# LESSONS LEARNED

From 28 Years of Remediation and Restoration in the Upper Clark Fork River Basin

CDM Smith

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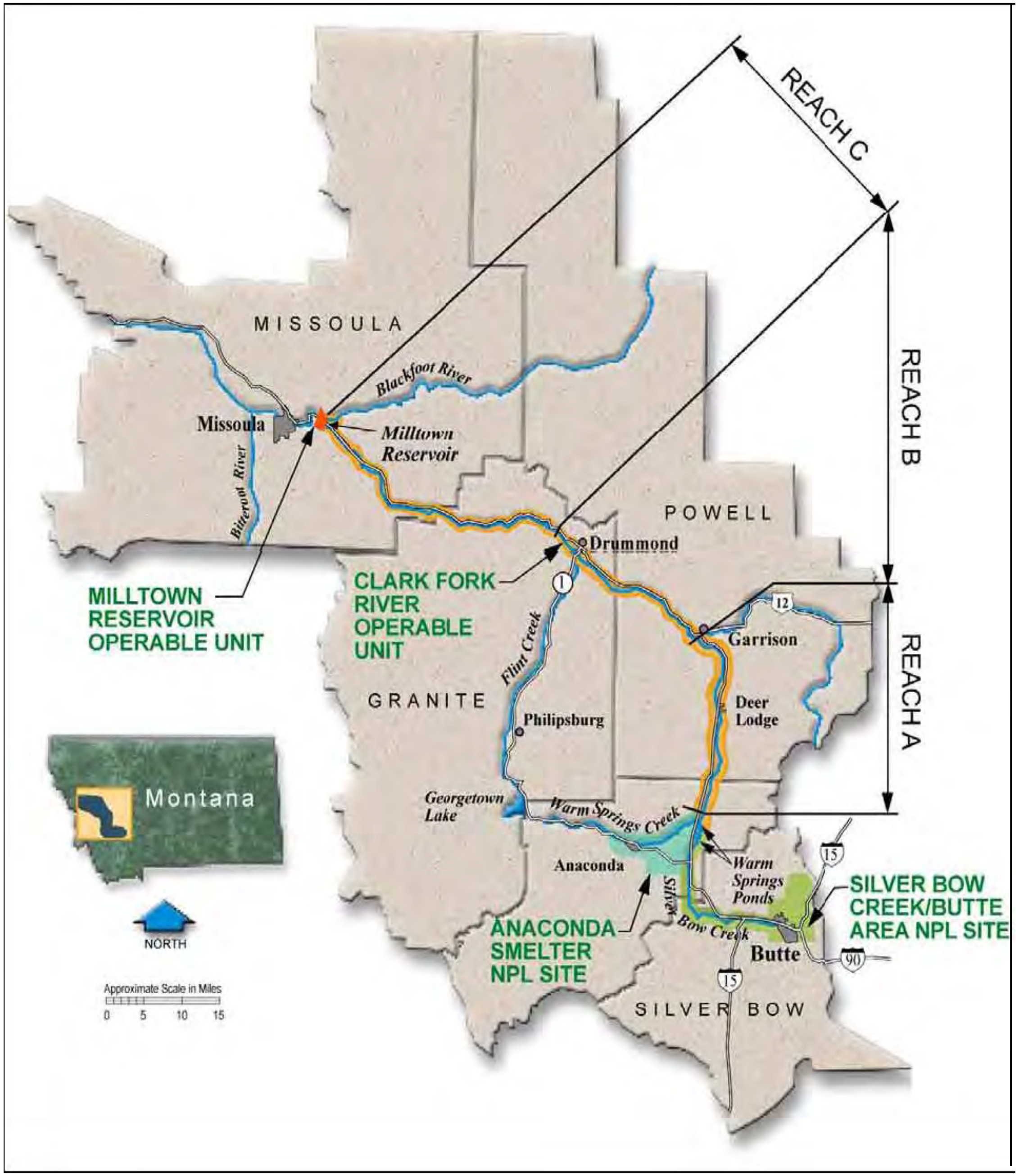
# My experience in the basin

- First sampling for Superfund on Silver Bow Creek, Warm Springs Ponds, and Clark Fork River started in 1984.
- Provided oversight for DEQ on ARCO investigations and designs in 1990s.
- Began the Silver Bow Creek design in 1997 with Interfluve and Mussetter Engineering.
- Reach A construction on Silver Bow Creek commenced in 1999.
- Led or assisted with designs down to Miles Crossing.
- Milltown Restoration design and construction – 2007 to 2010.
- Clark Fork River Phase 1 investigation and design - 2008.

# Upper Clark Fork River



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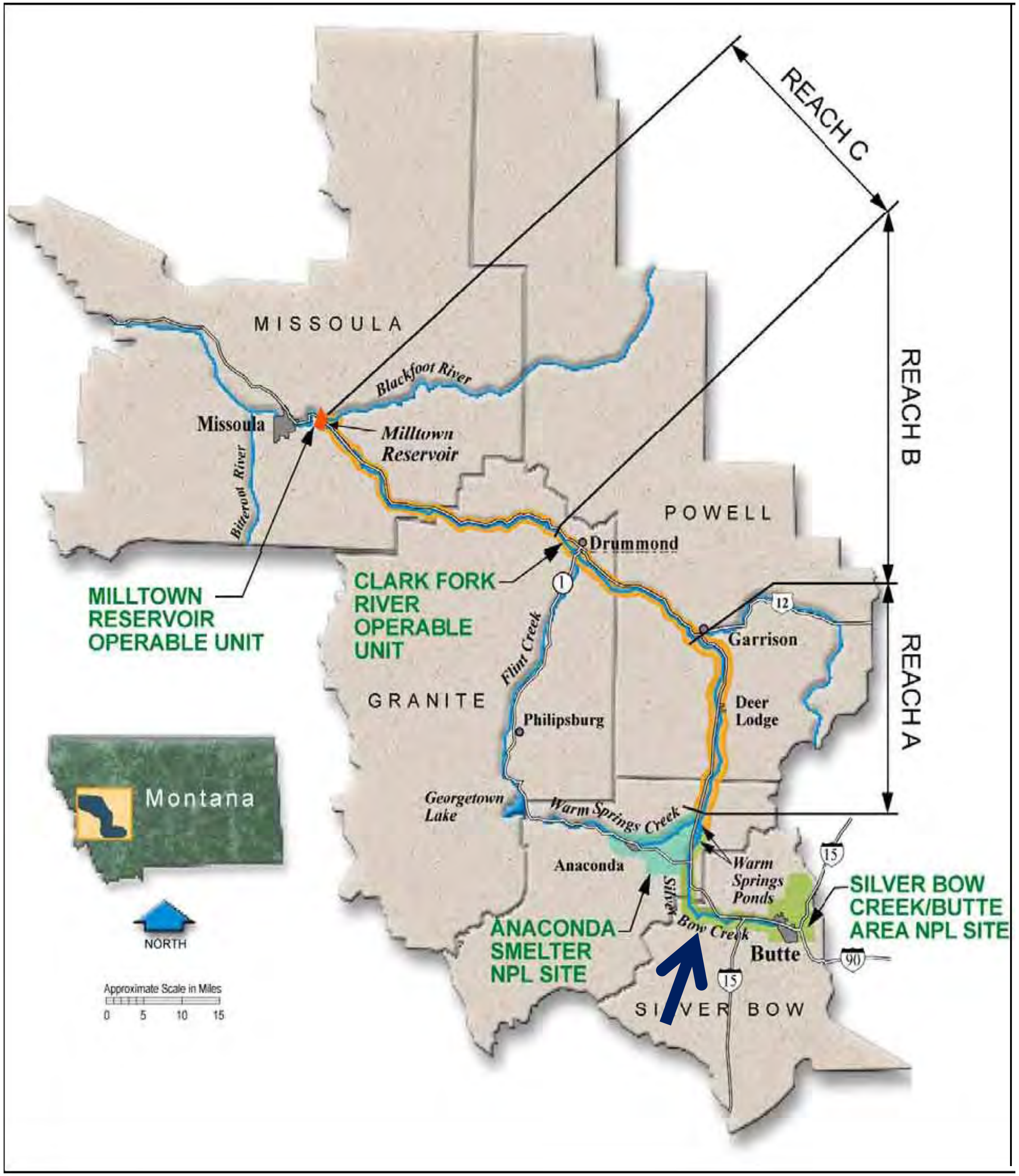

