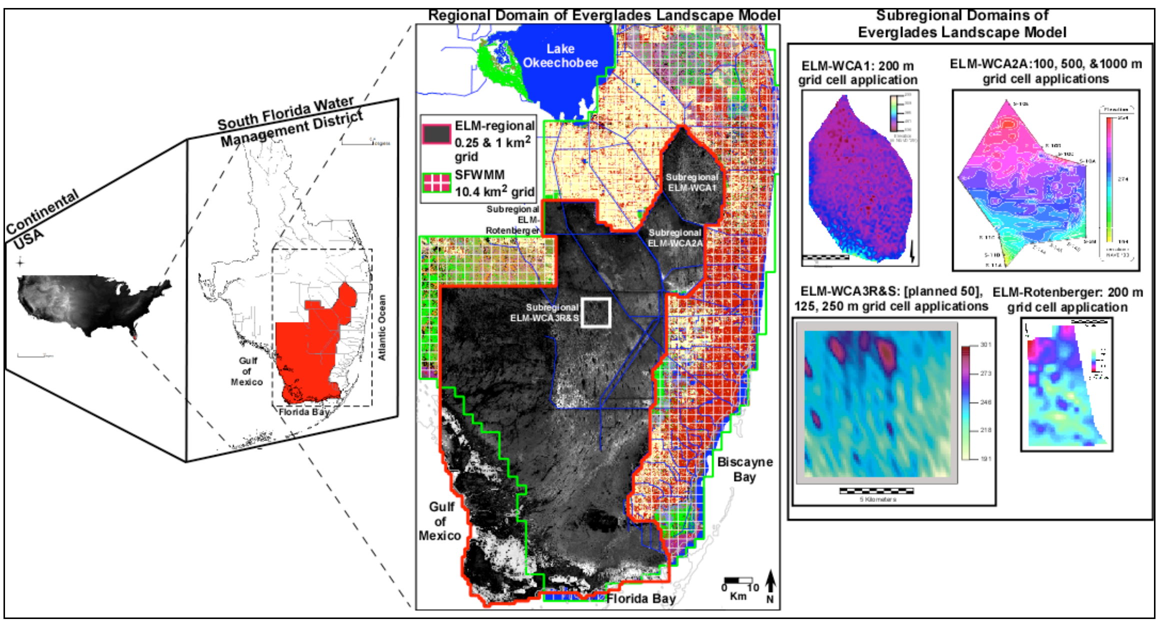
Documentation of the Everglades Landscape Model: Application of ELMwca1 v2.8



http://ecolandmod.ifas.ufl.edu

H. Carl Fitz, Assistant Professor
Soil and Water Science Department
Ft. Lauderdale Research and Education Center
IFAS, University of Florida
3205 College Ave.
Davie, FL 33314
email: cfitz@ufl.edu

March 31, 2008

Table of Contents

Preface

Documentation purpose

This documentation report provides the information necessary to fully understand the *goals & objectives, supporting data, algorithms, performance, and application* of the Everglades Landscape Model (ELM), relevant to its application in support of Water Conservation Area 1 restoration planning. This document, the model source code & data, and further supporting information will be maintained on the ELM-development web site:

http://ecolandmod.ifas.ufl.edu

The primary objective of the documentation is to present a fine-resolution application of ELM, for use in evaluating ecological responses to alternative management scenarios in WCA-1. 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 v2.5 to ELM v2.8. A number of original ELM v2.5 Documentation Chapters are not included here, as their content remains unchanged, and are available in the ELM application web site:

http://my.sfwmd.gov/elm

The only Chapters included in the ELMwca1 v2.8 Documentation Report 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 WCA-1 and the model ***Goals & Objectives***.

  *(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-1.
- 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-1 (1994 - 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: Descriptions of ***Model Application*** in support of WCA-1 restoration planning.

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

  *(see ELM v2.5) Chapter 10: A **User's Guide** that provides the simple steps to installing and running this Open Source model.*

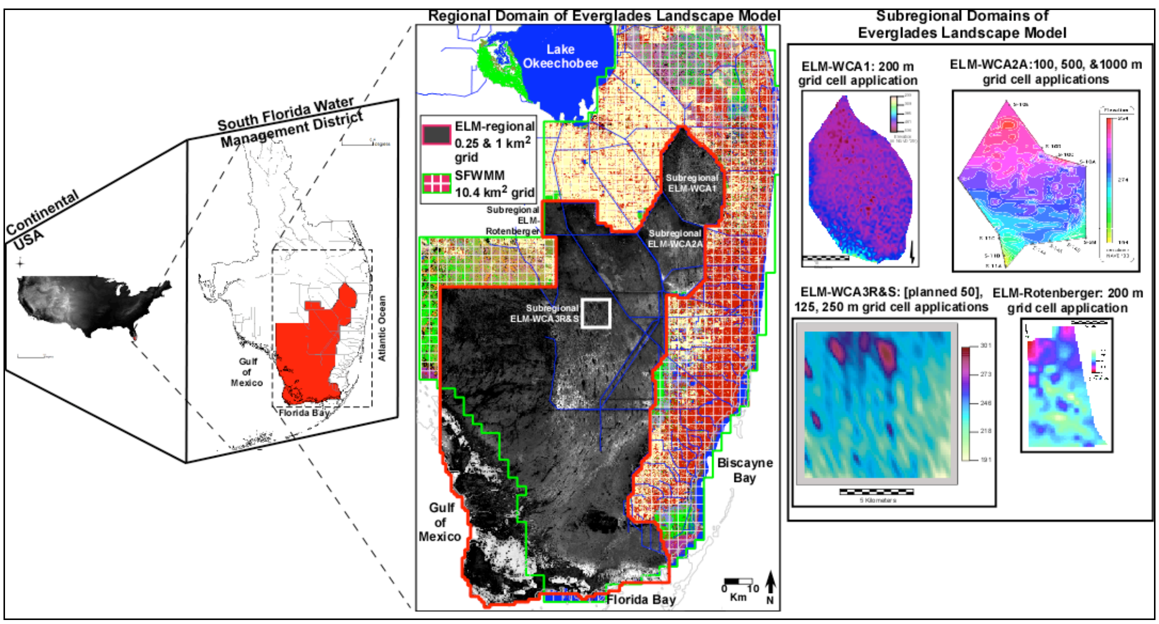
Acknowledgments

Funding for this ELM application in support of Water Conservation Area 1 restoration came from the Everglades Division 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 scientists and engineers in the Everglades Division and Watershed Management Department. M. Cook, T. Dreschel, S. Hagerthy, P. Linton, K. Rutchey, and F. Sklar provided their expertise in guiding valuable refinements to the model, developing new model application Performance Measures, and interpreting the results in support of wetland restoration. D. Powell and C. Merriam provided significant support towards making the project possible, with M. Jacoby guiding the project as Project Manager.

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 1 (WCA-1), part of the A.R. Marshall Loxahatchee National Wildlife Refuge, are exemplary of the hydrologic and water quality degradation associated with water management in an impounded Everglades basin.

To support scientific evaluations of plans to restore wetlands in WCA-1, 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 200 m grid resolution application used in evaluating restoration scenarios in Water Conservation Area 1.

A team of scientists in the Everglades Division of the South Florida Water Management District requested that an application of the ELM in WCA-1 be developed and refined, as a tool for scientific scrutiny of potential scenarios of ecological restoration of those wetlands. This ELMwca1 v2.8 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-1.*

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

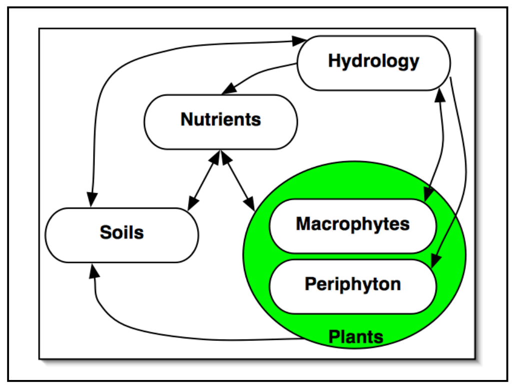
Design

• Can be applied at multiple spatial or temporal scales, for regional or subregional evaluations

- WCA-1 application at very fine resolution (260x finer than SFWMM[1])
- Multi-decadal (36-yr) simulation period

• Combine physics, chemistry, biology – *interactions*

- *Hydrology*: overland, groundwater, canal flows
- *Nutrients*: phosphorus cycling and transport
- *Periphyton*: response to nutrients and water
- *Macrophytes*: response to nutrients and water
- *Soils*: response to nutrients and water



• Combine ecological research with modeling

- research advances led to model refinements
- model output aided research designs

Reliability

• Excellent performance (WCA-1 application, 1994 – 2000 history-matching)

- *Water quality*: the offset (median bias) of predicted and observed values of phosphorus in the marsh was 0 ug L^{-1}; chloride was 2 mg L^{-1}.
- *Hydrology*: the offset (median bias) of predicted and observed values of water stage elevations in the marsh was 6 cm (2.4 inches)

• 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

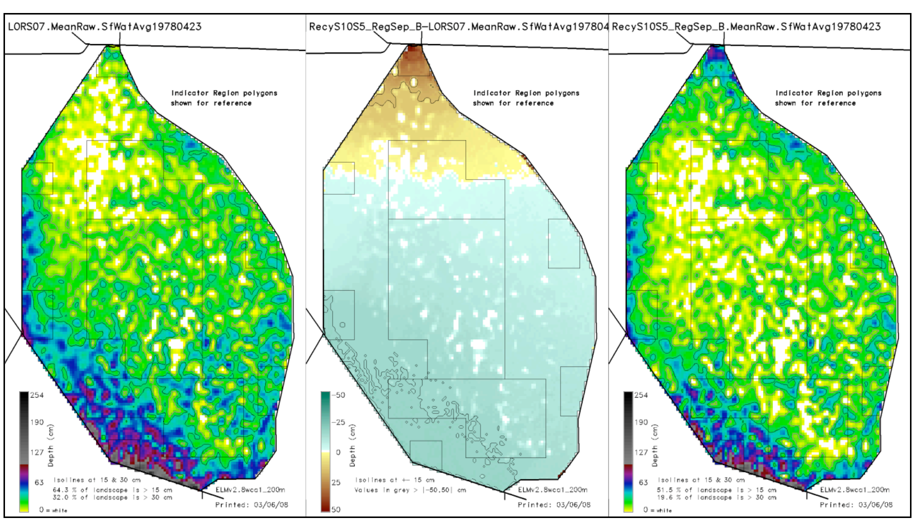
[1] South Florida Water Management Model, the widely-accepted simulation tool used for regional evaluations of water management alternatives

Model Reviews

- Open Source
    - All ELM data and computer source code freely available on web site
    - Requires only Open Source (free) supporting software
- Publications
    - 1996-2008: 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

Application to WCA-1

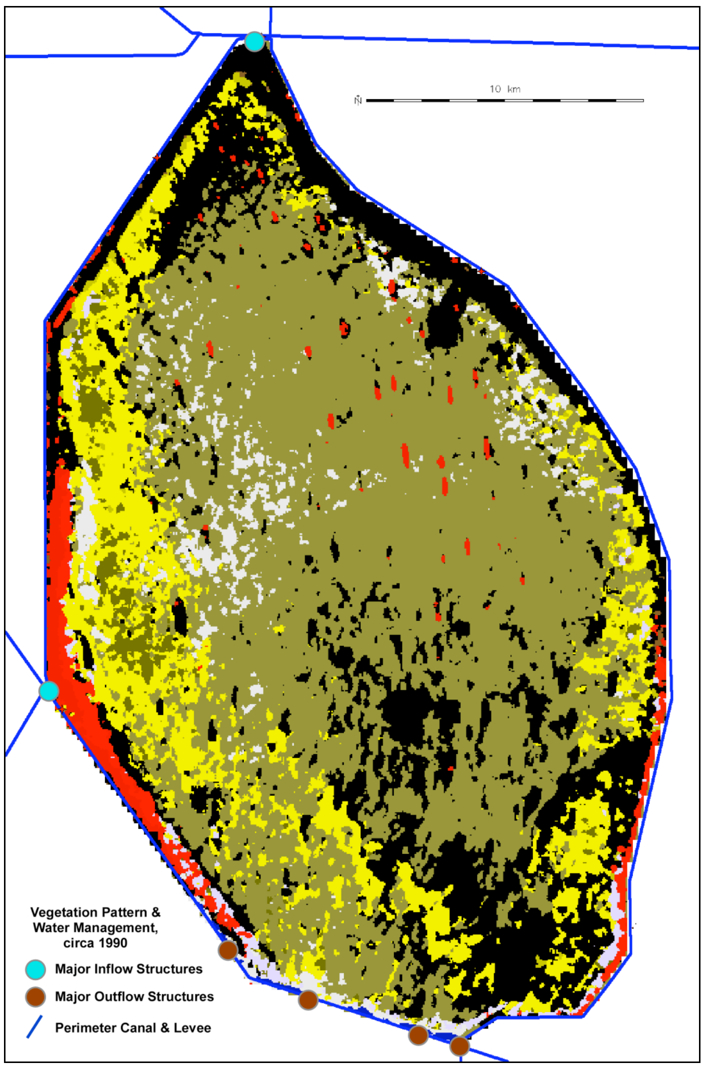
- Evaluate relative benefits among alternative scenarios, using Performance Measures of:
    - Surface water & ground water, depths and durations
    - Surface water chloride concentrations
    - Surface water phosphorus concentrations
- Implement simple water management rules
    - Water control structure inflows, outflows, and "recycling" water within basin
    - NSM-based stage regulation targets within marsh
    - Minimize chloride and phosphorus concentrations within marsh
- Twelve scenarios evaluated, one was "tentatively selected" alternative
    - "Tentatively selected" alternative required just 20% of water inputs relative to current baseline, and closely approximated hydrologic restoration targets
    - "Tentatively selected" alternative had improved water quality relative to current baseline, but may still have detrimental ecological responses to elevated chloride concentrations
    - Several additional management alternatives are planned for further analysis



Ponded depth, current mgmt   Ponded depth, difference   Ponded depth, restoration mgmt

Documentation of the Everglades Landscape Model: ELMwca1 v2.8

Chapter 1: Introduction, Goals & Objectives



http://ecolandmod.ifas.ufl.edu

March 31, 2008

This page left blank

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 1 (WCA-1) restoration. A brief overview is provided on water management for ecological benefits in WCA-1, 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 alternative project plans with respect to a number of hydro-ecological Performance Measures.

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.

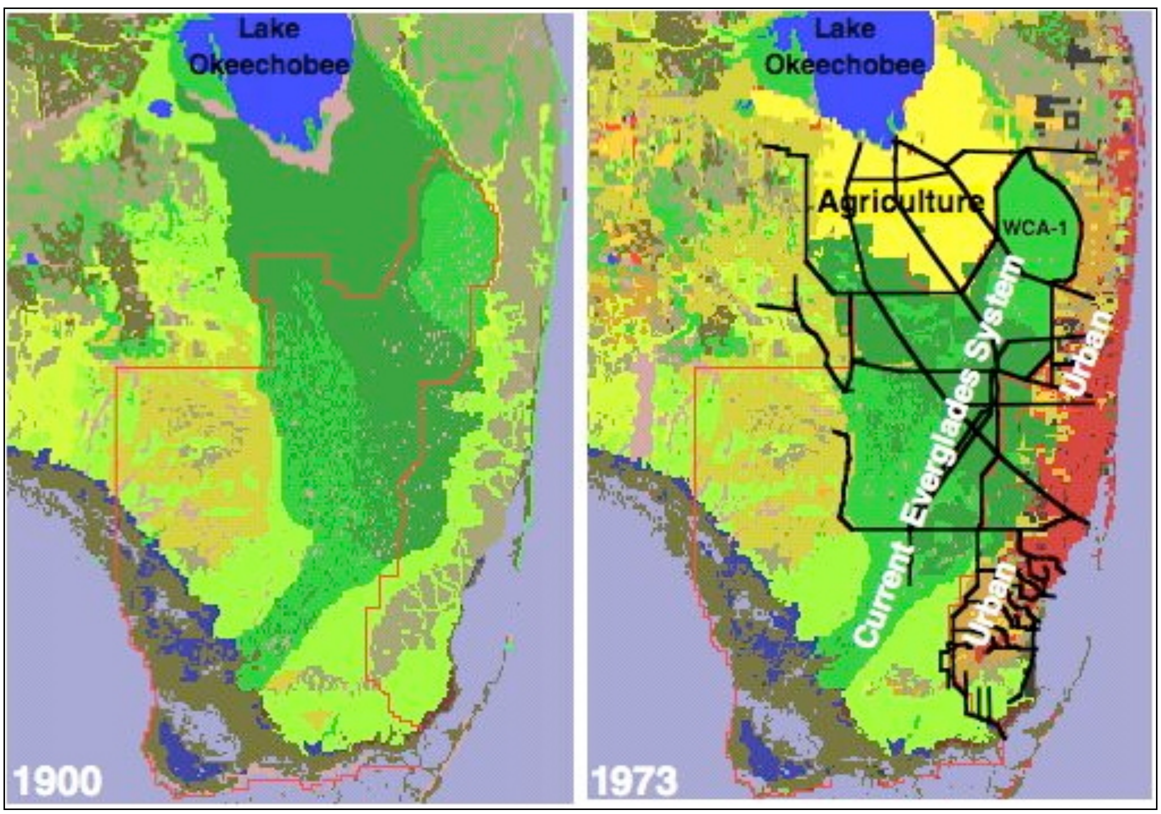


Figure 1.1. Agricultural (yellow) and urban (orange/red) land use expanded dramatically in south Florida during the 20’th century. Black lines denote some of the major canals & levees that were constructed as part of the C&SF Project. The red polygon is the domain of the regional application of the Everglades Landscape Model. The ELMwca1 application includes only the WCA-1 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 is being 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 2001a) is being implemented. The primary simulation tool used to date is the South Florida Water Management Model (SFWMM), a model with rule-based management of water flows and resultant water levels in the entire south Florida region, from Lake Okeechobee to the southern Everglades (HSM 1999). Most 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 1

In the northern Everglades, Water Conservation Area 1 (WCA-1) is an example of the results of impounding a large wetland. Comprising most of the Arthur R. Marshall Loxahatchee National Wildlife Refuge, WCA-1 is entirely surrounded by levees (Figure 1.2). Until the most recent 5-10 years, the principal managed inflows were restricted to two major pumping stations at the northern-most tip and a point along the western boundary; outflows were (and still are) principally from the perimeter canal along the (lower elevation) southern portion of the basin. 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. Superimposed on this north-south gradient is a less pronounced, but potentially significant, tendency towards higher land elevations (including tree islands) towards the center of the basin.

The regulation of the managed flows into and out of WCA-1 have generally been governed by attempts to balance goals involving (external) water supply, (external) flood protection, and ecological needs of the wetlands. Waldon (2007) recently provided an analysis of hydrologic needs of the basin under a variety of options of altered water management, assuming the 1995 regulation schedule (which is currently mandated) to be the management target for water levels. Brandt (2006) analyzed the relative degree of success in meeting the ecological goals of the most recent change in management rules, which was imposed in 1995. While in some cases data were lacking to form definitive conclusions, it was apparent that the current “regulation schedule” of water management may not be optimal for the entire landscape in WCA-1.

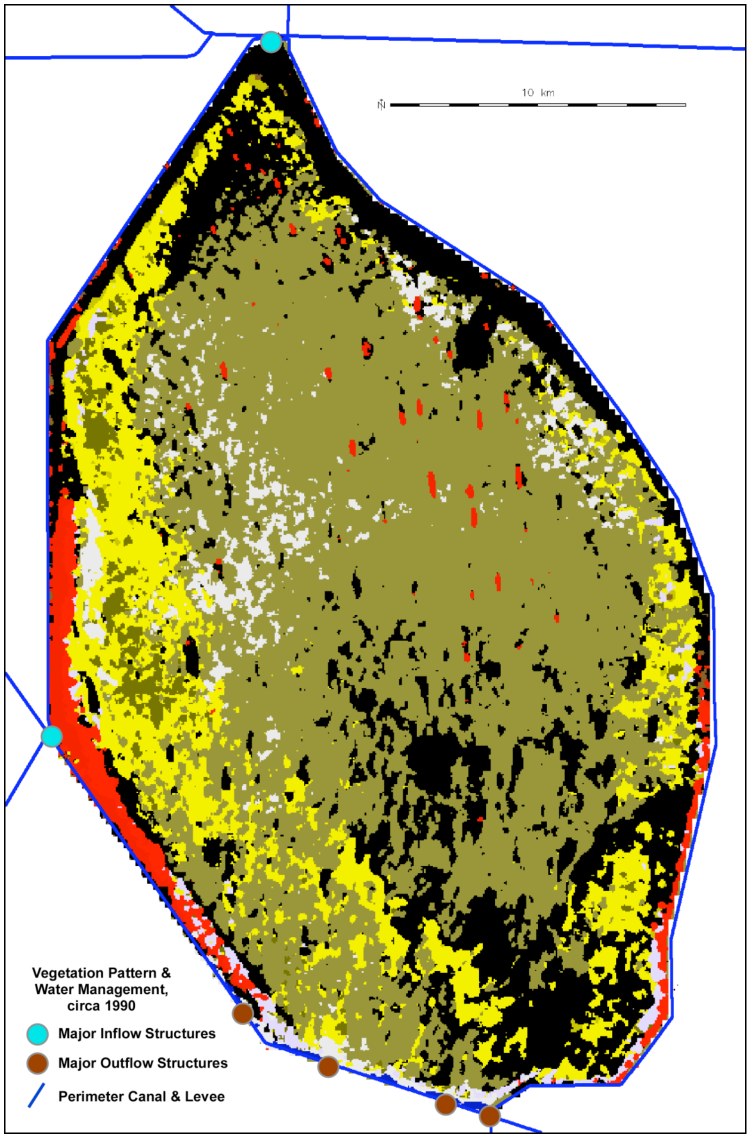


Figure 1.2. Late-1980's satellite imagery of WCA-1 was classified into eighteen vegetation types (Richardson et al. 1990), and further aggregated here to show the patterns of the dominant vegetation types within the impoundment. Note the pattern of vegetation delineating most of the perimeter of the region, adjacent to the perimeter canal on the interior side of the bounding levee.

While hydro-ecological benefits may be realized under novel management strategies in the WCA-1 basin, an important concern for ecological restoration is the water quality of the associated flows. This region is a predominantly "soft" water system (i.e., low in ionic strength), to which unique periphyton communities have adapted. Hagerthy et al. (submitted) showed that these communities shifted in composition rather rapidly in response to "hard" water incursions from canals. Moreover, flows derived from the perimeter canals in WCA-1 have historically had relatively high phosphorus concentrations, which have had well documented, deleterious effects on the wetland ecosystems, e.g., see Richardson et al. (1990), Newman et al. (1997) and McCormick et al. (2002). One of the challenges in hydrologic restoration of WCA-1 – and indeed, of the greater Everglades – is ensuring that beneficial hydration of over-drained wetlands does not become associated with the unintended consequence of ecosystem degradation from altered water quality.

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" (CERP_Team 2001b). 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 a regional-scale, integrated ecological assessment tool designed 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 alternative 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, ELMwca1

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 water quality of the greater Everglades region. The current version 2.8 continues to focus on those water quality objectives, with enhancements to the model capabilities and a finer spatial resolution than that used in regional applications. This new application is denoted ELMwca1, and was applied at a 200 m spatial resolution (compared to the 1000 m resolution of the regional model). The specific Performance Measures that were developed for use in the WCA-1 restoration evaluations are described in the Model Application Chapter 8. In general terms, the ELMwca1 v2.8 addressed the following Performance Measures:

***Specific objectives:** compare alternative management scenarios, predicting relative differences in ecological (hydrology & water quality) variables from a long-term perspective*

- Surface water and ground water depths and durations
- Concentration of Total Phosphorus (TP) in surface water
- Concentration of chloride (Cl) in surface water

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 200-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-1.

1.4.2 Relationship to other models

Another simulation model has been developed to evaluate hydrology and water quality for WCA-1. Most recently summarized by Meselhe and Waldon (2007), the goals of this hydrodynamic model overlap with those of the ELMwca1 application, and the hydrodynamic model may be available in the near future to evaluate scenarios of management in WCA-1. Comparisons of similarities, and differences, in the results from the two models may provide useful corroboration of our understanding of long-term flow and water quality characteristics under a range of management conditions.

1.5 Literature cited

Brandt, L. A. 2006. Benefits anticipated from the 1995 Water Regulation Schedule for Water Conservation Area 1: Review and analysis. A.R.M Loxahatchee NWR, Boynton Beach, FL USA.

CERP_Team. 2001a. RECOVER (REstoration COordination & VERification). http://www.evergladesplan.org/.

CERP_Team. 2001b. The Comprehensive Everglades Restoration Plan (CERP). http://www.evergladesplan.org/.

Chimney, M. J., M. K. Nungesser, J. Newman, K. Pietro, G. Germain, T. Lynch, G. Goforth, and M. Z. Moustafa. 2000. Stormwater Treatment Areas - status of research and monitoring to optimize effectiveness of nutrient removal and annual report on operational compliance. South Florida Water Management District, West Palm Beach, FL.

Costanza, R. 1975. The spatial distribution of land use subsystems, incoming energy and energy use in south Florida form 1900 to 1973. Masters. University of Florida.

FDEP. 2000. Everglades phosphorus criterion technical support document. Florida Department of Environmental Protection, http://www.dep.state.fl.us/water/wqssp/everglades/pctsd.htm.

Hagerthy, S. E., A. Gottlieb, S. Newman, and P. V. McCormick. submitted. Subtle Salinity Variations Affect the Spatial and Temporal Patterns of Freshwater Subtropical Peatland Desmids (Chlorophyta) and Diatoms Intrusion. Limnology and Oceanography.

HSM. 1999. A primer to the South Florida Water Management Model (Version 3.5). Page 233. Hydrologic Systems Modeling Division, South Florida Water Management District.

Light, S. S., and J. W. Dineen. 1994. Water control in the Everglades: a historical perspective. Pages 47-84 *in* S. M. Davis and J. C. Ogden, editors. Everglades: The Ecosystem and its Restoration. St. Lucie Press, Delray Beach, FL.

McCormick, P. V., S. Newman, S. L. Miao, D. E. Gawlik, D. Marley, K. R. Reddy, and T. D. Fontaine. 2002. Effects of anthropogenic phosphorus inputs on the Everglades. Pages 83-126 *in* J. W. Porter and K. G. Porter, editors. The Everglades, Florida Bay, and Coral Reefs of the Florida Keys: An ecosystem sourcebook. CRC Press, Boca Raton, FL.

Meselhe, E. A., and M. G. Waldon. 2007. Hydrodynamic and water quality modeling. Page 116 *in* USFWS, editor. Loxahatchee National Wildlife Refuge - Enhanced Water Quality Monitoring and Modeling Program - 3rd Annual Report LOXA07-005, U.S. Fish and Wildlife Service, Boynton Beach, FL.

Newman, S., K. R. Reddy, W. F. DeBusk, Y. Wang, G. Shih, and M. M. Fisher. 1997. Spatial distribution of soil nutrients in a northern Everglades marsh: Water Conservation Area 1. Soil Science Society of America Journal **61**:1275-1283.

Nungesser, M. K., J. Majer Newman, C. Combs, T. Lynch, M. J. Chimney, and R. Meeker. 2001. Optimization research for the Stormwater Treatment Areas. South Florida Water Management District, West Palm Beach, FL.

Odum, E. P. 1971. Fundamentals of Ecology. W.B. Saunders, Philadelphia.

Richardson, J. R., W. L. Bryant, W. M. Kitchens, J. E. Mattson, and K. R. Pope. 1990. An evaluation of refuge habitats and relationship to water quality, quantity and hydroperiod. A synthesis report., Arthur R Marshall Loxahatchee National Wildlife Refuge.

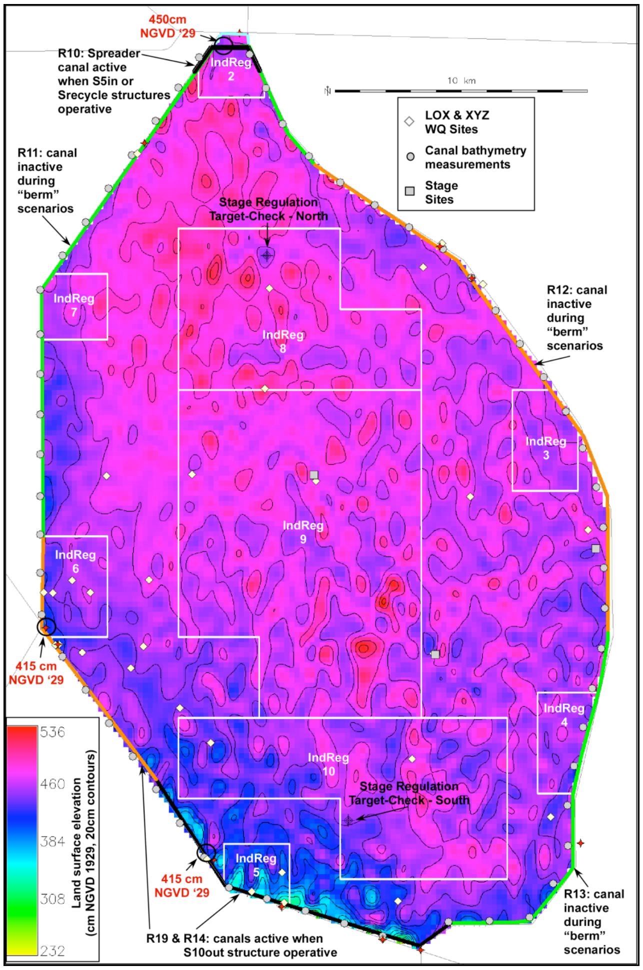
SFWMD. 1998. Natural Systems Model version 4.5 Documentation. South Florida Water Management District, West Palm Beach, FL.

USACE, and SFWMD. 1999. Central and Southern Florida Project, Comprehensive Review Study, Final Integrated Feasibility Report and Programmatic Environmental Impact Statement. US Army Corps of Engineers and South Florida Water Management District.

Waldon, M. G. 2007. Estimation of Refuge water needs: Draft report to the TOC working group on Refuge water needs. A.R.M Loxahatchee NWR, Boynton Beach, FL USA.

Documentation of the Everglades Landscape Model: ELMwca1 v2.8

Chapter 4: Data



http://ecolandmod.ifas.ufl.edu

March 28, 2008

This page left blank

Chapter 4: Data

4.1 Overview

The focus of this Chapter is the description of changes to data used in ELMwca1 v2.8, relative to those documented for the regional ELM v2.5. In its subregional (567 km^2, or 219 square miles) application at 200x200 m grid resolution, the ELMwca1 v2.8 was developed to evaluate the relative benefits among a suite of water management scenarios for ecological restoration of Water Conservation Area 1. 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 same original data. This ELMwca1 Data Chapter thus makes extensive reference to the regional ELM v2.5 Documentation Report's Data Chapter.

4.2 Background

4.2.1 Application summary

The ELMwca1 version 2.8[1] was developed in order to evaluate relative differences in ecological performance of Everglades Water Conservation Area 1 (WCA-1) water management plans. As described in this Data Chapter and the Model Structure Chapter 5, several modifications to code and data were made to the regional ELM v2.5 application in order to meet specific objectives of this WCA-1 restoration planning project. None of these changes resulted in significant differences in the performance characteristics of a regional application, but all provided either enhanced model functionality or incremental improvement to the predictive performance capabilities of the model at subregional and regional scales (the topic of the Model Performance Chapter 6).

The principal change between ELM v2.5 and the current ELM v2.8 was the restructuring and refinement of algorithms that define rule-based managed flows through water control structures. Integral with the goals and objectives of this restoration project, these modifications allowed evaluations of simple alternatives to hydrologic and water quality management of the WCA-1 landscape. (Rule-based managed flows were not used in the historical simulation evaluated in Chapter 6). Moreover, while of minor consequence in statistical evaluations of (history-matching) model performance or in evaluating relative differences among restoration scenarios, we added chloride inputs from (rainfall) atmospheric deposition.

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 0.04 km^2 (200x200 m) resolution application in the WCA-1 hydrologic basin. Most of the other data used in this application remain the same as those used in the regional ELM v2.5, and thus this Data Chapter 4 for this application makes extensive reference to the ELM v2.5 Documentation Report[2].

---

[1] The tertiary subversion designation of this v2.8 application release is v2.8.1.

[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.

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 serves to expand on the metadata by further detailing 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[3].

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
	HAB	Initial habitat type
	icMacBio	Initial total macrophyte biomass
Boundary conditions		
	BoundCond	Grid cells allowing boundary flows
	BoundCond_stage.BIN	Boundary stage/depth time series
	rain.BIN	Rainfall time series
	ETp.BIN	Potential ET time series
	CanalData.struct_wat	Structure: water flow time series
	CanalData.struct_TP	Structure: phosphorus conc. time series
	CanalData.struct_TS	Structure: salt (chloride) conc. 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

[3] Two other files, outside of the Project's "Data" directory in the "RunTime" directory, 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 ELMwca1 domain (infile = "ModArea")

The subregional ELM project for WCA-1 modeling encompasses the domain of the hydrologic basin of WCA-1. This subregional application uses 200x200 m square grid cells that encompass an area of 567 km^2 (219 mi^2). All of the maps of the regional application are bounded by the following rectangle of UTM coordinates in zone 17 (NAD 1927):

northing:	2,952,489 m
southing:	2,914,489 m
easting:	578,711 m
westing:	553,711 m

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

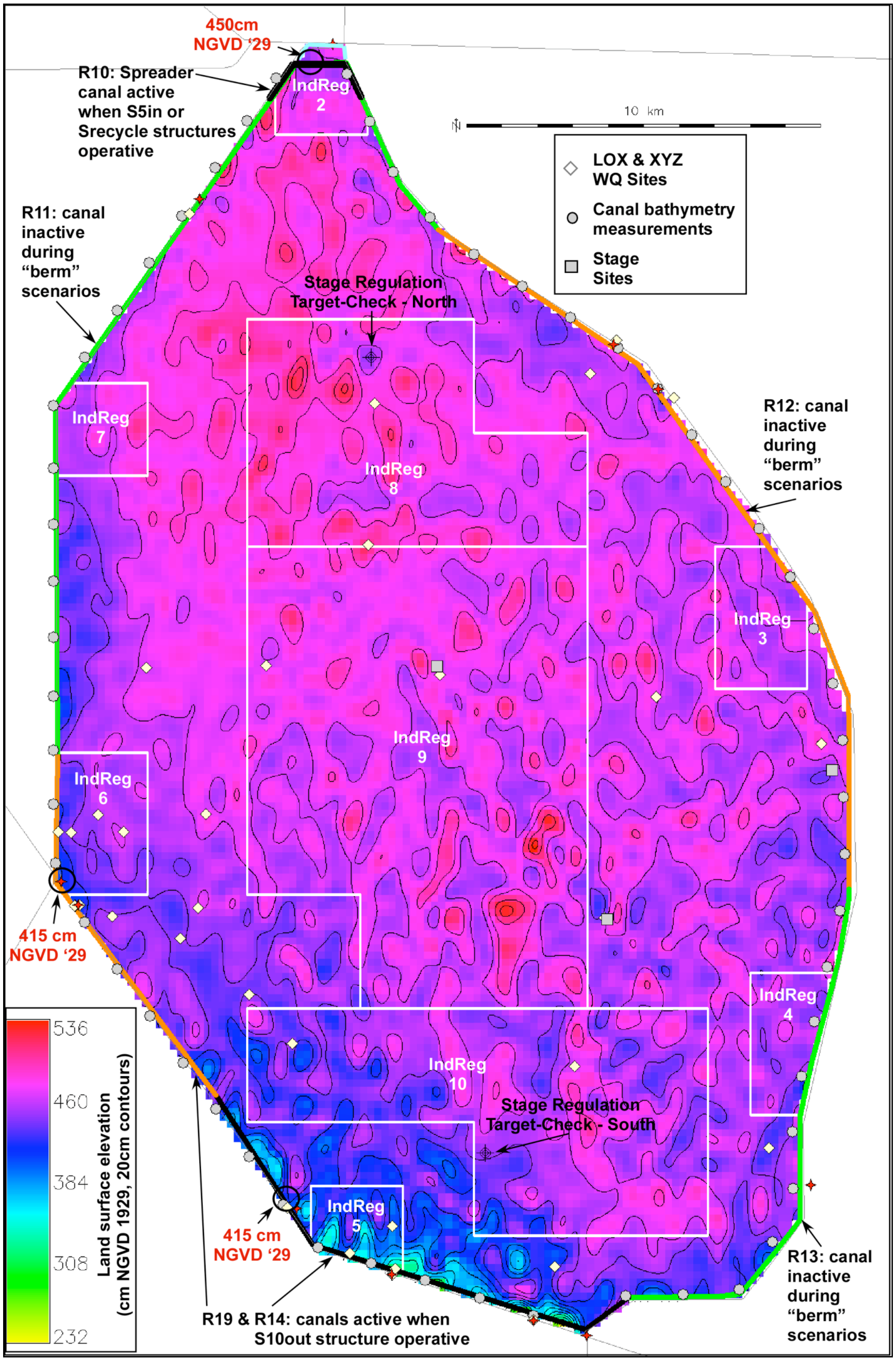
A variety of dynamic boundary condition data may be input from coarser model grids. The ELMwca1 v2.8 uses some dynamic boundary condition data (described in later sections) that are at the scale of the 2x2 mile (10.4 km^2) grid of the SFWMM. For regional or subregional applications of ELM, a "linked 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 (Figure 4.1) 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 1 surrounded by levees) or partial restrictions of overland flows (i.e., 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).

Figure 4.1. The configuration used in the historical simulation: ELMwca1 canal reach identities (R11 – R19), and initial land surface elevation. Also shown are configurations used in future scenarios: additional canal reach 10, stage regulation target trigger (check) cell locations, and outlines of Indicator Regions (see Chapter 8, Model Application).



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 ELMwca1 application is 1994 – 2000 (based primarily upon 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.

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")

1994: Output from the ELMv2.5 calibrated hydrology (initialized Jan 1, 1981) provided a snapshot of Jan 1, 1994 for initial ponded surface water depth. This regional 1km^2 snapshot was resampled for the WCA-1 200m grid model, input to ELMwca1 v2.8, run for 3 days, and the resulting ponded surface water depth was used to subsequently initialize the model for January 1, 1994.

1965: The initial ponded surface depth (negative stage minus land surface elevation) used in the SFWMM v5.5 future base runs[4] provided a snapshot of Jan 1, 1965 for initial ponded surface water depth. This regional ~10 km^2 snapshot was resampled for the WCA-1 200m grid model, input to ELMwca1 v2.8, 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")

1994: Output from the ELMv2.5 calibrated hydrology (initialized Jan 1, 1981) provided a snapshot of Jan 1, 1994 for initial unsaturated storage water depth. This regional 1km^2 snapshot was resampled for the WCA-1 200m grid model, input to ELMwca1 v2.8, run for 3 days, and the resulting unsaturated storage water depth was used to subsequently initialize the model for January 1, 1994.

---

[4] The Lake Okeechobee Regulation Schedule 2007 run is the future Base run that is used in the current ELMwca1 evaluation of future alternatives and Base run.

1965: The initial unsaturated storage depth (negative stage minus land surface elevation) used in the SFWMM v5.5 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-1 200m grid model, input to ELMwca1 v2.8, 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

We compiled a comprehensive topographic database that included the most up-to-date topographic point data from surveys distributed throughout the greater Everglades; in this project, for WCA-1. The most recent survey was conducted in 2004 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.

4.4.2.1 WCA1 elevation methods

The hydrologic basin was "masked" at a 200 m resolution, and a "regular spline with tension" method[5] was used to generate a 200 m resolution elevation map.

4.4.2.2 Initial land elevation, bathymetry maps (input = "Elevation", "Bathymetry")

The resulting "Elevation" map (Figure 4.1) was directly input to the ELMwca1 v2.8 model, to initialize the model.

The separate (required) "Bathymetry" map is used to represent negative values of elevation, such as those in the regional version of ELM associated with coastal creeks. The "Bathymetry" map for this project had values equal to zero in all cells.

4.4.3 Soils

Spatial maps of soil initial conditions were generated using the regular spline with tension method[6] to interpolate spatial point observations within WCA-1:

- WCA-1, 1991 survey, 94 points. (Reddy et al. 1993) (Newman et al. 1997)

4.4.3.1 Bulk density (input = "soilBD")

Soil bulk density was assumed constant throughout time during the simulation.

---

[5] 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.

[6] 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.

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[7].

4.4.3.3 Total phosphorus concentration (input = "soilTP")

The initial concentration of soil total phosphorus was taken to be the same values as those interpolated from the 1991 data collection survey.

4.4.4 Vegetation

4.4.4.1 Habitat type (input = "HAB")

To create WCA-1 basin habitat map, data from the following vegetation classification effort was used:

- WCA-1, 1987 satellite interpretation. (Richardson et al. 1990)

The original 10 m raster grid data were filtered[8] to obtain the modal vegetation class in a 21-cell neighborhood (across a moving window). The resulting data were resampled at 200 m resolution, then the original (Richardson et al. 1990) vegetation classes were aggregated to match those used in the regional ELM v2.5, resulting in a habitat map encompassing 7 classes for the ELMwca1 v2.8 domain.

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.

1994-2000: In ELMwca1 v2.8 historical simulation, there were 5 individual canal reaches within the WCA-1 basin, each identified by a numeric ID. While this was the same basic configuration of canal/levee vector topology as used in the regional ELM v2.5, a number of canal-depth and spatial location changes were made for this ELMwca1 v2.8 application. The topology of this vector network is shown in Figure 4.1, while Figure 4.2 shows the relationship between the canal and the marsh elevations along the entire perimeter of the WCA-1 basin.

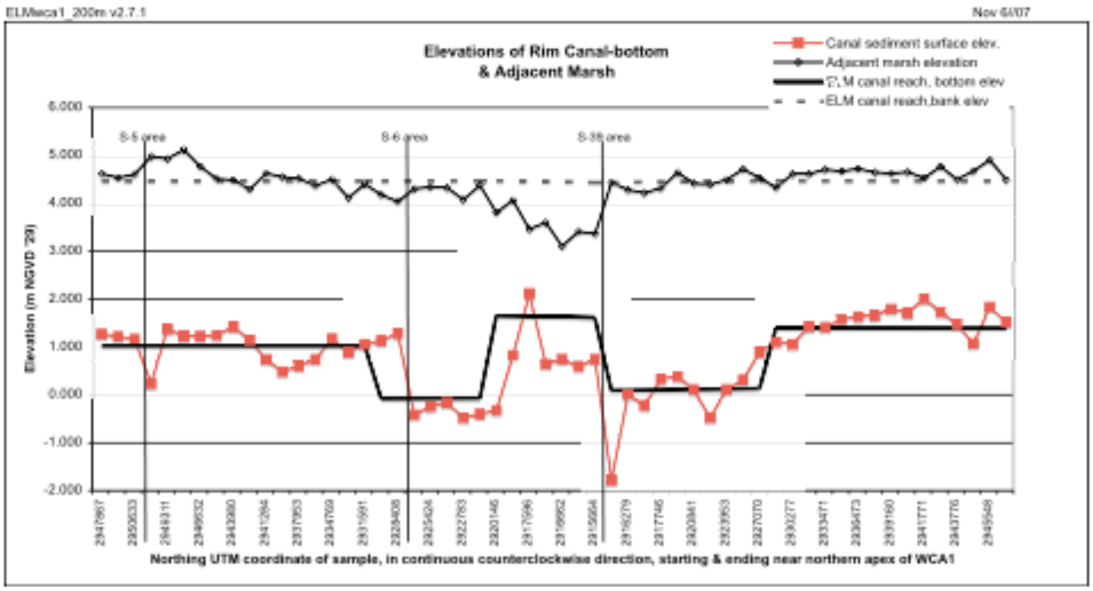
1965-2000: A variety of different canal and levee configurations were used for the Base run and different Alternative scenarios; please see the Application Chapter of this ELMwca1 v2.8 documentation.

---

[7] (1-(percent_ash/100))*soilBD, where percent_ash is the percent of ash weight relative to entire core weight

[8] Using GRASS GIS v6.2, r.neighbors command.

Figure 4.2. Relationship between canal bathymetry measurements by Daroub et al. (2002) (summarized by (Mesehle et al. 2005)) and marsh elevations in the closest (ca. 400 m) available proximity (Desmond 2004). The "Canal sediment surface elev" was calculated by subtracting the Daroub et al. measurements of canal depth from the adjacent marsh elevation. Marsh elevations were obtained from the "Elevation" input map described above. The five ELM canal reaches have a fixed slope from beginning to ending node of each of the (five) reaches, as shown in the Figure. (Note: the ELMwca1 v2.8 uses the same canal measurements as the ELMwca1 v2.7.1 shown in the Figure).



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

1994-2000: While spatial-location attributes are different, no change from ELM v2.5 (for structures associated with WCA-1); please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: A variety of different structures were used for the Base run and different Alternative scenarios; please see the Application Chapter of this ELMwca1 v2.8 documentation.

4.5.2 Model parameters

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

4.5.2.1 Global parameters (input = "GlobalParms_NOM")

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

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

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

4.5.2.3 Aquifer hydraulic conductivity (input = "HydrCond")

No change in data values from ELM v2.5: the 1km^2 ELM v2.5 map was resampled and filtered to obtain the 200x200 m grid data used in ELMwca1 v2.8; 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 (and 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 (and 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-1 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")

1994-2000: No change from ELM v2.5 (and SFWMM v5.4); please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: Used SFWMM v5.5 output for the Lake Okeechobee Regulation Schedule 2007; 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 (input = "CanalData.graph")

Not applicable.

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

1994-2000: No change from ELM v2.5 (for structures associated with WCA-1); please see the ELMv2.5 Documentation Report, Chapter 4.

1965-2000: Used either a) SFWMM v5.5 output for the Lake Okeechobee Regulation Schedule 2007 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 Nutrient/constituent inflows

4.6.3.1 Atmospheric phosphorus & chloride deposition

For phosphorus, there were no change from ELM v2.5; please see the ELMv2.5 Documentation Report, Chapter 4.

We added chloride inputs to the model from atmospheric deposition, using a rainfall concentration that was constant in time, at 1.7 mg l^{-1}.

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

1994-2000: No change from ELM v2.5 (for structures associated with WCA-1); 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 v5.5 output for the Lake Okeechobee Regulation Schedule 2007 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")

1994-2000: No change from ELM v2.5 (for structures associated with WCA-1); 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 v5.5 output for the Lake Okeechobee Regulation Schedule 2007 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-1); please see the ELMv2.5 Documentation Report, Chapter 4.

4.7.2 Water quality

4.7.2.1 Surface water quality constituents

Two stations were dropped from the list of canal water quality monitoring stations: in February 2008, the Technical Advisory Committee (formed from the "Settlement Agreement" associated with the 1994 Everglades Forever Act) held discussions that concluded the "L40-1" and "L40-2" water quality stations were not representative of WCA-1 canal waters; we subsequently dropped those monitoring stations from use in model evaluations.

No change to data from ELM v2.5 (for monitoring sites associated with WCA-1); 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.

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.

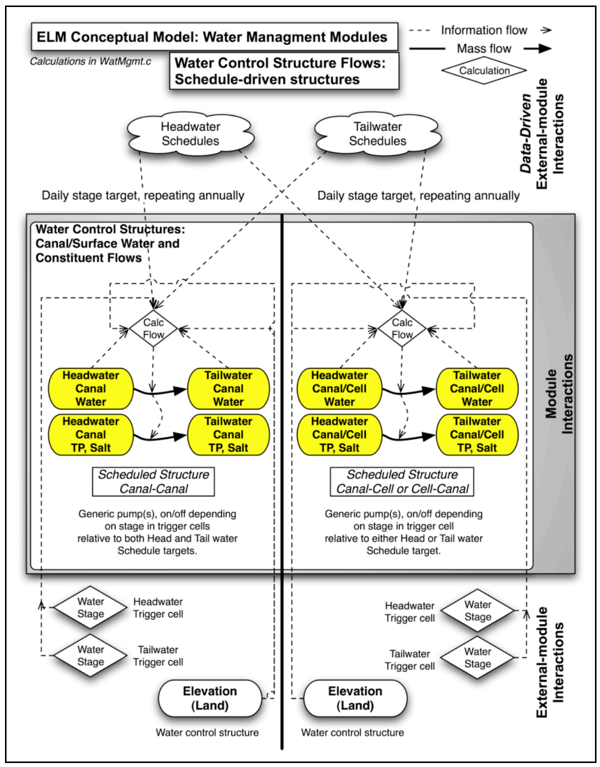
Newman, S., K. R. Reddy, W. F. DeBusk, Y. Wang, G. Shih, and M. M. Fisher. 1997. Spatial distribution of soil nutrients in a northern Everglades marsh: Water Conservation Area 1. Soil Science Society of America Journal **61**:1275-1283.

Reddy, K., W. DeBusk, Y. Wang, and S. Newman. 1993. Physico-chemical properties of soils in the water conservation area 1 (WCA-1) of the Everglades. UF, SFWMD.

Richardson, J. R., W. L. Bryant, W. M. Kitchens, J. E. Mattson, and K. R. Pope. 1990. An evaluation of refuge habitats and relationship to water quality, quantity and hydroperiod. A synthesis report., Arthur R Marshall Loxahatchee National Wildlife Refuge.

Documentation of the Everglades Landscape Model: ELMwca1 v2.8

Chapter 5: Model Structure



http://ecolandmod.ifas.ufl.edu

March 28, 2008

This page left blank

Chapter 5: Model Structure

5.1 Overview

The Everglades Landscape Model (ELM) is a spatially distributed simulation using integrated hydro-ecological process modules. With a structured programming approach, the hydrologic, biogeochemical, and biological processes (such as evapotranspiration, soil oxidation, and plant growth) are contained in code modules that are activated by the user at runtime. Being “data-driven”, the model relies on databases to modify scenarios of water management, while computer source code remains constant.

This Chapter on Model Structure for ELM v2.8 serves to update the Model Structure Chapter 5 of the complete ELM v2.5 Documentation Report. Therefore, this is not a “stand-alone” document on the model structure, but simply updates any algorithm which has changed to meet the objectives of different projects.

The focus of this Chapter involves the changes made primarily for the ELMwca1 project in support of WCA-1 restoration planning. Towards that end, the major change from ELM v2.5 to ELM v2.8 was the restructuring and refinement of algorithms that defined schedule-based managed flows through water control structures. Integral with the goals and objectives of the WCA-1 restoration project, these modifications allowed evaluations of simple alternatives to hydrologic and water quality management of the WCA-1 landscape.

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 v2.8.1 is not considered a public release at this point, as other components of the larger modeling framework (e.g., the regional applications at 500 m and 1 km resolutions) are incomplete.

Thus, the source code and data provided to the Everglades Division of SFWMD are not to be released to other parties until the remaining components of model framework have been completed.

5.2 Update summary, ELM v2.5 – v2.8

This Model Structure Chapter 5 describes ONLY changes that were made to algorithms and source code between the regional ELM v2.5 (July 2006, ELM v2.5 Documentation Report[1]) and the current ELM v2.8 (specifically, ELMwca1 v2.8.1). Therefore, this is not a "stand-alone" document on the model structure, but simply updates any algorithm which has changed to meet the objectives of different projects.

This update to the documentation is focused primarily on the objectives of the ELMwca1 project in support of WCA-1 restoration planning.

Several changes were made to accommodate specific objectives of the WCA-1 restoration project. As described later in this chapter, the principal changes were made to increase the functionality of the model in simulating managed flows through water control structures. In maintaining its design goals, the ELM v2.8 code remains general in scope, such that a change made to accommodate such new functionality does not affect other applications if that functionality is not needed. Thus, when referring to v2.8.1 of the ELM code, it does not matter whether the model project of interest is a regional or subregional application – the algorithms and code are general to all.

As summarized in Table 5.1, a variety of other modifications were made to the ELM between v2.5 and v2.8. None of these changes resulted in significant differences in the performance characteristics of a regional application, but all provided either enhanced model functionality or incremental improvement to the predictive performance capabilities of the model at subregional and regional scales (see Model Performance, Chapter 6).

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 v2.8.1 is not considered a public release at this point, as other components of the larger modeling framework (e.g., the regional applications at 500 m and 1 km resolutions) are incomplete.

Thus, the source code and data provided to the Everglades Division of SFWMD are not to be released to other parties until the remaining components of model framework have been completed.

[1] 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.

Table 5.1. Summary of updates to ELM applications, v2.5 through 2.8. Underlined entries denote changes specific to ELMwca1 project.

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 flexibillity 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)*
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.x	---	Public release	Future public release, regional and subregional applications

5.2.1 ELM v2.6

5.2.1.1 Summary

The update from ELM v2.5 to v2.6 was made during the Independent Peer Review (July-Dec 2006) of the regional ELM v2.5. The primary updates involved new source code utilities that increased functionality of boundary conditions, and new supplements to the model documentation that further described model performance under significant "perturbations"[2]. In order to maintain consistency of model results between v2.5 and v2.6, the ELM v2.6 did not involve changes to existing algorithms, with the secondary version attribute having been incremented to v2.6 in order to avoid confusion with the v2.5 public release. There was no new public release of v2.6 code and data.

5.2.1.2 Specifics

During the independent peer review of the ELM v2.5, a variety of requests were made by the review Panelists[3]. To meet one of the requests, source code changes were made to increase the number of options for defining boundary condition flows along the periphery of the model grid cell domain. These modifications were targeted towards new applications that were run for century time scales, under hypothetical overland inflow conditions. The modifications were verified to have not affected standard regional or subregional applications of ELM.

Several code bugs were identified (Oct 2006) during this update, and corrections were planned for a subsequent version update (v2.7, after completion of the Peer Review project).

5.2.2 ELM v2.7

5.2.2.1 Summary

In the update from ELM v2.6 to v2.7, two code bugs were corrected, and several refinements made to the model functionality. The update did not include changes to existing algorithms (beyond the bug fixes), but did include several enhancements to model output options and some initial re-structuring of source code involving water control structure flows. There was no new public release of code and data for v2.7, but several subregional and regional applications were developed and refined as part of this interim update.

5.2.2.2 Specifics

The correction to the "auto-scaling" algorithm of constituent dispersion did not affect

---

[2] See http://my.sfwmd.gov/elm , page at the "Implementation: v2.5" tab, in the "Supplemental Results" section.

[3] 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.

regional or subregional application results. Before and after the correction, the algorithm returned the intended scale of constituent (i.e., phosphorus and chloride) dispersion in surface water flows[4], provided that the correct dispersion scaling parameter was input to the model. The correction to the code bug was effectively a modification that aligned the code with the original documentation intent, allowing the user to apply the same model parameter file (Global_Parms_NOM) to model applications of any grid resolution, instead of a customized parameter file for each model application grid scale.

The correction to the code bug involving surface water flows across (un-leveed) domain boundaries could have had significant impacts on simulation results, but the overall statistical summaries of the regional application were negligibly affected due to the limited region of such surface water exchanges across the domain boundaries in that application. Such exchanges were generally limited to the Big Cypress National Park (BCNP) subregion, which is an area with low hydroperiods in the historical record. In such areas where overland flows were allowed across (un-leveed) boundaries, the algorithm evaluated differences in water stage elevations between internal and external grid cells, with stage in the external grid cells being derived from SFWMM output. However, (in ELM v2.5), an estimate of the external land surface elevation was not added to the SFWMM output data, which actually represented positive or negative water depths relative to local (SFWMM) land surface elevation. In ELM v2.5, hydrologic performance was poorest in the BCNP region relative to the other regions in the model domain. These performance characteristics were originally associated with the very high uncertainties that existed in the BCNP land surface elevation data that were used in the model. As noted in the ELM v2.5 Documentation Report, Data Chapter 4, the ELM v2.5 used different sources of data from the SFWMM in BCNP. The correction encoded into the ELM v2.7 simply involved applying the within-domain land surface elevation to the external cell, for an estimate of external stage. Using the original ELM v2.5 land surface elevation for BCNP, hydrologic performance did not improve after the correction to the code bug. However, with data from new land surface elevation surveys in this region (ELM v2.8, below) and correct boundary condition code for SFWMM-driven overland flows across the domain boundary, model evaluations showed significant improvements in hydrologic performance in this BCNP region. Those regional performance characteristics will be documented in the regional ELM v2.8 release.

Other changes made to code for ELM v2.7 involved enhancing the functionality of the model, providing several new variables as options to output. The first variable was that of surface water flow velocities, and another variable was that of the relative depths from the boundary condition model (i.e., SFWMM or NSM).

5.2.3 ELM v2.8

5.2.3.1 Summary

The principal change between ELM v2.7 and the current ELM v2.8 was the restructuring

[4] Fitz, H.C. Nov 22, 2006. Addendum to: ELM v2.5: Model Structure Chapter 5. http://my.sfwmd.gov/elm , page at the “Implementation: v2.5” tab, in the “Supplemental Results” section.

and refinement of algorithms that defined rule-based managed flows through water control structures. Integral with the goals and objectives of the WCA-1 restoration project, these modifications allowed evaluations of simple alternatives to hydrologic and water quality management of the WCA-1 landscape.

The primary focus of this Model Structure Chapter 5 for the ELM v2.8 is the description of those code changes.

Another change to code (and data) that was made in the v2.8 update was the addition of one equation to represent atmospheric deposition of chloride. In addition, output functionality was enhanced to meet new Performance Measure requirements imposed for evaluating hydrologic changes associated with the WCA-1 hydrologic restoration project.

5.2.3.2 Specifics

The equation for atmospheric deposition of chloride of a similar form as that for phosphorus, which was modified during the v2.6 update conducted during the ELM v2.5 Peer Review. In ELM v2.8, both phosphorus and chloride are (independently) input into the model domain by one of two options selected by the user:

1. Assume a constant concentration in rainfall inputs (wet deposition) to the model domain, resulting in spatial and temporal variation in constituent loads; or
2. Assume a temporally-constant loading rate of total (wet plus dry) deposition, which may vary in space (via a single input map of deposition).

If the user assigned a negative concentration value to the constituent (chloride or phosphorus) rainfall concentration parameter in the GlobalParms_NOM input parameter file, a domain-wide (constant or spatially variable across space) input map of the long-term daily mean of the mass loading rate was assigned to the (cell-specific) atmospheric load variable for the particular constituent. Otherwise, the non-negative constituent concentration was applied to the daily rainfall volume (in each grid cell), with the mass load assigned to the atmospheric load variable for the particular constituent.

The remainder of this chapter describes the specific changes to algorithms in the Horizontal solutions: Water Management: Structure Flows module. Please see the ELM v2.5 Documentation Report for the current documentation of other code modules, which did not change for ELM v2.8.

5.3 Horizontal solutions (updates)

The horizontal solution modules calculate spatial flows of surface water, groundwater, and associated constituents (phosphorus and salt/tracer) in the (mostly) horizontal dimensions across raster grid cells and vector canals.

For this ELM v2.8 update, only the Water Management: Water Control Structure Flows module descriptions are updated, corresponding to the primary updates to model source code for the ELMwca1 project.

See the ELM v2.5 Documentation Report for full descriptions of the other Vertical Solutions and Horizontal Solutions.

5.3.1 Water management: Water control structure flows

5.3.1.1 Overview

The Water Management Modules provide the mechanisms for distributing managed flows of water and constituents (phosphorus and salt/tracer) in a network of canals, levees, and water control structures. The ELM code for quantifying water control structure flows was significantly restructured in the process of the ELM v2.8 update, in order to increase the flexibility and modularity of these water management components. The Water Control Structure Flows set of modules includes eight methods (modules) to quantify water control structure flows, plus one controller module. The method defined for each structure flow module depends on its source-destination relationship, and whether the structure flow is data-driven or calculated internal to the model.

5.3.1.2 Controller Module

The attributes of the water control structures are defined in a relational (FilemakerPro) database, and exported into an ASCII (text) input file for the model. Among the variety of attributes in this database (CanalData.struct, see Data Chapter 4, ELM v2.5 Documentation Report) are the definitions of the source (canal ID or cell ID[5]) and destination (canal ID or cell ID) water and constituent storages. The database also defines whether flows are to be driven by time-series input data or to be calculated in the model.

There are two basic classes of water control structures in the ELM: a) structures that involve regulated flows, emulating "real-world" water management from either ELM calculations of flows, or input data on flows; and b) un-regulated "virtual" structures which are model constructs to support hydrologic assumptions, and which do not correspond to "real world" infrastructure.

Daily water and constituent flows are passed through a water control structure using one of four source-destination relationships: 1) flow from a canal to a canal, 2) flow from a cell to a cell, 3) flow from a canal to a cell, or 4) flow from a cell to a canal. Depending on the nature of the source-destination relationship, and the regulated or unregulated class of structure, one of eight (8) function methods are invoked by the controller.

Table 5.1 provides an overview of the decision matrix that is used by the controller to invoke the required method (module) for a water control structure defined in the input database.

Managed/regulated water control structures (i.e., "real-world" structures) may be either: 1) driven by daily time series flow data that is derived from historical observations or from output from other models such as the SFWMM; 2) driven by ELM-calculated structure flows based on targets of stage from other models such as the SFWMM; or 3) driven by management rules (via stage target "schedules") which determine whether a structure is "open" for flow that is calculated by the ELM.

---

[5] The cell ID is the row and column grid location, which is calculated in the database from the geographic coordinates of the structure, and is thus independent of the scale of the model application.

For any water control structure, external boundary condition flows (of water into or out of the active domain of the model) are fluxes to or from a reserved grid cell location (row 1, column 1) that always denotes a cell that is outside of the active model domain. In the case where the source of the water is outside of the model domain (i.e., "new" water), the values of concentration of constituents (phosphorus and salt/tracer) are defined (in the input attribute file CanalData.struct) by either a temporally-constant value, or a link to a time series of daily values. In the case of a time series of daily concentrations, the data were previously developed from either the output of another model, or from interpolations of observed data (see Data Chapter 4). A structure flow whose source water is internal to the model will always have a constituent concentration that is available from internal model calculations. In all cases, the source water's constituent concentration (mass $volume^{-1}$) is multiplied by the structure flow (volume) to determine the mass of constituent that is associated with the flow.

Table 5.1. Decision matrix for invoking different water control structure Modules in the WatMgmt.c code. The database (CanalData.struct) that is input to the model defines these attributes for each water control structure. Headwater and Tailwater denote the source and destination, respectively, of positive flows. Canals are always internal to the model domain; a grid cell external to the model domain is denoted by "CellExt". "Use Flow Data" indicates an available time series of daily flows that is input to the ELM (in lieu of internally-calculated flows). The Headwater or Tailwater Targets are stage data targets from either Regulation Schedules or other model outputs. A Trigger Cell may be either an internal or external cell (CellExt) location that is distant from the structure, evaluating stage at that location to "trigger" structure operations. A non-zero Flow Parameter drives the "generic pump" flux equation for calculated flows.

Headwater	Tailwater	Use Flow Data?	Headwater Target	Tailwater Target	Headwater Trigger Cell	Tailwater Trigger Cell	Flow Parameter	Module Invoked (8 total)	Description	Typical usage
Canal	Canal	yes						flowData_CanCan	Data-driven mgmt; internal only	Historical- or SFWMM- driven simulations
Canal	Cell	yes						flowData_CanCel	Data-driven mgmt; internal, or outflow from domain	Historical- or SFWMM- driven simulations
Cell	Canal	yes						flowData_CelCan	Data-driven mgmt; internal, or inflow to domain	Historical- or SFWMM- driven simulations
Cell	Cell	yes						flowData_CelCel	Data-driven mgmt; internal, or in/outflow to/from domain	Historical- or SFWMM- driven simulations
Canal	Canal						0	flowCalc_CanCan	Virtual structure (unregulated): "Instantly" equilibrate Canal-Canal stages; internal only	Connects multiple model canal reaches to represent one long "real world" canal.
Canal	Canal		Schedule	Schedule	Cell	Cell	>0	flowCalc_CanCan	Internal rule-based mgmt, minimize both Schedule-Cell stage differences	**New ELMwca1 v2.8, recycled water flows**
Canal	CellExt			OtherModel		CellExt	>0	flowCalc_CanCel	Outflow from domain, minimize Canal-CellExt (other model data) stage difference	Seepage management
Canal	CellExt			Schedule			>0	flowCalc_CanCel	Outflow from domain, minimize Schedule-Canal stage difference	Creek (vector) tidal boundary conditions
Canal	CellExt		Schedule		Cell		>0	flowCalc_CanCel	Outflow from domain, minimize Schedule-Cell stage difference	**New ELMwca1 v2.8, managed outflows**
CellExt	Canal		Schedule				>0	flowCalc_CelCan	Inflow to domain, minimize Schedule-Canal stage difference	Creek (vector) tidal boundary conditions
CellExt	Canal			Schedule		Cell	>0	flowCalc_CelCan	Inflow to domain, minimize Schedule-Cell stage difference	**New ELMwca1 v2.8, managed inflows**
Cell	Cell						0	flowCalc_CelCel	Virtual structure (unregulated): Manning's equation of overland marsh flow	Marsh flows thru levee gap (e.g., under I-75 Alligator Alley bridges)

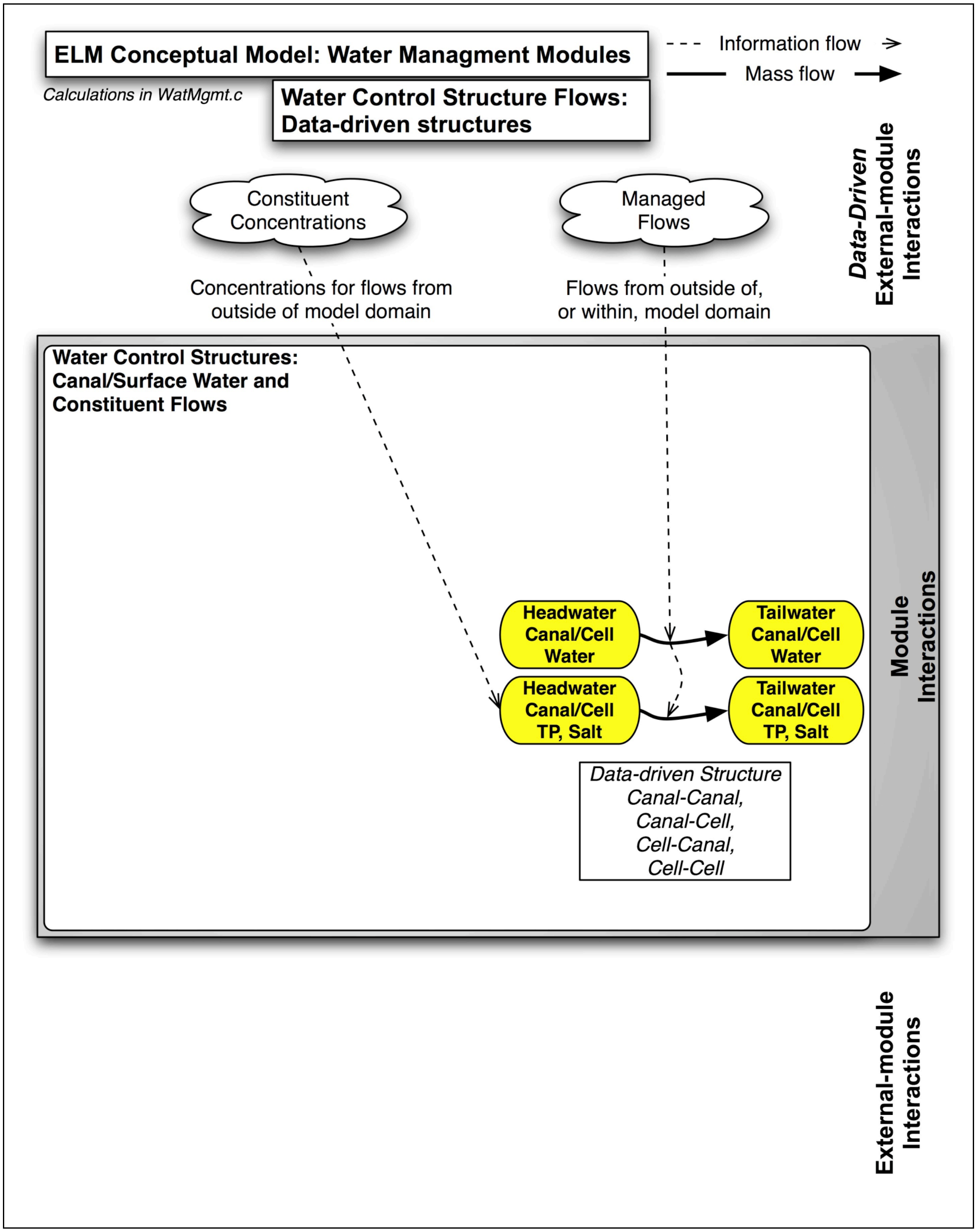
5.3.1.3 Data-driven structures

For data-driven structures, no changes were made to the methods in ELM v2.5 – v2.8.

For data-driven structure flows (Figure 5.1), external data sources (such as historical observations, or SFWMM output) are used for the daily flow values. Such flows may apply to structures which have both the source and the destination within the model domain, or to flows with either the source or the destination being external to the model domain.

Dependent on the (four) source-destination relationships, there are four modules that define water control structure flows that are "data-driven", for which the flows are not calculated by the model. In these modules (Table 5.1), the daily flow values (adjusted for the canal time step) from data sources (such as historical observations, or SFWMM output) are directly assigned to the model flow variable after being converted from English units (cfs, or cubic feet per second) to metric units (m^3 d^{-1}). Another computation that is made is an evaluation of any source-volume constraint. If the data-driven flow demand exceeds the source-volume, the flow is reduced to the volume that is defined to be available in the source. In such a case, a warning is printed to a debugging output file (Driver1.out).

Figure 5.1. Data-driven water control structures. Daily flows are input from data sources such as historical observations, or another model's forecasts for future managed flows (i.e., SFWMM). For a structure that introduces "new" water from outside of the ELM domain, input data are used to assign concentrations of (phosphorus and chloride) constituents to the flow.



5.3.1.4 Virtual structures

For virtual structures, no changes were made to the methods in ELM v2.5 – v2.8.

As indicated in the Water Management Canal-Marsh Flux Module section (see ELM v2.5 Documentation Report), because some canals extend over large distances, the model segments a number of "real world" Everglades canals into separate model canal reaches that are linked by "virtual" water control structures which equilibrate the stages in the two canal reaches at every canal time step (Figure 5.2). This segmentation minimizes the potential grid-cell dispersion of constituents (nutrients and salt/tracer) along canals spanning long distances, as constituents are assumed to be homogenous along the entire length of a canal reach.

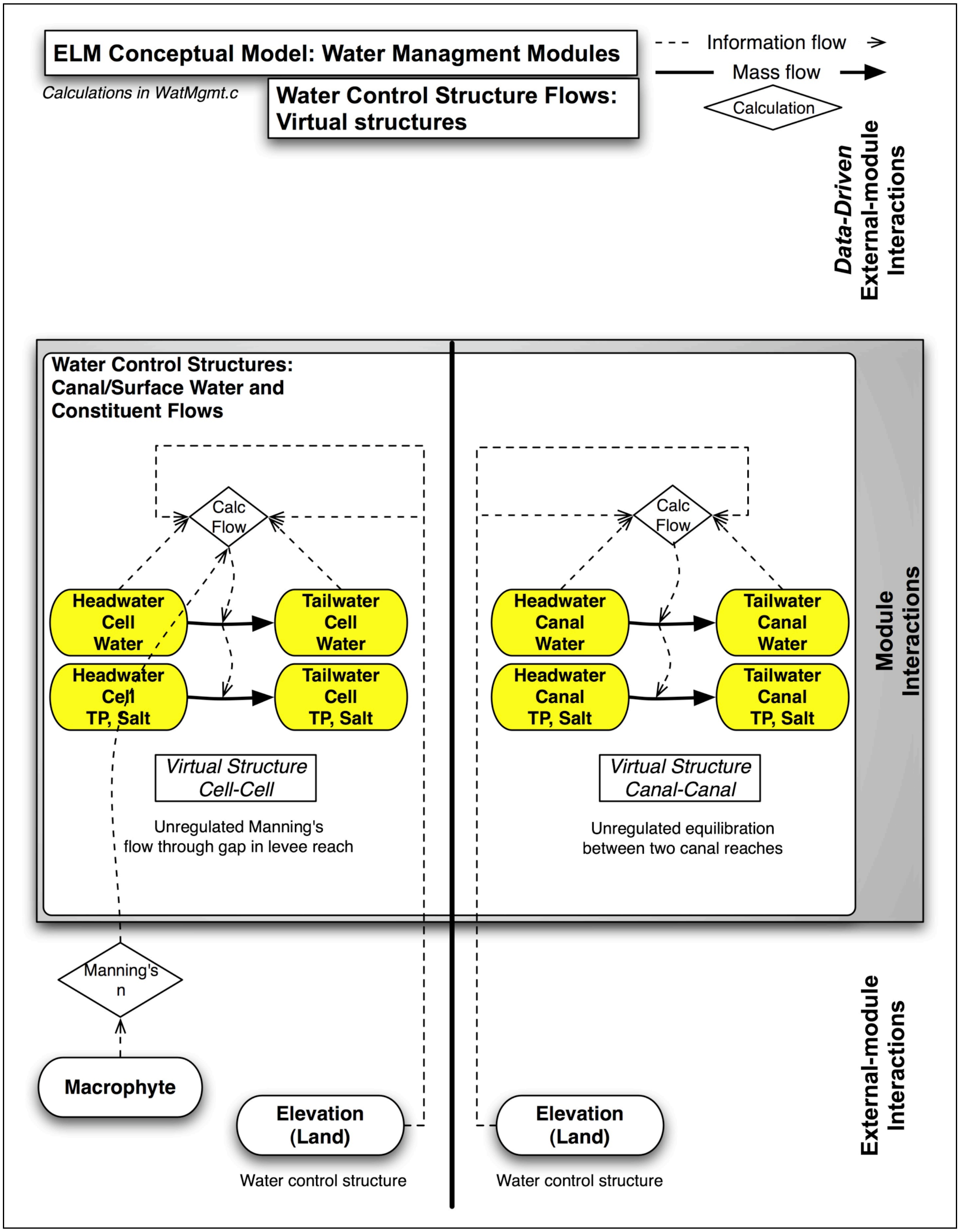
In the case of "virtual" structures that equilibrate two canal reaches (that are portions of a longer, continuous "real-world" canal), a simple mass-balance equilibrium is sought between the two canal reaches during each canal time step:

$$flux = \frac{A_s \cdot A_d}{A_s + A_d} H_{delta}$$

where *flux* is the flow volume (m^3) during a canal time step, A_s and A_d are the surface areas (m^2) of the source and destination canal reaches, respectively, and H_{delta} is the head difference (m) between the two canal reaches. This difference is taken to be the difference in stage elevations at the midpoints of the two reaches, with a constant depth assumed along the length of the reach. For each canal reach, the elevation drop along the length of the reach from the upstream end to downstream end is known from the initialization of the canal network topology. To obtain stage elevations, the depth (m) of water stored in each canal reach is added to the land surface elevation at the midpoint each canal reach: stages based on those elevations are equilibrated at every time step (in the positive downstream direction only).

In the case of an under-bridge "virtual" structure between wetland grid cells (Figure 5.2), the overland flow equation for grid cell fluxes is called to calculate the overland flow using an open-water Manning's n coefficient (see Surface Water Raster Flux Module for module and equation descriptions, ELM v2.5 Documentation Report).

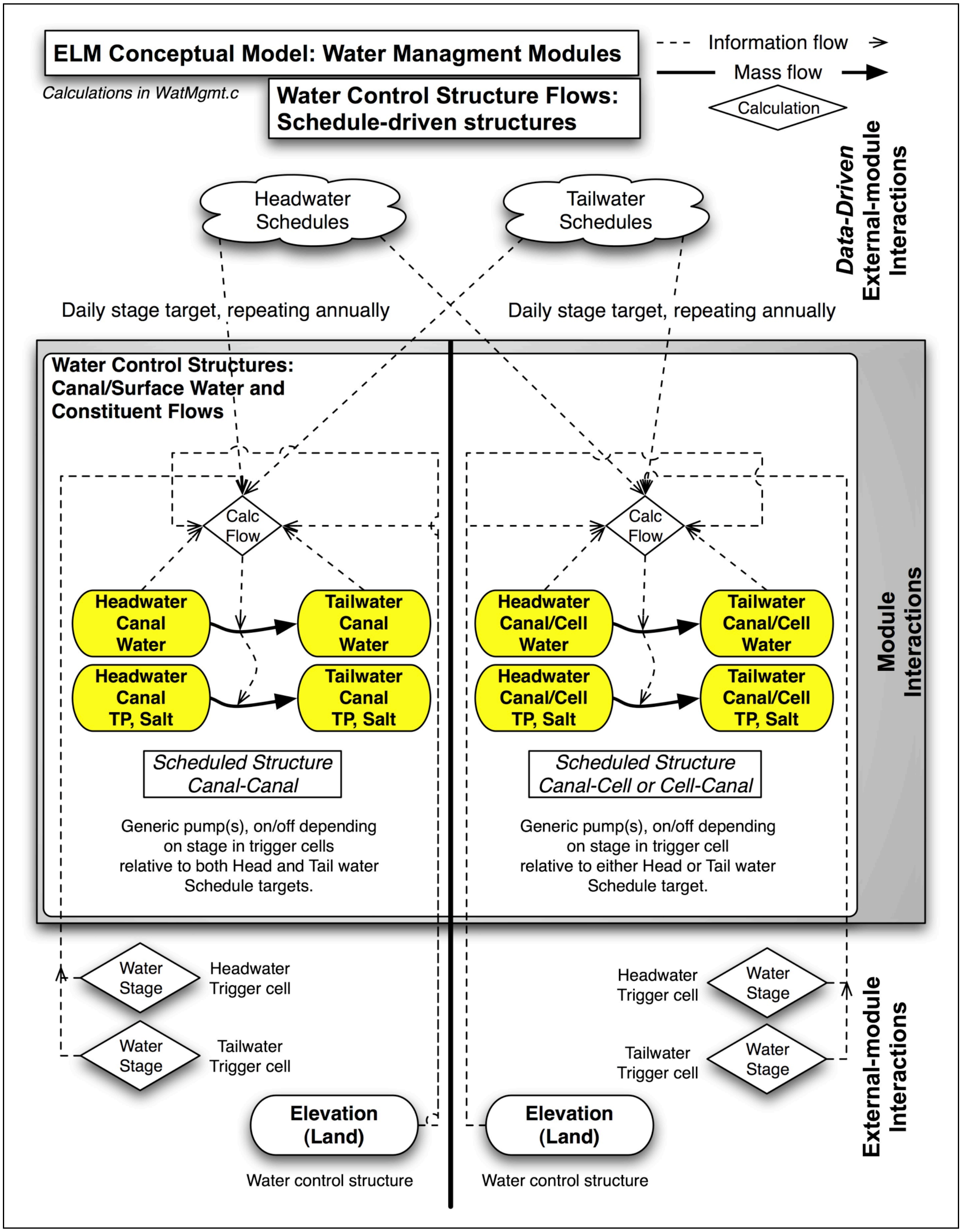
Figure 5.2. Virtual water control structures. Flows are calculated by the model to equilibrate stages between two canal reaches (right), or to provide a method for calculating overland marsh flows through a gap in a levee (left).



5.3.1.5 Schedule-driven structures

For ELM v2.8, a variety of new methods were developed for regulated, schedule-driven water control structure flows (Figure 5.3). While the new methods were associated with source code changes, the structure (fields per record) of the input database (CanalData.struct) required no associated changes.

Figure 5.3. Schedule-driven water control structures. Flows are calculated by the model to regulate water stage elevations in the marsh (grid cells), with the goal of minimizing the difference between the schedule target(s) and the trigger grid cell(s). Stage in the trigger cell(s) is (are) evaluated relative to the target stage. If the target is not met, a generic pump is invoked to move water between the head- and tail- water (source and destination) storage locations, with either a canal-canal, canal-cell, or cell-canal flow relationship.



Tidal boundary conditions

In ELM v2.5 – v2.8, tidal boundary conditions[6] were imposed with a "schedule"-driven head or tail water target stage for structures[7] that associated with vectors of tidal rivers/creeks (aka "canals") and cells external to the model domain. Long-term mean (Jan – Dec) monthly tidal stages recurred annually through use of a 12-month input graph function, and the data were interpolated to provide daily head- or tail- water target stages in an external source or destination grid cell associated with the creek/river vector (see Table 5.1).

A potential flux was calculated from the stage difference between the external (cell) schedule target and the internal river/creek vector, moving water and constituents between the source and destination (cell-canal, or canal-cell flow relationship). See the below section for the equation definitions that were common to these schedule-driven structures. If the source water was an external cell, a constant salinity that was input by the user was imposed on each tidal flux. As with any "canal" vector, creek/river vectors were segmented and linked by canal-canal (creek-creek) virtual structures as described above.

Managed flows

In ELM v2.8, the new water control structure methods managed water relative to the operational requirements dictated by schedule-driven head- and/or tail- water target stages relative to marsh stages in "trigger" cells (Figure 5.3). Coincident with the ecological goals of ELM applications, the water management algorithms are kept very simple, avoiding *any* level of design engineering for the infrastructure associated with "real world" water management in the Everglades. Therefore, the methods used in ELM water management are considered to be idealized "water movers" , and assume that engineering constraints and capacities of water control structures can be formally quantified with other (simulation and/or analytic) quantitative tools. The goals of water management methods in ELM are to simply move water in response to commonly-used schedules and triggers, but ignore possible hydraulic constraints associated with moving volumes of water between remote regions.

There were three managed water control structures that were encoded for ELM v2.8:

1) managed losses from the system, fluxing water and constituents from a canal to an external cell (canal-cell);
2) managed gains to the system, fluxing water from an external cell into a canal (cell-canal); and

---

[6] Not applicable to subregional applications lacking connections to an estuary.

[7] These tidal structures are "virtual" in that they are model constructs in order to most simply provide time-varying tidal boundary conditions. These implementations of schedule-driven "structures" do not correspond to "real world" infrastructure. However, for ease of categorization for this documentation, we consider them under the schedule-driven structure category. No changes in tidal boundary condition methods were made between ELM v2.5 and v2.8.

3) managed flows within the system (of a single hydrologic basin), “recycling” by moving water from one canal within the basin to a different canal in another location within the basin (canal-canal).

In a method analogous to that of the tidal boundary conditions, long-term mean (Jan – Dec) monthly target stages recurred annually through use of a 12-month input graph function (see Model Application Chapter 8 for data examples), and the data were interpolated to provide daily head- or tail- water target stages in internal and/or external source or destination grid cells (Table 5.1).

For structures with either a canal-cell or a cell-canal relationship of managed flows, an evaluation was made of the stage difference between the scheduled target stage and the trigger cell in the marsh. In the case of canal-cell managed losses from the system, if the stage in the marsh trigger cell exceeded that of the headwater target, the structure was classified as open, to provide inflow of water into the system. Similarly, in the case of cell-canal managed inputs to the system, if the headwater target stage exceeded that of the marsh trigger cell, the structure was classified as open, to provide inflow of water into the system

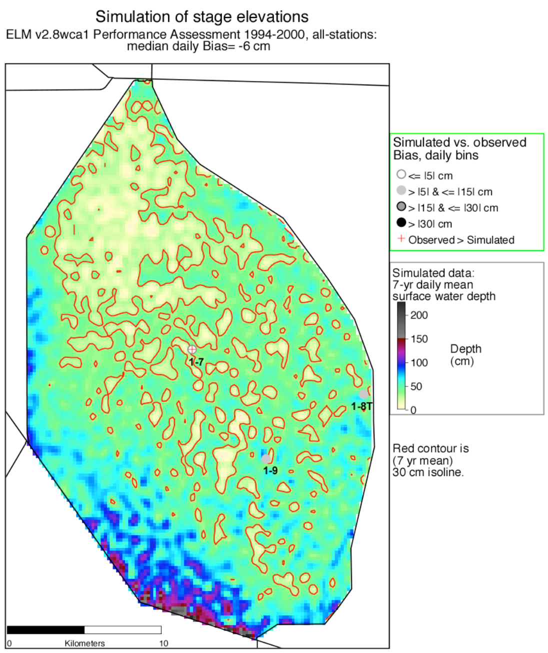
In all cases, the objective function of the water management structure was that of minimizing the difference between the schedule’s target stage and the stage in the remote marsh trigger cell. The water control structures in these cases were assumed to be an idealized, generic pump (or set of pumps), with variable RPM that decreased with decreasing difference between the existing (remote trigger cell) and targeted water levels:

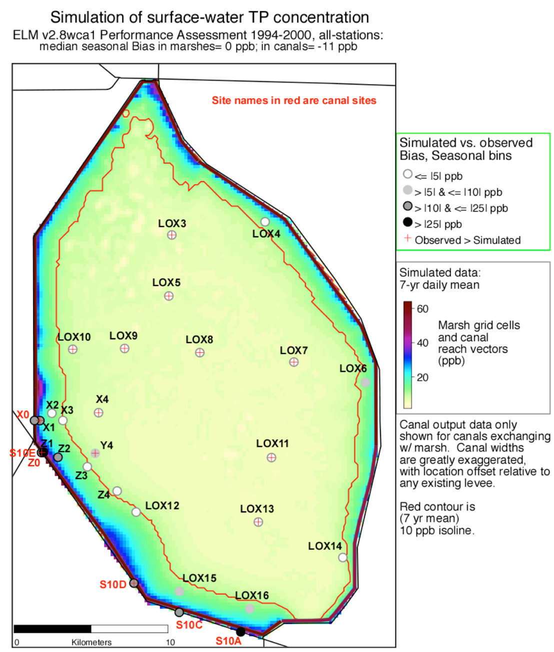
$$flux = Q_{\max} \cdot H_{N\_delta} \cdot dt_{can}$$

where *flux* is the potential flow volume (m^3) during a canal time step, Q_{max} is the maximum pump capacity ($m^3\ d^{-1}$), H_{N_delta} is the normalized head difference ($m\ m^{-1}$) between the target and existing stages, normalized to a 1-m deficit at maximum pump RPM. The actual flow volume (m^3) during a canal time step was constrained to not exceed the maximum available volume that was defined for the source water storage. This simple equation of potential *flux* ignores the engineering constraints of the head differential between the source and destination storages, assuming only that the idealized pump will increase in throughput as a linear function of the management demand.

Documentation of the Everglades Landscape Model: ELMwca1 v2.8

Chapter 6: Model Performance





http://ecolandmod.ifas.ufl.edu

March 28, 2008

This page left blank

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 ELMwca1 v2.8 subregional application for Water Conservation Area 1 (WCA-1), the specific Objectives of the model application are to support the Performance Measures involving hydrologic and "water quality" aspects of ecosystem dynamics across the landscape: 1) water stages/depths, 2) surface water chloride concentrations, and 3) surface water phosphorus concentrations. The model capabilities that are summarized here support the use of this application to evaluate relative differences in system behavior over decadal time scales, at a spatial resolution of 200 meters across more than 500 square kilometers

Overall, the fine-scale (200x200 m, or 0.04 km^2) ELMwca1 application further demonstrated the robust nature of the ELM code and data: without modifying algorithms or parameters for this subregional application, the new application exhibited improvements to model performance ("skill" in hindcasting observed data) relative to that of the regional, 1km^2 ELM v2.5 application. With that benchmark being one of the primary criteria for acceptance for use in WCA-1 restoration planning, the ELMwca1 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 ELMwca1 performance characteristics showed that predictive biases were small relative to important ecological dynamics: overall, water stage was simulated to within 6 cm of long-term observations, while aggregated phosphorus predictions in the marshes had a bias of 0 ug l^{-1}, and marsh chloride water quality predictions were biased by a mere 2 mg l^{-1} overall. 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-1 perimeter canal and the marshes of the interior region.

6.2 Background

6.2.1 Application summary

The ELMwca1 version 2.8[1] was developed in order to evaluate relative differences in ecological performance of Everglades Water Conservation Area 1 (WCA-1) water management plans. 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 application in order to meet specific objectives of this WCA-1 restoration planning project. None of these changes resulted in significant differences in the performance characteristics of a regional application, but all provided either enhanced model functionality or incremental improvement to the predictive performance capabilities of the model at subregional and regional scales (the topic of this Model Performance Chapter 6).

The principal change between ELM v2.5 and the current ELM v2.8 was the restructuring and refinement of algorithms that define rule-based managed flows through water control structures. Integral with the goals and objectives of this restoration project, these modifications allowed evaluations of simple alternatives to hydrologic and water quality management of the WCA-1 landscape. (Rule-based managed flows were not used in the historical simulation evaluated in this Chapter 6). Moreover, while of minor consequence in statistical evaluations of (history-matching) model performance or in evaluating relative differences among restoration scenarios, we added chloride inputs from (rainfall) atmospheric deposition.

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 0.04 km^2 (200x200 m) resolution application in the WCA-1 hydrologic basin.

6.2.2 ELMwca1 v2.8 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

[1] The tertiary subversion designation of this v2.8 application release is v2.8.1.

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.

While there are requests (and expectations) for ELM to address a larger suite of ecological questions, the relatively narrower subset of *current* model Performance Measures specify the range of the *current* application niche of the ELM. It is this application niche that is to be considered when evaluating the performance characteristics of the ELM.

For the current ELM v2.8 WCA-1 (ELMwca1) application, the available ecological Performance Measures continue to be those involving the hydrology and "water quality" aspect of ecosystem dynamics across the landscape. As with the regional ELM v2.5 application, the formal Performance Measures used to asses the "model skill" within the specific subregion (WCA-1) of interest included: 1) stage relative to land surface elevation, 2) surface water chloride concentration, and 3) surface water phosphorus concentration. 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-1 restoration 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) 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-1 restoration project.

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-1 subregional application.

6.4 Model configuration

While the topology of the perimeter canal along the boundary of WCA-1 was modified from regional ELM v2.5, no changes were made to any other parameters used in the model (i.e., in the HabParms or GlobalParms databases).

In ELM v2.8 WCA1 application, the model was configured to simulate historical conditions inclusive of the years 1994 – 2000, instead of the 1981-2000 period that was evaluated for the regional v2.5 application. The period of simulation was more restricted due to the limitations of 1994-2000 period of record for the primary "LOX" and "X, Y, Z" transect water quality observations in this region.

[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.

The domain was that of the subregional hydrologic basin of WCA-1, employing a 200x200m 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.

6.5 Performance results

6.5.1 Ecological performance

6.5.1.1 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 6.1 shows the statistical performance metrics for the simulated vs. observed total phosphorus concentration data at each location during the 1994-2000 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 1994-2000 period of simulation was 0 (zero) ug l^{-1} (ppb), with slight over-predictions (-11 ug l^{-1}) in canals.

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 mean daily TP concentration during 1994-2000. Statistics are detailed in Table 6.1.

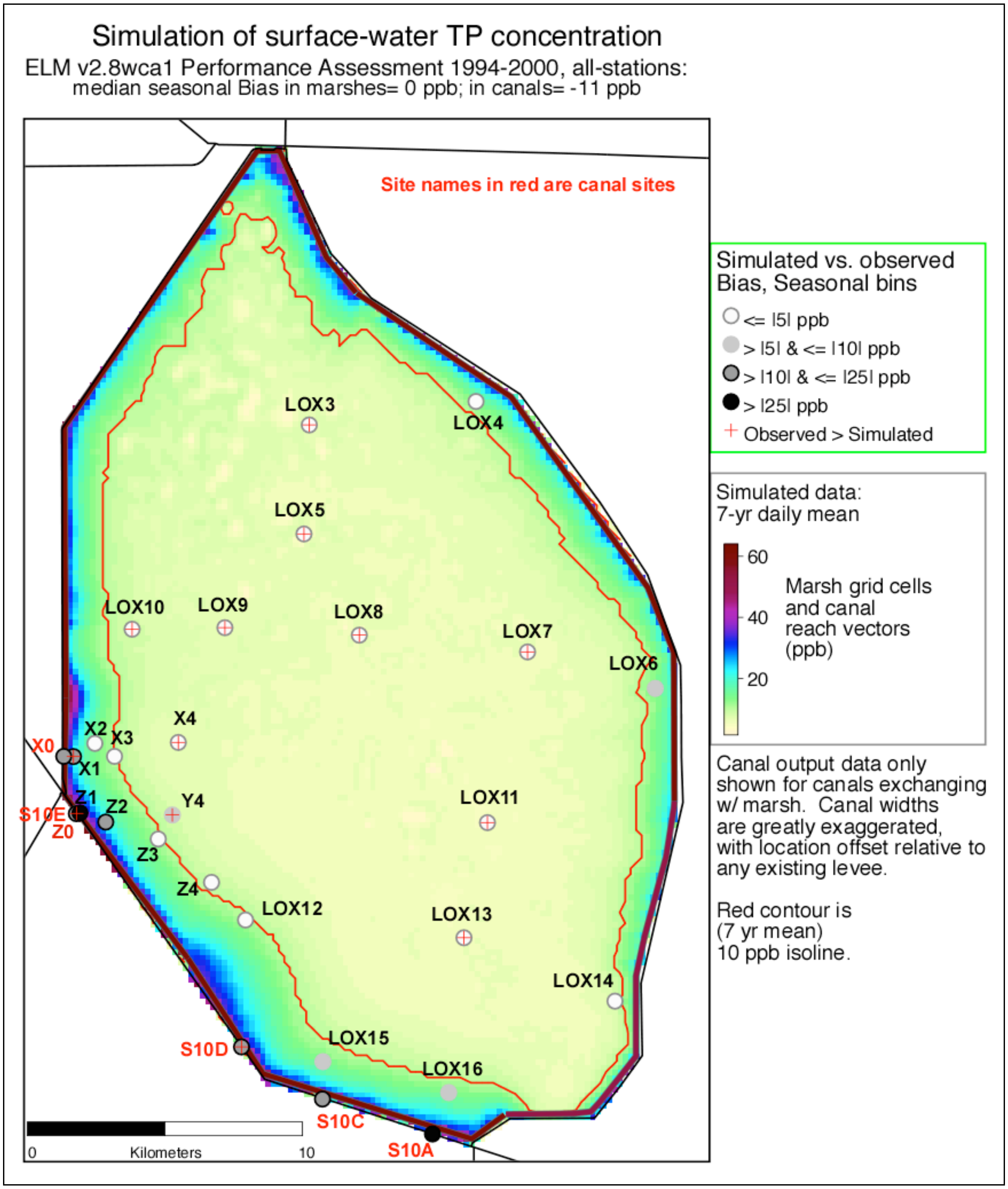


Table 6.1. Statistical evaluation of simulated vs. observed surface water phosphorus concentration, 1994 – 2000, aggregated by (wet vs. dry) seasons. Units of Bias (observed minus simulated) and RMSE are ug l^{-1} (ppb). Relative Bias (RelBias) is the proportion of Bias divided by the Observed Mean (ObsMean).

					1994-2000		
Site	Basin	Site type	N	ObsMean	RelBias	Bias	RMSE
LOX4	WCA1	Marsh	12	10	-0.35	-4	6
LOX3	WCA1	Marsh	11	11	0.42	5	7
LOX5	WCA1	Marsh	9	9	0.12	1	4
LOX9	WCA1	Marsh	13	9	0.37	4	5
LOX10	WCA1	Marsh	12	10	0.17	2	5
LOX8	WCA1	Marsh	14	9	0.28	2	4
LOX7	WCA1	Marsh	14	8	0.24	2	3
LOX6	WCA1	Marsh	13	8	-0.80	-6	8
LOX11	WCA1	Marsh	14	9	0.44	4	5
LOX12	WCA1	Marsh	14	8	-0.41	-3	4
LOX13	WCA1	Marsh	14	9	0.35	3	4
LOX14	WCA1	Marsh	14	8	-0.11	-1	2
LOX15	WCA1	Marsh	14	8	-0.88	-7	8
LOX16	WCA1	Marsh	14	9	-0.73	-6	7
X1	WCA1	Mar. trans.	10	40	0.32	13	25
X2	WCA1	Mar. trans.	10	16	-0.11	-2	9
X3	WCA1	Mar. trans.	10	11	-0.09	-1	8
X4	WCA1	Mar. trans.	9	10	0.30	3	4
Y4	WCA1	Mar. trans.	10	12	0.48	6	12
Z1	WCA1	Mar. trans.	10	42	-0.64	-27	31
Z2	WCA1	Mar. trans.	9	14	-0.78	-11	14
Z3	WCA1	Mar. trans.	10	10	-0.41	-4	7
Z4	WCA1	Mar. trans.	10	9	-0.03	0	5
S10A	WCA1	Canal	13	40	-0.87	-34	40
S10C	WCA1	Canal	13	60	-0.19	-11	21
S10D	WCA1	Canal	14	80	0.20	16	28
S10E	WCA1	Canal	13	78	0.01	1	22
X0	WCA1	Canal	8	53	-0.37	-20	29
Z0	WCA1	Canal	8	60	-0.19	-11	21
		Median All:	12	10	-0.09	-1	7
		Median Canal:	13	60	-0.19	-11	25
		Median Marsh:	12	9	-0.03	0	6

6.5.1.2 Phosphorus concentration: visualization indicators

The spatial distribution of the long-term (1994-2000) mean surface water TP concentration (Figure 6.1) indicated strong gradients of eutrophication in a localized band encircling the interior perimeter of WCA-1. 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[3] long-term mean value of 10 ug l^{-1} was plotted in Figure 6.3.

In the southern/southwest region (along the Hillsboro canal), the isoline of 10 ug l^{-1} (long term mean) extended approximately 2 – 2.5 km from the perimeter canal into the marsh. Long term mean TP concentrations in immediate proximity to the canal here were among the highest in the basin, on the order of 50 ug l^{-1}, decreasing very rapidly with distance from the canal. Along the western and northern portions of the basin, the long-term mean 10 ug l^{-1} isoline decreased to ca. 1.5 km in distance from the canal, and decreased further along the eastern boundaries (with approximately 1 km excursion distances). The lowest excursion distances were found in the south-southeastern portions of the basin, with the long-term mean 10 ug l^{-1} isoline generally being approximately 0.5 km from the perimeter canal.

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.31 show the sets of 1994-2000 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 three 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 6.2 shows the statistical performance metrics for the daily values of simulated vs. observed stage data at each location during the 1994-2000 period of simulation. The median bias of predicted stages was -6 cm (which represents slight over-predictions). The median Nash- Sutcliffe Efficiency statistic was 0.51 for the simulation.

---

[3] 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 of 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 1994-2000. Statistics are detailed in Table 6.2.

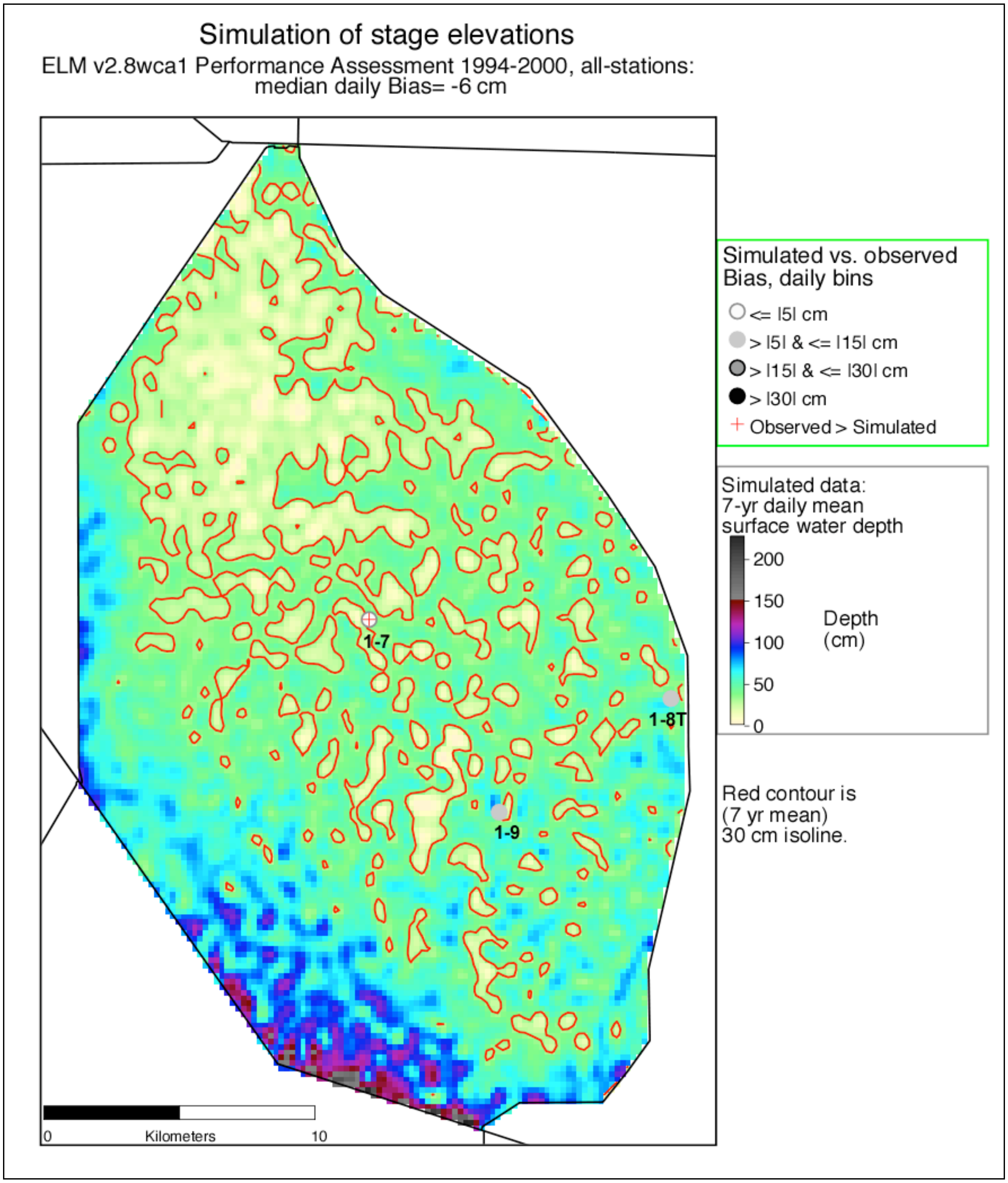


Table 6.2. Statistical evaluation of simulated vs. observed daily stage, 1994 – 2000. Units of Bias (observed minus simulated) and RMSE are meters.

		Stage 1994-2000				
Site	Basin	N	Bias (m)	RMSE (m)	R^2	NS Eff.
_1-7	WCA1	2557	0.00	0.10	0.72	0.51
1-8T	WCA1	2557	-0.08	0.12	0.81	0.63
_1-9	WCA1	2557	-0.06	0.11	0.81	0.46
	Median:	2557	-0.06	0.11	0.81	0.51

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 and east-west dimensions of the WCA-1 basin. Figure 6.2 shows the isoline of 30 cm depths, overlaid on the cell by cell depth distributions. Note that while the northern section of the WCA-1 basin had a broad distribution of depths below the 30 cm isoline (many depths in the 5-15 cm range), relatively isolated local topographic highs extended south-southwest within most of the interior of the basin, with concomitant shallower depths.

However, the southern and southwestern sections of the basin were dominated by very deep waters approaching 1 m (or more). These deepest waters extended ca. 5 km into the marsh along the Hillsboro canal in the southern-most region, and approximately 1-2 km into the marsh along the southern portion of the L-7 canal bordering the western portion of the basin (model reaches 14 and 19, respectively; see Data Chapter 4). Except in the northern-most section of the basin that had the lowest overall depths, intermediate surface water depths (ca. ½ m) predominated in marshes along most of the perimeter of the entire basin.

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.3 show the sets of 1994-2000 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 6.3 shows the statistical performance metrics for the simulated vs. observed Cl concentration data at each location during the 1994-2000 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 1994-2000 period of simulation was 2 mg L^{-1}, with some tendency towards under-predictions (21 mg L^{-1}) in canals.

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 1994-2000. Statistics are detailed in Table 6.3.

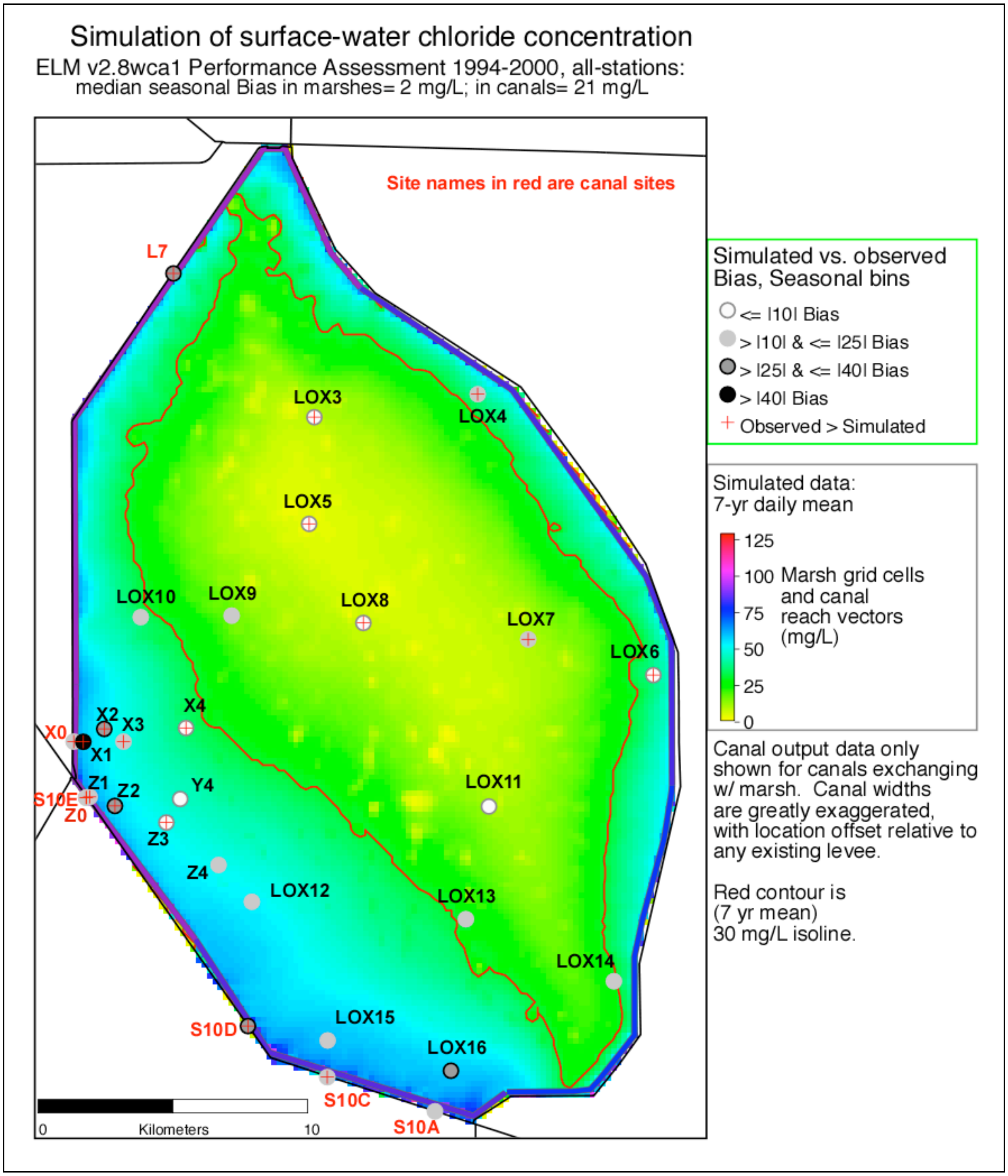


Table 6.3. Statistical evaluation of simulated vs. observed surface water chloride concentration, 1994 – 2000, aggregated by seasons. Units of Bias (observed minus simulated) and RMSE are mg l^{-1} (ppm). Relative Bias (RelBias) is the proportion of Bias divided by the Observed Mean (ObsMean).

			1994-2000				
Site	Basin	Site type	N	ObsMean	RelBias	Bias	RMSE
LOX4	WCA1	Marsh	6	68	0.33	23	32
LOX3	WCA1	Marsh	6	37	0.17	6	10
LOX5	WCA1	Marsh	4	16	0.61	10	11
LOX9	WCA1	Marsh	6	14	-1.02	-14	20
LOX10	WCA1	Marsh	6	28	-0.70	-20	23
LOX8	WCA1	Marsh	6	15	0.28	4	6
LOX7	WCA1	Marsh	6	29	0.53	15	18
LOX6	WCA1	Marsh	6	41	0.01	0	10
LOX11	WCA1	Marsh	6	13	-0.30	-4	7
LOX12	WCA1	Marsh	6	28	-0.96	-27	30
LOX13	WCA1	Marsh	6	12	-1.74	-21	25
LOX14	WCA1	Marsh	6	21	-0.73	-15	19
LOX15	WCA1	Marsh	6	48	-0.28	-13	26
LOX16	WCA1	Marsh	6	14	-3.20	-46	47
X1	WCA1	Mar. Trans.	10	122	0.46	56	56
X2	WCA1	Mar. Trans.	10	102	0.38	39	45
X3	WCA1	Mar. Trans.	10	86	0.26	22	37
X4	WCA1	Mar. Trans.	10	50	0.04	2	23
Y4	WCA1	Mar. Trans.	10	51	-0.12	-6	28
Z1	WCA1	Mar. Trans.	10	125	0.10	12	20
Z2	WCA1	Mar. Trans.	10	108	0.40	43	45
Z3	WCA1	Mar. Trans.	10	67	0.10	6	29
Z4	WCA1	Mar. Trans.	10	36	-0.61	-22	27
L7	WCA1	Canal	6	151	0.27	41	51
S10A	WCA1	Canal	8	85	-0.18	-16	32
S10C	WCA1	Canal	9	113	0.18	21	38
S10D	WCA1	Canal	14	135	0.26	35	46
S10E	WCA1	Canal	10	134	0.18	24	34
X0	WCA1	Canal	10	131	0.14	18	22
Z0	WCA1	Canal	10	133	0.14	19	24
		Median All:	7	51	0.12	6	27
		Median Canal:	10	133	0.18	21	34
		Median Marsh:	6	37	0.04	2	25

6.5.2.4 Chloride concentration: visualization indicators

The spatial distribution of the long-term (1994-2000) 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 between the perimeter canal and the mash, evidenced by the “ring” of higher Cl encircling WCA-1. 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[4] long-term mean value of 30 mg l^{-1} was plotted in Figure 6.3.

The same spatial pattern of “excursion distances” is found for Cl and TP concentrations in surface water, with decreases in distances (of the isoline from the perimeter canal) as one moves along the basin’s perimeter in a clockwise direction from the southern section of the basin. Because Cl is not removed from the water column to any significant extent by biological or chemical processes in the marsh[5], details of the pattern of Cl flows into the interior of the marsh differ somewhat from those of surface water phosphorus, which is rapidly absorbed by the marsh ecosystem. These differences in pattern are most pronounced in the region where the highest concentrations (and flows) were found. In the southern/southwest region (along the Hillsboro canal), the 30 mg l^{-1} (long term mean) isoline extended approximately 6 – 8 km from the perimeter canal into the marsh. Long term mean Cl concentrations in immediate proximity to the canal here were among the highest in the basin, on the order of 90 mg l^{-1}, decreasing with distance from the canal. The rate of concentration decreases along this gradient was not as extreme as that for phosphorus, which was rapidly absorbed by biological and chemical processes in the marsh.

Along the western and northern portions of the basin, the long-term mean 30 mg l^{-1} isoline decreased to ca. 2.5 km in distance from the canal, and decreased further along the eastern boundaries (with approximately 2 km excursion distances). The lowest excursion distances were found in the south-southeastern portions of the basin, with the long-term mean 30 mg l^{-1} isoline generally being approximately 0.5 km from the perimeter canal, or effectively the same as that found for the TP isoline at low input concentrations.

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.32 show the sets of 1994-2000 time series of chloride concentrations at each monitoring location at several temporal aggregations, including each site’s cumulative frequency distribution.

---

[4] 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}.

[5] The ELM assumes that no net change (uptake or release) in chloride occurs within the marsh (or canals).

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 spatial resolution less than 500 meters over tens of thousands of square kilometers:

6.6.1.1 Performance Measure results

- P concentration: median bias in predicting seasonal summaries of surface water total phosphorus (TP) concentrations was 0 ug l^{-1} for 23 marsh locations in WCA-1, which had long term mean observed concentrations ranging from 8 to 42 ug l^{-1}
- Water stage: median bias in predicting daily stage elevations was -6 cm (over-prediction) for 3 marsh locations in WCA-1, whose hydroperiod ranged from continuously flooded to intermittently flooded
- Cl concentration: distribution of chloride (Cl) concentrations throughout WCA-1 showed patterns of long-term flow regimes that were consistent with our understanding of major flow paths, with a median bias of 2 mg L^{-1} in the marshes, whose long term mean observed concentrations ranged from 12 to 37 mg l^{-1}.

6.6.1.2 Performance Measure comparisons

To determine the suitability of the new ELMwca1 subregional application for use in the WCA-1 restoration 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 ELMwca1 exhibited enhanced performance characteristics for all variables:

- P concentration: median seasonal bias of surface water TP concentration was 0 and 3 ug l^{-1} for 23 marsh locations in ELMwca1 v2.8 and ELM v2.5, respectively
- Water stage: median daily NS Efficiency was 0.51 and 0.46 (higher is better), and median daily bias was -6 and -3 cm, for 3 marsh locations in ELMwca1 v2.8 and ELM v2.5, respectively
- Cl concentration: median seasonal bias of surface water Cl concentration was 2 and -10 mg l^{-1} for 23 marsh locations in ELMwca1 v2.8 and ELM v2.5, respectively

[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.

6.6.1.3 Spatial trends

The model effectively captured the spatial patterns of eutrophication in the WCA-1 basin, with realistic patterns of "excursion distances" that depicted intrusion of canal-derived waters into the marsh. This pattern circumscribing the basin generally matched that evidenced in spatially-intensive synoptic surveys[7] (that were conducted during different flow conditions of a more recent time period than the simulation). The lack of spatial trends in relative bias and bias statistics (Figures 6.1 and 6.3, Tables 6.1 and 6.3) demonstrated that, relative to the variability of the observed data, the model effectively simulated the pattern of long-term mean concentrations of TP and Cl within the WCA-1 basin.

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). That generalization of hydrologic gradients is incomplete, however. The perimeter canal and levee was constructed such that the resulting impoundment would retain very deep surface water depths along the western and southwestern boundaries. To a lesser extent, the land elevation gradient across the basin in the east-west direction has relatively small, but significant, increases within the interior portions of the basin: in addition to the western region, ponded surface water tends to accumulate along most of the perimeter in the eastern perimeter area, with general topographic highs in the interior extending along most of the north-south axis of the basin. Thus, a further generalization of the simulated (and observed) hydrology of the WCA-1 basin is a tendency towards shallower surface water depths in much of the interior, with the land surface elevation vaguely resembling an elongated, inverted bowl. Thus, combined with the water quality characteristics described above, the marshes along the perimeter are most directly affected by managed flows – the topic to be further investigated via management scenarios for the current WCA-1 restoration project.

