Linking field and laboratory studies to investigate enhanced nitrate removal using permeable reactive barrier technology

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Groundwater Resources Association
Of California
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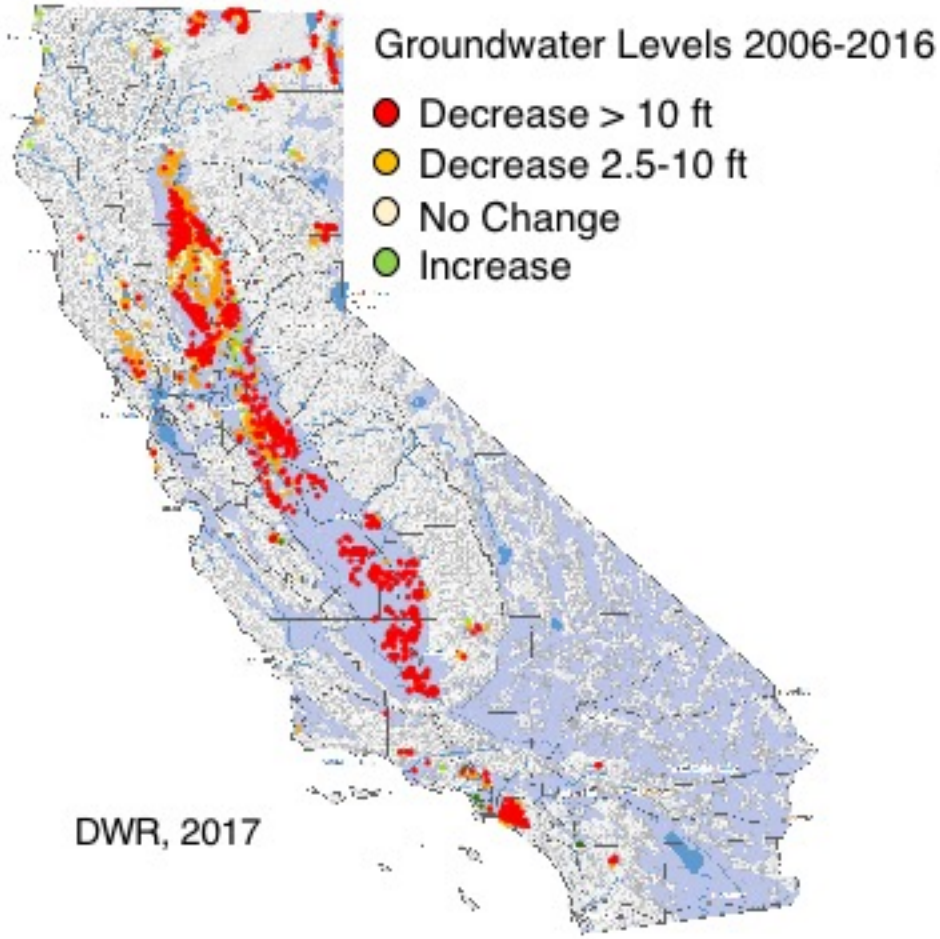
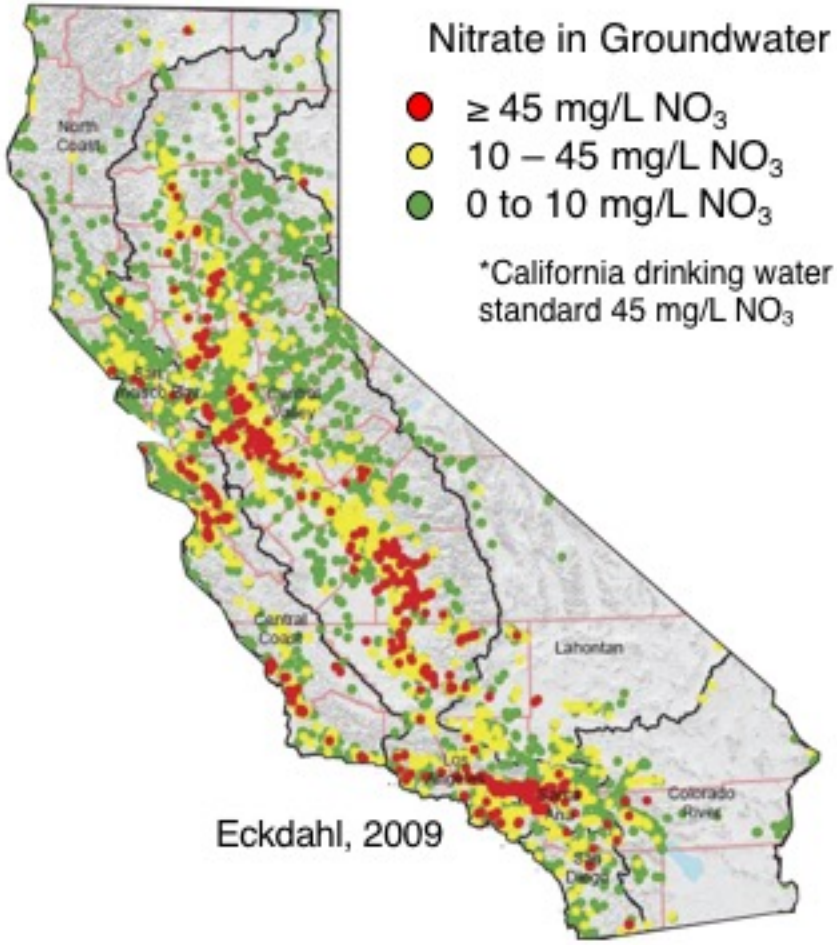
Water Quantity



