Impairments to Fluvial Processes and Development of Restoration Strategies on a Dam-Influenced Reach of the Madison River, Montana

RDG RIVER DESIGN GROUP | NOW PART OF SWCA ENVIRONMENTAL CONSULTANTS

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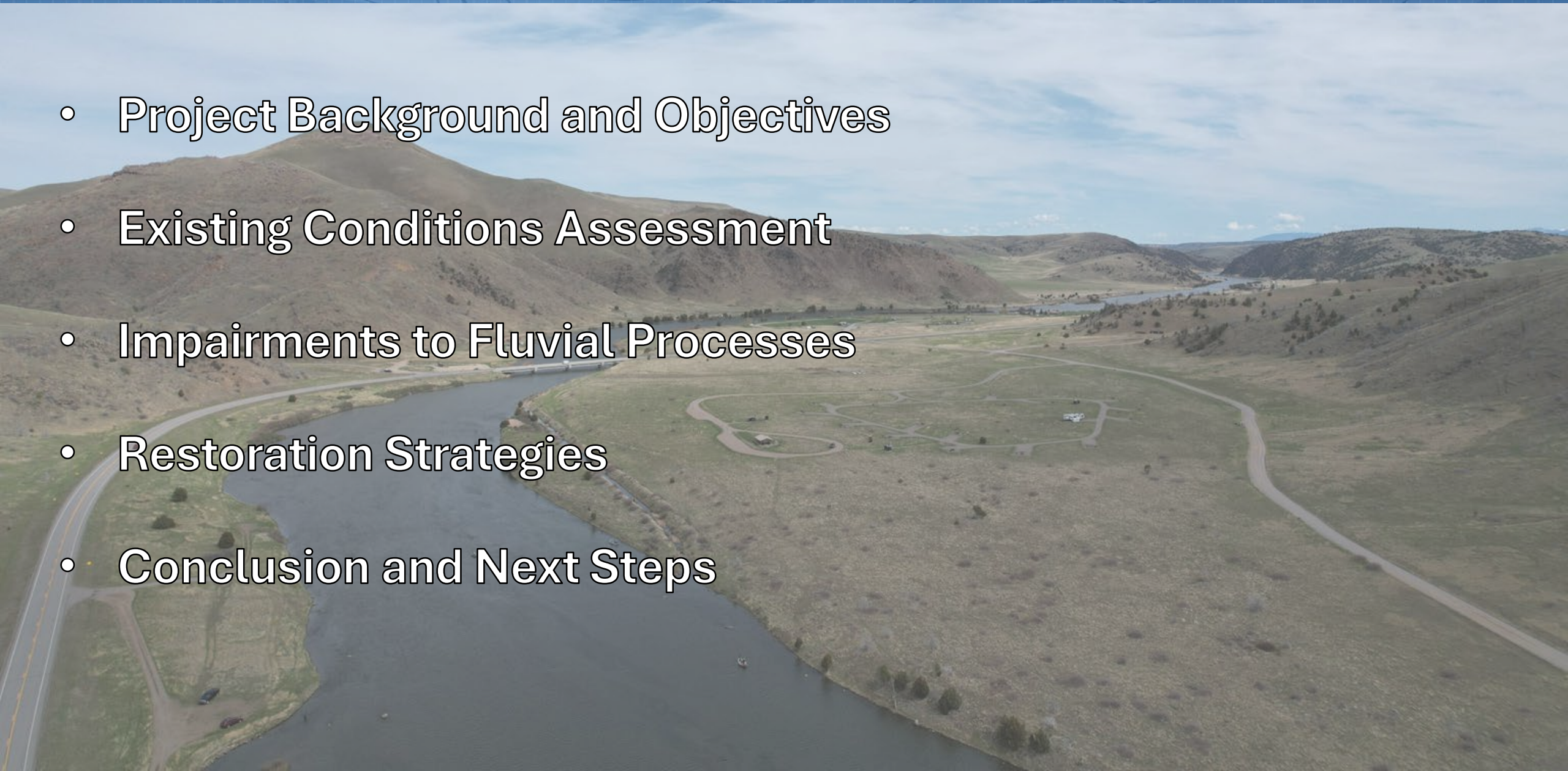
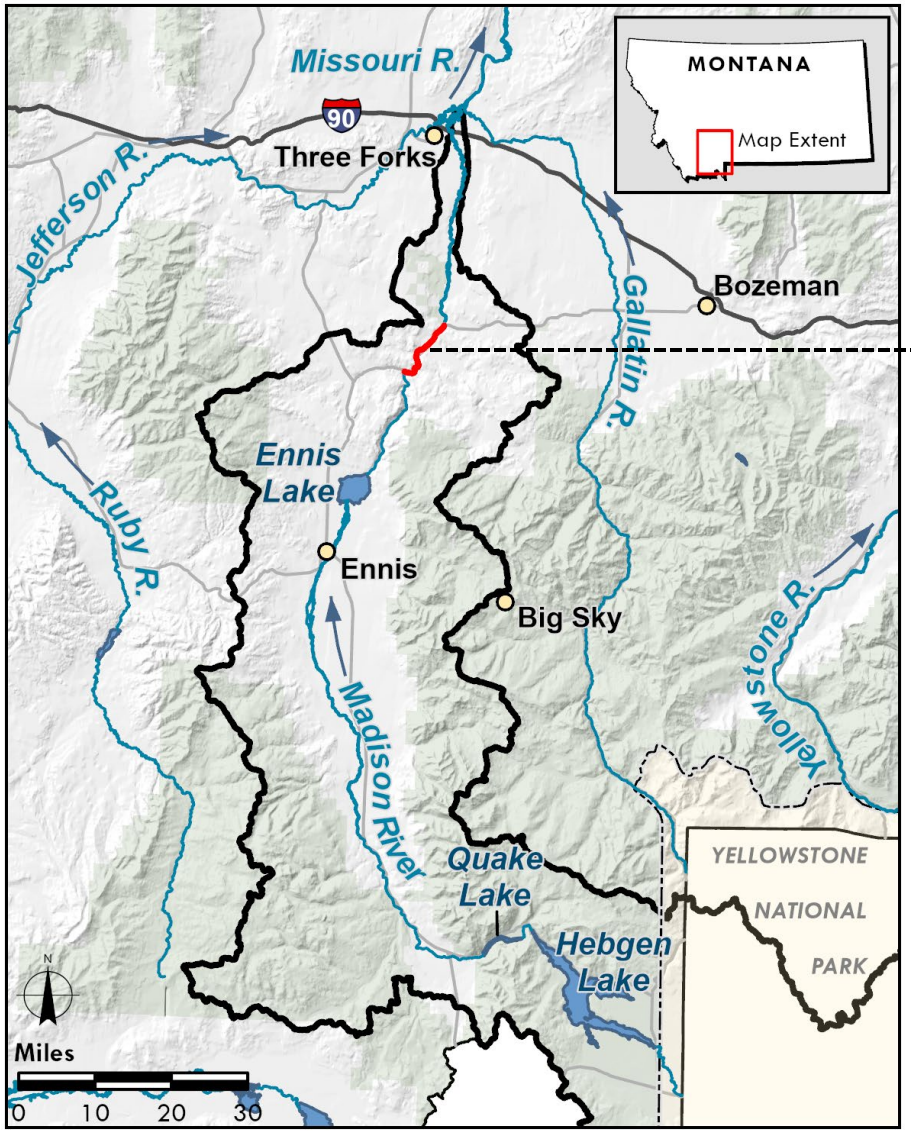
Montana AWRA 2024

