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Optimization Analysis of the City of Lakeland's Street Sweeping Program

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Stormwater Conference
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Chattanooga, TN

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Example of Vacuum Street Sweeper Truck

(Source: https://medium.com/@Haaker/why-construction-firms-should-get-vacuum-trucks-andstreet-sweepers-for-sale-8e2fda01ded0)

Background - Definitions

Streeping (or to streep)

The act of removing debris from streets using various types of sweeping technologies.

https://www.worldsweeper.com/History/AustinWestern.html

Background

- Why is Street Sweeping Done
  - Aesthetics
  - Maintenance
  - Pollutant Removal
  - Nutrient Reduction
  - Help NPDES Permit Compliance
  - Help Meet TMDL Goals

Background

- Florida FDEP provides pollutant removal credit through NPDES permit reporting of street sweeping mass collected
- Florida Stormwater Association (FSA) funded a UF study in 2011 to develop statewide values of nutrient concentrations to be used in calculating load reductions
  - Examined the nutrient removal benefit of street sweeping
  - Sampled 14 different MS4s across the state
  - Developed collection rate data
  - Developed nutrient content data
  - Statewide median values recommended

QUANTIFYING NUTRIENT LOADS ASSOCIATED WITH URBAN PARTICULATE MATTER (PM), AND BIOGENIC/LITTER RECOVERY THROUGH CURRENT MS4 SOURCE CONTROL AND MAINTENANCE PRACTICES

(Maintenance Matters !)

Final Report

To

Florida Stormwater Association Educational Foundation (FSAEF)

University of Florida (UF)
College of Engineering
Engineering School of Sustainable Infrastructure and Environment (ESSIE)
Gainesville, Florida 32611 USA

Christian Berretta, UF
Saurabh Raje, UF
John J. Sansalone, UF (Principal Investigator)

Draft Report: 21 February 2011
Draft Final Report Revised: 27 April 2011

Final Report: 31 May 2011

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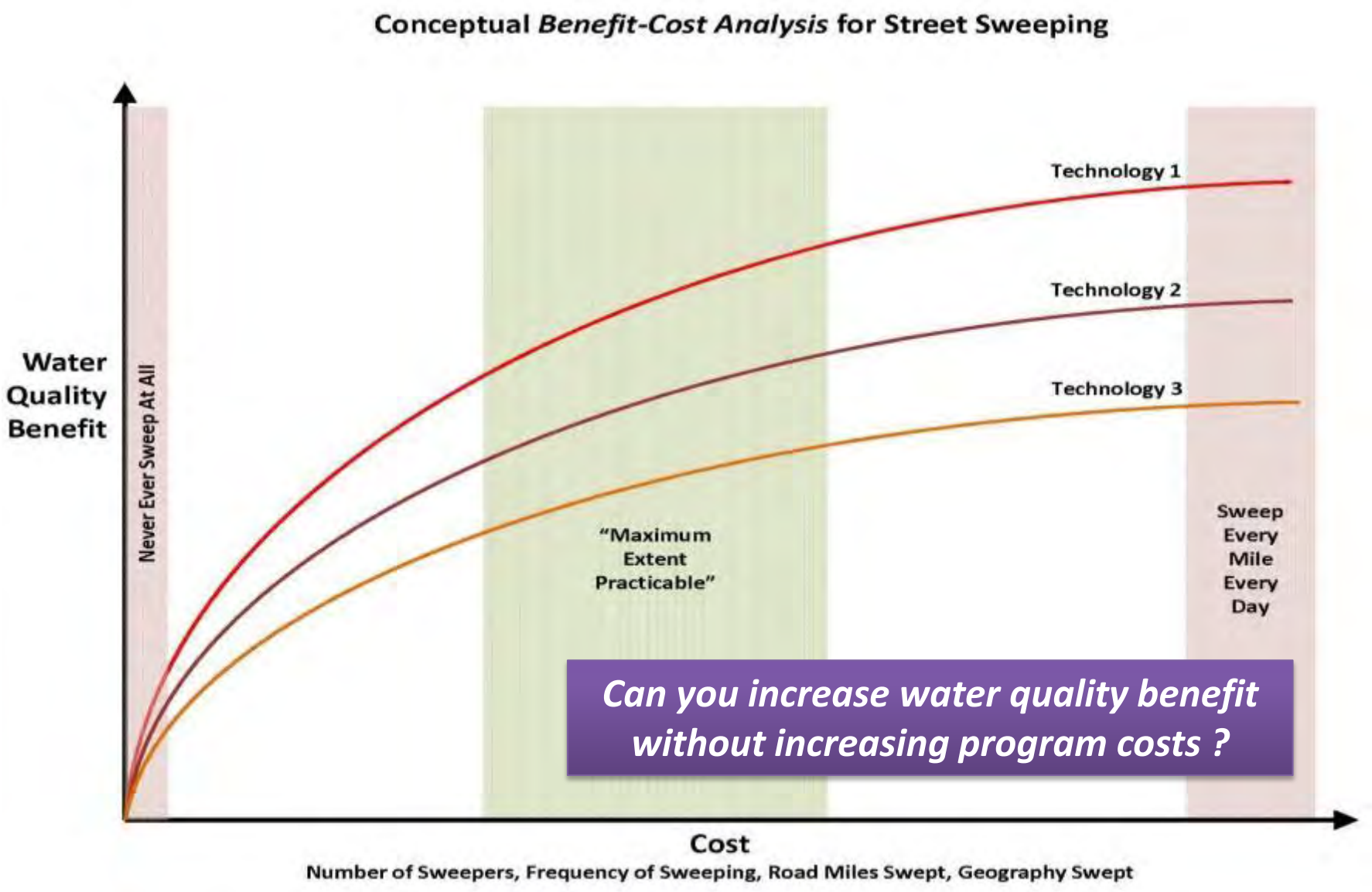
The more street sweeping debris mass you remove the more credit you get…

Background

So the more street sweeping debris mass you remove the more credit you get…

- Motivation for municipalities to look for ways to collect more street sweeping debris
- Questions to ask when concerned about nutrient reduction:
  - Are we sweeping enough ?
  - Are we sweeping the right areas ?
  - Are we sweeping the areas with the most debris ?
  - Is the nutrient content of our street sweeping debris higher than statewide averages ?
  - Is the nutrient content of street sweeping debris higher in some areas than others ?
  - What characteristics impact the nutrient content of street debris ?
  - Is our tracking system accurately reporting mass?
- Need for Program Optimization

Background – Why Optimize Your Street Sweeping Program



Can you increase water quality benefit without increasing program costs ?

Lakeland Case Study

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Study Objectives

- Objectives:
  - Evaluate current street sweeping practices and available data to determine if nutrient (TN/TP) removal can be increased by performing additional analysis
    - Proper characterization of street debris nutrient content and mass generation rate for street segments with different characteristics (i.e., tree canopy and land use)
    - Optimize the street sweeping program
      - Frequency analysis
      - Cluster map analysis
      - Route optimization analysis
      - Tracking, data management, and reporting

Study Objectives

- Objectives:
  - Characterize the street debris collected for street segments with different land use and tree canopy characteristics
    - Organic vs Inorganic
    - Nutrient content
  - Evaluate and optimize the street sweeping practices in the City of Lakeland
    - Streets currently being swept (all public curbed streets)
    - Divided into several zones

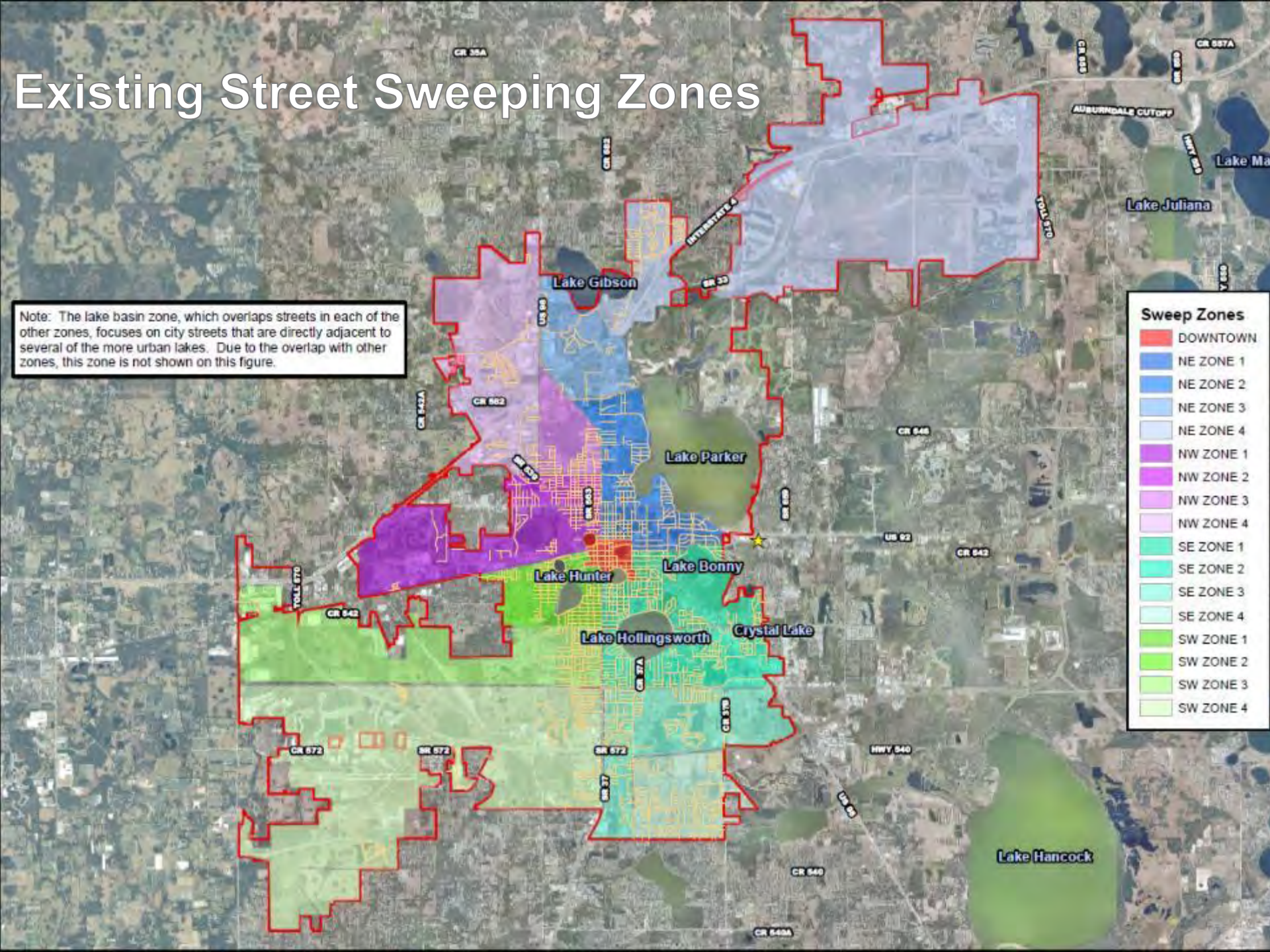
City Characteristics

- Relevant Spatial Characteristics
  - Topography – to understand water movement
  - Drainage Infrastructure – to understand water movement
  - Land Use – Different land uses have different pollutant loading potential
  - Soils – Impact runoff potential and erosion potential
  - Impaired Waters – Target areas for load reduction
  - Contributing Areas – Detailed drainage patterns
  - Reclaimed Water Infrastructure – to understand where it is used and potential impact
  - Tree Canopy – Quantify where high tree canopy covers streets which contribute to debris generation

