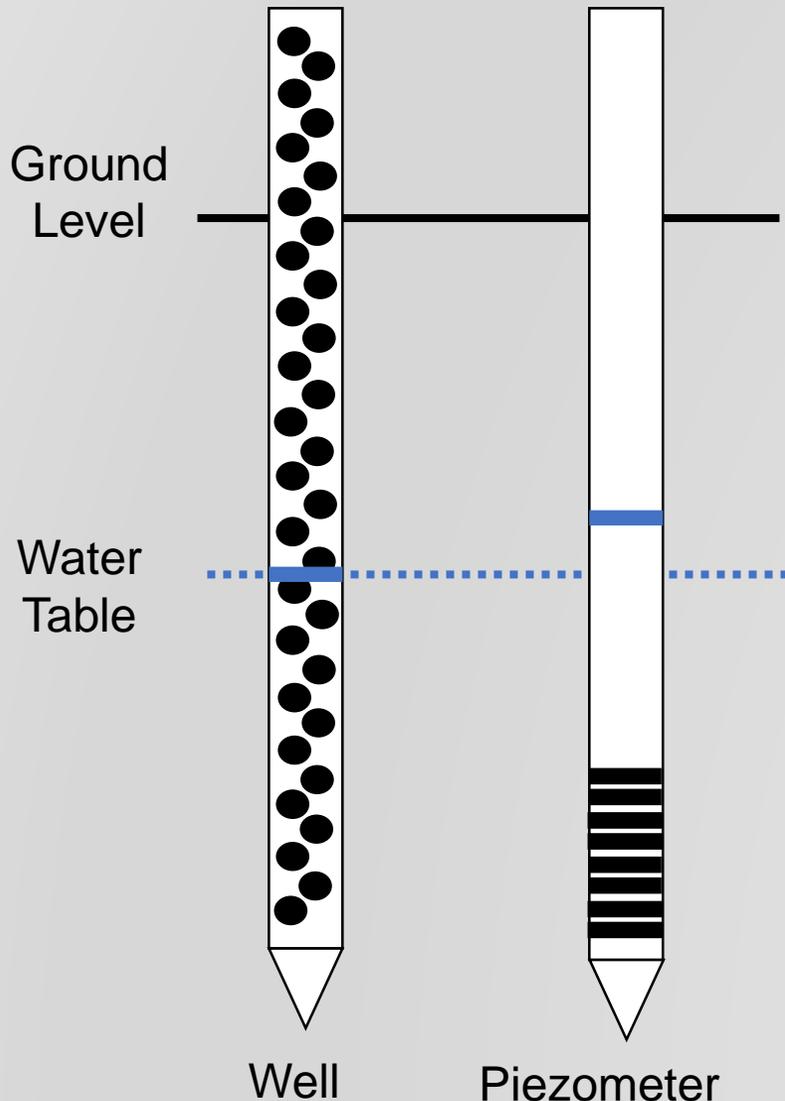


Restoration Effects on Groundwater

Study Questions

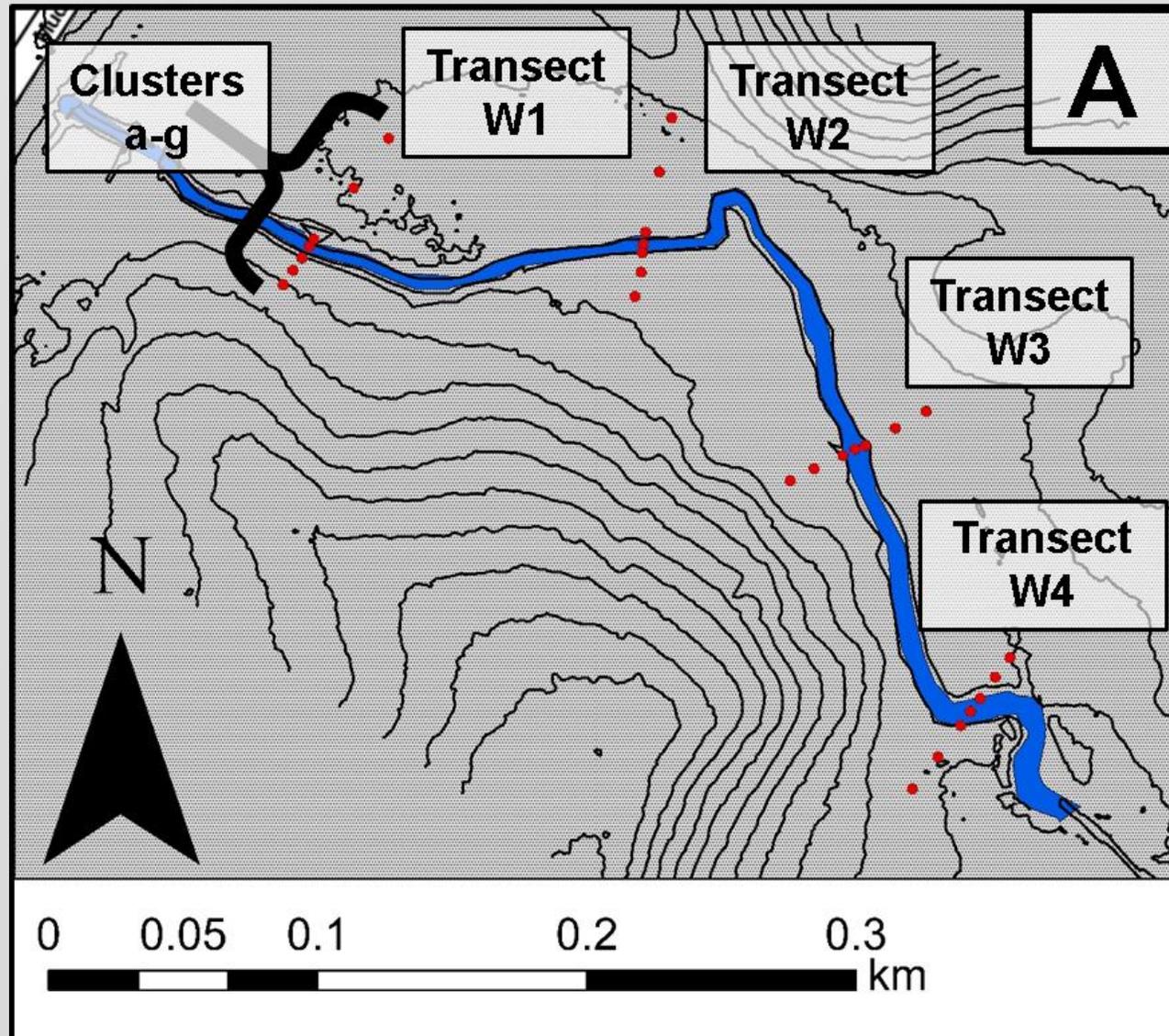
1. Did the restoration increase groundwater levels?
2. Did the restoration encourage higher rates of surface-groundwater exchange?
3. Did the stream restoration change groundwater chemistry?
4. Were there any tradeoffs in surface water quality?

Groundwater Monitoring



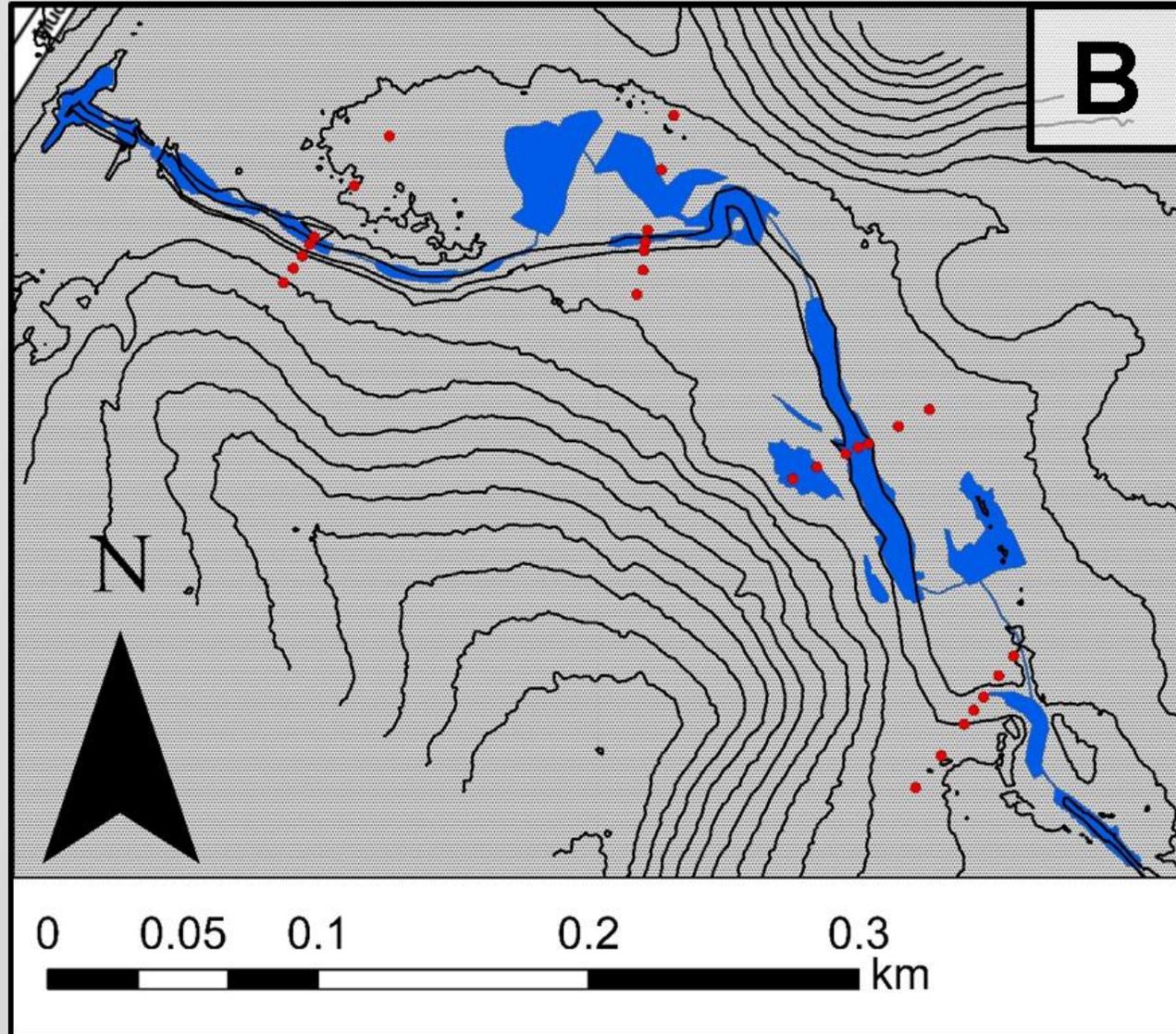
- Groundwater levels monitored within 4 transects, with 7 wells in each transect.
- Groundwater chemistry sampled within 52 piezometers at three depths, spaced 0.6 m apart.
- Groundwater levels monitored weekly, with chemistry monitored each month.