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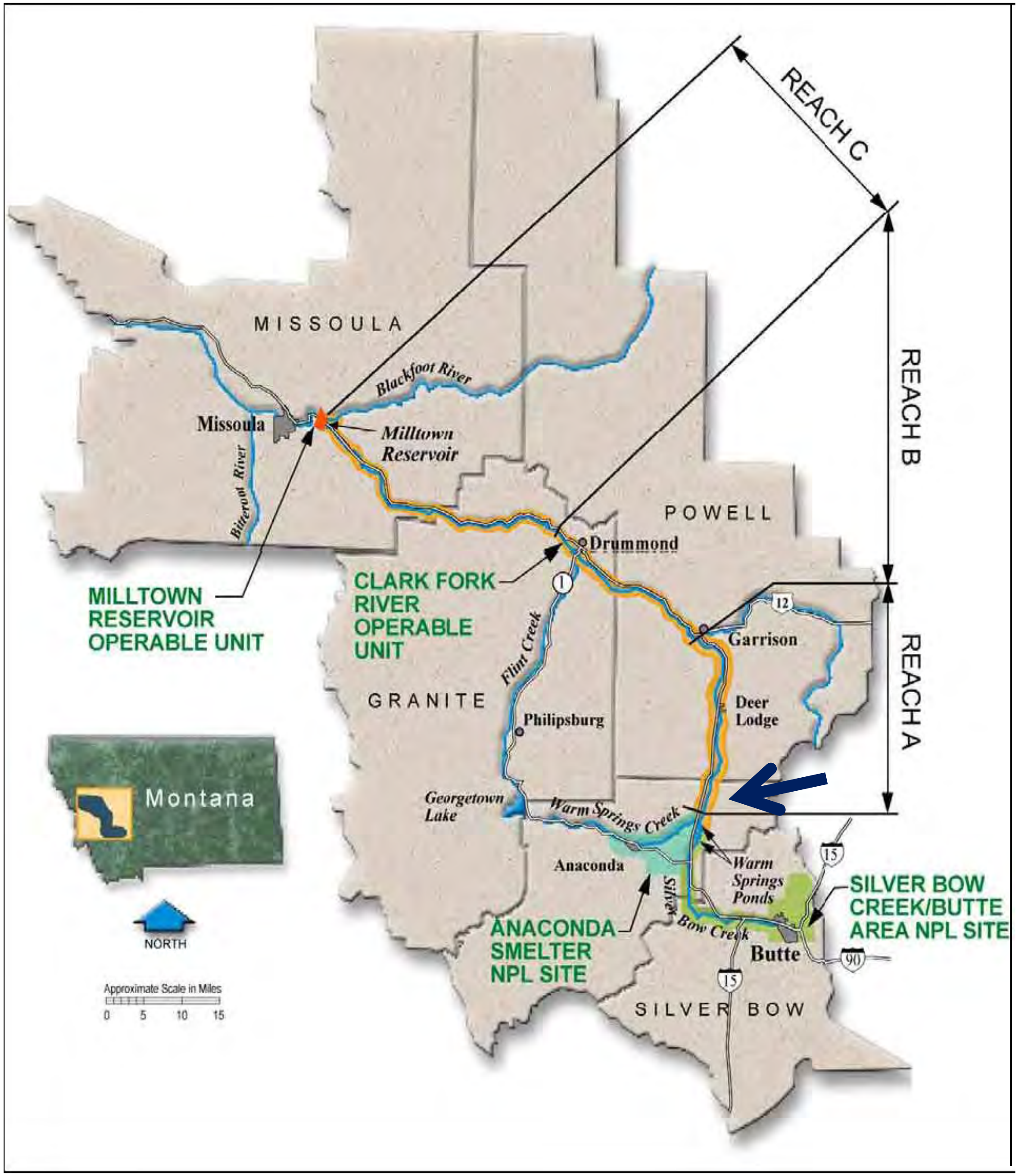

