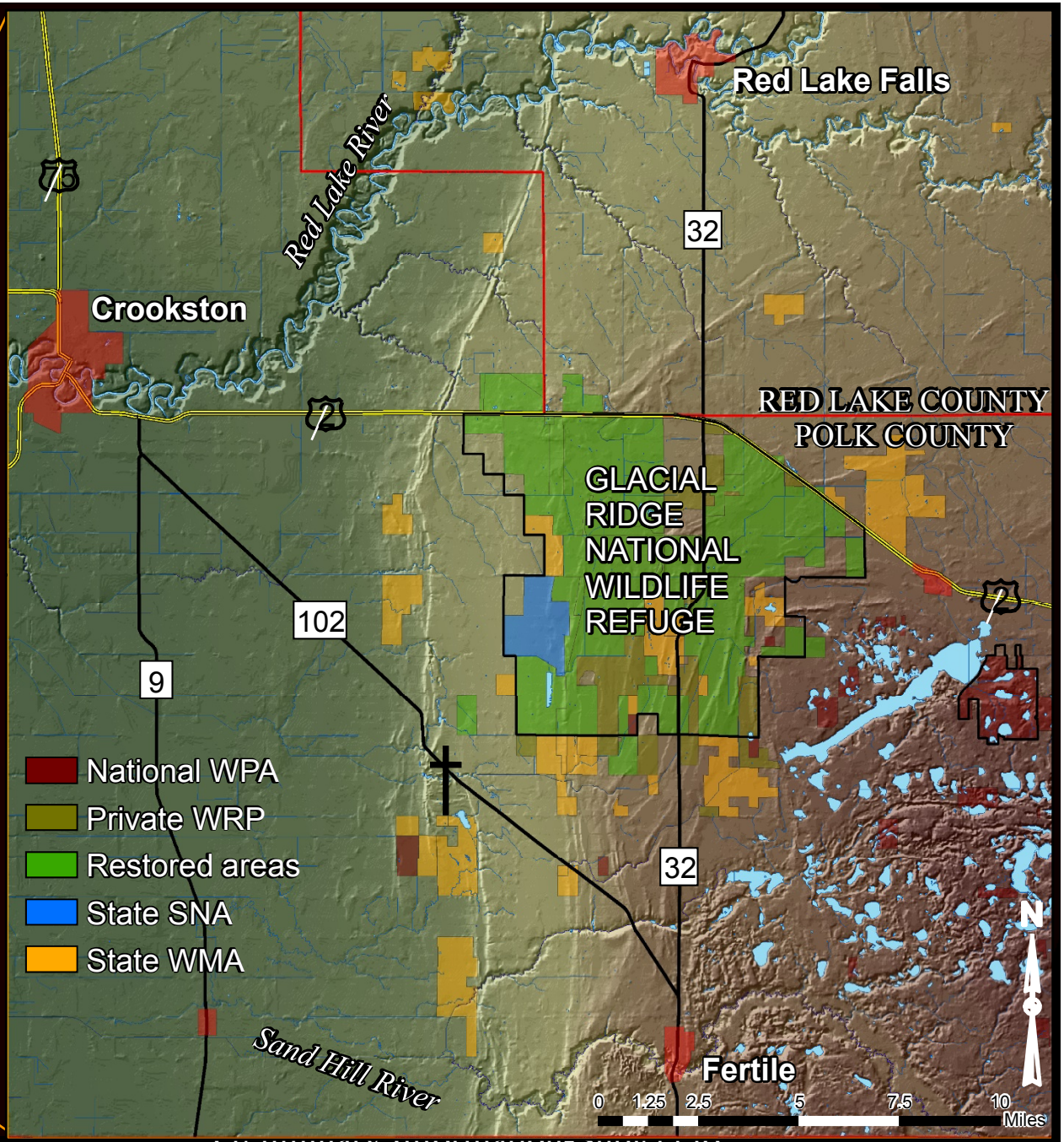
The Hydrologic Benefits of Restorations at Glacial Ridge NWR: Lessons Learned

Tim Cowdery
Upper Midwest Water-Science Center
Minnesota Office

This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Glacial Ridge area



Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Lake Agassiz

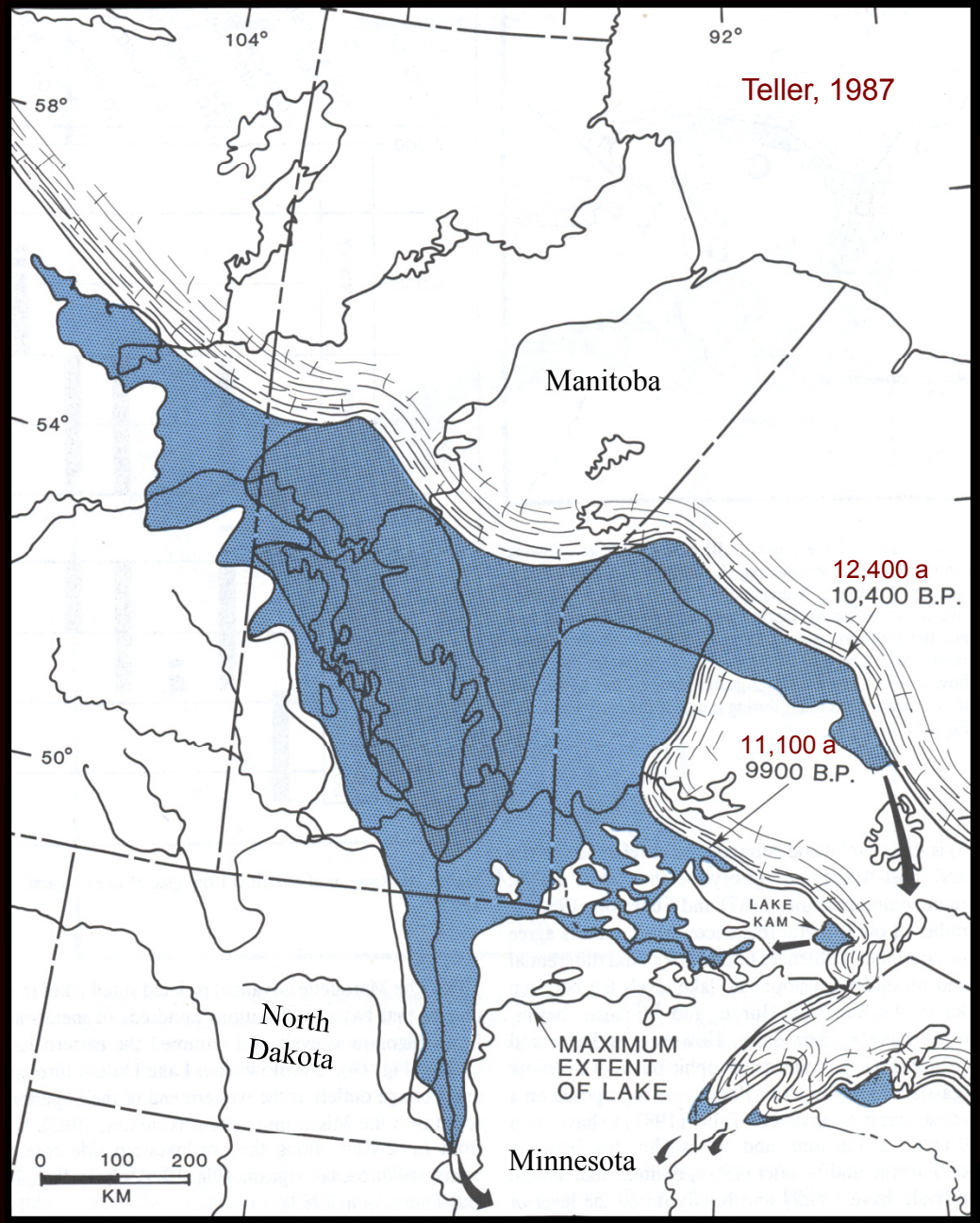
13,400 a Herman beach

Norcross beach

Upham beach

Tintah beach

10,100 a Campbell beach



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

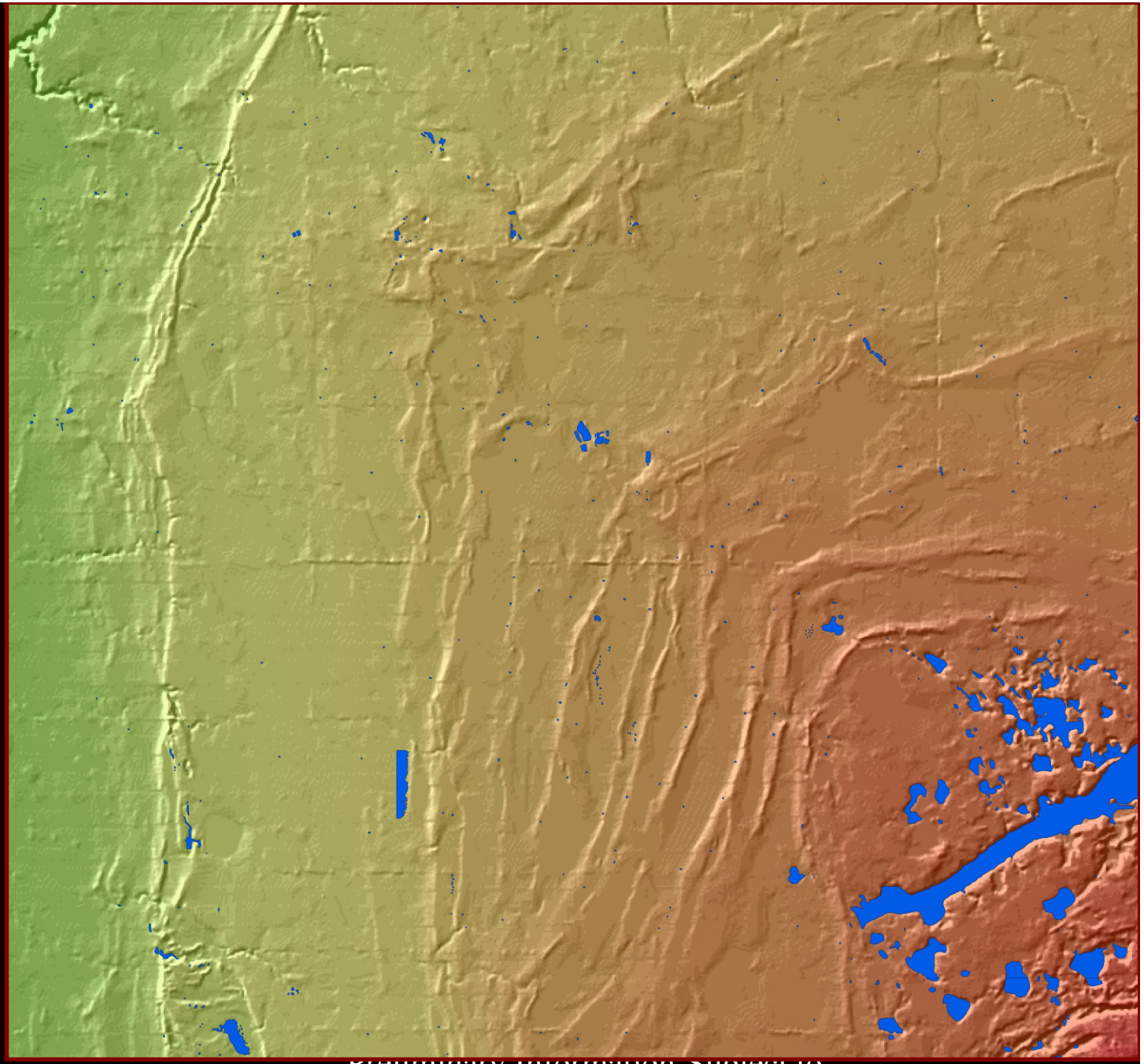
USGS

Why This Land?

