Southern Coastal Systems Performance Measure
Salinity in Florida Bay

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1.0 Background and Justification

Florida Bay is a complex, heterogeneous coastal environment that, prior to human intervention, varied due to natural factors including hurricanes, climatic variation and changing sea level (Nuttle 2003). Paleo-salinity records indicate oligohaline to mesohaline conditions (0.5-5 practical salinity units [psu] and 5-18 psu, respectively) existed in the nearshore embayments of Florida Bay around 1900, which could be considered to be a reasonable pre-water-management or pre-drainage time period (Willard et al. 1997). During that same time period, polyhaline (18-30 psu) conditions existed in Whipray Basin within central Florida Bay (Trappe and Brewster-Wingard 2001). The landscape and hydrological systems of South Florida have been altered significantly over the past hundred years as a result of water management practices primarily implemented to reduce flooding. Impacts of water management include altering natural watershed hydrology that impacts runoff patterns (Smith et al., 1989), seasonal inflow deliveries, and directly drives extreme salinity fluctuations in the northern and eastern part of Florida Bay (Brewster-Wingard, et al., 2001; Dwyer and Cronin, 2001; Wingard, et al., 2010).

The greatest fluctuations in salinity occur in eastern Florida Bay where both extreme low salinity and hypersalinity conditions occur (Kelble et al. 2007). This part of the bay receives a large proportion of its water via the C-111 Canal, especially during the wet season (June-November). This canal receives water that seeps from the eastern boundary of Everglades National Park and water that is conveyed from the north (via the L-31 Canal) in association with flood control operations. Such operations, often in association with large rainfall events, can result in rapid salinity decreases in near-shore environments. Limited inflow during the dry season often creates high salinity conditions, including hypersaline conditions (> 40 psu), particularly if the wet season rains are delayed in the area drained by the canal. Declines in diversity and increases in dominance of euryhaline species in several benthic invertebrate groups since the 1980s are evident in several parts of Florida Bay (Brewster-Wingard et al. 2001), which is a change likely caused by the operation of existing water management infrastructure.

Zones of hypersalinity have been documented to develop in the central bay zone (Figure 8) and can extend into other part of the bay (Kelble et al. 2007). Hydrologic and statistical modeling output of salinity under a pre-water management scenario indicates hypersalinity is more frequent today and of longer duration because freshwater levels driving flow to the coast have been lowered by operation of the upstream water management system of canals, levees and water conservation areas. For example, in the past decade, observed salinity has occasionally reached 70 psu and frequently reaches 50 psu in the north central bay. Hypersaline conditions often start in the dry season, following a wet season of below normal rainfall. Hypersaline conditions can persist into the wet season when the dry season also has low rainfall, and are exacerbated when

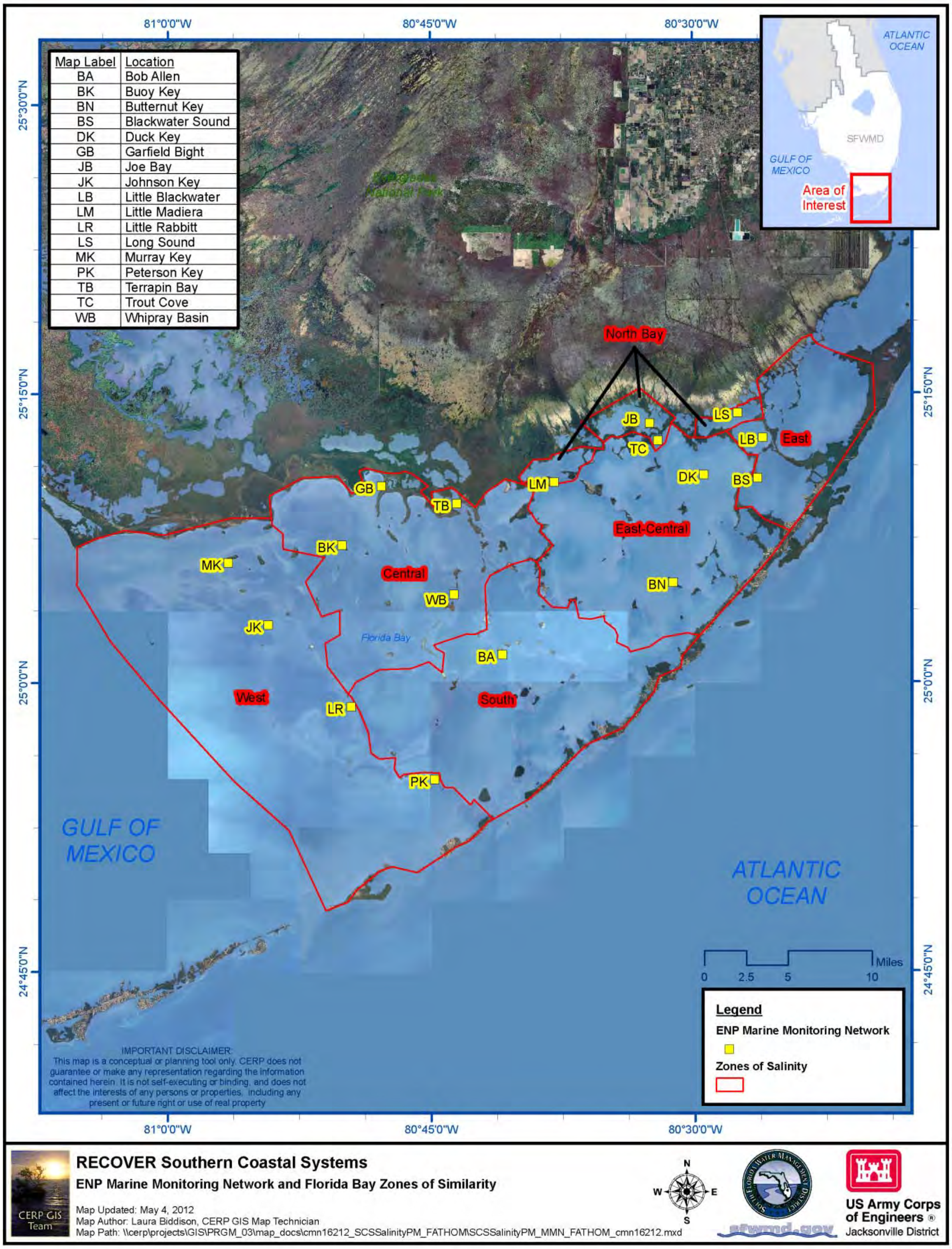


Figure 8. Map showing the locations of The Everglades National Park Marine Monitoring Network stations (squares) and six zones of similarity (Briceno and Boyer 2010) in Florida Bay based on water quality characteristics (outlined in red).

another wet season of low rainfall follows. In the mid-1970s and 1980s, hypersaline conditions persisted for several years.

With CERP implementation, water management actions that result in meeting the targets for Florida Bay (described below) are expected to reduce the intensity, frequency, duration and spatial extent of hypersaline events in Florida Bay and establish a persistent and resilient estuarine zone that extends further into the bay than currently exists. This is expected to improve the production of bay flora and fauna and increase biomass and diversity in the bay at large. The desired seagrass species, *Halodule wrightii* and *Ruppia maritima*, are anticipated to expand their current spatial coverage in the nearshore areas of northern and northeastern Florida Bay and, with persistent estuarine conditions, mature into rich forage habitat providing food and shelter to associated fauna (Madden et al. 2009).

