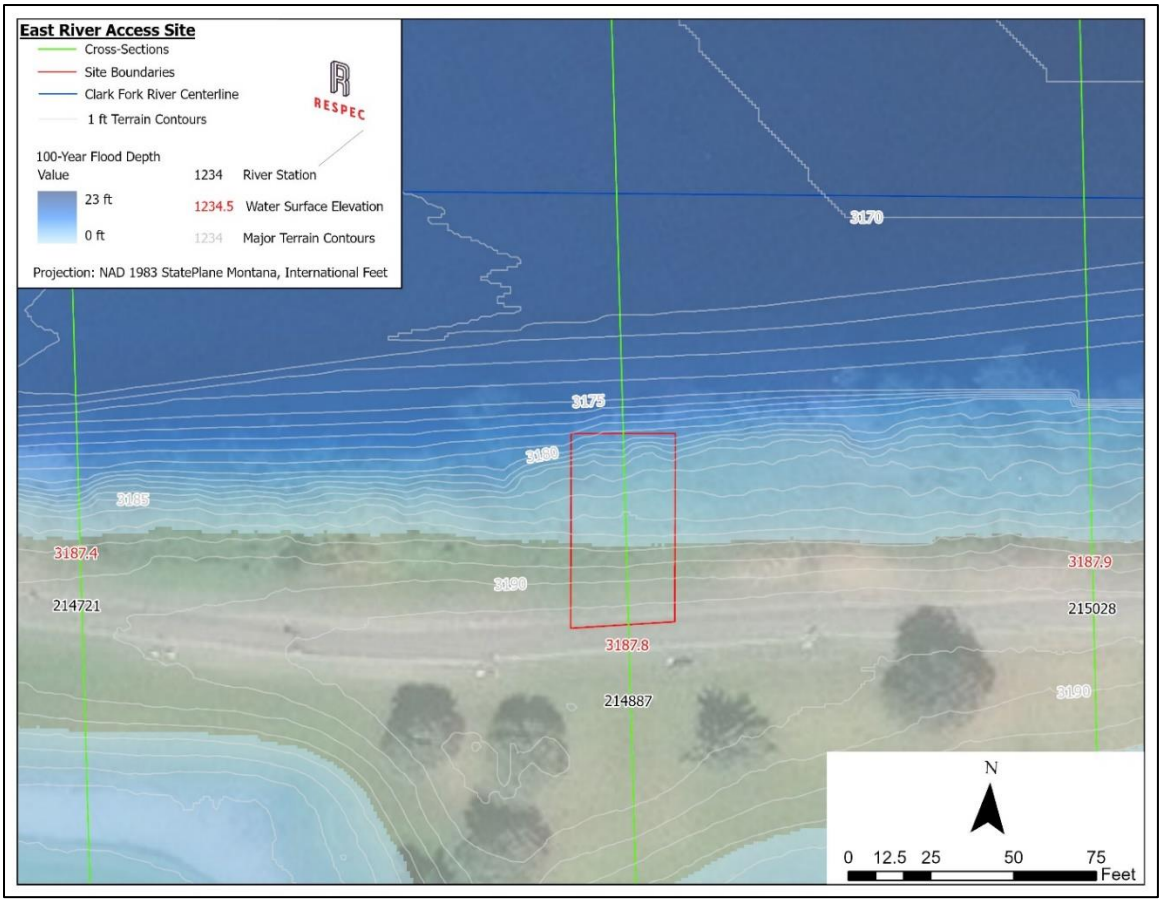


Figure 5. Cross-sections along the **East River Access** structure for existing and proposed water surface elevation, velocity, riprap, and scour analyses.

Table 5. Water surface elevation comparison for the East River Access structure.

Current Study RS (CE)	Existing Conditions (EC)	Proposed Conditions (PC)	Difference, PC-EC (ft)
	1% annual chance WSE (ft)	1% annual chance WSE (ft)	
215903	3189.2	3189.2	0.0
215510	3188.9	3188.9	0.0
215345 FA	3188.2	3188.2	0.0
215028	3187.9	3187.9	0.0
214887	3187.8	3187.8	0.0
214721	3187.4	3187.4	0.0
214360 EZ	3185.5	3185.5	0.0
213928	3183.2	3183.2	0.0
213559	3183.2	3183.2	0.0
213213 EY	3182.7	3182.7	0.0
213051	3182.5	3182.5	0.0
212761	3182.4	3182.4	0.0
212437 EX	3182.3	3182.3	0.0
212073	3182.2	3182.2	0.0
211719	3181.6	3181.6	0.0
211523 EW	3181.1	3181.1	0.0
211368	3180.3	3180.3	0.0
211060	3179.3	3179.3	0.0
210689 EV	3178.4	3178.4	0.0
210417	3176.9	3176.9	0.0
210120	3177.3	3177.3	0.0
209856 EU	3176.8	3176.8	0.0
209768	3176.1	3176.1	0.0
209592	3176.0	3176.0	0.0
209242 ET	3176.1	3176.1	0.0

