Transport of Cryptosporidium, Giardia, Source- Specific Indicator Organisms and Standard Water Quality Constituents in Massachusetts Watersheds During Storm Events

Transport of *Cyrptosporidium*, *Giardia*, Source-specific Indicator Organisms and Standard Water Quality Parameters in Massachusetts Watersheds during Storm Events

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UMASS

Presentation Outline

- Overview of the project
- Description of the study sites
- Description of the collected data
- Presentation of select results
- Summary observations
- Acknowledgements

Project Overview

- **Multi-phase sampling and multi-partner analysis effort:**
  - Monthly sampling
  - Indicator baseflow sampling
  - Event sampling
  - Targeted sampling
  - Continuous monitoring
- **To isolate and determine load magnitude and timing by land use type:**
  - Agricultural
  - Residential/Comercial
  - Pristine Wildlife

Project Overview

Motivation:

- Need for compliance with the Surface Water Treatment Rule Amendments to the Safe Drinking Water Act
- Need for additional monitoring strategies and tools for effective watershed management.
- Concern over emerging pathogens
- Concern over storm event loadings

Project Overview

Objectives:

1. Determination of the relative magnitude and timing of specific wq parameters from various land-use areas.
2. Identification of meteorological, hydrologic, basin, and/or land use characteristics which effect in-stream concentrations of wq parameters, particularly pathogens and bacterial indicators.
3. Identification of the best sampling techniques & no. of samples for adequate characterization of loads during storm events within reasonable economic and technical constraints.
4. Determination of the viability of source-specific indicator organisms and/or other parameters to identify pollutant source-areas & magnitudes during baseflow and stormflow.
5. To provide information on first flush timing and along-stream transport.

Project Study Sites

Three Study Sites:

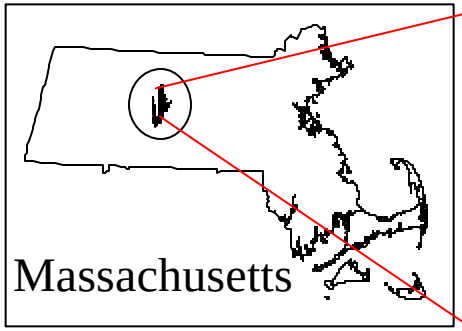
- Agricultural (Cow pasture)
- Residential/Commercial/Transportation
- Wildlife (Roaming wildlife vs beaver)

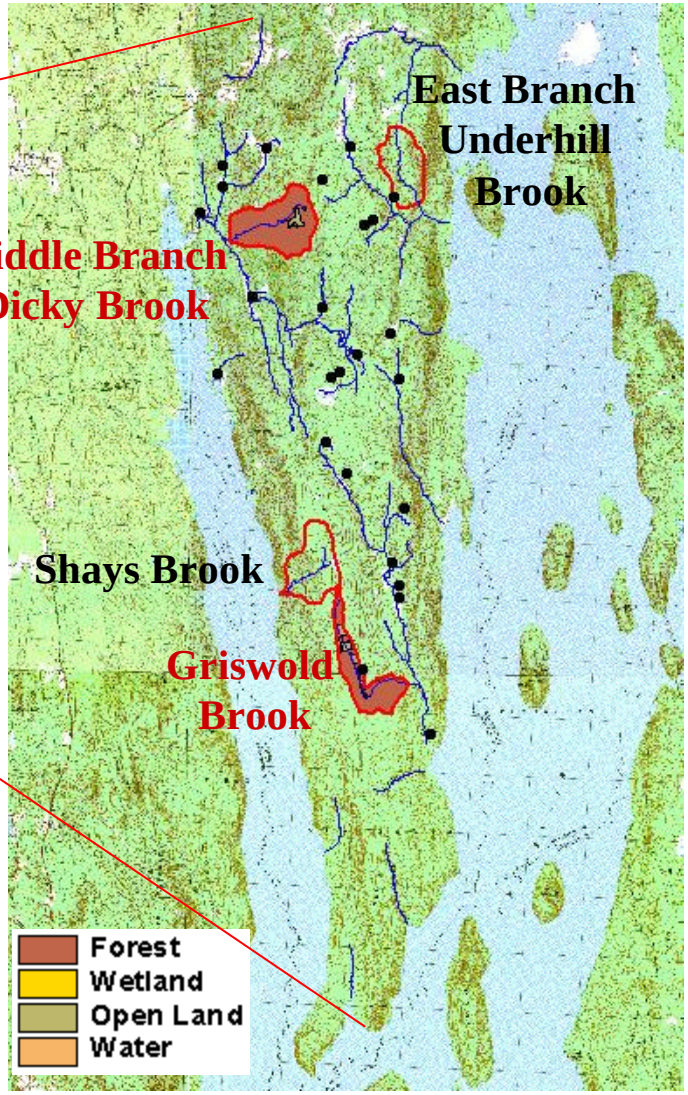
Site Design:

- Isolation of known or suspected pollution source
- Upstream/Downstream sampling at agricultural and residential sites
- Paired watershed sampling at wildlife site

Project Study Sites

➡ **WILDLIFE SITE –** The influence of beaver, a paired watershed study.





? Active beaver colony sites, 2000

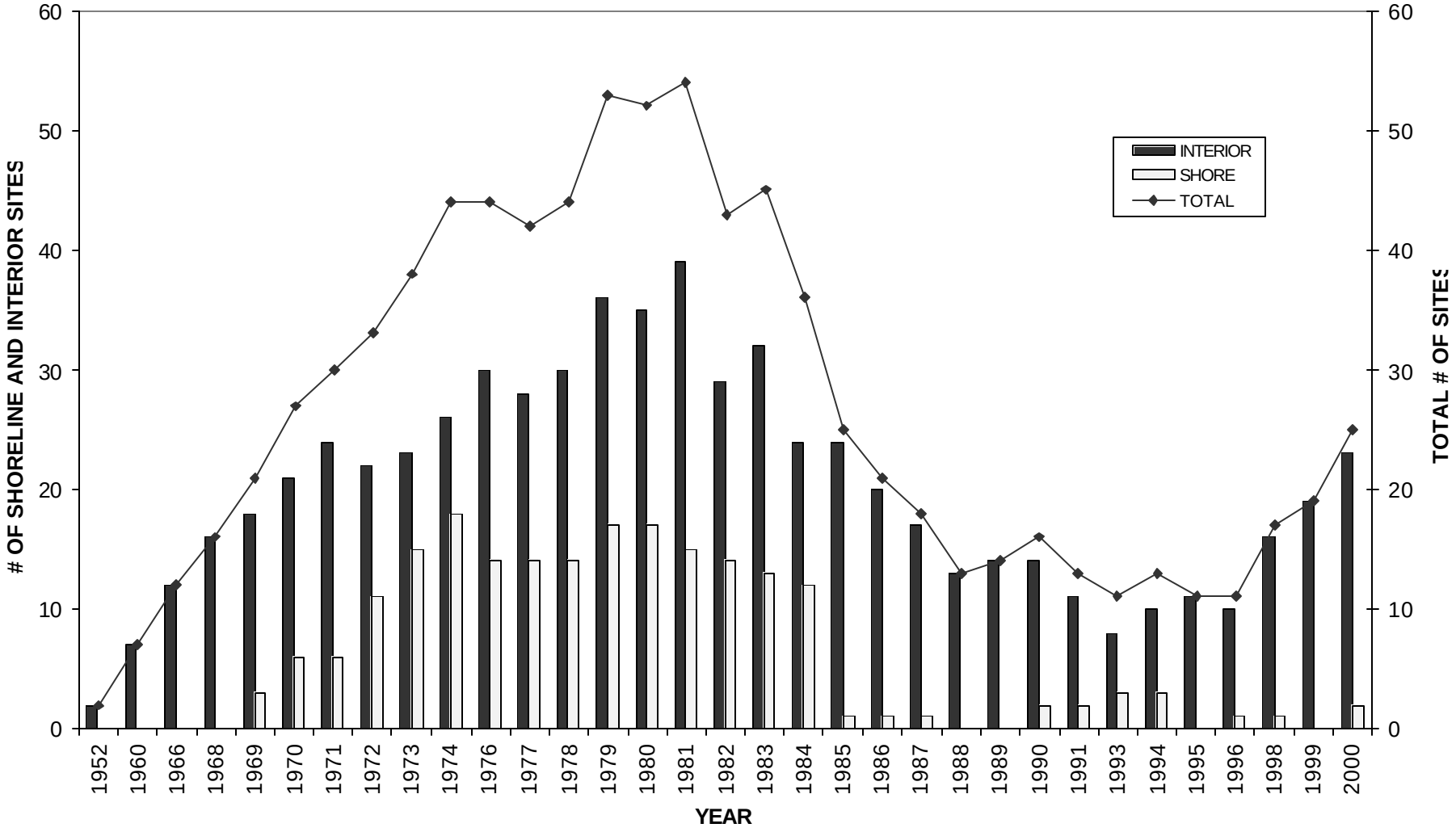
Project Study Sites

➡ WILDLIFE SITE –

Site Name	Total Area	Landuse Area			Stream Length	Slope	Date Installed
		Forest	Open Land	Water			
	(km^2)	Percent			(km)		(mm/yy)
Middle Branch Dickey Brook	1.15	95 %	4 %	1 %	1.6	0.057	12/00
Griswold Brook	0.79	87 %	10 %	3 %	1.8	0.047	06/01
Shay's Brook (Upstream)	0.42	97 %	3 %	-	0.4	0.14	06/01
Shay's Brook (Downstream)	0.89	99 %	1 %	-	1.3	0.116	05/01
East Branch Underhill Brook	0.75	96 %	4 %	-	1.7	0.042	12/00

