Best Management Practices for Pathogen Control

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BMP MASS BALANCE

INPUT 1
(direct deposition - wildlife)

INPUT 2
(Influent)
Storm Water
(load from wildlife, pets, SSOs, Septic Systems, etc.)

BMP Processes
Settling/Sedimentation
UV Radiation
Competition/Predation
Filtration/Infiltration
Temperature
Storm Volume Reduction
Reduction of Nutrients

OUTPUT
(Effluent)
Discharge to Rivers, Creeks, Bayous, Lakes, etc.)
# Bacteria Removal Efficiencies of BMPs from Literature

<table>
<thead>
<tr>
<th>BMP Tested</th>
<th>Percent Removal</th>
<th>No of BMPs Tested</th>
<th>Total Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Basin</td>
<td>90</td>
<td>1</td>
<td>N/R</td>
</tr>
<tr>
<td>Grassy Swale</td>
<td>-338</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Vegetative Filter Strips</td>
<td>32</td>
<td>18</td>
<td>N/R</td>
</tr>
<tr>
<td>Wet Basin</td>
<td>47</td>
<td>11</td>
<td>222</td>
</tr>
<tr>
<td>Wetland</td>
<td>88</td>
<td>82</td>
<td>981</td>
</tr>
</tbody>
</table>

N/R – Not Reported
BMPs in Harris County and City of Houston

Legend
- Wetland
- 10/100 Yr Basin
- Dry Basin
- Dyr/Wet Combination
- Grassy Swales
- Vegetation Filter Strips
- Wet Basin

Note: Map colors designate watershed boundaries
<table>
<thead>
<tr>
<th>AGENCY</th>
<th>BEST MANAGEMENT PRACTICE (BMP)</th>
<th>COUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harris County</td>
<td>Dry Basin</td>
<td>286</td>
</tr>
<tr>
<td></td>
<td>Wet Basin</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Flood Control/Water Quality Basin</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Wetland</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grass Swale</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Vegetative Filter Strips</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>186</td>
</tr>
<tr>
<td>City of Houston</td>
<td>Dry Basin</td>
<td>166</td>
</tr>
<tr>
<td></td>
<td>Wet Basin</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Flood Control/Water Quality Basin</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Grass Swale</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Vegetative Filter Strips</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Road sweeping &amp; minimization plans for street maintenance yards</td>
<td>75% of yards</td>
</tr>
<tr>
<td></td>
<td>Prevent Illicit discharges and Improper disposal</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Industrial and high risk runoff</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Wet screening of area served by the MS4</td>
<td>50% of total area</td>
</tr>
<tr>
<td></td>
<td>Manhole cleaning, storm sewer cleaning/flushing, repairs and investigations</td>
<td>N/R</td>
</tr>
</tbody>
</table>
## Permitted BMPs

<table>
<thead>
<tr>
<th>AGENCY</th>
<th>BEST MANAGEMENT PRACTICES (BMPs)</th>
<th>COUNT</th>
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</thead>
<tbody>
<tr>
<td><strong>Harris County Flood Control District (HCFCFD)</strong></td>
<td>Wet basins</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Detention basins</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Vegetation/Stabilization of Drainageways</td>
<td>&gt;50 miles of drainageways</td>
</tr>
<tr>
<td></td>
<td>Wet Pond Extended Retrofit Sampling</td>
<td>If Deemed Necessary</td>
</tr>
<tr>
<td></td>
<td>Inlet Basket to Surge Basin</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Maintenance of detention basins and drainage channels</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Monitoring of BMPs for Water Quality</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Trash Skimmer (Boat)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Netting overlay (at White Oak Bayou Basin Outfall)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Natural trash trap</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Planted Gabion Wall</td>
<td>1</td>
</tr>
<tr>
<td><strong>Texas Department of Transportation (TxDOT)</strong></td>
<td>Detention ponds</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Pump stations</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Grassy swales</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Vegetative filter strips</td>
<td>N/R</td>
</tr>
<tr>
<td></td>
<td>Public Education Programs (Don’t Mess W Texas, Adopt-A-Highway, etc.)</td>
<td>N/R</td>
</tr>
<tr>
<td><strong>Joint Task Force</strong></td>
<td>Public Education Program</td>
<td>N/R</td>
</tr>
</tbody>
</table>

N/R – Not Reported
BMPs Studied

- Dry Ponds 2006-07
- Wet Ponds
- Water Quality Basins 2007-08
- Swales
Dry and Wet Basins

- Structural BMPs
- Encourage sedimentation
- Increase exposure to other natural processes
- High reduction potential in literature BMP studies

In the Houston Metropolitan Area:
- Dry Basins 476 / 10,638 acres
- Wet Basins 70 / 3,695 acres
Dry Basins

Average literature value for bacteria reduction:
90% (with filter)
Wet Basins

Average literature value for bacteria reduction: 47% (Range: 3% to 98%)
Two Dry and Two Wet Basins were selected based on JTF requirements, implementation and maintenance.