- 25,000 acres of contiguous land with some native remnants
- Short period of plow agriculture
- Top of the ditch watersheds
- Surrounding public lands and private WRP lands
- Nesting area for threatened ground-nesting birds
- Rare wetland types and species (e.g. fens, orchids)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

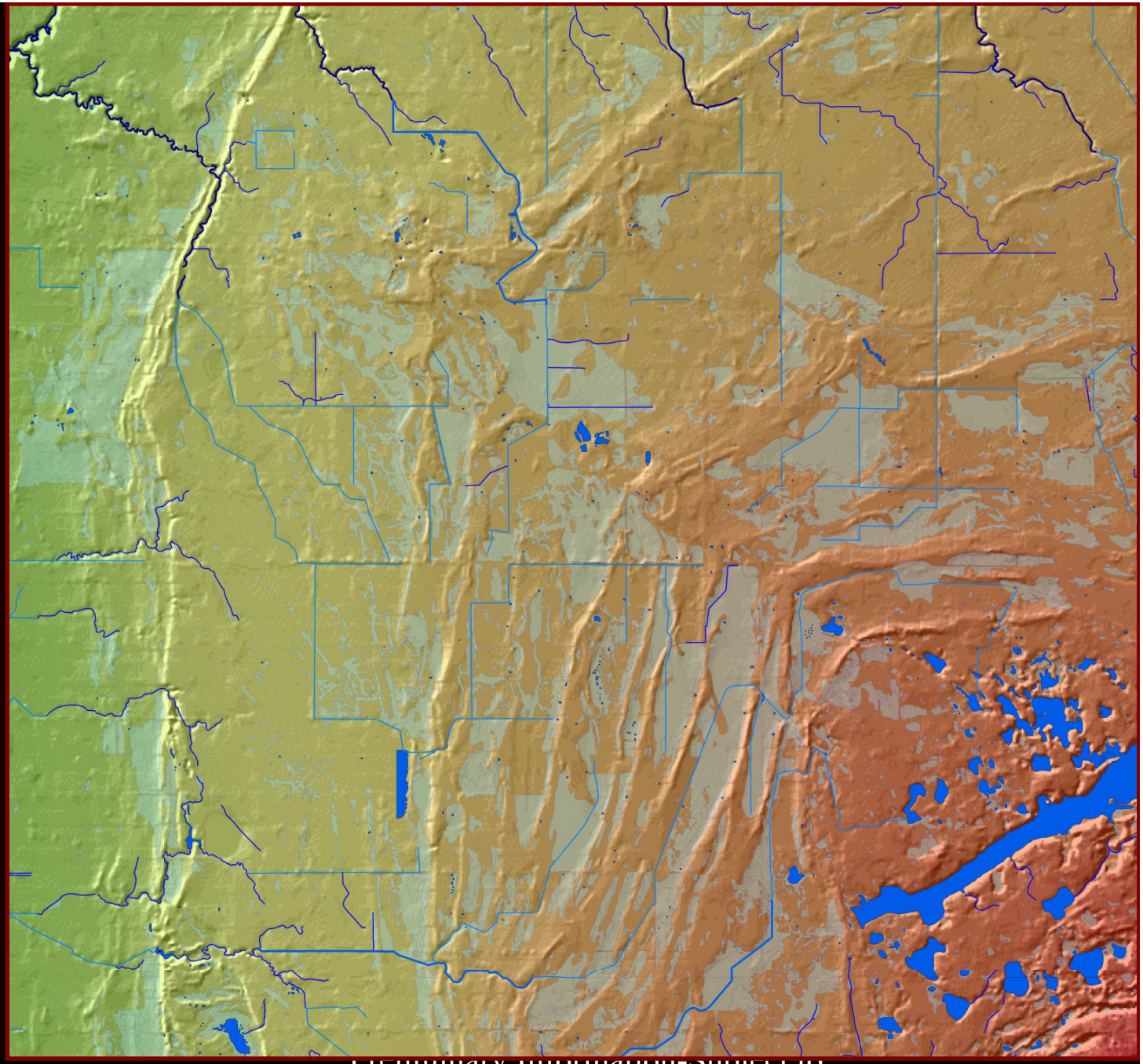
Glacial Ridge Beach Ridges



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

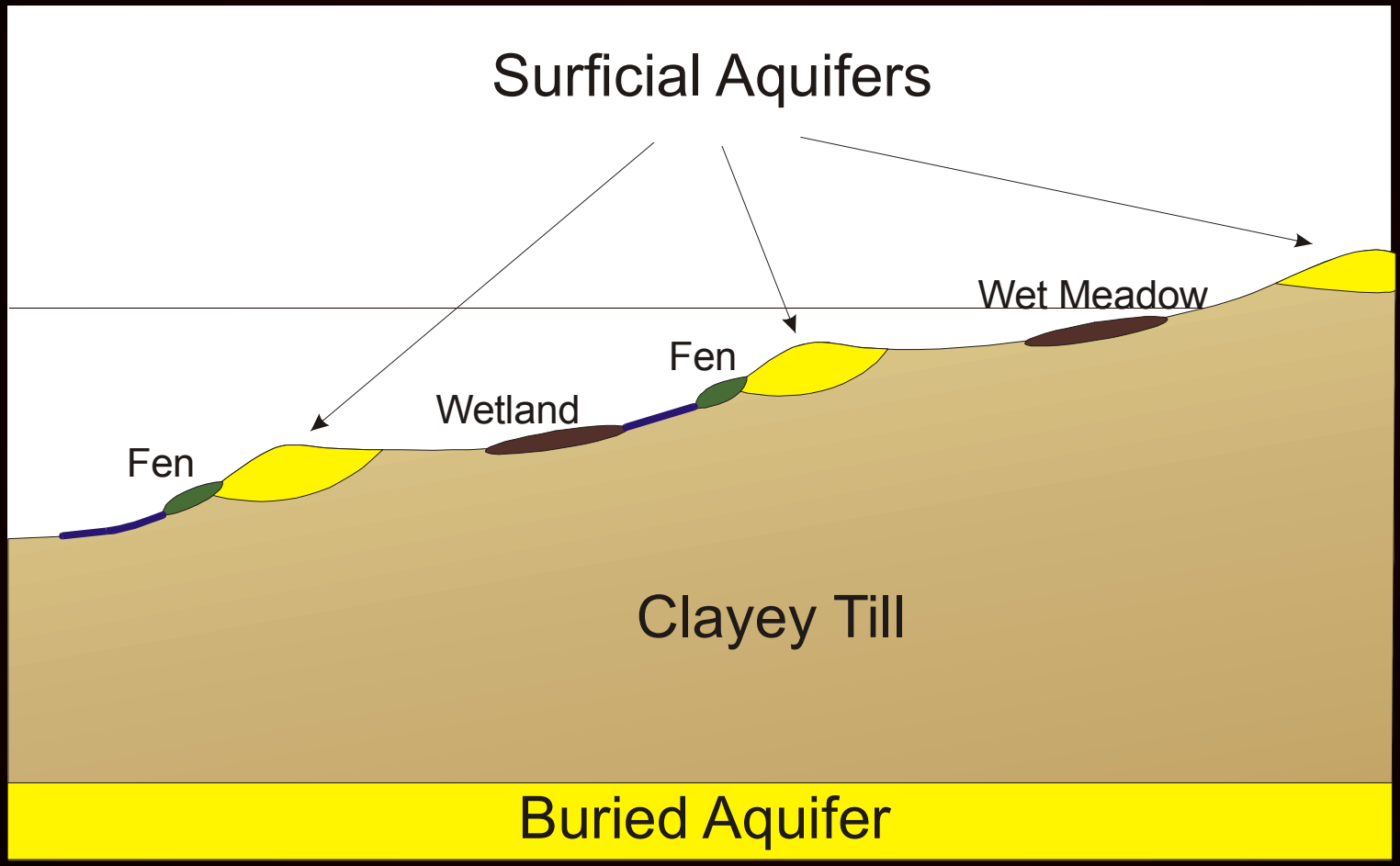
Wetland basins, streams and ditches, 2002



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

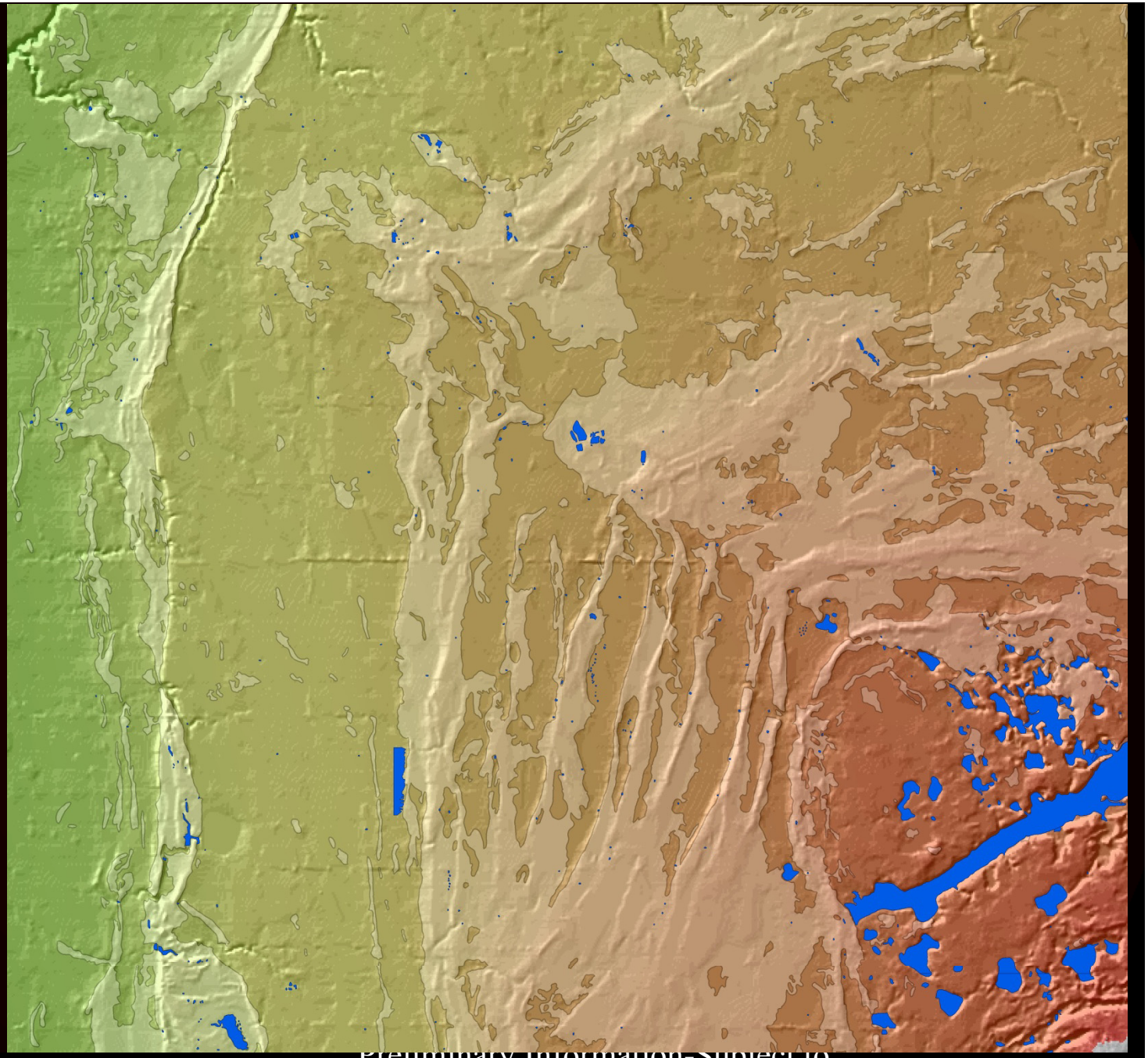
Looking North



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Surficial aquifers



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Back-beach wetland

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Fens

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

The big question:

What will happen to the hydrology (flow and quality) if the wetlands and prairies are restored?

