Biological Nitrogen Removal (BNR)
Two stage biofiltration is stable process

WW From Home

Primary Treatment

Mineralization of most organic N to ammonia (ammonia – NH_4)

STAGE 1 (Nitrification)

TKN (Ammonia and organic N) oxidized to nitrate (NO_3) by nitrifying bacteria, requires oxygen

STAGE 2 (Denitrification)

Nitrate converted to N_2-gas in anoxic environment; requires supply of electron donor

Dispersal

Effluent discharge to the soil or landscape

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*What are "passive" nitrogen reduction systems (PNRS)?

- Passive nitrogen reduction systems (PNRS) are OSTDS that reduce effluent N using reactive media for denitrification and a single liquid pump, if necessary.
- Two stage biofiltration process:
  - Stage 1: "nitrify" nitrogen compounds to NO_3 (nitrification)
  - Stage 2: "denitrify" NO_3 to nitrogen gas (denitrification)

nitrification media: Sand, expanded clay, clinoptilolite

denitrification media: lignocellulosics

denitrification media: elemental sulfur

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Biological denitrification

Reduction of nitrate to N_2 gas:

Heterotrophic (Schmidt, 2012)

$$5C_6H_{12}O_6 + 24NO_3^- + 24H^+ \Rightarrow 12N_2 + 42H_2O + 30CO_2$$

3.57 g alkalinity as $CaCO_3$ is produced per 1 g NO_3-N reduced to N_2

Autotrophic (Batchelor, 1978)

$$NO_3^- + 1.10\ S^0 + 0.40\ CO_2 + 0.76\ H_2O + 0.08\ NH_4^+ \Rightarrow 0.08\ C_5H_7O_2N + 1.10\ SO_4^{-2} + 0.50\ N_2 + 1.28H^+$$

7.54 g SO_4^{2-} generated per 1 g NO_3^-N reduced to N_2
4.57 g alkalinity as $CaCO_3$ is consumed per 1 g NO_3-N reduced to N_2

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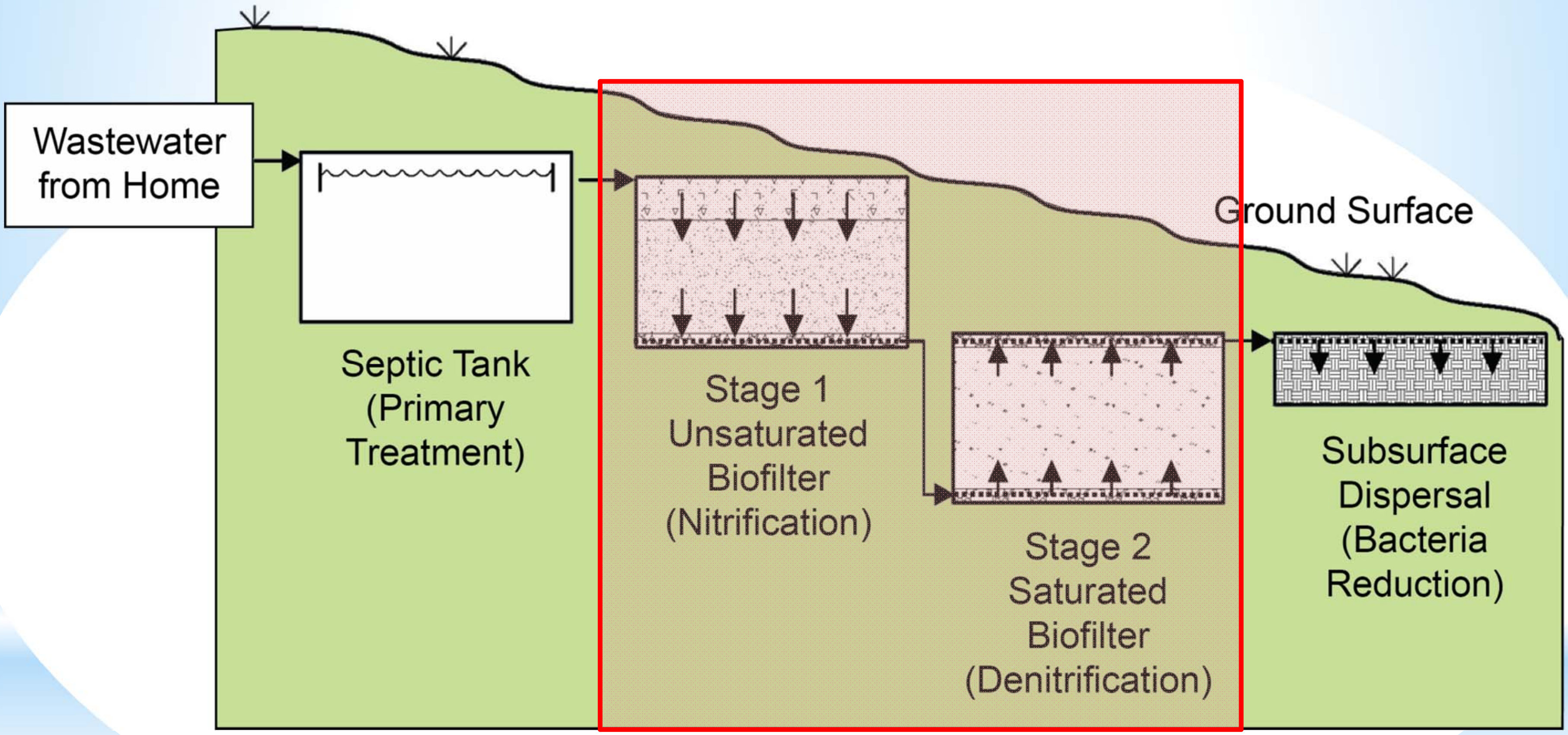
Full scale concepts complement existing OSTDS