Program Benefit Evaluation

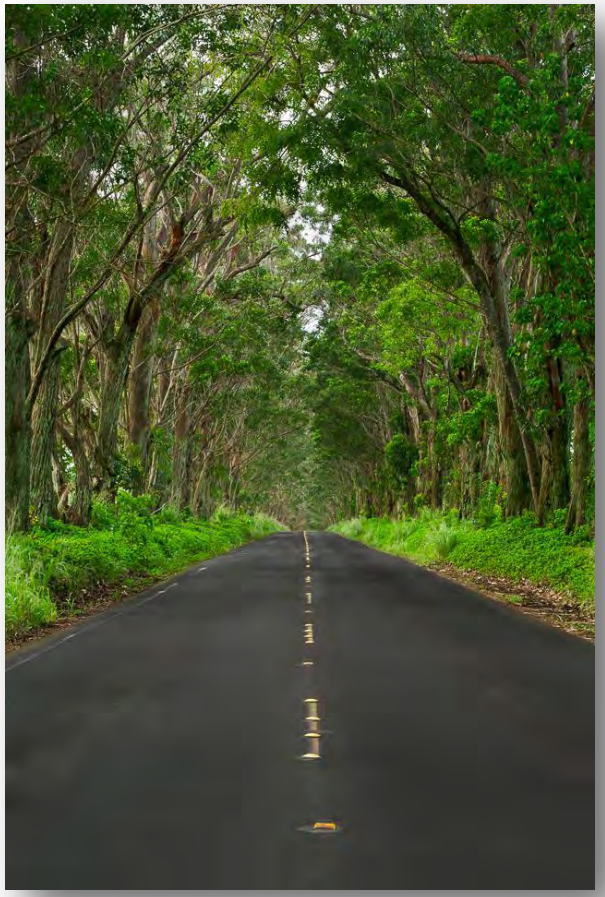
- Potential Optimization Benefits
  - Nutrient Characterization – Nutrient content and generation rates vary widely across the state
    - Thorough characterization of data could result in significant increases in nutrient removal credit
  - Frequency Optimization – Current sweeping frequencies could be optimized to sweep some zones more frequently and others less
    - Results of other studies show that this could result in significant increases in the nutrient content of collected street debris
  - Zone Optimization – Grouping street segments into new zones based on similar characteristics
    - New zones would be optimized relative to frequency based on score of each zone
  - Seasonal Optimization – Sweeping street segments with high tree canopy more frequently during periods of high leaf drop
    - Results from other studies show that this could result in significant increases in both the mass of street debris collected and the nutrient content of that collected
  - Enhanced Tracking and Reporting – Develop methods to more efficiently track sweepers and report mass removals

Existing Street Sweeping Zones



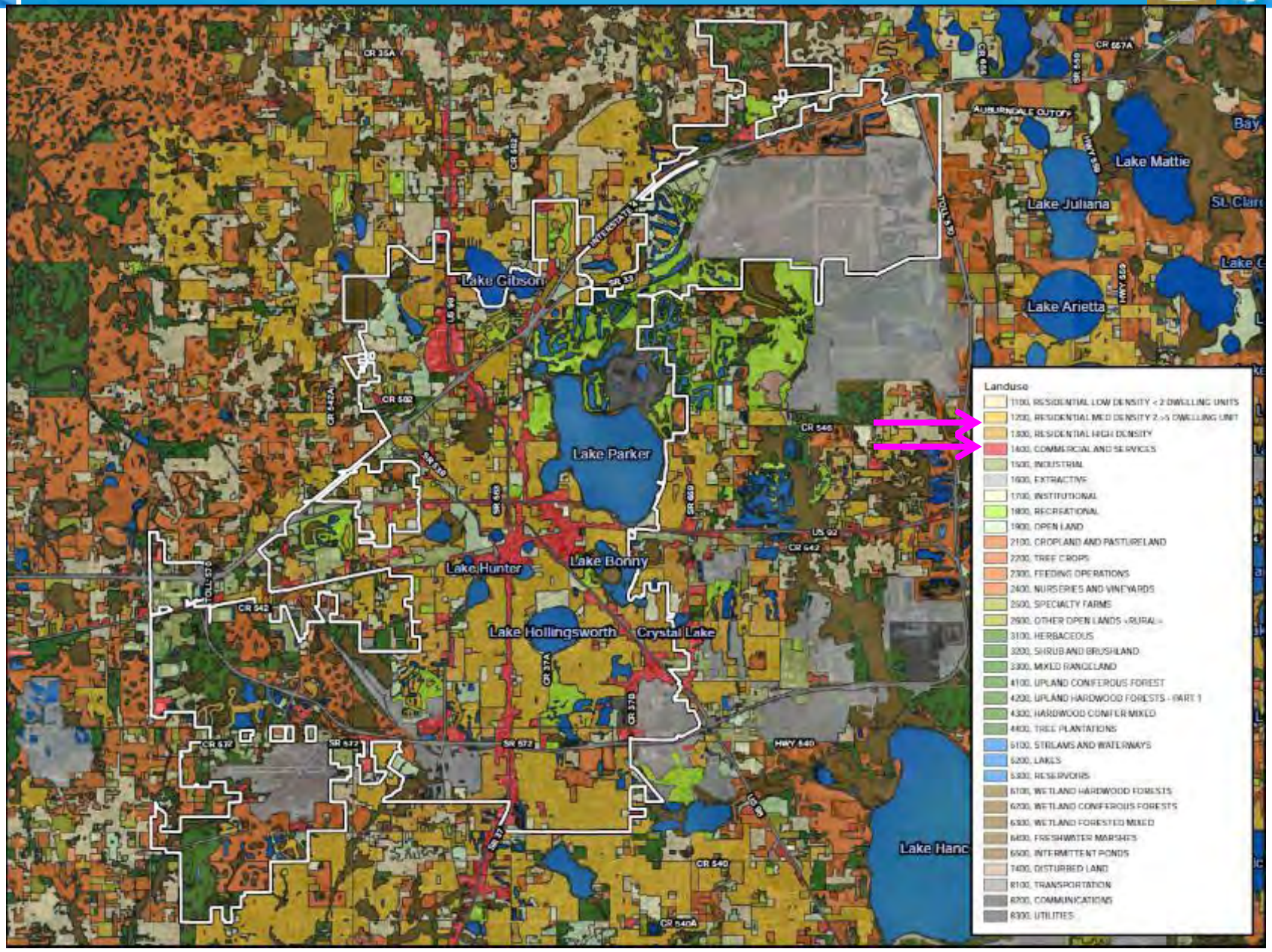
Variables of Interest

- Several variables were identified as potentially impacting the nutrient content of street debris
  - Land use (limited to areas currently being swept by the City)
    - Residential
    - Commercial
  - Tree Cover (assessed using the 2011 NLCD tree canopy raster)
    - High cover – typically associated with residential areas
    - Low cover – typically associated with commercial areas
  - Seasonality
    - Normal conditions
    - High leaf drop conditions

