Total Maximum Daily Load for Fecal Pathogens in Buffalo Bayou and Whiteoak Bayou

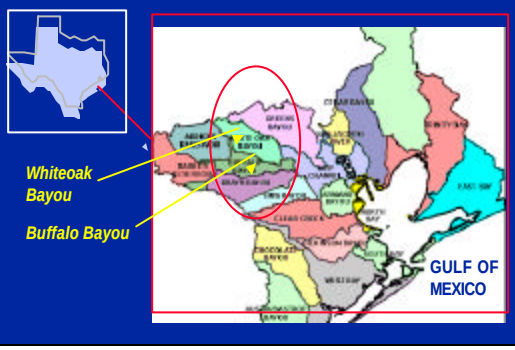
Technical Presentation at March 7,2002 Stakeholder Meeting

University of Houston
PBS&J

Major tasks

- Stakeholder/Public education and involvement
- Assess current levels and trends of bacterial indicators of fecal pathogens in the bayous
- Assess major sources, transport, and fate of bacterial indicators of fecal contamination
- Apply models to elucidate the sources and major processes controlling observed levels of FC
- TMDL allocation analysis

Buffalo and Whiteoak Bayous

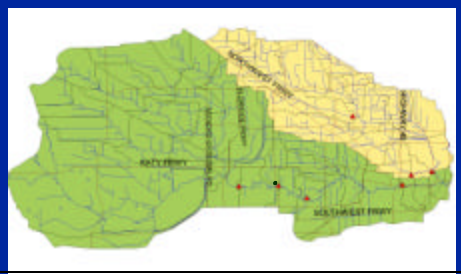


Assess current levels and trends of indicator bacteria in BB and WO

1. Assess bacteria levels resulting from moderate rainfall runoff events
2. Assess dynamics of bacteria within the bayous

Bacteria from rainfall runoff events

- Two runoff events: Aug 7-9 & Aug 28-30, 2001
- 4 BB stations, 2 WO locations, & 1 WO tributary



Rain and flow gage locations

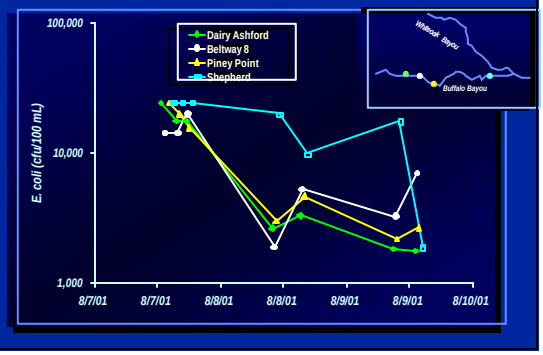
Daily rainfall data

	Date	RG15	RG30	RG31	RG34
Event 1	8/6/01	0.84	1.28	0.65	0.00
	8/7/01	0.11	0.00	0.02	0.28
	8/8/01	0.13	0.00	0.00	0.35
	8/9/01	0.05	0.00	0.00	0.00
Event 2	8/27/01	0.12	0.59	0.34	0.63
	8/28/01	0.16	1.74	0.39	0.51
	8/29/01	1.00	1.00	1.12	0.75
	8/30/01	1.36	1.12	1.09	1.76
	8/31/01	2.15	2.00	2.37	2.29

24 hr-rainfall data (inches)

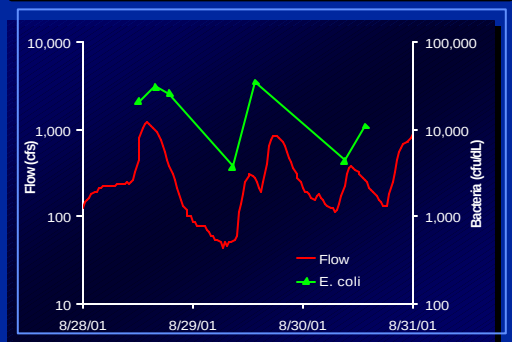
Relating City of Houston rain gages to sampling sites: RG15 (Cole Creek); RG30 (BB@Dairy Ashford); RG31 (BB@Beltway 8 & Piney Point); RG34 (BB@Shepherd and WO@Heights & Houston)

