Lower Naches River Geomorphic Atlas

Prepared for

Yakima County Water Resources Management Division

Prepared by

Northwest Hydraulic Consultants

Seattle, WA

September, 2015

NHC Ref No. 21792.1-19

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Introduction

As a part of our work to assist the County with their contribution to the Naches River PAS study, two NHC staff spent two days investigating conditions along the Naches River. We floated the entire river from the Wonderland Bridge upstream of the town of Naches to its confluence with the Yakima River, and collected photographs, field notes, and sediment samples along the river. In addition, we visited local sites along both the Tieton and Naches Rivers upstream of their confluence to better understand sediment inputs to the reach of interest. The following atlas combines these field observations and geospatial data to present an overview of key geomorphic features and processes operating along the Lower Naches River up to the present time. Ongoing river management activies are expected to locally change these processes in the coming years.

The atlas starts with a brief summary of basin characteristics, focuses on descriptions of individual, approximately 1-mile long, river segments shown on the map below, and concludes with summary data describing patterns along the river.

Data Sources

This atlas combines field observations and geographic data from a variety of sources:

Geospatial Data

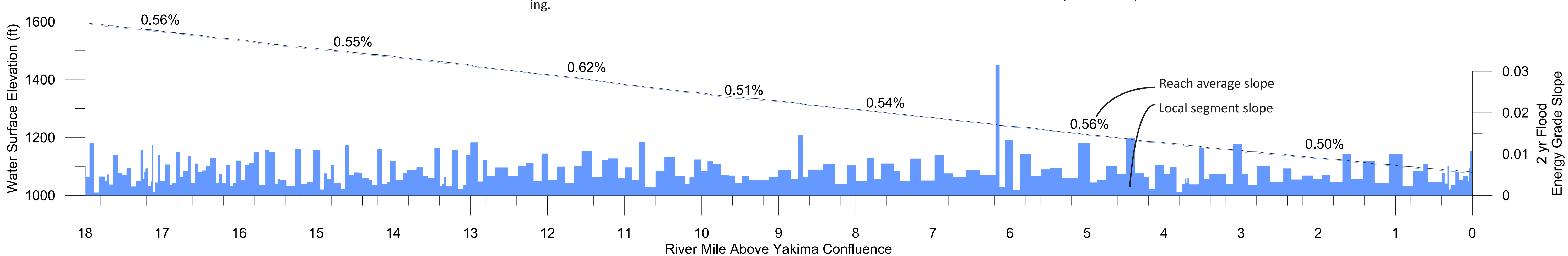
- Historical Aerial photos prior to 2006 were provided by Yakima County.
- 2006-2013 Aerial Photos Courtesy of USDA NAIP.
- 2013 LiDAR topography used to create the floodplain elevation map and for comparison with 2001 LiDAR created was created by Quantum Spatial (2014) for Rogers Surveying.
- 2001 LiDAR topography gridded by USACE (2015) from dataset created by Horizon (2001) for USBR. This dataset has low point density and high uncertainty. The channel water surface and areas under dense floodplain vegetation are particularly uncertain.

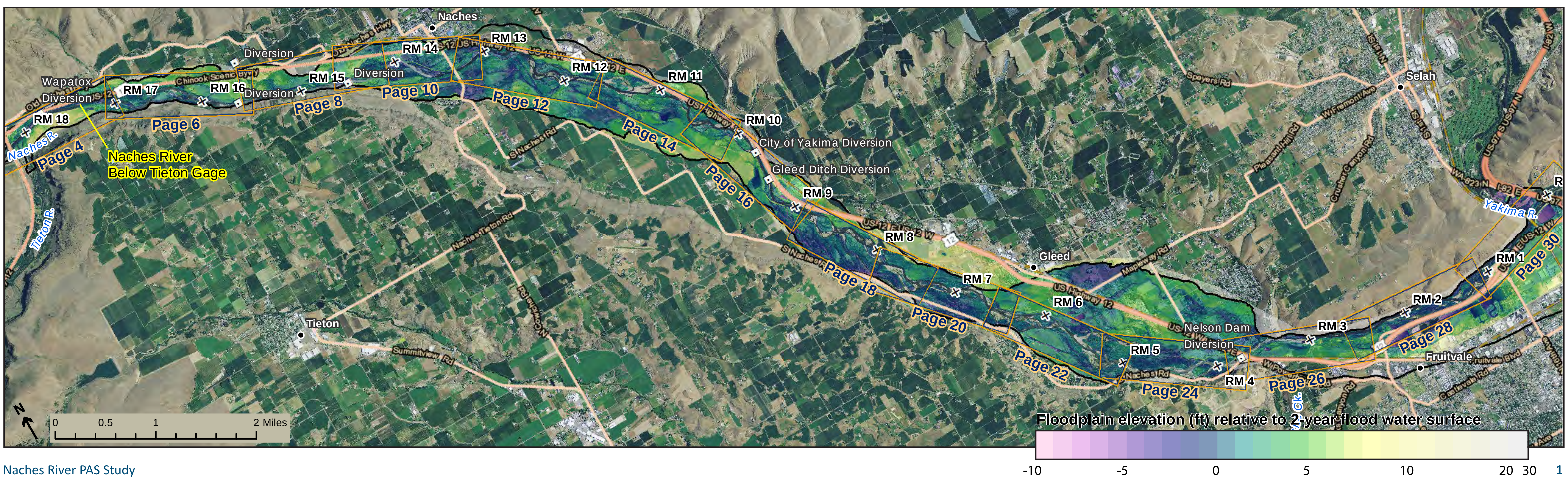
Field Data

Field observations were collected by NHC staff during a continuous raft transect along the river. Sediment samples were collected from bar-head locations believed to be representative of actively transported sediment using either 100-stone pebble counts or scaled bed images.

Hydraulic Data

Hydraulic Data included here are based on USACE's (2015) HEC-RAS model as preliminarily modified by NHC.





Physiography

The Naches River Basin is located on the East Slope of the Cascade Mountains, between the City of Yakima and Mount Rainier. It has high relief, with an elevation ranging from just over 1000 ft to 8100 ft and a mean slope of approximately 30%. It is largely underlain by a combination of volcanic rocks and moderately consolidated conglomerates including the Ellensburg formation and Thorp Gravel. Annual average precipitation generally increases from less than 15" in the eastern part of the basin to over 60" toward the crest of the Cascade Mountains.

Valley bottoms are irrigated and intensively used for fruit production agriculture, lower hills are covered in shrub-steppe vegetation and the slopes of the cascades are dominated by coniferous trees.

The combination of geologic, climate, and biological conditions in the upstream basin area supports relatively high clastic sediment supply to the Naches River. Further, because of the dominance of both alpine and arid conditions in the basin area, sediment supply to the Naches River and its tributaries likely occurs through high-magnitude low-frequency events such as debris flows and landslides.

Hydrology

Hydrologic data for this study originates from a stream gage located on the Naches River just downstream of the confluence with the Tieton River. From 1909 to 1979, the gage was operated by the USGS (Gage No: 12494000), but subsequent operation was transferred to the USBR (Gage ID: NACW).

Historic changes and decadal patterns in flood activity have implications with respect to the morphology of the reach as well as river training activities over the years. The magnitude of channel-forming flood flow peaks decreased substantially after the 1925 closure of Tieton Dam which created Rimrock Lake. Although the peaks decreased, the duration of flow above the threshold for sediment transport increased (Yakima County, pers. comm. 2015). Alternating decadal periods of relative hydrologic activity are also apparent in the flow history with numerous moderate to high flow events occurring during the 1950s, 70s, and to some extent since the 1996 flood event, the second largest flood of record since regulation.

Tieton Dam and Rimrock Lake.

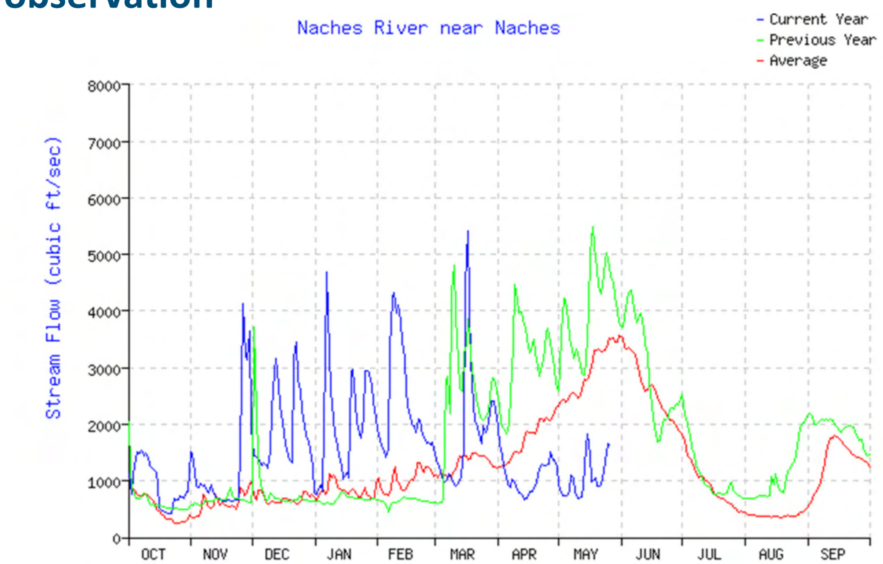
Photo courtesy of wikipedea user Pianoplayerontheroof, shared under a Creative Commons BY-SA 3.0 licencse.

Naches River Flood Frequency Discharges

Return Period	Annual Exceedance Probability	FEMA (2010) (cfs)	GeoEngineers (2003) (cfs)
1.01-year	99.99%	-	1,109
2-year	50%	-	6,696
5-year	20%	-	10,771
10-year	10%	12,500	13,955
20-year	5%	-	18,543
50-year	2%	20,000	22,380
100-year	1%	27,000	26,586
500-year	0.2%	47,500	-

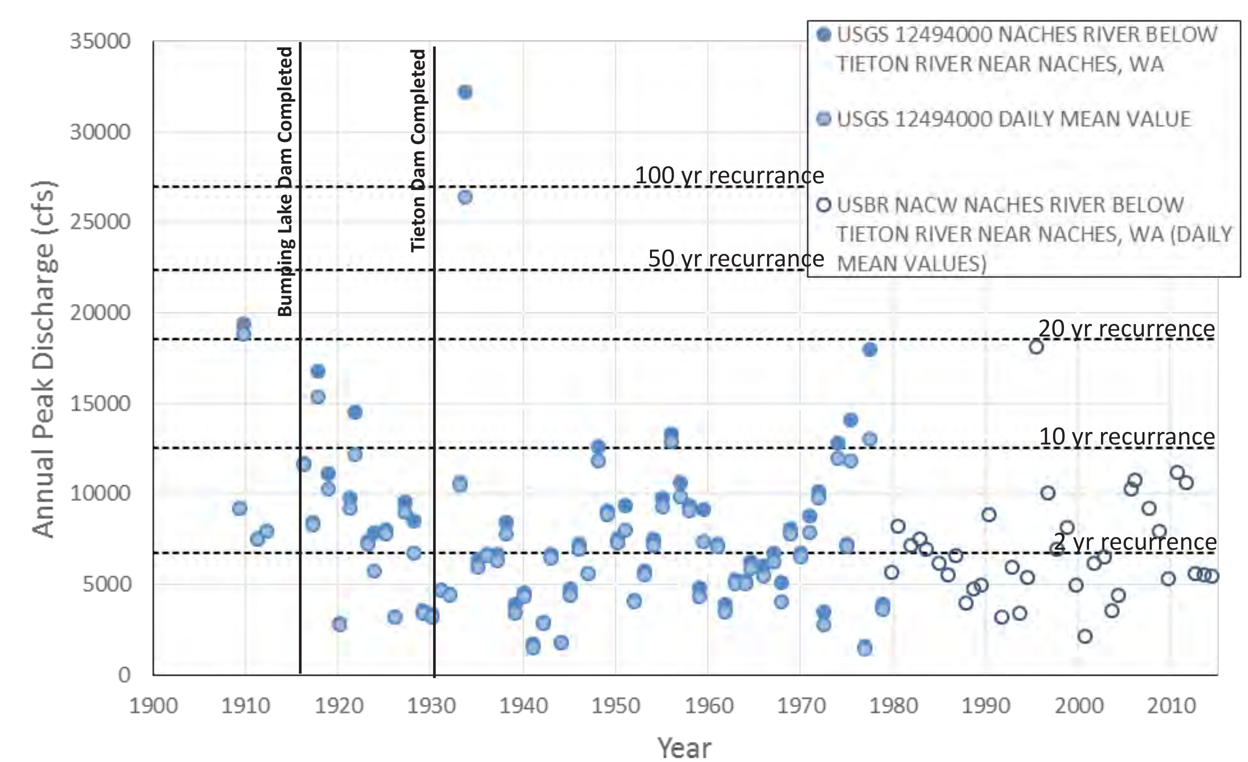
From USACE (2015)

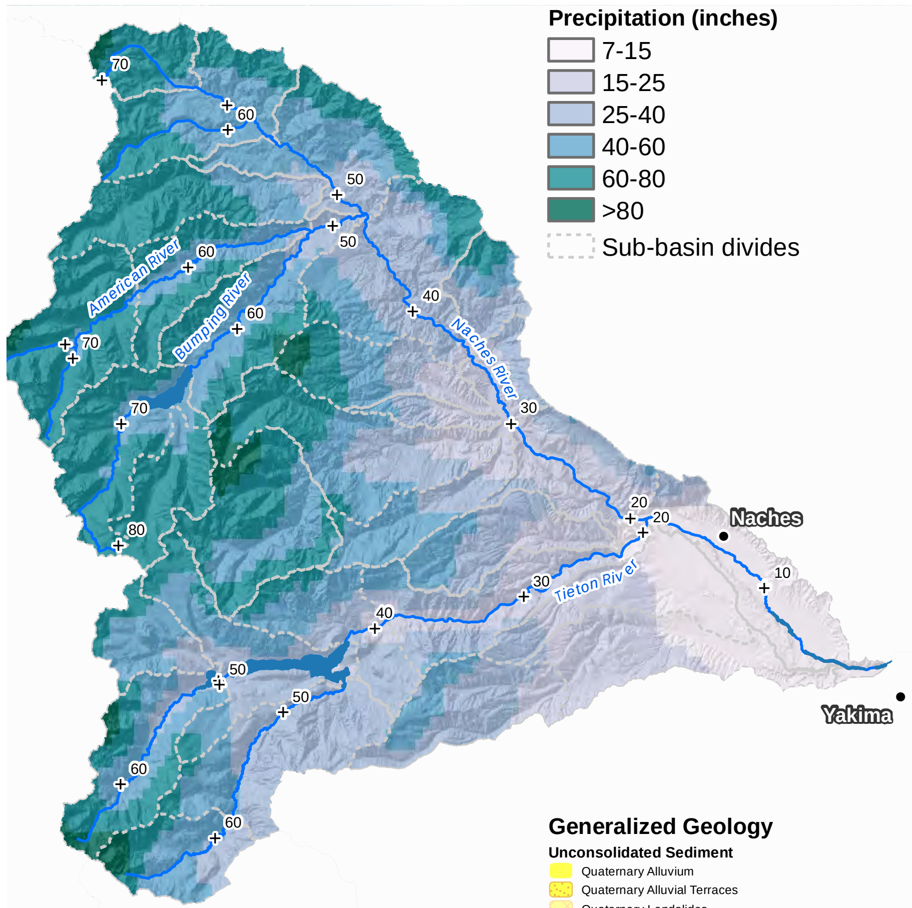
Typical hydrograph and recent flows at the time of observation

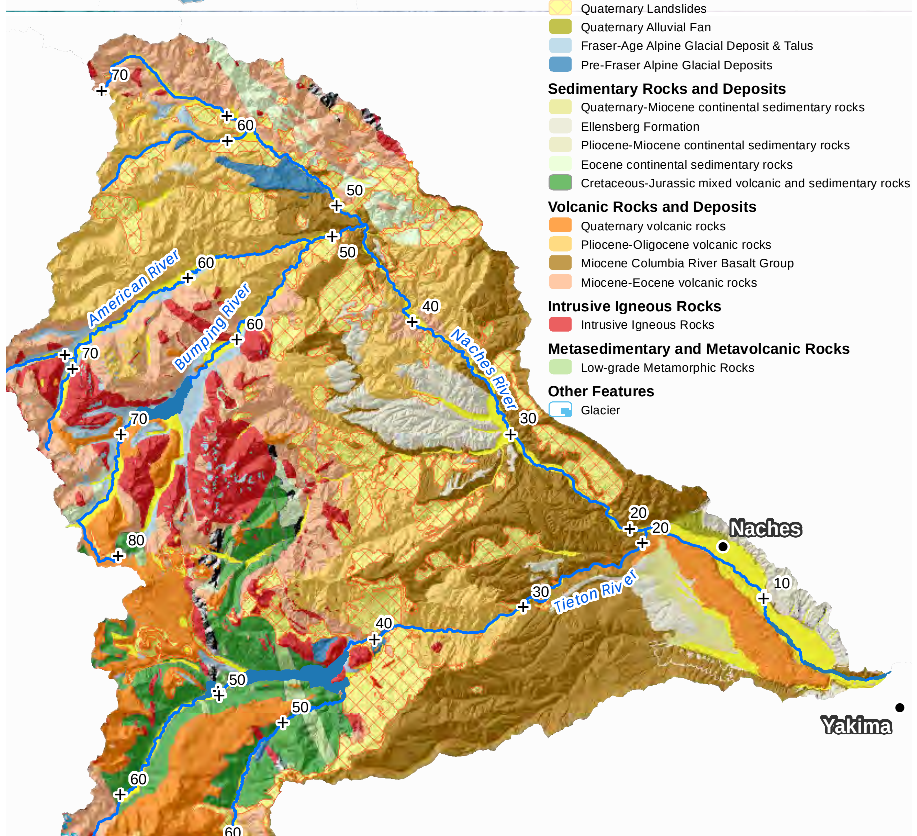


WY 2015 hydrograph at NACW gage compared to previous water year and average hydrographs (http://www.usbr.gov/pn-bin/graphwy.pl?nacw_q)

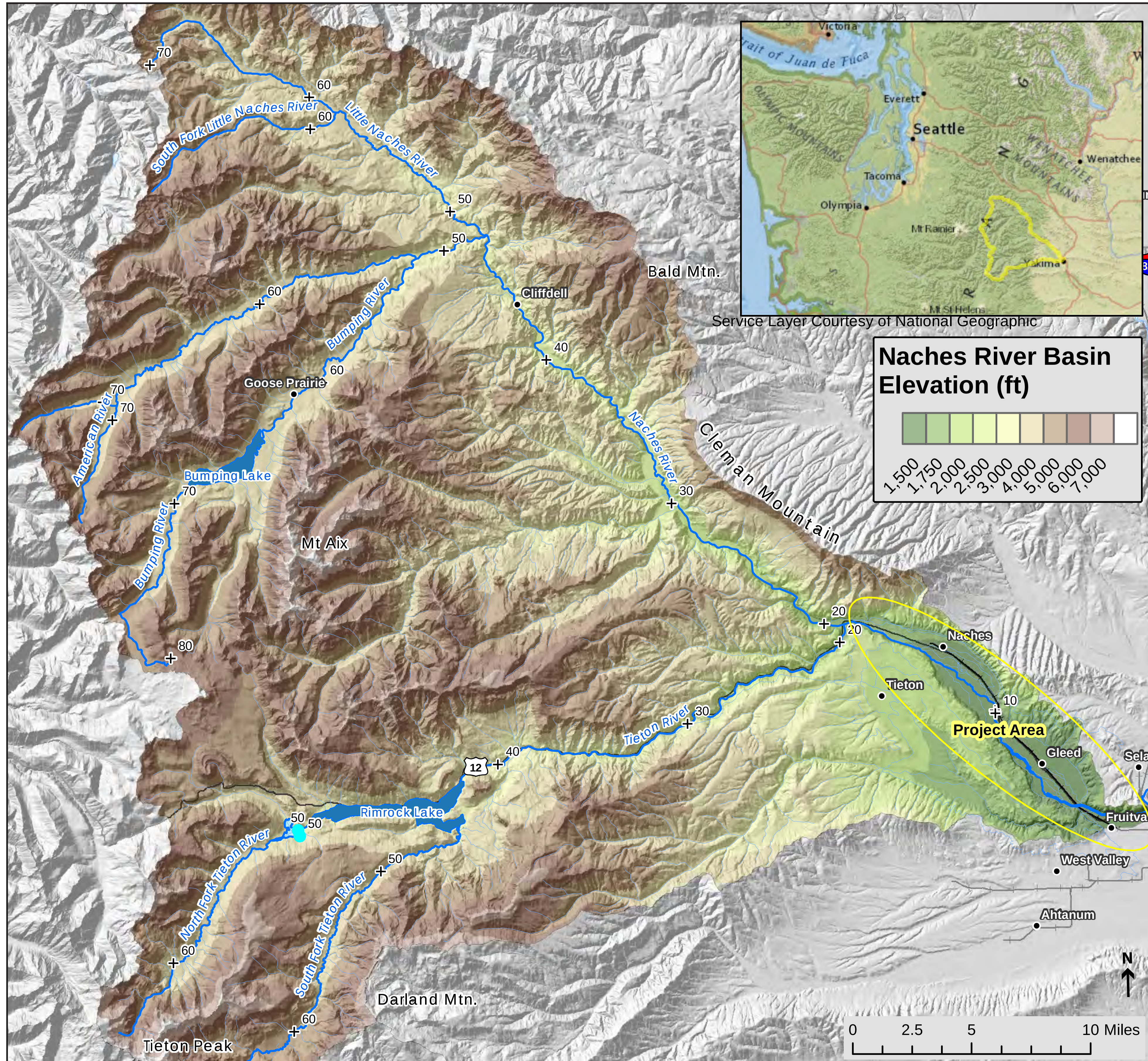
Flow History







Precipitation from PRISM (2015). Geology generalized from DNR (2010) 1:100,000 scale geologic mapping.



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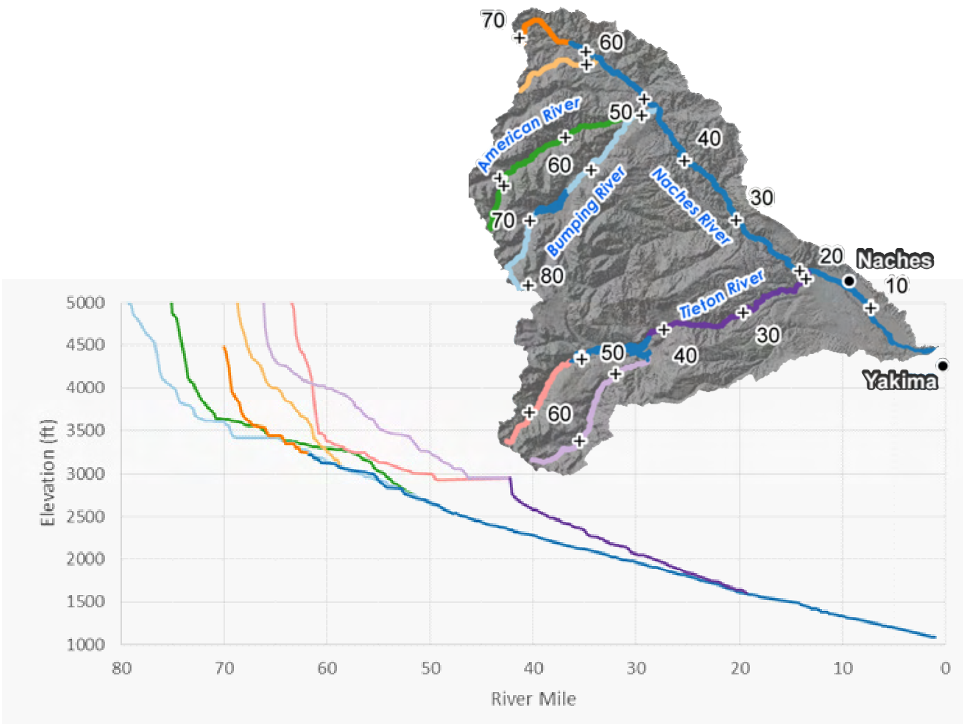
Naches and Tieton River Confluence: Inputs from Upstream

Upstream of their confluence, the Tieton's River has a steeper slope than the Naches. It increases from ~0.01 upstream of confluence to approximately 0.02 25 miles upstream of the confluence. In contrast, the slope of Naches River has a fairly consistent grade of approximately 0.005 along it's whole length downstream of the confluence with the Bumping River.



The Tieton River

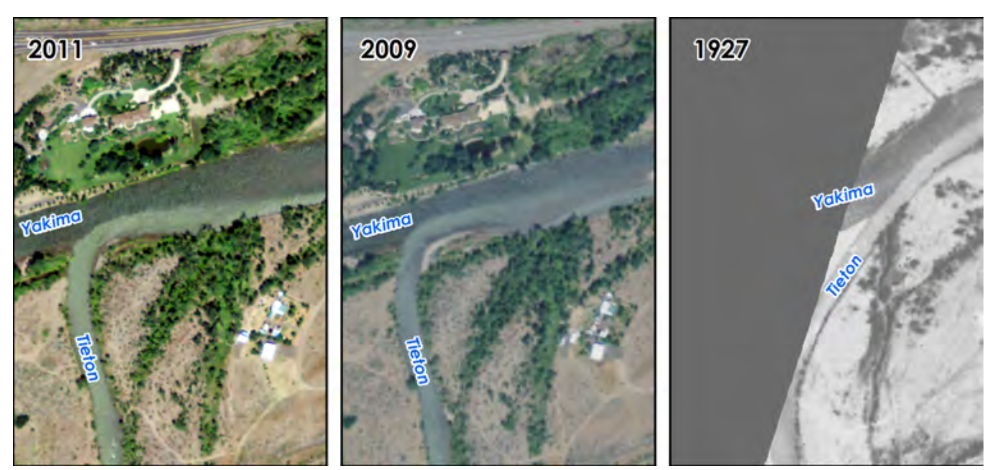
- Has a small fraction (13%) of the connected alluvial basin drainage area. It is steep, however, and contributes relatively coarse bed material
- Bed is mixed bedrock and boulder-cobble alluvium dominated, with local cobble-gravel bars. A Pebble Count was collected from mid-channel bar at RM 20.7, ~300 yards up valley from Tim Ponds — D50: 89 mm.
- At the time of observation the Tieton River was much more turbid than the Naches. Cursory review of aerial photos suggest that this is a typical, but not universal condition: 30% of photos show much more turbidity in the Tieton, 30% show slightly more turbidity in the Tieton, and 30% show approximately equal conditions in the Tieton and Naches. This suggests a major persistent fine sediment source is present somewhere along the course of the Tieton. This may include bank erosion in the Reservoir (J. Freudenthal pers... comm. 2015), and sediment sources below the dam. In particular, aerial photos show badlands topography and debris-torrented channels draining the E. aspect of Bethel Ridge, indicating high rates of erosion in this area.