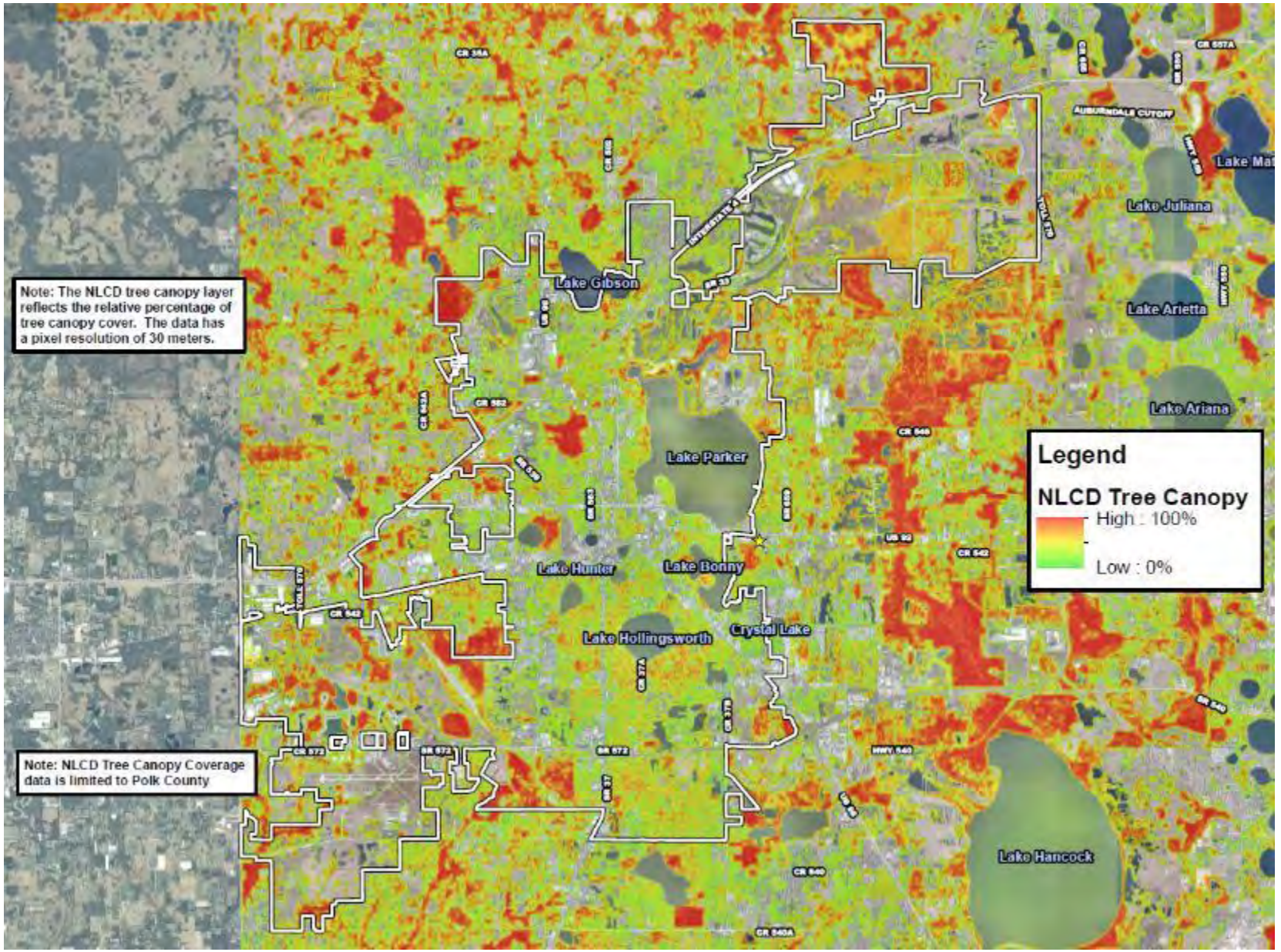


http://www.ianmcgillvrey.com/items/kauai-maluhia-road-tree-tunnel/

Variables of Interest – Land Use



Variables of Interest – Tree Cover



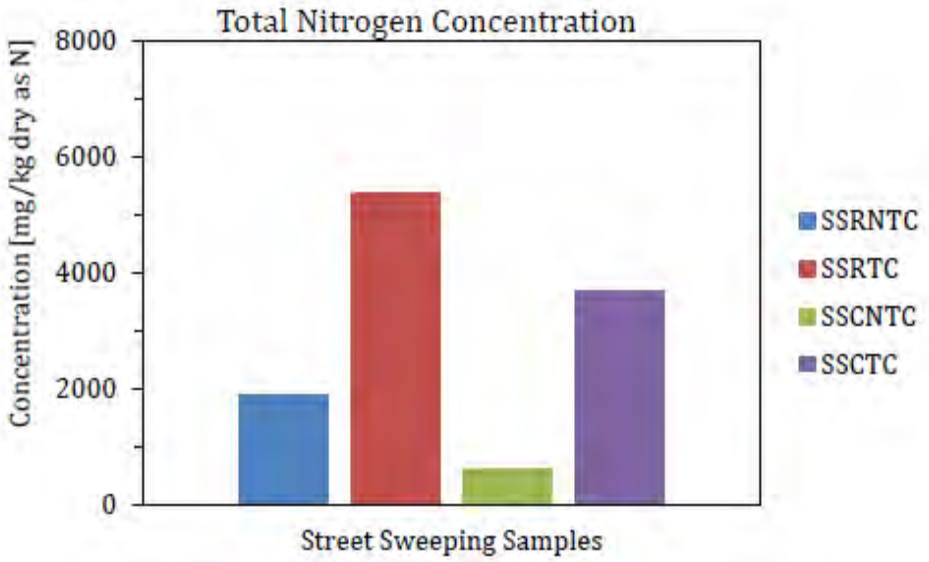
Sampling

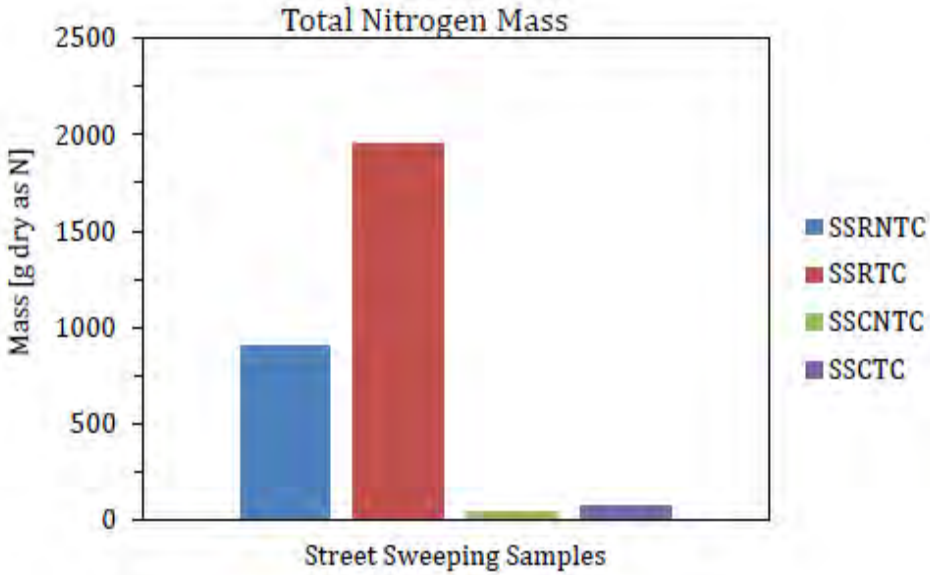
- Sampling was performed to evaluate the collected street debris for the following parameters
  - Phosphorus – TP and OP
  - Nitrogen – TN TKN, NOx, NH_4
  - Solids – TS, TVS
  - Organic content, moisture content, bulk density
  - Particle size
  - Extractable analysis – TN and TP

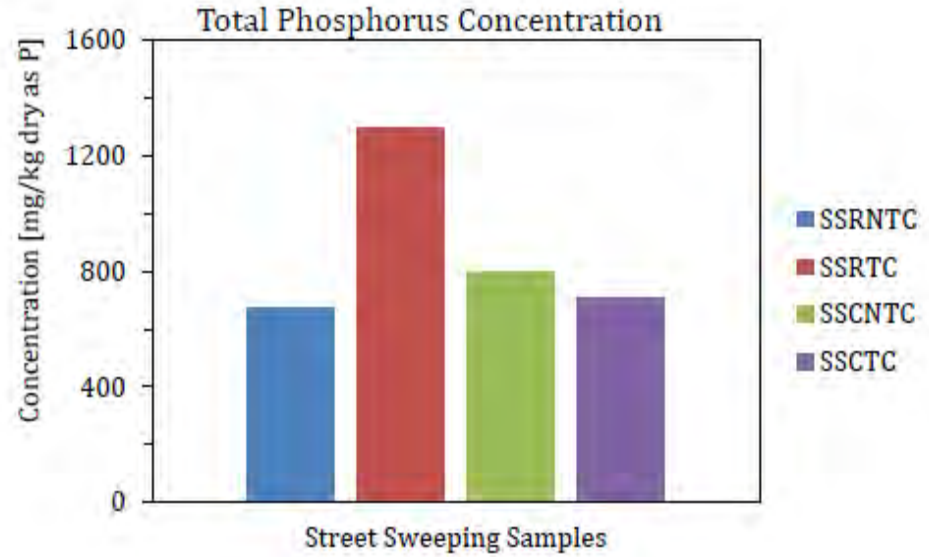
Sampling

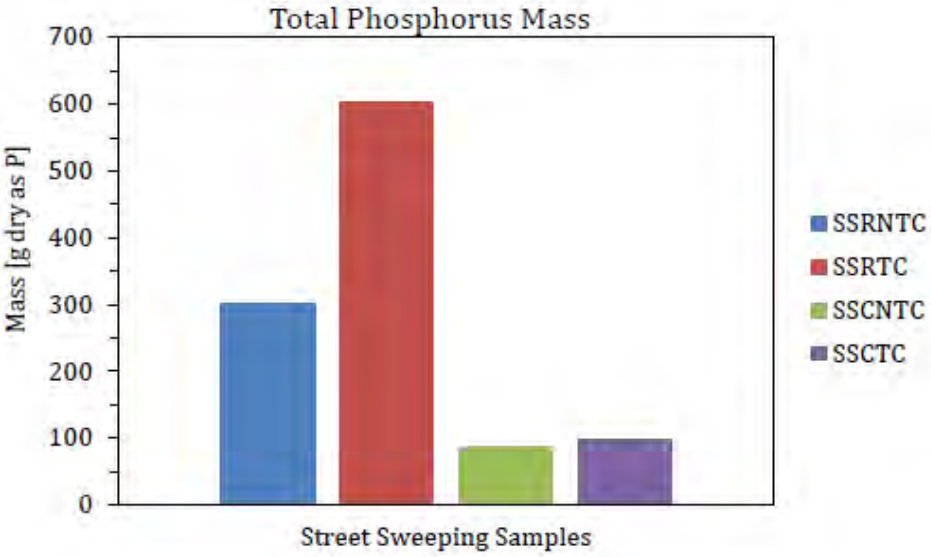
- Total of 12 sampling runs completed (Phase I)
  - 3 sampling runs for each land use and tree cover combination
- Seasonality required an additional 6 runs (Phase II)
  - 3 sampling runs for each land use, ONLY high tree cover was sampled

