HOLISTIC METHOD:

INTEGRATION OF MULTIPLE COMPONENTS IN FLOW MODELING

Presented to Third International Workshop on Instream Flows
Portland, Oregon – April 30, 2015

Thomas R. Payne
Normandeau Associates, Inc.

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HOLISTIC INSTREAM FLOW METHODS:

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HOLISTIC INSTREAM FLOW METHODS:

INTEGRATION OF MULTIPLE COMPONENTS IN HYDRAULIC HABITAT MODELING

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"HOLISTIC" – A DEFINITION

Holism: A theory or belief that the whole is greater than the sum of the parts.

Holistic: Relating to a study of the whole instead of a separation into parts.

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HOLISTIC METHODS

Derived from natural flow concepts

"Holistic methodologies aim to address the water requirements of the entire riverine ecosystem."
Arthington et al. 1992

"All components or attributes of an ecosystem and their interrelationships are addressed."
Tharme 1996

"The ecological integrity of river ecosystems depends on their natural dynamic character."
Poff et al. 1997

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HOLISTIC METHODS (1996)

- Building Block Methodology/DRIFT
- The Holistic Approach
- Expert Panel Assessment Method
- Multi-attribute Tradeoff Analysis
- Energy Analysis
- Habitat Analysis Method
- Flow Restoration Methodology

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"COMPREHENSIVE" - A DEFINITION

Comprehensive: complete; including all or nearly all elements or aspects of a topic

Does holistic equal integrative?

Does comprehensive equal analytic?

Which approach – holistic/integrative or comprehensive/analytic – is better for addressing uncertainty?

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HOLISTIC/COMPREHENSIVE METHODS

- Baxter – Scotland – 1961
  - "A variable compensation flow regime based on the seasonal needs of fish and of the river, and incorporating (essentially) provision for the release of freshets."
  - Hydrologic variability, salmon life history (attraction, spawning, incubation, maintenance), food supply, angling, freshets, percent ADF

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HOLISTIC/COMPREHENSIVE METHODS

- Tennant – Montana – 1975
  - "Flows to protect the aquatic resources in both warmwater and coldwater streams based on their average flow… to protect the natural environment on most streams."
  - Hydrologic variability, channel widths, depths, and velocities, wetted side channels, wildlife habitat (nesting, denning, nursery, refuge), water temperature, riparian vegetation, recreation, aesthetics, percent MAF

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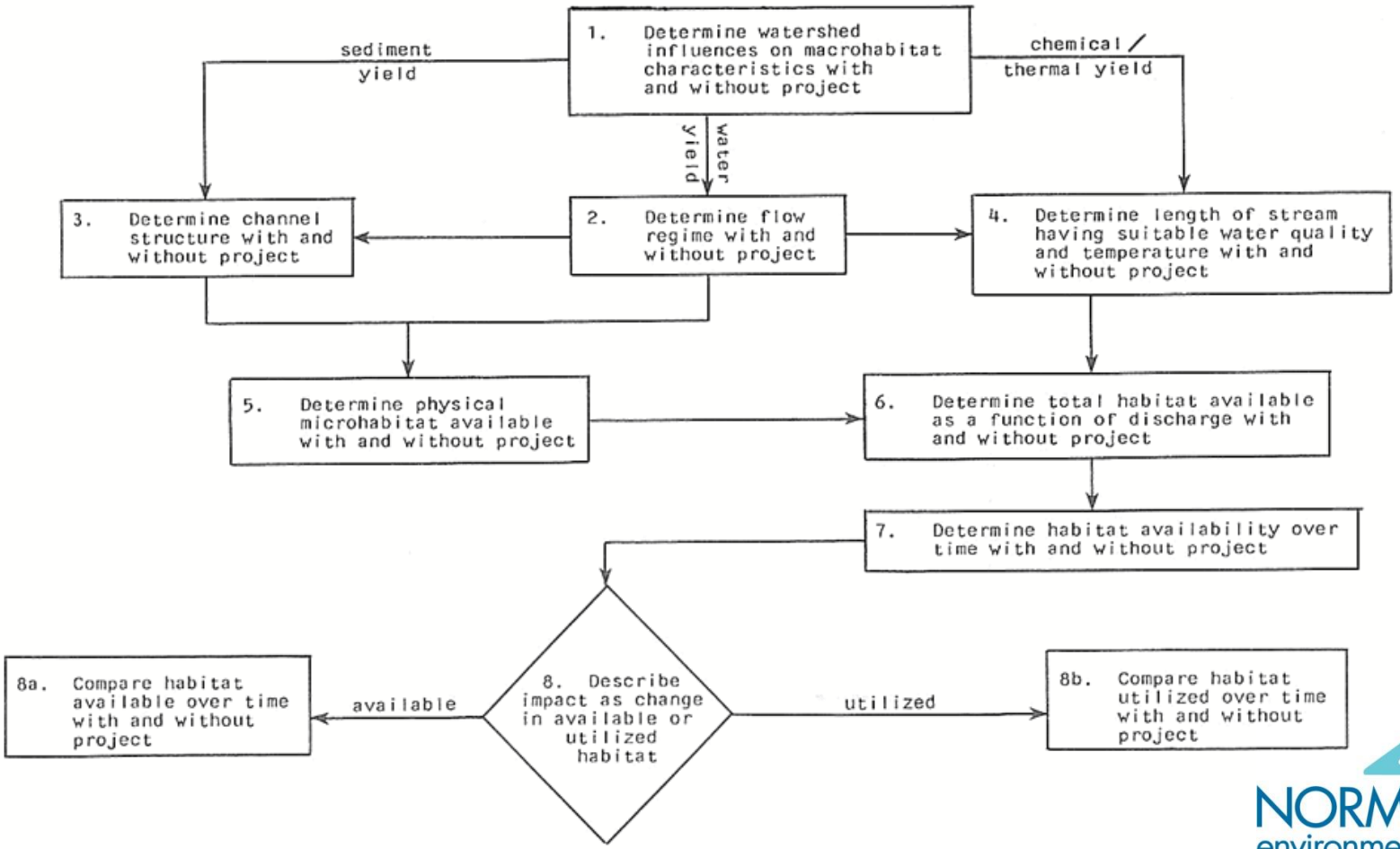
ANALYTIC/COMPREHENSIVE METHODS

Instream Flow Group – Colorado - 1978



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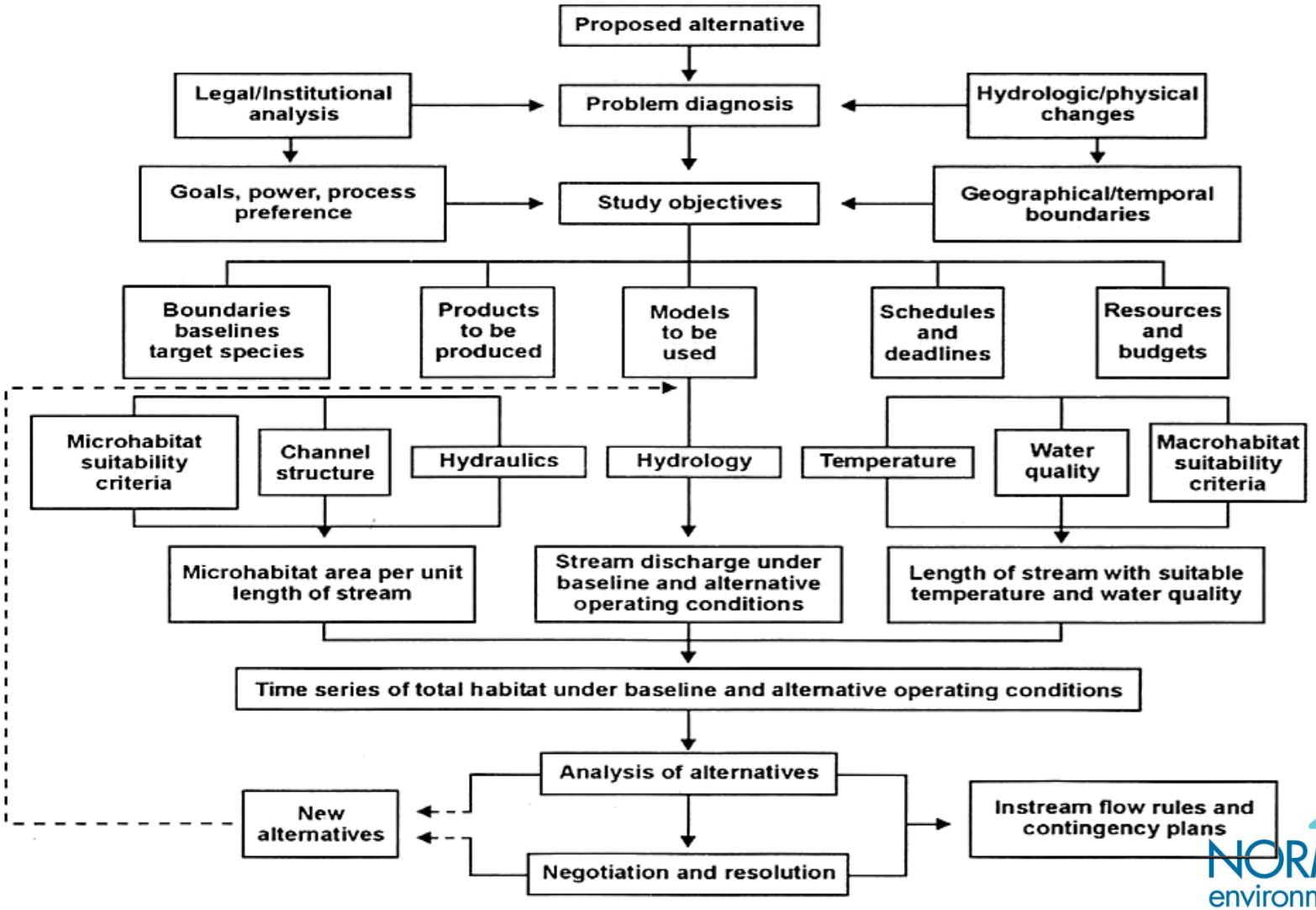
INSTREAM FLOW INCREMENTAL METHODOLOGY



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INSTREAM FLOW (U.S.) CIRCA 1990

- Instream flow management decisions
  - Single/few fish species management
  - Other species neglected
  - Ecosystem processes neglected
  - Riparian vegetation neglected
  - Geomorphic processes neglected
  - Hydrologic variability neglected
- You don't blame the cookbook when the chefs don't follow the recipe!

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REACTION FROM ECOLOGISTS

- 1990s approaches were "overly simplistic and reductionist" of complex ecosystem processes
  - Indicators of Hydrologic Alteration
    - Richter et al. 1996
  - Holistic Methods
    - Tharme 1996
  - Range of Variability Approach
    - Richter et al. 1997
  - The Natural Flow Regime
    - Poff et al. 1997

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SO WHERE ARE WE NOW?

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TWO MAJOR DIRECTIONS

- Holistic/Integrative – start with hydrology and incorporate ecological response mechanisms
- Comprehensive/Analytic – start with biological and physical mechanisms and incorporate hydrology

How do either or both help us deal with uncertainty?

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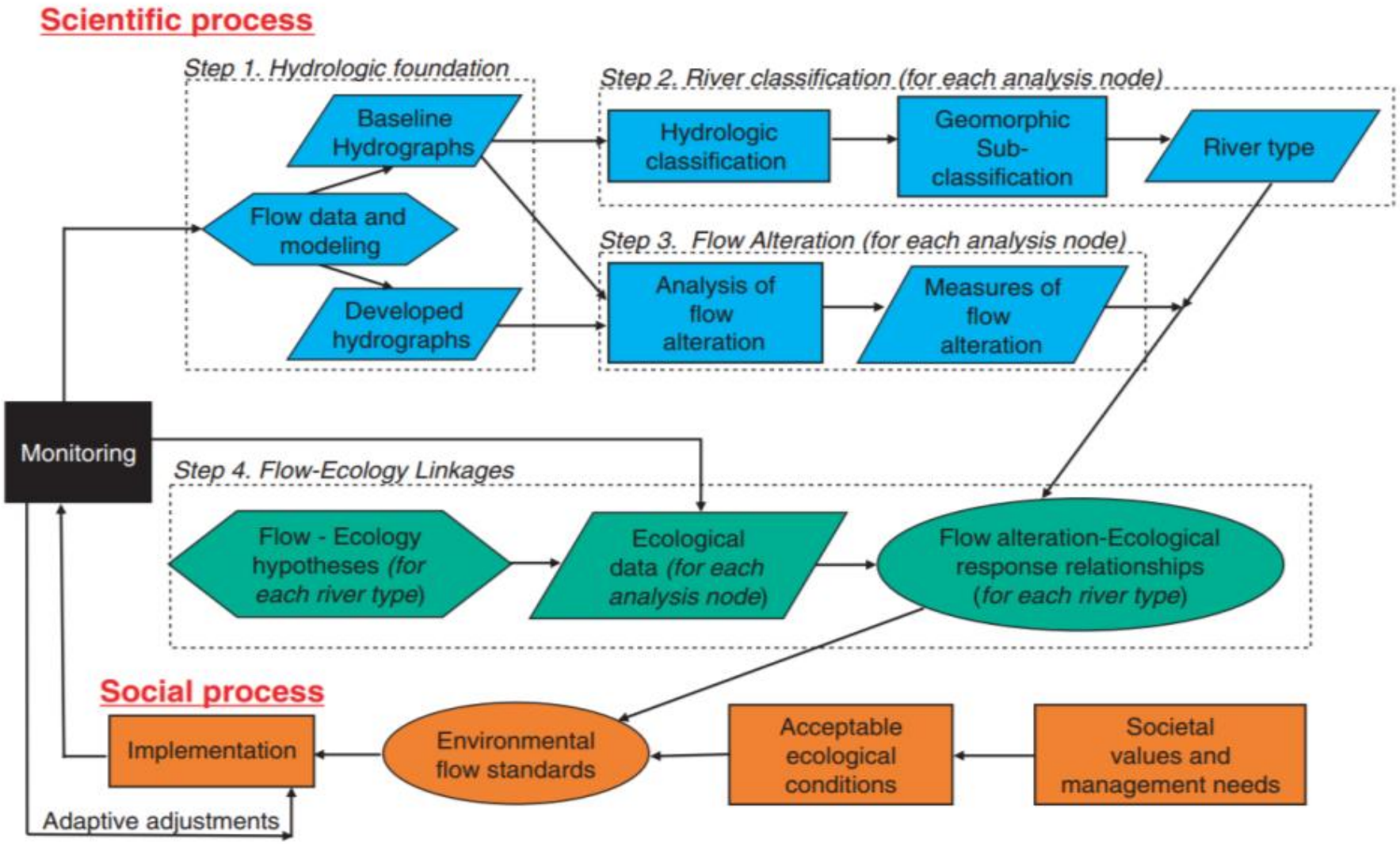
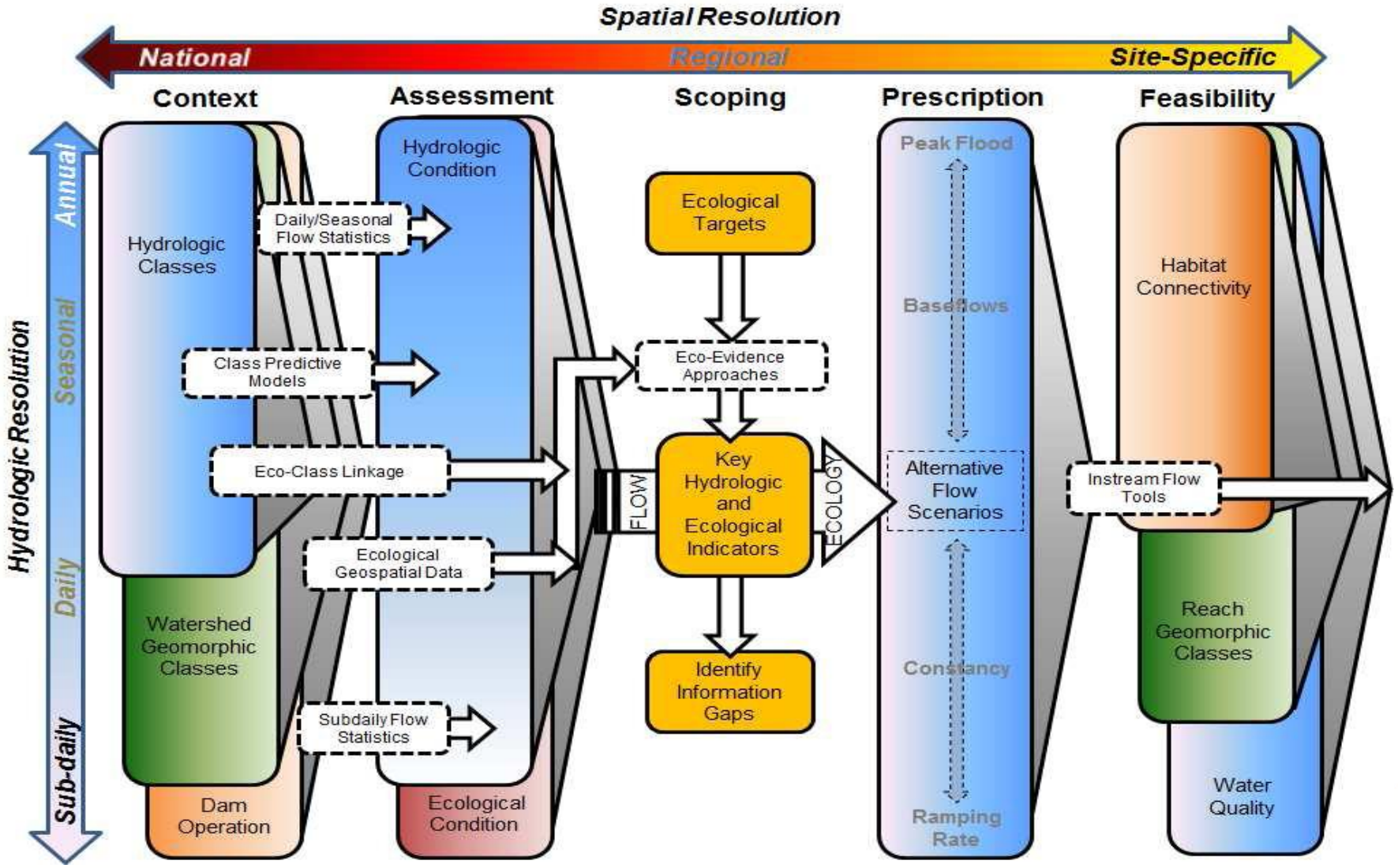
ELOHA (ECOLOGICAL LIMITS OF HYDROLOGIC ALTERATION)