Project Study Sites

➡ **WILDLIFE SITE –**



Project Study Sites

➡ **WILDLIFE SITE –**

	1988	1989	1990	1991	1993	1994	1995	1996	1998	1999	2000	2001
Griswold Brook	O	O	O	O	X	X	X	X	O	O	O	O
MBDB	X	X	X	X	X	X	O	X	O	X	X	X
EBUB	X	X	X	X	X	X	X	X	X	X	X	X
Shay's Brook	X	X	X	X	X	X	X	X	X	X	X	X

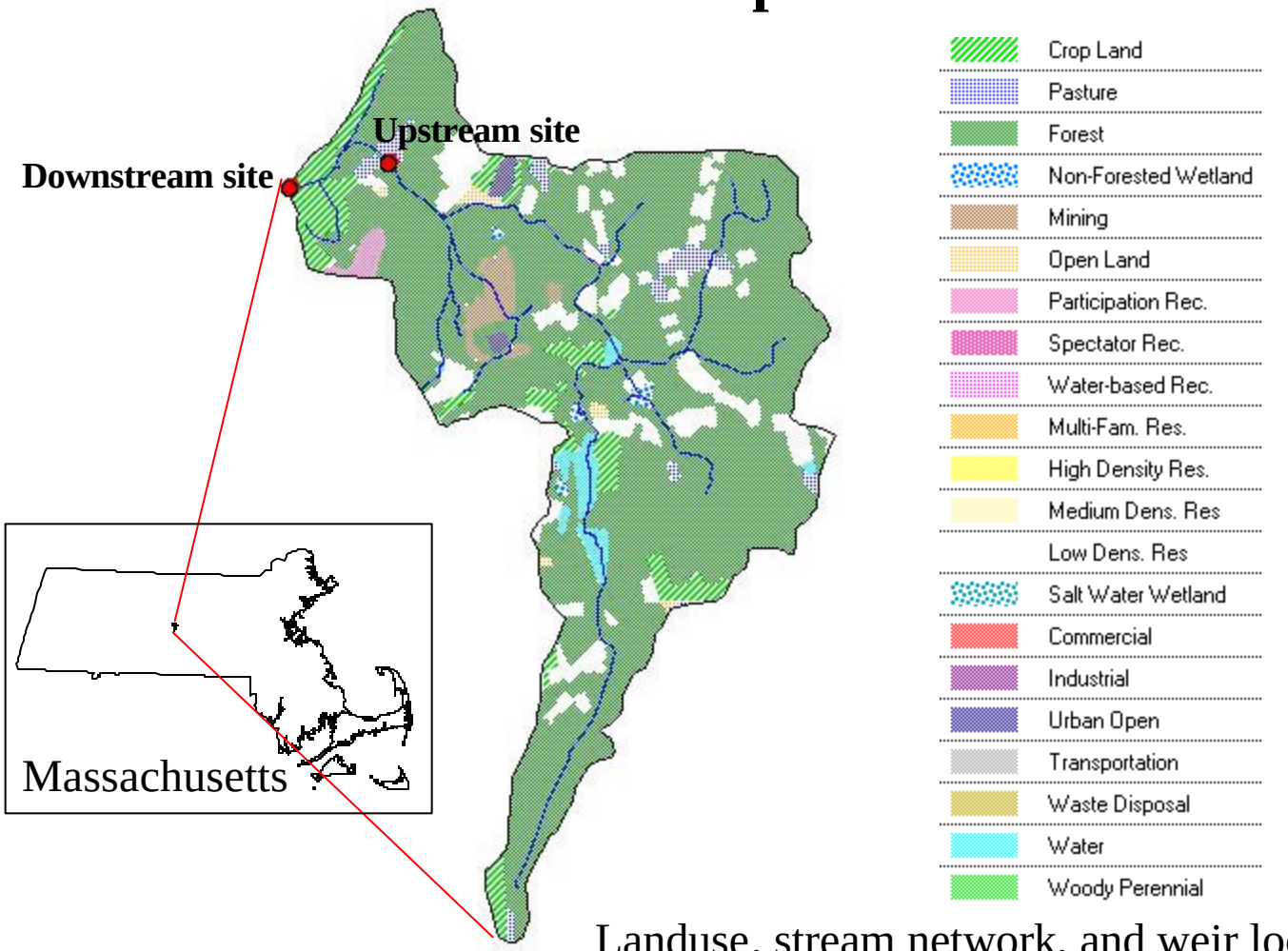
Timeline of the presence and absence of active beaver colonies within study watersheds

Project Study Sites

➡ **WILDLIFE SITE –**

Project Study Sites

AGRICULTURAL SITE – The influence of calves and heifers, an upstream / downstream study.



Landuse, stream network, and weir locations for the agricultural study site, Burrow Brook.

Project Study Sites

➡ **AGRICULTURAL SITE –**

Characteristics of the upstream and downstream agricultural sites.

Site Name	Total Area (km^2)	Land Use Type					Stream Length (km)
		Agriculture	Forest	Urban	Water	Other	
Burrow Bk (dwn)	8.96	9.7%	74.3%	10.6%	2.0%	3.4%	17.75
Burrow Bk (up)	7.82	6.7%	76.4%	11.5%	2.2%	3.2%	15.76

Project Study Sites

➡ **AGRICULTURAL SITE –**

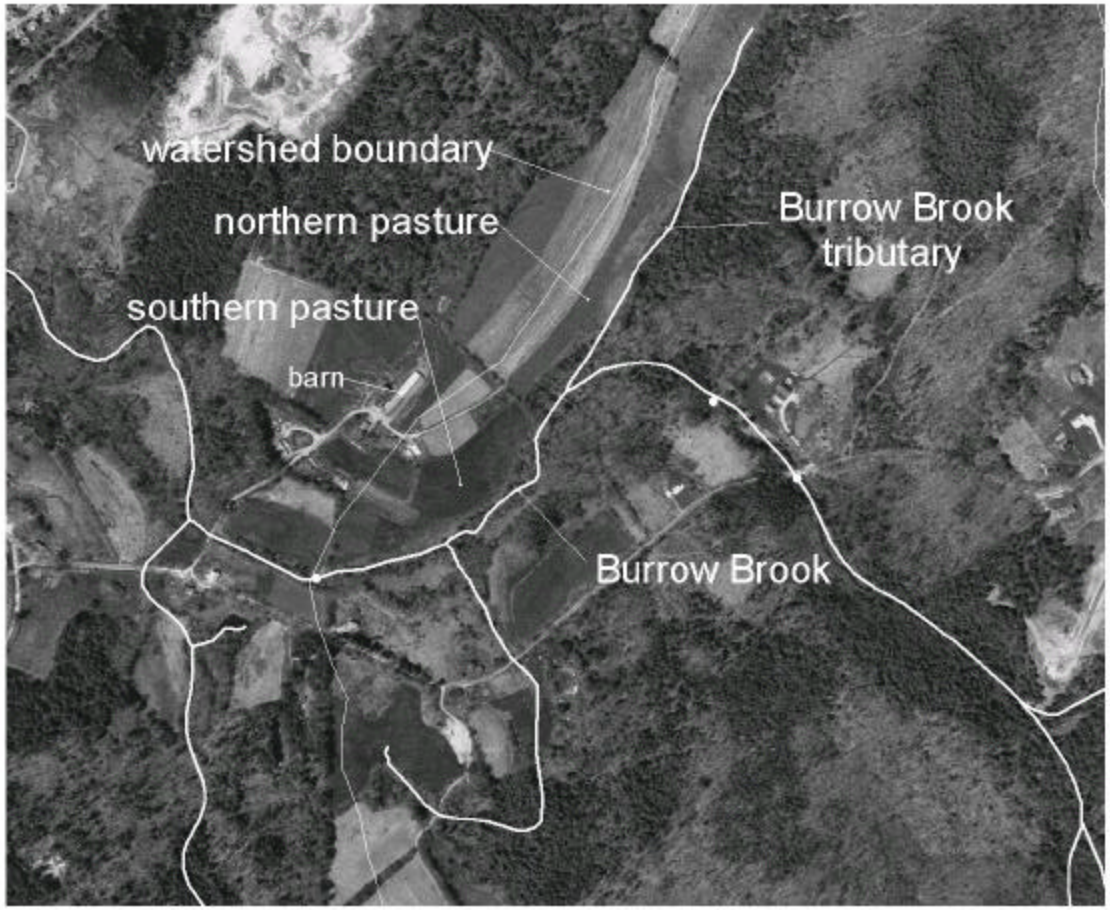
Project Study Sites

➡ AGRICULTURAL SITE –

- The cow heard consists of around 60 head of cattle, 20 of which are typically heifers.
- In the late spring and summer, the herd is typically allowed to graze in the steeply sloped northern pasture every 2 to 3 days. Runoff from this pasture enters Burrow Brook but the cows have no direct access.
- The herd is also allowed to graze in the abutting field, the southern pasture, on a rotating basis. From this field, the cows have direct access to Burrow Brook, which they use as a drinking water source.