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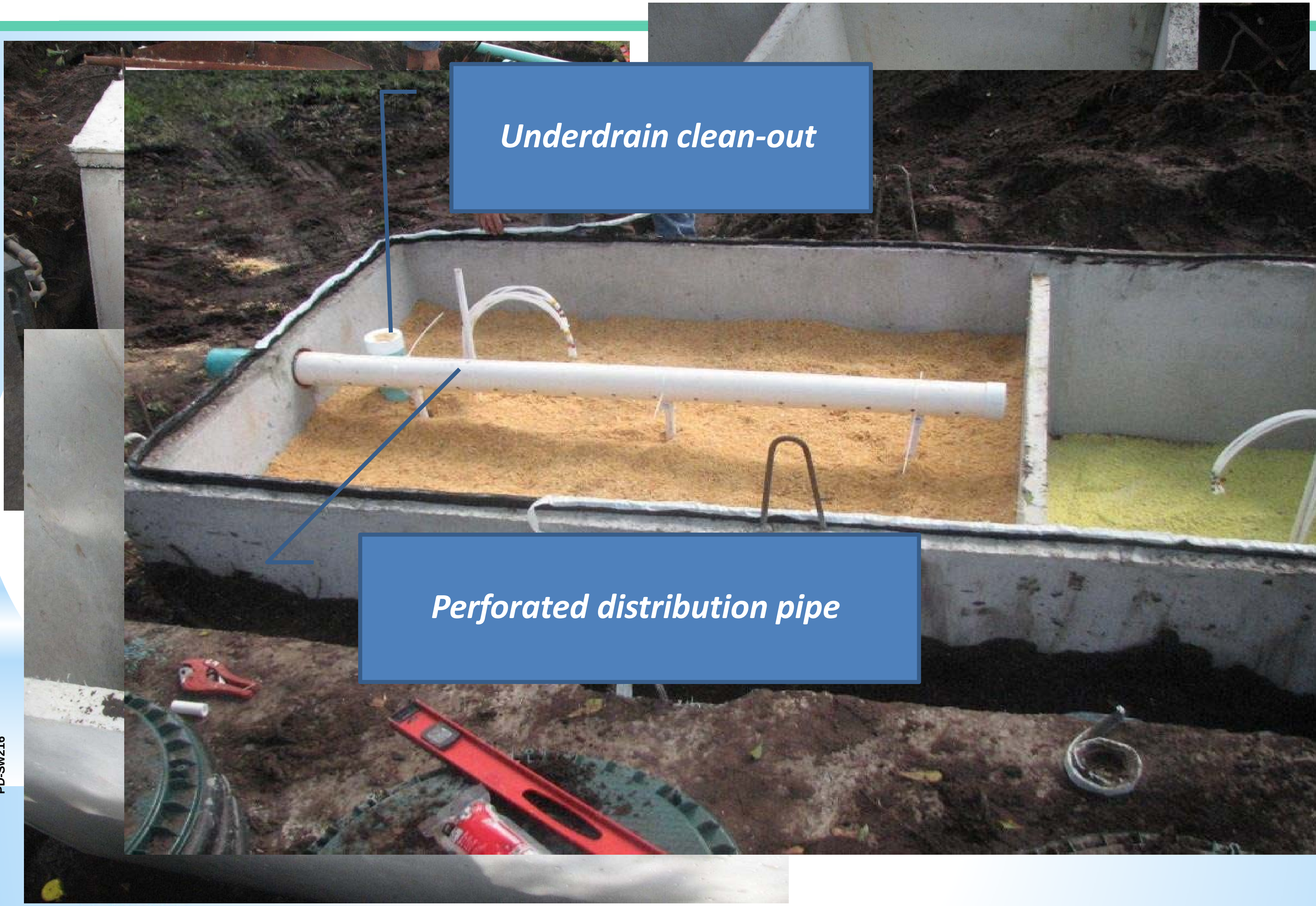
Stage 2 biofilter construction