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Approach

- Monitoring (pre- and post-restoration)
  - 12 continuous GW level and precip. sites
  - 6 ditch gages
  - ~100 synoptic WL sites
  - 18 water-quality sampling sites (nutrients, SS)
- Analysis (pre and post comparison by basin)
  - Water balance
  - Water-quality statistics
  - Storm-hydrograph modelling

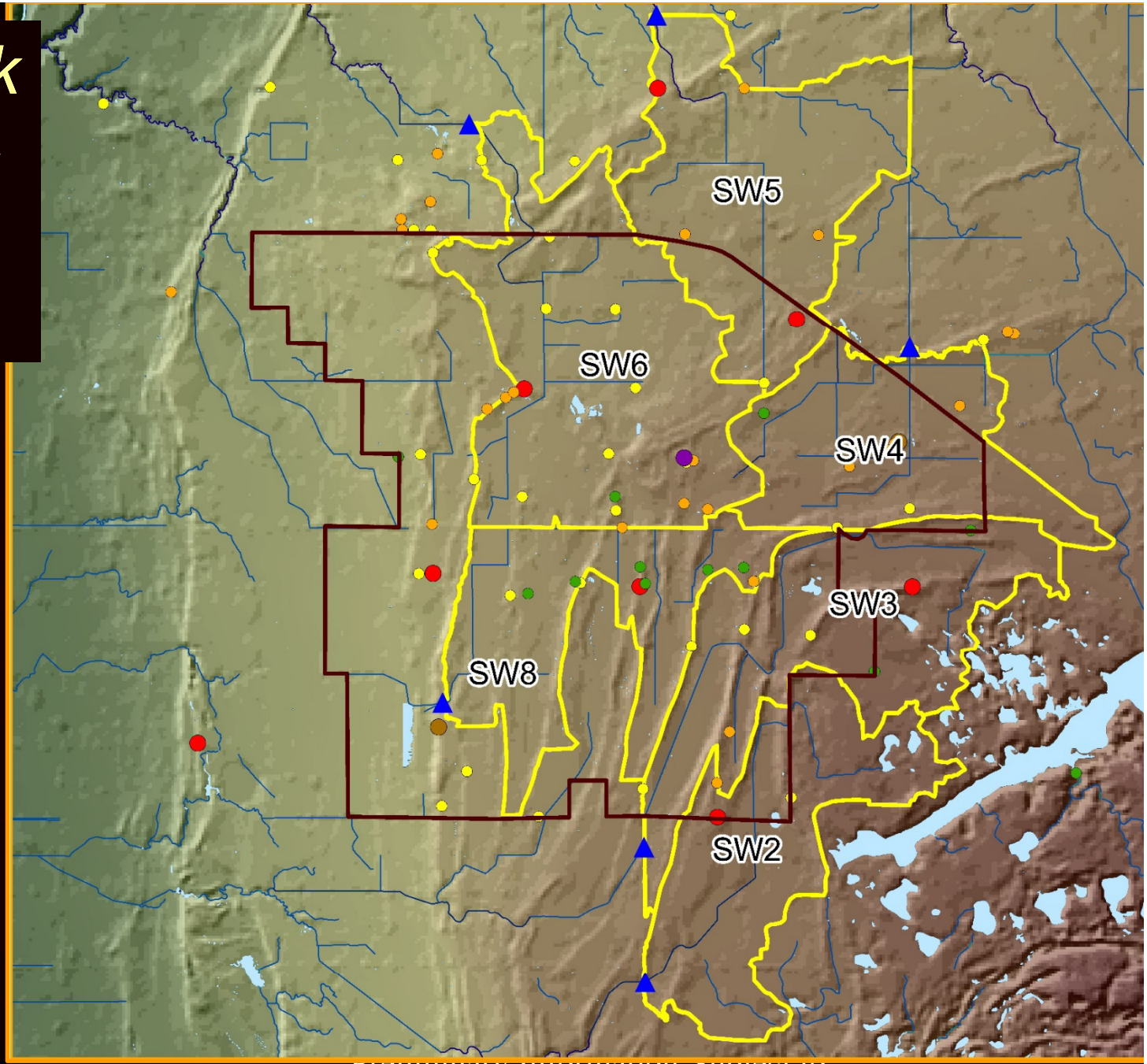
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Benefits Implications

- Correlating landscape and land-use factors
  - Aquifer area (soil types)
  - Stream and land slope
  - Land-use change
- Mapping in western Minnesota
  - Where is the bang for our restoration buck?

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

WL network and water-balance basins



- SW gage
- Well
- Well nest
- Weather stn.

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

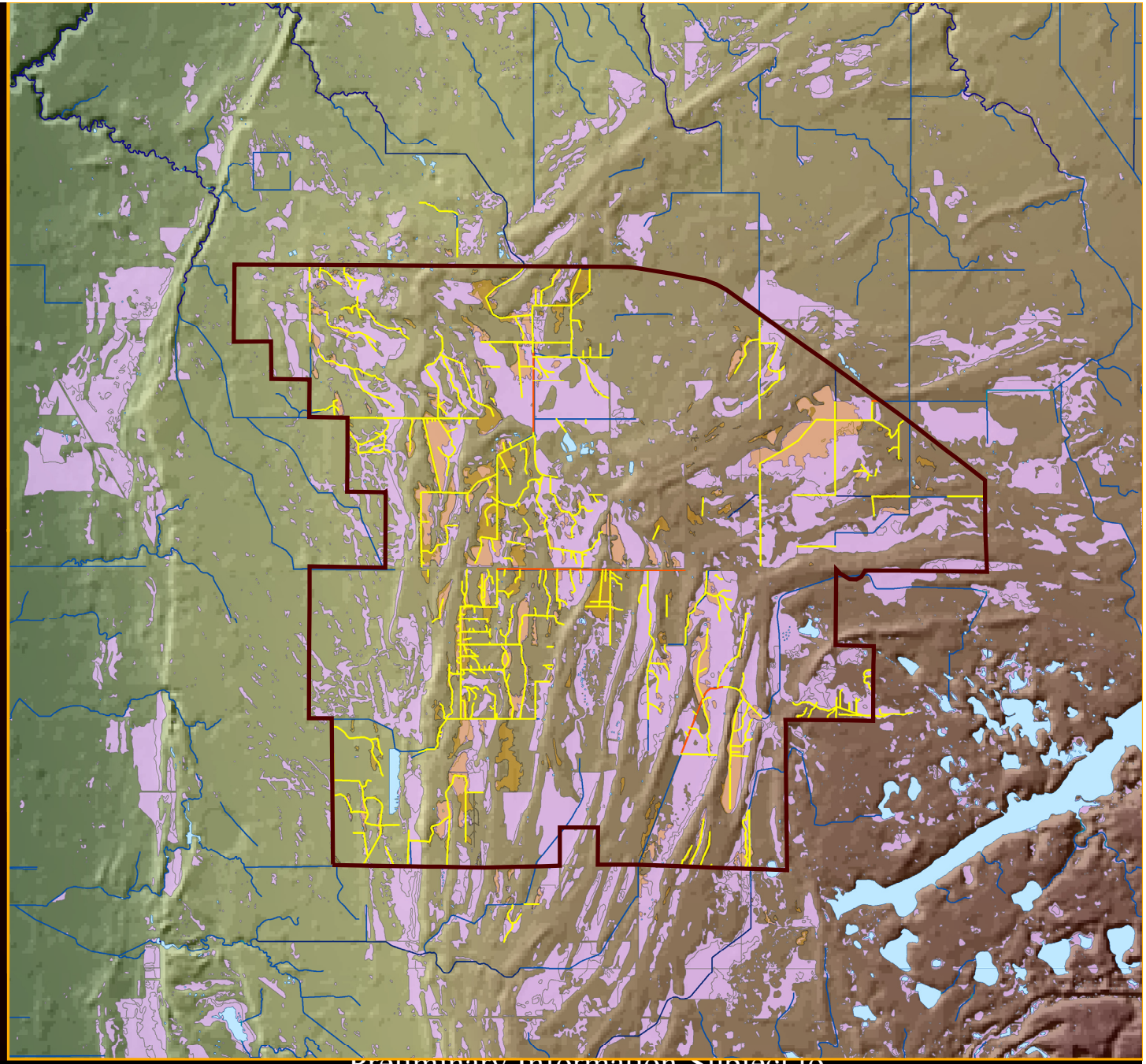
USGS

Restorations

- Total NWR area: 36,217 acres
- Wetlands restored: 2,977 acres
- Ditches abandoned: 50.1 miles
- Prairies seeded: 19,198 acres
- NWR owned: 25,658 acres (71%)
- Private WRP: 3,655 acres (10%)
- State WPA & SNA: 3,839 acres (11%)
- National WPA: 115 acres
- Total in natural land: 33,267 acres (92 %)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

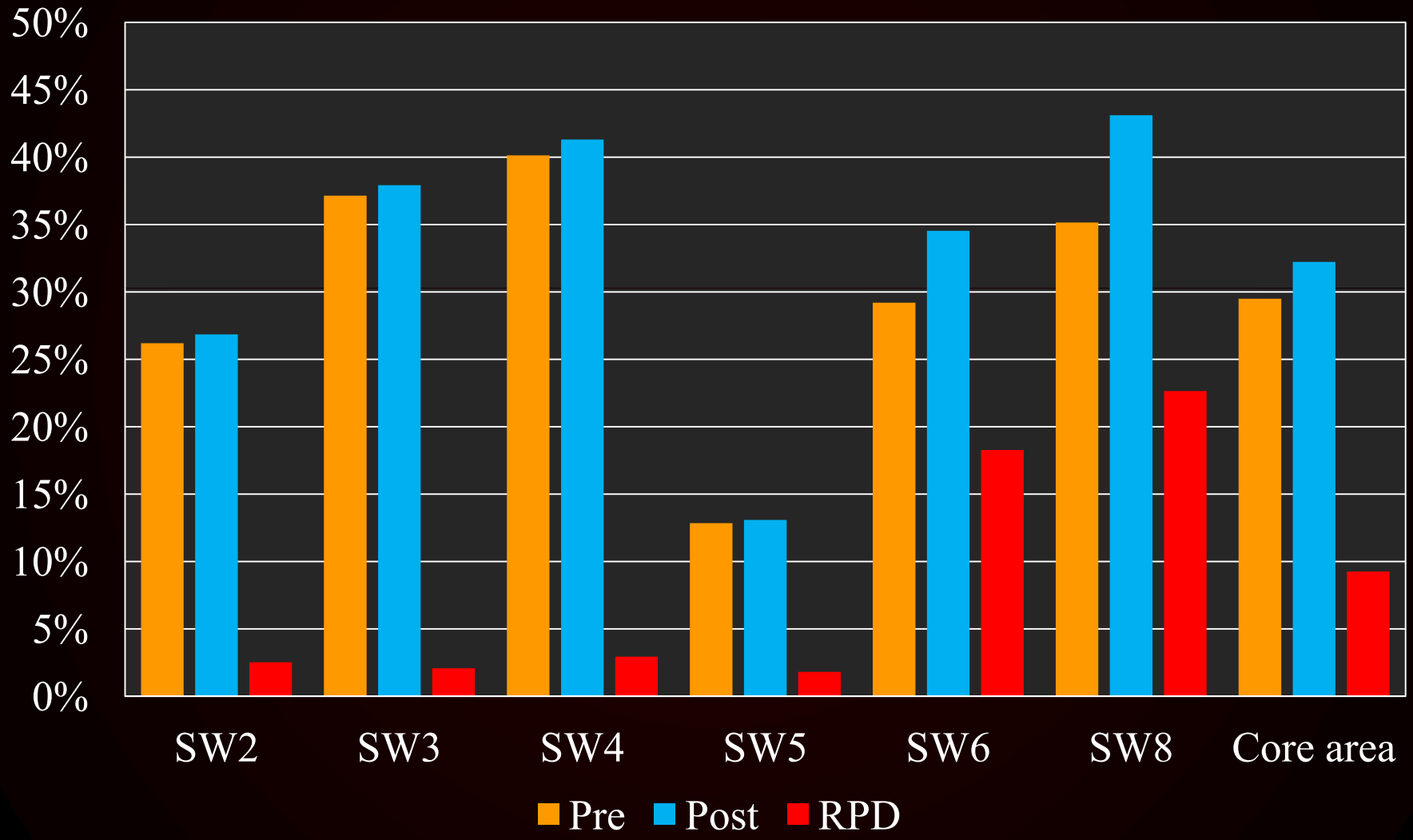
Restored wetlands and abandoned ditches, 2011



Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

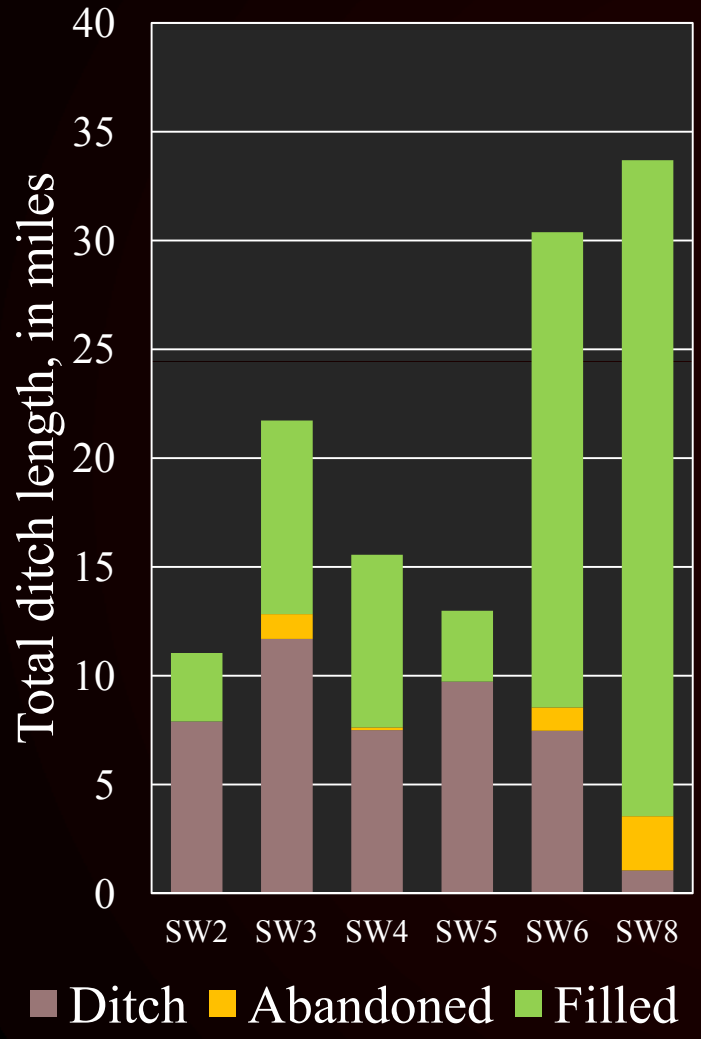
Wetland Restorations

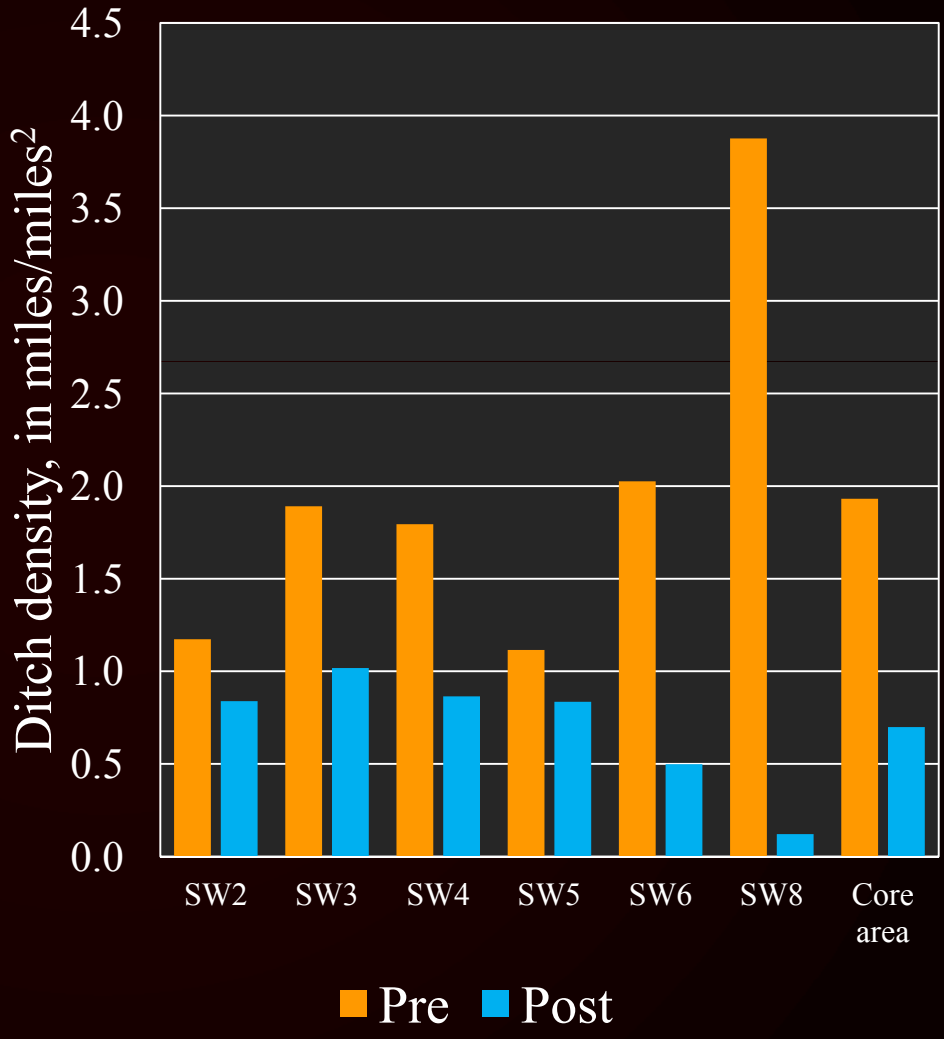


Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Ditch Restorations

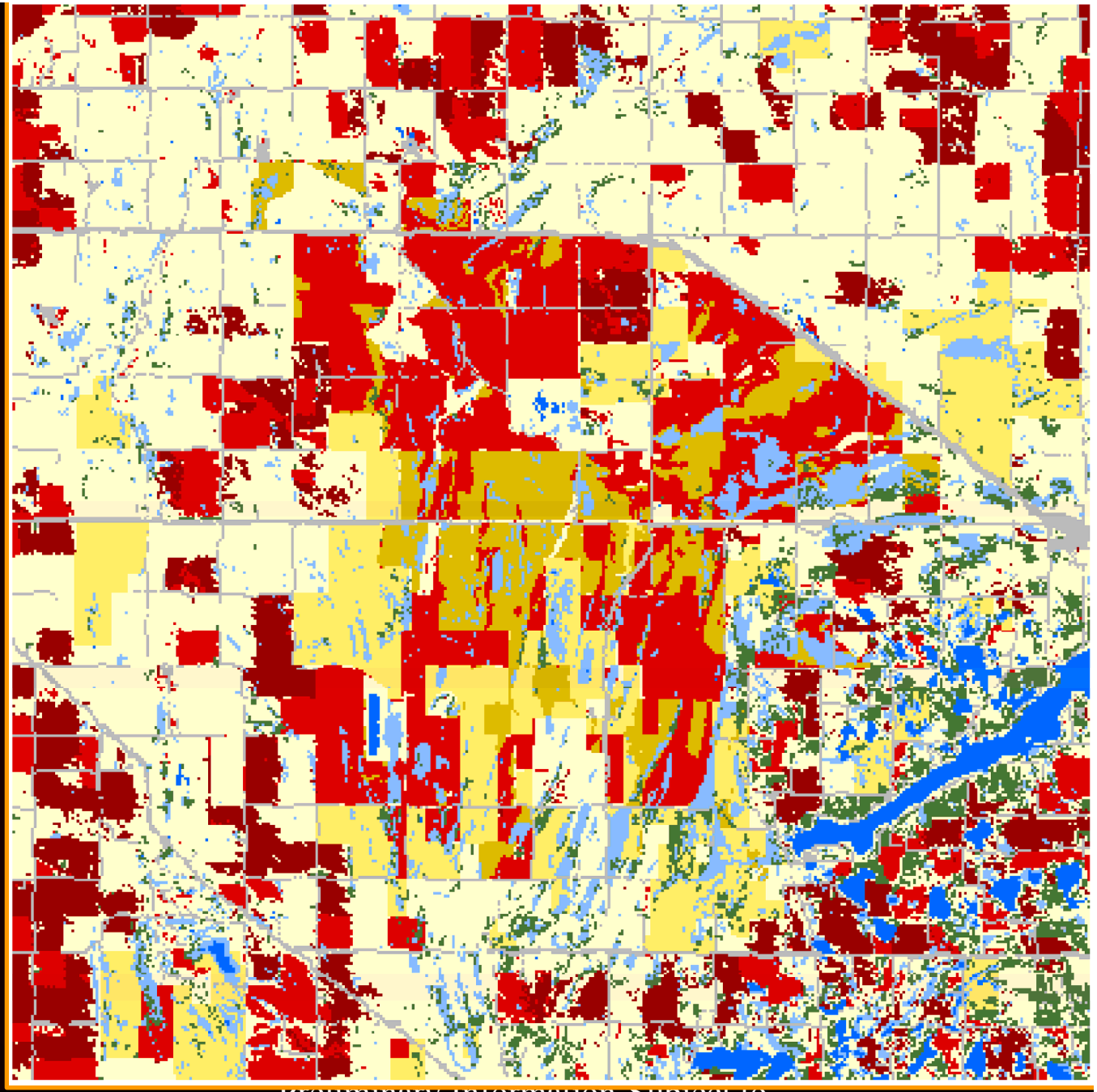




Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

2002 Land Use

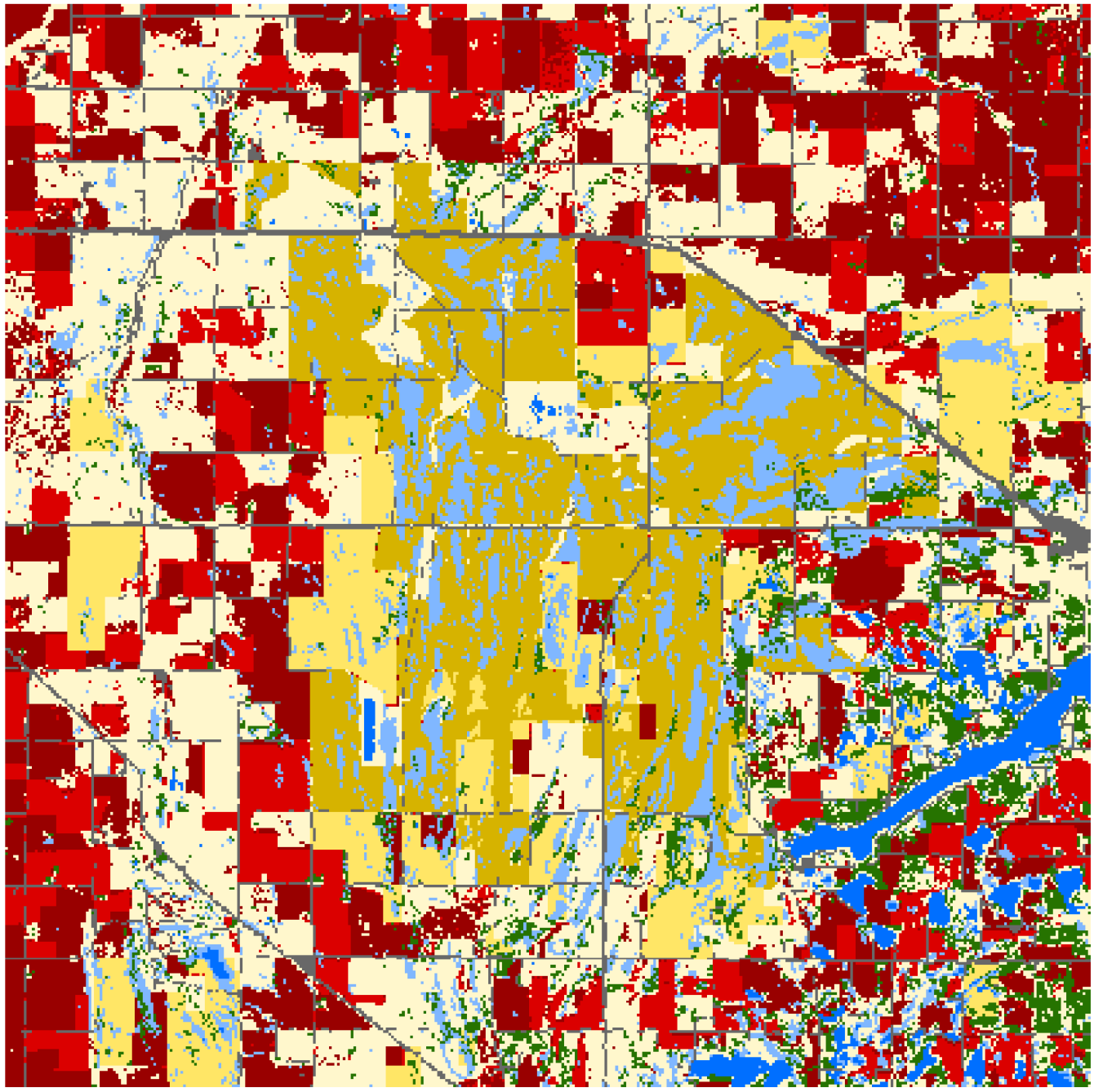


- Row crop
- Small grains
- Wetland
- Open water
- Forest
- Grass pasture, prairie
- State-managed lands
- Fallow, tame grass, non-crop
- Developed

