Enhanced Perspective on Onsite Wastewater Systems: A Public Health Contribution to the Wellbeing of Communities

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OUTLINE

- Why an enhanced perspective on OWW systems and why is this a public health contribution to community wellbeing?

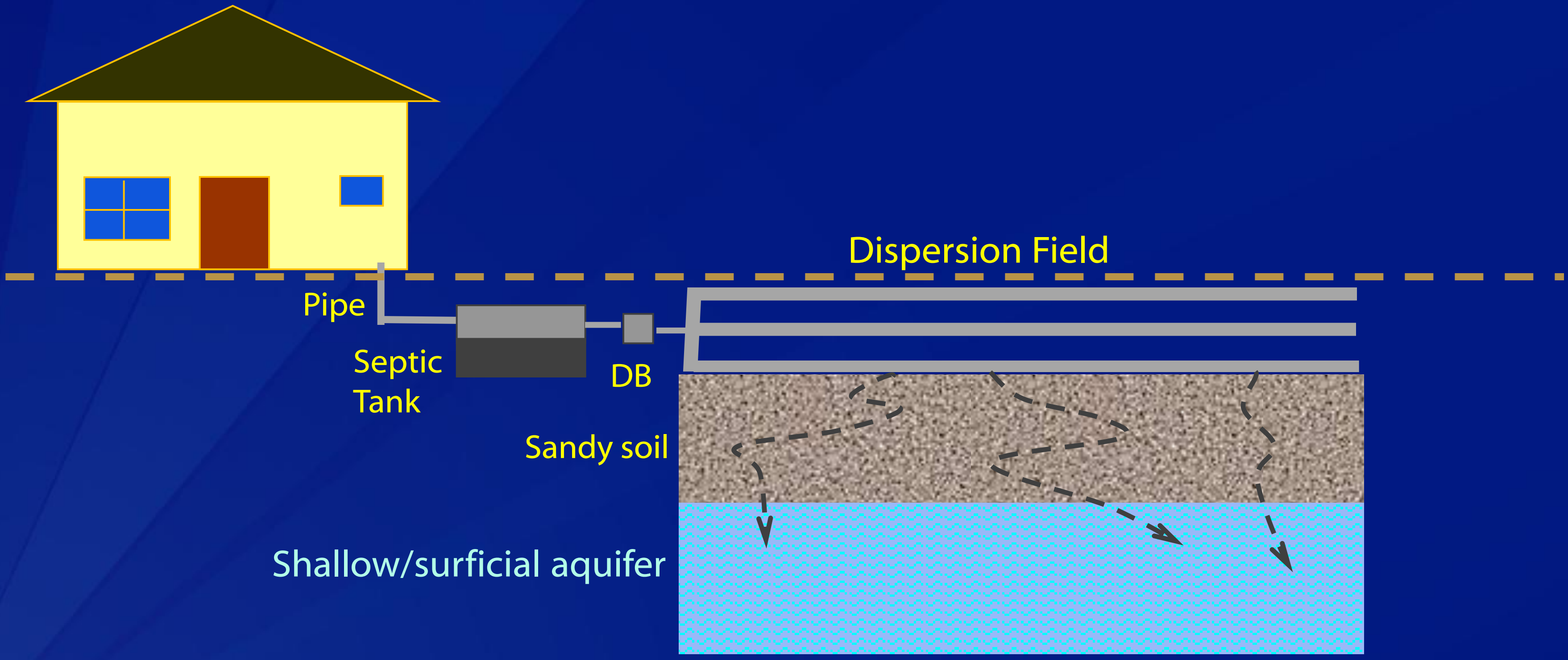
- Evaluating performance of OWW systems in Coastal North Carolina
  - Methodology
  - Findings
  - Accomplishments
  - Limitations

- Remaining promising and challenging aspects

WHY AN ENHANCED PERSPECTIVE ON ONSITE WASTEWATER SYSTEMS?

Why an enhanced perspective on OWW systems?

Conventional OWW System schematic in coastal areas (non-scale)