Salinity in Whipray Basin and other stations of the Everglades National Park (ENP) Marine Monitoring Network (MMN) (Figure 8) in central Florida Bay is significantly related to salinity in the coastal embayments (Marshall et al. 2011). These results, in conjunction with estimated historic salinity conditions ("paleo-salinity"), suggested freshwater flows into Florida Bay are ¼ to ½ of their pre-drainage quantities (Marshall et al. 2009, Marshall and Wingard 2012). Reducing hypersaline conditions and increasing polyhaline conditions in the central and western parts of the bay will favor the production of estuarine and marine biota including ecologically and economically important pink shrimp (Browder et al. 2002), spotted seatrout (Kelble et al. 2011), and forage species such as bay anchovy, clown goby, mojarras, pinfish, dwarf seahorse and Gulf pipefish (Johnson et al. 2002a, 2002b) that support game fish and wading birds. Other game fish species expected to benefit include common snook, gray snapper, and crevalle jack. The smalltooth sawfish, recently listed under the Endangered Species Act by the National Marine Fisheries Service, may also benefit in expanded nearshore mesohaline habitat.

2.0 Restoration Goals Pertaining to Salinity Condition

The restoration goals for Florida Bay that are addressed with the performance measures described in this document are to:

1. Restore oligohaline to mesohaline salinity patterns in the nearshore environment;
2. Lower the average salinity in the bay;
3. Reduce the frequency, duration, magnitude, and spatial extent of hypersaline (>40 psu) conditions throughout the bay; and
4. Restore seasonal deliveries of freshwater more typical of the natural system, e.g., extension of water deliveries into the dry season.

3.0 Metrics and Targets

Salinity targets (here called "paleo-adjusted NSM salinity targets") are derived using simulated historical hydrologic conditions with the South Florida Water Management District's Natural Systems Model (NSM) Version 4.6.2 (South Florida Water Management District and Interagency Modeling Center, 2005) and multiple linear regression (MLR) statistical models to estimate salinity response at all MMN stations in Florida Bay (Marshall et al. 2011). The NSM salinity time series values at each MMN station are then adjusted based on paleo-salinity information provided by USGS studies in Florida Bay (Marshall et al. 2009, Marshall and Wingard 2012, Wingard et al. 2007, Wingard et al. 2010, Wingard and Hudley 2011). These adjustments provide a more accurate pre-water management salinity condition than the unadjusted NSM provides. See Figure 8 for locations of all MMN stations in Florida Bay for which paleo-adjusted NSM salinity targets are available.

The paleo-adjusted NSM salinity targets are generally consistent with the former salinity target envelopes described in the previous version of this performance measure (http://www.evergladesplan.org/pm/recover/perf_se.aspx) that were based on salinity optima and preferences of plant and animal species common to historical (i.e., desired) communities in the various basins (Pattillo, et al., 1997), as well as best professional judgment. It is worth noting that the set of cores analyzed to estimate paleo-salinity conditions and NSM adjustments clustered in the central region of the bay and are certainly appropriate for making adjustments to MMN stations in that region. It would be preferable to make paleo-adjustments to NSM time series at MMN stations located in other regions of the bay using cores from those regions; however, insufficient information is currently available.

As for all CERP documents, "evaluation" refers to comparing CERP alternative scenarios against a restoration target; whereas, "assessment" refers to comparing observed data (current real-world condition) against a restoration target. For **evaluation** purposes with this performance measure, simulated hydrology produced by the South Florida Water Management Model (SFWMM) for each CERP alternative is post-processed using the MLR statistical models to predict salinities at the MMN stations. The CERP alternative salinity time series are then compared to the paleo-adjusted NSM target using the metrics described below. This approach is used to compare among various restoration scenarios. For **assessment** purposes, the observed salinity data from the MMN stations in Florida Bay are compared to the targets. Salinity data at other monitoring stations within the zones may be added to this evaluation in the future to enhance and expand spatial and temporal resolution.

The salinity performance measure for Florida Bay consists of three metrics by which the observed (assessment) data or predicted model (CERP alternative evaluations) output are compared against the target: (1) regime metric, (2) mean offset metric, and (3) high salinity metric. These metrics are described in detail below. Each metric is appraised on a monthly and seasonal basis (for this performance measure, wet season = June through November; dry season = December through May).

1. **Regime metric** – For each site, the distribution of salinities in the paleo-adjusted NSM record (target) is compared to the observed or predicted distribution of results between the 25th and 75th percentiles (hereafter referred to as the "mid-range"). Using values for the 2nd and 3rd quartiles provides useful information on the central tendency of the data and minimizes the confounding effects of outliers driven by events such as tropical storms or periodic influences such as the El Nino Southern Oscillation or the Atlantic Multi-decadal Oscillation. The mid-range distribution of paleo-adjusted NSM salinities in the period of record (POR; currently 1965-2000, but will likely be extended in the future) is evaluated on a cumulative monthly and seasonal basis to determine the target for this metric. This metric addresses **Goals 1, 2, and 4** stated earlier in this document (Section 2). It is assumed that a decrease in the mid-range salinity will also be reflected in the average.

   The mid-range distribution is determined for monthly and seasonal observational data at each MMN site and compared to the target distribution. Users of the performance measure are at liberty to assess any data period of interest, from one year to several. The overlap between the mid-range distributions is determined on a monthly and seasonal basis and is reported as a proportion of the mid-range values of the observed data that fall within the mid-range of the target.

The overlap metric (*OL)* is calculated as follows for a given month where:

a = the number of days (for either a month or season) the mid-range of the observed data fall within the mid-range of the paleo-NSM target and,

b = half the total number of days in either the month or season

$$OL = a \div b$$

For example, if the assessed month is June, there are 15 values in the observed data set (1/2 the total # of days in the month of June) that would comprise the observed mid-range subset. If 7 of those daily values fall within the target mid-range, then the score for that month would be 7 ÷ 15 = 0.46. This provides an "overlap score" for each month on a 0 to 1 scale.

2. **Mean Offset metric –** A measure of the magnitude that the observed data or predicted (CERP alternative) output may deviate from the target is determined by calculating absolute value of the difference between the target monthly (or seasonal) salinity mean and the observed (or predicted) monthly (or seasonal) salinity.

The mean offset metric (*OF)* has a psu value and is calculated as follows for a given month (or season) where:

$\overline{x_d}$ = the mean of the observed (or predictive) data

$\overline{x_T}$ = the mean of the paleo-NSM target

$$OF = |\overline{x_d} - \overline{x_T}|$$

This metric is most useful when the regime metric score (i.e., mid-range overlap) is zero. The mean offset metric addresses **Goals 1, 2, and 4** stated earlier in this document (Section 2).

3. **High salinity metric –** This metric focuses on the exceedences (in days) of the observed or predicted data above a high-salinity threshold. The high-salinity threshold is calculated using the 36-year period of record for the paleo-adjusted NSM. The 90th percentile value is determined separately for each MMN station and used as the high-salinity threshold. For example, the 90th percentile value for the paleo-adjusted NSM record at Whipray Basin is 41.0 psu.

