Appendix F:

Kachess River Bull Trout Habitat Designs

Hydraulic Modeling and Results Memorandum

inter-fluve

TECHNICAL MEMORANDUM

Prepared for:	Kittitas Conservation Trust
Prepared by:	Peter Benchetler PE [1], and Dan Miller PE[2], and Pollyanna Lind, PhD[3]
Project:	Upper Kachess River Bull Trout Habitat Design Project
Date:	September 2021
Re:	Hydraulic Modeling and Analysis – Draft Final Design Plans

Introduction

This memorandum presents a detailed description of the hydraulic analysis that was used to inform the Kachess River Bull Trout Restoration Project Draft design and is intended to supplement the brief description of the hydraulic analysis included in the basis of design report. Setup of the hydraulic model, input parameters, and general assumptions are described within this document. Discussion of key results for existing and proposed condition simulations is also included.

Model Overview

The hydraulic analysis was conducted using two-dimensional (2D) hydraulic models that were developed for existing conditions and the proposed design conditions within the U.S. Army Corps of Engineers HEC-RAS 5.0.7 software (USACE, 2019). 2D hydraulic computations are typically superior to one-dimensional (1D) computations when detailed analysis of river systems with multiple channels or flow paths is required. 2D computations were chosen for this project model to analyze split flows, channel-floodplain interactions, multiple tributary inputs along the project reach, and the relatively complex hydraulics associated with proposed design features.

MODEL CAPABILITIES AND LIMITATIONS

HEC-RAS 5.0.7 was used in its two-dimensional (2D) unsteady flow simulation mode with the capacity to model the complex flow patterns, and temporally variable boundary conditions. The 2D hydraulic model calculates depth averaged water velocities (including magnitude and direction), water surface elevation, and mesh cell face conveyance throughout the simulation. Other hydraulic parameters, such as depth, shear stress, and stream power, can be calculated by the model after the simulation. The model does not simulate vertical variations in velocities or complex three-dimensional (3D) flow eddies.

[1] Inter-Fluve, Design Consultant Lead Hydraulic Engineer
[2] Inter-Fluve, Design Consultant Project Engineer of Record
[3] Inter-Fluve, Senior Geomorphologists and Project Manager

Model Geometry

DIGITAL TERRAIN MODEL

The existing conditions digital terrain model (DTM) was developed using ground/bathymetric survey data collected by Inter-Fluve staff in 2018 and 2019 combined with aerial LiDAR acquired in 2018 (Quantum Spatial, 2018). Channel bathymetry was primarily based on ground survey data, while LiDAR data were used in the floodplain and in regions within the active channel that were outside of the extents of the survey. Some ground survey data were used to supplement floodplain topography where appropriate. Additional supplemental ground survey data were collected in the fall of 2020, and incorporated in the previously developed existing conditions DTM where appropriate.

COMPUTATIONAL DOMAIN

The computational domain for the project model extends from Little Kachess Lake at the downstream end, to upstream of the confluence of the Upper Kachess River and Mineral Creek at the upstream end. The model domain extends approximately 600 feet into Mineral Creek and 800 feet into Upper Kachess River. Inflows from Upper Kachess River and Mineral Creek were input separately. The width of the computational domain spans much of the Kachess River Valley to elevations well above the modeled 100-year flood elevation.

The 2D model geometry used a flexible computational mesh adjusted according to terrain complexity and areas of interest. The nominal mesh spacing ranges from 10 ft within the active channel to 25 feet in the floodplain, with smaller cell sizes applied to areas where higher resolution results were desired. Break lines were added along the tops of banks, channel alignments, and high ground features to further refine the mesh. Although the average computation mesh size was greater than the terrain resolution, the modeling capabilities of HEC-RAS 5.0.7 integrate the sub-grid terrain into the computations, thereby capturing much of the higher resolution terrain in the computational mesh.

Input Parameters

BOUNDARY CONDITIONS

2D hydraulic models require boundary conditions at locations where flow is expected to enter or exit the computational domain. Inflow hydrographs were based on the discharges of interest listed in Table 1. These discharges were incorporated into a synthetic hydrograph with periods of steady flow (at the discharges of interest and other intermediate discharges) connected by smooth transition periods to create a stair-step like pattern. The periods of steady flow allow the model to come to a quasi-steady state condition, which facilitates the interpretation of hydraulics at specific discharges.

Table 1. Summary of flows used in hydraulic modeling

Summary of Flows used in Hydraulic Modeling (all flows in cfs)								
Flow Recurrence Interval	**Upper Kachess**	**Mineral Creek**	**Watermelon Creek**	**Cold Creek**	**Magic Creek**	**Cedar Creek**	**Unnamed Tributary**	**Total Combined Flow at Little Kachess Lake**
95% Daily Exceedance	1.6	2.7	0.5	0.1	<0.1	0.1	0.4	5.4
50% Daily Exceedance	6.7	11.2	1.9	0.6	0.2	0.3	1.9	23
5% Daily Exceedance	29.6	49.7	8.5	3.6	1.0	1.8	44.8	139
1.5-year Flood[1]	193.4	325	55.6	4.5	3.4	6.8	53.8	643
2-year Flood	226	381	65	5	5	10	63	755
5-year Flood	363	610	104	8	9	16	101	1211
10-year Flood	456	766	131	10	11	20	126	1520
25-year Flood	579	973	167	13	14	25	159	1930
50-year Flood	672	1129	193	15	16	29	186	2240
100-year Flood	768	1291	221	17	18	33	211	2559

[1]*1.5-year flood (66.67%) was extrapolated from the 1% to 50% Annual Exceedance Probability curve*

The synthetic hydrograph approach described above was applied as the boundary condition for each of the flow input locations, which include Upper Kachess River, Mineral Creek, Watermelon Creek, Cold Creek, Magic Creek, Cedar Creek, and an additional unnamed tributary located on the westside of the valley. All flow inputs were applied assuming that peaks for different recurrence intervals occur simultaneously throughout the project reach. Additional contributions from spring and groundwater sources are expected; however, these sources were not quantified, are expected to be small in comparison to surface flows, and are assumed to be accounted for in the tributary flows.

The downstream boundary condition assumed normal flow depth at a friction slope estimated from the average channel slope (0.005 feet per foot) just upstream of the Little Kachess Lake water surface (representing low-pool) in the LiDAR data (approximately 2,226 feet of elevation). Additional high-pool simulations were performed to assess the potential backwater influence of high lake levels in Little Kachess Lake on hydraulics within the project reach, particularly where project design features are proposed. For these simulations a constant stage of 2,262 feet, which corresponds to high-pool lake data from (USBR, 2019; USBR & WADOE, 2018), was assumed as a downstream boundary condition. The model results for the high-pool simulations suggest that the backwater from Little Kachess Lake influences flow hydraulics in the lower 2,300 feet of the channel – matching the existing high-pool delta deposit that the channel is currently in the process of incising. The model results suggest that the hydraulic influence of high-pool conditions does not significantly impact the project design features, located more than 500 feet upstream from high-pool lake stage.

HYDRAULIC ROUGHNESS

A spatially varying roughness (Manning's n) layer was created by hand-digitizing regions with similar land cover. In general, roughness coefficients were applied to these regions based on field observations, aerial photos, and professional judgement. Roughness values for each region were based on published guidelines of one-dimensional roughness coefficients (Arcement & Schneider, 1989) for channel types and vegetation conditions, with the understanding that 2D roughness values can often vary substantially from those published for 1D models (Robinson et al., 2019). Table 2 summarizes the roughness coefficients used in both the existing and proposed conditions models. Given the dynamic nature of the project reach, roughness coefficients were modified in the proposed conditions models to represent immediate post-construction conditions.

Table 2: Roughness coefficients used in the 2D model

Region description	Manning's n value
Main active river channel; typical cobble/gravel bed with large boulders	0.03 - 0.06
Riparian areas; brush, trees and other dense vegetation	0.07 - 0.12
Gravel Road	0.02
Grass-Forbes	0.035
Brush Floodplain-varying densities	0.06 – 0.09
Forested Hillslopes	0.06 -0.1
Proposed side channel bed	0.055
Roughened Gravel Bar (post-construction condition)	0.065
Proposed large wood structures	0.10 – 0.25

CALIBRATION AND VALIDATION

Detailed model calibration for moderate to high flows was not possible as there were no discrete high flow water surface elevation data with corresponding discharge measurements available. There is currently no continuously operated gaging station within the vicinity of the project reach and therefore it is difficult to estimate the magnitude of high flow events without using approximate methods for ungaged streams. Given the absence of reliable high flow water surface elevation and corresponding discharge calibration data, the existing conditions model was validated and verified based on professional judgement, field observations, anecdotal observations provided by stakeholders whom are familiar with the project reach, and limited surrogate data such as the ordinary high water (OHW) survey of the vegetation line along the channel banks. The model results for low flow conditions were checked against water surface elevations obtained from pressure transducers placed throughout the project reach, however, given the nature of the large channel bed material the relative roughness of the channel substrate is expected to be much higher at low flows. Because detailed model calibration was not possible, conservative assumptions of higher energy conditions were made wherever possible, to account for any potential uncertainty related to model input parameters.

Results

Outputs from the hydraulic model were used in various capacities to assess the overall functionality of the project as well as assess any potential changes in hydraulic conditions under proposed conditions within the project reach relative to existing conditions. The hydraulic model was also used to inform key design decisions such as side channel inlet elevations and geometry, large wood placements and configuration. Hydraulic metrics such as velocity and depth were used to perform large wood stability and scour calculations. Select model outputs that encompass flow events ranging from the 95% daily exceedance flow to the 100-year flood event are provided in the attached hydraulic model output maps.

The model results demonstrate that the proposed design offers well-defined connectivity between the Kachess River and off-channel habitat areas during frequently occurring high flow events such as the 5% daily exceedance flow and the 1.5-year flood. Although modeled inundation appears more widespread to the south of Watermelon Creek under existing conditions, much of the inundated area is along an existing road with low habitat value and there is no direct connection with the Kachess River outside of the Watermelon Creek confluence. At the 5% daily exceedance flow, the proposed high flow channel becomes activated, providing a seasonal flow-through connection across the western floodplain that is not currently present under existing conditions.

The model results demonstrate increases in meaningful habitat (off-channel) during seasonal flow events, while also providing additional hydraulic complexity in the main channel during larger flood flows. Modeled inundation is substantially increased on the eastern floodplain between RM 0.9 and RM 1.4 at the 1.5-year flood.

The relative changes in modeled inundation and hydraulic patterns at the 5-year event are similar to the 1.5-year event, with noticeable increases in inundation of bars and floodplain areas. At higher flow events such as the 25-year and 100-year floods, the increased prevalence of low velocity area within the active channel and floodplain under proposed conditions is much more apparent. Lastly, it's important to note that spring-fed baseflow inputs are expected to provide some floodplain wetting; however, these inputs are not explicitly represented in the hydraulic model due to a lack of available data.

Additional discussion of the hydraulic model results as they pertain to the project design and habitat uplift is provided in the Basis of Design Report.

References

Arcement, G. J., & Schneider, V. R. (1989). Guide for selecting Manning's Roughness Coefficients for natural channels and floodplains. In *Report No FHWA-TS-84-204*. https://www.fhwa.dot.gov/bridge/wsp2339.pdf

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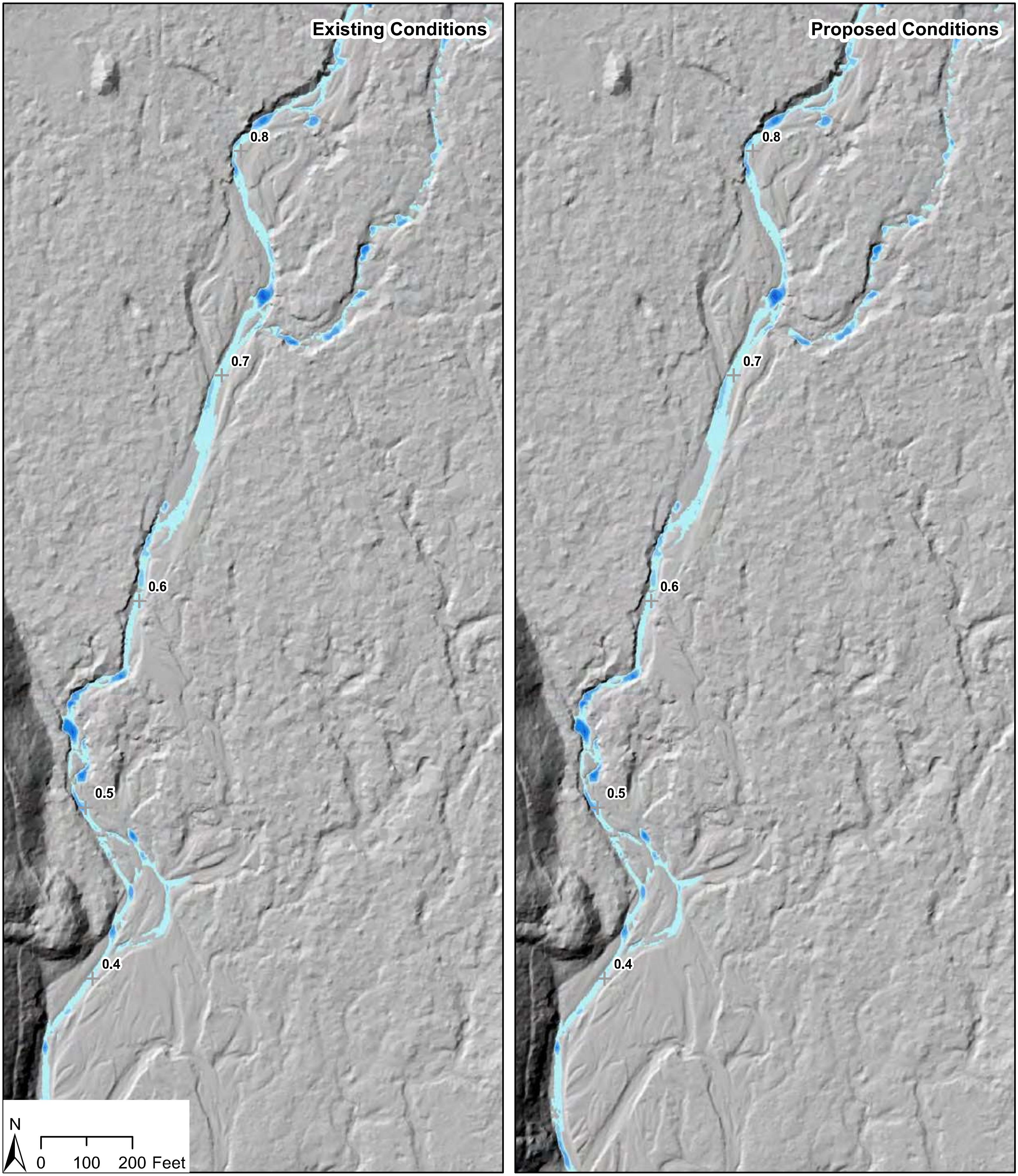


Modeled Depth (ft)

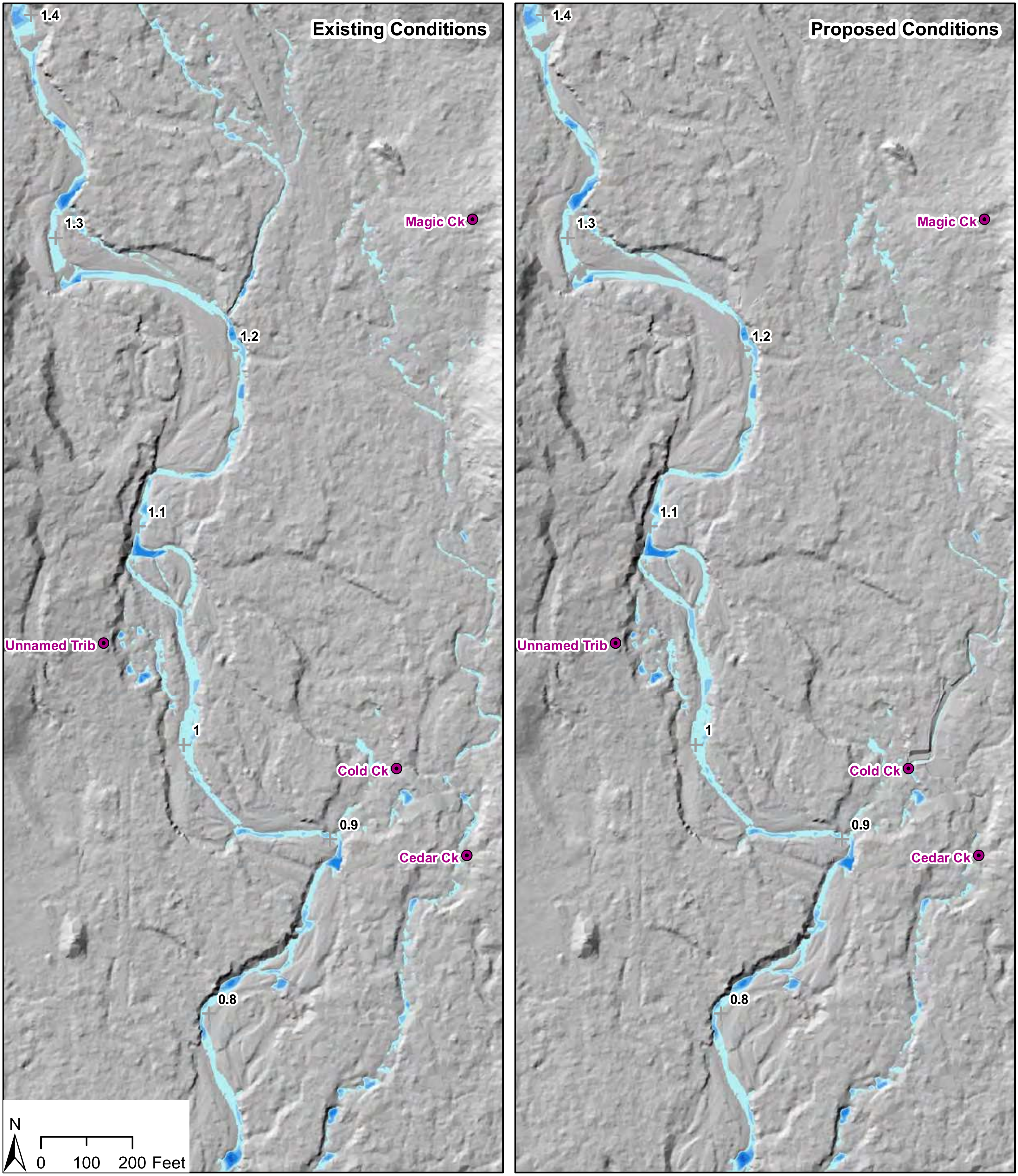
< 0.5 | 0.5 - 1 | 1 - 2 | 2 - 4 | 4 - 6 | 6 - 8 | > 8

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

95% Daily Exceedance Flow
(5 cfs at Downstream End)



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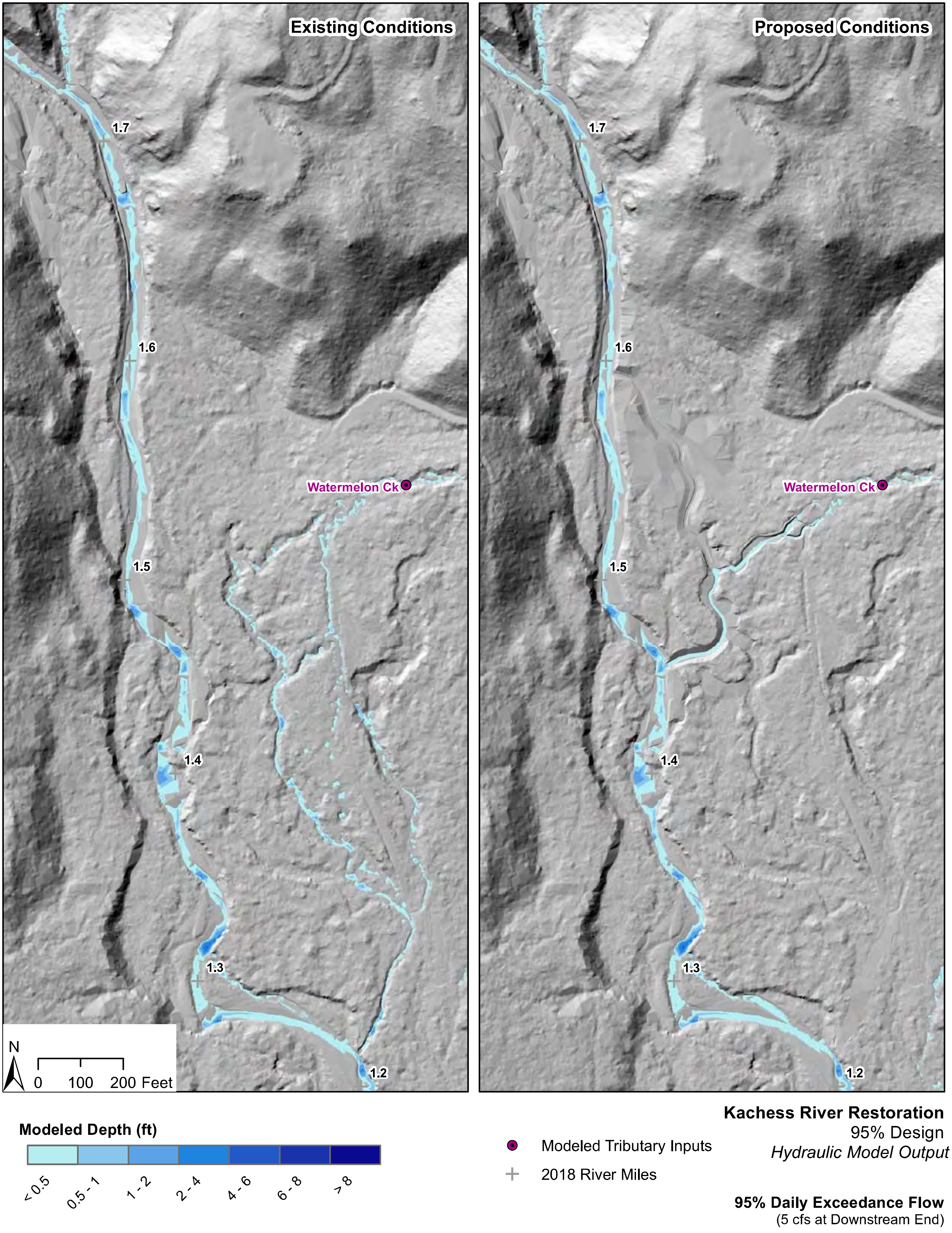

Existing Conditions
Proposed Conditions
1.7
1.6
1.5
1.4
1.3
1.2
Watermelon Ck
N
0 100 200 Feet
Modeled Depth (ft)
< 0.5
0.5 - 1
1 - 2
2 - 4
4 - 6
6 - 8
> 8
Modeled Tributary Inputs
2018 River Miles
Kachess River Restoration
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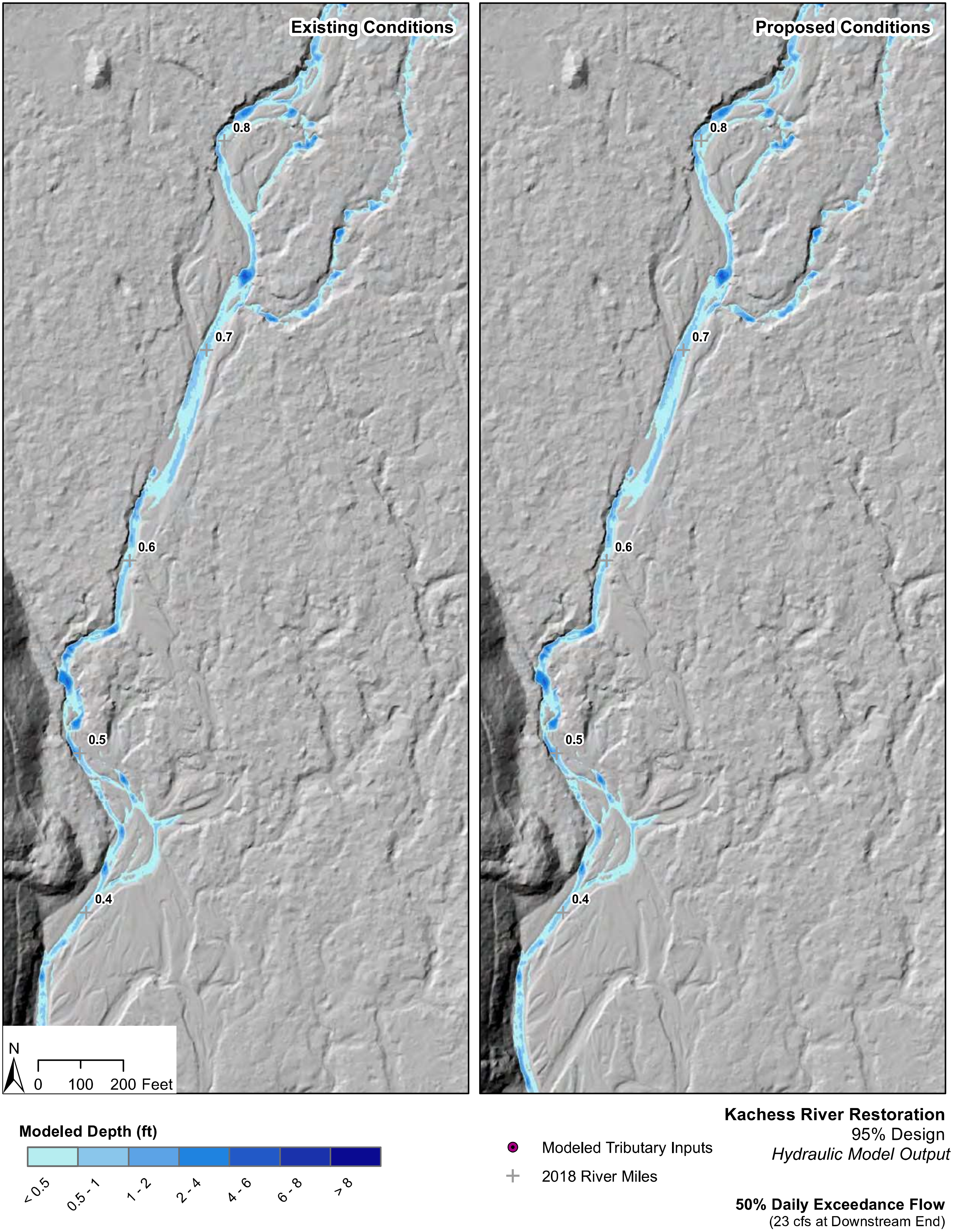
Hydraulic Model Output
95% Daily Exceedance Flow
(5 cfs at Downstream End)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Proposed Conditions
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0.7
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0.5
0.4
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Modeled Depth (ft)
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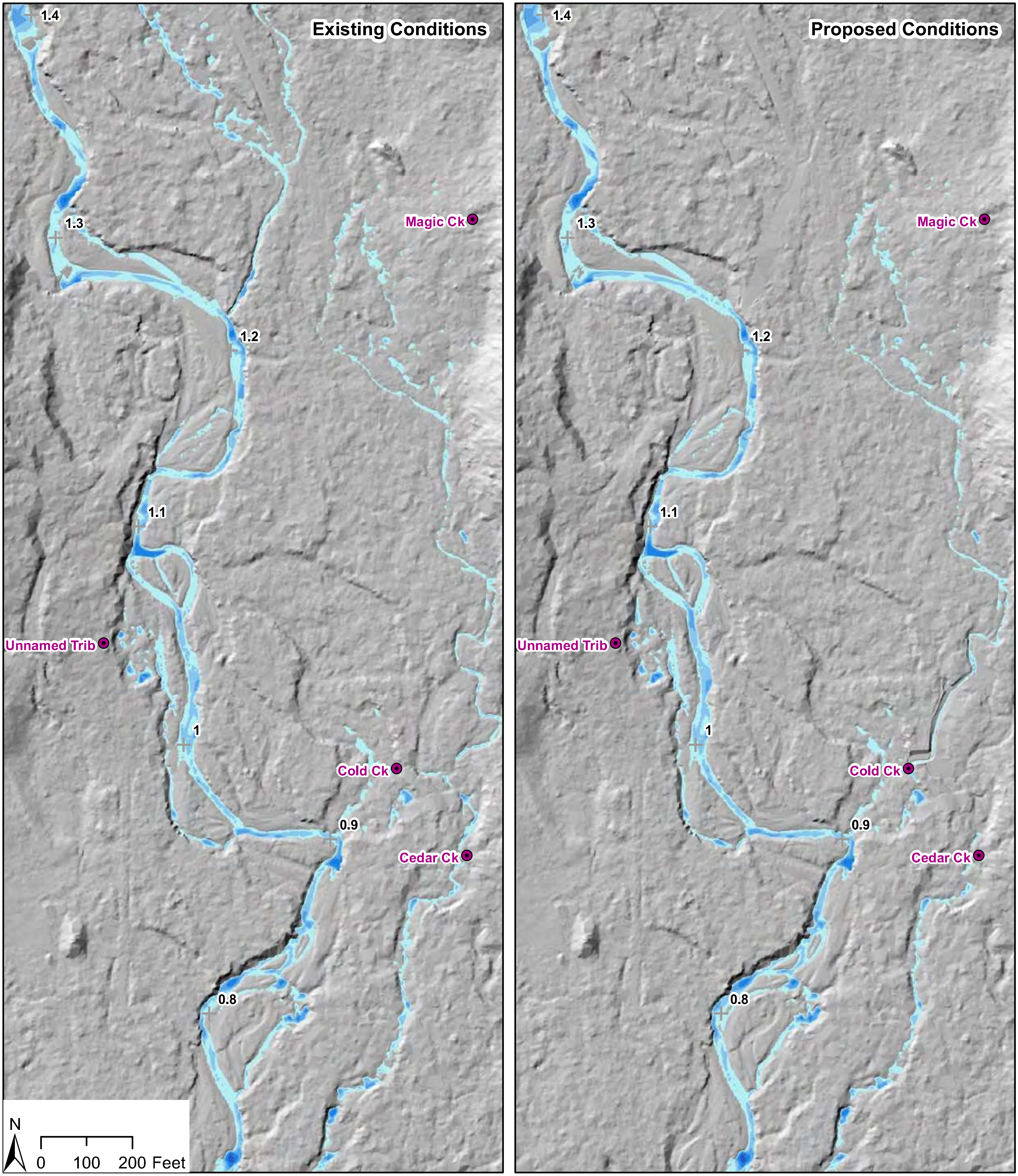
2 - 4
4 - 6
6 - 8
> 8
Modeled Tributary Inputs
2018 River Miles
Kachess River Restoration
95% Design
Hydraulic Model Output
50% Daily Exceedance Flow
(23 cfs at Downstream End)



Modeled Depth (ft)

