Use of Environmental Markers to Discern Stormwater Nutrient Impacts from Reclaimed Water

WateReuse Research Foundation Tailored Collaboration Project

July 2014

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BUILDING A BETTER WORLD

Participants

- South Florida Water Management District
- Southwest Florida Water Management District
- St. Johns River Water Management District
- Loxahatchee River District
- Hillsborough County
- Orange County
- Palm Beach County
- Pasco County
- City of Orlando
- City of North Port
- City of Pompano Beach
- Florida Department of Environmental Protection
- Jacksonville Electric Authority
- Miami-Dade Water and Sewer Department

Presentation Outline

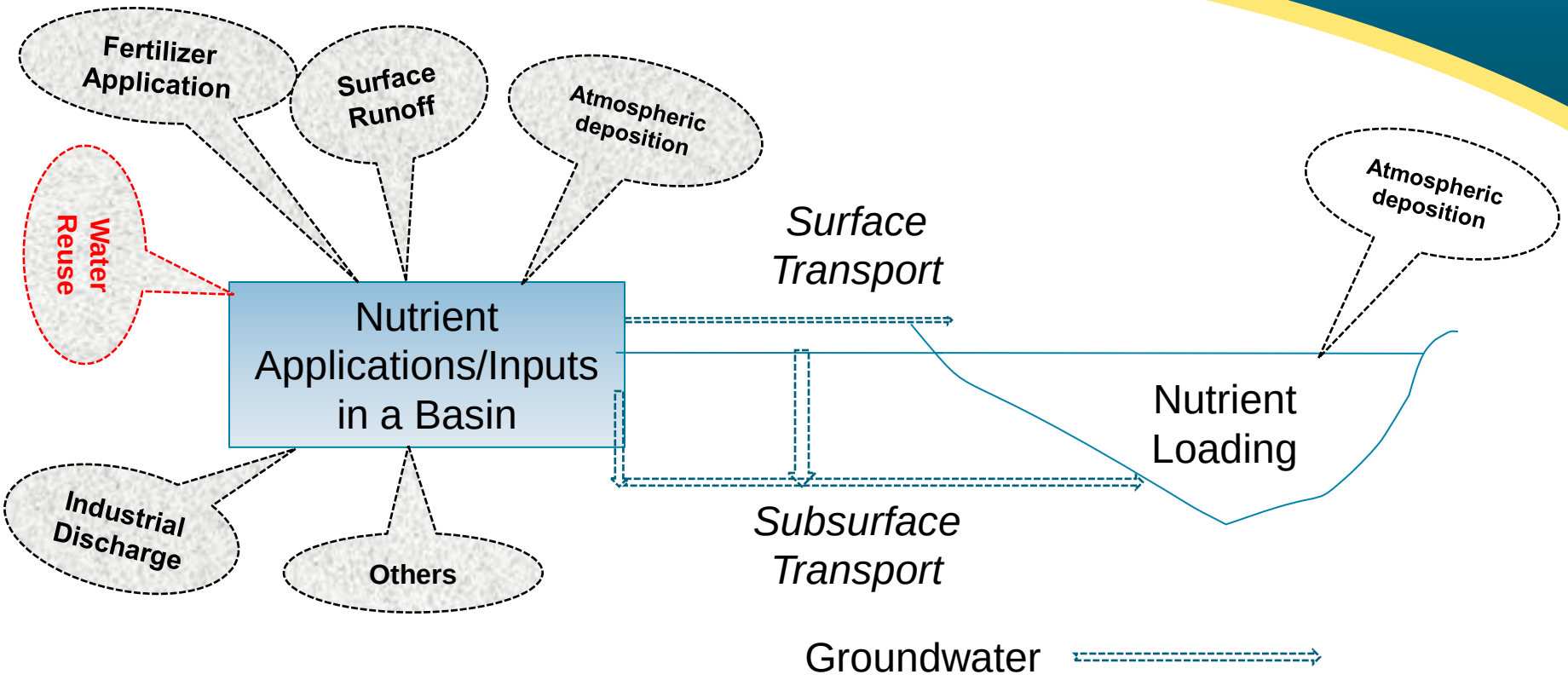
- Project Background & Objectives
- Project Approach & Key Findings
- Marker Selection & Behavior
- Field Sampling Results
- Study Conclusions
- Next Phase

Project Background & Objectives

Nutrient Issues in the Environment

- **Nutrient loading is a major cause of water quality impairment**
- **Vital to understand water reuse's contribution toward nutrient impairment of waterways**
- **Many TMDLs have nutrient load allocations associated with reclaimed water irrigation**

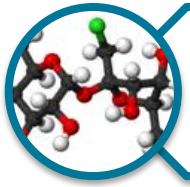
Nutrient Sources and Pathways



What factors impact nutrient application rate estimation and subsequent loading to water bodies ?

Project Objectives

Characterize reclaimed water irrigation as a nutrient source



Identify conservative marker(s) for assessing reclaimed water volumetric load contributions

Translate volumetric load contributions to nutrient loads from source concentrations and fate and transport behavior

Project Approach & Key Findings

Project Approach Overview

Study Approach

Nutrient and Marker Concentrations in Reclaimed Water

- Characterize Florida reuse facility effluent quality (50 plant survey)
- Identify universe of potential markers and develop marker short-list
- Conduct follow-up survey of 8 representative facilities, expanded to include analysis of markers

Marker Occurrence in other Sources and Transport Fate

- Assess marker presence and concentrations in reuse effluent and other sources
- Determine marker presence/absence in selected waterways
- Evaluate environmental fate and transport of markers through bench-scale studies

Positive and Negative Site Control Studies

- Assess marker and nutrient differences at sites irrigating with reclaimed water and groundwater
- Assess capability to distinguish reuse from stormwater and septic waste

Project Key Findings

- Sucralose can be used to identify reclaimed water/septic in nutrient impaired water bodies.
  - **NO** sucralose, **NO** reclaimed influence
  - Sucralose can provide a conservative estimate of nutrient contribution into a waterbody.