The Naches River

- Has a larger proportion of the basin area, but substantially lower slope than the Tieton.
- Has a mixed bedrock and bedrock and cobble-gravel alluvium dominated bed. A pebble count was collected from head of mid-channel bar 280 m upstream of Highway 12 Bridge crossing at Naches-Tieton confluence — D50: 51 mm. The sampled material had clearly been moved during recent floods, and is substantially finer than the dominant bed material cobble pavement.

Characteristic reach of the Tieton River approximately 9 miles upstream its confluence with the Naches.

Overview of Tieton River pebble count location and detail of sampled deposit.

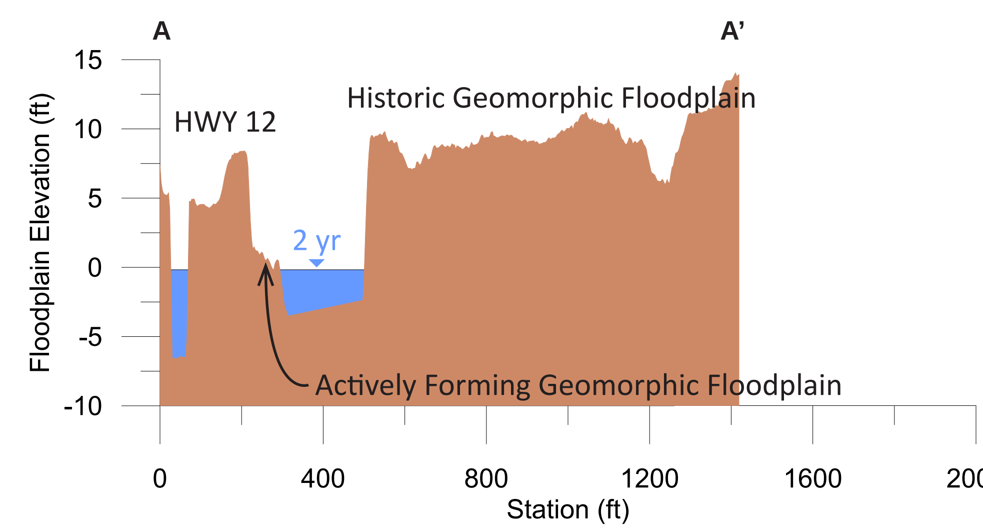


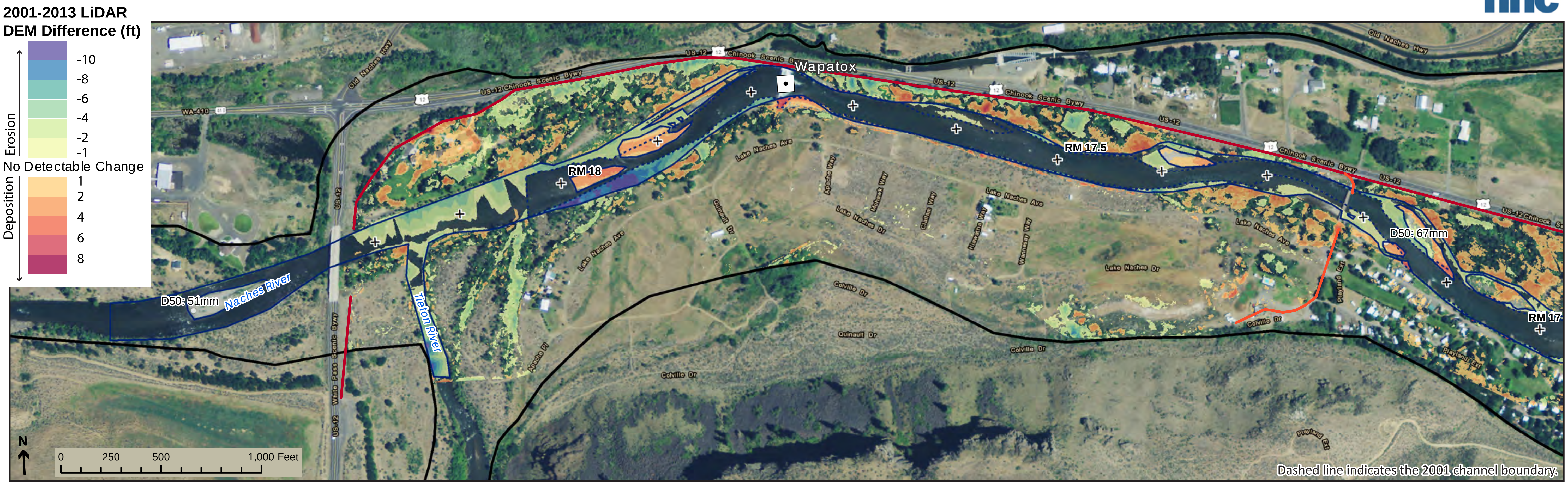
Aerial photos showing characteristic Tieton River turbidity

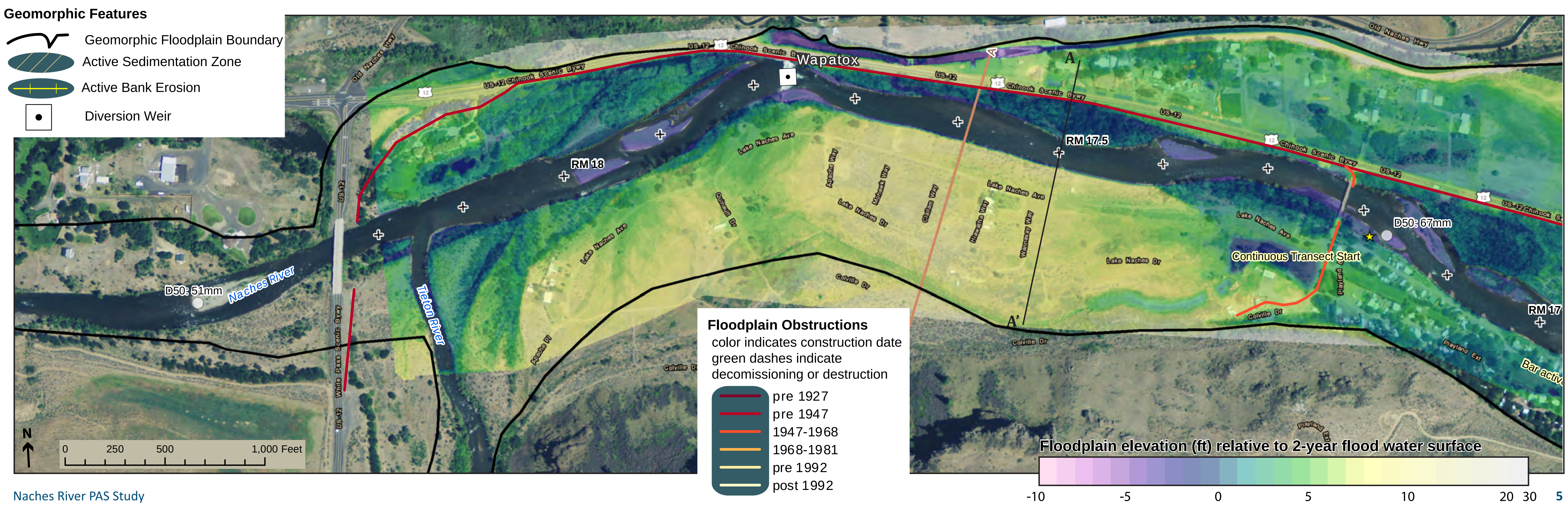
Overview of pebble count location on Wonderland Bar.

Geomorphic Conditions: Confluence to RM 17

- There is a sedimentation zone upstream of Wapatox Dam, but this was not visited on the ground
- Continuous observation started at RM 17.2, just downstream of Wonderland Bridge
- Rock barbs protect right bank along Wonderland RV Park
- Height of Geomorphic floodplain upstream of Wonderland bridge potentially indicates historic channel incision (see XS A-A').

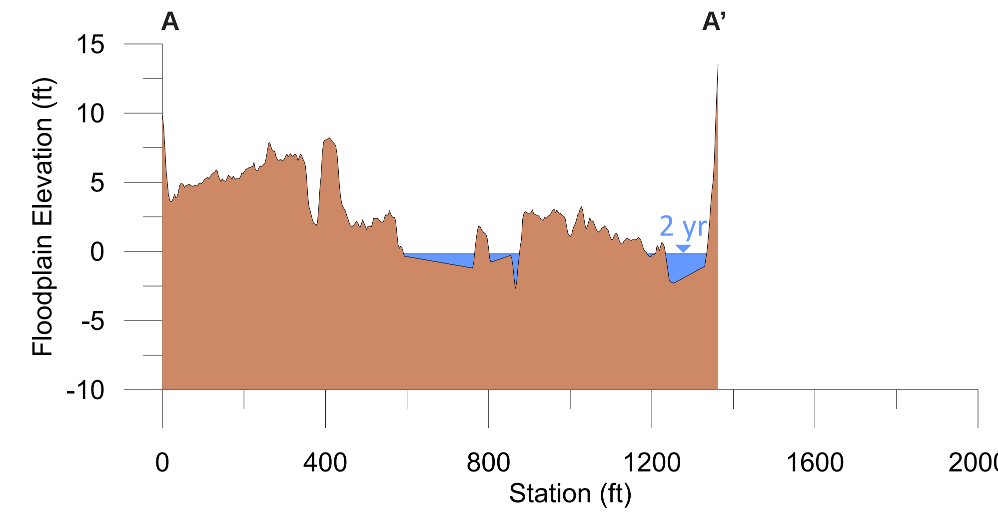



2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Wapatox
RM 18
RM 17.5
RM 17
D50: 51mm
D50: 67mm
Naches River
Tieton River
US-12 Chinook Scenic Byway
WA-410
Old Naches Hwy
Lake Naches Ave
Lake Naches Dr
Colville Dr
Quinault Dr
Playland Ext
N
0 250 500 1,000 Feet
Dashed line indicates the 2001 channel boundary.


Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Wapatox
RM 18
RM 17.5
RM 17
D50: 51mm
D50: 67mm
Naches River
Tieton River
A
A'
Continuous Transect Start
Bar activ
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30
N
0 250 500 1,000 Feet

Geomorphic Conditions: RM 17 to RM 16

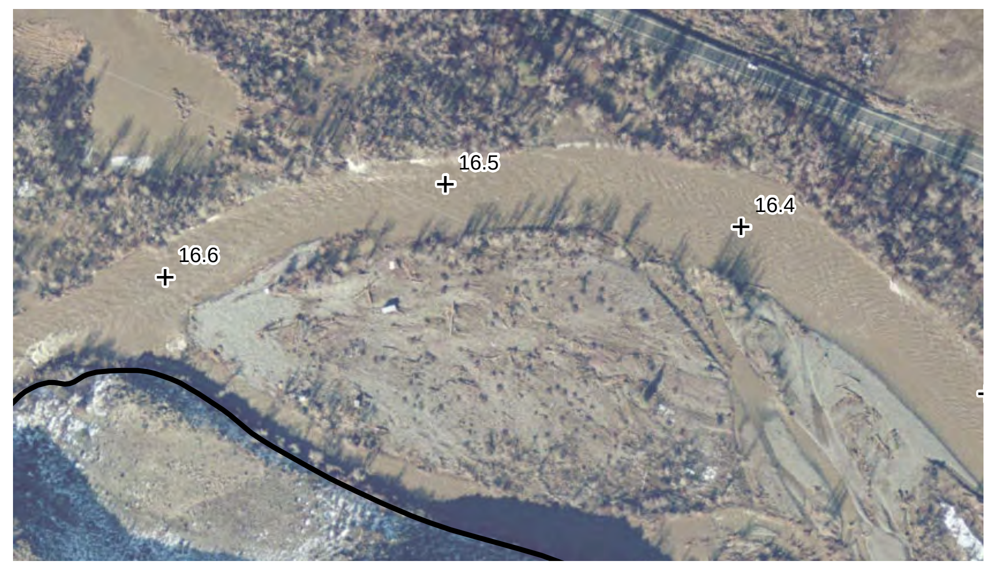
- Local floodplain widening followed by a constriction at RM 16 has created a moderately active sedimentation zone.
- The large bar in the vicinity of RM 16.5 has been very stable and not recently active, even though unvegetated . The last clear evidence of major sediment transport was during the 1996 flood, when a 3 ft high large cobble berm appears to have been emplaced at the head of the bar., and LWD accumulated on the bar surface.



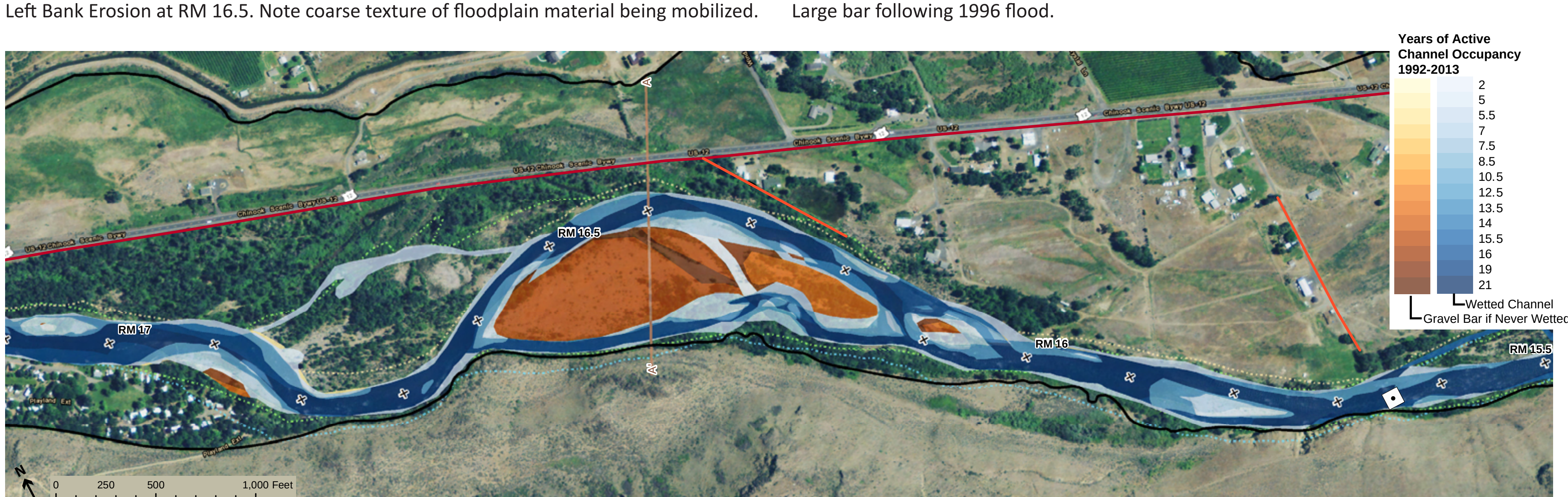
Slump in right valley wall near RM 16.

Gravel splay deposit in cross-bar channel at RM 16.3.

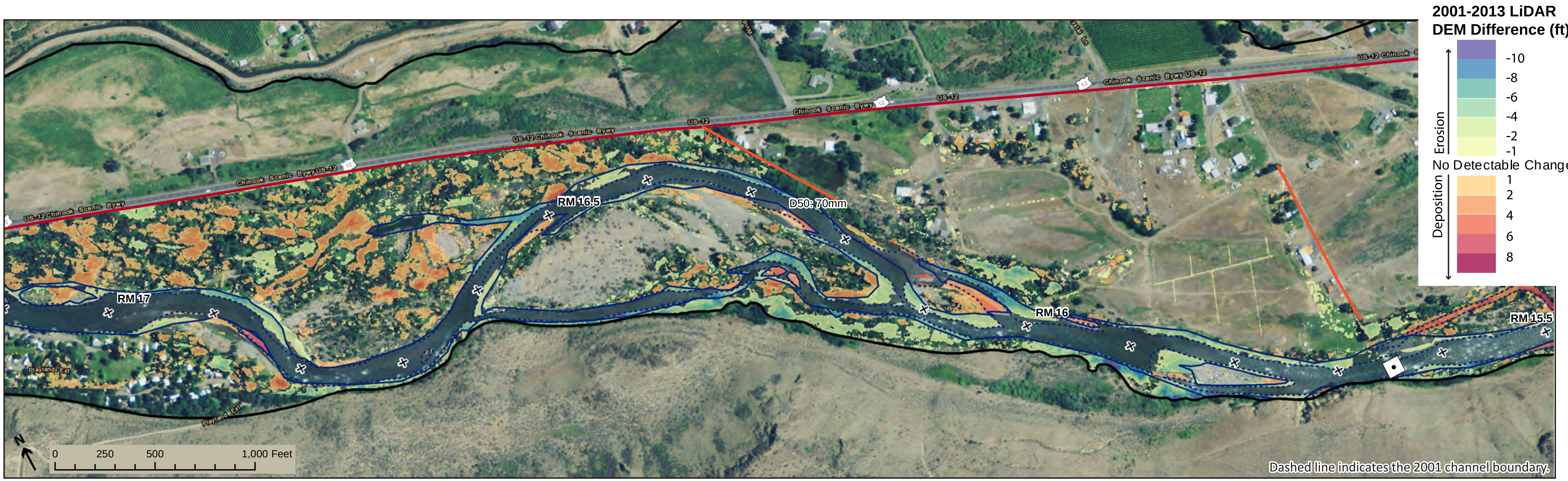
Left Bank Erosion at RM 16.5. Note coarse texture of floodplain material being mobilized.



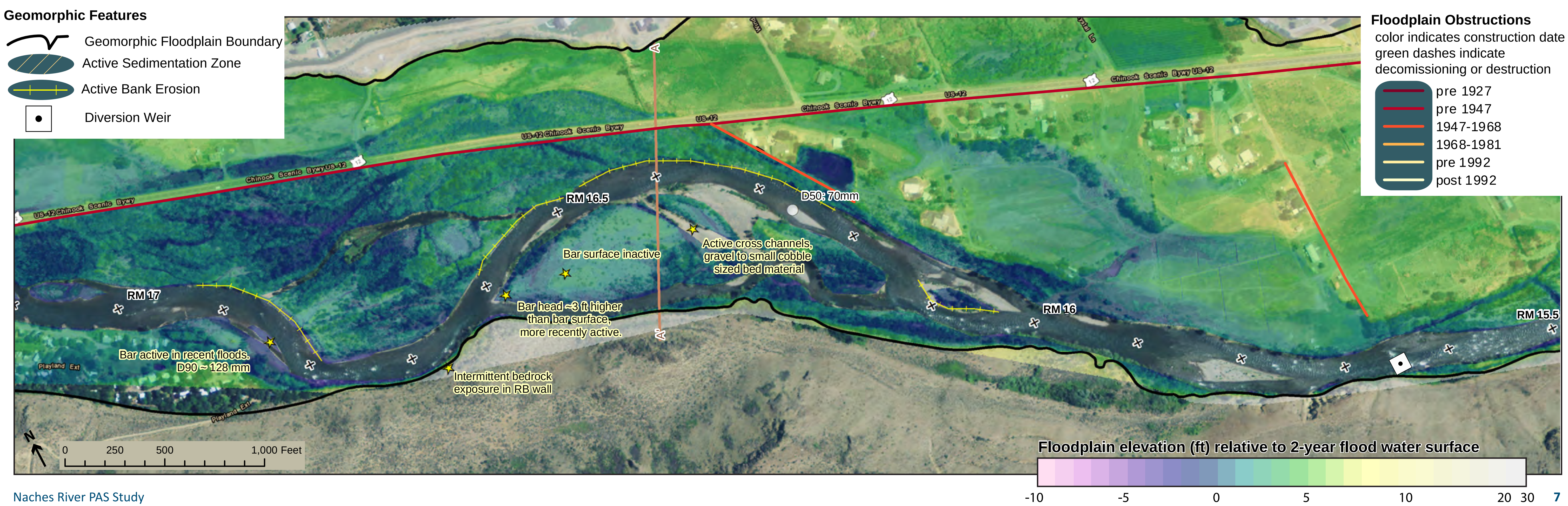
Large bar following 1996 flood.



Overview of pebble count location and detail of sampled deposit.



2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
RM 17
RM 16.5
RM 16
RM 15.5
D50: 70mm
0 250 500 1,000 Feet
N
Dashed line indicates the 2001 channel boundary.



Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
RM 17
RM 16.5
RM 16
RM 15.5
D50: 70mm
Bar surface inactive
Active cross channels, gravel to small cobble sized bed material
Bar head ~3 ft higher than bar surface, more recently active.
Bar active in recent floods. D90 ~ 128 mm
Intermittent bedrock exposure in RB wall
0 250 500 1,000 Feet
N
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

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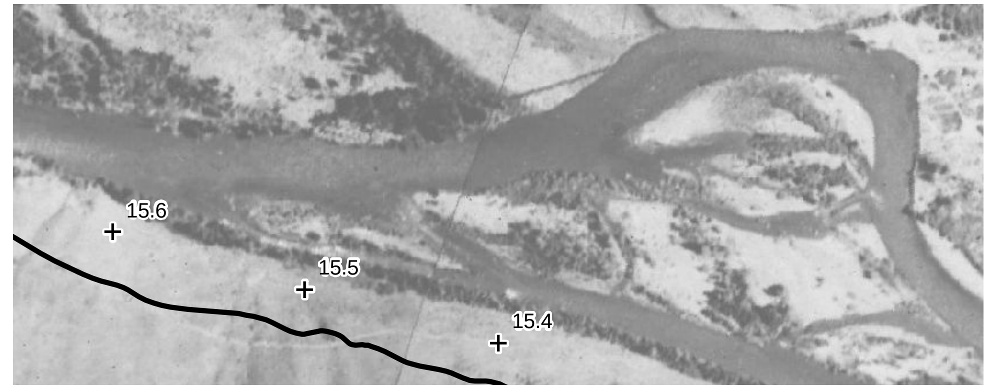
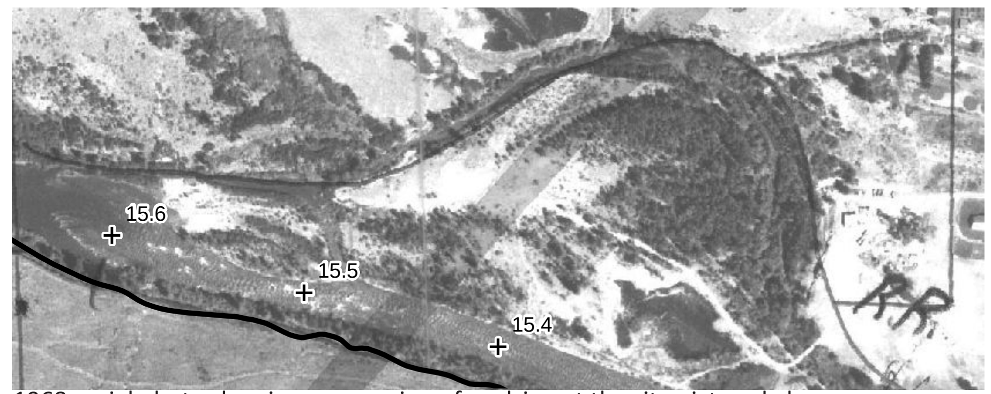
Geomorphic Conditions: RM 16 to RM 14.5

- This reach has been channelized by construction of revetments and, likely, dredging to straighten the channel, and possibly natural meander-cutoff avulsions.
- Left bank revetments and levees in the vicinity of RM 15 force the active channel against the valley wall. Hydraulic interaction with bedrock and colluvium in the valley wall may maintain persistent scour and hold the channel in place.
- Downcutting and supply of colluvium result in very coarse bed material through much of this reach.
- The N9 and N10 levees pinch the floodplain to a local width of only 300 ft.
- The effect of this constriction is amplified by the irrigation diversion at RM 14.5, which acts as a grade-control feature, encouraging localized sedimentation upstream, which has progressively blocked the left bank channel branch.

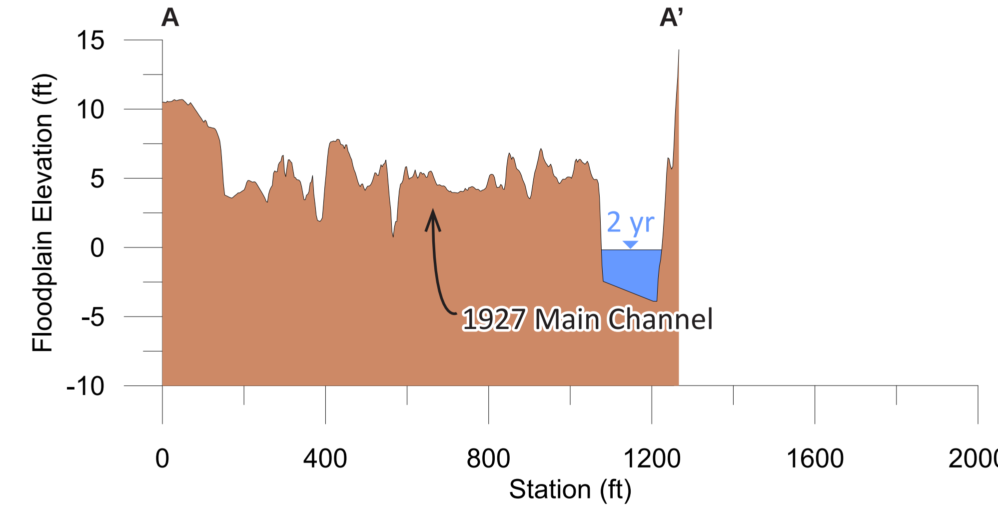
Water diversion at RM 14.5.