Water samples were collected during five runoff events.

Efficiencies calculated for each event at each basin.

Their effectiveness studied using the Buffalo Bayou HSPF model.

Stream reductions were calculated for different scenarios using HSPF.
BMP Efficiency and Effectiveness

• Efficiency
  – Comparison of outlet to inlet concentrations of pathogen indicator
  – Function of individual BMP design/maintenance
  – Function of storm events
  – Pool concentrations studied but not factored into efficiency calculations

• Effectiveness
  – Impact on in-stream flows and concentrations
  – Function of location within watershed
  – Function of individual BMP design
  – Influenced by other BMPs in watershed
Dry Basin Site One

- Conventional Detention Basin
- Selected because of design, variation from DB2, proximity, access, and stabilization
Dry Basin Site Two

- Extended Detention Basin
- Selected because of design, maintenance and stabilization
DB1 Efficiency

Event Efficiency: -1858%

Event Efficiency: -33.5%
DB2 Efficiency

Event Efficiency: 67.2%

Event Efficiency: 72.4%
Issues with Dry Basins & Why Poor Performance at DB1?
Pool Formation at DB1 and DB2

The graphs illustrate the depth changes over time for events at DB1 and DB2. The data shows a noticeable increase in depth followed by a decrease over the specified dates.

- DB1-Event 1: A significant rise in depth is observed from 5/30/06 to 6/2/06, peaking around 6/2/06, and then a gradual decrease until 6/20/06.
- DB1-Event 2: A more gradual increase in depth is seen from 6/19/06 to 6/20/06, with a slight fluctuation before a steady decrease.
- DB2-Event 1: A sharp rise in depth can be seen from 5/30/06 to 6/2/06, peaking around 6/2/06, and then a gradual decrease until 6/20/06.
- DB2-Event 2: A less pronounced increase in depth is observed from 6/19/06 to 6/20/06, followed by a decrease.

The photos on the right depict the physical aspects of the pool formation at DB1 and DB2.
Resuspension

DB1, Event 1

Graph showing turbidity changes over time:
- Inflow: Blue line
- Pool: Red line

DB1, Event 2

Graph showing turbidity changes over time:
- Inflow: Blue line
- Pool: Red line

DB2, Event 2

Graph showing turbidity changes over time:
- Inflow: Blue line
- Pool: Red line
- Outflow: Green line
To Increase Efficiency

- Improve maintenance procedures
- Increase and ensure complete stabilization by vegetation
- Increase discharge period
- Reduce initial discharge

<table>
<thead>
<tr>
<th>Detention Basin No.</th>
<th>Event</th>
<th>None</th>
<th>Day One</th>
<th>Day Two</th>
<th>Day Three</th>
<th>Day Four</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>-1858%</td>
<td>-806%</td>
<td>-426%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>-34%</td>
<td>64%</td>
<td>66%</td>
<td>74%</td>
<td>82%</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>67%</td>
<td>70%</td>
<td>79%</td>
<td>83%</td>
<td>86%</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>72%</td>
<td>74%</td>
<td>78%</td>
<td>90%</td>
<td>94%</td>
</tr>
</tbody>
</table>
Wet Basin Site One

- Well maintained and stabilized retention pond
- Distinct/separate sediment forebay
- Two fountains: One at forebay and one in permanent pool
- Residential drainage area
Wet Basin Site Two

- Large, well maintained and stabilized retention pond
- No sediment forebay
- During reconnaissance and runoff event 1, no fountain
- Residential drainage area
Event 1

Event Efficiency: 99.5%

Event 5

Event Efficiency: 97.3%
**WB2 Efficiency**

**Event Efficiency:**
- Event 4 Efficiency: 98.8%
- Event 3 Efficiency: 99.9%
- Event 5 Efficiency: 96.5%

![Graphs showing concentration over time for different events with labels](image)
Die-Off Study

- Understand fecal pathogen survival/regrowth in basins.
- Mortality rate of $1.69 \log_{10} \text{CFU} \times 100 \text{ml}^{-1} \times \text{day}^{-1}$ measured ($r^2$ of 0.93)
Buffalo Bayou HSPF Modeling to Evaluate Effectiveness

- HSPF Water quality model simulates the transport of contaminants from watershed to stream
- Hydrologic and water quality processes defined for pervious and impervious land and for in-stream processes
- Buffalo Bayou TMDL model modified to include BMPs
- BMP module added to incorporate reductions
- To simulate hydrologic changes caused by water quality basins, reach/reservoir segments added
- Observed flow rates and efficiencies used as model input
Vegetative Filter Strip Effectiveness