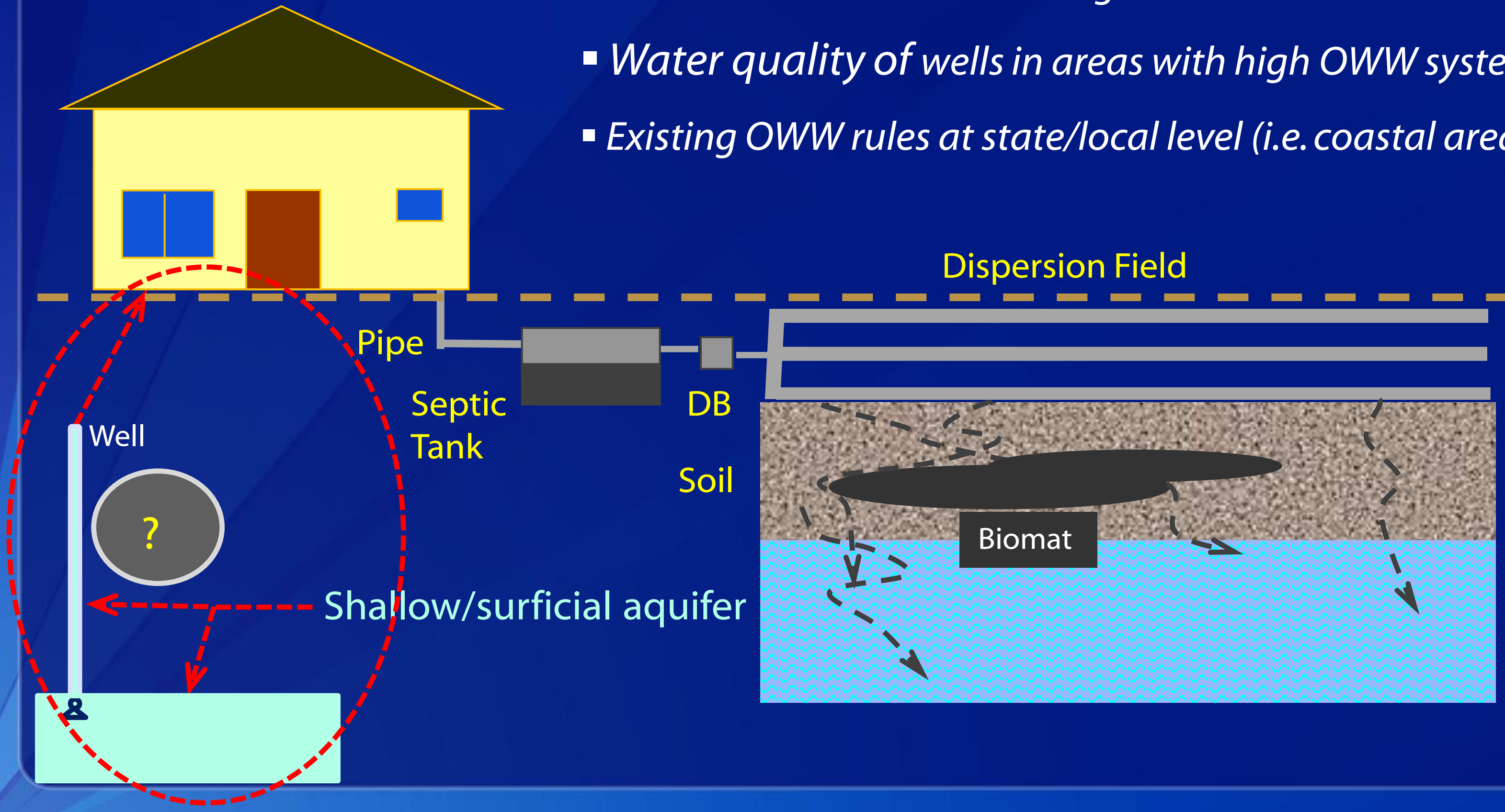


Why an enhanced perspective on OWW systems?

Conventional OWW System schematic in coastal areas (non-scale)

Basis for an enhanced perspective:

- *Knowledge of OWW systems' performance*
- *Fate of nutrients and microorganisms in the environment*
- *Water quality of wells in areas with high OWW systems' density*
- *Existing OWW rules at state/local level (i.e. coastal areas)*