Project Study Sites

➡ **AGRICULTURAL SITE –**



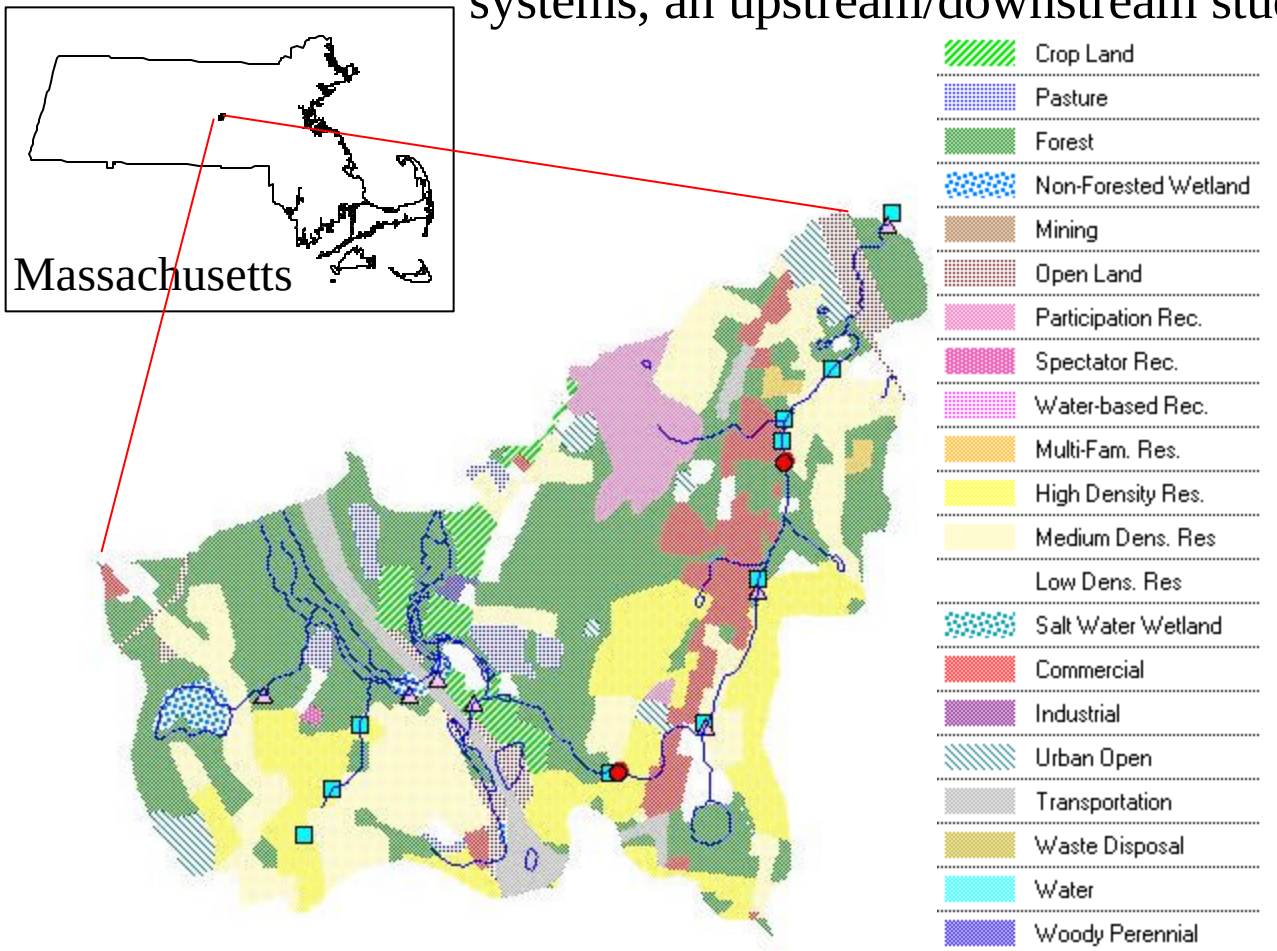
Detailed layout of cow farm site.

Project Study Sites

➡ **AGRICULTURAL SITE –**

Project Study Sites

RESIDENTIAL SITE – The influence of residential properties (septic and sewered), commercial properties, and transportation systems, an upstream/downstream study.



Landuse, stream network, and weir locations for the urban study site (shown in red).

Project Study Sites

➡ **RESIDENTIAL SITE –**

Characteristics of the upstream and downstream urban sites.

Site Name	Total Area (km^2)	Land Use Type				Stream Length (km)
		Agriculture	Forest	Urban	Other	
Gates Bk (dwn)	5.9	7.6%	36.3%	52.0%	4.1%	10.0
Gates Bk (up)	4.3	10.4%	41.0%	43.3%	5.3%	6.7
Intervening	1.6	0.02%	23.58%	75.58%	.01%	3.3

NOTES:
- There is a mixture of septic and sewered systems.
- Additional homes will move from septic to sewered over the course of the project.

Project Study Sites

- **RESIDENTIAL SITE –**

Project Data

➡ **MULTI-PHASE SAMPLING AND MULTI-PARTNER ANALYSIS EFFORT:**

- Monthly sampling
- Indicator baseflow sampling
- Event sampling
- Targeted sampling
- Continuous monitoring

Project Data

➡ **MONTHLY SAMPLING: MDC and MWRA**

Standard Analyses
Fecal Coliform Enumeration
Total Coliform Enumeration
Suspended Solids
Total Phosphorus
Organic Nitrogen
Nitrate/Nitrite (May ’02)

- Monthly samples collected the 2nd Wednesday or Thursday of every month. Wildlife – Nov ’01. Residential & Agriculture – Aug ’02.
- MDC coordinates MWRA bottle delivery and notification of MWRA labs that samples are on their way.

Project Data

➡ INDICATOR BASEFLOW SAMPLING: UMass

Special Analyses
F^- Coliphage Enumeration w/CN13 host
F^+ Coliphage Enumeration w/Famp host
*** R. *Coprophilus* Enumeration**
Clostridium perfringens
*** Sorbitol-fermenting *Bifidobacteria* Enumeration and Confirmation**

- R. *Coprophilus* at wildlife and agricultural site.
- *Bifidobacteria* at residential site.
- Samples collected mostly during baseflow, some high flow samples to get dilutions correct

Project Data

➡ EVENT SAMPLING:

- Three study sites; two sampling transects per each.
  - » For the agricultural and residential study sites, there are upstream and downstream sampling transects.
  - » For the wildlife study site, there are two watersheds, each with one sampling transect.
- Only one study site is active during a given event.
- The upstream and downstream transects (or paired watershed transects) are sampled simultaneously during a given event.
- Grab sampling.

Project Data

➡ EVENT SAMPLING:

- Events during all 4 seasons captured – two per season per study site over the course of the project (24 events total).
- Sampling is based on time increments, 30 minutes, rather than flow. Sometimes hourly or 15-minute sampling.
- Sampling is approximately initiated by the start of rainfall.
- Try and capture a good portion of the hydrograph fall.
- Aim to capture a range of precipitation events.
- For long events, only a portion of the collected samples are analyzed.

Project Data

EVENT SAMPLING:

Standard Analyses	Special Analyses
* Fecal Coliform Enumeration	F^- Coliphage Enumeration w/CN13 host
* Total Coliform Enumeration	F^+ Coliphage Enumeration w/Famp host
** Total Heterotrophic Plate Counts	R. *Coprophilus* Enumeration
Total Phosphorus	*Giardia*
Organic Nitrogen	*Cryptosporidium*
Nitrate/Nitrite (as of May '02)	*Clostridium perfringens*
Suspended Solids	Sorbitol-fermenting *Bifidobacteria* Enumeration and Confirmation
***UV254 (TOC, DOC)	

MDC-8 MWRA-16 UMass-3 Environmental Associates-3

Project Data

➡ **CONTINUOUS MONITORING: UMass**

Standard Parameters
Depth (Discharge)
pH
Temperature
Conductivity
Turbidity
Rainfall (one location per site)

- Solar panels provide battery backup.
- Check equipment as often as possible and calibrate once a month.
- Equipment is pulled when streams are expected to freeze.

Project Data

➡ **WATER- & VANDAL- PROOF HOUSING –**

To house an AXSYS MPU Datalogger, battery, and connectors.

Project Data

- **BACKUP POWER –**
  Solarex 20 Watt solar panel

Project Data

- **TIPPING BUCKET RAIN GAUGE –**
  Stevens/Greenspan

Project Data

- **CONDUCTIVITY / PH / TEMPERATURE –**
  Stevens/Greenspan CS4-1200

- **TURBIDITY –**
  Stevens/Greenspan TS1200

Project Data

Monitoring Flow:

WILDLIFE & AGRICULTURAL SITES –

- V-notch weirs monitor flow at these sites.

