

Total System Performance Measure Slough Vegetation

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1.0 Desired Restoration Condition

This performance measure has been developed to assess the hydrologic suitability for slough vegetation within the estimated pre-drainage ridge and slough geographic regions and does not attempt to serve as a performance measure to assess all ecosystem parameters within the Everglades. This performance measure is meant to be used in concert with other performance measures to ensure an ecosystem-wide perspective is provided for project evaluations.

Compilation of empirical evidence indicates the Everglades pre-drainage ridge and slough landscape was an extensive, interconnected system comprising the majority of modern day Loxahatchee National Wildlife Refuge (NWR), Water Conservation Area (WCA)-2, WCA-3, and Shark River Slough (McVoy et al., 2011; Plate 5). The paleoenvironmental record provides scientific evidence that *Nymphaea odorata* (white water lily) was a characteristic plant species within historic Everglades sloughs (Saunders et al., 2008; Bernhardt et al., 2004; Willard et al., 2001; Willard et al., 1997). During pre-drainage conditions, naturally occurring slough communities associated with tree islands and dense stands of *Cladium jamaicense* (sawgrass) were abundant within the ridge and slough habitat of the Everglades. This topography is termed “ridge and slough”, since the dense sawgrass ridge was historically approximately 1.5 ft (46 cm) higher than the adjacent slough (Willoughby, 1898; Stewart, 1907; Baldwin and Hawker, 1915; Marchman, 1947; Lodge, 2005). During pre-drainage times, the ridges and sloughs were oriented parallel to the direction of flow. This landscape was estimated to extend from the pine flatwoods of the Coastal Ridge on the east, to the Big Cypress Swamp on the west, to the sawgrass plains on the north, and to the mangrove estuary to the south (McVoy et al., 2011).

Implementation of the Central and Southern Florida (C&SF) Project altered hydro patterns and associated physical patterning processes causing a detrimental effect on the Everglades flora and fauna (SCT, 2003). The ridge and slough landscape has become more uniform both in topography and plant community composition (Richards et al., 2009; Sklar et al., 2000). The physical patterning of the ridge and slough topography has been significantly degraded compared to historical conditions with only a 0.33 ft (10 cm) average elevation difference now existing between ridges and sloughs within WCA-3A, WCA-3B, and Shark River Slough (Richards et al., 2009). The central portion of many sloughs, once thought to be a *N. odorata*-dominated plant community, now contain plant species characteristic of more transitional ridge and slough environments such as *Eleocharis cellulosa* (coastal spikerush) (Richards et al., 2009). Hydro patterns (i.e., water depth) reported in modern day Everglades “sloughs” in WCA-3A, WCA-3B, and Shark River Slough provide evidence that conditions have become more suitable for transitional species to invade the central portions of sloughs in WCA-2, WCA-3, and Shark River Slough (Richards et al., 2009). While distinct physiochemical and plant species composition differences still exist in ridges and sloughs today, shifts in plant species

composition and physical degradation of the ridge and slough habitat indicate that core ecological functions and processes in vegetation communities have degraded since pre-drainage times (Richards et al., 2009).

The desired restoration condition is the return of the hydroperiods that support the development and sustainability of the ridge and slough topography and the associated ecological functions provided by ridge and slough communities.

Our leading hypotheses for developing and maintaining suitable hydroperiods for slough vegetation indicator species *N. odorata* and *Eleocharis elongata* within the estimated historic ridge and slough habitat (McVoy et al., 2011) include natural, climate-induced hydroperiod variability over an extended period of record, but characterized as having:

- a near continuous 365-day calendar year hydroperiod (days water is above ground surface),
- limited dry down¹ events below 0.7 ft (20 cm), average wet season (June - October) water depths of approximately 2 - 3 ft (61.0 – 91.4 cm) and average dry season (November - May) water depths of approximately 1.5 - 2 ft (45.7 – 61.0 cm) (while still including natural, climate-induced variability), and
- threshold flow velocities of 2-3 cm/sec (Sklar et al., 2009; Harvey et al., 2009) essential for redistributing organic matter and sustaining the ridge and slough structure in peatlands.

Flow velocities cannot yet be reliably simulated across the Everglades landscape over an extended period of record, and as a result, no scoring methodology for this hydroperiod feature has been developed. For the Slough Vegetation Performance Measure, inundation duration, dry-down events¹, and average wet and dry season water depth metrics are computed to evaluate suitable hydroperiod conditions for slough vegetation indicator species.

1.1 Predictive Metric and Target

The Predictive Metric and Target conditions were developed in three phases (Figure 1). In phase I, scientific evidence derived from experimental mesocosm studies, paleoenvironmental seed and pollen studies, field studies, and historical reports as well as personal observations was compiled to generate hypotheses defining the type of plant indicator species and hydroperiods that characterized the pre-drainage native Everglades slough (For more detailed information on the empirical evidence gathered, please refer to Section 2.0 Justification). This synthesis of information led to phase II. Based on the gathered empirical evidence, metrics were developed that measured the suitability of hydrological conditions for the slough vegetation indicator species. The set of proposed metrics was next reconciled with the type and quality of hydrologic output available from modeling simulations (e.g., the South Florida Water Management Model [SFWMM], Regional Simulation Model [RSM], etc.) that would be feasible and readily available to compute the final set of metrics. Finally, in phase III,

¹ Note: The term “dry down” in this documentation sheet refers to water depths at 0.7 ft (20 cm) above the ground surface; the term dry out refers to a water depth of 0 ft (0 cm).

cells in the Natural Systems Model (NSM) version 4.6.2 were evaluated to select the NSM cell that most closely matched the scientific evidence defining suitable hydrological conditions for slough vegetation indicator species. The selected NSM cell was then used to develop the return frequency curves for each respective Slough Vegetation Performance Measure metric. This return frequency curve is the finalized target for each Slough Vegetation Performance Measure metric. The result was the development of a Slough Vegetation Performance Measure that consists of four hydrologic metrics and targets, as summarized in Table 1.

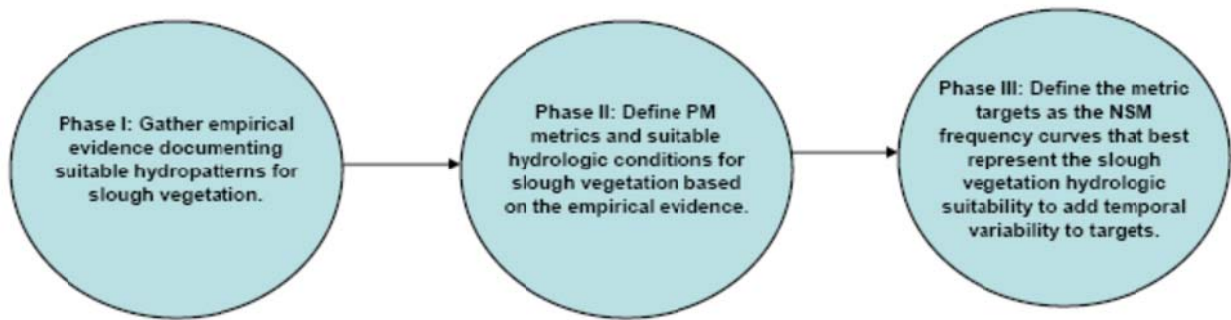


Figure 1. Pathways followed to determine the predictive metrics and targets for the Slough Vegetation Performance Measure.

Performance measure metric	Summarized scientific evidence used in performance measure metric target development	Performance measure metric target
continuous hydroperiod	near continuous inundation	NSM frequency curve that best represents near continuous inundation (The target is the PMtarget curve as shown in Figure 3.)
continuous dry down event below 0.7 ft (20 cm)	avoidance of dry down events below 0.7 ft (20 cm)	NSM frequency curve that best represents minimization of dry down events < 0.7 ft (20 cm) (The target is the PMtarget curve as shown in Figure 4.)
average wet season depth	approximately 2.0 - 3.0 ft (~61.0 - 91.4 cm)	NSM frequency curve that best represents an average wet season depth of ~ 2.0 - 3.0 ft (~61.0 - 91.4 cm) (The target is the PMtarget curve as shown in Figure 5.)
average dry season depth	approximately 1.5 - 2.0 ft (~45.7 - 61.0 cm)	NSM frequency curve that best represents a dry season average depth of ~1.5 - 2.0 ft (~45.7 - 61.0 cm) (The target is the PMtarget curve as shown in Figure 6.)

Table 1. Description of Slough Vegetation Performance Measure metrics, empirical evidence for performance measure metric targets, and performance measure metric targets. *Note: For a summary of the scientific evidence used to develop performance measure metric targets, please refer to Section 2.0, Justification.*

NSM version 4.6.2 Cell C25_R21 (which contains the NE2 gauge) closely matched the multi-year hydrologic patterns suitable for slough vegetation as defined by the compilation of the empirical evidence gathered in Phases I and II (Figure 1). For a more thorough description of how Cell C25_R21 closely matches the scientific evidence defining suitable hydrologic conditions for slough vegetation indicator species, please refer to Section 2.0, Justification.

The Slough Vegetation Performance Measure will be applied in RECOVER Indicator Regions (IRs) when evaluating SFWMM output since RECOVER IRs correlate well with calibration gauges (correlation coefficients of approximately greater than 0.6) and exclude domain areas known to produce unreliable output such as model edges and at operating structure locations (RECOVER, 2007). RECOVER IRs defined as ridge and slough are included in performance evaluations (RECOVER, 2004). In addition, pre-drainage IRs dominated by ridge and slough habitat per the McVoy et al. (2011) reference are included in the project evaluation. This includes the following RECOVER IRs shown in Figure 2: 100, 101, 102, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, and 160. IRs 141 and 190 were estimated to contain some historic ridge and slough habitat (McVoy et al., 2011) although these IRs were estimated to contain less than approximately 25% historic ridge and slough habitat coverage. An evaluation was conducted to determine if just those cells in IRs 141 and 190 containing historic ridge and slough could be included in the evaluation; however, this is not recommended since partial cells would need to be scored and this is not readily feasible due to the scale of the SFWMM. Therefore, IRs 141 and 190 are not included in the performance measure evaluations when evaluating SFWMM output.

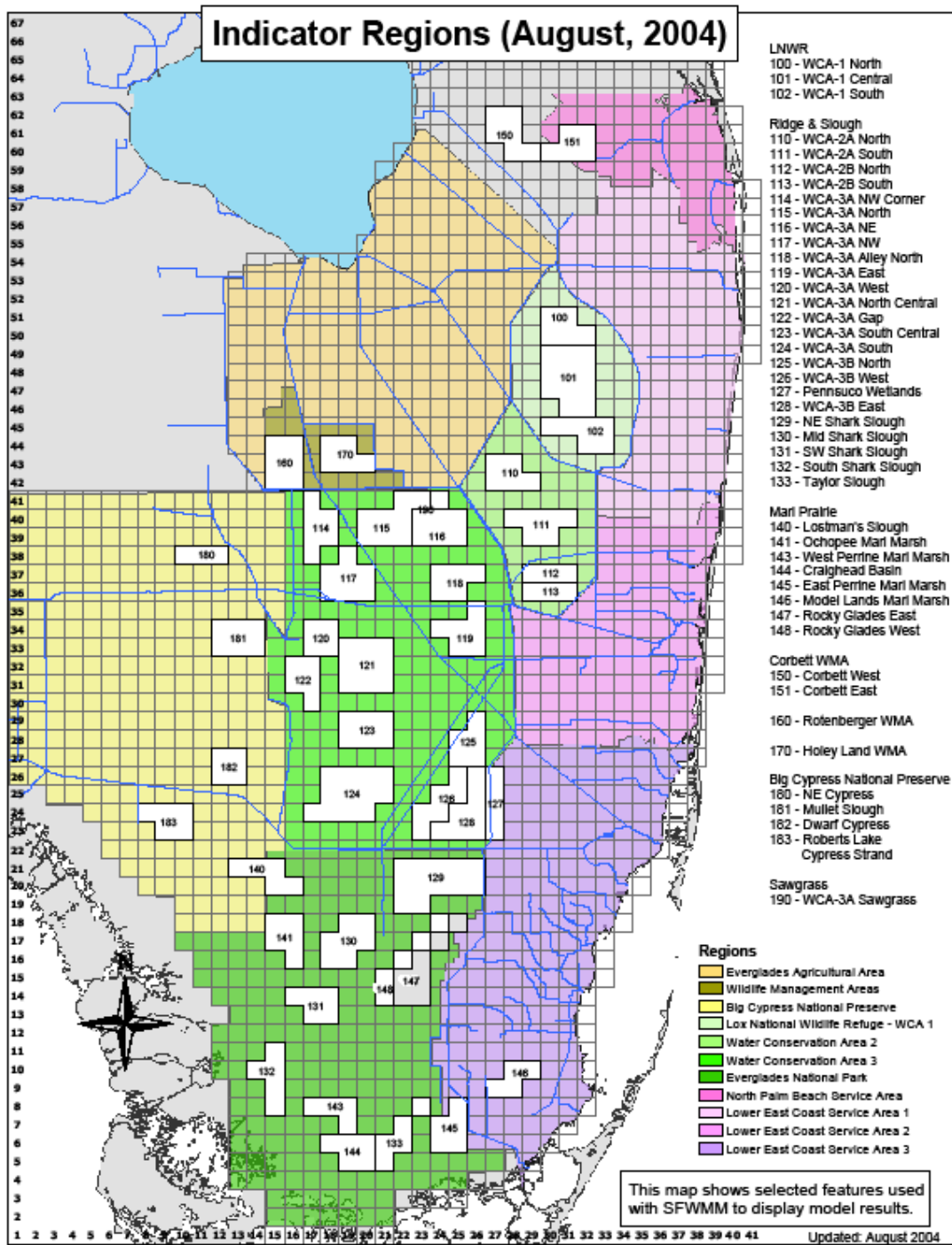


Figure 2. RECOVER IRs in the SFWMM within the Greater Everglades (RECOVER, 2004)

As an example application of the Slough Vegetation Performance Measure, Combined Structural and Operational Plan (CSOP) alternatives were evaluated by computing the deviation from the target (NSM Cell C25_R21) for each of the four performance measure metrics over a 36 year period of record (1965 – 2000) in IR 129, Northeast Shark River Slough (NESS) using SFWMM output. Example graphics of these comparisons are shown in Figures 3 – 6.

1.1.1 Hydroperiod

For the hydroperiod metric, the empirical hydroperiod frequency curve is simulated for annual maximum continuous hydroperiod (depth ≥ 0.0 ft (0.0 cm)), as shown in Figure 3, within applicable ridge and slough IRs. The target for this metric within each IR is the NSM return frequency curve (PMtarget) from Cell C25_R21 as shown in Figure 3. The PMtarget curve ranges during the driest of years (approximately 1 in 30 years) from an approximate 160-day annual hydroperiod to a 365-day annual hydroperiod in average to wet years (Figure 3).

