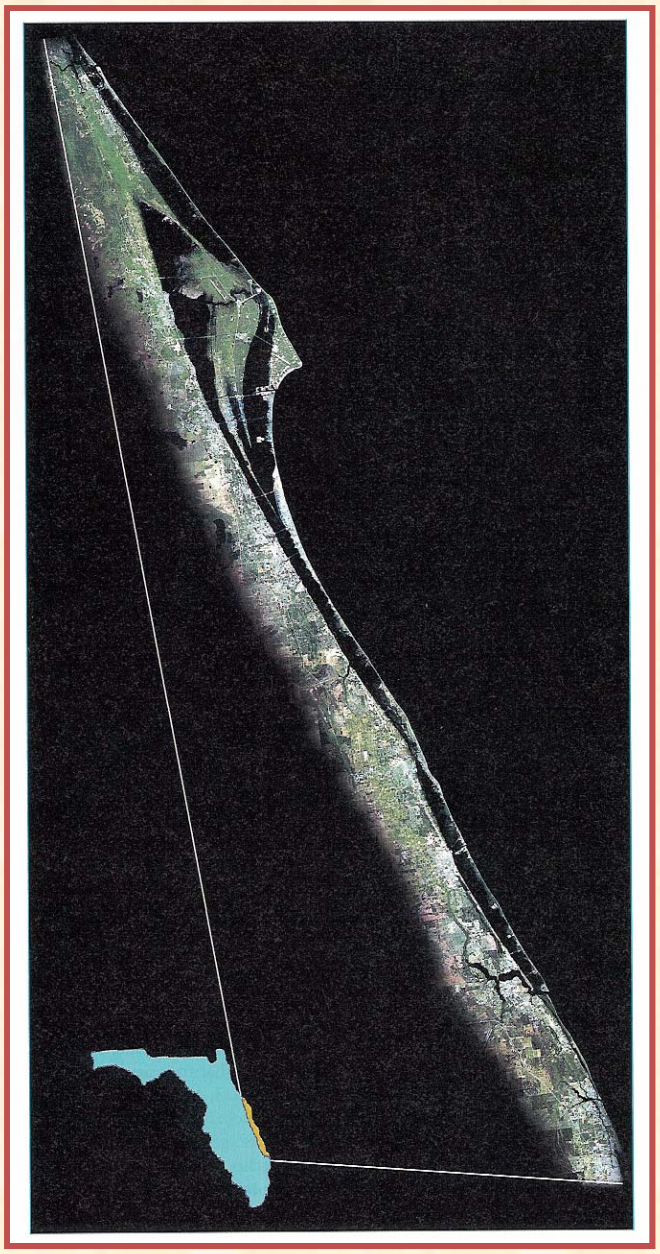


Indian River Lagoon

Seagrass-based Nutrient Load Limits: The method used to develop TMDLs & load reductions

SJRWMD: J. Steward, W. Green
FDEP: X. Gao

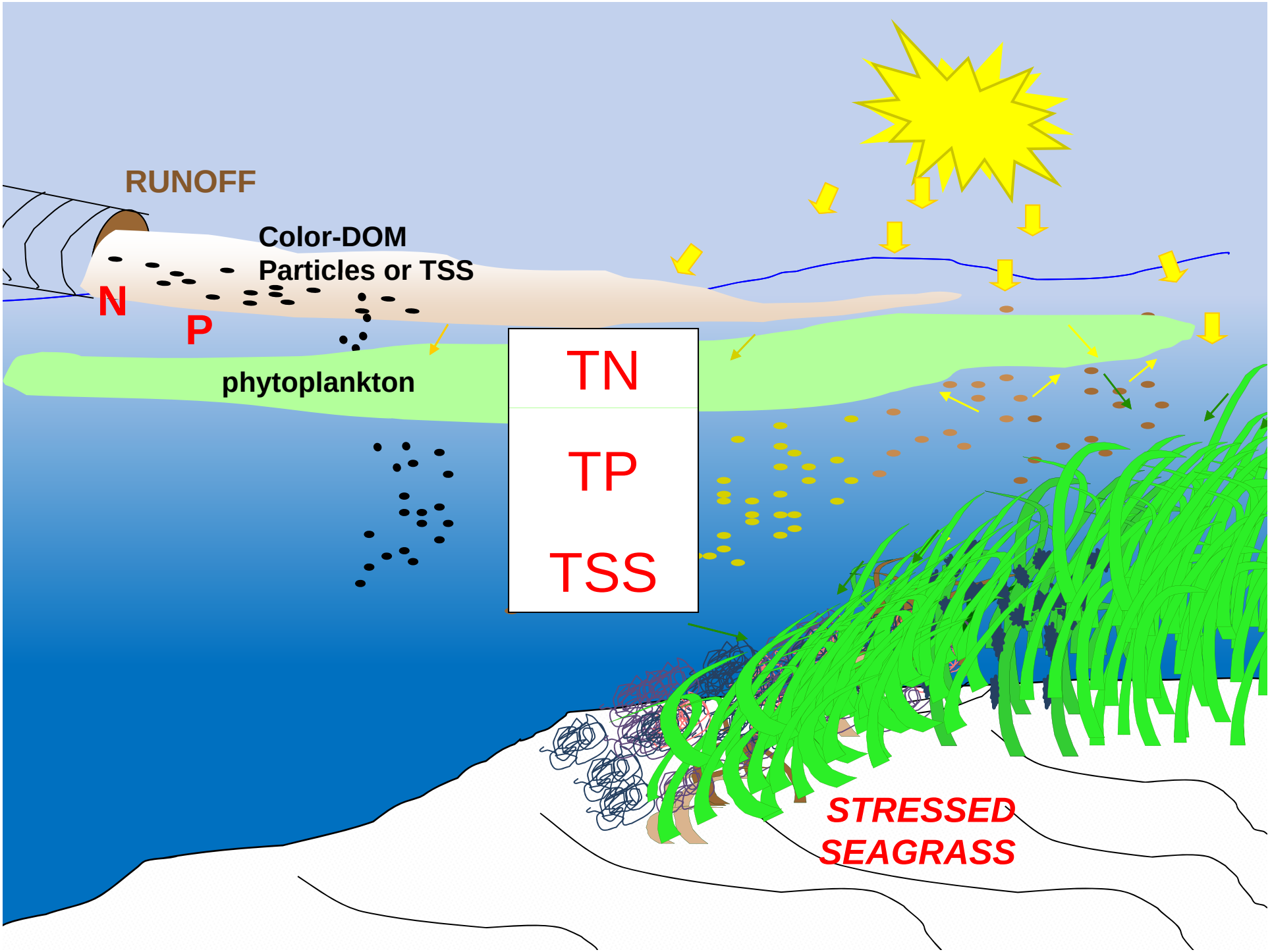
Indian River Lagoon

Seagrass-based Nutrient Load Limits

1. The method for developing load limits
2. Watershed loading models
3. Application of method toward TMDL development

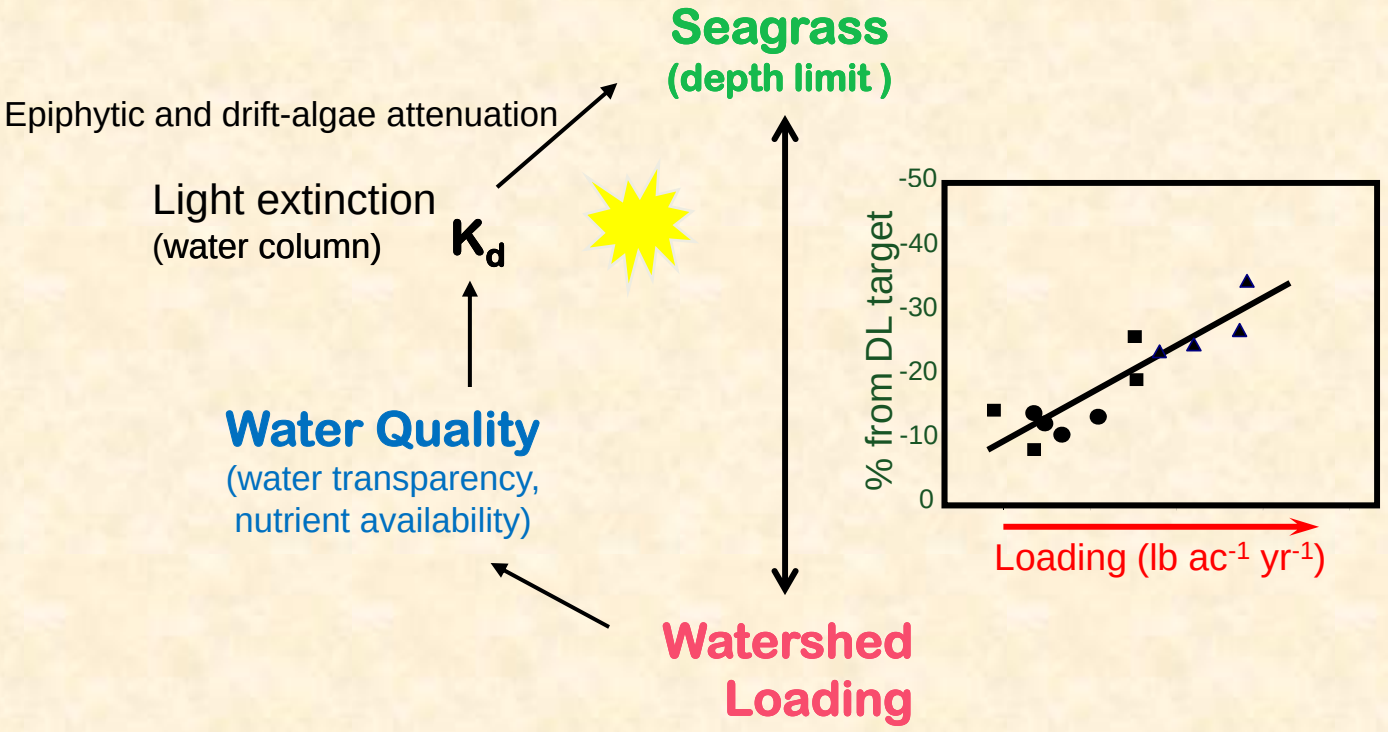
Part 1

Method for developing load limits

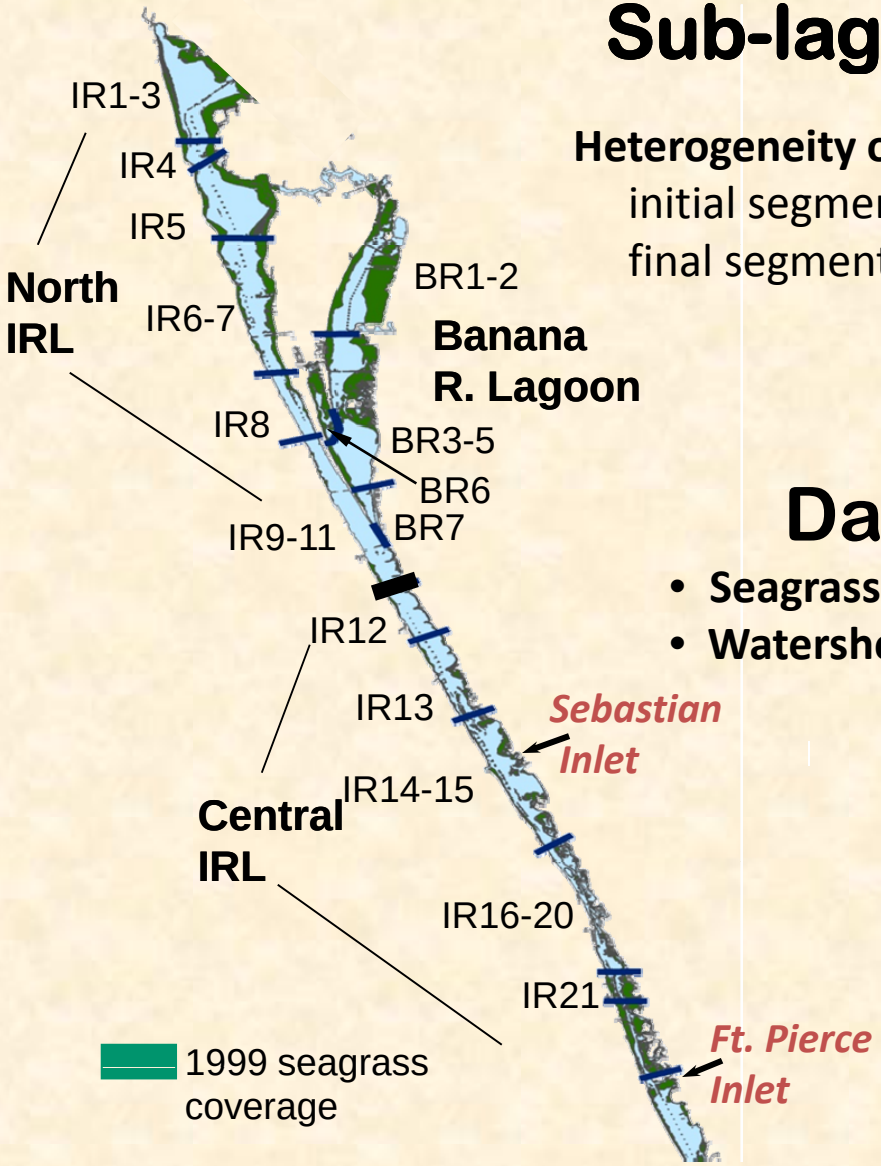

RUNOFF
Color-DOM
Particles or TSS
N
P
phytoplankton
TN
TP
TSS
STRESSED
SEAGRASS

An empirical load-limit model

transitive property of equality
transitive property of correlations
If a = b, b = c, and c = d, then a = d