RESIDENTIAL SITE –

Downstream

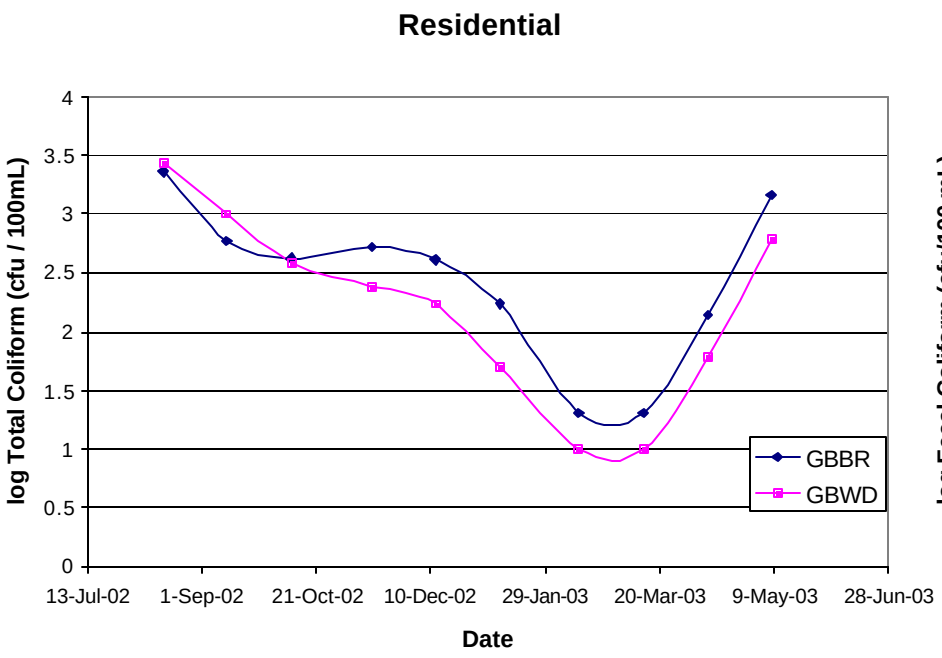
- The reinforced concrete box culvert at Braydon Rd is being used to monitor flow at the downstream site.
- This site is upstream of the Scarlett Brook confluence.

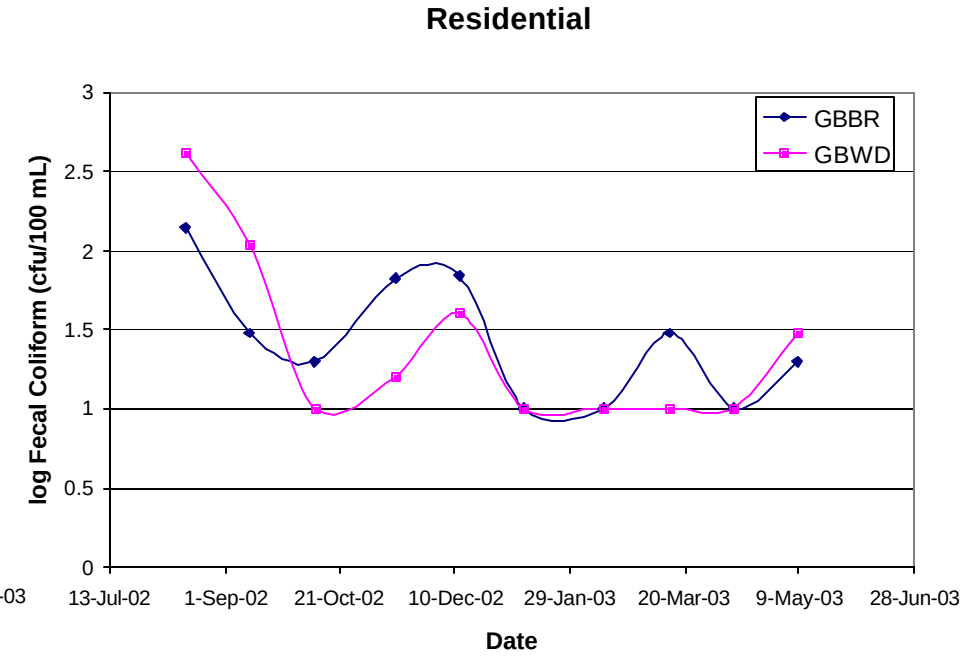
Upstream

- The bell end, circular reinforced concrete culvert at Woodland Street is being used to monitor flow at the upstream site.

