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Water Resources Management Using Coupled Models in Alberta and the U.S.

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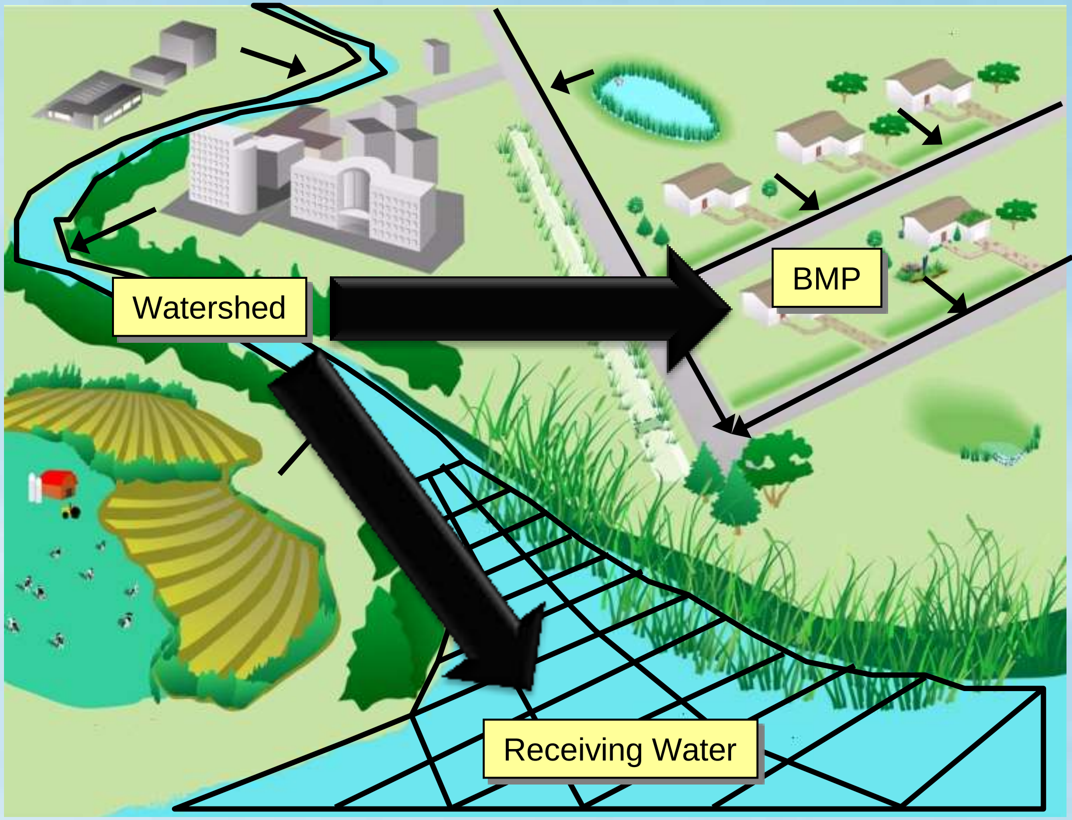
Environmental Modelling

- Effective tool for water resources management
- Coupling takes advantage of individual model strengths
- Focus on:
  - Watershed-Receiving Water
  - Watershed-BMP



Watershed-Receiving Water Models

- Cumulative Effects, Total Maximum Daily Load (TMDL), and comprehensive watershed management studies
- Watershed models
  - Predict time-variable hydrology and water quality for various land surface categories (typically surface and groundwater)
  - Evaluate land-based, climate change, and other scenarios
  - Determine source-based load distribution
  - Non-proprietary examples include LSPC, HSPF, SWAT, and SWMM
- Receiving water models
  - Simulate hydrodynamics and/or water quality processes in water bodies
  - Non-proprietary examples include EFDC, CE-QUAL-W2, and WASP

Watershed-BMP Models

- Watershed implementation driven
- Advanced BMP models
  - Simulate combinations of structural management practices
  - Enable users to optimize selection and placement of practices based on hydrology, water quality, and economic targets
  - Example: System for Urban Stormwater Treatment and Analysis IntegratioN (SUSTAIN)
- Evaluate potential benefits of costly infrastructure before spending limited resources on construction