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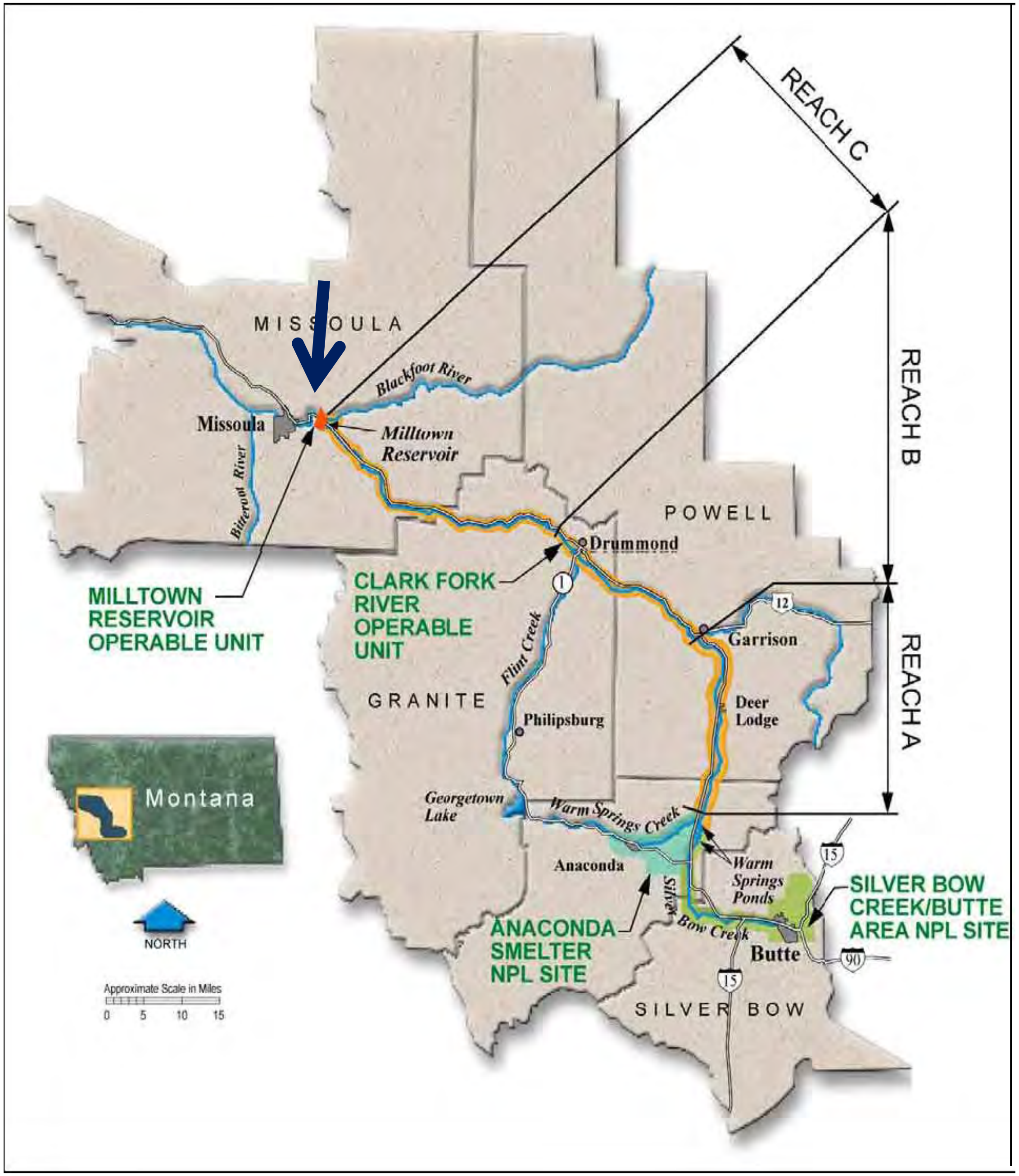
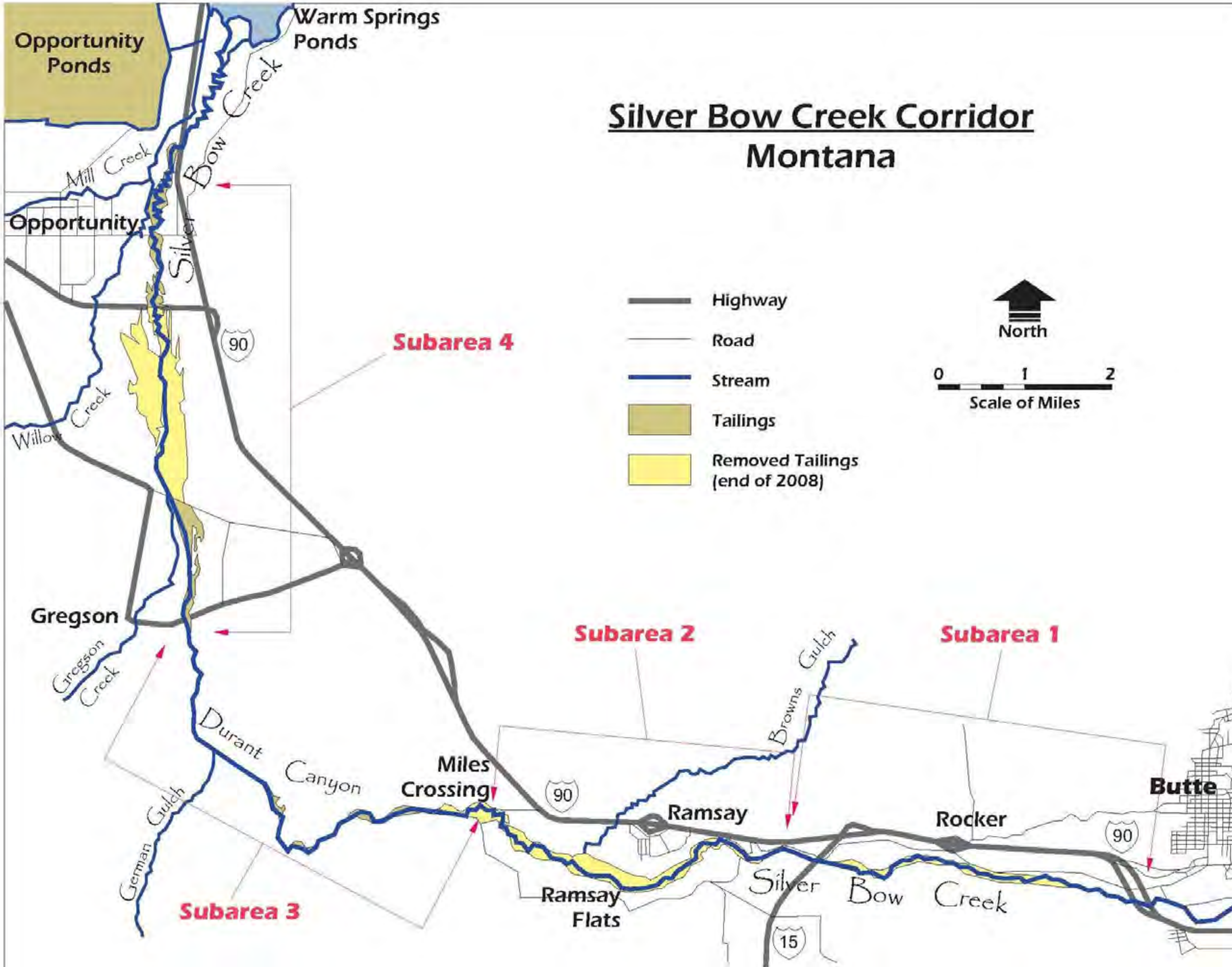
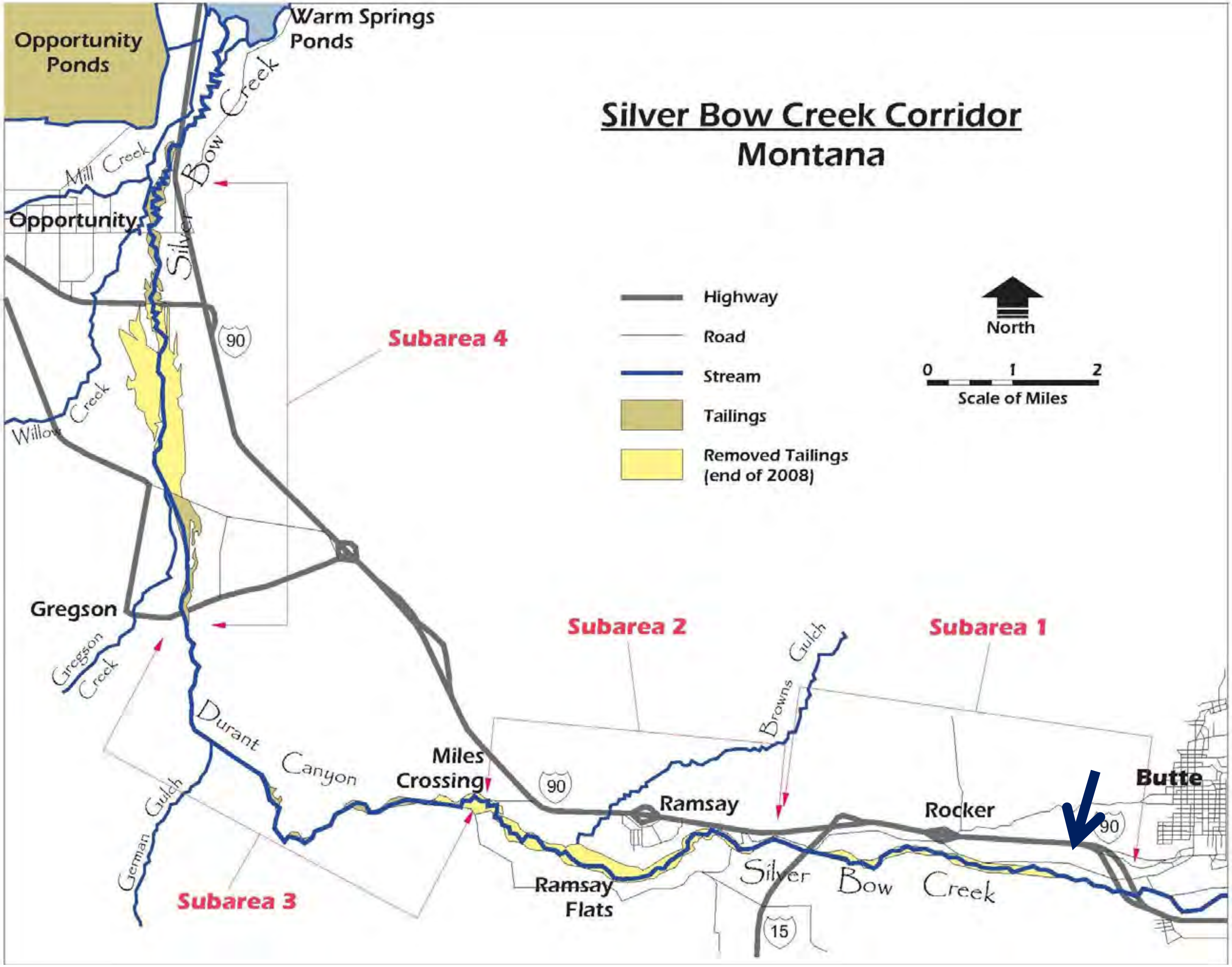