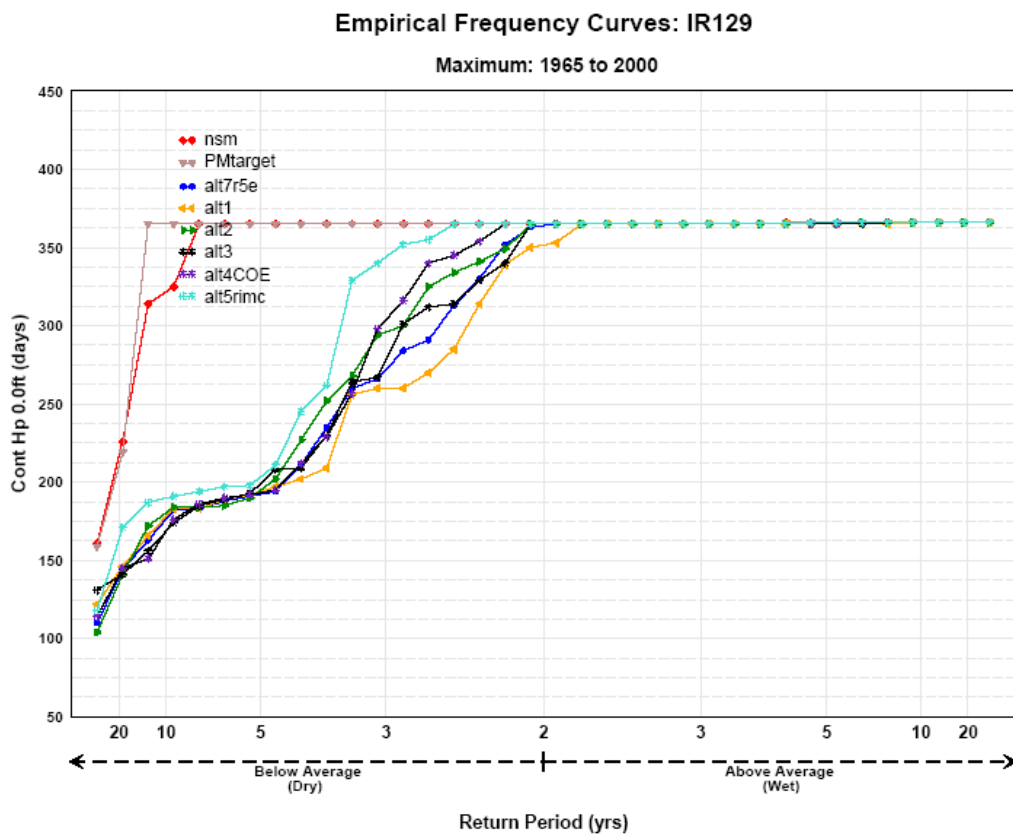


Figure 3. Empirical Hydroperiod Frequency Curves for Example Alternatives at IR 129. PMtarget is the empirical hydroperiod frequency curve for NSM v 4.6.2 at Cell C25_R21.

1.1.2 Continuous Dry Down Events

For the dry down metric, the empirical dry down frequency curve is simulated for annual maximum continuous dry down events (depth < 0.7 ft (20 cm)) within applicable ridge and slough IRs. The

PMtarget for this metric within each IR is the NSM return frequency curve from Cell C25_R21 as shown in Figure 4. The PMtarget ranges from approximately 174 days of continuous dry down below 0.7 ft (20 cm) in the driest year (approximately 1 in 30 years) to approximately zero dry down events (below 0.7 ft) in the average to wettest years (Figure 4).

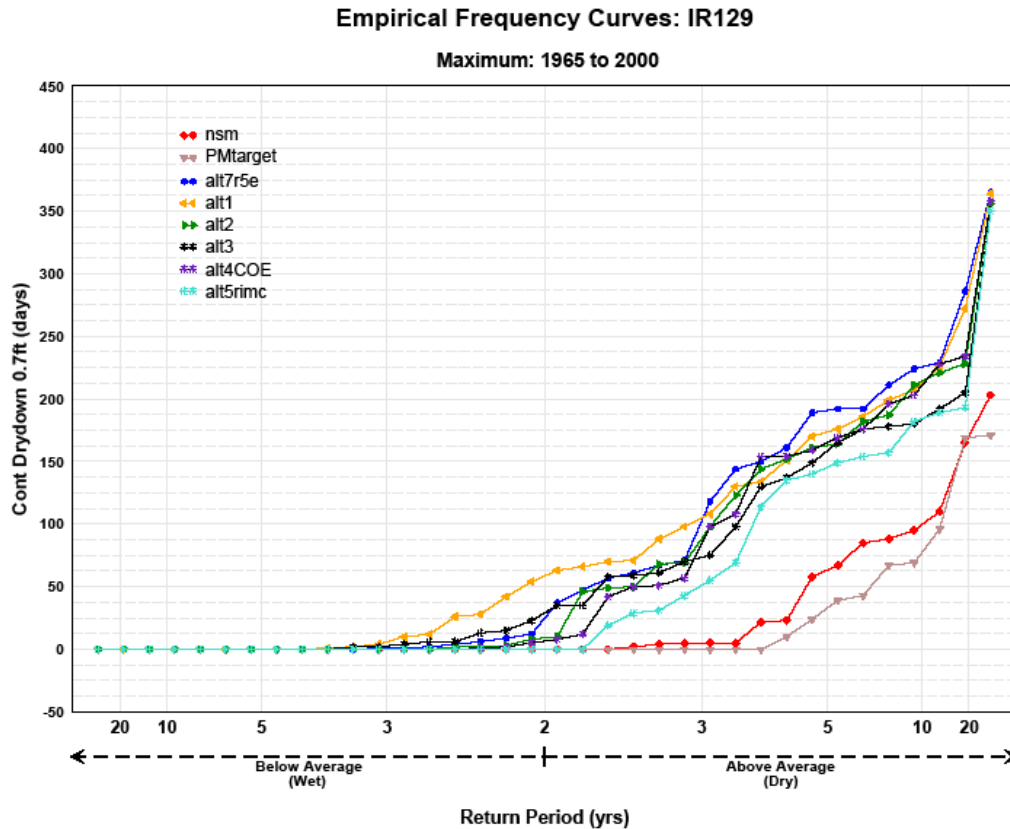


Figure 4. Empirical Dry Down (below 0.7 ft) Frequency Curves for Example Alternatives at IR 129. PMtarget is the empirical dry down frequency curve for NSM v 4.6.2 at Cell C25_R21.

1.1.3 Wet Season Average Depth

For the wet season (June through October) average depth metric, the empirical depth frequency curve is simulated in applicable ridge and slough IRs. The PMtarget for this metric within each IR is the NSM return frequency curve from Cell C25_R21 as shown in Figure 5. During an average year, the PMtarget curve shows an approximate wet season average depth of 2.25 ft (Figure 5) but ranges during the driest year (approximately 1 in 30 years) from an approximate average annual wet season of depth of 0.3 ft to 3.1 ft during the wettest of years (approximately 1 in 30 years) (Figure 5).

Empirical Frequency Curves: IR129

Wet Average: 1965 to 2000

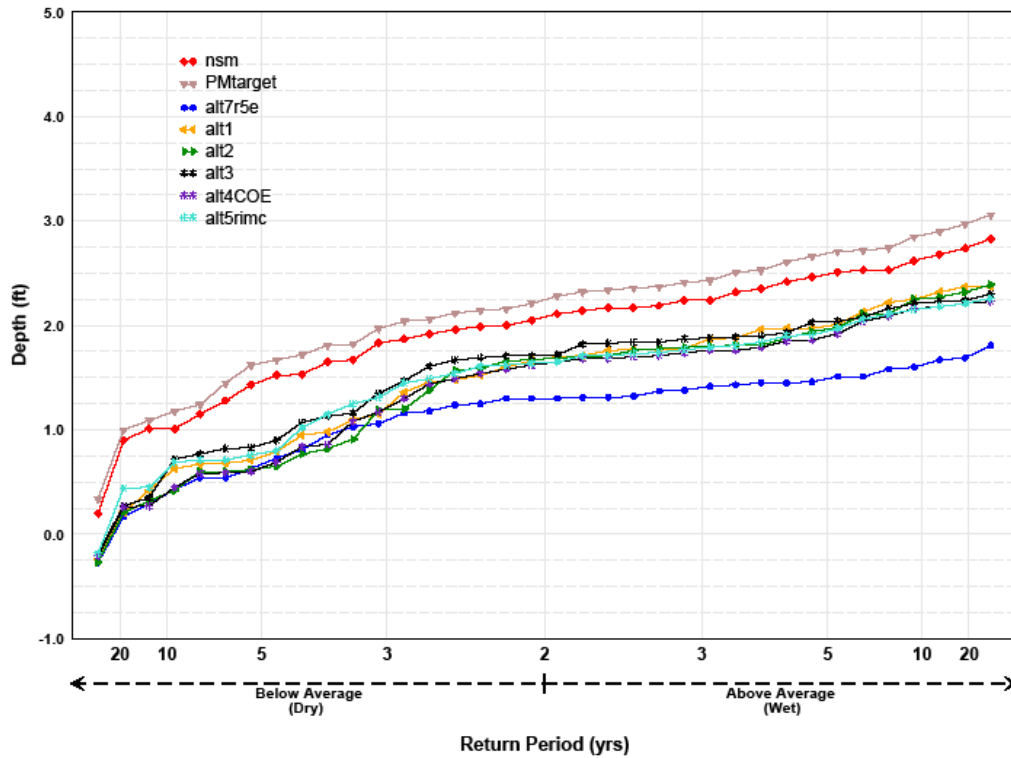


Figure 5. Empirical Depth Frequency Curve of Wet Season Average Depth for Example Alternatives at IR 129. PMtarget is the empirical depth frequency curve for NSM v 4.6.2 at Cell C25_R21.

1.1.4 Dry Season Average Depth

For the dry season (November through May) average depth metric, the empirical depth frequency curve for dry season average depth is simulated in applicable ridge and slough IRs. The target for this metric within each IR is the NSM return frequency curve from Cell C25_R21 as shown in Figure 6. During an average year, the PMtarget curve shows an approximate average dry season depth of 2.0 ft (Figure 6) but ranges during the driest of years (approximately 1 in 30 years) from an approximate average dry season of depth of 0.4 ft to 3.1 ft during the wettest of years (approximately 1 in 30 years) (Figure 6).

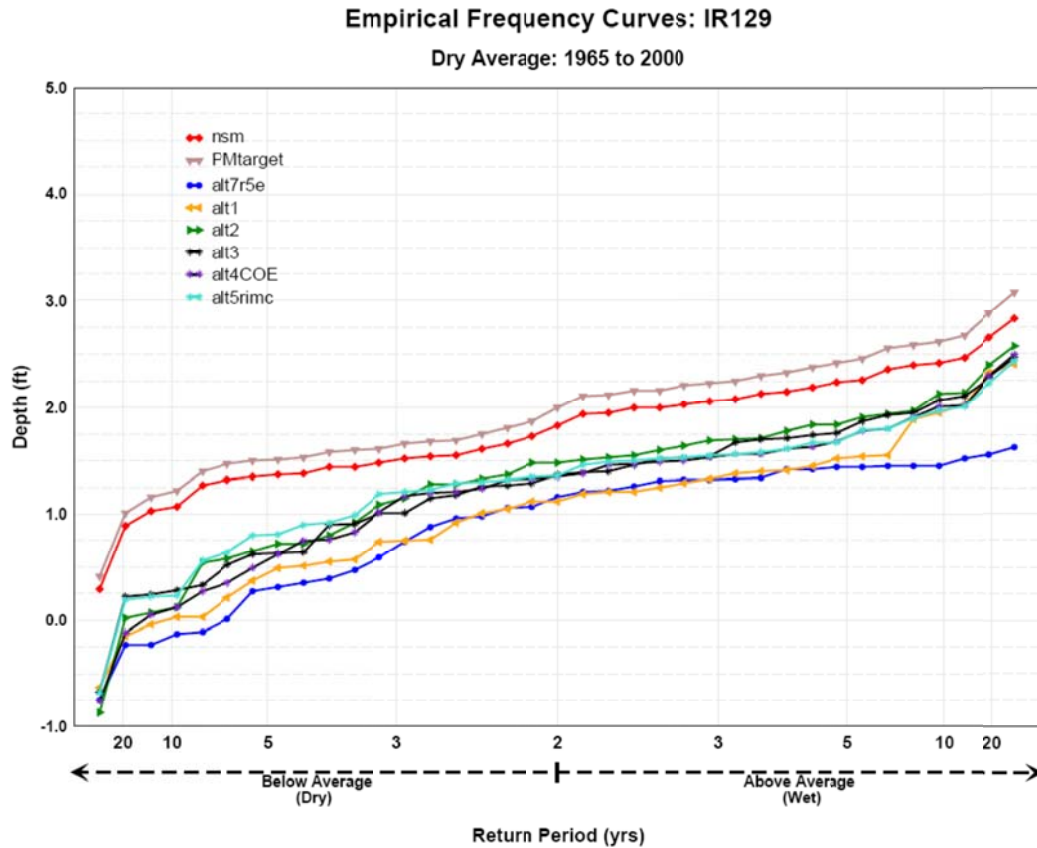


Figure 6. Empirical Depth Frequency Curves of Dry Season Average Depths for Example Alternatives at IR 129. The PMtarget is the dry season average depth curve for NSM v 4.6.2 at Cell C25_R21.

1.1.5 Calculation of Project Alternative Score and Spatial Output

To evaluate the Comprehensive Everglades Restoration Plan (CERP), Modified Water Deliveries (MWD), and other Everglades restoration project alternatives, the following landscape and project specific Slough Vegetation Performance Measure computations are recommended:

- Calculate the Slough Vegetation Performance Measure score for ridge and slough IRs historically estimated to be dominated by ridge and slough habitat (100, 101, 102, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, and 160) throughout the Everglades landscape. This is accomplished by averaging the IR scores within each applicable ridge and slough Everglades region Loxahatchee NWR, Water Conservation Area WCA-2, WCA-3, and Everglades National Park (ENP) and then weighting the average scores within each respective Everglades region by the total geographic area of estimated pre-drainage slough vegetation found in the ridge and slough Everglades region based on McVoy et al. (2011) in the estimated historical pre-drainage map (McVoy et al., 2011; Plate 5) (The Rotenberger area will be included in the WCA-3A score).

- Next, calculate the estimated area of slough vegetation affected by the project alternative being evaluated. This calculation includes only those IRs affected, either benefitted or impacted by the project alternative. This can be accomplished by comparing the existing conditions base (ECB) run to the project alternative. It is important to ensure that evaluators are clear about the ecological benefits that are derived from project alternatives versus other restoration actions which may be embedded in the simulation so that the project itself (or group of projects) can be evaluated.² Any areas showing a benefit or impact to slough vegetation as compared to the ECB run should be included in this evaluation. If this calculation involves separate IRs, weighing by regions is recommended as described previously.

It is essential both scores be reported to define any landscape level benefits/impacts of the project to slough vegetation, define the boundary area of effect of the project on slough vegetation, and calculate any project benefits/impacts to slough vegetation within the immediate project area. Thus, overall effects at the landscape level to slough vegetation should be described as well as any benefits/impacts to slough vegetation within the immediate project area.

- As requested, spatial maps can be provided that summarize individual Slough Vegetation Performance Measure metric scores and finalized scores (averages of all metrics) for individual cells throughout the Everglades ridge and slough landscape. While the spatial maps will not be used in the performance measure scoring calculations, they will serve as useful tools for illustrating landscape-level as well as finer scale patterns in slough vegetation changes across the Everglades landscape.