Results – Phase I Constituent Analysis









Results – Particle Size Analysis

3/8 & 3/4 inch

#4

#60

#100

#10

#40

#200

Fines

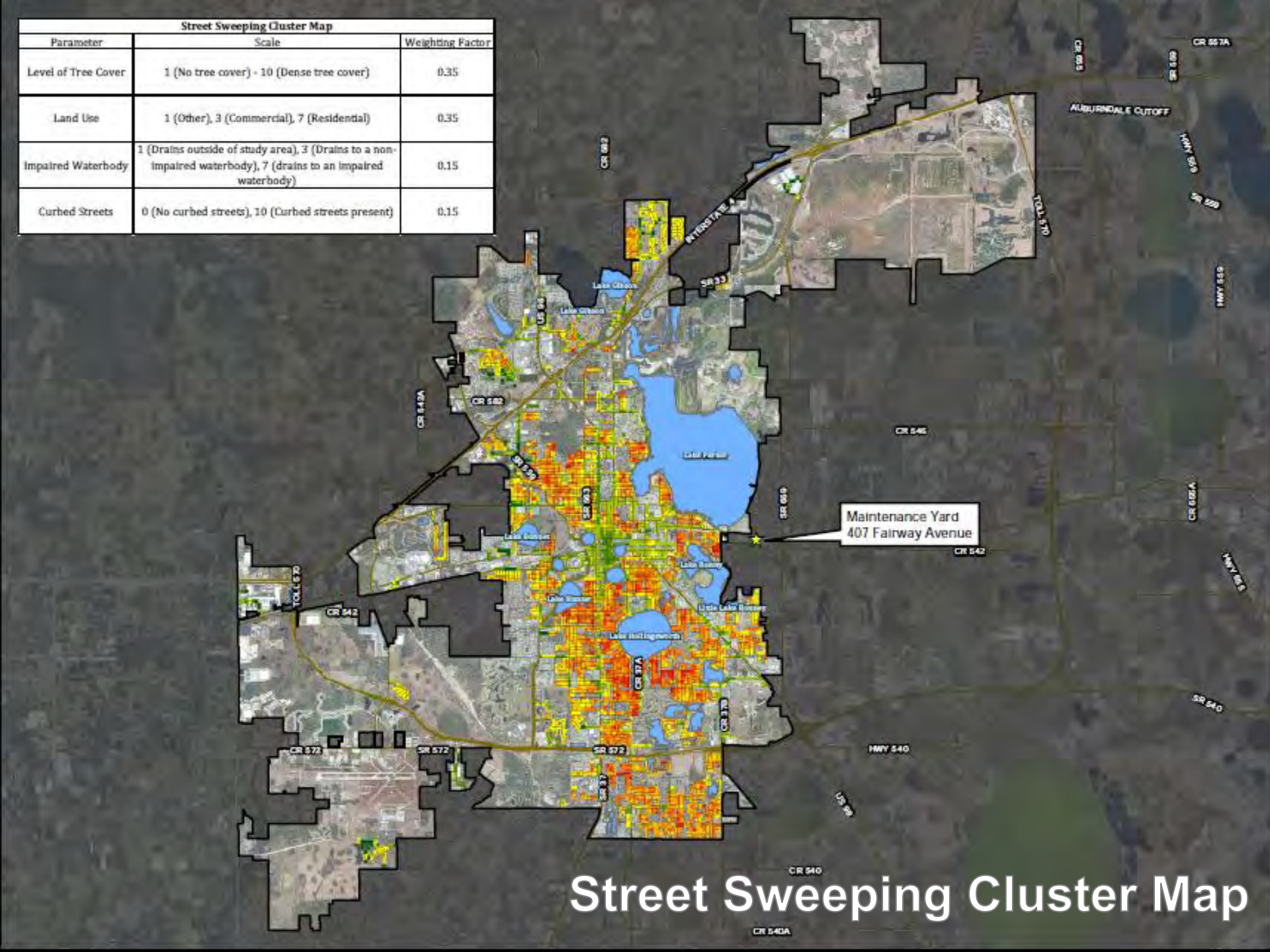
Street Sweeping Optimization

- Utilized cluster map analysis and spreadsheet simulation model
- Evaluated several scenarios
  - Historic NPDES average values
  - Existing practice
  - Alternative 1: Utilizing concentrations observed in the current study
  - Alternative 2: Utilizing concentrations observed in the current study and modified sweeping frequency of existing street sweeping zones
  - Alternative 3: Utilizing concentrations observed in the current study and creation of new, optimized street sweeping zones and sweeping frequency

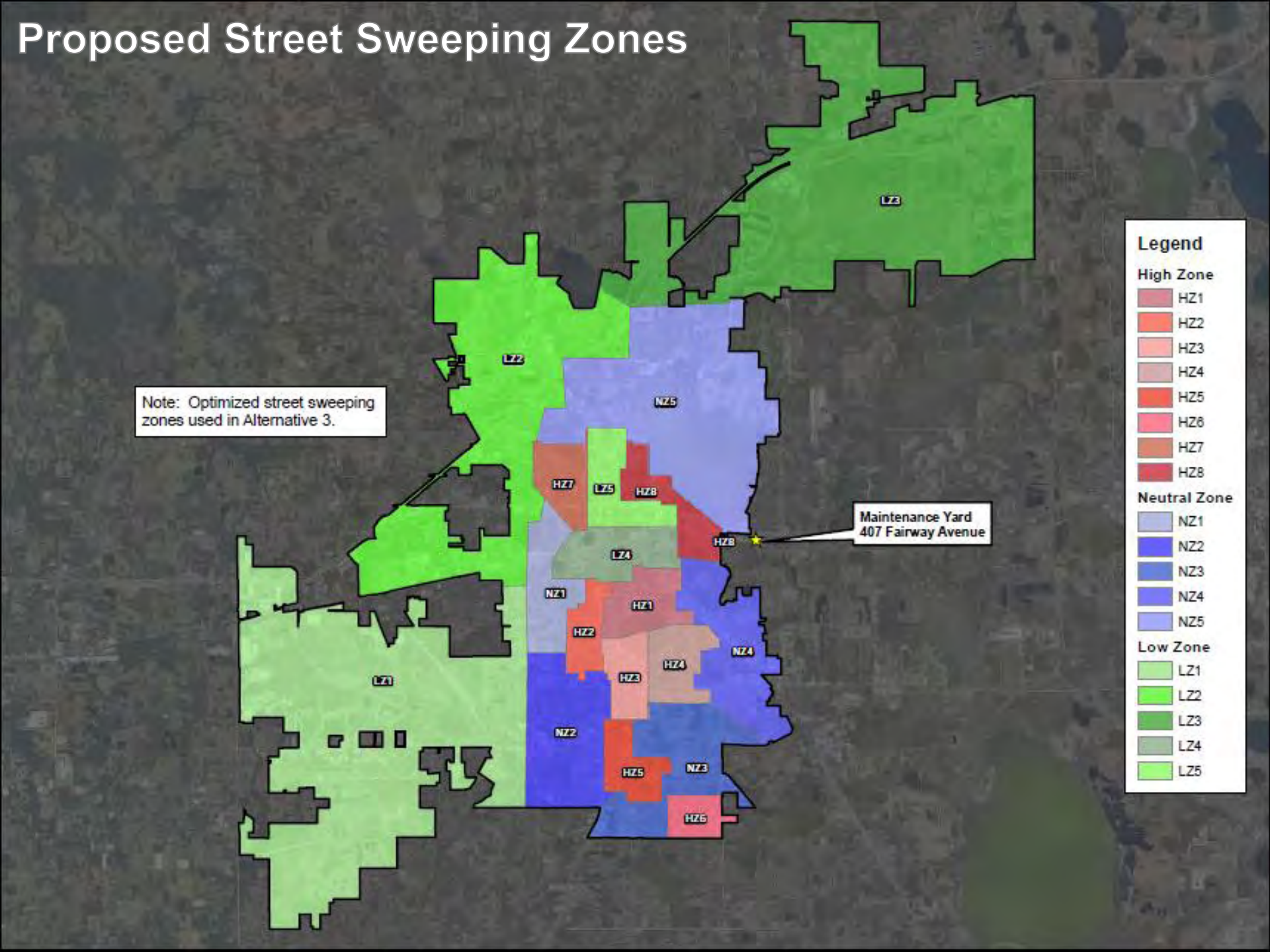
Street Sweeping Optimization

- Cluster map analysis
  - Applied weighting to variables of interest
    - Level of tree canopy
    - Land use type
    - Impaired waterbody
    - Curbed streets
  - Weightings applied spatially and “hot spots” identified
    - New sweeping frequencies of existing zones recommended based on this (Alternative 2)
    - New street sweeping zones and frequencies recommended based on this (Alternative 3)

Street Sweeping Cluster Map		
Parameter	Scale	Weighting Factor
Level of Tree Cover	1 (No tree cover) - 10 (Dense tree cover)	0.35
Land Use	1 (Other), 3 (Commercial), 7 (Residential)	0.35
Impaired Waterbody	1 (Drains outside of study area), 3 (Drains to a non-impaired waterbody), 7 (drains to an impaired waterbody)	0.15
Curbed Streets	0 (No curbed streets), 10 (Curbed streets present)	0.15