MADISON ST. BRIDGE

Madison St. Bridge access site is located on the northern bank of the Clark Fork River, partially underneath and downstream of the Madison St. Bridge (**Figure 6**). Additionally, the site is frequently accessed by recreators, and in the proposed design boulder stairs will extend down to the river's edge to provide bank stability and safer access to the water's edge.

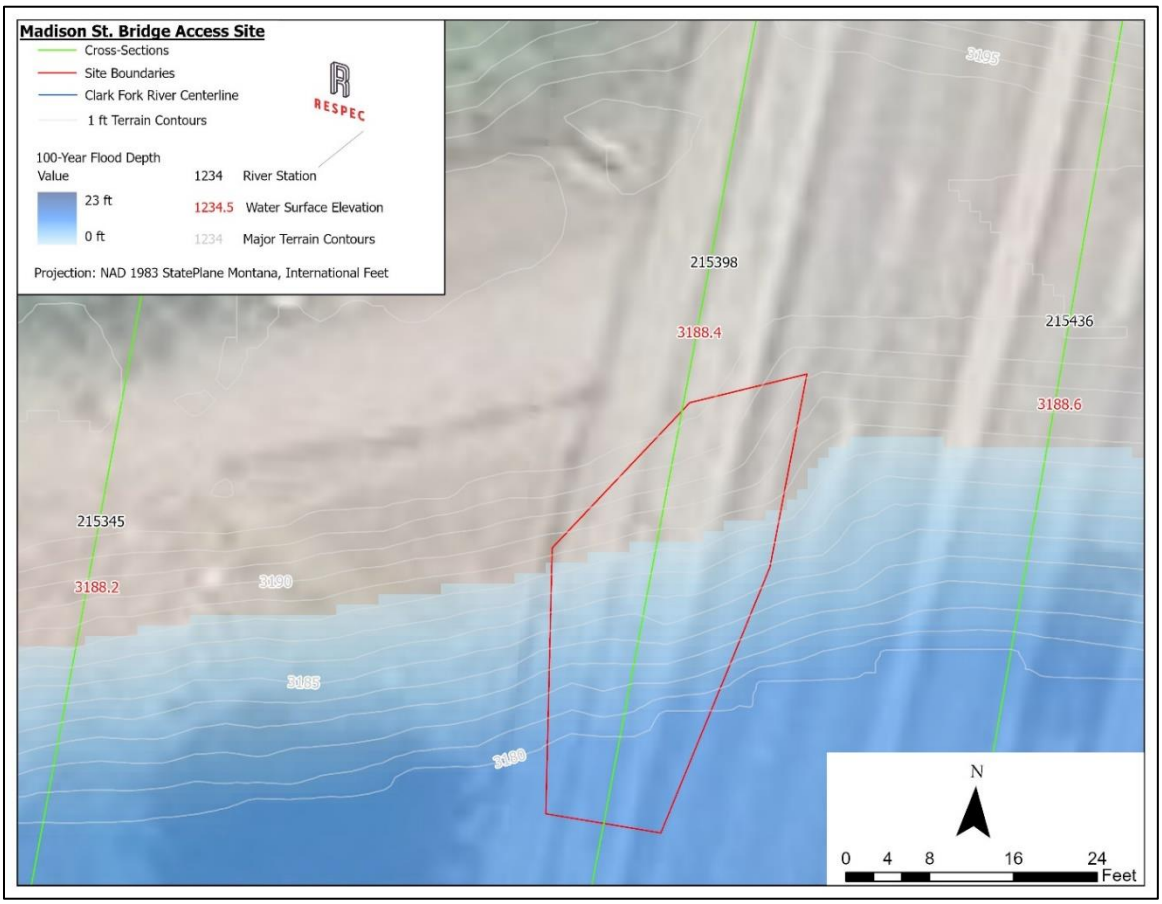


Figure 6. Cross-sections along the **Madison St. Bridge** structure for existing and proposed water surface elevation, velocity, riprap, and scour analyses.