1.2 Assessment Parameter and Target

The Sheetflow and Water Depth Patterns, Oligotrophic Nutrient Status and Landscape Patterns of Ridge and Slough Peatlands and Adjacent Marl Prairies in Relation to Sheet Flow, Water Depth Patterns and Eutrophication hypothesis clusters in the 2009 Monitoring and Assessment Plan (MAP) contain several monitoring activities which are used to determine if the restoration goals are being achieved. These include Regional Distribution of Soil Nutrients (MAP³ section 3.1.3.2), three activities associated with Landscape Pattern sampling: Vegetation Mapping (section 3.1.3.4), Marl Prairie/Slough Gradients (section 3.1.3.5), and Ridge, Slough, and Tree Island Mosaic (section 3.1.3.6) and South Florida Surface Water Monitoring (Everglades Depth Estimation Network [EDEN]) (section 3.5.4.1). In addition there is a MAP activity which is addressing Key Uncertainties

² For CERP and MWD projects, it is also recommended (if possible) that another evaluation be performed that includes the project alternative in a run with other restoration projects to examine the cumulative effect of the project in conjunction with other restoration actions. This will describe whether the project alternative can work together in concert with other restoration actions to provide incremental benefits.

³ Note: All section numbers are from the MAP 2004 (RECOVER, 2004). Table 3-4 of MAP 2009 (RECOVER, 2009) describes changes made to monitoring components from the 2004 MAP to the 2009 MAP.

and Supporting Research which is relevant to this Performance Measure, specifically: Mechanism of Ridge-Slough Maintenance and Degradation Across the Greater Everglades (section 3.1.4.4). The relationship between these assessment activities and the application of this performance measure is addressed in the Uncertainty (section 5.0) and the Monitoring and Assessment (section 6.0) portions of this document.

2.0 Justification

Historically, the pre-drainage ridge and slough landscape was an extensive, interconnected system comprising the majority of modern day Loxahatchee NWR, WCA-2, WCA-3, and Shark River Slough (McVoy et al., 2011). Sloughs are conspicuous and major landscape features in the southern Everglades and are the main pathway of water flow through the natural Everglades (Lodge 2005; Harvey et al., 2009). The slough vegetation community is present in Everglades habitats with the longest hydroperiods, the deepest water, and these areas rarely dry out. Slough habitats contain a distinct vegetation community that is a mixture of emergent, floating, and submerged forms. A dominant (biomass) and characteristic species of modern Everglades sloughs is *N. odorata* (white water lily); however, there are often other species of floating vegetation present which includes *Nymphoides aquatica* (floating hearts), and *Nuphar lutea ssp. advena* (spatterdock) (Goodrick, 1984). Submerged aquatic vegetation is also present and is represented by different species of bladderwort such as *Utricularia purpurea* (purple bladderwort), *Utricularia gibba* (two-flower bladderwort), and *Utricularia foliosa* (leafy bladderwort). Some species of emergents may also be present such as *E. elongata* (slim spikerush) and *Panicum hemitomom* (maidencane).

The paleoenvironmental record provides scientific evidence that *N. odorata* was a characteristic species in the historic Everglades ridge and slough landscape (Saunders et al., 2008; Bernhardt et al., 2004; Willard et al., 2001; Willard et al., 1997). Individual soil cores provide relatively continuous indications about the history of the local conditions in/around the soil core site based on the relative abundance of pollen and seeds. The assemblages observed in soil cores can be compared directly to pollen and seed assemblages observed in the current system. Cores taken at different sites can be directly compared in order to differentiate among portions of the historical record which may indicate local or regional differences in hydropatterns. Pollen surface data collected thus far indicate that *N. odorata* was historically and is currently a characteristic slough species within WCA-2A (Willard et al., 1997) and WCA-3A (Bernhardt et al., 2004). Pollen core data indicate that pre-drainage slough/sawgrass marsh areas transitioned to drier sawgrass marsh/wet prairie habitats within WCA-3A (Willard et al., 2001). Core pollen samples collected thus far provide evidence that *N. odorata* dominated historic WCA-3B sloughs (Bernhardt et al., 2004), and this finding supports soil core profile data showing that *N. odorata* was a dominant (seed abundance) species from ~2500 BC to ~1900 AD (Saunders et al., 2008) in WCA-3B. Seed core data collected within Shark River Slough (Saunders et al., 2008) has shown a transition from a *N. odorata*-dominated slough during pre-drainage conditions to a drier sawgrass community. In addition, historic expeditions through these regions largely would not have been possible with the current vegetation and hydropatterns; these accounts further support the concept of a landscape that contained open water sloughs as a predominant feature (SCT, 2003). Pollen core data collected in the south central portion of Taylor Slough indicates this area once was dominated by *N. odorata*-dominated sloughs during the 1760 BC-780 BC timeframe followed by plant community characterized by wet prairie and sawgrass marshes (Willard et al., 2001). Pollen core samples collected in southern Taylor Slough indicate this area was

a mixture of wet prairies, sawgrass marshes, and mangroves during pre-drainage times of the early 1800s (Willard et al., 2001). Compilation of the soil core data indicate Taylor Slough contains peat, mixed peat, and marl soils in contrast to the marl-based soils flanking Taylor Slough (McVoy et al., 2011). In addition, aerial inspection and photographs illustrate ridge and slough topography within Taylor Slough (McVoy et al., 2011). A historical account from John Kunkel and photograph (dated February 1916) describes a “deep slough in the Everglades east of Royal Palm Hammock” that is similar to other sloughs in the vicinity and that is rarely dry and supports prolific yellow water-lily (floating vegetation in photograph provided in McVoy et al. (2011) is *N. lutea ssp. advena*), pickerelweed, and maiden-cane (McVoy et al., 2011). Sawgrass, common reed and small hammocks were also reported to flank these deep sloughs in this historical account of northern Taylor Slough (McVoy et al., 2011). While this historical account does not specifically mention *N. odorata*, the dense growth of *N. lutea ssp. advena* documented and photographed during the dry season indicates suitable hydro patterns in northern Taylor Slough for a deep water slough that rarely dries down. *N. lutea ssp. advena* occupies a similar depth zone to *N. odorata* in Lake Tohopekaliga (Welch, 2004). While there is only limited scientific evidence available, it seems reasonable to assume a ridge and slough environment existed within (at least) portions of Taylor Slough during pre-drainage conditions.

Stober’s et al. (2001) quantitative analysis of plant associations across the Everglades identified a deep-water community that was characterized by *N. odorata* but also included species of bladderwort, *E. elongata* and *P. hemitomon*. Stober et al. (2001) identified many sites within ENP as “slough” plant communities, but only one of those sites contained *N. odorata*. This is consistent with surveys by Davis (1943), Gunderson (1994), and Olmsted and Armentano (1997). Stober et al. (2001) found that *N. odorata* was more common in Loxahatchee NWR, WCA-2 and WCA-3. Paleoenvironmental seed examination and peat core samples indicate that NESS slough vegetation communities were historically dominated by *N. odorata* prior to the implementation of the C&SF Project’s water management and control structures (Saunders et al., 2007). A recent investigation conducted in the modern day “ridge and slough” topography of WCA-3A, WCA-3B, and Shark River Slough found that *N. odorata*, once “the dominant species in sloughs”, are overall, no longer abundant in many of the sloughs sampled (Richards et al., 2009). The physical patterning of the ridge and slough topography has been significantly degraded compared to historical conditions with only a 0.33 ft (10 cm) average ground elevation difference between ridges and sloughs sampled within WCA-3A, WCA-3B, and Shark River Slough (Richards et al., 2009). The central portion of many sloughs, once a *N. odorata*-dominated community, now contain species more characteristic of transitional ridge and slough species such as *E. cellulosa* (Richards et al., 2009). Hydro patterns (i.e., water depth) reported in modern day “sloughs” also provide evidence that that conditions within some modern day “sloughs” in WCA-3A, WCA-3B, and Shark River Slough have become more suitable for transitional species to invade the central portions of many sloughs (Richards et al., 2009). While distinct physiochemical and species composition differences exist in ridges and sloughs today, shifts in species composition and physical degradation of the ridge and slough habitat indicate that core ecological functions and processes in sloughs have degraded over time (Richards et al., 2009).

A review of the scientific literature and reports on species that are present in a native Everglades slough vegetation community was conducted. Eventually two indicator species (*N. odorata*, and *E. elongata*) were selected as representative indicators of the pre-drainage Everglades slough vegetation community. Hydro pattern evidence gathered for the slough vegetation indicator species and plant communities (as well as some general references to “sloughs” and other species initially evaluated as

potential indicators) from the scientific literature, reports and personal observations, field studies, mesocosm experiments, and other empirical evidence are summarized in Table 2.

Table 2. Summary of studies providing scientific evidence that define hydrological conditions for slough vegetation.

* - Used Depth classes

** - Range of Inundation Frequency

*** - Used Hydroperiod classes

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
<i>N. odorata</i>		Seed and flower production highest at the 2.5 ft (75 cm) depth as compared to the 1.48 ft (45 cm) and 0.49 ft (15 cm) depths. Fruit mass approximately twice as high in the 2.5 ft (75 cm) depth treatment as compared to the 0.49 ft (15 cm) treatment. Flower production approximately 60% greater in the 2.5 ft (75 cm) depth treatment as compared to the 0.49 ft (15 cm) treatment.			Saunders et al., 2008	Mesocosm study at Florida International University (FIU), FL
<i>N. odorata</i>		Higher total leaf biomass and lamina/petiole weight at the 2.5 ft (75 cm) and 1.48 ft (45 cm) depths as compared to 0.49 ft (15 cm) depth. Larger leaves with increasing water depth treatments at the 0.49 ft (15 cm),	Plants with exposed shoot tips did not flower and had miniaturized leaves. Rapid reduction in leaf production during 0 ft (0 cm) dry out. When rewetted from		Richards et al., 2009	Mesocosm study at FIU, FL

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
		1.48 ft (45 cm), and 2.5 ft (75 cm) depths respectively.	0 cm to 0.7 ft (20 cm), plants increased leaf production, formed larger leaves and began flowering. Effects of dry out (to 0 ft (0 cm) to leaf and root biomass were still noted 4 months after rewetting to 0.7 ft (20 cm).			
<i>N. odorata</i>		Average annual mean inundation depth 1.8 ft +/- 0.7 (54 cm +/- 21)		Average annual (discontinuous) range 63-100%**	David, 1996	WCA-3A, FL
Plant community dominated (relative biomass and relative density) by <i>N. odorata</i> and <i>N. lutea ssp. advena</i> but associated with grasses and submersed aquatics including <i>Utricularia spp.</i>		Dominated the plant community at depths > 3.6 ft (110 cm) but occurred in depths ranging from 0.7 – 6.0 ft (20 – 180 cm)			Welch, 2004	Lake Tohopekaliga, FL
Slough community dominated (biomass) by <i>N. odorata</i>	Average annual discontinuous hydroperiod 348 (10 years)	Maximum wet season depth 3.5 ft (107 cm)	4 dry out events (42-day average duration of dry out event) in 10 yrs	Average annual discontinuous 95% (10 years); ranging from 83-100%**	Goodrick, 1984	WCA-3A, FL
<i>N. odorata</i>		Ranging from 0.8 – 3.3 ft (25-100 cm)			Conti and Gunther, 1984	Okefenokee Swamp, GA
Plant community dominated by <i>Najas flexilis</i> and <i>N. odorata</i>		Dominant (relative frequency and relative density) in the 0 – 1.5 ft (0 cm – 46.0 cm)			WI DNR, 2004	Mission Lake, WI

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
		zone* but was present in zones ranging from 0 ft to 5.0 ft (0 cm – 152 cm)*				
Open water community dominated (abundance) by <i>N. odorata</i>		Average annual depth during ponded conditions: 4.92 ft +/-0.66 ft (150 cm +/-20.1)		Hydroperiod Index of 3.8+-0.1 (index definitions 4.0 = continuously ponded; 3.0 = dry out in late summer or early autumn (August – October))***	De Steven and Toner, 2004	Upper Coastal Plain, SC
<i>N. odorata</i>		Dominated the plant community (relative frequency and relative density) in the 0-1.5*ft (0-45.7 cm*) zone; maximum depth of 5 ft (152 cm)			Konkel, 2007	Firth Lake, WI
Open-marsh environment dominated by <i>N. odorata</i>		depths “commonly” ranging from 0.98 – 3.28 ft (30-100 cm)		near continuous	Cohen et al.,1984	Okefenokee Swamp, GA
<i>N. odorata</i> and <i>Utricularia spp.</i>	196-252 day continuous hydroperiod during the period March 1–December 31*** Note: hydroperiod classes based on 3 rd quartile of the plant’s hydroperiod frequency distribution			64% - 82% continuous inundation during the period 1 March 1–December 31***	Mitchell, 2005	Pools in the Pawcatuck River Watershed, RI
Deep slough containing <i>Nymphoides aquatica</i> , <i>N.</i>		Average annual water depths ranging from approximately			Powers, 2005	WCA-3A, FL

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
<i>odorata</i> , and <i>Utricularia spp.</i>		1.0 - 3.5 ft (30.5 - 107 cm) Maximum depth \geq 2.91 ft (90 cm)				
Aquatic slough community containing <i>N. odorata</i> , <i>Utricularia spp.</i> , <i>E. elongata</i> , and <i>Bacopa caroliniana</i>				Aquatic slough average annual 93% <i>Ranges for aquatic slough species:</i> <i>N. odorata</i> – 60-94%** <i>Utricularia spp.</i> – 52-94%** <i>E. elongata</i> – 80-94%** <i>B. caroliniana</i> – 50-94%**	Zaffke, 1983	WCA-3A, FL
<i>E. elongata</i> slough (also containing <i>Eleocharis geniculata</i> , <i>N. odorata</i> , <i>Utricularia spp.</i> , and <i>Hymenocallis</i>)		Average annual water depth ranging from approximately 0.8 - 2.9 ft (24.4 to 88.4 cm)			Powers, 2005	WCA-3A, FL
<i>Utricularia spp.</i>		Average annual mean inundation depth 1.2 ft +/- 0.7 (37 cm +/- 22)		Average annual (discontinuous) range 48-100%**	David, 1996	WCA-3A, FL
Shallow slough mainly containing <i>Utricularia spp.</i> but also may include <i>Panicum hemitomon</i> , <i>Paspalidium geminatum</i> , <i>N. odorata</i> , and <i>N. aquatica</i>		Average annual water depth ranging from approximately 1.4 – 2.6 ft (42.7- 79.2 cm)			Powers, 2005	WCA-3A, FL

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
<i>E. elongata</i>		Growth and morphology shifts in response to water depth; plants in the 2.5 ft (75 cm) treatment produce more submerged photosynthetic shoots while plants in the 0.49 ft (15 cm) treatment produce more emergent shoots. Biomass greater at the 0.49 ft (15 cm) depth treatment as compared to the 1.48 ft (45 cm) and 2.5 ft (75 cm) treatments.	Number of plants with submerged shoots decreased in both the 2 month and 4 month dry out treatments (0 cm) while the number of plants with emergent shoots increased. Increased number of shoot tufts in 4 month dry out conditions in plants mainly with emergent shoots.		Richards et al., 2009	Mesocosm study at FIU, FL
<i>E. elongata</i>		Average annual mean inundation depth 2.3 ft +_ 0.4 (71 cm +/- 11)		Average annual (discontinuous) range 100%	David, 1996	WCA-3A, FL
Plant community dominated (biomass) by <i>N. odorata</i> and <i>E. elongata</i>	Average annual discontinuous hydroperiod 360	Max wet season depth = 4.2 ft (128 cm)	1 (48 day) dry out event in 10 yrs	Average annual discontinuous hydroperiod 99% (10 years); ranging from 87-100%**	Goodrick, 1984	WCA-2A, FL
Plant community containing <i>N. odorata</i> and <i>Utricularia spp.</i>	Average annual hydroperiod class 330-365***	Average annual depth class 1.0 – 2.0 ft (30.5-61.0 cm) Average annual wet season depth 3.1 ft (94.5 cm)		90-100%***	Stober et al., 2001	Greater Everglades, FL
Slough plant community containing <i>E. cellulosa</i> , <i>U. purpurea</i> , <i>N. odorata</i> , and <i>N. aquatica</i>	Average annual 355.3+-2.1	Mean annual water depth 1.48 ft +- 0.0525 (45.0 +-1.6 cm) but occurred over depths ranging from 0.820 –	6 dry out periods over a 6 year hydrologic record	97+-0.60%	Richards et al., 2009	WCA-3A, WCA-3B, and Shark River Slough (ENP), FL