The high salinity target is for high salinity threshold exceedences in observed data or model scenario output to be no more frequent than occurs in a comparable paleo-adjusted NSM time period (here called "target exceedences"). Target exceedences are calculated on a monthly and seasonal basis. For example, the target exceedence for April 1989 at Whipray Basin is determined by summing the number of days in the paleo-adjusted NSM record when salinity was above 41.0 psu, which was 9 days. For seasonal target exceedences, the same procedure is done for June through November 1988 (wet season) and December 1988 through May 1989 (dry season).

For assessment purposes, the number of days in a given month or season in the observed data for the year of interest exceeds the 90th percentile high salinity threshold value (41.0 psu in the example above) is determined. The metric score is then calculated by dividing the number of days of exceedence in the observed data into the target exceedence. As an example, if we use June 2000 to June 2001 as our assessment year (a dry water year), 29 of the 30 daily values in April in Whipray Basin exceeded the 41.0 psu high-salinity threshold. The high-salinity metric score is then calculated as $9 \div 29 = 0.31$. The desired metric score is 1.0. Note that for many assessment and evaluation periods, the number of observed exceedences may be less than the target exceedence or the observed exceedence may be zero, which cause problems with how the score is calculated. To avoid these problems, whenever the observed exceedences are less than the target, the metric score is set to 1.0.

For evaluation purposes, the same high salinity threshold value is used (i.e., the 90th percentile of the paleo-adjusted NSM value at each MMN station). However, target exceedences are determined by calculating the number of days on a monthly and seasonal basis that the full period of record paleo-adjusted NSM data exceeds the target. In the Whipray Basin example used above, the exceedence target for the month of April would be the total number of days during the 36 Aprils in the paleo-adjusted NSM period of record that exceeded the 41.0 psu high-salinity threshold. That number would be divided by the number of days in the 36 Aprils of a given CERP alternative that exceeded the high-salinity threshold. As with the assessment procedure, whenever the predicted exceedences for a given CERP alternative are less than the target exceedences or are zero, the metric score is set to 1.0.

This metric addresses **Goal 3** described earlier in this document (Section 2).

Examples of how the metrics are calculated are provided below. Figure 9 shows ribbon plots of the mid-range (25th to 75th percentile) salinity distributions for the paleo-adjusted NSM output and observed salinity data from 2003 for Whipray Basin. The target distribution is significantly wider than the 2003 observed data distribution because the target is a POR average distribution of a 36 year record versus only 1 year of observed data. In this example, the distributions show no overlap for the months of January through March, July through October, and December, so the scores for those months are zero (monthly scores for all metrics are provided just above the X-axis). The months of April through June and November show mid-range overlap of 0.20, 0.39, 0.73, and 0.53, respectively. Seasonal overlap scores are shown in the upper left corner of the plot. There are no months when the mid-range distribution of the observed data falls entirely within the target. In this example the seasonal overlap score for the dry season and wet season are 0.37 and 0.13, respectively compared to the ideal score of 1.0 if the mid-range overlapped completely.

Figure 9 also provides the mean offset scores for Whipray Basin for assessment year 2003 (monthly scores are shown just above the X-axis and the seasonal scores are shown in the upper left corner of the plot). For 2003, the offset during the wet season (4.51 psu) is larger than the offset during the dry season (2.24 psu). The ideal condition (i.e., desired) is a mean offset score of 0.0.

Lastly, Figure 9 provides the high salinity metric scores for Whipray Basin for assessment year 2003 (monthly scores are shown just above the X-axis and the seasonal scores are shown in the upper left corner of the plot). In this example, the months of February through June and November through December scored a maximum of 1.0, meaning that there was no appreciable concern with high salinities in Whipray Basin during that time period. The months of January, August, and September exhibited scores of 0.10 to 0.12, indicating a significant high salinity problem during those months.

Figure 10 shows an example of the utility of the mean salinity offset score. The panels illustrate the mid-range distributions of the target and observed data from Whipray Basin for 2005 (top panel) and 2006 (bottom panel). The apparent overlap between the target and observed data is minimal for both years; however, the decrease in offset by approximately 46% in the wet season and 39% in the dry season from 2005 to 2006 suggests an improvement in one aspect of the salinity condition (2005 wet season = 8.30, 2005 dry season = 7.94; and 2006 wet season = 4.49, 2006 dry season = 4.81).

Figure 11 shows an example of the metrics as used for CERP alternative evaluations. The top panel shows 2050B3 (i.e., future without CERP) compared to the target for Whipray Basin; the bottom panel shows CERP0 (i.e. future with CERP) versus the target for Whipray Basin. Note that CERP0 provides significant improvement for all three metrics during both the wet and dry seasons. For example, during the dry season, the regime overlap score increases from 0.21 to 0.65 under CERP0. Similarly the dry season mean offset decreases from 4.94 to 2.29 under CERP0, and the high salinity metric score increases from 0.30 to 0.56.

