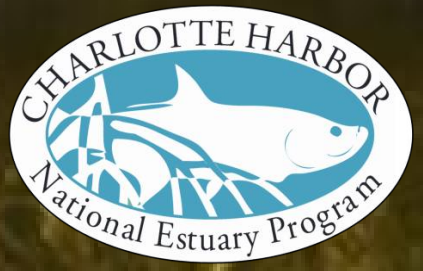
From Seagrasses to Numeric Nutrient Criteria: Charlotte Harbor NEP Water Quality Targets

SW FL Water Resources Conference 2010
Judy Ott , Charlotte Harbor NEP
Anthony Janicki, Janicki Environmental
Mike Wessel, Janicki Environmental
& CHNEP Seagrass & Water Quality Partners

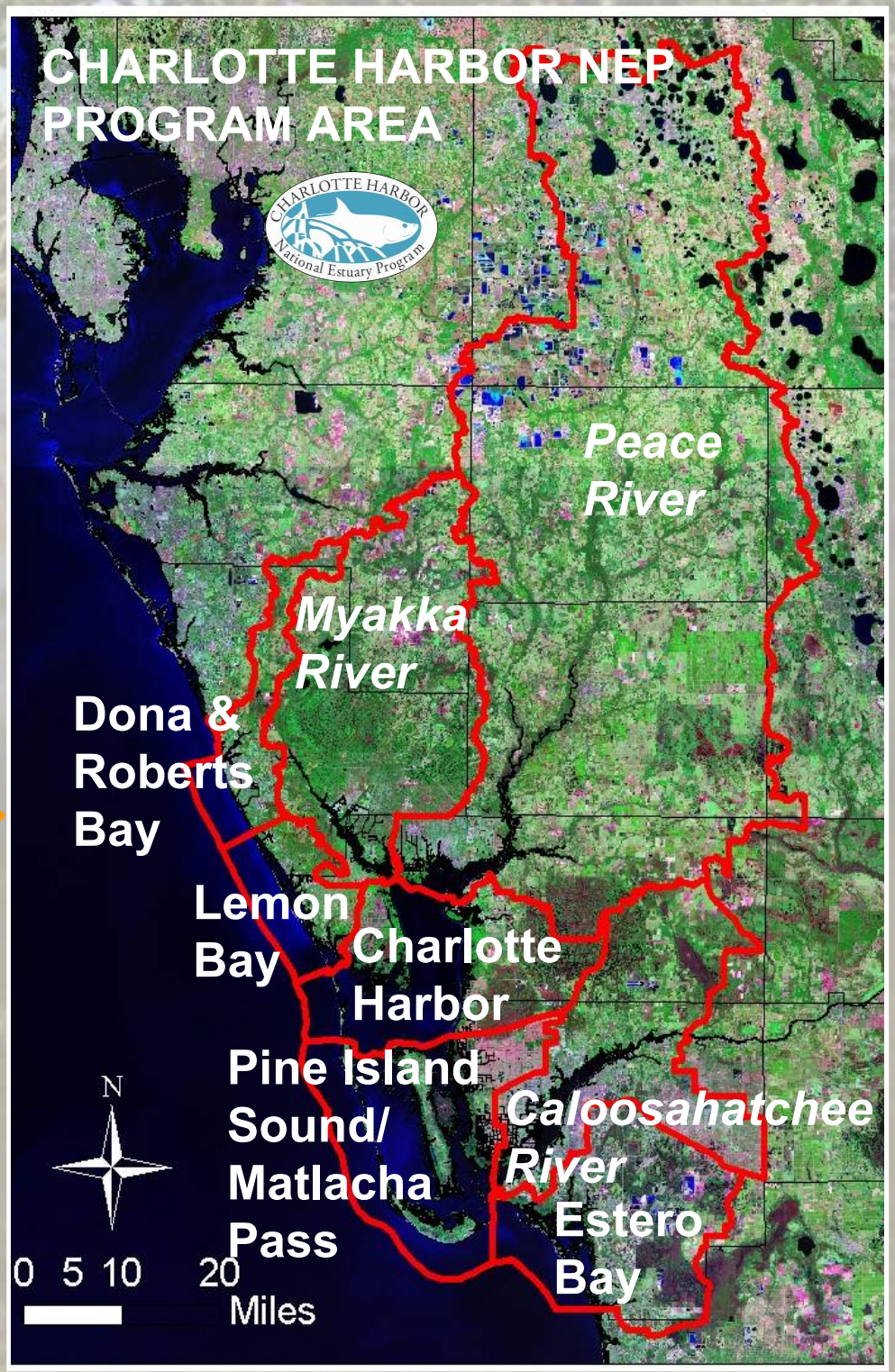


Presentation Overview

- Where is CHNEP?
- What & Where are Seagrasses Found in CHNEP?
- Why Use Seagrass as Basis for CHNEP Water Quality Targets?
- What Data are Used for CHNEP Water Quality Targets?
- How are CHNEP Water Quality Targets Being Developed?
- What are the Next Steps for CHNEP Water Quality Targets?

What & Where is Charlotte Harbor NEP?

- 1 of 28 NEPs
- Designated in 1995
- Partnership of Organizations
- Located in SW FL
- Watershed >12,170 km²
- 11 Estuaries >735 km²
- 3 Major Rivers & >20 Creeks
- 6 FL Aquatic Preserves



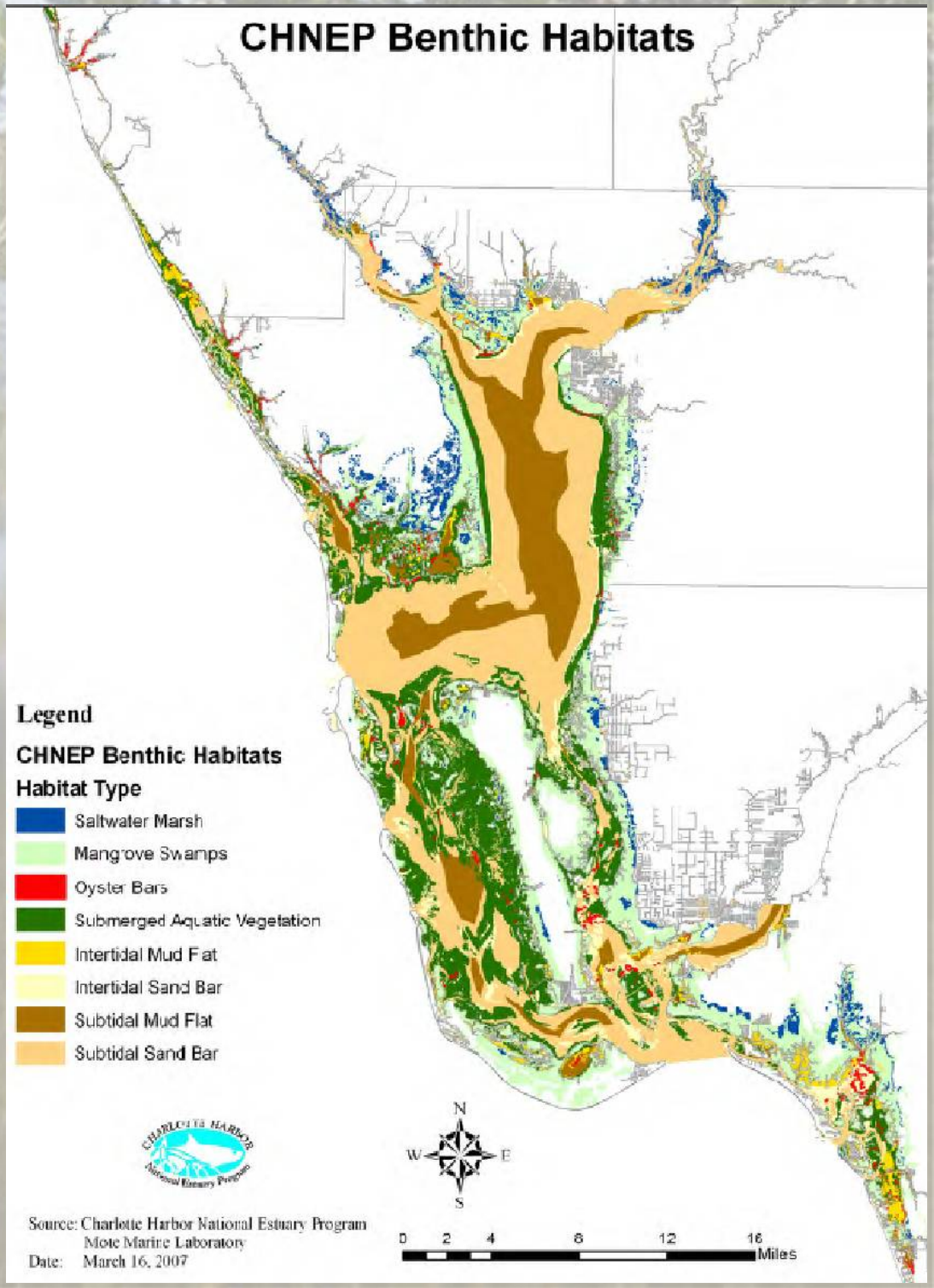
Estuaries in CHNEP

- Dona & Roberts Bay
- Roberts Bay
- Lemon Bay
- Cape Haze
- Tidal Myakka River
- Tidal Peace River
- Charlotte Harbor
- Pine Island Sound
- Matlacha Pass
- Tidal Caloosahatchee
- San Carlos Bay
- Estero Bay

Where are Seagrasses Found in CHNEP?

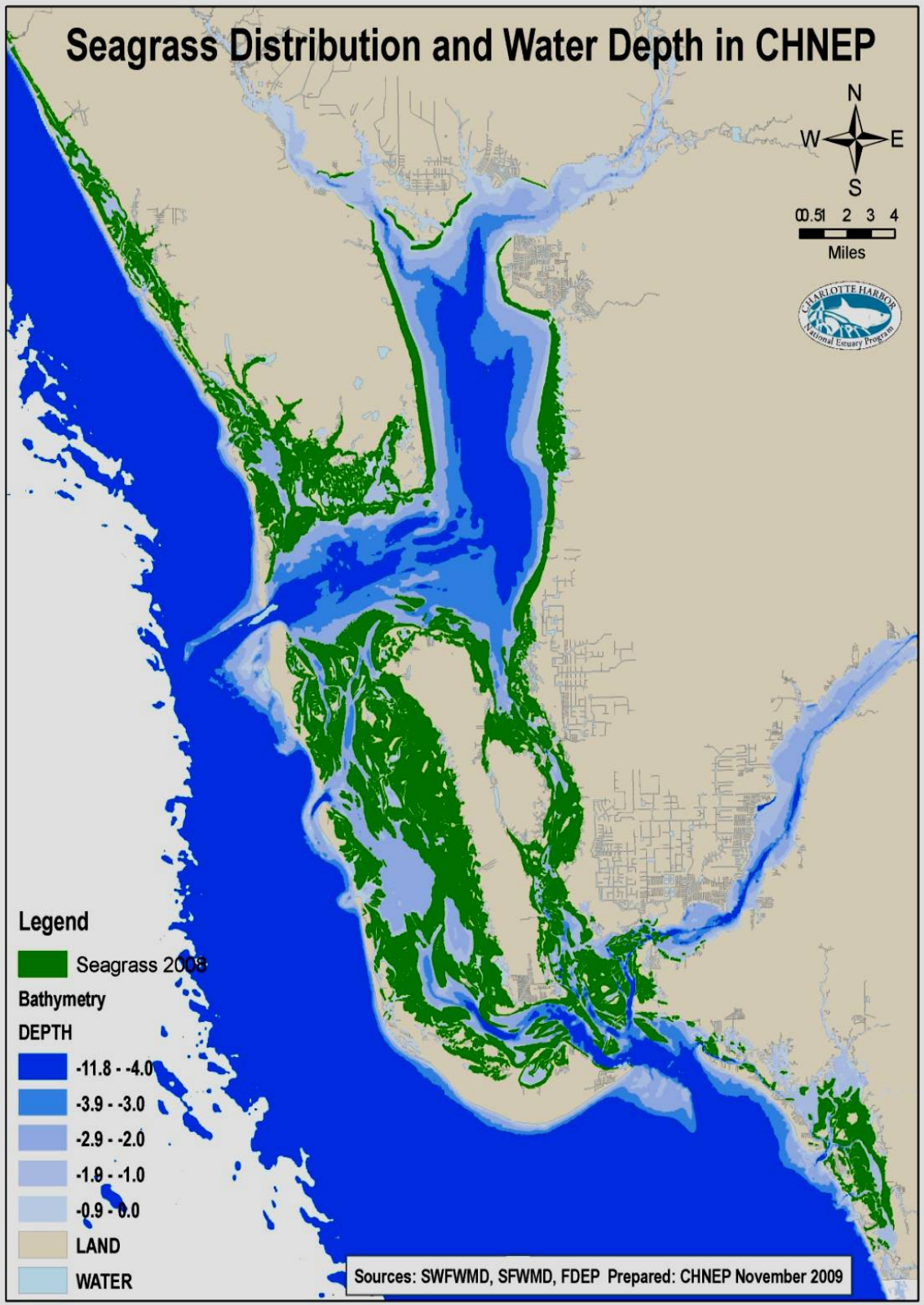
Benthic Habitats in Estuaries & Tidal Creeks