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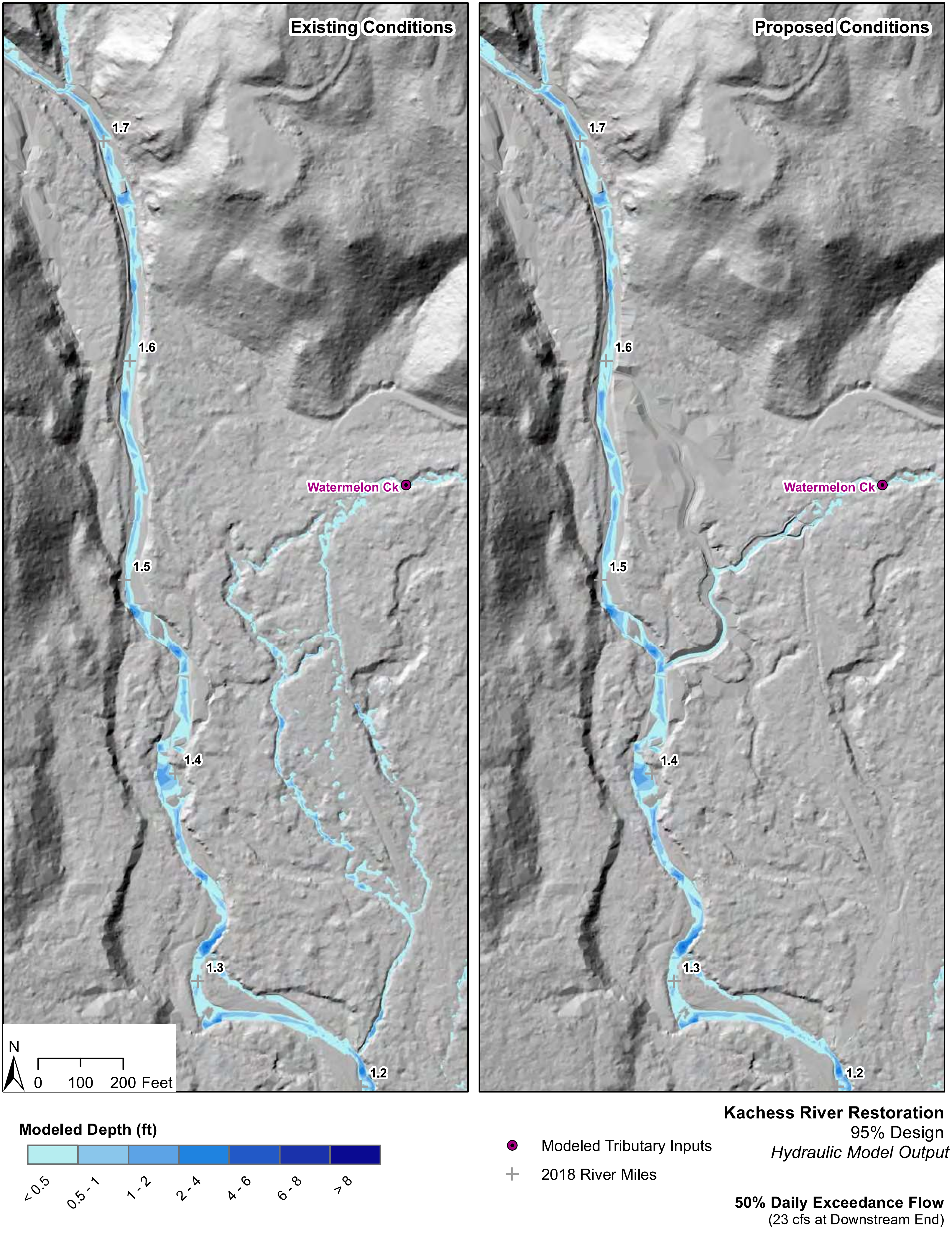
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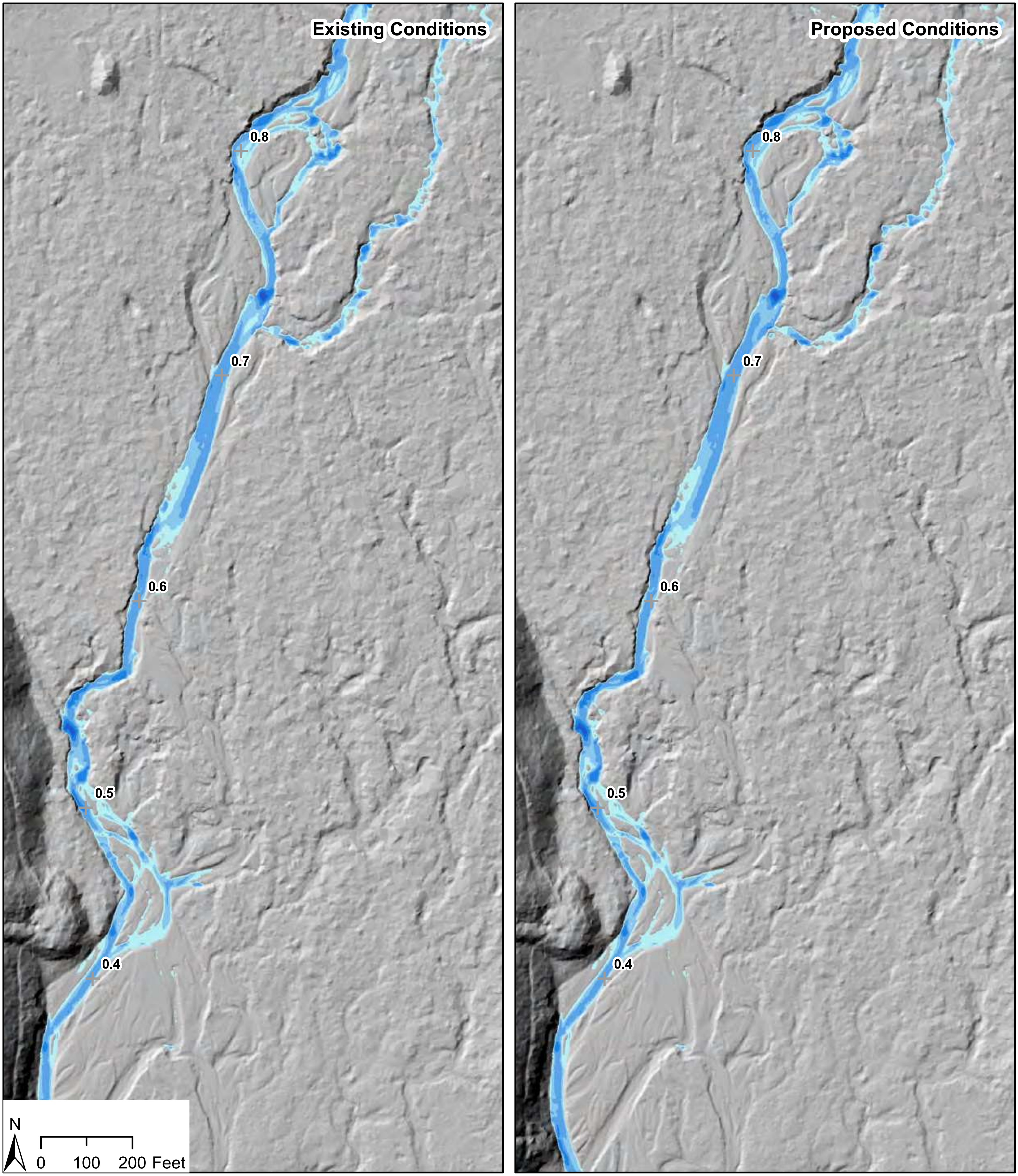

Modeled Depth (ft)

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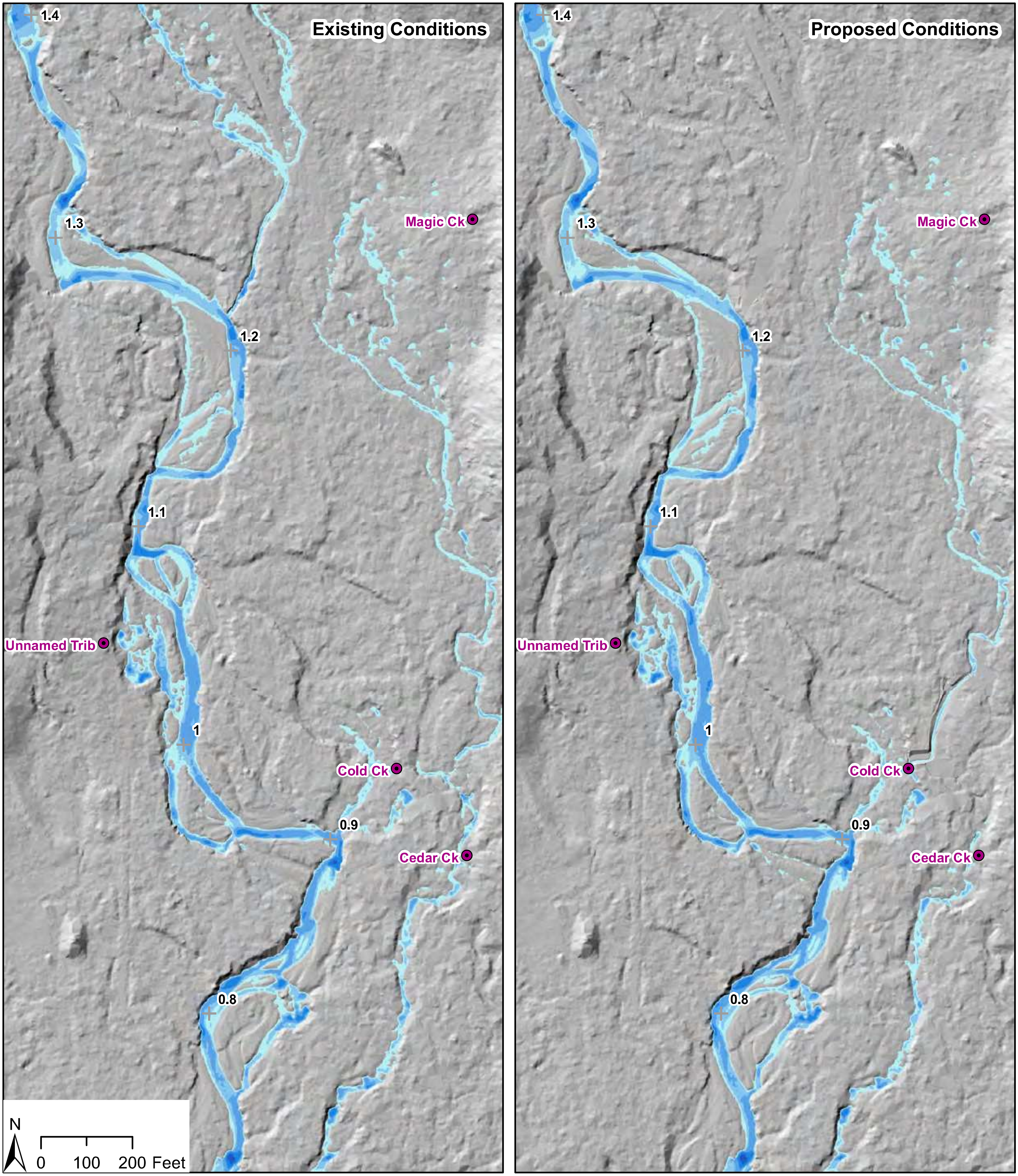
Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

5% Daily Exceedance Flow
(139 cfs at Downstream End)



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2018 River Miles

Kachess River Restoration

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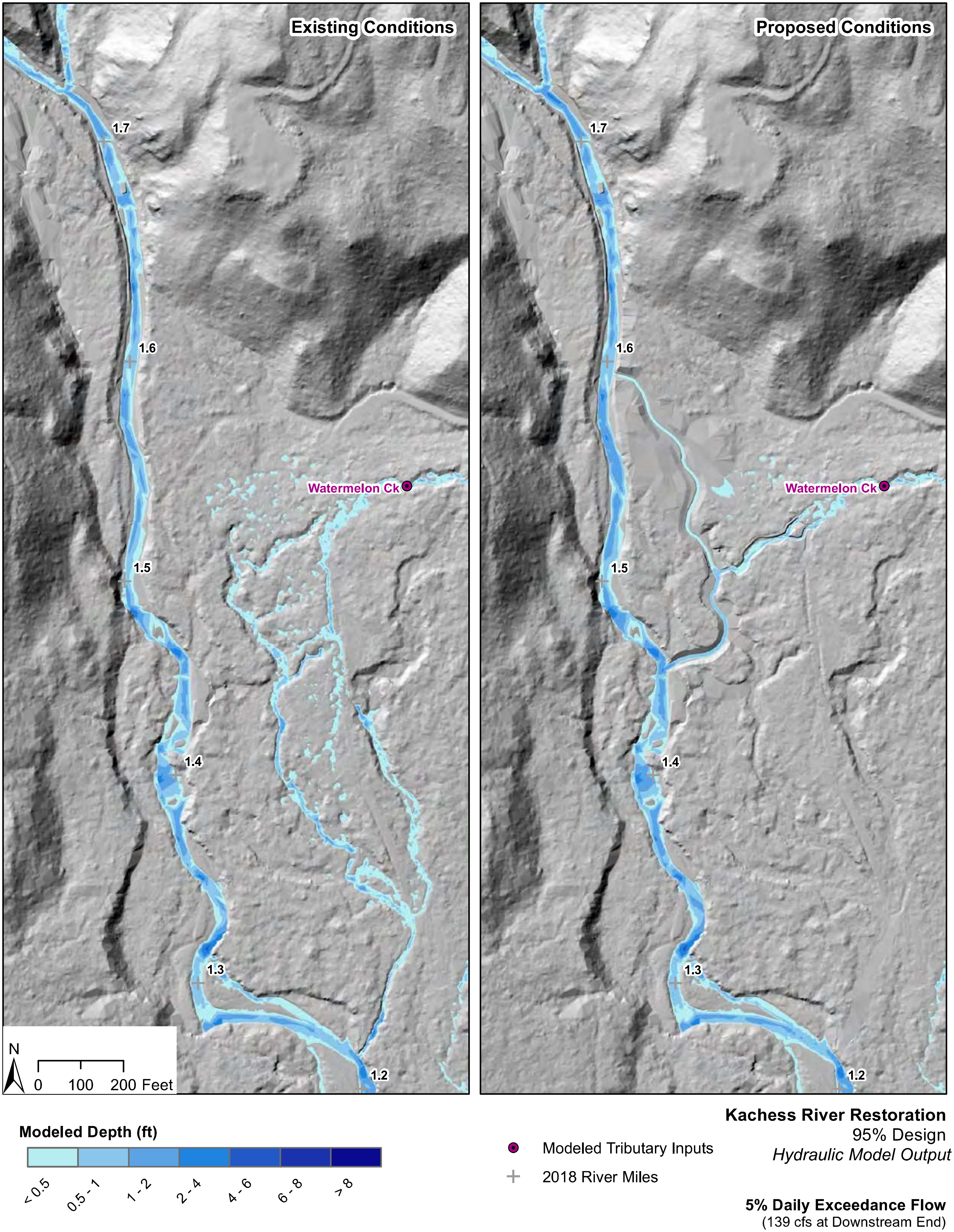

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Proposed Conditions
1.7
1.6
1.5
1.4
1.3
1.2
Watermelon Ck
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0 100 200 Feet
Modeled Depth (ft)
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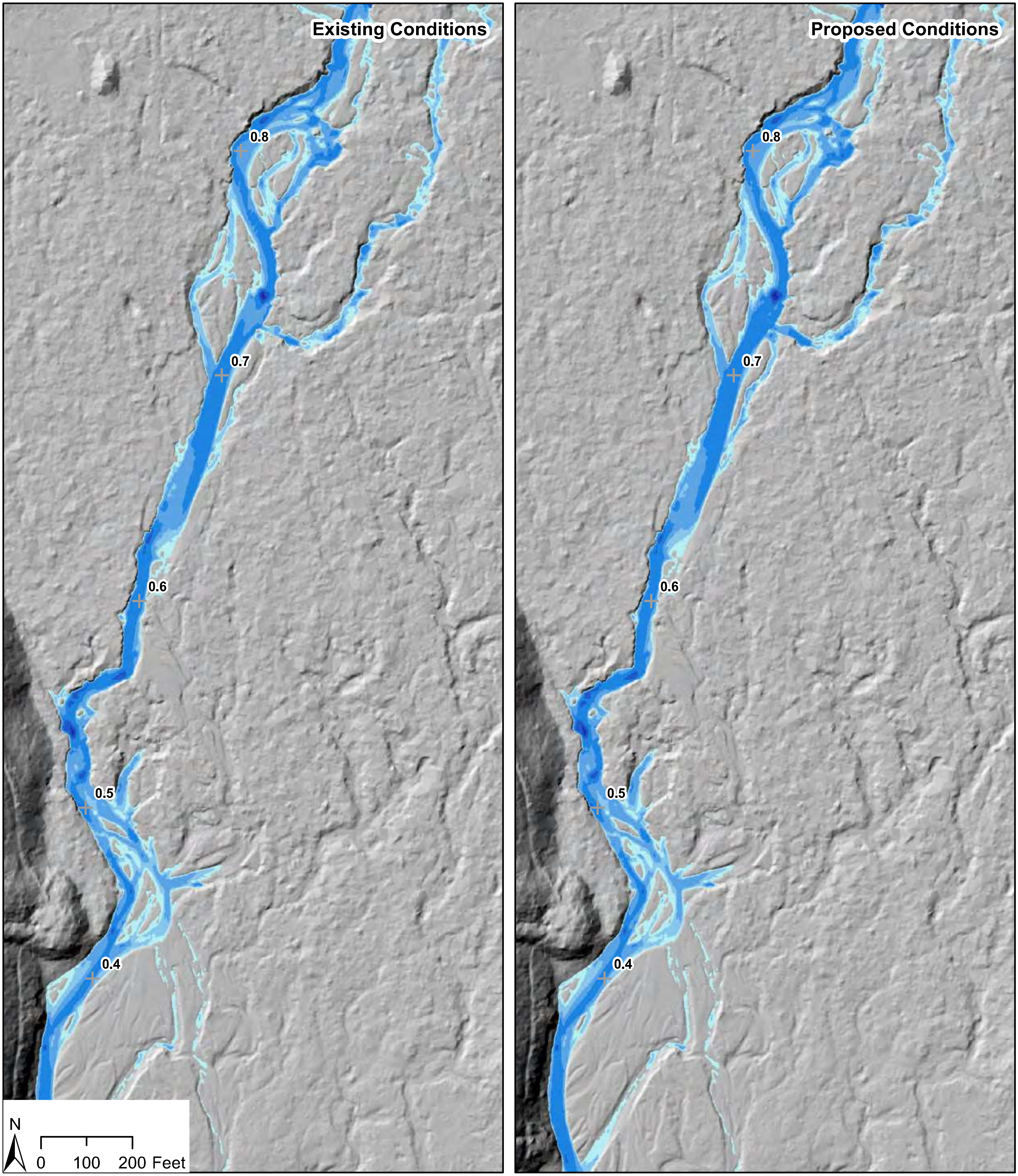


Modeled Depth (ft)

< 0.5 | 0.5 - 1 | 1 - 2 | 2 - 4 | 4 - 6 | 6 - 8 | > 8

Modeled Tributary Inputs

2018 River Miles

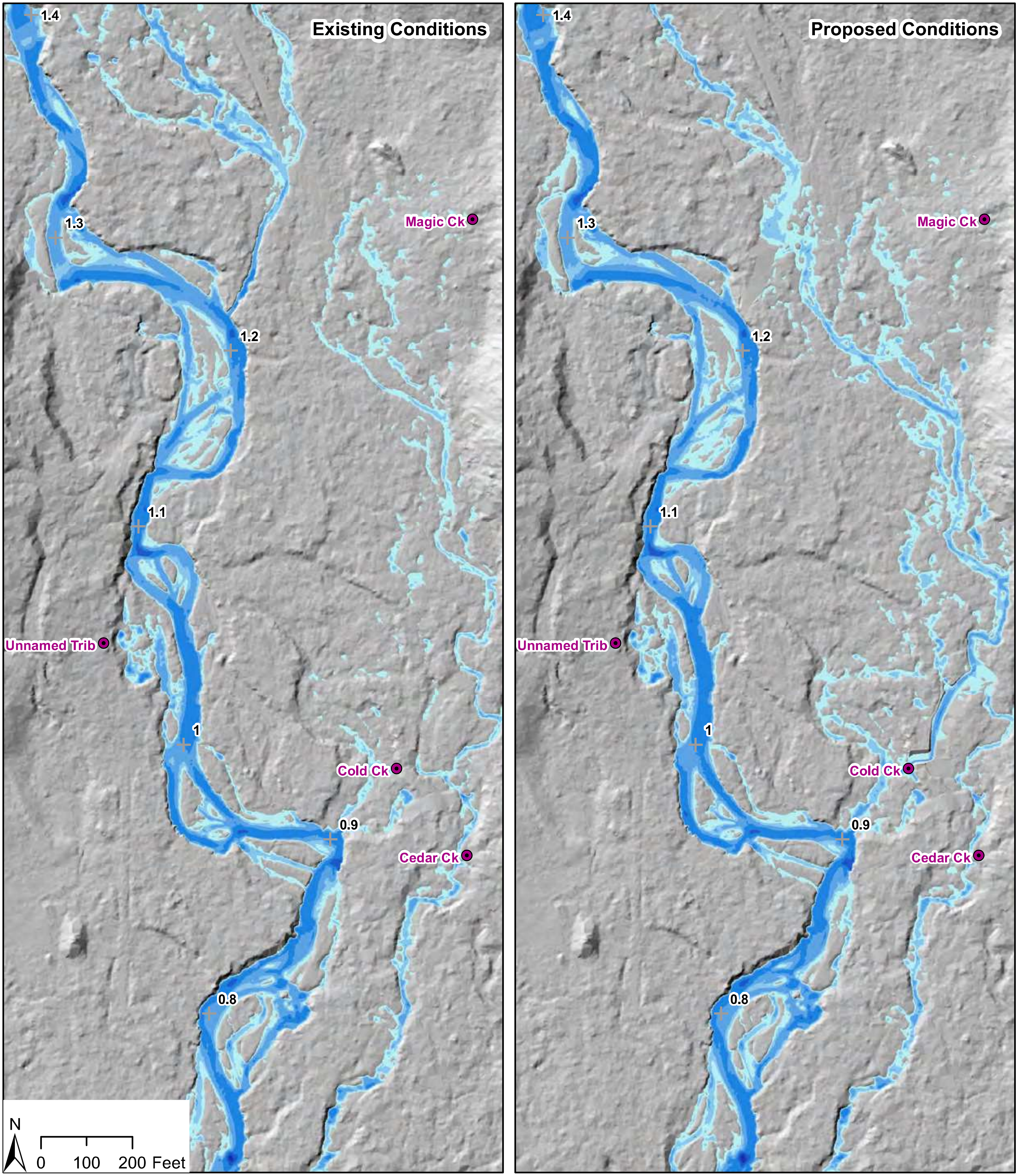
Kachess River Restoration

95% Design

Hydraulic Model Output

1.5-year Flood Event

(643 cfs at Downstream End)



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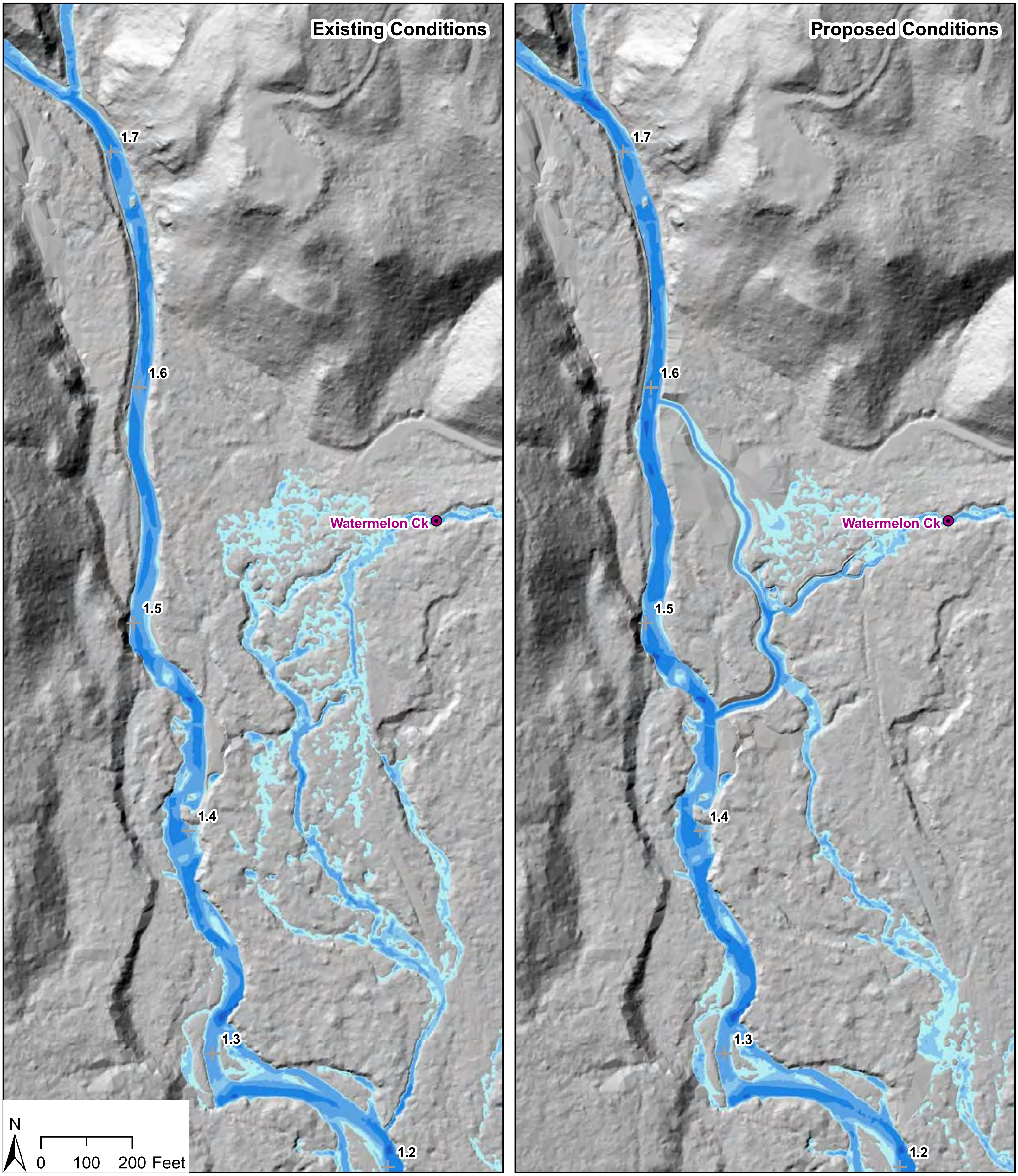

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Kachess River Restoration

95% Design

Hydraulic Model Output

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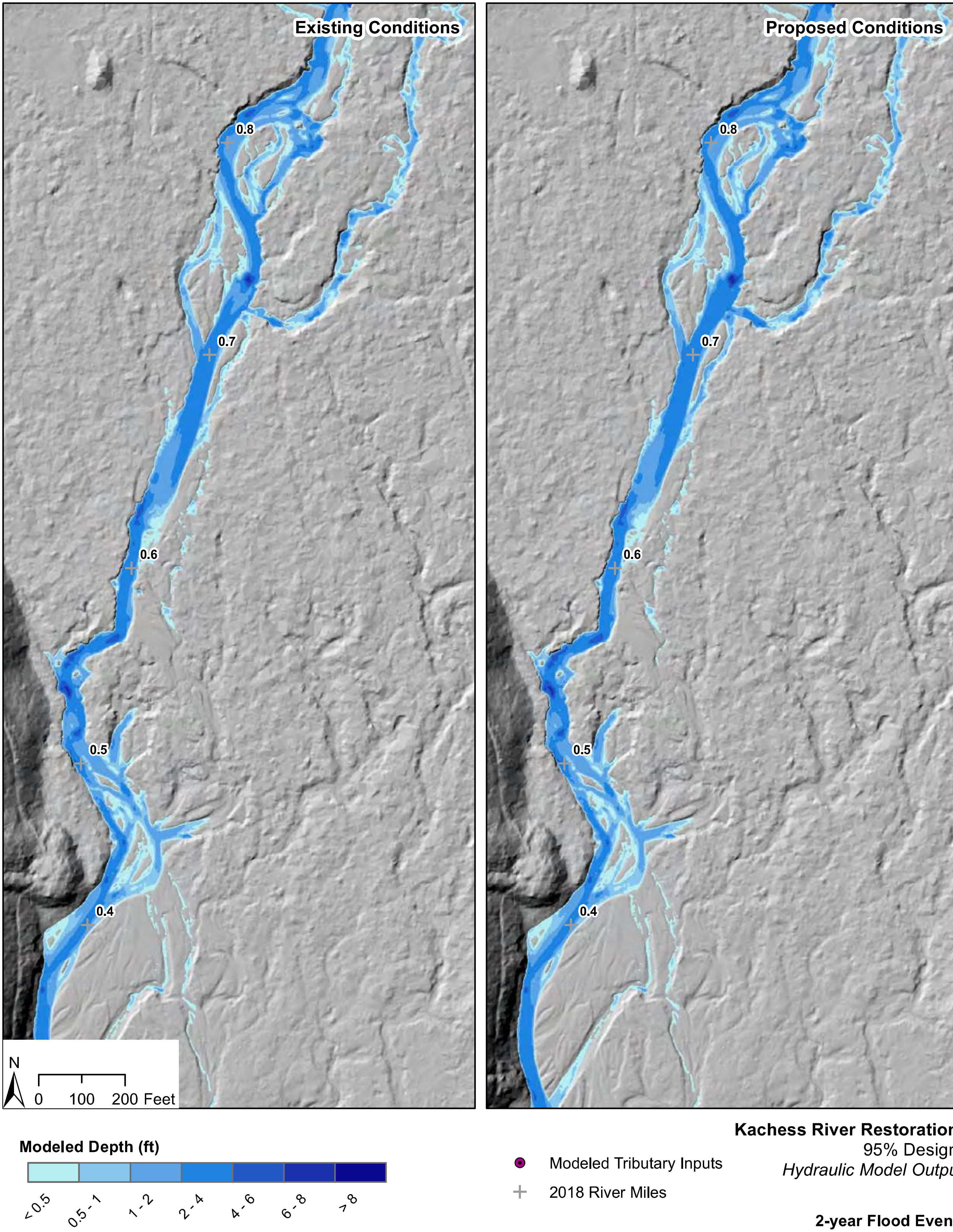
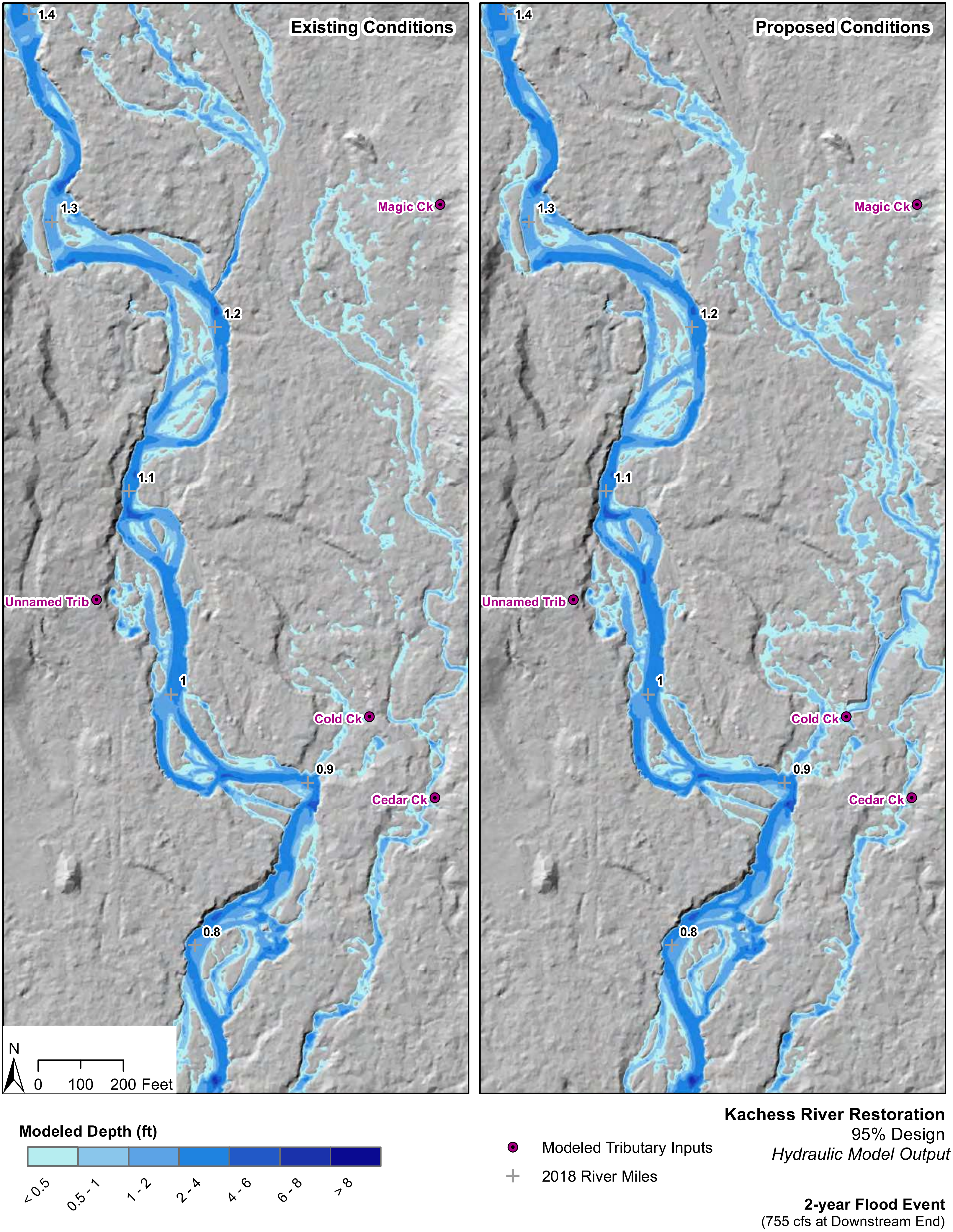