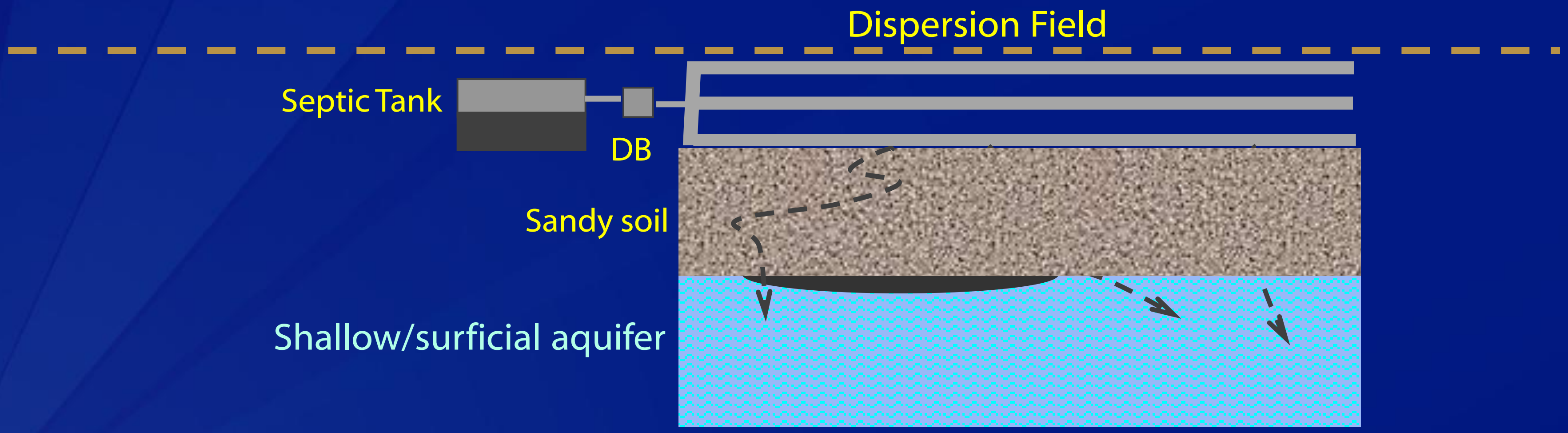


Why an enhanced perspective on OWW systems?

Conventional OWW System schematic in coastal areas (non-scale)

Environmental conditions in OWW systems' components:

- *Septic tank (facultative environment):*
  - *Anaerobic (bottom): reduction processes → sulfide production*
  - *Aerobic (top): oxidation processes → nitrification starts (?)*
- *Dispersion field:*
  - *Aerobic (top): Oxidation processes → nitrification; possibly anaerobic pockets*
- *Soil (may apply to shallow aquifer):*
  - *Aerobic (if aerated): continued oxidation processes*
  - *Anaerobic (where biomat forms): reduction processes → denitrification*



Why an enhanced perspective on OWW systems?

- **Environmental issues that might be attributed to malfunctioning OWW systems**
  - Excess nutrients transported to already nutrient-sensitive rivers
  - Microbial contamination – Closure of beaches and shellfisheries
    - ✓ 65% of shell-fishing waters in New Brunswick County closed in 1990s[a]
  - Florida: 0.60 m (24") vertical separation not safe for viruses (wet season)[b]

[a] Nearhoof and Cahoon. 2000. *Water quality and shellfisheries closure in a developing coastal region of North Carolina, USA: A preliminary overview*. Proceedings of the Gulf and Caribbean Fisheries Institute. No. 51, pp:441-450.

[b] Nicosia *et al*. 2001. A field study of virus removal in septic tank drainfields. *Journal of Environmental Quality*, 30(6):1933-1939.

Why an enhanced perspective on OWW systems?

- **Public Health issues potentially attributed to malfunctioning OWW systems**
  - Wisconsin:
    - Enteric viruses and *E. coli* isolated from samples of household wells near septage land application sites or in rural areas served by septic systems[c]
    - Sites with densities <50 OWW systems/mile^2 were associated with endemic diarrhea in children[d]
  - Wyoming: overloaded OWW system, not well suited to local soil/geologic conditions; drinking water system with no treatment or disinfection[e]
  - Coastal North Carolina: densities of >100 (common) and of >200 (found) OWW systems/mile^2 with vertical separation of 0.45 m (18")

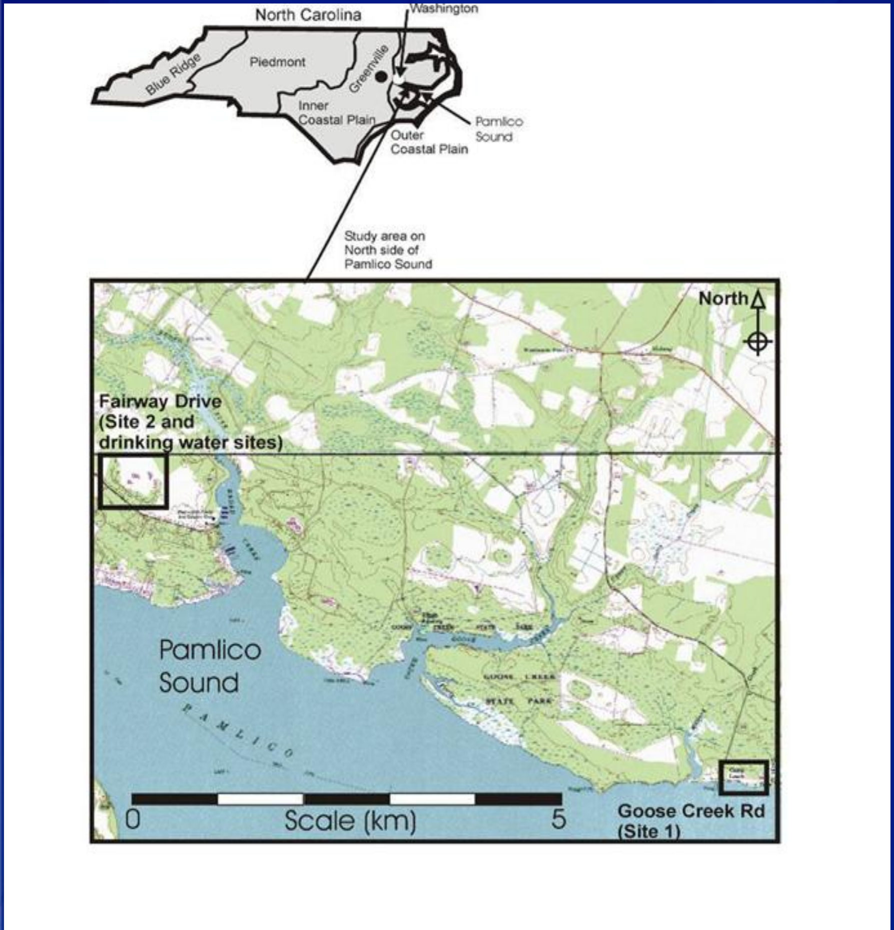
[c] Borchardt *et al*. 2003. Incidence of enteric viruses in groundwater from household wells in Wisconsin. *Appl Env Microbiol.*, 69(2):1172-1180.

