Dakota Prairie Grasslands
US Forest Service
Billings County, ND

ND FLAP 704(1) 795(1)

Magpie Creek and Whitetail Creek Crossings

Final Hydraulic Report

Federal Highway Administration
Central Federal Lands Highway Division

23 February 2023

Executive Summary

Hydrologic and hydraulic analyses were conducted for the ND FLAP 704(1) 795(1) Magpie Creek and Whitetail Creek Crossings Project. The objective of the project is to elevate the crossings out of the stream to provide safe vehicular passage during frequent stream flow. To achieve this, the existing natural surface low water crossings will be replaced with a bridge crossing at Magpie Creek and a culvert crossing at Whitetail Creek.

The design peak flow values for the project were estimated using USGS regression equations for North Dakota. For Magpie Creek, the 50-year flow was used to hydraulically size the crossing in accordance with Federal Lands Highway PDDM criteria. Scour depth estimates were conducted in accordance with HEC-18 using a 100-year scour design flood and 200-year scour check flood.

For Whitetail Creek a 25-year design flood was used to size the crossing in accordance with PDDM low standard hydraulic criteria for culverts.

Two-dimensional hydraulic modeling using SRH-2D was conducted to estimate water surface elevations (WSEL), depths, and flow velocities at the project site. At Magpie Creek the proposed configuration is a 114-foot bridge with 2H:1V spill-through abutment slopes. Abutment toes will be located near existing channel banks to allow conveyance of bankfull flows. The proposed low chord is 2,144.91 feet and provides a minimum 2 feet of freeboard above the 50-year WSEL.

At Whitetail Creek the proposed configuration is a two-barrel 12’ x 10’ concrete box culvert, embedded a minimum of 1-foot. The hydraulic recommendations for the Magpie Creek and Whitetail Creek crossings are shown in the following table:

Summary of Hydraulic Recommendations

Site	Location	Proposed Structure Type	Geometric Parameters	Remarks
704	Magpie Creek	3-Span Bridge	Bridge Length = 114 feet Bridge Low Chord = 2,144.91	• Class 3 riprap abutment protection
795	Whitetail Creek	Concrete Box Culvert	Number of Barrels = 2 Span x Height = 12-ft x 10-ft	• Culvert embedded 1-foot minimum. • Class 2 riprap outlet protection

The Magpie Creek bridge hydraulic data is summarized in the following table:

Summary of Magpie Creek Bridge Hydraulic Data

	Q (cfs)	V (ft/s)	WS El. (ft)	Scour El. (ft)
Q_2	397	3.9	2,138.52	---
Q_{50}	3,400	10.3	2,142.13	---
Q_{100}	4,170	10.7	2,142.91	2,127.21
Q_{200}	4,890	11.0	2,143.21	2,126.42
Notes:	Water surface elevations are at upstream face of bridge. 50-year WS. El. used to determine freeboard = 2,142.6' (measured 28 feet upstream of bridge). Hydraulic capacity requirements: Bridge low chord provides a minimum 2.0 feet of freeboard above 50-year water surface elevation.			

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1 PROJECT BACKGROUND INFORMATION

The purpose of this project is to provide safe travel and allow consistent access across Magpie Creek (Magpie Road) and Whitetail Creek (Whitetail Road). The scope of this project will include the construction of structures across Magpie Creek and Whitetail Creek to allow the passage of vehicles. Work will also include roadway work for the stream crossing approaches as appropriate.

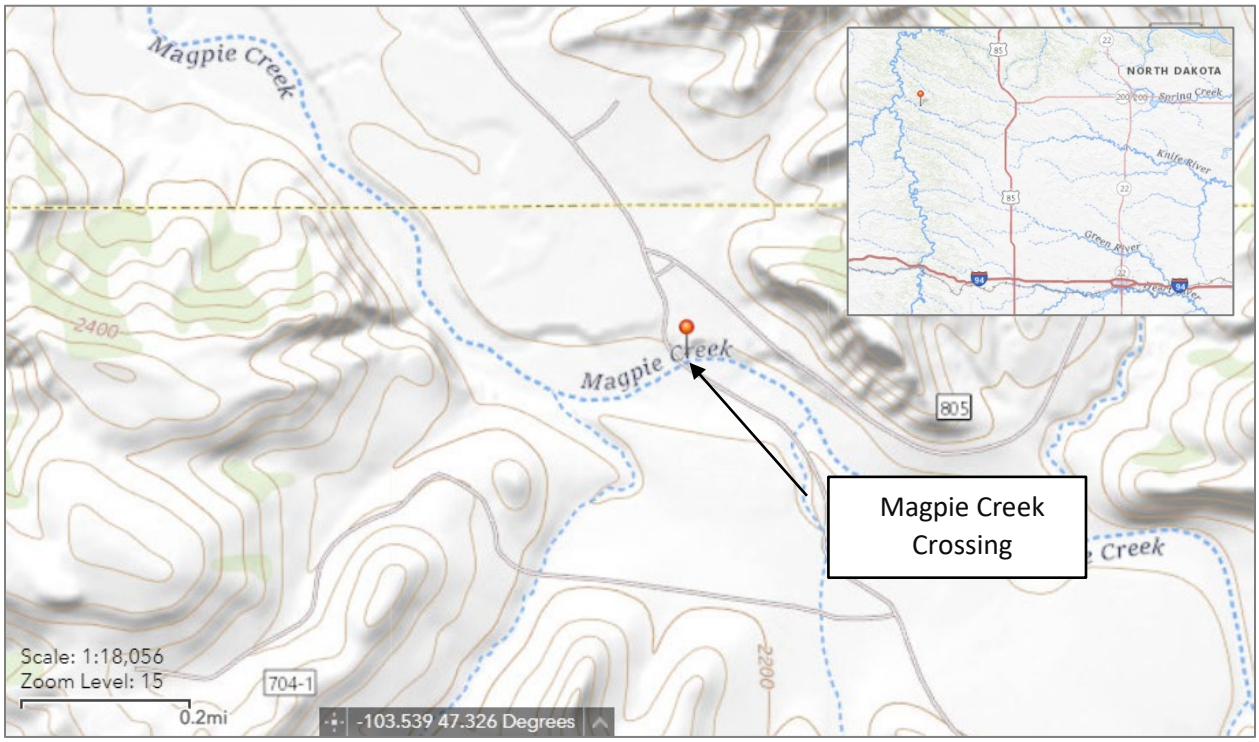

Figure 1: Magpie Creek Location Map

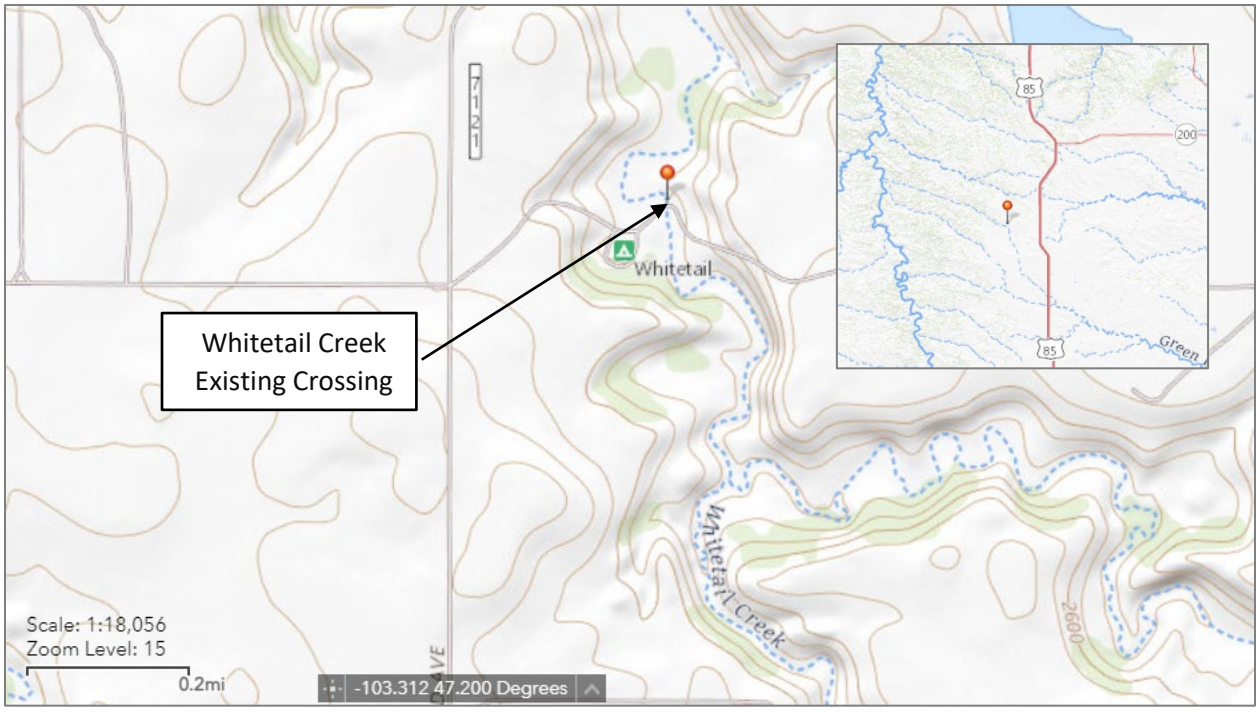

Figure 2: Whitetail Creek Location Map

2 HYDRAULIC DESIGN CRITERIA

Hydraulic design criteria for the project were obtained from the Federal Lands Highway Project Development and Design Manual (PDDM) (Federal Lands Highway 2012). Based on the project scoping summary, both the Magpie Creek and Whitetail Creek roads have an average daily traffic (ADT) of less than 200 vehicles. Based on these parameters, the road is classified as low standard for hydraulic design purposes according to the PDDM. The applicable FLH design criteria are listed in Table 1. Additional capacity design criteria based on ND Article 89-14 Public Highway Stream Crossings are shown in Table 2.

Table 1: FLH Hydraulic Design Criteria

Road Classification: Low-Standard Road (ADT < 200 vpd)			
Bridges	**Design Frequency**	**Check Frequency**	**Freeboard**
	50-year flood	Greater of 100-year or overtopping flood	• Minimum of 2 feet • 3.5 feet to 5 feet when woody debris potential is significant • 5 feet to 10 feet when ice flow potential is significant
Scour	**Scour Design Frequency**	**Scour Check Frequency**	**Scour Countermeasure Design Frequency**
	100-year flood	200-year flood	200-year flood
Culverts	**Design Frequency**	**Check Frequency**	**Allowable Headwater**

	25-year flood	Overtopping flood or 100-year	Minimum of: • Bottom of aggregate base layer • HW/D ratio of 1.2 for D > 48", 1.5 for D ≤ 48” • Heavy debris or sediment load concerns: 0.8 ≤ HW/D ≤ 1.0 • Unacceptable hazard to human life or property

Table 2: Stream Crossing Standards Article 89-14 ND Administrative Code

Road Classification: County, Rural System, Off System			
Bridges & Reinforced Concrete Boxes	**Design Frequency**	**Check Frequency**	**Remarks**
	15-year flood	Not specified	Discharges must be computed using United States geological survey report 92-4020 or other recognized hydrologic methods.

3 HYDROLOGY

3.1 HYDROLOGIC SETTING

The project is located within the Middle Little Missouri watershed (HUC 8: 10110203) and the Lower Little Missouri watershed (HUC 8: 10110205), a right bank tributary to the Little Missouri River. Whitetail Creek and Magpie Creek generally flow from south-east to north-west to their confluence with the Little Missouri River. The contributing drainage basins to the crossings were delineated using available 10-meter digital elevation model (DEM) and StreamStats (U.S. Geological Survey 2016). A summary of general basin properties is shown in Table 3.

Table 3: Basin Properties

Site	Drainage Area (mi^2)	Mean Basin Elevation (ft)	Mean Basin Slope (%)	Mean Annual Precipitation (in)
Magpie Creek Crossing	87.9	2,507	15.8	15.2
Whitetail Creek Crossing	16.7	2,722	5.37	14.9

3.2 FEMA FLOOD INSURANCE STUDY

According to FEMA Flood Insurance Rate Map (FIRM) Panel 380005 there is no FIRM data available for this region and is yet to be mapped.

3.3 AVAILABLE HYDROLOGIC DATA

According to the USGS National Water Information System (NWIS) there are no active USGS peak streamflow stations within the project limits. The closest USGS active station is located on Little Missouri River approximately 21 miles north-east of the confluence with Magpie Creek. Peak streamflow data from

this station was included in the development of the USGS regression equations for North Dakota described in Section 3.4. Table 4 summarizes the station location and period of record.

Table 4: Available Peak Streamflow Information

USGS Station	Location	Latitude	Longitude	Drainage Area	Period of Record	Total Peak Streamflow Records	Status
06337000	Little Missouri River NR Watford City, ND	47°35'43"	103°15'48"	8,310 mi^2	1935-2021	86	Active

3.4 REGRESSION EQUATION ESTIMATES

Regression Equations were used to estimate peak flows for the project basins. The equations for North Dakota are based on USGS Report 2015-5096 (Williams-Sether 2015). The site is located in the North Dakota hydrologic region B. The equations developed for region B relate peak discharge to drainage area, ruggedness number, and compactness ratio. The StreamStats web application (U.S. Geological Survey 2016) was used to perform the peak discharge estimates. 15-year and 200-year peak flows were estimated by fitting a logarithmic function to the regression data. The peak flow results and prediction errors for the project basins are shown in Table 5 and Table 6 for Magpie Creek and Whitetail Creek, respectively.

Table 5: Magpie Creek Creek Regression Peak Flow Estimates

Percent Chance Exceedance (%)	Return Period (year)	Peak Flow Estimate (cfs)	Average Standard Error of Prediction (ASPe)
50	2	397	75.3
20	5	1,110	60.3
10	10	1,730	58.0
6.7	15	2,253	N/A
4	25	2,660	58.8
2	50	3,400	60.7
1	100	4,170	63.5
.5	200	4,892	N/A

Table 6: Whitetail Creek Regression Peak Flow Estimates

Percent Chance Exceedance (%)	Return Period (year)	Peak Flow Estimate (cfs)	Average Standard Error of Prediction (ASPe)
50	2	119	75.3
20	5	340	60.3
10	10	538	58.0
6.7	15	708	N/A
4	25	836	58.8
2	50	1,070	60.7
1	100	1,320	63.5
.5	200	1,555	N/A

4 HYDRAULIC ANALYSIS

Hydraulic analyses were conducted for two crossing locations. The objective of the analyses was to establish the hydraulic capacity requirements using the available data and two-dimensional hydraulic modeling. The input data, model development, and results are discussed in the following sections.

4.1 TOPOGRAPHIC INFORMATION

Field survey information collected by Central Federal Lands was used to develop the hydraulic models for the sites. The survey information was processed to create triangular irregular network (TIN) surfaces to represent the topography in the streambed and floodplain areas near the existing crossings as shown in Figure 3 and Figure 4 for Magpie Creek and Whitetail Creek, respectively. LiDAR data obtained from the National Map was used to supplement the survey information where necessary. All elevations for the study are in units of feet and are referenced to the North American Vertical Datum of 1988 (NAVD 88).

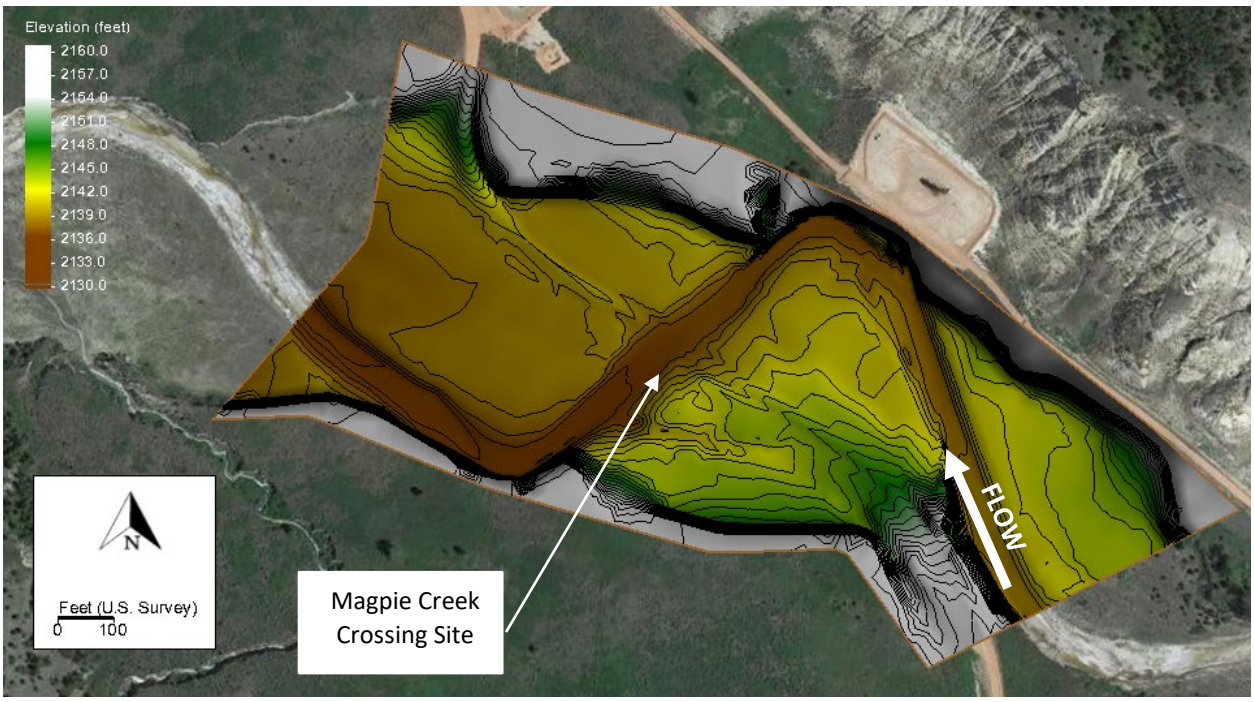

Figure 3: Magpie Creek Topographic Surface, Elevations in feet (NAVD88)

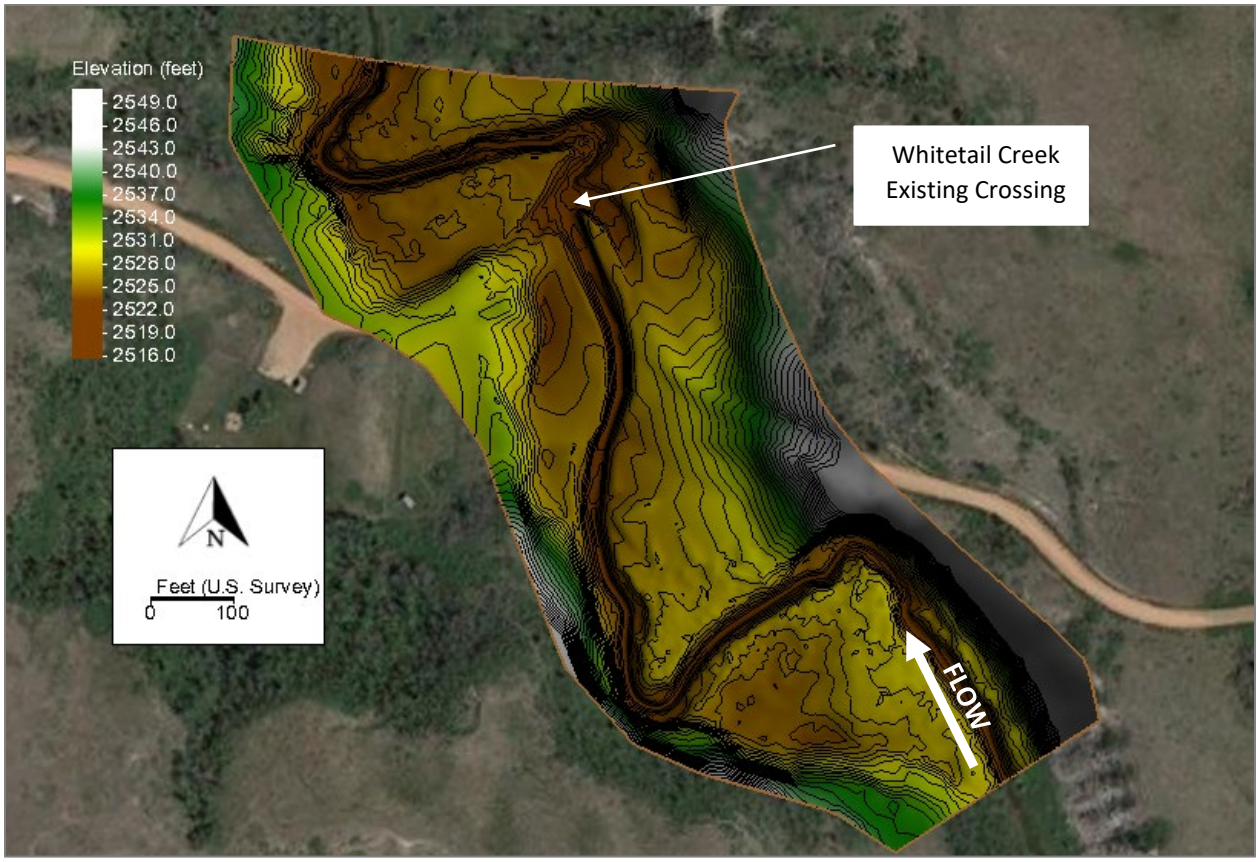

Figure 4: Whitetail Creek Topographic Surface, Elevations in feet (NAVD88)

4.2 HYDRAULIC MODEL DEVELOPMENT

Two-dimensional hydraulic simulations were conducted using SRH-2D (U.S. Bureau of Reclamation 2017) to estimate water surface elevations, water depth and flow velocities at the project site. The SRH-2D computational mesh generation and model pre- and post-processing was performed using the SMS 13.1 interface (Aquaveo 2022). SRH-2D uses a computational mesh to solve the two-dimensional flow equations (i.e., the depth-averaged St. Venant equations). The mesh defines the underlying topography and geometric properties of each computational element. The existing conditions SRH-2D computational meshes for Magpie Creek and Whitetail Creek are shown in Figure 5 and Figure 6, respectively.