EC data in BB from 7-9 Aug, 2001 event

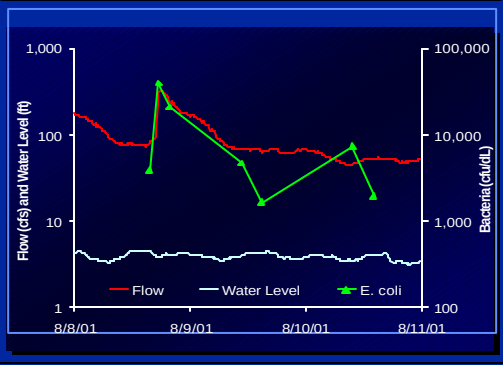


Runoff study – BB at Dairy Ashford

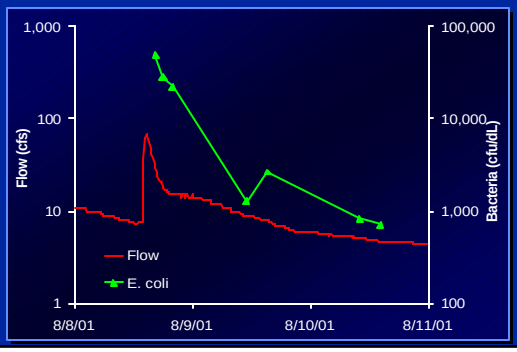
Runoff study – BB at Beltway 8



Runoff study – WO at Houston



Runoff study – Cole Creek at Deihl



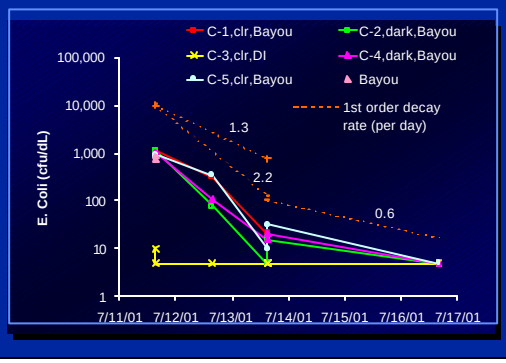
Dynamics studies

- Population change (light/dark chambers)
- Regrowth
- Resupply

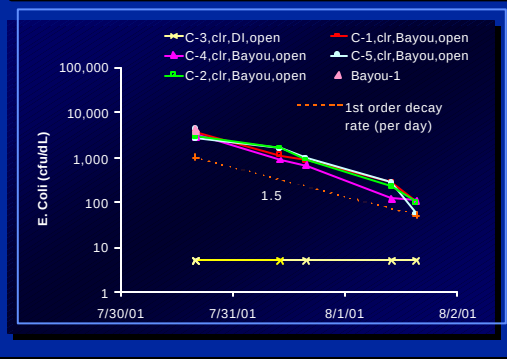
Light/dark dynamics results

	Initial EC (cfu/dL)	EC die-off rates (1/day) Covered clear	Covered dark	Open
BB – 7/11-16 (Beltway 8)	836-1145	1.3	2.2	
BB – 7/30-8/1 (Beltway 8)	2897-4082	1.4	1.4	1.5
WO – 8/1-3 (IH 610)	190-352	3.0	3.0	4.0
BB – 8/14-16 (Wilcrest)	426-565	1.6	1.6	
WO – 8/14-16 (IH 610)	379-452	1.6	1.6	

Light/dark effects, Buffalo Bayou



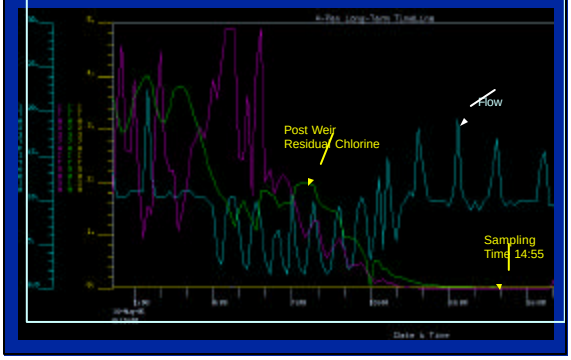
Light/dark Effects, BB, open chambers



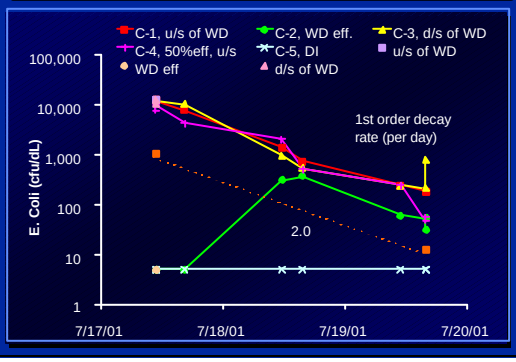
Regrowth results

WWTP	Initial EC (cfu/dL)	K (1/day)	EC regrowth
West District *(Buffalo B., 7/17-19/01)*	ND	2.0	yes
Turkey Creek *(Buffalo B., 7/17-19/01)*	ND	1.0	slight
Northwest *(Cole Creek, 7/24-26/01)*	5	1.4	yes
White Oak *(WO B., 7/17-19/01)*	15	1.4	neutral
West District *(Buffalo B., 8/14-16/01)*	19,863	0.9/4.5	no

West District WWTP on 8/14/01



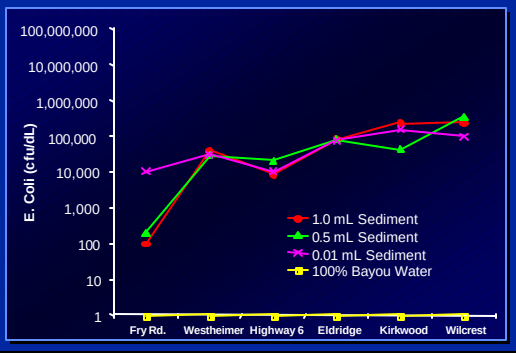
Regrowth – West District WWTP



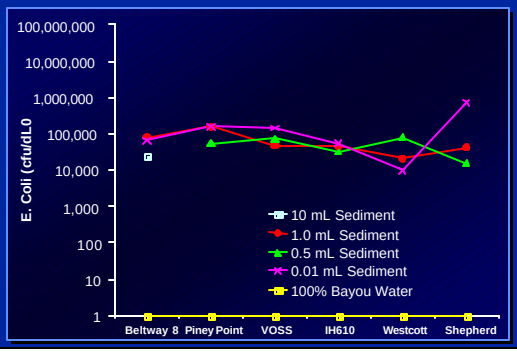
Sediment resupply

- Bacteria conc in sediments
- Resupply

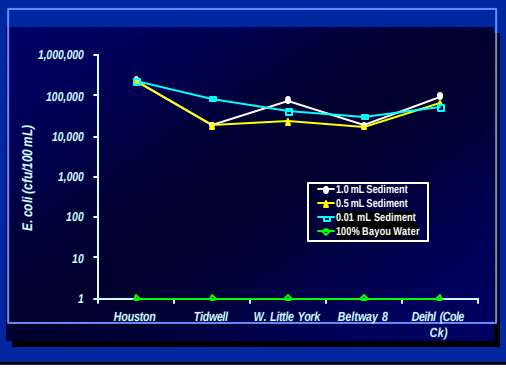
EC in BB sediments



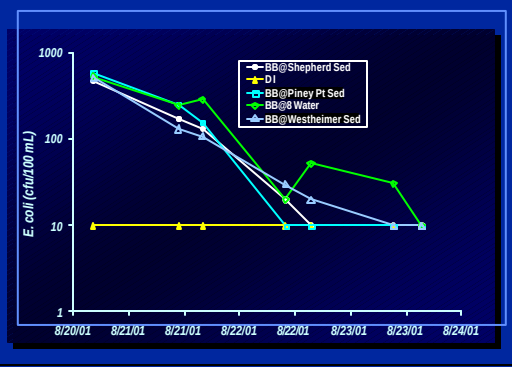
EC in BB sediments (cont'd)