6.6.2 Uncertainty considerations

There are a wide range of data used to "drive" a spatially explicitly model of hydrology and ecology. Uncertainties associated with those input data, with the model algorithms, and with calibration-target data, were discussed at length in the ELM v2.5 Documentation Report, with some of the more significant components analyzed in the Uncertainty Chapter 7 of that document.

While not formally analyzed for the current project, the altered model grid (and vector canal segmentation) of the current application may provide some preliminary insight into some of those uncertainty considerations.

6.6.2.1 Atmospheric deposition

Because the SFWMD project team members envisioned the use of Cl to evaluate biological responses at low concentrations of this ion (which served as a proxy for other

[7] Sklar, F. K. Rutchey, S. Hagerthy, M. Cook, S. Newman, A. Gottlieb, C. Coronado-Molina, J. Leeds, M. Korvela, L. Bauman, J. Newman, R. Wanvestraut and S. Miao. 2005. Ecology of the Everglades Protection Area. pp. 6.1 – 6.39 *In*: Redfield, G. 2005 South Florida Environmental Report. SFWMD, West Palm Beach, FL.

ions that appear to affect periphyton communities), the lack of low-level inputs of Cl from atmospheric sources in the ELM v2.5 was questioned. Relatively simple revisions were made to the ELM code and input data, using the same input options that were used for atmospheric TP deposition (see Model Structure Chapter 5) .

Similar to the previous results (ELM v2.5 Documentation Report, Chapter 4 Addendum, Nov 2006) for sensitivity to changes in atmospheric TP deposition, there was no difference in the overall median bias of predictions when atmospheric Cl inputs were included in the simulation. However, the seasonal bias at some monitoring sites that were in the "interior" or central area decreased in absolute value. For example, at the LOX8 station, the model under-predicted Cl concentration by 10 mg l^{-1} in the absence atmospheric Cl sources, but the model under-predicted Cl concentration by only 4 mg l^{-1} (Table 6.3) when atmospheric inputs were included.

6.6.2.2 Spatial scales

- Grid scale: the use of a relatively fine 200 m grid resolution may resulted in some improved performance characteristics relative to that of the regional ELM v2.5 application at 1 km^2. Improvements (e.g., bias closer to or equal to zero) in hydrology and water quality were seen relative to the coarser scale application. Any such benefit is likely due to better utilization of the (400 m) spacing of land surface elevation survey points, creating a land surface elevation map of enhanced resolution and accuracy that is supported by data.
- Elevations of perimeter canal and adjacent marsh: The ability of any model to simulate hydraulics (and, thus the associated water quality/ecology) of WCA-1 is dependent to a large extent by the model's representation of the perimeter canal which surrounds the entire marsh system. As noted in the ELM v2.5 Documentation Report, very large volumes of water flow into and out of the this canal via water management structures. Subsequent exchanges between the canal and adjacent marsh are dependent on water elevation (stage) differences between the canal and adjacent marsh. Critically, the elevation of the marsh land surface immediately adjacent to the canal, (and the presence of dense brush or other vegetation), can have a significant effect on the magnitude of flows. The presence of a "lip" or small berm[8] in this low-gradient system has the potential to significantly change the magnitude and location of canal-marsh exchanges. A major data-need for improving our understanding of canal-marsh exchanges within the basin is the acquisition of measurements on land elevation in close proximity to the canal – i.e., at a scale that is much smaller than the 400 m distance of the nearest existing surveyed land elevation data point.
- Perimeter canal segmentation: Improved segmentation of canal-reaches in the current model version (relative to v2.5, see Data Chapter 4 of this ELM v2.8 Documentation) is likely responsible for some of the improved model performance characteristics.

---

[8] The presence of a "lip" or small berm of is implied by anecdotal observations (from remotely sensed imagery and limited field visits) of bands of brush vegetation along the canal in multiple locations in the basin.

6.6.3 Conclusions

Overall, the fine-scale (200x200 m, or 0.04 km^2) ELMwca1 application further demonstrated the robust nature of the ELM code and data: without modifying algorithms or parameters for this subregional application, the new application exhibited improvements to model performance ("skill" in hindcasting observed data) relative to that of the regional, 1km^2 ELM v2.5 application. With that benchmark being one of the primary criteria for acceptance for use in WCA-1 restoration planning, the ELMwca1 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 ELMwca1 performance characteristics showed that predictive biases were small relative to important ecological dynamics: overall, water stage was simulated to within 6 cm of long-term observations, while aggregated phosphorus predictions in the marshes had a bias of 0 ug l^{-1}, and marsh chloride water quality predictions were biased by a mere 2 mg l^{-1} overall. 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-1 perimeter canal and the marshes of the interior region.

6.7 Appendix A: Time series & CFDs: TP

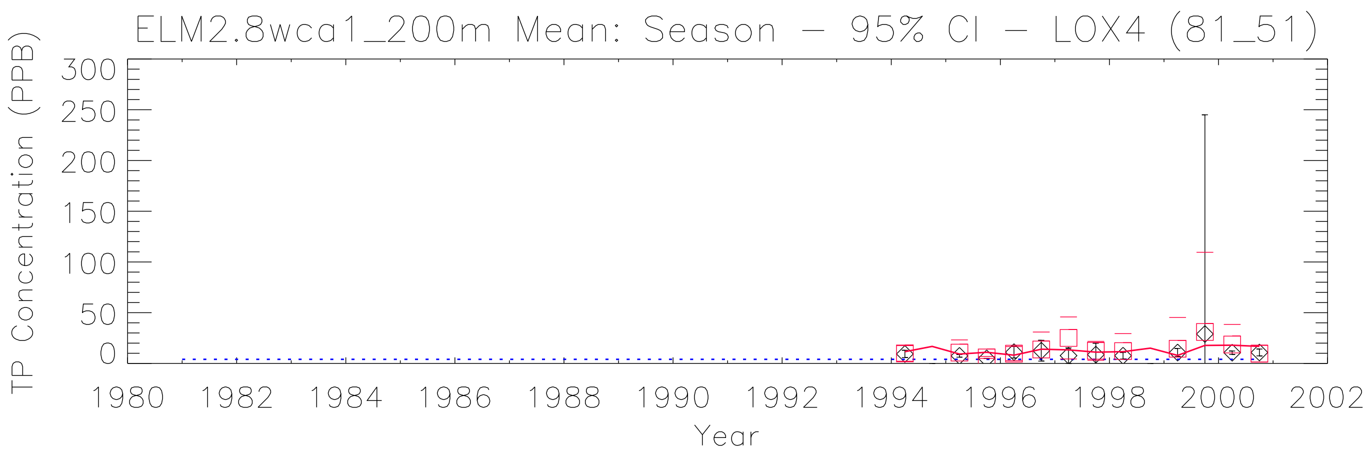
Figures A.1 – A.31. Time series plots of water column total phosphorus (TP) concentration and their associated Cumulative Frequency Distributions (CFD) for the period of record 1994-2000 at each monitoring location. The sequence of the figures is based on geographic location of marsh sites, starting 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.

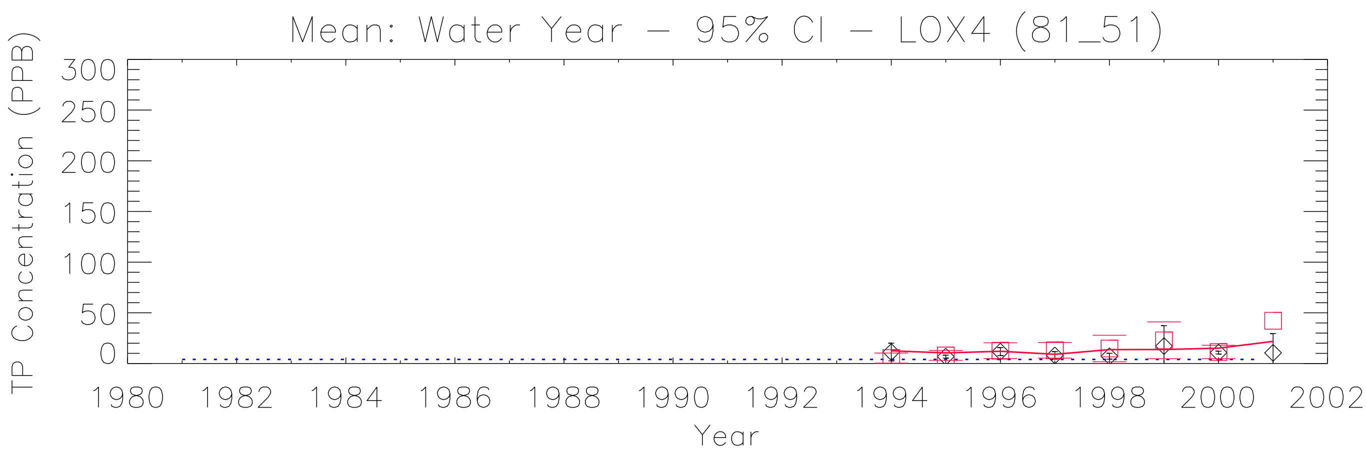
a) All data were aggregated into arithmetic mean values by wet and dry seasons within water years; the continuous lines pass through mean of all daily data points for each season; the mean of paired simulated and observed values are shown in red boxes and black diamonds, respectively; the 95% Confidence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

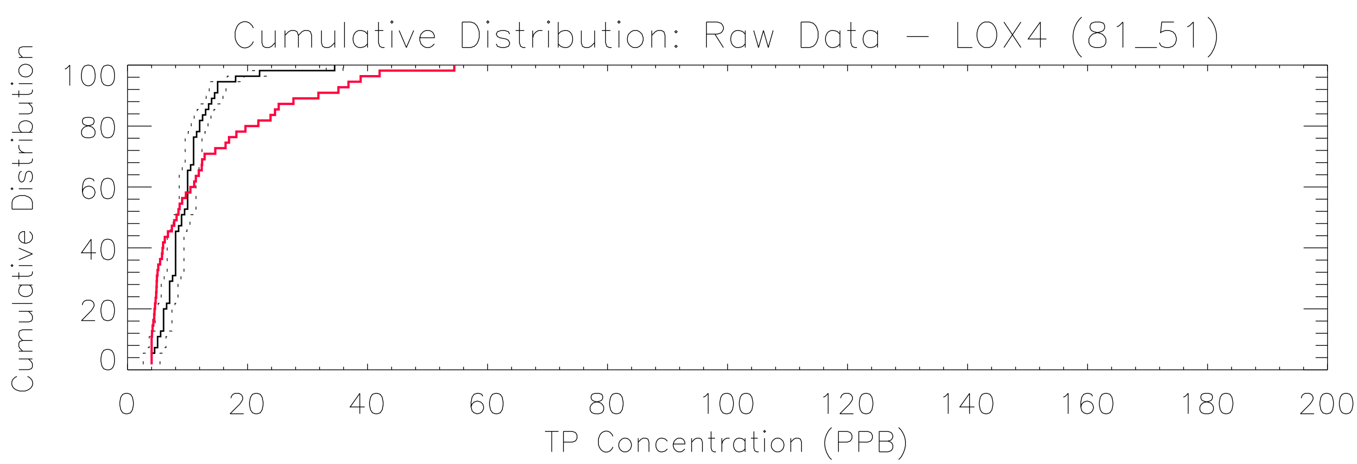
c) The CFDs of the simulated and observed (raw, un-aggregated) data; the 95% confidence interval for observed data is shown in the dashed black lines. Note that only paired simulated and observed data points are used.



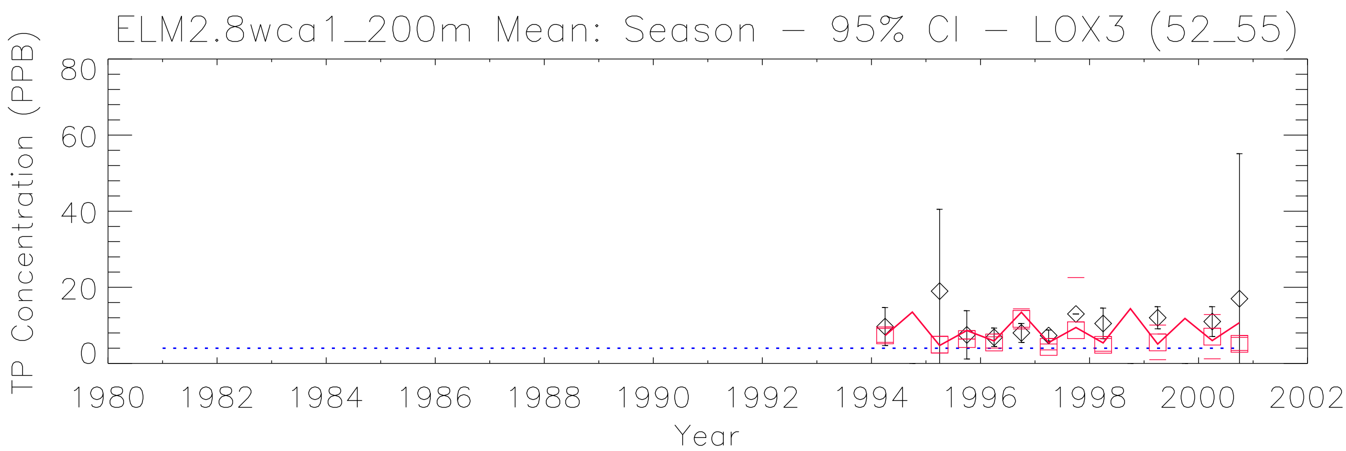
ELM2.8wca1_200m Mean: Season - 95% CI - LOX4 (81_51)
TP Concentration (PPB)
Year

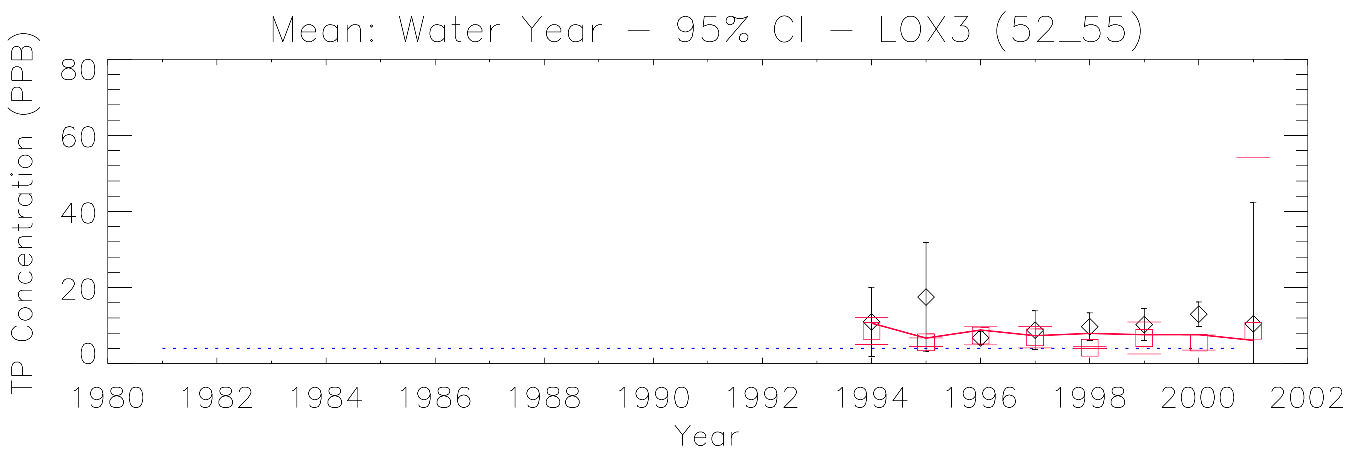


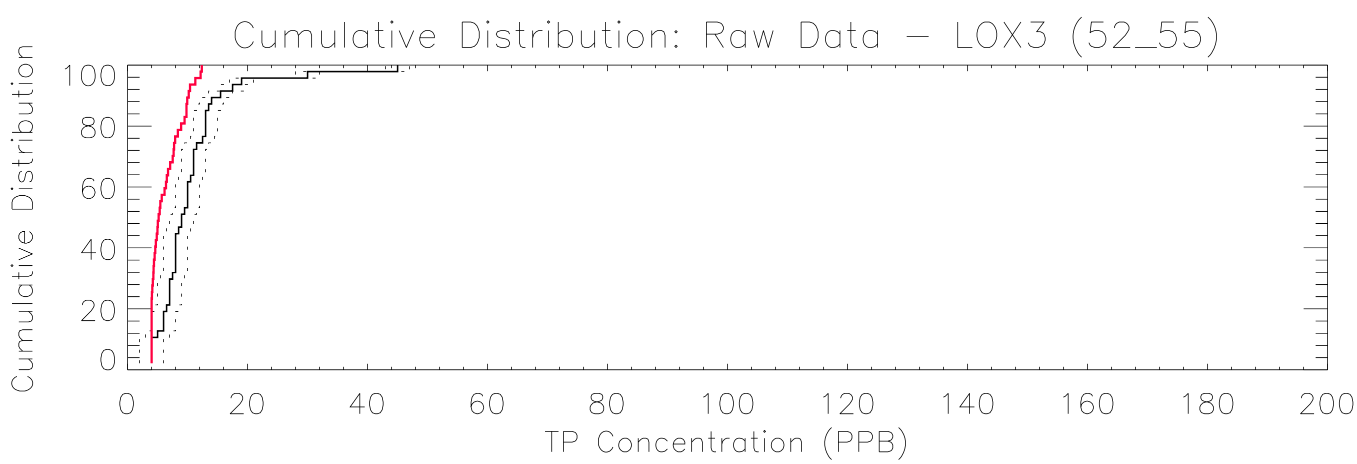
Mean: Water Year - 95% CI - LOX4 (81_51)
TP Concentration (PPB)
Year

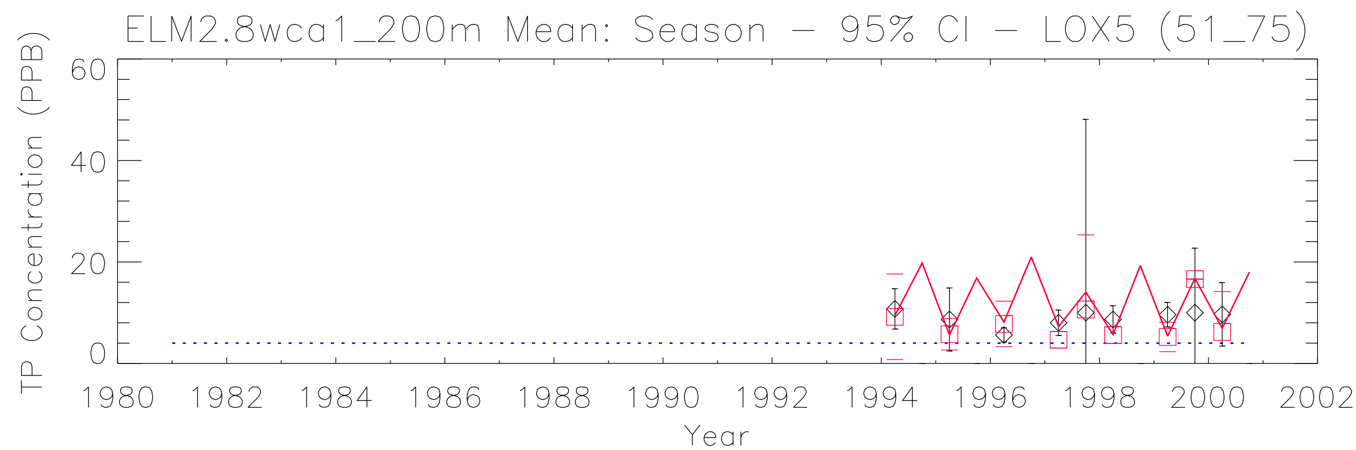


Cumulative Distribution: Raw Data - LOX4 (81_51)
Cumulative Distribution
TP Concentration (PPB)

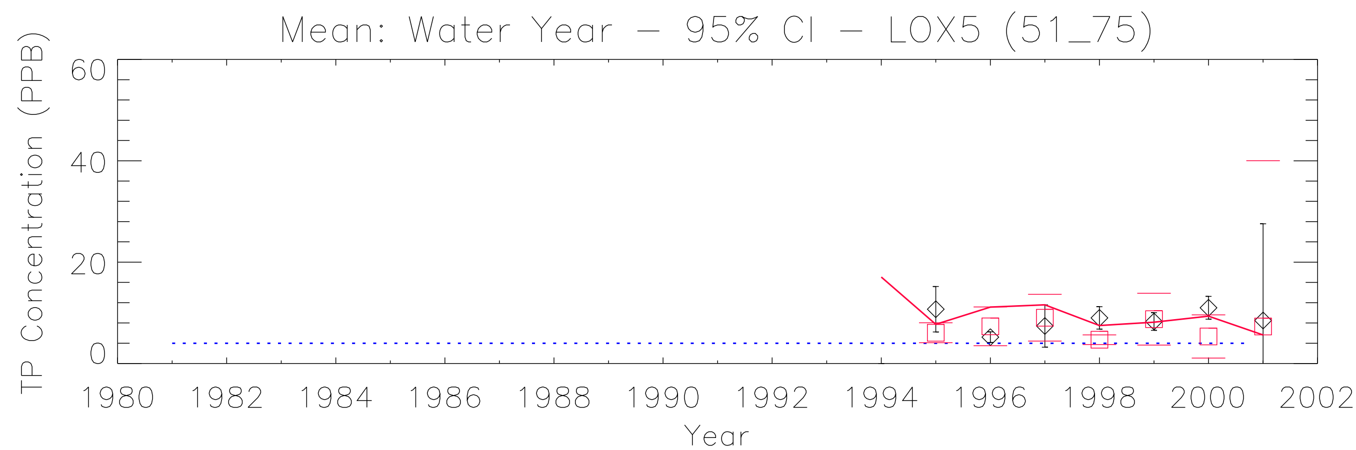

ELM2.8wca1_200m Mean: Season – 95% CI – LOX3 (52_55)
TP Concentration (PPB)
0
20
40
60
80
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – LOX3 (52_55)
TP Concentration (PPB)
0
20
40
60
80
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

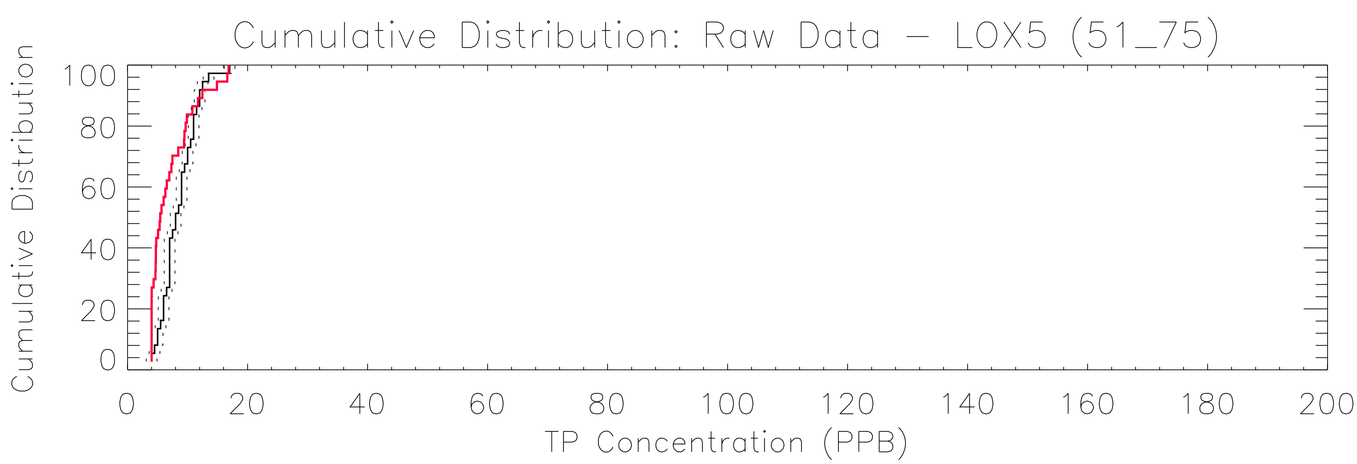

Cumulative Distribution: Raw Data – LOX3 (52_55)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)



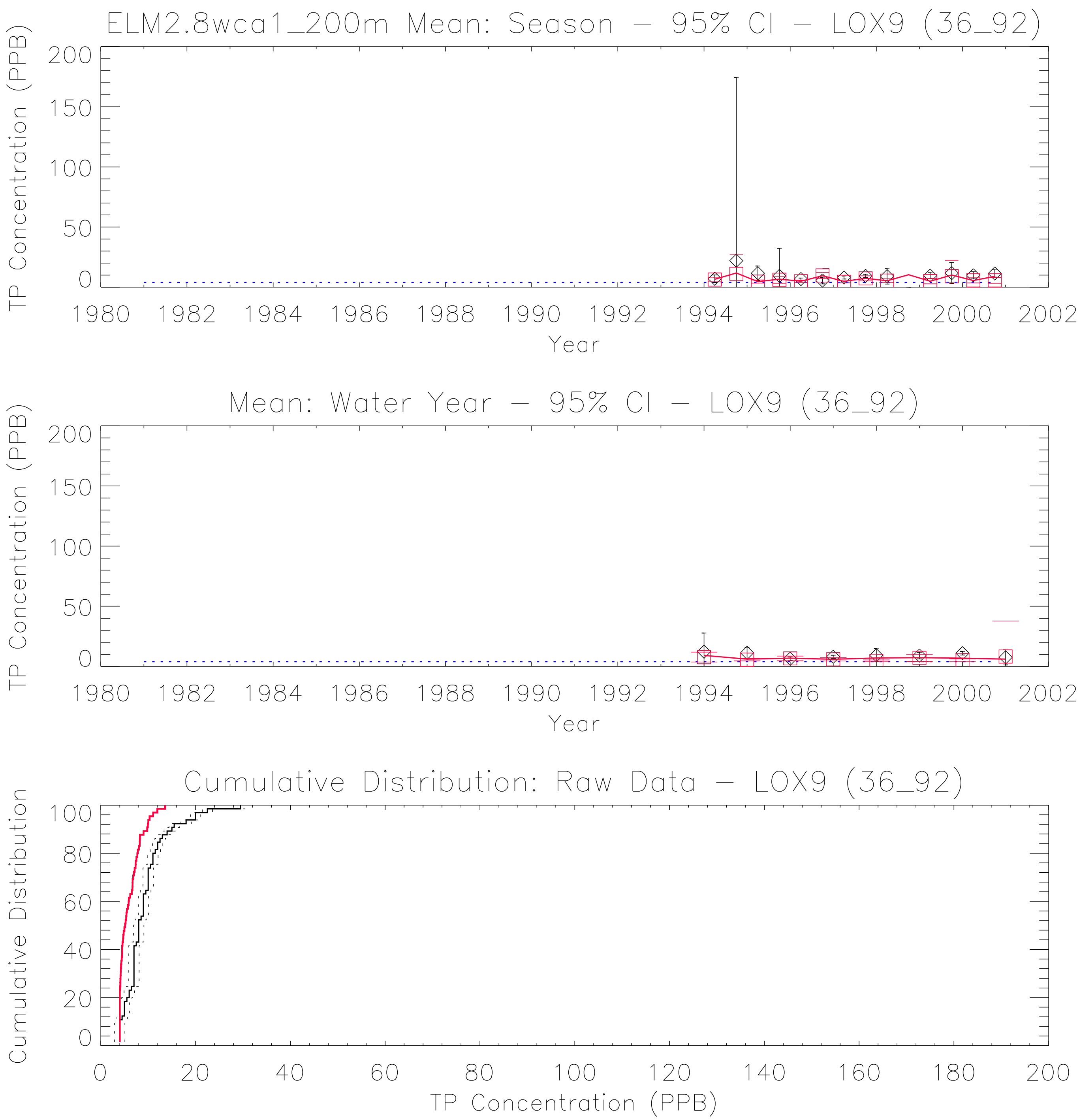
ELM2.8wca1_200m Mean: Season - 95% CI - LOX5 (51_75)
TP Concentration (PPB)
0
20
40
60
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

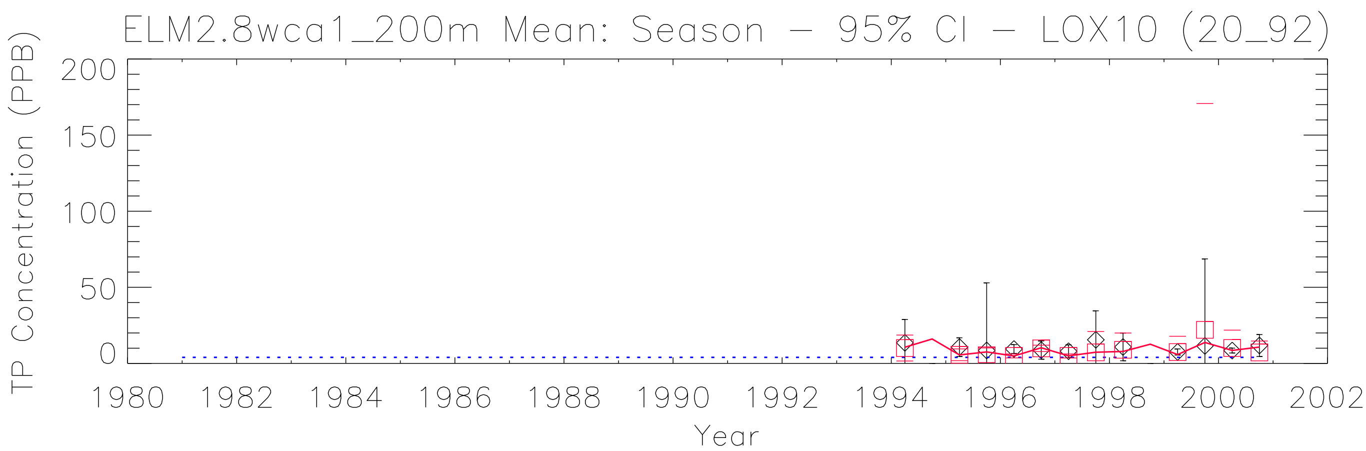


Mean: Water Year - 95% CI - LOX5 (51_75)
TP Concentration (PPB)
0
20
40
60
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

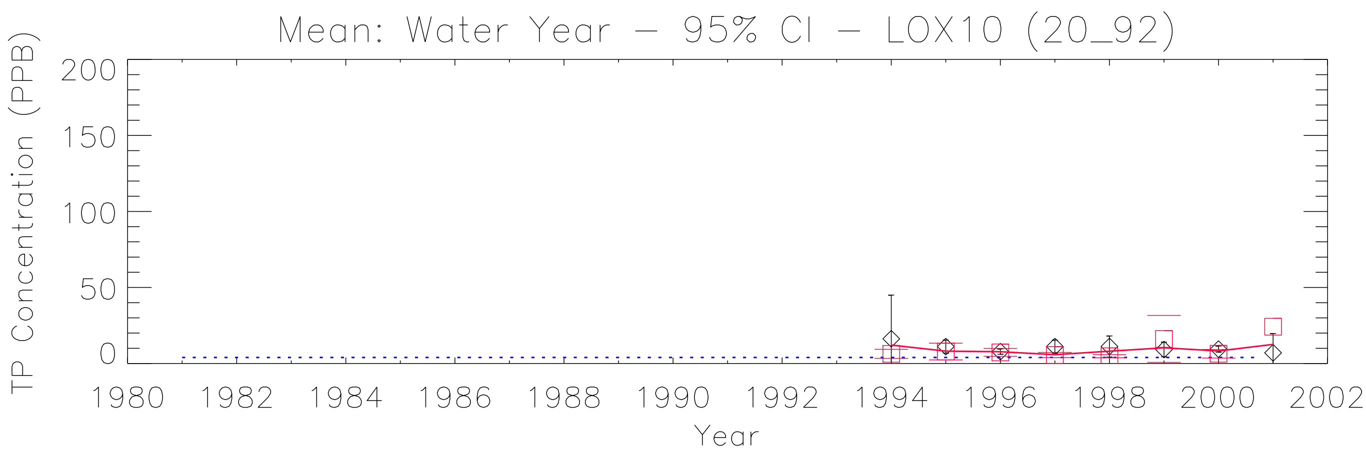


Cumulative Distribution: Raw Data - LOX5 (51_75)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

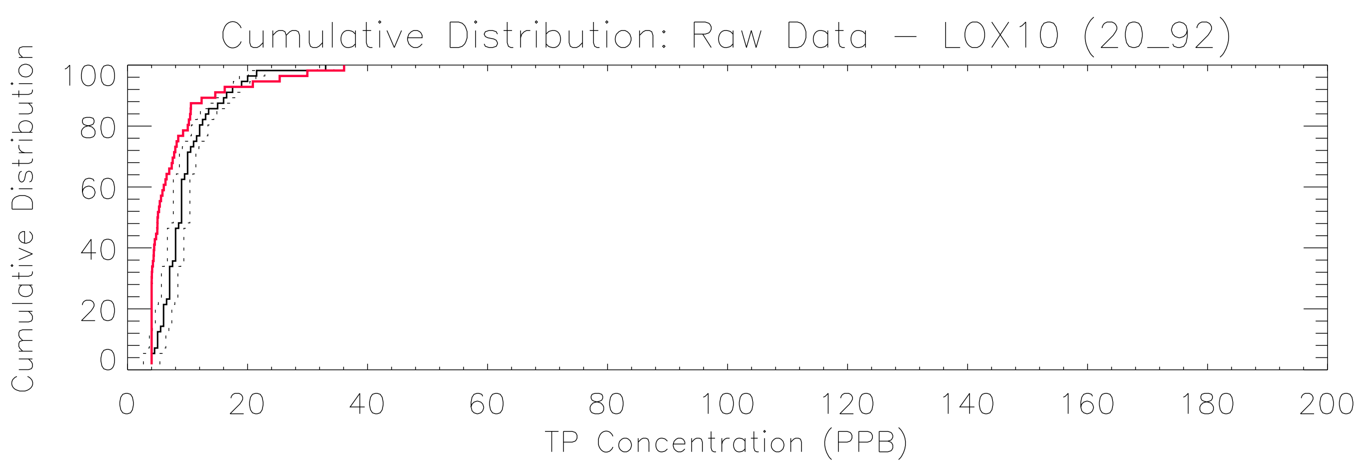

ELM2.8wca1_200m Mean: Season - 95% CI - LOX9 (36_92)
TP Concentration (PPB)
Year
Mean: Water Year - 95% CI - LOX9 (36_92)
TP Concentration (PPB)
Year
Cumulative Distribution: Raw Data - LOX9 (36_92)
Cumulative Distribution
TP Concentration (PPB)



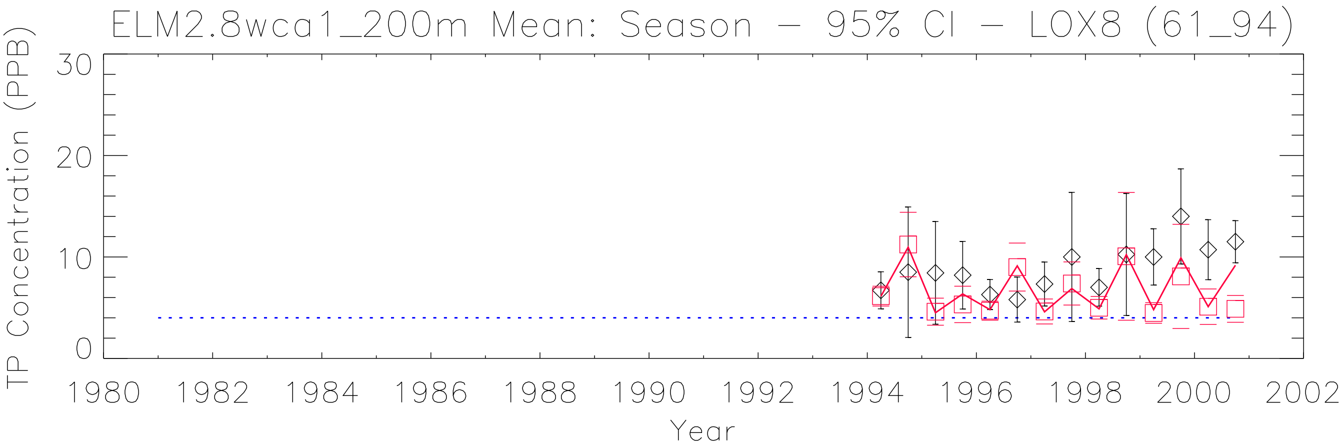
ELM2.8wca1_200m Mean: Season - 95% CI - LOX10 (20_92)
TP Concentration (PPB)
Year



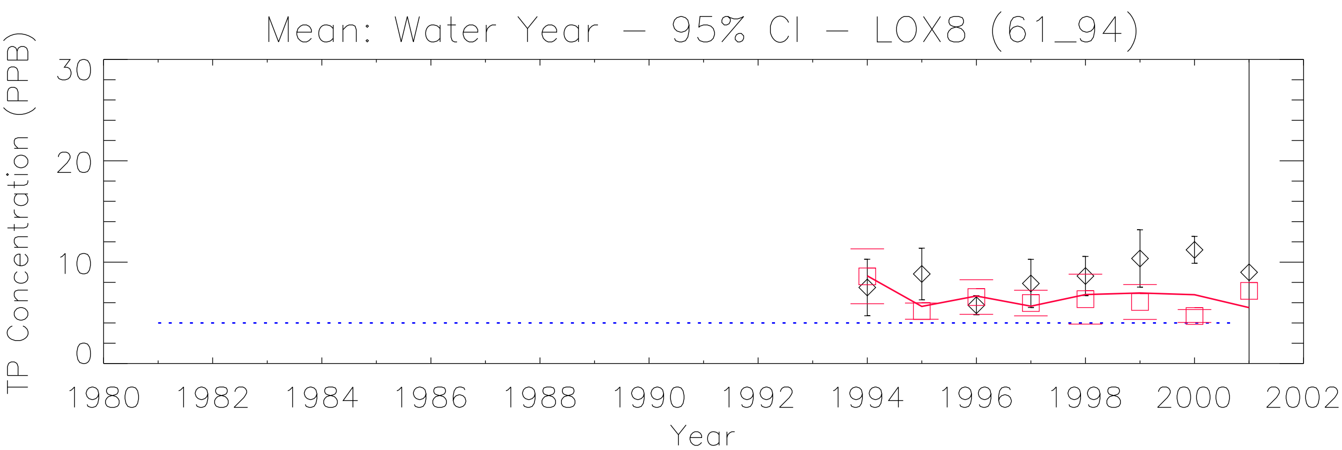
Mean: Water Year - 95% CI - LOX10 (20_92)
TP Concentration (PPB)
Year



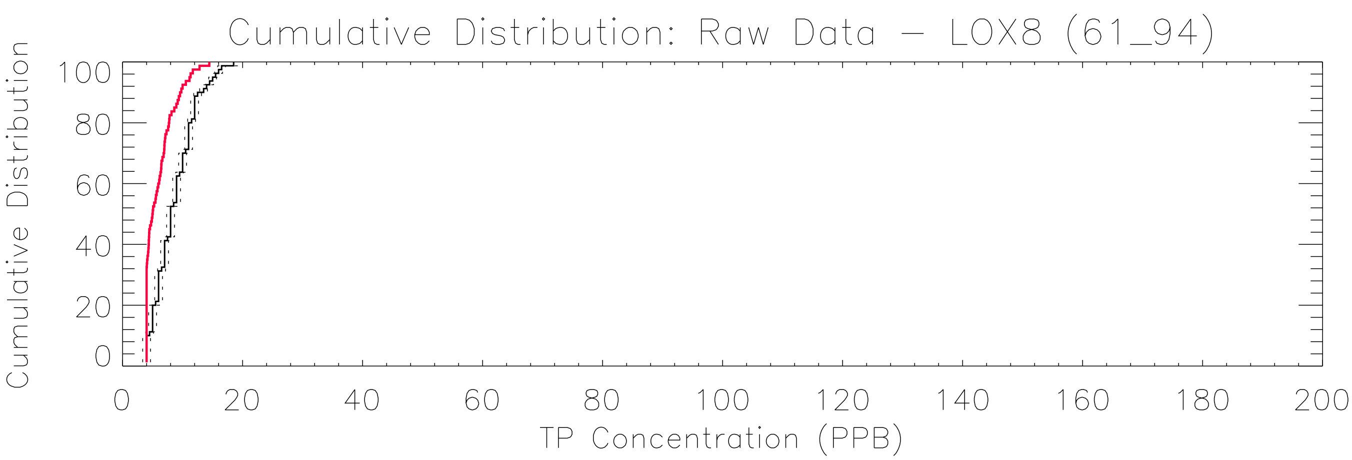
Cumulative Distribution: Raw Data - LOX10 (20_92)
Cumulative Distribution
TP Concentration (PPB)



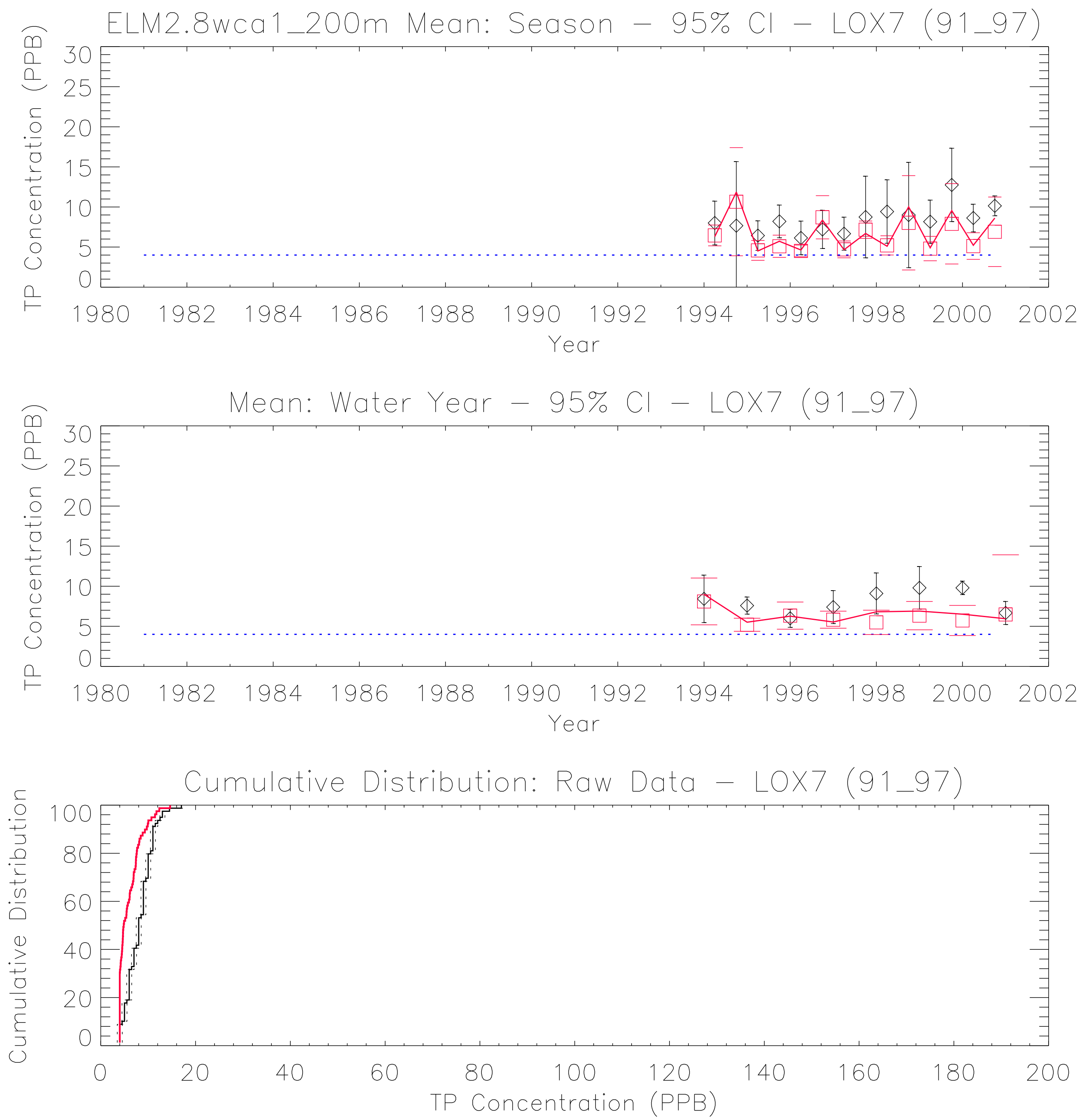
ELM2.8wca1_200m Mean: Season – 95% CI – LOX8 (61_94)
TP Concentration (PPB)
Year
0
10
20
30
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002



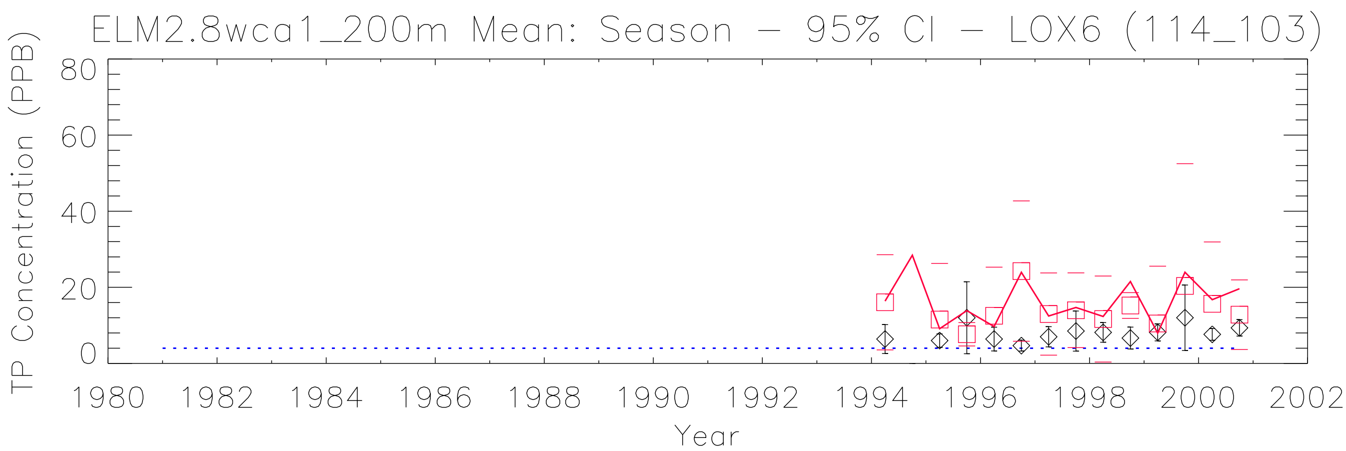
Mean: Water Year – 95% CI – LOX8 (61_94)
TP Concentration (PPB)
Year
0
10
20
30
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

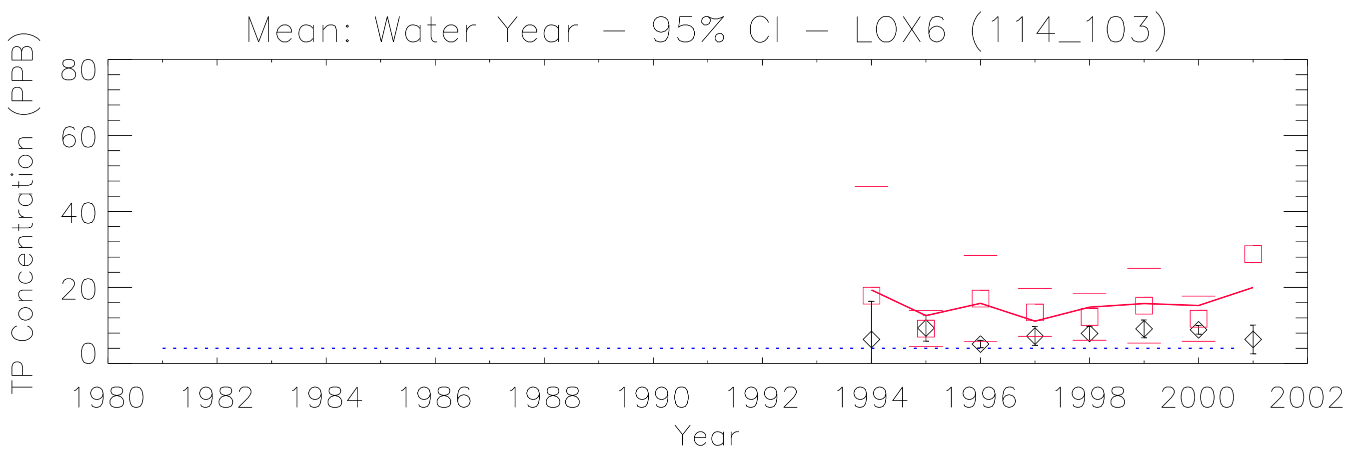


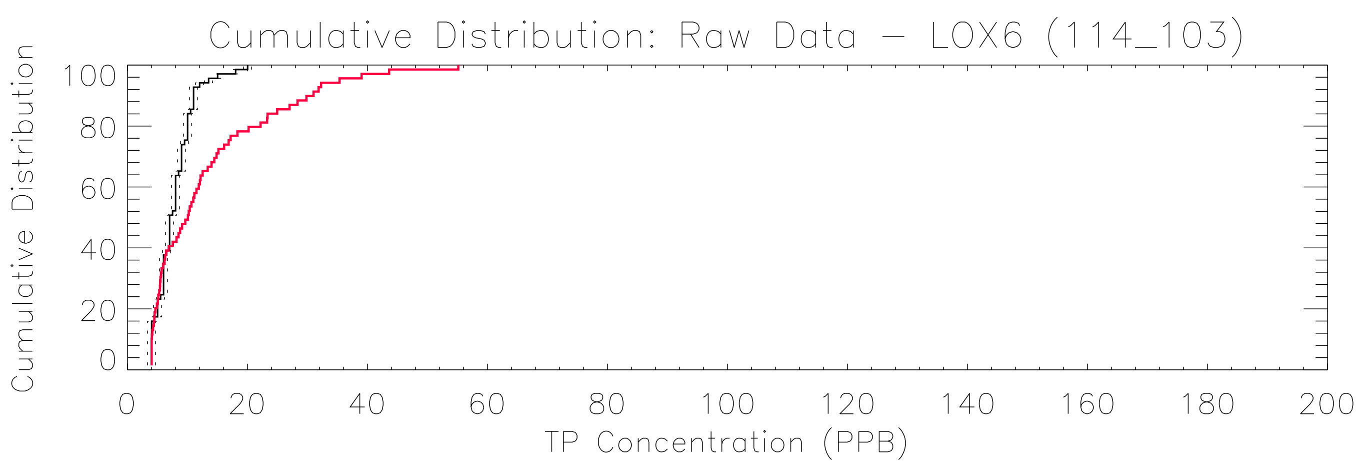
Cumulative Distribution: Raw Data – LOX8 (61_94)
Cumulative Distribution
TP Concentration (PPB)
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200

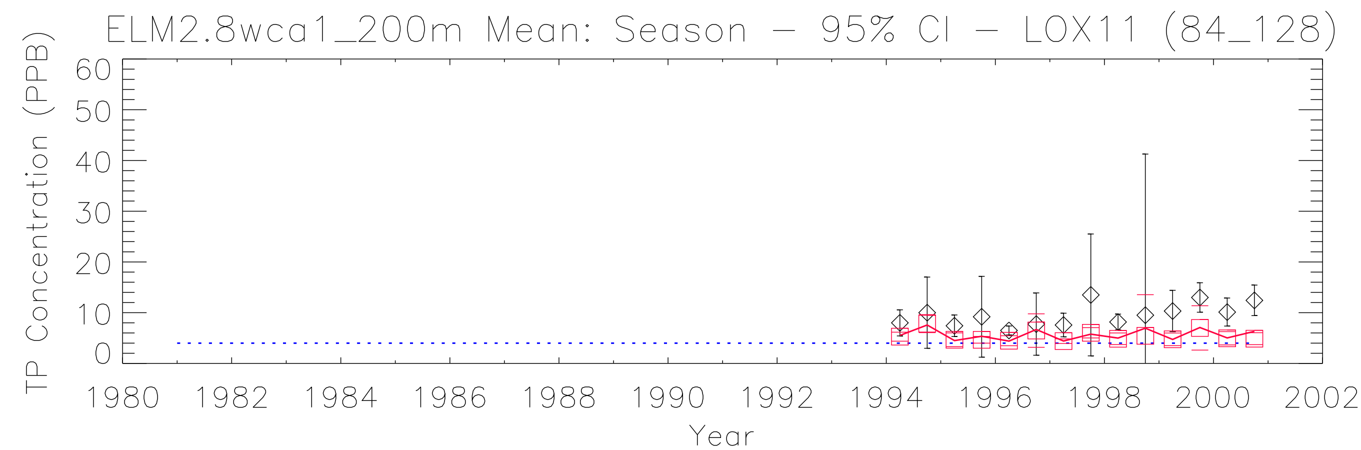


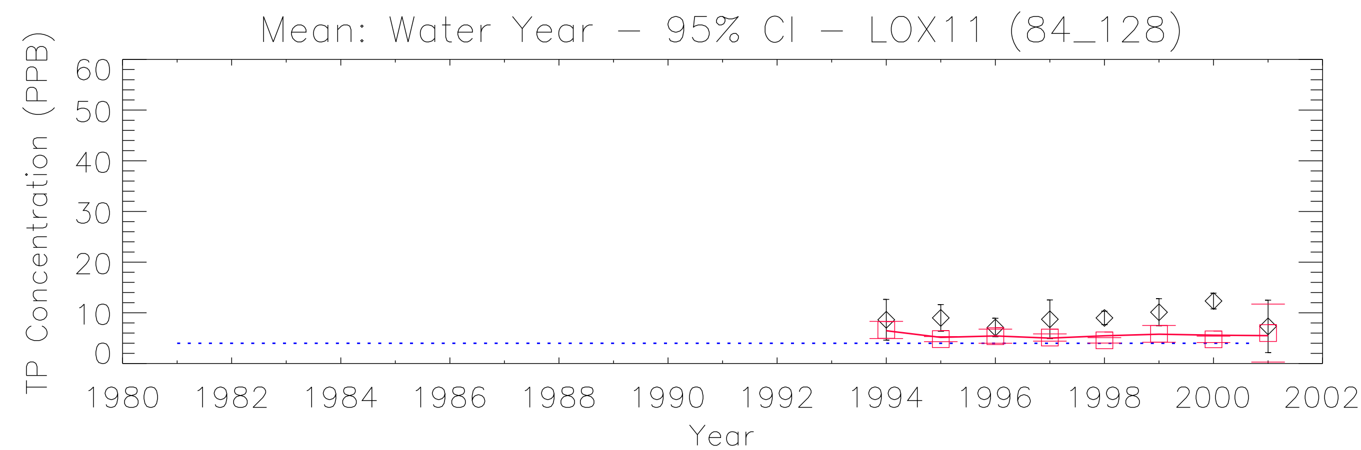
ELM2.8wca1_200m Mean: Season – 95% CI – LOX7 (91_97)
TP Concentration (PPB)
0
5
10
15
20
25
30
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
Mean: Water Year – 95% CI – LOX7 (91_97)
TP Concentration (PPB)
0
5
10
15
20
25
30
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
Cumulative Distribution: Raw Data – LOX7 (91_97)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

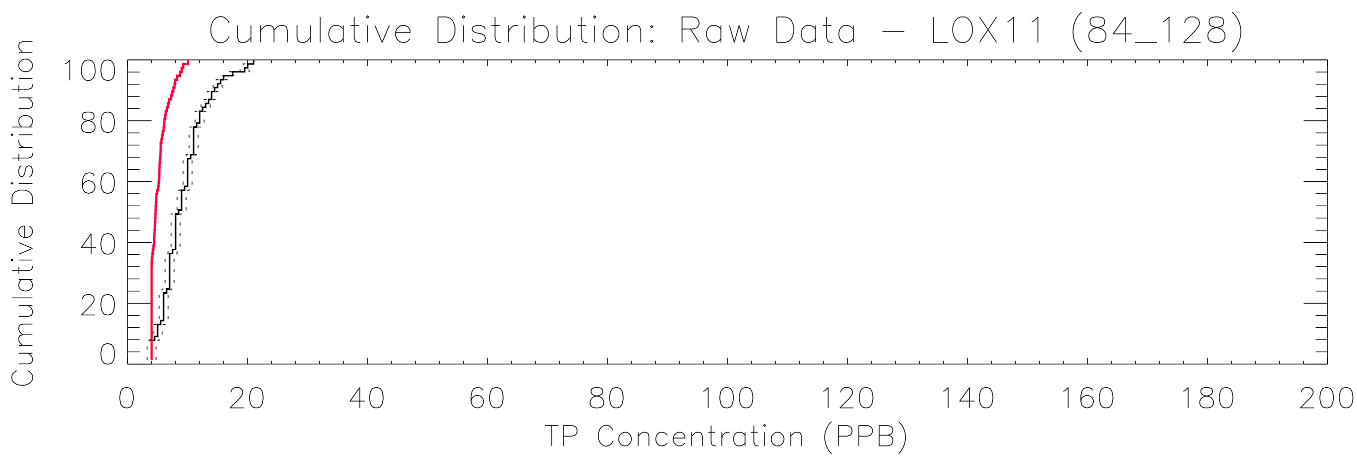

ELM2.8wca1_200m Mean: Season - 95% CI - LOX6 (114_103)
TP Concentration (PPB)
0
20
40
60
80
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

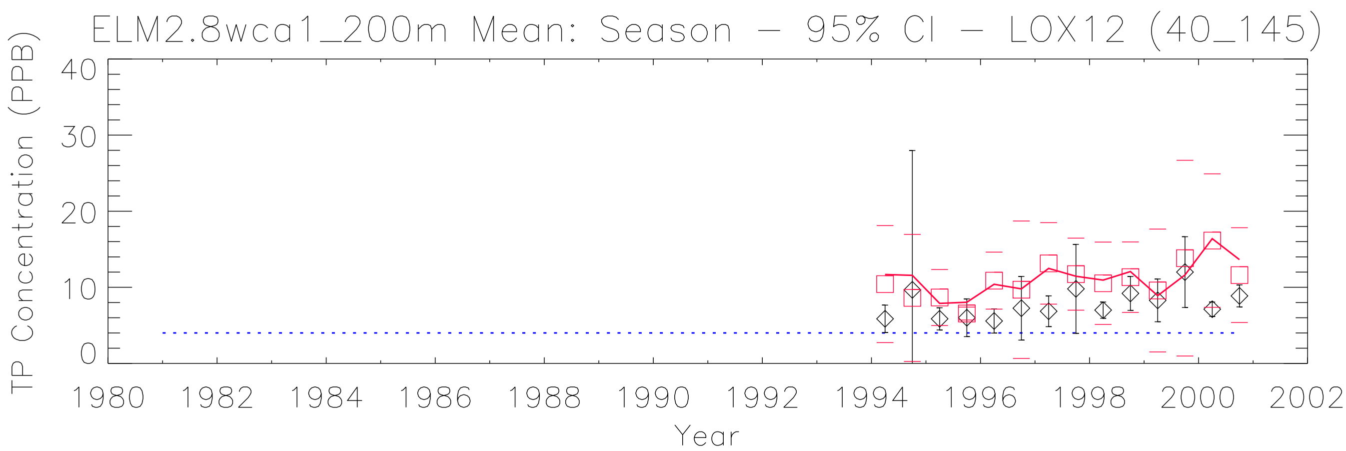

Mean: Water Year - 95% CI - LOX6 (114_103)
TP Concentration (PPB)
0
20
40
60
80
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

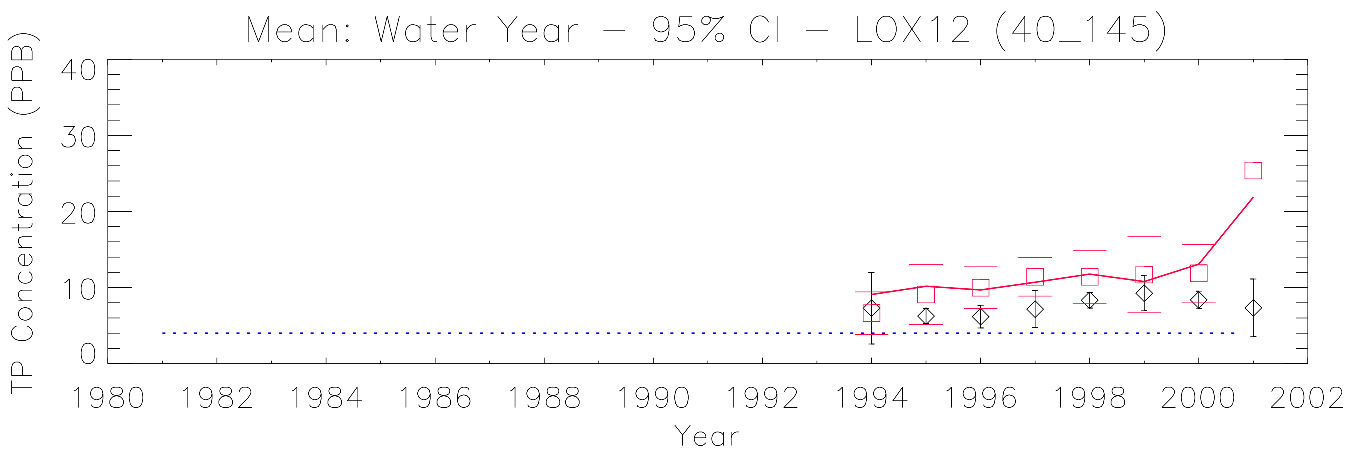

Cumulative Distribution: Raw Data - LOX6 (114_103)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

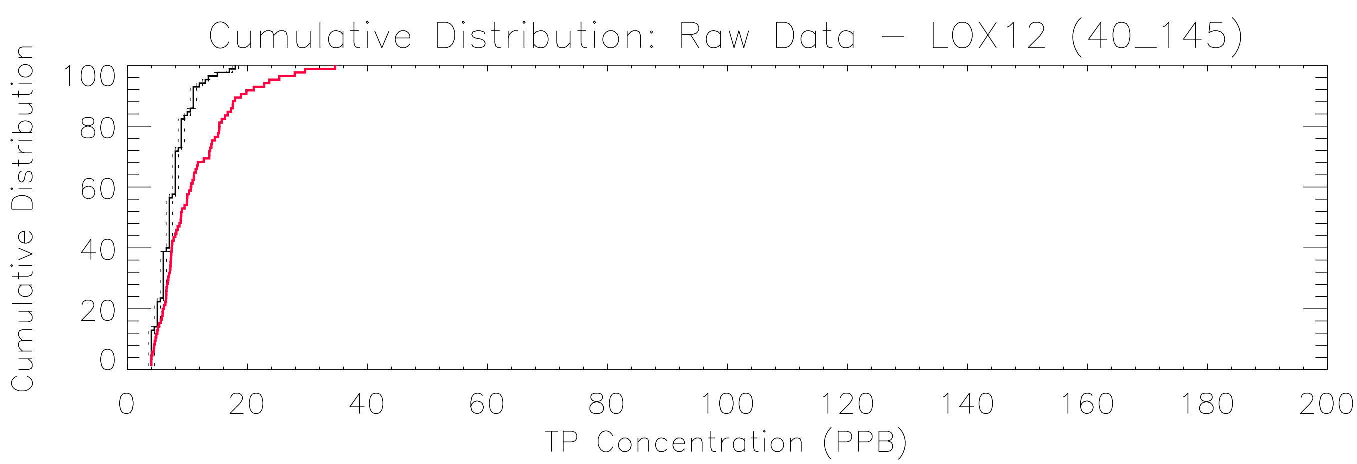

ELM2.8wca1_200m Mean: Season – 95% CI – LOX11 (84_128)
TP Concentration (PPB)
0
10
20
30
40
50
60
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

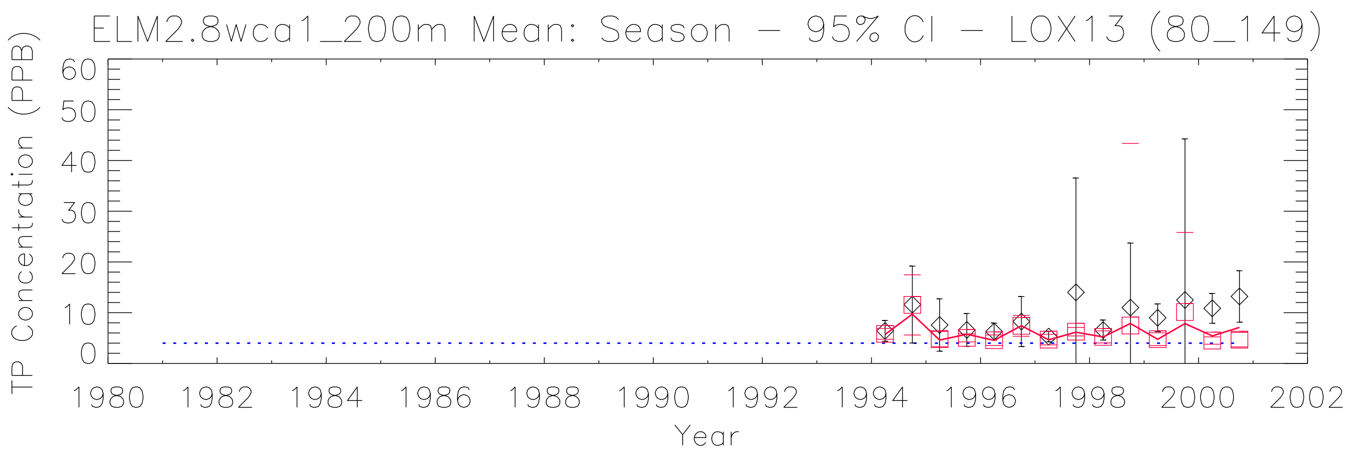

Mean: Water Year – 95% CI – LOX11 (84_128)
TP Concentration (PPB)
0
10
20
30
40
50
60
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

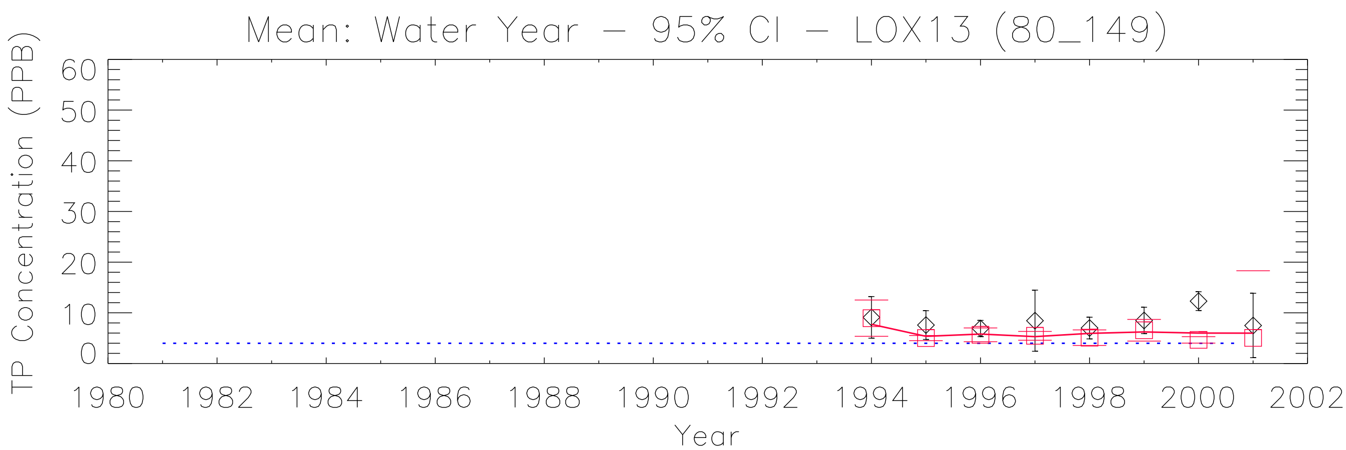

Cumulative Distribution: Raw Data – LOX11 (84_128)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

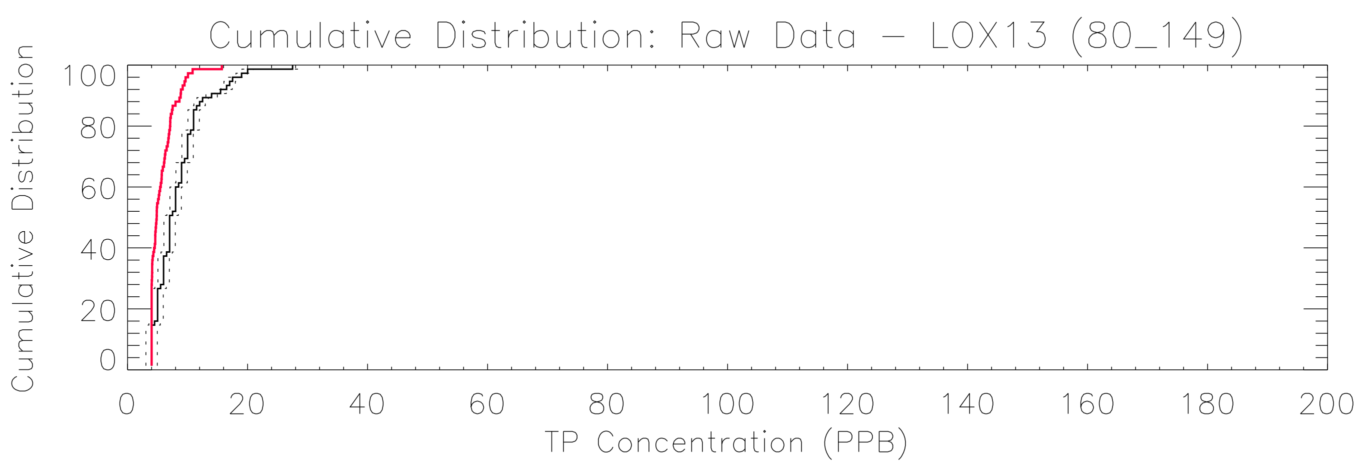

ELM2.8wca1_200m Mean: Season - 95% CI - LOX12 (40_145)
TP Concentration (PPB)
Year
0
10
20
30
40
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

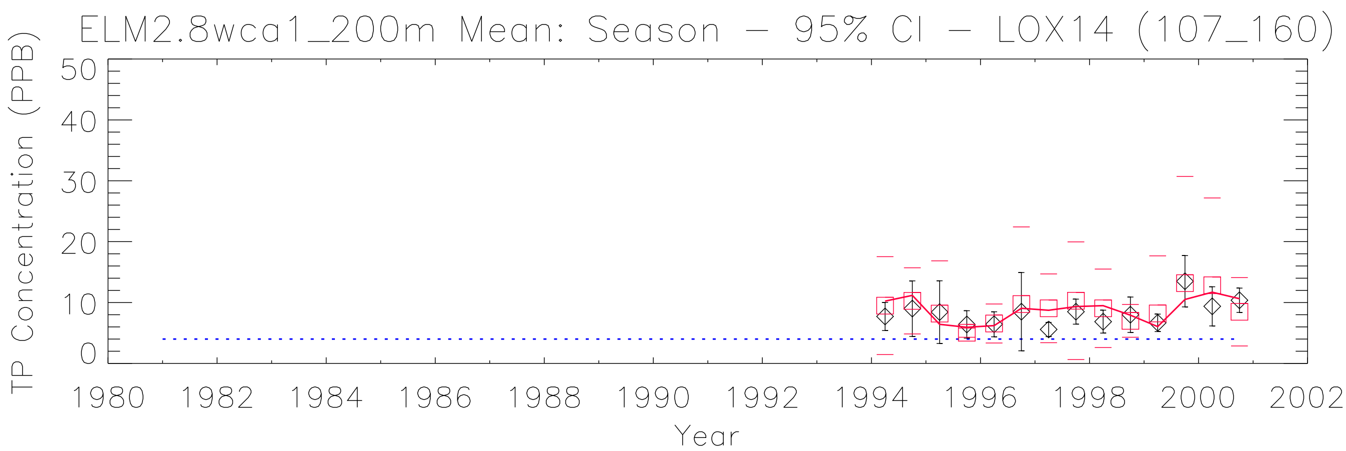

Mean: Water Year - 95% CI - LOX12 (40_145)
TP Concentration (PPB)
Year
0
10
20
30
40
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

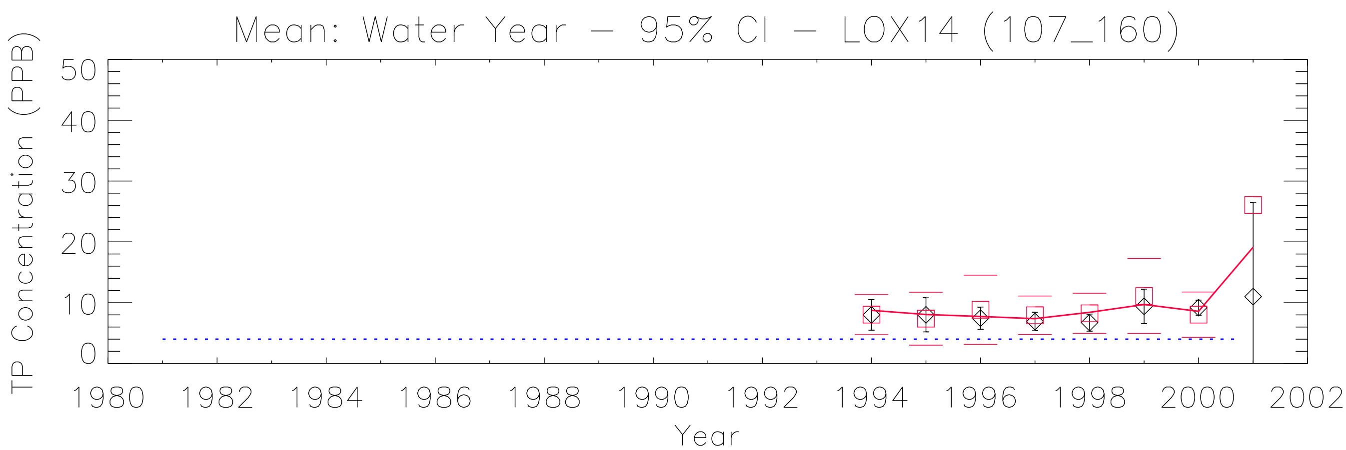

Cumulative Distribution: Raw Data - LOX12 (40_145)
Cumulative Distribution
TP Concentration (PPB)
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200

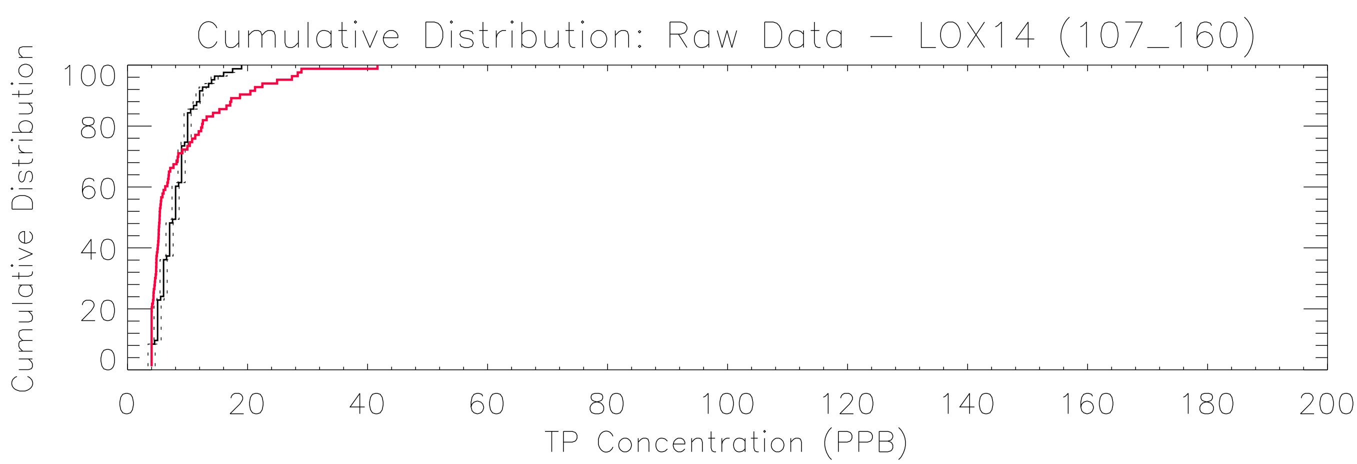

ELM2.8wca1_200m Mean: Season – 95% CI – LOX13 (80_149)
TP Concentration (PPB)
0
10
20
30
40
50
60
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

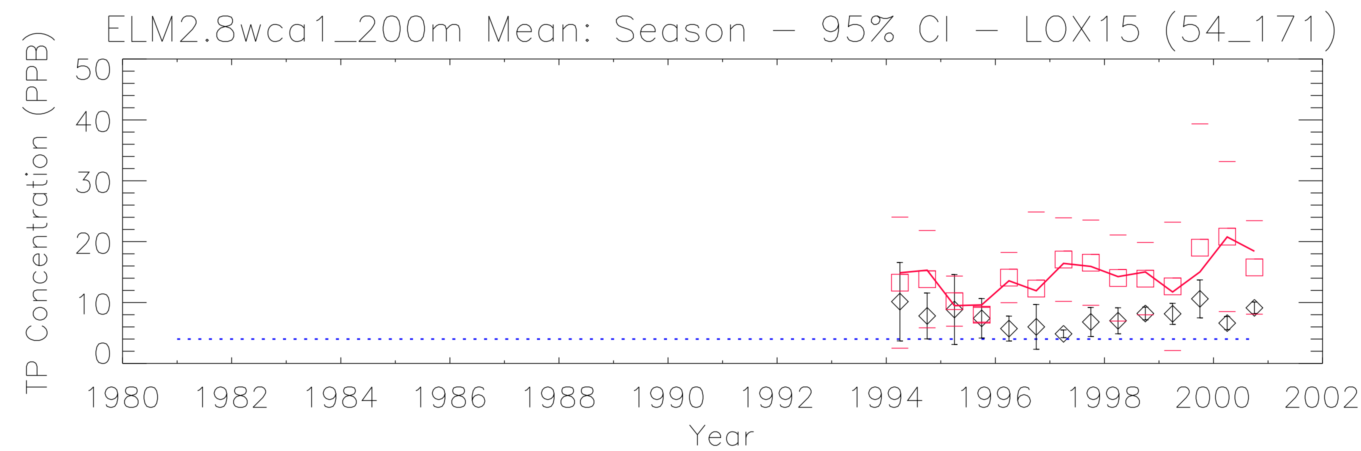

Mean: Water Year – 95% CI – LOX13 (80_149)
TP Concentration (PPB)
0
10
20
30
40
50
60
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data – LOX13 (80_149)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

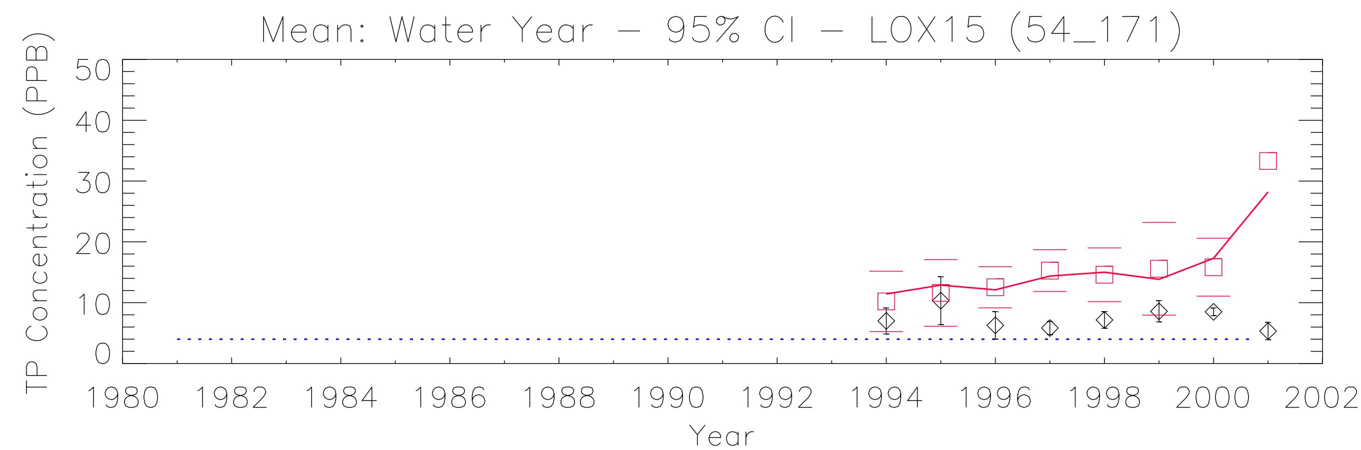

ELM2.8wca1_200m Mean: Season - 95% CI - LOX14 (107_160)
TP Concentration (PPB)
Year


Mean: Water Year - 95% CI - LOX14 (107_160)
TP Concentration (PPB)
Year

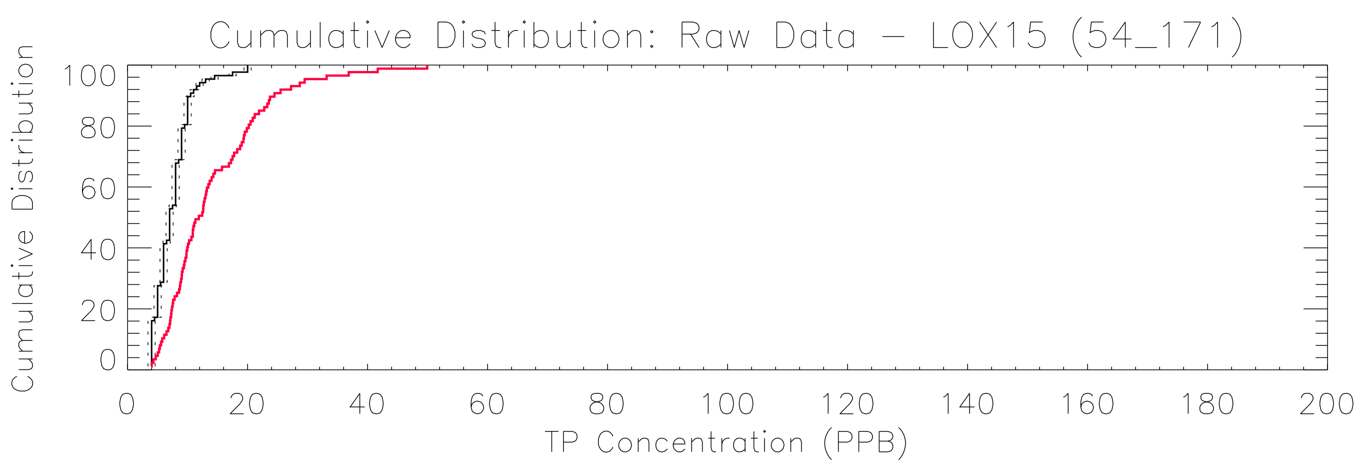

Cumulative Distribution: Raw Data - LOX14 (107_160)
Cumulative Distribution
TP Concentration (PPB)



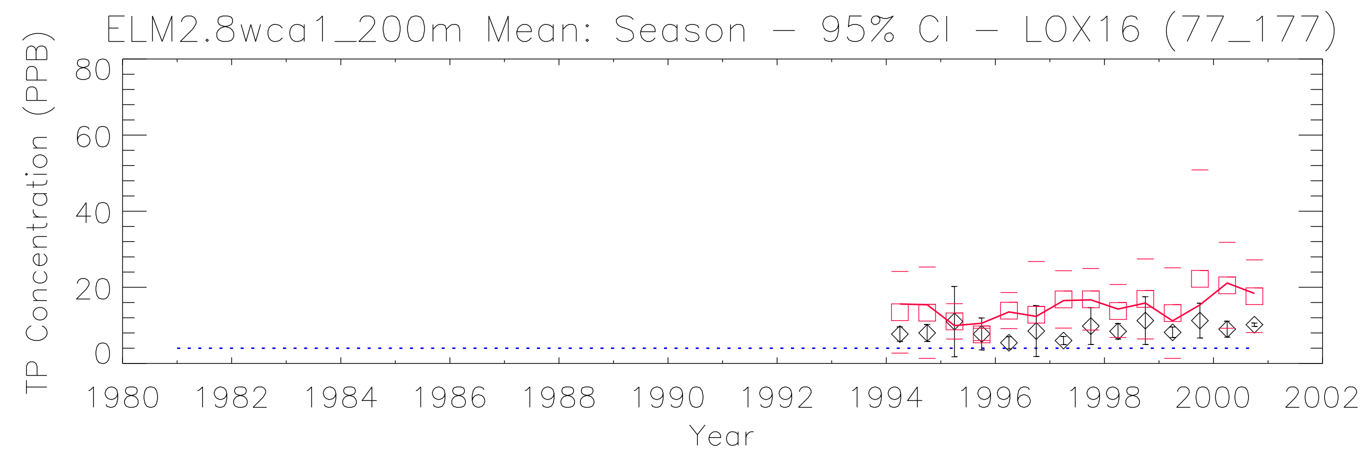
ELM2.8wca1_200m Mean: Season – 95% CI – LOX15 (54_171)
TP Concentration (PPB)
0
10
20
30
40
50
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

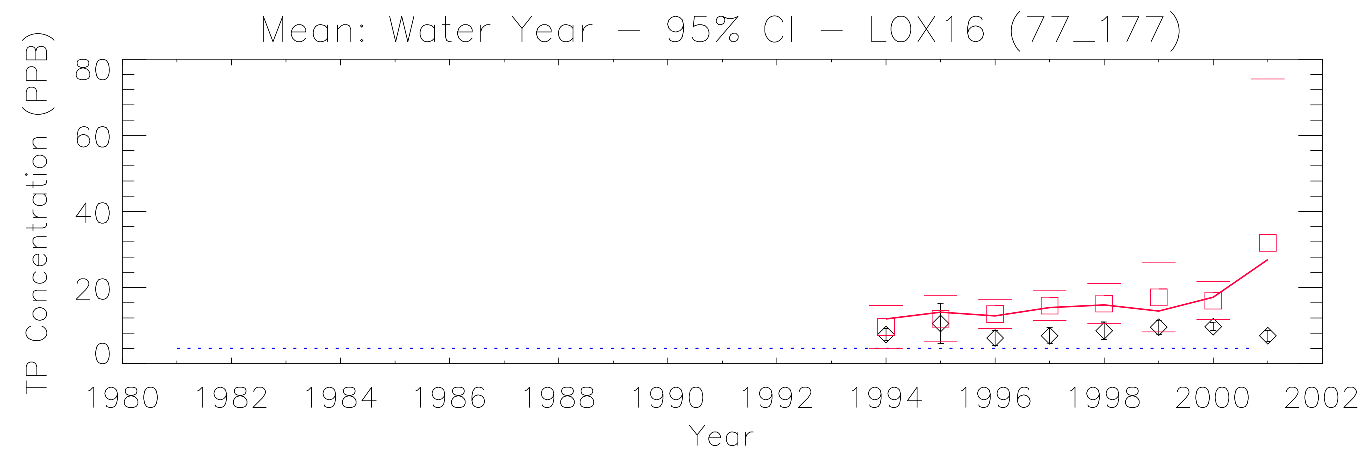


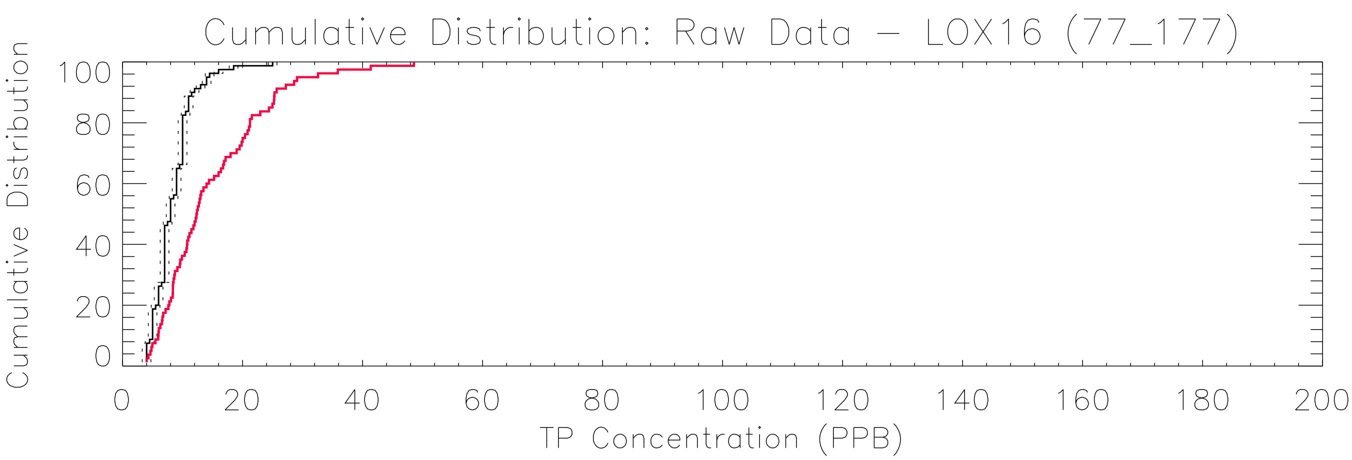
Mean: Water Year – 95% CI – LOX15 (54_171)
TP Concentration (PPB)
0
10
20
30
40
50
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

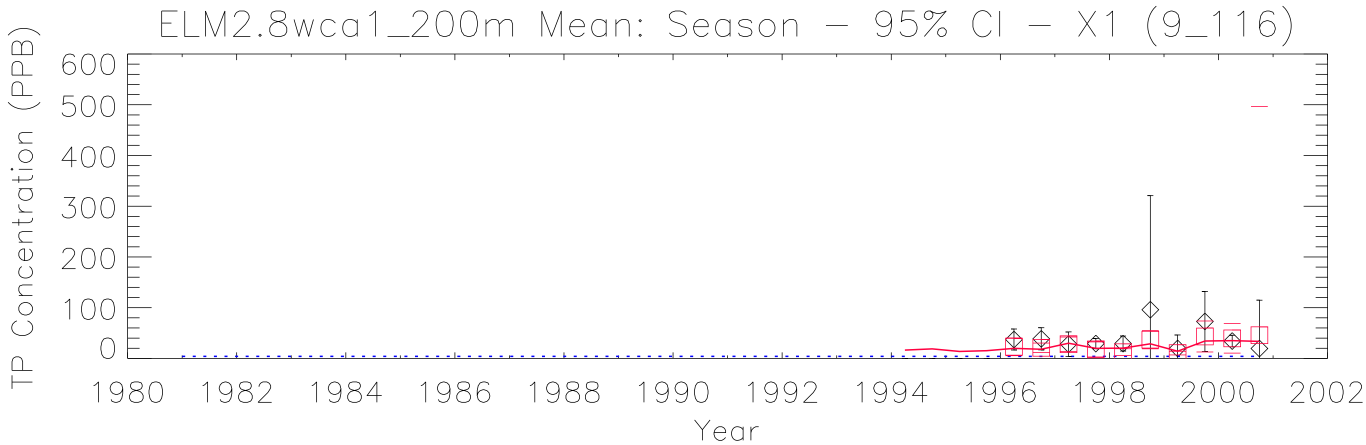


Cumulative Distribution: Raw Data – LOX15 (54_171)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

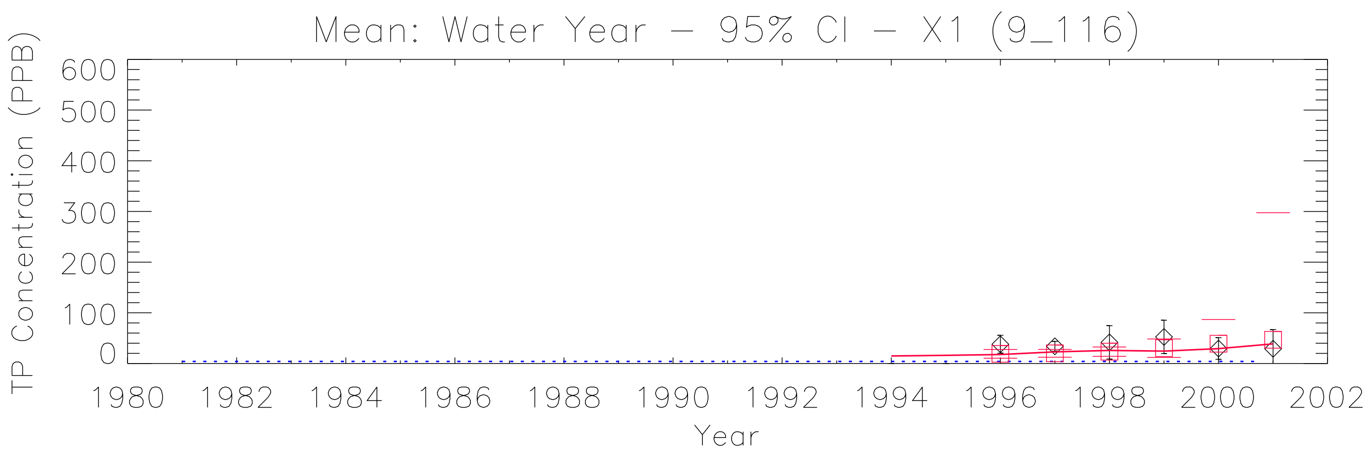

ELM2.8wca1_200m Mean: Season – 95% CI – LOX16 (77_177)
TP Concentration (PPB)
0
20
40
60
80
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – LOX16 (77_177)
TP Concentration (PPB)
0
20
40
60
80
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

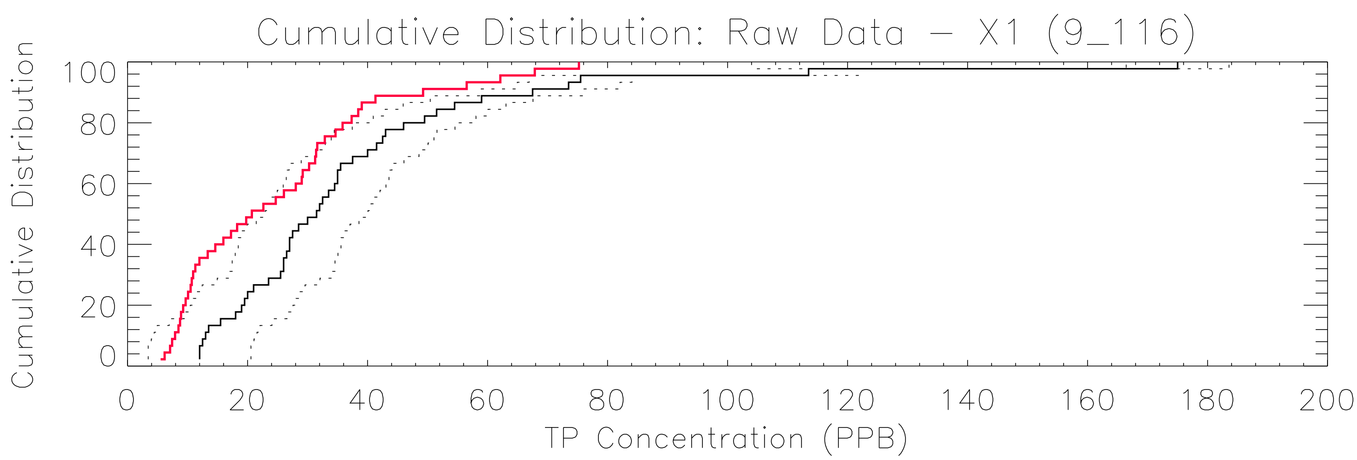

Cumulative Distribution: Raw Data – LOX16 (77_177)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)



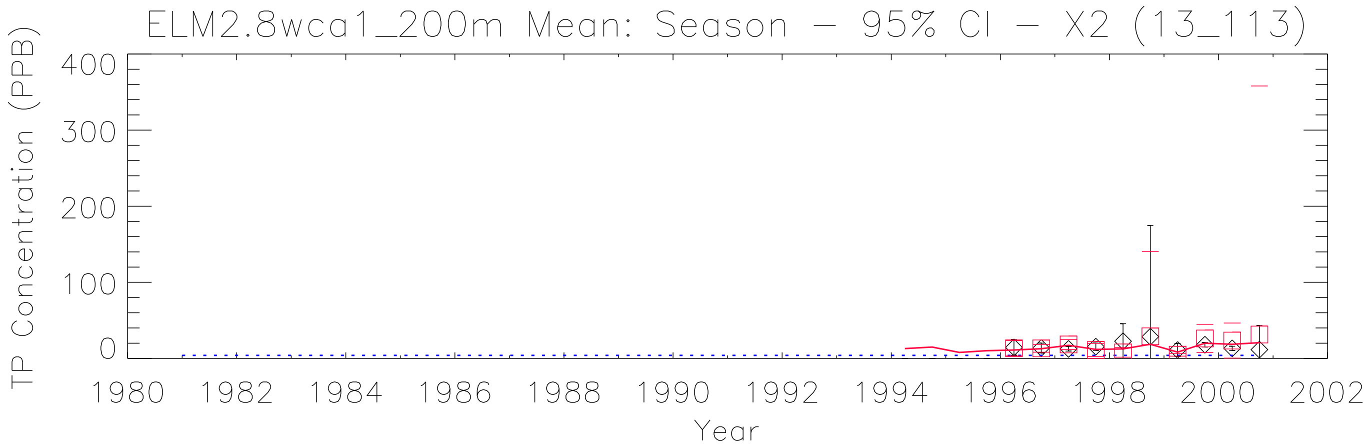
ELM2.8wca1_200m Mean: Season – 95% CI – X1 (9_116)
TP Concentration (PPB)
0
100
200
300
400
500
600
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

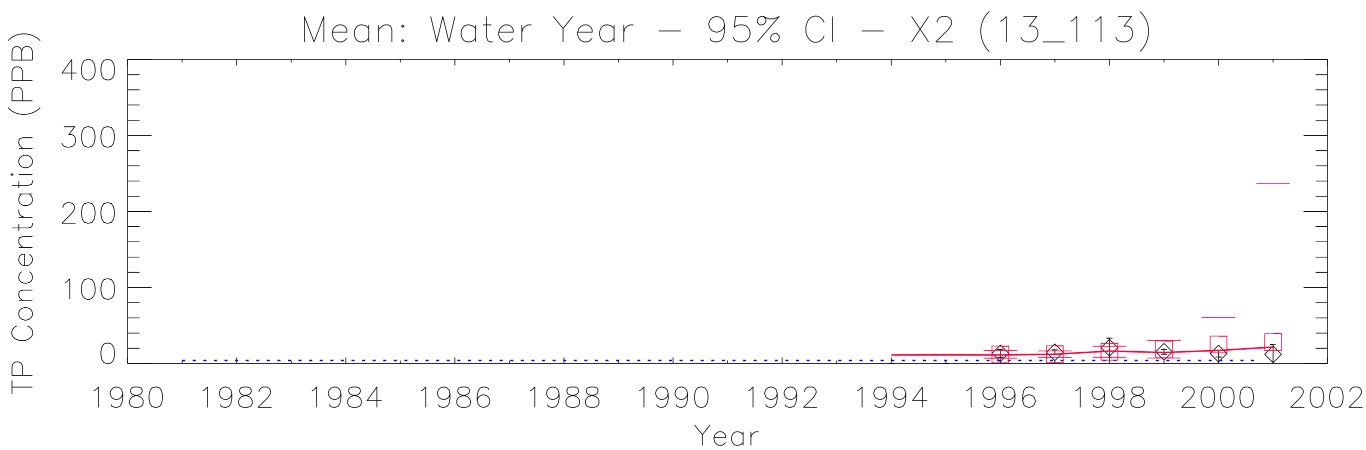


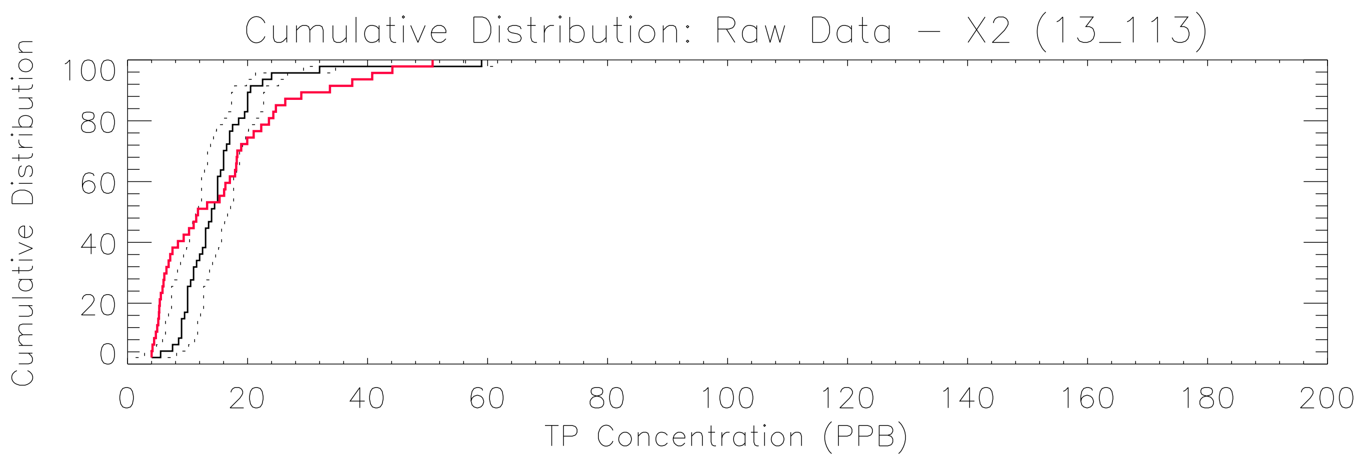
Mean: Water Year – 95% CI – X1 (9_116)
TP Concentration (PPB)
0
100
200
300
400
500
600
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

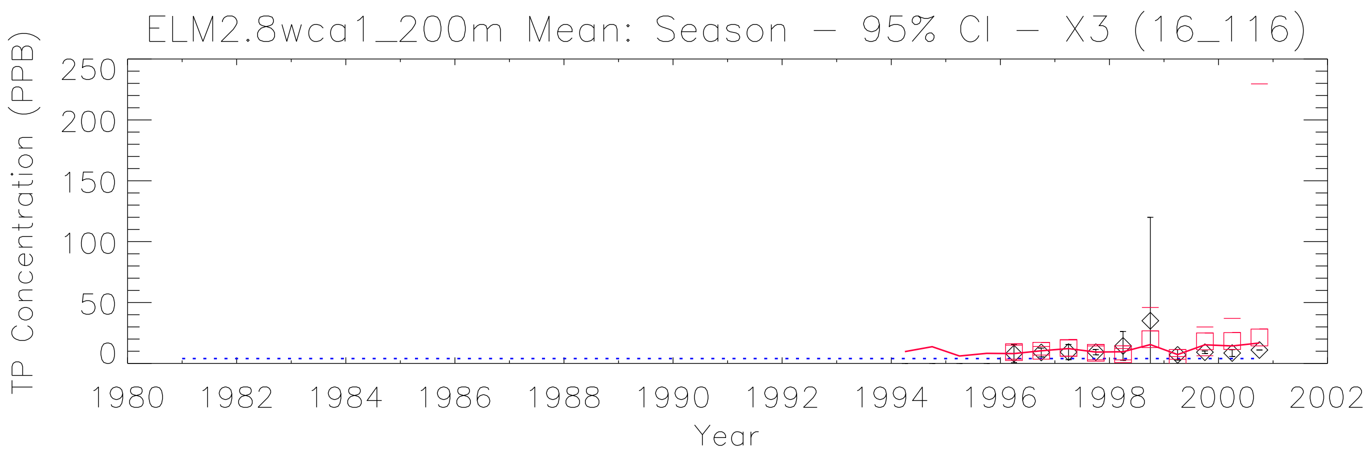


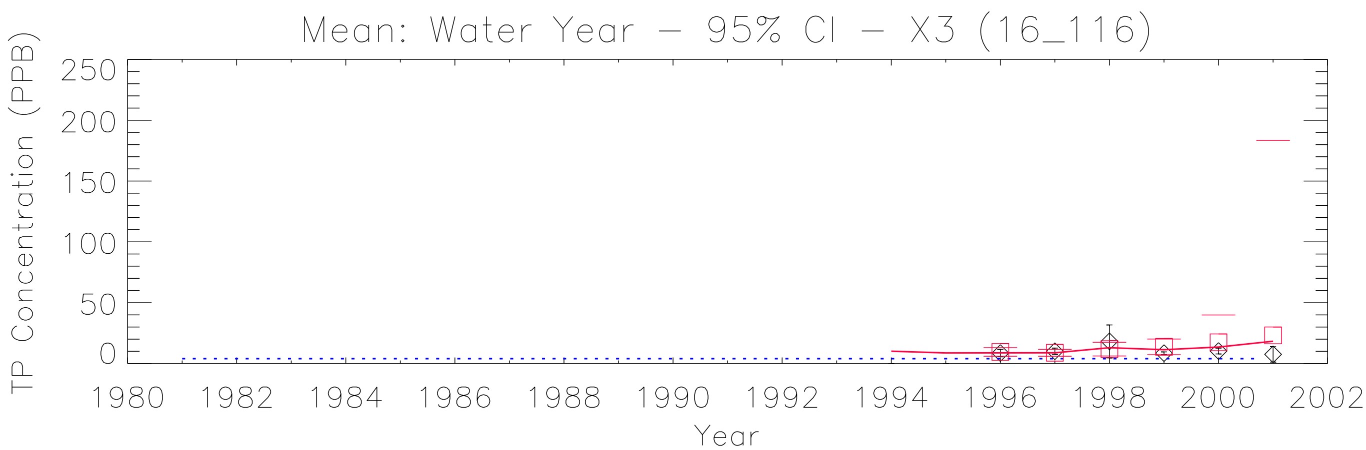
Cumulative Distribution: Raw Data – X1 (9_116)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

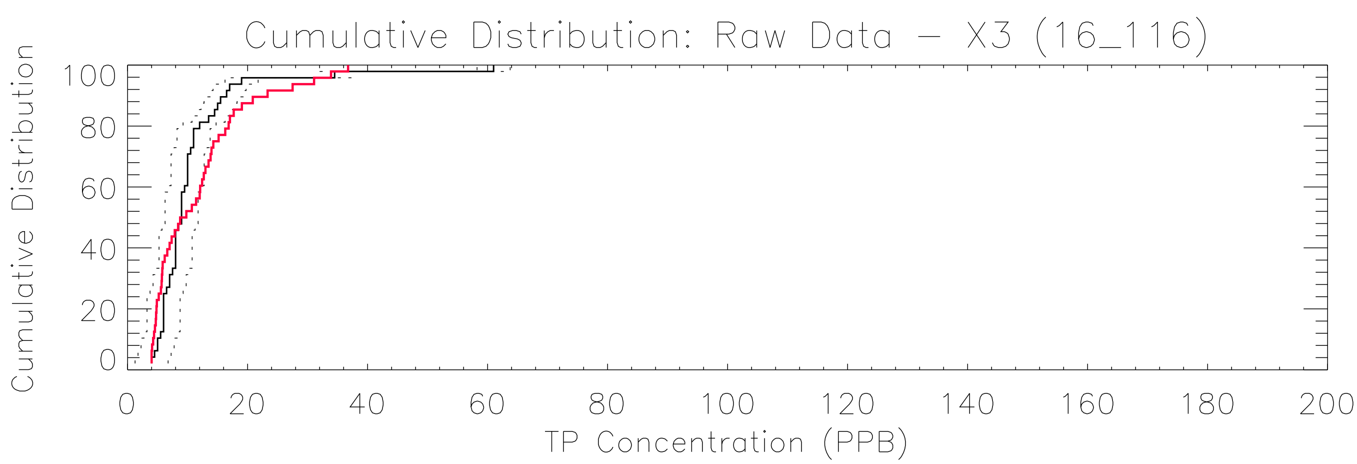

ELM2.8wca1_200m Mean: Season - 95% CI - X2 (13_113)
TP Concentration (PPB)
0
100
200
300
400
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

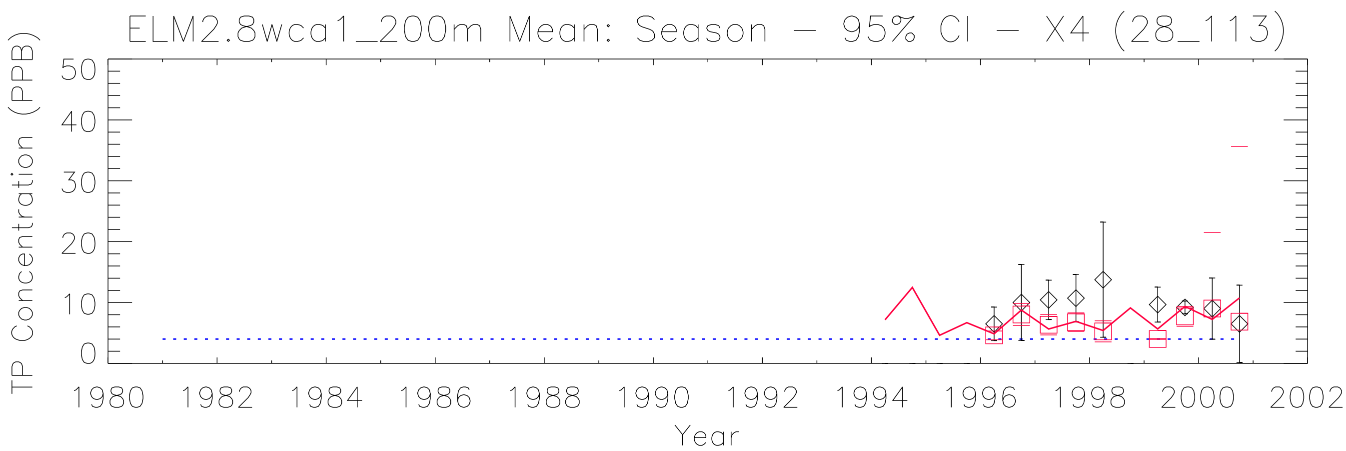

Mean: Water Year - 95% CI - X2 (13_113)
TP Concentration (PPB)
0
100
200
300
400
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

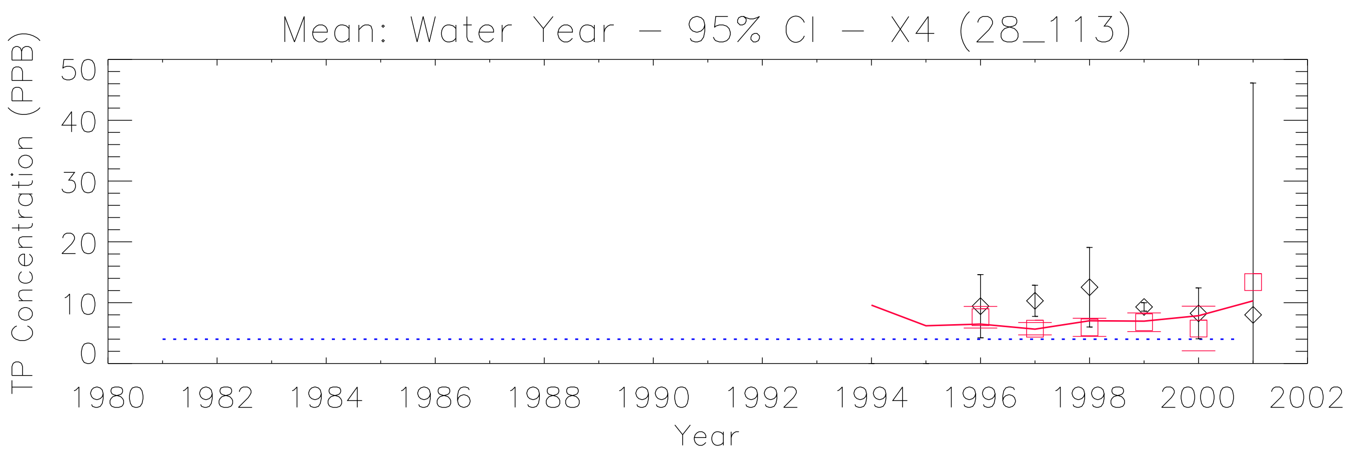

Cumulative Distribution: Raw Data - X2 (13_113)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

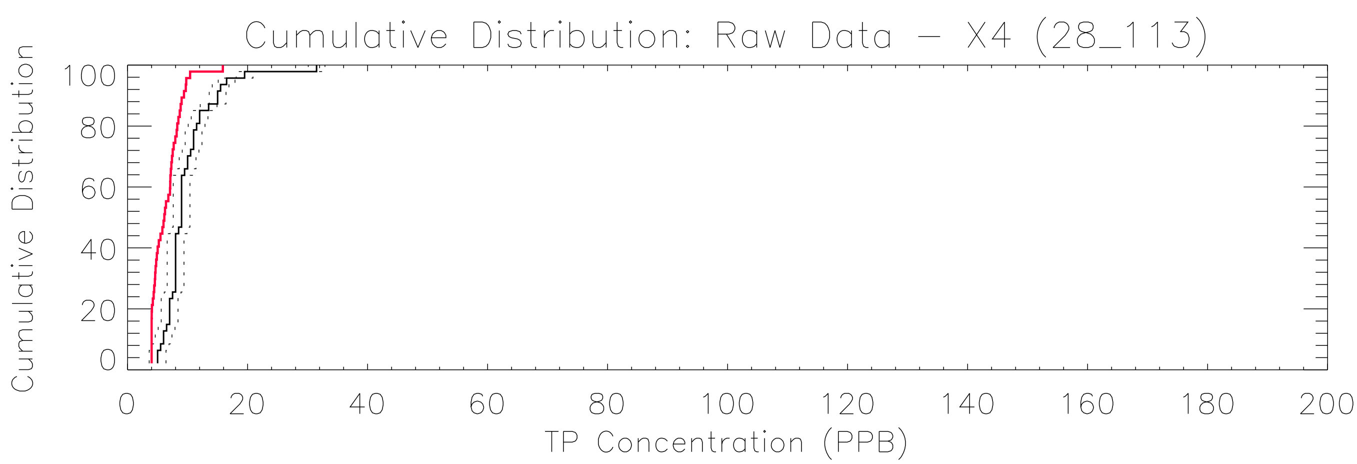

ELM2.8wca1_200m Mean: Season – 95% CI – X3 (16_116)
TP Concentration (PPB)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