Habitat	Acres	%
Subtidal Mud & Sand	131,370	46%
Mangrove Swamp	58,870	21%
Seagrass	58,670	21%
Intertidal Mud & Sand	24,500	9%
Saltwater Marsh	12,200	4%
Oyster Bars	250	1%
Total	285,860	100%



Seagrass Distribution CHNEP in Estuaries

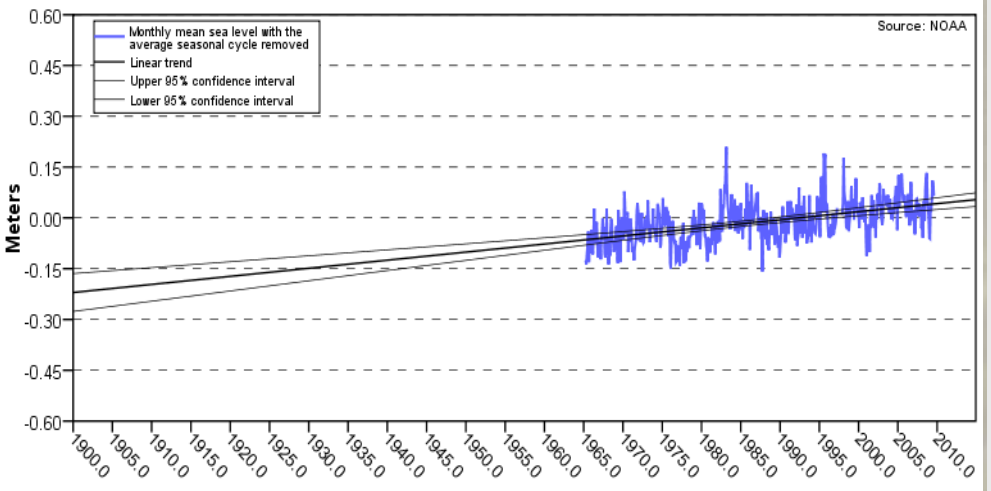
- In estuarine waters < 2 m deep
- Primary submerged habitat
- ± 24,000 hectares
- vary by estuary,
  by year,
  by season &
  by species

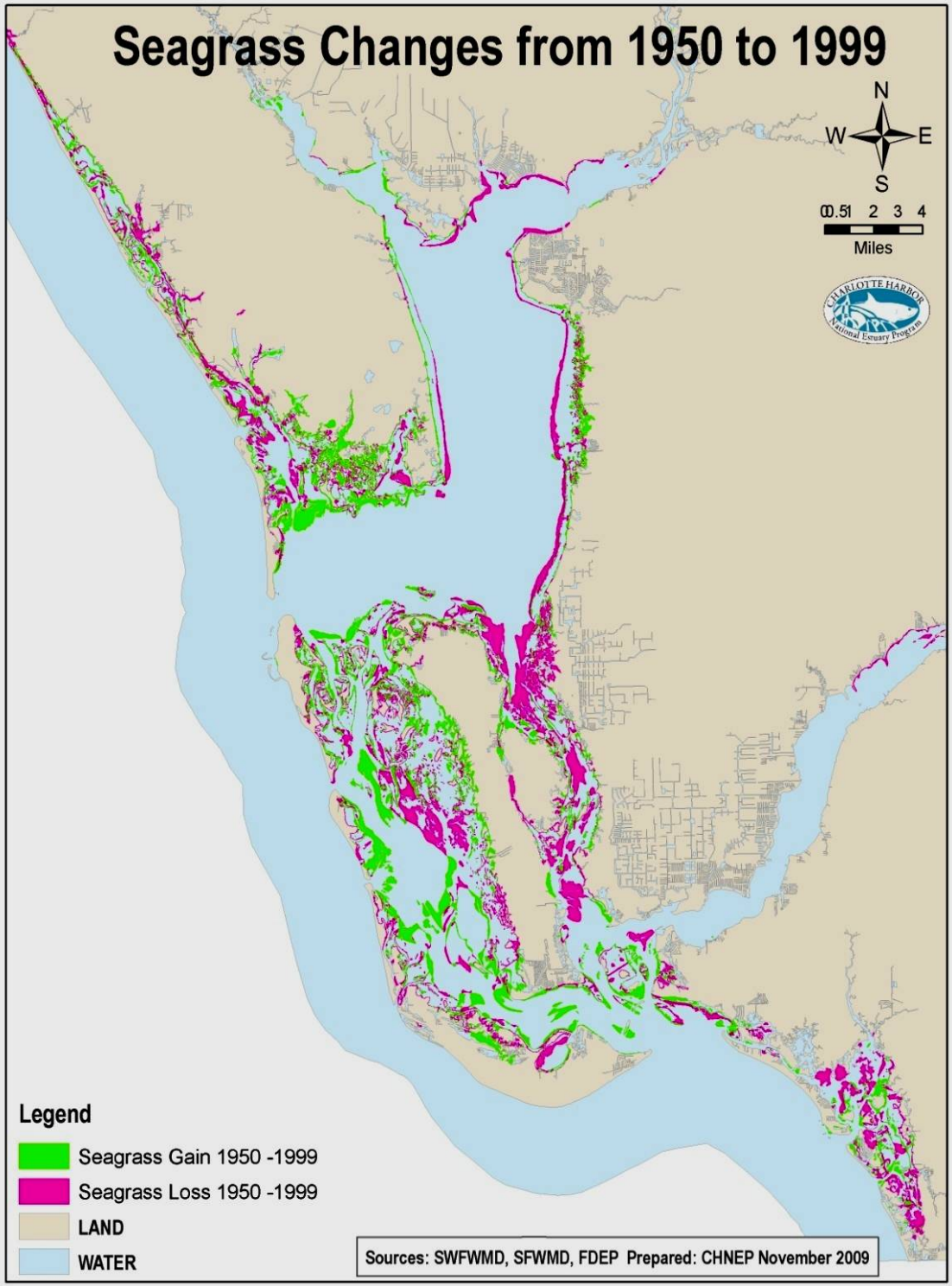


Seagrasses Declined Over the Long Term in CHNEP…

- Seagrass loss from 1950-1999 = ±1,020 ha
- Seagrass loss affected by dredge & fill activities, decreasing water clarity, changing salinity & increasing sea level

Mean Sea Level Trend 1965 – 2006
NOAA Tide Station at Fort Myers
2.4 cm/decade

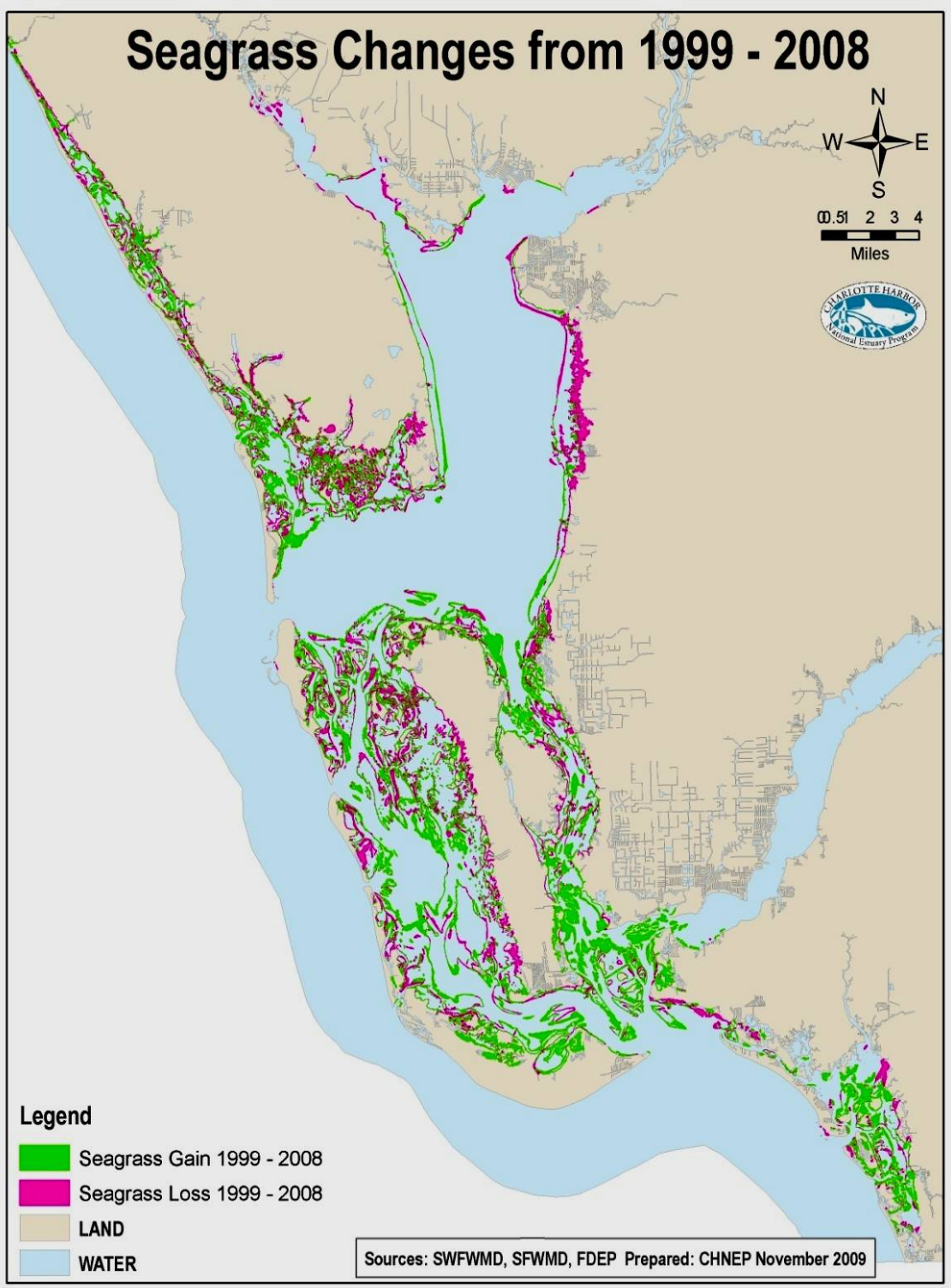




Seagrasses Increased Over the Short Term…

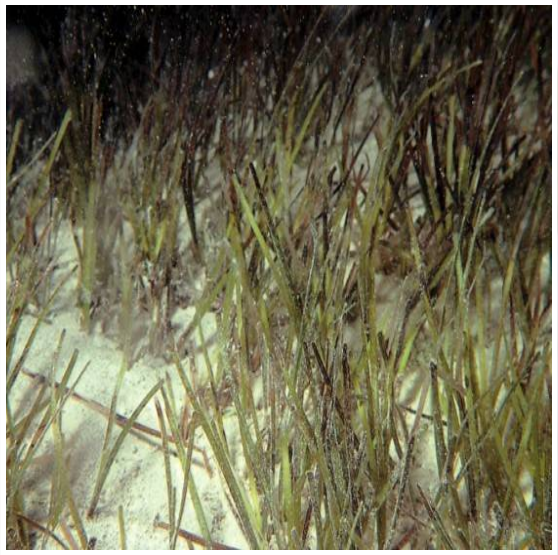
- Seagrass acres relatively stable since 1982
- Acres & density vary by year
- Seagrass gain from 1999-2008 = ±2,595 ha
- Influenced annually by rainfall

Total Annual Rainfall for Charlotte County	
1948-1949	102 cm
1998-1999	150 cm
2007-2008	94 cm