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

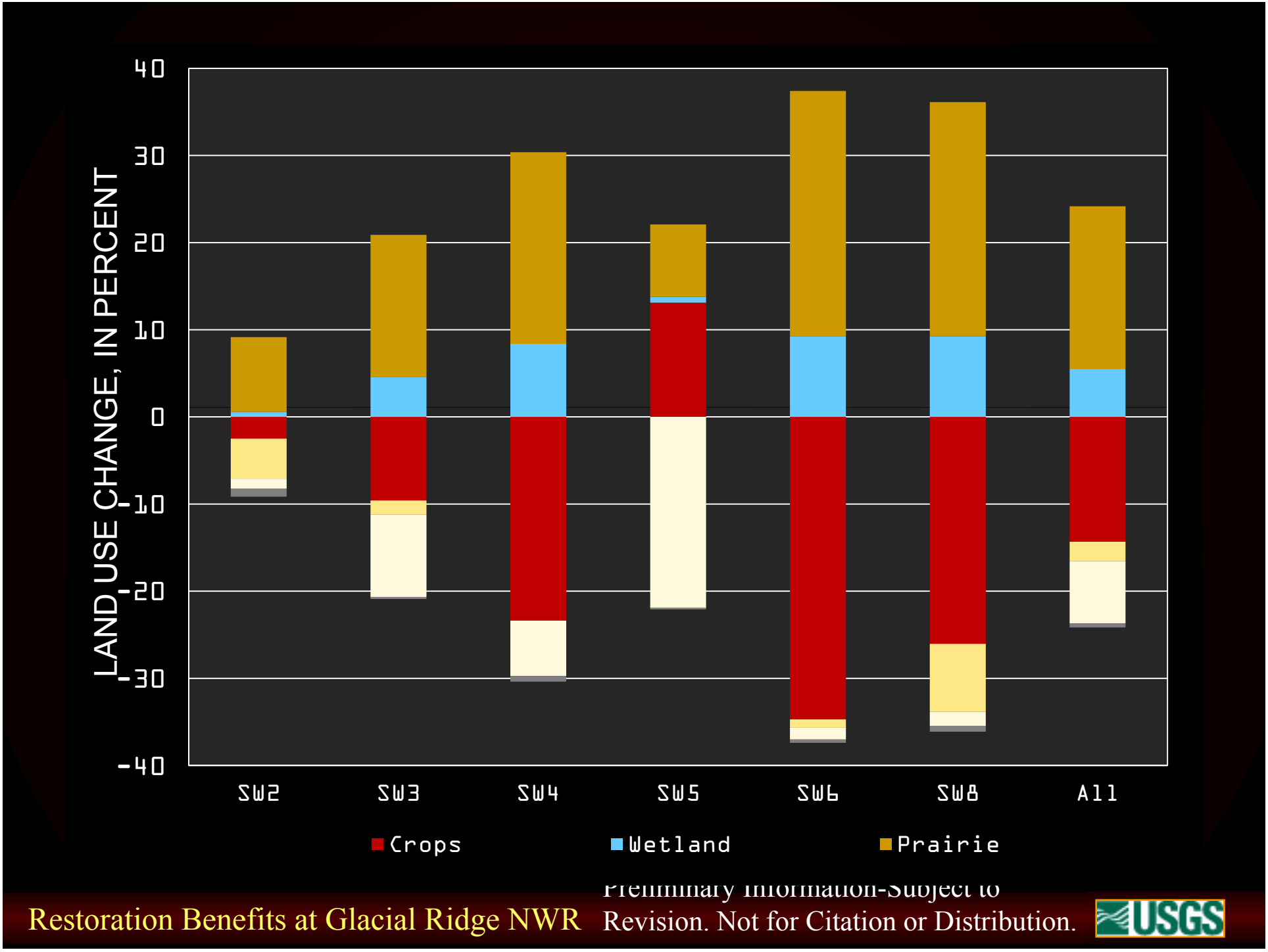
2015 Land Use



- Row crop
- Small grains
- Wetland
- Open water
- Forest
- Grass pasture, prairie
- State-managed lands
- Fallow, tame grass, non-crop
- Developed

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS



Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

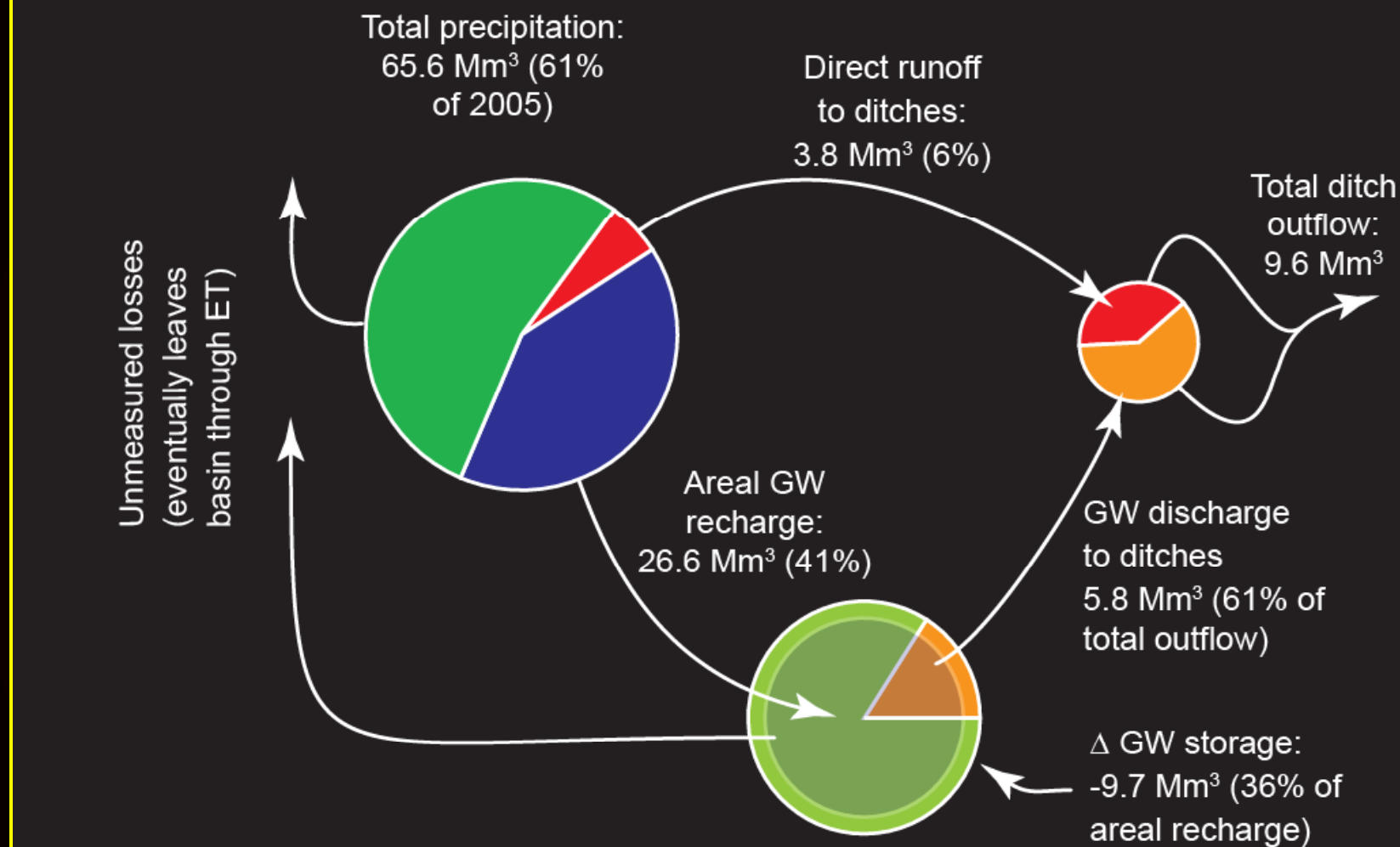
USGS

Net mass balances

- 41,542 acres (32% of the study area)
- Pre: 2002–2005; Post: 2012–2015
- Unmeasured GW losses = GW recharge – GW discharge to ditches – GW ET– Δ storage
- Unmeasured SW losses = total precip. + GW discharge – GW recharge – SW ET - ditch outflow
- 6 ditches: 15 minute discharge
- 8 gages: 15 minute precipitation
- 6 wells: hourly GW levels

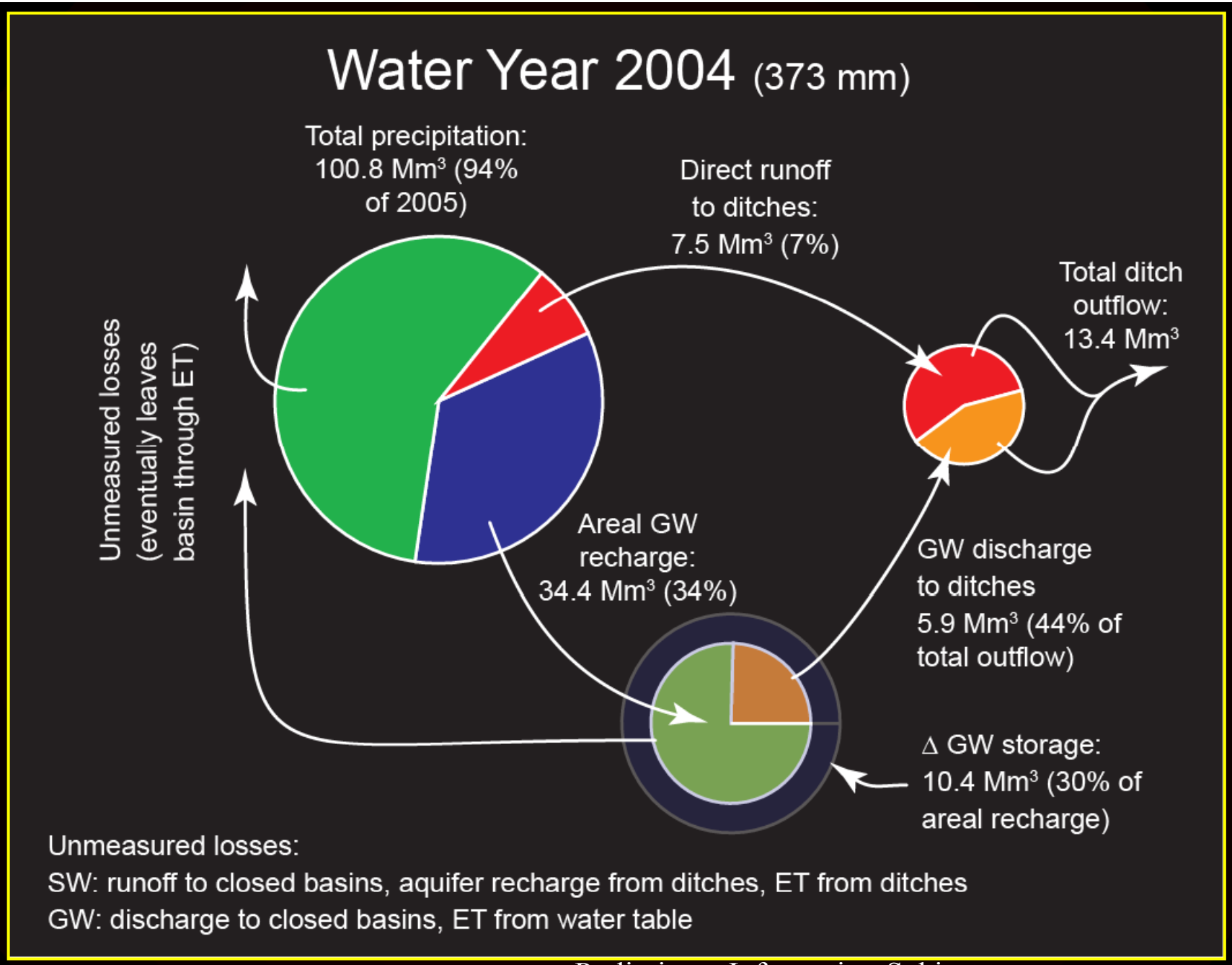
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Water Year 2003 (239 mm)