Kachess River Restoration
95% Design
Hydraulic Model Output

2-year Flood Event
(755 cfs at Downstream End)


Existing Conditions
Proposed Conditions
1.4
1.3
1.2
1.1
1
0.9
0.8
Magic Ck
Unnamed Trib
Cold Ck
Cedar Ck
N
0
100
200 Feet
Modeled Depth (ft)
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0.5 - 1
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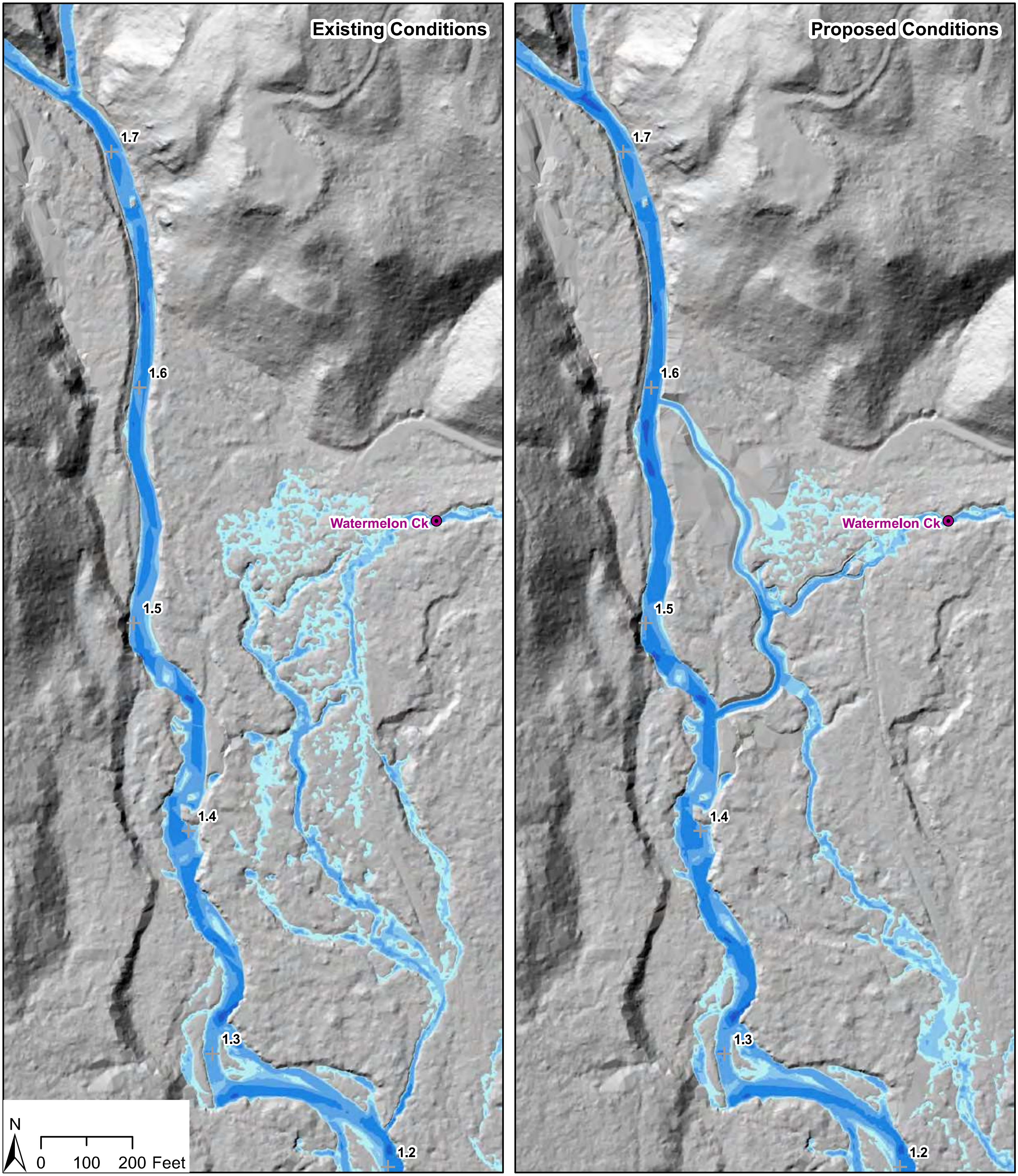

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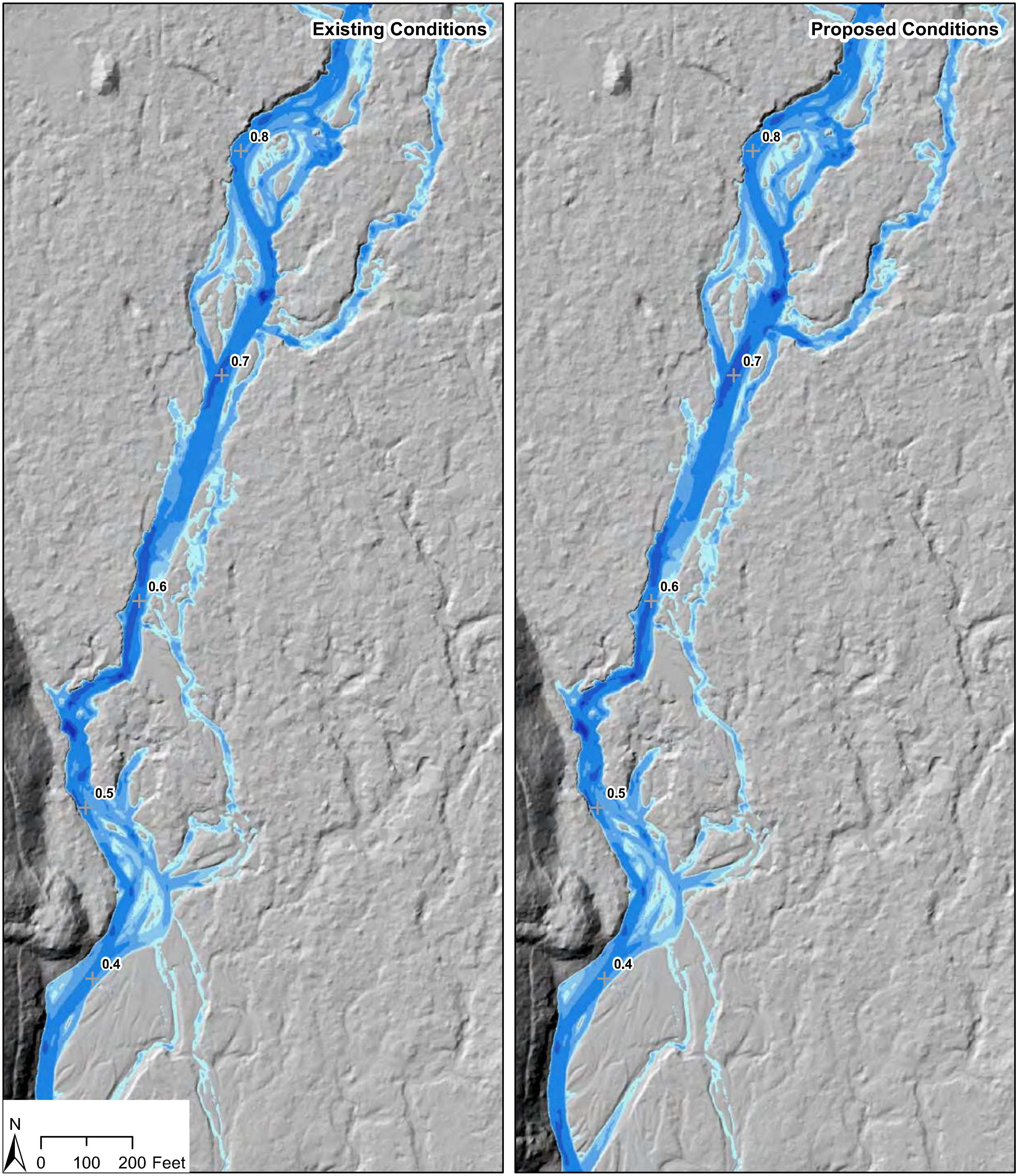

Modeled Depth (ft)

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Modeled Tributary Inputs

2018 River Miles

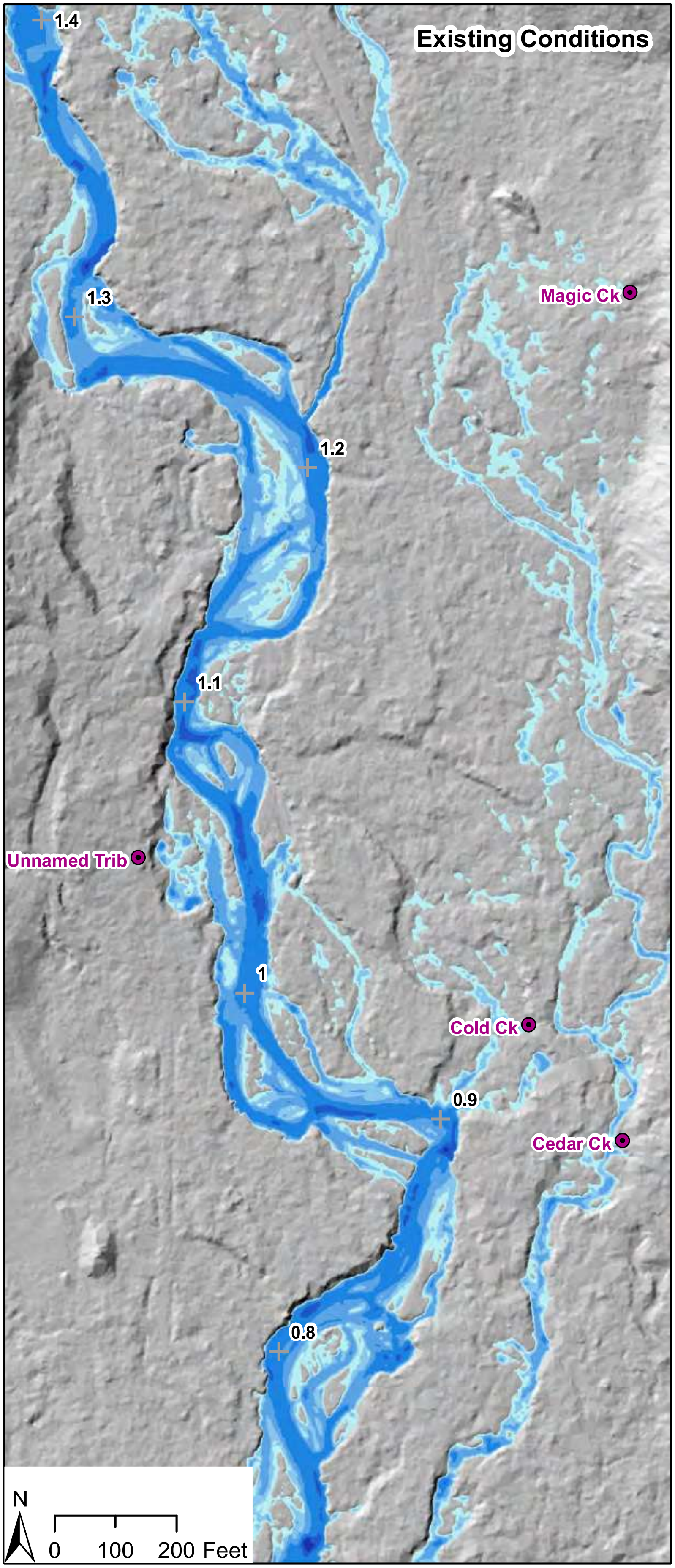
Kachess River Restoration

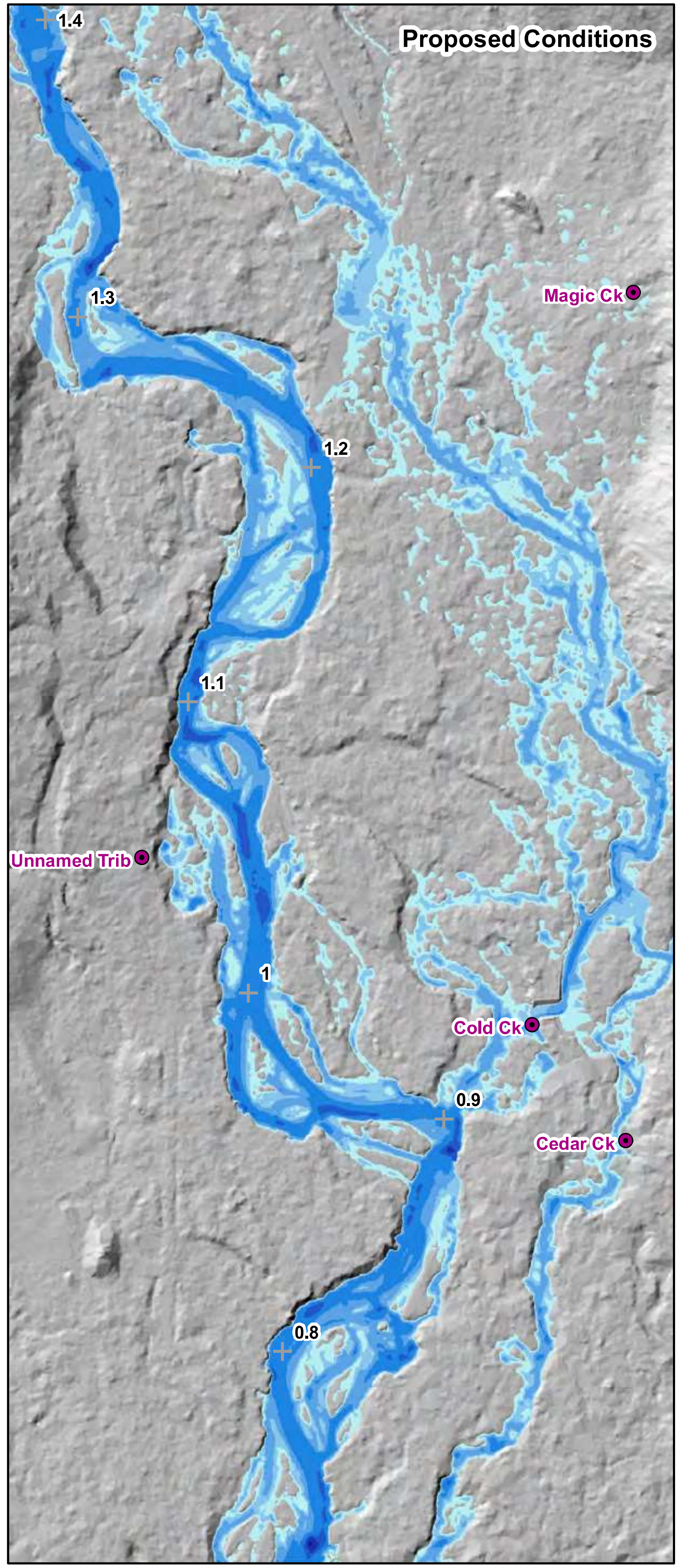
95% Design

Hydraulic Model Output

5-year Flood Event

(1,211 cfs at Downstream End)





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2018 River Miles

Kachess River Restoration

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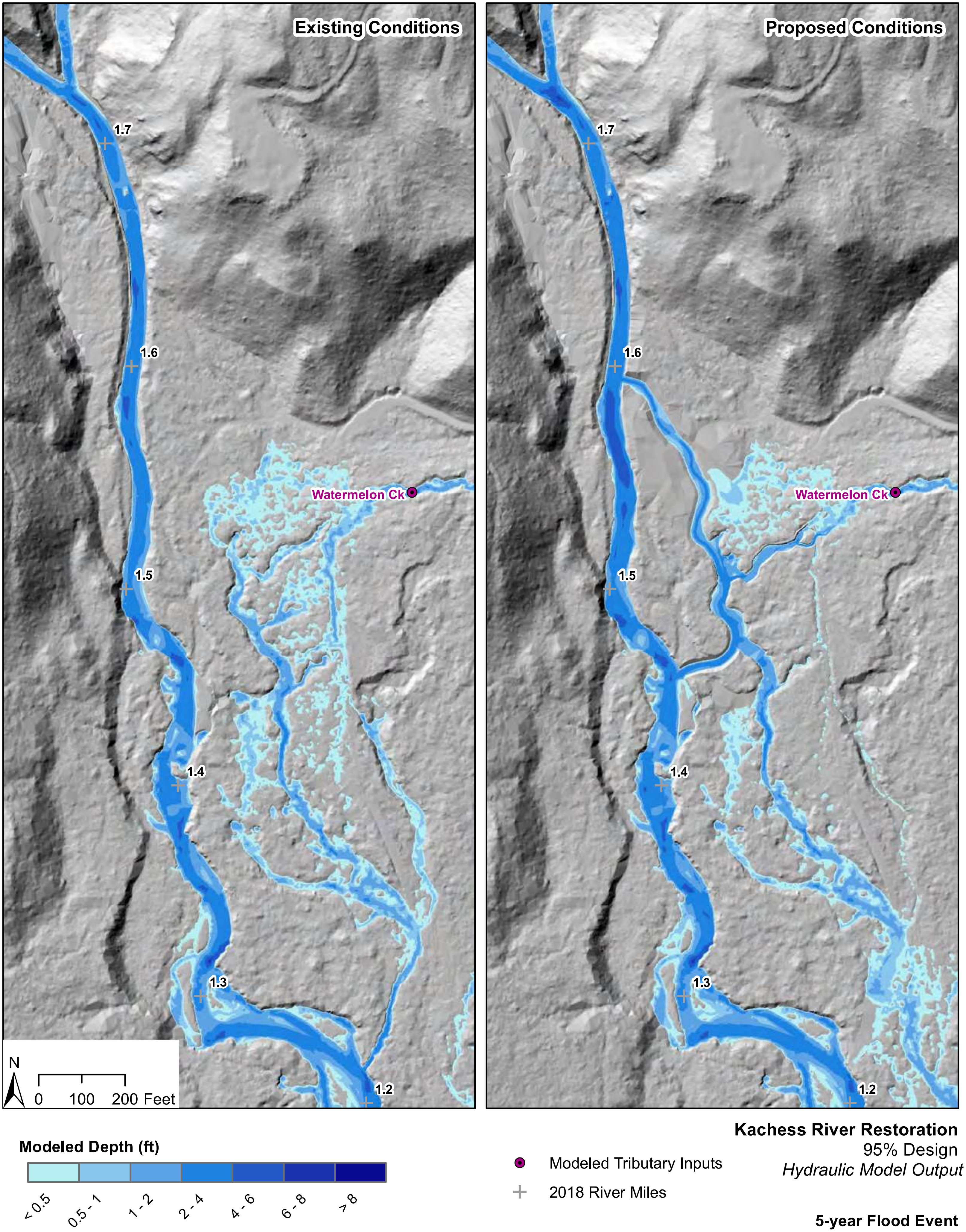
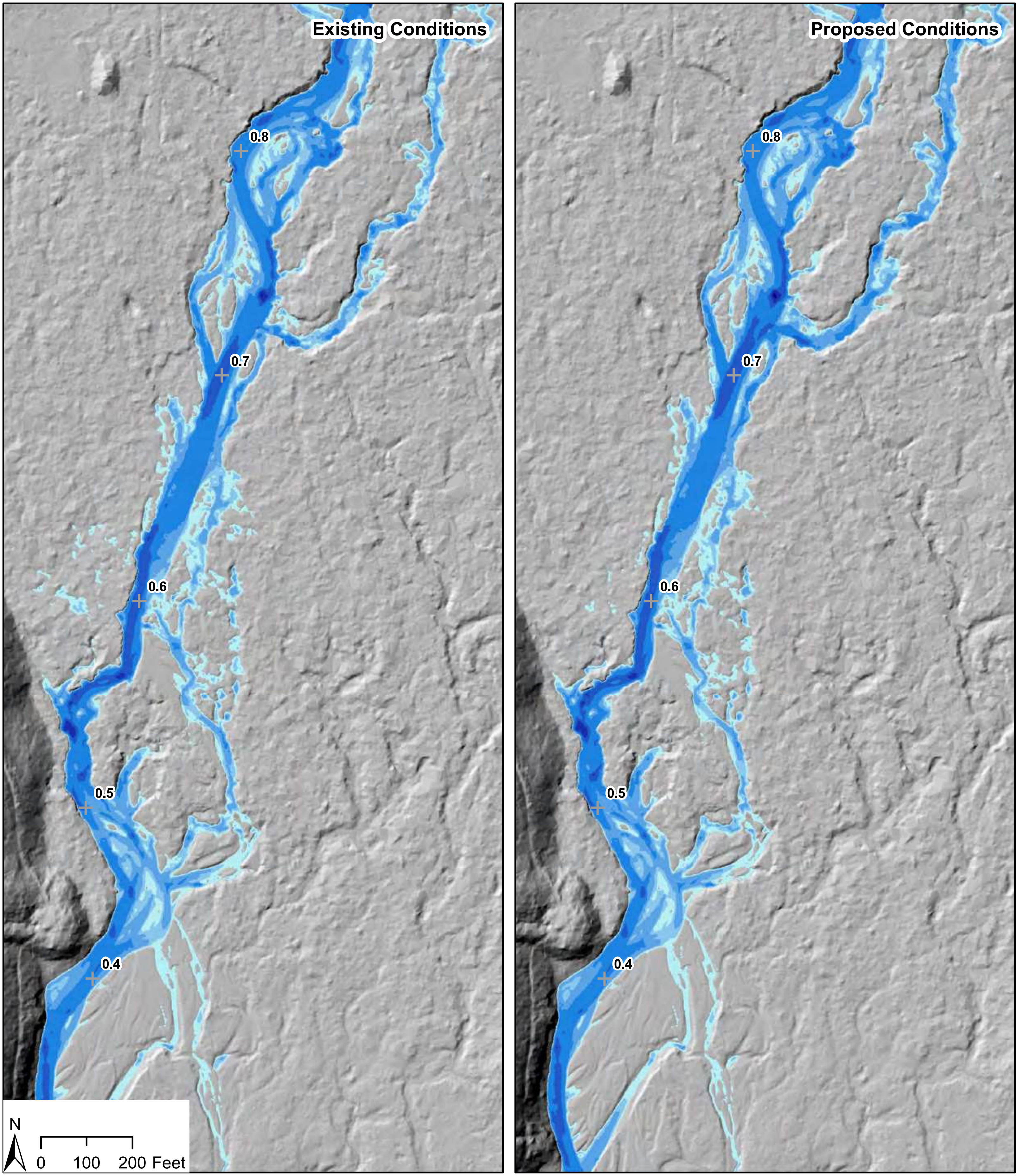


Kachess River Restoration
95% Design
Hydraulic Model Output

5-year Flood Event
(1,211 cfs at Downstream End)



Modeled Depth (ft)

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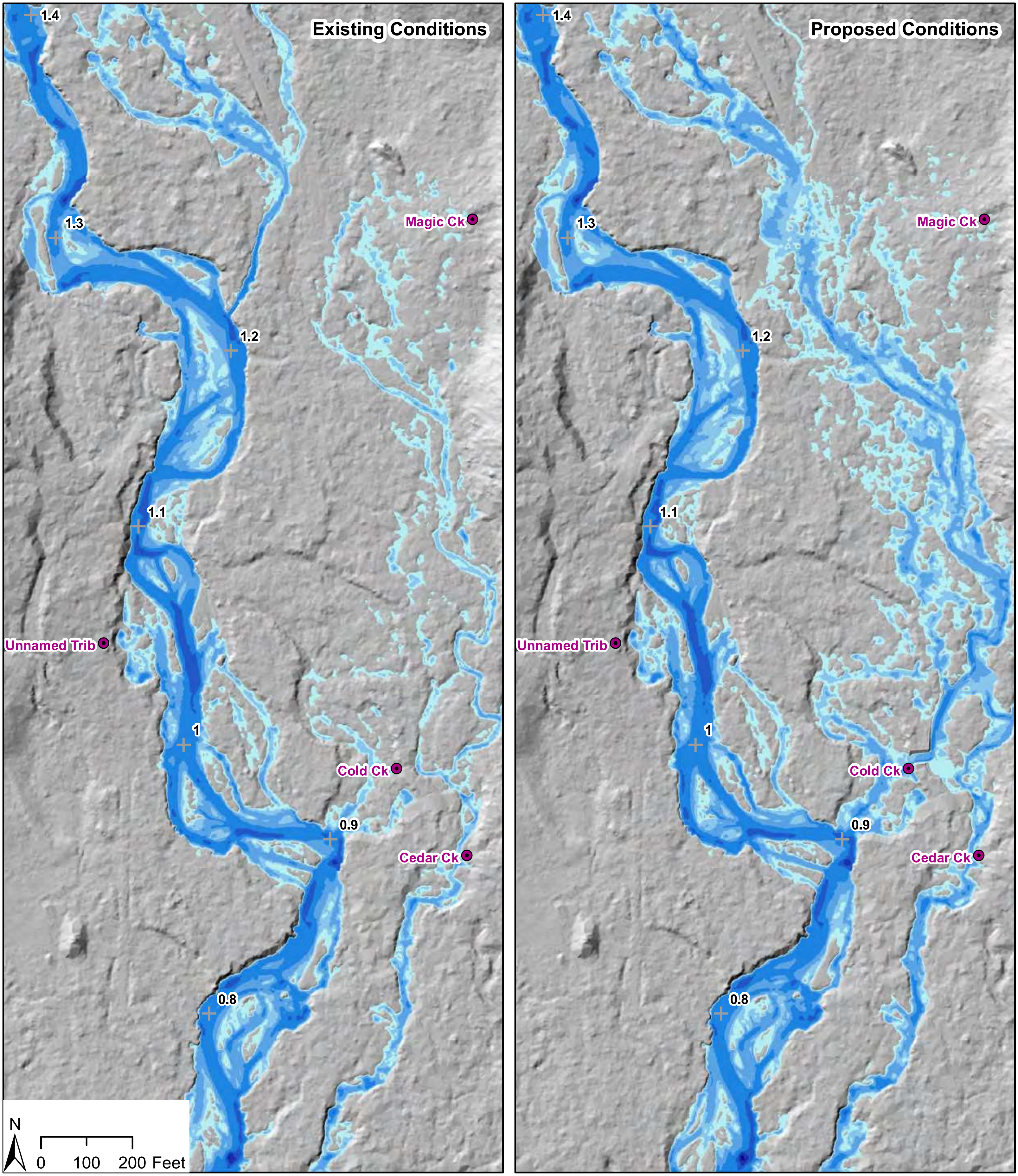
Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

10-year Flood Event
(1,520 cfs at Downstream End)



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Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
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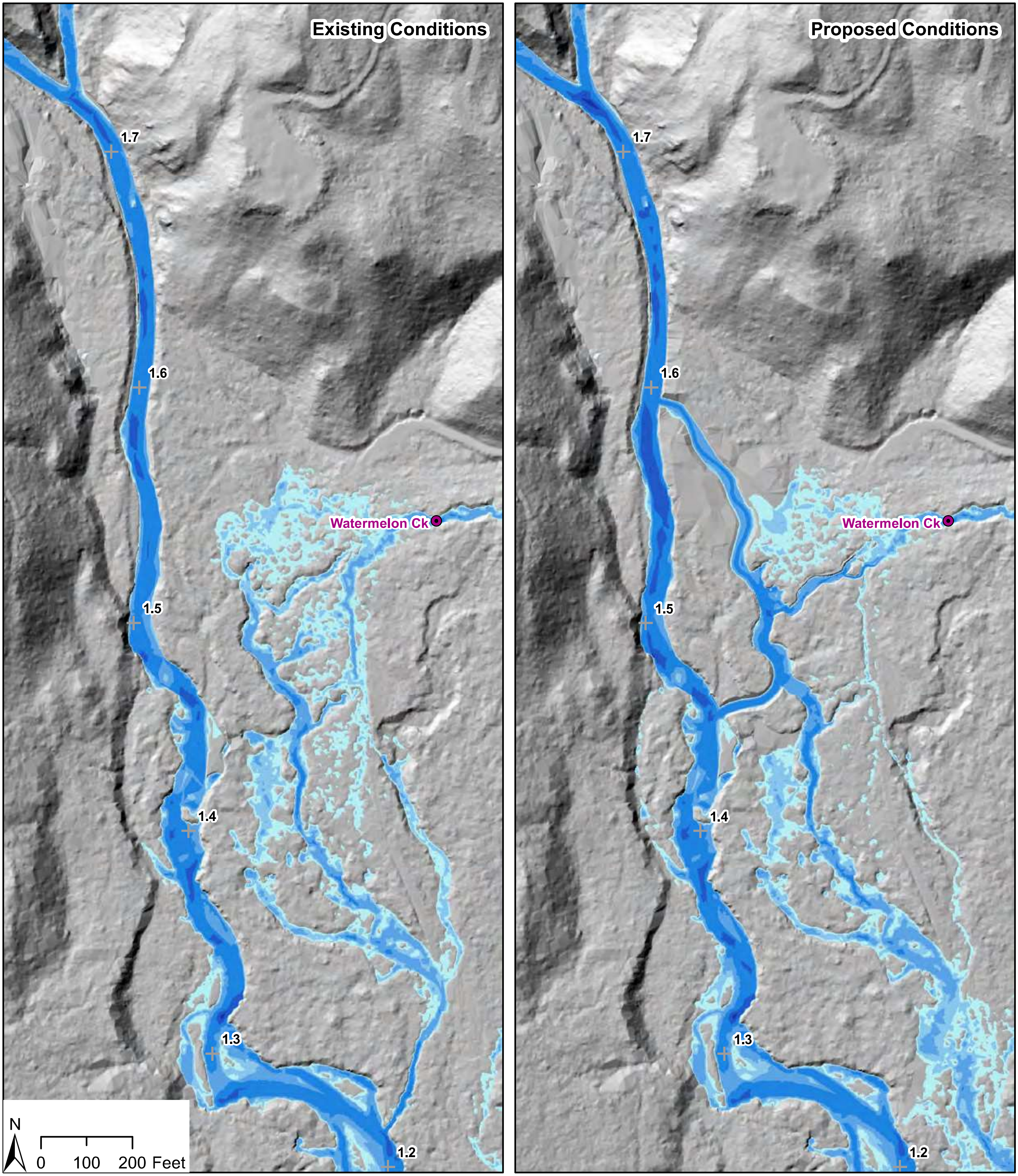