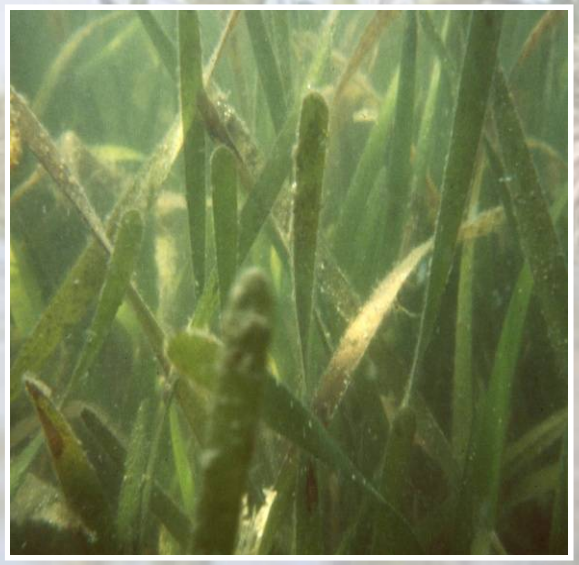
Seagrass Species in CHNEP

Shoal



Halodule wrightii

Turtle

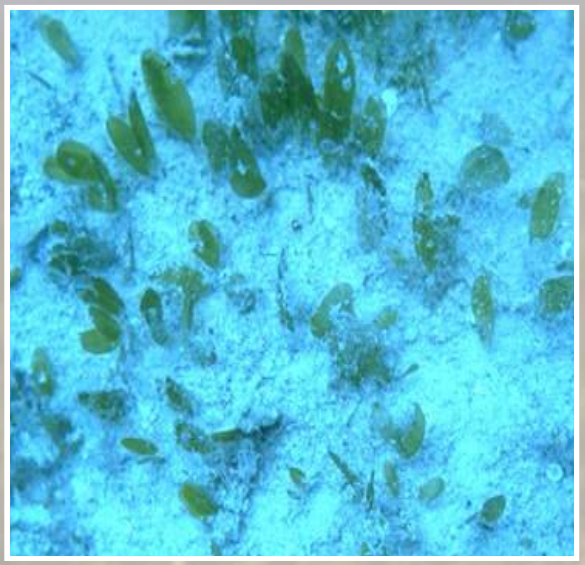


Thalassia testudinum

Manatee

Syringodium filiforme

Paddle



Halophila decipiens

Star

Halophila engelmannii

Widgeon

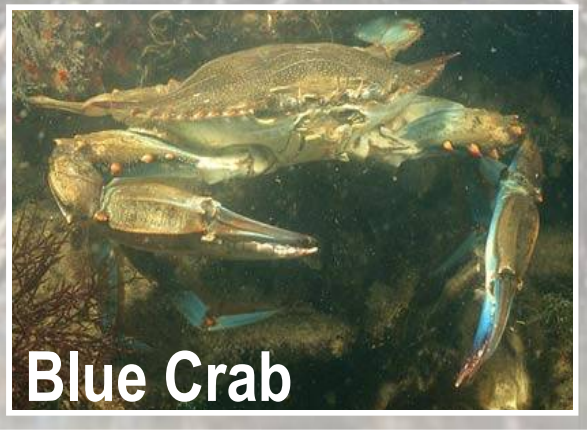
Ruppia maritima

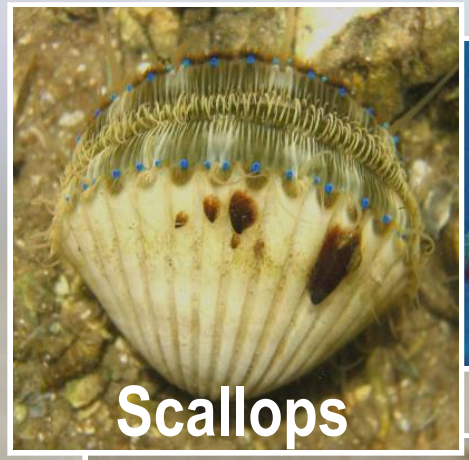
Why Use Seagrass as Basis for CHNEP Water Quality Targets?

- Implement CHNEP CCMP
- Guide restoration & maintenance
- Seagrasses are widely distributed
- Seagrasses are quantifiable
- Serve as environmental indicator
- Responsive to changes in water clarity, water quantity, hydrology & salinity
- Seagrass responses are measurable & "modelable"
- Use to estimate needed pollutant load reductions & effectiveness management actions
- Meet EPA requirement for FL to develop numeric nutrient criteria for fresh & estuarine waters…

And Seagrasses Support a Great Diversity of Life

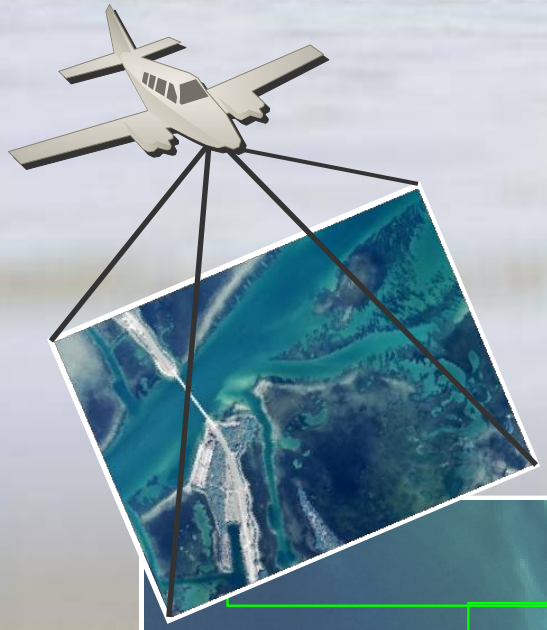
- epiphytes (algae & invertebrates)
- macroinvertebrates
- crustaceans
- shellfish
- fisheries
- mammals
- listed species



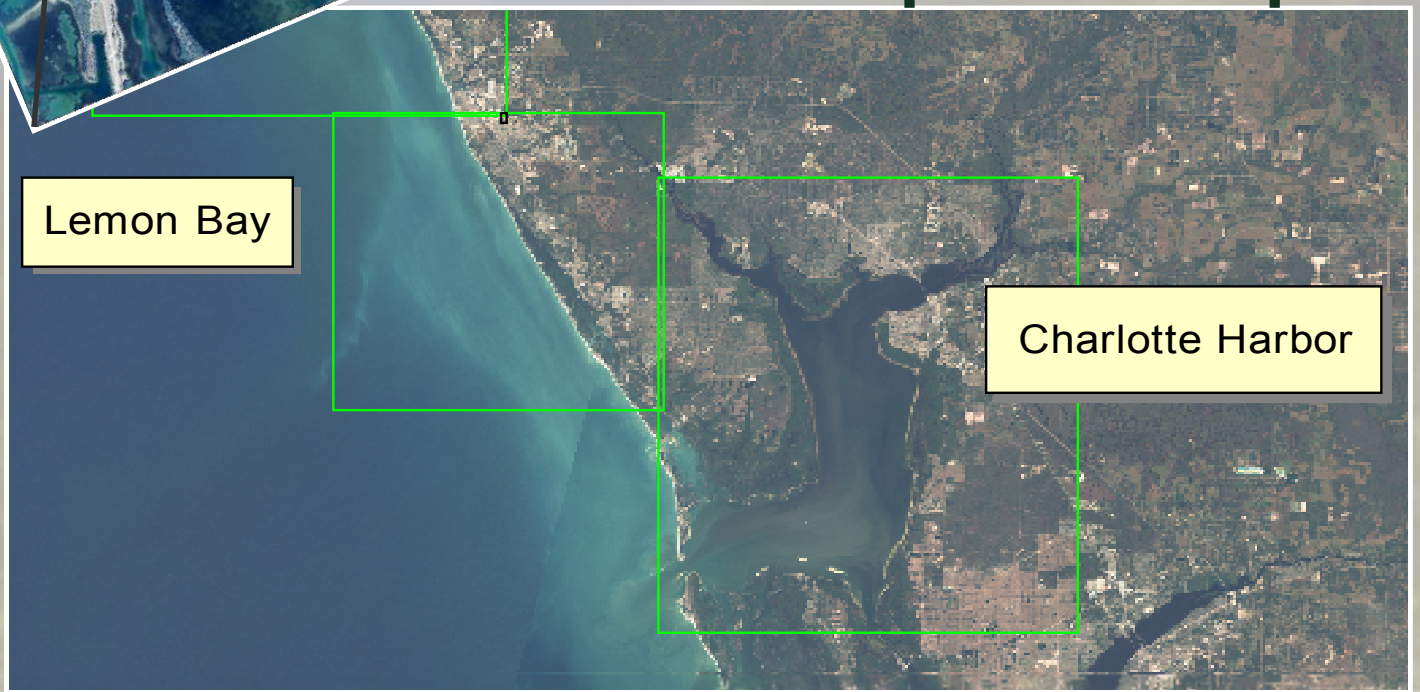


What Data is Used for CHNEP Water Quality Targets?

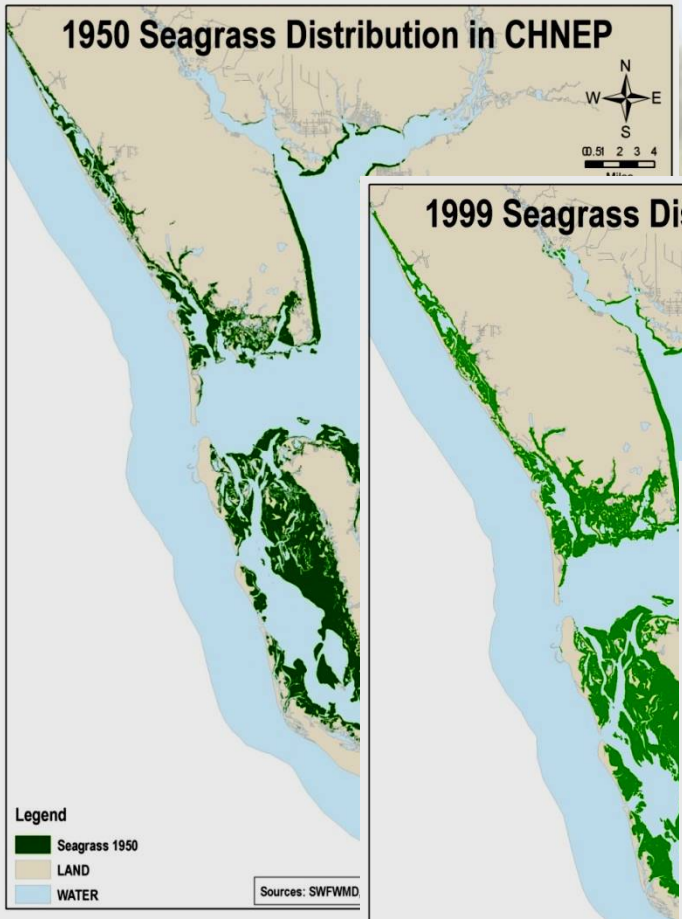
Seagrass Aerial Photography by Water Management Districts

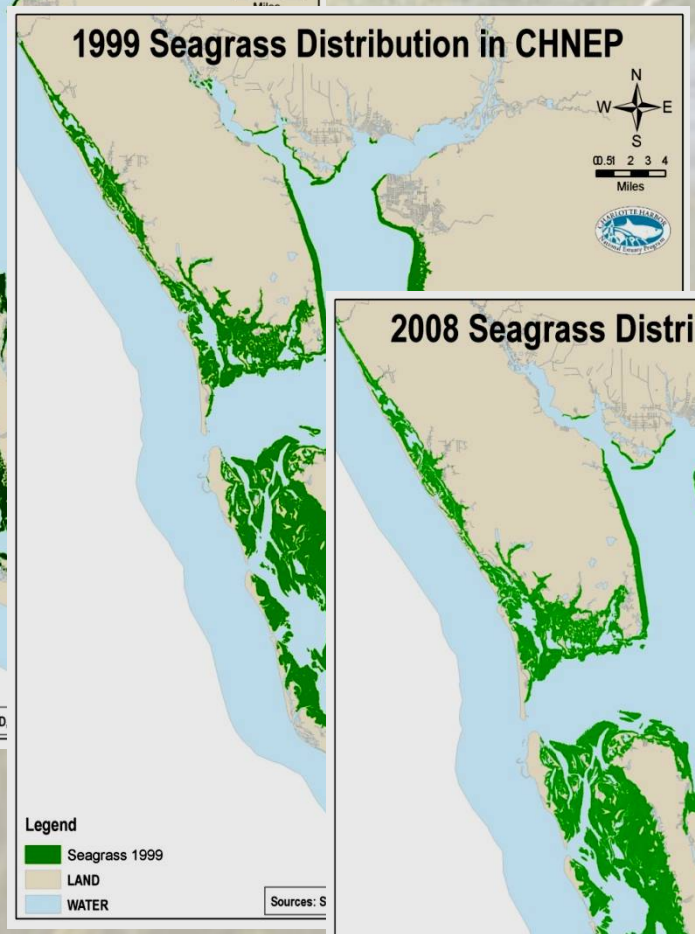


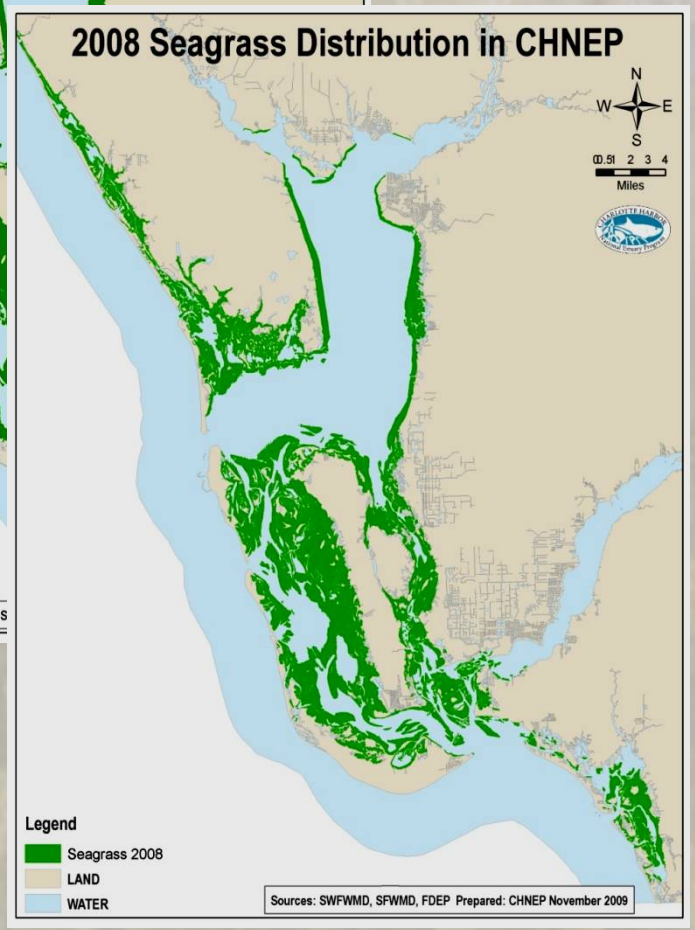
- Began in 1988
- True Color (≤2004) & Digital (≥2006)
- 0.5 ac minimum mapping unit (1’ pixel)
- 5 FL Land Cover Classifications (FLUCCS)
- Field & interpretation quality assurance