Poff et al. 2009



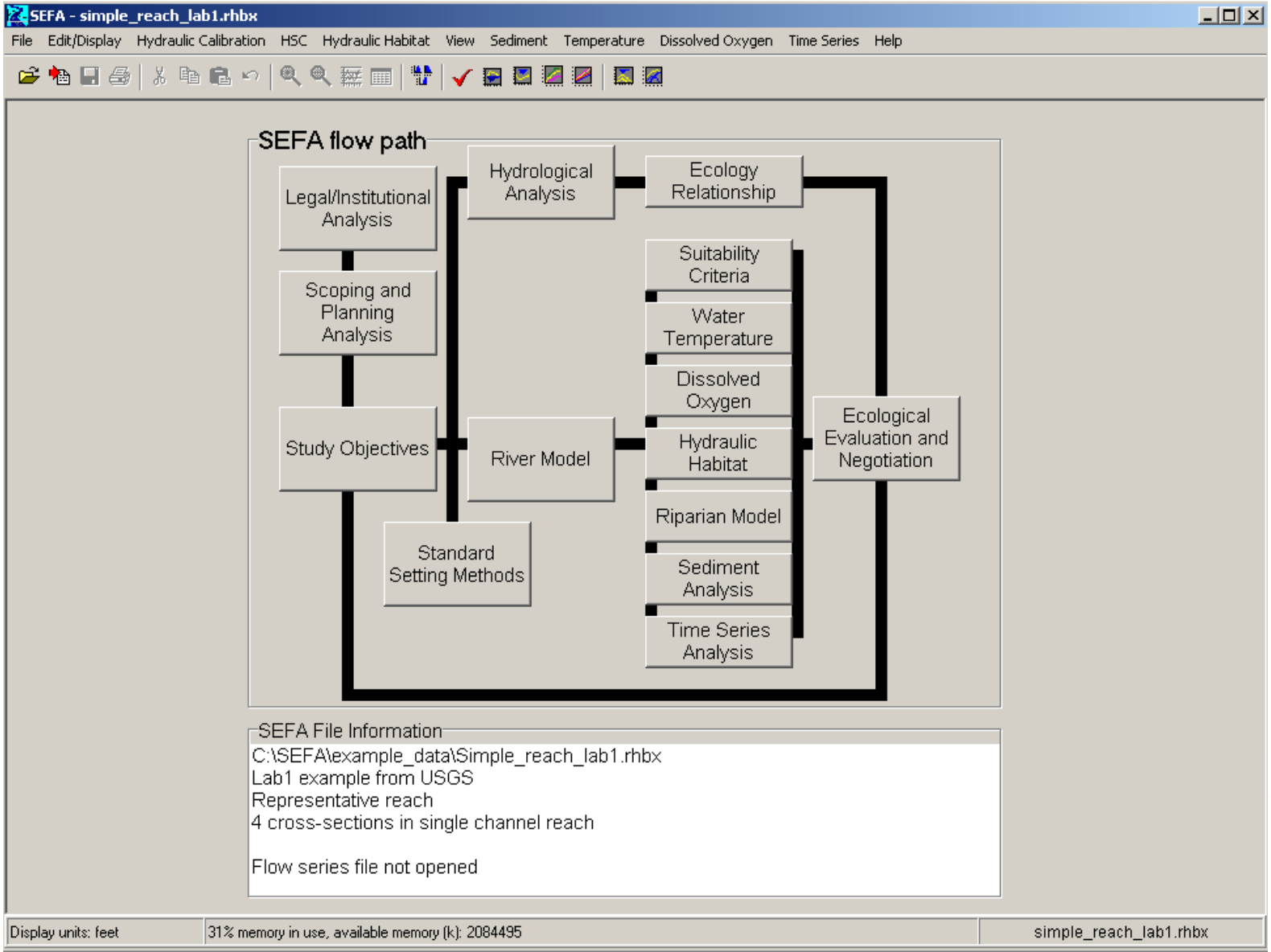
HEFLOW (HYDROPOWER ENVIRONMENTAL FLOW)

McManamay and Bevelheimer 2013



SEFA (SYSTEM FOR ENVIRONMENTAL FLOW ANALYSIS)

Payne and Jowett 2012



SEFA (SYSTEM FOR ENVIRONMENTAL FLOW ANALYSIS)

- Merges PHABSIM (Milhous), RHABSIM (Payne), and RHYHABSIM (Jowett)
- Based on IFIM implementation schematic and includes numerous analytic elements
- User-friendly format, menu-driven, report-quality graphics, interactive help files
- Contains several environmental flow methods, with the ability to incorporate, compare, or contrast alternative approaches

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ELEMENTS OF SEFA

- Hydraulic Habitat Analysis (1D and 2D import)
- Habitat Suitability Criteria (HSC)
- Water Temperature Modeling (reach daily)
- Water Quality Modeling (D.O., dilution)
- Sediment Analysis (flushing, transport, deposition)
- Riparian Vegetation Analysis (inundation, scour)
- Hydrologic Analysis (IHA and statistics)
- Habitat Duration and Time Series
- Legal-Institutional Analysis (LIAM)

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IMPLEMENTATION OF SEFA

- Completely open to user choice:
  - Start from the first module
  - Start anywhere within the program
  - Select modules to run or not run
  - Use alternative models and return with data
- Link results from different elements
  - Habitat analysis with water temperature
  - Combine 1D and 2D habitat modeling

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HYDRAULIC MODELING ELEMENT

- Log-log floating or bound regression, channel conveyance, and step-backwater water surface simulation methods
- Manning's n, hydraulic conveyance, and logD velocity simulation methods
- Interactive water surface calibration
- Interactive water velocity calibration
- Models split channels in a single file
- Uses either metric or US units

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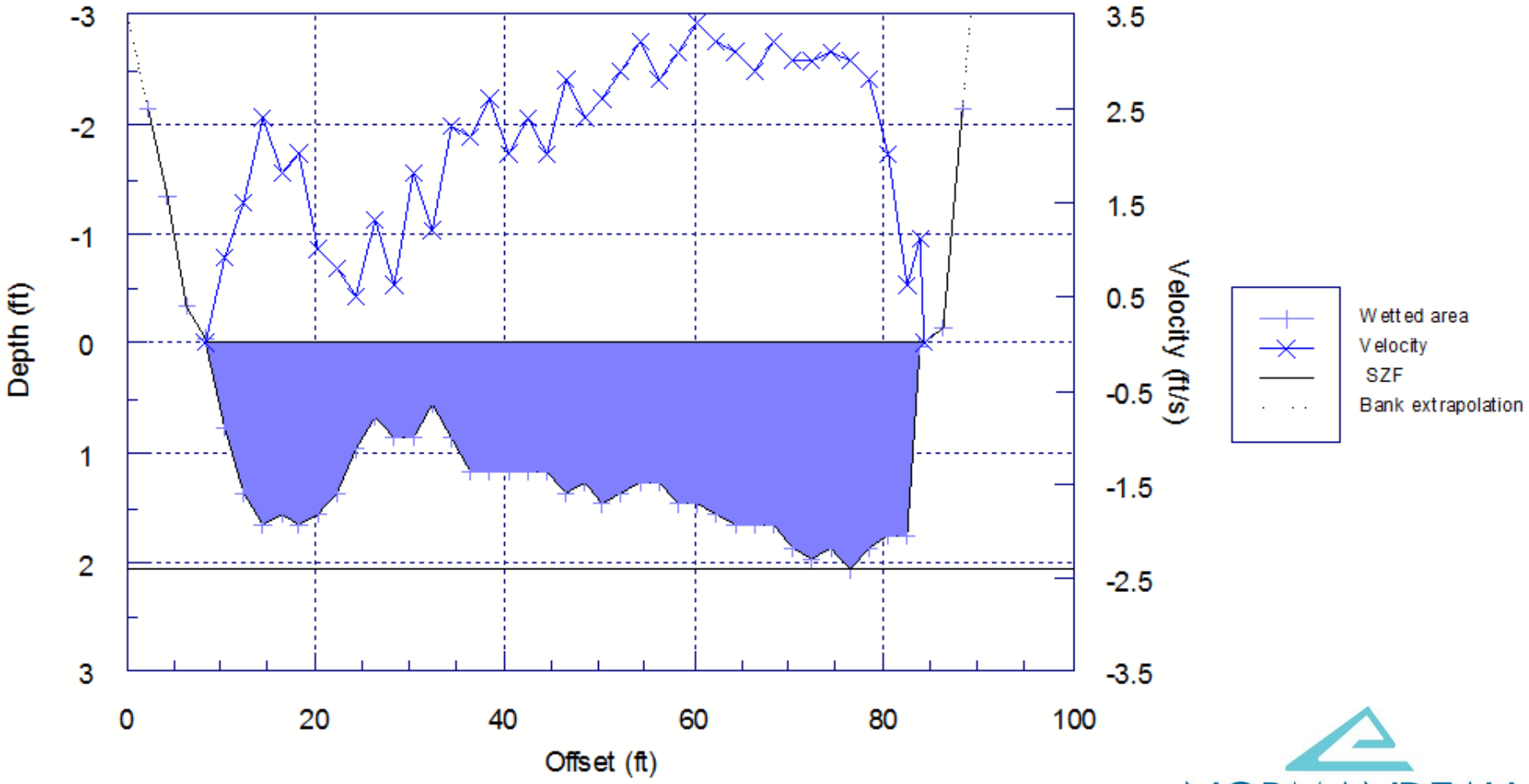
CROSS SECTION PROFILE AND VELOCITY



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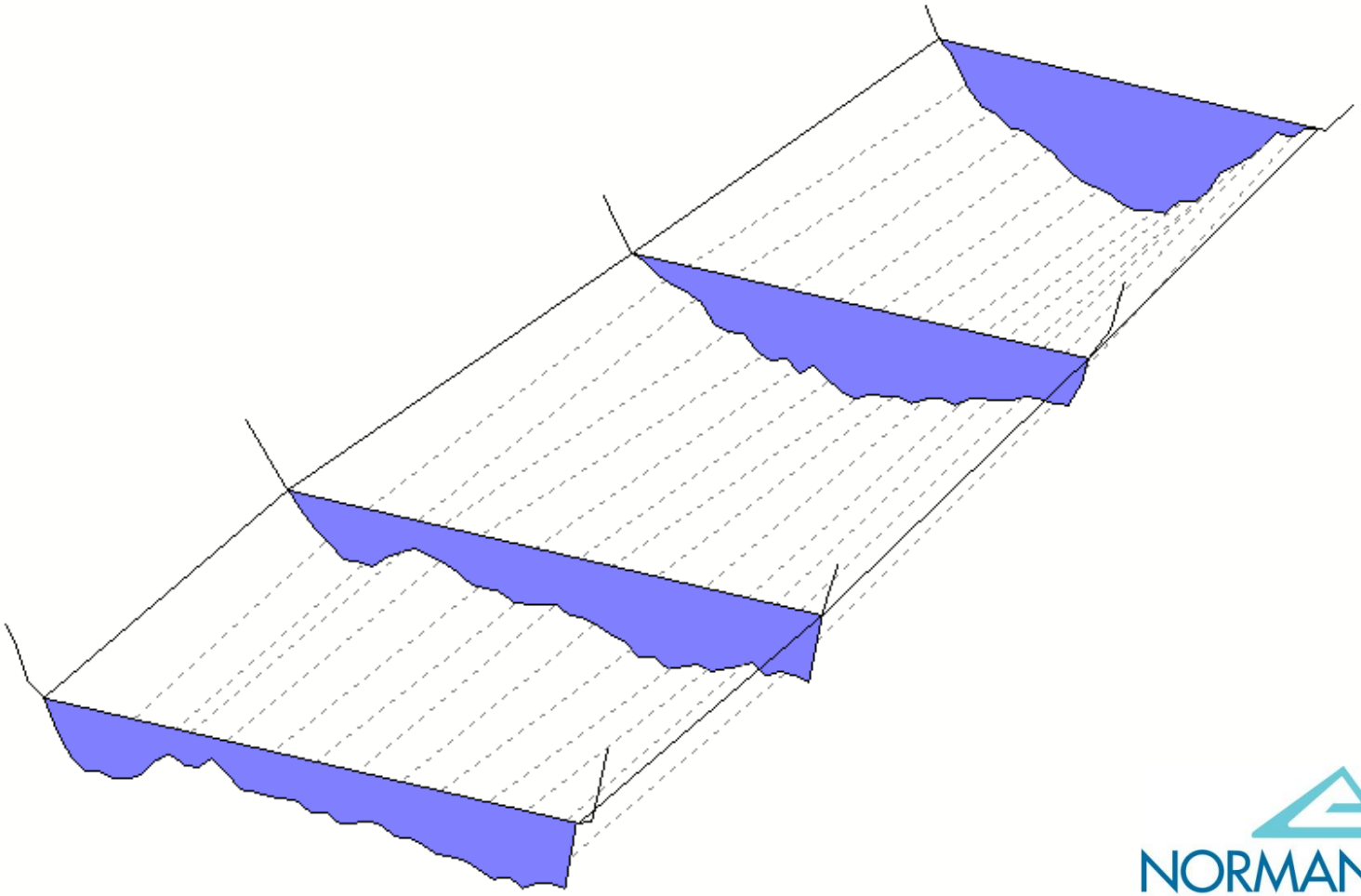
ISOMETRIC VIEW OF CROSS SECTIONS



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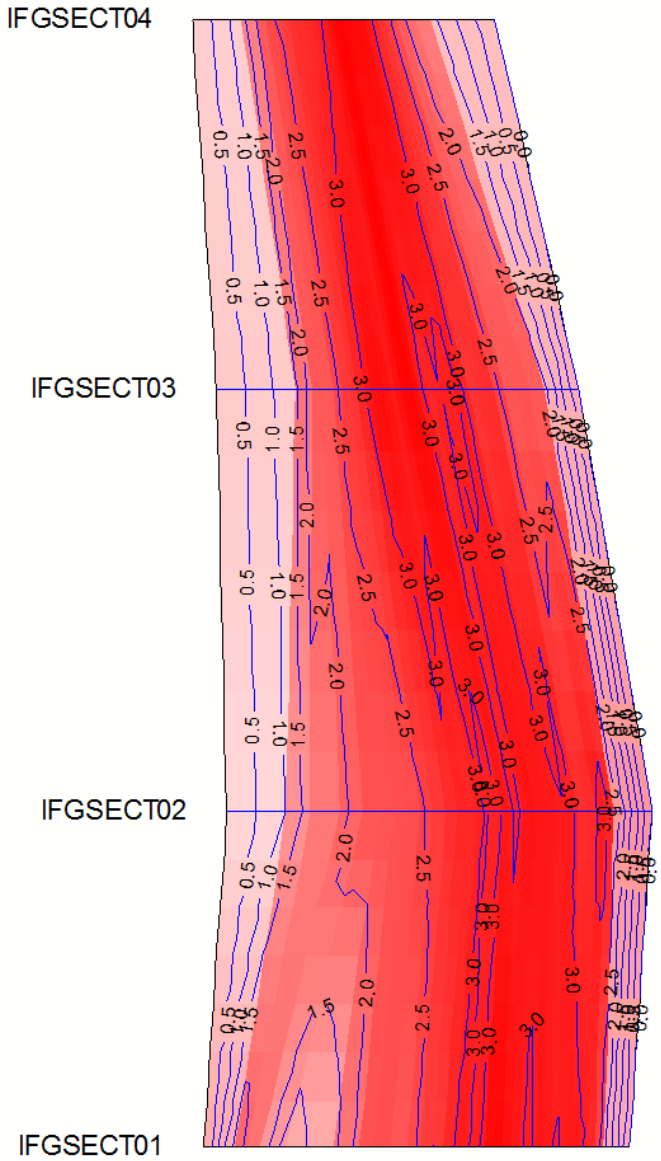
REACH PLAN VIEW OF CROSS SECTIONS