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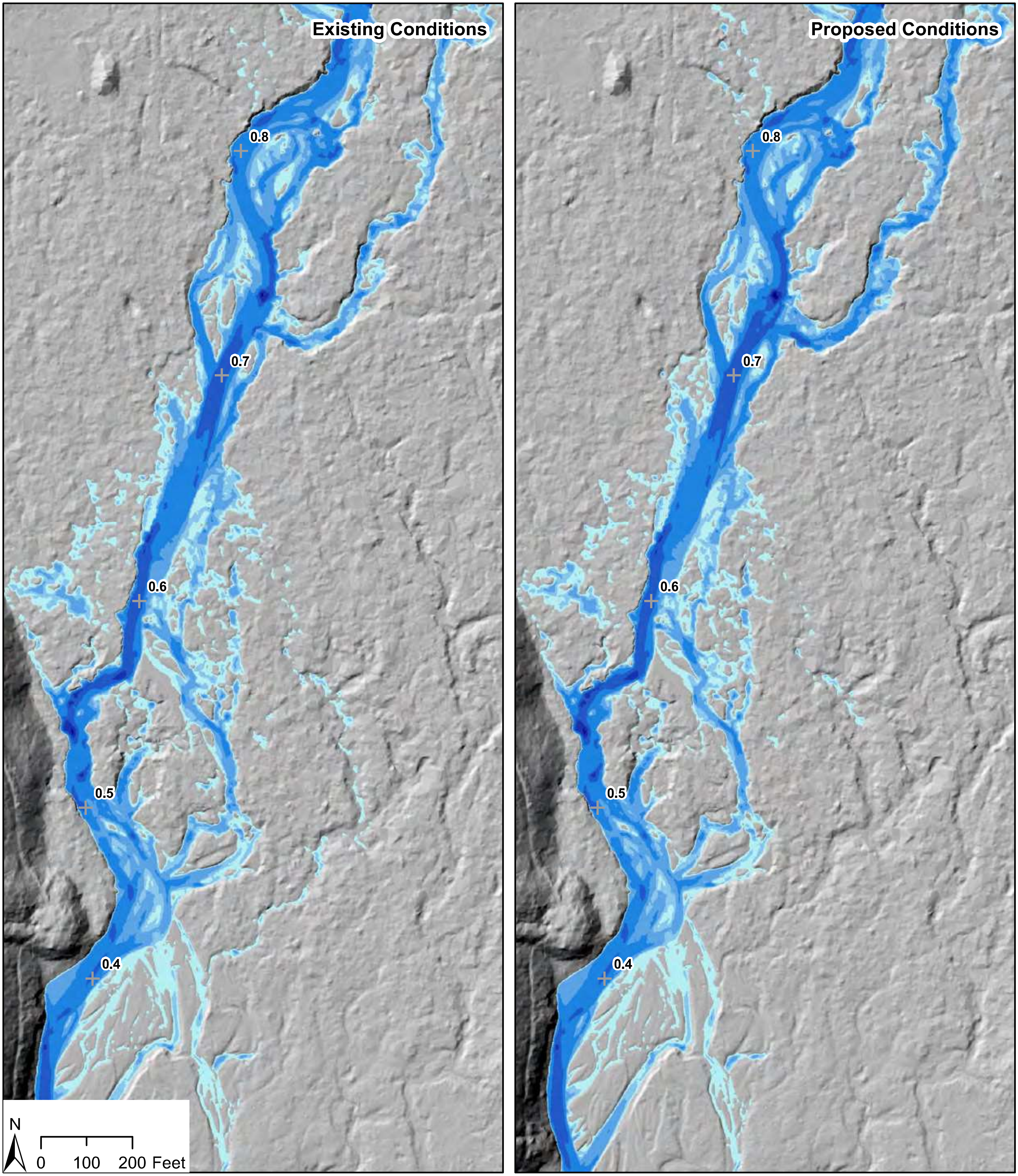


Modeled Depth (ft)

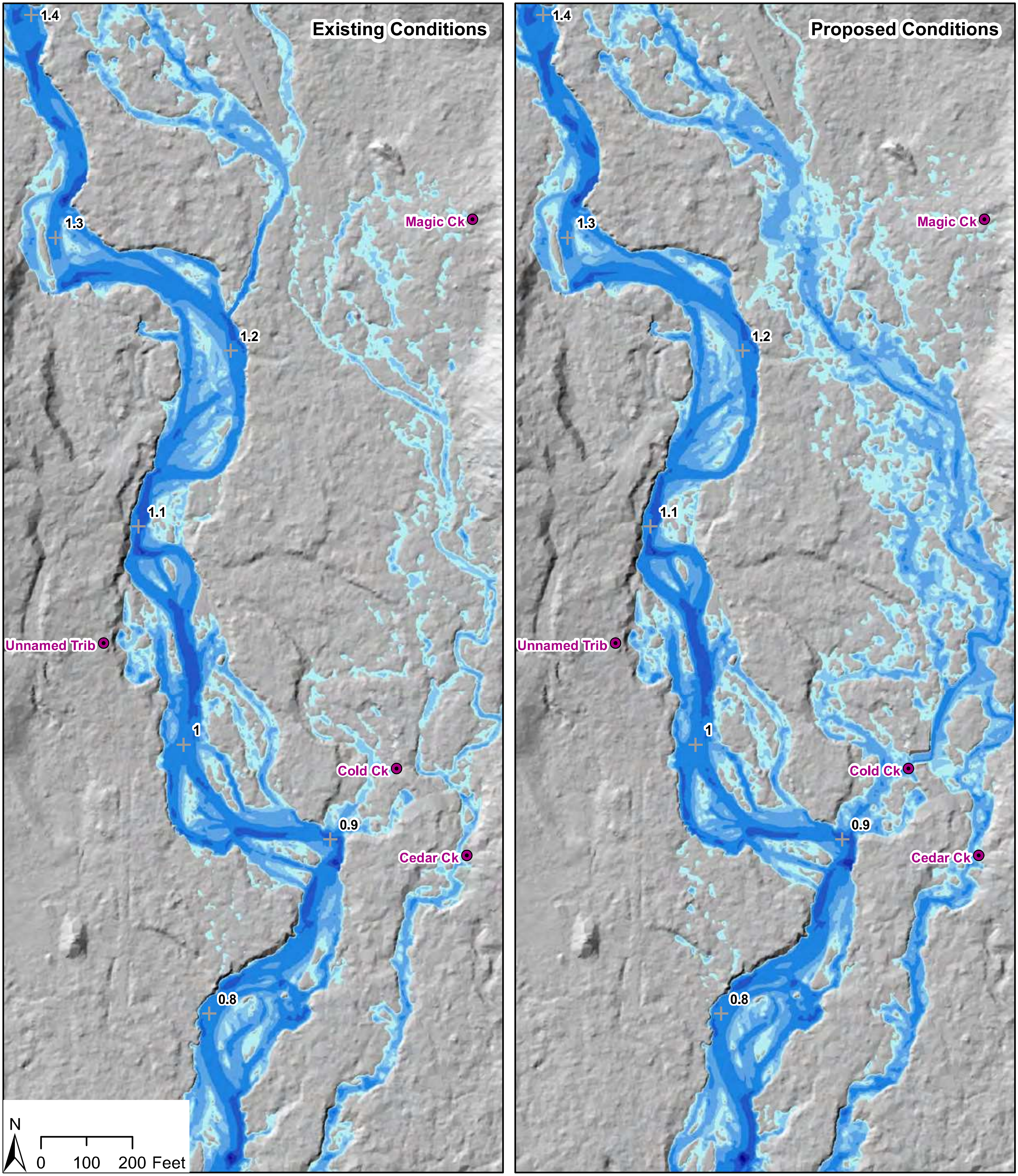
< 0.5 | 0.5 - 1 | 1 - 2 | 2 - 4 | 4 - 6 | 6 - 8 | > 8

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

25-year Flood Event
(1,930 cfs at Downstream End)



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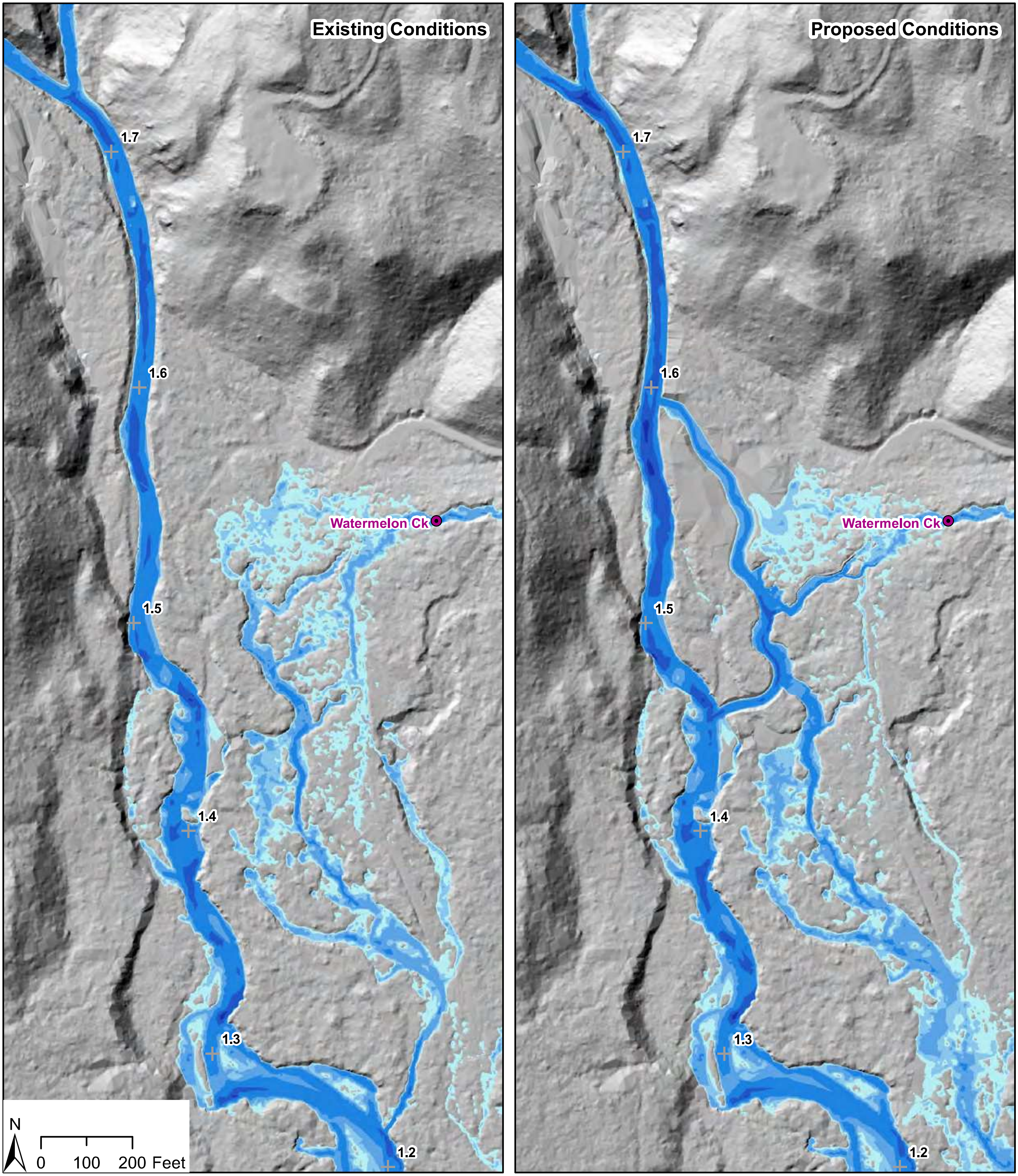
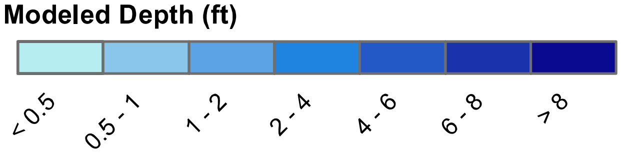
25-year Flood Event

(1,930 cfs at Downstream End)



Modeled Depth (ft)

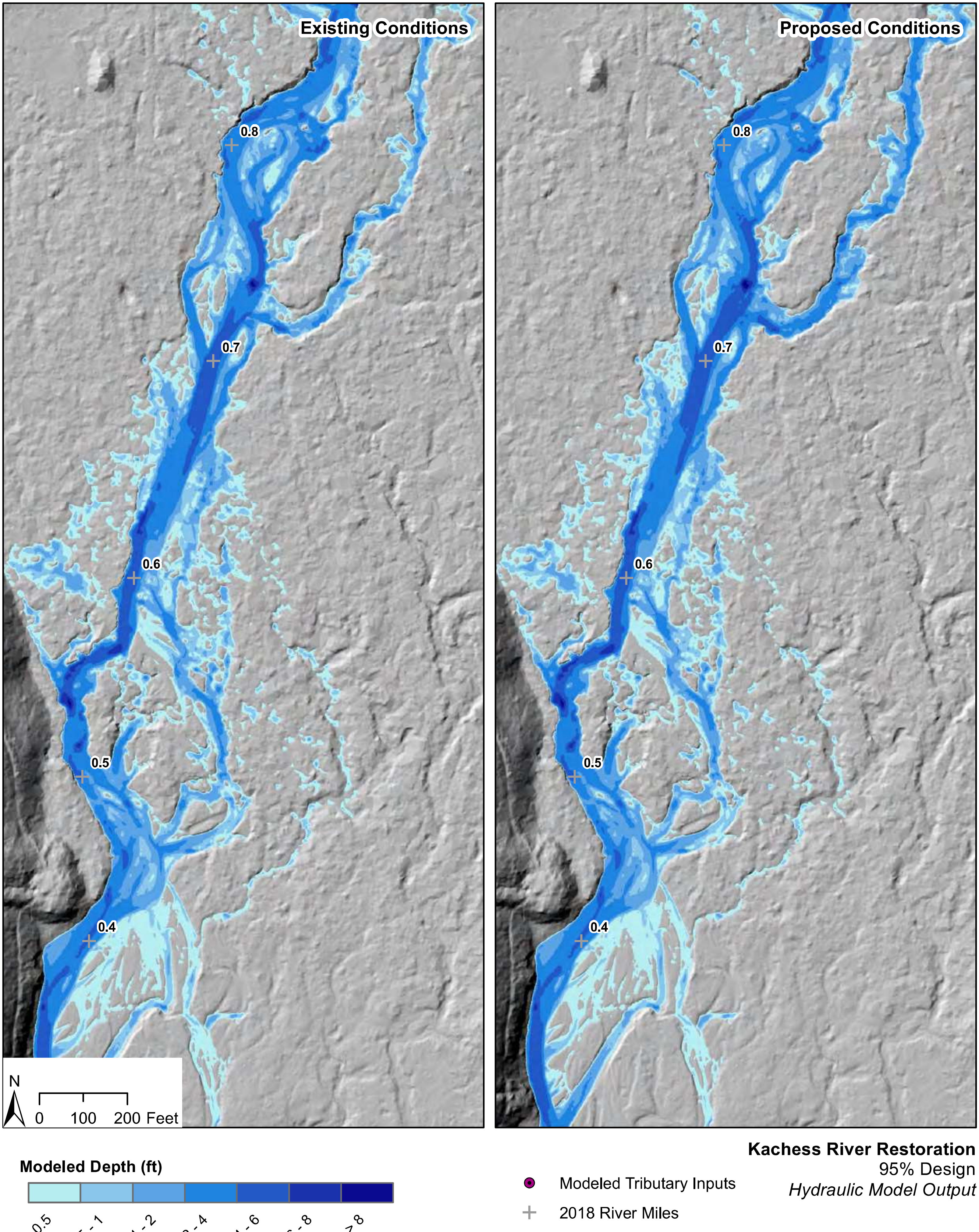


Modeled Tributary Inputs

2018 River Miles

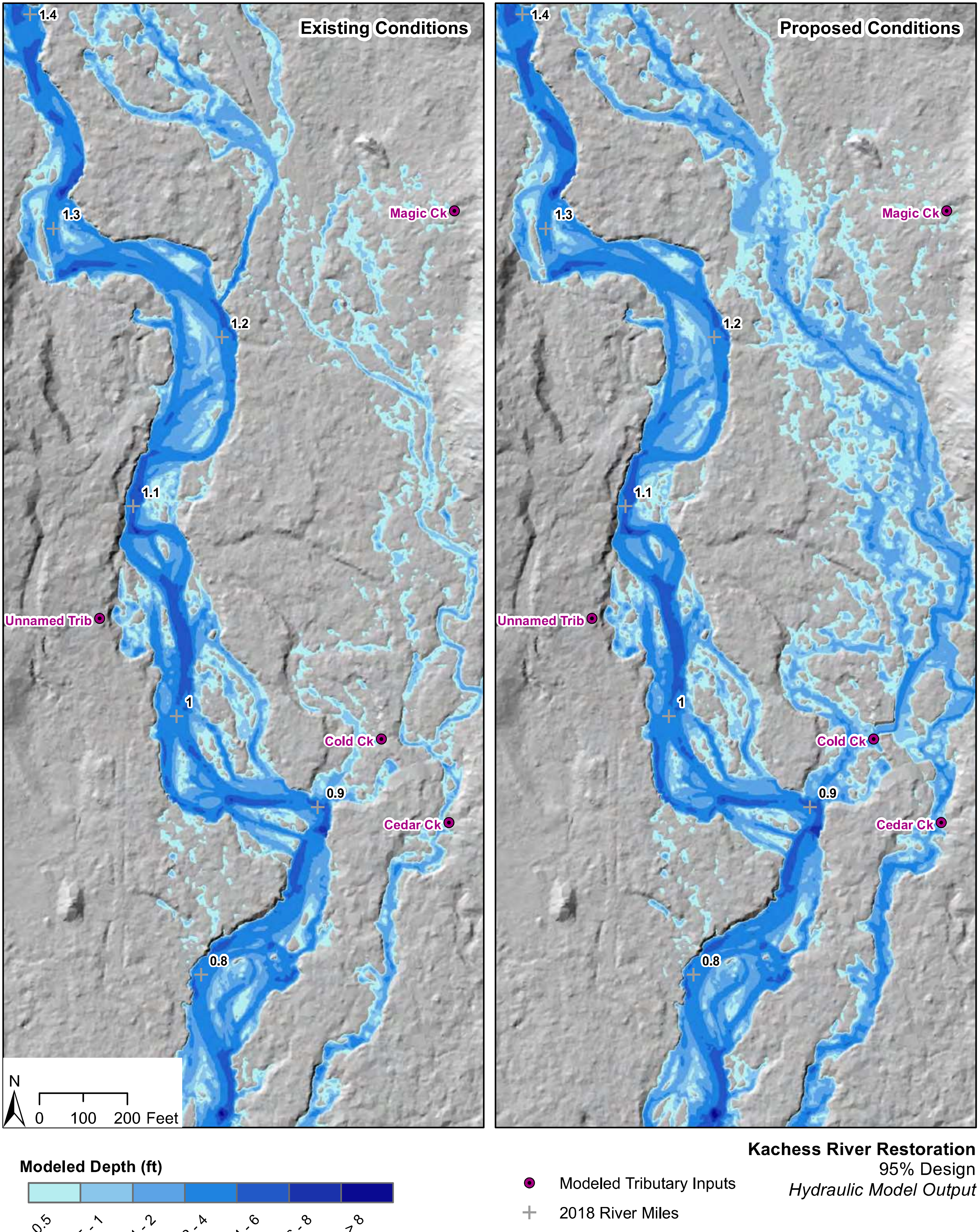
Kachess River Restoration
95% Design
Hydraulic Model Output

25-year Flood Event
(1,930 cfs at Downstream End)



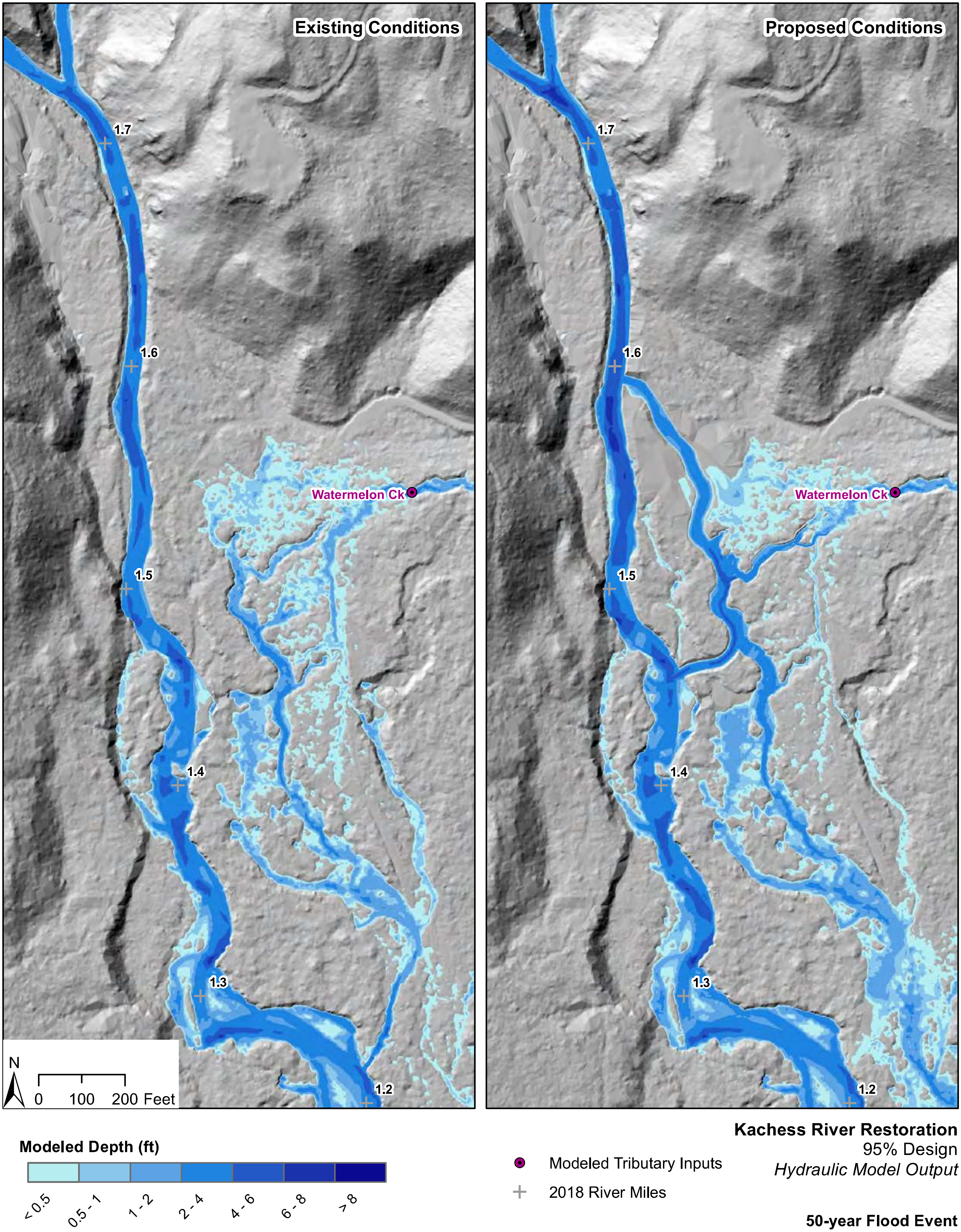
Kachess River Restoration
95% Design
Hydraulic Model Output

50-year Flood Event
(2,240 cfs at Downstream End)



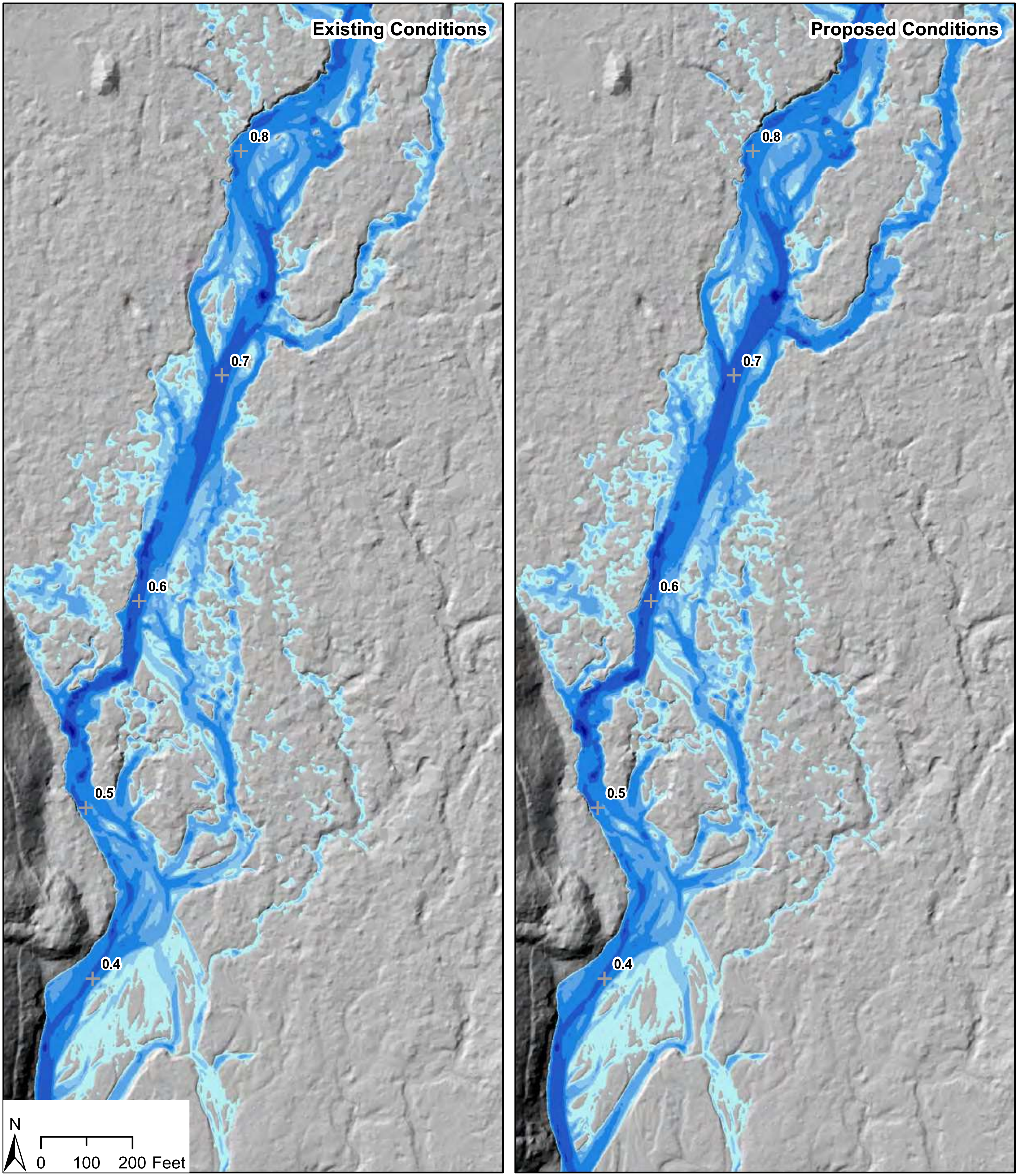
Kachess River Restoration
95% Design
Hydraulic Model Output

50-year Flood Event
(2,240 cfs at Downstream End)



Kachess River Restoration
95% Design
Hydraulic Model Output

50-year Flood Event
(2,240 cfs at Downstream End)



Modeled Depth (ft)

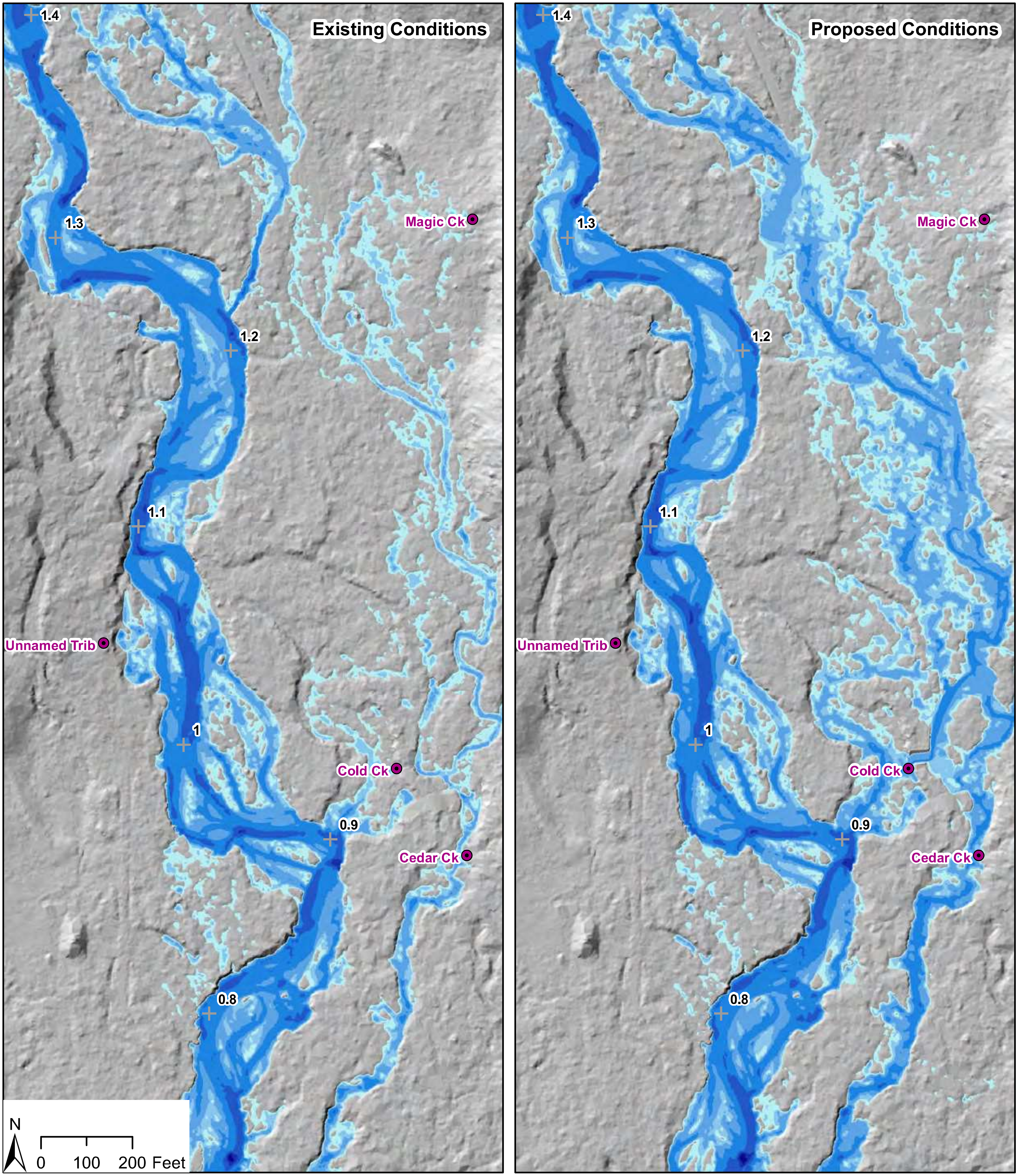
<0.5 | 0.5 - 1 | 1 - 2 | 2 - 4 | 4 - 6 | 6 - 8 | >8

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

100-year Flood Event
(2,559 cfs at Downstream End)



Modeled Depth (ft)

< 0.5 | 0.5 - 1 | 1 - 2 | 2 - 4 | 4 - 6 | 6 - 8 | > 8

Modeled Tributary Inputs

2018 River Miles

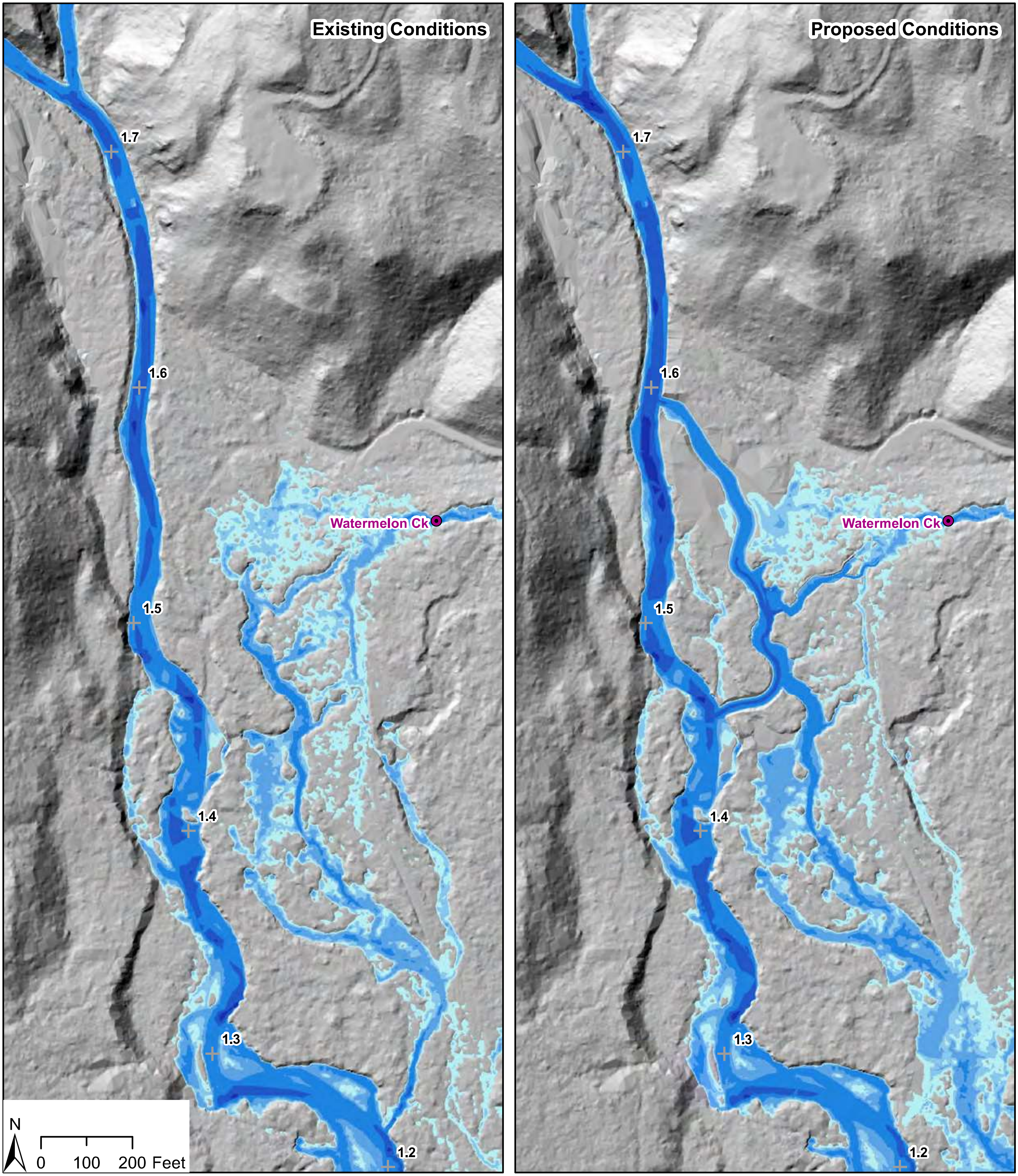
Kachess River Restoration

95% Design

Hydraulic Model Output

100-year Flood Event

(2,559 cfs at Downstream End)