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* Results over 18 months of operation

Water Quality Parameter	Statistical Parameter	Septic Tank Effluent	Stage 1 Effluent	Stage 2A Lignocellulosic Effluent	Stage 2B Sulfur Effluent
	n	12	12	12	12
$CBOD_5$ mg/L	mean	136.9±53.0	8.8±6.2	12.7±6.6	12.3±8.2
TSS mg/L	mean	61.1±21.0	9.4±6.1	5.3±3.7	4.1±2.3
TKN mg N/L	mean	70.0±9.8	12.0±7.5	8.7±6.2	6.6±4.4
NH_3 mg N/L	mean	62.3±7.3	8.1±8.2	5.6±6.2	4.4±4.0
NO_x mg N/L	mean	0.1±0.2	33.6±15.5	3.2±4.1	0.8±2.7
TN mg N/L	mean	70.1±10.0	45.6±10.6	11.8±4.4	7.4±4.9
Sulfate mg/L	mean	1.7±1.5	19.7±3.1	14.7±7.5	37.2±17.6
Fecal Coliform (Ct/100mL)	geomean	48,499	2,764	1,150	409
TP mg/L	mean	9.4±2.1	3.3±1.5	2.7±1.4	2.6±1.1

TN Reduction
Stage 1, 35%
Stage 2b, 89%
prior to STU/drainfield

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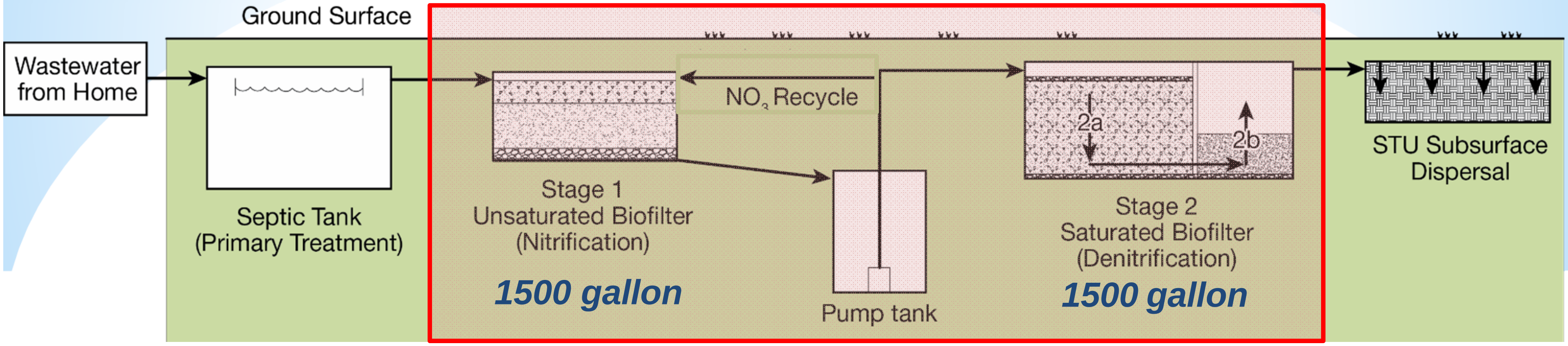
*Flow schematic



- Stage 1 media = expanded clay
- Stage 2a media = urban waste wood
- Stage 2b media = 90% sulfur & 10% oyster shell