- **Seagrass maps are compiled for CHNEP study area from aerial photos at regular intervals**



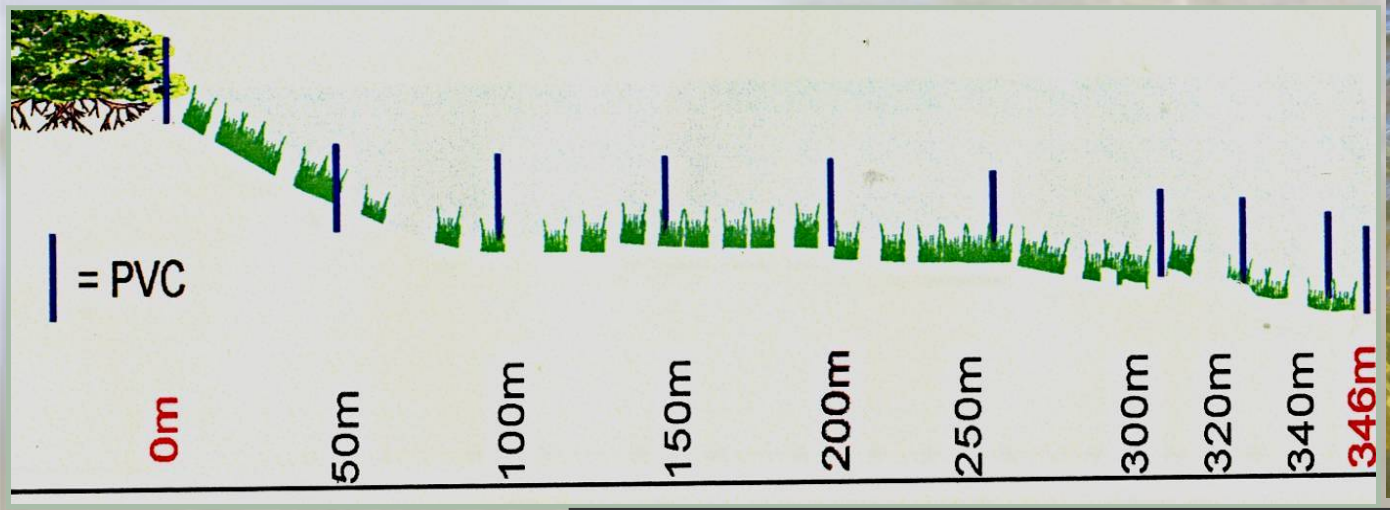


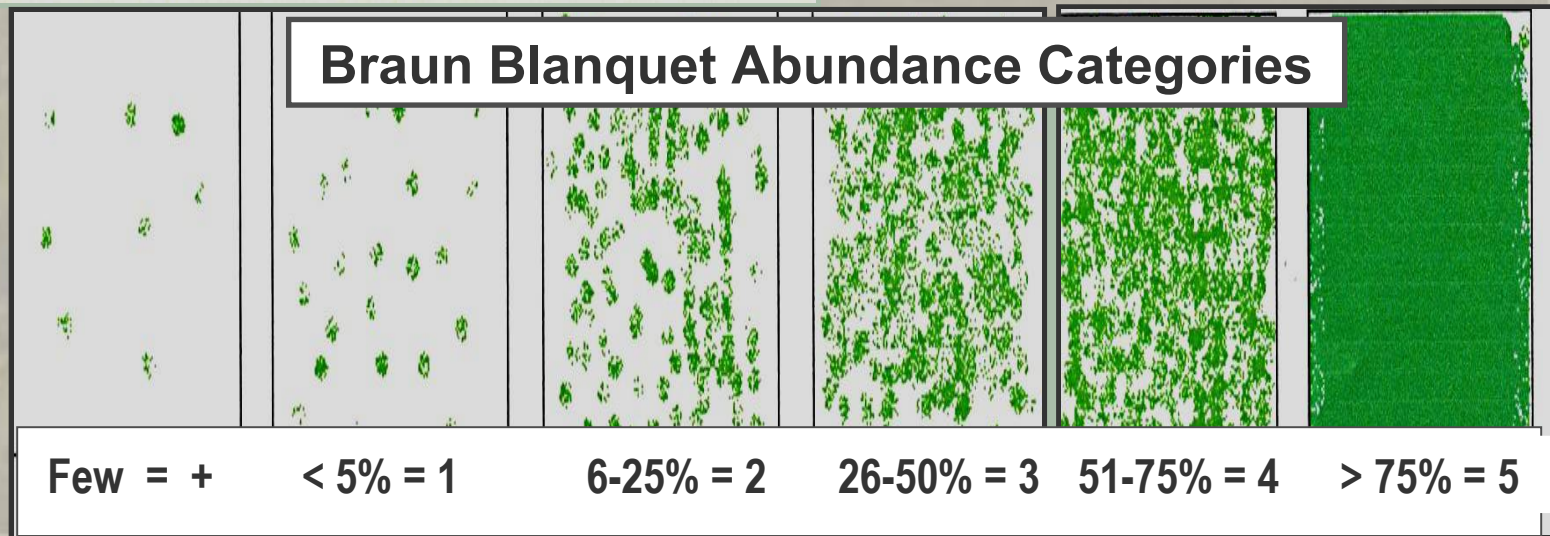


SWFWMD		SFWMD	
Dona Roberts Lemon Bays	Upper Charlotte Harbor	Lower Charlotte Harbor	Estero Bay
1988	1988	---	---
---	1992	---	---
1994	1994	---	---
1996	1996	---	---
1999	1999	1999	1999
2001	2001	---	---
---	---	2003	2003
2004	2004	2004	2004
2006	2006	2006	2006
2008	2008	2008	2008

Seagrass Transect Monitoring by FDEP

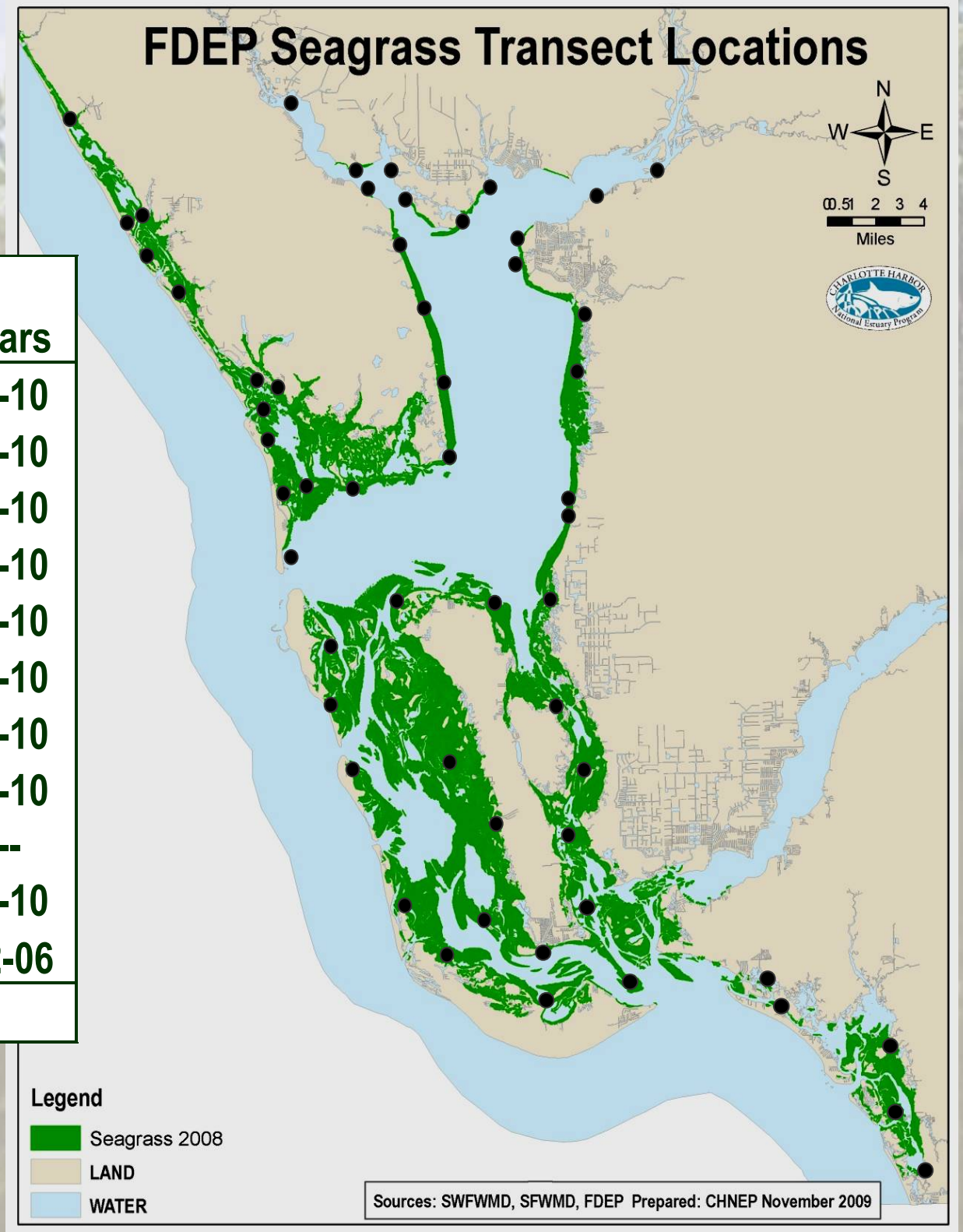
- Fixed transects from shallow to deep edge of seagrass
- 1 m^2 Grids at defined intervals along each transect
- Use Braun Blanquet abundance categories
- 5 seagrass & 6 physical parameters





- **55 Seagrass transects monitored annually since 1999**

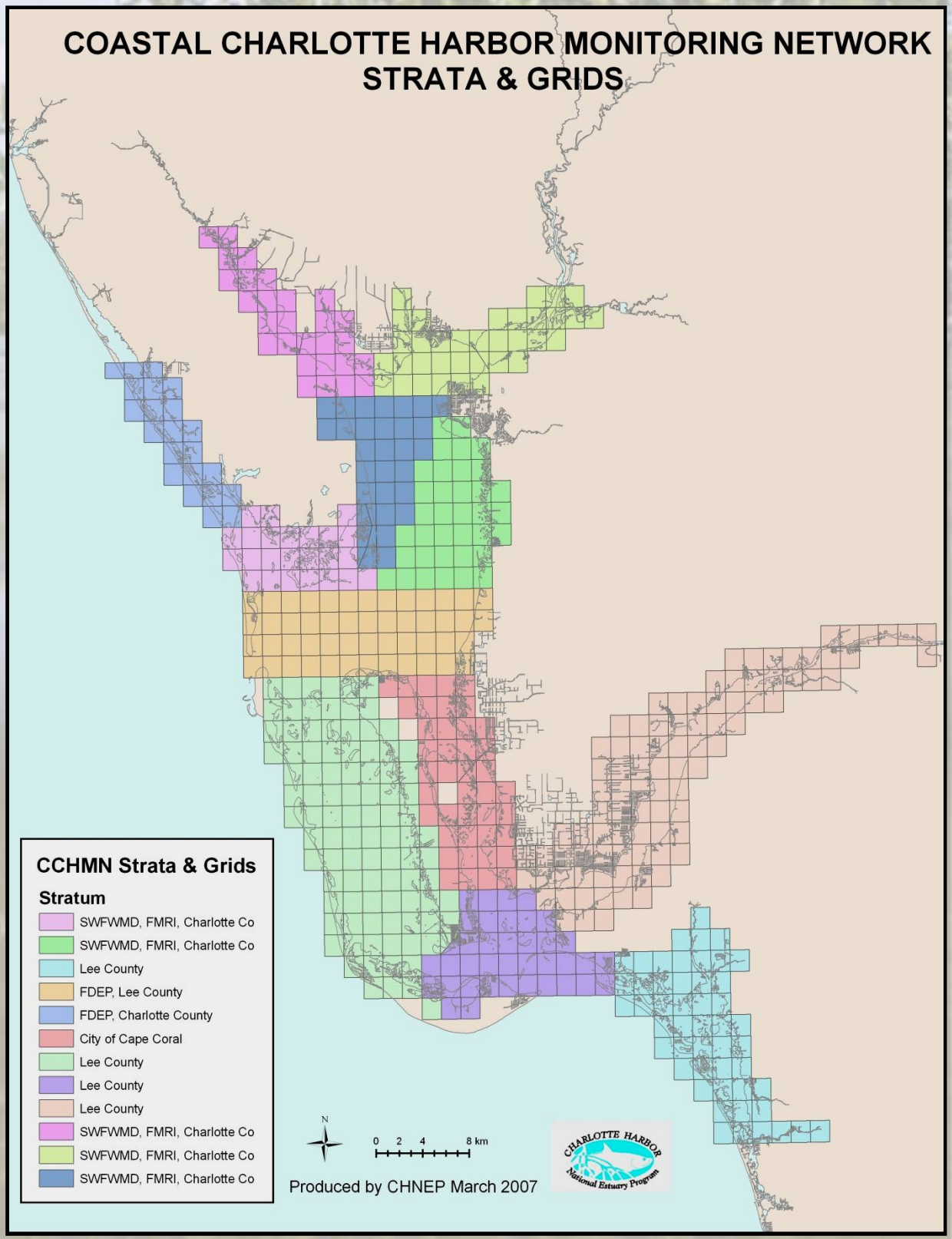
Estuary	# Sites	Years
Lemon Bay	6	99-10
Cape Haze	5	99-10
Myakka River Tidal	5	99-10
Peace River Tidal	5	99-10
Charlotte Harbor East/West	7	99-10
Charlotte Harbor Lower	5	99-10
Pine Island Sound	9	99-10
Matlacha Pass	4	99-10
Caloosahatchee R Tidal	---	---
San Carlos Bay	4	99-10
Estero Bay	5	02-06
Total	55	



