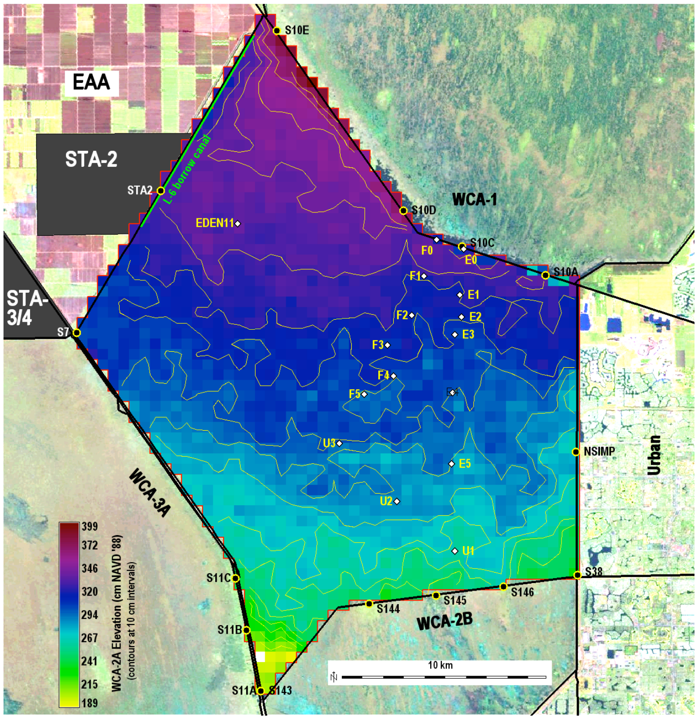
Documentation of the Everglades Landscape Model: ELM v2.9.0 - Wading Bird Suitability



Project Web Page for all assumptions & results:
http://www.ecolandmod.com/projects/ELMwca2a

Submitted to the
Marsh Ecology Research Group
Everglades Systems Assessment Section
SFWMD

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Preface

Documentation purpose

This report documents the update of the Everglades Landscape Model (ELM) from v2.8.6 to v2.9.0 with a new **consumer (wading bird)** module. This includes information on goals & objectives, supporting data, algorithms, performance, and application of the subregional WCA-2A ELM application for the "Incorporating Wading Bird Suitability into the Everglades Landscape Model" project. This document and further supporting information are maintained on the EcoLandMod web site:

http://www.ecolandmod.com

The primary objective of the documentation is to present a subregional application of ELM, for use in evaluating ecological responses to hypothetical water management scenarios in WCA-2A. This is a documentation update of model source code and input data, limited to describing changes that were made in model design and data during the transition from ELM v2.8.6 to ELM v2.9.0. A number of original ELM v2.5 - ELM v2.8.6 Documentation Chapters are not included here, as their content remains unchanged, and are available on the above EcoLandMod web site.

The only five Chapters included here are those that contain significant new information that is relevant to current application objectives.

Document organization

Each Chapter of this document has its own Table of Contents.

- Chapter 1: ***Introduction*** to the model ***Goals & Objectives*** for the Wading Bird Suitability Project in WCA-2A.

  *(see ELM v2.5) Chapter 2: General overview of **Wetland Ecological Models**.*

  *(see ELM v2.5) Chapter 3: Graphical and verbal descriptions of the South Florida and General Ecosystem **Conceptual Models** on which the ELM is based.*

- Chapter 4: Graphical, verbal, and statistical-summary descriptions all of the updates to ***Data*** that are used in the model application in WCA-2A.
- Chapter 5: Graphical, verbal, and mathematical descriptions of the updates to ***Model Structure*** and algorithms (including links to source code).
- Chapter 6: Analysis of ***Model Performance*** relative to the historical period of record in WCA-2A (1981 - 2000).

  *(see ELM v2.5) Chapter 7: Aspects of **Uncertainty** in the model and associated data, including sensitivity analysis, appropriate model expectations, and model complexity.*

- Chapter 8: Summaries of ***Model Applications*** in support of the Wading Bird Suitability project.

  *(see ELM v2.5) Chapter 9: Descriptions of past and planned **Model Refinements**, including an overview of its current limitations.*

  *(see ELM v2.8.4) Chapter 10: A **User's Guide** that provides the simple steps to installing and running this Open Source model.*

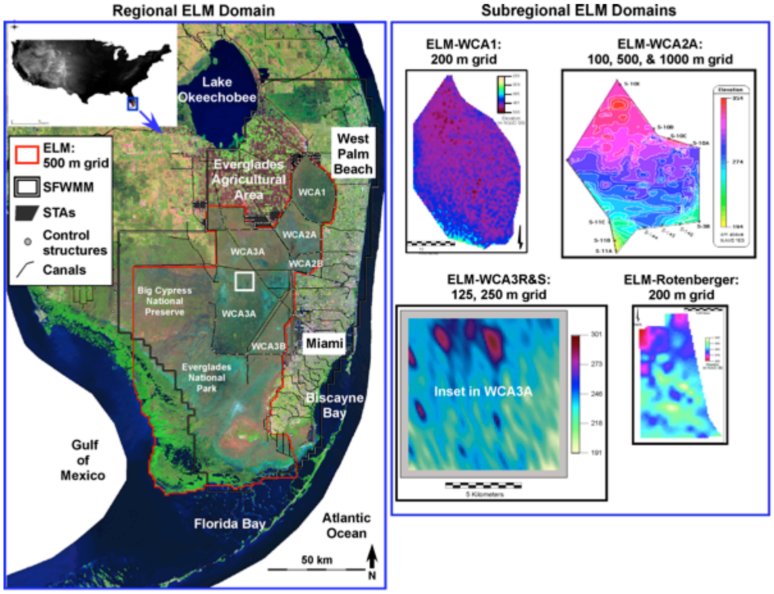
Acknowledgments

Funding for this ELM application update came from the Everglades Systems Assessment Section of the South Florida Water Management District. S. Newman provided the scientific leadership in advancing the application into a tool that was used by the team of SFWMD scientists. M. Cook, Colin Saunders, Christa Zweig, Mike Manna, and F. Sklar provided their expertise in project research and development. I also express sincere thanks to the many individuals who have contributed in developing the ELM framework over the years, as cited in prior documentation reports and journal publications.

Executive Summary

Today's Everglades are significantly different from the landscape that existed a century ago. Humans compartmentalized a once-continuous watershed, altering the distribution and timing of water flows, and increasing the quantity of nutrients that move into the Everglades. The result is a degraded mosaic of ecosystems in a region that is highly controlled by water management infrastructure. The wetlands in the northern Everglades' Water Conservation Area 2A (WCA-2A) are exemplary of the hydrologic and water quality degradation associated with water management in an impounded Everglades basin.

To support scientific evaluations of water management alternatives in WCA-2A, computer simulation models can be used to predict the relative benefits of one alternative plan over another. One such tool is the Everglades Landscape Model (ELM). The ELM is designed to improve understanding of the ecology of the Everglades landscape, and can be applied at a range of spatial and temporal scales depending on the project requirements. This model integrates, or dynamically combines, the hydrology, water quality, and biology of the mosaic of habitats in the Everglades landscape. It is a state-of-the-art *model that is capable of evaluating long-term benefits of alternative project plans with respect to hydrology, water quality* and other ecological Performance Measures.



Existing regional and subregional applications of the ELM, including the 500 m grid resolution application used in evaluating management scenarios in Water Conservation Area 2A.

A team of scientists in the Everglades Systems Assessment Section of the South Florida Water Management District requested that an application of the ELM in WCA-2A be created, including a new Consumer Module for assessment of a ***hypothetical regulation schedule that is intended to provide depths and hydropatterns that are more suitable for wading birds*** (and other wildlife) in this wetland. This Documentation Report includes the information necessary for scientists and planners to understand this application of ELM, including a) the ELM objectives, b) how it works, c) how well it works, and d) results of alternative management strategies for WCA-2A.

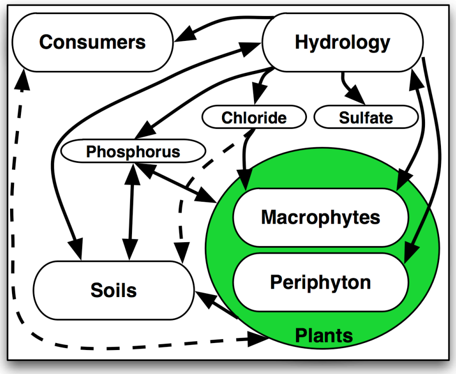
The **new Consumer module** incorporated two sets of hydrologic suitability metrics: a) 5 classes of Wading Bird Water Depth suitability metrics, and b) 6 classes of Wading Bird Water Recession Rate (rate at which surface water recedes in depth) suitability metrics. We used these and other hydro-ecological Performance Measures to help evaluate multi-decadal, landscape responses to hypothetical water management alternatives for the Wading Bird Suitability Project in WCA-2A.

Model Goals (see http://www.ecolandmod.com/background)

- Develop a simulation modeling tool for integrated ecological assessment of water management scenarios for Everglades restoration
    - Integrate hydrology, biology, and nutrient cycling in spatially explicit, dynamic simulations
    - Synthesize these interacting hydro-ecological processes at scales appropriate for regional assessments,
    - **Understand and predict the relative responses of the landscape to different water and nutrient management scenarios**
    - Provide a conceptual and quantitative framework for collaborative field research and other modeling efforts

Model Design (see http://www.ecolandmod.com/models)

- Regional application at fine resolution (40x finer than SFWMM[1])
- Subregional applications at very fine resolutions
- Multi-decadal (36-yr) simulation period



- Combine physics, chemistry, biology – *interactions*
    - *Hydrology*: overland, groundwater, canal flows
    - *Chloride & sulfate*: transport and fate
    - *Phosphorus*: cycling and transport
    - *Periphyton*: response to phosphorus and water
    - *Macrophytes*: response to phosphorus, chloride and water
    - *Soils*: response to phosphorus, chloride, and water
    - *Consumers:* wading bird hydrologic suitability
- Combine ecological research with modeling
    - research advances led to model refinements
    - model output aided research designs

Model Reliability (see http://www.ecolandmod.com/publications)

- Very good performance (WCA-2A application, 1981 – 2000 history-matching)
    - *Water quality*: the offset (median bias) of predicted and observed values of phosphorus in the marsh was 8 ug L^{-1}; chloride was 32 mg L^{-1}.
    - *Hydrology*: the offset (median bias) of predicted and observed values of water stage elevations in the marsh was -2 cm (0.8 inches)

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[1] South Florida Water Management Model, the widely-accepted simulation tool used for regional evaluations of water management alternatives

- Tested computer code
    - evaluated model response to wide range of conditions (sensitivity analyses)
    - years of experience in testing and refining code
    - applied at different scales for regional and sub-regional evaluations
- Uses best available data
    - comprehensive, unique summary of Everglades ecology
    - thorough QA/QC of input data
    - continuous interactions with other Everglades scientists and engineers

Model Reviews (see http://www.ecolandmod.com/publications)

- Open Source
    - All ELM data and computer source code freely available on web site
    - Requires only Open Source (free) supporting software
- Publications
    - 2006-2015: Model documentation reports (ELM v2.5 - 2.9)
    - 1996-2011: Peer-reviewed scientific journals and book chapters
    - 1993-2006: Technical reports published by SFWMD
- CERP Model Refinement Team
    - 2003: Recommended independent peer review
- Independent Panel of Experts
    - 2006: Peer review of ELM by an independent panel of experts

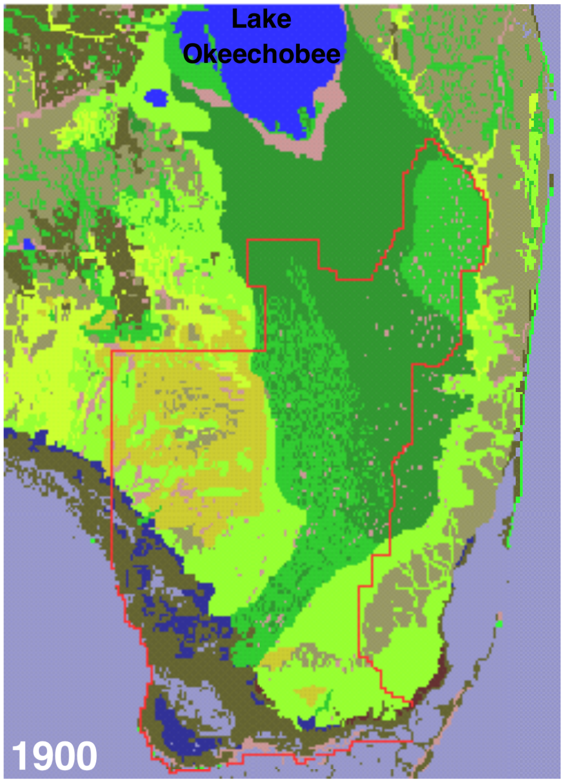
Model Applications (see http://ecolandmod.ifas.ufl.edu/projects)

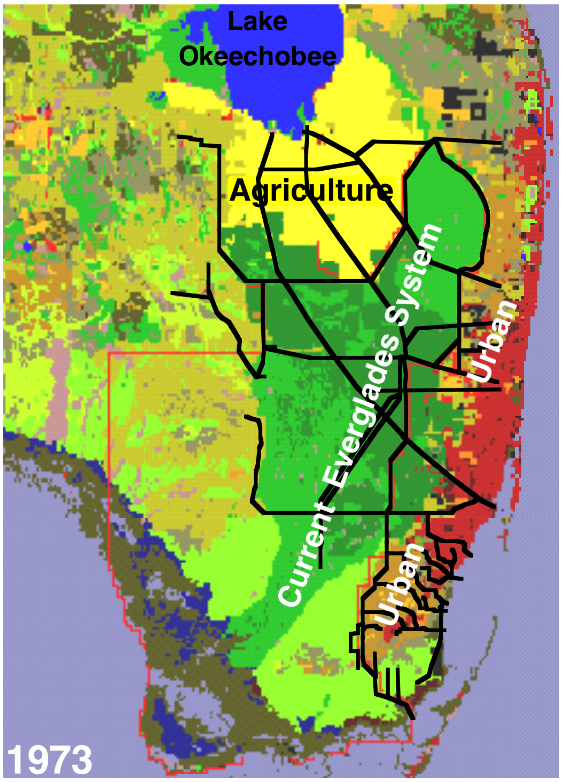
- Specific **model objectives** (Performance Measures, multi-decadal scales)
    - **Fine-scale hydrologic** output for use in “driving” other ecological models
    - **Phosphorus** 1) water column concentrations and 2) accumulation in soils along spatial gradients
    - Other ecological Performance Measures as needed for projects: **soil accretion/loss**; **vegetation succession**; **periphyton** dynamics; **sulfate** dynamics; **wading bird** hydrologic suitability
- Appropriate interpretation
    - **Relative comparisons** of Performance Measures under scenarios of alternative water management plans, at multi-decadal, landscape scales
- Recent applications (ELM v2.8 - 2.9)
    - ELM v2.8.1 application to large marsh impoundment near **Davis Pond, Louisiana**, 30 m grid resolution; initial application for use in evaluating **landscape evolution scenarios** in a highly managed coastal marsh
    - ELM v2.8.2 application to subregional domain of **Water Conservation Area 1**, 200 m grid resolution; evaluated hydrologic and water quality responses to **simple management & restoration scenarios**
    - ELM v2.8.4 application to **regional Everglades**, 500 m grid resolution; evaluated water quality and other ecological responses to **CERP Decomp project** Alternatives

- ELM v2.8.4 application to **regional Everglades**, 500 m grid resolution; for **SERES project**, evaluated water quality and other ecological responses to novel CERP project Alternatives
- ELM v2.8.5 application to **southeast Spain** region, 200 m grid resolution; evaluating **water resource sustainability** in response to land use & climate change
- ELM v2.8.6 application to **regional Everglades**, 500 m grid resolution; evaluated sulfate water quality responses to **CERP ASR project** Alternatives
- ELM v2.8.6 application to **regional Everglades**, 500 m grid resolution; evaluated hydro-ecological responses to **scenarios of sea level rise and climate change**
- ELM v2.9.0 application to subregional domain of **Water Conservation Area 2A**, 500 m grid resolution; evaluated hypothetical regulation schedule that is intended to provide **depths and hydropatterns that are more suitable for wading birds** (and other wildlife)

Documentation of the
Everglades Landscape Model:
ELM v2.9.0

Chapter 1: Introduction, Goals & Objectives





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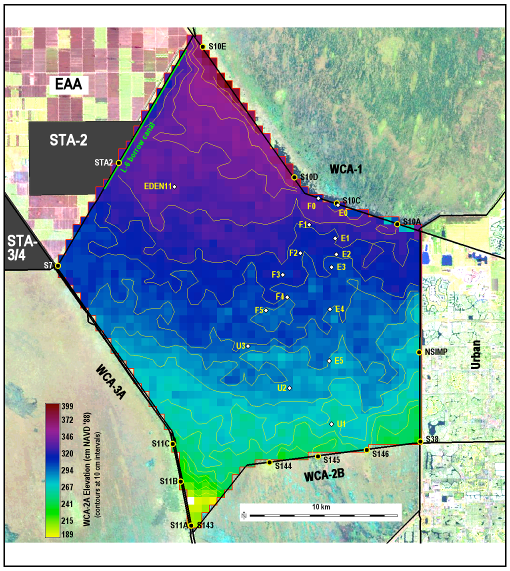
June 16, 2015

Chapter 1: Introduction, Goals & Objectives

1.1 Overview

This Chapter provides the background for the Everglades Landscape Model (ELM) documentation that was developed in support of Water Conservation Area 2A (WCA-2A) water management. A brief overview is provided on water management for ecological benefits in WCA-2A, and how the ELM is intended to be applied towards understanding and better managing the system. This Chapter introduces the ELM as a model that is designed to evaluate the multi-decadal benefits of hypothetical water management plans with respect to a number of hydro-ecological Performance Measures, with a primary focus on hydrologic suitability metrics for wading birds.



1.2 Introduction

The Everglades region of south Florida, USA, is currently a vast system of neo-tropical estuaries, wetlands, and uplands interspersed among agricultural and urban land uses. Starting in the early part of the 20'th century, long stretches of canals were dug in attempts to drain the relatively pristine Everglades for agriculture. However, after severe flooding in 1947, the Central and South Florida (C&SF) Project was initiated. In this massive engineering feat, the U.S. Army Corps of Engineers developed an elaborate network of canals, levees, and water control structures to improve regional flood control and water supply (Light and Dineen 1994). It was ultimately very effective in managing water for those purposes, enhancing the development of urban and agricultural sectors of the region. As shown in Figure 1.1 below, dramatic increases in such land uses occurred during the 20'th century, significantly reducing the spatial extent of the "natural" Everglades system by the mid 1970's. Agricultural and urban development has generally continued through the present day, particularly along the corridors east and north of the Everglades. While the C&SF Project led to a reduction in spatial extent of the Everglades, it also fragmented the once-continuous Everglades wetlands into a series of large impoundments.

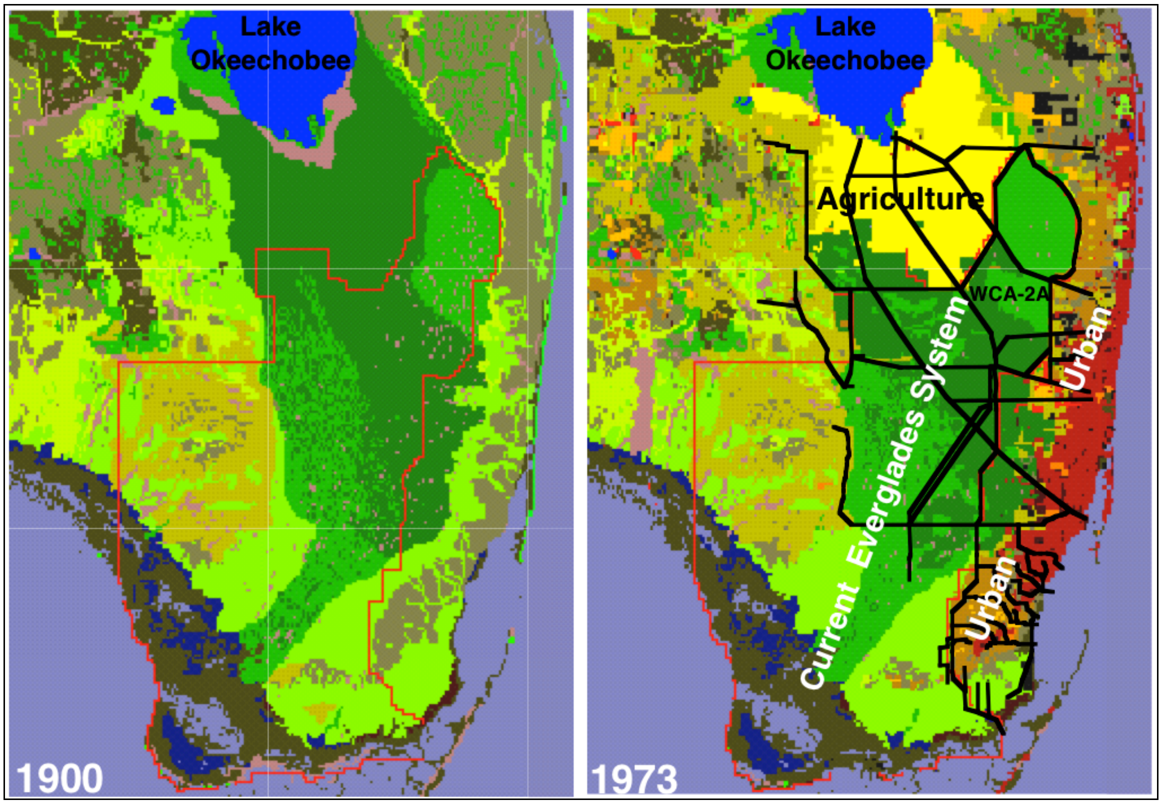


Figure 1.1. Agricultural (yellow) and urban (orange/red) land use expanded dramatically in south Florida during the 20'th century. Black lines denote some of the major canals & levees that were constructed as part of the C&SF Project. The red polygon is the domain of the regional application of the Everglades Landscape Model. The ELMwca2 application includes only the WCA-2A basin in the northern Everglades. Land use data from Costanza (1975).

Water historically flowed from the northern parts of the region into and through the Everglades largely as overland sheet flow. With fragmentation, this flow regime changed to point releases at the pumps and weirs of water control structures. Operational criteria for these managed flows dictated the timing and magnitude of water distribution into and within the Everglades, further modifying its hydrology. Many of these inflows also carried higher loads of nutrients into the historically oligotrophic Everglades, as a result of agricultural and urban development. The altered distribution and timing of flows in a fragmented watershed, combined with increased nutrient loads into the Everglades, changed this mosaic of habitats. Increasingly, the public and scientific communities were concerned that ecological structure and function would continue to decline within this nationally and internationally protected landscape. In the late 20th century, it became apparent that revisions in the infrastructure and operations of the C&SF Project were necessary in order to halt further ecological degradation, and a plan to restore the Everglades was developed by federal and state agencies (USACE and SFWMD 1999). After years of effort, the Comprehensive Everglades Restoration Plan (CERP) was developed, and has been implemented as a thirty year project to address the future of south Florida's ecology – while also enhancing urban and agricultural water supply for what is anticipated to be a doubling of the regional population by 2050.

In the Everglades, the existing management infrastructure bisects the area into a series of impoundments, or Water Conservation Areas (WCAs). Everglades National Park is south of these WCAs, while Big Cypress National Preserve is to the west. Agricultural land uses dominate the area just north of the Everglades, while extensive urban land uses predominate along the eastern boundary of the Everglades. Lake Okeechobee, historically bounding the northern Everglades marshes, is now connected to those marshes via canal routing.

Anthropogenic nutrient enrichment was introduced into the Everglades from management of agricultural, and to a lesser extent, urban runoff. Because of the significant, negative, impacts of this nutrient loading on the naturally oligotrophic system, a series of wetlands were created along the northern periphery of the Everglades. These Stormwater Treatment Areas (STAs) are intended to serve as natural nutrient filters to remove nutrients (primarily phosphorus) from waters flowing into the Everglades. The first constructed wetlands to be in operation were effective in reducing phosphorus concentrations well below the interim target of 50 $ug{\cdot}L^{-1}$ (Chimney et al. 2000, Nungesser et al. 2001), and will be supplemented with other phosphorus removal mechanisms and on-farm best management practices to reduce Everglades inflow concentrations to the threshold target of 10 $ug{\cdot}L^{-1}$ (FDEP 2000).

The managed system enables a variety of flow distributions. Operation of the entire system for flood control, water supply, and the environment is governed by a complex set of rules adopted and modified over time by the South Florida Water Management District and the U.S. Army Corps of Engineers. Control over this system is managed by operating a large number of pumps, weirs, and culverts to pass water into the canals and wetlands, distributing it as needed in various parts of the regional system. Thus, different regions of the Everglades experienced different hydrologic regimes, often to the detriment of the wetland ecosystems. Under the CERP, there will be significant decompartmentalization of the levees impounding parts of the Everglades, increased storage above and below ground, and modified flows throughout the south Florida landscape (USACE and SFWMD 1999).

Changes to the hydrologic and nutrient management under the CERP is anticipated to provide some level of restoration of the Everglades system. However, there is significant uncertainty in the potential ecological response. In order to better understand and plan the restoration process, 1) predictive simulation models are being used to refine the plan, and 2) an extensive monitoring and adaptive assessment procedure (CERP_Team 2001) is being implemented. The primary simulation tools used to date are the South Florida Water Management Model (SFWMM) (SFWMD 2005a) and Regional Simulation Model (RSM) (SFWMD 2005b), which are hydrologic models with rule-based management of water flows and resultant water levels in the entire south Florida region, from Lake Okeechobee to the southern Everglades. Many of the Everglades restoration targets were derived from the Natural System Model. This hydrologic companion to the SFWMM is basically the SFWMM with the water management infrastructure removed, adjusting various data to attempt to simulate the regional hydrology prior to any drainage efforts (SFWMD 1998). The Everglades Landscape Model (ELM) is a process-oriented simulation tool designed to develop an understanding of the ecological interactions in the greater Everglades landscape. Scalable so that it may be applied at different resolutions (i.e., "pixel" size) depending on the objectives, the ELM integrates modules describing the hydrology, biogeochemistry, and biology of ecosystems in a heterogeneous mosaic of habitats that comprise the Everglades.

1.2.1 Water Conservation Area 2A

In the northern Everglades, Water Conservation Area 2A (WCA-2A) is an example of the results of impounding a large (433 km^2) wetland. WCA-2A is entirely surrounded by levees (Figure 1.2). Until the implementation of Stormwater Treatment Area 2 in 2001 along the northwest section of the basin (Garrett and Ivanoff 2008), the principal managed inflows were restricted to the S-10 series of gated spillways in the northeastern basin, and the S-7 structure at the western boundary; outflows continue to be principally from the perimeter canal along the (lower elevation) southern portions of the basin. WCA-2A has undergone a number of operational changes during its history (Light and Dineen 1994), regulated for various combinations of water storage (relatively deep inundation) and environmental protection (lower, varying stages) of the marshes and tree islands in the area. Due to the land surface elevation gradient which generally decreases from north to south, water depths in the southern portion are generally much deeper, for a longer period, than found in the northern sections of the basin.

Water flow through these structures has varied dramatically within and among years. Seasonal and interannual changes in rainfall intensity alter the inflows to the WCA, water management regulation schedules have varied over the years, and deviations from those targets occurred based on overriding water supply and flood control needs elsewhere. Interannual variations in structure discharges are large, with a pattern that generally follows the trends in annual rainfall

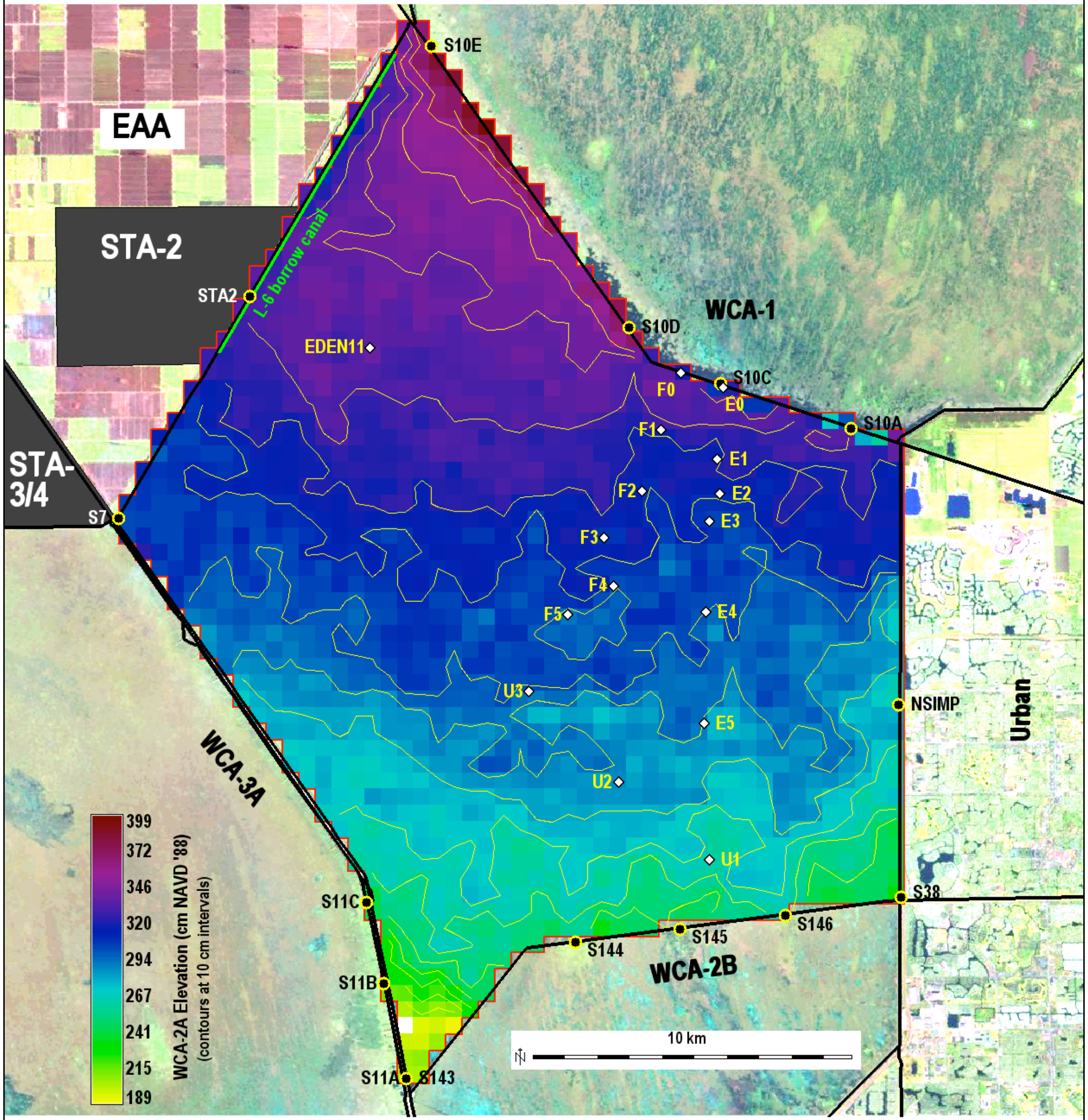


Figure 1.2. WCA-2A land surface elevation, water control structures, and marsh monitoring stations.

1.3 Purpose of models

Simulation models are explicit abstractions of reality, and at best are tools that should provide insights into a better understanding of a problem. The Everglades hydrologic simulation models referenced above have provided very useful insight. However, they do not, and were not intended to, provide by themselves a full understanding of the long term ecosystem dynamics in the Everglades. “Restoring” the Everglades ecology involves “getting the water right” (USACE and SFWMD 1999). However, even if a "perfectly" accurate model of water depths and flows were available, there still would exist significant uncertainties in how much water is needed at which times, over what spatial and temporal scales. Importantly, the nutrients associated with that water are fundamental components of the ecosystem function in the landscape.

To better understand the long term ecological effects of changing hydrologic regimes, it is important to assess the *cumulative* influence of the magnitude and timing of the changes. Interacting with these hydrologic dynamics are the nutrient transformations and transport. As the physical and chemical dynamics interact with the biological communities, the system dynamics cumulatively define the transient ecosystem states under different conditions. While the basics are well-understood, and many of the details known, there remain uncertainties in predicting all potential changes in the Everglades. We do, however, have a very good understanding of the interactions among general ecosystem processes, and of the nature of changes at the landscape scale.

Interactions are the essence of ecosystem science. Ecology has been classically defined as the interactions of organisms (including plants) and their environment (Odum 1971). For the Everglades region as an entity, a relatively simple model is desired that can capture the cumulative, interactive nature of the ecosystem dynamics, synthesizing the state of our understanding of the general ecosystem processes. The level (or scale) of computational complexity can be relatively coarse, which is dependent upon our current scientific knowledge-base. Fundamentally, there is a need for a model - or models - that can quantify the relative potential (or probability) of long-term cumulative ecosystem responses to altered hydrologic and nutrient inputs across the greater Everglades landscape. The challenge is to synthesize Everglades habitat change, with habitats being an integrated combination of hydrologic, water quality, soils, and periphyton/plant variables that are simulated with a reasonable degree of relative certainty. With such a model, the trends in relative habitat change could be evaluated under different scenarios of hydrologic/nutrient management.

1.4 ELM goals and objectives

The ELM is an integrated ecological assessment tool with the overall goal to understand and predict the relative response of the landscape to different water management scenarios in south Florida, USA. In simulating changes to habitat distributions, the ELM dynamically integrates hydrology, water quality, soils, periphyton, and vegetation in the Everglades region. The model has been used as a research tool to better understand the dynamics of the Everglades, enabling hypothesis formulation and testing. This is a critical, ongoing application of the model. However, one of the primary objectives of this simulation project is to evaluate the relative ecological performance of hypothetical water management scenarios.

***Goals**: Develop a simulation modeling tool for integrated ecological assessment of water management scenarios for Everglades restoration*

- Integrate hydrology, biology, and nutrient cycling in spatially explicit, dynamic simulations
- Synthesize these interacting hydro-ecological processes at scales appropriate for regional assessments
- **Understand and predict the relative responses of the landscape to different water and nutrient management scenarios**
- Provide a conceptual and quantitative framework for collaborative field research and other modeling efforts

1.4.1 Objectives, ELMwca2a

The ELM simulates an integrated set of dynamic ecosystem interactions, but was initially focused on the "water quality" component of those dynamics for regional applications. The first regional application of ELM was released in the spring of 2000. That version (ELM v2.1) was intended to address several Performance Measures that relate to the phosphorus water quality of the greater Everglades region. The current version 2.9 continues to focus on those and other hydro-ecological objectives, with enhancements to the model capabilities at multiple spatial resolutions.

Being scalable depending on the objectives, the subregional application for WCA-2A runs with a 500 m spatial resolution. The specific Performance Measures that were developed for use in the WCA-2A Wading Bird Suitability project are described in a separate Model Application document, available at http://www.ecolandmod.com/projects/ELMwca2a/. In general terms, the ELMwca2 v2.9 addressed the following Performance Measures:

***Specific objectives:** compare (hypothetical) water management scenarios, predicting relative differences in ecological (primarily wading bird) variables from a long-term perspective*

- *Primary objectives:* Stages, surface water depths, and depth recession rates (with new metrics that are specific to wading bird hydrologic suitability)
- Concentration of total phosphorus (P) in surface water, soils, rates of P accumulation in soils/ecosystem, and P load to basin
- Peat accretion rates, and cattail extent/biomass

The spatial and temporal scales associated with these Performance Measures are relative to the goal of understanding and predicting relative differences in system response over long time scales across the modeled system. A seasonal to annual temporal grain, and gradients with a 500-m spatial grain, are consistent with our ability to discriminate ecologically significant spatial patterns and temporal trends across local and basin-wide gradients in WCA-2A.

1.4.2 Relationship to other models

While there are no other models that simulate the range of integrated hydro-ecological variables of ELM, the wading bird metrics employed in the new ELM v2.9 are based on those developed by Cook, Beerens and colleagues (Beerens et al. 2011, Beerens 2014). Those wading bird models involved the application of hydrologic models: Everglades Depth Estimation Network (Telis 2006), SFWMM (SFWMD 2005a), and RSM (SFWMD 2005b).

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Documentation of the
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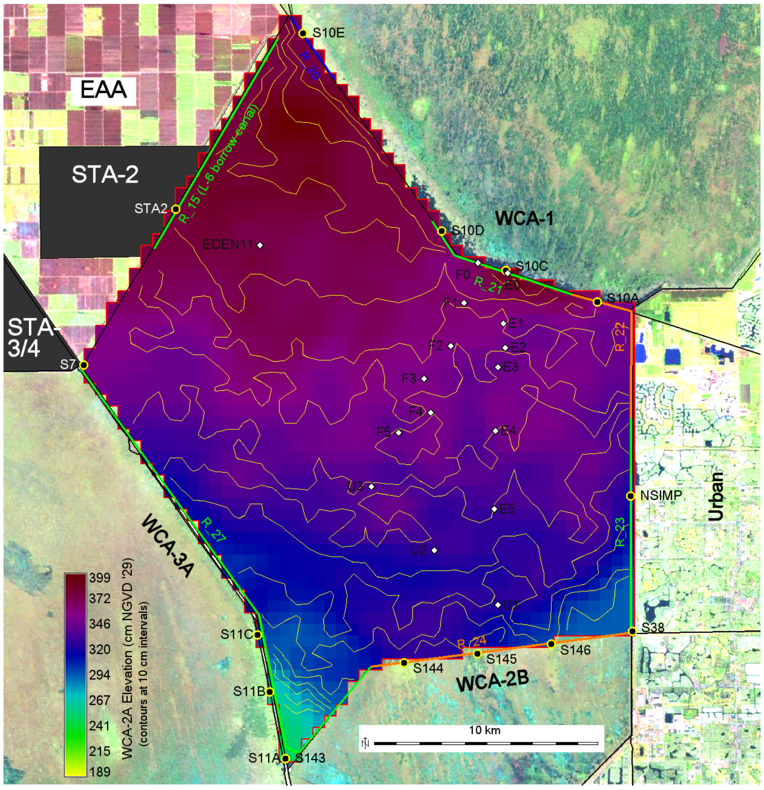
ELM v2.9.0

Chapter 4: Data



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Chapter 4: Data

4.1 Overview

The focus of this Chapter is the description of data used in ELMwca2a v2.9, relative to those documented for the regional ELM v2.5 - v2.8. In its subregional (433.5 km^2, 167.4 mi^2) application at 500x500 m grid resolution, the ELMwca2a v2.9 was developed to evaluate the relative benefits among a suite of water management scenarios for ecological benefits in Water Conservation Area 2A. For this subregional application, most of the data remain the same as those used for the ELM v2.5 regional application. The principal changes involved “resampling” data from the regional map inputs, or generating new spatial interpolations of the original data. This ELMwca2a Data Chapter thus makes extensive reference to the regional ELM v2.5 - v2.8 Documentation Reports' Data Chapters.

4.2 Background

4.2.1 Application summary

The ELMwca2a version 2.9[1] was developed in order to evaluate relative differences in ecological performance of Everglades Water Conservation Area 2A (WCA-2A) water management plans. As described in this Data Chapter and the Model Structure Chapter 5, a new Consumer Module was created, containing wading bird hydrologic suitability metrics.

Because the ELM was designed to be explicitly scalable, it is relatively simple to adapt (spatial input map) data to accommodate the scientific objectives that may call for a particular scale of grid resolution or extent. The SFWMD science team determined that a 0.25 km^2 (500x500 m) resolution application would be a suitable scale to meet the project objectives. All of the other data (e.g., parameters) used in this application remain the same as those used in the regional ELM v2.5 - 2.8, and thus this Data Chapter 4 for this application makes extensive reference to the ELM v2.5 through v2.8 Documentation Reports, available at http://www.ecolandmod.com/publications.

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[1] The tertiary subversion designation of this v2.9 application release is v2.9.0.

4.2.2 Metadata

All of the input data files used in the model have metadata directly associated with them in the project data directories. Those metadata provide the information necessary to use and interpret the input data files in model applications, while this documentation Chapter details the sources and derivation of the data themselves. The following table lists all of the files that are input to the ELM and described in this Chapter[2].

Type	Input filename	Description
Model domains		
	ModArea	Define spatial domain
	gridmapping.txt	Link coarse-fine grids
Initial condition maps		
	icSfWt	Initial surface water
	icUnsat	Initial unsaturated water
	Elevation	Initial land elevation
	Bathymetry	Initial (and constant) creek bathymetry
	soilBD	Initial (and constant) soil bulk density
	soil_orgBD	Initial (and constant) soil organic bulk density
	soilTP	Initial soil phosphorus
	soilTPpore	Initial soil porewater phosphorus
	HAB	Initial habitat type
	icMacBio	Initial total macrophyte biomass
Boundary conditions		
	BoundCond	Grid cells allowing boundary flows
	BoundCond_stage.BIN	Boundary stage/depth spatial time series
	rain.BIN	Rainfall spatial time series
	ETp.BIN	Potential ET spatial time series
	CanalData.struct_wat	Structures: water flow point time series
	CanalData.struct_TP	Structures: phosphorus conc. point time series
	CanalData.struct_TS	Structures: salt (chloride) conc. point time series
	CanalData.struct_TSO4	Structures: sulfate conc. point time series
	CanalData.graph	Recurring annual time series of stage regulation
Static attributes		
	CanalData.chan	Canal/levee parameters/locations
	CanalData.struct	Water control structure attributes
	basins	Basin/Indicator Region locations
	basinIR	Basin/Indicator Region hierarchy
	GlobalParms_NOM	Parameters: global
	HabParms_NOM	Parameters: habitat-specific
	HydrCond	Parameters: hydraulic conductivity

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[2] Two other files are input to the model and serve to configure the model at runtime. See the User Guide Chapter for information on the “Driver.parm” and “Model.outList” configuration files.

4.3 Model domains

4.3.1 Spatial domain

The ELM can be applied at a variety of grid scale resolutions and extents without changing any source code. For an application at a particular spatial grain and/or extent, the following data files are used to define the model at the desired scale: 1) the appropriate grid resolution/extent of each of the map input files; 2) the grid resolution and geographic (upper left) origin in the two databases that define the canal/levee locations and water control structure attributes; and 3) the linked-list text file that maps coarser-grid data to the selected model application. The User Manual Chapter explains these steps needed to develop an application at a new spatial resolution/extent.

All spatial data are referenced to zone 17 of the Universal Transverse Mercator (UTM) geographic coordinate system, relative to the 1927 North American Datum (NAD).

4.3.1.1 ELMwca2a domain (infile = "ModArea")

The subregional ELM project for WCA-2A modeling encompasses the domain of the hydrologic basin of WCA-2A. This subregional application uses 500x500 m square grid cells that encompass an area of 433.5 km^2 (167.4 mi^2), with 66 columns by 68 rows. All of the maps of the regional application are bounded by the following rectangle of UTM coordinates in zone 17 (NAD 1927):

northing:	2,928,489 m
southing:	2,894,489 m
easting:	575,711 m
westing:	542,711 m

4.3.1.2 Multi-scale grid-mapping (input = "gridmapping.txt")

A variety of dynamic boundary condition data may be input from coarser model grids. The ELMwca2a v2.9 uses some dynamic boundary condition data (described in later sections) that are at the scale of the 2x2 mile (10.4 km^2) grid of the SFWMM. For regional or subregional applications of ELM, a "linked list" is generated to map boundary condition data from a coarse grid (usually that from the SFWMM) to the ELM grid. These data are generated from the pre-processor GridMap tool, and input to the ELM via the "gridmapping.txt" file.

4.3.1.3 Basins & Indicator Regions (input = "basins", "basinIR")

The map of the Basins and Indicator Regions defines the spatial distribution of the (single) hydrologic Basin and multiple Indicator Regions (BIR). These BIR spatial distinctions do not affect any model dynamics, but are used in summarizing nutrient & water budgets and selected ecological Performance Measures. Budgets and preset Performance Measure variables are output at the different spatial scales defined by the BIR. The Indicator Regions are particularly useful for summarizing model dynamics along ecological gradients.

The largest spatial unit is Basin 0, the "basin" of the entire domain. Hydrologic basin(s) within the domain are regions with either complete restrictions on overland flows (such as Water Conservation Area 2A surrounded by levees) or partial restrictions of overland flows (i.e., in the regional application, Water Conservation Area 3A is bounded by levees except along part of its western boundary). Hydrologic basins are “parent” regions that (may) contain “child” Indicator Regions. Indicator Regions are drawn within a hydrologic basin boundary (but an Indicator Region may not belong to two parent basins). In reporting BIR output data, parent basins’ data include (e.g., sum) the data on all child Indicator Regions contained within them. When re-drawing the BIR (“basins”) map, the user must edit the “basinIR” text file that defines the inheritance characteristics and allowable surface flows of the BIRs (such as the flow allowed to/from Water Conservation Area 3A through the gap mentioned above).

4.3.2 Temporal domain

The ELM can be applied at a variety of time scales, depending on the objective and the availability of boundary condition data. The temporal extent of the historical period used in evaluating model performance (calibration/validation) for this ELMwca2A application is 1981 – 2000 (based primarily upon stage and water quality monitoring data that are limited to that time period).

The temporal extent of the available meteorological record (used in future alternative model evaluations) is 1965 – 2000. As detailed later in this Chapter for each boundary condition data file, the temporal grain of these input data is 1-day. As described in the Model Structure chapter, the time step (dt) of the vertical solutions is 1-day, while the time step for horizontal solutions varies with the model grid resolution, but is 36 minutes at the 500 m grid resolution.

4.4 Initial condition maps

There are a number of map data files that are necessary to implement this spatially explicit landscape model. Those that are used in defining the initial conditions of the simulation were developed using the methods described below for each specific data set. Note that the initial conditions for some variables do not have individual input map files (see the descriptions of the Global and the Habitat-specific parameter databases).

4.4.1 Water depths

4.4.1.1 Surface water depth (input = “icSfWt”)

1981: The initial ponded water depth from the ELMv2.8.4 calibrated hydrology (initialized Jan 1, 1981) was resampled, to include only WCA-2A.

1965: The initial ponded surface depth (negative stage minus land surface elevation) used in the SFWMM v6.6 future base runs[3] provided a snapshot of Jan 1, 1965 for initial ponded surface water depth. This regional ~10 km^2 snapshot was resampled for the WCA-2A 500m grid model, input to ELMwca2a v2.9, run for 3 days, and the resulting ponded surface water depth was used to subsequently initialize the model for January 1, 1965.

4.4.1.2 Unsaturated water depth (input = “icUnsat”)

1981: The initial unsaturated water depth from the ELMv2.8.4 calibrated hydrology (initialized Jan 1, 1981) was resampled, to include only WCA-2A.

1965: The initial unsaturated storage depth (negative stage minus land surface elevation) used in the SFWMM v6.6 future base runs provided a snapshot of Jan 1, 1965 for initial unsaturated storage water depth. This regional ~10 km^2 snapshot was resampled for the WCA-2A 500m grid model, input to ELMwca2a v2.9, run for 3 days, and the resulting unsaturated storage water depth was used to subsequently initialize the model for January 1, 1965.

4.4.2 Land surface elevation (input = “Elevation”)

We compiled two separate spatial data sets of land surface elevation: one for initializing the historical simulation (1981), the other for initializing (2010) the future simulations (Figure 4.1). Point data for elevations were interpolated using a “regular spline with tension” method[4]. For consistency with SFWMD practices, we used the NGVD 1929 vertical datum.

For the historical simulation, we modified the Keith and Schnars (1993) survey by subtracting 3 cm uniformly across space to account for soil accretion (Reddy et al., 1993) during the 12 yr between 1981 and the elevation measurements.

For the future scenarios initialized at 2010, we used the 2004 survey done by the US Geological Survey (USGS) as part of their High Accuracy Elevation Data (HAED) Collection project (Desmond 2004). Data were reported using the vertical datum NAVD88 and horizontal datum NAD83. We used CORPSCON for Windows (v6.0.1) for conversion of horizontal and vertical datums. Stated vertical accuracy of the original data was 15 cm overall.

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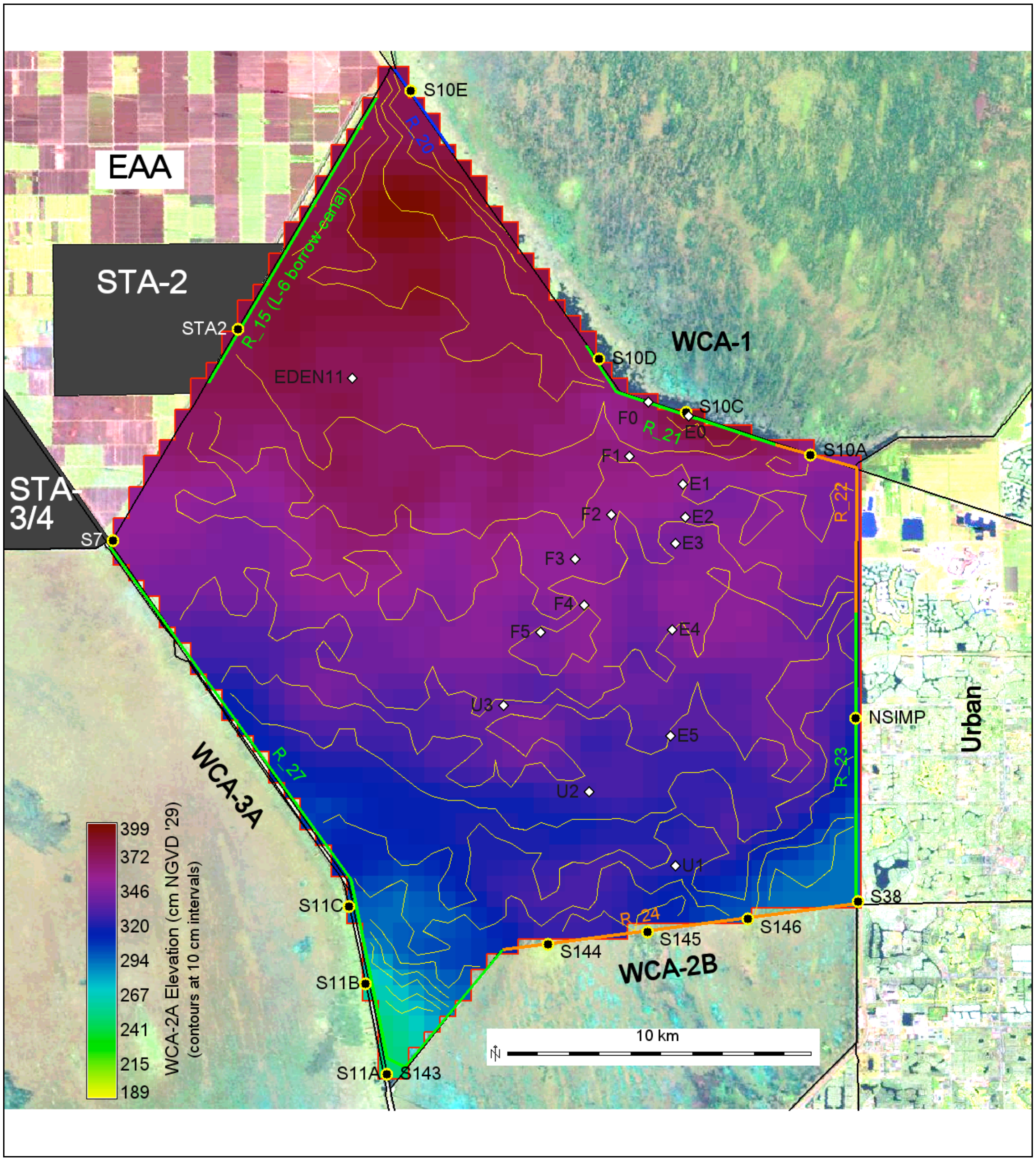
[4] Using GRASS GIS v6.2, v.surf.rst command, low smoothing (smooth=0.1), tension parameter at default value=40, anisotropy scaling factor in north-south direction (scalex=90). This method was developed, and documented within GRASS manual pages, specifically for interpolations of elevation and soils data sets at a variety of scales.

Figure 4.1. The configuration used in the simulations for WCA-2A: ELMwca2a canal reach identities (R_15 – R_27), water control structures, marsh/canal monitoring locations, and initial land surface elevation (for the future scenarios). STA2 inflows are not operative during the 1981-2000 historical simulation.



4.4.3 Soils

Spatial maps of initial conditions in the 0-10 cm upper layer soil layer were generated using the regular spline with tension method[5] to interpolate spatial point observations within WCA-2A.

For the historical simulation, we used modified (see below) data collected by Reddy et al. (1991).

For the future scenarios initialized at 2010, we used the (unmodified) 2003 survey done by the University of Florida and SFWMD (Rivero et al. 2007, Osborne et al. 2011).

4.4.3.1 Bulk density (input = "soilBD")

Soil bulk density was assumed constant throughout time during the simulations, using unmodified data for both the historical and future simulations.

4.4.3.2 Organic bulk density (input = "soil_orgBD")

The organic bulk density is the bulk density of only the organic (ash-free) mass of the soil layer[6], using unmodified data for both the historical and future simulations..

4.4.3.3 Total phosphorus concentration (input = "soilTP")

For the historical simulation, the initial (1981) concentration of soil total phosphorus was modified from Reddy et al. (1991), reducing TP along the northeast eutrophication gradient total P, based on observations of Davis (1989) in WCA-2A from the late 1970's[7].

For the future scenarios initialized at 2010, we used the (unmodified) 2003 survey done by the University of Florida and SFWMD (Rivero et al. 2007, Osborne et al. 2011). See the Chapter 8 Model Application chapter for initial (and other time periods') soil TP concentrations.

4.4.4 Vegetation

4.4.4.1 Habitat type (input = "HAB")

For the historical simulation, we used the 1982 cattail and sawgrass distribution map (Jensen et al., 1995), aggregated from 30 m to 500 m resolution using modal frequencies within the model grid cells.

For the future scenarios initialized at 2010, we used 2003 cattail-presence data from {Zweig, 2009 #2598}.

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[5] Using GRASS GIS v6.2, v.surf.rst command, low smoothing (smooth=0.1), tension parameter at default value=40, no anisotropy. This method was developed, and documented within GRASS manual pages, specifically for interpolations of elevation and soils data sets at a variety of scales.

[6] (1-(percent_ash/100))*soilBD, where percent_ash is the percent of ash weight relative to entire core weight

[7] Maximum in northern WCA-2A was approximately 300 mg TP kg^{-1}

4.4.4.2 Macrophyte biomass (input = "icMacBio")

For the historical simulation, the initial total carbon biomass (of photosynthetic and non-photosynthetic components) of macrophytes was estimated at approximately 25-35% of the habitat-specific maximum biomass (parameter in HabParms database), with the within-habitat variation based on the estimated soil nutrient gradient in 1981 (described above for soils). This coarse adjustment was made by running the model for one year (1981) under all of the other imposed initial and boundary conditions described above, and then using the resulting biomass for subsequent initial biomass conditions.

For the future scenarios initialized at 2010, the initial carbon biomass was assigned the end-of-simulation values from the historical simulation.

4.5 Static attributes

4.5.1 Water management infrastructure

4.5.1.1 Canal and levee network (input = "CanalData.chan")

For documentation of the data file syntax and use, please see the ELMv2.5 Documentation Report, Chapter 4.

1981-2000: In ELMwca2a v2.9 historical simulation, there were 7 individual canal reaches within the WCA-2A basin that have marsh-canal overbank flows, each identified by a numeric ID. For WCA-2A, this was the same configuration of canal/levee vector topology as used in the regional ELM v2.5 - v2.8. The topology of this vector network is shown in Figure 4.1, including the relationship between the canals and the marsh elevations along the perimeter of the basin.

1965-2000: For the future simulations, the same canal and levee configurations were used (Figure 4.1).

4.5.1.2 Water control structures (input = "CanalData.struct")

1981-2000: In ELMwca2a v2.9 historical simulation, with the exception of grid cell identities, no change from ELM v2.5 (for structures associated with WCA-2A); the subset of WCA-2A structures and their attributes are shown in Figure 4.2. Note that only structures with the yellow "Calib 2.8" box checked are applicable to this historical, calibration run. (The "2.8" is also applicable to this v2.9 run).

1965-2000: For the 2010 Base run, additional structures were used (named the same as those in the SFWMM v6.6 2010 Base run). Those additional structures are designated by the orange "LORS07" check box in Figure 4.2 (the dbase does not have a separate check box for 2010 Base).

For the other future simulations (see Model Application Chapter 8), a subset of structures were operational with ELM-calculated structure flows. Inflows were: S-10A,C,D,E; STA2. Outflows were: S-11A,B,C; S-144,145,146. We chose to not include the S-7 inflow, in order to obtain a more consistent north-south flow distribution.

Figure 4.2 (next 3 pages). The water control structures used in the simulations for WCA-2A. Note that the "Alt button" designates whether a structure is used in a) the historical calibration run (the yellow "Calib 2.8" button, unchanged for v2.9), or the 2010 future Base run (the orange "LORS07" button, unchanged between older LORS07 base and the newer 2010 Base run).