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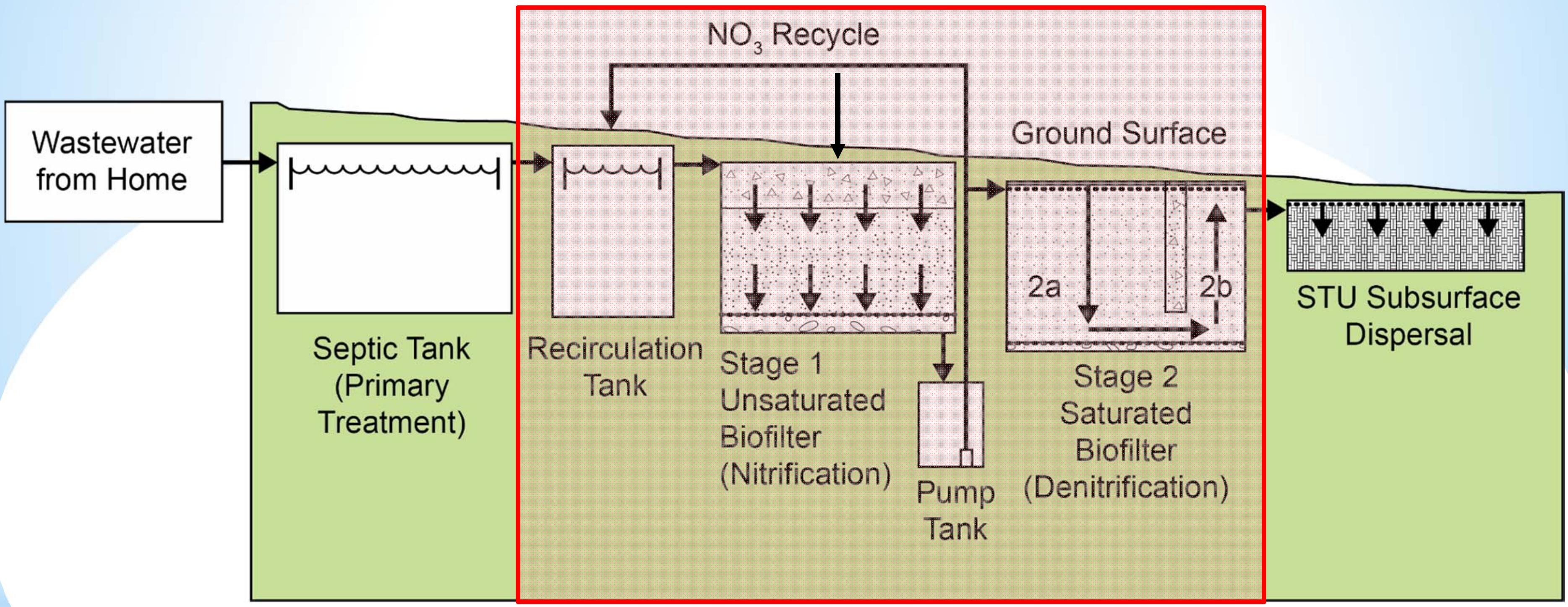
*Flow schematic



- Stage 1 media = expanded clay
- Stage 2a media = sawdust
- Stage 2b media = sulfur & oyster shell

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* Development of in-ground PNRS concepts

* Tank based PNRS performed extremely well, but large tankage requirements make retrofit installation expensive
* Desired an in-ground system that could be constructed like
* a soil treatment unit (drainfield)
* Conceptual ideas revolved around a vertically stacked PNRS, where Stage 1 media was placed over the Stage 2 media
* Liner could be used to saturate Stage 2 media and collect treated effluent

