Evaluation of Water Quality Changes for Two Tributaries with Basins Having Undergone Residential Septic-to-Sewer Conversions, Duval County, FL

Leel Knowles, Jr.

U.S. Geological Survey
in cooperation with
City of Jacksonville
Problem

Fecal Coliform Bacteria in Jacksonville’s Tributaries

- 51 of 76 tributary basins sampled by the City Of Jacksonville are identified as “impaired” due to fecal coliform bacteria, most likely from septic sources.
- Effect of removing septic-tank systems on receiving ground and surface waters is not well documented.
Purpose

- Provide “real-life” empirical data describing pollution load reduction from reducing septic-tank influences
- Assist in TMDL implementation and Basin Management Action Plan (B-MAP) development
- Water-quality based justification for supporting centralized sewer conversion of septic-tank failure areas
Study Objectives

- Compile basin characteristics to facilitate the transferability of results to other locations (Phase I)
- Document baseline stream water-quality conditions prior to connection of target areas to a centralized sewer system (Phase I)
- Document changes in water quality that may result from septic to sewer system conversion (Phase II)
Location of Study Sites

Base modified from U.S. Geological Survey digital data, 1:100,000, 1985
Albers Equal-Area Conic projection
Fishing Creek
Upstream site at Wesconnett Blvd.
Fishing Creek
Downstream site at 110th St.
South Branch Big Fishweir Creek
Upstream site at Cassat Ave. (Phase I)
South Branch Big Fishweir Creek
Upstream site at Yerkes St.
(Phase II)
South Branch Big Fishweir Creek
Upstream site at Yerkes St.
during Tropical Storm Fay (Aug. 22, 2008)
South Branch Big Fishweir Creek
Downstream site at Blanding Blvd.
(Upstream side)
South Branch Big Fishweir Creek
Downstream site at Blanding Blvd.
(Downstream side)
South Branch Big Fishweir Creek
Downstream site at Blanding Blvd.
during Tropical Storm Fay (Aug. 22, 2008)
### Subdivision and Basin Characteristics

- Approximately 155 acres in each subdivision drains to a receiving stream.
- Greater than 90 percent of the land-use in each basin is single- or multi-family residences.

<table>
<thead>
<tr>
<th>Subdivision</th>
<th>Basin</th>
<th>Drainage area (acres)</th>
<th>Subdivision</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Area (acres)</td>
<td>Population (count)</td>
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<tr>
<td>Pernecia/Johnnie</td>
<td>Fishing Creek</td>
<td>812.8</td>
<td>193.2</td>
<td>522</td>
</tr>
<tr>
<td>Murray Hill B</td>
<td>South Branch Big Fishweir Creek</td>
<td>428.8</td>
<td>464.8</td>
<td>2,766</td>
</tr>
</tbody>
</table>
Data Collection

- Physical water properties (temperature, dissolved oxygen, pH, specific conductance, turbidity)
- Streamflow measurements
- Water samples
  - Nutrients (nitrogen and phosphorus)
  - 63 organic wastewater compounds (caffeine, camphor, DEET, fragrances, menthol, phenol, etc.)
Data Collection (cont...)

- Water Samples (cont...)
  - Fecal coliform bacteria (Phase I)
    - Most probable number per 100 mL
    - Classification of bacteria sources using antibiotic resistance pattern testing
  - Fecal coliform bacteria (Phase II)
    - Counts per 100 mL by membrane filtration method
    - Detection and quantification of the Fecal Bacteroidetes and Enterococcus faecium esp human-gene biomarker for human fecal contamination by Real-Time Quantitative Polymerase Chain Reaction (qPCR) DNA Analytical Technology
Rainfall at Jacksonville NAS

Annual Rainfall, in Inches

47.71 inches average annual rainfall (1945-2008), in inches

USGS: science for a changing world
Measured Streamflow
Fishing Creek

EXPLANATION
SCHEMATIC BOXPLOT

11 13
18 17
11 18 17
11 18 17
11 18 17
11 18 17

number of values
upper detached
upper outside
75th percentile
median
25th percentile
lower outside
lower detached
Measured Streamflow
South Branch Big Fishweir Creek

Measured Streamflow, in cubic feet per second

- Cassat Ave.
- Blanding Blvd.
- Cassat Ave. (Yerkes St.)
- Blanding Blvd.