Select Results

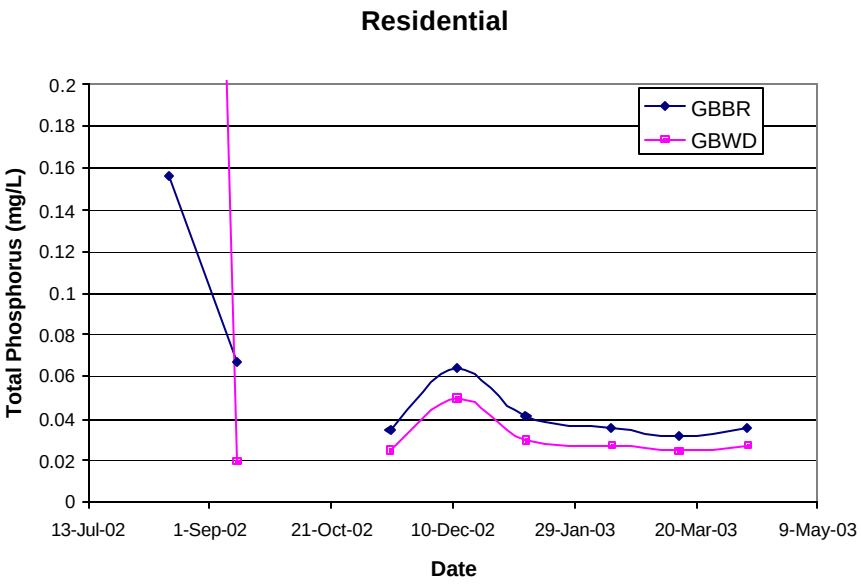
➡ MONTHLY – Residential

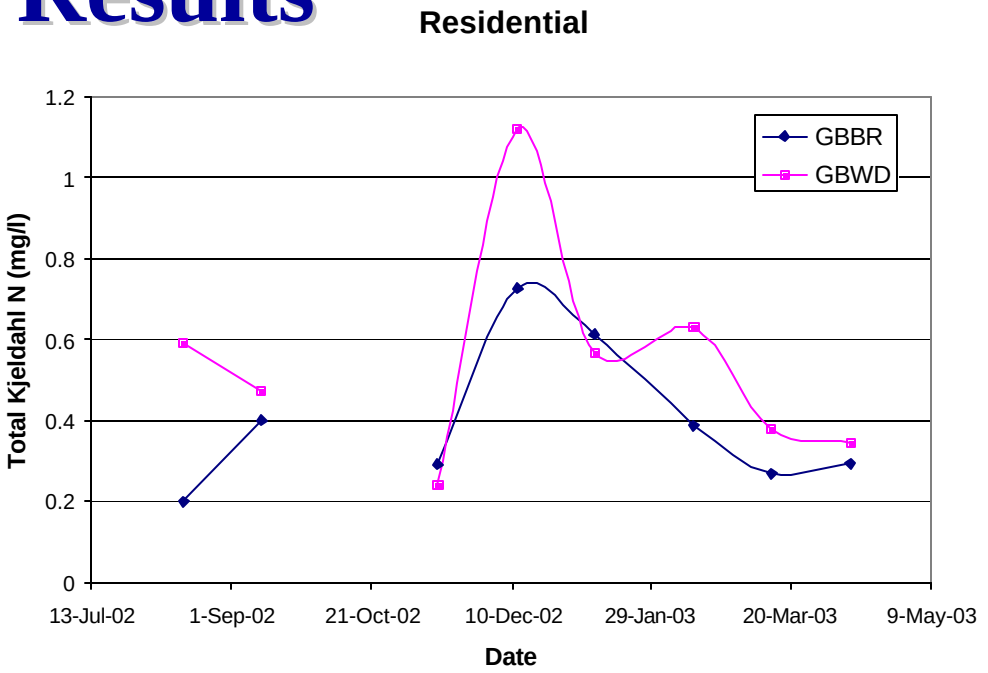


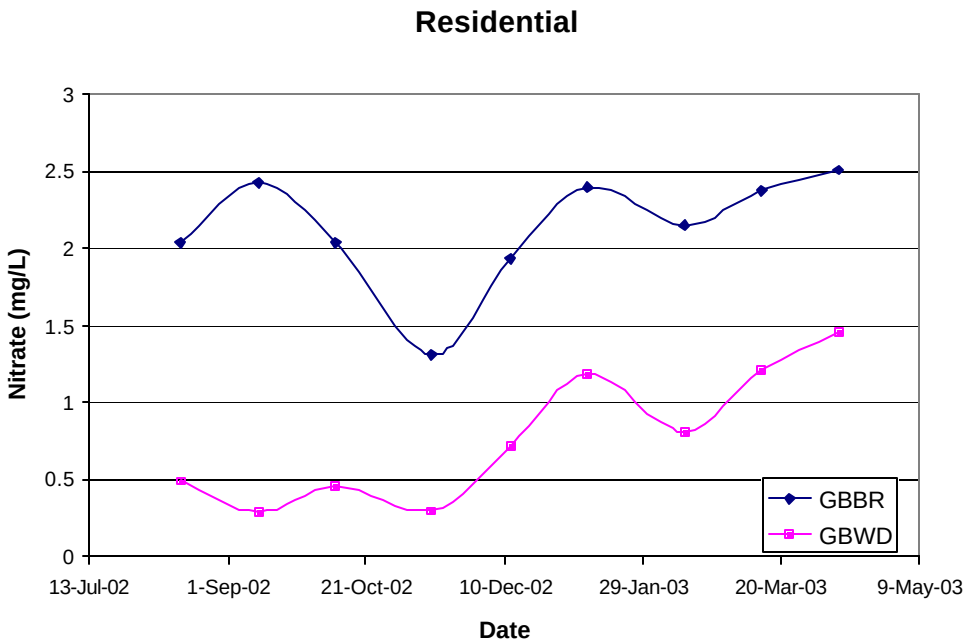


Select Results

➡ MONTHLY – Residential

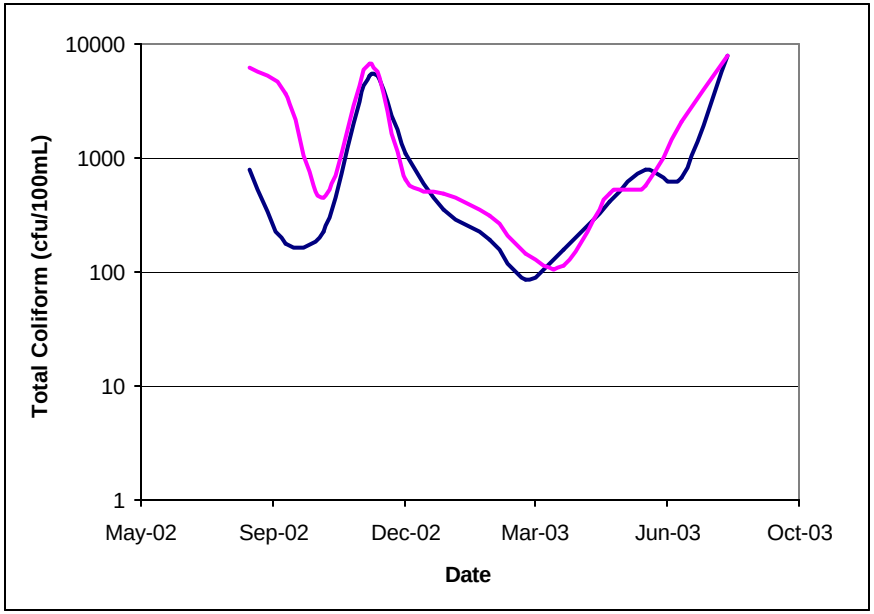


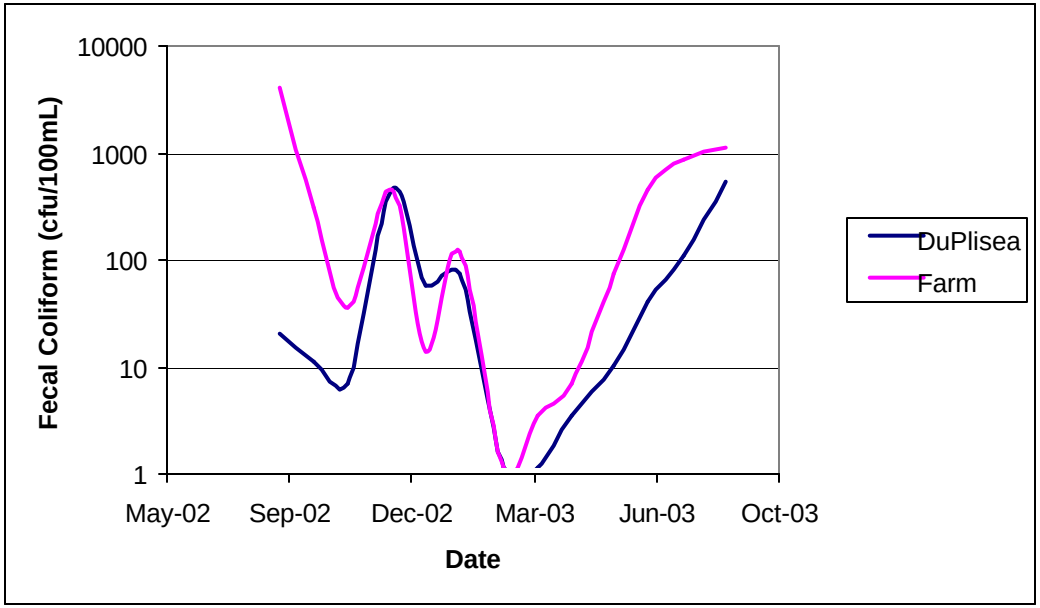




Select Results

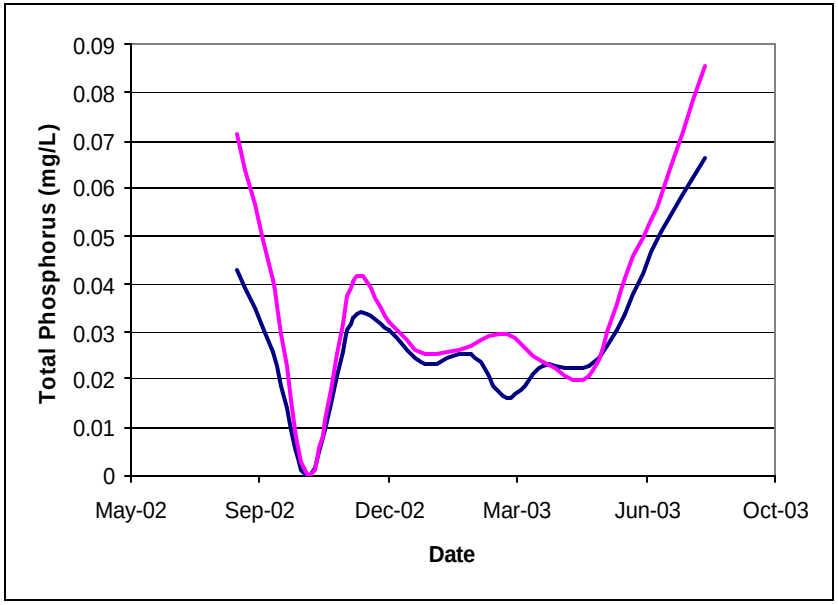
➡ MONTHLY – Agriculture

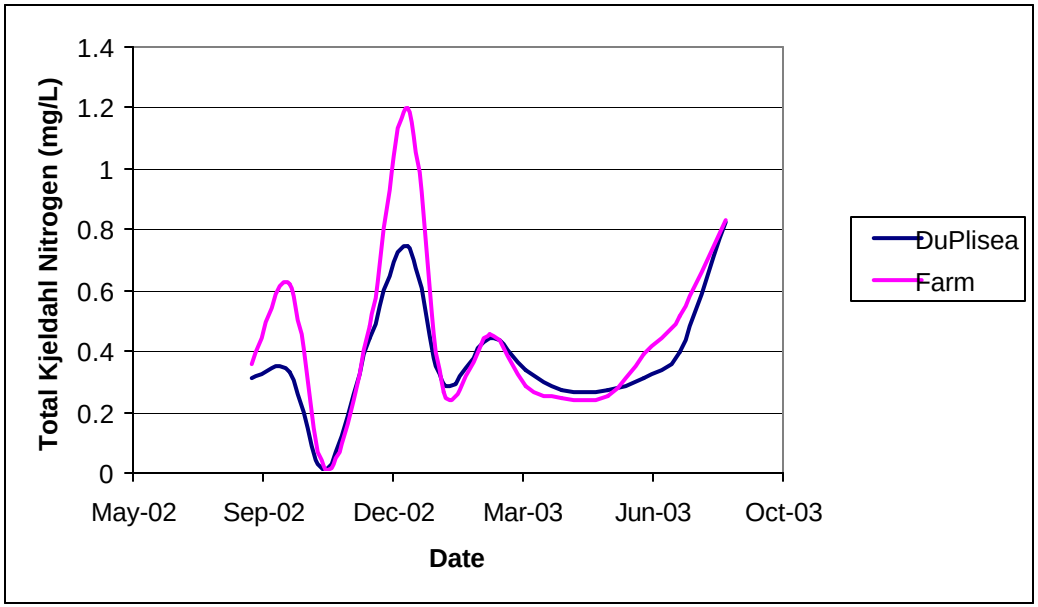


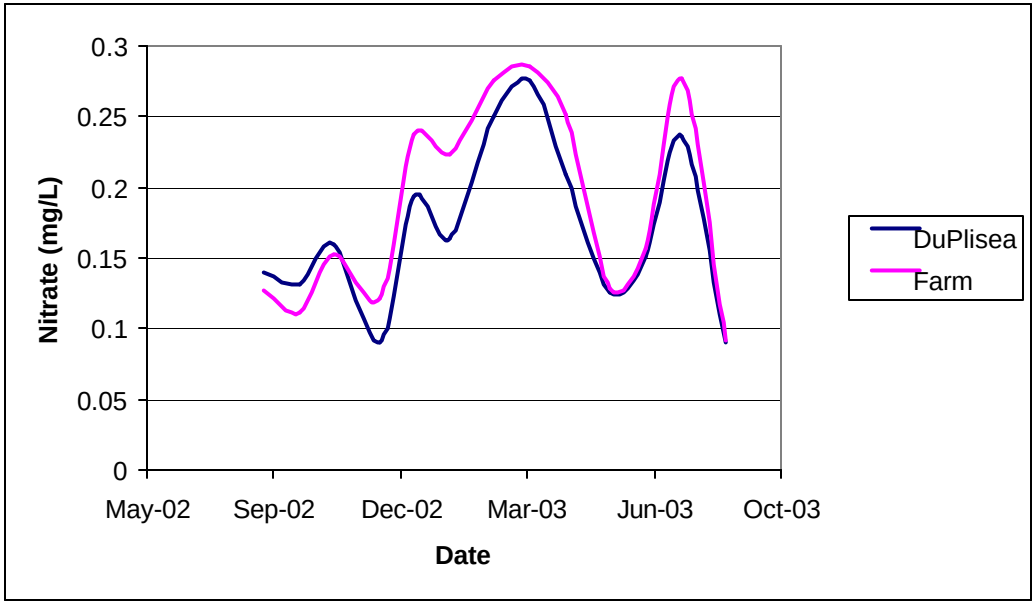


Select Results

➡ MONTHLY – Agriculture

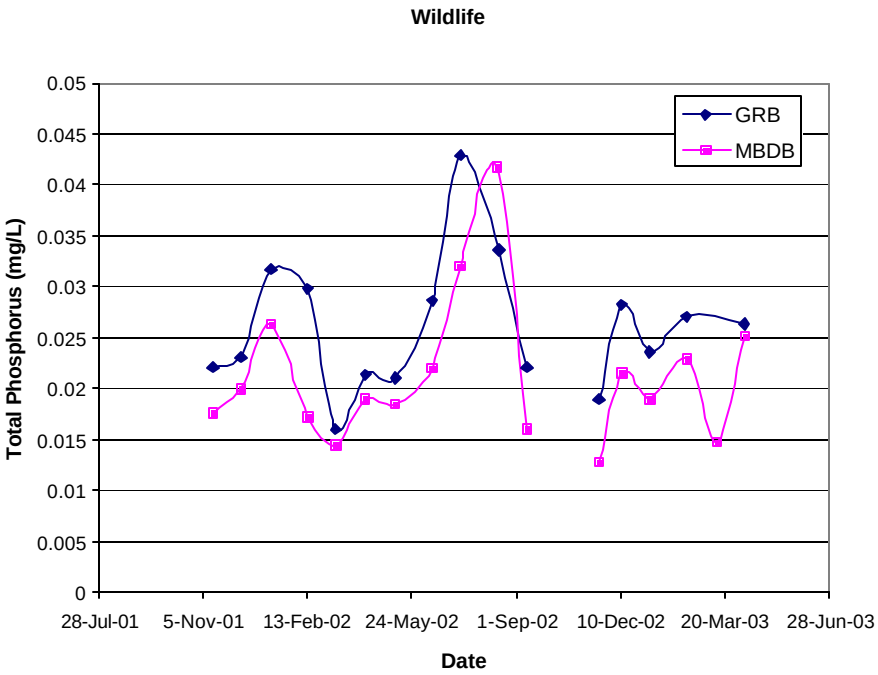


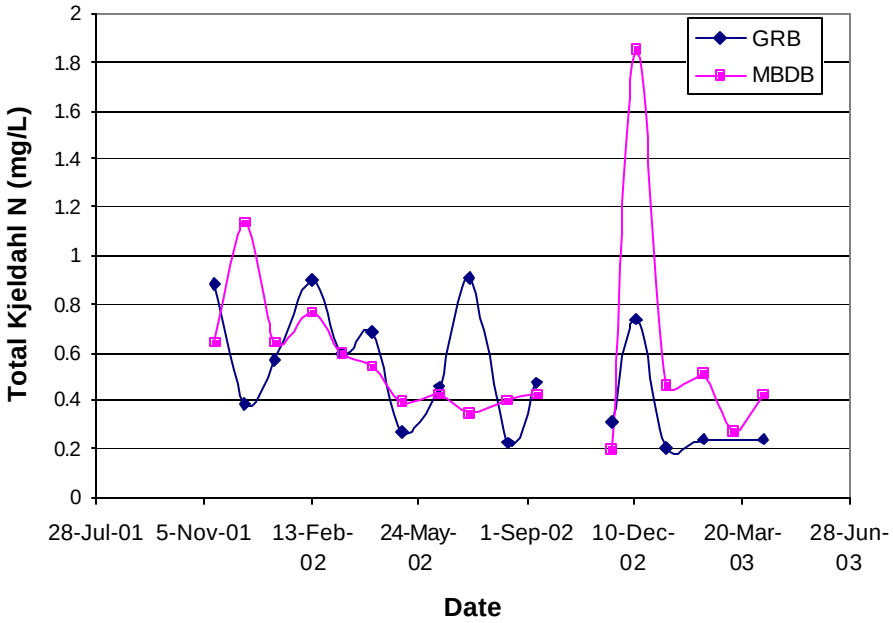


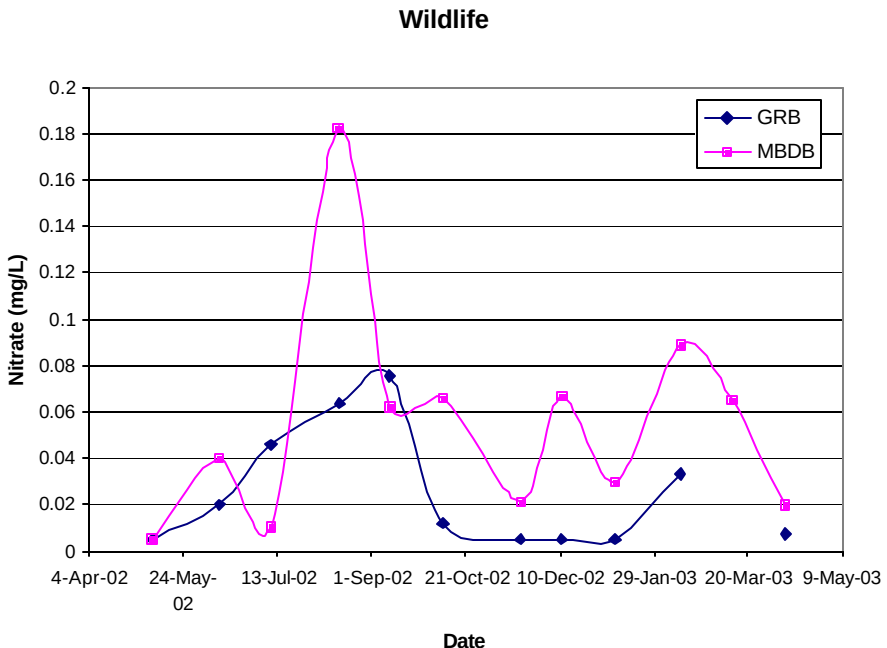


Select Results

MONTHLY – Wildlife







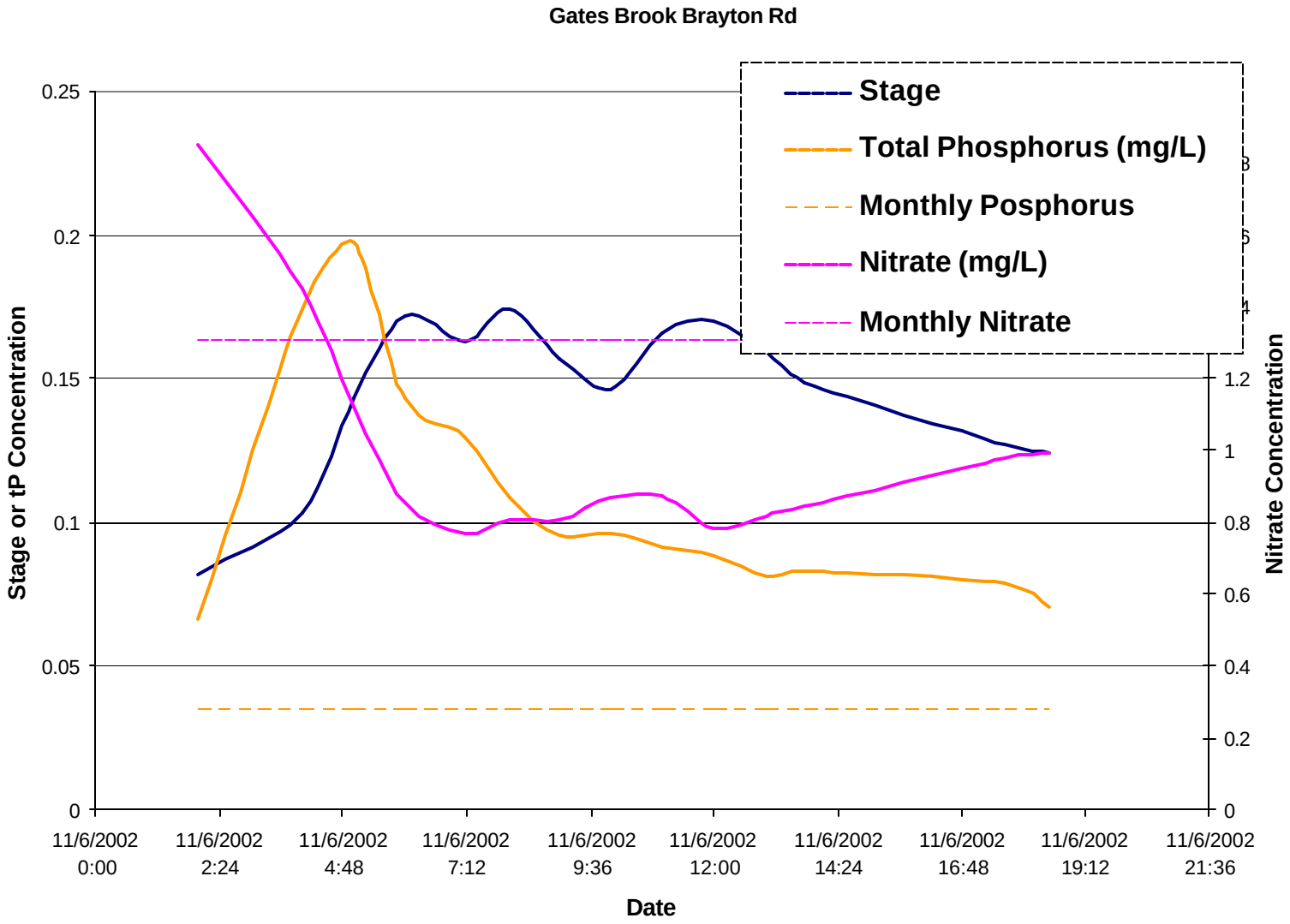
Select Results

➡ **MONTHLY – Average values over period of record in mg/L or log cfu/100 mL**

	Nitrate	Total Kjeldahl N	Total Phosphorus	Susp. Sediment	Log Total Coliform	Log Fecal Coliform
MBDB	0.055	0.591	0.021	7.75	2.45	0.95
GRB	0.025	0.504	0.026	3.43	2.38	0.62
BBWR	0.171	0.388	0.028	4.5	2.74	1.53
BBFM	0.190	0.480	0.036	4.83	3.17	2.19