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
		2.33ft (25-71 cm) <i>N. odorata</i> and <i>U. purpurea</i> occurring at the highest frequencies in the 1.25 – 2.20 ft (38-67 cm) depth range.				
Flooded slough (open water) plant community dominated (community composition) by <i>N. odorata</i> , <i>Utricularia spp.</i> , and periphyton Emergent slough plant community “often” dominated (community composition) by <i>Eleocharis spp.</i>		<u>Flooded slough:</u> <i>Central WCA-3A</i> – average annual water depth 1.82+- 0.0394 ft (55.6 +- 1.2 cm); minimum water depth 0.528 ft +- 0.0427 ft (16.1+- 1.3 cm); maximum water depth 3.04+- 0.0459 ft (92.6+- 1.4 cm) <i>Southern WCA-3A</i> - average annual water depth 2.57+- 0.0623 (78.4+- 1.9 cm); minimum water depth 1.18+- 0.0525 ft (36.0+- 1.6); maximum water depth 3.75+- 0.0656 ft (114.3+- 2.0 cm) <u>Emergent slough:</u> <i>Central WCA-3A</i> - average annual water depth 1.78+- 0.0591 ft (54.2+- 1.8 cm); minimum water depth 0.489+- 0.0623 ft (14.9+- 1.9 cm); maximum water depth 2.98+- 0.0722 ft (90.9+-		Average annual hydroperiod: <u>Flooded slough:</u> <i>Central WCA-3A</i> : 364+-0.2 (99.7+- 0.055%) <i>Southern WCA-3A</i> : 365+-0.1 (100+-0.028%) <u>Emergent slough:</u> <i>Central WCA-3A</i> : 363+-0.5 (99.5+-0.14%) <i>Southern WCA-3A</i> : 365+-0.1 (100+-0.028%)	Givnish et al., 2008	WCA-3A, FL

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
		2.2 cm) <i>Southern WCA-3A</i> - average annual water depth 2.65+-0.0591 (80.9+-1.8 cm); minimum water depth 1.21+-0.0427 (36.9+-1.3 cm); maximum water depth 3.76+-0.0623ft (114.7+-1.9 cm)				
Flooded slough (open water) plant community dominated (community composition) by <i>N. odorata</i> , <i>Utricularia spp.</i> , and periphyton Emergent slough plant community “often” dominated (community composition) by <i>Eleocharis spp.</i>		<u>Flooded slough:</u> <i>Southern WCA-3B</i> - average annual water depth 1.69+-0.0427 ft (51.6+-1.3 cm); minimum water depth 0.518+-0.0427 ft (15.8+-1.3 cm); maximum water depth 2.67+-0.0525 (81.3+-1.6 cm) <u>Emergent slough:</u> <i>Southern WCA-3B</i> - average annual water depth 1.65+-0.0558 ft (50.3+-1.87 cm); minimum water depth 0.531+-0.0623 ft (16.2+-1.9 cm); maximum water depth 2.62+-0.0656 ft (79.8+-2.0 cm)		Average annual hydroperiod <u>Flooded slough:</u> <i>Southern WCA-3B</i> : 359+-1.3 (98+-0.36%) <u>Emergent slough:</u> <i>Southern WCA-3B</i> : 357+-2.1 (98+-0.58%)	Givnish et al., 2008	WCA-3B, FL
Pre-drainage sloughs (1800s – prior to 1880)		Average Annual Low: 1 ft (30.5 cm) Average Annual		100%	McVoy et al., 2011	Pre-drainage Everglades, FL

Species/Plant Community	Hydroperiod Annual (days) unless noted otherwise	Depth	Dry Out/Down Tolerance	Hydroperiod Multi-year (%) or (days)	Reference	Location
		High: 3 ft (91.4 cm)				

Compilation of the scientific evidence indicates that slough vegetation communities containing *N. odorata* and *E. elongata* are characterized by an annual average discontinuous hydroperiod (expressed as an average annual %) of 90% or higher that can range from approximately 60% - 100% (continuous inundation) (Richards et al., 2009; Givnish et al., 2008; Stober et al., 2001; David, 1996; Goodrick, 1984; Zaffke, 1983). *Utricularia spp.*(i.e., *Utricularia purpurea*) associates in Everglades sloughs are more commonly found in wet and marl prairies and are thought to be more drought tolerant (Stober et al., 2001). For this reason, *N. odorata* and *E. elongata* were considered more representative indicators of slough habitats that are an important component of the Everglades vegetation mosaic landscape. During mesocosm experiments, dry outs to ground surface induced a rapid physiological response in *N. odorata* characterized by reduced leaf production, cessation of flowering, and miniaturized leaves in emergent portions of the plants (Richards et al., 2009); this further supports scientific evidence indicating that near continuous inundation provides suitable conditions for slough vegetation. Thus, while it is clear that *N. odorata* can tolerate some dry out conditions to 0 ft (0 cm), the 0.7 ft (20 cm) depth provides more suitable conditions for leaf growth and flower production (Richards et al., 2009). Based on the compilation of the empirical evidence, near continuous hydroperiod will provide suitable conditions for both *N. odorata* and *E. elongata*.

Continuous Hydroperiod Metric

The Slough Vegetation Performance Measure includes a metric to calculate the annual continuous hydroperiod throughout the period of record at applicable ridge and slough IRs. SFWMM output was reviewed for continuous days (hydroperiod) that the water elevation was above ground surface in ridge and slough Everglades IRs for NSM. The results from NSM Cell C25_R21, located near the NE2 gauge in Northeast Shark Slough (IR 129) closely matched the scientific evidence defining suitable hydroperiod conditions for the slough vegetation indicator species *N. odorata* and *E. elongata*. The PMtarget curve ranges during the driest of years (approximately 1 in 30 years) from an approximate 160-day annual hydroperiod to a 365-day annual hydroperiod in average to wet years (Figure 3). Thus, our performance measure target closely matches the empirical evidence that near continuous hydroperiods provide suitable conditions for both *N. odorata* and *E. elongata*.

Continuous Dry Down Events Metric

The frequency of continuous dry down events (to 0.7 ft (20 cm)) is another metric that can be used to evaluate suitable hydrological conditions for slough vegetation. A mesocosm study clearly documented the consequences of exposing *N. odorata* to dry out conditions (to the ground surface); these physiological effects started to improve after fourth months of rewetting the plants to a depth of 0.7 ft (20 cm) (Richards et al., 2009). In contrast, *E. elongata* mesocosm studies revealed that *E. elongata* has varying responses to dry out conditions depending on the morphological adaptations of

the plant to local hydroperiod conditions (Richards et al., 2009). The number of *E. elongata* plants adapted to deeper water conditions (with more submerged shoots) decreased in both the 2-month and 4-month mesocosm dry out treatments (to 0 ft (0 cm)) while the number of *E. elongata* plants adapted to shallower conditions (with more emergent shoots) increased (Richards et al., 2009). The number of shoot tufts in 4-month dry out mesocosm treatments increased in plants mainly with emergent shoots (Richards et al., 2009). Richards et al. (2009) reported 6 dry down events over a 6-year hydrologic record for the slough plant community containing *E. cellulosa*, *U. purpurea*, *N. odorata*, and *N. aquatica* in WCA-3A, WCA-3B, and ENP. Goodrick (1984) noted only one 48-day dry out in 10 years in a plant community dominated (biomass) by *N. odorata* and *E. elongata* in WCA-2A. A plant community dominated (biomass) by *N. odorata* had only 4 dry out events (of an average duration of 42 days) in 10 years in WCA-3A (Goodrick, 1984). While the mesocosm experiments indicated *E. elongata* can respond favorably to dry out conditions (to ground surface) when dominated by emergent shoots, the field evidence indicates this species occurs in areas with few dry out events (Goodrick, 1984). While this may seem contradictory, one plausible explanation is that *E. elongata* can proliferate during dry out conditions (to ground surface) in the absence of competition but it may be outcompeted by other species in frequent dry out (to ground surface) field conditions (Richards, personal communication). The Slough Vegetation Performance Measure includes a metric to calculate the number of continuous dry down events with water depths less than 0.7 ft (20 cm) throughout the period of record at applicable ridge and slough IRs. Based on the scientific evidence, suitable conditions for our slough vegetation indicator species will be to minimize dry down events below 0.7 ft (20 cm), the critical depth threshold defined in the mesocosm experiments for *N. odorata* (Richards et al., 2009).

SFWMM frequency curves were reviewed for continuous dry down events at or below 0.7 ft (20 cm) in ridge and slough Everglades IRs for NSM. The results from NSM Cell C25_R21 in IR 129 best fit the scientific evidence defining the frequency of dry down events. The PMtarget ranges from approximately 174 days of continuous dry down below 0.7 ft (20 cm) in the driest year (approximately 1 in 30 years) to approximately zero dry down events (below 0.7 ft) in the average to wettest years (Figure 4). Because the NSM at Cell C25_R21 closely matched the scientific evidence to minimize dry down events below 0.7 ft (20 cm), a dry down frequency curve from this location is the target for this metric.

Water Depths (Dry and Wet Season) Metrics

Based on the scientific evidence, water depths are additional metrics that can be used to evaluate suitable hydrological conditions for slough vegetation. During experimental mesocosm studies of *N. odorata*, significantly larger leaves and higher petiole weight and lamina weight were observed at the 2.5 ft (75 cm) depth as compared to the 1.48 ft (45 cm) and 0.49 ft (15 cm) depths; higher total leaf biomass was reported at the 2.5 ft (75 cm) and 1.48 ft (45 cm) depths as compared to 0.49 ft (15 cm) depth (Richards et al., 2009). Flower production was approximately 60% higher in the 2.5 ft (75 cm) depth treatment as compared to the 0.49 ft (15 cm) treatment for *N. odorata* in mesocosm experiments (Saunders et al., 2008). *E. elongata* adapts to fluctuating water depths by producing more photosynthetic shoots in deeper water while producing more emergent shoots in shallower water (Richards et al., 2009). During experimental mesocosm studies, *E. elongata* had significantly higher biomass at the shallowest depth examined 0.49 ft (15 cm) as compared to the deeper depths of 1.48 ft (45 cm) and 2.5 ft (75 cm). However, *E. elongata* also exhibited a prolific growth of submergent

shoots in the deep water mesocosm treatments (Richards et al., 2009). Thus, *E. elongata* grows and physiologically adapts to both shallow and deeper water depths as evidenced in the mesocosm experiments (Richards et al., 2009). Field evidence indicates *E. elongata* sloughs are dominant plant communities at average annual water depths ranging from approximately 0.8 ft to 2.9 ft in WCA-3A (Powers, 2005). The field evidence from WCA-3A (Powers, 2005) reflects *E. elongata*'s ability to respond to large fluxes in water depth conditions. Field studies on Everglades plant communities containing *N. odorata* and/or *E. elongata*, reported maximum water depths ranging from approximately 2.91 - 6.0 ft (88.1-183 cm) (Givnish et al., 2008; Konkel, 2007; Welch, 2004; Powers, 2005; Goodrick, 1984) and average annual water depths ranging from approximately 0.8 – 3.5 ft (24.4 – 107 cm) (Richards et al., 2009; Givnish et al., 2008; Stober et al., 2008; Powers, 2005). Givnish et al. (2008) reported minimum water depths of plant communities dominated (community composition) by *N. odorata* and *E. elongata* to range from 0.489+- 0.0623 ft (14.9+- 1.9 cm) to 1.21+- 0.0427 (36.9+- 1.3 cm). In McVoy's et al. (2011) review of historical records of pre-drainage water depths, average annual high water depths in sloughs were estimated to be 3 ft (91.4 cm). Compilation of historical accounts indicates that the pre-drainage minimum depth for sloughs were approximately 1.0 ft (30.5 cm) (McVoy et al., 2011). While depth maxima and minima would be good indicators for slough vegetation suitability, the models perform better at simulating seasonal depth averages (Bras et al., 2005). The Slough Vegetation Performance Measure includes a wet season average depth metric and a dry season average depth metric to be calculated throughout the period of record at applicable ridge and slough IRs. Based on the majority of the available scientific evidence, suitable wet season average depths for our slough vegetation indicator species will range from approximately 2.0 ft (61.0 cm) to 3.0 ft (91.4 cm). A bit more interpretation was required to select the suitable dry season average depths for slough vegetation since much of the data is recorded as a minimum depth versus an average depth during the dry season. Thus, much of the field study data of minimum depth may be more reflective of a capacity of individual species to tolerate sub-optimal conditions versus an ability to exploit more suitable conditions.

SFWMM frequency curves were reviewed for wet season maximum and average depths and dry season average depths in the ridge and slough IRs for NSM. Mean wet season average depths of 3 ft (91.4 cm) were never reached in any of the CSOP project alternatives. However, in the preliminary evaluations using both simulated hydrology and gage readings, it was found that a maximum wet season depth of approximately 3 ft (91.4 cm) results in an average wet season depth of approximately 2.5 ft (76.2 cm). Because NSM Cell C25_R21 in IR 129 best represented the scientific evidence to achieve average depths of approximately 2.0 - 3.0 ft (61.0 – 91.4 cm) during the wet season and average depths of approximately 1.5 - 2.0 ft (45.7 – 61.0 cm) during the dry season, it is used as the target in other ridge and slough IRs.

3.0 Scientific Basis

3.1 Relationship to Conceptual Ecological Models

Slough vegetation is listed as an ecological attribute in the Everglades Ridge and Slough Conceptual Ecological Model (CEM) (Ogden, 2005). This performance measure represents an attempt to reconcile the working hypotheses for the hydrologic features that are indicative of a restored slough community with the inherent limitations of simulation models. The Everglades Ridge and Slough

Conceptual Ecological Model provides a conceptual description of how CERP implementation will lead to restoration of Everglades sloughs.

3.2 Relationship to Adaptive Assessment Hypothesis Clusters

This Performance Measure is based in part on the information derived from the Landscape Patterns of Ridge and Slough Peatlands and Adjacent Marl Prairies in Relation to Sheet Flow, Water Depth Patterns and Eutrophication Hypothesis Cluster. The working hypothesis from this cluster is: “The loss of elongated patterns of ridges, sloughs, and tree islands in the direction of water flow in the ridge and slough landscape of the Everglades is attributed to disrupted sheet flow and related changes in localized elevation patterns which have significant consequence on realized water depths at individual locations. Eutrophication and the spread of cattail further contribute to this loss. Spatial patterning and topographic relief of ridges and sloughs are directly related to the volume, timing and distribution of sheet flow and related water depth patterns, which drive processes of sediment accretion and loss. Resumption of sheet flow and related water depth patterns, in combination with maintenance or restoration of oligotrophic nutrient status, is very likely to slow and may possibly reverse the trend of degradation of the ridge, slough, and tree island landscape.”

4.0 Evaluation Application

4.1 Performance Measure Metrics

The four hydrologic metrics used to determine suitability for slough vegetation are:

1. continuous hydroperiod;
2. continuous dry down events below 0.7 ft (20 cm);
3. wet season average depth (June-October); and
4. dry season (November-May) average depth.