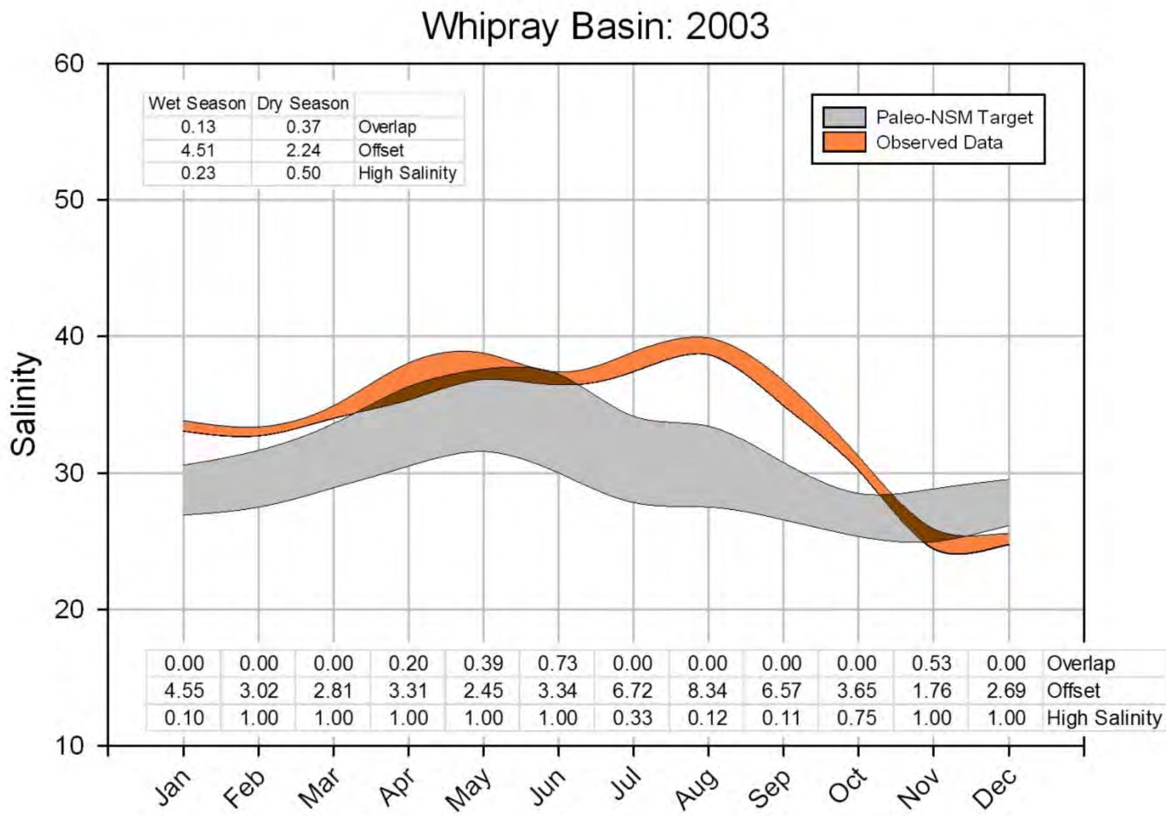
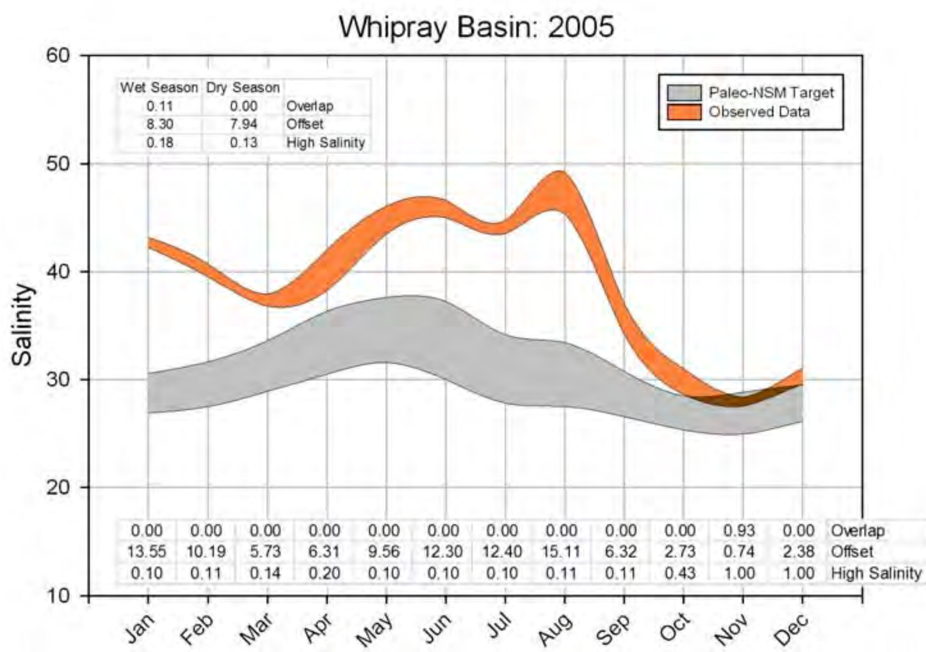


Figure 9. A graphical display of the performance measure metrics applied to 2003 observed data for Whipray Basin. The gray ribbon represents the mid-range distribution of the paleo-adjusted NSM target and the orange ribbon represents the mid-range of the 2003 observed data. The darker orange ribbon represents the overlap area of the observed data and the paleo-adjusted NSM target. The monthly overlap, mean offset, and high salinity metric scores are provided at the bottom of the plot on the x-axis. The seasonal overlap, mean offset, and high salinity metric scores are shown in the upper left corner.



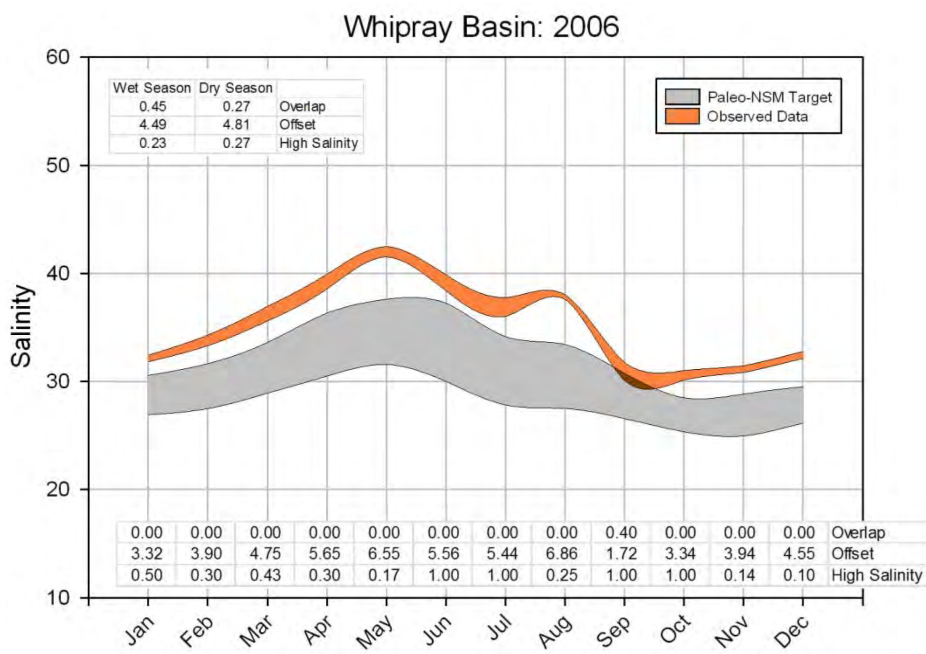
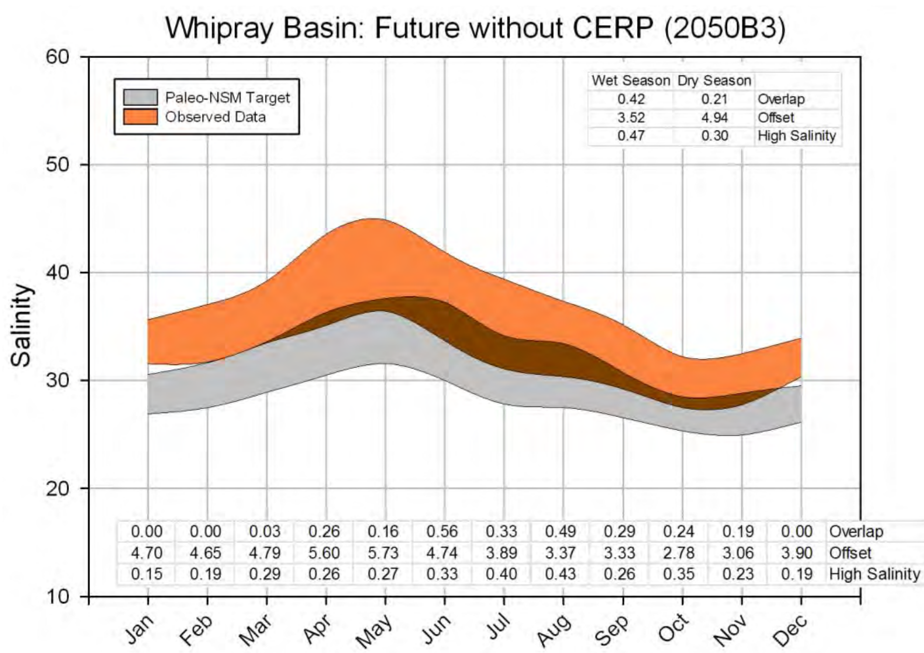


Figure 10. A graphical display of the performance measure metrics applied to 2005 (top) and 2006 (bottom) observed data for Whipray Basin to illustrate the utility of the mean offset metric when the regime overlap score is at or near zero. The gray ribbon represents the mid-range distribution of the paleo-adjusted NSM target and the orange ribbon represents the mid-range of the 2005 and 2006 observed data. The darker orange ribbon represents the overlap area of the observed data and the paleo-adjusted NSM target. The monthly overlap, mean offset, and high salinity metric scores are provided at the bottom of the plot on the x-axis. The seasonal overlap, mean offset, and high salinity metric scores are shown in the upper left corner.