Stream *E. coli* concentrations With No Detention and 50% Removal

**E. coli** standard: 126 MPN/100mL
Wet Basin Effectiveness

Stream *E. coli* concentrations with 7 Day Detention and 50% Removal
Wetland Effectiveness

Stream *E. coli* concentrations with 7 Day Detention and 90% Removal
## Use of Inline BMPs to Treat SSOs

### Percent of Days that Exceed the Bacteria Standard (126MPN/100mL)

<table>
<thead>
<tr>
<th>Subbasin</th>
<th>Efficiency</th>
<th>Normal discharge</th>
<th>2 Day Detention</th>
<th>7 Day Detention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sbsn 26</td>
<td>0% reduction</td>
<td>29%</td>
<td>29%</td>
<td>24%</td>
</tr>
<tr>
<td>Sbsn 26</td>
<td>50% reduction</td>
<td>15%</td>
<td>26%</td>
<td>21%</td>
</tr>
<tr>
<td>Sbsn 26</td>
<td>90% reduction</td>
<td>10%</td>
<td>16%</td>
<td>7%</td>
</tr>
<tr>
<td>Sbsn 27</td>
<td>0% reduction</td>
<td>45%</td>
<td>15%</td>
<td>29%</td>
</tr>
<tr>
<td>Sbsn 27</td>
<td>50% reduction</td>
<td>33%</td>
<td>33%</td>
<td>18%</td>
</tr>
<tr>
<td>Sbsn 27</td>
<td>90% reduction</td>
<td>7%</td>
<td>7%</td>
<td>2%</td>
</tr>
</tbody>
</table>

### The Geometric Mean at Subbasins 26 and 27

<table>
<thead>
<tr>
<th>Subbasin</th>
<th>Efficiency</th>
<th>Normal discharge</th>
<th>48 hour detention</th>
<th>7 day detention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sbsn 26</td>
<td>0% reduction</td>
<td>11</td>
<td>28</td>
<td>19</td>
</tr>
<tr>
<td>Sbsn 26</td>
<td>50% reduction</td>
<td>10</td>
<td>22</td>
<td>15</td>
</tr>
<tr>
<td>Sbsn 26</td>
<td>90% reduction</td>
<td>7</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>Sbsn 27</td>
<td>0% reduction</td>
<td>51</td>
<td>52</td>
<td>23</td>
</tr>
<tr>
<td>Sbsn 27</td>
<td>50% reduction</td>
<td>30</td>
<td>30</td>
<td>14</td>
</tr>
<tr>
<td>Sbsn 27</td>
<td>90% reduction</td>
<td>9</td>
<td>9</td>
<td>5</td>
</tr>
</tbody>
</table>
Basin Modeling Scenarios

• Numerous model runs developed to test the effects of basins on stream water quality

• Two sets of analyses were performed:
  – Set 1:
    • type of basin (dry vs. wet)
    • number of basins implemented
    • type of drainage area (pervious vs. impervious)
    • efficiency of basin
  – Set 2:
    • locations of basins
    • type of basin and discharge rate
Effect of Basins on Runoff

No Basins

5% Efficiency; 10% Effectiveness

98% Efficiency; 52% Effectiveness

Standard = 126 MPN/100ml
Effectiveness Versus Basin Type

Effectiveness in Subbasin 27

- Dry Basin (All Impervious-61%)
- Wet Basin (All Impervious-61%)

Effectiveness on Subbasin 119

- Wet Basin (All Impervious-7%)
- Dry Basin (All Impervious-7%)
Effectiveness Versus Number of Basins

**Subbasin 27**
- Wet Basin (10%)
- Wet Basin (50%)

**Subbasin 119**
- Dry Basin (10%)
- Dry Basin (50%)
Pervious or Impervious

Effectiveness in Subbasin 27

- Wet Basin (50%)
- Wet Basin (All Impervious-61%)

Effectiveness in Subbasin 119

- Dry Basin (50%)
- Dry Basin (All Impervious-7%)
Effectiveness Versus Efficiency

- **Wet Basin (All Impervious-61%)**
  - Effectiveness in Subbasin 27
  - Efficiency

- **Dry Basin (All Impervious-7%)**
  - Effectiveness on Subbasin 119
  - Efficiency
How Often Is the Standard Met?