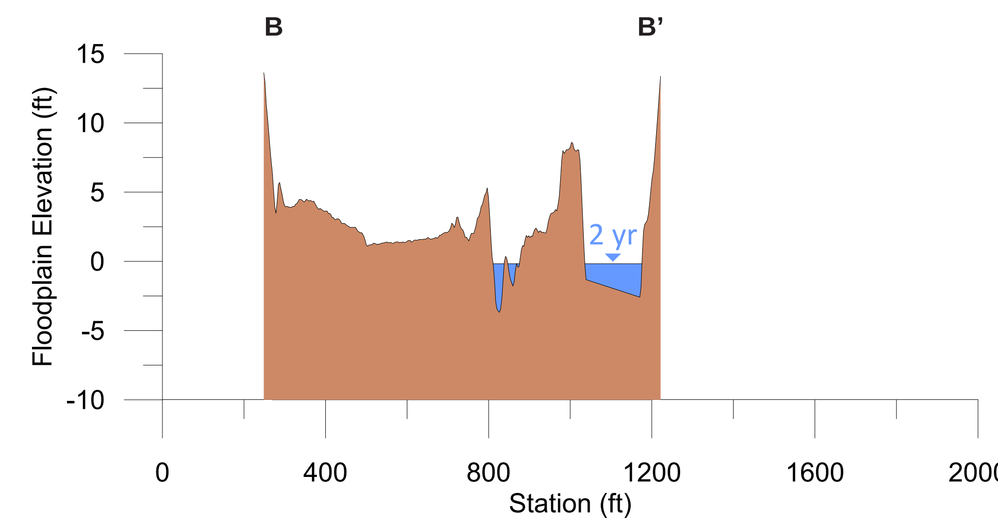


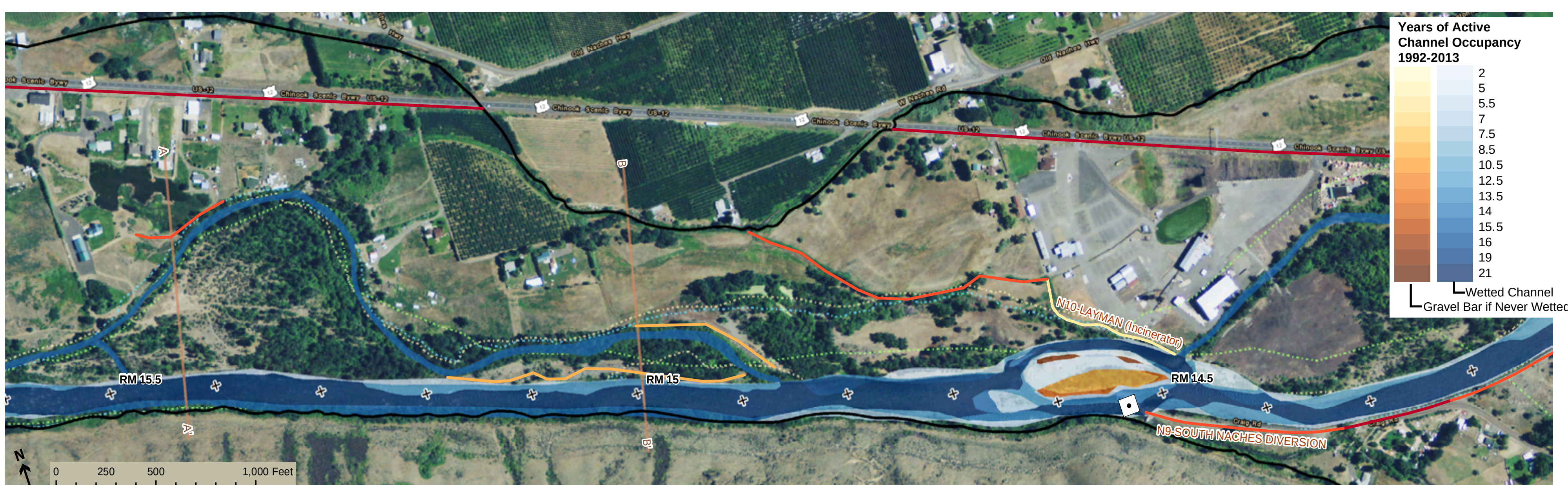
1927 aerial photo showing main channel in left bank floodplain area. Note that the main channel bifurcation near RM 15.4 is presently approximately 4 feet above the present-day 2-year flood water surface elevation.



1968 aerial photo showing progression of avulsion at the site pictured above.







Overview of pebble count location and detail of sampled deposit.


2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Old Naches Hwy
Chinook Scenic Bywy US-12
W Naches Rd
N10-LAYMAN (Incinerator)
RM 15.5
RM 15
RM 14.5
D50: 57mm
N9-SOUTH NACHES DIVERSION
Craig Rd
0 250 500 1,000 Feet
N
Dashed line indicates the 2001 channel boundary.

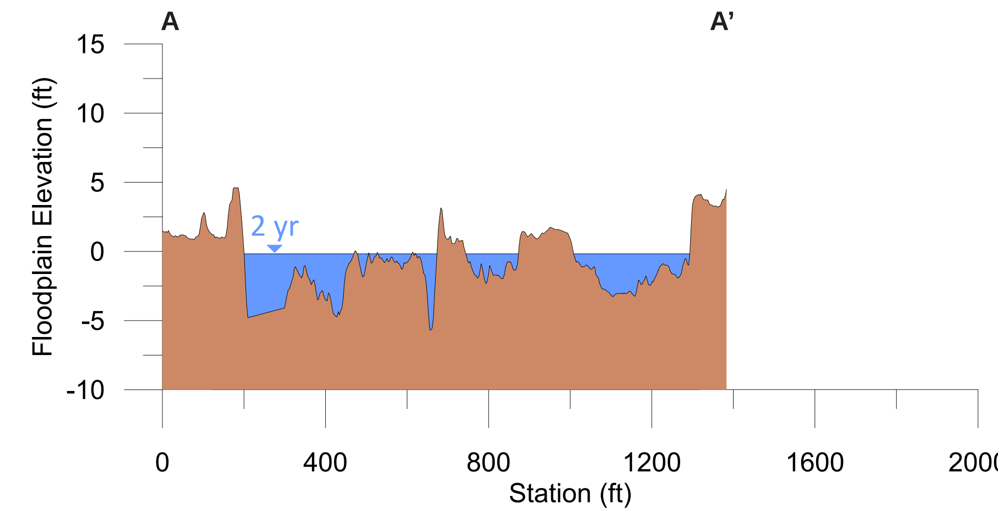

Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
A
A'
B
B'
N10-LAYMAN (Incinerator)
RM 15.5
RM 15
RM 14.5
D50: 57mm
N9-SOUTH NACHES DIVERSION
0 250 500 1,000 Feet
N
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

nhc

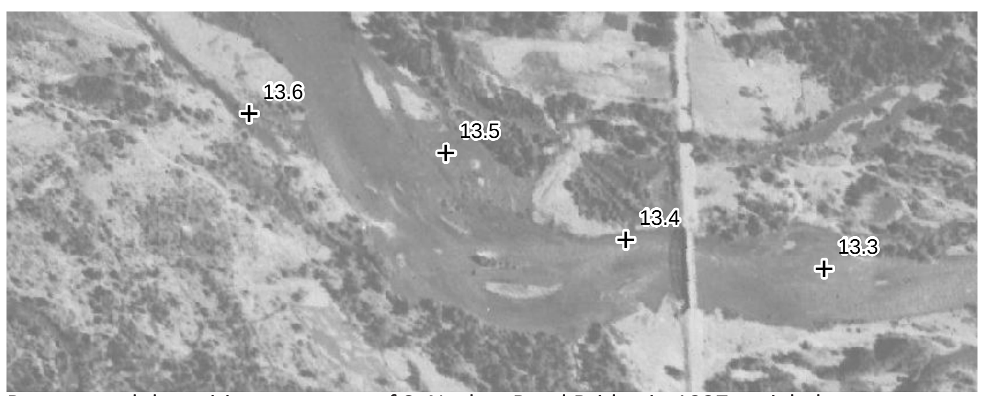
Geomorphic Conditions: RM 14.5 to RM 13.3

- The dominant feature in this reach is a major sedimentation zone formed by the back-water of the S. Naches Road Bridge. The focus of deposition is presently the bar complex located 500-1000 ft above the bridge, which is growing and forcing the channel to rapidly erode the right bank. The gradual flow constriction provided by N7 and N8 levees up-stream of the bridge helps funnel flow under the bridge and increase the efficiency of the narrow opening.
- The lower portion of the N9 levee and upper portion of the N7 levee locally constrict the floodplain to ~500 ft width. The impact of this constriction, however, is overshadowed by the S. Naches Road Bridge constriction just downstream and N9/N10 constriction just upstream.

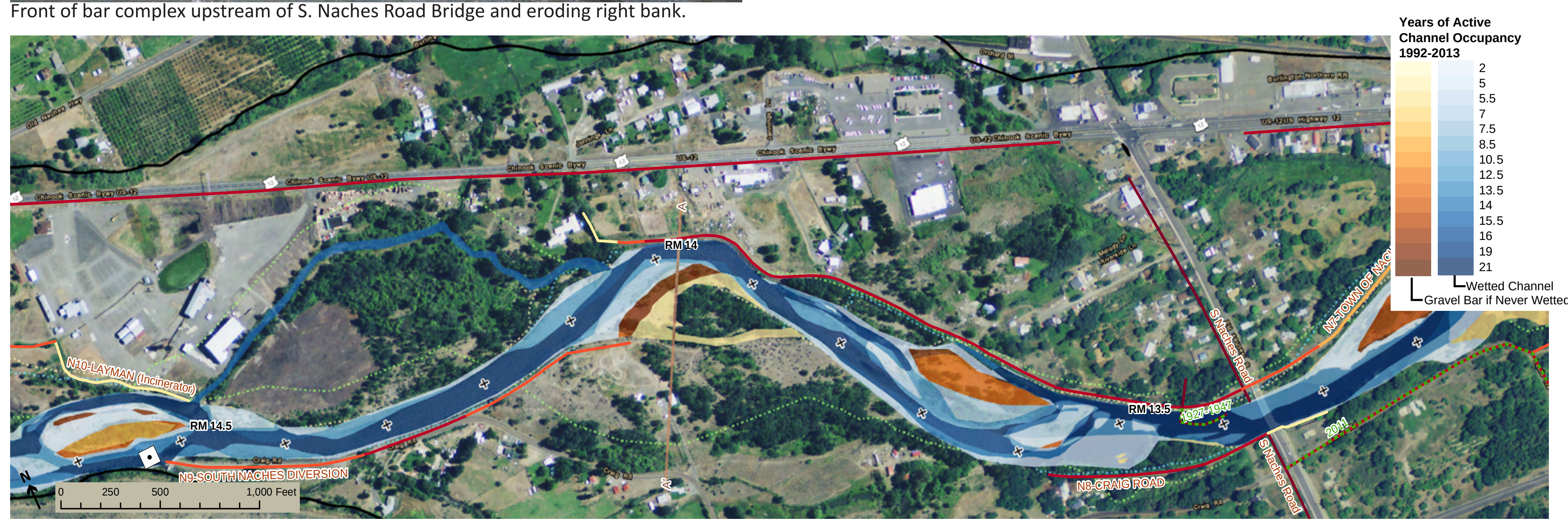
Front of bar complex upstream of S. Naches Road Bridge and eroding right bank.



Thalweg held against upstream portion of N7 levee near RM 14.0.

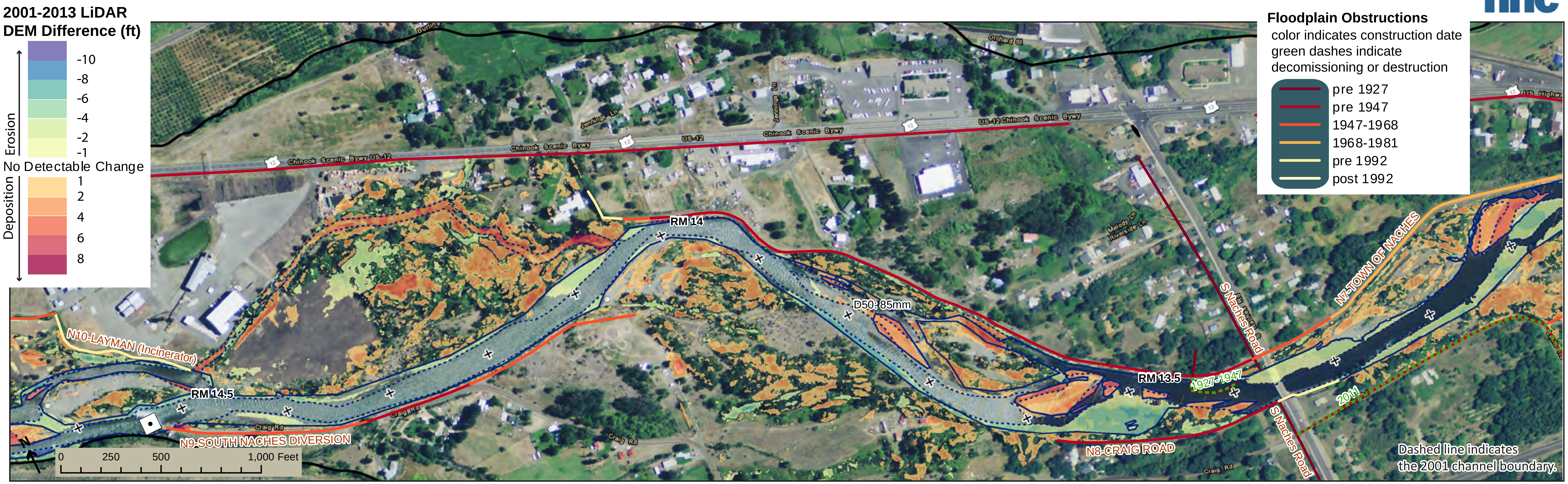


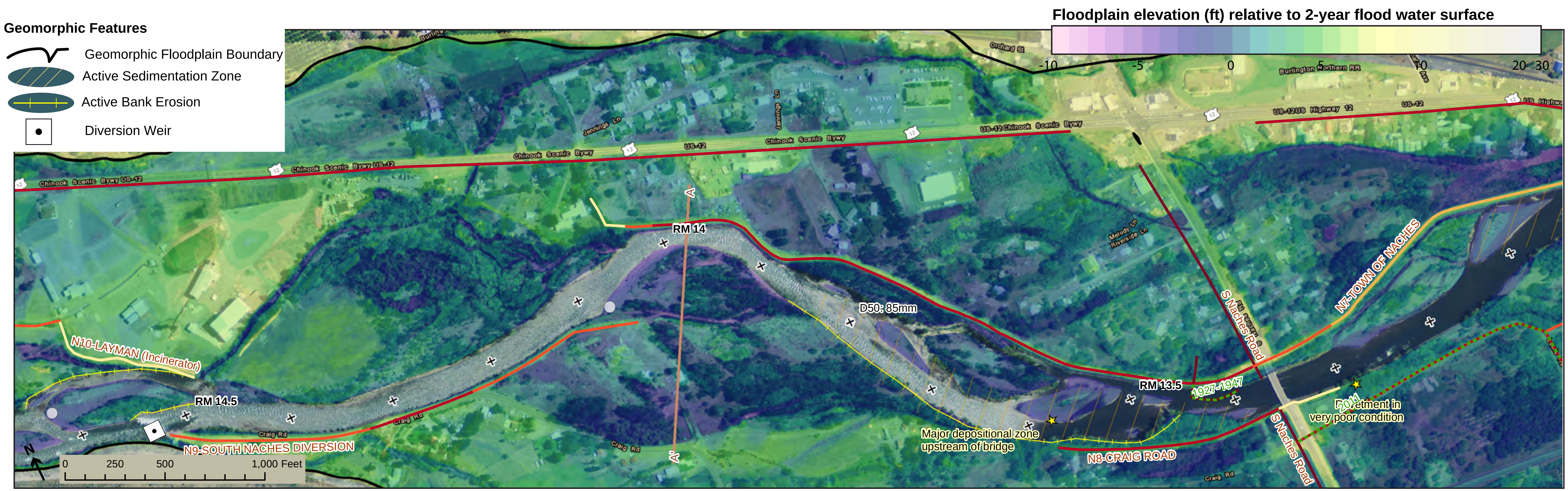
Pronounced deposition upstream of S. Naches Road Bridge in 1927 aerial photo.



Low floodplain area blocked by downstream portion of N9 levee and private berm (left of side of photo), which are planned to be removed in 2016.

Overview of pebble count location and detail of sampled deposit.


2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Floodplain Obstructions
color indicates construction date
green dashes indicate decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
RM 14
RM 14.5
RM 13.5
D50: 85mm
N10-LAYMAN (Incinerator)
N9-SOUTH NACHES DIVERSION
N8-CRAIG ROAD
N7-TOWN OF NACHES
S Naches Road
1927-1947
2011
Chinook Scenic Byway US-12
Craig Rd
0 250 500 1,000 Feet
N
Dashed line indicates the 2001 channel boundary.

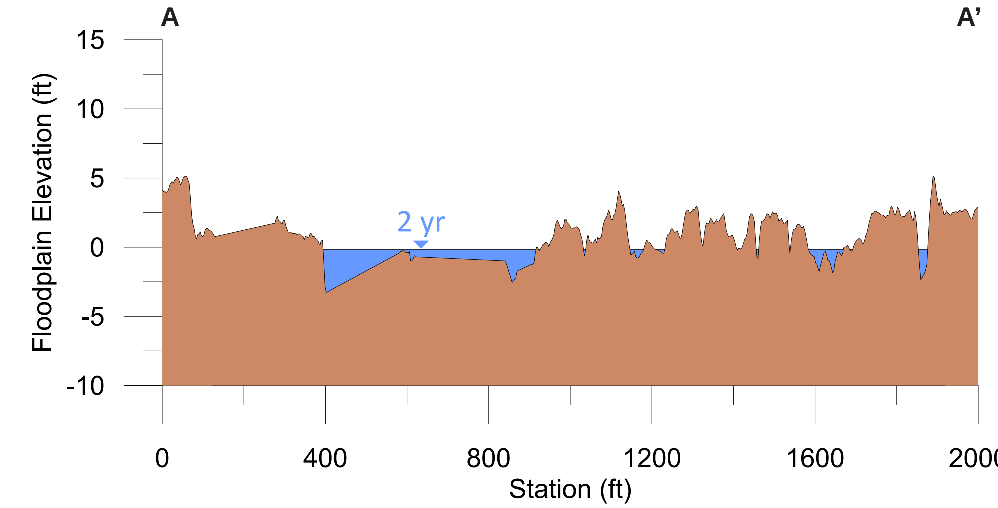

Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30
RM 14
RM 14.5
RM 13.5
D50: 85mm
N10-LAYMAN (Incinerator)
N9-SOUTH NACHES DIVERSION
N8-CRAIG ROAD
N7-TOWN OF NACHES
S Naches Road
1927-1947
2011
A
A'
Major depositional zone upstream of bridge
Revetment in very poor condition
Burlington Northern RR
US-12 US Highway 12
0 250 500 1,000 Feet
N

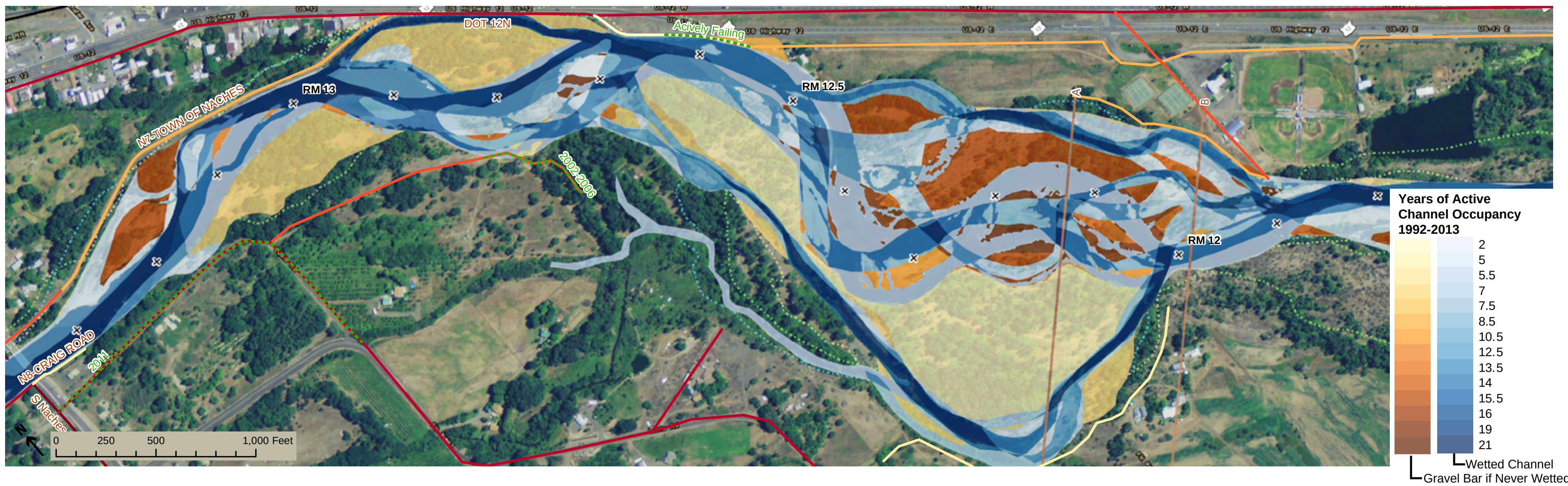
nhc

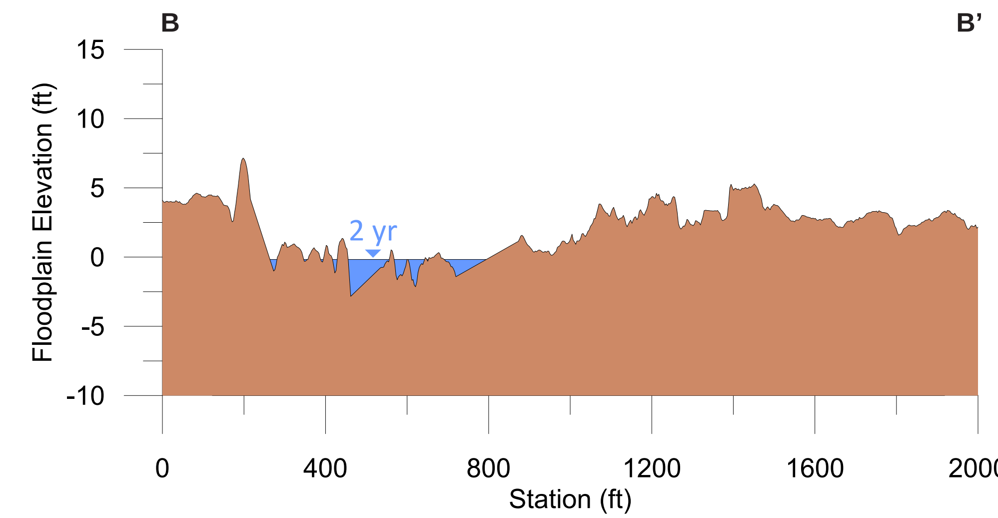
Geomorphic Conditions: RM 13.3 to 11.6

- Channel position is relatively stable in the first 1500 ft downstream of the S. Naches Road Bridge.
- Below this, widening of the floodplain and backwater from the Clemen's View Park constriction at RM 11.9 conspire to produce an extremely unstable sedimentation zone.
- The pebble count sampled bar-head is representative of the dominant main-channel bed material; however, smaller gravel-dominated material makes up a large proportion of accumulating gravel bars and channel-filling sediment plugs.
- The channel returns to relative stability downstream of the Clemen's View Park constriction. Nonetheless, the left bank revetment protecting the floodplain pit from channel migration is in notably poor condition.
- Deposition on the right bank bar between RM 11.9 and 11.8 has been dominated by large cobble material much coarser than the gravel in the major depositional zone upstream of the Clemen's View Park constriction.


Sandy gravel dominates material deposited in right bank bar at RM 12.4

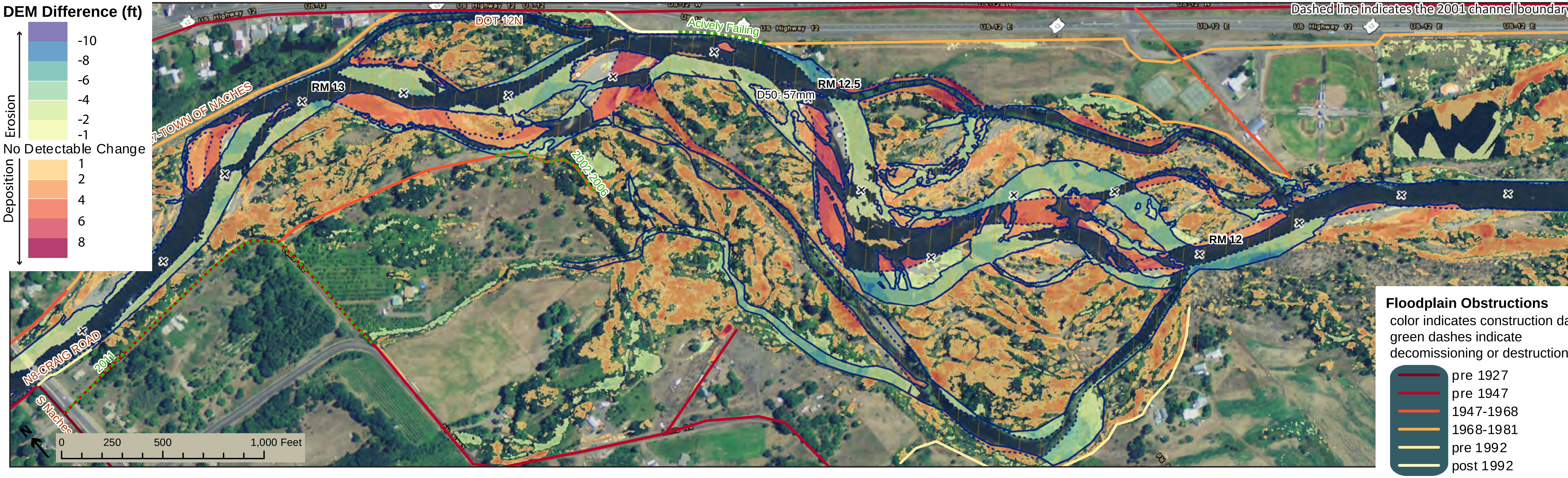


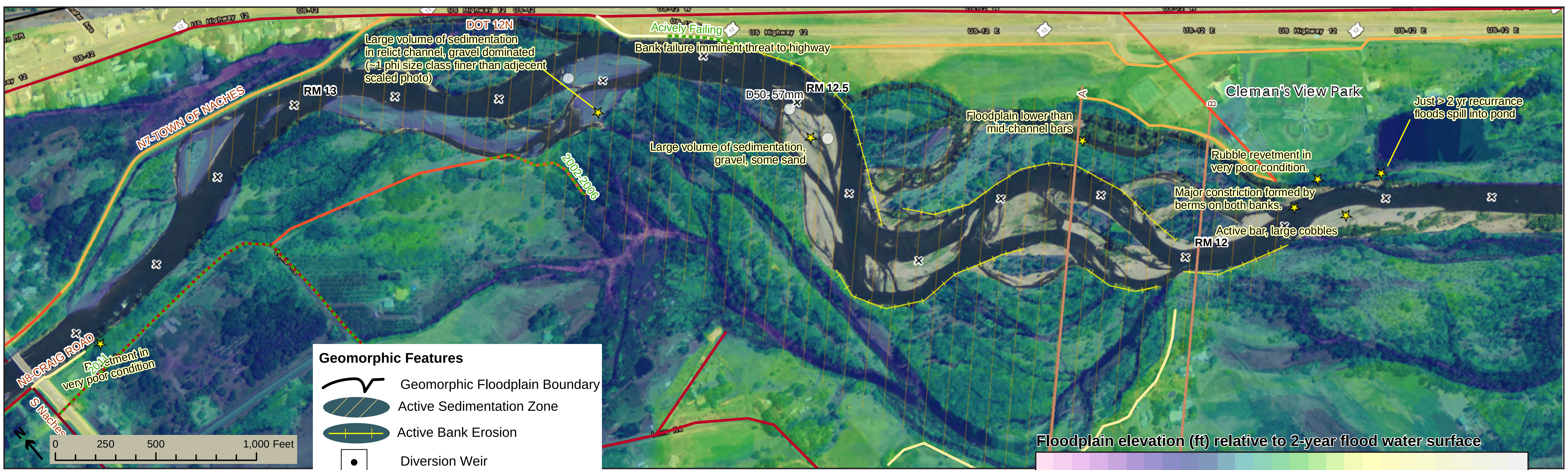





Gravel-dominated sediment plug filling right bank channel at RM 12.8.