Detailed Project Key Findings

Nutrient and Marker Concentrations in Reclaimed Water

- Florida reuse facility effluent 50th percentile TN is 6 mg/L
- Florida reuse facility effluent 50th percentile TP is close to 1 mg/L
- Sucralose (Splenda®) is the best conservative marker of reclaimed water loading

Marker Occurrence in other Sources and Transport Fate

- Sucralose also found in septic samples
- Gd anomaly and carbamazepine are two other good reclaimed water markers that occur infrequently in septic, so ratios of markers might work in distinguishing reuse and septic inputs
- Transport fate of these markers differ, but sucralose is most recalcitrant to all fate processes

Positive and Negative Site Control Studies

- Sucralose, Gd anomaly, and carbamazepine are detectable in golf course runoff irrigating with reclaimed water
- These same markers are absent from golf course runoff irrigating with groundwater
- These same markers absent in stormwater ponds & present in irrigation collection ponds

Marker Selection & Behavior

Two Types of Markers

- Conservative Source Markers: source specific stable concentrations with conservative transport behavior
- Nutrient Fate Markers: mimic environmental fate properties of nutrients

Short-list of Markers

Marker	Usage
Atenolol	Beta blocker
Carbamazepine	Mood stabilizer
Gadolinium	NMR imaging compound
Galaxolide (HHCB)	Synthetic musk fragrance
Iohexal	X-ray contrast media
Sucralose	Sugar substitute (Splenda®)
Stable C,N,O Isotopes	Naturally present

Detailed Approach and Findings

Survey Nutrient and Marker Concentrations in Reclaimed Water

- Characterize Florida reuse facility effluent quality (50 plant survey)
- Identify universe of potential markers and develop marker short-list
- Conduct follow-up survey of 8 representative facilities, expanded to include analysis of markers

Marker Occurrence and Fate in the Environment

- **Assess marker presence and concentrations in reuse effluent and other sources**
- **Determine marker presence/absence in selected waterways**
- **Evaluate environmental fate and transport of markers through bench-scale studies**

Positive and Negative Site Control Studies

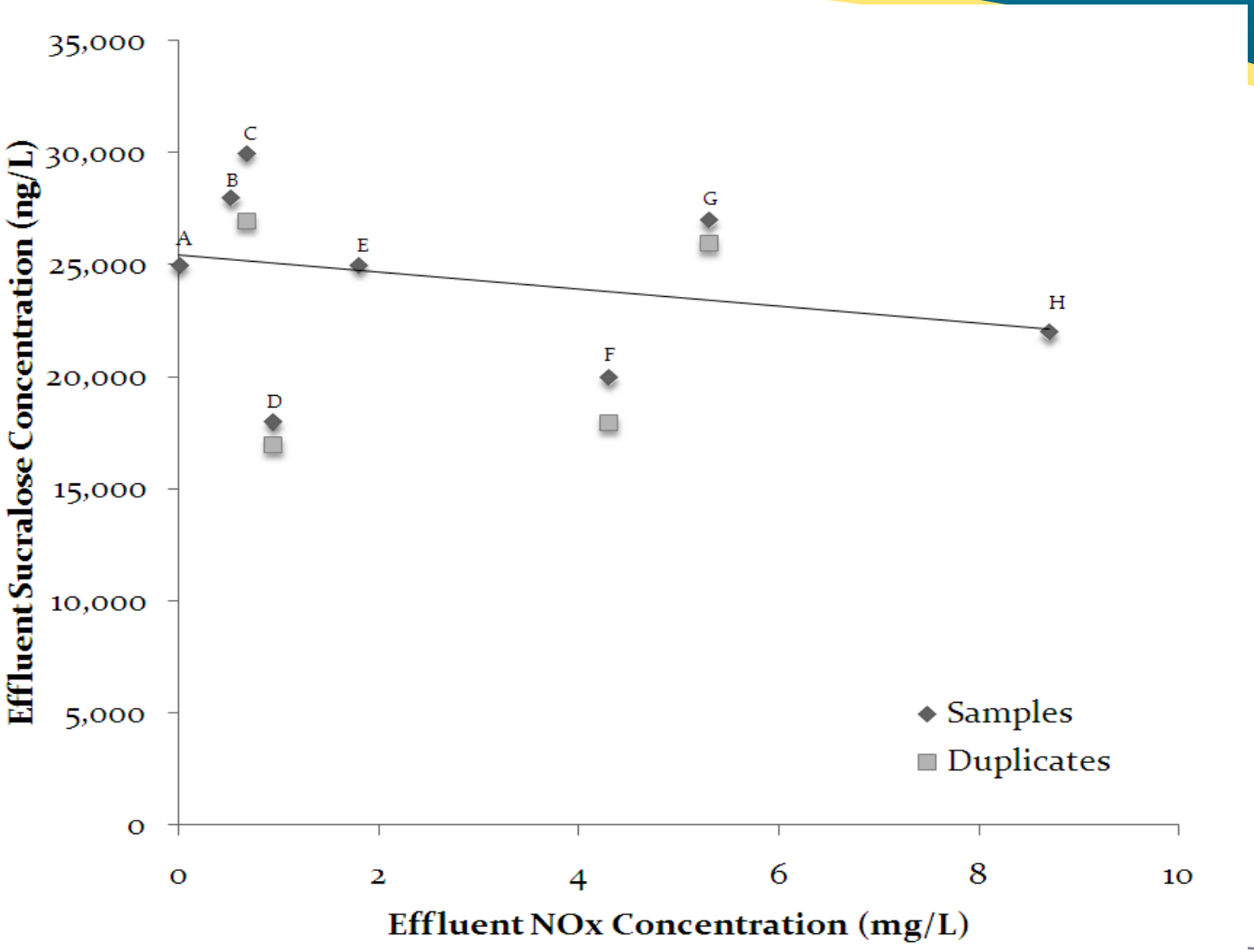
- Assess marker and nutrient differences at sites irrigating with reclaimed water and groundwater
- Assess capability to distinguish reuse from stormwater and septic waste

Marker Presence in US Waterways with and without Municipal Wastewater Discharges

Compound (MRL, ng/L)	Wastewater Effluent Mean (ng/L)	Waterway with WW Discharges (% Detects)	Waterway without WW Discharges (% Non-detects)
Sucralose (100)	27,000	100	100
Carbamazepine (5)	416	36	100
Atenolol (5)	1310	45	92
Iohexal (10)	4780	45	100

Oppenheimer et al. "Occurrence and suitability of sucralose as an indicator compound of wastewater loading to surface waters in urbanized regions", Water Research 45:2011:4019-4027.