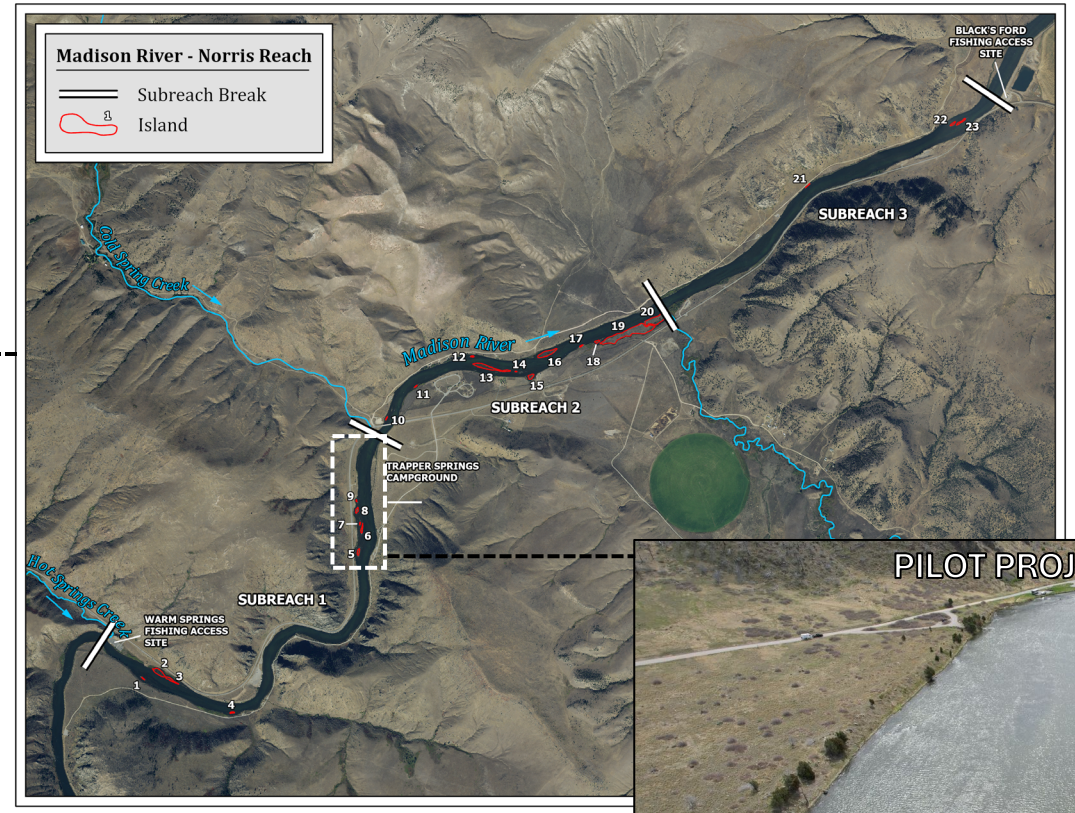
Presentation Overview



- Project Background and Objectives
- Existing Conditions Assessment
- Impairments to Fluvial Processes
- Restoration Strategies
- Conclusion and Next Steps

Project Background

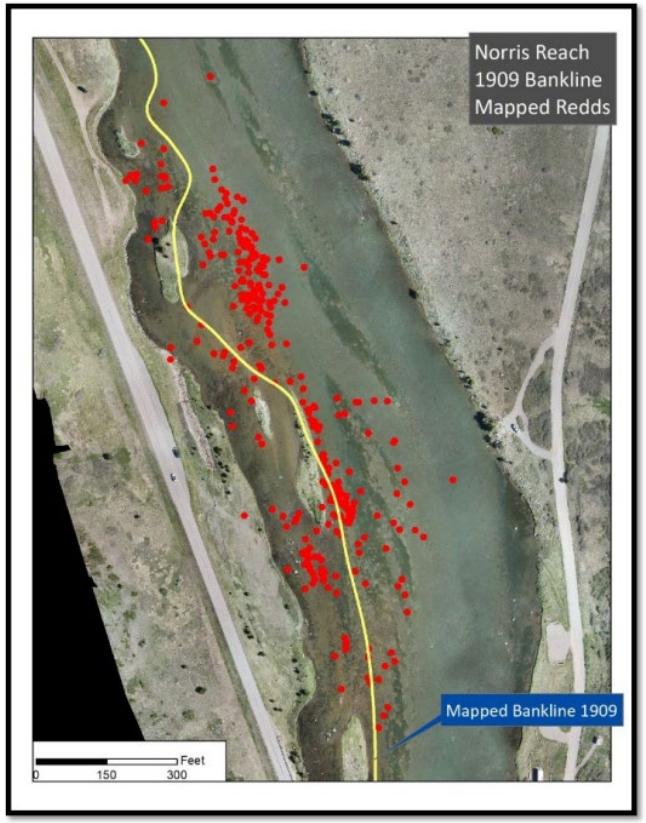




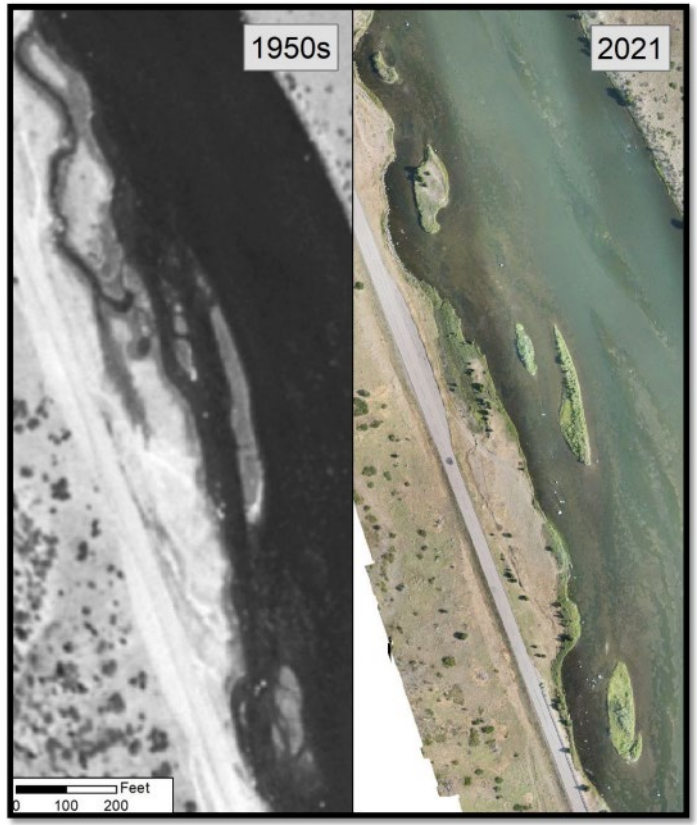
Project Background

Madison River Sediment Mobility Assessment *(Pioneer et al., 2022)*

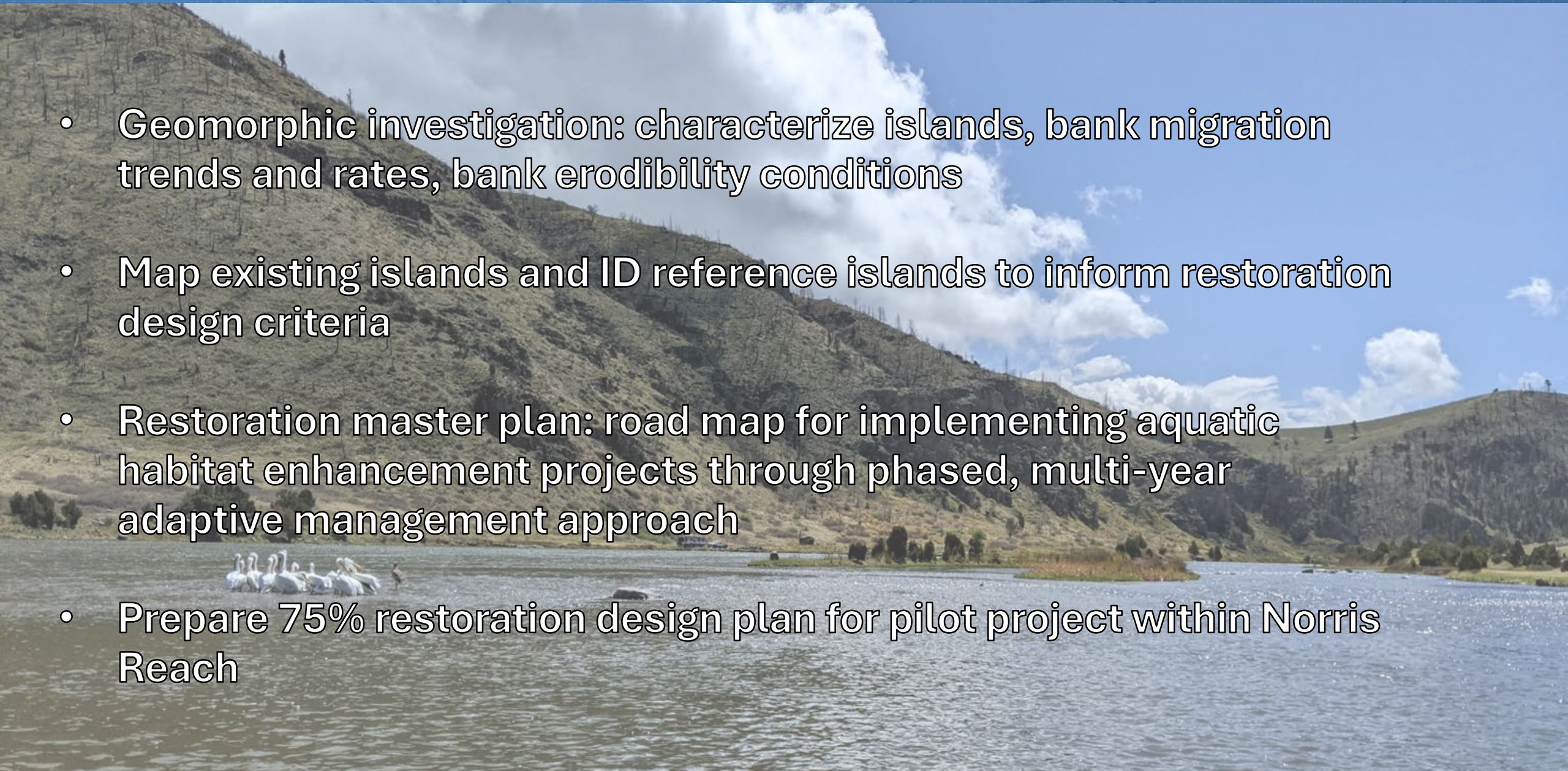
- Norris Reach is becoming progressively depleted of islands
- Ongoing erosion occurring on both island margins and streambanks
- Primary cause for net export of sediment is likely limited sediment supply below Madison Dam
- Redds are concentrated in shallow, low energy areas and on channel and island margins
- Deep, high velocity channel areas exhibit armoring and are deficient in spawning gravels
- D_{50} not mobilized until ~5-year recurrence interval flow