For simplicity, we show one table that has a combination of the calibration and Base runs. Inflow structures have TP, SO4, and Cl concentrations that are fixed in time for the 2010 Base run, with the three dbase fields showing the assigned concentrations. The calibration run, however, used historical time series of those constituents (see Section 4.6.3 below). Moreover, the dbase has a constraint that incorrectly shows the source basin of the S-10 structures to be an STA. Note that we assumed a fixed TP inflow concentration for those inflows to be 10 ppb (ug/L) in the 2010 Base and all other future scenarios.

ELM Water Control Structure Attributes

Click Alt button for structure list

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Model ID WMM	Model ID ELM	Name	TP (ppb)	TN (ppb)	SO4 (ppt)	Cl (ppt)	Basin From	Basin To	Fr: Cell_X	Fr: Cell_Y	Fr: CanalID	To: Cell_X	To: Cell_Y	To: CanalID	Calib 2.8	LOR S07	Dcmp ECB	Dcmp FWO	2050 B2	D13R	CERP 0	Dcmp AltA	Dcmp AltB	Dcmp AltG	Dcmp AltE	Notes	grid	flag	hist	Structure loc UTM,NAD'27 N	Structure loc UTM,NAD'27 E
S10	S10	S-10A,C,D	10		0.05	0.13	STA	WCA2A	1	1				21	☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	SFWWM aggregated A,C,&D into one flow; we partion the flow equally among those structures WCA2A app - source is external (WCA1, not STA directly)	500	2	☐	2916812	564597
S10A	S10A	S-10A	10		0.05	0.13	STA	WCA2A	1	1				22	☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From Hillsboro Canal in WCA-1 to NE region of WCA-2A. S10-A,C,D similar. (SFWWM aggregates A,C,&D into 1 flow, RSM/ELM separates structures). WCA2A app - source is external (WCA1, not STA directly)	500	20	☒	2915509	568595
S10C	S10C	S-10C	10		0.05	0.13	STA	WCA2A	1	1				21	☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From Hillsboro Canal in WCA-1 to NE region of WCA-2A. S10-A,C,D similar. (SFWWM aggregates A,C,&D into 1 flow, RSM/ELM separates structures). WCA2A app - source is external (WCA1, not STA directly)	500	20	☒	2916812	564597
S10D	S10D	S-10D	10		0.05	0.13	STA	WCA2A	1	1				21	☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From Hillsboro Canal in WCA-1 to NE region of WCA-2A. S10-A,C,D similar. (SFWWM aggregates A,C,&D into 1 flow, RSM/ELM separates structures). WCA2A app - source is external (WCA1, (not STA directly)	500	20	☒	2918674	561603
S10E	S10E	S-10E	10		0.05	0.13	STA	WCA2A	1	1		25	2		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From Hillsboro Canal in WCA-1 to northern tip of WCA-2A. Much smaller structure than other S-10s (A,C,D). Is all-zero in most future sims WCA2A app - source is external (WCA1, not STA directly)	500	1	☒	2927215	555559
	S11	S11					WCA2A	WCA3A			27	1	1		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From North New River Canal in SW WCA-2A into L-38W canal in NE WCA-3A. S-11-A,B,C similar. SFWWM aggregates A,B,&C into 1 flow. For future base/alts, ELM partitions the flow among structs. ELM calib uses indiv. flows. WCA2A app.	500	3	☒	2895631	554989
S11A	S11A	S-11A					WCA2A	WCA3A			27	1	1		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From North New River Canal in SW WCA-2A into L-38W canal in NE WCA-3A. S-11-A,B,C similar. SFWWM aggregates A,B,&C into 1 flow. For future base/alts, ELM partitions the flow among structs. ELM calib uses indiv. flows. WCA2A app.	500	30	☒	2895631	554989
S11B	S11B	S-11B					WCA2A	WCA3A			27	1	1		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From North New River Canal in SW WCA-2A into L-38W canal in NE WCA-3A. S-11-A,B,C similar. SFWWM aggregates A,B,&C into 1 flow. For future base/alts, ELM partitions the flow among structs. ELM calib uses indiv. flows. WCA2A app.	500	30	☒	2897537	554772
S11C	S11C	S-11C					WCA2A	WCA3A			27	1	1		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From North New River Canal in SW WCA-2A into L-38W canal in NE WCA-3A. S-11-A,B,C similar. SFWWM aggregates A,B,&C into 1 flow. For future base/alts, ELM partitions the flow among structs. ELM calib uses indiv. flows. WCA2A app.	500	30	☒	2901011	553772
S143	S143	S-143					WCA2A	WCA2B			27	1	1		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From south WCA-2A into NNRiver canal reach above S-34 (which controls further down-canal flows); G-123 pumps north across S-34; S-141 is release from 2B above S-34); S-142 is in/out of 3A above S-34. NNRiver Canal does not exchange with 2B marsh, thus not part of basin 2B sfwmm budget. WCA2A app.	500	1	☒	2895631	554989
S144	S144	S-144					WCA2A	WCA2B			24	1	1		☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	From L35B borrow in south WCA-2A into WCA2B (three identical structs, 144,145,146) WCA2A app.	500	1	☒	2900000	560159

ELM Water Control Structure Attributes

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WMM Model ID	ELM Model ID	Name	TP (ppb)	TN (ppb)	SO4 (ppt)	Cl (ppt)	Basin From	Basin To	Fr: Cell_X	Fr: Cell_Y	Fr: CanalID	To: Cell_X	To: Cell_Y	To: CanalID	Calib 2.8	LOR S07	Dcmp ECB	Dcmp FWO	2050 B2	D13R	CERP 0	Dcmp AltA	Dcmp AltB	Dcmp AltG	Dcmp AltE	Description	grid	flag	hist	Structure loc UTM,NAD'27 N	Structure loc UTM,NAD'27 E
S145	S145	S-145					WCA2A	WCA2B			24	1	1		xx	x	☐	☐	x	x	x	☐	☐	☐	☐	From L35B borrow in south WCA-2A into WCA2B (three identical structs, 144,145,146) WCA2A app.	500	1	x	2900492	563348
S146	S146	S-146					WCA2A	WCA2B			24	1	1		x	x	☐	☐	x	x	x	☐	☐	☐	☐	From L35B borrow in south WCA-2A into WCA2B (three identical structs, 144,145,146) WCA2A app.	500	1	x	2900608	566565
S38	S38	S-38 S-38A					WCA2A	LEC			24	1	1		x	x	☐	☐	x	x	x	☐	☐	☐	☐	From L-38 canal in SE WCA-2A into C-14 canal of LEC (see also S-38A,B) WCA2A app.	500	1	x	2901181	570113
S7BPMR	S7BPMR	S-7	85		0.05	0.13	EAA	WCA2A	1	1				26	☐	x	☐	☐	x	x	x	☐	☐	☐	☐	EAA runoff bypassing STA3/4 that is contribution to S-7 inflow into WCA-2A ST3TS7+WL1351+S7BPMR+WLES7) = S7 WCA2A app.	500	1	☐	2912764	546237
ST2BYP	ST2BYP	G-335	99		0.05	0.13	EAA	WCA2A	1	1				15	☐	x	☐	☐	x	x	x	☐	☐	☐	☐	STA2 bypass of EAA runoff into 2A into distribution canal along NW region. (Historical TP=163 ug/L; reduce 25% for BMPs) WCA2A app.	500	1	☐	2919559	550433
ST3TS7	ST3TS7	S-7	10		0.05	0.13	STA_2	WCA2A	1	1				26	☐	x	☐	☐	x	x	x	☐	☐	☐	☐	STA 3/4 contribution to S-7 inflow into WCA-2A (ST3TS7+WL1351+S7BPMR+WLES7) = S7 (STA3/4 out=> G-376, G-379, G-381) WCA2A app.	500	1	☐	2912764	546238
STA2EO	STA2EO	G-336A-F	10		0.05	0.13	STA	WCA2A	1	1				15	☐	x	☐	☐	x	x	x	☐	☐	☐	☐	STA2 outflow into NW WCA-2A Germain etal 2011 SFER: 1994-2010 FWMean TP=23 ug/L (G-334, G-332, G-330A-E from Cells, then to G-335 into canal, then south for distribution or north to G-336A-F inflows into WCA-2A). WCA2A app.	500	1	☐	2919559	550433
STA2MO	STA2MO	G-336A-F	10		0.05	0.13	STA	WCA2A	1	1				15	☐	x	☐	☐	x	x	x	☐	☐	☐	☐	STA2 outflow into NW WCA-2A Germain etal 2011 SFER: 1994-2010 FWMean TP=23 ug/L (G-334, G-332, G-330A-E from Cells, then to G-335 into canal, then south for distribution or north to G-336A-F inflows into WCA-2A). WCA2A app	500	1	☐	2919559	550433
STA2WO	STA2WO	G-336A-F	10		0.05	0.13	STA	WCA2A	1	1				15	☐	x	☐	☐	x	x	x	☐	☐	☐	☐	STA2 outflow into NW WCA-2A Germain etal 2011 SFER: 1994-2010 FWMean TP=23 ug/L (G-334, G-332, G-330A-E from Cells, then to G-335 into canal, then south for distribution or north to G-336A-F inflows into WCA-2A). WCA2A app.	500	1	☐	2919559	550433
	VS2A4	VS2A4					WCA2A	WCA2A			21			22	x	x	☐	☐	x	x	x	☐	☐	☐	☐	A virtual structure linking borrow along northeast corner of WCA2A WCA2A app.	500	0	☐	2915855	567481
	VS2A5	VS2A5					WCA2A	WCA2A			22			23	x	x	☐	☐	x	x	x	☐	☐	☐	☐	A virtual structure linking borrow along eastern WCA2A to south WCA2A app.	500	0	☐	2911466	570068

ELM Water Control Structure Attributes

Click Alt button for structure list

GO TO: Details

Model ID		Name	TP (ppb)	TN (ppb)	SO4 (ppt)	Cl (ppt)	Basin From	Basin To	Fr: / To:	Cell_X	Cell_Y	CanalID	Calib 2.8	LOR S07	Dcmp ECB	Dcmp FWO	2050 B2	D13R	CERP 0	Dcmp AltA	Dcmp AltB	Dcmp AltG	Dcmp AltE		grid	flag	hist	Structure loc UTM,NAD'27
WMM		VS2A6					WCA2A	WCA2A	Fr:			23	☒	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	A virtual structure linking borrow along SE WCA2A to L-35B WCA2A app.	500	0	☐	N 2901521
ELM	VS2A6								To:			24																E 570057
WMM	WL1351	S-7	108		0.05	0.13	LOK	WCA2A	Fr:	1	1		☐	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	LEC water supply from LOK contribution to S-7 inflow into WCA-2A (ST3TS7+WL1351+S7BPMR+WLES7) = S7 Historical TP=78 ug/L WCA2A app	500	1	☐	N 2912764
ELM	WL1351								To:			26																E 546237
WMM	WLES7	S-7	85		0.05	0.13	EAA	WCA2A	Fr:	1	1		☐	☒	☐	☐	☒	☒	☒	☐	☐	☐	☐	LEC water supply from EAA contribution to S-7 inflow into WCA-2A (reduce 159 ppb by 25% to accomodate BMPs) (ST3TS7+WL1351+S7BPMR+WLES7) = S7 WCA2A app	500	1	☐	N 2912764
ELM	WLES7								To:			26																E 546237

4.5.2 Model parameters

None of these parameters have been updated from ELM v2.5 - v2.8; please see the ELMv2.5 - v2.8 Documentation Reports, Chapter 4.

4.5.2.1 Global parameters (input = "GlobalParms_NOM")

None of these parameters have been updated from ELM v2.5 - v2.8; please see the ELMv2.5 - v2.8 Documentation Reports, Chapter 4.

4.5.2.2 Habitat-specific parameters (input = "HabParms_NOM")

None of these parameters have been updated from ELM v2.5 - v2.8; please see the ELMv2.5 - v2.8 Documentation Reports, Chapter 4.

4.5.2.3 Aquifer hydraulic conductivity (input = "HydrCond")

No change in data values from ELM v2.5 - v2.8: the 1km^2 ELM v2.5 map was resampled and filtered to obtain the 500x500 m grid data used in ELMwca2a v2.9; for map data description and methods, please see the ELMv2.5 Documentation Report, Chapter 4.

4.6 Boundary conditions

4.6.1 Meteorological

4.6.1.1 Rain (input = "rain.BIN")

No change from ELM v2.5 - v2.8 (uses gridIO file used by SFWMM v5.4); please see the ELMv2.5 Documentation Report, Chapter 4.

4.6.1.2 Evapotranspiration (input = "ETp.BIN")

No change from ELM v2.5 - v2.8 (uses gridIO file used by SFWMM v5.4); please see the ELMv2.5 Documentation Report, Chapter 4.

4.6.2 Hydrologic

4.6.2.1 Flow constraints (input ="BoundCond")

The WCA-2A basin is a no-flow boundary for surface water; for map data description and methods, please see the ELMv2.5 Documentation Report, Chapter 4.

4.6.2.2 Stage/depth (input = "BoundCond_stage.BIN")

1981-2000: No change from ELM v2.5 (and SFWMM v5.4) historical simulation; please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: Used SFWMM v6.6 output from the 2010 Base simulation; for those assumptions, please see Application Chapter of this document; for input data methods, please see the ELMv2.5 Documentation Report, Chapter 4.

4.6.2.3 Tidal height and/or stage regulation schedule (input = "CanalData.graph")

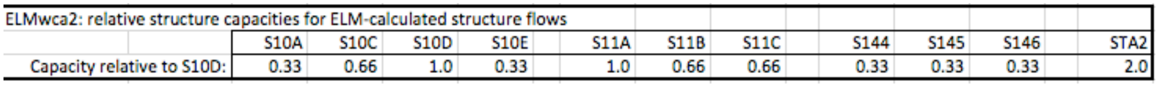
Not applicable for either the historical calibration run nor the 2010 Base run, which both have assigned daily time series of all water control structure flows. For the other future scenario runs, two different stage regulation schedules were used. Please see the Chapter 8 Model Application chapter for definitions of those regulation schedules.

4.6.2.4 Managed structure flows (input = "CanalData.struct_wat")

1981-2000: No change from ELM v2.5 - v2.8 historical simulation (for structure flows associated with WCA-2A); please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: Used either a) SFWMM v6.6 output from the 2010 Base simulation or b) ELM-calculated managed flows; for those assumptions, please see Application Chapter of this document. Figure 4.3 shows the relative flow capacities of all of the inflow and outflow structures for the ELM-calculated managed flow structures. For input data methods, please see the ELMv2.5 Documentation Report, Chapter 4.

Figure 4.3. For the structures with ELM-calculated flows, the flow capacity of each structure as a proportion of that of S-10D. The actual capacities were sized to approximate those in the SFWMM v6.6 2010 Base run simulation.



ELMwca2: relative structure capacities for ELM-calculated structure flows

	S10A	S10C	S10D	S10E	S11A	S11B	S11C	S144	S145	S146	STA2
Capacity relative to S10D:	0.33	0.66	1.0	0.33	1.0	0.66	0.66	0.33	0.33	0.33	2.0

4.6.3 Nutrient/constituent inflows

4.6.3.1 Atmospheric phosphorus & chloride deposition

For phosphorus and chloride, there were no changes from ELM v2.8; please see the ELM v2.8 Documentation Report, Chapter 4.

4.6.3.2 Phosphorus in structure inflows (input = "CanalData.struct_TP")

1981-2000: No change from ELM v2.5 - v2.8 (for structures associated with WCA-2A); please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: Used concentrations that were constant in time, for water control structure flows from either a) SFWMM v6.6 output for the 2010 Base simulation or b) ELM-calculated managed flows; for those assumptions, please see Application Chapter of this document; for input data methods, please see the ELMv2.5 Documentation Report, Chapter 4.

4.6.3.3 Chloride in structure inflows (input = "CanalData.struct_TS")

1981-2000: No change from ELM v2.5 - v2.8 (for structures associated with WCA-2A); please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: Used concentrations that were constant in time, for water control structure flows from either a) SFWMM v6.6 output for the 2010 Base simulation or b) ELM-calculated managed flows; for those assumptions, please see Application Chapter of this document; for input data methods, please see the ELMv2.5 Documentation Report, Chapter 4.

4.7 Performance assessment targets

4.7.1 Hydrologic

4.7.1.1 Stage

No change from ELM v2.5 (for monitoring sites associated with WCA-2A); please see the ELMv2.5 Documentation Report, Chapter 4.

4.7.2 Water quality

4.7.2.1 Surface water quality constituents

No change to data from ELM v2.5 - v2.8 (for monitoring sites associated with WCA-2A); please see the ELMv2.5 Documentation Report, Chapter 4.

4.8 Literature cited

Daroub, S., J. D. Stuck, R. W. Rice, T. A. Lang, and O. A. Diaz. 2002. Implementation and Verification of BMPs for Reducing Loading in the EAA and Everglades Agricultural Area BMPs for Reducing Particulate Phosphorus Transport. Phase 10 Annual Report WM 754, Everglades Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida. Belle Glade, FL.

Davis, S. M. 1989. Sawgrass and cattail production in relation to nutrient supply in the Everglades. Pages 325-341 *in* R. R. Sharitz and J. W. Gibbons, editors. Freshwater Wetlands and Wildlife, DOE Symposium Series No. 61. USDOE Office of Scientific and Technical Information, Oak Ridge, Tennessee.

Desmond, G. 2004. High Accuracy Elevation Data Collection. World Wide Web, USGS, http://sofia.usgs.gov/projects/elev_data/.

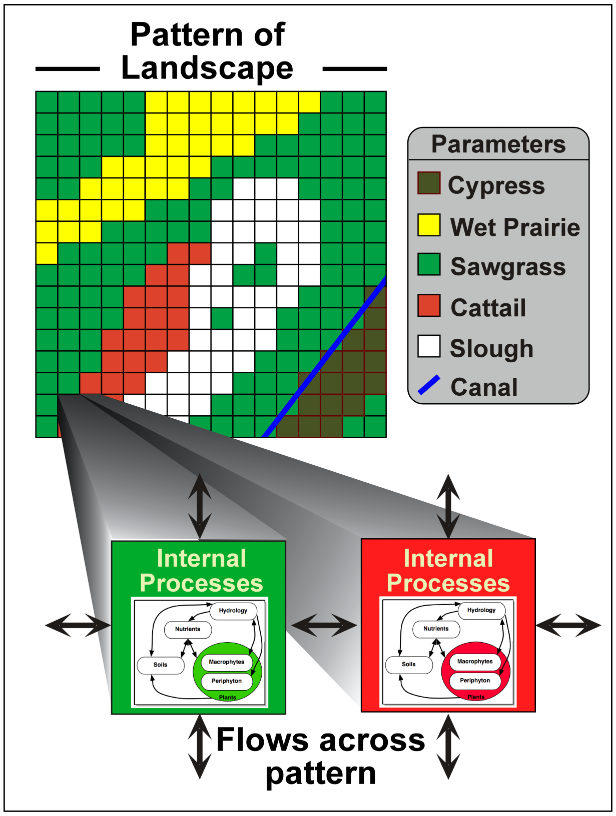
Mesehle, E. A., A. G. Griborio, and S. Gautam. 2005. Hydrodynamic and water quality modeling for the A.R.M. Loxahatchee National Wildlife Refuge: Phase I: Preparation of Data. Report #LOXA05-014. University of Louisiana - Lafayette, Lafayette, LA.

Osborne, T. Z., S. Newman, D. J. Scheidt, P. I. Kalla, G. L. Bruland, M. J. Cohen, L. J. Scinto, and L. R. Ellis. 2011. Landscape Patterns of Significant Soil Nutrients and Contaminants in the Greater Everglades Ecosystem: Past, Present, and Future. Critical Reviews in Environmental Science and Technology **41**:121 - 148.

Rivero, R. G., S. Grunwald, T. Z. Osborne, K. R. Reddy, and S. Newman. 2007. Characterization of the spatial distribution of soil properties in water conservation Area 2A, Everglades, Florida. Soil Sci. Soc. Am. J. **172**:149–166.

Documentation of the Everglades Landscape Model: ELM v2.9.0

Chapter 5: Model Structure



http://www.ecolandmod.com

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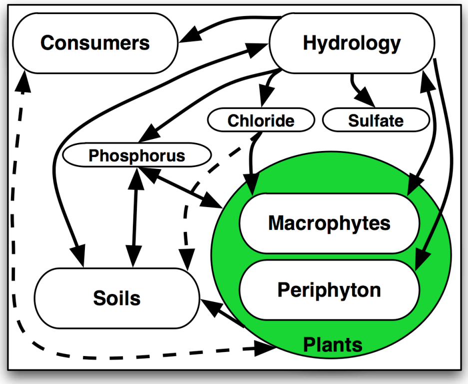
June 16, 2015

Chapter 5: Model Structure

5.1 Overview

The focus of this Chapter is the description of a new Consumers module. For this ELM v2.9.0 Wading Bird Suitability project, we added a new module with simple calculations of hydrologic suitability for wading birds. This module has no affect on any of the other simulated hydrologic, biogeochemical, or biological dynamics.



The Consumers module simulates the "vertical solutions" of calculations of five discrete suitability categories of surface water depths, and six discrete suitability categories of surface water recession rates (i.e., the rate at with surface water depths decrease with time). The module calculates the rate at which surface water depth decreases over a discrete time period. Twelve new parameters were added to the GlobalParms.xlsx input file (see Data Chapter 4), classifying the relative suitability of water depths for wading birds, and the relative suitability of recession rates for wading birds, during a prescribed time interval during a prescribed season of wading bird breeding.

This Chapter on Model Structure for ELM v2.9.0 serves to update the ELM v2.8.6, 2.8.4, and v2.5.2 Documentation Reports, which are available at: http://www.ecolandmod.com/publications. Therefore, this is not a “stand-alone” document on the overall model structure, but simply describes the new Consumer (wading bird) module. For reader convenience, we also provide an updated table summarizing all code revisions since ELM v2.5.2.

The source code and data of the ELM are Open Source, in order to encourage collaboration in the research and modeling community. However, the current ELM v2.9.0 is not considered a public release at this point.

Thus, the source code and data provided to the Everglades Systems Assessment Section (and Interagency Modeling Center) of SFWMD are ***not to be released to other parties***.

5.2 Background

5.2.1 Application summary

The South Florida Water Management District provided the funding to develop a new ELM module to simulate consumer dynamics, specifically hydrologic suitability indices for wading birds. The only model structure (source code) changes for this new ELM v2.9.0 application involved those associated with the Consumers module. All of the other code used in this application remain the same as those used in the regional ELM v2.8.6, and thus documentation of those are found in prior publications: ELM v2.8.6 Documentation Report[1], ELM v2.8.4 Documentation Report[2], and the ELM v2.5 Documentation Report[3].

We applied this (subregional) v2.9.0 application to help evaluate wading bird responses to hypothetical scenarios of water management alternatives in WCA-2A. As always with ELM design, the same code is used in model applications at any spatio-temporal scale. The results of that application are posted on the EcoLandMod web site at http://www.ecolandmod.com/projects/ELMwca2a.

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[1] Fitz, H. C. 2013. Documentation of the Everglades Landscape Model: ELM v2.8.6 - Sulfate Module. Ft. Lauderdale Research and Education Center, University of Florida. http:// www.ecolandmod.com//publications/. 128 pp.

[2] Fitz, H.C., and R. Paudel. 2012. Documentation of the Everglades Landscape Model: ELM v2.8.4. Ft. Lauderdale Research and Education Center, University of Florida. http://www.ecolandmod.com/publications/. 364 pp.

[3] Fitz, H.C., and B. Trimble. 2006. Documentation of the Everglades Landscape Model: ELM v2.5. South Florida Water Management District, http://ecolandmod.ifas.ufl.edu/publications (Reviewed by independent expert panel, review report at http:// www.ecolandmod.com//publications) 664 pages.

5.3 Update summary, ELM v2.5 – v2.9

This Model Structure Chapter 5 for ELM v2.9.0 describes ONLY changes that were made for the new Consumers module.

As summarized in Table 5.1, a variety of other modifications were made to the ELM between v2.5 and v2.9.0. For details on each update, see the Documentation Reports (http://www.ecolandmod.com/publications) associated with the updates.

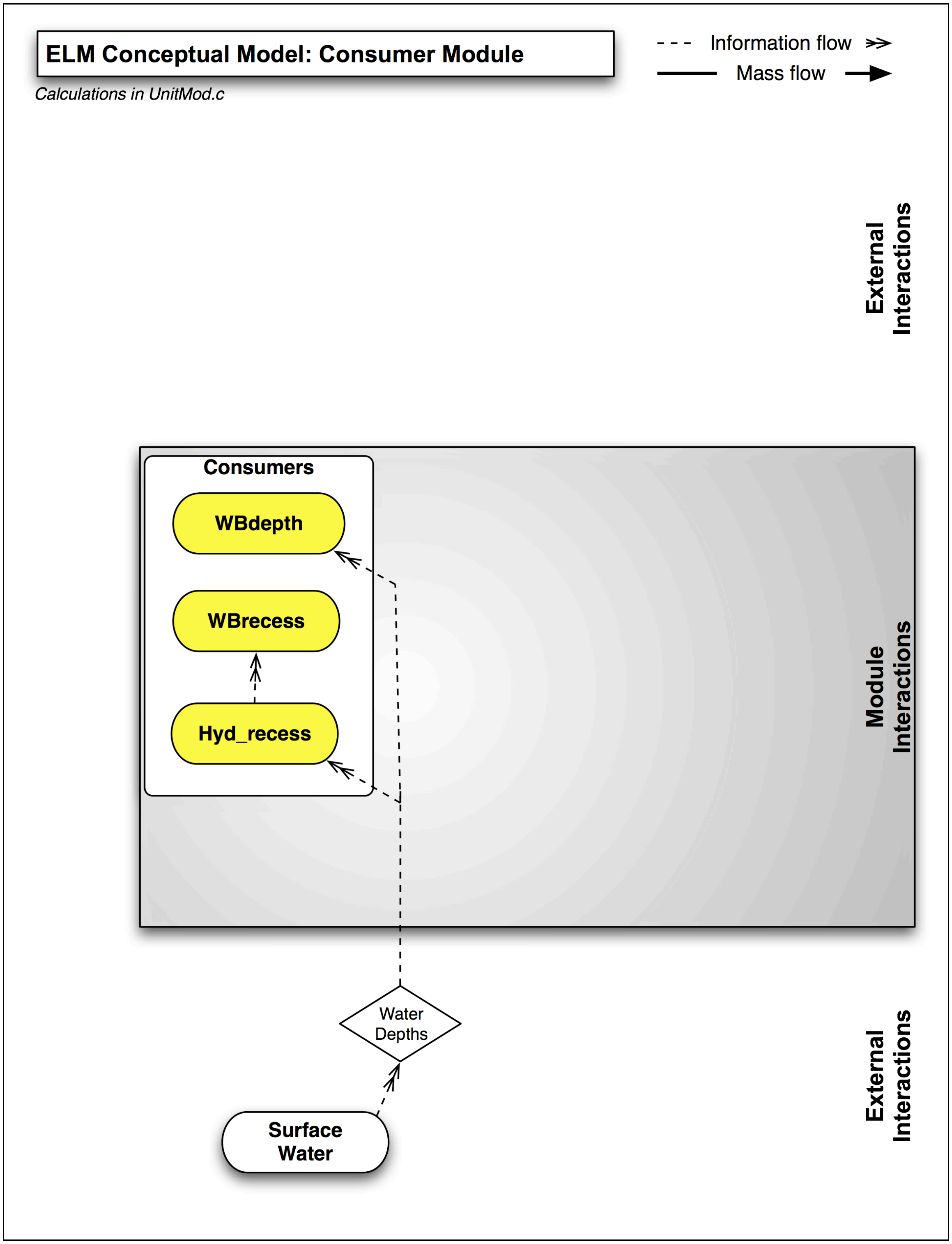
Table 5.1. Summary of updates to code for ELM applications, v2.5 through 2.9.

Version	**Date**	**Purpose**	**Description/*detail***
2.5.2	Jul-06	Public release	Complete documentation, source code, data for regional application
2.6.0	Nov-06	Expand functionality	In response to Peer Review Panel requests, modified input/output utility functions, for greater flexibility in boundary conditions *a) new data for Ridge&Slough subregional application, century time scales*
2.6.1	Jan-07	Documentation update	Following Peer Review project, misc updates to code and data documentation, for finalizing results of Peer Review project
2.7.a	Jul-07	No code changes	New spatial data, for prototype of new regional application at 500 m grid resolution; improved model-installation methods
2.7.0	Oct-07	Expand functionality; bug fixes	Formalize velocity calculations for sediment transport; enhance multi-grid modeling capabilities *a) increased number of point time series locations that may be output;* *b) corrected stage vs. depth code for overland flows from SFWMM at domain periphery (identified during Peer Review)* *c) corrected code that was intended to "auto-scale" constituent dispersion at different grid resolutions (identified during Peer Review)* *d) option to output surface water flow velocities in grid cells*
2.7.1	Nov-07	Expand functionality	Prototyping for increased flexibility in water management options (designing to be limited in scope/complexity) *a) prototype restructuring of modules for rule-based water control structure flow* *b) option to output grid-cell information from boundary-condition model (e.g., SFWMM)*

Table 5.1 (continued). Summary of updates to code for ELM applications, v2.5 through 2.9.

Version	**Date**	**Purpose**	**Description/*detail***
2.8.0	Dec-07	No code changes	New land surface elevation map & new vertical datum, for optional use in new regional application at 500 m grid resolution
2.8.1	Feb-08	Expand functionality	Completed update to rule-based water management modules; other extensions to capabilities *a) increased modularity to support expanded capabilities in triggering rule-based managed flows* *b) added chloride atmospheric deposition equation and supporting dbase change* *c) added option to output new Basin/Indicator-Region file; extended option to output boundary-condition model data (e.g., NSM/SFWMM)*
2.8.2	Jul-08	Expand functionality	Additional spatial array (map) output capabilities *a) added floating point spatial array output options* *b) added self-documenting netCDF spatial array output options* *c) added units to Model.outList (runtime configuration) file, to support self-documenting netCDF format*
2.8.3	Feb-09	Public release	Documentation for public release, regional and subregional applications
2.8.4	Jan-12	Public release	Documentation for public release, regional and subregional applications. ELM v2.8.4 is used in CERP Decomp project (Minor changes to some data, added model performance analysis, changes to user-guide. Minor version documentation update provided for complete documentation of version used in CERP Decomp)
2.8.6	Jan-13	Expand functionality	Documentation for new sulfate water quality module, regional (and subregional) applications. ELM v2.8.6 is used in CERP ASR project. (Minor version documentation updated provided for complete documentation of version used in CERP ASR)
2.9.0	Jun-15	Expand functionality	Documentation for new Consumers module, incorporating hydrologic suitability calculations for wading birds, and subregional application to WCA-2A

5.4 Consumers module (v2.9.0)



5.4.1 Overview: Consumers Module

The new Consumers module simply calculates hydrologic suitability indices for wading birds, with Surface Water Depth being the only driving variable, and the indices do not influence any other model variable. During every daily iteration, a surface water depth weekly recession rate is calculated across a parameter-defined time interval (currently using 2 weeks). During the (parameter-defined) months of the wading bird breeding season (currently December 1 - May 31), a) the recession rate is classified into six (parameter defined) categories of suitability for wading birds, and b) the water depth is classified into five (parameter defined) categories of suitability for wading birds. The parameters and specific Performance Measures are described in the Data Chapter 4 and the Wading Bird Suitability Project application report (available at http://www.ecolandmod.com/publications).

5.4.2 Consumers Module Equations

All vertical solution modules are processed in the UnitMod.c source code file (Consumers module is cell_dyn5) within a spatial loop across columns and rows of the model grid (see ELM v2.5.2 Documentation Report, Chapter 5 Model Structure). In the Generic_Driver.c source code file, the global timer (C language) structure determines whether the current day iteration is within the wading bird season (defined by two Global Parameters defining the beginning and ending days of the breeding season), contained within the (C language) structure SimTime.IsWB_breed.

During every daily iteration within each wading bird breeding season day, for each grid cell address (cellLoc), the surface water depth (SURFACE_WAT[cellLoc]) is used to classify the variable WBdepth[cellLoc] into five categories defined by Global Parameters input from the GlobalParms_NOM (see Data Chapter 4):

Category	Description
1	WBdepth_dry = sfwat<GP_WBdepth_Dry
2	WBdepth_subopt_dry = sfwat ≥ GP_WBdepth_Dry && sfwat <GP_WBdepth_optLow
3	WBdepth_opt = sfwat ≥ GP_WBdepth_optLow && sfwat <GP_WBdepth_optHi
4	WBdepth_subopt_wet = sfwat ≥ GP_WBdepth_optHi && sfwat <GP_WBdepth_Wet
5	WBdepth_wet = sfwat ≥ GP_WBdepth_Wet

During every daily iteration, a (C language) structure Hist_depth[jj].mapDepth[cellLoc] stores a temporal 2D spatial array of historical water depths within the recession rate interval number of days, defined by the Global Parameter GP_WBrecc_Intvl (currently 14 days). Every daily iteration, a weekly recession rate is calculated by:

```
Hyd_recc[cellLoc] = (Hist_depth[0].mapDepth[cellLoc] -
        Hist_depth[ii].mapDepth[cellLoc])*100.0/(GP_WBrecc_Intvl/7.0)
```

where Hyd_recc is the recession rate (cm/week), Hist_depth[0].mapDepth is the SURFACE_WAT (m) at the beginning time 0 of each recession rate interval, Hist_depth[ii].mapDepth is the SURFACE_WAT (m) at the current time ii, 100.0 is the conversion of m to cm, and 7.0 is the number of days per week.

During every daily iteration within each wading bird breeding season day, for each grid cell address (cellLoc), the recession rate is classified within the variable WBrecc[cellLoc] into six categories defined by Global Parameters input from the GlobalParms_NOM (see Data Chapter 4):

Category	Description
0	WBrecc_srev = Hyd_recc<GP_WBrecc_srev
1	WBrecc_rev = Hyd_recc ≥ GP_WB_srev && Hyd_recc<GP_WBrecc_rev
2	WBrecc_subopt_slow = Hyd_recc ≥ GP_WBrecc_rev && Hyd_recc <GP_WBrecc_optSlow
3	WBrecc_opt = Hyd_recc ≥ GP_WBrecc_optSlow && Hyd_recc < GP_WBrecc_optFast
4	WBrecc_subopt_fast = Hyd_recc ≥ GP_WBrecc_optFast && Hyd_recc <GP_WBrecc_Fast
5	WBrecc_fast = Hyd_recc≥GP_WBrecc_Fast

During every daily iteration, counters increment the spatial area and total number of days during the breeding season for each of the categories of the WBdepth and WBrecc variables, and the results appended to two summary text files (CONS_WB_1 and CONS_WB_2) at the end of each breeding season. The variables are also available for user-defined output as standard spatial map variables.

Documentation of the
Everglades Landscape Model:
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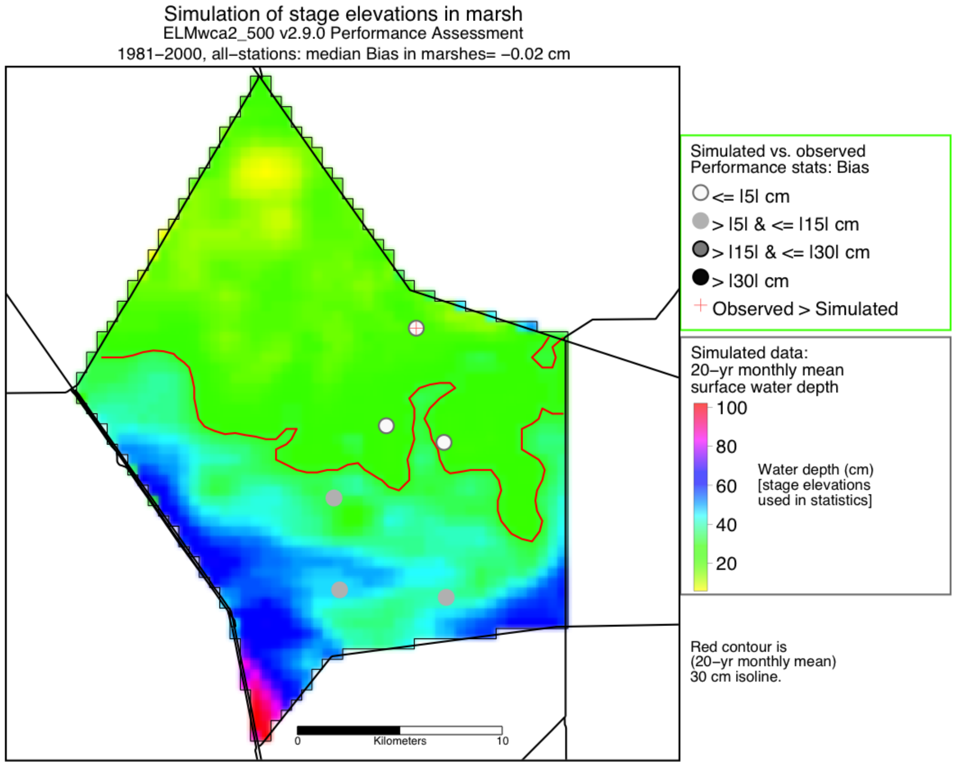
Chapter 6: Model Performance



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June 2, 2015

Chapter 6: Model Performance

6.1 Executive summary

As described in the Introduction Chapter of this documentation, an overarching Goal of the ELM is to understand and predict ecological dynamics across the greater Everglades landscape. For the current ELMwca2a v2.9.0 subregional application for Water Conservation Area 2A (WCA-2A), we are evaluating ecological responses to spatio-temporal changes in water depth in WCA-2A, specifically to evaluate a water management scenario: a hypothetical regulation schedule that is intended to provide depths and hydropatterns that are more suitable for wading birds (and other wildlife). We are specifically interested in assessing hydrology in areas which are currently unsuitable habitat due to nutrient enrichment, but may become suitable with active management improvement strategies. The model capabilities that are summarized here support the use of this application to evaluate relative differences in system hydrologic (and ecological) behavior over decadal time scales, at a spatial resolution of 500 meters across more than 400 square kilometers

Overall, the fine-scale (500x500 m, or 0.25 km^2) ELMwca2a application further demonstrated the robust nature of the ELM code and data: without modifying algorithms or parameters for this subregional application (beyond the addition of a new Consumer module), the new application exhibited improvements to model performance ("skill" in hindcasting observed data) relative to that of the regional, 1km^2 ELM v2.5 and 0.25 km^2 ELM v2.8 applications. With that benchmark being one of the primary criteria for acceptance for use in WCA-2A planning, the ELMwca2a appears to be an application well-suited to meet the objectives of this project. In support of this conclusion are the quantitative and qualitative lines of evidence. The statistical metrics of ELMwca2a performance characteristics showed that predictive biases were small relative to important hydrologic (and ecological) dynamics: overall, water stage was simulated to within 2 cm of long-term observations, while aggregated phosphorus and chloride predictions were low relative to the observed data (although those dynamics are not explicitly being used in the current project). Importantly, temporal and spatial trends in hydrologic (and water quality) predictions were consistent with our understanding of the complex exchanges of water and constituents along the significant hydro-ecological gradients within the marshes of this hydrologic basin.

6.2 Background

6.2.1 Application summary

The ELMwca2a version 2.9[1] was developed in order to evaluate relative differences in ecological (primarily wading bird) performance of Everglades Water Conservation Area 2A (WCA-2A). As described in the Data Chapter 4 and Model Structure Chapter 5, we created a new Consumer module that currently only includes Wading Bird hydrologic suitability metrics. All other model code and data components remain the same as those described for the most recent regional application, ELM v2.8.6 (http://www.ecolandmod.com/publications/index.html#ELM286).

6.2.2 ELMwca2a v2.9 application niche

As described in the Introduction Chapter of this documentation, an overarching Goal of the ELM is to understand and predict long-term ecological dynamics across the greater Everglades landscape. As our understanding of the Everglades system improves with research and monitoring, a model such as ELM can be used for an increased range of applications - within an application niche of the model.

The ELM application niche is broadly defined in the Introduction Chapter of this documentation, and is further specified in this Model Performance Chapter and in the Model Application Chapter. The model Performance Measures are central to the concept of an application niche. The (relative) predictions of the behavior of Performance Measure variables at specific spatio-temporal scales define the bounds of the application niche, and the objectives of the model are simply to support applications involving analysis of those Performance Measures. Thus, this Model Performance Chapter is intended to provide users with an understanding of the degree of confidence to use in evaluating relative differences among alternative scenarios – i.e., quantitative metrics of the "model skill" in depicting ecosystem dynamics - and in this case, primarily hydrologic dynamics.

For the current ELM v2.9 WCA-2 (ELMwca2a) application, the available ecological Performance Measures include those specific to Wading Bird ecology, and supplementary metrics related to water quality. For scenario analyses in the Model Application Chapter, these variables were used in a broader array of Performance Measures that were deemed important for the WCA-2A research project. For these Performance Measures, the appropriate spatial and temporal scales were maintained relative to this Chapter's "model skill" assessment.

For the regional (ELM v2.5, v2.8) application, other ecological variables (such as soil phosphorus, cattail succession) were examined for determining the "ecological consistency" between predicted and observed data. While those comparisons remain appropriate for understanding model capabilities in general, they were not repeated for this subregional application, as those variables were not necessary to meet the goals of the WCA-2A research project.

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[1] The tertiary subversion designation of this v2.9 application release is v2.9.0.

6.3 Performance evaluation methods

The methods used to aggregate simulated and observed data, and statistically evaluate the comparisons among data, were described in the ELM v2.5 Documentation Report[2], and are not repeated here. The same methods were used to evaluate the model performance within this subset of space and time for the WCA-2A subregional application.

6.4 Model configuration

While the topology of the canals along the boundary of WCA-2A were slightly modified from regional ELM v2.8, no changes were made to any other parameters used in the model (i.e., in the HabParms or GlobalParms databases).

In the ELM v2.9 WCA2A application, the model was configured to simulate historical conditions inclusive of the years 1981 – 2000.

The domain was that of the subregional hydrologic basin of WCA-2A, employing a 500x500m m grid mesh encompassing that hydrologic domain. The vector topology of the canal/levee network and the point locations of water control structures were constant during the historical simulation period. The habitat succession module was operating, as were all other ecological modules, providing dynamic feedbacks among the physics, chemistry, and biology of the mosaic of ecosystems in the landscape. Dynamic boundary conditions included daily data on rainfall, potential evapotranspiration, managed water control structure flows with associated constituent concentrations, and stage (along the borders of the domain). Full descriptions of the requisite data and the functionality of the algorithms and source code are provided in other Chapters of this documentation.

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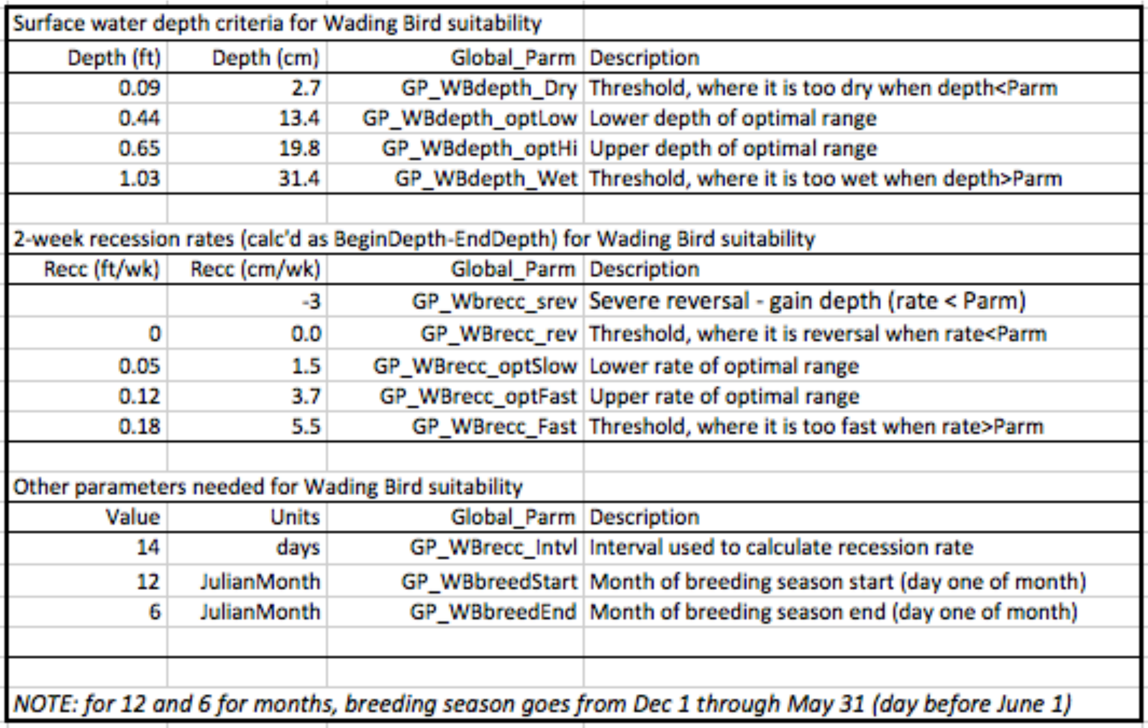
[2] Fitz, H.C., and B. Trimble. 2006. Documentation of the Everglades Landscape Model: ELM v2.5. South Florida Water Management District. http://my.sfwmd.gov/elm Reviewed by independent expert panel, reported at http://my.sfwmd.gov/elm 664 pages.

6.5 *Performance results*

6.5.1 Ecological performance

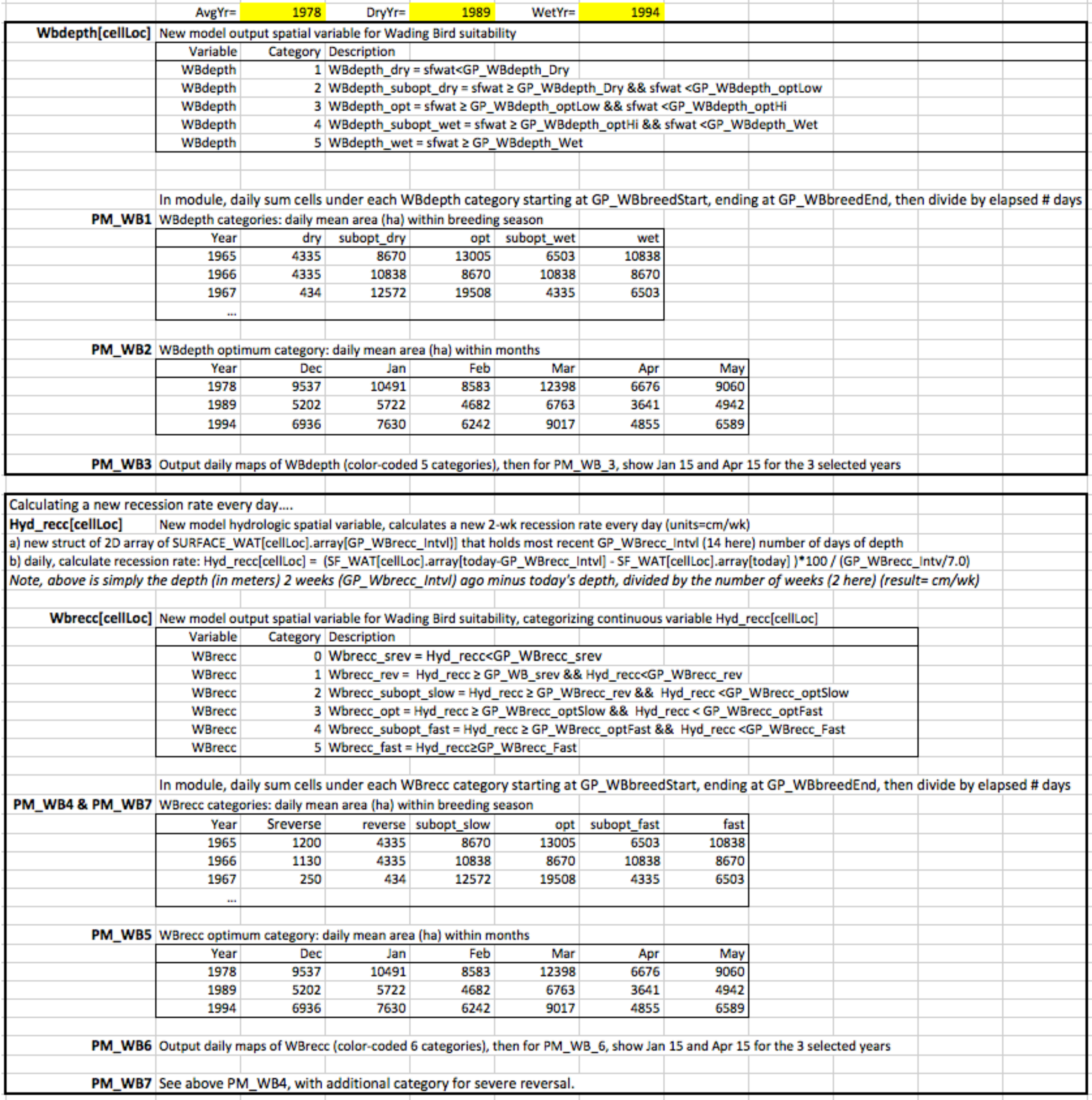
6.5.1.1 Wading Bird Suitability

The Consumer (now only Wading Bird) module uses a variety of new Global Parameters that are input to the model at the beginning of a run. These are:



Surface water depth criteria for Wading Bird suitability			
Depth (ft)	Depth (cm)	Global_Parm	Description
0.09	2.7	GP_WBdepth_Dry	Threshold, where it is too dry when depth<Parm
0.44	13.4	GP_WBdepth_optLow	Lower depth of optimal range
0.65	19.8	GP_WBdepth_optHi	Upper depth of optimal range
1.03	31.4	GP_WBdepth_Wet	Threshold, where it is too wet when depth>Parm
2-week recession rates (calc'd as BeginDepth-EndDepth) for Wading Bird suitability			
Recc (ft/wk)	Recc (cm/wk)	Global_Parm	Description
	-3	GP_Wbrecc_srev	Severe reversal - gain depth (rate < Parm)
0	0.0	GP_WBrecc_rev	Threshold, where it is reversal when rate<Parm
0.05	1.5	GP_WBrecc_optSlow	Lower rate of optimal range
0.12	3.7	GP_WBrecc_optFast	Upper rate of optimal range
0.18	5.5	GP_WBrecc_Fast	Threshold, where it is too fast when rate>Parm
Other parameters needed for Wading Bird suitability			
Value	Units	Global_Parm	Description
14	days	GP_WBrecc_Intvl	Interval used to calculate recession rate
12	JulianMonth	GP_WBbreedStart	Month of breeding season start (day one of month)
6	JulianMonth	GP_WBbreedEnd	Month of breeding season end (day one of month)
NOTE: for 12 and 6 for months, breeding season goes from Dec 1 through May 31 (day before June 1)			

The six Wading Bird-specific Performance Measures have 4 sets of tables, and 2 map sets. These are described below:



AvgYr= 1978 DryYr= 1989 WetYr= 1994

Wbdepth[cellLoc] New model output spatial variable for Wading Bird suitability

Variable	Category	Description
WBdepth	1	WBdepth_dry = sfwat<GP_WBdepth_Dry
WBdepth	2	WBdepth_subopt_dry = sfwat ≥ GP_WBdepth_Dry && sfwat <GP_WBdepth_optLow
WBdepth	3	WBdepth_opt = sfwat ≥ GP_WBdepth_optLow && sfwat <GP_WBdepth_optHi
WBdepth	4	WBdepth_subopt_wet = sfwat ≥ GP_WBdepth_optHi && sfwat <GP_WBdepth_Wet
WBdepth	5	WBdepth_wet = sfwat ≥ GP_WBdepth_Wet

In module, daily sum cells under each WBdepth category starting at GP_WBbreedStart, ending at GP_WBbreedEnd, then divide by elapsed # days

PM_WB1 WBdepth categories: daily mean area (ha) within breeding season

Year	dry	subopt_dry	opt	subopt_wet	wet
1965	4335	8670	13005	6503	10838
1966	4335	10838	8670	10838	8670
1967	434	12572	19508	4335	6503
...					

PM_WB2 WBdepth optimum category: daily mean area (ha) within months

Year	Dec	Jan	Feb	Mar	Apr	May
1978	9537	10491	8583	12398	6676	9060
1989	5202	5722	4682	6763	3641	4942
1994	6936	7630	6242	9017	4855	6589

PM_WB3 Output daily maps of WBdepth (color-coded 5 categories), then for PM_WB_3, show Jan 15 and Apr 15 for the 3 selected years

Calculating a new recession rate every day....

Hyd_recc[cellLoc] New model hydrologic spatial variable, calculates a new 2-wk recession rate every day (units=cm/wk)

a) new struct of 2D array of SURFACE_WAT[cellLoc].array[GP_WBrecc_Intvl)] that holds most recent GP_WBrecc_Intvl (14 here) number of days of depth

b) daily, calculate recession rate: Hyd_recc[cellLoc] = (SF_WAT[cellLoc].array[today-GP_WBrecc_Intvl] - SF_WAT[cellLoc].array[today])*100 / (GP_WBrecc_Intv/7.0)

Note, above is simply the depth (in meters) 2 weeks (GP_Wbrecc_Intvl) ago minus today's depth, divided by the number of weeks (2 here) (result= cm/wk)

Wbrecc[cellLoc] New model output spatial variable for Wading Bird suitability, categorizing continuous variable Hyd_recc[cellLoc]

Variable	Category	Description
WBrecc	0	Wbrecc_srev = Hyd_recc<GP_WBrecc_srev
WBrecc	1	Wbrecc_rev = Hyd_recc ≥ GP_WB_srev && Hyd_recc<GP_WBrecc_rev
WBrecc	2	Wbrecc_subopt_slow = Hyd_recc ≥ GP_WBrecc_rev && Hyd_recc <GP_WBrecc_optSlow
WBrecc	3	Wbrecc_opt = Hyd_recc ≥ GP_WBrecc_optSlow && Hyd_recc < GP_WBrecc_optFast
WBrecc	4	Wbrecc_subopt_fast = Hyd_recc ≥ GP_WBrecc_optFast && Hyd_recc <GP_WBrecc_Fast
WBrecc	5	Wbrecc_fast = Hyd_recc≥GP_WBrecc_Fast

In module, daily sum cells under each WBrecc category starting at GP_WBbreedStart, ending at GP_WBbreedEnd, then divide by elapsed # days

PM_WB4 & PM_WB7 WBrecc categories: daily mean area (ha) within breeding season

Year	Sreverse	reverse	subopt_slow	opt	subopt_fast	fast
1965	1200	4335	8670	13005	6503	10838
1966	1130	4335	10838	8670	10838	8670
1967	250	434	12572	19508	4335	6503
...						

PM_WB5 WBrecc optimum category: daily mean area (ha) within months

Year	Dec	Jan	Feb	Mar	Apr	May
1978	9537	10491	8583	12398	6676	9060
1989	5202	5722	4682	6763	3641	4942
1994	6936	7630	6242	9017	4855	6589

PM_WB6 Output daily maps of WBrecc (color-coded 6 categories), then for PM_WB_6, show Jan 15 and Apr 15 for the 3 selected years

PM_WB7 See above PM_WB4, with additional category for severe reversal.

We ran the historical calibration run spanning January 1, 1981 through December 31, 2000, and ran the future 2010 Base simulation[3] spanning the same years, with identical parameters (except those related to altered water management).

EcoLandMod, Inc. does not have historical data for these dynamics, and thus the tabular Wading Bird Performance Measures are provided to the SFWMD team to view the relative differences in performace between ***a) how the system actually operated during those years (calib) and b) how the system would (approximately) have operated had the existing (BAS2010) water management operations had been practiced (with associated current human population, water demands, etc***.). See Tables 6.1.a and 6.1.b.

Note that the 2010 Base is always considered to be a "Future Base" for project planning purposes, although its interpretation may be construed to be a potential-hindcast in some contexts: strictly-speaking, one would not apply current/future populations and water demands etc to a time period decades in the past - a different set of SFWMM assumptions would be necessary to truly develop a hindcast of what would have happened in the past if the current regulation schedule were being used.

To complement those Wading Bird Performance Metrics, Figure 6.0 shows the simulated stage at the 2-17 gauge under both the historical calibration run and the future 2010 Base, along with the (annually-recurring) target stage regulation curve.

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[3] SFWMM v6.6.4, run 11/12/2012 by J. Barnes & J. Obesekera, SFWMD

Table 6.1.a. Annual summaries: first table = historical (calib); second table = existing condition future base (BAS2010).

ELMwca2_500 v.2.9 calib calib_2.9Test3 scenario: Wading Bird Suitability. During breeding season, daily mean of a) area of marsh with surface water depths that were within 5 wading bird suitability classes; and b) area of marsh with surface water recession rates that were within 5 wading bird suitability classes.

Units = ha. (Season start=12/01, end=day prior to 6/01; total area = 43350.0 ha).