Sucralose Presence in Reuse Effluent Independent of Treatment



Marker Data in Sources

Compound	Reuse Water (n=8)	Septic Tank* (n=8)	Rain-water
Sucralose	29,000 ± 6,000	40,000 ± 24,700	<100
Carbamazepine	230 ± 8	16 ± 20	<5
Atenolol	1,300 ± 880	8.1 ± 6.3	<5
Iohexol	5,400 ± 3500	<10 ± 0.7	<5
Galaxolide	1,000 ± 300	2,700 ± 2,700	<5
Gd Anomaly	30 ± 14	1.5 ± 1.3	1.1

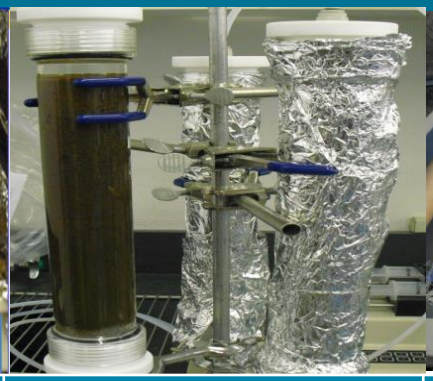
* Units are in ng/L and only 4 samples for carbamazepine, atenolol, and iohexol in reuse water

8 Florida Septic System Marker Levels

Sucralose (ng/L)	Carbamazepine (ng/L)	Gadolinium Anomaly* (ng/L)
69,000	<5	0
40,000	40	4
80,000	<5	0
42,000	<5	3
24,000	55	1
40,000	<5	1
12,000	<5	1
12,000	<5	2

***Ranged from 17 to 139 in 12 water reuse effluent samples**

Fate Behavior from Bench-scale Experiments




Compound	Adsorption	Biodegradation	Photodegradation
Atenolol	Yes	Yes	Yes
Carbamazepine	No	No	Yes
Gadolinium	Yes	No	No
Galaxolide	Yes	No data	No data
Iohexal	No	No	Yes
Sucralose	No	No	No

Yes = >10% adsorption, >15% biodegradation, >10% photolysis

Field Sampling Results

Detailed Approach and Findings

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Marker Occurrence and Fate in the Environment

- Assess marker presence and concentrations in reuse effluent and other sources
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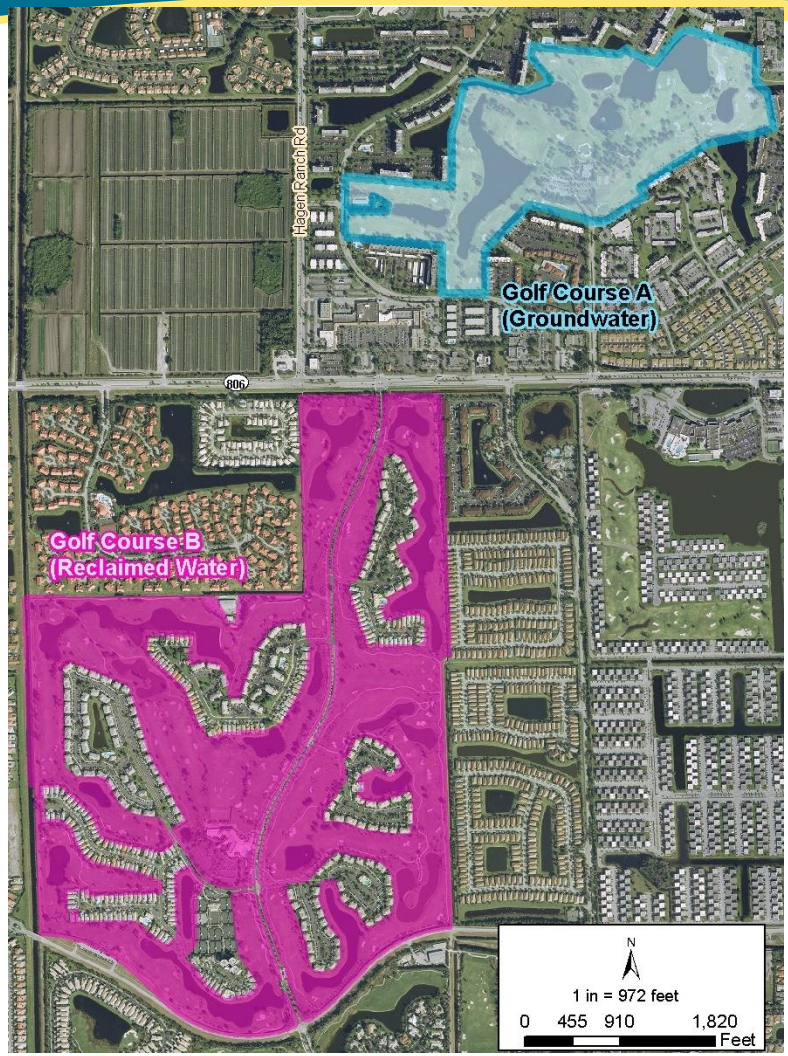
Positive and Negative Site Control Studies

- **Assess marker and nutrient differences at golf courses irrigating with reclaimed water and groundwater**
- **Assess capability to distinguish reuse effluent from stormwater and septic infiltration**