Pioneer et al., 2022



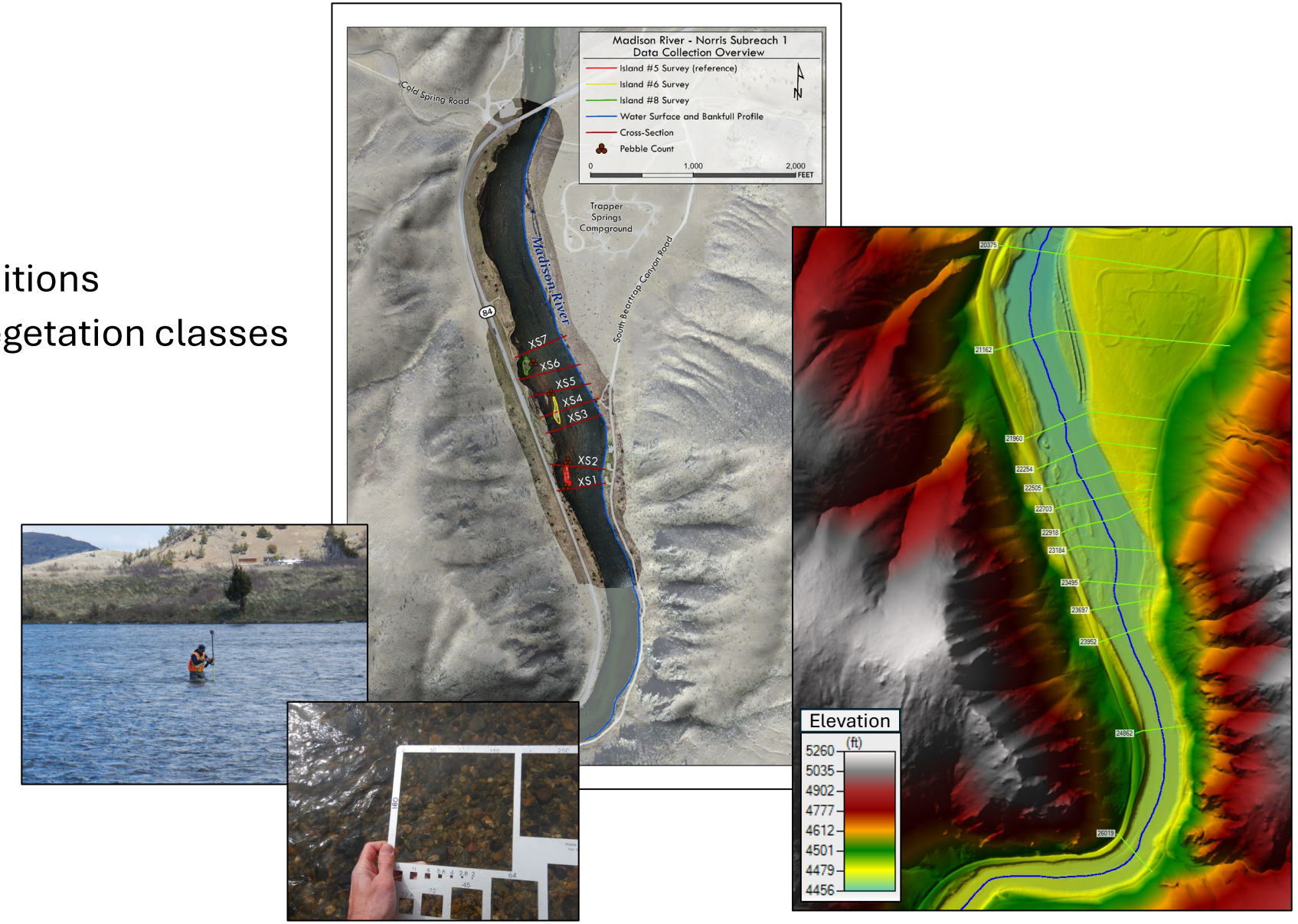
Project Objectives



- Geomorphic investigation: characterize islands, bank migration trends and rates, bank erodibility conditions
- Map existing islands and ID reference islands to inform restoration design criteria
- Restoration master plan: road map for implementing aquatic habitat enhancement projects through phased, multi-year adaptive management approach
- Prepare 75% restoration design plan for pilot project within Norris Reach

Existing Conditions Assessment

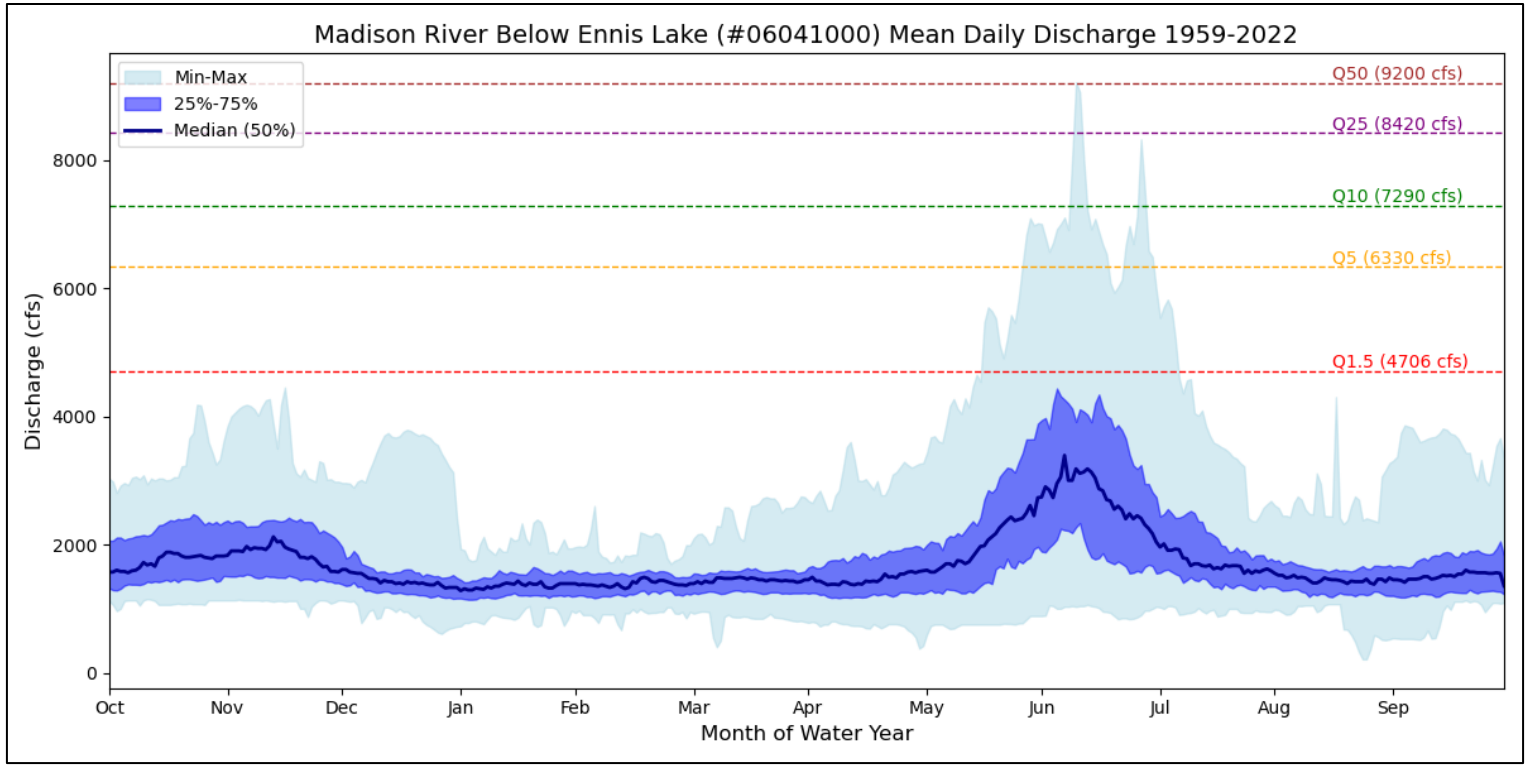
- Hydrology
- Field Assessment
  - Cross sections
  - Longitudinal profile
  - Substrate and bank conditions
  - Island topography and vegetation classes
- Remote Sensing
  - Channel turnover
  - Bank migration
  - Relative elevation model
- 1D Hydraulic Modeling