Silver Bow Creek Corridor
Montana
Highway
Road
Stream
Tailings
Removed Tailings
(end of 2008)
North
0
1
2
Scale of Miles
Opportunity Ponds
Warm Springs Ponds
Silver Bow Creek
Mill Creek
Opportunity
90
Subarea 4
Willow Creek
Gregson
Gregson Creek
Subarea 2
Subarea 1
Browns Gulch
Durant Canyon
Miles Crossing
90
Ramsay
Rocker
Butte
90
German Gulch
Subarea 3
Ramsay Flats
Silver Bow Creek
15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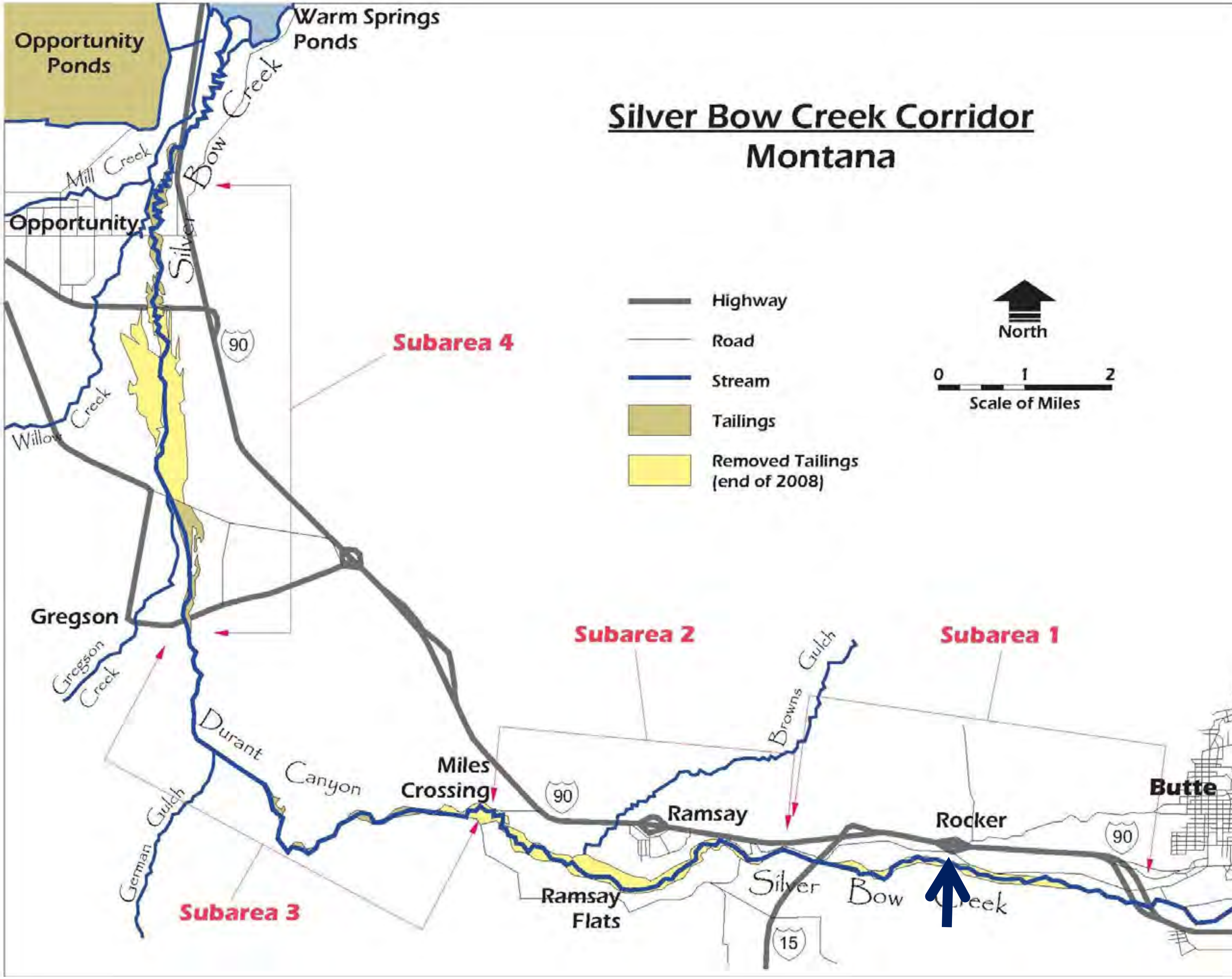
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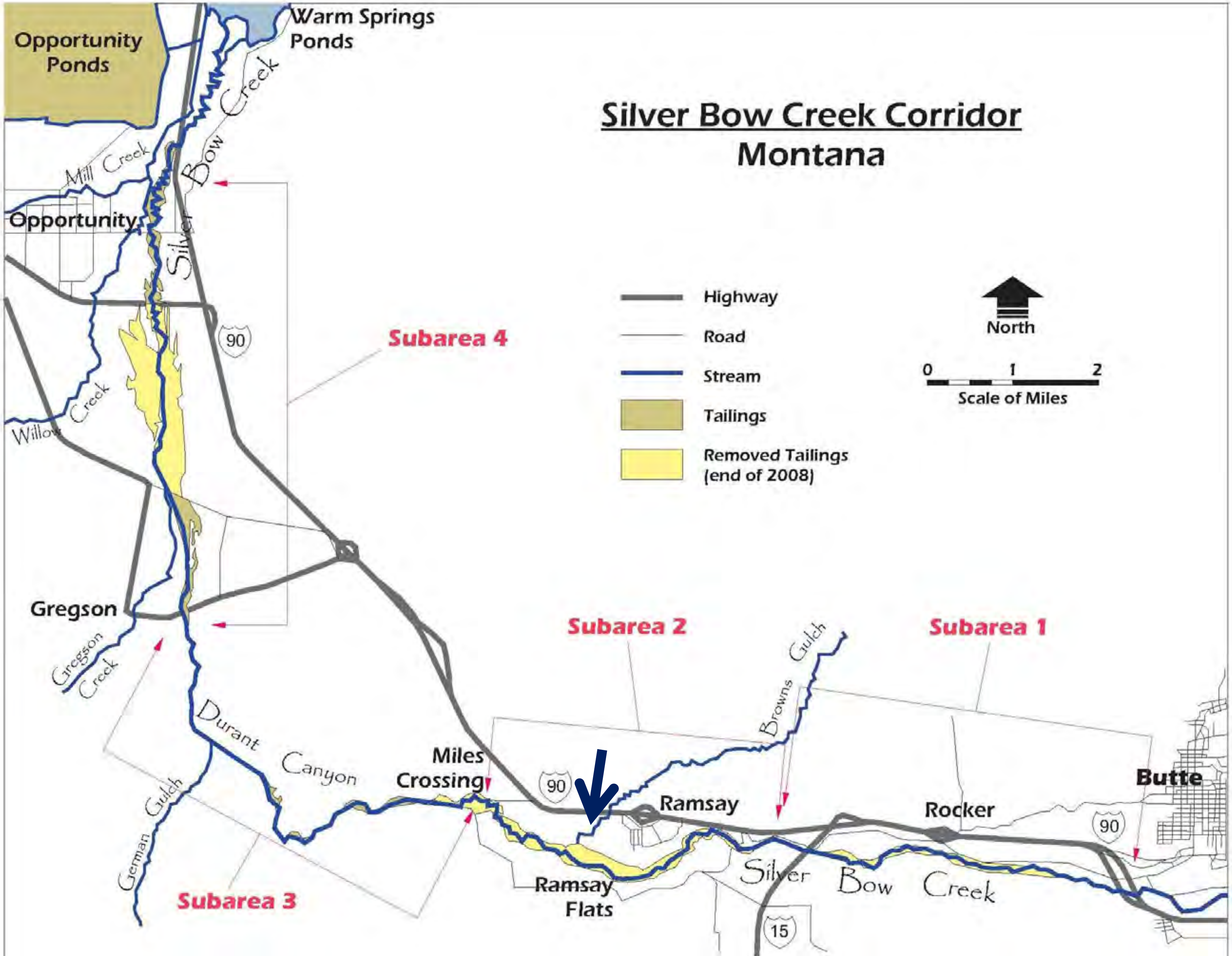