Field Sampling Event : Golf Courses

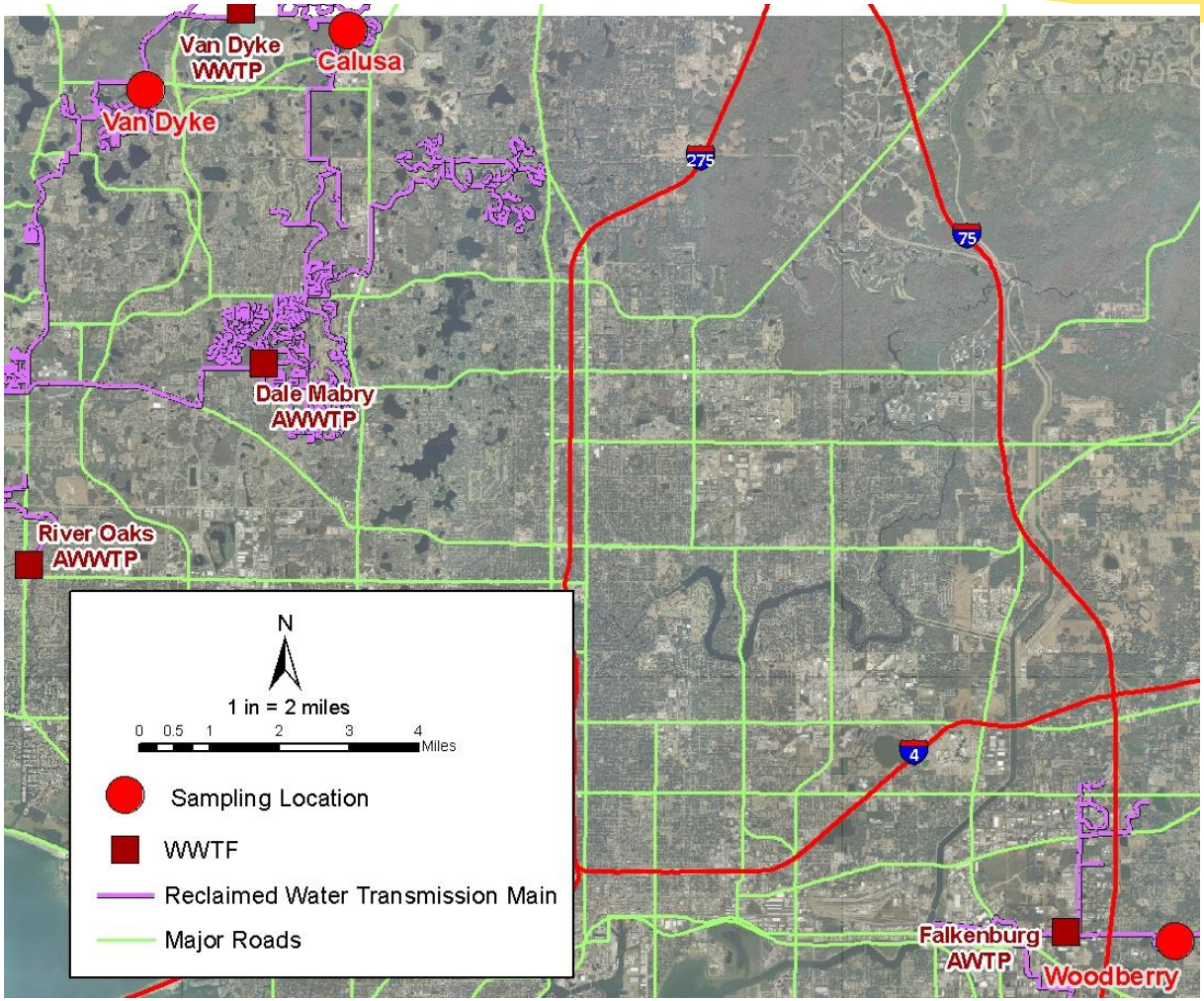


- Sampled stormwater runoff and stormwater ponds from two golf courses
  - Golf Course A: Groundwater Irrigation
  - Golf Course B: Reclaimed Water
- Controlled irrigation
- Both golf courses apply fertilizer
- Samples obtained after rain event from:
  - Water used for irrigation (end of pipe)
  - Stormwater runoff
  - Stormwater pond

Marker Values at PBC Golf Courses Irrigating with Reclaimed Effluent & Groundwater

Marker	Rainfall	Reclaimed Effluent Source	Ground Water Source	Reclaimed Effluent Runoff	Ground Water Runoff
δC13 ($^{o}/_{oo}$)	-22.76	-31.19	-24.05	-20.28	-19.93
Sucralose (ng/L)	<100	14,000	<100	1,100	<100
Carbamazepine (ng/L)	<5	160	<5	33	<5
Atenolol (ng/L)	<5	290	<5	<5	<5
Iohexal (ng/L)	<5	<5	<5	<5	<5
Galaxolide (ng/L)	<5	3800	<5	<5	<5
Gd Anomaly (ng/L)	1.1	68	2	29	3.5

Field Sampling Event: Retention Ponds RW



- Objective: Evaluate level of markers and nutrients in retention ponds located in residential areas irrigating with reclaimed water
- Uncontrolled irrigation
- Wastewater treated to advance waste treatment levels - 5/5/3/1 mg/L (BOD_5/SS/TN/TP)
- No septic influence

Field Sampling Event: Retention Ponds RW

Compound	Units	Woodberry	Calusa	Van Dyke
Total Nitrogen[1]	mg/L	2.9	0.74	0.84
Total-P	mg/L	0.26	0.1	0.027
Sucralose	ng/L	3,300	4,400	5,500
Gd Anomaly	ng/L	2	4	3
Carbamazepine	ng/L	5.3	7.8	5.3
Iohexol	ng/L	<PQL	28	<PQL
Atenolol	ng/L	29	21	14