Water Quality Random Sampling by CHNEP Partners

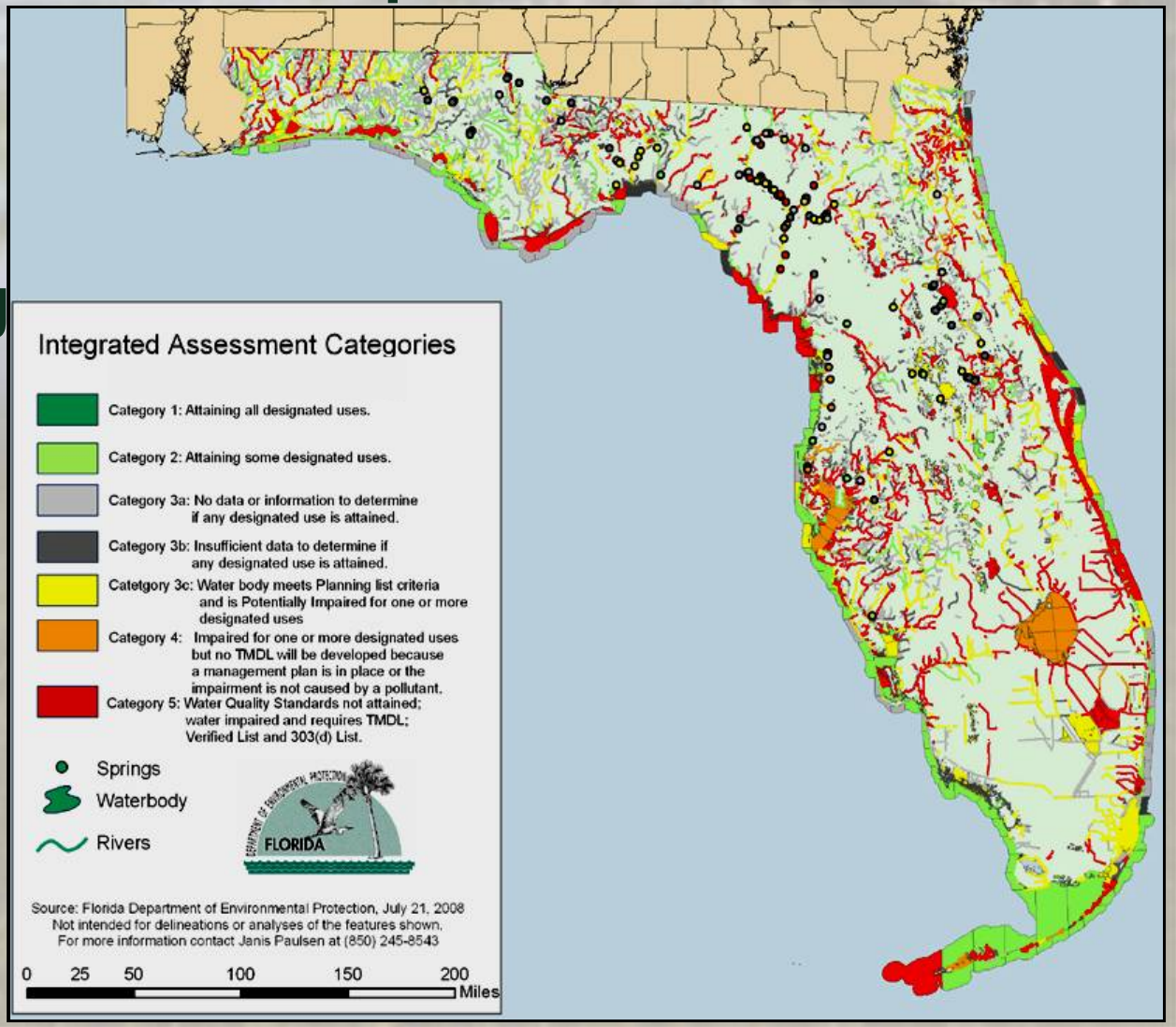
- Coastal Charlotte Harbor Monitoring Network (CCHMN) coordinated by CHNEP since 2002
- 8 Partner field sampling & laboratory partners
- Probabilistic design based on randomly selected square mile grids monitored monthly
- Approved SOPs, annual quality assurance field audits & certified labs
- 15 Physical & chemical parameters including: depth, secchi, dissolved oxygen, pH, conductivity, nutrients, chlorophyll *a*, turbidity & light availability as photosynthetically active radiation (PAR)

- 60 Randomly selected sites monitored each month
- 12 Strata with 5 sites per strata



Water Quality Monitoring for FL Integrated Water Quality Assessment by FDEP & Partners

- Conducted to meet CWA & FL regulatory requirements
- Entered into EPA & FL STORET databases
- For status & trends, determine impairments & regulatory questions
- Probabilistic & fixed station designs
- Many sites on rotating schedule
- Field & laboratory quality assurance



What & How are CHNEP Water Quality Targets Being Developed?

Started with Previous Research, including:

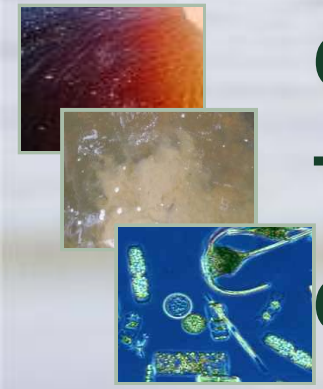
- 1987 McPherson & Miller: Vertical attenuation of light in Charlotte Harbor.
- 1990 Hammett: Land use, water use, stream flow & water quality of Charlotte Harbor inflow area.
- 1886 Gallegos: Refining habitat requirements of submerged aquatic vegetation: role of optical models.
- 1994 Kirk: Light & Photosynthesis in Aquatic Ecosystems.
- 1999 Dixon & Kirkpatrick: Causes of light attenuation to Seagrasses in Charlotte Harbor.
- 1999 Tomasko & Hall: Productivity & biomass of *Thalassia* along a gradient of freshwater in Charlotte Harbor.
- 2003 Janicki Environmental: Water quality data analysis & report for CHNEP. 2005 Tomasko et al: Spatial & temporal variation in seagrass coverage in SW FL.

Original CHNEP Water Quality Targets Developed in 2005 by Corbett & Hale

- Recognized historic loss of seagrasses & increasing urbanization, pollutant loadings & hydrologic changes
- Developed an optical model to set targets for color, turbidity & chlorophyll *a* for each estuary segment
- Based on deep edge of seagrass as measured from seagrass transects
- Determined 25% of light needed at deep edge of seagrasses, based on previous studies in Charlotte Harbor

Estuary Segment	# Transects (1999-2005)	Max Depth Mean (m)
Lemon Bay	4-6	1.7
Cape Haze	4-5	1.9
Myakka River Tidal	3-5	0.8
Peace River Tidal	2-4	1.0
Charlotte Harbor West Wall	3-5	1.4
Charlotte Harbor East Wall	1-2	1.4
Charlotte Harbor Lower	3-5	1.5
Pine Island Sound	8-11	1.9
Matlacha Pass	2-4	1.5
San Carlos Bay	3-6	2.0
Caloosahatchee R Tidal		1.2
Estero Bay	4-5	1.0

- Calculated water clarity targets using Lambert-Beer Law to determine light extinction coefficient needed for 25% light at seagrass maximum depth
- Determined partial contributions of light attenuation from 3 primary components:



Color - dissolved organic matter (13-66% of total)

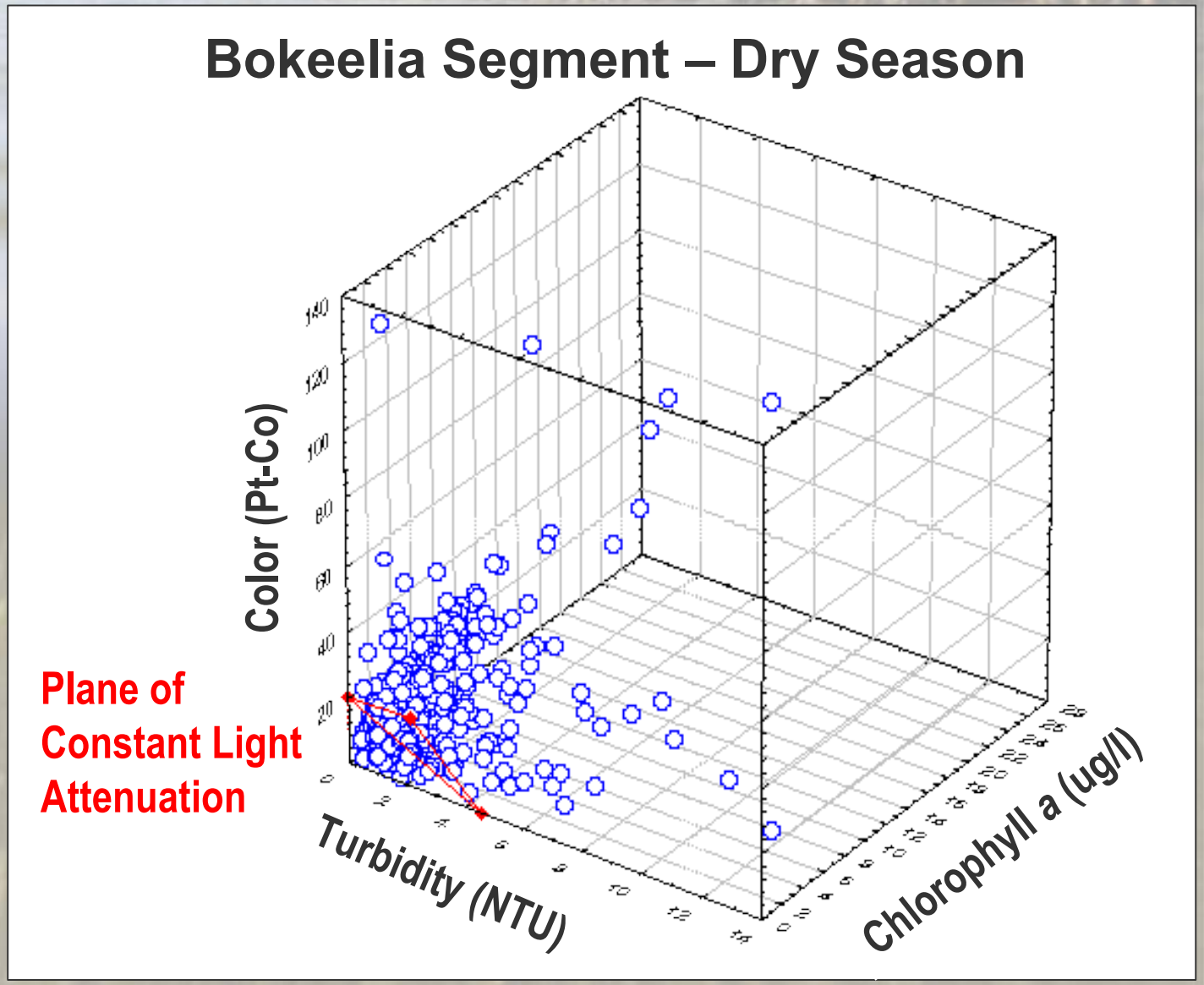
Turbidity - detritus, minerals, cells (30-5% of total)

Chlorophyll *a* – phytoplankton (4-18% of total)

- Estimated concentrations of these 3 constituents using an optical model derived from McPherson & Miller (1992)