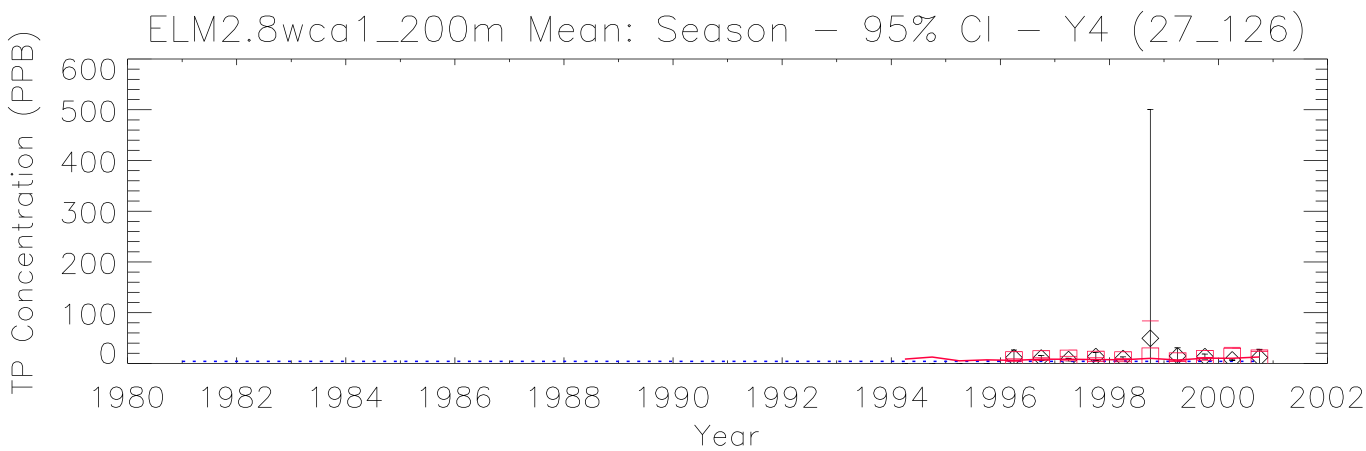

Mean: Water Year – 95% CI – X3 (16_116)
TP Concentration (PPB)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

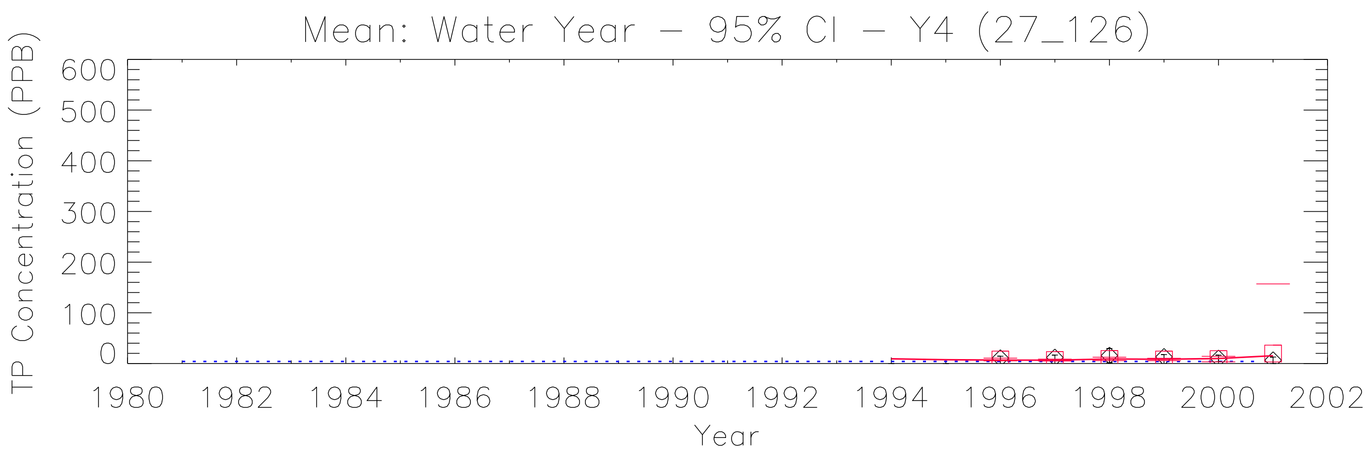

Cumulative Distribution: Raw Data – X3 (16_116)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

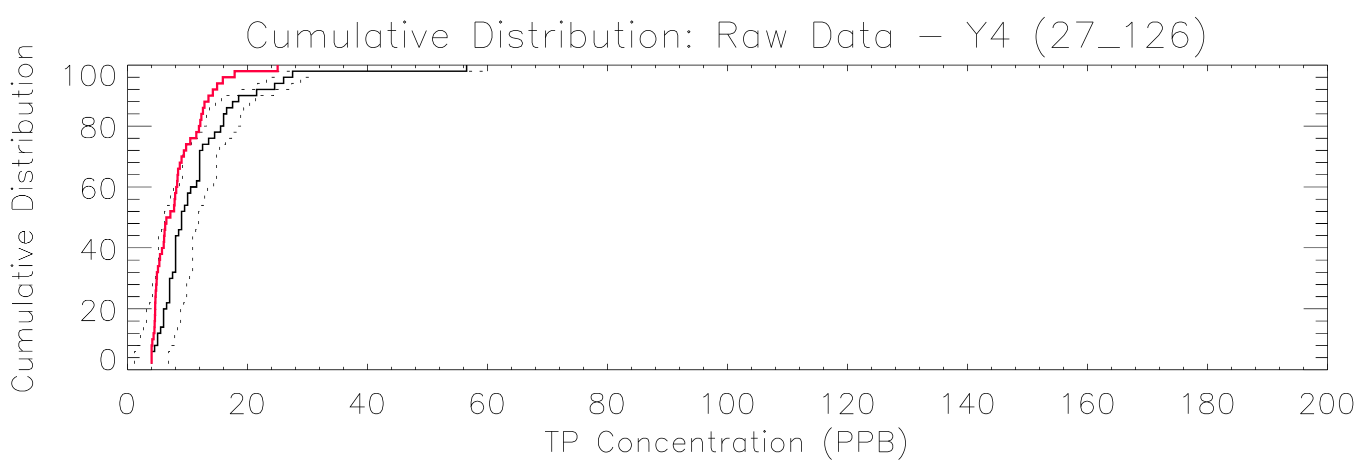

ELM2.8wca1_200m Mean: Season - 95% CI - X4 (28_113)
TP Concentration (PPB)
Year
0
10
20
30
40
50
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

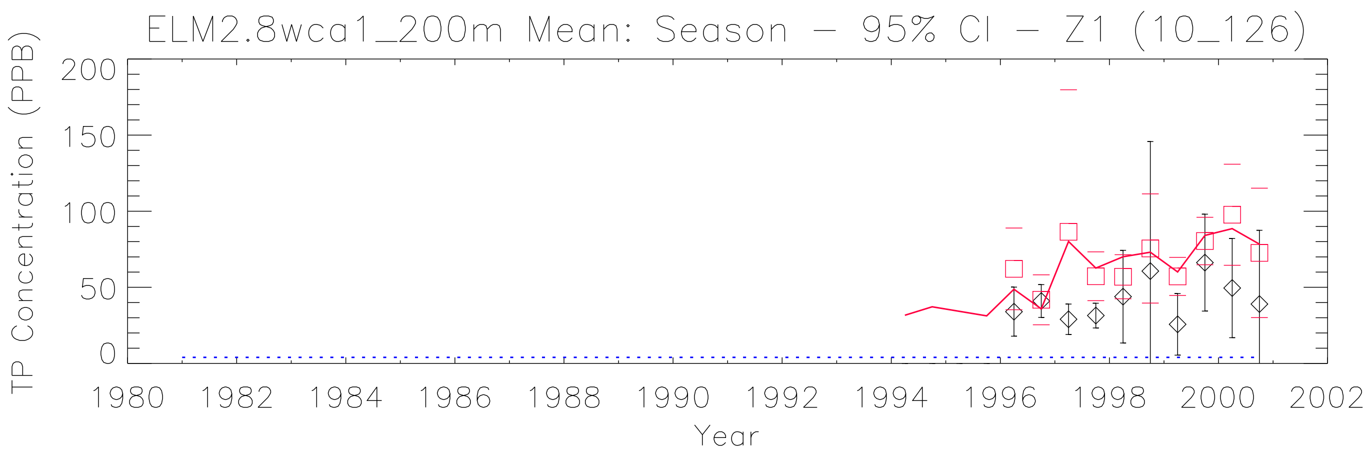

Mean: Water Year - 95% CI - X4 (28_113)
TP Concentration (PPB)
Year
0
10
20
30
40
50
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002


Cumulative Distribution: Raw Data - X4 (28_113)
Cumulative Distribution
TP Concentration (PPB)
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200

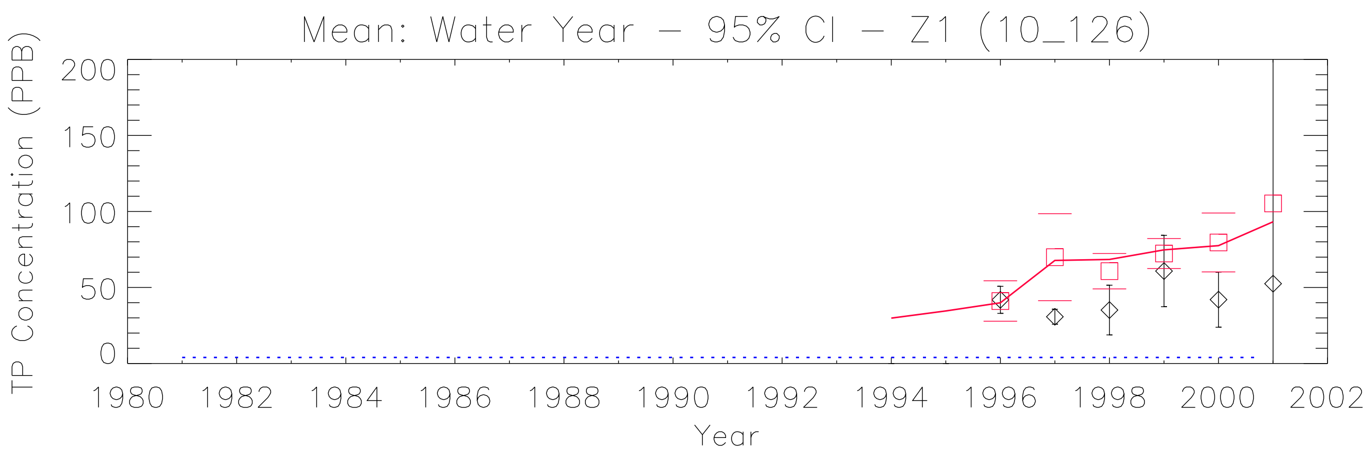

ELM2.8wca1_200m Mean: Season - 95% CI - Y4 (27_126)
TP Concentration (PPB)
600
500
400
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year - 95% CI - Y4 (27_126)
TP Concentration (PPB)
600
500
400
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

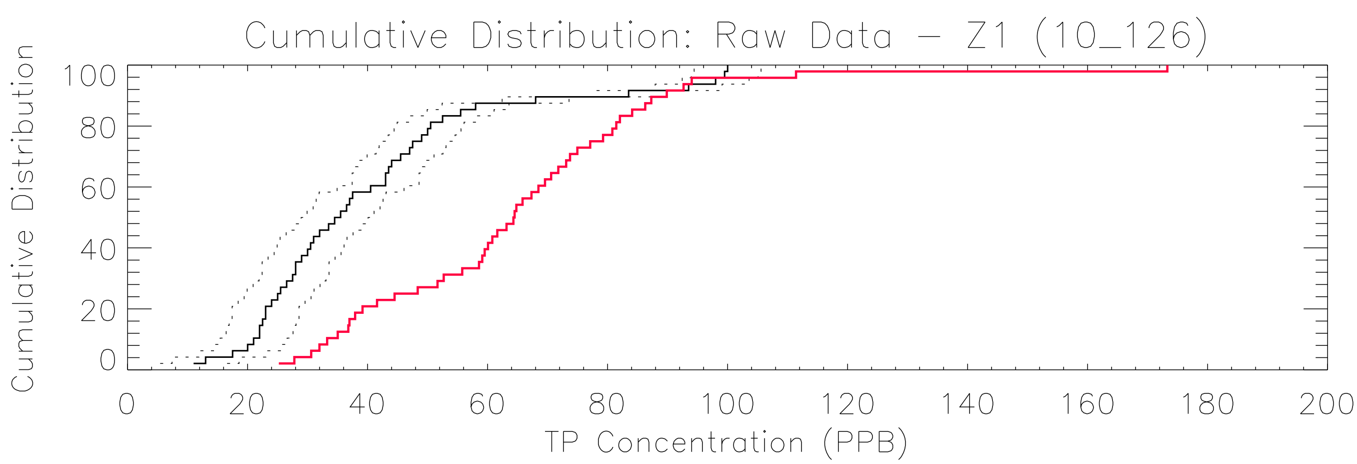

Cumulative Distribution: Raw Data - Y4 (27_126)
Cumulative Distribution
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)



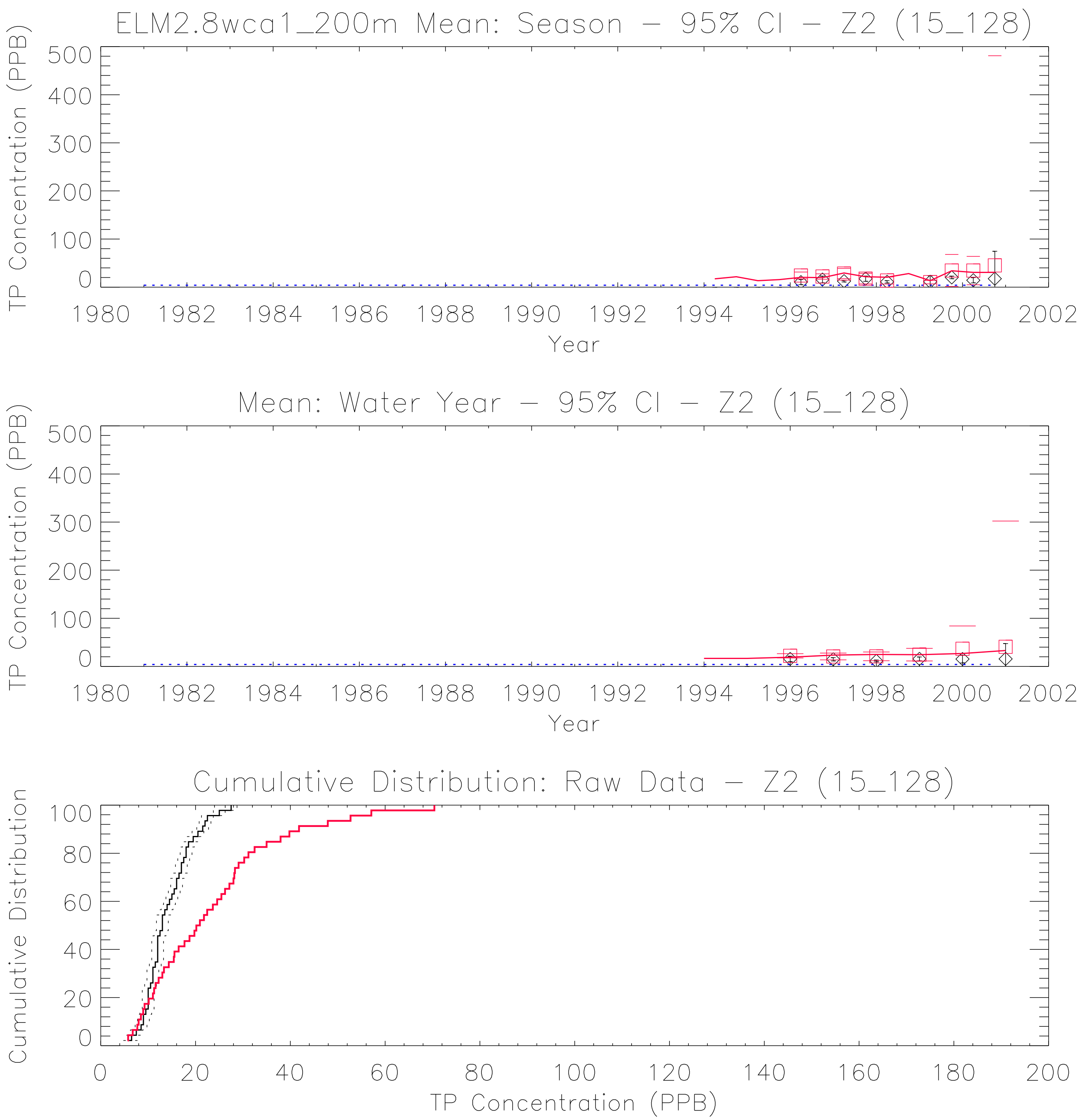
ELM2.8wca1_200m Mean: Season - 95% CI - Z1 (10_126)
TP Concentration (PPB)
Year

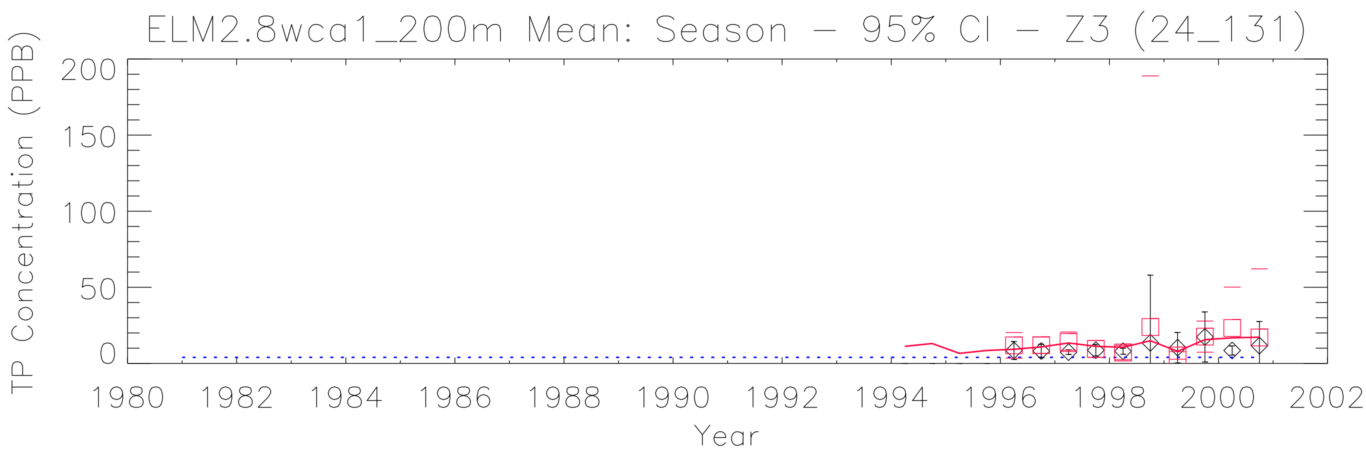


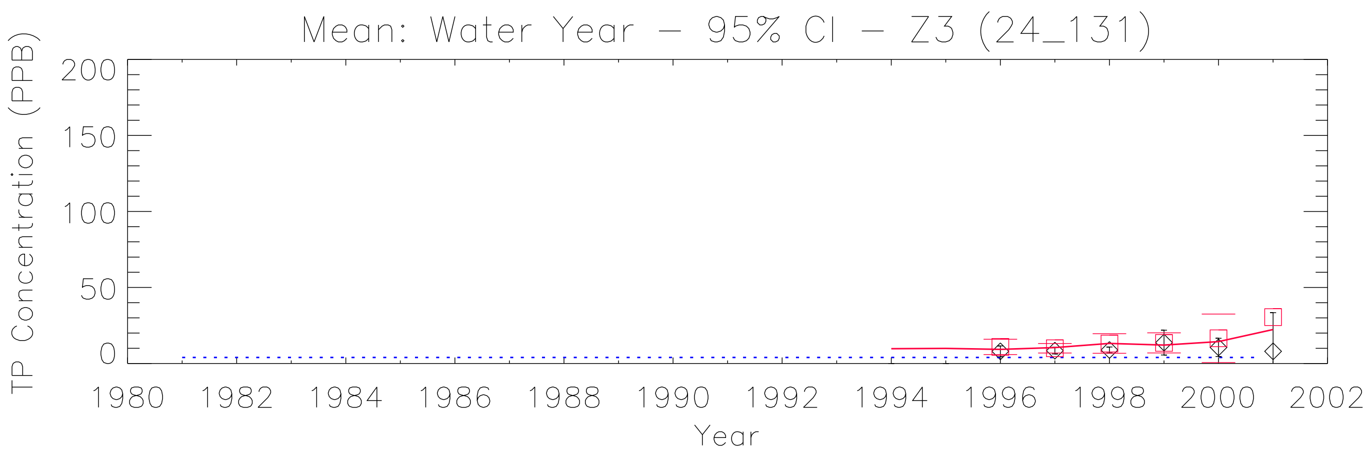
Mean: Water Year - 95% CI - Z1 (10_126)
TP Concentration (PPB)
Year

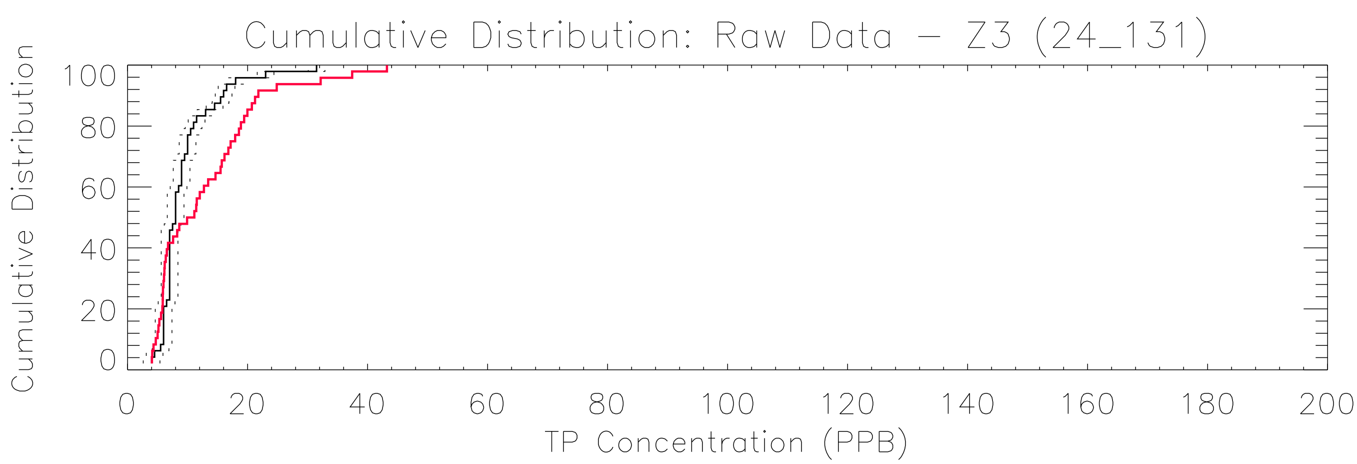


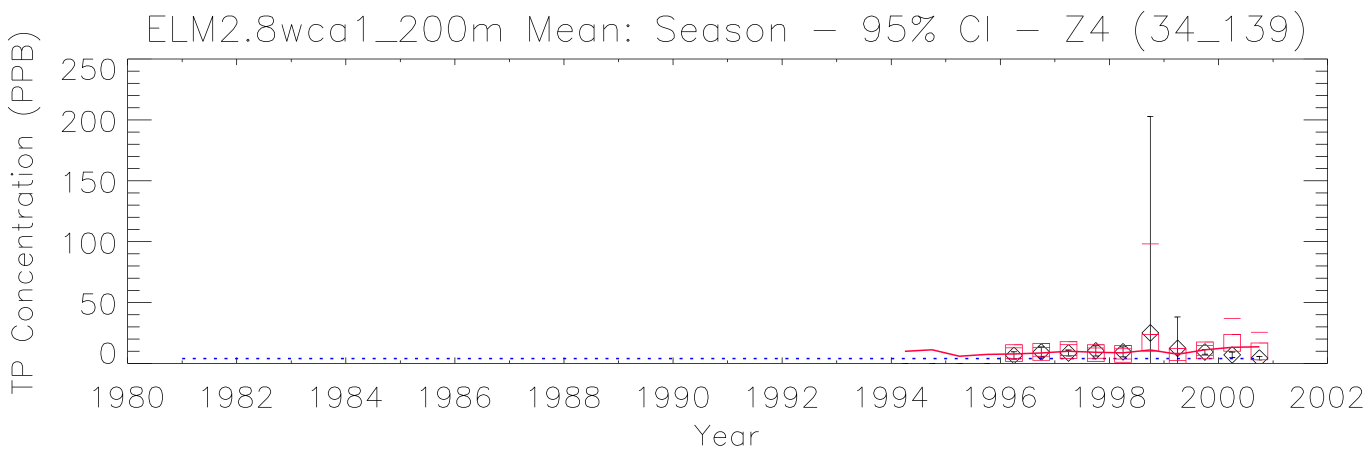
Cumulative Distribution: Raw Data - Z1 (10_126)
Cumulative Distribution
TP Concentration (PPB)

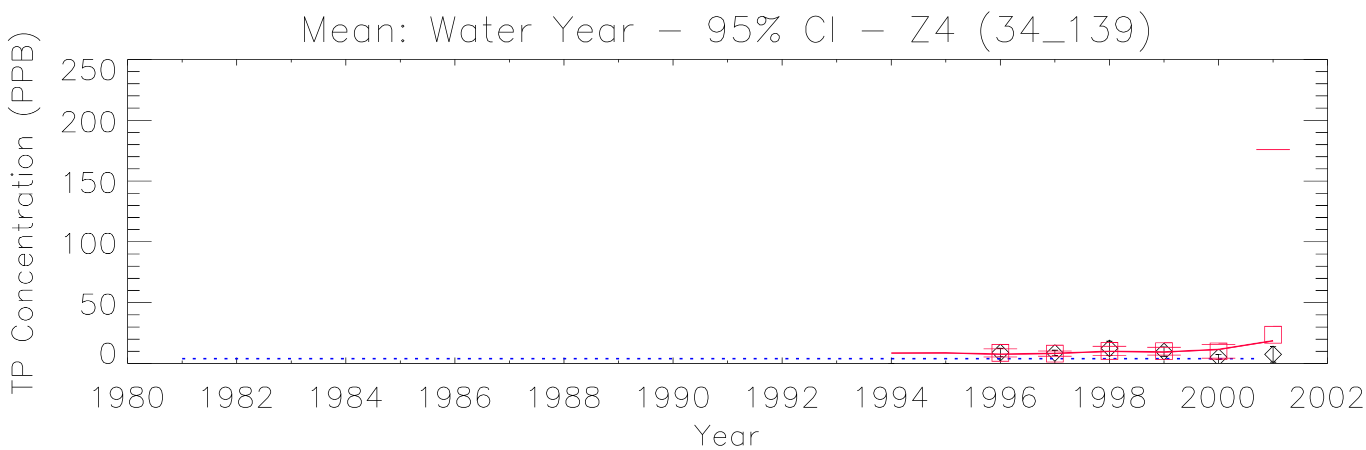

ELM2.8wca1_200m Mean: Season - 95% CI - Z2 (15_128)
TP Concentration (PPB)
Year
Mean: Water Year - 95% CI - Z2 (15_128)
TP Concentration (PPB)
Year
Cumulative Distribution: Raw Data - Z2 (15_128)
Cumulative Distribution
TP Concentration (PPB)

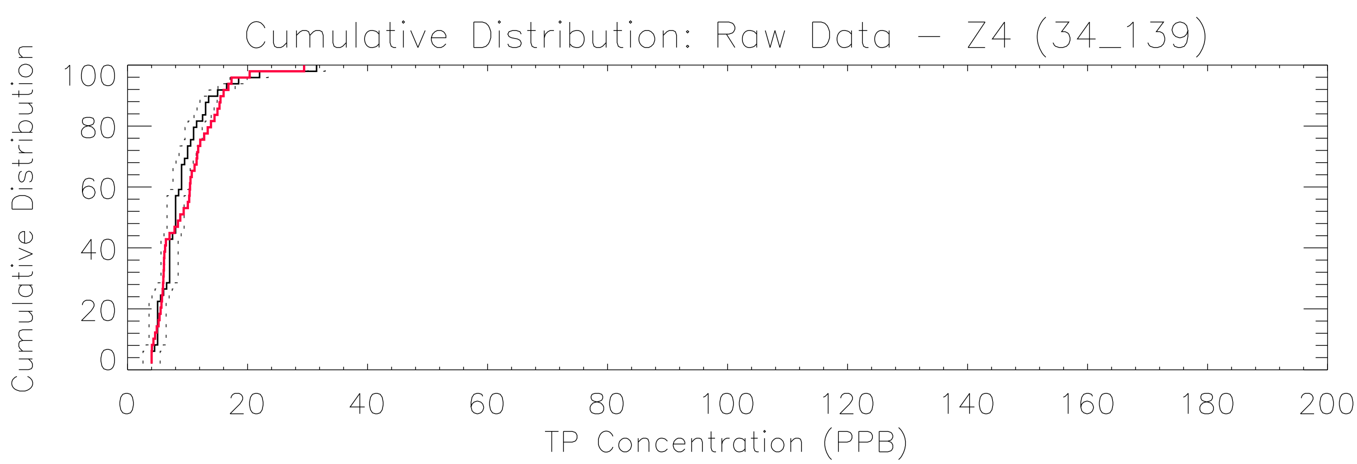

ELM2.8wca1_200m Mean: Season - 95% CI - Z3 (24_131)
TP Concentration (PPB)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

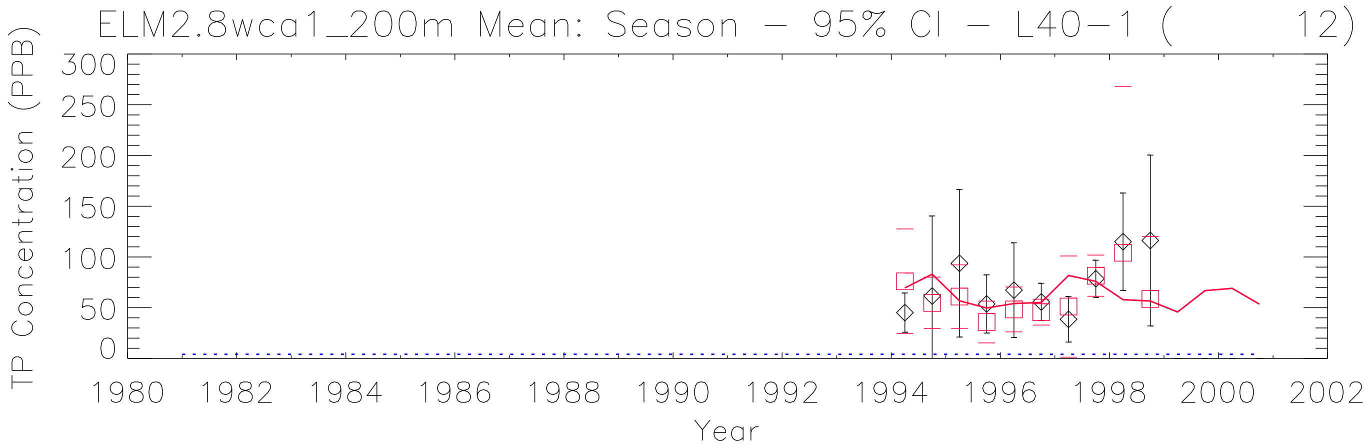

Mean: Water Year - 95% CI - Z3 (24_131)
TP Concentration (PPB)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

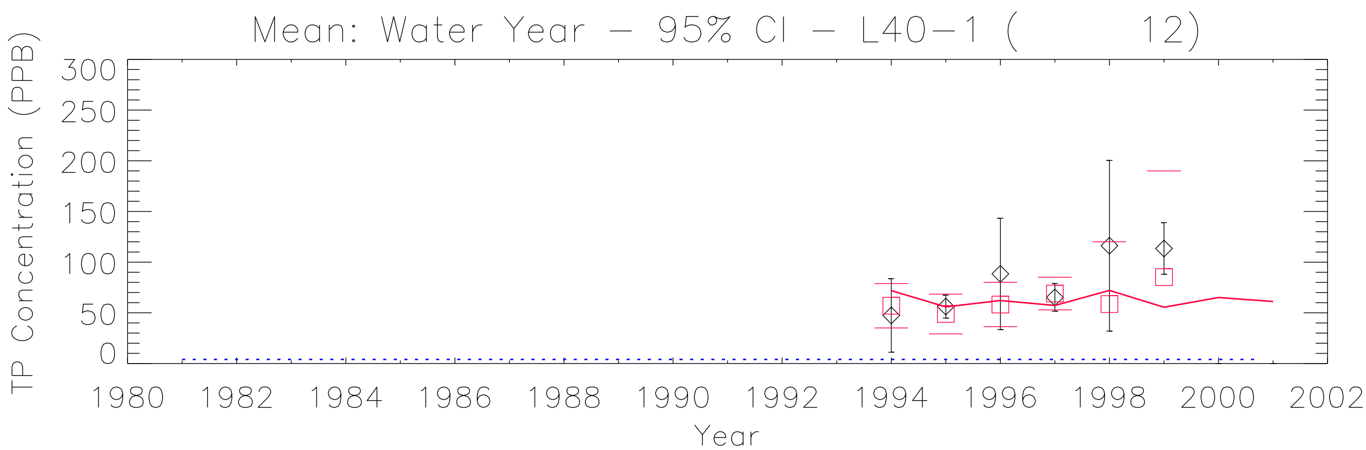

Cumulative Distribution: Raw Data - Z3 (24_131)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

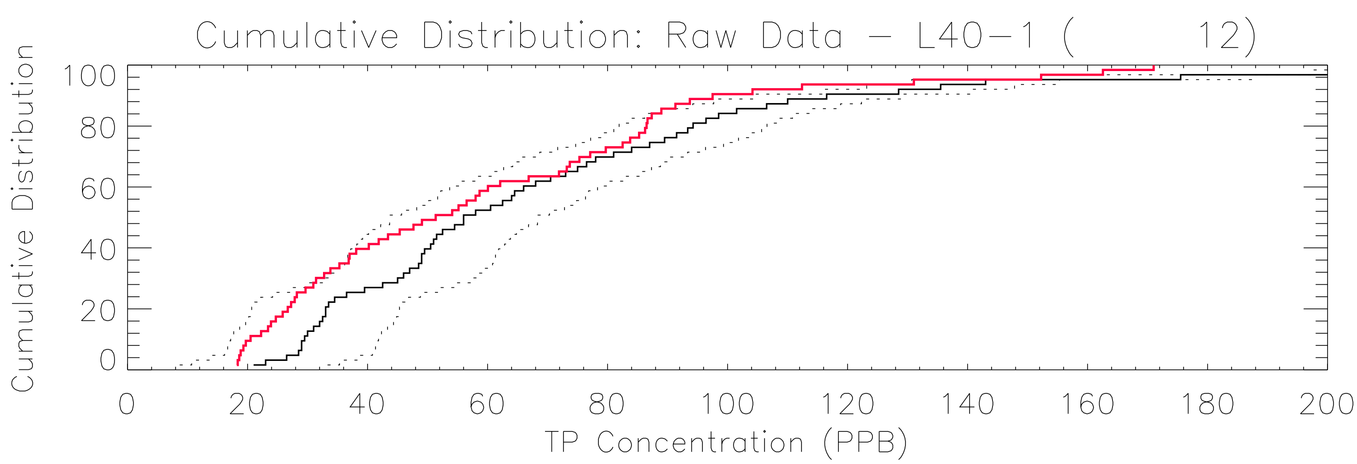

ELM2.8wca1_200m Mean: Season – 95% CI – Z4 (34_139)
TP Concentration (PPB)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

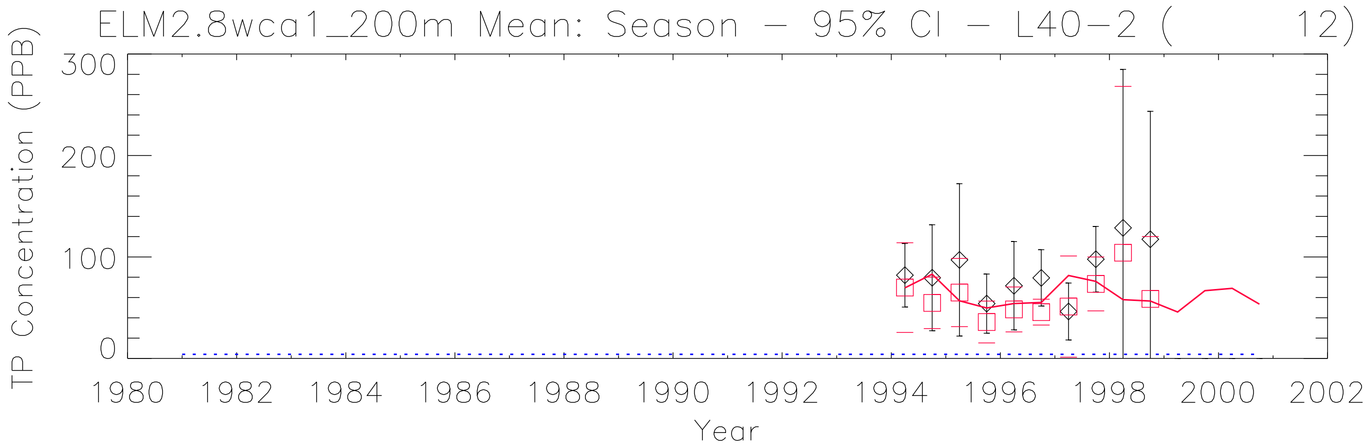

Mean: Water Year – 95% CI – Z4 (34_139)
TP Concentration (PPB)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

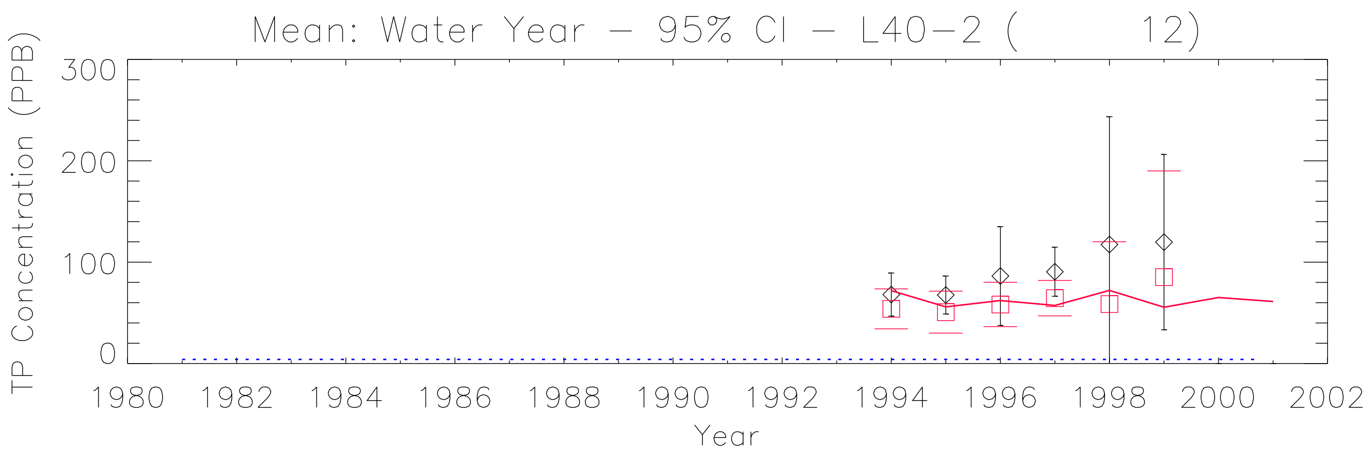

Cumulative Distribution: Raw Data – Z4 (34_139)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

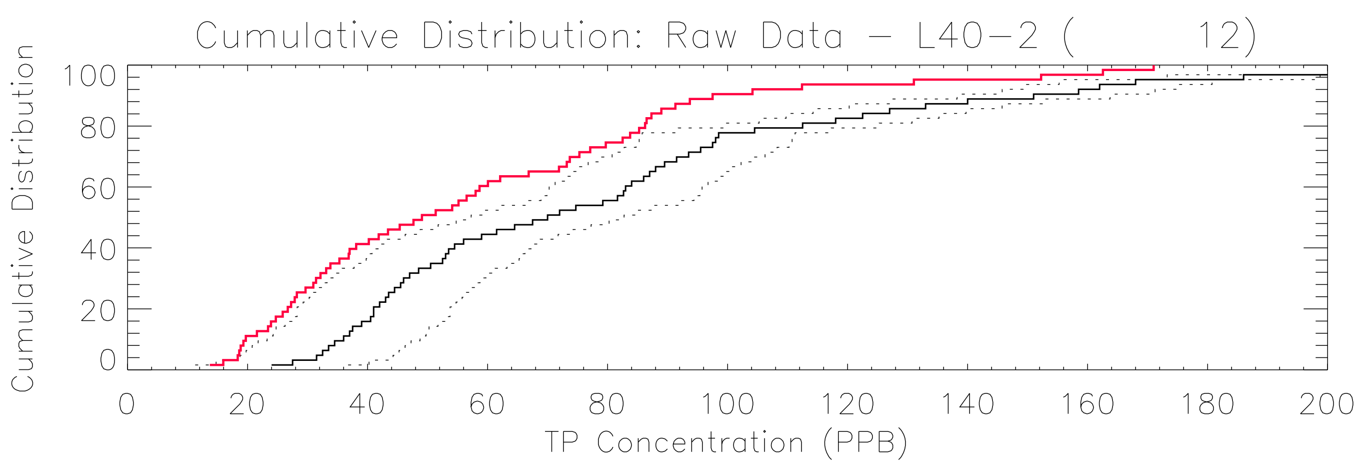

ELM2.8wca1_200m Mean: Season – 95% CI – L40–1 (12)
TP Concentration (PPB)
Year

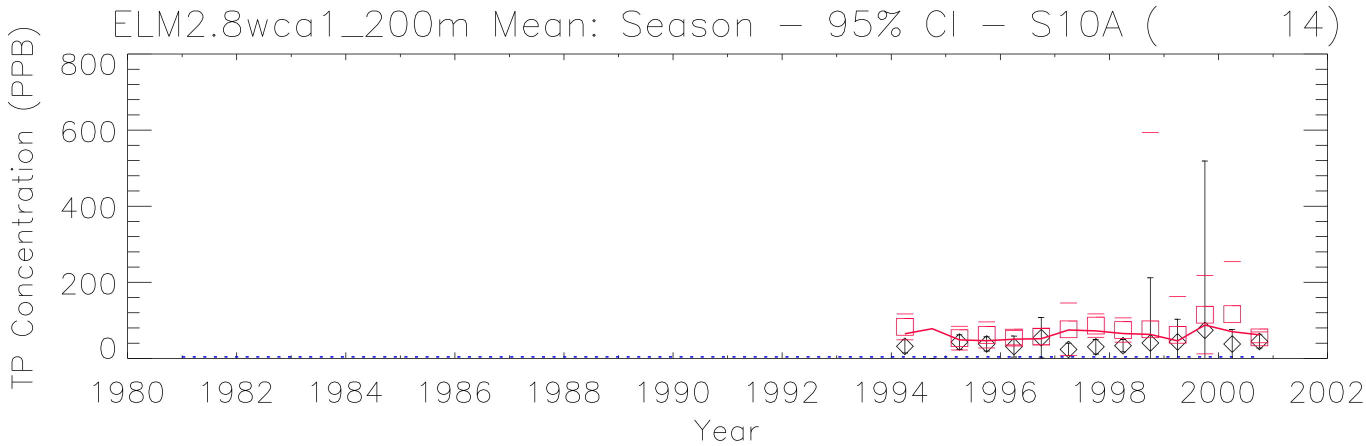

Mean: Water Year – 95% CI – L40–1 (12)
TP Concentration (PPB)
Year

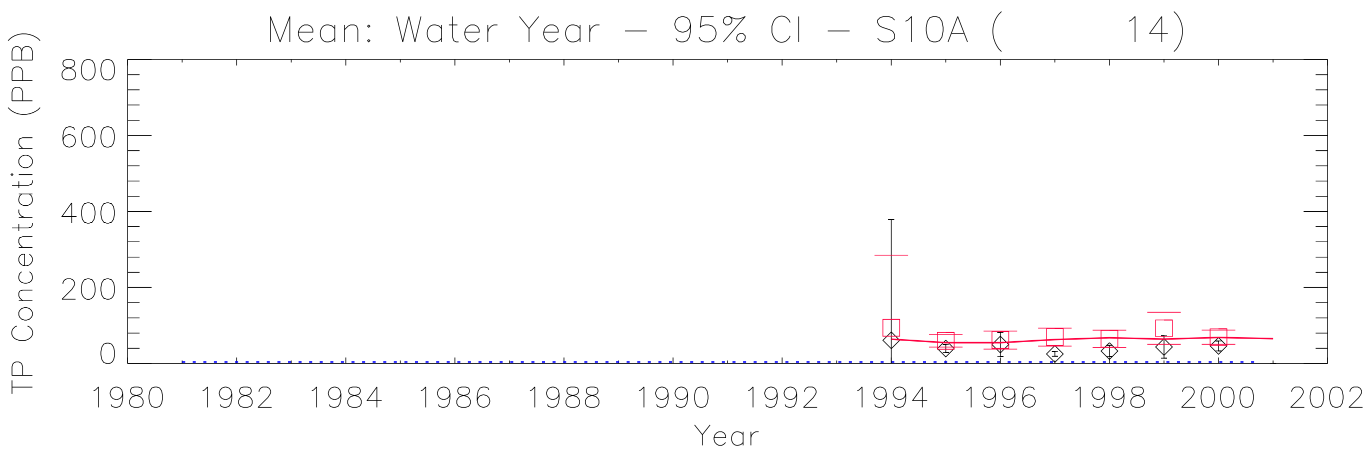

Cumulative Distribution: Raw Data – L40–1 (12)
Cumulative Distribution
TP Concentration (PPB)

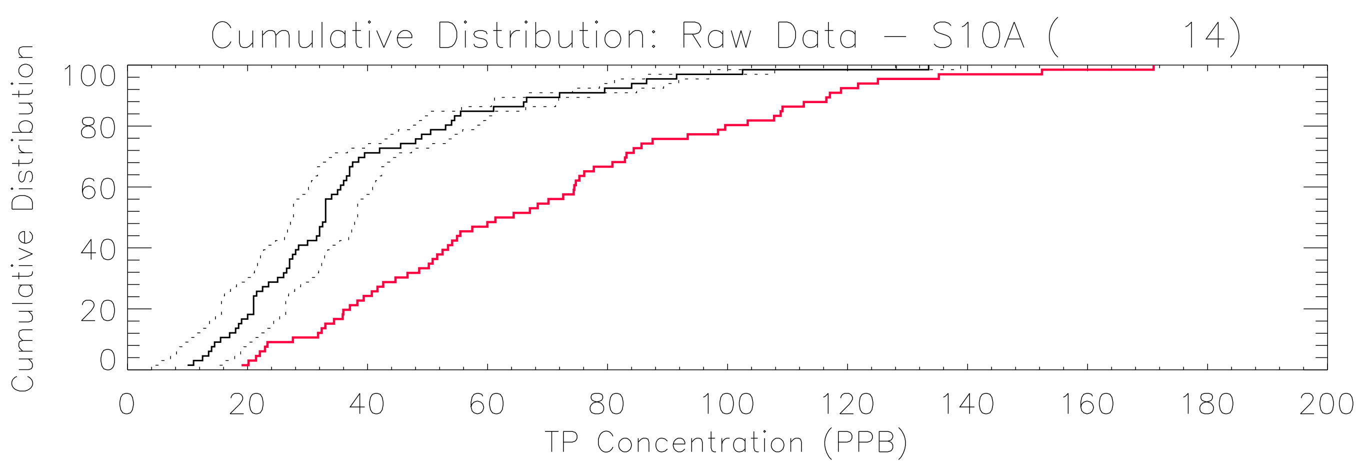

ELM2.8wca1_200m Mean: Season - 95% CI - L40-2 (12)
TP Concentration (PPB)
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

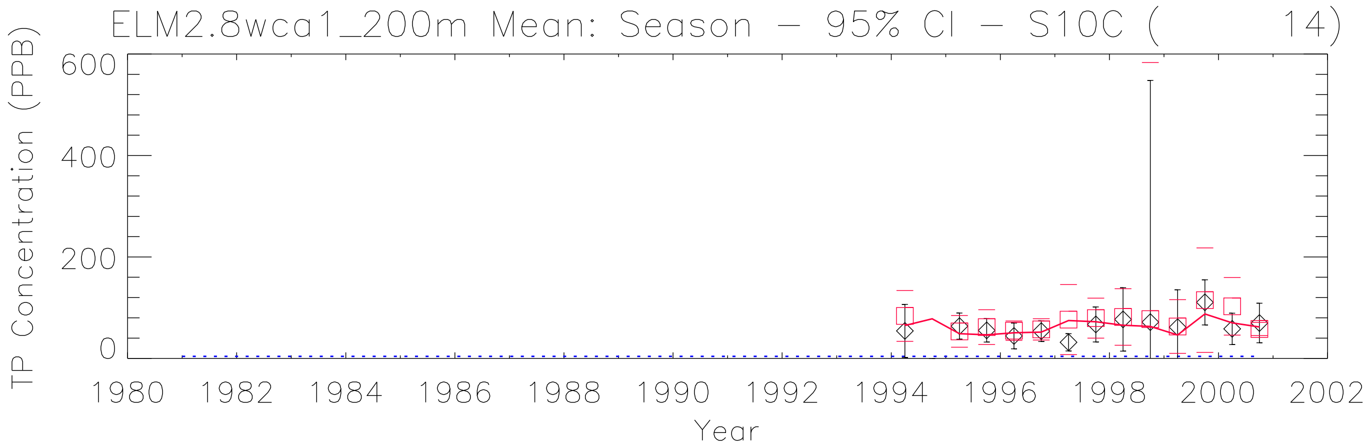

Mean: Water Year - 95% CI - L40-2 (12)
TP Concentration (PPB)
300
200
100
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

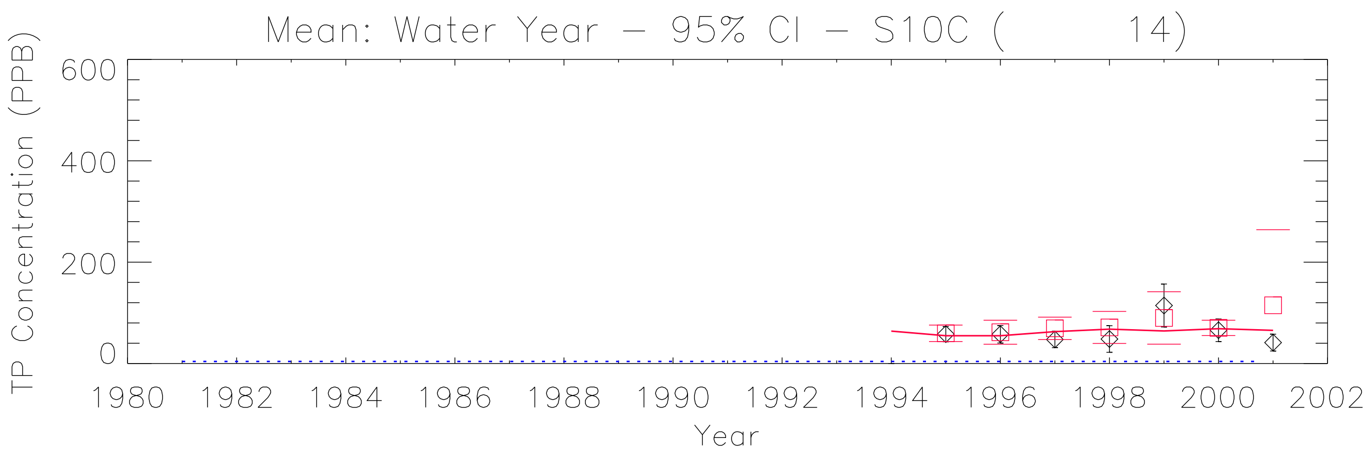

Cumulative Distribution: Raw Data - L40-2 (12)
Cumulative Distribution
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

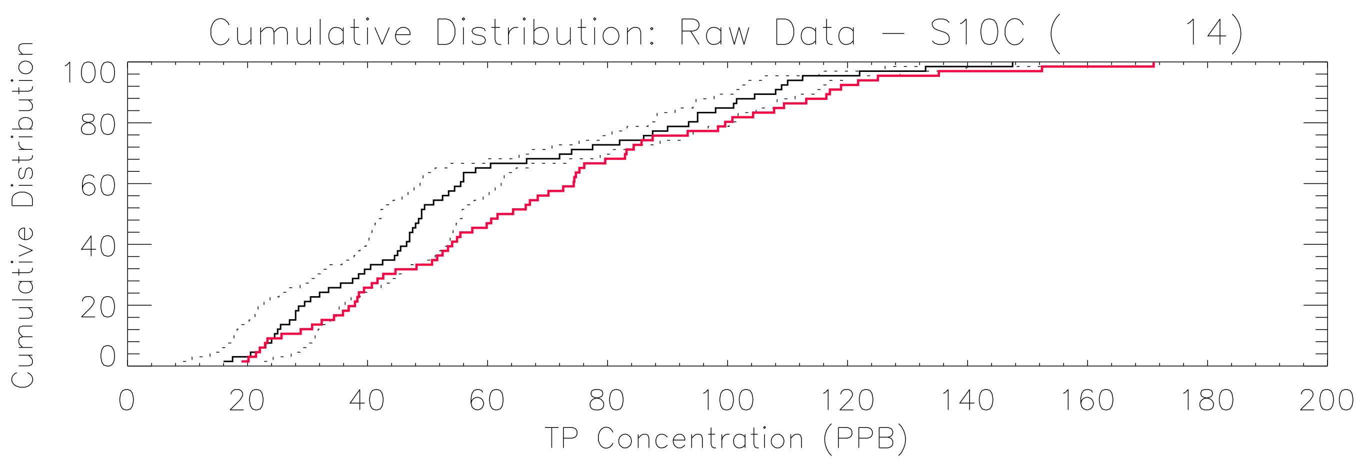

ELM2.8wca1_200m Mean: Season - 95% CI - S10A (14)
TP Concentration (PPB)
0
200
400
600
800
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

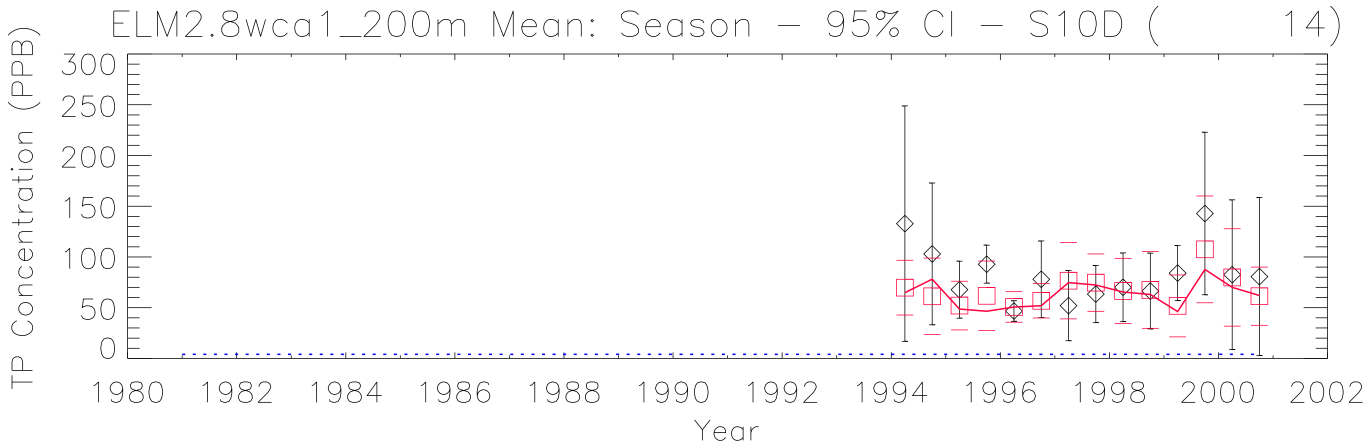

Mean: Water Year - 95% CI - S10A (14)
TP Concentration (PPB)
0
200
400
600
800
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data - S10A (14)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

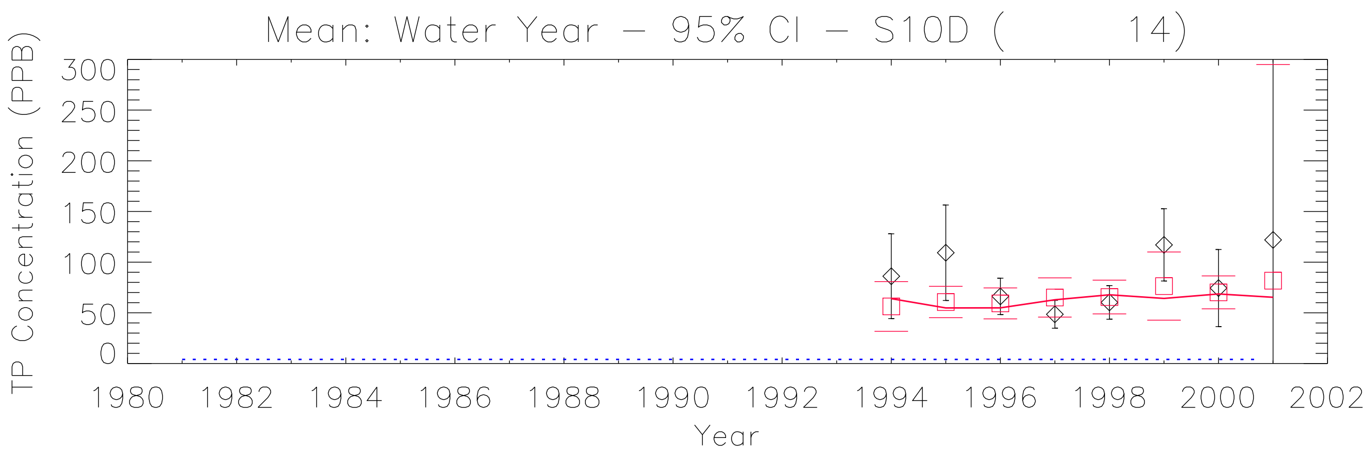

ELM2.8wca1_200m Mean: Season – 95% CI – S10C (14)
TP Concentration (PPB)
600
400
200
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – S10C (14)
TP Concentration (PPB)
600
400
200
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

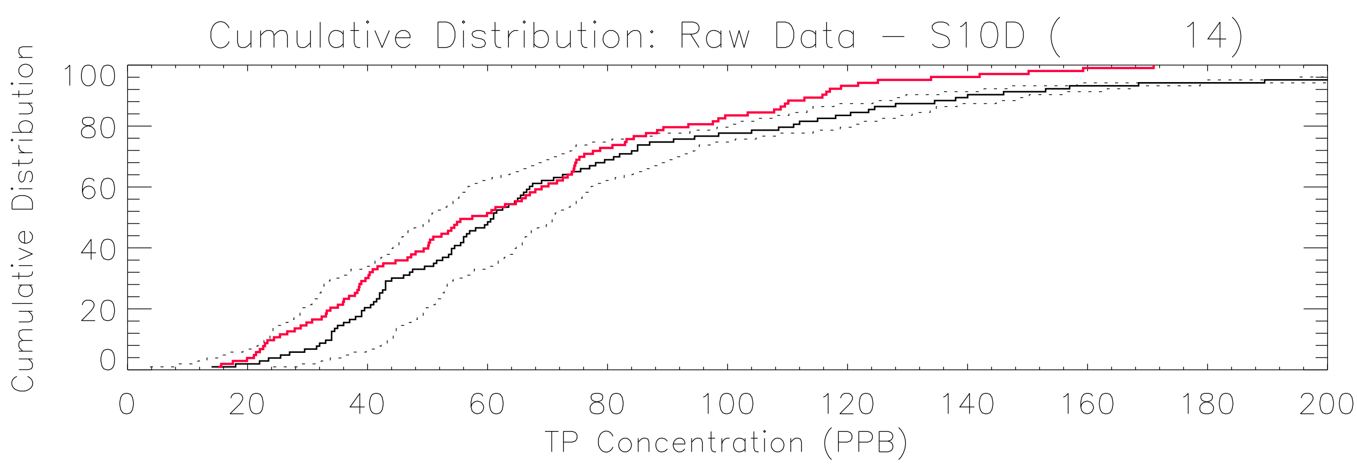

Cumulative Distribution: Raw Data – S10C (14)
Cumulative Distribution
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)



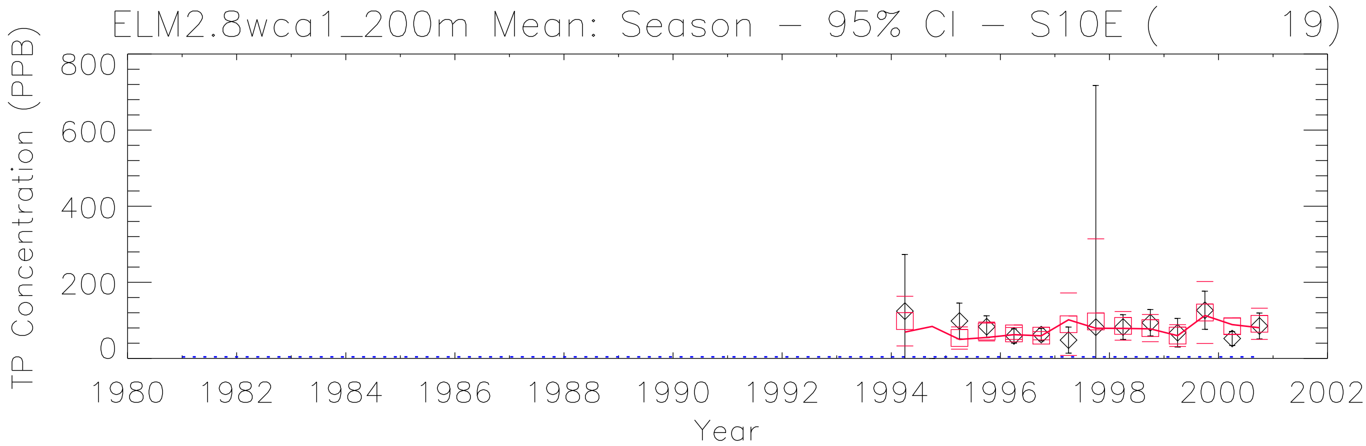
ELM2.8wca1_200m Mean: Season – 95% CI – S10D (14)
TP Concentration (PPB)
0
50
100
150
200
250
300
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

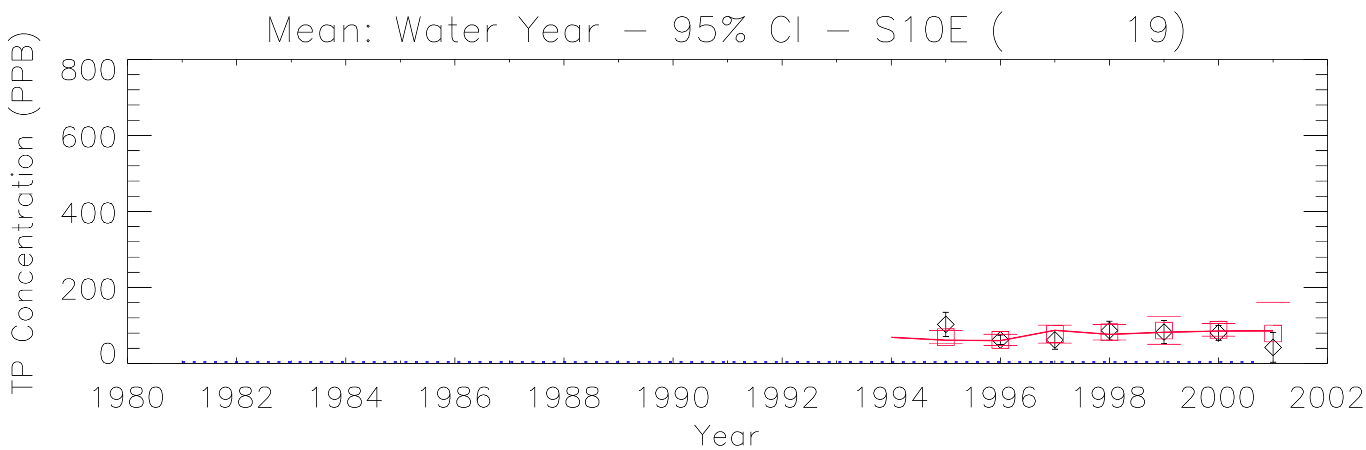


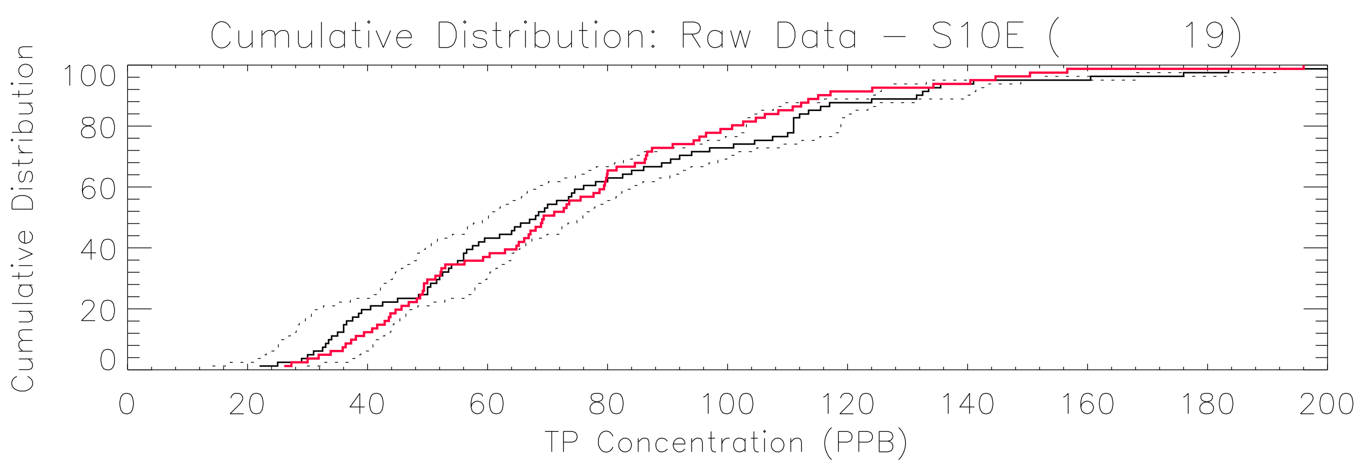
Mean: Water Year – 95% CI – S10D (14)
TP Concentration (PPB)
0
50
100
150
200
250
300
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

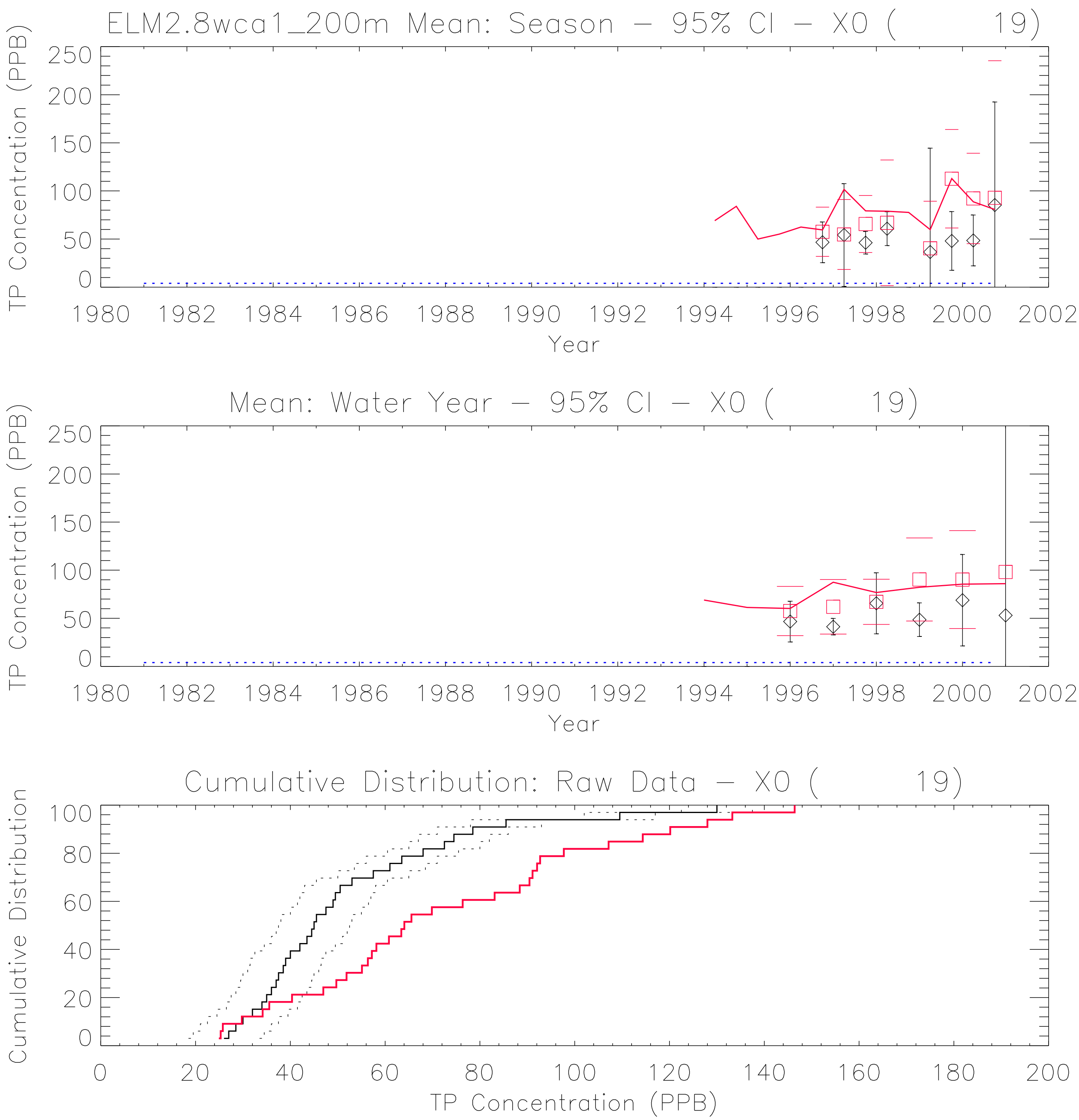


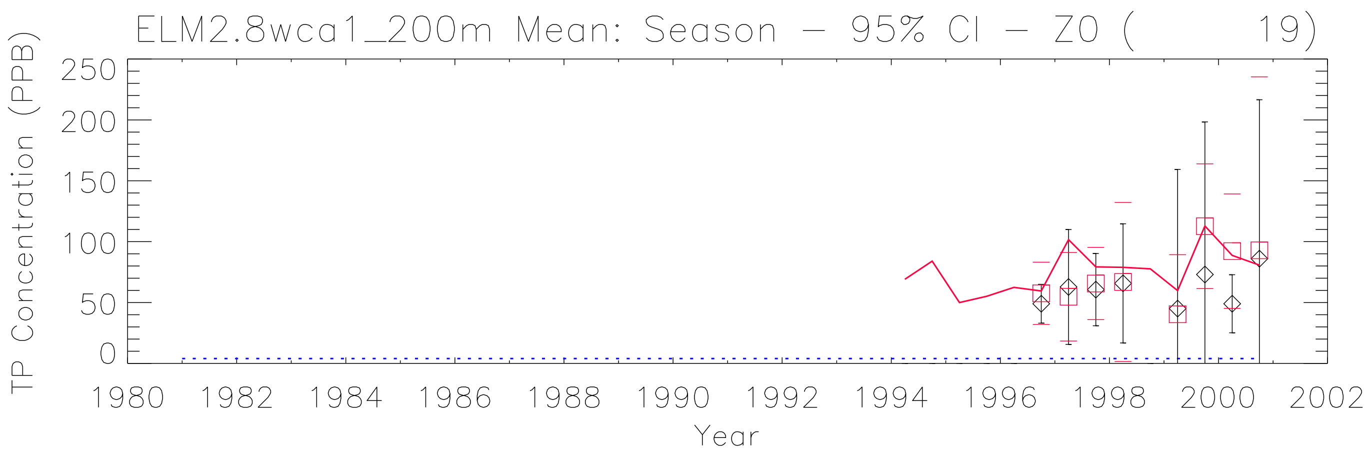
Cumulative Distribution: Raw Data – S10D (14)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

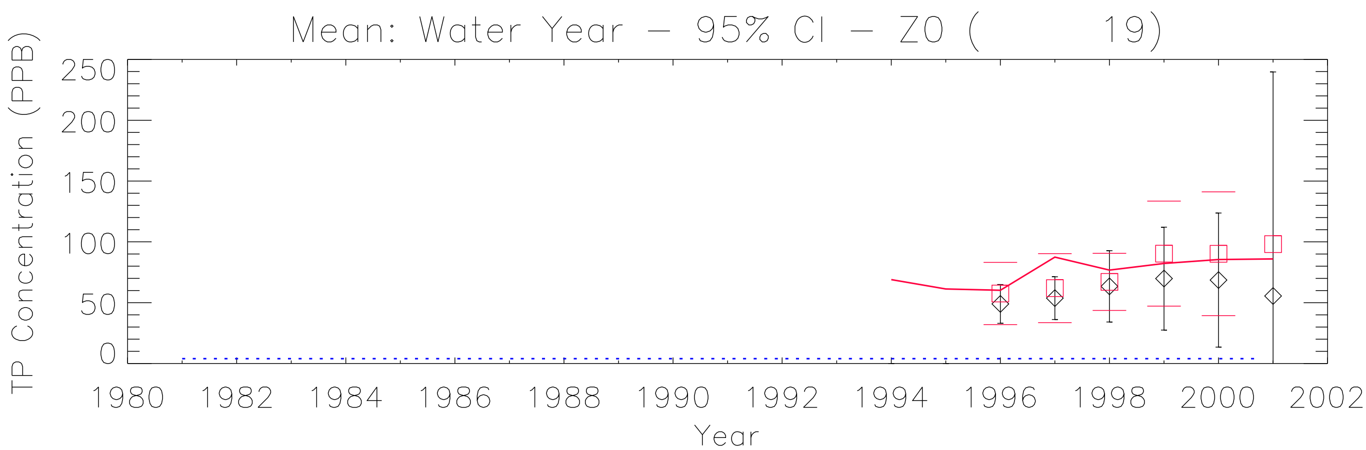

ELM2.8wca1_200m Mean: Season – 95% CI – S10E (19)
TP Concentration (PPB)
0
200
400
600
800
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

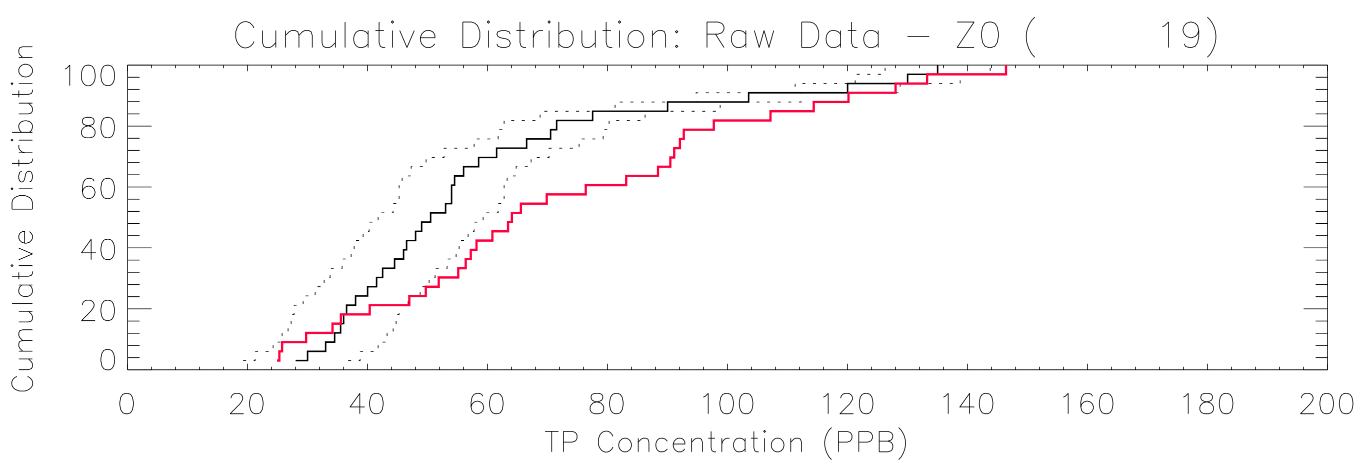

Mean: Water Year – 95% CI – S10E (19)
TP Concentration (PPB)
0
200
400
600
800
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data – S10E (19)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)


ELM2.8wca1_200m Mean: Season – 95% CI – X0 (19)
TP Concentration (PPB)
Year
Mean: Water Year – 95% CI – X0 (19)
TP Concentration (PPB)
Year
Cumulative Distribution: Raw Data – X0 (19)
Cumulative Distribution
TP Concentration (PPB)


ELM2.8wca1_200m Mean: Season - 95% CI - Z0 (19)
TP Concentration (PPB)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year - 95% CI - Z0 (19)
TP Concentration (PPB)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data - Z0 (19)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
TP Concentration (PPB)

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 1994-2000 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.

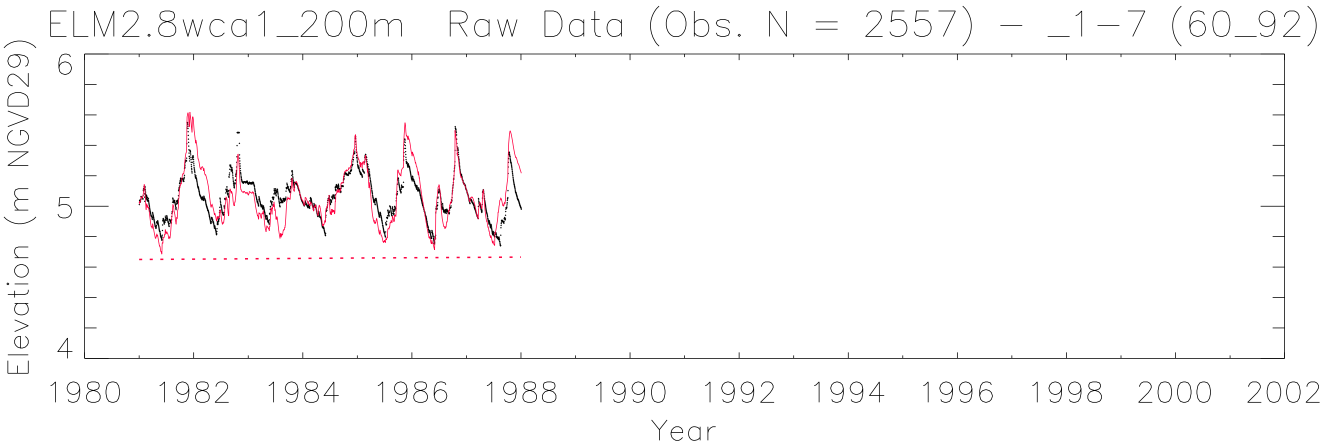
The red dashed line in the stage hydrographs is the model grid cell's land surface elevation, which is a time-varying output variable of the model. The model grid cell column and row locations are shown in parentheses (col_row) of each plot's title.

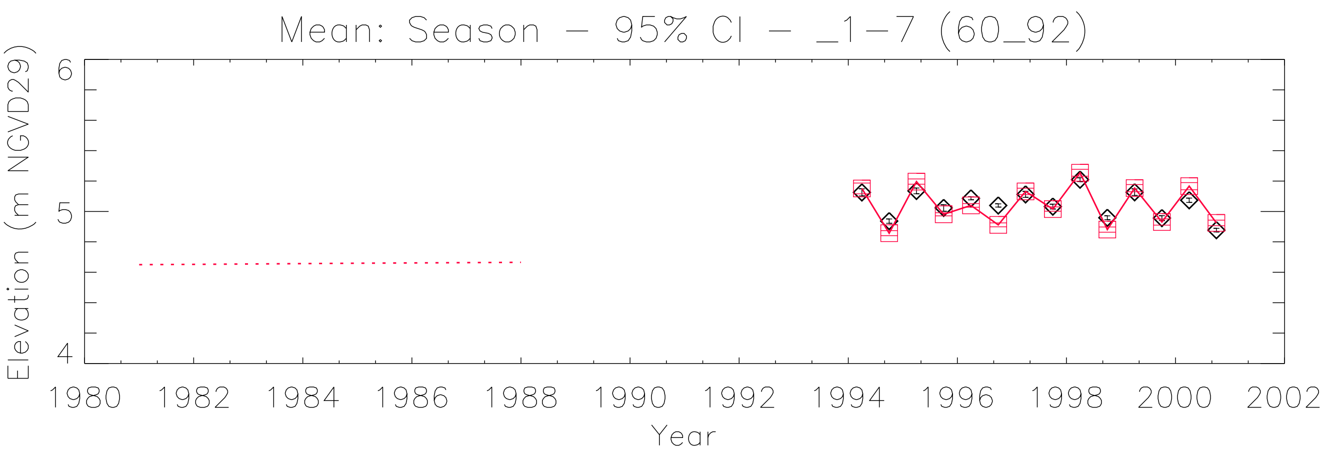
a) All data, with no temporal aggregation, of daily observations (black dots) and model results (red line).

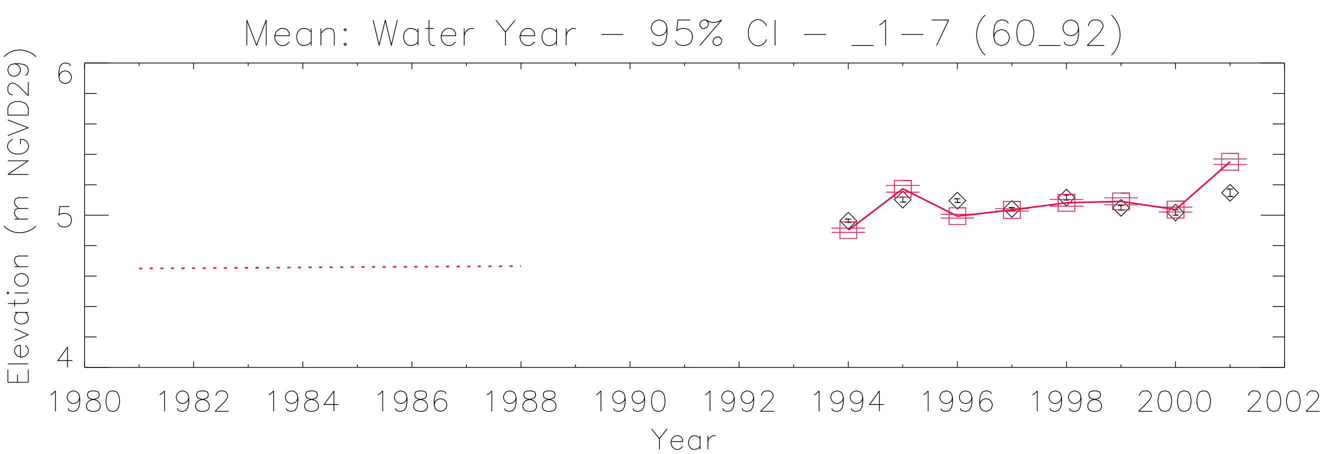
b) All data were aggregated into arithmetic mean values by wet and dry seasons within water years; the continuous lines pass through mean of all daily data points for each season; the mean of paired simulated & observed values are shown in red boxes and black diamonds, respectively; the 95% Confidence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

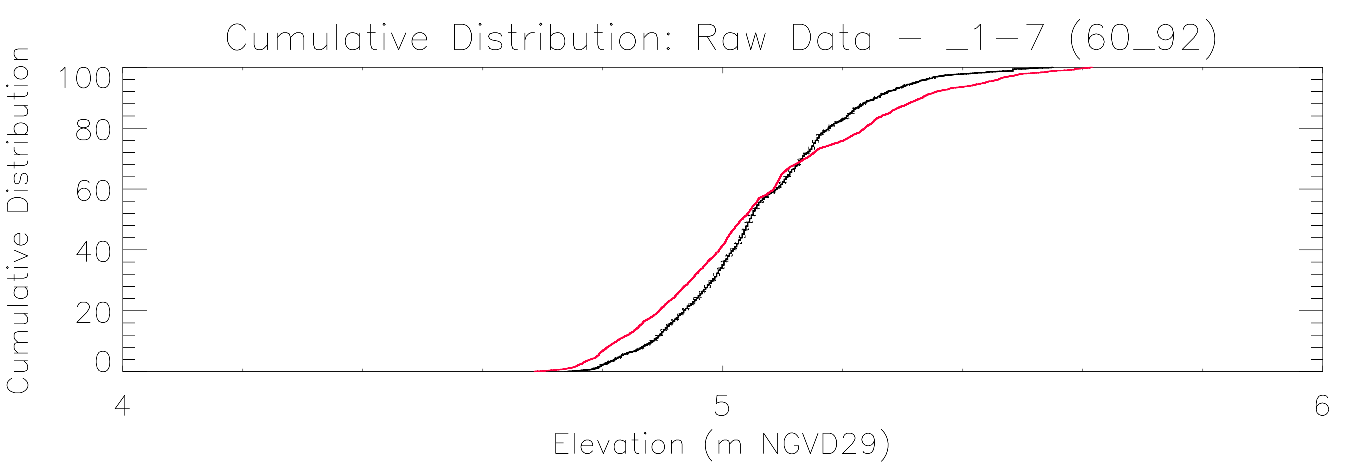
c) All data aggregated into arithmetic mean values by water year, with the same treatment as in plot b).

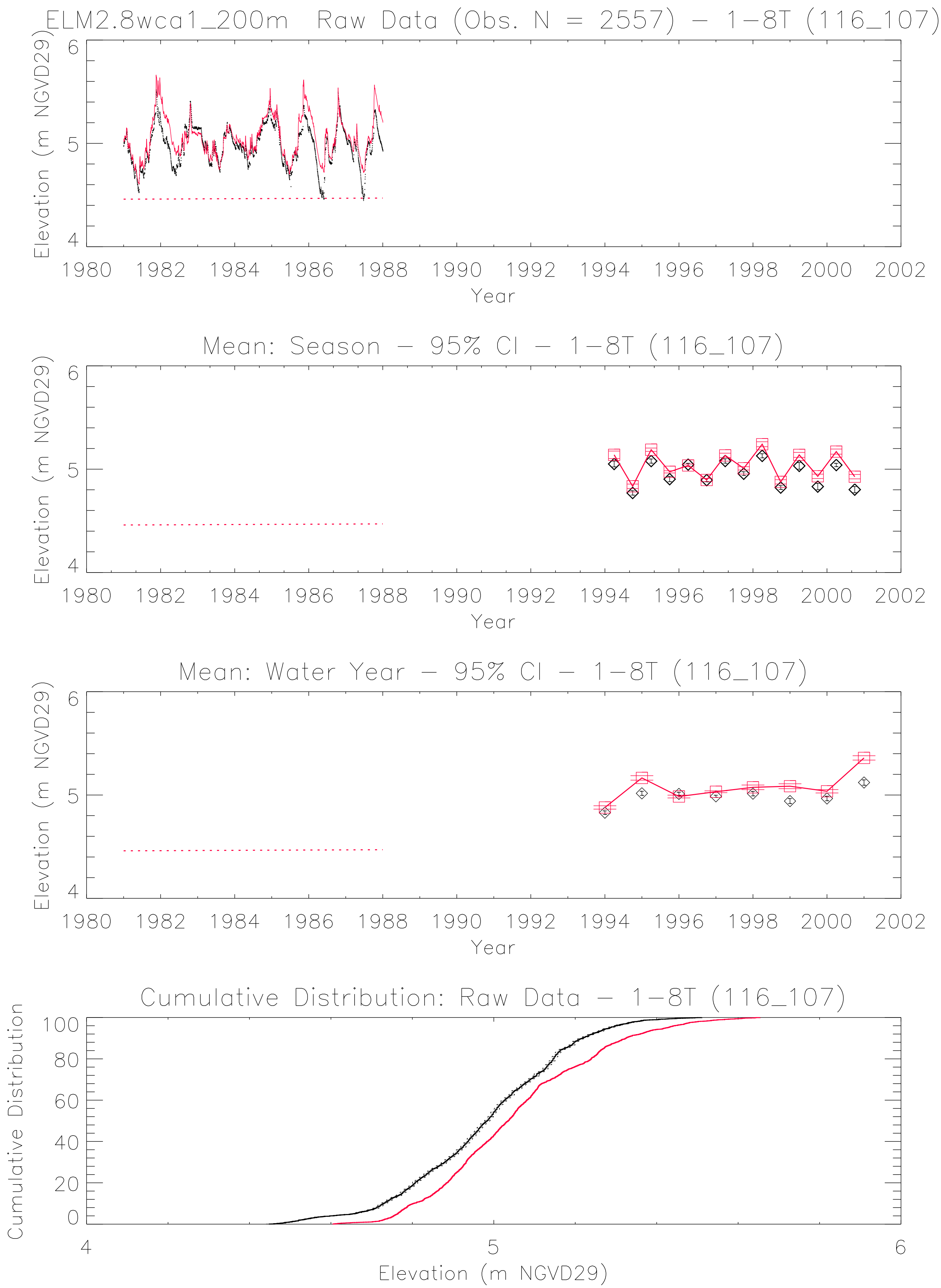
d) The cumulative frequency distributions of the simulated and observed (raw, un-aggregated) data; the 95% confidence interval for observed data is shown in the dashed black lines. Note that only paired simulated and observed data points are used.

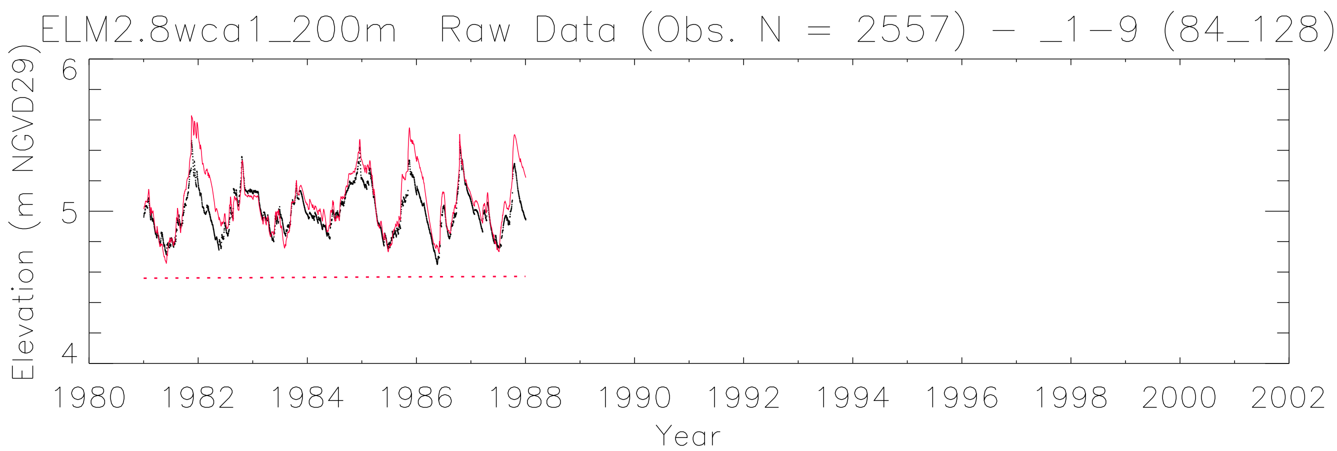

ELM2.8wca1_200m Raw Data (Obs. N = 2557) – _1–7 (60_92)
Elevation (m NGVD29)
6
5
4
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

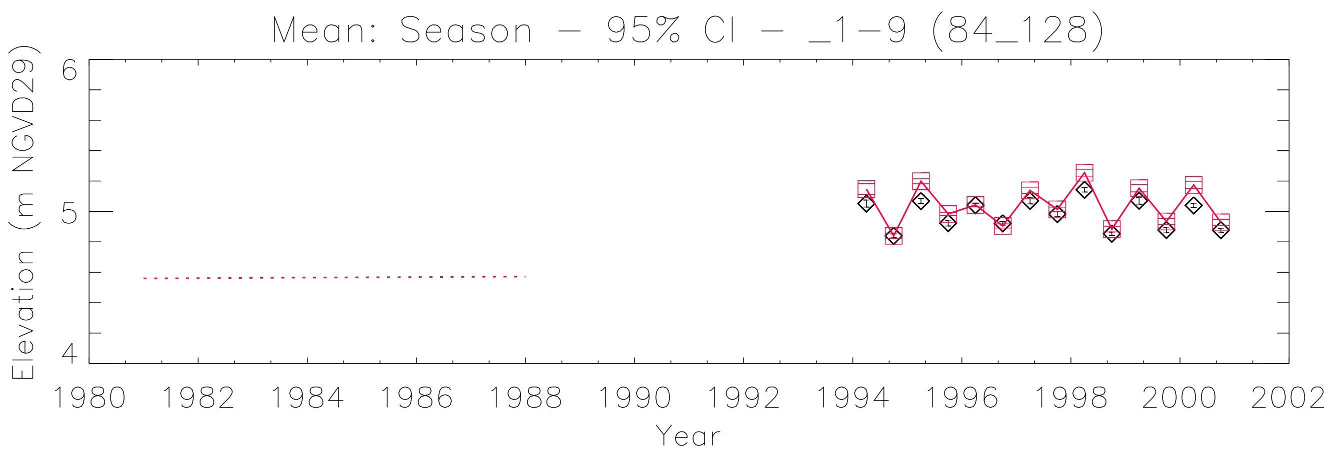

Mean: Season – 95% CI – _1–7 (60_92)
Elevation (m NGVD29)
6
5
4
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

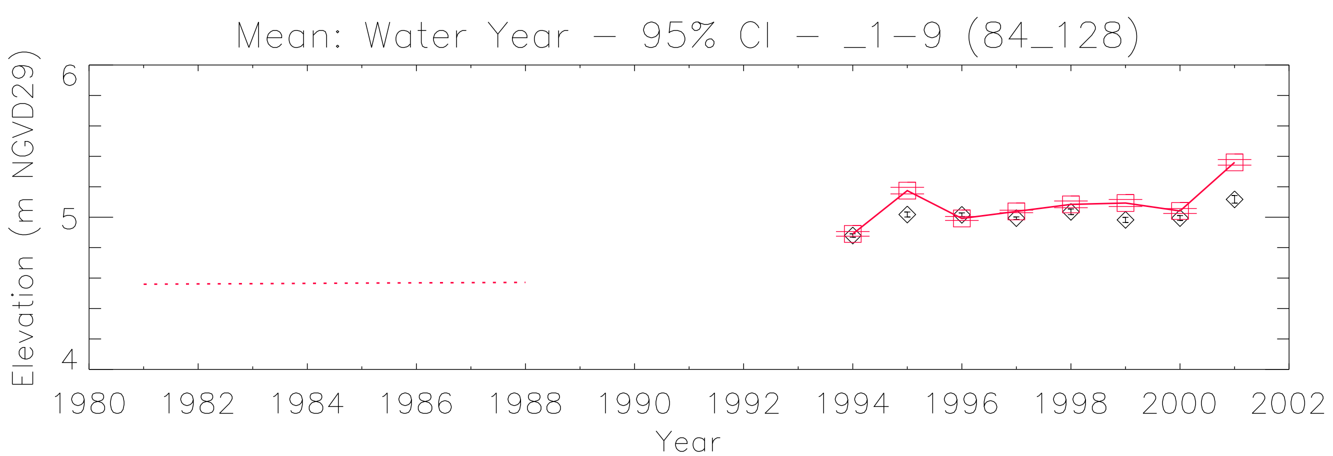

Mean: Water Year – 95% CI – _1–7 (60_92)
Elevation (m NGVD29)
6
5
4
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

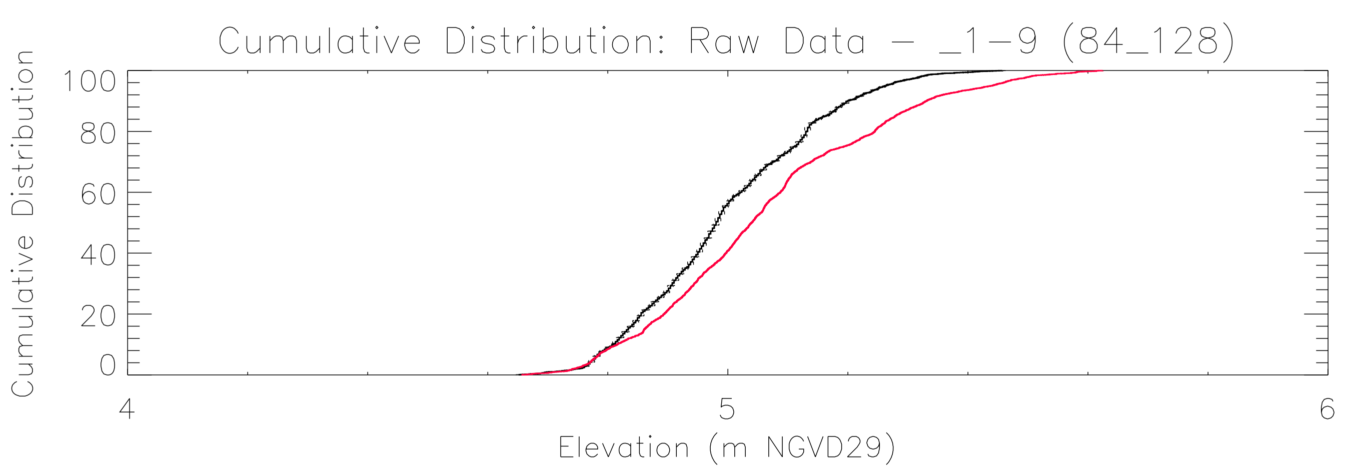

Cumulative Distribution: Raw Data – _1–7 (60_92)
Cumulative Distribution
100
80
60
40
20
0
4
5
6
Elevation (m NGVD29)


ELM2.8wca1_200m Raw Data (Obs. N = 2557) – 1–8T (116_107)
Elevation (m NGVD29)
Year
Mean: Season – 95% CI – 1–8T (116_107)
Elevation (m NGVD29)
Year
Mean: Water Year – 95% CI – 1–8T (116_107)
Elevation (m NGVD29)
Year
Cumulative Distribution: Raw Data – 1–8T (116_107)
Cumulative Distribution
Elevation (m NGVD29)


ELM2.8wca1_200m Raw Data (Obs. N = 2557) - _1-9 (84_128)
Elevation (m NGVD29)
Year


Mean: Season - 95% CI - _1-9 (84_128)
Elevation (m NGVD29)
Year


Mean: Water Year - 95% CI - _1-9 (84_128)
Elevation (m NGVD29)
Year


Cumulative Distribution: Raw Data - _1-9 (84_128)
Cumulative Distribution
Elevation (m NGVD29)

6.9 Appendix C: Time series & CFDs: CL

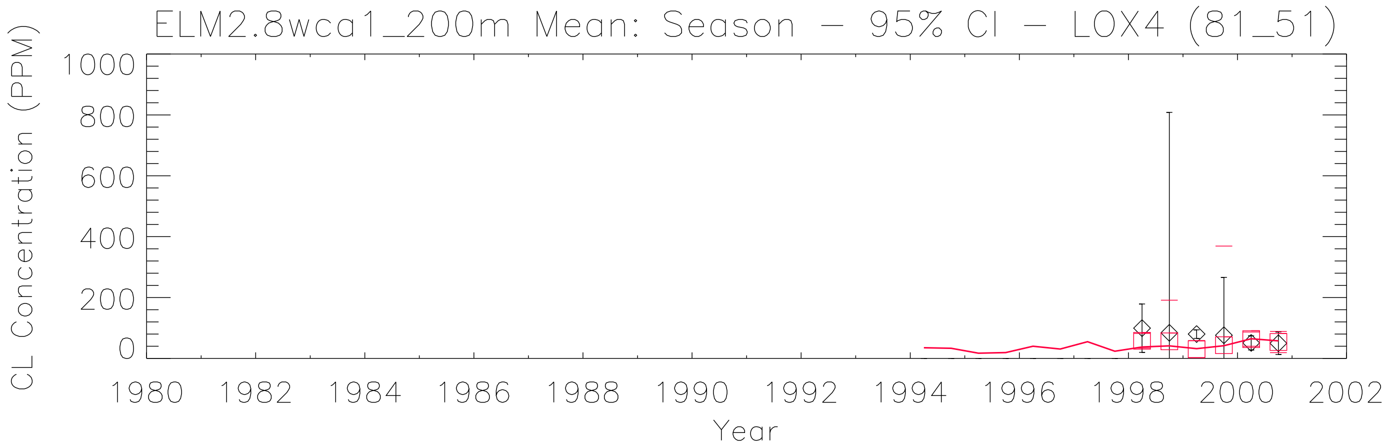
Figures C.1 – C.32. Time series plots of water column chloride (CL) concentration and their associated Cumulative Frequency Distributions (CFD) for the period of record 1994-2000 at each monitoring location. The sequence of the figures is based on geographic location of marsh sites, starting in northwest, 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.

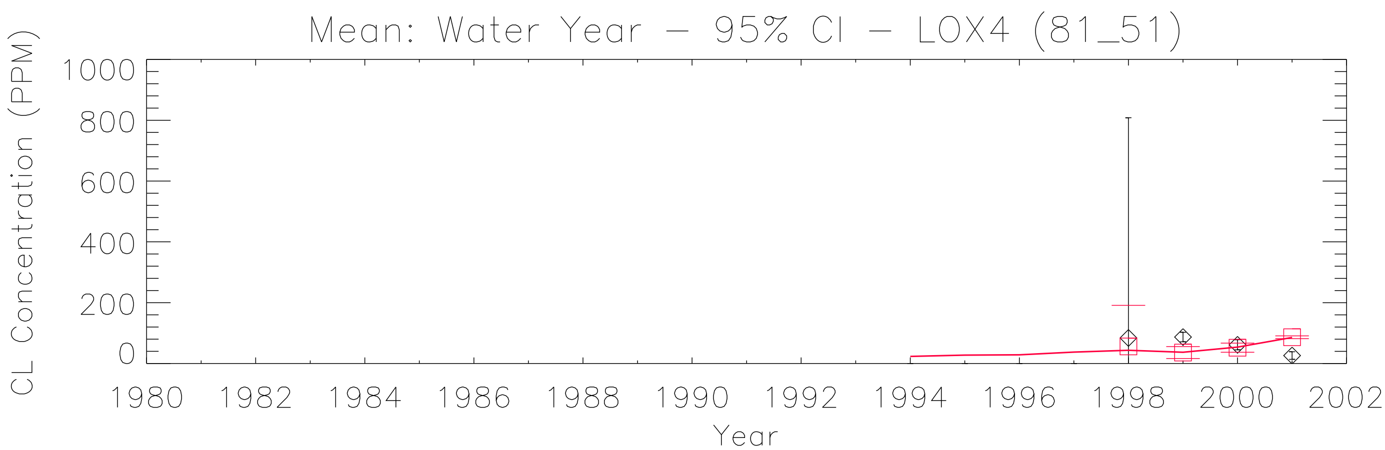
The model grid cell column and row locations (col_row) or canal reach identifier (single integer) are shown in parentheses of each plot's title.

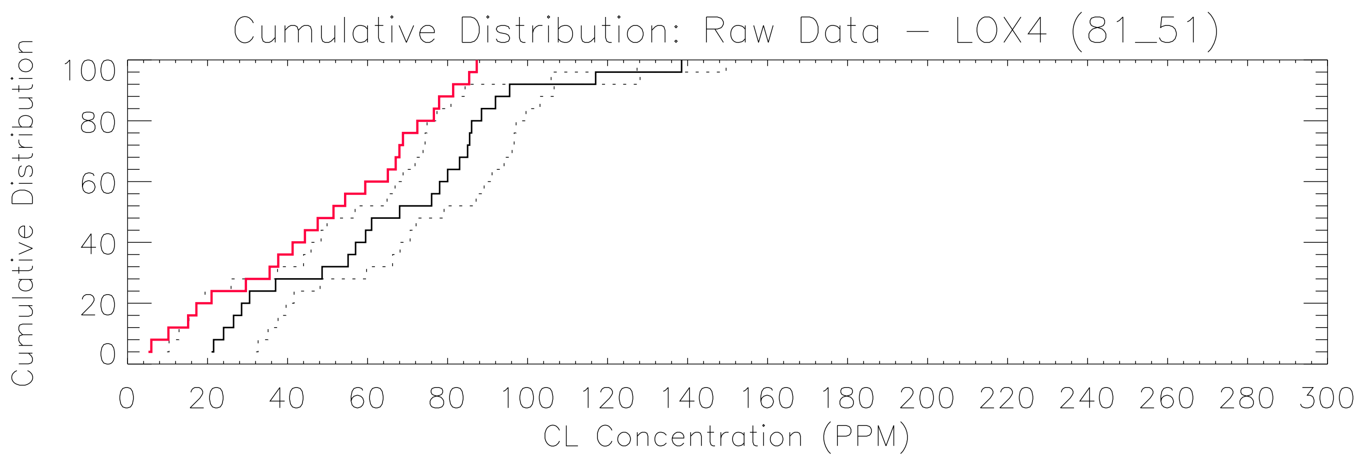
a) All data were aggregated into arithmetic mean values by wet and dry seasons within water years; the continuous lines pass through mean of all daily data points for each season; the mean of paired simulated & observed values are shown in red boxes and black diamonds, respectively; the 95% Confidence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

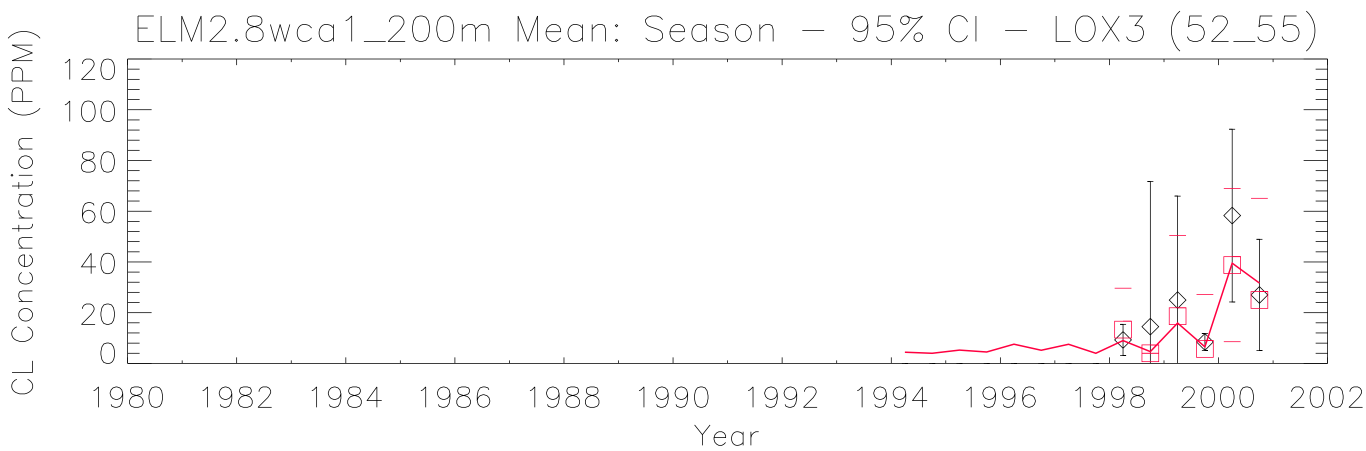
b) All data aggregated into arithmetic mean values by water year, with the same treatment as in plot a).

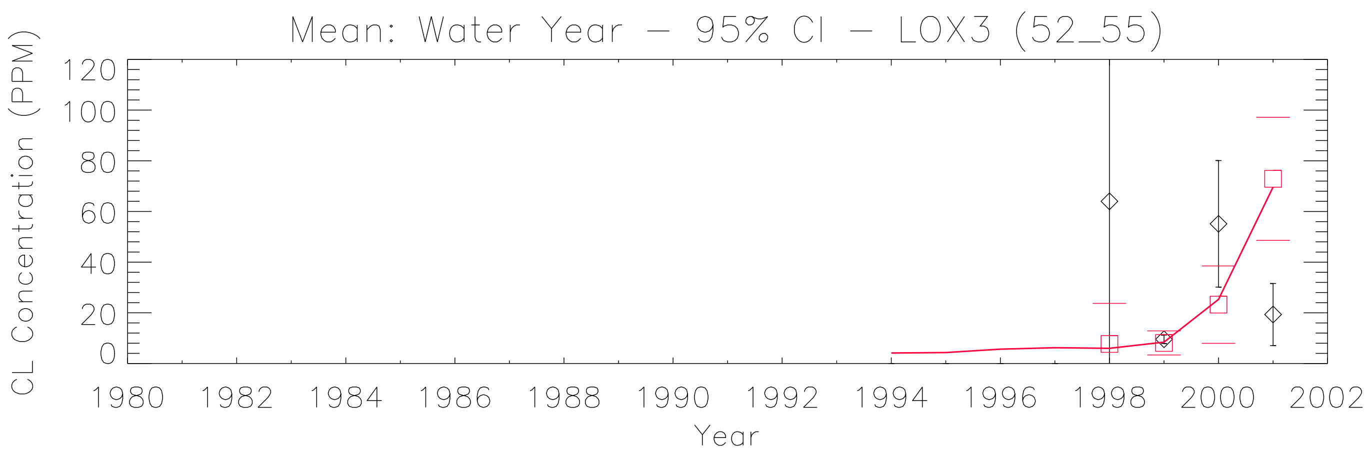
c) The cumulative frequency distributions of the simulated and observed (raw, un-aggregated) data; the 95% confidence interval for observed data is shown in the dashed black lines. Note that only paired simulated and observed data points are used.