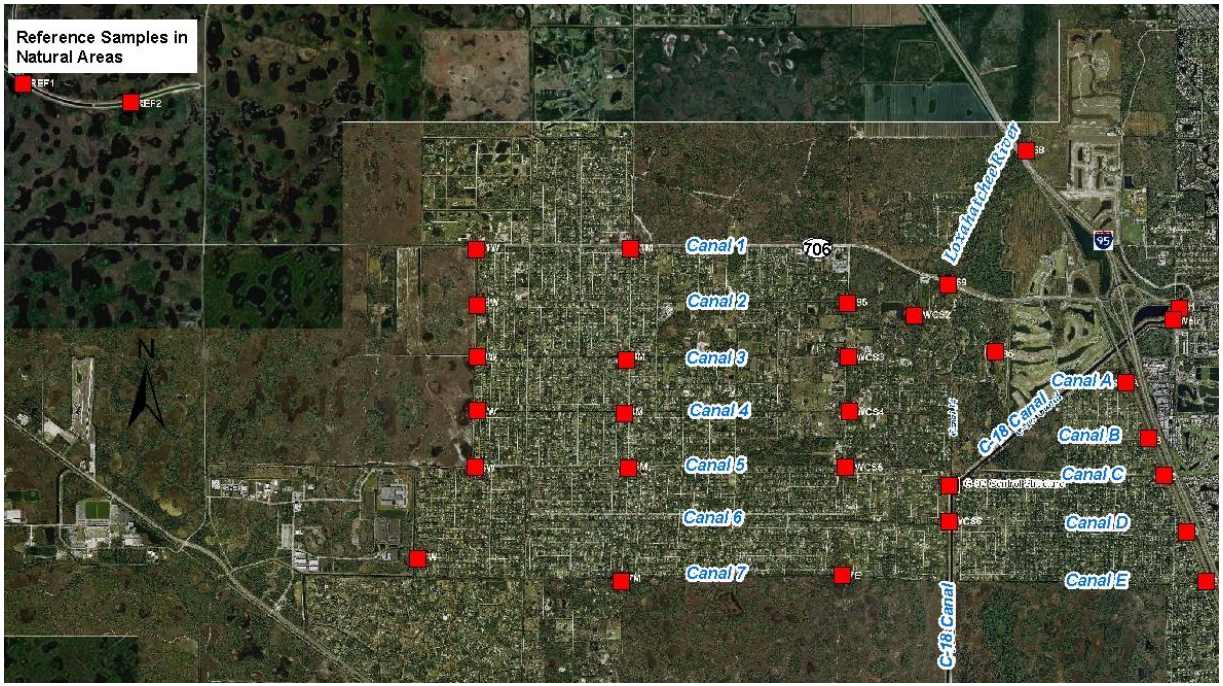
[1] Total nitrogen was present as organic nitrogen at all sites with exception of Woodberry which had 0.61 mg/L of ammonia

Distinguishing Reuse from Stormwater

Site Type	Sucralose (ng/L)	Carbamazepine (ng/L)
SW Retention Pond (n=3)	ND*	ND
Irrigation Collection Pond (n=3)	3300-5500	5.3 – 7.8

*One detect @ 150 ng/L

Field Sampling Event: Canals/Septic



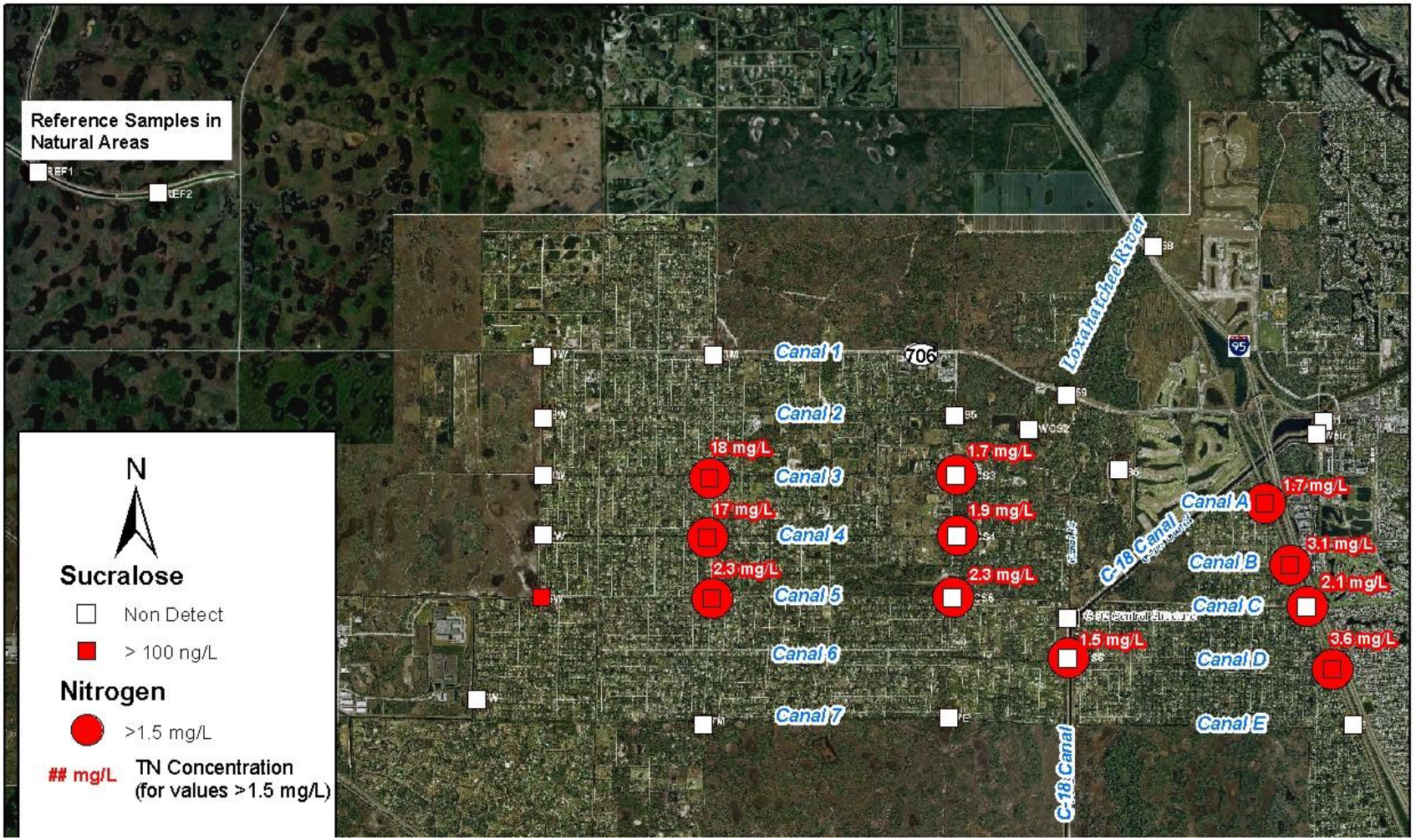
- Objective: Assess the presence of markers and nutrients in canals adjacent to areas with septic systems.
- Canals discharge into the Loxahatchee River, Florida's only Wild and Scenic River
- 29 sample locations plus two reference points located in a non-urbanized area
- Samples taken during Florida's dry and wet seasons