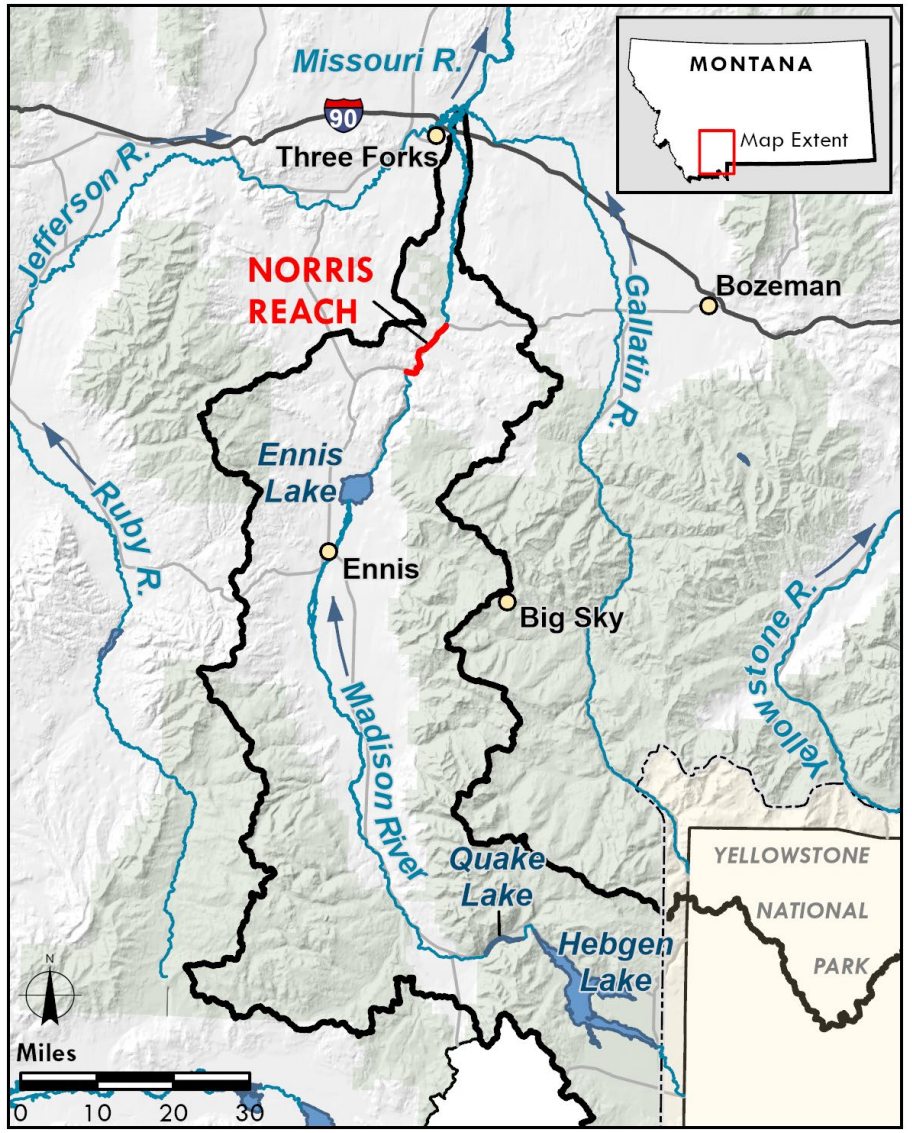


Impaired Fluvial Processes

Flow Regime

- Historical snowmelt-driven hydrology
- 1906: Madison Dam constructed
- 1914: Hebgen Dam constructed
- 1959: Hebgen Lake earthquake and formation of Quake Lake





Impaired Fluvial Processes

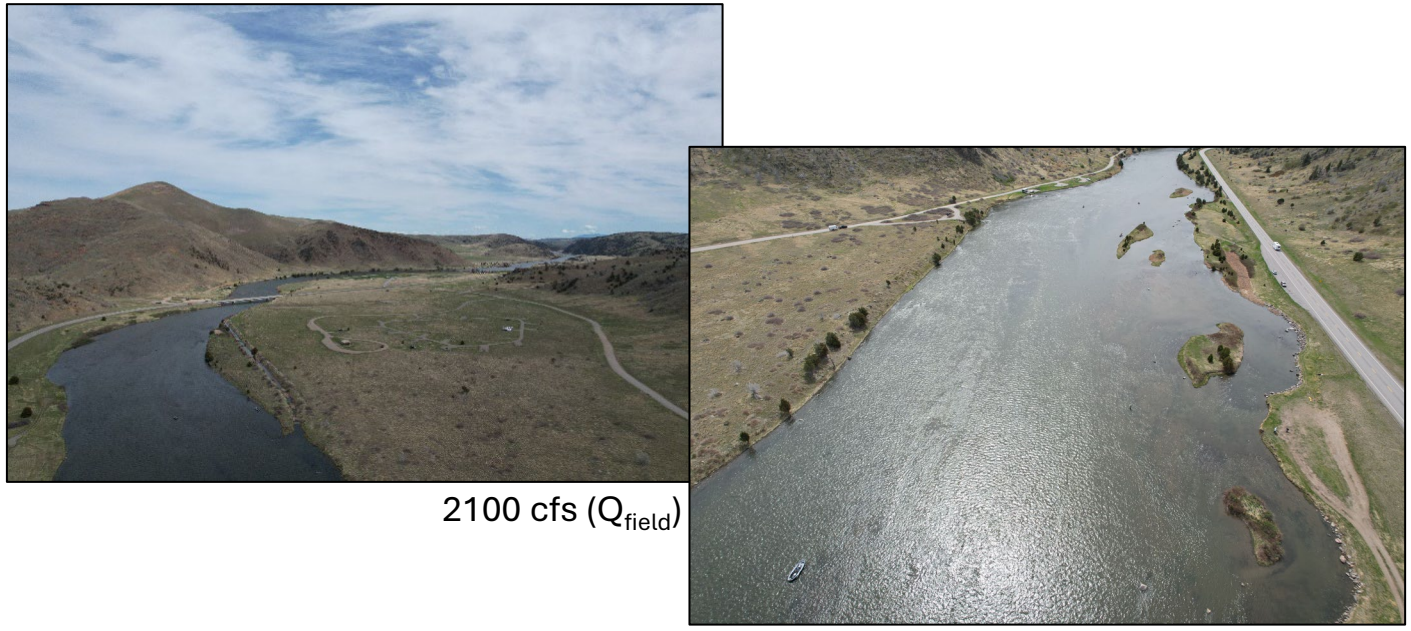
Sediment Regime

- Only wash load transported below Madison Dam (*R2 Resource Consultants Inc., 2018*)
- Substrate primarily composed of large, mostly immobile cobbles
- Limited spawning gravel recruitment and retention
- Elevated fine sediment from tributaries and bank erosion