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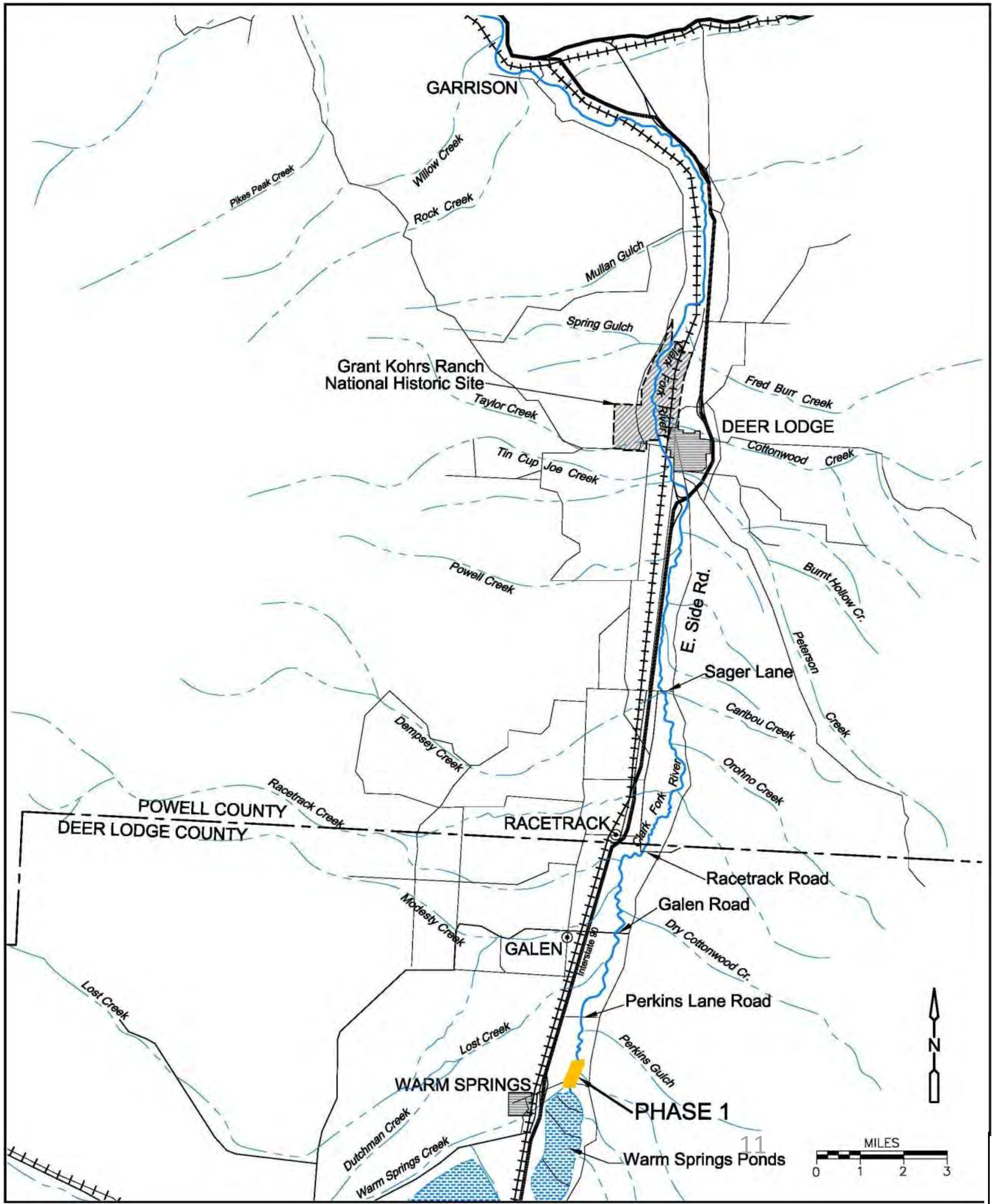
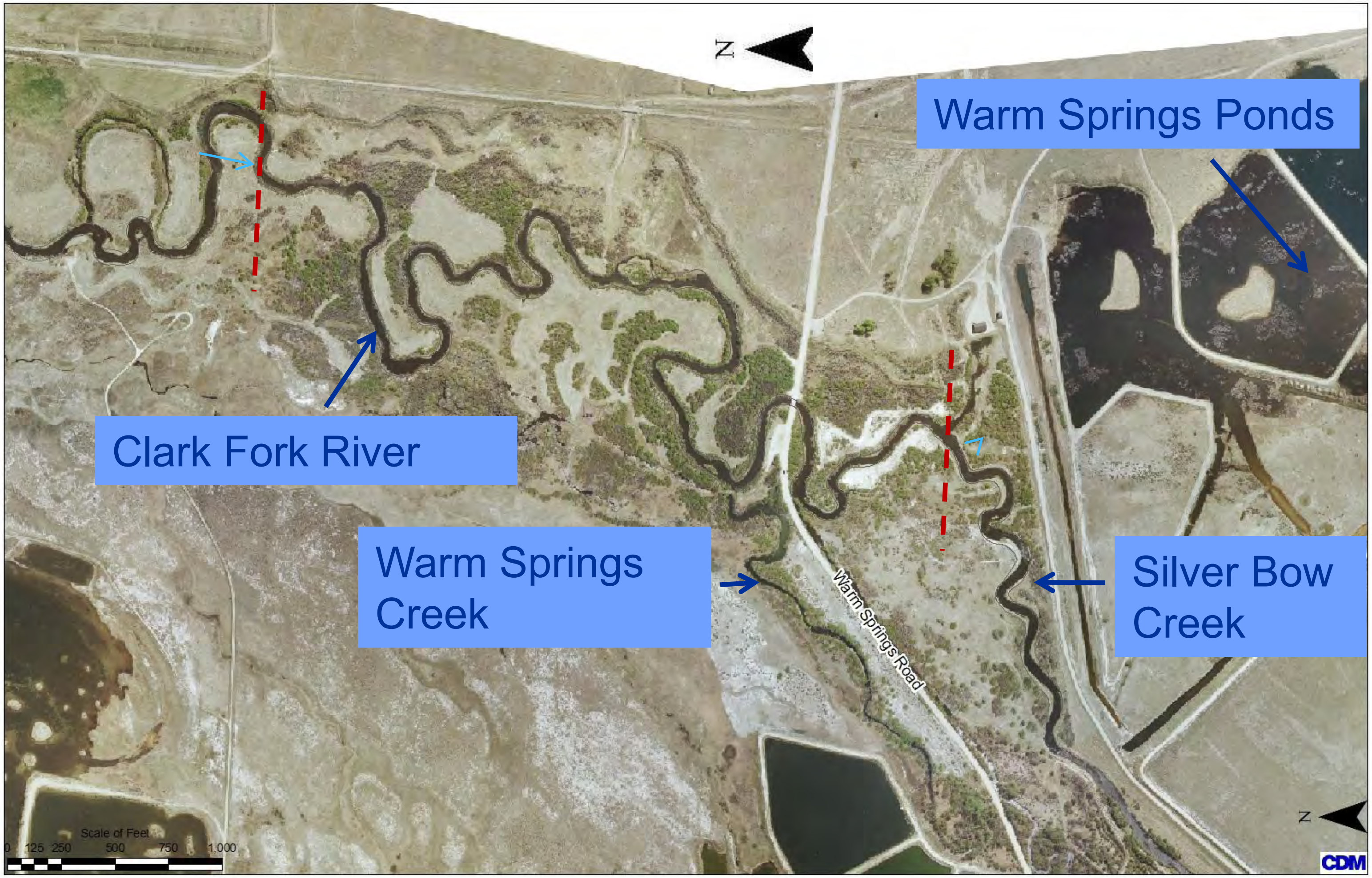
# Clark Fork River Reach A



# Clark Fork River - Phase 1 Area



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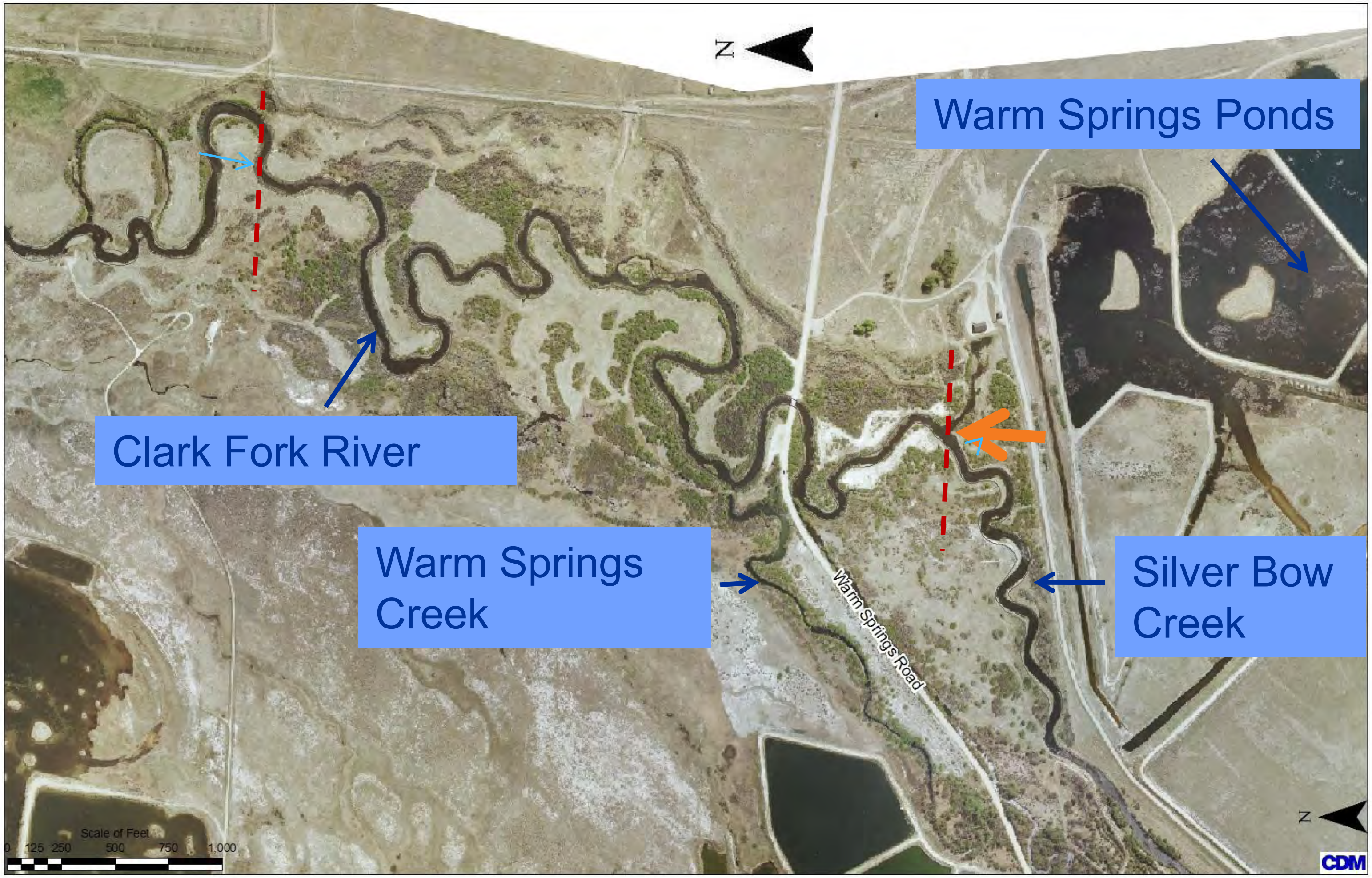