Field Sampling Result: Canals/Septic

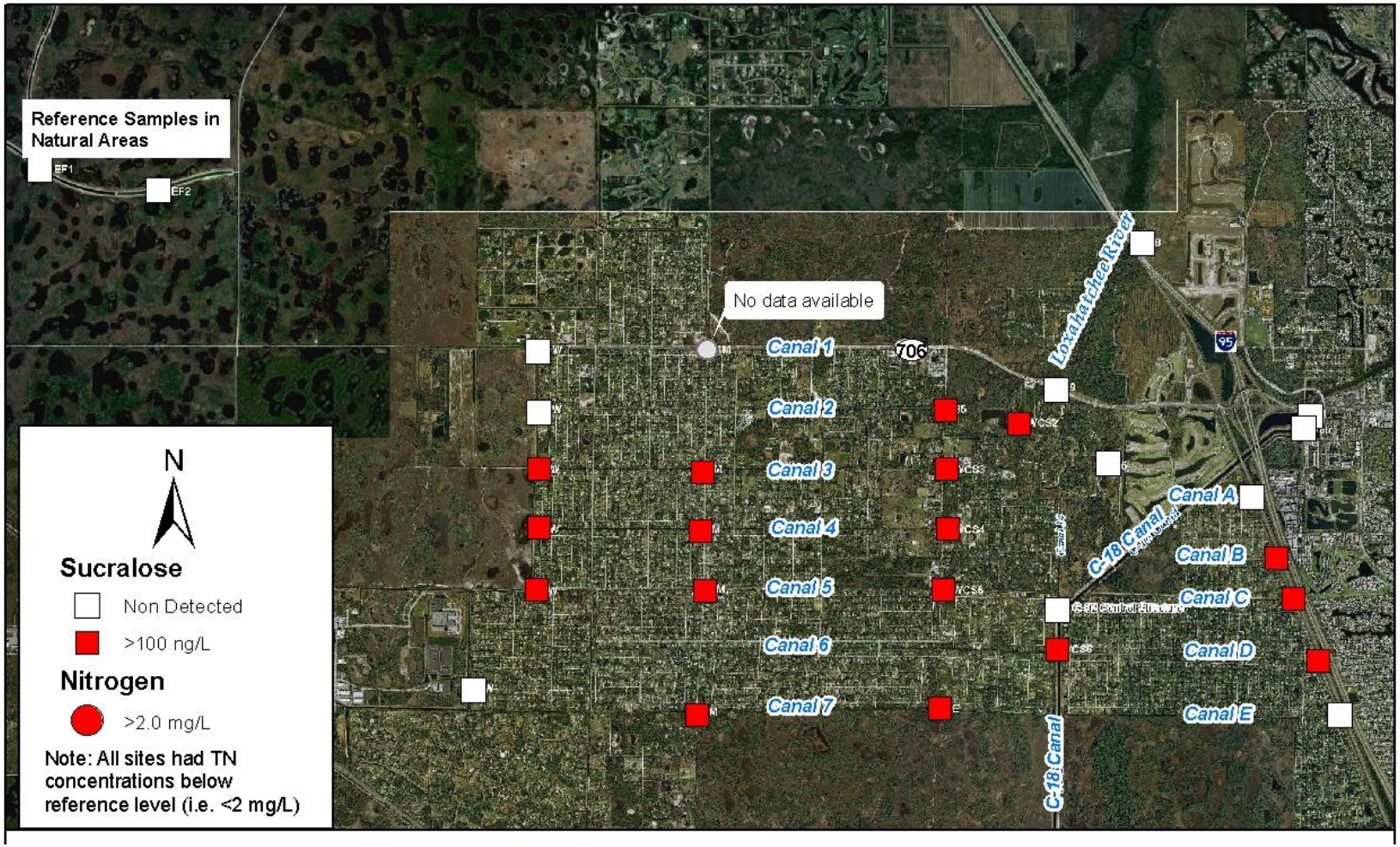
Compound	Units	Septic System	Canals Dry Season	Canals Wet Season
Total Nitrogen	mg/L	32 -130	0.67 - 18	0.74 - 1.84
Total Phosphorus	mg/L	5.3 -15	0.012 - 1.7	0.012 - 0.16
Sucralose	ng/L	40,000 - 80,000	ND[1] - 750	ND[1] - 310

[1]ND=non- detect; however sucralose was found in all samples except the 2 reference locations when levels between the MDL and PQL were included.

Presence of Sucralose in Loxahatchee Canals (Dry Season)