Commonly Coupled USEPA Models

- LSPC (Watershed)
  - Snow, flow, temperature, sediment, water quality (HSPF routines)
  - Object-oriented environment and relational database
  - Tailored for large-scale watershed modelling and TMDLs
- EFDC (Receiving Water)
  - Fully integrated hydrodynamics, sediment, and water quality
  - 1, 2, or 3-dimensional simulation of rivers, lakes/reservoirs, estuaries
- SUSTAIN (BMP)
  - Implementation planning framework
  - Determine cost-effective mix of BMPs to meet flow/load goals
- All are public domain – freely available at http://www.epa.gov

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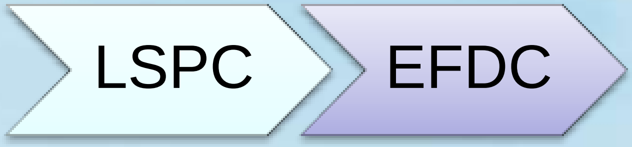
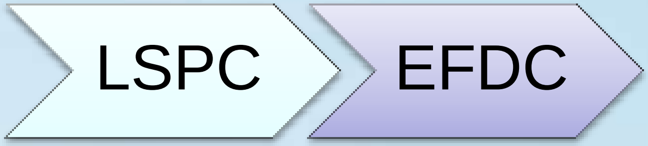
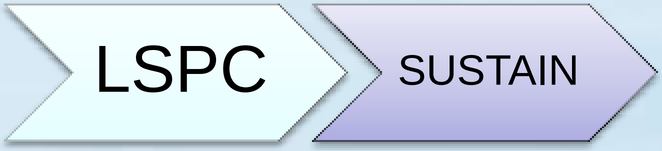
Case Studies



- Watershed Management and Cumulative Effects Assessment
  - *North Saskatchewan River*



- Reservoir Management
  - *Lake Lanier, Georgia*

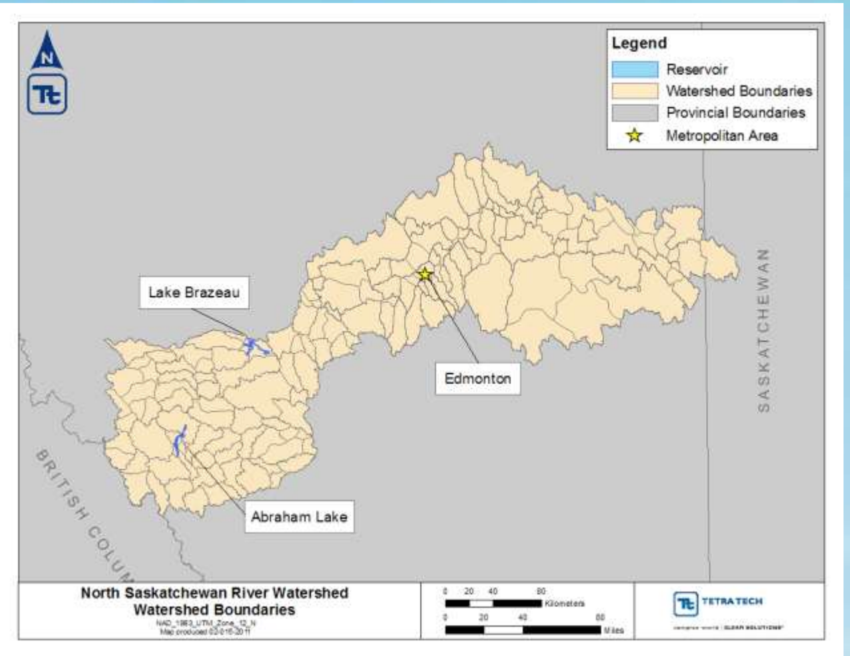


- Optimal Implementation Planning
  - *Milwaukee, Wisconsin Metropolitan Sewer District*