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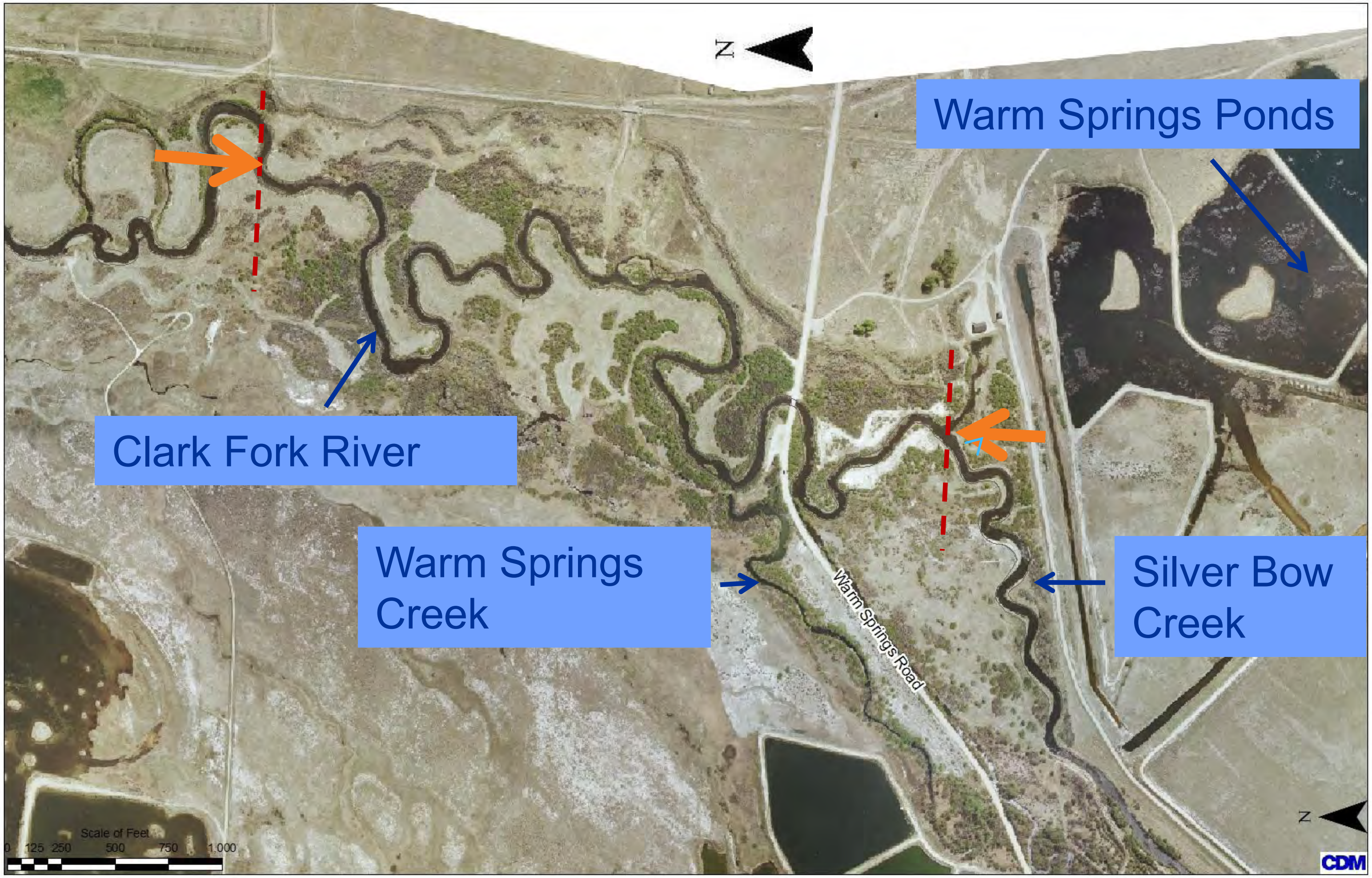

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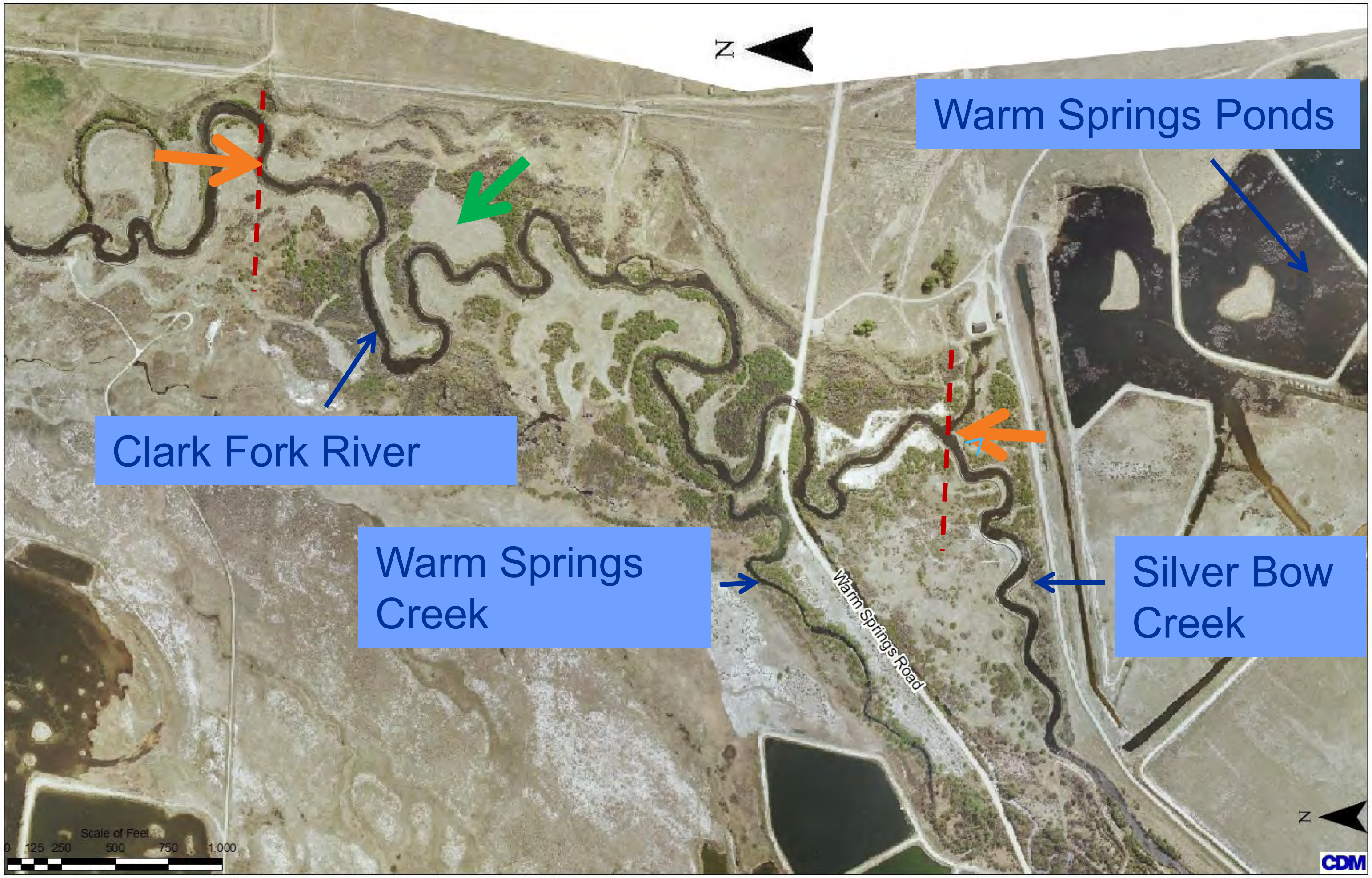