Impaired Fluvial Processes

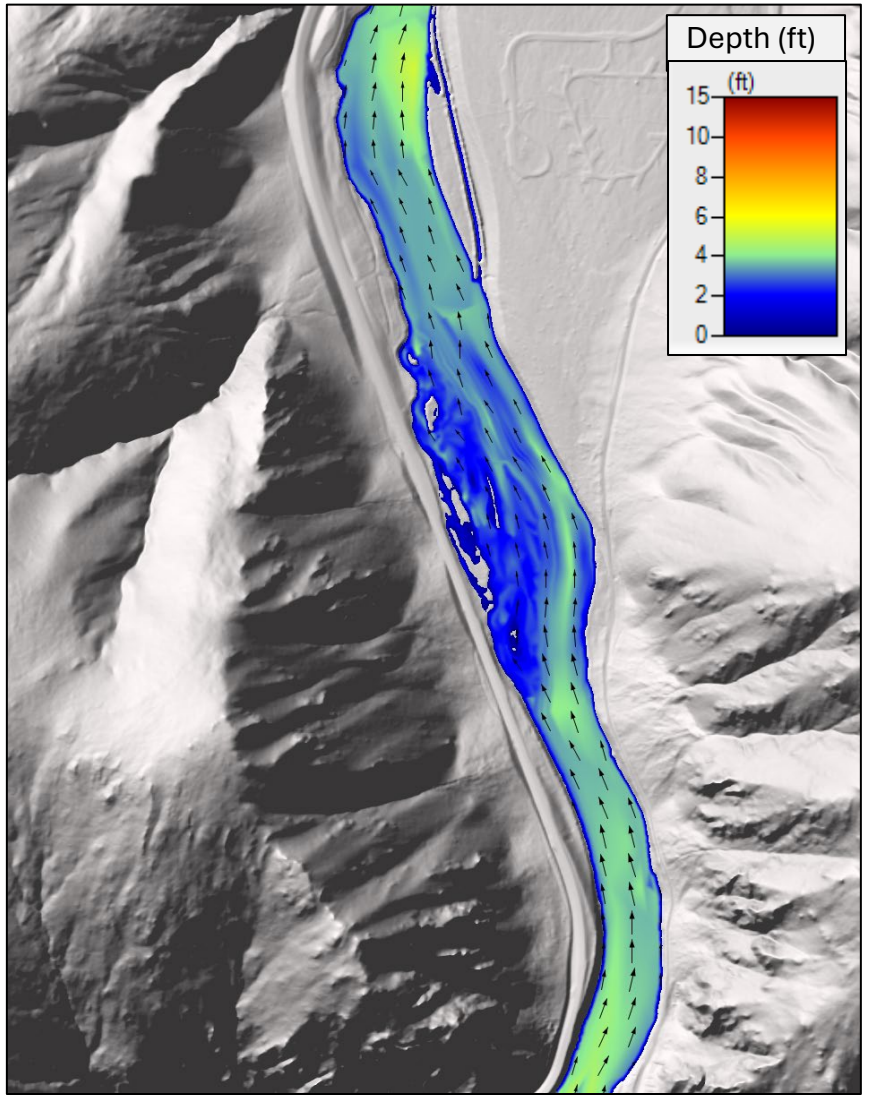
Hydraulic Complexity

- Critical for:
  - Habitat diversity for all life stages of aquatic biota
  - Sediment erosion, deposition, and sorting
  - Hyporheic exchange
  - Water quality (O_2, nutrient cycling)
  - Resilience to disturbance (floods, drought)
  - Refugia during high flows and high temperatures



2100 cfs (Q_{field})

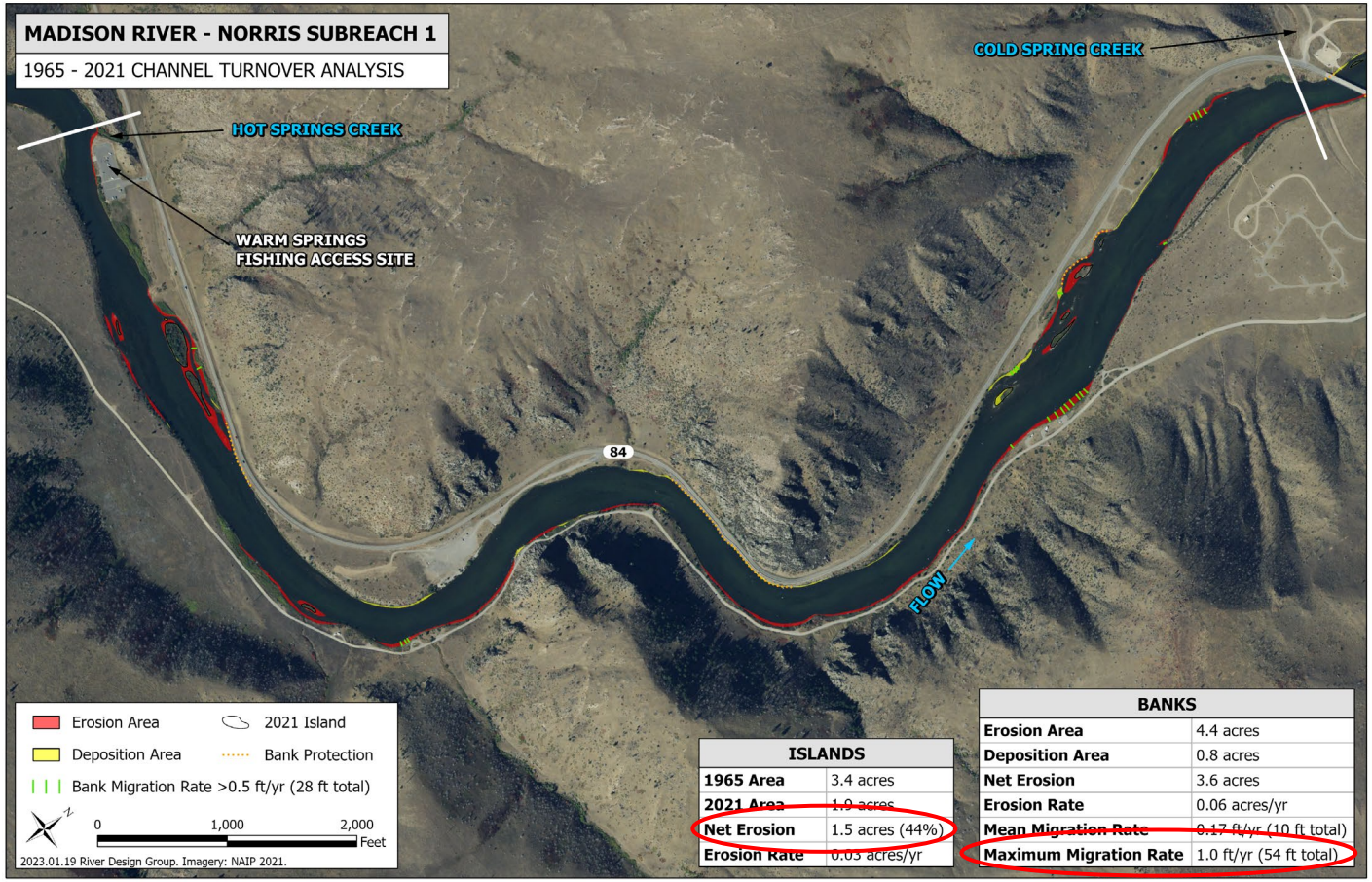
4706 cfs ($Q_{1.5}$)