North Saskatchewan River

LSPC → EFDC

- ► Developed coupled watershed-receiving water models for AESRD
- ► Hydrology, hydrodynamics, and water quality
- ► LSPC for basin-wide simulation
- ► EFDC for main-stem river, Lake Brazeau, and Abraham Lake



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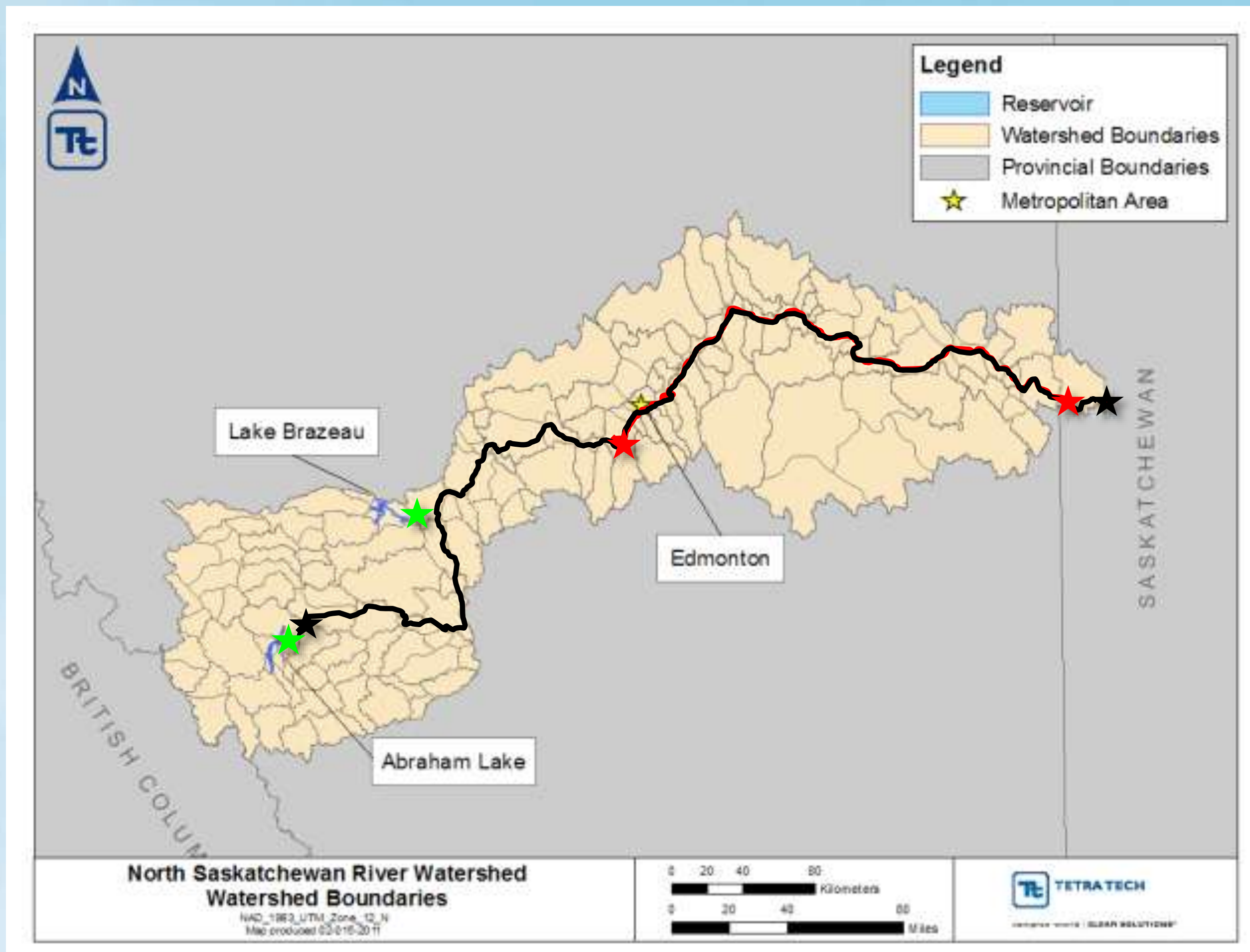
Phased Modelling Process