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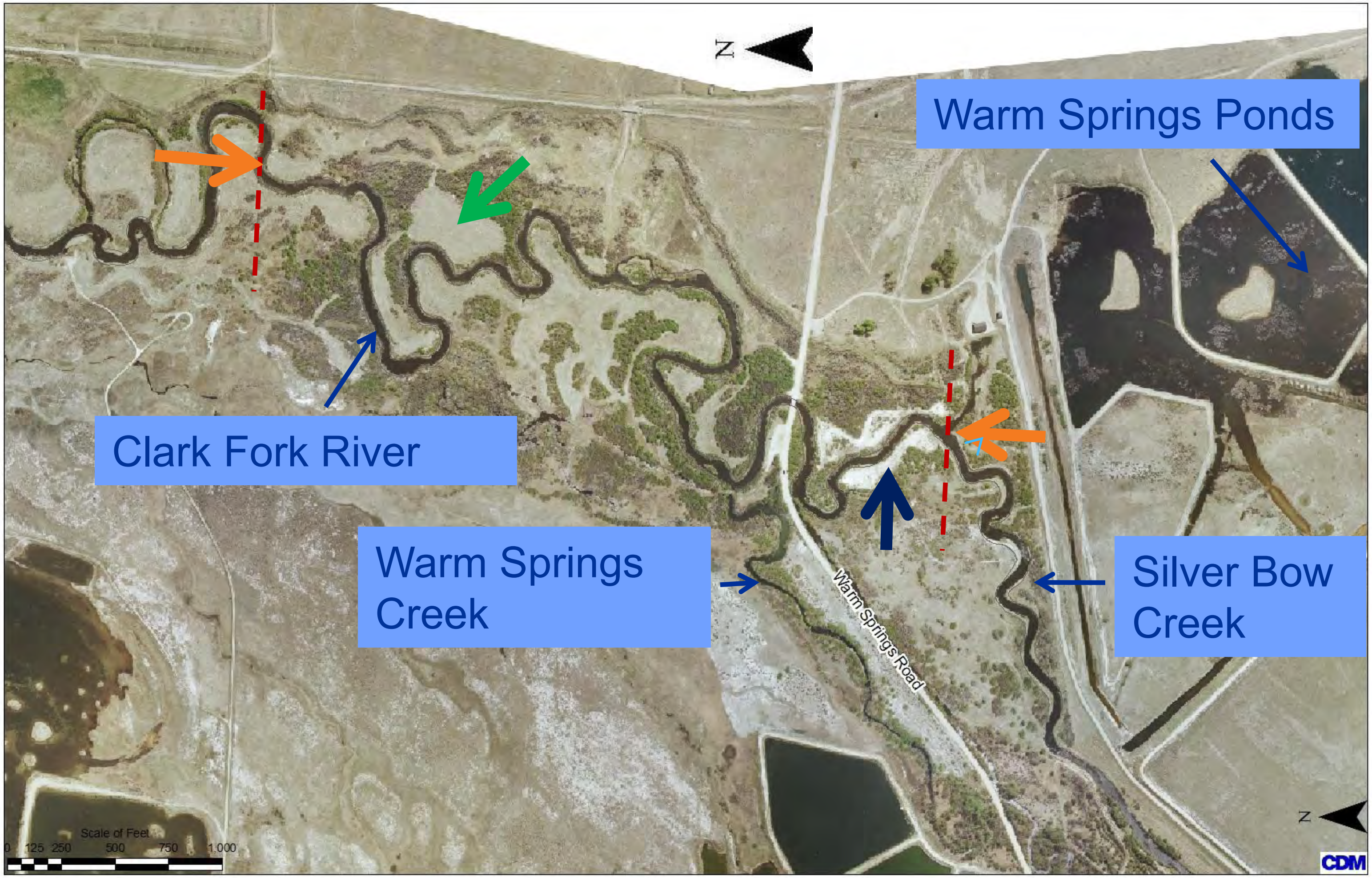
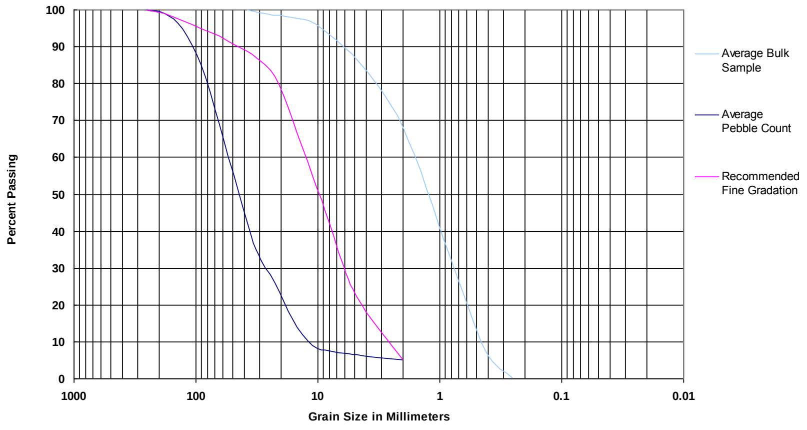




CDM

# Topics to be covered:

- Contaminant removal
- Hydrology
- Stream design
  - Reference reaches
  - Structures
  - New channel construction
  - Stream gradient
  - Deformable Channel
  - Bed Materials
  - Streambank design




# Contaminant Removal

<u>Things we got right:</u>

- Why removal?
- Identifying the 'Base of Tailings'
- Central repository
- Removal of Ramsay Flats tailings

<u>Things we missed:</u>

- Lime amending waste disposal at local repositories
- Planting on in-place material

# Contaminant Removal – Why Removal?

<u>The Alternative: Lime Amendment</u>

- Lime amendment can be less costly.
- Lime does not immobilize arsenic.
- Lime is hazardous to work with and requires respiratory protection.
- In-situ placement of lime is limited at depth by groundwater and feasibility of incorporation.
- Lime incorporated in the channel migration zone will eventually be lost.

# Contaminant Removal – Why Removal?

<u>Advantages of Removal</u>

- Removes contaminants permanently from the fluvial environment.
- Best chance of reducing groundwater and surface water contamination.

<u>Limitations of Removal</u>

- Generally not possible to remove all contamination.
- Can be more costly than the alternative.

# Contaminant Removal – Base of Tailings

- Contaminants of Concern are arsenic, cadmium, copper, lead, zinc and mercury (SBC).
- Definition of 'Base of Tailings' can vary but preferably should be concentration based.
- Concentrations often abruptly decrease below base.

# Contaminant Removal – Base of Tailings

- In fluvial environments, pit sampling is usually feasible.
- Sample in increments and screen samples with XRF for submittal to a lab for accurate analysis.
- If material may be lime amended, retain materials above base for additional analysis (acid-base accounting).

# Contaminant Removal – Base of Tailings

- Geostatistical analysis of elevations (Kriging) of tailings base allows modeling of removal surface.
- Kriging analyzes variance in base of tailings and allows prediction of the percent removal of tailings.
- For Reach A of Silver Bow Creek, we predicted that over-excavation of 6 inches of material below the base of tailings would remove 90% of the contaminants (as defined by the removal criteria).
- Because 6 inches of over-excavation proved to be correct (based on verification sampling) but did not allow provide sufficient margin of assurance, over-excavation was increased to 9 inches at downstream reaches.

# Contaminant Removal – Ramsay Flats

- Tailings deposit up to 8 feet deep originally slated for lime amendment.
- Mostly barren tailings, copper salts would wick up in some years creating an additional surface water load to Silver Bow Creek.
- Stream was incised in tailings creating unstable banks.
- Removal allowed realignment of a longer stream channel and creation of wetlands.

# Contaminant Removal – Waste Disposal

- Local Repository (Reach A)
  - Design required lime amendment of waste
  - Lime did not control arsenic
  - Arsenic control with zero-valent iron was impractical
  - Vegetative cap effectiveness could be questioned
- Advantages of a regional waste repository
  - Consolidate all waste in one area for long-term monitoring and maintenance
  - Offers better choices for repository siting
  - Use of rail transport was very economic

# Contaminant Removal

- Base of tailings is not always well defined particularly when in contact with groundwater.
- On Silver Bow Creek, most metals could be below removal levels but zinc remained high (thousands of ppm).
- Attributed to relatively high solubility and mobility of zinc in groundwater.
- Groundwater zinc concentrations often remain high (greater than 1 mg/L) after removal.
- Even with verification monitoring and hotspot removal, don’t expect “complete removal.”

# Hydrology - can we get it right?

- In 1999 (first Silver Bow Creek Design), we had 15 years of record on the gages, now we have almost twice that (28 years).
  - Changes 2-yr peak flow from 235 cfs to 196 cfs.
  - Only 3 years since 1999 have exceeded 235 cfs.
  - USGS regression equations predict 244 cfs at this location.
- Design flows for Subareas 1-3

| | Subarea 1 | Subarea 2 | Subarea 3 |
|---|---|---|---|
| 2-yr. | 235 cfs | 250 cfs | 267 cfs |
| 10-yr. | - | 1,230 cfs | 1,470 cfs |
| 100yr. | - | 2,420 cfs | 3,050 cfs |

# Hydrology - can we get it right?

- Initially, upper Silver Bow Creek had very flashy storms; flood of record was in 1998 (447 cfs) during thunderstorms.
- Peaks of flashy storms probably attenuated in downstream direction.
- Installation of storm water retention in Butte (Missoula Gulch) has altered runoff pattern - runoff is less flashy.
- Recent peaks have been snowmelt/spring rain events with broader peaks.
- Flood of 2011 was only a three year event on Silver Bow Creek (based on gage record below Blacktail Creek).
- Consequence for Silver Bow Creek is the initial design flows may have been too high.