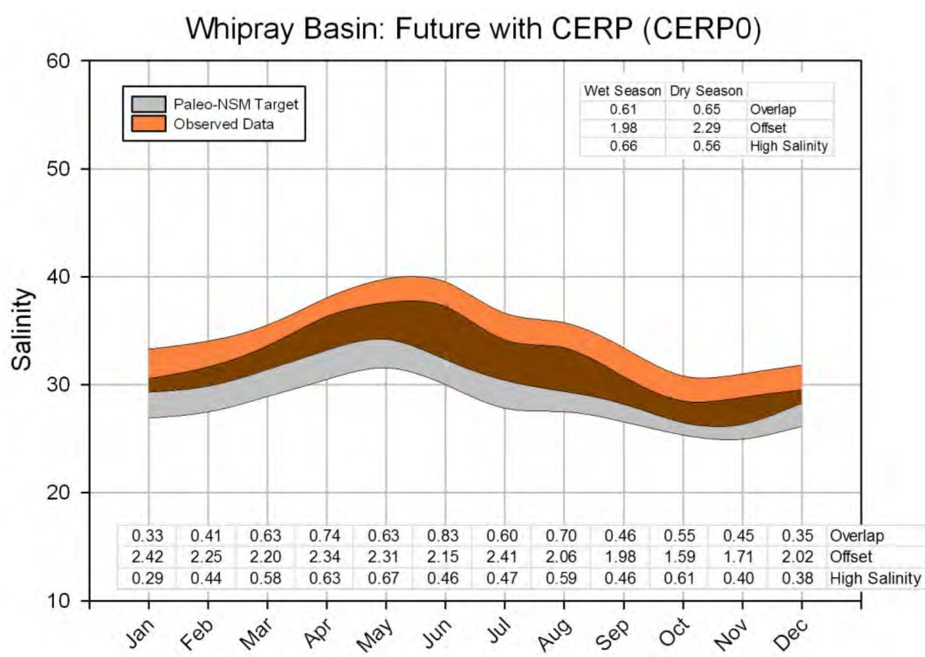


Figure 11. A graphical display of the performance measure metrics applied to the ”Future without CERP” (top) and “Future with CERP” (bottom) planning scenarios of Whipray Basin conditions. The gray ribbon represents the mid-range distribution of the paleo-adjusted NSM target and the orange ribbon represents the mid-range of the planning scenario data. The darker orange ribbon represents the overlap area of the planning scenario data and the paleo-adjusted NSM target. The monthly overlap, mean offset, and high salinity metric scores are provided at the bottom of the plot on the x-axis. The seasonal overlap, mean offset, and high salinity metric scores are shown in the upper right corner.

4.0 Metric Summarization and Reporting

The information generated from the three metrics will be used to evaluate an alternative or assess a period of observed data compared to the target using a "stoplight report-card" approach. This approach is a common format for displaying high-level, highly aggregated information to scientists and resource managers (Harwell et al. 1999, Doren et al. 2009). A red stoplight color indicates substantial deviations from restoration targets creating severe negative conditions that merit action. Yellow indicates that the current condition does not meet restoration targets and merits attention. Green indicates good conditions and restoration goals or trends toward those goals have been reached. End users need to consider all the information generated by the metrics, not just summary statistics and stoplight colors to understand the assessments/evaluations.

For the regime overlap and high salinity metrics, the stoplight scale shown below will be used. Those two metrics are normalized to a 0-1 scale and threshold values to determine stoplight colors are adopted from Lorenz et al. (2009) for scores relative to a target, with each color category comprising one third of the 0-1 range.

Score **Regime Overlap and High-salinity Metrics**	**Stoplight Evaluation**
<0.33	**Red**
0.33-0.67	**Yellow**
>0.67	**Green**

For the mean offset metric, a statistical approach is used to determine stoplight colors. First, the mean and 90% confidence limit (CL) is calculated for the paleo-adjusted NSM salinity at each MMN station, which is the restoration target and defines the green stoplight threshold. Second, the mean and 90% CL is calculated for the paleo-adjusted NSM salinity for the 1989-90 time period (NSM-dry) for each MMN station, which defines the red stoplight condition threshold. The 1989-90 period was an extremely dry two years which resulted in very high, harmful salinities in Florida Bay. It is highly likely that salinities would have been high during this time even under pre-drainage conditions resulting in severe negative conditions for flora and fauna. The next step is to calculate the mean and 90% CL for the assessment year(s) (or evaluation scenario). Then, the mean of the assessment period (or evaluation scenario) is compared to the target and NSM-dry means. If the assessment period mean (or evaluation scenario mean) falls above the NSM-dry condition mean, that results in a red condition. If the assessment period mean or (evaluation scenario mean) falls below the restoration target mean, the condition is green.

If the assessment period mean or evaluation scenario mean falls between the target and NSM-dry means, then the 90% CLs are used to determine stoplight condition. In those cases, if the 90% CL of the assessment period (or evaluation scenario) does not overlap the 90% CL of either the target or NSM-dry, then the condition is yellow. If the 90% CL of the assessment period (or evaluation scenario) overlaps the 90% CL of the restoration target, the condition is green. Conversely, if the 90% CL of the assessment period (or evaluation alternative) overlaps the 90% CL of the NSM-dry, the condition is red.

Figure 12 provides an example of how the mean offset stoplight condition is determined. In this example from Whipray Basin during the dry season, the yellow stoplight condition occurs for years 2000, 2003, 2004, and 2006-2008. Red stoplight conditions occur for years 2005, which was a very dry year, and for 2001. Note that 2001 is considered a red stoplight condition because the 90th percentile of the observed data overlaps the 90th percentile of the red condition threshold. A green stoplight condition existed for 2002 because the 90th percentile of the observed data overlaps the 90th percentile of the restoration target.