Table 6. Water surface elevation comparison for the Madison St. Bridge structure.

Current Study RS (CE)	Existing Conditions (EC)	Proposed Conditions (PC)	Difference, PC-EC (ft)
	1% annual chance WSE (ft)	1% annual chance WSE (ft)	
215903	3189.1	3189.1	0.0
215510	3188.8	3188.8	0.0
215436	3188.6	3188.6	0.0
215398	3188.4	3188.4	0.0
215345 FA	3188.2	3188.2	0.0
215028	3187.9	3187.9	0.0
214721	3187.4	3187.4	0.0
214360 EZ	3185.5	3185.5	0.0
213928	3183.2	3183.2	0.0
213559	3183.2	3183.2	0.0
213213 EY	3182.7	3182.7	0.0
213051	3182.5	3182.5	0.0
212761	3182.4	3182.4	0.0
212437 EX	3182.3	3182.3	0.0
212073	3182.2	3182.2	0.0
211719	3181.6	3181.6	0.0
211523 EW	3181.1	3181.1	0.0
211368	3180.3	3180.3	0.0
211060	3179.3	3179.3	0.0
210689 EV	3178.4	3178.4	0.0
210417	3176.9	3176.9	0.0
210120	3177.3	3177.3	0.0
209856 EU	3176.8	3176.8	0.0
209768	3176.1	3176.1	0.0
209592	3176.0	3176.0	0.0
209242 ET	3176.1	3176.1	0.0

MANNING'S N VALUES

Table 7. Summary of range in Manning's n values used in all existing and proposed hydraulic models.

Existing Model			Proposed Model		
Left Overbank	Channel	Right Overbank	Left Overbank	Channel	Right Overbank
0.016-0.08	0.03 - 0.06	0.016 - 0.08	0.016-0.08	0.03-0.06	0.016-0.08

VELOCITY

The velocity distribution across the channel for each of the cross-sections along the Clark Fork River has no significant difference from existing to proposed conditions in the hydraulic models. To ensure no undermining of installed structures, boulder stairs/seating will be grouted in place, vegetated riprap will be added, and existing vegetation will be preserved to the extent possible. These proposed features will increase bank roughness and facilitate a more stable bank structure.

RIPRAP AND SCOUR ANALYSIS

The 100-year event was utilized to define riprap sizing and scour analysis along Beartracks Bridge, Toole Park, West River Access, East River Access, and Madison St. Bridge. To properly size riprap along the proposed project area, the radius of curvature, side slope angle, safety factor, and angle of repose were determined for each cross-section and input into Maynord's equation. These parameters calculate a stable d30 particle size which is compared to gradation curves created from Montana Department of Transportation (MDT) specifications of Class I, II, and III random riprap (**Table 8**). The proposed riprap sizes that will result in a stable embankment slope at each cross-section along the structures is MDT Class III riprap. The riprap will be used to protect the structure and prevent undermining during large events.

For the scour analysis, the use of grout along boulder stairs and seating, utilizing existing vegetation, and vegetated Class III riprap will create increased bank roughness. Through utilizing these parameters in design, scour will be negligible along all sites and increase bank stability.

Table 8. MDT specifications for random riprap gradations.