Modeled Depth (ft)

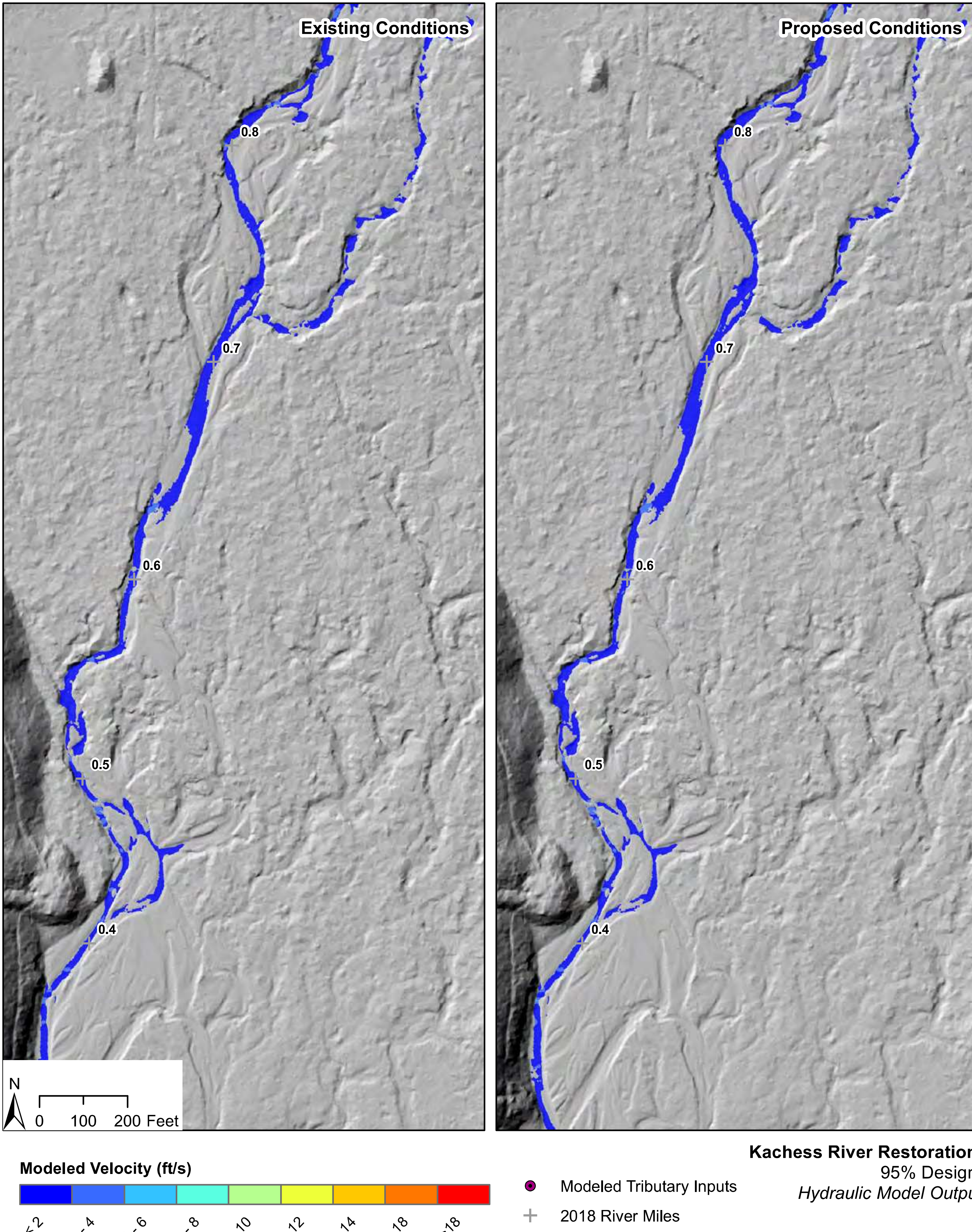
< 0.5 | 0.5 - 1 | 1 - 2 | 2 - 4 | 4 - 6 | 6 - 8 | > 8

Modeled Tributary Inputs

2018 River Miles

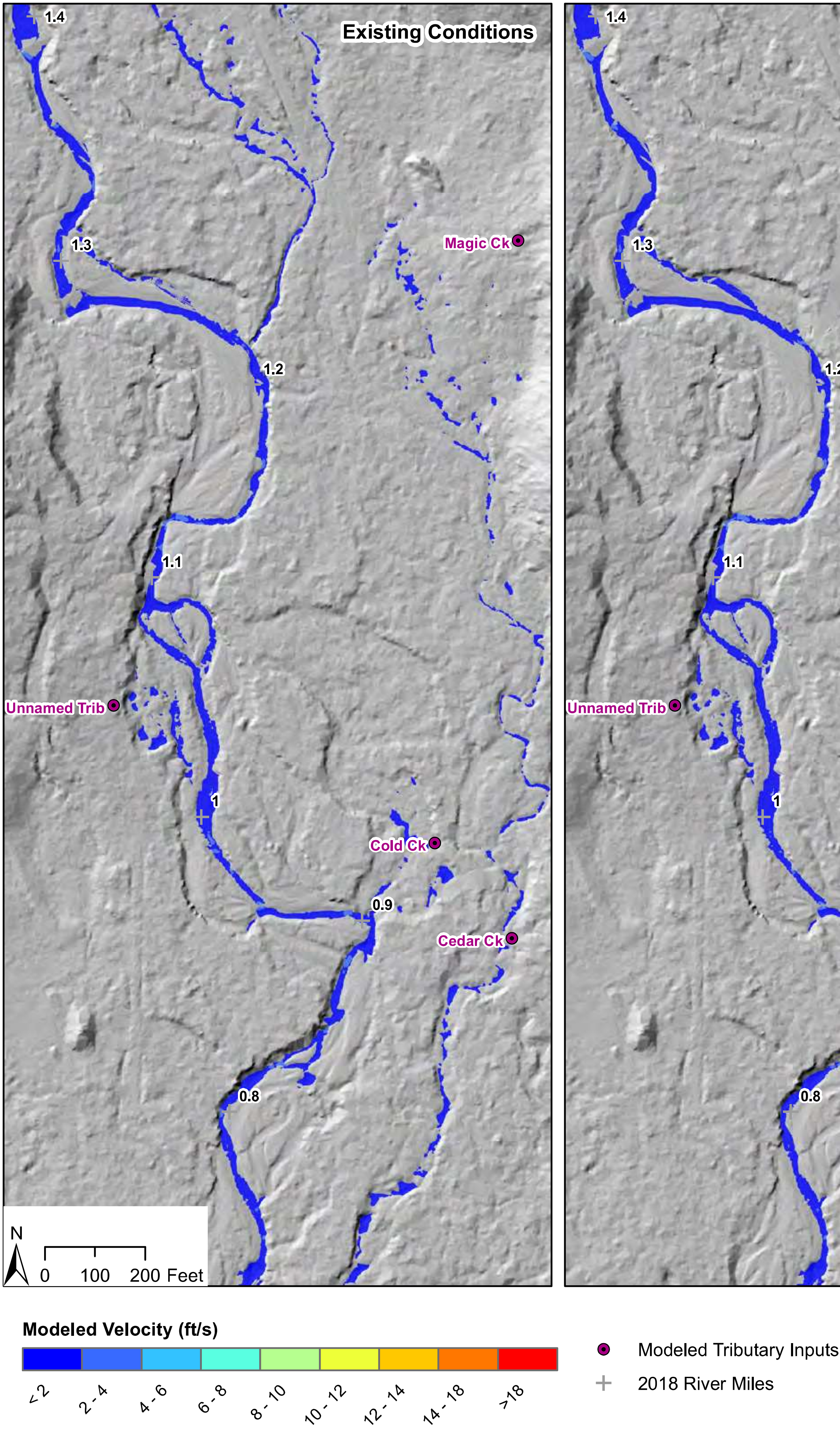
Kachess River Restoration
95% Design
Hydraulic Model Output

100-year Flood Event
(2,559 cfs at Downstream End)



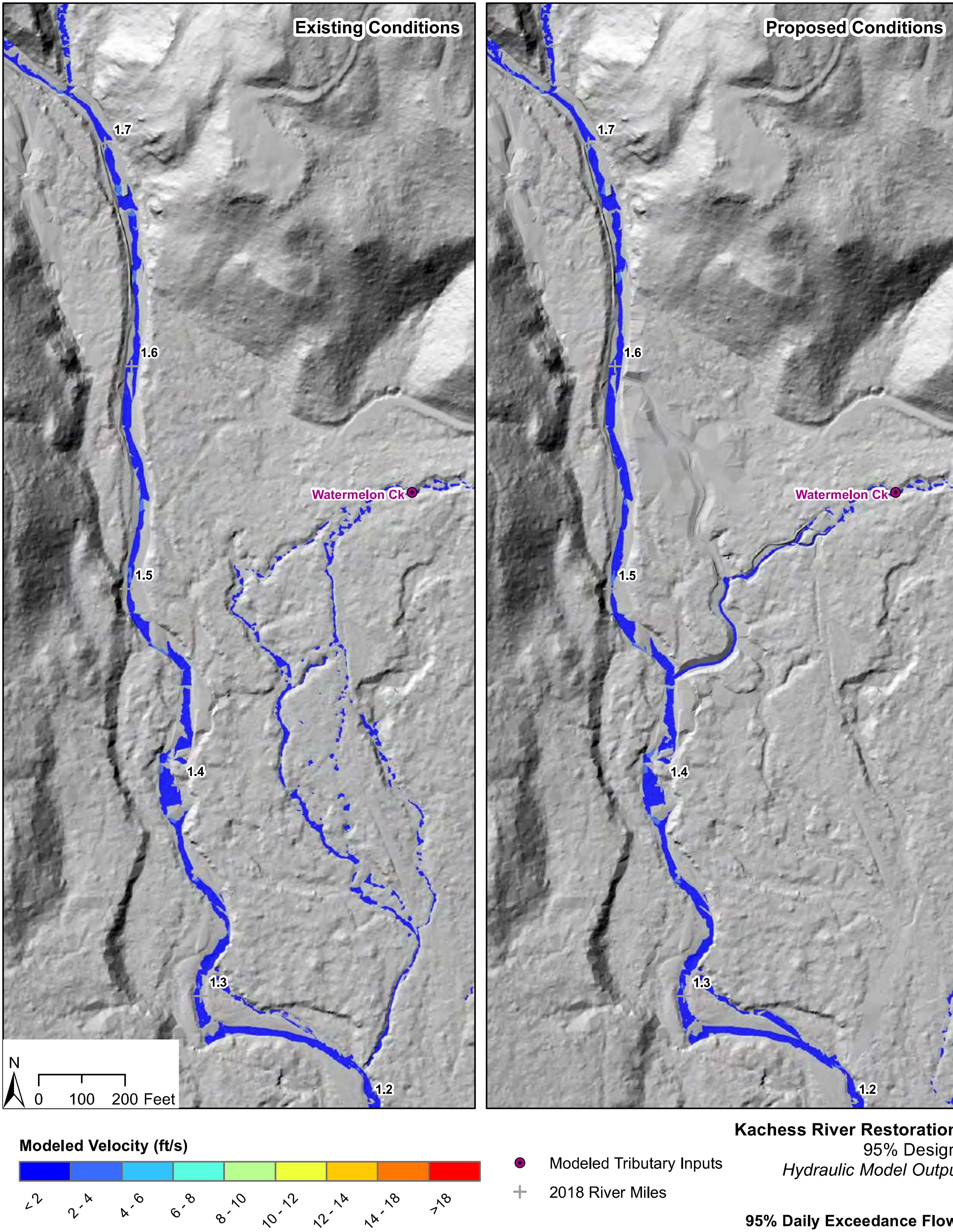
Kachess River Restoration
95% Design
Hydraulic Model Output

95% Daily Exceedance Flow
(5 cfs at Downstream End)



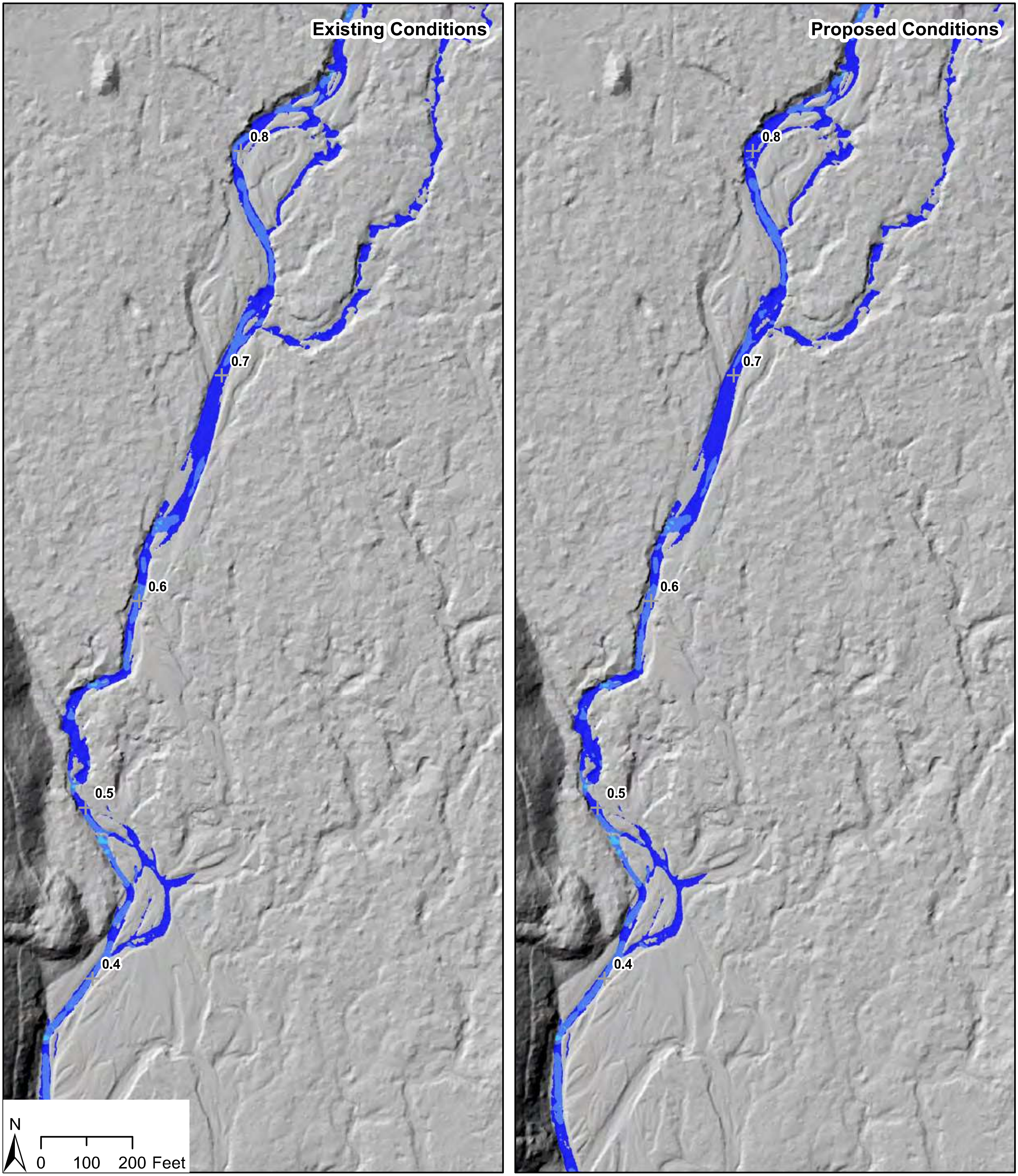
Kachess River Restoration
95% Design
Hydraulic Model Output

95% Daily Exceedance Flow
(5 cfs at Downstream End)



Kachess River Restoration
95% Design
Hydraulic Model Output

95% Daily Exceedance Flow
(5 cfs at Downstream End)



Modeled Velocity (ft/s)

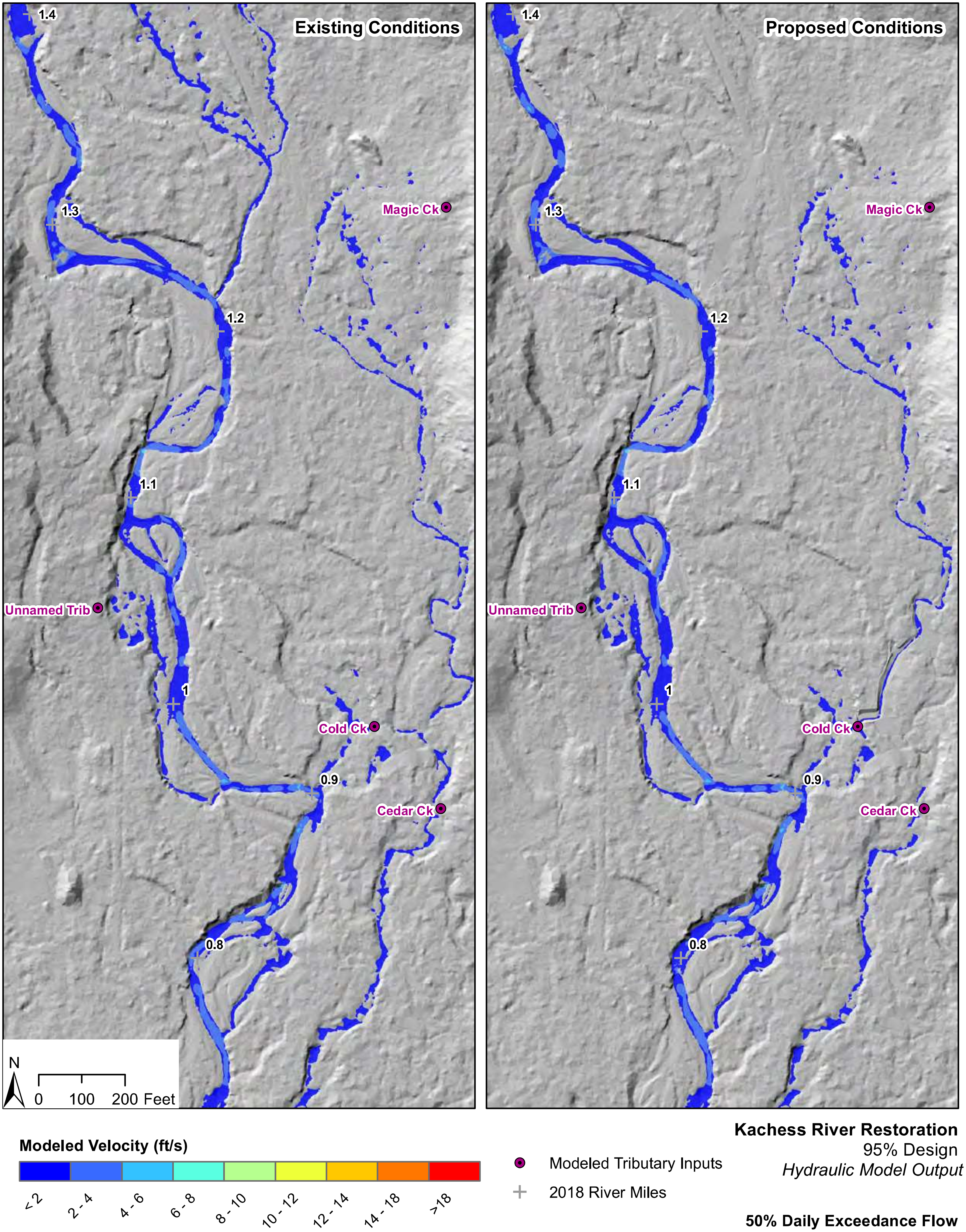
<2, 2 - 4, 4 - 6, 6 - 8, 8 - 10, 10 - 12, 12 - 14, 14 - 18, >18

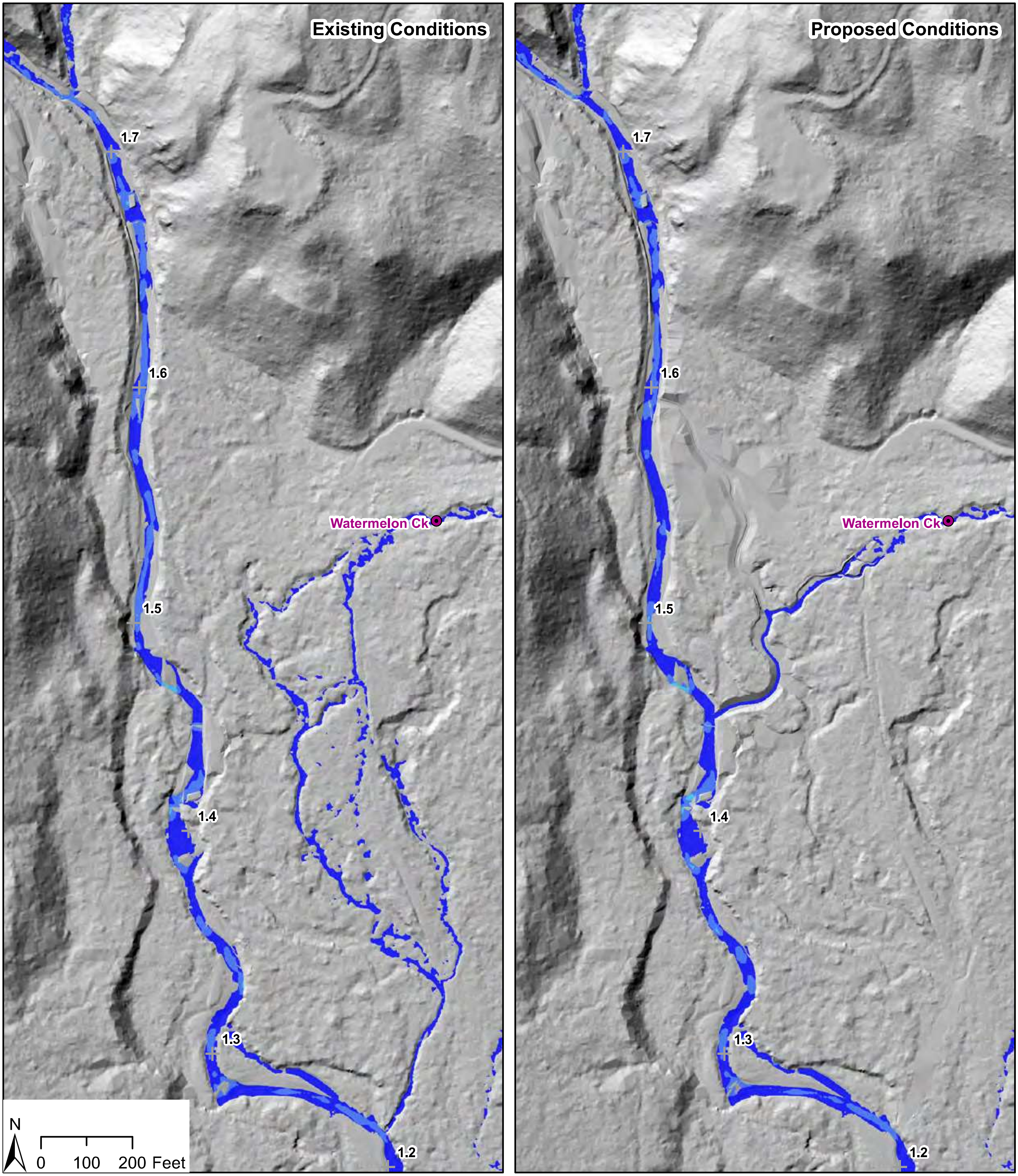
Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

50% Daily Exceedance Flow
(23 cfs at Downstream End)


Existing Conditions
Proposed Conditions
1.4
1.3
1.2
1.1
1
0.9
0.8
Magic Ck
Unnamed Trib
Cold Ck
Cedar Ck
N
0
100
200 Feet
Modeled Velocity (ft/s)
<2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 18
>18
Modeled Tributary Inputs
2018 River Miles
Kachess River Restoration
95% Design
Hydraulic Model Output
50% Daily Exceedance Flow
(23 cfs at Downstream End)



Modeled Velocity (ft/s)

< 2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

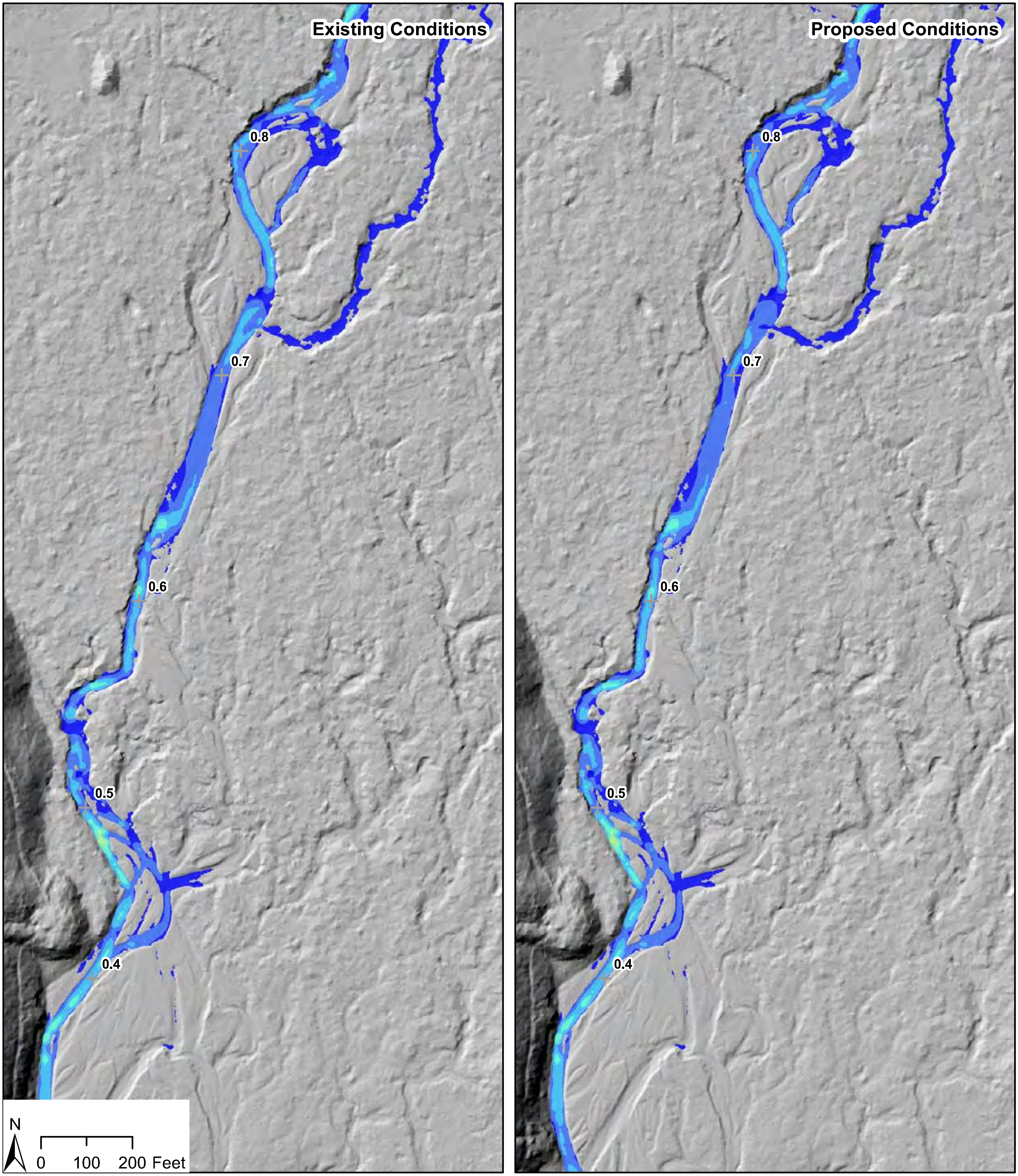
Kachess River Restoration

95% Design

Hydraulic Model Output

50% Daily Exceedance Flow

(23 cfs at Downstream End)



Modeled Velocity (ft/s)

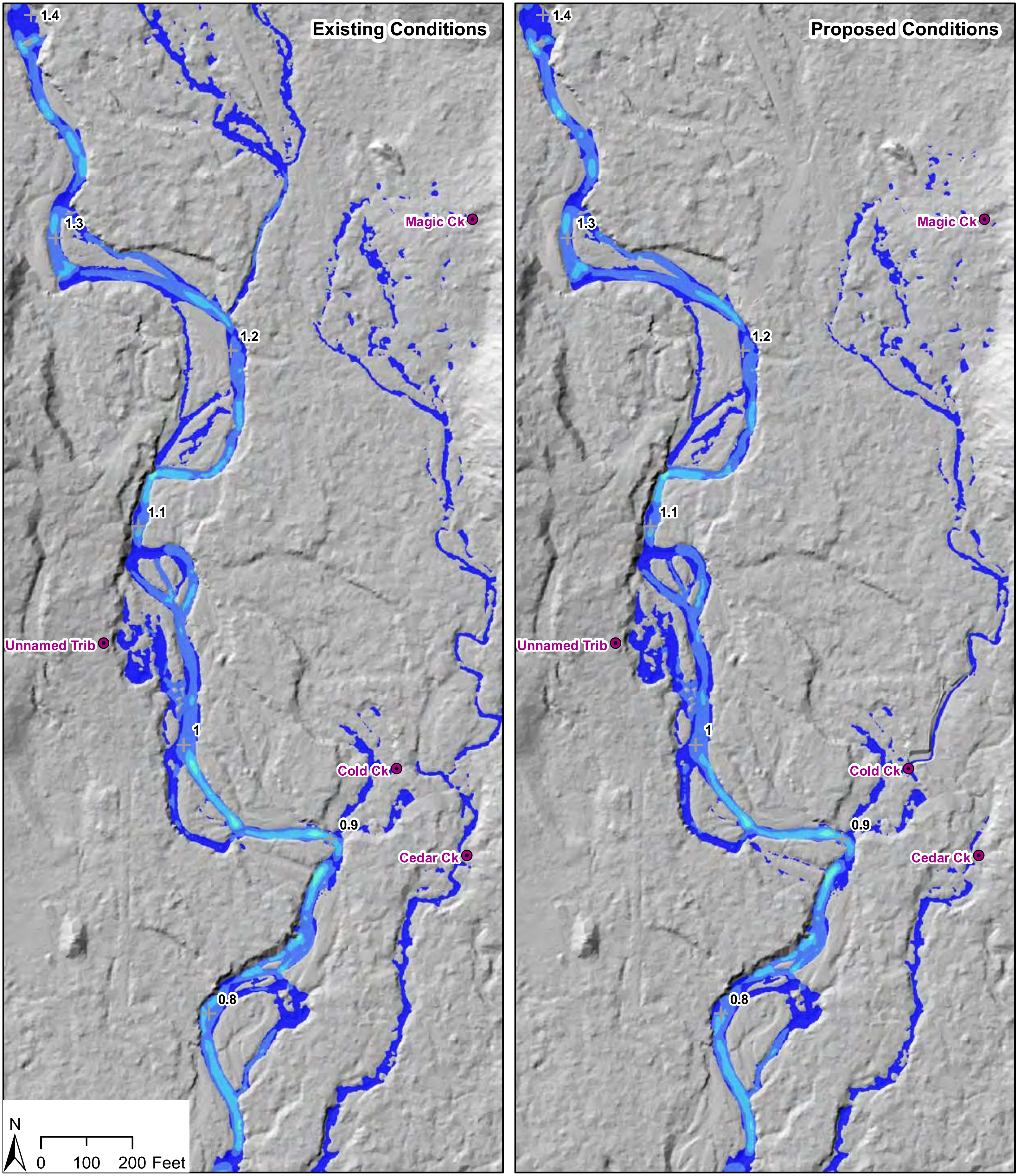
< 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 18
>18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