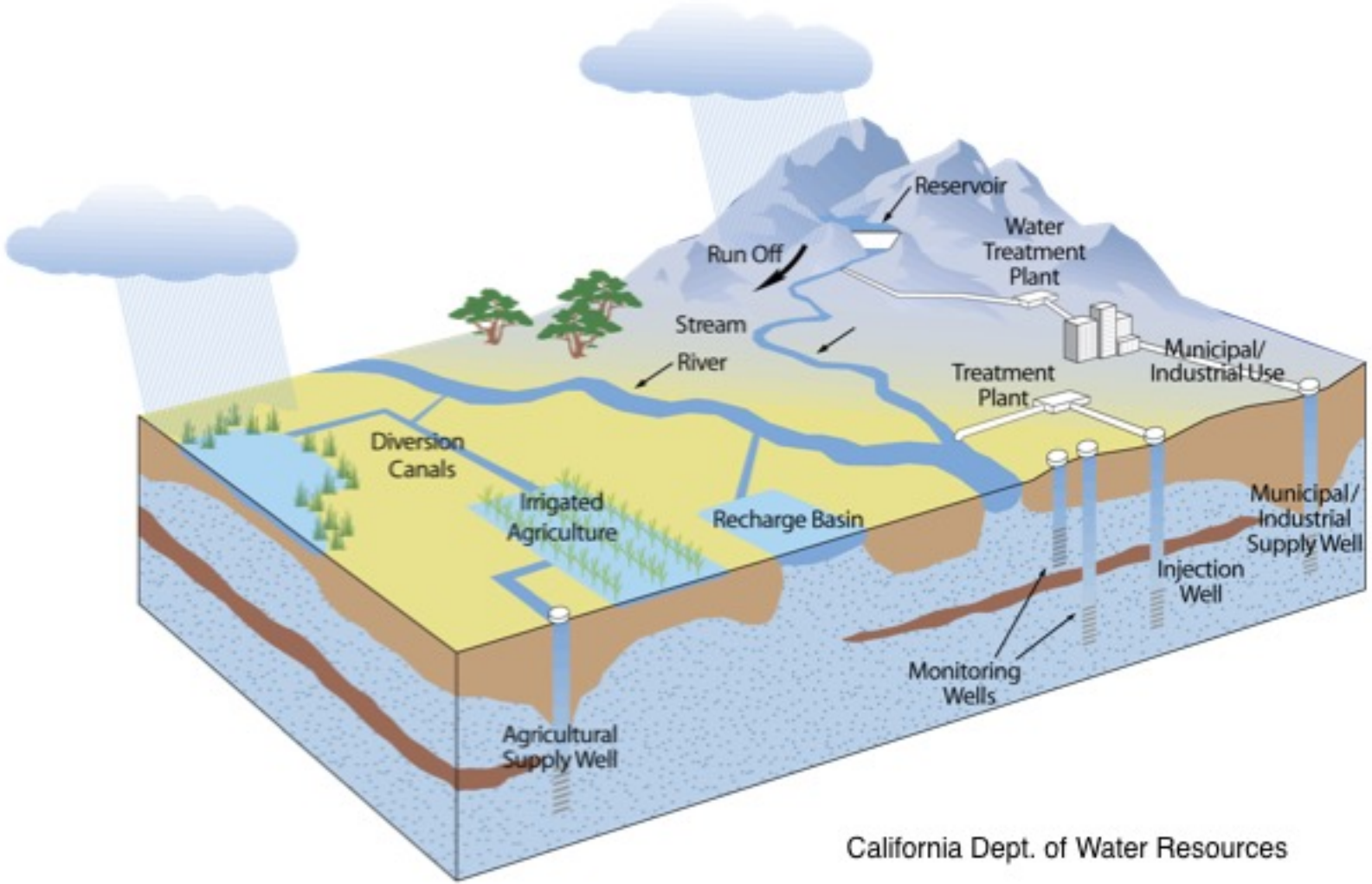
DWR, 2017

Water Quality



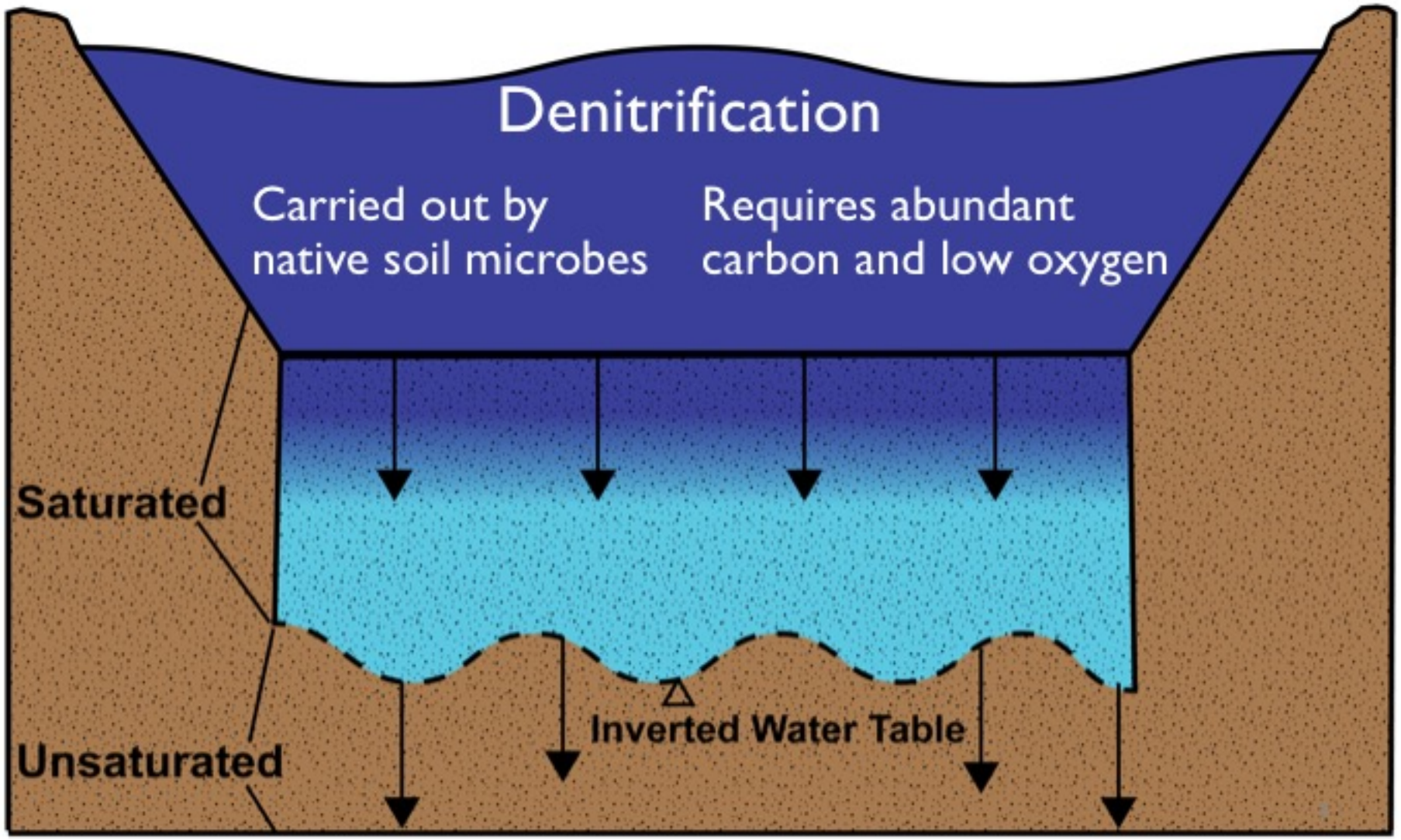
Eckdahl, 2009

Managed Aquifer Recharge (MAR) is uniquely suited to address both challenges

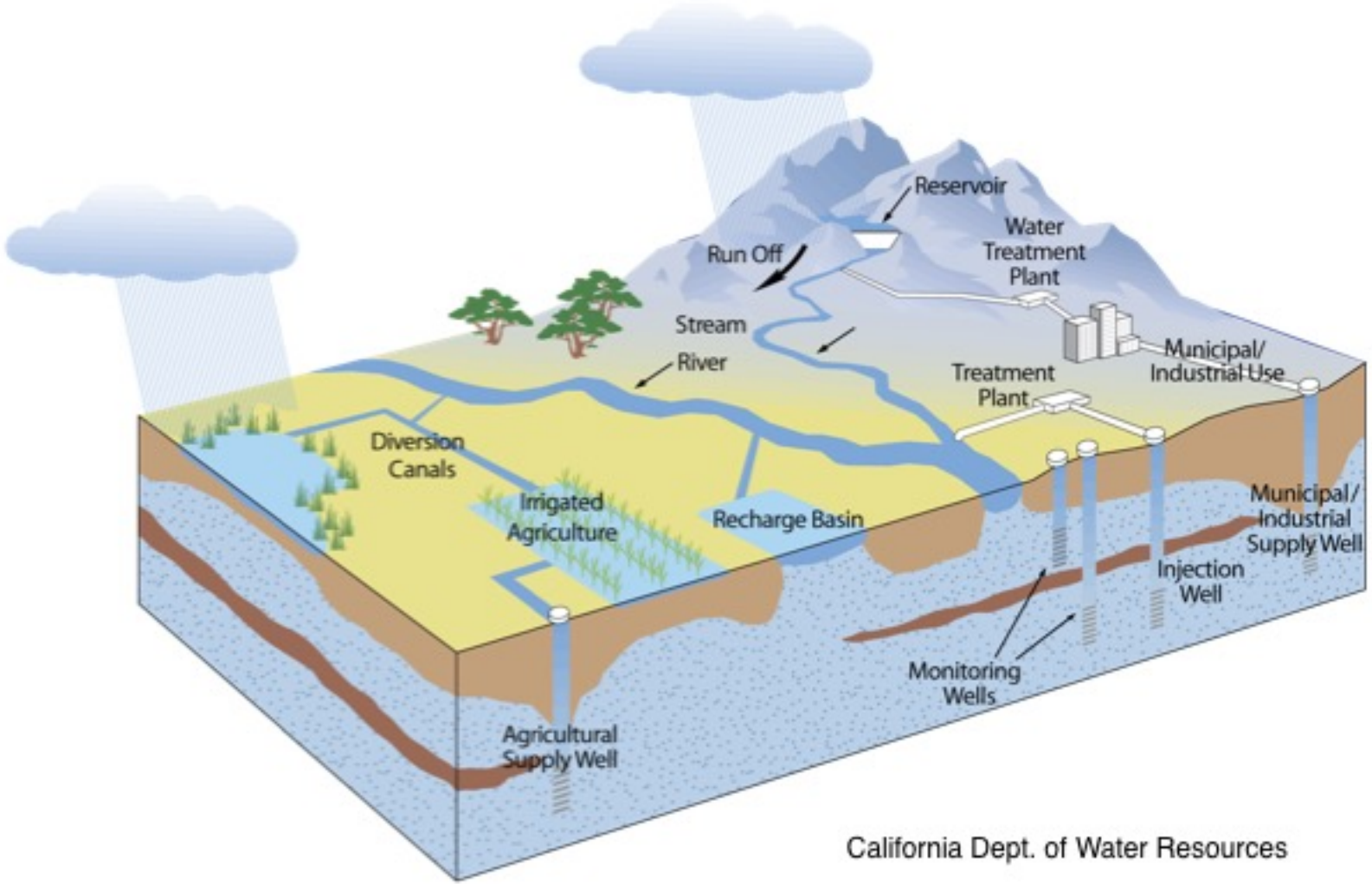


California Dept. of Water Resources

MAR can enhance water quality through naturally occurring processes

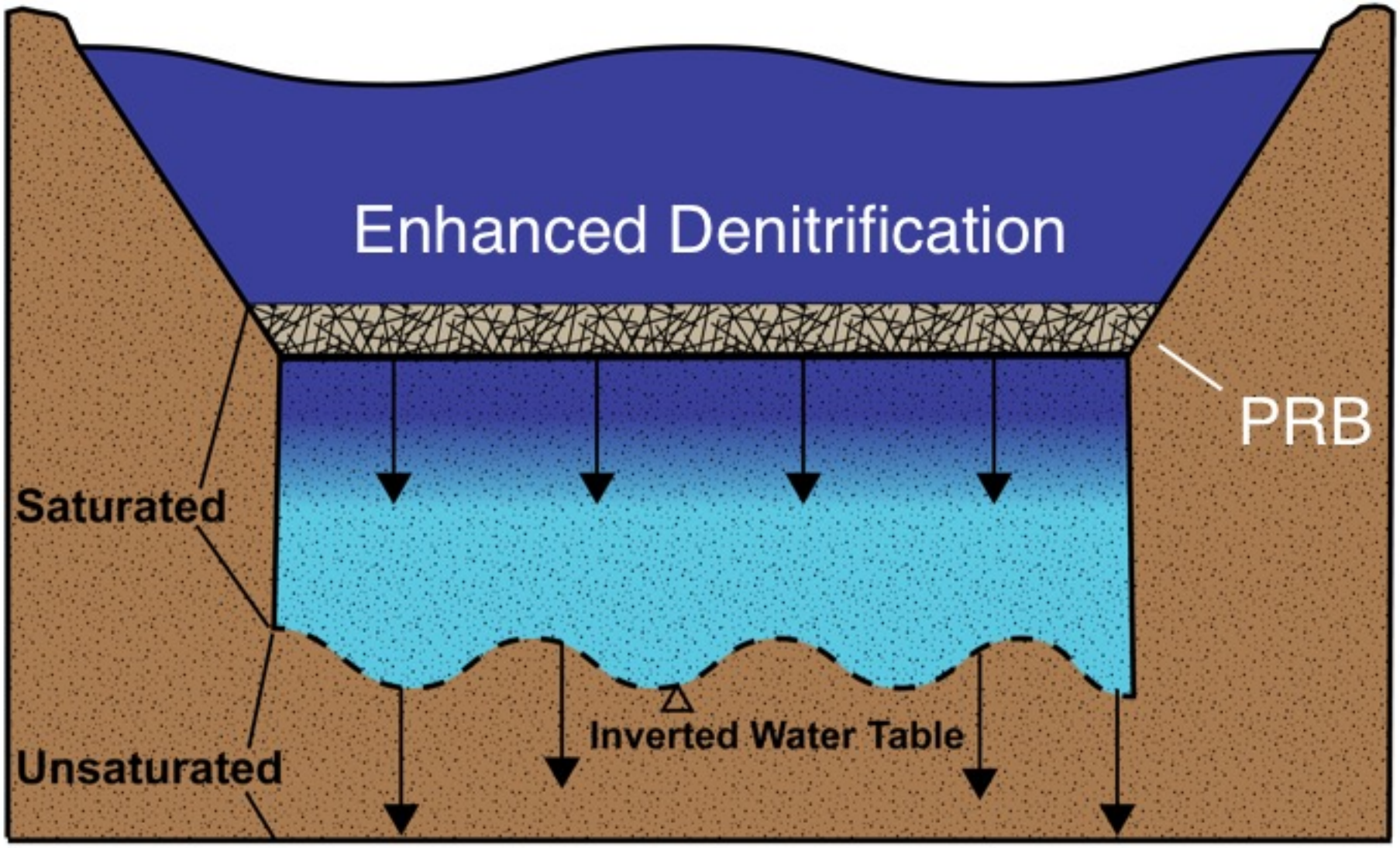


Managed Aquifer Recharge (MAR) is uniquely suited to address both challenges



California Dept. of Water Resources