The evaluation protocol for each of these four metrics is described below. Model versions for the example alternatives used in the graphics below are: alt7r5e = SFWMM version 5.4.1.1; alt1 = SFWMM version 5.5; alt2 = SFWMM version 5.5.5; alt3 = SFWMM version 5.5.4; alt4COE = SFWMM version 5.5.6; alt5rimc = SFWMM version 5.5.6.1; and NSM version 4.6.2.

4.1.1 Continuous Hydroperiod

Metric: The metric is a “percent of target achieved relative to base conditions.” It is a measure of lift above the base conditions, and a measure of how closely the alternative realizes the target.

Target: The performance measure target is an empirical frequency curve that most closely matches suitable hydroperiod conditions for slough vegetation that have been obtained from scientific evidence, mainly from mesocosm experiments and the scientific literature. At present, the location in NSM v 4.6.2 that most closely matches suitable hydropattern conditions for slough vegetation is cell

C25_R21 in NESS. Therefore, the frequency curve of annual maximum continuous hydroperiod (days with depth ≥ 0.0 ft (0.0 cm) at NSM cell C25_R21 is used to provide a target which fully describes the inter-annual variability in hydroperiods. Figure 7 shows the target continuous hydroperiod frequency curve for slough vegetation.

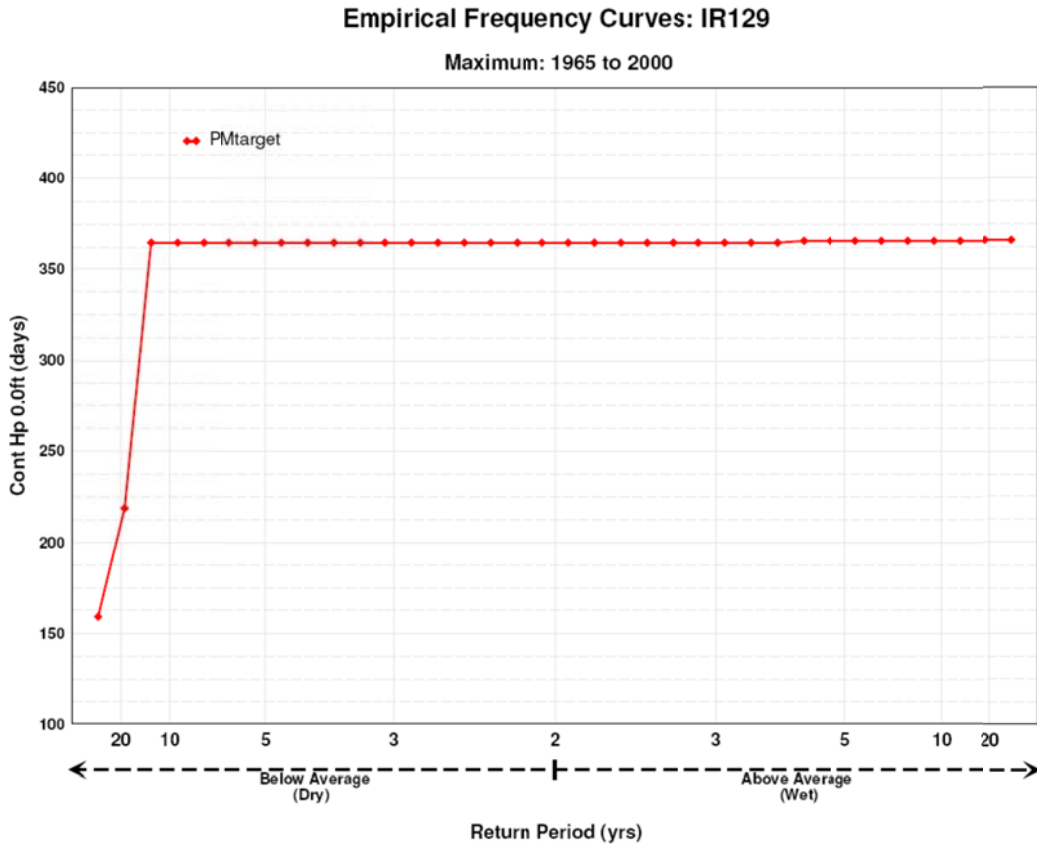


Figure 7. Target Hydroperiod Frequency Curve for Slough Vegetation. PMtarget is the empirical hydroperiod frequency curve for NSM v 4.6.2 at Cell C25_R21.

Evaluation protocol:

- 1) Plot return periods (years) of annual maximum continuous hydroperiod, as defined above, for the period of record (1965-2000) for each alternative at each IR.
- 2) Compute percent target achieved (%) for each year plotted on the frequency curve:

$$\text{IF } b \geq t \ \& \ z < t \quad \% = -100$$

$$\text{IF } z \geq t \quad \% = 100$$

Otherwise,

$$\%* = (((t-b)-(t-z))/(t-b))*100$$

Where:

z = alternative annual maximum continuous hydroperiod in days,

b = base condition annual maximum hydroperiod, and

t = target annual maximum continuous hydroperiod

*Note: if computed value for % > 100, % = 100; If computed value for % < -100, % = -100.

EXCEL pseudocode:

=MAX(-100,IF(Z>=T,100,IF(AND(B>=T,Z<T),-100,MIN((((T-B)-(T-Z))/(T-B))*100,100))))

- 3) The alternative's score for this metric at each IR is computed by averaging the percent of target achieved for all years. Figure 8 shows example alternative scores for the continuous hydroperiod metric.

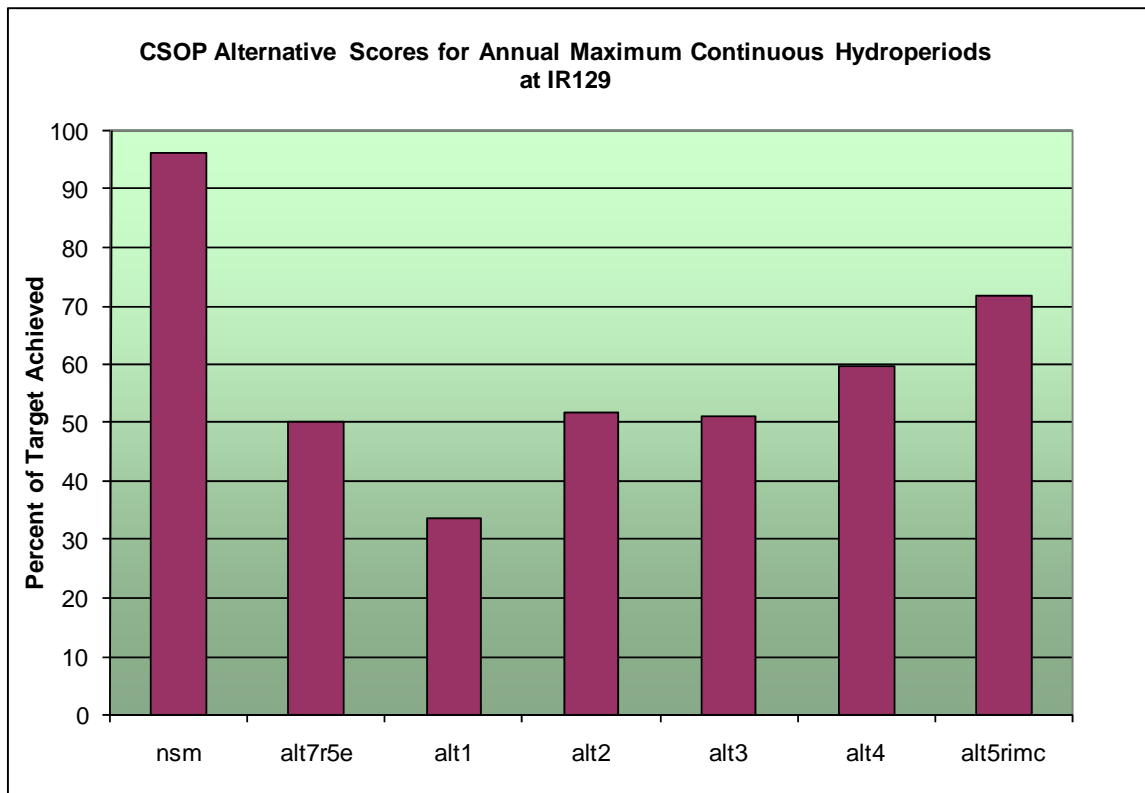


Figure 8. Example Alternative Scores for Continuous Hydroperiod at IR 129.

4.1.2 Continuous Dry Down Events

Metric: This metric is a “percent of target achieved relative to base conditions.” It is a measure of lift above the base conditions, and a measure of how closely the alternative realizes the target.

Target: The PMtarget is an empirical frequency curve that most closely matches suitable dry down conditions for slough vegetation that have been obtained from scientific evidence, mainly from mesocosm experiments and the scientific literature. At present, the location in NSM v 4.6.2 that most closely matches the suitable hydropatterns for slough vegetation is cell C25_R21 in NESS. Therefore, the frequency curve of annual maximum continuous dry down events below 0.7 ft (20 cm), at NSM Cell C25_R21, is used to provide a target which fully describes the inter-annual variability in dry downs. Figure 9 shows the target continuous dry down frequency curve for slough vegetation.

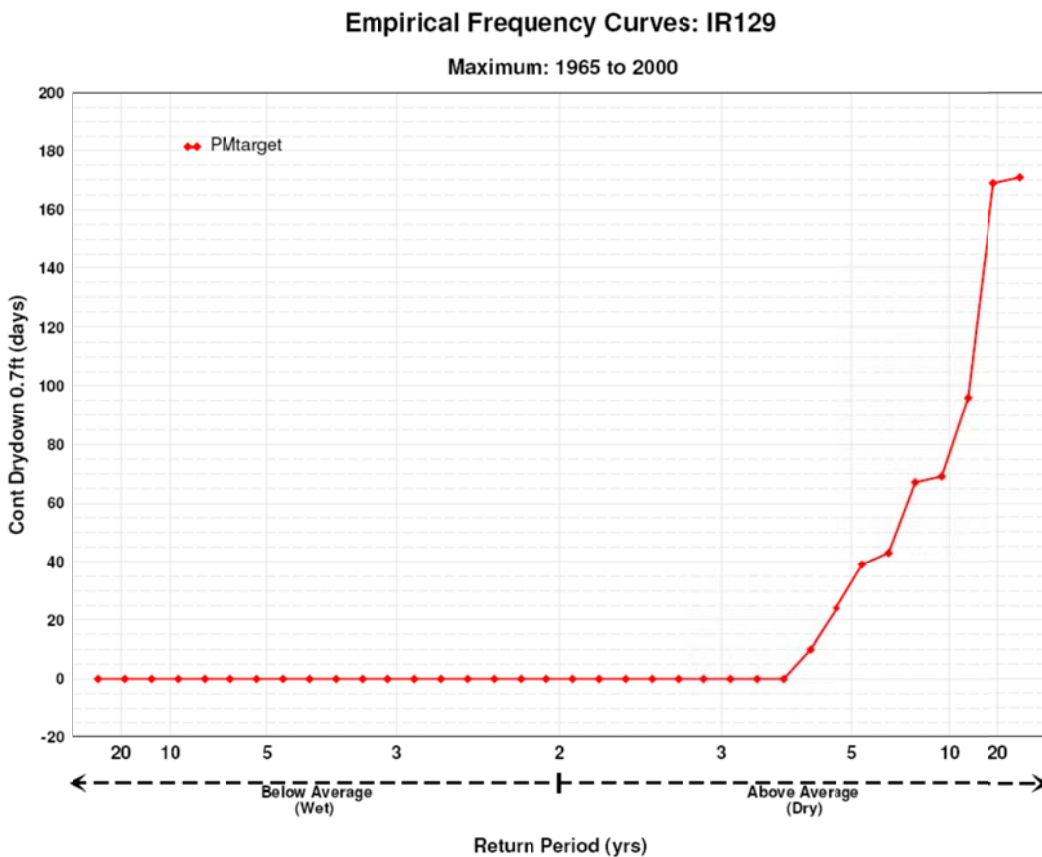


Figure 9. Target Dry Down Frequency Curve for Slough Vegetation. PMtarget is the empirical dry down 0.7 ft (20 cm) frequency curve for NSM v 4.6.2 at Cell C25_R21.

Evaluation protocol:

- 1) Plot return periods (years) of annual maximum dry down (dry down frequency curves), as defined above, for the period of record (1965-2000) for each alternative at each IR.

2) Compute percent of target achieved (%) for each year plotted on the frequency curve:

IF $b \leq t$ & $z > t$ % = -100

IF $z \leq t$ % = 100

Otherwise,

$$\% = \frac{((t-b)-(t-z))}{(t-b)} * 100$$

Where:

z = alternative maximum annual continuous dry down in days,

b = base condition annual maximum dry down in days, and

t = target annual maximum continuous dry down

*Note: if computed value for % > 100, % = 100; If computed value for % < -100, % = -100.

EXCEL pseudocode:

=MAX(-100,IF(Z<=T,100,IF(AND(B<=T,Z>T),-100,MIN((((T-B)-(T-Z))/(T-B))*100,100))))

3) The alternative's score for this metric at each IR is computed by averaging the percent of target achieved for all years. Figure 10 shows the example alternative scores for the continuous dry down metric.

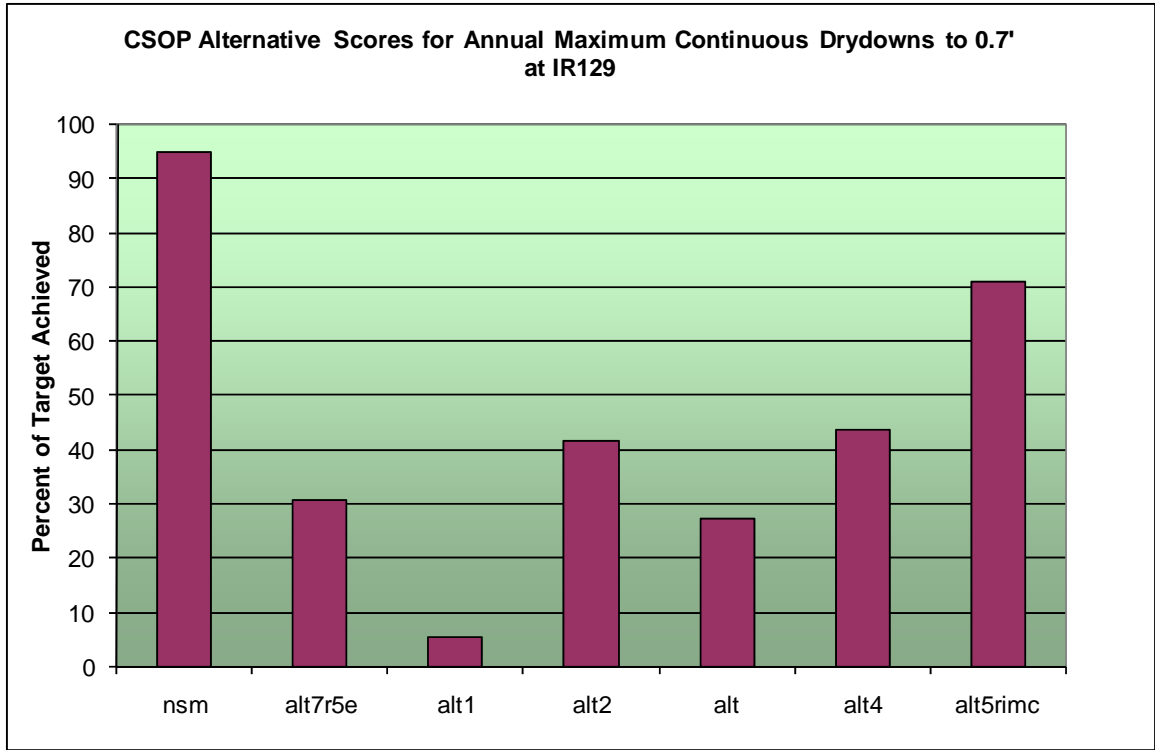


Figure 10. Example Alternative Scores for Continuous Dry Down to 0.7 ft (20 cm) at IR 129.

