Memorandum

To: Chris Ewing, King County Water and Land Resources Division

From: Marissa Karpack, PE and Larry Karpack, PE, Watershed Science & Engineering

Date: November 8, 2023

Re: Miller River Hydraulic Change Modeling

1 INTRODUCTION

The Miller River is a tributary to the South Fork Skykomish River in north King County on an active alluvial fan. In January 2011, the Miller River avulsed through the Old Cascade Highway and cut off access to the bridge that spans the former channel. King County (the County) ultimately decided to close the road indefinitely and is exploring options to restore and enhance habitat on the lower Miller River. The County retained Watershed Science and Engineering (WSE) to provide hydrologic and hydraulic analysis to support feasibility analysis of restoration opportunities on the lower Miller River.

2 HYDROLOGY

The Miller River drains a 46 square mile, largely forested basin. There is no current flow gaging on the Miller River, but the USGS previously operated a flow gage near the Miller River Road Revetment which recorded daily flows from 1911 to 1946 (USGS Gage 12132000). Additionally, Herrera Environmental Consultants (Herrera) conducted limited gaging of river stages at the Miller River Road Revetment between September and December 2012 (Herrera, 2013).

Flow frequency quantiles for the Miller River have been estimated previously using several different methodologies. Herrera estimated flow frequencies on the lower Miller River in their 2013 Restoration Feasibility Report. Their method involved subtracting the flow contribution from the South Fork Skykomish River at Skykomish and North Fork Skykomish River from the flows on the Skykomish River at Gold Bar, and then apportioning this remaining flow contribution to the Miller River basin based on basin area and mean annual precipitation (Herrera, 2013). A County memo from 2017 recommended using the current USGS regional regression equations in StreamStats to estimate the appropriate frequency flows for the Miller River (Comanor, 2017). The USGS has since published updated regional regression equations that provide slightly different flow estimates. Additionally, WSE recently completed a Flood Insurance Study for the South Fork Skykomish River that included estimating inflows from the Miller River and development of long-term gage records for the South Fork Skykomish River based on synthesis of nearby gage data sources (WSE, 2023). Because of the limited direct observations of flow on the Miller River, WSE considered all of the above sources of hydrologic information in determining the appropriate inflows for the hydraulic model.

The frequency analysis for the South Fork Skykomish River at Skykomish included in the recent Flood Insurance Study was based on a combined gage record of 49 annual peaks, including data through WY 2022. Additionally, the USGS operated a gage near Skykomish that recorded daily flows during some of the period that the USGS gage on the Miller River was operational. This approximately 4-year period of overlap of flow observations was used to determine a transposition factor between flows on the South Fork Skykomish at Skykomish and the lower Miller River of 0.308 (correlation coefficient of 0.73). The frequency flows computed for the South Fork Skykomish at Skykomish were multiplied by this scalar to estimate flow frequency quantiles on the Miller River.

There is considerable uncertainty in the flows on the Miller River, largely due to the lack of long term or recent flow observations. For this analysis, the flow estimates scaled from the South Fork Skykomish frequency analysis were used in the hydraulic modeling. These flows were chosen as they 1) were within the bounds of other estimates of flow on the Miller River, and 2) made use of the available observed Miller River flow data in their computation. The flows used in this analysis as well as other flow estimates for the Miller River described above are summarized in Table 1.

Table 1. Frequency flow estimates for the lower Miller River, including those ultimately used in the hydraulic model (bold).

Return Period	Herrera (2013) Flow Estimates, cfs	2017 StreamStats Estimates, cfs	Current StreamStats Estimates, cfs	Flow Scaled from SF Skykomish @ Skykomish, cfs
2-year	5,570	5,130	4,100	**4,160**
10-year	14,350	9,600	7,430	**8,220**
100-year	28,700	16,200	11,600	**14,600**
500-year	-	-	14,500	**19,870**

As the Miller River basin is approximately one-sixth the size of the South Fork Skykomish River basin at their confluence, it is expected that during large floods on the Miller River the concurrent flow on the South Fork Skykomish River would be a more frequent (less rare) event. It is likely that the smaller Miller River basin would also produce an earlier peak flow, but as the modeling in this investigation uses steady hydrographs, the results are not sensitive to timing of the peak flows. The corresponding events modeled for the South Fork Skykomish River for each frequency event on the Miller River are listed in Table 2.

Table 2. Concurrent frequency flows on the Miller and South Fork Skykomish Rivers.

Event on Miller River	Concurrent Event on SF Skykomish River
2-year	2-year
10-year	2-year
100-year	10-year
500-year	100-year

WSE visited the lower Miller River on March 9th, 2023 and identified high water marks throughout the reach. From gaging on the South Fork Skykomish River, a high flow event occurred in November 2022. The peak flow on the Miller River for this event was estimated by scaling flows from the South Fork Skykomish at Skykomish gage as described above for an estimated peak flow of 4,990 cfs on the Miller River, which is slightly larger than a 2-year event.

The hydraulic model was run using “pseudo-steady state” flows, where the inflows gradually increase up to the desired flow value and then maintain constant inflow until steady state conditions are reached.

3 HYDRAULIC MODEL

The hydraulic model of the lower Miller River used in this analysis was based on a primarily 1D model of the South Fork Skykomish River developed for the recent Flood Insurance Study (WSE, 2023). The model was updated to HEC-RAS version 6.3.1 and a 2D computational mesh was added for the lower 1 mile of the Miller River, with the 1D reach of the South Fork Skykomish as a downstream boundary condition. The Miller River model mesh is predominately 20-foot cells with 10-foot cells in the channel and around key topographic features. Breaklines were used to define features such as channels, roads, levees, and high ground. The Miller River 2D area was connected to the 1D South Fork Skykomish River using lateral structures set at the ground elevation and computing transfer of flows between the two model areas using the 2D equations. The 2D model domain, breaklines, and connection to the South Fork Skykomish 1D reach can be seen in Figure 1.

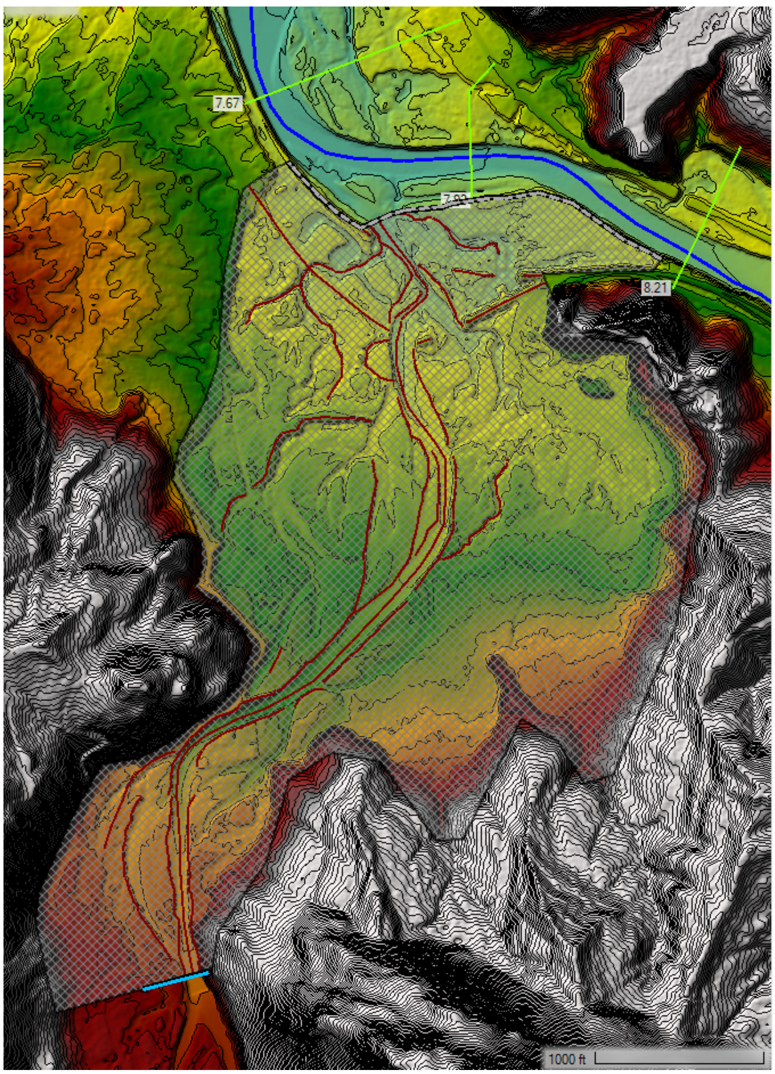


Figure 1. Miller River 2D model domain with breaklines and connection to the 1D South Fork Skykomish reach.

3.1 TOPOGRAPHIC DATA

The hydraulic model terrain is a combination of several topographic data sources. The South Fork Skykomish 1D reach is based on April 2020 LiDAR and March 2020 bathymetric cross section surveys that were collected along the river for the Flood Insurance Study. The terrain for the Miller River and its floodplain was from a 2020 county-wide LiDAR collection. King County also collected LiDAR in this area in 2021; however, the 2021 LiDAR contained excessive hydroflattening that removed dry mid- and side-channel bars, and therefore overrepresented the channel area. As negligible channel movement was identified between 2020 and 2021, the 2020 LiDAR with better defined channel extents and bars was used for the 2D model terrain surface.

No bathymetric data were available for the Miller River. Based on WSE field observations, the Miller River channel was estimated to average about one-foot deep below the water surface at the time of the LiDAR and thus a 1 foot deep trapezoidal channel was cut into the model terrain surface.

3.2 Roughness and Model Calibration

Manning's n roughness regions were delineated based on 2021 aerial imagery and LiDAR. The initial roughness values were based on the calibrated Manning's n values from the South Fork Skykomish study and field observations. The Miller River Manning's n values were roughly calibrated using the November 2022 event. Although there were no surveyed high water mark elevations for comparison, many side channels had evidence of recent shallow flow. Roughness values were adjusted such that the model inundated similar floodplain flow paths as observed in the field. The final Manning's n values for the Miller River 2D area are shown in Table 3.

Table 3. Calibrated Manning's n values for the Miller River 2D area.

Landcover Type	Manning's n value
Main channel	0.05
Gravel bar	0.06
Active side channel	0.06
Inactive side channel	0.08
Lightly forested	0.08
Densely forested	0.11

3.3 Conceptual Design Scenarios

The hydraulic model of the lower Miller River was used to analyze the existing hydraulic conditions and the change in hydraulic conditions for three conceptual design scenarios. The first design scenario involved removing all fill in the floodplain, including the Miller River Road Revetment, Miller River Curve Revetment, the Old Cascade Highway road fill and bridge abutment fill, and the right bank levee downstream of the Old Cascade Highway bridge. Additionally, the first design scenario included excavating pilot channels through the areas where fill was removed. The resulting terrain for Scenario 1 with these modifications indicated is shown in Figure 2.

The second design scenario was similar to Scenario 1 except that the upper portion of the Miller River Curve Levee was maintained and the Old Cascade Highway road fill and revetment downstream on the right bank were also not removed. The same pilot channels from Scenario 1 were included in Scenario 2, with three additional pilot channels added that connect the main channel to remnant channels on the left floodplain. Finally, a high levee was added on the upstream left bank on County property to cut off overbank flow to the private parcels near Miller River Road. The resulting terrain for Scenario 2 is shown in Figure 3.

The third design scenario was a combination of elements from Scenarios 1 and 2 with added channel-spanning obstructions in the main channel. The obstructions in the channel were placed approximately 300 to 600 feet apart and were located just downstream of connections to floodplain channels. The obstructions were modeled as small, five foot high berms or dams across the entire channel with sloping upstream and downstream faces. In addition to the channel obstructions, Scenario 3 did not remove the Miller River Road Revetment or the upper end of the Miller River Curve Revetment, but otherwise included the same fill removals as Scenario 1. Scenario 3 also included the same pilot channels as Scenario 2. The resulting terrain for Scenario 3 is shown in Figure 4.

For each conceptual design scenario modeled, the Manning's n roughness delineation was revised to match the updated terrain conditions.

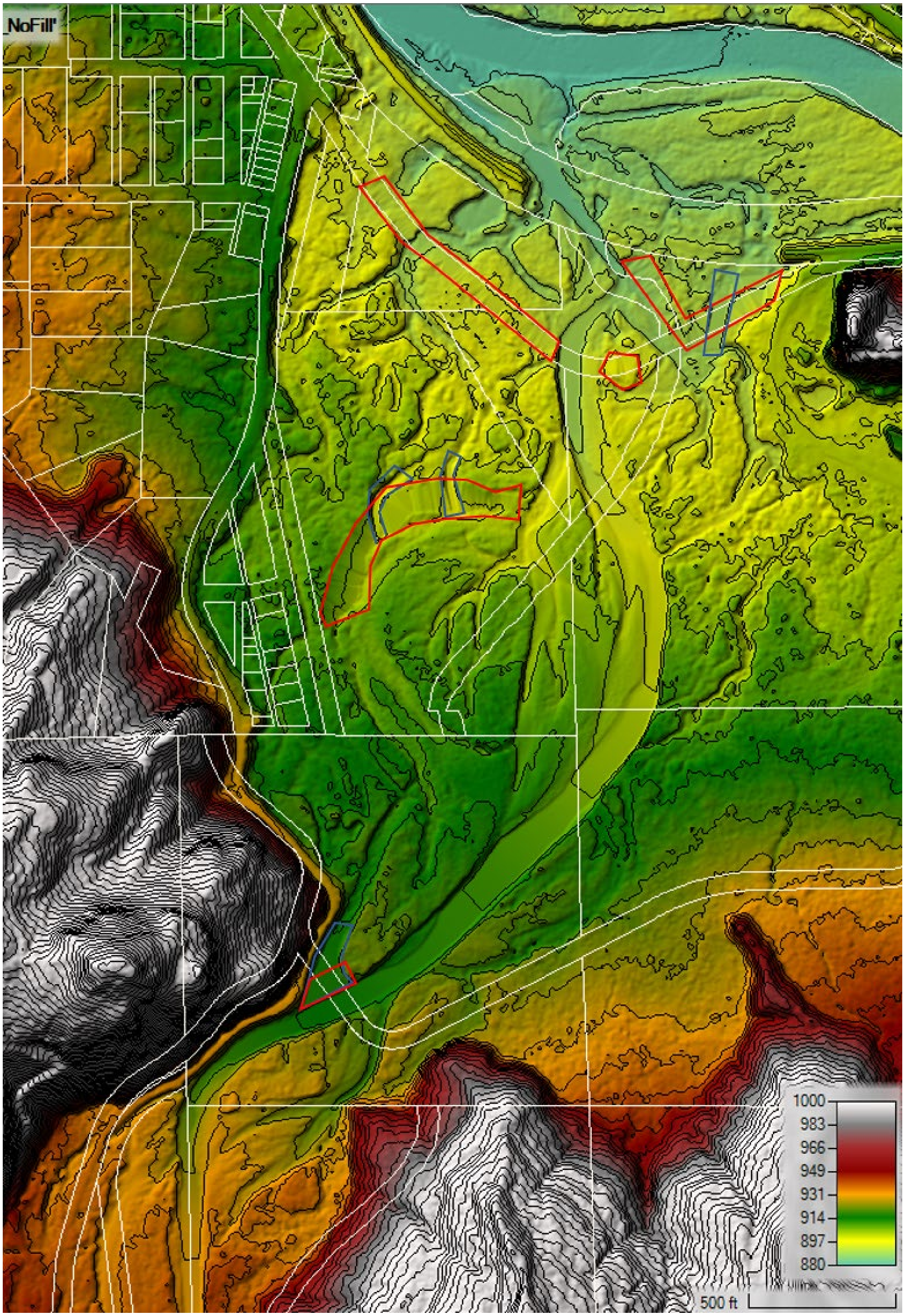


Figure 2. Scenario 1 model terrain with parcel boundaries (white), areas of removed fill (red), and pilot channels (blue).