- 2D/1D model of NSR
  - Devon to Saskatchewan
- 1D model of NSR
  - Abraham Lake to Saskatchewan
- Watershed model
- 3D models of lakes
  - Abraham Lake
  - Lake Brazeau
- Watershed model enhancements



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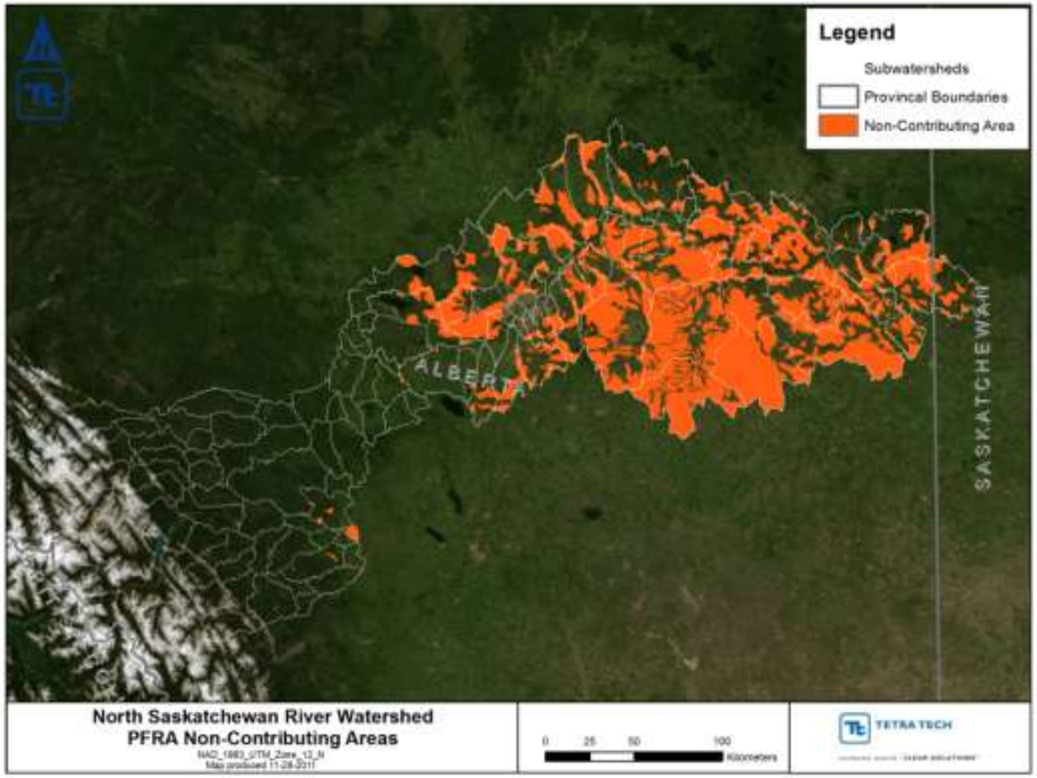
LSPC Enhancements

- ► Improved meteorological input data/snow representation
- ► Increased number of calibration locations
- ► Quantified impact and modelled behavior of hydrologically non-contributing areas
- ► Multi-faceted water quality calibration