Year	DaysSeas	WBdepth_dry	WBdepth_subopt_dry	WBdepth_opt	WBdepth_subopt_wet	WBdepth_wet	Wbrecc_rev	Wbrecc_slow	Wbrecc_subopt_slow	Wbrecc_opt	Wbrecc_subopt_fast	Wbrecc_fast
1981	151	36,833	4,322	993	752	451	280	10,492	27,474	3,991	1,017	97
1982	182	12,891	14,339	4,293	5,672	6,155	2,546	6,473	10,739	21,436	1,138	1,017
1983	182	1,505	5,733	2,829	5,118	28,165	10,402	3,732	3,652	10,509	3,509	11,546
1984	183	9,894	14,633	5,116	6,531	7,177	4,817	10,293	11,230	10,292	4,393	2,325
1985	182	29,155	7,753	2,210	2,444	1,789	2,903	8,469	23,651	7,055	908	364
1986	182	6,316	15,689	7,223	6,509	7,614	5,580	10,013	8,644	9,810	4,692	4,610
1987	182	12,807	16,491	4,467	4,697	4,889	3,726	10,996	11,011	10,479	3,659	3,479
1988	183	5,960	13,624	5,535	7,949	10,282	3,187	11,726	11,190	11,478	3,013	2,757
1989	182	29,909	5,931	2,348	3,046	2,116	67	10,551	25,511	6,670	327	224
1990	182	32,597	6,266	1,744	1,693	1,050	490	11,507	22,613	7,929	574	237
1991	182	6,028	7,796	6,462	8,164	14,901	12,066	7,583	8,611	10,625	3,480	985
1992	183	8,066	14,919	5,523	7,003	7,839	4,064	10,697	11,840	12,834	2,720	1,196
1993	182	205	1,528	2,056	4,947	34,614	11,234	5,061	3,932	8,429	5,745	8,949
1994	182	1,400	10,596	5,250	9,016	17,089	5,275	6,871	9,912	14,346	5,238	1,708
1995	182	216	1,428	1,065	2,354	38,288	2,137	4,940	4,475	9,295	7,358	15,145
1996	183	488	5,839	5,770	8,808	22,445	3,795	10,028	7,685	15,621	1,533	4,689
1997	182	2,231	7,296	4,453	7,871	21,499	1,648	8,855	8,859	21,160	2,170	657
1998	182	4,150	8,548	4,376	7,131	19,146	8,464	7,770	7,525	6,575	4,362	8,654
1999	182	18,210	10,423	3,645	4,631	6,441	25	9,189	18,810	7,540	3,051	4,735
2000	183	457	2,701	2,546	4,771	32,875	3,305	3,050	2,790	12,031	16,264	5,911
Mean:	181	10,966	8,793	3,895	5,455	14,241	4,300	8,415	12,008	10,905	3,757	3,964
StDev:	7	11,970	4,810	1,829	2,446	11,959	3,644	2,636	7,513	4,505	3,489	4,206

ELMwca2_500 v.2.9 BAS2010 BAS2010_20yr scenario: Wading Bird Suitability. During breeding season, daily mean of a) area of marsh with surface water depths that were within 5 wading bird suitability classes; and b) area of marsh with surface water recession rates that were within 5 wading bird suitability classes.

Units = ha. (Season start=12/01, end=day prior to 6/01; total area = 43350.0 ha).

Year	DaysSeas	WBdepth_dry	WBdepth_subopt_dry	WBdepth_opt	WBdepth_subopt_wet	WBdepth_wet	Wbrecc_rev	Wbrecc_slow	Wbrecc_subopt_slow	Wbrecc_opt	Wbrecc_subopt_fast	Wbrecc_fast
1981	151	35,154	5,877	1,088	848	384	526	10,389	26,101	5,569	628	137
1982	182	12,737	11,827	5,848	7,230	5,708	6,133	8,051	12,279	9,857	4,633	2,397
1983	182	7,265	11,286	5,053	9,317	10,429	7,661	3,211	8,870	14,783	6,121	2,704
1984	183	6,153	15,477	7,981	9,433	4,307	9,441	7,090	6,139	10,129	5,718	4,833
1985	182	29,069	10,146	2,246	1,311	578	1,618	6,907	22,322	8,935	2,555	1,014
1986	182	5,247	15,029	8,244	9,673	5,157	8,202	5,958	6,438	11,624	6,437	4,692
1987	182	7,181	20,333	7,049	5,692	3,095	6,192	9,351	6,406	11,270	6,224	3,907
1988	183	13,743	14,662	5,804	5,412	3,728	625	7,148	20,281	12,847	2,215	235
1989	182	35,964	4,780	1,040	928	638	180	8,519	27,115	5,729	1,572	236
1990	182	22,301	12,757	2,951	2,907	2,435	1,277	9,331	16,111	14,822	1,635	175
1991	182	2,141	11,196	8,973	12,011	9,029	8,188	7,353	7,242	14,858	4,088	1,621
1992	183	14,533	20,240	4,207	2,833	1,537	3,432	9,453	16,246	11,039	2,112	1,069
1993	182	4,616	13,951	8,180	10,049	6,554	8,021	6,778	5,209	11,241	6,582	5,519
1994	182	12,094	17,859	5,248	5,793	2,356	6,272	12,766	10,395	8,847	2,478	2,592
1995	182	11,539	10,221	3,202	3,928	14,460	2,487	9,617	9,572	8,513	5,010	8,150
1996	183	19,023	16,788	3,839	2,543	1,158	5,704	10,211	18,507	6,208	1,939	781
1997	182	15,693	17,823	5,024	3,128	1,682	4,538	14,949	11,687	8,779	2,512	885
1998	182	5,481	12,408	9,003	12,276	4,182	7,176	11,128	7,988	9,855	3,709	3,494
1999	182	19,627	13,384	4,968	3,892	1,479	614	10,437	16,781	11,028	2,711	1,779
2000	183	22,129	13,175	3,479	3,189	1,378	5,515	9,559	13,711	8,526	3,231	2,809
Mean:	181	15,084	13,461	5,171	5,620	4,014	4,690	8,910	13,470	10,223	3,606	2,451
StDev:	7	9,924	4,100	2,478	3,685	3,712	3,079	2,550	6,736	2,767	1,866	2,136

Table 6.1.b. Monthly summaries: first table = historical (calib); second table = existing condition future base (BAS2010).

ELMwca2_500 v.2.9 calib calib_2.9Test3 scenario: Wading Bird Suitability. During breeding season, daily mean of a) area of marsh with surface water depths that were optimal for wading bird suitability during each month; and b) area of marsh with surface water recession rates that were optimal for wading bird suitability during each month.

Units = ha. (Season start=12/01, end=day prior to 6/01; total area = 43350.0 ha)... Developer's NOTE v2.9.0: Hardcoded Months for this output!!!.

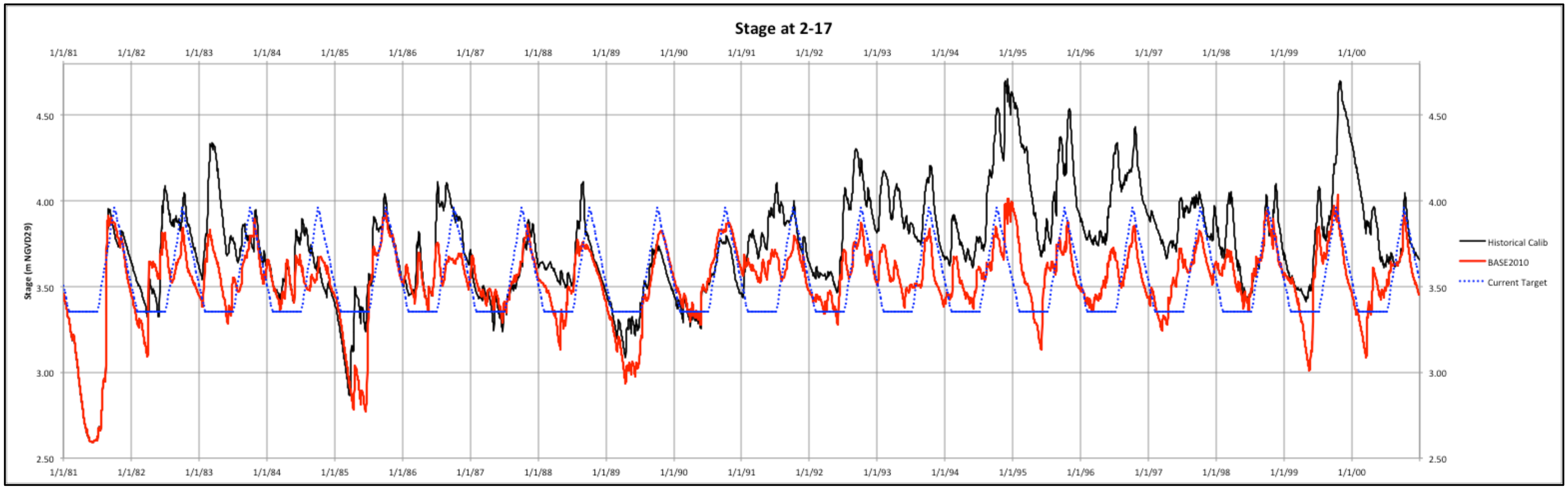
Year	Depth_Dec	Depth_Jan	Depth_Feb	Depth_Mar	WDepth_Apr	Depth_May	WRecc_Dec	Recc_Jan	Recc_Feb	Recc_Mar	WRecc_Apr	Recc_May
1981	-	2,521	1,393	682	145	236	-	10,646	2,127	4,435	1,464	1,020
1982	4611.3	4,404	5,408	3,166	5,415	2,898	39,714	32,693	16,382	18,368	6,331	14,155
1983	4792.7	5,034	2,964	24	93	3,989	32,407	18,577	381	6,056	3,313	1,109
1984	5721.8	6,936	4,292	3,038	6,337	4,360	14,226	12,560	11,159	7,073	5,264	11,365
1985	3404	1,484	1,168	1,816	2,997	2,314	15,403	12,064	1,378	403	4,168	8,273
1986	5525.8	9,219	13,348	8,215	5,803	1,773	23,473	8,531	3,520	6,760	8,937	7,003
1987	6188.7	7,607	2,588	3,842	4,672	1,729	16,076	13,403	9,385	3,914	9,652	10,310
1988	5556.5	6,300	5,193	6,433	4,703	4,977	9,122	8,502	13,132	9,660	17,243	11,499
1989	4694.4	2,082	1,605	1,801	1,899	1,919	22,121	11,582	2,438	52	188	3,021
1990	3925	1,971	1,184	1,508	1,439	371	19,228	12,532	6,072	2,968	3,534	2,918
1991	3565.3	8,286	6,599	7,965	6,240	6,123	17,085	4,978	5,641	16,044	4,828	14,503
1992	5074.2	4,496	6,756	6,654	5,677	4,566	11,204	24,500	4,397	10,345	4,879	20,875
1993	4497.6	2,073	-	1,767	285	3,457	16,992	2,203	12,191	4,126	4,806	10,506
1994	4868.5	4,613	1,992	6,845	6,598	6,309	27,260	8,134	3,555	15,396	17,946	12,855
1995	0	-	-	-	1,087	5,199	8,700	12,796	8,073	6,894	2,422	16,548
1996	1966.9	5,307	5,835	8,848	6,645	6,052	10,598	41,055	11,887	16,237	8,433	5,044
1997	2587.1	5,257	4,213	4,682	4,653	5,311	28,932	17,974	39,584	22,890	10,389	8,628
1998	4579.8	6,101	5,587	1,202	5,184	3,743	3,230	10,397	1,890	5,151	5,613	12,685
1999	5826.6	5,002	3,894	2,706	1,993	2,422	7,288	18,445	10,305	8,142	834	279
2000	5.6	22	605	5,426	4,342	4,809	22,351	20,078	5,924	1,523	12,636	9,297
Mean:	3,870	4,436	3,731	3,831	3,810	3,628	17,270	15,082	8,471	8,322	6,644	9,095
StDev:	1,975	2,627	3,153	2,854	2,327	1,852	9,976	9,224	8,617	6,369	4,960	5,592

ELMwca2_500 v.2.9 BAS2010 BAS2010_20yr scenario: Wading Bird Suitability. During breeding season, daily mean of a) area of marsh with surface water depths that were optimal for wading bird suitability during each month; and b) area of marsh with surface water recession rates that were optimal for wading bird suitability during each month.

Units = ha. (Season start=12/01, end=day prior to 6/01; total area = 43350.0 ha)... Developer's NOTE v2.9.0: Hardcoded Months for this output!!!.

Year	Depth_Dec	Depth_Jan	Depth_Feb	Depth_Mar	WDepth_Apr	Depth_May	WRecc_Dec	Recc_Jan	Recc_Feb	Recc_Mar	WRecc_Apr	Recc_May
1981	-	2,603	1,768	998	103	-	-	12,365	5,422	7,008	2,350	581
1982	5515.3	2,565	2,553	6,729	8,739	8,760	17,221	19,024	4,451	2,007	5,575	10,201
1983	6795.2	3,381	3,099	2,827	10,872	3,340	18,863	11,504	1,689	15,869	21,623	18,102
1984	9948.4	10,477	5,717	4,348	11,693	5,673	10,699	8,448	22,913	7,387	2,958	8,963
1985	8004	1,441	289	75	2,363	1,118	19,300	21,746	4,899	497	1,663	4,877
1986	12287.1	12,075	6,538	6,070	8,448	3,889	19,586	8,377	14,246	8,565	5,724	13,311
1987	7666.9	9,340	5,500	9,124	9,364	1,224	19,154	2,981	20,289	6,099	7,973	11,891
1988	10731.5	10,474	6,858	3,446	2,038	1,226	21,034	13,102	14,445	12,432	10,581	5,517
1989	3687.1	1,520	450	459	32	-	15,867	11,009	4,016	1,275	1,265	632
1990	5222.6	4,486	3,397	3,579	777	219	29,851	23,560	10,480	12,519	10,026	1,923
1991	4843.5	6,677	10,402	11,016	11,494	9,626	31,294	13,917	13,871	12,457	6,992	10,269
1992	7291.1	2,560	4,972	2,350	5,463	2,698	15,368	14,958	6,003	10,976	1,200	17,086
1993	9844.4	5,492	8,475	10,713	11,428	3,263	12,645	1,293	6,494	13,048	14,993	18,636
1994	838.7	2,444	8,736	10,389	4,482	4,911	14,783	105	2,630	10,666	17,408	7,163
1995	254.8	2,123	8,623	7,831	419	397	4,170	5,600	8,546	12,153	19,154	1,802
1996	3078.2	575	641	1,207	9,613	7,898	17,011	6,227	1,793	949	4,308	6,616
1997	2812.1	1,159	2,224	6,701	9,648	7,480	20,082	6,299	8,000	1,328	5,834	10,961
1998	11479	15,259	10,272	7,632	6,879	2,553	7,077	20,893	671	9,323	8,839	11,402
1999	11848.4	9,984	5,535	1,757	481	111	19,590	10,365	8,935	22,880	3,565	390
2000	4221.8	404	629	1,352	8,656	5,594	19,688	9,696	833	721	2,622	16,911
Mean:	6,319	5,252	4,834	4,930	6,150	3,499	16,664	11,073	8,031	8,408	7,733	8,862
StDev:	3,897	4,450	3,354	3,645	4,384	3,126	7,422	6,621	6,320	6,028	6,180	6,061

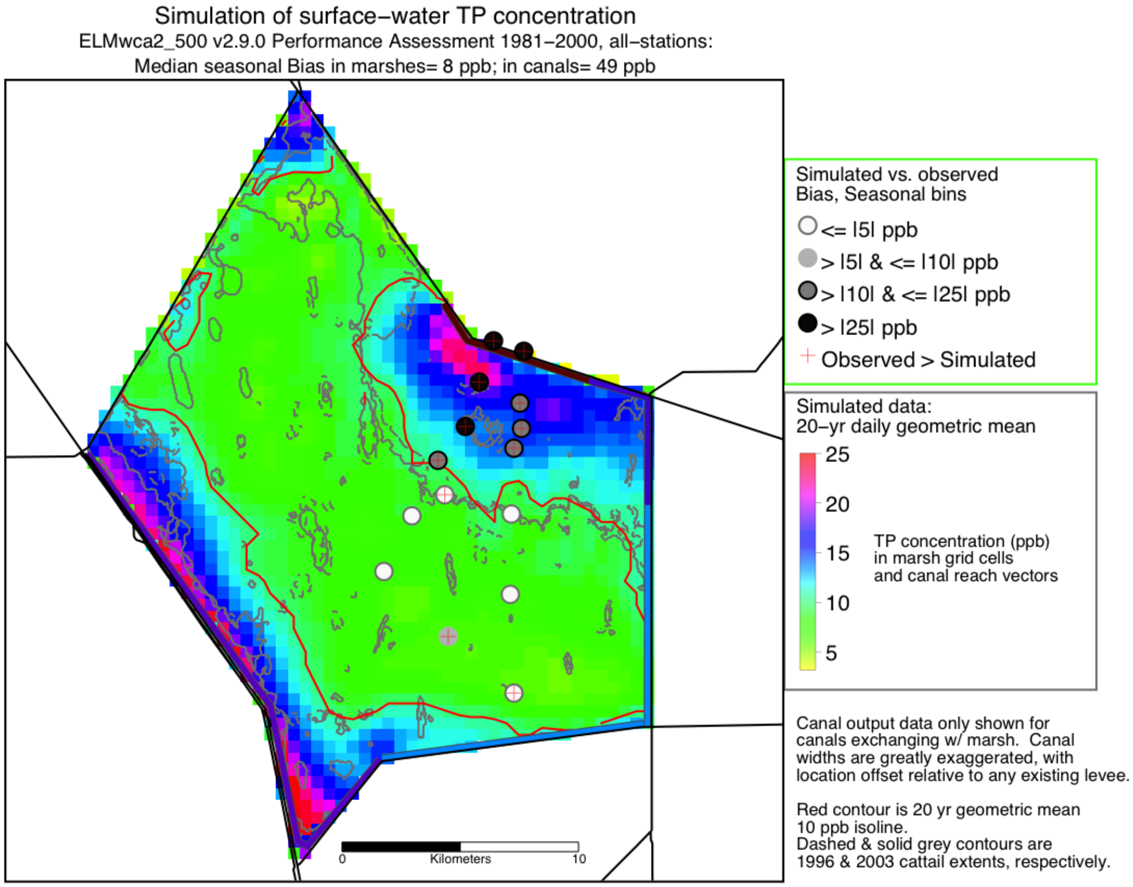
Figure 6.0 Simulated stage at the WCA-2A 2-17 gauge under the historical calibration run (what "really" happened), the 2010 Base run (what "would have" happened if current operations and other assumptions were operating), and the current stage regulation schedule target at the 2-17 gauge.



6.5.1.2 Phosphorus concentration: statistical metrics

The surface water marsh and canal total phosphorus (TP) concentration monitoring locations used in evaluating the model performance are shown in Figure 6.1, including the results for seasonal bias statistics. Table 6.2 shows the statistical performance metrics for the simulated vs. observed total phosphorus concentration data at each location during the 1981-2000 simulation period, aggregated by (November-April dry and May-October wet) seasons. The median seasonal Bias of all predicted TP concentrations in the marsh for the 1981-2000 period of simulation was 8 ug l^{-1} (ppb), with larger biases (49 ug l^{-1}) in canals that exhibited very high TP concentrations.

Figure 6.1 Map of statistical Bias in model predictions of observed total phosphorus (TP) concentrations in marsh and canal locations, aggregated into bins of (wet and dry) seasons. Background map is the simulated daily geometric mean TP concentration during 1981-2000. Statistics are detailed in Table 6.2.



Simulation of surface−water TP concentration
ELMwca2_500 v2.9.0 Performance Assessment 1981−2000, all−stations:
Median seasonal Bias in marshes= 8 ppb; in canals= 49 ppb

Canal output data only shown for canals exchanging w/ marsh. Canal widths are greatly exaggerated, with location offset relative to any existing levee.

Red contour is 20 yr geometric mean 10 ppb isoline.
Dashed & solid grey contours are 1996 & 2003 cattail extents, respectively.

Table 6.2. Statistical evaluation of simulated vs. observed surface water phosphorus concentration, 1981 – 2000, aggregated by (wet vs. dry) seasons. Units of Bias (observed minus simulated) and RMSE are ug l^{-1} (ppb). Relative Bias (RelBias) is the proportion of Bias divided by the Observed Mean (ObsMean).

					1981-2000		
Site	Basin	Site type	N	ObsMean	RelBias	Bias	RMSE
E1	WCA2A	Marsh	13	66	0.35	23	36
E2	WCA2A	Marsh	12	58	0.36	21	30
E3	WCA2A	Marsh	12	39	0.30	12	20
E4	WCA2A	Marsh	13	15	-0.14	-2	5
E5	WCA2A	Marsh	13	9	-0.34	-3	5
F1	WCA2A	Marsh	13	125	0.62	77	104
F2	WCA2A	Marsh	13	67	0.59	40	54
F3	WCA2A	Marsh	13	30	0.39	12	15
F4	WCA2A	Marsh	13	19	0.19	4	6
F5	WCA2A	Marsh	13	11	-0.18	-2	5
U1	WCA2A	Marsh	13	11	0.27	3	8
U2	WCA2A	Marsh	13	14	0.60	8	30
U3	WCA2A	Marsh	14	9	-0.18	-2	5
E0	WCA2A	Canal	13	86	0.54	47	59
F0	WCA2A	Canal	12	93	0.56	52	60
		Median All:	13	30	0.35	12	20
		Median Canal:	13	90	0.55	49	60
		Median Marsh:	13	19	0.30	8	15

6.5.1.3 Phosphorus concentration: visualization indicators

The spatial distribution of the long-term (1981-2000) mean surface water TP concentration (Figure 6.1) indicated strong gradients of eutrophication downstream of the S-10 water control structures. Within and immediately adjacent to canals, higher variability associated with higher observed mean concentrations resulted in higher biases. For a visualization reference, an isoline of a biologically-meaningful[4] long-term mean value of 10 ug l^{-1} was plotted in Figure 6.1.

Visualizations of the temporal trends in simulated and observed data are an important component of understanding the model performance, particularly with respect to recognizing any unique aspects of the data dynamics at a particular site. Appendix A: Figures A.1 – A.15 show the sets of 1981-2000 time series of total phosphorus concentrations at each monitoring location at several temporal aggregations, including each site's cumulative frequency distribution.

6.5.2 Hydrologic performance

6.5.2.1 Water stage and depth: statistical metrics

The six available marsh stage monitoring locations used in evaluating the model performance are shown in Figure 6.2, including the results for daily bias statistics. Table 6.3 shows the statistical performance metrics for the daily values of simulated vs. observed stage data at each location during the 1981-2000 period of simulation. The median bias of predicted stages was -2 cm (which represents slight over-predictions). The median Nash- Sutcliffe Efficiency statistic was 0.60 for the simulation.

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[4] Multiple lines of evidence (citations in ELM v2.5 Documentation Report, Model Application Chapter 8) indicated that significant ecosystem changes have occurred in waters that are associated with TP concentrations >10 ug l^{-1}.

Figure 6.2 Map of statistical Bias in model predictions of daily observed water stage elevations in marsh locations. Background map is the simulated mean surface water depth during 1981-2000. Statistics are detailed in Table 6.3.

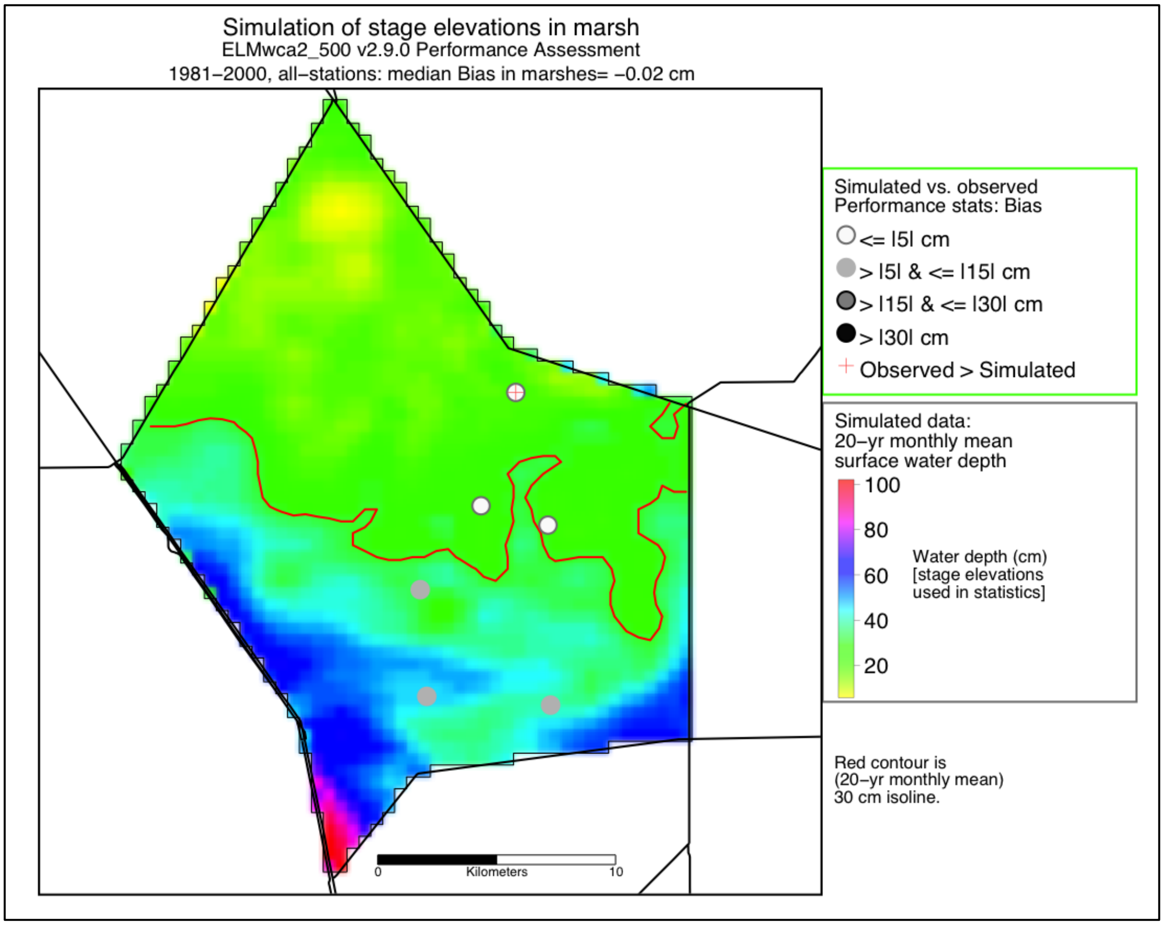

Table 6.3. Statistical evaluation of simulated vs. observed daily stage, 1981 – 2000. Units of Bias (observed minus simulated) and RMSE are meters.

		Stage 1981-2000				
Site	Basin	N	Bias (m)	RMSE (m)	R^2	NS Eff.
F1	WCA2A	2259	0.04	0.17	0.75	0.60
F4	WCA2A	1941	-0.04	0.17	0.68	0.54
E4	WCA2A	2260	-0.02	0.17	0.71	0.60
2A-17_B	WCA2A	7305	-0.06	0.18	0.71	0.54
2A-300_B	WCA2A	7278	-0.07	0.18	0.73	0.68
U1	WCA2A	2150	-0.07	0.21	0.66	0.58
	Median:	2259	-0.02	0.17	0.71	0.60

6.5.2.2 Water stage and depth: visualization indicators

The distribution of the long-term mean surface water depths (above local land surface elevation) generally was associated the topographic gradients in the north-south dimensions of the WCA-2A basin. Figure 6.2 shows the isoline of 30 cm depths, overlaid on the cell by cell depth distributions.

Visualizations of the temporal trends in simulated and observed data are an important component of understanding the model performance, particularly with respect to recognizing any unique aspects of the data dynamics at a particular site. Appendix B: Figures B.1 – B.6 show the sets of 1981-2000 time series of stage elevations at each monitoring location at several temporal aggregations, including each site's cumulative frequency distribution.

6.5.2.3 Chloride concentration: statistical metrics

The surface water marsh and canal chloride (Cl) concentration monitoring locations used in evaluating the model performance are shown in Figure 6.3, including the results for seasonal bias statistics. Table 6.4 shows the statistical performance metrics for the simulated vs. observed Cl concentration data at each location during the 1981-2000 simulation period, aggregated by (November-April dry and May-October wet) seasons. The median seasonal Bias of all predicted Cl concentrations in the marsh for the 1981-2000 period of simulation was 32 mg L^{-1}, with similar tendency towards under-predictions (54 mg L^{-1}) in canals (with both marsh and canals having very high Cl concentrations).

Figure 6.3 Map of statistical Bias in model predictions of observed chloride (Cl) concentrations in marsh and canal locations, aggregated into bins of (wet and dry) seasons. Background map is the simulated mean daily Cl concentration during 1981-2000. Statistics are detailed in Table 6.4.

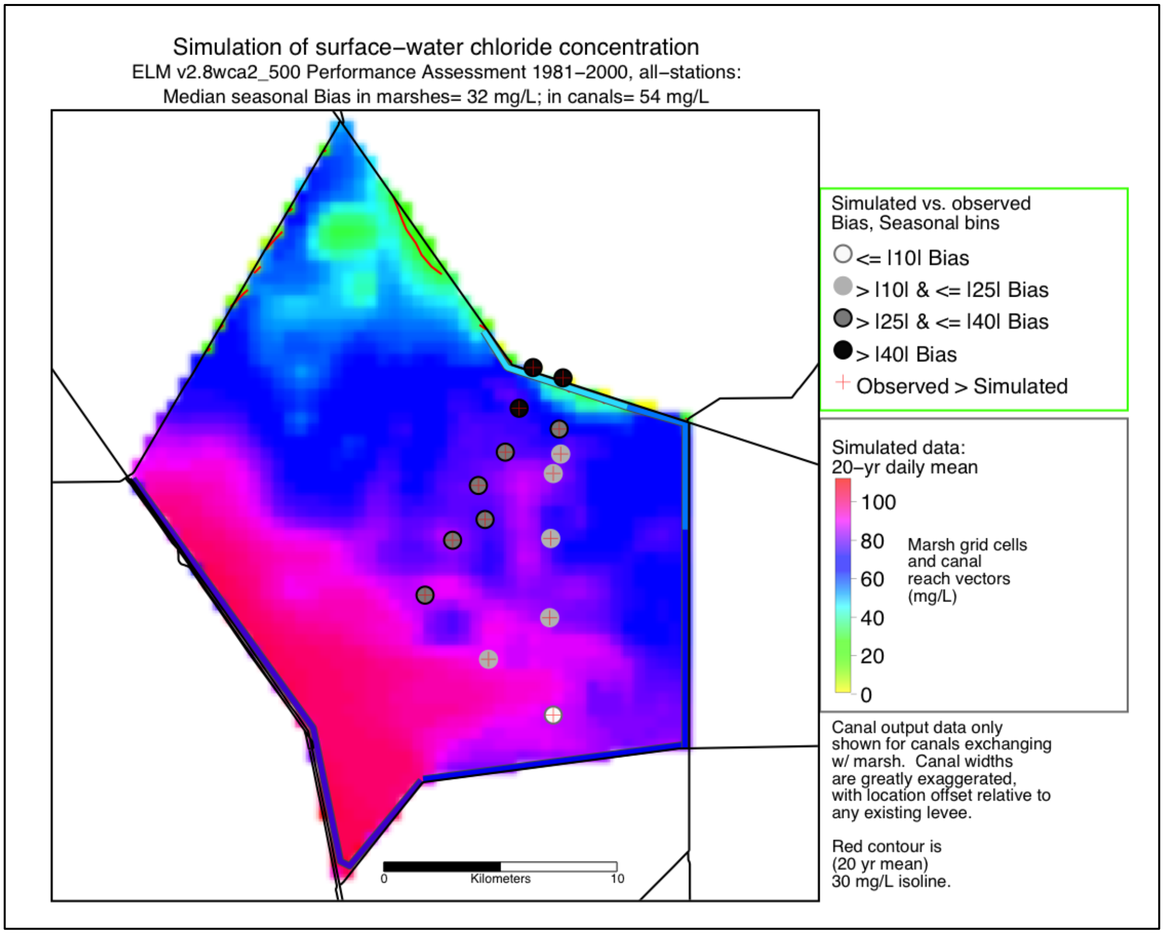

Table 6.4. Statistical evaluation of simulated vs. observed surface water chloride concentration, 1981 – 2000, aggregated by seasons. Units of Bias (observed minus simulated) and RMSE are mg l^{-1} (ppm). Relative Bias (RelBias) is the proportion of Bias divided by the Observed Mean (ObsMean).

			1981-2000				
Site	Basin	Site type	N	ObsMean	RelBias	Bias	RMSE
E1	WCA2A	Marsh	14	148	0.33	49	57
E2	WCA2A	Marsh	14	125	0.23	28	38
E3	WCA2A	Marsh	14	124	0.21	26	37
E4	WCA2A	Marsh	14	122	0.13	16	22
E5	WCA2A	Marsh	14	113	0.10	11	15
F1	WCA2A	Marsh	13	157	0.33	51	59
F2	WCA2A	Marsh	14	149	0.28	42	47
F3	WCA2A	Marsh	14	142	0.25	35	40
F4	WCA2A	Marsh	14	137	0.24	32	39
F5	WCA2A	Marsh	14	143	0.24	34	37
U1	WCA2A	Marsh	14	102	0.04	4	12
U2	WCA2A	Marsh	14	129	0.22	29	31
U3	WCA2A	Marsh	14	133	0.24	32	35
E0	WCA2A	Canal	14	128	0.41	52	59
F0	WCA2A	Canal	14	132	0.43	56	62
		Median All:	14	132	0.24	32	38
		Median Canal:	14	130	0.42	54	61
		Median Marsh:	14	133	0.24	32	37

6.5.2.4 Chloride concentration: visualization indicators

The spatial distribution of the long-term (1981-2000) mean surface water Cl concentration (Figure 6.3) showed patterns of long-term flow regimes that were consistent with our understanding of major flow exchanges. Within and immediately adjacent to canals, higher variability associated with higher observed mean concentrations resulted in higher biases, similar to the gradient trends of phosphorus concentrations. For a visualization reference, an isoline of a biologically-meaningful[5] long-term mean value of 30 mg l^{-1} was plotted in Figure 6.3 - note that virtually the entire basin exceeded that threshold.

Visualizations of the temporal trends in simulated and observed data are an important component of understanding the model performance, particularly with respect to recognizing any unique aspects of the data dynamics at a particular site. Appendix C: Figures C.1 – C.15 show the sets of 1981-2000 time series of chloride concentrations at each monitoring location at several temporal aggregations, including each site's cumulative frequency distribution.

6.6 Discussion

6.6.1 Model performance summary

Multiple methods were used to evaluate the performance characteristics of this model of greater Everglades ecology. The following summarizes those performance evaluations, which support the use of this application for evaluating relative differences in system behavior over decadal time scales, at a spatial resolution of 500 meters:

6.6.1.1 Performance Measure comparisons

To determine the suitability of the new ELMwca2a subregional application for use in the WCA-2 research project, one set of criteria was that it should perform at least as well as the regional ELM v2.5 that was approved for applications by the Independent Peer Review Panel[6]. The ELMwca2a exhibited enhanced performance characteristics for all variables:

- Water stage: median bias (-0.02 m) was improved within WCA-2A relative to the regional v2.8 (median bias in WCA-2A=0.08 m), which was improvement over the regional ELM v2.5

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[5] S. Hagerthy, SFWMD (pers. comm.) indicated that periphyton community succession appears to occur in waters that are associated with Cl concentrations of 25-30 mg l^{-1}.

[6] Mitsch, W. J., L. E. Band, and C. F. Cerco. 2007. Everglades Landscape Model (ELM), Version 2.5: Peer Review Panel Report. Submitted January 3, 2007 to the South Florida Water Management District, West Palm Beach, FL. http://my.sfwmd.gov/elm (Peer Review: Comments tab). 35 pp.

- P concentration: median bias (8 ppb in marshes) was the same within WCA-2A relative to the regional ELM v2.8 (8 ppb in marshes), which was improvement over the regional ELM v2.5
- Cl concentration: median bias (32 mg/L) slightly improved within WCA-2A relative to the regional ELM v2.8 (35 mg/L in marshes), which was improvement over the regional ELM v2.5

6.6.1.2 Spatial trends

The spatial pattern of water depths reflected the underlying topographic gradients in this impounded basin, with long-term mean depths shallow in the north, and extremely deep in the south (Figure 6.2). The model also effectively captured the spatial patterns of eutrophication in the WCA-2A basin, with realistic patterns of “excursion distances” that depicted intrusion of canal-derived waters into the marsh. The lack of spatial trends in bias statistics (Figures 6.1, 6.2 and 6.3, Tables 6.2, 6.3 and 6.4) demonstrated that, relative to the variability of the observed data, the model effectively simulated the pattern of long-term mean concentrations of stage, TP, and Cl within the WCA-2A basin (although we do not explicitly use TP and Cl to assess Wading Bird Suitability, which is the focus of this project).

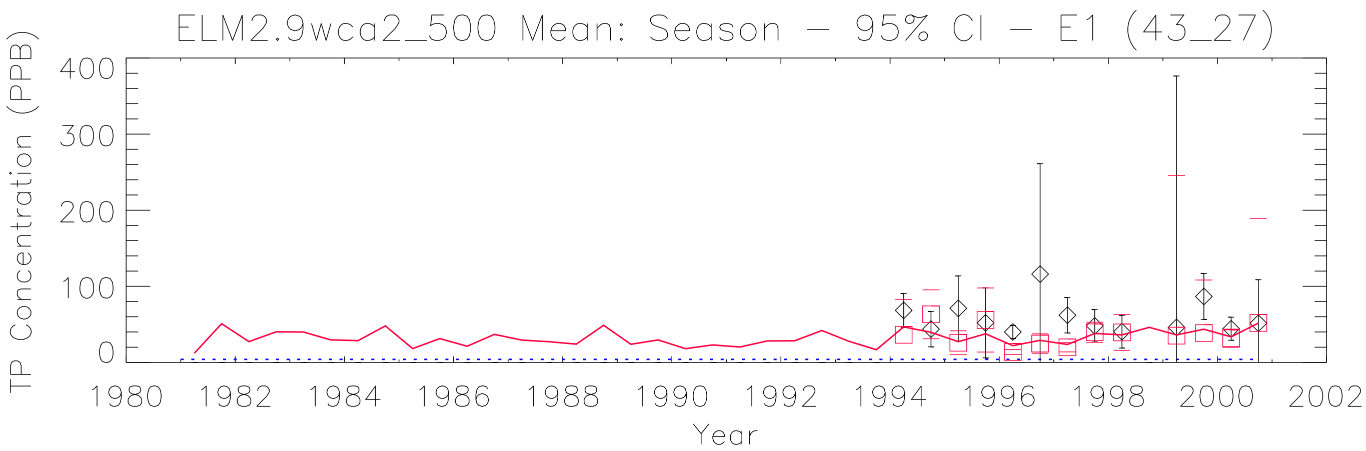
6.6.2 Conclusions

Overall, the fine-scale (500x500 m, or 0.25 km^2) ELMwca2a application further demonstrated the robust nature of the ELM code and data: without modifying algorithms or parameters for this subregional application (beyond the new consumer module, not assessed here due to lack of data available to EcoLandMod, Inc.), the new application exhibited improvements to model performance (“skill” in hindcasting observed data) relative to that of the regional, ELM v2.5 1km^2 and v2.8 0.25 km^2 applications. With that benchmark being one of the primary criteria for acceptance for use in WCA-2A research, the ELMwca2a appears to be an application well-suited to meet the objectives of this project. In support of this conclusion are the quantitative and qualitative lines of evidence. The statistical metrics of ELMwca2a performance characteristics showed that predictive biases were small relative to important ecological dynamics: overall, water stage was simulated to within 2 cm of long-term observations, while aggregated phosphorus and chloride were well within the bounds of acceptance in this basin with regions that are eutrophic (and generally high chloride concentrations). Importantly, temporal and spatial trends in hydrologic and water quality predictions were consistent with our understanding of the complex exchanges of water and constituents between the WCA-2A perimeter canal and the marshes of the interior region.

6.7 Appendix A: Time series & CFDs: TP

Figures A.1 – A.31. Time series plots of water column total phosphorus (TP) concentration and their associated Cumulative Frequency Distributions (CFD) for the period of record 1981-2000 at each monitoring location. The sequence of the figures is based on geographic location of marsh sites, starting in northwest, moving towards the southeast; following the set of plots of all marsh sites, the canal monitoring sites are similarly sequenced. A map of all sites is provided in the Model Performance Chapter.

> *The constant dashed line indicates the TP field sampling Detection Limit (DL = 4 ug l^{-1} for the model period of record), which was the minimum value used for observed data in plots and statistics. To enable equivalent comparisons, any simulated value which was below the DL was set equal to the DL. The model grid cell column and row locations (col_row) or canal reach identifier (single integer) are shown in parentheses of each plot's title.*
>
> a) All data were aggregated into arithmetic mean values by wet and dry seasons within water years; the continuous lines pass through mean of all daily data points for each season; the mean of paired simulated and observed values are shown in red boxes and black diamonds, respectively; the 95% Confidence Interval (CI) of the paired means are shown by the "__" symbols in the red for the model and black for the observed data.
>
> b) All data aggregated into arithmetic mean values by water year, with the same treatment as in plot a).
>
> c) The CFDs of the simulated and observed (raw, un-aggregated) data; the 95% confidence interval for observed data is shown in the dashed black lines. Note that only paired simulated and observed data points are used.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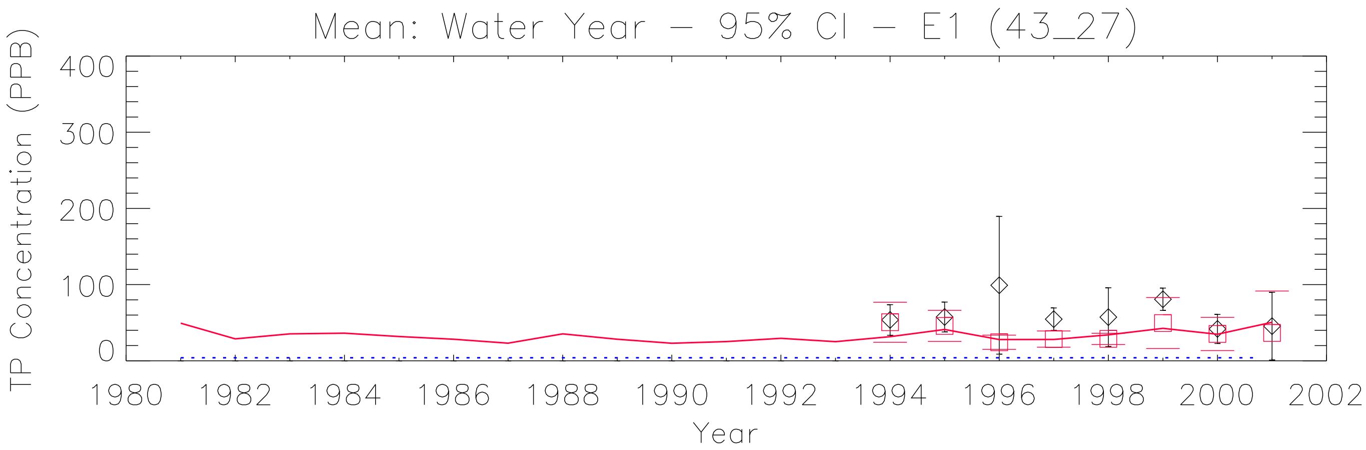
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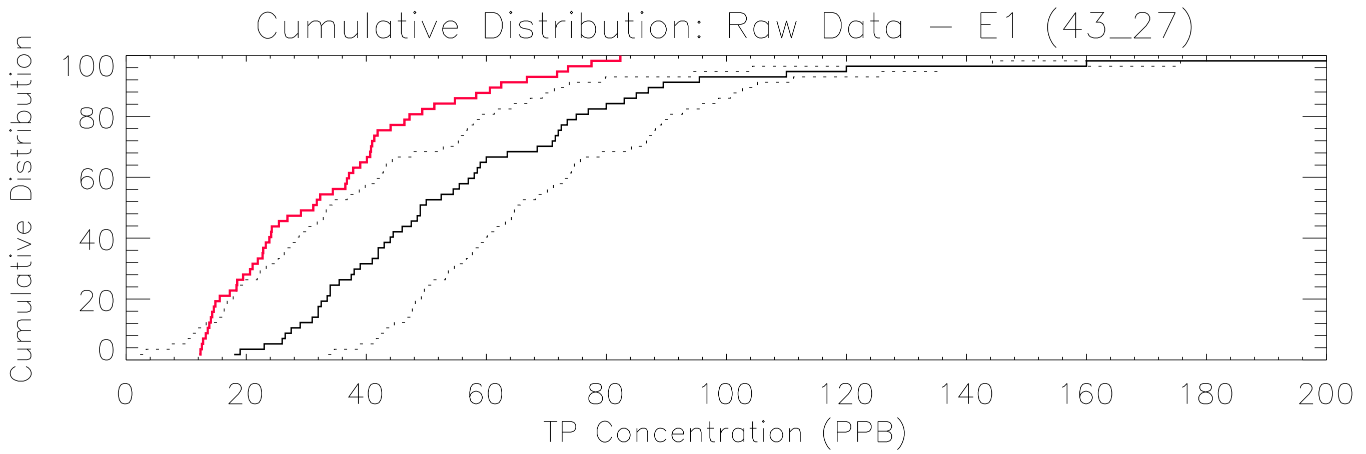
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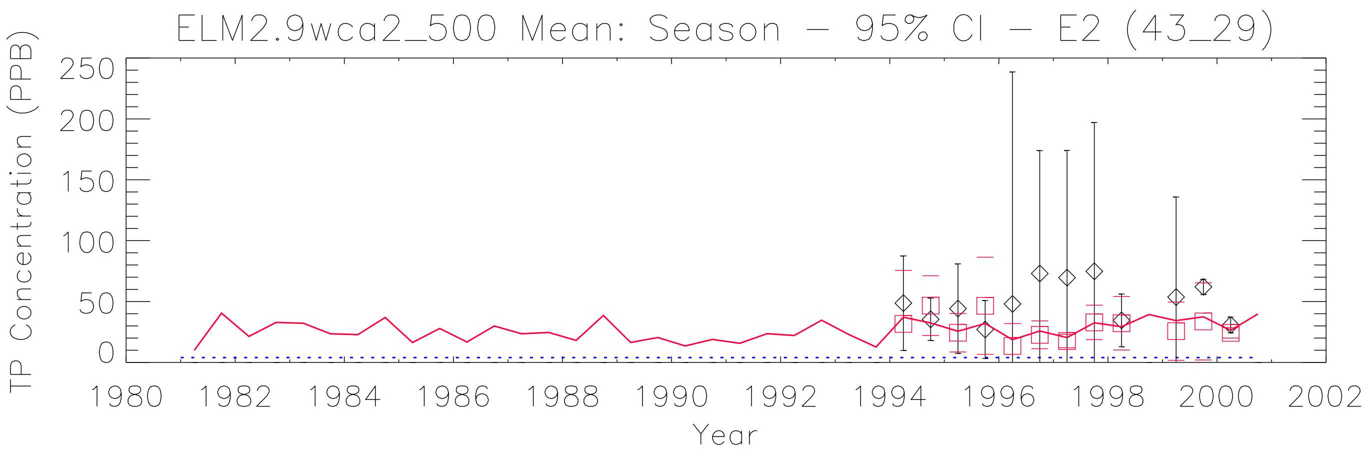
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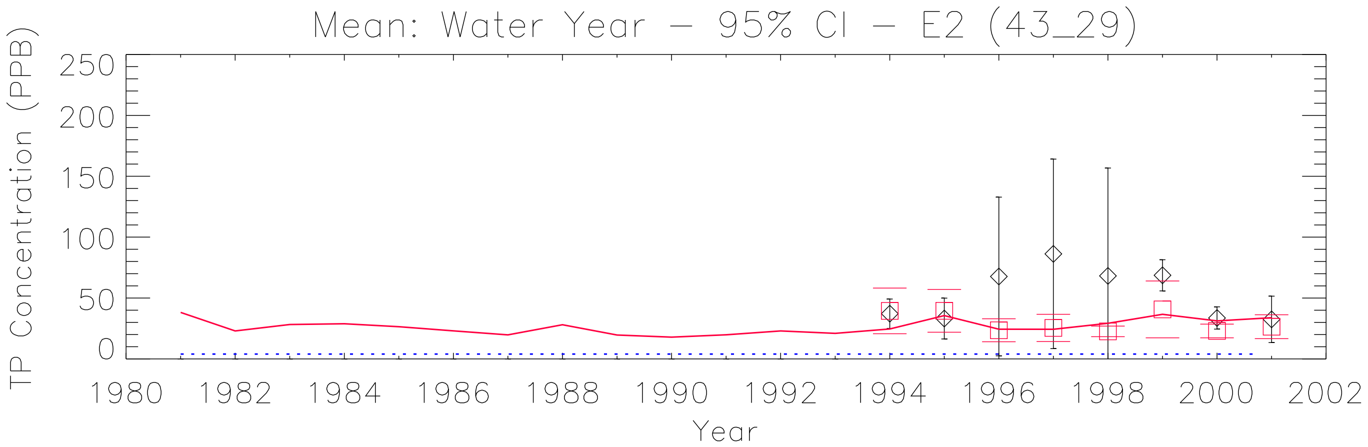
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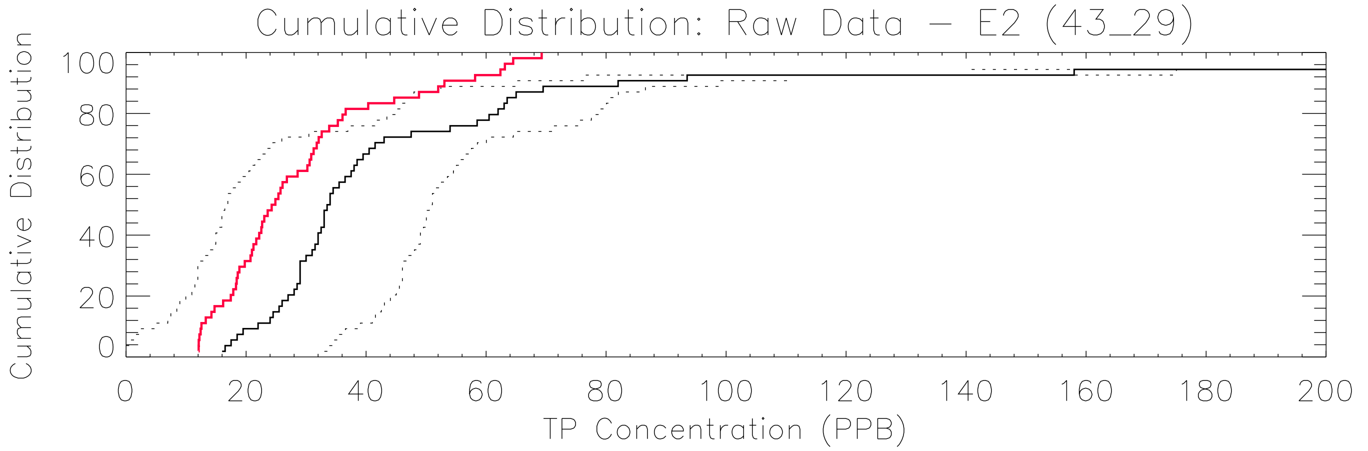
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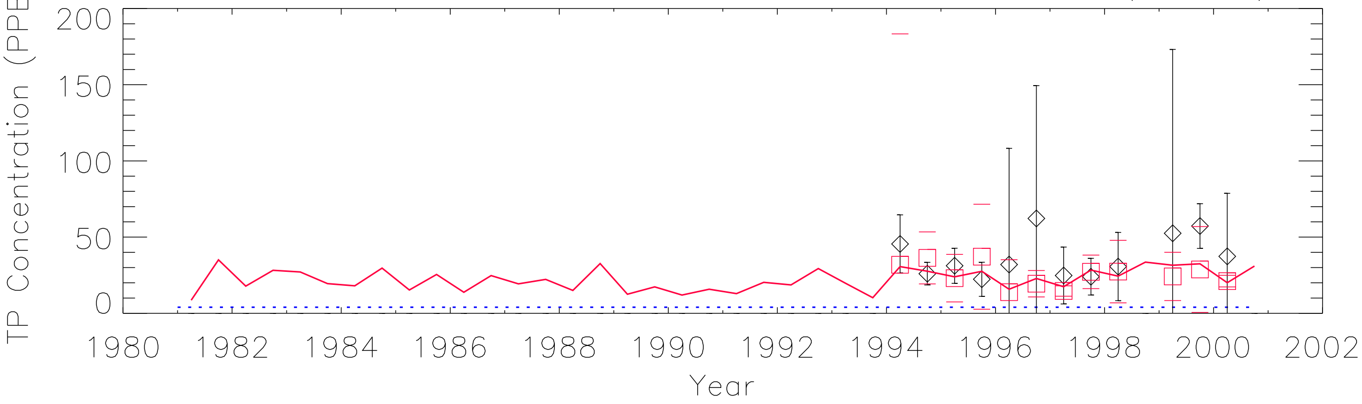
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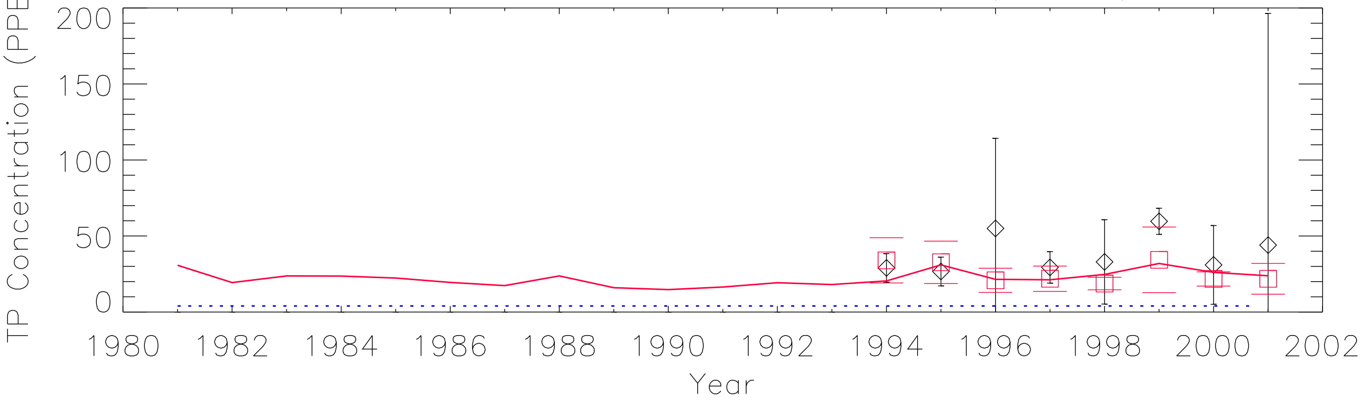
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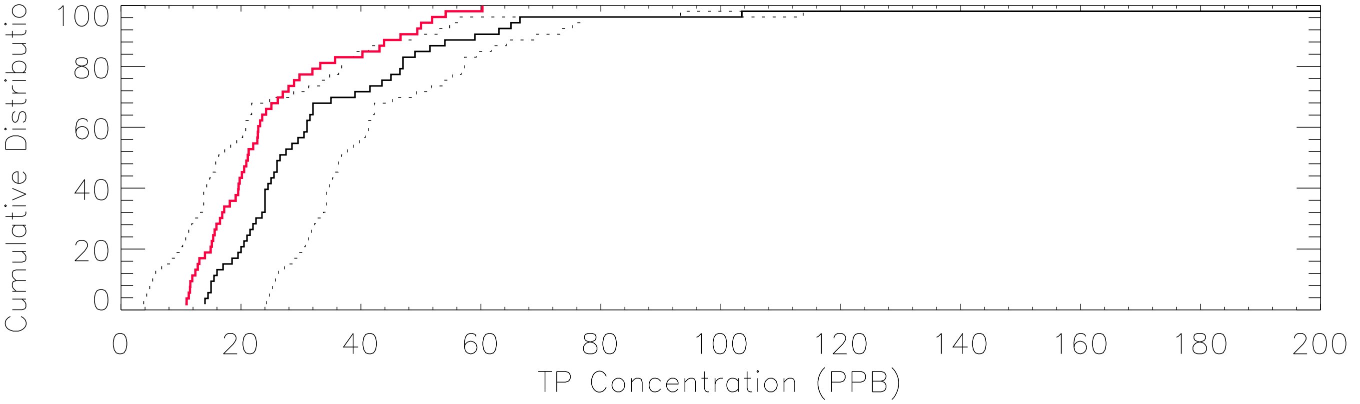
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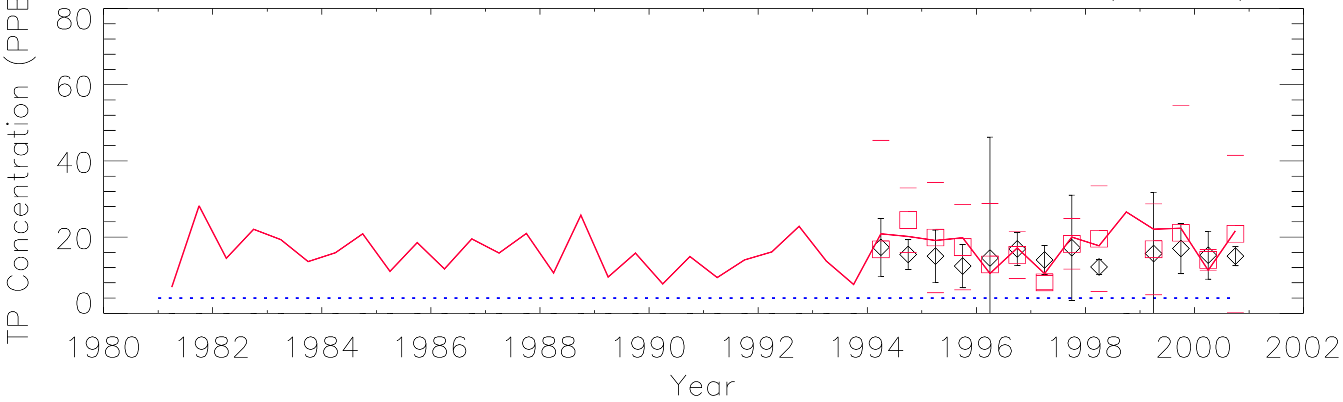