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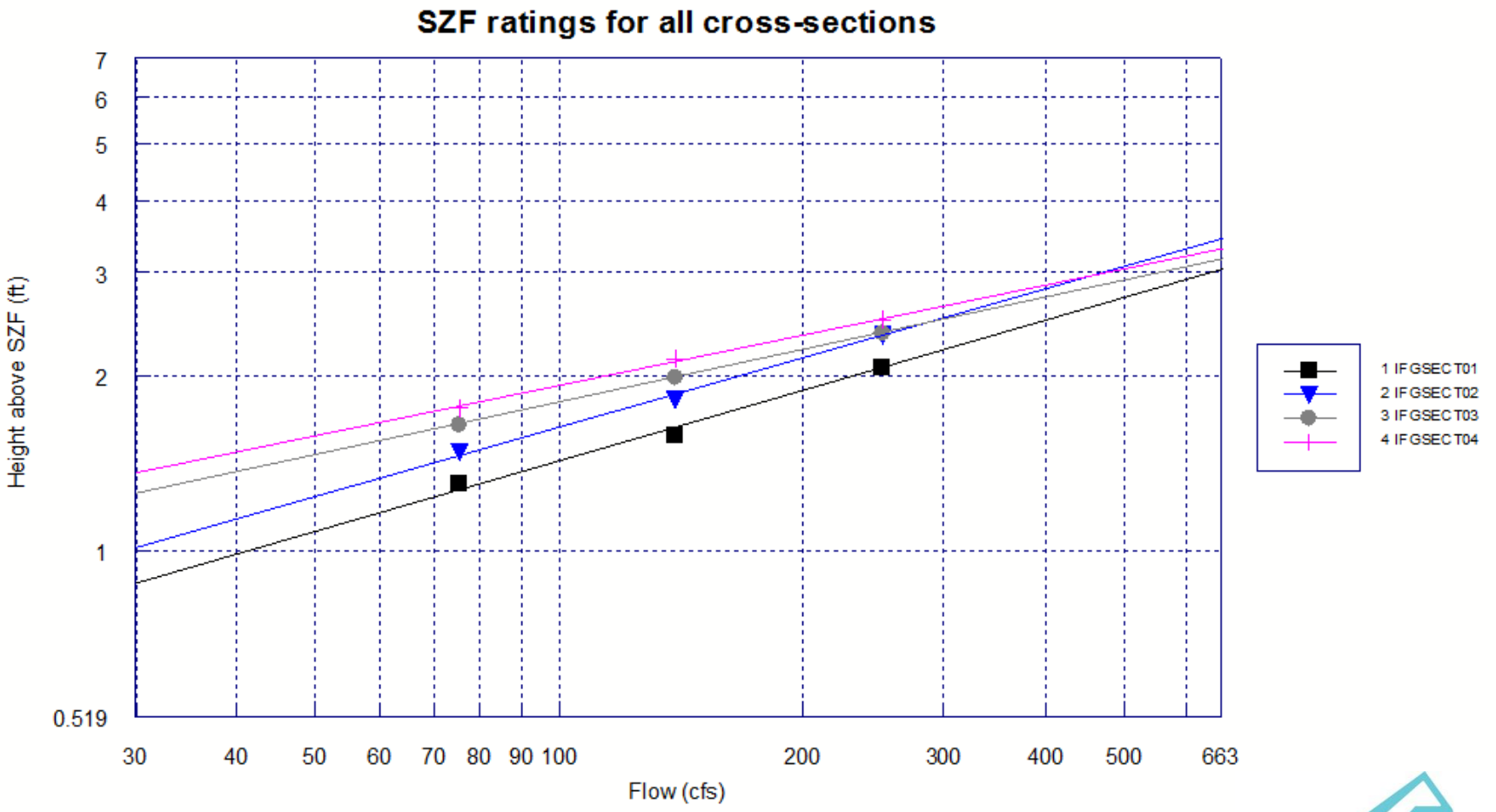
STAGE-DISCHARGE RATING CURVES



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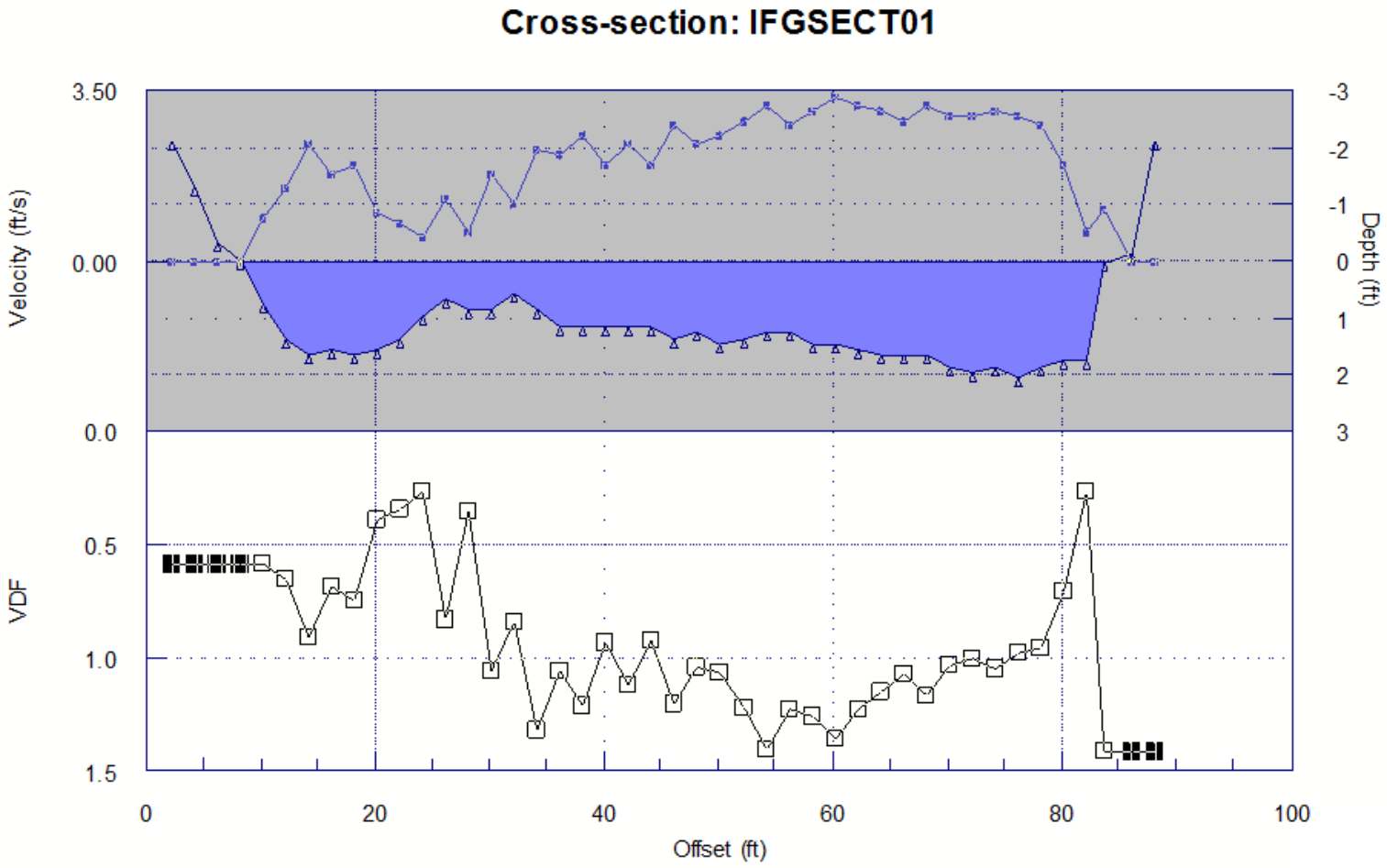
WATER VELOCITY CALIBRATION



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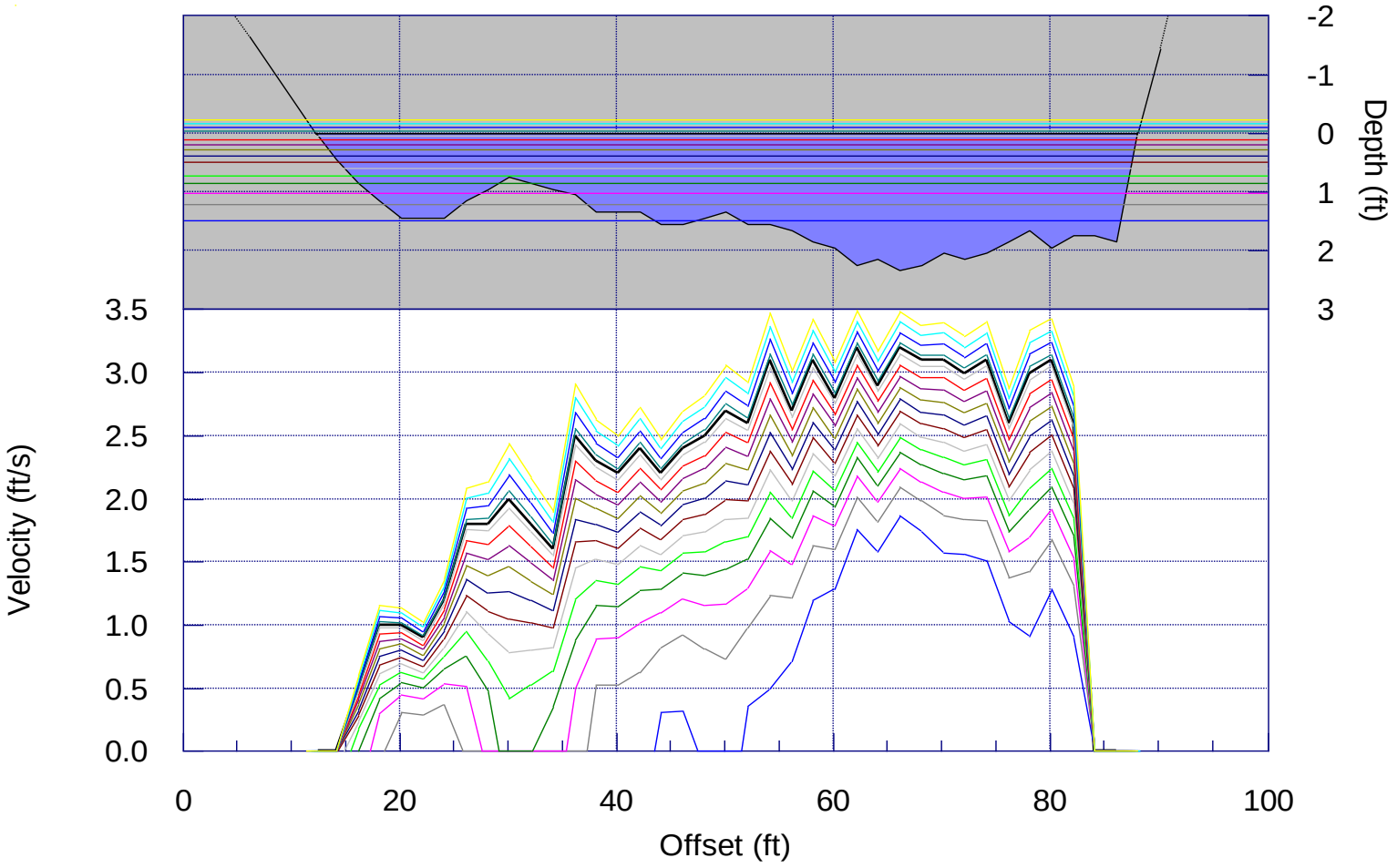
VELOCITY AND DEPTH SIMULATION



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HABITAT SUITABILITY CRITERIA ELEMENT

- Maintains libraries of HSC
- Creates HSC from sampling data
- Linear, kernal, lowess, and loess smoothing
- Multiple regression models
- Generalized additive models (GAMS)
- Generalized linear models
- Variable interactivity evaluation

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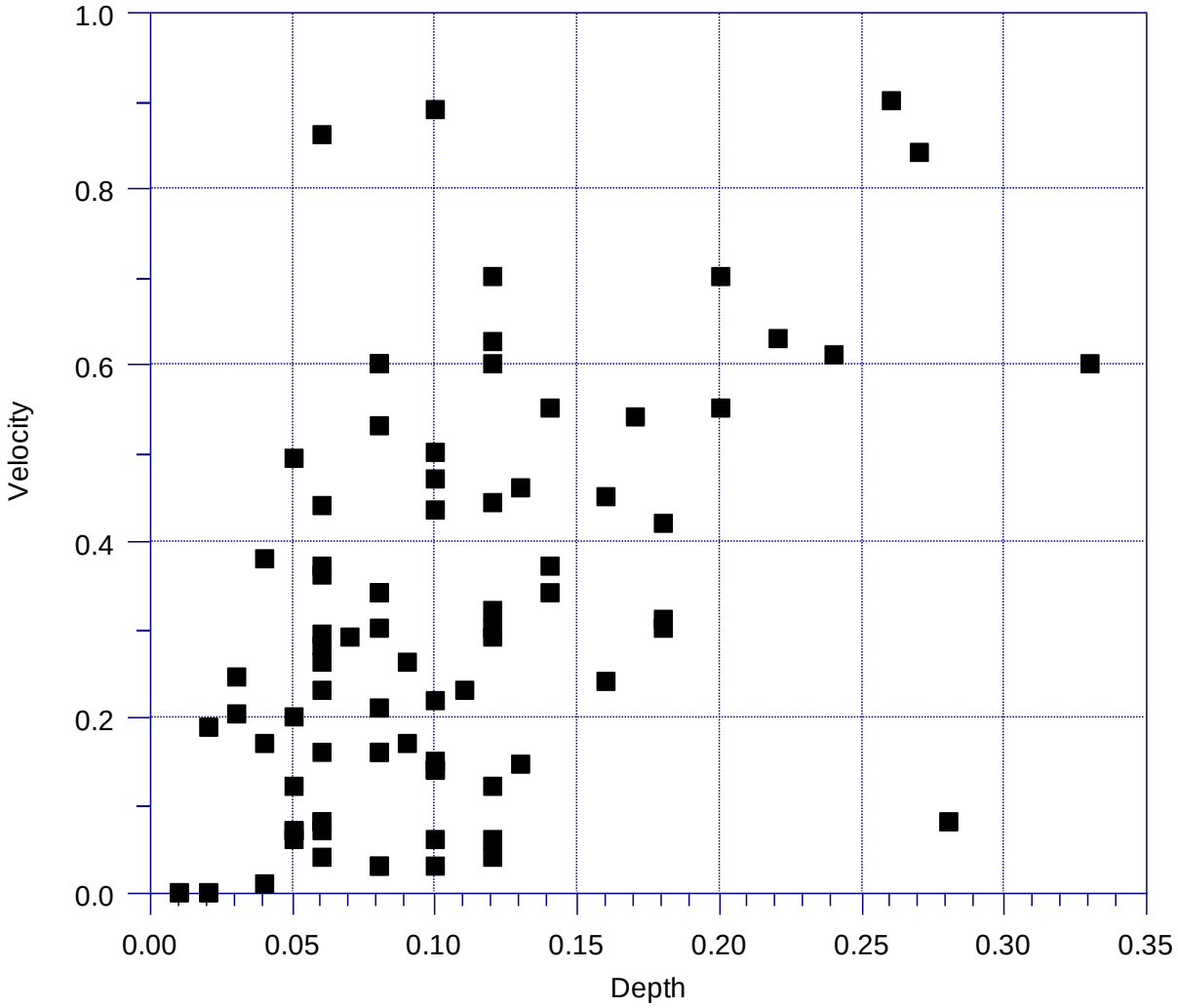
FISH OBSERVATION SCATTER PLOT