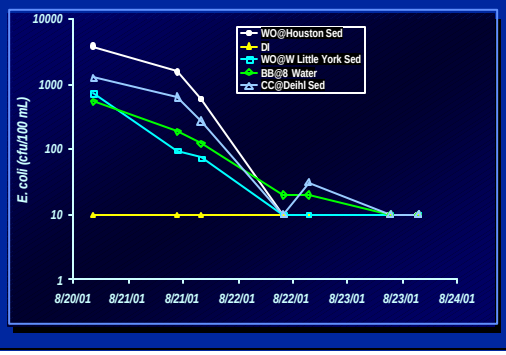
EC in WO sediments



BB sediment resupply



WO sediment resupply

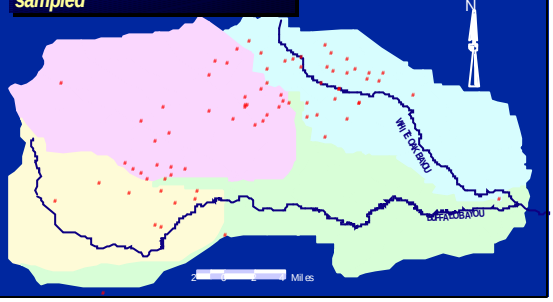


Assess major sources of bacteria in BB and WO

1. Sample point source discharges during low flow conditions
2. Monitor storm sewers discharging to bayous during dry weather conditions to assess potential illicit discharges

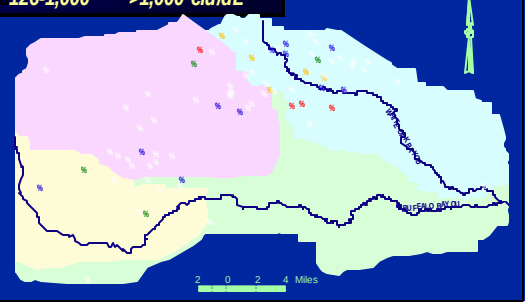
Point source sampling

A total of 76 WWTPs were sampled



EC data from point source sampling

< 10 10-50 50-126 126-1,000 >1,000 cfu/dL

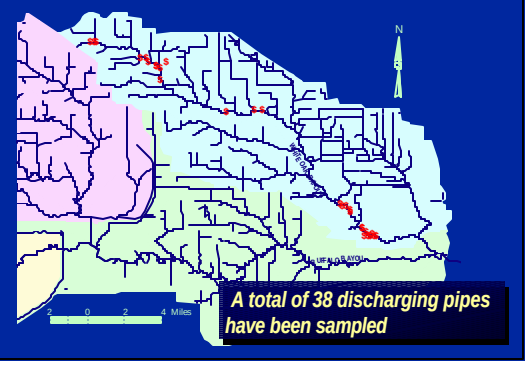


Summary of point source sampling

	All samples		Peak flow samples		Off-peak flow samples	
	EC	FC	EC	FC	EC	FC
Geomean	2.7	0.5	3.2	0.7	2.3	0.3
Range	0-2,347	0-5,000	0-2,347	0-5,000	0-759	0-150
% >std[1]	7.2%	2.0%	8.8%	3.8%	5.6%	0%

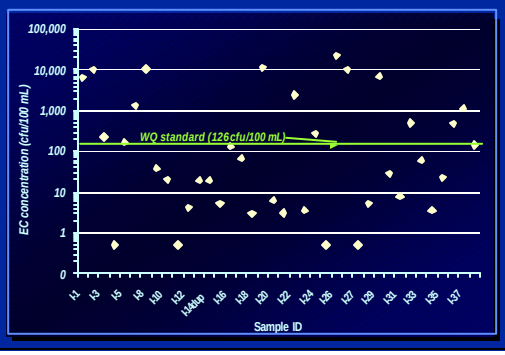
[1] regulatory limits: 126 cfu/dL for EC and 200 cfu/dL for FC
All the values given in cfu/dL

Storm sewer sampling



A total of 38 discharging pipes have been sampled

EC data from storm sewer sampling



Summary of storm sewer sampling

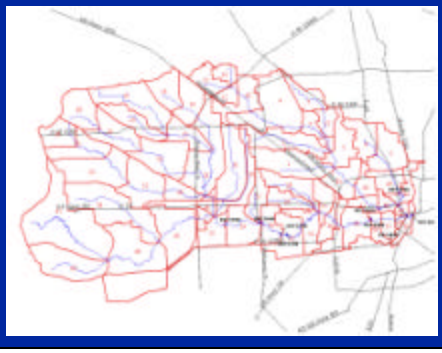
	EC (cfu/dL)	FC (cfu/dL)
Number samples	38	30
Geomean	73	16
Range	0-22,027	0-5,600
% Exceeding WQ criterion[1]	44.7%	26.7%

[1] regulatory limits: 126 cfu/dL for EC and 200 cfu/dL for FC

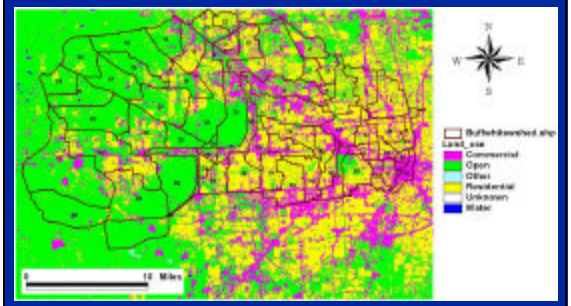
Modeling activities

1. Delineation of subwatersheds
2. Data preparation and compilation
3. Modeling calibration
4. Sensitivity analysis
5. Model runs ? load allocations