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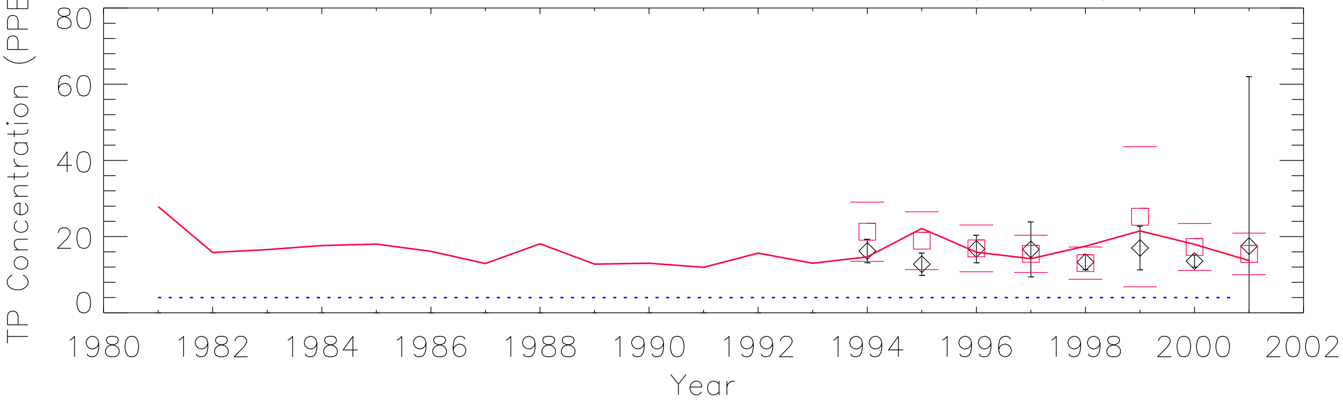

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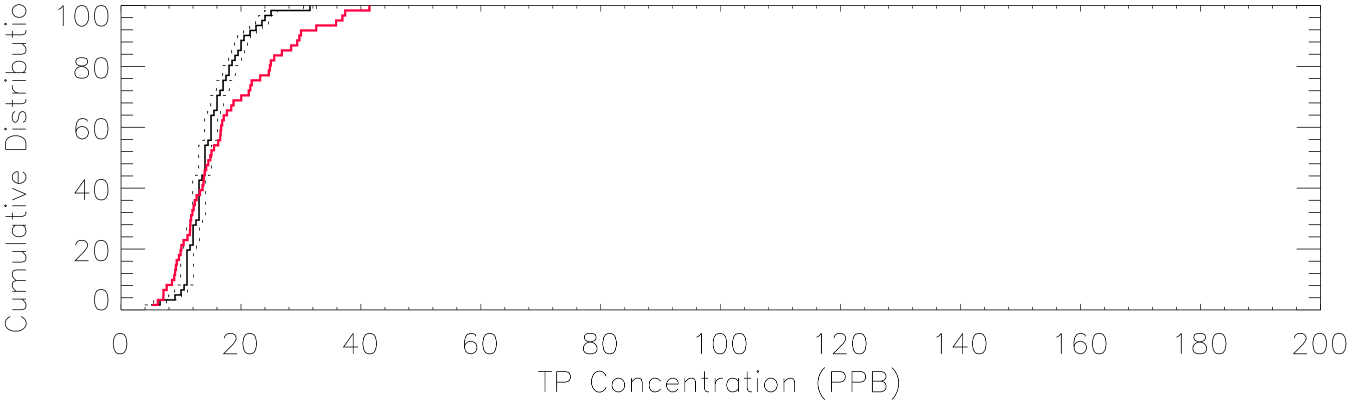

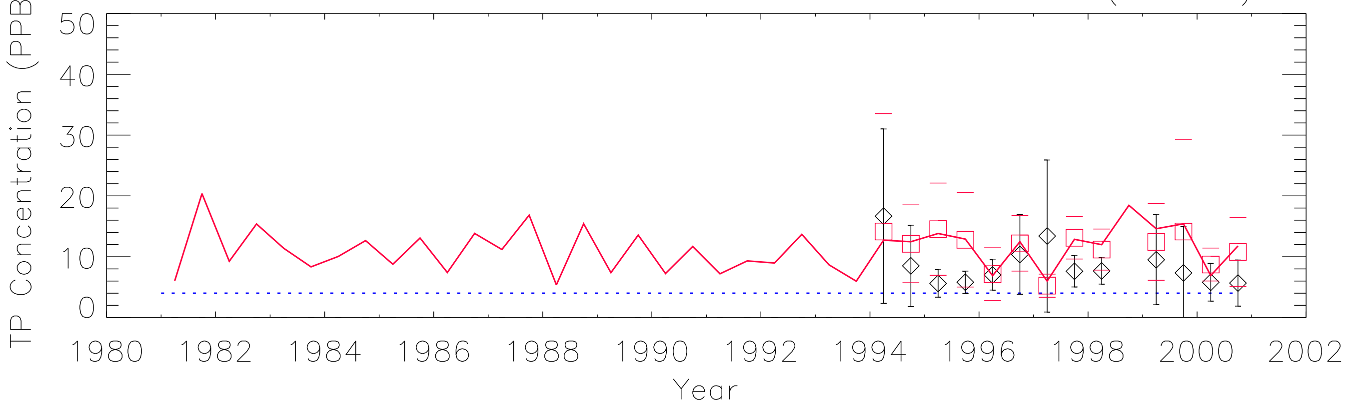
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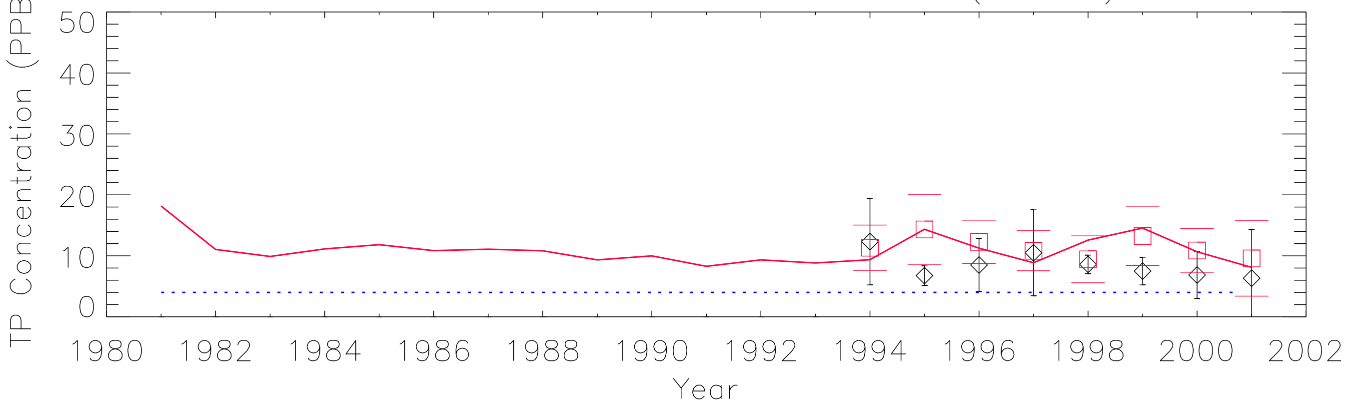
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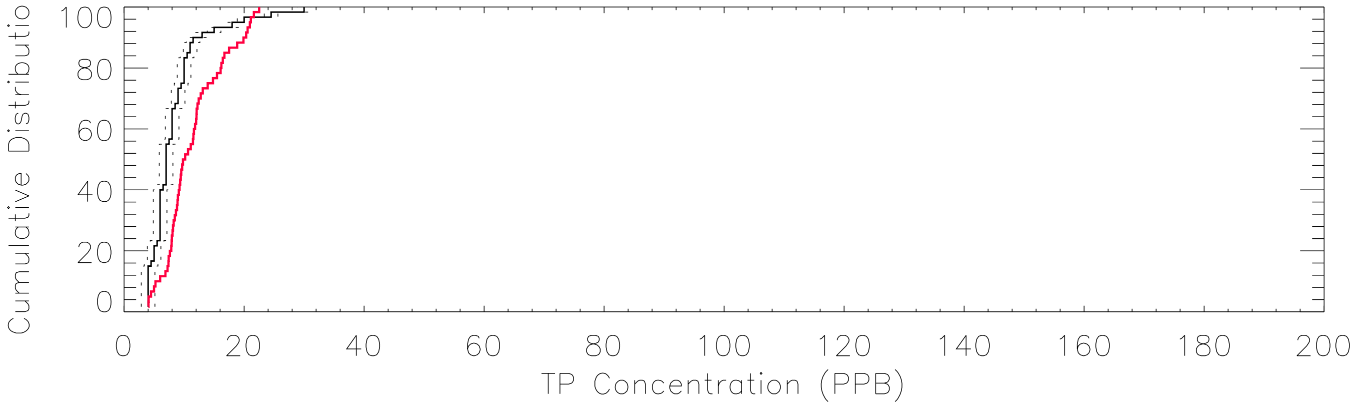
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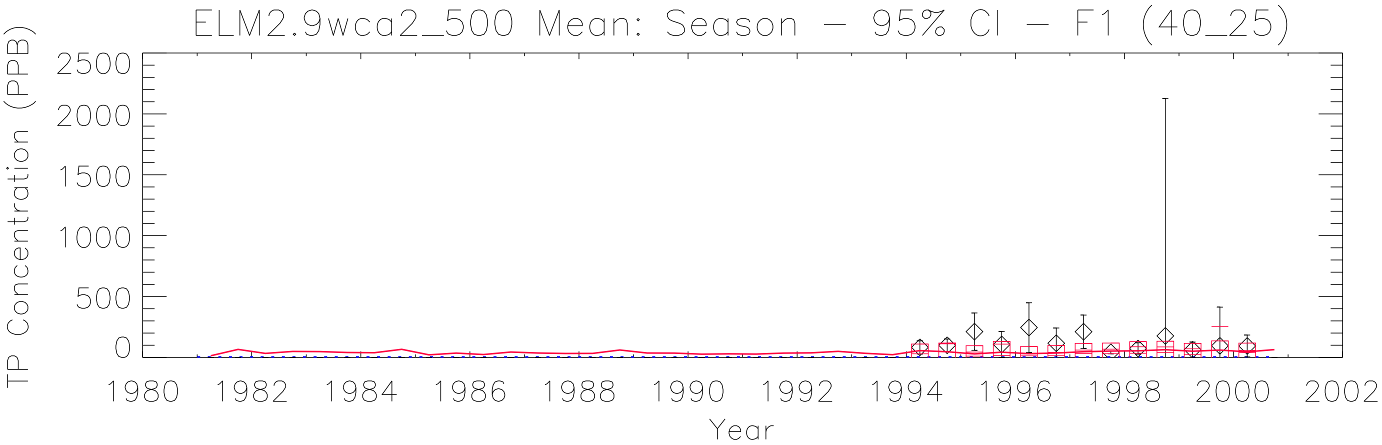
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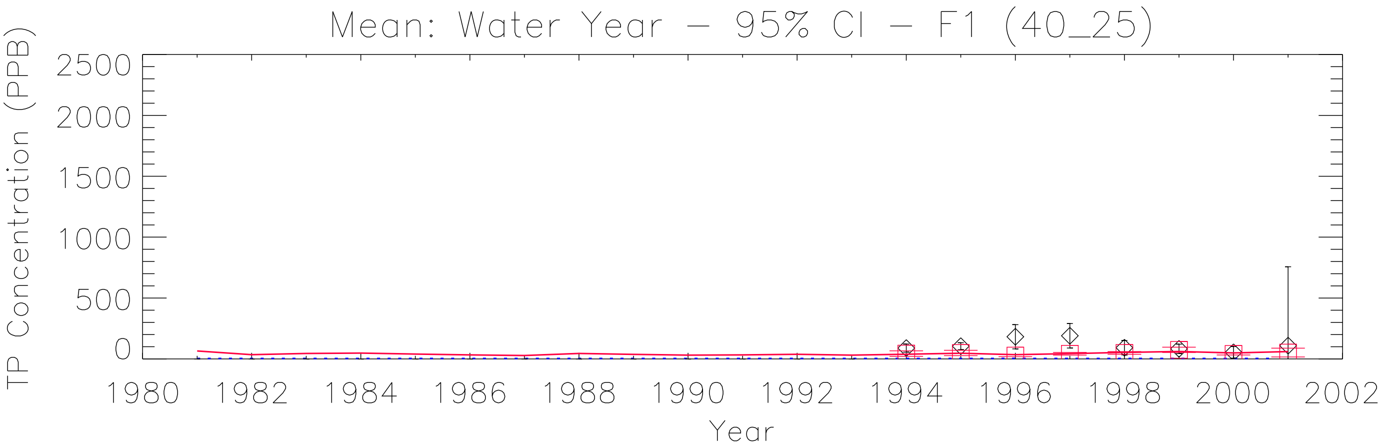
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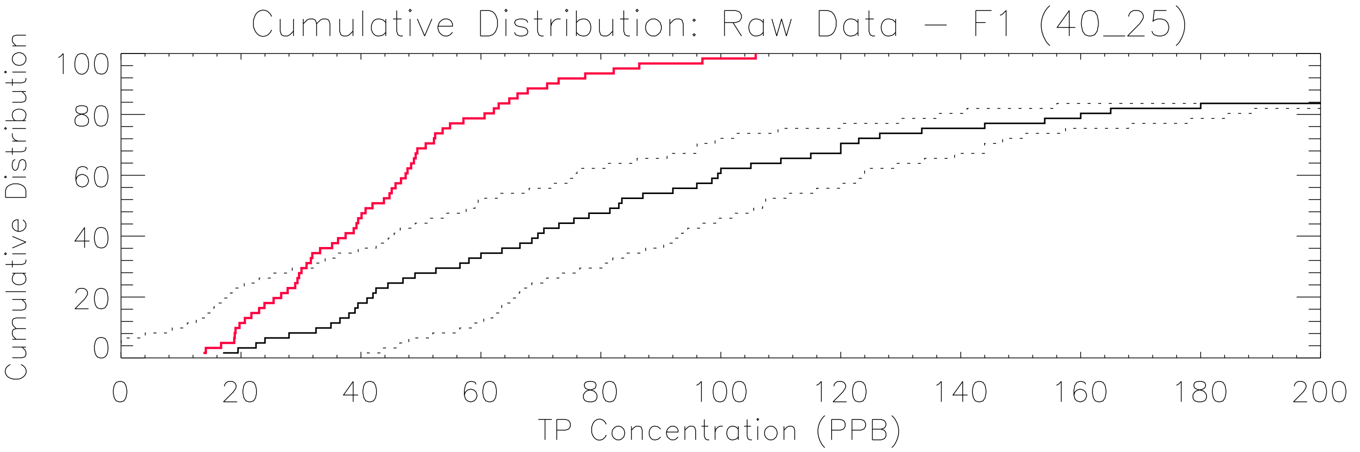
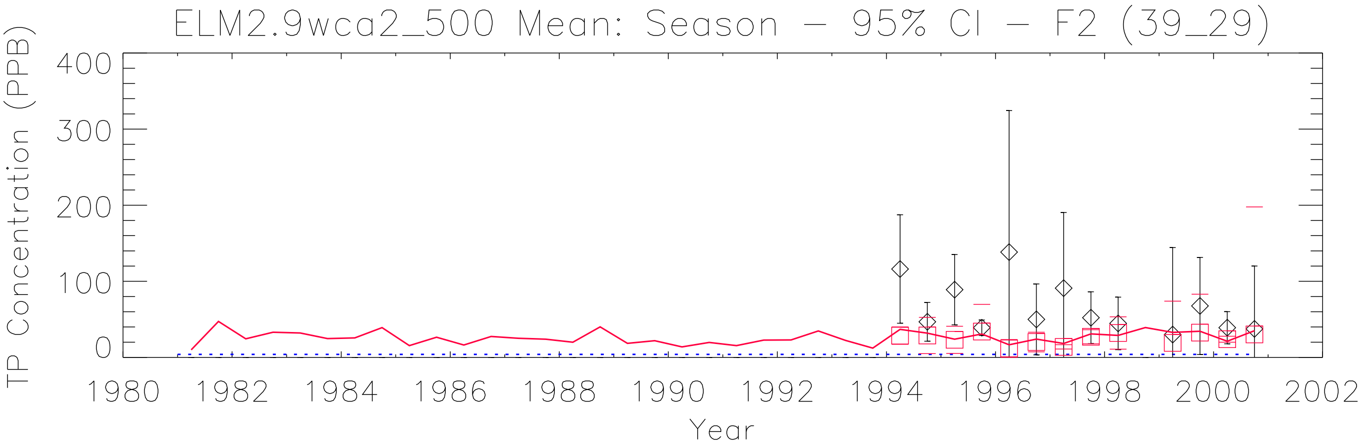

Cumulative Distribution: Raw Data – F1 (40_25)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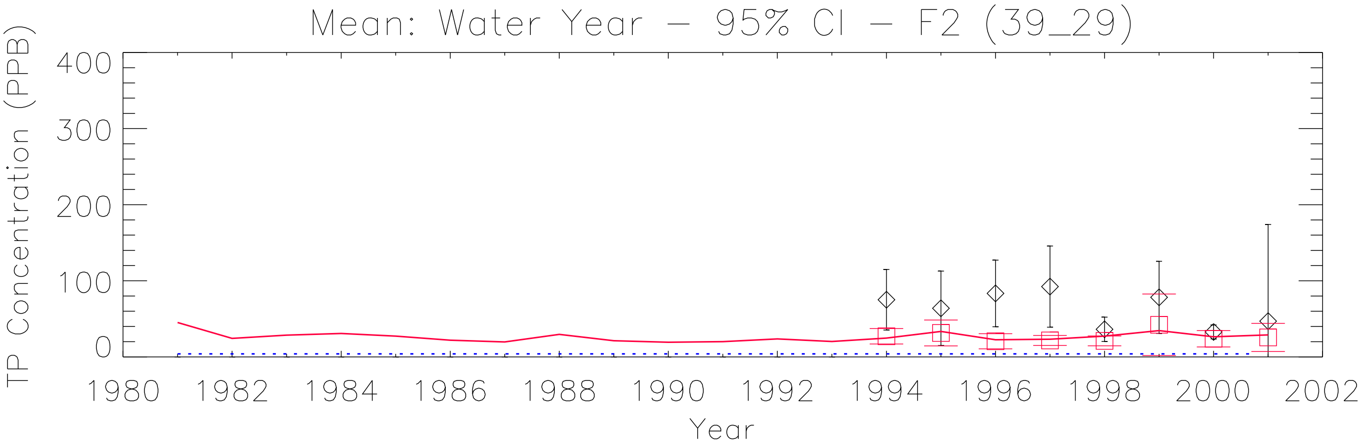
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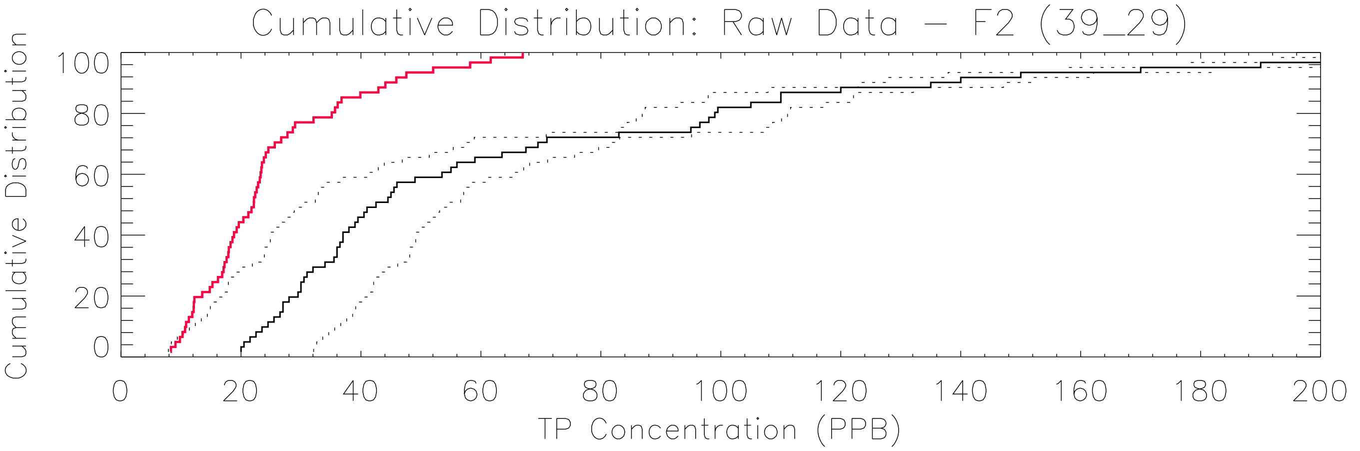
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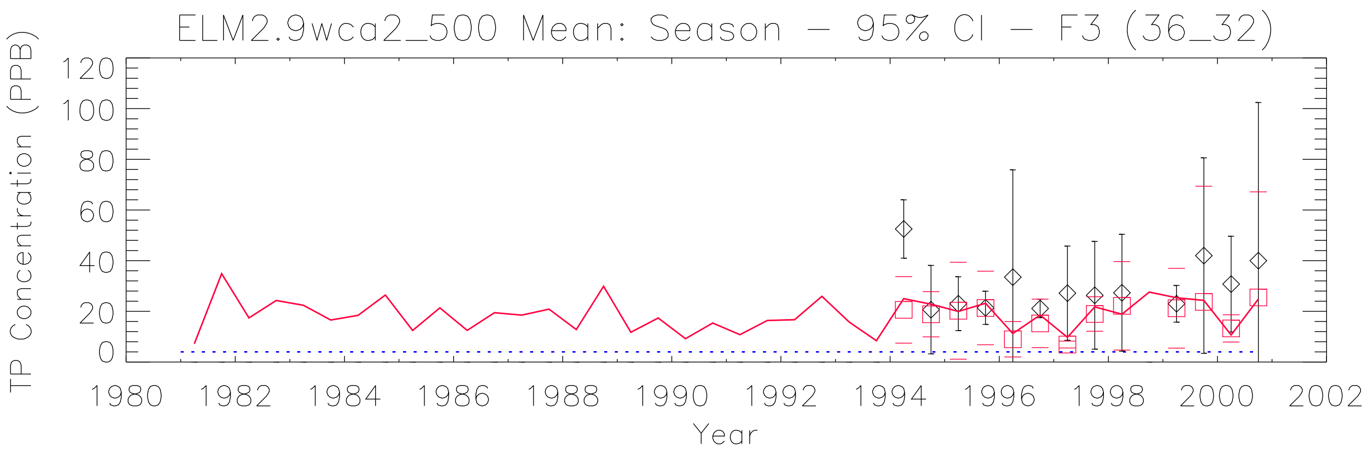

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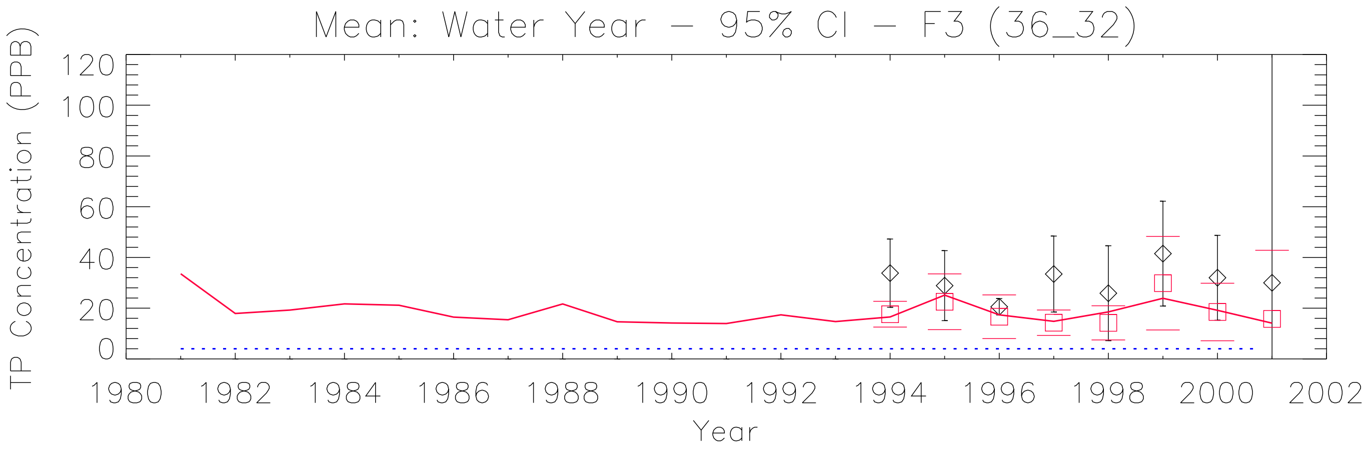
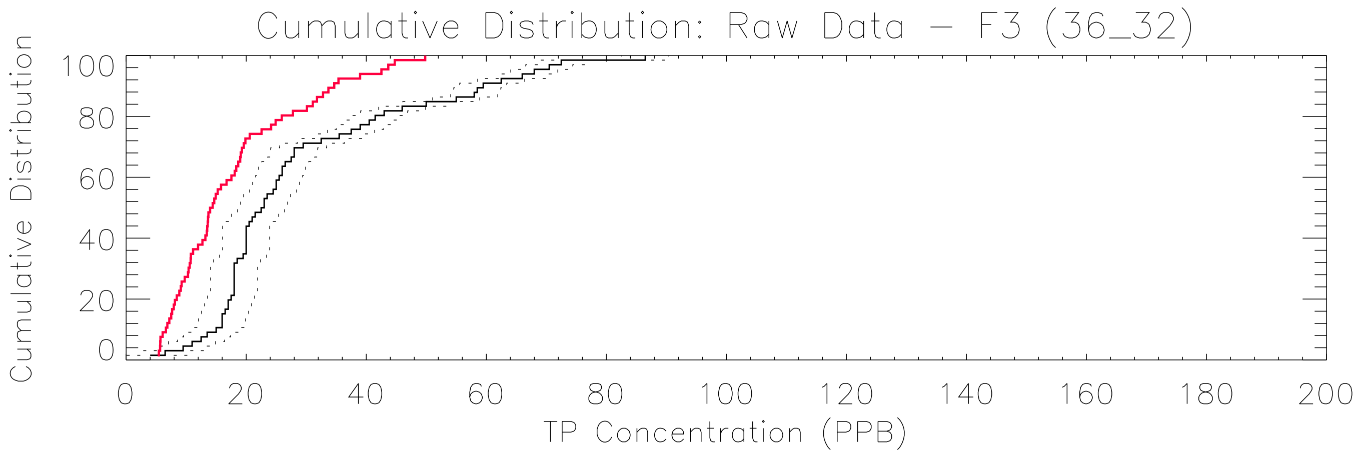
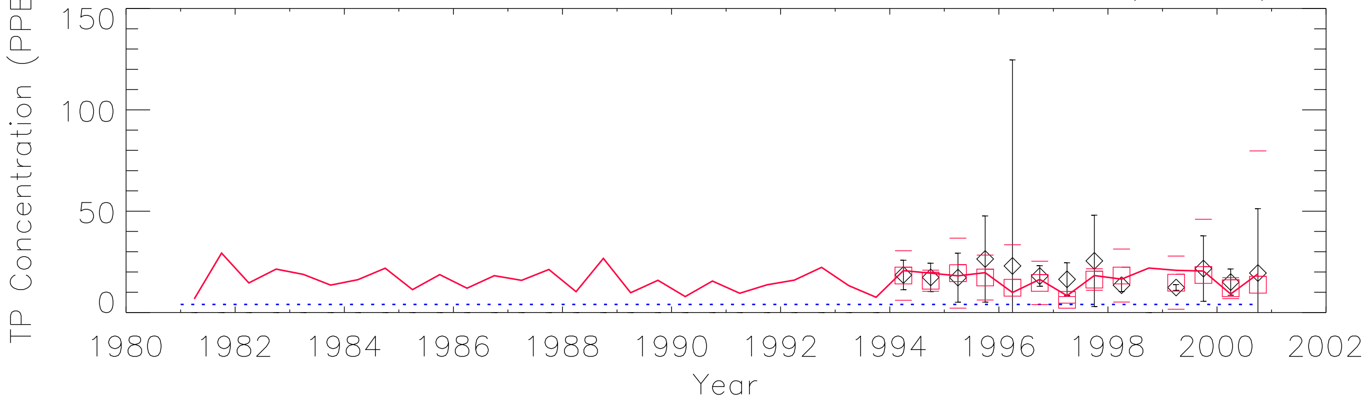


Mean: Water Year – 95% CI – F3 (36_32)

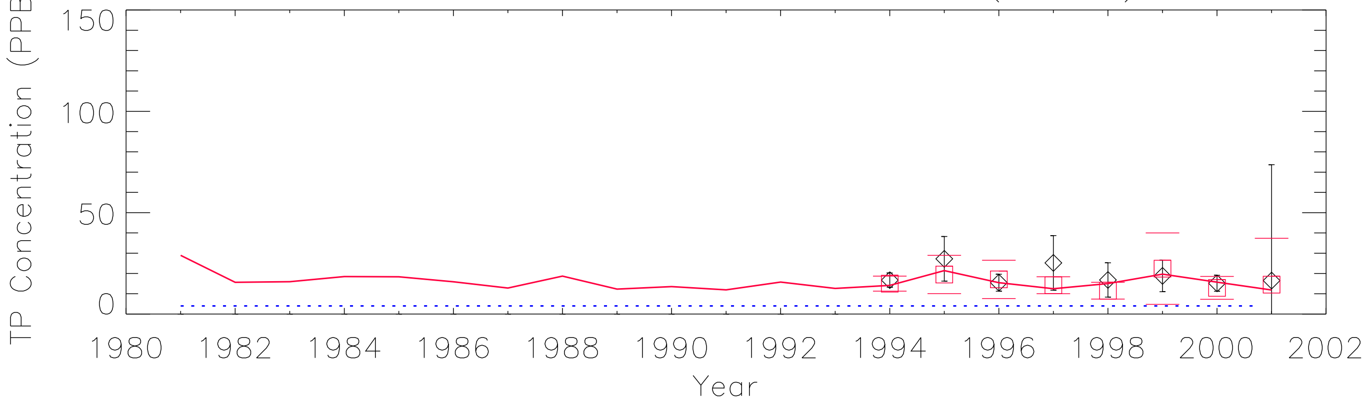


Cumulative Distribution: Raw Data – F3 (36_32)

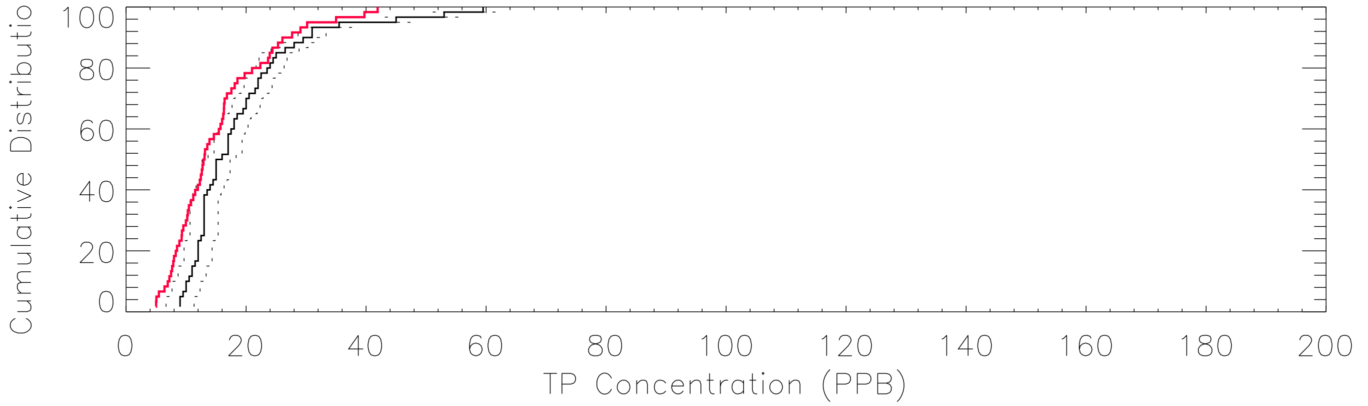
ELM2.9wca2_500 Mean: Season - 95% CI - F4 (37_35)

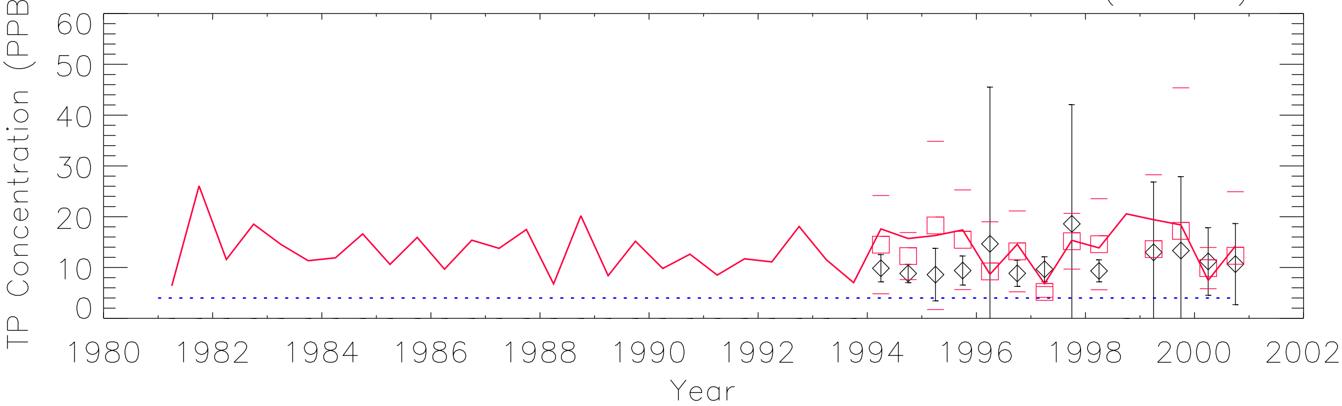


Mean: Water Year - 95% CI - F4 (37_35)

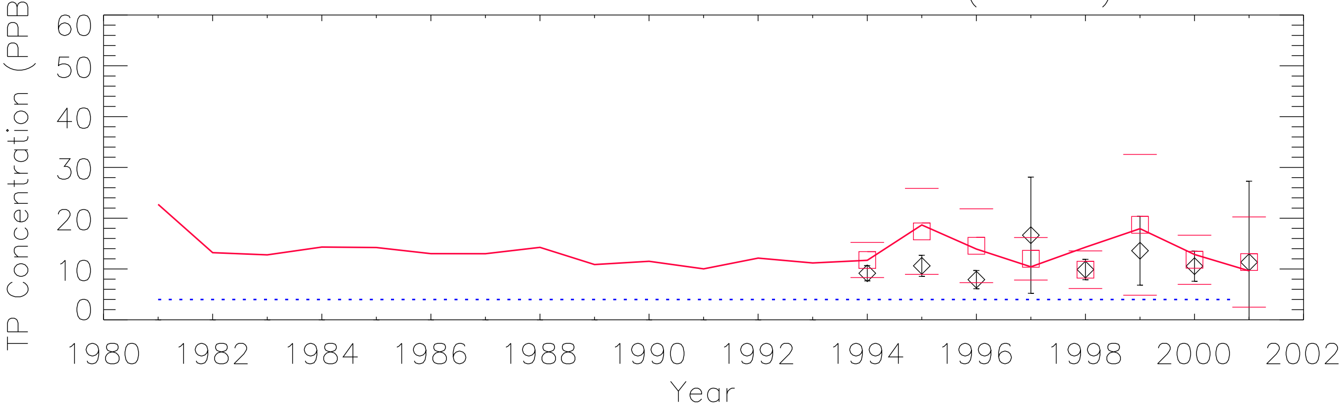


Cumulative Distribution: Raw Data - F4 (37_35)

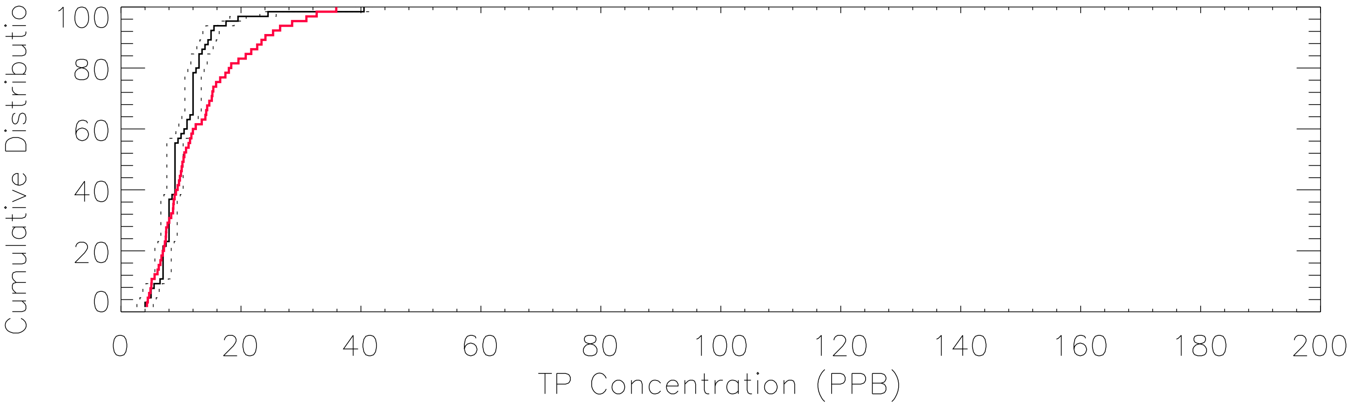




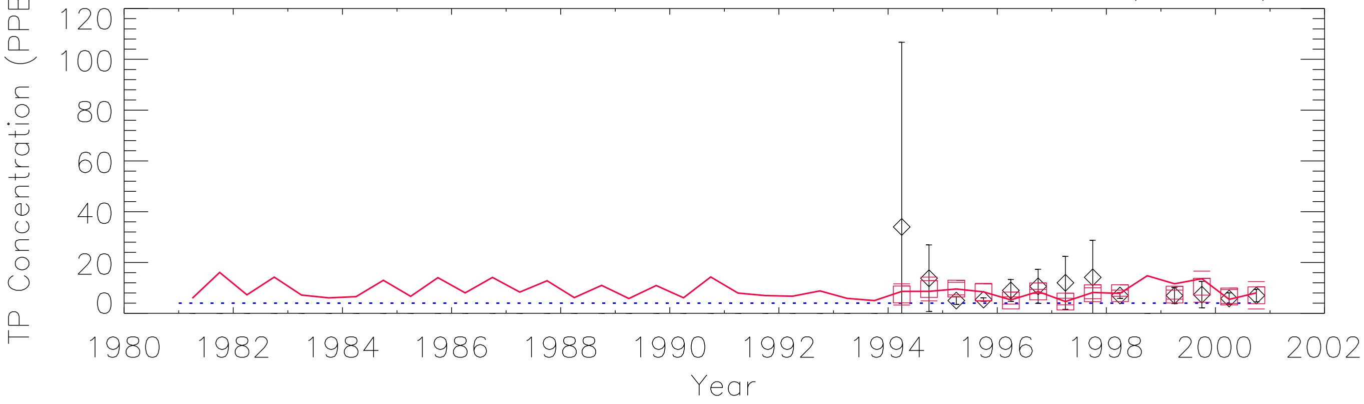
ELM2.9wca2_500 Mean: Season – 95% CI – F5 (34_36)



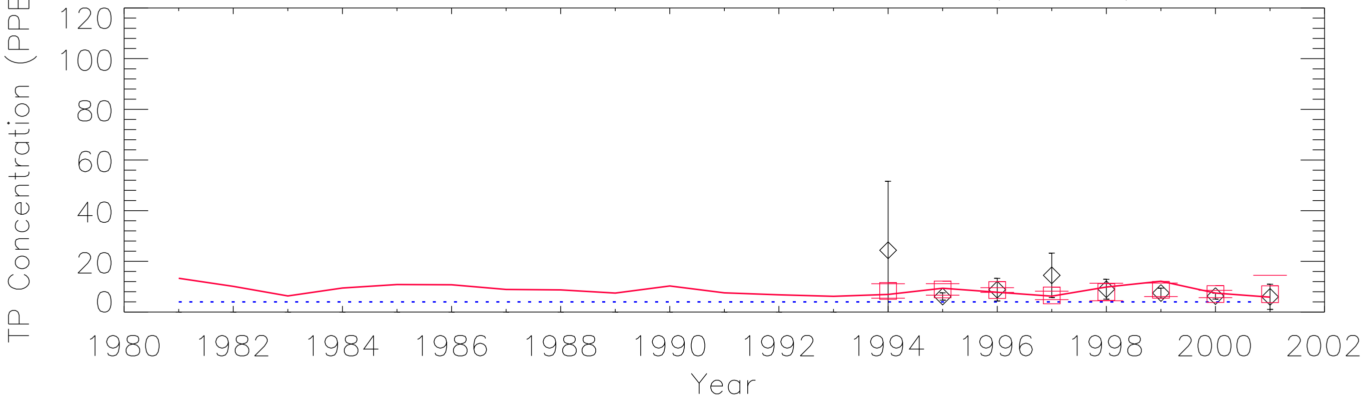
Mean: Water Year – 95% CI – F5 (34_36)



Cumulative Distribution: Raw Data – F5 (34_36)



ELM2.9wca2_500 Mean: Season - 95% CI - U1 (43_51)



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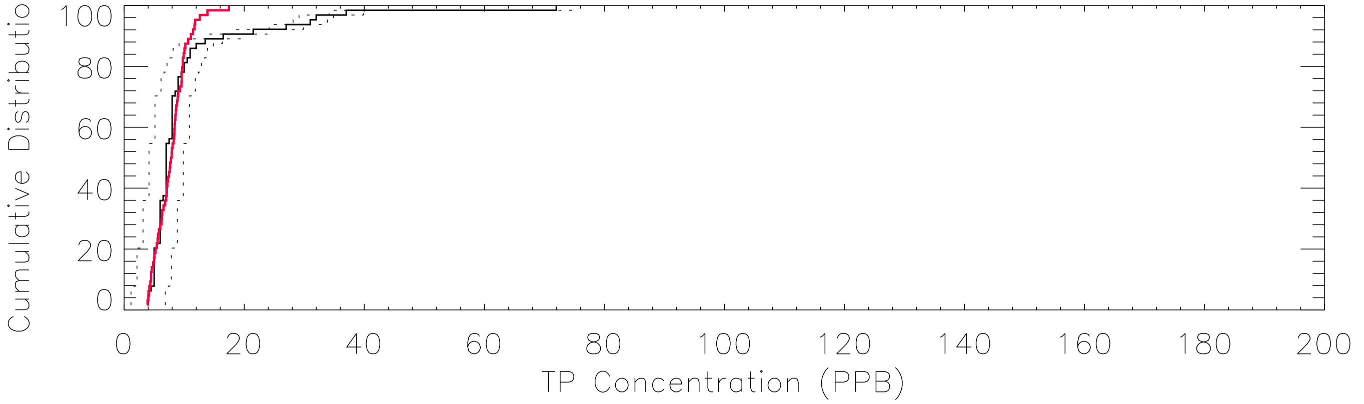
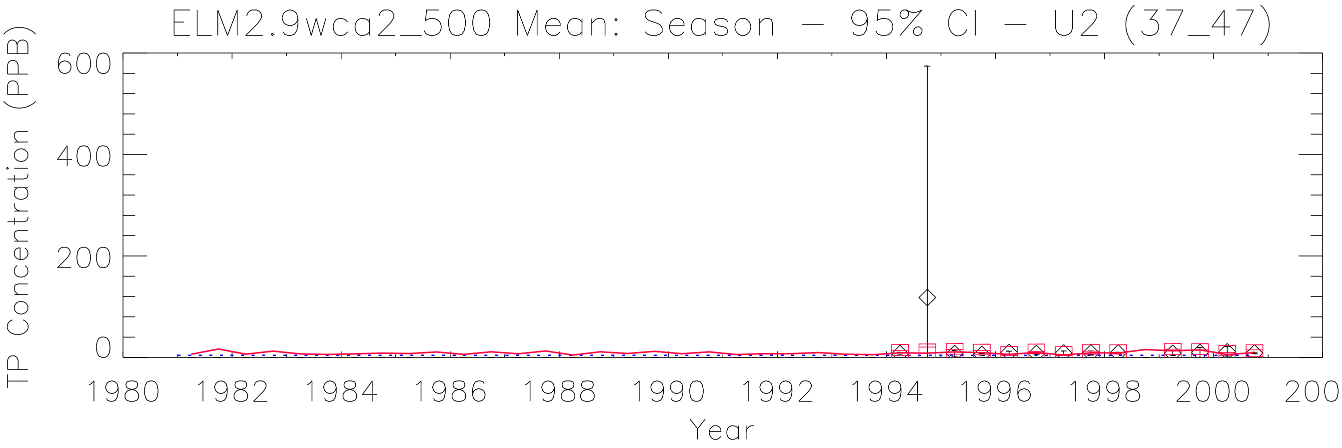
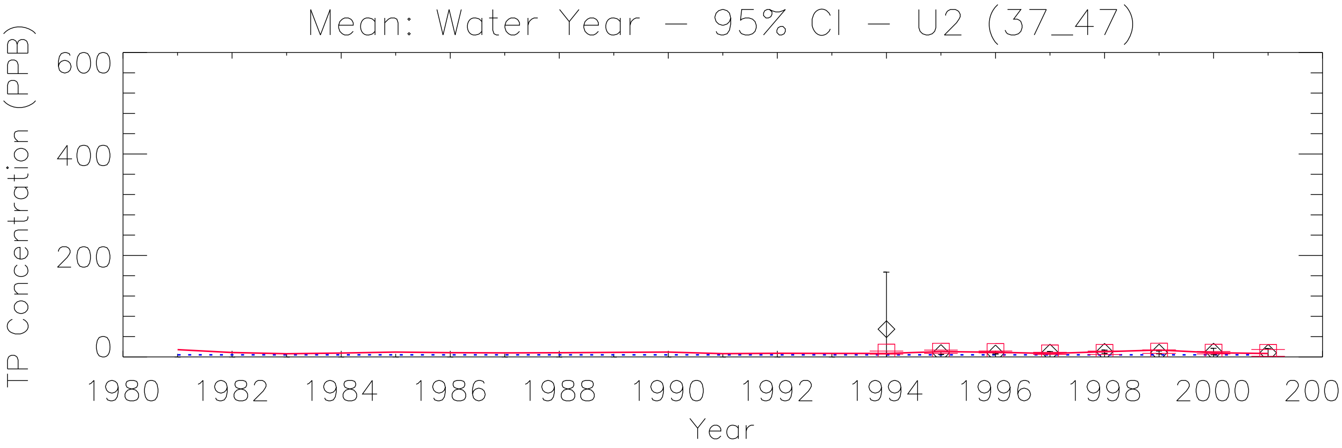
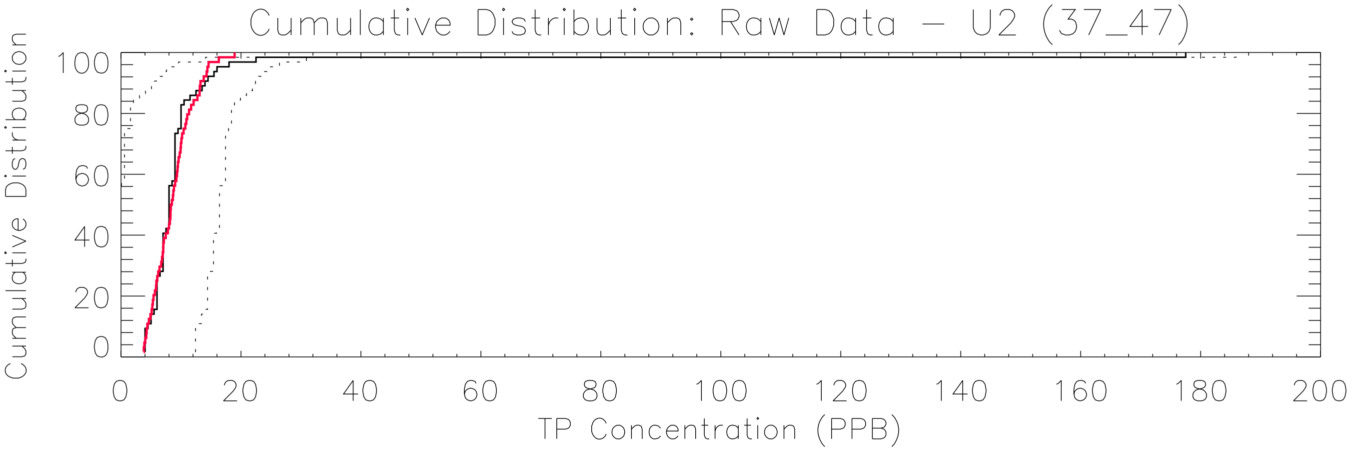
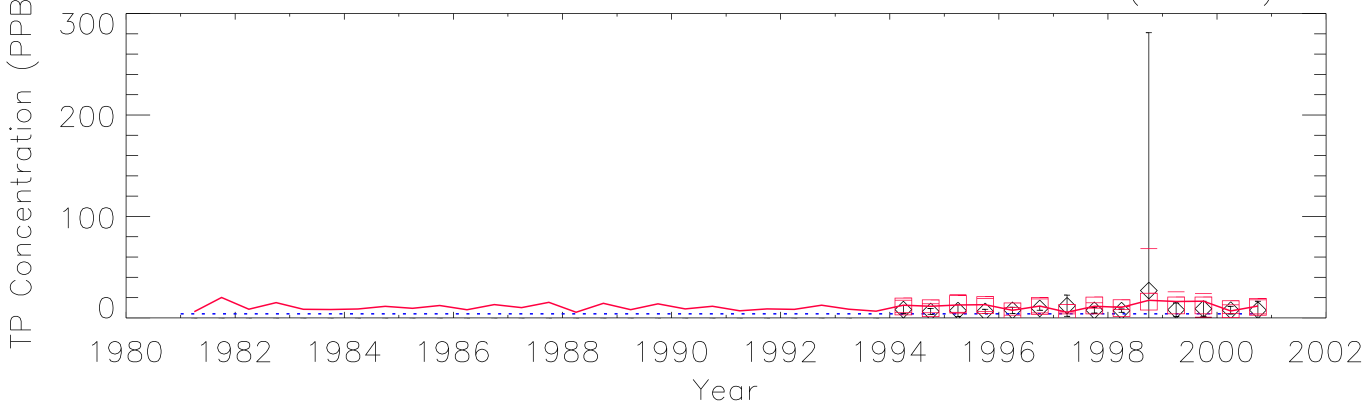


Cumulative Distribution: Raw Data - U1 (43_51)

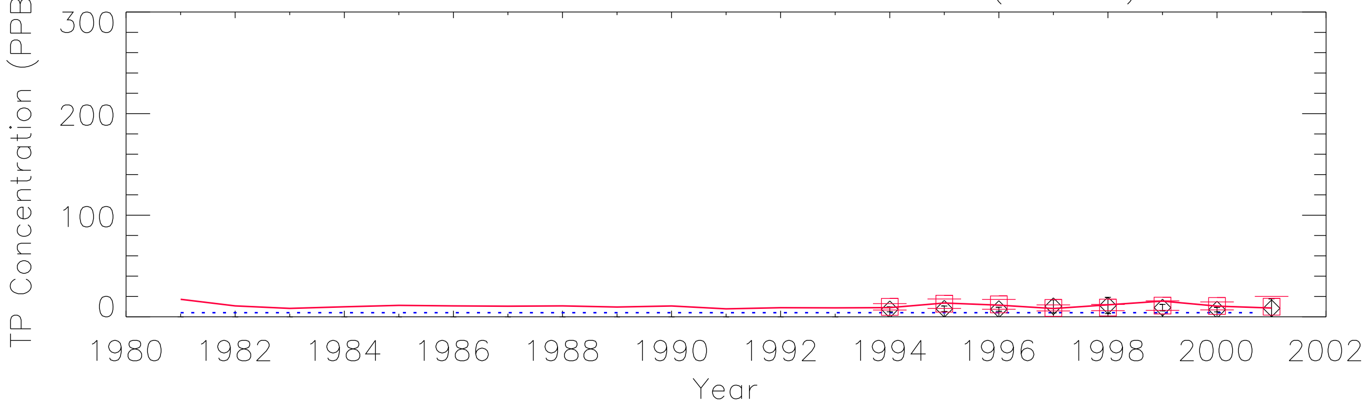

ELM2.9wca2_500 Mean: Season – 95% CI – U2 (37_47)


Mean: Water Year – 95% CI – U2 (37_47)

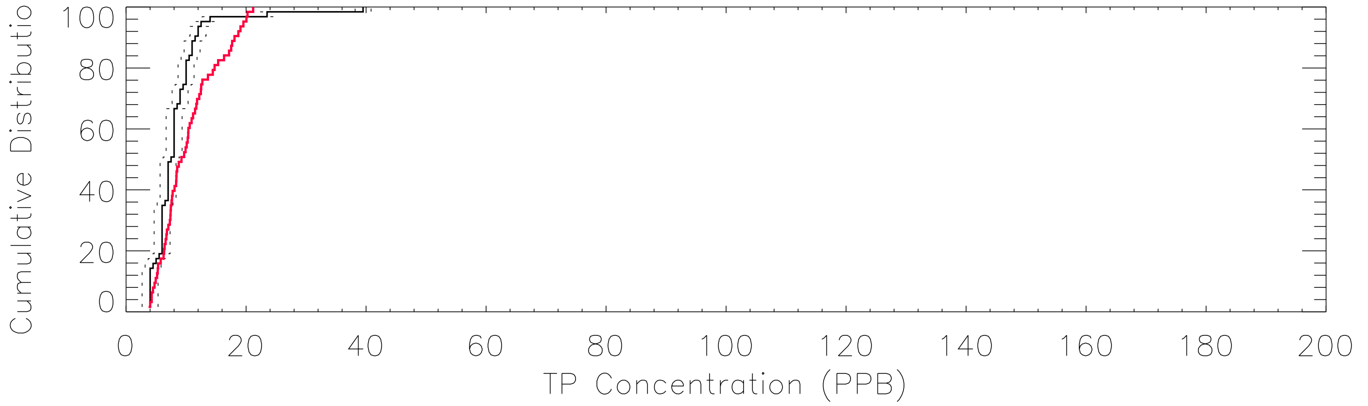

Cumulative Distribution: Raw Data – U2 (37_47)



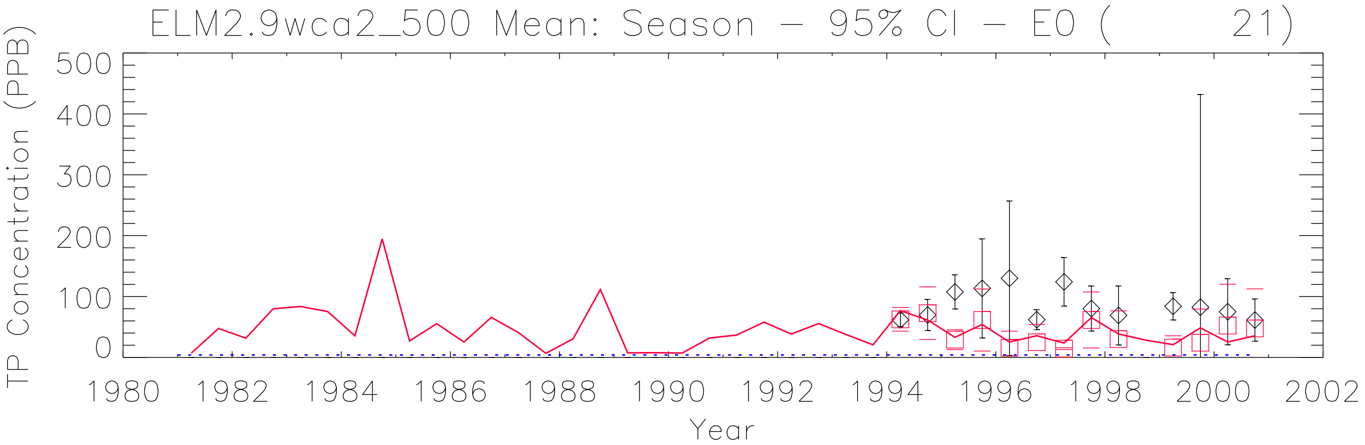
ELM2.9wca2_500 Mean: Season – 95% CI – U3 (32_41)