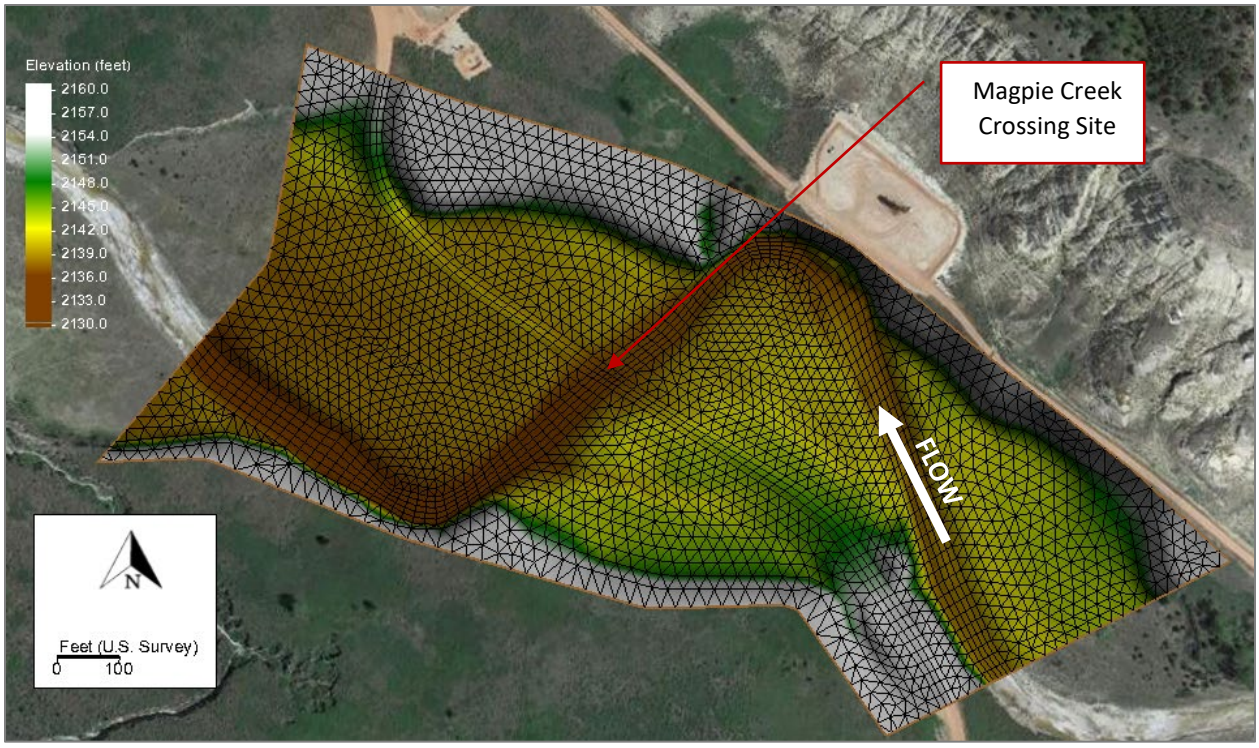

Figure 5: Magpie Creek Existing SRH-2D Mesh

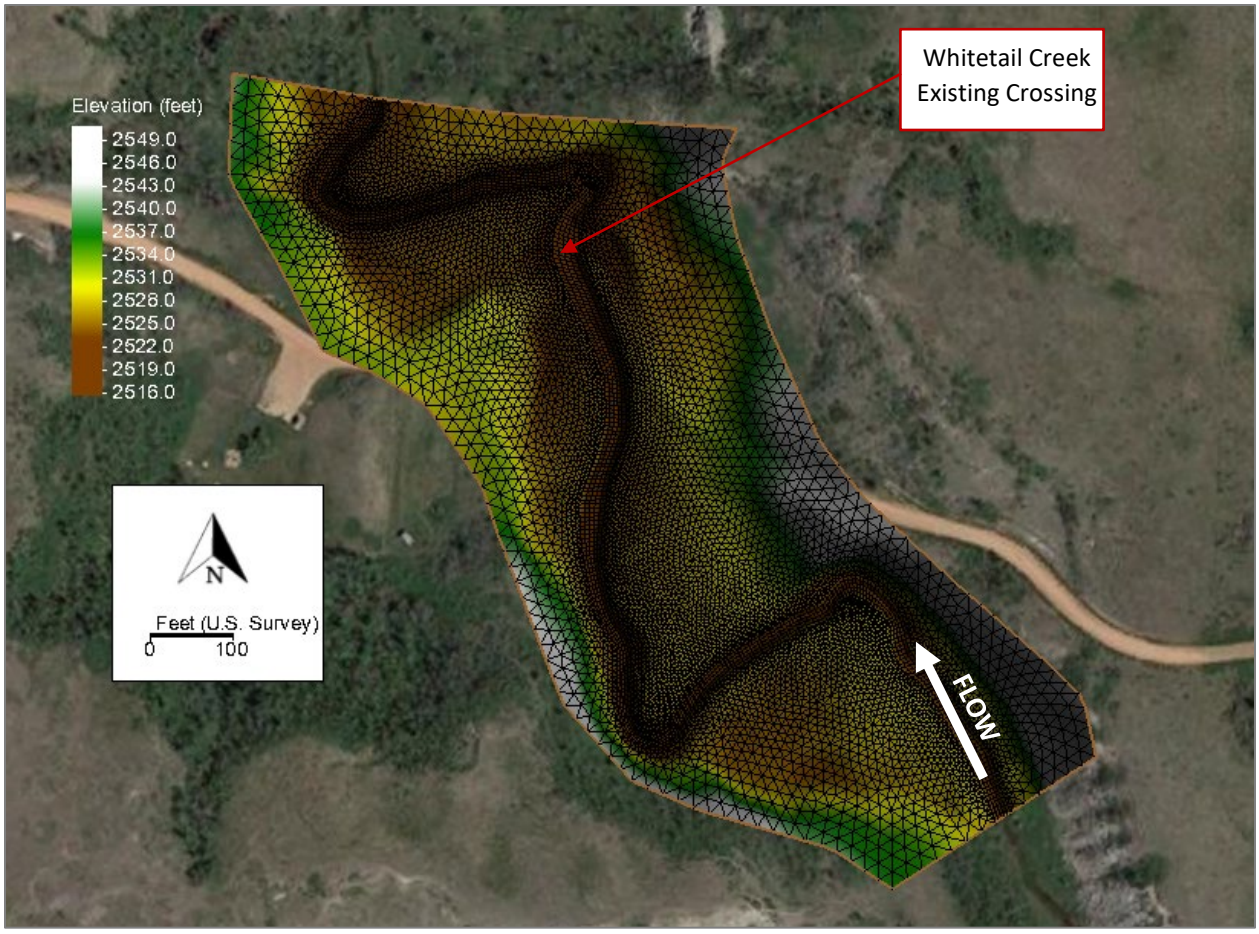

Figure 6: Whitetail Creek Existing SRH-2D Mesh

The upstream boundary conditions in the model were specified as a constant discharge using the peak flow values discussed in section 3.4. The downstream boundary conditions were specified as known water surface elevations obtained using Manning's equation and a energy grade line slope assumed to equal the streambed slope near the model downstream boundary.

SRH-2D uses Manning's "n" values to calculate bed friction. The land use types were delineated using a combination of field assesment and aerial imagery as shown in Figure 7 and Figure 8 for Magpie and Whitetail Creek, respectively. The roughness values used in the model are shown in Table 7.

Table 7: Project Land Cover Types and Manning's Roughness

Land Use	Manning's "n"
Main Channel	0.03
Floodplain Brush	0.05
Floodplain Trees	0.08
Gravel Road	0.025

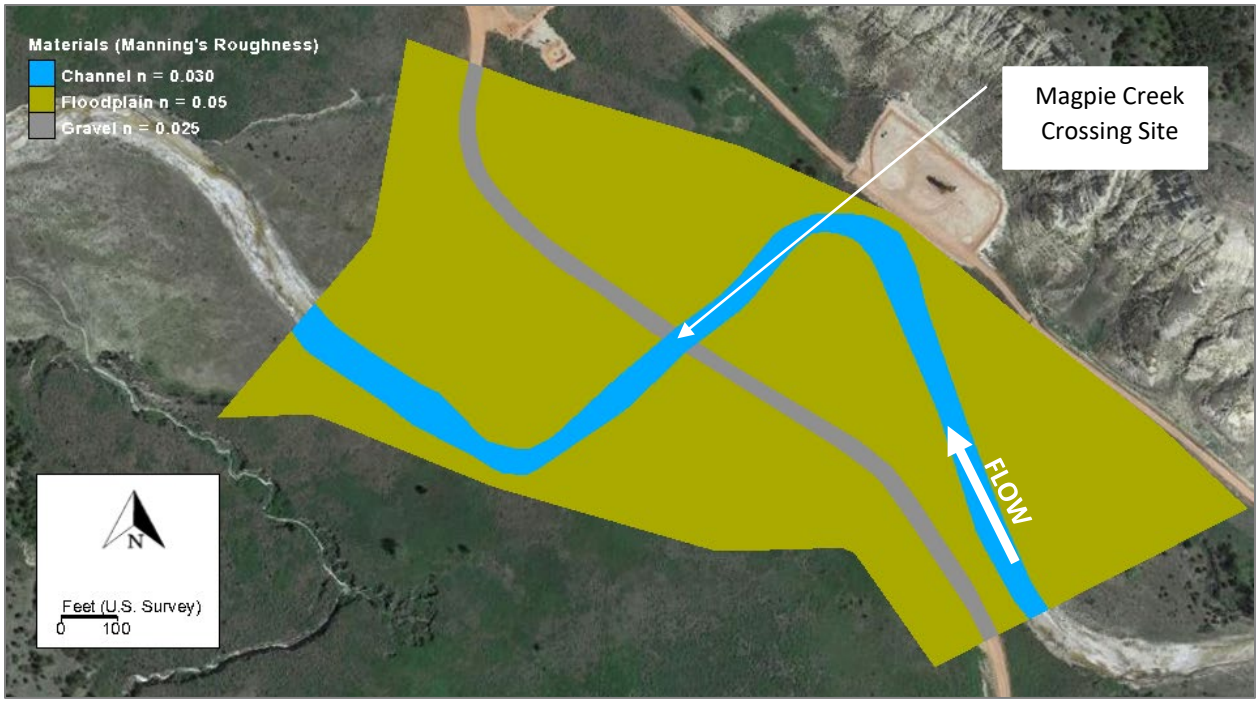

Figure 7: Magpie Creek Land Cover Types and Manning's Roughness

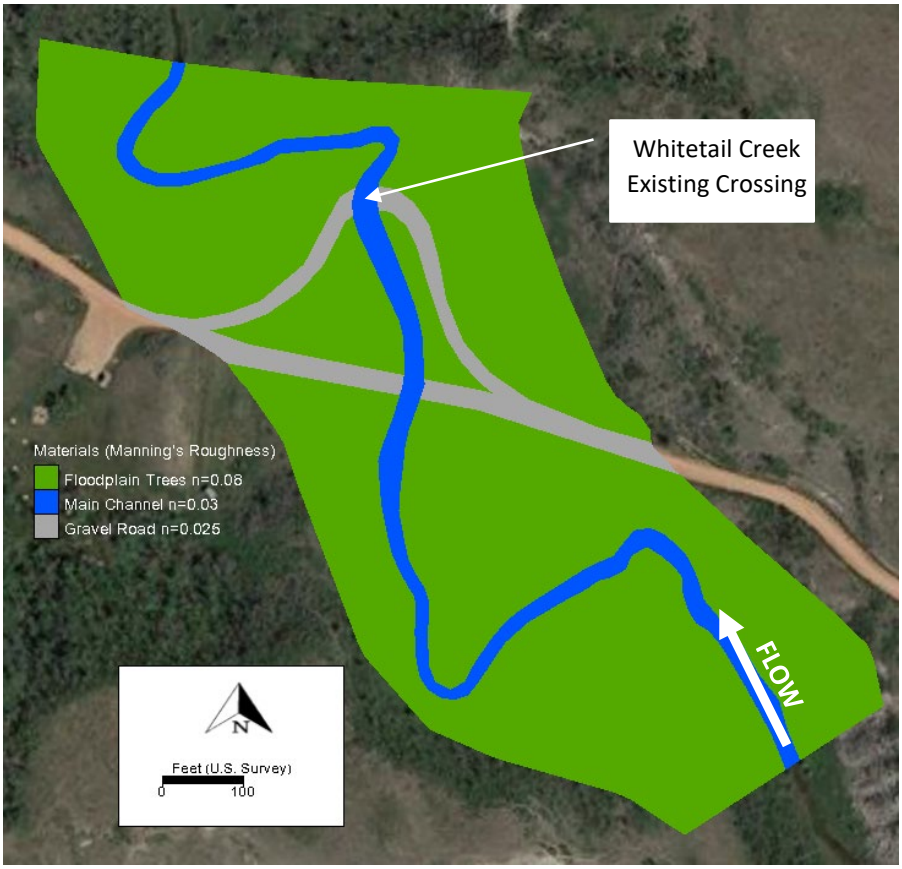

Figure 8: Whitetail Creek Land Cover Types and Manning's Roughness

4.3 HYDRAULIC MODEL RESULTS

4.3.1 Magpie Creek Existing Conditions

The existing crossing at Magpie Creek is a natural bottom low water crossing, the crossing becomes impassable during flow periods and is a safety and mobility problem. Existing conditions model results show a depth greater than 2 feet at the stream thalweg for the 2-year flow and greater than 4 feet for the 10-year flow. The 10-year flow exhibits significant overbank flooding as expected. Depth results are graphically shown in Figure 9 and Figure 10 for the 2-year and 10-year events, respectively.

Figure 9: Magpie Creek 2-Year Water Depth

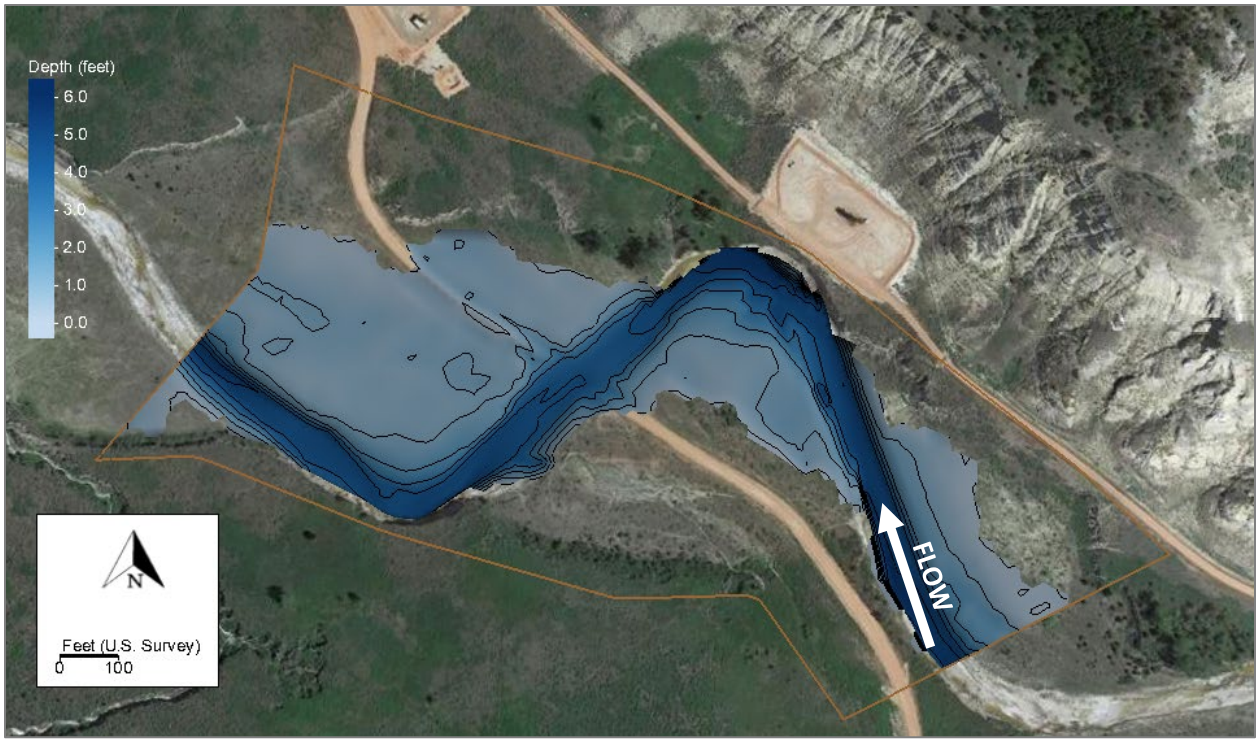

Figure 10: Magpie Creek 10-Year Water Depth

4.3.2 Magpie Creek Proposed Conditions

For Magpie Creek, the proposed crossing is a 114-feet three-span bridge with 2H:1V spill-through abutment slopes supported on groups of cylindrical piers. The proposed roadway will be raised to an approximate elevation of 2,148 feet. The waterway bottom width is approximately 70-feet. The SRH-2D mesh was modified to include the roadway embankment. The bridge low chord allows conveyance of the 200-year peak flow without pressure flow; therefore, a pressure flow boundary condition was not used in the model. The piers were modeled as holes in the mesh to obtain detailed hydraulic results to be used in the pier scour equations discussed in the following sections. An excerpt of the proposed SRH-2D mesh near the bridge is shown in Figure 11.

Summary hydraulic results and water surface profiles were extracted along cross sections and profile baseline as shown in Figure 12. The water surface profile is shown in Figure 13. Due to the two-dimensional model domain, the profiles do not represent the maximum water surface elevations. Average and maximum hydraulic results at the selected cross sections are shown in Table 8 to Table 10 for 2-year, 50-year, 100-year, and 200-year return periods, respectively. Maps showing water surface elevations for various return periods are included in Appendix B.