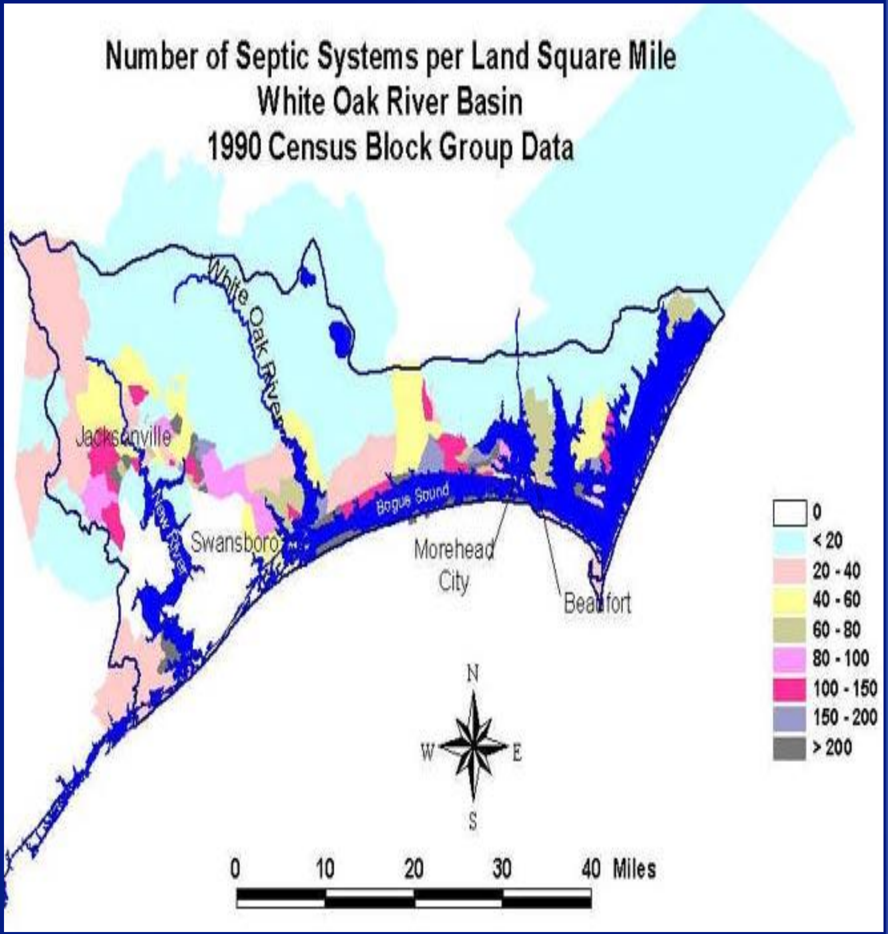
[d] Borchardt *et al*. 2003. Septic system density and infectious diarrhea in a defined population of children. *Environ Health Perspect* 111:742–748.

[e] Gelting *et al*. 2005. Use of a systems-based approach to an environmental health assessment for a waterborne disease outbreak investigation at a snowmobile lodge in Wyoming. *Int J Hyg Environ Health*, 208:67–73.

WHY IS THIS A PUBLIC HEALTH CONTRIBUTION TO COMMUNITY WELLBEING?

Why is this a public health contribution to community wellbeing?





Base map is from the USGS Blounts Bay quadrangle (1993)

Why is this a public health contribution to community wellbeing?

Because of reasons related to the environment, human health, and economic development nexus:

- Enhanced knowledge of:
  - OWW systems and WW management at local level
  - Potential environmental and public health risks
- Design and implementation of corrective actions to prevent future risks –if needed
- Communities can benefit from assessing water resources in a more interconnected and integrated manner

Why is this a public health contribution to community wellbeing?