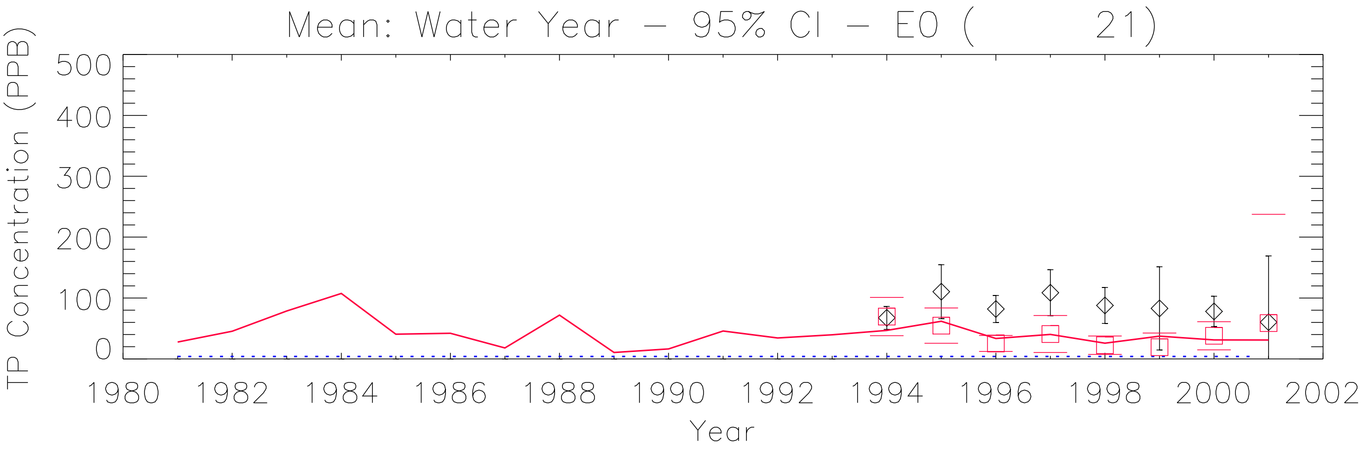
Mean: Water Year – 95% CI – U3 (32_41)



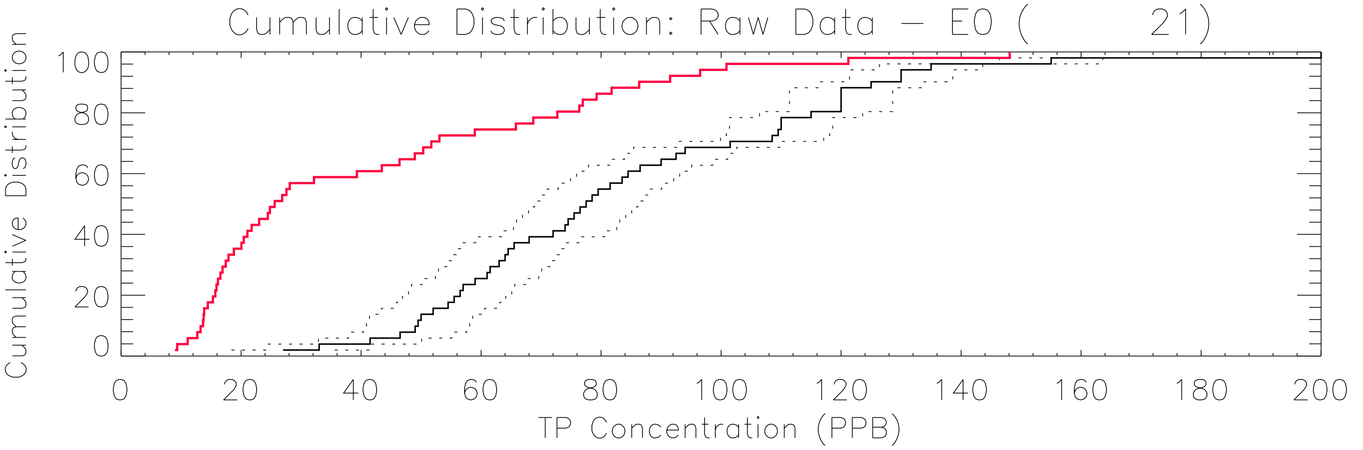
Cumulative Distribution: Raw Data – U3 (32_41)



ELM2.9wca2_500 Mean: Season – 95% CI – E0 (21)

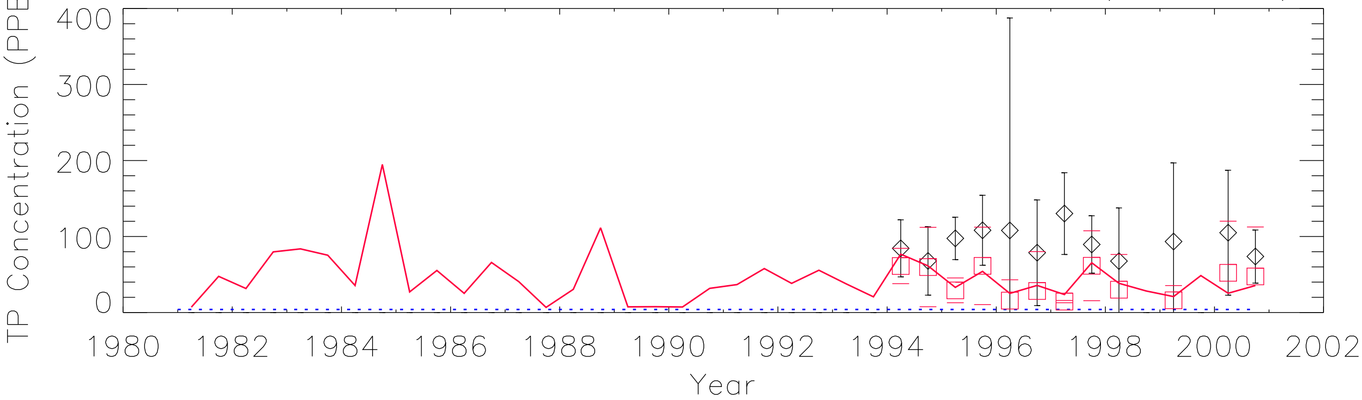


Mean: Water Year – 95% CI – E0 (21)

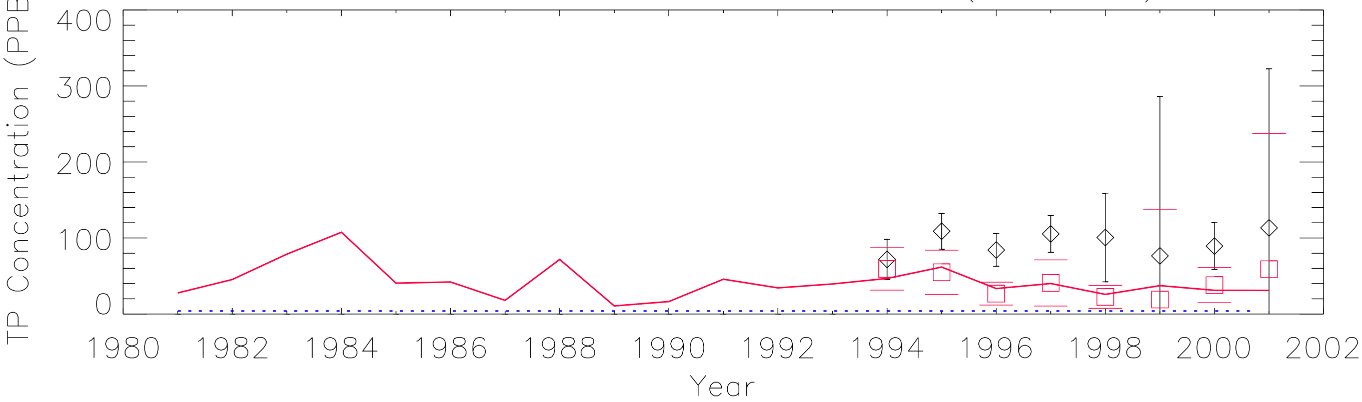


Cumulative Distribution: Raw Data – E0 (21)

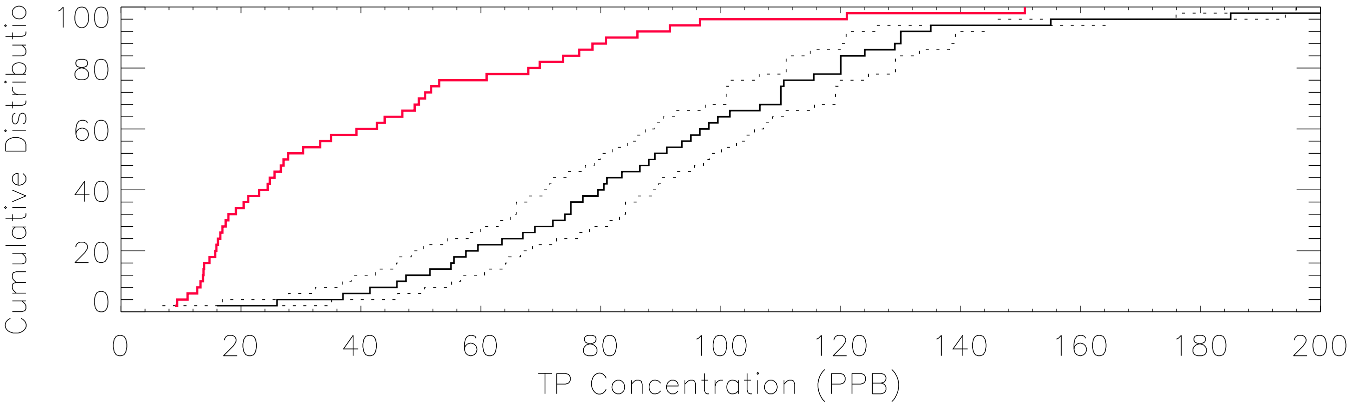
ELM2.9wca2_500 Mean: Season – 95% CI – F0 (21)



Mean: Water Year – 95% CI – F0 (21)



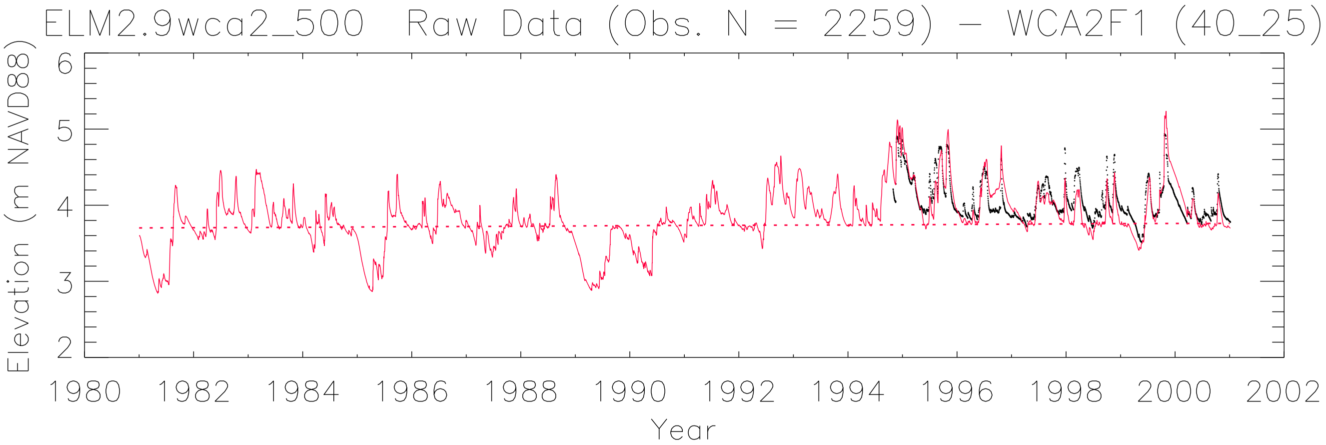
Cumulative Distribution: Raw Data – F0 (21)

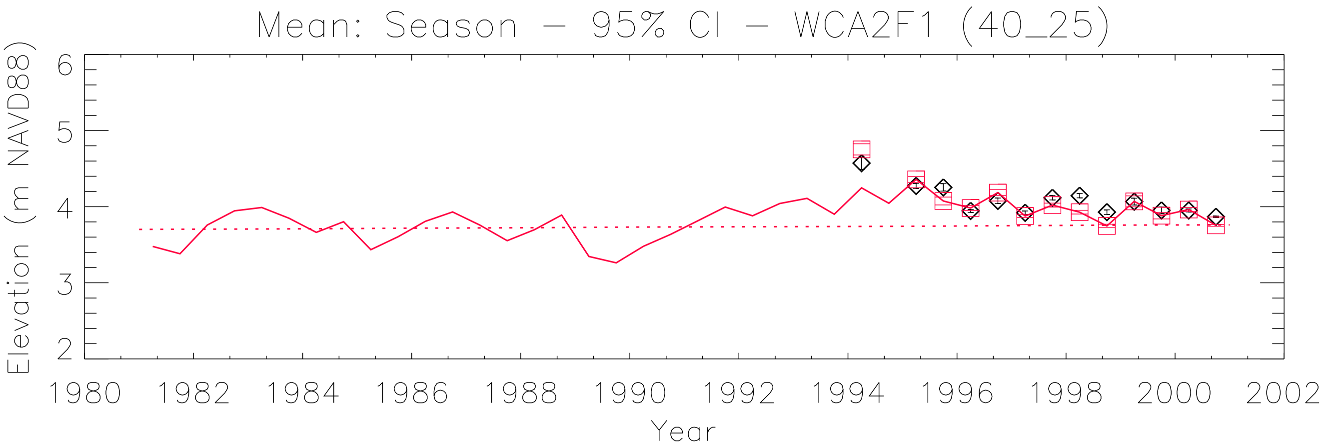


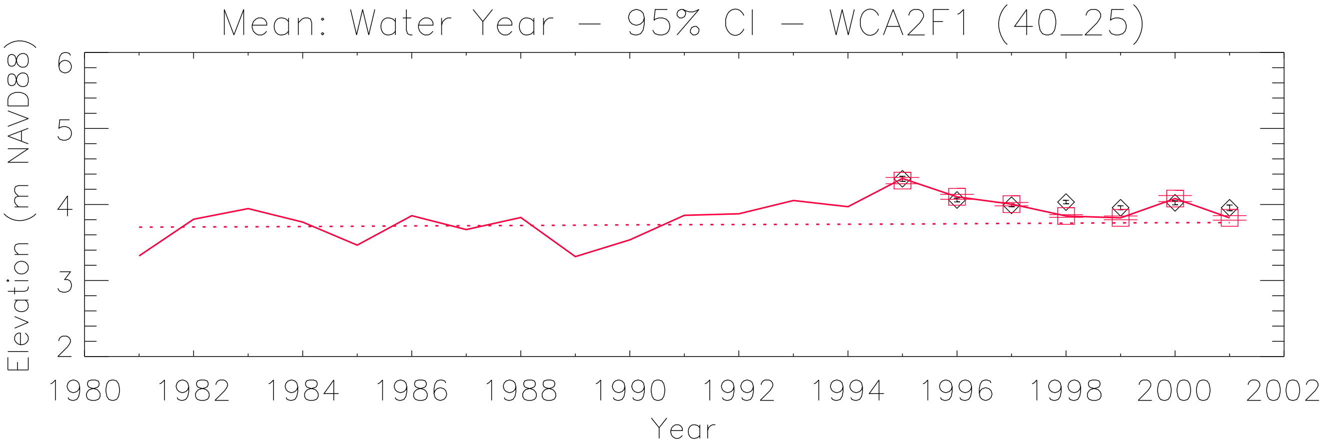
6.8 Appendix B: Time series & CFDs: stage

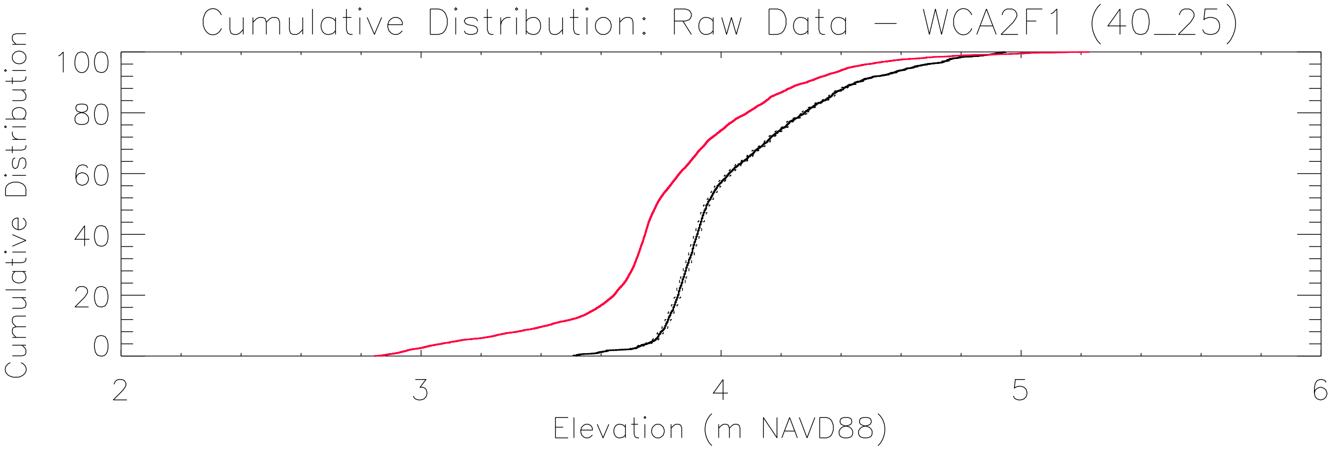
Figures B.1 – B.3. Plots of stage hydrographs and their associated Cumulative Frequency Distributions (CFD) for the period of record 1981-2000 at each monitoring location. The sequence of the figures is based on geographic location, starting in the northwest, moving towards the southeast. A map of all sites is provided in the Model Performance Chapter.

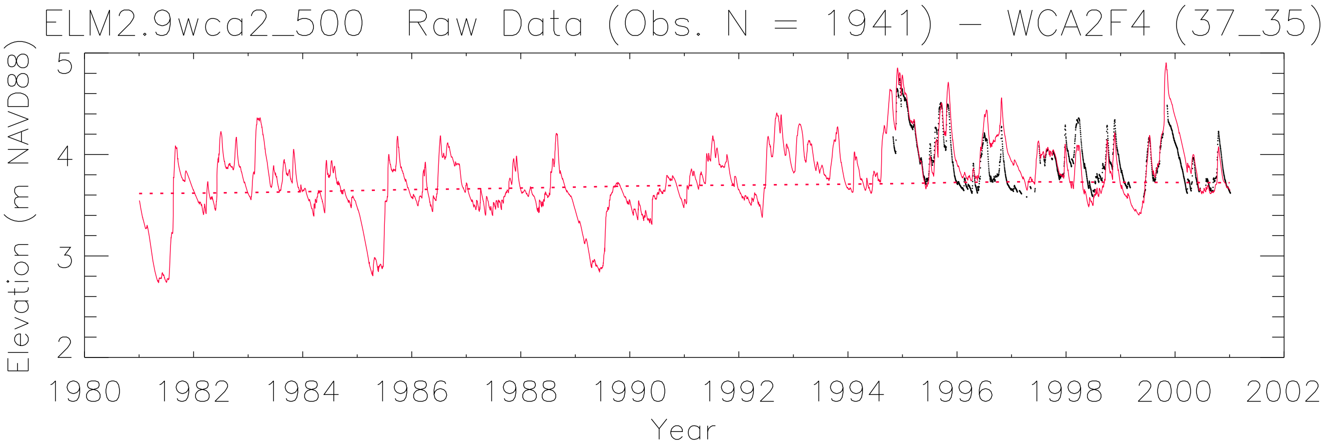
> *The red dashed line in the stage hydrographs is the model grid cell's land surface elevation, which is a time-varying output variable of the model. The model grid cell column and row locations are shown in parentheses (col_row) of each plot's title.*
>
> a) All data, with no temporal aggregation, of daily observations (black dots) and model results (red line).
>
> b) All data were aggregated into arithmetic mean values by wet and dry seasons within water years; the continuous lines pass through mean of all daily data points for each season; the mean of paired simulated & observed values are shown in red boxes and black diamonds, respectively; the 95% Confidence Interval (CI) of the paired means are shown by the "__" symbols in the red for the model and black for the observed data.
>
> c) All data aggregated into arithmetic mean values by water year, with the same treatment as in plot b).
>
> d) The cumulative frequency distributions of the simulated and observed (raw, un-aggregated) data; the 95% confidence interval for observed data is shown in the dashed black lines. Note that only paired simulated and observed data points are used.

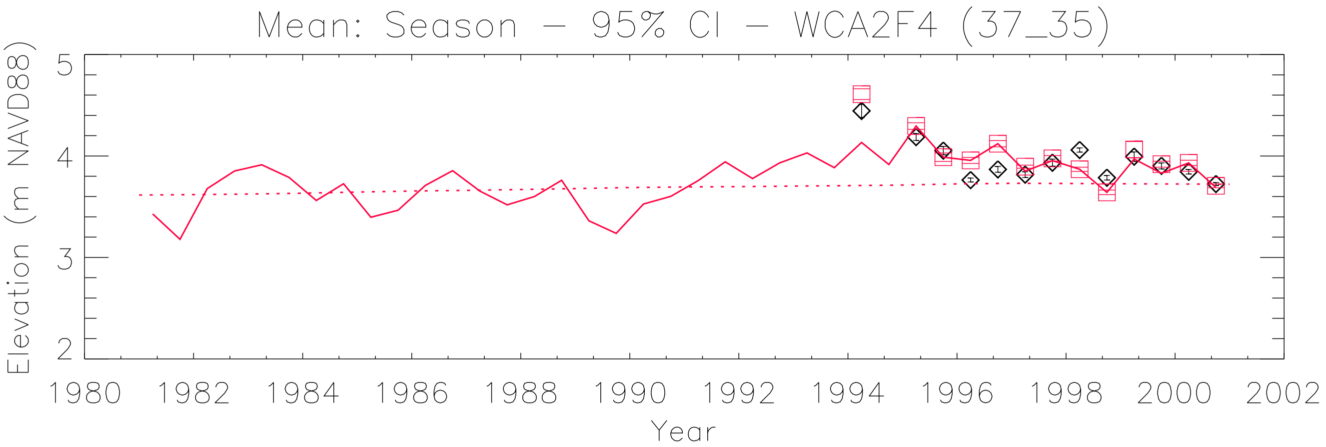

ELM2.9wca2_500 Raw Data (Obs. N = 2259) – WCA2F1 (40_25)
Elevation (m NAVD88)
2
3
4
5
6
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

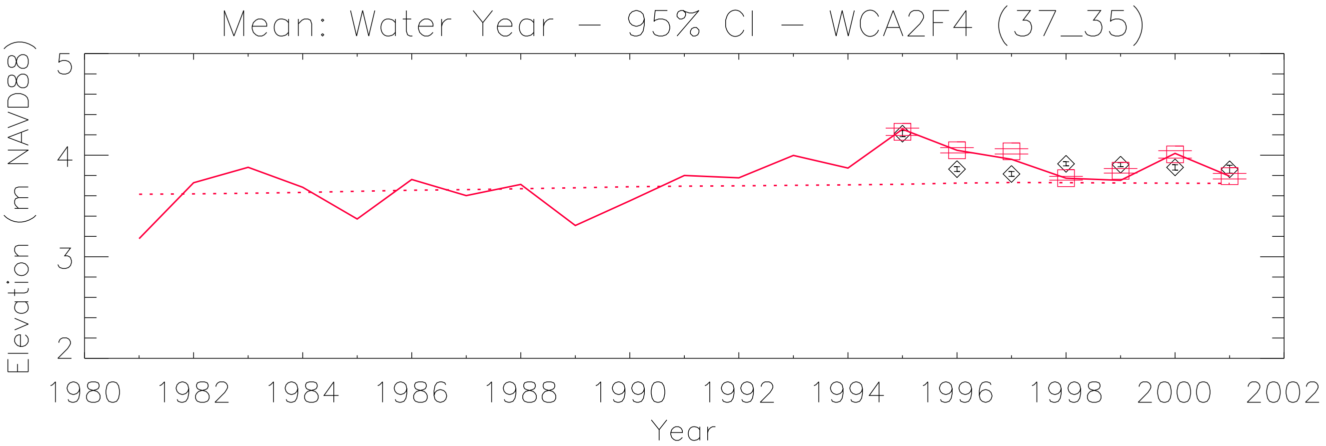

Mean: Season – 95% CI – WCA2F1 (40_25)
Elevation (m NAVD88)
2
3
4
5
6
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

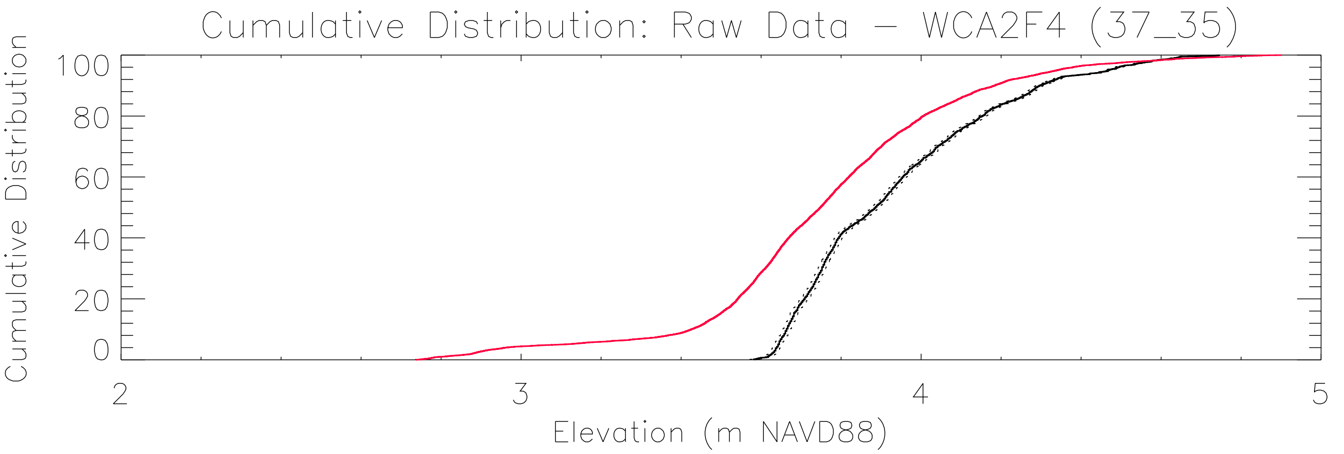

Mean: Water Year – 95% CI – WCA2F1 (40_25)
Elevation (m NAVD88)
2
3
4
5
6
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

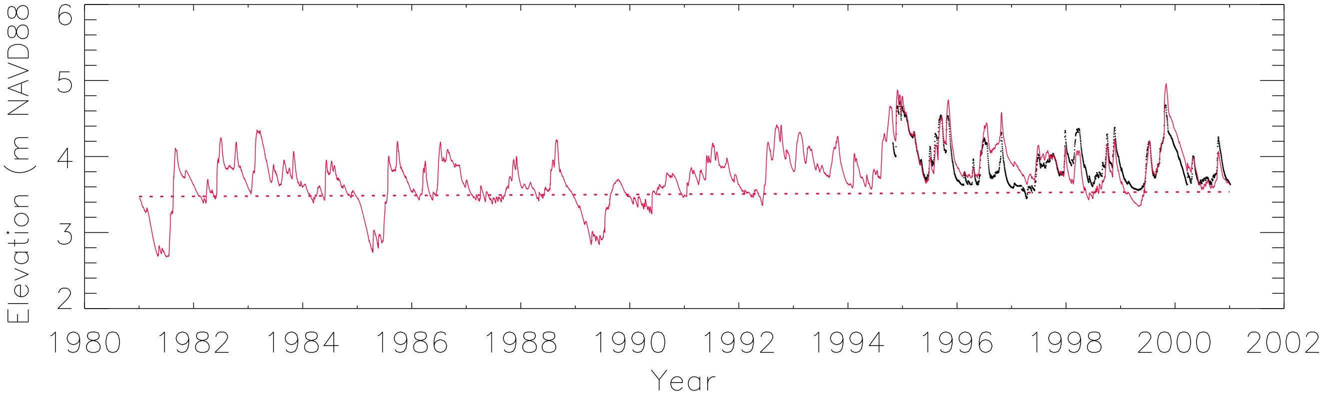

Cumulative Distribution: Raw Data – WCA2F1 (40_25)
Cumulative Distribution
0
20
40
60
80
100
2
3
4
5
6
Elevation (m NAVD88)


ELM2.9wca2_500 Raw Data (Obs. N = 1941) – WCA2F4 (37_35)
Elevation (m NAVD88)
2
3
4
5
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

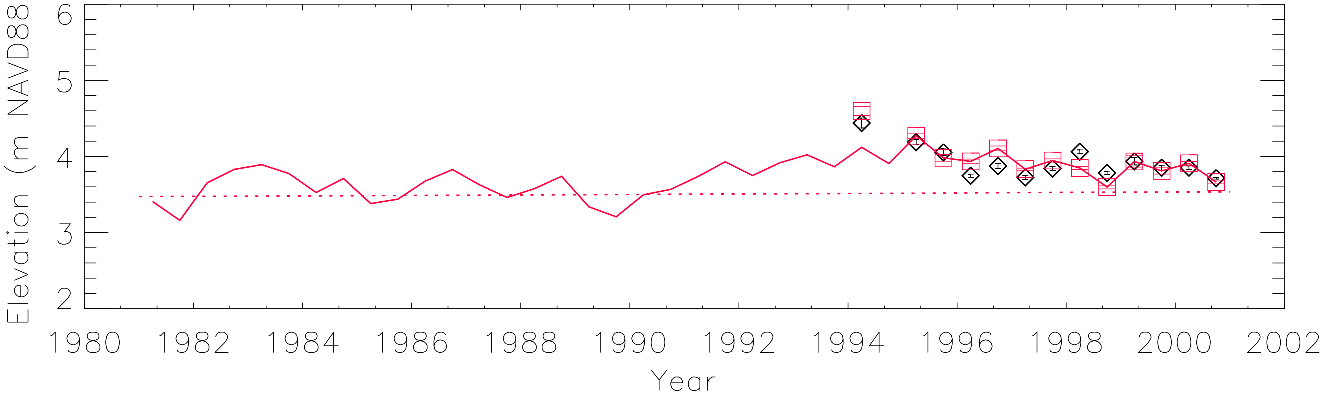

Mean: Season – 95% CI – WCA2F4 (37_35)
Elevation (m NAVD88)
2
3
4
5
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – WCA2F4 (37_35)
Elevation (m NAVD88)
2
3
4
5
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

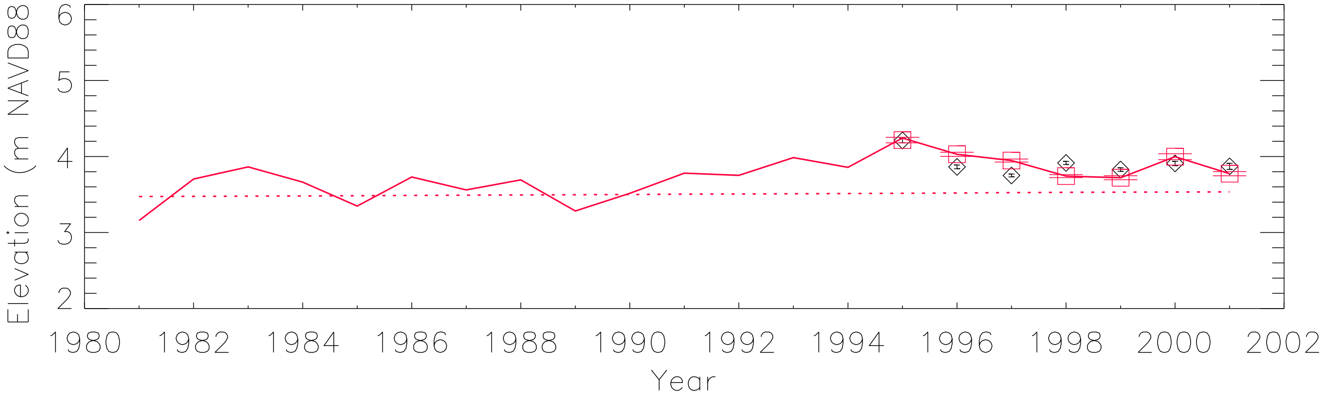

Cumulative Distribution: Raw Data – WCA2F4 (37_35)
Cumulative Distribution
0
20
40
60
80
100
2
3
4
5
Elevation (m NAVD88)



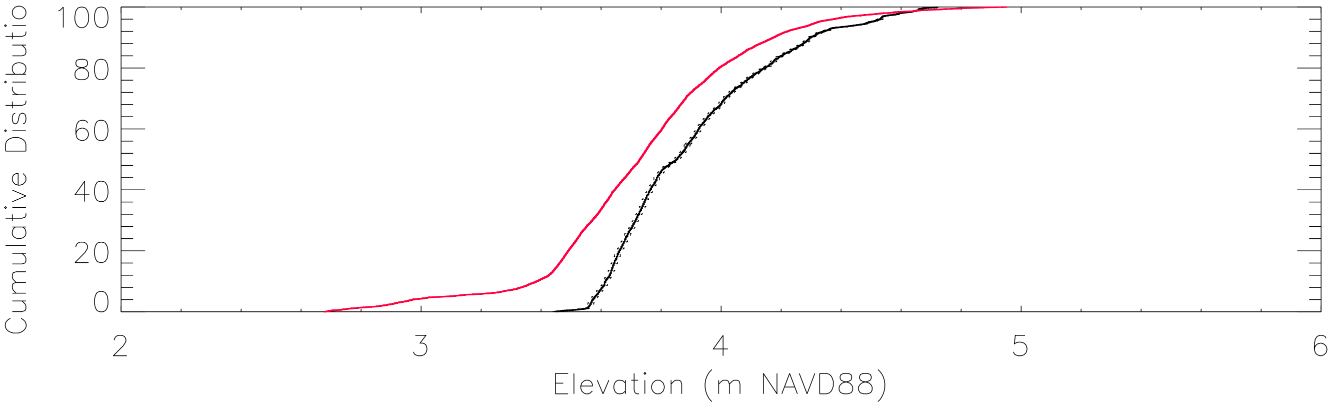
ELM2.9wca2_500 Raw Data (Obs. N = 2260) - WCA2E4 (42_37)



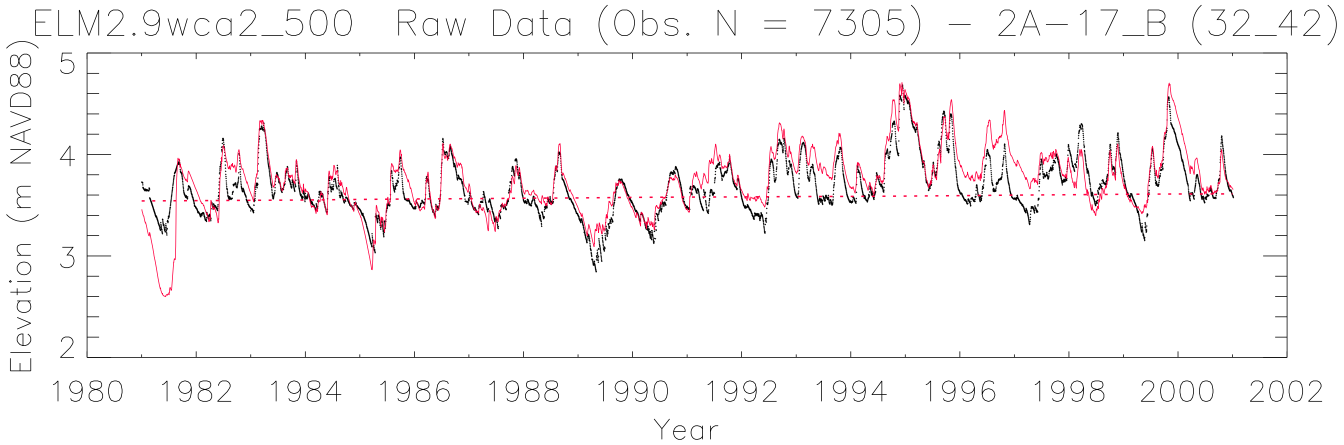
Mean: Season - 95% CI - WCA2E4 (42_37)

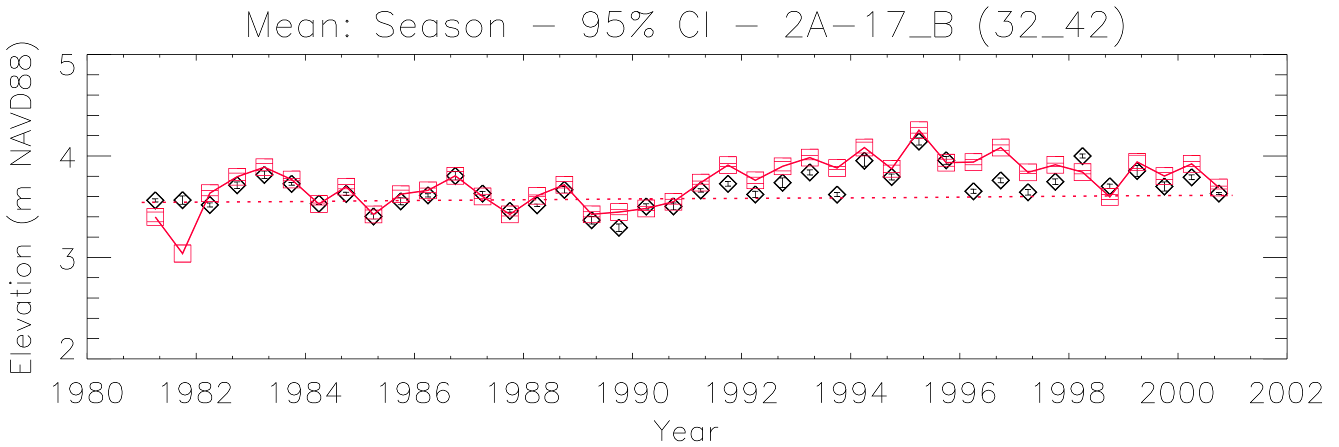


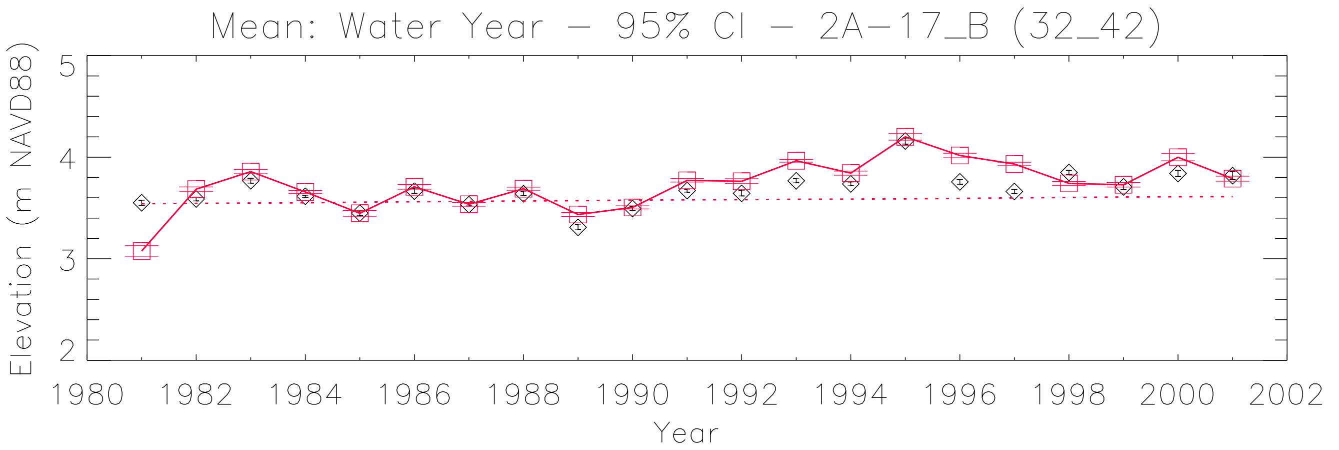
Mean: Water Year - 95% CI - WCA2E4 (42_37)

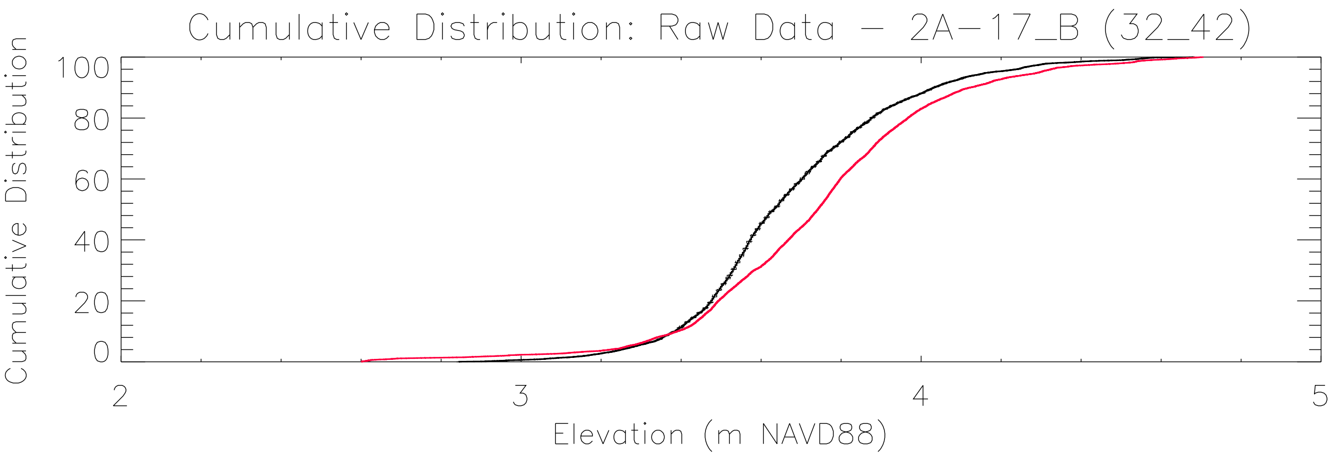


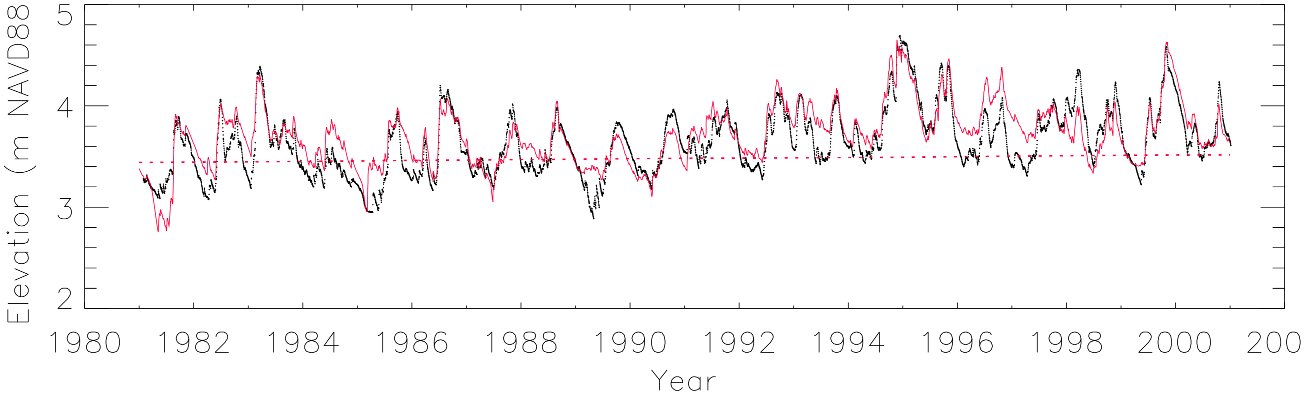
Cumulative Distribution: Raw Data - WCA2E4 (42_37)

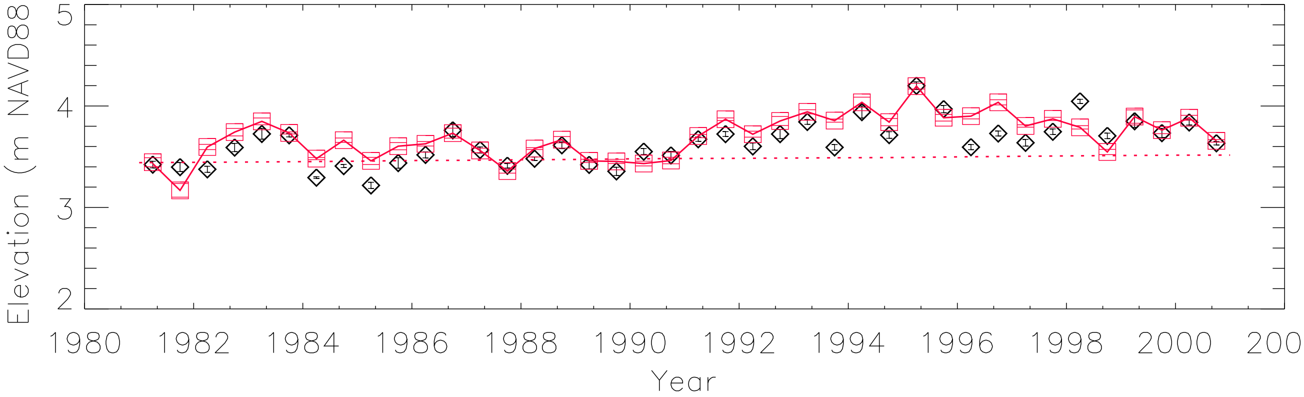

ELM2.9wca2_500 Raw Data (Obs. N = 7305) – 2A–17_B (32_42)

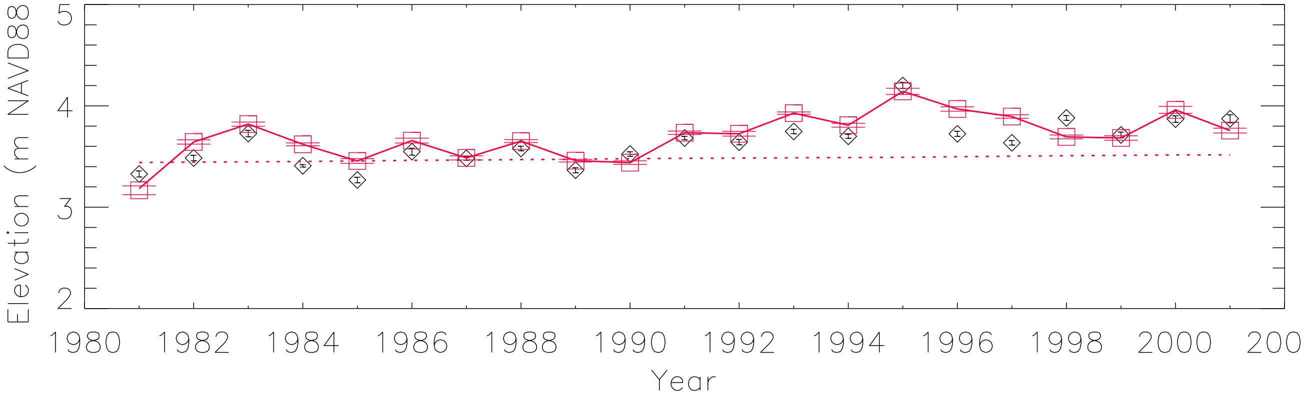

Mean: Season – 95% CI – 2A–17_B (32_42)

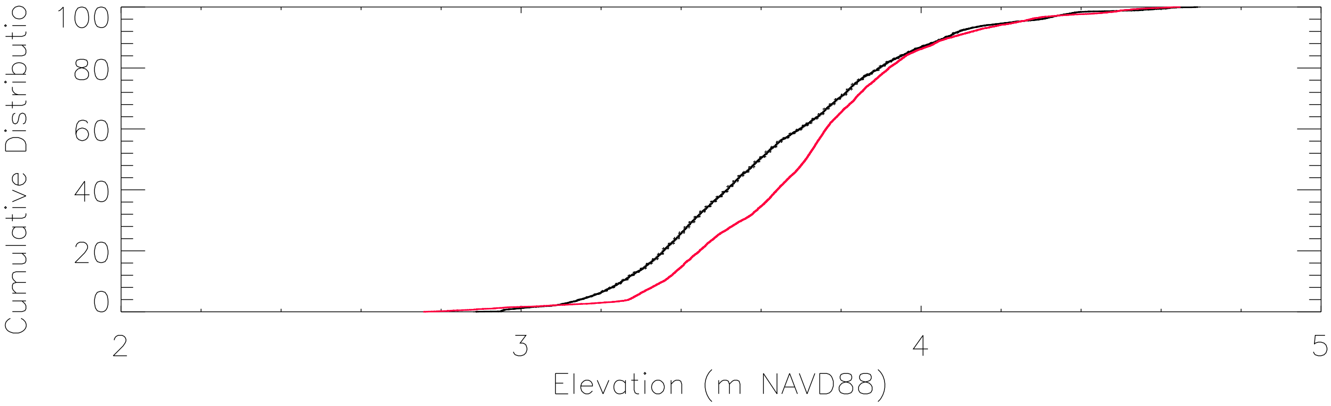

Mean: Water Year – 95% CI – 2A–17_B (32_42)

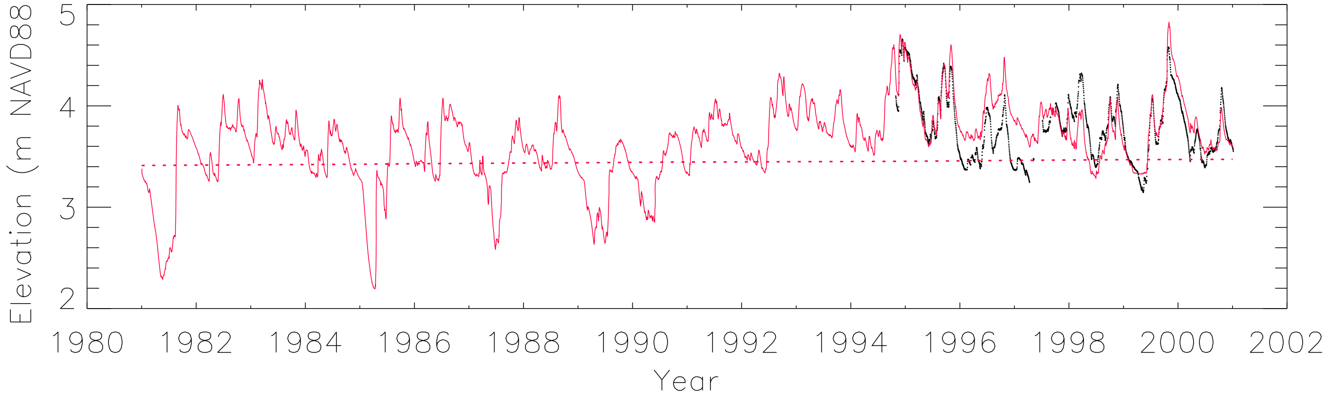

Cumulative Distribution: Raw Data – 2A–17_B (32_42)


ELM2.9wca2_500 Raw Data (Obs. N = 7278) − 2A−300_B (32_51)

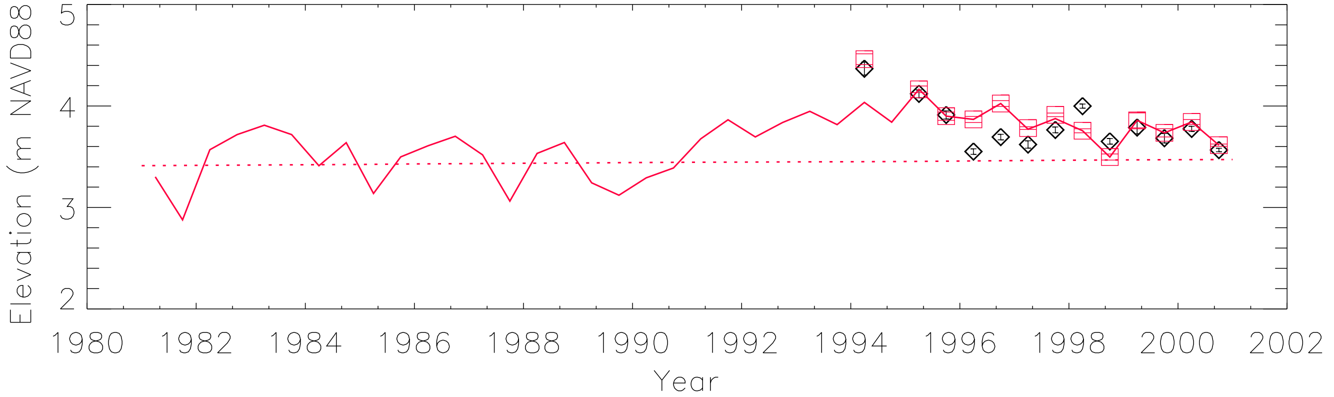

Mean: Season − 95% CI − 2A−300_B (32_51)


Mean: Water Year − 95% CI − 2A−300_B (32_51)

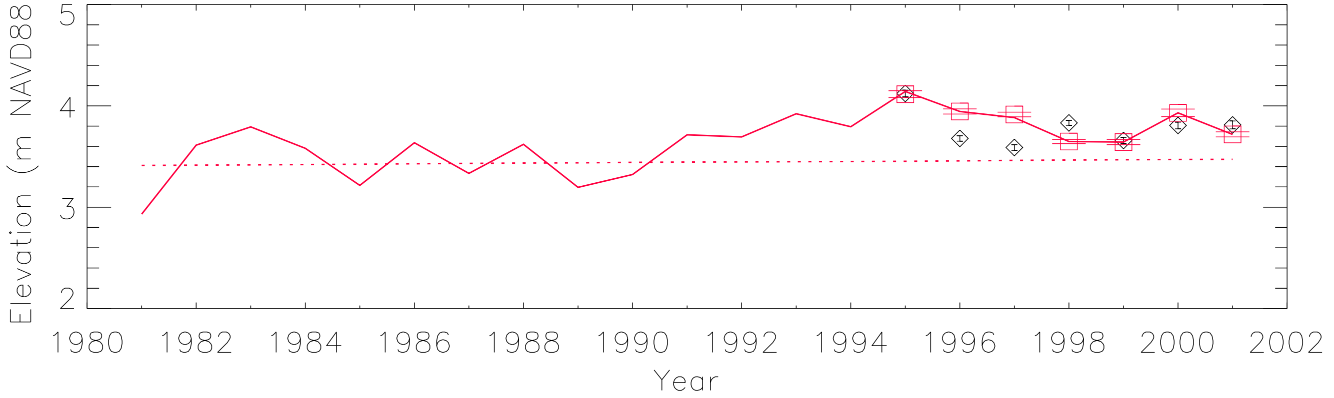

Cumulative Distribution: Raw Data − 2A−300_B (32_51)



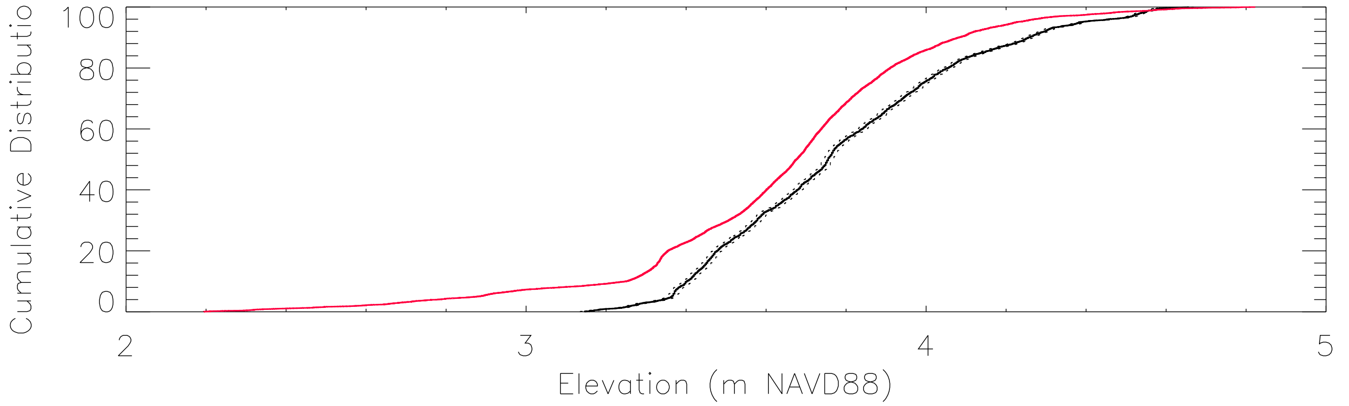
ELM2.9wca2_500 Raw Data (Obs. N = 2150) – WCA2U1 (43_52)



Mean: Season – 95% CI – WCA2U1 (43_52)



Mean: Water Year – 95% CI – WCA2U1 (43_52)



Cumulative Distribution: Raw Data – WCA2U1 (43_52)

6.9 Appendix C: Time series & CFDs: CL

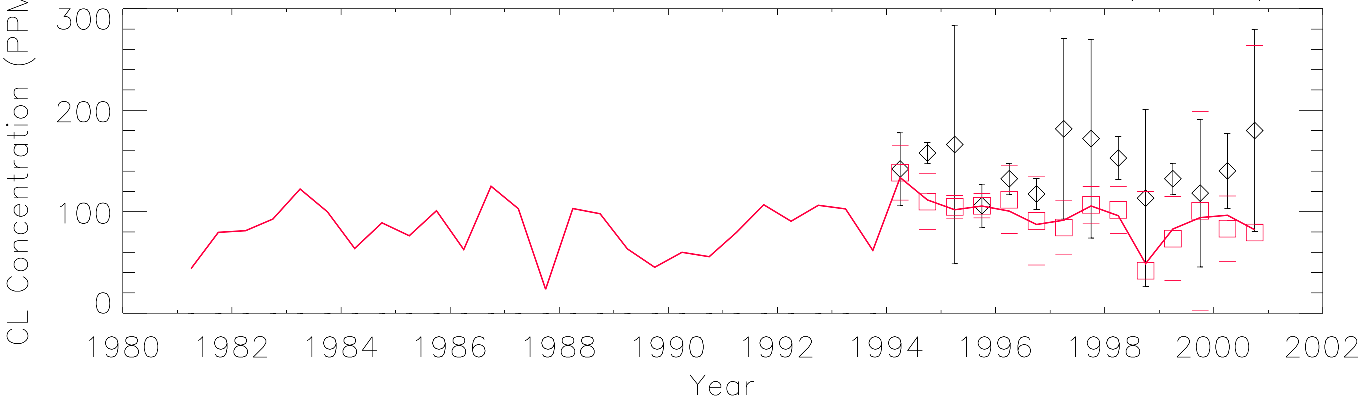
Figures C.1 – C.32. Time series plots of water column chloride (CL) concentration and their associated Cumulative Frequency Distributions (CFD) for the period of record 1981-2000 at each monitoring location. The sequence of the figures is based on geographic location of marsh sites, starting in northwest, moving towards the southeast; following the set of plots of all marsh sites, the canal monitoring sites are similarly sequenced. A map of all sites is provided in the Model Performance Chapter.