Impaired Fluvial Processes

Streambank and Island Erosion

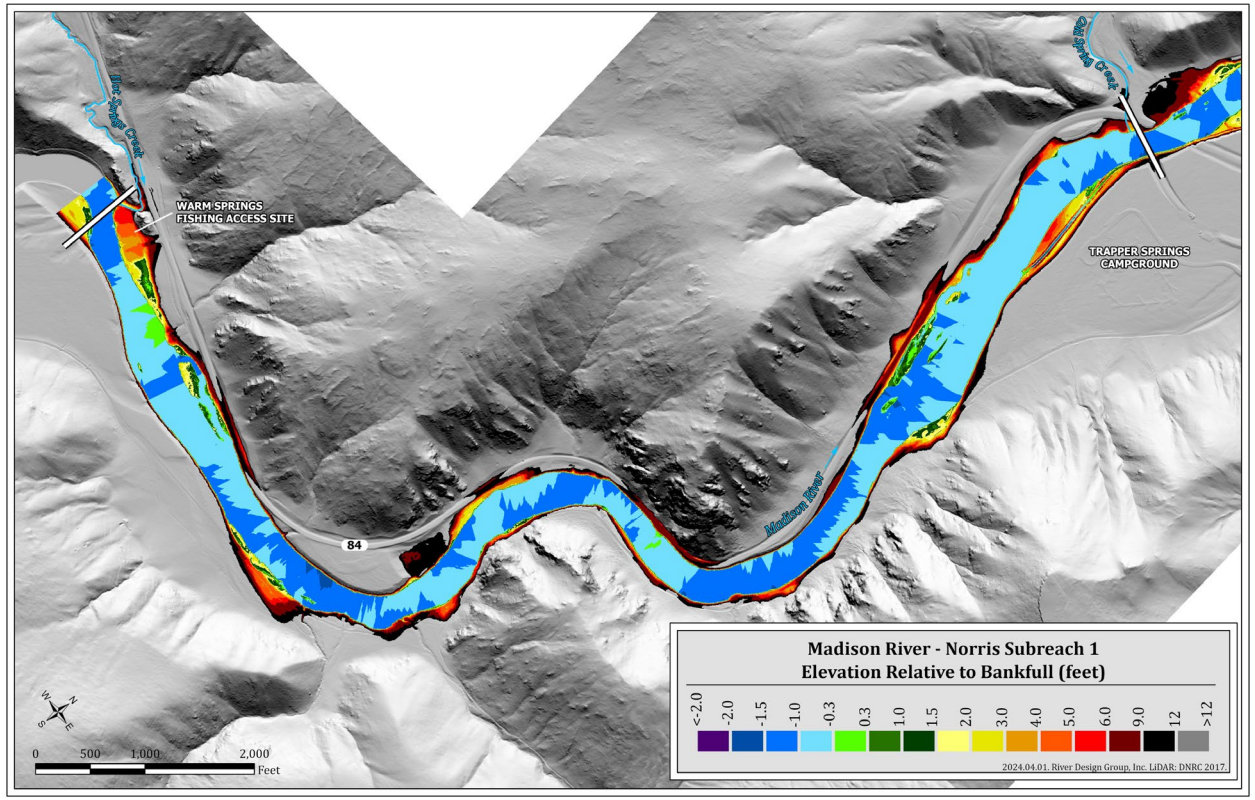
- Driven by:
  - Low sediment supply; channel degradation
  - Lack of woody riparian vegetation
  - Few means of energy dissipation
- Contributes to:
  - Excess fine sediment
  - Loss of geomorphic and hydraulic complexity



Impaired Fluvial Processes

Floodplain Connectivity

- Critical for:
  - Water storage
  - Sediment storage
  - Nutrient cycling
  - Off-channel habitat for aquatic and terrestrial wildlife



Impaired Fluvial Processes

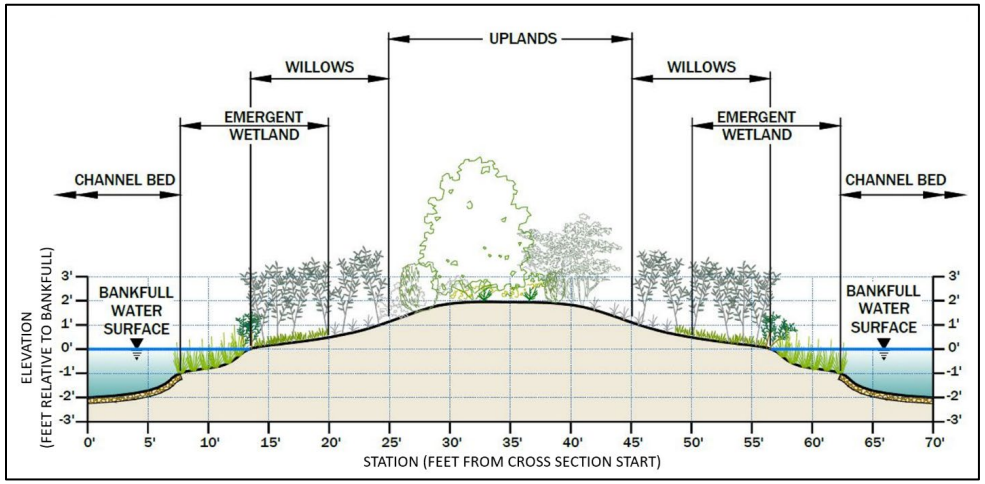
Woody Riparian Vegetation Succession

- Critical for:
  - Quality riparian habitat
  - Large woody debris recruitment
  - Modulating bank erosion
  - Aquatic habitat cover and shade
- Driven by:
  - Floodplain disconnection
  - Vegetation conversion

Restoration Strategies

Island Expansion and Creation

- Increase hydraulic and geomorphic complexity
- Provide shallow, low energy areas that retain gravels
- Low angle side slopes to provide full range of wetland and riparian habitat
- Integrate roughness and revegetation on disturbed surfaces
- Provide source of spawning gravels over the long term



Bayha Island expansion four years post construction, Snake River, ID.

Reference island

Restoration Strategies

Floodplain Creation

- Increase riparian habitat area
- Proposed along high elevation terraces and erosion-prone areas
- Built out from or carved into existing banks to accommodate riprap/infrastructure constraints
- Hydrologically connected at bankfull stage
- Integrate roughness and revegetation on disturbed surfaces
- Vegetated wood matrix bank treatments

Example floodplain roughness post-construction.

Inset floodplain and revegetation, Kootenai River, ID.

Restoration Strategies

Side Channel and Alcove Construction

- Increase hydraulic (*i.e.* habitat) diversity and complexity
- Provide shallow, low energy areas that retain gravels
- Active at baseflow
- Proposed on existing low surfaces or new inset floodplain surfaces

Constructed side channel and alcove, Clark Fork River, MT.

Restoration Strategies

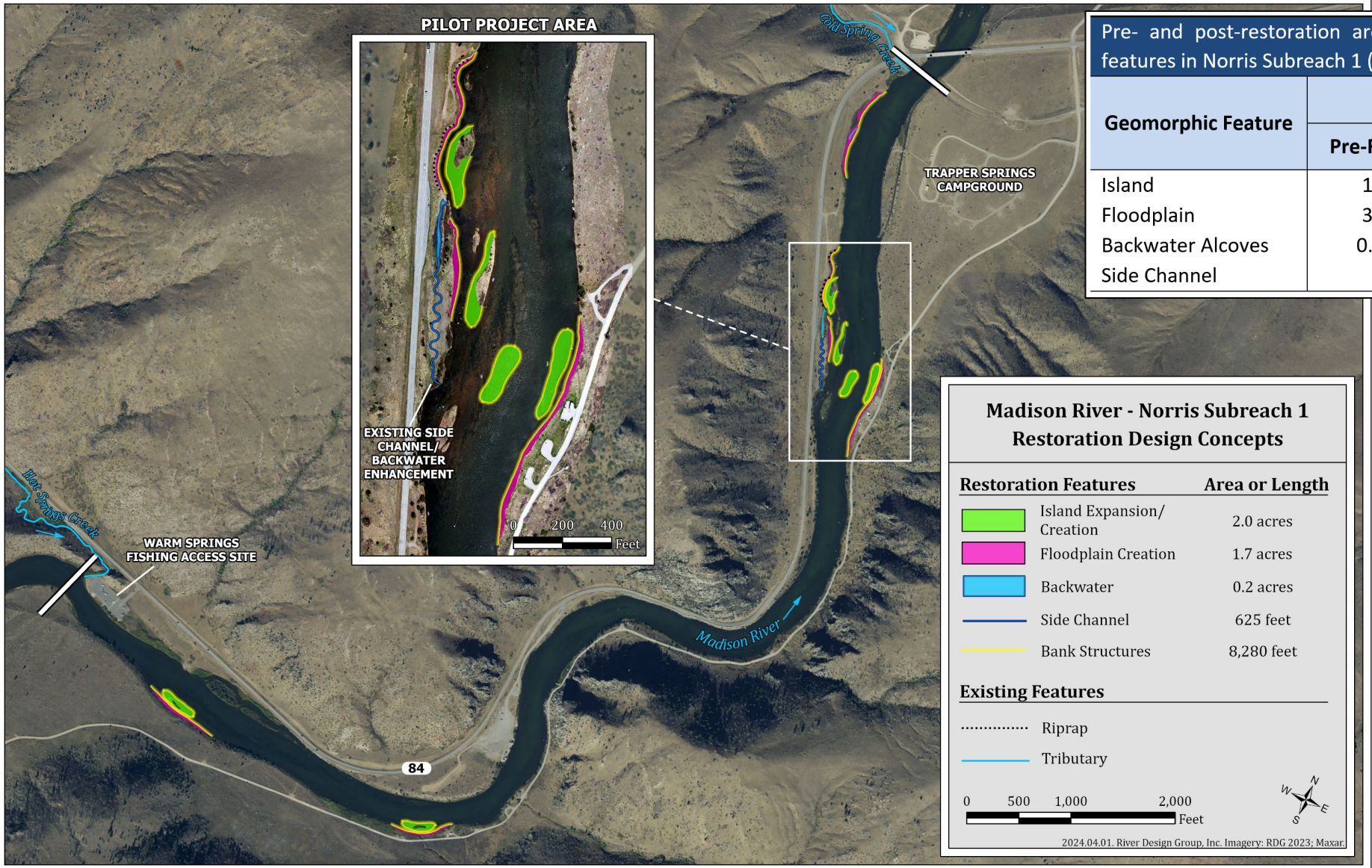
Vegetated Bank Treatments

- Incorporated on new floodplain and side channel margins
- Provide complex habitat, cover, and shade
- Provide temporary stability until riparian vegetation is established
- Provide source of instream wood over the long term

Vegetated wood matrix structures.