Because of reasons related to the environment, human health, and economic development nexus:

- Protection of the environment and public health
- Contribution to the economic development and wellbeing of communities

EVALUATING PERFORMANCE OF OWW SYSTEMS IN COASTAL NORTH CAROLINA

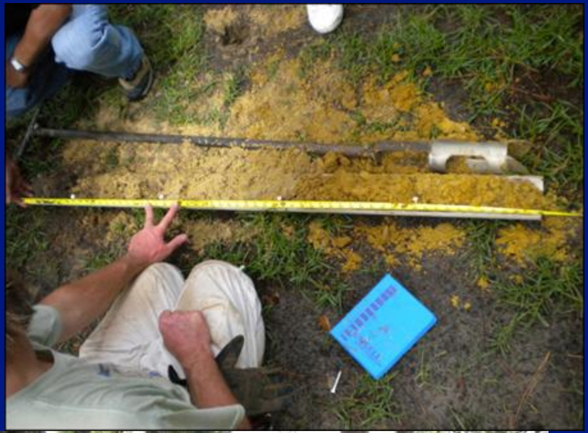
Methodology – 2 year project

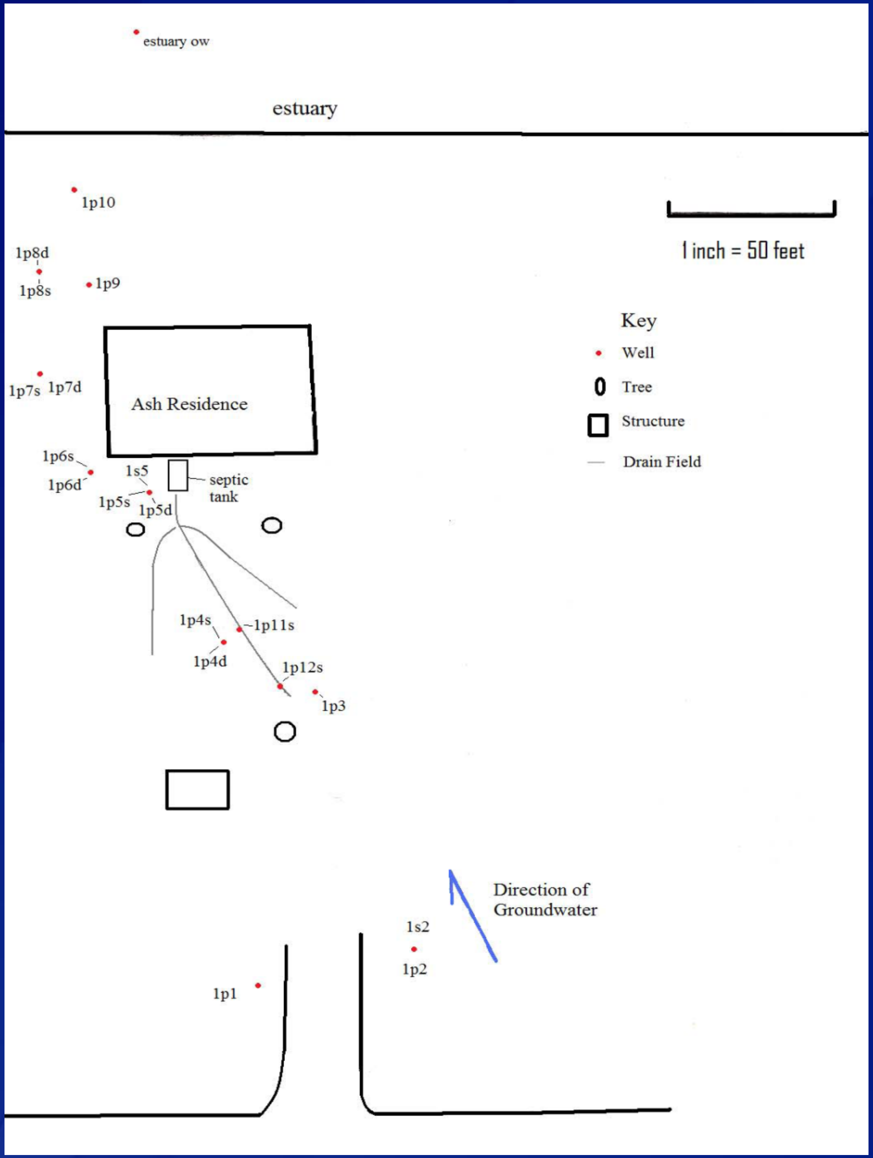
❑ Approach:

1. Multidisciplinary team (ECU, NCSU, NEHA, CDC)
2. Site selection, soil morphology, and identification of OWW Systems' components
3. Characterization of the shallow aquifer (flow direction)
4. Delineation of wastewater plume orientation
5. Monitoring performance of OWW Systems [a, b]:
    - Septic tanks (installation of lids/tubing)
    - Network of piezometers in shallow aquifers doubled for the 2nd year compared to the 1st at Site 1