4.1.3 Wet Season Average Depth

Metric: This metric is a “percent of target achieved relative to base conditions.” It is a measure of lift above the base conditions, and a measure of how closely the alternative realizes the target.

Target: The PMtarget is an empirical frequency curve that most closely matches suitable wet season average depths for slough vegetation that have been obtained from empirical evidence, mainly from scientific experiments and the scientific literature. At present, the location in NSM v 4.6.2 that most closely matches the suitable conditions for slough vegetation is cell C25_R21 in NESS. Therefore, the frequency curve of wet season average depths at NSM Cell C25_R21 is used to provide a target which fully describes the inter-annual variability in water depths. Figure 11 shows the target wet season average depth frequency curve for slough vegetation.

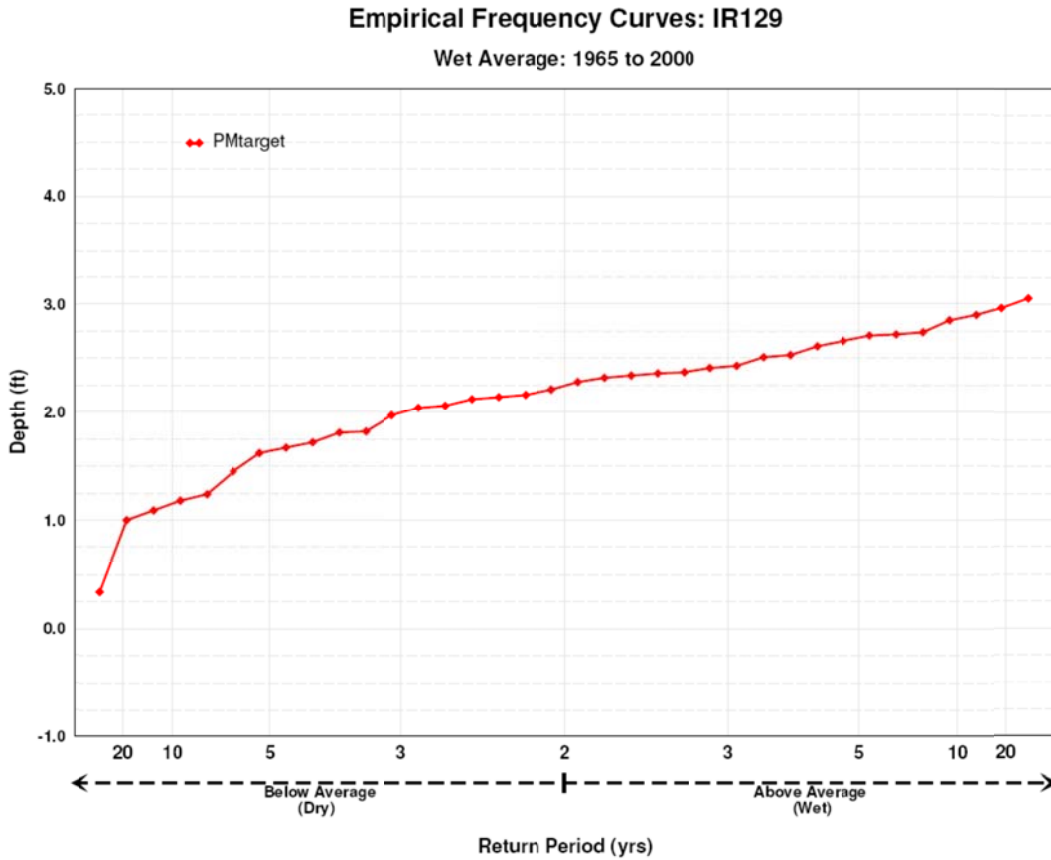


Figure 11. Target Wet Season Average Depth frequency curve for Slough Vegetation. The PMtarget is the empirical wet season average depth frequency curve for NSM v 4.6.2 at Cell C25_R21.

Evaluation Protocol:

- 1) Plot return periods (years) of wet season average depth (depth frequency curves) for the period of record (1965-2000) for each alternative at each IR.
- 2) Compute percent of target achieved (%) for each year plotted on the frequency curve:

IF $b \geq t$ & $z < t$ % = -100

IF $z \geq t$ % = 100

Otherwise,

$$\%* = \frac{((t-b)-(t-z))}{(t-b)} * 100$$

Where:

z = alternative mean wet season water depth,

t = target mean wet season water depth, and

b = base condition mean wet season water depth

*Note: if computed value for % > 100, % = 100; if computed value for % < -100, % = -100.

EXCEL pseudocode:

=MAX(-100,IF(Z>=T,100,IF(AND(B>=T,Z<T),-100,MIN((((T-B)-(T-Z))/(T-B))*100,100))))

- 3) The alternative's score for this metric at each IR is computed by averaging the percent of target achieved for all years. Figure 12 shows the example alternative scores for the wet season average depth metric.

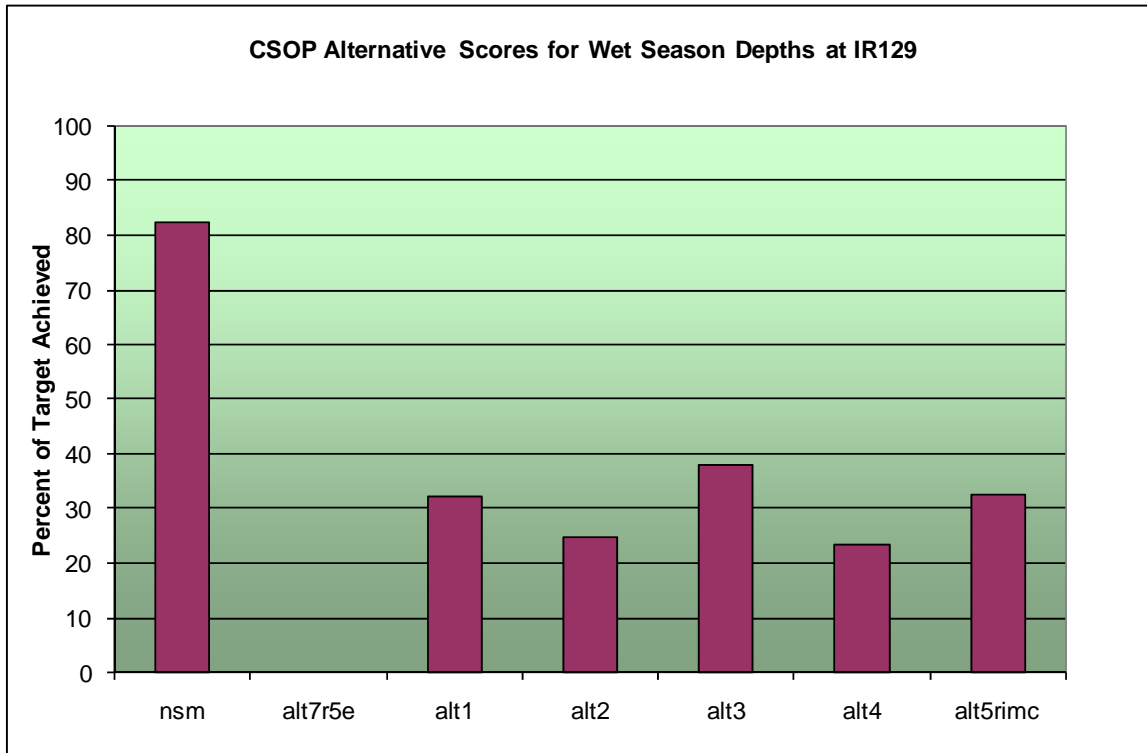


Figure 12. Example Alternative Scores for Wet Season Depths at IR 129.

4.1.4 Dry Season Average Depth

Metric: This metric is a “percent of target achieved relative to base conditions.” It is a measure of lift above the base conditions, and a measure of how closely the alternative realizes the target.

Target: The PMtarget is an empirical frequency curve that most closely matches suitable dry season average depths for slough vegetation that have been obtained from empirical evidence, mainly from

scientific experiments and the scientific literature. At present, the location in NSM v 4.6.2 that most closely matches the suitable hydropattern conditions for slough vegetation is cell C25_R21 in NESS. Therefore, the frequency curve of dry season average depths at NSM Cell C25_R21 is used to provide a target which fully describes the inter-annual variability in water depths. Figure 13 shows the target dry season average depth frequency curve for slough vegetation.

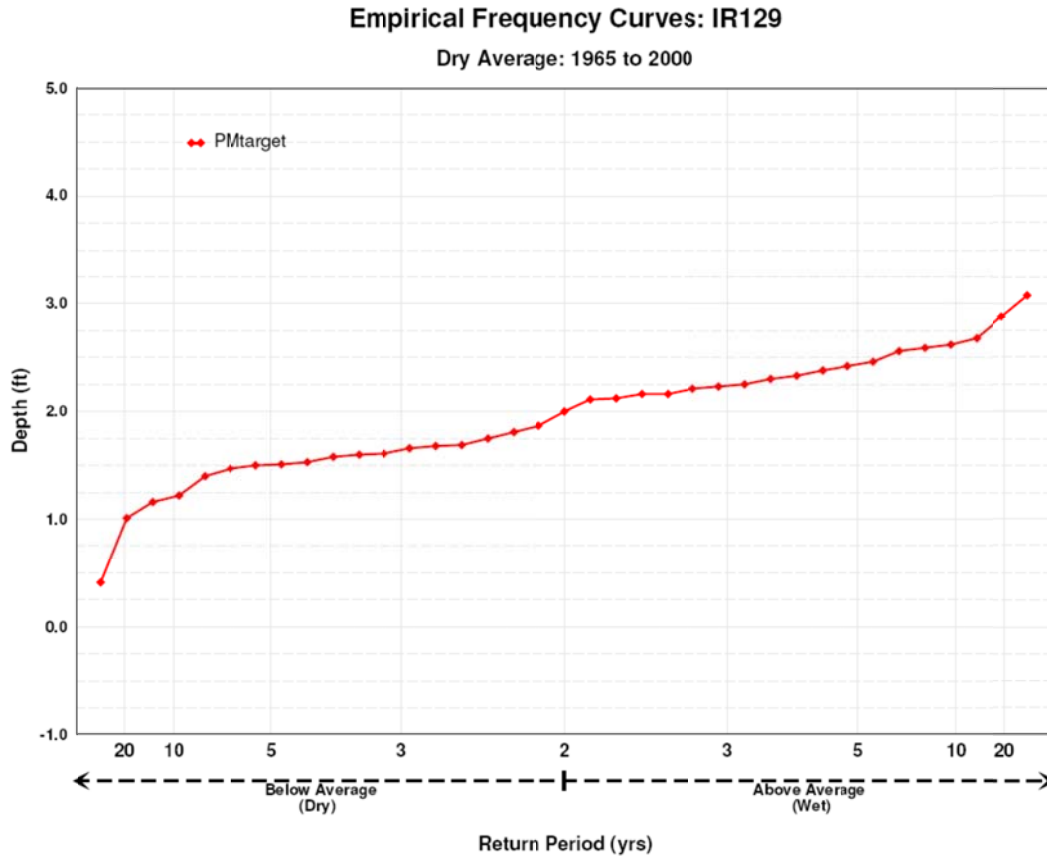


Figure 13. Target Dry Season Average Depth Frequency Curve for Slough Vegetation. The PMtarget is the empirical dry season average depth frequency curve for NSM v 4.6.2 at Cell C25_R21.

Evaluation Protocol:

- 1) Plot return periods (years) of dry season average depth (depth frequency curves) for the period of record (1965-2000) for each alternative at each IR.
- 2) Compute absolute percent of target achieved (%) for each year plotted on the frequency curve:

IF $b=t$ & $z \neq t$ % = -100

IF $z=t$ % = 100

Otherwise,

$$\%* = (((ABS(t-b)-ABS(t-z))/ABS(t-b))*100$$

Where:

z = alternative mean dry season water depth,

t = target mean dry season water depth, and

b = base condition mean dry season water depth

*Note: if computed value for % > 100, % = 100; if computed value for % < -100, % = -100.

EXCEL pseudocode:

```
=MAX(-100,IF(Z=T,100,IF(AND(B=T,Z<>T),-100,MIN(((ABS(T-B)-ABS(T-Z))/ABS(T-B))*100,100))))
```

- 3) The alternative's score for this metric at each IR is computed by averaging the percent of target achieved for all years. Figure 14 shows example alternative scores for the dry season average depth metric at IR 129.

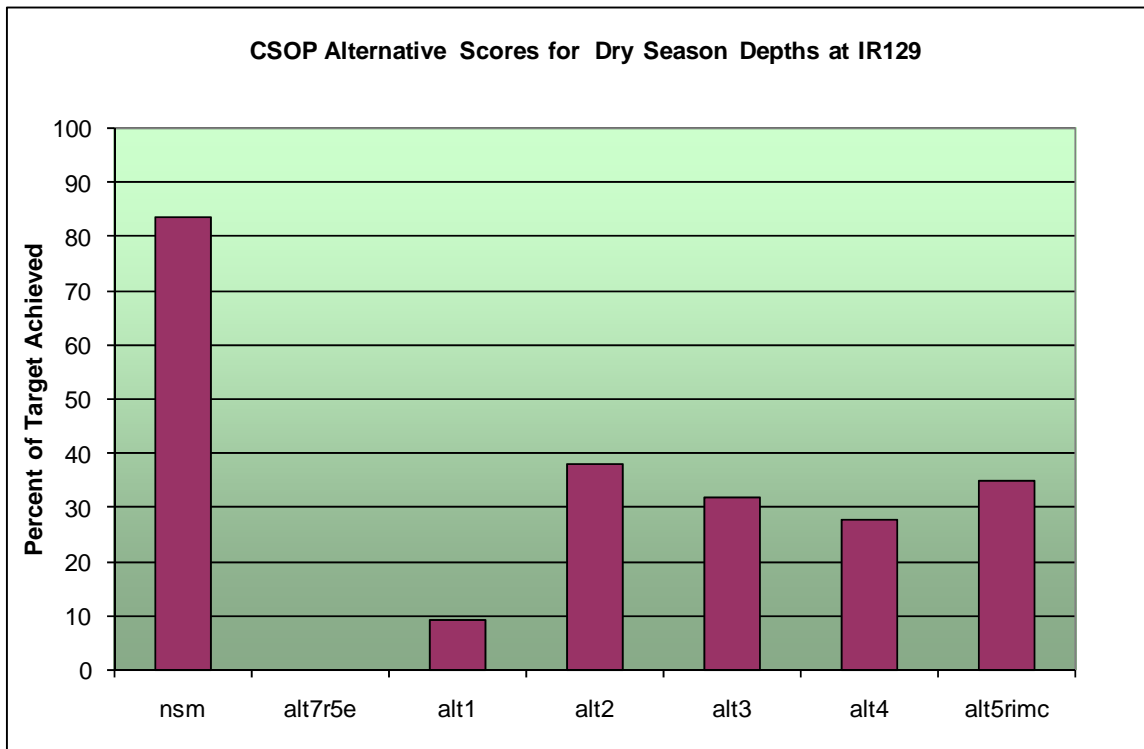


Figure 14. Example Alternative Scores for Dry Season Depths at IR 129.