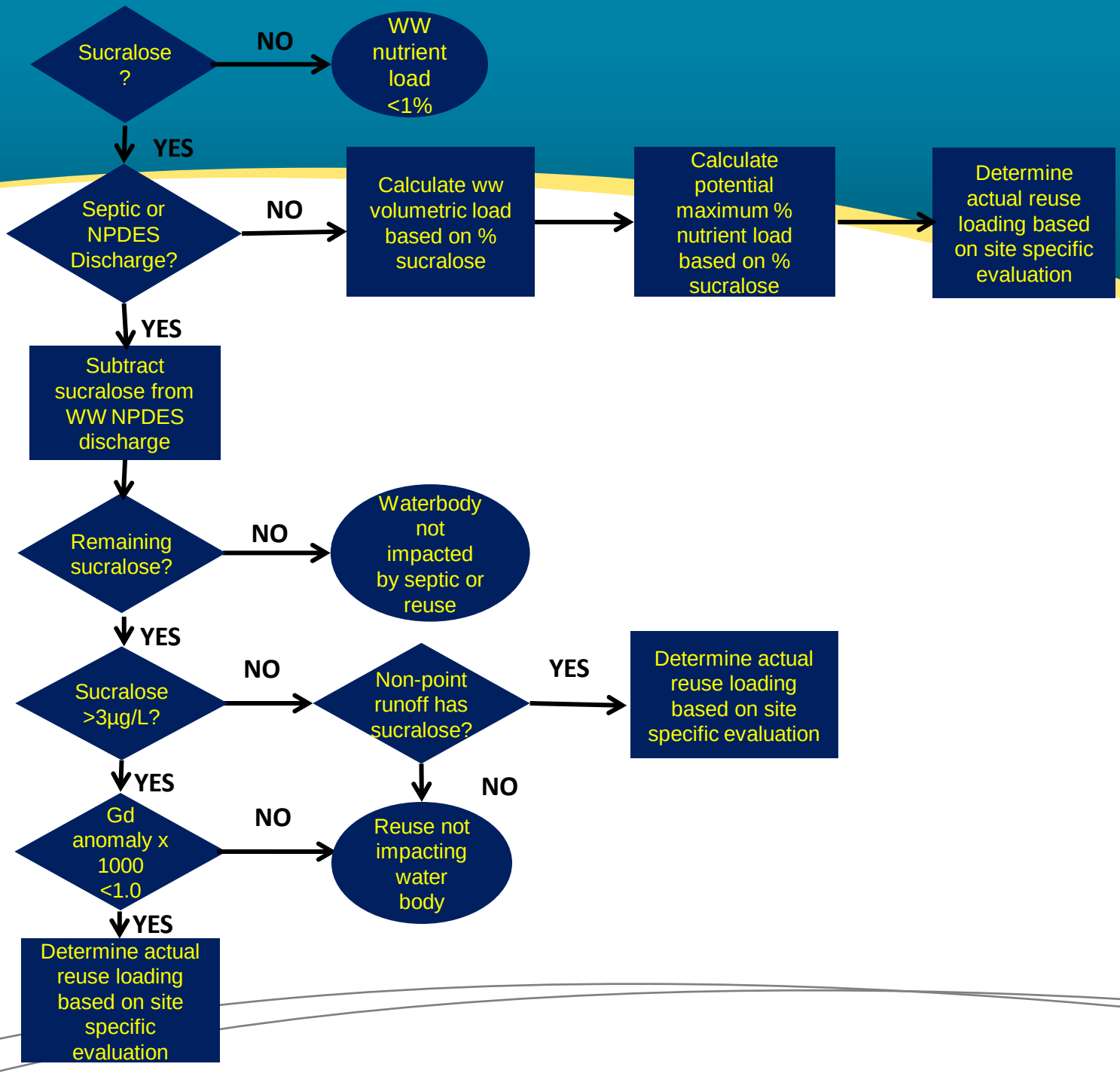
Presence of Sucralose in Loxahatchee Canals (Wet Season)



Study Conclusions

Study Conclusions

1) Identified sucralose as a master diagnostic tool to distinguish wastewater derived nonpoint sources
2) Absence of sucralose indicates <1% loading
3) Sucralose concentration estimates wastewater load fraction in receiving water
4) Secondary microconstituents can be developed to utilize in tandem with sucralose in order to differentiate between septic and reuse sources of wastewater derived nonpoint loading