[a] *Site 2 monitored only during year 1*

[b] *Wells of deeper aquifers were also sampled in Site 2's neighborhood*





Sampling points at Site 1, years 1 and 2

Findings

- **Characterization of the shallow aquifer and WW plume**
  - Flow direction and delineation of wastewater plume → estimated by electrical resistivity surveying
    - Geoprobe sediment cores collected up to depths of 5 m
      - Relatively homogeneous sandy soils
      - Low permeability organic-rich clays and wood debris found in deepest 0.20 m (site 2)
    - Characteristics of shallow aquifers: relatively homogeneous sandy sediments
    - OWW systems in coastal areas, depending on their location, can be vulnerable to the effects of severe weather events (i.e. Site 1, Year 2)

Findings

- Monitoring performance of OWW Systems: parameters measured

Physical-chemical	Physical-chemical (cont'd)
pH Temperature Turbidity and Total Suspended Solids Chloride Specific conductance Dissolved Oxygen Biochemical Oxygen Demand (5 and 7) Total Nitrogen Nitrogen species: ammonia (ion ammonium), nitrite, nitrate, dissolved Kjeldahl nitrogen ***Isotopic analyses:*** ^{15}N and $^{18}O \rightarrow \delta^{15}N^{18}O_3^-$ N_2/Ar	Pharmaceuticals and Personal Care Products (PPCPs) **Microbiological** *Escherichia Coli* *Enterococci* *Clostridium Perfringens* MS2 – F+ phage Somatic phage (ΦX174)

Additional data gathered in the field: hourly fluctuations of water level and rainfall

Findings

❑ Nutrients fate

- Nutrients observed at ~40-50 m from the dispersion field
- OWWs in sandy soils may add dissolved organic nitrogen (DON) loading to adjacent surface waters