Sub-lagoons & Segments



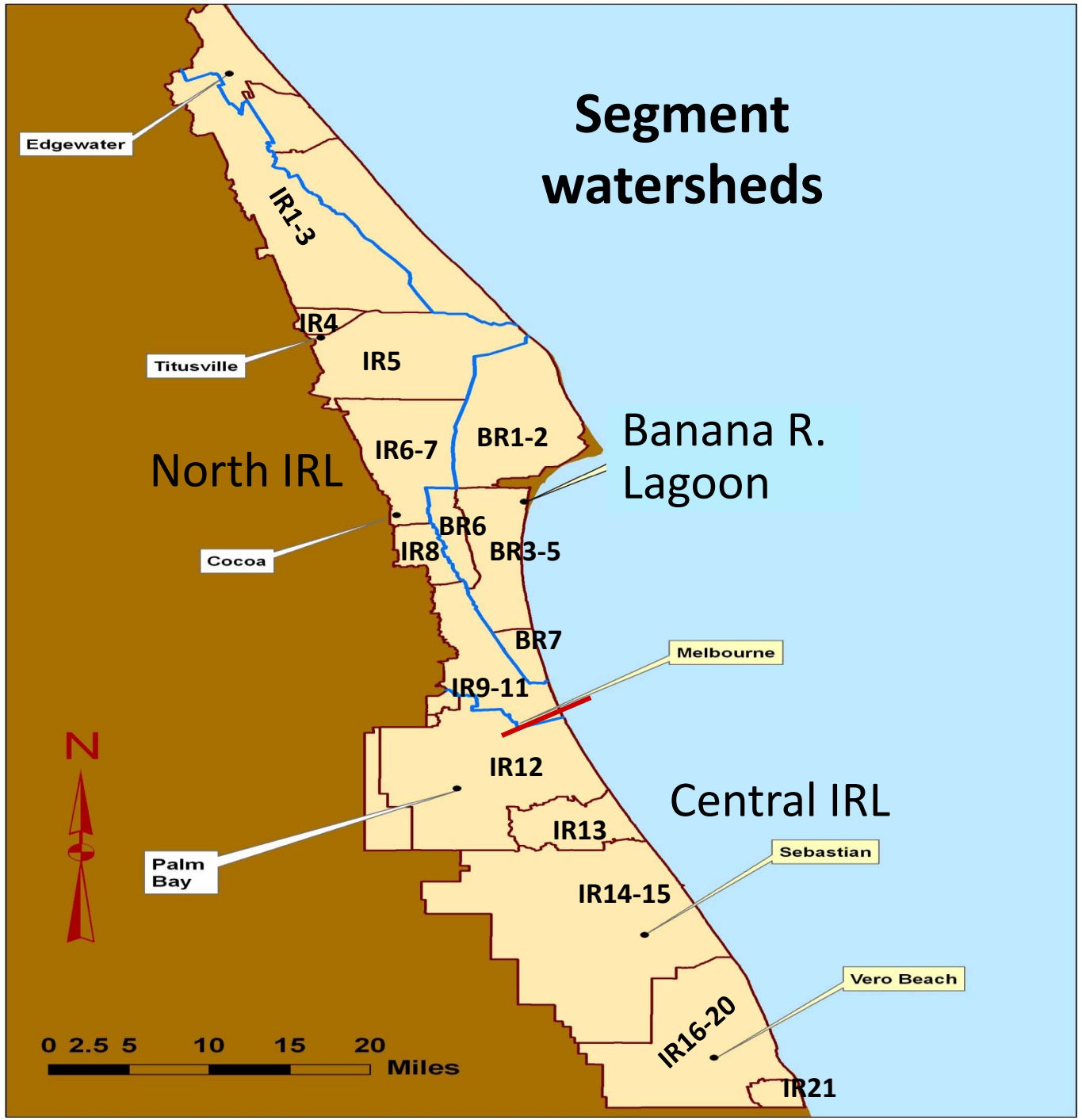
Heterogeneity of seagrass distribution and WQ

initial segmentation (cswys, seagrass) – 25 segments

final segmentation based on spatial WQ – 15 segments

Data Requirements

- **Seagrass depth limits → DL Targets per segment**
- **Watershed loadings (TN, TP, TSS) per segment**


Segment watersheds
Edgewater
IR1-3
IR4
Titusville
IR5
IR6-7
BR1-2
North IRL
Banana R. Lagoon
BR6
IR8
BR3-5
Cocoa
BR7
Melbourne
IR9-11
N
IR12
Central IRL
IR13
Palm Bay
Sebastian
IR14-15
Vero Beach
IR16-20
IR21
0 2.5 5 10 15 20
Miles

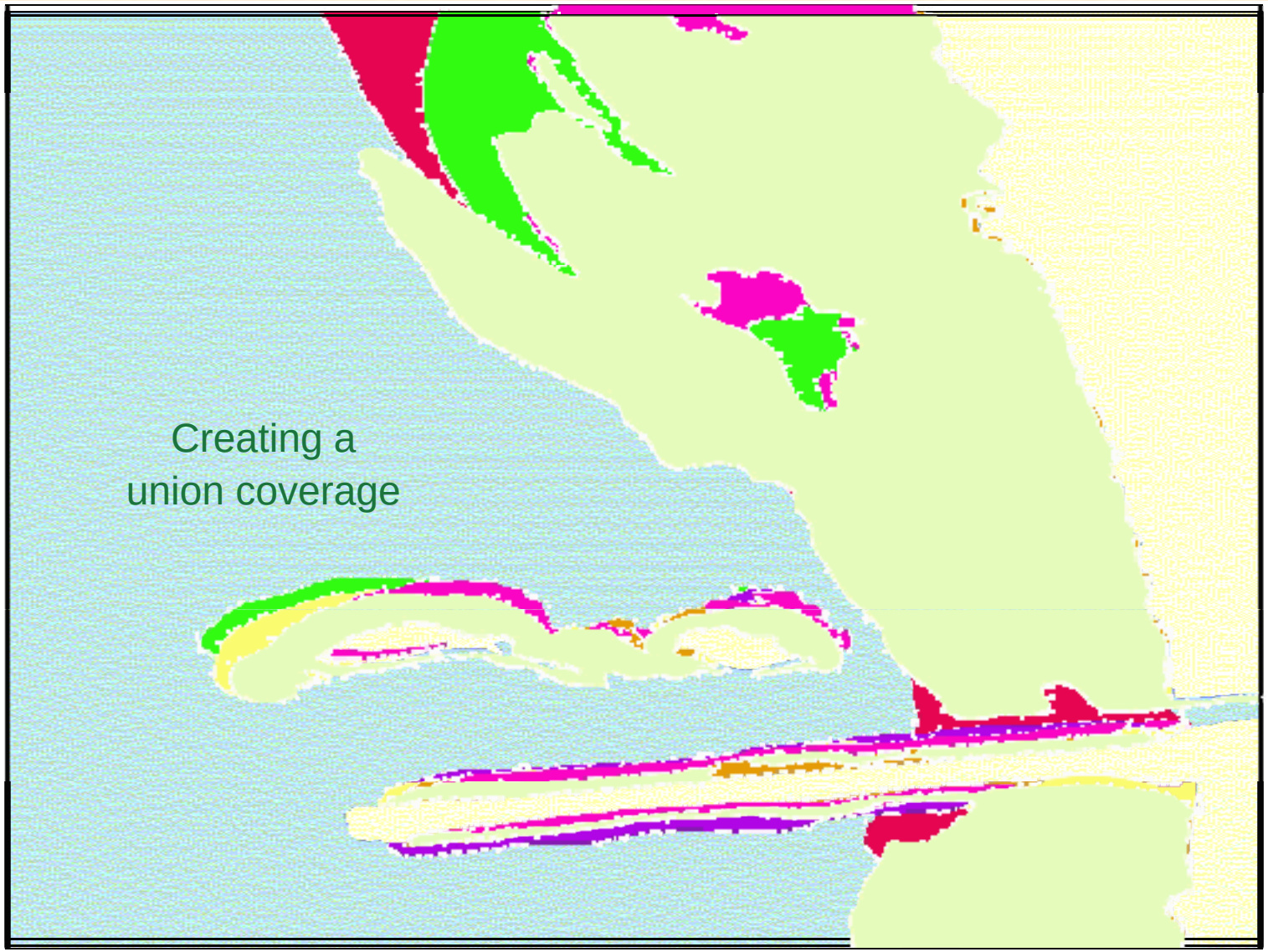
Seagrass DL data & targets

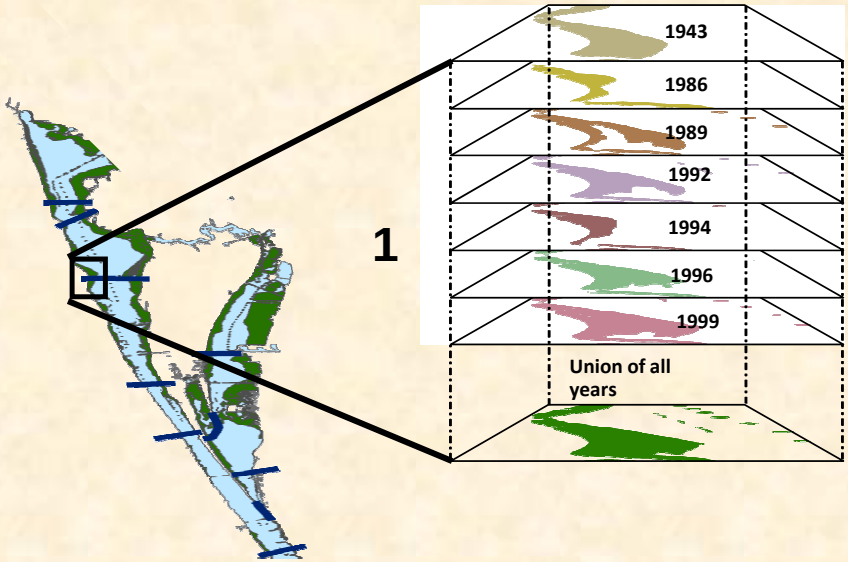
Maps

Photo

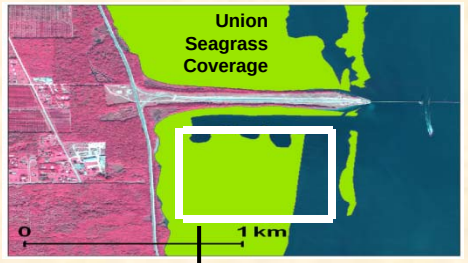
GIS coverage

Available mapping years: 1943, 1986, 1989, 1992, 1994, 1996, 1999


Creating a
union coverage



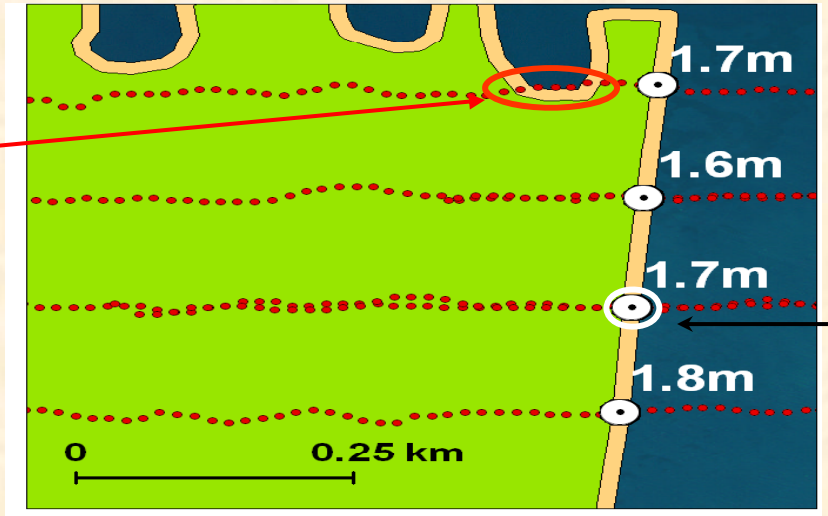
DL targets



3

Bathymetry

Depth point exclusion rules
e.g., depth points @ dredged areas excluded.



Depth points nearest union boundary determined the depth limit.