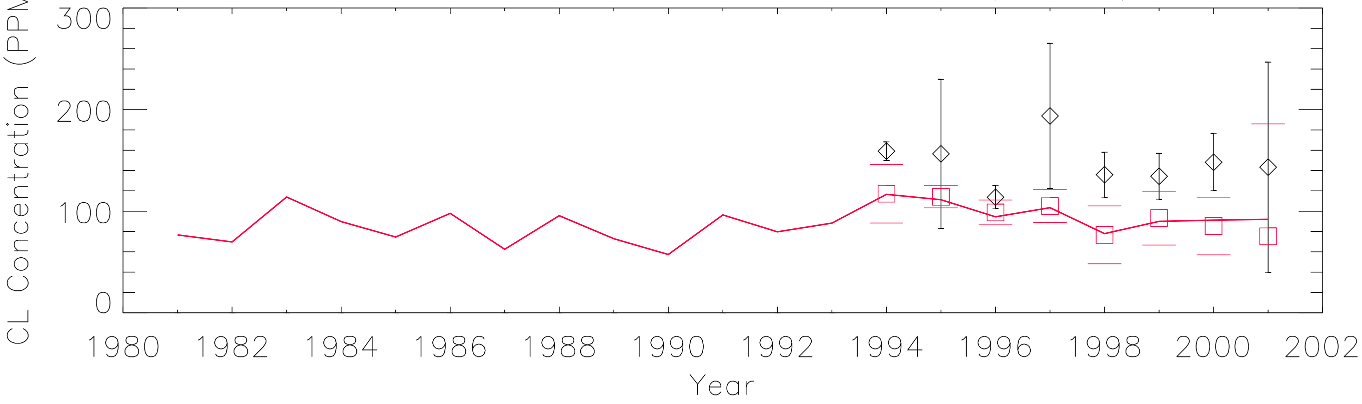
The model grid cell column and row locations (col_row) or canal reach identifier (single integer) are shown in parentheses of each plot's title.

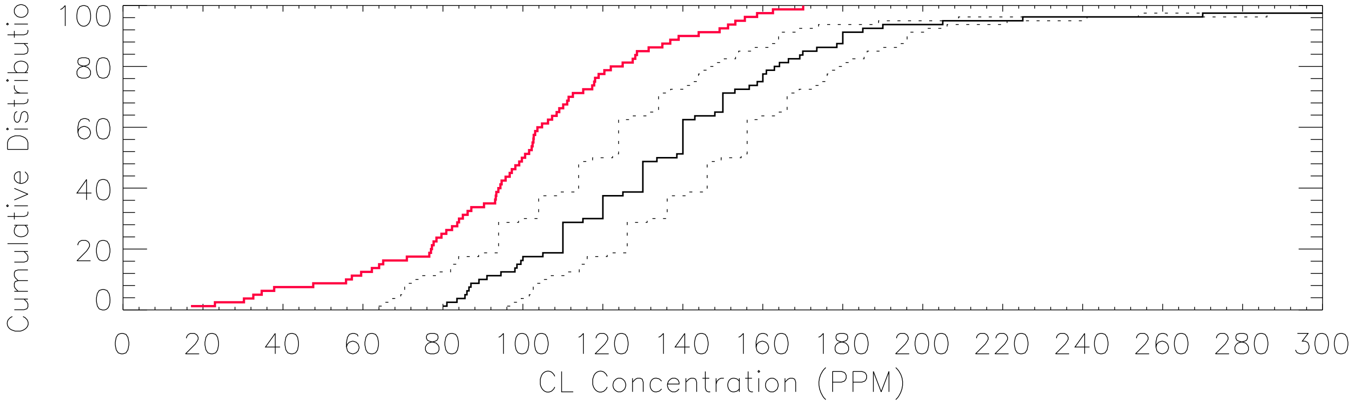
a) All data were aggregated into arithmetic mean values by wet and dry seasons within water years; the continuous lines pass through mean of all daily data points for each season; the mean of paired simulated & observed values are shown in red boxes and black diamonds, respectively; the 95% Confidence Interval (CI) of the paired means are shown by the "__" symbols in the red for the model and black for the observed data.

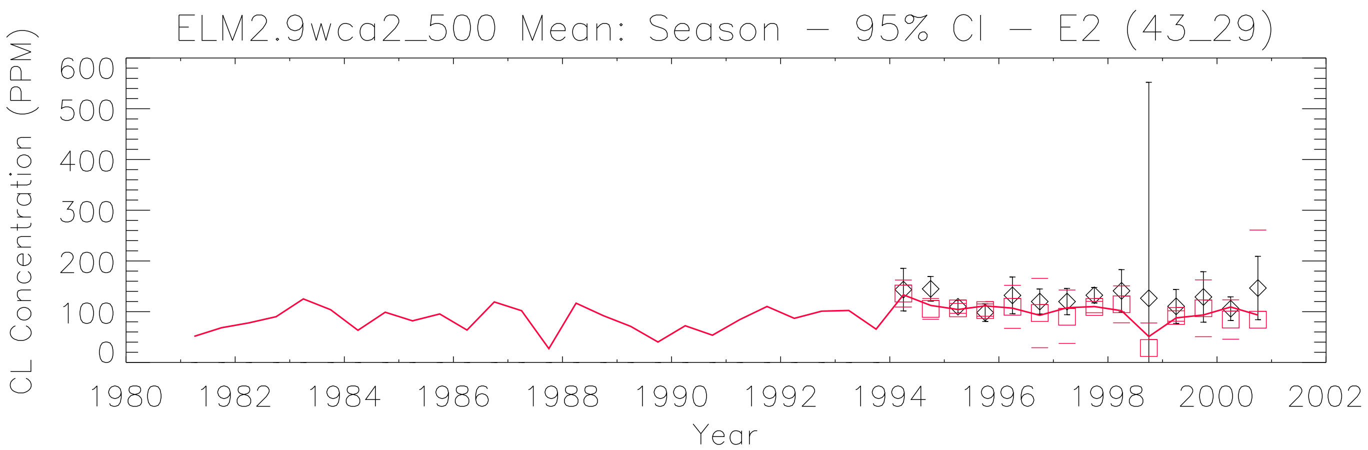
b) All data aggregated into arithmetic mean values by water year, with the same treatment as in plot a).

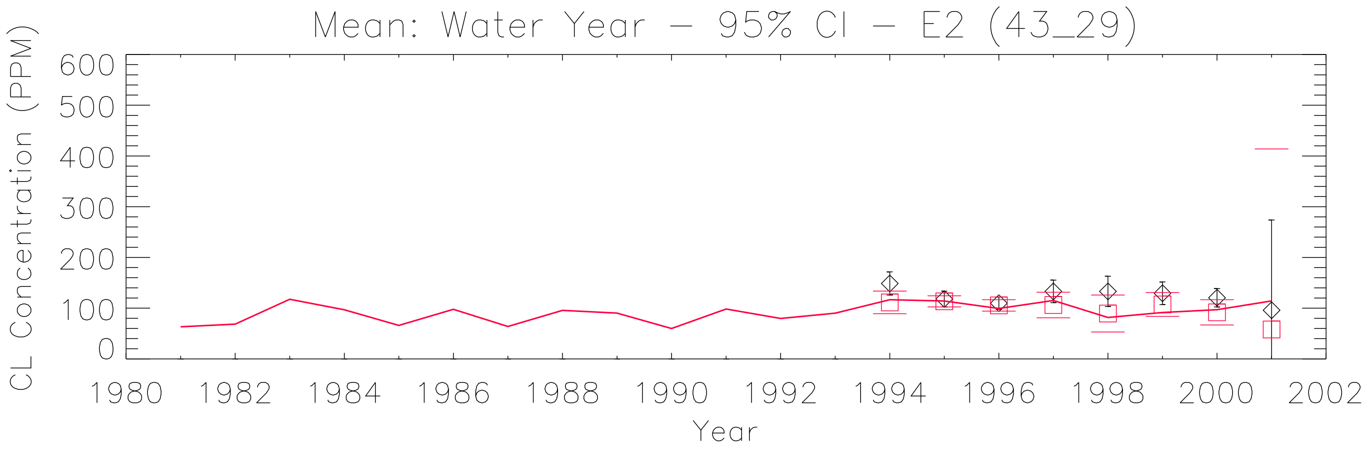
c) The cumulative frequency distributions of the simulated and observed (raw, un-aggregated) data; the 95% confidence interval for observed data is shown in the dashed black lines. Note that only paired simulated and observed data points are used.

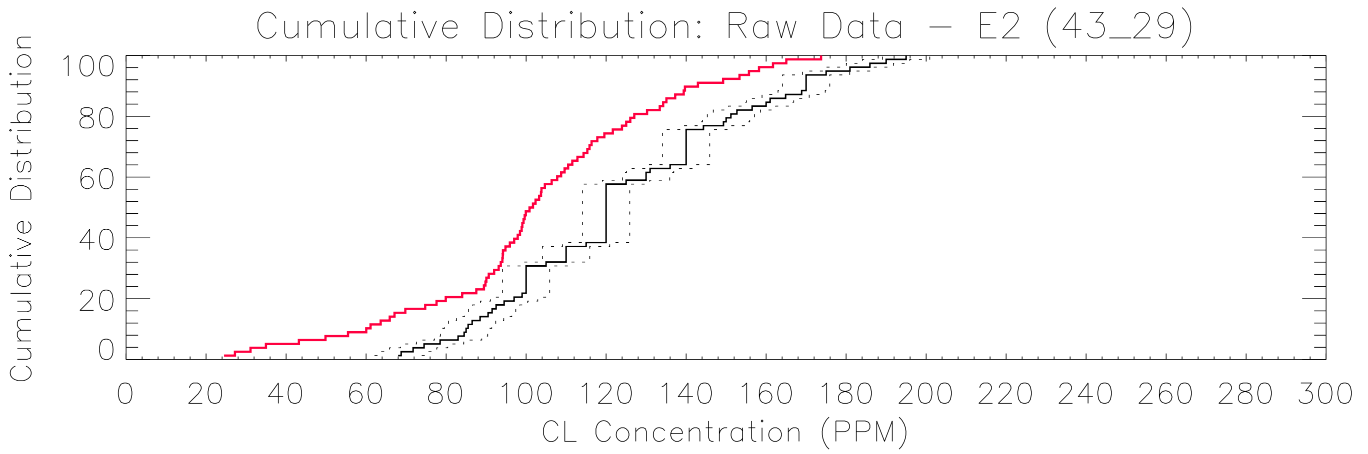

ELM2.9wca2_500 Mean: Season – 95% CI – E1 (43_27)

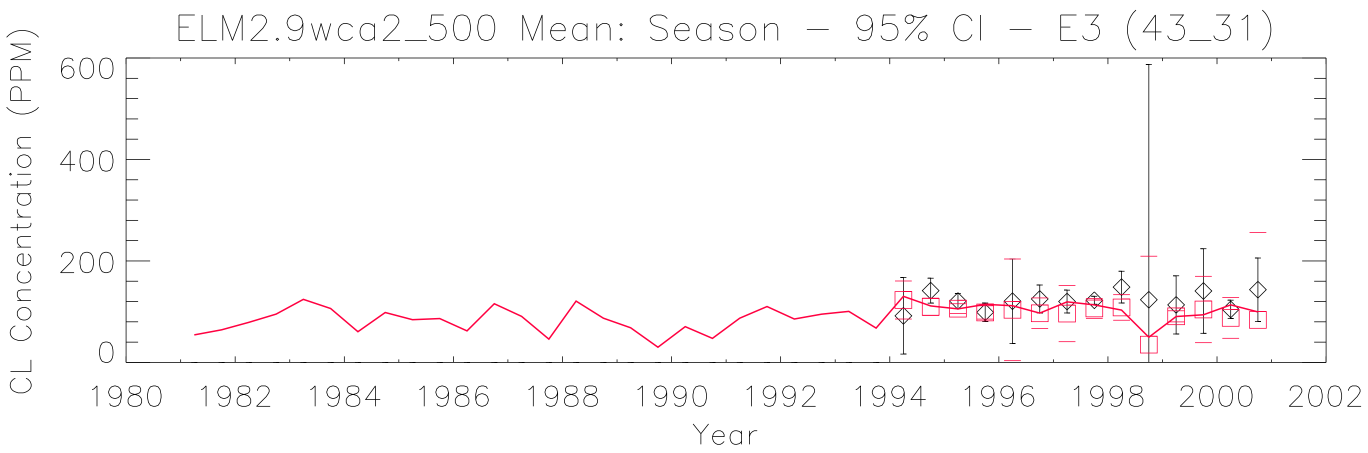

Mean: Water Year – 95% CI – E1 (43_27)

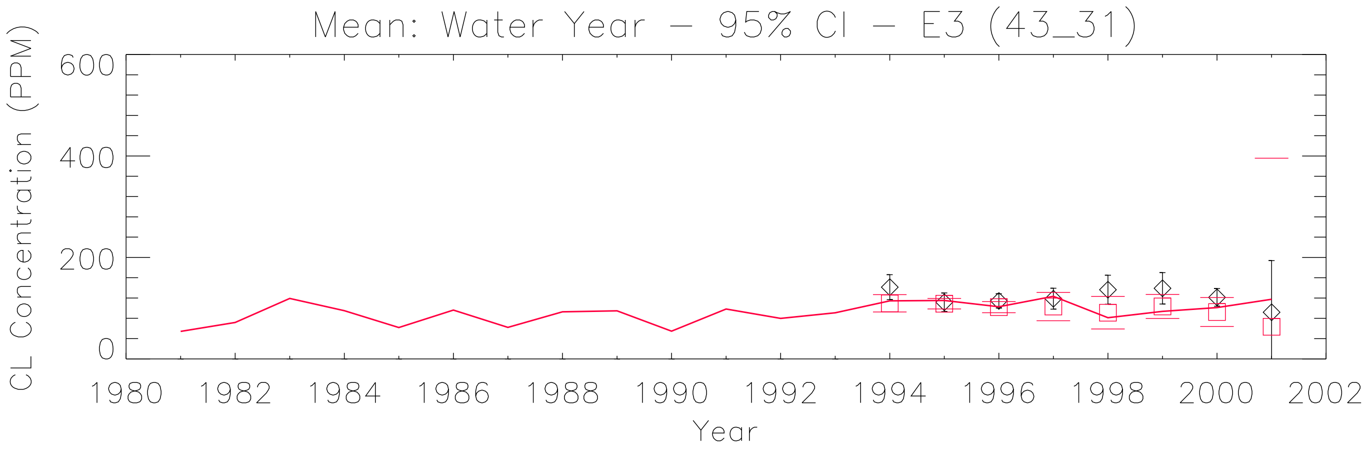

Cumulative Distribution: Raw Data – E1 (43_27)

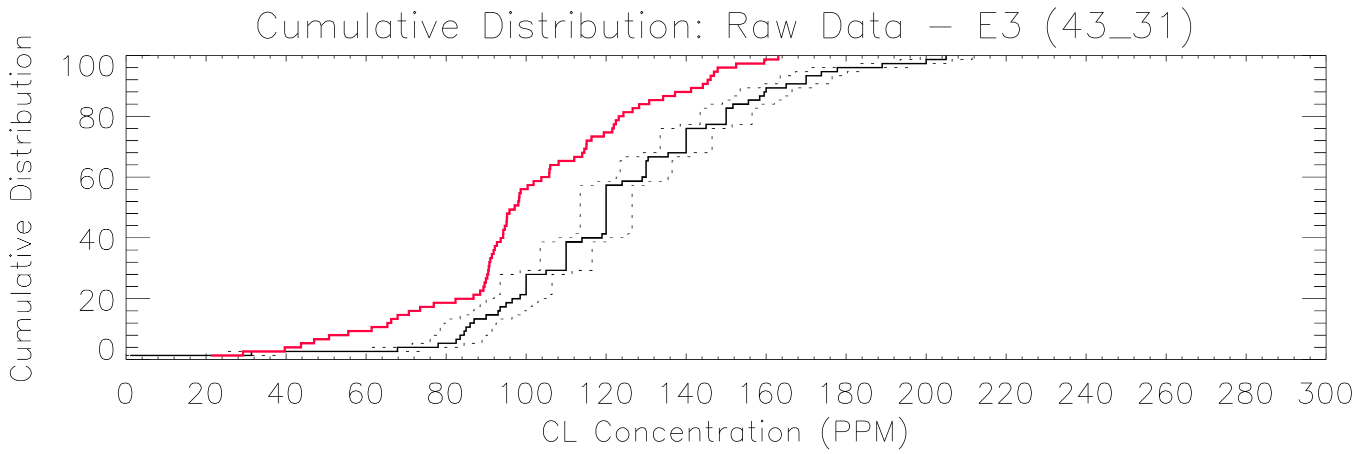

ELM2.9wca2_500 Mean: Season – 95% CI – E2 (43_29)

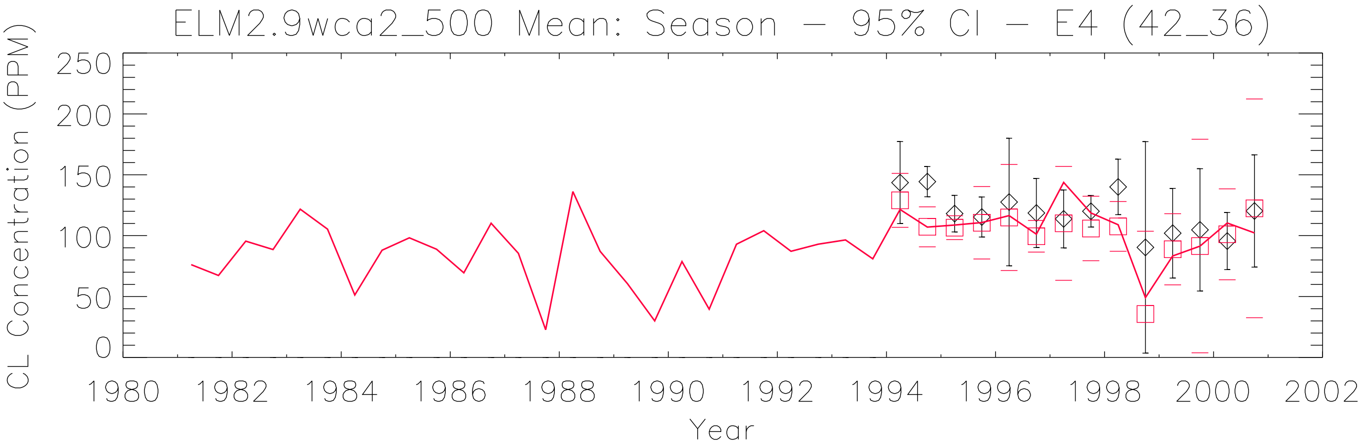

Mean: Water Year – 95% CI – E2 (43_29)

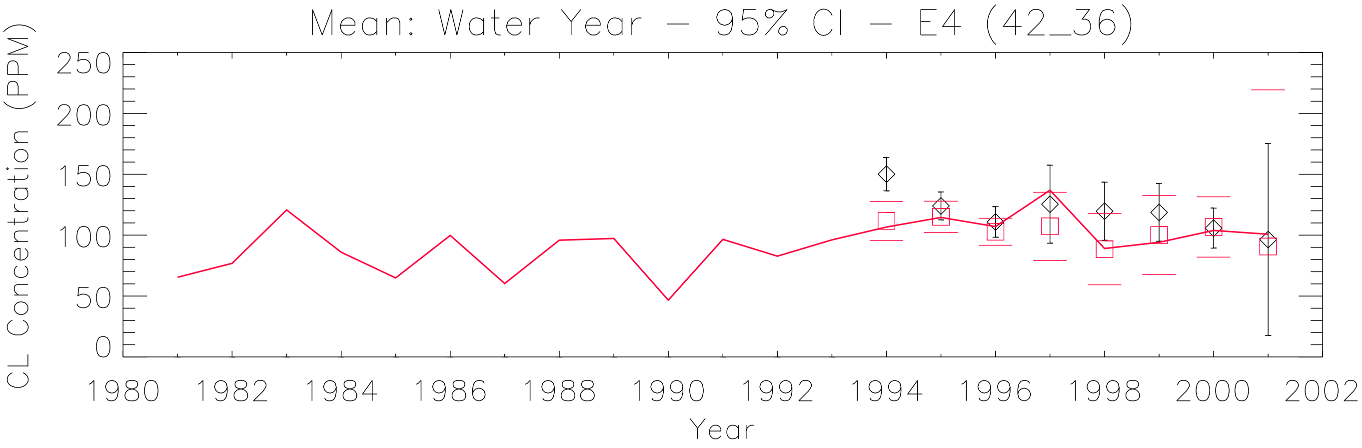

Cumulative Distribution: Raw Data – E2 (43_29)

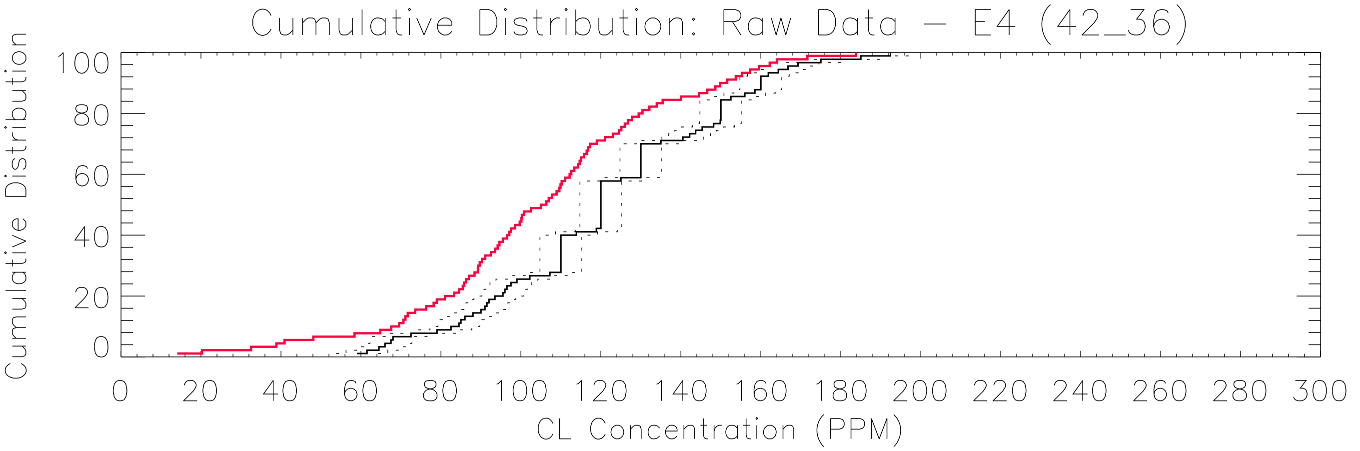

ELM2.9wca2_500 Mean: Season – 95% CI – E3 (43_31)
CL Concentration (PPM)
0
200
400
600
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

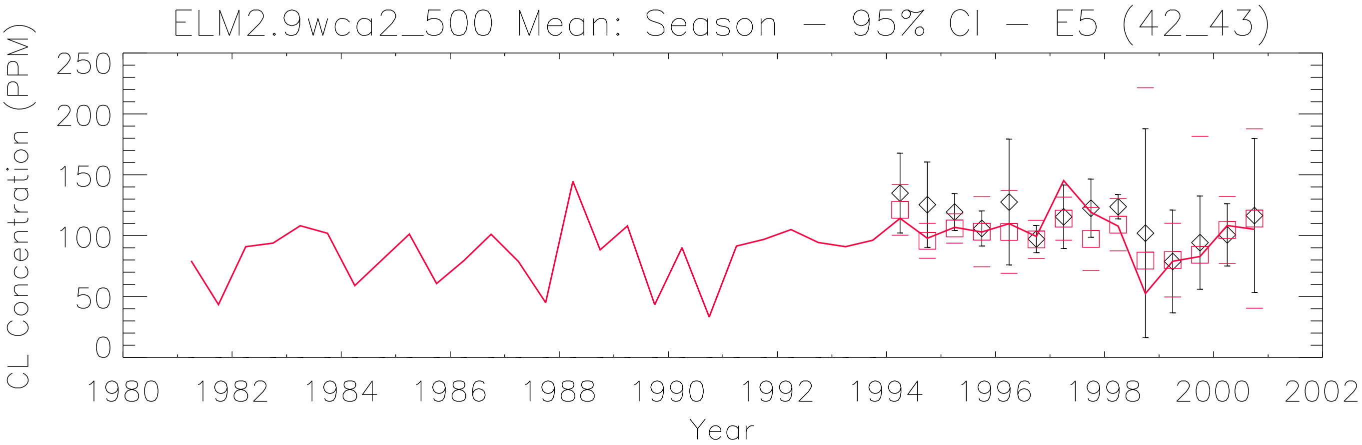

Mean: Water Year – 95% CI – E3 (43_31)
CL Concentration (PPM)
0
200
400
600
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

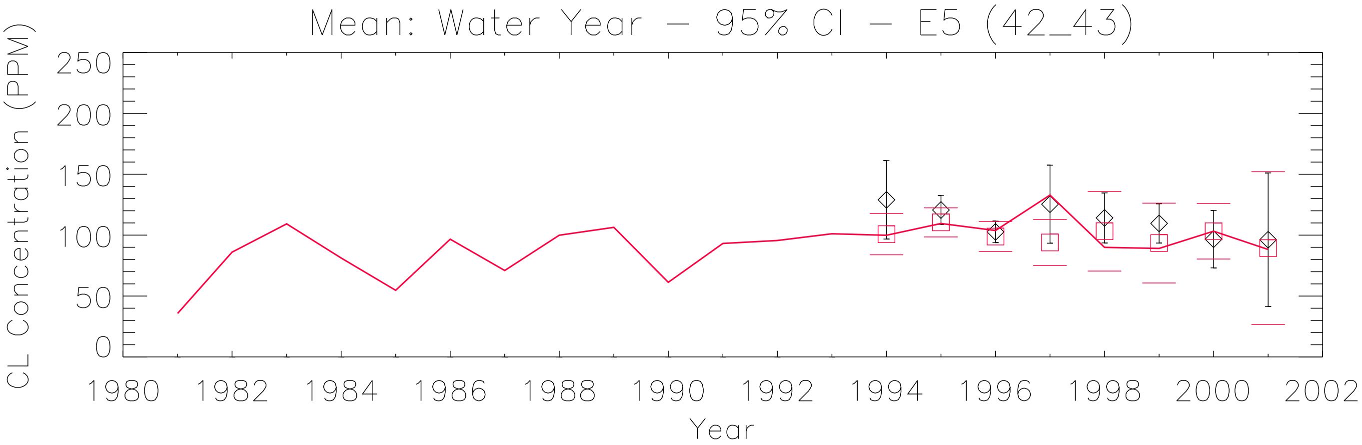

Cumulative Distribution: Raw Data – E3 (43_31)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

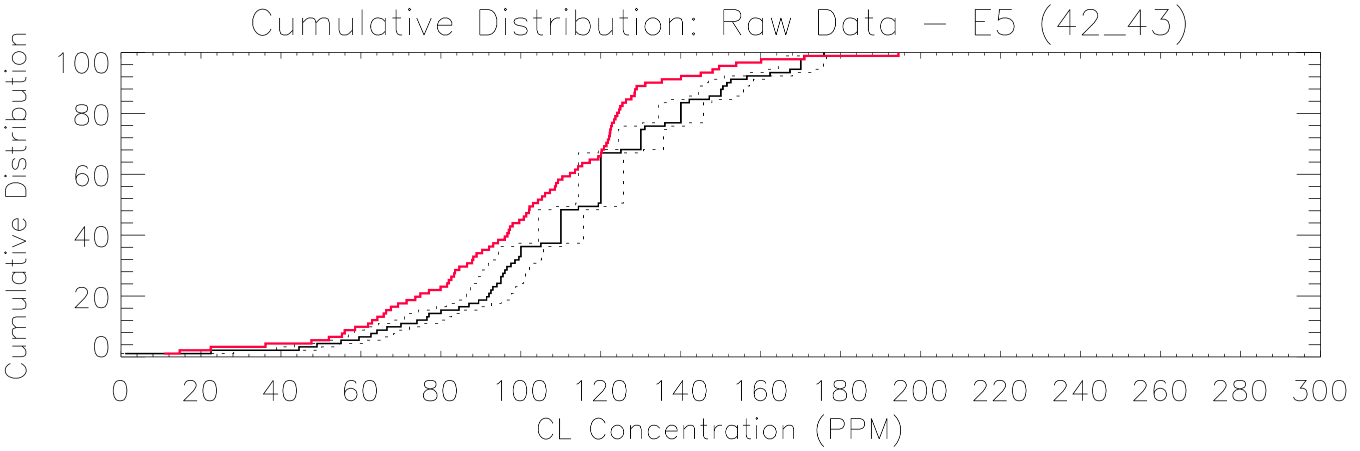

ELM2.9wca2_500 Mean: Season – 95% CI – E4 (42_36)
CL Concentration (PPM)
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – E4 (42_36)
CL Concentration (PPM)
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data – E4 (42_36)
Cumulative Distribution
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)


ELM2.9wca2_500 Mean: Season – 95% CI – E5 (42_43)
CL Concentration (PPM)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – E5 (42_43)
CL Concentration (PPM)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data – E5 (42_43)
Cumulative Distribution
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40
60
80
100
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60
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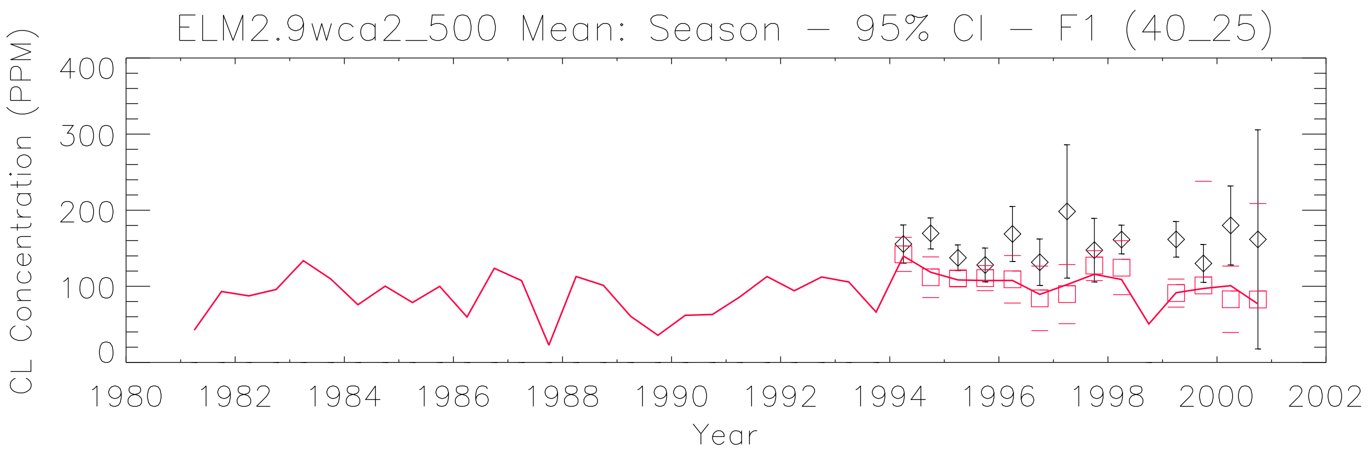
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)


ELM2.9wca2_500 Mean: Season – 95% CI – F1 (40_25)
CL Concentration (PPM)
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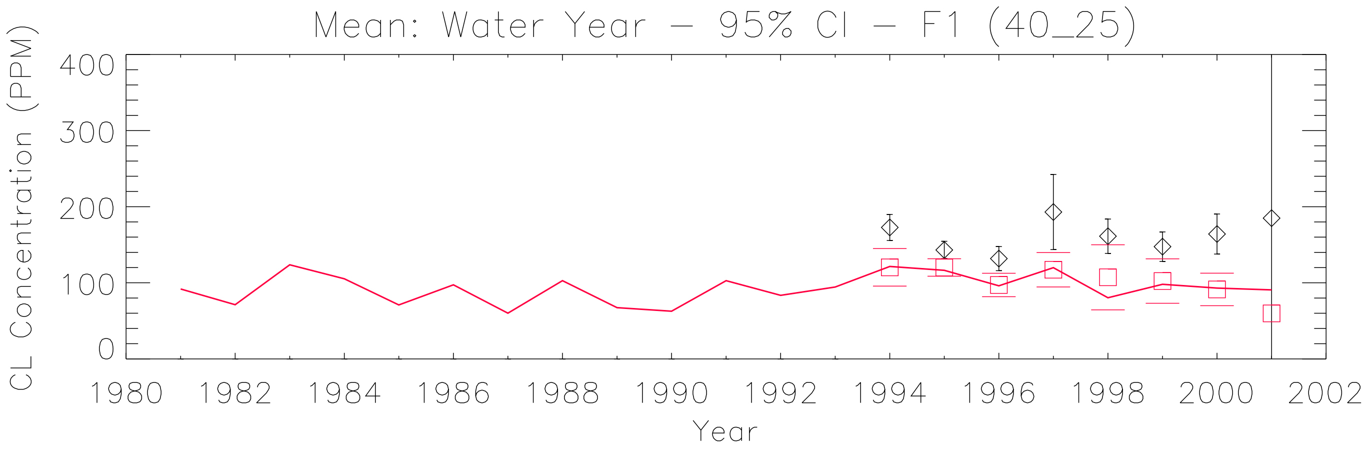
200
300
400
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – F1 (40_25)
CL Concentration (PPM)
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100
200
300
400
1980
1982
1984
1986
1988
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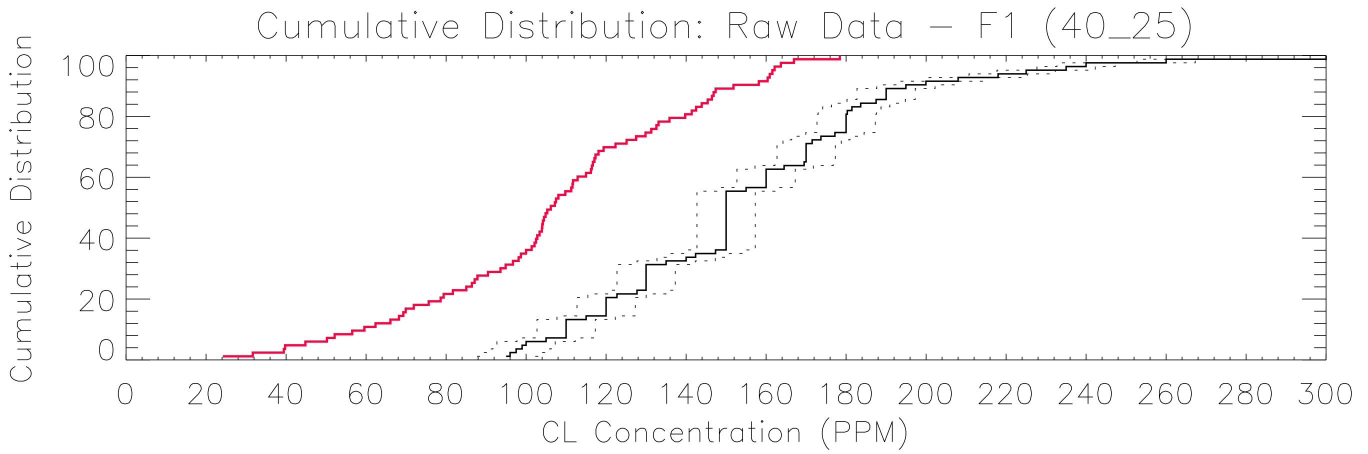
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data – F1 (40_25)
Cumulative Distribution
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20
40
60
80
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0
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60
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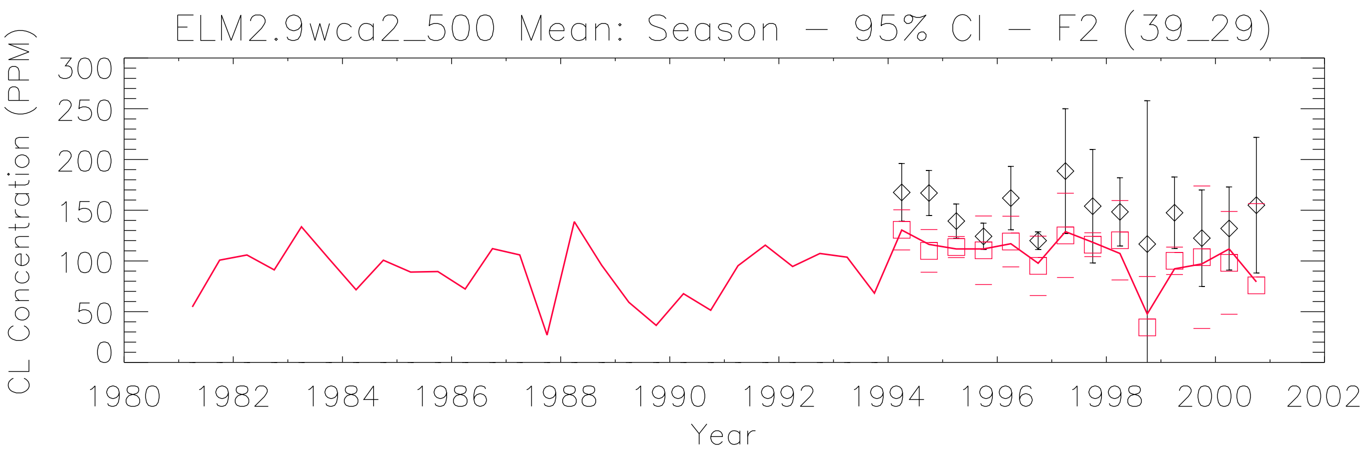
260
280
300
CL Concentration (PPM)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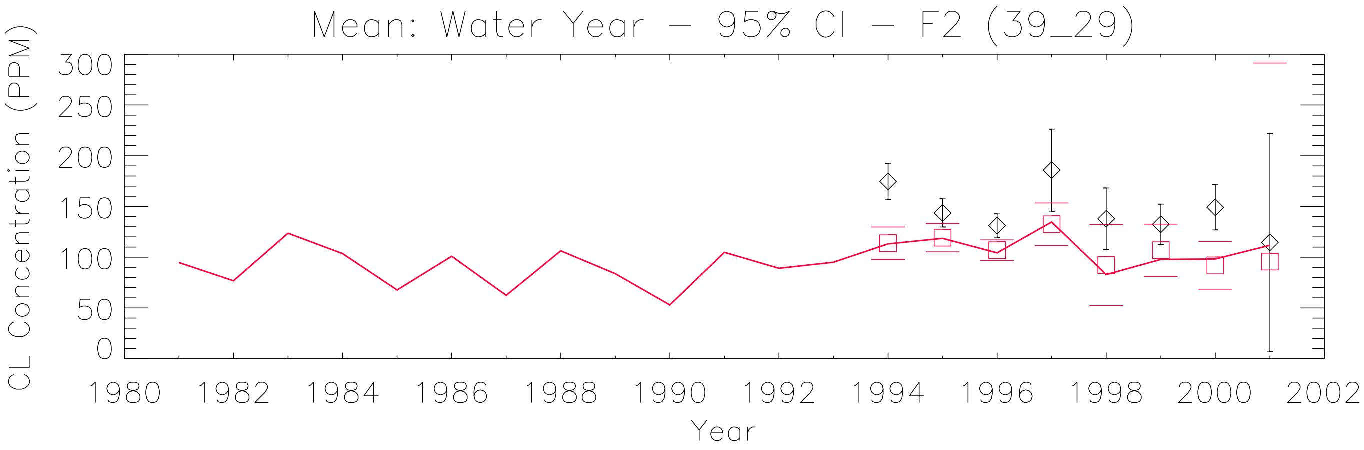
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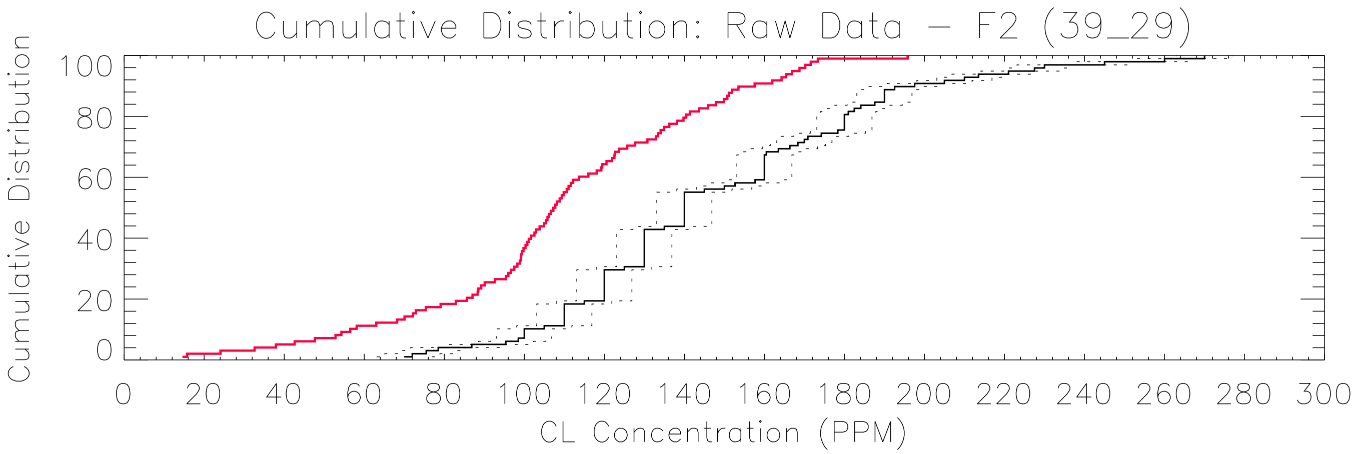
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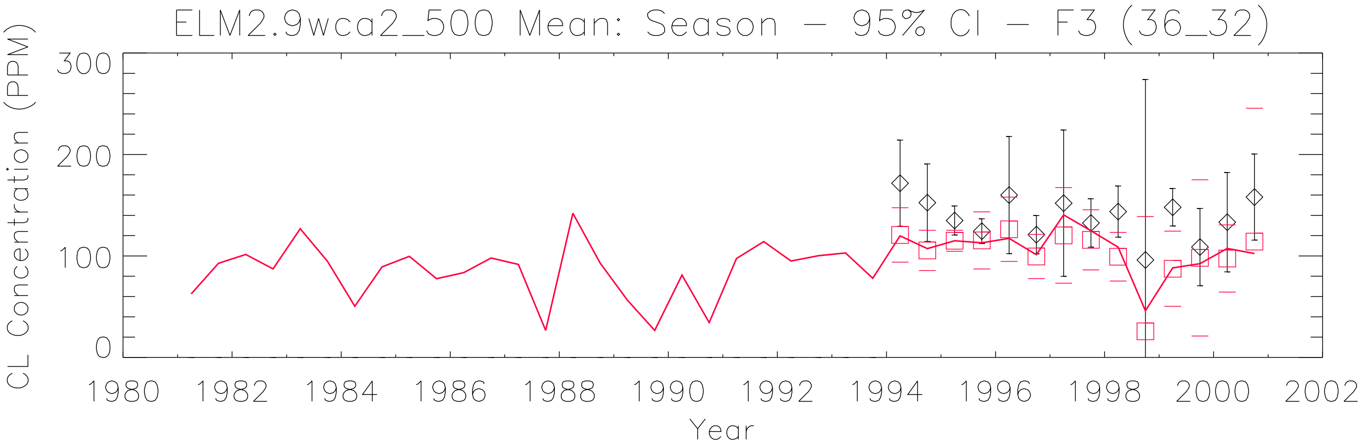
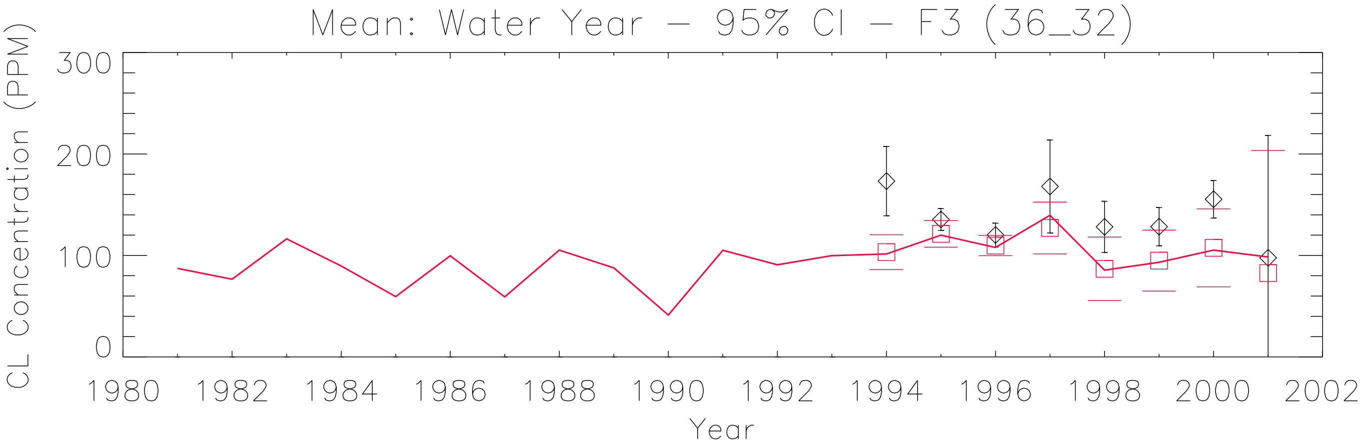

ELM2.9wca2_500 Mean: Season – 95% CI – F3 (36_32)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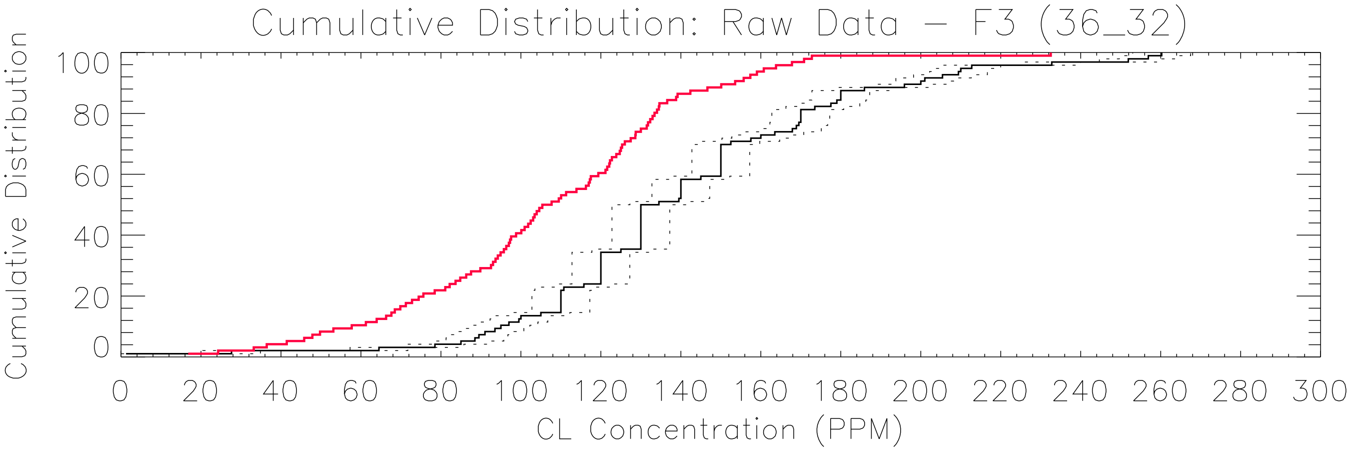
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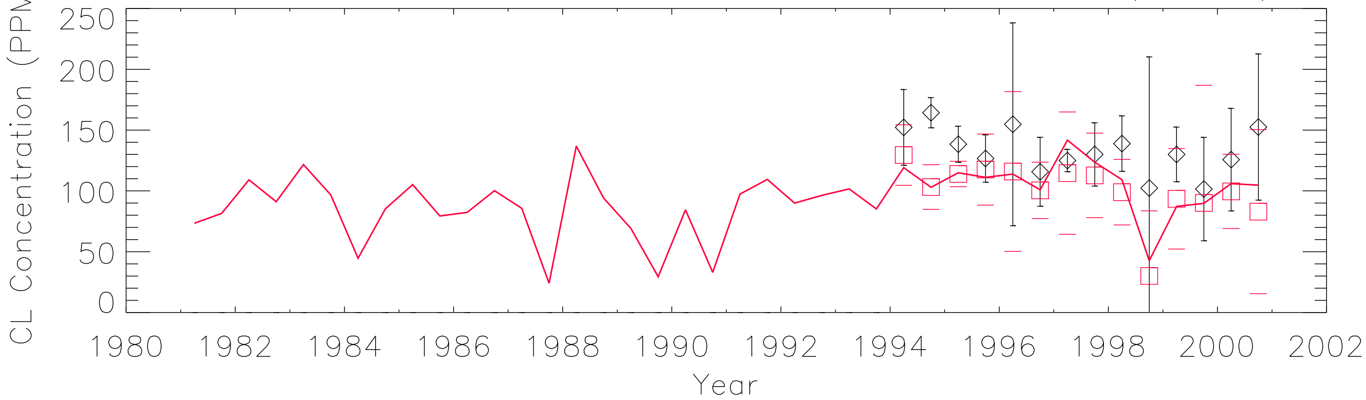
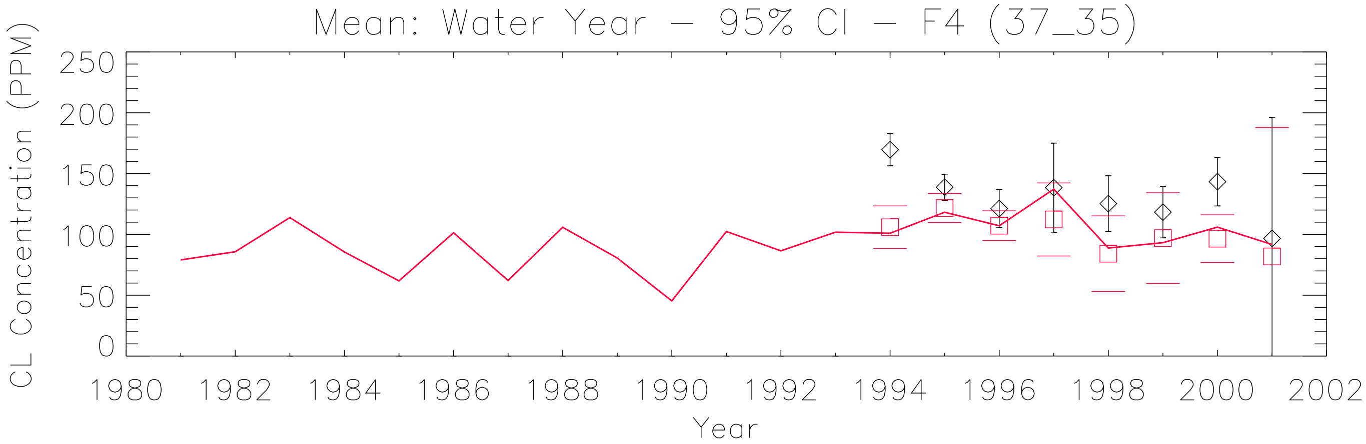
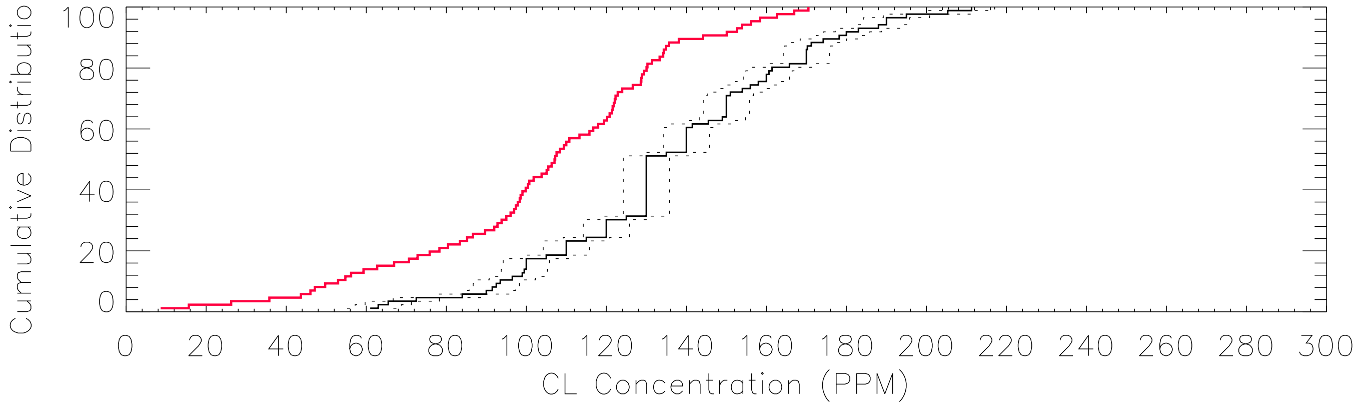
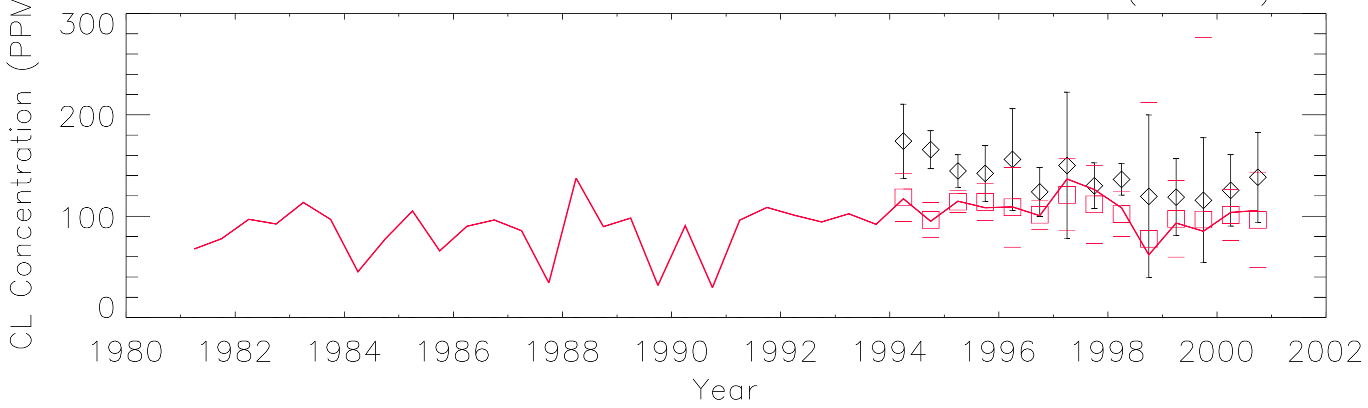
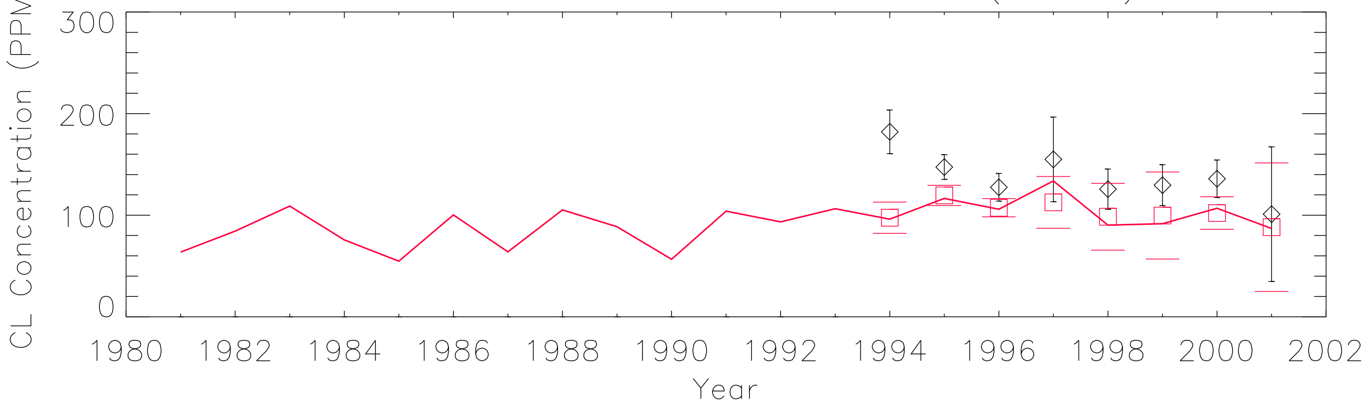
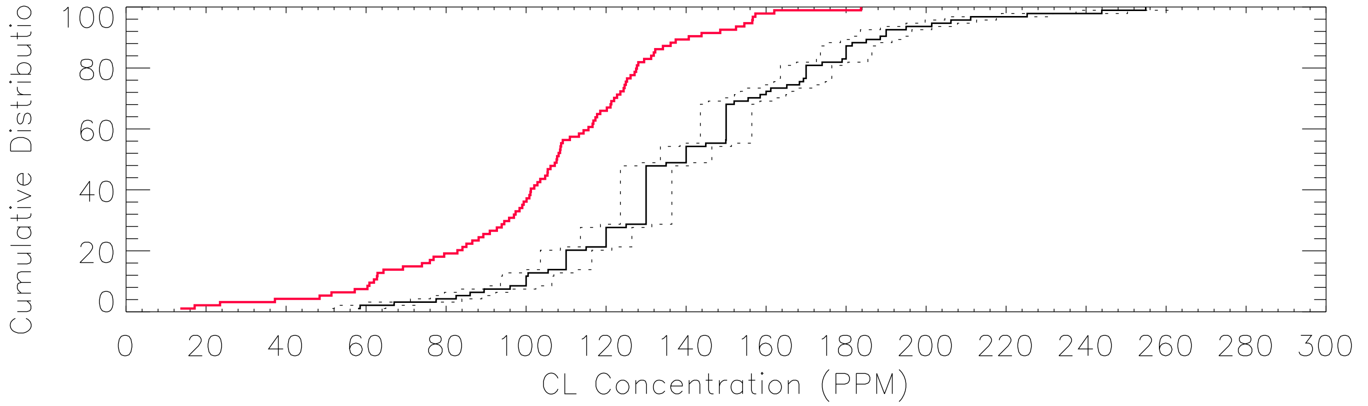