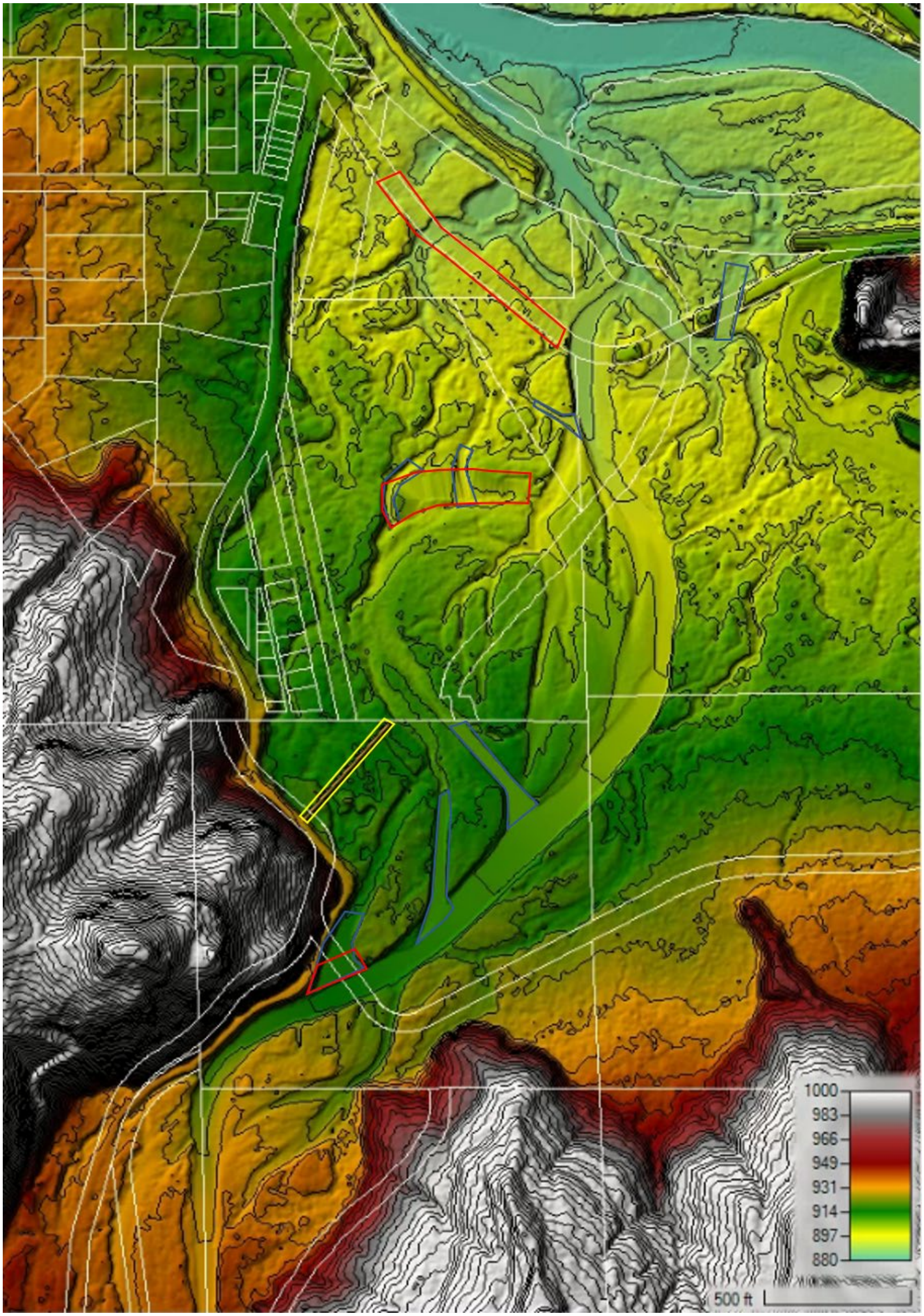


Figure 3. Scenario 2 model terrain with parcel boundaries (white), areas of removed fill (red), pilot channels (blue), and added levee (yellow).

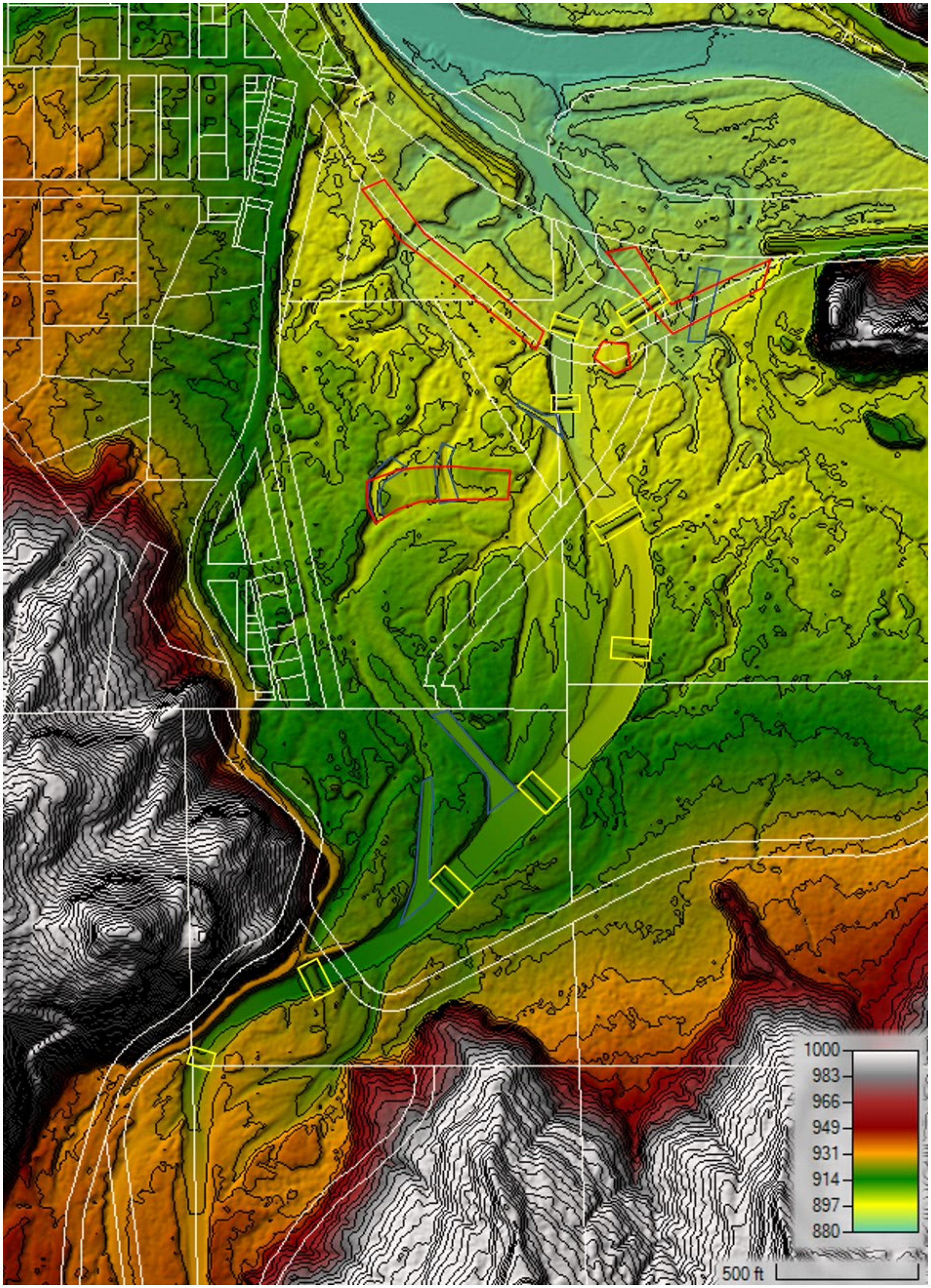
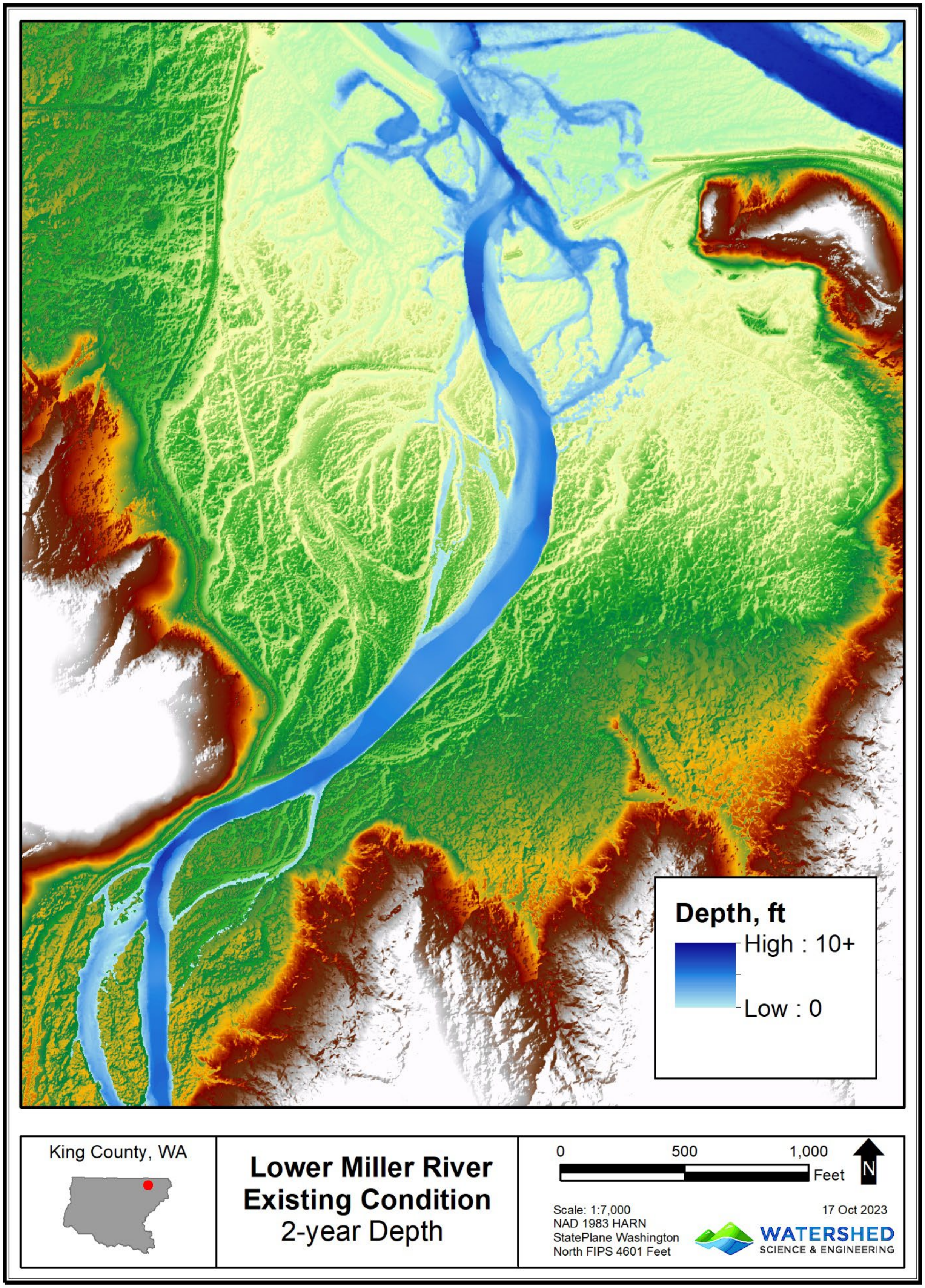
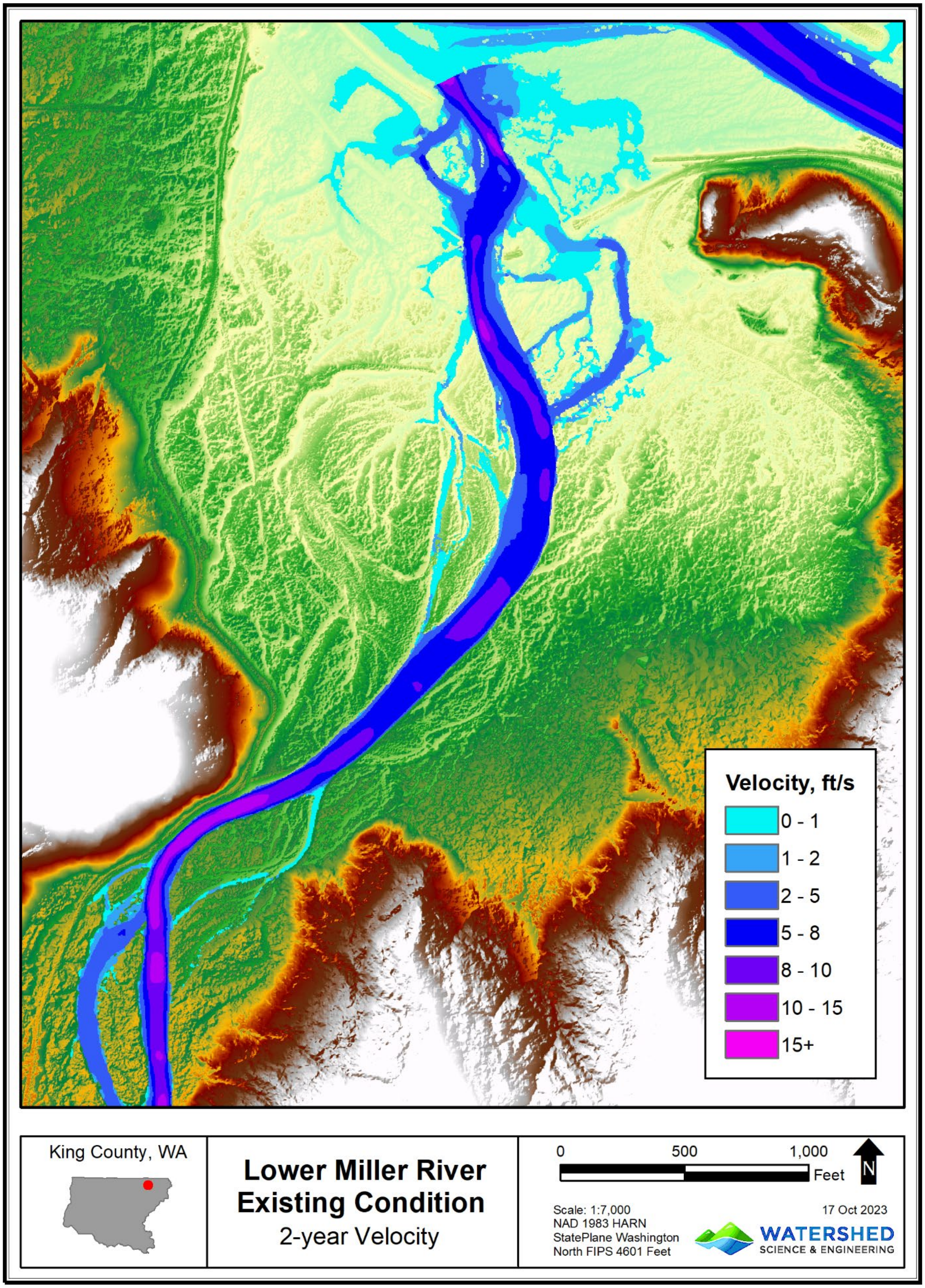


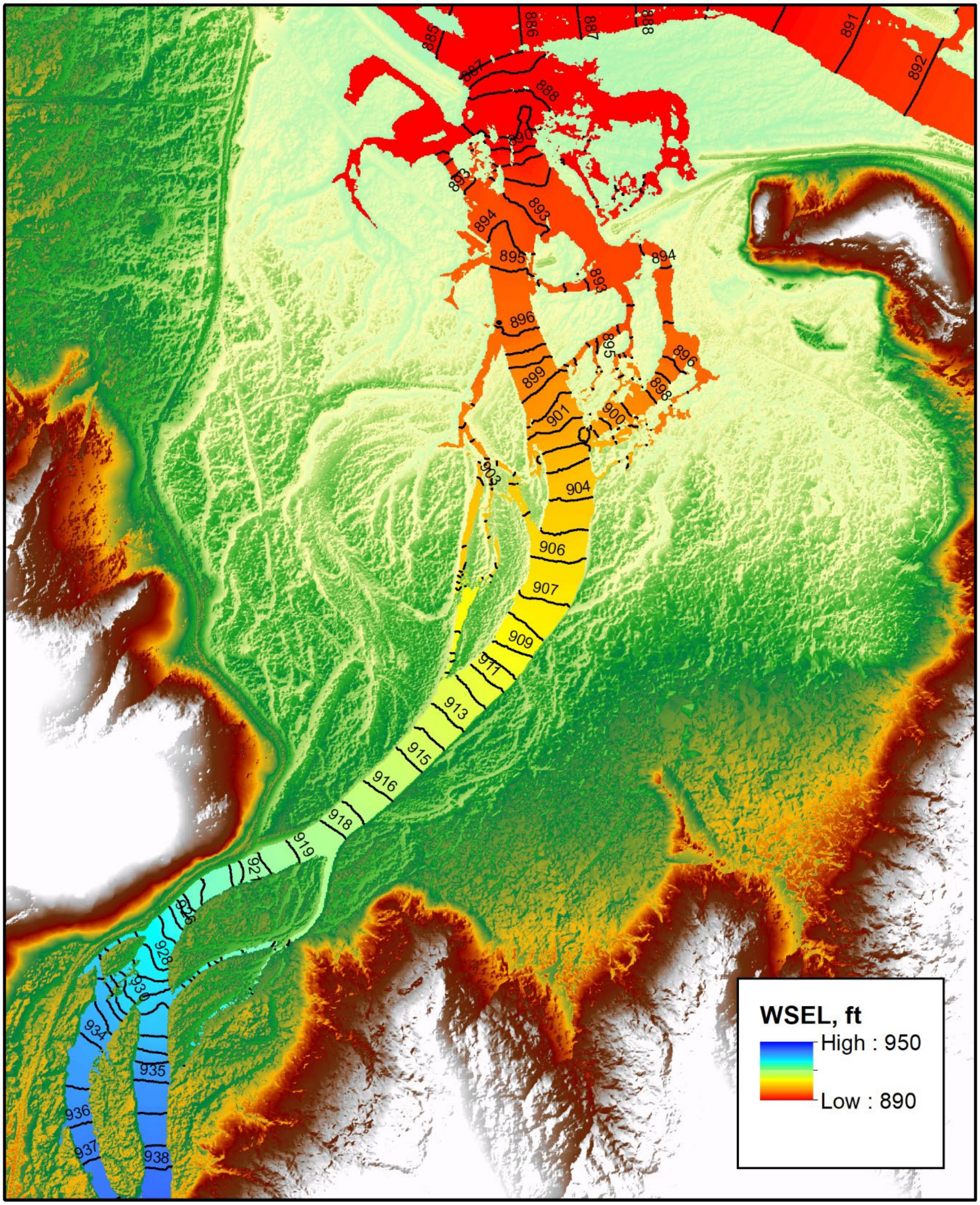
Figure 4. Scenario 3 model terrain with parcel boundaries (white), areas of removed fill (red), pilot channels (blue), and added channel obstructions (yellow).