GBWD	0.769	0.543	0.178	5.67	2.19	1.39
GBBR	2.13	0.397	0.058	5.33	2.42	1.44

Select Results

EVENT – DOWNSTREAM RESIDENTIAL – November 02



Select Results

➡ EVENT – WILDLIFE 11-Jun-03

	Kjeldahl Nitrogen		Total Phosphorus		Total Suspended Solids	
	GRB	MBDB	GRB	MBDB	GRB	MBDB
Load (g)	490	68.9	53.4	8.37	24,180	2,946
Flow Weighted Mean Conc. (mg/L)	0.557	.441	0.061	.054	27.5	18.9
Time Weighted Mean Conc. (mg/L)	0.552	.465	0.060	.058	27.2	20.8

Select Results

➡ EVENTS

Summary of select events *Cryptosporidium* oocysts or *Giardia* cysts results for events where detected.

Site/Season	Date	Rain Total (mm)	*Crypto* Detected		*Giardia* Detected	
Wildlife			*MBDB*	*GRB*	*MBDB*	*GRB*
Spring	11-Jun-03	1.78	No	No	No	No
Summer	28-Jul-02	2.03	No	No	No	No
	26-Sep-02	55.12	No	No	No	No
Fall	14-Dec-01	12.19	NA	NA	NA	NA
	27-Oct-03					
Winter	26-Mar-02	11.43	No	Yes	Yes	Yes

Select Results

➡ EVENTS

Summary of select events *Cryptosporidium* oocysts or *Giardia* cysts results for events where detected.