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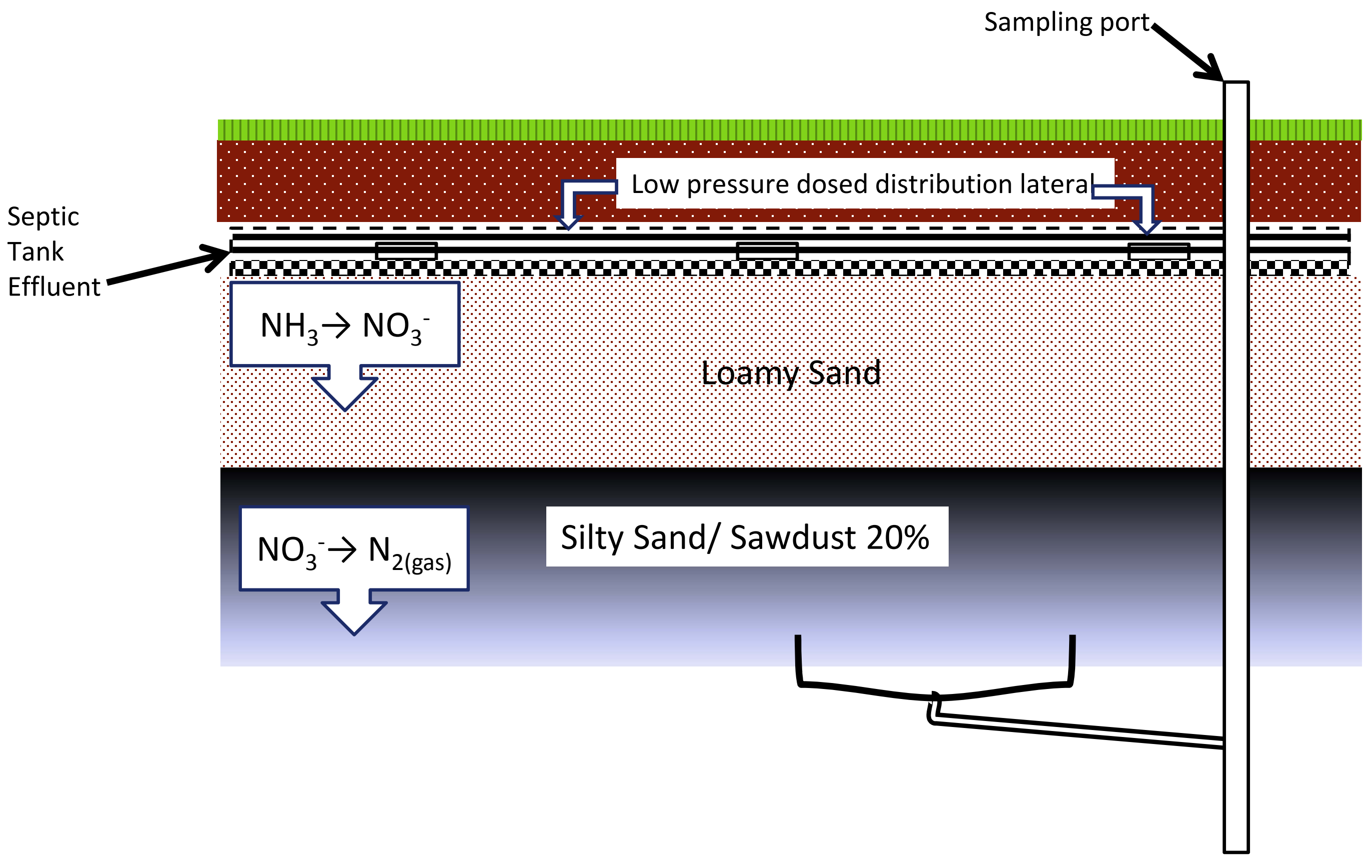
Large scale "permeable reactive barrier" system (Silt-sawdust layer)



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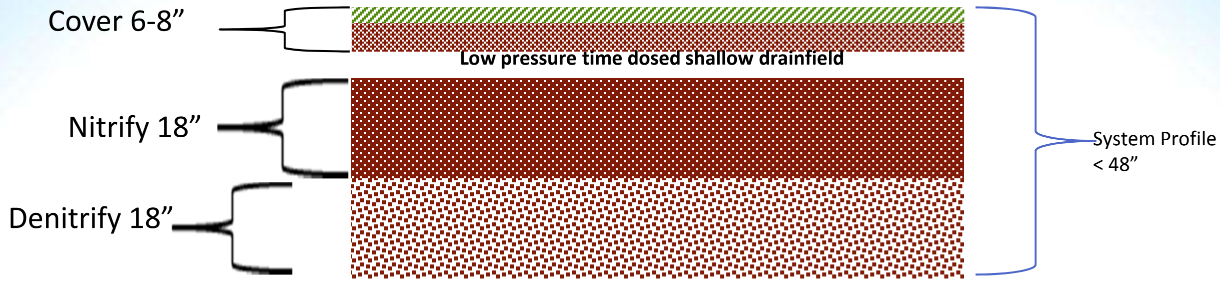