Denitrification can be enhanced using a permeable reactive barrier (PRB)

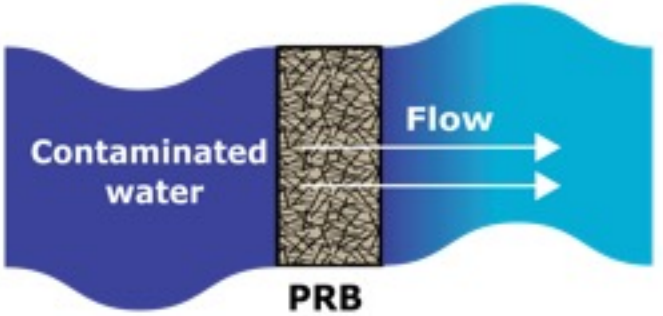


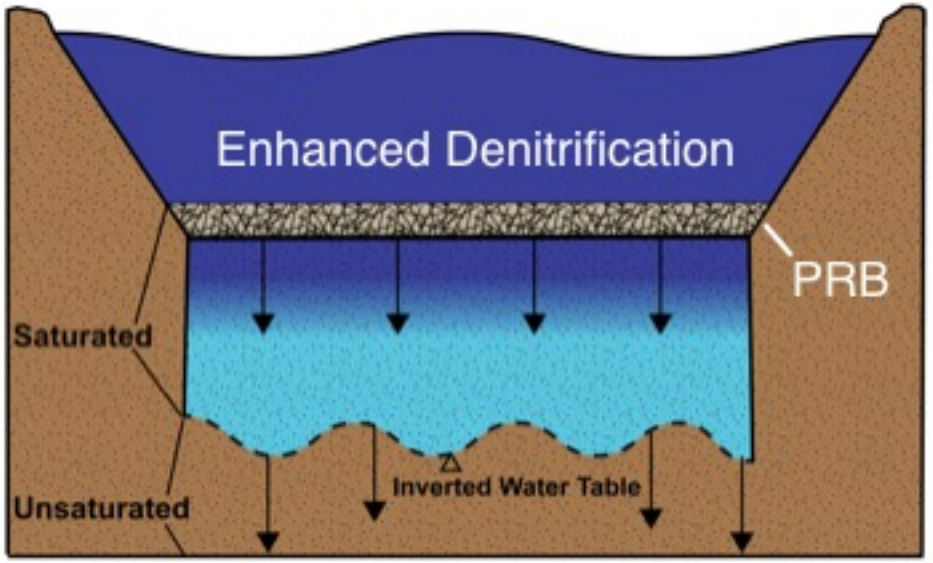
Experimental Questions

1. By what mechanism can a PRB stimulate nitrogen cycling, and how do these vary with different PRB materials?

2. How does infiltration rate affect the amount and rate of nitrate removal in the presence of a PRB?

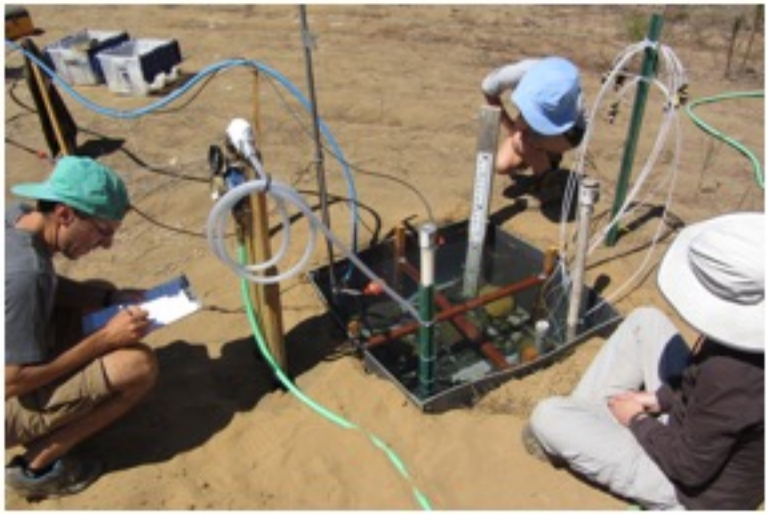
3. How can this information help in the design and operation of MAR systems to improve water quality and quantity simultaneously?