Overview of pebble count location and detail of sampled deposit. Also note pronounced erosion of gravel & cobble alluvium from the left bank between RM 12.6 and 12.5.


2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Dashed line indicates the 2001 channel boundary.
DOT 12N
Acively Failing
RM 13
RM 12.5
D50: 57mm
RM 12
N7-TOWN OF NACHES
2002-2006
N8-CRAIG ROAD
2011
S Naches
0 250 500 1,000 Feet
Floodplain Obstructions
color indicates construction date
green dashes indicate decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992


DOT 12N
Acively Failing
Bank failure imminent threat to highway
Large volume of sedimentation in relict channel, gravel dominated (~1 phi size class finer than adjecent scaled photo)
RM 13
RM 12.5
D50: 57mm
N7-TOWN OF NACHES
2002-2006
Large volume of sedimentation, gravel, some sand
Floodplain lower than mid-channel bars
Cleman's View Park
Just > 2 yr recurrance floods spill into pond
Rubble revetment in very poor condition.
Major constriction formed by berms on both banks.
Active bar, large cobbles
RM 12
N8-CRAIG ROAD
2011
Revetment in very poor condition
S Naches
0 250 500 1,000 Feet
Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

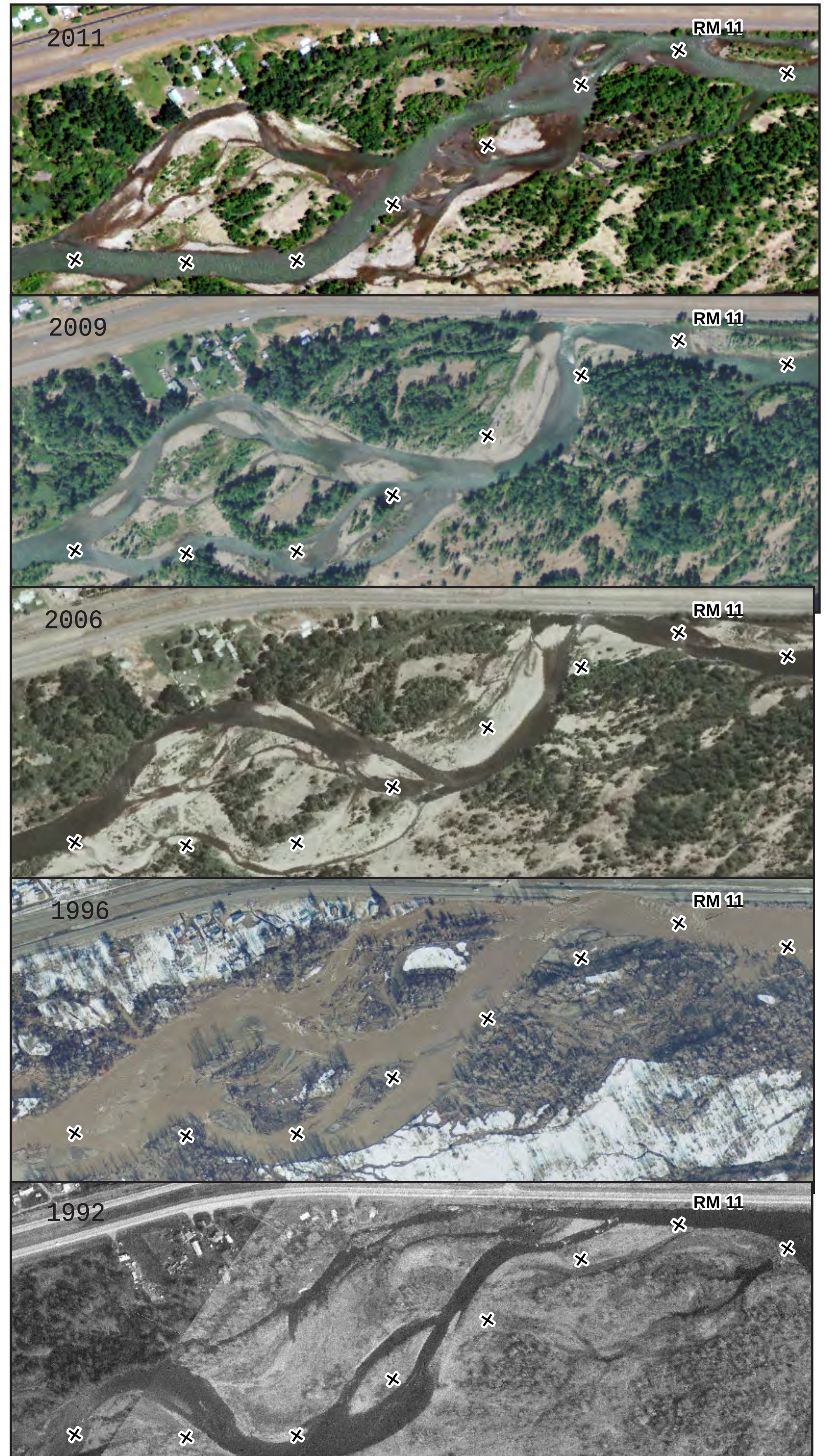
nhc

Geomorphic Conditions: RM 11.6 to RM 10.6

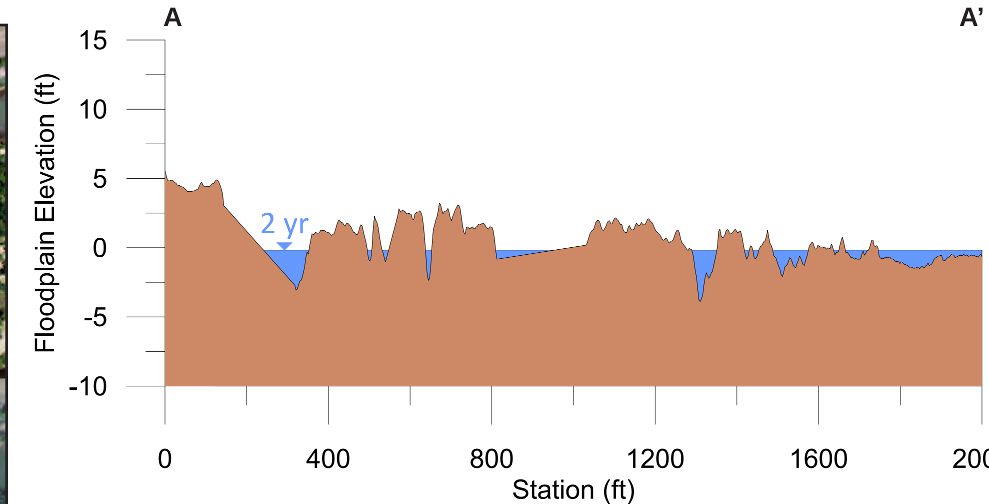
- At least 4 major avulsions have characterized channel mobility in this reach.
- The pebble count at this location sampled a moderately imbricated cobble deposit that has filled and largely blocked the 2011 dominant channel, driving an avulsion through the floodplain between RM 10.9 and 11.15.
- Though the sampled material is relatively coarse, the channel-blocking sediment plug in this reach is overall relatively coarse compared to the material accumulating between RM 13 and RM 11.6.
- This most recent avulsion (2011-present) is simultaneously activating several flow paths through the floodplain, both near the upstream avulsion node and near the confluence of the avulsion channel and abandoned main channel.

Plug of cobble-dominated sediment filling the 2011 main channel. View is downstream from RM 11.35 to RM 11.15.

Enlarging avulsion channel between RM 10.9 and 11.15.

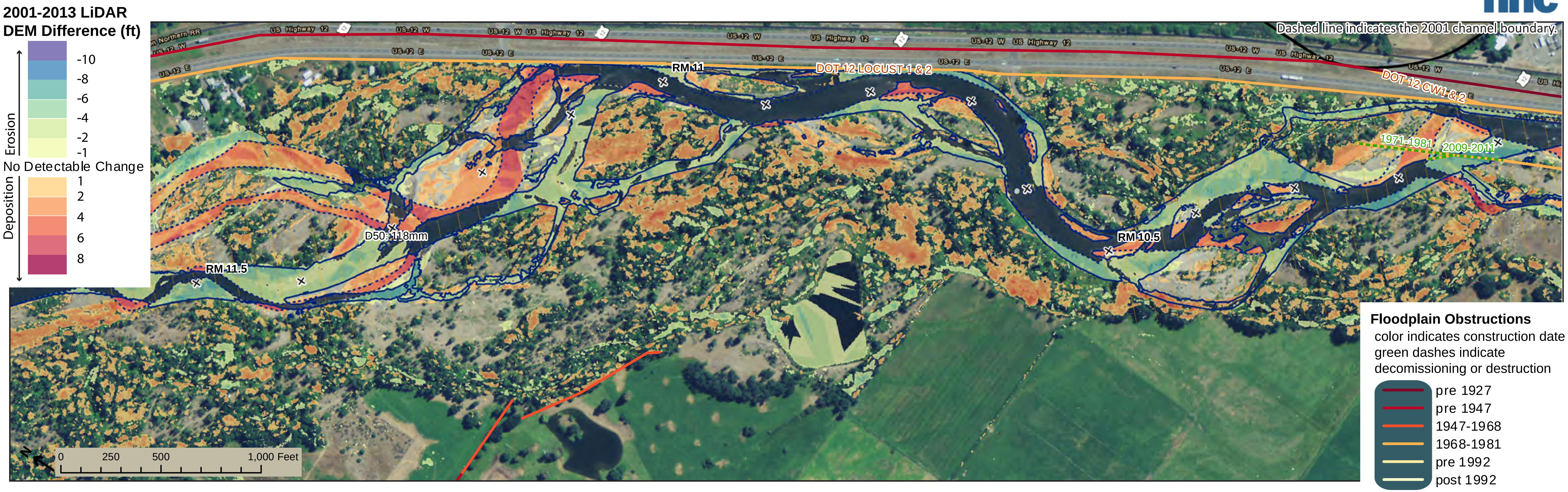


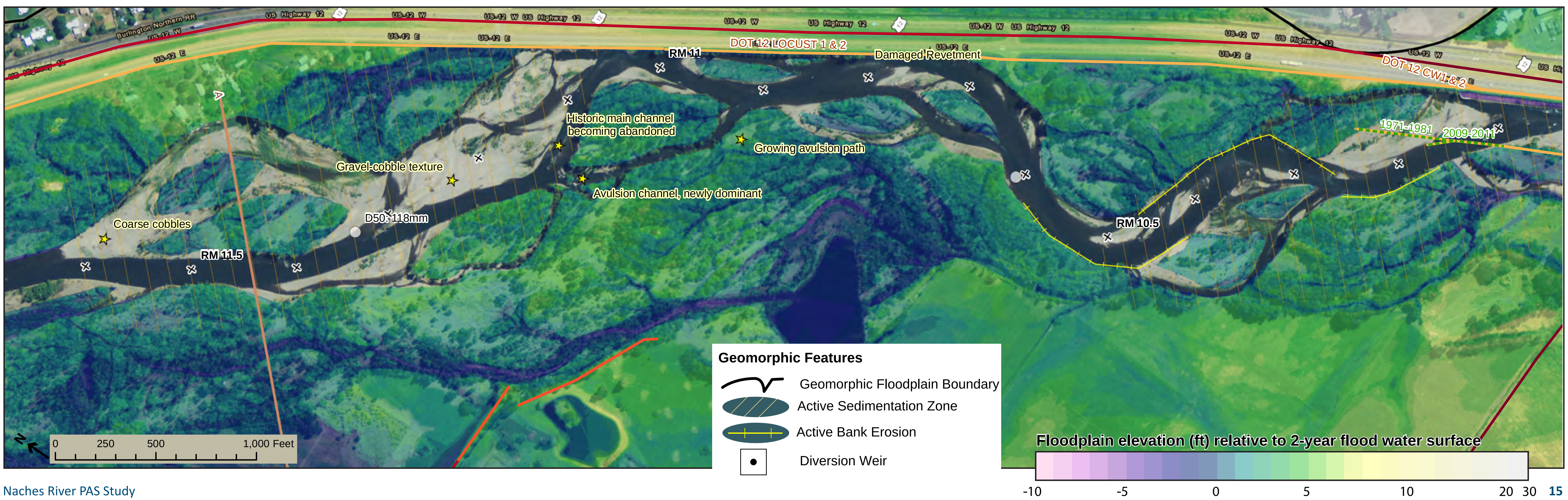
Sequence of aerial photos showing multiple avulsions between RM 10.9 and RM 11.6.



Secondary avulsion channel forming near RM 10.95

Overview of pebble count location and detail of sampled deposit.


2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Dashed line indicates the 2001 channel boundary.
RM 11
RM 11.5
RM 10.5
DOT 12 LOCUST 1 & 2
DOT 12 CW1 & 2
1971-1981
2009-2011
D50: 118mm
US Highway 12
US-12 W
US-12 E
Burlington Northern RR
0 250 500 1,000 Feet
Floodplain Obstructions
color indicates construction date
green dashes indicate decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992

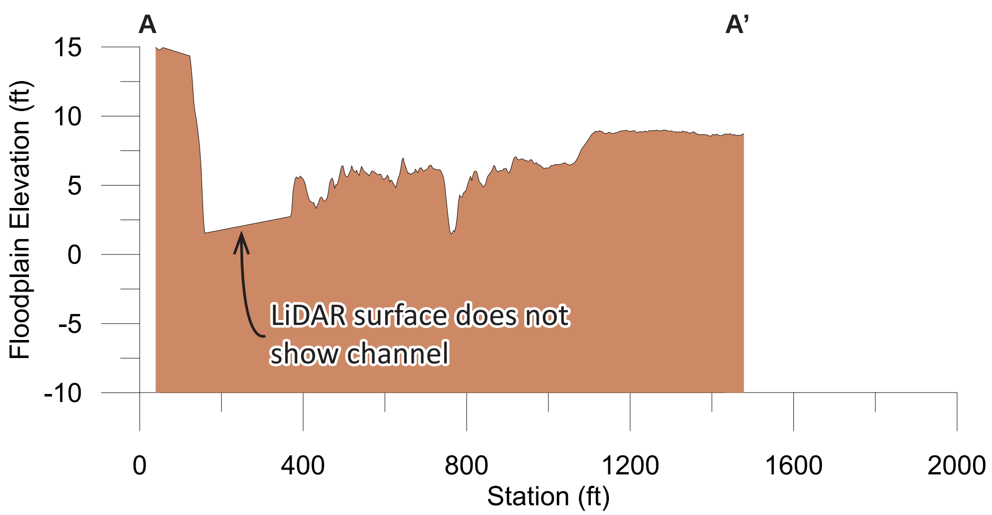

RM 11
RM 11.5
RM 10.5
DOT 12 LOCUST 1 & 2
DOT 12 CW1 & 2
Damaged Revetment
1971-1981
2009-2011
Historic main channel becoming abandoned
Growing avulsion path
Gravel-cobble texture
Avulsion channel, newly dominant
Coarse cobbles
D50: 118mm
US Highway 12
US-12 W
US-12 E
Burlington Northern RR
0 250 500 1,000 Feet
Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

Geomorphic Conditions: RM 10.6 to RM 9.7

- Channel constriction and grade control at the City of Yakima Water Diversion have created a zone of instability and sedimentation upstream.
- This instability and management response to it has destroyed (or caused removal of) most of the length of levees upstream of the diversion, and is now positioned to allow flanking erosion to damage the Gleed Diversion levee.

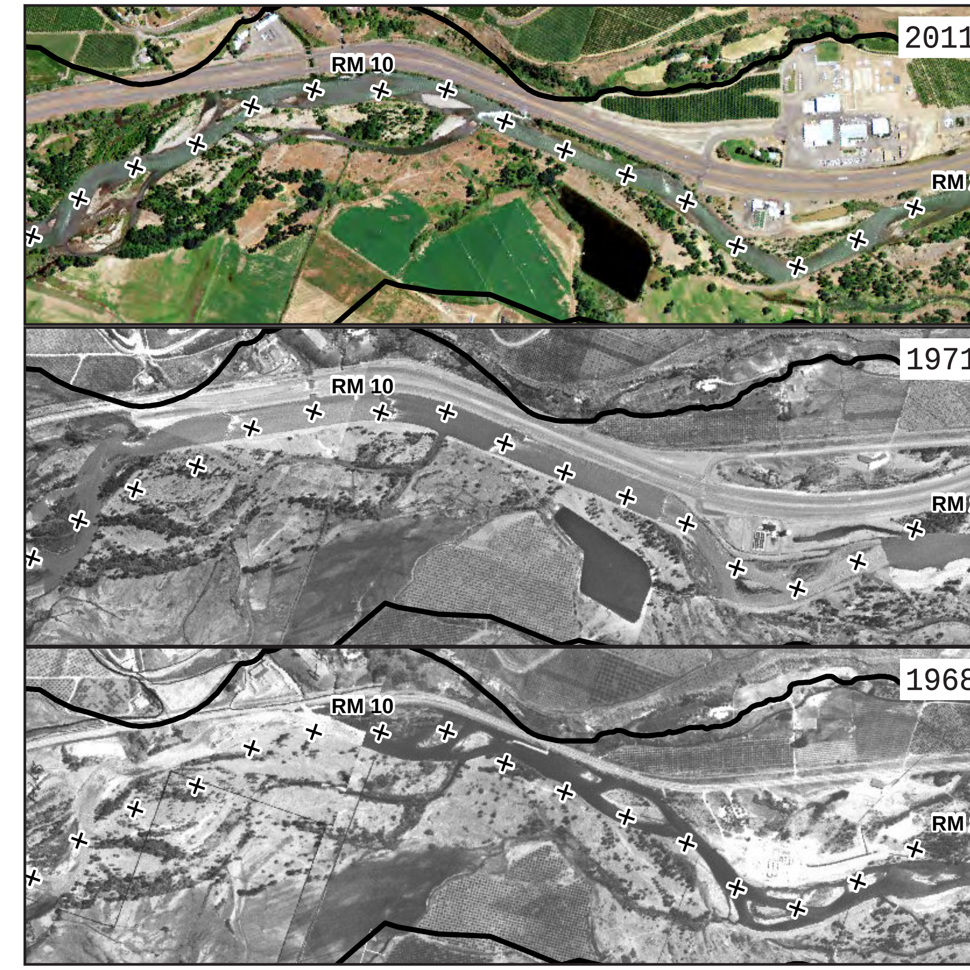
Geomorphic Conditions: RM 9.7 to RM 9.1

- This reach of the river is tightly constrained by bounding levees and revetments and has been historically very stable. Relatively high geomorphic floodplain elevations (~10 ft above 2-yr water surface) indicate possible channel downcutting in this reach during the historic period.
- Failure of the Gleed diversion grade control during the 2011 flood caused a notable headcut to move through this reach (J. Freudenthal pers. comm. 2015). Grade control failure also suggests the reach may be downcutting.
- A knickpoint initiated by the recent (2009-2013) avulsion downstream at Eschbach Park is presently at the downstream edge of this reach and may trigger future downcutting.



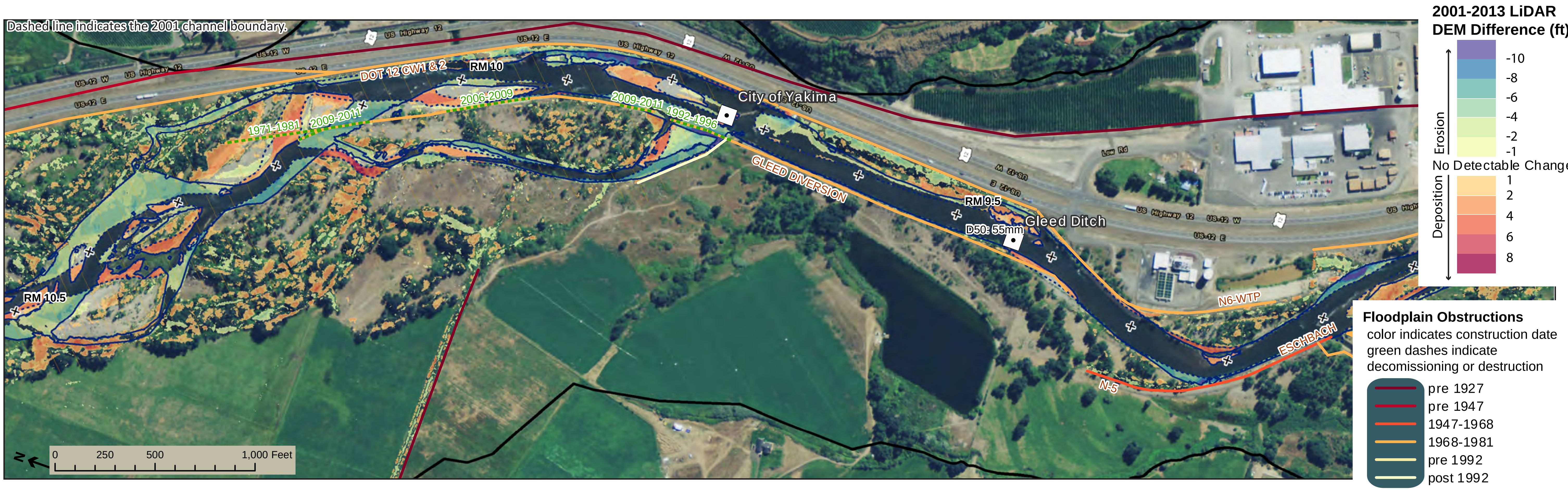
Overview of unsampled right bank bar at RM 10.6 and detail of bar surface material.

City of Yakima water diversion structure.

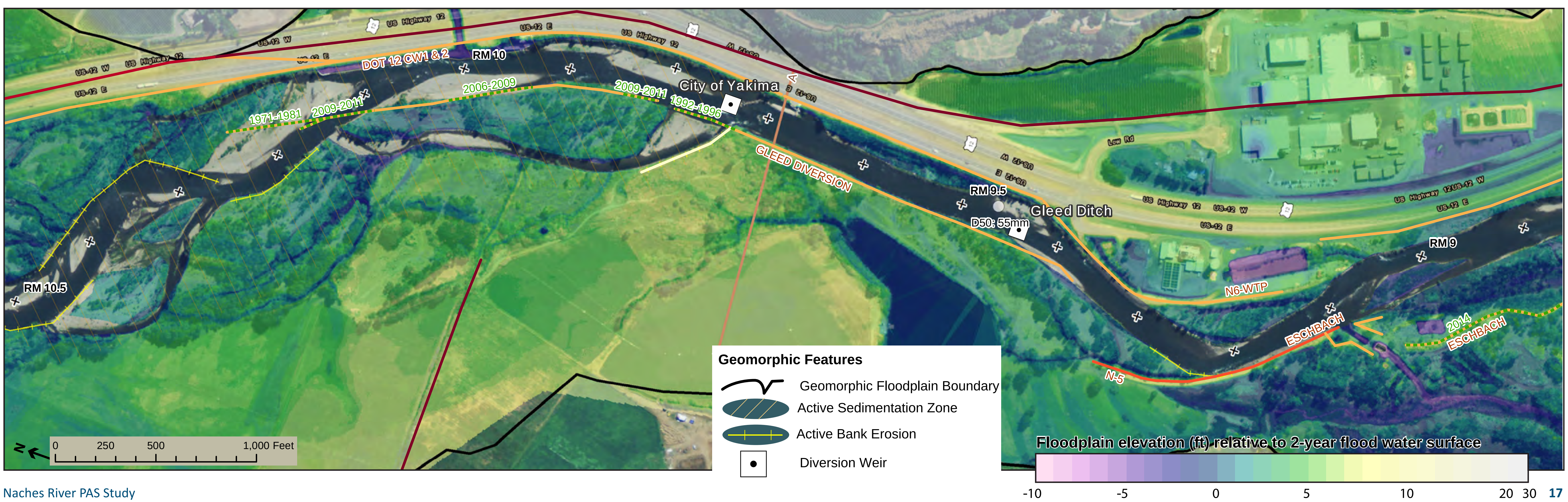


Construction of Highway 12 and associated river engineering measures tightly constrained this segment of the river. However, in the past couple of decades, sediment accumulation upstream of the constriction has driven channel migration that is destroying the right bank levee.

Overview of pebble count location at RM 9.45.



Dashed line indicates the 2001 channel boundary.
2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
DOT 12 CW1 & 2
RM 10
2006-2009
2009-2011
1971-1981
2009-2011 1992-1996
City of Yakima
GLEED DIVERSION
RM 9.5
Gleed Ditch
D50: 55mm
N6-WTP
ESCHBACH
N-5
RM 10.5
0 250 500 1,000 Feet



DOT 12 CW1 & 2
RM 10
2006-2009
1971-1981
2009-2011
2009-2011 1992-1996
City of Yakima
GLEED DIVERSION
RM 9.5
Gleed Ditch
D50: 55mm
RM 9
N6-WTP
ESCHBACH
2014
ESCHBACH
N-5
RM 10.5
0 250 500 1,000 Feet
Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

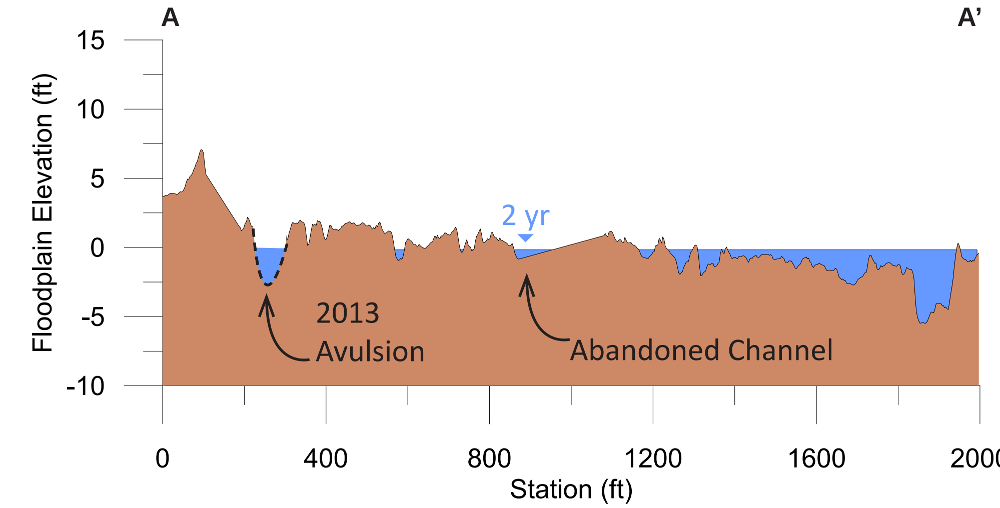
nhc

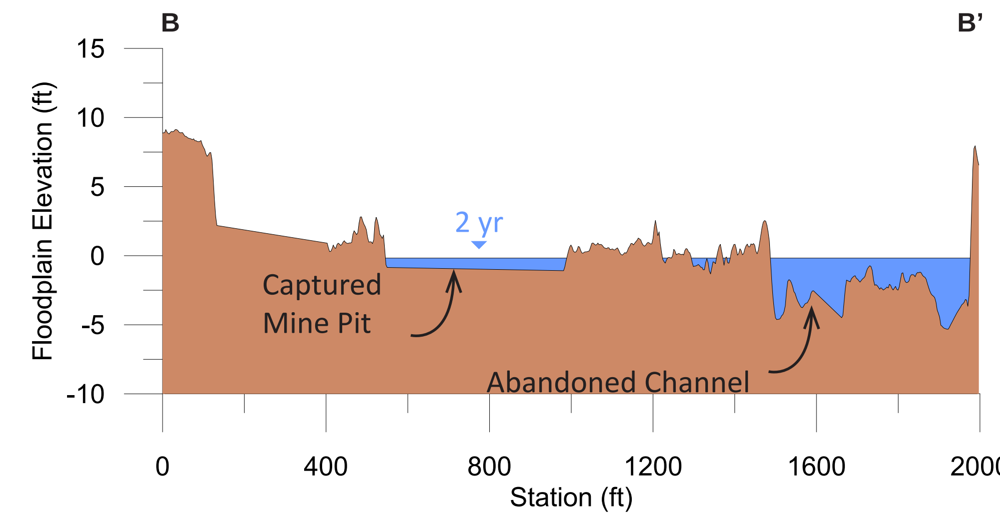
Geomorphic Conditions: RM 9.1 to RM 8.1

- Flow expansion downstream of the Gleed Diversion, WWTP, and Eschbach levees has created a major deposition zone in the vicinity of Eschbach Park.
- The reach is still recovering from two major avulsions. One (node at RM 8.5) occurred in the downstream portion of the reach during the 1996 flood, while the other (node at RM 8.9) occurred gradually by side channel expansion between 2009 and 2013.
- Sediment filling the historic main channel near Eschbach Park is gravel-dominated, this site acted as a large bed-material trap and this material likely represents the dominant material transported by this reach of the Naches.
- Scour along the upstream avulsion path has severely damaged the revetment protecting the N4 levee
- The downstream 1996 avulsion channel remains unstable, with rapid channel migration rates and constant shifting of large bar complexes.
- This instability has caused lateral migration to intersect a floodplain mine pit (Kershaw Pond) at RM 8. This intersection is triggering further instability both in the reach considered here and the downstream reach.