Site/Season	Date	Rain Total (mm)	*Crypto* Detected		*Giardia* Detected	
Agricultural			***BBWR***	***BBFM***	***BBWR***	***BBFM***
Spring	**28-May-03**	**2.79**	**No**	**Yes**	**No**	**Yes**
	18-June-03	**7.37**	**No**	**No**	**No**	**No**
Summer	**12-Aug-03**	**47.0**	**No**	**No**	**No**	**No**
	19-Sep-03	**10.16**				
Fall	**11-Nov-03**	**4.57**				

Select Results

➡ EVENTS

Summary of select events *Cryptosporidium* oocysts or *Giardia* cysts results for events where detected.

Site/Season	Date	Rain Total (mm)	*Crypto* Detected		*Giardia* Detected	
Residential			***GBWD***	***GBBR***	***GBWD***	***GBBR***
Spring	**2-May-03**	**3.81**	**No**	**No**	**No**	**No**
Summer	**1-Aug-03**	**7.62**	**No**	**No**	**No**	**No**
	1-Sep-03	**18.5**				
Fall	**6-Nov-02**	**18.03**	**No**	**No**	**No**	**No**
Winter	**4-Feb-03**	**9.40**	**No**	**No**	**Yes**	**Yes**

Select Results

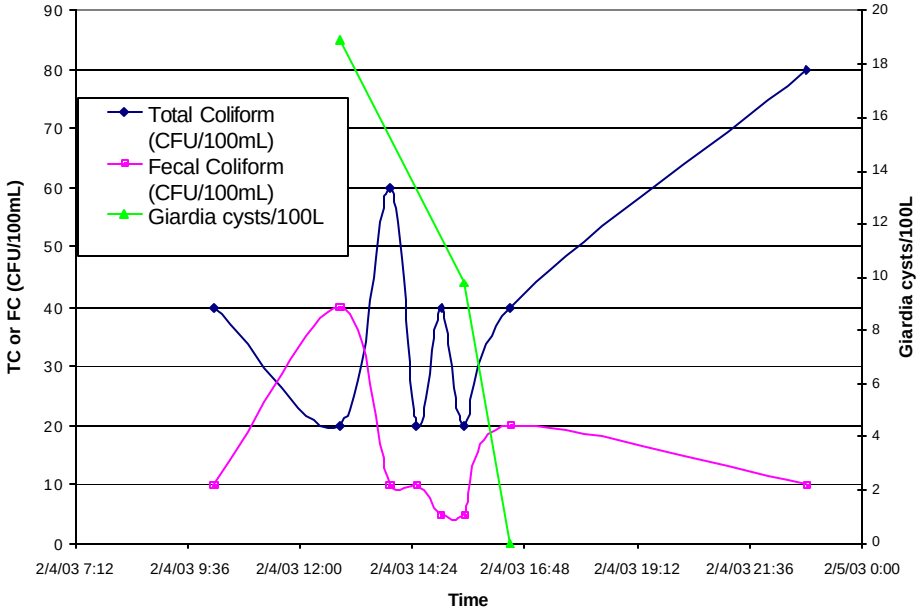
➡ EVENTS

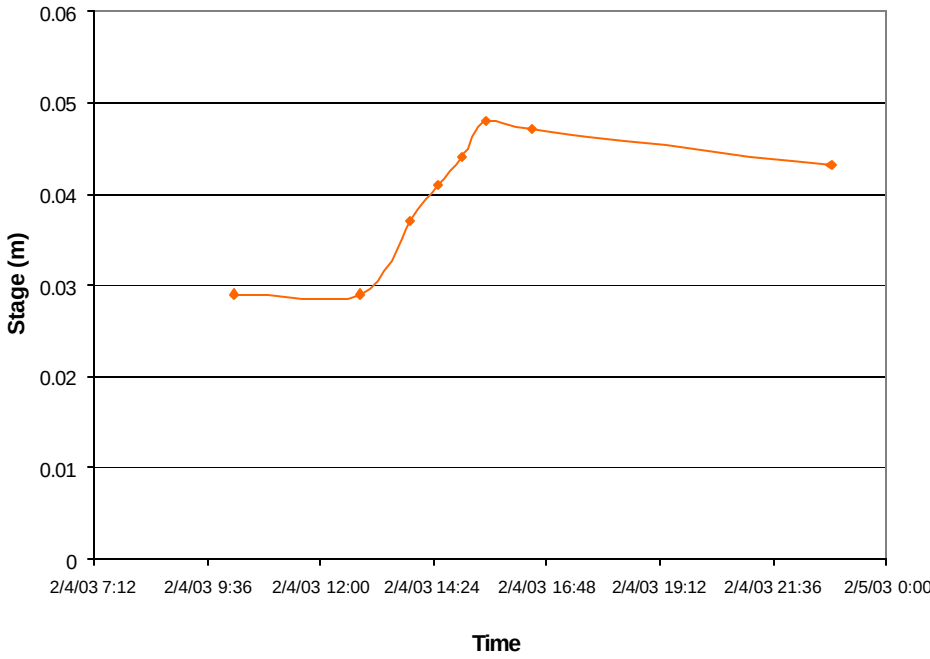
Summary of select events *Cryptosporidium* oocysts or *Giardia* cysts results for events where detected.