ELM2.9wca2_500 Mean: Season – 95% CI – F4 (37_35)


Mean: Water Year – 95% CI – F4 (37_35)

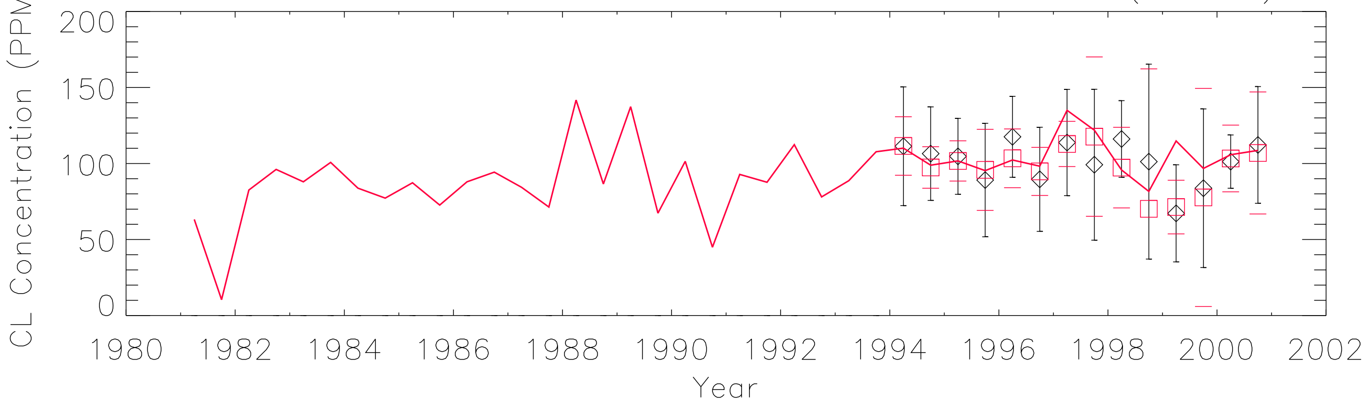

Cumulative Distribution: Raw Data – F4 (37_35)


ELM2.9wca2_500 Mean: Season – 95% CI – F5 (34_36)

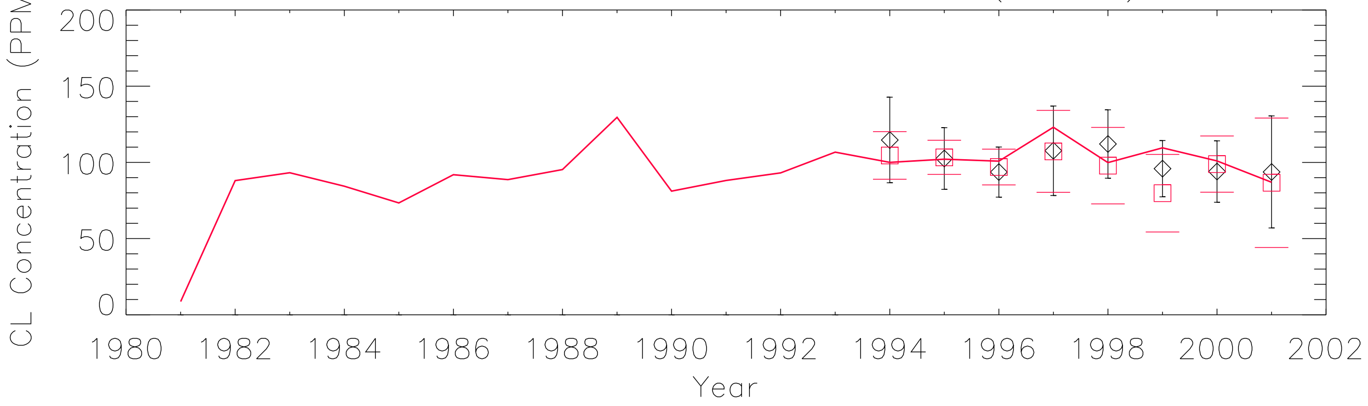

Mean: Water Year – 95% CI – F5 (34_36)


Cumulative Distribution: Raw Data – F5 (34_36)

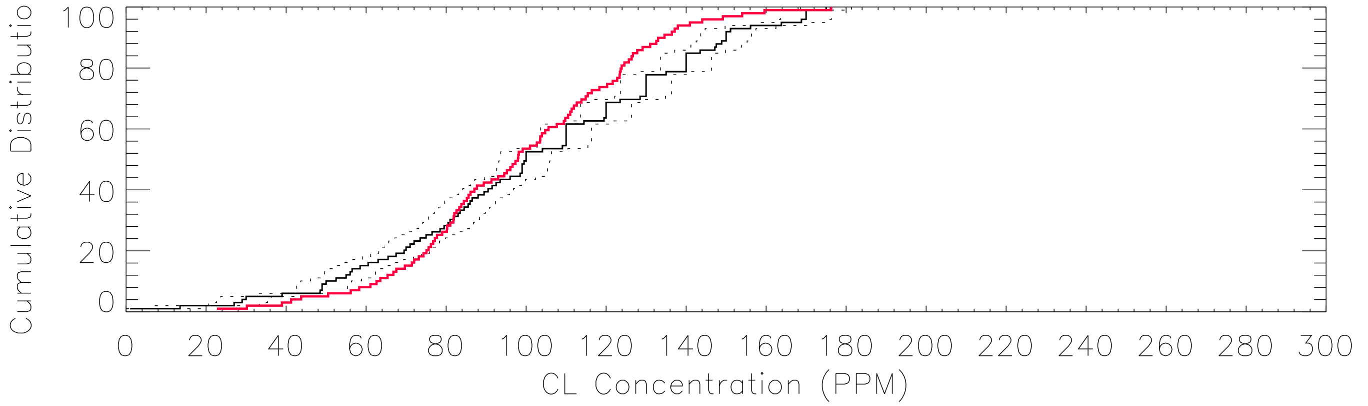
ELM2.9wca2_500 Mean: Season – 95% CI – U1 (43_51)

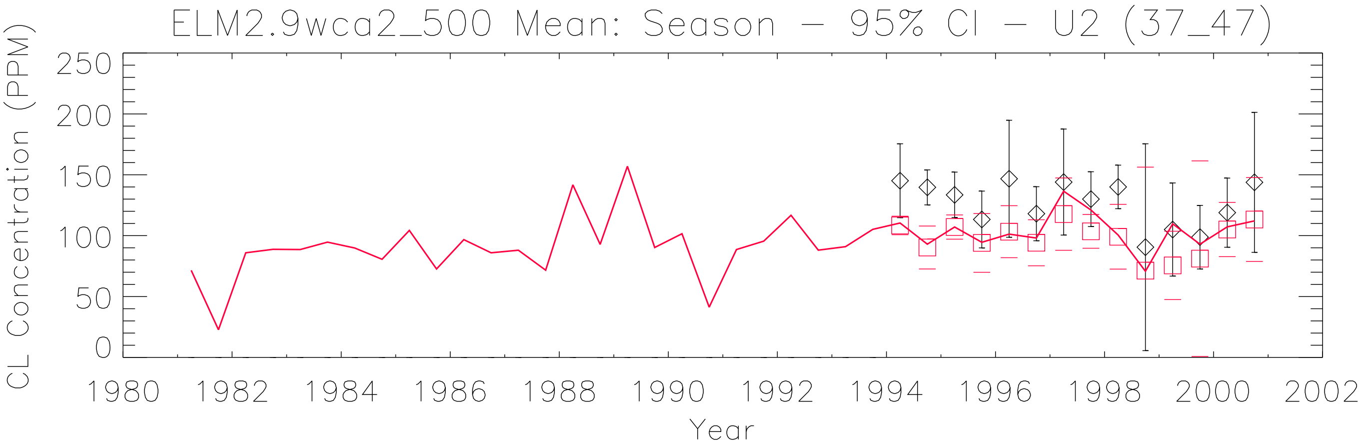


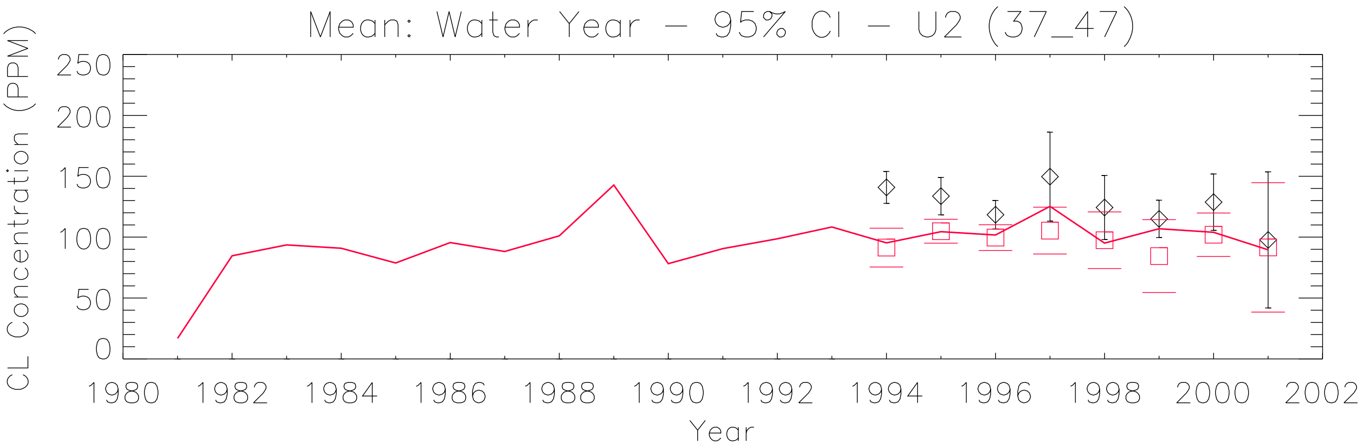
Mean: Water Year – 95% CI – U1 (43_51)

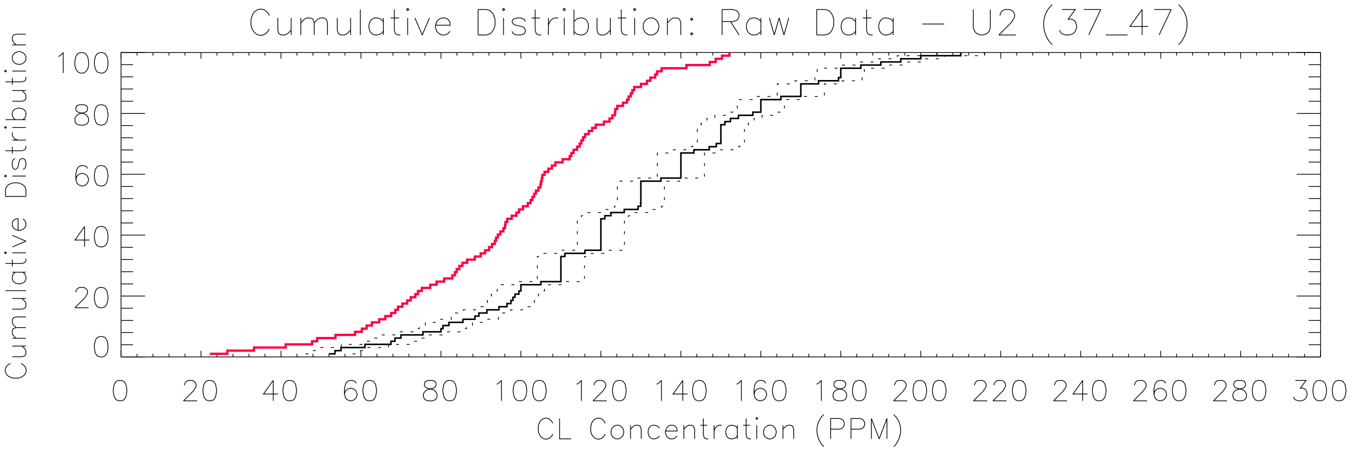


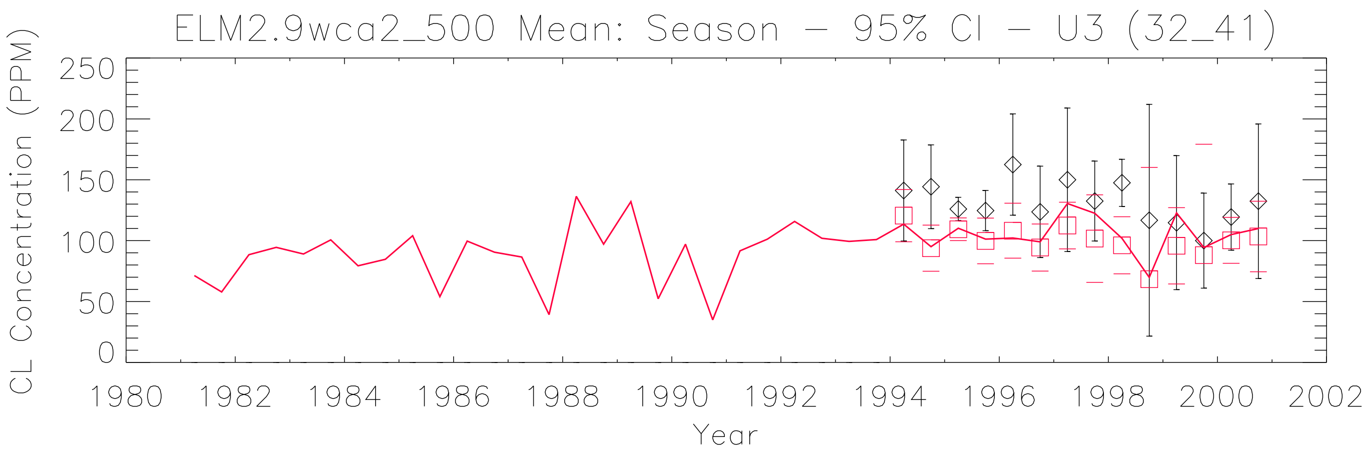
Cumulative Distribution: Raw Data – U1 (43_51)

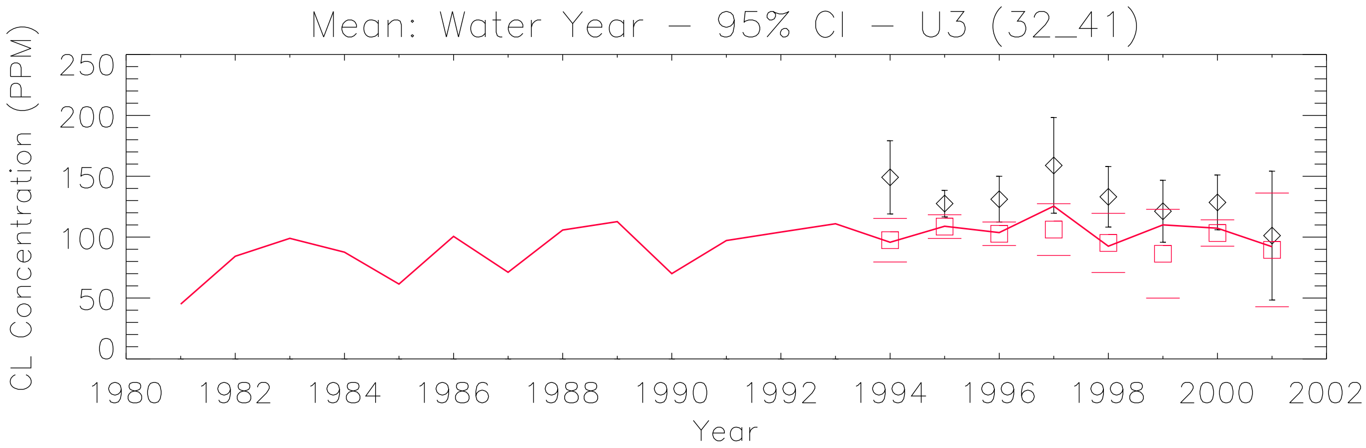


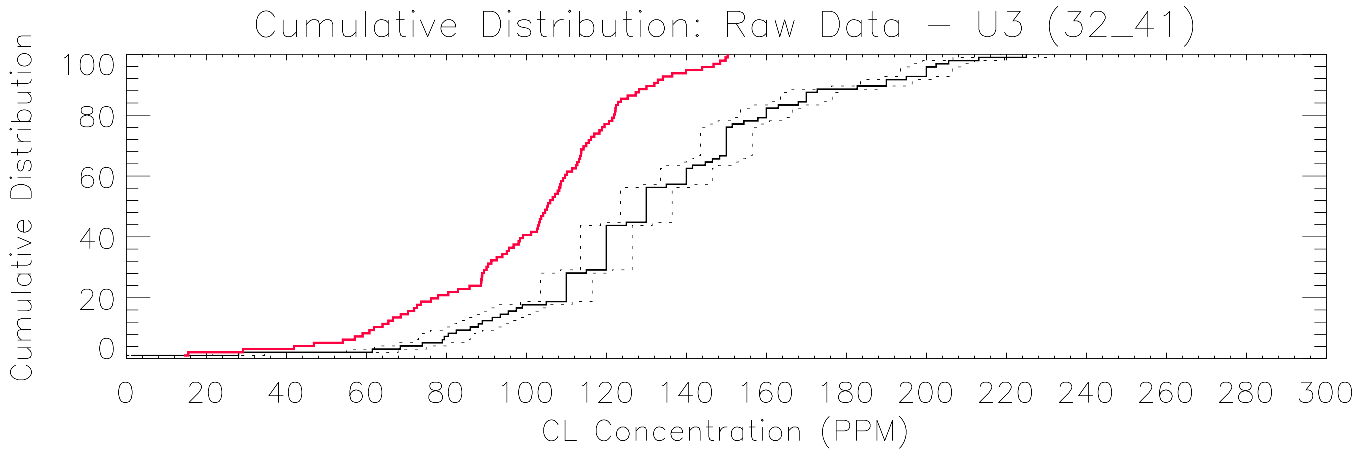

ELM2.9wca2_500 Mean: Season – 95% CI – U2 (37_47)


Mean: Water Year – 95% CI – U2 (37_47)


Cumulative Distribution: Raw Data – U2 (37_47)


ELM2.9wca2_500 Mean: Season – 95% CI – U3 (32_41)


Mean: Water Year – 95% CI – U3 (32_41)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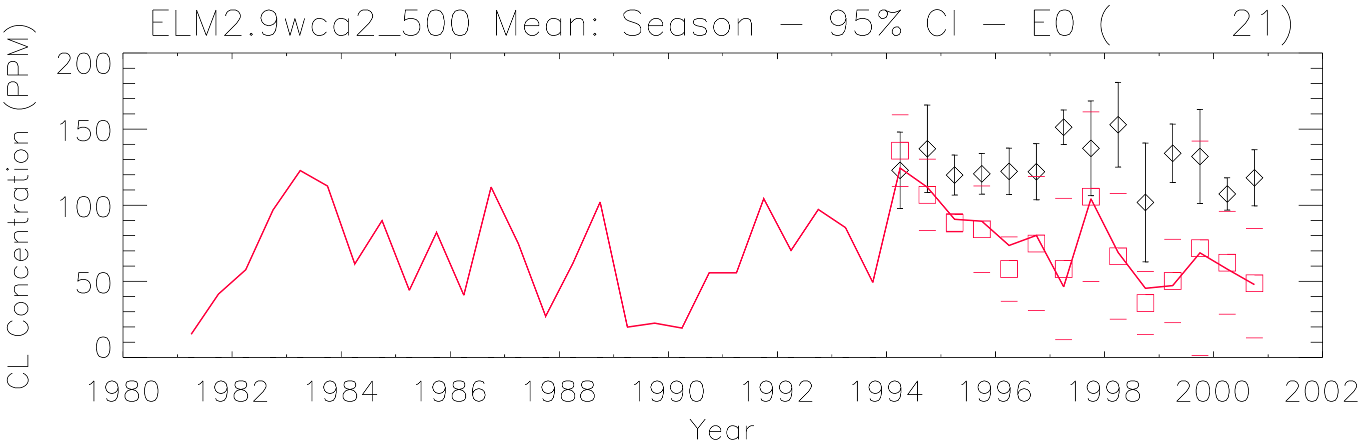
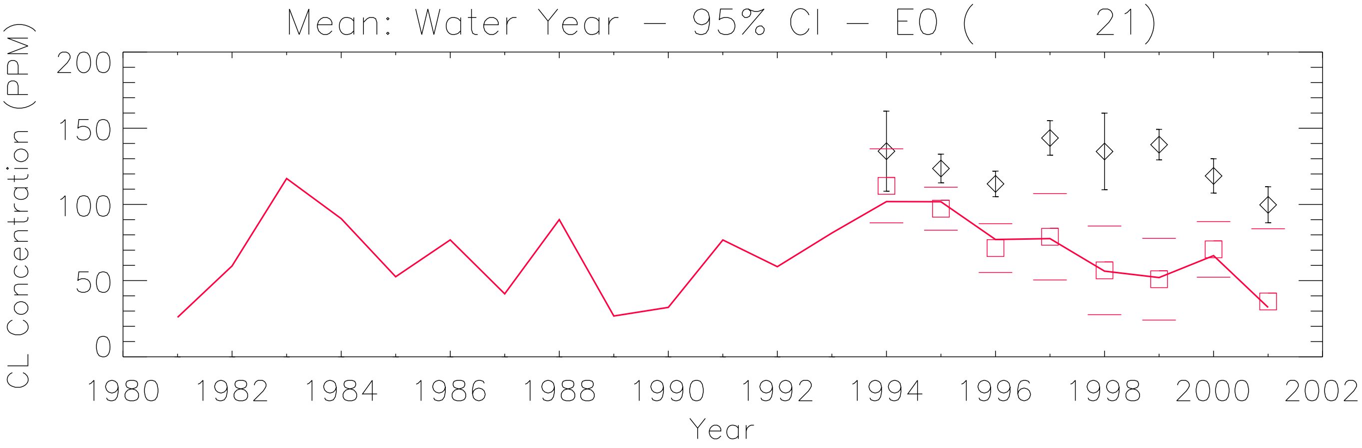
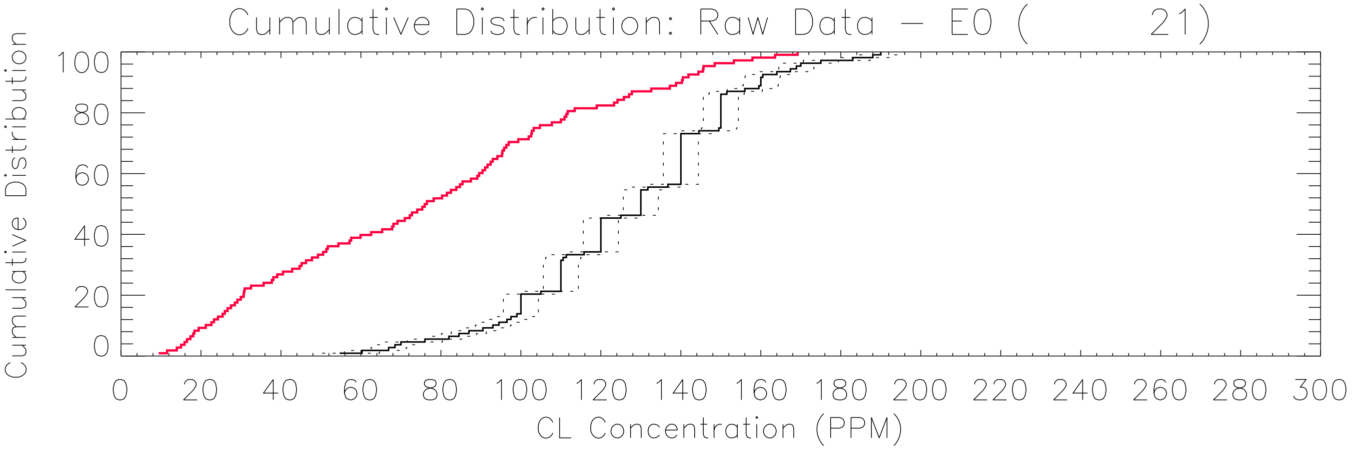


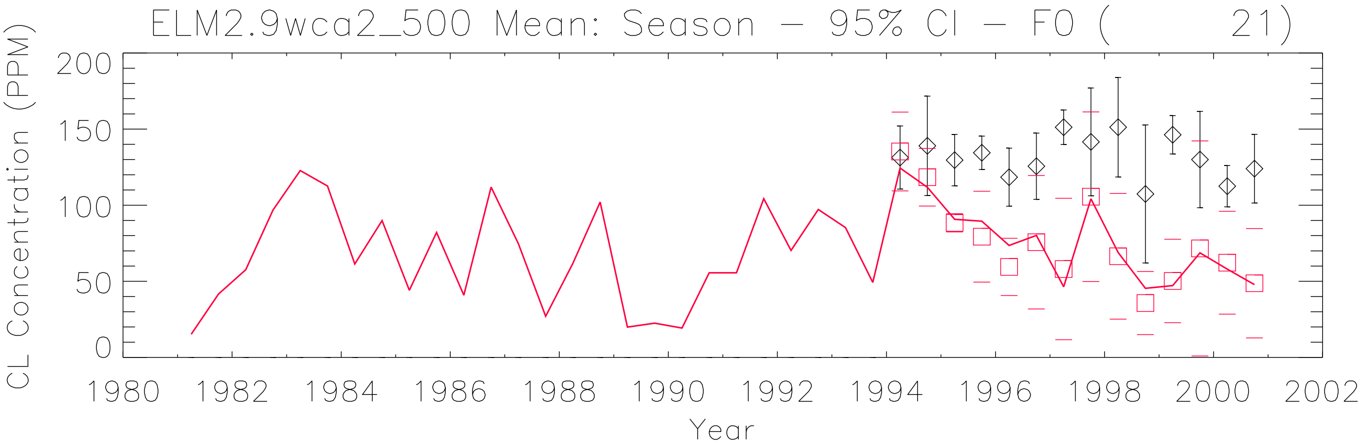
ELM2.9wca2_500 Mean: Season – 95% CI – E0 (21)

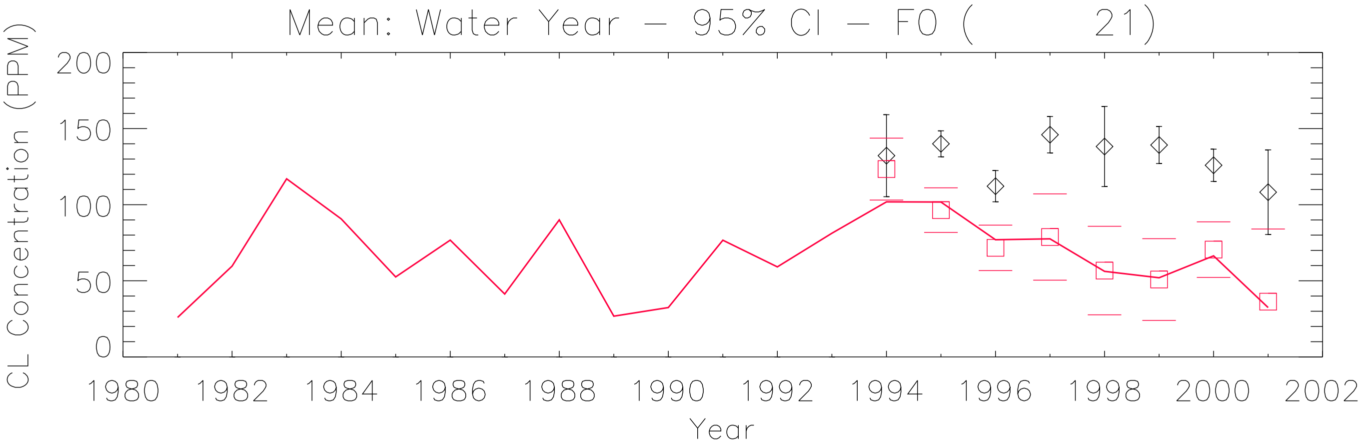


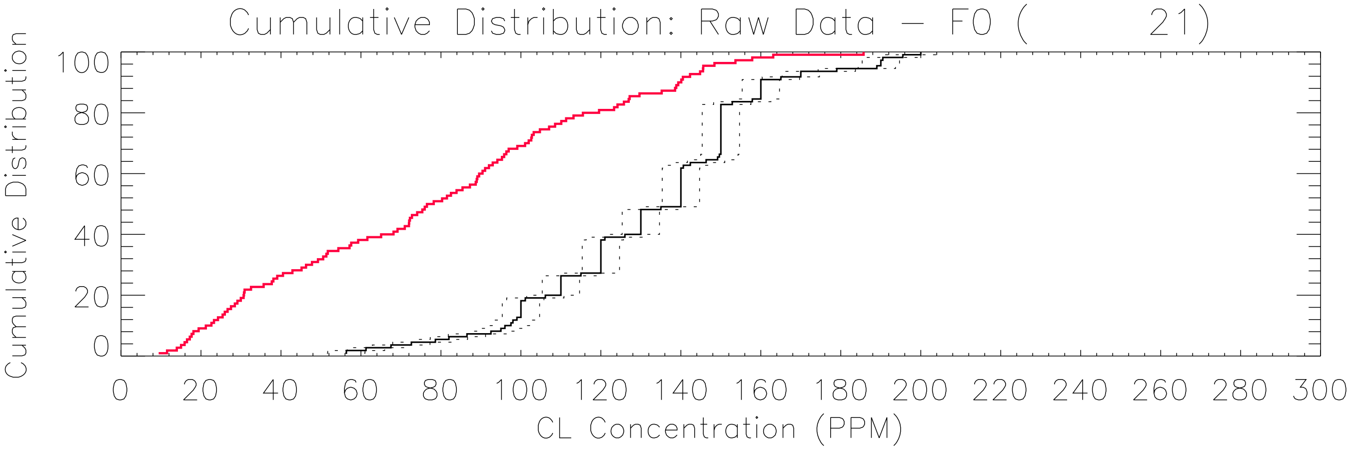
Mean: Water Year – 95% CI – E0 (21)



Cumulative Distribution: Raw Data – E0 (21)


ELM2.9wca2_500 Mean: Season – 95% CI – F0 (21)


Mean: Water Year – 95% CI – F0 (21)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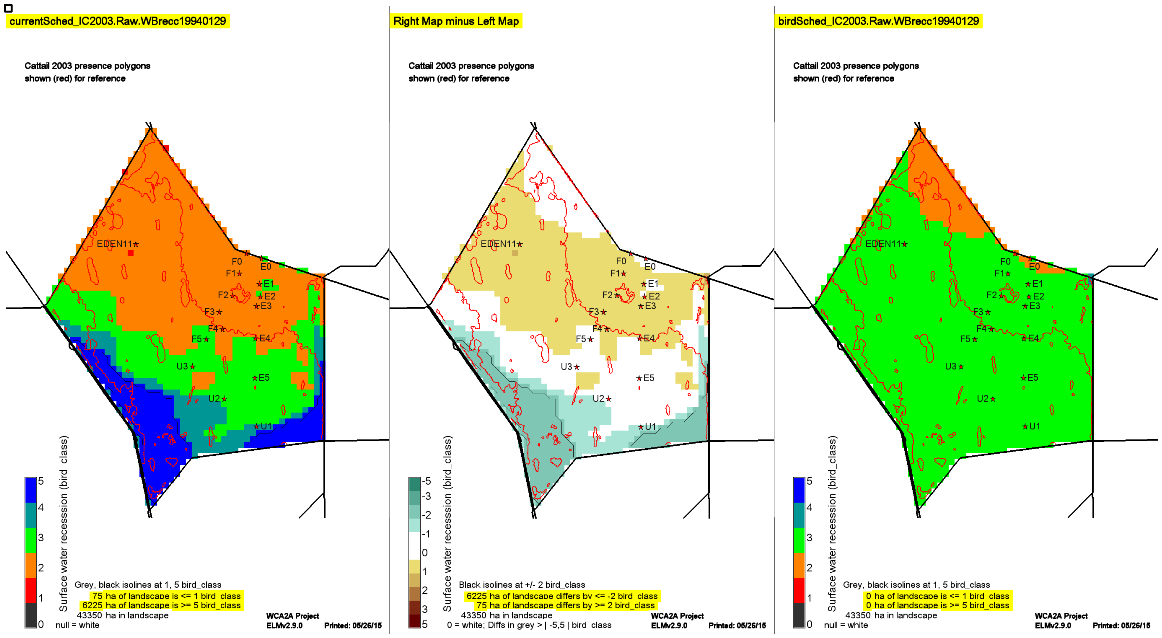
Documentation of the Everglades Landscape Model: ELM v2.9.0

Chapter 8: Model Applications



http://www.ecolandmod.com

H. Carl Fitz

Ecological Landscape Models

EcoLandMod, Inc.

July 15, 2015

Chapter 8: Model Application

8.1 Executive summary

The Model Performance Chapter 4 of this ELMwca2a documentation provided good evidence of model skill in predicting hydrologic and water quality trends at scales necessary for analysis of wading bird suitability metrics. In its subregional (433 km^2, or 167 square miles) application at 500 m grid resolution, the model was used to evaluate the relative benefits of alternative stage regulation schedules in WCA-2A.

A new Consumers module was developed for the "Incorporating Wading Bird Suitability into the Everglades Landscape Model" project. As detailed in Chapter 5 Model Structure, a variety of metrics were encoded to estimate the suitability of hydrologic conditions for wading bird ecology.

The primary objectives of this Model Application Chapter are to provide: 1) brief summaries of the recent applications of regional and subregional applications of ELM; 2) brief summaries of the quantitative results of a suite of simulation scenarios for the WCA-2A wading bird suitability project, and 3) brief synthesis of the overall findings. The full set of quantitative Performance Measure results (and other documentation for the project) are available at: http://www.ecolandmod.com/projects/ELMwca2a/.

The SFWMD science team will use these Performance Measure results to evaluate the relative benefits of the current and proposed stage regulation schedules. It appeared that the proposed stage regulation schedule generally had more suitable recession rates, but generally less suitable (deeper) depths. However, those moderately deep (ca. 20-30 cm) waters likely are likely more suitable to support other ecosystem dynamics. Both regulation schedules were similar in phosphorus and other biological (peat, macrophyte biomass and habitat type) dynamics.

8.2 Background

8.2.1 Recent ELM applications

Ongoing. Following up on 2013 work for the CERP ASR project (below), the USGS is funding a project to assess the Everglades-wide effects of reducing sulfate loads under a range of sulfate source-management practices in the EAA.

Dec 2014 completion. We posted (http://www.ecolandmod.com/projects/ELM_FCE) the assumptions and results of a collaborative effort to explore regional Everglades hydro-ecological (soils, water quality, hydrology) responses to altered climate and Sea Level Rise. In collaboration with Dr. J. Obeysekera and Jenifer Barnes of SFWMD, we used output from their recent SFWMM simulations (Obeysekera et al., 2014, "Climate Sensitivity Runs....") to assess responses to these altered drivers. This is part of ongoing, longer term modeling & research as part of the Florida Coastal Everglades LTER project, for which I am co-lead of the Modeling and Scenarios working group.

July 2014 completion. For the Synthesis of Everglades Research and Ecosystem Services (SERES) project, we posted (http://www.ecolandmod.com/projects/ELMreg500SERES) the assumptions and regional results of soil (and other ecological) responses to some altered-CERP scenarios (2 Bases and 4 scenarios), driven by SFWMM output run by Dr. T. Van Lent of the Everglades Foundation. This is part of a broad collaboration across multiple agencies & universities (Everglades Foundation subcontract from funding from Everglades National Park), and output from the ELM was also used as input to a periphyton model developed by Gaiser et al. of FIU.

May 2013 completion. We finalized regional-ELM simulations of sulfate distributions in support of the CERP Regional ASR Study. This work involved the development and application of a new sulfate module, and was funded by the USACE. The regional applications involved 2 Bases and 3 Alternative simulations, posted at http://www.ecolandmod.com/projects/ELMreg500mASR.

January 2012 completion. The USACE funded applications of the regional-ELM in support of the CERP Decomp PIR1 project, which involved the development of new Performance Measures and applications for 3 Bases and 8 Alternative simulation runs. Reports, assumptions, and results are posted at http://www.ecolandmod.com/projects/ELMreg500mDecompPIR1.

May 2008 completion. The reports, assumptions and results of a WCA-1 restoration modeling project are available at http://www.ecolandmod.com/projects/ELMwca1/ . Funded by the SFWMD, this involved the development of multiple new Performance Measures, development of new source code for water management operations, and multiple subregional applications evaluating alternative restoration scenarios.

8.2.2 ELM v2.9 WCA-2A application summary

The purpose of this project is to utilize the ELM to analyze relative differences between two hypothetical water management scenarios for WCA2A, one aimed at maintaining the current regulation schedule (at the 2-17 stage gage in the central basin), and another aimed at moving the 2A-17 stage regulation schedule to a new temporal dynamic (shown in later section below). A wading bird module was added to ELM to incorporate how model scenarios translate into wading bird habitat suitability. While for this exercise wading bird habitat suitability was simplified to encompass only hydrologic variables, the new ELM module is extensible, and was made capable of evaluating effects of other habitat factors (e.g., vegetation type and density) as this information becomes available at a later date as well. As a proof-of-concept modeling exercise, this work served to demonstrate that the ELM is an appropriate tool to spatially compare wading bird suitability and other ecological parameters across multiple timescales, and that the chosen performance metrics output from ELM are sufficiently sensitive to assess ecologically meaningful differences among simulated water management scenarios.

As described in the Data Chapter 4 and Model Structure Chapter 5, several modifications to code and data were made to the regional ELM v2.5 - v2.8 applications in order to meet specific objectives of this project.

The primary focus of these applications was hydrologic suitability of alternative stage regulation schedules for wading bird ecology. Those Performance Measures involved the depths of ponded surface water during the breeding season, and the recession rate (rate of depth decreases) of surface water during the breeding season. In addition, a range of other hydro-ecological Performance Measures included responses of soils, macrophytes, water quality, and hydrology.

Because the ELM was designed to be explicitly scalable, it is relatively simple to adapt (spatial input map) data to accommodate the scientific objectives that may call for a particular scale of grid resolution or extent. The SFWMD science team determined that a relatively fine scale model application would be most useful to meet the project goals. Thus, we altered input map data in order to create a 0.25 km^2 (500x500 m) resolution application in the WCA-2A hydrologic basin, and evaluated hydro-ecological responses over 36-year future scenarios.

8.2.3 ELM v2.9 WCA-2A application niche

The Performance Measures to be used in model applications are quantitative metrics that are used to evaluate the benefits of one simulation scenario relative to another. While models can potentially produce a very large suite of outputs, the intent of formalizing a small set of Performance Measures is to distill the model results into scientifically definitive summaries of the modeled scenarios. Generally, Performance Measures themselves are developed and reviewed by users of the model, preferably in collaboration with the model developers. For this restoration project, the Performance Measures (described in subsequent section of this document) were developed by the SFWMD science team and the model developers, and are consistent with the model application niche for which the ELM was developed.

A model application niche is the intersection of A) the real or perceived needs of the “users” and B) the realistic capabilities portrayed by the model developers. For regional applications in the entire greater Everglades system, the application niche of the ELM was presented (ELM v2.5 Documentation Report[1]) with a focus on phosphorus water quality Performance Measure evaluations. Integral with such water quality evaluations is reliable simulation of water depths (stage) and flows (chloride tracer), which were a major component of the ELM review by an Independent Panel[2].

For this subregional application of ELM v2.9, we applied the ELM code and data to questions of hydro-ecological (principally wading bird) dynamics in WCA-2A, using Performance Measures involving water depths and recession rates, phosphorus concentrations in surface water and soils, soil accretion rates, and macrophyte biomass and habitat type.

8.3 Assumptions - General

In simulating the response of the Everglades to scenarios of future managed flows of water, projections of those managed flows through water control structures are required. The South Florida Water Management Model (SFWMM v6.6) is currently an accepted tool for such planning. The assumptions that are involved in initializing and simulating regional water management for future project alternative plans (i.e., scenarios) are relatively complex, involving the entire south Florida regional system. Model developers and stakeholders collaborated on developing the assumptions concerning future climate, land use, water use, and many other factors. Documentation of the SFWMM and its primary assumptions is found at the South Florida Water Management District web site[3], and assumptions specific to particular planning projects should be found in the project's web site.

In simulating project planning alternatives, the SFWMM uses the climate record that was observed between 1965 and 2000. This 36-year period encompasses periods of both extreme rainfall and drought conditions. Relative differences in system behavior under different project alternatives reflect how the system would likely respond to the alternative management, given the same climate forcing data that has been observed in the past.

The ELM uses databases of 1965-2000 rainfall and potential evapotranspiration that are identical to inputs to the SFWMM. In applying the ELM to evaluate future conditions, a number of other assumptions are generally required for initializing and simulating ecological dynamics. As with the SFWMM, the specific assumptions for the ecological simulation must be determined for each project application. The following summarizes the nature of these assumptions that are in addition to those for simulating future managed flows in the SFWMM.

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[1] Fitz, H.C., and B. Trimble. 2006. Documentation of the Everglades Landscape Model: ELM v2.5. South Florida Water Management District.http://www.ecolandmod.com/publications Reviewed by independent expert panel, reported at 664 pages.

[2] Mitsch, W. J., L. E. Band, and C. F. Cerco. 2007. Everglades Landscape Model (ELM), Version 2.5: Peer Review Panel Report. Submitted January 3, 2007 to the South Florida Water Management District, West Palm Beach, FL. http://www.ecolandmod.com/publications. 35 pp.

[3] SFWMM documentation is currently (July 2015) found at http://my.sfwmd.gov/ , click on "What we do", then "Simulation Modeling".

All equations and related algorithm assumptions (see Model Structure Chapter) remain unchanged from historical simulations (and thus no changes are made to source ELM code for future scenarios). Likewise, all habitat-specific parameters (HabParms, see Data Chapter) were unchanged from historical simulations. Global parameters (GlobalParms, see Data Chapter) remained unchanged from historical simulations.

8.3.1 Assumptions Common to Base & Scenario Runs

The data that are common to the 2010 Base and the stage regulation schedule scenarios include initial conditions and boundary conditions, which are fully described in the Data Chapter 4. In summary, initial conditions used soils, vegetation, and land elevation data that represented circa 2003 conditions. All managed inflows into the WCA-2A basin assumed a fixed phosphorous concentration of 10 ug l^{-1}, with the exception of the 2010 Base run (driven by SFWMM water control structure flows) which had some STA bypass events (see Data Chapter 4).

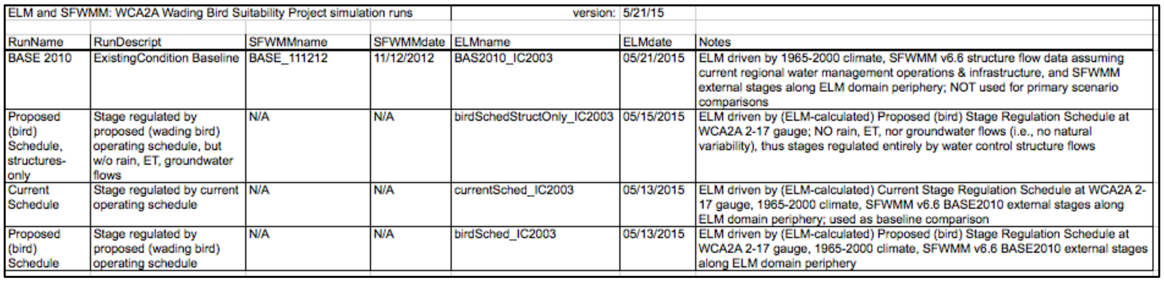
8.4 Assumptions - specific to scenarios

Table 8.1 describes some of the general characteristics of the 2010 Base and the three scenarios of stage regulation schedules. The objective of this project was to simply compare the current regulation schedule (currentSched) in WCA-2A to a newly proposed schedule (birdSched).

Because water management of WCA-2A currently must consider water supply and flood control in basins upstream and downstream, the 2010 Base does not always strictly adhere to the current Schedule (see Model Performance Chapter 6), and the only use of the 2010 Base in this project to better understand how closely stages in WCA-2A adhered to the schedule itself.

Similarly, one of the scenarios was just used for better understanding dynamics associated with regulating stage in WCA-2A. That birdSchedStructOnly scenario did not have any rainfall or groundwater inflows, and did not have any ET or groundwater outflows: thus, stage was regulated in that scenario to adhere to the proposed birdSched, but without any natural variability that can result in deviations from intended stage regulations.

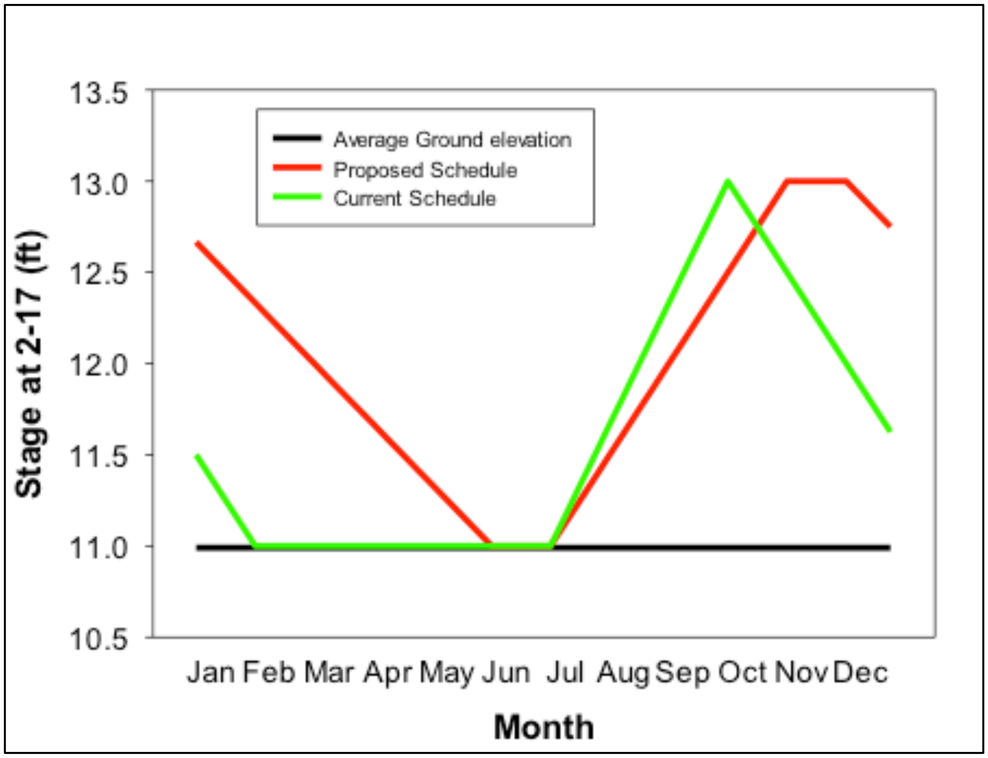
Table 8.1. The general characteristics of the four simulation runs used in this project. All simulation names are appended with the "_IC2003" phrase, simply indicating that all had Initial Conditions based upon 2003 data (see Data Chapter 4).



ELM and SFWMM: WCA2A Wading Bird Suitability Project simulation runs				version:	5/21/15	
RunName	RunDescript	SFWMMname	SFWMMdate	ELMname	ELMdate	Notes
BASE 2010	ExistingCondition Baseline	BASE_111212	11/12/2012	BAS2010_IC2003	05/21/2015	ELM driven by 1965-2000 climate, SFWMM v6.6 structure flow data assuming current regional water management operations & infrastructure, and SFWMM external stages along ELM domain periphery; NOT used for primary scenario comparisons
Proposed (bird) Schedule, structures-only	Stage regulated by proposed (wading bird) operating schedule, but w/o rain, ET, groundwater flows	N/A	N/A	birdSchedStructOnly_IC2003	05/15/2015	ELM driven by (ELM-calculated) Proposed (bird) Stage Regulation Schedule at WCA2A 2-17 gauge; NO rain, ET, nor groundwater flows (i.e., no natural variability), thus stages regulated entirely by water control structure flows
Current Schedule	Stage regulated by current operating schedule	N/A	N/A	currentSched_IC2003	05/13/2015	ELM driven by (ELM-calculated) Current Stage Regulation Schedule at WCA2A 2-17 gauge, 1965-2000 climate, SFWMM v6.6 BASE2010 external stages along ELM domain periphery; used as baseline comparison
Proposed (bird) Schedule	Stage regulated by proposed (wading bird) operating schedule	N/A	N/A	birdSched_IC2003	05/13/2015	ELM driven by (ELM-calculated) Proposed (bird) Stage Regulation Schedule at WCA2A 2-17 gauge, 1965-2000 climate, SFWMM v6.6 BASE2010 external stages along ELM domain periphery

The two stage regulation schedules that drove the ELM water control structure operations are shown in Figure 8.1. Note that the proposed birdSched generally has deeper water in the early part of the calendar year through May, during much of the wading bird breeding season.

Figure 8.1. The two WCA-2A stage regulation schedules that were compared for this project. The simulation based on the proposed schedule is named "birdSched", while the simulation based on the current schedule is named "currentSched" (see Table 8.1).



The Data Chapter 4 details the water management infrastructure and operations; briefly:

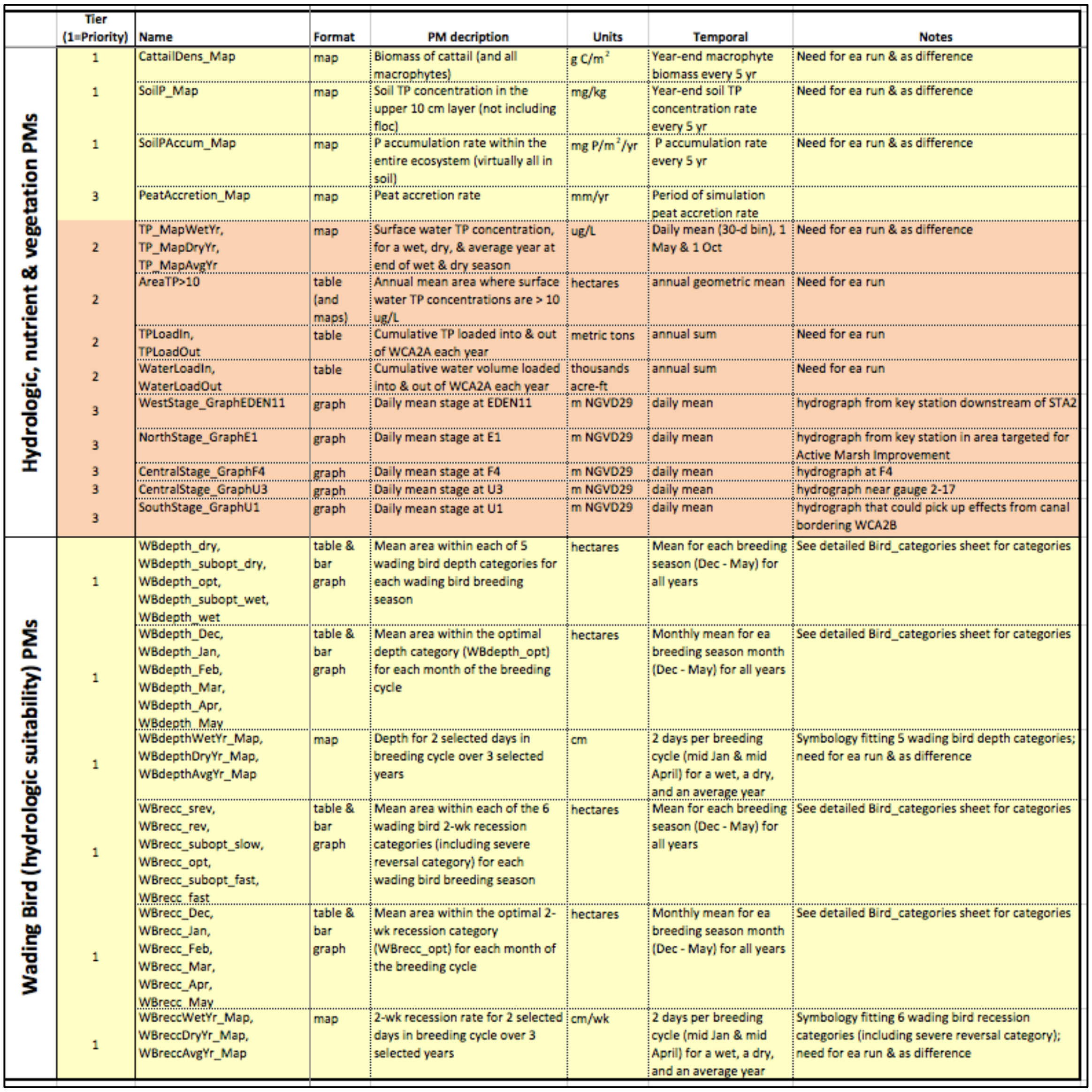
- Inflow sources: STA-2, S-10A-E
- Outflow sources: S-11A-C, S144-146
- Evaluate time-varying Target stage (NGVD ‘29) at WCA-2A 2-17 gauge
- Inflow when stage < (Target - Offset) {2 cm Offset}
- Outflow when stage > (Target + Offset) {2 cm Offset}
- All Inflow magnitudes assume unlimited sources (i.e., no limits of water availability, or water quality, for inflows)
- All Outflow magnitudes assume unconstrained flows allowed into receiving basins (i.e., no limits to water outflows)

8.5 Performance Measures

Table 8.2 contains descriptions of all of the Performance Measures that were developed for this project. The majority of these Performance Measures were proposed by the

SFWMD science team, and their background and support is found in other documents. The matrix contains information on how each Performance Measure was implemented in the spatial and temporal scales of the ELMwca1 model.