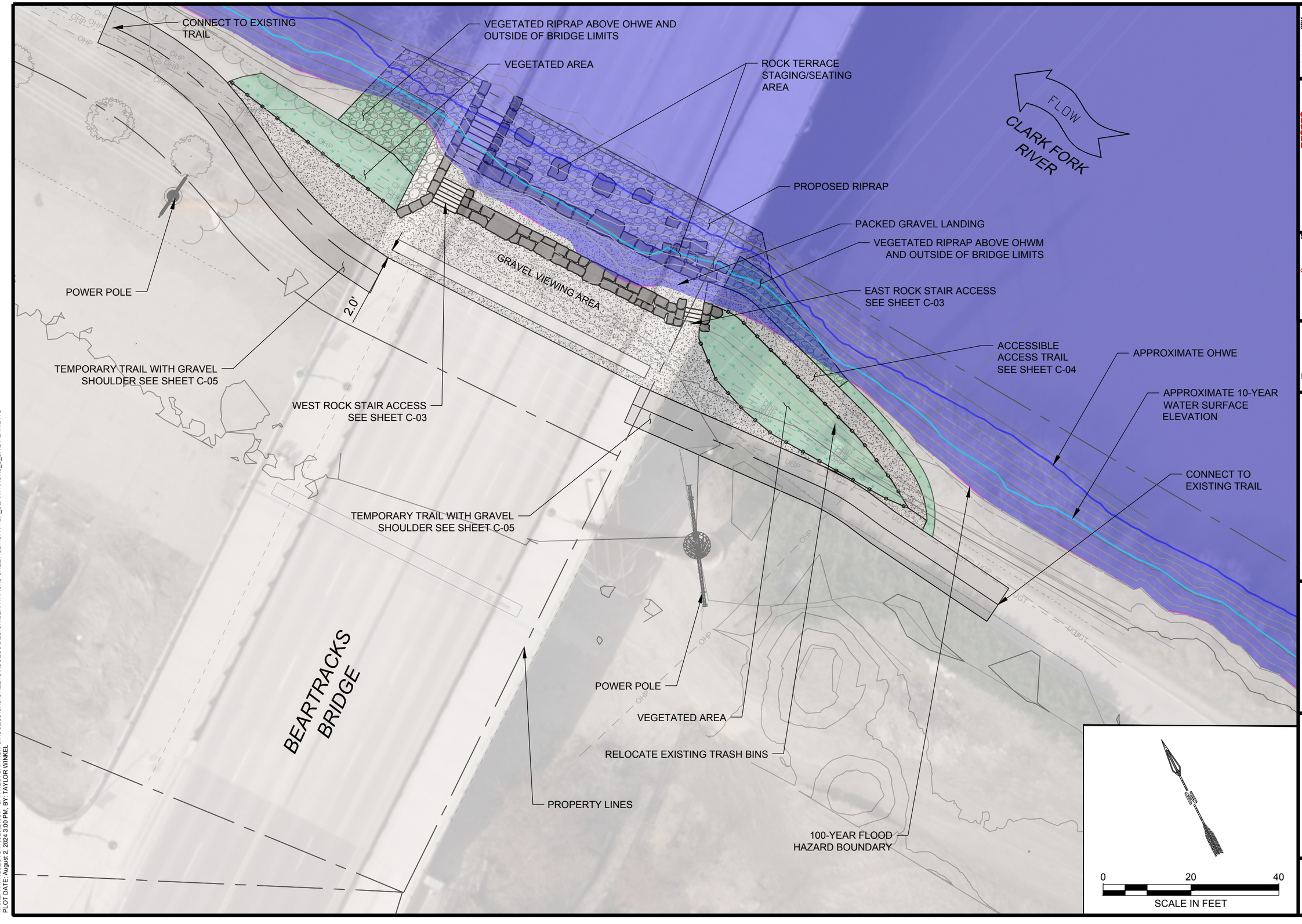
Class	Mean Particle Size Inches (mm)	% of Mean Particle Size Passing
I	13 (330)	100
	11 (280)	70-90
	8 (205)	40-60
	3 (75)	0-10
II	24 (610)	100
	21 (530)	70-90
	16 (405)	40-60
	7 (175)	0-10
III	36 (915)	100
	30 (760)	70-90
	24 (610)	40-60
	9 (230)	0-10

SUMMARY

Based on the hydraulic analyses, the proposed project features (Beartracks Bridge to Madison St. Bridge) would have no negative impacts on the Clark Fork River and the associated floodplain. Water surface elevations maintained the 0" rise requirement between the existing and proposed conditions for upstream, downstream, and each proposed project area. In addition, velocities differences are negligible along the proposed sites with incorporation of vegetation (willow plantings) that would result in increased, near-bank roughness. The riprap sizing and scour analysis recommended MDT Class III riprap along the sites. Placement of riprap will ensure a stable side slope along riverbanks and prevent any scour or undermining of the proposed installations, terrace seating, boulder stairs, and trails near the river's edge. Additionally, the boulder seating/stairs will be grouted to ensure that the structure is not undermined during high flow events.