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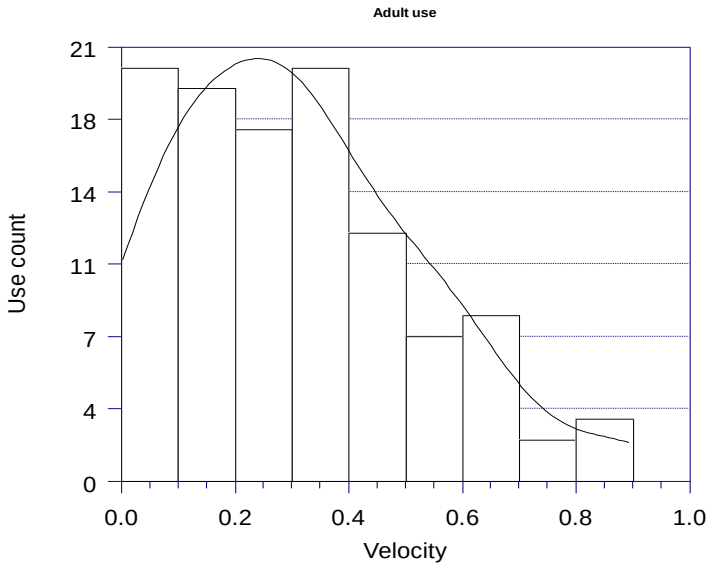
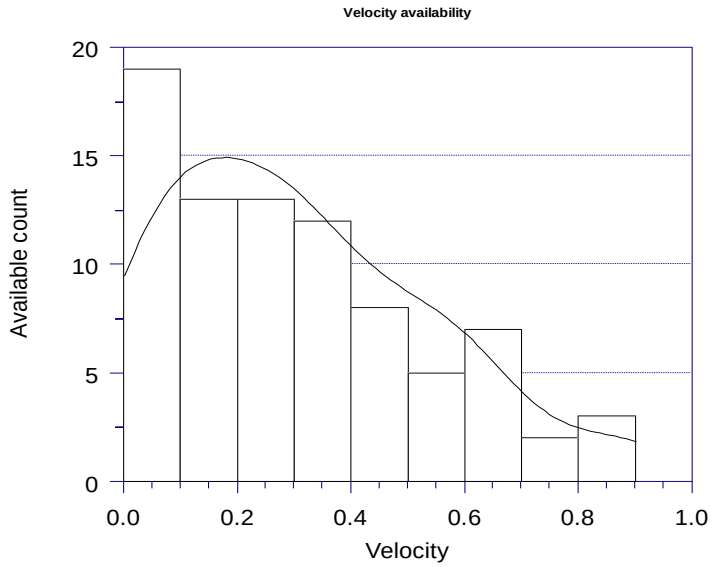
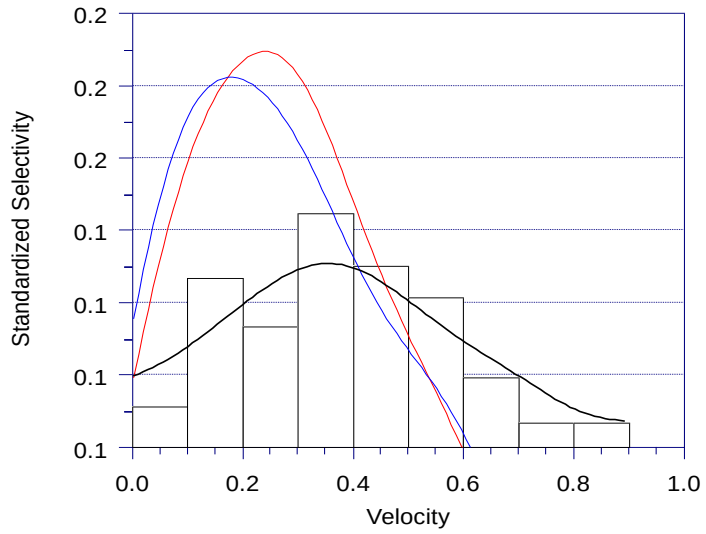
HSC DEVELOPMENT AND EVALUATION







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HYDRAULIC HABITAT SIMULATION

- Links hydraulics with HSC to compute Area Weighted Suitability (AWS) (~~WUA~~)
- Multiple methods of linkage
  - Multiplication of individual suitabilities
  - Geometric mean of individual suitabilities
  - Minimum of individual suitabilities
- Habitat predictions for points (~~cells~~), cross-sections, and reaches
- Sensitivity analysis

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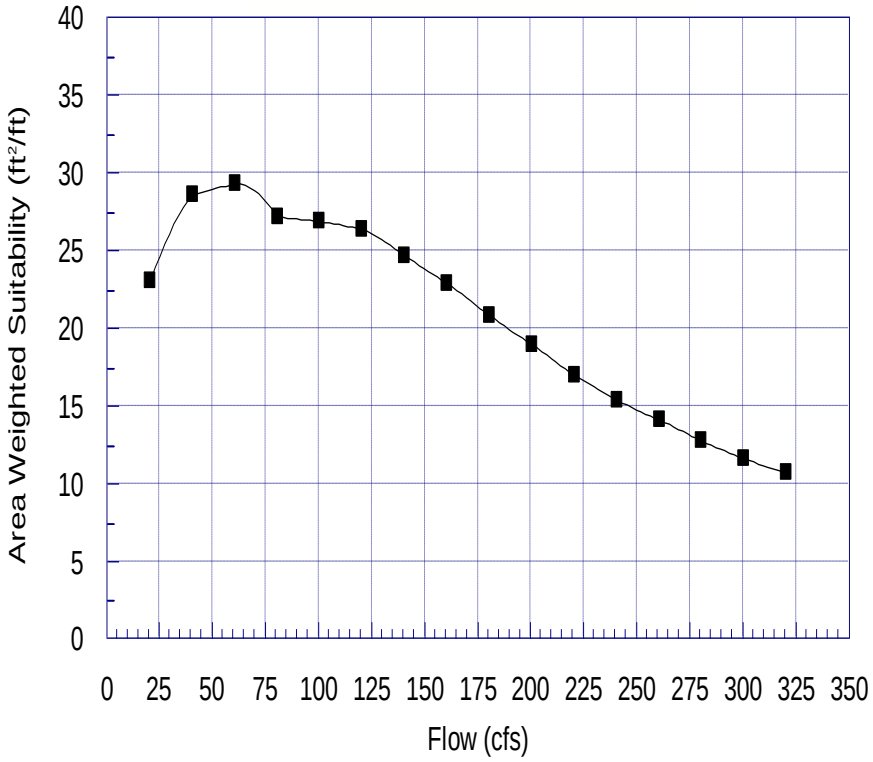
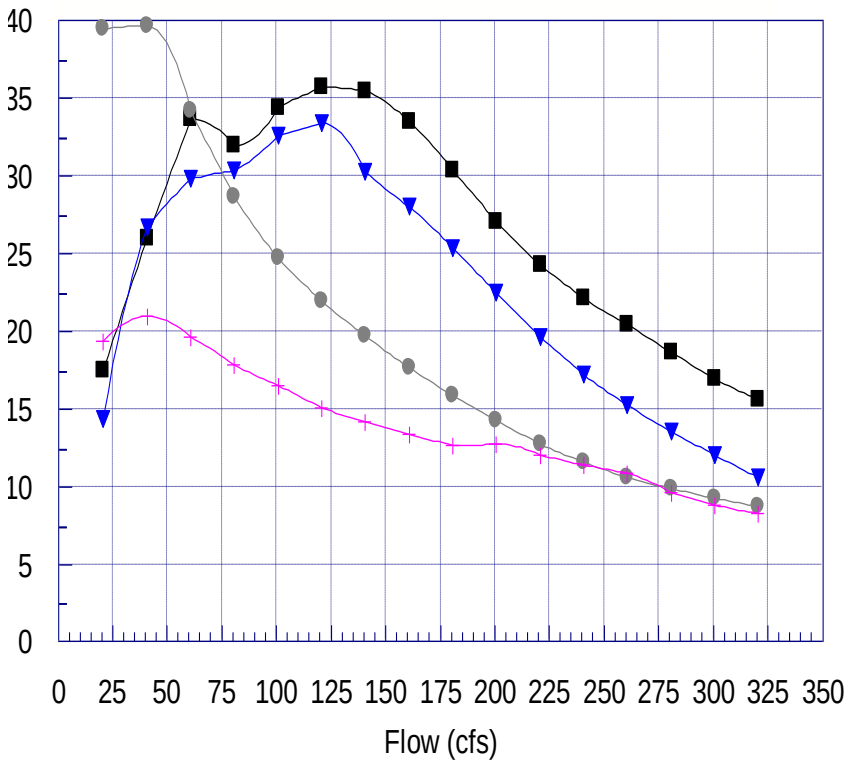
HABITAT INDEX BY REACH AND TRANSECT





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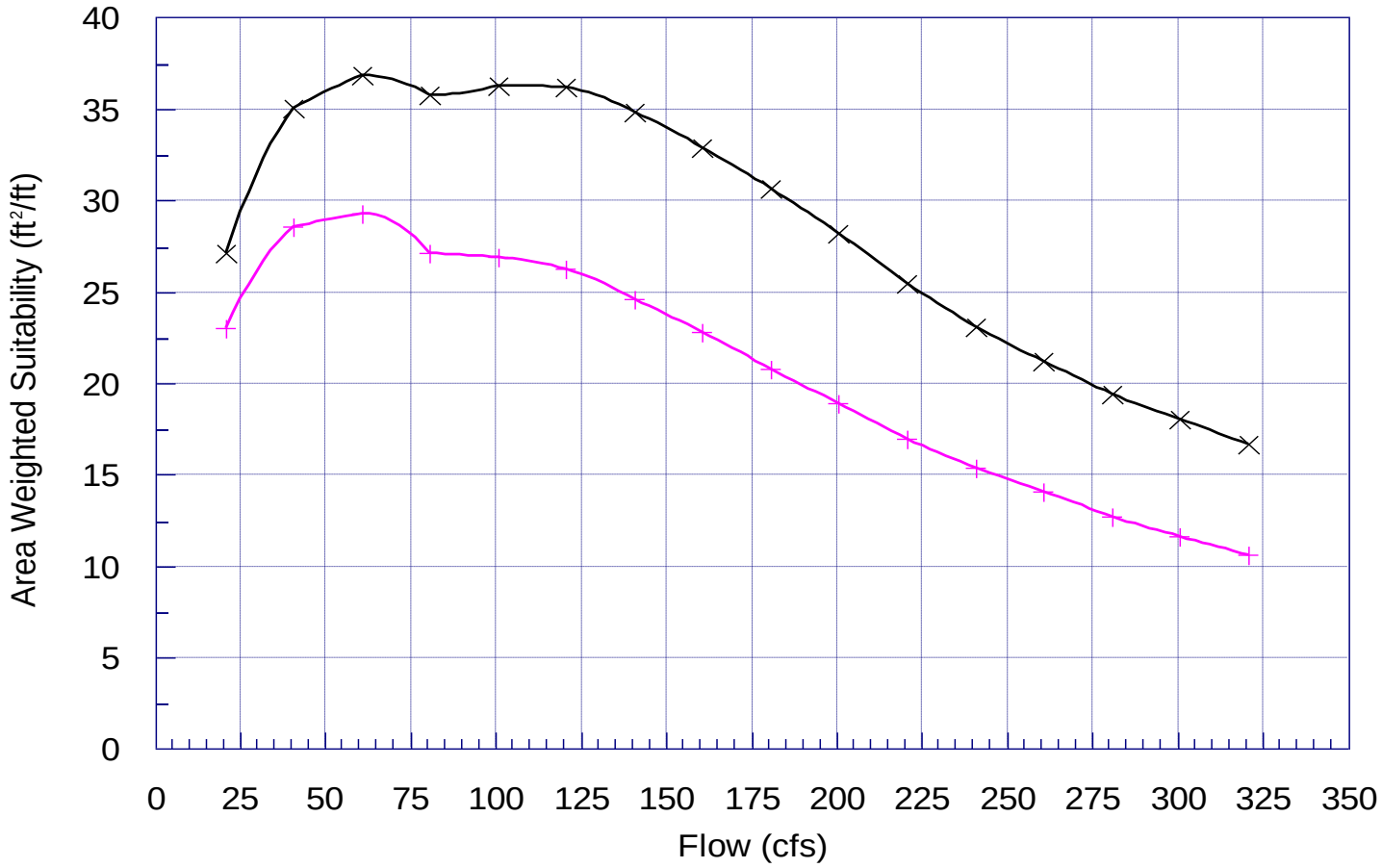
HABITAT INDEX OVERLAY



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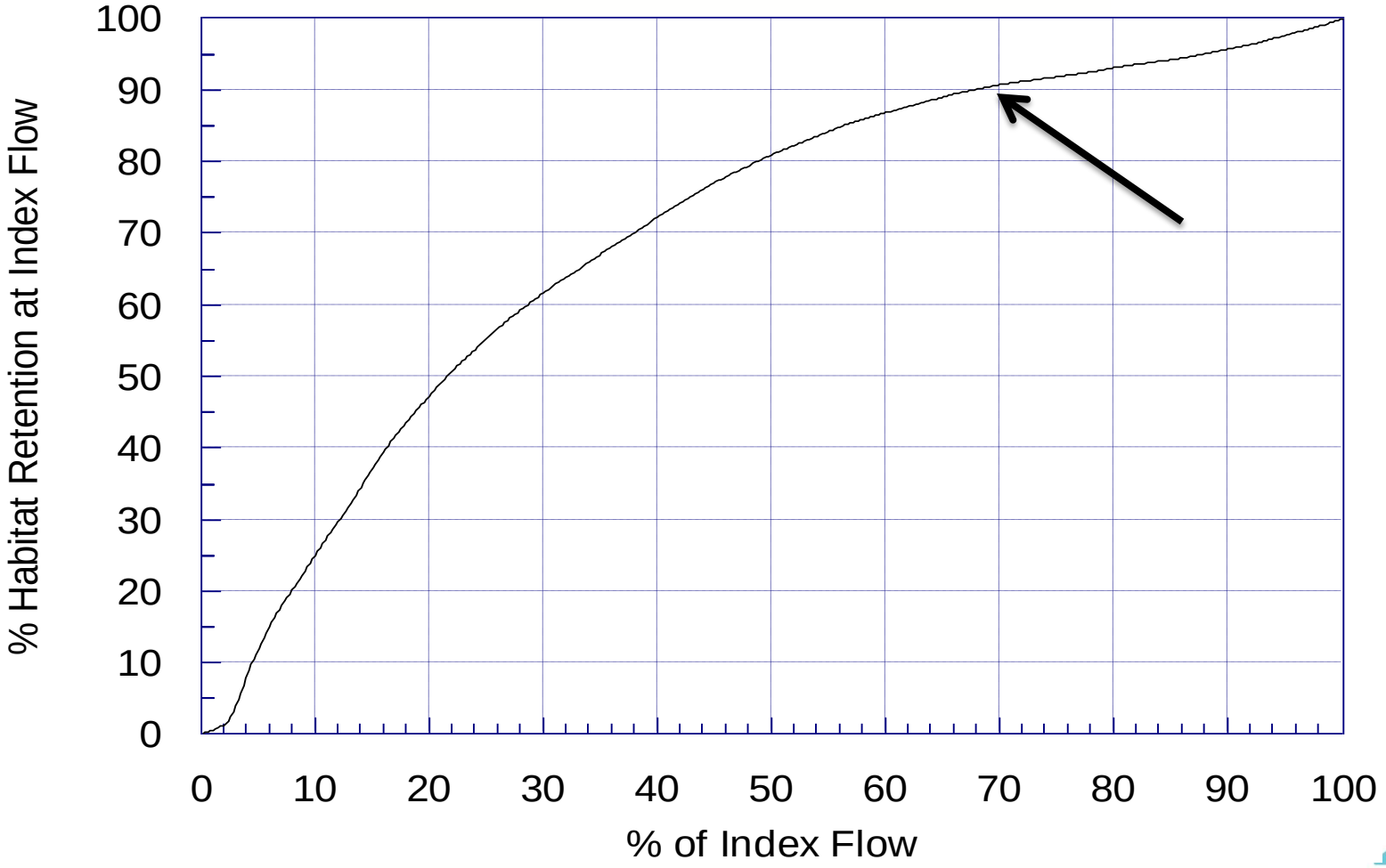
HABITAT RETENTION METHOD

STANDARD SETTING



e.g. Habitat retention set to 90% of MALF (index)