Groundwater Monitoring



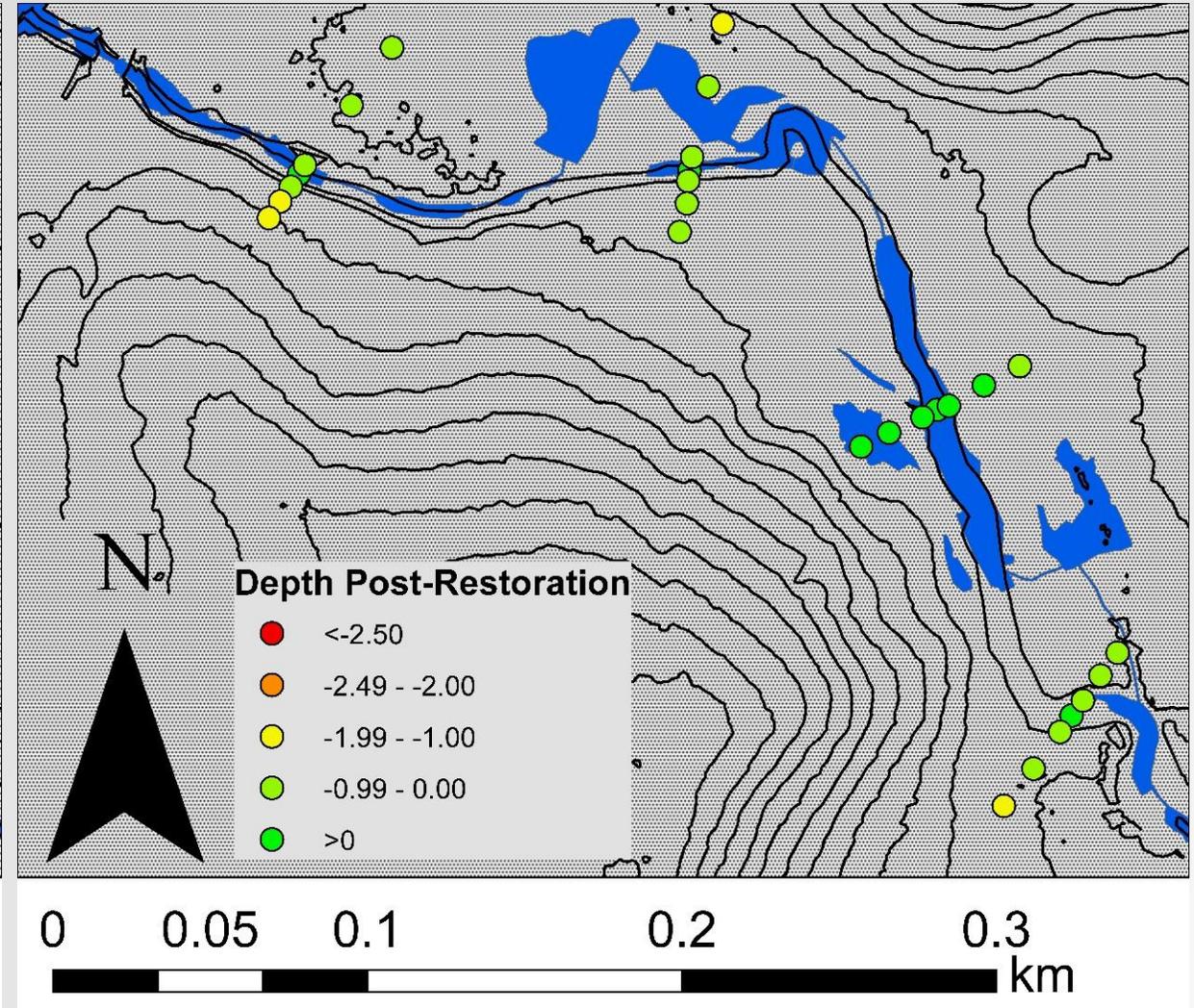
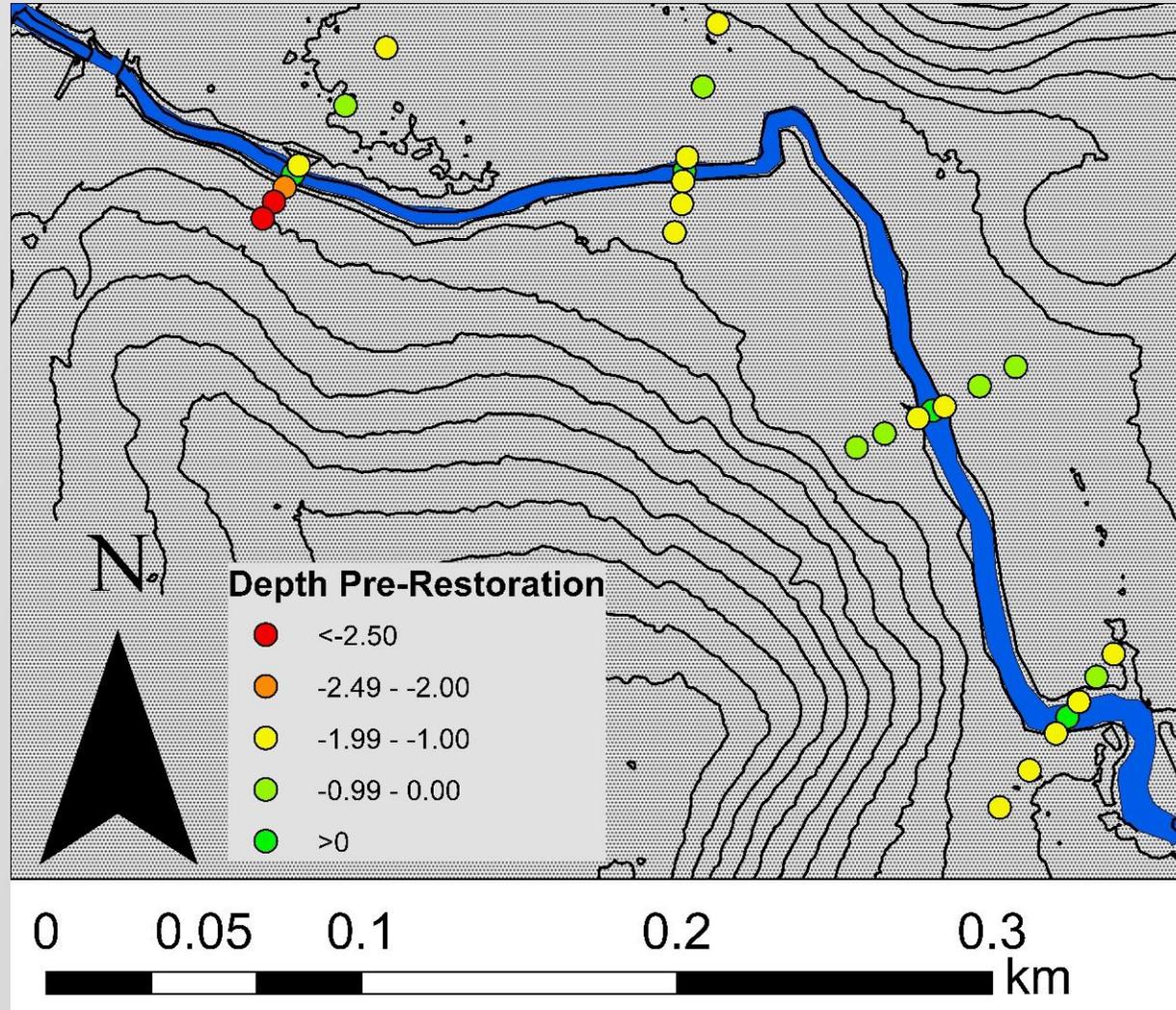
- Groundwater levels monitored within 4 transects, with 7 wells in each transect.
- Groundwater chemistry sampled within 52 piezometers at three depths, spaced 0.6 m apart.
- Groundwater levels monitored weekly, with chemistry monitored each month.