Estuary Segment	Color (Pt-Co)	Turbidity (NTU)	Chl *a* (ug/l)
Lemon Bay	28.6	6.5	8.2
Cape Haze	31.2	7.0	8.9
Myakka River Tidal	89.7	20.3	25.6
Peace River Tidal	78.6	17.7	22.4
Charlotte Harbor West Wall	50.0	11.3	14.3
Charlotte Harbor East Wall	50.0	11.3	14.3
Charlotte Harbor Lower	20.2	4.6	5.8
Pine Island Sound	24.0	5.4	6.9
Matlacha Pass	28.6	6.5	8.2
San Carlos Bay	24.0	5.4	6.9
Caloosahatchee R Tidal	61.9	14.0	17.7
Estero Bay	41.1	9.3	11.7

- Used estimated concentrations to plot plane of constant light attenuation for each estuary segment
- Plotted derived planes of constant light attenuation over water quality data to show times & locations where water clarity targets weren't met



Refined Water Quality Targets Currently being Developed by Janicki Environmental

- Recognized need to revisit original water quality targets regularly
- Recognized limitations of original optical model in some tidal river segments & availability of new data
- Recognize value of using consistent approaches as other SW FL NEPs
- Contracted with Janicki Environmental using support from CHNEP FY09 Workplan & partners
- Developed project scope of work with sequence of tasks, each to be approved by CHNEP Management Conference & Technical Working Group

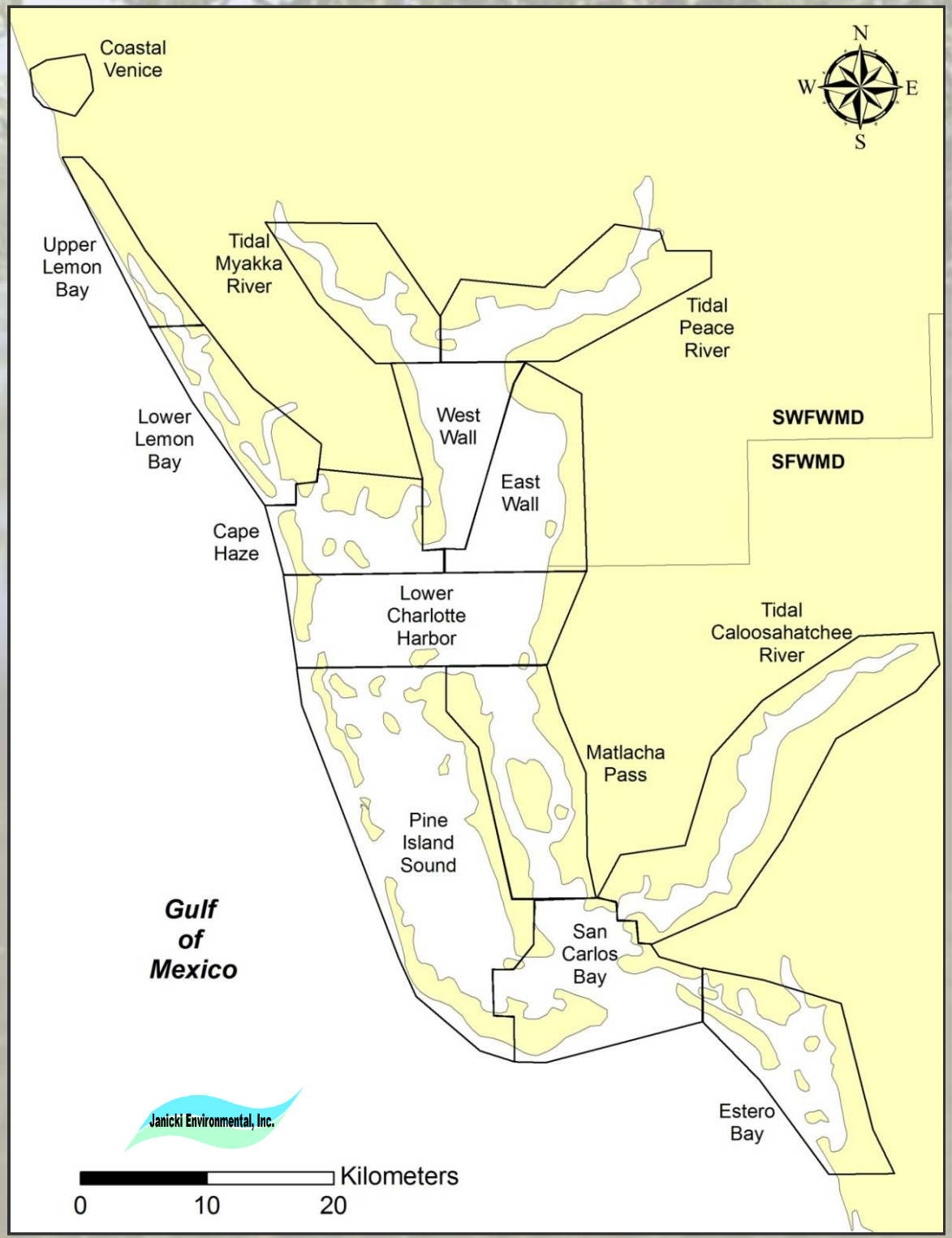
Janicki Environmental, Inc.

Task 1: Verified Estuary Segments to be Used for Water Quality Targets

- Reviewed estuary segmentation schemes used by:
  - ~ Coastal Charlotte Harbor Monitoring Network (CCHMN)
  - ~ Water Management District Seagrass Analyzes
  - ~ FL Aquatic Preserves
  - ~ FDEP Waterbody Identifiers
- Reviewed reasons to analyze data for each CHNEP estuary segment because of unique:
  - ~ physical conditions (bathymetry, watershed:water area)
  - ~ dynamic processes (residence times)
  - ~ seagrass depth & acreage
  - ~ % light available for seagrasses
  - ~ water quality, watershed loads & hydrology

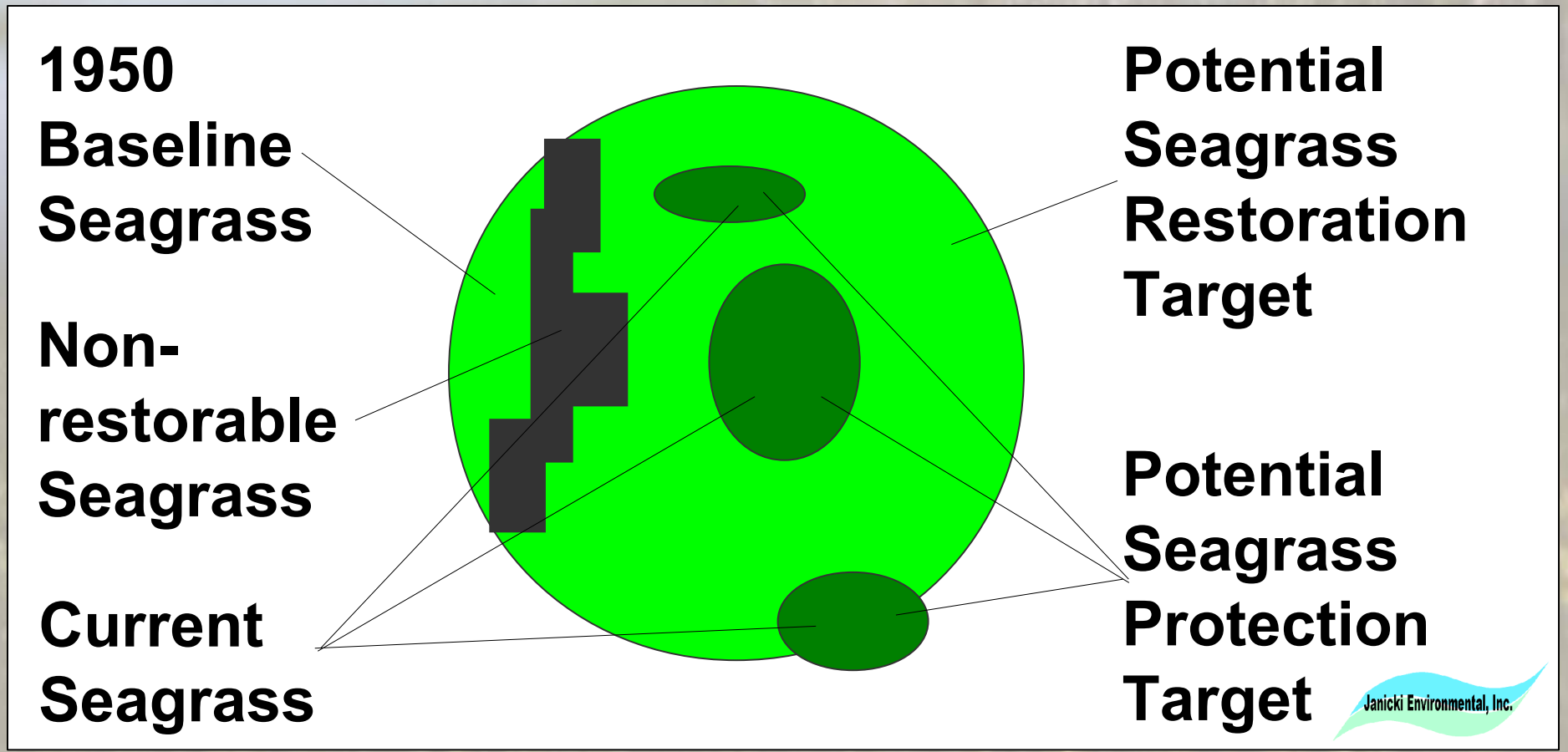
- **Consensus to use 14 estuary segments used by CCHMN**

CCHMN Estuary Segments
Dona & Roberts Bay
Upper Lemon Bay
Lower Lemon Bay
Cape Haze
Myakka River Tidal
Peace River Tidal
Charlotte Harbor West Wall
Charlotte Harbor East Wall
Charlotte Harbor Lower
Pine Island Sound
Matlacha Pass
Caloosahatchee R Tidal
San Carlos Bay
Estero Bay

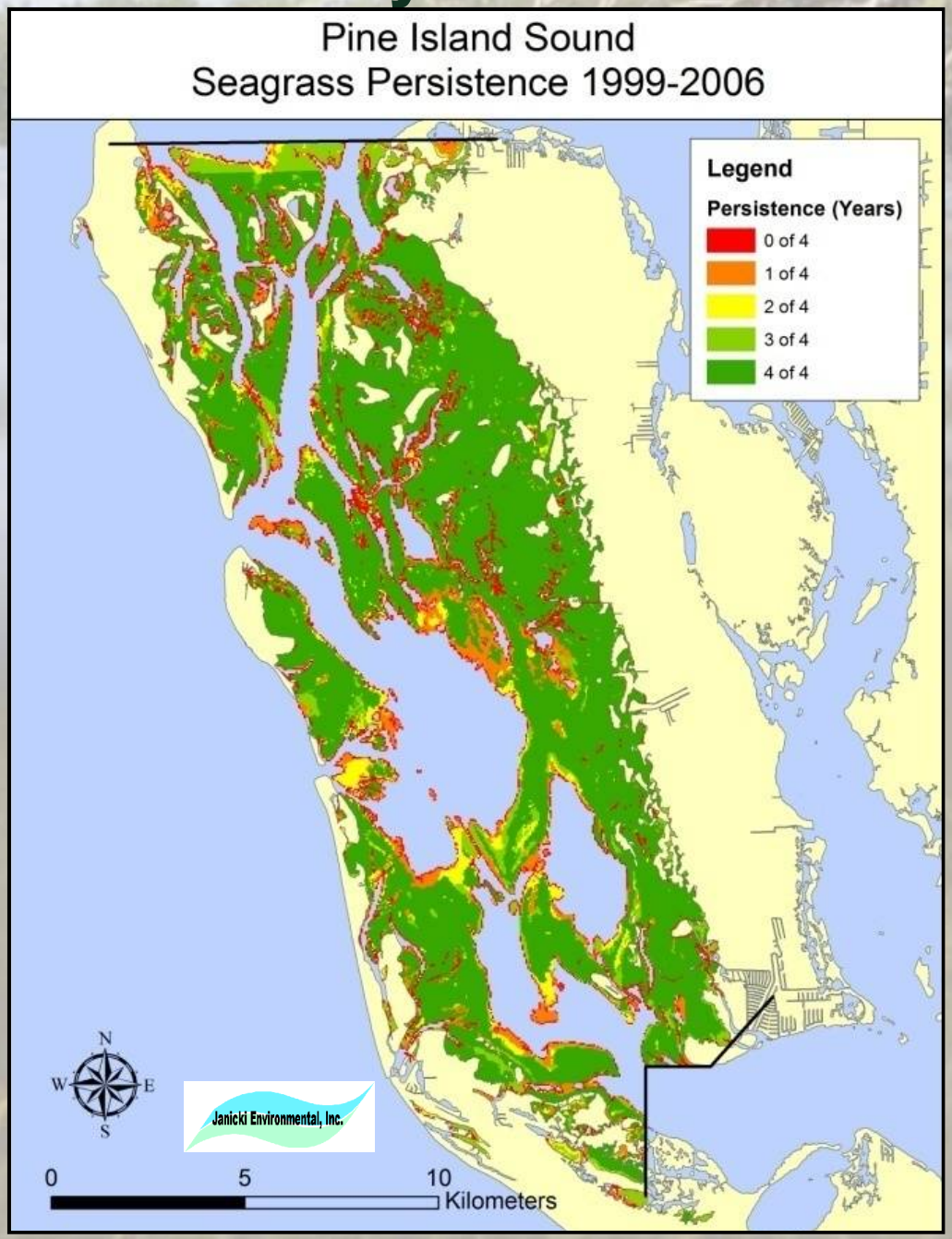


Task 2: Identified Seagrass Protection & Restoration Targets

- Identified baseline seagrass areas from1950 aerials
- Subtracted “non-restorable” areas (lost to dredge & fill)
- Overlaid current seagrass areas from recent aerials
- Identified potential seagrass protection & restoration areas