4 MODEL RESULTS

The following figures include plots of modeled depth, velocity and water surface elevation for the existing condition and conceptual design scenarios 1, 2 and 3. Figures are included in this report for the 2- and 100-year event results. Screenshots of model results and rasters of depth, velocity and water surface elevation for all modeled events (2-, 10-, 100-, and 500-year) for the existing condition and conceptual design scenarios 1, 2 and 3 have been provided to the County.


Depth, ft
High : 10+
Low : 0
King County, WA
Lower Miller River
Existing Condition
2-year Depth
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING


Velocity, ft/s
0 - 1
1 - 2
2 - 5
5 - 8
8 - 10
10 - 15
15+
King County, WA
Lower Miller River
Existing Condition
2-year Velocity
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING



King County, WA

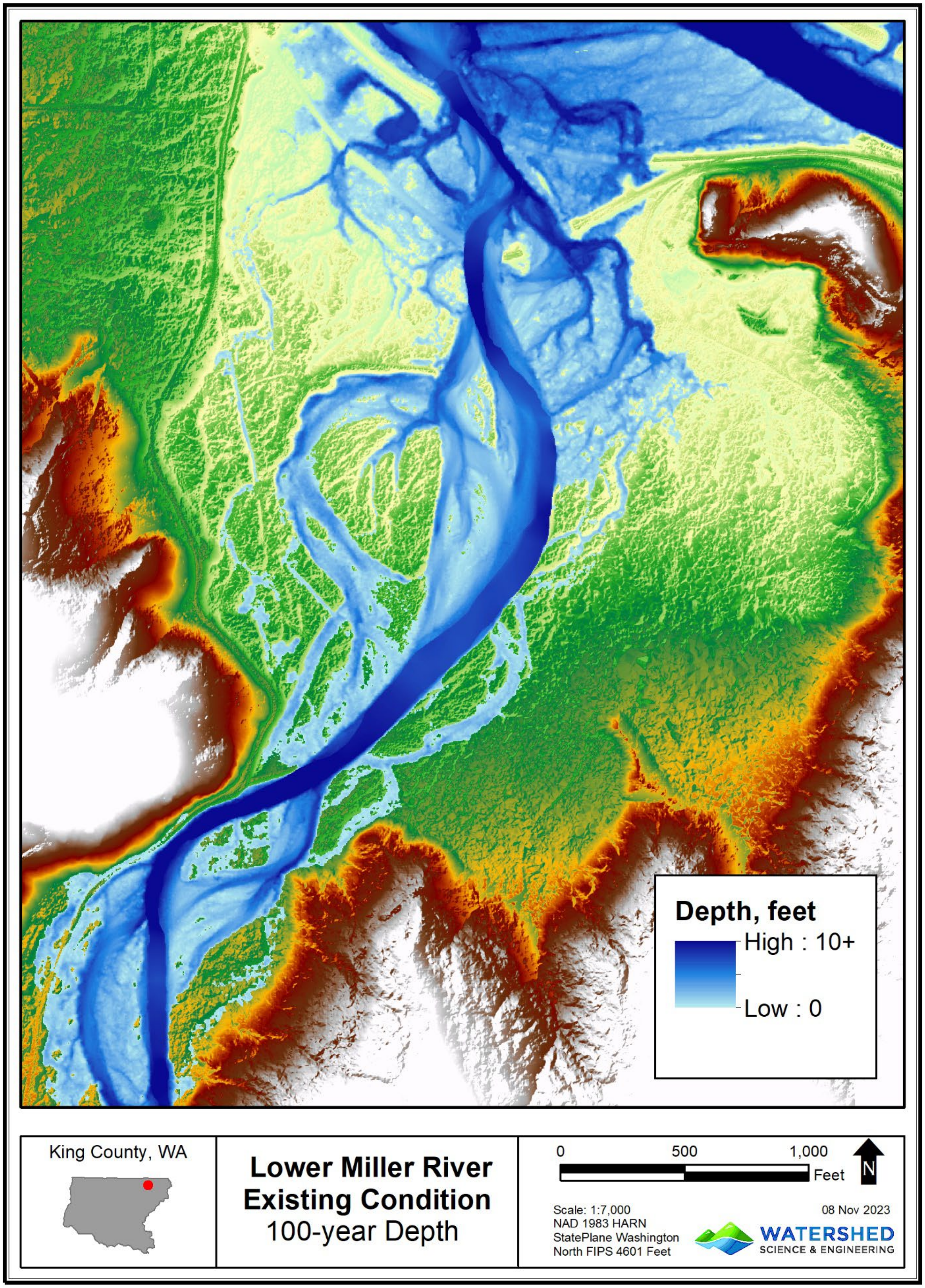
Lower Miller River
Existing Condition
2-year
Water Surface Elevation

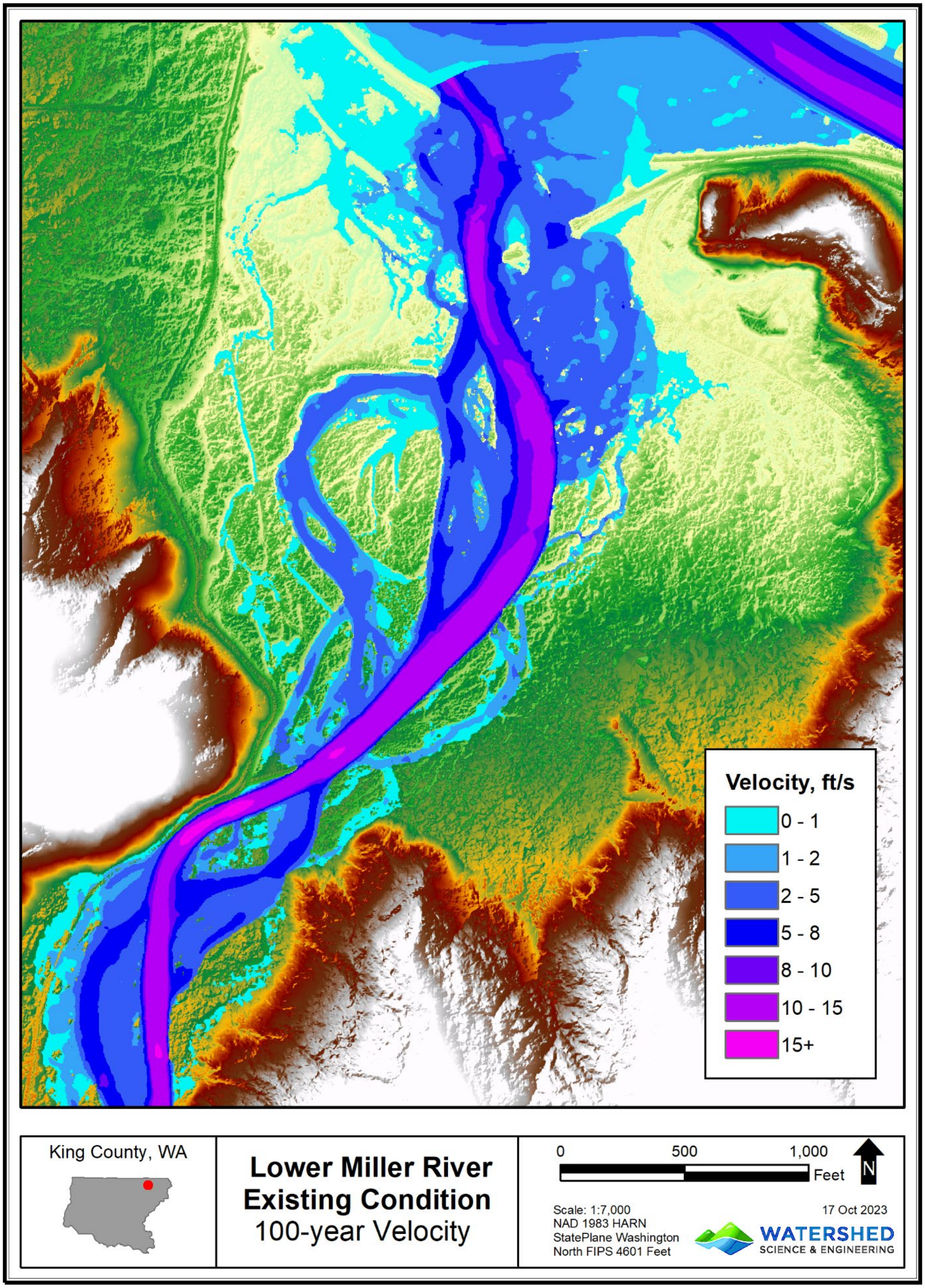
0 500 1,000 Feet
N

Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

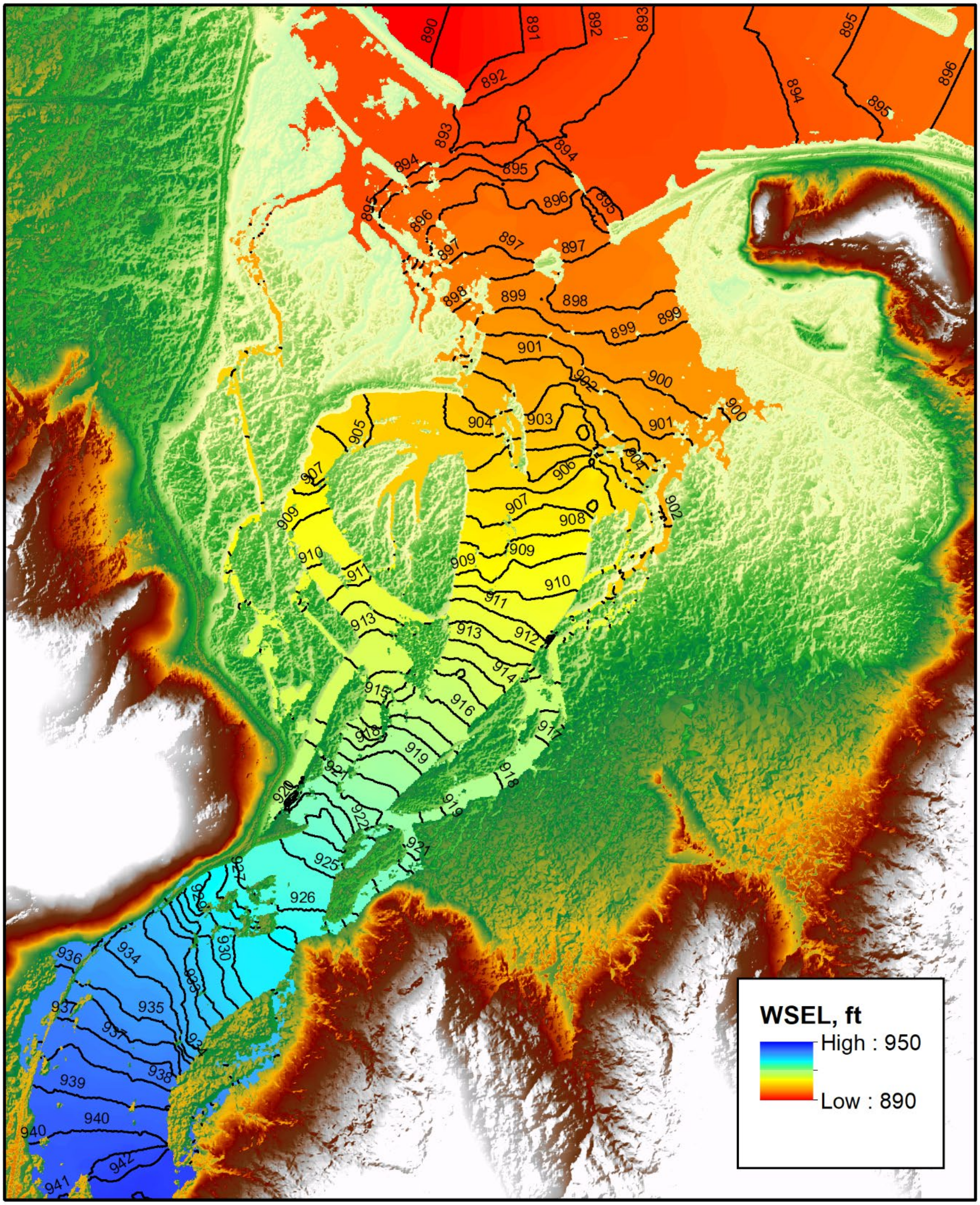
17 Oct 2023

WATERSHED SCIENCE & ENGINEERING


Depth, feet
High : 10+
Low : 0
King County, WA
Lower Miller River
Existing Condition
100-year Depth
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
08 Nov 2023
WATERSHED
SCIENCE & ENGINEERING



Velocity, ft/s
0 - 1
1 - 2
2 - 5
5 - 8
8 - 10
10 - 15
15+
King County, WA
Lower Miller River
Existing Condition
100-year Velocity
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING



King County, WA

Lower Miller River Existing Condition

100-year
Water Surface Elevation

0 500 1,000 Feet N

Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

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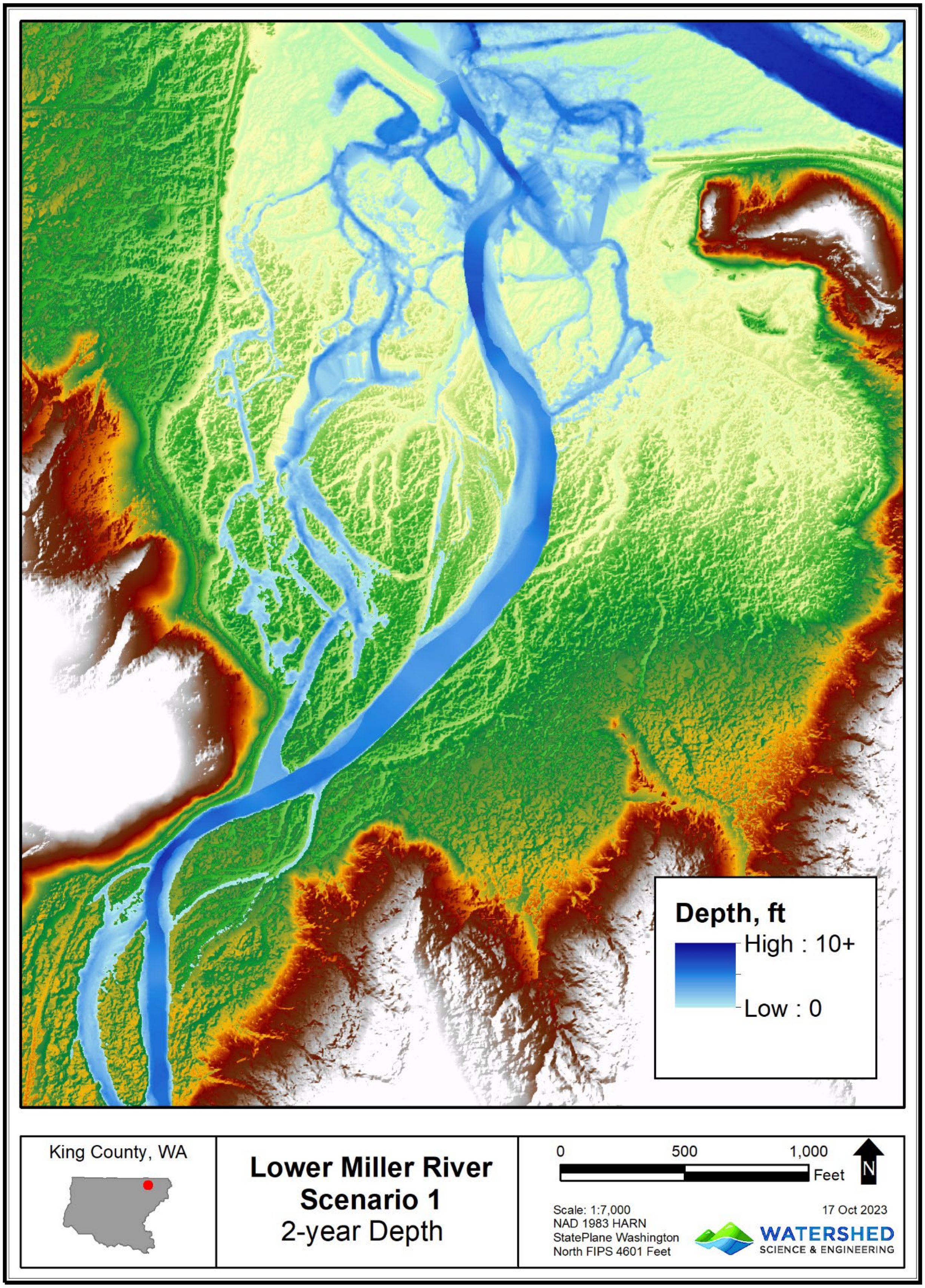
Depth, ft
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King County, WA
Lower Miller River
Scenario 1
2-year Depth
0
500
1,000
Feet
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Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
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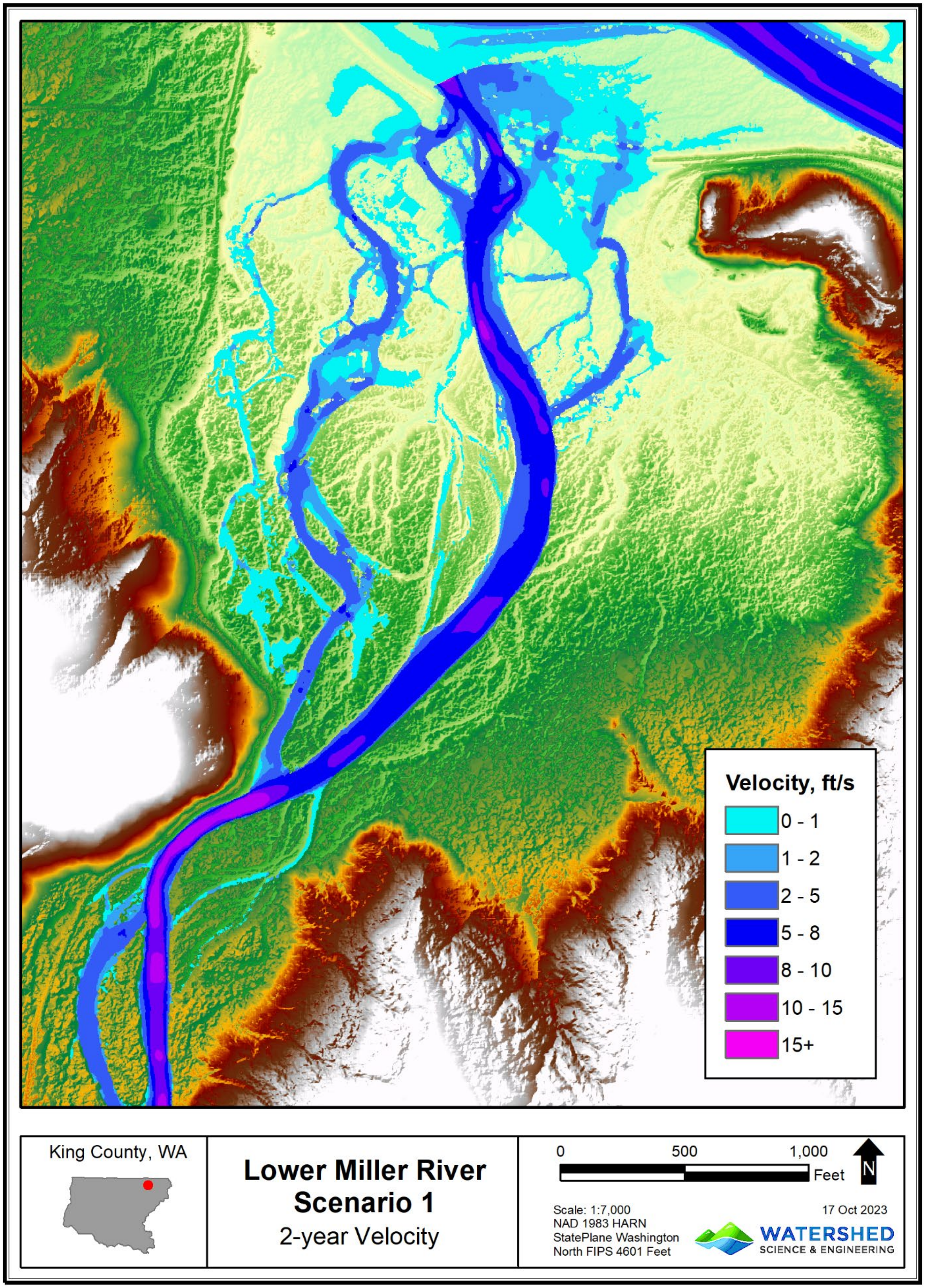

Velocity, ft/s
0 - 1
1 - 2
2 - 5
5 - 8
8 - 10
10 - 15
15+
King County, WA
Lower Miller River
Scenario 1
2-year Velocity
0
500
1,000
Feet
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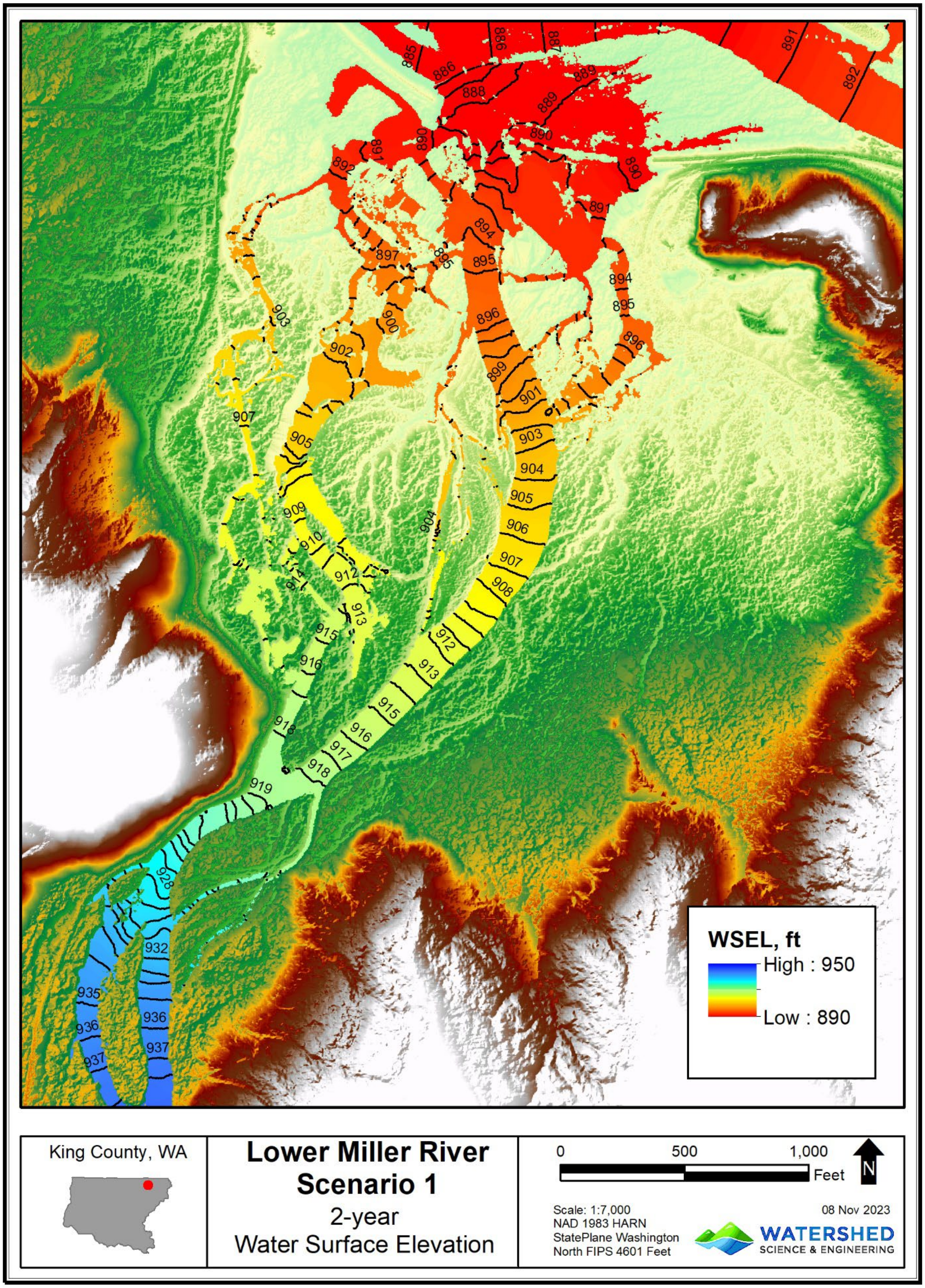
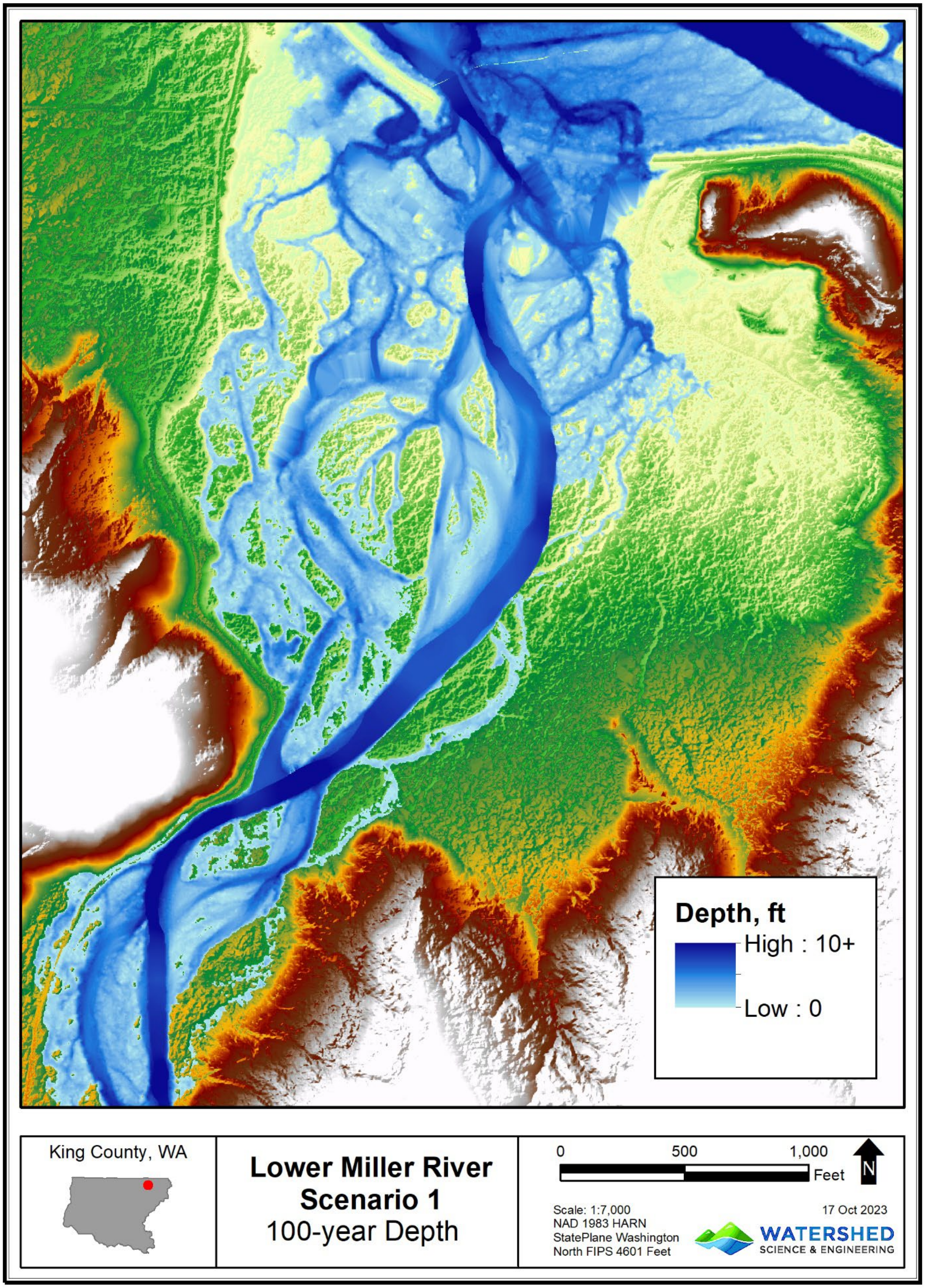
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING


WSEL, ft
High : 950
Low : 890
King County, WA
Lower Miller River
Scenario 1
2-year
Water Surface Elevation
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
08 Nov 2023
WATERSHED
SCIENCE & ENGINEERING