Median depth-limit targets per segment

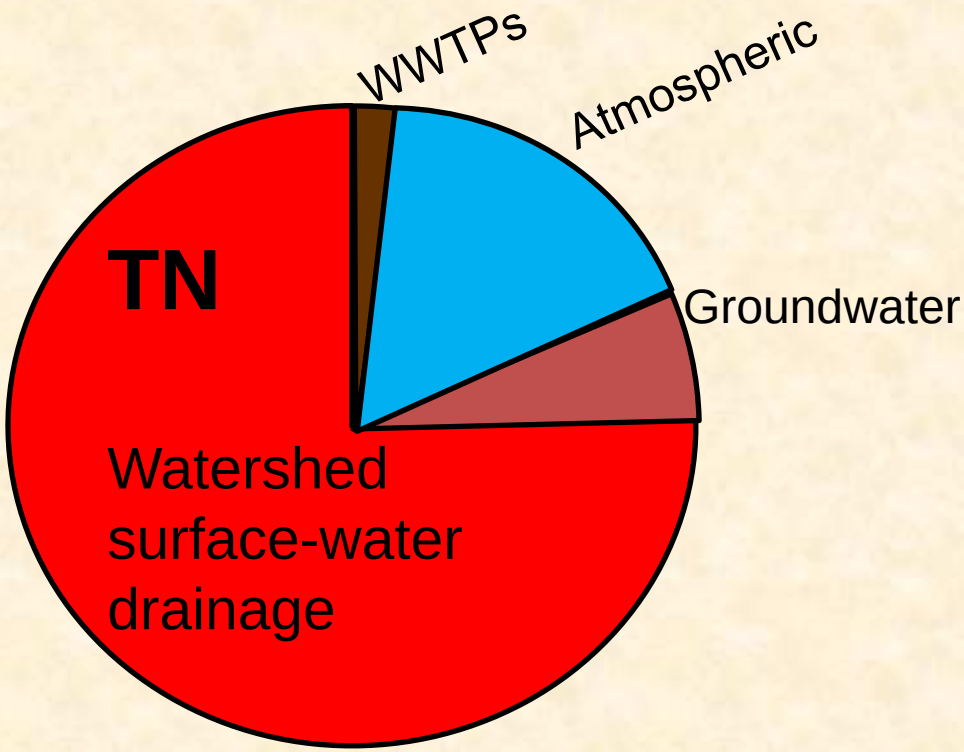
North IRL	Targets (m)
IR1-3	1.60
IR4	1.57
IR5	1.72
IR6-7	1.54
IR8	1.57
IR9-11	1.81
Central IRL	
IR12	1.39
IR13	1.35
IR14-15	1.39
IR16-20	1.18
IR21	1.52
Banana R. Lagoon	
BR1-2	1.75
BR3-5	1.57
BR6	1.63
BR7	1.42

Range of targets: 1.18 to 1.81m

IRL system's ECD for seagrasses.

Loading Data: TN, TP, TSS

Proportion of external loads by source Lagoon-wide



~70% to ~80% of external nutrient loads is conveyed by runoff

Loading Data: TN, TP, TSS

Loading data (lb/ac/yr) per segment developed by calibrated watershed models

- Pollutant Load Screening Model -- PLSM
- Hydrologic Simulation Program - Fortran -- HSPF

Loading data concurrent with a seagrass mapping years: *1943, 1996, 1999, and 2001*

Loading-seagrass regression model

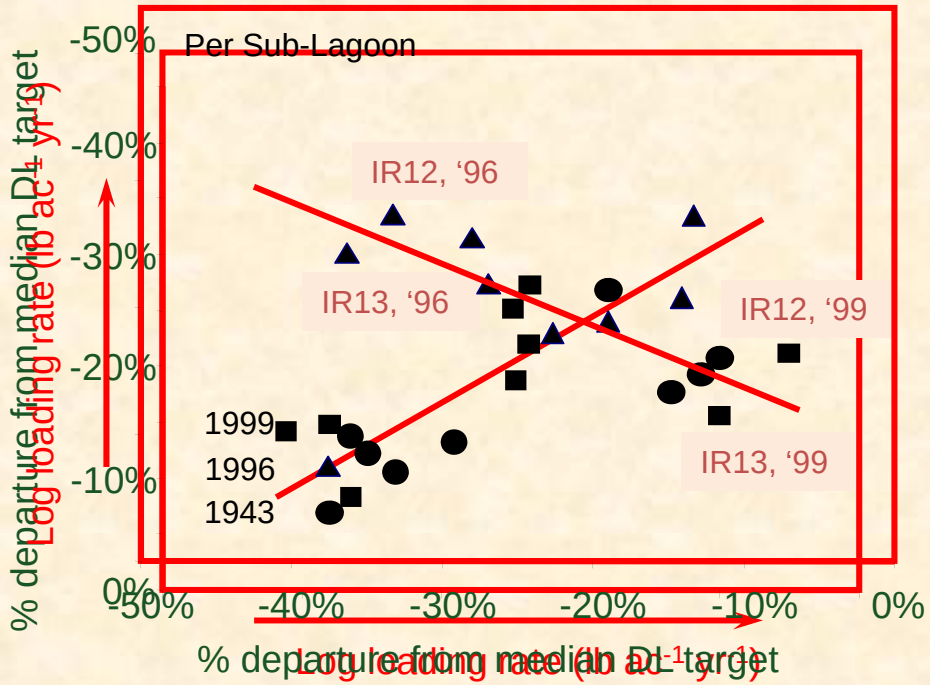
✓Areal loadings per segment watershed per year
Log transformed:

- normally distributed data set
- appropriate ecologically

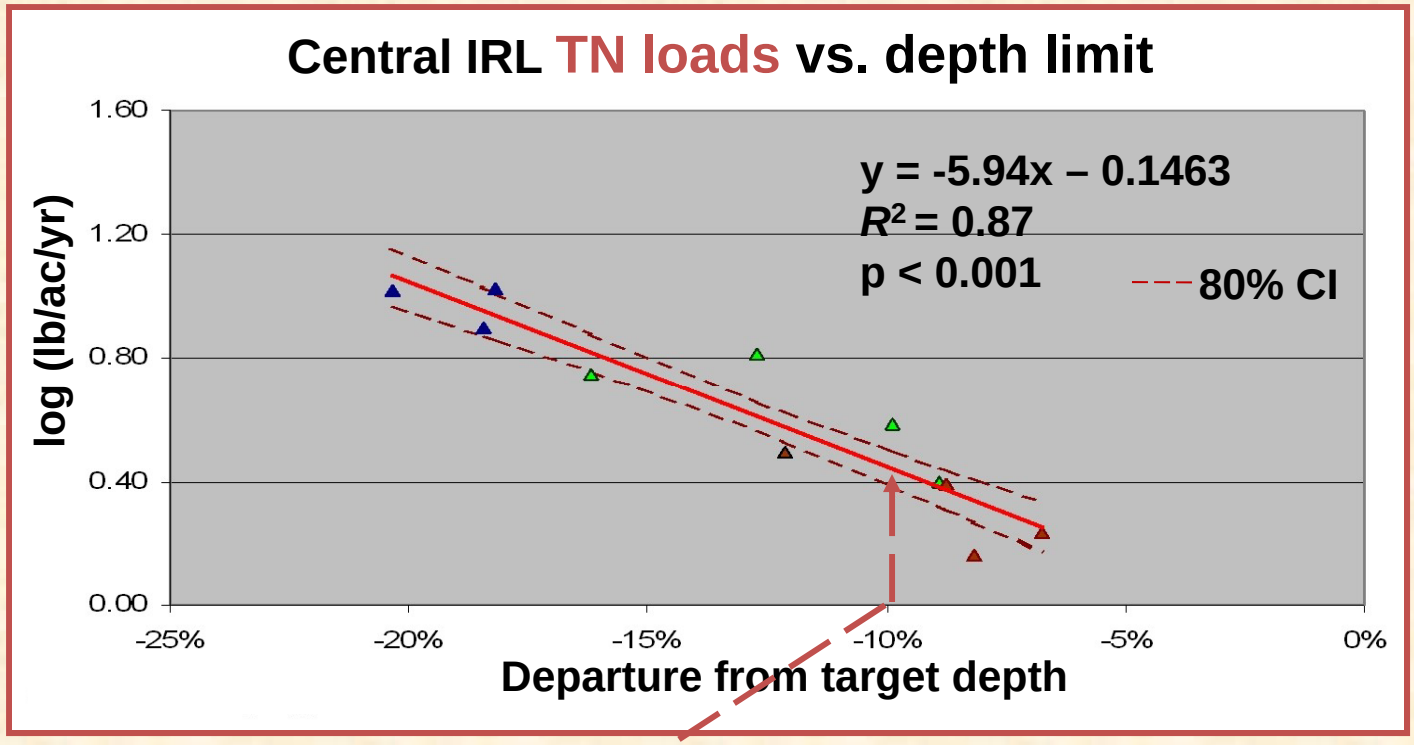
✓Median depth limits per segment per year (’43, ‘96, ’99,’01)
represented as *% departure from median depth-limit target*

Example: ***Segment IR12*** → *DLTarget: 1.39 m*
1943*: 1.23 m or -12% from DL target*

Parent regression equation was transformed to back-predict load limits from pre-determined depth limits.



Application Example:



TN = 2.9 lb/ac/yr (nonpoint + point source)
@ -10% departure from DL target

***consistent with water transparency standard* – no more than *10% decrease* in depth of compensation point for photosynthetic activity under background conditions.**

Types of Results – Nutrient Load Criteria

1. *Areal load limits (lb/ac/yr)*

   Example: Central IRL -- 2.9 lb/ac/yr TN

2. *Total allowable load (lb/yr) = areal load limit (lb/ac/yr) x watershed area (ac)*

   Example: Central IRL -- 821,282 lb/yr TN

   … was further allocated per segment according to current NPS load distribution + PS

Comparison of load limits to areal loadings from minimally developed basins

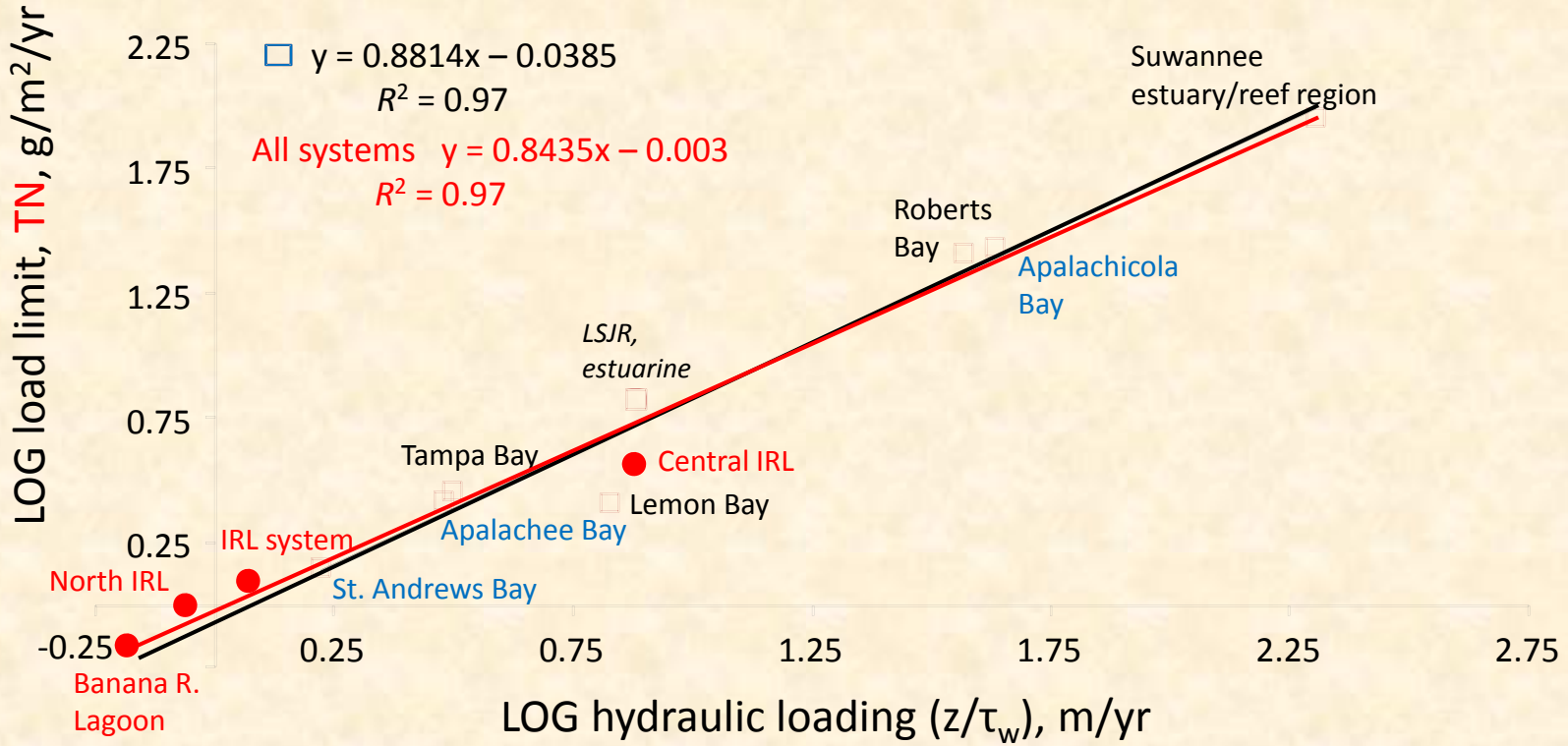
Comparison of TN Areal Loadings (lb/ac/yr): IRL TMDLs vs. loadings from minimally developed watersheds	
IRL TN load limits (PLRGs,TMDLs)	~2.2 to 2.9 lb TN/ac/yr
Turnbull, N. BRL, S. Mosquito Lagoon; ---------- 1990 land use ----------	1.3, 1.7, 1.1 lb TN/ac/yr, respectively

Comparison to other estuaries w/ moderate to heavy development

Comparison of TN Load Reductions (%): IRL system vs. other coastal systems	
IRL TN load reduction	~34% to 63% per sublagoon
Tampa Bay, Lemon Bay, Chesapeake Bay, Narragansett Bay	>60%, 54.7%, 40%, 50%

TN load limit vs. hydraulic loading

Bay and lagoonal estuaries in Florida (seagrass ecosystems)



Part 2

Watershed loading models

The Pollutant Load Screening Model (PLSM)

PLSM is a GIS-based model that simulates annual non-point source loads generated by a watershed through a relationship between land use and soil type .