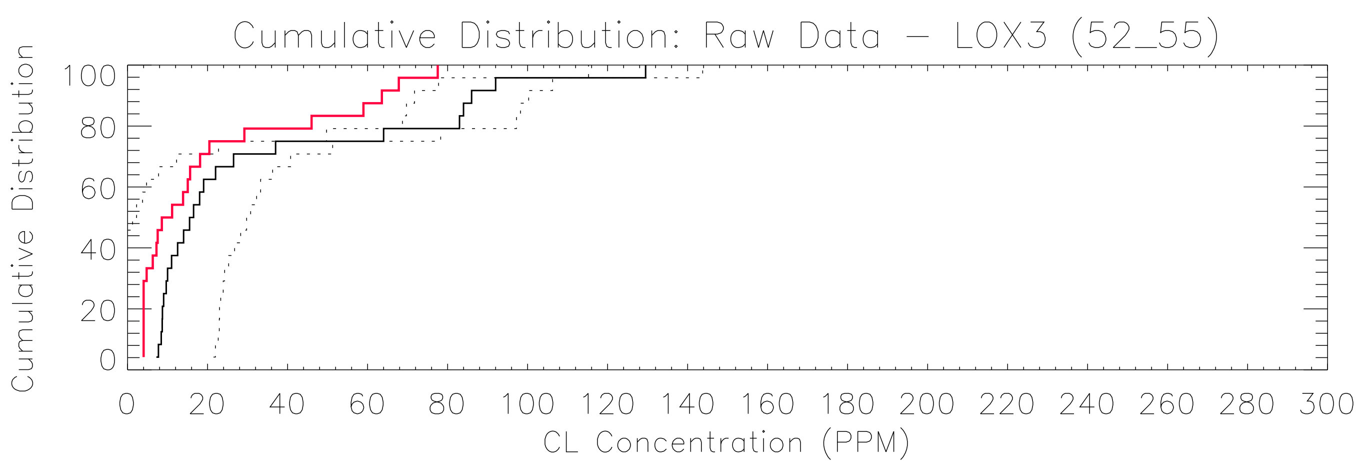

ELM2.8wca1_200m Mean: Season - 95% CI - LOX4 (81_51)
CL Concentration (PPM)
0
200
400
600
800
1000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

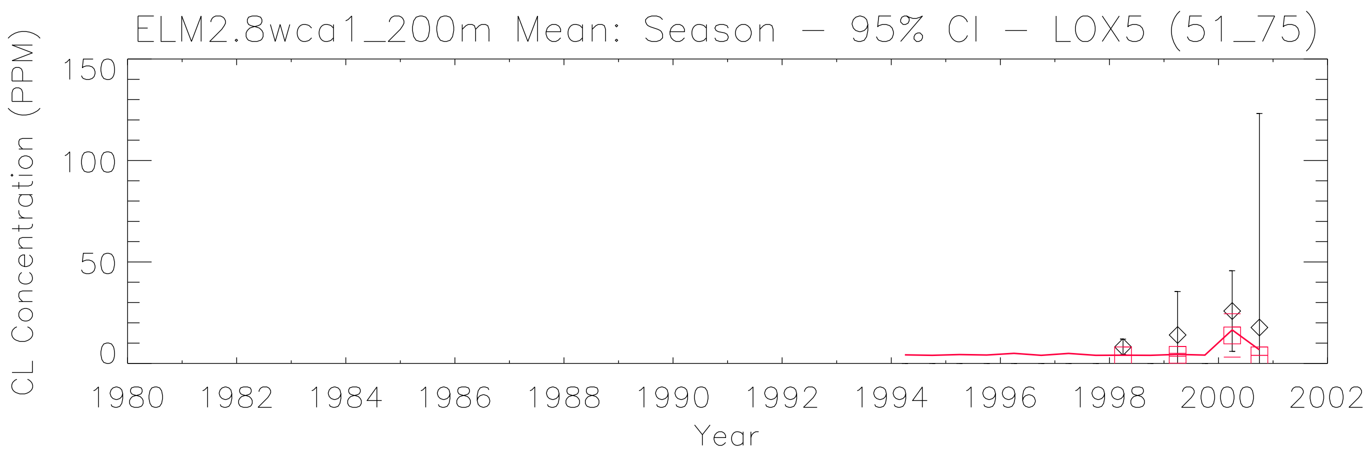

Mean: Water Year - 95% CI - LOX4 (81_51)
CL Concentration (PPM)
0
200
400
600
800
1000
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data - LOX4 (81_51)
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)

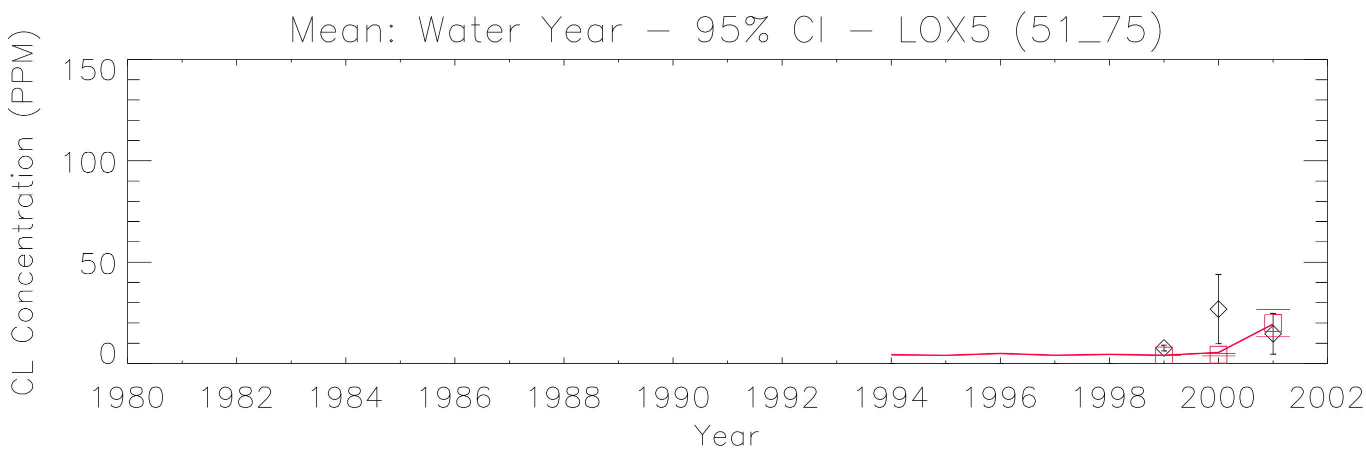

ELM2.8wca1_200m Mean: Season − 95% CI − LOX3 (52_55)
CL Concentration (PPM)
0
20
40
60
80
100
120
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year − 95% CI − LOX3 (52_55)
CL Concentration (PPM)
0
20
40
60
80
100
120
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

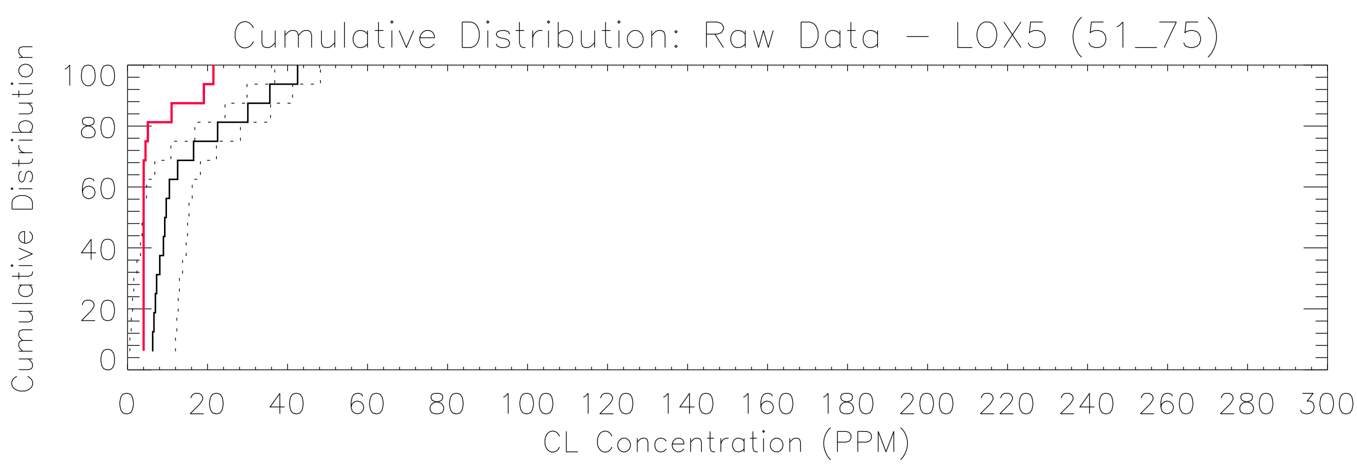

Cumulative Distribution: Raw Data − LOX3 (52_55)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)



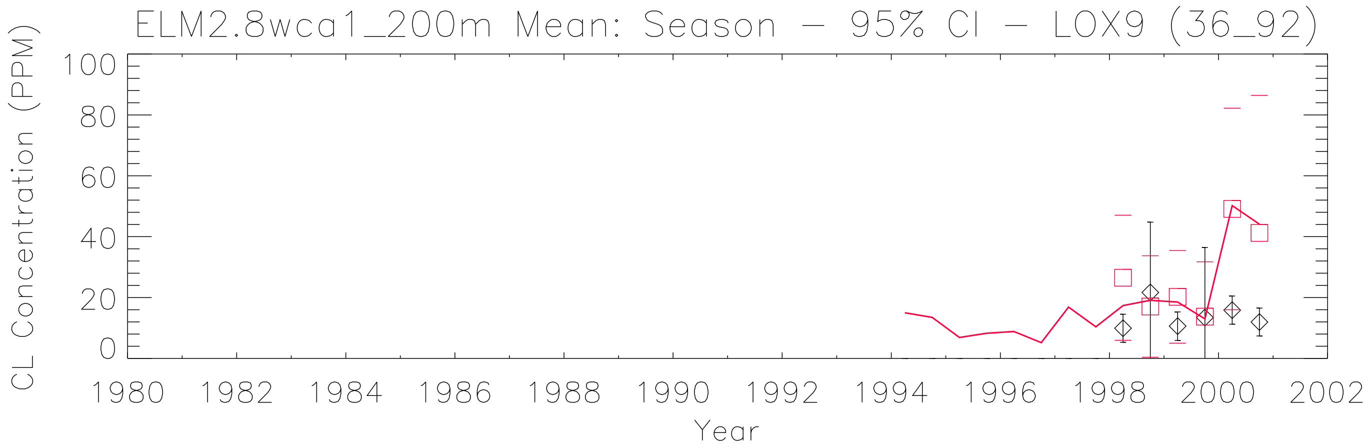
ELM2.8wca1_200m Mean: Season – 95% CI – LOX5 (51_75)
CL Concentration (PPM)
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

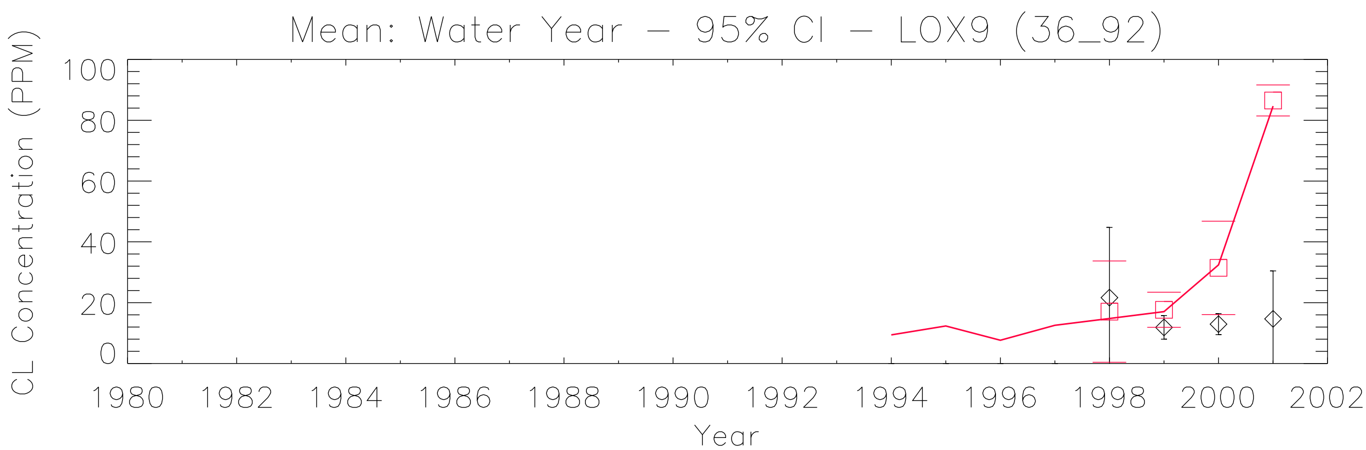


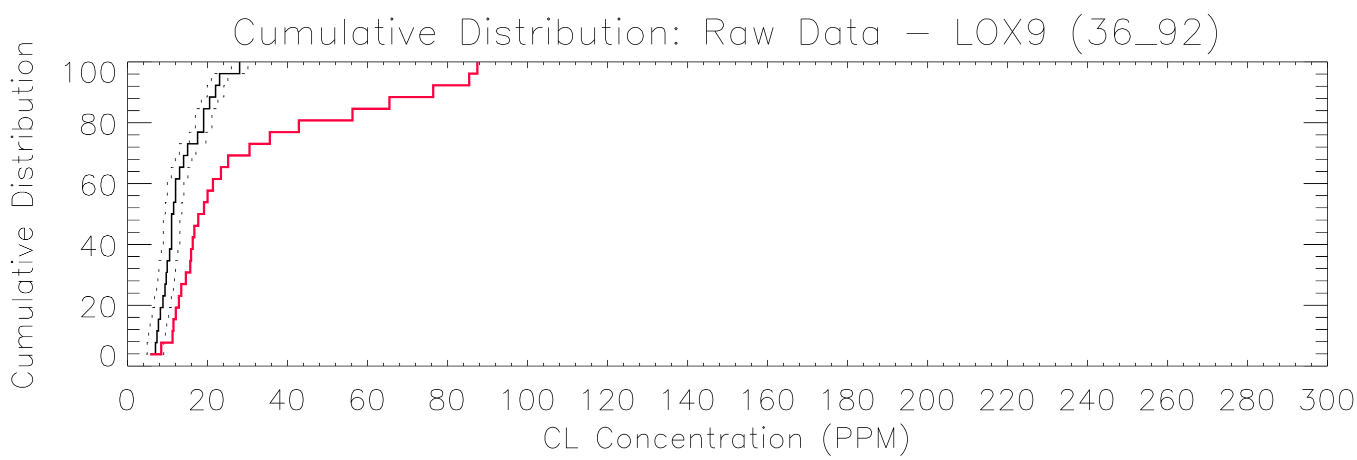
Mean: Water Year – 95% CI – LOX5 (51_75)
CL Concentration (PPM)
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

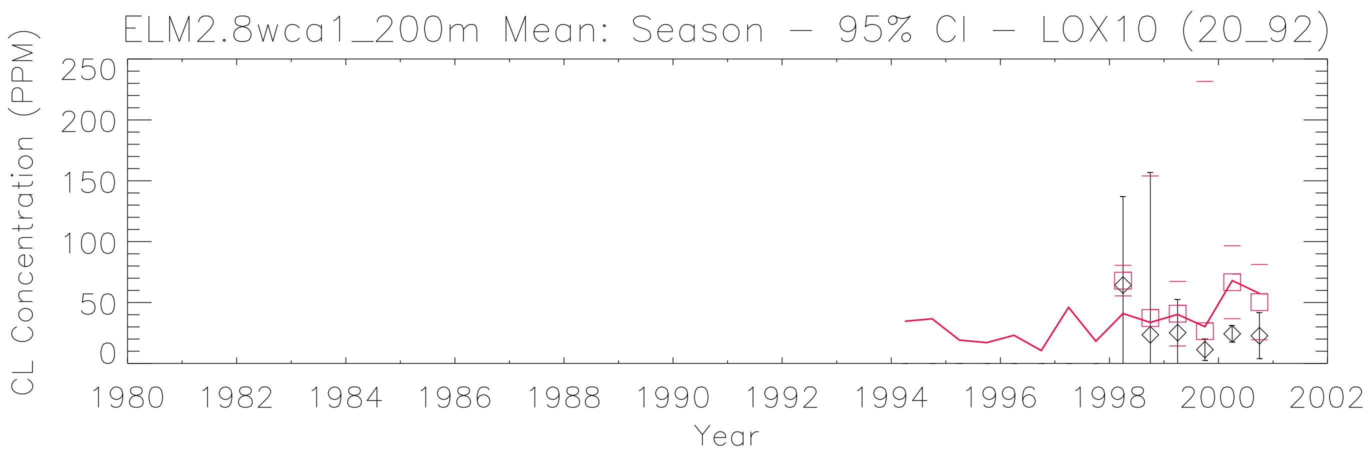


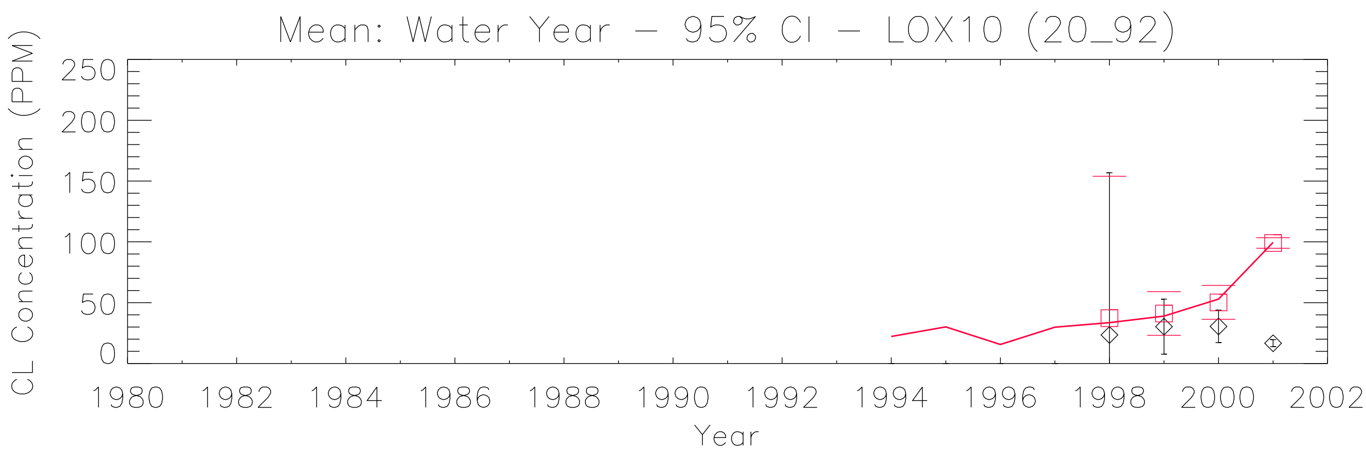
Cumulative Distribution: Raw Data – LOX5 (51_75)
Cumulative Distribution
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

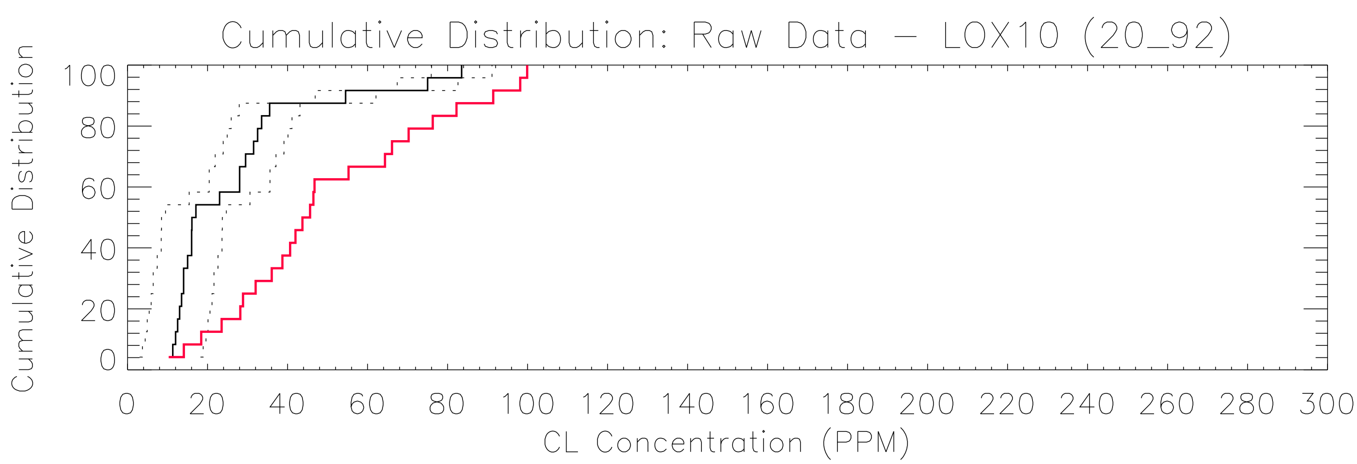

ELM2.8wca1_200m Mean: Season - 95% CI - LOX9 (36_92)
CL Concentration (PPM)
0
20
40
60
80
100
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

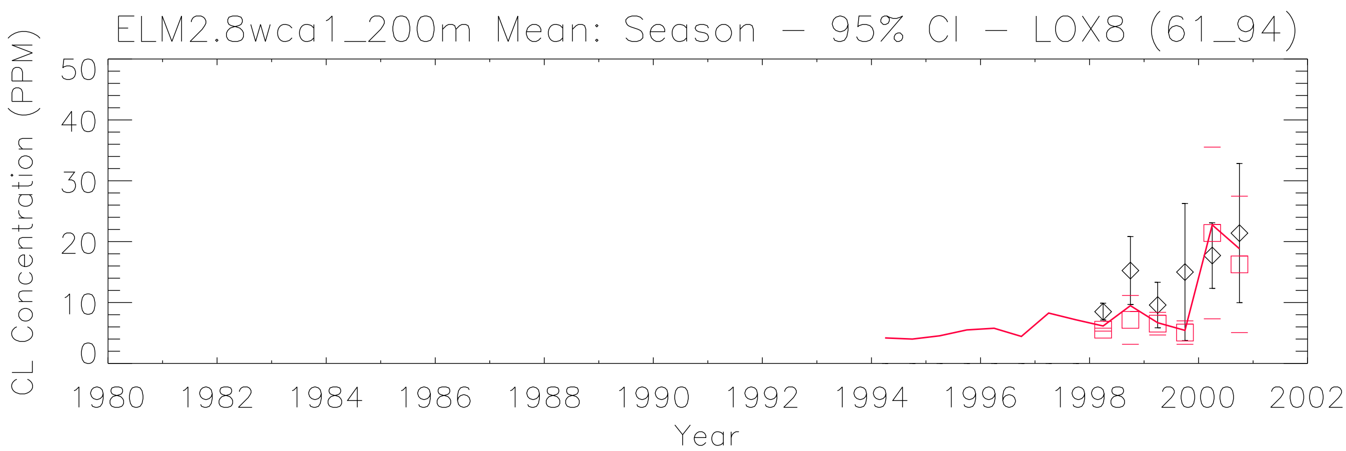

Mean: Water Year - 95% CI - LOX9 (36_92)
CL Concentration (PPM)
0
20
40
60
80
100
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

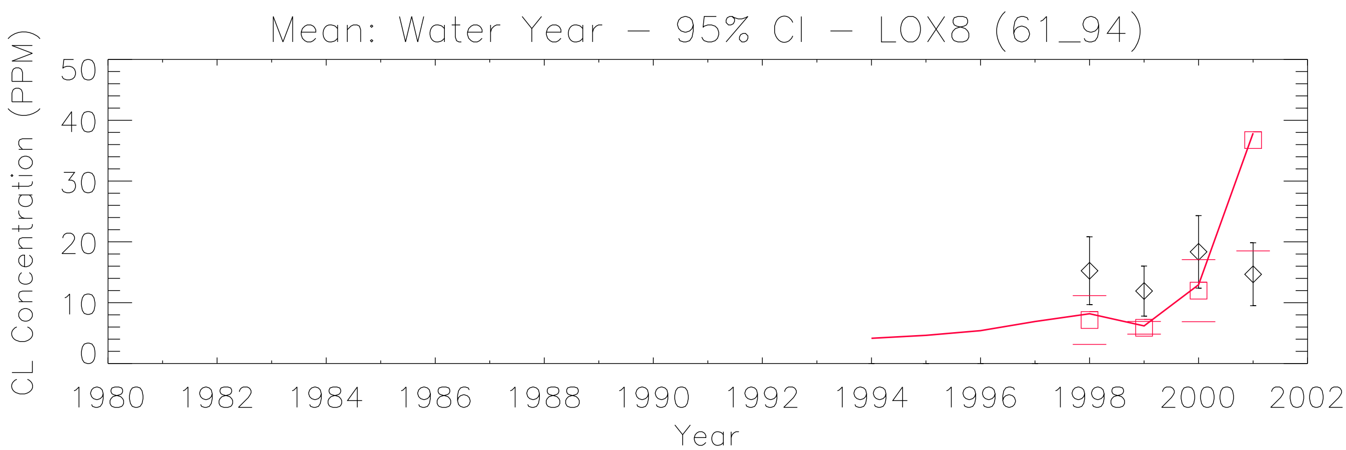

Cumulative Distribution: Raw Data - LOX9 (36_92)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

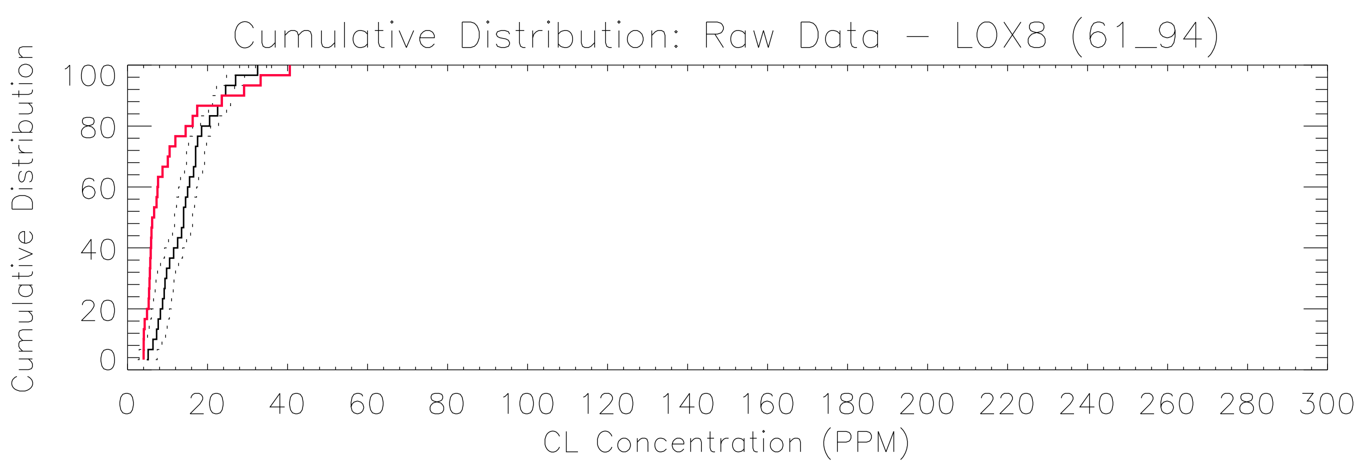

ELM2.8wca1_200m Mean: Season - 95% CI - LOX10 (20_92)
CL Concentration (PPM)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

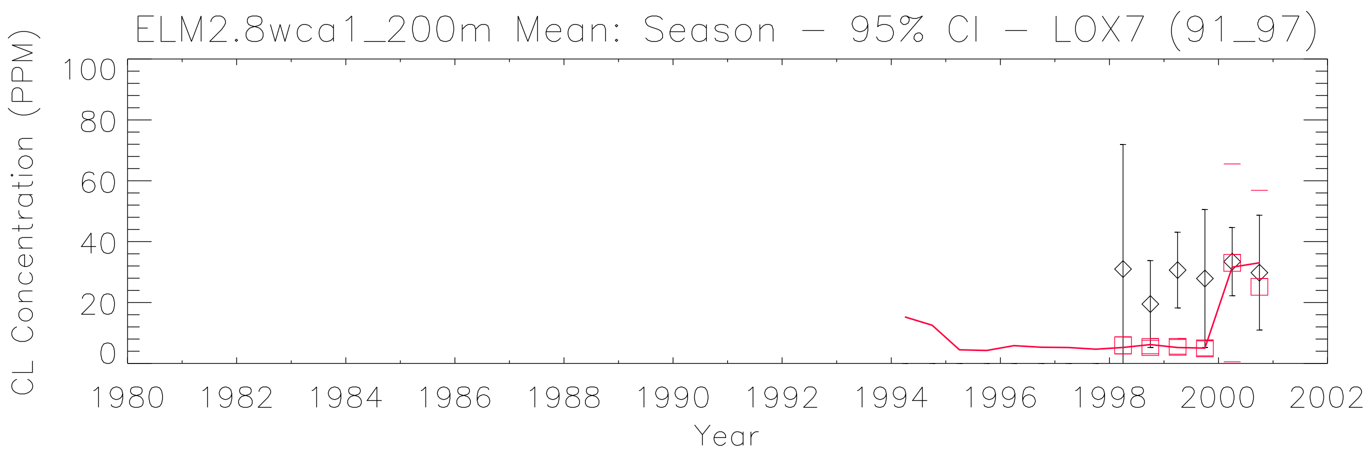

Mean: Water Year - 95% CI - LOX10 (20_92)
CL Concentration (PPM)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

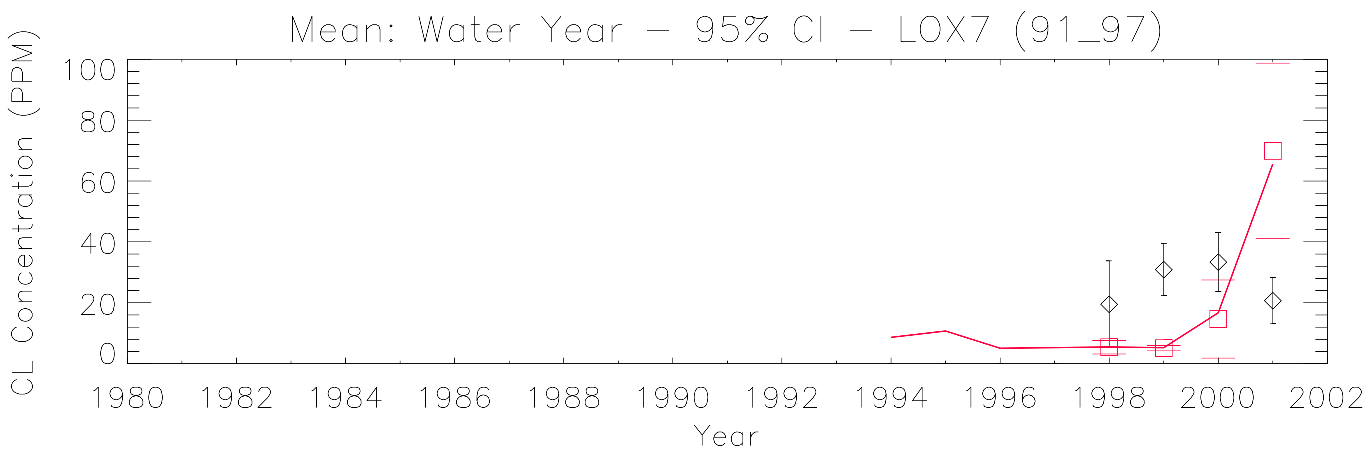

Cumulative Distribution: Raw Data - LOX10 (20_92)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

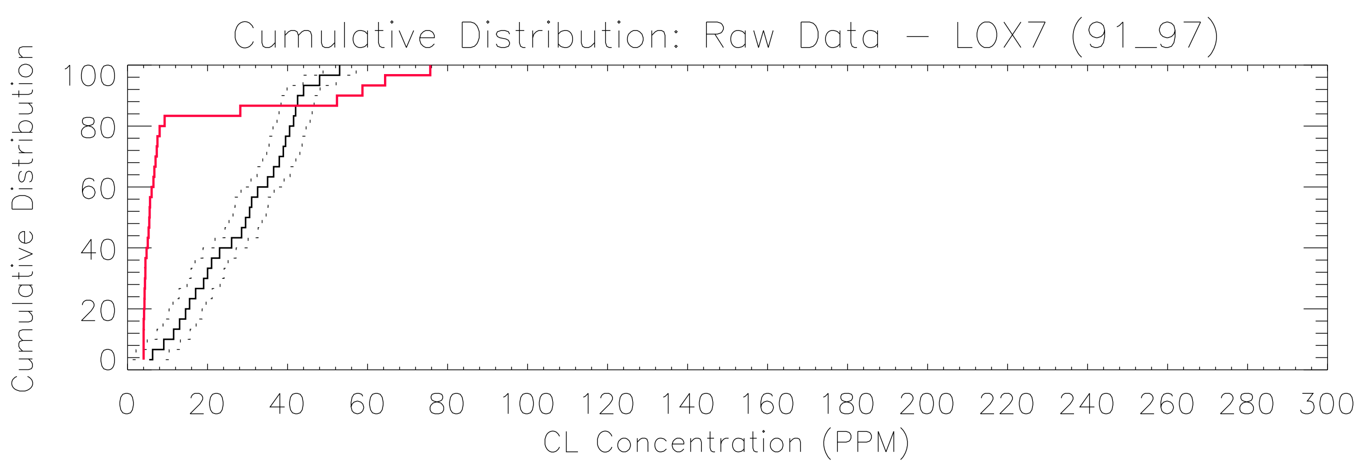

ELM2.8wca1_200m Mean: Season - 95% CI - LOX8 (61_94)
CL Concentration (PPM)
0
10
20
30
40
50
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

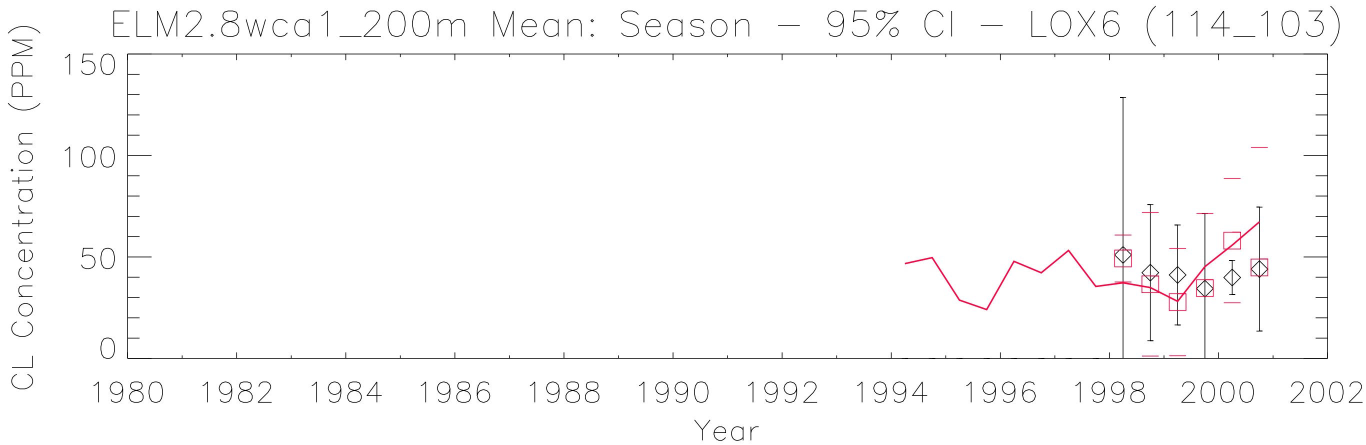

Mean: Water Year - 95% CI - LOX8 (61_94)
CL Concentration (PPM)
0
10
20
30
40
50
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

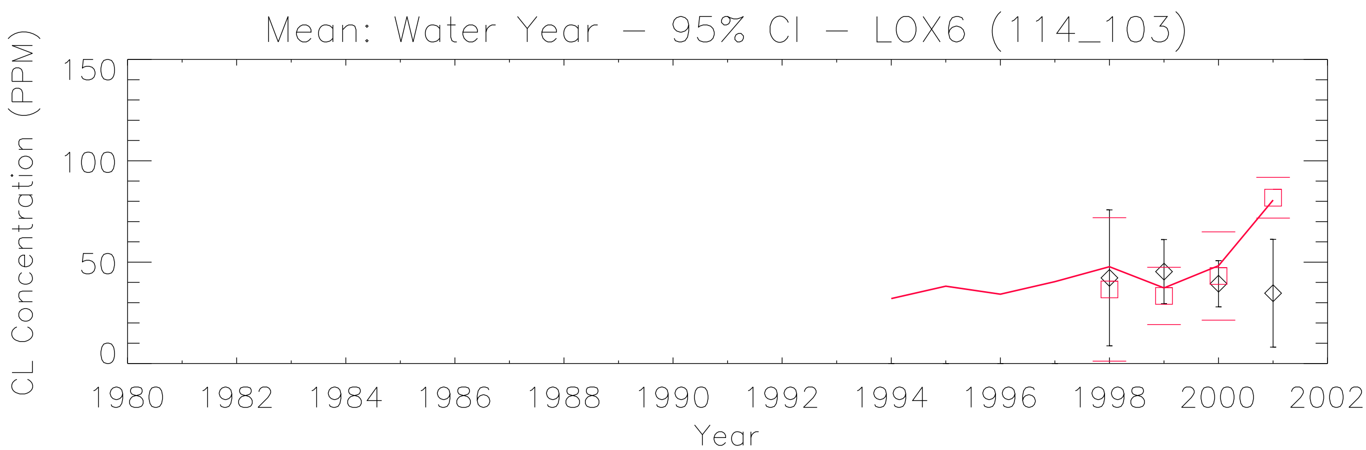

Cumulative Distribution: Raw Data - LOX8 (61_94)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

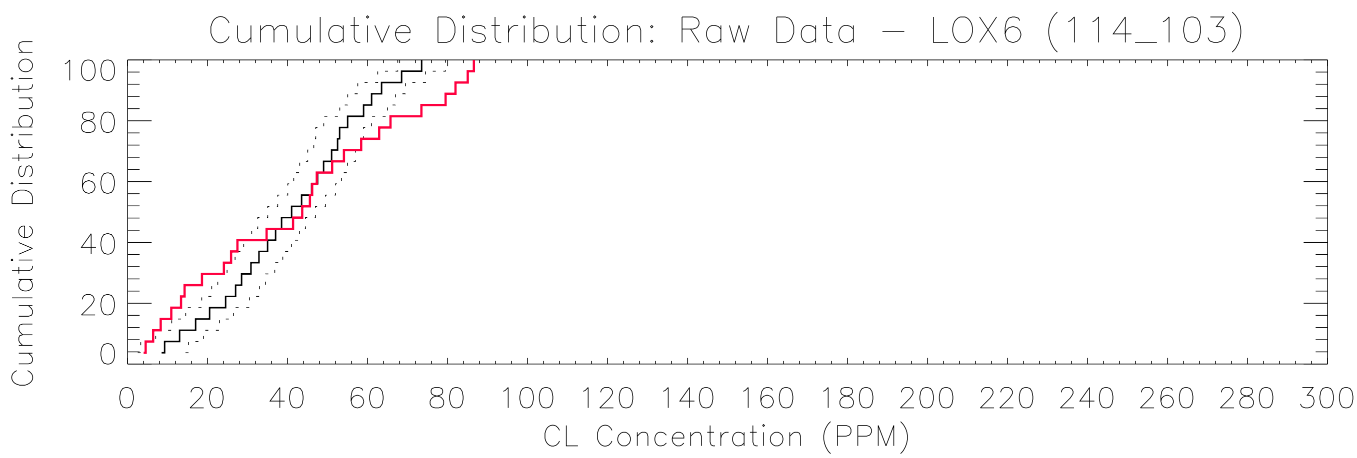

ELM2.8wca1_200m Mean: Season - 95% CI - LOX7 (91_97)
CL Concentration (PPM)
Year

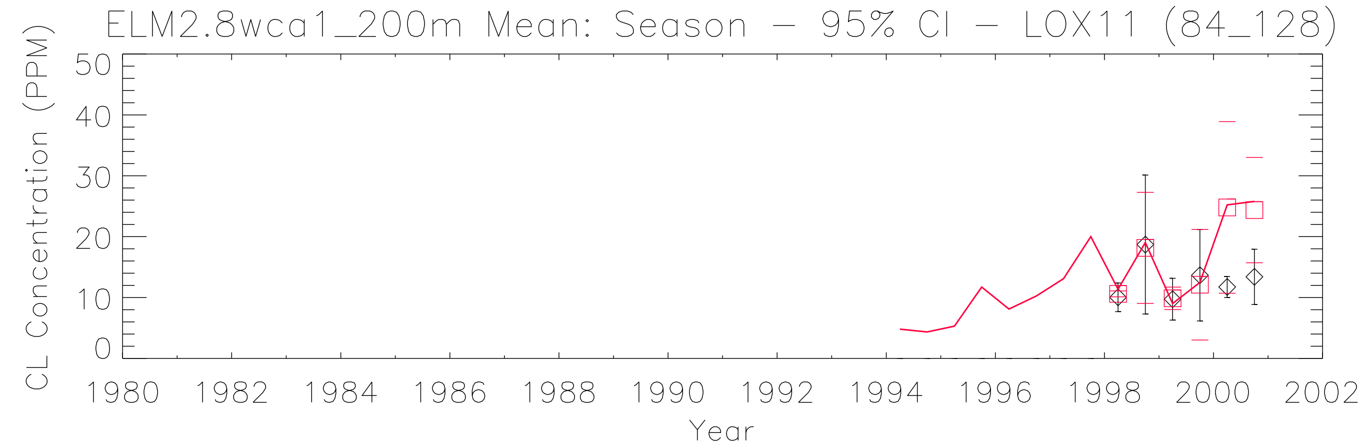

Mean: Water Year - 95% CI - LOX7 (91_97)
CL Concentration (PPM)
Year

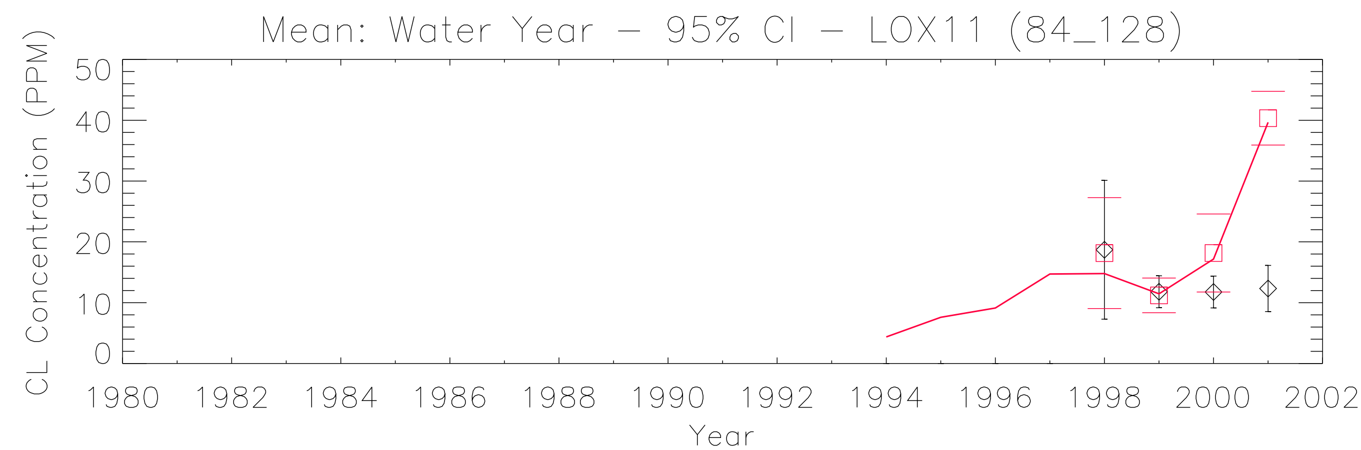

Cumulative Distribution: Raw Data - LOX7 (91_97)
Cumulative Distribution
CL Concentration (PPM)

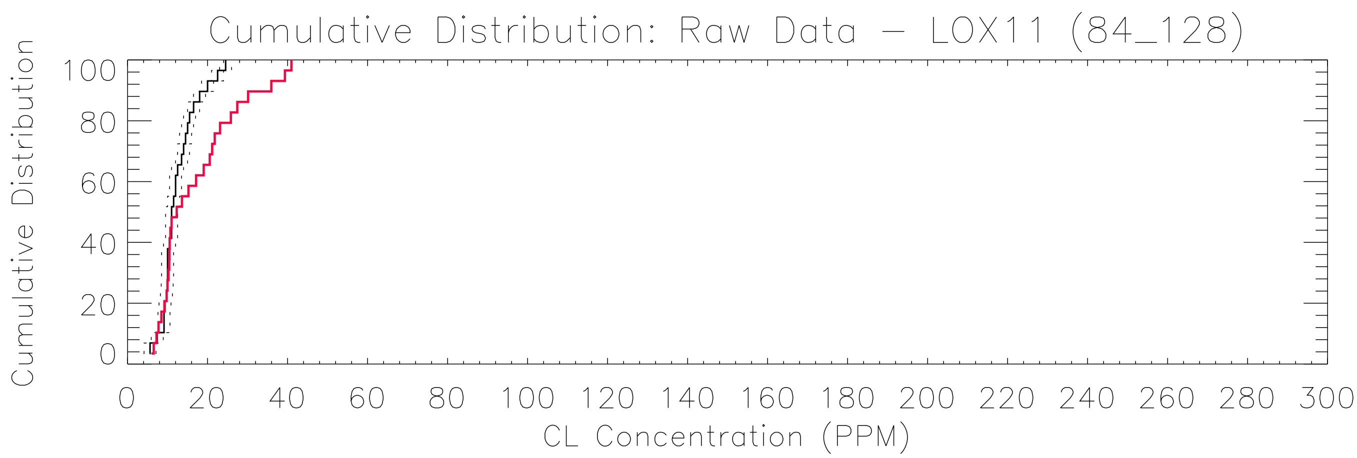

ELM2.8wca1_200m Mean: Season – 95% CI – LOX6 (114_103)
CL Concentration (PPM)
Year

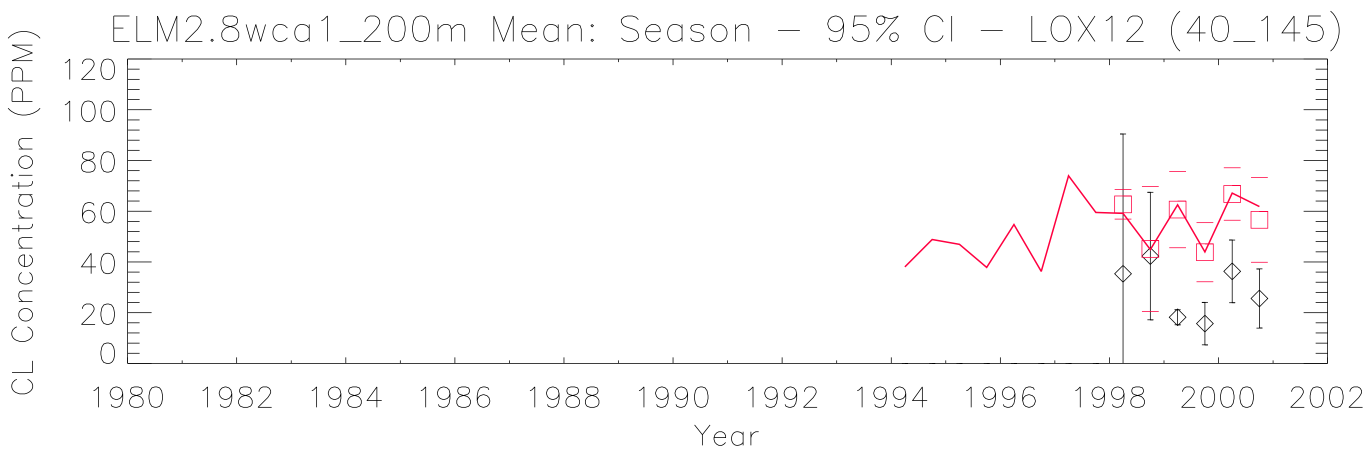

Mean: Water Year – 95% CI – LOX6 (114_103)
CL Concentration (PPM)
Year

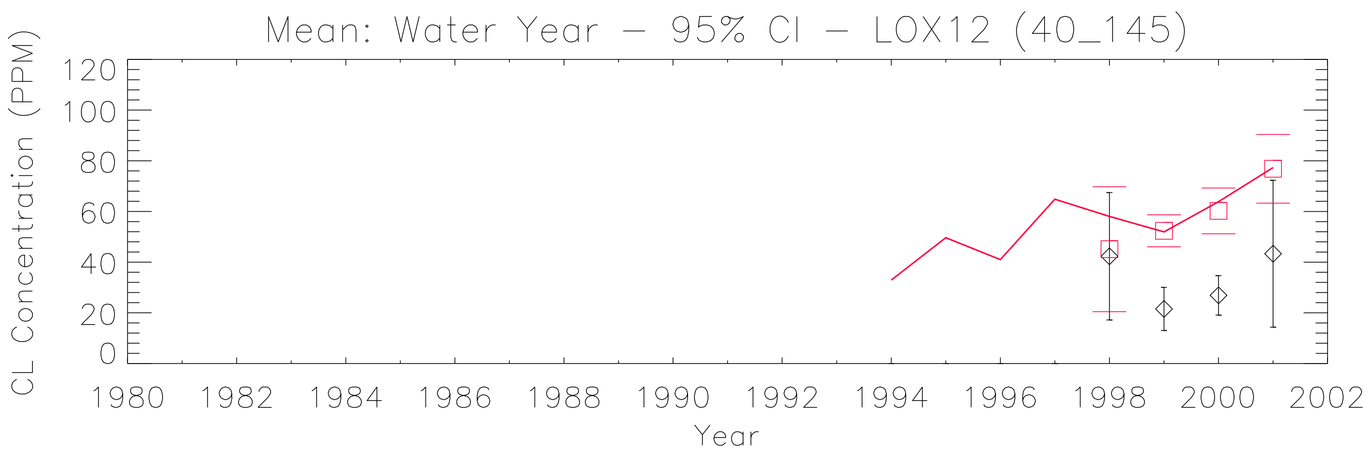

Cumulative Distribution: Raw Data – LOX6 (114_103)
Cumulative Distribution
CL Concentration (PPM)

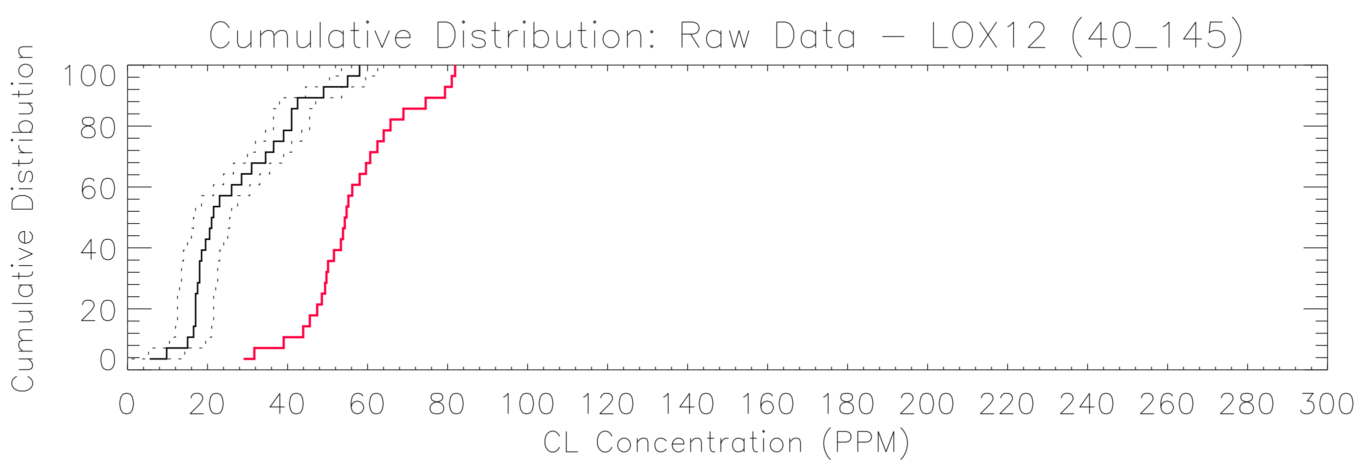

ELM2.8wca1_200m Mean: Season - 95% CI - LOX11 (84_128)
CL Concentration (PPM)
50
40
30
20
10
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

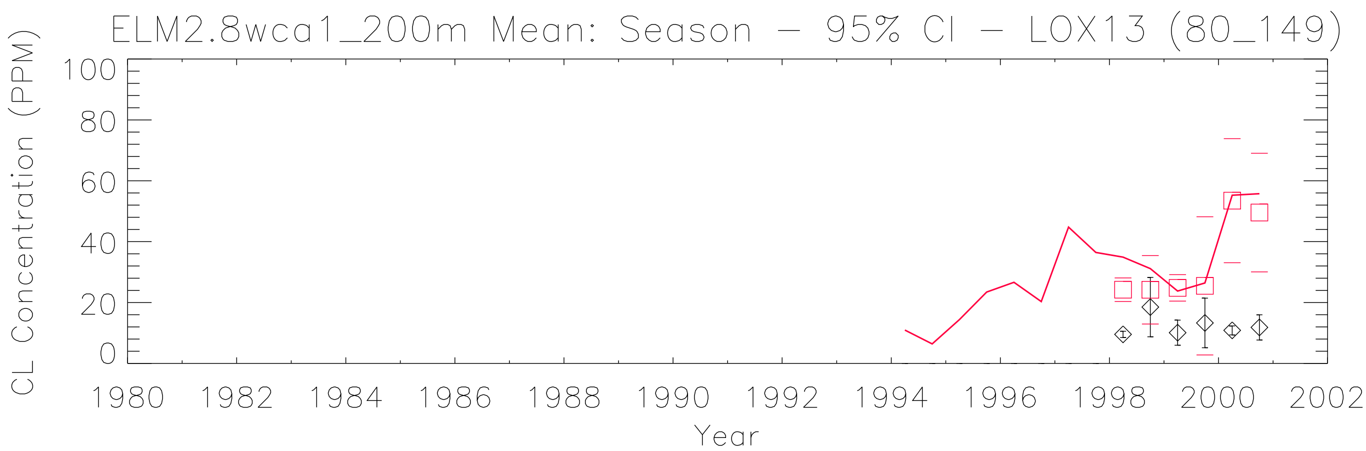

Mean: Water Year - 95% CI - LOX11 (84_128)
CL Concentration (PPM)
50
40
30
20
10
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data - LOX11 (84_128)
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)

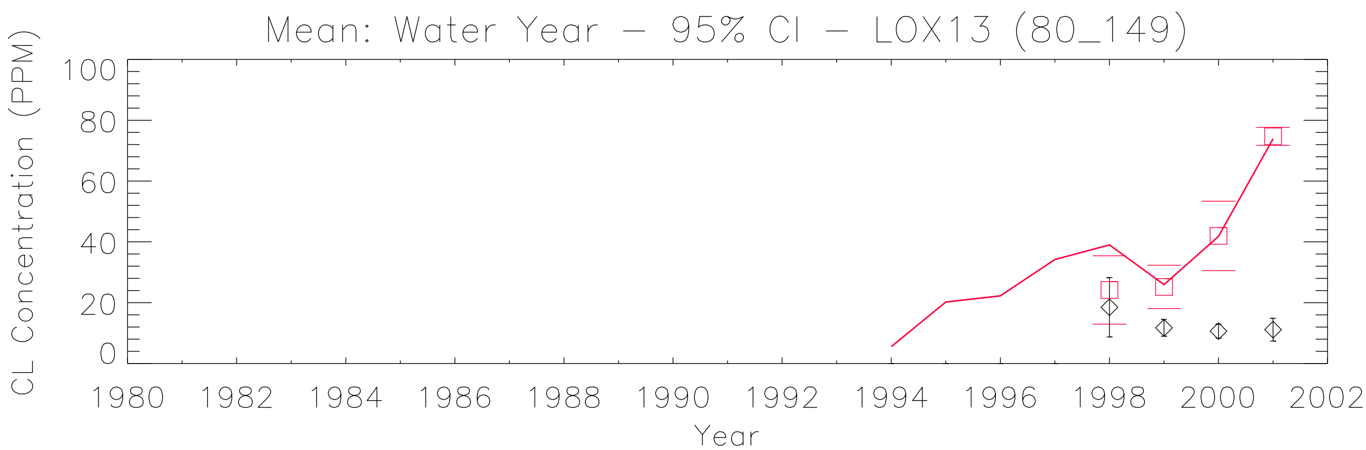

ELM2.8wca1_200m Mean: Season - 95% CI - LOX12 (40_145)
CL Concentration (PPM)
0
20
40
60
80
100
120
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year - 95% CI - LOX12 (40_145)
CL Concentration (PPM)
0
20
40
60
80
100
120
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

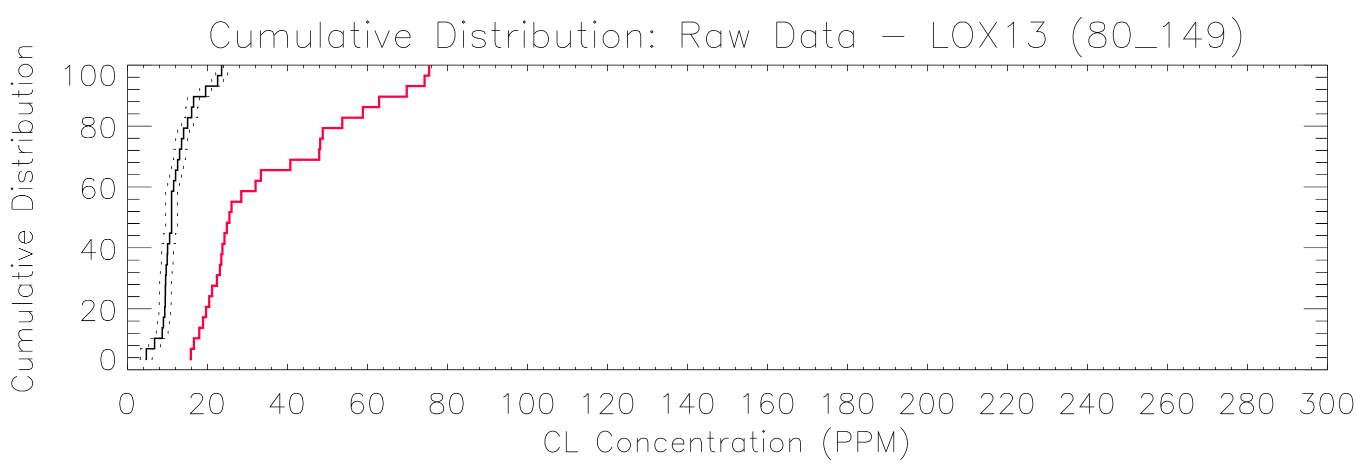

Cumulative Distribution: Raw Data - LOX12 (40_145)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)



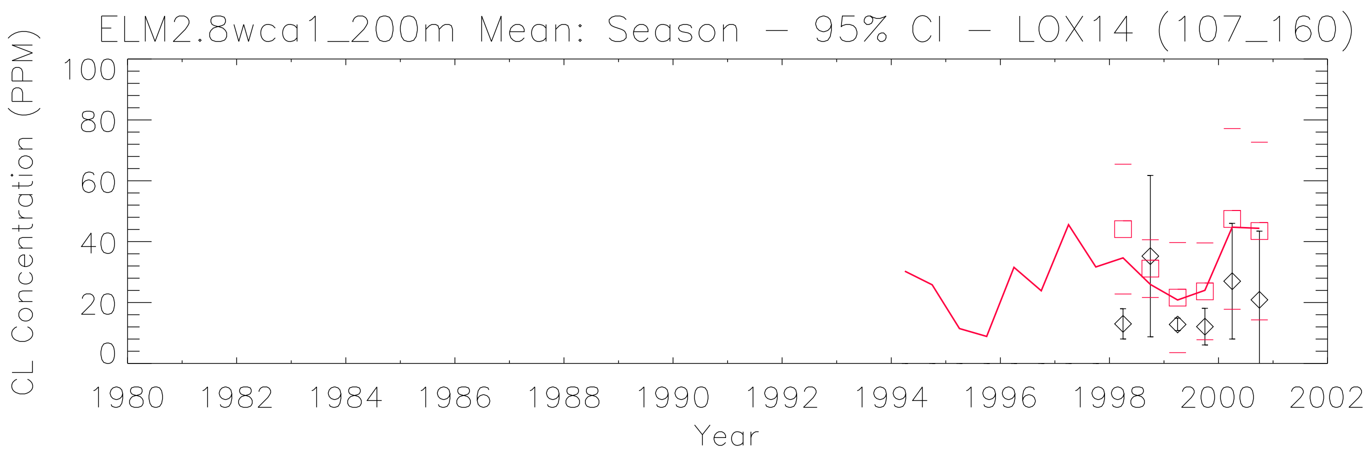
ELM2.8wca1_200m Mean: Season - 95% CI - LOX13 (80_149)
CL Concentration (PPM)
Year

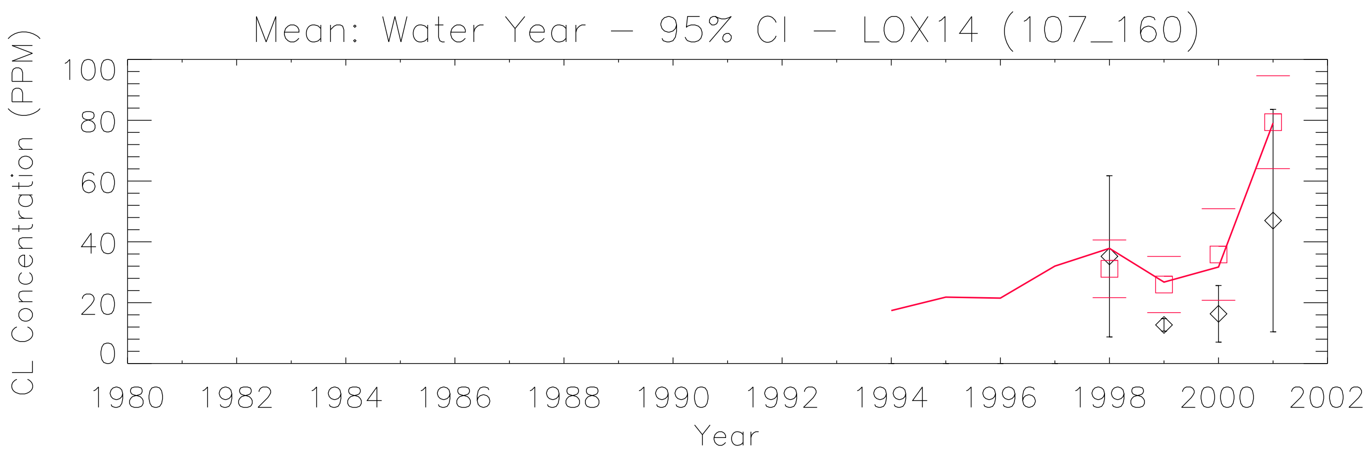


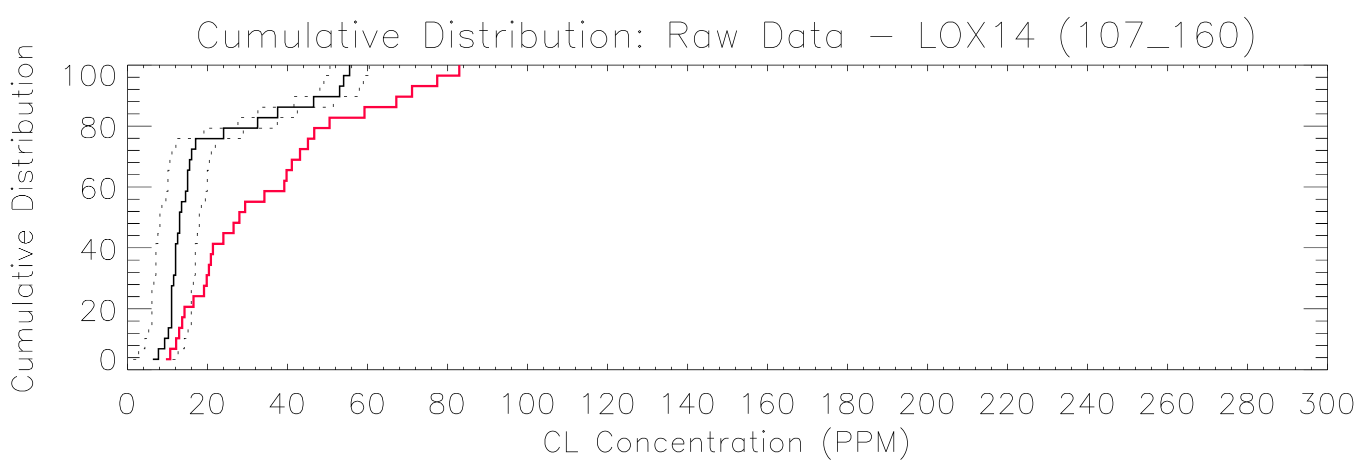
Mean: Water Year - 95% CI - LOX13 (80_149)
CL Concentration (PPM)
Year

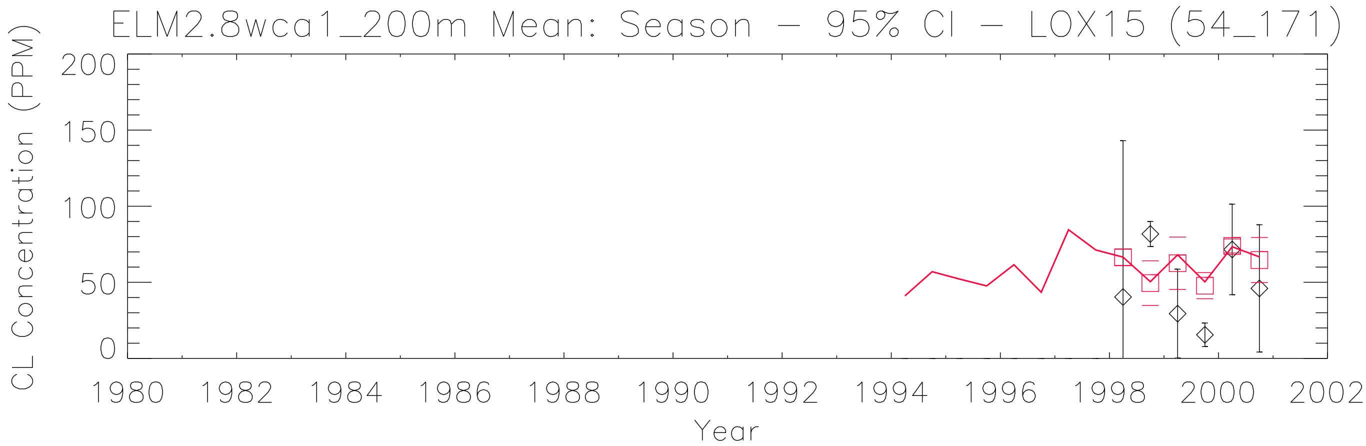


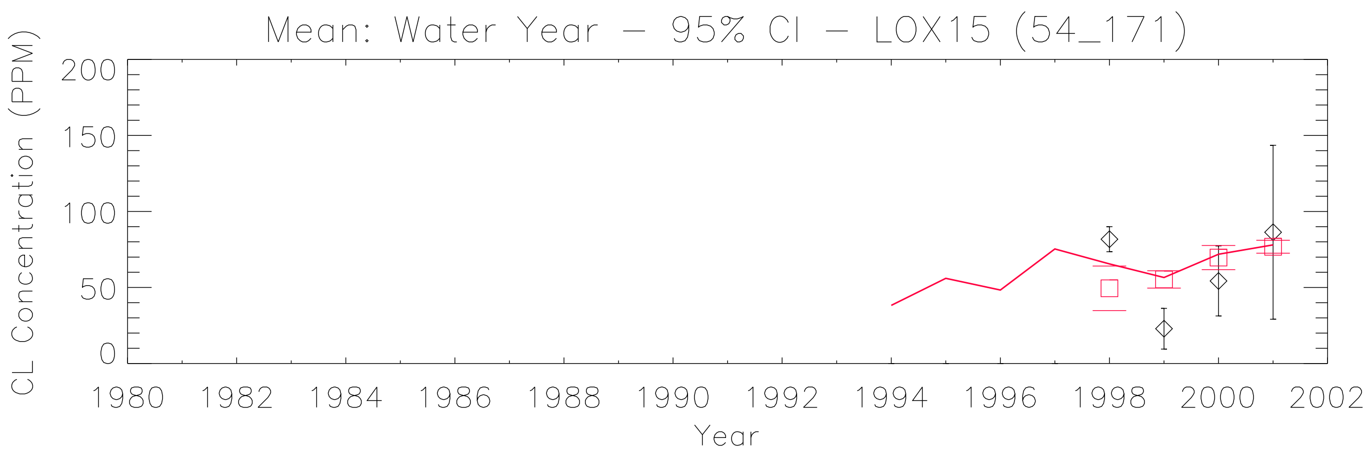
Cumulative Distribution: Raw Data - LOX13 (80_149)
Cumulative Distribution
CL Concentration (PPM)

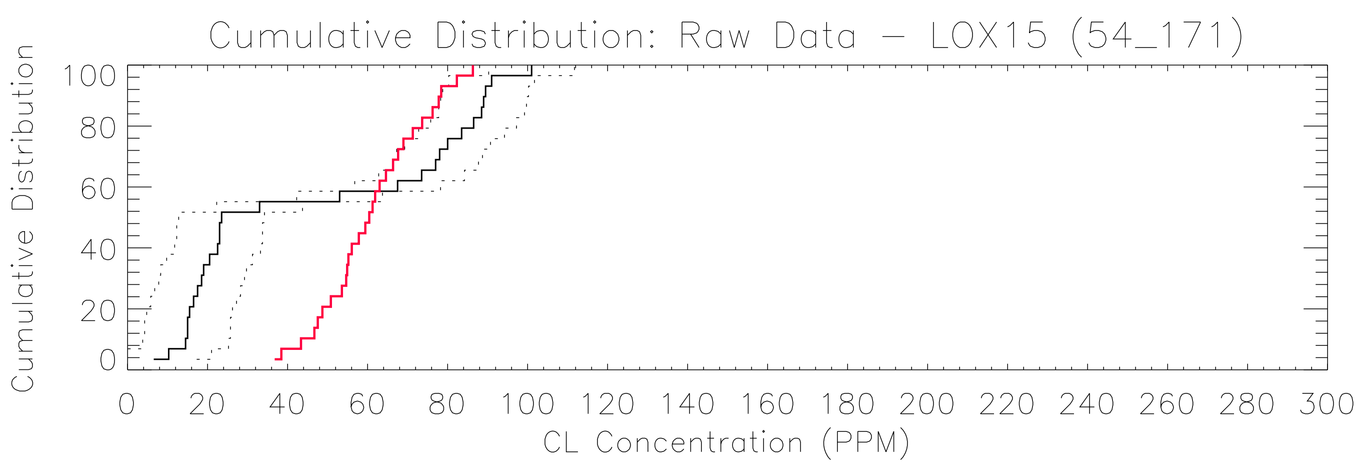

ELM2.8wca1_200m Mean: Season - 95% CI - LOX14 (107_160)
CL Concentration (PPM)
Year

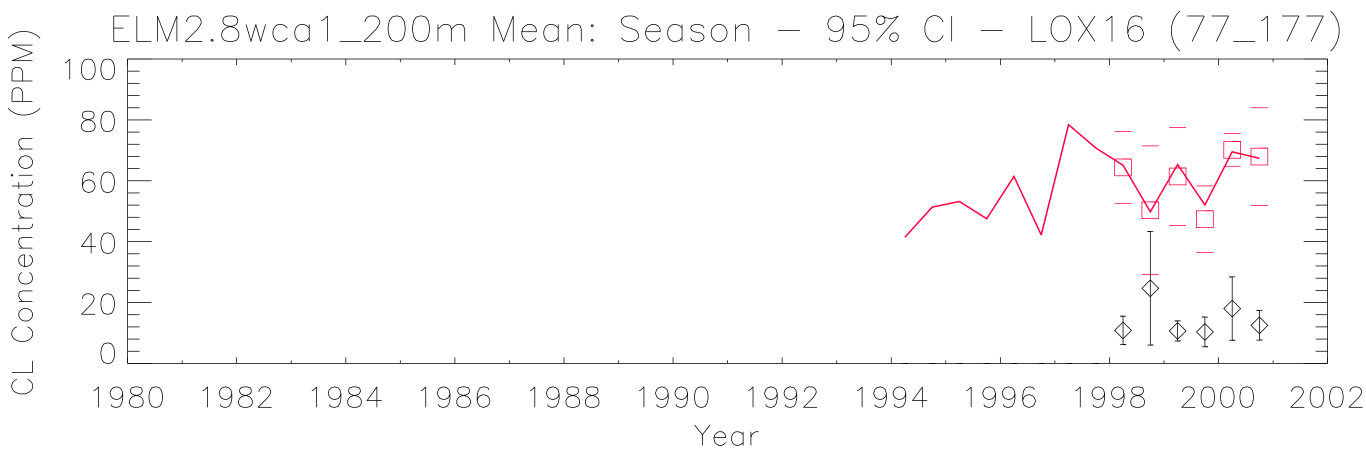

Mean: Water Year - 95% CI - LOX14 (107_160)
CL Concentration (PPM)
Year


Cumulative Distribution: Raw Data - LOX14 (107_160)
Cumulative Distribution
CL Concentration (PPM)

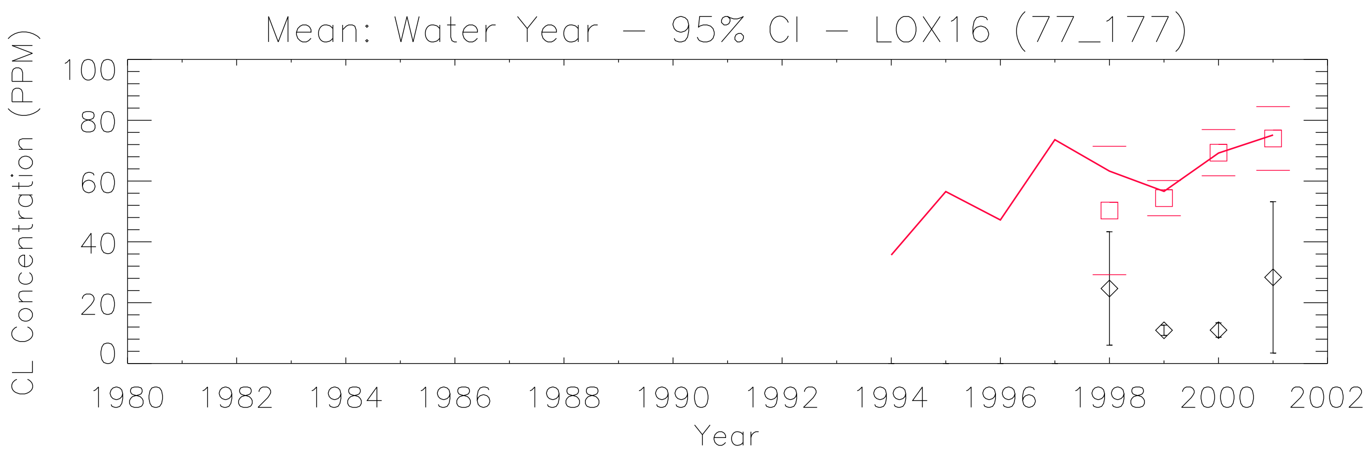

ELM2.8wca1_200m Mean: Season – 95% CI – LOX15 (54_171)
CL Concentration (PPM)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – LOX15 (54_171)
CL Concentration (PPM)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

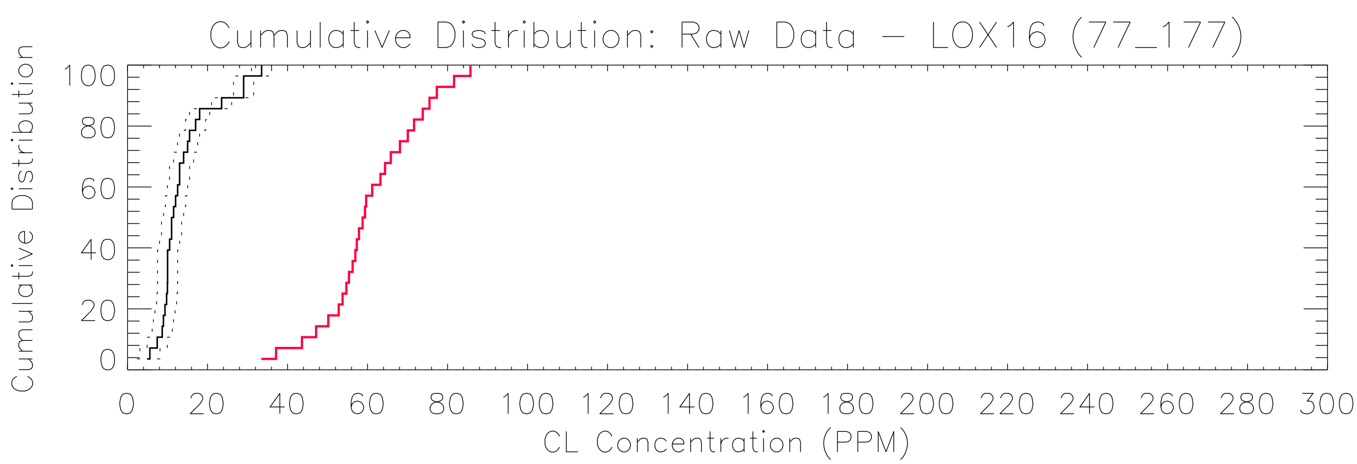

Cumulative Distribution: Raw Data – LOX15 (54_171)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)



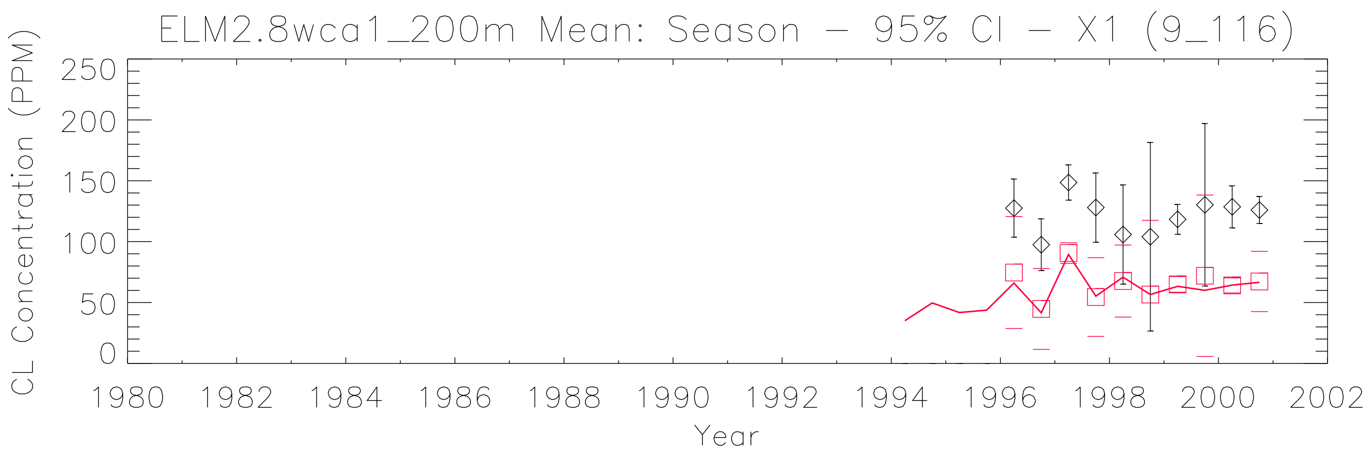
ELM2.8wca1_200m Mean: Season - 95% CI - LOX16 (77_177)
CL Concentration (PPM)
0
20
40
60
80
100
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

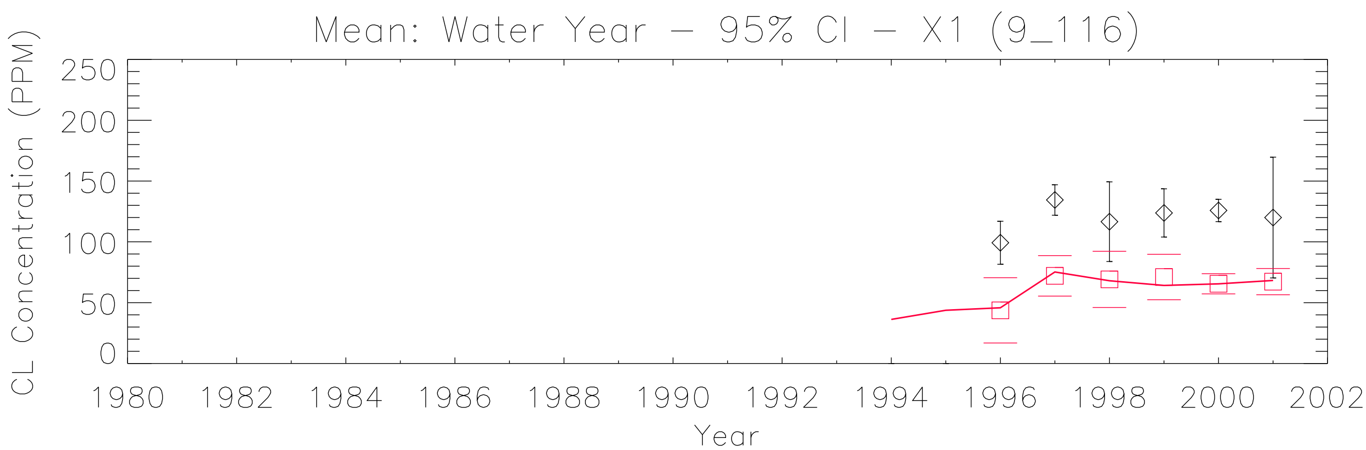


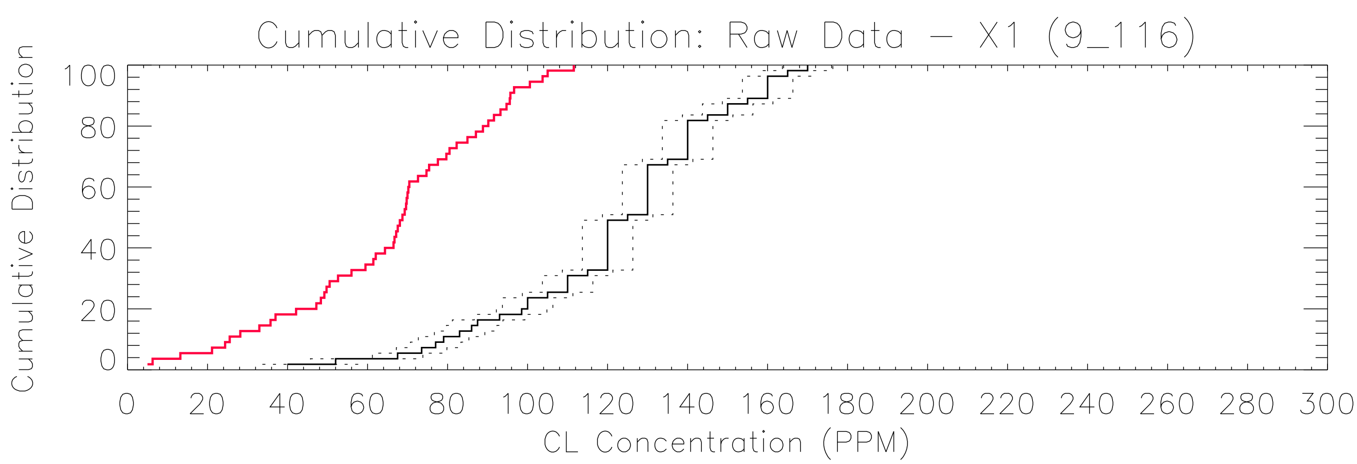
Mean: Water Year - 95% CI - LOX16 (77_177)
CL Concentration (PPM)
0
20
40
60
80
100
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

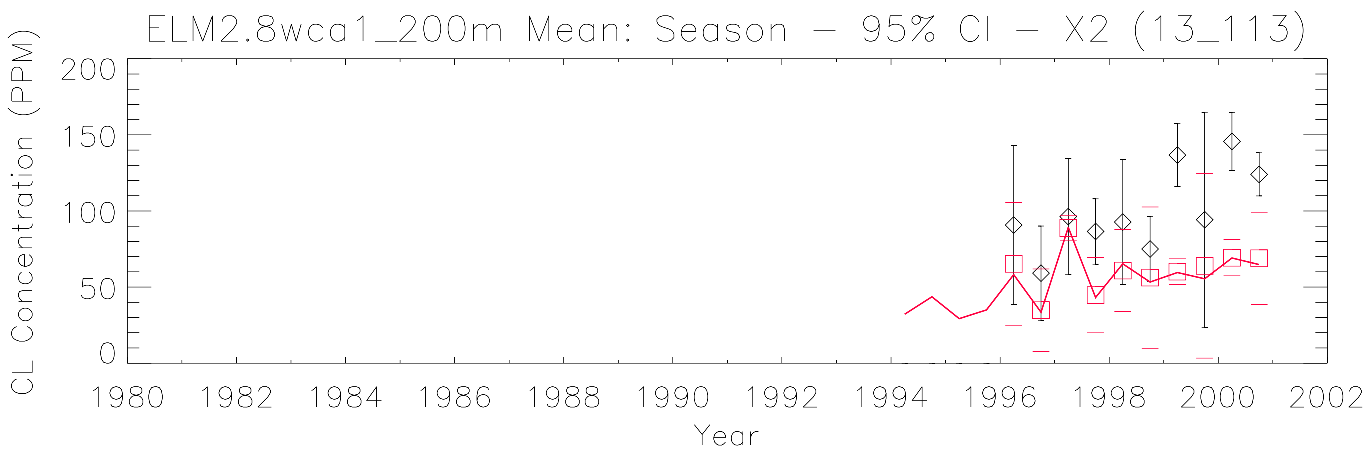


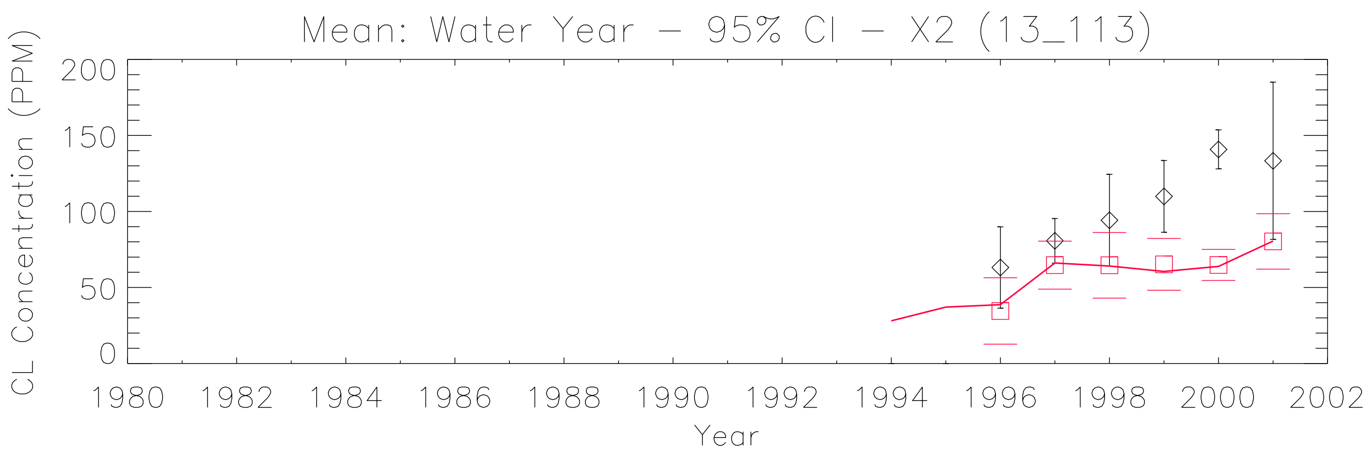
Cumulative Distribution: Raw Data - LOX16 (77_177)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

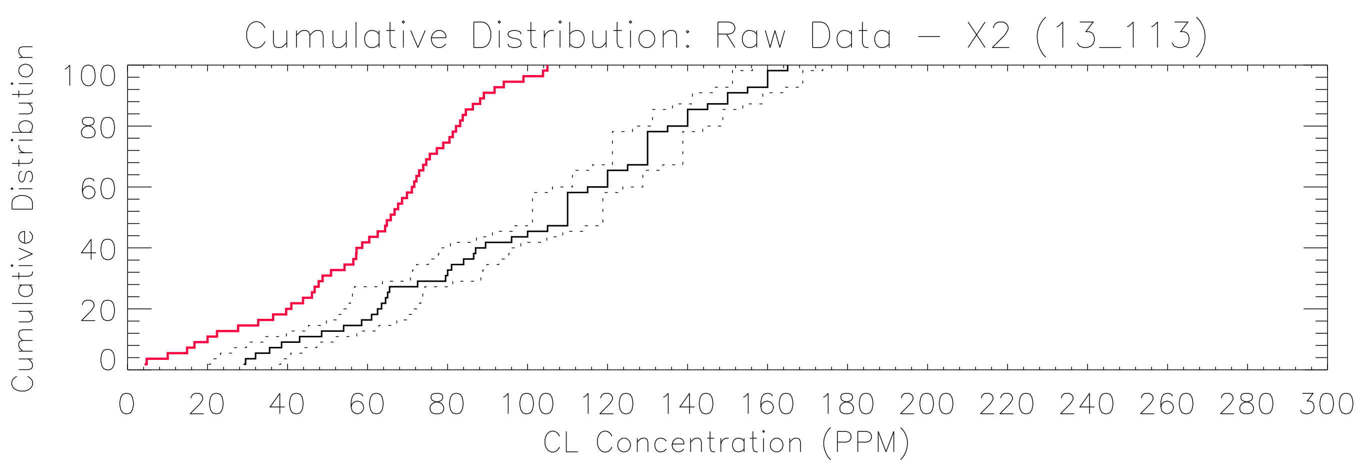

ELM2.8wca1_200m Mean: Season - 95% CI - X1 (9_116)
CL Concentration (PPM)
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

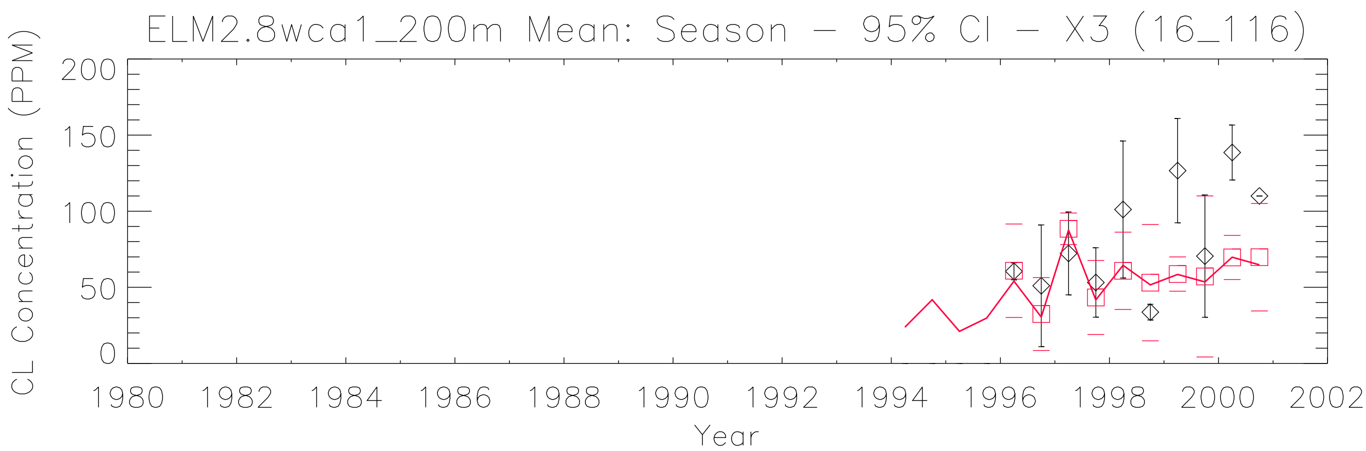

Mean: Water Year - 95% CI - X1 (9_116)
CL Concentration (PPM)
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data - X1 (9_116)
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)

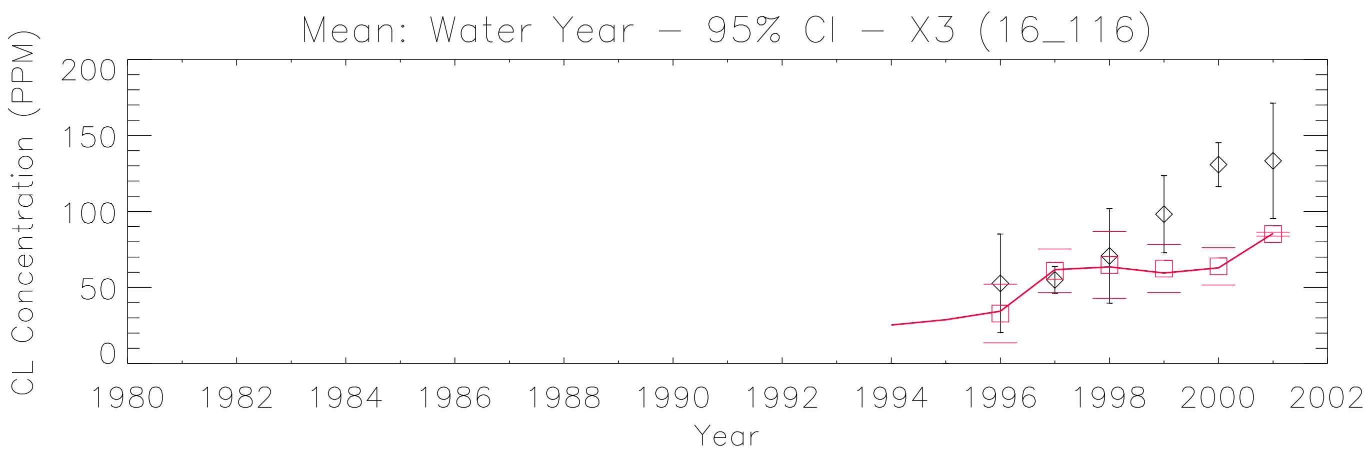

ELM2.8wca1_200m Mean: Season - 95% CI - X2 (13_113)
CL Concentration (PPM)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year - 95% CI - X2 (13_113)
CL Concentration (PPM)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

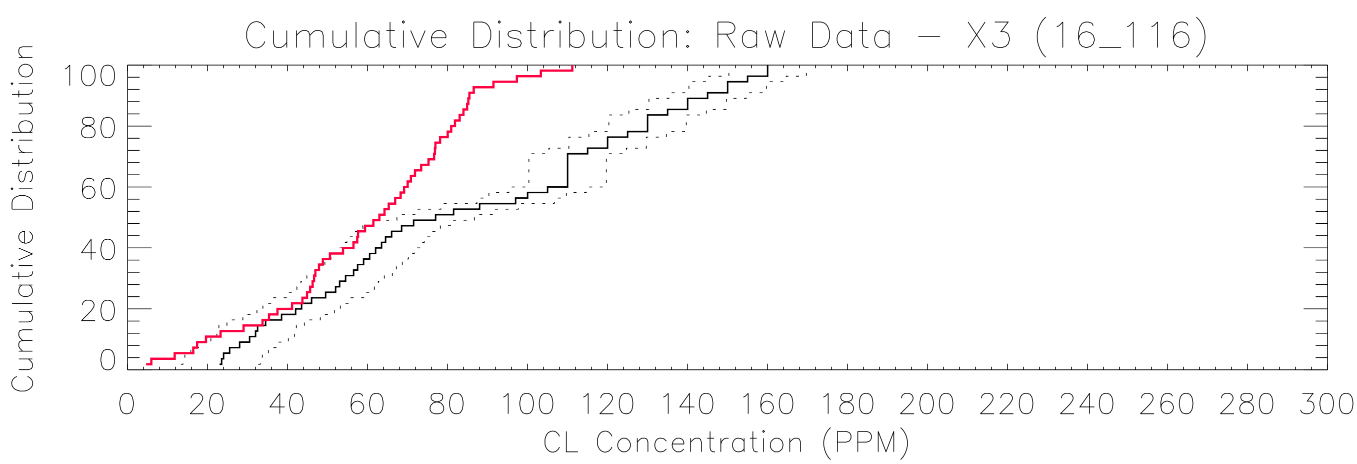

Cumulative Distribution: Raw Data - X2 (13_113)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)



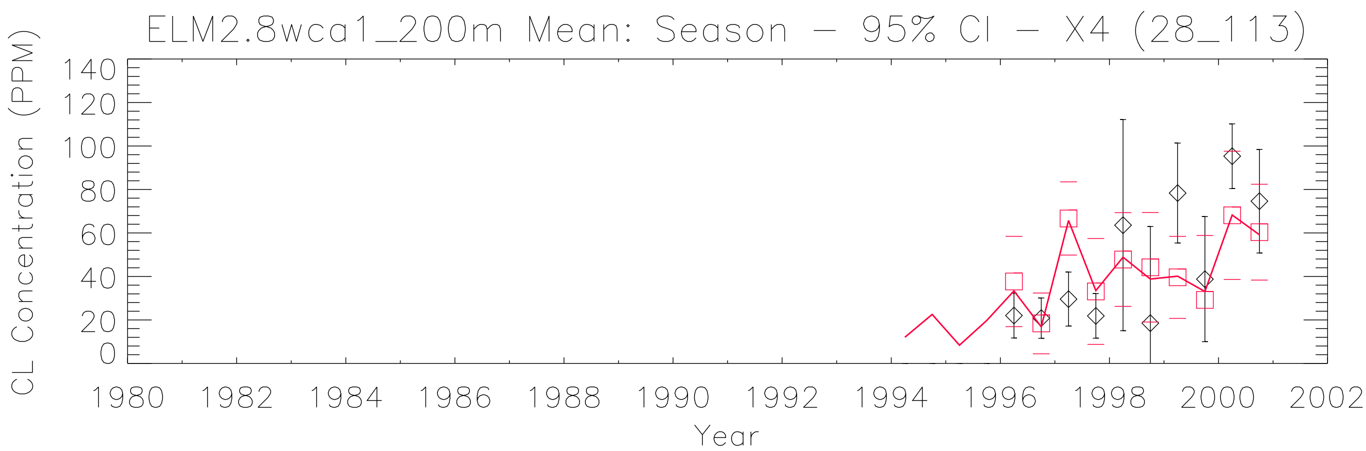
ELM2.8wca1_200m Mean: Season - 95% CI - X3 (16_116)
CL Concentration (PPM)
Year

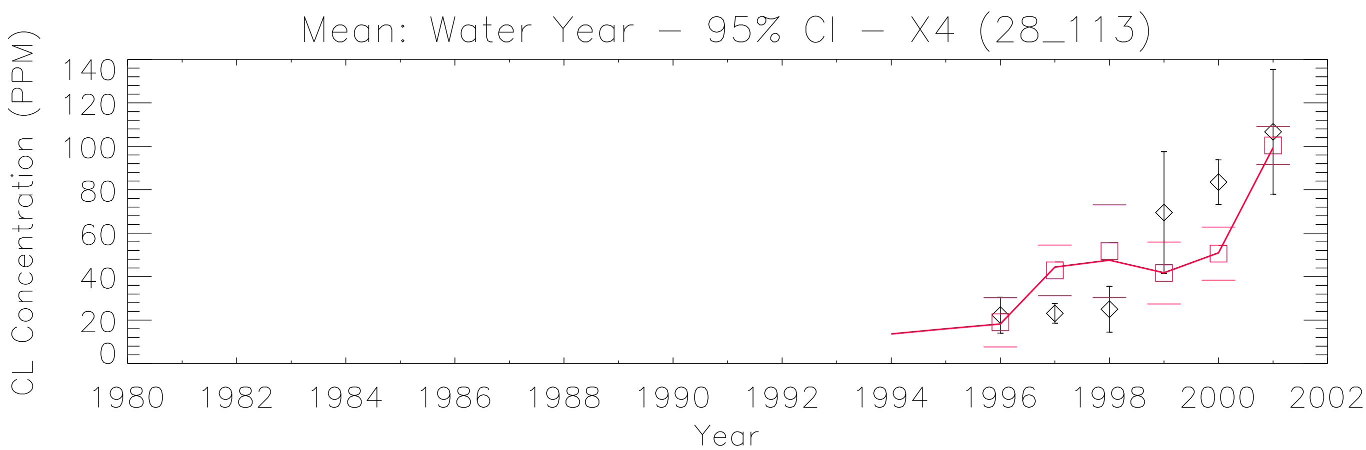


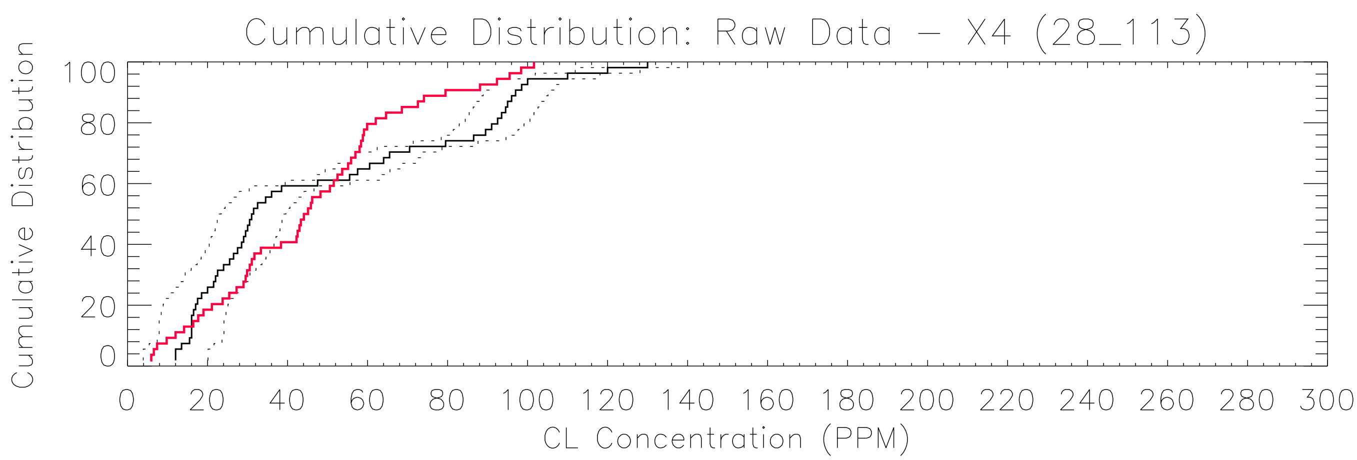
Mean: Water Year - 95% CI - X3 (16_116)
CL Concentration (PPM)
Year

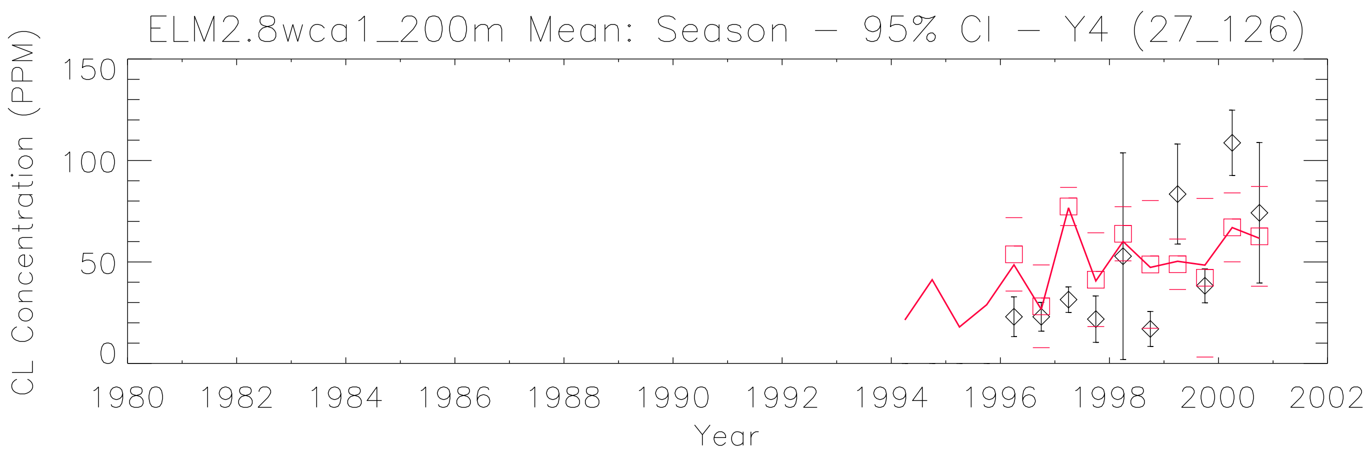


Cumulative Distribution: Raw Data - X3 (16_116)
Cumulative Distribution
CL Concentration (PPM)

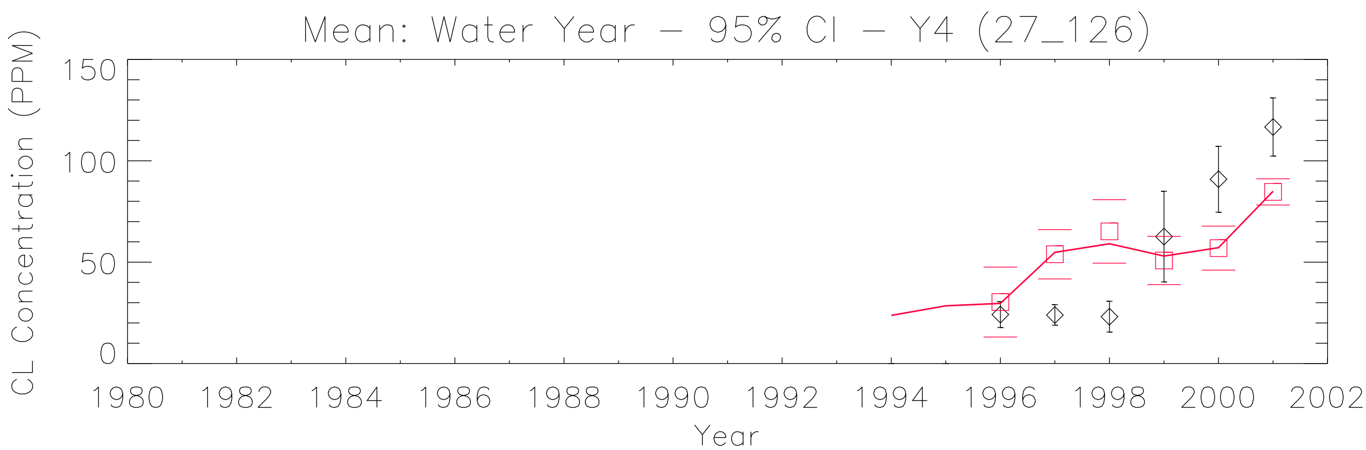

ELM2.8wca1_200m Mean: Season – 95% CI – X4 (28_113)
CL Concentration (PPM)
0
20
40
60
80
100
120
140
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Mean: Water Year – 95% CI – X4 (28_113)
CL Concentration (PPM)
0
20
40
60
80
100
120
140
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

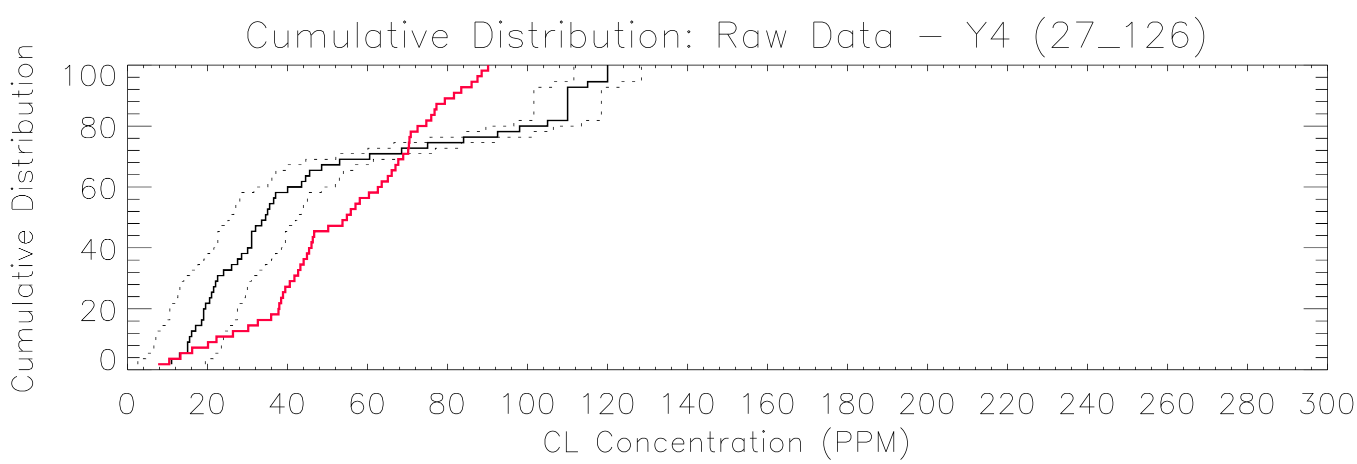

Cumulative Distribution: Raw Data – X4 (28_113)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)



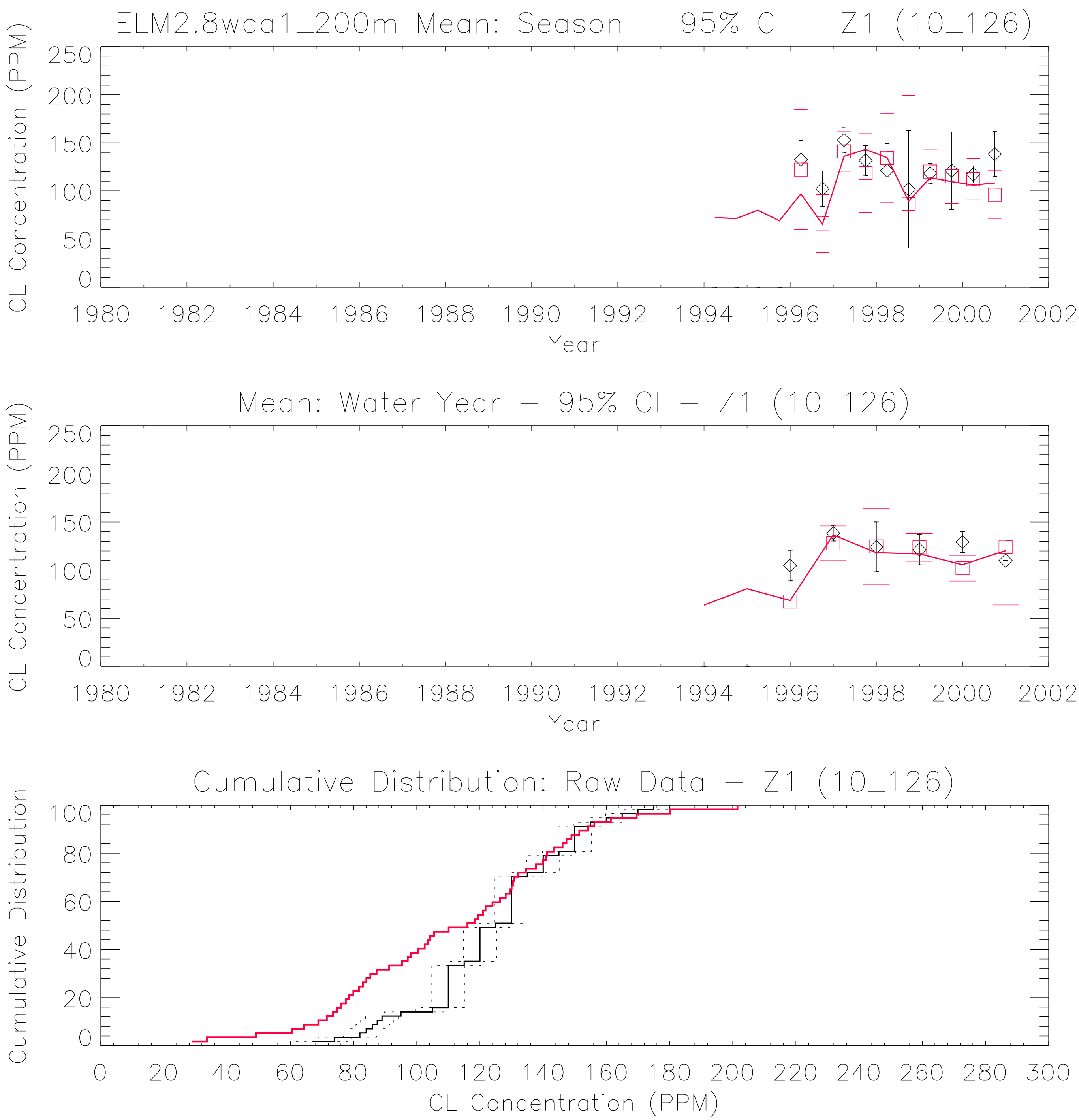
ELM2.8wca1_200m Mean: Season - 95% CI - Y4 (27_126)
CL Concentration (PPM)
Year



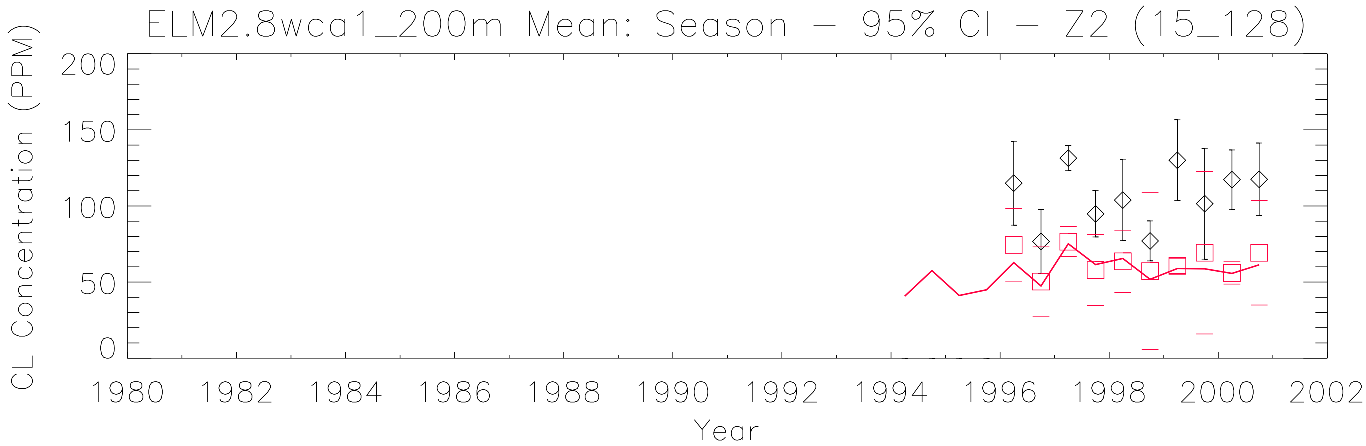
Mean: Water Year - 95% CI - Y4 (27_126)
CL Concentration (PPM)
Year

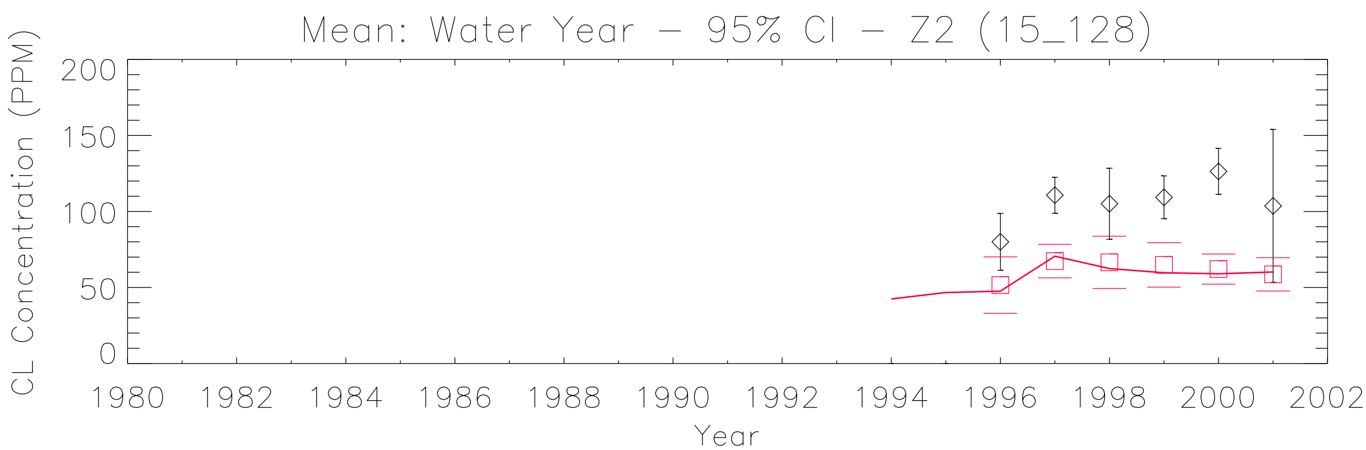


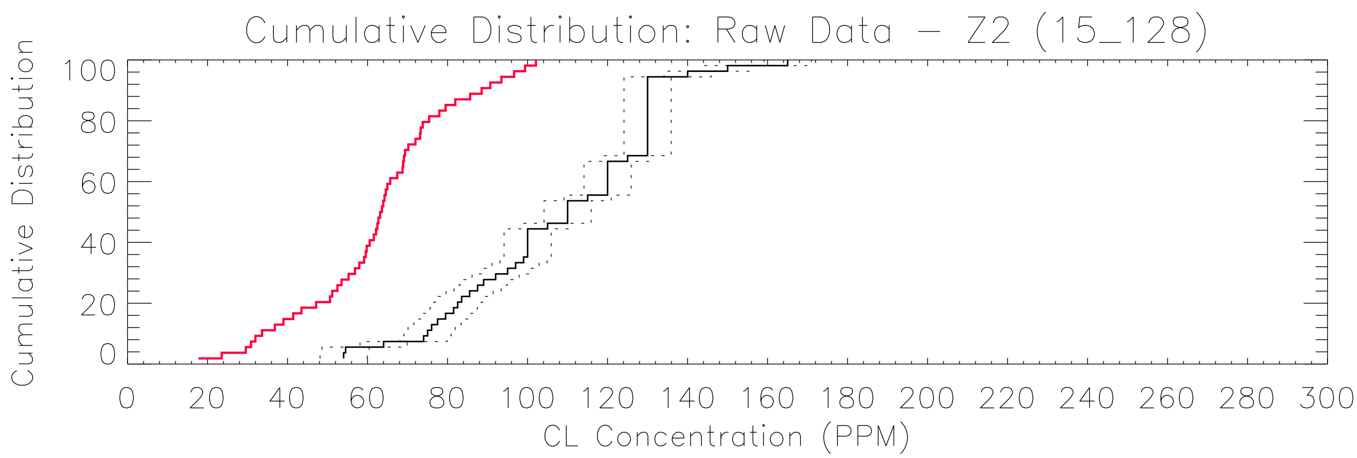
Cumulative Distribution: Raw Data - Y4 (27_126)
Cumulative Distribution
CL Concentration (PPM)