Groundwater Monitoring



- Groundwater monitored pre and post restoration.
- Additional piezometers installed in channel fill material.

Restoration effects on groundwater levels: Depth below surface

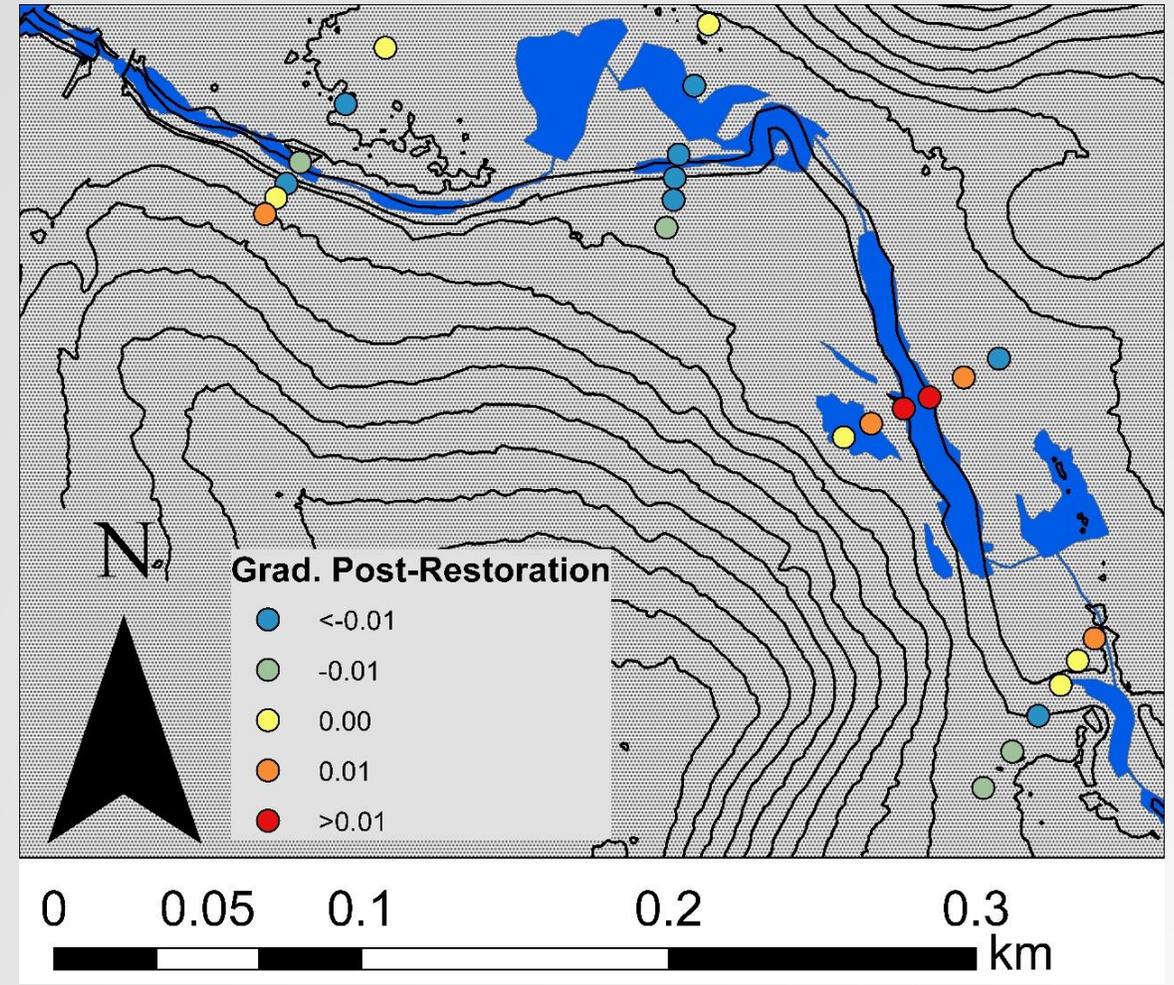
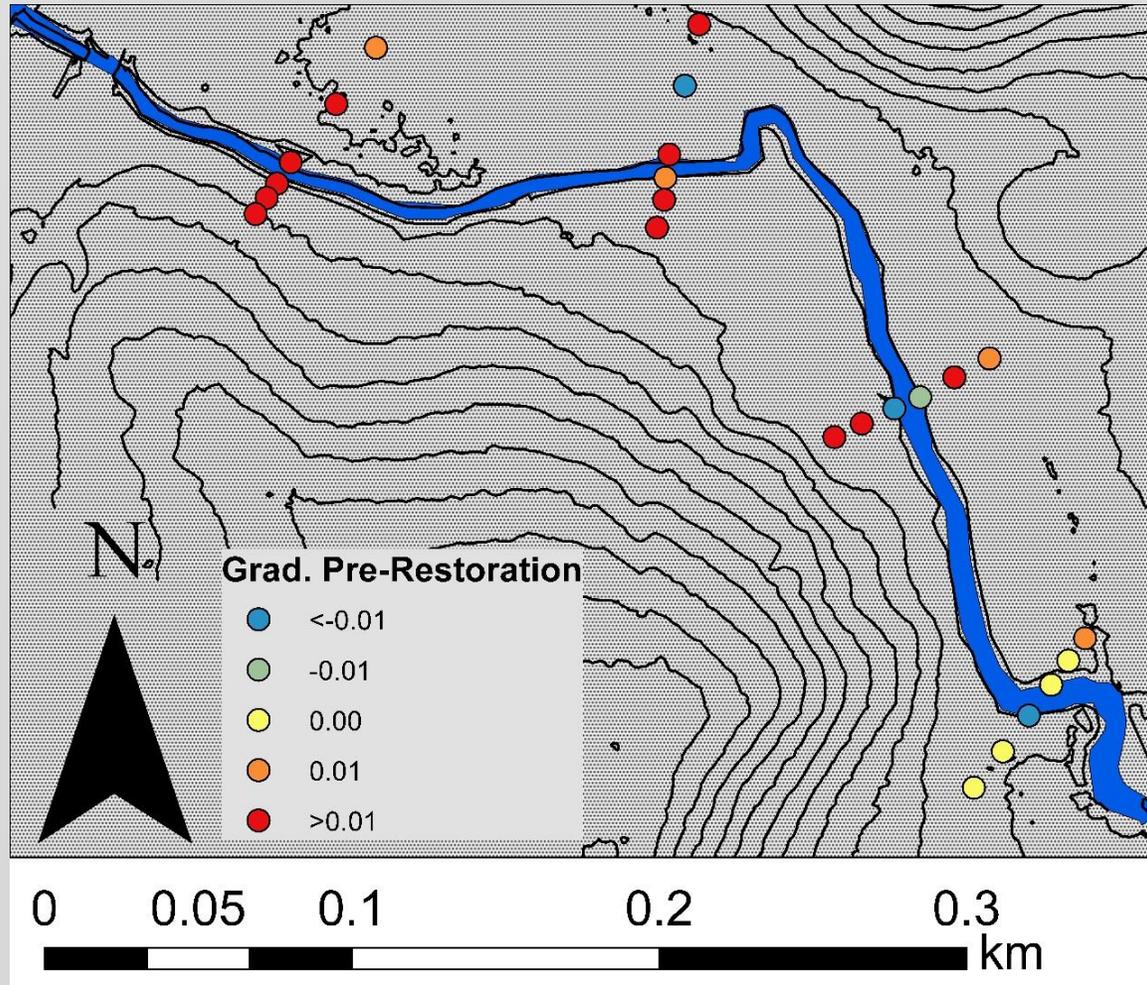