Subwatershed definition for modeling

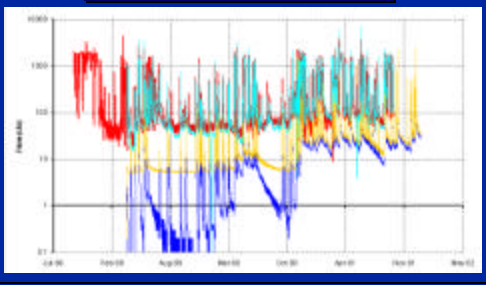


Compilation of input data



Preliminary model output - BB flow @ West Beltway

___ USGS Gage ___ HSPF no PS, no U/S
___ HSPF w/PS, no U/S ___ HSPF w/PS, w/U/S



Summary of Findings

Sources

- Point sources: 11 out of 76 plants exceeded EC criterion while 3 out of 76 exceeded FC limit
- Storm sewer sampling showed higher EC and FC levels than WWTP monitoring

Summary of Findings cont'd

Current levels

- Runoff exhibited high concentrations of EC
- Runoff concentrations appear to track with variations in flow

Summary of Findings cont'd

Dynamics

- High first-order die-off rates with no relation to light intensity
- Regrowth exists but may not be a major process
- Sediment resuspension when bayou flows increase may play significant role
- Quiescent conditions reduce EC levels rapidly

Future Tasks

- Complete HSPF modeling of bayou bacteria levels
- Apply the model to analyze alternatives
- Load allocations

Total Maximum Daily Load for Fecal Pathogens in Buffalo Bayou and Whiteoak Bayou

Technical Presentation at June 26,2002 Stakeholder Meeting

University of Houston
PBS&J

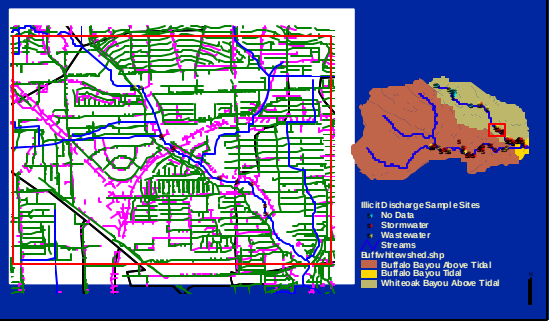
Major Tasks

- Stakeholder/Public education and involvement
- Assess current levels and trends of bacterial indicators of fecal pathogens in the bayous
- Assess major sources, transport, and fate of bacterial indicators of fecal contamination
- Apply models to elucidate the sources and major processes controlling observed levels of FC
- TMDL allocation analysis

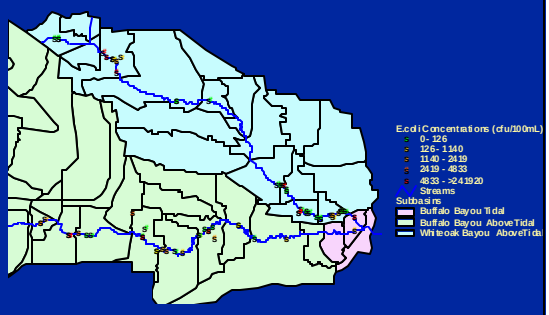
Progress to Date

- Quarterly Report completed and submitted – 6/11/02
- Storm sewer sampling mostly completed
- HSPF model developed for both bayous

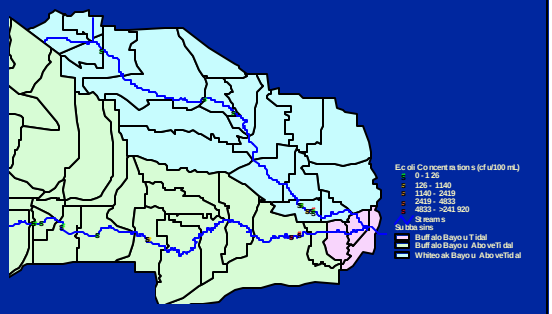
Storm and Wastewater Sewer Sampling Locations



EC concentrations in Storm Sewers



EC concentrations in Wastewater Sewers



Summary of Storm Sewer Sampling

	All samples		Wastewater Sewers		Stormwater Sewers	
	EC	FC	EC	FC	EC	FC
Geomean	161	62.9	191.2	30.8	153.8	76.5
Range	0-241,920	0-26,000	0-241,920	0-20,000	0-241,920	0-26,000
% >std[1]	52.9%	42.9%	55.6%	33.3%	58.2%	44.8%

[1] regulatory limits: 126 MPN/dL for EC and 200 cfu/dL for FC
EC values given in MPN/dL; FC values give in cfu/dL

Storm Sewer Sampling Summary by Watershed

	Buffalo Bayou		Whiteoak Bayou	
	EC	FC	EC	FC
Wastewater	73.9	18.9	408.9	45.3
Stormwater	261.1	307.9	100.1	23.9

EC values in MPN/dL; FC values in cfu/dL. Values presented are geometric means.