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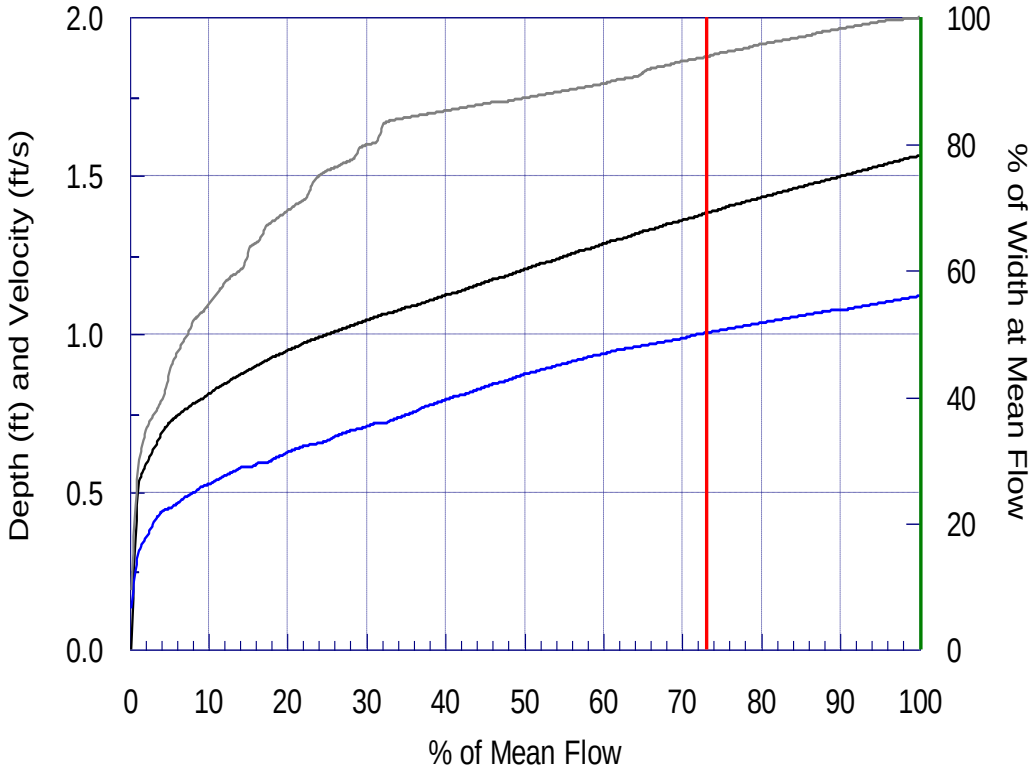
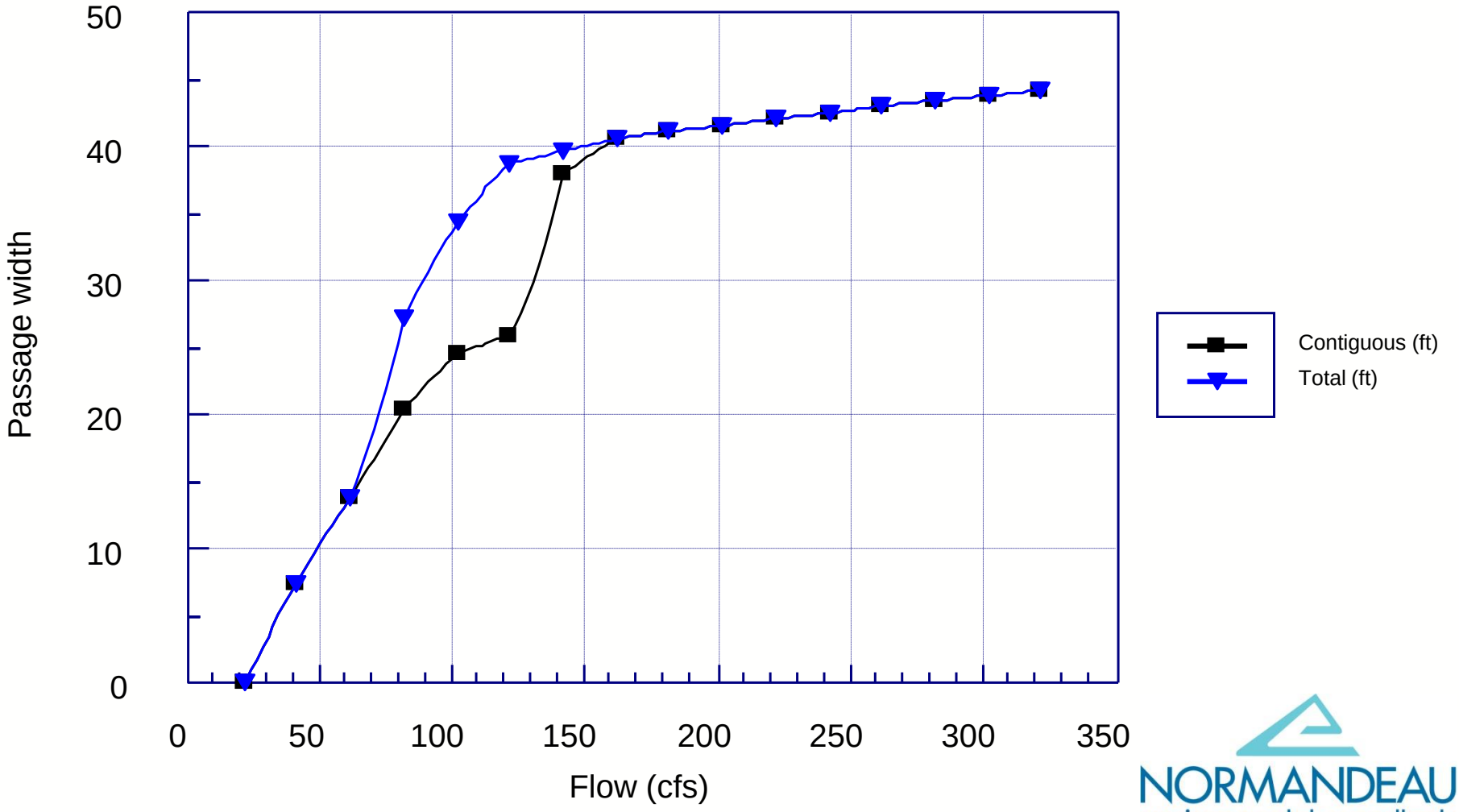
TENNANT METHOD
STANDARD SETTING

Maintenance state	Recommended base flow regimens (cfs)			
	Winter (Oct.-Mar.)		Summer (Apr.-Sept.)	
Flushing or maximum	458.1	200%	458.1	200%
Optimum range	137.4-229.1	60%-100%	137.4-229.1	60%-100%
Outstanding	91.6	40%	137.4	60%
Excellent	68.7	30%	114.5	50%
Good	45.8	20%	91.6	40%
Fair or degrading	22.9	10%	68.7	30%
Poor or minimum	22.9	10%	22.9	10%
Severe degradation	0-22.9	0-10%	0-22.9	0-10%



FISH PASSAGE ANALYSIS



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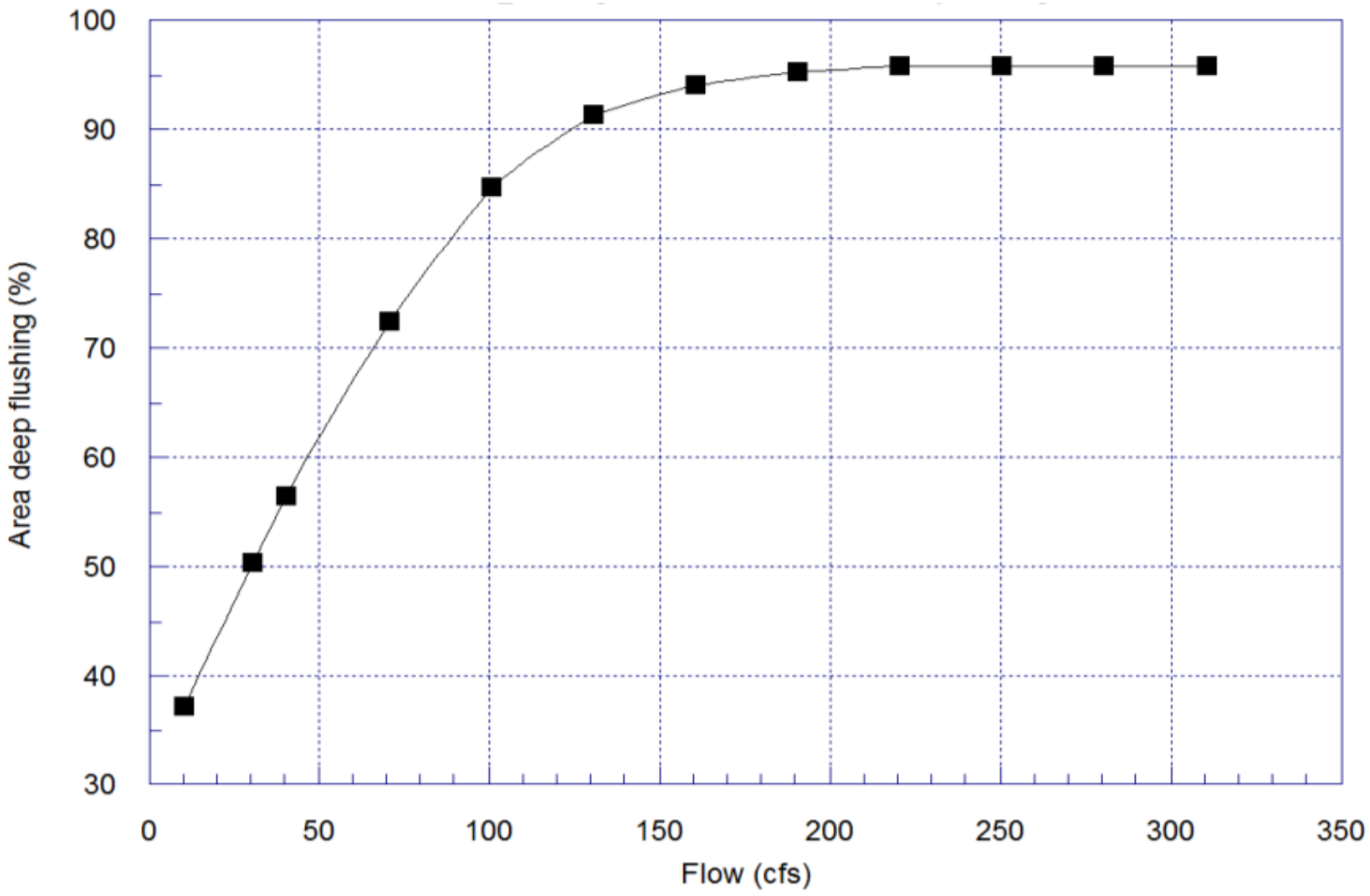
SEDIMENT FLUSHING FLOW ANALYSIS



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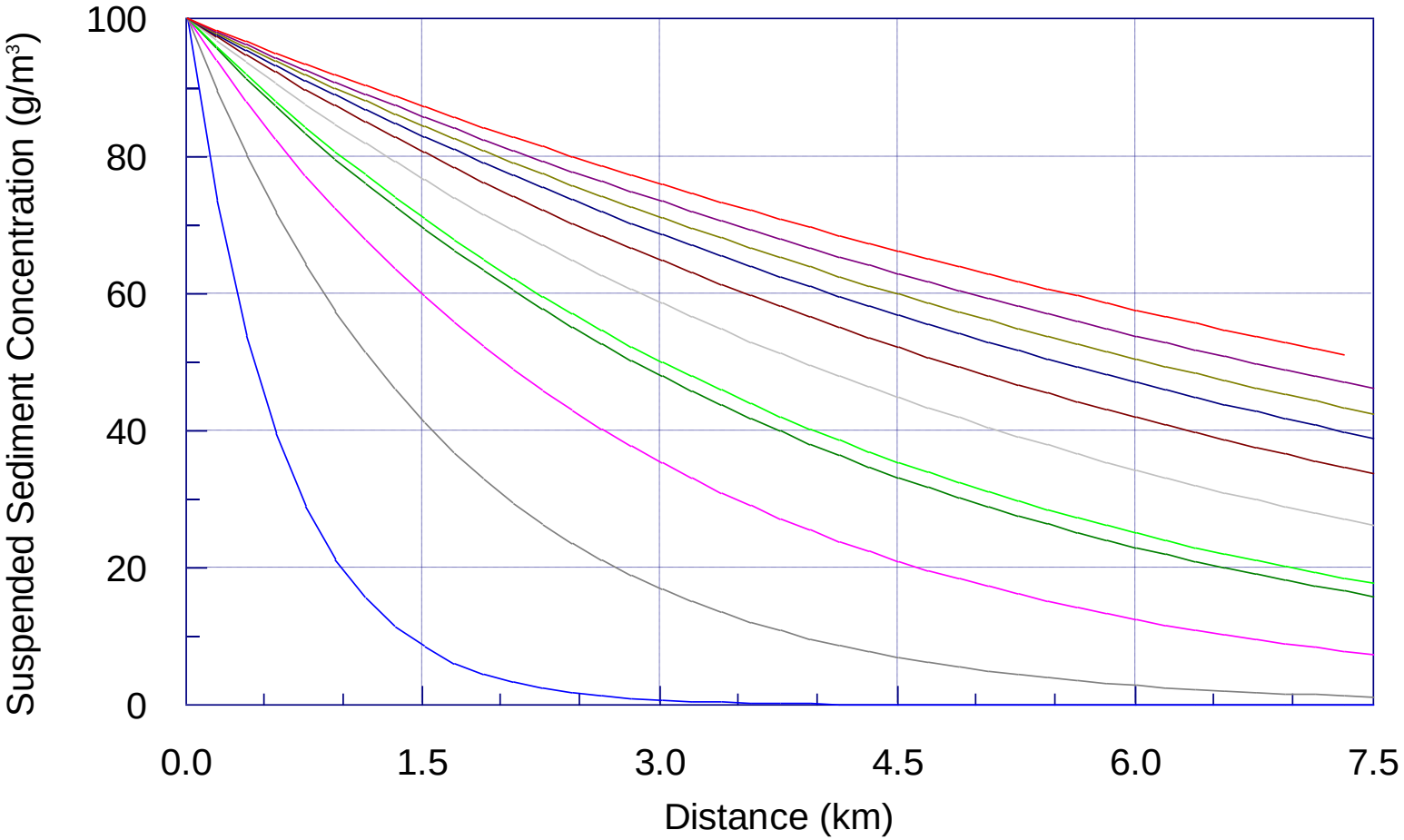
SUSPENDED SEDIMENT ANALYSIS



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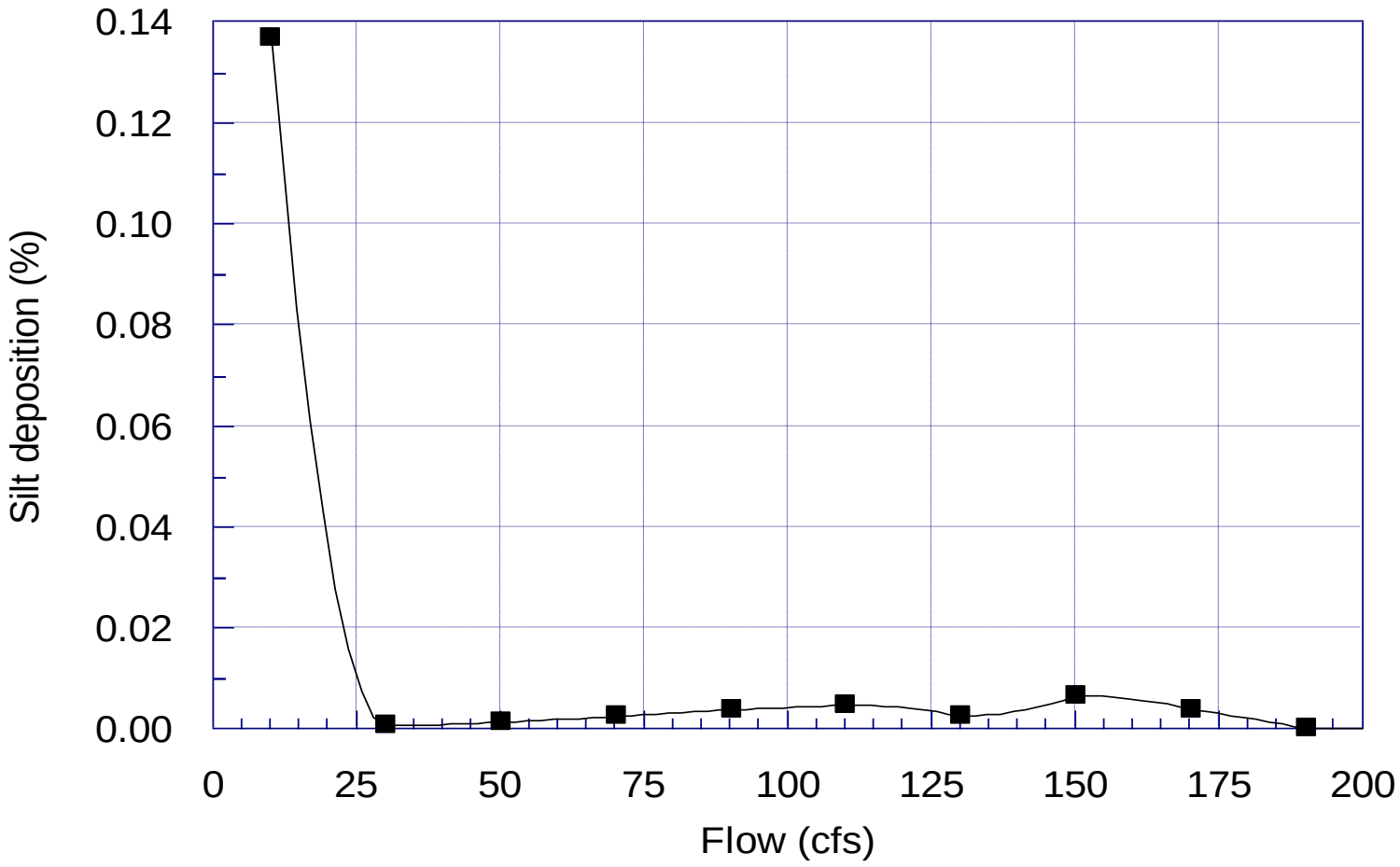
SEDIMENT DEPOSITION ANALYSIS