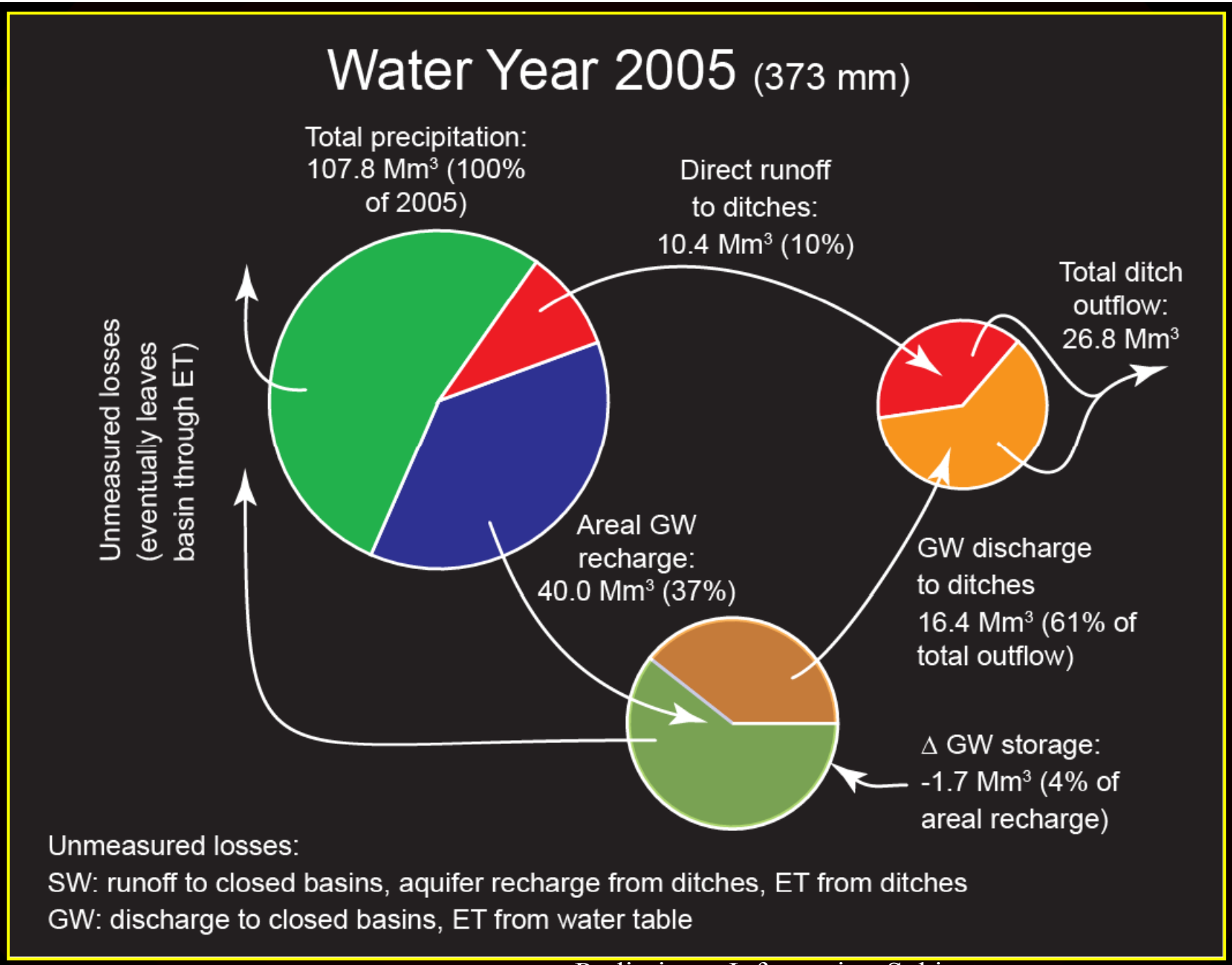
Unmeasured losses:
SW: runoff to closed basins, aquifer recharge from ditches, ET from ditches
GW: discharge to closed basins, ET from water table

Preliminary Information-Subject to Revision. Not for Citation or Distribution.



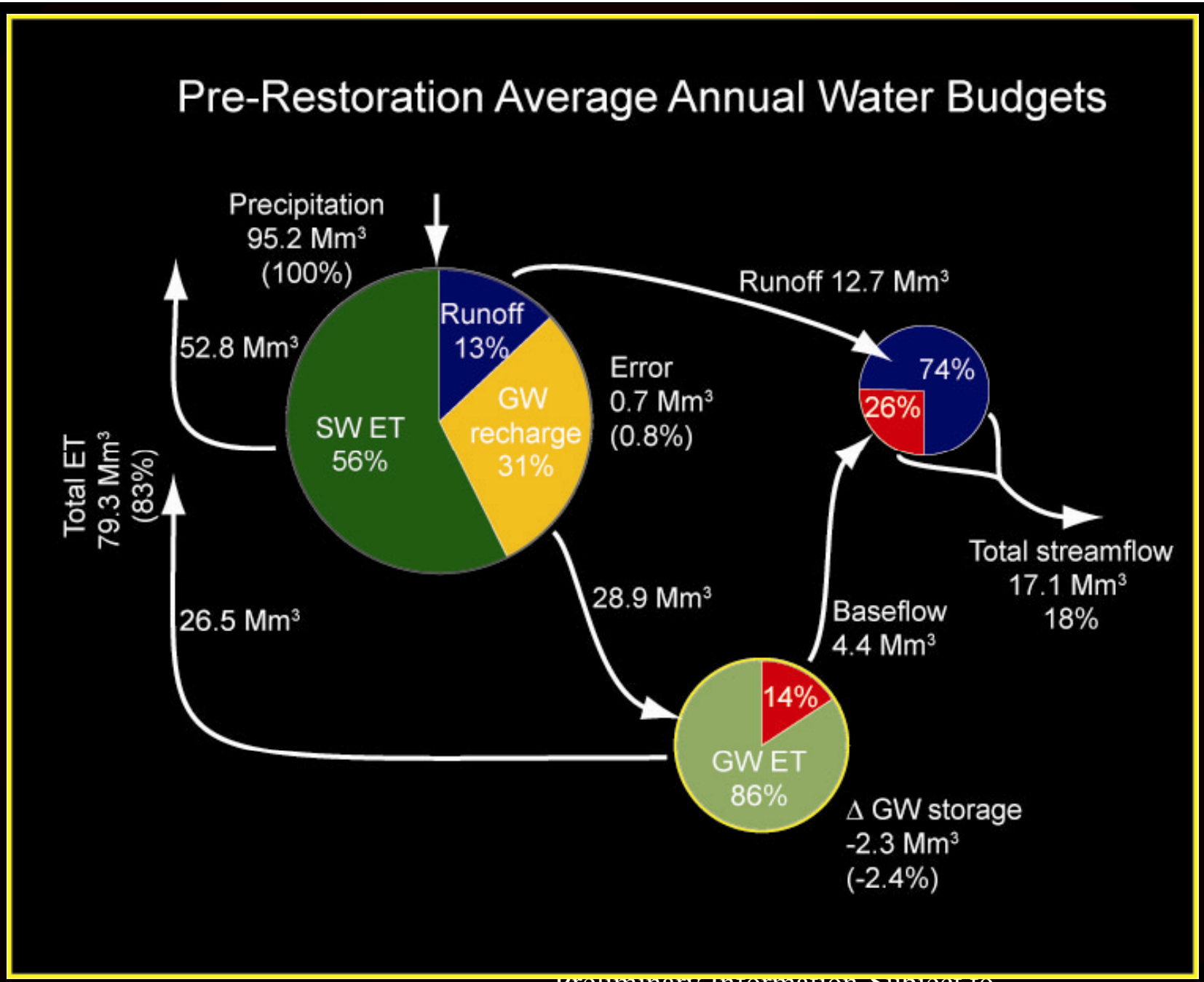
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS



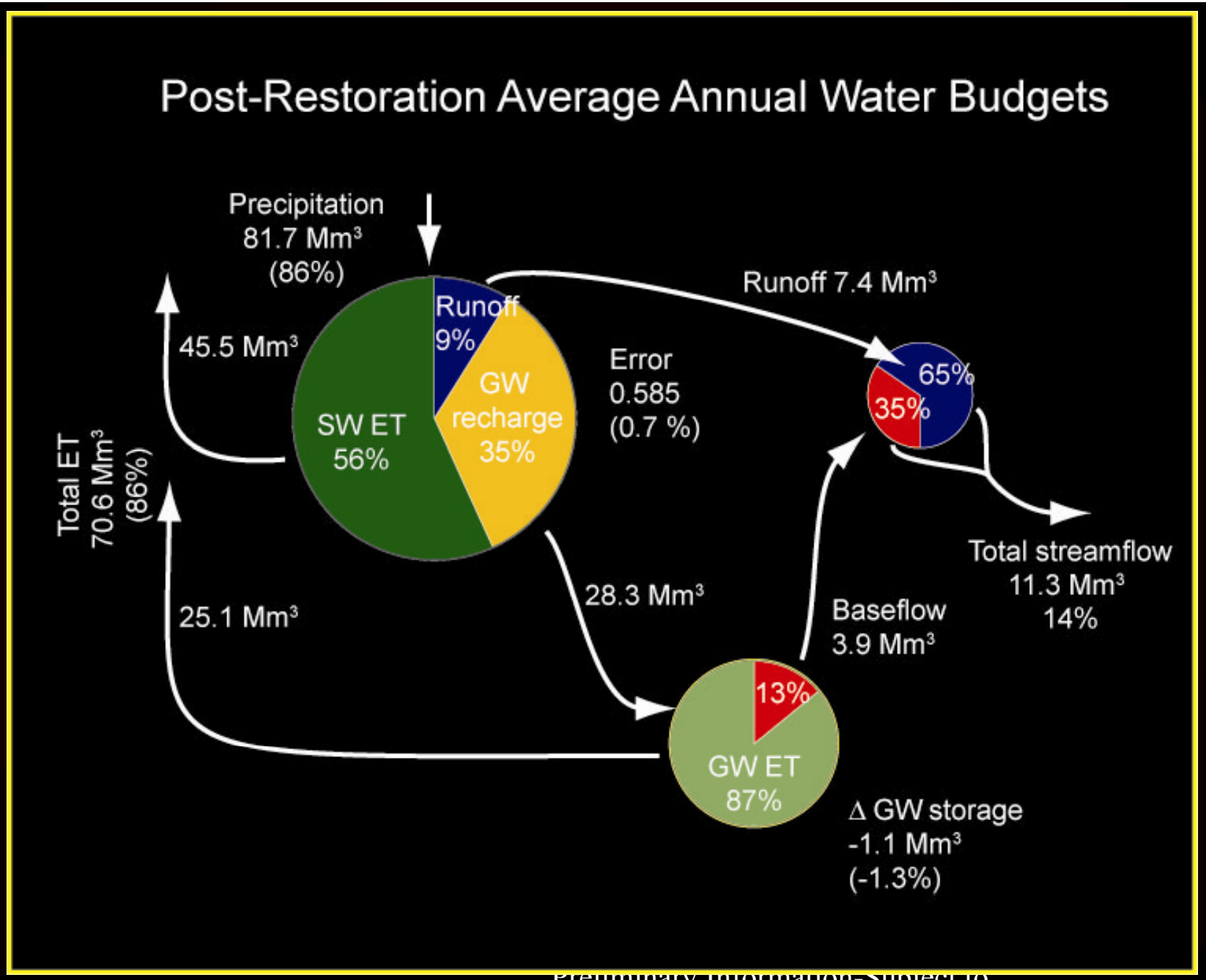
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS



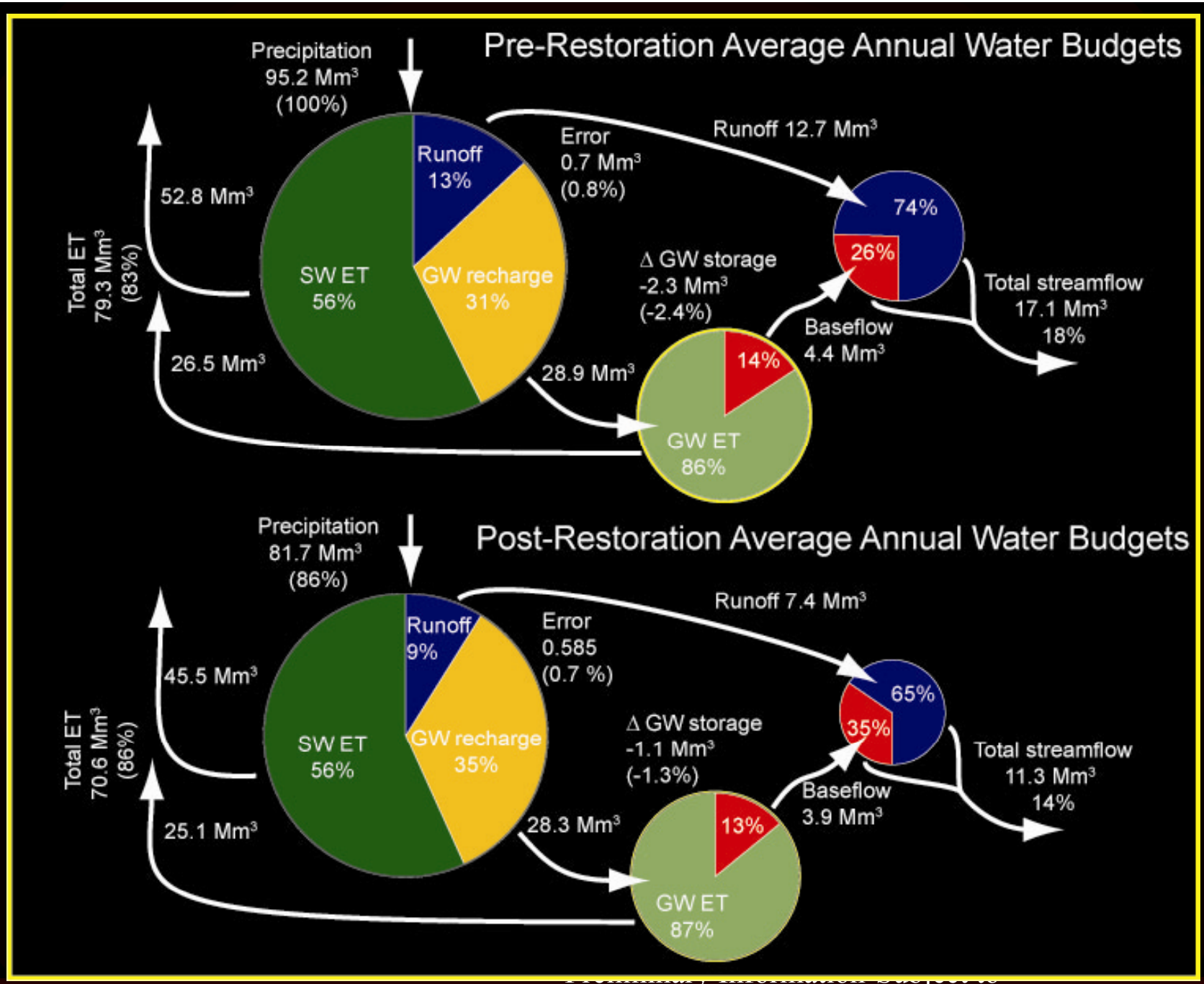
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