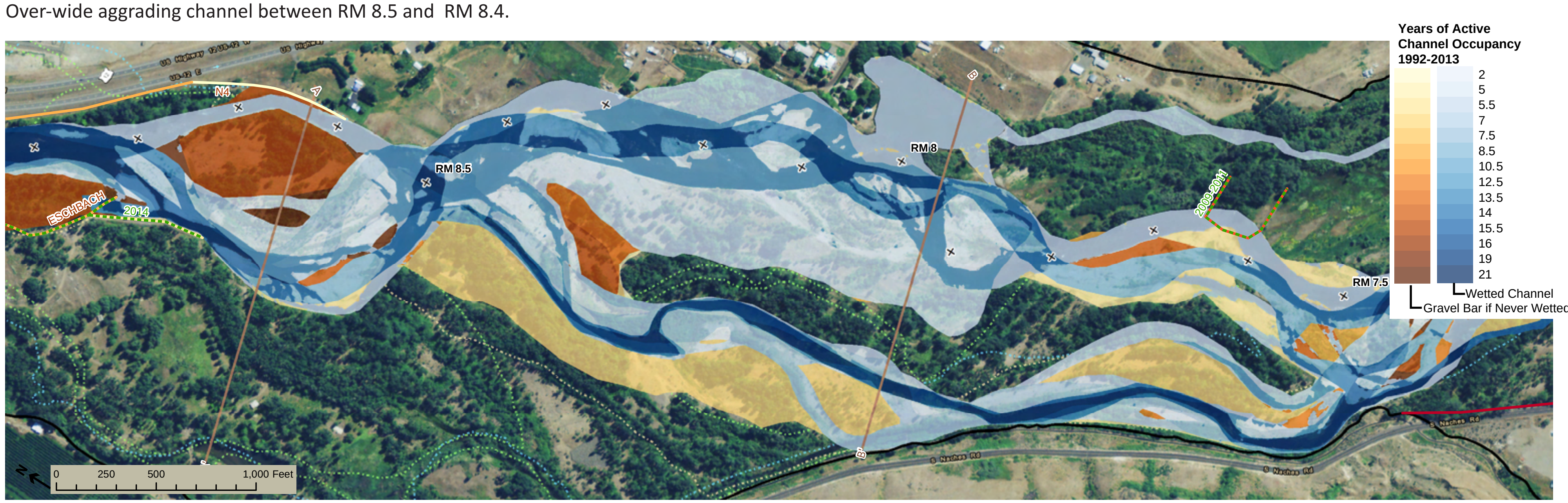

Failing revetment along avulsion path near RM 8.6.

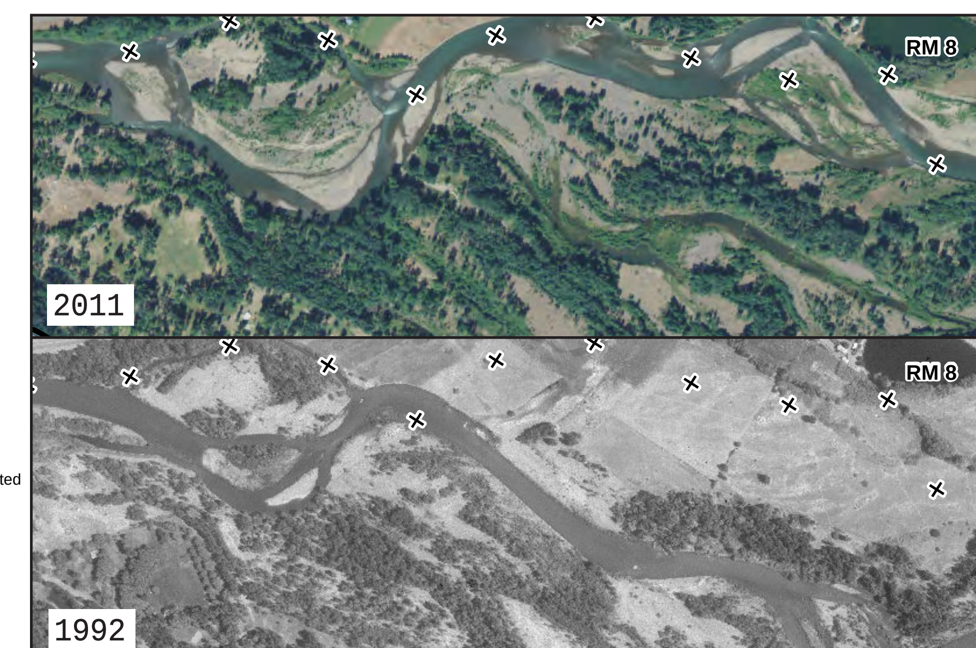

Overview of main-channel pebble count location at RM 8.4.





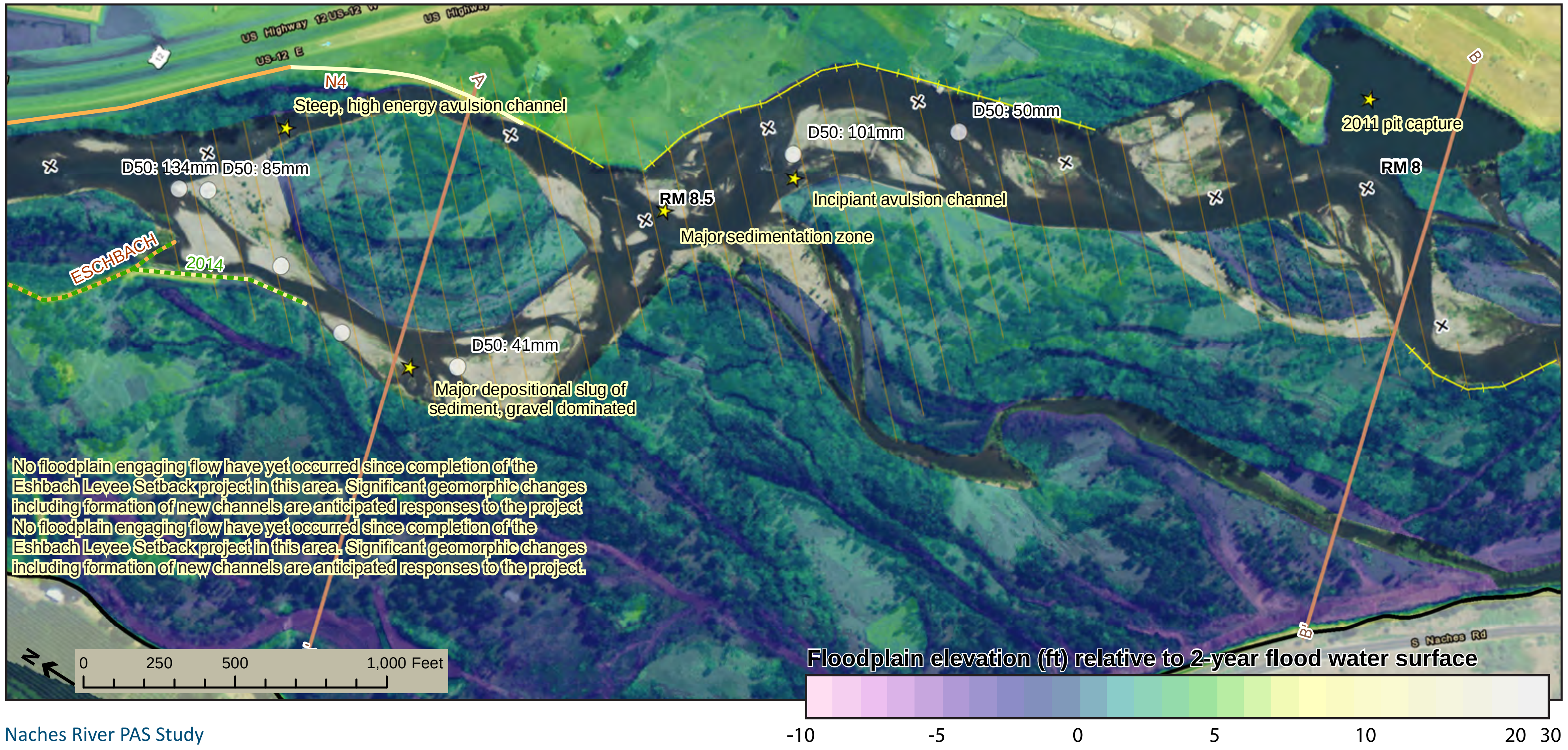

Over-wide aggrading channel between RM 8.5 and RM 8.4.





Historic aerial photos showing major avulsions.

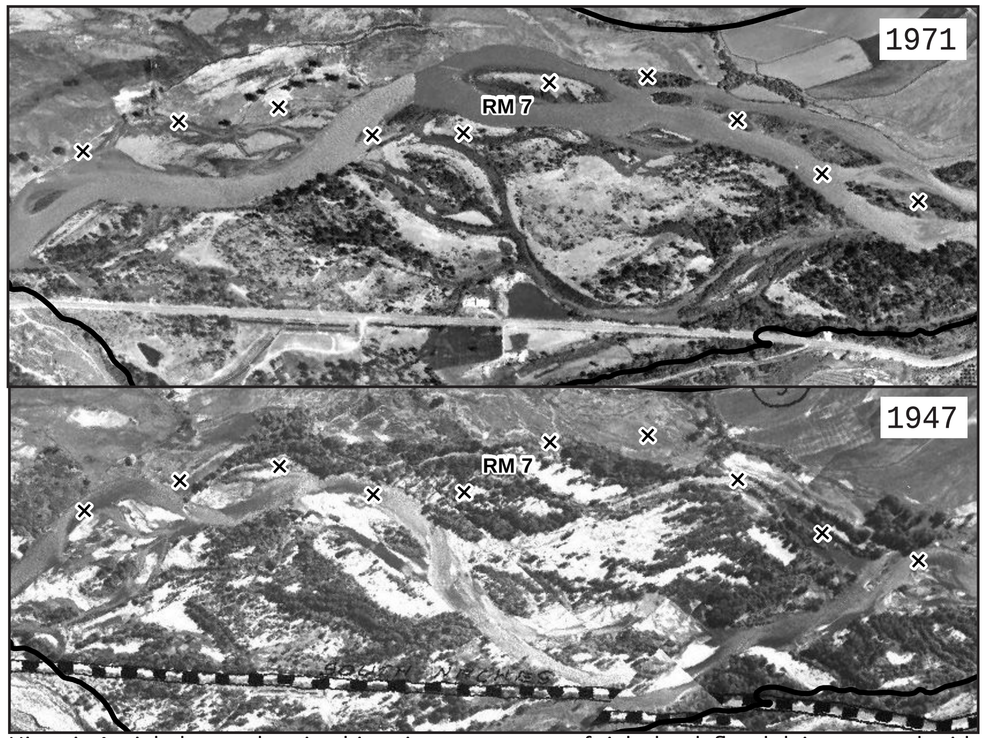
Eschbach Park Channel Filling Gravel Slug



nhc

Geomorphic Conditions: RM 8.1 to RM 6.4

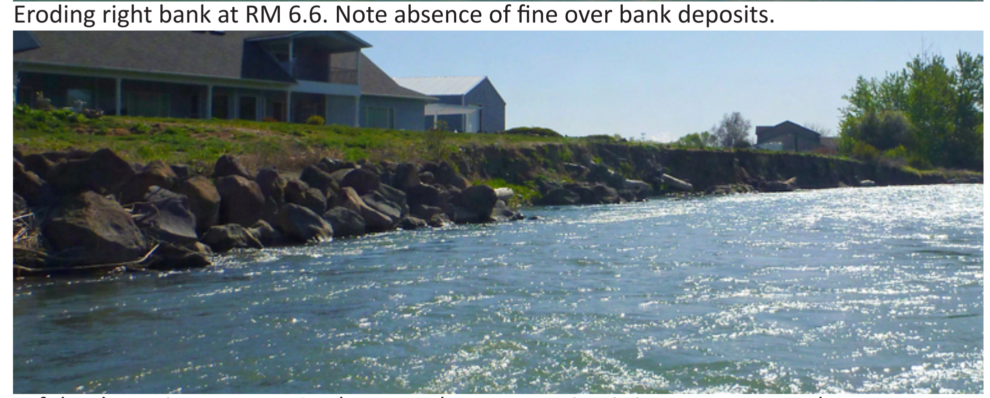
- This reach is strongly impacted by ongoing instability of the 1996 RM 8.5 avulsion channel and 2011 capture of the Kershaw floodplain pit pond.
- As with the reach upstream, the 1996 avulsion channel has not yet stabilized, and is characterized by high lateral migration rates.
- A slug of sediment, likely eroded from the 1996 avulsion channel is in the lower part of the reach (RM 6.4 to 7.4), and is causing channel instability and rapid migration in this area, including bank erosion that threatens homes near RM 6.8.
- The Kershaw floodplain pit pond capture has diverted a substantial amount of flow into two separate over bank flow pathways. At present, the entrance to these pathways is dammed by accumulations of large wood, limiting the amount of flow that they can take, but potential expansion of these flow paths in the future is likely.

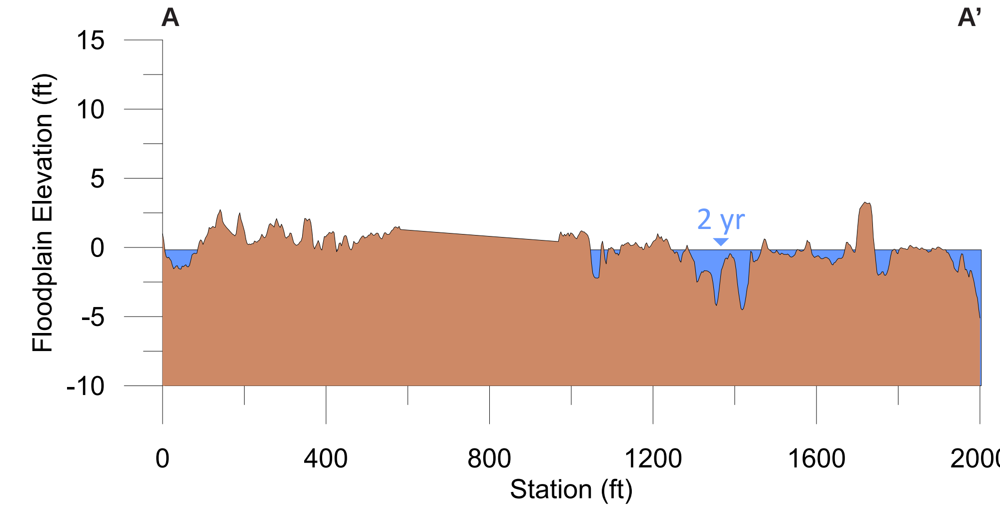


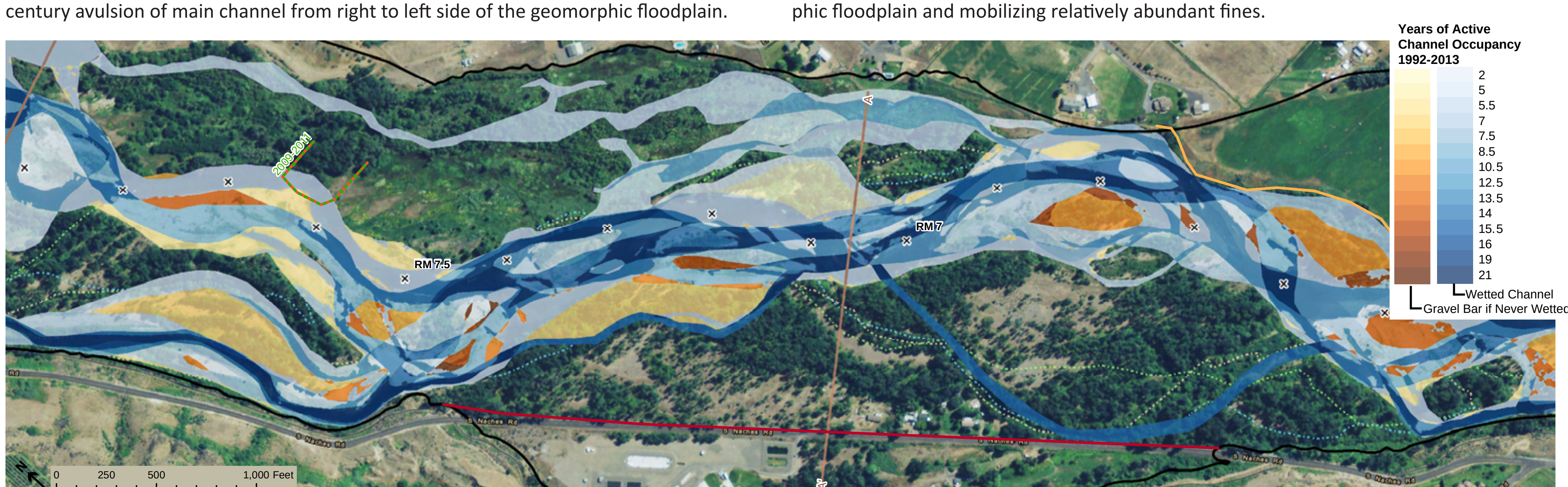
Historic Aerial photos showing historic engagement of right bank floodplain area and mid-century avulsion of main channel from right to left side of the geomorphic floodplain.


Low floodplain and potential avulsion path (left bank, RM 7.2).


Eroding right bank at RM 6.6. Note absence of fine over bank deposits.

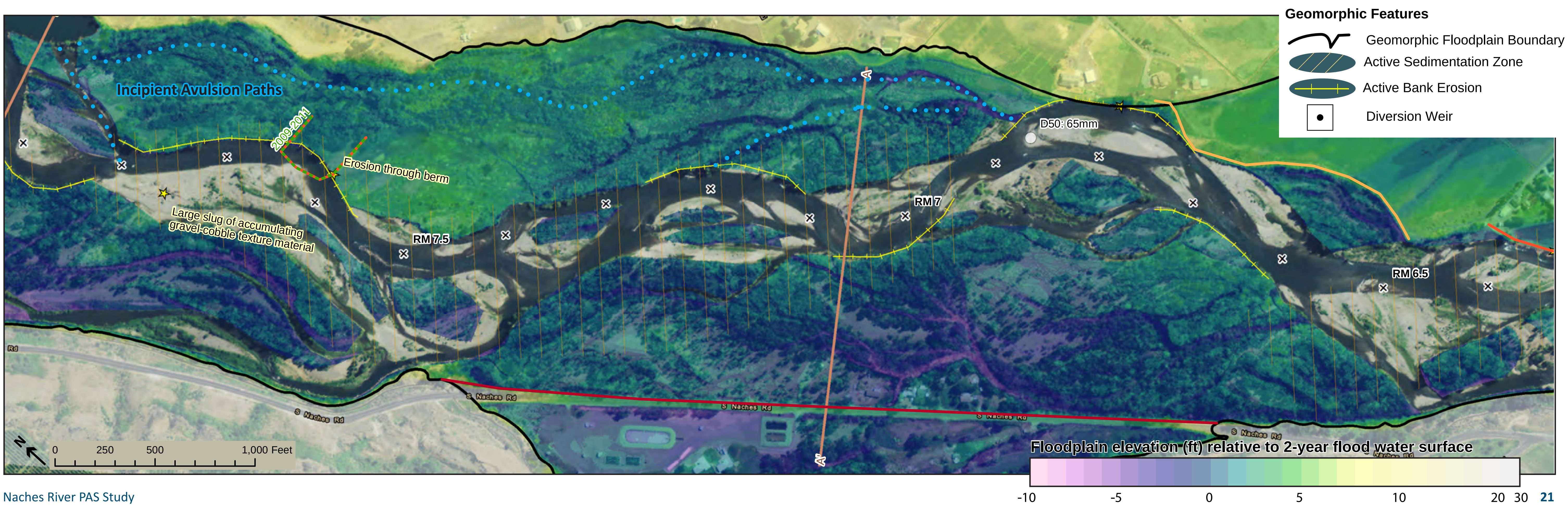

Left bank Erosion at RM 7.85 threatens homes. Erosion is into 1st terrace above geomorphic floodplain and mobilizing relatively abundant fines.






Overview of pebble count location at RM 7.85 and detail of sampled deposit.

2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Floodplain Obstructions
color indicates construction date
green dashes indicate decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
D50: 65mm
2009-2011
RM 7.5
RM 7
RM 6.5
S Naches Rd
0 250 500 1,000 Feet



Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Incipient Avulsion Paths
2009-2011
Erosion through berm
Large slug of accumulating gravel-cobble texture material
D50: 65mm
RM 7.5
RM 7
RM 6.5
S Naches Rd
0 250 500 1,000 Feet
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

nhc

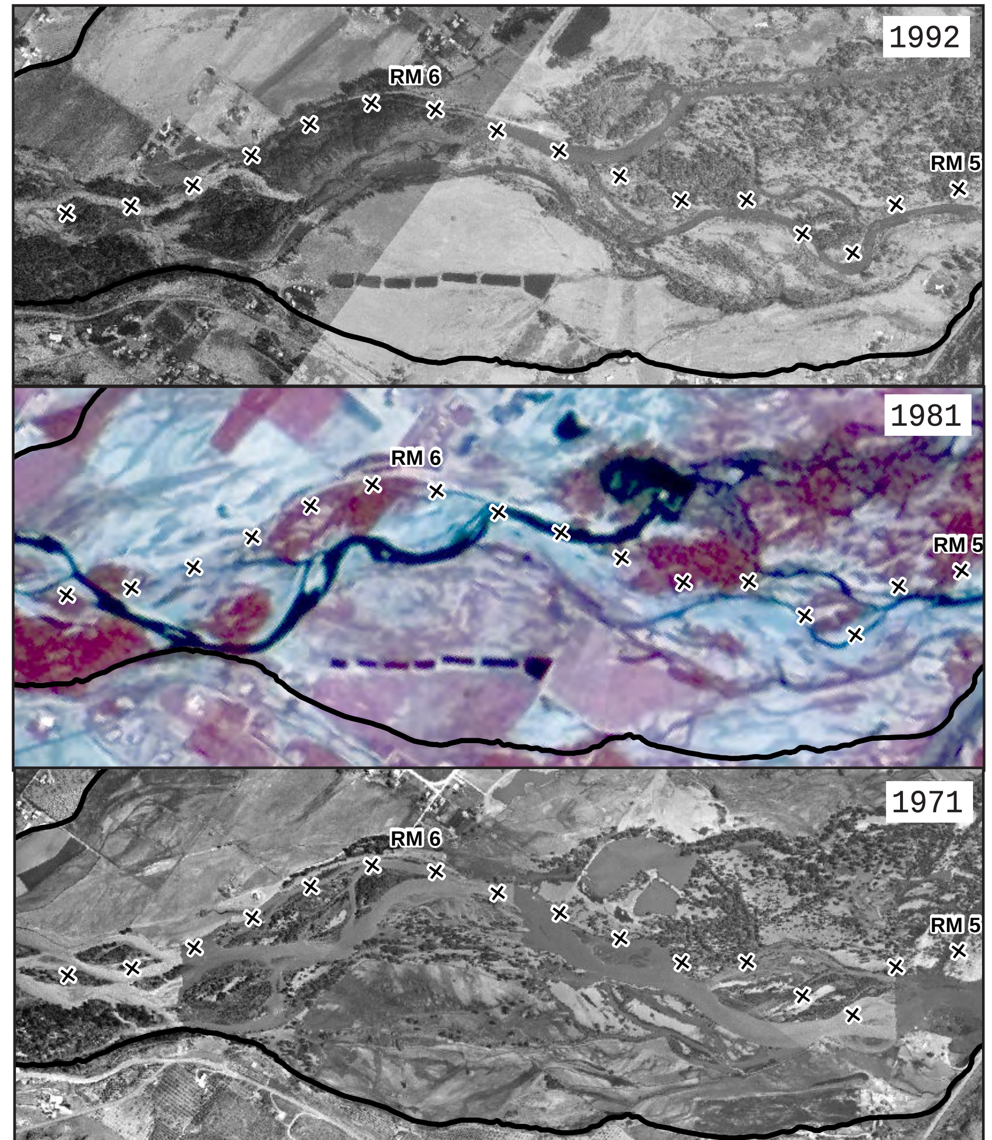
Geomorphic Conditions: RM 6.5 to RM 5.8

- This reach presently has a relatively stable wandering planform reminiscent of likely historic conditions along the whole lower Naches River. Even though the active floodplain has been narrowed relative to historic conditions, it has a fairly consistent width that, apparently, is sufficient to convey enough flow to avoid concentration of the flow in the main channel and consequent channel incision as is observed in other areas of major constriction.
- The Trout Meadows Ponds and surrounding floodplain are quite high relative to the channel (1-3 ft above the 2-yr flood water surface) but were occupied by active side channels in 1927, suggesting substantial channel downcutting has occurred in this reach.