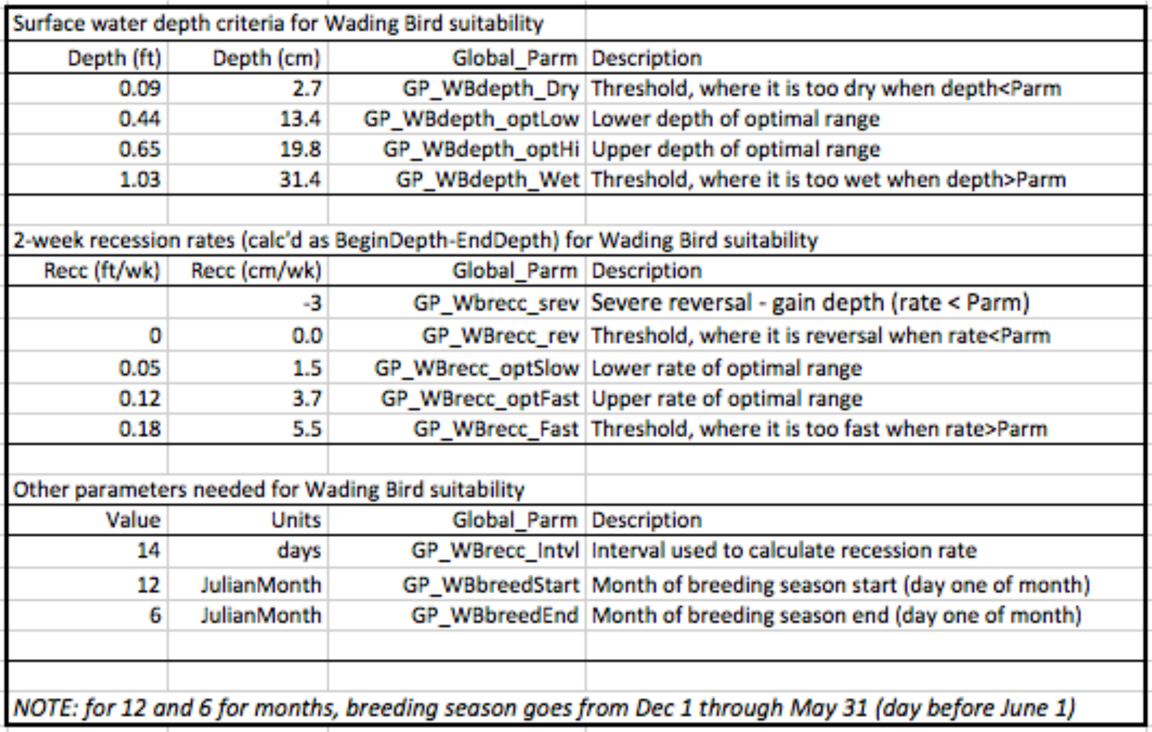
Table 8.2. The complete listing of all Performance Measures used to evaluate relative hydro-ecological differences between the current and proposed stage regulation schedules.



	Tier (1=Priority)	Name	Format	PM decription	Units	Temporal	Notes
Hydrologic, nutrient & vegetation PMs	1	CattailDens_Map	map	Biomass of cattail (and all macrophytes)	$g\ C/m^2$	Year-end macrophyte biomass every 5 yr	Need for ea run & as difference
	1	SoilP_Map	map	Soil TP concentration in the upper 10 cm layer (not including floc)	mg/kg	Year-end soil TP concentration rate every 5 yr	Need for ea run & as difference
	1	SoilPAccum_Map	map	P accumulation rate within the entire ecosystem (virtually all in soil)	$mg\ P/m^2/yr$	P accumulation rate every 5 yr	Need for ea run & as difference
	3	PeatAccretion_Map	map	Peat accretion rate	mm/yr	Period of simulation peat accretion rate	
	2	TP_MapWetYr, TP_MapDryYr, TP_MapAvgYr	map	Surface water TP concentration, for a wet, dry, & average year at end of wet & dry season	ug/L	Daily mean (30-d bin), 1 May & 1 Oct	Need for ea run & as difference
	2	AreaTP>10	table (and maps)	Annual mean area where surface water TP concentrations are > 10 ug/L	hectares	annual geometric mean	Need for ea run
	2	TPLoadIn, TPLoadOut	table	Cumulative TP loaded into & out of WCA2A each year	metric tons	annual sum	Need for ea run
	2	WaterLoadIn, WaterLoadOut	table	Cumulative water volume loaded into & out of WCA2A each year	thousands acre-ft	annual sum	Need for ea run
	3	WestStage_GraphEDEN11	graph	Daily mean stage at EDEN11	m NGVD29	daily mean	hydrograph from key station downstream of STA2
	3	NorthStage_GraphE1	graph	Daily mean stage at E1	m NGVD29	daily mean	hydrograph from key station in area targeted for Active Marsh Improvement
	3	CentralStage_GraphF4	graph	Daily mean stage at F4	m NGVD29	daily mean	hydrograph at F4
	3	CentralStage_GraphU3	graph	Daily mean stage at U3	m NGVD29	daily mean	hydrograph near gauge 2-17
	3	SouthStage_GraphU1	graph	Daily mean stage at U1	m NGVD29	daily mean	hydrograph that could pick up effects from canal bordering WCA2B
Wading Bird (hydrologic suitability) PMs	1	WBdepth_dry, WBdepth_subopt_dry, WBdepth_opt, WBdepth_subopt_wet, WBdepth_wet	table & bar graph	Mean area within each of 5 wading bird depth categories for each wading bird breeding season	hectares	Mean for each breeding season (Dec - May) for all years	See detailed Bird_categories sheet for categories
	1	WBdepth_Dec, WBdepth_Jan, WBdepth_Feb, WBdepth_Mar, WBdepth_Apr, WBdepth_May	table & bar graph	Mean area within the optimal depth category (WBdepth_opt) for each month of the breeding cycle	hectares	Monthly mean for ea breeding season month (Dec - May) for all years	See detailed Bird_categories sheet for categories
	1	WBdepthWetYr_Map, WBdepthDryYr_Map, WBdepthAvgYr_Map	map	Depth for 2 selected days in breeding cycle over 3 selected years	cm	2 days per breeding cycle (mid Jan & mid April) for a wet, a dry, and an average year	Symbology fitting 5 wading bird depth categories; need for ea run & as difference
	1	WBrecc_srev, WBrecc_rev, WBrecc_subopt_slow, WBrecc_opt, WBrecc_subopt_fast, WBrecc_fast	table & bar graph	Mean area within each of the 6 wading bird 2-wk recession categories (including severe reversal category) for each wading bird breeding season	hectares	Mean for each breeding season (Dec - May) for all years	See detailed Bird_categories sheet for categories
	1	WBrecc_Dec, WBrecc_Jan, WBrecc_Feb, WBrecc_Mar, WBrecc_Apr, WBrecc_May	table & bar graph	Mean area within the optimal 2-wk recession category (WBrecc_opt) for each month of the breeding cycle	hectares	Monthly mean for ea breeding season month (Dec - May) for all years	See detailed Bird_categories sheet for categories
	1	WBreccWetYr_Map, WBreccDryYr_Map, WBreccAvgYr_Map	map	2-wk recession rate for 2 selected days in breeding cycle over 3 selected years	cm/wk	2 days per breeding cycle (mid Jan & mid April) for a wet, a dry, and an average year	Symbology fitting 6 wading bird recession categories (including severe reversal category); need for ea run & as difference

The parameters used for the wading bird (hydrologic suitability) Performance Measures are shown in Table 8.3 below.

Table 8.3. The parameters used in the Consumers module, for the wading bird Performance Measures.



Surface water depth criteria for Wading Bird suitability			
Depth (ft)	Depth (cm)	Global_Parm	Description
0.09	2.7	GP_WBdepth_Dry	Threshold, where it is too dry when depth<Parm
0.44	13.4	GP_WBdepth_optLow	Lower depth of optimal range
0.65	19.8	GP_WBdepth_optHi	Upper depth of optimal range
1.03	31.4	GP_WBdepth_Wet	Threshold, where it is too wet when depth>Parm
2-week recession rates (calc'd as BeginDepth-EndDepth) for Wading Bird suitability			
Recc (ft/wk)	Recc (cm/wk)	Global_Parm	Description
	-3	GP_Wbrecc_srev	Severe reversal - gain depth (rate < Parm)
0	0.0	GP_WBrecc_rev	Threshold, where it is reversal when rate<Parm
0.05	1.5	GP_WBrecc_optSlow	Lower rate of optimal range
0.12	3.7	GP_WBrecc_optFast	Upper rate of optimal range
0.18	5.5	GP_WBrecc_Fast	Threshold, where it is too fast when rate>Parm
Other parameters needed for Wading Bird suitability			
Value	Units	Global_Parm	Description
14	days	GP_WBrecc_Intvl	Interval used to calculate recession rate
12	JulianMonth	GP_WBbreedStart	Month of breeding season start (day one of month)
6	JulianMonth	GP_WBbreedEnd	Month of breeding season end (day one of month)
NOTE: for 12 and 6 for months, breeding season goes from Dec 1 through May 31 (day before June 1)			

8.6 Scenario comparisons

The remainder of this document contains **examples** of the tables, graphs, and maps of the Performance Measures for ELMwca2a outputs, allowing relative comparisons among two stage regulation schedule scenarios. The full set of Performance Measure results are available at:

http://www.ecolandmod.com/projects/ELMwca2a/#ResultsAlts

Figure 8.2. Simulated stage at the 2-17 gauge for the 2010 Base, birdSched, currentSched, and birdSched_structOnly scenarios, showing only 5 of the 36 years simulated in order to view the details. Note that the 2010 Base (driven entirely by SFWMM output for all water control structures) is based on the current schedule operations, but other water supply and flood control considerations led to deviation from the regulation schedule. Moreover, it is clear that rainfall and ET natural variability resulted in deviations from the intended regulation schedule (birdSched vs. birdSched_structOnly).

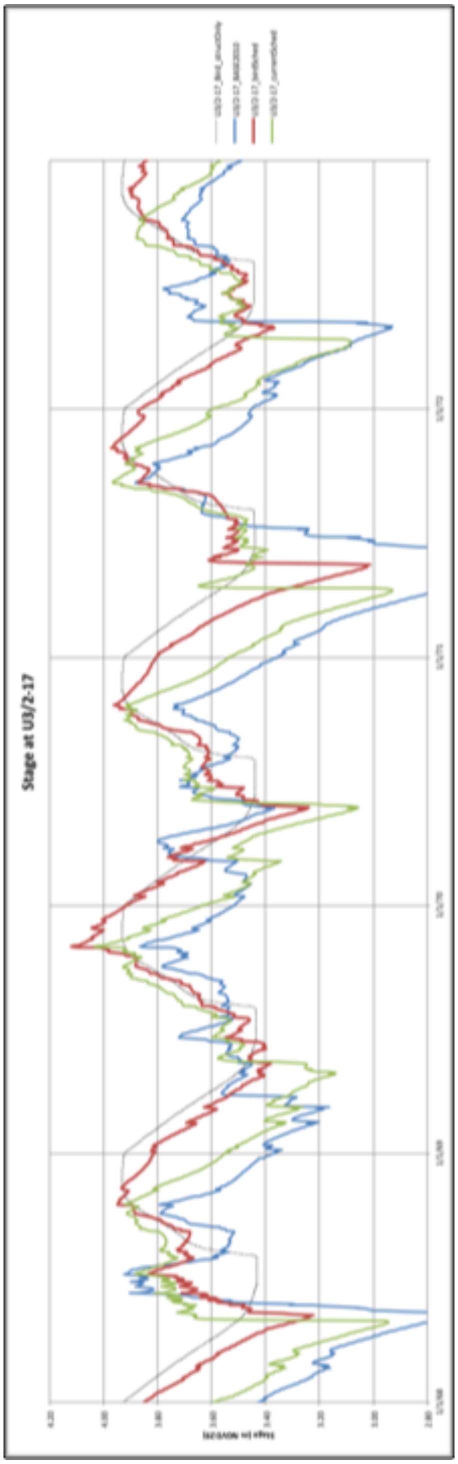
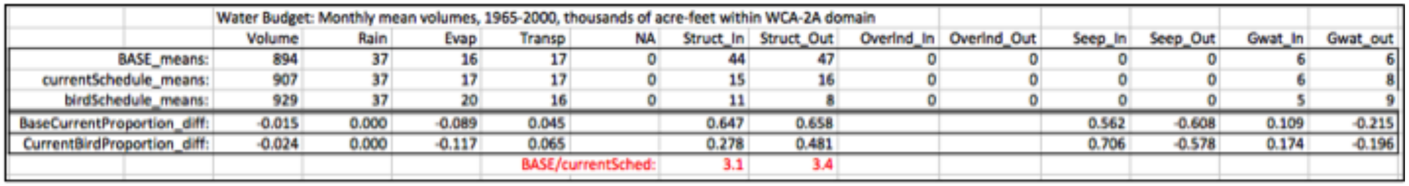


Figure 8.3. Monthly mean flows for the WCA-2A water budgets for the 1965-2000 simulation period (2010 Base, current Schedule, bird Schedule). Note that the 2010 Base had significantly higher managed inflows (Struct_In) and outflows (Struct_Out), and the bird schedule had the lowest volumes of managed flows (due to the timing of the regulation schedule, Figure 8.1).



Water Budget: Monthly mean volumes, 1965-2000, thousands of acre-feet within WCA-2A domain

	Volume	Rain	Evap	Transp	NA	Struct_In	Struct_Out	Overlnd_In	Overlnd_Out	Seep_In	Seep_Out	Gwat_In	Gwat_out
BASE_means:	894	37	16	17	0	44	47	0	0	0	0	6	6
currentSchedule_means:	907	37	17	17	0	15	16	0	0	0	0	6	8
birdSchedule_means:	929	37	20	16	0	11	8	0	0	0	0	5	9
BaseCurrentProportion_diff:	-0.015	0.000	-0.089	0.045		0.647	0.658			0.562	-0.608	0.109	-0.215
CurrentBirdProportion_diff:	-0.024	0.000	-0.117	0.065		0.278	0.481			0.706	-0.578	0.174	-0.196
					BASE/currentSched:	3.1	3.4						

Figure 8.4. Annual mean water inflows and phosphorus (P) loading for the WCA-2A water budgets (2010 Base, current Schedule, bird Schedule). Note that P concentrations in all inflows were fixed at 10 ug l^{-1} for both simulations, thus the water and P budgets are directly correlated.

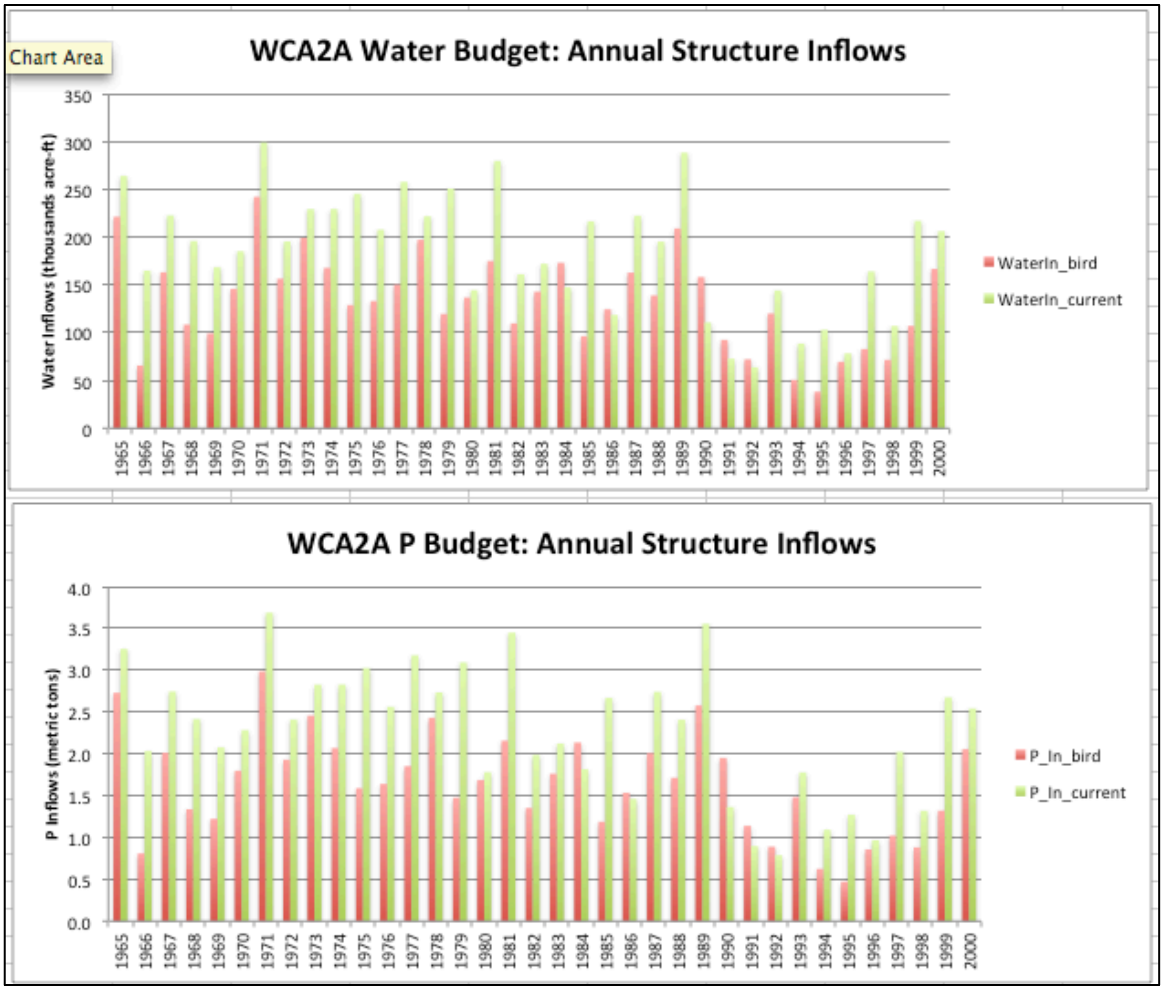


Figure 8.5. Annual mean marsh areas with specific water depth and recession rate classes during the breeding season (2010 Base, current Schedule, bird Schedule, and bird Schedule with only-structure flows). See Table 8.3 for definitions of the classes for depths and recession rates (depth classified as either dry, suboptimally dry, optimal, suboptimally wet, and wet; recession rates classified as either severe reversal, reversal, suboptimally slow, optimal, suboptimally fast, and fast).

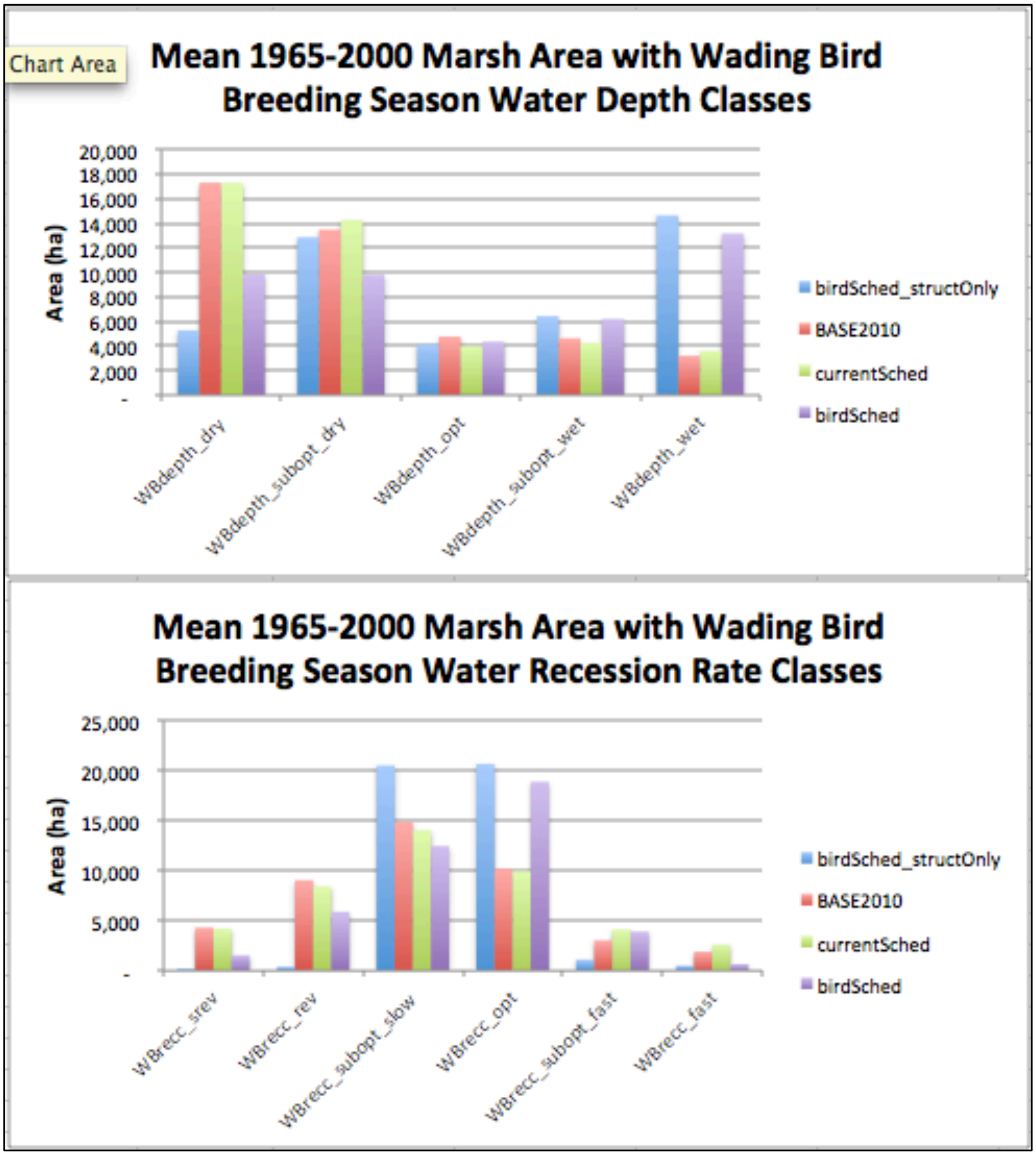


Figure 8.6. Monthly mean marsh areas with optimal water depth and recession rate classes during each month of the breeding season (2010 Base, current Schedule, bird Schedule, and bird Schedule with only-structure flows). See Table 8.3 for definitions of the optimal classes for depths and recession rates.

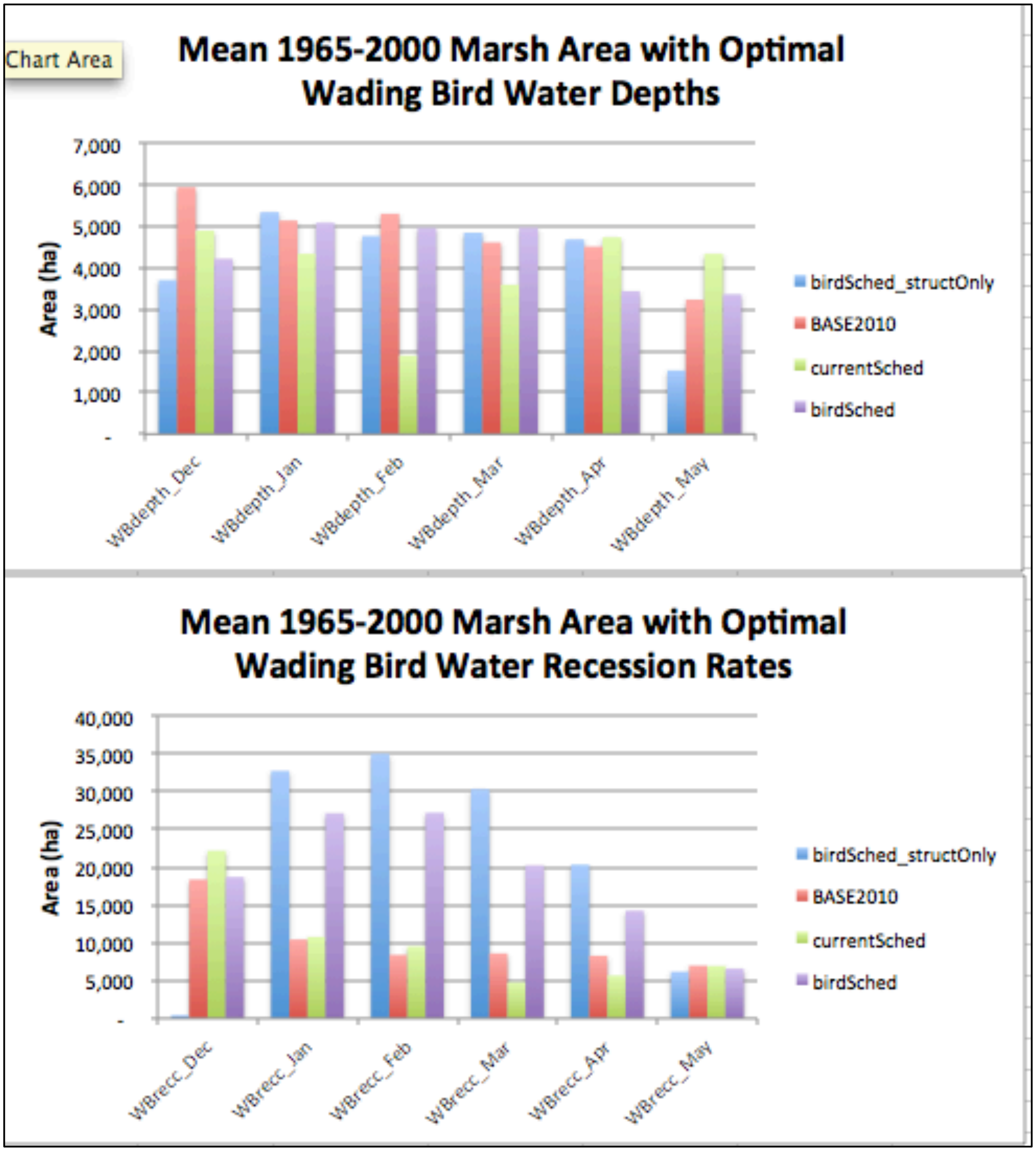


Figure 8.7. Example difference map comparison, for the depth classes for a 1-day snapshot in late January during a year (1994) with above average rainfall. The red contour shows the extent of cattail observed in 2003. For all difference maps: Map header (yellow highlight) label-syntax: ScenarioName.TemporalStatistic.VariableName_DateOfOutput; the temporal statistics are either Raw (raw output, no summary), MeanRaw (daily mean over a 30d bin), MeanPOS (mean over the 36yr Period Of Simulation), GeoMeanAnn (annual geometric mean), or for calculated rates - the rate between a beginning-date and ending-date (for P accumulation and peat accretion rates).

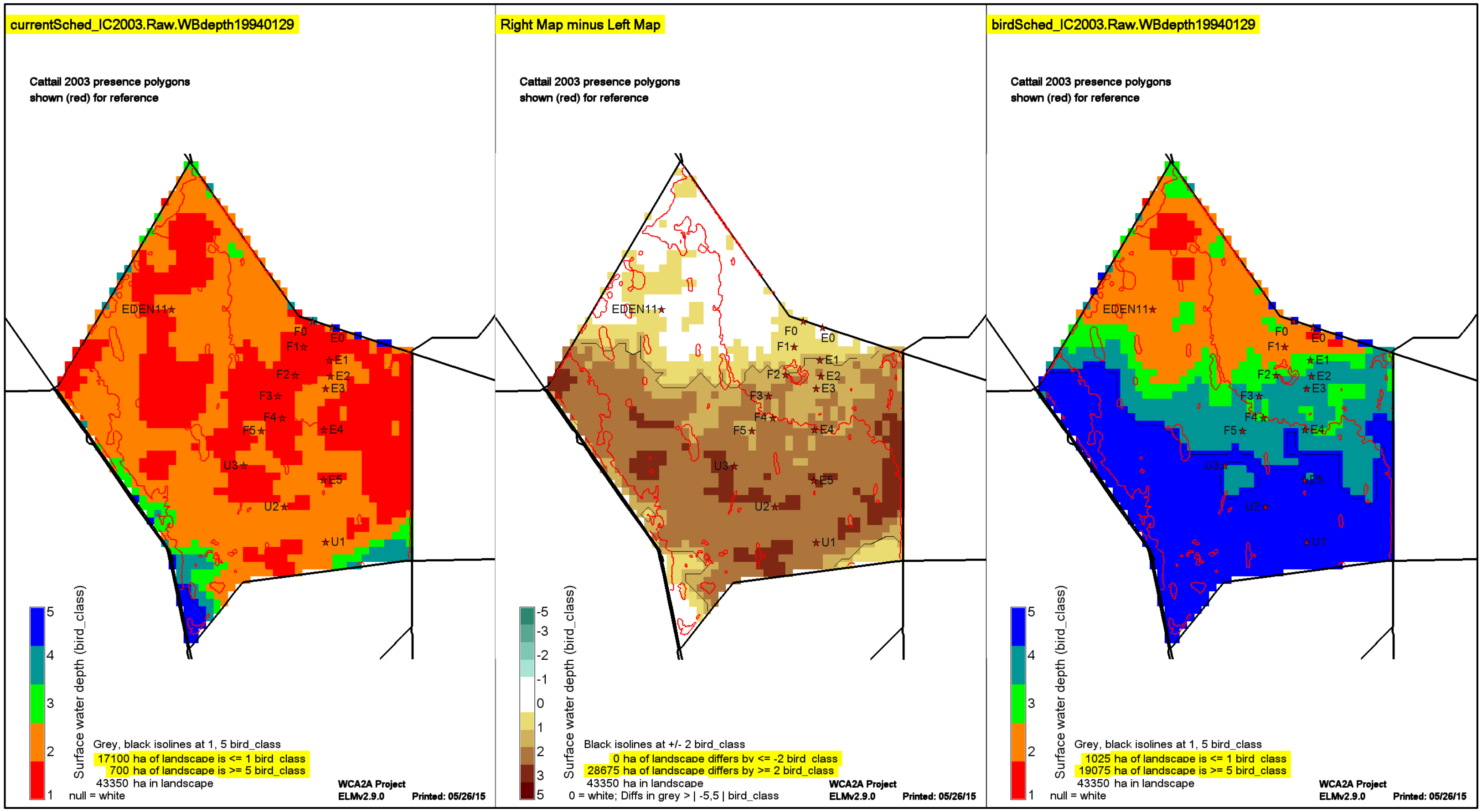


Figure 8.8. Example difference map comparison, for the recession rate classes for a 1-day snapshot in late January during a year (1994) with above average rainfall.

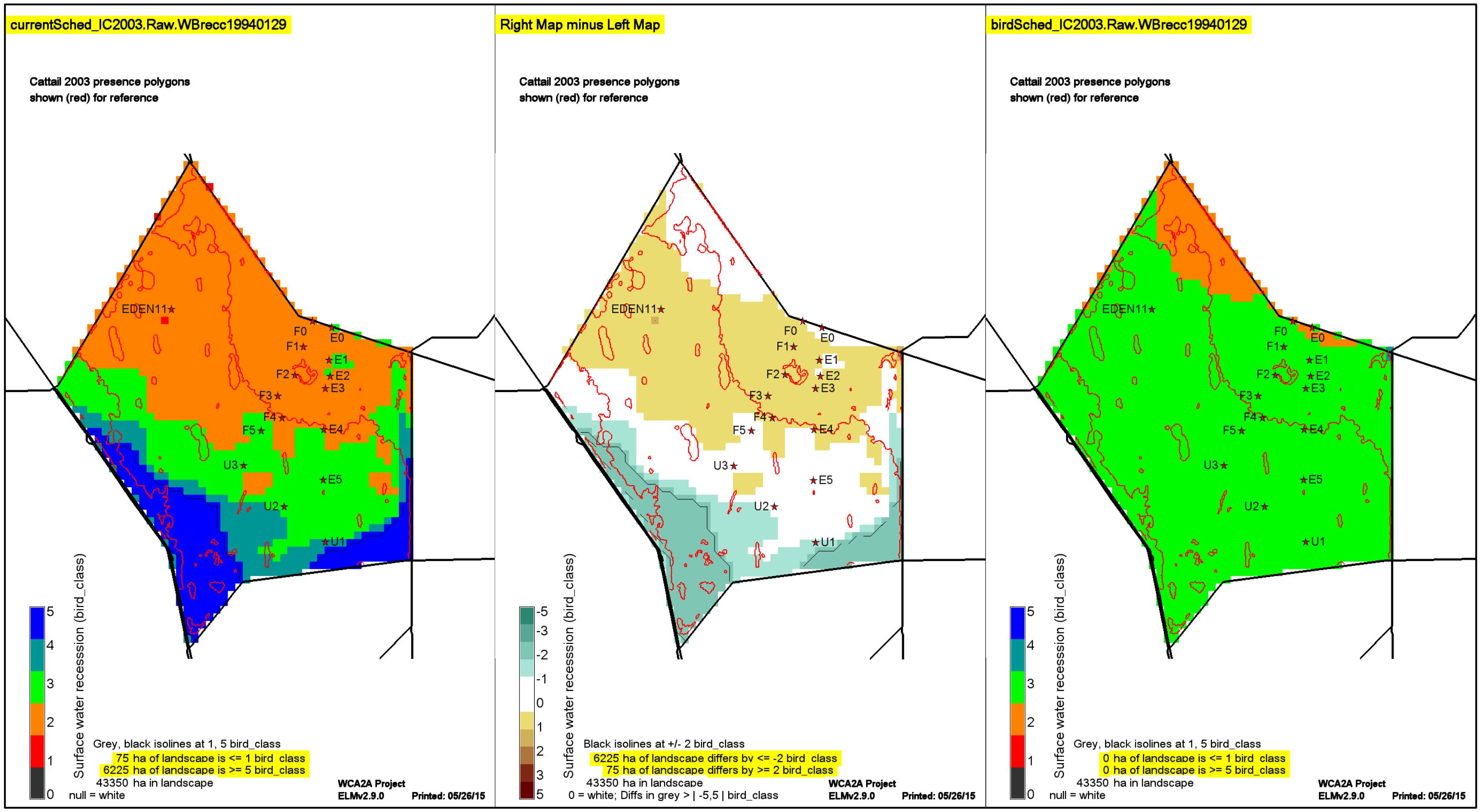


Figure 8.9. Example difference map comparison, for the P accumulation rate between 1990 and 1995.

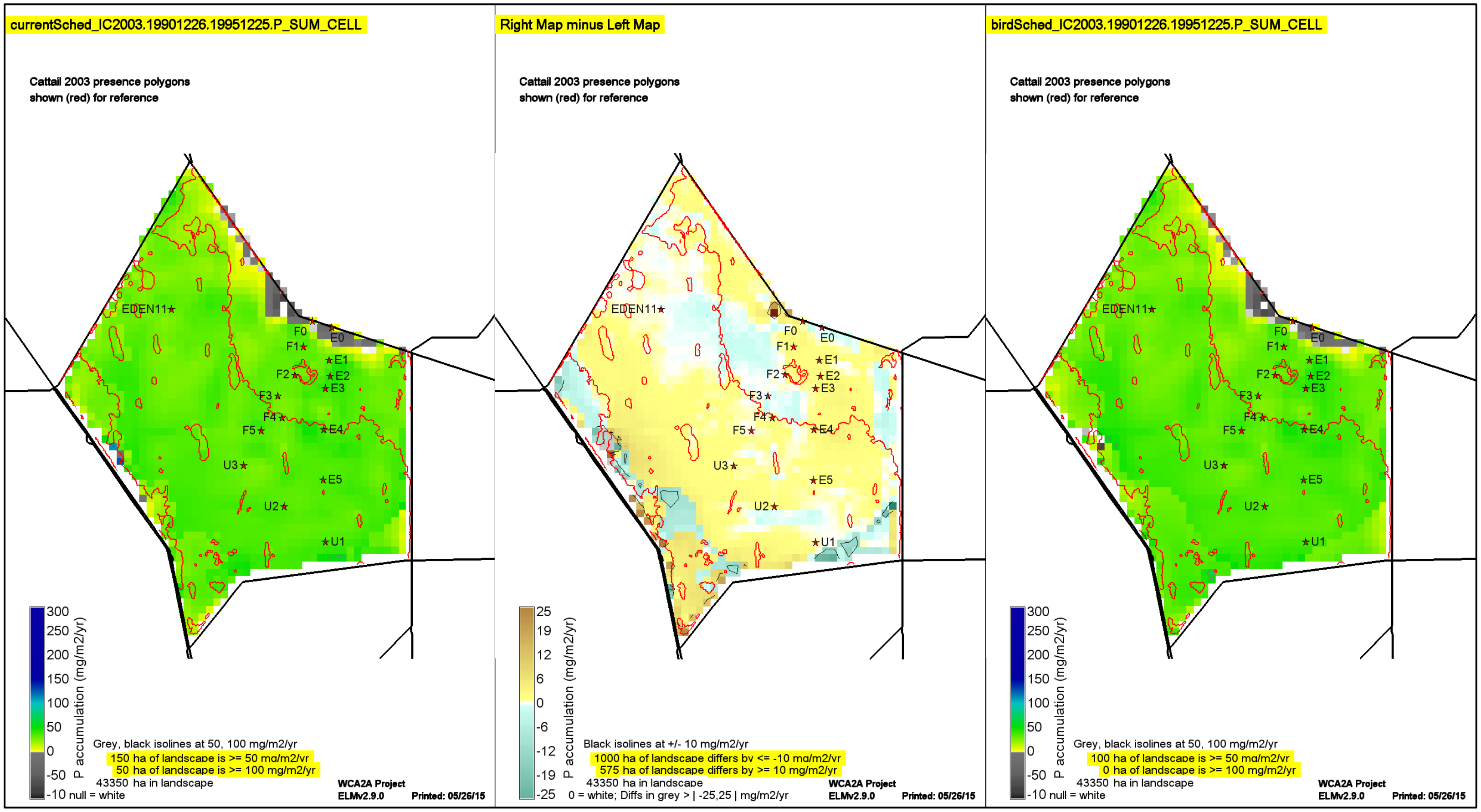


Figure 8.10. Example difference map comparison, for the soil P concentration at the end of 1995.

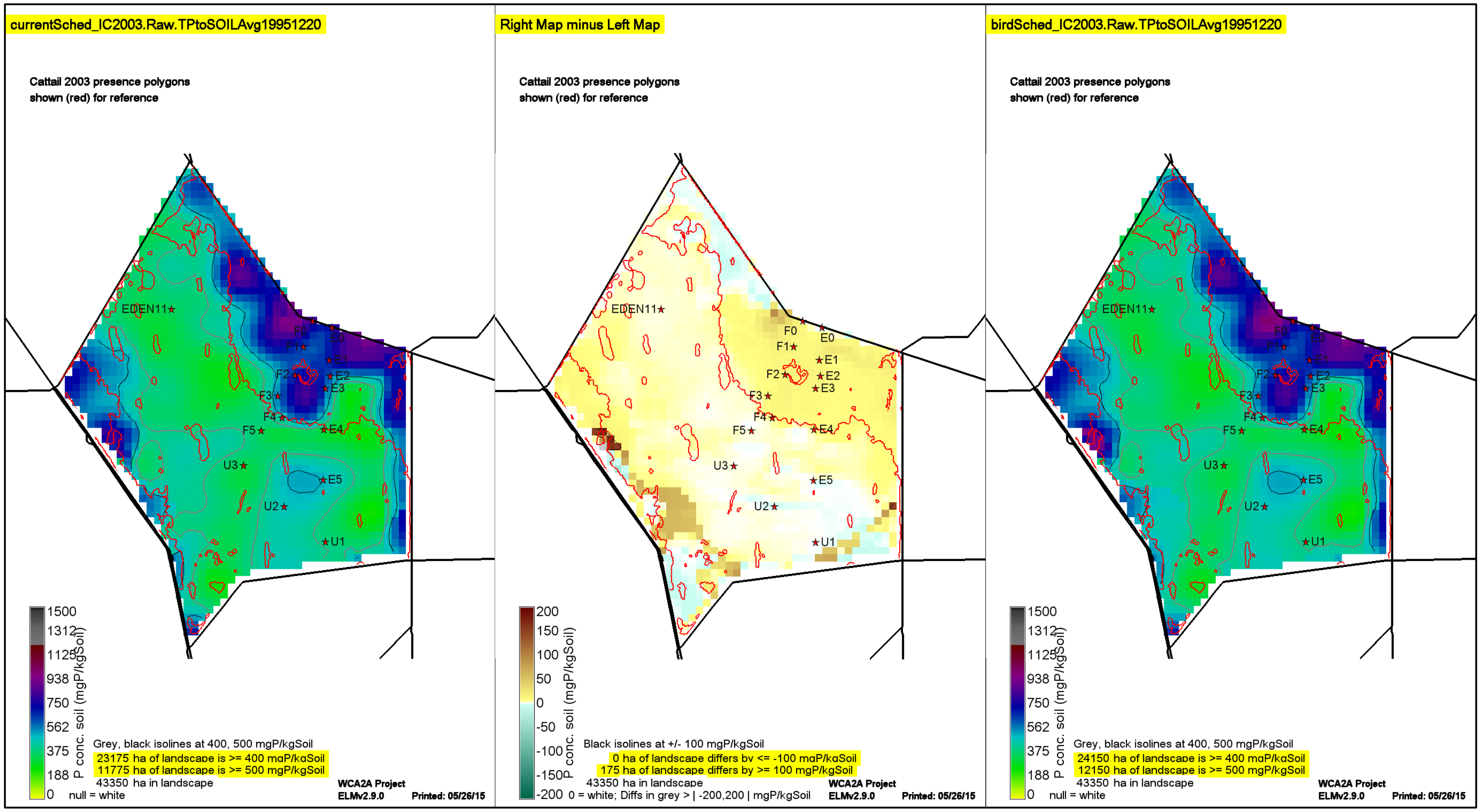


Figure 8.11. Example difference map comparison, for the annual geometric mean surface water P concentration for the year 1995.

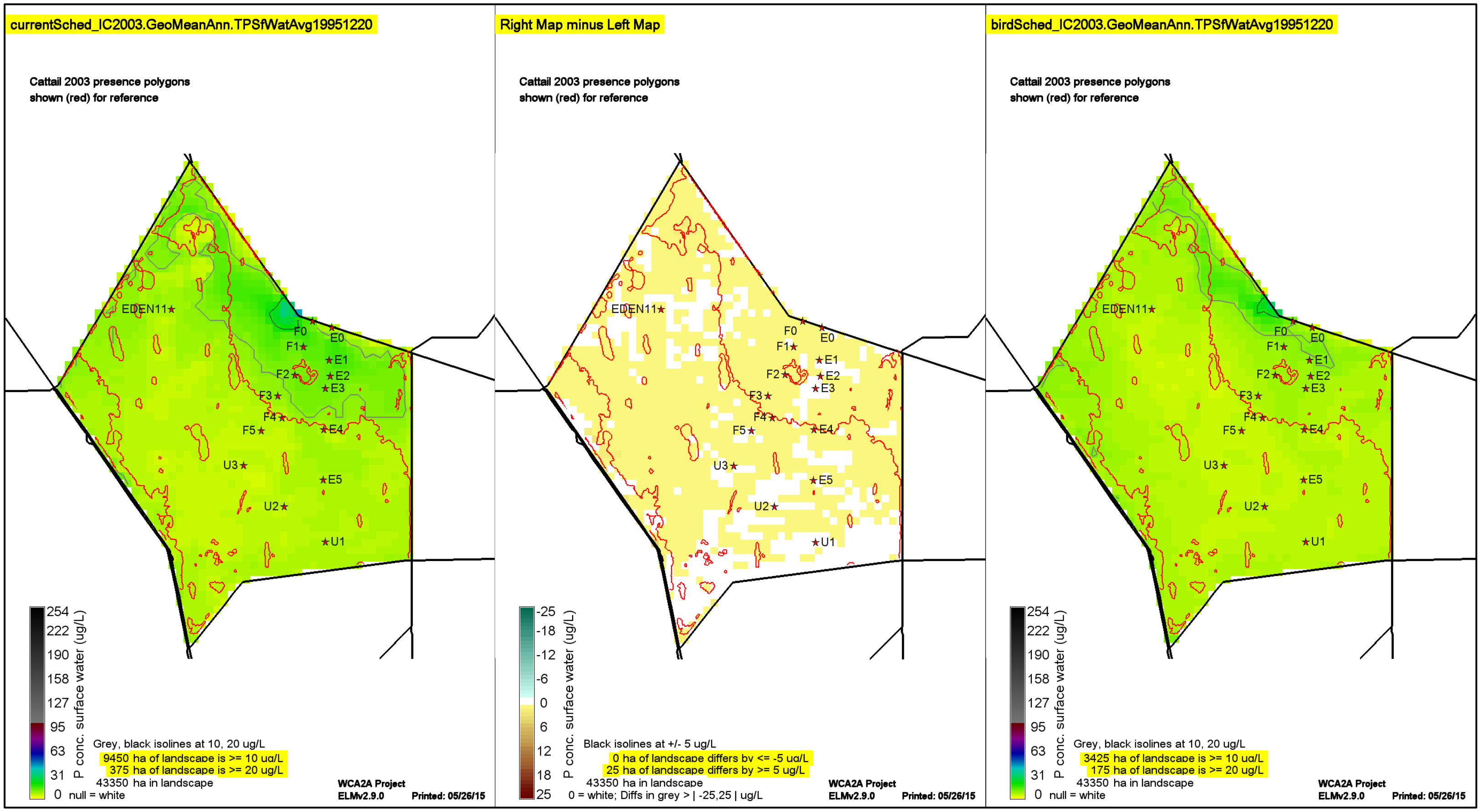


Figure 8.12. Example difference map comparison, for the habitat type (changes due to succession) at the end of 1995. Red is cattail, green is sawgrass, and blue is open water/slough.

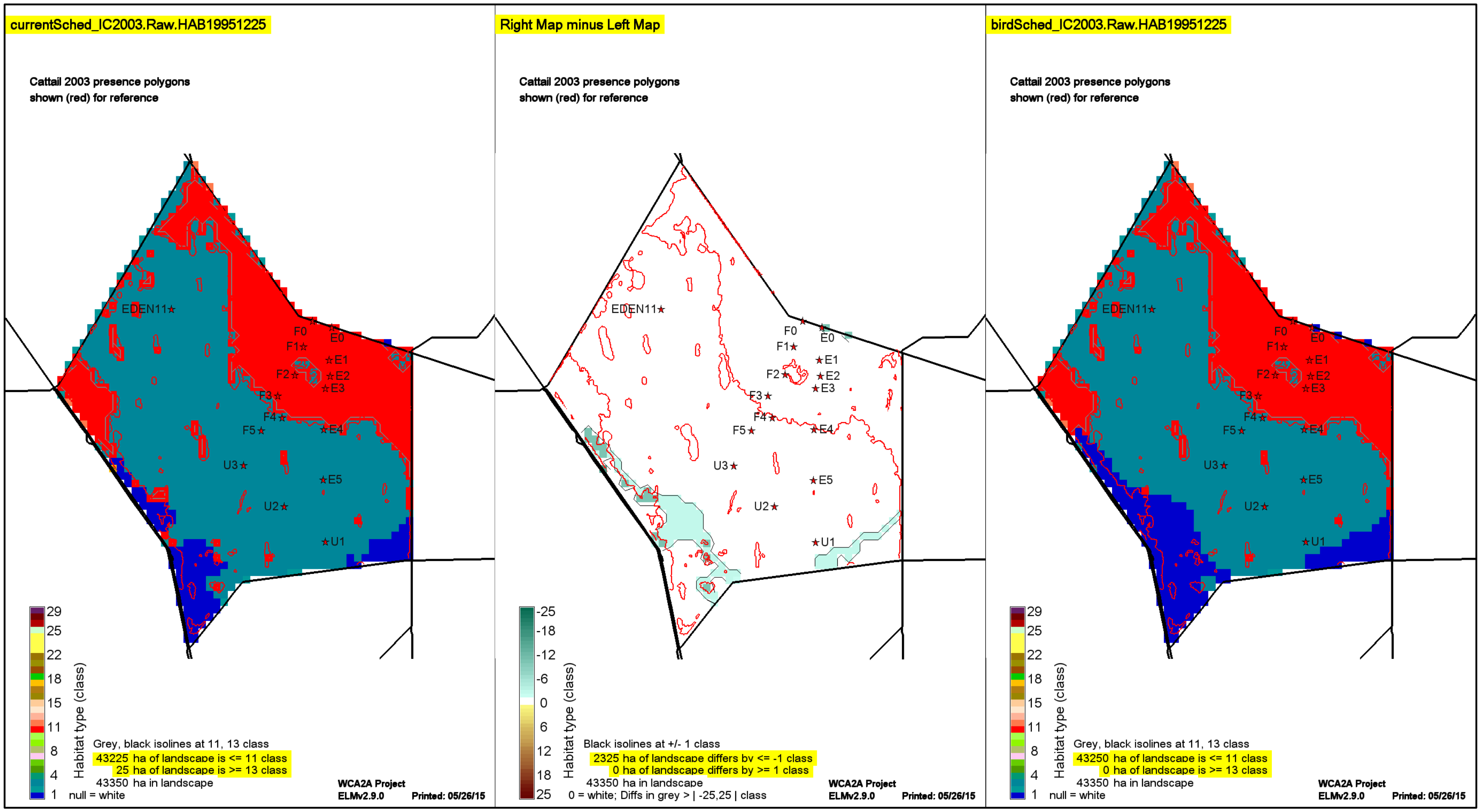


Figure 8.13. Example difference map comparison, for the macrophyte biomass at the end of 1995.

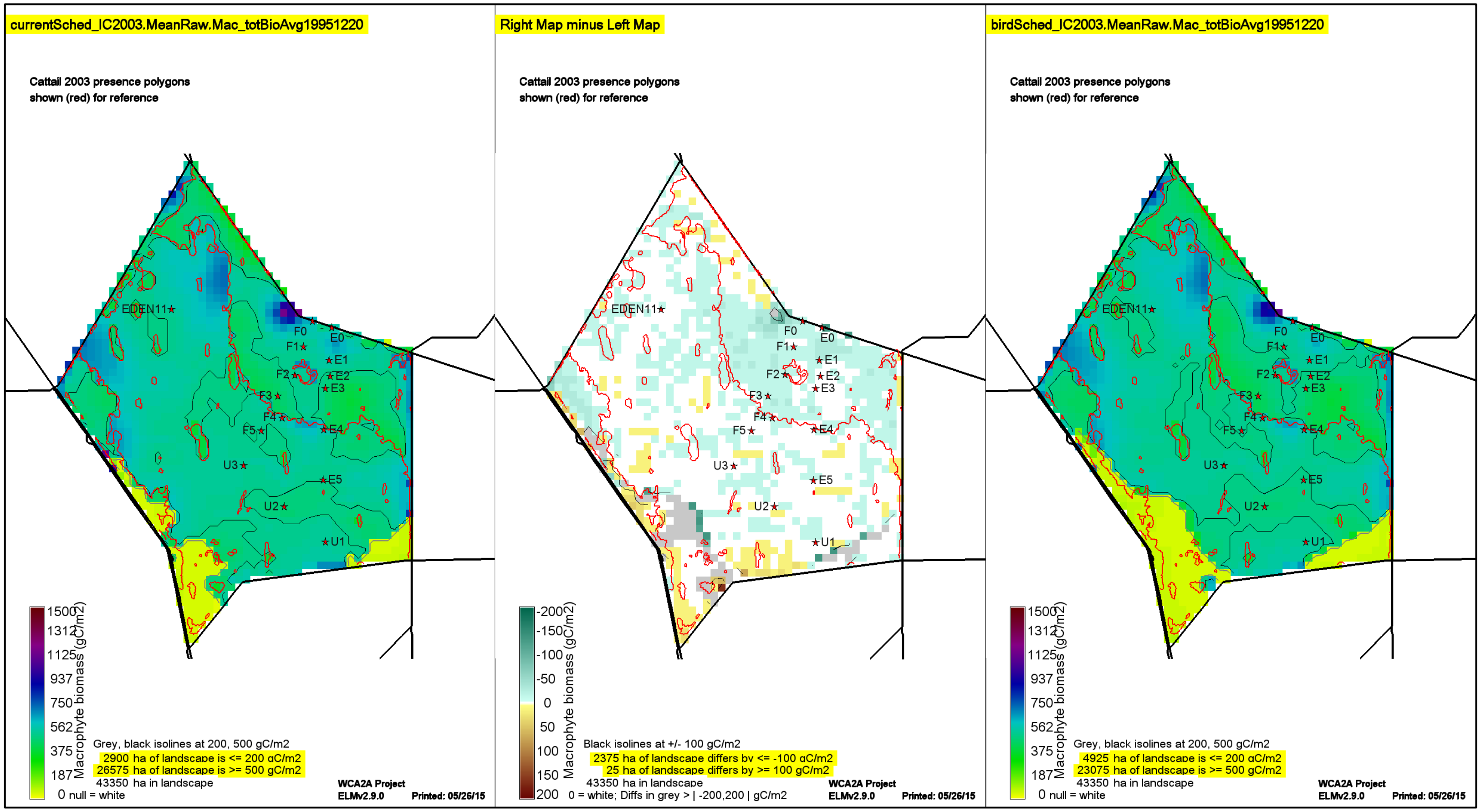
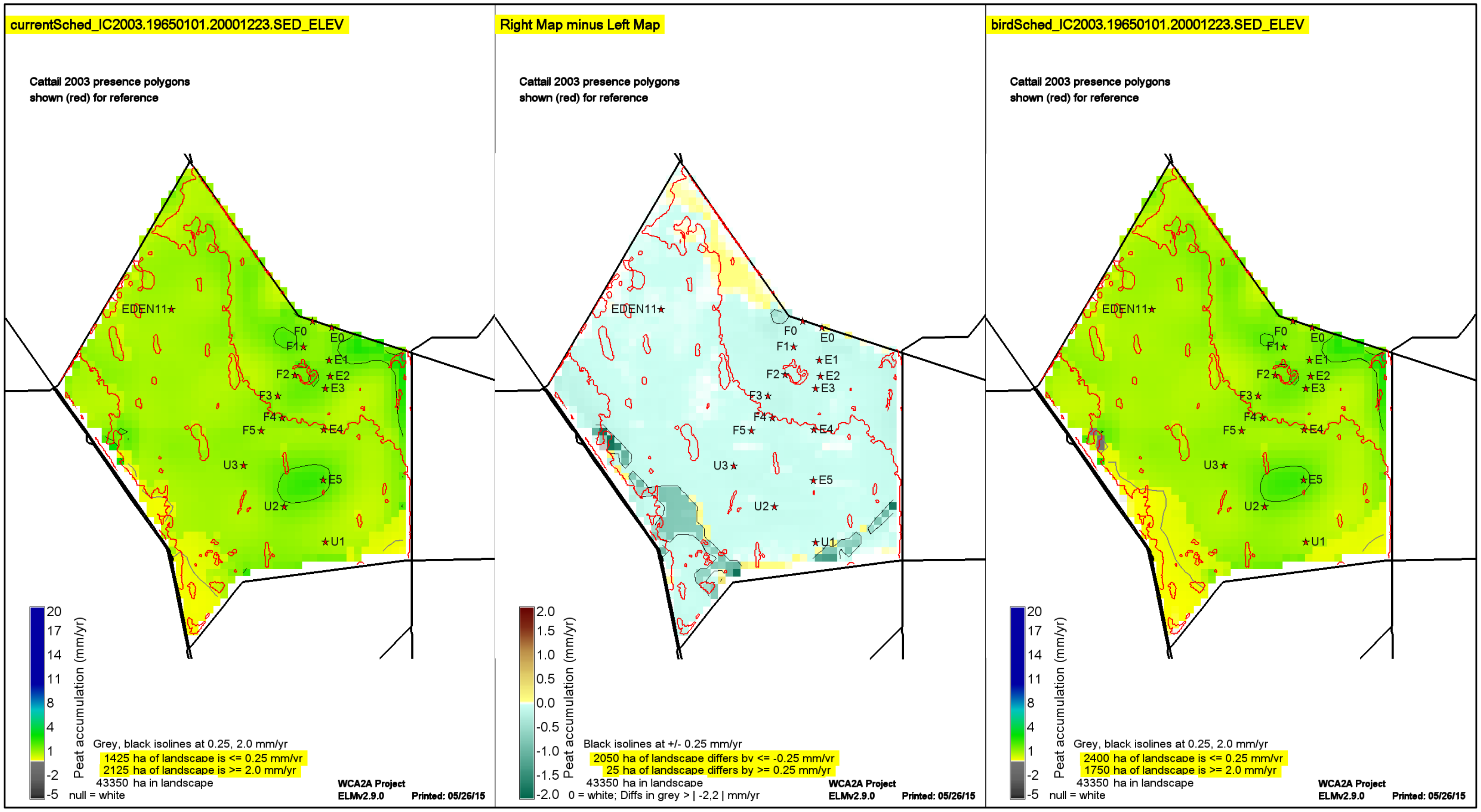


Figure 8.13. Example difference map comparison, for the peat accretion rate between 1990 and 1995.



8.7 Synthesis

The SFWMD science team will use these Performance Measure results to evaluate the relative benefits of the current and proposed stage regulation schedules (complete Performance Measure set available at http://www.ecolandmod.com/projects/ELMwca2a/#ResultsAlts).

Here, we briefly summarize some general trends/observations:

- **Current Schedule vs. SFWMM 2010 Base**
    - **3X more water flows into-out-of basin than necessary for only maintaining stage at regulation levels**
- **Bird Schedule vs. Current Schedule**
    - **BirdSched requires less total water**
    - **BirdSched generally more suitable recession rates, but generally less suitable (deeper) depths**
    - **… but those deeper depths probably more suitable to support other ecosystem dynamics…**
    - **Both generally similar regarding phosphorus, soils, & vegetation**
- **Future development/application**
    - **Improve depth distributions (& wading bird suitability) by using stage targets in north & south (instead of 1 central gauge)**
    - **Incorporate “hooks” to affect birds by vegetation density, fish indices (planning to incorporate statistical model developed by J. Trexler, FIU)**
    - **Make regional evaluations of bird suitability**