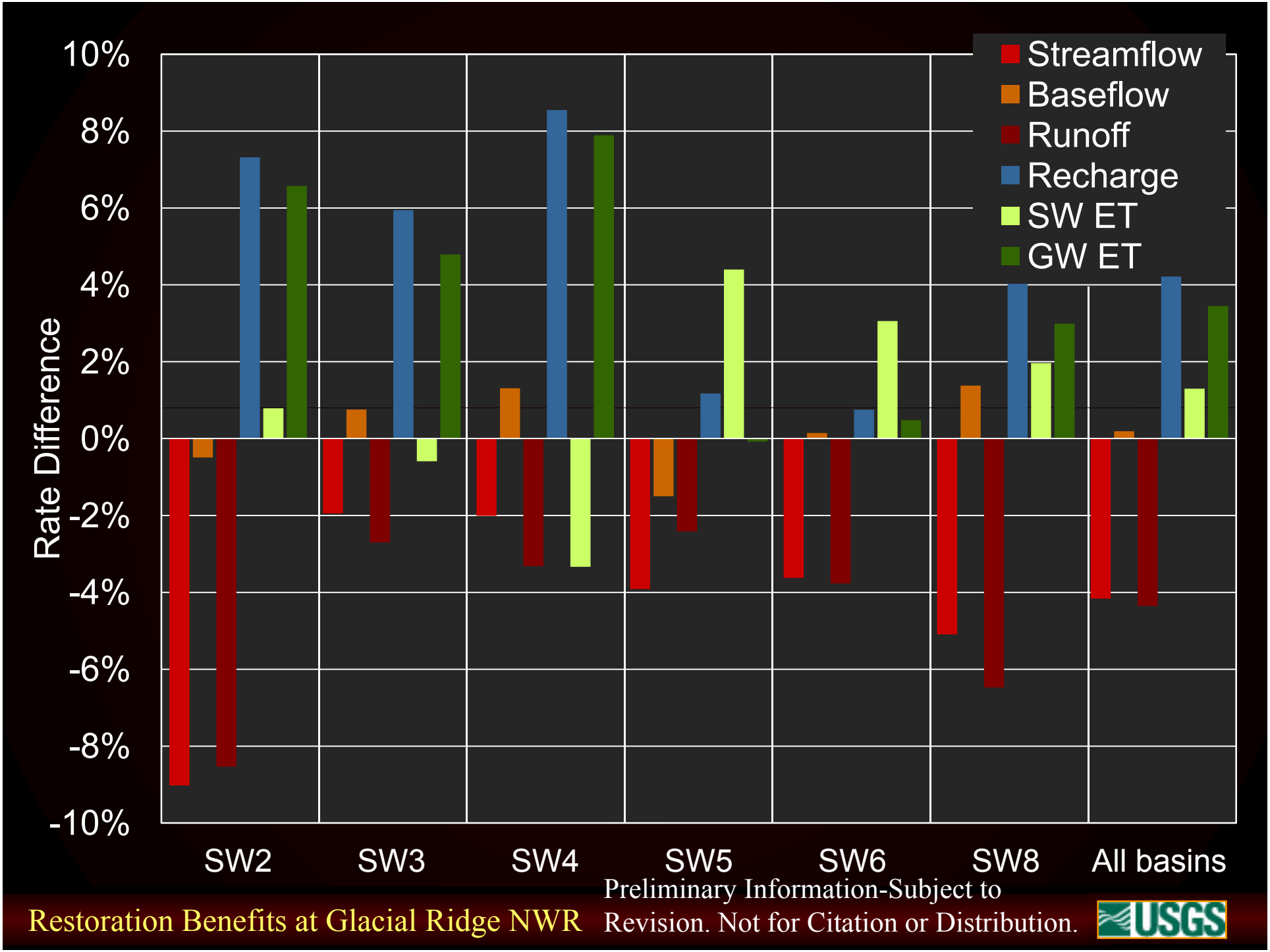


Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS



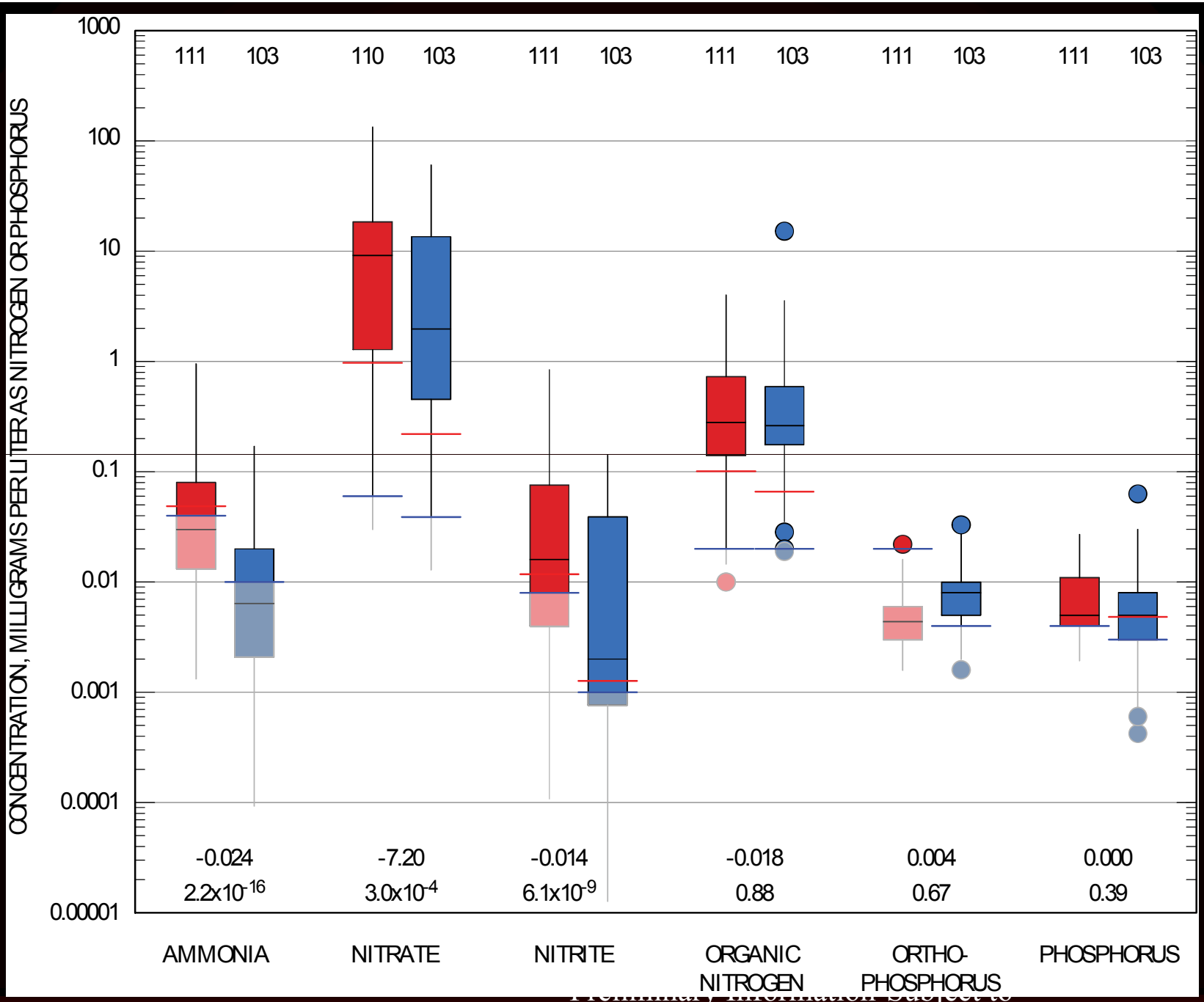
Revision. Not for Citation or Distribution.



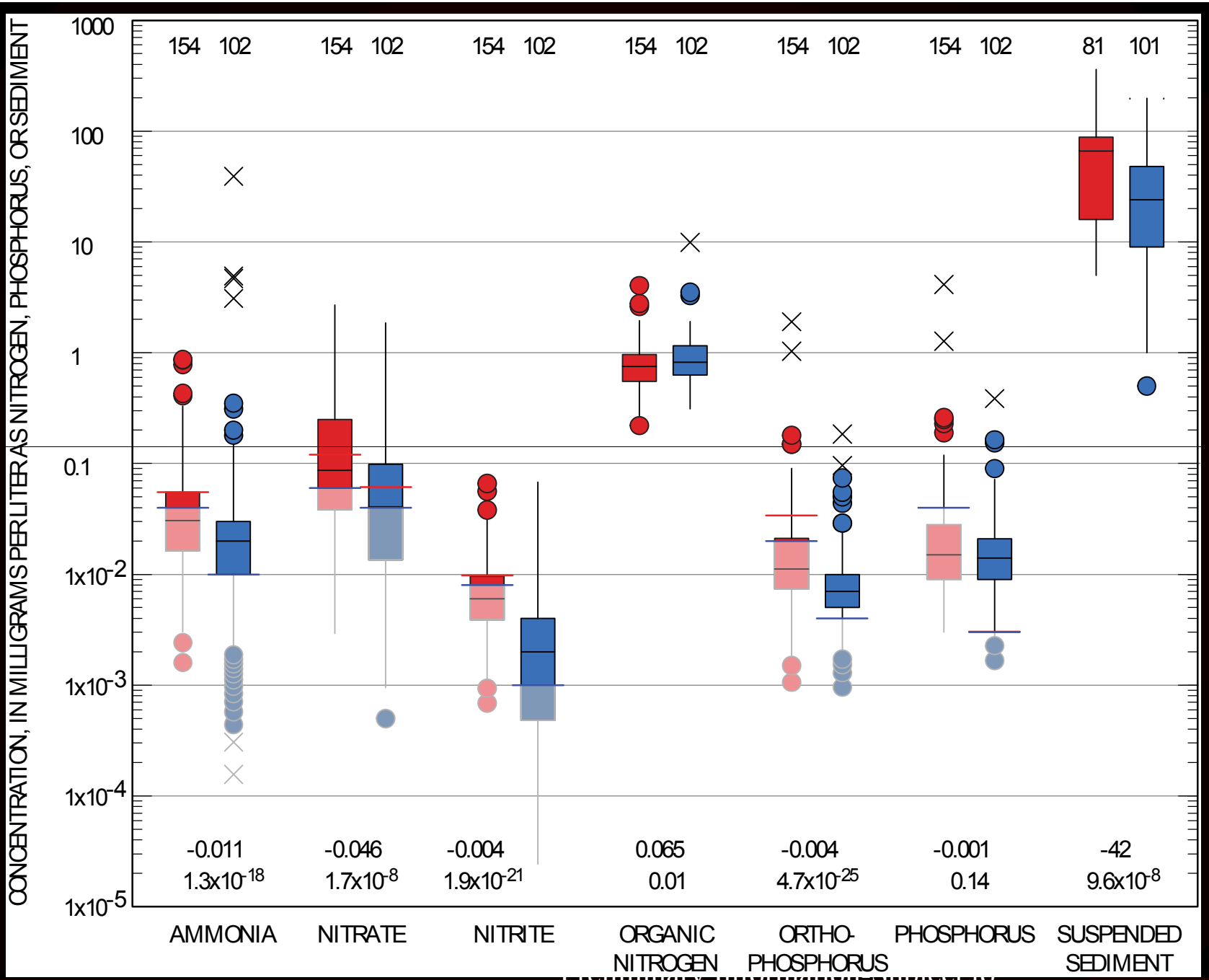
Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS



Revision. Not for Citation or Distribution.



Preliminary Information Subject to Revision. Not for Citation or Distribution.

14-years later, what di

Land-use changes:

- +19% prairie
- +6% wetlands
- -14% cropland
- -63% decrease in ditch density (RPD)

Water-flow changes:

- -23% ditch flow
- -33% runoff
- +15% recharge
- +6% ET

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

14-years later, what di

Water-quality changes:

- -7.2 mg/L-N GW mean nitrate (RPD: -79%)
- Decreases in other GW nitrogen compounds
- -42 mg/L ditch suspended sed. (RPD: -64%)
- -0.05 mg/L-N ditch water nitrate (RPD: -53%)
- Decreases in all ditch-water

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Where else will this work?