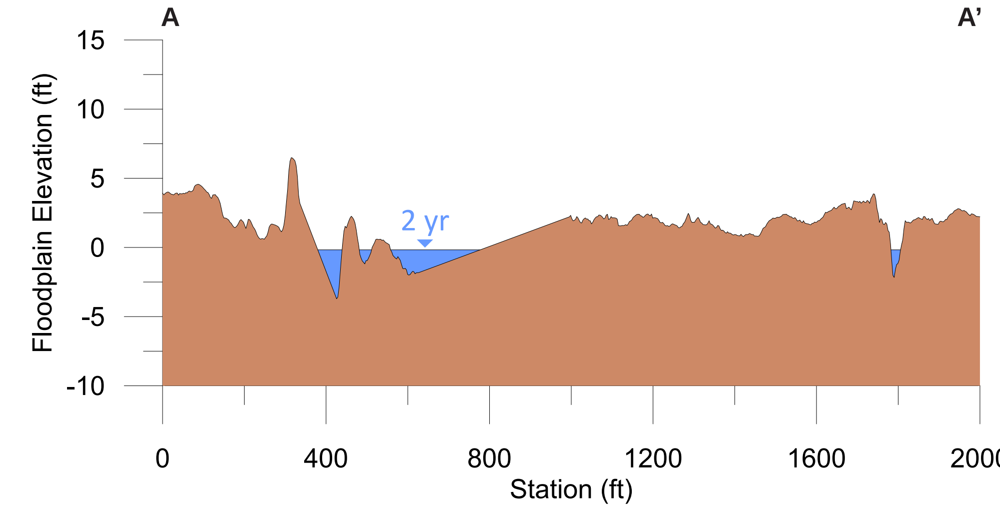
Geomorphic Conditions: RM 5.8 to RM 4.7

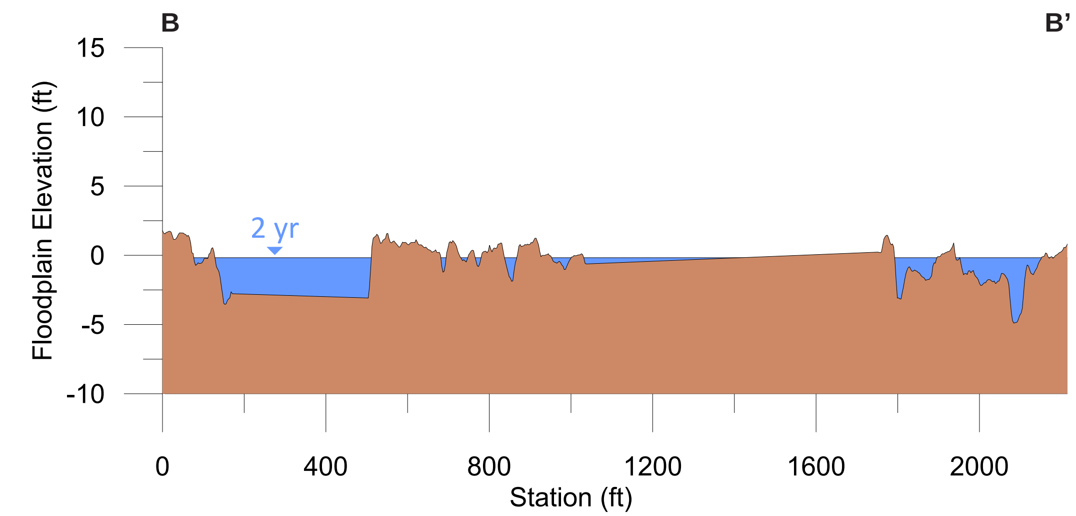
- This reach has a distinctly different character then that immediately upstream. It is intensely braided and very unstable. Factors that have influenced this downstream reach include capture of a floodplain gravel pit near RM 5.6 and spreading of the flow into a very wide floodplain area at the downstream extent of the N2 Levee. It is also possible that upstream-propogating aggradation above the Nelson Dam constriction may influence this reach, although the pattern of instability suggests the abrupt floodplain widening downstream of the N2 Levee is the dominant controlling factor.
- A large slug of sediment has been emplaced in the channel between RM 5 and 6.7, driving rapid lateral channel migration, and elevating the main channel well above relict channels to either side, particularly in the area of RM 5.2 to RM 5.5.

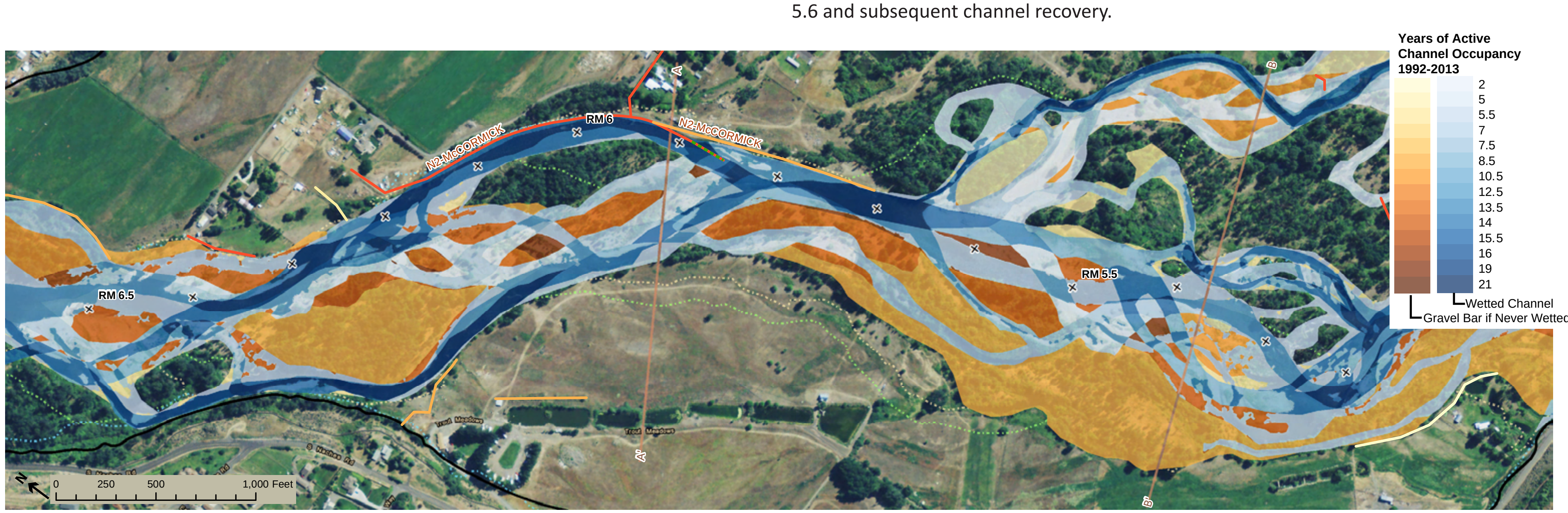
Growing avulsion channel at RM 5.3 (left bank).



Sequence of historic aerial photos showing avulsion through floodplain pit pond at RM 5.6 and subsequent channel recovery.

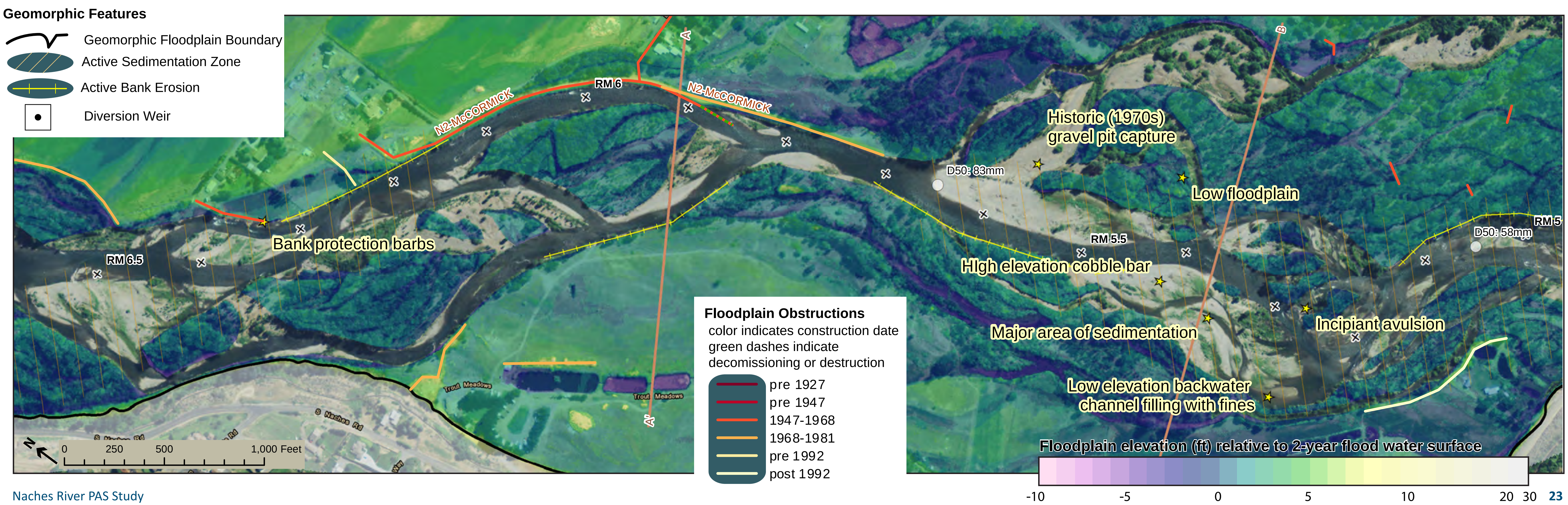






Overview of pebble count location at RM 5.65.

2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Dashed line indicates the 2001 channel boundary.
RM 6
N2-McCORMICK
N2-McCORMICK
D50: 83mm
RM 5.5
RM 5
D50: 58mm
Trout Meadows
S Naches Rd
0
250
500
1,000 Feet



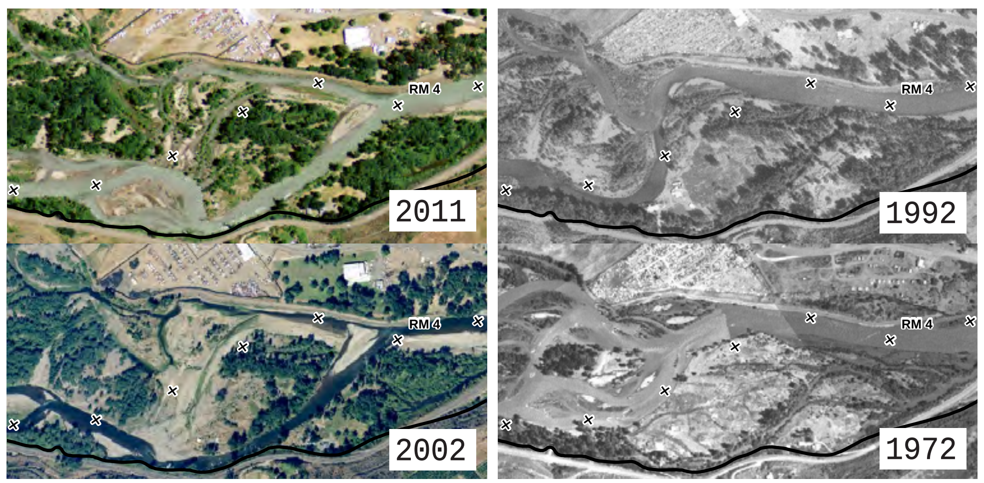
Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
RM 6
N2-McCORMICK
N2-McCORMICK
A
A'
B
RM 6.5
Bank protection barbs
Historic (1970s) gravel pit capture
D50: 83mm
Low floodplain
RM 5.5
HIgh elevation cobble bar
Major area of sedimentation
Incipiant avulsion
Low elevation backwater channel filling with fines
RM 5
D50: 58mm
Floodplain Obstructions
color indicates construction date
green dashes indicate decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30
0
250
500
1,000 Feet

Geomorphic Conditions: RM 5.8 to RM 4.7 (continued)

- The texture of gravel bars in the sediment slug fines systematically from upstream to downstream (compare pebble counts from RM 5.65 and 5.25).
- Main channel aggradation has blocked abandoned avulsion channels to form backwater channels that are not infiling with fine sediment.

Geomorphic Conditions: RM 4.7 to RM 3.8

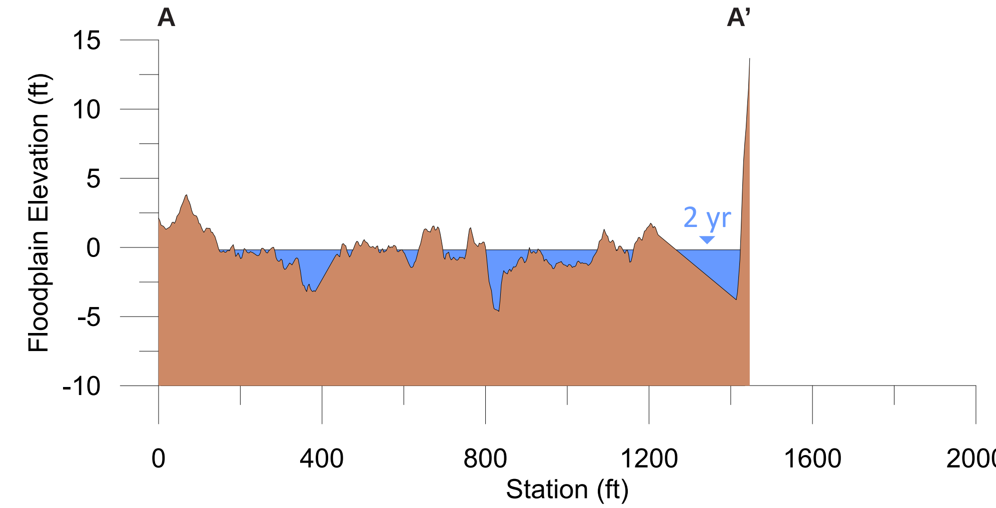
- The upstream portion of this reach (RM 4.8 to RM 4.4) is entrenched against the right valley wall. Hydraulic interaction with colluvium on the valley wall has maintained persistent scour and held the channel in place.
- The downstream portion of this reach (RM 4.4 to RM 3.8) is controlled by the pronounced constriction and grade control at Nelson Dam, an 8 ft high low-head weir.
- RM 4.4 has been the location of a persistent avulsion node (2 major avulsions since 1992), suggesting that this is a site of pronounced deposition (at least during some flow conditions) controlled by the Nelson Dam and possibly Rambler's Park Levee backwater.
- The Rambler's Park levee has recently been set back, which may possibly cause the site of persistent sedimentation to shift downstream. It does not, however, change the hydraulics at the primary constriction and grade control at Nelson Dam, itself.

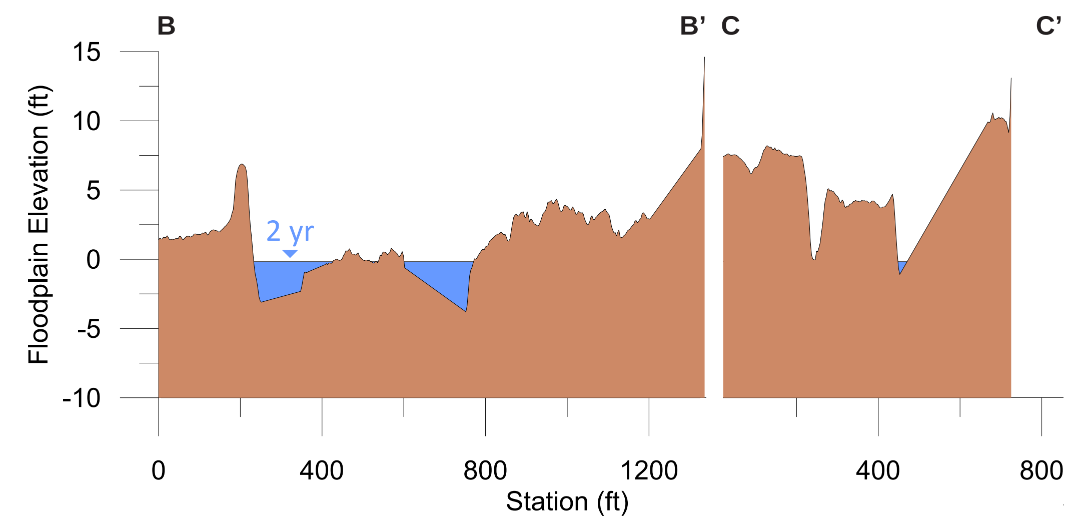


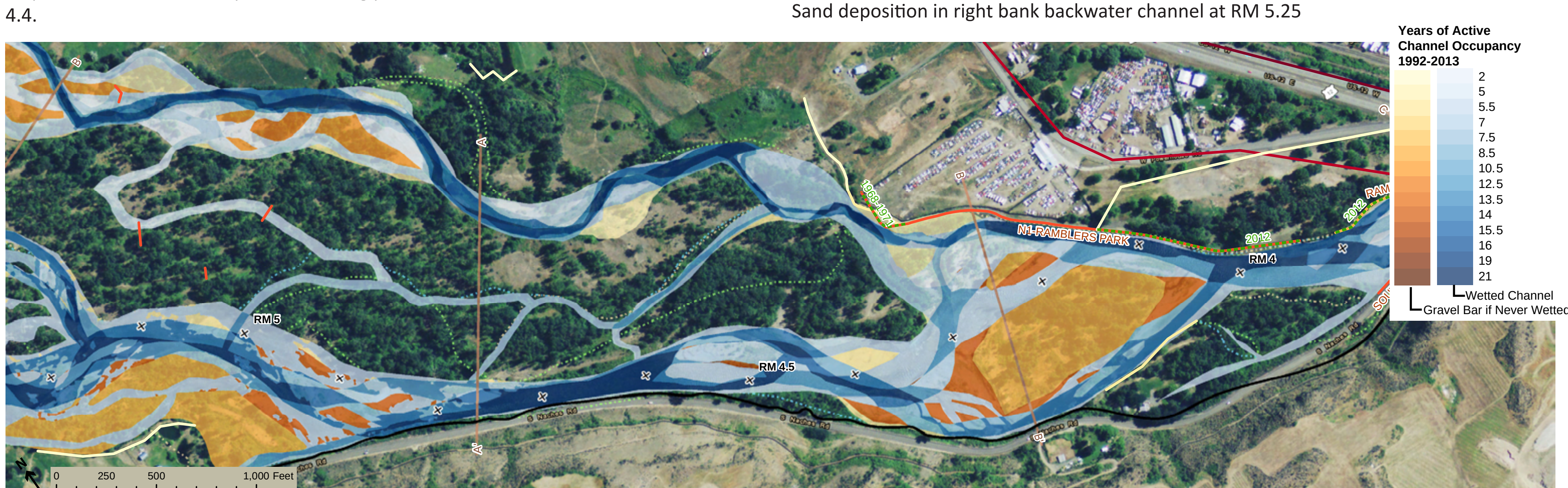
Sequence of historic aerial photos showing persistent sedimentation and avulsion at RM 4.4.

Overview of pebble count location at RM 5.05 and detail of sampled deposit.

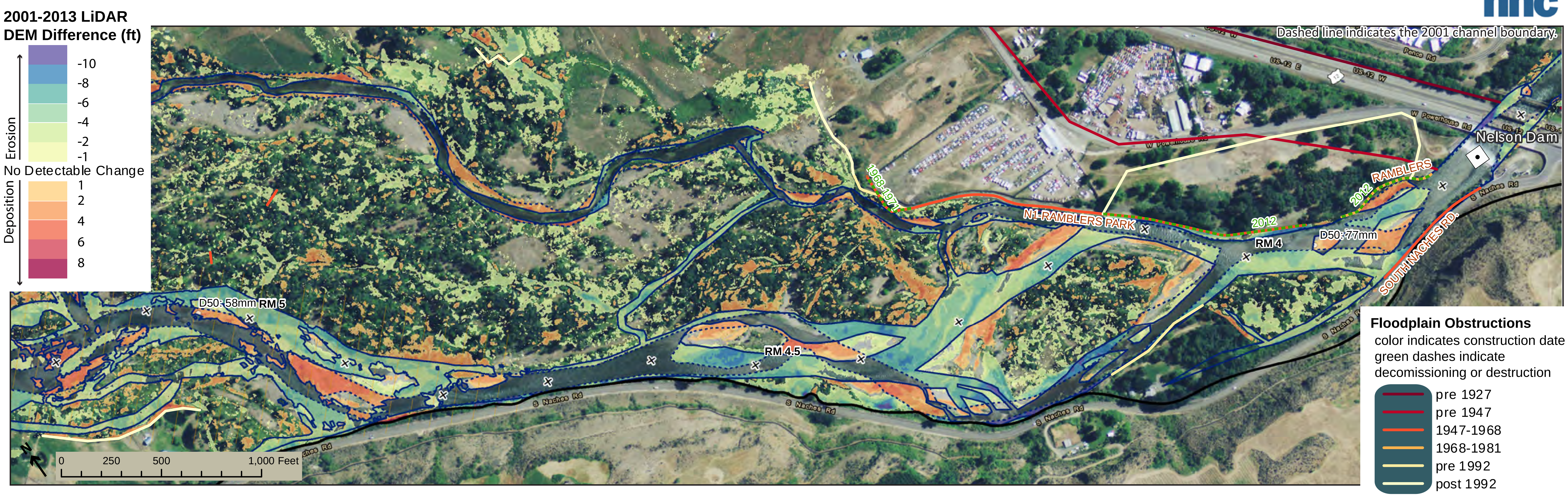
Sand deposition in right bank backwater channel at RM 5.25

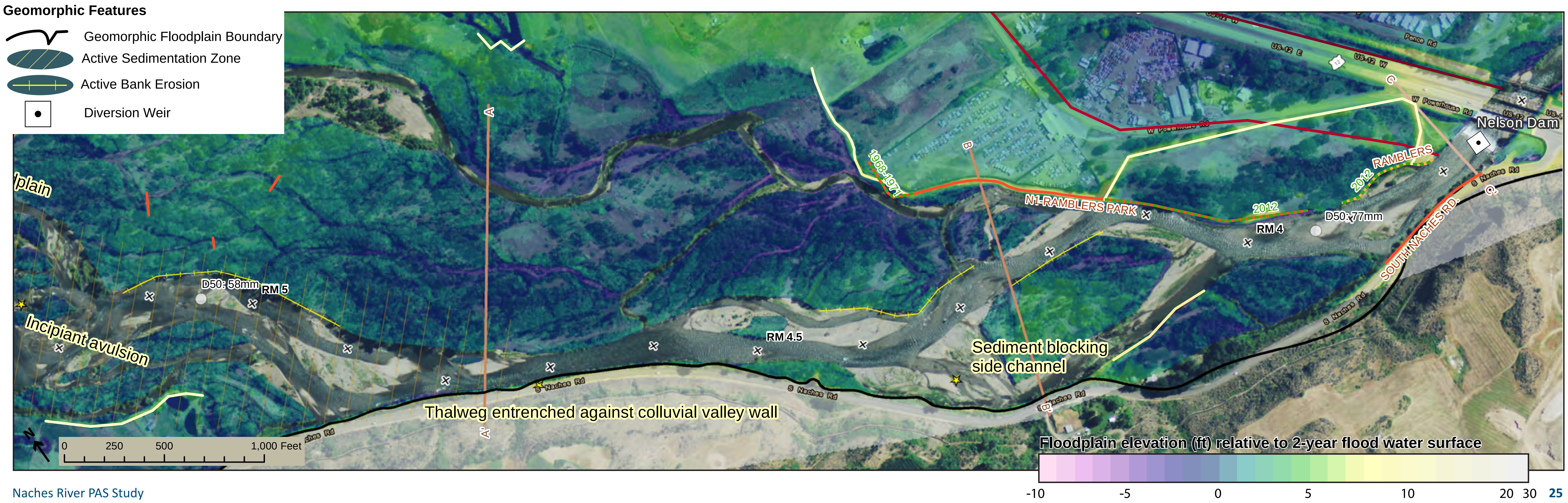






Overview of pebble count location at RM 3.95 and detail of sampled deposit.

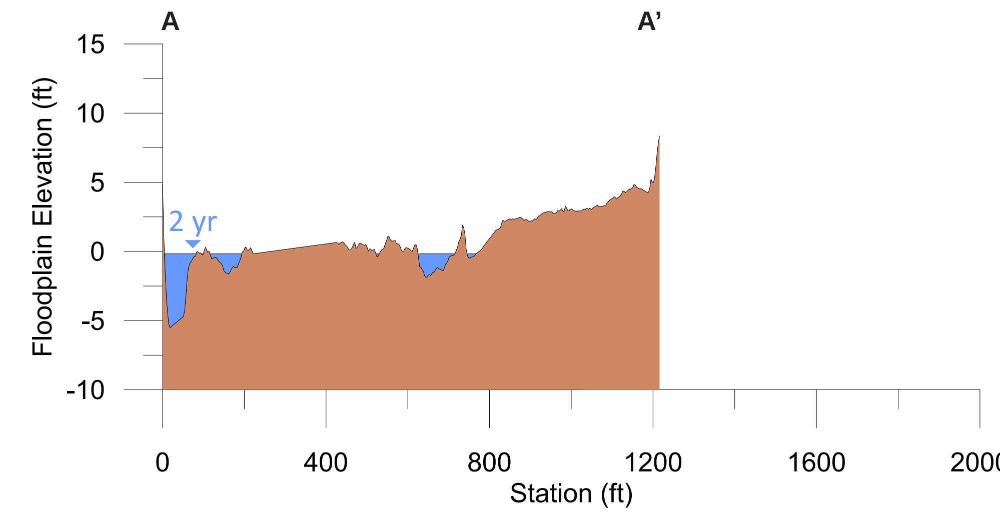

nhc
2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Dashed line indicates the 2001 channel boundary.
Nelson Dam
RAMBLERS
2012
1968-1971
N1-RAMBLERS PARK
RM 4
D50: 77mm
SOUTH NACHES RD.
D50: 58mm
RM 5
RM 4.5
S Naches Rd
W Powerhouse Rd
US-12 E
US-12 W
Pence Rd
0 250 500 1,000 Feet
Floodplain Obstructions
color indicates construction date
green dashes indicate decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992

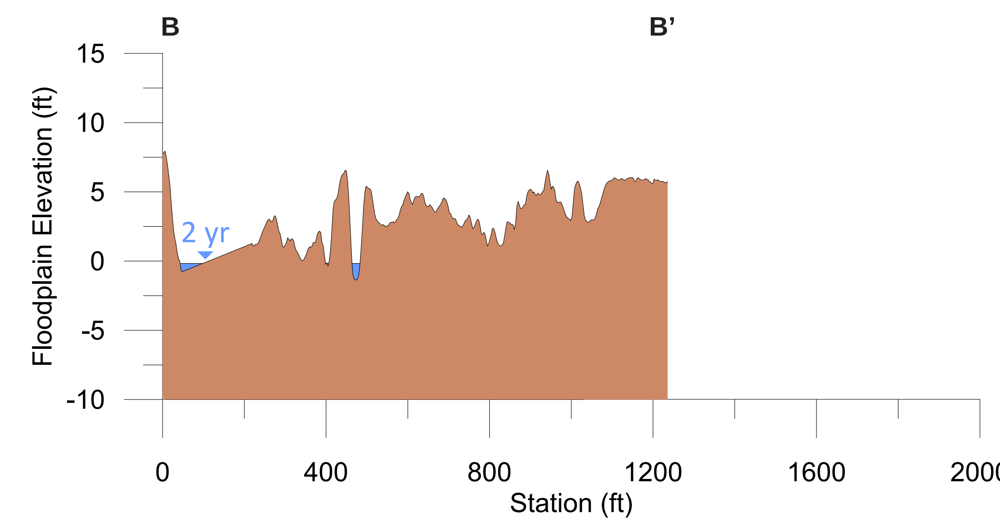

Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Nelson Dam
RAMBLERS
2012
1968-1971
N1-RAMBLERS PARK
RM 4
D50: 77mm
SOUTH NACHES RD.
D50: 58mm
RM 5
RM 4.5
lplain
Incipiant avulsion
Sediment blocking side channel
Thalweg entrenched against colluvial valley wall
A
A'
B
B'
C
C'
S Naches Rd
0 250 500 1,000 Feet
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

Geomorphic Conditions: RM 3.8 to RM 1.6

- Channel position in this reach is governed by Nelson Dam, downstream bridge abutments, and the bedrock valley wall. The dam and bridge abutments force the channel diagonally across the valley to where it abuts the left bank bedrock valley wall and is turned downstream.
- Extreme reach-wide constriction compared to historical conditions in this reach has concentrated flow in the active channel and caused it to shift from a historic wandering planform to a nearly straight, single-thread planform.
- Local pronounced constrictions, such as at the confluence of Cowiche Creek and the Naches River, do appear to promote upstream sedimentation and channel migration.
- Floodplain pits in the vicinity of RM 2.2 to RM 1.4 were captured in the 1970s. Even though not entirely filled, these are now largely isolated from the active channel.