MODEL INPUT

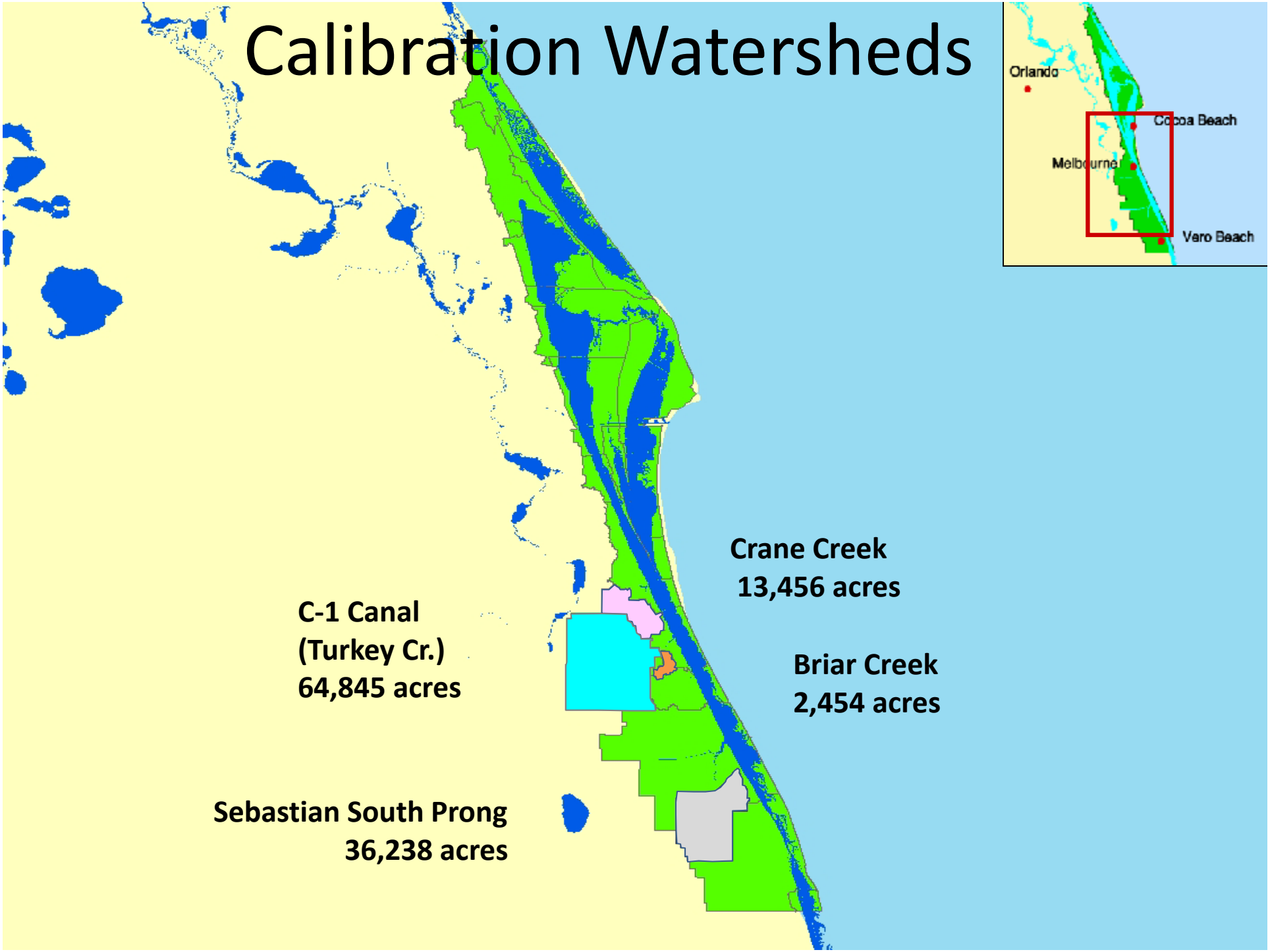
- **Spatial Data Layers**: drainage area, land use (FLUCCS), soil hydrologic group (SSURGO), annual rainfall (April – March of year preceding seagrass mapping)
- **Runoff Coefficients**: volumetric ratio of annual rainfall excess (runoff) to total annual rainfall. Derived from literature or calculated from % impervious surface
- **Runoff Concentrations**: (mg/L) literature values derived from field studies
- **BMP Treatment Efficiencies**: (% reduction) literature values applied to development occurring after 1989 – earliest available year following stormwater rule implementation.

  No regional BMPs.

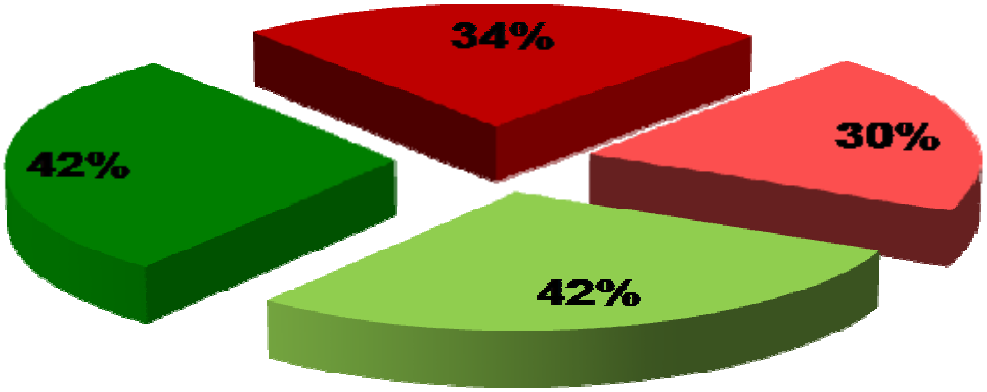
Calibration of PLSM

- Conducted simultaneously upon four distinct watersheds for which sufficient data existed to calculate an annual load
- Exported from GIS into Excel workbooks & linked together through a master lookup table
- Adjusted runoff concentrations and coefficients to minimize the total error and achieve best fit to the measured data
- Comparisons then made to other models used in three of the four watershed

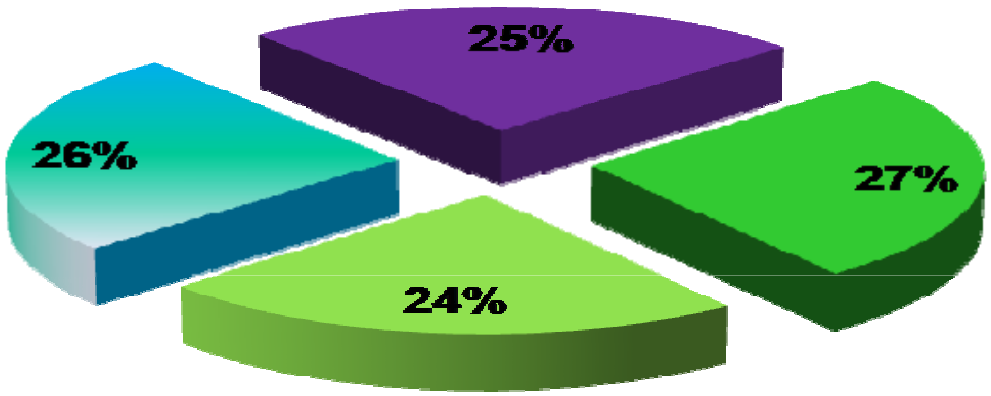
Calibration Watersheds



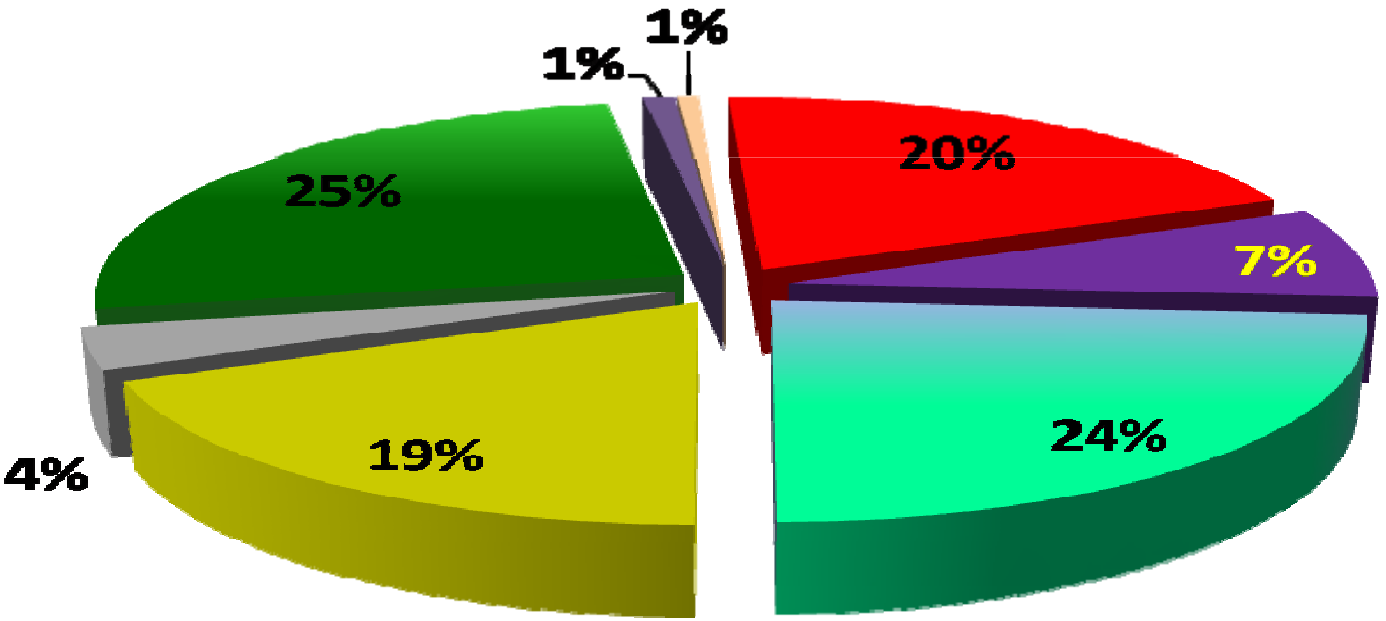
Primary Land Use in PLSM-Calibrated Watersheds