# Hydrology – Challenges for the Clark Fork River

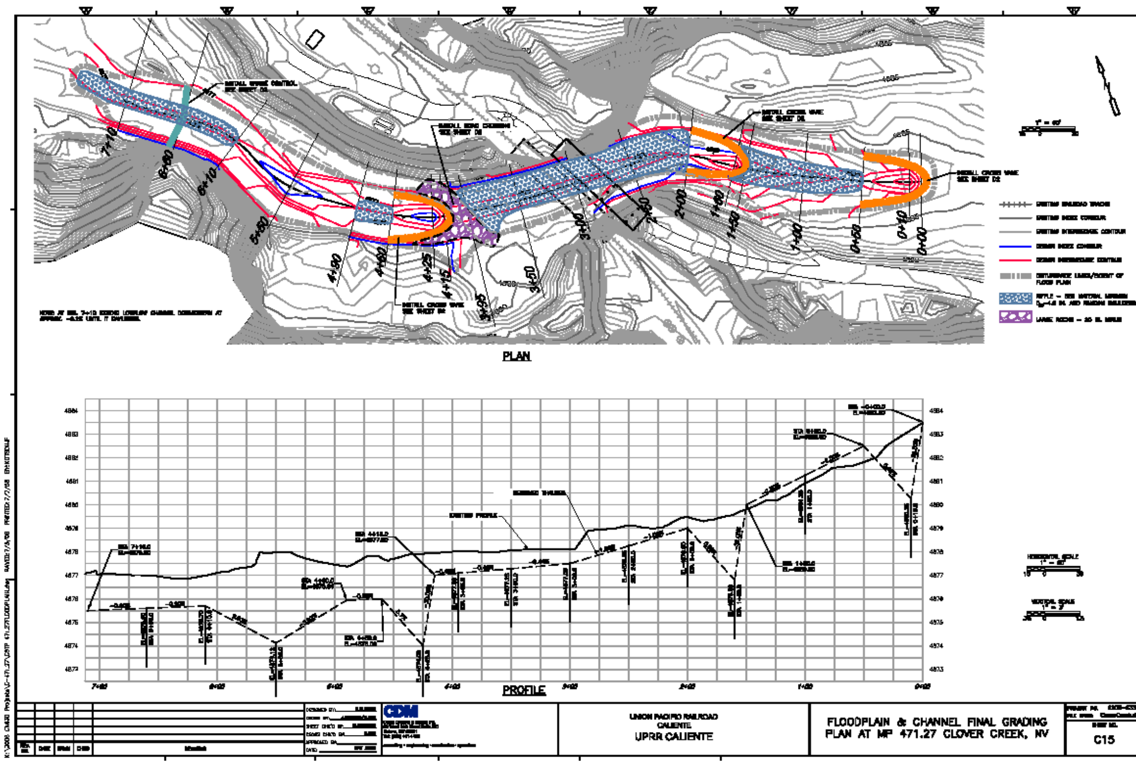
- Warm Springs Ponds immediately upstream of Clark Fork River attenuate peak flows.
- Pond surface area (almost 4 square miles) allows detention of water.
- Daily average flow of 1,300 cfs at the gage on Silver Bow Creek at Opportunity on February 11, 1996 resulted in a discharge of only 217 cfs at the gage below the ponds.
- CDM Smith estimates that the 2-yr peak flow on the Clark Fork River near Galen could increase from 522 to 737 cfs if the ponds are taken off line.

# Hydrology – Challenges for the Clark Fork River

- Decided to use flows based on ponds remaining on-line because the expectation is that the ponds will remain for a long period.
- If the ponds are taken off line in the future, revegetation should be robust enough to minimize damage from large floods.
- However, 100-year floodplain may expand considerably if the ponds are taken off line.
- Conclusion:  Peak flow hydrology is one of the larger areas of uncertainty for remediation and restoration planning in the upper Clark Fork River basin.

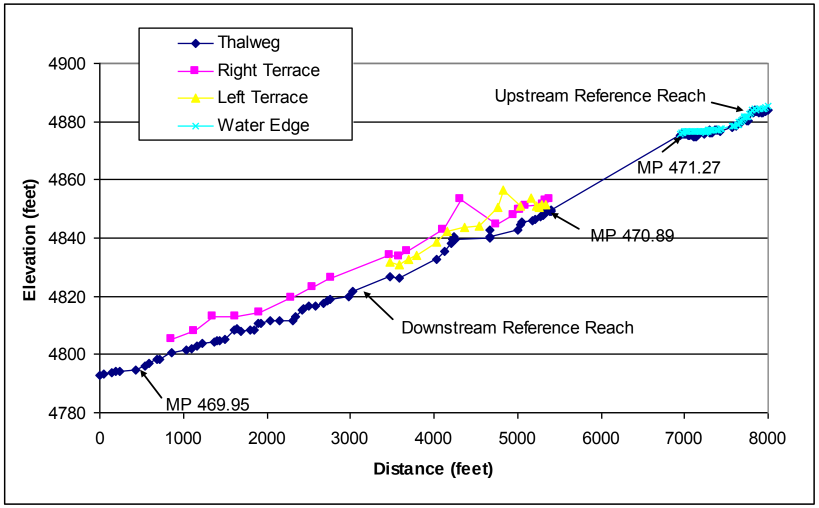
# Stream Design

- Reference reaches
- Structures
- Stream design details



# Stream Design – Reference Reaches

- Difficult to find appropriate reference reaches on neighboring streams for a given stream reach.
  - Valley type
  - Catchment area
  - Stream slope
  - Sinuosity
  - Bed materials



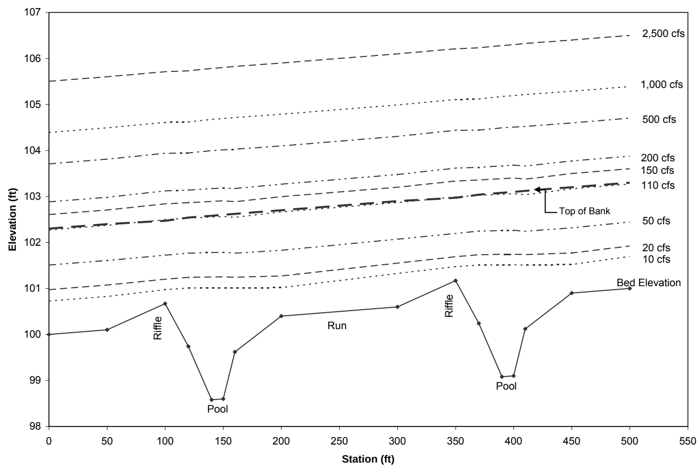

- Can be easier to find a "self reference" reach on same stream.
  - Find reach that appears to be relatively stable and in equilibrium for sediment transport.

# Stream Design – Structures

- Structures were useful on Silver Bow Creek in confined reaches (Reaches D and E) where we need to lose elevation.
- Constructed drop structures some in conjunction with existing bedrock controls and bridges.
- At some sites, no structures are planned including Clark Fork River Phase 1.

# Stream Design Details

- Hits
  - Construct entirely new channel
  - Deformable channel concept
  - Riffle pool sequence
  - Improve sediment transport
  - Install bank toes
- Misses
  - Overflow diversion
  - Oversized channel
  - Uniform channel bed material
  - Large bend radii




# Stream Design – New Channel Construction

- New Channel
  - Possible because of consolidated ownership
  - Allowed removal of most contaminants
  - Allowed freedom in planform and stream gradient design
  - Greater ease of channel construction
  - Diversion of small stream was relatively easy

# Stream Design – Stream Gradient

- Generally matched grade at existing bridges to maintain current hydraulic conditions.
- Stream profile had a hump in it at Rocker.
- Most feasible remedy was to build a new railroad bridge that would be designed to work with lowered stream elevation.
- Redesigned stream transports sediment and prevents aggradation.

# Stream Design – New Channel Construction

- Clark Fork River
  - Well vegetated banks in many places
  - Larger stream would be more expensive to divert and rebuild

# Stream Design – New Channel Construction

- Clark Fork River
  - Will be doing an entire removal with stream diversion for short segment in a deep tailings area.

# Stream Design – Overflow Diversion on Silver Bow Creek

- Attempt to save money on expected high cost of fabric encapsulated soil (FES) lifts.
- Overflow diversion would route flows (starting at 50 cfs) through a rock lined channel in Reach A.
- Banks would consist of soil covered with coir fabric but no FES lifts.
- After bank vegetation was established, diversion structure and channel would be removed.
- Concept worked well (no bank failures) but there was probably no cost savings.

# Stream Design – Streambanks

- Silver Bow Creek Streambanks
  - Banks generally were two FES lifts with planted willows.
  - Point bars did not include FES lifts; just gravel and cobble.
  - Good success with lifts for growing vegetation and stability in Subareas 1 and 2.
  - Although willows were often lost, sedges have provided needed bank strength.

# Stream Design – Streambanks

- Clark Fork streambanks
  - Build Bank toe if needed!

# Conclusion

# Thanks!