REFERENCES

1. *Allied Engineering Services, Inc. Clark Fork River Enhanced Hydraulic Analysis and Flood Plain Mapping Report Granite County and Missoula County, Montana. Helena: Montana Department of Natural Resource and Conservation, 2022.*
2. *Standard Specifications for Road and Bridge Construction 2020 Edition V5.0. Standard Specification. Helena: Montana Department of Transportation, 2024. Document.*
3. *Transportation, Montana Department of. Standard Specifications for Road and Bridge Construction 2020 Edition V5.0. 11 January 2024.*
4. *United States Army Corps of Engineers (USACE), HEC-RAS 6.4.1 Hydraulic Modeling Software, 2023.*
5. *United States Army Corps of Engineers, HEC-RAS 6.4 Hydraulic Reference Manual, 2023.*



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PLOT DATE: August 2, 2024 3:00 PM, BY: TAYLOR WINKEL

DESIGNED	SRK
DRAWN	SRK
CHECKED	MAR
DATE	05/2024

REVISION

RESPEC
WATER & NATURAL RESOURCES
3810 VALLEY COMMONS DR SUITE 4
BOZEMAN, MT 59718
WWW.RESPEC.COM PHONE: (406)284-2525

STAMP
90% REVIEW
PRELIMINARY
NOT FOR CONSTRUCTION
8/2024

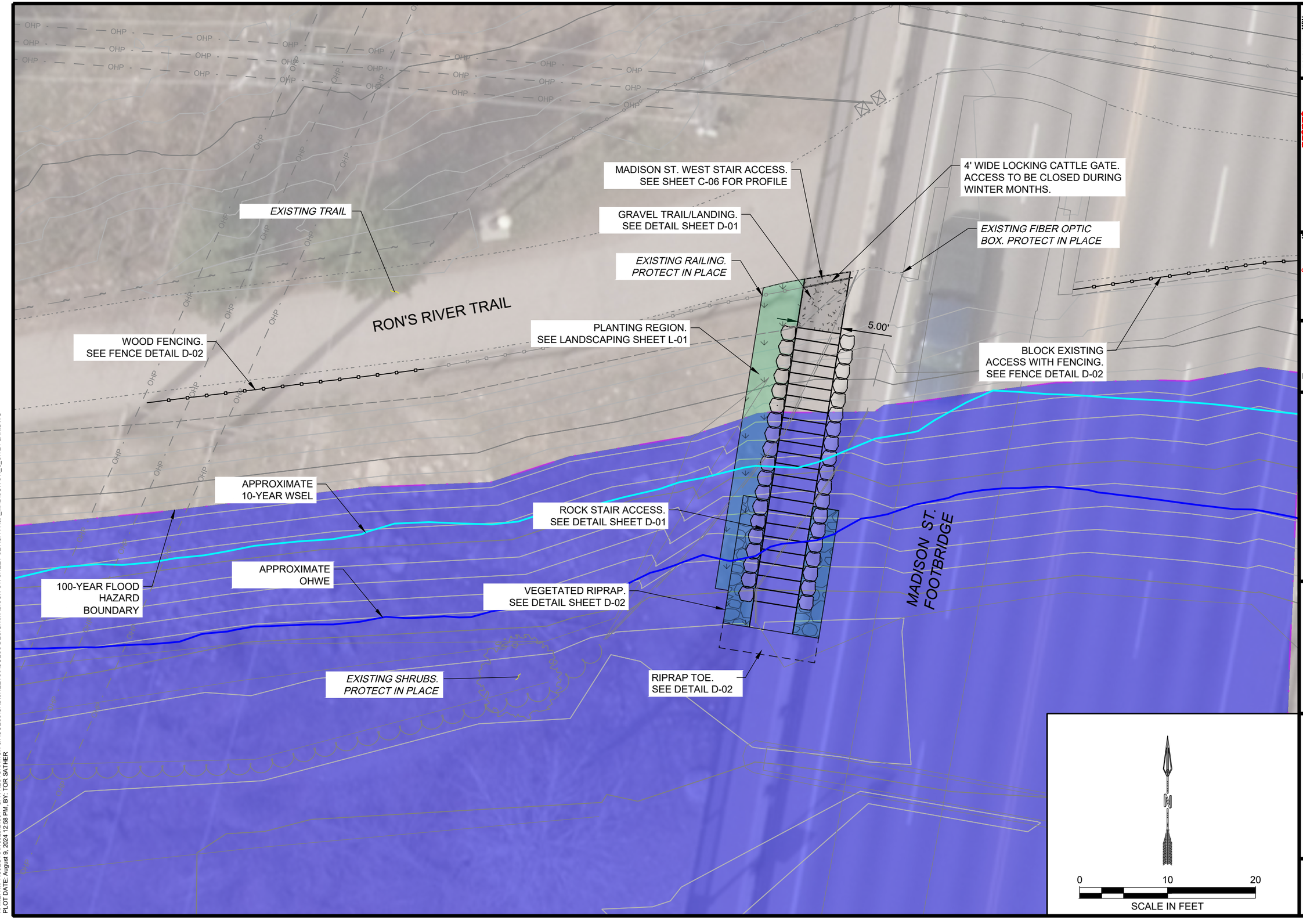
811 Know what's below. Call before you dig.