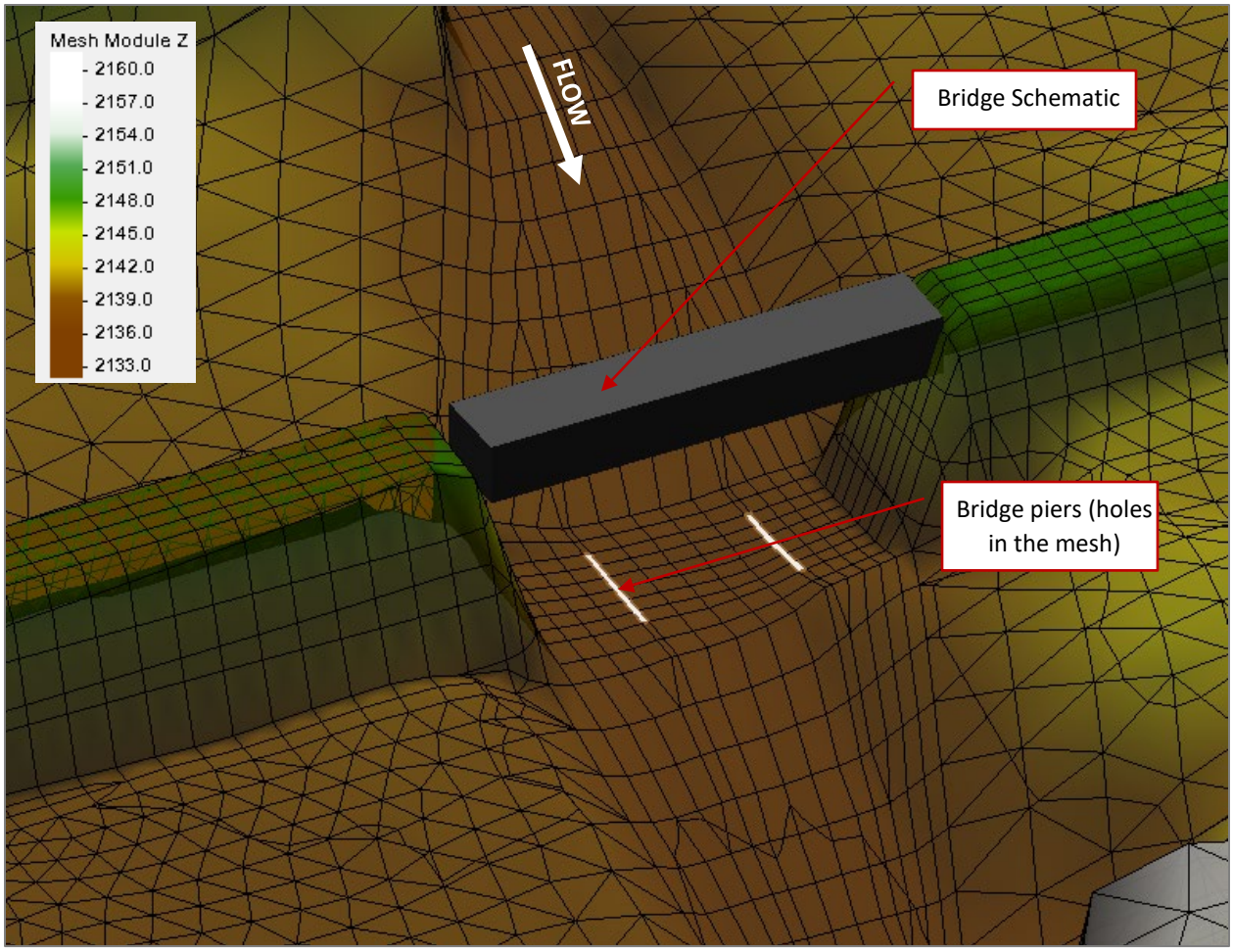

Figure 11: Magpie Creek Proposed Conditions SRH-2D Mesh

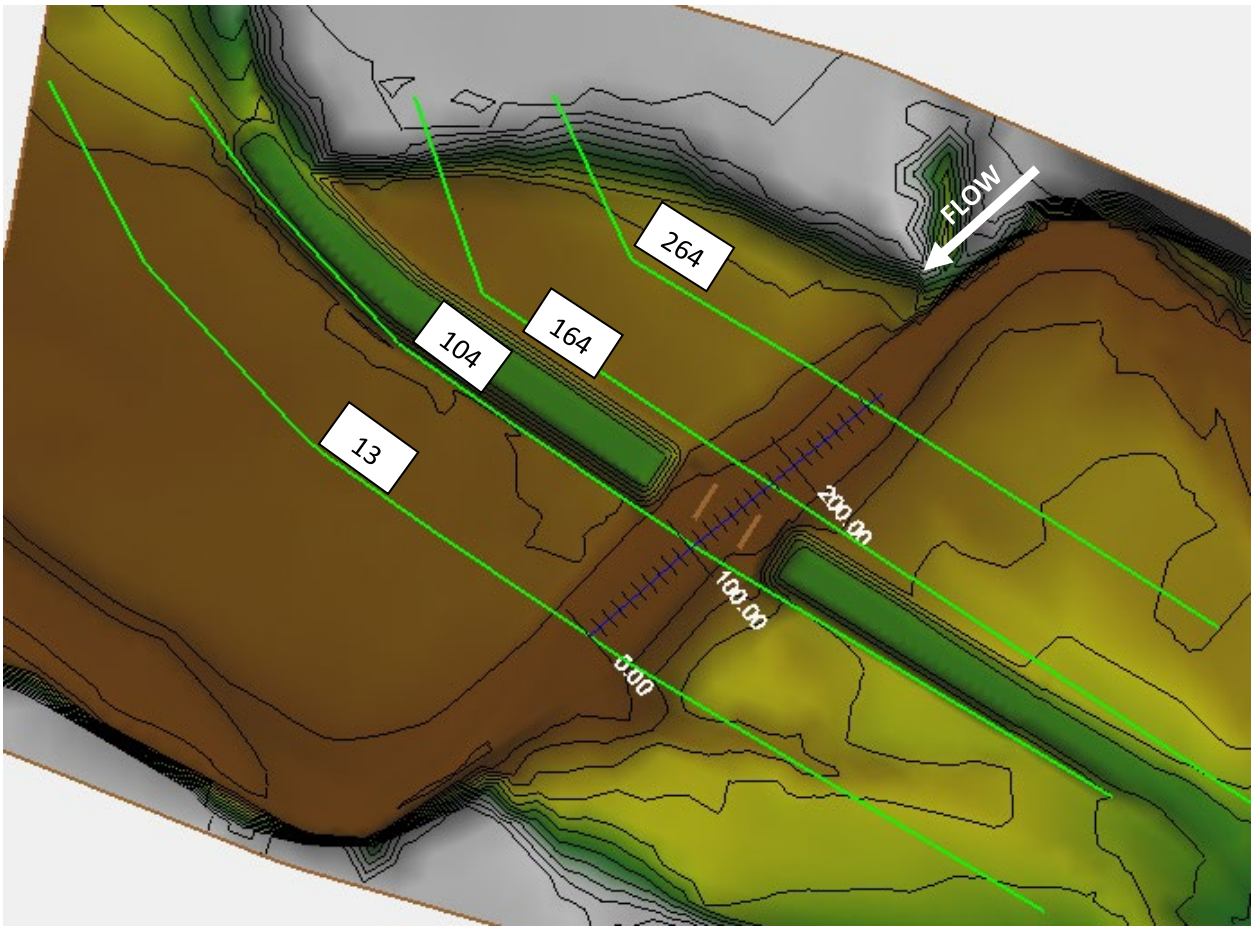

Figure 12: Magpie Creek Cross Sections and Profile Baseline

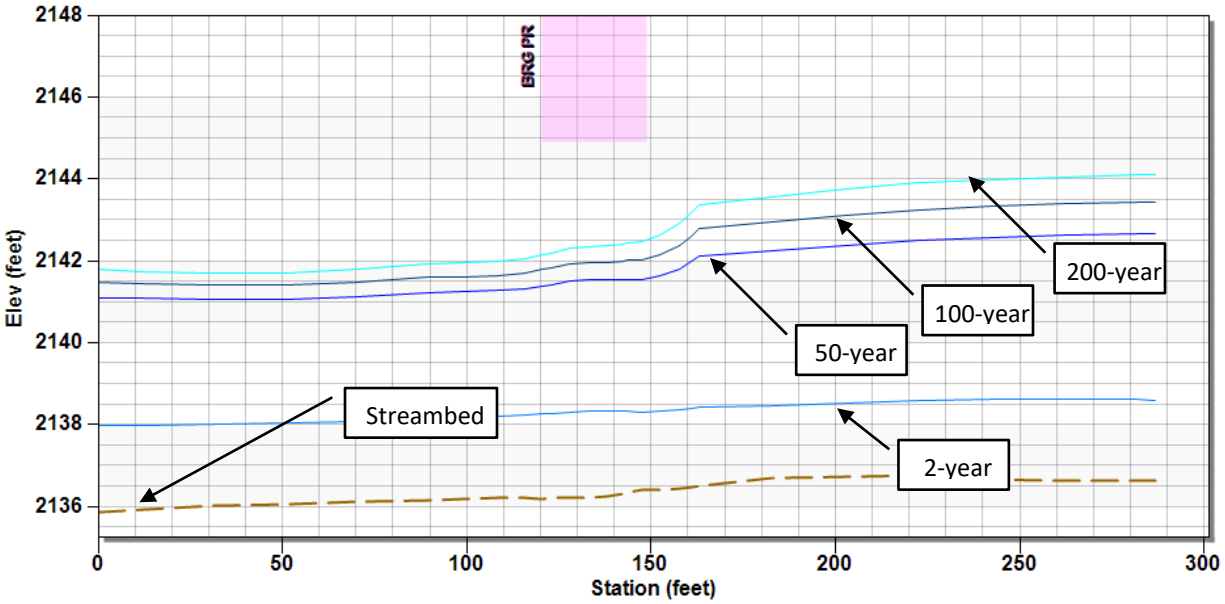

Figure 13: Proposed Magpie Creek Water Surface Profiles

Table 8: Magpie Creek 2-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
13	2.2	3.6	1.5	2.3	2,138.0	2,138.0
104	2.4	4.1	1.3	2.0	2,138.2	2,138.5
164	2.6	3.9	1.3	1.9	2,138.5	2,138.6
264	2.7	4.3	1.5	2.0	2,138.6	2,138.6

Table 9: Magpie Creek 50-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
13	2.6	8.1	1.7	5.4	2,140.3	2,141.1
104	3.1	9.9	2.1	5.1	2,140.7	2,141.7
164	1.8	7.5	2.9	5.6	2,142.6	2,143.2
264	2.7	6.8	2.9	6.0	2,142.9	2,143.6

Table 10: Magpie Creek 100-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
13	3.1	9.8	2.1	6.1	2,140.9	2,141.9
104	3.6	12.3	2.5	5.9	2,141.2	2,142.5
164	2.2	7.8	3.8	7.0	2,144.1	2,144.7
264	2.9	6.2	4.1	7.5	2,144.2	2,144.7

Table 11: Magpie Creek 200-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
13	2.9	9.0	1.9	5.8	2,140.6	2,141.5
104	3.4	11.4	2.4	5.5	2,140.9	2,142.1
164	2.1	7.6	3.4	6.3	2,143.4	2,144.1
264	2.8	6.4	3.5	6.8	2,143.6	2,144.2

To estimate freeboard requirements, the average 50-year water surface elevation was extracted 28 feet upstream of the bridge to approximate the point of maximum backwater and avoid uncertainty associated with the rapid drawdown of water at the bridge opening. Table 12 shows the minimum low chord elevation to meet 2 feet of freeboard requirement.

Table 12: 50-year Proposed Conditions Freeboard

Proposed Bridge	Return Period (year)	Maximum WSEL (ft) (28 feet upstream)	Minimum Freeboard (ft)	Minimum Low Chord (ft)
114' Bridge	50	2,142.6	2	2,144.6

While the project is not in a special flood hazard area mapped by FEMA, the impact of the proposed crossing on 100-year water surface elevations was evaluated. Figure 14 shows proposed minus existing 100-year water surface elevation. The results show that upstream of the proposed bridge the increase in 100-year water surface varies from 1 to 2.4 feet, shaded yellow and orange in the figure, for approximately 200 feet upstream. Beyond 200 feet the increase is less than 1-foot, shaded green in the figure, which is the PDDM backwater increase requirement in unmapped zones. At the upstream limit of the model domain the difference in water surface elevation is approximately 0.07 feet.

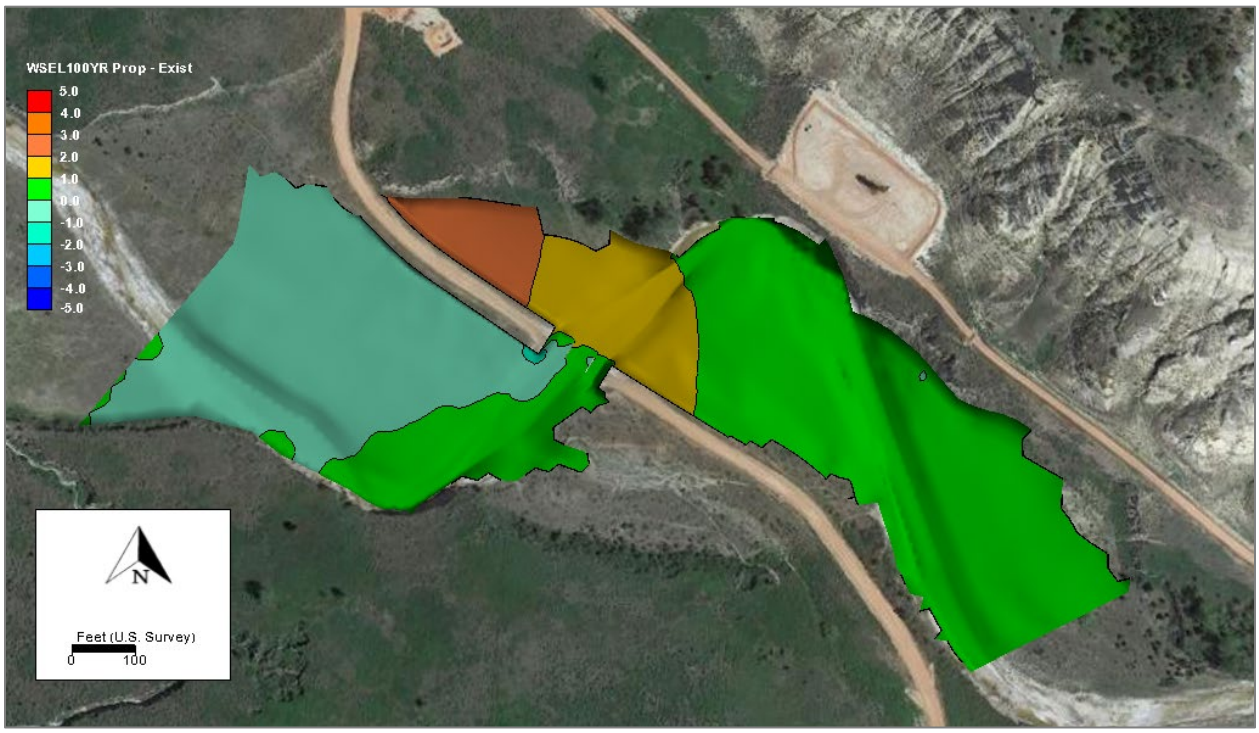

Figure 14: Magpie Creek 100-Year WSEL Difference (Proposed – Existing)

4.3.3 Whitetail Creek Existing Conditions

The existing crossing at Whitetail Creek is a natural bottom low water crossing, the crossing becomes impassable during flow periods and is a safety and mobility problem. Existing conditions model results show a depth greater than 2 feet at the stream thalweg for the 2-year flow and approximately 6 feet for the 10-year flow. Although Whitetail Creek is in a more confined setting, the 10-year flow exhibits shallow

overbank flooding as expected. Depth results are graphically shown in Figure 15 and Figure 16 for the 2-year and 10-year events, respectively.

Figure 15: Whitetail Creek 2-Year Water Depth

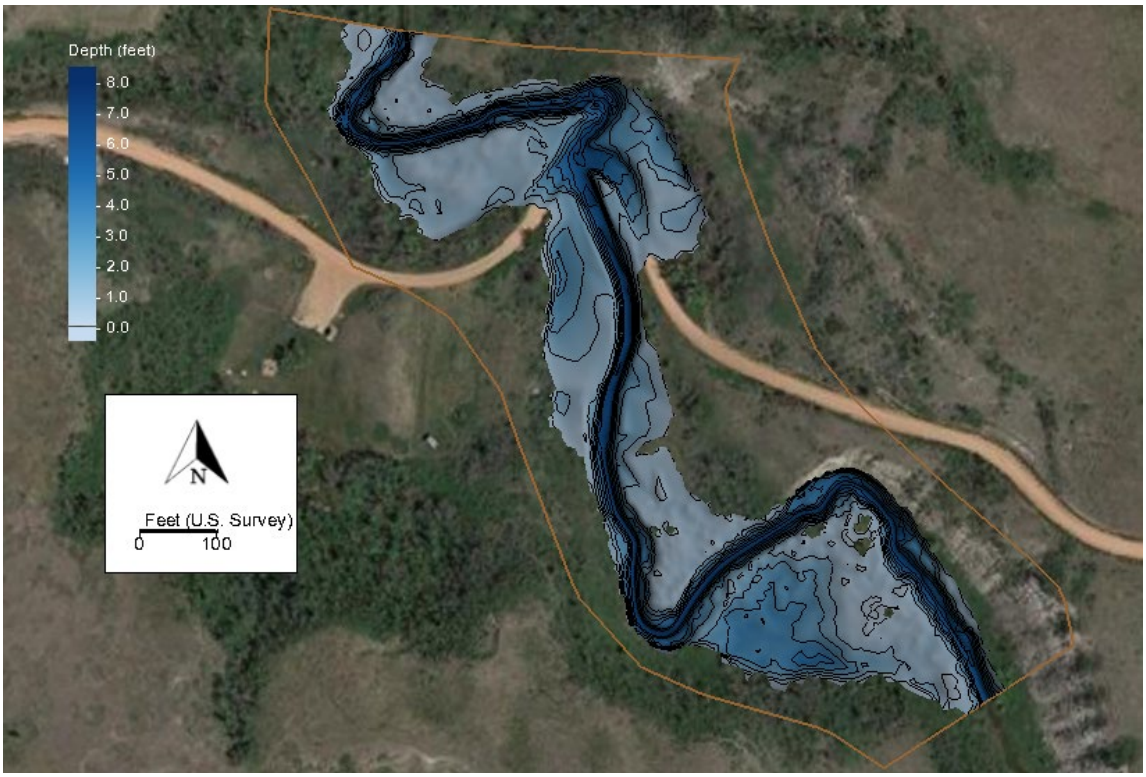

Figure 16: Whitetail Creek 10-Year Water Depth

4.3.4 Whitetail Creek Proposed Conditions

For Whitetail Creek, the proposed crossing will be elevated to maintain vehicles out of the flowing stream. Curve straightening will be required to meet the roadway geometric requirements and to locate the proposed crossing in a hydraulically favorable location. The bankfull width has been identified in previous reports as approximately 19 feet. The proposed crossing is a two-barrel concrete box culvert (CBC) that will convey the 25-year flow without overtopping of the roadway embankment. The proposed CBC consists of 12' span x 10' height barrels embedded a minimum of 1 foot. Proposed culvert characteristics are shown in Table 13.

Table 13: Whitetail Proposed Culvert Characteristics

Location	Type	Size (ft) (Span x height)	Number of Barrels	Length (ft)	Upstream Channel Invert (ft)	Downstream Channel Invert (ft)	Upstream Culvert Invert (ft)	Downstream Culvert Invert (ft)	Overtopping Elevation (ft)
Whitetail Creek	Concrete Box Culvert	12 x 10	2	34	2,519.4	2,519.2	2,518.4	2,518.2	2,529.3

The SRH-2D mesh was modified to include the proposed roadway embankment. The culvert was modeled as a pressure flow boundary condition. The barrel wall was modeled as a 1-ft wide obstruction. An excerpt of the SRH-2D mesh in the vicinity of the crossing is shown in Figure 17.

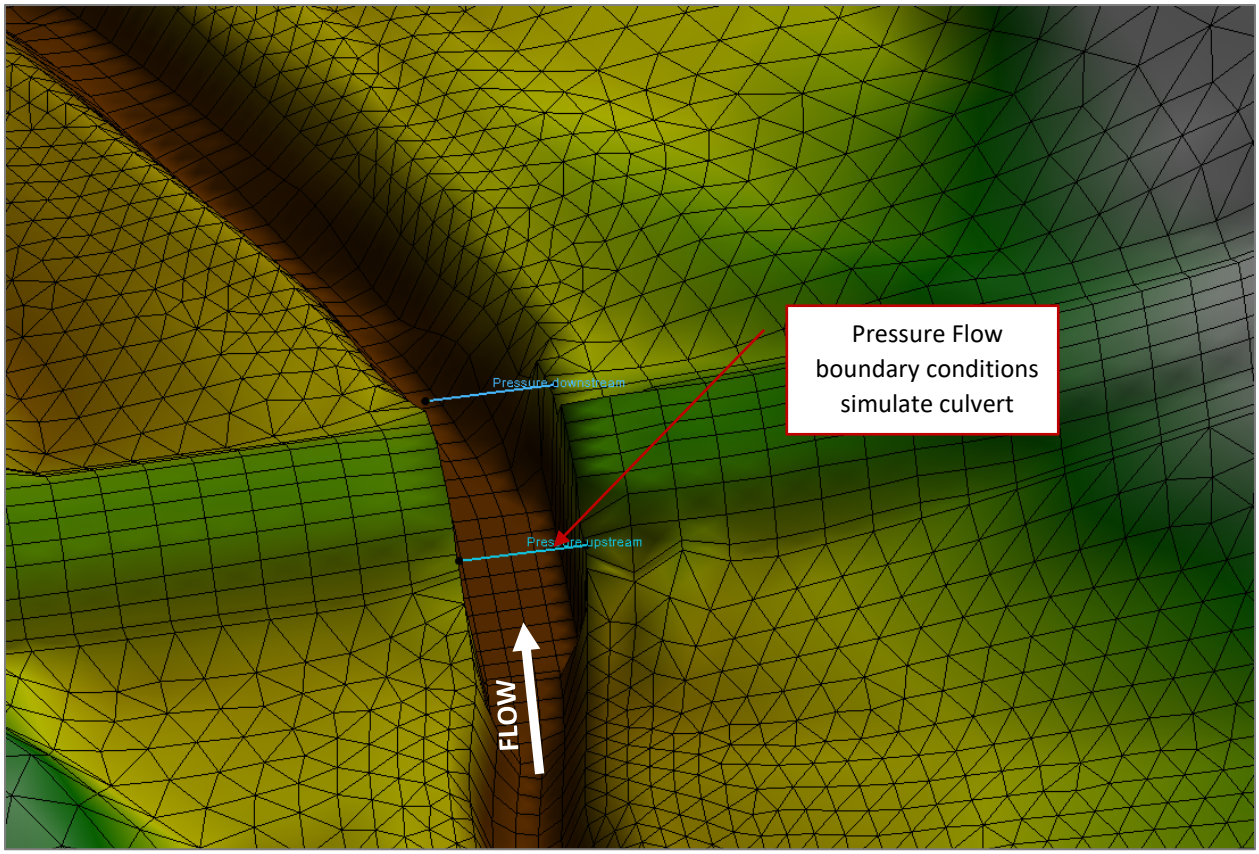

Figure 17: Whitetail Creek Proposed SRH-2D Mesh

Summary hydraulic results and water surface profiles were extracted along cross sections and profile baseline as shown in Figure 18. The water surface profile is shown in Figure 19. Due to the two-dimensional model domain, the profiles do not necessarily represent the maximum water surface elevations. Average and maximum hydraulic results at the selected cross sections are shown in Table 14 to Table 17 for 2-year, 15-year, 25-year, and 100-year return periods, respectively. Maps showing water surface elevations for various return periods are included in Appendix B.