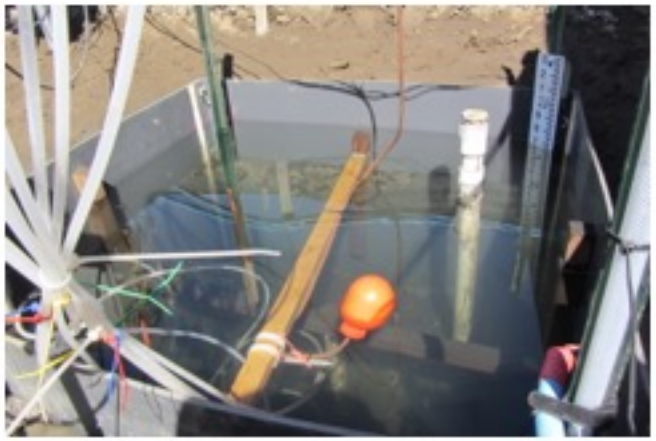




Field Experiments

Percolation tests emulate basin scale infiltration dynamics





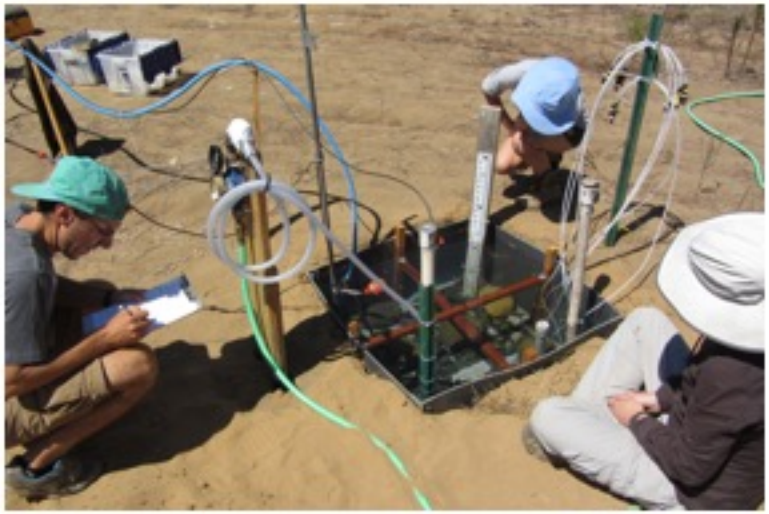
Maintained saturation using an automated switch and in-flow management system

Side-by-side plots:

Woodchip PRB
Biochar PRB
Native Soil (control)

Field Experiments

Percolation tests emulate infiltration dynamics at a infiltration basin scale



Lab Experiments

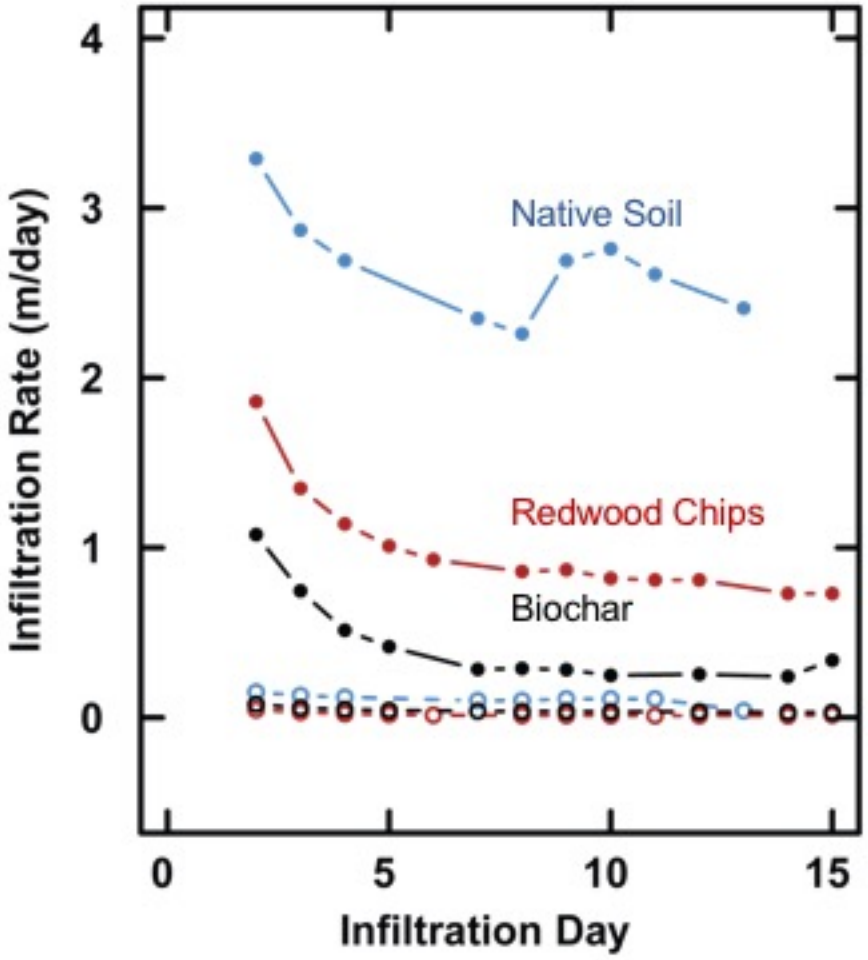
Lab experiments expand the range of infiltration rates

Collected intact cores from field site

Amended with redwood chips or biochar

Artificial groundwater pumped through the cores at known rates

Field Studies – Results: Infiltration Rates

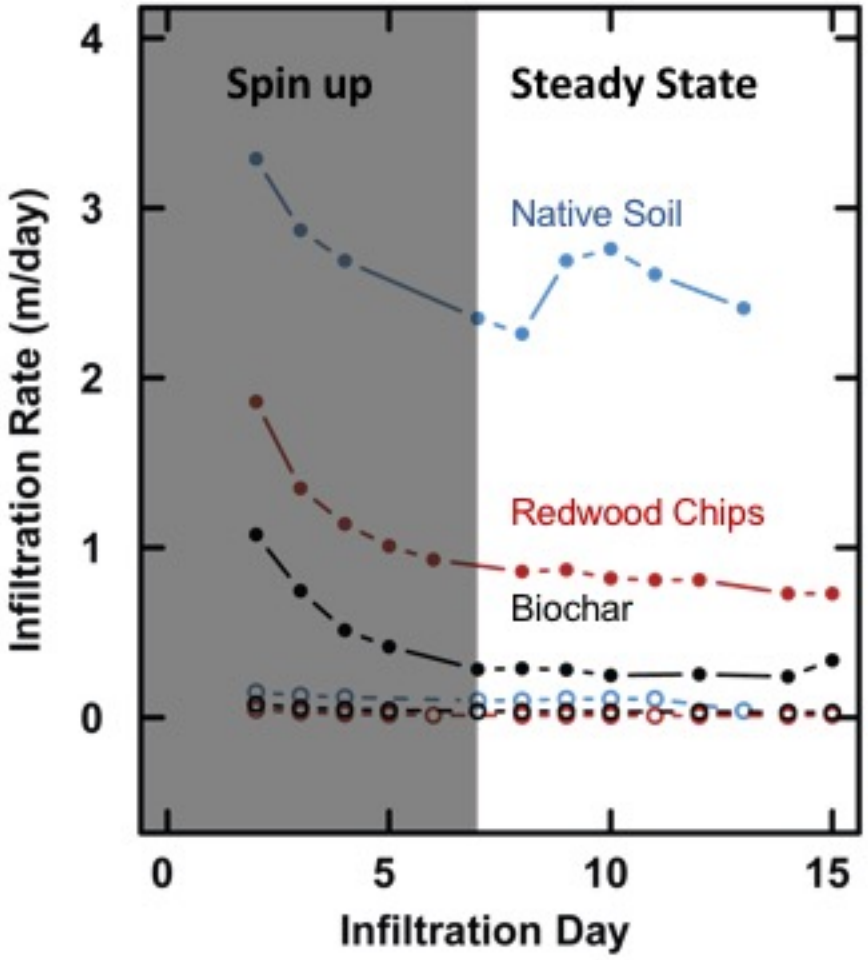


Infiltration rates vary based on soil heterogeneity *not* the presence of a PRB.

Total rates are much higher than vertical rates due to horizontal flow.

Treatment	Total Infiltration Rate (m/day)	Vertical Infiltration Rate (m/day)
Native Soil	2.5	0.096
Redwood Chips	0.8	0.034
Biochar	0.3	0.011