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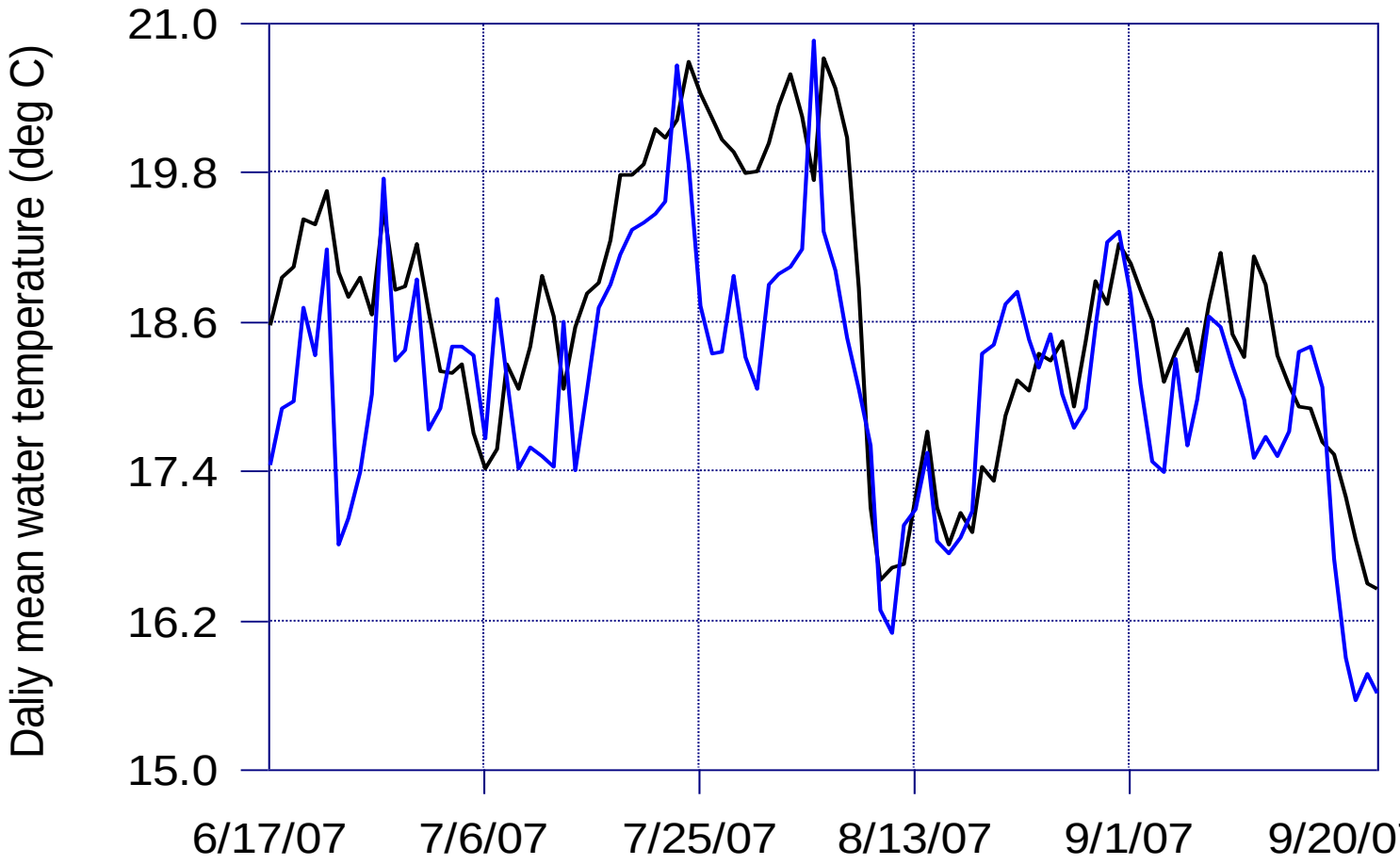
WATER TEMPERATURE MODELING

Daily water temperature calibration



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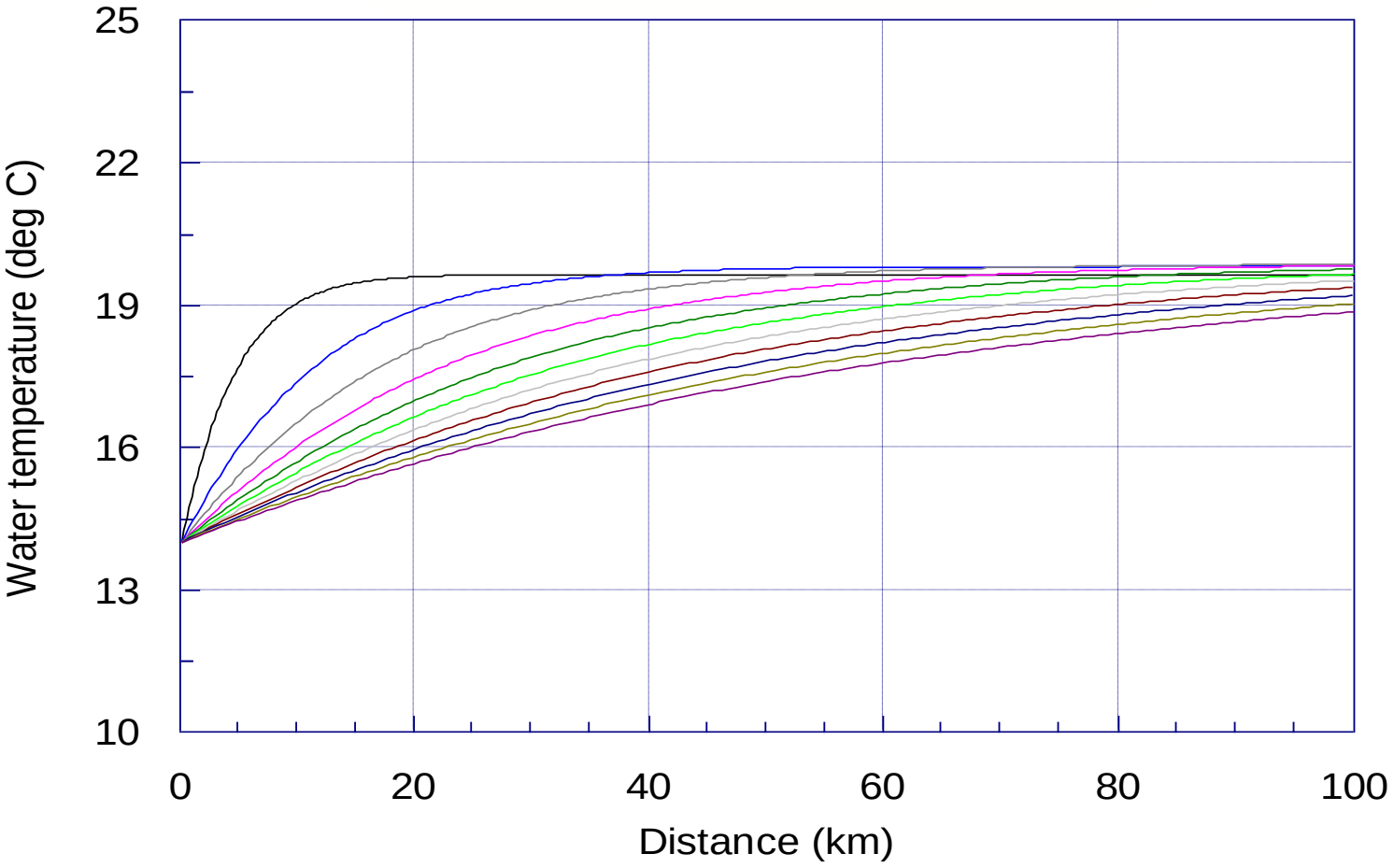
WATER TEMPERATURE MODELING

Downstream water temperature simulation



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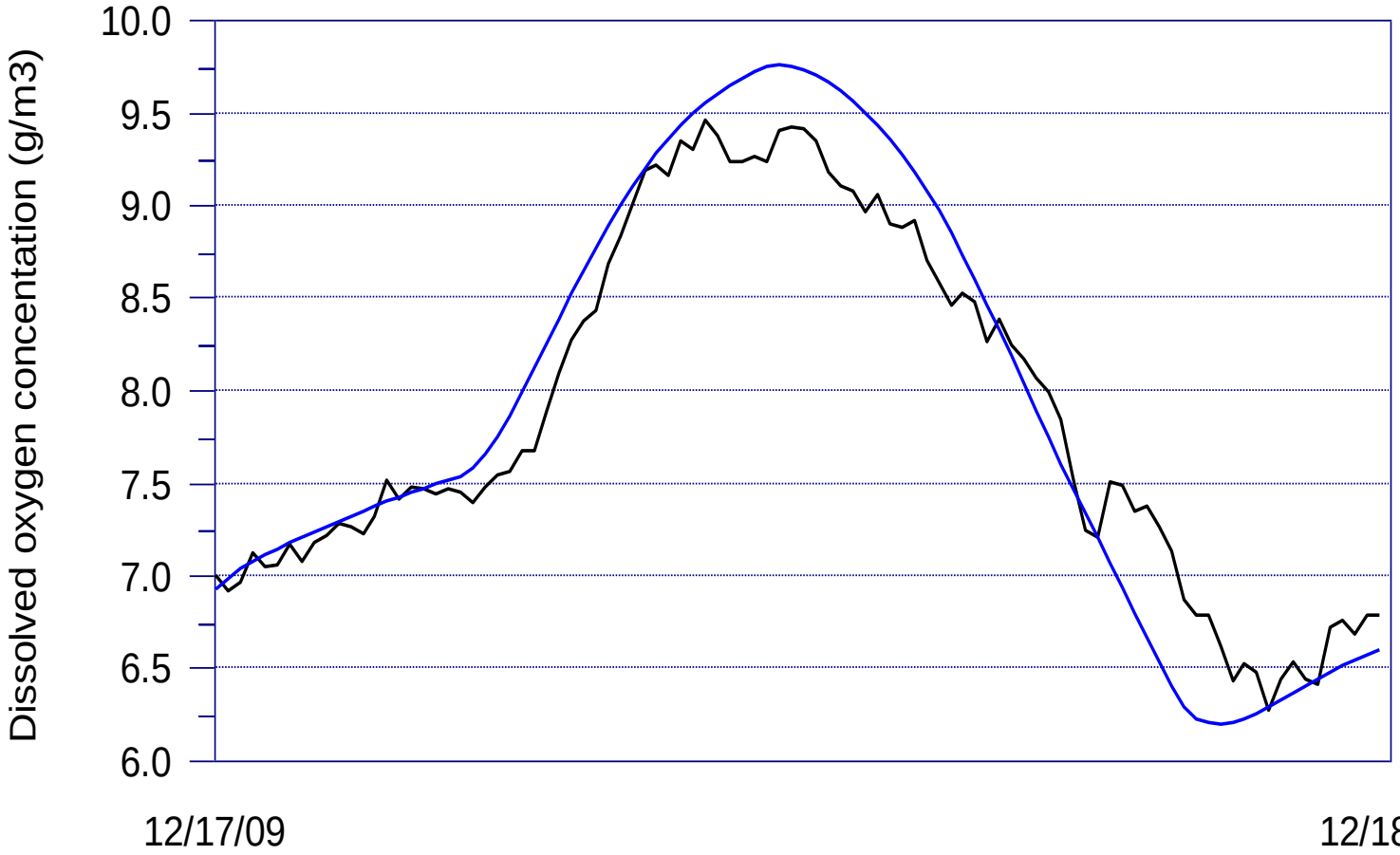
DISSOLVED OXYGEN MODELING

Daily DO cycle calibration



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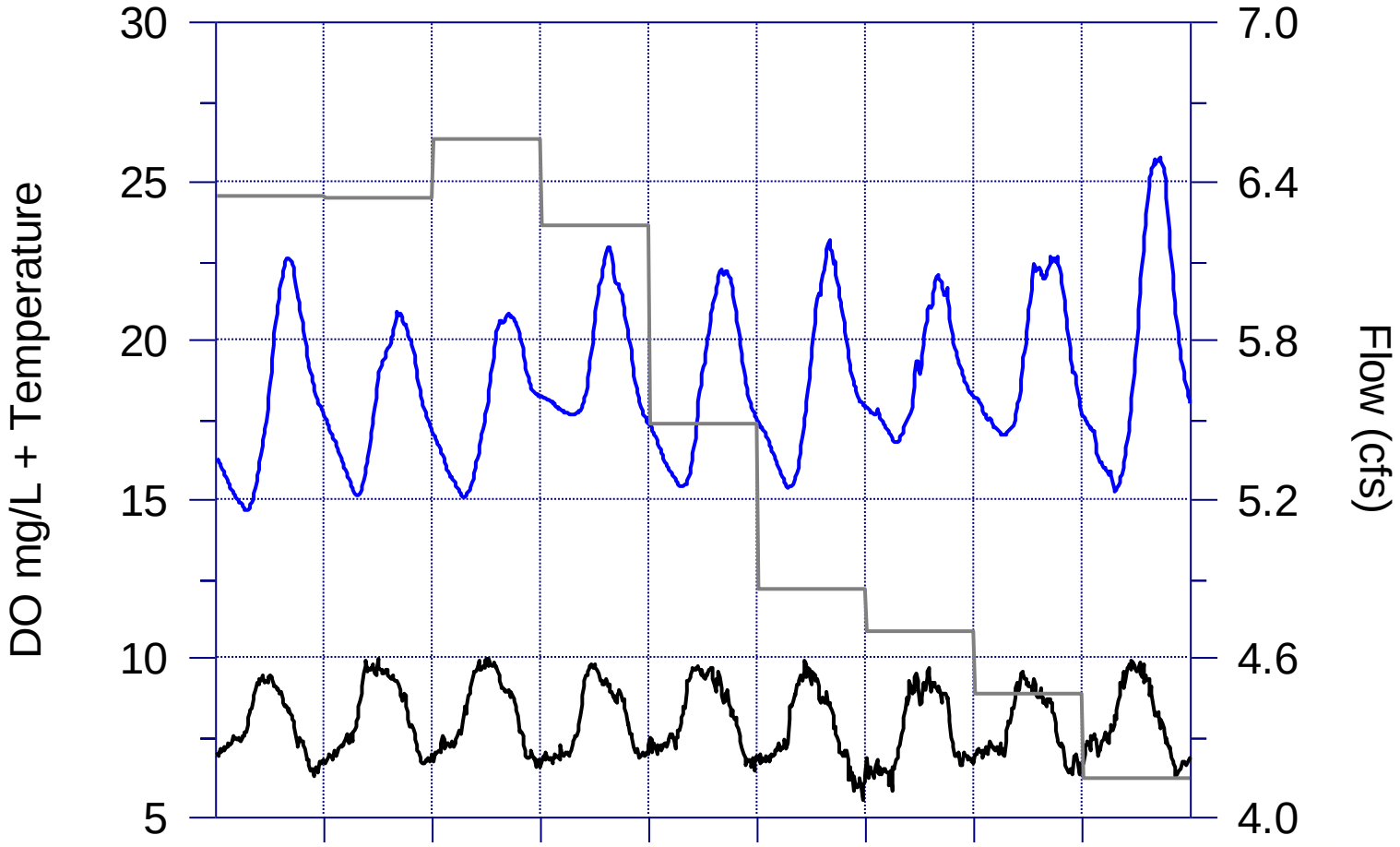
DISSOLVED OXYGEN MODELING