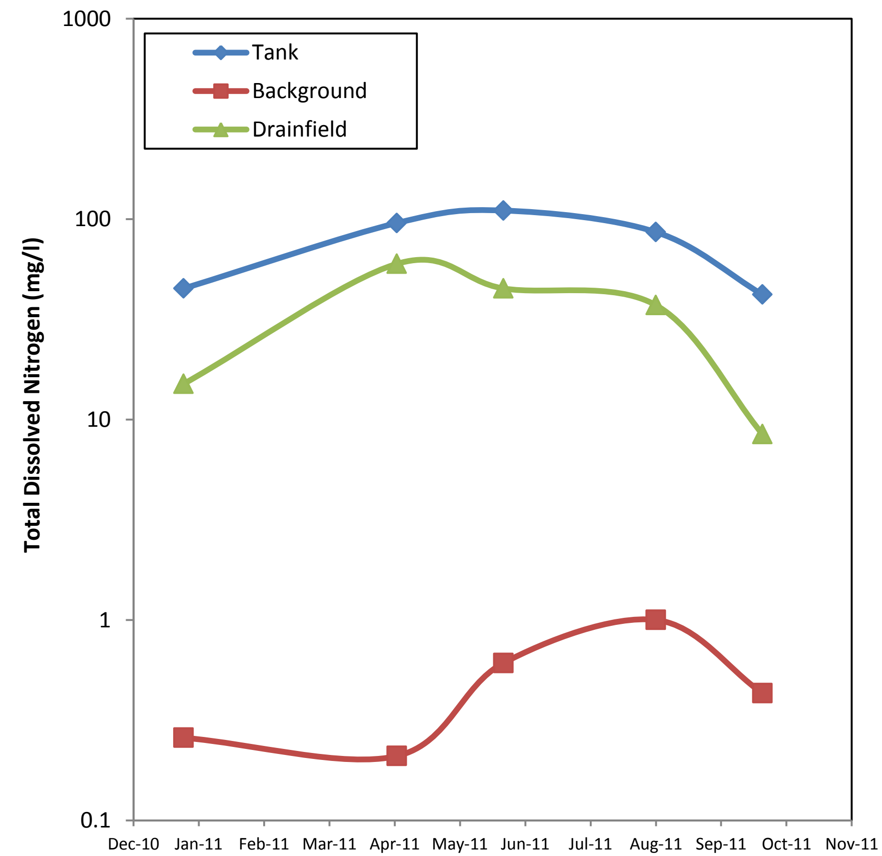
❑ Microbial fate

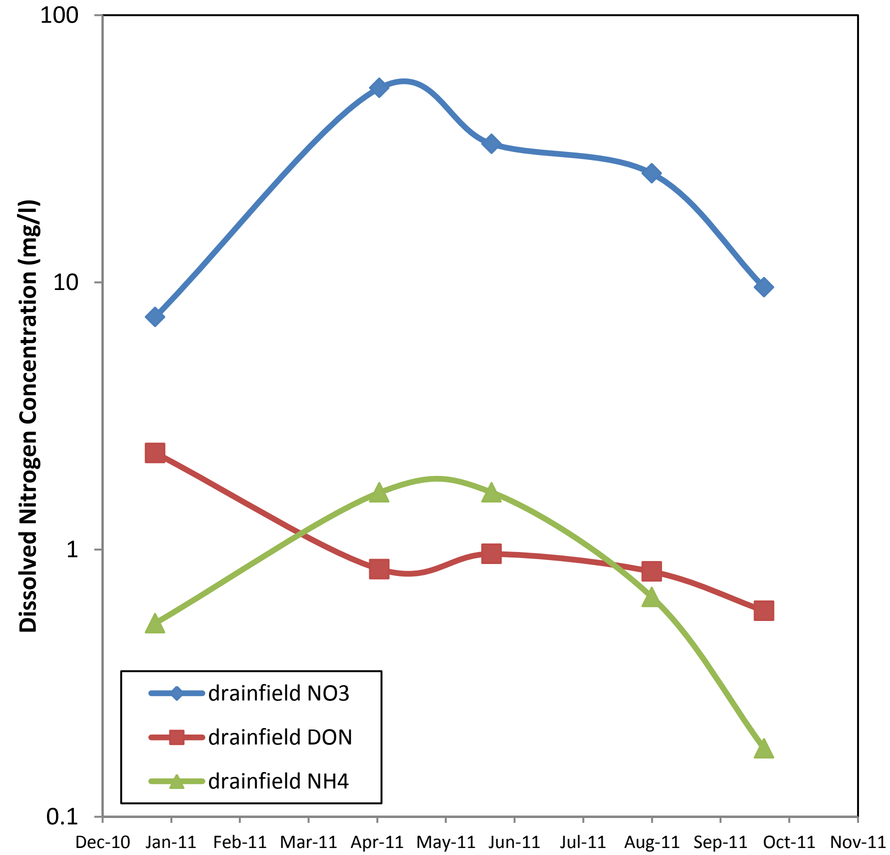
- Indicator data more spatially and temporally variable than nutrient data
- *E.coli* and enterococci densities declined to less than background levels at within and outside dispersion field area
- Found elevated microbial densities during several sampling events in background wells or in wells >30 m from dispersion field
- Deeper aquifers s appear not to be contaminated (year 1, site 2)

Findings

Monitoring performance of OWW Systems:

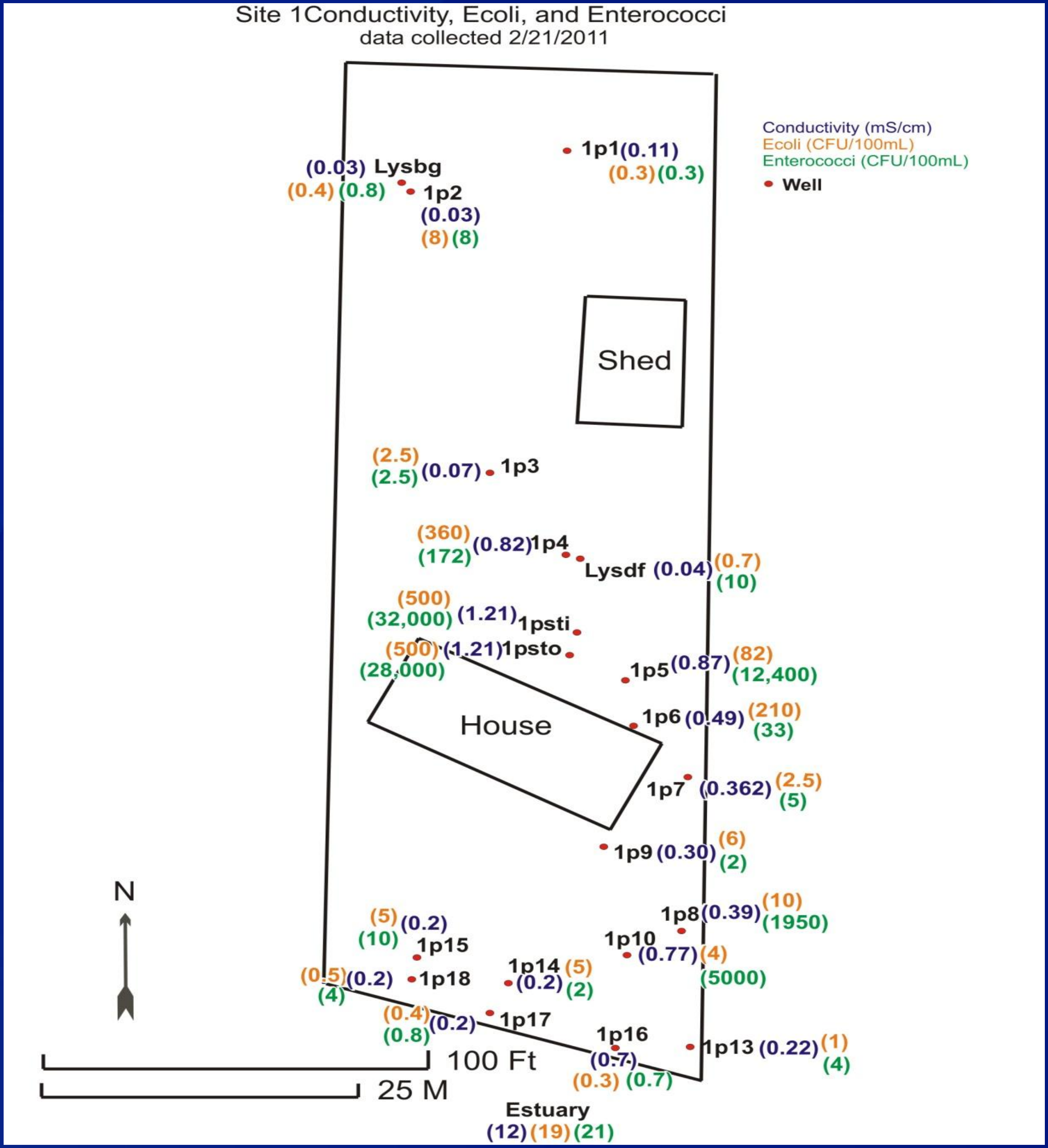
- Median TDN and DON, NO_3^--N, and NH_4-N in OWW systems. TDN levels in septic tank, dispersion field piezometers and lysimeters, and background piezometers and lysimeters.