PRE-SEWERED
POST-SEWERED

EXPLANATION SCHEMATIC BOXPLOT

- 14 number of values
- o upper detached
- x upper outside
- 75th percentile
- median
- 25th percentile
- x lower outside
- o lower detached
Results

- **Nutrients exceeded EPA Ecoregion XII criteria**
  (concentration - 25 percentile based)

- **PHASE I**
  - 49 percent of 51 total nitrogen samples (0.9 mg/L)
  - 96 percent of 51 total phosphorus samples (0.04 mg/L)

- **PHASE II**
  - 51 percent of 65 total nitrogen samples
  - 89 percent of 65 total phosphorus samples
Total Nitrogen Concentration
Fishing Creek

EXPLANATION SCHEMATIC BOXPLOT

- 11 number of values
- o upper detached
- x upper outside
- 75th percentile
- median
- 25th percentile
- x lower outside
- o lower detached

Note: Boxes with same colors are not statistically different after de-trending for stream discharge.
Total Nitrogen Concentration
South Branch Big Fishweir Creek

PRE-SEWERED

POST-SEWERED

EXPLANATION
SCHEMATIC BOXPLOT

14  number of values
o  upper detached
x  upper outside

75th percentile
median
25th percentile

x  lower outside
o  lower detached

Note: Boxes with same colors are not statistically different after de-trending for stream discharge.
Total Phosphorus Concentration
Fishing Creek

EXPLANATION
SCHEMATIC BOXPLOT

11 number of values
○ upper detached
x upper outside

75th percentile
median
25th percentile

x lower outside
○ lower detached

Note: Boxes with same colors are not statistically different after de-trending for stream discharge.
Total Phosphorus Concentration
South Branch Big Fishweir Creek

PRE-SEWERED

POST-SEWERED

TOTAL PHOSPHORUS CONCENTRATION,
IN MILLIGRAMS PER LITER

Note: Boxes with same colors are not statistically different after de-trending for stream discharge.
Results

- Organic Wastewater Compounds detected at or above the lab reporting level

  - PHASE I
    - Detergents, Fragrances, Antioxidants, Flame Retardants, Polycarbonate Resins, Industrial Solvents, DEET, Caffeine, and Nicotine

  - PHASE II
    - DEET, Caffeine, Camphor, Phenol, Antioxidants*, Industrial Solvents*, Fragrances, Pesticides, Herbicides, Flame Retardants, and Combustion Products
      - *SB Big Fishweir Creek only
Detections of Organic Wastewater Compounds At or Above the Minimum Laboratory-Reporting Level

Fishing Creek
Detections of Organic Wastewater Compounds At or Above the Minimum Laboratory-Reporting Level
South Branch Big Fishweir Creek

PRE-SEWERED

- Cassat Ave. (Yerkes St.)
- Blanding Blvd.

POST-SEWERED

- Cassat Ave. (Yerkes St.)
- Blanding Blvd.
Results

- **Fecal Coliform Bacteria**

  - **PHASE I**
    - 63 percent of 115 samples exceeded State of Florida Class III water standards for E. Coli (800 counts/100mL)
    - 100 percent of 16 MST samples detected human fecal pollution: 67 percent of the overall fecal pollution from human sources

  - **PHASE II**
    - 77 percent of 65 samples exceeded State of Florida Class III water standards for E. Coli – all 33 samples exceeded standard at SB Big Fishweir Creek
    - 47 percent of 30 MST samples detected human fecal pollution at SB Big Fishweir Creek: 43 percent of the overall fecal pollution from human sources
Results

- Fecal Coliform Bacteria
- PHASE II (cont …)
  - 1 of 2 samples detected human fecal pollution at Fishing Creek (Wesconnett Blvd upstream site): 95-100 percent of the overall fecal pollution from human sources
  - E. Coli (total) concentrations generally were lower with lower rainfall (winter) and higher (post storm) streamflows
  - *Bacteroidetes* human-gene biomarkers were detected in 6 of 15 sampling months indicating recent human fecal pollution in SB Fishweir Creek
  - Human fecal pollution in SB Big Fishweir Creek seems to appear for up to several days following significant rainfall (greater than 0.5 inches)
Fecal Coliform Bacteria
Fishing Creek

PRE-SEWERED
Wesconnett Blvd.
110th St.