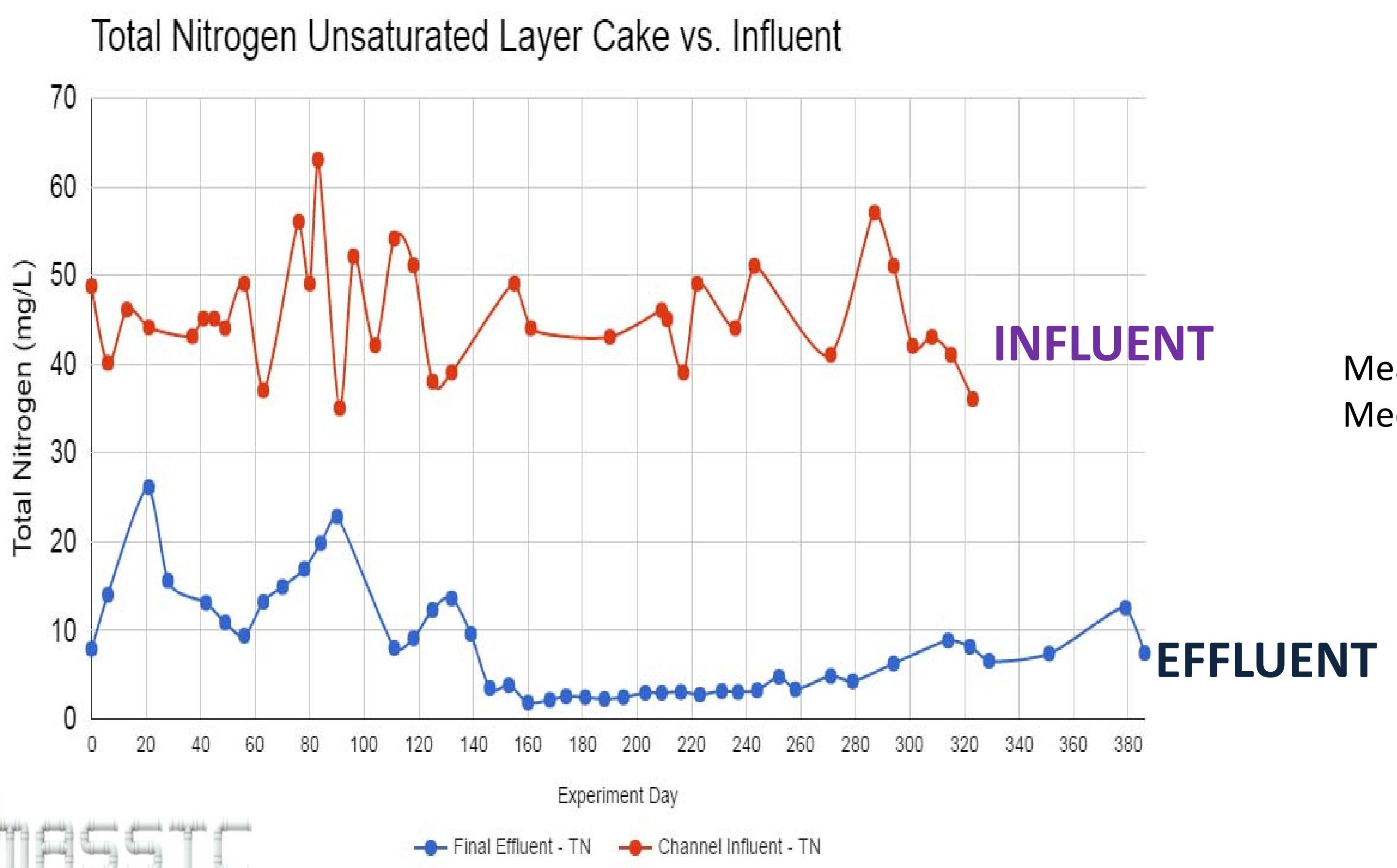

Mean 8.2 mg/L TN
Median 7.4 mg/L TN

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Installation of collection system for sampling port below "permeable reactive barrier"

* Prototype In-ground PNRS Construction

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Prototype in-ground PNRS performance

Mean results over 8 sample events, 523 days of operation

	n	TKN mg N/L	NH_3 mg N/L	NO_x mg N/L	TN mg N/L	Sulfate mg/L	Fecal Coliform (Ct/100 mL)	% TN Reduction
		mean	mean	mean	mean	mean	geomean	
STE Drip	8	65.1	55.60	0.29	65.4	40.6	59,834	
Stage 1 18" Sand	8	3.2	0.03	33.13	36.3	49.4	Non-detect	44%
Stage 2a ligno/sand	9	3.0	0.36	3.55	6.5	115.7	2.3	90%
Stage 2b sulfur tank	8	3.4	0.95	0.06	3.5	292.9	6.5	95%

DISPERSAL

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*Presentation Credits

Slides 1-9 and 13-14

Florida Department of Health

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Slides 10-12

Barnstable County Department of Health and Environment

* Massachusetts Alternative Septic System Test Center