Secondary Land Use in PLSM-Calibrated Watersheds



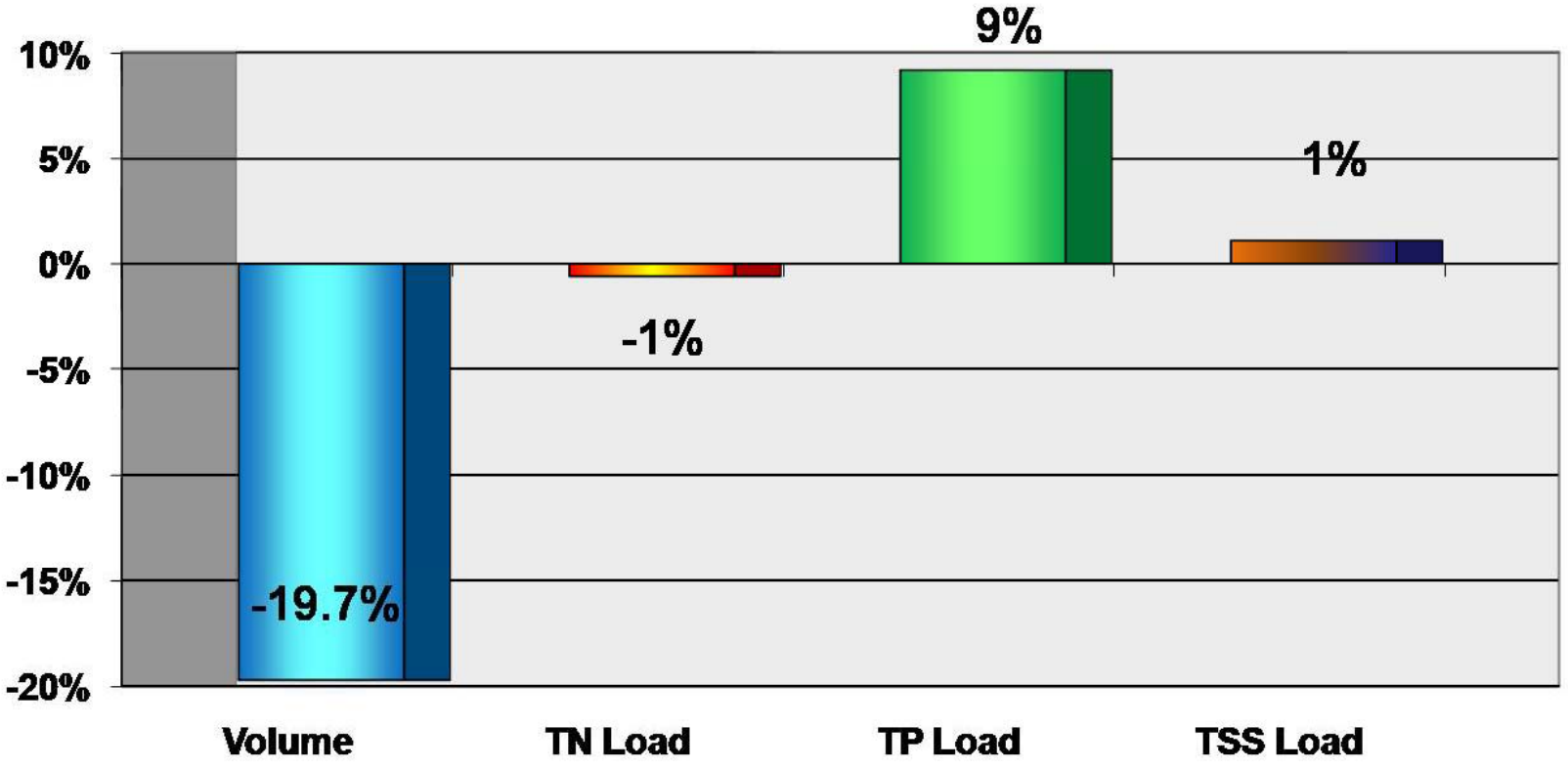
IRL 2000 Land Use Composition



Citrus-Agriculture
Disturbed
Forest/Rangeland
Other
Open
Residential
Urban Core
Water/Wetlands

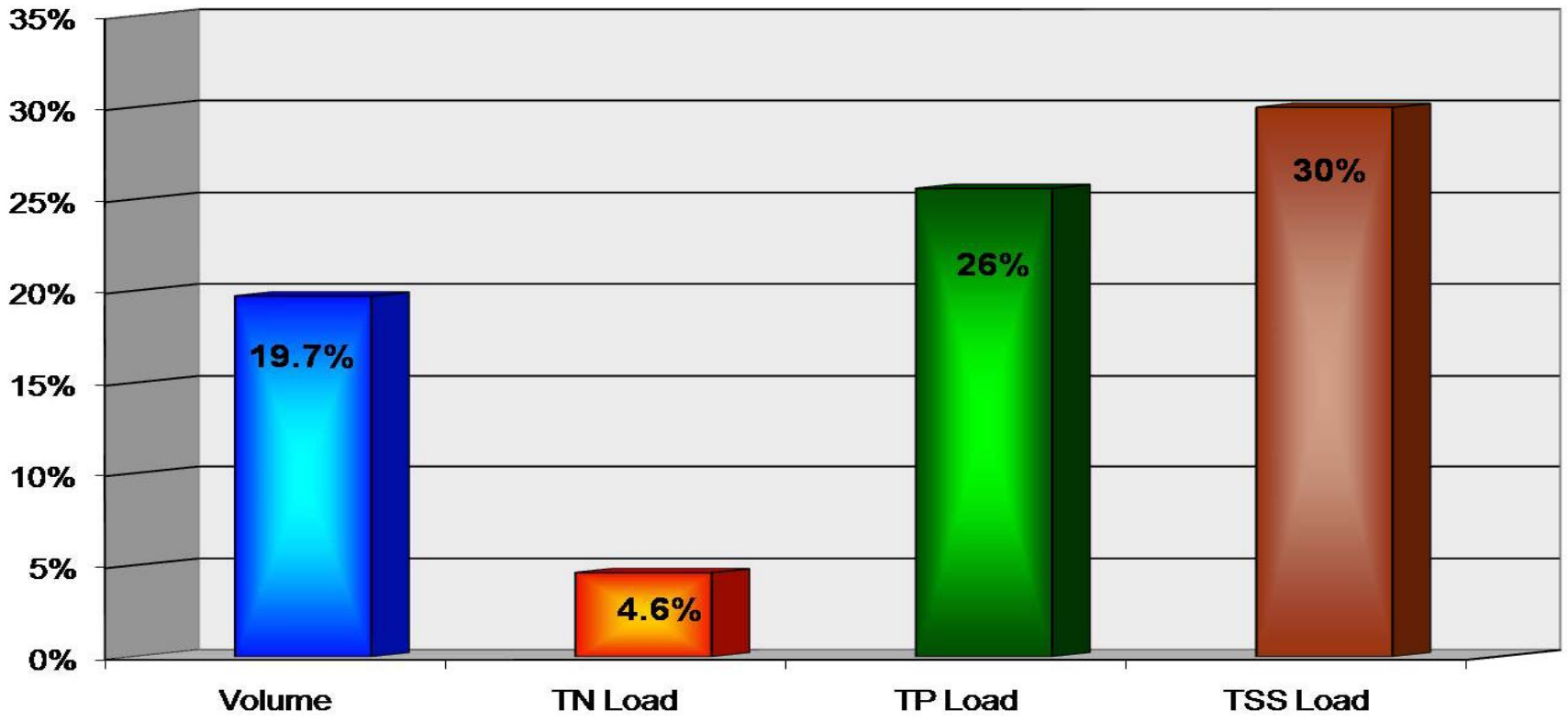
Difference in total flow & loads between PLSM and measured data for combined watersheds

$$\sum_{i=1}^{n} \left(ML_i - PL_i\right) / ML_i$$



Absolute difference in cumulative flow and loadings between PLSM and measured data

$$\sum_{i=1}^{n} \left| ML_i - PL_i \right| \Big/ ML_i$$

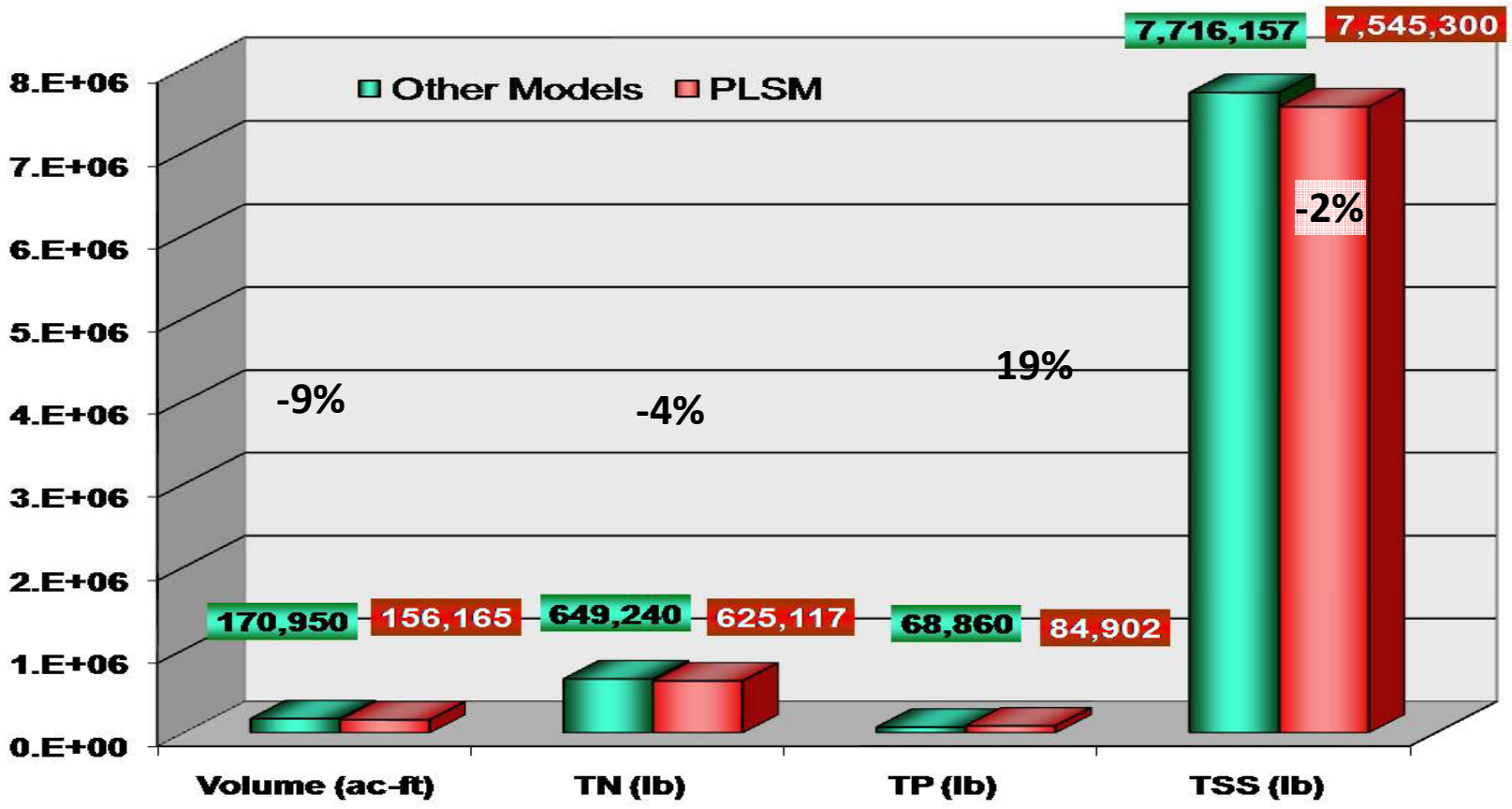


Rated results of PLSM cumulative loads compared to measured

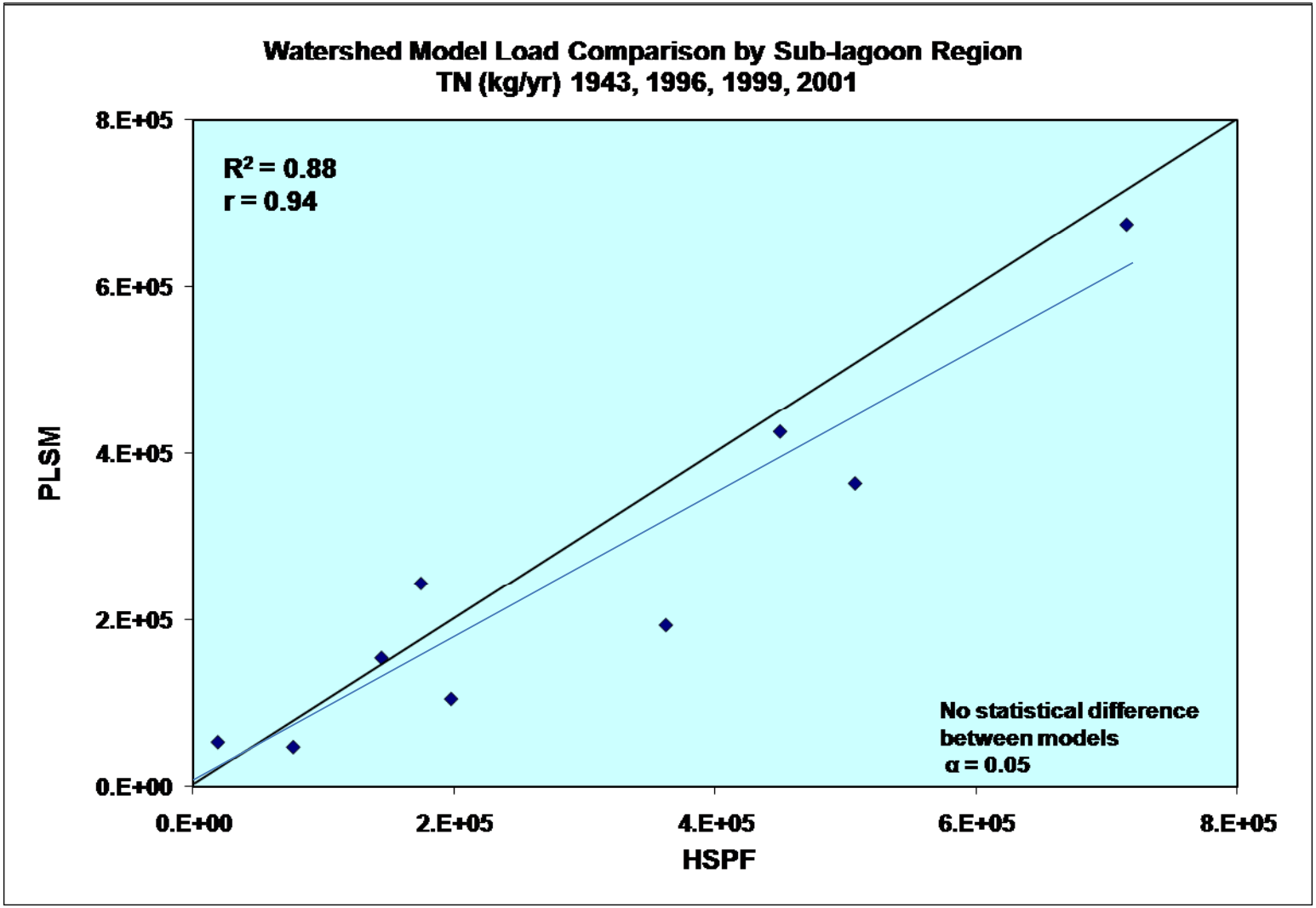
Pollutant	PLSM total	Rating*	PLSM absolute	Rating*
TN	-1%	Very Good	4.6%	Very Good
TP	9%	Very Good	26%	Good
TSS	1%	Very Good	30%	Fair