- **Because of annual variability in seagrass, "current" seagrass areas were determined by persistence of seagrasses over recent years from aerials**

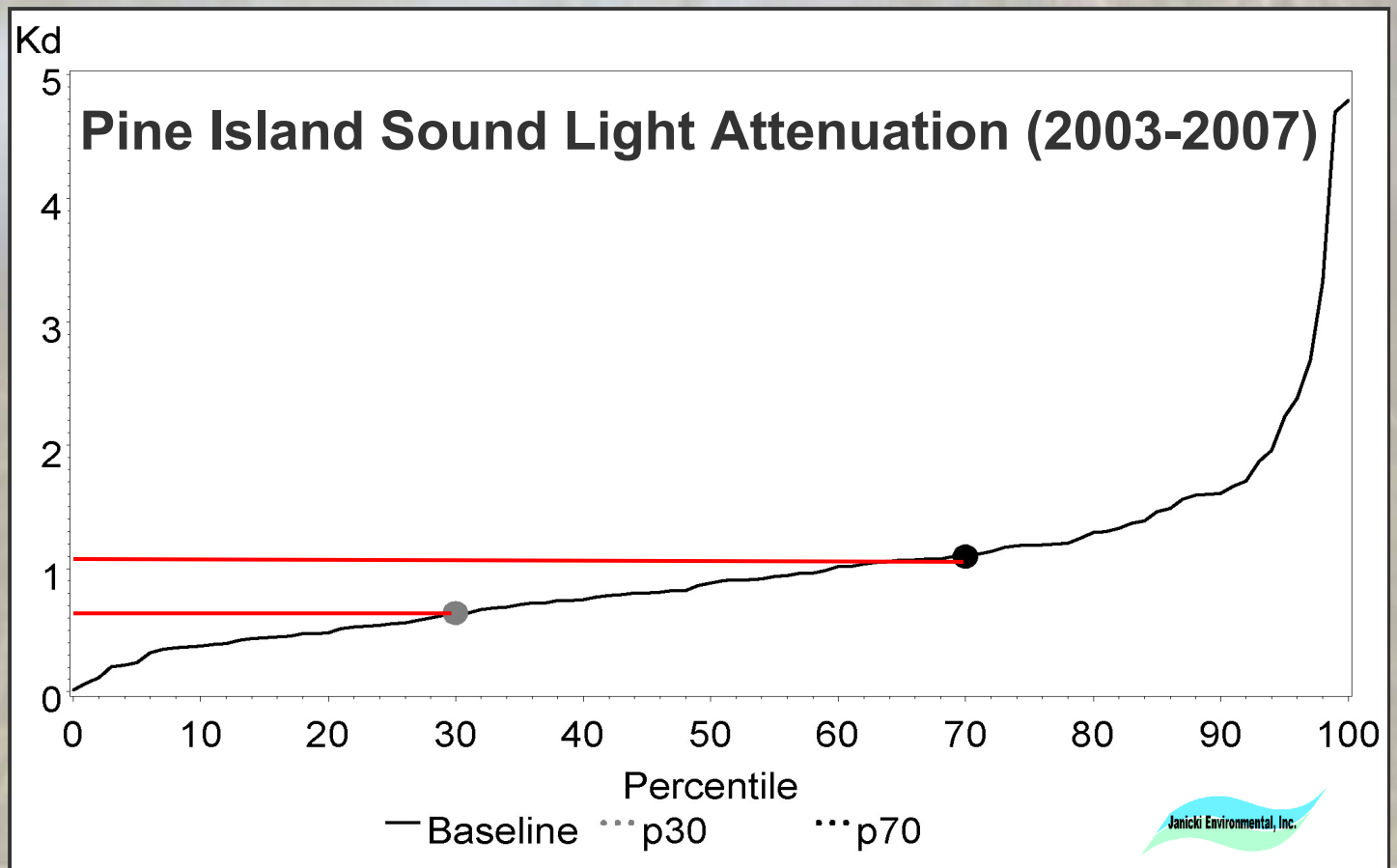


- **Final seagrass protection & restoration acres were determined for each estuary segment**

Estuary Segment	Baseline (historic, adjusted) (acres)	Mean Annual (1988-2006) (acres)	Protective Target (highest) (acres)	Restoration Target (difference) (acres)	Total Seagrass Target (acres)
Dona & Roberts Bay	112	91	91	21	112
Lemon Bay Upper	880	1,009	1,009		1,009
Lemon Bay Lower	2,882	2,502	2,502	380	2,882
Cape Haze	5,670	6,998	6,998		6,998
Myakka River Tidal	344	456	456		456
Peace River Tidal	975	384	384	591	975
Charlotte Harbor West Wall	2,106	1,907	1,907	199	2,106
Charlotte Harbor West Wall	3,898	3,465	3,465	433	3,898
Charlotte Harbor Lower	2,964	3,342	3,342		3,342
Pine Island Sound	23,757	26,837	26,837		26,837
Matlacha Pass	9,315	7,582	7,582	1,733	9,315
San Carlos Bay	3,118	4,372	4,372		4,372
Caloosahatchee R Tidal	93	87	87	6	93
Estero Bay	3,662	3,071	3,071	591	3,662
Total	59,776	62,103	62,103	3,954	66,057

Task 3: Developed Water Clarity Targets

- Evaluated original optical model for reliability
- Reviewed measured light attenuation field data
- Compared predicted & observed light attenuation values
- Estimated percent time observed values exceed established targets
- Plotted cumulative distribution frequency of light attenuation values for each estuary segment



- Used cumulative distribution frequencies to establish target (low; 30%) & threshold (high; 70%) light attenuation values for each estuary segment

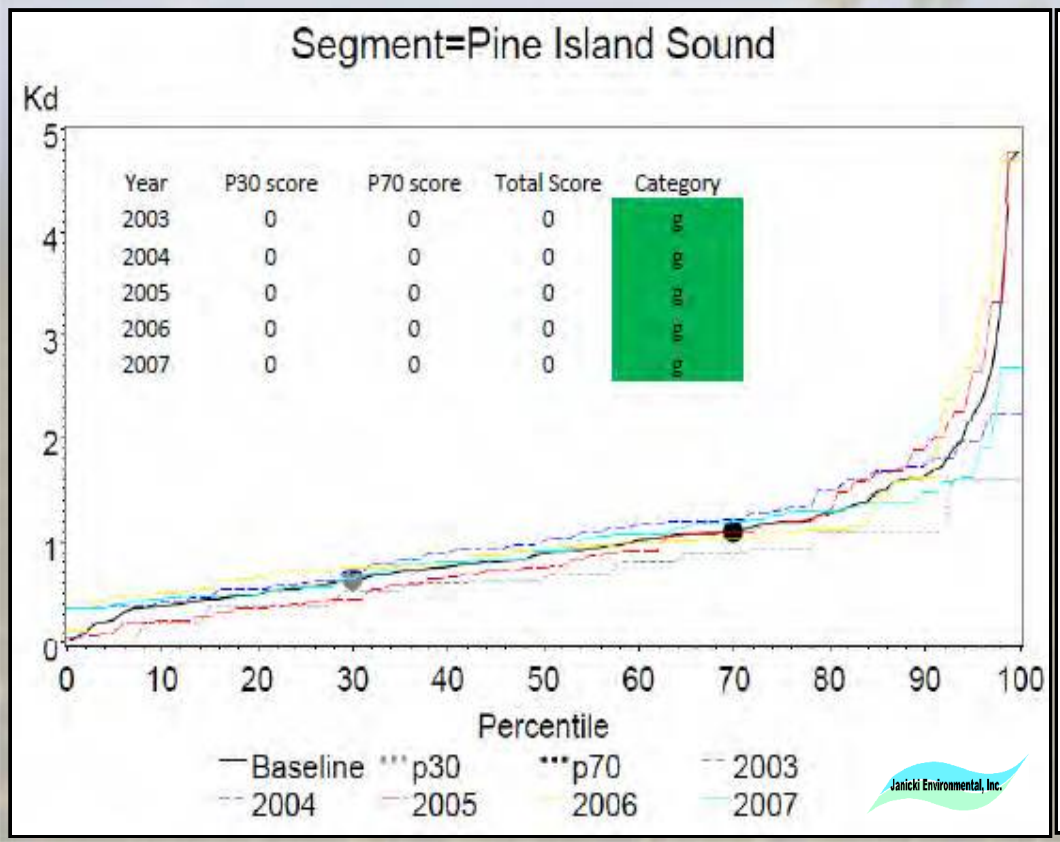
Empirical Light Attenuation Values (2003-2007)		
Estuary Segment	30th percentile (K_d m^{-1}) Target	70th percentile (K_d m^{-1}) Threshold
Dona & Roberts Bay	0.64	1.04
Lemon Bay Upper	0.73	1.18
Lemon Bay Lower	0.73	1.12
Cape Haze	0.63	1.15
Myakka River Tidal	1.30	2.27
Peace River Tidal	1.06	2.40
Charlotte Harbor West Wall	0.73	1.36
Charlotte Harbor East Wall	0.64	1.16
Charlotte Harbor Lower	0.58	1.16
Pine Island Sound	0.64	1.10
Matlacha Pass	0.73	1.63
San Carlos Bay	0.73	1.16
Caloosahatchee R Tidal	1.58	2.93
Estero Bay	0.91	1.58

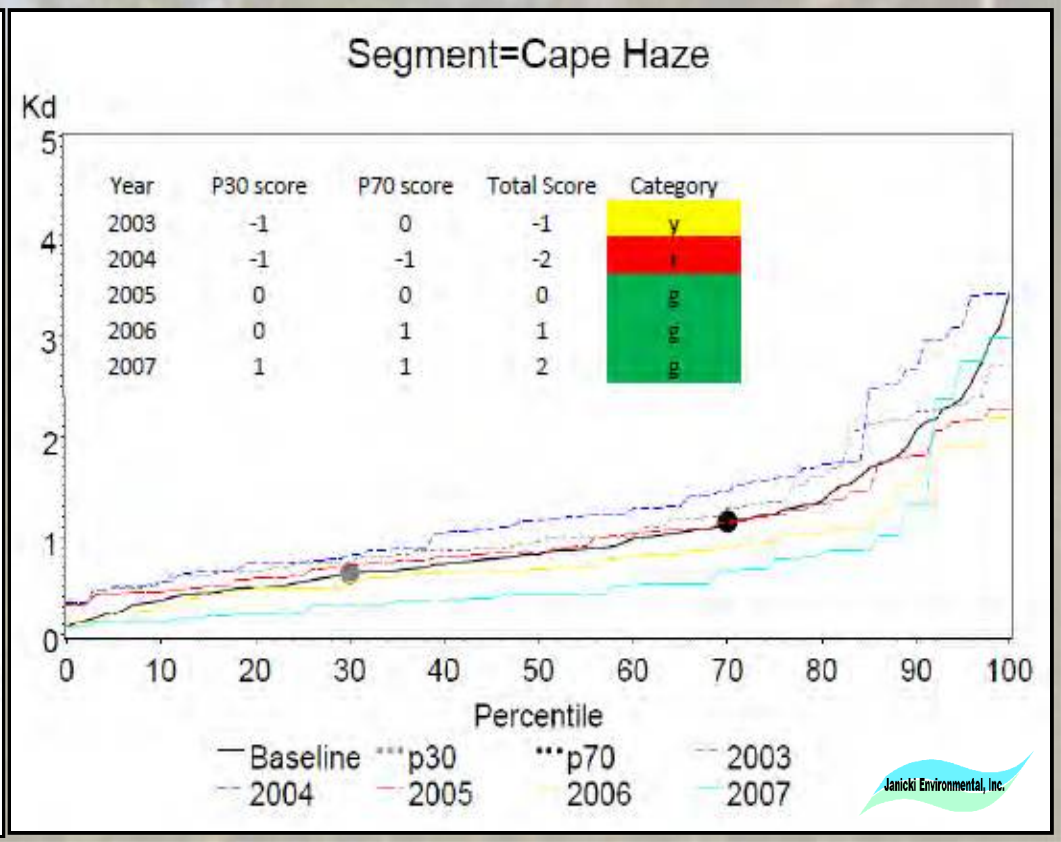
- **Suggested a decision rule to assess if water clarity targets are being met based on annual analysis of water quality data:**

  ~ if >30% of values are <30th percentile, water quality is improving & assigned a value of +1
  ~ if <30% of values are< 30th percentile, water quality is degrading & assigned a value of -1
  ~ Otherwise, water quality is stable & assigned a 0
  ~ Scoring is performed for both endpoints (30th & 70th percentile)
  ~ Values are summed for each segment & the range of scores is -2 to +2
  ~ Different grading systems are used for estuary segments with protection vs. restoration targets