Large wood habitat structure, Clark Fork River, MT.

Restoration Strategies



Pre- and post-restoration area or length of geomorphic and aquatic habitat features in Norris Subreach 1 (2.7 miles in length).

Geomorphic Feature	Area or Length		% Increase
	Pre-Restoration	Post-Restoration	
Island	1.9 acres	3.9 acres	105%
Floodplain	3.0 acres	4.7 acres	57%
Backwater Alcoves	0.13 acres	0.33 acres	54%
Side Channel	0 feet	625 feet	62,500%

Conclusion and Next Steps

- Important habitat for rainbow, brown, and westslope cutthroat trout
- Fluvial processes adversely impacted by Madison Dam
  - Flow and sediment regime
  - Hydraulic complexity
  - Streambank and island erosion
  - Floodplain connectivity
  - Woody riparian vegetation succession
- Restoration strategies:
  - Island expansion and creation
  - Floodplain creation
  - Side channel and alcove construction
  - Bank treatments and revegetation
- Next steps:
  - Develop final restoration design plans for pilot project
  - Phased, multi-year implementation to accommodate funding and permitting requirements and **adaptive management**
  - Pilot project implementation planned for 2025

Acknowledgements

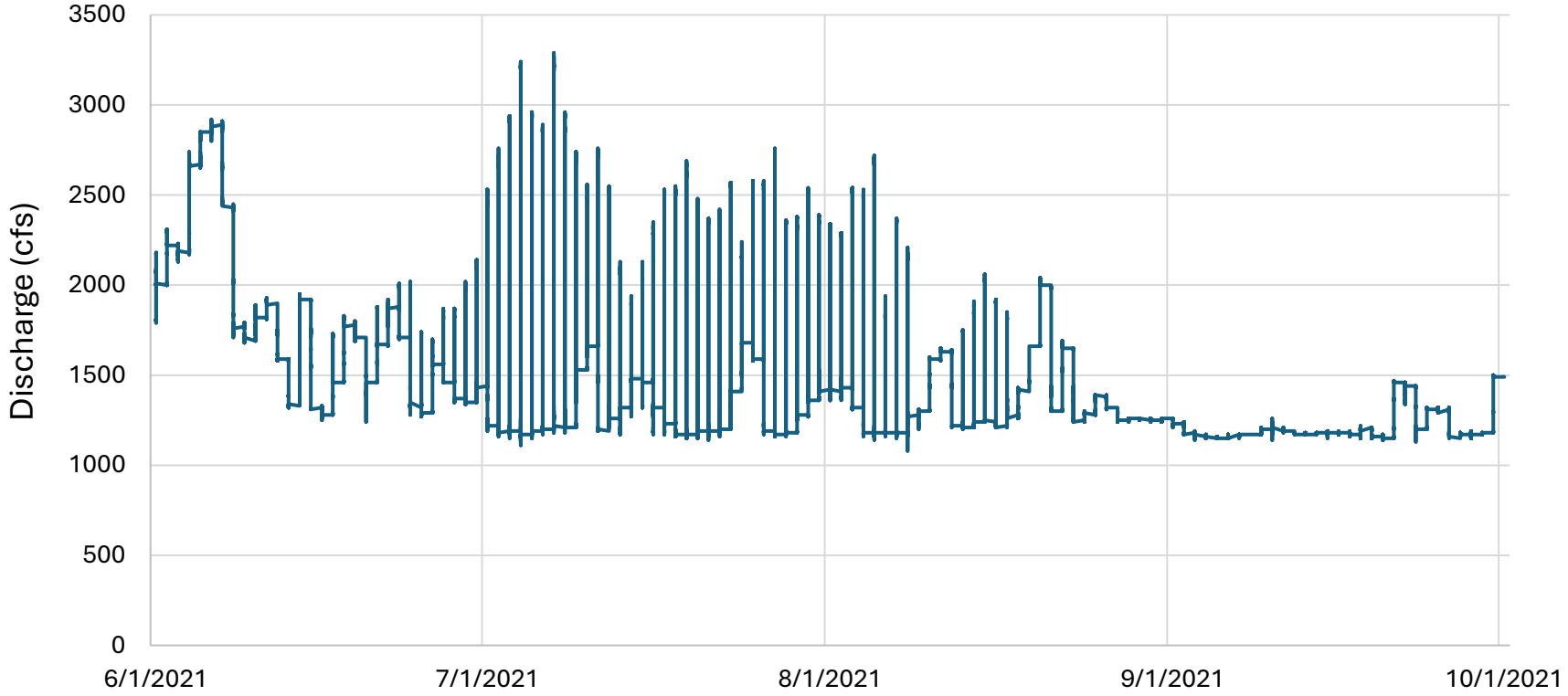
Restoration Constraints

- Madison Dam (flow and sediment regime)
- Infrastructure (riprap, roads, campgrounds)
- Recreational boating

Existing Conditions Assessment

Hydrology

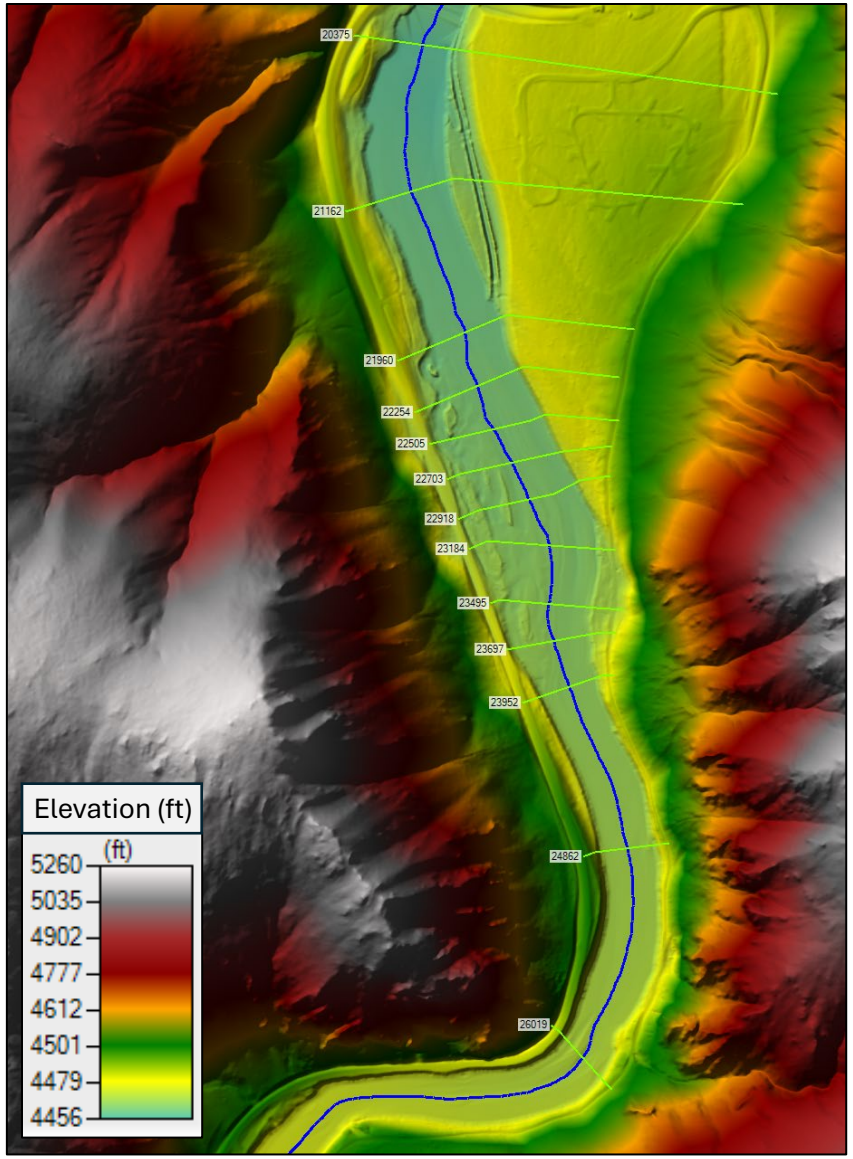
- June-August daily pulse flow releases up to 2000-3000 cfs
  - Flush fine sediments