5% Daily Exceedance Flow
(139 cfs at Downstream End)



Modeled Velocity (ft/s)

<2, 2 - 4, 4 - 6, 6 - 8, 8 - 10, 10 - 12, 12 - 14, 14 - 18, >18

Modeled Tributary Inputs

2018 River Miles

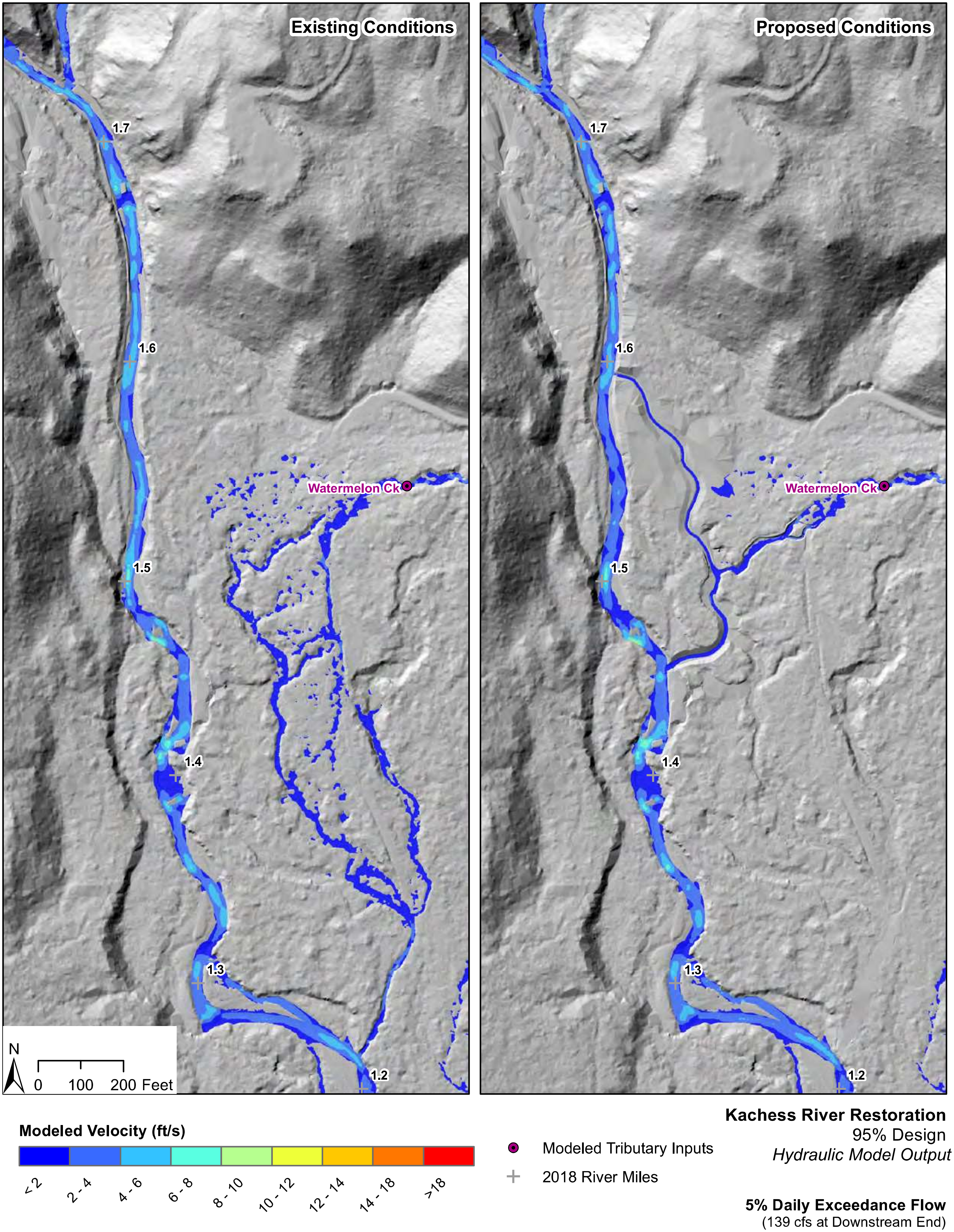
Kachess River Restoration

95% Design

Hydraulic Model Output

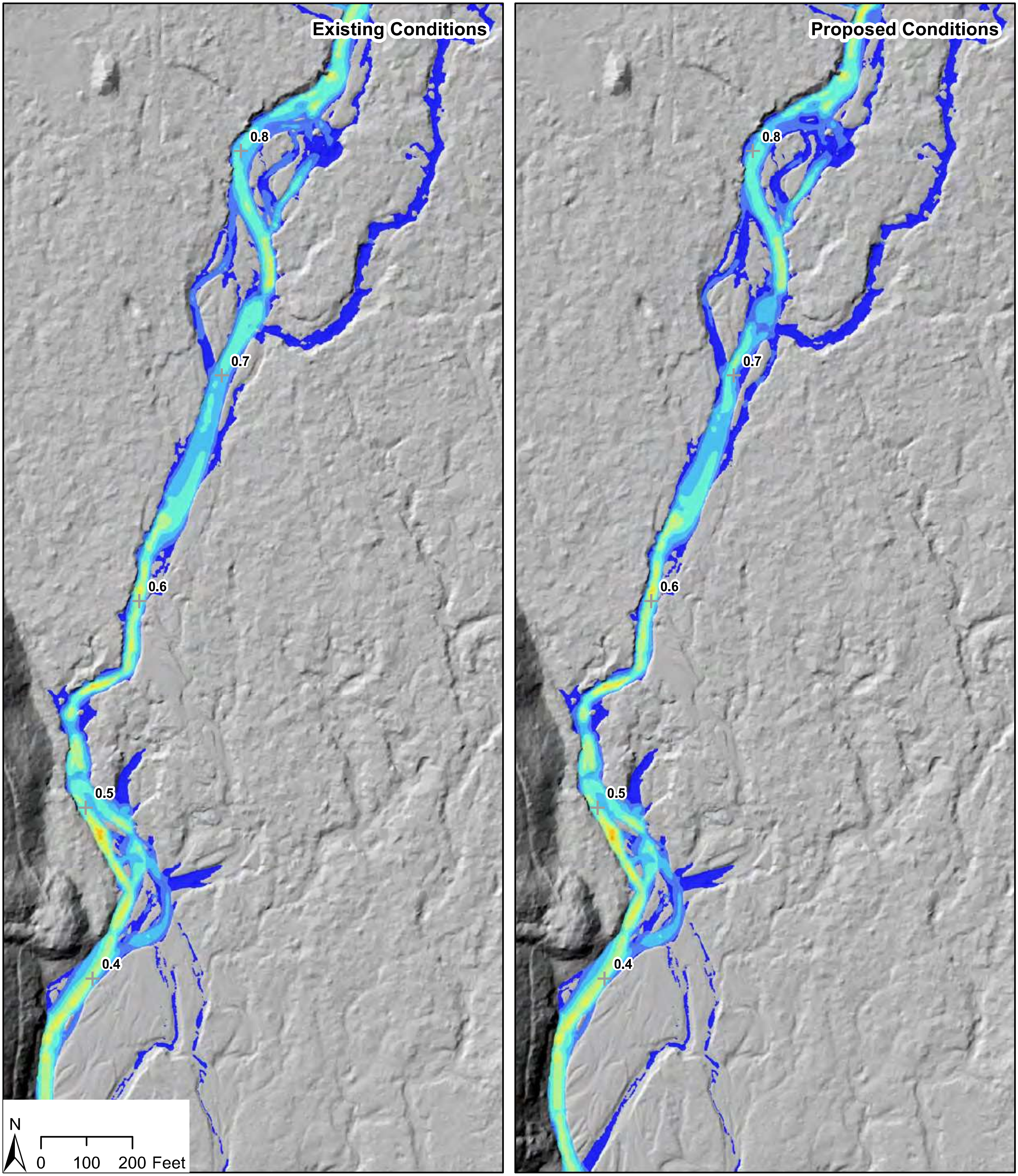
5% Daily Exceedance Flow

(139 cfs at Downstream End)



Kachess River Restoration
95% Design
Hydraulic Model Output

5% Daily Exceedance Flow
(139 cfs at Downstream End)



Modeled Velocity (ft/s)

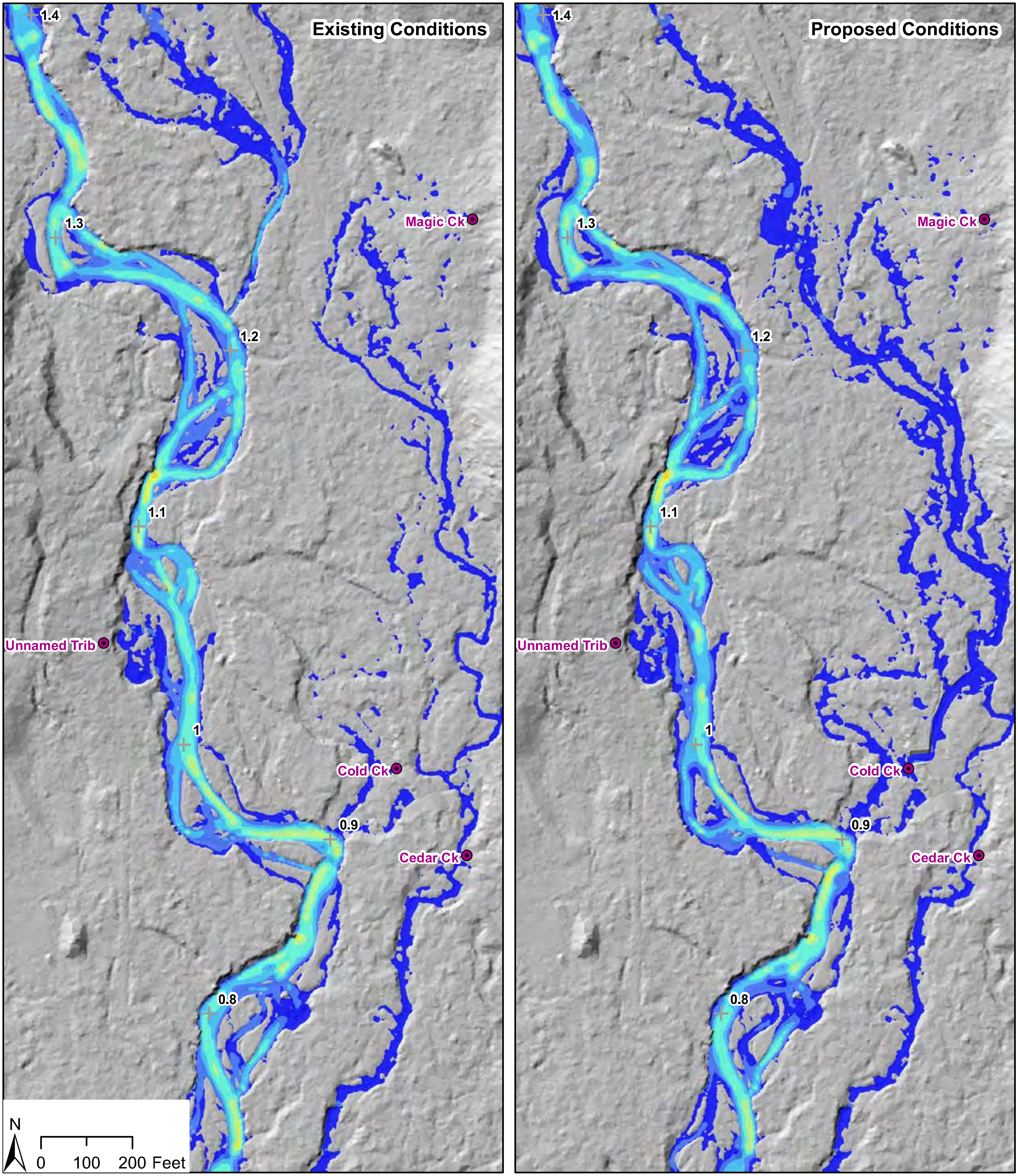
< 2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

1.5-year Flood Event
(643 cfs at Downstream End)



Modeled Velocity (ft/s)

<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

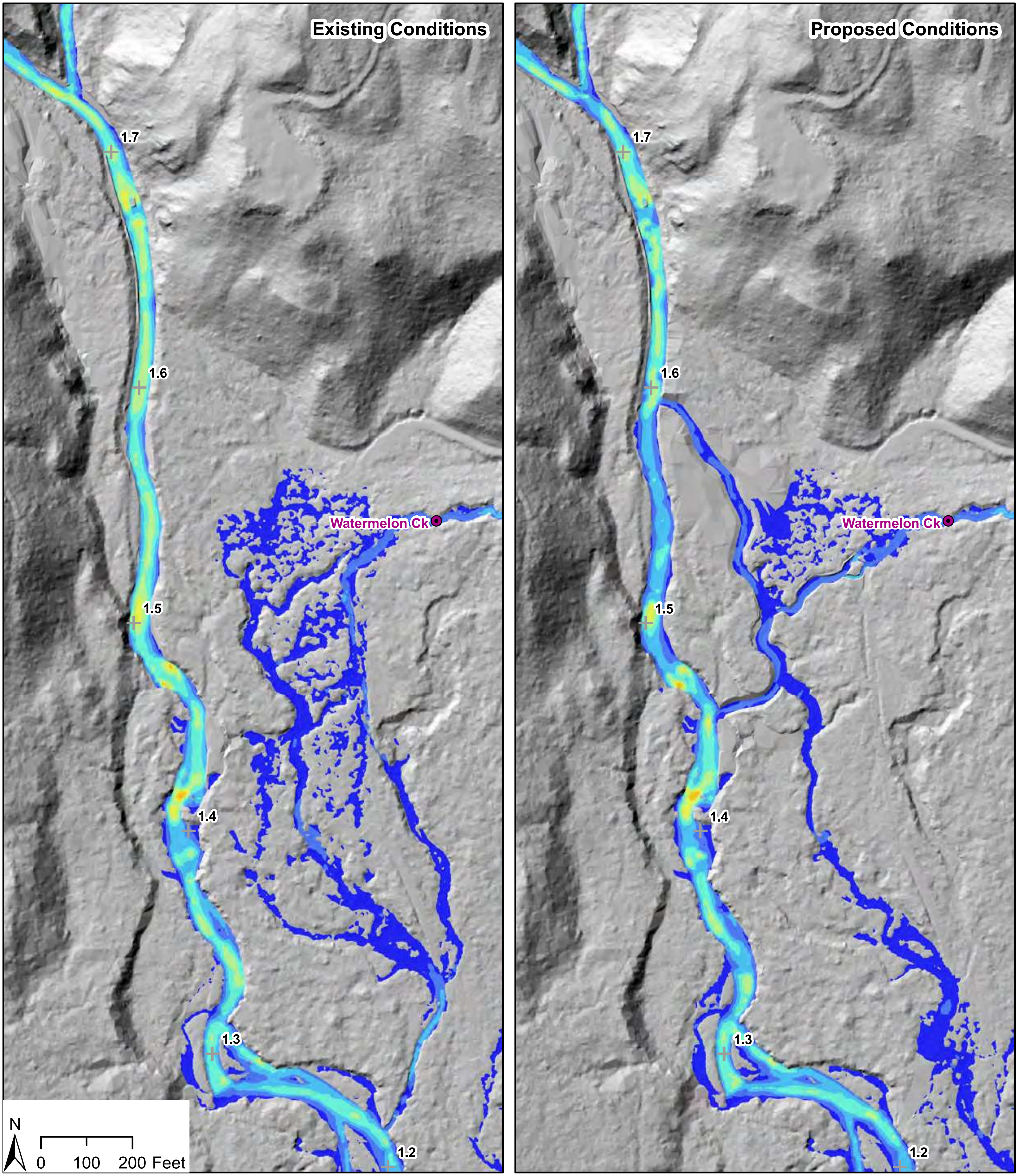
Kachess River Restoration

95% Design

Hydraulic Model Output

1.5-year Flood Event

(643 cfs at Downstream End)



Modeled Velocity (ft/s)

<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

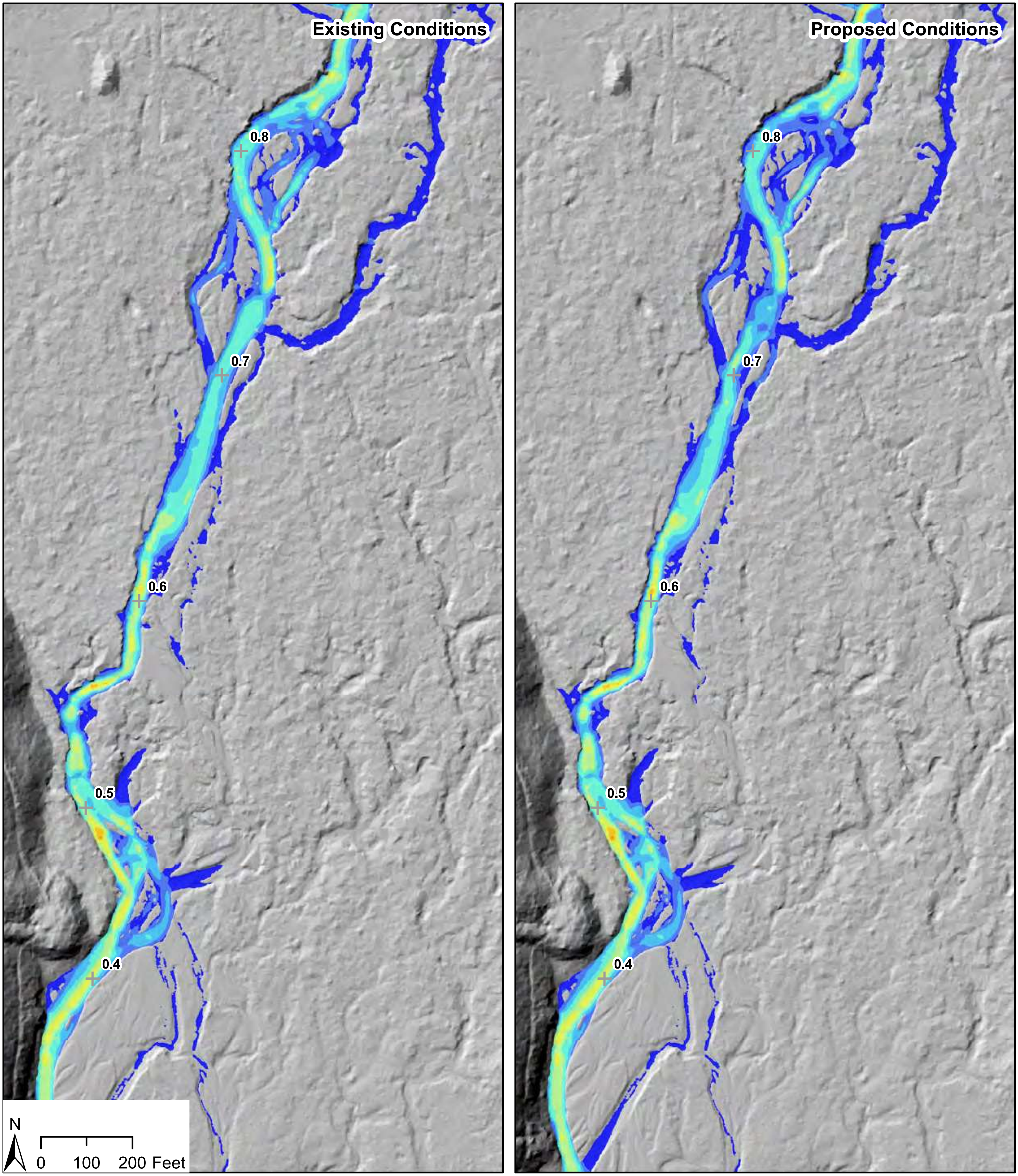
Kachess River Restoration

95% Design

Hydraulic Model Output

1.5-year Flood Event

(643 cfs at Downstream End)



Modeled Velocity (ft/s)

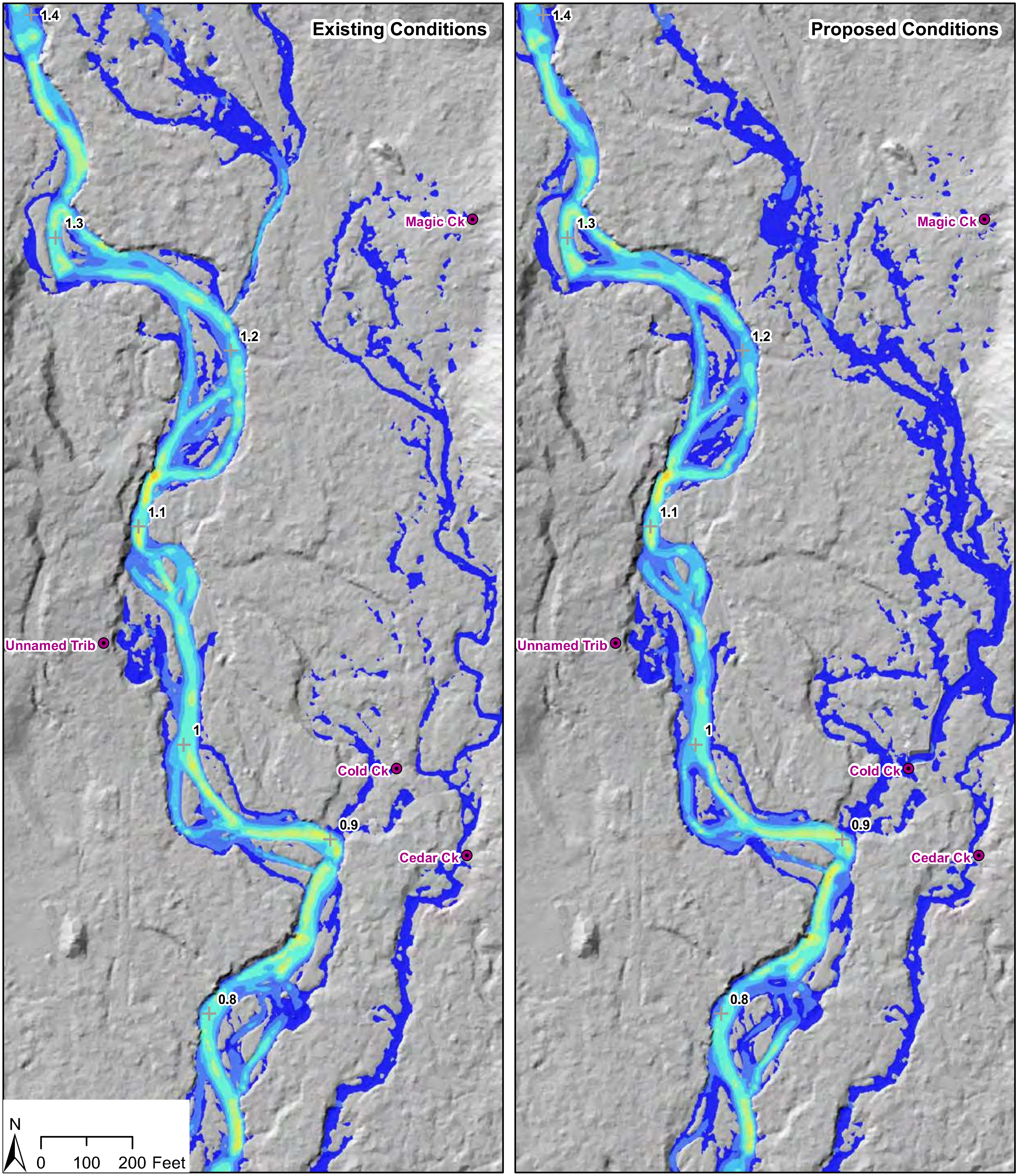
< 2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

2-year Flood Event
(755 cfs at Downstream End)



Modeled Velocity (ft/s)

<2, 2 - 4, 4 - 6, 6 - 8, 8 - 10, 10 - 12, 12 - 14, 14 - 18, >18

Modeled Tributary Inputs

2018 River Miles

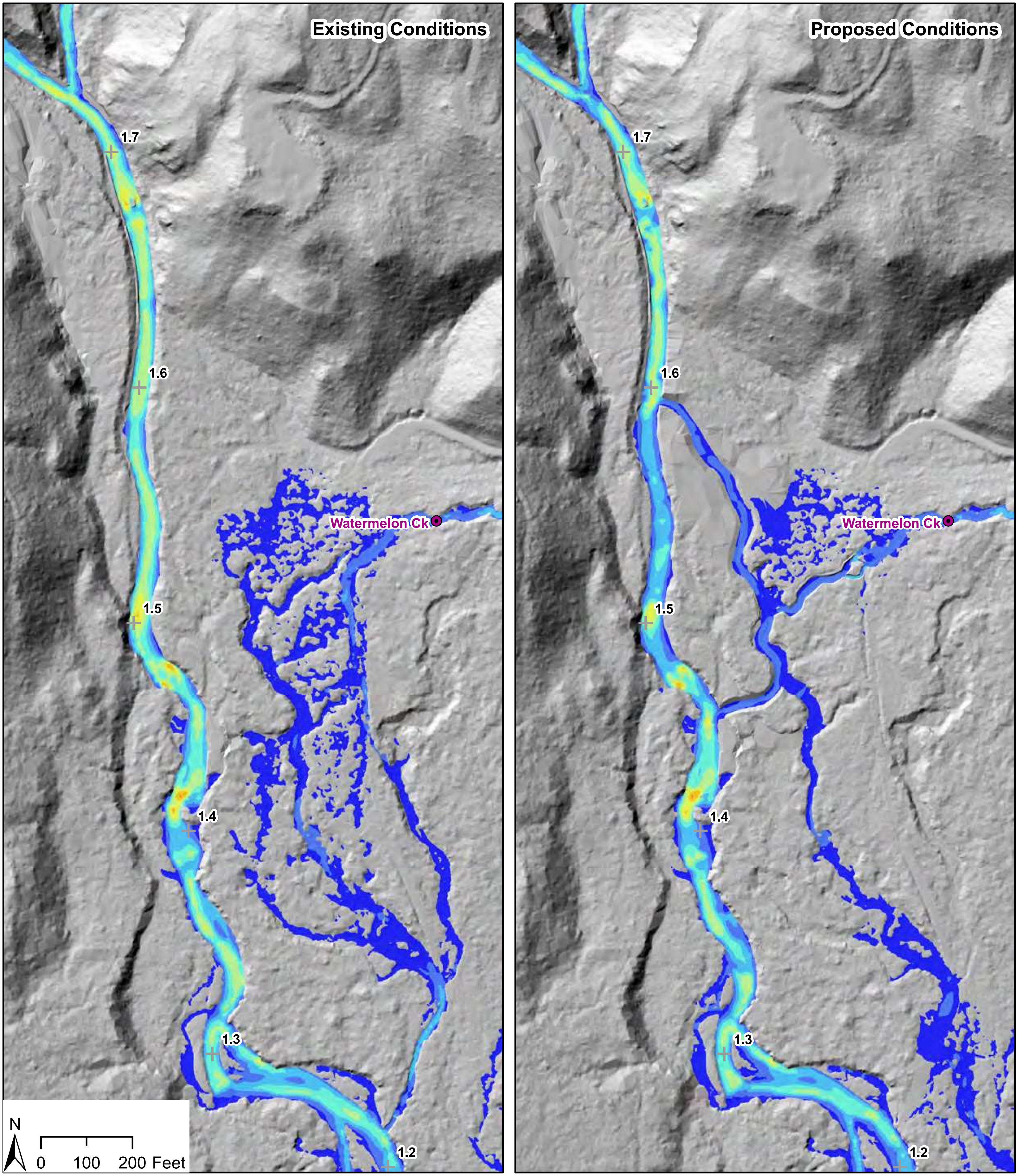
Kachess River Restoration

95% Design

Hydraulic Model Output

2-year Flood Event

(755 cfs at Downstream End)



Modeled Velocity (ft/s)

<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

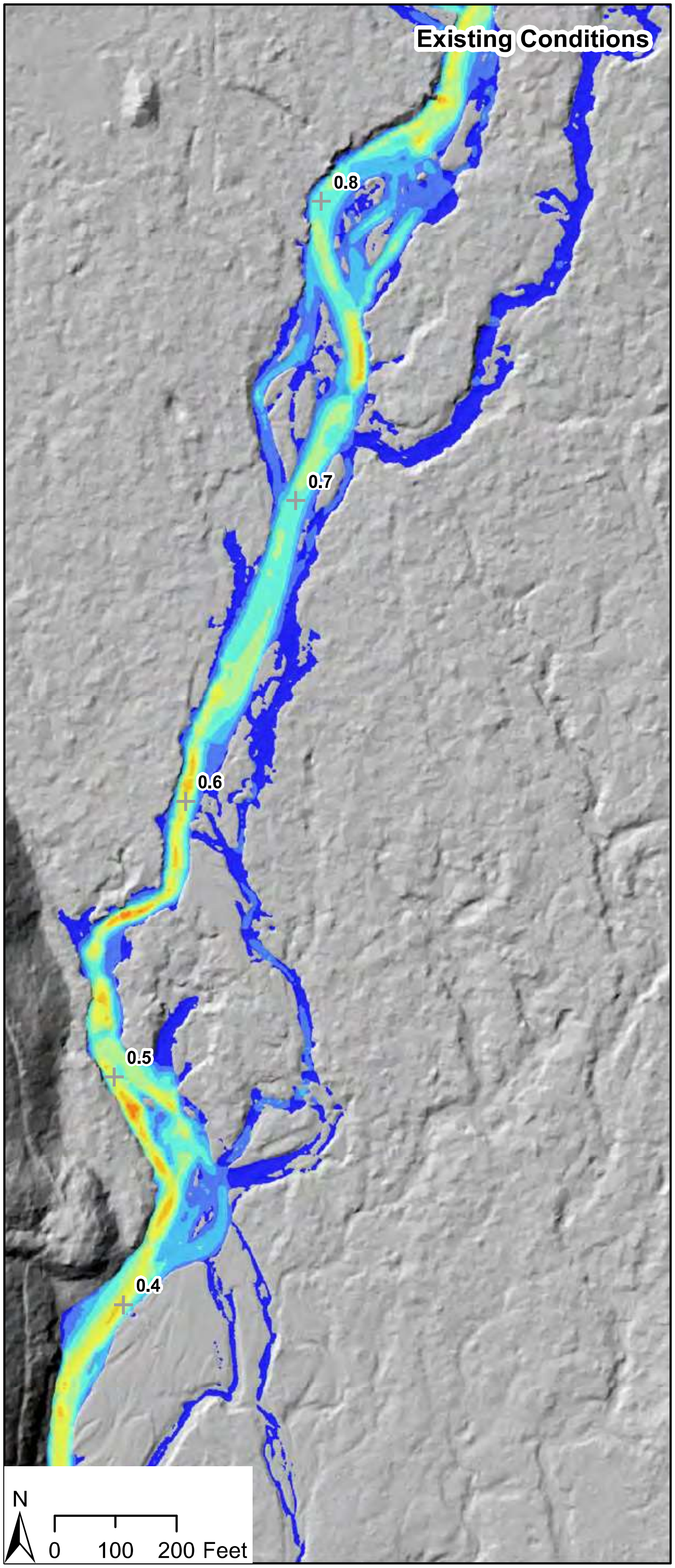
Kachess River Restoration

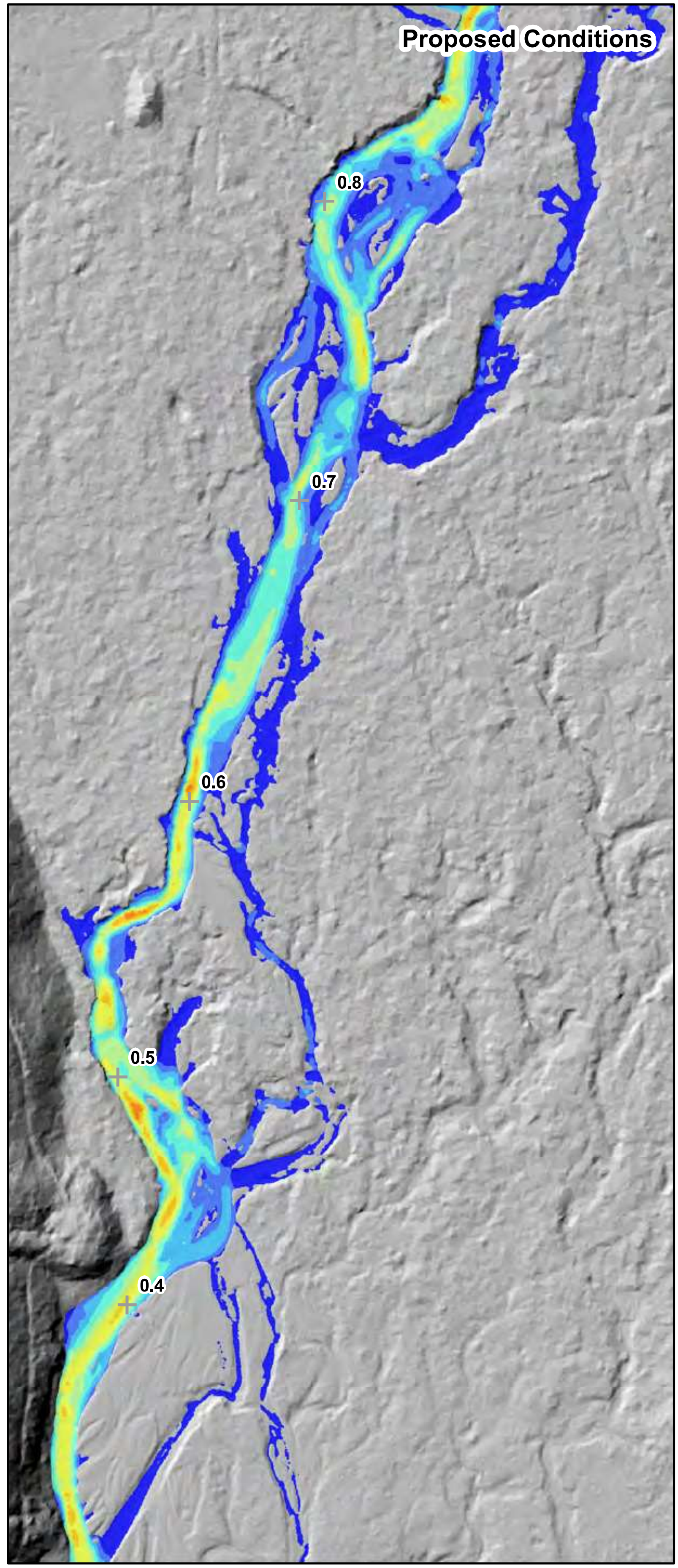
95% Design

Hydraulic Model Output

2-year Flood Event

(755 cfs at Downstream End)