4.1.5 Final Score at each Indicator Region

An alternative's score at each IR is computed by averaging the percent of target achieved from the 4 metrics that comprise the Slough Vegetation Performance Measure. Figure 15 shows example alternative scores for the four performance measure metrics combined.

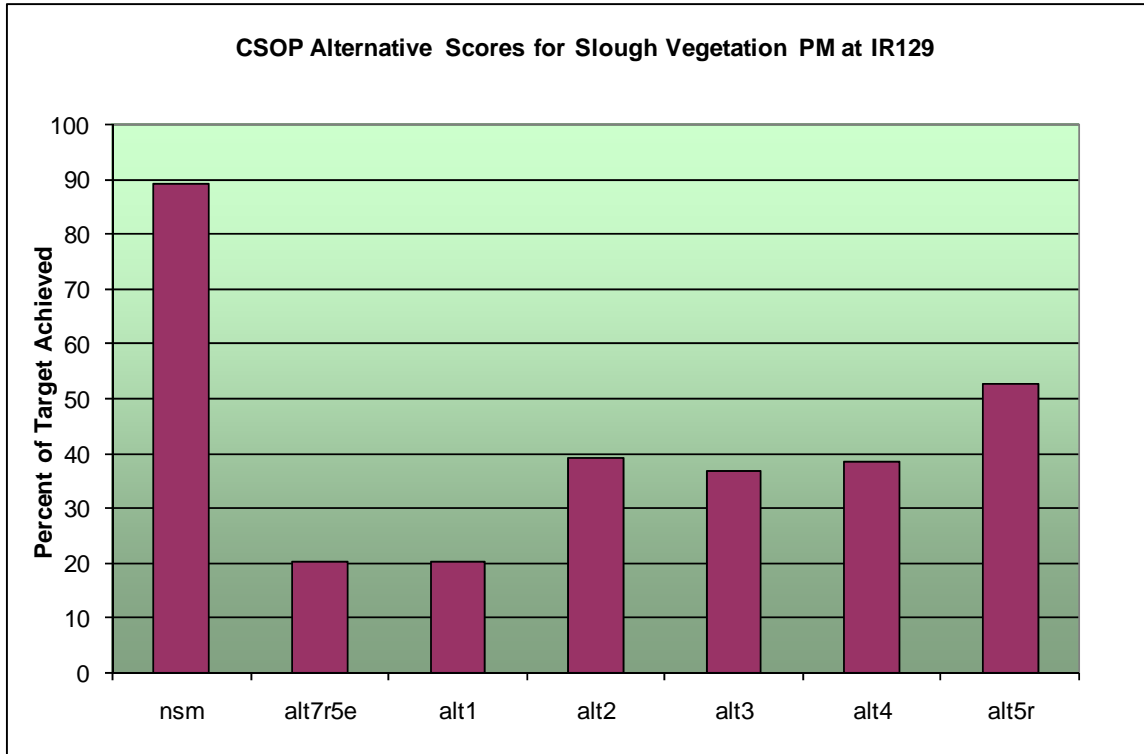


Figure 15. Example Alternative Scores for Slough Vegetation Performance Measure at IR 129.

4.2 Normalized Performance Output

The scores as shown above are scaled from -100 to 100.

The Slough Vegetation Performance Measure can be calculated with any model output that provides the hydroperiods, dry down frequencies, and water depths needed to calculate the individual metrics that comprise this performance measure. The Natural System Model (NSM v. 4.6.2), the South Florida Water Management Model (SFWMM), and the Regional Simulation Model (RSM) all provide the necessary hydrologic output.

Cell C25_R21 in the NSM v. 4.6.2 was used to develop the target frequency curves because this cell closely matches the scientific evidence defining suitable hydropatterns for slough vegetation. The NSM target frequency curves can be reevaluated as new evidence defining slough vegetation hydropattern suitability becomes available and/or improved versions of the NSM become available.

5.0 Uncertainty

Other Factors Influencing Vegetation Community

The specific hydrological requirements for a persistent Everglades slough vegetation community are not fully understood because of the limited scientific evidence from the pre-drainage era and the complexity of the processes that support and maintain slough vegetation. At present, paleo-environmental investigations, field studies, and controlled mesocosm experiments provide the best sources of information for understanding slough vegetation composition, distribution, and suitable hydropatterns.

Slough vegetation is assessed solely by hydrologic conditions with this performance measure. While hydropatterns such as water depth have been attributed as major factors driving Everglades slough vegetation community composition (Richards et al., 2009; Powers, 2005), other factors including water quality, fire patterns, disturbance, seed sources, soil, and meteorological conditions including climate change, also may affect vegetation community composition in the landscape. Because other factors besides hydropatterns are important in determining suitable conditions for slough vegetation, several key uncertainties which are hypothesized to influence the slough vegetation community are being systematically addressed in the context of the Monitoring and Assessment Program and other non-CERP funded research and monitoring projects (including the Long Term Ecological Research (LTER) program funded by the National Science Foundation).

Uncertainties Associated with Elevation

There is a level of error associated with the reference elevations at each survey site. The error analysis is documented in Donalson et al. (2006). Water elevations simulated from hydrologic models and postprocessing efforts are affected by various sources of uncertainty. Uncertainty is reduced, especially when model data are aggregated and when the focus is on general spatial patterns. However, the performance measures are useful for relative comparisons between different scenarios.

One critical issue affecting the ability to apply this performance measure in a meaningful fashion is our ability to effectively understand and control for variability in topographical patterns within each grid cell of a hydrologic simulation model. There are a range of elevations within any given region of the simulation models while a single elevation is chosen for defining hydropatterns in each cell of the simulation model. However, the goal of restoration is to sustain a vegetation mosaic, and therefore, variability of depths and hydroperiods within individual cells is desirable. This uncertainty is an implicit element of the “working hypothesis” statement defined by the Landscape Patterns of Ridge and Slough Peatlands and Adjacent Marl Prairies in Relation to Sheet Flow, Water Depth Patterns and Eutrophication Hypothesis Cluster (section 3.2 of this document), and is noted in the following passage of section 1.0 of this document:

“The dense sawgrass ridges were approximately 1.5 ft (46 cm) higher than the adjacent slough (Willoughby, 1898, Stewart, 1907; Baldwin and Hawker, 1915; Marchman, 1947; Clark et al. 2009; Lodge, 2005).”

Application of the Slough Vegetation Performance Measure

Application of this performance measure should be made with caution in several regions. Due to the limited available empirical evidence (McVoy et al., 2011; Willard et al., 2001), the dominant pre-drainage vegetation composition throughout Taylor Slough proves difficult to reconstruct. This performance measure can be used to assess relative changes in Taylor Slough; however, application of this performance measure in Taylor Slough (or parts of Taylor Slough) may need revision should additional evidence be provided in the future. Another region that requires mention is the impounded regions of the Everglades. The ultimate goals of impounded regions of the Everglades need to be evaluated in the context of existing management regulation schedules and with the recognition that key uncertainties about the role of relatively high velocity water pulse events in reestablishing ridge and slough landscapes remain to be resolved. These uncertainties do not appear to affect to application of dry season water depth, inundation duration, or dry down frequency targets for these areas.

6.0 Monitoring and Assessment Approach

6.1 MAP Module and Section

The following Greater Everglades Wetlands Module monitoring activities contributed to the development and application of this performance measure, and all are a part of the Sheetflow and Water Depth Patterns, Oligotrophic Nutrient Status and Landscape Patterns of Ridge and Slough Peatlands and Adjacent Marl Prairies in Relation to Sheet Flow, Water Depth Patterns and Eutrophication Hypothesis Clusters (see section 1.2 for MAP section numbers):

- *Landscape Pattern – Ridge, Slough and Tree Island Mosaic* (J. Heffernan, Florida International University, FY10 – present)
- *Mechanism of Ridge-Slough Maintenance and Degradation Across the Greater Everglades* (M. Cohen, T. Osborne, M. Clark, University of Florida FY07 – present)
- *Marl Prairie/Slough Gradients* (M. Ross and J. Sah, Florida International University, FY05 – present)
- *Everglades National Park/Big Cypress National Preserve Vegetation Mapping Project* (K. Rutchey, SFWMD, FY03 – FY09; K. Whelan, NPS – SFCN and T. Schall, USACE, FY10 – present)
- *Regional Distribution of Soil Nutrients - Hierarchical Soil Nutrient Mapping for Improved Ecosystem Change Detection* (M. Cohen, T. Osborne, S. Lamsal, M. Clark, University of Florida, FY07 – FY08)
- *South Florida Surface Water Monitoring Network for Support of MAP Projects (EDEN)* (P. Telis, USGS, FY05 – present)

6.2 Assessment Approach

The monitoring components and sampling design for this hypothesis cluster includes landscape monitoring and vegetation mapping. The attributes to be monitored long-term will be determined based on the results of initial field work and from cost-benefit analyses. The systematic implementation of the landscape sampling design across the ridge and slough

landscape and adjacent marl prairies began in 2008. The objective of the Vegetation Mapping monitoring component is to produce a spatially and thematically accurate baseline vegetation map of Everglades National Park and the Big Cypress National Preserve to be used in monitoring the spatial extent, pattern and proportion of plant communities within this region.

7.0 Future Tool Development Needed to Support Performance Measure

7.1 Evaluation Tools Needed

7.2 Assessment Tools Needed

8.0 Notes

This performance measure has been developed to assess the hydrologic suitability for slough vegetation within the estimated pre-drainage ridge and slough geographic regions and does not attempt to serve as a performance measure to assess all ecosystem parameters within the Everglades. Thus, this performance measure is meant to be used in concert with other performance measures to ensure an ecosystem-wide perspective is provided for project evaluations.

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Appendix 1

Slough Vegetation Performance Measure Depth Targets in Relation to Model Scale

Perhaps the most common comment about using performance measure depth targets with model output is that the ground surface elevation of a model cell represents an average elevation over a large area, and this average value masks the range of depths and variability in vegetation types within a model cell or indicator region. In areas of ridge and slough, the low areas will be slough, while the “high” areas will generally be sawgrass ridges, emergent marsh or tree islands. In the pre-drainage Everglades, the ridges were approximately 1.5 feet higher than the neighboring sloughs, and tree islands at greater than 1.5 feet above the slough were scattered throughout the landscape (Lodge, 2005)(References can be found in the Slough Vegetation Performance Measure Documentation Sheet). Performance measure depth targets for a specific vegetation type need to consider model scale in order to achieve the desired depths at a sub-cell level. Today, however, reduced flow and soil oxidation have resulted in a loss of topographic variability in areas of organic soils, and therefore model scale issues are reduced.

As part of the Everglades Depth Estimation Network project (EDEN), the average elevations of both the major and secondary vegetation types were estimated in the vicinity of approximately 130 gages throughout the Greater Everglades⁴. The notes at the end of this document describe how the data were collected. Approximately 50 of these gages are located in ridge and slough or degraded slough areas. Table A-1 shows the average elevation differences between the major and secondary vegetation types, as measured by the EDEN project, at the 50 gage sites most representative of ridge and slough. For areas where only one vegetation type was found, the difference between the minimum and maximum observed elevation was used in the table.

Table A-1 shows that in the Everglades wetlands today the difference in elevation between the average ground surface elevation in the slough (or local low point) and the average ground surface over a larger area, including ridges, typically is only on the order of 0.10 to 0.20 feet. Therefore, the depth targets for slough should be reduced by 0.10 to 0.20 feet when using the average elevation over a larger area. If a tree island of significant size is present in the cell or indicator region, and the elevation of the tree island was included in the average cell elevation, then the difference in elevation between the slough and the mean cell elevation would be greater than 0.20 feet. However, tree islands were intentionally excluded from the surveys used to develop the elevation data sets for most of the models, including the SFWMM and the RSM. For a tree island performance measure, mapped tree island elevations must be overlaid on the model cell elevations to determine depths at tree islands.

Based on research findings, the desired typical wet season *maximum* (short duration) depth in the slough is approximately 3.0 feet (Powers, 2005). In dry years 3.0 feet will not be reached, while in wet years 3.0 feet will be exceeded (See the Slough Vegetation Performance Measure Documentation Sheet for details on how targets were developed). For the Slough Vegetation Performance Measure, the average year *mean* wet season depth target is approximately 2.25 feet. In most years the target mean wet season depths falls between 2.0 and 3.25 feet. The mean wet season depth is the average depth for the June through October period. Figure A-1, frequency curves of wet season maximum and mean depths, illustrates that, based on modeling, a mean wet season depth of 2.25 feet translates into a wet season maximum depth of approximately 2.75 feet(In other words, the maximum depth achieved

⁴ A map of the EDEN gauges is available on the EDEN website at <http://sofia.usgs.gov/eden/>

will be approximately 0.5 feet above the seasonal average depth). Note that the average year has a return period of 2 years, which falls at the center of the x-axis. Therefore, with a mean wet season depth of 2.25 feet, we should see short duration depths approaching 3.0 feet in the slough, and 2.75 feet average over an indicator region.

The desired dry season or minimum depths are not as well defined as the other performance measure metrics for slough vegetation. Research indicates that significant stress to slough vegetation occurs at depths of less than approximately 0.7 feet (Richards, 2007). Although some of the dominant slough vegetation species do not require a period of dry-down, a seasonal dry-down to shallow depths is a defining characteristic of the Everglades, and therefore dry season depths are included as a metric with the slough vegetation performance measure. A dry-down to shallow depths is beneficial to some emergent slough species (The Slough Vegetation Performance Measure Documentation Sheet has a list of references with detailed information on the water depth requirements for slough vegetation). As seen in Figure A-2, based on modeling, generally the minimum annual depth will be approximately 0.5 to 1.0 feet less than the dry season average depth. For a typical (2 year) event, the performance measure *mean* dry season depth target of 2.0 feet translates into a dry season short duration minimum depth of 1.3 feet. Dry years will fall significantly short of 2.0 feet, while in wet years 2.0 feet will be exceeded. For the entire period-of-record, the mean dry season depth targets range from approximately 0.4 to 3.1 feet, which translates into annual minimum depths ranging from approximately -0.9 feet in the driest year to 2.4 feet in the wettest year. In most years the target mean dry season depths falls between 1.5 and 2.5 feet. If 0.2 feet is added to the to the target curve (to account for model scale), modeling shows that the minimum annual depths will fall below 0.7 feet in approximately 8 out of 35 years, meaning that significant stress to slough vegetation is expected in 8 out of 35 years with the performance measure dry season depth targets.

Alternatively, observed data may be used for the above evaluation. Although slough vegetation is found in WCA-3A, most of the area today does not have the desired densities of the indicator slough species, white water lily and slim spikerush. Frequency curves of mean wet and dry season depths at 4 gages with slough vegetation are shown on Figures A-3 and A-4, respectively. Of the gages evaluated, Gage 3A28 (Site 65) has the highest percentage of the desired slough species. In average-to-wet years, the observed dry season water depths at 3A28 (Figure A-4) match the target depths quite well. In 1995, the wettest year in the period of record, the observed depths exceeded the targets. In dry years, however, the observed dry season depths generally fall approximately 0.5 to 1.0 foot below the target depths. Overall, the gage location which is most representative of ridge and slough, and best supports slough vegetation, also has water depths which best match the performance measure targets. Based on the scientific evidence, however, no area today has optimal hydrologic conditions for the slough vegetation community that existed pre-drainage. In particular, conditions in dry years today are markedly different from pre-drainage conditions. Also, if model cells selected for an indicator region all are expected to support the same vegetation communities (e.g., ridge and slough vegetation), the depth targets described above are appropriate at the scale of the indicator region. Thus, based on our analysis, we are not recommending revision to any of the Slough Vegetation performance measure depth targets.