E. coli load for Point Source and Illicit Discharges

	Point Sources (MPN/yr)	Illicit Discharges (MPN/yr)
Buffalo Bayou	1.82E+12	7.89E+13
Whiteoak Bayou	5.83E+14	7.24E+13
Total	6.09E+14	2.31E+14

HSPF Modeling

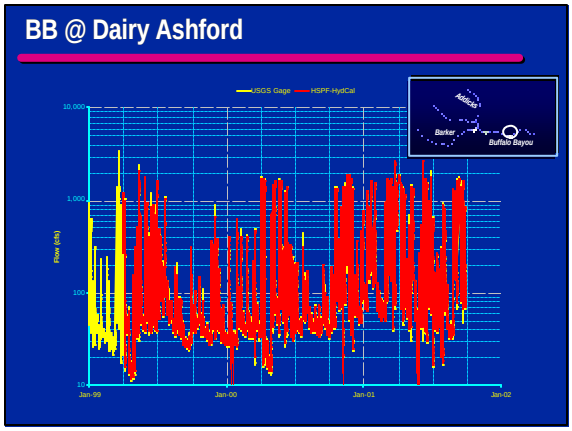
- Hydraulic calibration and sensitivity analysis completed for both Buffalo and Whiteoak Bayous
- Bacteria calibration and sensitivity analysis ongoing

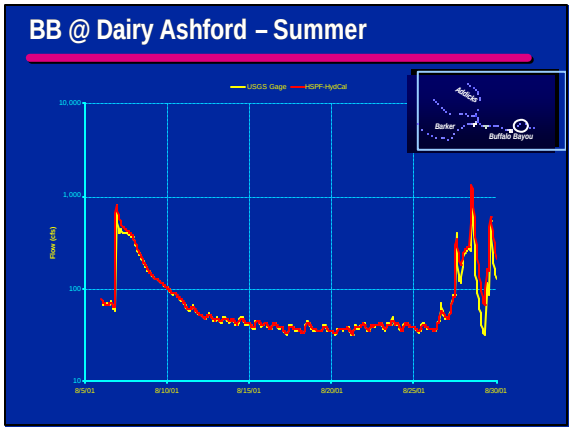
Hydraulic Calibration & Sensitivity Analysis

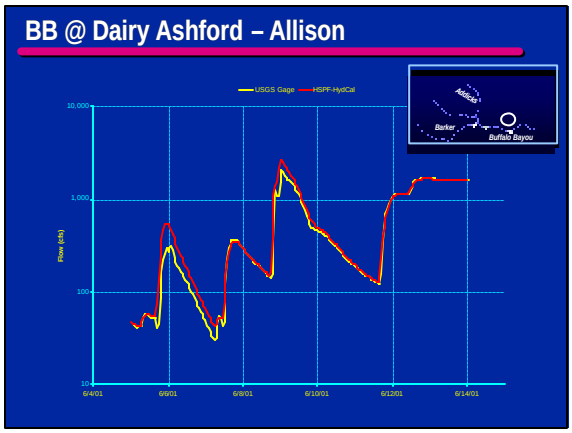
- Change hydraulic parameters one by one
- Calculate Root Mean Square difference between model output and USGS gaged flow data
- Calibration points: BB @ Dairy Ashford, West Belt, Piney Point and Shepherd; WO @ Heights; CC @ Deihl

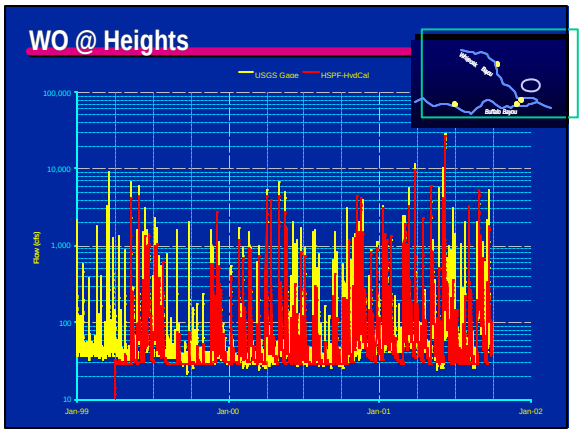
Hydraulic Calibration & Sensitivity Analysis (cont'd)

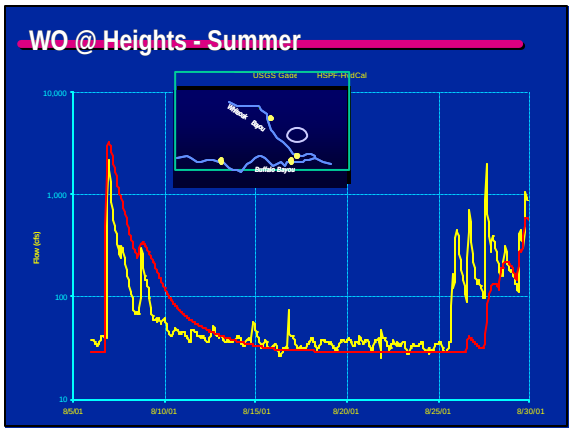
- "Best match" values (minimizing total RMS) of parameters within reasonable range selected
- Number of simulations conducted:
  - BB: 51; WO: 41


BB @ Dairy Ashford
USGS Gage
HSPF-HydCal
Flow (cfs)
10,000
1,000
100
10
Jan-99
Jan-00
Jan-01
Jan-02
Allison
Barker
Buffalo Bayou


BB @ Dairy Ashford – Summer
USGS Gage
HSPF-HydCal
Flow (cfs)
10,000
1,000
100
10
8/5/01
8/10/01
8/15/01
8/20/01
8/25/01
8/30/01
Allison
Barker
Buffalo Bayou


BB @ Dairy Ashford – Allison
USGS Gage
HSPF-HydCal
Flow (cfs)
10,000
1,000
100
10
6/4/01
6/6/01
6/8/01
6/10/01
6/12/01
6/14/01
Allison
Barker
Buffalo Bayou


WO @ Heights
USGS Gage
HSPF-HydCal
Flow (cfs)
100,000
10,000
1,000
100
10
Jan-99
Jan-00
Jan-01
Jan-02
Buffalo Bayou