* Source: Donigian, et al. 1984. Application Guide for Hydrological Simulation Program-Fortran (HSPF)

Comparison of PLSM to other model loads for C-1 Canal, South Prong, and Briar Creek



Comparison of PLSM to HSPF model loads by sub-lagoon region



Part 3

Application of method toward TMDL development

TMDLs Ask Three Questions

- What are the water quality targets?
  - Responder targets: -10% departure from the full DL target
  - Pollutant concentration targets: Not defined in this TMDL
- What is the target pollutant loads?
  - PLRG TN and TP target loads were adopted as part of the TMDLs.
  - Atmospheric direct deposition loads were added into the TMDLs.
  - TMDLs were generally split to Load Allocation (LA) for nonpoint sources and Waste Load Allocation (WLA) for point sources.
  - Lagoon PLRG segment loads were aggregated into WBID loads.
- What are the percent reduction needed to achieve the target loads?

  (Existing Load – TMDL)/Existing Load *100%

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  - **TMDLs were generally split to Load Allocation (LA) for nonpoint sources and Waste Load Allocation (WLA) for point sources.**
  - **Lagoon PLRG segment loads were aggregated into WBID loads.**
- What are the percent reduction needed to achieve the target loads?

  (Existing Load – TMDL)/Existing Load *100%

Direct Atmospheric Deposition

- SJRWMD did not find a functional relationship between atmospheric direct deposition load and seagrass DL.
- However, by definition, TMDLs need to include loads from all the sources, including the load from atmospheric deposition.
- Atmospheric deposition loads were calculated as the product of lagoon segment surface water area and areal deposition rates.
- Bulk areal deposition rates were provided by the SJRWMD based on data collected from Site IRL 141 located at the Sebastian Inlet.

Direct Atmospheric Deposition

Sublagoon	Lagoon Segment	Lagoon Surface (acres)	TN Areal Deposition Rate (lbs/ac/yr)	TP Areal Deposition Rate (lbs/ac/yr)	Annual TN Atmospheric Load (lbs/yr)	Annual TP Atmospheric Load (lbs/yr)
North IRL	IR1-3	21,763	4.09	0.093	88,898	2,013
	IR4	2.367	4.09	0.093	9,670	219
	IR5	16,556	4.09	0.093	67,630	1,532
	IR6-7	16,042	4.09	0.093	65,531	1,484
	IR8	3,803	4.09	0.093	15,535	352
	IR9-11	12,209	4.09	0.093	49,875	1,129
Central IRL	IR12	8,566	4.09	0.093	35,051	794
	IR13	3,645	4.09	0.093	14,915	338
	IR14-15	13,865	4.09	0.093	56,734	1,285
	IR16-20	6,010	4.09	0.093	24,591	557
	IR21	2,545	4.09	0.093	10,415	236
Banana River Lagoon	BR1-2	18,755	3.92	0.093	73,486	1,649
	BR3-5	21,338	3.92	0.088	83,604	1,876
	BR6	3,872	3.92	0.088	15,172	340
	BR7	1,905	3.92	0.088	7,465	168
Total		**153,241**			**618,570**	**13,972**

Direct Atmospheric TN Deposition

Sublagoon	Lagoon Segment	Atmospheric Deposition Load	Drainage Basin Load	Total Load	% Atmospheric Loads in the Total Load
North IRL	IR1-3	88,898	134,968	223,866	40%
	IR4	9,670	20,743	30,413	32%
	IR5	67,630	125,855	193,485	35%
	IR6-7	65,531	115,901	181,432	36%
	IR8	15,535	24,288	39,823	39%
	IR9-11	49,875	154,658	204,533	24%
Central IRL	IR12	35,051	508,473	543,524	6%
	IR13	14,915	62,789	77,704	19%
	IR14-15	56,734	728,453	785,187	7%
	IR16-20	24,591	484,025	508,616	5%
	IR21	10,415	12,323	22,738	46%
Banana River Lagoon	BR1-2	73,486	127,782	201,268	37%
	BR3-5	83,604	73,704	157,308	53%
	BR6	15,172	46,213	61,385	25%
	BR7	7,465	41,418	48,883	15%
Total		**618,570**	**2,661,593**	**3,280,163**	**19%**

Direct Atmospheric TP Deposition

Sublagoon	Lagoon Segment	Atmospheric Deposition Load	Drainage Basin Load	Total Load	% Atmospheric Loads in the Total Load
North IRL	IR1-3	2,013	13,901	15,914	13%
	IR4	219	4,435	4,654	5%
	IR5	1,532	20,377	21,909	7%
	IR6-7	1,484	18,618	20,102	7%
	IR8	352	4,418	4,770	7%
	IR9-11	1,129	31,758	32,887	3%
Central IRL	IR12	794	81,661	82,455	1%
	IR13	338	7,743	8,081	4%
	IR14-15	1,285	121,192	122,477	1%
	IR16-20	557	96,052	96,609	1%
	IR21	236	2,359	2,595	9%
Banana River Lagoon	BR1-2	1,649	20,660	22,309	7%
	BR3-5	1,876	17,044	18,920	10%
	BR6	340	9,724	10,064	3%
	BR7	168	7,553	7,721	2%
Total		**13,972**	**457,495**	**471,467**	**3%**

Calculation of Needed Percent Reduction with And without Atmospheric Deposition

WBID	TN (Without Atmospheric Deposition)			TN (With Atmospheric Deposition)		
	Existing Year-2000 (lbs/yr)	LA (lbs/yr)	% Reduction	Existing Year-2000 (lbs/yr)	LA (lbs/yr)	% Reduction
2963F	134,968	88,322	35%	223,866	177,220	21%
2963E	146,598	95,932	35%	223,898	173,232	23%
2963D	115,901	73,882	36%	181,432	139,413	23%
2963B+2963C	178,946	114,459	36%	244,355	179,868	26%
5003D+2963A	1299,715	577,183	56%	1,406,416	683,884	51%
5003B+5003C	496,348	217,877	56%	531,353	252,882	52%
3057C	127,782	41,614	67%	201,268	115,100	43%
3057A+3057B	115,122	47,539	59%	206,190	138,607	33%
3044A	46,213	15,489	66%	61,385	30,661	50%

Calculation of Needed Percent Reduction with And without Atmospheric Deposition

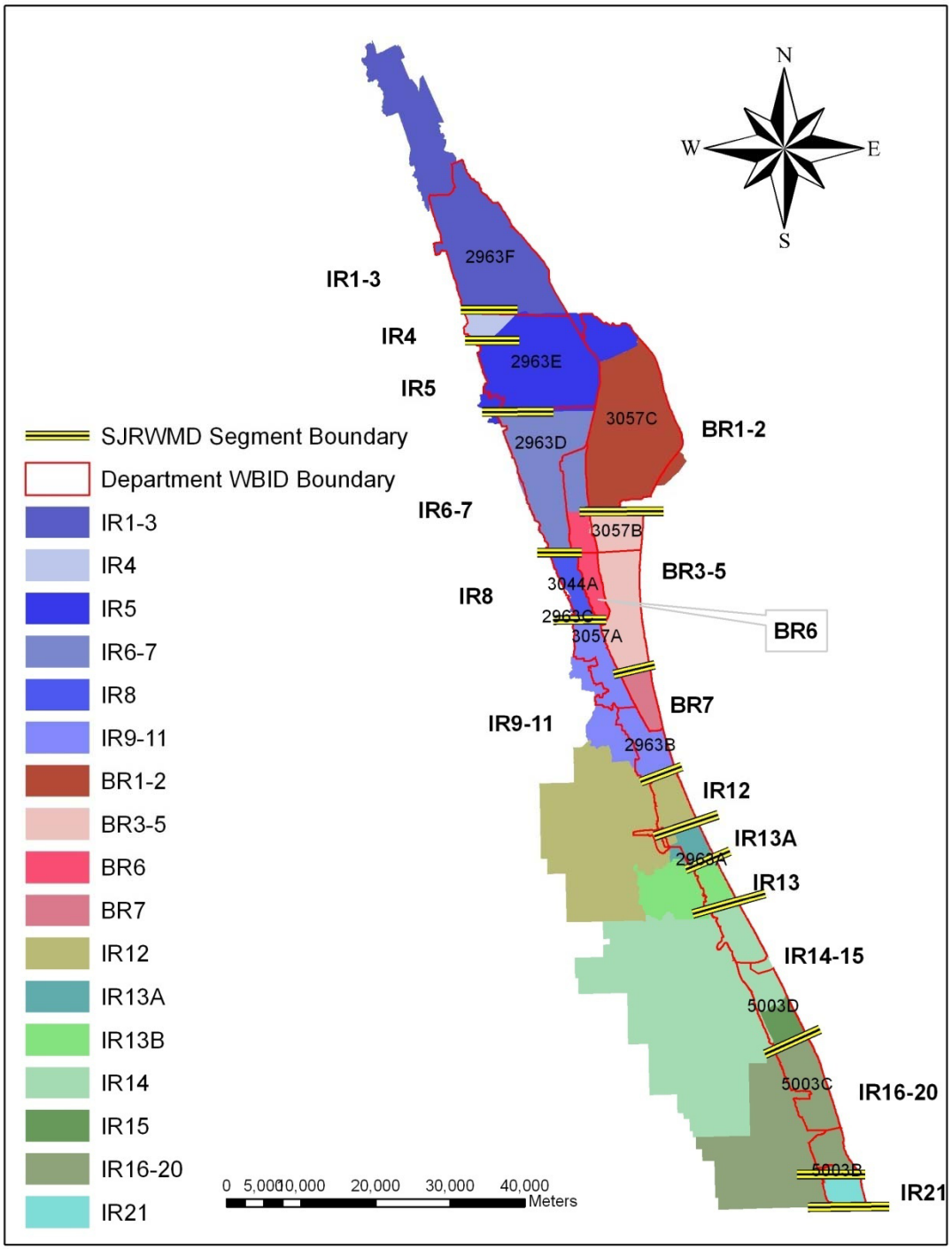
WBID	TP (Without Atmospheric Deposition)			TP (With Atmospheric Deposition)		
	Existing Year-2000 (lbs/yr)	LA (lbs/yr)	% Reduction	Existing Year-2000 (lbs/yr)	LA (lbs/yr)	% Reduction
2963F	13,901	7,307	47%	15,914	9,320	41%
2963E	24,812	13,042	47%	26,563	14,793	44%
2963D	18,618	8,752	53%	20,102	10,236	49%
2963B+2963C	36,176	18,886	48%	37,657	20,367	46%
5003D+2963A	210,596	109,055	48%	213,013	111,472	48%
5003B+5003C	98,411	50,857	48%	99,204	51,650	48%
3057C	20,660	5,874	72%	22,309	7,523	66%
3057A+3057B	24,597	8,916	64%	26,641	10,960	59%
3044A	9,724	2,907	70%	10,064	3,247	68%