Table A-1. Mean Elevations for Major and Secondary Vegetation Communities for 50 Gages within the Greater Everglades Landscape.

Station	Vegetation Community (Major)	Vegetation Community (Secondary)	Avg elev all veg types	Avg elev at "slough"	Correction for model scale
3A10	Exotics and cattail	na	9.13	8.95	0.18
3ANE	Exotics and cattail	Ridge or sawgrass and emergent marsh	8.89	8.84	0.05
SITE_19	Exotics and cattail	Slough or open water	9.51	9.16	0.35
SITE_63	Exotics and cattail	Slough or open water	7.45	7.33	0.12
BCA2	Other (mostly wetland shrub and wetland forested)	Ridge or sawgrass and emergent marsh	11.73	11.46	0.27
NP62	Other (mostly wetland shrub and wetland forested)	Ridge or sawgrass and emergent marsh	0.75	0.53	0.22
NP67	Other (mostly wetland shrub and wetland forested)	Ridge or sawgrass and emergent marsh	0.45	0.34	0.11
CT27R	Ridge or sawgrass and emergent marsh	Exotics and cattail	0.27	0.21	0.06
EDEN_3	Ridge or sawgrass and emergent marsh	Exotics and cattail	-0.25	-0.40	0.15
A13	Ridge or sawgrass and emergent marsh	na	3.24	3.17	0.07
C111_wetland	Ridge or sawgrass and emergent marsh	na	0.02	-0.04	0.06
EDEN_10	Ridge or sawgrass and emergent marsh	na	4.87	4.69	0.18
EDEN_11	Ridge or sawgrass and emergent marsh	na	11.04	10.98	0.06
EDEN_9	Ridge or sawgrass and emergent marsh	na	8.11	7.97	0.14
EVER4	Ridge or sawgrass and emergent marsh	na	-0.49	-0.57	0.08
NESRS3	Ridge or sawgrass and emergent marsh	na	4.40	4.33	0.07
NP46	Ridge or sawgrass and emergent marsh	na	-0.08	-0.15	0.07
P33	Ridge or sawgrass and emergent marsh	na	3.92	3.81	0.11
P35	Ridge or sawgrass and emergent marsh	na	-0.24	-0.35	0.11
SITE_76	Ridge or sawgrass and emergent marsh	na	5.32	5.14	0.18
TMC	Ridge or sawgrass and emergent marsh	na	2.63	2.52	0.11
3AS3W1	Ridge or sawgrass and emergent marsh	Slough or open water	7.09	6.30	0.79
EDEN_13	Ridge or sawgrass and emergent marsh	Slough or open water	6.94	6.41	0.53
MET-1	Ridge or sawgrass and emergent marsh	Slough or open water	4.25	4.15	0.10
NE1	Ridge or sawgrass and emergent marsh	Slough or open water	4.29	4.21	0.08
P36	Ridge or sawgrass and emergent marsh	Slough or open water	1.30	0.23	1.07

Station	Vegetation Community (Major)	Vegetation Community (Secondary)	Avg elev all veg types	Avg elev at "slough"	Correction for model scale
SITE_62	Ridge or sawgrass and emergent marsh	Slough or open water	8.37	8.32	0.05
SITE_71	Ridge or sawgrass and emergent marsh	Slough or open water	4.88	4.43	0.45
CP	Slough or open water	Other (mostly wetland shrub and wetland forested)	-1.22	-1.51	0.29
NCL	Slough or open water	Other (mostly wetland shrub and wetland forested)	-1.24	-1.31	0.07
SITE_7	Slough or open water	Other (mostly wetland shrub and wetland forested)	13.46	13.28	0.18
SITE_9	Slough or open water	Other (mostly wetland shrub and wetland forested)	13.50	13.22	0.28
WCA1ME	Slough or open water	Other (mostly wetland shrub and wetland forested)	13.93	13.70	0.23
3A9	Slough or open water	Ridge or sawgrass and emergent marsh	8.25	8.19	0.06
3ANW	Slough or open water	Ridge or sawgrass and emergent marsh	9.95	9.86	0.09
3AS	Slough or open water	Ridge or sawgrass and emergent marsh	8.03	7.85	0.18
EDEN_12	Slough or open water	Ridge or sawgrass and emergent marsh	5.61	5.59	0.02
EDEN_4	Slough or open water	Ridge or sawgrass and emergent marsh	5.85	5.77	0.08
EDEN_7	Slough or open water	Ridge or sawgrass and emergent marsh	4.81	4.80	0.01
EDEN_8	Slough or open water	Ridge or sawgrass and emergent marsh	6.16	5.73	0.43
SITE_64	Slough or open water	Ridge or sawgrass and emergent marsh	7.18	6.97	0.21
SITE_65	Slough or open water	Ridge or sawgrass and emergent marsh	6.03	5.86	0.17
SOUTH_CA1	Slough or open water	Ridge or sawgrass and emergent marsh	11.37	11.05	0.32
TI-8	Slough or open water	Ridge or sawgrass and emergent marsh	4.28	4.16	0.12
TI-9	Slough or open water	Ridge or sawgrass and emergent marsh	4.77	4.75	0.02
W11	Slough or open water	Ridge or sawgrass and emergent marsh	7.26	7.00	0.25
W18	Slough or open water	Ridge or sawgrass and emergent marsh	7.81	7.71	0.10
W5	Slough or open water	Ridge or sawgrass and emergent marsh	6.27	6.18	0.09
L28_GAP	Slough or open water	Wet prairie	10.12	9.80	0.32
W15	Slough or open water	Wet prairie	7.51	7.02	0.49
				average	0.20
				median	0.12

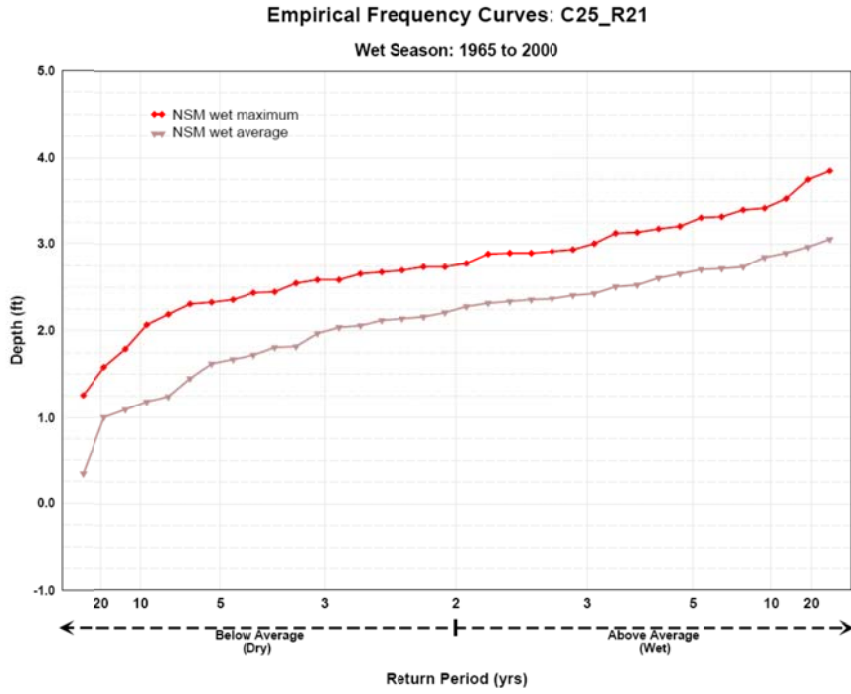


Figure A-1. Depth Frequency Curves of Wet Season Maximum and Mean Wet Season Depths at C25_R21 in the NSM.

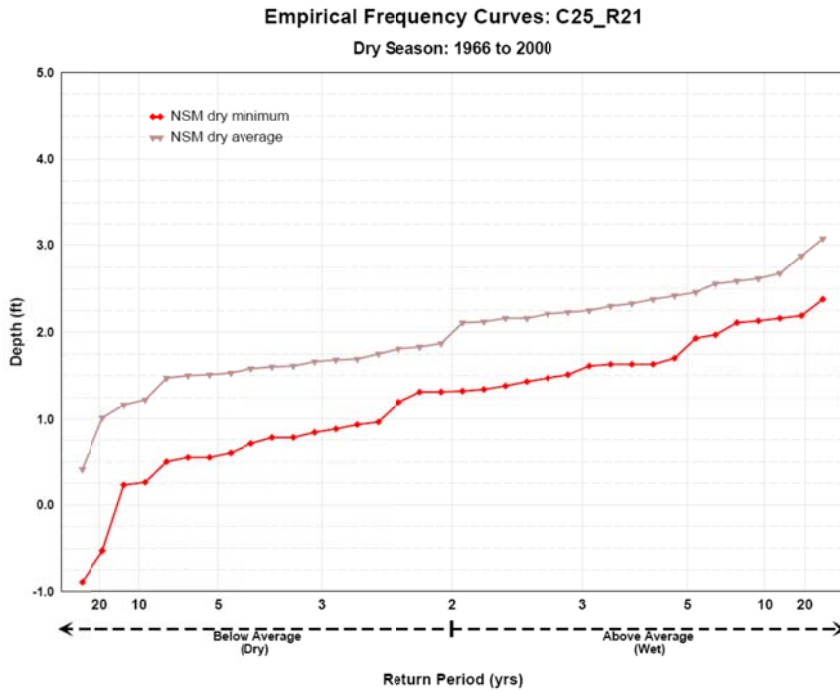


Figure A-2. Depth Frequency Curves of Dry Season Minimum and Mean Dry Season Depths at C25_R21 in the NSM.

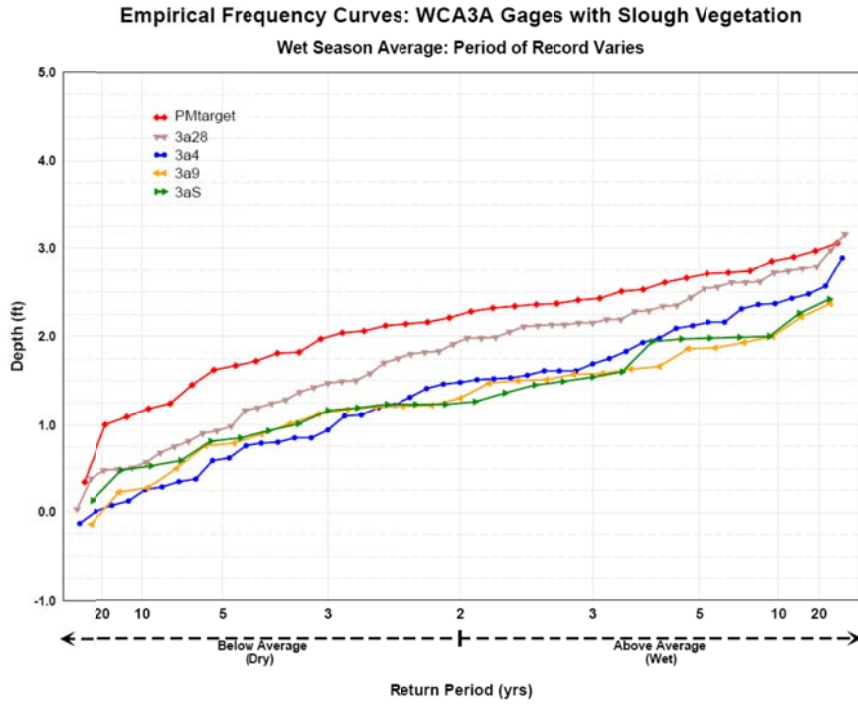


Figure A-3. Depth Frequency Curves of Observed Mean Wet Season Depths at Selected Gages in WCA-3A.

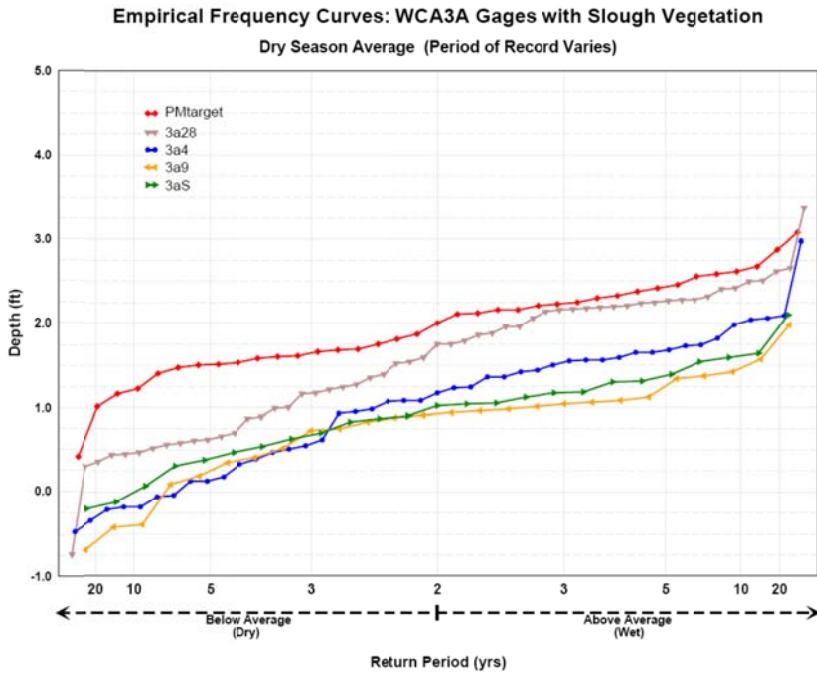


Figure A-4. Depth Frequency Curves of Observed Mean Dry Season Depths at Selected Gages in WCA-3A.

Notes:

From *EDEN_Gage_Data_Download_Readme.txt* file at EDEN website.

The basic protocol for collection of data at a water level (stage) gage:

- The water level was recorded from the staff gage at the stage gage or at a nearby location. In the case of an unavailable or missing staff gage, the water depth was measured at an reference mark (R.M.) or well. GPS coordinates were collected at every staff gage.
- The major vegetative community at the stage gage was identified.
- Water depth was recorded at 6 random locations at least 10 meters apart and distributed around the gage in the major vegetative community. Data was collected along 6 spokes radiating out from the gage that are 10 paces long (approximately 10 meters). The spokes were aligned in the following directions: 0°, 60°, 120°, 180°, 240°, and 300°. The measurements were performed using a surveyor's level rod with a flared rubber base. The measuring stick was allowed to rest on top of the bottom surface. Every data measurement was recorded. Measurements were not made in disturbed locations, such as in airboat trail or where a helicopter has landed. If a disturbed area was located, the data collector continued walking away from the gage and measured in an undisturbed area. GPS coordinates were collected at every measured point.
- If the gage was on the edge or transition of a community, a judgment was made to determine the major vegetation community. The data collector walked 20 paces from the gage into the adjacent major community and used that as the center point to begin walking the "spokes".
- Water depth was also recorded at 3 random locations at least 10 meters apart and not more than 400 meters from the gage in the next major vegetative community. If there was no next major vegetative community within 400 meters of the gage, none available was recorded. If more than one vegetative community was identified, then both are reported. These points were centered twenty paces into the community from the edge, with the 10-pace spokes oriented at 0°, 120°, and 240°. Measurements were not collected in communities that were too small to conduct the random measurements.
- NA is recorded if the major or secondary vegetation community was dry during the site visit and no ground elevation could be computed.