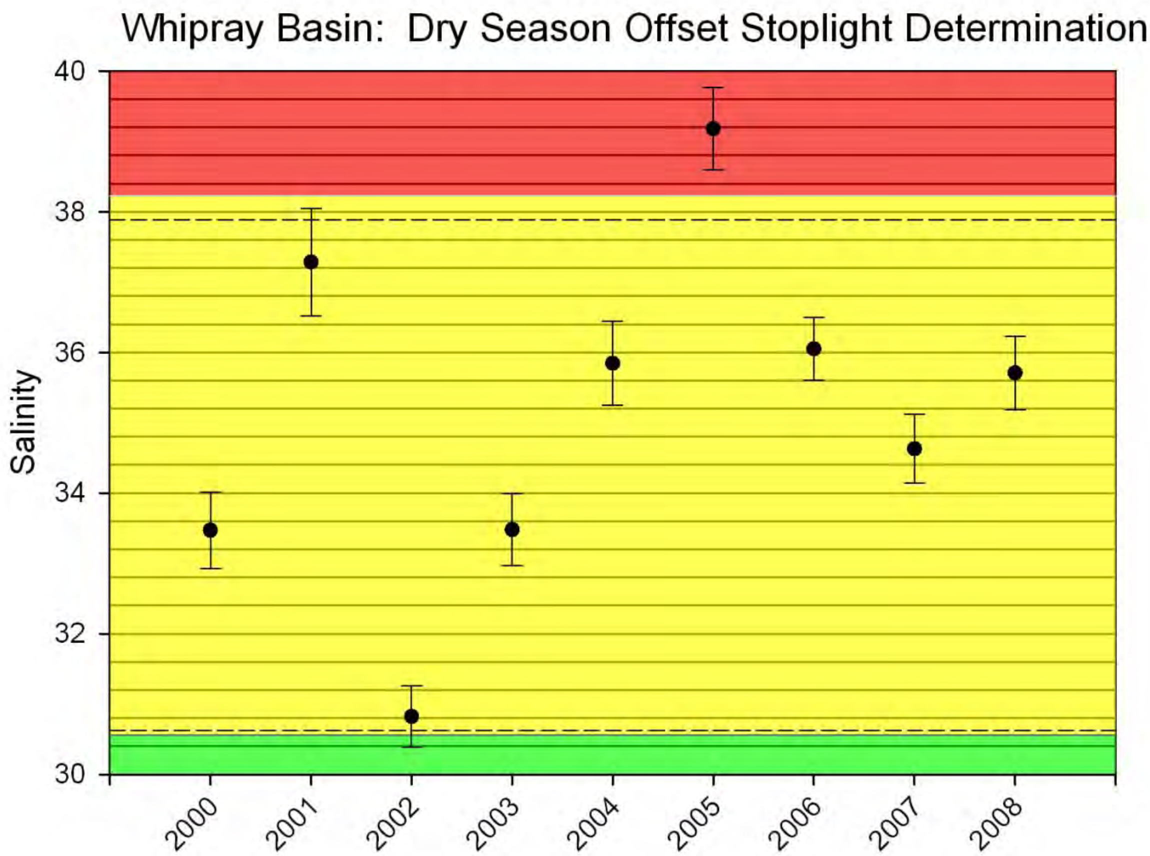


Figure 12. A graphical display of how the mean offset metric stoplight color is determined. The red, yellow, and green areas represent the salinity range encompassed by the stoplight color. The dashed lines represent the 90% confidence limits above the green target mean and below the red target. The circles represent the mean dry season salinity for a given year in Whipray Basin. The whiskers represent the 90% confidence limit around the means of the assessment data.

The overall seasonal stoplight values can be obtained by aggregating individual metric stoplight values. This is determined by re-assigning a numeric value to the stoplight colors (red=0, yellow=0.5, green=1). The seasonal stoplight value is then calculated by taking the arithmetic mean of the 3 performance measure metrics for each MMN station and applying the mean to the stoplight scale above (i.e., the scale for regime and high-salinity stoplights) to obtain the overall stoplight condition (Lorenz et al. 2009). For example, according to Table 7, the Murray Key (MK) assessment for 2003 dry season resulted in yellow scores for two metrics and a green score for one metric. Using the stoplight color assignments described above, this results in an overall stoplight score of 0.66 [$(0.5 + 0.5 + 1.0) \div 3 = 0.66$] or the color value of yellow.

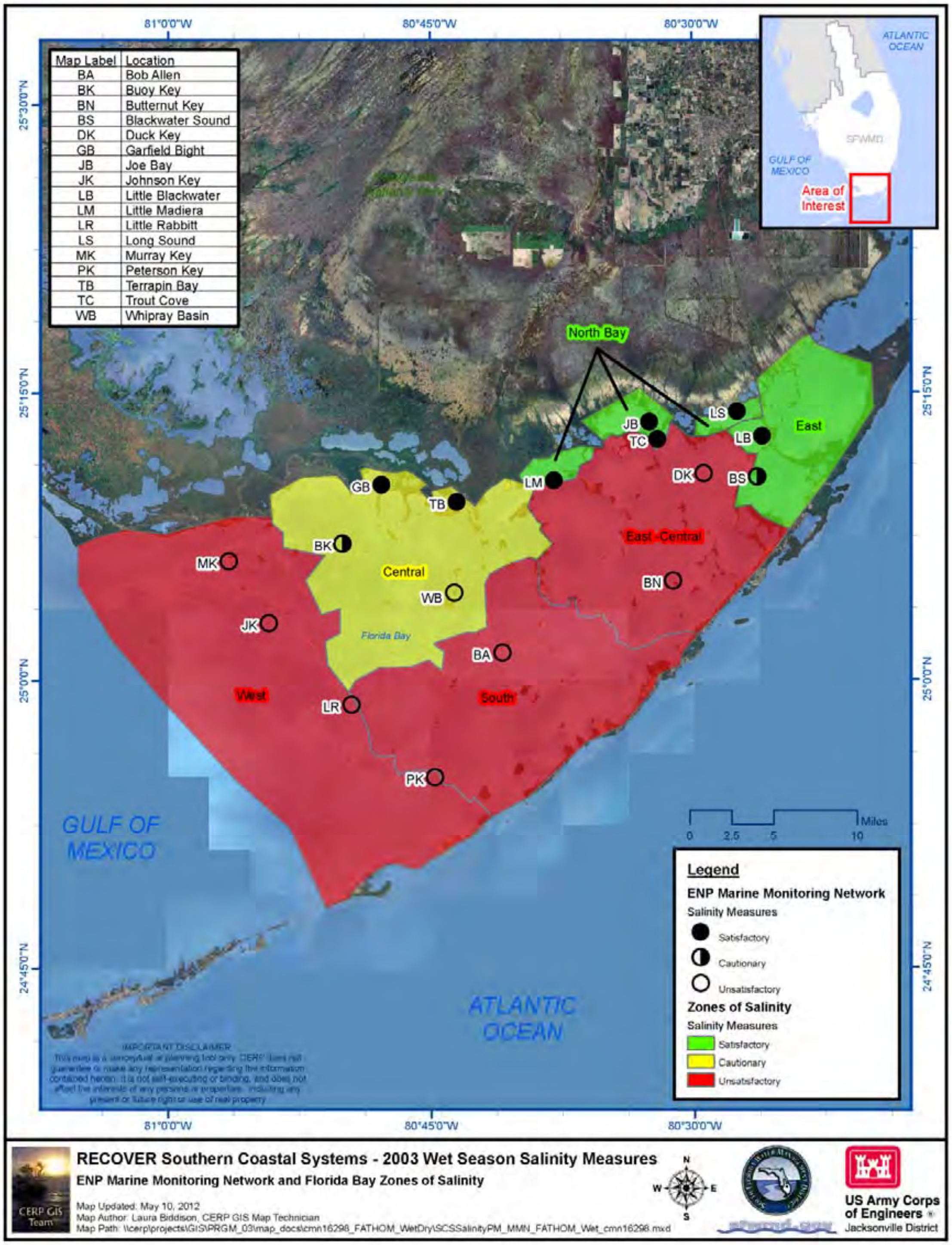
Table 7 shows an example of aggregated metrics taken from an assessment of 2003 conditions at all MMN stations. Figure 13 shows how the seasonal aggregated stoplight scores can be rolled up to show a spatial representation of average conditions in the 6 zones of similarity for both wet (Figure 13a) and dry (Figure 13b) seasons. The colors on the maps represent the overall seasonal stoplight score for the basin average taken from Table 7. The symbols on the maps represent the overall seasonal stoplight score for the station taken from Table 7.