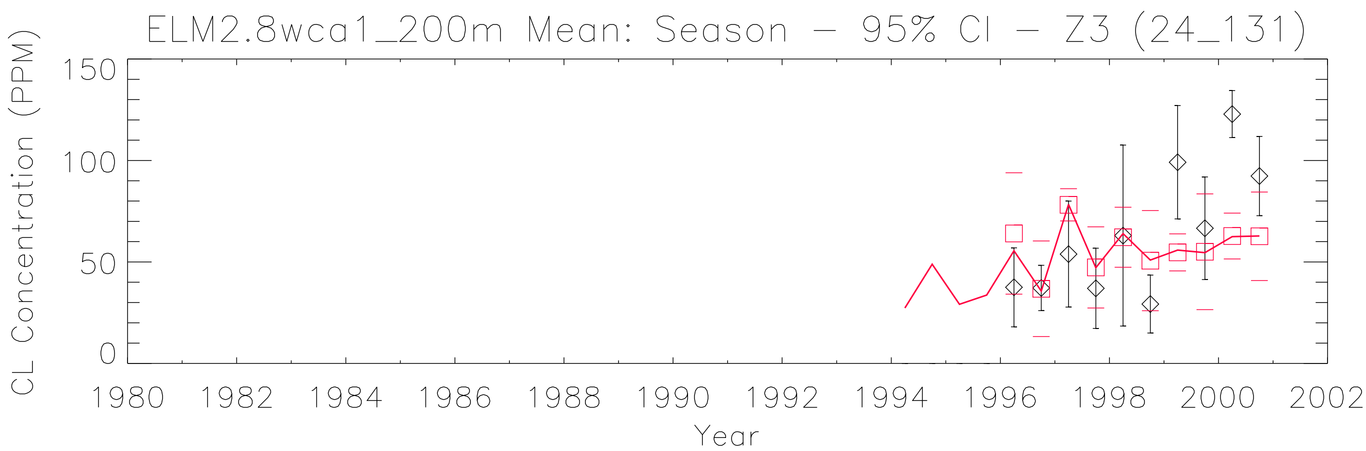


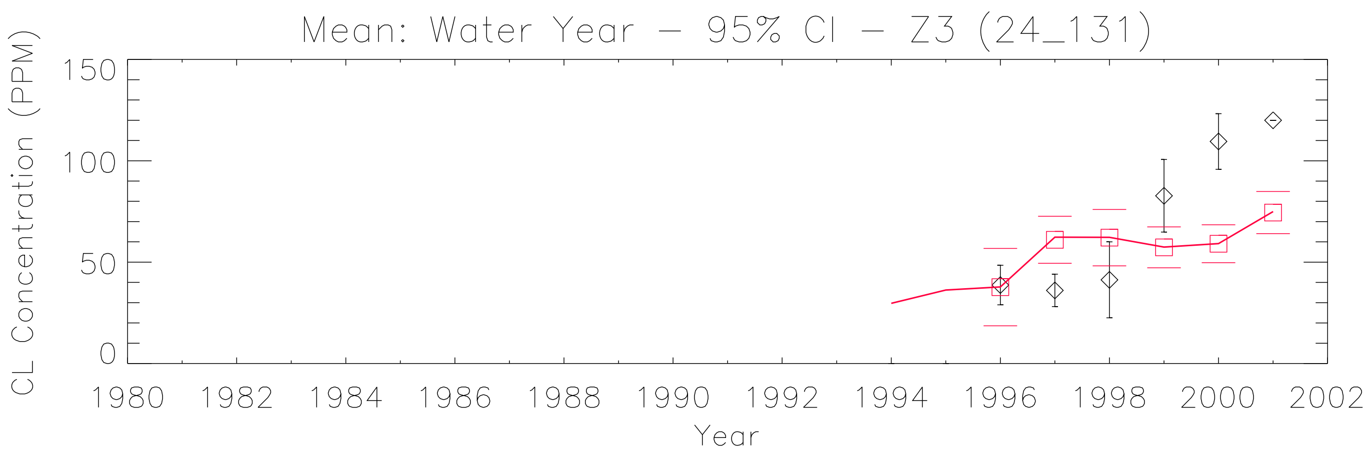
ELM2.8wca1_200m Mean: Season - 95% CI - Z1 (10_126)
CL Concentration (PPM)
Year
Mean: Water Year - 95% CI - Z1 (10_126)
CL Concentration (PPM)
Year
Cumulative Distribution: Raw Data - Z1 (10_126)
Cumulative Distribution
CL Concentration (PPM)

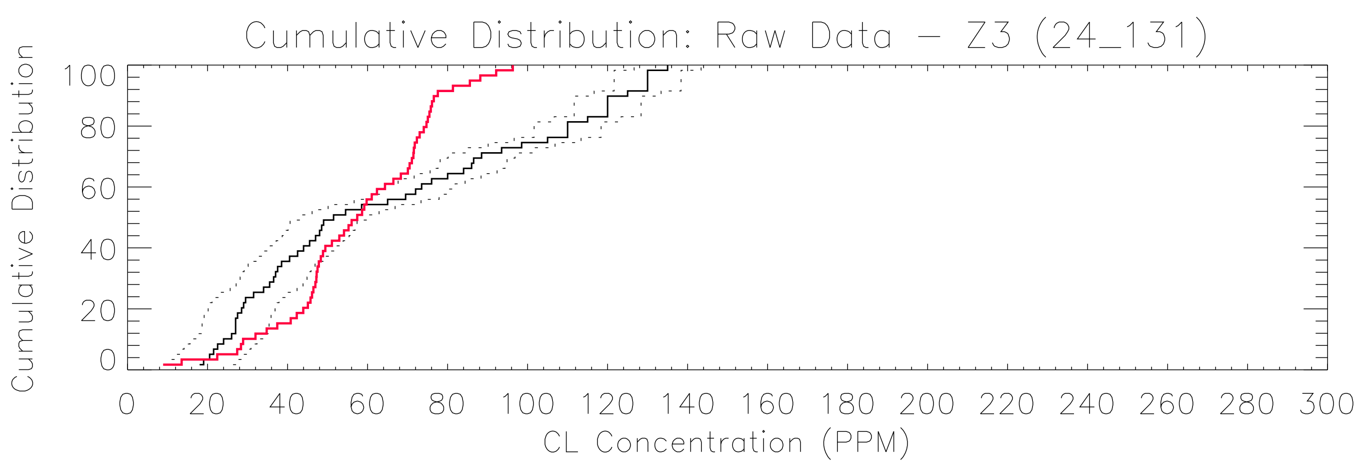

ELM2.8wca1_200m Mean: Season - 95% CI - Z2 (15_128)
CL Concentration (PPM)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

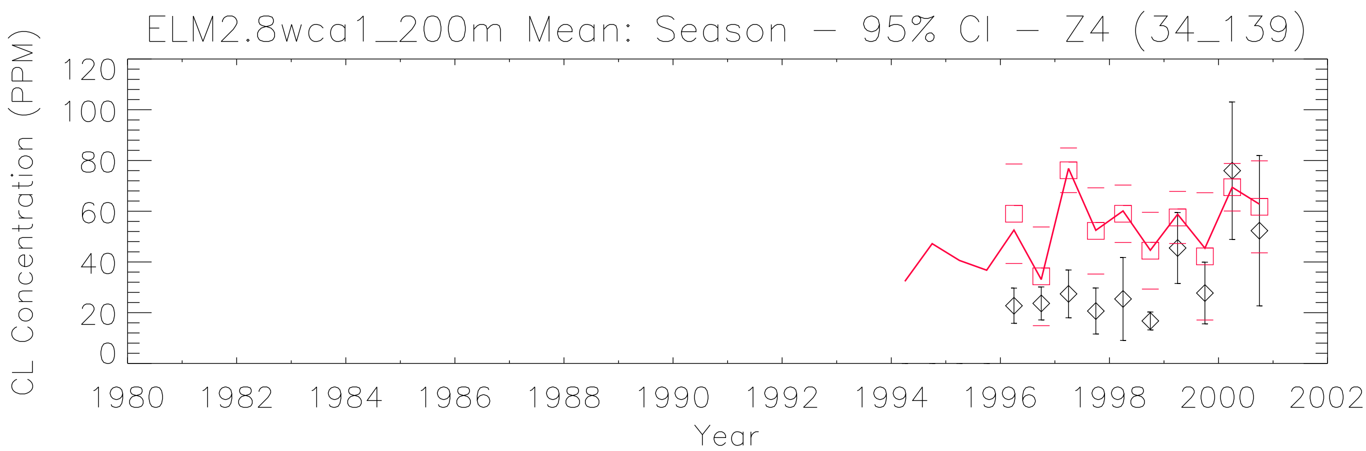

Mean: Water Year - 95% CI - Z2 (15_128)
CL Concentration (PPM)
0
50
100
150
200
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

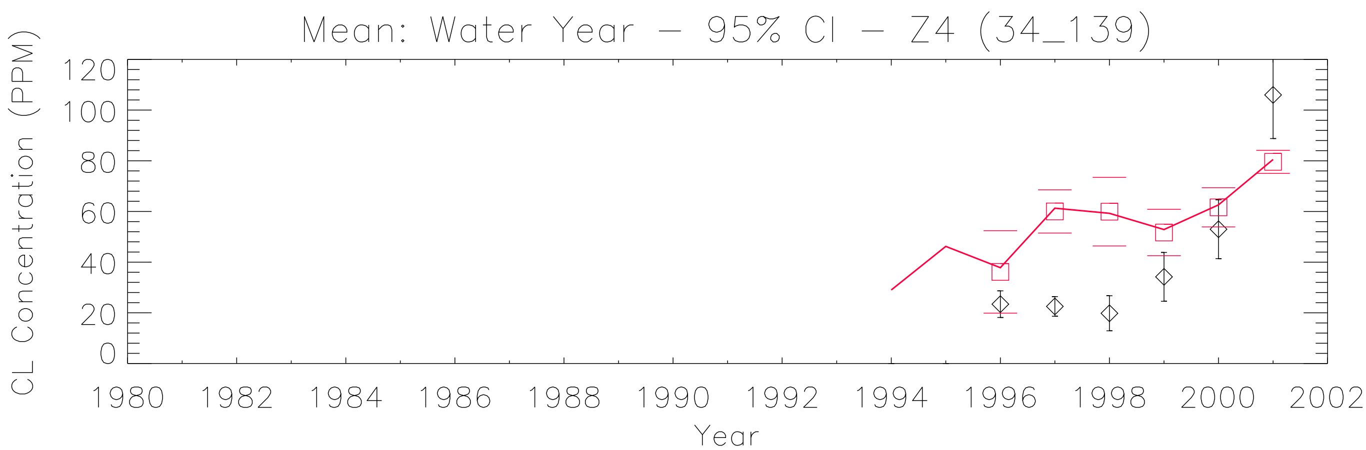

Cumulative Distribution: Raw Data - Z2 (15_128)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

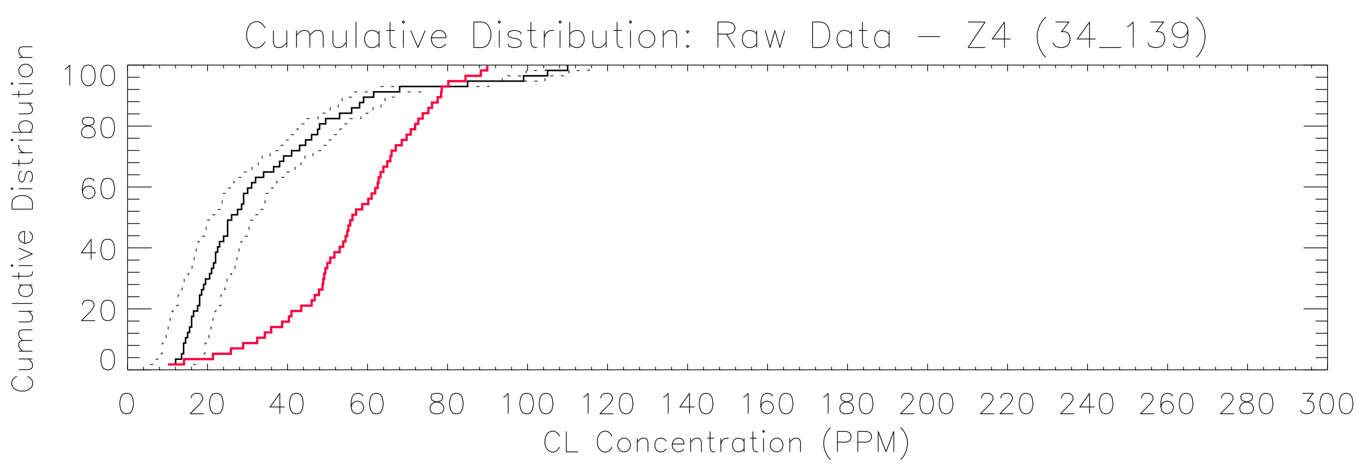

ELM2.8wca1_200m Mean: Season - 95% CI - Z3 (24_131)
CL Concentration (PPM)
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

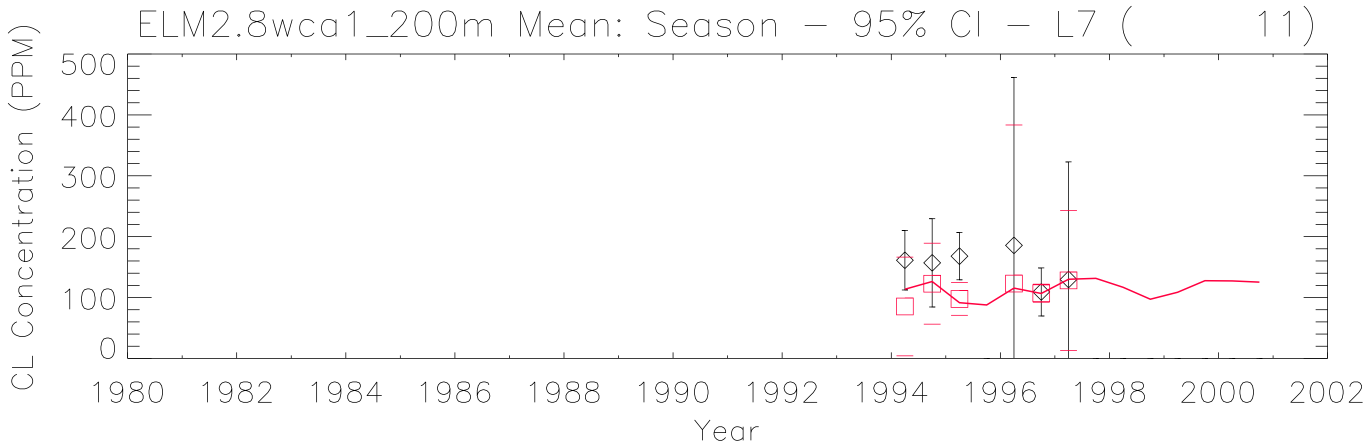

Mean: Water Year - 95% CI - Z3 (24_131)
CL Concentration (PPM)
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year


Cumulative Distribution: Raw Data - Z3 (24_131)
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)

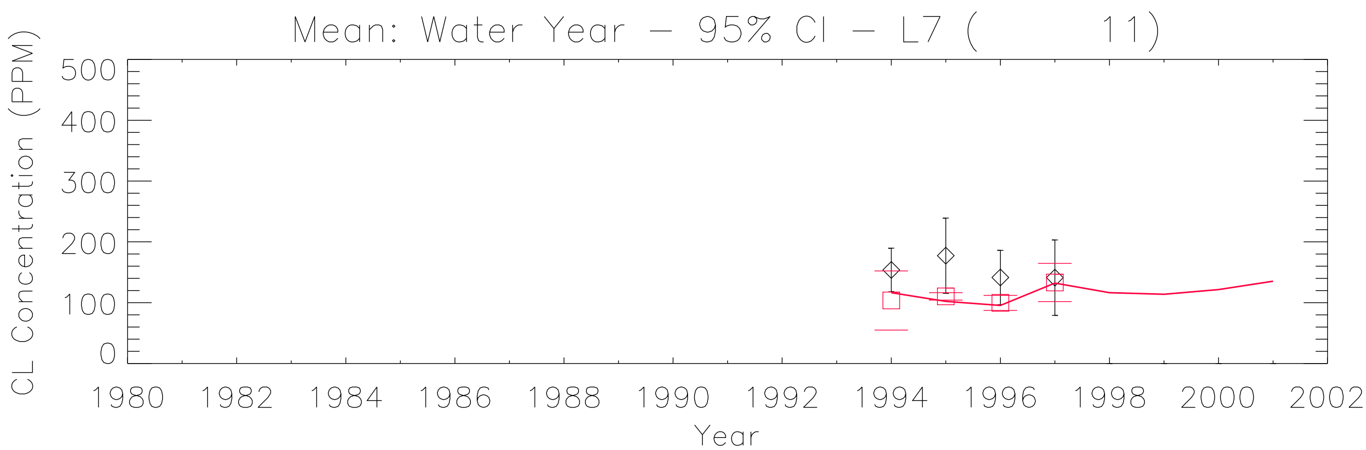

ELM2.8wca1_200m Mean: Season - 95% CI - Z4 (34_139)
CL Concentration (PPM)
Year


Mean: Water Year - 95% CI - Z4 (34_139)
CL Concentration (PPM)
Year

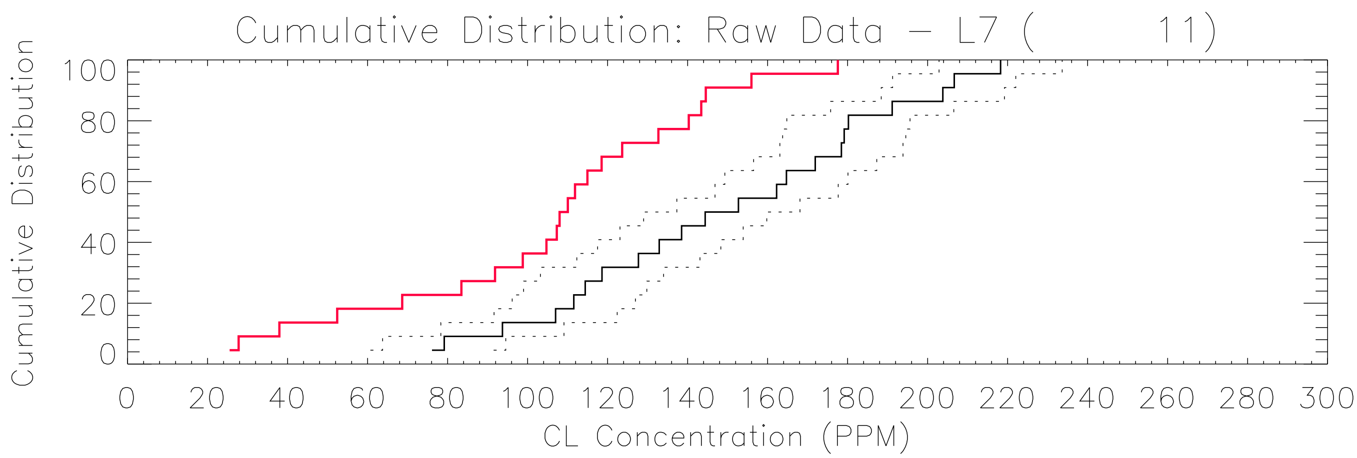

Cumulative Distribution: Raw Data - Z4 (34_139)
Cumulative Distribution
CL Concentration (PPM)



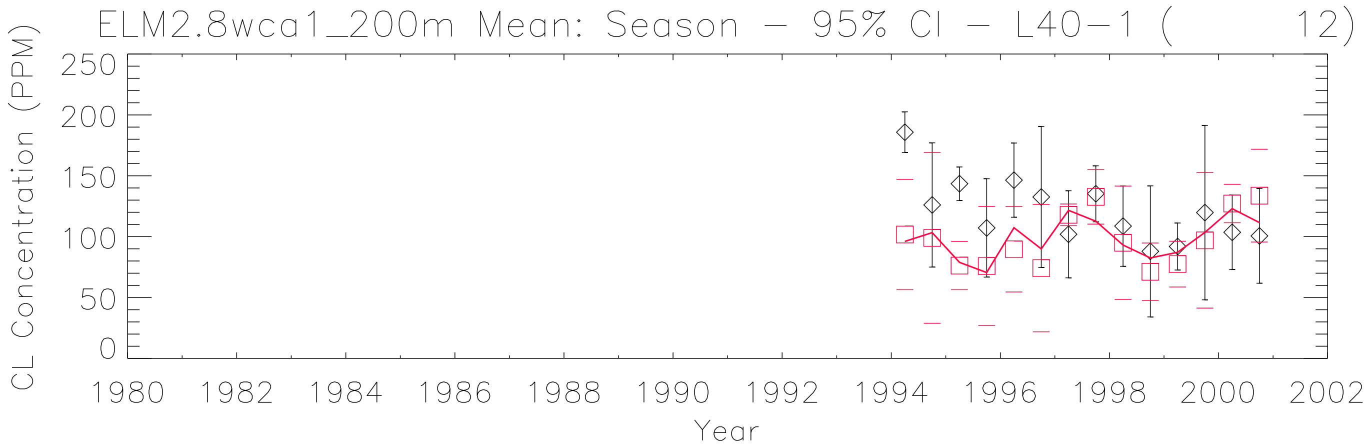
ELM2.8wca1_200m Mean: Season – 95% CI – L7 (11)
CL Concentration (PPM)
0
100
200
300
400
500
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

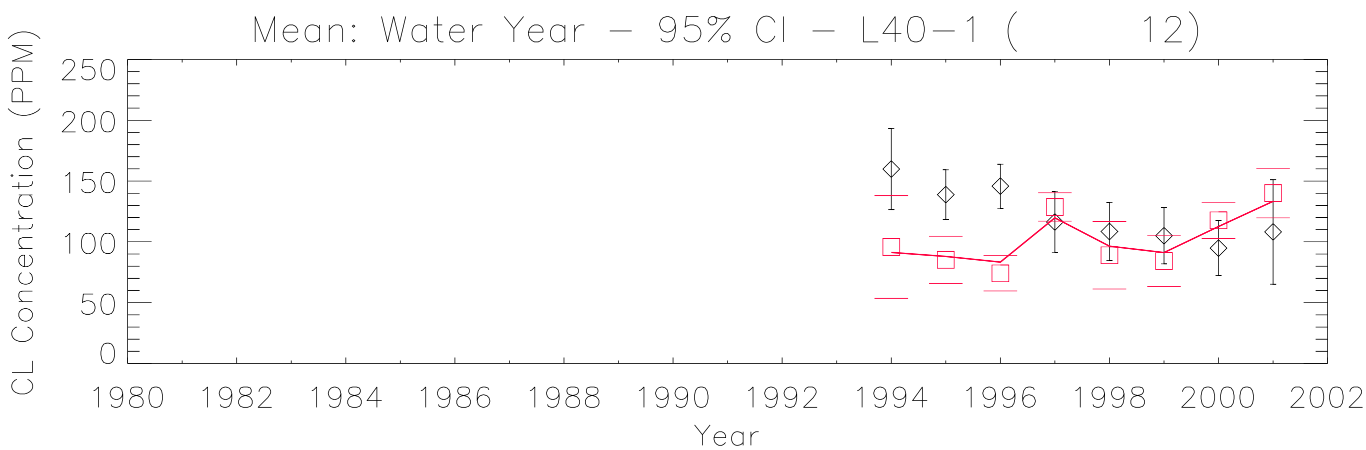


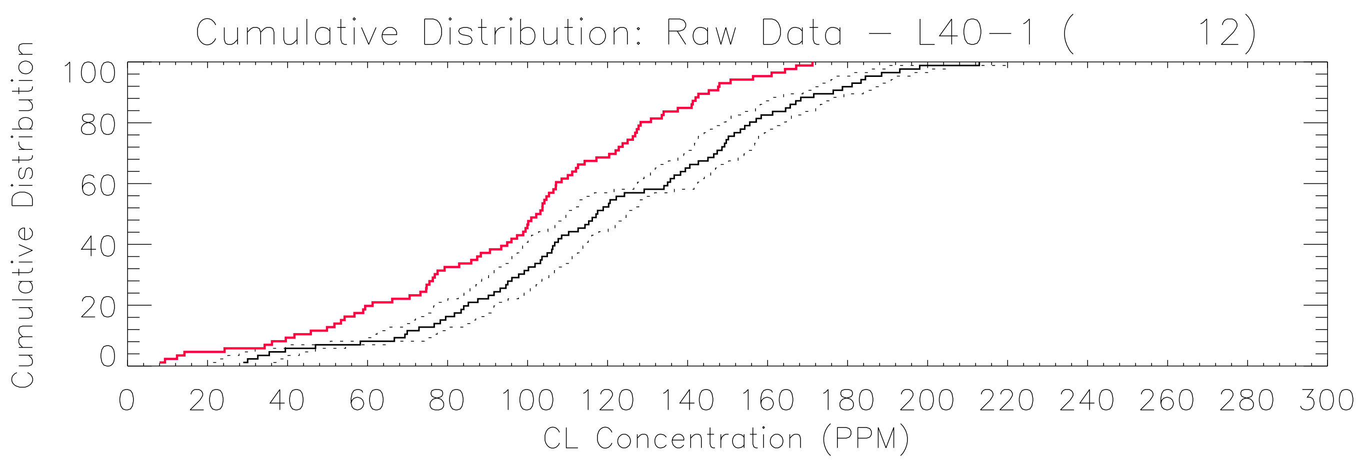
Mean: Water Year – 95% CI – L7 (11)
CL Concentration (PPM)
0
100
200
300
400
500
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

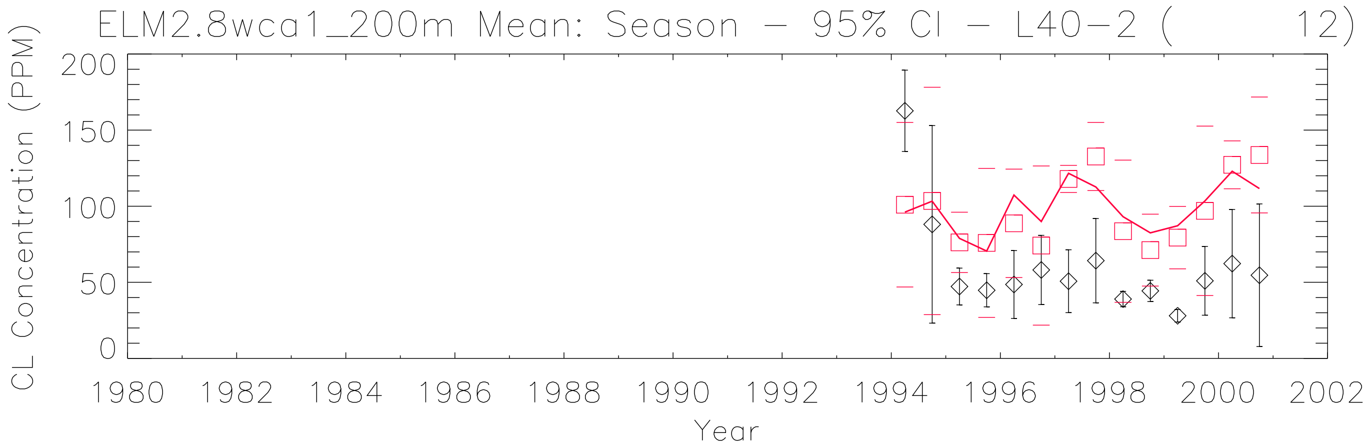


Cumulative Distribution: Raw Data – L7 (11)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

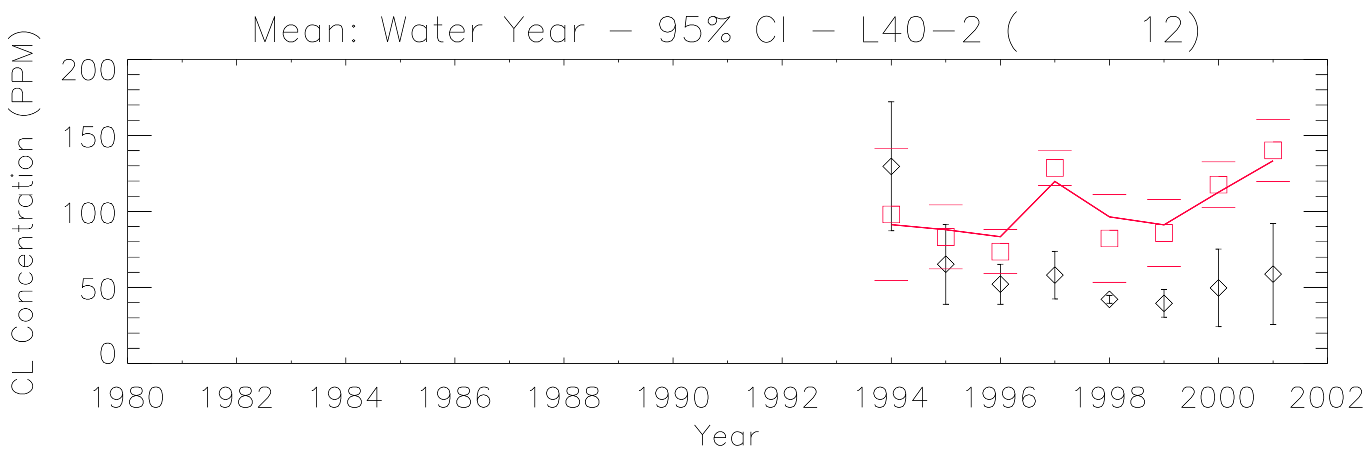

ELM2.8wca1_200m Mean: Season - 95% CI - L40-1 (12)
CL Concentration (PPM)
Year
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002


Mean: Water Year - 95% CI - L40-1 (12)
CL Concentration (PPM)
Year
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002

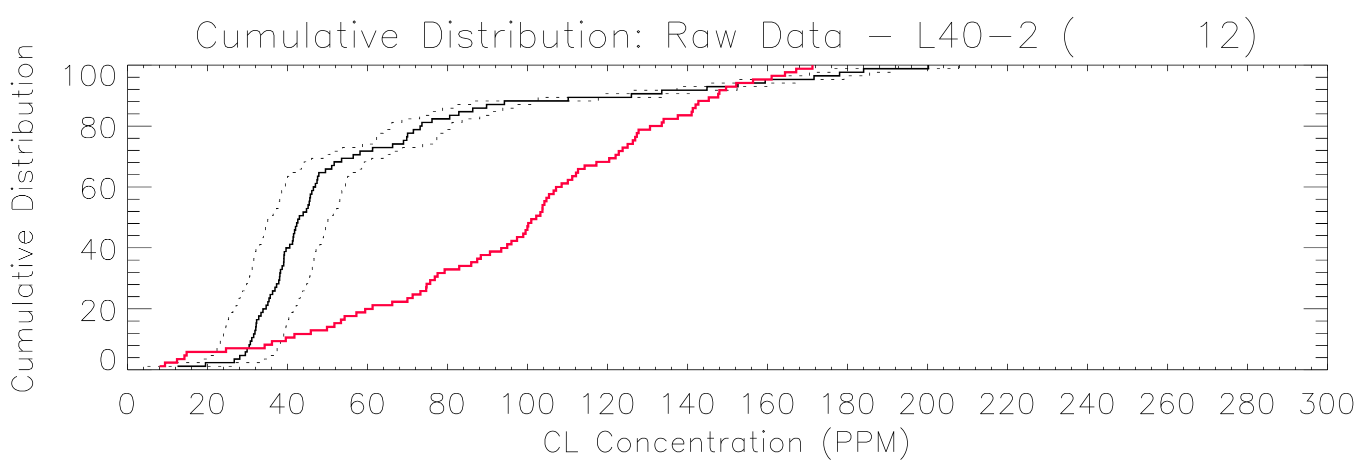

Cumulative Distribution: Raw Data - L40-1 (12)
Cumulative Distribution
CL Concentration (PPM)
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300



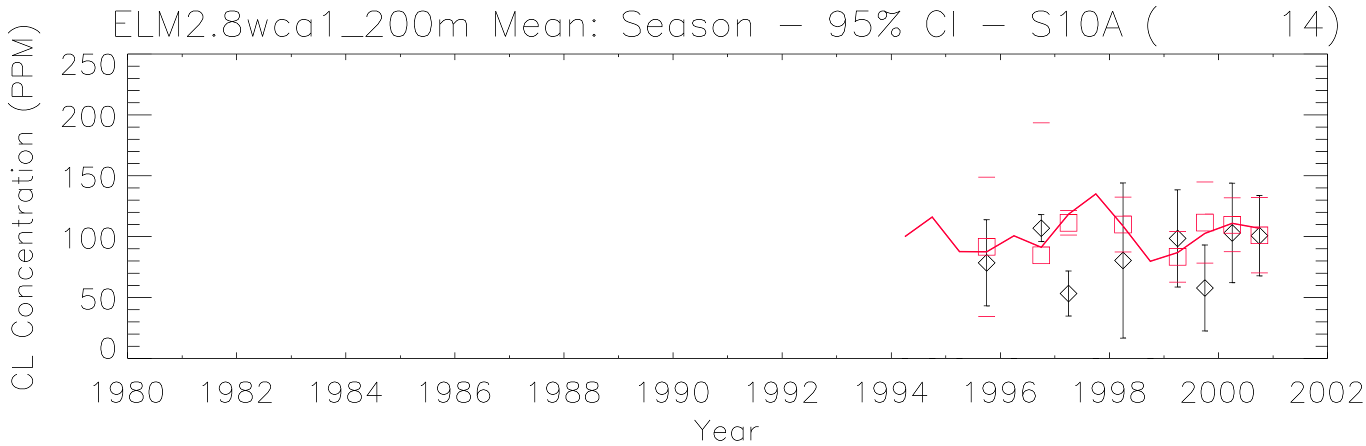
ELM2.8wca1_200m Mean: Season - 95% CI - L40-2 (12)
CL Concentration (PPM)
Year



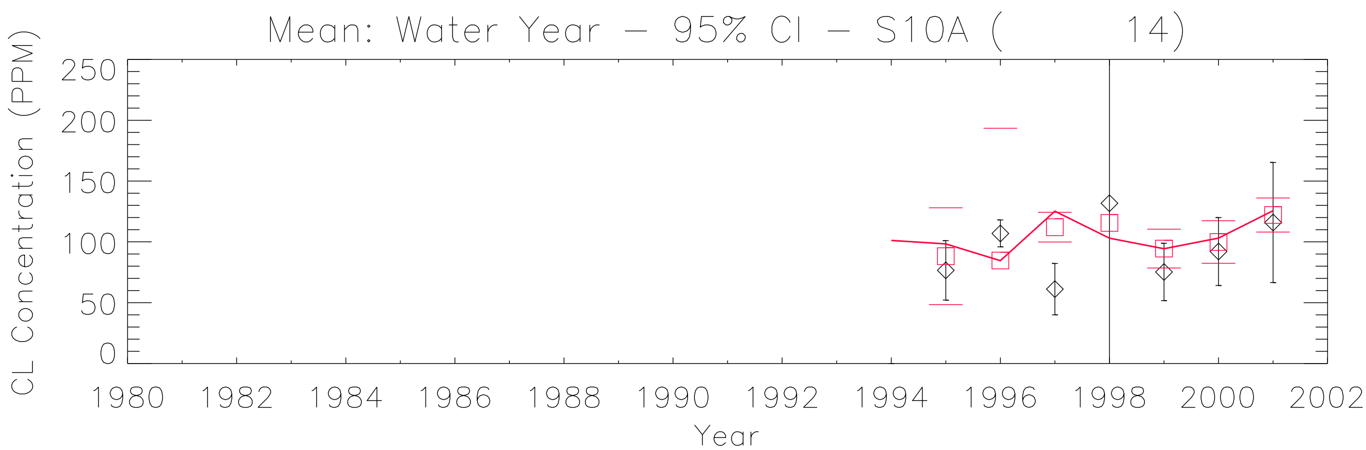
Mean: Water Year - 95% CI - L40-2 (12)
CL Concentration (PPM)
Year



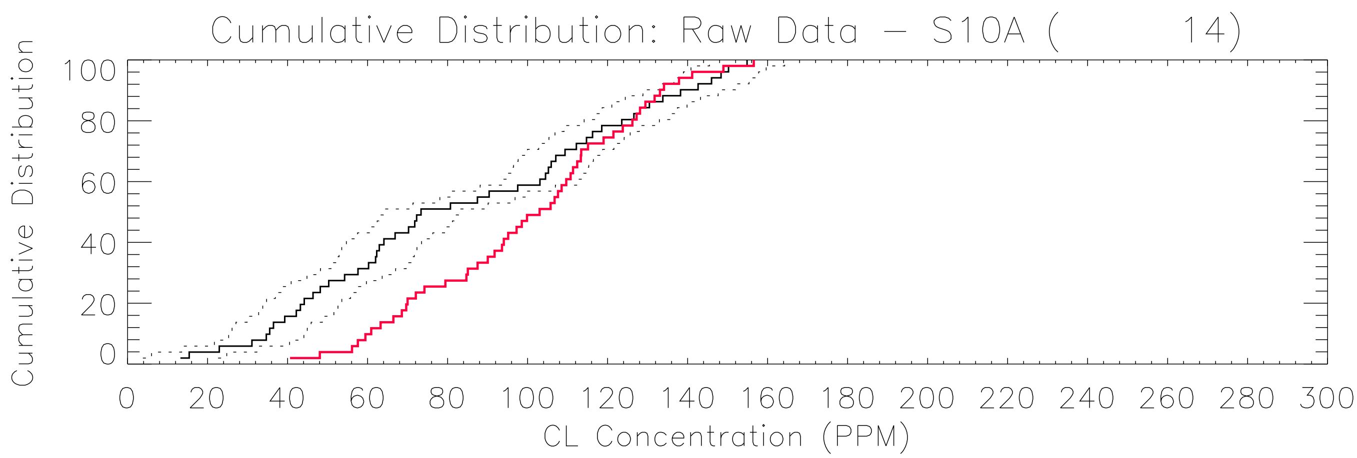
Cumulative Distribution: Raw Data - L40-2 (12)
Cumulative Distribution
CL Concentration (PPM)



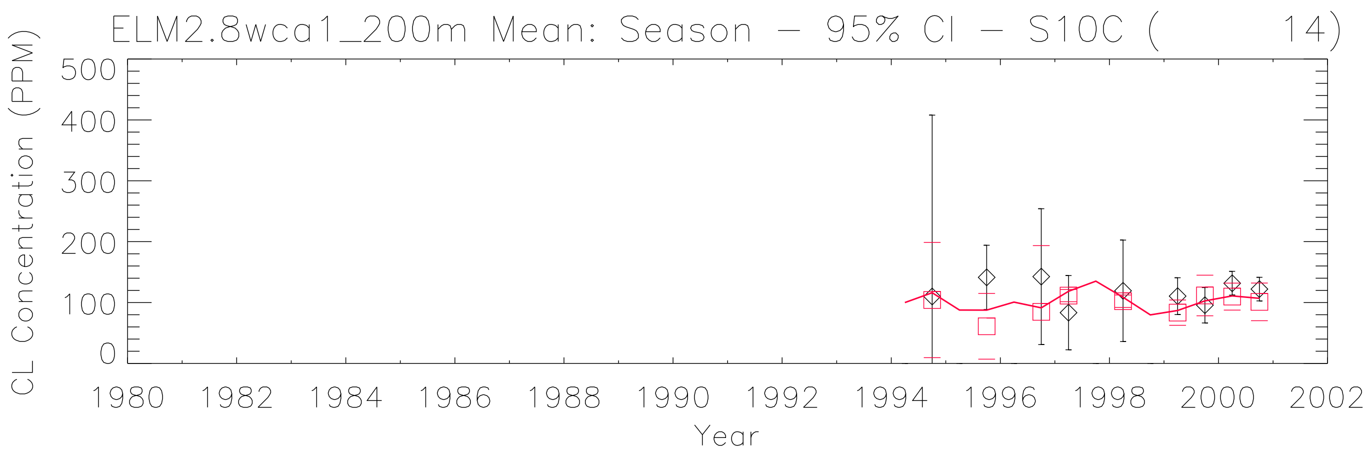
ELM2.8wca1_200m Mean: Season – 95% CI – S10A (14)
CL Concentration (PPM)
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

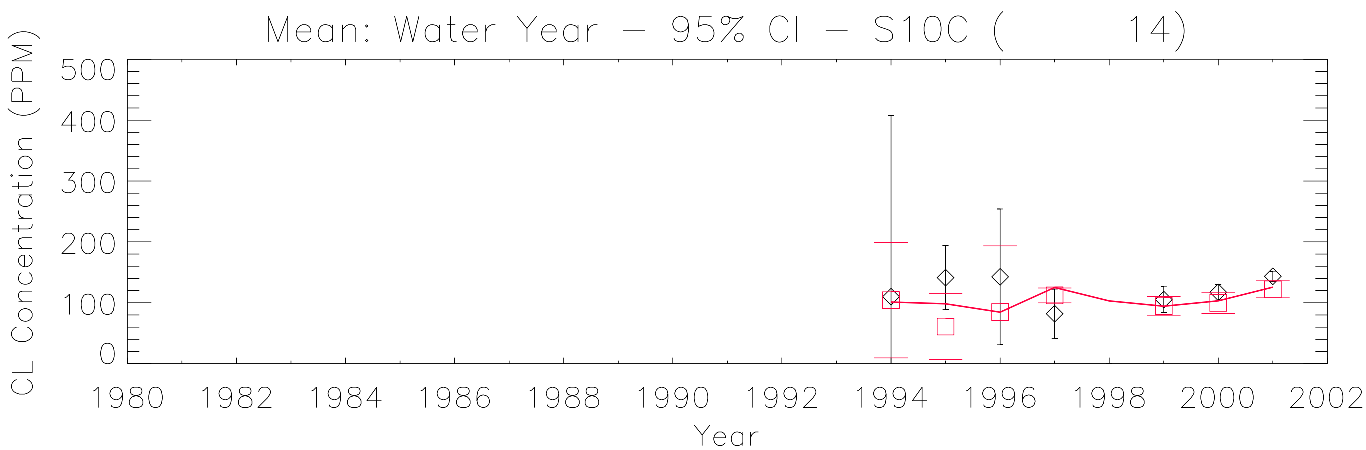


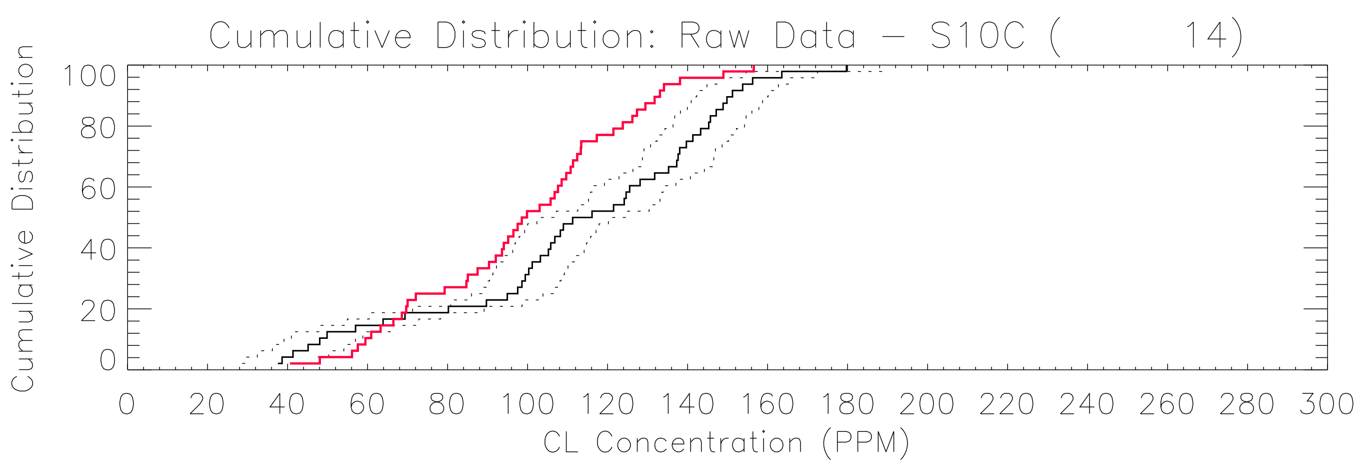
Mean: Water Year – 95% CI – S10A (14)
CL Concentration (PPM)
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

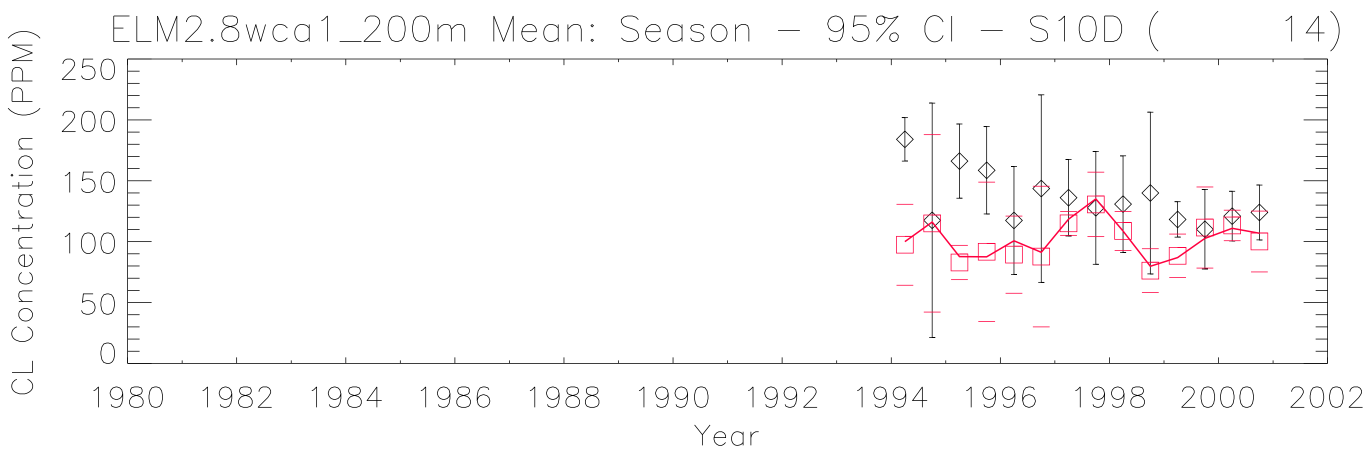


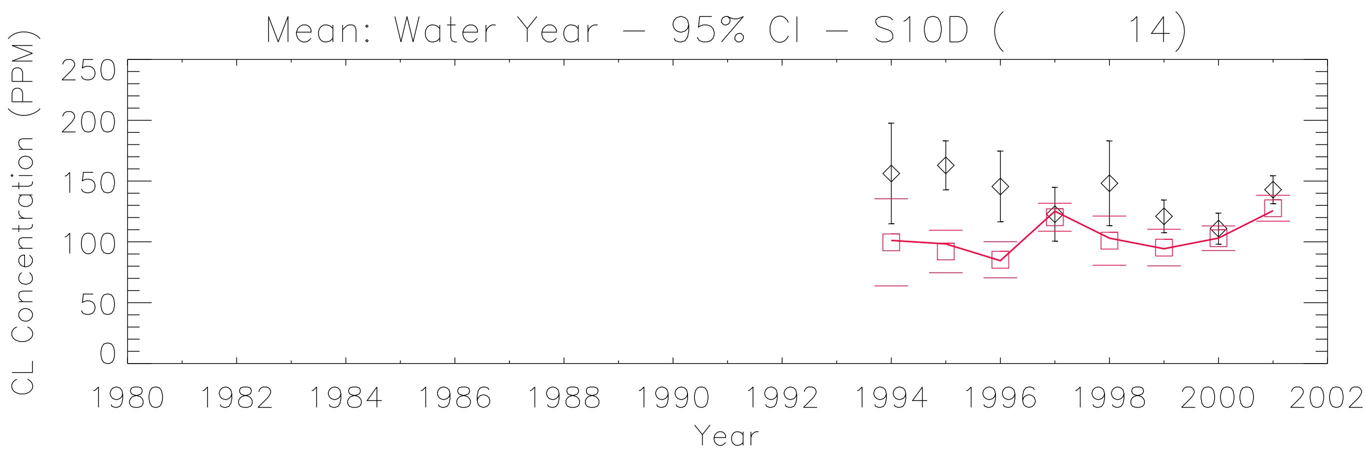
Cumulative Distribution: Raw Data – S10A (14)
Cumulative Distribution
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

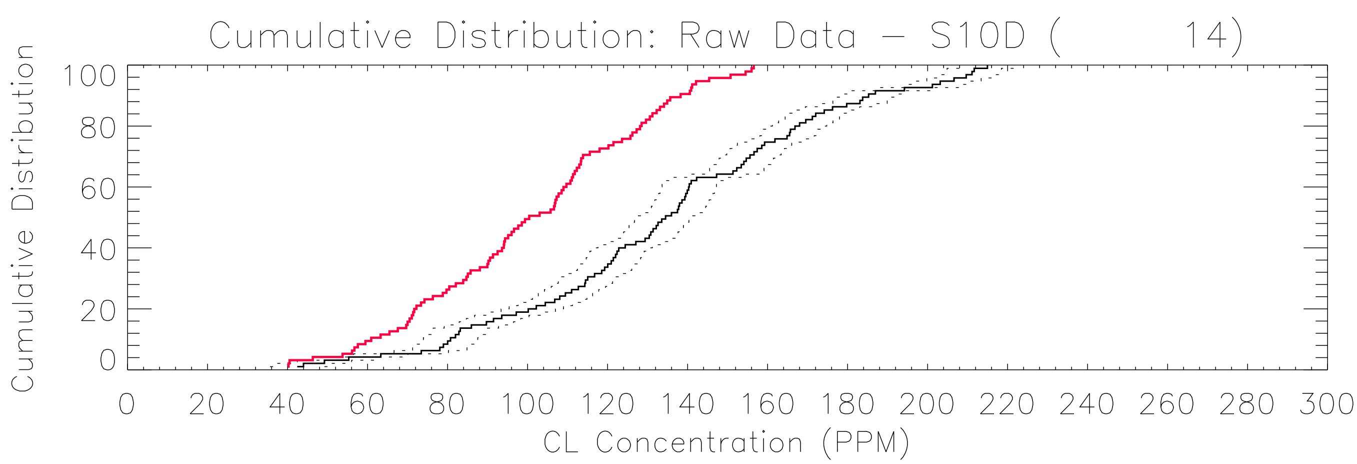

ELM2.8wca1_200m Mean: Season – 95% CI – S10C (14)
CL Concentration (PPM)
0
100
200
300
400
500
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

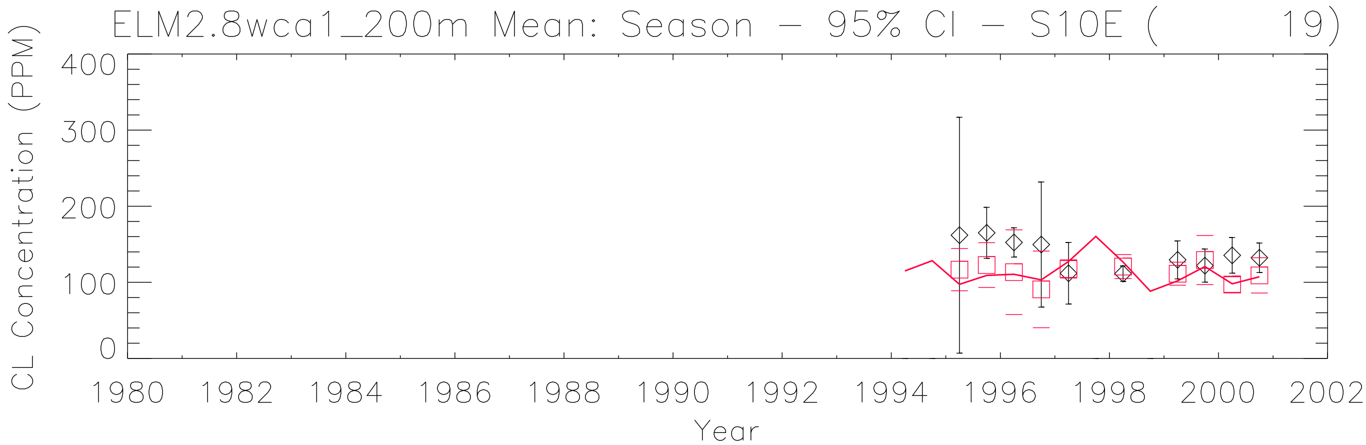

Mean: Water Year – 95% CI – S10C (14)
CL Concentration (PPM)
0
100
200
300
400
500
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

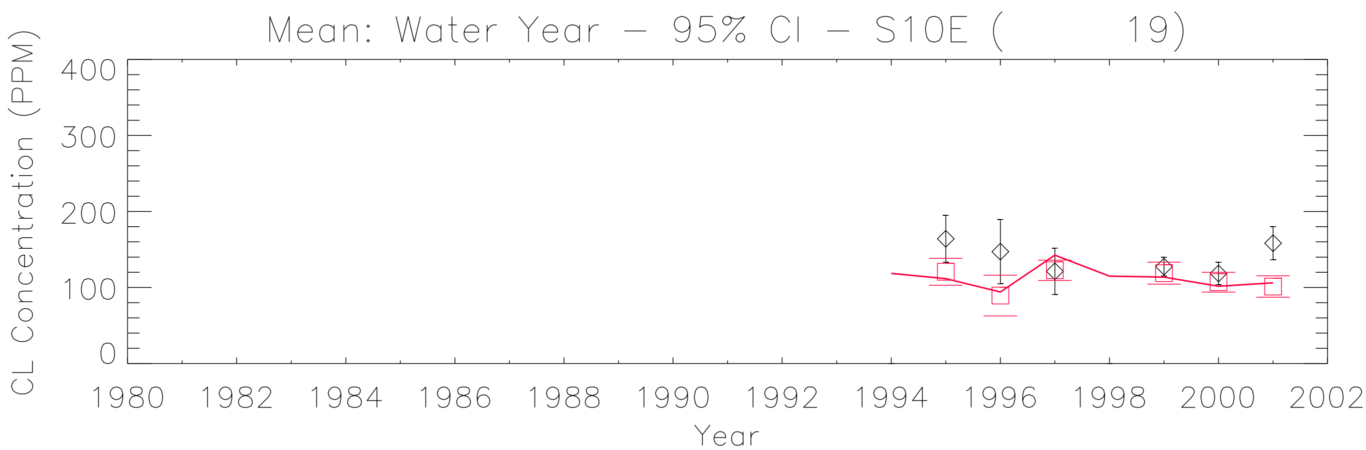

Cumulative Distribution: Raw Data – S10C (14)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

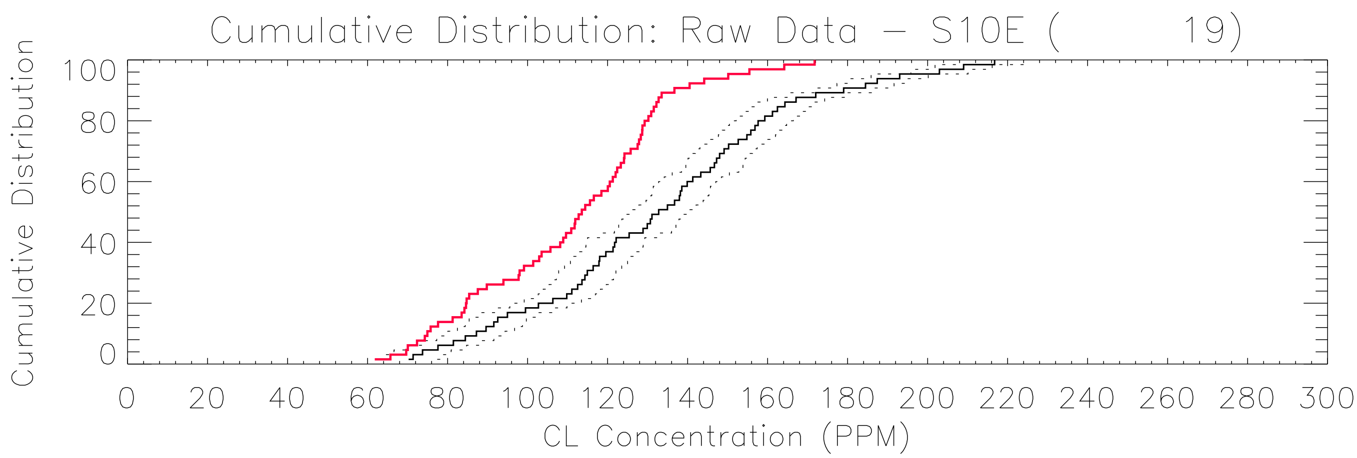

ELM2.8wca1_200m Mean: Season – 95% CI – S10D (14)
CL Concentration (PPM)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

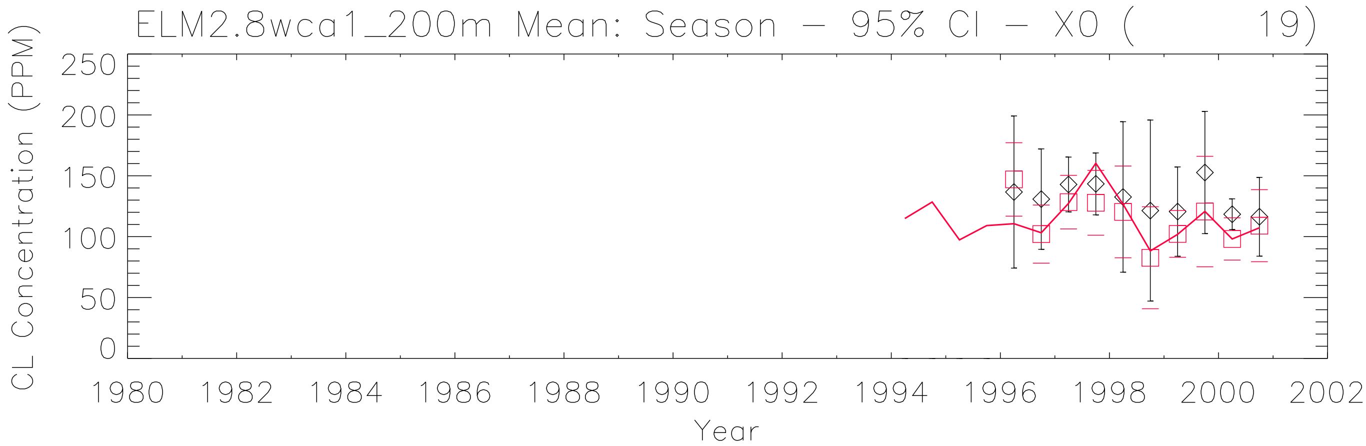

Mean: Water Year – 95% CI – S10D (14)
CL Concentration (PPM)
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year

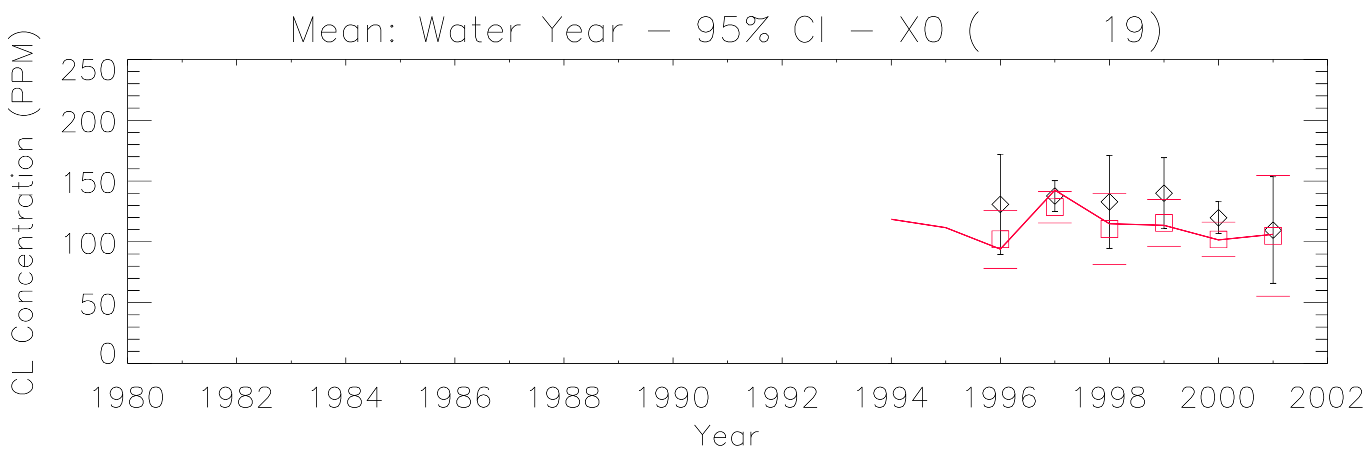

Cumulative Distribution: Raw Data – S10D (14)
Cumulative Distribution
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
CL Concentration (PPM)

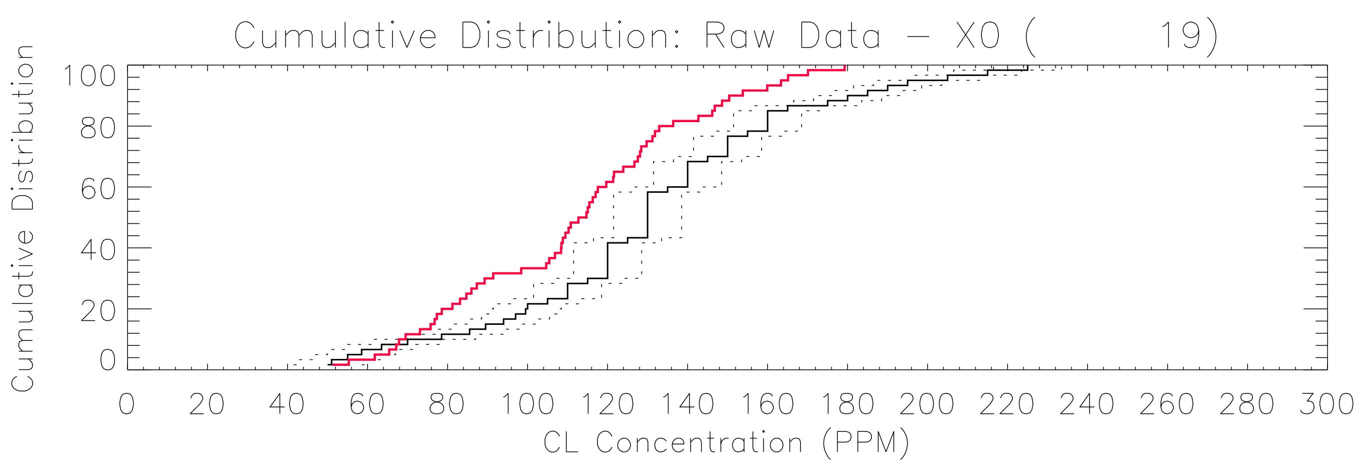

ELM2.8wca1_200m Mean: Season - 95% CI - S10E (19)
CL Concentration (PPM)
Year

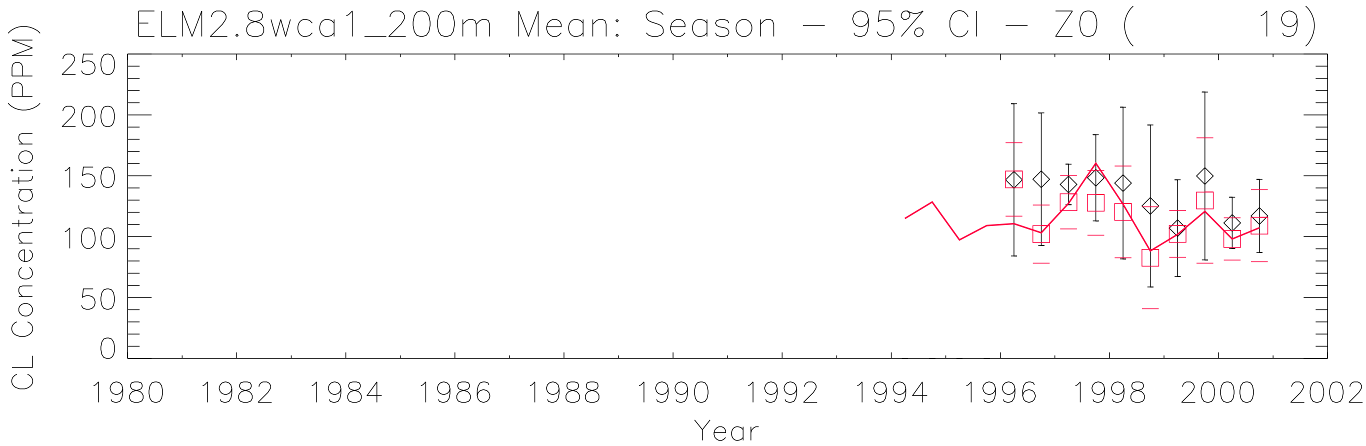

Mean: Water Year - 95% CI - S10E (19)
CL Concentration (PPM)
Year

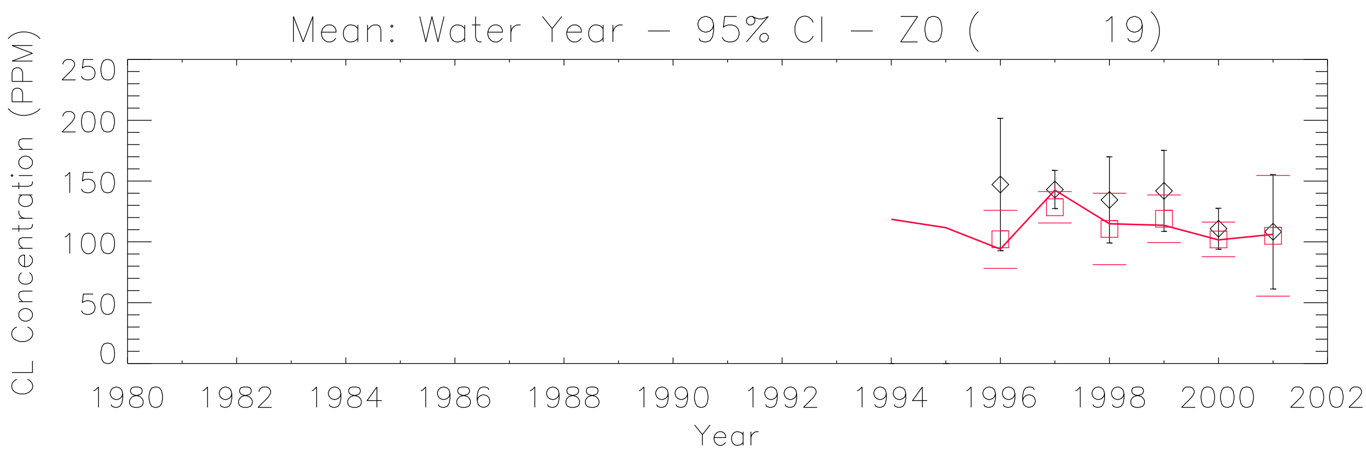

Cumulative Distribution: Raw Data - S10E (19)
Cumulative Distribution
CL Concentration (PPM)

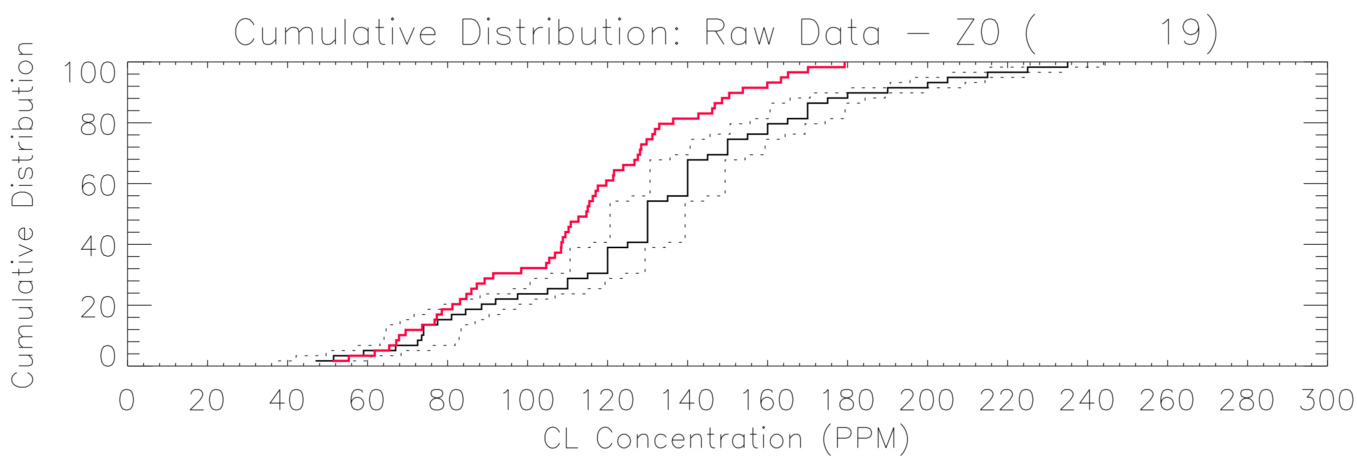

ELM2.8wca1_200m Mean: Season - 95% CI - X0 (19)
CL Concentration (PPM)
Year
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002


Mean: Water Year - 95% CI - X0 (19)
CL Concentration (PPM)
Year
0
50
100
150
200
250
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002


Cumulative Distribution: Raw Data - X0 (19)
Cumulative Distribution
CL Concentration (PPM)
0
20
40
60
80
100
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300


ELM2.8wca1_200m Mean: Season - 95% CI - Z0 (19)
CL Concentration (PPM)
Year

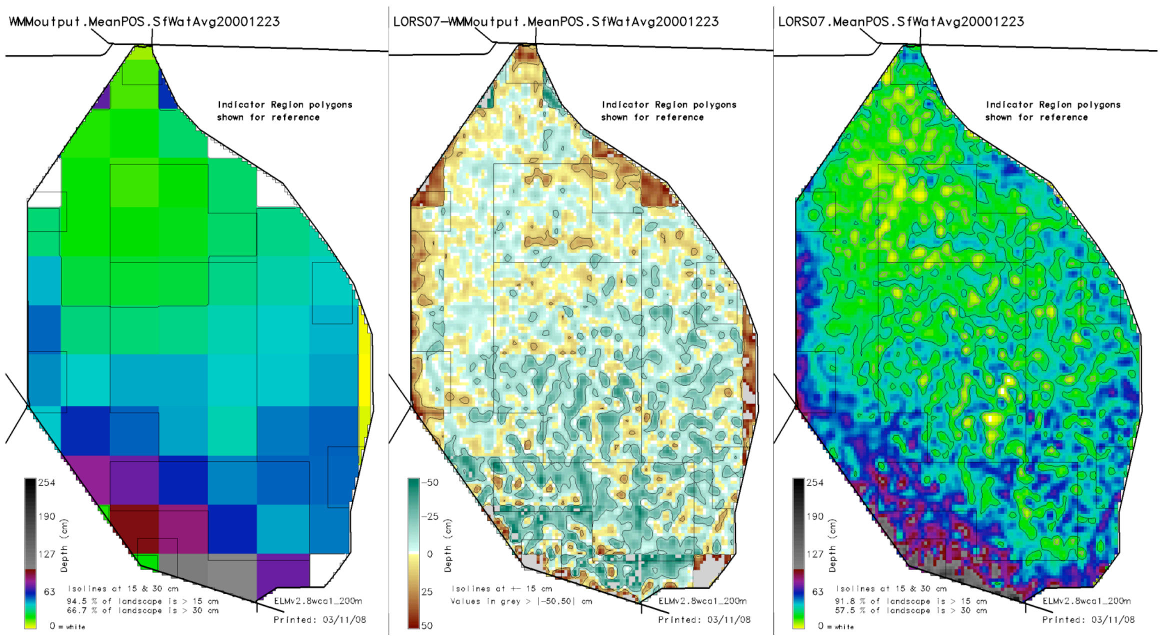

Mean: Water Year - 95% CI - Z0 (19)
CL Concentration (PPM)
Year


Cumulative Distribution: Raw Data - Z0 (19)
Cumulative Distribution
CL Concentration (PPM)

This page left blank

Documentation of the Everglades Landscape Model: ELMwca1 v2.8

Chapter 8: Model Application



http://ecolandmod.ifas.ufl.edu

March 28, 2008

This page left blank

Chapter 8: Model Application

8.1 Executive summary

The Model Performance Chapter of this ELMwca1 documentation provided strong evidence of model skill in predicting hydrologic and water quality trends at scales necessary for analysis of ecological restoration of WCA-1. In its subregional (567 km^2, or 219 square miles) application at 200 m grid resolution, the model was used to evaluate the relative benefits among water management scenarios for ecological restoration.

The principal changes made to the ELM since the Independent Peer Review of ELM v2.5 involved the addition and/or refinement of rule-based water management algorithms. This enhanced model functionality allowed evaluations of the ecological benefits of *alternative management infrastructure and operations*, with the overall goal being to aid in the planning process for marsh restoration within WCA-1.

The objectives of this Model Application Chapter are to provide 1) the quantitative results of a suite of simulation scenarios and 2) basic interpretations, for use by the SFWMD science team in selecting the preferred alternative scenario for restoration planning. To organize the large amount of model output, a "tentative selection" of a preferred scenario was made from the 12 that were simulated. Alternative conclusions (regarding a preferred scenario) may likely be reached after more thorough scrutiny by the SFWMD science team, considering potential trade-offs between hydrologic restoration, water quality restoration, water availability, and other constraints.

Of twelve alternative scenarios, *the final scenario that was run appeared to perform best from the combined hydrologic and water quality perspectives*. This *tentatively "selected"* scenario was close to approximating generalized target stages in mid-WCA-1 with respect to the seasonality and magnitude of the maxima and minima of water depths. In a variety of other characteristics, that restoration scenario usually appeared closer to targeted (generalized NSM) trends than other scenarios, when considering multiple Performance Measures associated with both ponding and dry-out depths and durations .

The current (i.e., baseline) system dries out to excess in the north, while being excessively wet in the south. However, the tentatively selected scenario showed an *ecologically significant reduction in the depth-discrepancies between northern and southern areas of the system.*

Finally, chloride water quality was among the best in the tentatively selected scenario compared to other scenarios with external inputs, as this scenario required the least volume of external inflows that increased the chloride and phosphorus loading to the system. ***Relative to the external water demands in the Base run, the tentatively selected plan required only 20% of the inflows*** of "new" external water resources, while substantially improving the hydro-ecology of the system.

The volume of water that was recycled in the tentatively selected scenario was intermediate among managed scenarios with such a structure, and the selected scenario had the lowest managed outflows of excess water. The resulting average *overland flow velocities in most (north through south) subregions of the basin were representative of a "flowing" system*, although realistic flow velocity targets are unknown.

Background

8.1.1 Objectives of this document

The objectives of this Model Application Chapter are to provide 1) the quantitative results of a suite of simulation scenarios and 2) basic interpretations, for use by the SFWMD science team in selecting the preferred alternative scenario for restoration planning. The text descriptions of the relative benefits among scenarios are broad and simple descriptions, intended to aid the interpretation and discussion of model results.

To attempt to best organize the large amount of post-processed model output, the model developer framed this discussion by making a "tentative selection" of a preferred scenario from the 12 that were developed and simulated, with those results presented in the body of the document. All other tables, graphs, and maps of results are found in the Appendix.

Alternative conclusions (regarding a preferred scenario) may likely be reached after more thorough scrutiny by the SFWMD science team, considering potential trade-offs between hydrologic restoration, water quality restoration, water availability, and other management constraints.

8.1.2 Application summary

The ELMwca1 version 2.8[1] was used to evaluate relative differences in ecological performance of Everglades Water Conservation Area 1 (WCA-1) water management plans. 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 application in order to meet specific objectives of this WCA-1 restoration planning project. None of these changes resulted in significant differences in the performance characteristics of a regional application, but all provided either enhanced model functionality or incremental improvement to the predictive performance capabilities of the model at subregional and regional scales (see Model Performance, Chapter 6).

The principal change between ELM v2.5 and the current ELM v2.8 was the restructuring and refinement of algorithms that define rule-based managed flows through water control structures. Integral with the goals and objectives of this restoration project, these modifications allowed evaluations of simple alternatives to hydrologic and water quality management of the WCA-1 landscape. Moreover, while of minor consequence in statistical evaluations of (history-matching) model performance or in evaluating relative differences among restoration scenarios, we added chloride inputs from (rainfall) atmospheric deposition.

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 0.04 km^2 (200x200 m) resolution application in the WCA-1 hydrologic basin.

---

[1] The tertiary subversion designation of this v2.8 application release is v2.8.1.

8.1.3 ELM v2.8 (WCA-1) 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[2]) 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[3].

For this subregional application of ELM v2.8, we applied the ELM code and data to questions of hydrologic and water quality restoration of WCA-1, using Performance Measures involving water depths and durations, chloride concentrations, and phosphorus concentrations. Thus, this model application niche remains oriented towards the water quality component of ecological analysis, but is expanded to more explicitly include more of the hydrologic attributes that underlie water quality characteristics. The Model Performance Chapter 6 of this ELM v2.8 documentation provided strong evidence of model skill in supporting these Performance Measures at scales necessary for analysis of ecological restoration of Everglades Water Conservation Area 1 (WCA-1).

8.2 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 v5.5) is currently the 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

---

[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.

[3] 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.

primary assumptions is found at the South Florida Water Management District web site[4], 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.

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.

8.2.1 Assumptions Common to Base & Scenario Runs

The baseline (Base) run used as a reference point for comparison of restoration scenarios was the Lake Okeechobee Regulation Schedule (LORS) 2007, which is summarized in a later section. Likewise, specific scenarios simulated for this WCA-1 restoration project are described in their specific sections of this document.

Common to ELMwca1 simulations of the LORS07 Base run and restoration scenarios are the following data, in addition to those data that remain unchanged from the historical simulations (described in Data Chapter 4, Model Performance Chapter 6).

Initial conditions

The initial land surface elevation used in the ELMwca1 was an updated data set (see Data Chapter 4), relative to the 1980's data used in the SFWMM. There are differences between the two data sets that introduce different slopes in the landscape, and thus can potentially result in differences between the two models' outputs (which also differ by ~250x in spatial resolution). (Note: this land elevation is the same as that used to initialize the 1994 historical simulation).

Maps of the initial surface and unsaturated water depths were derived from the (January 1965) initial conditions of the SFWMM.

[4] SFWMM v5.5 documentation is currently (March 2008) found at http://my.sfwmd.gov/ , click on "What we do", then "Simulation Modeling".

Boundary conditions: Peripheral stages

For the ELMwca1 LORS07 Base run (see below) and all scenario runs, daily stages (relative to local land elevation) from the SFWMM v5.5 simulation of the LORS07 Base run were used as stage boundary conditions in cells along the periphery of the ELMwca1 domain (i.e., external stages immediately along the domain periphery).

Boundary conditions: climate

Daily inputs of spatial maps of rainfall and potential evapotranspiration were the same in the ELMwca1 and SFWMM (v5.5, LORS07), with no smoothing or interpolation for the finer-scaled ELMwca1. (Note: where time domains overlap, these are the same data used in the historical simulation).

As done for the historical simulations (Model Performance Chapter 6), atmospheric deposition of phosphorus and chloride were input to the model as constant concentrations in rainfall to achieve long-term, data derived targets of total deposition.

Boundary conditions: Managed flows & concentrations

One of the objectives of this project was to select a scenario that used managed flows that provided the best relative ecological benefit to the ecology of the marsh in WCA-1. Thus, different methods were used to determine daily flows through all managed water control structures, depending on the Scenario or Base run, and are described in specific sections later in this document

However water quality associated with inflow of "new" water introduced into the domain was assumed to be fixed (constant) among all scenarios and the LORS07[5] Base run:

Total phosphorus (TP) and chloride (Cl) concentrations are estimated for all managed water control structure flows whose source water is external to the ELM domain. Several methods may be used for these estimates, including the use of other models such as the DMSTA. For the objectives of this project, the simplest option was employed: we applied a temporally-constant TP concentration (all scenarios, 20 ug L^{-1}) and a temporally-constant Cl concentration (all scenarios, 130 mg L^{-1}) to water volumes in each inflow of "new" water into the model domain.

8.3 Assumptions - Specific

Table "0" provides an overview of the specific assumptions that were used to configure and run the LORS07 and eleven restoration scenario simulation runs. Detailed definitions of the table attributes follow in separate sections of this document.

[5] As seen in a later section, some minor inflows for the LORS07 Base run had other concentration values

Table 0. Description of Scenarios simulated by ELM, for WCA-1 restoration project. Stage Regulation Schedules described in graphs for each scenario.

Scenario	Description	Canals	Schedule	StructIn	StructOut	StructRecy	InputTP (ug/L)	InputCL (g/L)
LORS07	LORS BASE Run: LO Reg. Sched. 2007, WCA1 regulation schedule used was ~current (1995 plan); see Cadavid memo for details	existing	~1995	existing (see below)	existing (see below)	N/A	STA=20; other	0.130
Cans_NoMgdFlo	No managed flows, existing canal/levee infrastructure	existing	N/A	N/A	N/A	N/A	N/A	N/A
Cans_S10	Managed outflow, existing canal/levee infrastructure; Schedule Ver. 1	existing	Ver1	N/A	S10out	N/A	N/A	N/A
Berm_NoMgdFlow	No managed flows, berm along most of perimeter	berm	N/A	N/A	N/A	N/A	N/A	N/A
Berm_S10	Managed outflow, berm along most of perimeter; Schedule Ver. 1	berm	Ver. 1	N/A	S10out	N/A	N/A	N/A
RecyS10	Recycle South->North, managed outflow, berm along most of perimeter, with short spreader canal reach in north; Schedule Ver. 1	berm	Ver. 1	N/A	S10out	Srecycle	N/A	N/A
RecyS10S5	Recycle South->North, managed outflow, managed inflow via S5in, berm along most of perimeter, with short spreader canal reach in north; Schedule Ver. 1	berm	Ver. 1	S5in	S10out	Srecycle	20	0.13
RecyS10S5_Reg-6	Recycle South->North, managed outflow, managed inflow via S5in, berm along most of perimeter, with short spreader canal reach in north; Schedule Ver. 2 (Ver. 1 plus single change, 6cm lower North target)	berm	Ver. 2	S5in	S10out	Srecycle	20	0.13
RecyS10S5_RegSep	Recycle South->North, managed outflow, managed inflow via S5in, berm along most of perimeter, with short spreader canal reach in north; Schedule Ver. 3 (Ver 2 plus single change, a separate target for S5in that is 3cm lower than Srecycle's North target)	berm	Ver. 3	S5in	S10out	Srecycle	20	0.13
Cans_RecyS10S5_RegSep	Recycle South->North, managed outflow, managed inflow via S5in, existing canal/levee infrastructure; Schedule Ver. 3	existing	Ver. 3	S5in	S10out	Srecycle	20	0.13
S10S5_Reg-6	Managed outflow, managed inflow via S5in, berm along most of perimeter, with short spreader canal reach in north; Schedule Ver. 2	berm	Ver. 2	S5in	S10out	N/A	20	0.13
RecyS10S5_RegSepB	Recycle South->North, managed outflow, managed inflow via S5in, berm along most of perimeter, with short spreader canal reach in north; Schedule Ver. 4 (Ver 3 plus single change, 6cm higher South-ceiling target for S10out releases)	berm	Ver. 4	S5in	S10out	Srecycle	20	0.13

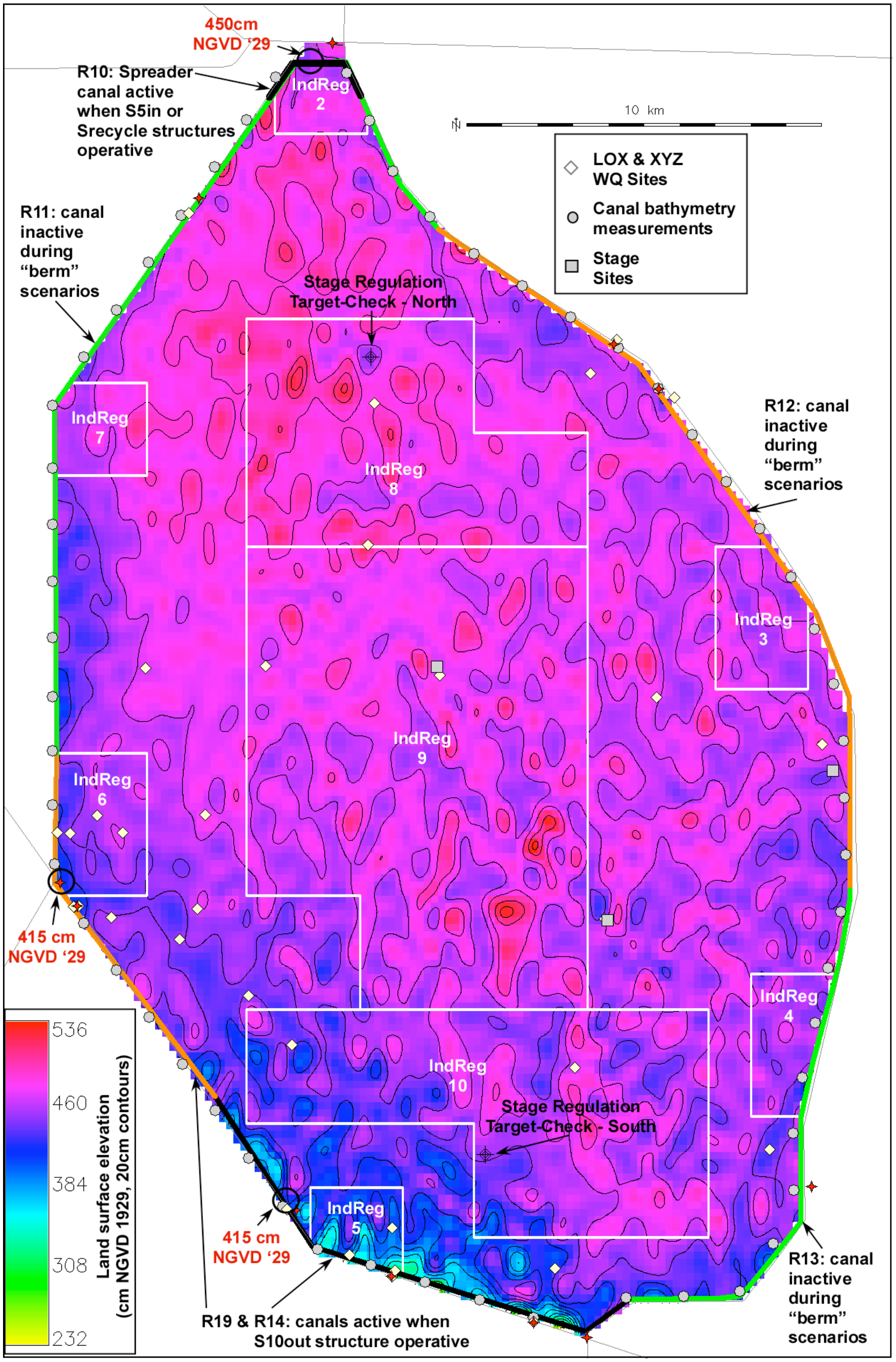
Scenarios, managed flow structures

StructIn	StructOut	StructRecy	InputTP (ug/L)	InputCL (g/L)
S5in			20	0.130
	S10out			
		Srecycle		

LORS BASE,managed flow structues

StructIn	StructOut	InputTP (ug/L)	InputCL (g/L)
ACME12		94	0.130
	ACME2		
	G94AB		
	G94C		
L101OT		35	0.130
	S10		
	S10A		
	S10C		
	S10D		
	S10E		
	S39		
S5AWC1		122	0.130
	S5A2NO		
S6LCWS		78	0.130
ST1EEO		20	0.130
ST1EWO		20	0.130
ST1WQ1		20	0.130

Figure 8.1. The configuration used in all restoration scenarios: ELMwca1 canal reach identities (R10 – R19), stage regulation target trigger (check) cell locations, outlines of Indicator Regions, and initial land surface elevation.



8.3.1 LORS07 Base Run

8.3.1.1 Water management assumptions

Canals/levees

For the ELMwca1 v2.8 LORS07 Base run, one change was made to canal/levee (CanalData.chan) input data file relative to that used for the historical 1994-2000 simulation (Model Performance, Chapter 6). The LORS07 Base run included the "L-101" canal and levee at the northern tip of WCA-1. No changes were made to depth or width attributes.

Boundary conditions: Managed flows

Daily flows through managed water control structures from the SFWMM v5.5 simulation of the LORS07 Base run were used to drive the ELMwca1 v2.8 LORS07 Base run. The assumptions used in developing the relatively complex management rules for this SFWMM regional simulation are described in documents available from the South Florida Water Management District (L. Cadavid, pers. comm., document dated Oct 29, 2007). However, the primary basis for managed flows in the WCA-1 basin in LORS07 is the most "current", 1995, regulation schedule.

8.3.2 Scenarios: water management assumptions

8.3.2.1 Canal & levee infrastructure

Berm

As described in the Data Chapter 4, a continuous canal encircles the entire perimeter of the WCA-1 hydrologic basin. This perimeter canal normally may exchange water with the adjacent marsh, impeded only by local marsh elevation gradients and local marsh vegetation. Directly associated with this perimeter canal is a perimeter levee (on the opposite side of the canal from the marsh interior) that blocks all overland exchanges with areas that are external to the WCA-1 basin.

The "berm" scenarios in this restoration project assumed the removal of most of this perimeter canal. For simplicity, a model canal reach that was to be "bermed off" from all marsh-canal exchanges via a future berm (or, perhaps more appropriately, a levee) was simply "turned off" in the model (i.e., canal reaches R11, R12, R13 in Figure 8.1) by assigning a negative width to the canal reach in the CanalData.chan input data file. This completely bypassed any initialization or dynamic calculation that would otherwise have be performed on the canal reach and its associated levee – thus that infrastructure ceased to exist in the simulation.

While most of the canal system was "removed" from operation in a berm scenario, the (real-world) Hillsboro Canal and a small, southern segment of the L-7 Canal were assumed to continue to exist for a berm scenario (i.e., canal reaches R14, R19 in Figure 8.1). Draining a low-elevation section of the southwestern quadrant of the WCA-1 basin, these canal reaches had relatively little influence on draining the higher elevation quadrants of WCA-1, and served to collect water for outflow distribution.

Bounding-levee

In all scenarios (with and without a berm), the perimeter levee which encircles the WCA-1 basin was assumed to always exist, allowing no overland surface water exchanges across the periphery of the model domain boundary (via attributes assigned to the BondCond input map, which defined the nature of any surface or ground water exchanges across the model domain boundary, Chapter 4).

Existing-canal/levee infrastructure

In all scenarios that were based on existing canals/levees, the LORS07 Base run canal/levee (CanalData.chan) input data file was used; this canal/levee topology includes the "L-101" canal and levee at the northern tip of WCA-1. (The L-101 did not exist for the 1994-2000 historical simulations, Chapter 6). No changes were made to depth or width attributes for the scenarios with existing canal/levee infrastructure. No "plugs" that would prevent within-canal or canal-to-canal flows were evaluated for the current set of scenarios (March 2008).

Northern spreader canal

In "berm" scenarios that required inflows of water and constituents into the northern portion of the model domain, a new spreader canal was configured. Placed within the alignment of portions of the (real-world canals) L-7, L-40, and L-101 (model reach R11), this spreader was relatively shallow (2.5 m) and of moderate width (25 m), with no levee on either side.

Note: In the "Cans_RecyS10S5_RegSep" scenario that included recycling flows from south to north, the inputs to the northern region were made to the canal reach R11 (not the new spreader canal reach R10), consistent with the LORS07 Base run.

8.3.2.2 Water management structures

The management rules encoded into the ELM v2.8 (Model Structure Chapter 5) are much simpler than those employed by the SFWMM, and are restricted to a limited set of objectives that involve local ecological evaluations, i.e., with a focus that is specific to a single hydrologic basin.

Virtual water control structures

Virtual structures (see Model Structure Chapt 5) are model constructs, used to discretize a continuous, uninterrupted "real world" canal into multiple canal reaches (commonly referred to as segments in some other models). A virtual structure ~instantly equilibrates (within one model time step) the water stages in two canal reaches[6].

For the scenarios that included the existing canal/levee infrastructure, multiple pairs of canal reaches were linked by one virtual structure per pair, equilibrating the stages in the canal pairs.

[6] As discussed in Model Structure Chapter 5, this disaggregation of a single canal into multiple canal reaches is necessary for water quality modeling in this type of simulation framework. Without the multiple reaches (or segments), a constituent introduced at one end of a long canal would otherwise be homogenously distributed throughout the entire canal within one time step.

For the berm scenarios of this project[7], a single virtual structure was needed to equilibrate stages between one pair of canal reaches (R14 and R19).

Managed water control structures

As seen in the above summary Table 0 describing the scenarios, there were a maximum of three separate managed water control structures used in any scenario. (The ELMwca1 LORS07 Base run includes 16 managed water control structures, as used in the SFWMM). The purpose of each of the three structures in restoration scenarios are listed here:

1. **S5in** – generic pump, inflow of "new" water from sources external to the WCA-1 basin;
    a. ***source*** is assumed to be an STA, including but not limited to, STA-1E and STA-1W; source is assumed to have unlimited water availability
    b. ***destination*** is the receiving canal (R11) or spreader canal (R10) in the vicinity of the existing L-101 in the northernmost location of WCA-1 (canal reach identity depends on the canal infrastructure for the scenario, see above)
    c. ***triggered*** by deficit of stage elevation in grid cell in northern region of WCA-1 basin
    d. ***capacity*** was generally constrained to < 1,000 cfs (cubic feet per second)
2. **S10out** – generic pump, outflow of "excess" water from the WCA-1 basin;
    a. ***source*** is the canal reach R14 (Hillsboro Canal) in southern portion of WCA-1 basin
    b. ***destination*** is an external basin, with water permanently lost from the WCA-1 basin; destination does not impose tailwater constraints on managed flows
    c. ***triggered*** by excess of stage elevation in grid cell in southern region of WCA-1 basin
    d. ***capacity*** was generally constrained to < 1,000 cfs
3. **Srecycle** – generic pump, inflow of "recycled" water from the southern portion to the northern portion of the WCA-1 basin;
    a. ***source*** is the canal reach R14 (Hillsboro Canal) in southern portion of WCA-1 basin
    b. ***destination*** is the spreader canal R10 in the vicinity of the existing L-101 in the northernmost location of WCA-1; destination does not impose tailwater constraints on managed flows
    c. ***triggered*** by 1) deficit of stage elevation in grid cell in northern region of WCA-1 basin, AND 2) sufficiently high stage elevation in grid cell in southern region of WCA-1
    d. ***capacity*** was generally constrained to approximately 500 cfs

Note that the naming convention is not meant to imply direct comparisons to attributes of existing "real-world" structures. However, the conceptual functions of the **S5in** and **S10out** model structures are similar in nature to the "real world" S-5S and S-10A-D structures.

---

[7] It is anticipated that additional scenarios could be deemed of interest for restoration project objectives, wherein the existing canal/levee network is left in place, but flow between canal reaches is "plugged" by simply not including virtual structures.

Stage Regulation Schedules

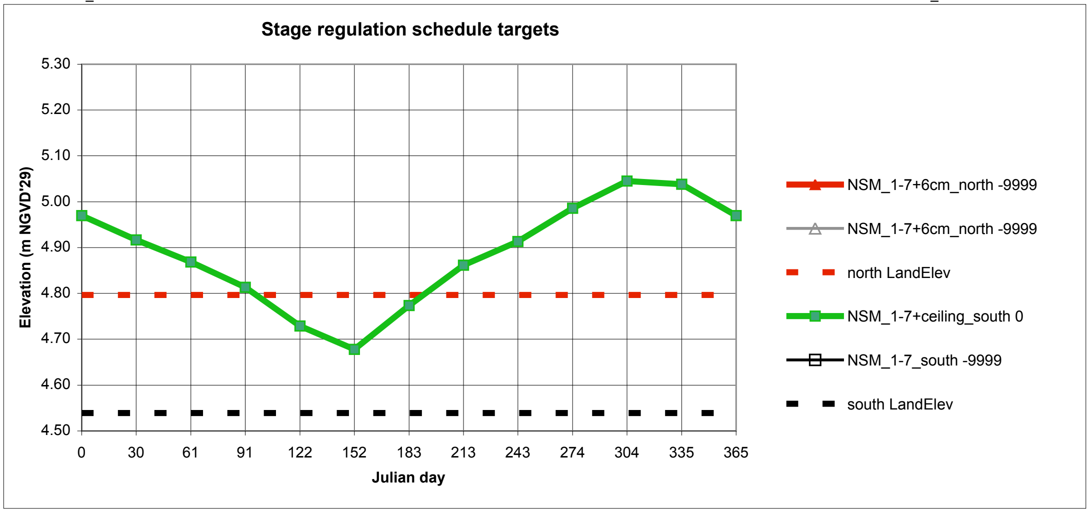
A variety of options were investigated to choose the "targets" to regulate flows through water management structures that were defined for the WCA-1 restoration simulations. To enhance understanding of what may represent "good" water levels during wet and dry seasons, we averaged the monthly water depths (relative to local land surface elevation) across long time scale from several data sources.

We evaluated the historical water levels in regions of the Everglades that currently exhibit some (but not all) attributes of a reasonably-well functioning wetland ecosystem. To screen the type of seasonal variability that may be desirable, we synthesized 20-year stage records from central Water Conservation Area 3A and Shark River Slough (see bottom panel of "Screening Tool" Figure 8.4 in later section). While both areas are known to have been impacted by water management practices, the differences in maxima and minima, and seasonal rates of change, provided useful benchmarks for understanding the ranges of wetland restoration water depth targets.

We also evaluated the output from the Natural System Model (NSM) in different regions of the Everglades, including central WCA-1 and central WCA-3A (see bottom panel of "Screening Tool" Figure 8.4 in later section).

Ultimately, the similarities of the magnitudes and seasonality of the two NSM data sets and the historical Shark River Slough data set led to our consensus to use the NSM depths at the 1-7 gage in WCA-1 to form the basis of our Stage Regulation Schedules for our restoration objectives.

The specifics used to trigger each structure are described in the following pages, with separate Stage Regulation Schedules for each scenario that involved managed flows.



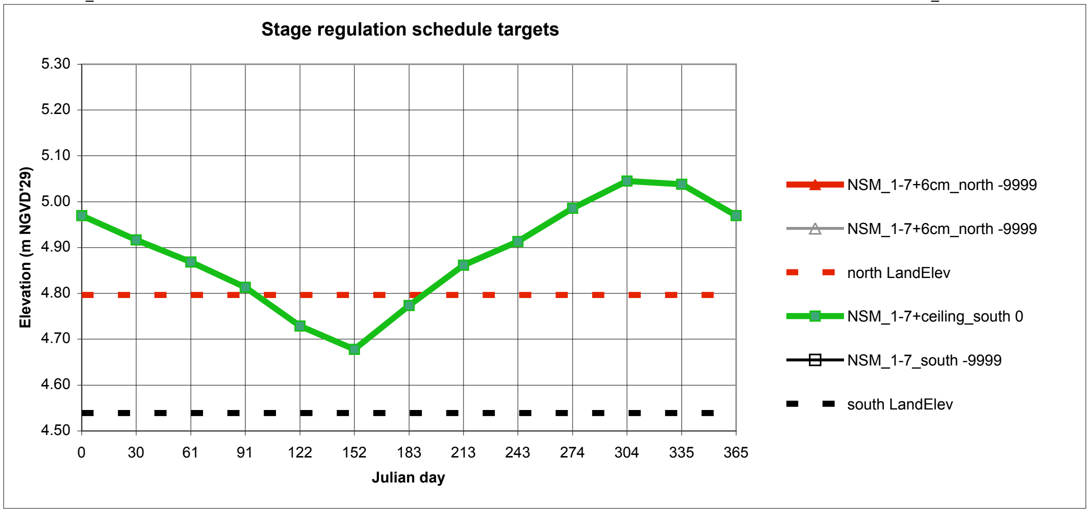
Stage targets. The targeted-stage regulation schedules used in the 'Cans_S10' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)
Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)
Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);
Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).
NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.
NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.
('-9999' = schedule not used)

ELM2.8wca1_200m Scenario Name: Berm_S10



Stage targets. The targeted-stage regulation schedules used in the 'Berm_S10' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)

Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)

Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);

Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).

NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.

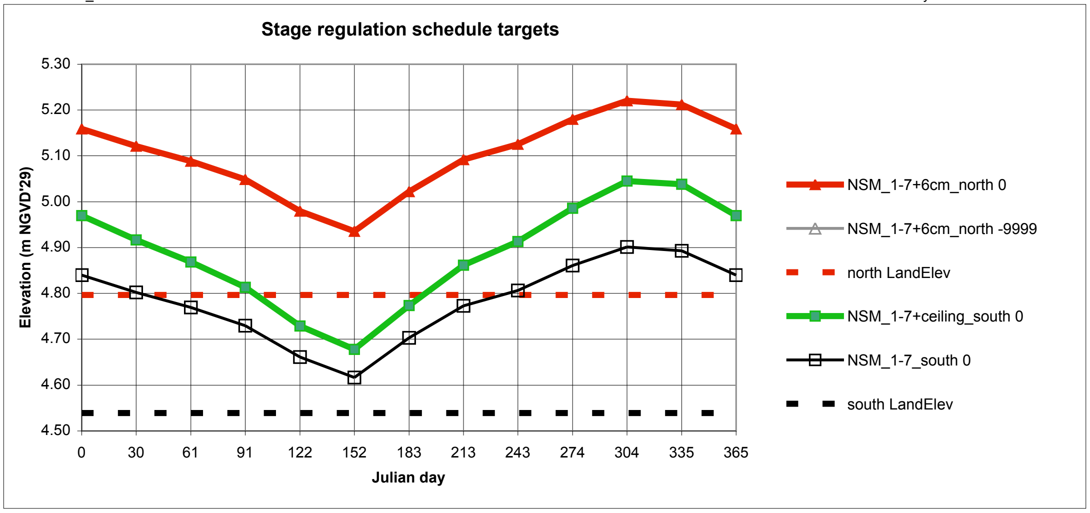
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.

('-9999' = schedule not used)

ELM2.8wca1_200m Scenario Name: RecyS10

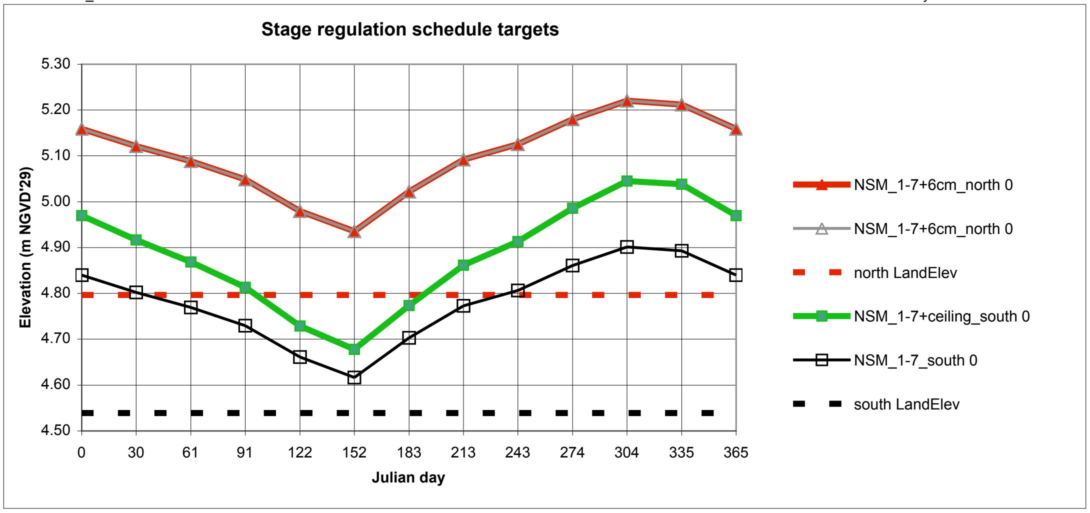


Stage targets. The targeted-stage regulation schedules used in the 'RecyS10' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)
Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)
Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);
Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).
NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.
NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.
('-9999' = schedule not used)



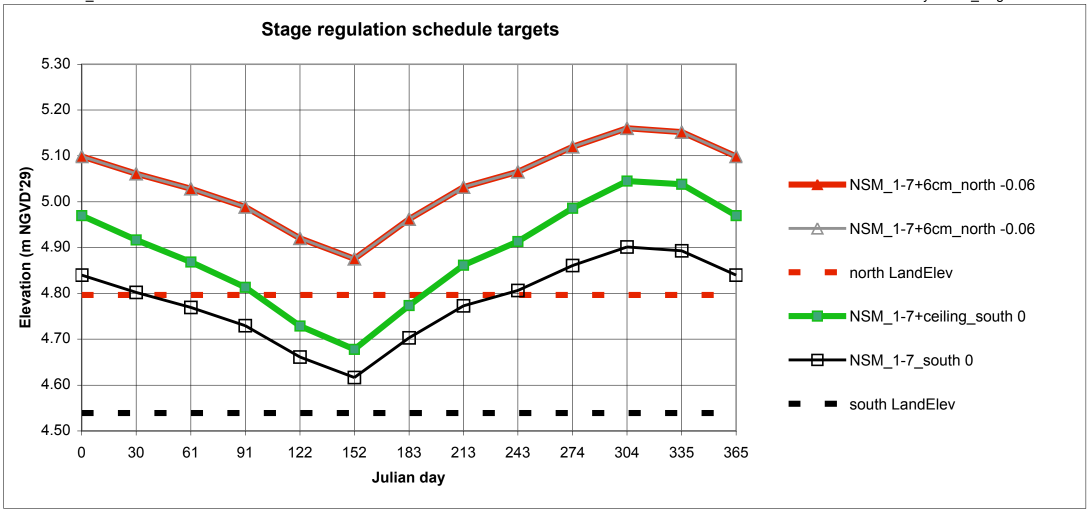
Stage targets. The targeted-stage regulation schedules used in the 'RecyS10S5' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)
Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)
Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);
Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).
NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.
NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.
('-9999' = schedule not used)

ELM2.8wca1_200m Scenario Name: RecyS10S5_Reg-6



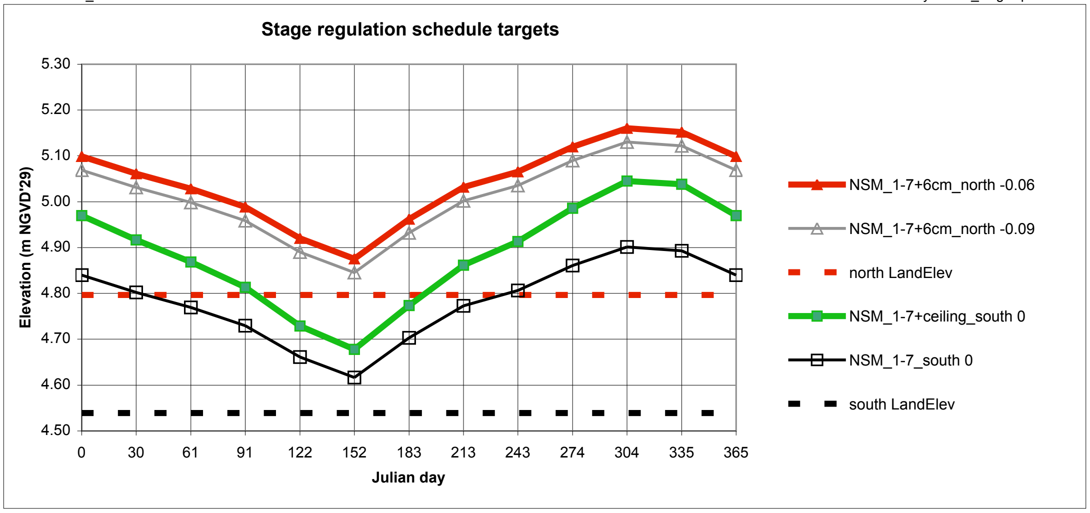
Stage targets. The targeted-stage regulation schedules used in the 'RecyS10S5_Reg-6' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)
Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)
Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);
Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).
NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.
NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.
('-9999' = schedule not used)

ELM2.8wca1_200m Scenario Name: RecyS10S5_RegSep



Stage targets. The targeted-stage regulation schedules used in the 'RecyS10S5_RegSep' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)

Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)

Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);

Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).

NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.

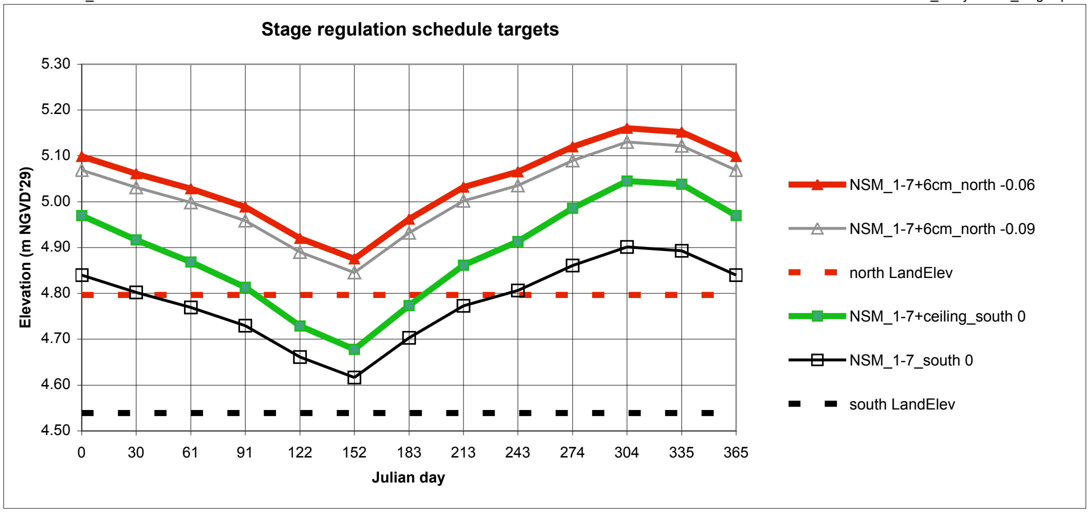
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.

('-9999' = schedule not used)

ELM2.8wca1_200m Scenario Name: Cans_RecyS10S5_RegSep



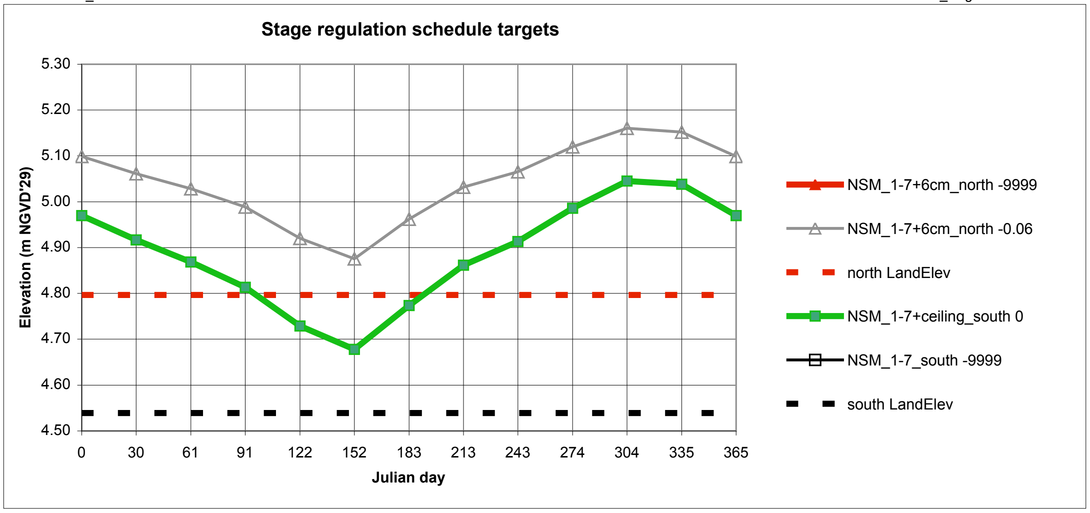
Stage targets. The targeted-stage regulation schedules used in the 'Cans_RecyS10S5_RegSep' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)
Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)
Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);
Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).
NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.
NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.
('-9999' = schedule not used)

ELM2.8wca1_200m Scenario Name: S10S5_Reg-6



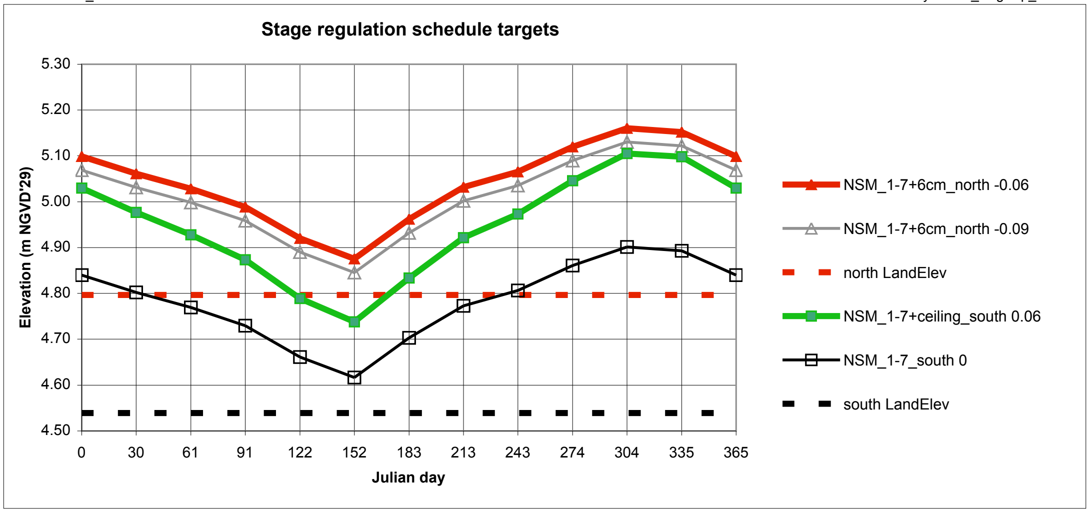
Stage targets. The targeted-stage regulation schedules used in the 'S10S5_Reg-6' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)
Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)
Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);
Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).
NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.
NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.
NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.
('-9999' = schedule not used)

ELM2.8wca1_200m   Scenario Name: RecyS10S5_RegSep_B



Stage targets. The targeted-stage regulation schedules used in the 'RecyS10S5_RegSep_B' scenario of the ELM2.8wca1_200m project. Managed water (and constituent) flows through water control structures were simulated by minimizing the difference between simulated and targeted stages in a north and in a south (grid cell) location.

Red line (if shown) is maximum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red)

Grey line (if shown) is maximum stage to trigger inflows of 'external' water into north (inflow of 'external' water IF north stage < Grey)

Green line (if shown) is minimum stage to trigger outflows from south (outflow to 'external sink' IF south stage > Green);

Black line (if shown) is minimum stage to trigger recycling from south into north (recycle IF south stage > Black, AND north stage < Red).