Depth, ft
High : 10+
Low : 0
King County, WA
Lower Miller River
Scenario 1
100-year Depth
0
500
1,000
Feet
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Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
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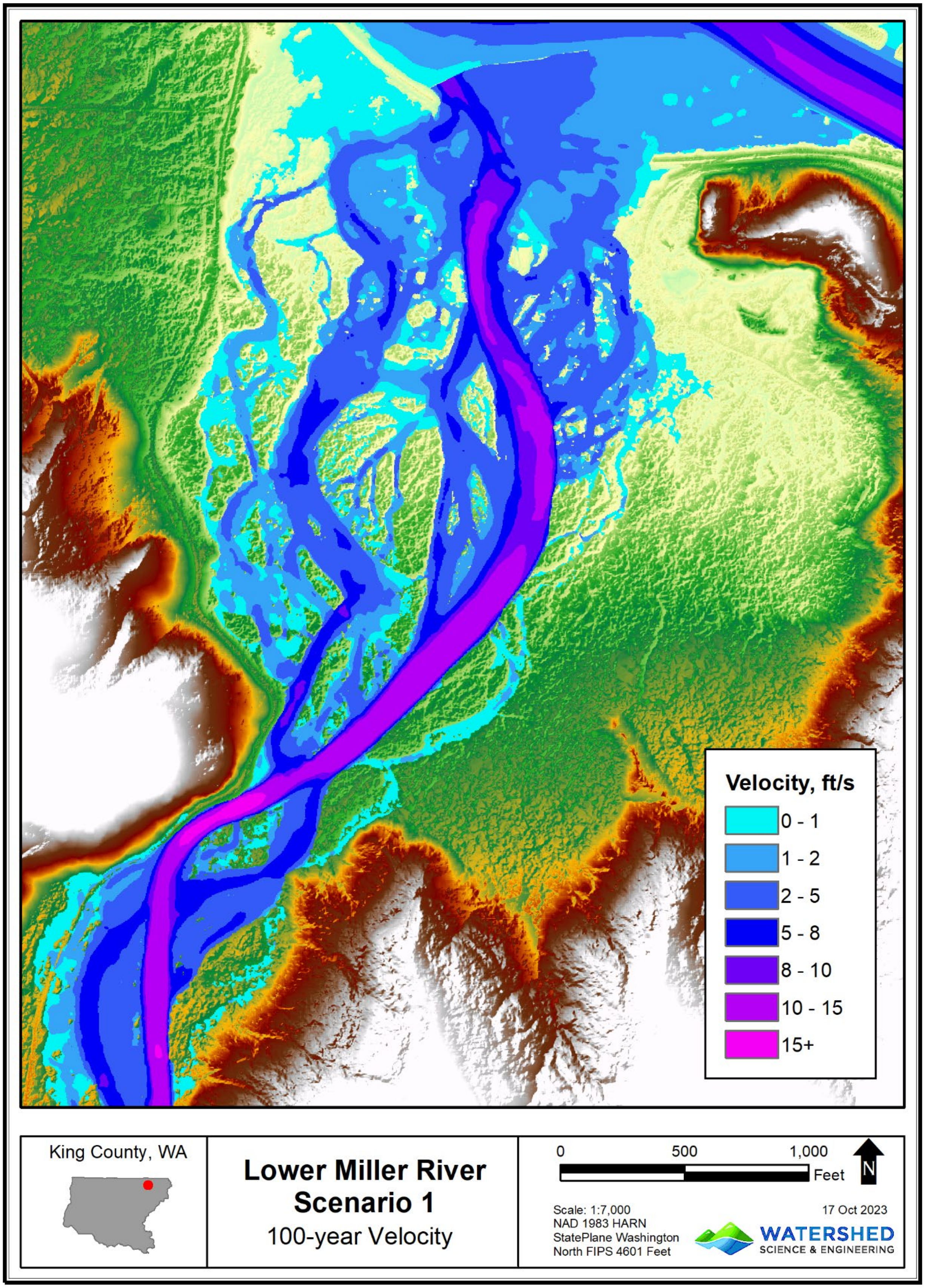
Velocity, ft/s
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King County, WA
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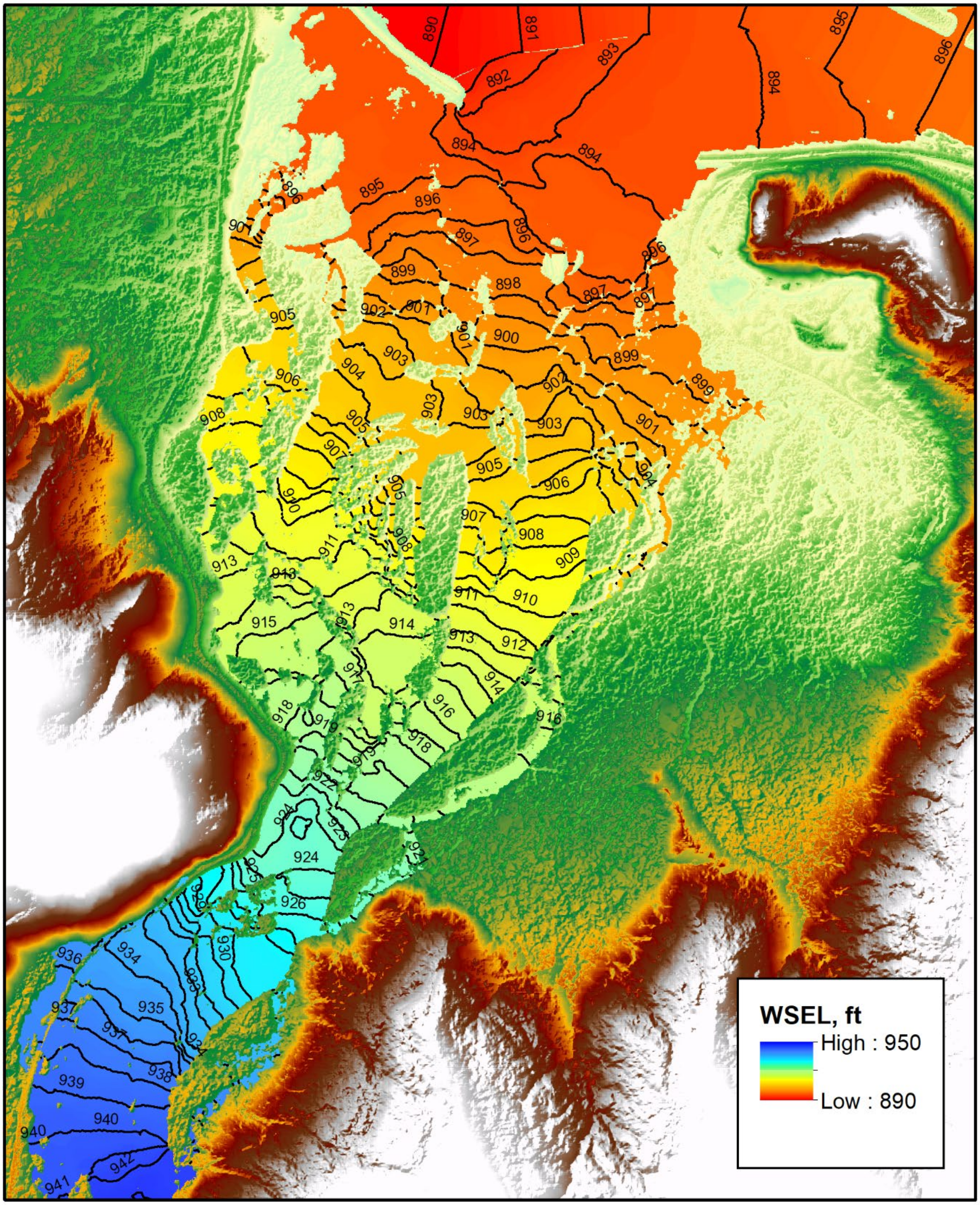


King County, WA

Lower Miller River
Scenario 1
100-year
Water Surface Elevation

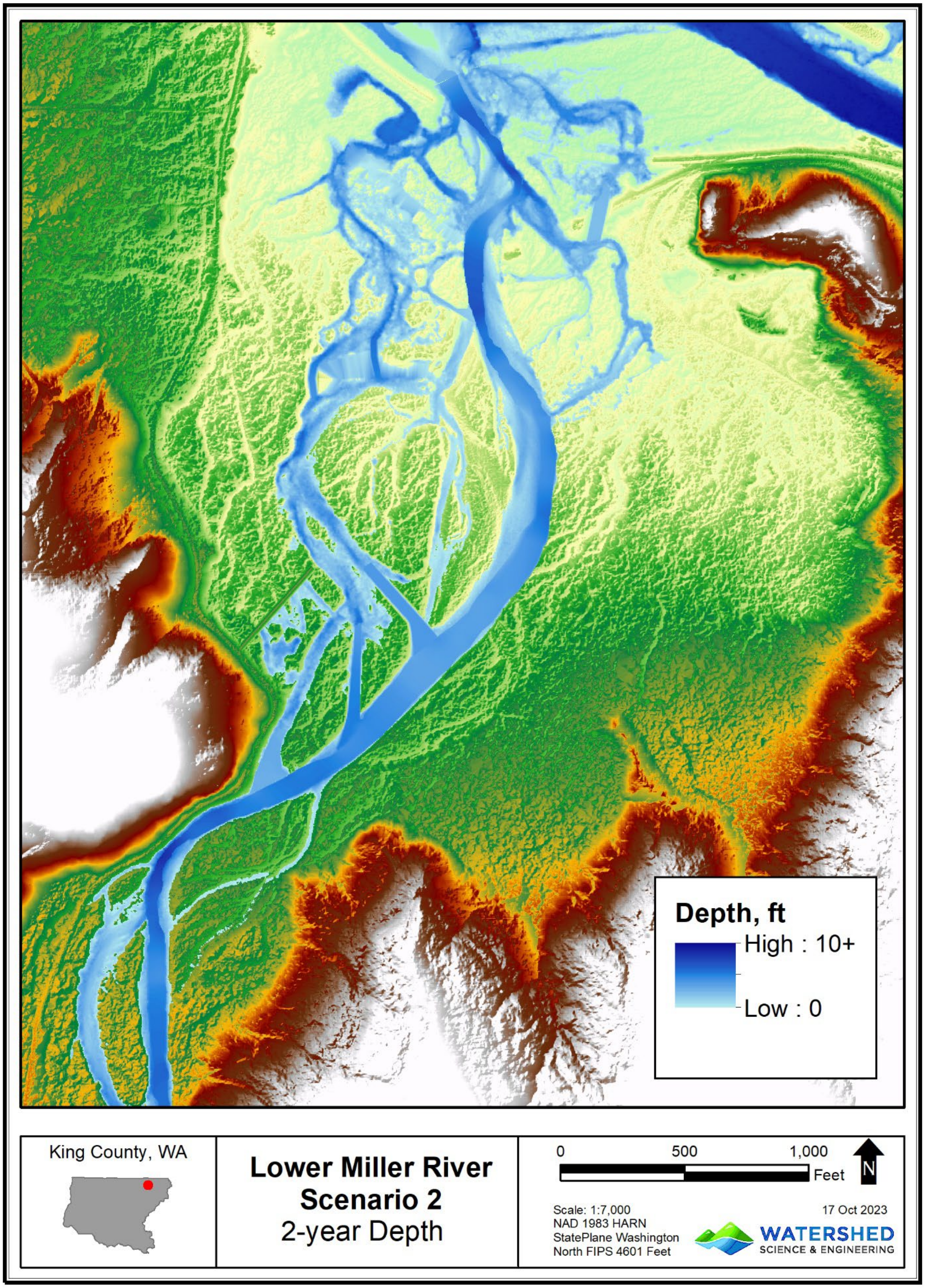
0 500 1,000 Feet

N

Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

17 Oct 2023

WATERSHED SCIENCE & ENGINEERING



Depth, ft
High : 10+
Low : 0
King County, WA
Lower Miller River
Scenario 2
2-year Depth
0
500
1,000
Feet
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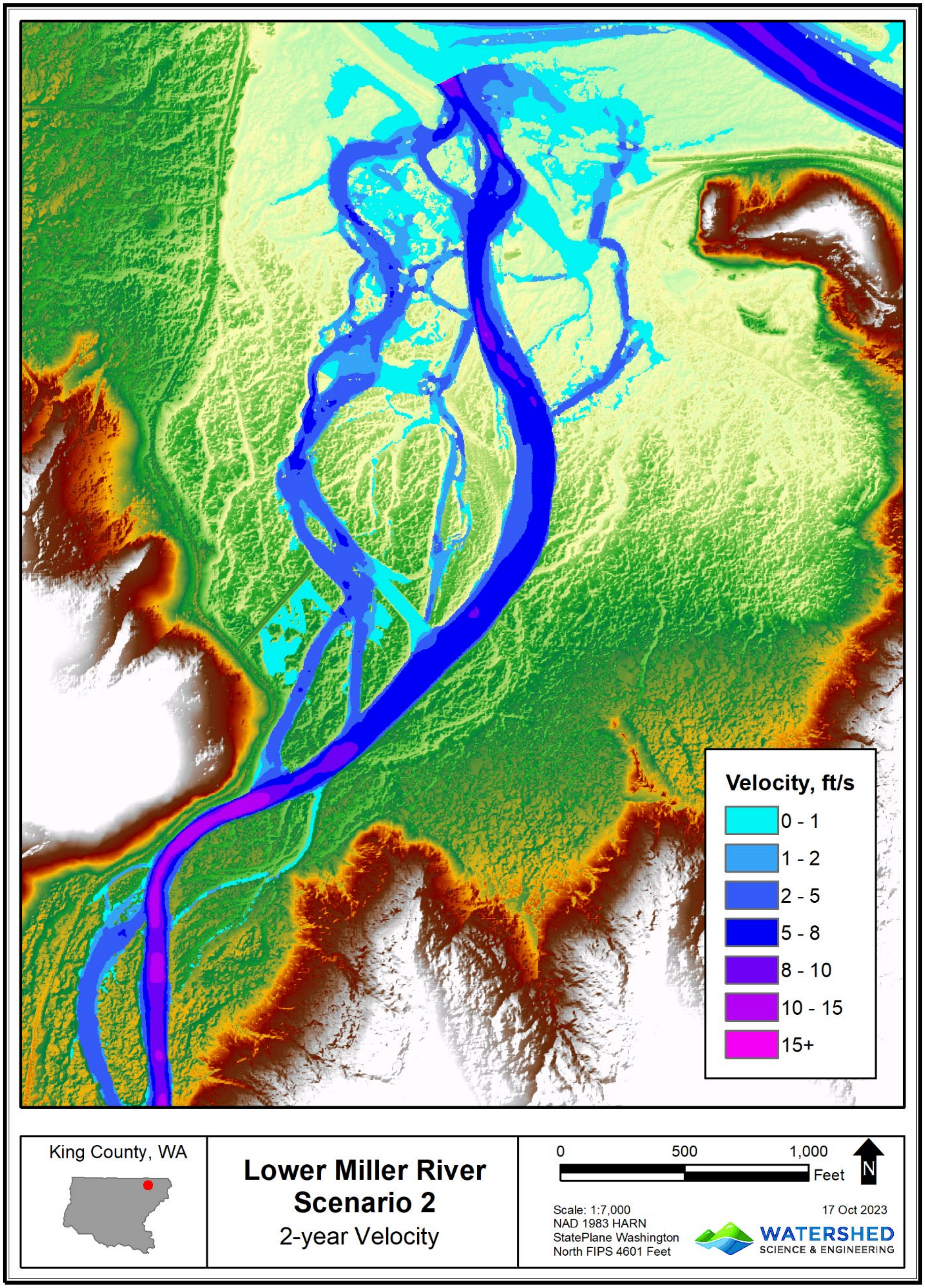
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING


Velocity, ft/s
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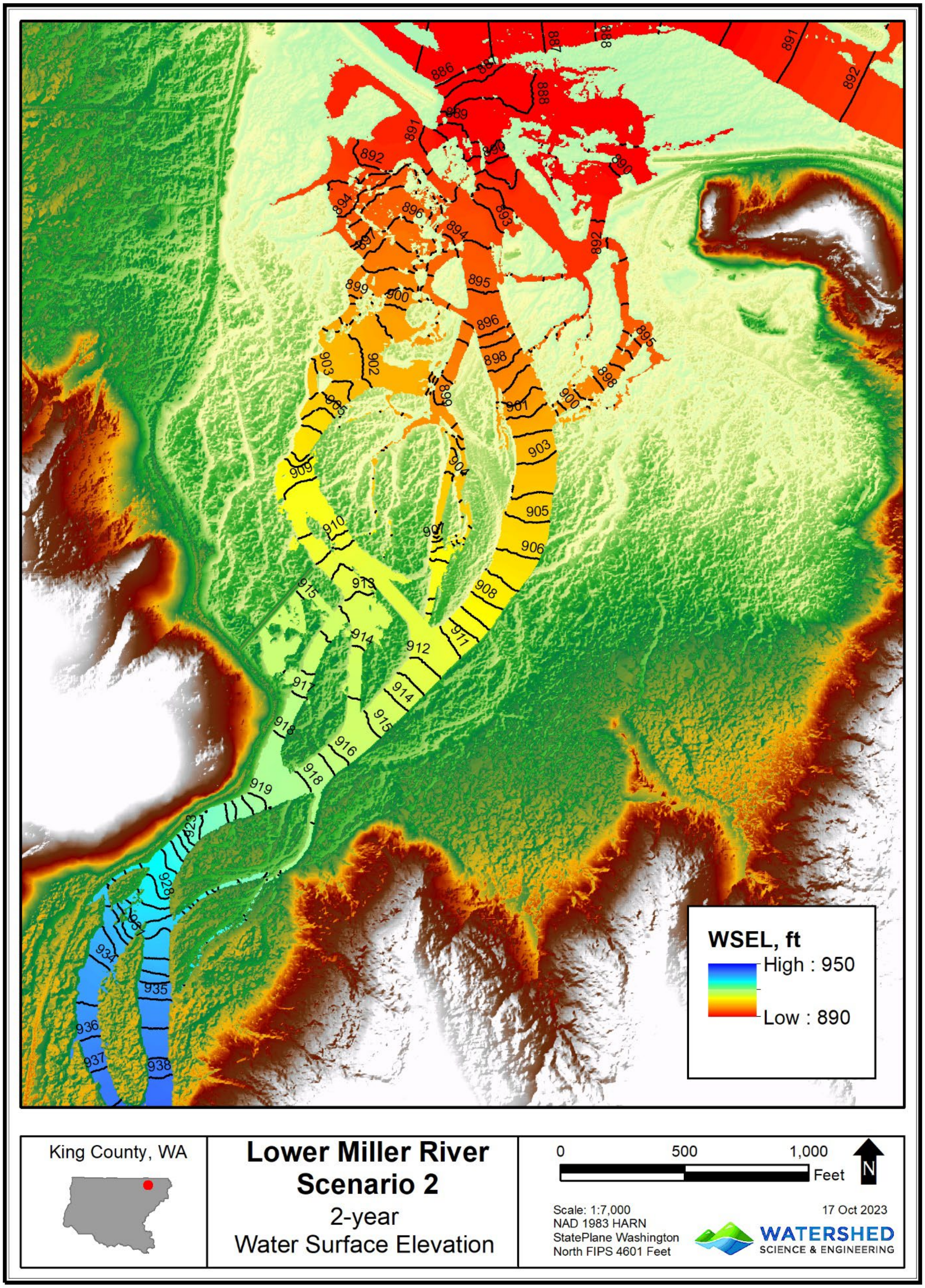
WSEL, ft
High : 950
Low : 890
King County, WA
Lower Miller River
Scenario 2
2-year
Water Surface Elevation
0
500
1,000
Feet
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Scale: 1:7,000
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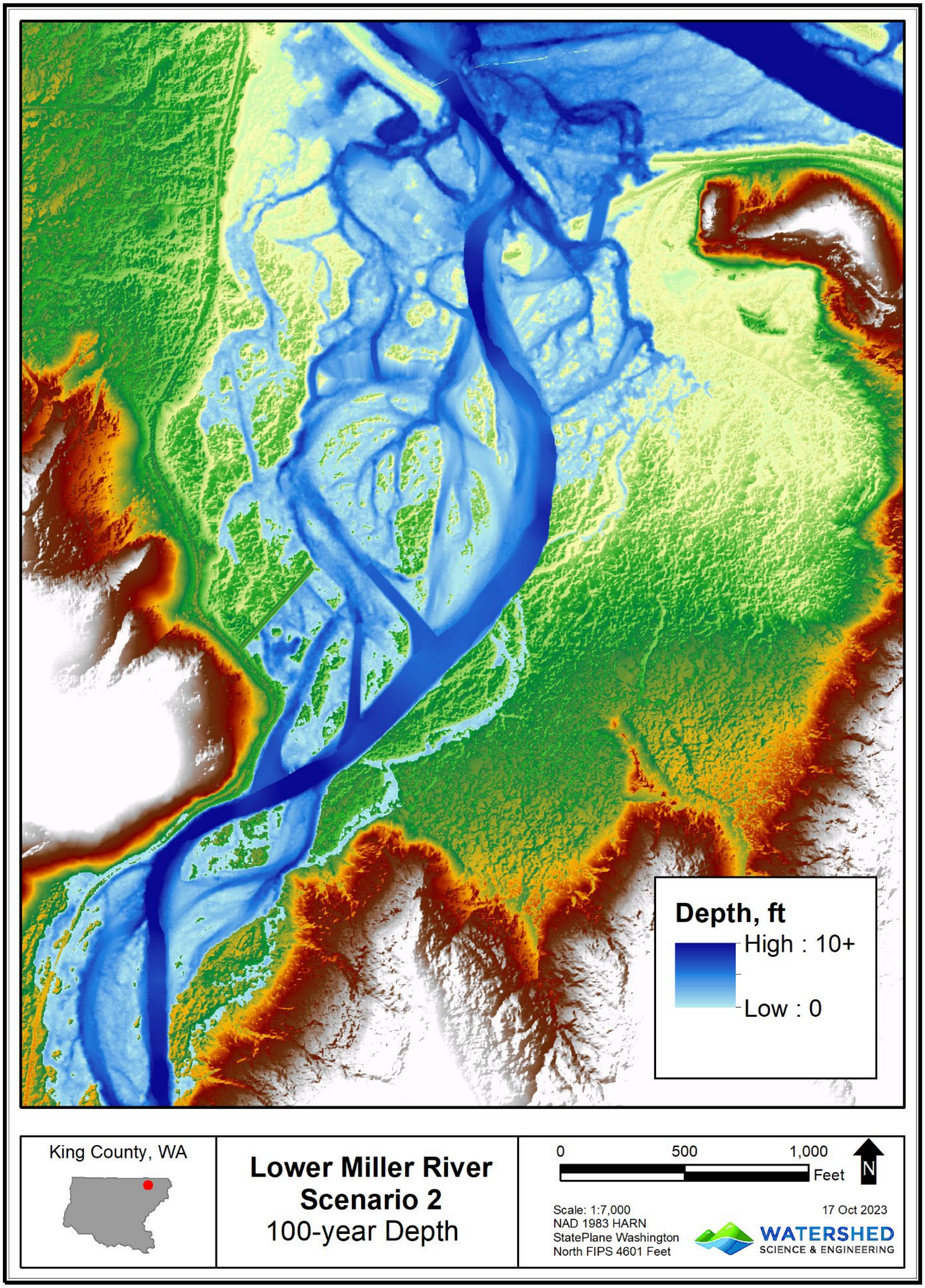
Depth, ft
High : 10+
Low : 0
King County, WA
Lower Miller River
Scenario 2
100-year Depth
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Scale: 1:7,000
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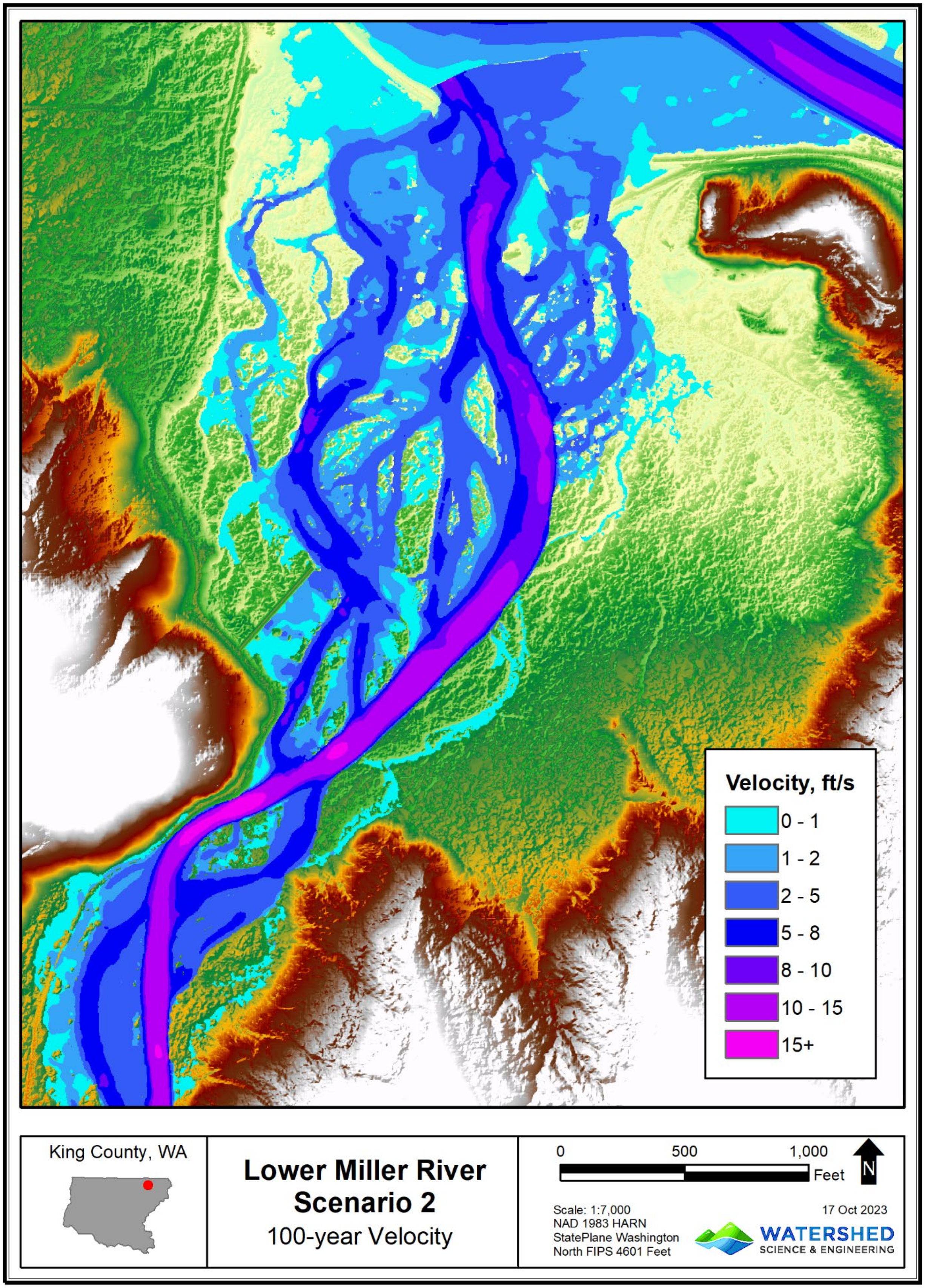
Velocity, ft/s
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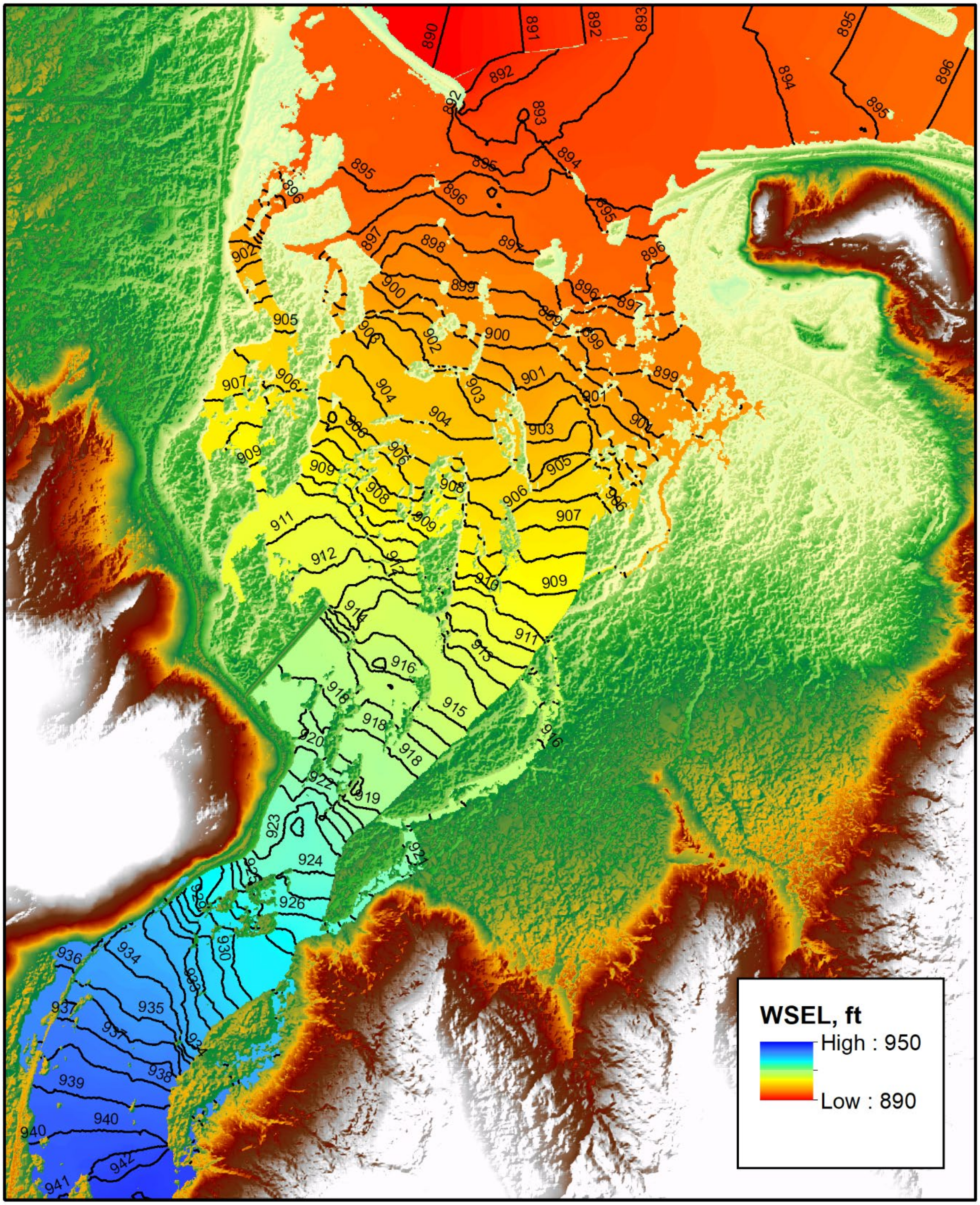


King County, WA

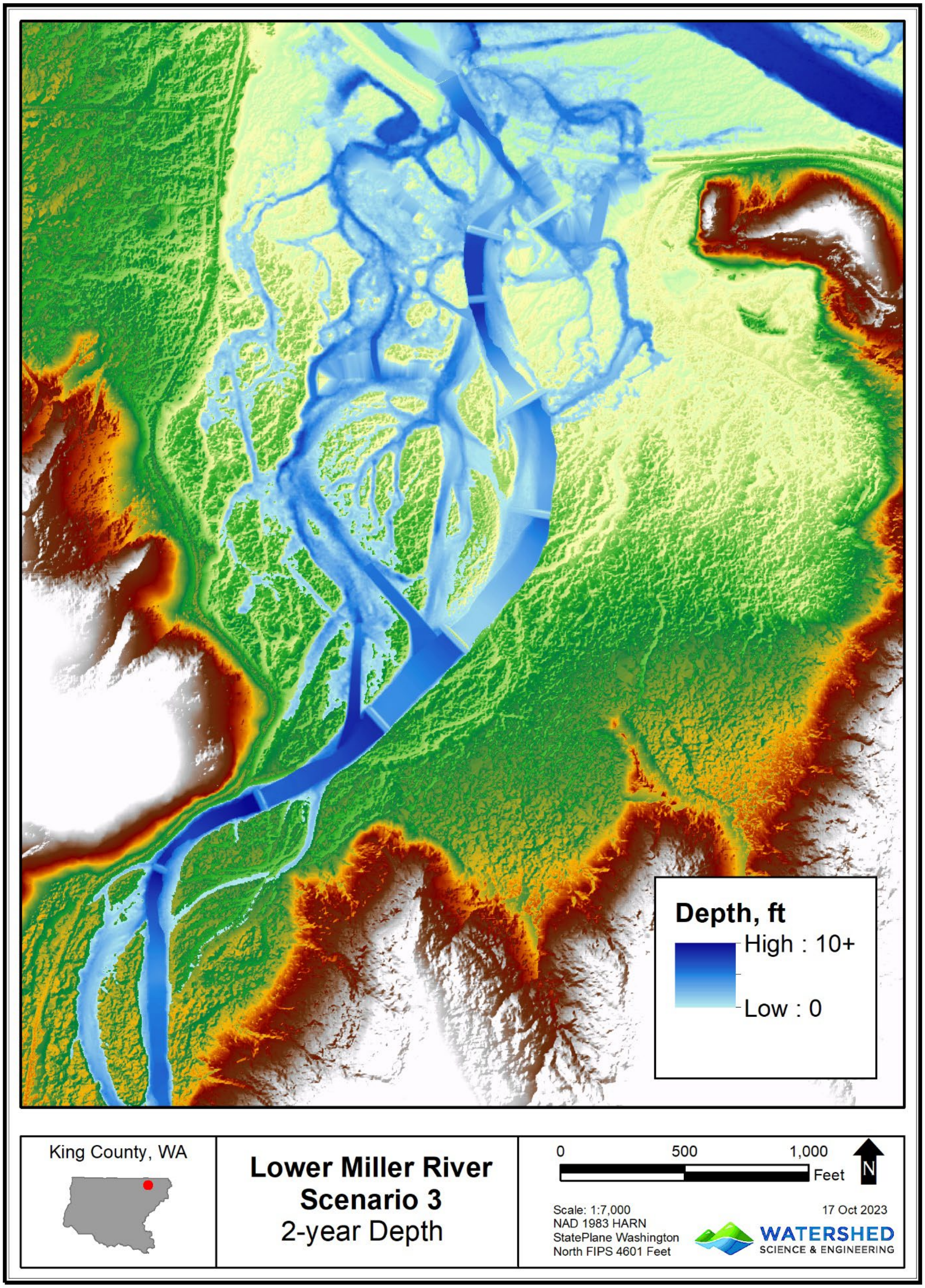
Lower Miller River
Scenario 2
100-year
Water Surface Elevation