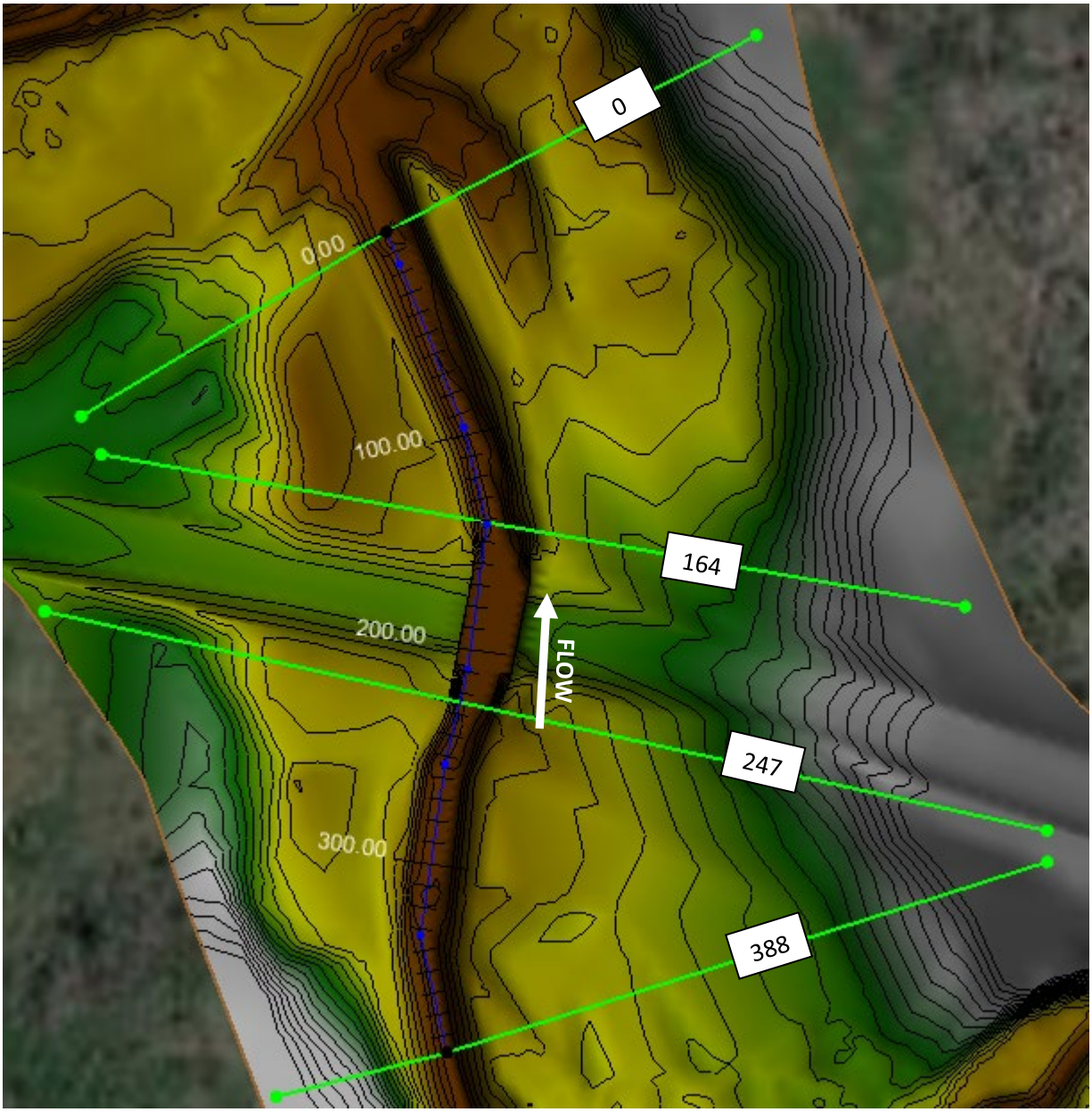

Figure 18: Whitetail Creek Cross Sections and Profile Baseline

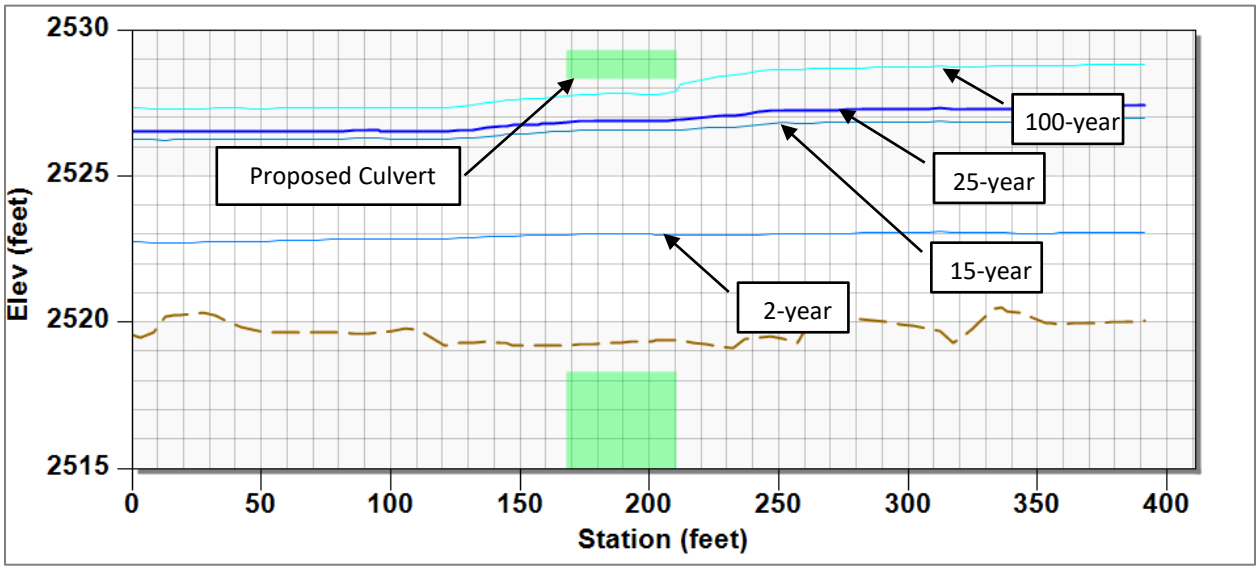

Figure 19: Proposed Whitetail Creek Water Surface Profiles

Table 14: Whitetail Creek 2-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
0	2.4	3.7	1.5	3.1	2,523.1	2,523.1
164	1.8	2.4	3.0	3.8	2,523.0	2,523.0
247	1.5	2.3	2.0	3.7	2,522.9	2,523.0
388	0.8	2.4	1.3	3.3	2,522.7	2,522.7

Table 15: Whitetail Creek 15-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
0	1.7	4.9	1.8	7.0	2,527.0	2,527.1
164	1.0	4.9	2.1	7.5	2,526.8	2,526.9
247	1.2	4.9	2.4	7.2	2,526.3	2,526.6
388	0.8	4.1	2.5	6.8	2,526.3	2,526.3

Table 16: Whitetail Creek 25-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
0	1.8	4.7	2.1	7.4	2,527.4	2,527.5
164	1.1	5.2	2.4	7.9	2,527.2	2,527.3
247	1.3	5.5	2.6	7.4	2,526.6	2,526.9
388	0.9	4.4	2.8	7.1	2,526.5	2,526.5

Table 17: Whitetail Creek 100-year Proposed Conditions Hydraulic Results

Station	Velocity (ft/s)		Depth (ft)		WSEL (ft)	
	Average	Maximum	Average	Maximum	Average	Maximum
0	1.9	4.2	2.9	8.8	2,528.8	2,528.9
164	1.3	5.6	3.2	9.3	2,528.7	2,528.7
247	1.7	7.0	3.0	8.3	2,527.4	2,527.8
388	1.4	5.7	3.5	7.9	2,527.3	2,527.4

For the 25-year event the maximum headwater elevation is 2,527.3 feet which results in a headwater to depth ratio (HW/D) of 0.88 assuming a 9-foot opening height after embedment. For the 100-year event the maximum headwater elevation is 2,528.7 feet which results in a headwater to depth ratio (HW/D) of 1.03. There is no embankment overtopping for the 25-year or 100-year events. Figure 20 shows a sample embankment cross section taken approximately 50-feet west of the culvert. The cross section shows approximately 1.4 feet of freeboard with respect to the edge of shoulder for the 25-year event. The 100-year event reaches the edge of shoulder but doesn't encroach into the traveled way.

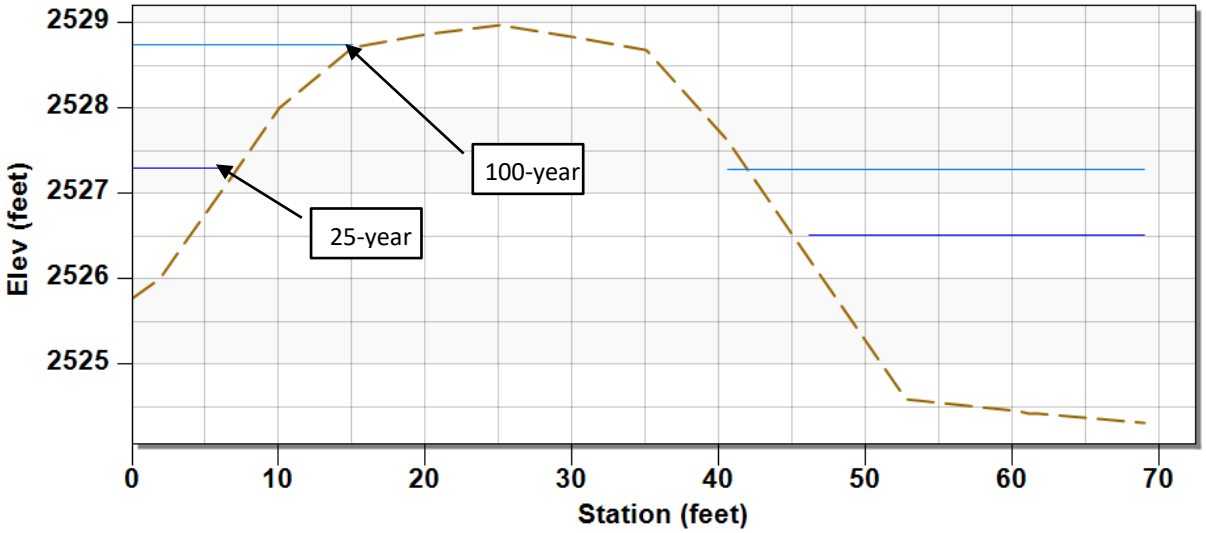

Figure 20: WSEL - Embankment Cross Section

While the project is not in a special flood hazard area mapped by FEMA, the impact of the proposed crossing on 100-year water surface elevations was evaluated. Figure 21 shows proposed minus existing 100-year water surface elevation. The results show that upstream of the proposed culvert the increase in 100-year water surface varies from 0 to 1-foot, shaded green in the figure, for approximately 500 feet. Beyond 500 feet water surface elevation decreases from 0 to 1-foot. The proposed crossing meets the PDDM backwater requirement for unmapped zones.

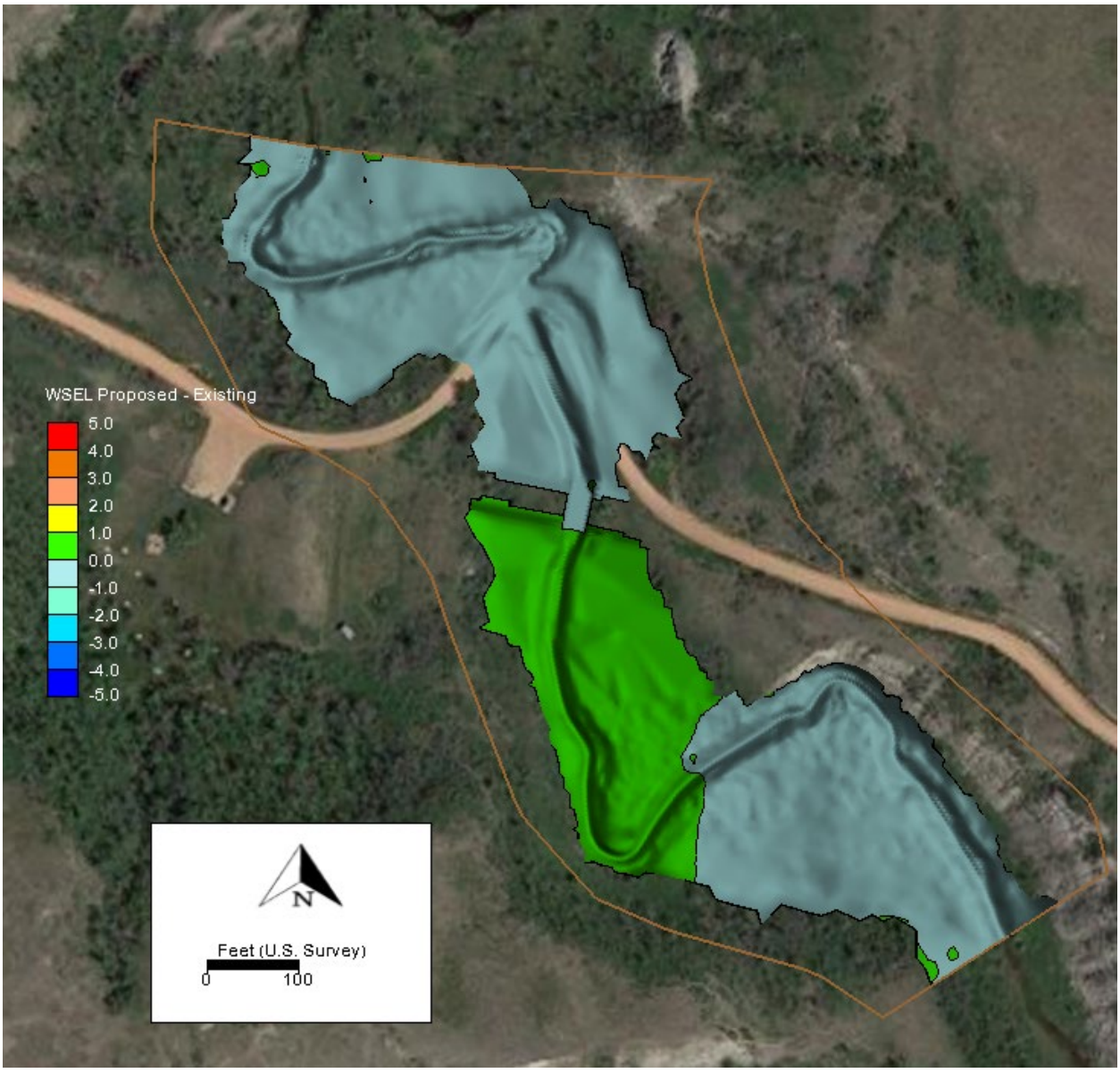

Figure 21: Whitetail Creek 100-Year WSEL Difference (Proposed – Existing)

4.4 MAGPIE CREEK SCOUR ASSESSMENT

4.4.1 Geotechnical Investigation

The geotechnical investigation was conducted in October 2018. For the Magpie Creek site, streambed soils are generally classified as well graded sand with silt (SW-SM). Based on the laboratory results, the median particle size (D50) of the streambed material is 4.1 mm (0.013 ft). For the scour evaluation a D50= 0.2 mm was chosen, this value represents the lower bound of the contraction scour equations. Based on

the boring logs there is the potential for finer material to be present in the soil column. Additional details can be found in the project Geotechnical Report.

4.4.2 Scour Estimates

Scour depth estimates were conducted in accordance with HEC-18 (Federal Highway Administration 2012) for the 100-year scour design flood and the 200-year scour check flood. Total scour is the combination of long-term degradation, contraction scour and local scour (abutment scour and pier scour). For this study, abutment scour was estimated using the NCHRP 24-20 method. Long-term degradation was assumed to be zero.

Contraction scour can occur under two conditions: live-bed and clear-water. Live-bed scour occurs when there is sediment transport of bed material from the upstream reach into the bridge section. Clear-water scour occurs when there is no transport of bed material into the bridge section. The applicable scour case is determined by comparing the mean velocity of the channel with the critical velocity for initiation of motion using the median size (D_{50}) of the streambed materials. Based on the materials observed on site and the results of the geotechnical investigation a live bed scour condition can be expected. A summary of contraction scour depths is shown in Table 18. In these tables negative scour values imply that zero scour is expected.

Table 18: Magpie Creek Contraction Scour Estimates

Parameter	100-Year	200-Year
D50 (ft)	0.0007	
Average Flow Depth Upstream of Contraction(ft)	6.65	7.12
Critical Velocity (ft/s)	1.33	1.35
Average Velocity Upstream (ft/s)	6.25	6.68
Scour Condition	Live Bed	Live Bed
Contraction Scour Depth (ft)	0.88	1.04
Adopted Contraction Scour Depth (ft)	**0.88**	**1.04**

Abutment scour was estimated using the NCHRP 24-20 method which applies an amplification factor to the contraction scour at the abutments, i.e., it includes contraction scour at each abutment as part of the estimate. A type a (main channel) scour condition was assumed in accordance with HEC-18. A summary of abutment scour depths is shown in Table 19.

Table 19: Magpie Creek Abutment Scour Estimates

Parameter	Left Abutment (Abut.1)		Right Abutment (Abut. 2)	
	100-Year	200-Year	100-Year	200-Year
D50 (ft)	0.0007		0.0007	
q2/q1	1.46	1.47	1.46	1.47
Amplification Factor	1.52	1.50	1.52	1.50
Average Velocity Upstream (ft/s)	6.25	6.68	6.25	6.68

Scour Condition	Type a Live Bed	Type a Live Bed	Type a Live Bed	Type a Live Bed
Abutment Scour Depth (ft)	8.45	8.94	9.23	9.73
Adopted Abutment Scour Depth (ft)	**8.45**	**8.94**	**9.23**	**9.73**

Pier scour was estimated using the HEC-18 pier scour equation.

Table 20: Magpie Creek Pier Scour Estimates

Parameter	Pier 1		Pier 2	
	100-Year	200-Year	100-Year	200-Year
Depth Upstream (ft)	6.30	6.86	6.30	6.86
Velocity Upstream (ft/s)	7.88	8.18	7.88	8.18
Width of Pier	1.50	1.50	1.50	1.50
Angle of Attack (°)	32.79	33.48	17.23	15.89
Column Spacing (ft)	7.50	7.50	7.50	7.50
Number of Columns	3	3	3	3
Pier Scour Depth (ft)	7.60	7.86	6.29	6.33
Total Pier Scour Depth Including Contraction Scour (ft)	**8.48**	**8.90**	**7.17**	**7.37**

It is recommended that the maximum scour elevations are applied to both abutments and that they are referenced to the channel thalweg. In addition, it is recommended that these elevations are also applied to the channel piers due to the potential for overlapping scour holes and uncertainty with the angle of attack estimate. A summary of total scour depths and recommended scour elevations are shown in Table 21.

Table 21: Magpie Creek Total Abutment Scour Results

Design Flood	Long Term Degradation (ft)	Contraction Scour (ft)	Adopted Pier/Abutment Scour Depth (ft)	Thalweg Elevation (ft)	Total Scour Elevation (ft)
100-year Scour Design Flood	0	0.88	8.94	2,136.15	2,127.21
200-year Scour Check Flood	0	1.04	9.73	2,136.15	2,126.42

Embankment abutment protection was designed in accordance with HEC-23 Design Guideline 14 (Federal Highway Administration 2009). Class 3 riprap is recommended based on the results of the hydraulic model. The recommended abutment protection layout is shown in Figure 22.

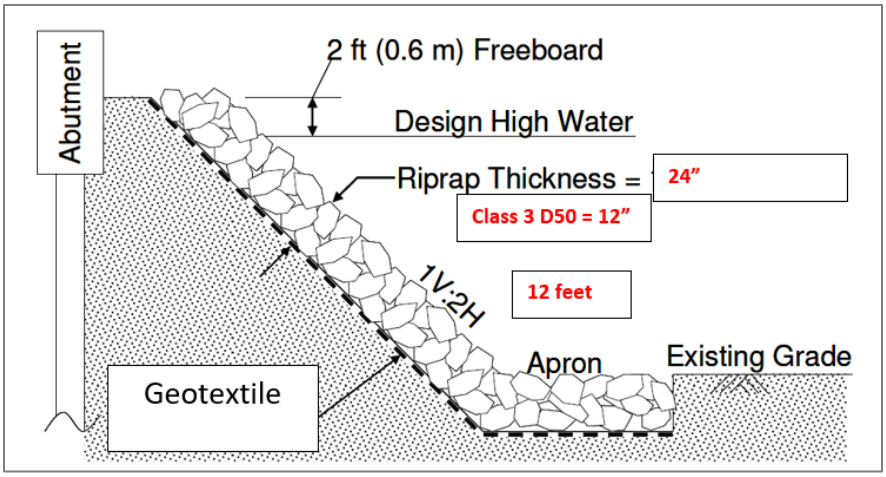

Figure 22: Recommended Abutment Protection

5 SUMMARY OF HYDRAULIC RECOMMENDATIONS

Hydrology and hydraulics analyses were conducted for the Magpie Creek and Whitetail Creek crossings as discussed in the preceding sections. Table 22 shows the summary of hydraulic recommendations.