Restoration effects on groundwater levels: Water table elevation

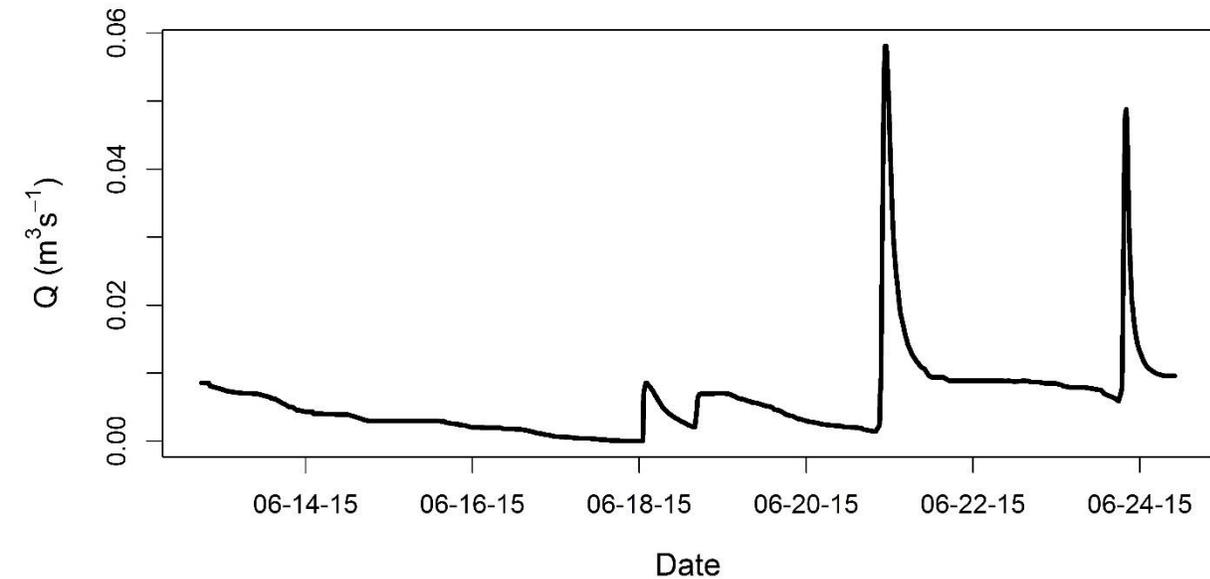
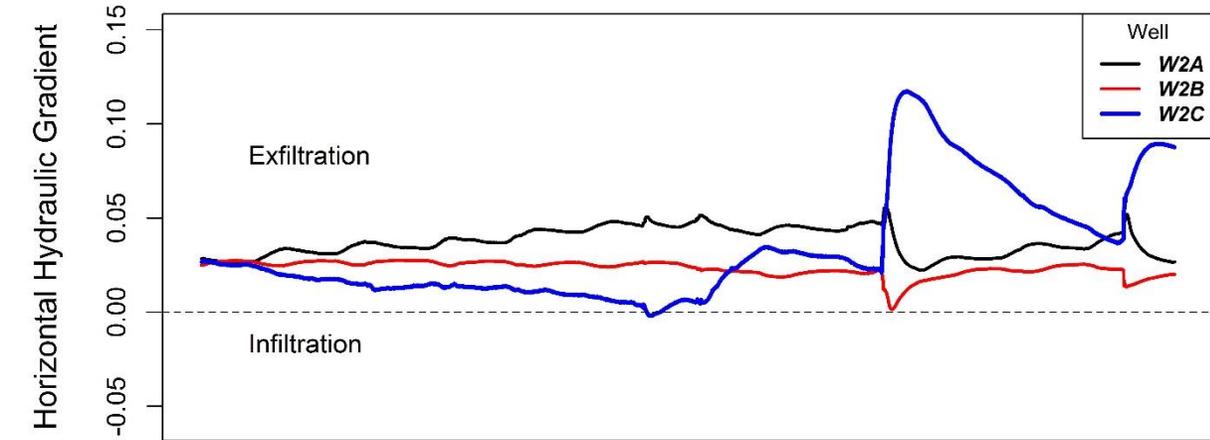
Fixed effects	Estimate	Pr (>Chisq)
Before:After (W1)	0.7684	< 2.2e-16
Rainfall (W1)	0.0001	0.02747
Before:After (W2)	0.9491	< 2.2e-16
Rainfall (W2)	0.0016	0.102
Before:After (W3)	0.7648	< 2.2e-16
Rainfall (W3)	0.0020	0.0166
Before:After (W4)	0.4904	< 2.2e-16
Rainfall (W4)	0.0023	0.0003
Before:After (All)	0.7453	< 2.2e-16
Rainfall (All)	0.0015	2.851e-06

- Rainfall accounted for minor variance in groundwater levels before and after restoration (0.15 cm).
- Before vs. after was a highly significant factor in the change in groundwater levels increasing levels by 0.75 m.

Restoration effects on groundwater dynamics: Horizontal hydraulic gradient

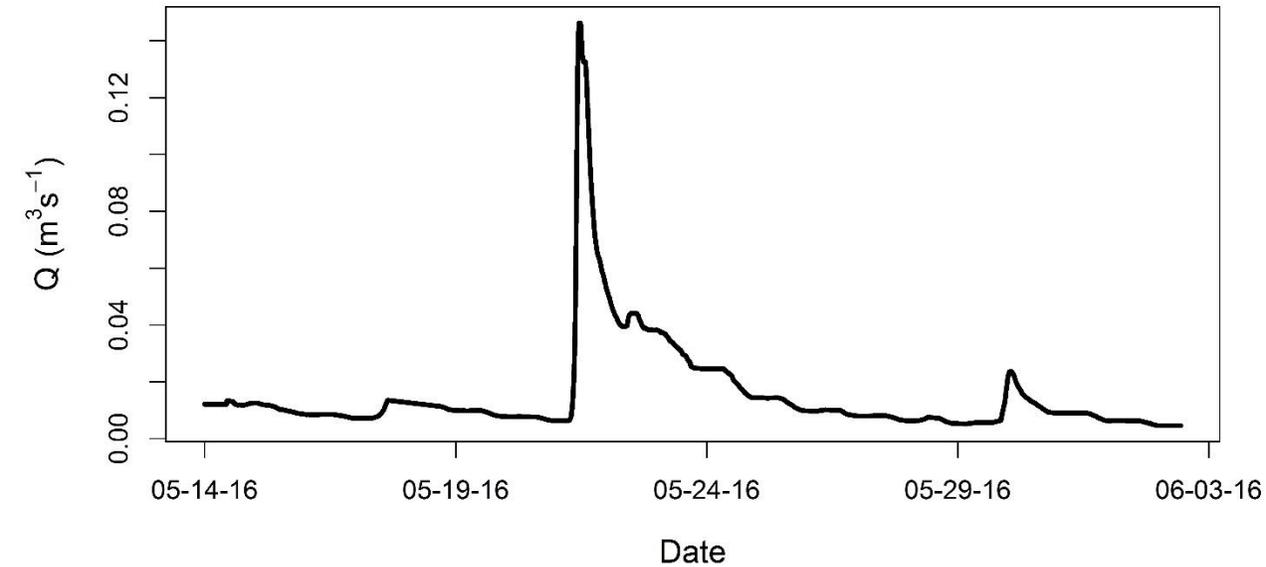
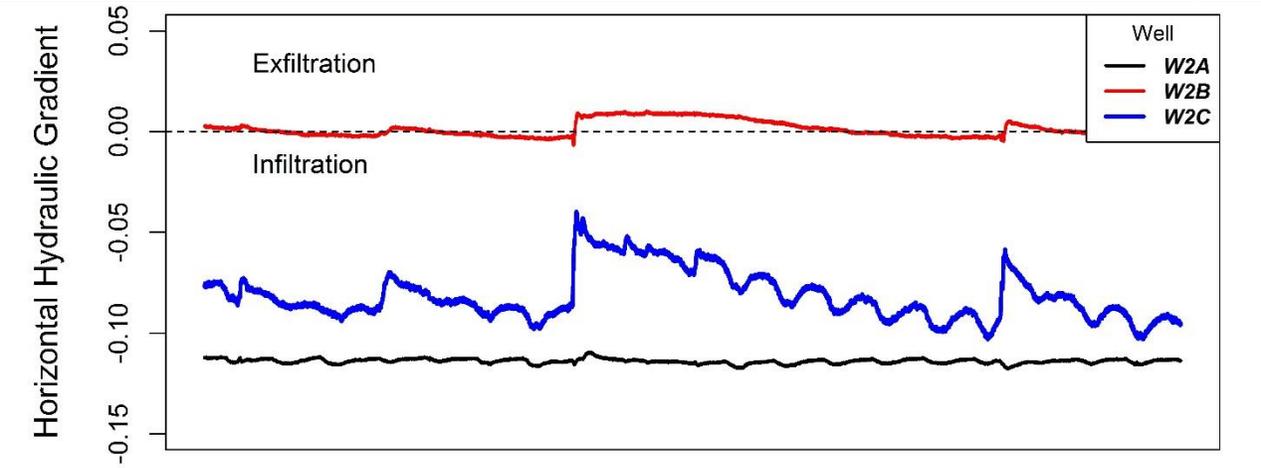


Restoration effects on groundwater dynamics: Horizontal hydraulic gradient



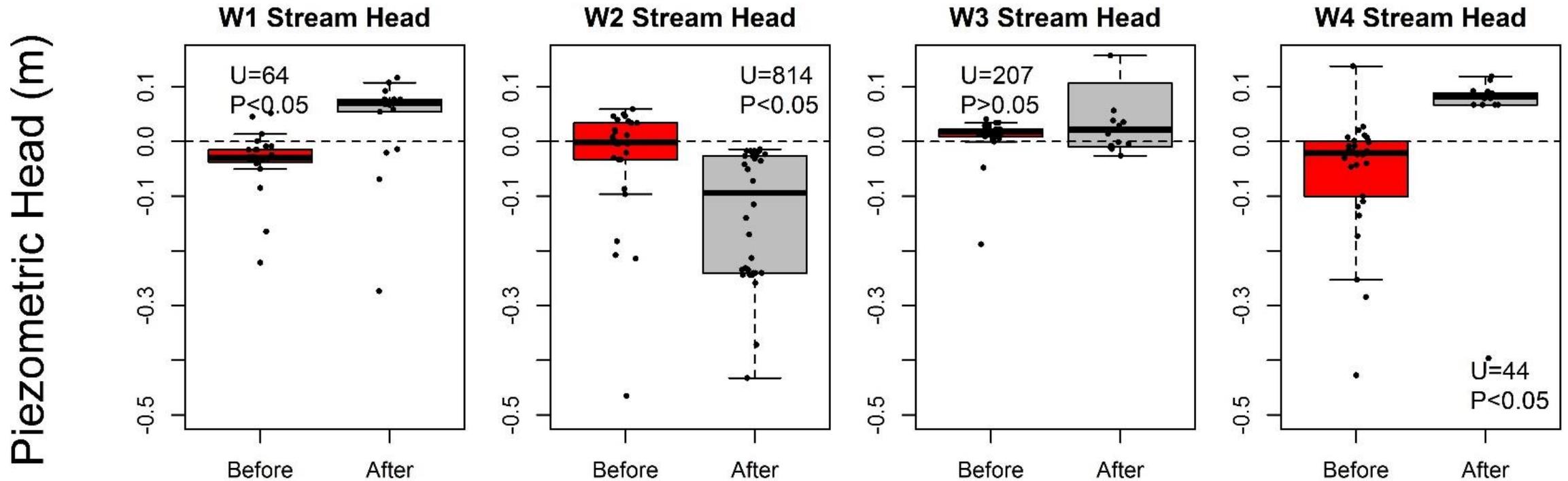
- Example of high-resolution monitoring of water table from pressure transducers within wells.
- Prior to restoration, horizontal gradients indicated exfiltration into the stream, even during high flows.