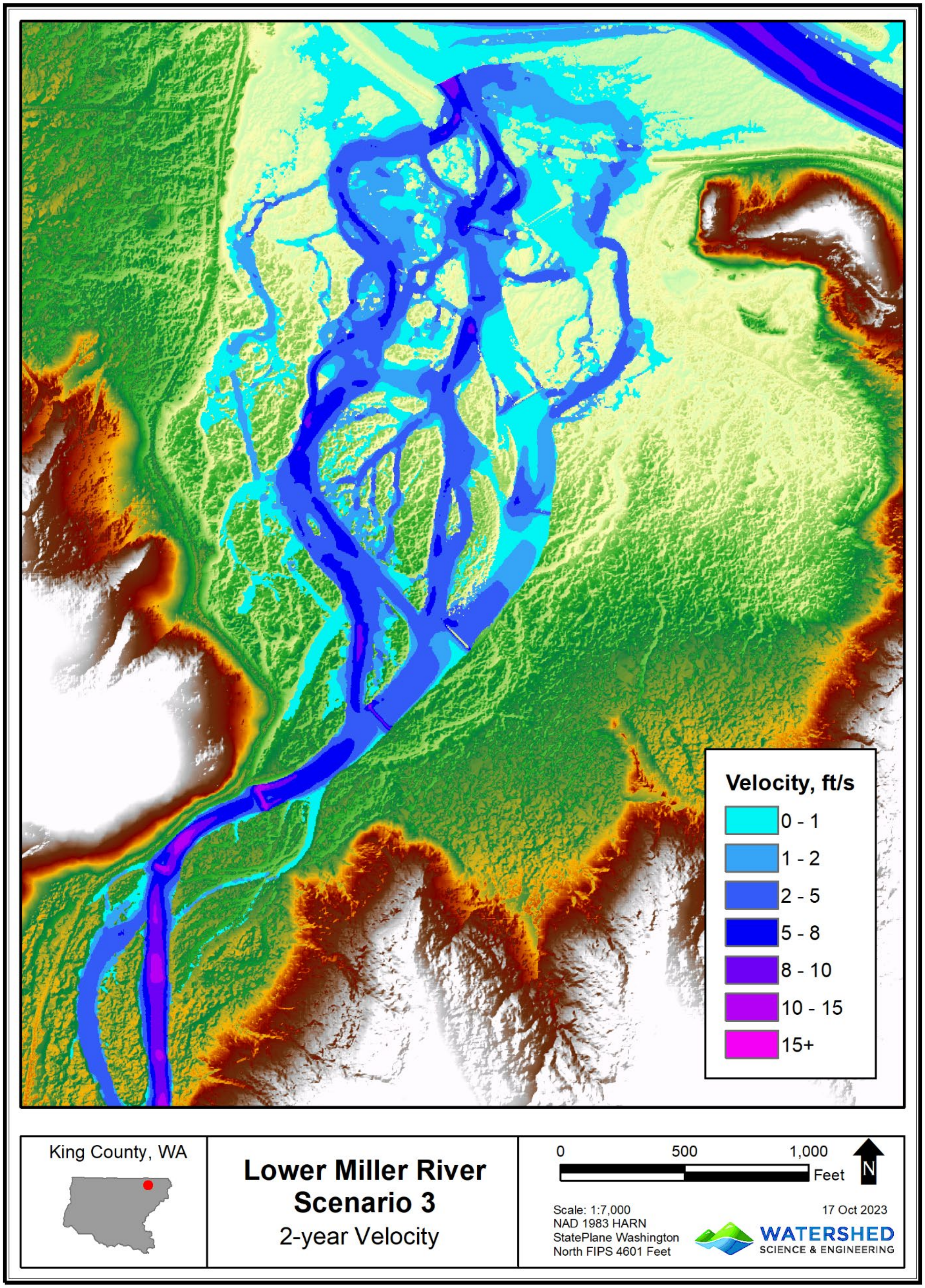
0 500 1,000 Feet
N

Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet

17 Oct 2023

WATERSHED SCIENCE & ENGINEERING


Depth, ft
High : 10+
Low : 0
King County, WA
Lower Miller River
Scenario 3
2-year Depth
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING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2 - 5
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King County, WA
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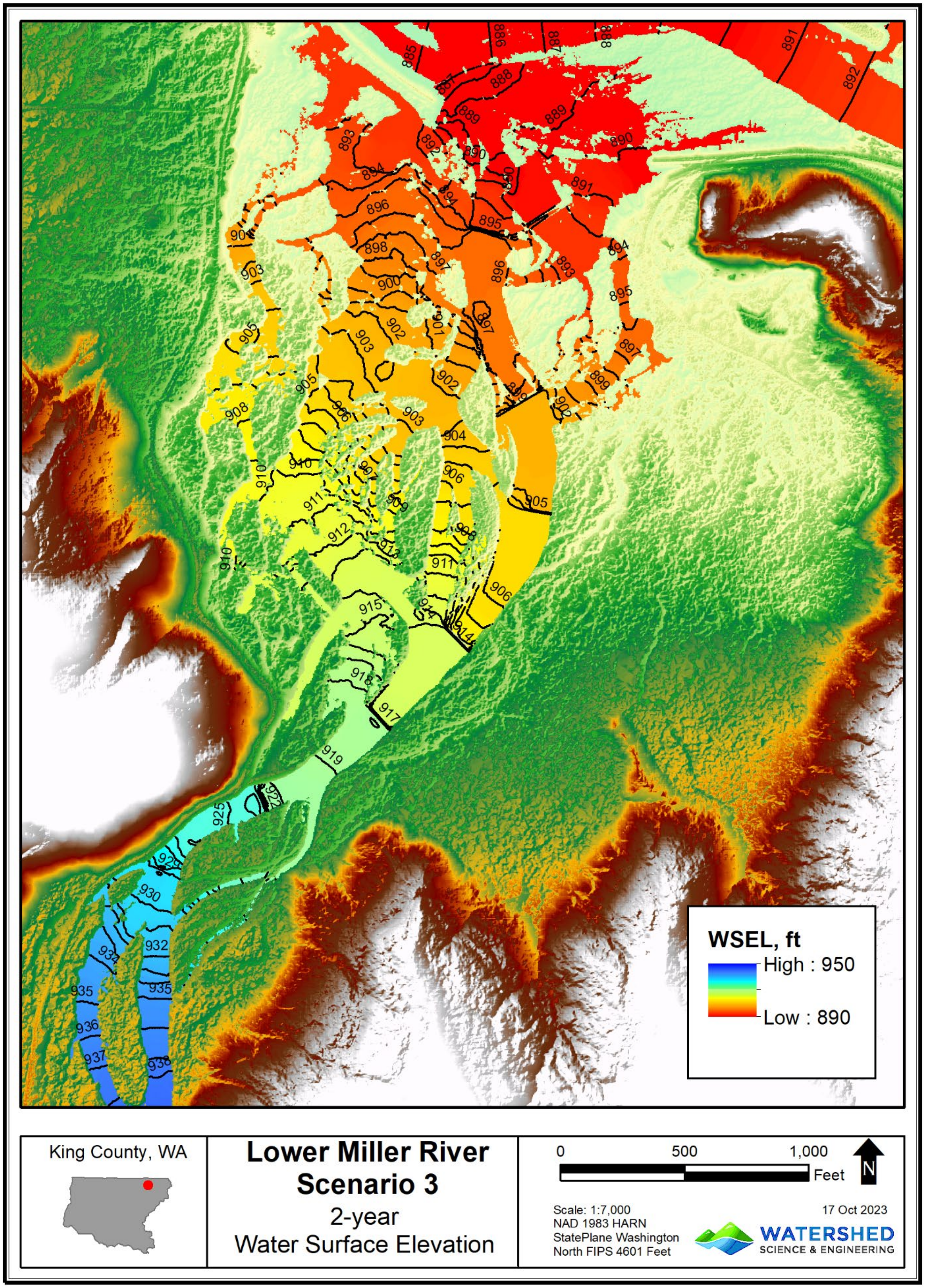
SCIENCE & ENGINEERING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Scenario 3
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StatePlane Washington
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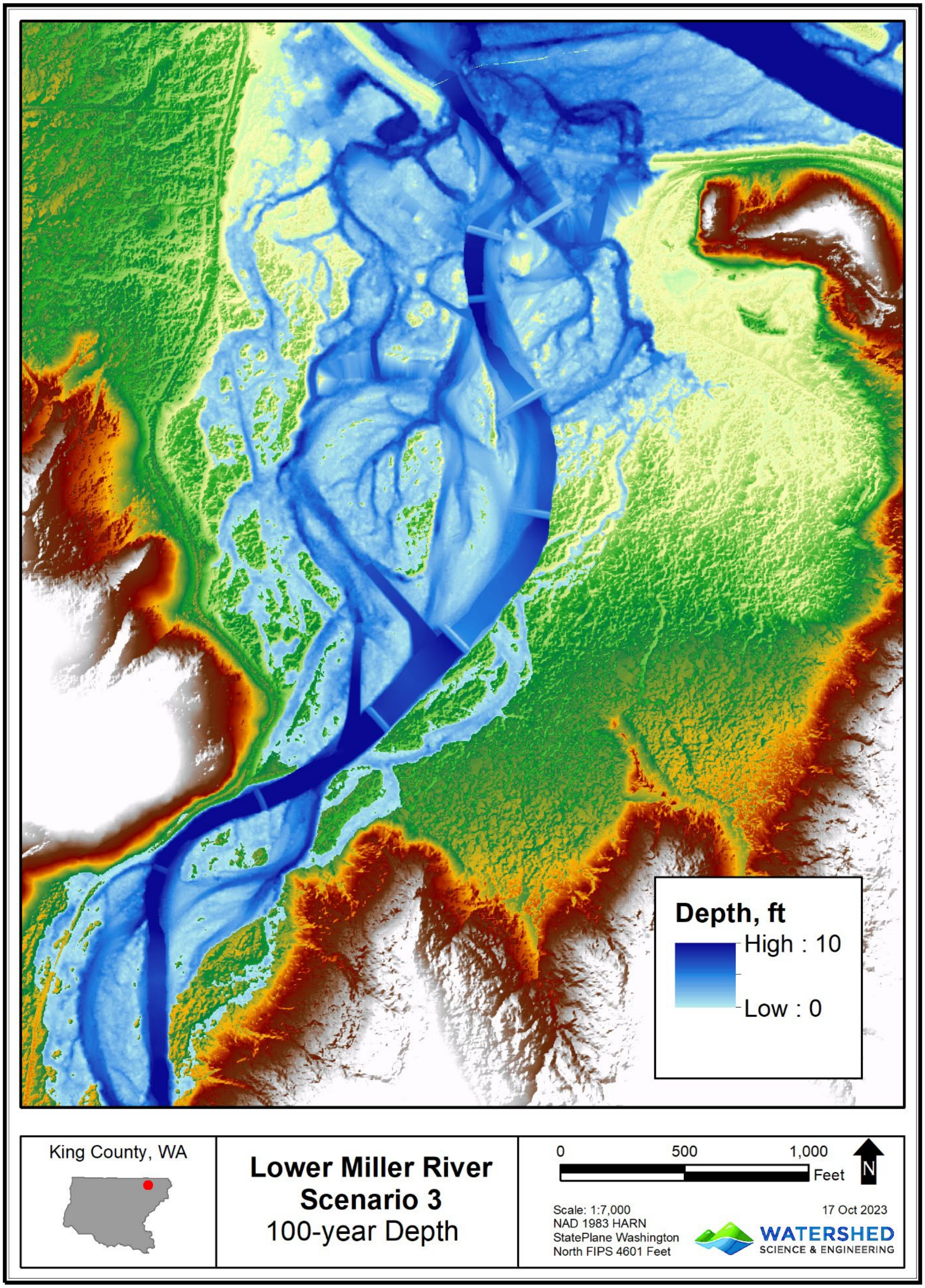
SCIENCE & ENGINEERING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1,000
Feet
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North FIPS 4601 Feet
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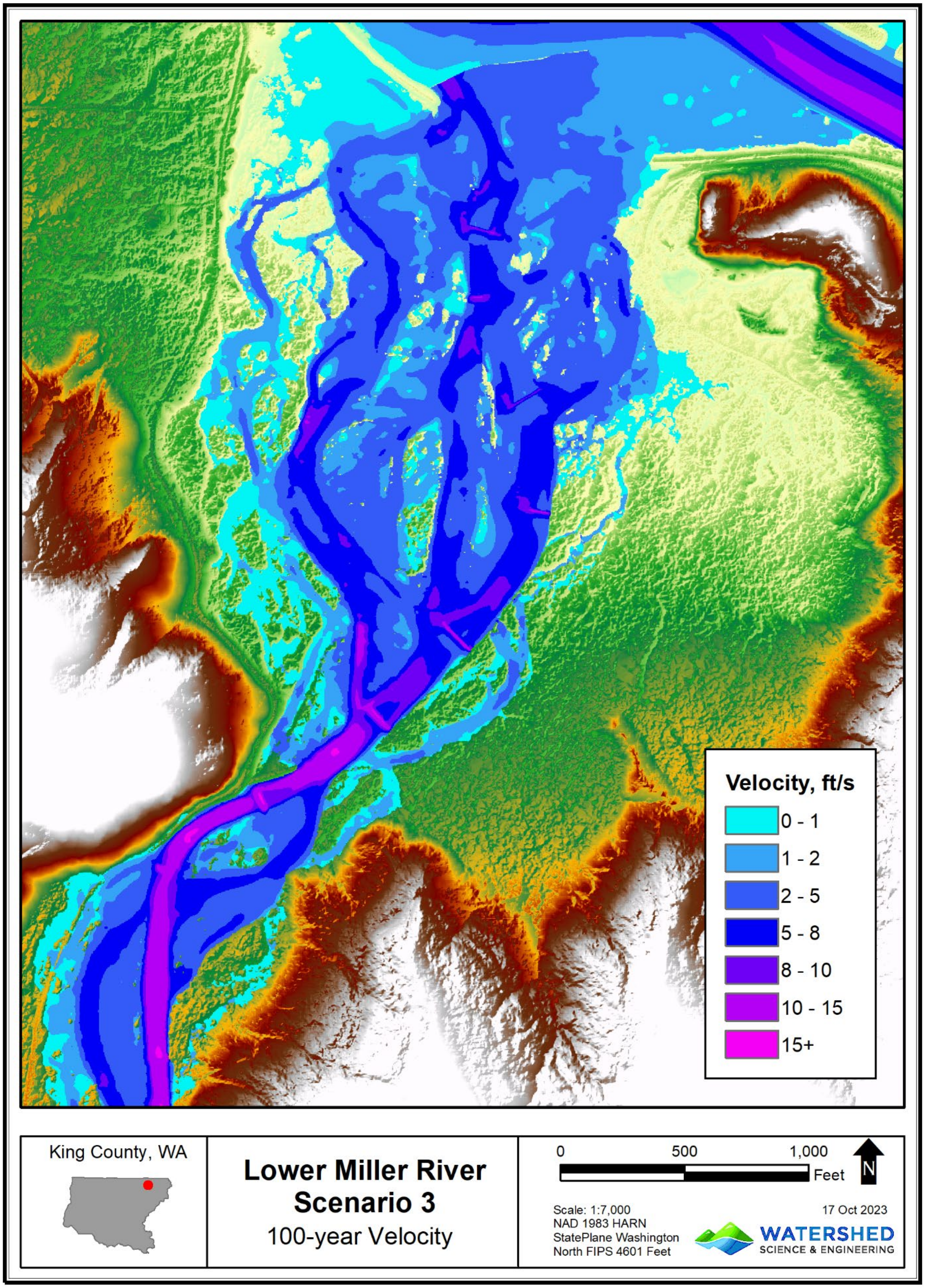
WATERSHED
SCIENCE & ENGINEERING