Table 22: Summary of Hydraulic Recommendations

Site	Location	Proposed Structure Type	Geometric Parameters	Remarks
704	Magpie Creek	3-Span Bridge	Bridge Length = 114 feet Bridge Low Chord = 2,144.91	• Class 3 riprap abutment protection
795	Whitetail Creek	Concrete Box Culvert	Number of Barrels = 2 Span x Height = 12-ft x 10-ft	• Culvert embedded 1-foot minimum. • Class 2 riprap outlet protection

6 REFERENCES

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Williams-Sether, Tara. 2015. "Regional Regression Equations to Estimate Peak-Flow Frequency at Sites in North Dakota using Data Through 2009." U.S. Geological Survey Scientific Investigations Report 2015-5096.

Appendix A: Hydrology

Appendix B: Hydraulics

Appendix A: Hydrology

Magpie Creek StreamStats Report

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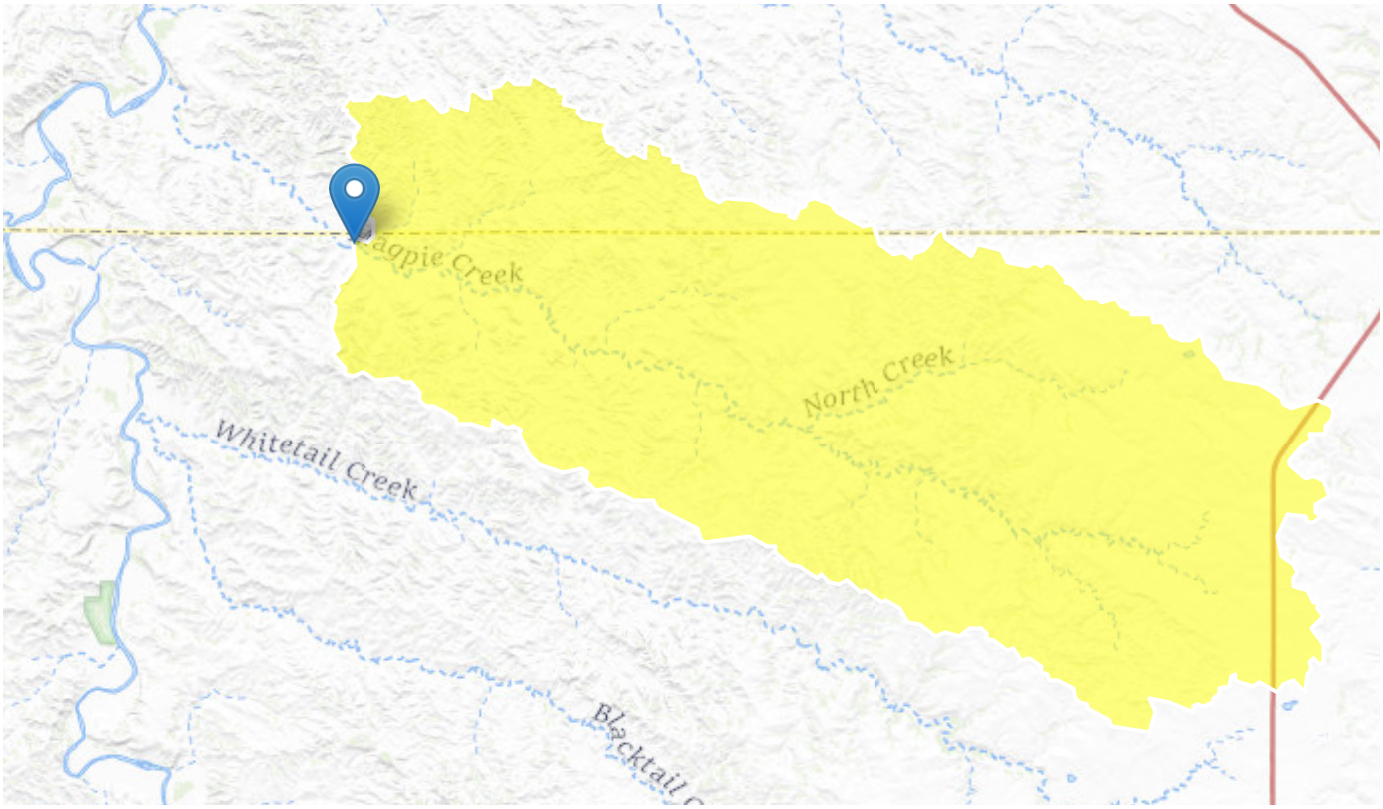

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	87.9	square miles
RUGGED	Ruggedness number computed as stream density times basin relief	1770	feet per mi
COMPRAT	A measure of basin shape related to basin perimeter and drainage area	2.17	dimensionless
AG_OF_DA	Agricultural Land in Percentage of Drainage Area (Idaho Logistic Regression Equations SIR 2006-5035	3.45	percent

Parameter Code	Parameter Description	Value	Unit
BASINPERIM	Perimeter of the drainage basin as defined in SIR 2004-5262	72.1	miles
BSLDEM10M	Mean basin slope computed from 10 m DEM	15.8	percent
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	17.13	feet per mi
ELEV	Mean Basin Elevation	2507	feet
ELEVMAX	Maximum basin elevation	2817	feet
ISOLAKEDA	Percent of total drainage area to isolated lakes	0.46	
ISOLAKESUM	Drainage area of isolated lakes	0.4	square miles
LAKEAREA	Percentage of Lakes and Ponds	0.0109	percent
LAKEAREASU	Total area of isolated lakes and ponds	0.00957	square miles
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	0.41	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.16	percent
LFPLENGTH	Length of longest flow path	30.2	miles
MINBELEV	Minimum basin elevation	2139	feet
PRECIP	Mean Annual Precipitation	15.2	inches
SLOPERAT	Slope ratio computed as longest flow path (10-85) slope divided by basin slope	0.0206	dimensionless
SOILPERM	Average Soil Permeability	1.65	inches per hour
STRMTOT	total length of all mapped streams (1:24,000-scale) in the basin	229	miles

Peak-Flow Statistics Parameters [Peak Region B 2015 5096]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	87.9	square miles	0.11	8343
RUGGED	Ruggedness_Number	1770	feet per mi	68	7820

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
COMPRAT	Compactness Ratio	2.17	dimensionless	1.4	3.48

Peak-Flow Statistics Flow Report [Peak Region B 2015 5096]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	ASEp
50-percent AEP flood	397	ft^3/s	75.3
20-percent AEP flood	1110	ft^3/s	60.3
10-percent AEP flood	1730	ft^3/s	58
4-percent AEP flood	2660	ft^3/s	58.8
2-percent AEP flood	3400	ft^3/s	60.7
1-percent AEP flood	4170	ft^3/s	63.5
0.2-percent AEP flood	5970	ft^3/s	70.1

Peak-Flow Statistics Citations

Williams-Sether, T.,2015, Regional regression equations to estimate peak-flow frequency at sites in North Dakota using data through 2009: U.S. Geological Survey Scientific Investigations Report 2015–5096, 12 p. (http://dx.doi.org/10.3133/sir20155096)

Application Version: 4.6.2
StreamStats Services Version: 1.2.22
NSS Services Version: 2.1.2

Whitetail StreamStats Report

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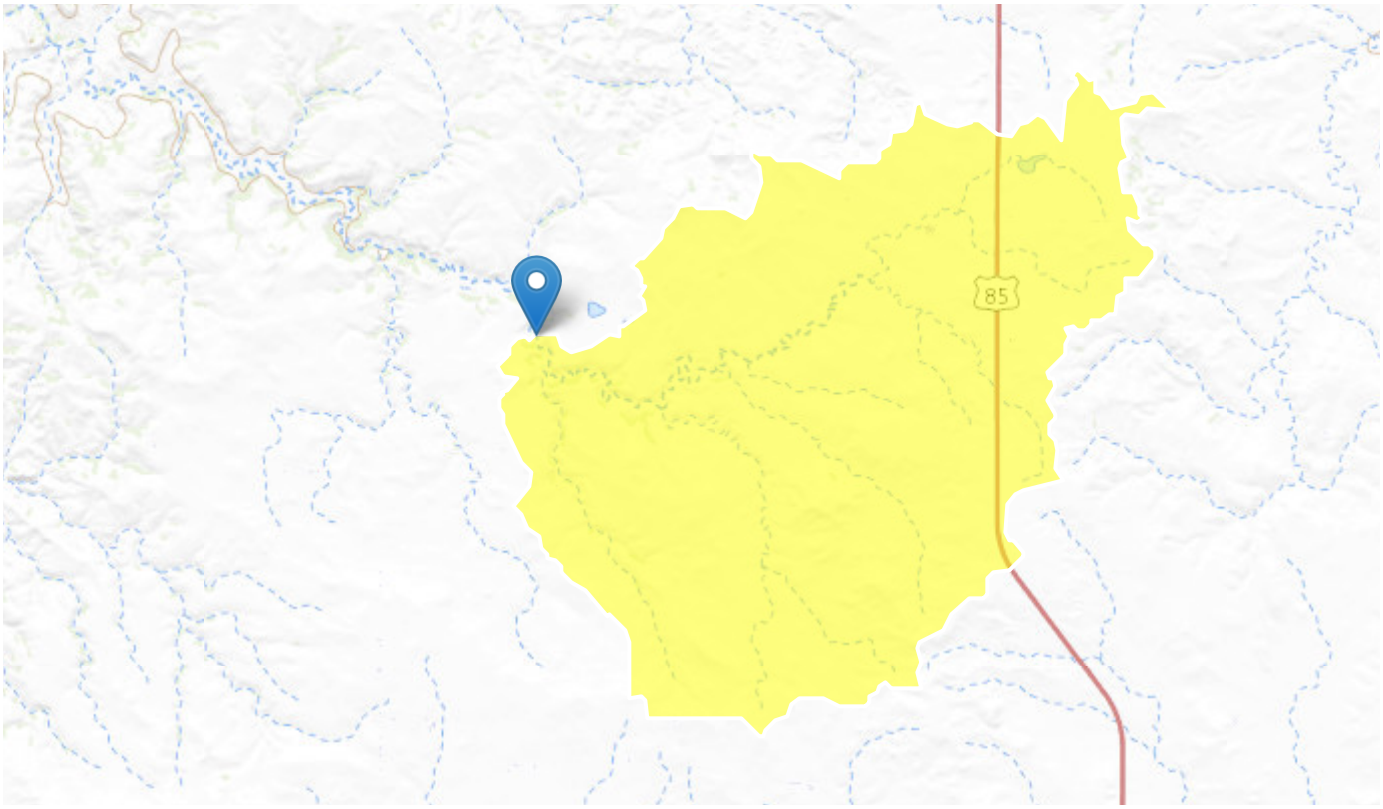


Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	16.7	square miles
RUGGED	Ruggedness number computed as stream density times basin relief	892	feet per mi
COMPRAT	A measure of basin shape related to basin perimeter and drainage area	1.94	dimensionless
AG_OF_DA	Agricultural Land in Percentage of Drainage Area (Idaho Logistic Regression Equations SIR 2006-5035	15.3	percent
BASINPERIM	Perimeter of the drainage basin as defined in SIR 2004-5262	28.1	miles

Parameter Code	Parameter Description	Value	Unit
BSLDEM10M	Mean basin slope computed from 10 m DEM	5.38	percent
CSL1085LFP	Change in elevation divided by length between points 10 and 85 percent of distance along the longest flow path to the basin divide, LFP from 2D grid	19.58	feet per mi
ELEV	Mean Basin Elevation	2722	feet
ELEVMAX	Maximum basin elevation	2896	feet
ISOLAKEDA	Percent of total drainage area to isolated lakes	0	
ISOLAKESUM	Drainage area of isolated lakes	0	square miles
LAKEAREA	Percentage of Lakes and Ponds	0	percent
LAKEAREASU	Total area of isolated lakes and ponds	0	square miles
LC11DEV	Percentage of developed (urban) land from NLCD 2011 classes 21-24	1.67	percent
LC11IMP	Average percentage of impervious area determined from NLCD 2011 impervious dataset	0.37	percent
LFPLENGTH	Length of longest flow path	11.1	miles
MINBELEV	Minimum basin elevation	2535	feet
PRECIP	Mean Annual Precipitation	14.9	inches
SLOPERAT	Slope ratio computed as longest flow path (10-85) slope divided by basin slope	0.069	dimensionless
SOILPERM	Average Soil Permeability	1.34	inches per hour
STRMTOT	total length of all mapped streams (1:24,000-scale) in the basin	41.3	miles

Peak-Flow Statistics Parameters [Peak Region B 2015 5096]

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	16.7	square miles	0.11	8343
RUGGED	Ruggedness_Number	892	feet per mi	68	7820
COMPRAT	Compactness Ratio	1.94	dimensionless	1.4	3.48

Peak-Flow Statistics Flow Report [Peak Region B 2015 5096]

PIl: Prediction Interval-Lower, PIu: Prediction Interval-Upper, ASEp: Average Standard Error of Prediction, SE: Standard Error (other -- see report)

Statistic	Value	Unit	ASEp
50-percent AEP flood	119	ft^3/s	75.3
20-percent AEP flood	340	ft^3/s	60.3
10-percent AEP flood	538	ft^3/s	58
4-percent AEP flood	836	ft^3/s	58.8
2-percent AEP flood	1070	ft^3/s	60.7
1-percent AEP flood	1320	ft^3/s	63.5
0.2-percent AEP flood	1910	ft^3/s	70.1

Peak-Flow Statistics Citations

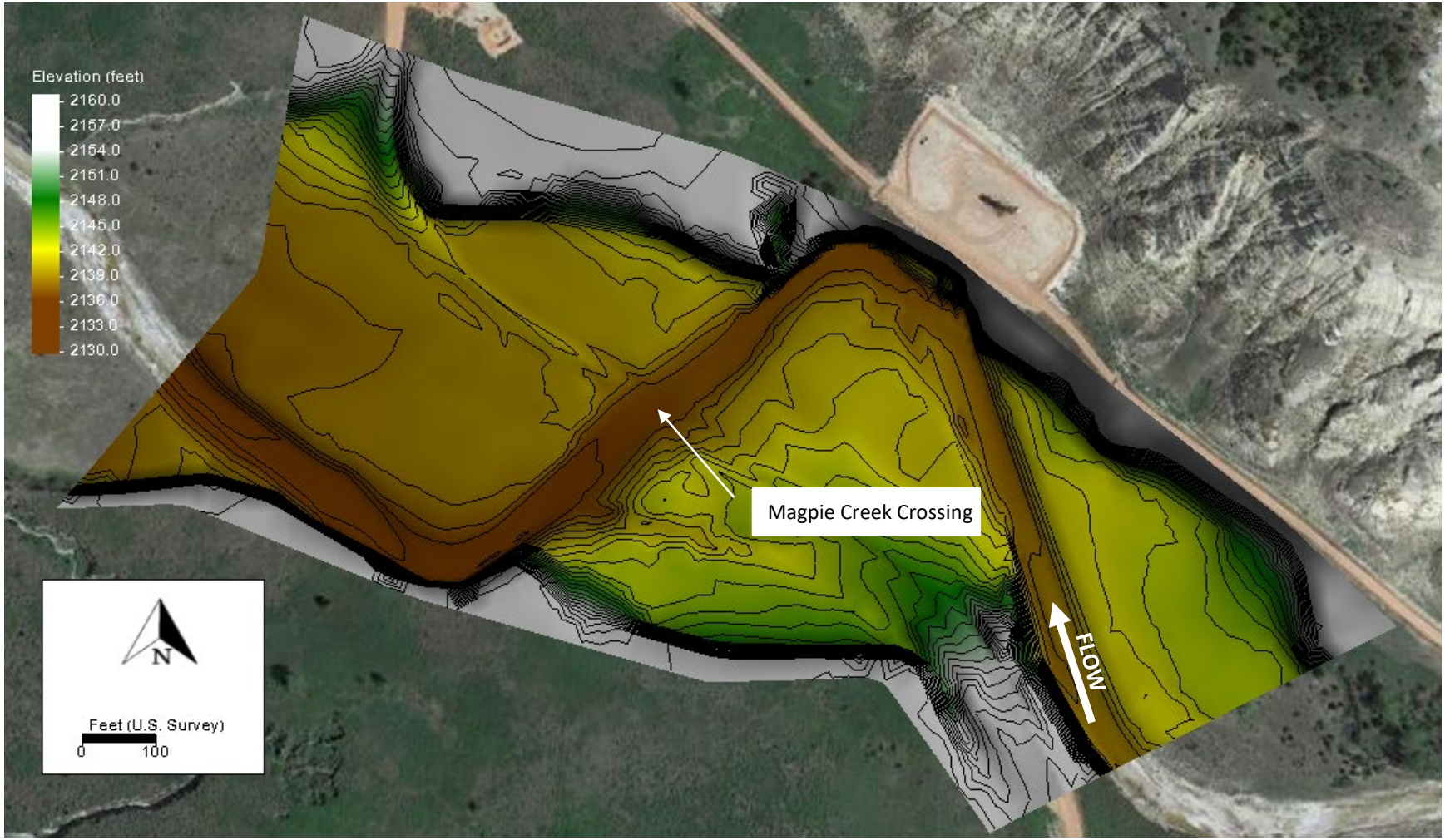
Williams-Sether, T.,2015, Regional regression equations to estimate peak-flow frequency at sites in North Dakota using data through 2009: U.S. Geological Survey Scientific Investigations Report 2015–5096, 12 p. (http://dx.doi.org/10.3133/sir20155096)

Application Version: 4.6.2
StreamStats Services Version: 1.2.22
NSS Services Version: 2.1.2

Appendix B: Hydraulics

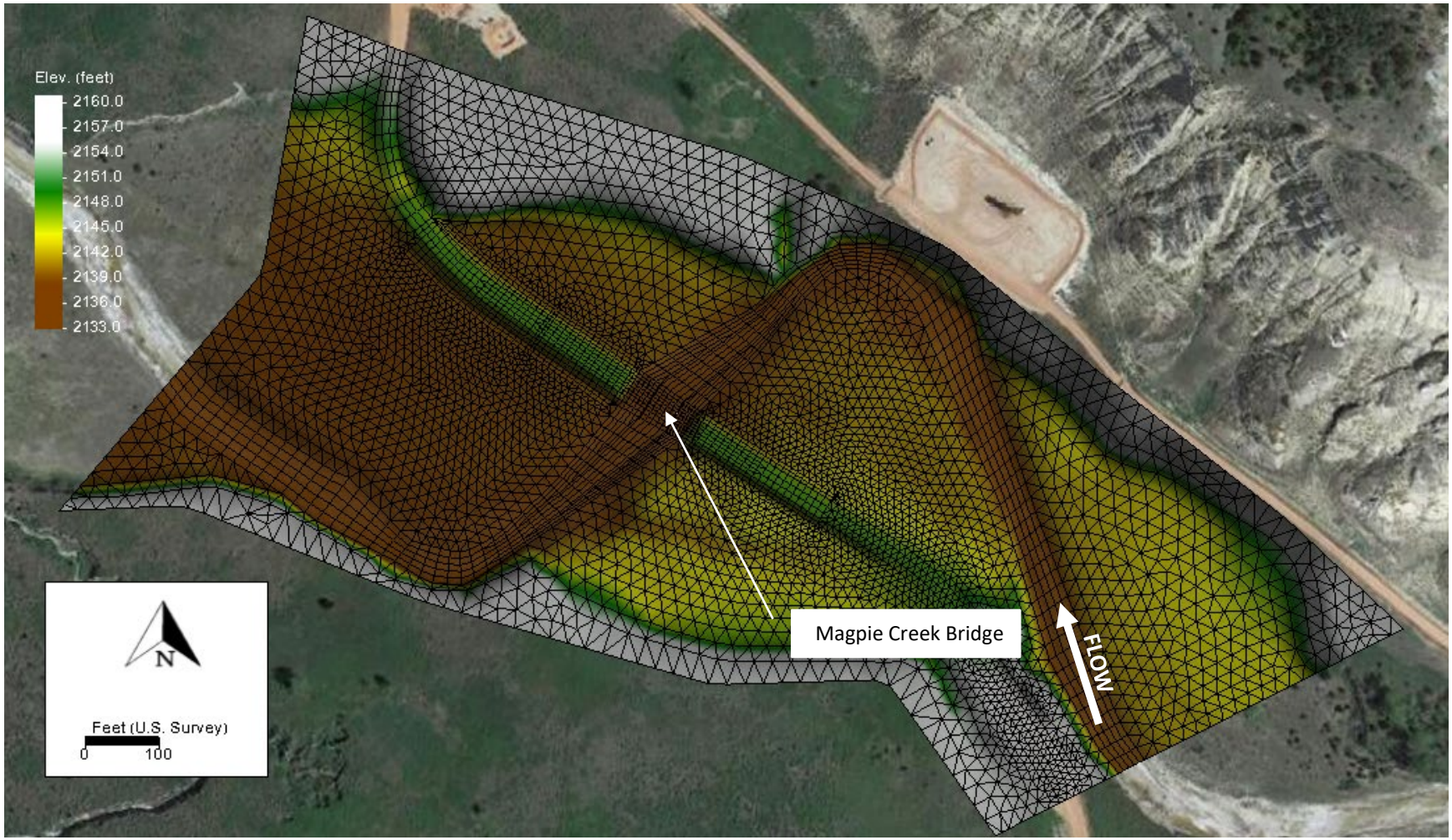
Magpie Creek SRH-2D Information

Scatter Data (Topographic Surface)



Magpie Creek SRH-2D Information (cont.)