Proposed Street Sweeping Zones

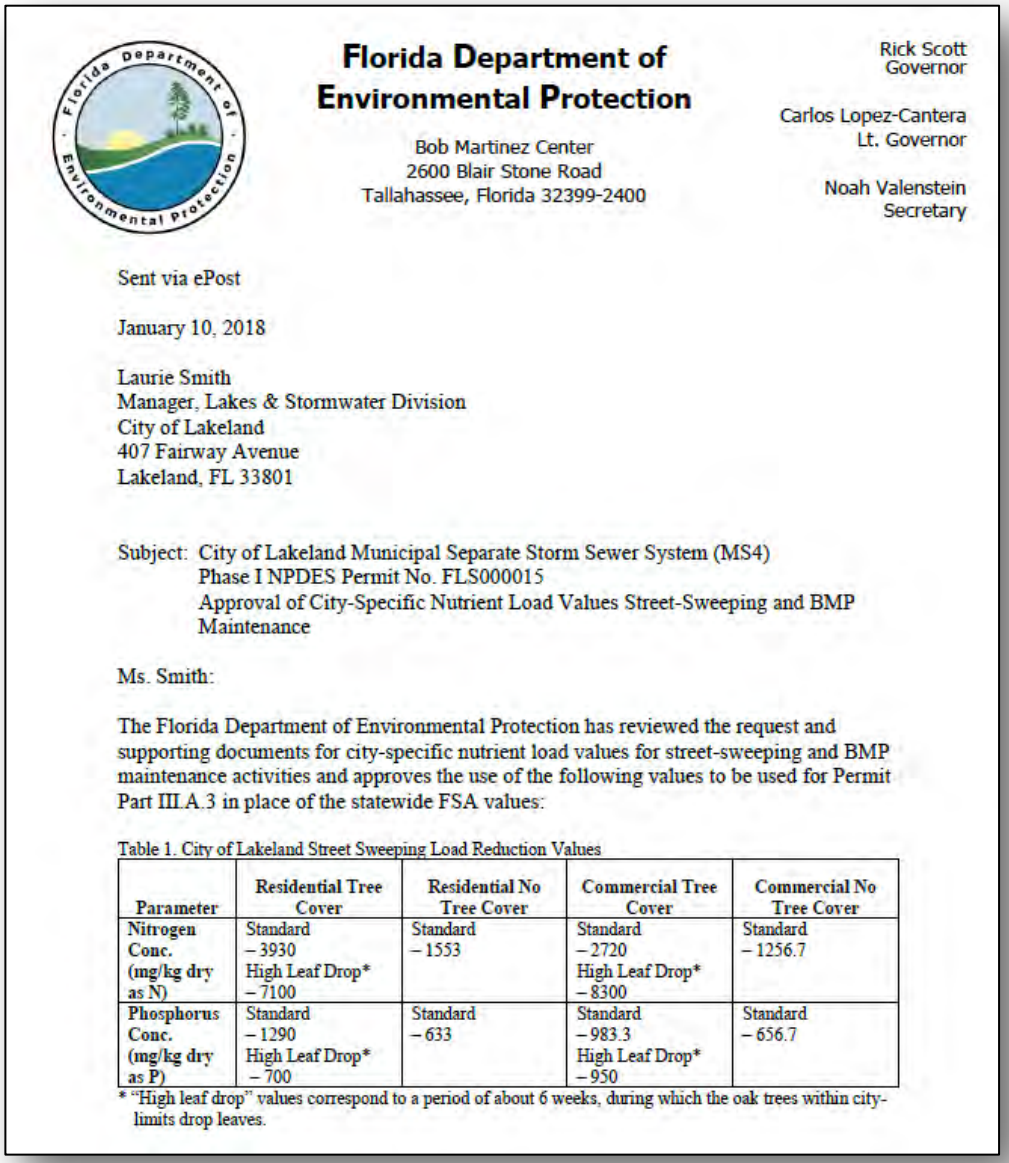


Street Sweeping Optimization

Scenario	Cost ($)	Curb Miles Swept (mi)	Mass of Street Debris Collected (lb)	TN (lb)	TP (lb)	TN ($/lb)	TP ($/lb)	TN (lb/$1000)	TP (lb/$1000)
NPDES	689,779	16,584	3,544,577	2578	1335	267.58	516.81	3.74	1.93
Existing	689,779	16,584	3,274,021	2501	1231	275.81	560.37	3.63	1.78
Alternative 1	689,779	16,584	3,271,511	6908	2508	99.85	275.04	10.02	3.64
Alternative 2	693,027	16,662	3,264,861	7110	2541	97.47	272.79	10.26	3.67
Alternative 3	681,164	16,377	3,252,778	7211	2553	94.47	266.79	10.59	3.75

Outcome

- Lakeland received approval from FDEP to use site specific nutrient concentration data in future NPDES reporting.



Florida Department of Environmental Protection

Bob Martinez Center
2600 Blair Stone Road
Tallahassee, Florida 32399-2400

Rick Scott
Governor

Carlos Lopez-Cantera
Lt. Governor

Noah Valenstein
Secretary

Sent via ePost

January 10, 2018

Laurie Smith
Manager, Lakes & Stormwater Division
City of Lakeland
407 Fairway Avenue
Lakeland, FL 33801

Subject: City of Lakeland Municipal Separate Storm Sewer System (MS4)
Phase I NPDES Permit No. FLS000015
Approval of City-Specific Nutrient Load Values Street-Sweeping and BMP Maintenance

Ms. Smith:

The Florida Department of Environmental Protection has reviewed the request and supporting documents for city-specific nutrient load values for street-sweeping and BMP maintenance activities and approves the use of the following values to be used for Permit Part III.A.3 in place of the statewide FSA values:

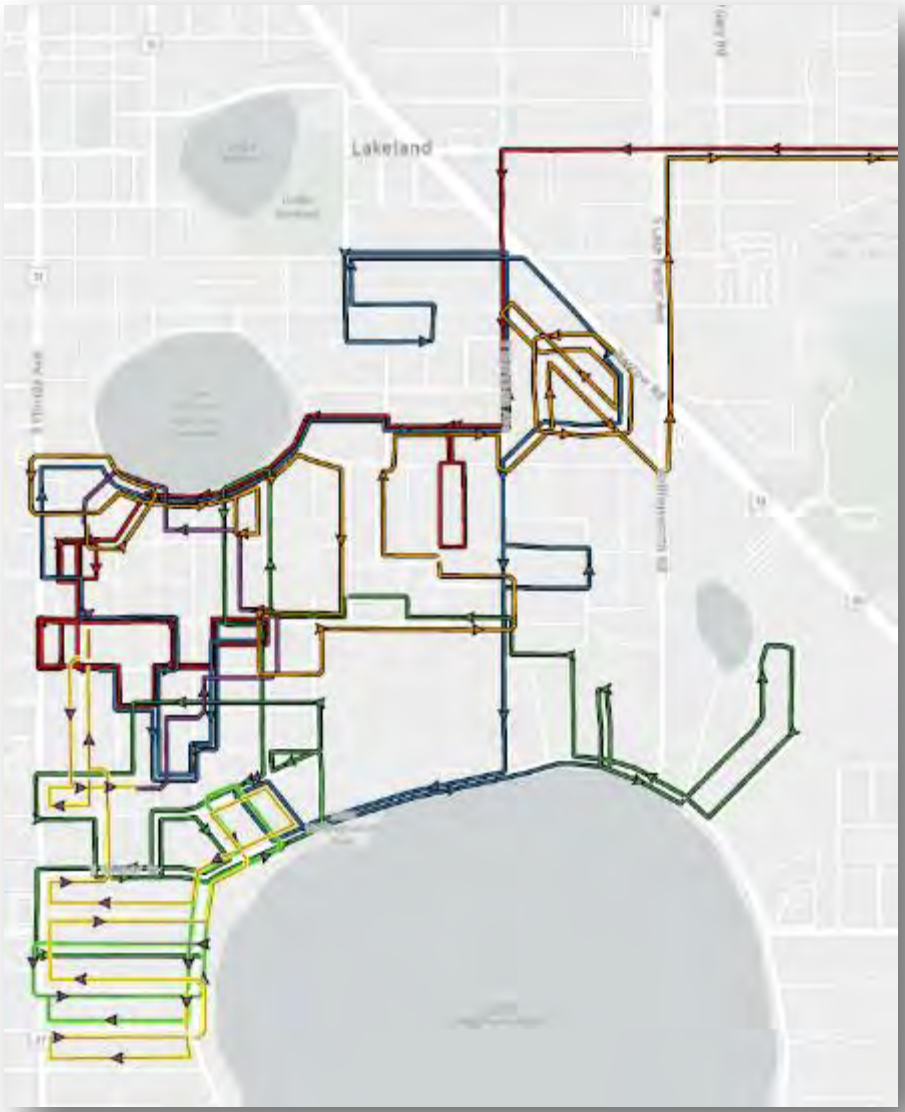
Table 1. City of Lakeland Street Sweeping Load Reduction Values

Parameter	Residential Tree Cover	Residential No Tree Cover	Commercial Tree Cover	Commercial No Tree Cover
Nitrogen Conc. (mg/kg dry as N)	Standard – 3930 High Leaf Drop* – 7100	Standard – 1553	Standard – 2720 High Leaf Drop* – 8300	Standard – 1256.7
Phosphorus Conc. (mg/kg dry as P)	Standard – 1290 High Leaf Drop* – 700	Standard – 633	Standard – 983.3 High Leaf Drop* – 950	Standard – 656.7

* "High leaf drop" values correspond to a period of about 6 weeks, during which the oak trees within city-limits drop leaves.

Route Optimization

- Optimize routes by zones and trips to minimize travel time and save fuel costs
- Spatial and Network Analyst GIS Tools



Data Tracking and Management

- Web based data entry and reporting

Settings

Landuse / Tree Canopy / Frequency Combination	Generation Rate (lb/curb mi)
Residential / High / High	162
Residential / Low / High	158
Residential / High / Medium	263
Residential / Low / Medium	127
Residential / High / Low	318
Residential / Low / Low	162
Commercial / High / High	191
Commercial / Low / High	163
Commercial / High / Medium	86
Commercial / Low / Medium	186
Commercial / High / Low	133
Commercial / Low / Low	210

Landuse / Tree Canopy Combination	Associated TN Conc. (mg/lb)	Associated TP Conc. (mg/lb)
Residential / High	1782	585
Residential / Low	704	287
Commercial / High	1234	446
Commercial / Low	570	298

Landuse / Tree Canopy / Frequency Combination	Generation Rate (lb/curb mi)
Residential / High / High	198
Residential / Low / High	158
Residential / High / Medium	401
Residential / Low / Medium	127
Residential / High / Low	348
Residential / Low / Low	162
Commercial / High / High	206
Commercial / Low / High	163
Commercial / High / Medium	313
Commercial / Low / Medium	186
Commercial / High / Low	203
Commercial / Low / Low	210

Landuse / Tree Canopy Combination	Associated TN Conc. (mg/lb)	Associated TP Conc. (mg/lb)
Residential / High	3220	317
Residential / Low	704	287
Commercial / High	3764	431
Commercial / Low	570	298

Landuse / Tree Canopy Combination	Percent Solids
Residential / High	77.7
Residential / Low	77.8
Commercial / High	85.7
Commercial / Low	76.0