Findings

Microbial indicators:



Accomplishments

- **Capacity building:**
  - Future environmental scientists addressing local needs
  - Network of collaborators (e.g. LHDs, neighborhood associations)
- **Enhanced understanding of OWWT systems adjacent to nutrient-sensitive waters – Products:**
  - Two Master's Theses in Geological Sciences – Spring 2012
  - Dissemination of study findings at numerous events nationwide (e.g. NEHA AEC, ASCE, GSA)
  - Manuscripts submitted to the *JEH*; others in preparation
- **New funding opportunities (e.g. NC-DENR, ECU)**

Limitations

Reduced funding impacted on:

- **Initial study duration reduced from 3 to 2 years:**
  - 3rd year included the conduct an epidemiologic study
  - Monitoring water quality from private wells (quarterly sampling)
- **Low number of households studied**
  - Robustness of data set
  - Number of private wells tested; duration of monitoring
- **Human resources:**
  - Limited personnel (field and laboratory work are labor intensive)

REMAINING PROMISING AND CHALLENGING ASPECTS

Remaining promising and challenging aspects

Challenging aspects –after findings of NC study:

- Elevated nutrient concentrations observed at ~40-50 m from dispersion field can be an effect of wastewater input
- Dissolved P returns to background levels over a shorter distance than dissolved N concentrations
- Microbial indicators in groundwater more spatially and temporally variable than nutrients:
  - *E.coli* and Enterococci densities declined from septic tank to dispersion field

Remaining promising and challenging aspects

Challenging aspects –after findings of NC study

- Need of a more comprehensive tracing of human waste in subsurface:
  - Tracers to consider: bacterial source tracking, specific conductance, PPCPs, O^{18}
- Extreme meteorological events contribute to data variability:
  - Groundwater data shown that most of the site was affected
  - Septic tank flooded

Remaining promising and challenging aspects

Challenging aspects –after findings of NC study

- Denitrification:
  - Powerful greenhouse gas N_2O could be generated
- Climate change may have a large influence on OWW treatment in coastal areas

Remaining promising and challenging aspects

Promising aspects –after findings of NC study:

- Denitrification – Coastal NC study (Years 1-2):
  - Positive: apparent reduction of NO_3^--N levels in groundwater by conversion to N_2 (g)
- Data from study and other ongoing coastal NC studies useful in:
  - Building database of groundwater quality down-gradient from OWW systems.
  - Future modeling approaches to scale up estimates of nutrient loading to surface water bodies in coastal NC

Remaining promising and challenging aspects

Promising aspects –additional information:

- Decentralized reuse applications widened due to onsite energy and resource efficiency (water-energy nexus):
  - Industrial and commercial applications
  - Buildings seeking Leadership in Energy and Environmental Design (LEED) certification –it can be energy intensive though
- Decentralized, OWW systems can save a high portion of the tremendous energy costs and emissions associated with pumping in centralized WWTFs:
  - Almost 20% of California's electricity is consumed by water-related energy use, which includes WW collection, treatment, and disposal[a]

[a] CEC. 2005. *California's Water – Energy Relationship*. Final Staff Report, CEC-700-2005-011-SF. November; 180 pp.

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Questions?

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