NSM_1-7 = NSM v4.6.2 depths applied to mean land surface elevation in ELM2.8wca1_200m application's cells in a targeted Indicator Region (IR).

NSM_1-7 '+6cm_north': added a constant 6 cm to NSM_1-7, applied to mean land surface elevation of IR 8 (==SFWMM IR 100), targets checked in 'north' target cell.

NSM_1-7 '+ceiling_south': added time-varying values to NSM_1-7, applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

NSM_1-7 '_south' : applied to mean land surface elevation of IR 10 (==SFWMM IR 102), targets checked in 'south' target cell.

Number suffixed to figure legend labels (e.g., '0', '-0.06', etc.) is the height (m) that was added/subtracted to/from the above, for the final values plotted here and used in a scenario.

('-9999' = schedule not used)

8.5 Performance Measures

The matrix table on the following page 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.

Performance Measure Matrix: WCA-1 Restoration Planning, ELMwca1_200m, v2.8 9 = # Indicator Regions

Version Date: Mar 7/2008 12 = # Scenarios

There are 32 individual Performance Measures, each evaluated in a variety of temporal and/or spatial summaries, resulting in 286 individual Tables, Graphs, and Maps.

Name	**Format**	**PM description**	**Units**	**Target**	**Spatial**	**Temporal**	**# Products**	**Notes on implementation**
SurfaceRecess	Table1	Average weekly water recession rate during the dry season (Nov 30th to May 31st)	mm/wk	None	Indicator Regions	Seasonal mean	0.5	Using daily surface water means per month, converting to weekly rate
SurfaceInund	Table1	Average weekly water inundation rate during the wet season (June 1st to Oct 31st)	mm/wk	None	Indicator Regions	Seasonal mean	0.5	Using daily surface water means per month, converting to weekly rate
DryTime	Table2	Average number of months when water levels are below ground surface	months	None	Indicator Regions	Annual mean	0.5	Using daily means per month; only consider data where (positive) unsat zone depth is greater than threshold (currently using 3 cm)
DryDepth	Table2	Average Depth below ground surface	m	None	Indicator Regions	Daily mean	0.5	Using mean of daily means per month; only consider data where (positive) unsat zone depth is greater than threshold (currently using 3 cm)
DryDeepDepth	Table3	Average Depth >=1 ft below ground surface	m	None	Indicator Regions	Daily mean	0.5	Using mean of daily means per month that exceed threshold; only consider data where (positive) unsat zone depth is greater than or equal to 1 ft
DryMaxDepth	Table3	Max Depth below ground surface	m	None	Indicator Regions	Maximum of daily mean per month	0.5	Using maximum of daily means per month.
WetTime	Table4	Average number of months when water levels are above ground surface	months	None	Indicator Regions	Annual mean	0.5	Using daily means per month; only consider data where (positive) surface water depth is greater than threshold (currently using 3 cm)
WetDepth	Table4	Average depth above ground surface	m	None	Indicator Regions	Daily mean	0.5	Using mean of daily means per month; only consider data where (positive) surface water depth is greater than threshold (currently using 3 cm)
WetDeepDepth	Table5	Average Depth >=1 ft above ground surface	m	None	Indicator Regions	Daily mean	0.5	Only consider data where (positive) surface water depth is greater than or equal to 1 ft
WetMaxDepth	Table5	Max Depth above ground surface	m	None	Indicator Regions	Maximum of daily mean per month	0.5	Using maximum of daily means per month.
DryAnnMaxDepth	TableSet	Annual Max Depth below ground surface	m	None	Indicator Regions	Maximum annual, individual years	12.0	Max for individual years, 1 table per scenario
WetAnnMaxDepth	TableSet	Annual Max Depth above ground surface	m	None	Indicator Regions	Maximum annual, individual years	12.0	Max for individual years, 1 table per scenario
DryDeepAnnTime	Table6	Annual mean number of weeks when the weekly (7-d) mean water levels was >1ft below ground surface.	weeks	None	Indicator Regions	Annual mean	0.5	Created new output file of daily values to calculate this
DryDeepEventTime	Table6	Mean event duration, where an event is defined as a 7-d mean water level that is > 1ft below ground surface.	weeks	None	Indicator Regions	Event mean	0.5	Created new output file of daily values to calculate this
DryDeepTimeMax	Table7	Maximum event duration, where an event is defined as a 7-d mean water level that is > 1ft below ground surface.	weeks	None	Indicator Regions	Maximum duration of event, across simulation period	1.0	Created new output file of daily values to calculate this
		Muck fire index, as the number of days that upper soil horizon is relatively deep & dry	*days*	*None*	*Indicator Regions*	*Annual mean*		*Count of days during which unsaturated zone depth (in each grid cell within an IR) is deeper than a 15 cm, AND the unsaturated moisture percentage is less than 50%.*
VelocIndex	Table8	Velocity index: net daily surface water flow to/from each grid cell (all values positive).	m/d	None	Indicator Regions	Mean daily, across simulation period	0.3	Index of velocity magnitude. Future intent is to use in re-implementing sedimentation-erosion algorithm.
Cl_conc	Table8	Chloride concentration in surface water.	g/L	None	Indicator Regions	Mean daily, across simulation period	0.3	Surface water chloride concentration (and TP conc etc) is only reported when the surface water depth is deeper than 1 cm. Otherwise, a value of 0.000000 is reported.
		Total Phosphorus concentration in surface water. [Placeholder only, Cl tracer captures relative diffs in water quality among scenarios/alternatives]	*mg/L*	*None*	*Indicator Regions*	*Mean daily, across simulation period*		*There are (potential) differences in surface water P conc. among alts, depending on soil P mineralization re. drydowns… etc.*
WaterInput	GraphSet1 & Table9	Total volume of managed flows of water into the model domain	1,000's of acre-ft	None	Domain-wide	Annual mean sum	0.3	Annual mean of the total water control structure inflows to the WCA-1 basin during the simulation.
WaterRecycle	GraphSet1 & Table9	Total volume of managed flows of water recycled from south to north in model domain	1,000's of acre-ft	None	Domain-wide	Annual mean sum	0.3	Annual mean of the total water control structure recycling flows from the southern end to the northern end of the WCA-1 basin during the simulation.
WaterOutput	GraphSet1 & Table9	Total volume of managed flows of water out of the model domain	1,000's of acre-ft	None	Domain-wide	Annual mean sum	0.3	Annual mean of the total water control structure outflows from the WCA-1 basin during the simulation.
RelativeDepth	GraphSet2	Time series hydrographs, (positive surface, positive unsaturated) water depth relative to local land surface elevation	m	None	Indicator Regions	Daily mean, each month of simulation	18.0	1 graph per Indicator Region, 6 scenarios are maximum on any graph
StageDuration	GraphSet3	Cumulative frequency distribution of 'stage minus land surface elevation'	m	None	Indicator Regions	Daily mean, each week of simulation	18.0	1 graph per Indicator Region, 6 scenarios are maximum on any graph
StageMonthly PeriodOfSimulation	GraphSet4	Mean daily stage per month of Period of Simultion	m	None	Single location, the 1-7 gage	Daily mean, per (1-12) month of simulation	1.0	Screening tool; 1 graph includes all scenarios
SfWatMapDryYr	MapSet1	Surface water depth, for a dry year a) mean during ending month of the dry season and b) mean during ending month of wet season	m	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
SfWatMapWetYr	MapSet2	Surface water depth, for a wet year a) mean during ending month of the dry season and b) mean during ending month of wet season	m	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
SfWatMapAvgYr	MapSet3	Surface water depth, for an average year a) mean during ending month of the dry season and b) mean during ending month of wet season	m	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
CL_MapDryYr	MapSet4	Surface water chloride concentration, for a dry year a) mean during ending month of the dry season and b) mean during ending month of wet season	mg/L	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
CL_MapWetYr	MapSet5	Surface water chloride concentration, for a wet year a) mean during ending month of the dry season and b) mean during ending month of wet season	mg/L	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
CL_MapAvgYr	MapSet6	Surface water chloride concentration, for avg year a) mean during ending month of the dry season and b) mean during ending month of wet season	mg/L	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
TP_MapDryYr	MapSet7	Surface water TP concentration, for a dry year a) mean during ending month of the dry season and b) mean during ending month of wet season	ug/L	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
TP_MapWetYr	MapSet8	Surface water TP concentration, for a wet year a) mean during ending month of the dry season and b) mean during ending month of wet season	ug/L	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances
TP_MapAvgYr	MapSet9	Surface water TP concentration, for an average year a) mean during ending month of the dry season and b) mean during ending month of wet season	ug/L	None	Domain-map	Daily mean, month near end-of-season	24.0	2 pages of maps per set: Visualize Base run, Scenario run, and difference map, including contours of threshold exceedances

There are 32 individual Performance Measures, each evaluated in a variety of temporal and/or spatial summaries, resulting in 286 individual Tables, Graphs, and Maps.

8.6 Results

8.6.1 LORS07 Base Run

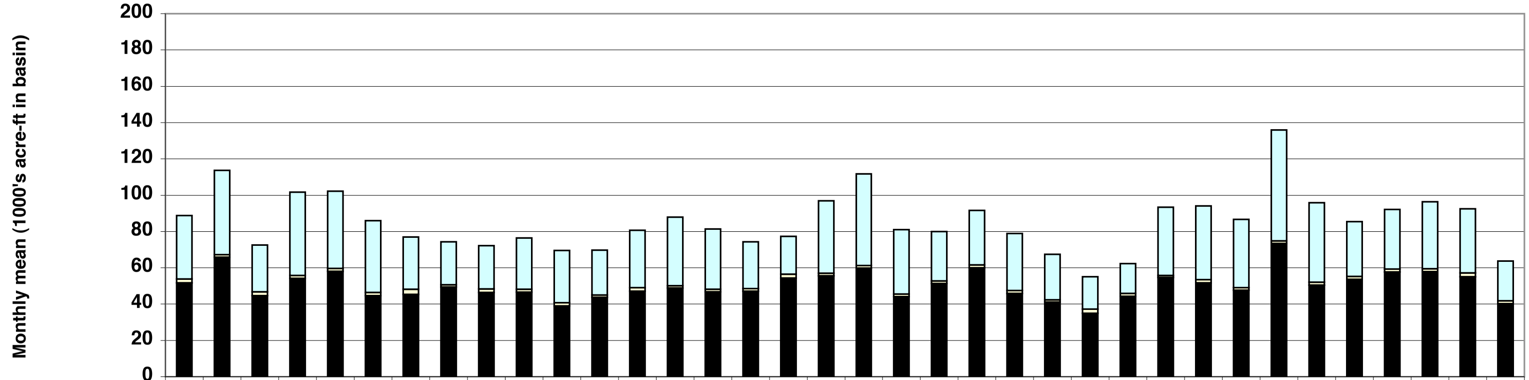
8.6.1.1 ELMwca1 - SFWMM output consistency

Water Budgets

An important assumption is that the hydrologic output of the ELMwca1 is reasonably consistent with results from the SFWMM, even if the two models are at very different scales (with ELMwca1 at ~250 times finer resolution than that of SFWMM). While consistency with the SFWMM has previously been demonstrated in the regional ELM v2.5, it was considered desirable to verify that the two models provided consistent results for the current subregional project.

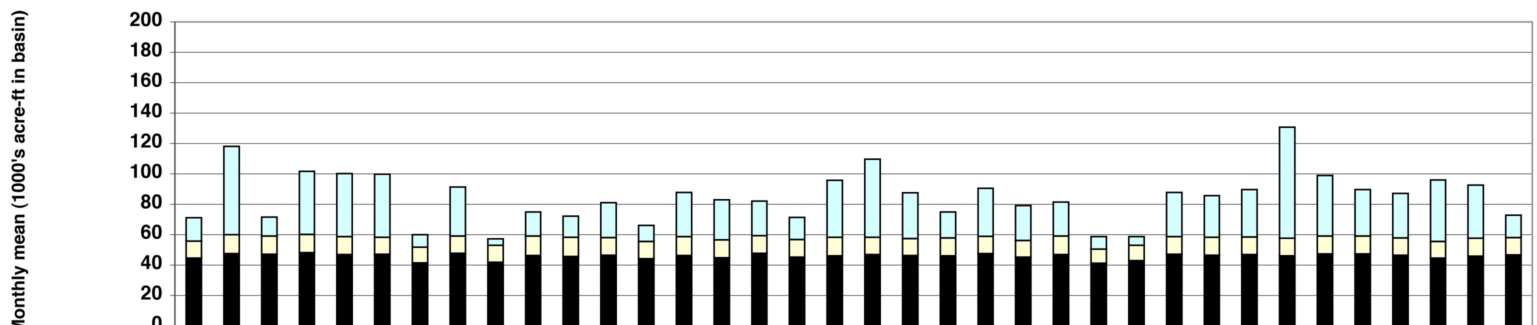
When comparing results with the SFWMM, an important comparison is the consistency in annual water budgets for major hydrologic basins, which in this case is limited to WCA-1. Figure 8.2 shows that both total inputs and total outputs were generally consistent between models, with an average annual difference of less than 2,000 acre-ft in both total inputs and total outputs, while the total annual inputs and outputs ranged from approximately 50,000 to 150,000 acre-ft per year.

WCA1 ELM Inflows



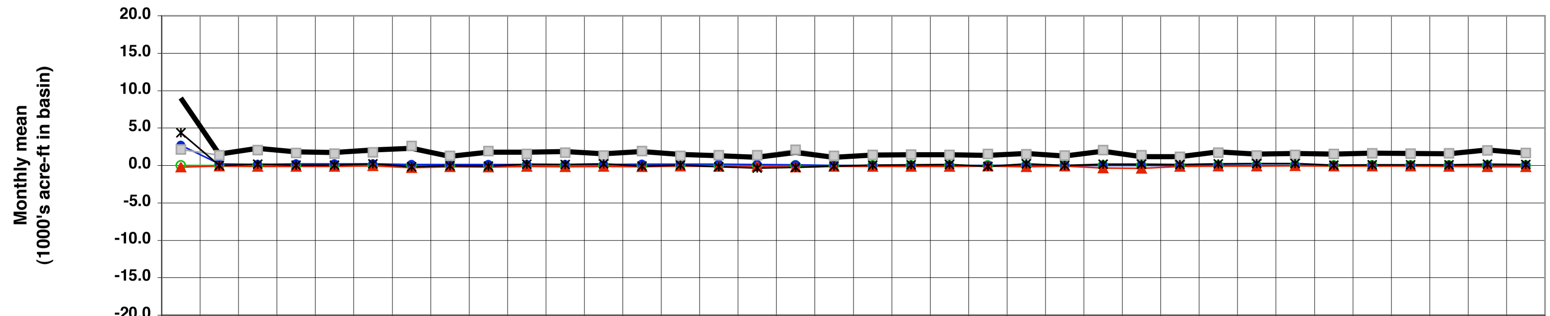
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Structure In 1	35	47	26	46	43	39	29	24	24	28	29	25	32	38	33	26	21	40	50	35	27	30	31	25	18	16	38	40	38	61	44	30	33	37	35	22
Groundwater In 1	2	1	2	2	2	2	3	1	2	2	2	1	2	1	1	1	2	1	1	2	1	2	2	1	2	2	1	2	1	1	2	2	2	2	2	2
Seepage In 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rain 1	52	66	45	54	58	45	45	49	46	47	39	44	47	49	47	47	54	56	60	44	51	60	46	41	35	44	55	52	48	73	50	54	58	58	55	40

WCA1 ELMOutflows



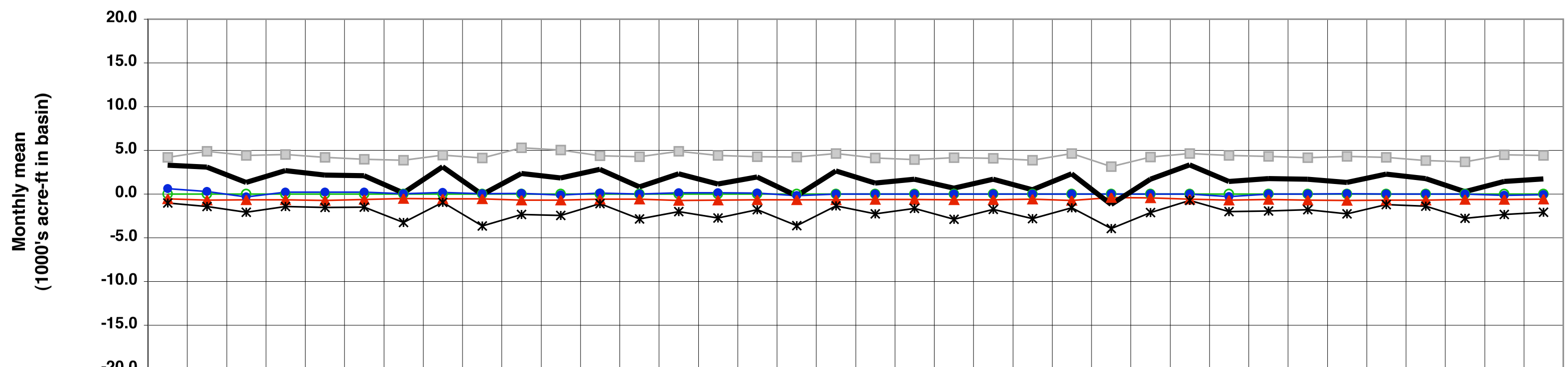
	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Structure Out 1	15	58	13	41	41	42	8	32	4	16	14	23	10	29	26	23	15	38	51	30	17	32	23	22	8	6	29	27	31	73	40	30	29	40	35	15
Groundwater Out 1	11	12	12	12	12	11	10	11	11	13	13	11	11	13	12	12	12	12	12	11	12	11	11	12	9	10	12	12	12	12	12	12	11	11	12	12
Seepage Out 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evapotranspiration 1	45	48	47	48	47	47	41	48	42	46	46	47	44	46	45	48	45	46	47	46	46	47	45	47	41	43	47	46	47	46	47	47	47	45	46	47

WCA1 ELM-SFWMM Inflow Differences



	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Overland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Structure	2.7	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Groundwater	2.1	1.4	2.1	1.7	1.6	1.7	2.6	1.3	1.9	1.6	1.7	1.3	1.9	1.3	1.4	1.4	2.1	1.3	1.4	1.5	1.4	1.5	1.5	1.3	2.0	1.4	1.2	1.7	1.3	1.4	1.5	1.6	1.6	1.6	2.0	1.7
Seepage	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
Rain	4.4	0.0	0.2	0.0	0.0	0.2	-0.	-0.	-0.	0.2	0.1	0.2	-0.	0.1	-0.	-0.	-0.	-0.	0.1	0.1	0.1	-0.	0.2	0.0	0.2	0.2	0.1	0.2	0.3	0.2	0.0	0.1	0.1	0.1	0.2	0.1
Sum	9.0	1.5	2.3	1.8	1.7	2.1	2.3	1.2	1.7	1.7	1.8	1.5	1.8	1.5	1.3	1.1	1.7	1.1	1.4	1.4	1.4	1.3	1.6	1.2	1.9	1.1	1.2	1.8	1.5	1.6	1.5	1.6	1.6	1.6	2.0	1.6

WCA1 ELM-SFWMM Outflow Differences

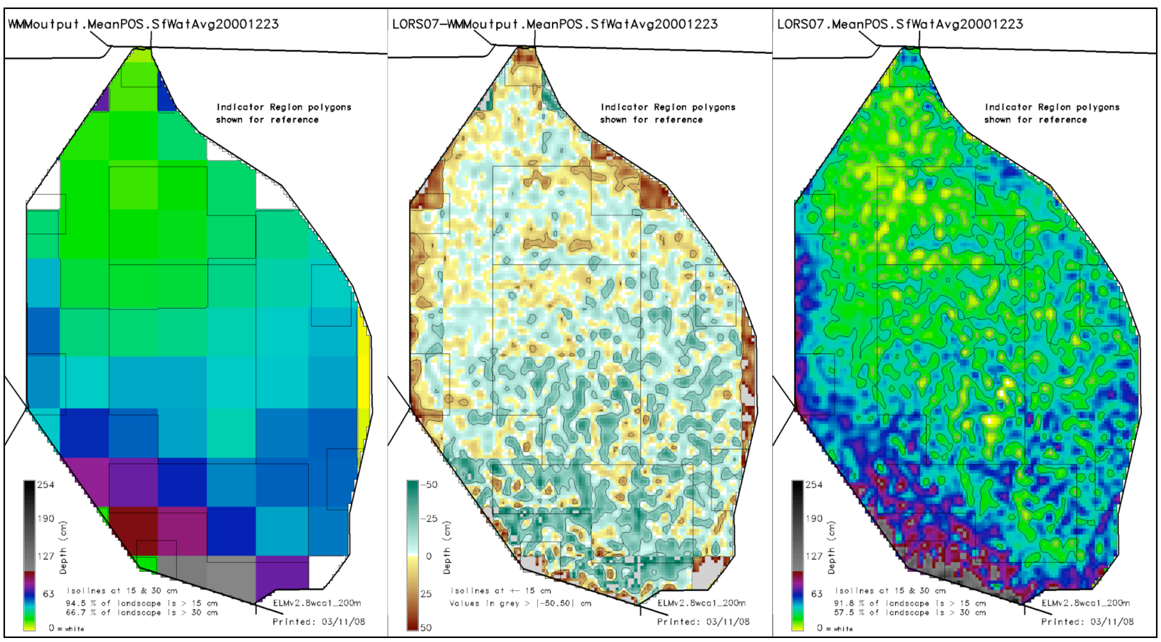


	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00
Overland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Structure	0.6	0.3	-0.3	0.2	0.2	0.2	0.0	0.2	0.0	0.1	-0.1	0.1	0.0	0.1	0.1	0.1	-0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
Groundwater	4.2	4.9	4.4	4.5	4.2	4.0	3.9	4.5	4.1	5.3	5.1	4.4	4.3	4.9	4.4	4.3	4.2	4.6	4.1	3.9	4.2	4.1	3.9	4.6	3.1	4.2	4.6	4.4	4.3	4.2	4.3	4.2	3.8	3.7	4.5	4.4
Seepage	-0.6	-0.7	-0.7	-0.7	-0.7	-0.6	-0.5	-0.6	-0.6	-0.7	-0.7	-0.6	-0.6	-0.7	-0.7	-0.7	-0.7	-0.7	-0.6	-0.6	-0.7	-0.6	-0.6	-0.7	-0.4	-0.4	-0.6	-0.7	-0.6	-0.7	-0.7	-0.7	-0.7	-0.6	-0.6	-0.6
ET	-1.0	-1.4	-2.1	-1.4	-1.5	-1.5	-3.3	-0.9	-3.7	-2.3	-2.4	-1.1	-2.9	-2.0	-2.7	-1.8	-3.6	-1.4	-2.3	-1.7	-2.9	-1.8	-2.8	-1.6	-3.9	-2.1	-0.7	-2.0	-2.0	-1.8	-2.3	-1.2	-1.4	-2.8	-2.3	-2.1
Sum	3.3	3.1	1.3	2.6	2.2	2.1	0.1	3.1	-0.1	2.3	1.8	2.8	0.8	2.3	1.1	1.9	-0.2	2.6	1.2	1.7	0.6	1.7	0.5	2.3	-1.2	1.7	3.3	1.4	1.7	1.7	1.3	2.3	1.7	0.3	1.4	1.7

Water depths

The pattern and magnitude of simulated surface water depths were similar between the two models, as indicated the 36-yr mean daily depths depicted in Figure 8.3. Because of the significant variation in the numerous (approximately 250) ELMwca1 cells relative to any corresponding single SFWMM cell, the range of depths in the ELM is significantly higher. As described in the "Assumptions common to Base and Scenario Runs" section above, the ELMwca1 used (updated) land surface elevation data, leading to some differences in land surface slopes between the two models, beyond the differences due to dramatic differences in model scales.

Figure 8.3. Mean daily surface water depths for the 36-yr period of simulation of the LORS07 Base run: SFWMM v5.5 (left) , ELM2.8wca1 (right), and their difference. Note the high degree of spatial aggregation in the SFWMM values (>10 km^2 grid cell resolution) compared to the 0.04 km^2 grid resolution of the ELM application. The two models do not use the same land surface elevation data (see text).



8.6 Scenario comparisons

The remainder of this document contains tables, graphs, and maps of the Performance Measures for ELMwca1 outputs, allowing relative comparisons among restoration scenarios and the LORS07 Base run. Additionally, output from the Natural System Model (NSM) v4.6.2 (with >10 km^2 grid resolution) was post-processed using the same methods as the ELMwca1 simulation runs, serving as another benchmark of hydrologic performance for relative comparisons to the ELMwca1 scenarios.

While the water levels simulated by the NSM may be useful benchmarks from a broad (spatial and temporal) perspective, no specific targets (i.e., values for water depths and/or duration) of NSM output in space nor time were established for evaluating the relative benefits of these restoration scenarios. However, *surface water depths simulated by the*

NSM were used to generate the Stage Regulation Schedules that operated the opening and closing of water management structures (described in previous section, Assumptions - Specific).

8.6.1 Screening

Figure 8.4. Screening tools: UPPER frame: temporal aggregation of 1965-2000 Period of Simulation, for all restoration scenarios, LORS07 Base, and NSM. For ELMwca1 output, the temporal mean stage per month was determined in the 200 m grid cell at the location of the '1-7' stage gage. The NSM monthly mean values were derived from NSM output of relative water depths (stage minus land surface elevation) at the '1-7' stage gage, applied to the mean land elevation in the (200 m grid) ELMwca1 Indicator Region 9. LOWER frame: temporal aggregation of multi-year stage and/or relative depth data, normalized to local lands surface elevation. Used in screening potential stage regulation targets.

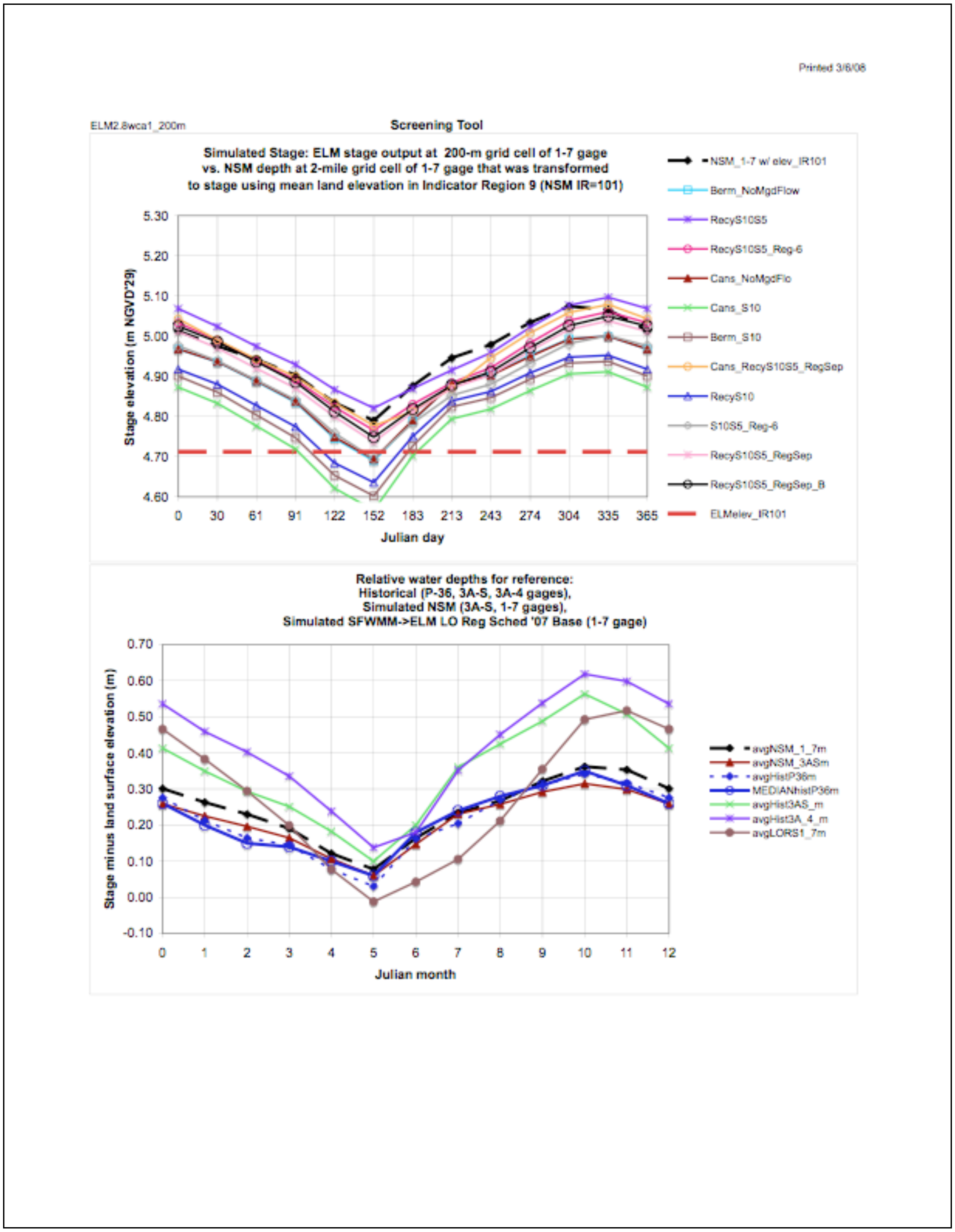


Table: Managed flow summary, Screening tool. Summaries of the annual mean volume of total water flows through structures that introduced "new" water into the WCA-1 hydrologic basin (Basin_IN), structures that removed water permanently from the WCA-1 hydrologic basin (Basin_OUT), and the Srecycle structure that "recycled" water from the southern to the northern portions of the basin (Recycle).

Printed 3/7/08

Table: Managed flow summary. *ELMwca1_200m*

Scenario	Mean annual sums, thousands acre-ft Basin_IN	Basin_OUT	Recycle
LORS07	397	329	N/A
Cans_NoMgdFlo	0	0	N/A
Cans_S10	0	65	N/A
Berm_NoMgdFlo	0	0	N/A
Berm_S10	0	47	N/A
RecyS10	0	33	78
RecyS10S5	170	105	92
RecyS10S5_Reg-6	125	82	58
RecyS10S5_RegSep	89	60	70
Cans_RecyS10S5_RegSep	960	904	379
S10S5_Reg-6	165	115	N/A
RecyS10S5_RegSep_B	81	43	72

8.6.2 Performance Measure Tables, Tentatively Selected Scenario

Tables 1 – 8 follow on the next four pages, comparing the scenario that was selected to have provided the best hydrologic and water quality benefits relative to other simulated scenarios. The LORS07 Base run and the NSM v4.6.2 are included for use as benchmarks for relative comparison.

For each table, the Indicator Region number refers to the polygon delimited in Figure 8.1. All data are spatially aggregated to include all model grid cells within the designated Indicator Region.

The Appendix contains Performance Measure Tables for all of the simulated scenarios.

Model Project: ELMwca1_200m v.2.8

Summary Table 1. Surface Water: Recession (Reces_#) and Inundation (Inun_#) rates within each Indicator Region #: mean mm / week during all Dry (Nov1 - May31) and Wet (Jun1 - Oct31) seasons, respectively.

Scenario	Reces_10	Inun_10	Reces_9	Inun_9	Reces_8	Inun_8	Reces_7	Inun_7	Reces_6	Inun_6	Reces_5	Inun_5	Reces_4	Inun_4	Reces_3	Inun_3	Reces_2	Inun_2	Reces_1	Inun_1
NSM4.6.2	7	7	8	8	7	8	8	8	9	9	7	8	6	6	7	7	8	9	7	8
RecyS10S5_RegSep_B	10	11	9	9	8	8	11	11	12	14	13	16	10	11	9	9	10	14	10	10
LORS07	18	23	16	20	15	18	18	22	19	24	20	25	19	24	18	22	17	21	17	21
NULL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NULL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NULL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Summary Table 2. Unsaturated z: Dry-downs, as duration & depth of the unsaturated zone within each Indicator Region #: 'Mon_#' = mean duration (months), and 'Dep_#' = mean depth (m).
Both statistics included only values of unsaturated zone depth that exceeded threshold of >0.03 m.

Scenario	Mon10	Dep10	Mon_9	Dep_9	Mon_8	Dep_8	Mon_7	Dep_7	Mon_6	Dep_6	Mon_5	Dep_5	Mon_4	Dep_4	Mon_3	Dep_3	Mon_2	Dep_2	Mon_1	Dep_1
NSM4.6.2	0.9	0.12	0.8	0.11	0.6	0.10	0.9	0.16	1.1	0.13	0.9	0.14	1.0	0.13	0.6	0.11	0.3	0.12	0.9	0.11
RecyS10S5_RegSep_B	1.8	0.06	2.7	0.07	2.2	0.06	1.5	0.07	0.8	0.06	0.0	#N/A	0.6	0.06	0.6	0.06	0.0	#N/A	1.6	0.06
LORS07	0.8	0.08	2.1	0.09	3.7	0.11	2.6	0.18	0.5	0.11	0.0	#N/A	0.6	0.09	1.4	0.15	2.9	0.26	2.0	0.10
NULL	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
NULL	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
NULL	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A

Summary Table 3. Unsaturated z: Extreme dry-downs, as the maximum unsaturated zone depth, and the mean unsaturated zone depths that exceeded a threshold, within each Indicator Region #:
'Max_#' = maximum of the mean daily value (m), and 'Deep_#' = mean depth of all values >=0.3048 m.

Scenario	Max10	Deep10	Max_9	Deep_9	Max_8	Deep_8	Max_7	Deep_7	Max_6	Deep_6	Max_5	Deep_5	Max_4	Deep_4	Max_3	Deep_3	Max_2	Deep_2	Max_1	Deep_1
NSM4.6.2	0.29	#N/A	0.32	0.32	0.29	#N/A	0.45	0.36	0.35	0.35	0.31	0.31	0.33	0.33	0.28	#N/A	0.25	#N/A	0.31	0.31
RecyS10S5_RegSep_B	0.13	#N/A	0.31	0.31	0.17	#N/A	0.27	#N/A	0.14	#N/A	0.02	#N/A	0.12	#N/A	0.16	#N/A	0.01	#N/A	0.17	#N/A
LORS07	0.25	#N/A	0.47	0.43	0.63	0.51	0.79	0.48	0.31	0.31	0.02	#N/A	0.31	0.31	0.60	0.47	1.14	0.64	0.45	0.42
NULL	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
NULL	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
NULL	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A

Model Project: ELMwca1_200m v.2.8

Summary Table 4. Surface z: Wet-ups, as duration & depth of the surface water within each Indicator Region #: 'Mon_#' = mean duration (months), and 'Dep_#' = mean depth (m).
Both statistics included only values of surface water depth that exceeded threshold of >0.03 m.

Scenario	Mon10	Dep10	Mon_9	Dep_9	Mon_8	Dep_8	Mon_7	Dep_7	Mon_6	Dep_6	Mon_5	Dep_5	Mon_4	Dep_4	Mon_3	Dep_3	Mon_2	Dep_2	Mon_1	Dep_1
NSM4.6.2	10.9	0.23	11.0	0.27	11.2	0.26	10.6	0.25	10.7	0.28	11.0	0.26	10.6	0.19	11.1	0.25	11.5	0.30	11.0	0.25
RecyS10S5_RegSep_B	12.0	0.29	11.5	0.19	12.0	0.18	11.9	0.26	11.9	0.36	12.0	0.82	11.9	0.30	12.0	0.27	12.0	0.52	12.0	0.28
LORS07	12.0	0.47	11.6	0.32	11.0	0.25	11.0	0.34	11.9	0.54	12.0	1.02	11.8	0.45	11.6	0.38	10.9	0.32	11.9	0.39
NULL	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
NULL	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
NULL	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A

Summary Table 5. Surface z: Extreme wet-ups, as the maximum surface water depth, and the mean surface water depth that exceeded a threshold, within each Indicator Region #:
'Max_#' = maximum of the mean daily value (m), and 'Deep_#' = mean depth of all values >=0.3048 m.

Scenario	Max10	Deep10	Max_9	Deep_9	Max_8	Deep_8	Max_7	Deep_7	Max_6	Deep_6	Max_5	Deep_5	Max_4	Deep_4	Max_3	Deep_3	Max_2	Deep_2	Max_1	Deep_1
NSM4.6.2	0.51	0.36	0.55	0.39	0.54	0.38	0.56	0.38	0.60	0.41	0.54	0.38	0.43	0.35	0.51	0.37	0.60	0.40	0.53	0.37
RecyS10S5_RegSep_B	0.59	0.39	0.49	0.35	0.47	0.35	0.57	0.36	0.64	0.43	1.13	0.82	0.61	0.40	0.63	0.38	0.91	0.52	0.56	0.37
LORS07	0.87	0.56	0.73	0.48	0.63	0.45	0.72	0.49	0.94	0.59	1.43	1.02	0.86	0.56	0.80	0.52	0.69	0.48	0.79	0.52
NULL	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
NULL	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A
NULL	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A	0.00	#N/A

Model Project: ELMwca1_200m v.2.8

Summary Table 6. Unsaturated z duration: Duration of extreme drydowns within each Indicator Region #: Wk/yr == Mean # weeks/year; Wk/evt == Mean # weeks/event.
An 'event' is any 7-day period with mean unsaturated zone depth that exceeded 0.30 m.

Scenario	Wk/yr10	Wk/evt10	Wk/yr_9	Wk/evt_9	Wk/yr_8	Wk/evt_8	Wk/yr_7	Wk/evt_7	Wk/yr_6	Wk/evt_6	Wk/yr_5	Wk/evt_5	Wk/yr_4	Wk/evt_4	Wk/yr_3	Wk/evt_3	Wk/yr_2	Wk/evt_2	Wk/yr_1	Wk/evt_1
NSM4.6.2	0.1	2.0	0.1	4.0	0.1	3.0	0.5	3.6	0.2	6.0	0.1	2.0	0.2	3.5	0.1	2.0	0.0	1.0	0.1	3.0
RecyS10S5_RegSep_B	0.0	#N/A	0.2	3.0	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	1.0	0.0	#N/A	0.0	#N/A
LORS07	0.0	#N/A	0.5	6.0	1.0	7.2	2.4	7.2	0.1	2.5	0.0	#N/A	0.2	3.0	0.9	6.2	3.5	7.5	0.4	8.0
NULL	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A
NULL	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A
NULL	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A	#NUM!	#N/A

Summary Table 7. Unsaturated z: Maximum duration of extreme drydown events within each Indicator Region #: MaxWk == Maximum # weeks in simulation period.
An 'event' is any 7-day period with mean unsaturated zone depth that exceeded 0.30 m.

Scenario	MaxWk10	MaxWk_9	MaxWk_8	MaxWk_7	MaxWk_6	MaxWk_5	MaxWk_4	MaxWk_3	MaxWk_2	MaxWk_1
NSM4.6.2	2	4	3	8	6	3	5	2	1	3
RecyS10S5_RegSep_B	0	4	0	0	0	0	0	1	0	0
LORS07	0	8	14	16	4	0	4	13	19	10
NULL	0	0	0	0	0	0	0	0	0	0
NULL	0	0	0	0	0	0	0	0	0	0
NULL	0	0	0	0	0	0	0	0	0	0

Model Project: ELMwca1_200m v.2.8

Summary Table 8. Velocity and Cl: Mean daily surface water flow velocity index (Vel#, m/d); mean daily surface water chloride concentration (CL, g/L), within each Indicator Region #.

Scenario	Vel10	CL10	Vel_9	CL_9	Vel_8	CL_8	Vel_7	CL_7	Vel_6	CL_6	Vel_5	CL_5	Vel_4	CL_4	Vel_3	CL_3	Vel_2	CL_2	Vel_1	CL_1
NSM4.6.2	#N/A	0.005	#N/A	0.005	#N/A	0.004	#N/A	0.003	#N/A	0.005	#N/A	0.005	#N/A	0.005	#N/A	0.005	#N/A	#N/A	#N/A	0.005
RecyS10S5_RegSep_B	37	0.026	63	0.033	108	0.037	84	0.042	76	0.038	15	0.031	40	0.028	54	0.036	273	0.043	71	0.034
LORS07	28	0.053	20	0.036	23	0.023	23	0.046	29	0.065	15	0.073	26	0.056	33	0.049	21	0.055	26	0.044
NULL	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
NULL	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
NULL	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

8.7.3 Cumulative Frequency Distribution Graphs, Selected Scenario

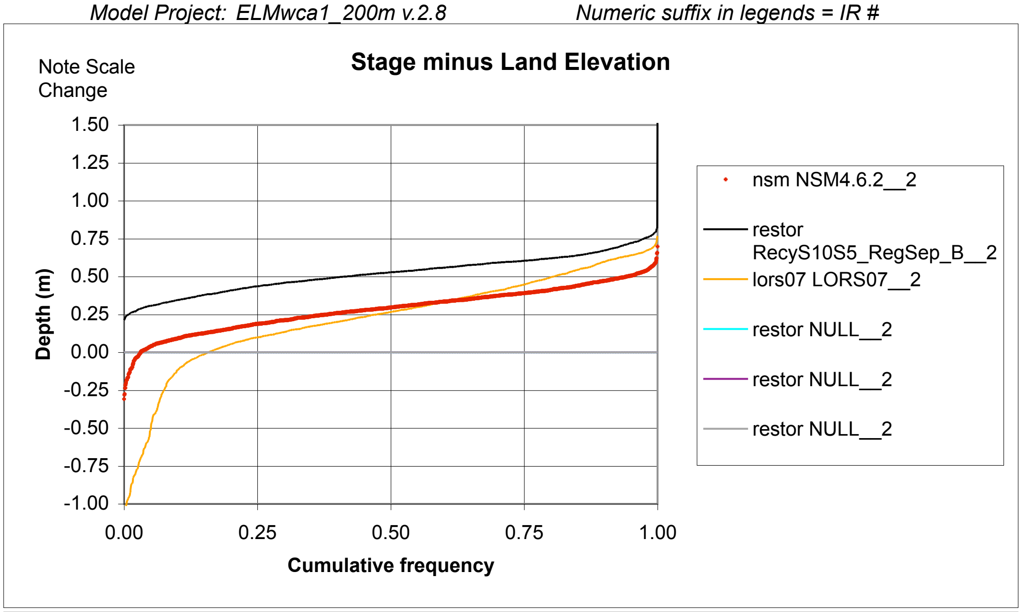
Graphs of the Cumulative Frequency Distributions of water depths (relative to local land surface elevations) follow on the next three pages, including the restoration scenario that was selected to have provided the best hydrologic and water quality benefits relative to other simulated scenarios. The LORS07 Base run and the NSM v4.6.2 are included for use as benchmarks for relative comparison.

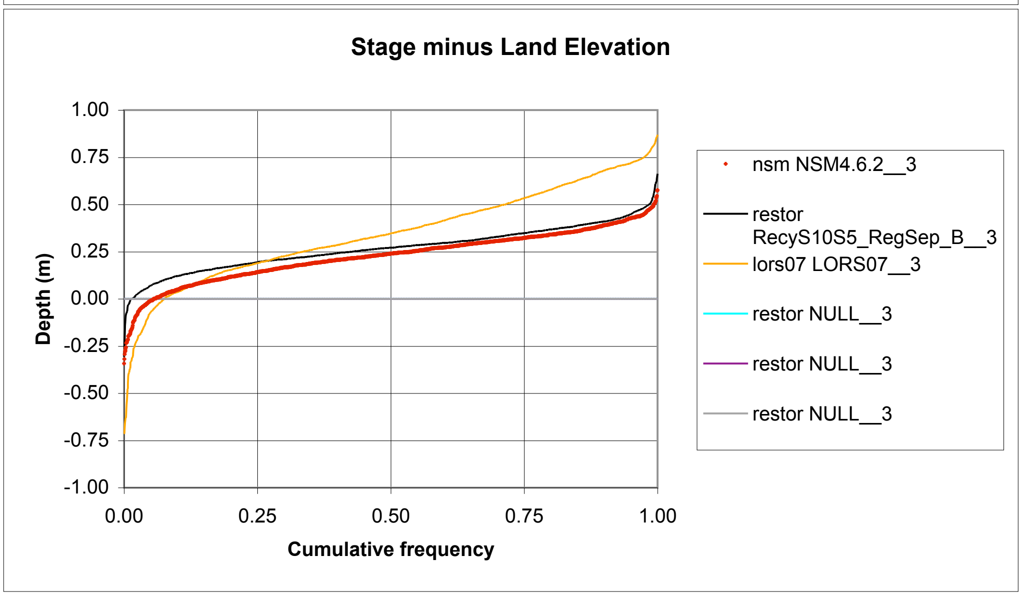
For each figure, the number appended to the legend labels denote the Indicator Region number (see Figure 8.1). All data are spatially aggregated to include all model grid cells within the designated Indicator Region.

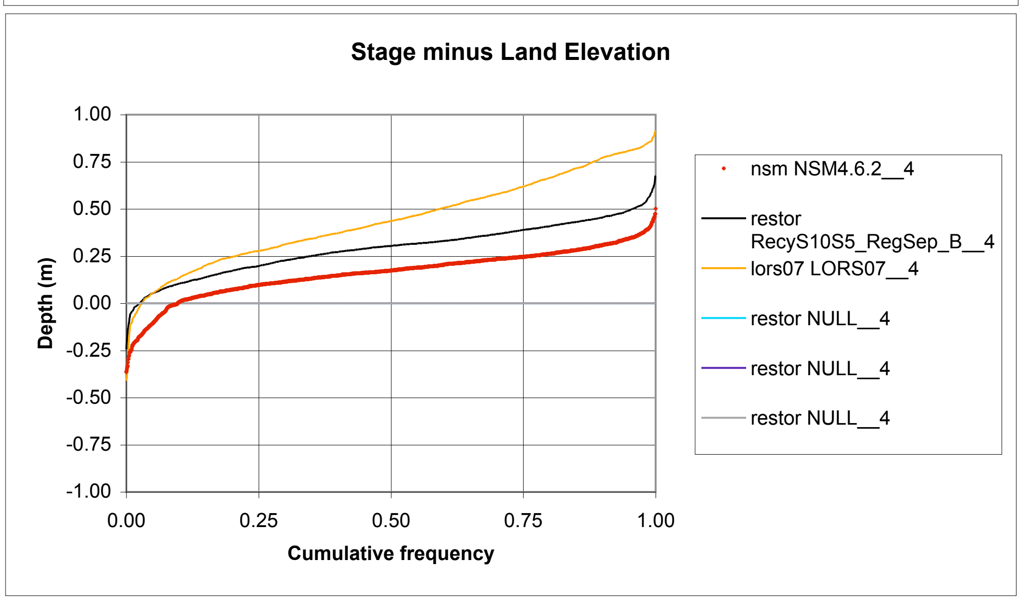
The Appendix contains Cumulative Frequency Distribution graphs for all of the simulated scenarios.

Cumulative Frequency Distribution Graphs

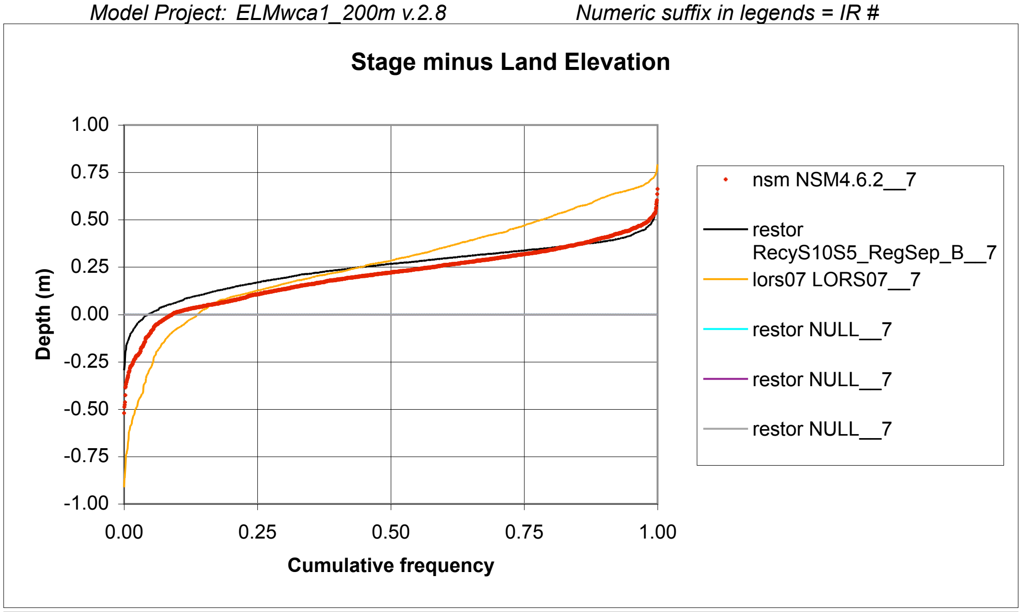
Model Project: ELMwca1_200m v.2.8 *Numeric suffix in legends = IR #*

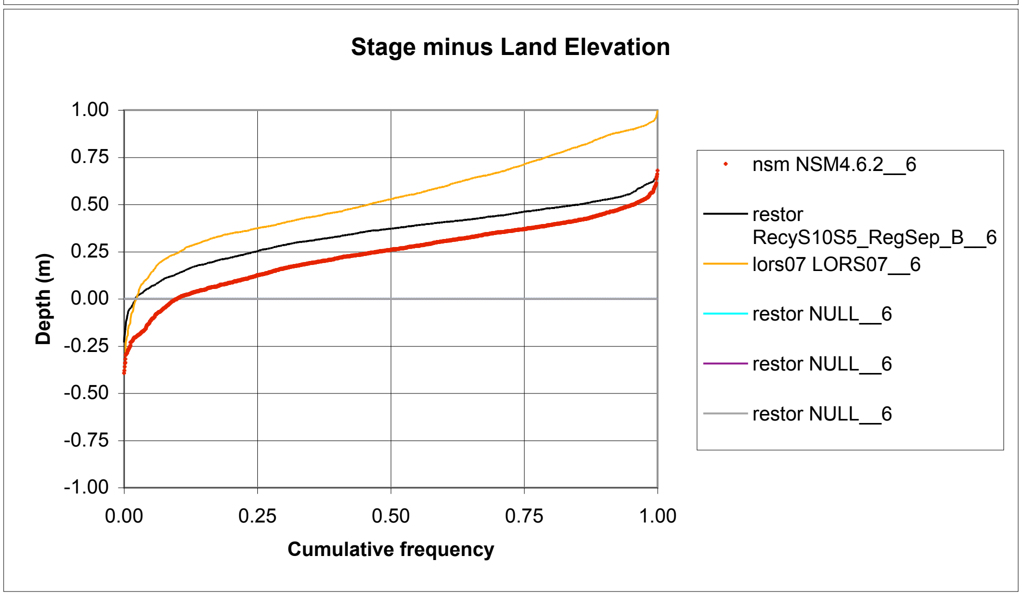


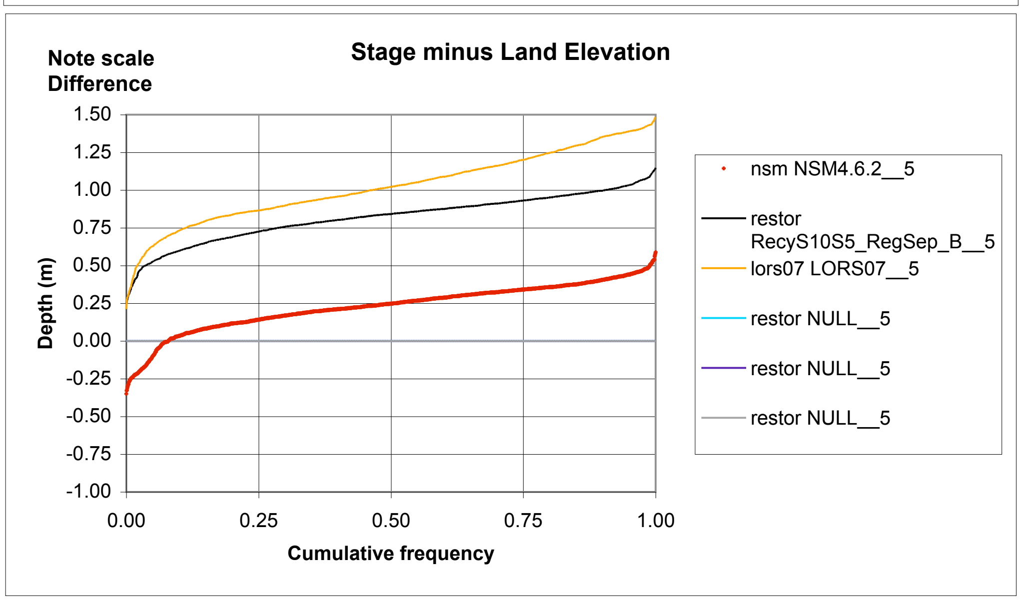




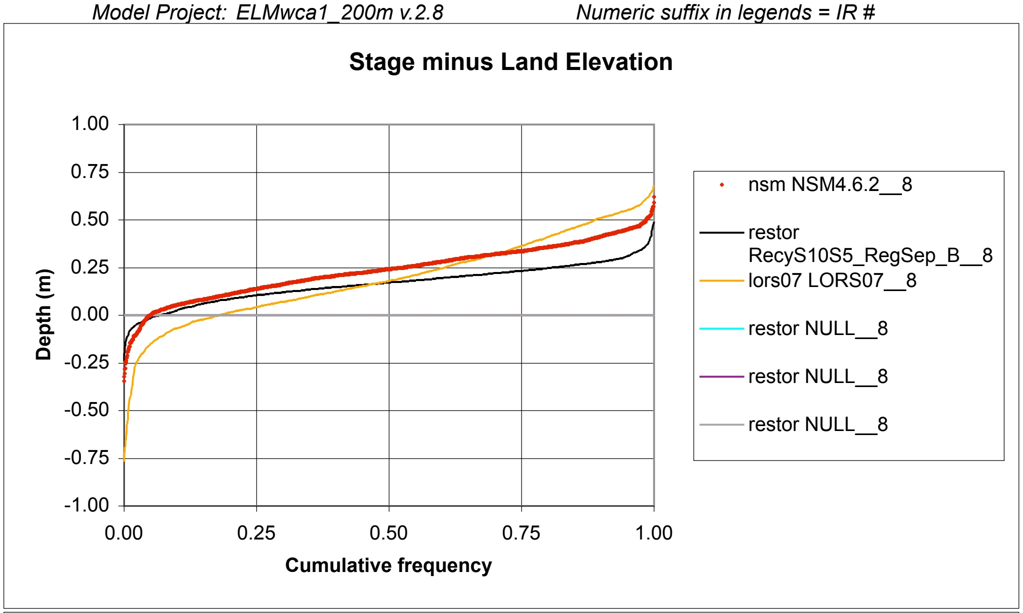
Cumulative Frequency Distribution Graphs
Model Project: ELMwca1_200m v.2.8 *Numeric suffix in legends = IR #*

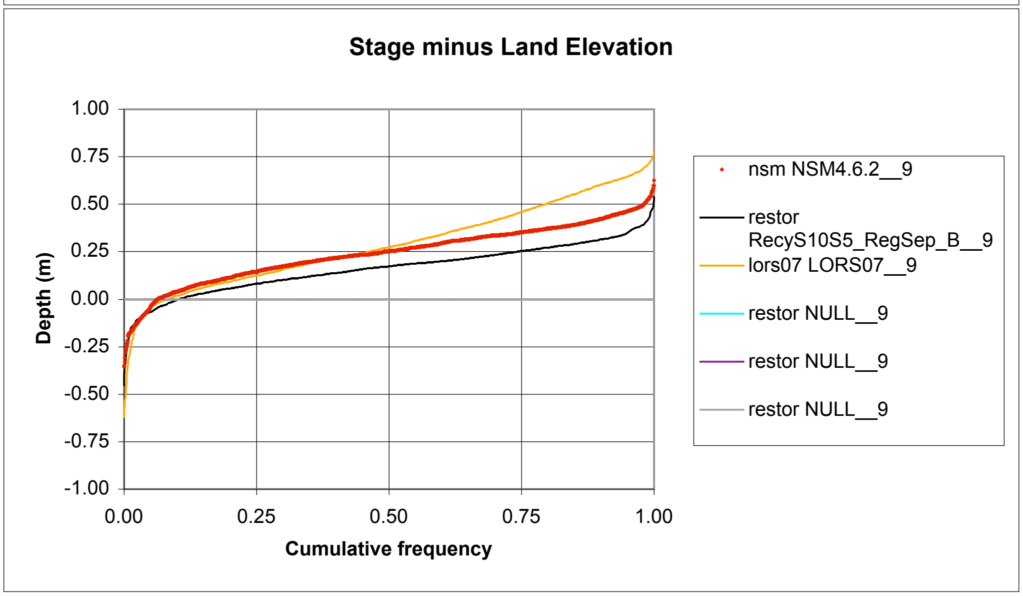


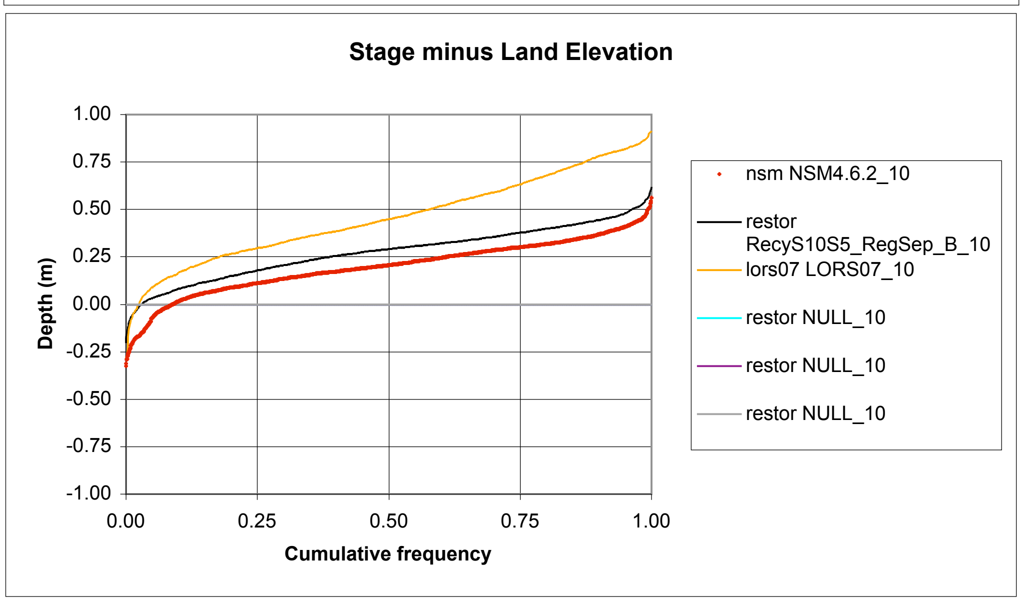




Model Project: ELMwca1_200m v.2.8 *Numeric suffix in legends = IR #*







8.7.4 Hydrographs, Tentatively Selected Scenario

Hydrographs of the ponded surface water depths (left frames) and depth of the unsaturated zone (right frames) follow on the next three pages, including the restoration scenario that was selected to have provided the best hydrologic and water quality benefits relative to other simulated scenarios. The LORS07 Base run and the NSM v4.6.2 are included for use as benchmarks for relative comparison.

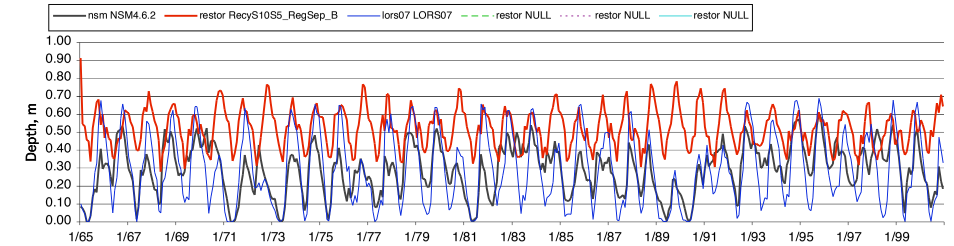
For each figure, the “Basin” number in the figure titles denotes the Indicator Region number (see Figure 8.1). All data are spatially aggregated to include all model grid cells within the designated Indicator Region.

The Appendix contains hydrographs for all of the simulated scenarios.

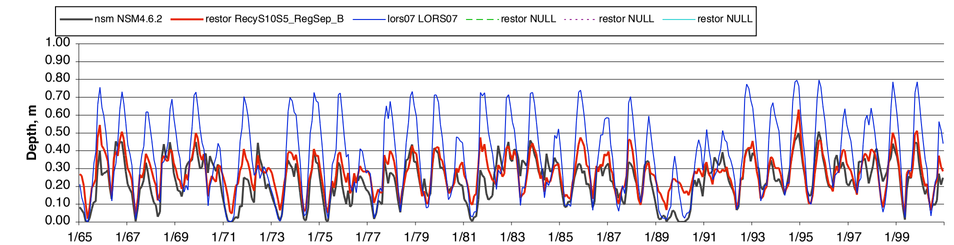
ELMwca1_200m v.2.8

Ecological Variables: Surface water depth in North - South Indicator regions

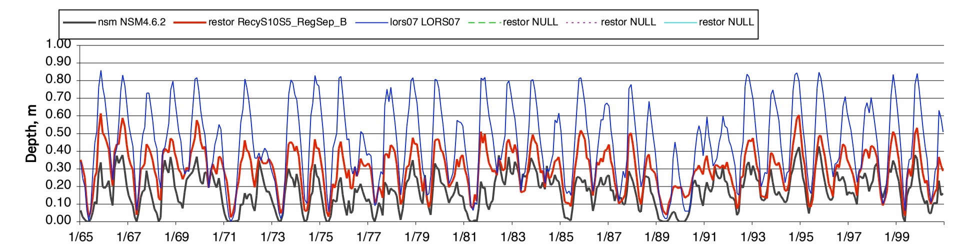
Basin_2: Surface Water Depth



Basin_3: Surface Water Depth



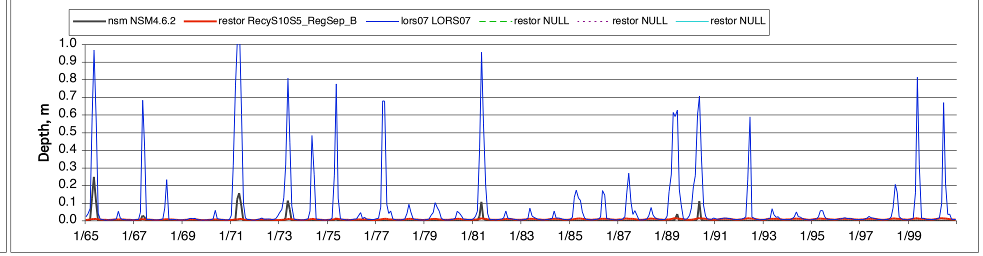
Basin_4: Surface Water Depth



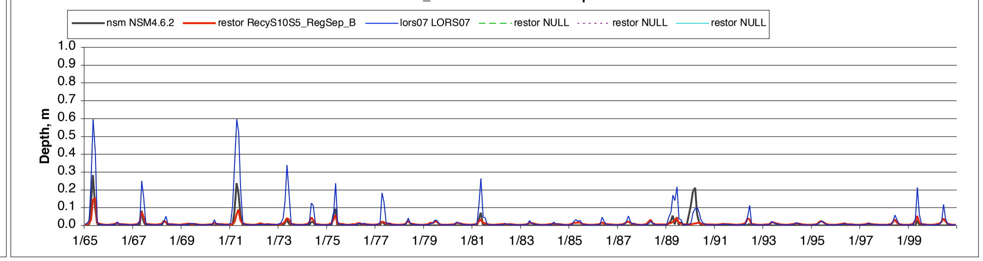
ELMwca1_200m v.2.8

Ecological Variables: Unsaturated water depth in North - South Indicator regions

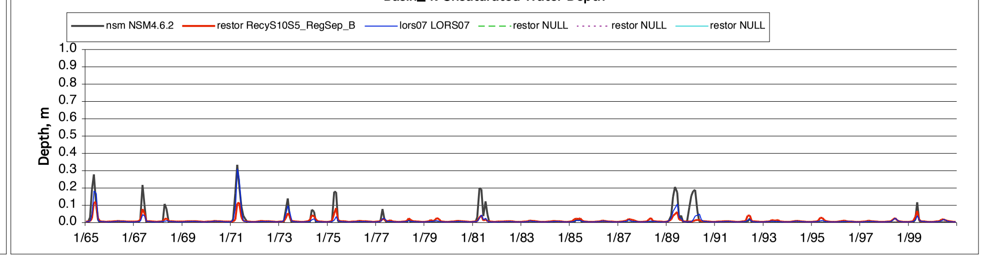
Basin_2: Unsaturated Water Depth



Basin_3: Unsaturated Water Depth

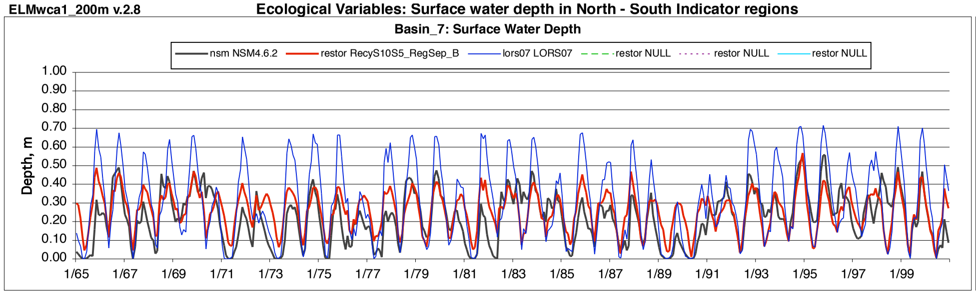


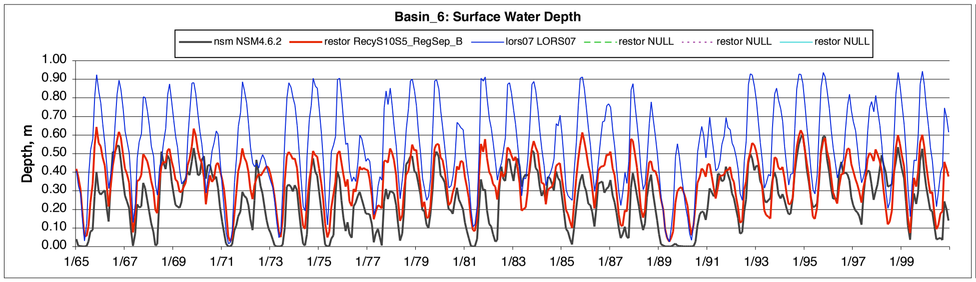
Basin_4: Unsaturated Water Depth

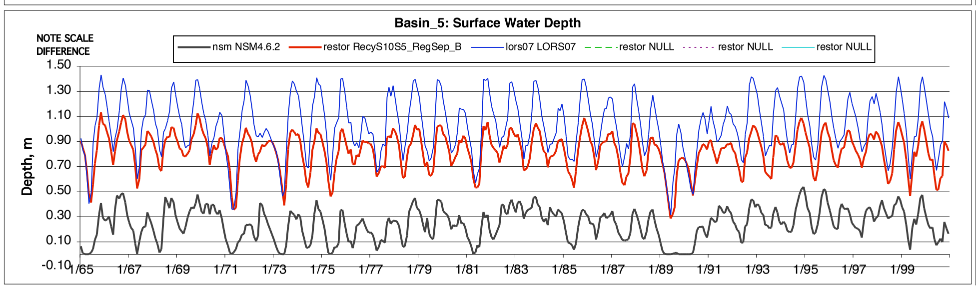


ELMwca1_200m v.2.8

Ecological Variables: Surface water depth in North - South Indicator regions

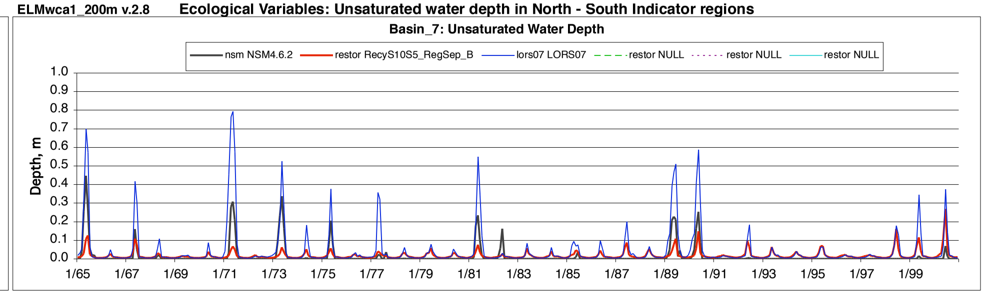


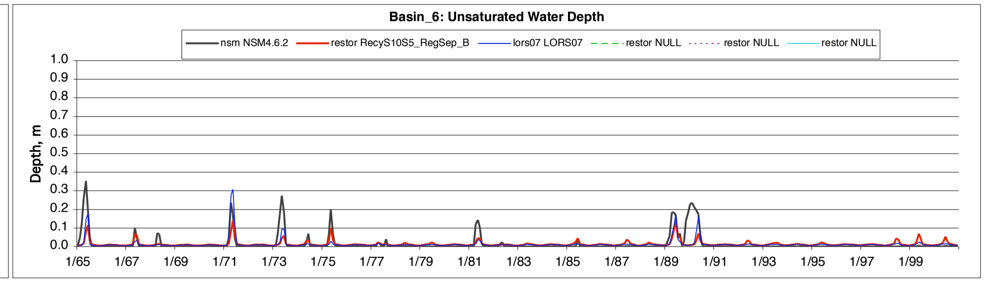


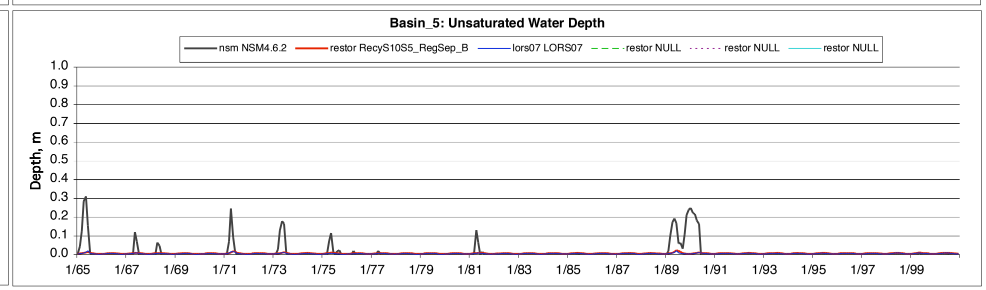


ELMwca1_200m v.2.8

Ecological Variables: Unsaturated water depth in North - South Indicator regions

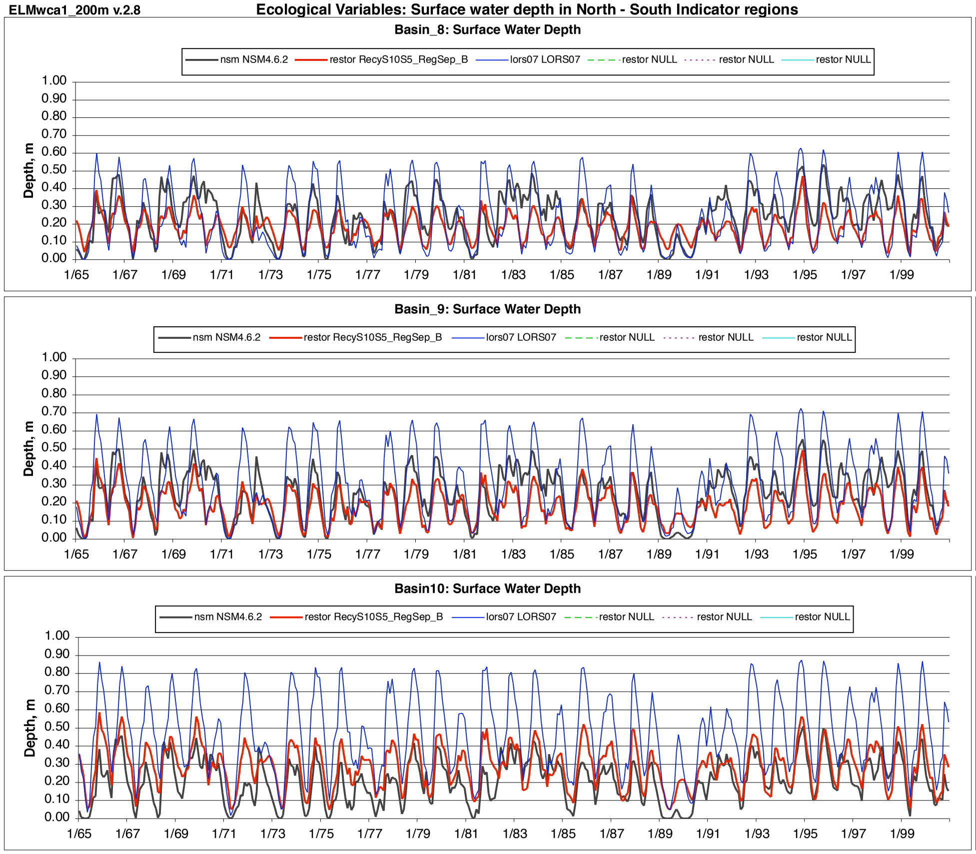






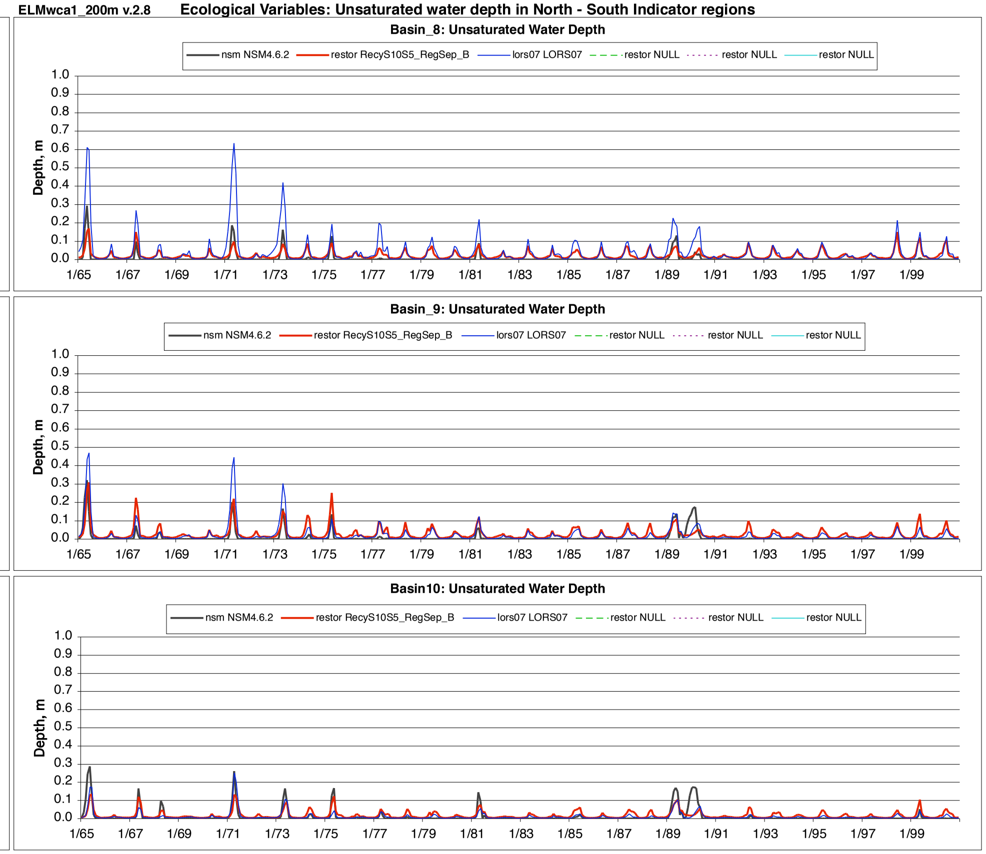
ELMwca1_200m v.2.8

Ecological Variables: Surface water depth in North - South Indicator regions



ELMwca1_200m v.2.8

Ecological Variables: Unsaturated water depth in North - South Indicator regions



8.7.5 Map comparisons, Tentatively Selected Scenario

The next page contains the figure caption that defines the data in all of the map comparison figures.

Following the caption page are (24 pages of) figures showing spatial maps of among-simulation comparisons of a) ponded surface water depth, b) surface water chloride concentration, and c) surface water total phosphorus concentration, including the restoration scenario that was selected to have provided the best hydrologic and water quality benefits relative to other simulated scenarios. For the surface water variable, the first set of comparisons is between the selected scenario and the LORS07 Base run; immediately following is the second set of hydrologic comparisons, between the selected scenario and the NSM v4.6.2 run. Chloride and phosphorus are not contained in the time series of NSM outputs, and thus are not included in the comparisons to the selected scenario; chloride and phosphorus are compared between the LORS07 Base run and the selected scenario in the remaining figures.

The Appendix contains map comparisons for all of the simulated scenarios relative to the LORS07 Base run.

Map Figures. Between-scenario comparisons: Monthly-mean values. All map data are daily mean values within a 30-day period that was close to the end of the wet or end of the dry season, with the ending date of that 30-day period indicated in the figure headings.

All figures follow the same format:

left frame is daily Mean within the 30-day period (MeanRaw) - scenarioA;

right frame is daily Mean within the 30-day period (MeanRaw) - scenarioB;

middle frame is daily Mean within the 30-day period (MeanRaw) - difference = scenarioB minus scenarioA.

Scenarios are described in Table 0 above.

Variables:

SfWatAvgYYYYMMDD = Surface water depth, interval ending on YYYYMMDD

SaltSfAvgYYYYMMDD = Surface water chloride ("salt") concentration, interval ending on YYYYMMDD

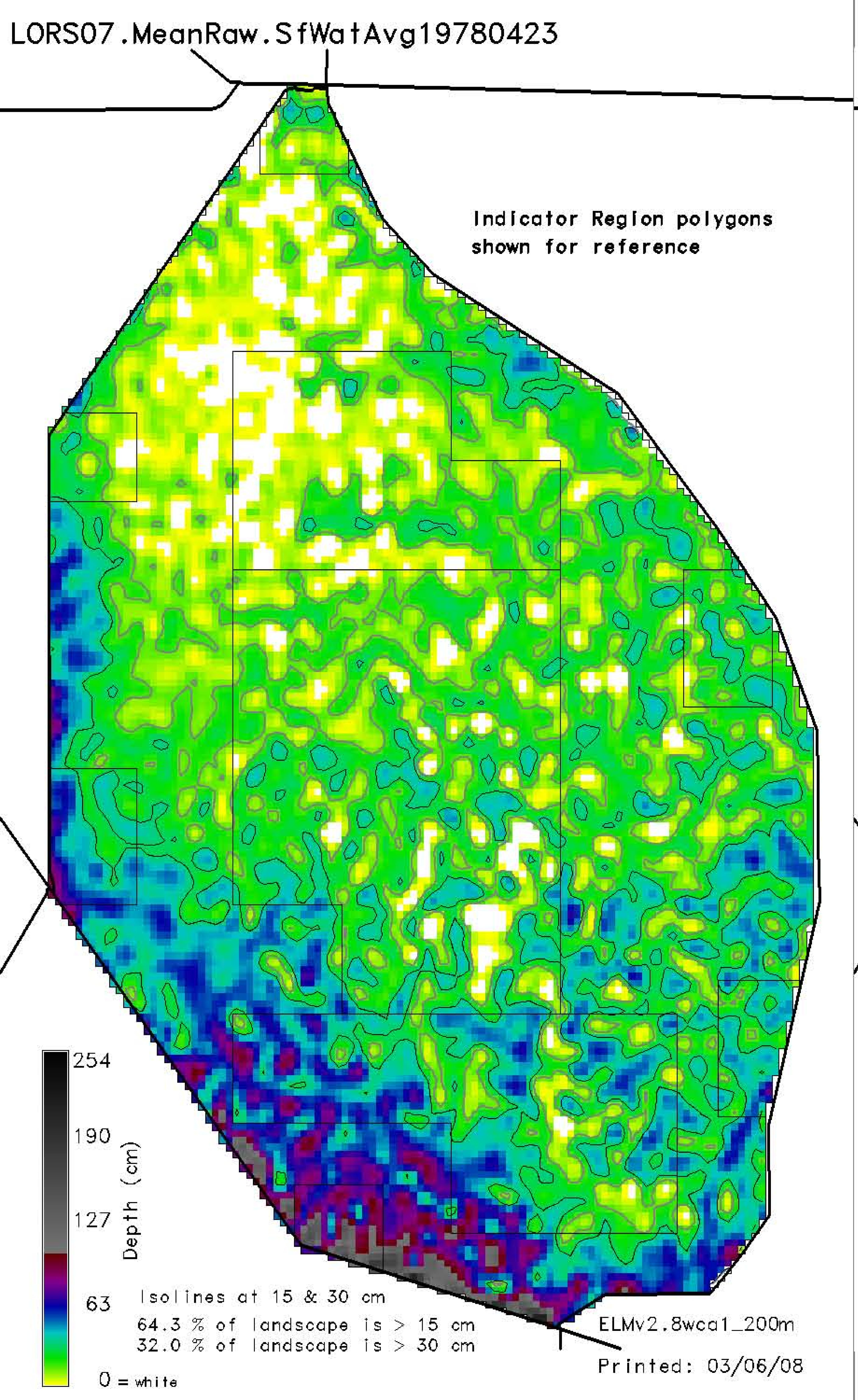
TPSfWatAvgYYYYMMDD = Surface water TP concentration, interval ending on YYYYMMDD.

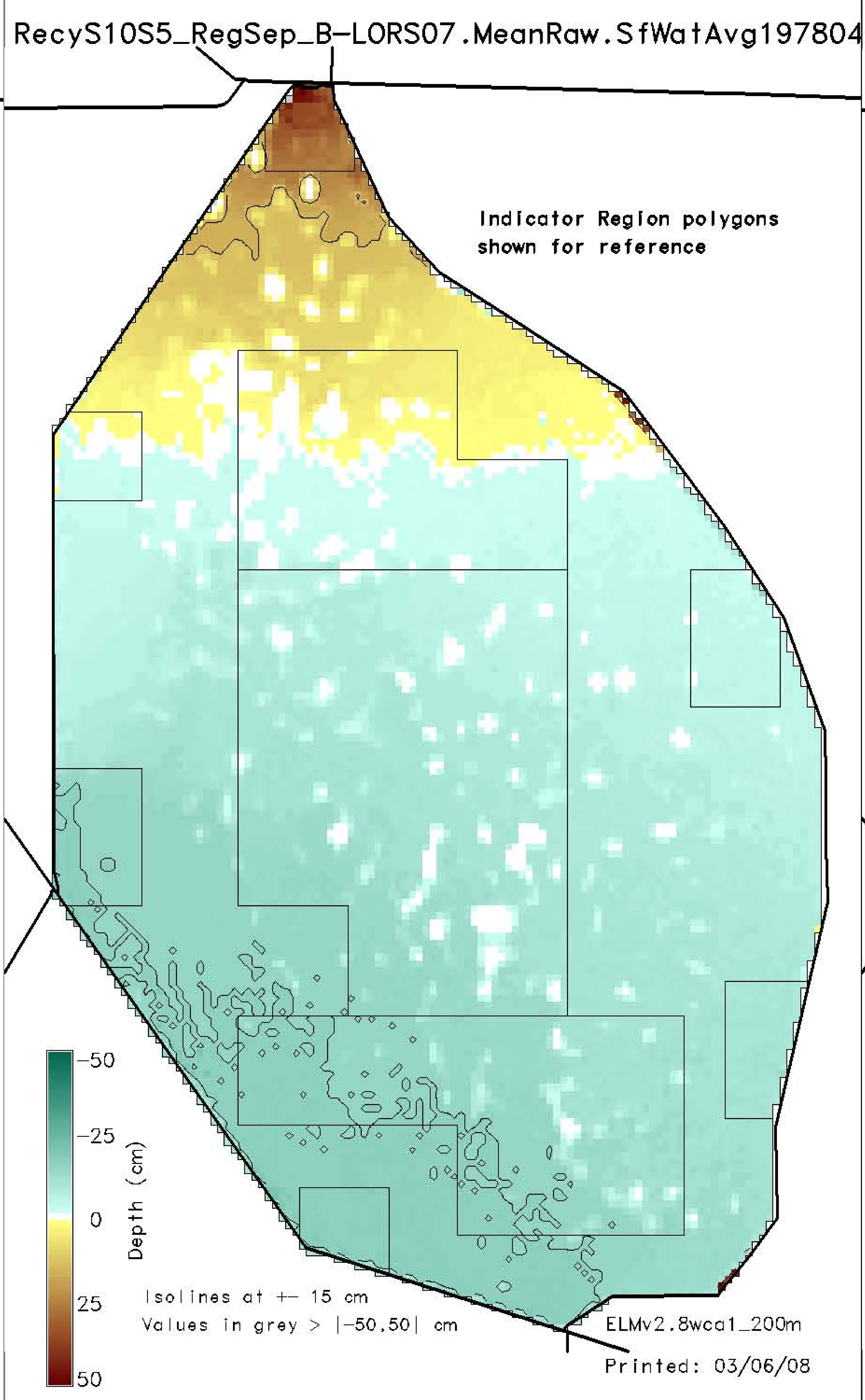
Selected wet/dry seasons, years:

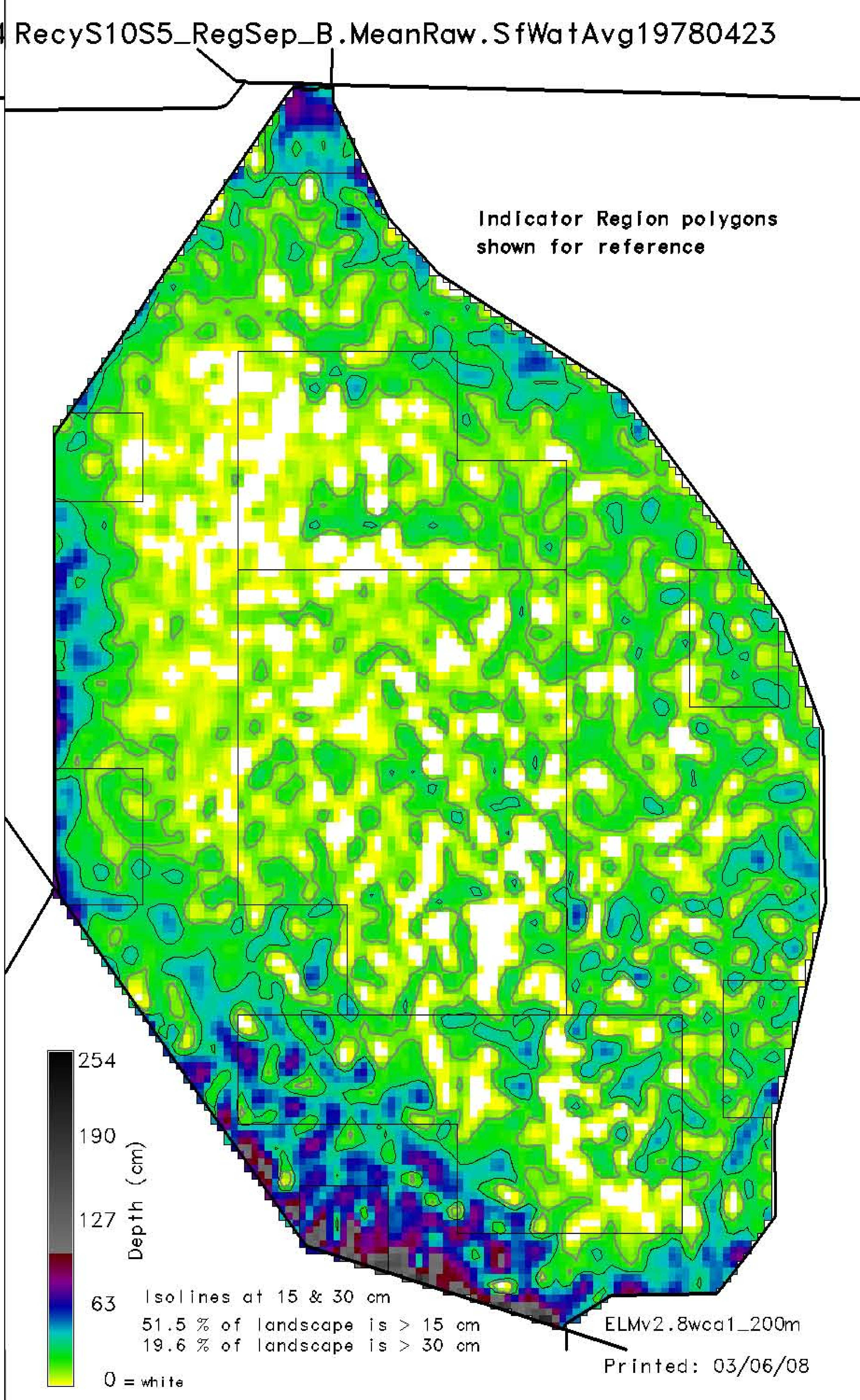
Wet Year: 1994
Dry Year: 1989
Average Year: 1978

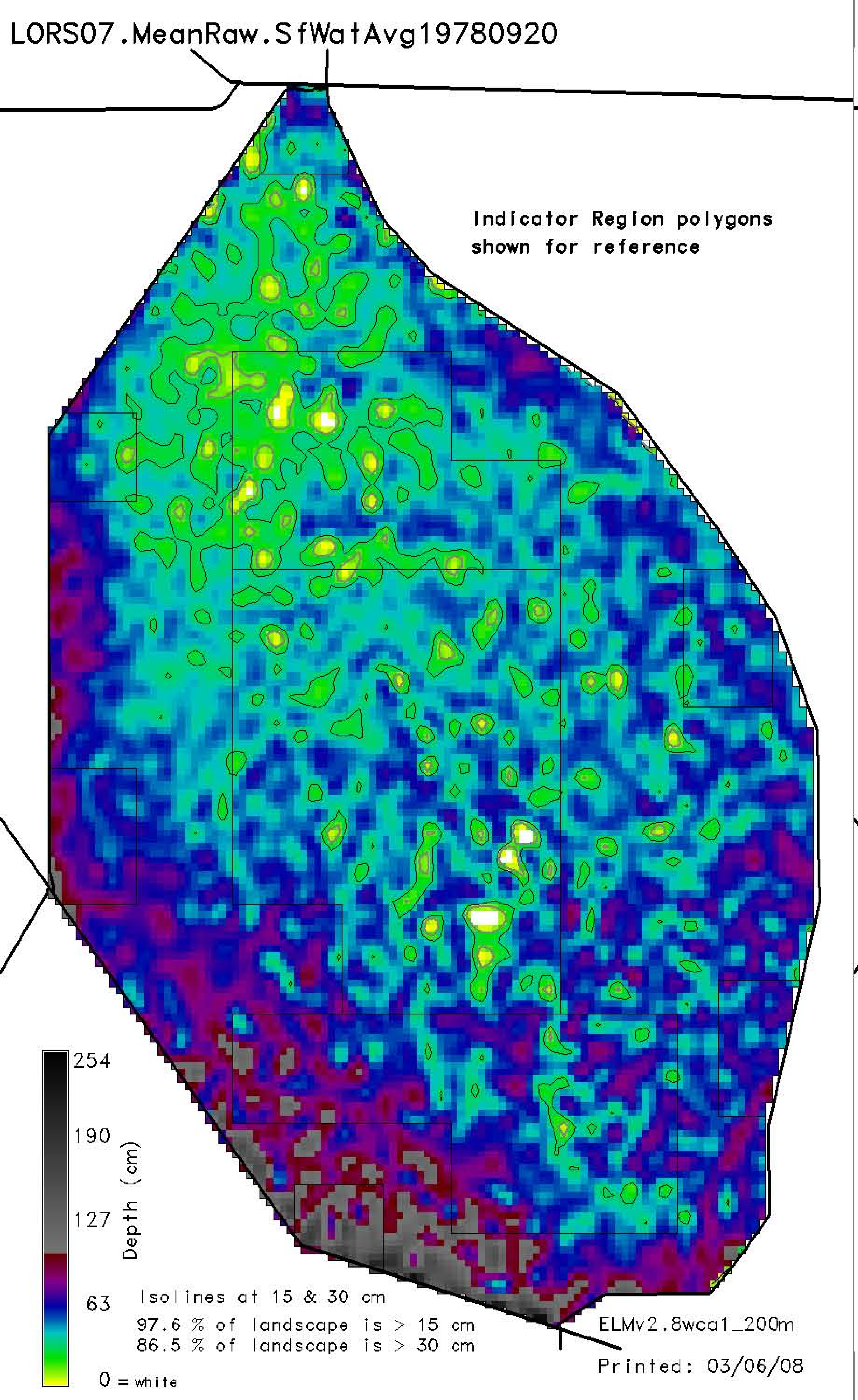
Wet season: ends on October 31 of any given year.
Dry season: ends on May 31 of any given year.

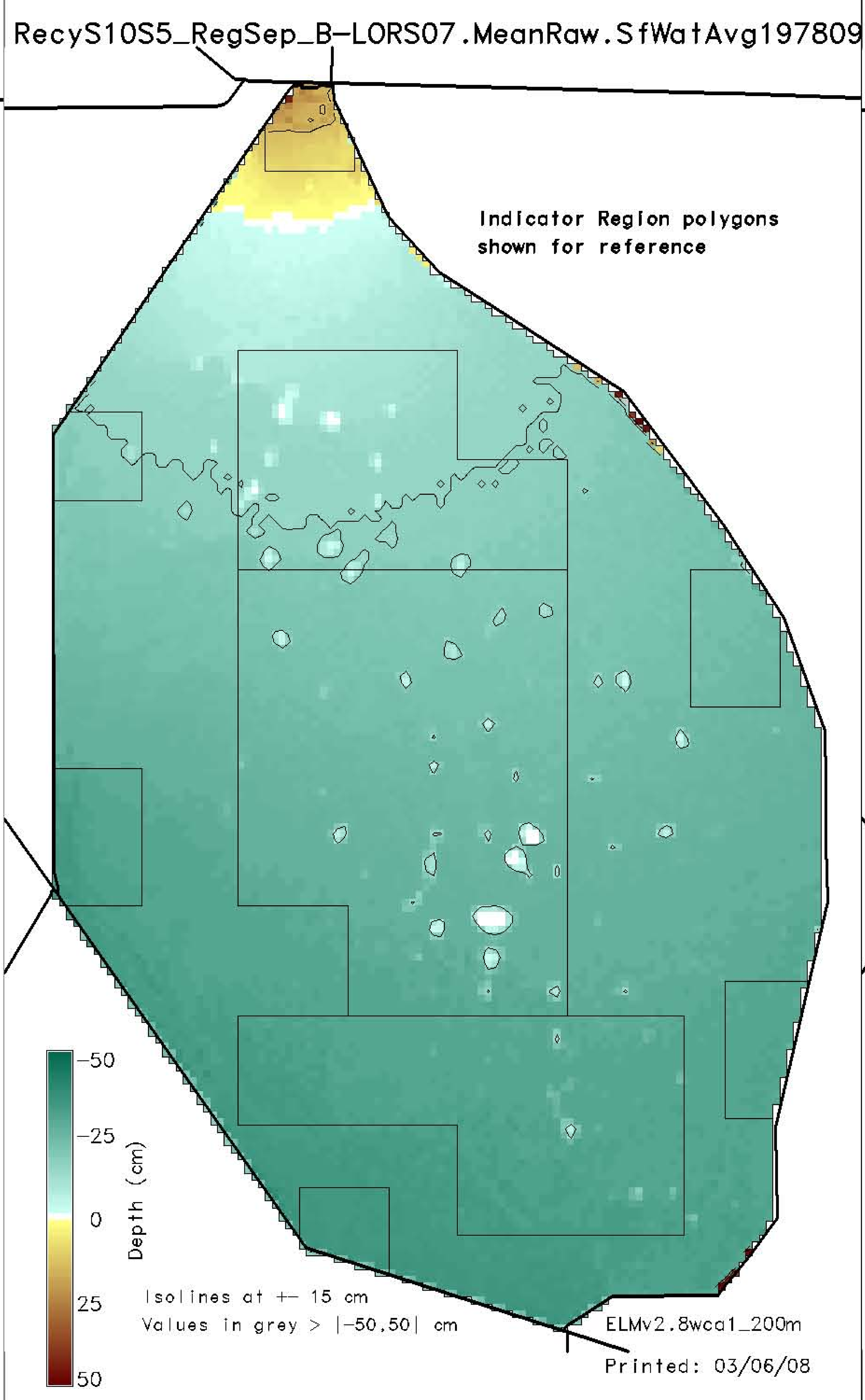
Calculation methods: The 'raw' ELM output used here were daily mean values of each variable within 30-day intervals (output every 30 days); for difference maps (middle frame), the difference was calculated between 'raw' output maps.

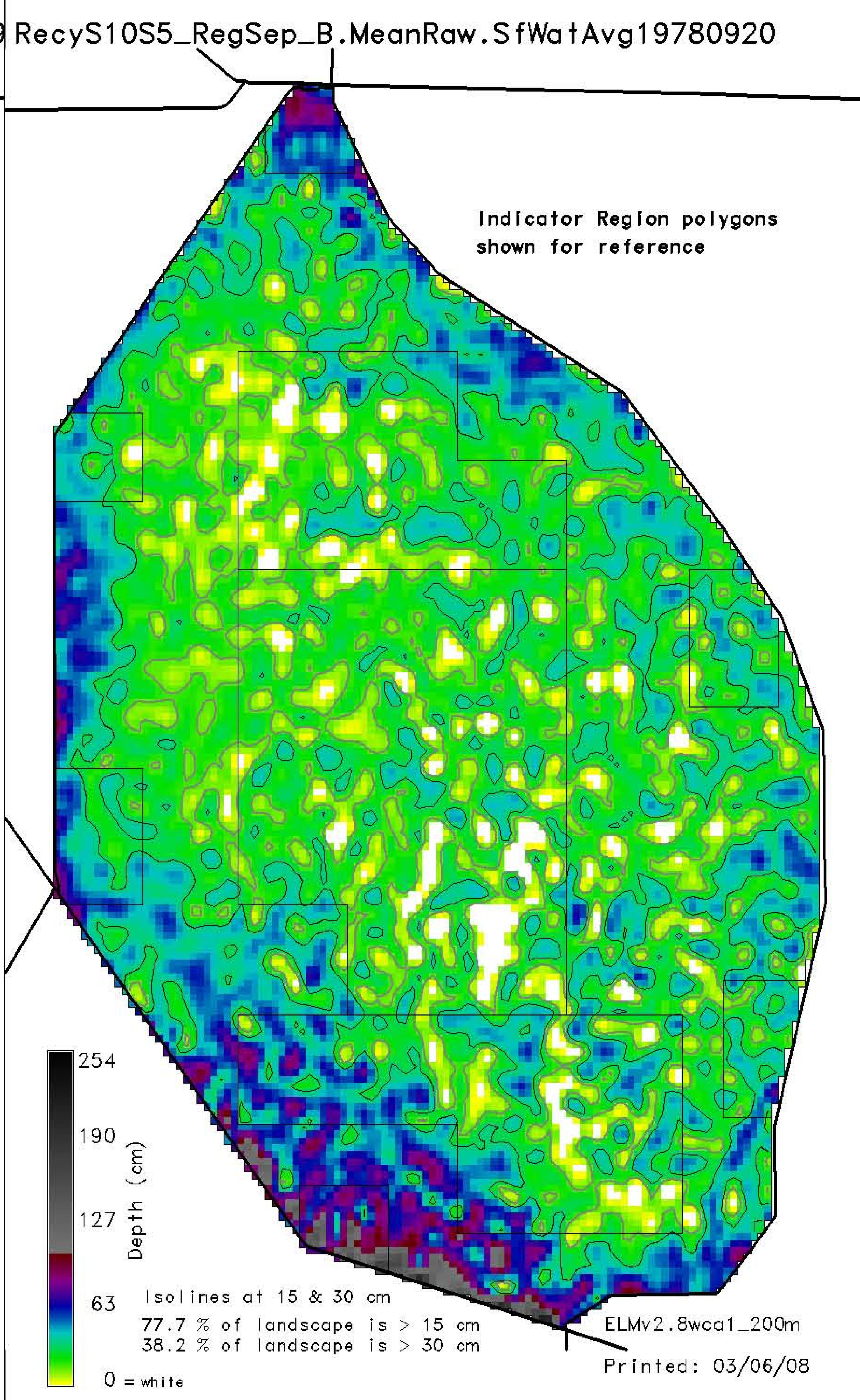

LORS07.MeanRaw.SfWatAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
64.3 % of landscape is > 15 cm
32.0 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B-LORS07.MeanRaw.SfWatAvg197804
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08

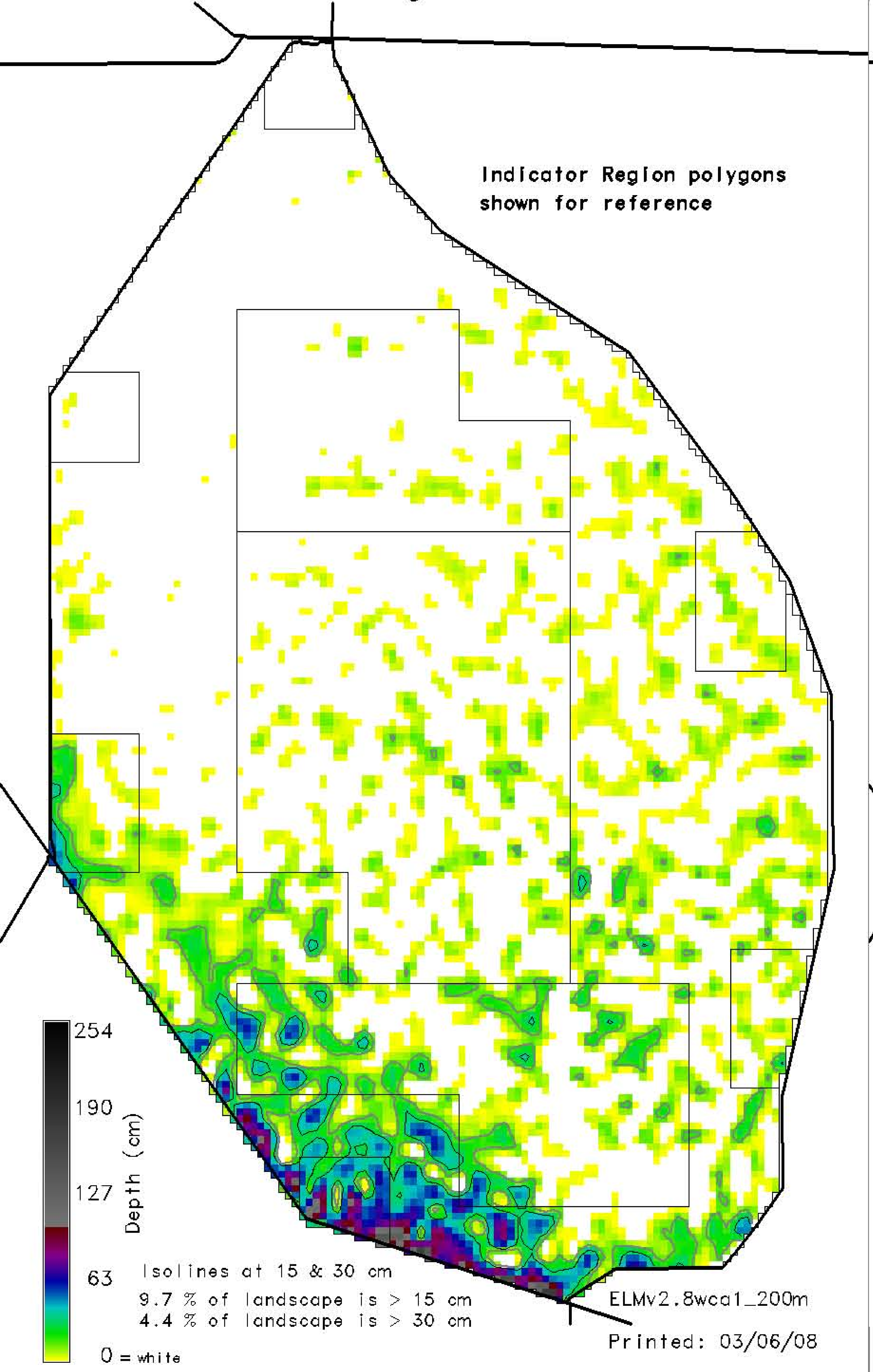

RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
51.5 % of landscape is > 15 cm
19.6 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


LORS07.MeanRaw.SfWatAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Depth (cm)
Isolines at 15 & 30 cm
97.6 % of landscape is > 15 cm
86.5 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

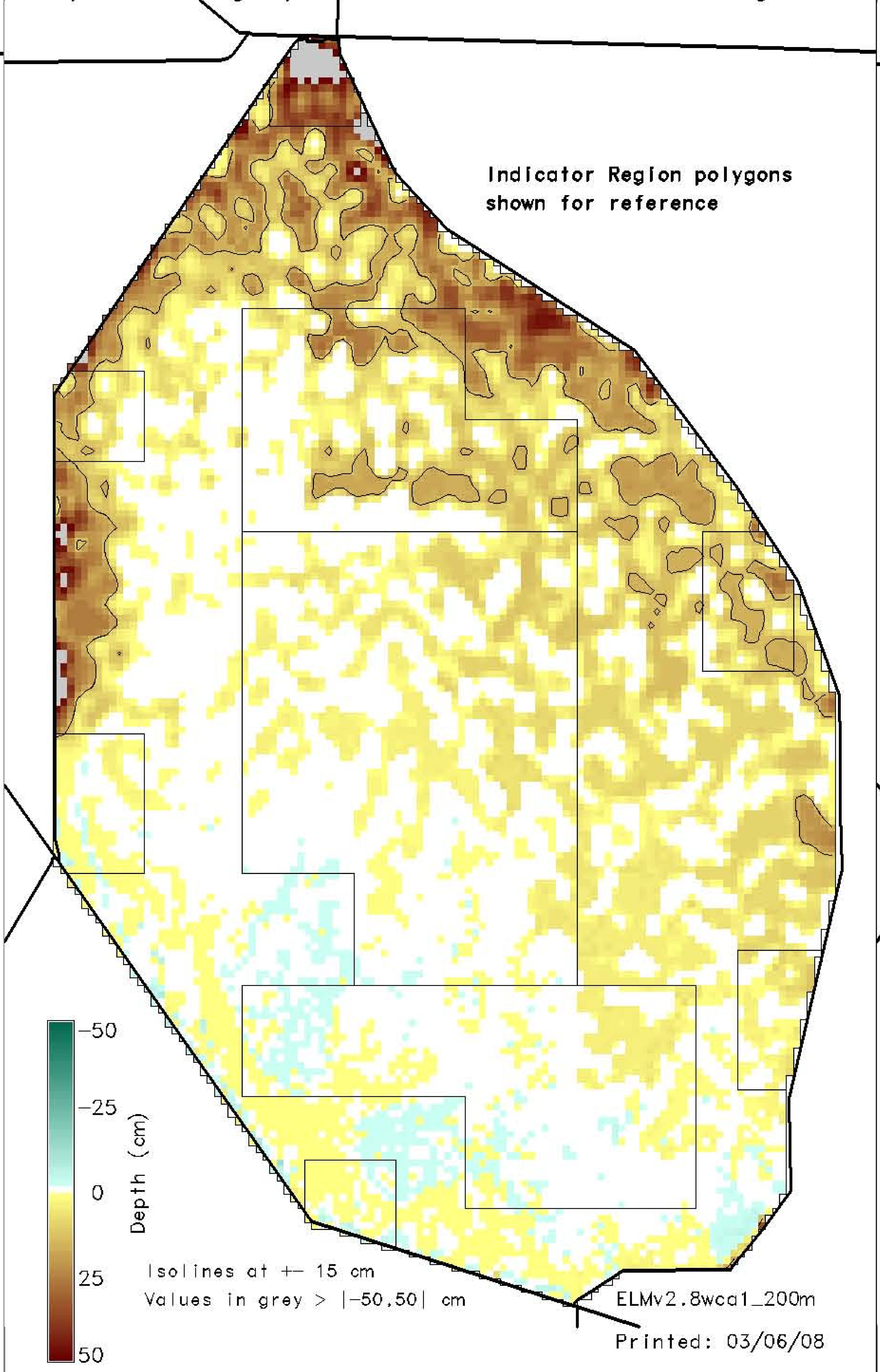

RecyS10S5_RegSep_B-LORS07.MeanRaw.SfWatAvg197809
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Depth (cm)
Isolines at 15 & 30 cm
77.7 % of landscape is > 15 cm
38.2 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

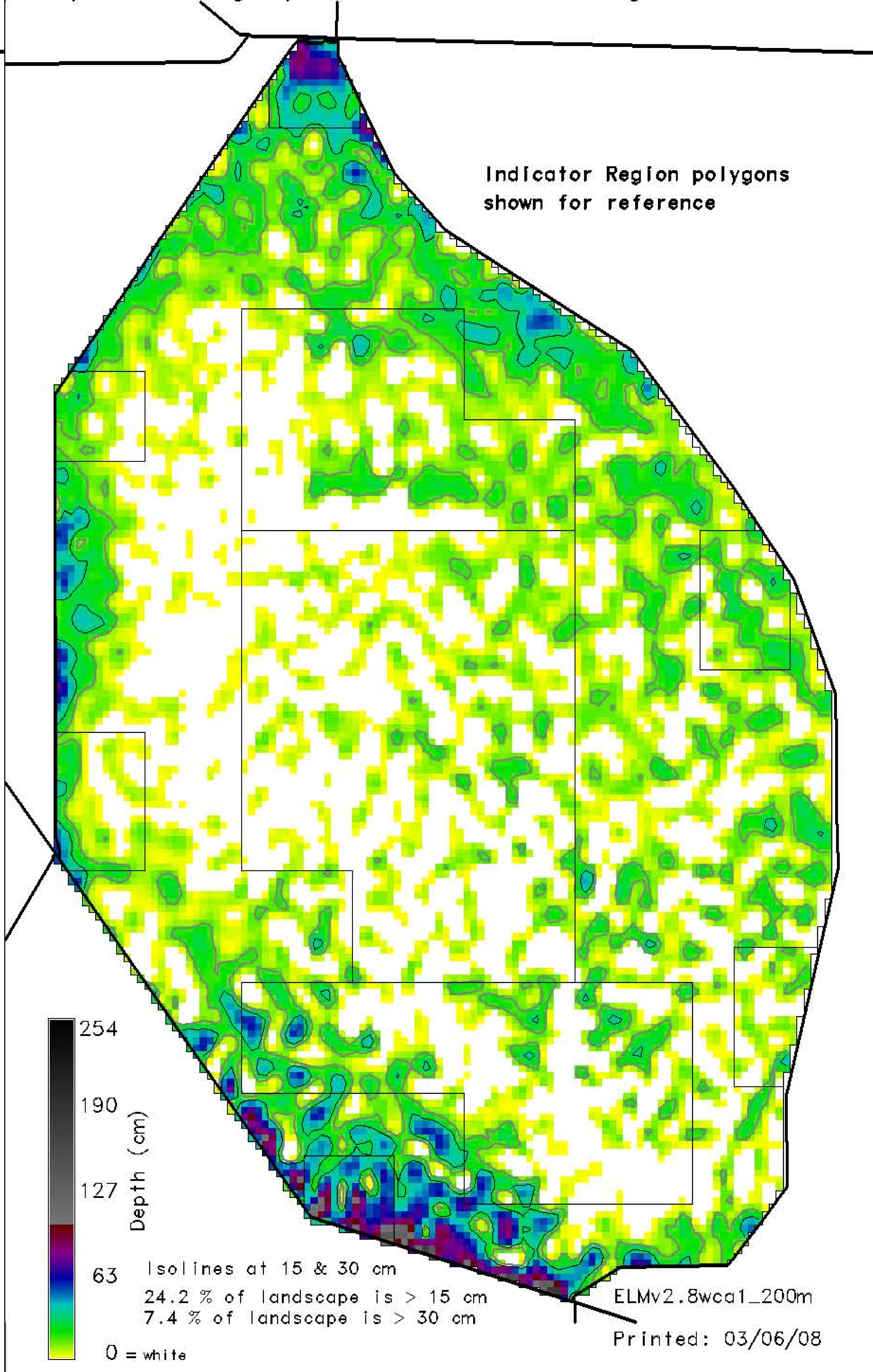
LORS07.MeanRaw.SfWatAvg19890425

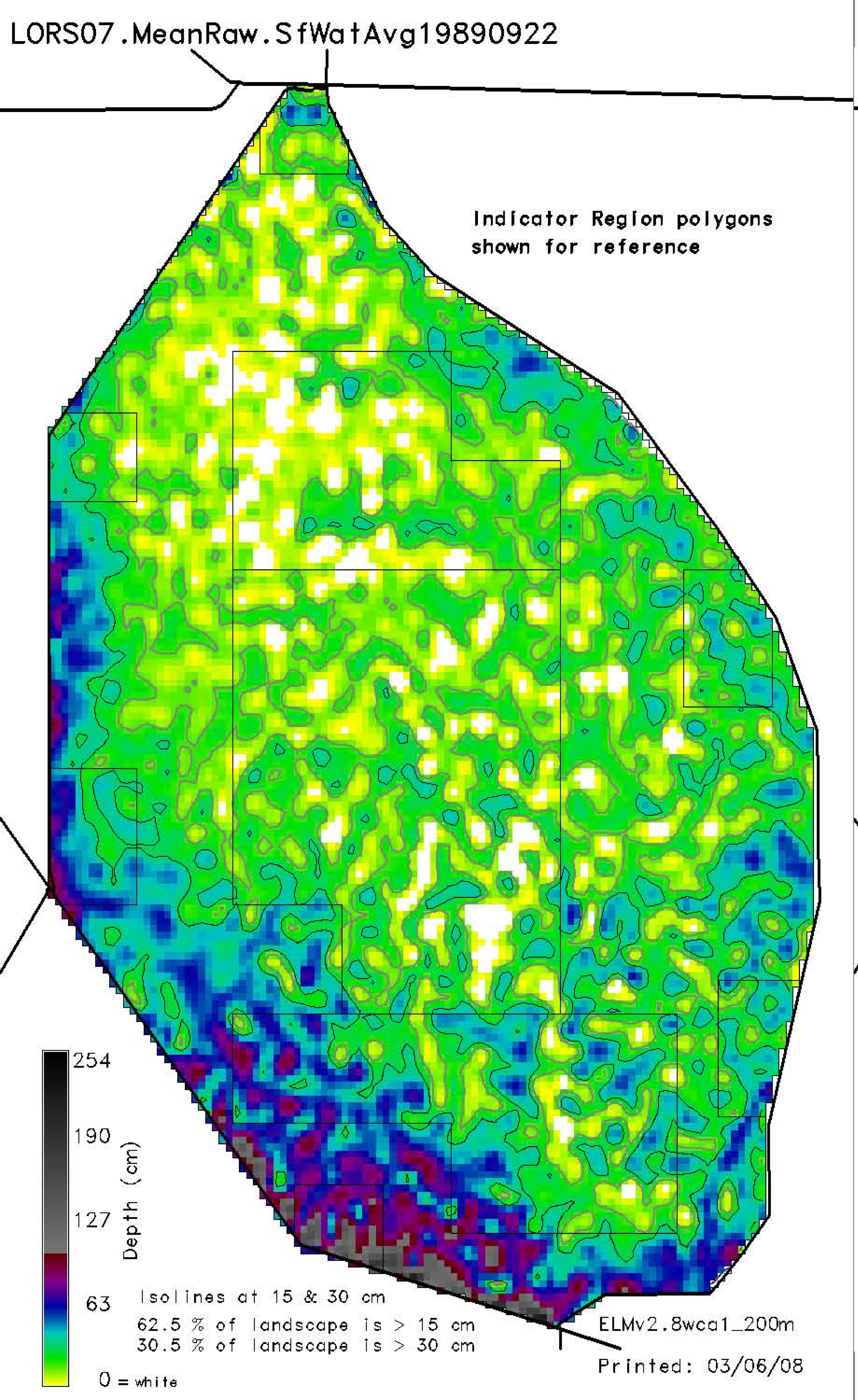


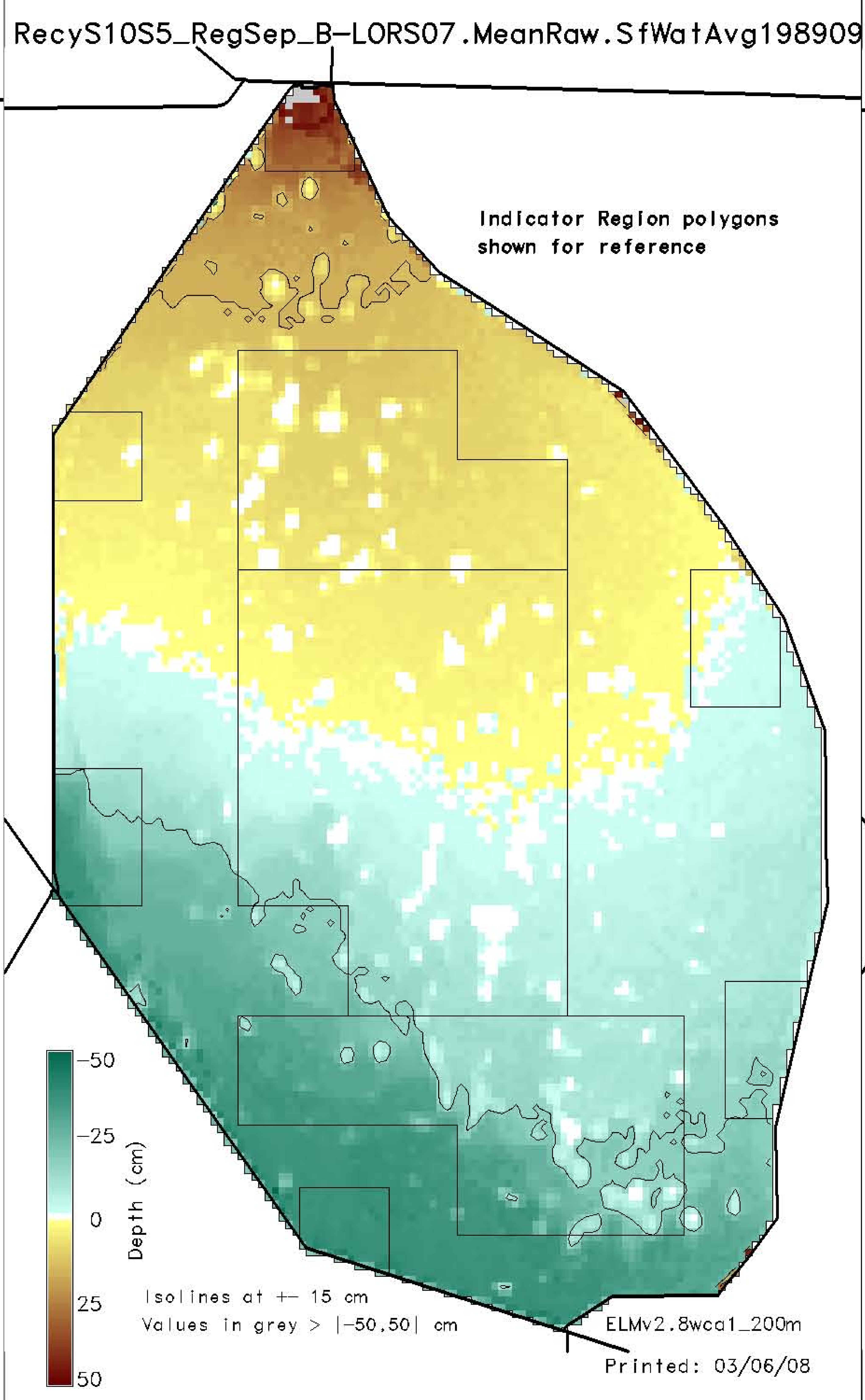
RecyS10S5_RegSep_B-LORS07.MeanRaw.SfWatAvg198904