POST-SEWERED
Wesconnett Blvd.
110th St.

EXPLANATION
SCHEMATIC BOXPLOT

24 number of values
○ upper detached
x upper outside

17 ○ 15 ○

75th percentile
median
25th percentile

x lower outside
○ lower detached

Note: Boxes with same colors are not statistically different after de-trending for stream discharge.

FL Class III Waters Classification
Fecal Coliform Bacteria
South Branch Big Fishweir Creek

FECAL COLIFORM BACTERIA, IN COLONIES PER 100 MILLILITERS

PRE-SEWERED  POST-SEWERED

Yerkes St. Yerkes St.

EXPLANATION SCHEMATIC BOXPLOT

30 number of values
○ upper detached
x upper outside
75th percentile
median
25th percentile
x lower outside
○ lower detached

Note: Boxes with same colors are not statistically different after de-trending for stream discharge.

FL Class III Waters Classification

FLGS science for a changing world
## Estimates of Ground-Water Flow Travel Times

### Average Linear Pore-Water Velocity

<table>
<thead>
<tr>
<th>For:</th>
<th>Closest Septic (within 100 ft of trib; dry conditions)</th>
<th>Best Estimate (not considering attenuating factors e.g., adsorption or degradation)</th>
<th>Using doubled values of porosity and conductance</th>
<th>Best Estimate:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L ft</td>
<td>100 100 100 100</td>
<td>100 100 100 100</td>
<td>100 100 100 100</td>
<td></td>
</tr>
<tr>
<td>ΔH ft</td>
<td>0.1 0.1 0.1 0.1</td>
<td>0.1 0.1 0.1 0.1</td>
<td>0.1 0.1 0.1 0.1</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>0.1 0.1 0.1 0.1</td>
<td>0.2 0.2 0.2 0.4</td>
<td>0.2 0.2 0.4 0.4</td>
<td></td>
</tr>
<tr>
<td>K [ft/d]</td>
<td>1 1 10 10</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
<td></td>
</tr>
</tbody>
</table>

Values of n from "Soil Survey of the City of Jacksonville, Duval County, Florida" by USGS 1990; reprinted as liquid limit in Table 16, ranged 0-45%.

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>t [yr]</td>
<td>24000 48000</td>
<td>24000 48000</td>
<td>24000 48000</td>
<td>24000 48000</td>
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<tr>
<td>t [yr]</td>
<td>27.37850787</td>
<td>54.757022</td>
<td>27.37850787</td>
<td>54.757022</td>
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<tr>
<td>t [m]</td>
<td>144000000</td>
<td>288000000</td>
<td>144000000</td>
<td>288000000</td>
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</tbody>
</table>

**For: Closest Septic (within 100 ft of trib; wet conditions)**

<table>
<thead>
<tr>
<th>L ft</th>
<th>100 100 100 100</th>
<th>100 100 100 100</th>
<th>100 100 100 100</th>
<th>100 100 100 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH ft</td>
<td>4</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>n</td>
<td>0.1</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>K [ft/d]</td>
<td>1 1 10 10</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t [d]</th>
<th>200 400 20 40</th>
<th>5 10 2.5 5</th>
<th>20 10 40 20</th>
<th>10-40 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>t [yr]</td>
<td>4800 9600 4800 9600</td>
<td>240 480 240 480</td>
<td>240 480 240 480</td>
<td></td>
</tr>
<tr>
<td>t [yr]</td>
<td>0.647501157 1.09514 0.045757 0.106514</td>
<td>0.045757 0.027379 0.106514 0.045757</td>
<td></td>
<td></td>
</tr>
<tr>
<td>t [m]</td>
<td>288000 576000 288000 576000</td>
<td>288000 576000 288000 576000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**For: Farthest Septic (1,500 ft from trib; dry conditions)**