Table 7. Summary of metric scores and stoplight evaluation for each MMN station within Florida Bay for 2003 (a relatively wet year) and averages of the scores within each zone (Figure 13 geographic distribution). Open circles represent red condition, half-empty circles represent yellow, and closed circles represent green. MMN stations have been grouped according to zones as determined by Briceno and Boyer 2010 (see Future Tool Development and Data Needs Section below), and zone averages (the mean of MMN station values within each zone) have been calculated.

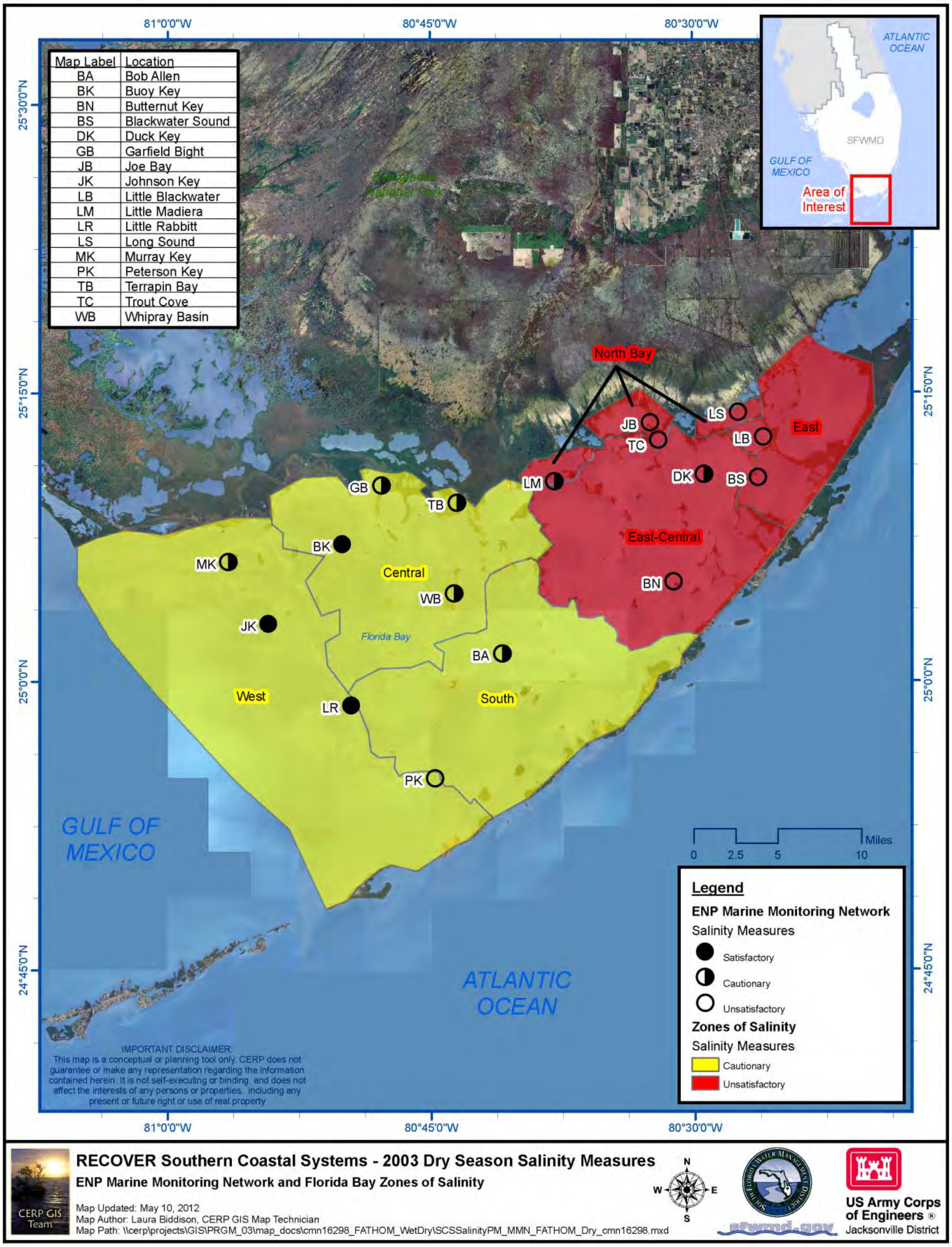
	Dry Season				Wet Season			
MMN Station	Mid-range Overlap	Mean Offset	High Salinity	Overall Stoplight Score	Mid-range Overlap	Mean Offset	High Salinity	Overall Stoplight Score
Joe Bay (JB)	○	○	○	○	●	●	●	●
Little Madeira Bay (LM)	◑	◑	○	◑	●	●	●	●
Long Sound (LS)	○	◑	○	○	●	●	●	●
Trout Cove (TC)	○	○	○	○	◑	●	●	●
North Bay average	○	○	○	○	●	●	●	●
Blackwater Sound (BS)	○	◑	○	○	◑	◑	●	◑
Little Blackwater Sound (LB)	○	○	○	○	●	◑	●	●
East average	○	○	○	○	●	◑	●	●
Butternut Key (BN)	○	◑	○	○	○	◑	○	○
Duck Key (DK)	○	◑	◑	◑	○	◑	○	○
East-central	○	◑	○	○	○	◑	○	○
Buoy Key (BK)	●	◑	●	●	●	◑	◑	◑
Garfield Bight (GB)	◑	◑	◑	◑	●	◑	●	●
Terrapin Bay (TB)	◑	◑	◑	◑	●	●	●	●
Whipray Basin (WB)	◑	◑	◑	◑	○	◑	○	○
Central average	◑	◑	◑	◑	●	◑	◑	◑
Bob Allen Key (BA)	○	◑	●	◑	○	◑	○	○
South average	○	◑	●	◑	○	◑	○	○
Johnson Key (JK)	●	◑	●	●	○	○	○	○
Little Rabbit Key (LR)	●	●	●	●	○	○	○	○
Murray Key (MK)	◑	◑	●	◑	○	◑	○	○
Peterson Key (PK)	○	◑	○	○	○	◑	○	○
West average	◑	◑	●	◑	○	○	○	○
Taylor River (TR)	●	◑	◑	●	●	●	●	●

Figures 13a & 13b. Spatial representation of zone averages from Table 7 for 2003 wet (a) and dry (b) season. The colors represent the Overall Stoplight Score for the basin average. The symbols represent the Overall Stoplight Score for the station (open circles represent red condition, half-empty circles represent yellow, and closed circles represent green).