Field Studies – Results: Infiltration Rates



Experiments can be divided into "spin up" and "steady state" periods

Treatment	Total Infiltration Rate (m/day)	Vertical Infiltration Rate (m/day)
Native Soil	2.5	0.096
Redwood Chips	0.8	0.034
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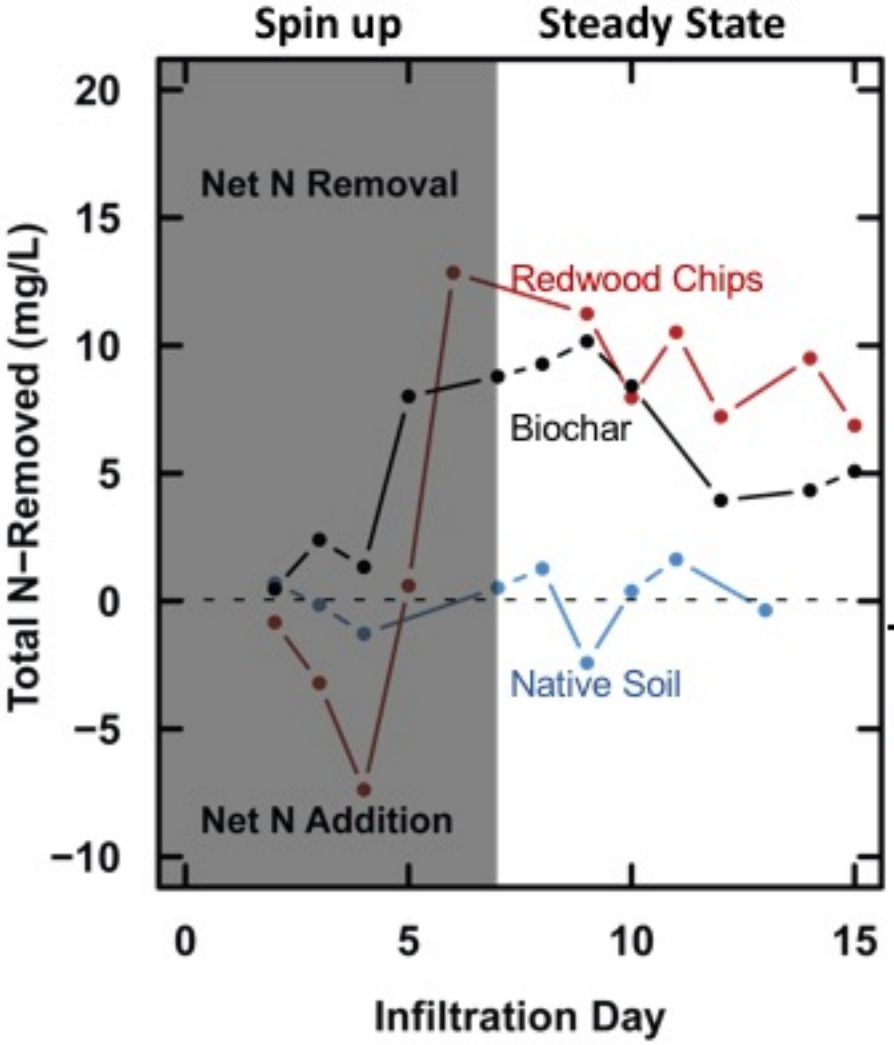
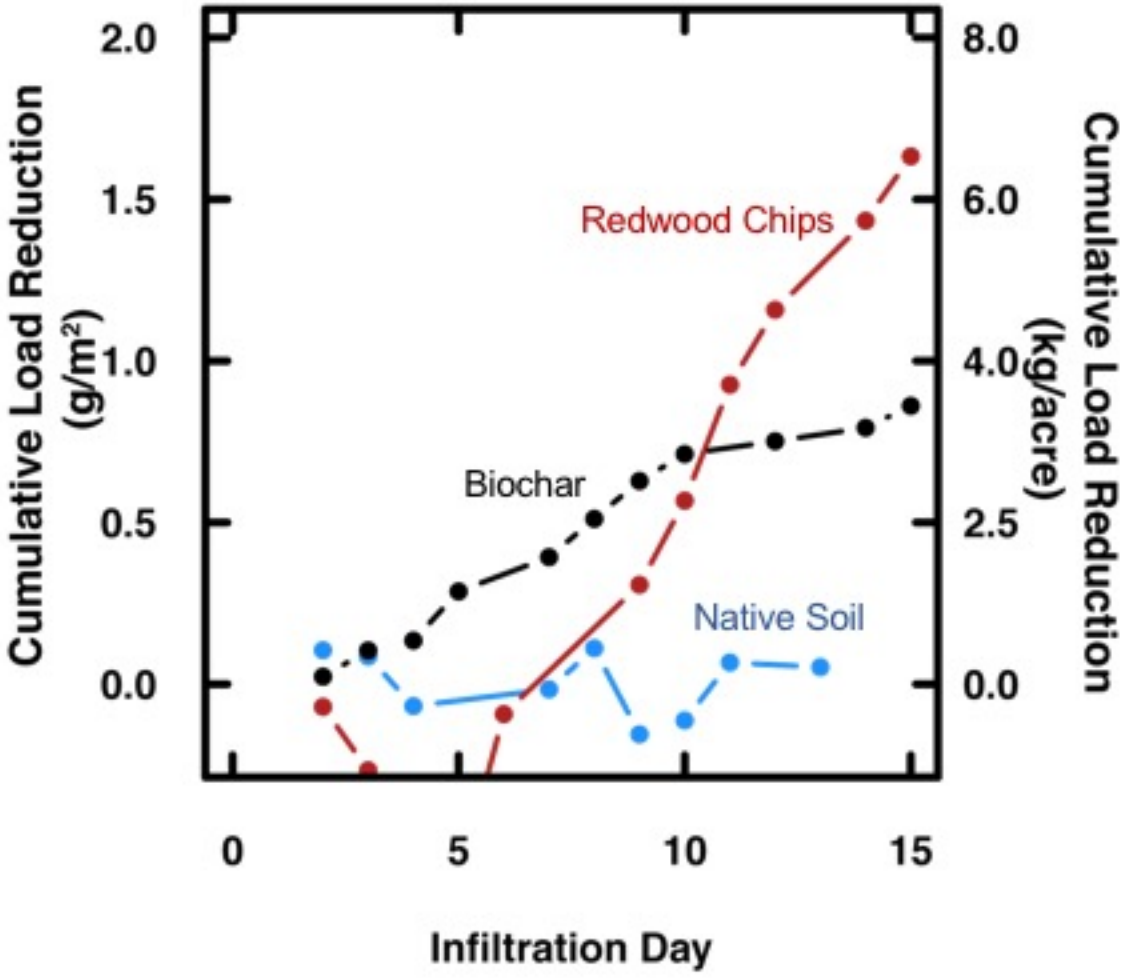
Field Studies – Results: Nitrate Removal



Redwood chips and biochar plots removed 30-40% of the initial nitrate

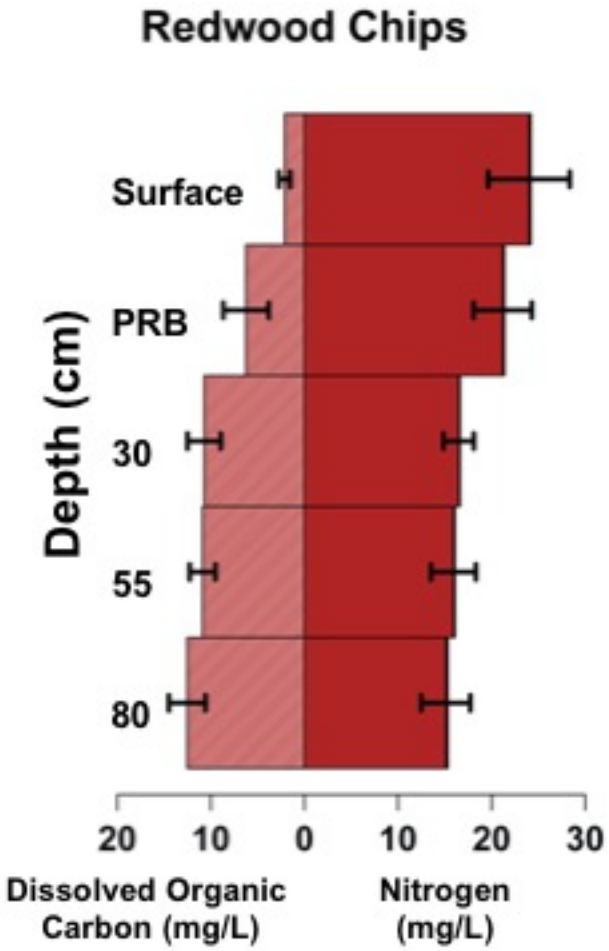
Treatment	Total Nitrogen Removed (mg/L)	Percent Nitrogen Removed (%)
Native Soil	0.1	1.2
Redwood Chips	8.9	37.1
Biochar	6.9	33.1

Field Studies – Results: Cumulative Nitrate Load Reduction



Combining flow rate and concentration show that redwood chips remove more nitrogen over the course of the experiment