Restoration effects on groundwater dynamics: Horizontal hydraulic gradient



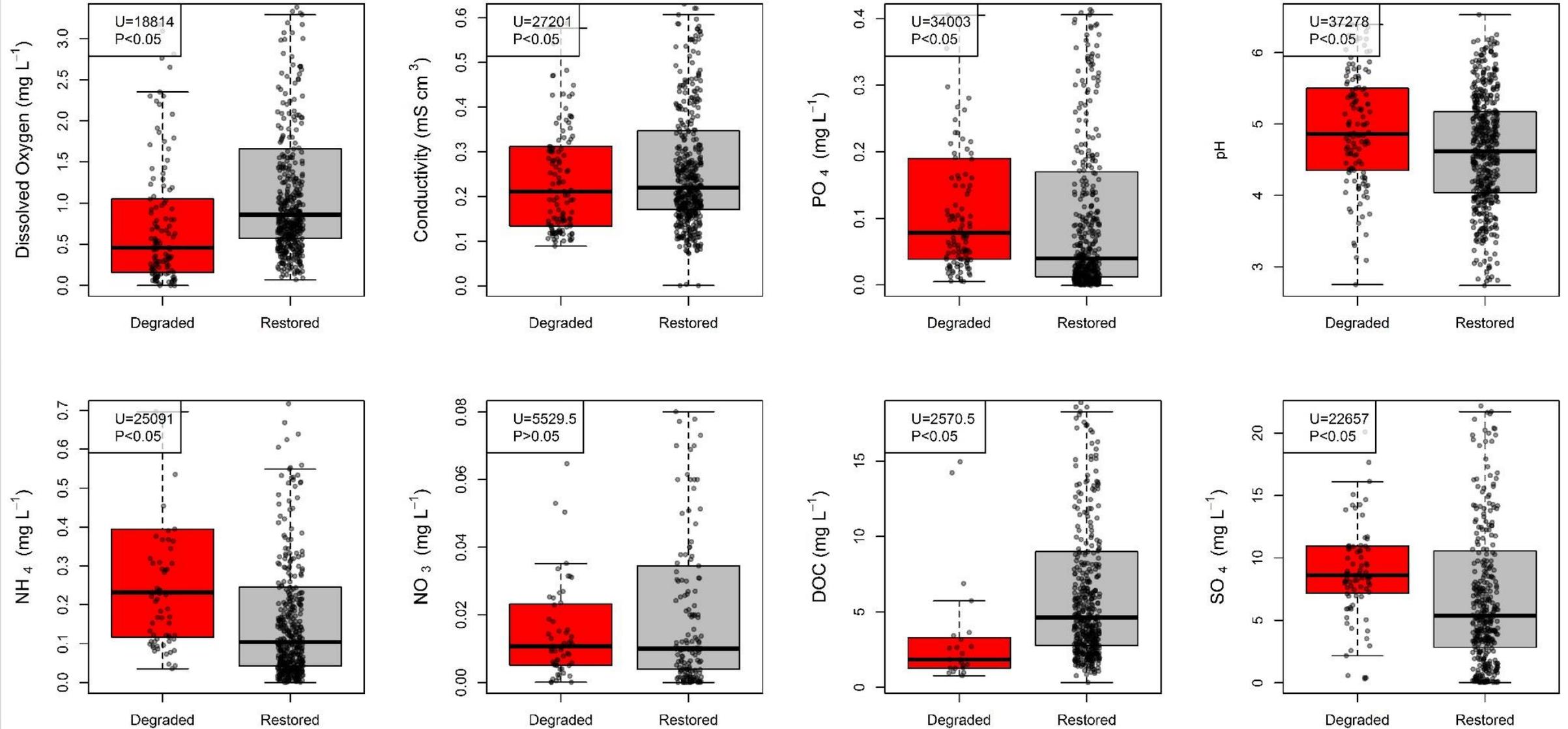
- After restoration, horizontal gradients were either negative or zero, indicating limited exfiltration.

Restoration effects on groundwater dynamics: Stream piezometric head

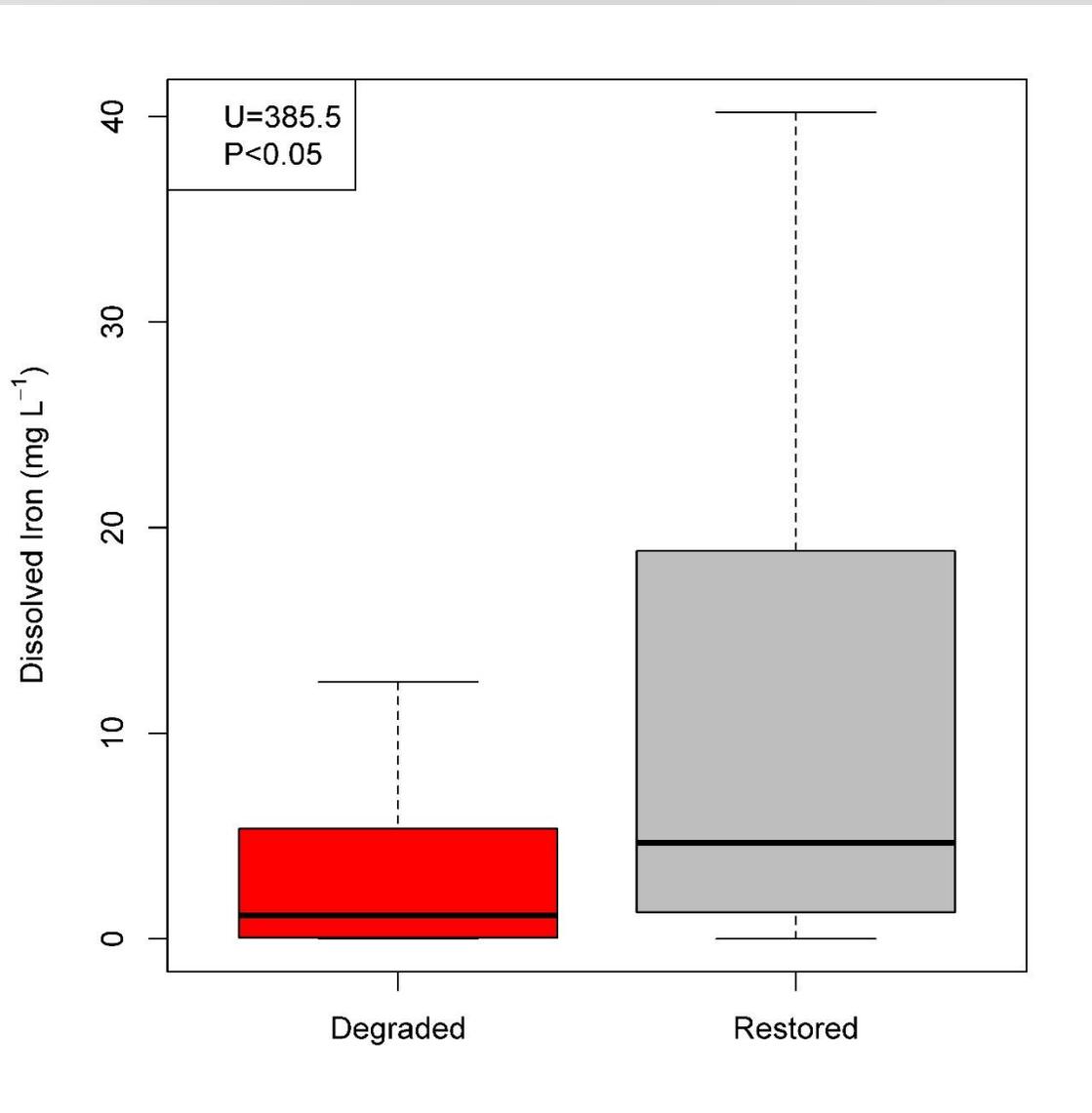


- After restoration, groundwater typically emerged at the top and bottom of the reach with downwelling observed in the middle.