CITY OF MISSOULA
PARKS AND RECREATION
DEPARTMENT
600 CREGG LANE
MISSOULA, MT 59801

CLARK FORK RIVER RESTORATION AND ACCESS - BEARTRACKS BRIDGE

SITE PLAN

SHEET NUMBER:
C-01
SHEET



NAME: N:\PROJECTS\W0020.21001 - CFR RESTORATION & ACCESS\CAD\SHEETS\ACCESS DESIGN\MADISON ST. SHEET SET\CFR R&A_MADISON ST._S_SITE PLAN.DWG
PLOT DATE: August 9, 2024 12:58 PM, BY: TOR SATHER

DESIGNED	MDH
DRAWN	MDH
CHECKED	MAR
DATE	03/2024

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DEPARTMENT
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MISSOULA, MT 59801

CLARK FORK RIVER
RESTORATION AND
ACCESS - MADISON ST.
& TOOLE PARK

SITE PLAN -
MADISON ST.
BRIDGE

SHEET NUMBER:
C-02
SHEET

APPROXIMATE OHWE

EXISTING SHRUBS PROTECT IN PLACE

APPROXIMATE 10-YEAR WSEL

RIPRAP TOE EXTENT

BOULDER TERRACE
SEE PROFILE SHEET C-07

RIPRAP TOE
SEE DETAIL SHEET D-02

EXISTING TREES PROTECT IN PLACE

VEGETATED RIPRAP
SEE DETAIL SHEET D-02

3.0- 4.0'

PLANTING REGION

PLANTING REGION
SEE LANDSCAPING
SHEET L-01

ROCK STAIR ACCESS
SEE DETAIL SHEET C-07

100-YEAR FLOOD
HAZARD BOUNDARY

4.0'

GRAVEL TRAIL
SEE DETAIL SHEET
D-02.

MILWAUKEE TRAIL

WOOD FENCE
SEE DETAIL SHEET D-02

TOOLE PARK RIVER ACCESS TRAIL
SEE SHEET C-07 FOR PROFILE

N

0 5 10
SCALE IN FEET

NAME: N:\PROJECTS\W0020.21001 - CFR RESTORATION & ACCESS\CAD\SHEETS\ACCESS DESIGN\MADISON ST. SHEET SET\CFR R&A_MADISON ST._S_SITE PLAN.DWG
PLOT DATE: August 2, 2024 2:52 PM, BY: TAYLOR WINKEL

DESIGNED MDH
DRAWN MDH
CHECKED MAR
DATE 03/2024

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BOZEMAN, MT 59718
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PARKS AND RECREATION
DEPARTMENT
600 CREGG LANE
MISSOULA, MT 59801

CLARK FORK RIVER
RESTORATION AND
ACCESS - MADISON ST.
& TOOLE PARK

SITE PLAN - TOOLE
PARK

SHEET NUMBER:
C-03
SHEET

EXISTING TREES
PROTECT IN PLACE

RIPRAP TOE EXTENT

APPROXIMATE
OHWE

RIPRAP TOE
SEE DETAIL SHEET D-02

EXISTING SHRUBS
PROTECT IN PLACE

APPROXIMATE
10-YEAR
WSEL

VEGETATED RIPRAP
SEE DETAIL SHEET D-02

ROCK STAIR ACCESS
SEE DETAIL SHEET D-01

PLANTING REGION
SEE LANDSCAPING SHEET L-02

4.0'