(a)



(b)



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BK | Buoy Key
BN | Butternut Key
BS | Blackwater Sound
DK | Duck Key
GB | Garfield Bight
JB | Joe Bay
JK | Johnson Key
LB | Little Blackwater
LM | Little Madiera
LR | Little Rabbitt
LS | Long Sound
MK | Murray Key
PK | Peterson Key
TB | Terrapin Bay
TC | Trout Cove
WB | Whipray Basin
ATLANTIC OCEAN
SFWMD
GULF OF MEXICO
Area of Interest
North Bay
East
East-Central
Central
West
South
Florida Bay
GULF OF MEXICO
ATLANTIC OCEAN
Miles
0 2.5 5 10
Legend
ENP Marine Monitoring Network
Salinity Measures
Satisfactory
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Zones of Salinity
Salinity Measures
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RECOVER Southern Coastal Systems - 2003 Dry Season Salinity Measures
ENP Marine Monitoring Network and Florida Bay Zones of Salinity
Map Updated: May 10, 2012
Map Author: Laura Biddison, CERP GIS Map Technician
Map Path: \\cerp\projects\GIS\PRGM_03\map_docs\cmn16298_FATHOM_WetDry\SCSSalinityPM_MMN_FATHOM_Dry_cmn16298.mxd
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5.0 Uncertainty

It is uncertain if the volume of water that is identified as needed to achieve restoration targets can be delivered from upstream. It is also unclear if CERP projects (e.g., C-111 Spreader Canal and Biscayne Bay Coastal Wetlands) will perform as anticipated.

It is also understood that the SFWMM (all versions) does not perform well at the southern end of the model grid (2 to 3 cells from the edge) primarily as a function of poorly constrained boundary conditions typical of hydrologic models. Most selected gauge/grid locations used in the MLR salinity models are located in areas where the SFWMM has been documented as reliable based on calibration/verification analysis. The ability of the MLR salinity models to simulate the observed conditions can be evaluated using a number of error statistics. Uncertainty will be continually reevaluated by comparison with assessment data. The error statistics for the MLR salinity models are presented in Table 8 and defined below.

Table 8. Error statistics for the MLR salinity models, including root mean square error (Root MSE) and adjusted R^2 (Adj R^2).

MMN Station	Root MSE (psu)	Adj R^2
North Bays		
Joe Bay (JB)	5.5	0.71
Little Madeira Bay (LM)	4.1	0.59
Long Sound (LS)	4.4	0.71
Trout Cove (TC)	6.3	0.63
East		
Blackwater Sound (BS)	3.5	0.60
Little Blackwater Sound (LB)	4.0	0.69
East-Central		
Butternut Key (BN)	3.7	0.67
Duck Key (DK)	4.2	0.45
Central		
Buoy Key (BK)	3.1	0.48
Garfield Bight (GB)	6.0	0.58
Terrapin Bay (TB)	6.1	0.73
Whipray Basin (WB)	3.7	0.63
South		
Bob Allen Key (BA)	3.2	0.67
West		
Johnson Key (JK)	2.9	0.44
Little Rabbit Key (LR)	2.5	0.27
Murray Key (MK)	2.8	0.33
Peterson Key (PK)	2.1	0.55

Root Mean Square Error - The Root Mean Square Error is a weighted measure of the error where the largest deviations between observed and predicted values contribute most to this uncertainty statistic. This statistic has units that are the same as the observed and predicted values. It is thought to be the most rigorous test of absolute error.

Adjusted – R^2 - The Coefficient of Multiple Determination (R^2) is the most common measure of the explanatory capability of a model. R^2 measures the percentage reduction in the total variation of the dependent variable associated with the use of the set of independent variables that comprise the model. When there are many variables in the model, it is common to use the Adjusted Coefficient of Multiple Determination, which is R^2 divided by the associated degrees of freedom.

6.0 Sustainability

Continued salinity monitoring at the MMN sites and the USGS flow monitoring sites are essential to CERP's ability to assess salinity PMs in Florida Bay. Also, the structural features and operations of the C-111 Spreader Canal Project and other new water management features are likely to change the flow-to-salinity relationships, hence the need to also retain the USGS flow monitoring network in Florida Bay and the southwest Florida coast for the long term to revise the MLRs as needed and to allow for continued assessment of the projects and impacted areas.

7.0 Future Tool Development and Needs

The MLR models may be improved over time using improvements in statistical relationships for salinity, stage, sea level, and wind parameters, and knowledge gained through development of statistical models. Also, additional paleo-salinity information, particularly from northeastern Florida Bay, would strengthen the paleo-adjustments to the MLR output. However, it may be more beneficial to complete the development of a hydrologic model that can relate salinity to upstream flow. Models being developed by the USGS, ENP, and others are being considered for Interagency Modeling Center review and implementation. The Flux Accounting and Tidal Hydrology at the Ocean Margin (FATHOM) model (Crosby et al. 2010) may be useful as a corroborating tool for the MLR salinity models because the spatial domains are similar and FATHOM is driven by freshwater flow and tide data, which provides an independent comparison of salinity output. The model is a spatially-explicit, mass-balance model that divides Florida Bay into >50 individual basins or embayments. However, FATHOM output is a monthly average condition for each large volume basin, as compared to the MLR salinity models' daily average at a point station output.

Also, recent studies have shown that Florida Bay can be divided into six zones based upon water quality/salinity characteristics (Briceno and Boyer 2010). The stations, basins, and zones provide options to expand the evaluation to better interpret the influence of any future project on the area. The zones and basins closest to the transition zone, (e.g. North Bay, East, and Central) should have the greatest influence from restoration resulting in salinity reduction. Analyzing results by these basins and zones will enhance CERP's ability to accurately interpret results.

The SFWMD Regional Simulation Model (RSM) may now be available for simulating CERP alternative stage levels and flows as an improvement to the current use of the SFWMM for this purpose. Additional analysis of the RSM output is needed to determine if RSM provides benefits for the application of this salinity performance measure across the domain of the RECOVER Southern Coastal Systems module. Short-term use of RSM would require continued development and refinement of MLR models to accept RSM input.

Long-term hydrologic analysis for CERP assessment and evaluation, however, would greatly benefit by the development of hydrodynamic models that can evaluate a changing linkage of the Everglades watershed to the coastal wetlands to coastal and estuarine waters. This is especially important for the analysis of effects on Florida Bay of waters pluming from Shark River Slough and the effects of sea-level rise and climate change on freshwater inflows and salinity. The Tides and Inflows in the Mangrove Ecotone (TIME) model and Environmental Fluid Dynamics Code (EFDC) models are examples of tools for hydrodynamic calculations in the Everglades coastal wetlands and coastal waters that already have extensive development; these models could be refined and applied.

Using both existing and newly developed modeling capability for Florida Bay and the southern Everglades, the salinity performance measure described in this document should be subject to future revision and improvement. One need is to assess and evaluate large-scale spatial patterns of freshwater flow and coastal and estuarine salinity along the entire coastline from Biscayne Bay to the Ten Thousand Islands to include the coastal lake region of Florida Bay (e.g., Seven Palm, Cuthbert, and Monroe Lakes) with the expectation that CERP will restore natural spatial patterns of freshwater flow and coastal and estuarine salinity. This includes assessment and evaluation of Florida Bay's salinity response to increased inflow quantities through Shark River Slough and Taylor Slough and an increased proportion of flow delivered via Taylor Slough, compared to flow via the C-111 Canal. Another need is the analysis of the effectiveness of CERP in eliminating rapid salinity decreases along the entire shoreline from northeastern Florida Bay to Biscayne Bay that are caused by flood control operations.

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