Field Studies – Results: Nutrient Changes by Depth



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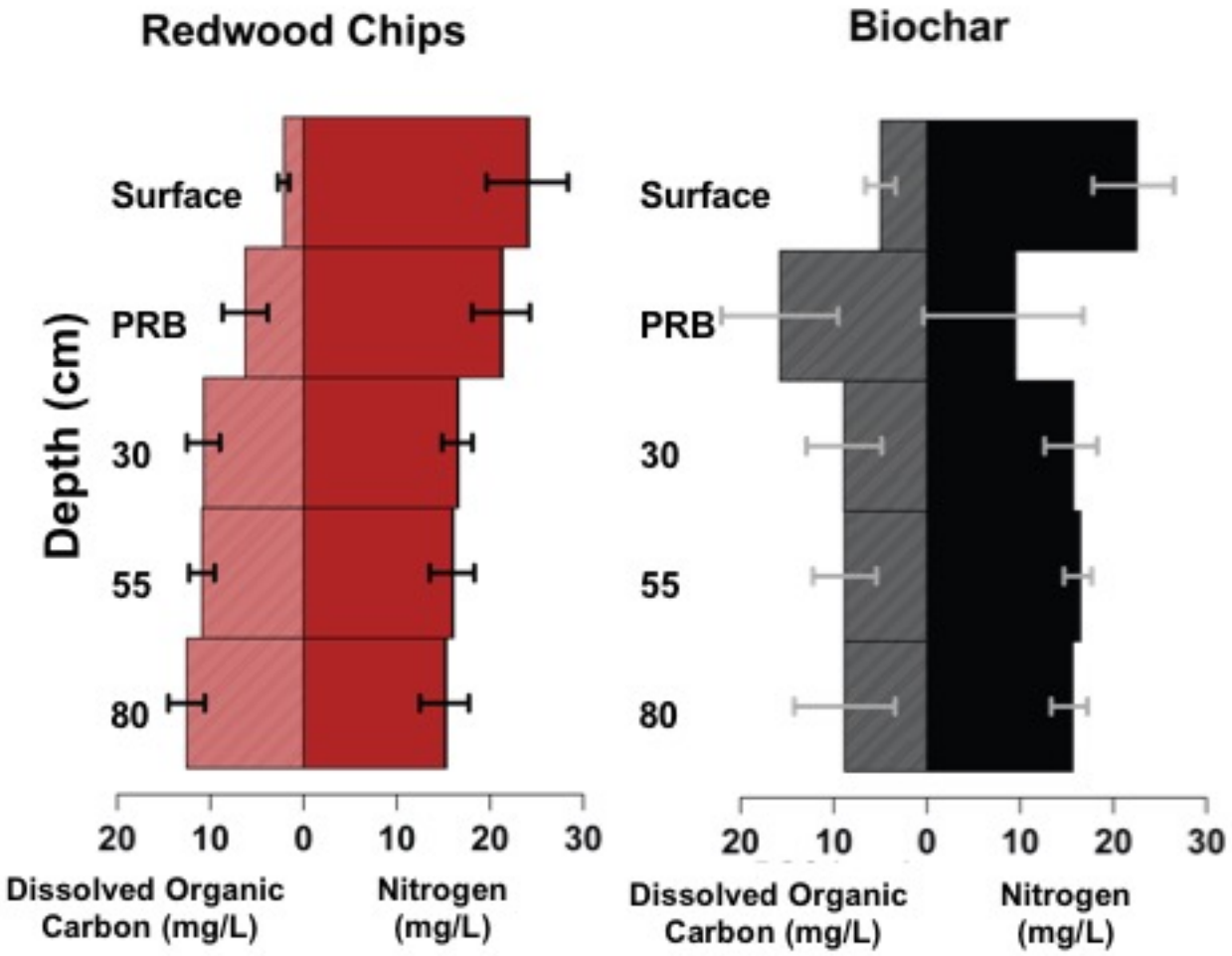

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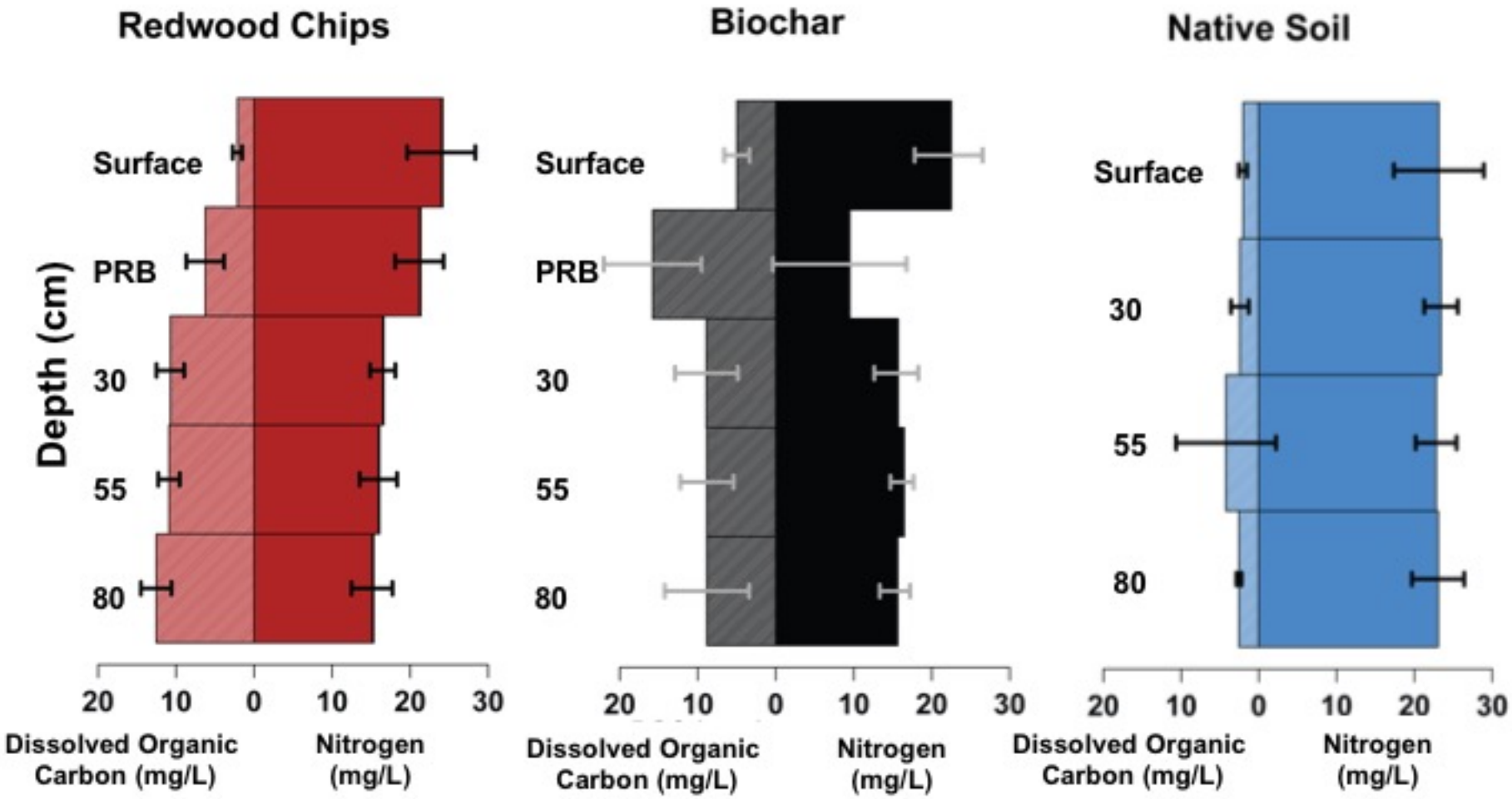
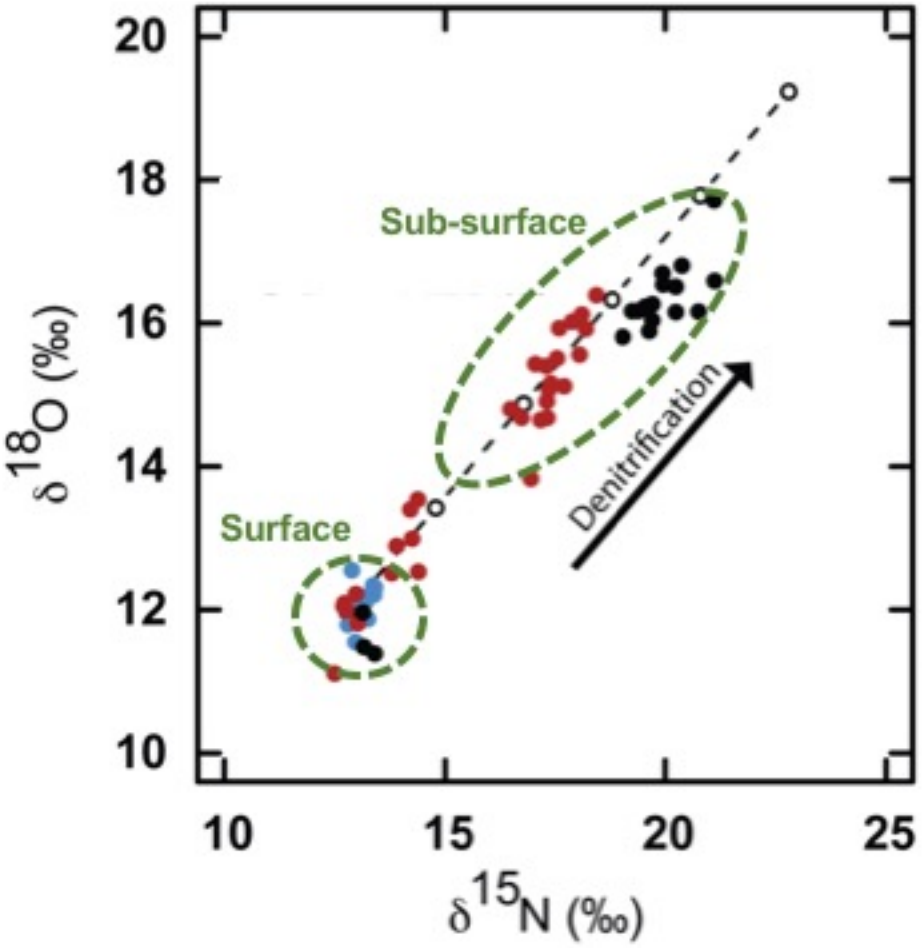