SRH-2D Computational Mesh and Elevations



Magpie Creek SRH-2D Information (cont.)

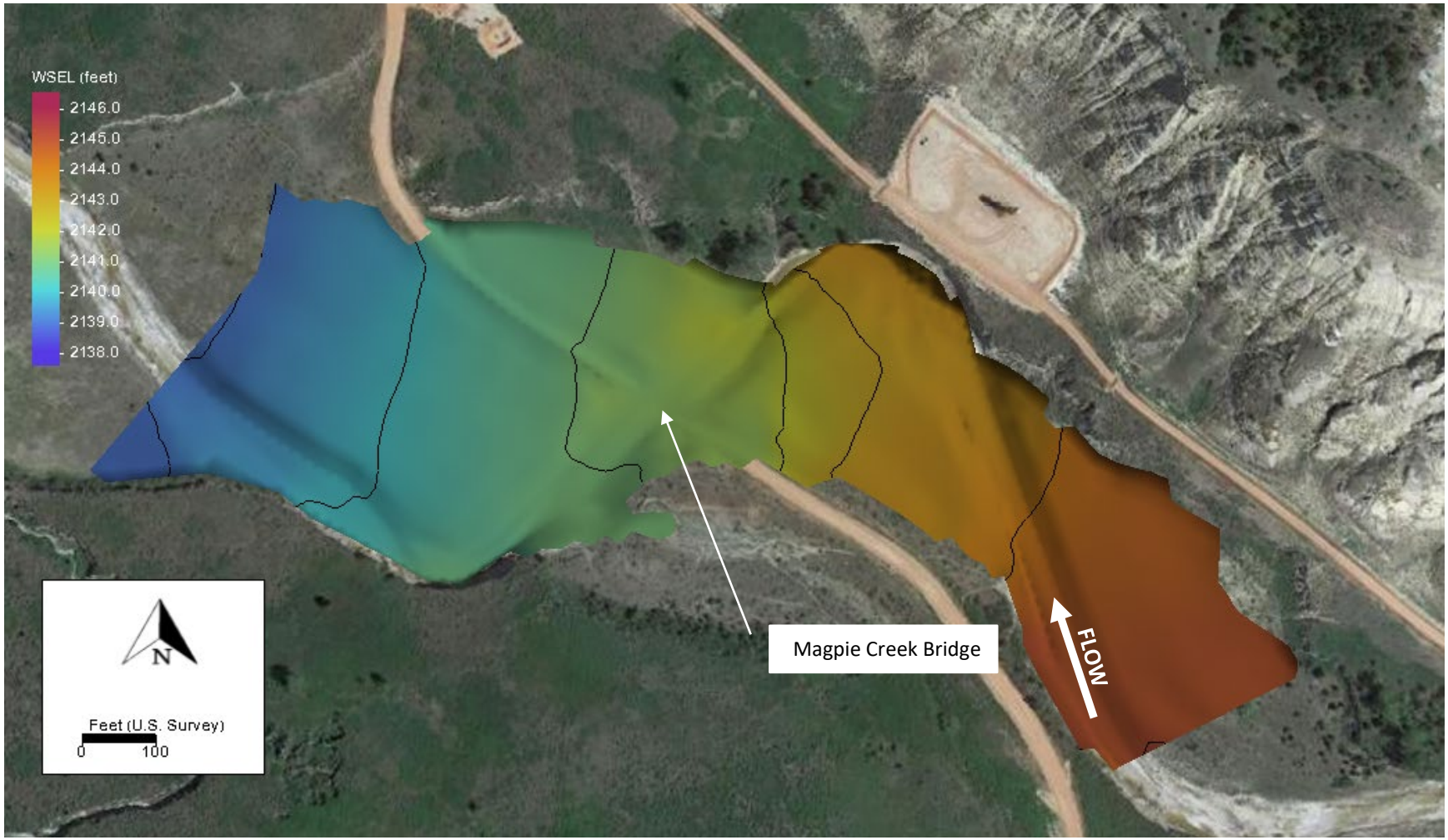
Land Use – Manning's Roughness Coefficients

MagpieCreek SRH-2D Information (cont.)

2-Year Water Surface Elevation – Existing Conditions

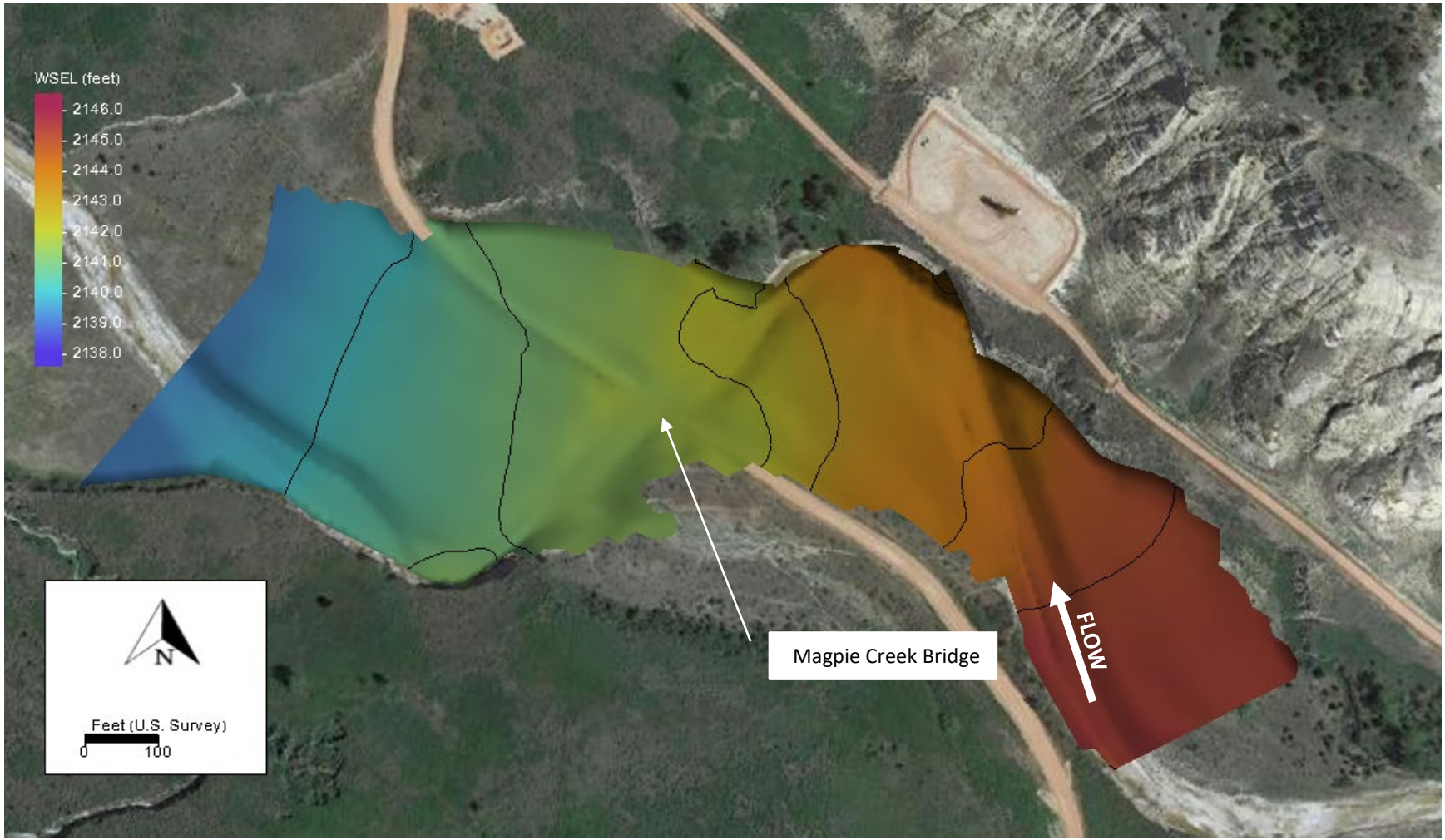
Magpie Creek SRH-2D Information (cont.)

50-Year Water Surface Elevation – Existing Conditions



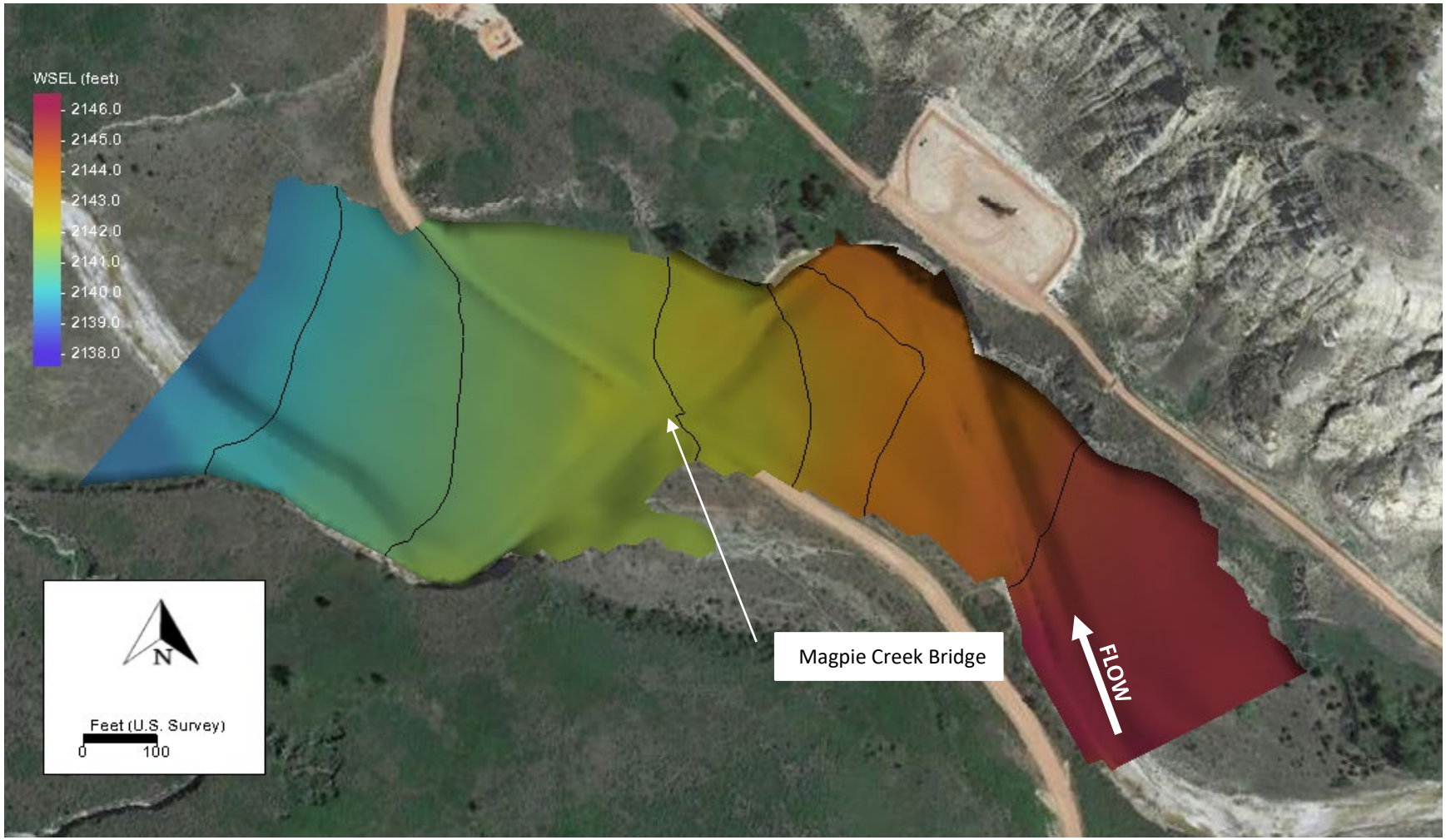
MagpieCreek SRH-2D Information (cont.)

100-Year Water Surface Elevation – Existing Conditions



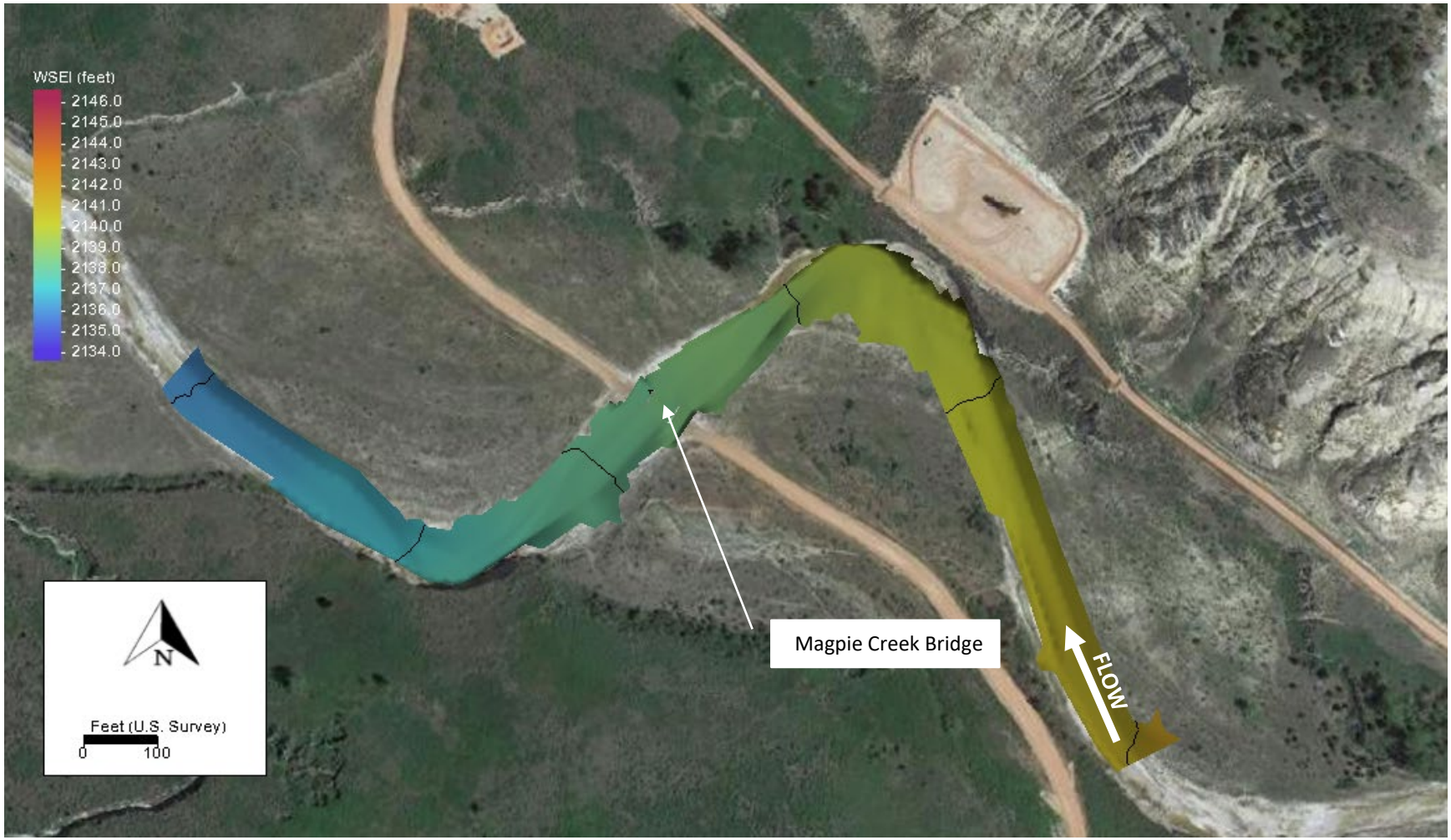
Magpie Creek SRH-2D Information (cont.)

200-Year Water Surface Elevation – Existing Conditions



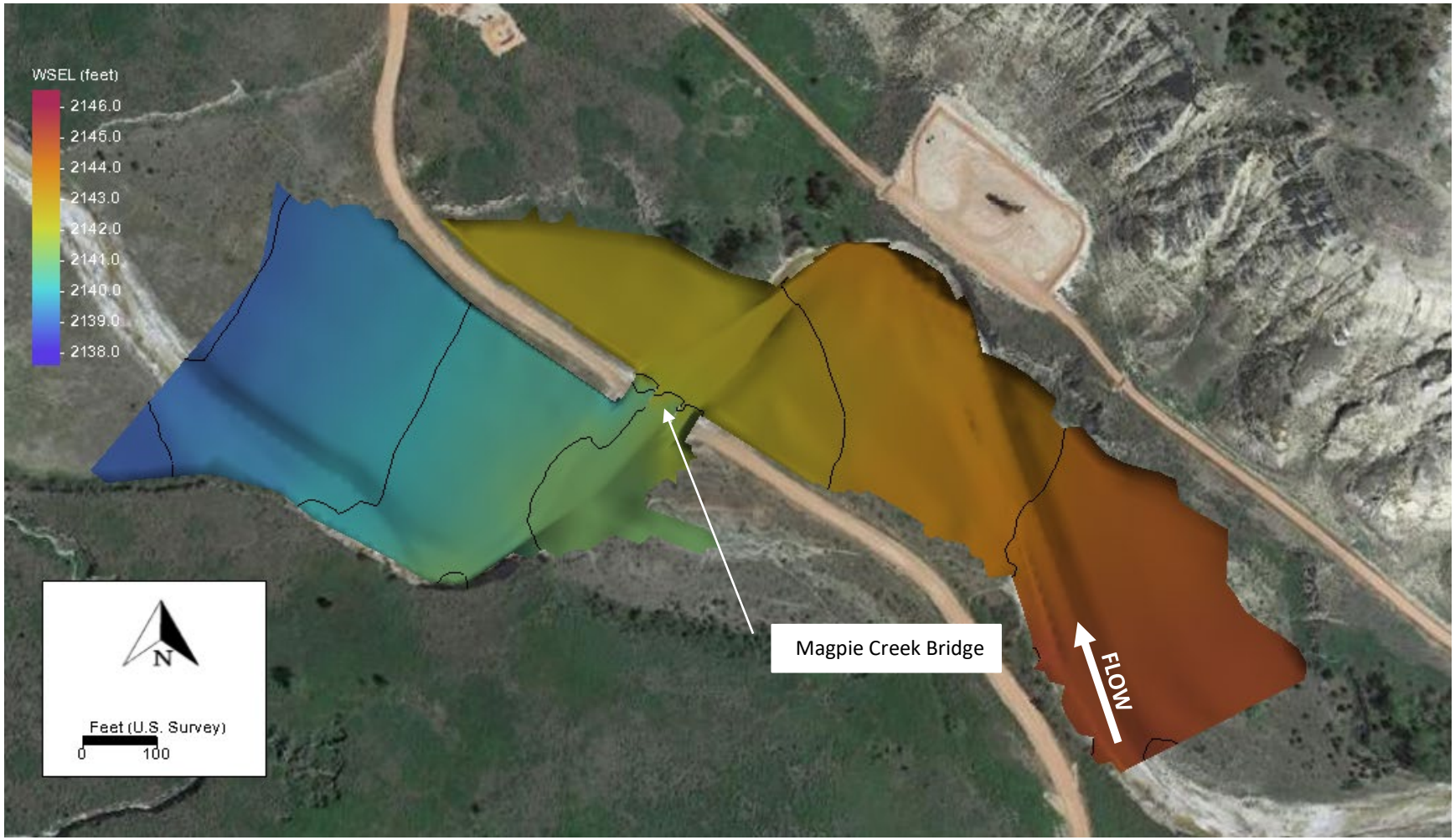
Magpie Creek SRH-2D Information (cont.)