TMDL General Allocation

- TMDL = ΣWLAs + ΣLAs + MOS
  - WLA = Wasteload Allocation (including wastewater and MS4 stormwater)
  - LA = Load Allocation (nonpoint sources)
- WLAs were determined according to:
  - Those facilities that already achieve advanced wastewater treatment (AWT) and/or discharge infrequently were allocated annual TN and TP loads equivalent to the 95th percentile of their discharged nutrient loads for 2001 to 2005.
  - For facilities that haven't met the AWT level requirements and discharge a relatively large quantity of nutrients into the lagoon system, the long-term average annual TN and/or TP loads are assigned as the facilities' WLA.
  - Some exceptions
- ΣLAs = TMDL - ΣWLAs

TMDL Rule Language
Clarification on the Calculation of Needed Percent Reduction

- The rule language (62-304 FAC) for the IRL Nutrient TMDLs includes five parts:
  1. TMDL (includes the atmospheric direct deposition)
  2. WLA to the wastewater facilities
  3. WLA to the municipal separate storm sewer system (MS4) facilities (represented as needed percent reduction, not includes the atmospheric direct deposition)
  4. LA to the nonpoint sources (represented as needed percent reduction, not includes the atmospheric direct deposition)
  5. Margin of safety

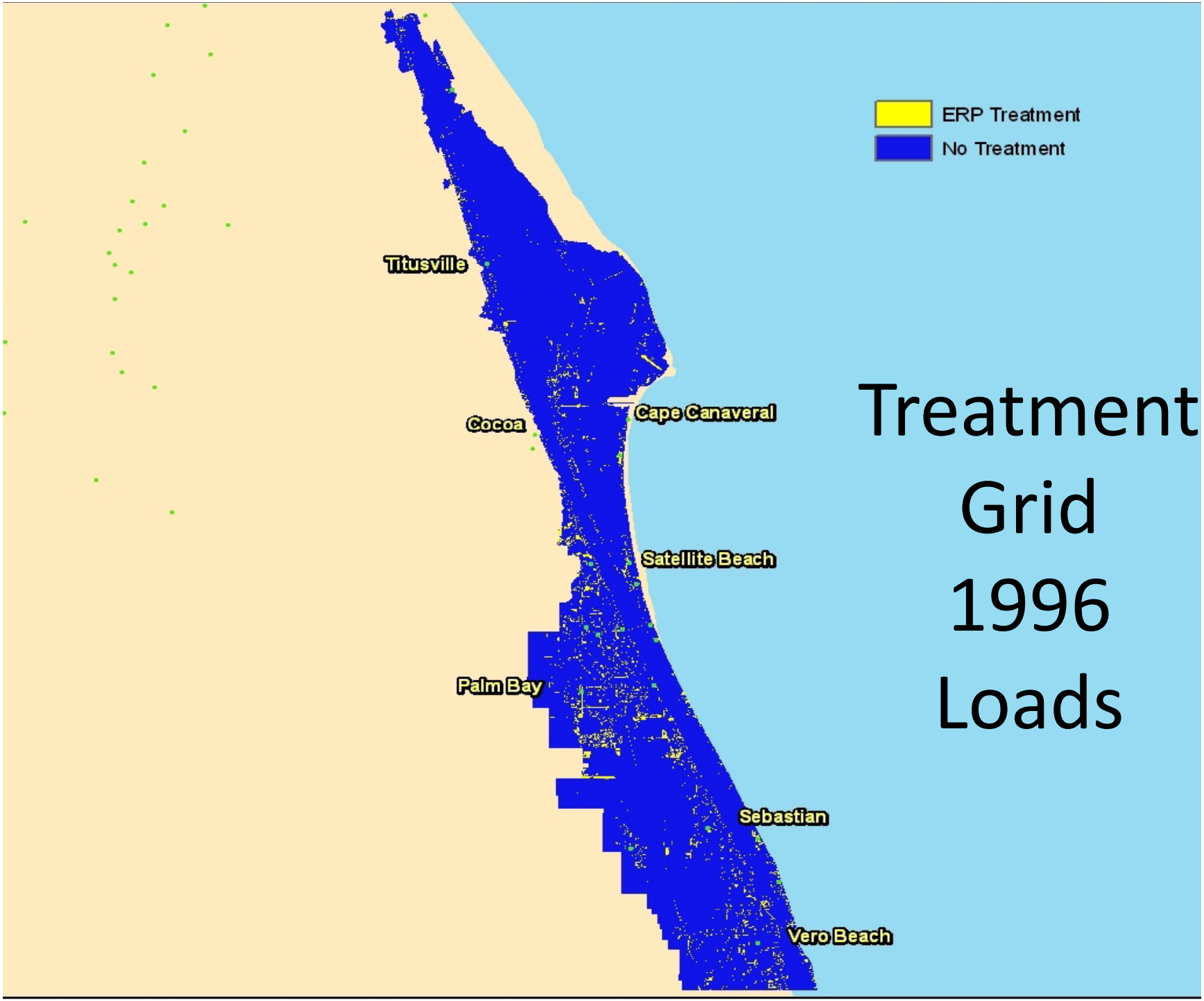


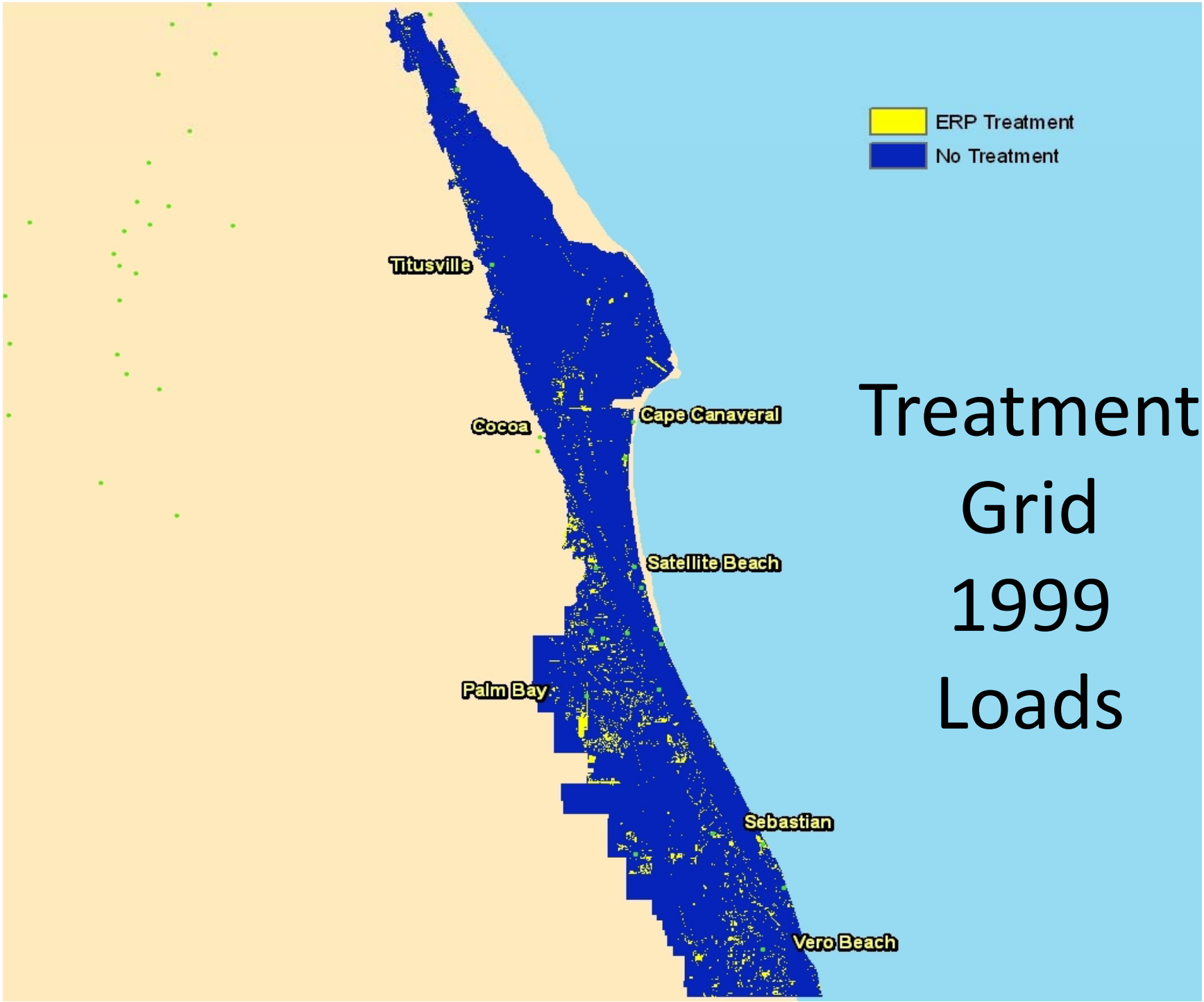
Aggregate PLRG Lagoon Segments into TMDL WBIDs

WBIDs	Segments
North IRL (total)	
2963F	IR1-3
2963E	IR4+IR5
2963D	IR6-7
2963B+2963C	IR8+IR9-11
Central IRL (total)	
5003D+2963A	IR12+IR13 +IR14-15
5003B+5003C	IR16-20+IR21
Banana River Lagoon (total)	
3057C	BR1-2
3057A+3057B	BR3-5+BR 7
3044A	BR6

RESERVE SLIDES

This is where we can place additional slides that may help us answer questions after the formal presentation


ERP Treatment
No Treatment
Titusville
Cocoa
Cape Canaveral
Satellite Beach
Palm Bay
Sebastian
Vero Beach
Treatment
Grid
1996
Loads


ERP Treatment
No Treatment
Titusville
Cocoa
Cape Canaveral
Satellite Beach
Palm Bay
Sebastian
Vero Beach
Treatment
Grid
1999
Loads

PLSM Calibration Results by Watershed

Watershed	Volume (ac-ft)	TN (lb)	TP (lb)	TSS (lb)
CC PLSM	24,502	89,676	18,459	2,971,959
Crane Creek Measured 2002-03	26,610	87,013	24,375	4,210,654
South Prong PLSM	59,684	248,826	46,491	3,000,496
South Prong Measured 1999	74,066	240,954	43,138	1,841,738
C-1 Turkey PLSM	59,590	199,099	20,883	2,608,862
C-1 Turkey Measured 1991	79,447	213,455	10,270	2,454,296
Briar Creek PLSM	4,423	11,031	1,900	82,355
Briar Creek Measured 1999	4,477	10,496	2,586	63,349
Total PLSM	148,199	548,632	87,733	8,663,672
Total Measured	184,600	551,918	80,368	8,570,037
Total Difference	-36,401	-3,287	7,365	93,634
Total Absolute Difference	36,401	25,425	20,570	2,571,026

Wet Detention Treatment

Treatment Site	Hydraulic Res Time (days)	Reduction TN (%)	Reduction TP (%)	Reduction TSS (%)
[1] Lansing, MI-S	1.1	5%	12%	32%
[1] Ann Arbor, MI - Pitt AA	2.2	12%	18%	32%
[1] Ann Arbor, MI - Swift Run	6.2	45%	3%	85%
[1] Long Island – Unqua	34.3	0%	45%	60%
[1] Washington DC, Westleigh	33.2	27%	54%	81%
[1] Glen Ellyn, IL	43.5	nd	34%	84%
[1a] Waverly Hills, Michigan	39.9	62%	79%	91%
[2] Columbia, MO – Callahan	10.6	nd	74%	85%
[3] Boca Raton, FL – Timbercreek	8.3	30%	60%	64%
[4] Tampa FL - Office Pond	1.7	14%	67%	55%
[5] Tampa FL - Office Pond	14.0	61%	87%	95%
[6] Orlando, FL – Greenview	nd	19%	23%	46%
[7] Palm Bay Basin 7	14.0	33%	54%	76%
[8] Frisco Lake, Mo	28.0	11%	65%	88%
[9] Springhill, FL	64.3	79%	64%	nd
[10] Melbourne Detention Pond	14.0	36%	65%	nd
[10] Melbourne Pond B	7.0	33%	56%	nd
[11] Sebastian Stormwater Park	69.6	27%	60%	90%
Mean	23.05	31%	50%	71%