Field Experiments Results – Stable Isotopes of Nitrate



Stable isotopes of residual nitrate confirm denitrification

$\delta^{18}O$ and $\delta^{15}N$ of show enrichment with depth

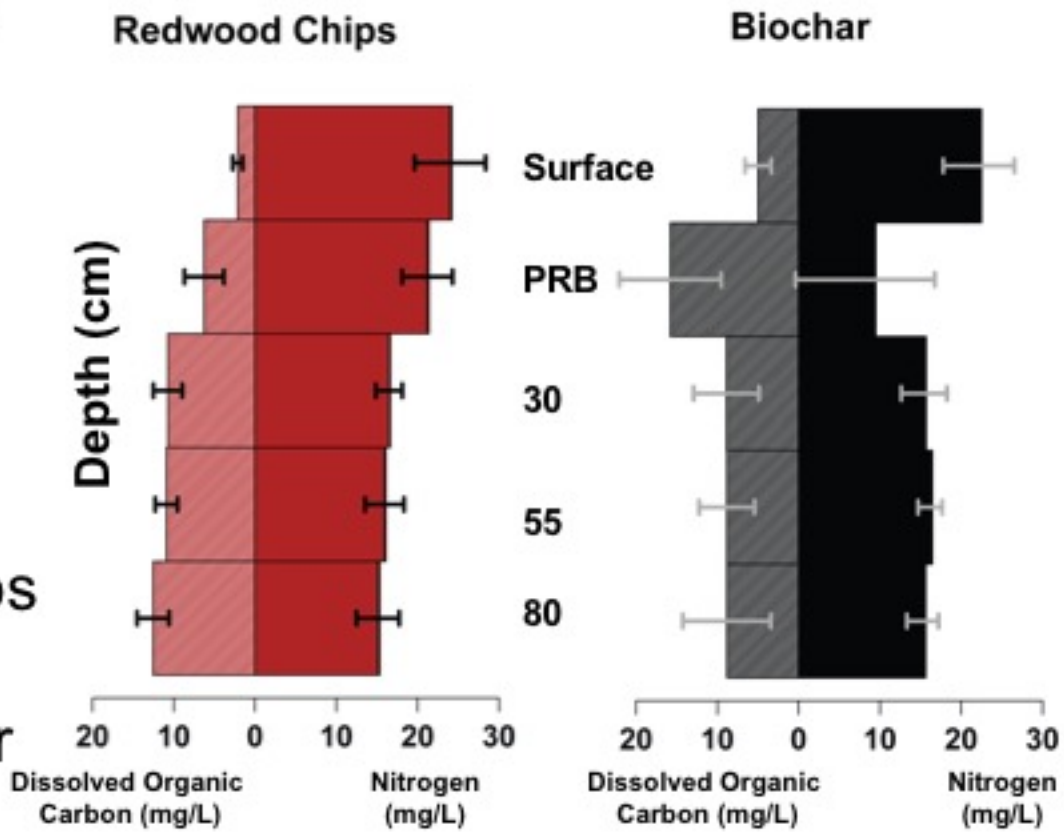
$\varepsilon N = -10.02$ ‰

$\varepsilon O = -7.26$ ‰

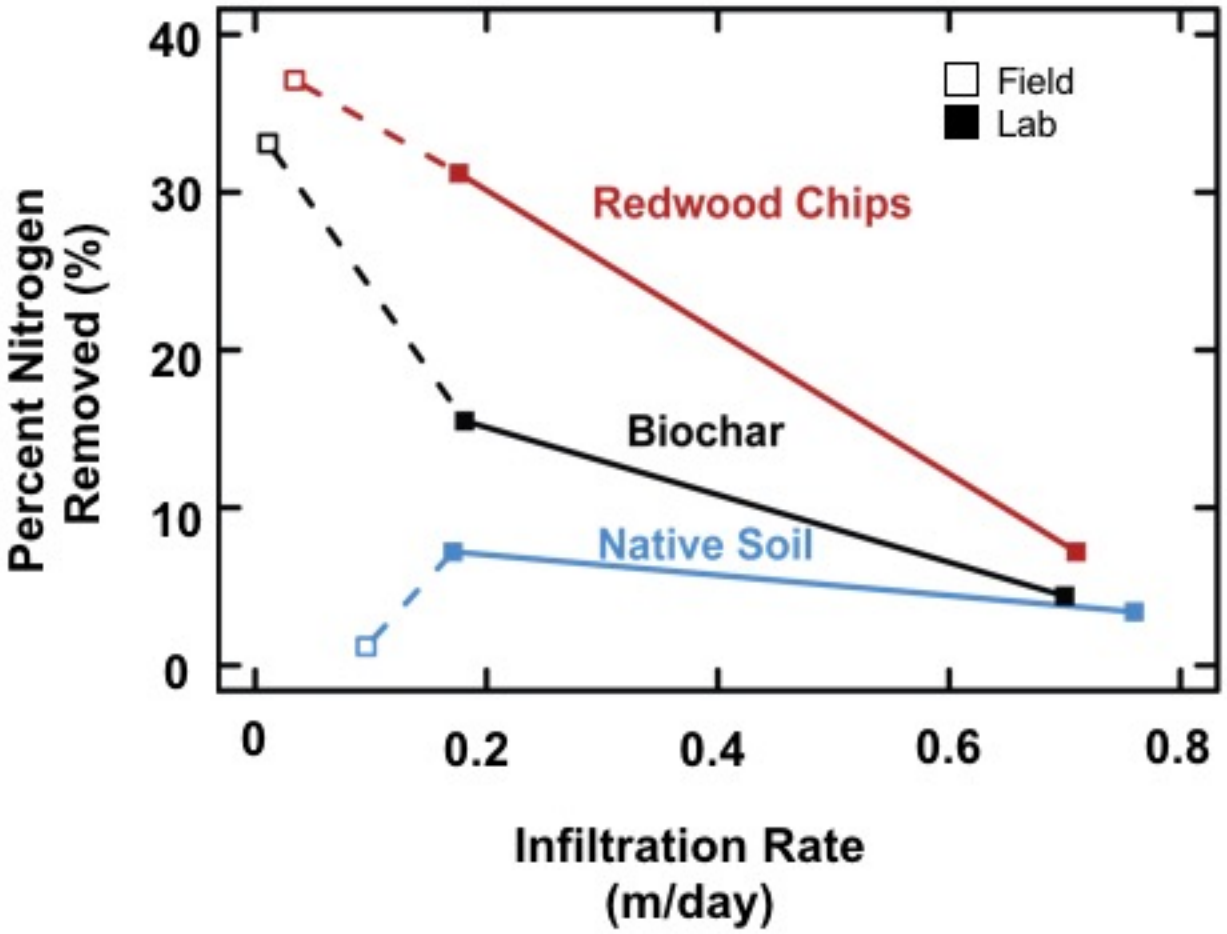
Experimental Questions -- #1

By what mechanism can a PRB stimulate nitrogen cycling, and how do these vary with different PRB materials?

Both redwood chips and biochar can enhance denitrification during infiltration. Redwood chips provide carbon to the subsurface, while biochar provides habitat.