Modeled Velocity (ft/s)

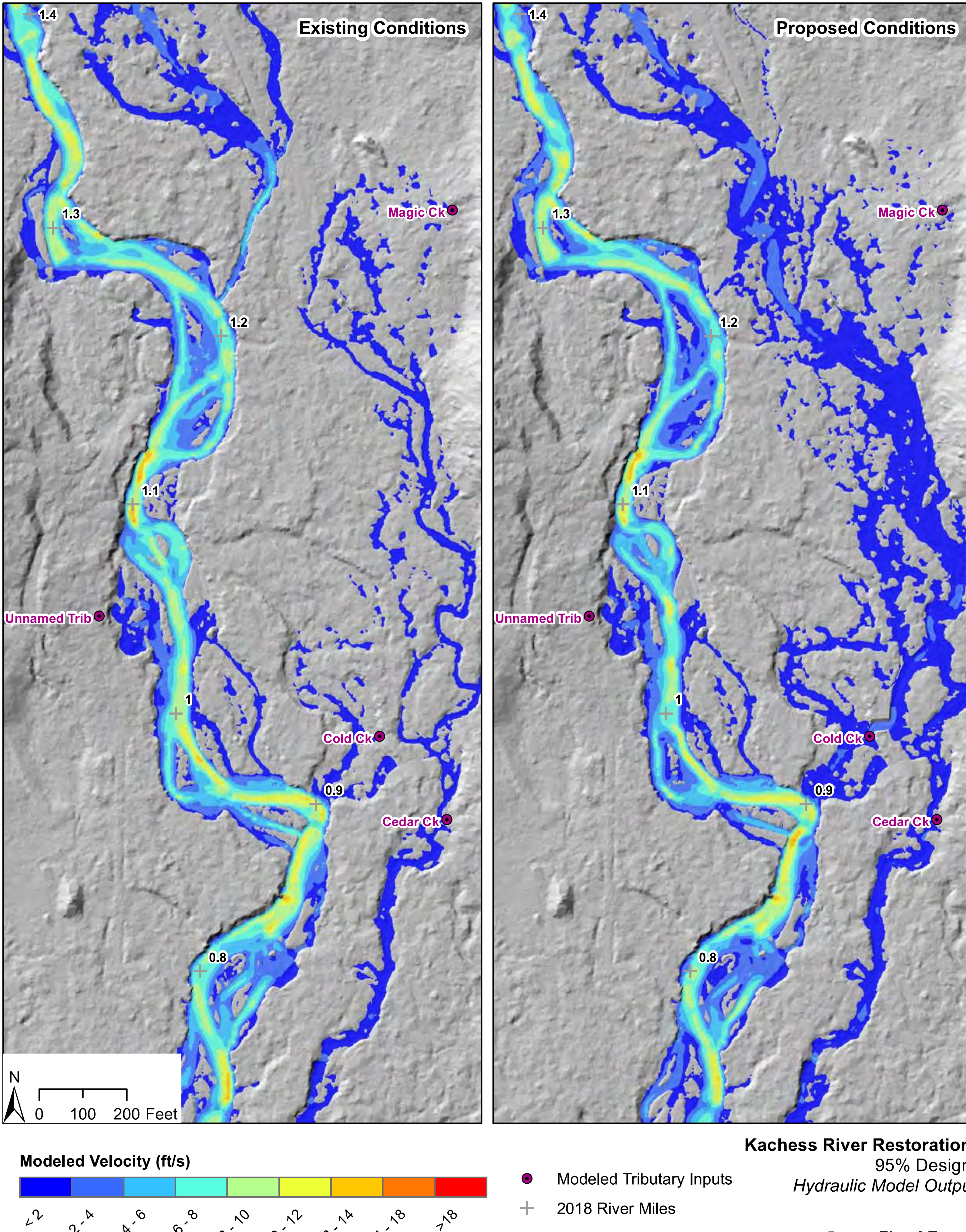
<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

5-year Flood Event
(1,211 cfs at Downstream End)



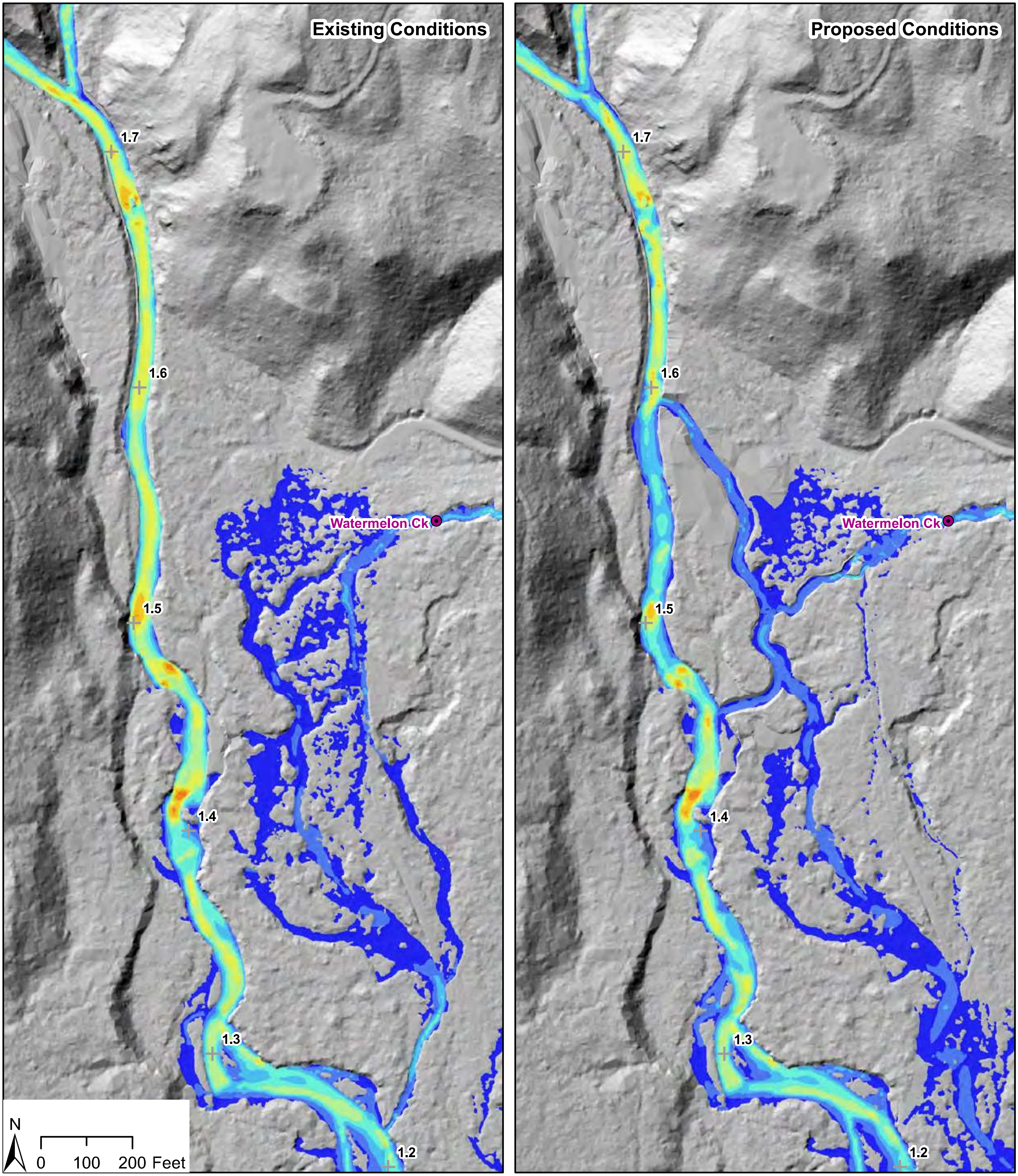
Kachess River Restoration

95% Design

Hydraulic Model Output

5-year Flood Event

(1,211 cfs at Downstream End)



Modeled Velocity (ft/s)

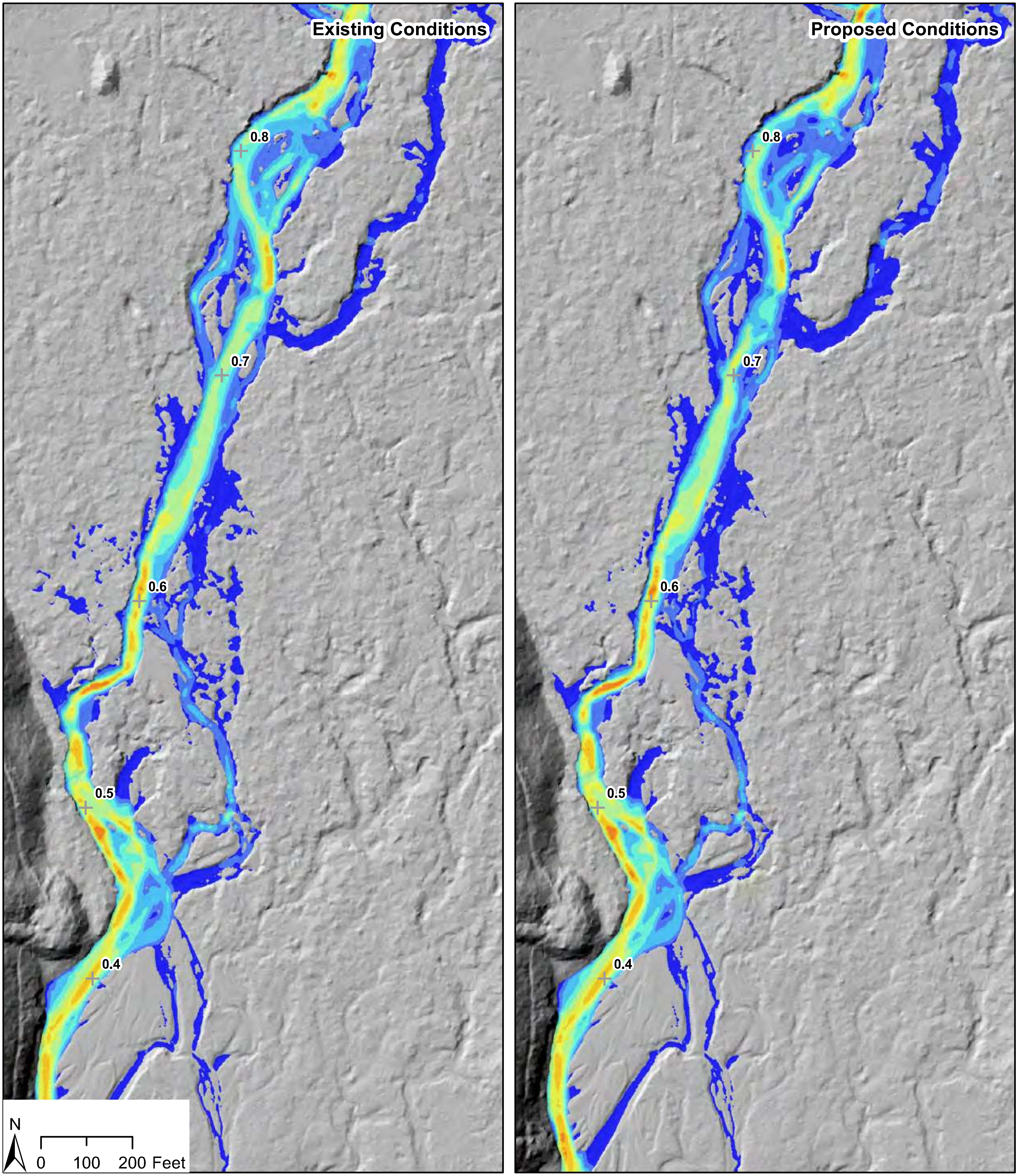
<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

5-year Flood Event
(1,211 cfs at Downstream End)



Modeled Velocity (ft/s)

< 2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

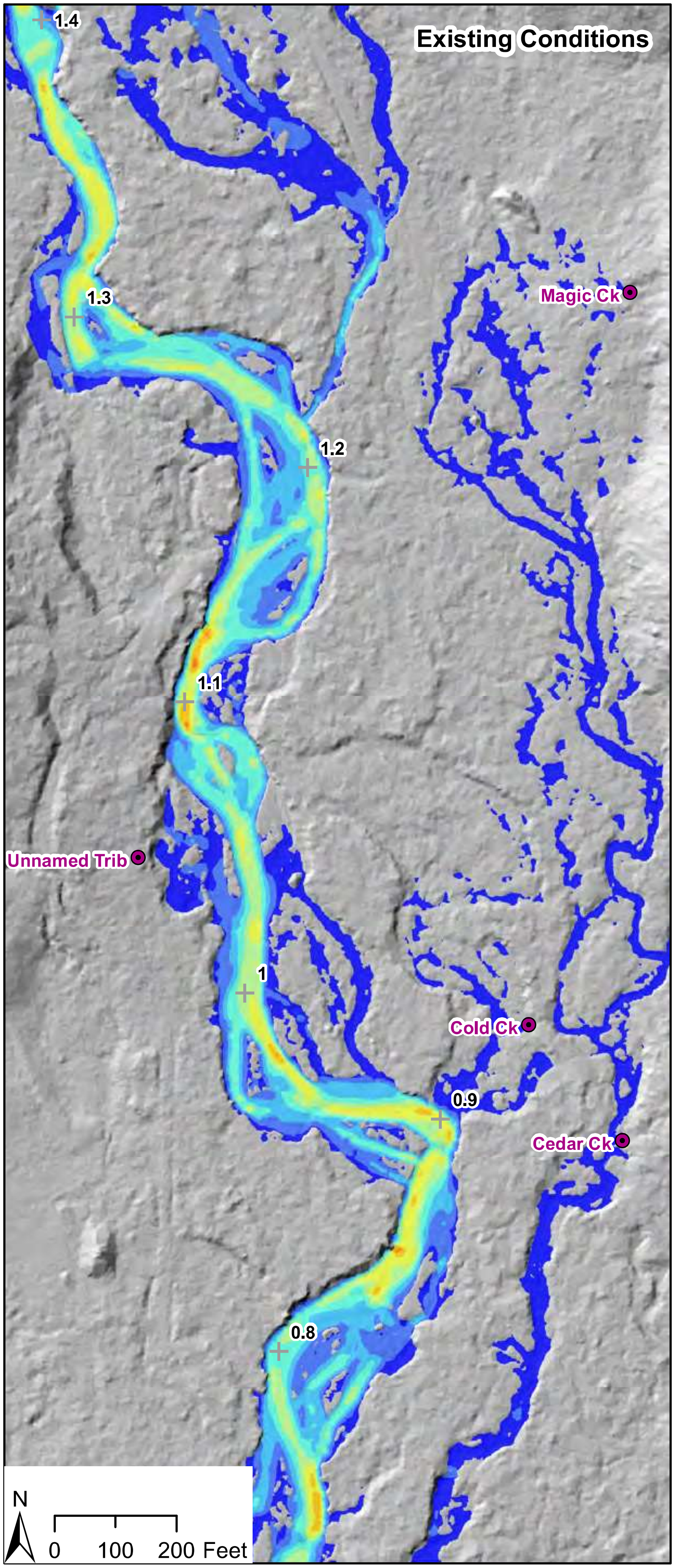
Kachess River Restoration

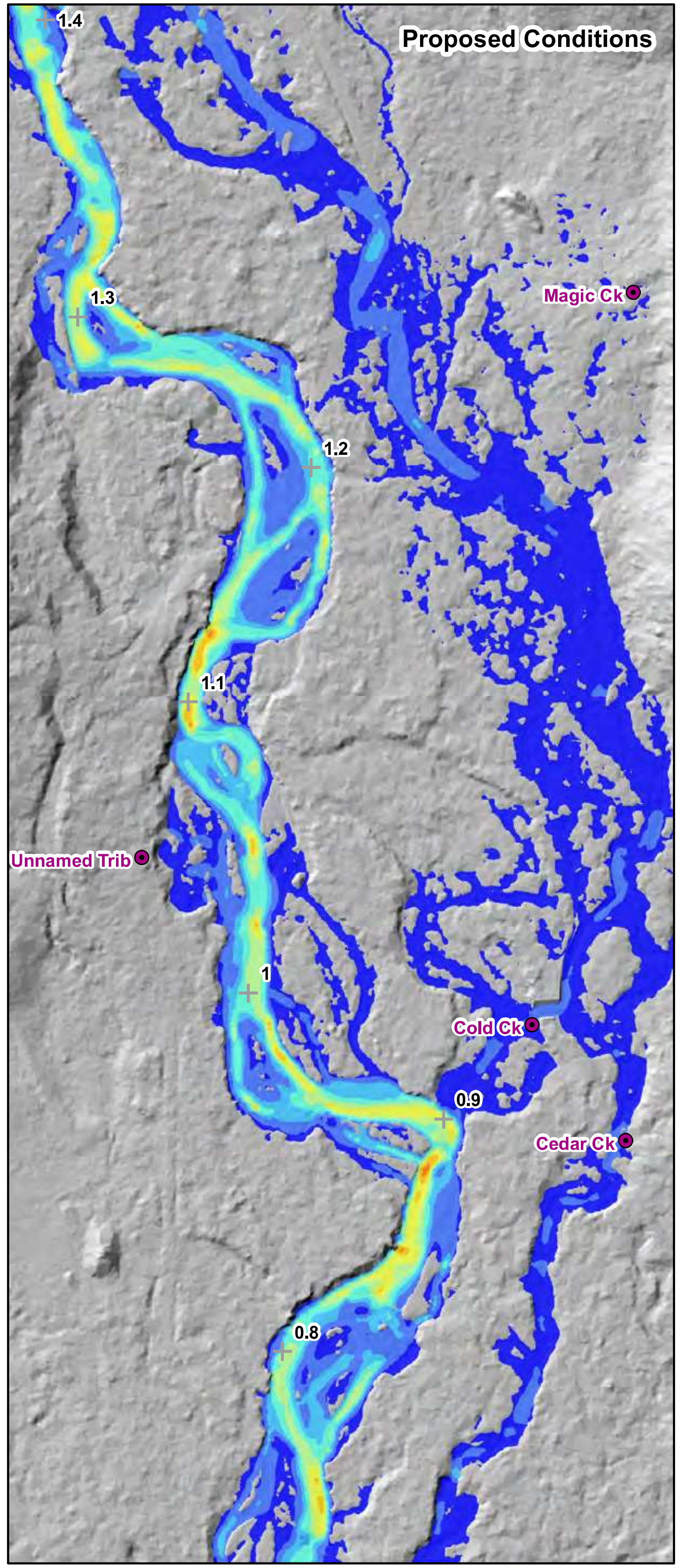
95% Design

Hydraulic Model Output

10-year Flood Event

(1,520 cfs at Downstream End)





Modeled Velocity (ft/s)

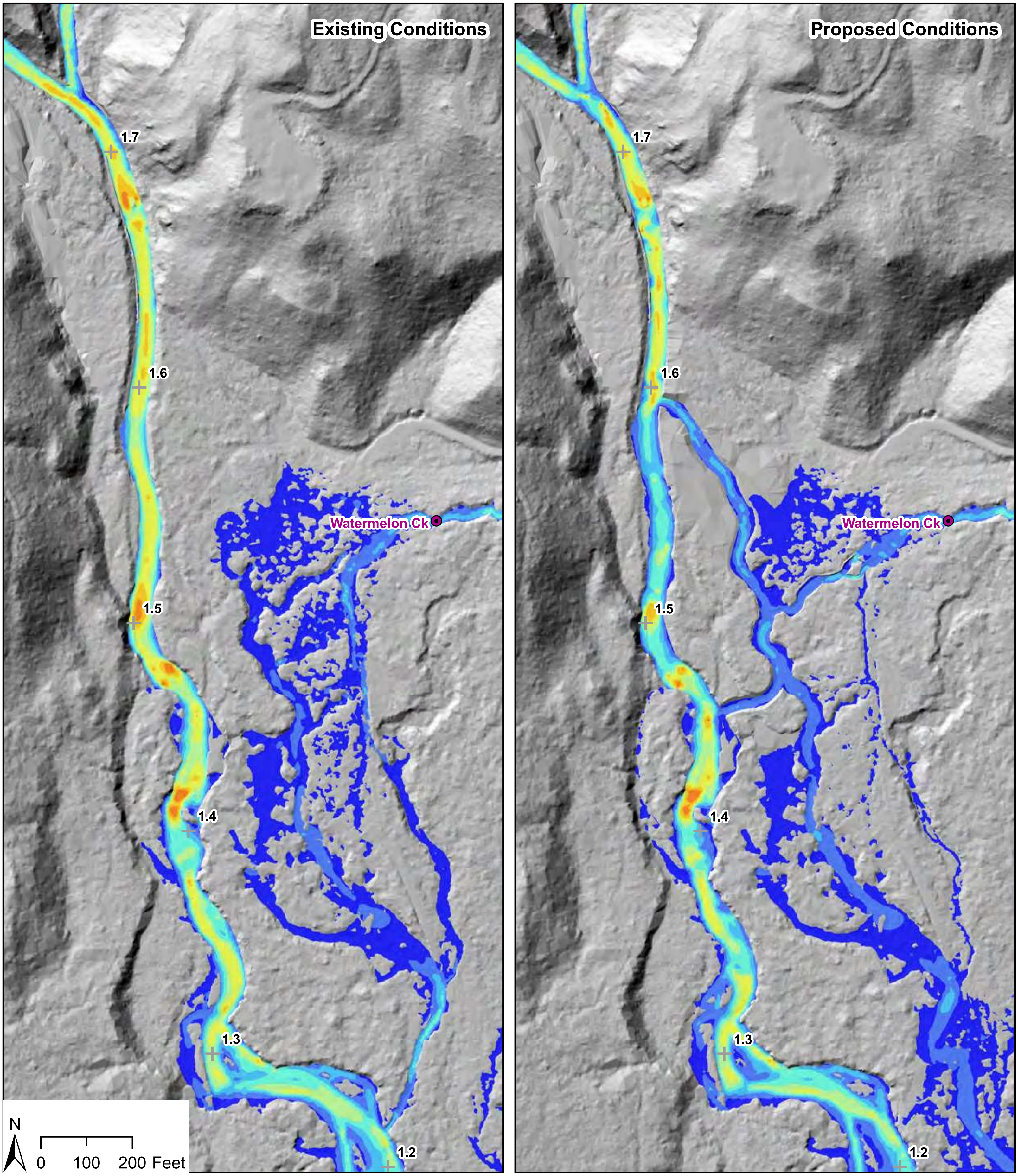
< 2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

10-year Flood Event
(1,520 cfs at Downstream End)



Modeled Velocity (ft/s)

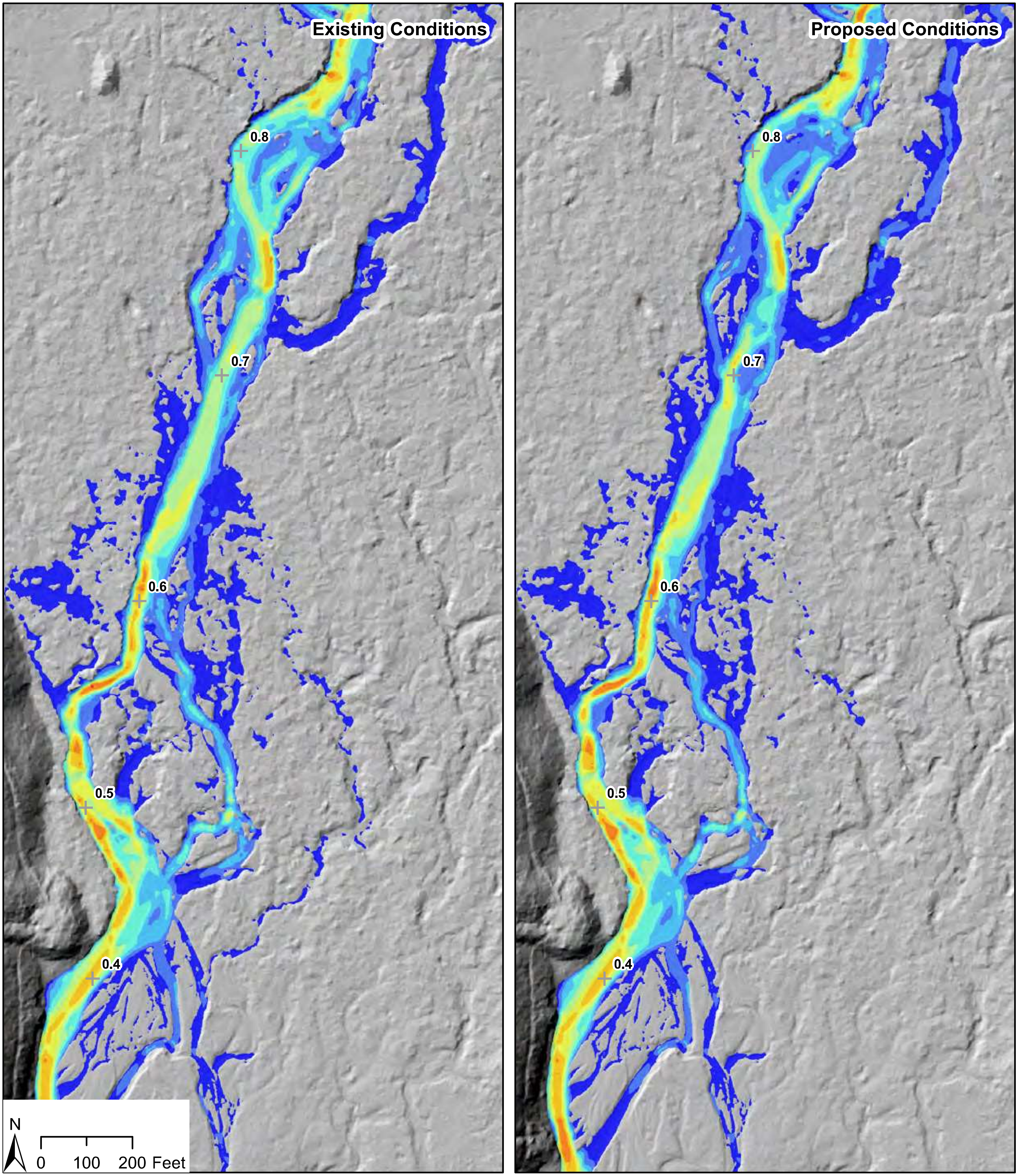
< 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 18
>18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

10-year Flood Event
(1,520 cfs at Downstream End)



Modeled Velocity (ft/s)