2-Year Water Surface Elevation – Proposed Conditions



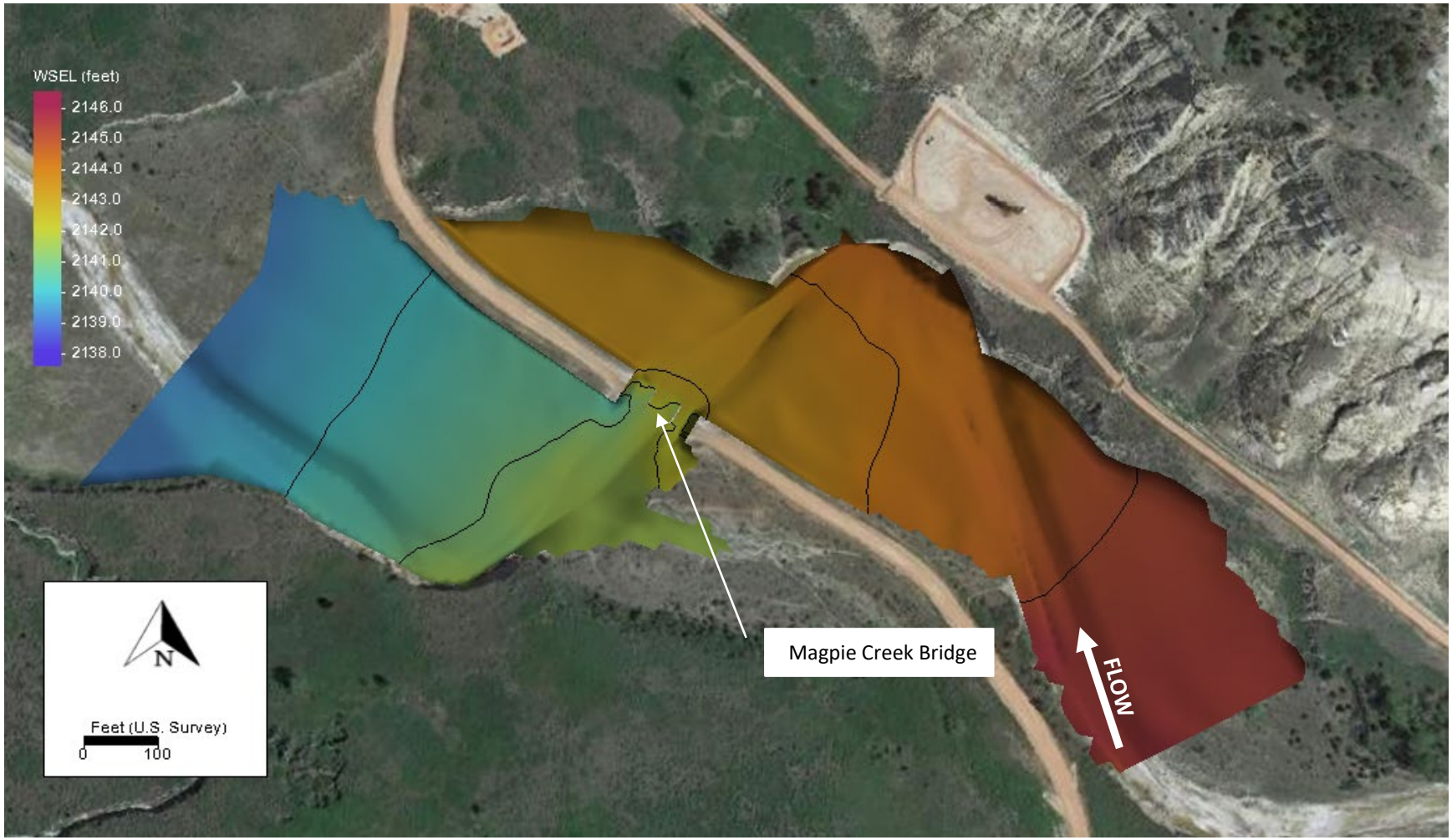
Magpie Creek SRH-2D Information (cont.)

50-Year Water Surface Elevation – Proposed Conditions



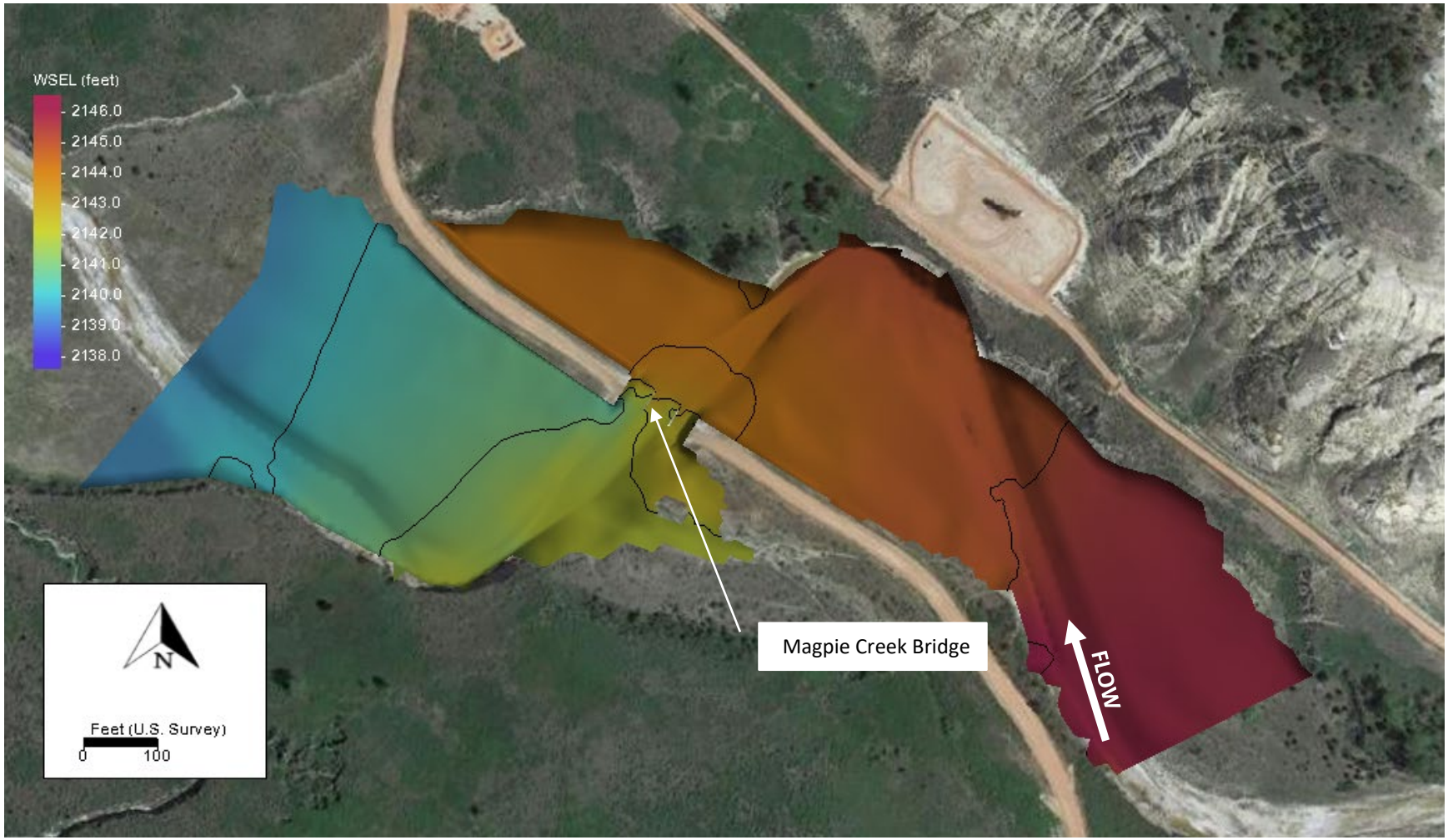
Magpie Creek SRH-2D Information (cont.)

100-Year Water Surface Elevation – Proposed Conditions



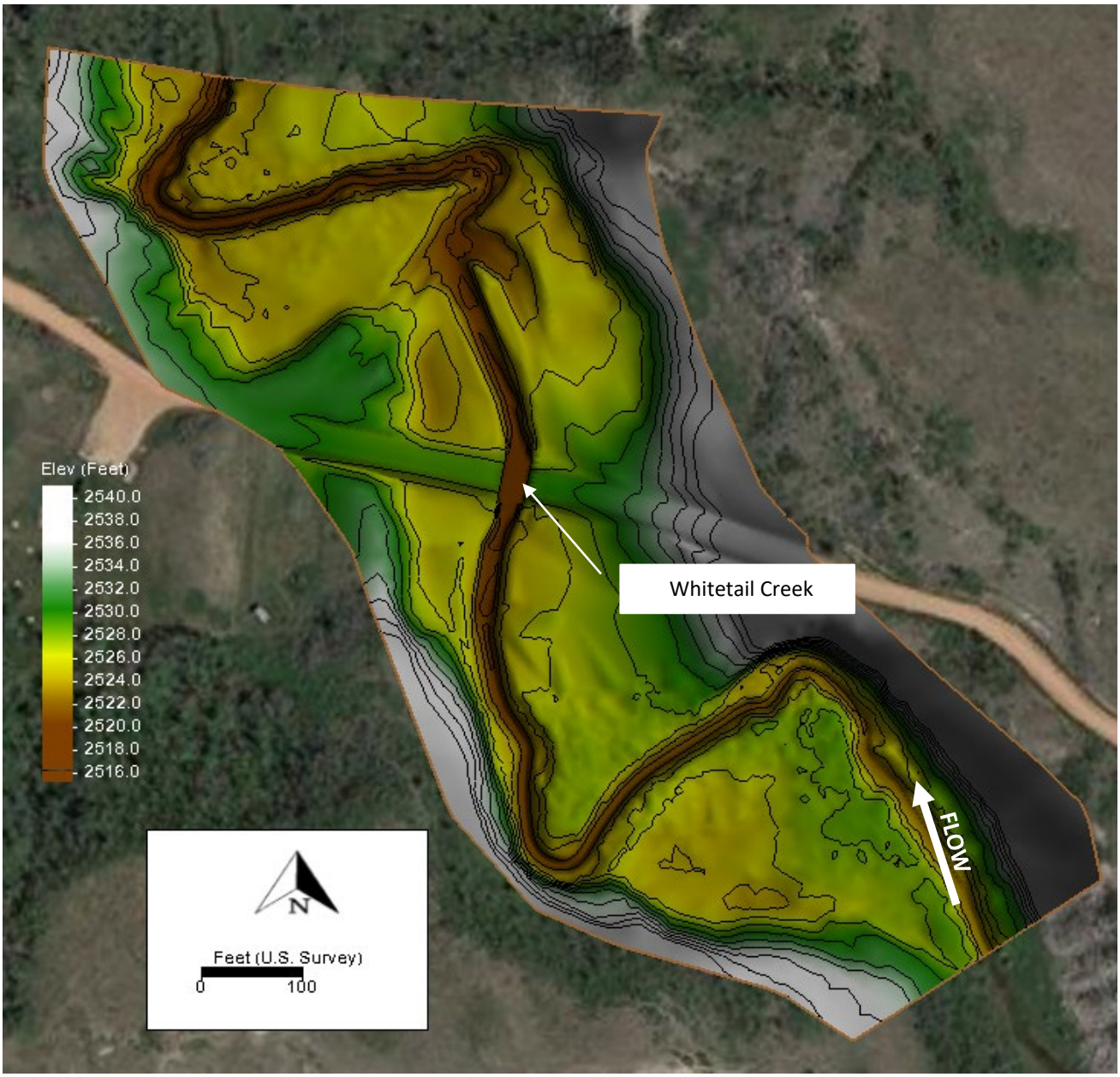
Magpie Creek SRH-2D Information (cont.)

200-Year Water Surface Elevation – Proposed Conditions



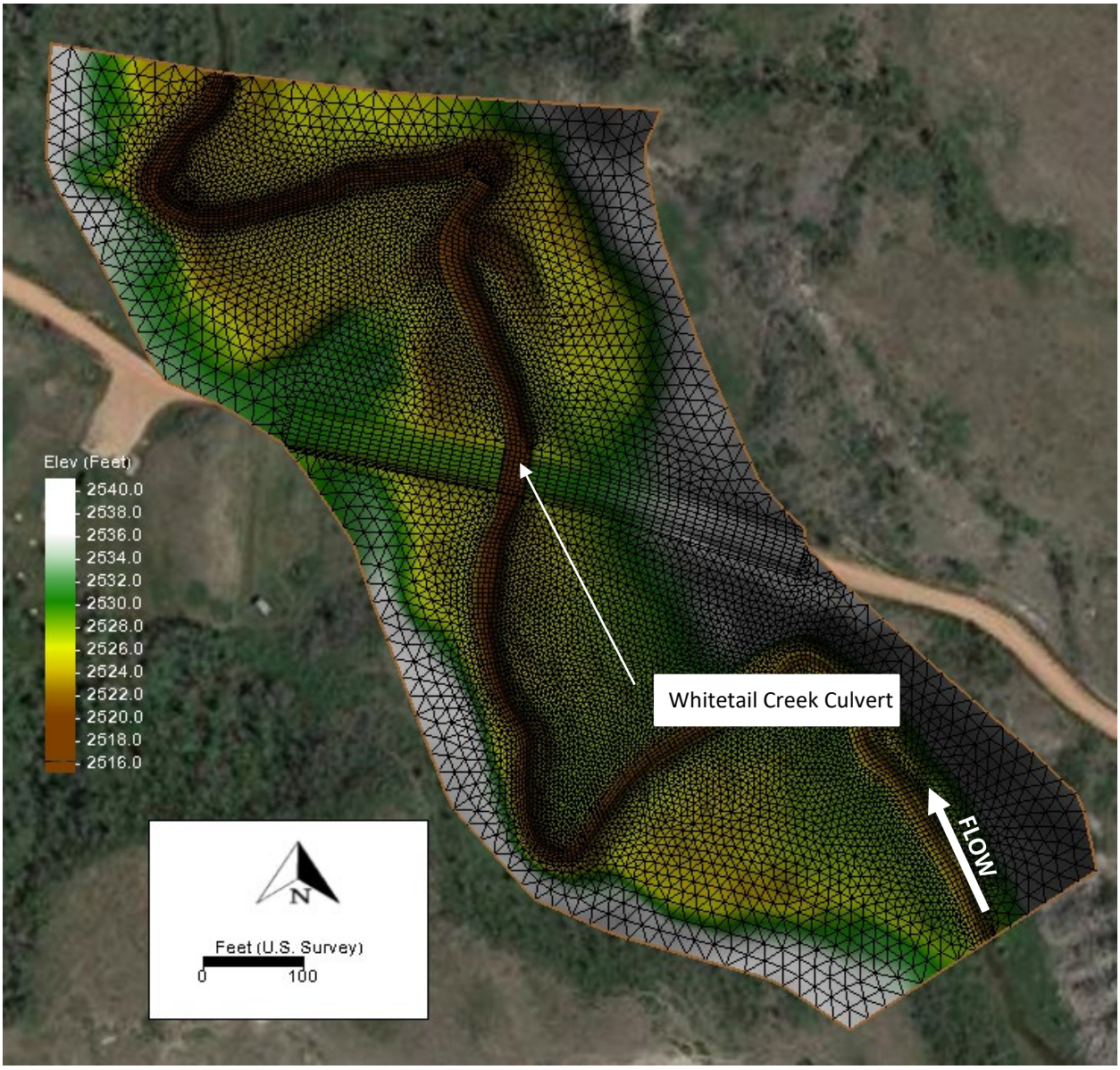
Whitetail Creek SRH-2D Information

Scatter Data (Topographic Surface)



Whitetail Creek SRH-2D Information (cont.)

SRH-2D Computational Mesh and Elevations

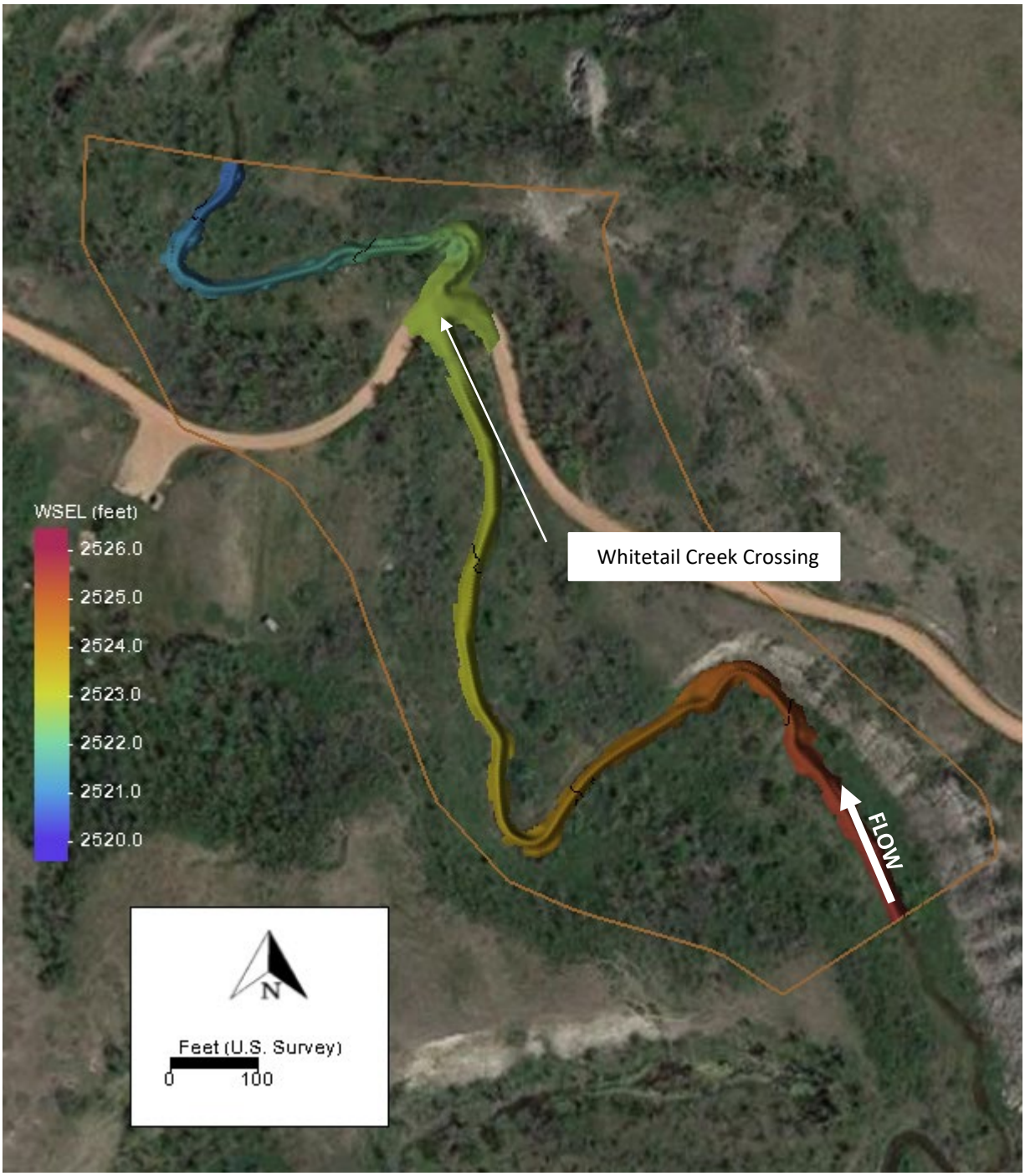


Whitetail Creek SRH-2D Information (cont.)

Land Use – Manning's Roughness Coefficients

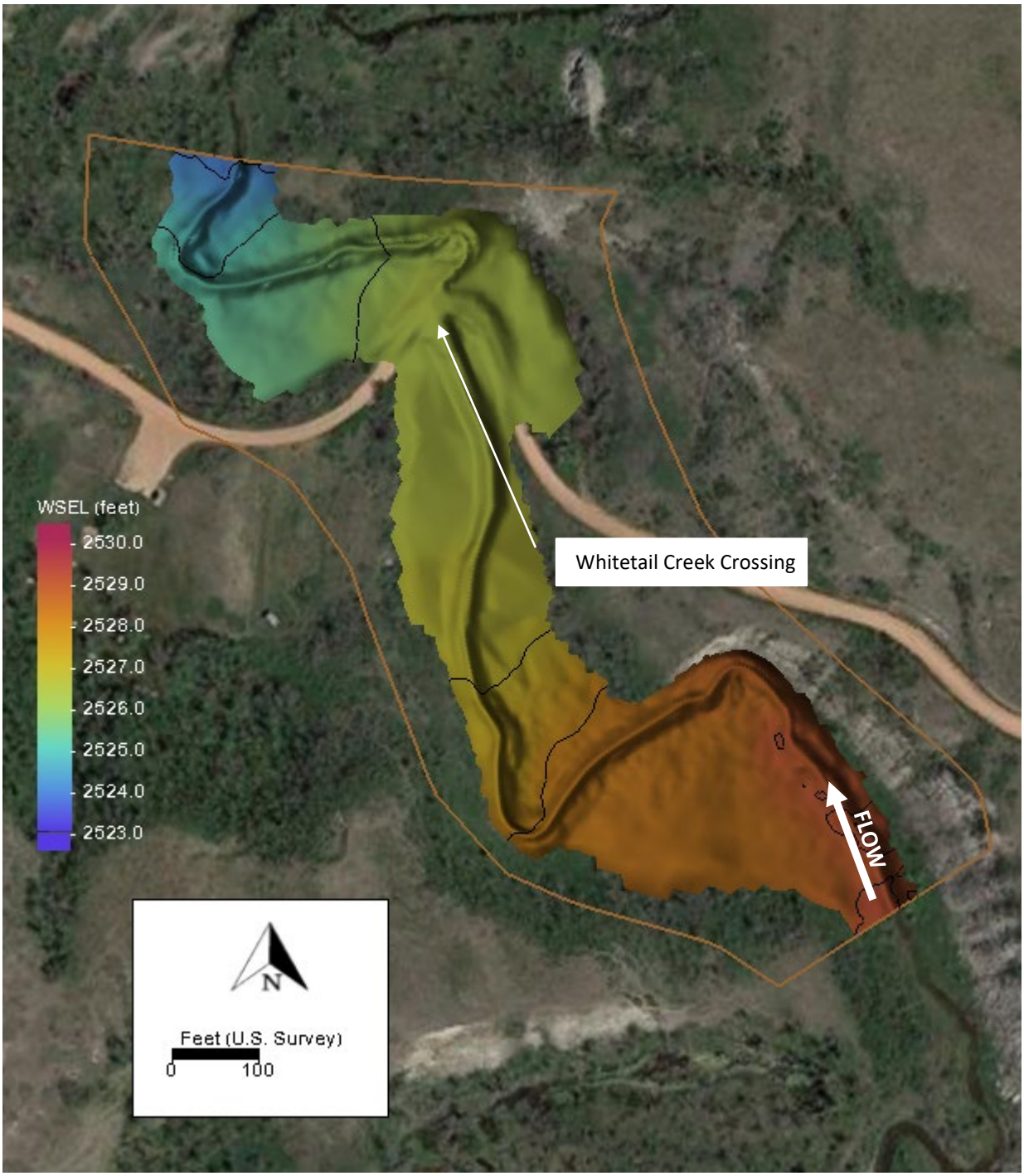
WhitetailCreek SRH-2D Information (cont.)