<table>
<thead>
<tr>
<th>L ft</th>
<th>1500 1500 1500 1500</th>
<th>1500 1500 1500 1500</th>
<th>1500 1500 1500 1500</th>
<th>1500 1500 1500 1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH ft</td>
<td>4 6 6 6</td>
<td>6 5 5 5</td>
<td>6 5 5 5</td>
<td>6 5 5 5</td>
</tr>
<tr>
<td>n</td>
<td>0.1 0.2 0.1 0.2</td>
<td>0.2 0.2 0.4 0.4</td>
<td>0.2 0.2 0.4 0.4</td>
<td>0.2 0.2 0.4 0.4</td>
</tr>
<tr>
<td>K [ft/d]</td>
<td>1 1 10 10</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t [d]</th>
<th>20000 40000 20000 40000</th>
<th>10 15 15 15</th>
<th>5 10 2.5 5</th>
<th>10-40 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>t [yr]</td>
<td>10600000 21000000 10600000 21000000</td>
<td>10600000 21000000</td>
<td>10600000 21000000</td>
<td></td>
</tr>
<tr>
<td>t [yr]</td>
<td>122 240 12 25</td>
<td>12.25 years</td>
<td>7.5 15 15 15</td>
<td>12.25 years</td>
</tr>
<tr>
<td>t [m]</td>
<td>64800000 1.3E+08 64800000 1.3E+08</td>
<td>64800000 1.3E+08</td>
<td>64800000 1.3E+08</td>
<td></td>
</tr>
<tr>
<td>t [m]</td>
<td>1500 1500 1500 1500</td>
<td>1500 1500 1500 1500</td>
<td>1500 1500 1500 1500</td>
<td></td>
</tr>
</tbody>
</table>

**For: Farthest Septic (1,500 ft from trib; wet conditions)**

<table>
<thead>
<tr>
<th>L ft</th>
<th>1500 1500 1500 1500</th>
<th>1500 1500 1500 1500</th>
<th>1500 1500 1500 1500</th>
<th>1500 1500 1500 1500</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔH ft</td>
<td>4 6 6 6</td>
<td>6 5 5 5</td>
<td>6 5 5 5</td>
<td>6 5 5 5</td>
</tr>
<tr>
<td>n</td>
<td>0.1 0.2 0.1 0.2</td>
<td>0.2 0.2 0.4 0.4</td>
<td>0.2 0.2 0.4 0.4</td>
<td>0.2 0.2 0.4 0.4</td>
</tr>
<tr>
<td>K [ft/d]</td>
<td>1 1 10 10</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
<td>20 40 20 40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>t [d]</th>
<th>15000 30000 15000 30000</th>
<th>15000 30000 15000 30000</th>
<th>15000 30000 15000 30000</th>
<th>15000 30000 15000 30000</th>
</tr>
</thead>
<tbody>
<tr>
<td>t [yr]</td>
<td>360000 720000 360000 720000</td>
<td>360000 720000 360000 720000</td>
<td>360000 720000 360000 720000</td>
<td></td>
</tr>
<tr>
<td>t [yr]</td>
<td>20 40 8 5.5</td>
<td>40 years 8 years 5.5 8</td>
<td>40 years 8 years 5.5 8</td>
<td>40 years 8 years 5.5 8</td>
</tr>
<tr>
<td>t [m]</td>
<td>21600000 43200000 21600000 43200000</td>
<td>21600000 43200000 21600000 43200000</td>
<td>21600000 43200000 21600000 43200000</td>
<td></td>
</tr>
<tr>
<td>t [m]</td>
<td>20 40 8 5.5</td>
<td>40 years 8 years 5.5 8</td>
<td>40 years 8 years 5.5 8</td>
<td>40 years 8 years 5.5 8</td>
</tr>
</tbody>
</table>

**Median Travel Time for 100 ft:**

- 3.7 years

**Median Travel Time for 1,000 ft:**

- 8.2 years
USGS Online Reports

- [http://fl.water.usgs.gov/publications/online/online.html](http://fl.water.usgs.gov/publications/online/online.html)
- Wicklein, Shaun M., 2004, WRIR 03-4299