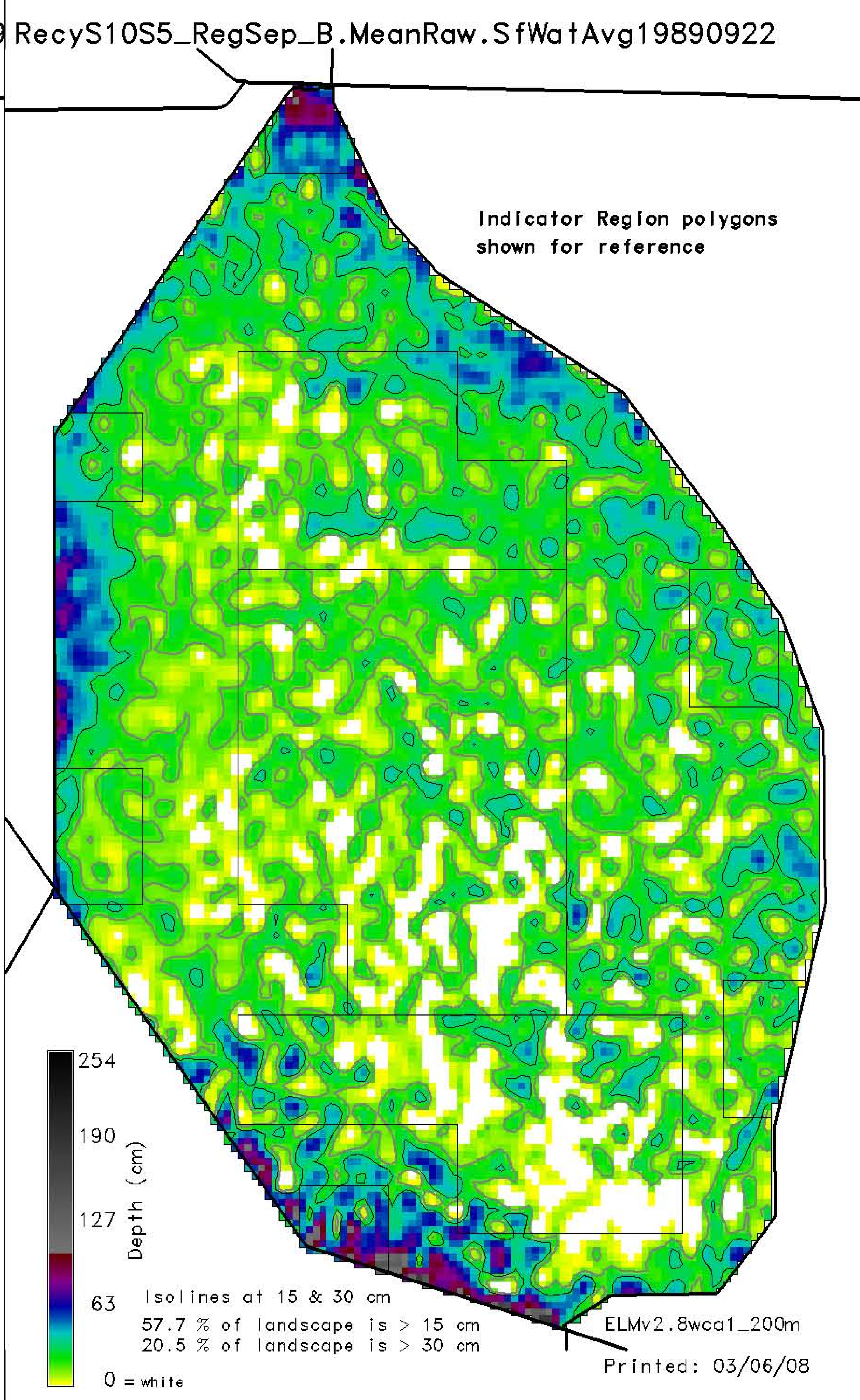


RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19890425



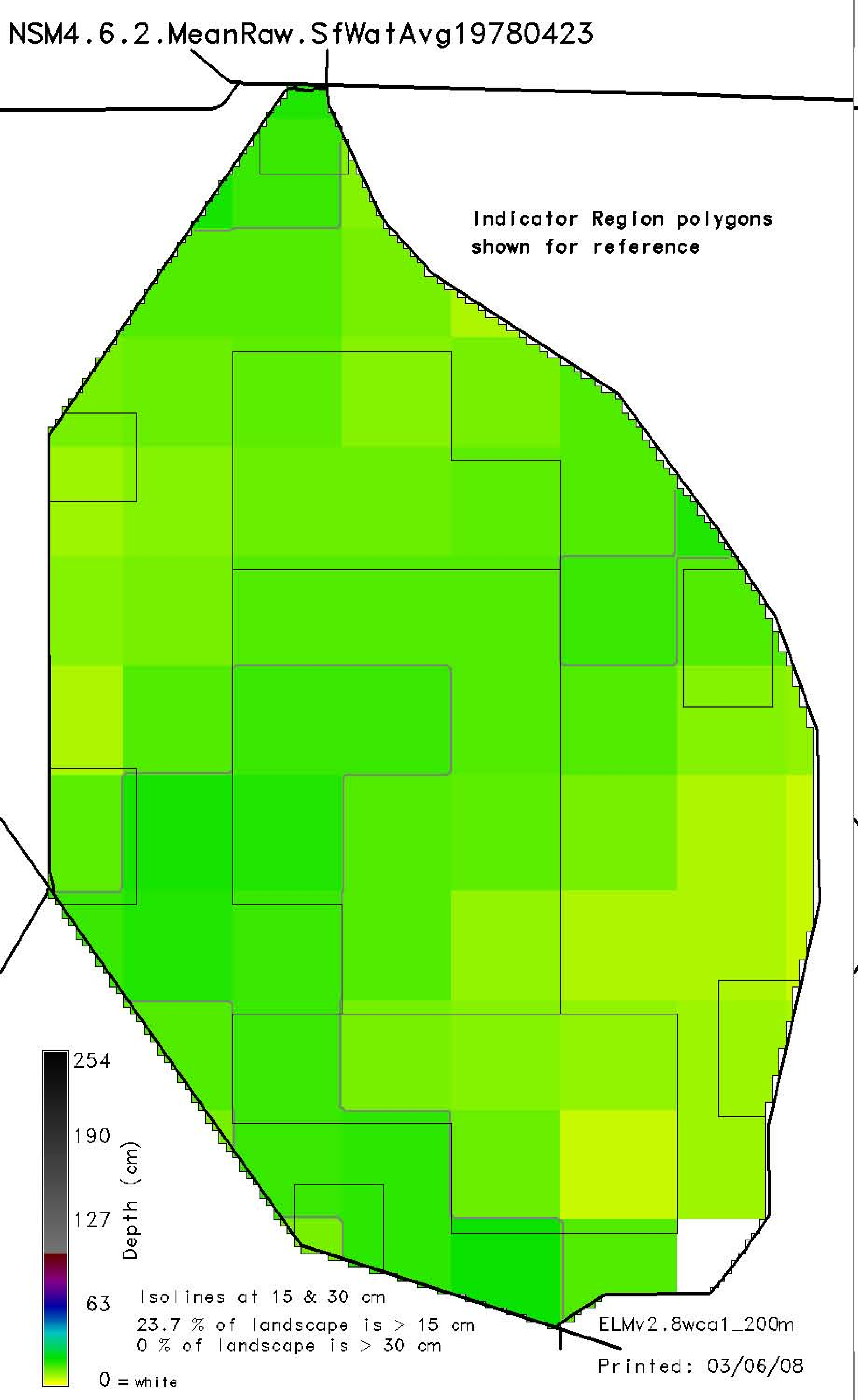

LORS07.MeanRaw.SfWatAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
62.5 % of landscape is > 15 cm
30.5 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

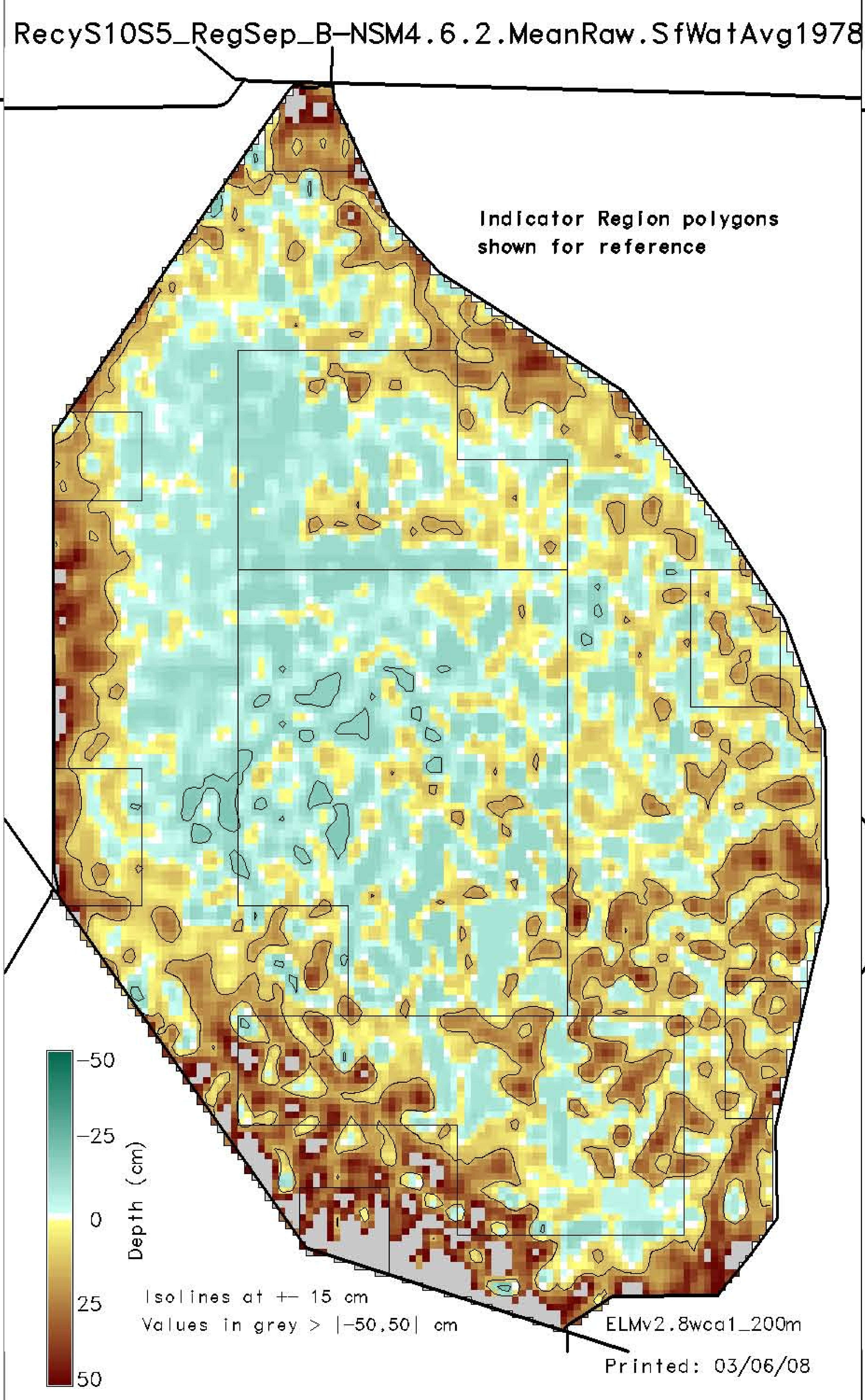

RecyS10S5_RegSep_B-LORS07.MeanRaw.SfWatAvg198909
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08

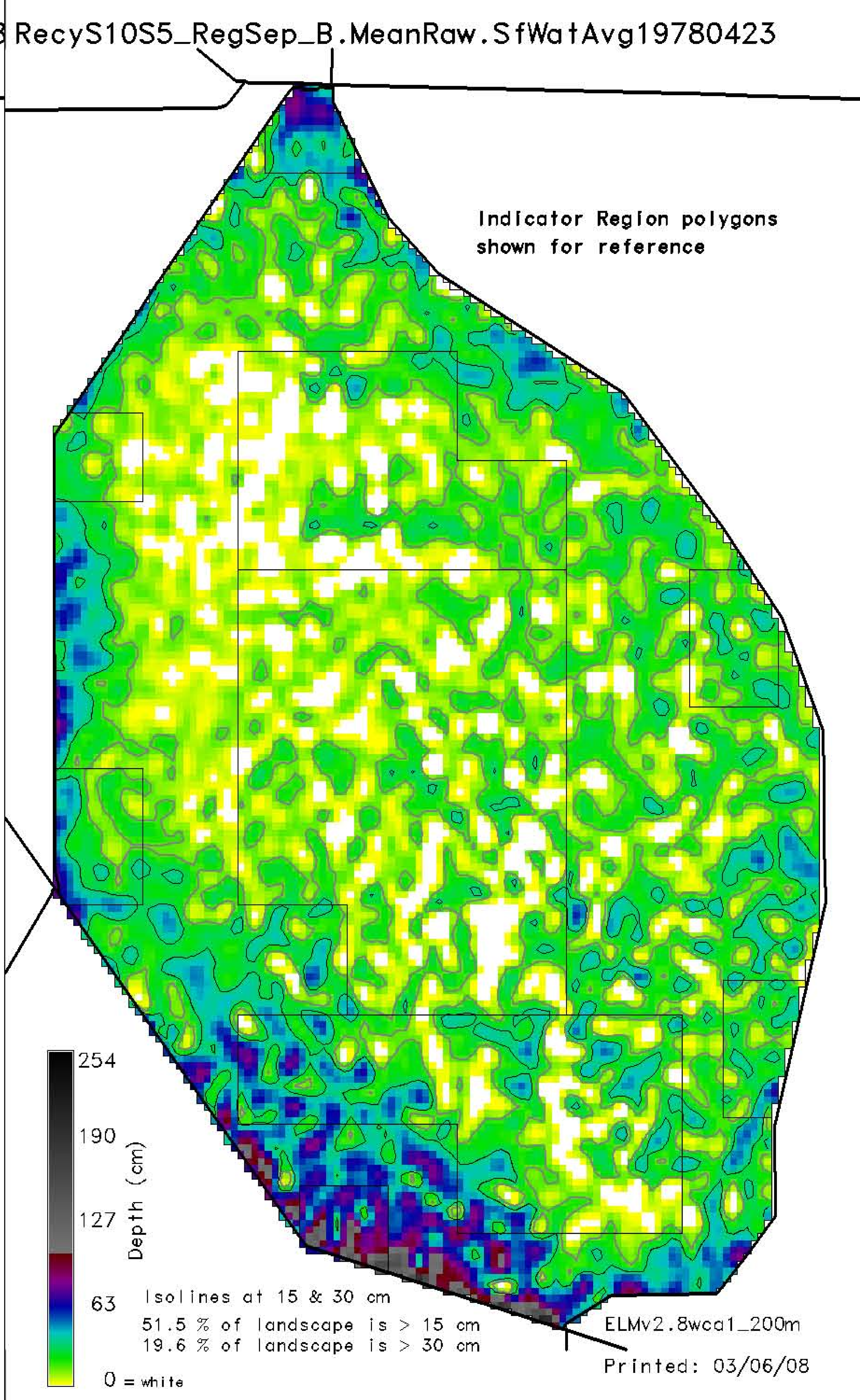

RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
57.7 % of landscape is > 15 cm
20.5 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


LORS07.MeanRaw.SfWatAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Depth (cm)
Isolines at 15 & 30 cm
65.8 % of landscape is > 15 cm
33.6 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.SfWatAvg199404
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Depth (cm)
Isolines at 15 & 30 cm
51.7 % of landscape is > 15 cm
19.8 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

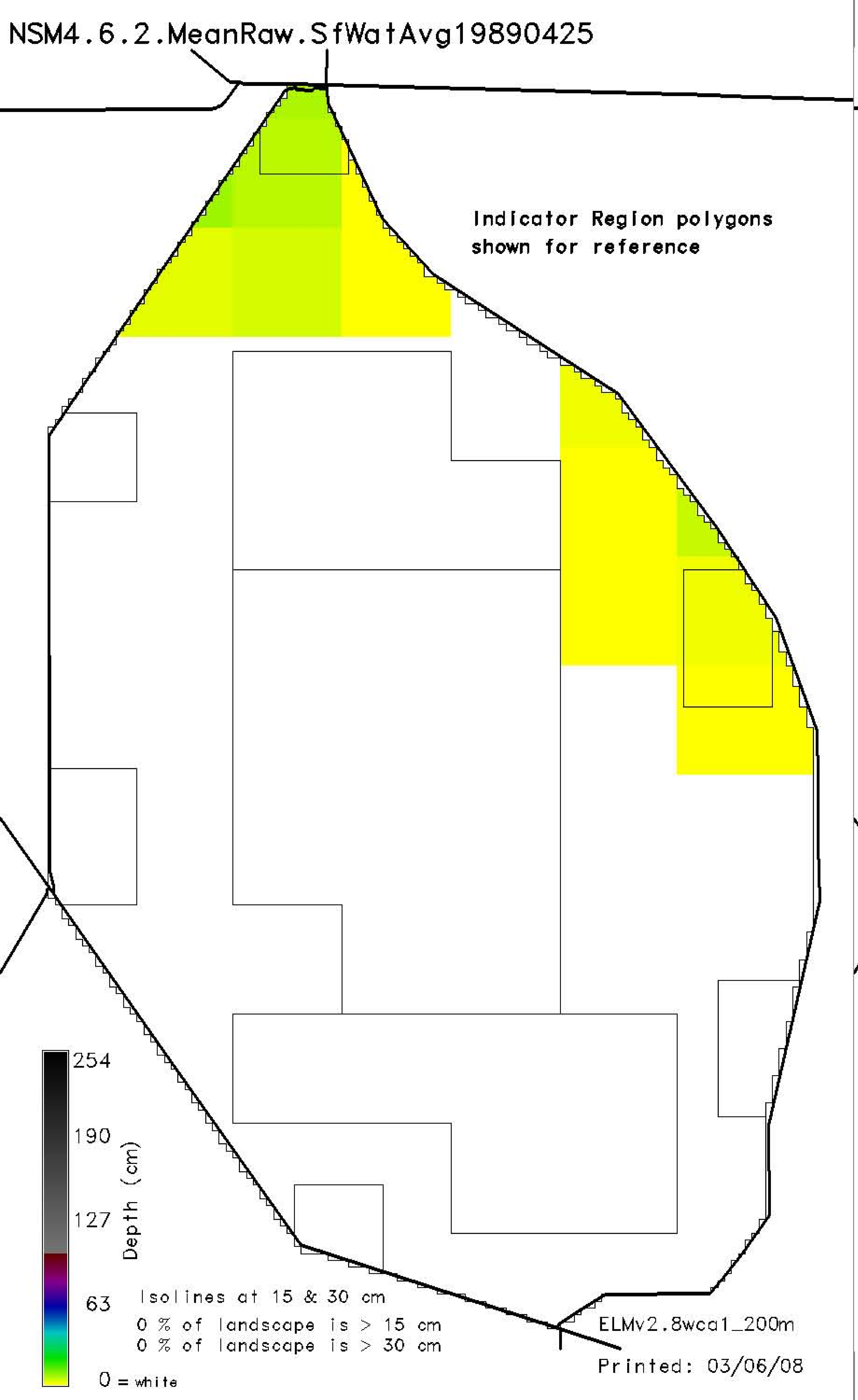

LORS07.MeanRaw.SfWatAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
99.4 % of landscape is > 15 cm
96.6 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.SfWatAvg199409
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
92.5 % of landscape is > 15 cm
62.8 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

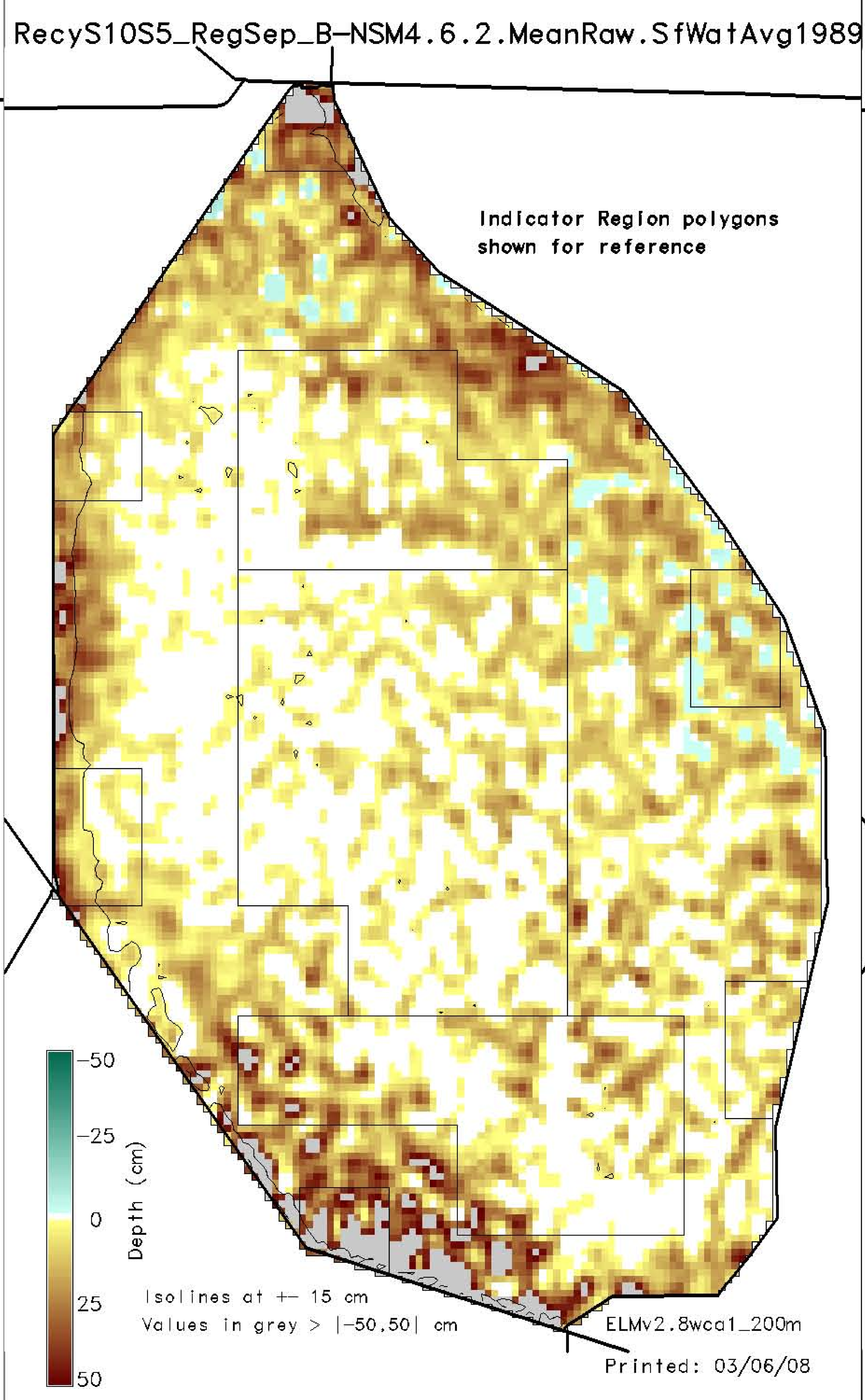

NSM4.6.2.MeanRaw.SfWatAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
23.7 % of landscape is > 15 cm
0 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

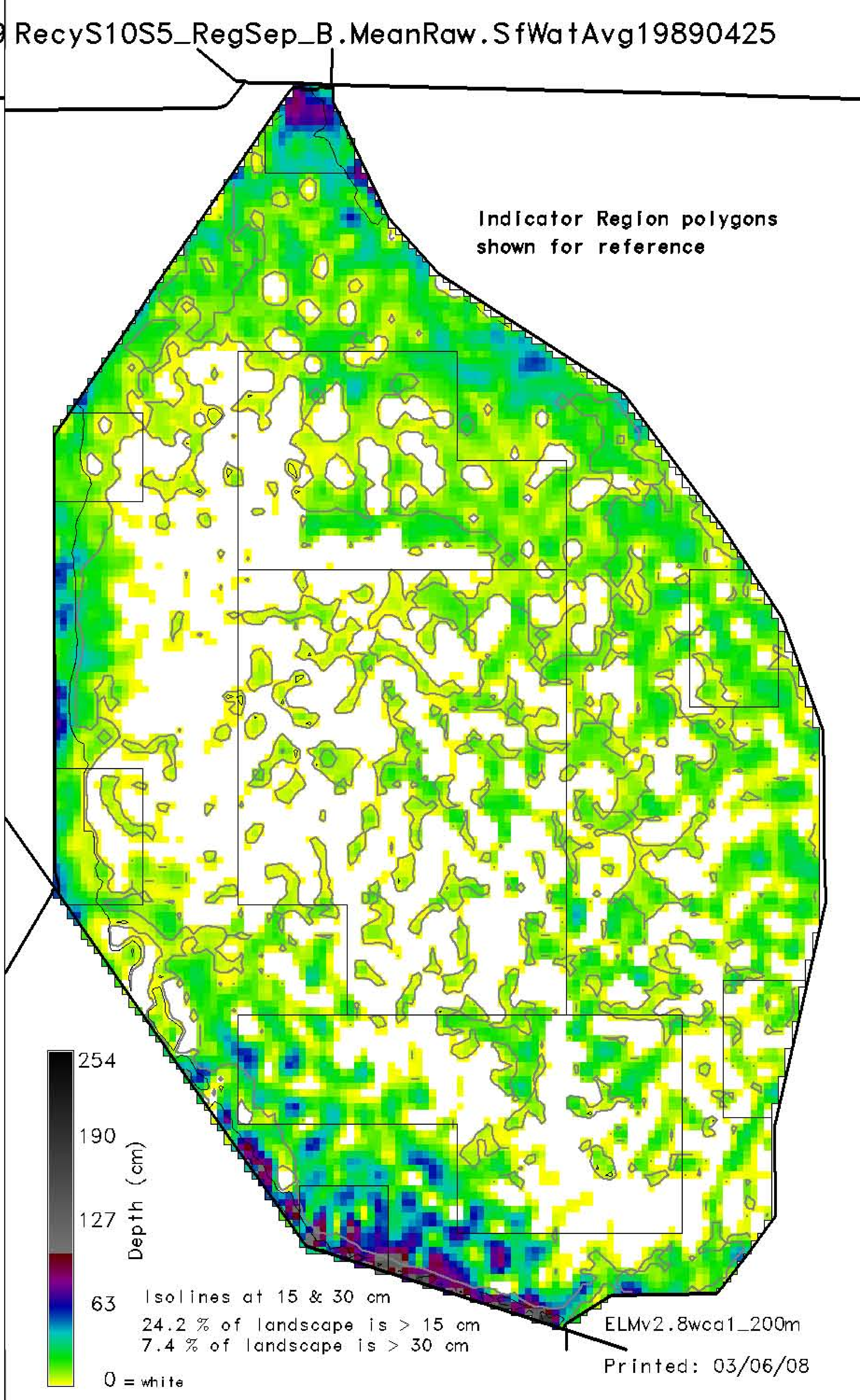

RecyS10S5_RegSep_B-NSM4.6.2.MeanRaw.SfWatAvg1978
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08

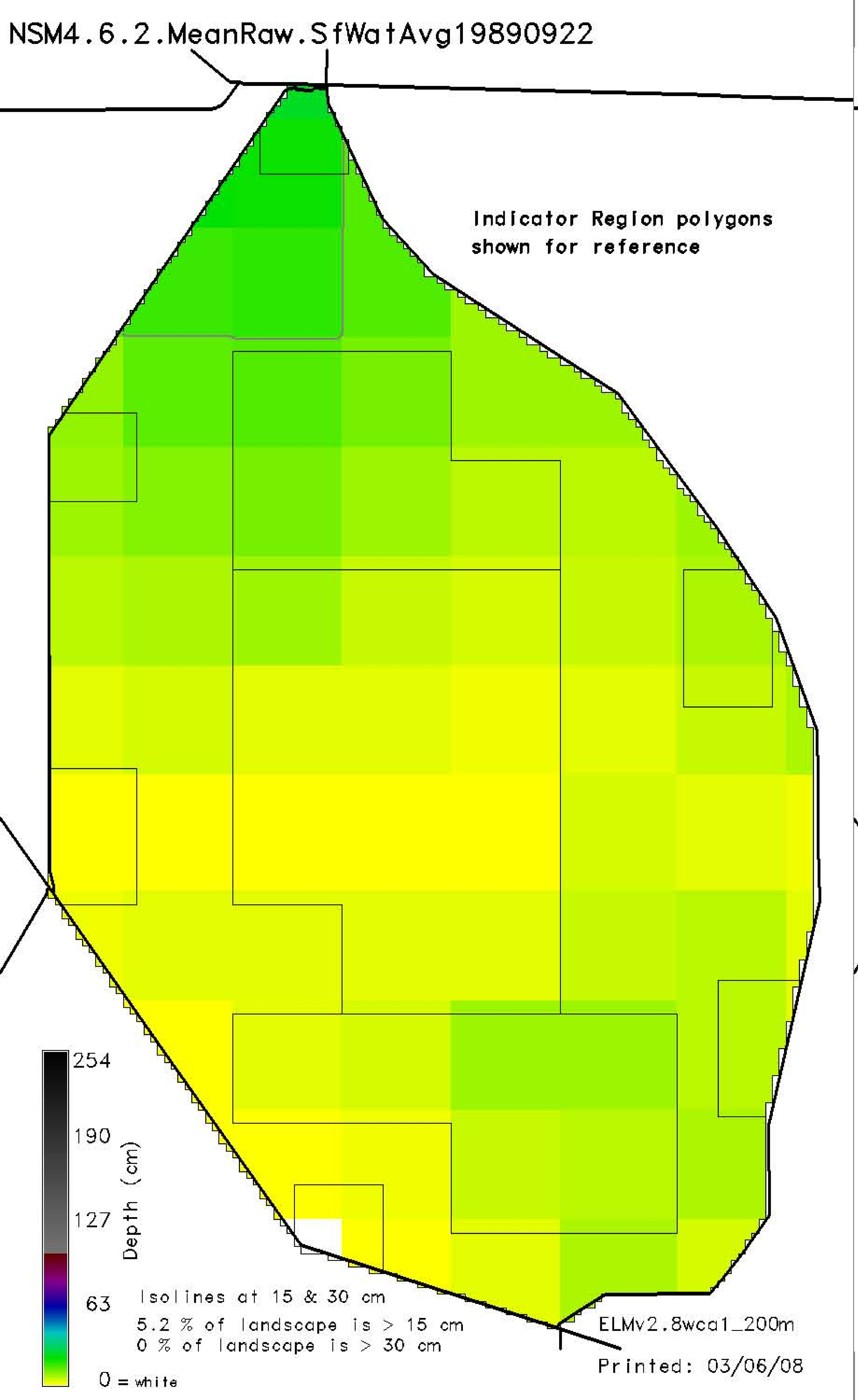

RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
51.5 % of landscape is > 15 cm
19.6 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

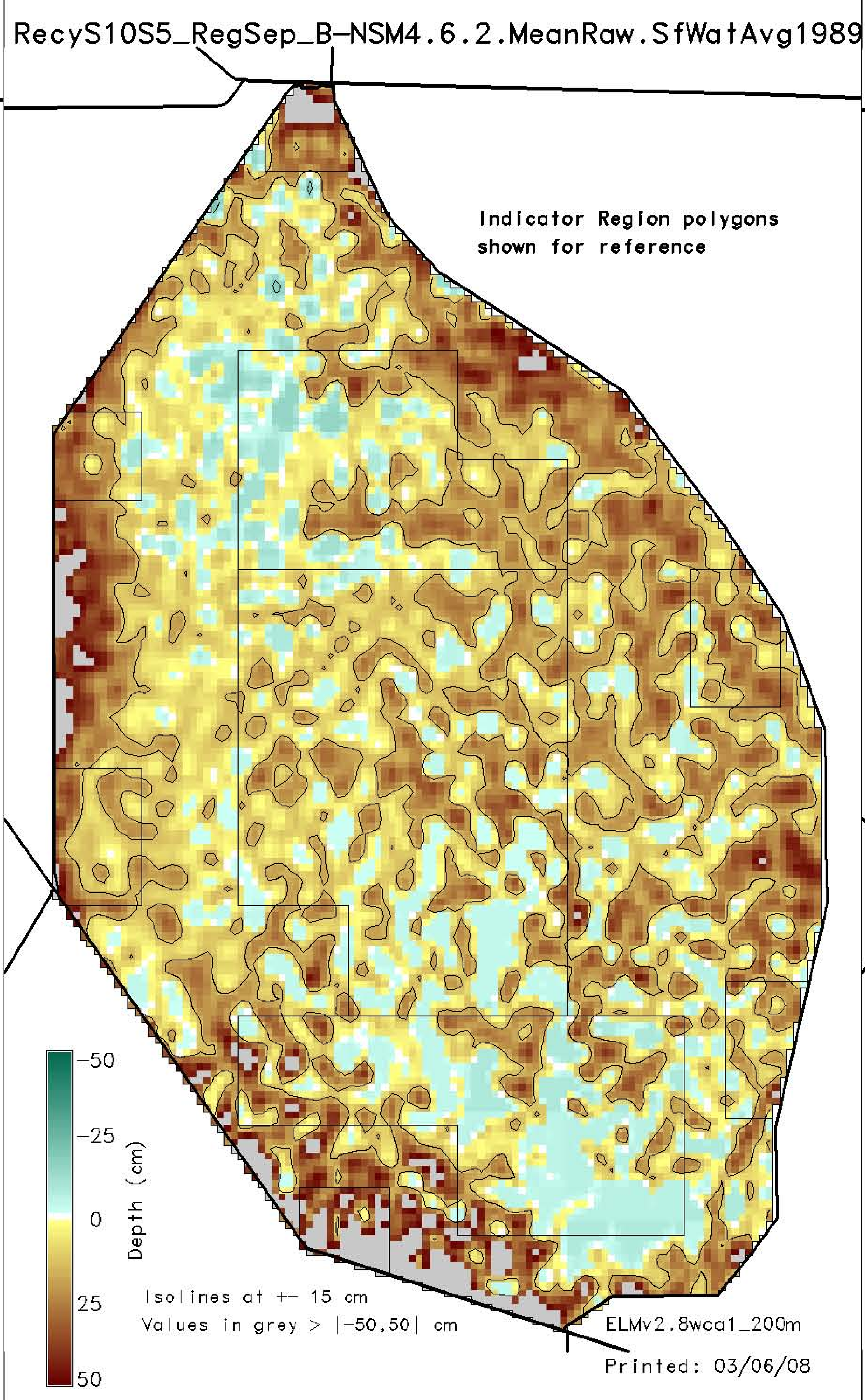

NSM4.6.2.MeanRaw.SfWatAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
99.3 % of landscape is > 15 cm
79.8 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-NSM4.6.2.MeanRaw.SfWatAvg1978
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
77.7 % of landscape is > 15 cm
38.2 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

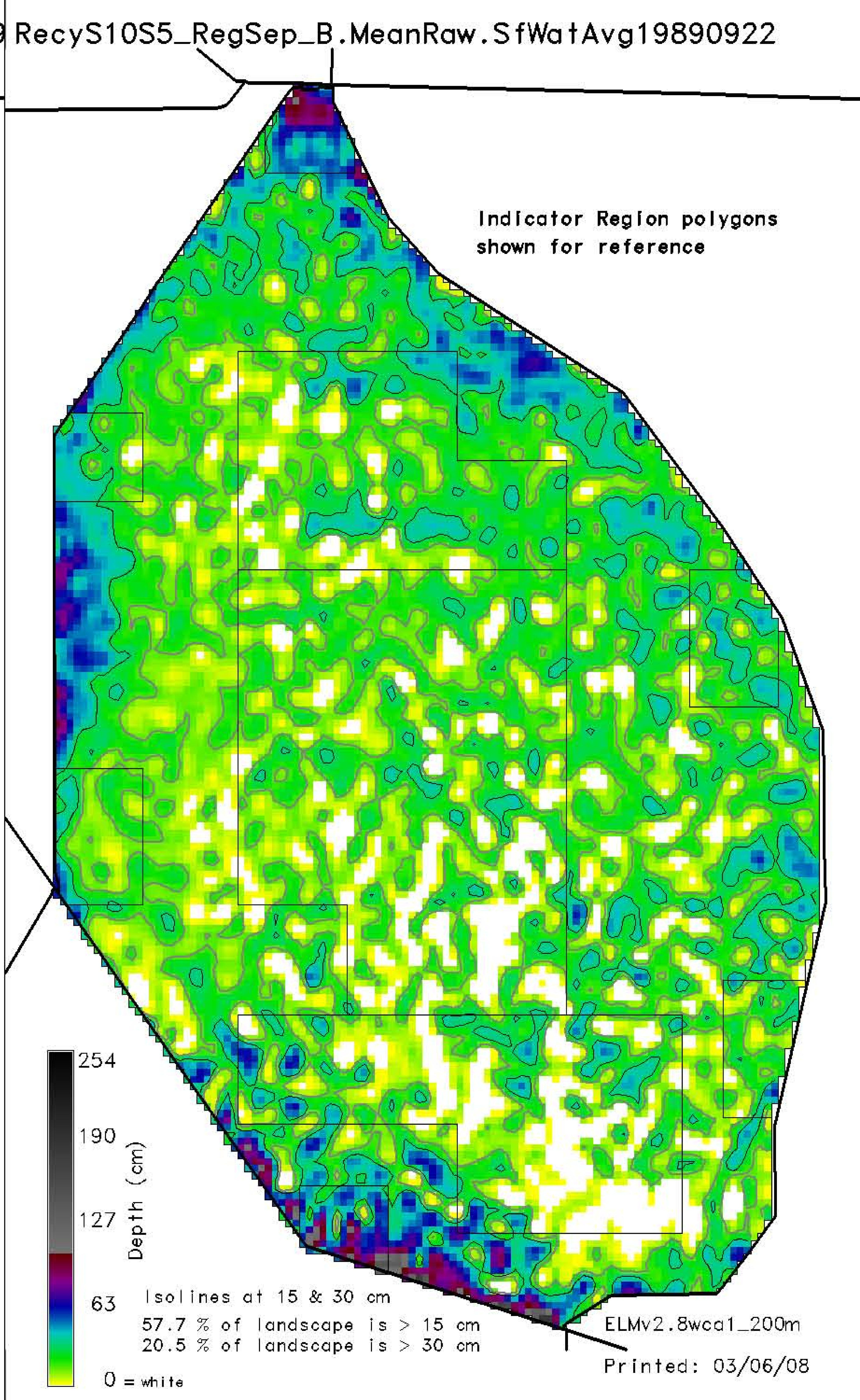

NSM4.6.2.MeanRaw.SfWatAvg19890425
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
0 % of landscape is > 15 cm
0 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

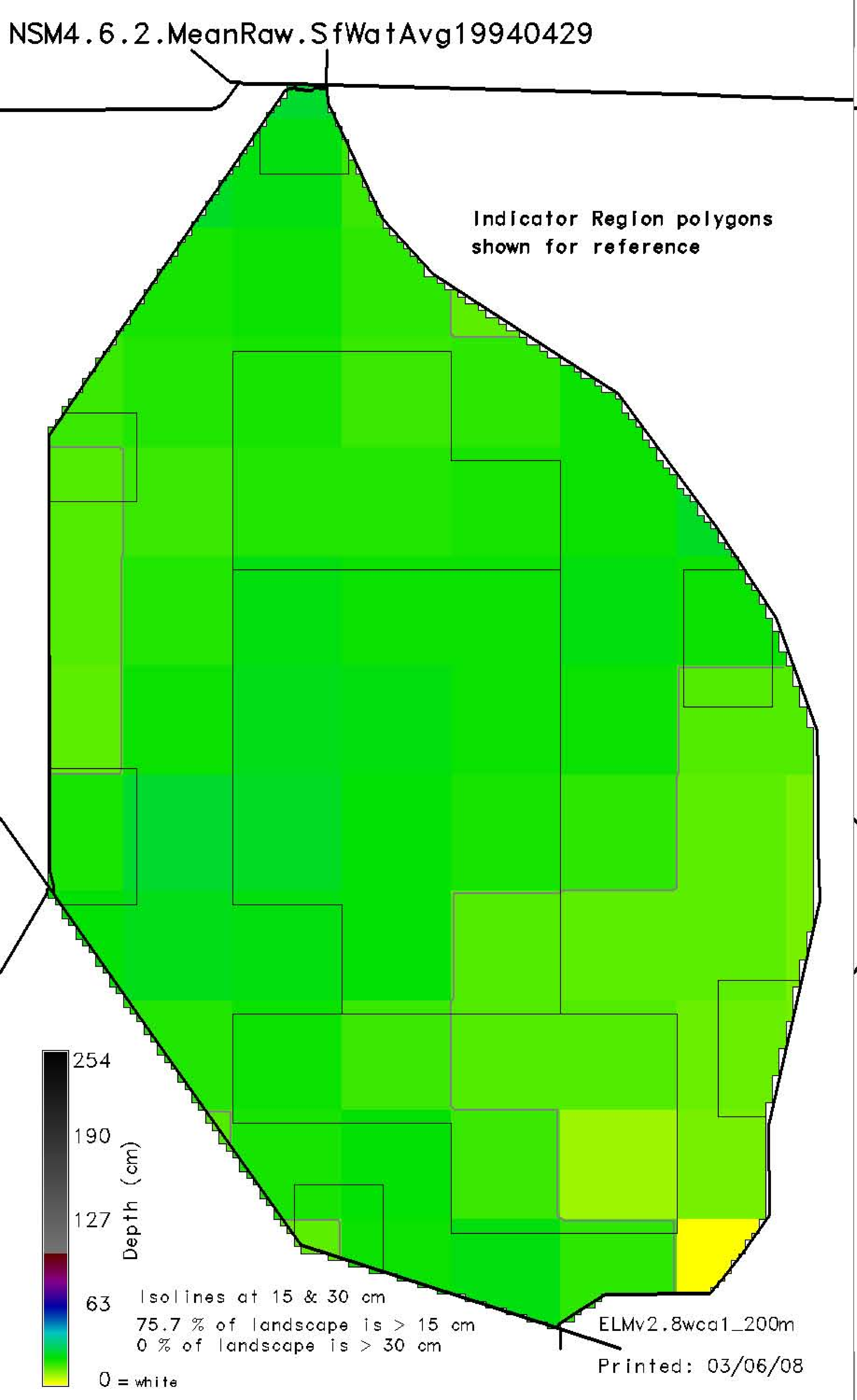

RecyS10S5_RegSep_B-NSM4.6.2.MeanRaw.SfWatAvg1989
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08

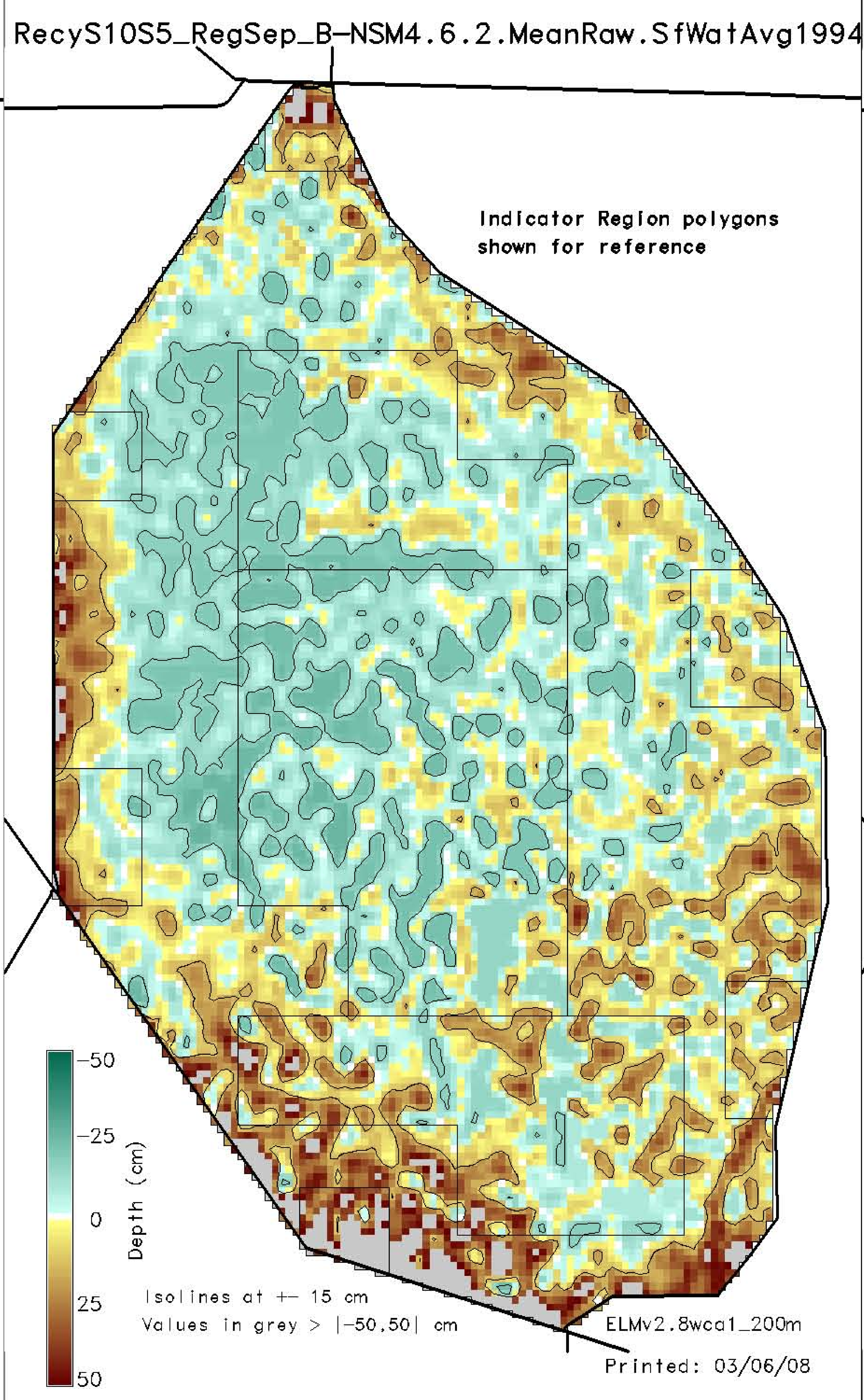

RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19890425
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
24.2 % of landscape is > 15 cm
7.4 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

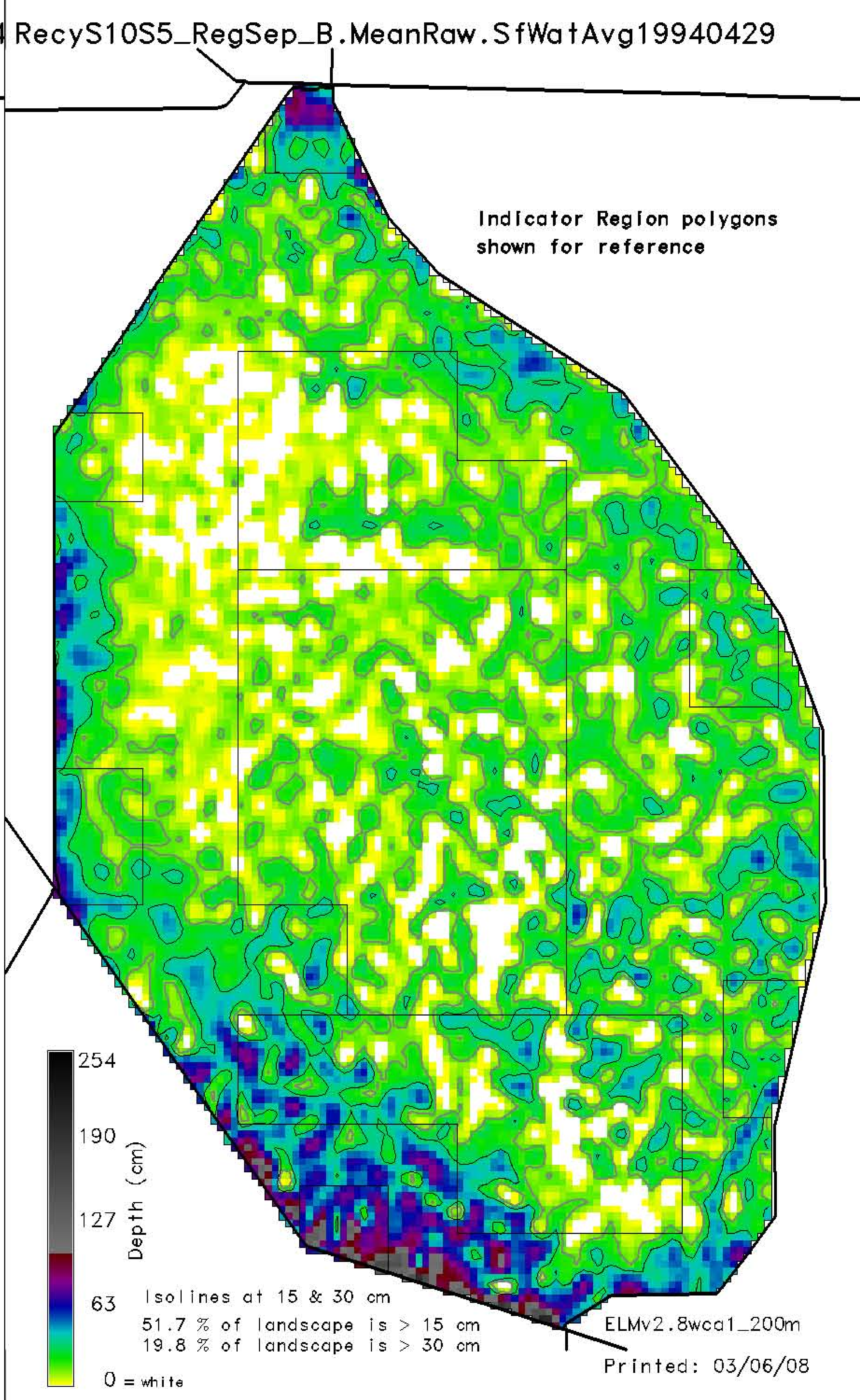

NSM4.6.2.MeanRaw.SfWatAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
5.2 % of landscape is > 15 cm
0 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

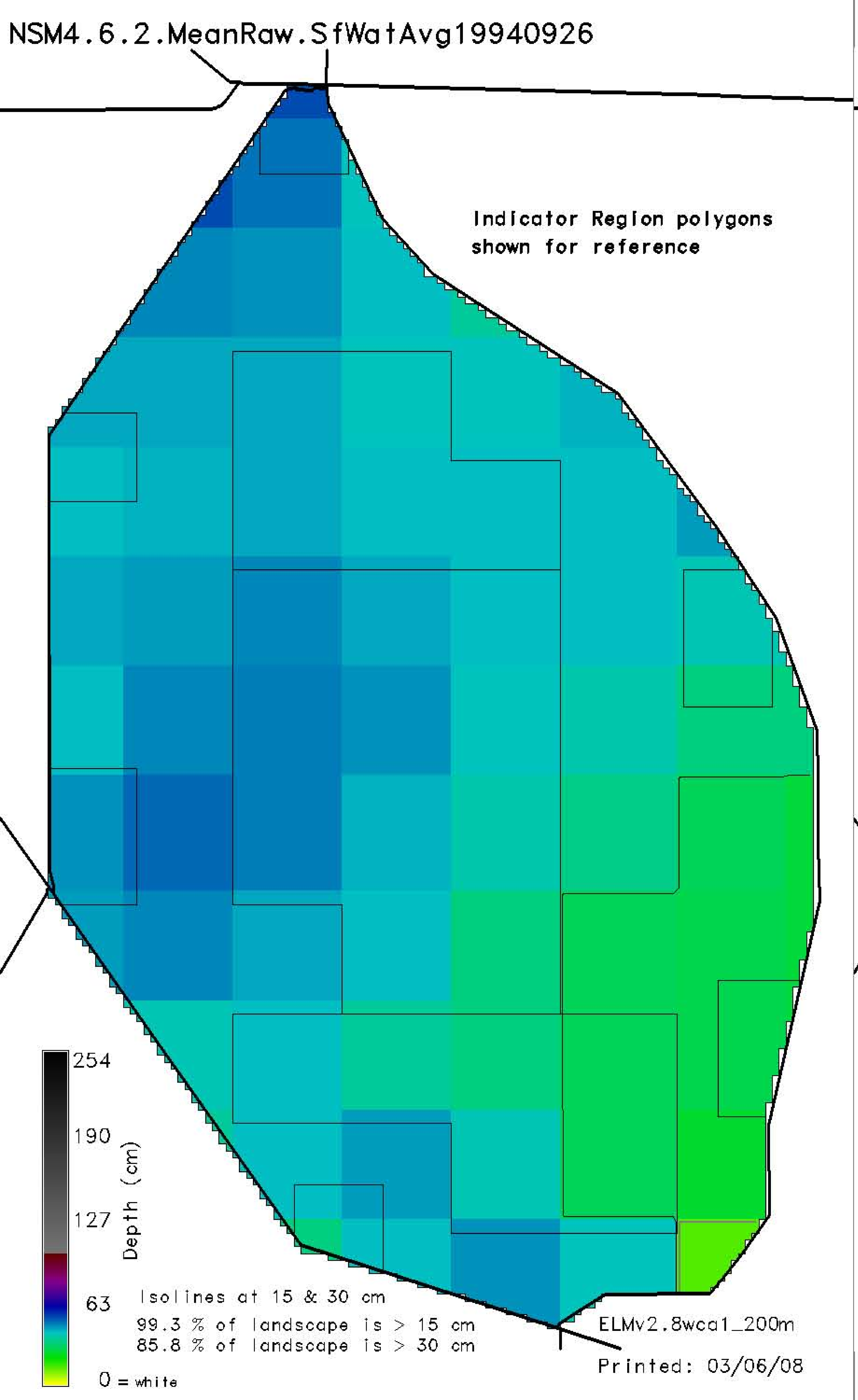

RecyS10S5_RegSep_B-NSM4.6.2.MeanRaw.SfWatAvg1989
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08

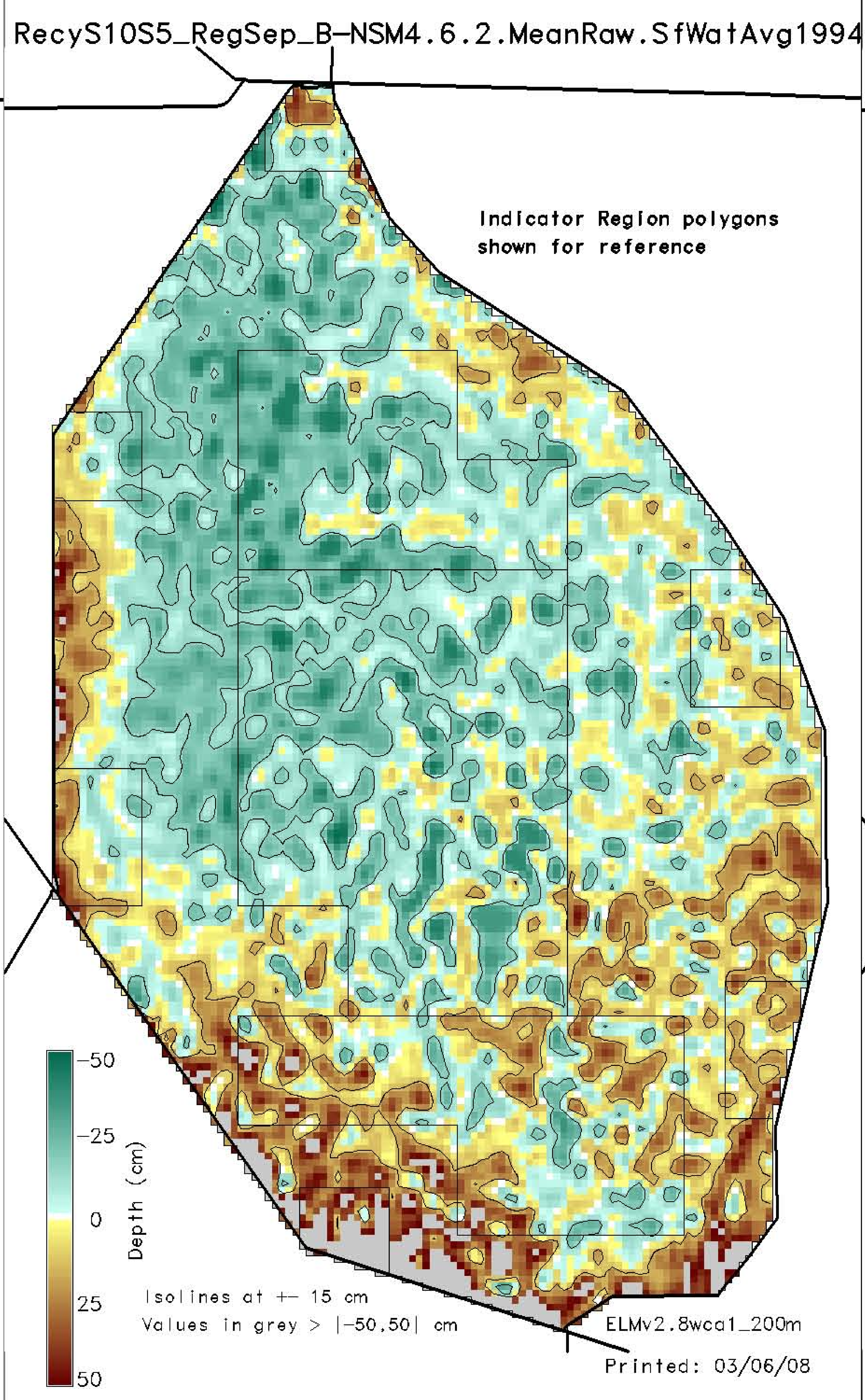

RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
57.7 % of landscape is > 15 cm
20.5 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08

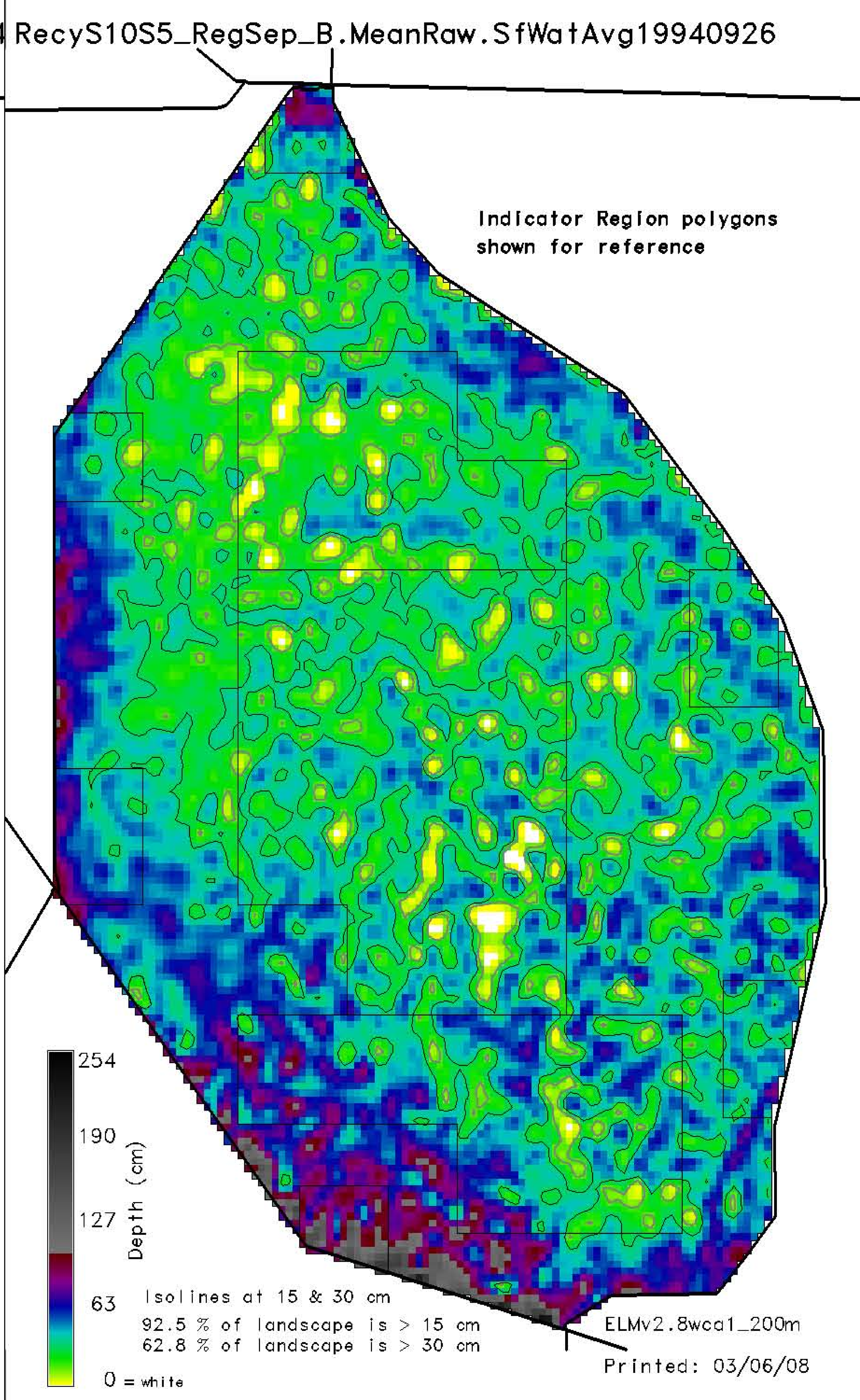

NSM4.6.2.MeanRaw.SfWatAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
75.7 % of landscape is > 15 cm
0 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B-NSM4.6.2.MeanRaw.SfWatAvg1994
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
51.7 % of landscape is > 15 cm
19.8 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


NSM4.6.2.MeanRaw.SfWatAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
99.3 % of landscape is > 15 cm
85.8 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B-NSM4.6.2.MeanRaw.SfWatAvg1994
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Depth (cm)
Isolines at +- 15 cm
Values in grey > |-50,50| cm
ELMv2.8wca1_200m
Printed: 03/06/08

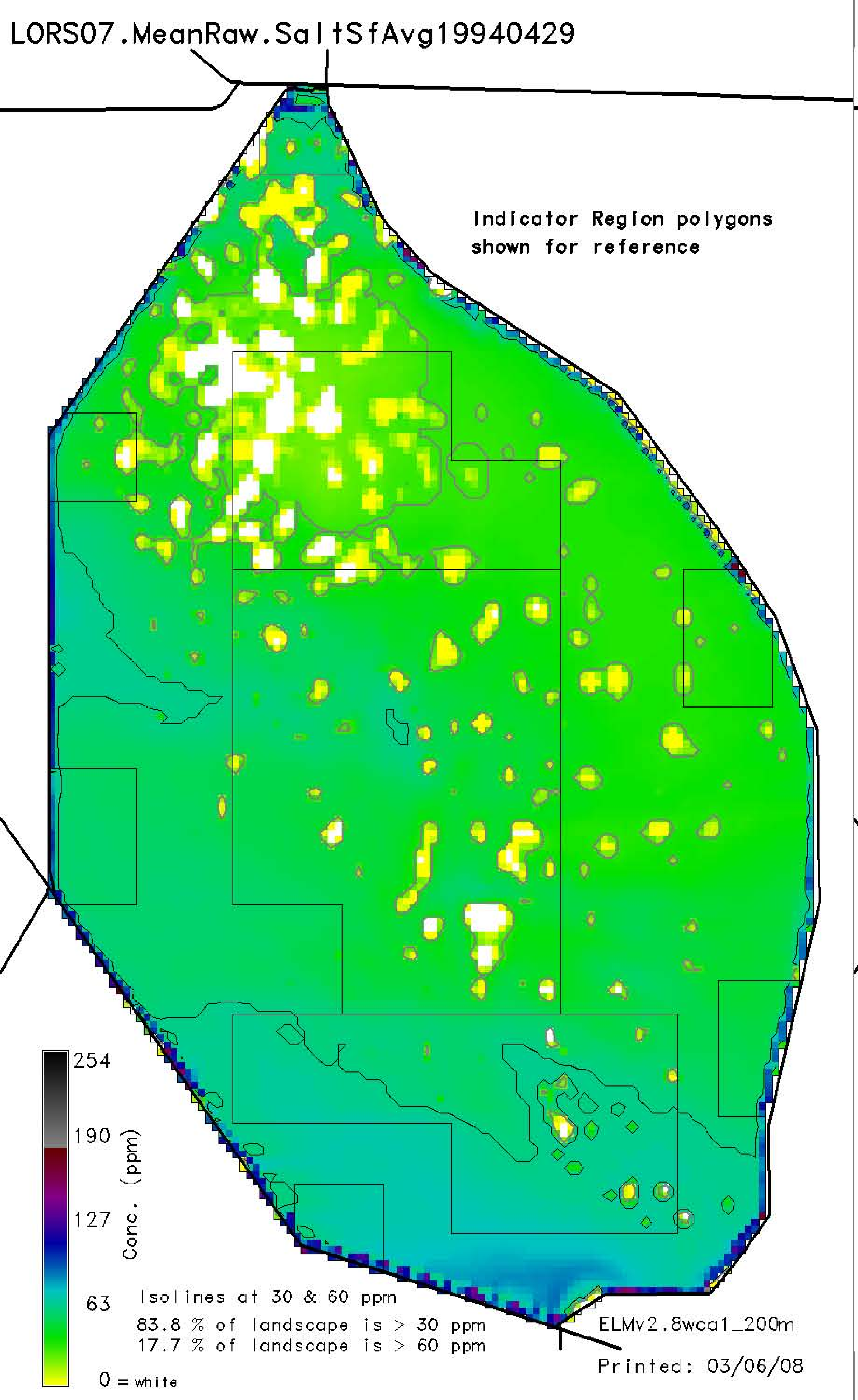

RecyS10S5_RegSep_B.MeanRaw.SfWatAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
Depth (cm)
0 = white
Isolines at 15 & 30 cm
92.5 % of landscape is > 15 cm
62.8 % of landscape is > 30 cm
ELMv2.8wca1_200m
Printed: 03/06/08


LORS07.MeanRaw.SaltSfAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppm)
0 = white
Isolines at 30 & 60 ppm
66.4 % of landscape is > 30 ppm
30.4 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.SaltSfAvg19780
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppm)
Isolines at +- 30 ppm
Values in grey > |-50,50| ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SaltSfAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppm)
0 = white
Isolines at 30 & 60 ppm
84.1 % of landscape is > 30 ppm
9.5 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

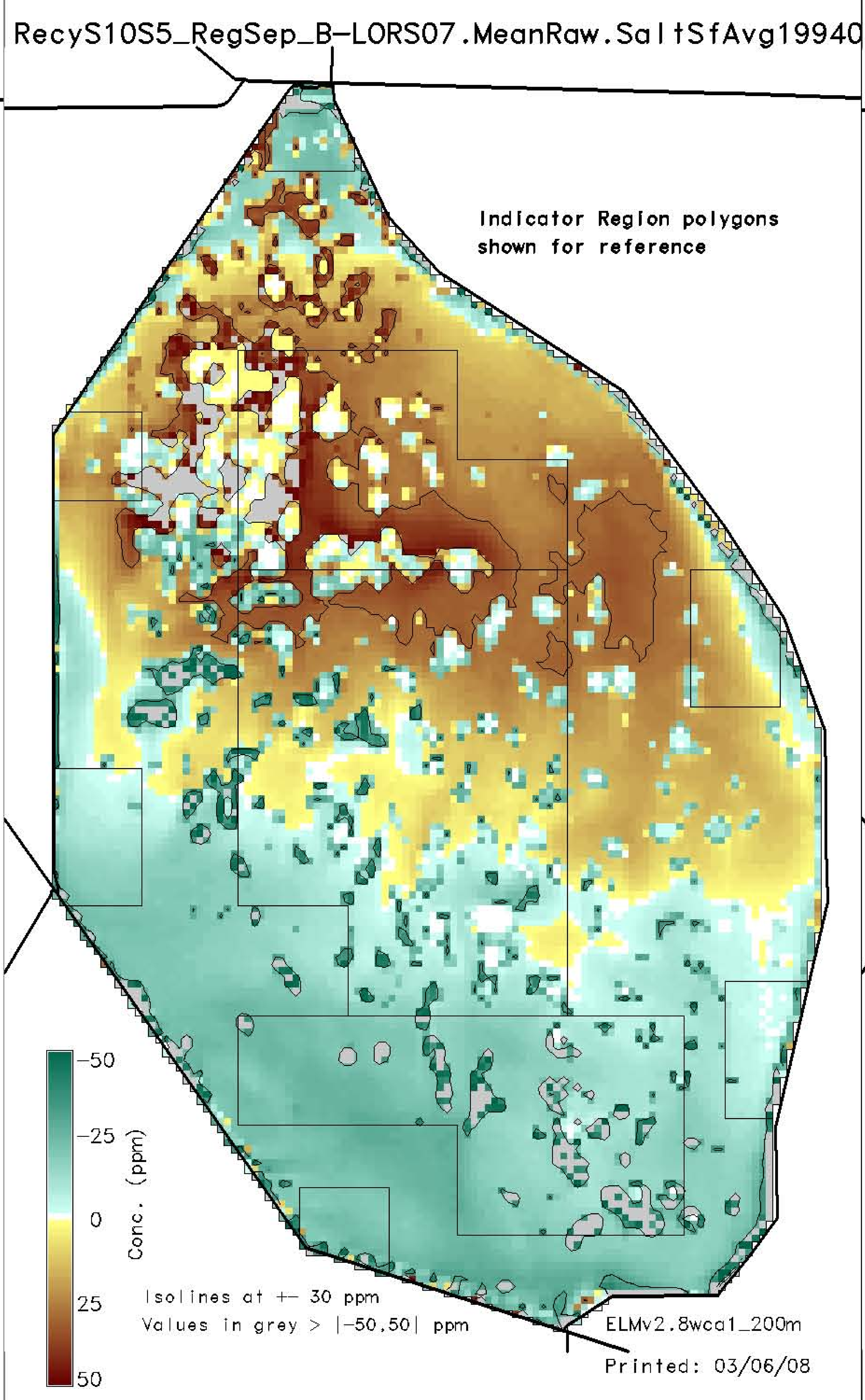

LORS07.MeanRaw.SaltSfAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppm)
Isolines at 30 & 60 ppm
81.8 % of landscape is > 30 ppm
64.0 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.SaltSfAvg19780
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppm)
Isolines at +- 30 ppm
Values in grey > |-50,50| ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SaltSfAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppm)
Isolines at 30 & 60 ppm
26.0 % of landscape is > 30 ppm
0.1 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

LORS07.MeanRaw.SaltSfAvg19890425
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppm)
0 = white
Isolines at 30 & 60 ppm
29.0 % of landscape is > 30 ppm
20.3 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.SaltSfAvg19890
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppm)
Isolines at +- 30 ppm
Values in grey > |-50,50| ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SaltSfAvg19890425
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppm)
0 = white
Isolines at 30 & 60 ppm
65.4 % of landscape is > 30 ppm
58.1 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

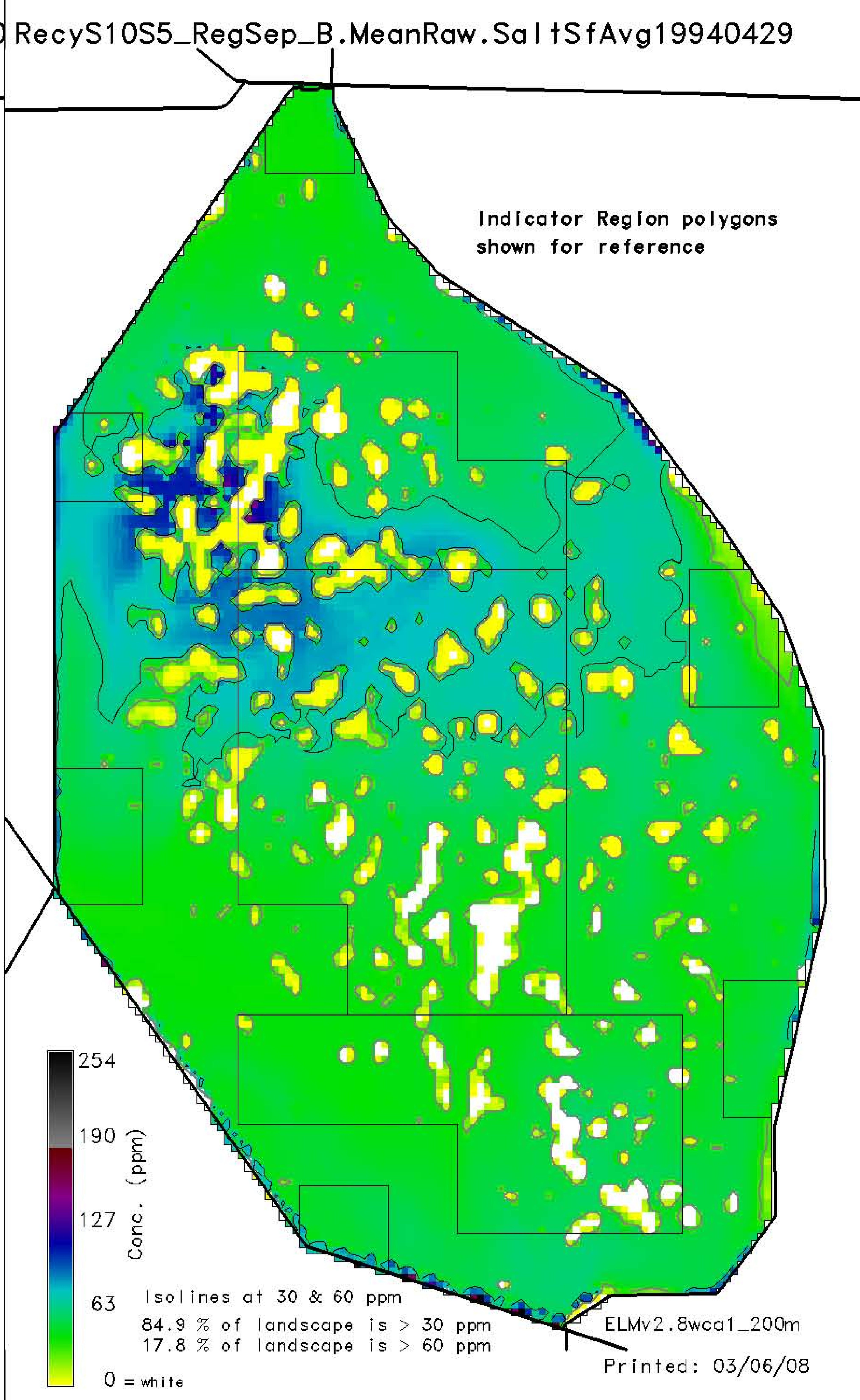
LORS07.MeanRaw.SaltSfAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppm)
0 = white
Isolines at 30 & 60 ppm
69.3 % of landscape is > 30 ppm
56.0 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.SaltSfAvg19890
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppm)
Isolines at +- 30 ppm
Values in grey > |-50,50| ppm
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.SaltSfAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppm)
0 = white
Isolines at 30 & 60 ppm
78.7 % of landscape is > 30 ppm
7.1 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08



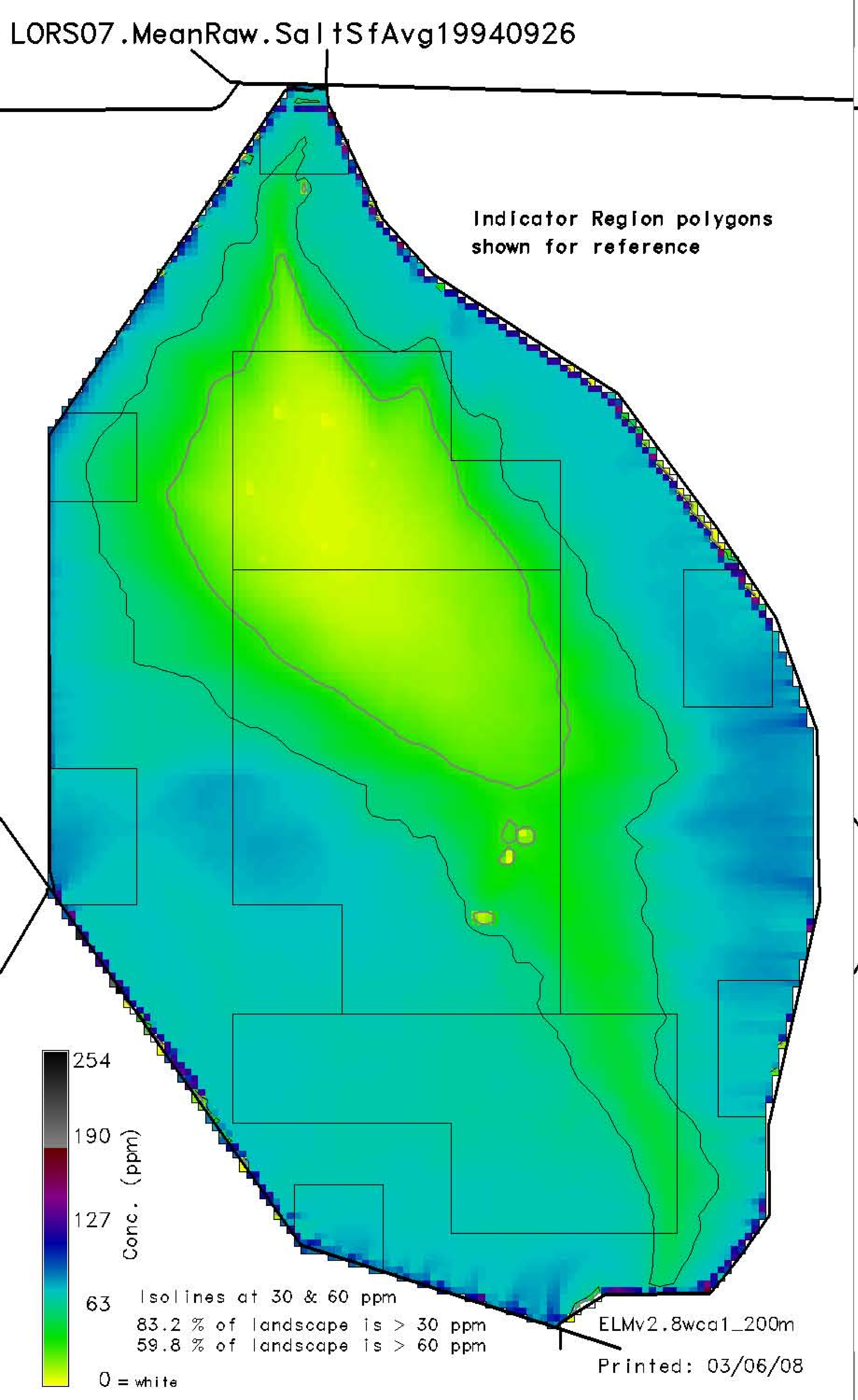
LORS07.MeanRaw.SaltSfAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppm)
Isolines at 30 & 60 ppm
83.8 % of landscape is > 30 ppm
17.7 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

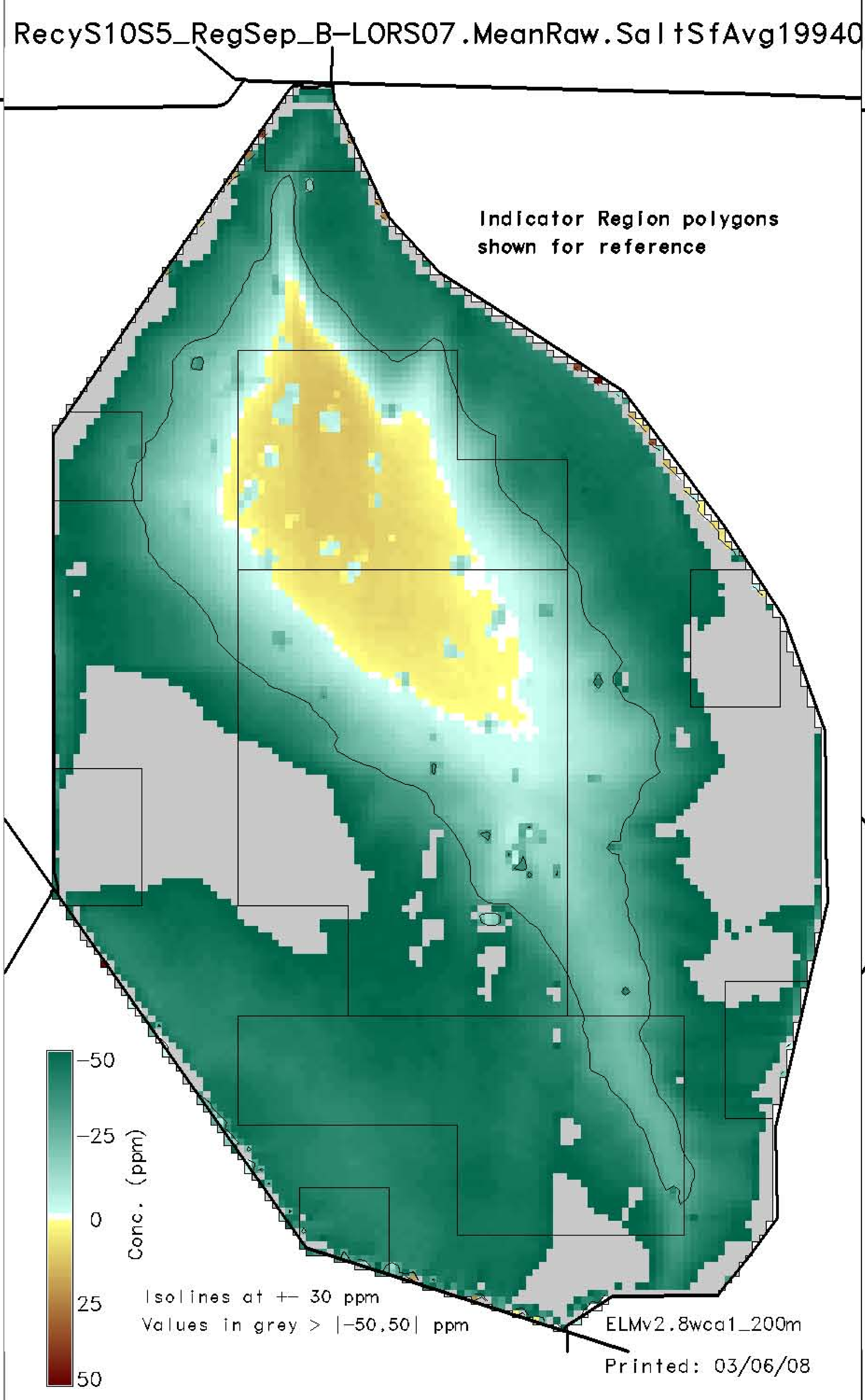


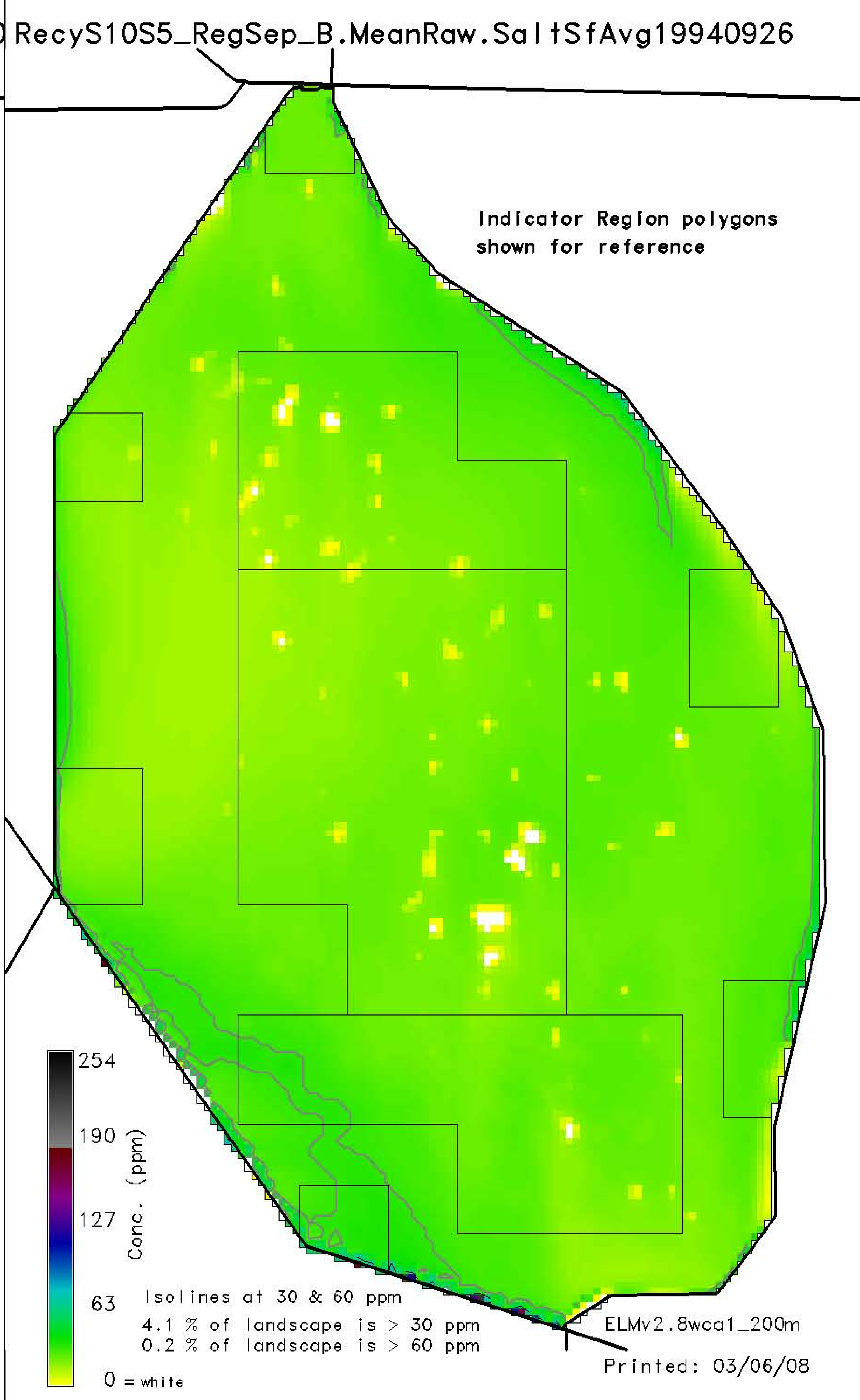
RecyS10S5_RegSep_B-LORS07.MeanRaw.SaltSfAvg19940
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppm)
Isolines at +- 30 ppm
Values in grey > |-50,50| ppm
ELMv2.8wca1_200m
Printed: 03/06/08



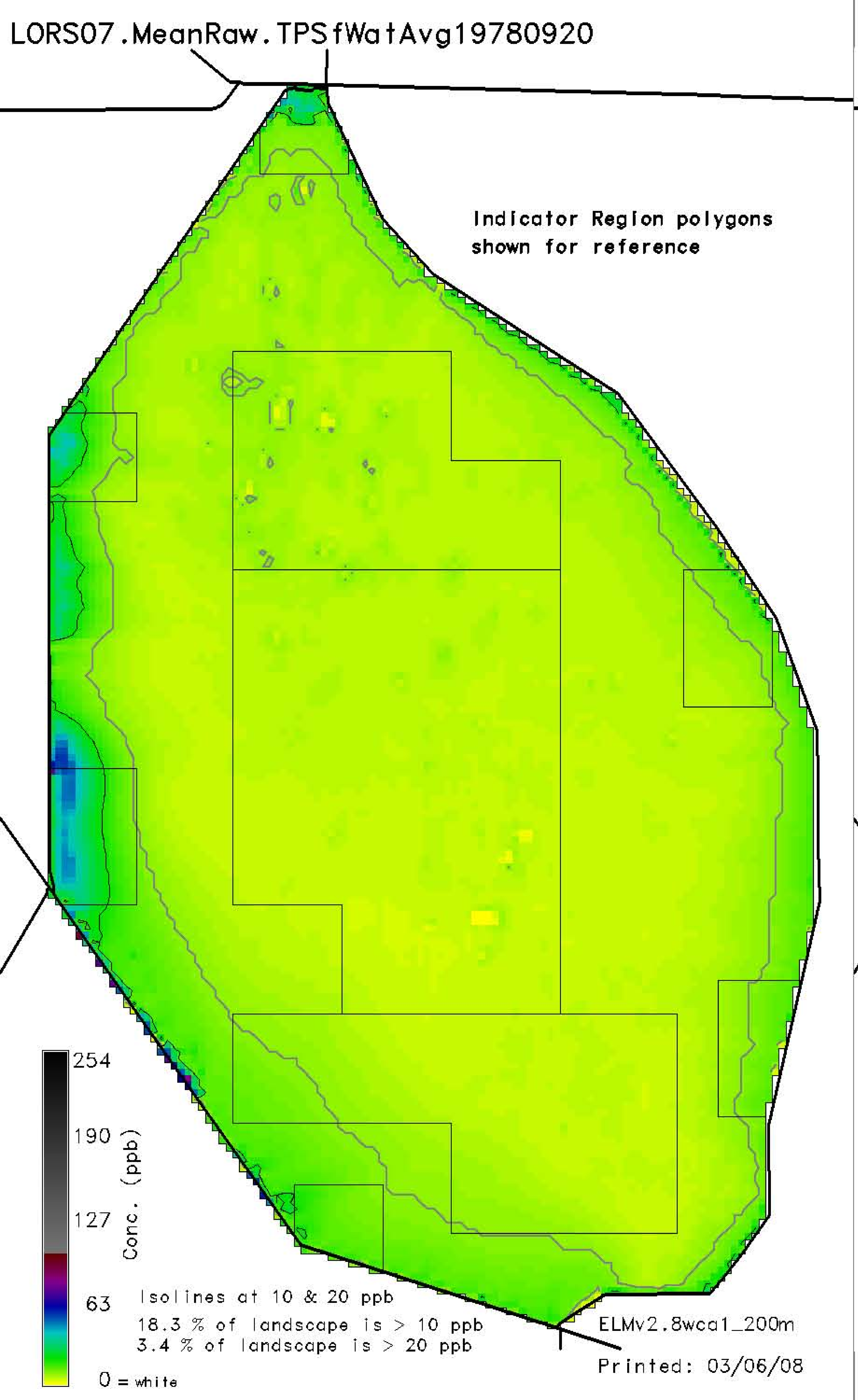
RecyS10S5_RegSep_B.MeanRaw.SaltSfAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppm)
Isolines at 30 & 60 ppm
84.9 % of landscape is > 30 ppm
17.8 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

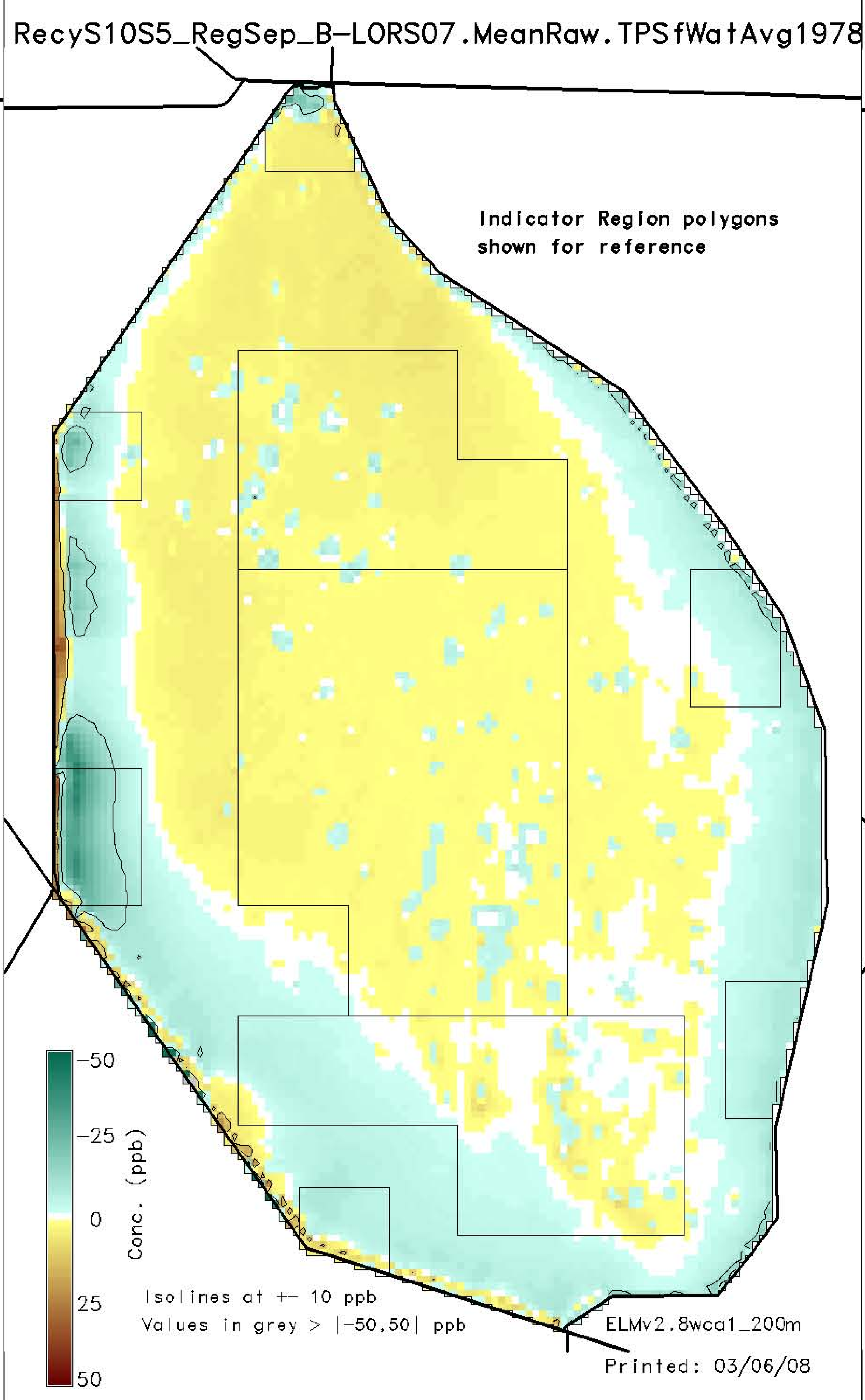

LORS07.MeanRaw.SaltSfAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppm)
Isolines at 30 & 60 ppm
83.2 % of landscape is > 30 ppm
59.8 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

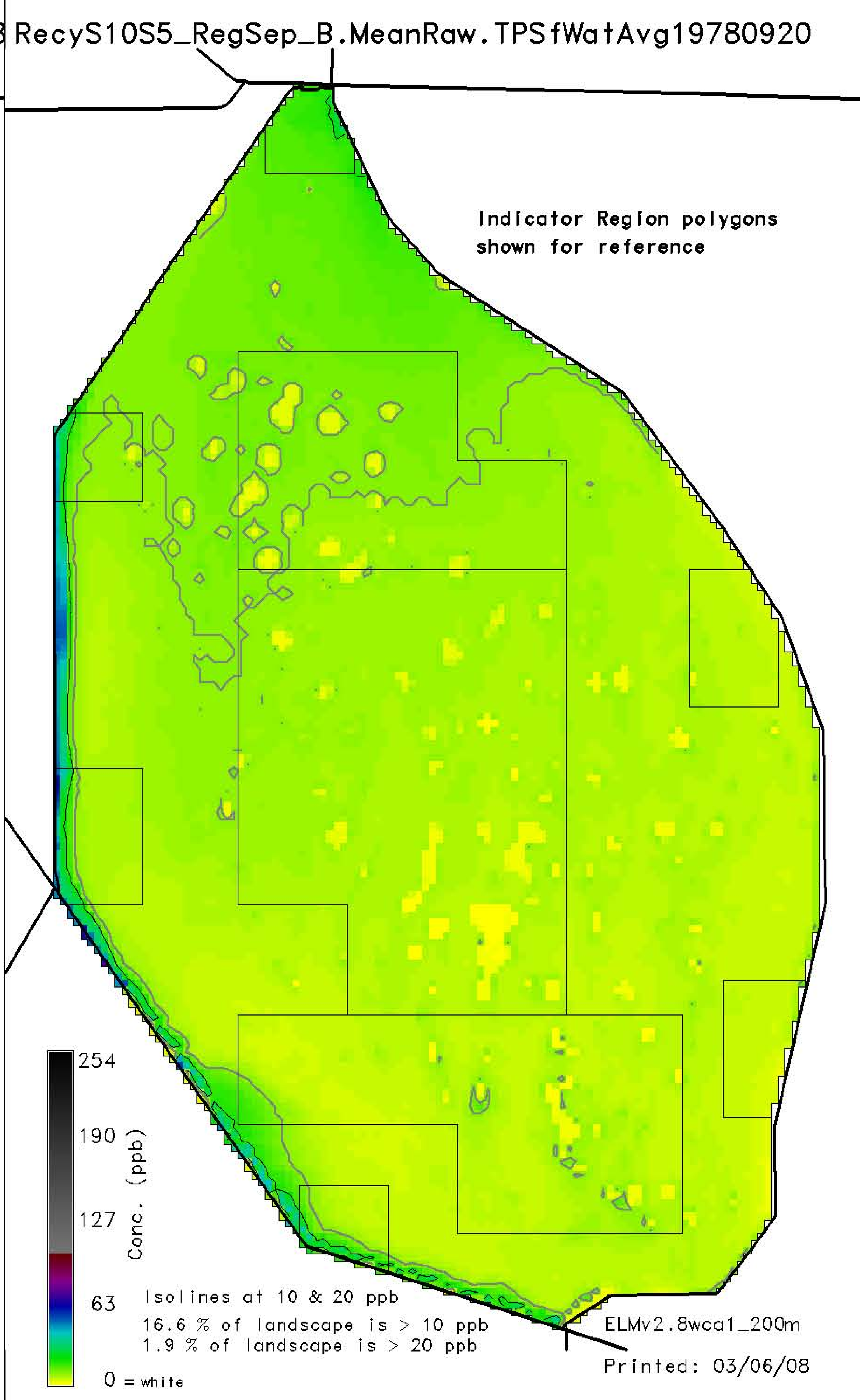

RecyS10S5_RegSep_B-LORS07.MeanRaw.SaltSfAvg19940
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppm)
Isolines at +- 30 ppm
Values in grey > |-50,50| ppm
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B.MeanRaw.SaltSfAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppm)
Isolines at 30 & 60 ppm
4.1 % of landscape is > 30 ppm
0.2 % of landscape is > 60 ppm
ELMv2.8wca1_200m
Printed: 03/06/08

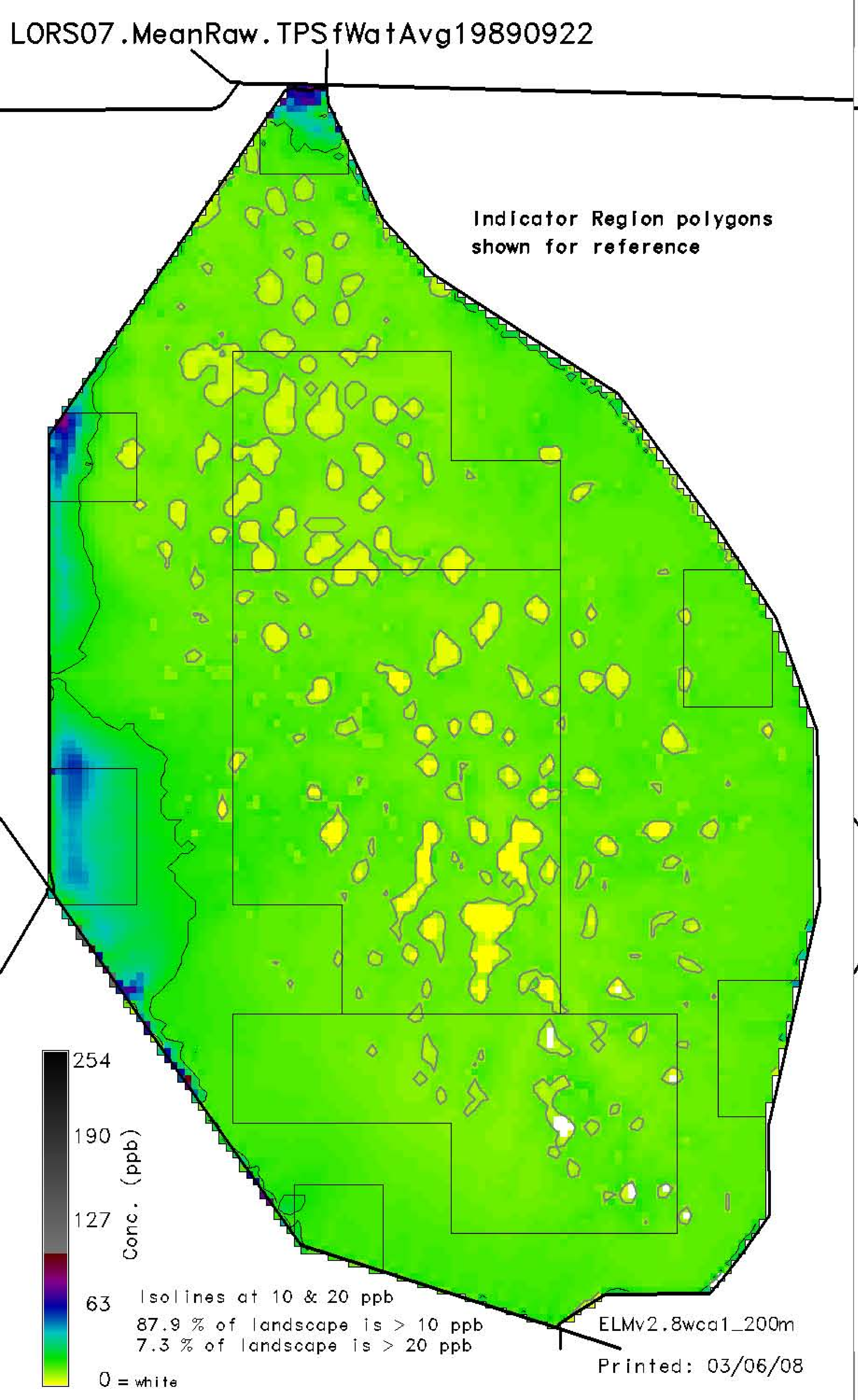

LORS07.MeanRaw.TPSfWatAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
Isolines at 10 & 20 ppb
4.3 % of landscape is > 10 ppb
1.9 % of landscape is > 20 ppb
0 = white
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.TPSfWatAvg1978
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppb)
Isolines at +- 10 ppb
Values in grey > |-50,50| ppb
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.TPSfWatAvg19780423
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
Isolines at 10 & 20 ppb
9.3 % of landscape is > 10 ppb
1.7 % of landscape is > 20 ppb
0 = white
ELMv2.8wca1_200m
Printed: 03/06/08

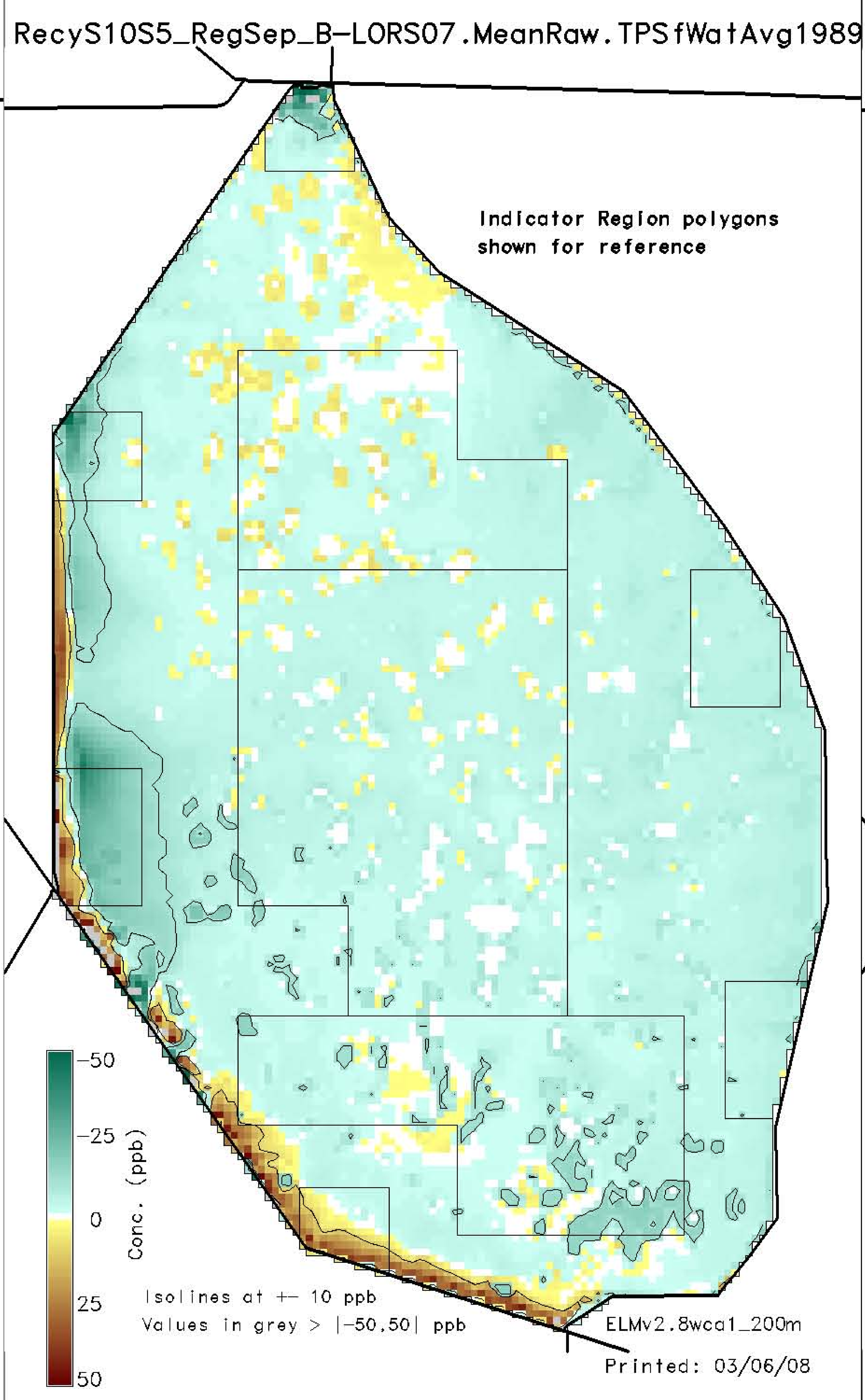

LORS07.MeanRaw.TPSfWatAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppb)
Isolines at 10 & 20 ppb
18.3 % of landscape is > 10 ppb
3.4 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08

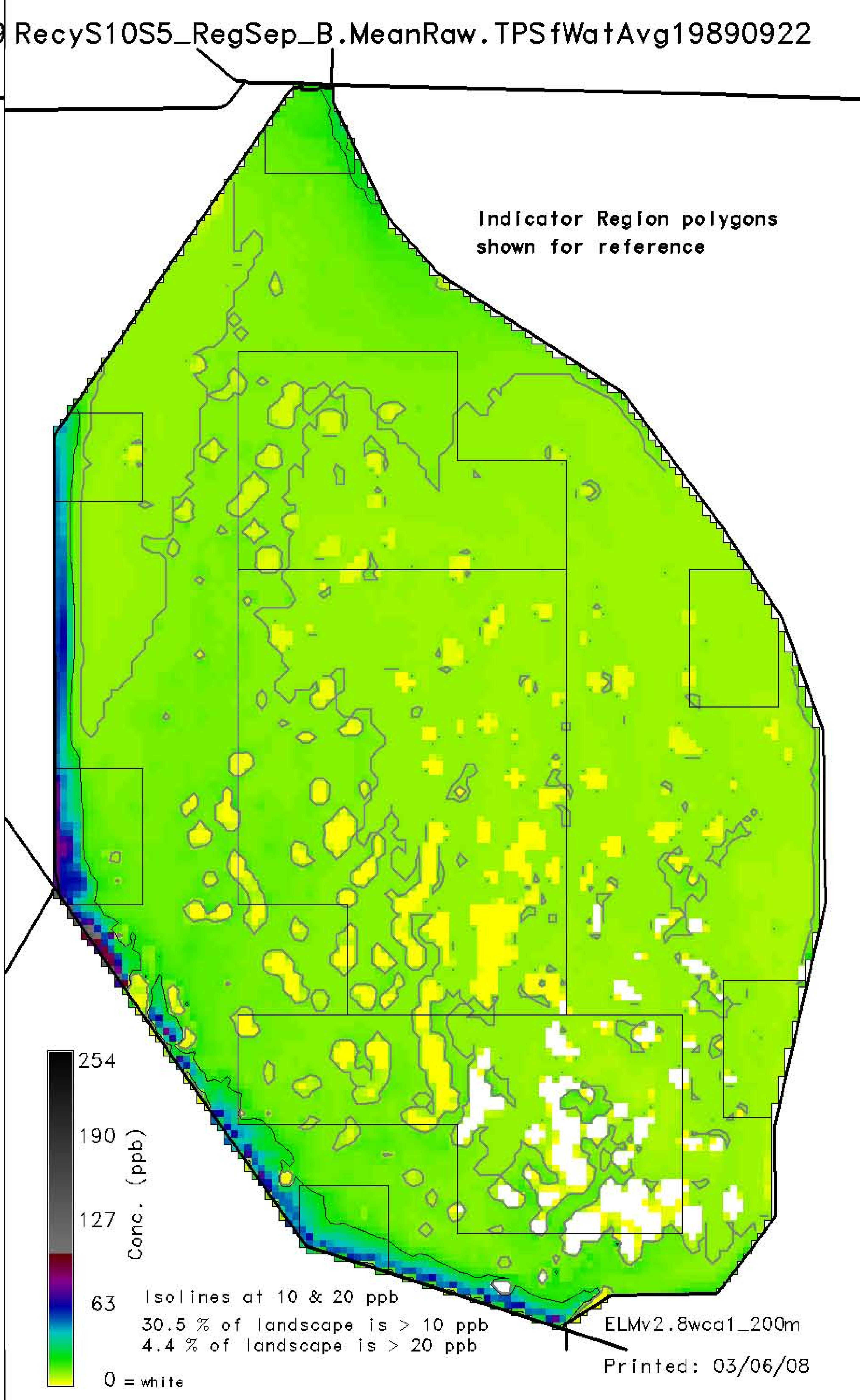

RecyS10S5_RegSep_B-LORS07.MeanRaw.TPSfWatAvg1978
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppb)
Isolines at +- 10 ppb
Values in grey > |-50,50| ppb
ELMv2.8wca1_200m
Printed: 03/06/08

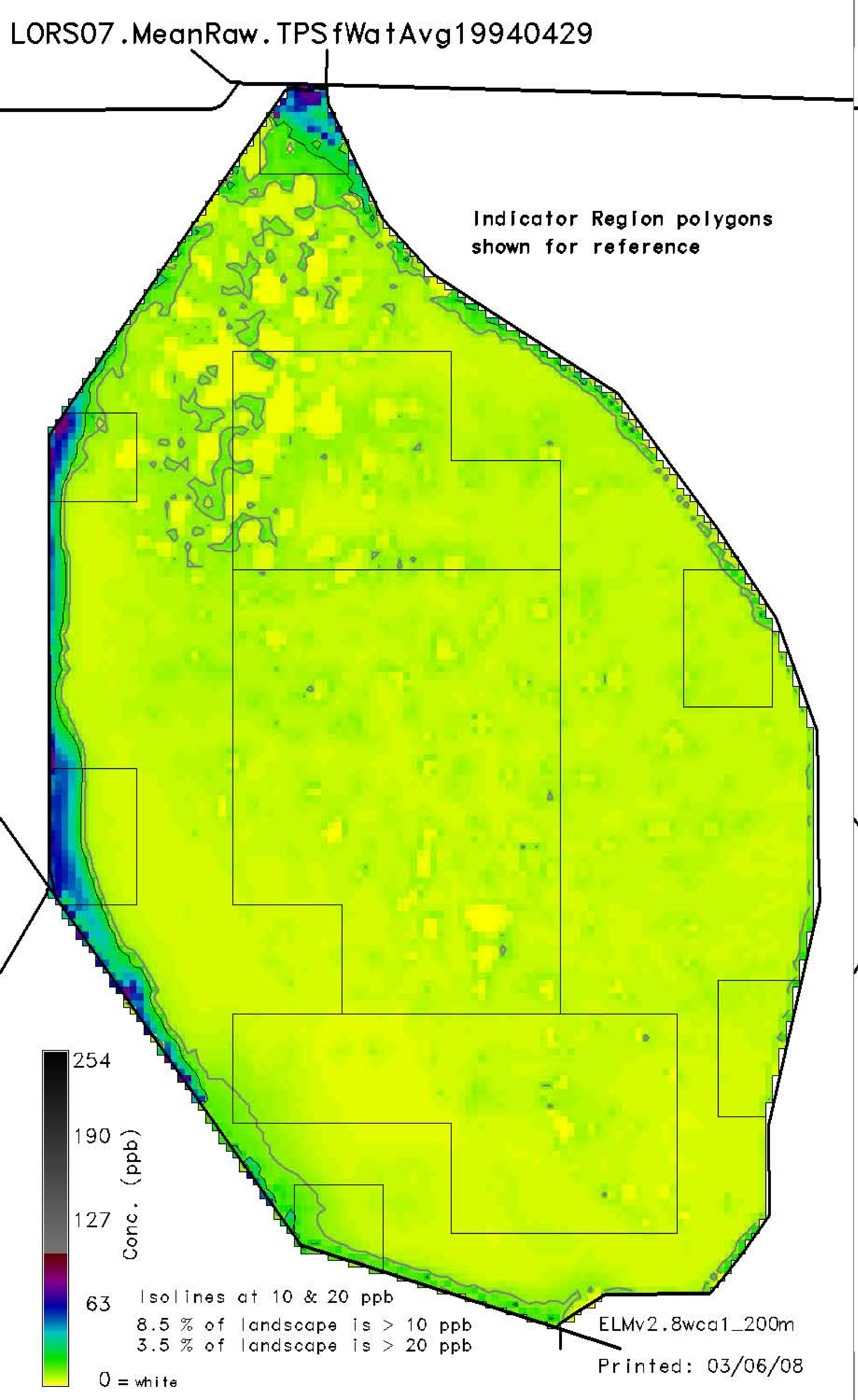

RecyS10S5_RegSep_B.MeanRaw.TPSfWatAvg19780920
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppb)
Isolines at 10 & 20 ppb
16.6 % of landscape is > 10 ppb
1.9 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08

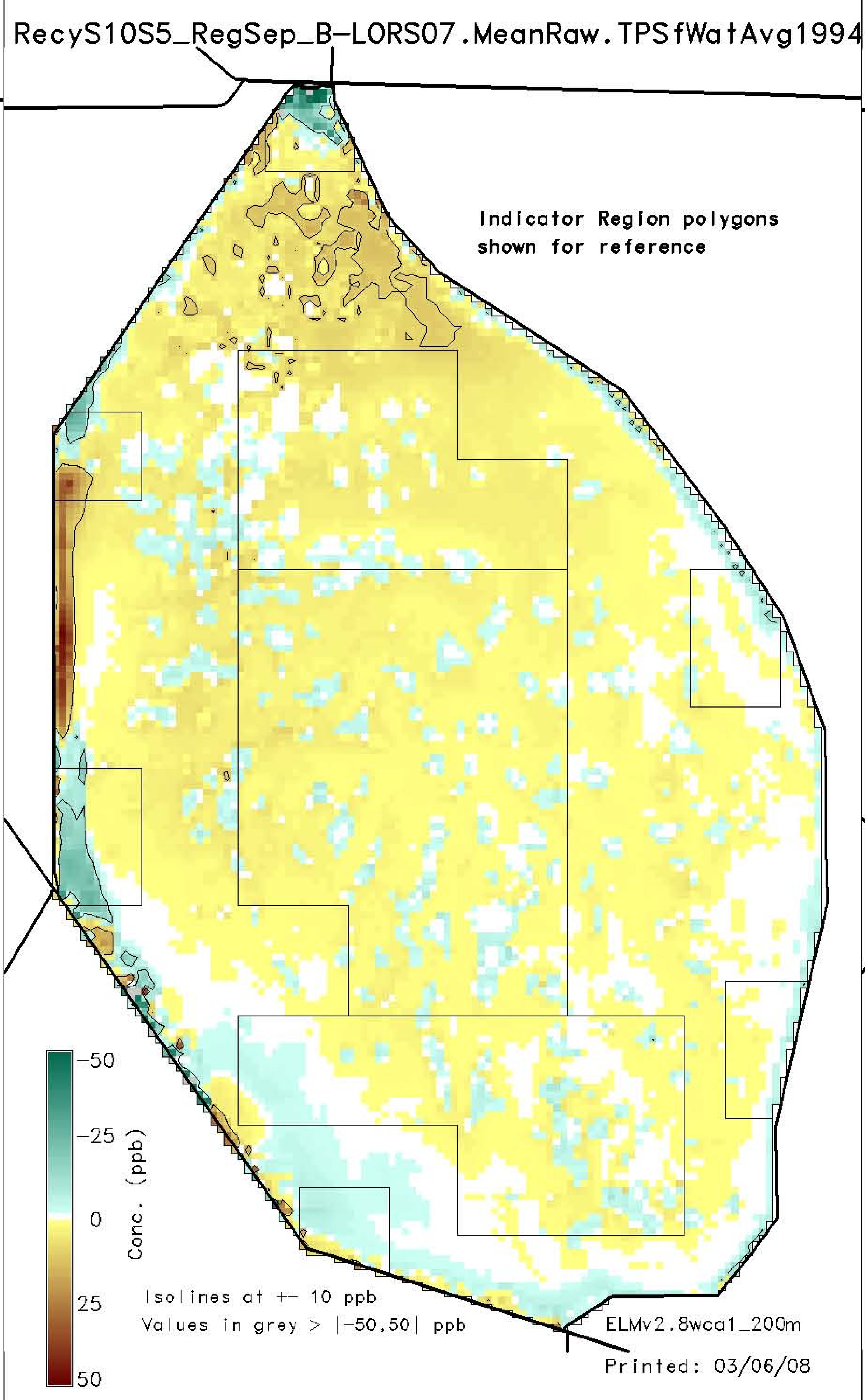

LORS07.MeanRaw.TPSfWatAvg19890425
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
0 = white
Isolines at 10 & 20 ppb
16.9 % of landscape is > 10 ppb
2.5 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.TPSfWatAvg1989
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppb)
Isolines at +- 10 ppb
Values in grey > |-50,50| ppb
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.TPSfWatAvg19890425
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
0 = white
Isolines at 10 & 20 ppb
26.0 % of landscape is > 10 ppb
3.6 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08

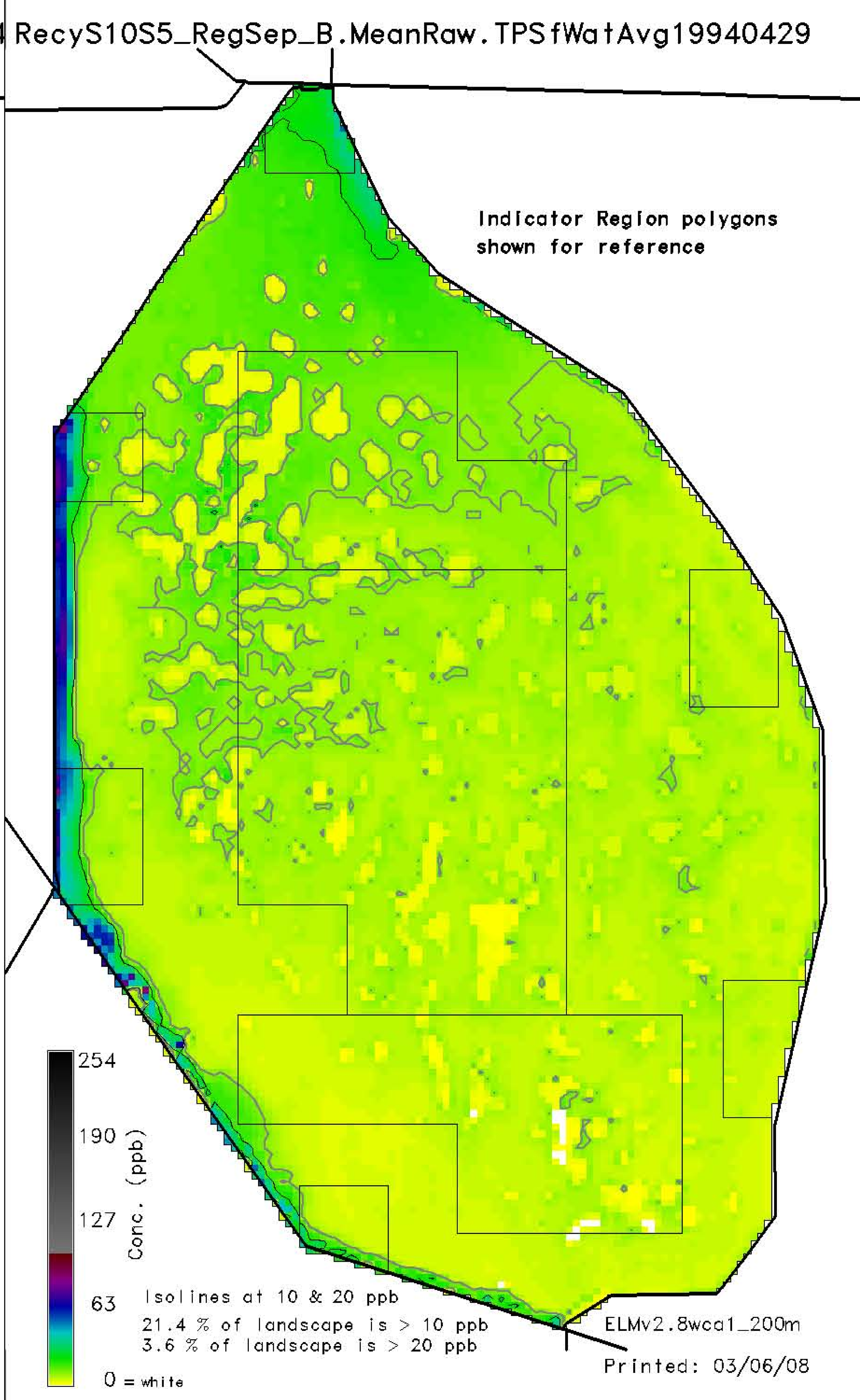

LORS07.MeanRaw.TPSfWatAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
0 = white
Isolines at 10 & 20 ppb
87.9 % of landscape is > 10 ppb
7.3 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B-LORS07.MeanRaw.TPSfWatAvg1989
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppb)
Isolines at +- 10 ppb
Values in grey > |-50,50| ppb
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B.MeanRaw.TPSfWatAvg19890922
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
0 = white
Isolines at 10 & 20 ppb
30.5 % of landscape is > 10 ppb
4.4 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08


LORS07.MeanRaw.TPSfWatAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
Isolines at 10 & 20 ppb
8.5 % of landscape is > 10 ppb
3.5 % of landscape is > 20 ppb
0 = white
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B-LORS07.MeanRaw.TPSfWatAvg1994
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppb)
Isolines at +- 10 ppb
Values in grey > |-50,50| ppb
ELMv2.8wca1_200m
Printed: 03/06/08


RecyS10S5_RegSep_B.MeanRaw.TPSfWatAvg19940429
Indicator Region polygons
shown for reference
254
190
127
63
Conc. (ppb)
Isolines at 10 & 20 ppb
21.4 % of landscape is > 10 ppb
3.6 % of landscape is > 20 ppb
0 = white
ELMv2.8wca1_200m
Printed: 03/06/08

LORS07.MeanRaw.TPSfWatAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppb)
Isolines at 10 & 20 ppb
26.3 % of landscape is > 10 ppb
5.0 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B-LORS07.MeanRaw.TPSfWatAvg1994
Indicator Region polygons
shown for reference
-50
-25
0
25
50
Conc. (ppb)
Isolines at +- 10 ppb
Values in grey > |-50,50| ppb
ELMv2.8wca1_200m
Printed: 03/06/08
RecyS10S5_RegSep_B.MeanRaw.TPSfWatAvg19940926
Indicator Region polygons
shown for reference
254
190
127
63
0 = white
Conc. (ppb)
Isolines at 10 & 20 ppb
15.3 % of landscape is > 10 ppb
3.7 % of landscape is > 20 ppb
ELMv2.8wca1_200m
Printed: 03/06/08

8.7 Conclusions: tentatively selected scenario

The objectives of this Model Application Chapter are to provide 1) the quantitative results of a suite of simulation scenarios and 2) basic interpretations, for use by the SFWMD science team in selecting the preferred alternative scenario for restoration planning. The text descriptions of the relative benefits among scenarios are broad and simple descriptions, intended to aid the interpretation and discussion of model results.