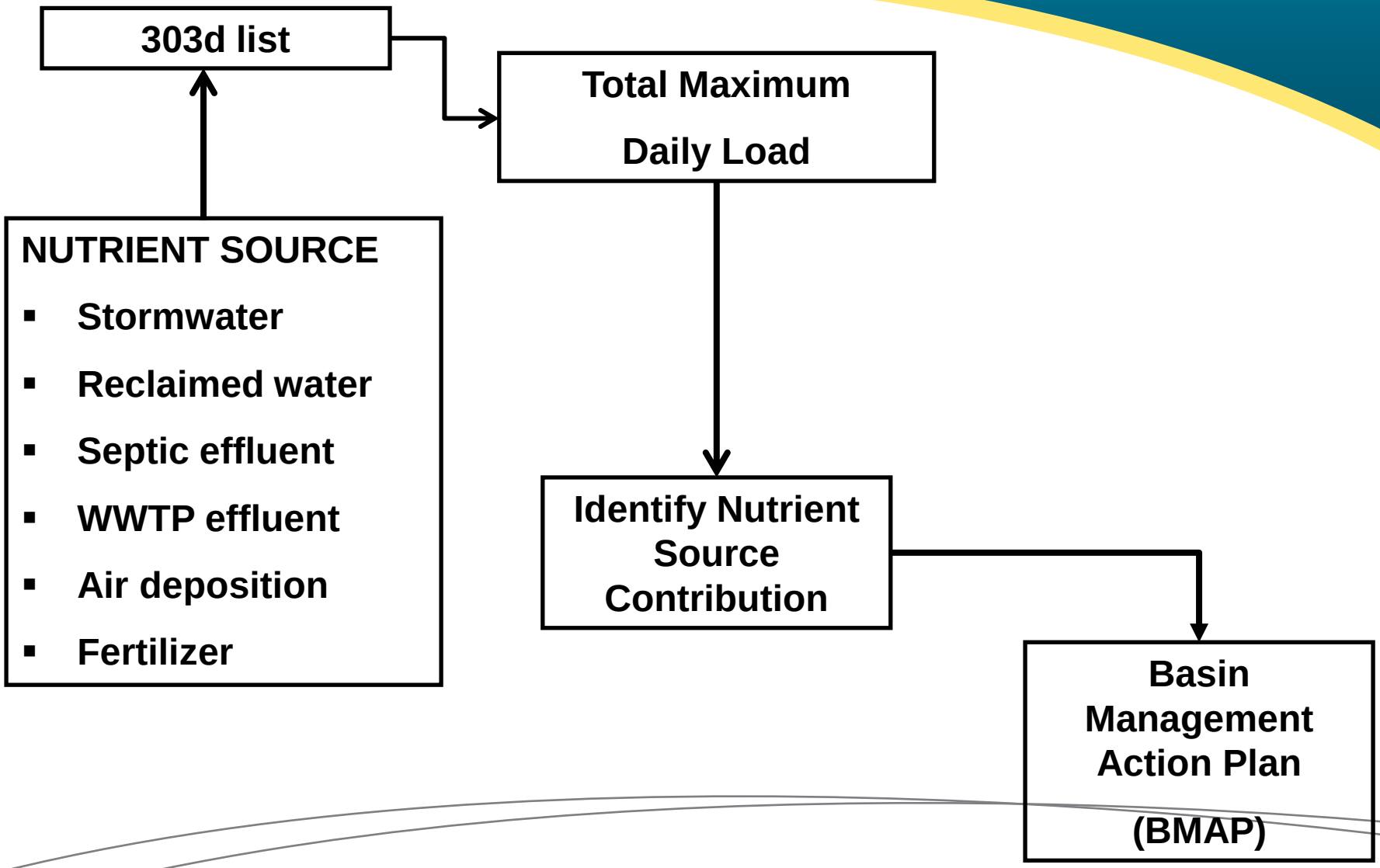

Sucralose ?
NO
WW nutrient load <1%
YES
Septic or NPDES Discharge?
NO
Calculate ww volumetric load based on % sucralose
Calculate potential maximum % nutrient load based on % sucralose
Determine actual reuse loading based on site specific evaluation
YES
Subtract sucralose from WW NPDES discharge
Remaining sucralose?
NO
Waterbody not impacted by septic or reuse
YES
Sucralose >3µg/L?
NO
Non-point runoff has sucralose?
YES
Determine actual reuse loading based on site specific evaluation
NO
YES
Gd anomaly x 1000 <1.0
NO
Reuse not impacting water body
YES
Determine actual reuse loading based on site specific evaluation

Next Phase

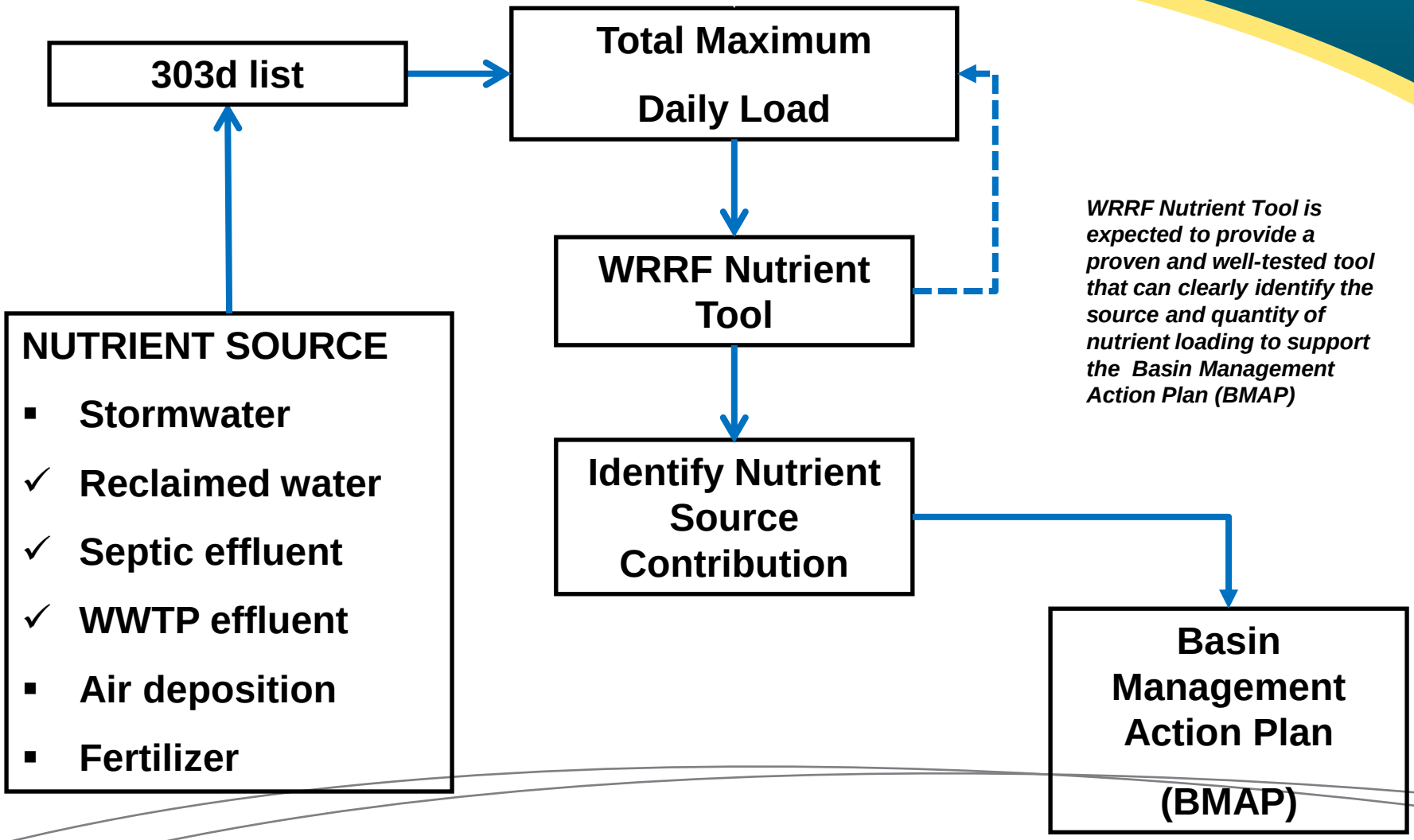
Assessment of Nutrient Impaired Water Bodies

- Conduct survey of representative statewide nutrient impaired water bodies to assess wastewater loading impacts by:
  - Analyzing for presence of sucralose
  - Analyzing additional markers as sucralose ratios in order to identify presence of septic loading
  - Interpret data findings as approximate relative percentages of wastewater and septic source loading
  - Translate each source load to a worst-case nutrient load estimate
- Establish links between water quality models and proven markers

TMDL Process



WRRF Nutrient Tool in TMDL Process



WRRF Nutrient Tool is expected to provide a proven and well-tested tool that can clearly identify the source and quantity of nutrient loading to support the Basin Management Action Plan (BMAP)

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