WO @ Heights - Summer
USGS Gage
HSPF-HydCal
Flow (cfs)
10,000
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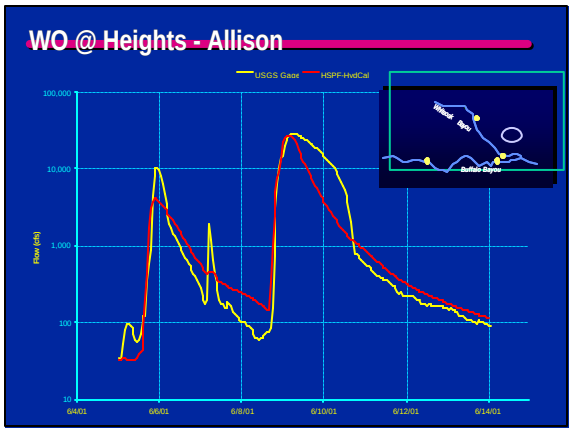
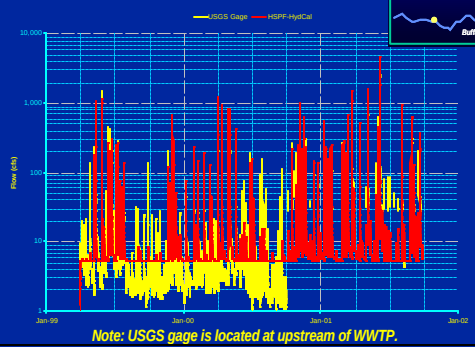
8/20/01
8/25/01
8/30/01
Buffalo Bayou

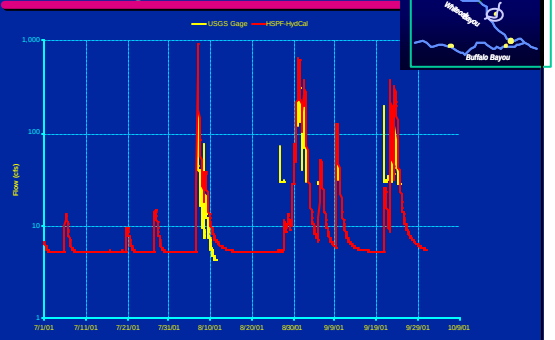

WO @ Heights - Allison
USGS Gage
HSPF-HydCal
Flow (cfs)
100,000
10,000
1,000
100
10
6/4/01
6/6/01
6/8/01
6/10/01
6/12/01
6/14/01
Buffalo Bayou

Cole Creek @ Deihl



Note: USGS gage is located at upstream of WWTP.

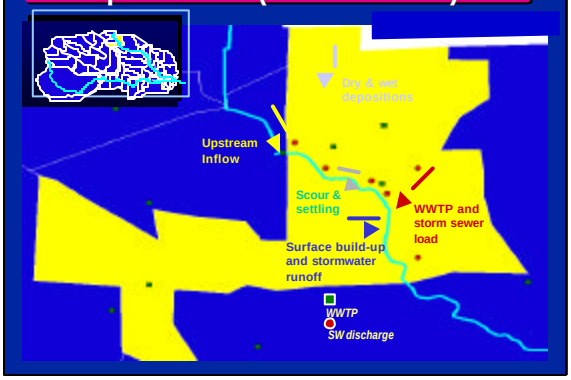
Cole Creek @ Deihl - Summer



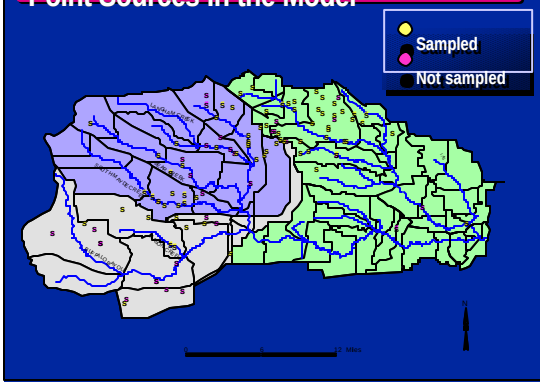
Bacteria Modeling

- Sources and sinks of bacteria
  - Point sources
  - Storm Sewers
  - Dry and wet deposition
  - Sediments (Scour, erosion and settling)
    Stormwater Runoff (Build-up & Wash-off)
  - Upstream inflows
- Fate and transport
  - Net decay (die-off minus regrowth)
- Calibration against historical data

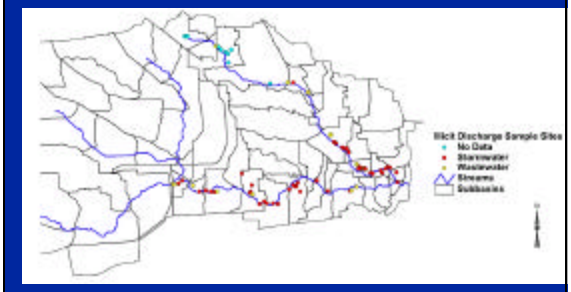
Conceptual Model (Subwatershed 10)



Point Sources in the Model



Illicit Discharge Data in the Model



WWTP and Storm Sewers

- WWTP Flow Data:
  - DMR data from 1995 to 2000 provided by TNRCC
  - Average flow for each WWTP
  - Total WWTP per subwatershed
- WWTP Effluent Concentrations (this project)
- Storm Sewer Flows & Conc (this project)
- Assign Average Values to Unsampled Subwatersheds
- Combine WWTP & Storm Sewer Values (Add flows, Calc flow-weighted concs)
- Assume Constant Over Time

Dry and Wet Deposition

- Sources:
  - Bird droppings
  - Pet wastes
  - Wastes of other animals
  - Other bacteria loadings on surface
- Modeled as Loading Rates
  - In cfu/acre/month
  - Subwatershed specific
  - Season specific
- Treated as calibration parameters

Sediment Source and Sink

- Sediment Simulations
  - Soil detachment from pervious lands
  - Atm Deposition of Sediment (lb/ac/d)
  - Build-up and wash-off
  - Scouring based on Shear Stress (lb/ft^2)
  - Settling based on particle size, density, settling velocity & shear stress (summer 01 data)
  - Bacteria adsorbed to sediment
  - Transfer rates (1/day) between adsorbed and desorbed states
  - Most are calibration parameters