<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

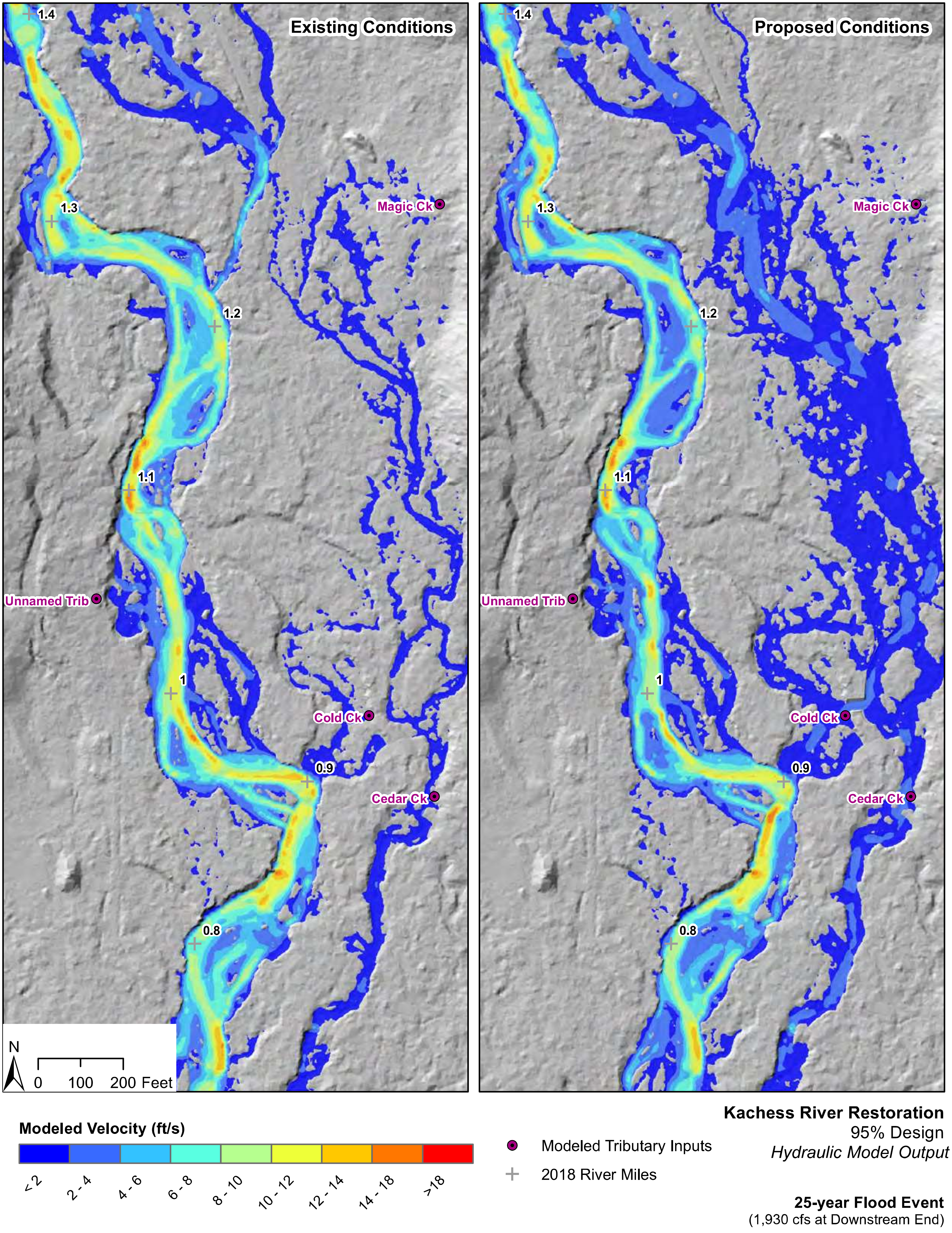
Kachess River Restoration

95% Design

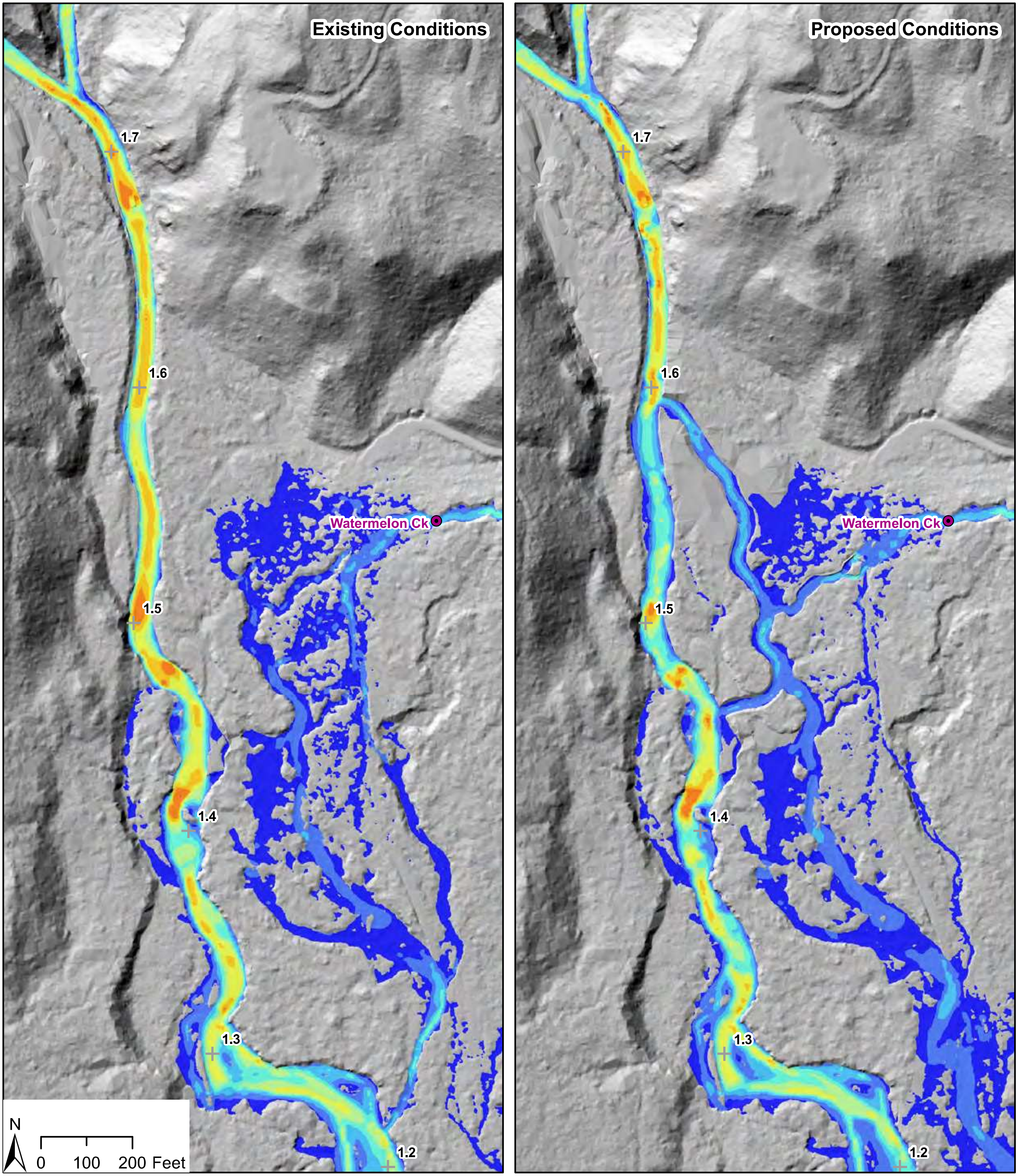
Hydraulic Model Output

25-year Flood Event

(1,930 cfs at Downstream End)



Existing Conditions
Proposed Conditions
1.4
1.3
1.2
1.1
1
0.9
0.8
Magic Ck
Unnamed Trib
Cold Ck
Cedar Ck
N
0
100
200 Feet
Modeled Velocity (ft/s)
< 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 18
>18
Modeled Tributary Inputs
2018 River Miles
Kachess River Restoration
95% Design
Hydraulic Model Output
25-year Flood Event
(1,930 cfs at Downstream End)



Modeled Velocity (ft/s)

<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

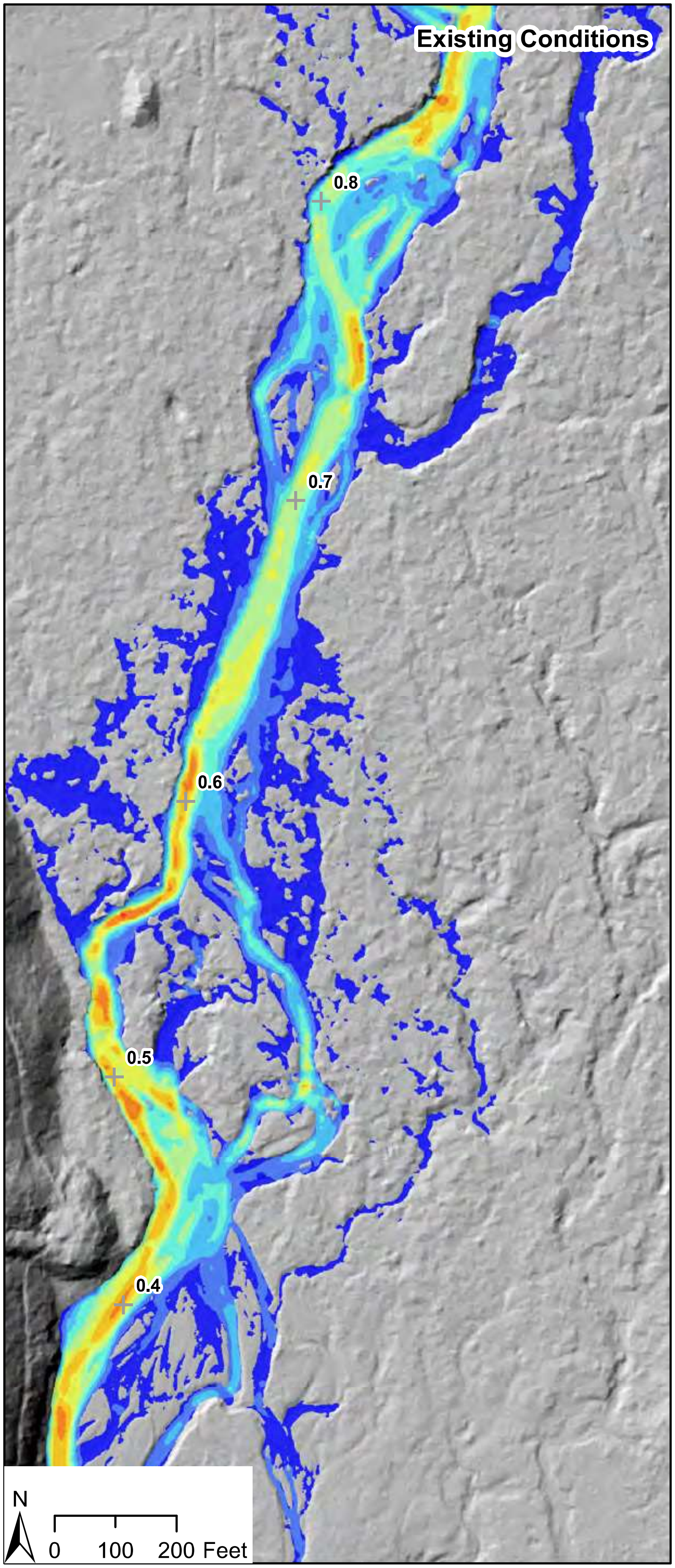
Kachess River Restoration

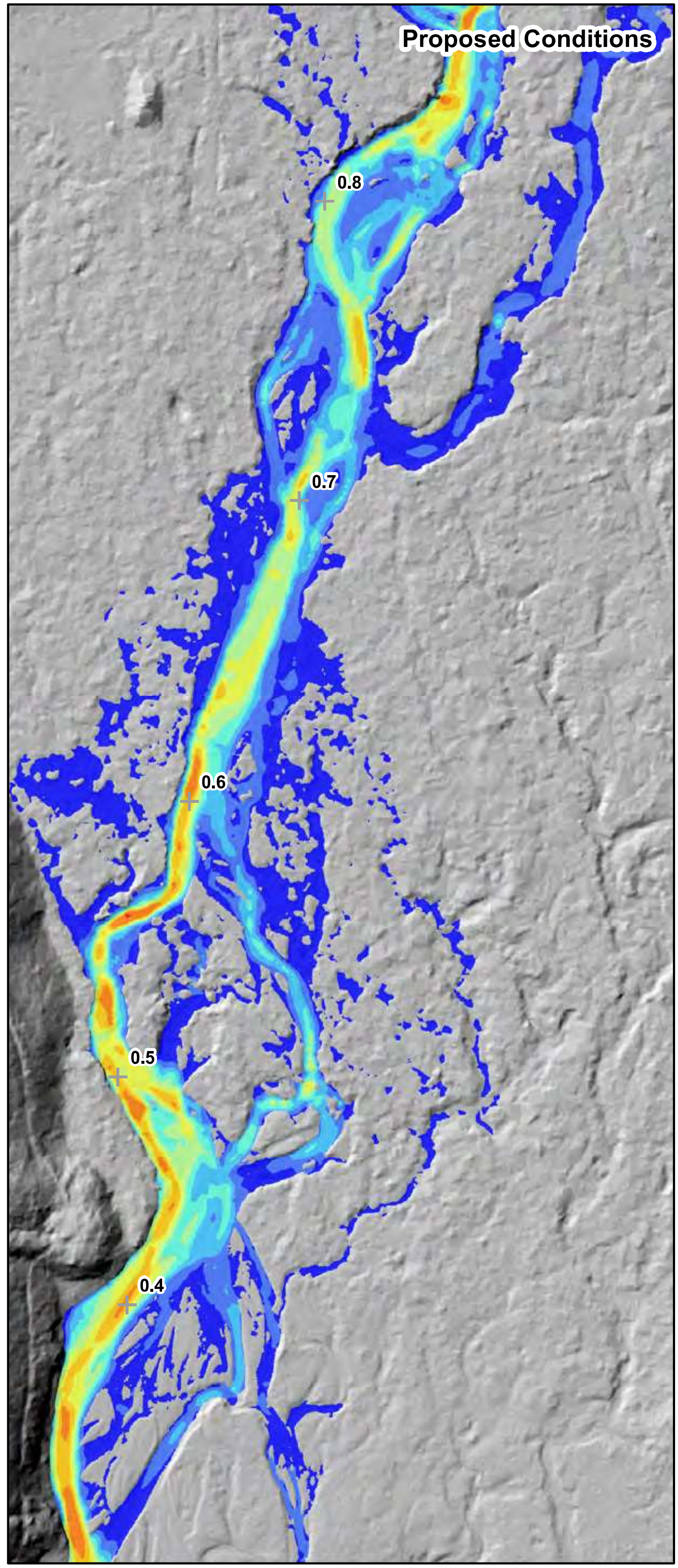
95% Design

Hydraulic Model Output

25-year Flood Event

(1,930 cfs at Downstream End)





Modeled Velocity (ft/s)

<2, 2 - 4, 4 - 6, 6 - 8, 8 - 10, 10 - 12, 12 - 14, 14 - 18, >18

Modeled Tributary Inputs

2018 River Miles

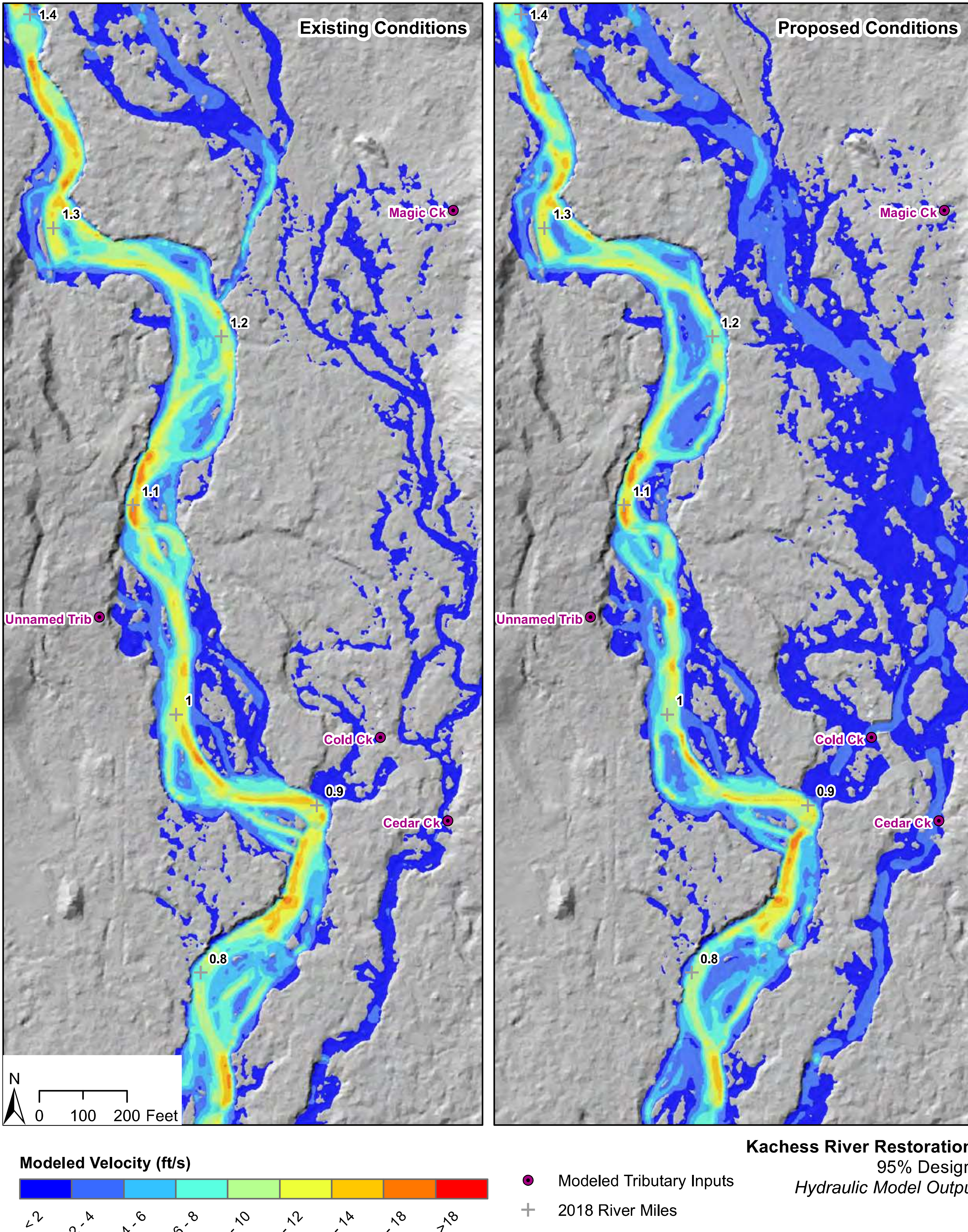
Kachess River Restoration

95% Design

Hydraulic Model Output

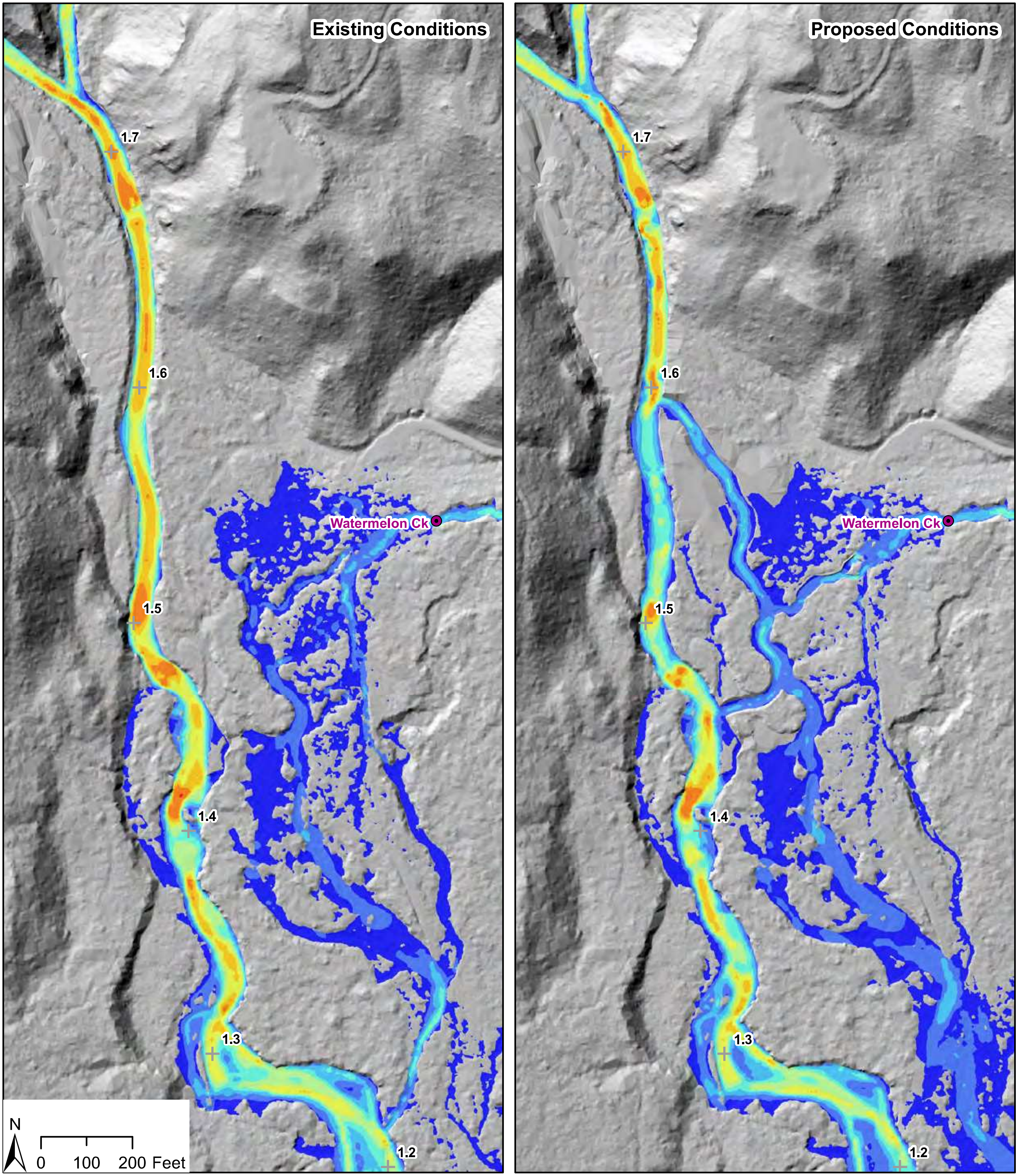
50-year Flood Event

(2,240 cfs at Downstream End)



Kachess River Restoration
95% Design
Hydraulic Model Output

50-year Flood Event
(2,240 cfs at Downstream End)



Modeled Velocity (ft/s)

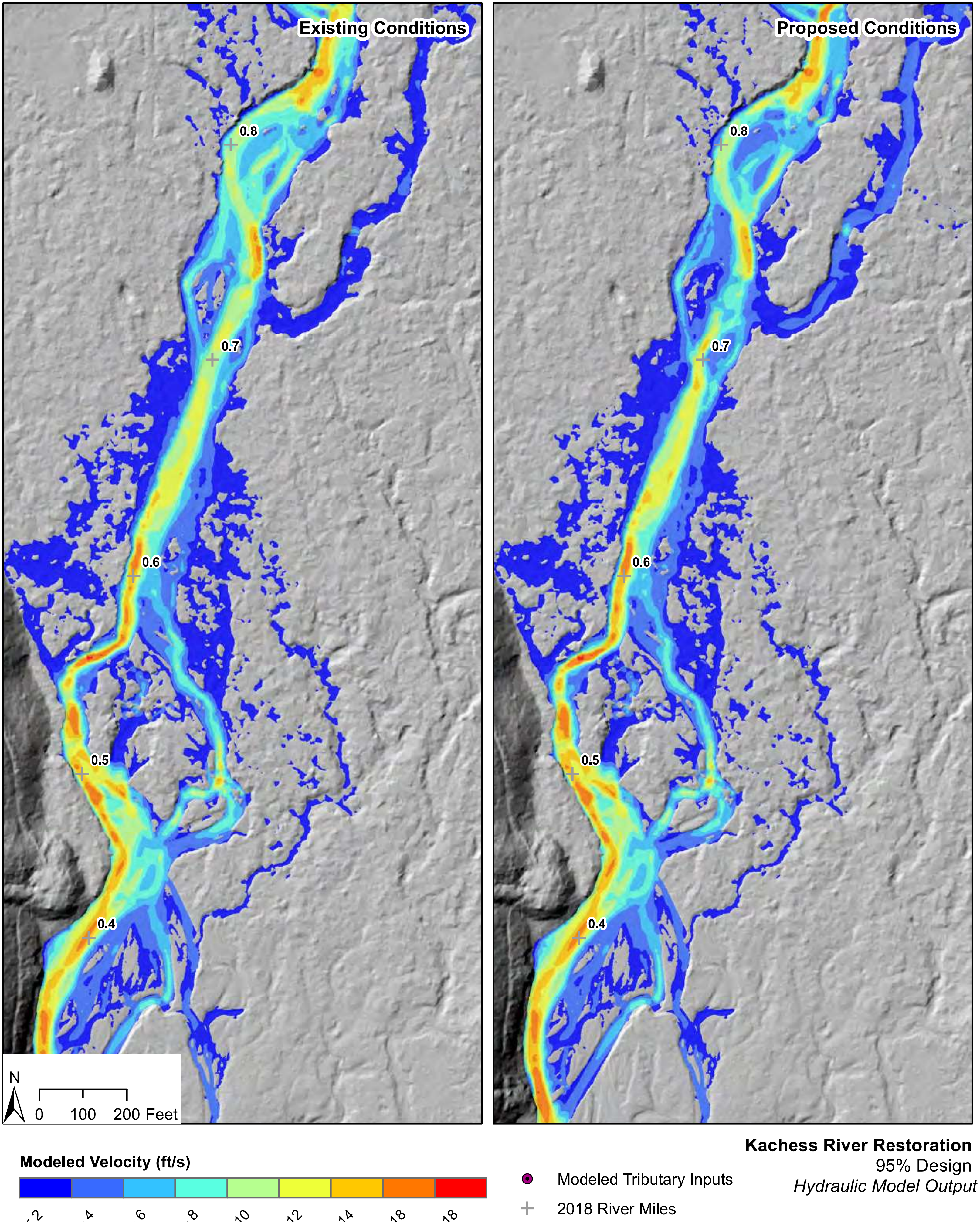
<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

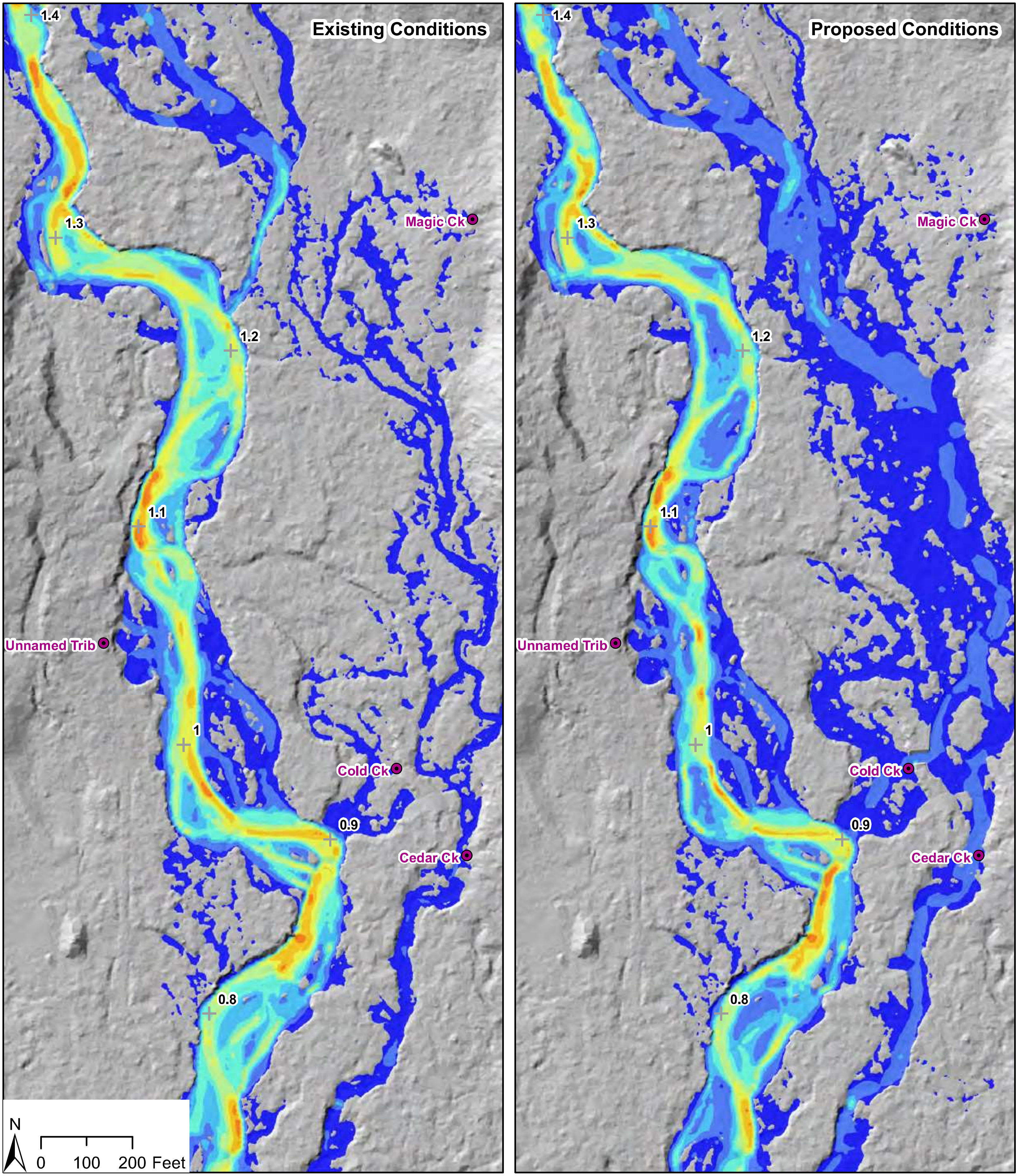
Kachess River Restoration
95% Design
Hydraulic Model Output

50-year Flood Event
(2,240 cfs at Downstream End)



Kachess River Restoration
95% Design
Hydraulic Model Output

100-year Flood Event
(2,559 cfs at Downstream End)



Modeled Velocity (ft/s)

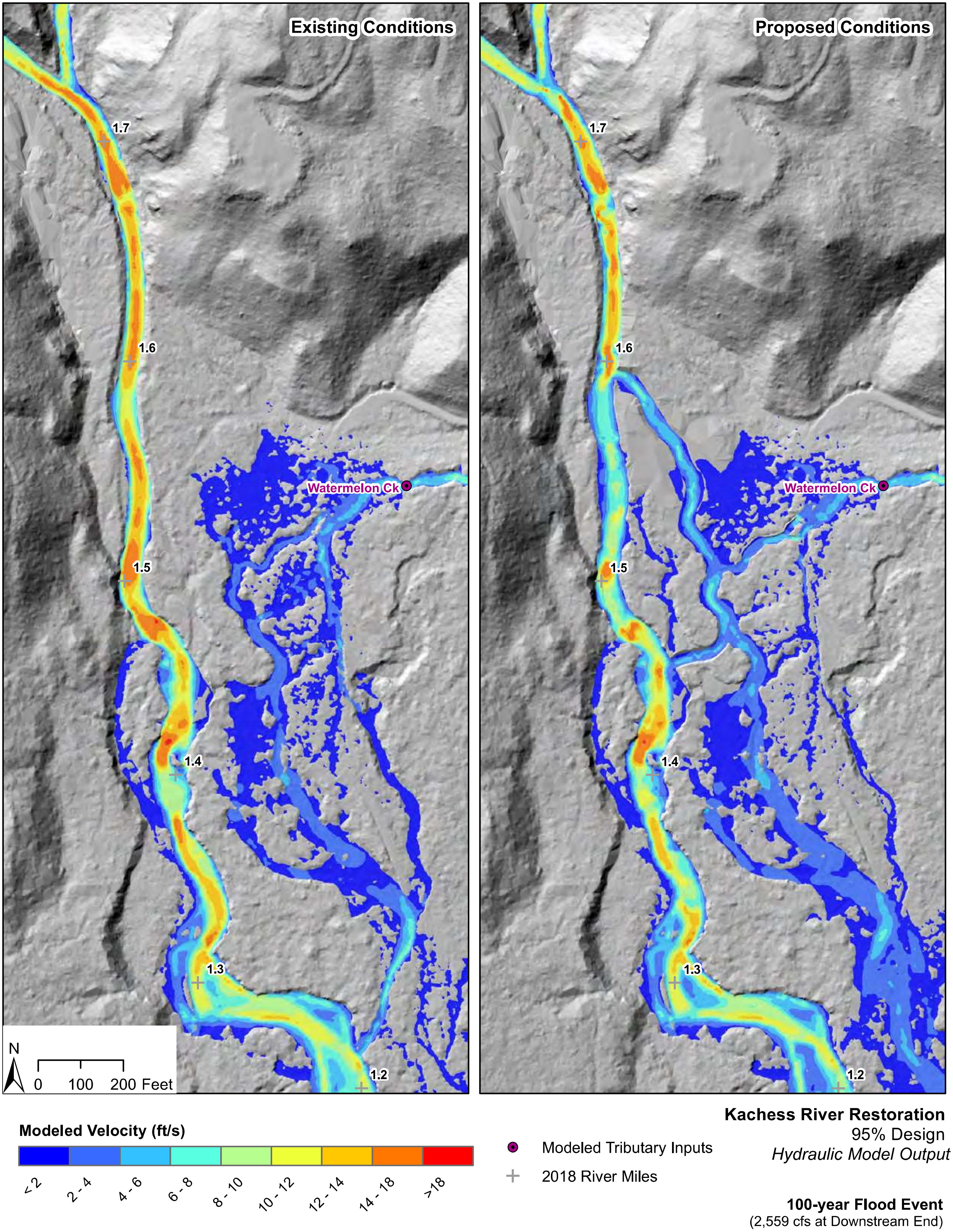
<2 | 2 - 4 | 4 - 6 | 6 - 8 | 8 - 10 | 10 - 12 | 12 - 14 | 14 - 18 | >18

Modeled Tributary Inputs

2018 River Miles

Kachess River Restoration
95% Design
Hydraulic Model Output

100-year Flood Event
(2,559 cfs at Downstream End)



Existing Conditions
Proposed Conditions
1.7
1.6
1.5
1.4
1.3
1.2
Watermelon Ck
N
0 100 200 Feet
Modeled Velocity (ft/s)
< 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 12
12 - 14
14 - 18
>18
Modeled Tributary Inputs
2018 River Miles
Kachess River Restoration
95% Design
Hydraulic Model Output
100-year Flood Event
(2,559 cfs at Downstream End)