Velocity, ft/s
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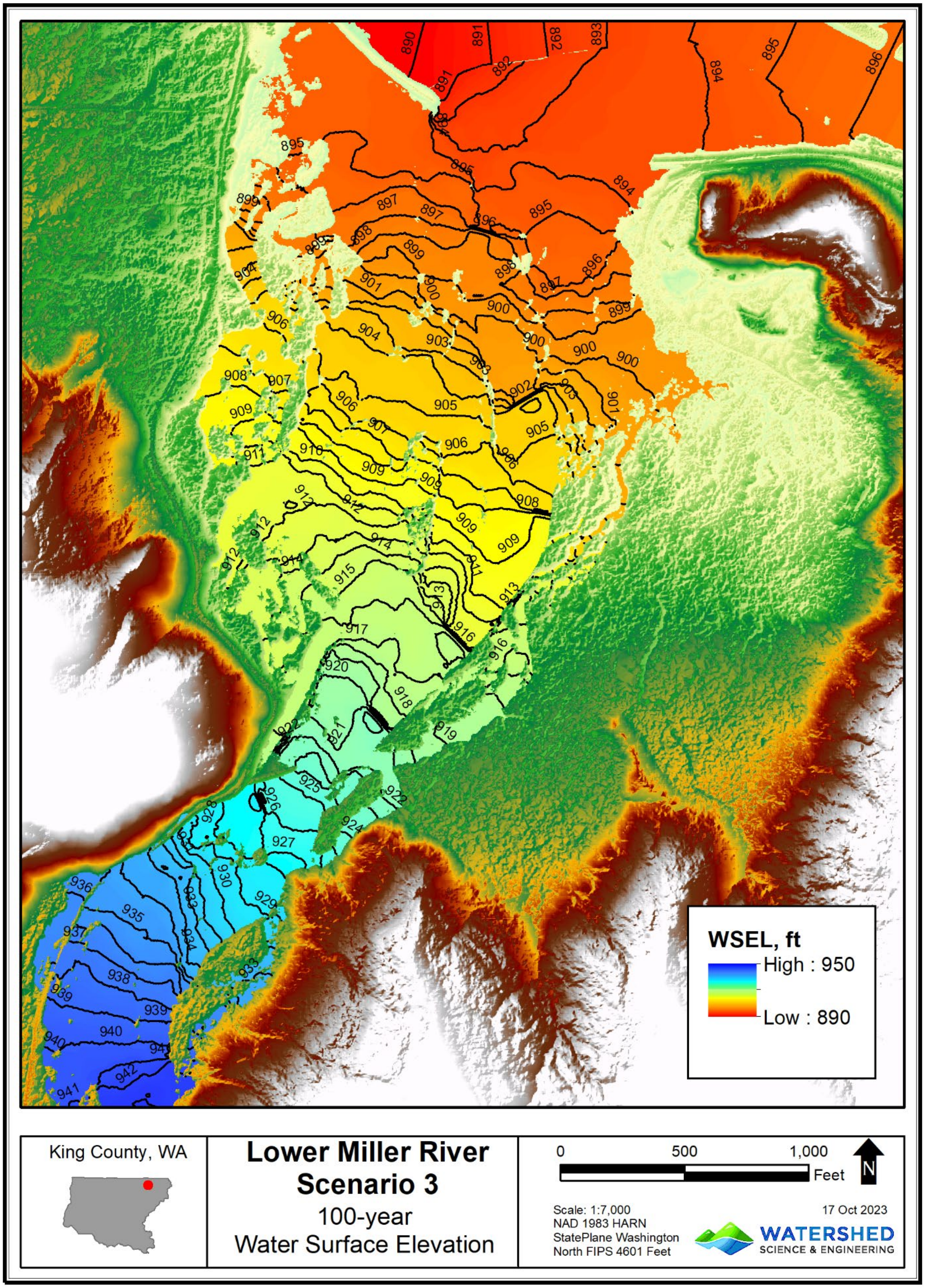
1 - 2
2 - 5
5 - 8
8 - 10
10 - 15
15+
King County, WA
Lower Miller River
Scenario 3
100-year Velocity
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
WATERSHED
SCIENCE & ENGINEERING


WSEL, ft
High : 950
Low : 890
King County, WA
Lower Miller River
Scenario 3
100-year
Water Surface Elevation
0
500
1,000
Feet
N
Scale: 1:7,000
NAD 1983 HARN
StatePlane Washington
North FIPS 4601 Feet
17 Oct 2023
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5 PERMITTING CONSIDERATIONS

Any restoration activities on the lower Miller River will need to comply with local and federal permitting requirements, including the following floodplain development regulations.

5.1 KING COUNTY REGULATIONS

King County requires a Floodplain Development Permit “prior to conducting work on a site or lot that contains or is adjacent to a flood hazard area even if the flood hazard area has not yet been delineated by King County or FEMA” (King County, 2020), which would include the Miller River floodplain. This permit requires the project to meet compensatory storage standards and no-rise within the King County Zero-Rise Floodway, which is defined as the 100-year floodplain. Additionally, a King County Flood Hazard Certification will be required to demonstrate compliance with County floodplain development regulations (King County, 2023).

All three of the design scenarios explored in this analysis involve significant removal of fill from the floodplain. As such, meeting King County compensatory storage requirements should not be a major constraint on the restoration design. However, the intention of the restoration projects on the lower Miller River is to increase connection between the Miller River and its floodplain. As such, meeting the restoration goals of increased side channel and floodplain inundation will inherently cause a rise in water surface elevations relative to the current condition. WSE believes that 1D hydraulic modeling is more suited to no-rise floodplain compliance than 2D. However, an appropriate 1D model of the post-project condition will likely need to include branched flow paths, and therefore will show a rise in overflow paths if the project’s stated goal of increasing floodplain connecting is achieved.

The King County Flood Hazard Certification form does not provide an option or guidance for how to proceed with a project that will change base flood elevations (similar to submitting a Conditional Letter of Map Revision for FEMA-regulated areas). King County Permitting Division may allow exceptions to no rise regulations for restoration activities when the rise is contained to County owned or public parcels, but this should be verified with County permitting staff before further alternatives analysis is conducted. If variances are allowed for rises on County property, a major design constraint of the restoration project will be preventing water surface elevation increases on the private parcels on the left floodplain. Alternatively, the County could explore acquisition of private parcels in the lower Miller River floodplain.

5.2 FEMA REGULATIONS

The Miller River has not been mapped in a FEMA Flood Insurance Rate Map and thus the flooding on the Miller River is not subject to FEMA regulations. The South Fork Skykomish River does have a FEMA mapped Special Flood Hazard Area and floodway. WSE recently submitted a Letter of Map Revision to revise the floodplain and floodway for the South Fork Skykomish River. This letter is currently pending FEMA approval. In the area near the confluence with the Miller River, the 100-year floodplain inundation area is mostly reduced in the revised map relative to the effective FEMA floodplain due to the improved and updated topography (Figure 5).

FEMA requires a no-rise analysis for development within mapped floodways, but none of the restoration scenarios explored in this analysis are within the South Fork Skykomish floodway (effective or revised). Some of the proposed terrain alterations for the Miller River project fall within the mapped Zone AE (100-year floodplain) for the South Fork Skykomish River and would likely inundate previously dry areas. However, as the changes are outside the mapped floodway, a Letter of Map Revision would only be needed if the County wished to update the Flood Insurance Rate Maps to reflect the change in the floodplain with the altered (i.e., post-restoration) topography. As the revisions to the South Fork Skykomish floodplain would be within public property, this minor map revision would likely be of low importance to the County.

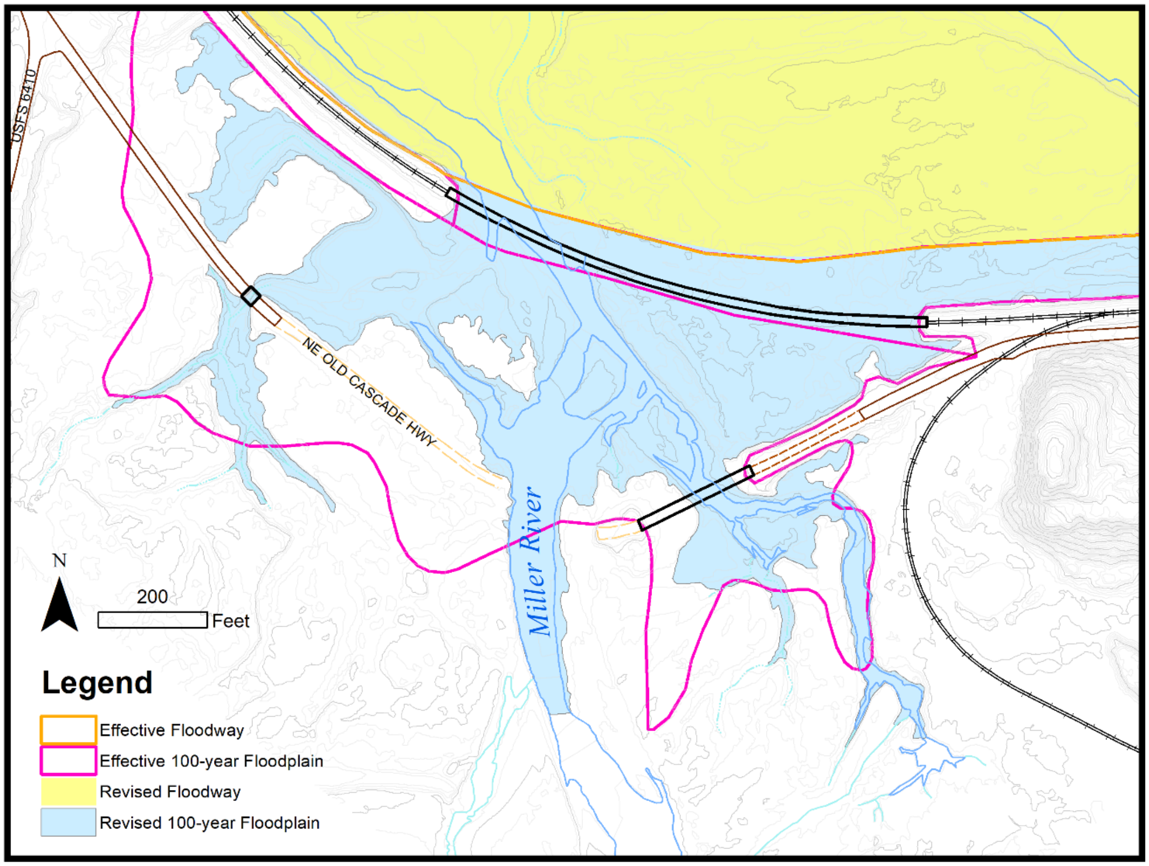

Figure 5. South Fork Skykomish River FEMA mapped effective and revised floodplain and floodway in project vicinity.

6 CONCLUSIONS

WSE provided hydrologic and hydraulic analysis to support feasibility analysis of restoration opportunities for the lower Miller River. WSE estimated frequency flows for the Miller River by scaling flows from the South Fork Skykomish River, but noted that there is significant uncertainty in flow estimates for this location. WSE added a 2D area representing the lower Miller River to an existing HEC-RAS model of the South Fork Skykomish River, and used this model to simulate existing hydraulic conditions and three potential design scenarios. Figures of the model results for the 2- and 100-year events are included in this report and results for all modeled flows and design scenarios have been provided to the County separately. Moving forward with conceptual designs for this project, WSE recommends: 1) Determining if/how King County permitting variances are granted for floodplain development projects with effects fully within public property; 2) Installing gaging on the Miller River and/or collecting high water marks for any high flow events; and 3) Collecting updated topographic and bathymetric data as necessary.

REFERENCES

Comanor , K., 2017. *Memo: Review of Miller River Hydrology*. From Kyle Comanor. To Dan Heckendorf. May 10, 2017.

Herrera, 2013. *Restoration Feasibility Report: Lower Miller River*. Prepared by Herrera Environmental Consultants, Inc. Prepared for King County Department of Natural Resources and Parks. April 17, 2013.

King County, 2020. *Floodplain Development Permit Information.* Prepared by King County Department of Local Service, Permitting Division. October 2020.

King County, 2023. *Flood Hazard Certification.* Prepared by King County Department of Local Service, Permitting Division. January 30, 2023.

WSE, 2023. *South Fork Skykomish River Flood Study: South Fork Skykomish River and Maloney Creek*. Prepared by Watershed Science and Engineering. Prepared for King County Department of Natural Resources and Parks. February 2023.

7 APPENDIX: FLOW FLUX LINES

Flow flux lines were used to evaluate the changes in flow in the main channel and both overbanks for the potential project scenarios. Flow flux lines were drawn along the railroad alignment, the Old Cascade Highway alignment, and through the middle of the project site as shown in Figure 6 below. Modeled flows across each line were computed for the 2-year event for the existing condition and the three restoration scenarios and are summarized in the tables below.

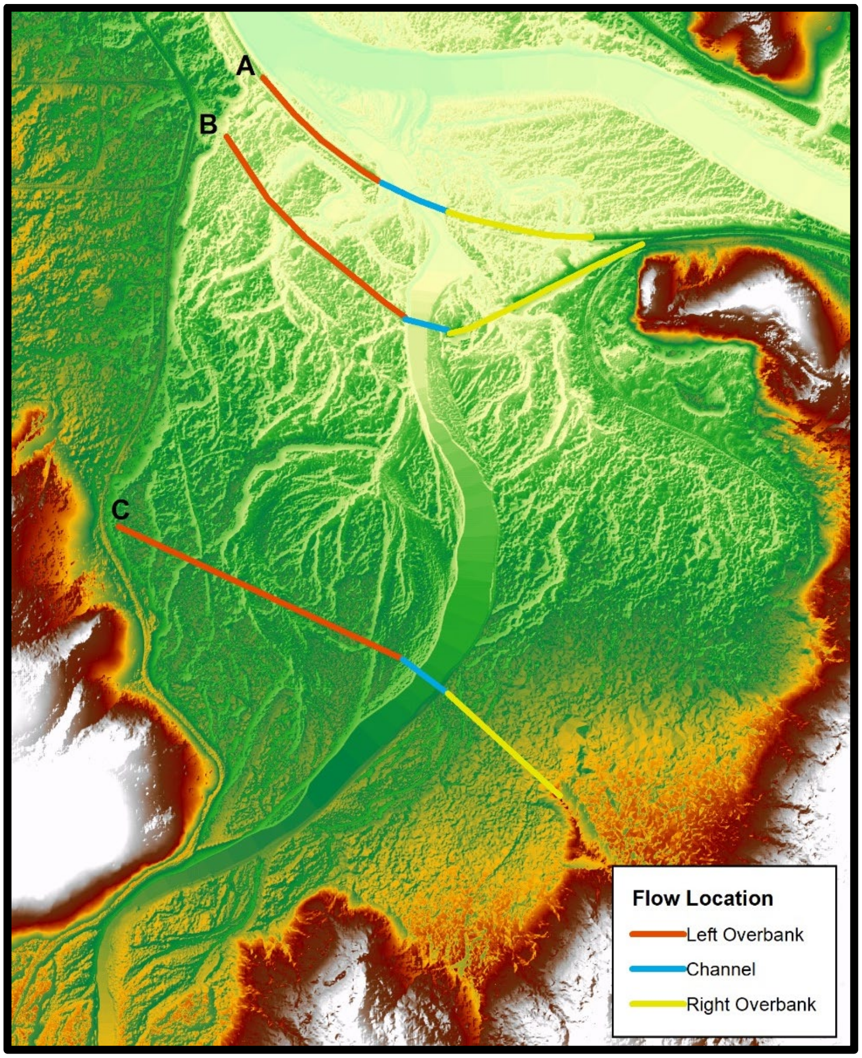

Figure 6. Flux line locations for flow computation.

Table 4. Flows across flux line A in the 2-year event.

	Flow, cfs		
	Left Overbank	Main Channel	Right Overbank
Existing Conditions	0	4,153	7
Scenario 1	0	3,488	673
Scenario 2	0	3,892	268
Scenario 3	0	3,596	564

Table 5. Flows across flux line B in the 2-year event.

	Flow, cfs		
	Left Overbank	Main Channel	Right Overbank
Existing Conditions	13	3,766	382
Scenario 1	473	3,393	298
Scenario 2	924	3,030	207
Scenario 3	1,998	1,677	553

Table 6. Flows across flux line C in the 2-year event.

	Flow, cfs		
	Left Overbank	Main Channel	Right Overbank
Existing Conditions	7	4,153	0
Scenario 1	500	3,661	0
Scenario 2	1,203	2,957	0
Scenario 3	3,654	507	0