Storm Water Runoff and Upstream Inflow

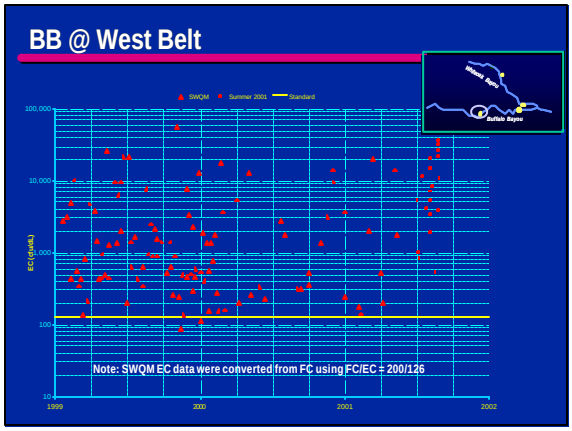
- Bacteria Buildup and Wash-off
  - Accumulation rate (cfu/ac/day)
  - Wash-off potency
  - Runoff rate for removing 90% of surface storage
- Inflow from Upstream Subwatershed
  - Flow
  - Dissolved Conc
  - Conc in Sediment

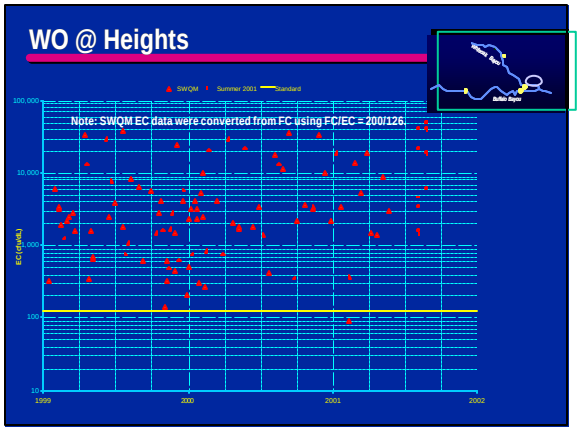
Fate and Transport

- First-Order Decay Rates
  - Decay in water
  - Decay in sediment
  - Based on Summer 01 data

Bacteria Calibration

- Compare output against historical data
- Buffalo Bayou:
  - R-45-BB@Shepherd
  - R-53-BB@VOSS
  - R-39-BB@West Belt
  - R-55-BB@Dairy Ashford
  - R-54-BB@Briar Forest
- White Oak Bayou:
  - R-41-WO@Height
  - R-2-CC@Bolivia
  - R-48-Little WO@WO Dr
- Assume FC/EC = 200/126


BB @ West Belt
SWQM
Summer 2001
Standard
100,000
10,000
1,000
100
10
EC(cfu/dL)
Note: SWQM EC data were converted from FC using FC/EC = 200/126
1999
2000
2001
2002
Mission Bay
Buffalo Bayou


WO @ Heights
SWQM
Summer 2001
Standard
100,000
10,000
1,000
100
10
EC(cfu/dL)
Note: SWQM EC data were converted from FC using FC/EC = 200/126
1999
2000
2001
2002
Mission Bay
Buffalo Bayou

Total Maximum Daily Load for Fecal Pathogens in Buffalo Bayou and Whiteoak Bayou

Responses to Comments from Last Meeting

University of Houston
PBS&J

Comment 1

RELATIONSHIP OF FERTILIZERS AND LEVELS OF BACTERIA IN THE BAYOUS

Comment 2

SOURCE TRACKING SHOWING SOURCES OF NON-HUMAN ORIGIN

Methods

- DNA
  - Polymerase Chain Reaction
  - Pulsed -field gel electrophoresis
  - Ribotyping
- BIOCHEMICAL
  - Antibiotic resistance
- CHEMICAL
  - Caffeine or optical brighteners

Active Efforts

- TAMU, TAMU-CC, UT ++
- USGS
- USDA
- Others

Key Points

- Most methods require large fingerprint database
- Utility of database appears to decrease with distance
- Full characterization of sources would be significant undertaking

Comment 3

CONTRIBUTION OF BACTERIA FROM SEDIMENT ON STREAM BANKS

Bank Sediments

- Heat-tolerant bacteria exist in natural environment, including soils, vegetation, etc.
- Collected two soil samples on 6/13/02 from Buffalo Bayou at West Belt from under and away from the bridge
- Samples analyzed by City of Houston PW&E WW Operation QC Lab

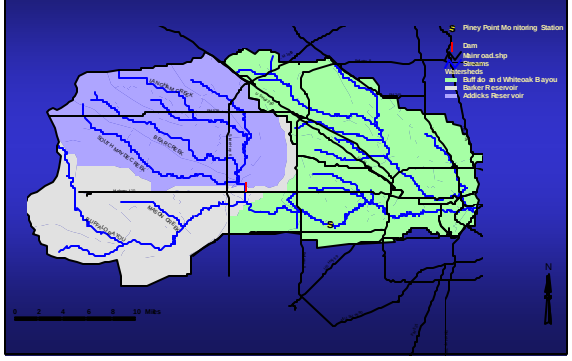
Bank Sediments (cont'd)

- Resulting FC Levels (MPN/g dry wt):
  - Under bridge: 760
  - Away from bridge: 820
- Assuming 80% moisture content and 2.63 g/cm ^{3} soil density, then
  - 800 MPN/g dry wt = 42,080 MPN/dL wet wt
- Within the range of results obtained last summer using bottom sediments (24,192 to 77,000 MPN/dL wet wt)