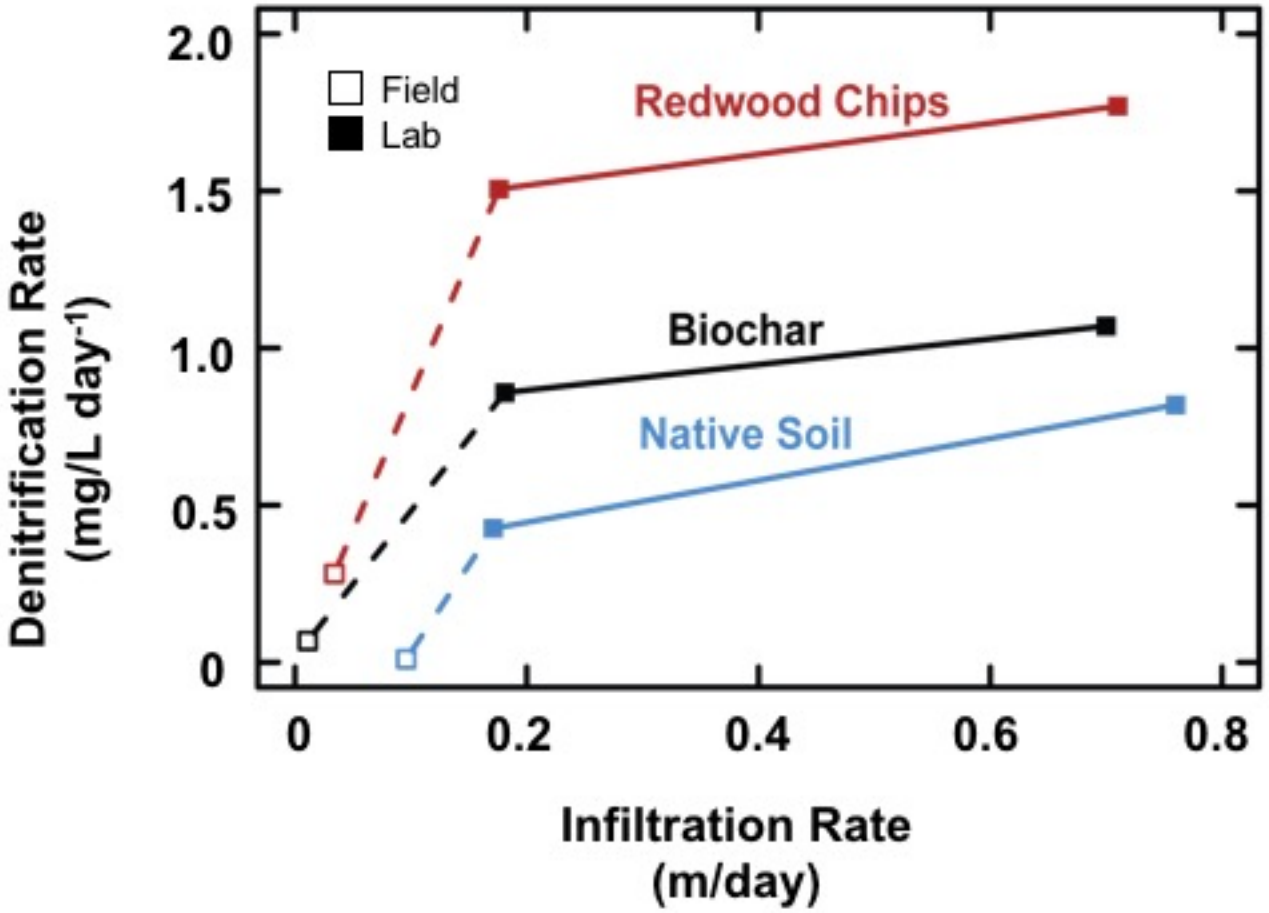
Lab Studies – Results: Infiltration Rate and Nitrate Removal



Increased flow rates lead to less nitrate removal in all treatments

Relationships from field tests are consistent across infiltration rates

Lab Experiments Results – Infiltration Rate and Denitrification Rate



Denitrification rates may increase with higher infiltration rates

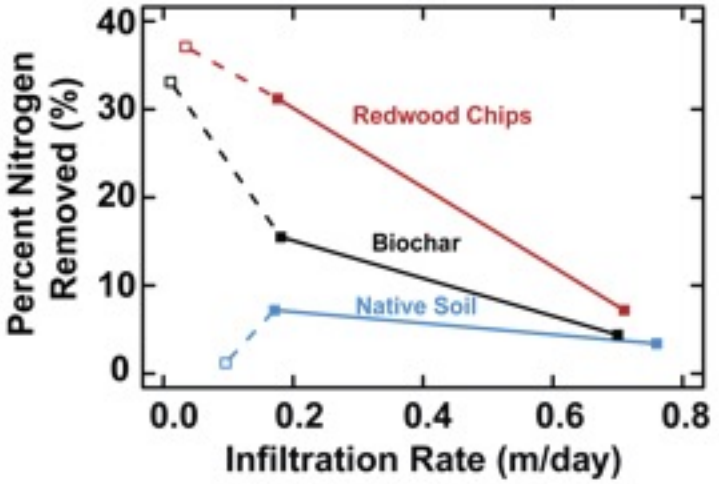
Relationships from field tests are consistent across infiltration rates

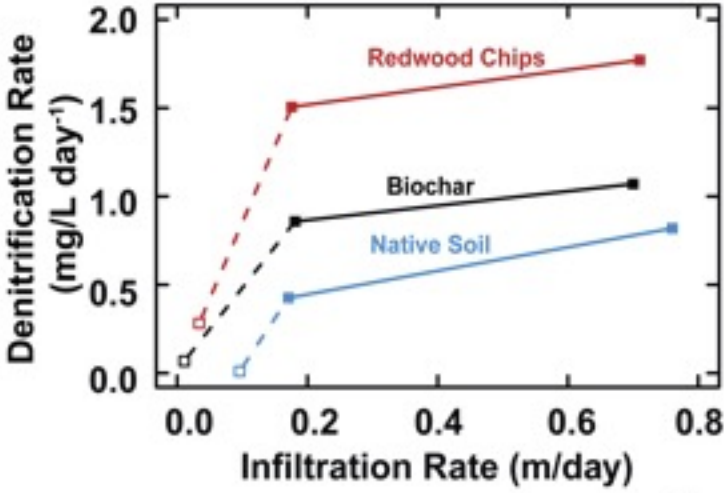
Experimental Questions -- #2

How does infiltration rate affect the amount and rate of nitrate removal?

At higher infiltration rates the percentage of nitrate removed decreases, but the rate of removal may increase.

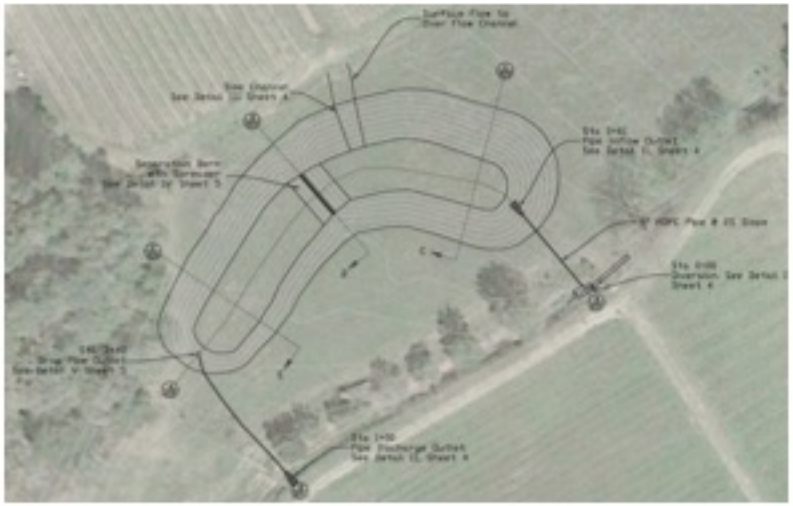
Increased denitrification in the presence of a PRB is consistent across infiltration rates.





Experimental Questions -- #3

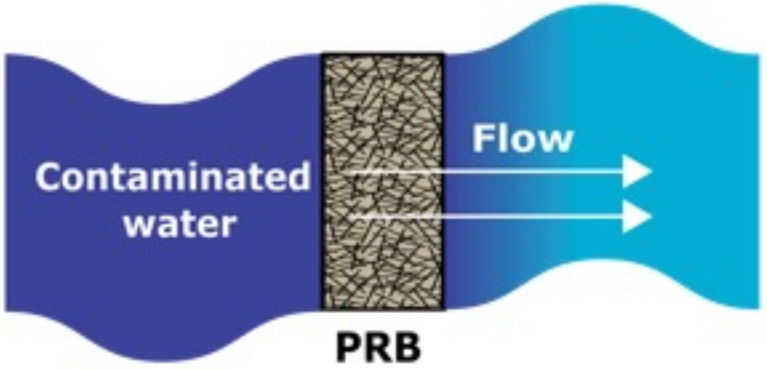
How can this information help in the design and operation of MAR systems to improve water quality and quantity simultaneously.



We have installed plots with PRB materials at an MAR site that will be active during the 2018 water year.

Combining technologies to improve water quantity and water quality

The addition of a PRB enhances nitrate removal during infiltration across a range of infiltration rates



MAR combined with a PRB provides the unique opportunity to improve water quantity and quality simultaneously

Acknowledgements

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