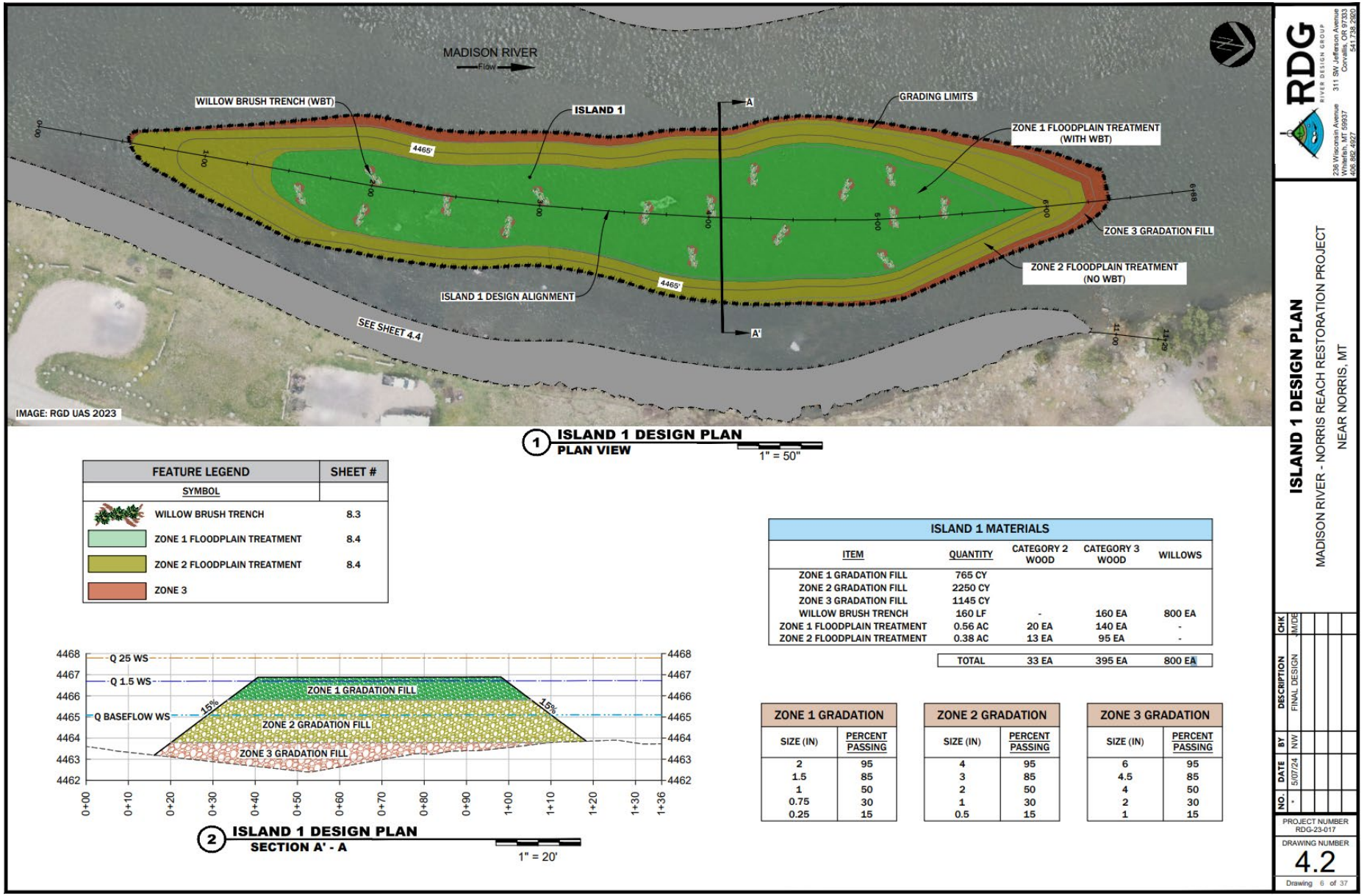
Existing Conditions Assessment

1D Hydraulic Modeling

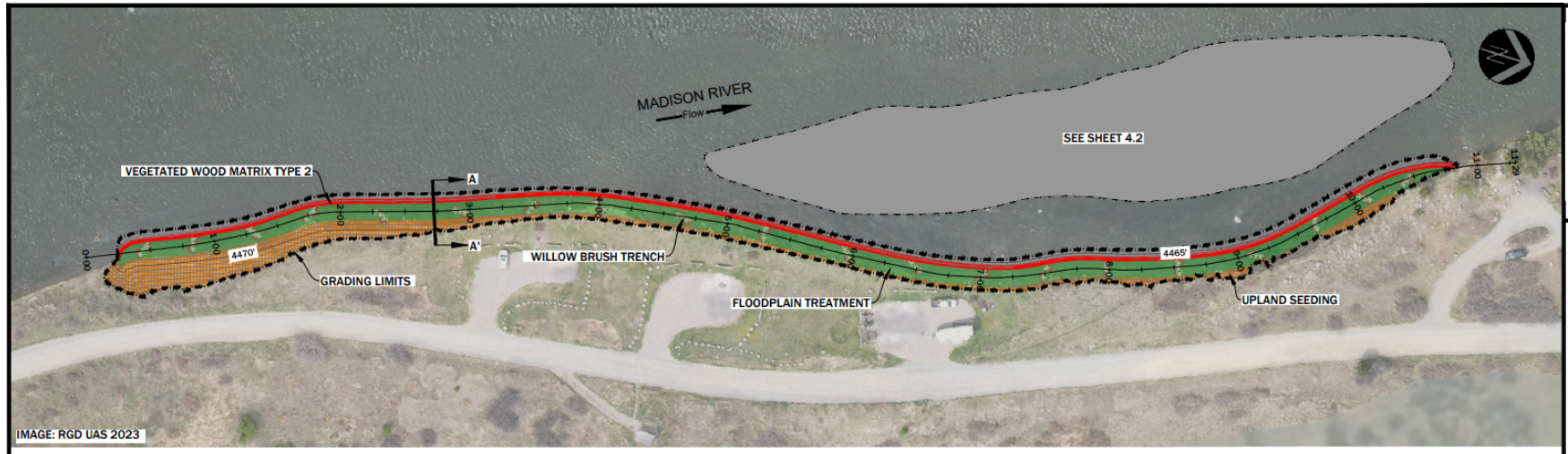
- Terrain: composite DEM from 2017 LiDAR and 2023 bathymetry
- Calibrated using known field discharge and water surface profile
- Simulated $Q_{baseflow}$ – Q_{100}



Restoration Strategies

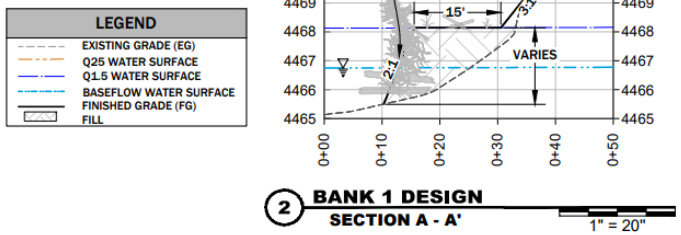


Restoration Strategies



1 BANK 1 DESIGN PLAN
PLAN VIEW
1" = 80'

FEATURE LEGEND	SHEET #
SYMBOL	
WILLOW BRUSH TRENCH	8.3
FLOODPLAIN TREATMENT	8.4
VEGETATED WOOD MATRIX TYPE 2	8.1
UPLAND SLOPE SEEDING	9.0



2 BANK 1 DESIGN
SECTION A - A'
1" = 20'

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BANK 1 DESIGN PLAN
MADISON RIVER - NORRIS REACH RESTORATION PROJECT
NEAR NORRIS, MT

NO.	DATE	BY	DESCRIPTION	CHK
-	5/07/24	NW	FINAL DESIGN	JM/DE

PROJECT NUMBER
RDG-23-017

DRAWING NUMBER
4.6
Drawing 10 of 37

Restoration Strategies