Comment 4

CONTRIBUTION FROM UPSTREAM OF BARKER AND ADDICKS

Barker and Addicks Reservoirs

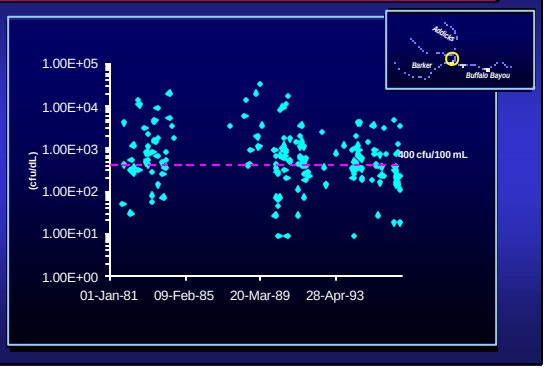


Reservoir Historical Data – USGS

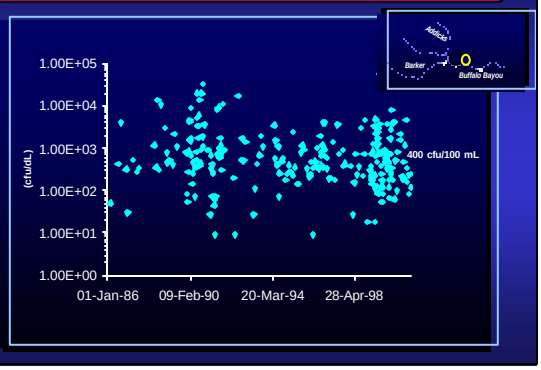
Reservoir	*Location*	*Mean FC (cfu/dL)*
Addicks	Tributaries	6307
	Reservoir	1090
	Discharge	737
Barker	Tributaries	3220
	Reservoir	763
	Discharge	663

Source: USGS WRI 86-4356, 1987. Samples collected from 1978-1981.

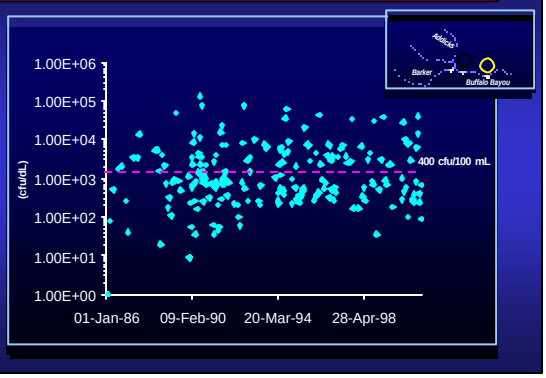
Time Series of FC Data at Barker Dam



Time Series of FC Data at Hwy 6



Time Series of FC Data at Dairy Ashford

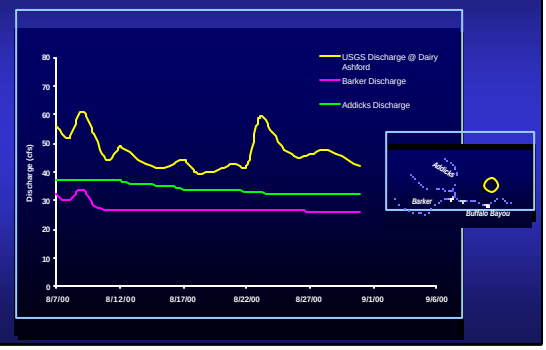


Downstream Monitoring Stations

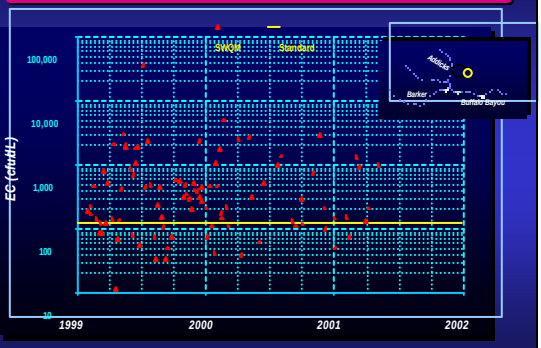
	Range	N	Geo Mean	% > Std [1]
Barker Dam	9 – 58,000	122	899	71%
Highway 6	9 – 58,000	232	579	59%
Dairy Ashford	9 – 130,000	185	1,263	72%

[1] regulatory limits: 400 cfu/dL for FC. All the values given as FC in cfu/dL. Data from 1990 onward.

Dry weather Reservoir and Dairy Ashford Hydrograph



BB @ State Highway 6



Note: SWQM EC data were converted from FC using FC/EC = 200/126.

Reservoir Summary

- Historically high levels of fecal coliform are observed within and downstream of the reservoirs
- Reservoirs are attenuating the bacteria levels
- During dry weather conditions, most of the upstream bayou flow originates from the reservoirs
- Reservoirs will be treated as a single input in the TMDL

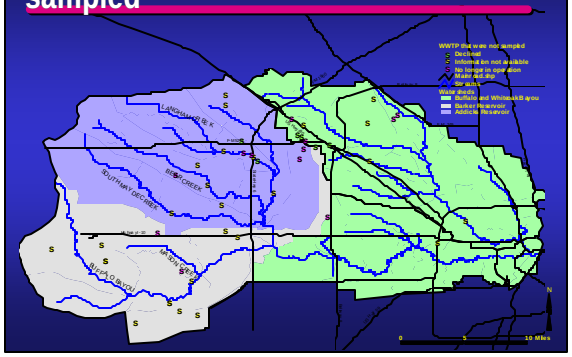
Comment 5

CONTRIBUTION OF 45 WWTPs NOT SAMPLED

Reasons that WWTPs were not sampled

	# of Plants
Facility no longer in operation	14
Request to collect samples was declined	6
Information from TNRCC database regarding location and/or operator incorrect or operator non-responsive.	25

Distribution of plants that were not sampled



Significance of unsampled WWTPs

- Geometric mean of *E. coli* at WWTPs is 3.4 cfu/100 mL
- For plants that we have not sampled, we will assign an EC value based on the flow-weighted geometric mean of the subwatershed
- Resources shifted to illicit discharge sampling

Comment 6

POSSIBLE MODIFICATIONS TO STANDARDS IN NEXT REVISIONS