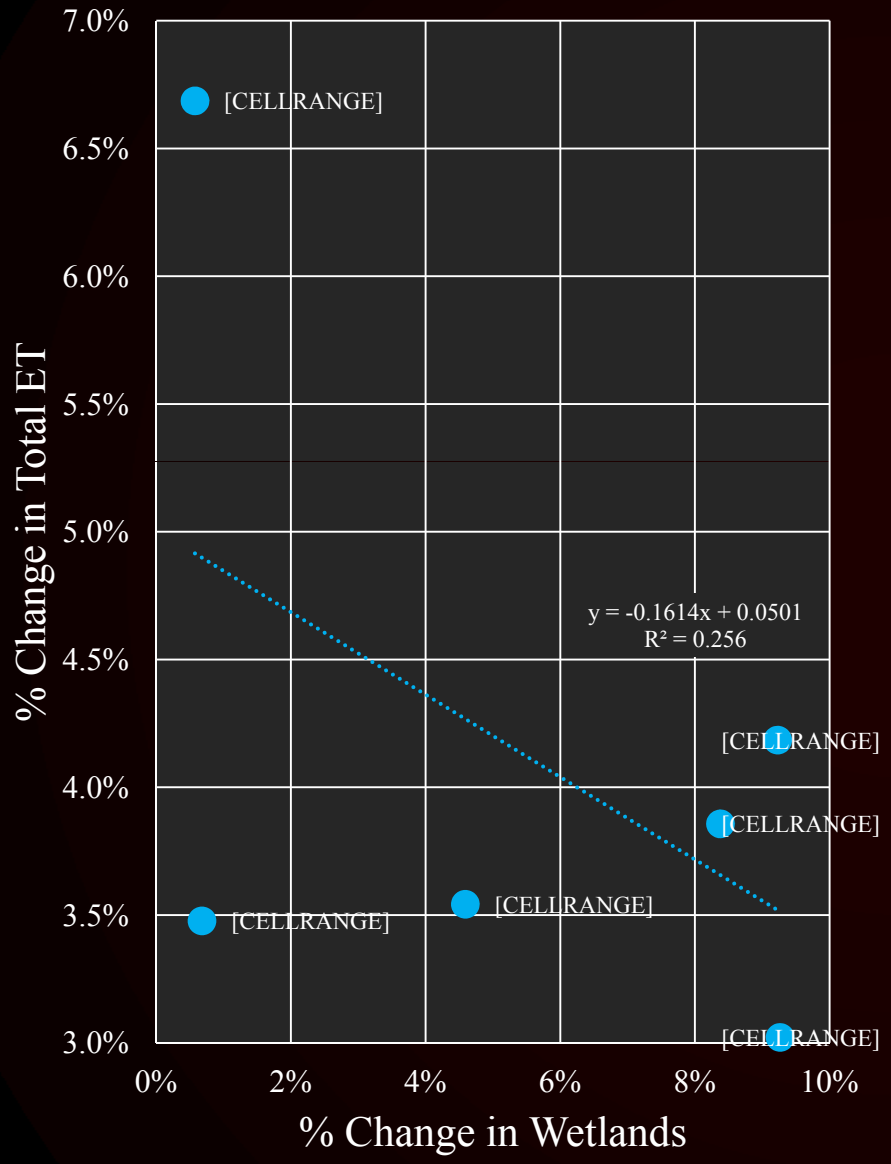
Use the restoration change and benefits among each ditch basin to identify correlations

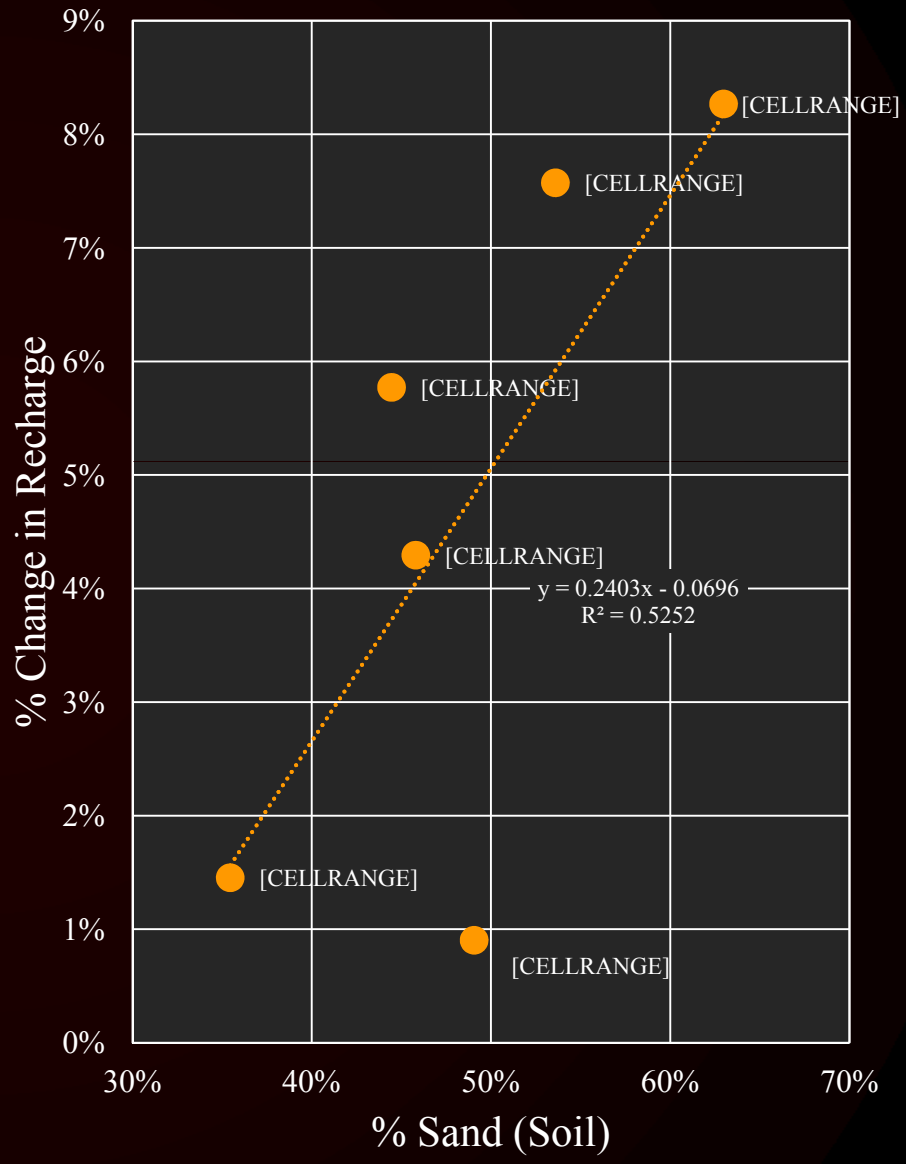
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Ditch basin factor		2002-15 change as a percentage of precipitation					
		Recharge		Runoff		ET	
		R^2	dir.	R^2	dir.	R^2	dir.
Percent of area	Surficial aquifer	0.45	+	0.17	-	0.17	+
	Sand soils	0.53	+	0.09	-	0.10	+
	Till soils	0.39	-	0.23	+	0.08	-
	Wave-washed till soils	0.60	-	0.01	+	0.27	-
	Wetland soils	0.25	+	0.13	-	0.25	+
Ditch channel slope, in feet/mile	StreamStats	0.04	+	0.22	-	0.02	+
	First report	0.49	+	0.07	-	0.01	-
	This report	0.04	-	0.04	+	0.00	-
	Mean basin slope, in percent	0.02	+	0.00	+	0.00	-
2002-15 percent change in area	Wetland	0.01	-	0.01	+	0.26	-
	Total restorations	0.02	-	0.00	+	0.25	-
	Cropland	0.05	-	0.02	+	0.09	+
	Fallow land	0.11	+	0.50	-	0.10	+
	Restored wetlands	0.11	-	0.02	+	0.34	-

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

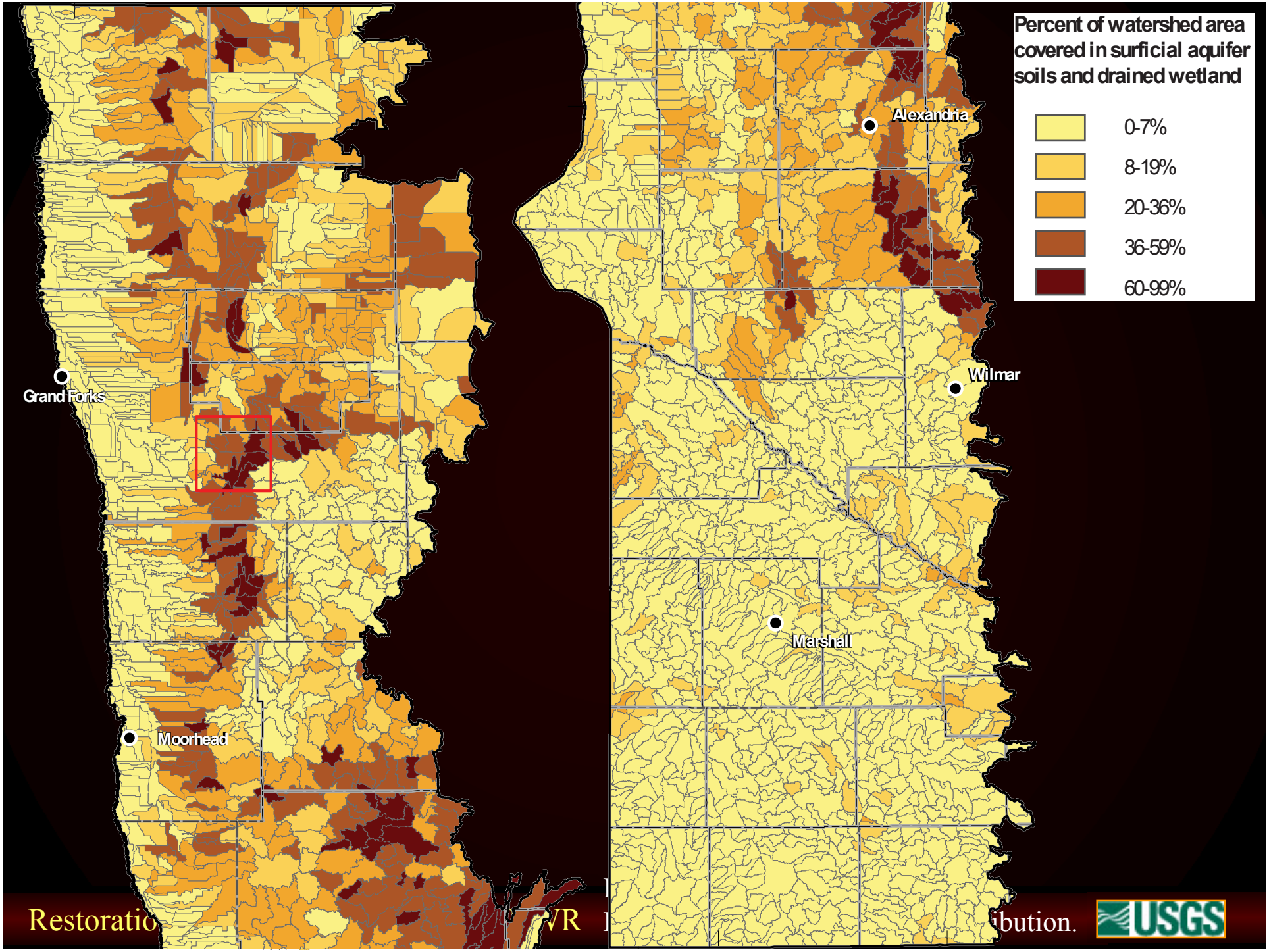
Benefit correlations





Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS


Percent of watershed area covered in surficial aquifer soils and drained wetland
0-7%
8-19%
20-36%
36-59%
60-99%
Alexandria
Wilmar
Marshall
Grand Forks
Moorhead
USGS

Summary

- SW and GW form one hydrologic system
- Flow is very shallow
- Ditches short-circuit natural flow
- Most water leaves through ET
- System is interconnected and resilient
- GW buffers rainfall variability for SW
- Less surface runoff, more ET after restoration

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Summary

- Nutrients decreased substantially
- Phosphorus increased slightly in GW
- Ditch sediment decreased substantially
- Restorations are most effective over surficial aquifers and where there are wetlands to restore
- These are the beach ridges of Glacial Lake Agassiz and the Alexandria Moraine

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Restoration Benefits at Glacial Ridge NWR

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS

Preliminary Information-Subject to Revision. Not for Citation or Distribution.

USGS