Restoration effects on groundwater chemistry

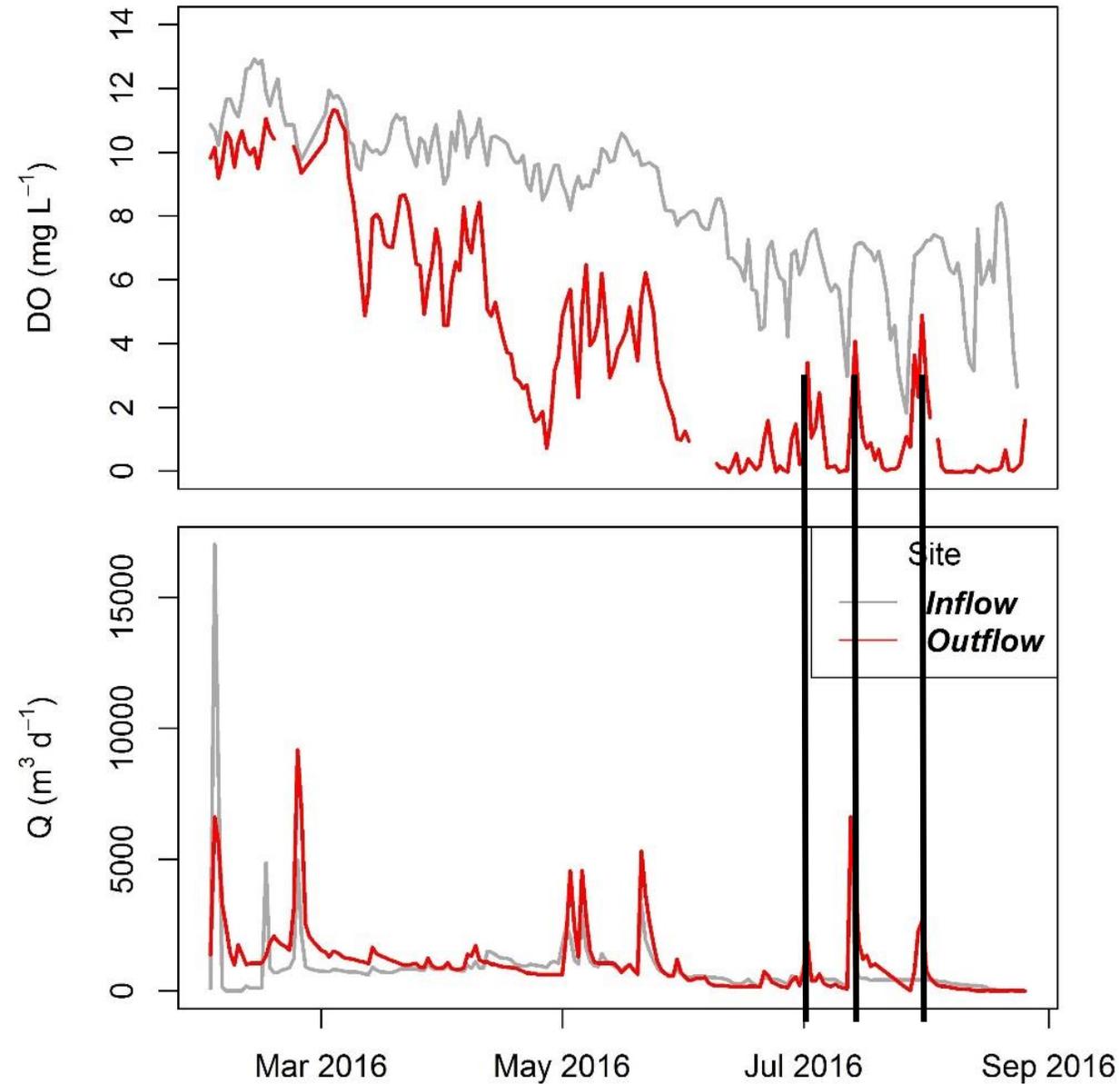


Restoration effects on groundwater chemistry: Dissolved iron



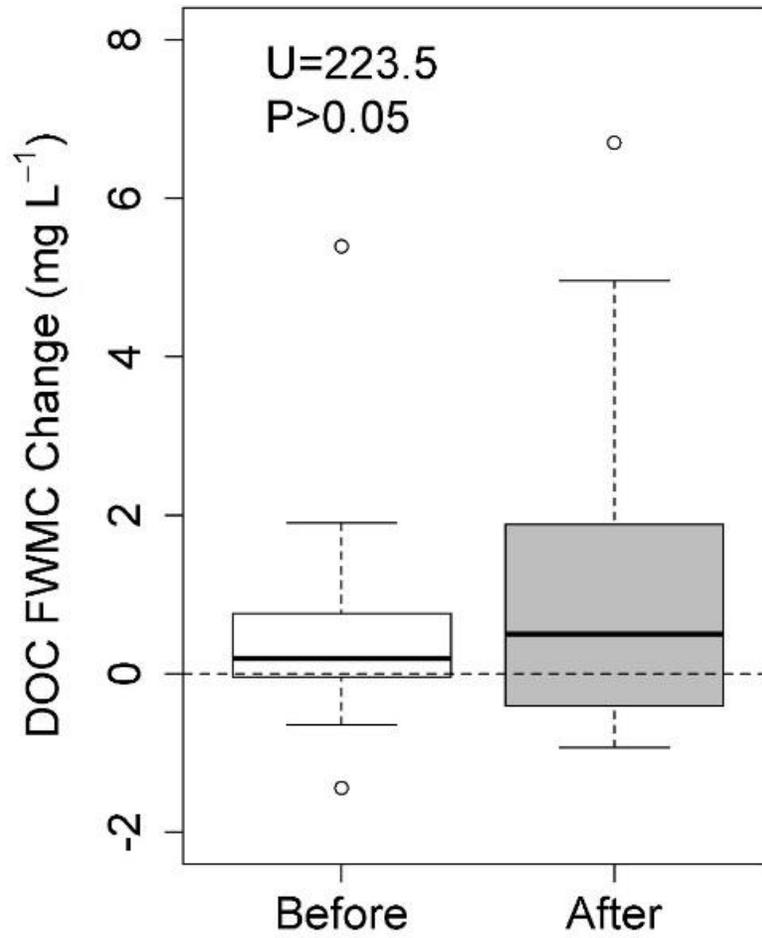
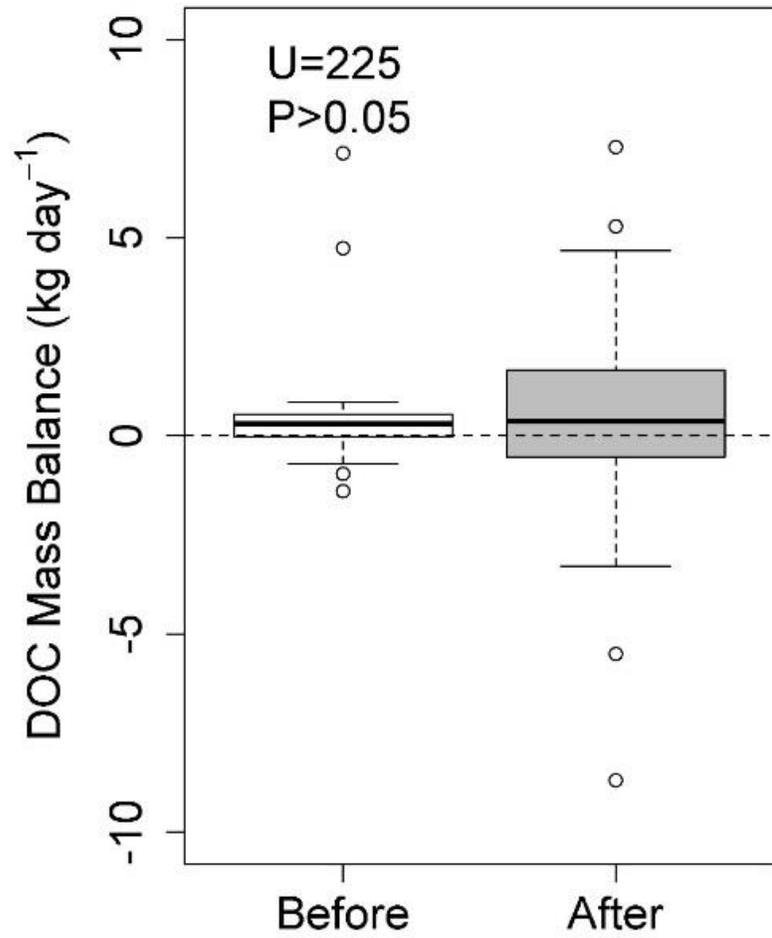
- Dissolve Fe was found to increase since restoration.
- Increases were variable and probably reflective of Fe concentration in the soil profile. However, there was some indication that Fe increased with increasing DOC.
- Most parameters were varied with changes in DO.