[1] EPA NURP Final Report, 1983

[1a] Schueler (1992) - Metropolitan Washington Council

[2] Rausch and Schreiber, 1981

[3] Whalen & Cullum, 1984, 1988

[4] Rushton & Dye, 1993

[5] Rushton, et al, 1997

[6] Yousef, et al., 1990

[7] Harper, 2003

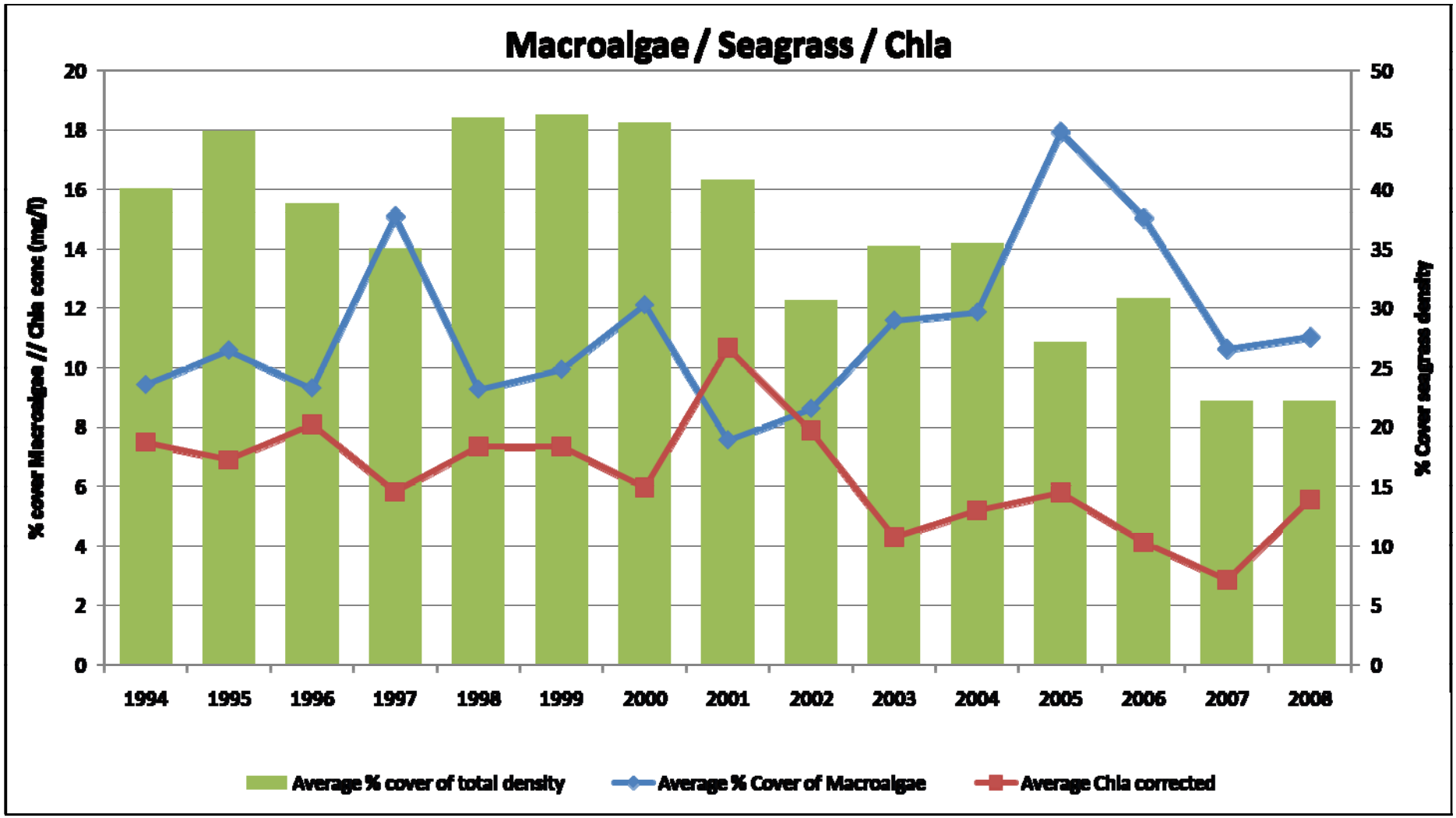
[8] Oliver and Grigoropoulos, 1981

[9] Holler, J. D., 1989

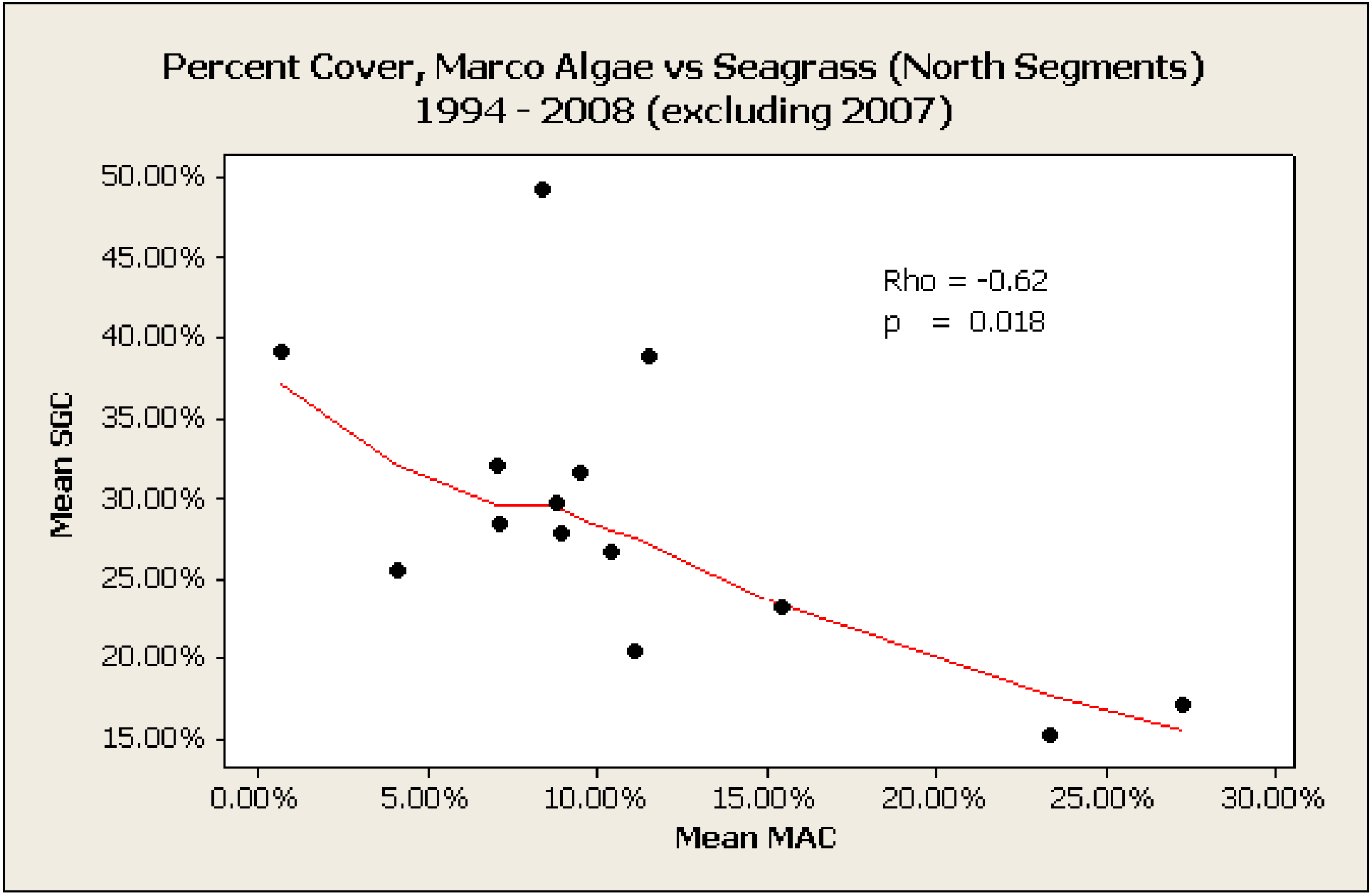
[10] Harper, 2007

[11] CDM Report, edited December 2008

Variations in percent cover between seagrass and drift algae within IRL seagrass beds



Correlation: macroalgae & seagrass



Distribution of land-use loading

PLSM Loading Distribution C-1

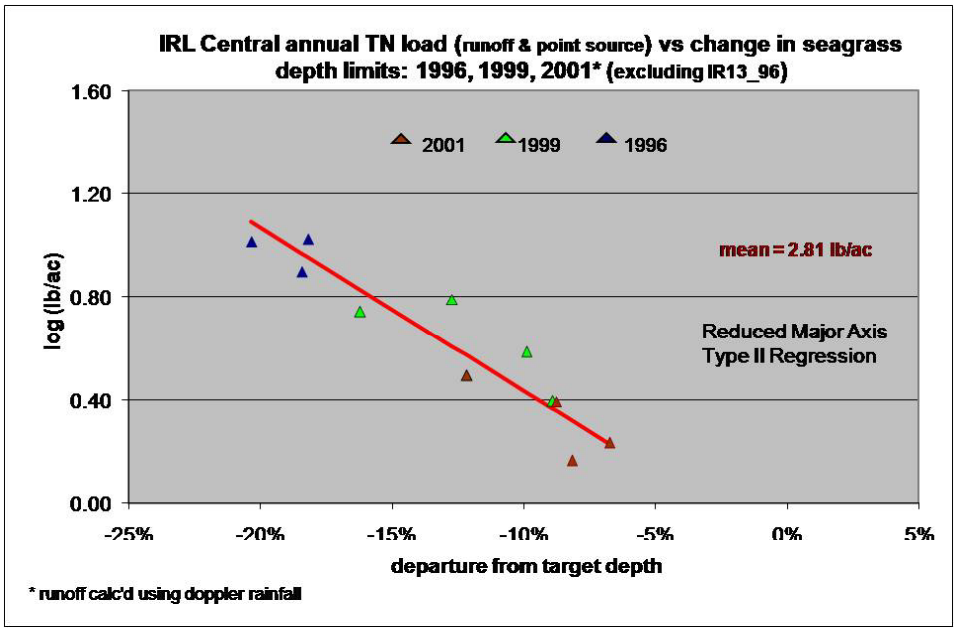
Land Use Type	Volume	TN	TP	TSS
Med density Residential	**21%**	**33%**	**43%**	**32%**
Unimproved Pasture	**15%**	**24%**	**8%**	**18%**
Rangeland	**17%**	**13%**	**7%**	**3%**

PLSM Loading Distribution Crane Creek

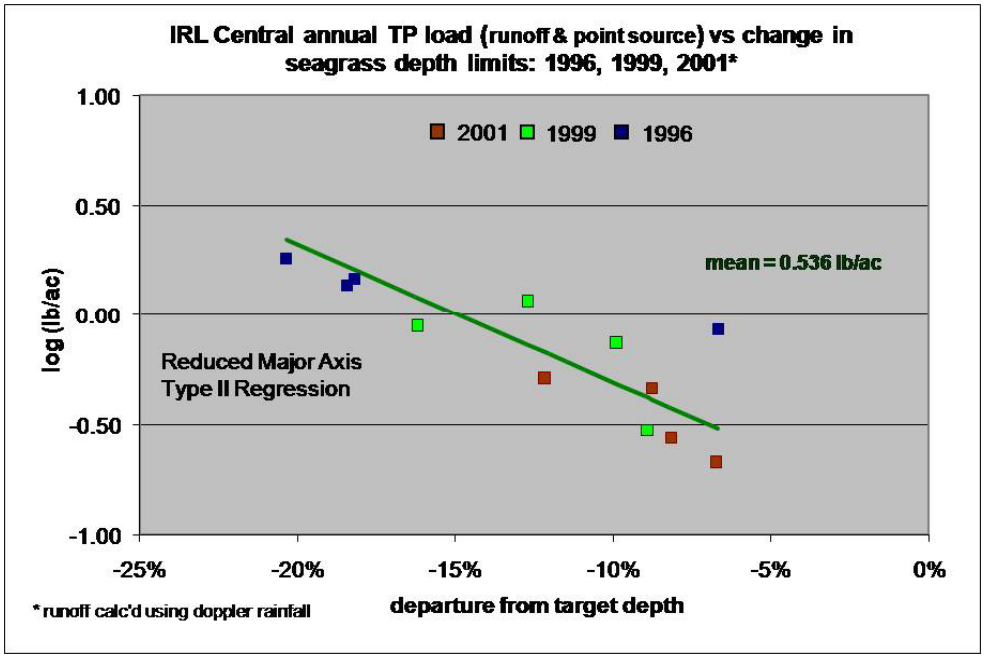
Land use Type	Volume	TN	TP	TSS
Commercial high	**15%**	**23%**	**25%**	**35%**
Industrial	**5%**	**5%**	**7%**	**13%**
Residential high	**11%**	**13%**	**17%**	**12%**
Residential medium	**17%**	**22%**	**21%**	**12%**

PLSM Loading Distribution South Prong

Land Use Type	Volume	TN	TP	TSS
Med Density Residential	**7%**	**10%**	**8%**	**10%**
Improved pasture	**10%**	**18%**	**23%**	**17%**
Citrus	**24%**	**30%**	**48%**	**52%**



Type II regressions



Types of Results – Nutrient Load Criteria (cont.)

allowable loads & load reductions by segment

load reduction = current or build-out load - allowable load (NPS+PS).

EXAMPLE: ***821,282 lb/yr TN allowable load for Central IRL***

Allocate per segment according to current NPS distribution + PS

226,361 lb/yr TN allowable load for segment IR12
(225,902 lb NPS allowable + 459 lb PS)

Load reduction for IR12

Current
282,571 lb/yr TN (55.5%)

Build-out
406,539 lb/yr TN (64.2%)