Daily DO simulation with temperature and flow



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TIME SERIES ANALYSIS

Import and analysis

- Works with any data type over time
  - Discharge (text, Excel, USGS format input)
  - AWS habitat index
  - Lake or spring elevations
  - Turbidity
  - Temperature
  - Dissolved oxygen
  - Primary productivity

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TIME SERIES ANALYSIS

Available processes

- Plots of variable over time
- Duration graphs w/ time filters
- Box & whisker plots w/ time filters and statistics (max, min, mean, median, percent exceedance
- Multiple event occurrence analysis
- Indicators of Hydrologic Alteration (with daily flow data)

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TIME SERIES ANALYSIS

Available processes (continued)

- Import of any habitat index (2D model, Demonstration Flow, MesoHABSIM, etc.)
- Habitat duration graphs w/ time filters
- Habitat event occurrence analysis
- UCUT – (Uniform Continuous Under Threshold analysis)
- Riparian inundation analysis
- Benthic population modeling

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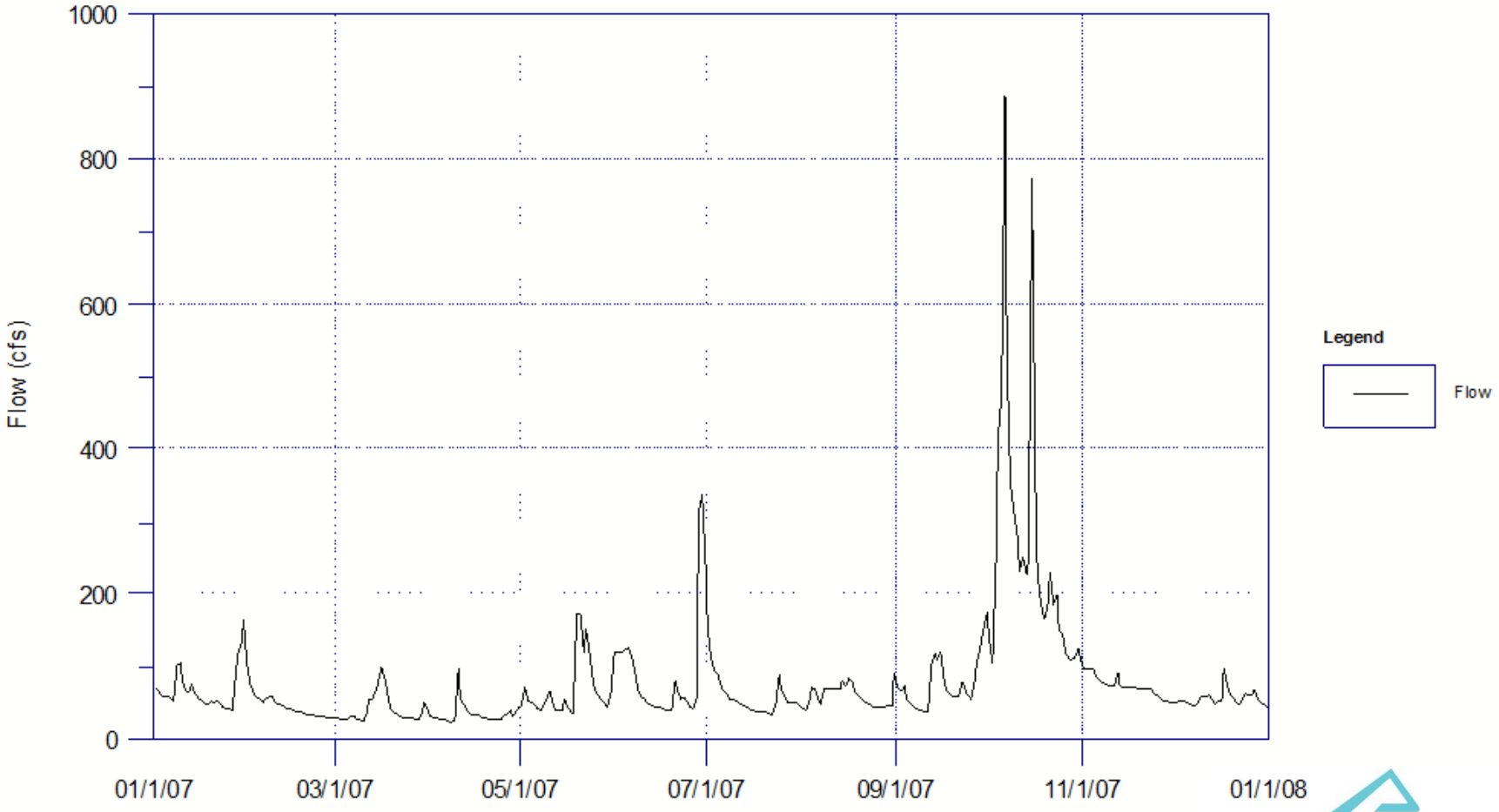
FLOW TIME SERIES



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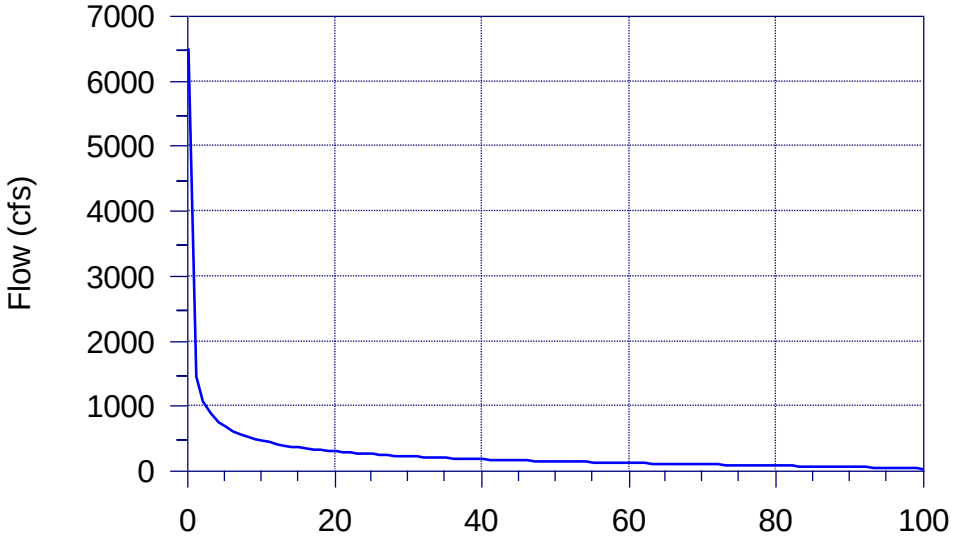
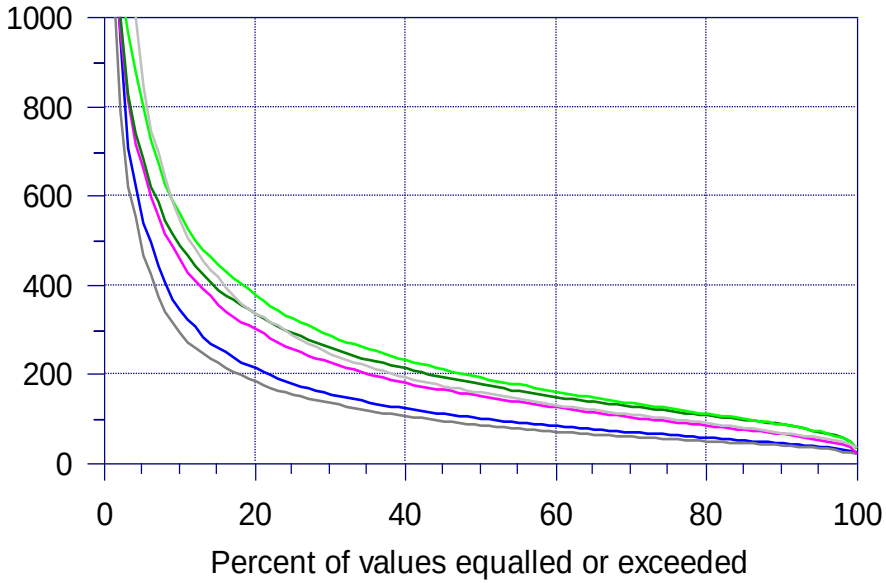
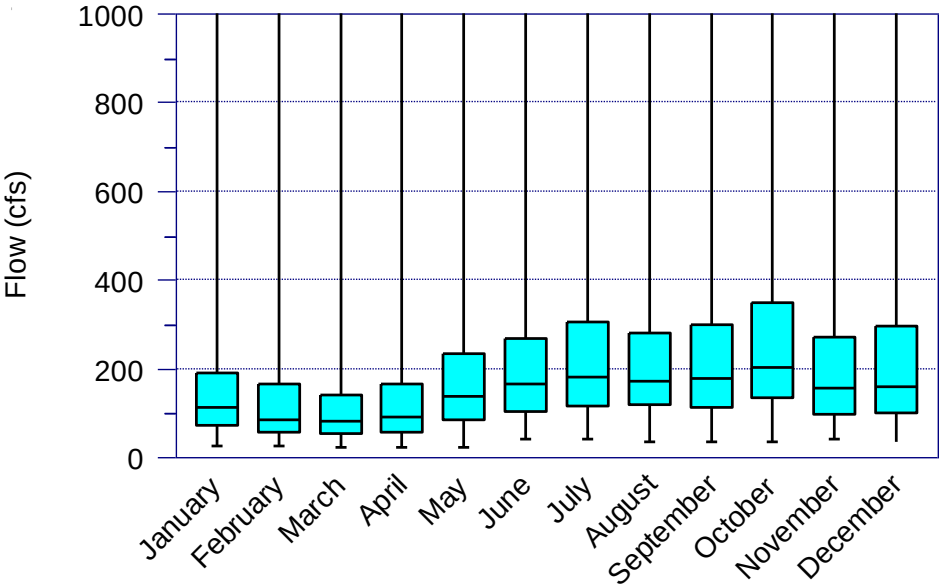
FLOW DURATION ANALYSIS







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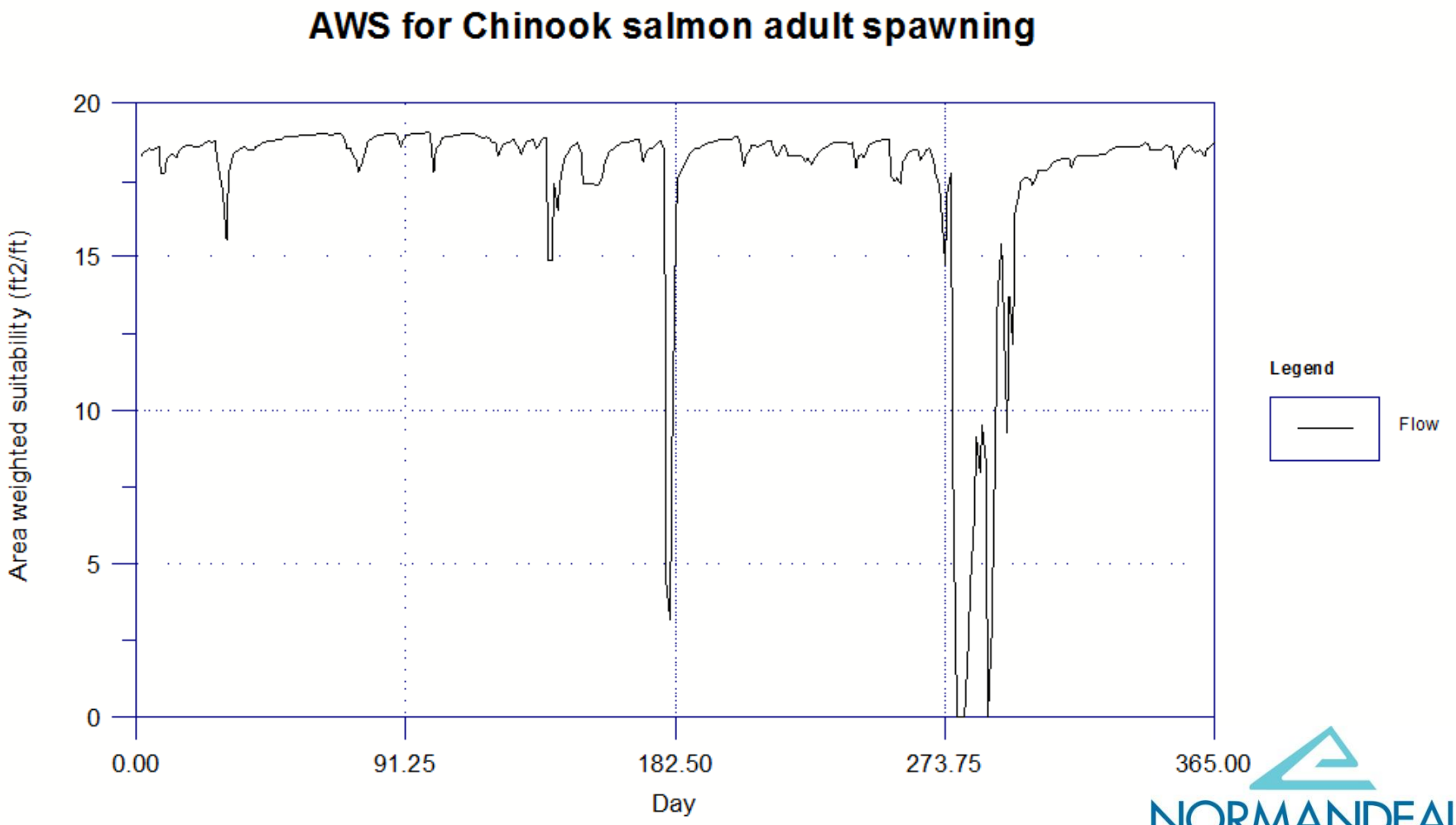
AWS TIME SERIES



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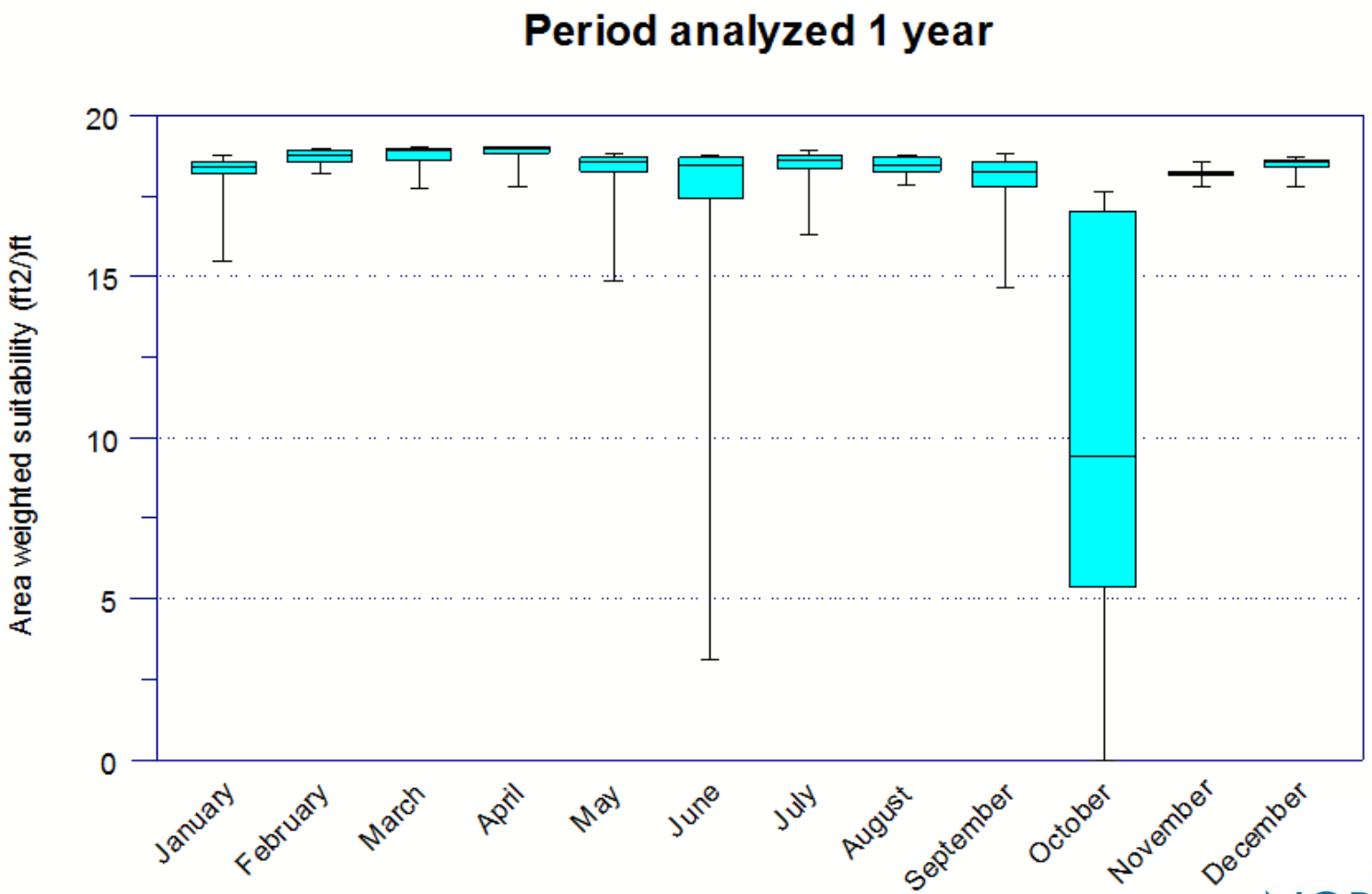
AWS EVENT ANALYSIS BY TIME PERIOD