PLANTING REGION

100-YEAR FLOOD
HAZARD BOUNDARY

GRAVEL TRAIL
SEE DETAIL SHEET D-02

WOOD FENCE
SEE DETAIL SHEET D-02

MILWAUKEE TRAIL

SOUTH BANK RIVER ACCESS TRAIL (WEST)
SEE SHEET C-08 FOR PROFILE

N

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SCALE IN FEET

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PLOT DATE: August 2, 2024 2:52 PM, BY: TAYLOR WINKEL

DESIGNED	MDH
DRAWN	MDH
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DATE	03/2024

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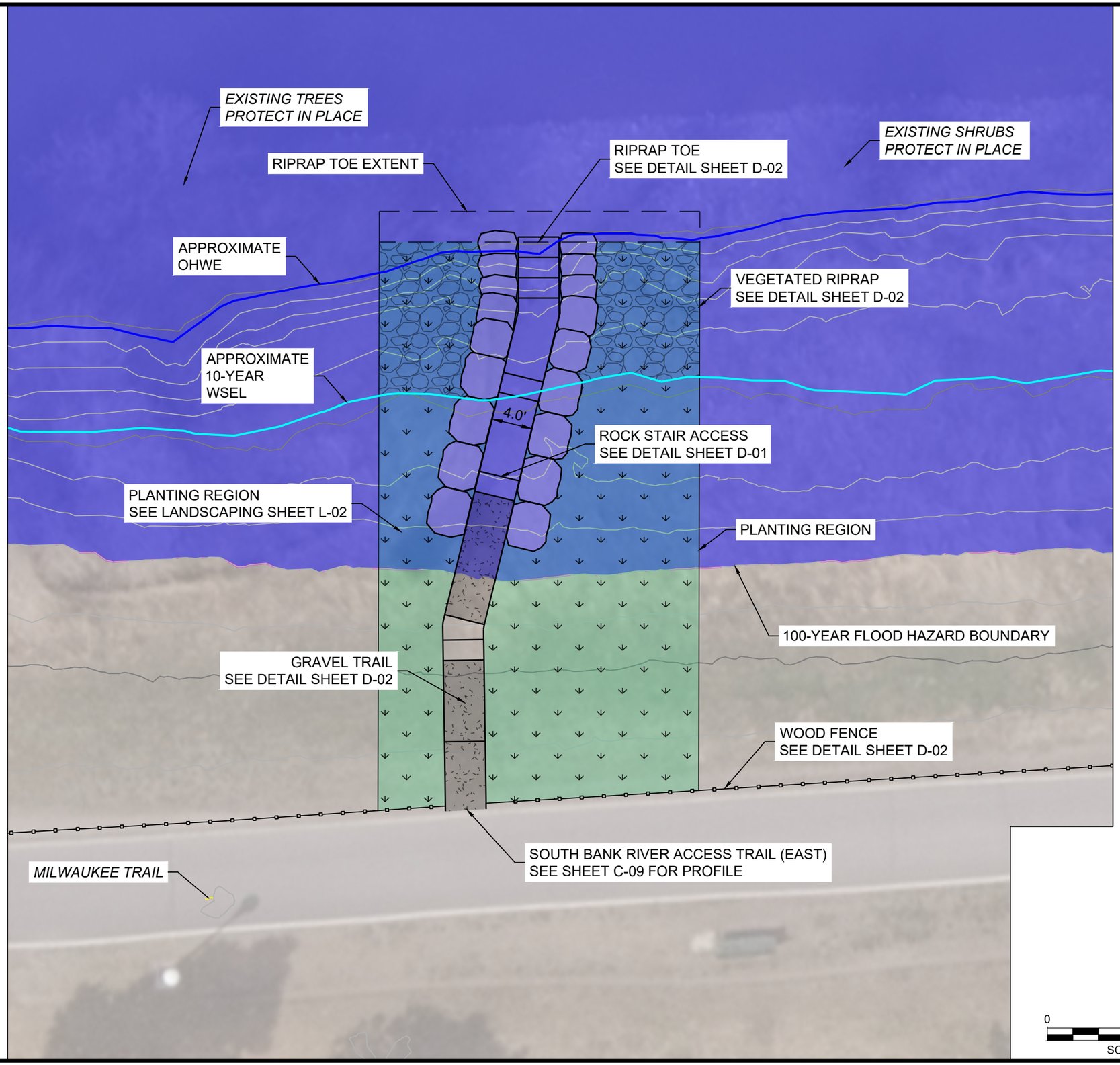
SITE PLAN - WEST
ACCESS

SHEET NUMBER:
C-04
SHEET



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