Overview of pebble count location at RM 3.6.

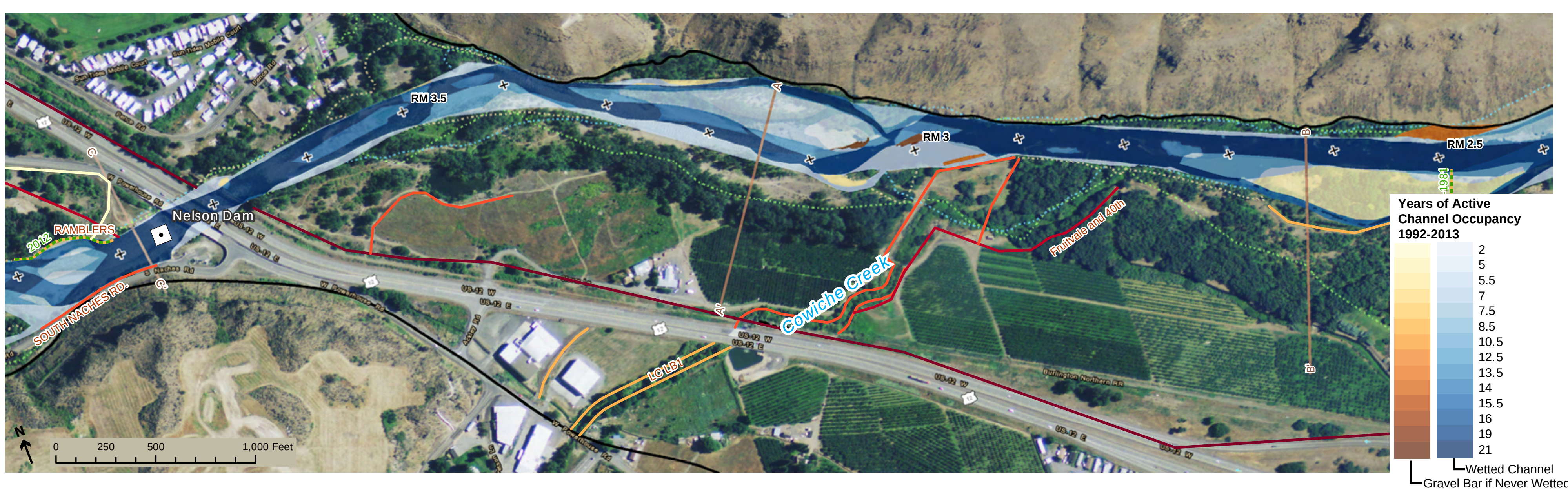


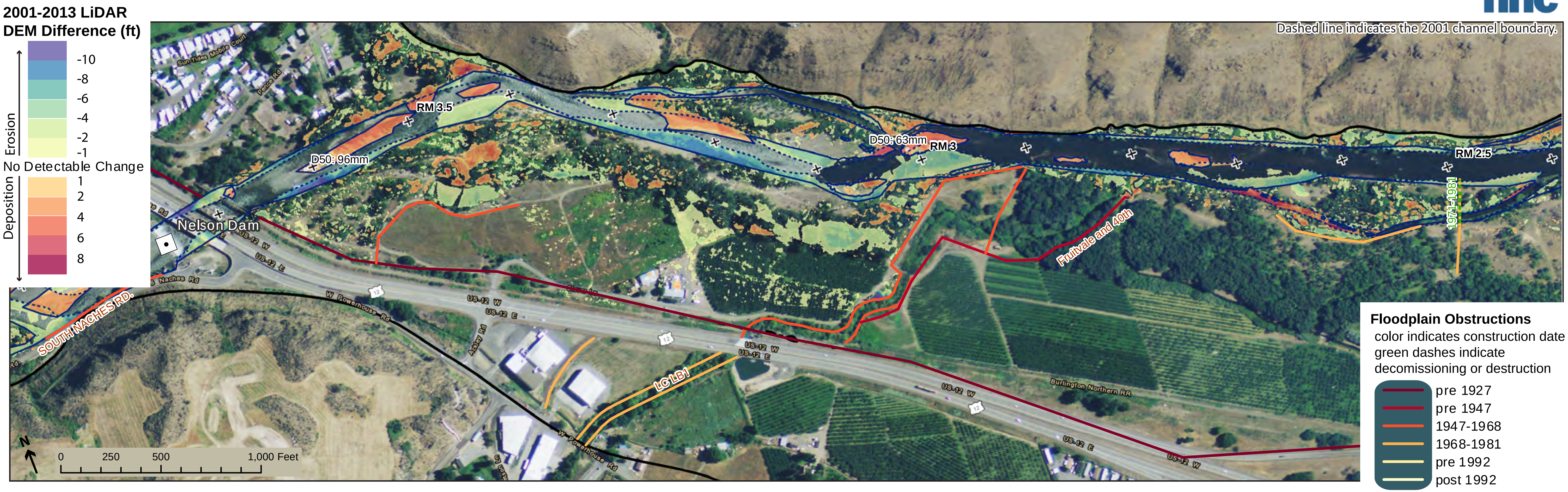


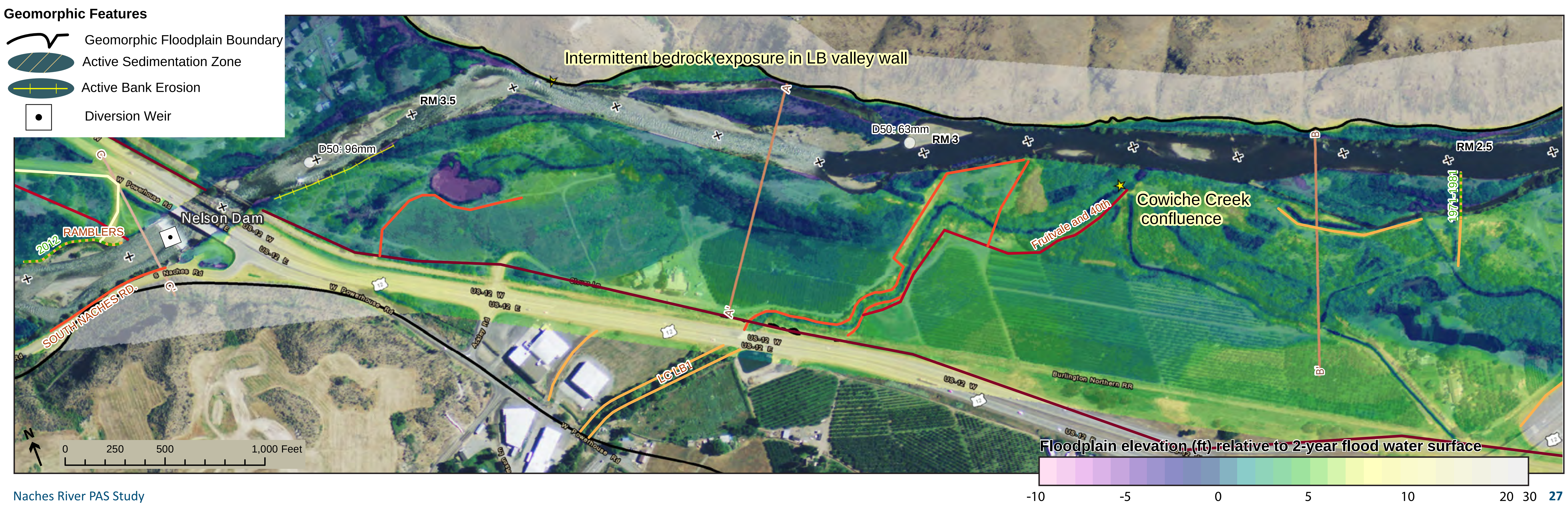

Nelson Dam viewed from under the Highway 12 Bridge.


Left bank bedrock outcrop at RM 3.35.


Overview of pebble count location at RM 3.0 and detail of sampled deposit.




2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Dashed line indicates the 2001 channel boundary.
RM 3.5
D50: 96mm
D50: 63mm
RM 3
RM 2.5
Nelson Dam
1971-1981
Fruitvale and 40th
SOUTH NACHES RD.
LC LB1
US-12 W
US-12 E
W Powerhouse Rd
Burlington Northern RR
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
N
0
250
500
1,000 Feet

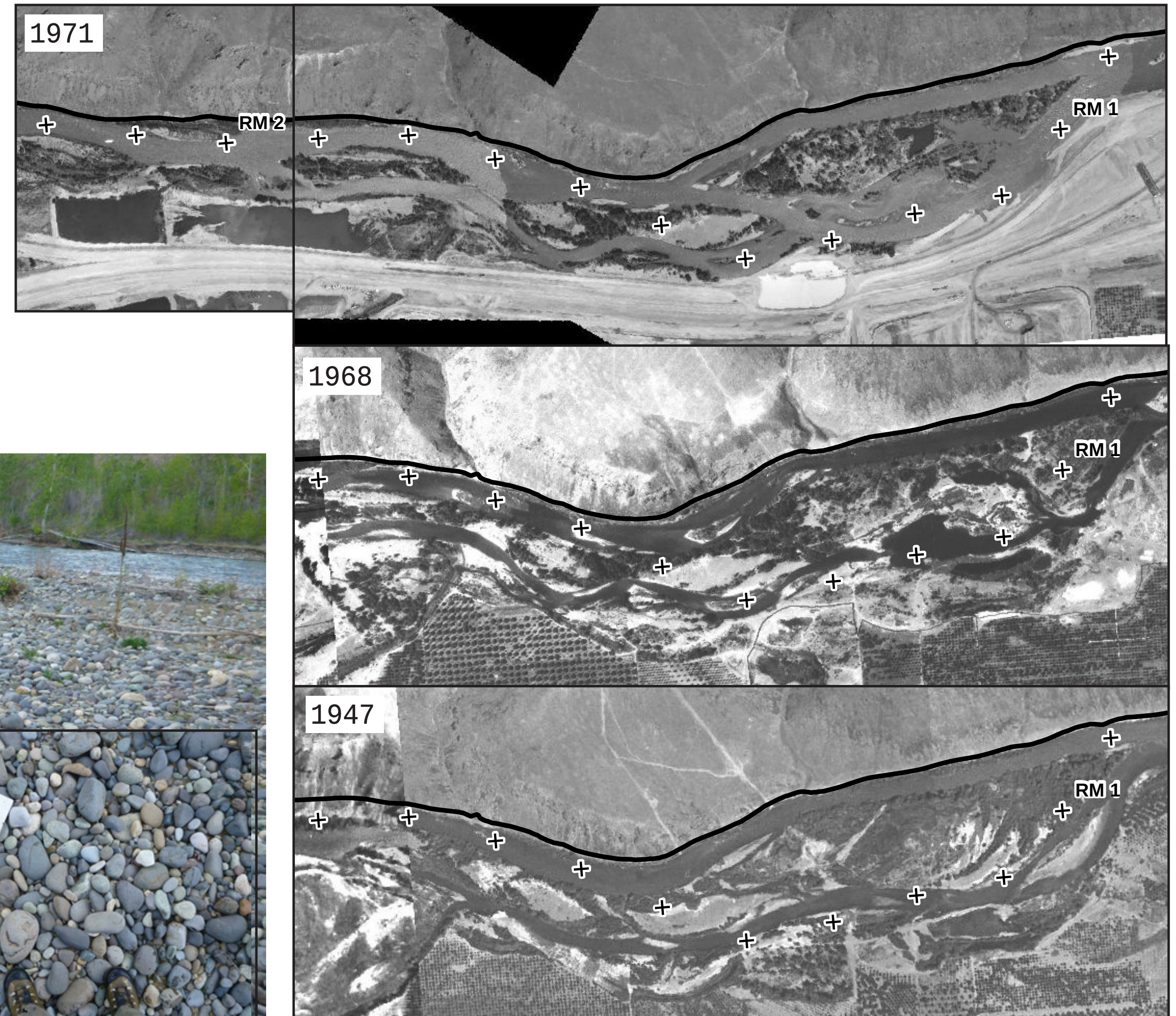

Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Intermittent bedrock exposure in LB valley wall
RM 3.5
D50: 96mm
D50: 63mm
RM 3
RM 2.5
Nelson Dam
RAMBLERS
2012
1971-1981
Fruitvale and 40th
Cowiche Creek confluence
SOUTH NACHES RD.
LC LB1
US-12 W
US-12 E
W Powerhouse Rd
Burlington Northern RR
N
0
250
500
1,000 Feet
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

nhc

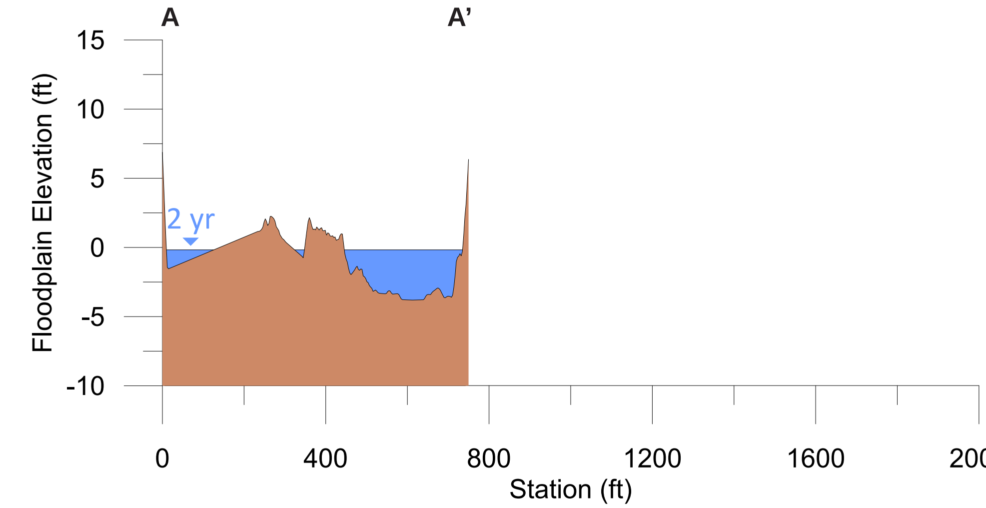
Geomorphic Conditions: RM 1.6 to RM 0.9

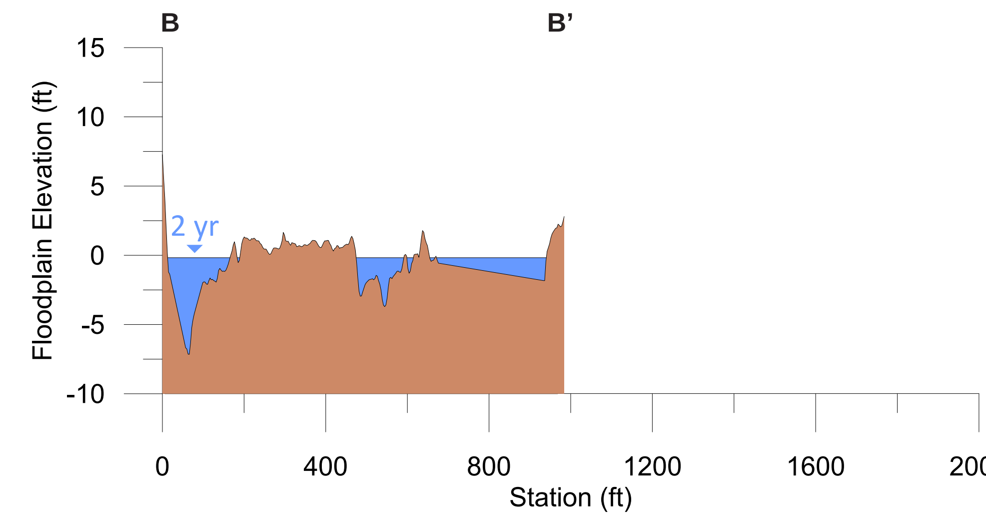
- A pronounced constriction at RM 0.9 creates a zone of persistent sedimentation through this reach upstream.
- This constriction was a nodal point in the active channel in the early 20th century, but was built to a high elevation that blocked floodplain flow conveyance during construction of Highway 12 between 1968 and 1971.
- Presently, a set of rock barbs protect Highway 12 between RM 1.5 and RM 1.0. These have induced local deposition of sandy gravel.

Overview of pebble count location at RM 3.0 and detail of sampled deposits. The right detail image is the unwinnowed gravel deposit, while the left detail image is from the bar apex and shows the texture of the material after armor development.



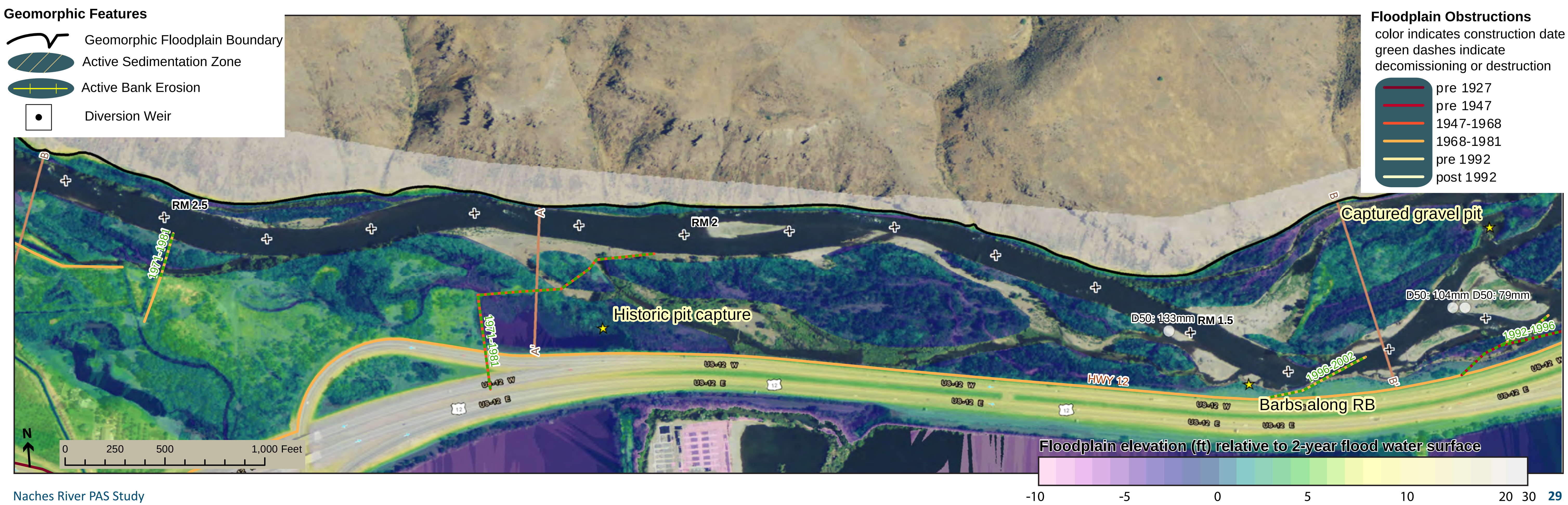
Sequence of mid-century historical aerial photos showing persistent node at RM 0.9 and several aggregate pits excavations.





Overview of pebble count location at RM 1.5 and detail of sampled deposit.

2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
Dashed line indicates the 2001 channel boundary.
RM 2.5
RM 2
RM 1.5
D50: 133mm
D50: 104mm D50: 79mm
1971-1981
1996-2002
1992-1996
HWY 12
N
0 250 500 1,000 Feet

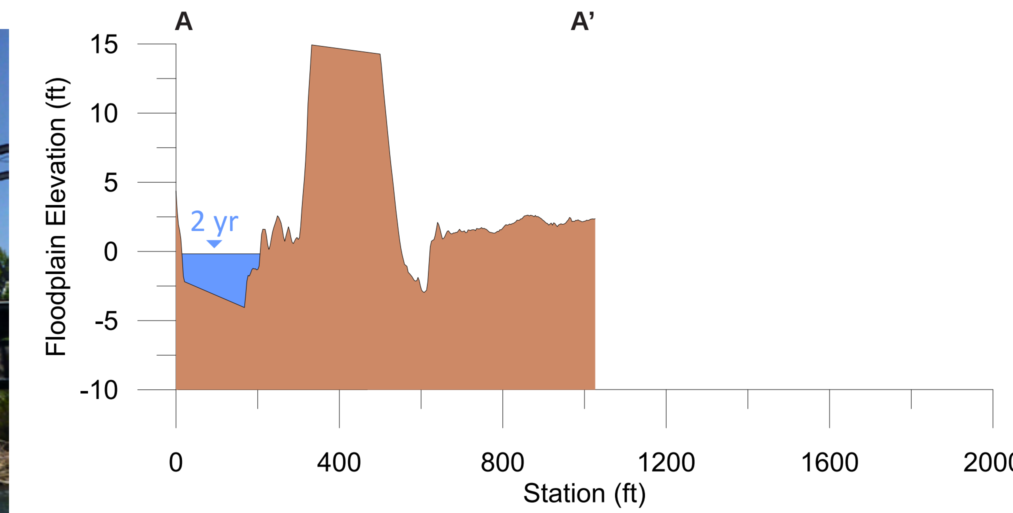


Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
RM 2.5
RM 2
RM 1.5
Historic pit capture
Captured gravel pit
Barbs along RB
D50: 133mm
D50: 104mm D50: 79mm
1971-1981
1996-2002
1992-1996
HWY 12
N
0 250 500 1,000 Feet
Floodplain elevation (ft) relative to 2-year flood water surface
-10 -5 0 5 10 20 30

nhc

Geomorphic Conditions: RM 0.9 to RM 0.0

- Persistent confinement along this reach by Highway 12, a railroad bridge, levees, and the I-82 bridges maintains efficient conveyance of flow and sediment through this reach.
- During some flow conditions, the backwater affects from the Yakima River may influence this reach, causing bedload conveyed by the Naches to temporarily accumulate, but bars indicative of this process are very small, suggesting that common flows are sufficient to push this material through to the Yakima River.



Bridge-confined corridor of the lower portion of this reach.

Historic Aerial photos showing early and dramatic confinement of the reach. Note sedimentation upstream of the Railway bridge in 1927.

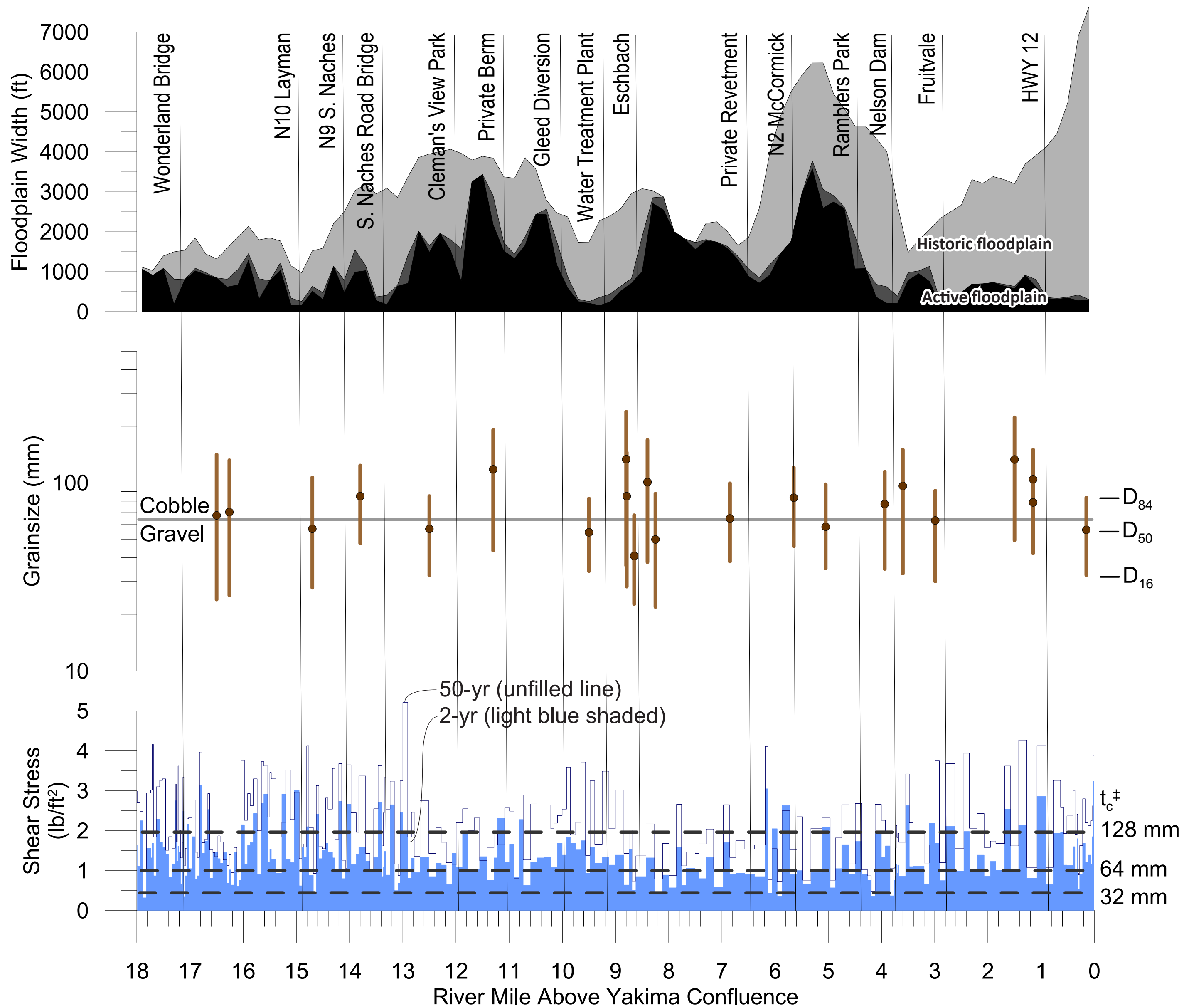
Mouth-bar at RM 0.7 indicative of sediment deposition into a backwatered environment.