- **Grading for segments with protection targets, would be:**
  - **Green = scores > -1 = Stable**
  - **Yellow = scores ≤ -1 = Caution**
  - **Red = scores < -1 (consecutive years) = Degrading**

- **Grading for segments with restoration targets, would be:**
  - **Green = scores > +1 = Improving towards target**
  - **Yellow = scores between -1 & +1 = Caution**
  - **Red = scores < -1 = Degrading**





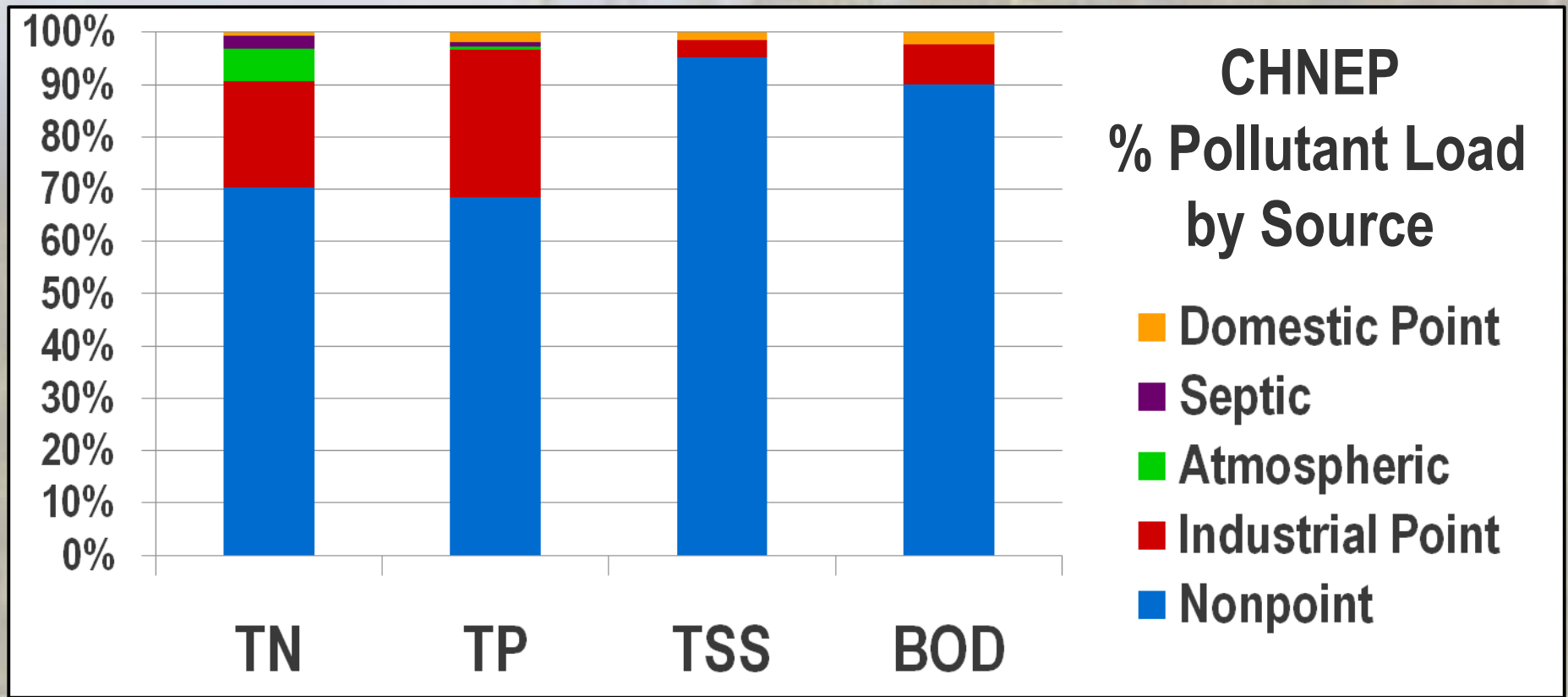
Task 4: Estimated Watershed Pollutant Loadings

- Described hydrology, land use & soils for each segment
- Described methods used to develop loadings from:
  - ~ atmospheric deposition,
  - ~ nonpoint sources
  - ~ septic tanks
  - ~ point sources
  - ~ gauged & ungauged basins
- Developed pollutant loadings (1995-2007) X segment for:
  - ~ Total Nitrogen
  - ~ Total Phosphorus
  - ~ Biochemical Oxygen Demand
  - ~ Total Suspended Solids
- Provided temporal & spatial loadings & trends
- Developed Best Management Practice (BMP) tool to calculate changes in loadings based on land use changes & BMP implementation

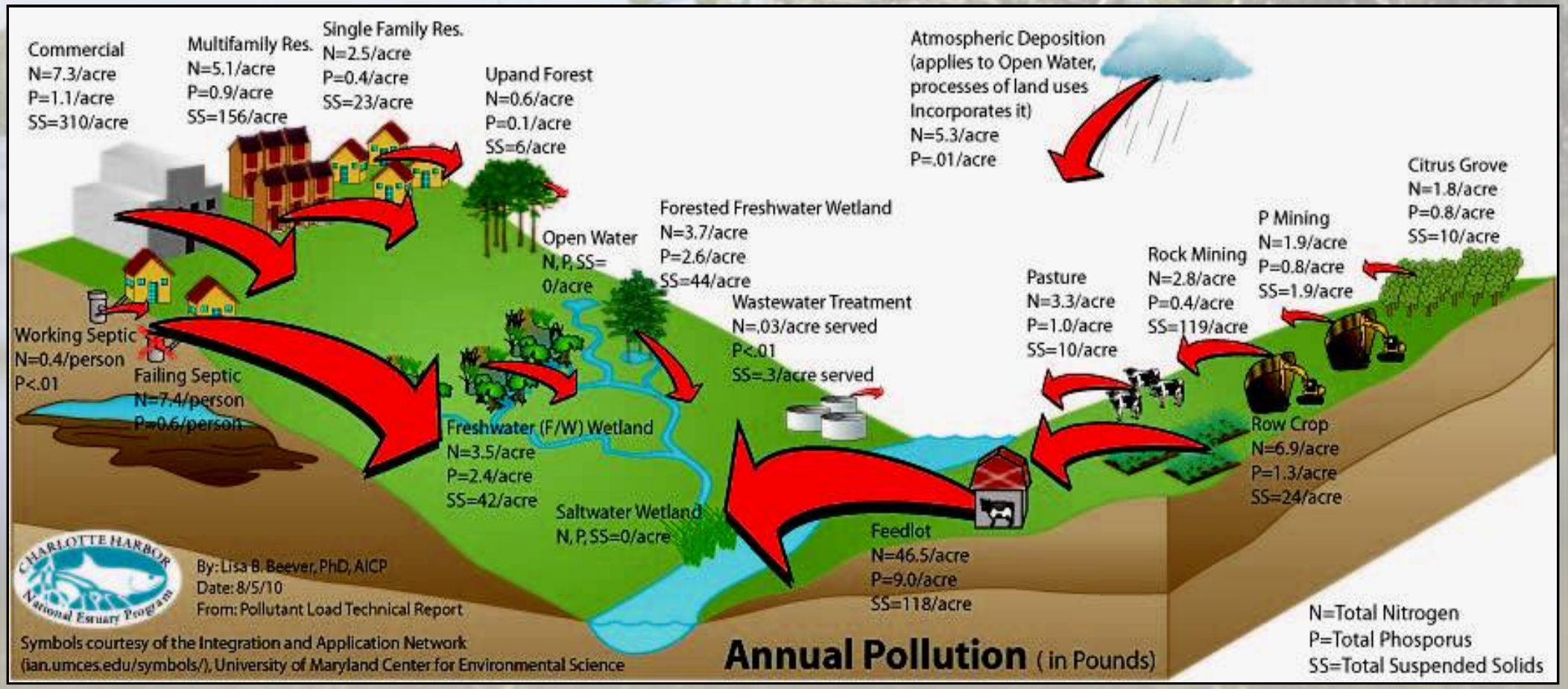
- Results showed wettest years had highest total loadings & driest years had lowest loadings for each pollutant

Highest & Lowest Annual Pollutant Loadings for CHNEP (1995-2007)					
	Year	TN Load (tons/yr)	TP Load (tons/yr)	TSS Load (tons/yr)	BOD Load (tons/yr)
Highest	2005	18,289	3,798	125,568	39,468
Lowest	2007	2,099	492	10,427	6,265

- Nonpoint Sources contributed the highest percent load for each pollutant



- **Pollutant loadings per acre for different land uses were calculated for the CHNEP study area**



- **Pollutant loadings results are being used with water quality data for each estuary segment to develop segment specific numeric nutrient criteria**

Task 5-8: Developing Numeric Nutrient Criteria as Loads & Concentrations

- Compiled complete water quality, nutrient loading, seagrass & hydrologic data sets for each estuary segment

- Developed data analysis approach for determining chlorophyll thresholds (related to seagrass or DO) & numeric nutrient criteria based on most statistically rigorous relationships ("weight of evidence" approach)

- Developed Chlorophyll *a* targets & thresholds necessary to meet seagrass targets that will be used to generate Total Nitrogen & Total Phosphorus criteria

- **Developed Chlorophyll *a* targets & thresholds necessary to meet seagrass targets that will be used to generate Total Nitrogen & Total Phosphorus criteria**

Proposed Chlorophyll *a* Targets & Thresholds for CHNEP						
	Seagrass Targets			Reference Period (2003-2007) Chl *a*		
Estuary Segment	Preserve or Restore?	Water Clarity Trends	Seagrass Trends	Target (Mean) (ug/l)	Preservation Threshold (Mean +1 SD)	Restoration Threshold (Mean +1/2 SD)
Dona & Roberts Bay	restore	n/a	n/a	**4.3**	5.4	**4.9**
Lemon Bay Upper	preserve	none	improving	**6.7**	**8.9**	---
Lemon Bay Lower	restore	none	stable	**5.1**	7.1	**6.1**
Myakka River Tidal	preserve	none	n/a	**8.9**	**11.7**	---
Peace River Tidal	restore	none	n/a	**10.6**	14.6	**12.6**
Charlotte Harbor Proper (Cape Haze, West Wall, East Wall, Lower)	both	none	stable	**4.9**	7.3	**6.1**
Pine island Sound	preserve	improving	improving	**5.1**	**6.5**	---
Matlacha Pass	restore	improving	stable	**4.0**	8.1	**6.1**
San Carlos Bay	restore	improving	improving	**2.8**	**3.5**	---
Caloosahatchee R Tidal	restore	none	n/a	**9.0**	**TMDL 6.9**	??
Estero Bay	restore	improving	improving	**4.9**	6.9	**5.9**

- **Developing Total Nitrogen & Total Phosphorus criteria as concentrations & loads**

Working Draft Total Nitrogen Criteria for CHNEP				
Estuary Segment	TN Criteria (mg/L)	TN Load Criteria (tons/year)	TP Criteria	TP Load Criteria
Dona & Roberts Bay	**0.52**	TBD	TBD	TBD
Lemon Bay Upper	**0.69**	TBD	TBD	TBD
Lemon Bay Lower	**0.55**	TBD	TBD	TBD
Myakka River Tidal	TBD	**1,330**	TBD	TBD
Peace River Tidal	TBD	**4,663**	TBD	TBD
Charlotte Harbor Proper (Cape Haze, West Wall, East Wall, Lower)	**0.99**	TBD	TBD	TBD
Pine island Sound	**0.52**	TBD	TBD	TBD
Matlacha Pass	TBD	**430**	TBD	TBD
San Carlos Bay	TBD	**2,520**	TBD	TBD
Caloosahatchee R Tidal	TBD	TBD	TBD	TBD
Estero Bay	TBD	**954**	TBD	TBD

Next Tasks:

- Develop Down Stream Protective Values for upstream & “terminal” segments
- Demonstrate that Numeric Nutrient Criteria protect Dissolved Oxygen Values
- Develop Numeric Nutrient Criteria Implementation Plan

What's the Big Picture for CHNEP Water Quality Targets?

- Develop final estuary specific water quality targets & numeric nutrient criteria based on seagrass light requirements based on "weight of evidence" approach (to EPA in Early Spring 2011)
- Continue seagrass monitoring & mapping
- Evaluate response of seagrasses to resource management actions regularly
- Re-evaluate water quality targets & criteria regularly
- Implement projects to reduce pollutant loadings & restore natural hydrology to protect & restore seagrass
- Maintain & restore natural shorelines to enhance seagrass adaptation to sea level rise & climate change

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- Phil Stevens & Staff, FL Wildlife Research Institute
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- Jaime Boswell, Johnson Engineering
- Dave Tomasko, PBS&J
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- CHNEP Management Committee Members
- & Many Others

Questions?

For More Information:

- Project Reports are available at www.chnep.org
- Judy Ott, Program Scientist jott@swfrpc.org
- Lisa Beever, Director lbeever@swfrpc.org
- Liz Donley, Deputy Director ldonley@swfrpc.org
- Maran Hilgendorf, Communications Manager mhilgendorf@swfrpc.org