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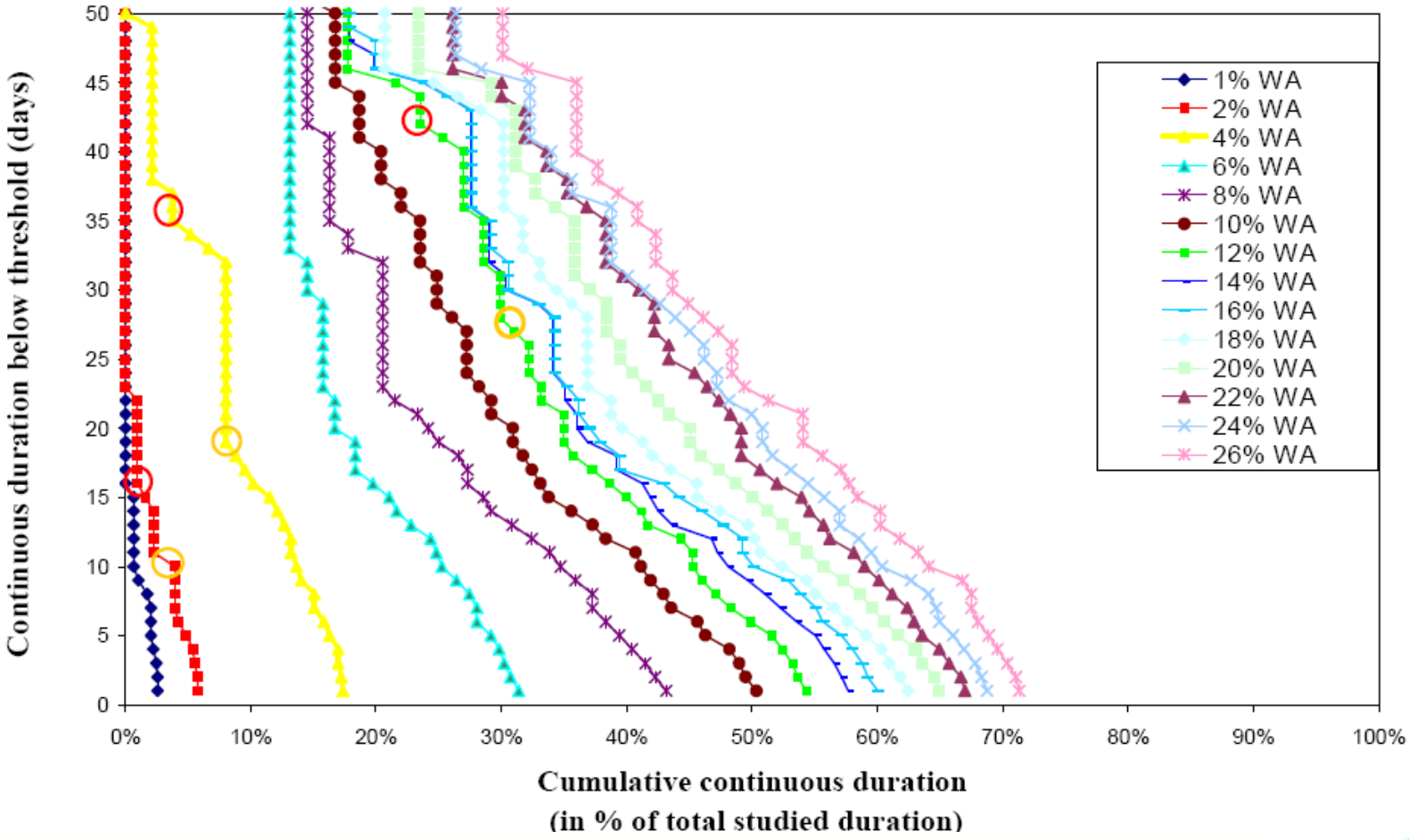
UCUT
(Capra et al. 1995, Parasiewicz 2007)



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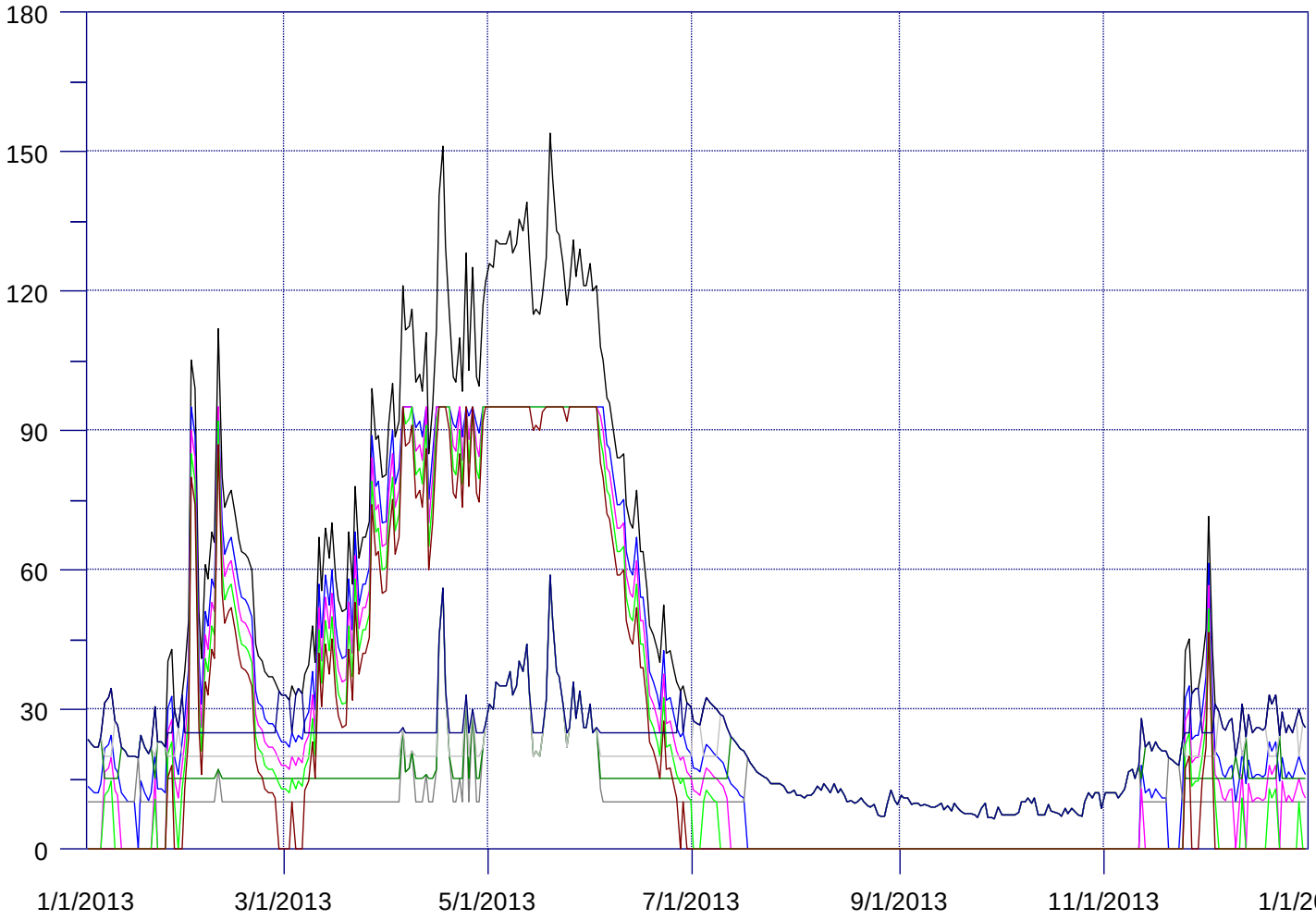
HYDRO OPERATIONS ANALYSIS

(Under construction)



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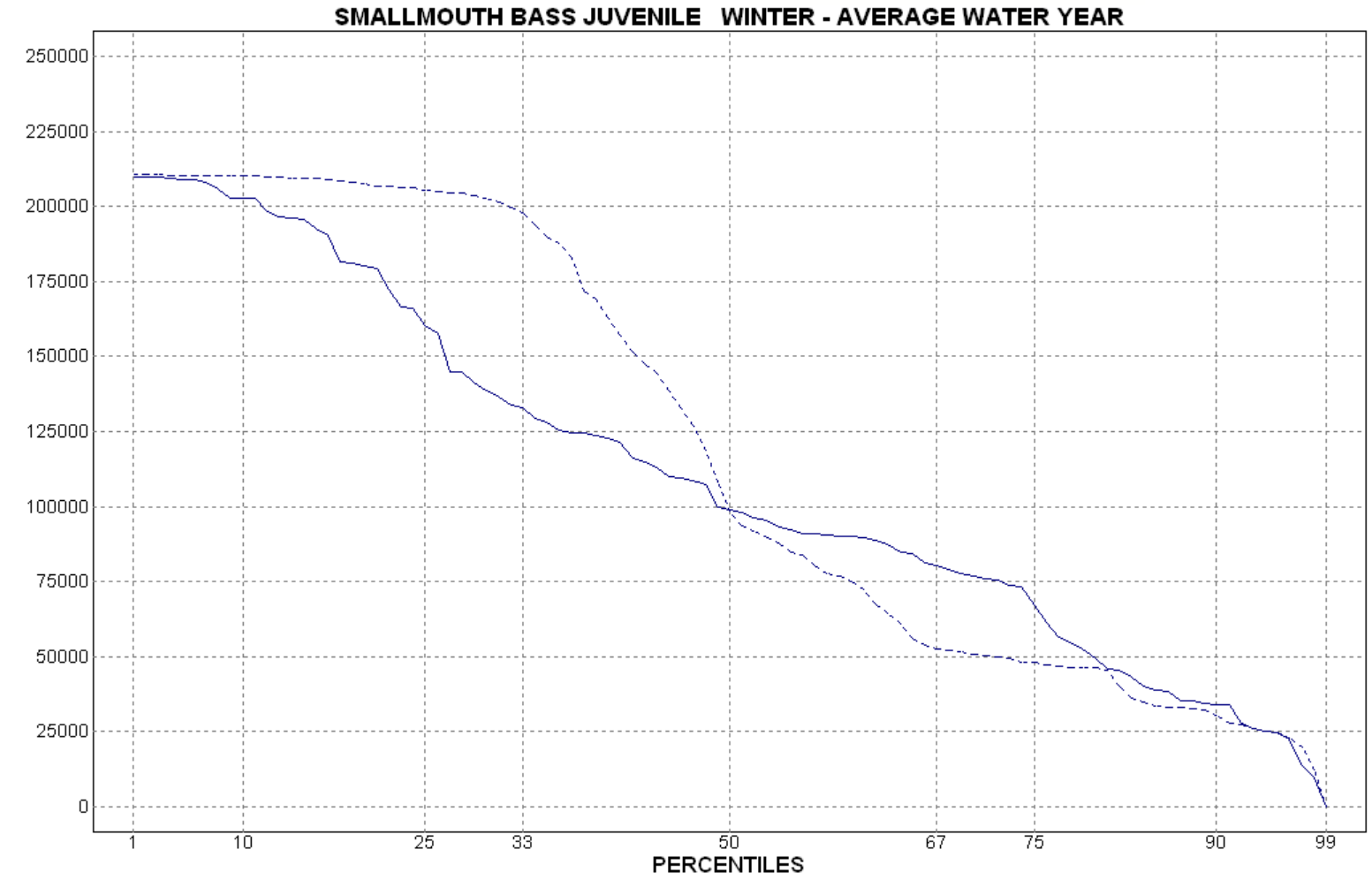
AREA-UNDER-THE-CURVE ANALYSIS

(Under construction)



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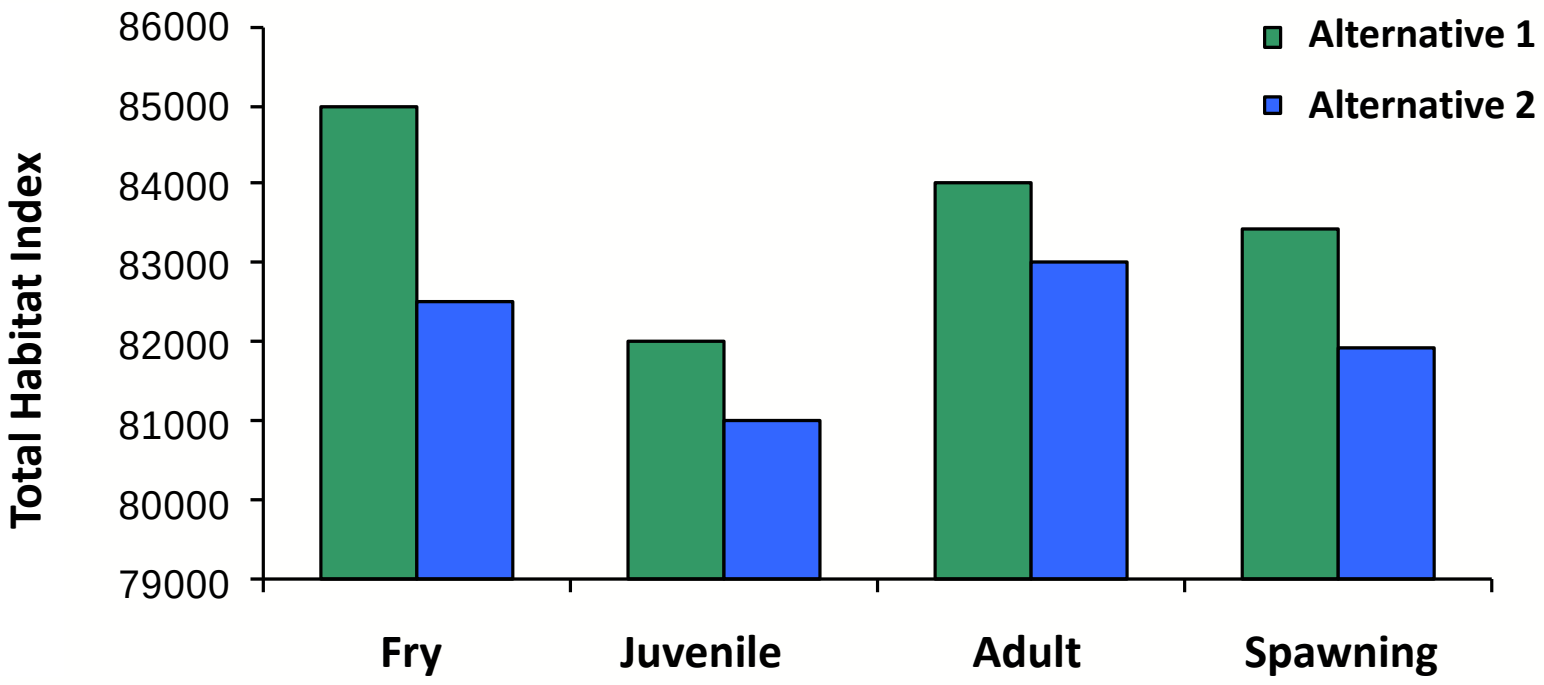
TOTAL HABITAT TIME SERIES
(Under construction)



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MAINTENANCE OF SEFA

- Web site (www.sefa.co.nz) for information, version upgrades, bug fixes, and suggestions
- Available at minimal cost or 30-day free trial
- "Advanced Habitat Modeling with SEFA"
  Jowett, Milhous, Payne @ Ft. Collins 10/13-15/15
- Continuous improvements, including links to other models and incorporation of new models and features

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CONCLUSIONS

- Both the holistic/integrative and the comprehensive/analytic approaches are still developing
- The trends appear to show some level of convergence between the approaches
- Both approaches could use better ecological models
- Only increased knowledge will further decrease uncertainty

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Thank you!