Single Sample Limit – 394 MPN/100ml
Locations for HSPF Analysis - Set Two

Legend
- Dry/Wet Basin Group A
- Dry/Wet Basin Group B
- Dry/Wet Basin Group C
- No Basins
- HSPF Monitoring Locations

Note: Map colors designate watershed boundaries.
## Location and Basin Type

<table>
<thead>
<tr>
<th>Group</th>
<th>Downstream Average</th>
<th>Midstream Average</th>
<th>Upstream Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>B</td>
<td>11%</td>
<td>38%</td>
<td>0%</td>
</tr>
<tr>
<td>C</td>
<td>7%</td>
<td>26%</td>
<td>92%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basin</th>
<th>Downstream Average</th>
<th>Midstream Average</th>
<th>Upstream Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB</td>
<td>15%</td>
<td>21%</td>
<td>30%</td>
</tr>
<tr>
<td>DB2</td>
<td>15%</td>
<td>20%</td>
<td>30%</td>
</tr>
<tr>
<td>WB</td>
<td>20%</td>
<td>24%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Values for most effective scenarios highlighted

1 DB – detention basin
   DB2 – detention basin with twice observed discharge rate
   WB – wet basin

2 Group refers to the location of the water quality basins
Summary for Wet & Dry Basins

- Wet basins efficiencies from 95% to 99%
- Dry basins efficiencies ranged from 67% to 72% for extended detention and -34% to -1858% for conventional basin
- Implementation/Stabilization and temporal variation in Dry Basins have important effects on efficiency
- Effectiveness depends upon type, number, location, drainage area (pervious and impervious), and efficiency
- Due to the extension of the hydrograph, basins may worsen water quality when not performing efficiently
- Greatest water quality benefit for impervious regions
Location of FCM/WQ Basin

A Map of Rain Gages and Flood Control/Water Quality Basin
FCWQ Basin

Outlet Structure

Interconnecting Concrete Channel
**E. coli** concentrations during 4 events

**E. coli Concentrations at FC/WQ**

**Event 1 – Sept 07**

- Inlet/Manhole: 5651, 340, 489
- Basin 1 Outlet: 250
- Basin 2 Outlet: 47

*0.28 in RF: 97% decline*

**E Coli Concentrations in FCWQ in Event 2**

- Inlet: 22, 14, 24, 37
- Pool: 47
- Outlet: 22

*0.63 in RF: - 20% decline*

**Event 4 lasted 1 day**

*Interrupted by Maintenance.*

**E Coli Concentrations in FCWQ in Event 3**

- Inlet: 47, 14, 24, 37
- Pool: 47
- Outlet: 22

*0.56 in RF: 20% decline*

**Background Event**
Studied Swale 1

31NS
Studied Swale 3
Studied Swale 4
## Swale Design Characteristics

<table>
<thead>
<tr>
<th>Grass Swale ID</th>
<th>Length (ft)</th>
<th>Average Channel Side Slope (%)</th>
<th>Vegetative Height(ft)</th>
<th>Drainage Area (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31 NS</td>
<td>510.1</td>
<td>3.1</td>
<td>5</td>
<td>1.3</td>
</tr>
<tr>
<td>47 SS</td>
<td>667.4</td>
<td>3</td>
<td>6</td>
<td>1.6</td>
</tr>
<tr>
<td>51 SS</td>
<td>226.7</td>
<td>2.7</td>
<td>4</td>
<td>0.6</td>
</tr>
<tr>
<td>42 SS</td>
<td>603.3</td>
<td>4.1</td>
<td>5</td>
<td>1.4</td>
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</table>
## Efficiencies of Grass Swales

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Rainfall (in)</th>
<th>31 NS</th>
<th>42 SS</th>
<th>47 SS</th>
<th>51 SS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event 1</td>
<td>June 19, 08</td>
<td></td>
<td>99%</td>
<td>99%</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Event 2</td>
<td>June 23, 08 – 0.83 in</td>
<td></td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
<td>98%</td>
</tr>
<tr>
<td>Event 3</td>
<td>June 26, 08 – 0.16 in</td>
<td></td>
<td>56%</td>
<td>56%</td>
<td>56%</td>
<td>56%</td>
</tr>
<tr>
<td>Event 4</td>
<td>July 24, 08 – 1.04 in</td>
<td></td>
<td></td>
<td>97%</td>
<td></td>
<td>97%</td>
</tr>
<tr>
<td>Event 5</td>
<td>Aug 15, 08 – 0.91 in</td>
<td></td>
<td></td>
<td></td>
<td>-1010%</td>
<td></td>
</tr>
<tr>
<td>Event 6</td>
<td>Aug 16, 08 – 0.35 in</td>
<td></td>
<td></td>
<td>93%</td>
<td>-3726%</td>
<td></td>
</tr>
<tr>
<td>Event 7</td>
<td>Aug 20, 08</td>
<td></td>
<td></td>
<td>-428%</td>
<td></td>
<td>38%</td>
</tr>
</tbody>
</table>
Summary FC/WQ & Swales

- Variable efficiencies
- Highly dependent on maintenance & vegetation
- Swale residence time may be too small for pathogen removal
- Effectiveness for in-stream concentration reduction unknown