2-Year Water Surface Elevation – Existing Conditions



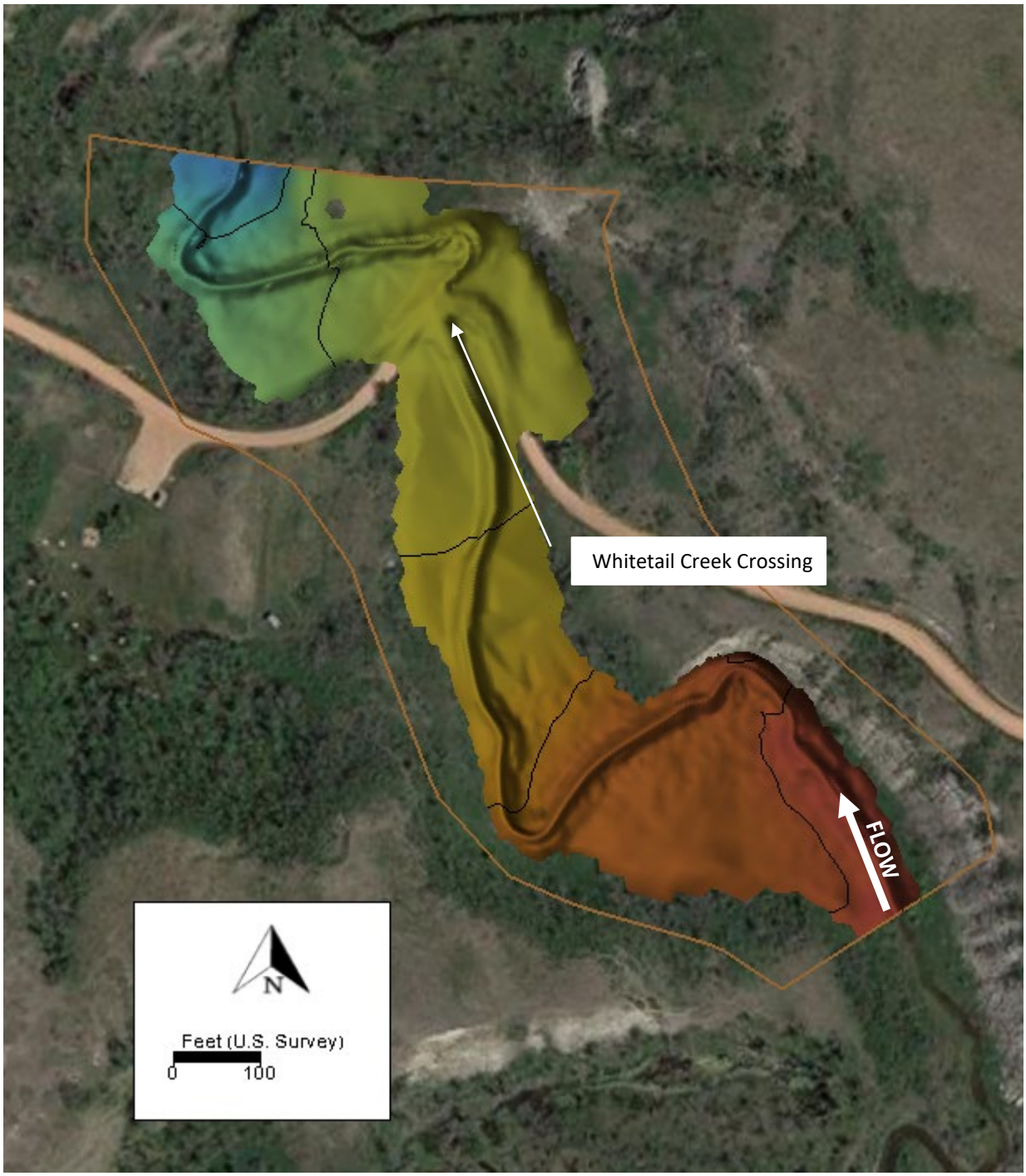
Whitetail Creek SRH-2D Information (cont.)

15-Year Water Surface Elevation – Existing Conditions



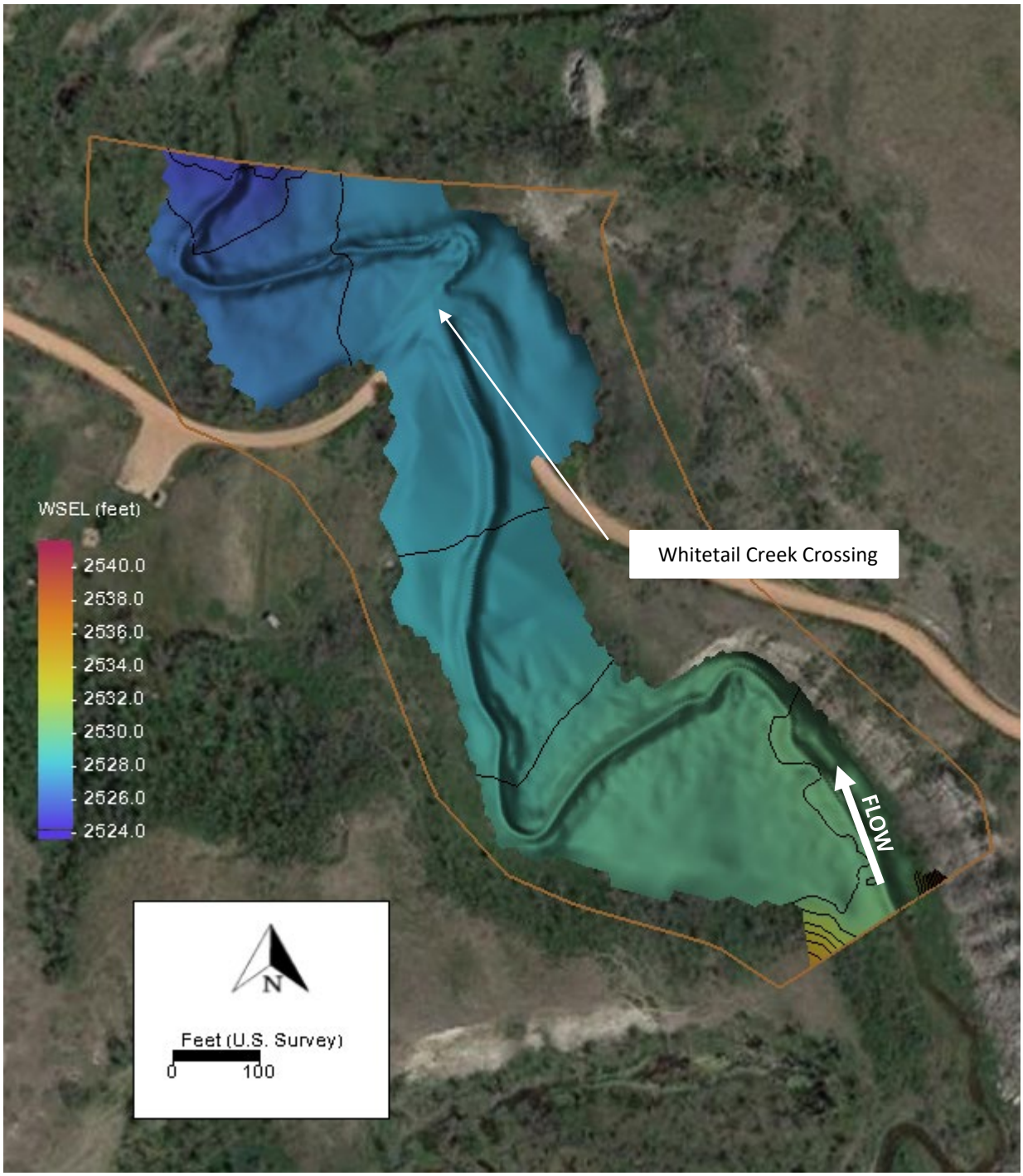
WhitetailCreek SRH-2D Information (cont.)

25-Year Water Surface Elevation – Existing Conditions



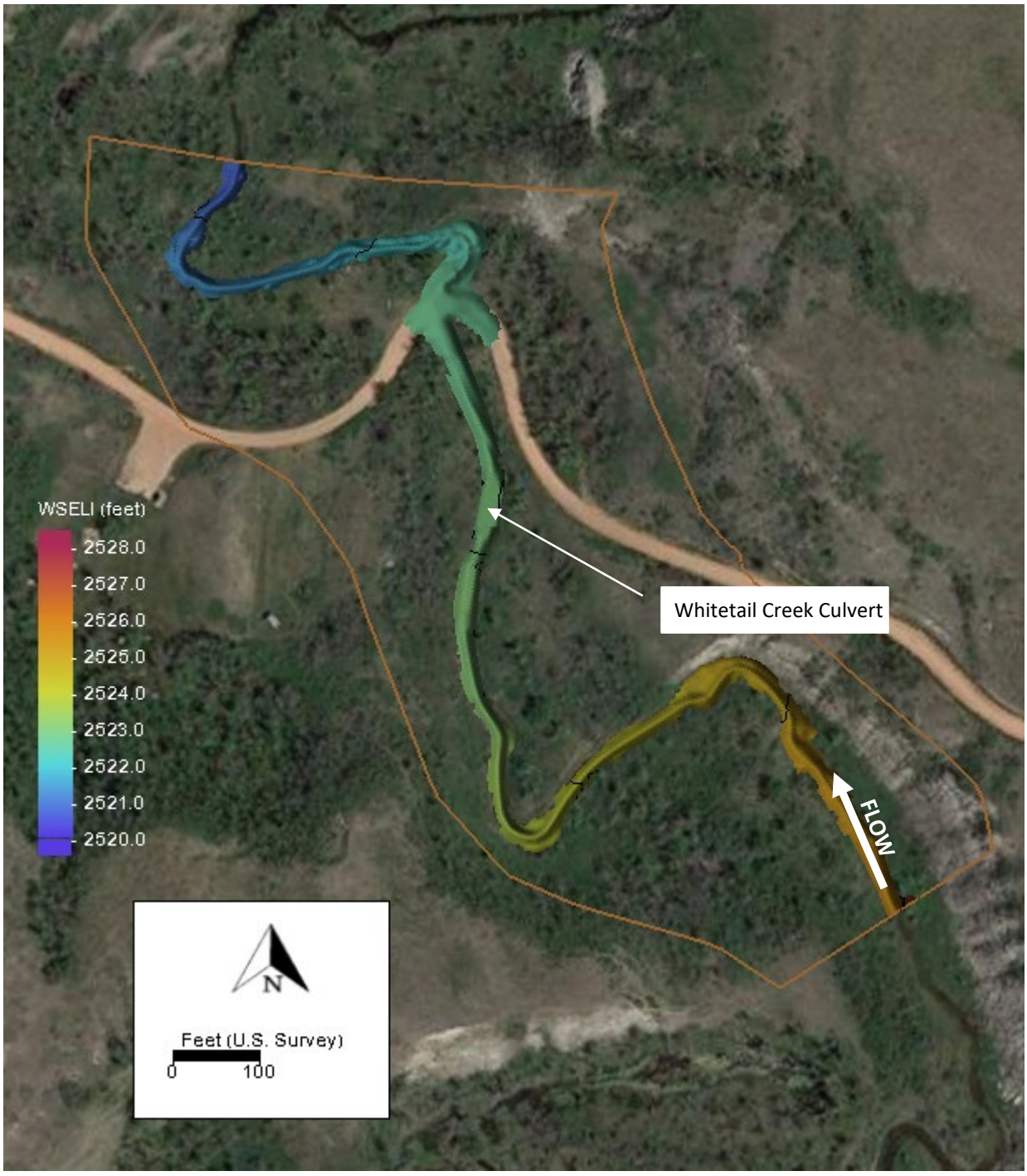
Whitetail Creek SRH-2D Information (cont.)

100-Year Water Surface Elevation – Existing Conditions



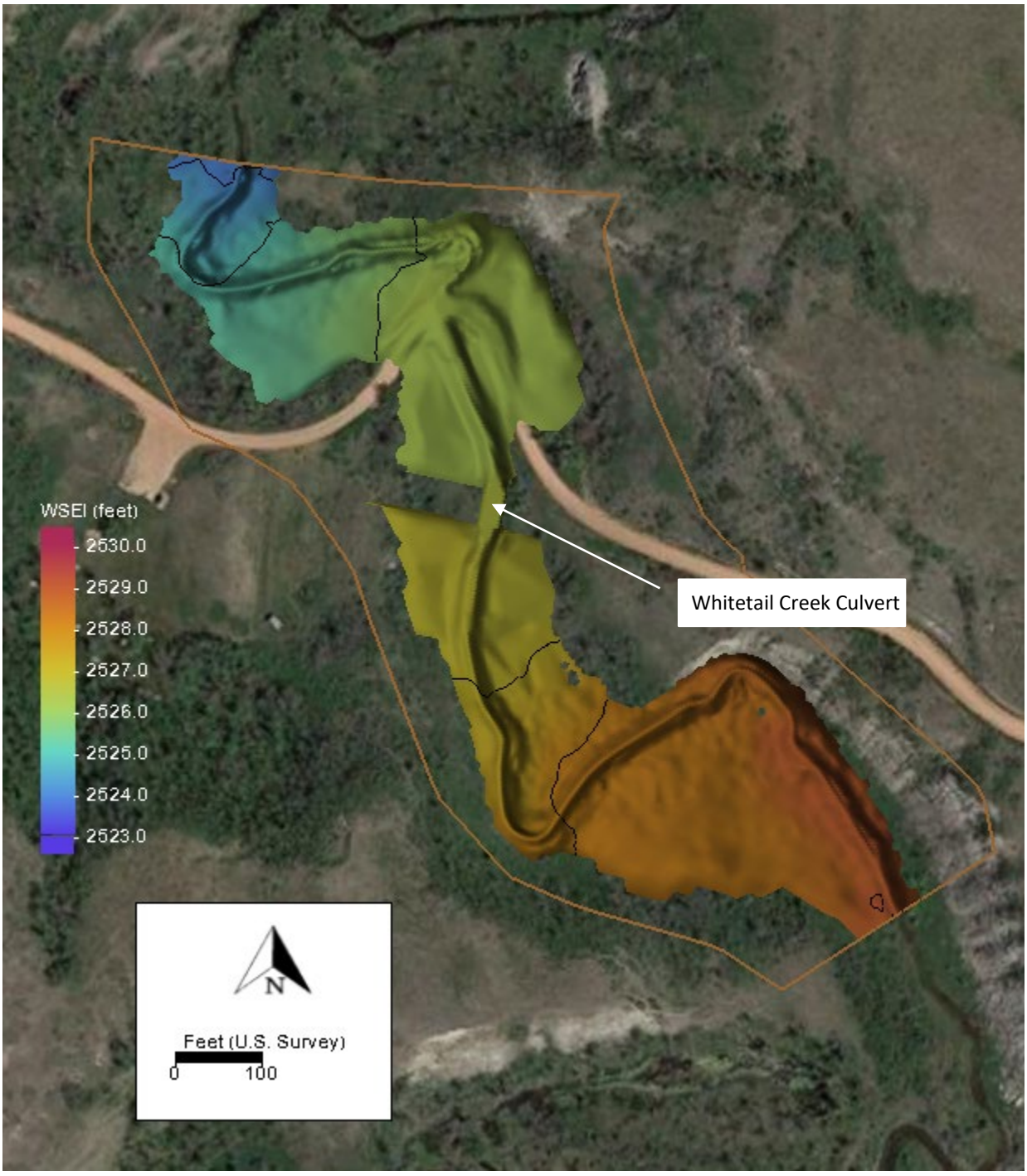
Whitetail Creek SRH-2D Information (cont.)

2-Year Water Surface Elevation – Proposed Conditions



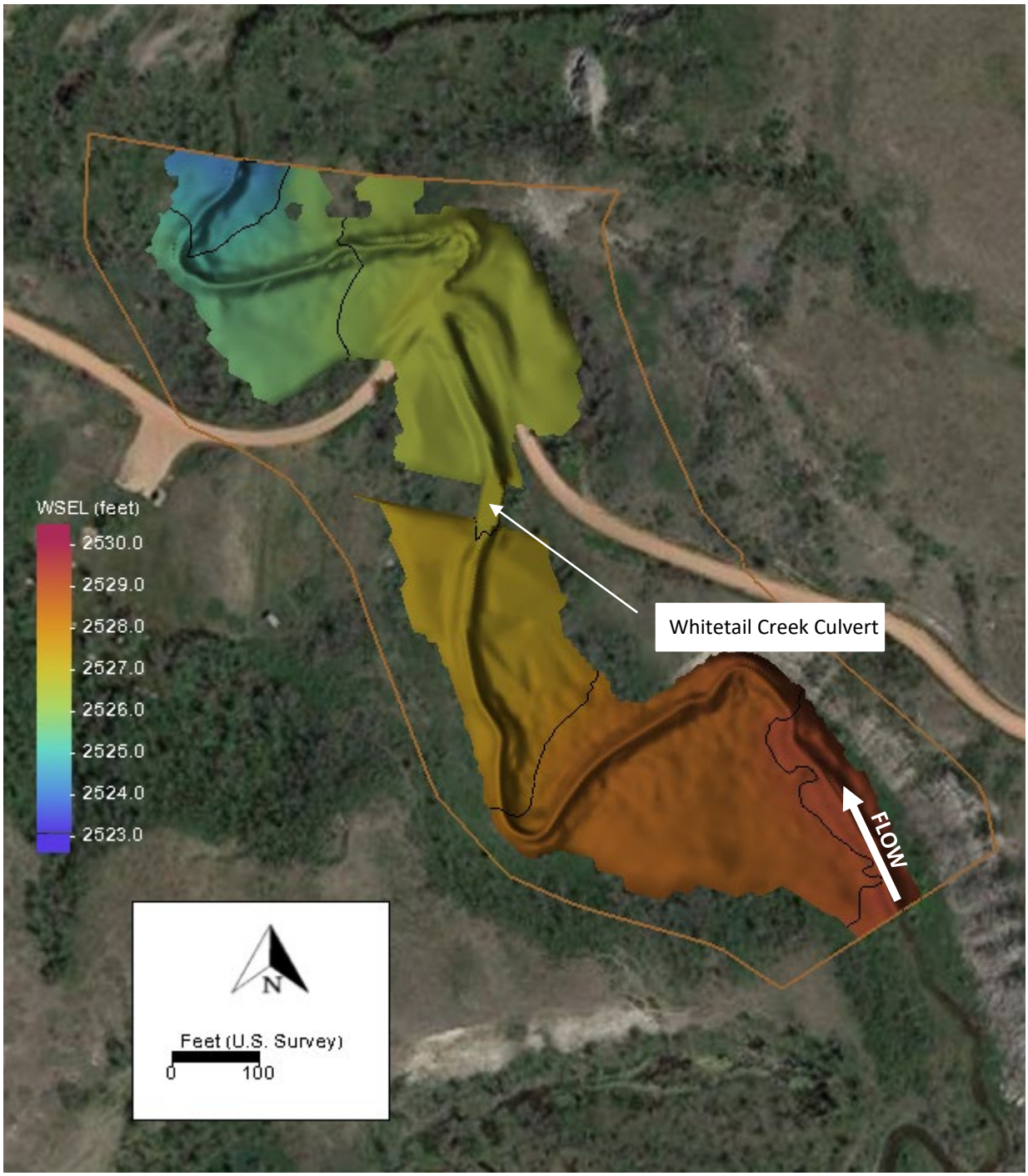
Whitetail Creek SRH-2D Information (cont.)

15-Year Water Surface Elevation – Proposed Conditions



Whitetail Creek SRH-2D Information (cont.)

25-Year Water Surface Elevation – Proposed Conditions



Whitetail Creek SRH-2D Information (cont.)

100-Year Water Surface Elevation – Proposed Conditions