Lakeland Conclusions

- Land use and density of tree canopy were shown to be important variables impacting the nutrient content of street debris.
- Use of GIS spatial tools can provide highly useful information to support programmatic optimization
- Optimization shows that the City can decrease the cost per pound of TN or TP removed utilizing new zones and frequencies

Largo Case Study

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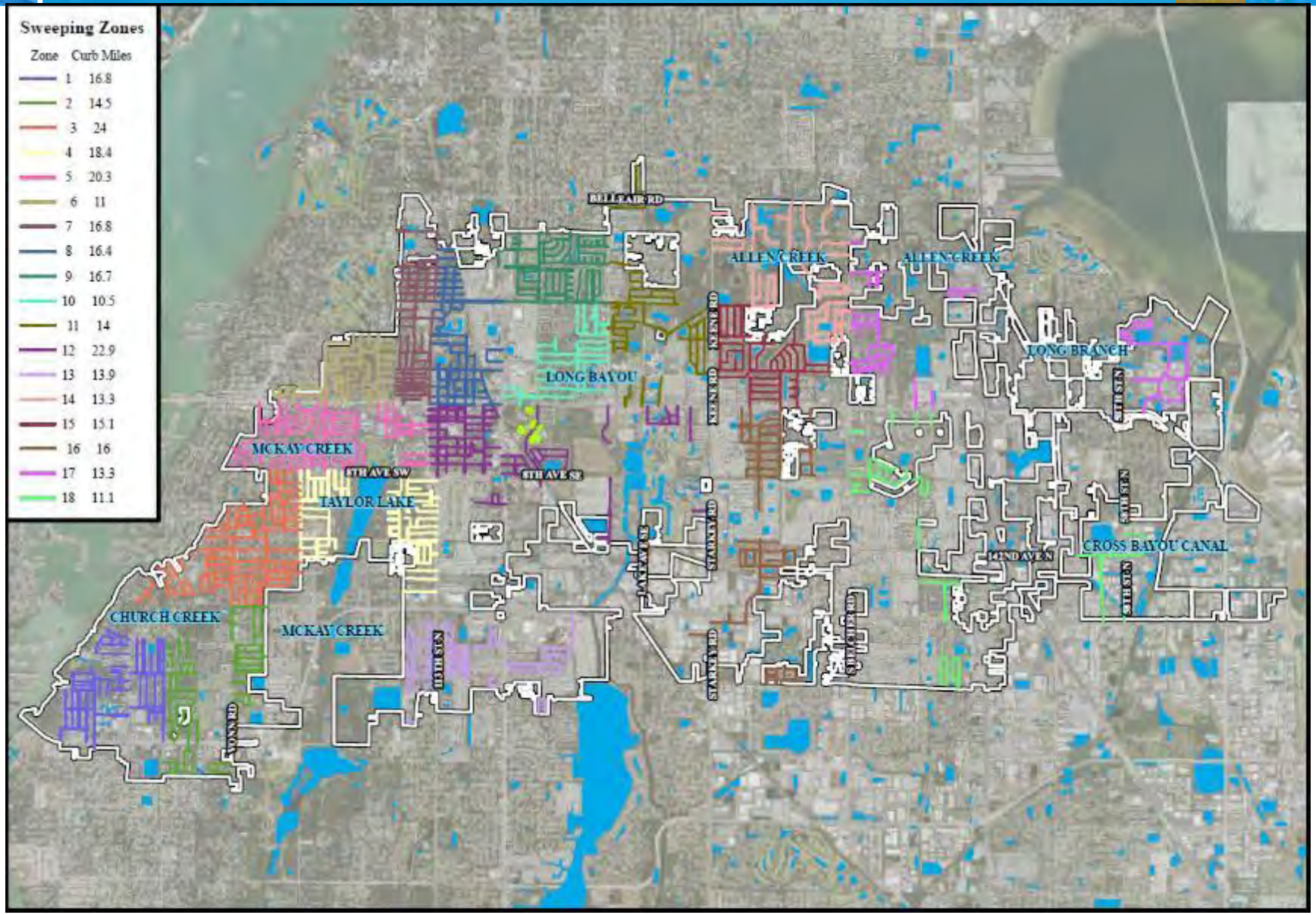
Current Program Review

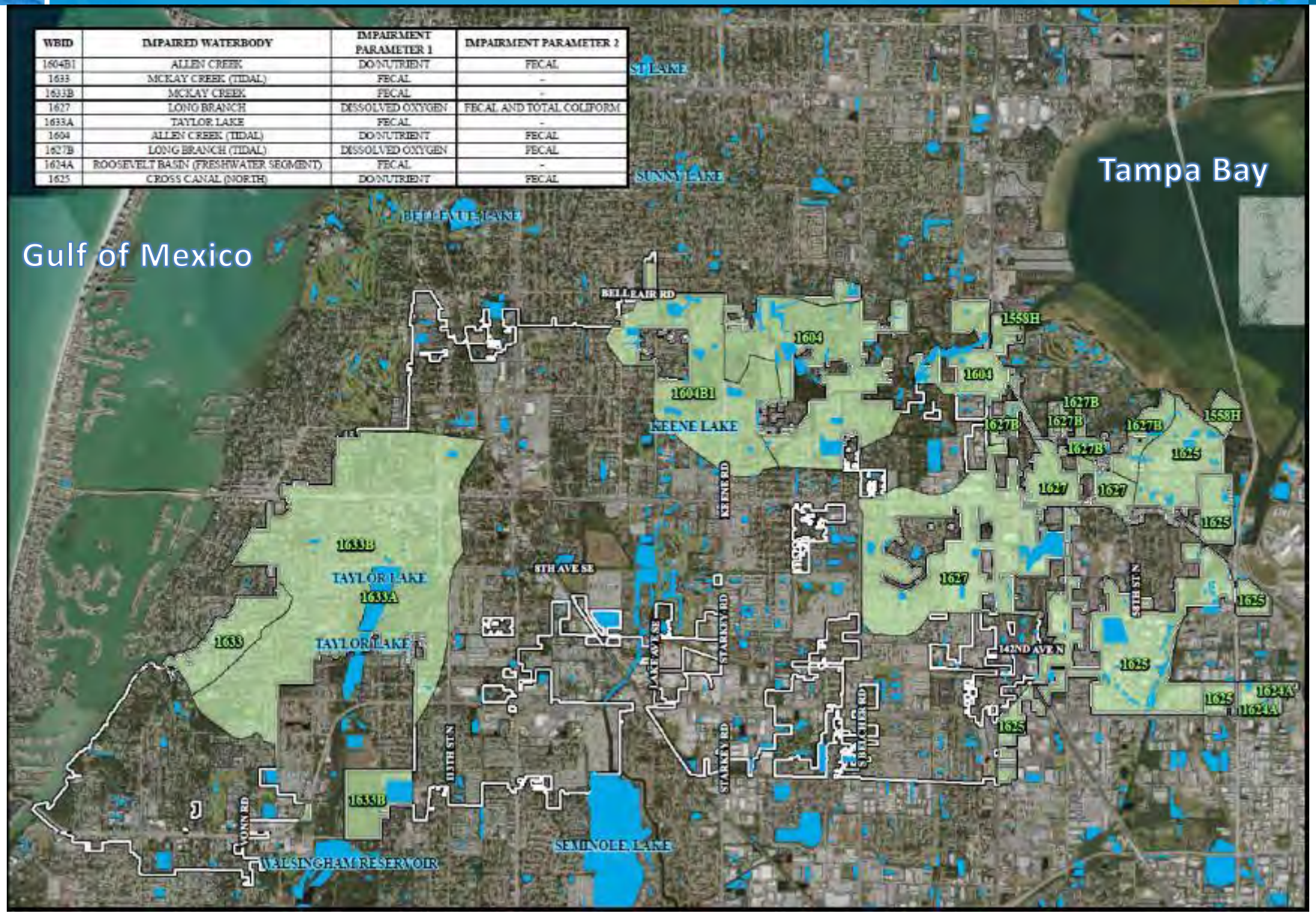
- Currently sweeps City owned streets and other areas (parking lots) during high leaf drop periods
- City has 3 vacuum sweepers
- City sweeps 284.9 curb miles
- No set frequency - sweep all streets in zone and then start over
- Street segments divided into 18 different zones
- Challenge meeting TMDL load reduction goals