Tradeoffs in surface water quality: Dissolved oxygen



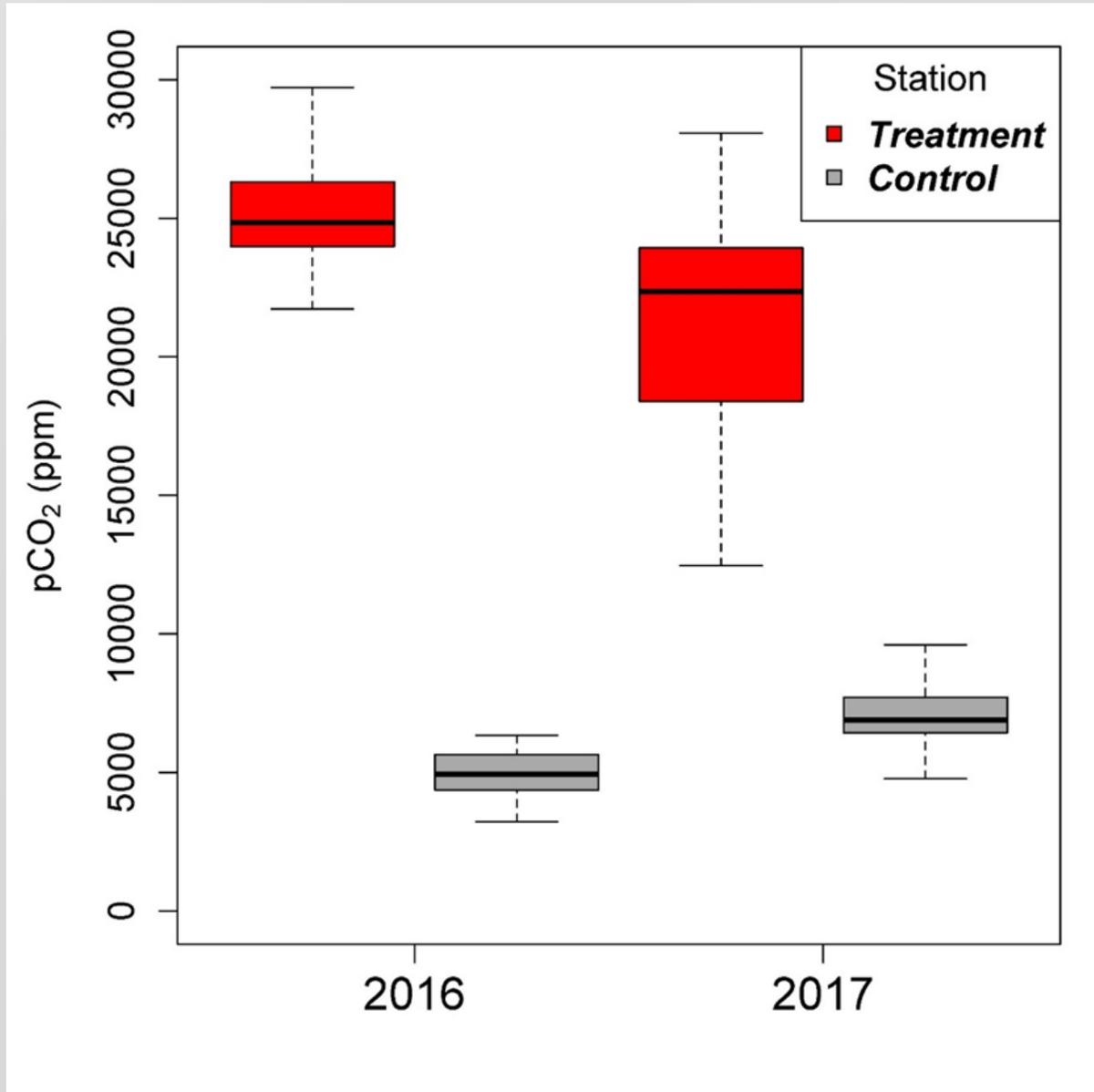
- Low DO concentrations observed in surface water in outflowing vs. inflowing waters.
- High flow events associated with temporal increased in outflowing DO.

Tradeoffs in surface water quality: DOC



- No significant increases in stream DOC was found either in daily load retention or average concentrations.

Tradeoffs in surface water quality: Daily average summer carbon dioxide



- Hypoxic conditions observed in stream water associated with elevated pCO₂ concentrations – indicating extreme metabolism.

Summary

1. Did the restoration increase groundwater levels?

Average increases of ~0.7 meters were observed.

2. Did the restoration encourage higher rates of surface-groundwater exchange?

Hydraulic gradients became much more spatially heterogeneous after restoration with complex patterns of infiltration and exfiltration.

Summary

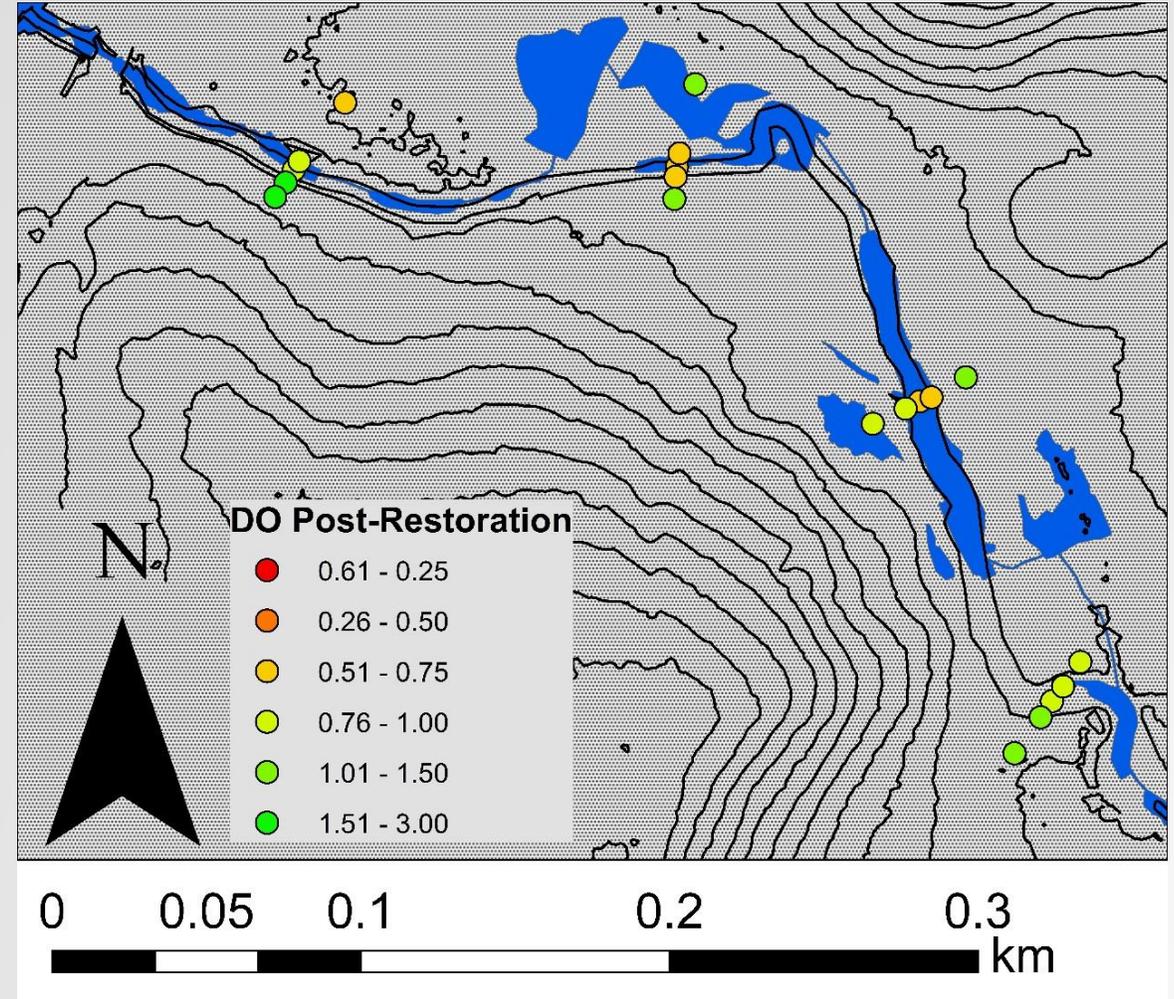
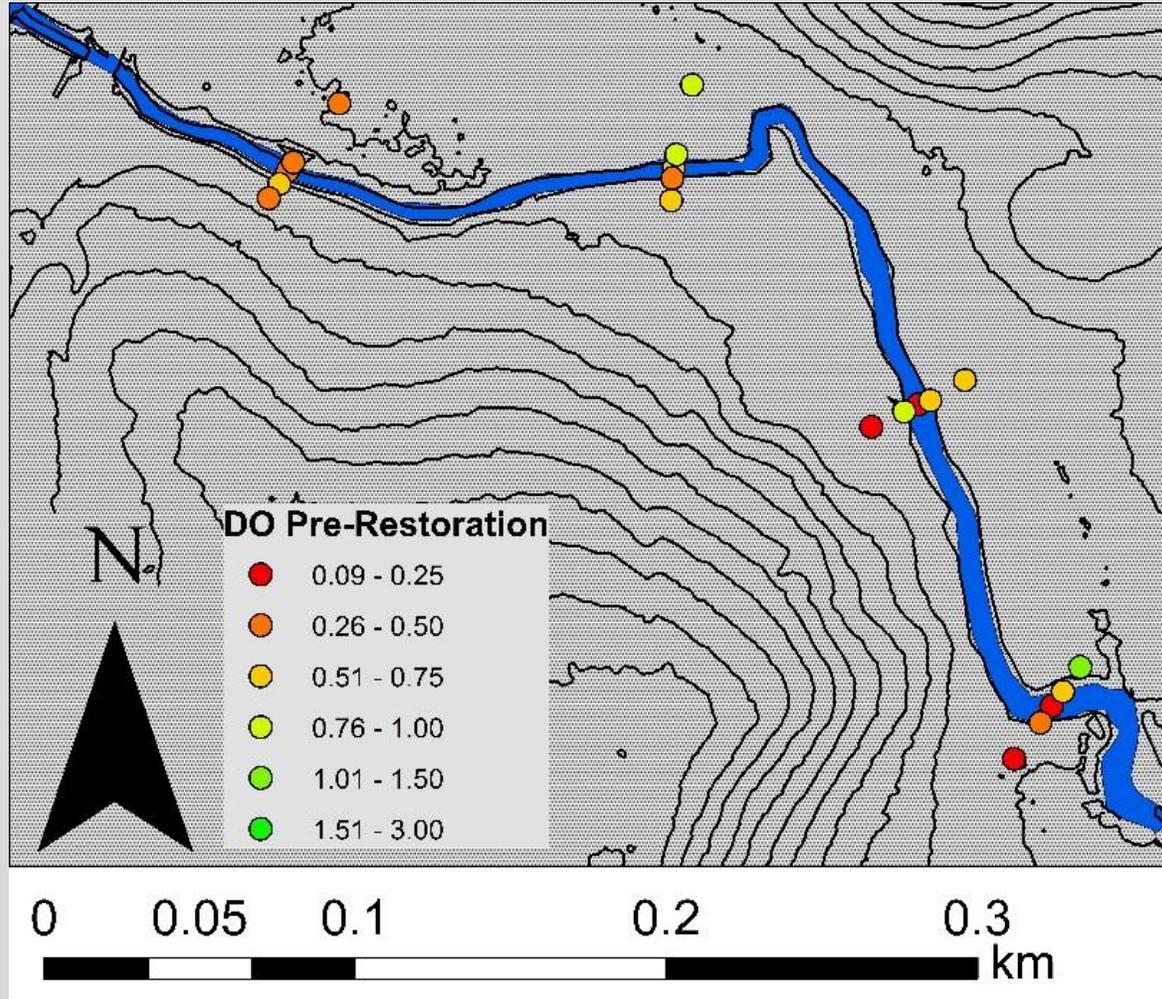
3. Did the stream restoration change groundwater chemistry?