			Rising	Near Peak	Falling
26-Mar-02	*Crypto*	GRB	2	2	<2
Wildlife					
	Giardia	MBDB	14	32	16*
		GRB	256	160	36
28-May-03	*Crypto*	BBFM	20	100	<10
Agricultural					
	Giardia	BBFM	10	698	<10
4-Feb-03	*Giardia*	GBWD	19	10	<5
Residential		GBBR	64	94	208

Select Results

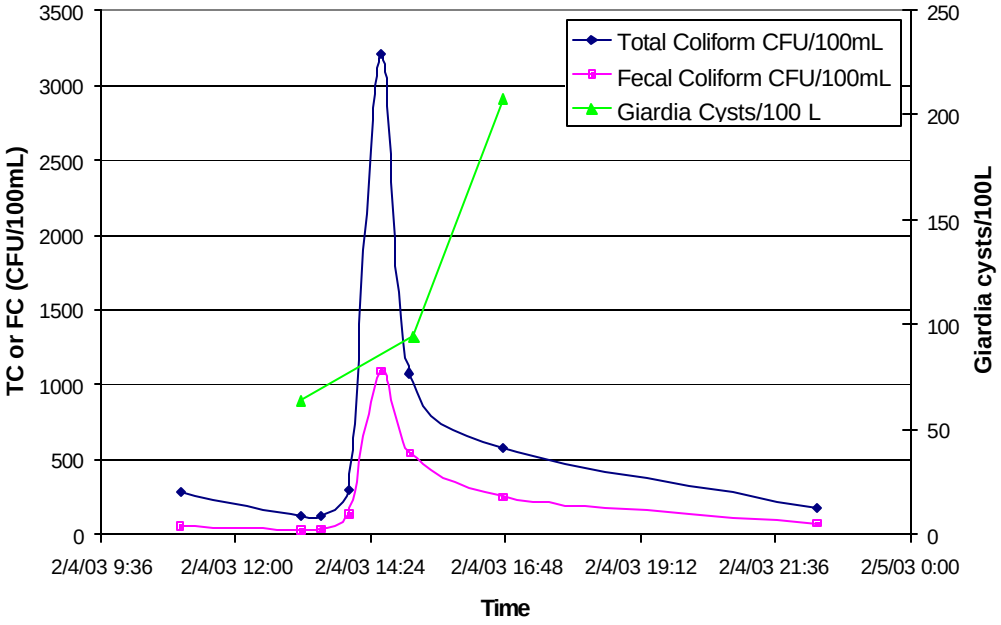
➡ EVENT – UPSTREAM RESIDENTIAL – February 03

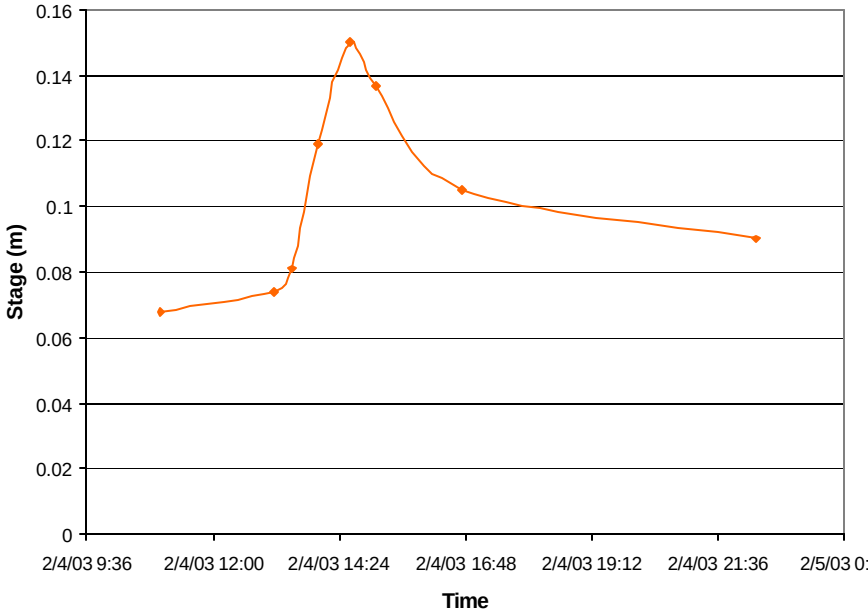




Select Results

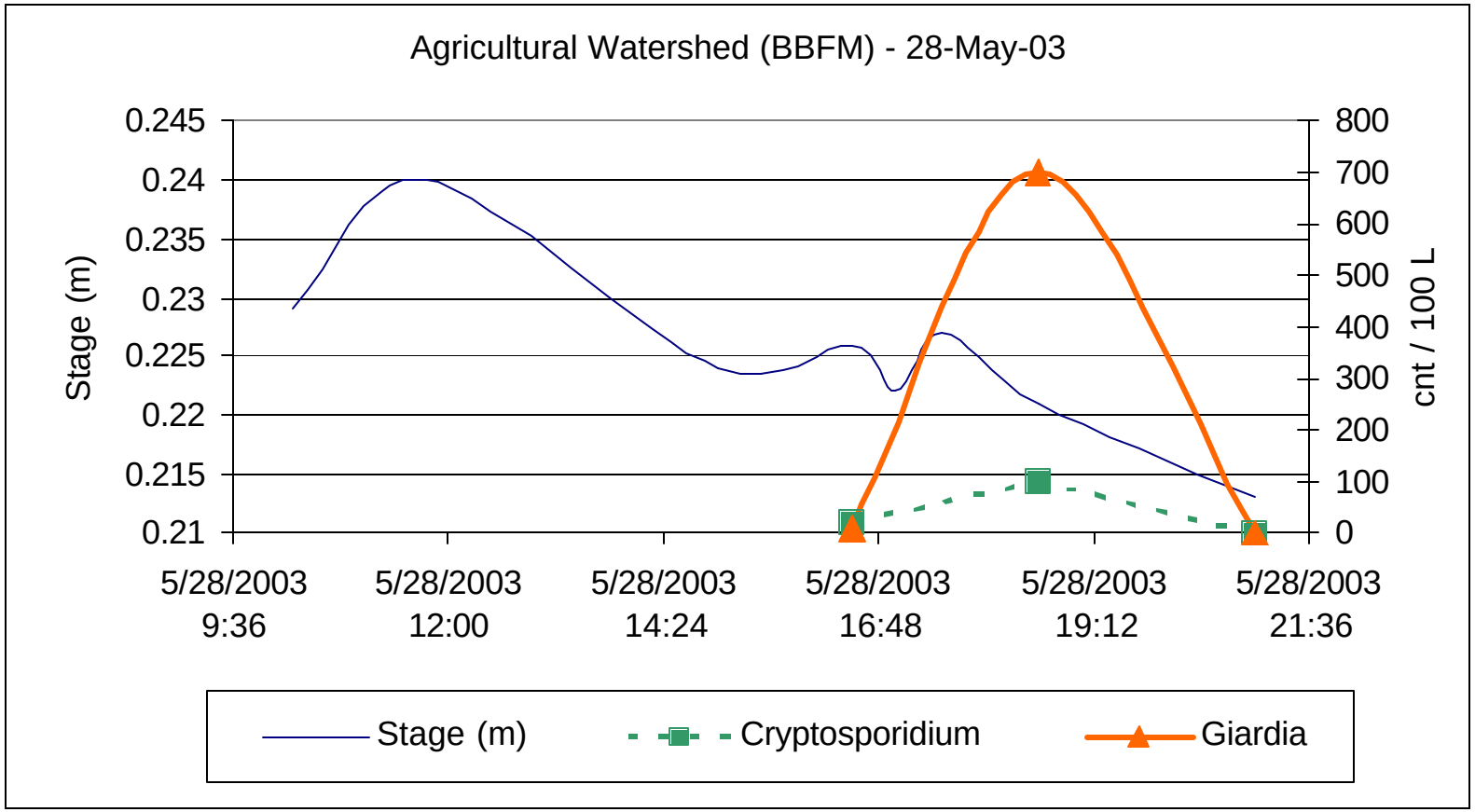
➡ EVENT – DOWNSTREAM RESIDENTIAL – February 03





Select Results

➡ EVENT – DOWNSTREAM AGRICULTURAL May 03



Summary Observations

- In both the monthly and event data, downstream locations exhibit marked differences in concentrations for many parameters.
- There are notable differences in the average monthly concentrations of typical water quality parameters between the three land use types.
- Nutrient, fecal coliform, and total coliform concentrations observed during monthly sampling and storm sampling vary considerably.
- The statistical significance of these observations will be evaluated in the near future.

Summary Observations

- The data collected to date suggest that *Cryptosporidium* and *Giardia* occurrence may have a seasonal trend in Massachusetts surface waters.
- Cryptosporidium oocysts and Giardia cysts have been observed during both heavy and light rainfall.
- While for some sites/events, Cryptoporidium and Giardia levels track the rise and fall of the hydrograph, in others they do not.
- Sites located downstream of suspected pollutant sources exhibit a strong flushing mechanism on the rising hydrograph limb for many parameters.

Summary Observations

- The data collected to date suggest that *Cryptosporidium* and *Giardia* occurrence may have a seasonal trend in Massachusetts surface waters.
- Cryptosporidium cysts and Giardia oocysts have been observed during both heavy and light rainfall.
- While for some sites/events, Cryptoporidium and Giardia levels track the rise and fall of the hydrograph, in others they do not.
- Sites located downstream of suspected pollutant sources exhibit a strong flushing mechanism on the rising hydrograph limb for many parameters.

Acknowledgements

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- Special thanks to graduate students Rebecca Baker, Dan Bourdeau, Ruoting Pei, Austin Falaxa, Tiffany Tauscher, Greg Devine, James Mangarillo and numerous others for their efforts.
- Additional thanks to the MDC and MWRA labs.
- Professors Paul Barten (NRC) and Sharon Long (CEE) are Co-PI’s on this project.

Disclaimer

The content of the research reported, the opinions, and statements of fact are solely those of the authors and do not necessarily reflect the opinions of AwwaRF or MDC.