Current Program Review

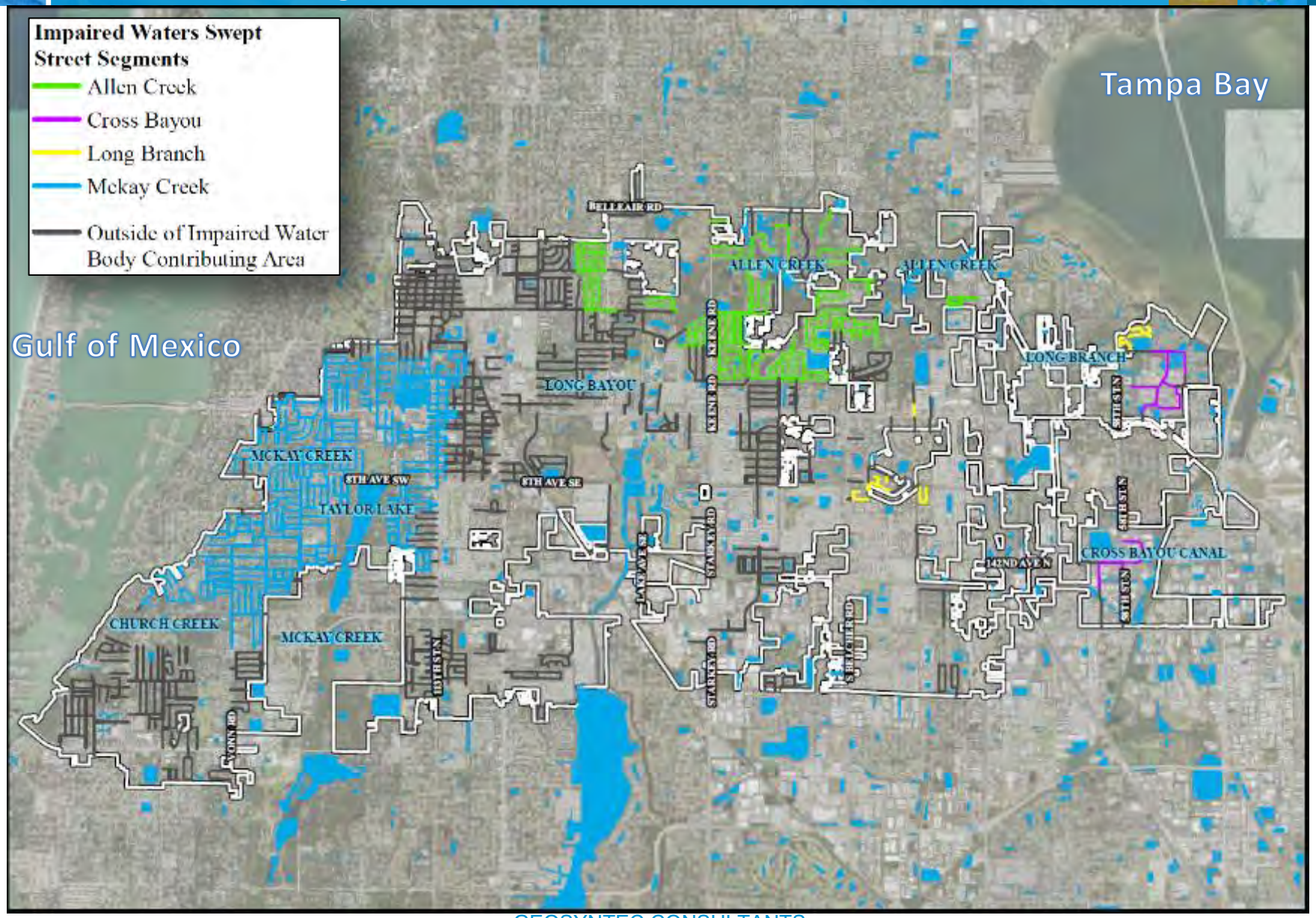


City Characteristics – Impaired Waters

WBID	IMPAIRED WATERBODY	IMPAIRMENT PARAMETER 1	IMPAIRMENT PARAMETER 2
1604B1	ALLEN CREEK	DO/NUTRIENT	FECAL
1633	MCKAY CREEK (TIDAL)	FECAL	-
1633B	MCKAY CREEK	FECAL	-
1627	LONG BRANCH	DISSOLVED OXYGEN	FECAL AND TOTAL COLIFORM
1633A	TAYLOR LAKE	FECAL	-
1604	ALLEN CREEK (TIDAL)	DO/NUTRIENT	FECAL
1627B	LONG BRANCH (TIDAL)	DISSOLVED OXYGEN	FECAL
1624A	ROOSEVELT BASIN (FRESHWATER SEGMENT)	FECAL	-
1625	CROSS CANAL (NORTH)	DO/NUTRIENT	FECAL



Attribution of Street Sweeping GIS Feature Class Contributing Area to Impaired Water



Largo Conclusions

- It was recommended that the City move forward with additional evaluation of the following:
  - Nutrient Characterization to better quantify the nutrient content of city specific street debris
  - Frequency Optimization to sweep street segments based on the City's spatial characteristics that have been shown to impact the nutrient content of street debris
  - Zone Optimization to group street segments together based on similar characteristics and optimize the frequencies of new zones
  - Seasonal Optimization to maximize the nutrients collected during high leaf drop periods
  - Enhanced Tracking and Reporting to more efficiently track and report nutrient mass removal due to street sweeping

Seminole County Case Study

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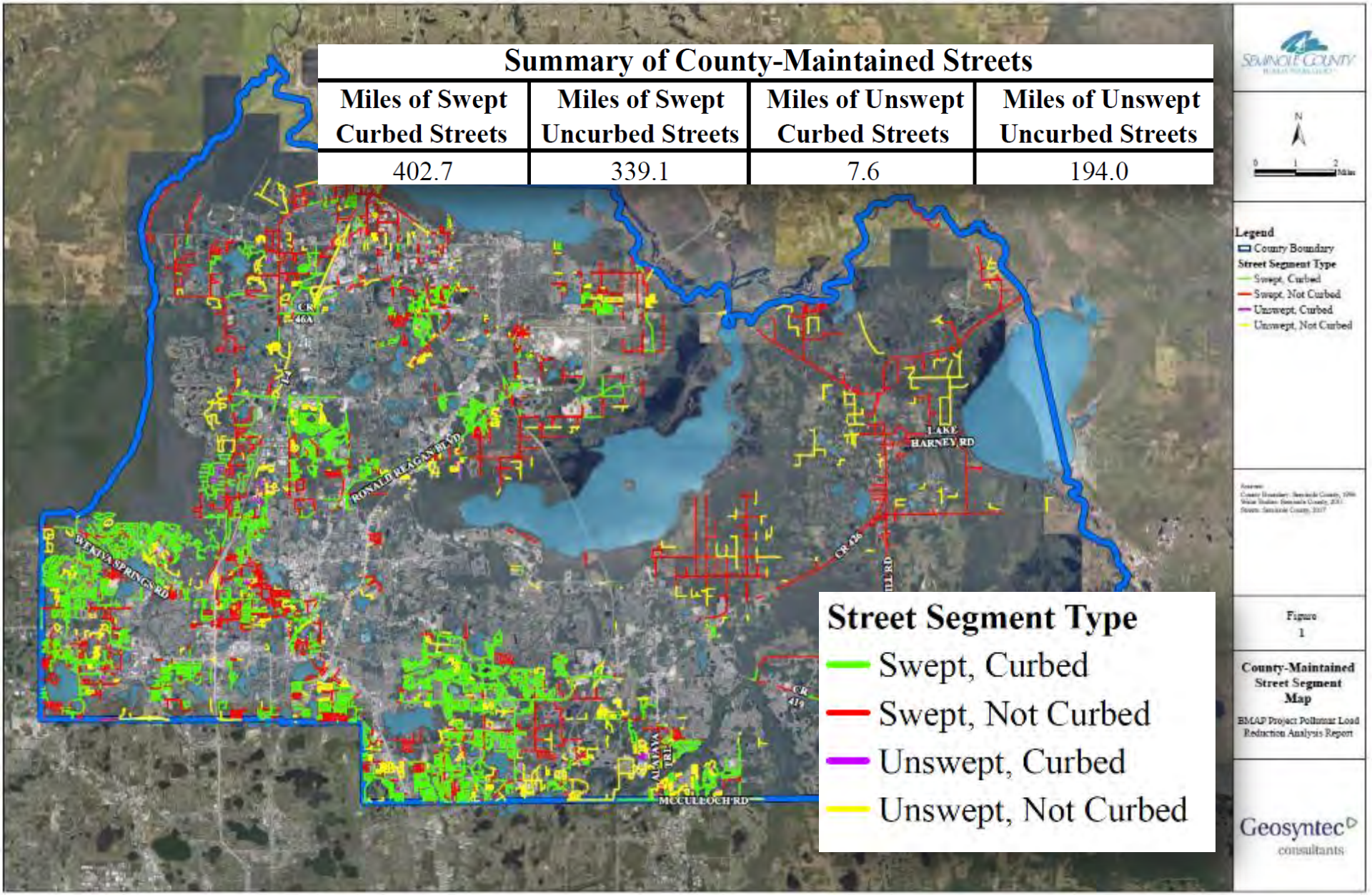
Objectives and Goals

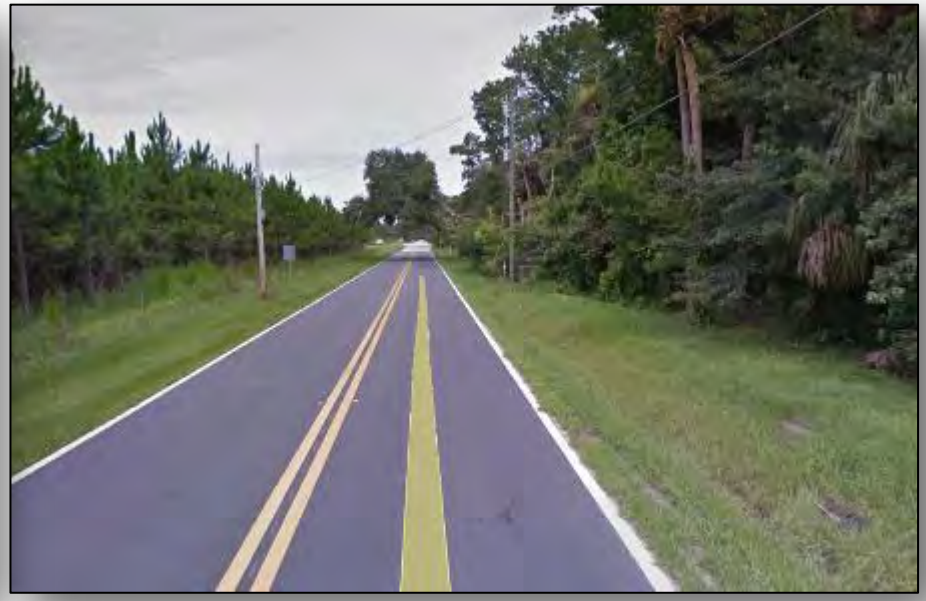
- The County's current street sweeping program includes efforts to sweep select arterial/collector roads four times per year and select subdivision (local) roads two times per year
- The County desired to develop an improved street sweeping program to increase the amount of pollutants collected, which in turn could result in higher TMDL and NPDES permit credits.
- Leverage available spatial data to determine target areas for additional street sweeping (high tree canopy, etc.) to recommend an enhanced program with the goal of increasing the amount of pollutant mass removed.
- Increase the frequency of target street segments that are currently swept as well as the sweeping of additional target street segments that are not currently swept.