Overview of pebble count location at RM 0.15 and detail of sampled deposit.

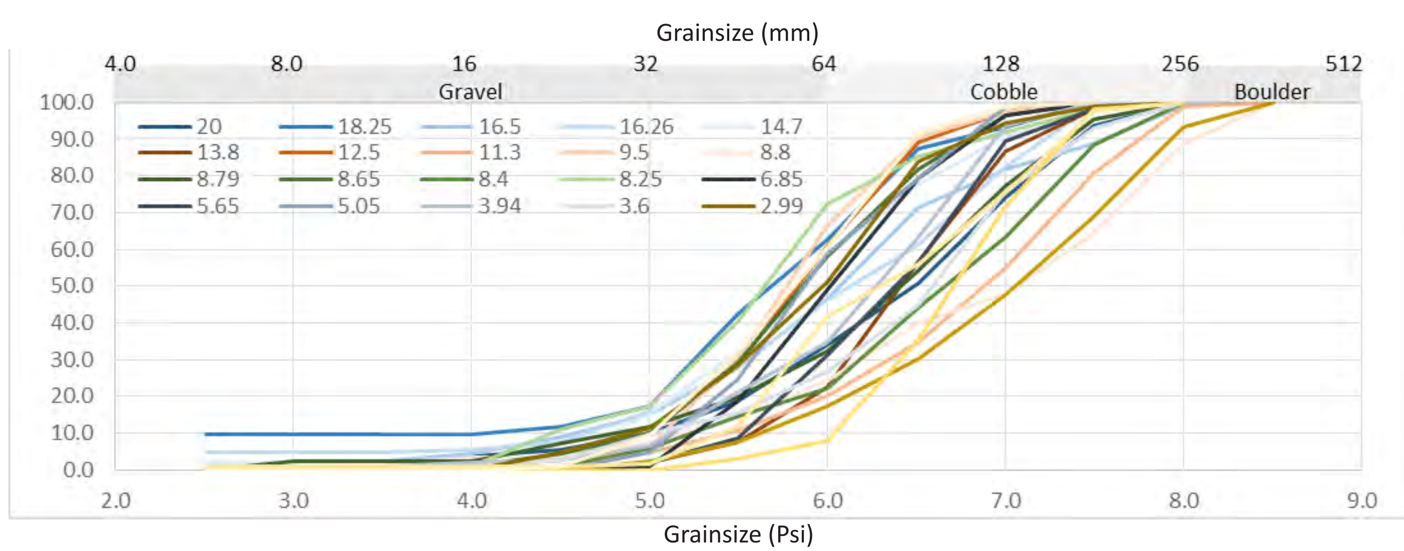

Dashed line indicates the 2001 channel boundary.
2001-2013 LiDAR DEM Difference (ft)
Erosion
-10
-8
-6
-4
-2
-1
No Detectable Change
Deposition
1
2
4
6
8
RM 0
RM 0.5
RM 1
D50: 56mm
D50: 79mm
D50: 104mm
1981-1992
1992-1996
FEDERAL RIGHT BANK UPPER
HWY 12
0 250 500 1,000 Feet
N


Geomorphic Features
Geomorphic Floodplain Boundary
Active Sedimentation Zone
Active Bank Erosion
Diversion Weir
Floodplain Obstructions
color indicates construction date
green dashes indicate
decomissioning or destruction
pre 1927
pre 1947
1947-1968
1968-1981
pre 1992
post 1992
gravel pit
RM 0
RM 0.5
RM 1
D50: 56mm
D50: 79mm
D50: 104mm
1981-1992
1992-1996
FEDERAL RIGHT BANK UPPER
HWY 12
0 250 500 1,000 Feet
N
Floodplain elevation (ft) relative to 2-year flood water surface
-10
-5
0
5
10
20
30

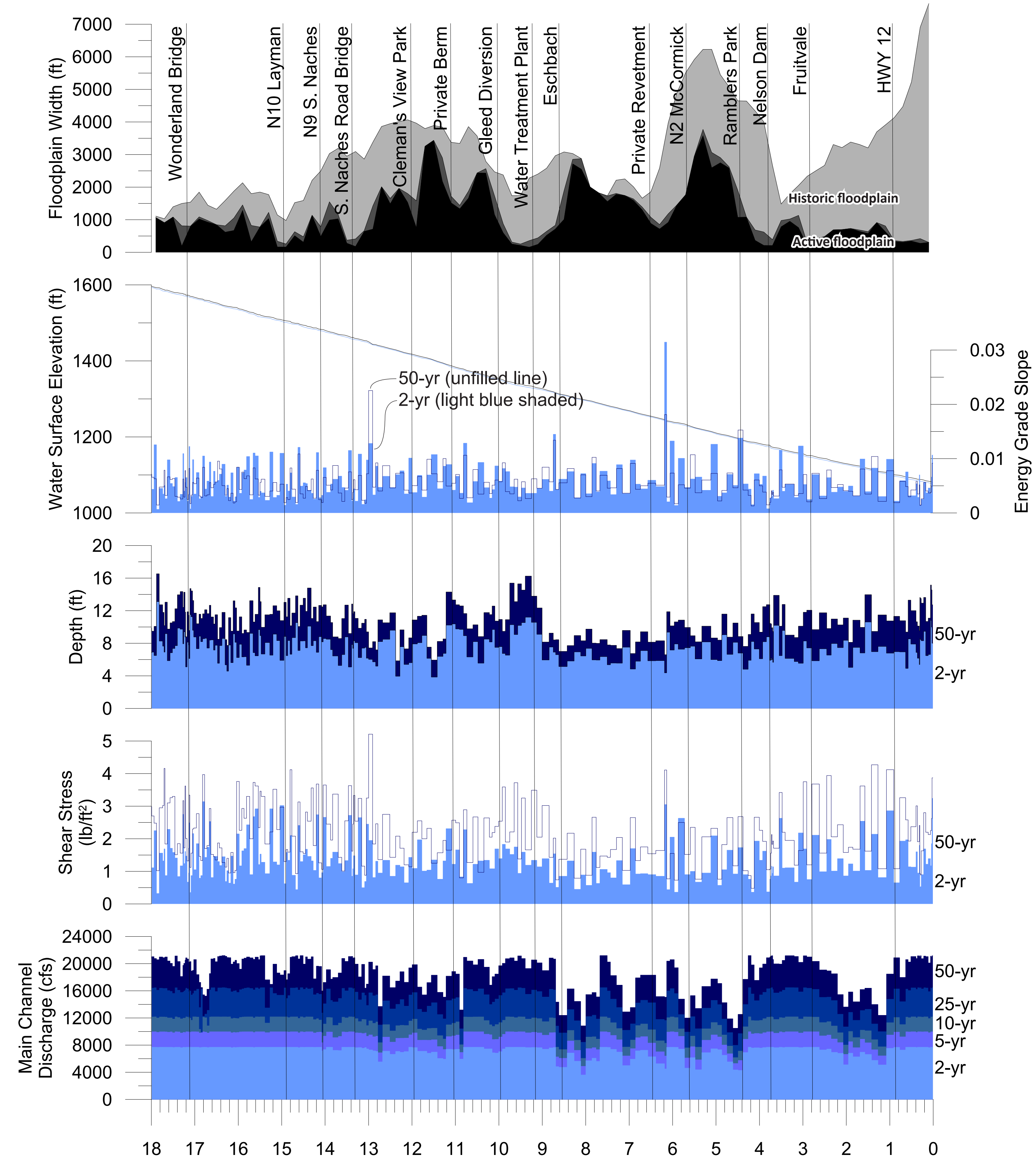
Active Bed Material



‡ Assuming t*c = 0.045

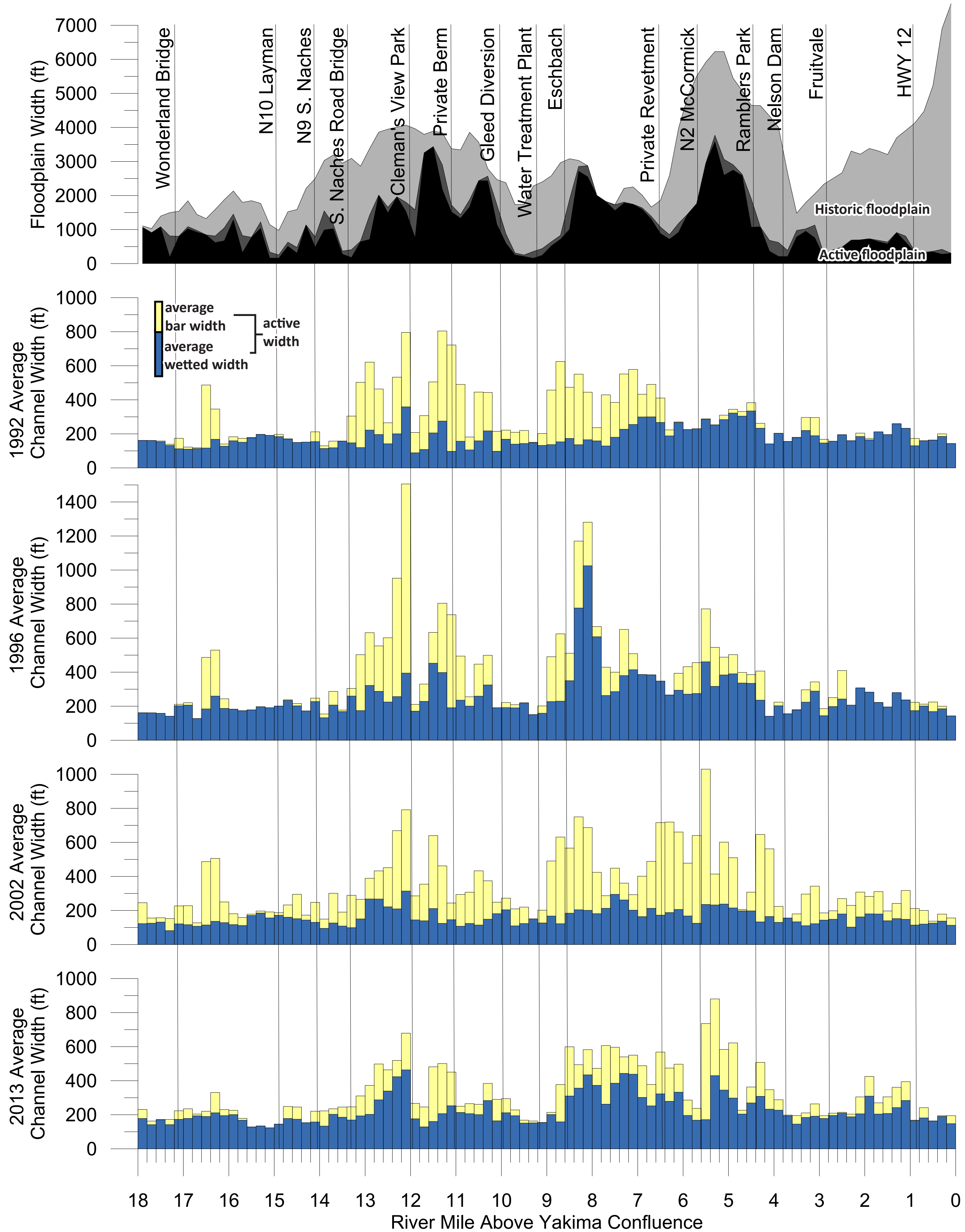


Hydraulics (preliminary)

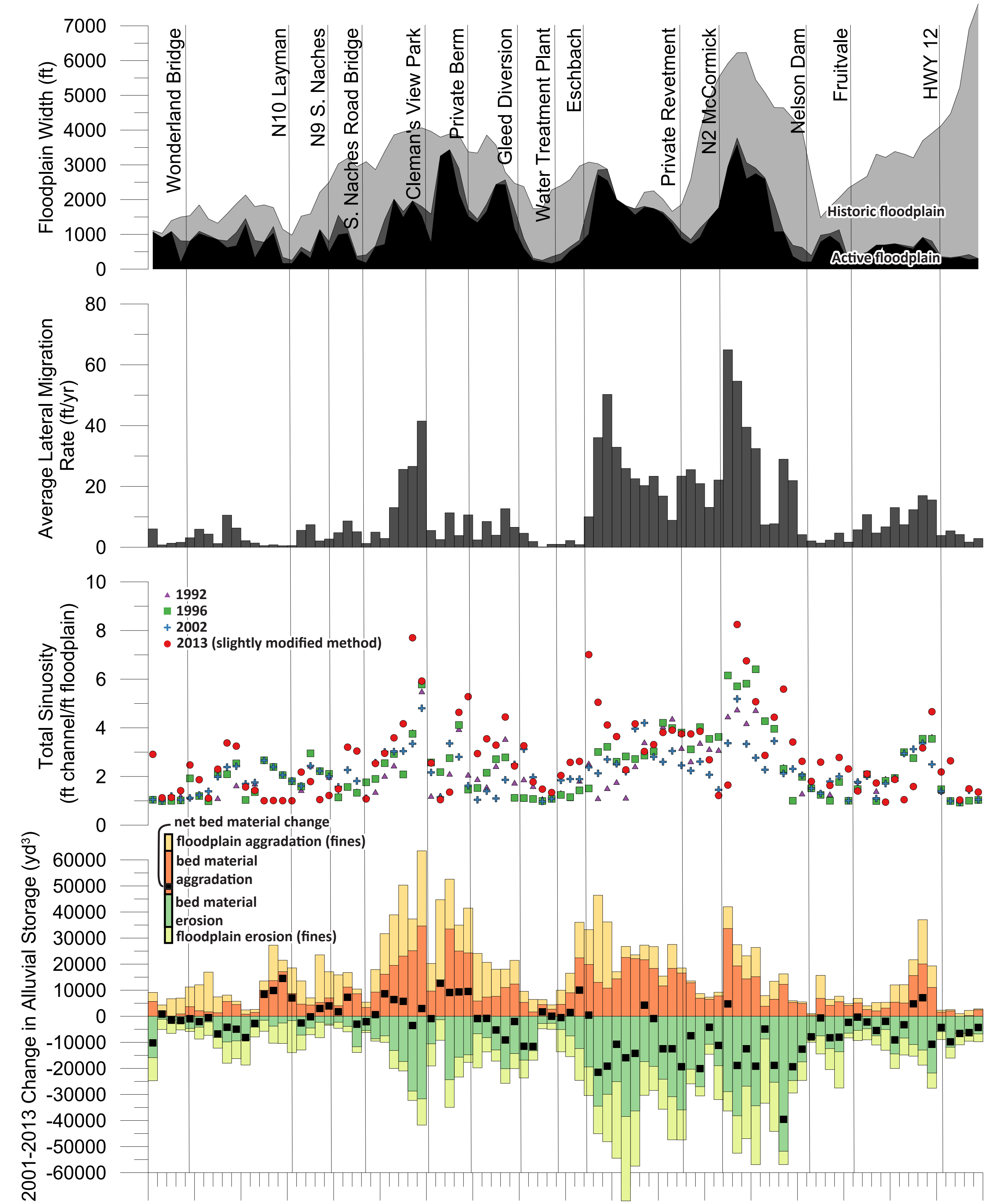


Note: Discontinuities in main channel discharge indicate floodplain conveyance.

Channel Width



Channel Stability



Geomorphic Conditions Summary

The Lower Naches River is a steep (0.5 to 0.62%) gravel and cobble-bedded river (NHC, 2015 p. 1). It is characterized by a laterally active, wandering planform with two or three channels anabranching around forested islands. Howver, revetments and other constrictions have locally created long single thread reaches and some other areas are braided, with four to eight channels conveying water around unstable bars during low-flow conditions (p.33). Wandering gravel bed rivers (Type 5 of Nanson and Knighton, 1996) are a transitional form between meandering and braided systems, they commonly occur in mountainous regions. In these systems, meander amplification and sedimentation within the main active channel occasionally reduce flow conveyance in that channel to the point that flow spills onto the floodplain, forming avulsion channels.

In 2013 aerial photos, the wetted channel (including all branches in multi-thread segments) ranges from about 100 to 500 feet wide, and the active channel ranges from about 150 to 900 feet wide. This variability in channel width reflects variability in bank strength, floodplain conveyance, and vertical channel stability along the reach.

Regime models accounting for these factors can elucidate the magnitude of influence these various factors play in governing channel planform and width (Eaton et al., 2004; Eaton, 2006; Eaton et al., 2010; Millar et al., 2014). These models, when applied to various combinations of controlling factors (acting either presently or historically) along the Lower Naches show the following patterns:

Increasing bank strength either through vegetative establishment or placement of revetments is expected to reduce the number of channels and total active width. If grainsize and bank strenght are held constant, increasing the proportion of flow in the main channel by blocking floodplain conveyance is expected to increase the total active width and number of channels in the area of concentrated flow. Deviation from predicted regime dimensions can provide an indication of vertical stability:

- Over-wide reaches (acitve width greater than approximately 400-500 ft) suggest channel aggradation may be occurring.
- Narrow reaches (active width less than approximately 300 ft) indicate high bank strength, channel downcutting, or both factors.

Often, a combination of both downcutting and high bank strength can influence channel planform in confined reaches (Germanoski and Schumm, 1993; Church, 2006), as is likely the case along the Gleed Diversion reach from RM 7.1 to 10.1 (p. 17) or downstream of Nelson Dam from RM 1.5 to 3.7 (pp. 27-29). On the Lower Naches, reaches where floodplain conveyance is blocked by levees tend to be relatively narrow, suggesting that the influence of increased bank strength from revetments and channel downcutting overpower the influence of increased discharge in the channel.

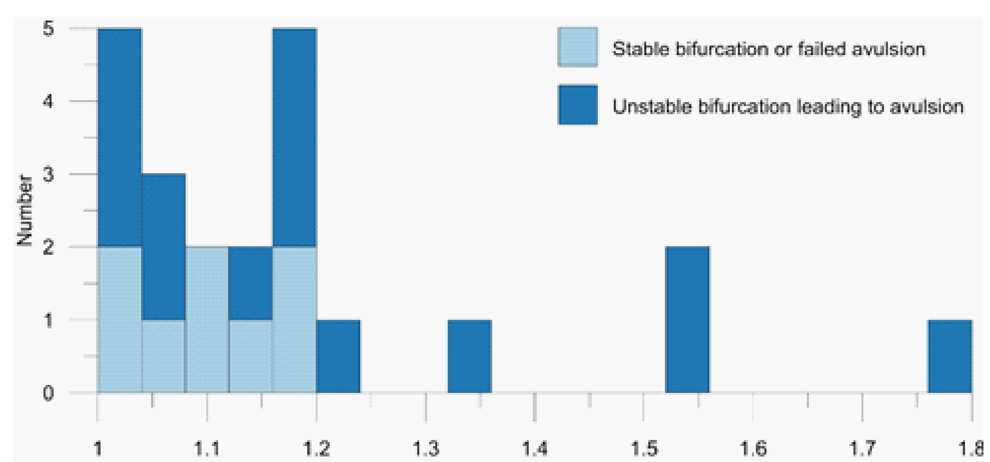
The regime model also suggusts that, assuming a pre-regulation formative discharge of 9,500 cfs prior to regulation, the active channel may have been 50% wider and dominated by a braided planform morphology.

Channel Migration

Migration of the lower Naches River occurs through two dominant processes, gradual meander bend shifting and abrupt avulsion (p. 4-31). Observed lateral migration rates along the lower Naches vary dramatically between reaches (p. 33), from near zero in channelized reaches with armored banks to 20-60 feet per year in unstable areas.

In cases of meander bend migration, point bar growth on the inside of the bend (and occasionally mid-channel bar formation) and erosion of the bank along the outside of the bend typically exchange approximately equal volumes of bed material on the lower Naches River, because point bars are typically built to near-floodplain elevation (p. 33). Most of the material eroded from these banks consists of coarse cobble-gravel alluvium comparable to typical bed material in the river. Observations of eroding banks along the continuous transect suggest that about 90% of the total volume of bank erosion comes from such coarse alluvium, based on a weighted average of observed material in eroding banks. The remaining 10% consists of sand and silt overbank deposits that would be carried as wash load in the river.

On the lower Naches, avulsions typically occur after meander amplification has lengthened the course of the main channel and reduced its slope to the point where a large volume of flow escapes the channel during floods, crosses the floodplain, and excavates a shorter, more hydraulically efficient path. Numerous historic, active, and incipient avulsions are apparent from both field observations and GIS analysis (pp. 13-25, 29). As with meander migration, the floodplain material excavated by avulsions is likely coarse alluvium similar to the river's present bed material. Material filling abandoned river channels, however, is often the finest observable in the system and can range from cobble-gravel alluvium to sand and silt in backwatered abandoned channels (e.g. p. 19 and p. 24). Two parameters generally specify conditions in which avulsions are likely to occur: superelevation and slope ratio . Superelevation is a measure of how high the channel is perched above the surrounding floodplain, and slope ratio is defined as the ratio of the slope of a possible avulsion path to the down channel slope. Histograms of observed slope ratios at stable bifurcations (n=8) and unstable avulsions (n=15) on the lower Naches indicate that avulsions may occur at very low slope ratios of one to two.



Histograms of lower Naches River bifurcation slope ratios.

Lateral meander migration destroying an abandoned structure at RM 8.3.

Enlarging floodplain avulsion channel at RM 11.15

Sediment Transport

It is critical to hold the channel migration dynamics of a river in mind while considering sediment transport, as the two processes are intimately connected (Wickert et al., 2013; Constantine et al., 2014; Nelson and Dubé, in revision). In sedimentation reaches[1] of the lower Naches, field observations and grainsize distributions suggest that bed load is typically mobilized from eroding banks, transported a short distance downstream (1-2 meander wavelengths or 1-2 times the distance between major bars), and deposited locally in bars. These bars then often stabilize with vegetation and become floodplain until the channel again —perhaps after decades or centuries— migrates into that position, erodes the material and passes it to bars downstream. This pattern of bed material transport, where sediment transport occurs primarily through channel migration is characteristic of wandering gravel bed river like the lower Naches (Neill, 1983; Church, 2010; Reid and Church, 2015). The exception to this pattern occurs in reaches laterally constricted by infrastructure such as in the vicinity of the Gleed Diversion (p. 17), where revetments make the banks immobile. High shear stress in these areas flushes bedload downstream and may move it directly from active bar to active bar without long immobile periods in the floodplain. A combination of reduced local sediment supply from bank erosion, channel planform response to bank strengthening, and increased shear stress can cause these reaches to downcut (Galay, 1983; Reid and Church, 2015).

Because most bedload transport in sedimentation reaches occurs through the process of bank migration and bar growth, cut and fill volumes between the 2001 and 2013 LiDAR datasets can be used to estimate the river's bedload transport rate. Over this period, cut and fill analysis of the LiDAR data shows that local erosion and deposition volumes in sedimentation zones were typically between 10,000 and 40,000 yd^3 per 0.2 mile segment of the river (p. 33), which gives a range from 0.8 to 3 yd^3/ft/yr. Before this value can be converted to a sediment transport rate, the distance material moves after it is eroded from a bank must be determined to define the appropriate scale of aggregation. The minimum plausible distance is the typical length of eroding banks (930 ± 430 ft). The estimated virtual velocity for the sediment based on the regression of Beechie (2001), which scales as approximately 20 times the river's bankfull width probably provides the best estimate. Applying this range of input parameters and correcting for the estimate of 10% washload for areas of floodplain erosion gives a morphologic estimate of the rivers bed material load transport rate, shown in Table 1. This estimate is comparable to bed load estimates from typical regional sediment yield and bed load fractions, shown in Table 2. These two estimates provide bounds on likely bed load transport rates in the river, useful for evaluation of numerical modeling approaches described later. Through a broad range of plausible values are presented, the 20X bfw (narrow) condition (Table 1) and some value between the Yakima River and Church and Slaymaker (1989) main trend are likely the best estimates. Taken together, these suggest a bed material transport rate in the range of 3,000 to 10,000 yd^3/yr.

These estimates are consistent with the modeled bed load transport from the Naches River to the Yakima, which was used as one upstream boundary condition for the Naches River sediment transport model by USACE (2015). Hilldale and Godaire (2010) used a rating curve which produces 3,900 yd^3/yr of bedload transport when applied to a 25 year hydrograph record for the Naches.

Example of typical coarse alluvium supplied by eroding banks.

Table 1: Morphologic Bed Material Transport Estimate, given in yd^3/yr

Typical volumetric change (yd^3/ft/yr)	----------- transport step length estimate ----------- Mean eroding bank length 930 ft	Mean eroding bank length +1 σ 1360 ft	20 X bfw (narrow) 4000 ft	20 X bfw (medium) 6000 ft
0.8	670 yd^3	980 yd^3	2,900 yd^3	4,300 yd^3
3	2,500 yd^3	3,700 yd^3	11,000 yd^3	16,000 yd^3

Table 2: Empirical Bedload Transport Estimate

Sediment Yield Estimate Source	sediment yield (tons/mi^2/yr)	total load* yd^3/yr	bed load assuming various bed load fractions** (yd^3/yr) 0.4	0.2	0.1
Yakima River at Yakima (Hilldale and Godaire, 2010)	30	18,000	7,100	3,500	1,800
Church and Slaymaker (1989) BC trend	100	60,000	24,000	12,000	6000
Average of Czuba et al (2011) & upper bound of Church & Slaymaker main trend	480	290,000	110,000	57,000	28,500

* assuming 660 mi^2 bed load contributing basin and bulk density of 1.1 tons/yd^3. A total load approaching or greater than 87,000 yd^3/yr is unlikely given that figure is Hilldale and Godaire's (2010) estimate of the average annual total load for the Gap to Gap reach of the Yakima River.

** These values represent the likely range of bed load fraction for the Naches, based on regional experience (Dunne et al., 1980) and empirical estimates by basin area (Turowski et al., 2010). Values as low as zero are possible, and values between 10 and 20% are most likely.

[1] A stream reach that flows through a relatively unconfined valley where bar formation forces active channel migration (sensu. Church, 1983). This does not necessarily imply channel bed aggradation or a net increase in sediment storage.

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