Dissolved oxygen increased, PO_4 decreased, NH_4 decreased, and DOC increased greatly, particularly in channel fill.

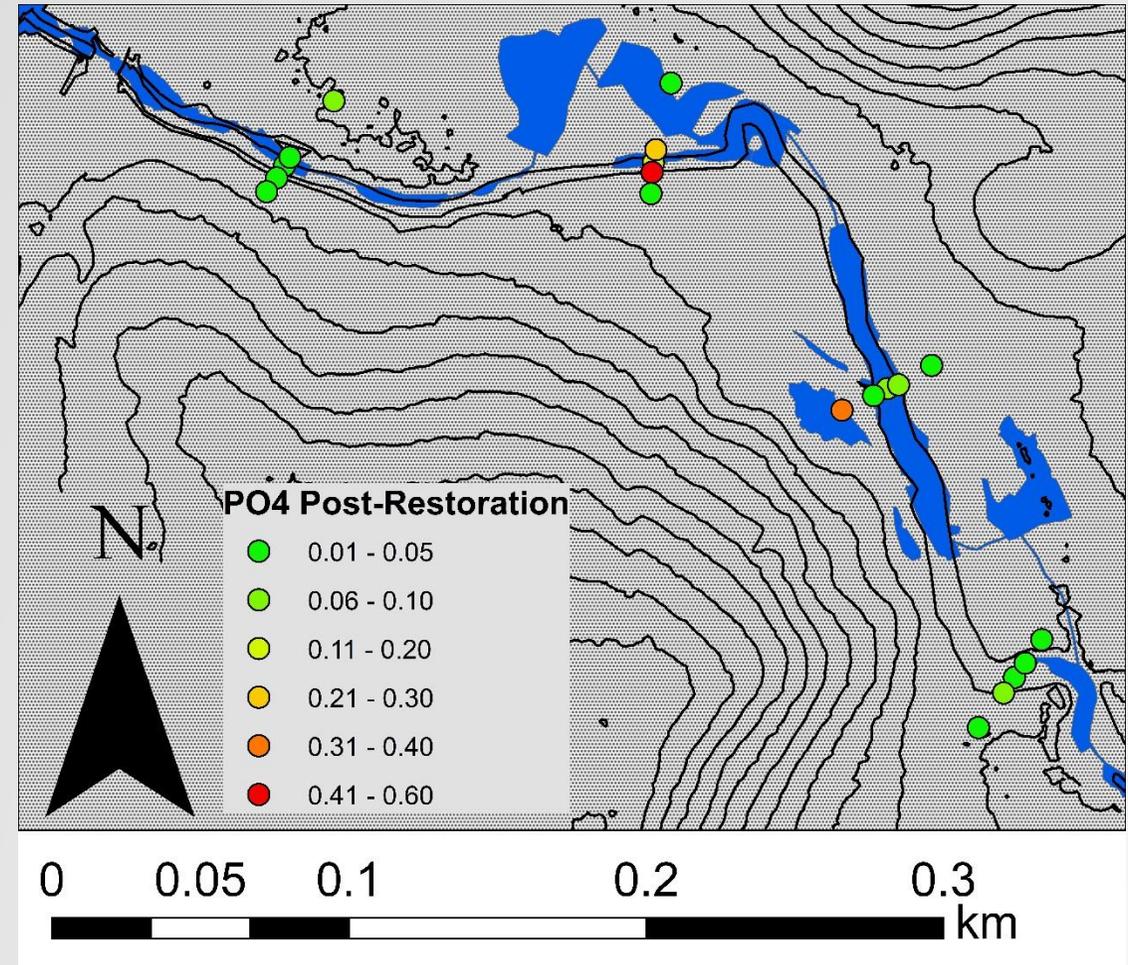
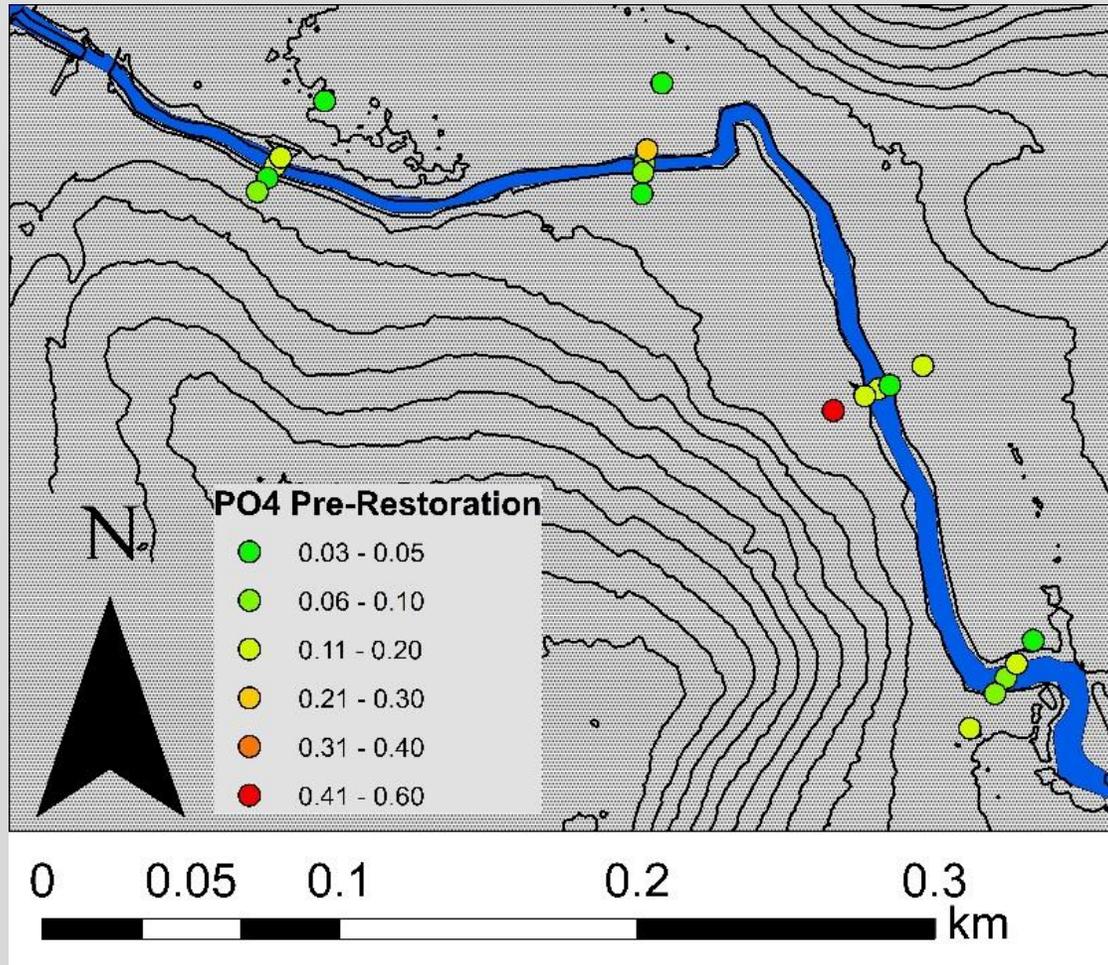
4. Were there any tradeoffs in surface water quality?

Stream dissolved oxygen decreased causing outflowing stream water to become hypoxic. Stream pCO_2 was 5 times higher than the control, although DOC not increase.

Restoration effects on groundwater chemistry: Dissolved oxygen



Restoration effects on groundwater chemistry: Phosphate



Restoration effects on groundwater chemistry: Ammonium