Street Sweeping Areas

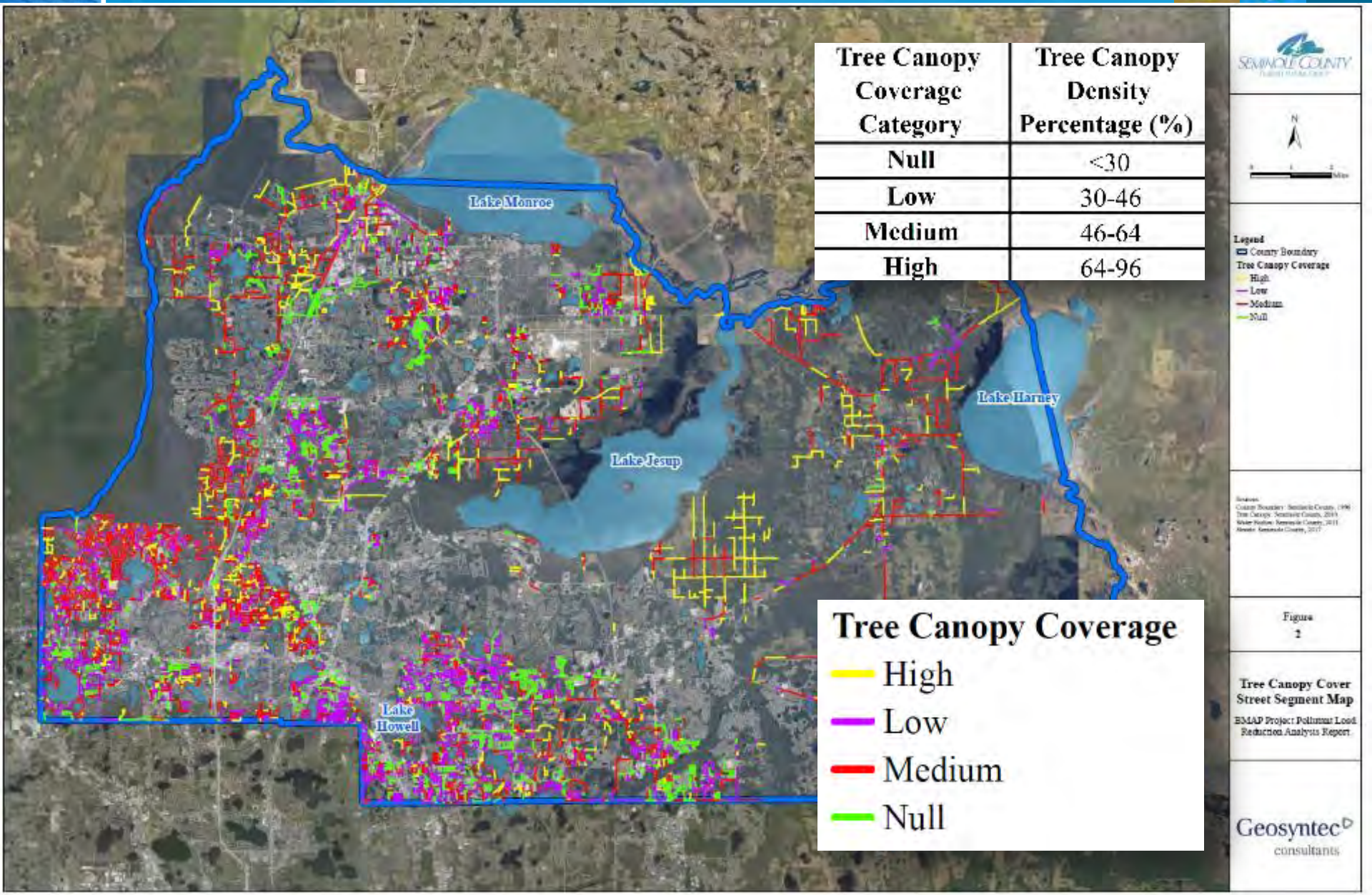


Street Sweeping Uncurbed Roads

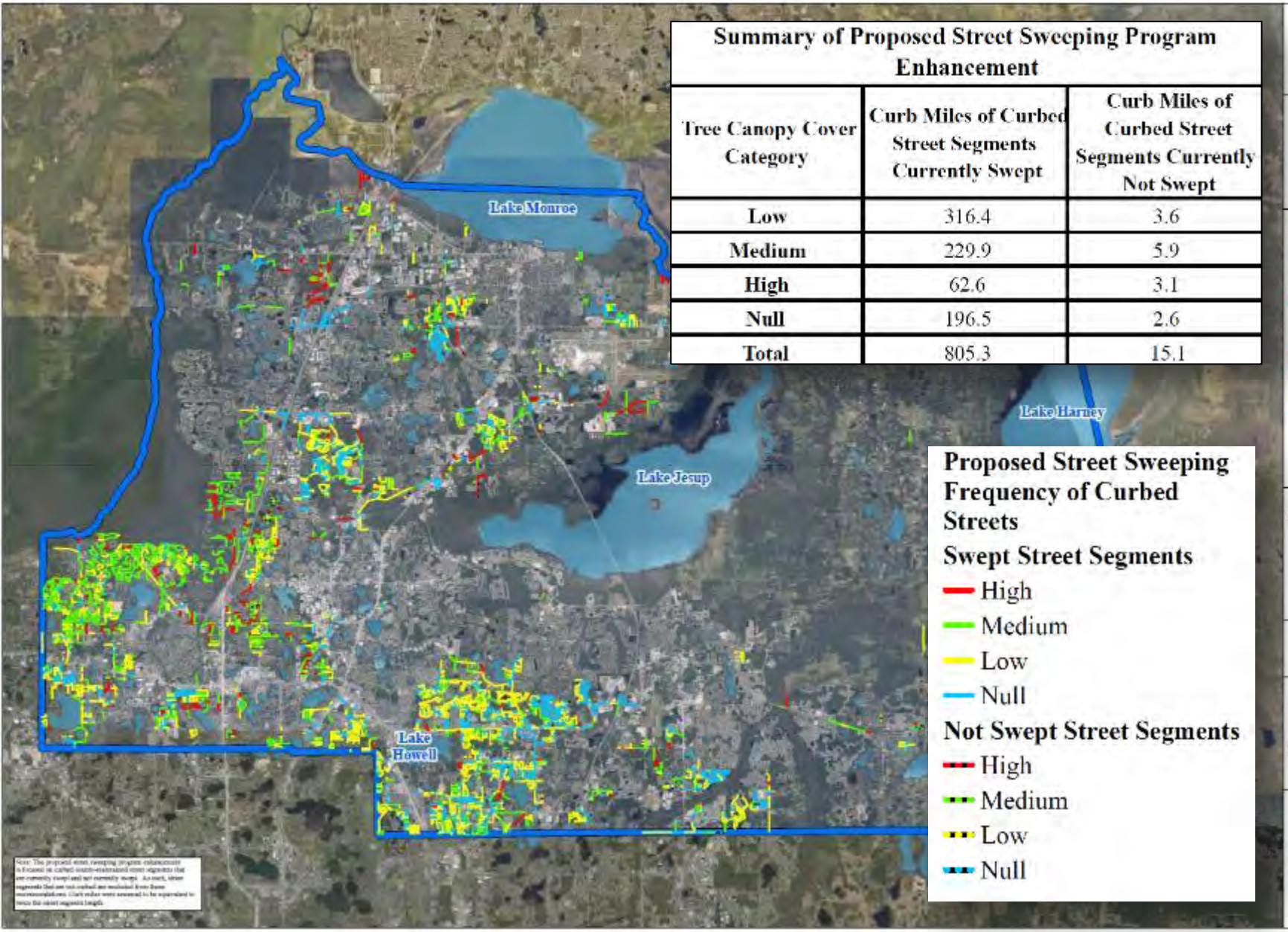
- Examples of uncurbed roads swept – “grass curbs”



Leveraging Tree Canopy Data



Recommended Program



Benefit Cost Analysis

Table 5. Summary of Benefit Cost Associated with Proposed Street Sweeping Program Enhancement

Frequency Category	Curbed Street Segment Description	Additional Recommended Frequency (times/yr)	Total Miles	Approximate TN Removal (lb/yr)	Approximate TP Removal (lb/yr)	Total Annual Cost ($/yr)
Low	Currently swept	None	158.2	None	None	None
	Not Swept	4	1.8	4.6	1.8	$315
Medium	Currently swept	8	115.0	588.8	230.0	$40,250
	Not Swept	12	2.9	22.3	8.7	$1,523
High	Currently swept	48	31.3	961.5	375.6	$65,730
	Not Swept	52	1.5	49.9	19.5	$3,413
Total	-	-	**310.7**	**1627.1**	**635.6**	**$111,230**
TN Benefit Cost ($/lb/yr)						**$68**
TP Benefit Cost ($/lb/yr)						**$175**

Note: Frequency of currently swept streets was assumed up to 4 times per year, based on information provided by Seminole County. Additional recommended frequency is the difference between the recommended frequency of the proposed program enhancement and the current frequency associated with the current program. Based on data provided by Seminole County (12/10/19), nutrient removals were assumed to be 0.64lb-TN/mile and 0.25 lb-TP/mile. Based on vendor invoices, streets are swept at a current rate of $43.74/mile. It should be noted that the origin of the TN and TP removal rates presented in the provided spreadsheet is unknown. Collecting additional data could result in additional benefit to the proposed street sweeping program enhancement.

Summary

Geosyntec consultants

Street Sweeping Program Benefit Evaluation

- Potential Optimization Benefits
  - Nutrient Characterization – Nutrient content and generation rates vary widely
    - Thorough characterization of data could result in significant increases in nutrient removal credit
  - Frequency Optimization – Current sweeping frequencies could be optimized to sweep some zones more frequently and others less
    - Results of studies show that this could result in significant increases in the nutrient content of collected street debris
  - Zone Optimization – Grouping street segments into new zones based on similar characteristics
    - New zones could be optimized relative to frequency based on score of each zone
  - Seasonal Optimization – Sweeping street segments with high tree canopy more frequently during periods of high leaf drop
    - Results from studies show that this could result in significant increases in both the mass of street debris collected and the nutrient content of that collected
  - Enhanced Tracking and Reporting – Develop methods to more efficiently track sweepers and report mass removals
  - Optimization could be applied without increasing overall program cost

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Thank You!

Questions?

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