To attempt to best organize the large amount of post-processed model output, the model developer framed this discussion by making a "tentative selection" of a preferred scenario from the 12 that were developed and simulated, with those results presented in the body of the document. All other tables, graphs, and maps of results are found in the Appendix.

Alternative conclusions (regarding a preferred scenario) may likely be reached after more thorough scrutiny by the SFWMD science team, considering potential trade-offs between hydrologic restoration, water quality restoration, water availability, and other management constraints.

The last scenario that was run ("RecyS10S5_RegSepB", Table 0) appeared to be preferred from both the hydrologic and water quality perspectives. This scenario was close to approximating NSM stages in mid-WCA-1 (Screening tool, Figure 8.4) with respect to the seasonality and magnitude of the maxima and minima of water depths. In a variety of other general characteristics, that restoration scenario usually appeared closer to NSM trends than other scenarios, when considering multiple Performance Measures associated with both ponding and dry-out depths and durations (Tables 1-7, Appendix Tables 1-7).

The current (i.e., LORS07) system dries out to excess in the north, while being excessively wet in the south. However, the tentatively selected scenario showed an ecologically significant reduction in the depth-discrepancies between northern and southern areas of the system. For example, Table 4 shows that the mean depth in the northern IR 8 was shallower than that in the southern IR 10 by over 20 cm in the LORS07 Base run, whereas the mean difference between north and south was reduced to half that (~10 cm) in the tentatively selected scenario. Extreme dry-downs in excess of 1 foot (30 cm) did not occur in the tentatively selected scenario within (all grid cells averaged in) the northern Indicator Region 8, while such events occurred there (with a mean of) one week per year in the LORS07 Base run.

Finally, chloride water quality was among the best in the tentatively selected scenario compared to other scenarios with external inputs (Appendix Table 8), as this scenario required the least volume of external inflows (Table Managed flow summary) that increased the chloride and phosphorus loading to the system. Relative to the external water demands in the LORS07 Base run, the tentatively selected plan required only 20% of the inflows of "new" external water resources, while substantially improving the hydro-ecology of the system.

The volume of water that was recycled in the tentatively selected scenario was intermediate among managed scenarios with such a structure, and the selected scenario had the lowest managed outflows of excess water. The resulting average overland flow velocities in most (north through south) subregions of the basin were representative of a "flowing" system, although realistic flow velocity targets are unknown.

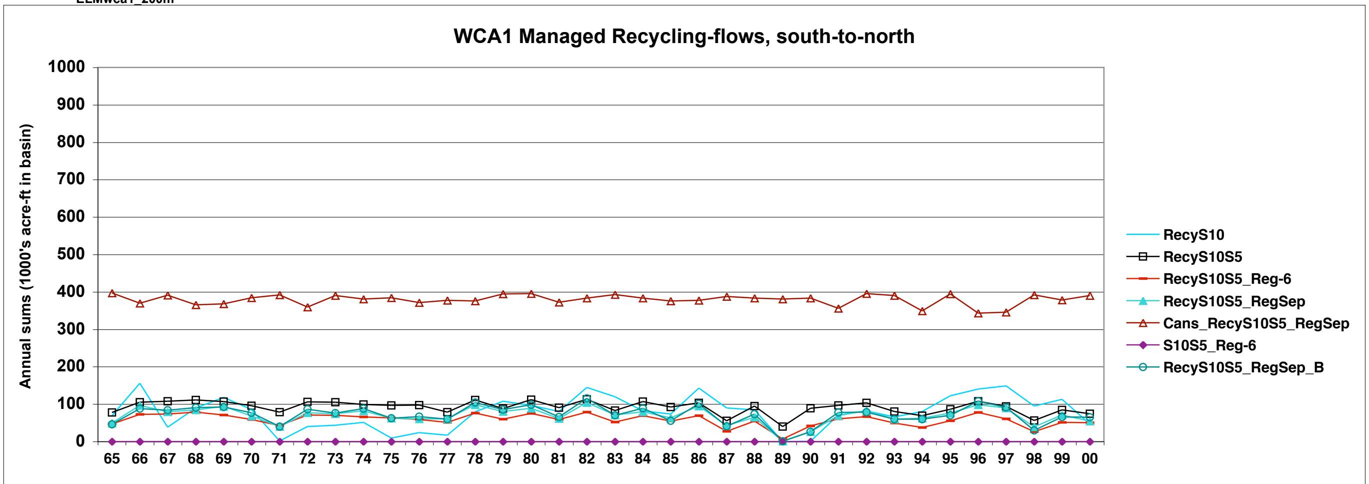
8.8 Appendix: Comparisons, all scenarios

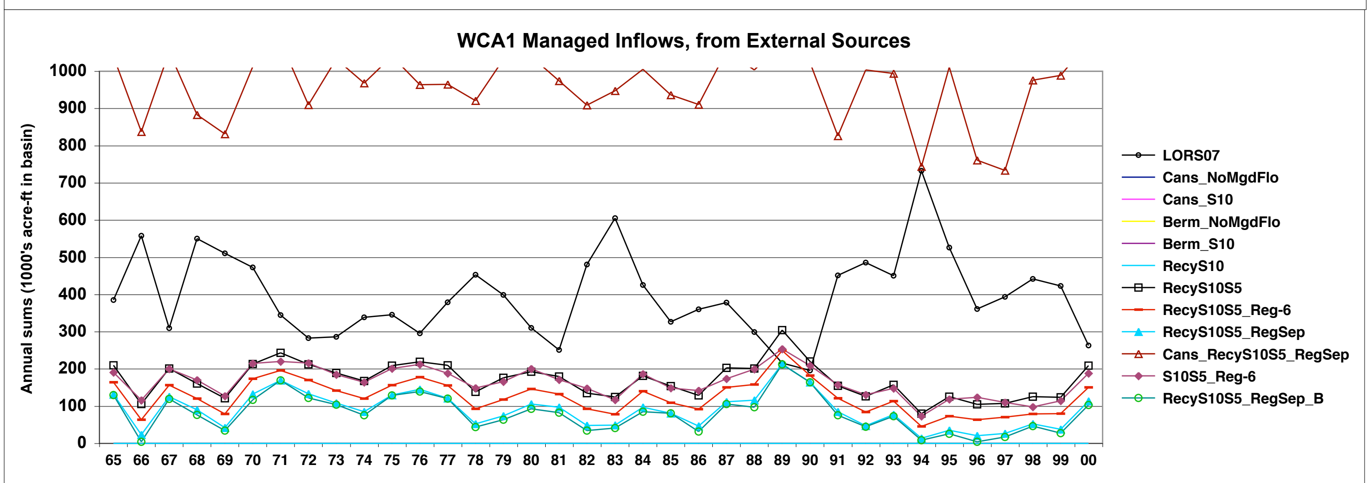
The body of the main document contains results for the “tentatively selected” scenario compared to the NSM v4.6.2 and LORS07 Base simulation runs.

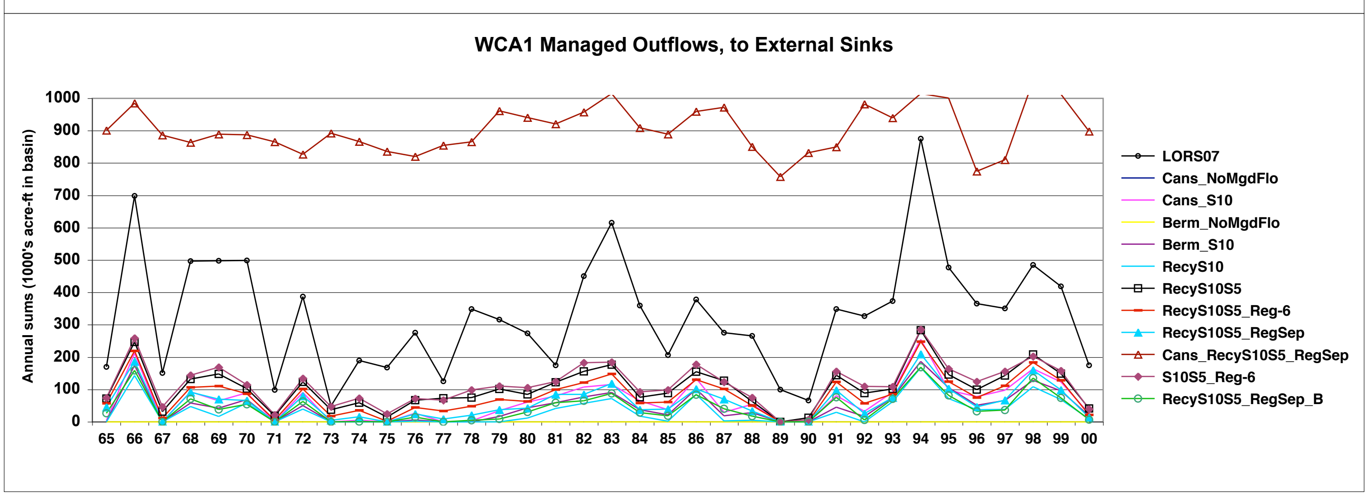
This Appendix contains results for all of the scenarios compared to the NSM v4.6.2 and/or LORS07 Base simulation runs.

This Appendix does NOT contain the map comparison figures for those scenarios. Those figures are contained in a separate “zipped” digital archive of graphic files. When un-zipped, the files will be found in a separate directory for each scenario. There are 12 (twelve) directories, each containing eighteen (18) “png” graphic files, for a total of 216 individual files.

ELMwca1_200m







Model Project: ELMwca1_200m v.2.8

Summary Table 1. Surface Water: Recession (Reces_#) and Inundation (Inun_#) rates within each Indicator Region #: mean mm / week during all Dry (Nov1 - May31) and Wet (Jun1 - Oct31) seasons, respectively.

Scenario	Reces_10	Inun_10	Reces_9	Inun_9	Reces_8	Inun_8	Reces_7	Inun_7	Reces_6	Inun_6	Reces_5	Inun_5	Reces_4	Inun_4	Reces_3	Inun_3	Reces_2	Inun_2	Reces_1	Inun_1
LORS07	18	23	16	20	15	18	18	22	19	24	20	25	19	24	18	22	17	21	17	21
Cans_NoMgdFlo	9	9	7	7	5	5	7	7	10	11	11	13	9	10	8	8	7	7	8	8
Cans_S10	9	10	6	6	4	3	6	7	11	13	13	15	10	11	8	8	5	6	7	8
Berm_NoMgdFlo	9	9	7	7	5	5	7	8	10	11	11	13	9	9	8	8	7	7	8	8
Berm_S10	9	10	6	6	4	4	7	7	11	13	13	16	9	9	8	7	6	5	7	8
RecyS10	9	9	6	6	5	5	8	8	11	12	13	15	9	9	7	7	8	10	8	8
NSM4.6.2	7	7	8	8	7	8	8	8	9	9	7	8	6	6	7	7	8	9	7	8
RecyS10S5	11	13	9	10	8	9	10	12	12	15	13	16	11	12	9	10	12	16	10	11
RecyS10S5_Reg-6	11	12	9	9	8	8	11	11	12	15	13	17	11	11	9	9	10	14	10	11
RecyS10S5_RegSep	10	11	8	9	8	7	11	11	12	15	13	16	10	11	9	9	10	14	10	10
Cans_RecyS10S5_RegSep	10	12	9	11	8	9	9	11	11	13	11	14	11	13	10	12	9	11	10	11
S10S5_Reg-6	11	13	9	10	8	8	11	11	13	16	13	17	11	12	10	10	9	13	10	11

Summary Table 2. Unsaturated z: Dry-downs, as duration & depth of the unsaturated zone within each Indicator Region #: 'Mon_#' = mean duration (months), and 'Dep_#' = mean depth (m).
Both statistics included only values of unsaturated zone depth that exceeded threshold of >0.03 m.

Scenario	Mon10	Dep10	Mon_9	Dep_9	Mon_8	Dep_8	Mon_7	Dep_7	Mon_6	Dep_6	Mon_5	Dep_5	Mon_4	Dep_4	Mon_3	Dep_3	Mon_2	Dep_2	Mon_1	Dep_1
LORS07	0.8	0.08	2.1	0.09	3.7	0.11	2.6	0.18	0.5	0.11	0.0	#N/A	0.6	0.09	1.4	0.15	2.9	0.26	2.0	0.10
Cans_NoMgdFlo	2.0	0.09	3.7	0.12	5.6	0.14	3.9	0.15	1.1	0.12	0.1	0.04	1.4	0.09	2.4	0.11	4.1	0.15	3.3	0.11
Cans_S10	3.4	0.09	5.8	0.12	8.1	0.15	6.2	0.15	1.6	0.13	0.1	0.05	2.3	0.09	4.0	0.11	6.1	0.14	5.1	0.11
Berm_NoMgdFlo	2.3	0.09	3.8	0.12	5.4	0.14	3.7	0.16	1.3	0.13	0.2	0.05	1.2	0.09	1.8	0.10	3.0	0.14	3.2	0.11
Berm_S10	3.4	0.08	5.2	0.12	7.1	0.14	5.3	0.16	1.9	0.12	0.2	0.05	1.7	0.09	2.4	0.10	3.2	0.14	4.5	0.11
RecyS10	3.4	0.08	5.0	0.12	5.3	0.14	4.1	0.17	2.0	0.12	0.2	0.05	1.7	0.09	2.0	0.10	2.4	0.14	3.8	0.11
NSM4.6.2	0.9	0.12	0.8	0.11	0.6	0.10	0.9	0.16	1.1	0.13	0.9	0.14	1.0	0.13	0.6	0.11	0.3	0.12	0.9	0.11
RecyS10S5	1.2	0.05	1.7	0.05	0.8	0.04	0.1	0.05	0.2	0.04	0.0	#N/A	0.2	0.05	0.1	0.04	0.0	#N/A	0.7	0.04
RecyS10S5_Reg-6	1.8	0.05	2.5	0.07	1.9	0.05	1.1	0.05	0.6	0.05	0.0	#N/A	0.5	0.05	0.3	0.05	0.0	#N/A	1.4	0.05
RecyS10S5_RegSep	2.1	0.06	2.9	0.08	2.4	0.06	1.7	0.07	0.9	0.06	0.0	#N/A	0.7	0.06	0.7	0.05	0.0	#N/A	1.8	0.06
Cans_RecyS10S5_RegSep	0.0	0.03	1.5	0.05	3.9	0.08	0.7	0.04	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.9	0.04	1.1	0.04
S10S5_Reg-6	1.4	0.05	2.4	0.06	2.0	0.05	1.1	0.05	0.4	0.04	0.0	#N/A	0.3	0.05	0.3	0.05	0.0	#N/A	1.2	0.05

Summary Table 3. Unsaturated z: Extreme dry-downs, as the maximum unsaturated zone depth, and the mean unsaturated zone depths that exceeded a threshold, within each Indicator Region #:
'Max_#' = maximum of the mean daily value (m), and 'Deep_#' = mean depth of all values >=0.3048 m.

Scenario	Max10	Deep10	Max_9	Deep_9	Max_8	Deep_8	Max_7	Deep_7	Max_6	Deep_6	Max_5	Deep_5	Max_4	Deep_4	Max_3	Deep_3	Max_2	Deep_2	Max_1	Deep_1
LORS07	0.25	#N/A	0.47	0.43	0.63	0.51	0.79	0.48	0.31	0.31	0.02	#N/A	0.31	0.31	0.60	0.47	1.14	0.64	0.45	0.42
Cans_NoMgdFlo	0.30	#N/A	0.53	0.42	0.72	0.42	0.68	0.49	0.40	0.36	0.05	#N/A	0.34	0.34	0.45	0.39	0.66	0.43	0.47	0.39
Cans_S10	0.46	0.42	0.68	0.42	0.79	0.45	0.72	0.46	0.51	0.39	0.06	#N/A	0.45	0.40	0.55	0.42	0.70	0.43	0.58	0.40
Berm_NoMgdFlo	0.33	0.33	0.56	0.42	0.72	0.42	0.68	0.48	0.45	0.41	0.06	#N/A	0.32	0.32	0.39	0.36	0.54	0.39	0.48	0.39
Berm_S10	0.46	0.43	0.67	0.43	0.78	0.46	0.71	0.46	0.53	0.44	0.09	#N/A	0.40	0.40	0.46	0.40	0.54	0.38	0.57	0.40
RecyS10	0.43	0.40	0.64	0.42	0.77	0.44	0.70	0.46	0.52	0.43	0.08	#N/A	0.38	0.38	0.44	0.38	0.50	0.38	0.54	0.41
NSM4.6.2	0.29	#N/A	0.32	0.32	0.29	#N/A	0.45	0.36	0.35	0.35	0.31	0.31	0.33	0.33	0.28	#N/A	0.25	#N/A	0.31	0.31
RecyS10S5	0.10	#N/A	0.14	#N/A	0.06	#N/A	0.07	#N/A	0.05	#N/A	0.01	#N/A	0.07	#N/A	0.04	#N/A	0.01	#N/A	0.07	#N/A
RecyS10S5_Reg-6	0.11	#N/A	0.24	#N/A	0.12	#N/A	0.20	#N/A	0.10	#N/A	0.02	#N/A	0.10	#N/A	0.11	#N/A	0.01	#N/A	0.13	#N/A
RecyS10S5_RegSep	0.13	#N/A	0.31	0.31	0.17	#N/A	0.31	0.31	0.14	#N/A	0.02	#N/A	0.12	#N/A	0.16	#N/A	0.01	#N/A	0.17	#N/A
Cans_RecyS10S5_RegSep	0.03	#N/A	0.09	#N/A	0.27	#N/A	0.09	#N/A	0.01	#N/A	0.01	#N/A	0.02	#N/A	0.03	#N/A	0.10	#N/A	0.06	#N/A
S10S5_Reg-6	0.10	#N/A	0.21	#N/A	0.12	#N/A	0.19	#N/A	0.08	#N/A	0.01	#N/A	0.08	#N/A	0.10	#N/A	0.01	#N/A	0.11	#N/A

Model Project: ELMwca1_200m v.2.8

Summary Table 4. Surface z: Wet-ups, as duration & depth of the surface water within each Indicator Region #: 'Mon_#' = mean duration (months), and 'Dep_#' = mean depth (m).
Both statistics included only values of surface water depth that exceeded threshold of >0.03 m.

Scenario	Mon10	Dep10	Mon_9	Dep_9	Mon_8	Dep_8	Mon_7	Dep_7	Mon_6	Dep_6	Mon_5	Dep_5	Mon_4	Dep_4	Mon_3	Dep_3	Mon_2	Dep_2	Mon_1	Dep_1
LORS07	12.0	0.47	11.6	0.32	11.0	0.25	11.0	0.34	11.9	0.54	12.0	1.02	11.8	0.45	11.6	0.38	10.9	0.32	11.9	0.39
Cans_NoMgdFlo	11.9	0.34	10.6	0.21	9.7	0.15	10.2	0.22	11.7	0.41	12.0	0.89	11.5	0.32	11.1	0.25	10.3	0.19	11.8	0.27
Cans_S10	11.7	0.24	9.9	0.13	8.3	0.09	9.1	0.13	11.7	0.30	12.0	0.78	11.2	0.22	10.4	0.16	9.0	0.11	11.6	0.18
Berm_NoMgdFlo	11.8	0.32	10.5	0.21	9.8	0.16	10.3	0.23	11.6	0.39	12.0	0.85	11.5	0.32	11.4	0.26	10.7	0.23	11.7	0.26
Berm_S10	11.7	0.24	10.1	0.14	9.1	0.11	9.6	0.17	11.6	0.30	12.0	0.75	11.3	0.24	11.3	0.20	10.6	0.19	11.6	0.20
RecyS10	11.7	0.23	10.2	0.15	9.8	0.15	10.1	0.20	11.6	0.29	12.0	0.73	11.3	0.24	11.3	0.22	11.0	0.35	11.6	0.21
NSM4.6.2	10.9	0.23	11.0	0.27	11.2	0.26	10.6	0.25	10.7	0.28	11.0	0.26	10.6	0.19	11.1	0.25	11.5	0.30	11.0	0.25
RecyS10S5	12.0	0.31	12.0	0.22	12.0	0.24	12.0	0.33	12.0	0.38	12.0	0.84	12.0	0.32	12.0	0.31	12.0	0.68	12.0	0.32
RecyS10S5_Reg-6	12.0	0.29	11.7	0.19	12.0	0.19	11.9	0.27	12.0	0.35	12.0	0.82	12.0	0.30	12.0	0.28	12.0	0.56	12.0	0.28
RecyS10S5_RegSep	12.0	0.27	11.4	0.18	12.0	0.18	11.9	0.25	11.9	0.33	12.0	0.80	11.9	0.28	12.0	0.26	12.0	0.52	12.0	0.26
Cans_RecyS10S5_RegSep	12.0	0.37	12.0	0.22	11.7	0.15	12.0	0.25	12.0	0.45	12.0	0.94	12.0	0.36	12.0	0.28	12.0	0.24	12.0	0.30
S10S5_Reg-6	12.0	0.30	11.8	0.20	12.0	0.19	11.9	0.27	12.0	0.37	12.0	0.84	12.0	0.31	12.0	0.28	12.0	0.54	12.0	0.29

Summary Table 5. Surface z: Extreme wet-ups, as the maximum surface water depth, and the mean surface water depth that exceeded a threshold, within each Indicator Region #:
'Max_#' = maximum of the mean daily value (m), and 'Deep_#' = mean depth of all values >=0.3048 m.

Scenario	Max10	Deep10	Max_9	Deep_9	Max_8	Deep_8	Max_7	Deep_7	Max_6	Deep_6	Max_5	Deep_5	Max_4	Deep_4	Max_3	Deep_3	Max_2	Deep_2	Max_1	Deep_1
LORS07	0.87	0.56	0.73	0.48	0.63	0.45	0.72	0.49	0.94	0.59	1.43	1.02	0.86	0.56	0.80	0.52	0.69	0.48	0.79	0.52
Cans_NoMgdFlo	0.88	0.45	0.71	0.40	0.61	0.39	0.71	0.40	0.97	0.49	1.45	0.89	0.86	0.44	0.78	0.42	0.67	0.39	0.79	0.41
Cans_S10	0.50	0.37	0.35	0.33	0.25	#N/A	0.33	0.32	0.57	0.41	1.09	0.78	0.50	0.37	0.40	0.34	0.32	0.31	0.41	0.34
Berm_NoMgdFlo	0.86	0.44	0.71	0.39	0.62	0.39	0.73	0.40	0.95	0.48	1.41	0.86	0.85	0.44	0.79	0.41	0.70	0.39	0.79	0.41
Berm_S10	0.51	0.38	0.43	0.34	0.41	0.38	0.50	0.35	0.58	0.41	1.08	0.77	0.54	0.38	0.57	0.35	0.51	0.36	0.50	0.35
RecyS10	0.51	0.36	0.45	0.35	0.44	0.35	0.54	0.36	0.57	0.40	1.05	0.75	0.56	0.38	0.60	0.36	0.69	0.49	0.52	0.36
NSM4.6.2	0.51	0.36	0.55	0.39	0.54	0.38	0.56	0.38	0.60	0.41	0.54	0.38	0.43	0.35	0.51	0.37	0.60	0.40	0.53	0.37
RecyS10S5	0.55	0.39	0.46	0.35	0.46	0.34	0.55	0.39	0.59	0.45	1.07	0.84	0.60	0.40	0.61	0.39	1.14	0.68	0.53	0.39
RecyS10S5_Reg-6	0.54	0.39	0.45	0.34	0.44	0.33	0.53	0.37	0.59	0.43	1.08	0.82	0.58	0.39	0.59	0.38	0.98	0.56	0.52	0.37
RecyS10S5_RegSep	0.53	0.38	0.45	0.34	0.43	0.34	0.53	0.36	0.59	0.42	1.07	0.80	0.57	0.39	0.59	0.37	0.91	0.53	0.52	0.37
Cans_RecyS10S5_RegSep	0.57	0.42	0.43	0.34	0.33	0.32	0.41	0.35	0.62	0.47	1.13	0.94	0.57	0.42	0.48	0.37	0.39	0.34	0.50	0.38
S10S5_Reg-6	0.55	0.40	0.45	0.34	0.43	0.34	0.53	0.37	0.60	0.45	1.08	0.84	0.59	0.40	0.59	0.38	0.93	0.54	0.52	0.38

Model Project: ELMwca1_200m v.2.8

Summary Table 6. Unsaturated z duration: Duration of extreme drydowns within each Indicator Region #: Wk/yr == Mean # weeks/year; Wk/evt == Mean # weeks/event.
An 'event' is any 7-day period with mean unsaturated zone depth that exceeded 0.30 m.

Scenario	Wk/yr10	Wk/evt10	Wk/yr_9	Wk/evt_9	Wk/yr_8	Wk/evt_8	Wk/yr_7	Wk/evt_7	Wk/yr_6	Wk/evt_6	Wk/yr_5	Wk/evt_5	Wk/yr_4	Wk/evt_4	Wk/yr_3	Wk/evt_3	Wk/yr_2	Wk/evt_2	Wk/yr_1	Wk/evt_1
LORS07	0.0	#N/A	0.5	6.0	1.0	7.2	2.4	7.2	0.1	2.5	0.0	#N/A	0.2	3.0	0.9	6.2	3.5	7.5	0.4	8.0
Cans_NoMgdFlo	0.1	4.0	1.2	5.3	2.8	6.7	2.6	5.8	0.3	2.8	0.0	#N/A	0.2	3.5	0.6	4.2	2.7	6.5	0.7	4.0
Cans_S10	0.2	8.0	2.2	6.1	4.3	7.8	4.0	6.9	0.6	3.7	0.0	#N/A	0.3	4.5	1.0	3.3	3.6	6.7	1.3	4.2
Berm_NoMgdFlo	0.1	5.0	1.3	5.8	2.7	6.5	2.7	6.0	0.5	3.6	0.0	#N/A	0.1	2.5	0.3	5.5	1.7	4.4	0.7	4.0
Berm_S10	0.3	4.5	2.0	5.5	3.7	8.8	3.7	7.1	0.6	3.8	0.0	#N/A	0.2	4.0	0.5	8.5	1.7	4.4	1.1	4.2
RecyS10	0.2	4.0	1.7	6.1	2.9	7.1	3.2	6.1	0.6	4.4	0.0	#N/A	0.2	3.5	0.4	7.5	1.5	4.4	0.9	4.7
NSM4.6.2	0.1	2.0	0.1	4.0	0.1	3.0	0.5	3.6	0.2	6.0	0.1	2.0	0.2	3.5	0.1	2.0	0.0	1.0	0.1	3.0
RecyS10S5	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
RecyS10S5_Reg-6	0.0	#N/A	0.1	2.0	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
RecyS10S5_RegSep	0.0	#N/A	0.2	3.0	0.0	#N/A	0.1	3.0	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	1.0	0.0	#N/A	0.0	#N/A
Cans_RecyS10S5_RegSep	0.0	#N/A	0.0	#N/A	0.0	1.0	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A
S10S5_Reg-6	0.0	#N/A	0.0	1.0	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A	0.0	#N/A

Summary Table 7. Unsaturated z: Maximum duration of extreme drydown events within each Indicator Region #: MaxWk == Maximum # weeks in simulation period.
An 'event' is any 7-day period with mean unsaturated zone depth that exceeded 0.30 m.

Scenario	MaxWk10	MaxWk_9	MaxWk_8	MaxWk_7	MaxWk_6	MaxWk_5	MaxWk_4	MaxWk_3	MaxWk_2	MaxWk_1
LORS07	0	8	14	16	4	0	4	13	19	10
Cans_NoMgdFlo	4	11	18	16	5	0	5	10	15	10
Cans_S10	8	17	24	22	10	0	7	12	19	13
Berm_NoMgdFlo	5	12	18	16	9	0	4	6	11	10
Berm_S10	8	17	21	20	11	0	6	11	11	13
RecyS10	6	14	21	17	10	0	5	10	11	12
NSM4.6.2	2	4	3	8	6	3	5	2	1	3
RecyS10S5	0	0	0	0	0	0	0	0	0	0
RecyS10S5_Reg-6	0	2	0	0	0	0	0	0	0	0
RecyS10S5_RegSep	0	4	0	3	0	0	0	1	0	0
Cans_RecyS10S5_RegSep	0	0	1	0	0	0	0	0	0	0
S10S5_Reg-6	0	1	0	0	0	0	0	0	0	0

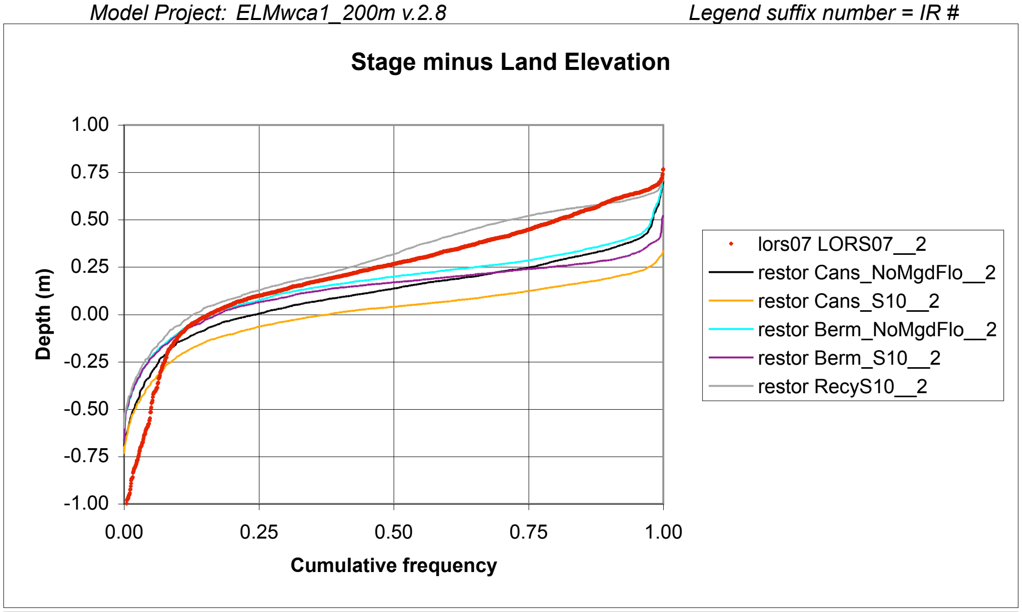
Model Project: ELMwca1_200m v.2.8

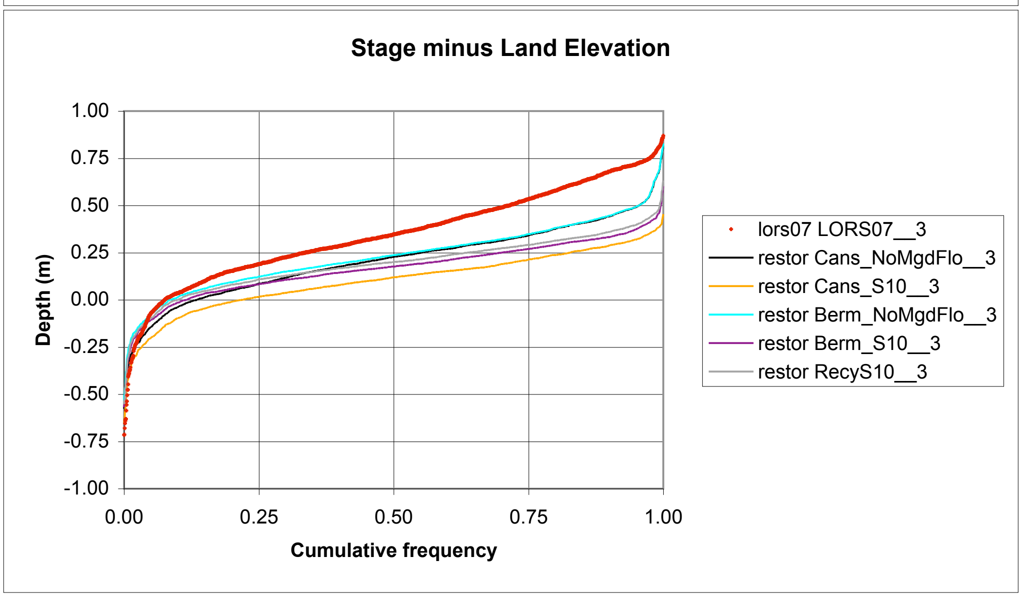
Summary Table 8. Velocity and Cl: Mean daily surface water flow velocity index (Vel#, m/d); mean daily surface water chloride concentration (CL, g/L), within each Indicator Region #.

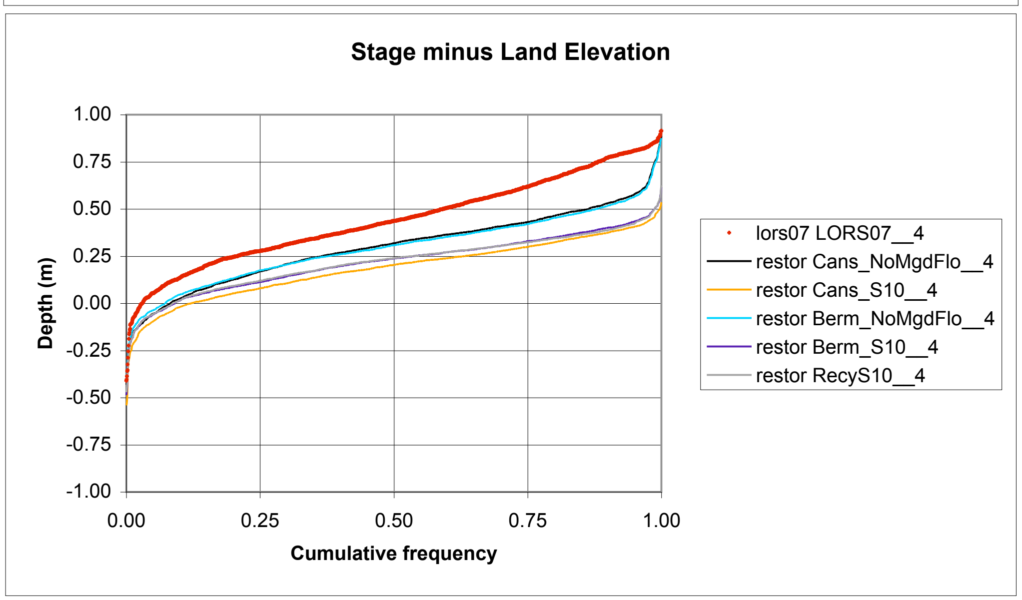
Scenario	Vel10	CL10	Vel_9	CL_9	Vel_8	CL_8	Vel_7	CL_7	Vel_6	CL_6	Vel_5	CL_5	Vel_4	CL_4	Vel_3	CL_3	Vel_2	CL_2	Vel_1	CL_1
LORS07	28	0.053	20	0.036	23	0.023	23	0.046	29	0.065	15	0.073	26	0.056	33	0.049	21	0.055	26	0.044
Cans_NoMgdFlo	24	0.004	20	0.004	19	0.003	21	0.004	24	0.004	13	0.005	17	0.004	24	0.004	21	0.004	22	0.004
Cans_S10	25	0.004	22	0.003	24	0.002	26	0.003	28	0.004	14	0.004	23	0.003	32	0.003	20	0.003	26	0.003
Berm_NoMgdFlo	20	0.004	20	0.004	21	0.003	22	0.003	27	0.005	11	0.005	19	0.004	20	0.003	16	0.002	21	0.004
Berm_S10	28	0.004	29	0.003	26	0.002	27	0.003	40	0.005	15	0.004	28	0.004	26	0.002	19	0.002	28	0.003
RecyS10	38	0.004	53	0.003	71	0.003	60	0.003	68	0.005	16	0.005	40	0.004	43	0.003	194	0.003	55	0.003
NSM4.6.2	#N/A	0.005	#N/A	0.005	#N/A	0.004	#N/A	0.003	#N/A	0.005	#N/A	0.005	#N/A	0.005	#N/A	0.005	#N/A	#N/A	#N/A	0.005
RecyS10S5	50	0.044	91	0.052	153	0.056	112	0.062	117	0.061	17	0.051	50	0.047	69	0.057	308	0.060	97	0.053
RecyS10S5_Reg-6	42	0.034	72	0.043	123	0.049	94	0.055	89	0.050	16	0.041	43	0.036	60	0.047	282	0.055	80	0.044
RecyS10S5_RegSep	40	0.027	68	0.034	113	0.039	89	0.045	83	0.040	16	0.032	43	0.029	58	0.038	276	0.047	75	0.035
Cans_RecyS10S5_RegSep	34	0.065	23	0.057	28	0.043	31	0.070	45	0.072	17	0.086	32	0.067	40	0.061	27	0.072	32	0.060
S10S5_Reg-6	39	0.037	64	0.051	113	0.058	85	0.065	77	0.059	16	0.047	39	0.040	54	0.052	276	0.067	73	0.051

Cumulative Frequency Distribution Graphs

Model Project: ELMwca1_200m v.2.8 *Legend suffix number = IR #*

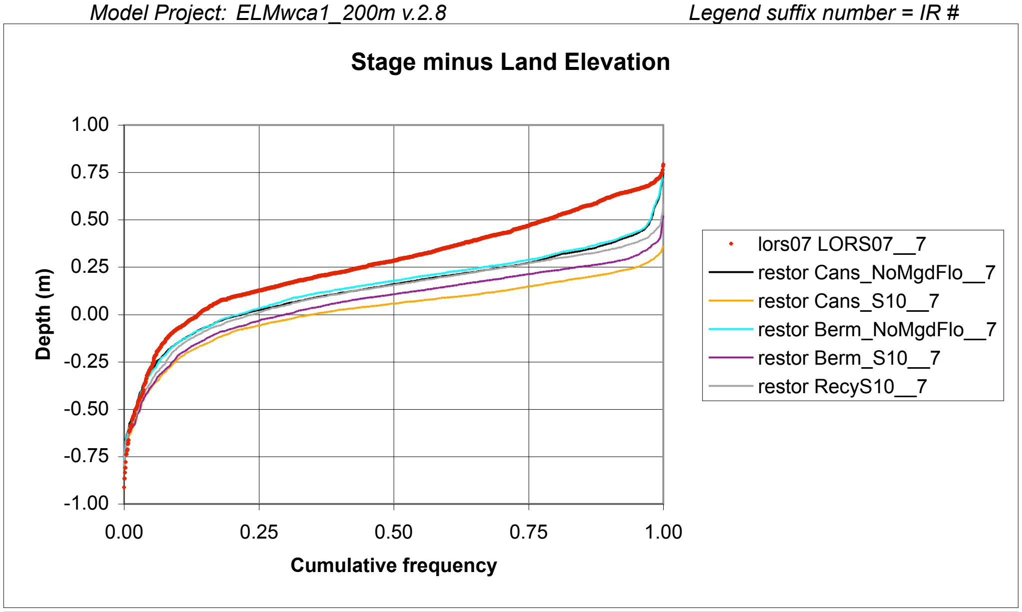


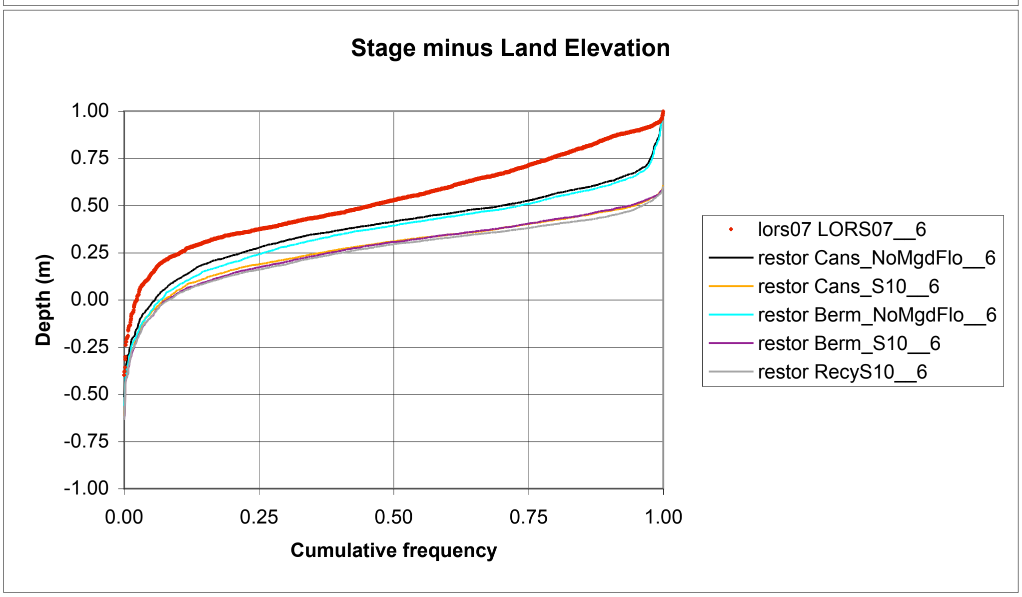


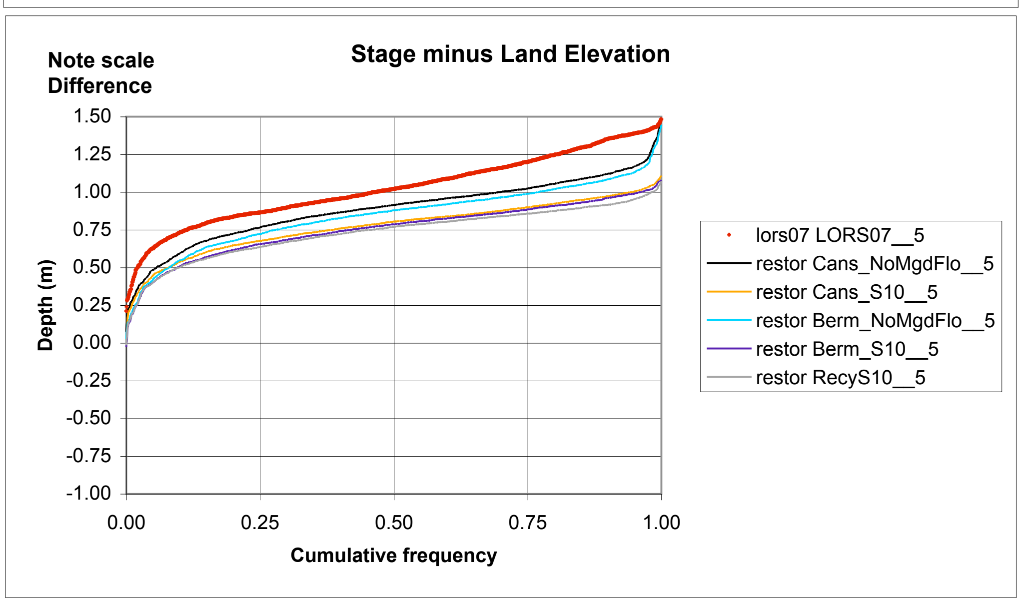


Cumulative Frequency Distribution Graphs

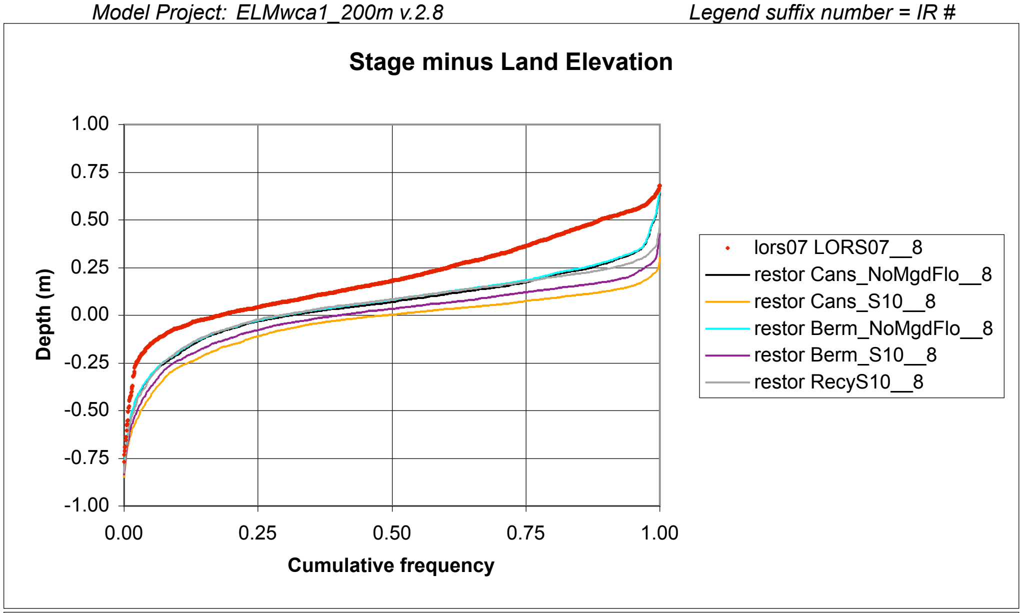
Model Project: ELMwca1_200m v.2.8 *Legend suffix number = IR #*

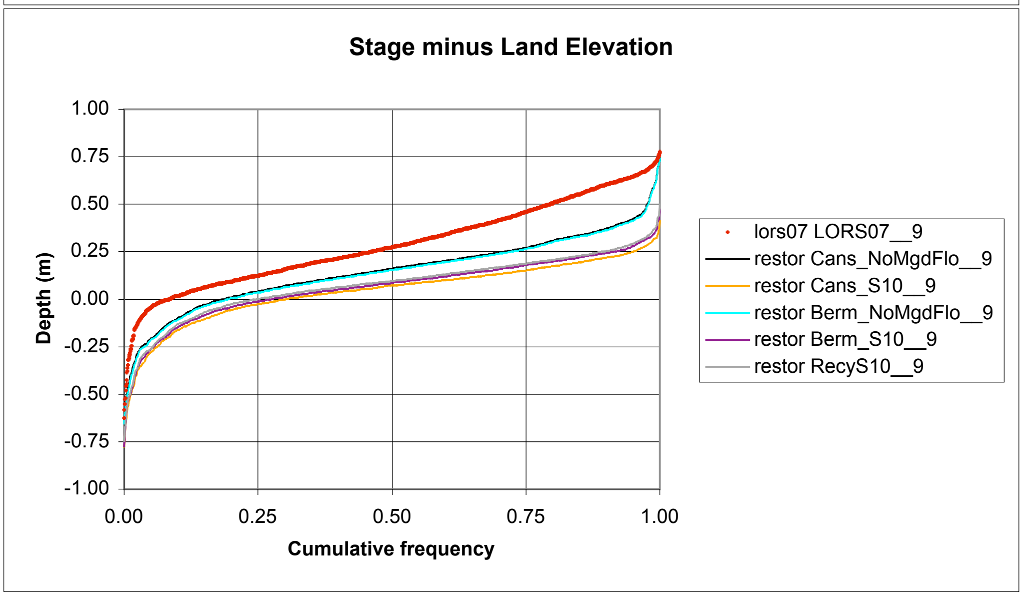


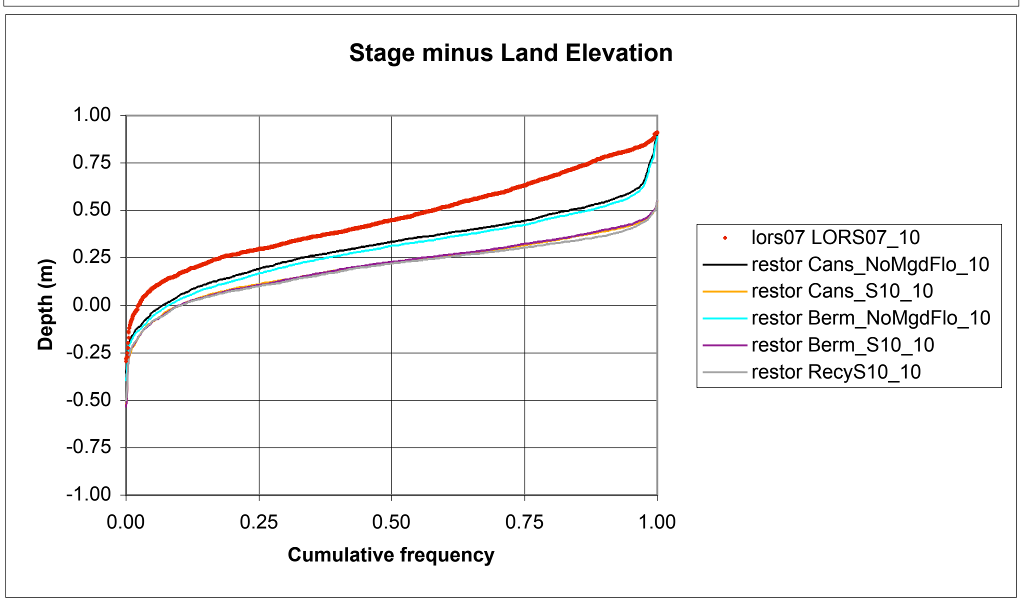




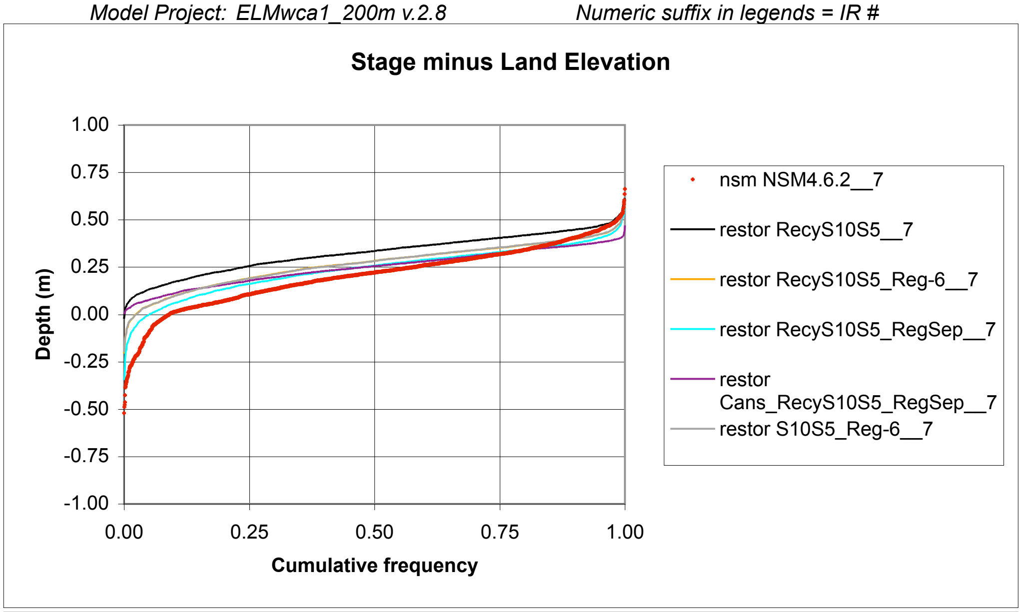
Model Project: ELMwca1_200m v.2.8 *Legend suffix number = IR #*

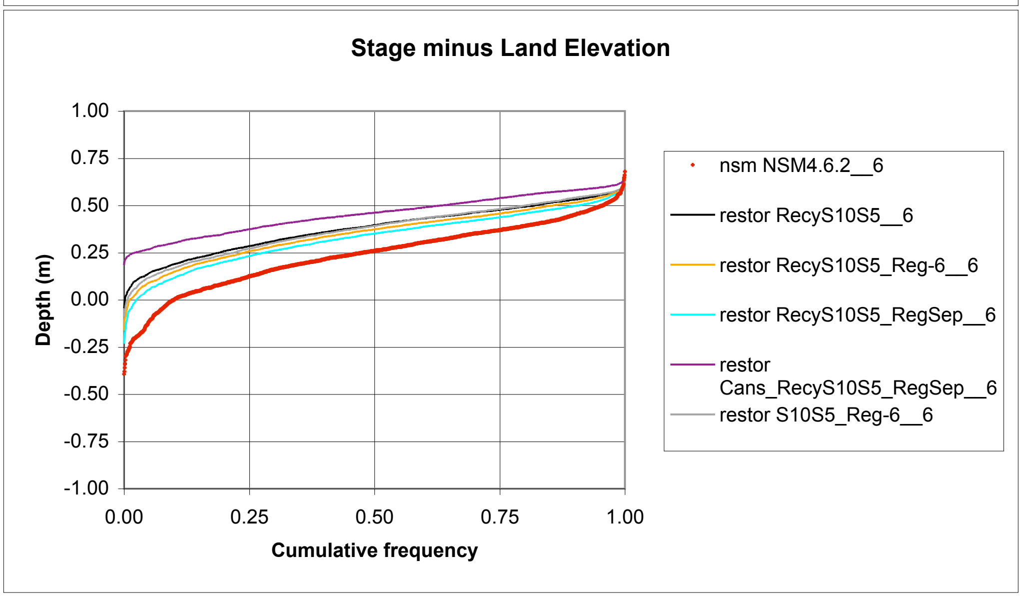


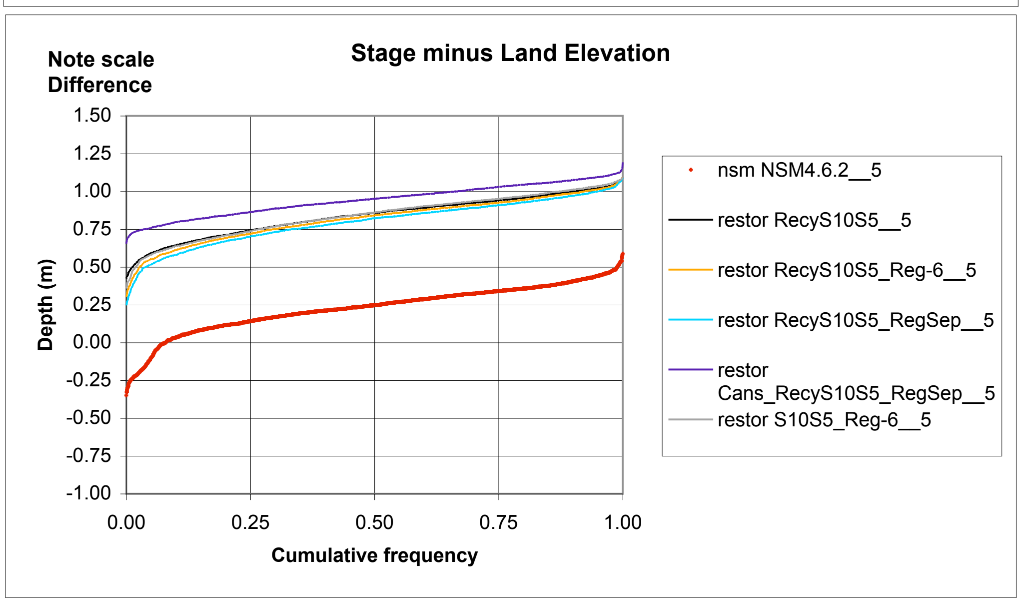




Cumulative Frequency Distribution Graphs
Model Project: ELMwca1_200m v.2.8 *Numeric suffix in legends = IR #*

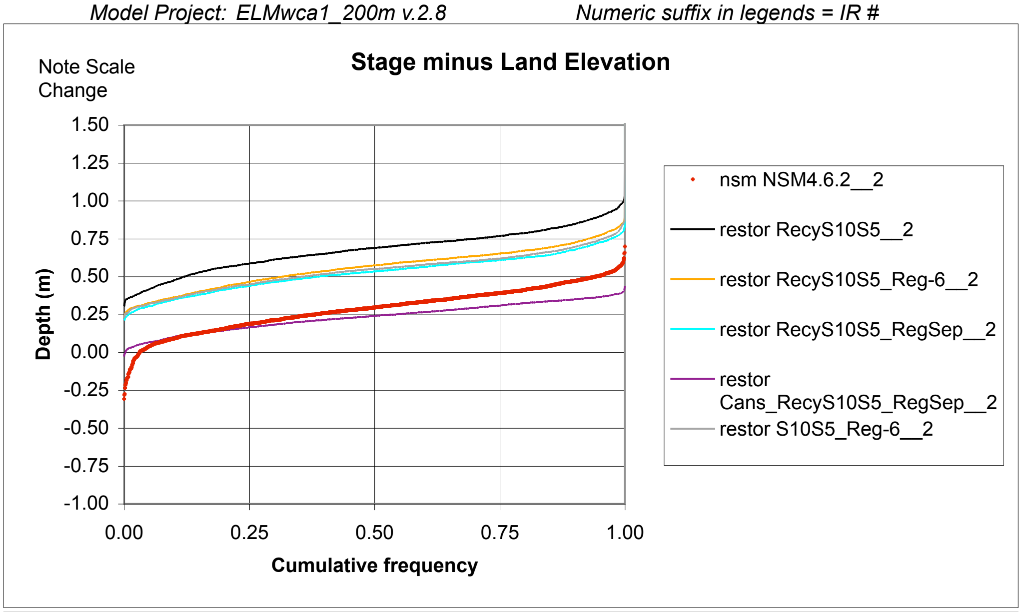


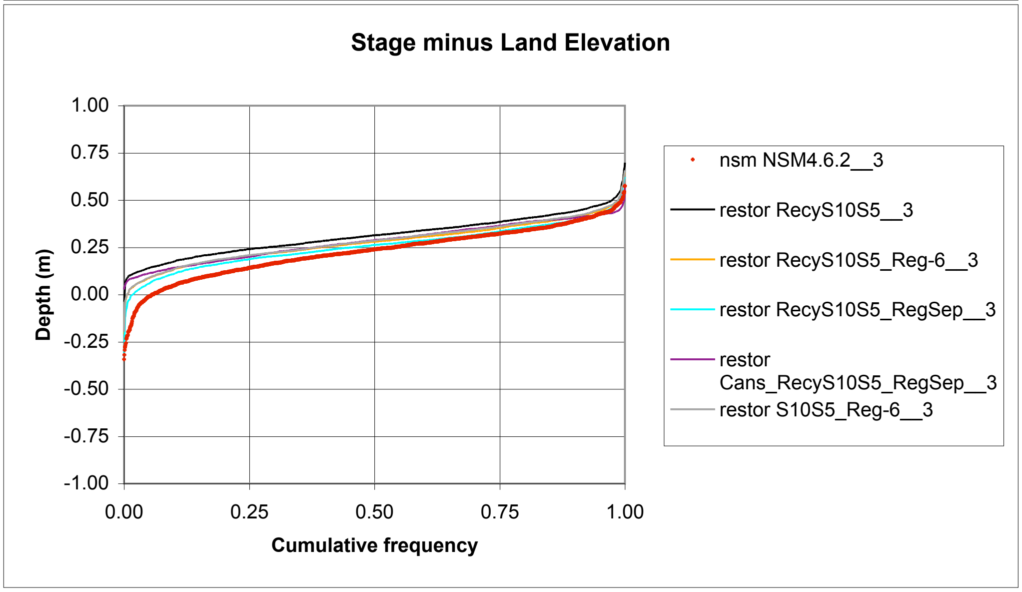


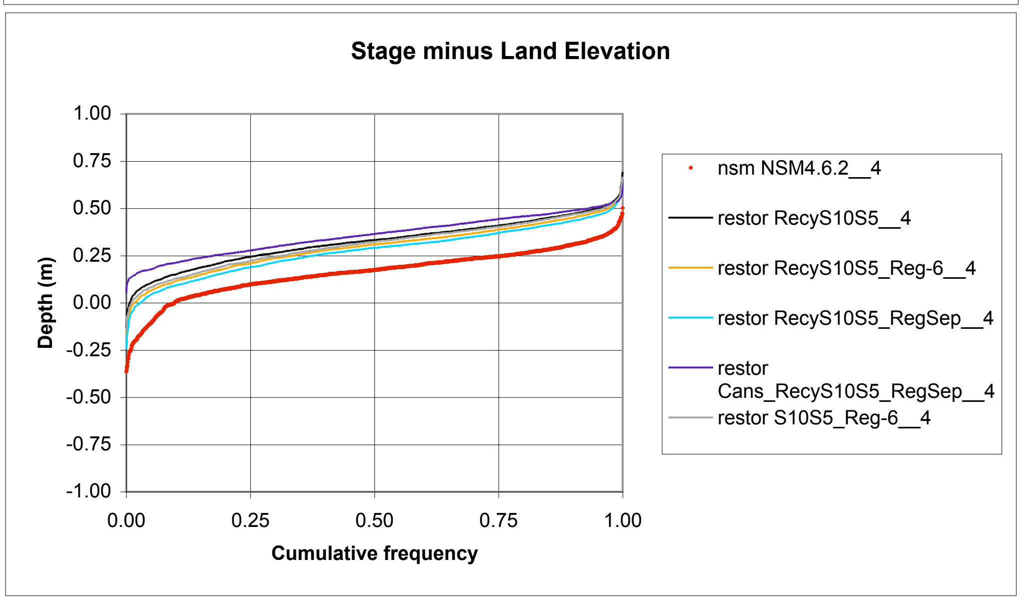


Cumulative Frequency Distribution Graphs

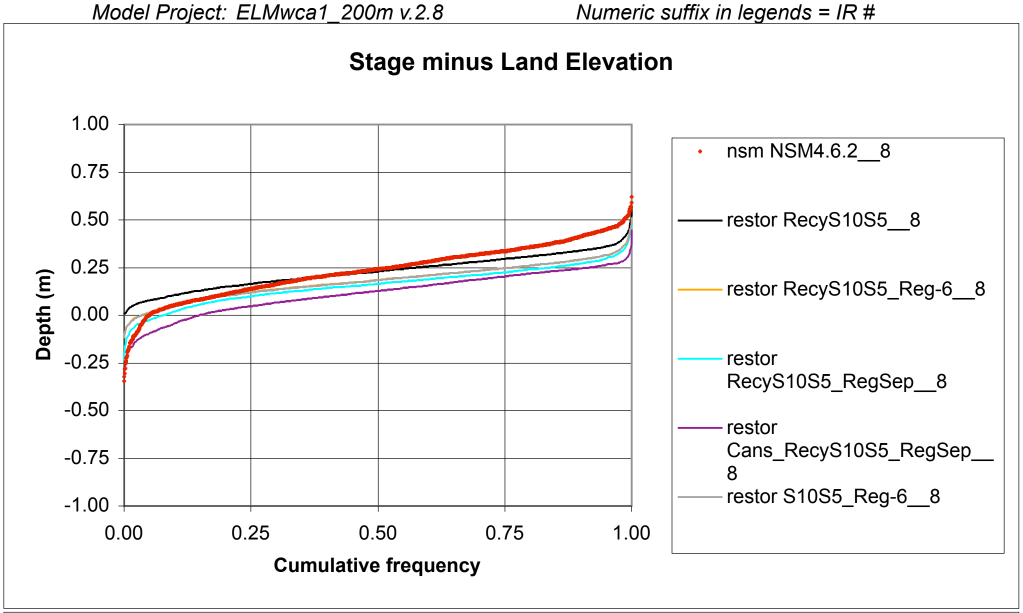
Model Project: ELMwca1_200m v.2.8 *Numeric suffix in legends = IR #*

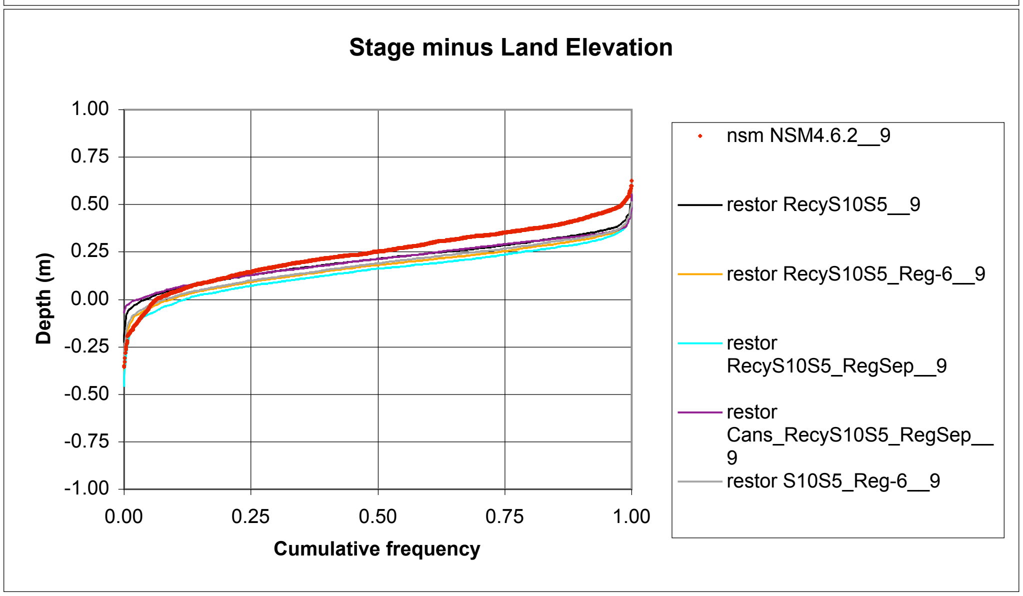


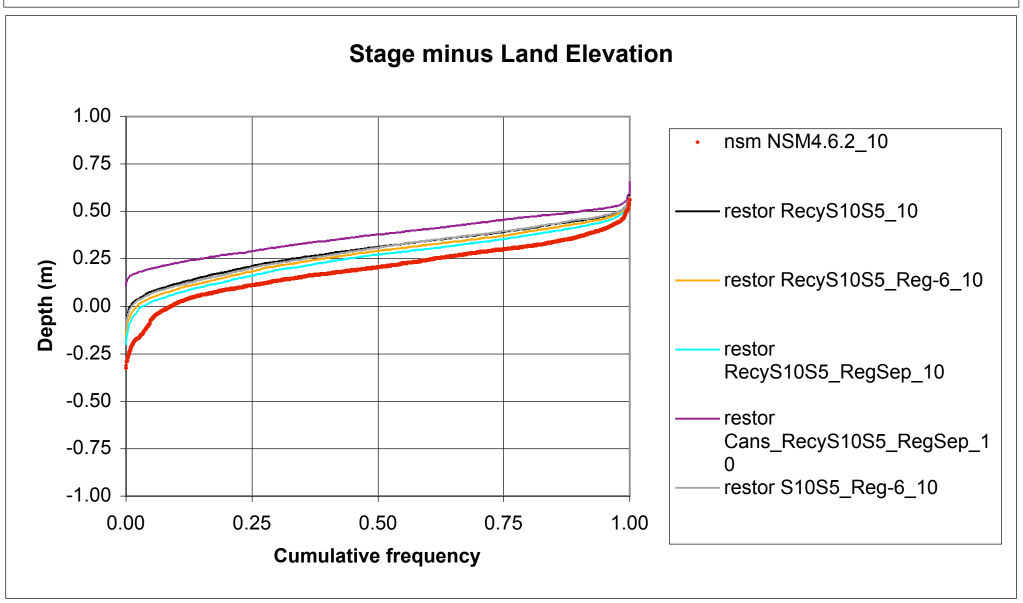




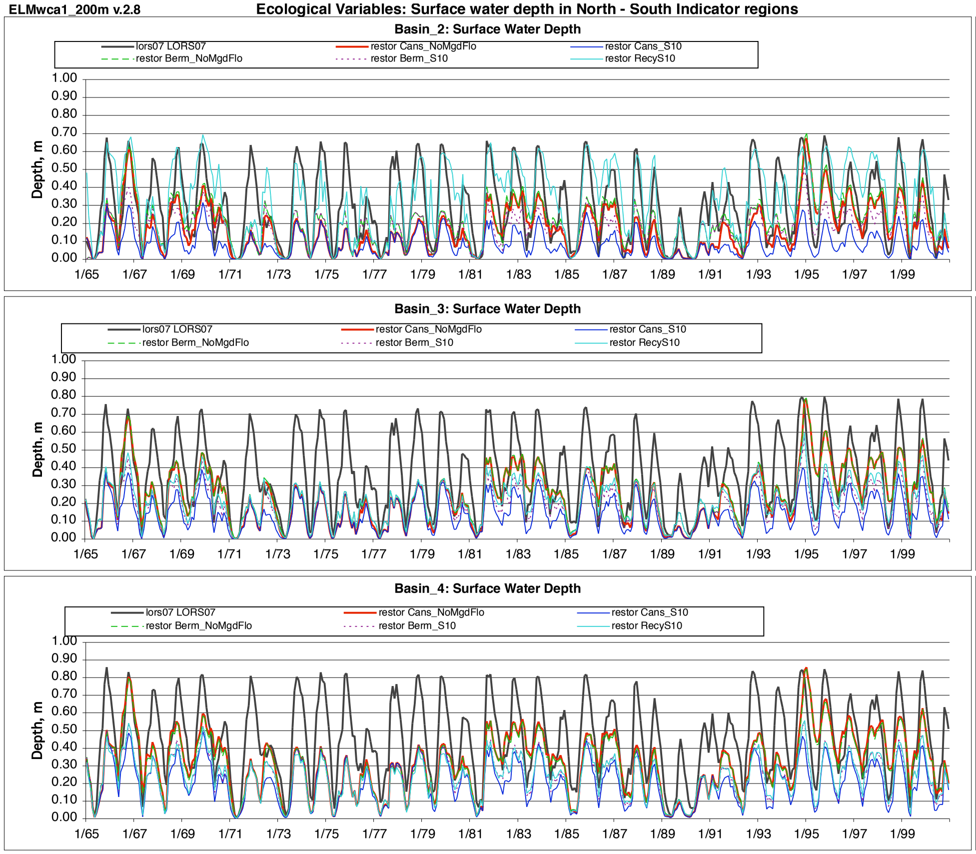
Model Project: ELMwca1_200m v.2.8 *Numeric suffix in legends = IR #*



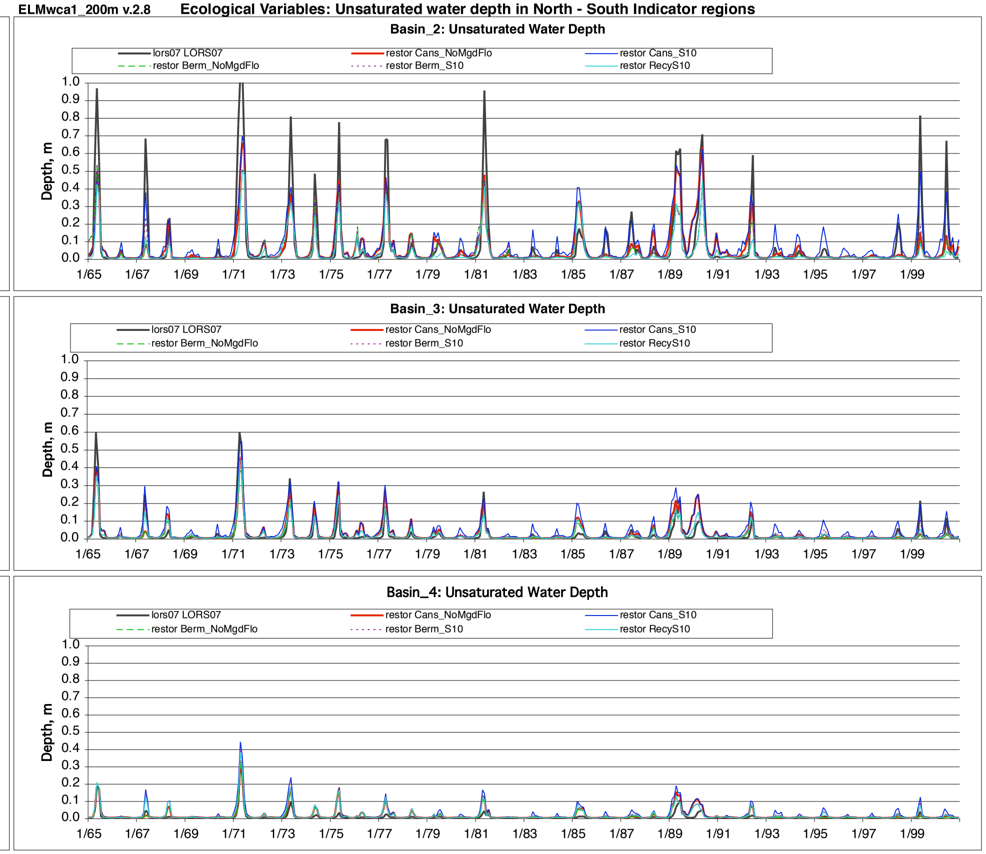




ELMwca1_200m v.2.8 **Ecological Variables: Surface water depth in North - South Indicator regions**

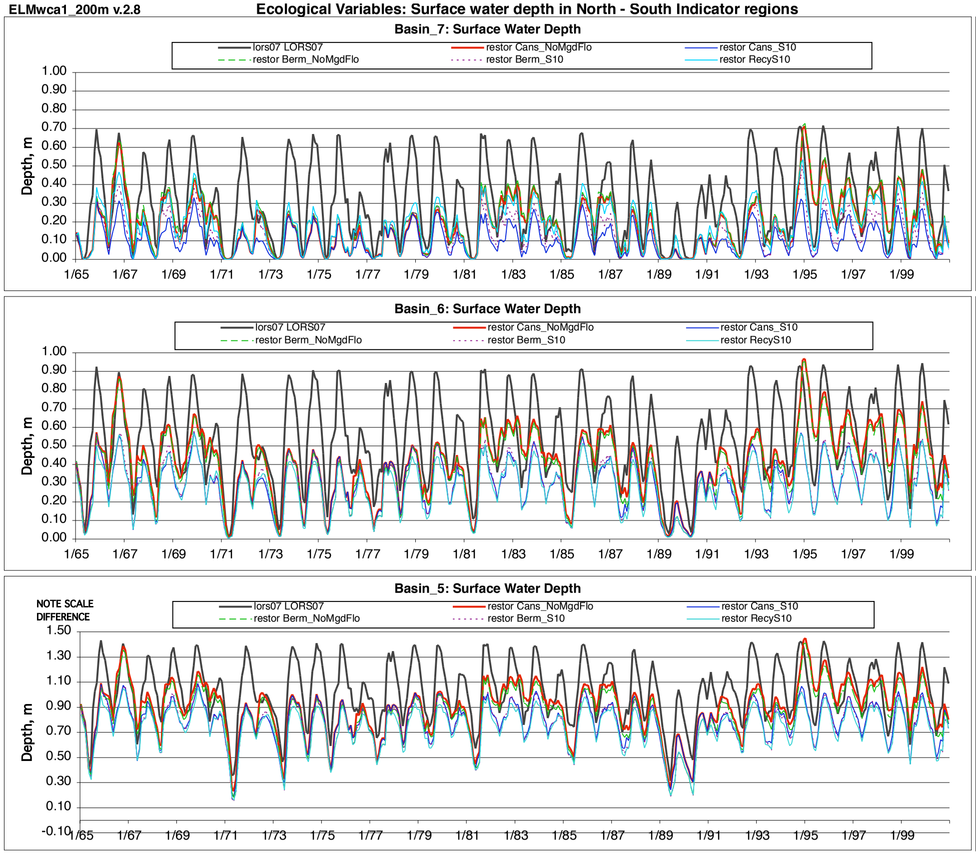


ELMwca1_200m v.2.8 **Ecological Variables: Unsaturated water depth in North - South Indicator regions**



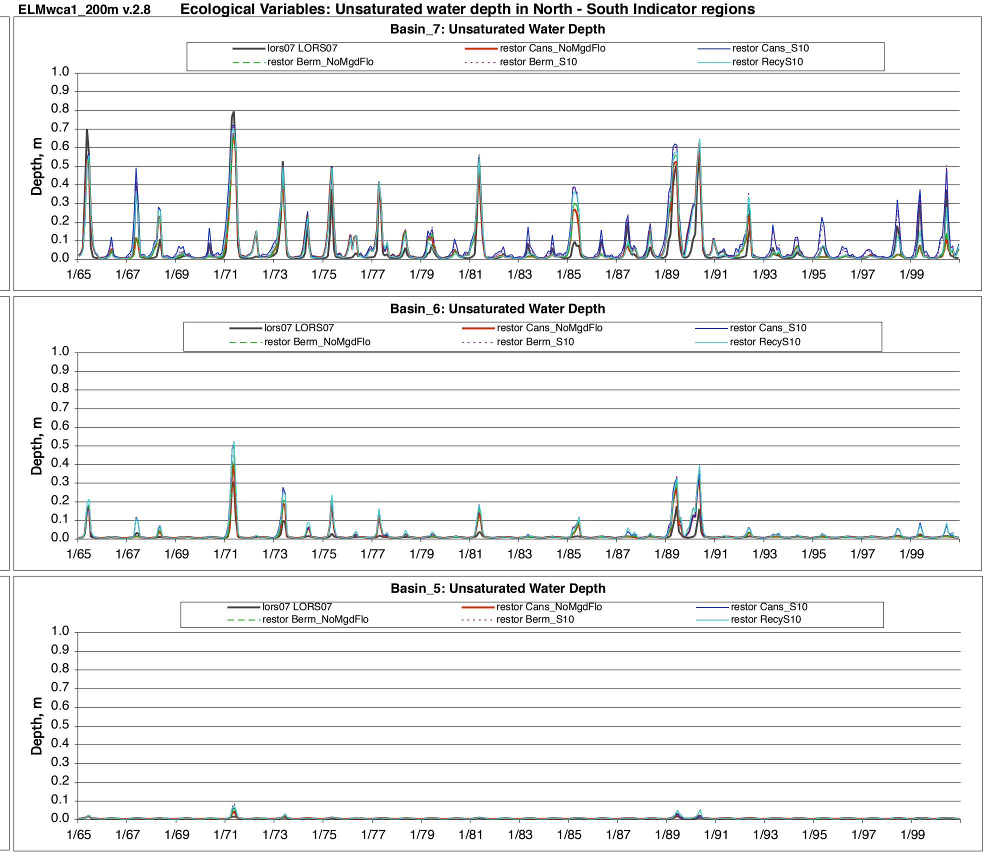
ELMwca1_200m v.2.8

Ecological Variables: Surface water depth in North - South Indicator regions



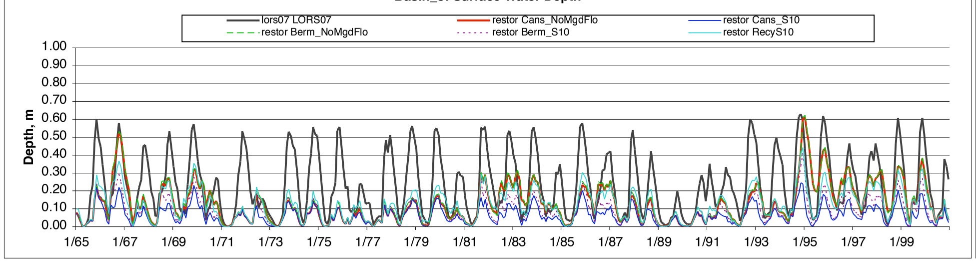
ELMwca1_200m v.2.8

Ecological Variables: Unsaturated water depth in North - South Indicator regions

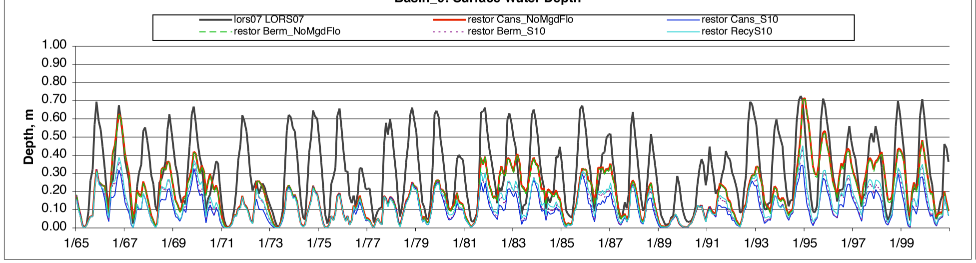


ELMwca1_200m v.2.8 **Ecological Variables: Surface water depth in North - South Indicator regions**

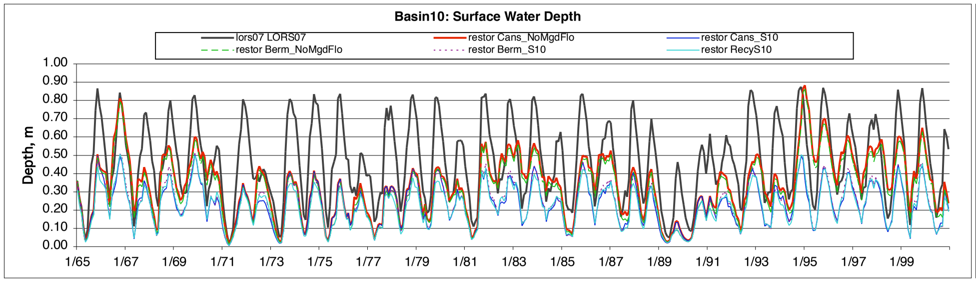
Basin_8: Surface Water Depth



Basin_9: Surface Water Depth

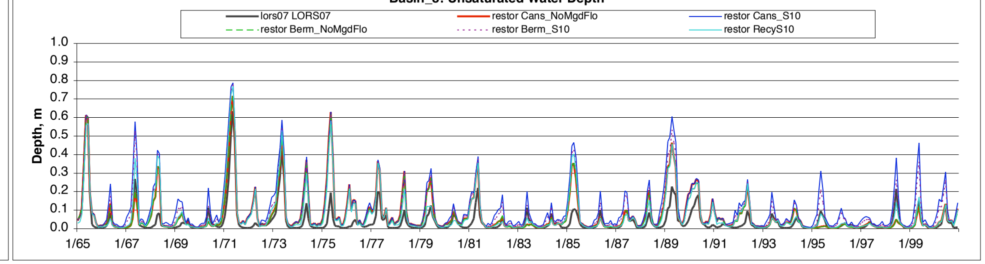


Basin10: Surface Water Depth

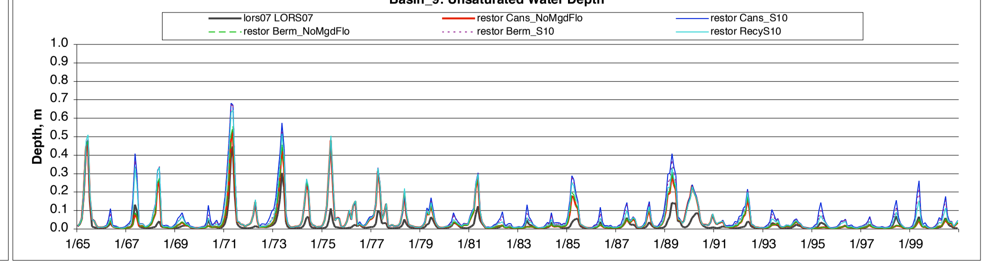


ELMwca1_200m v.2.8 **Ecological Variables: Unsaturated water depth in North - South Indicator regions**

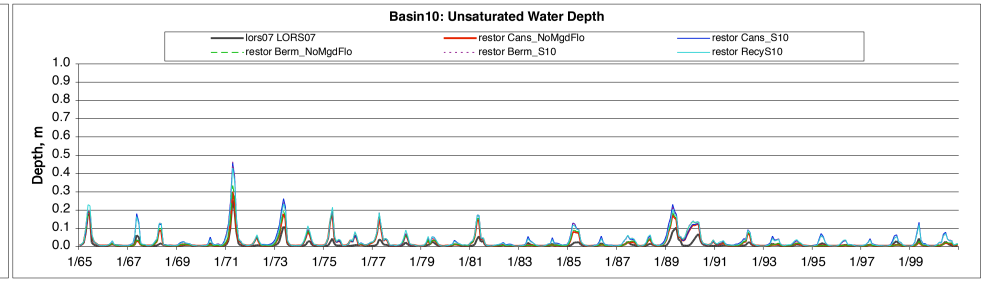
Basin_8: Unsaturated Water Depth



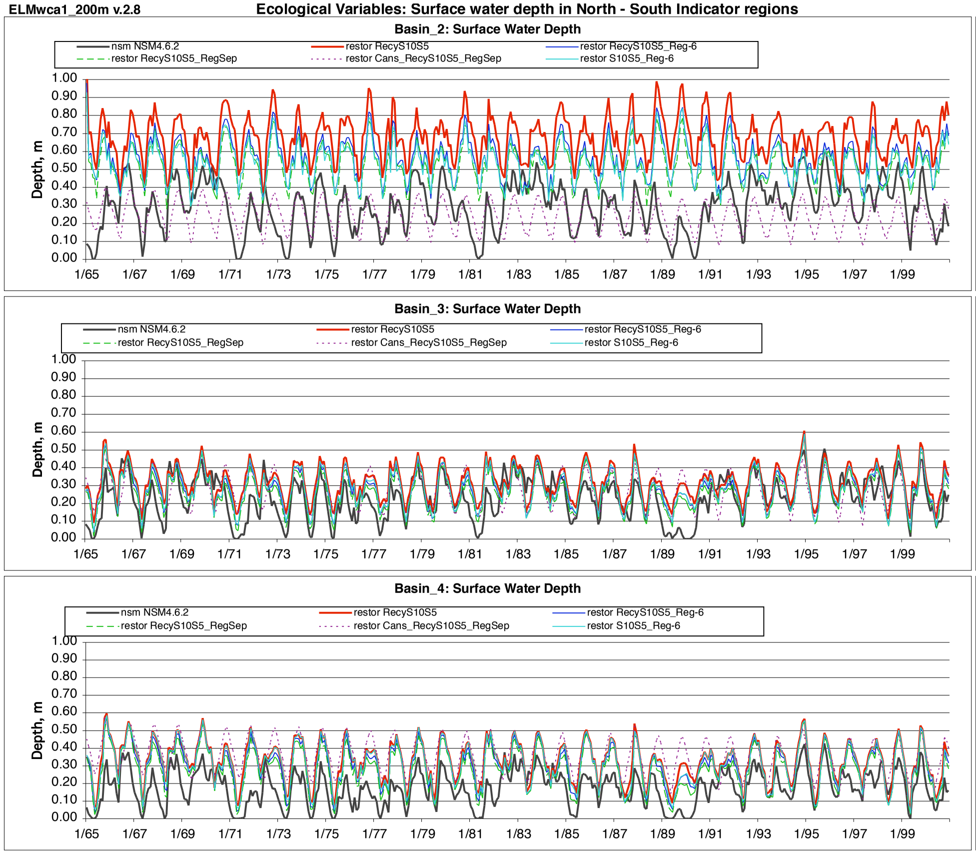
Basin_9: Unsaturated Water Depth



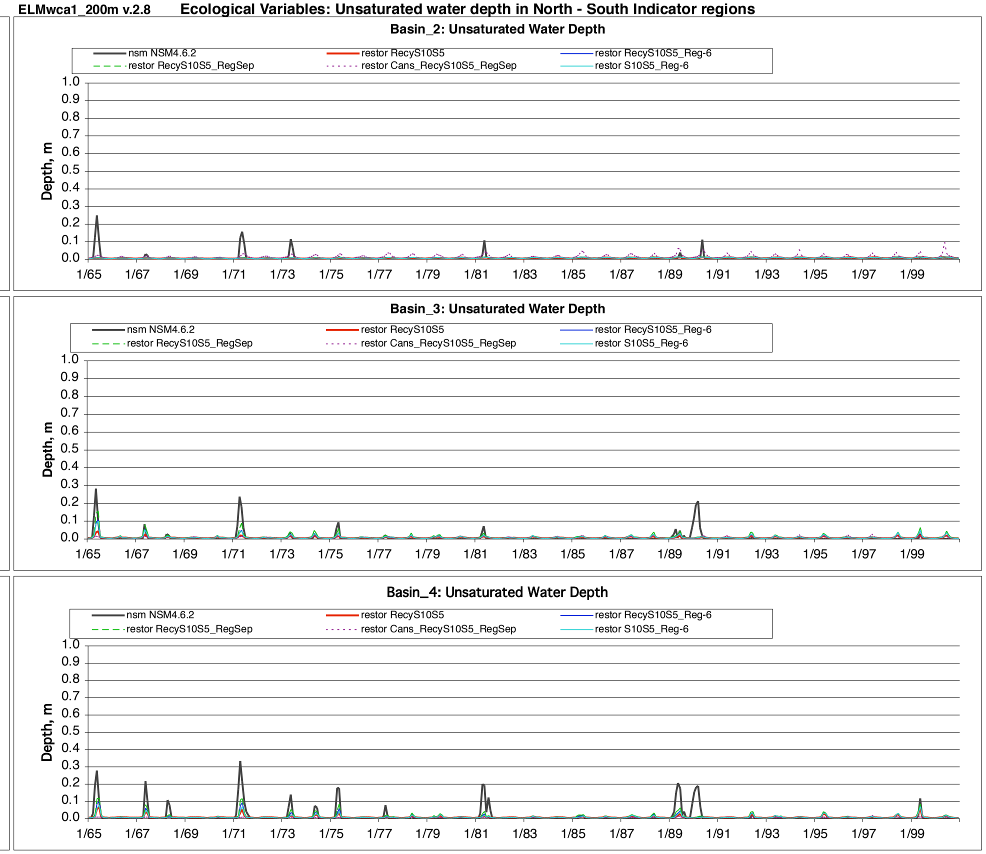
Basin10: Unsaturated Water Depth



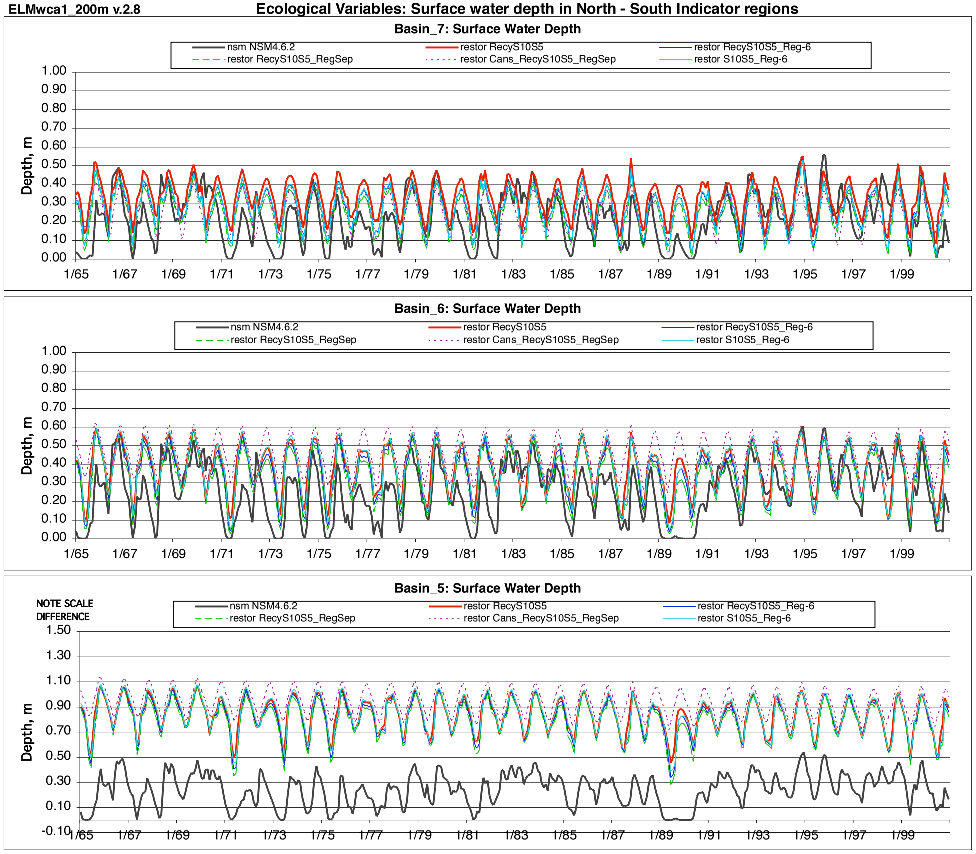
ELMwca1_200m v.2.8 **Ecological Variables: Surface water depth in North - South Indicator regions**



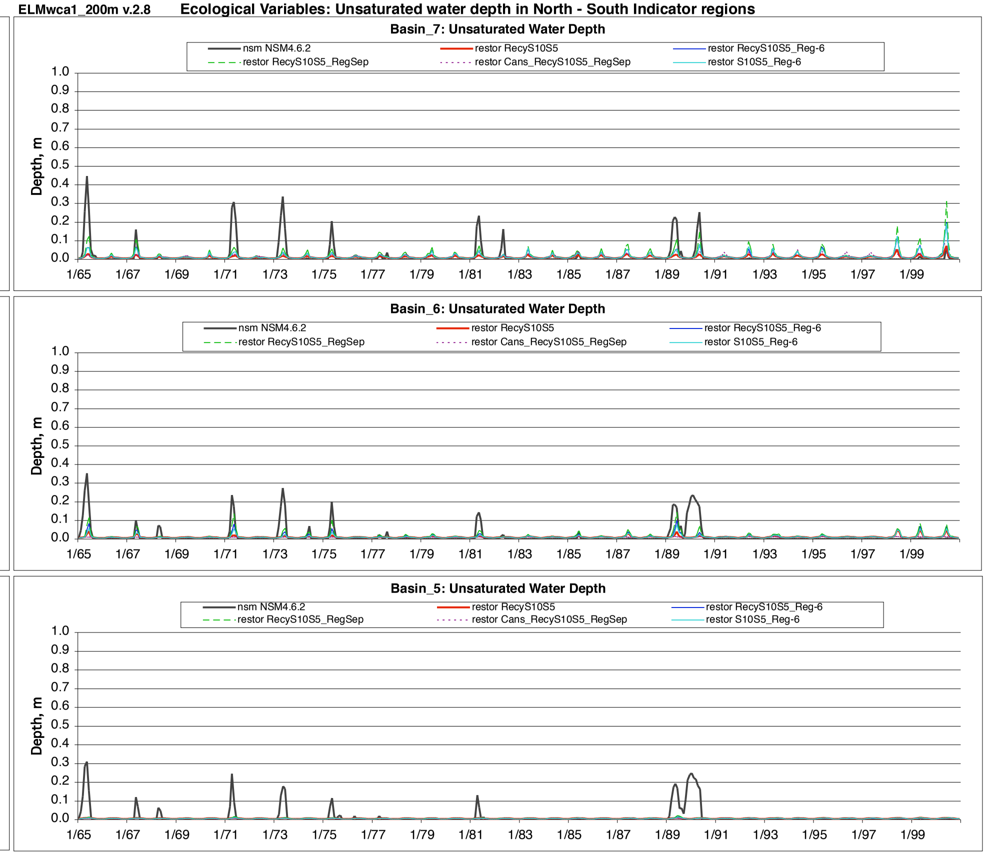
ELMwca1_200m v.2.8 **Ecological Variables: Unsaturated water depth in North - South Indicator regions**



ELMwca1_200m v.2.8 **Ecological Variables: Surface water depth in North - South Indicator regions**



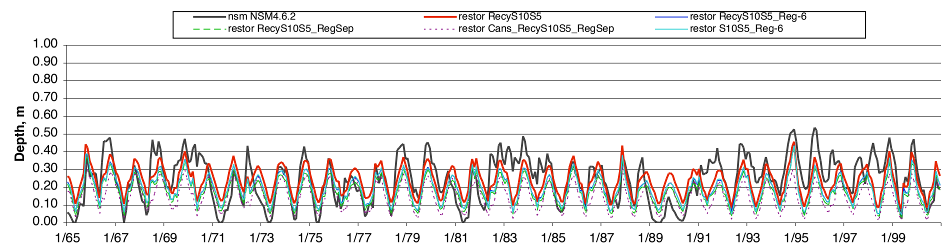
ELMwca1_200m v.2.8 **Ecological Variables: Unsaturated water depth in North - South Indicator regions**



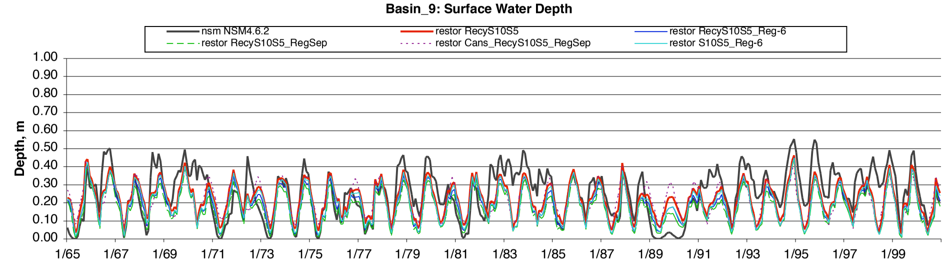
ELMwca1_200m v.2.8

Ecological Variables: Surface water depth in North - South Indicator regions

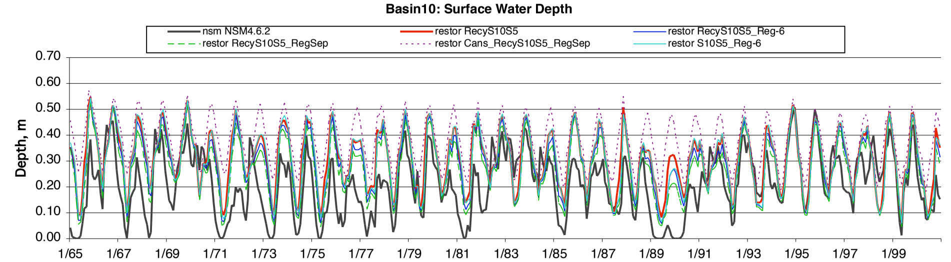
Basin_8: Surface Water Depth



Basin_9: Surface Water Depth



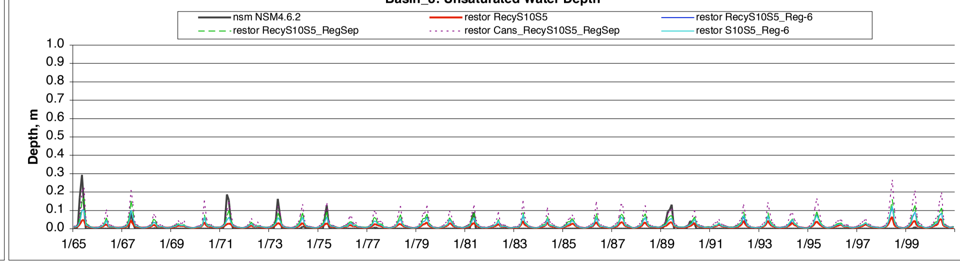
Basin10: Surface Water Depth



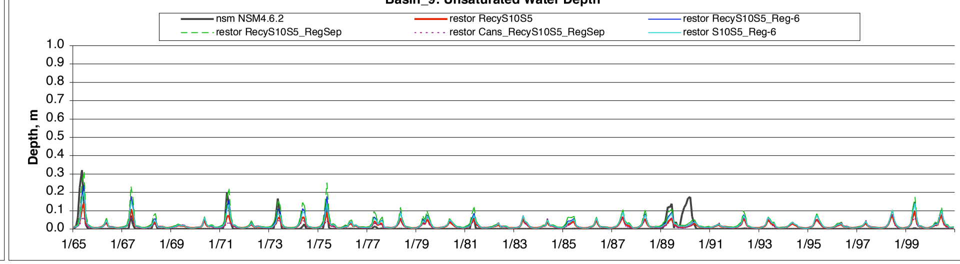
ELMwca1_200m v.2.8

Ecological Variables: Unsaturated water depth in North - South Indicator regions

Basin_8: Unsaturated Water Depth



Basin_9: Unsaturated Water Depth



Basin10: Unsaturated Water Depth