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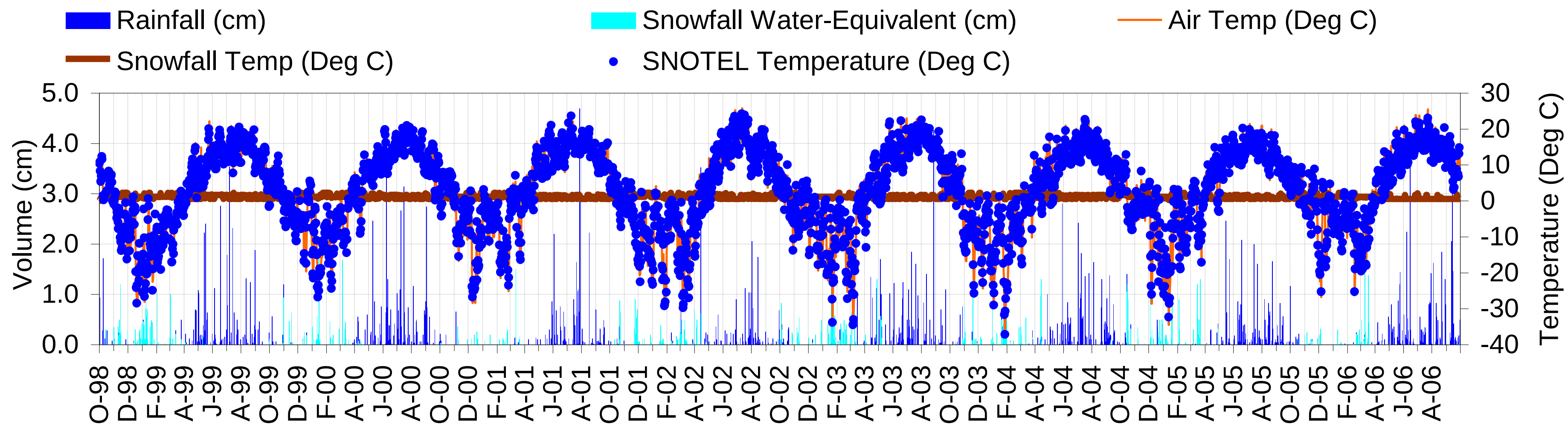

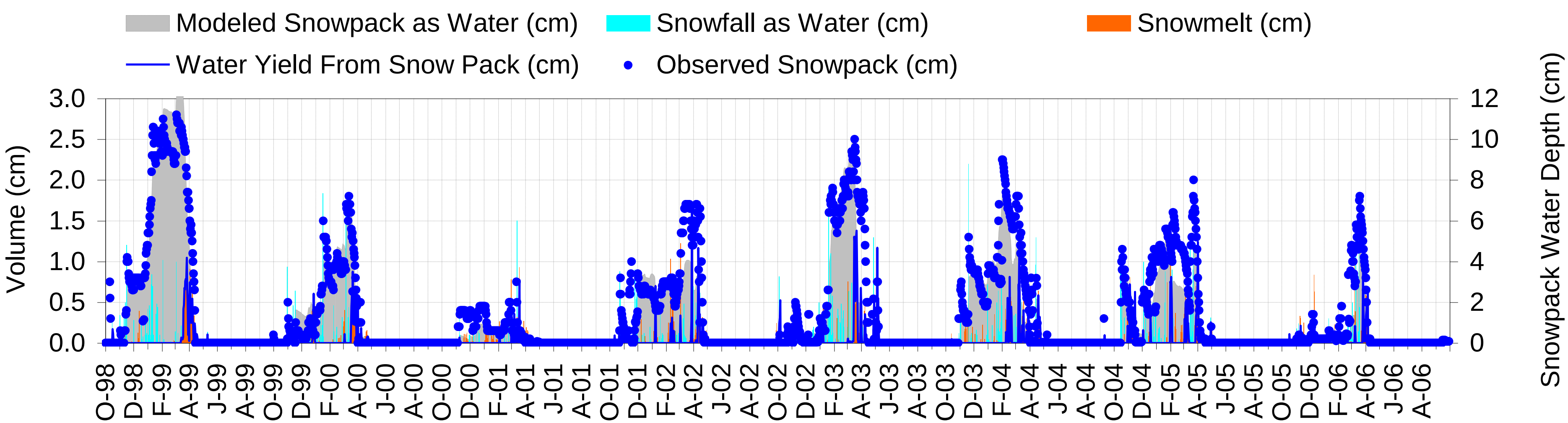

LSPC snow calibration at Edmonton Woodbend (10/1/1998 to 9/30/2006)

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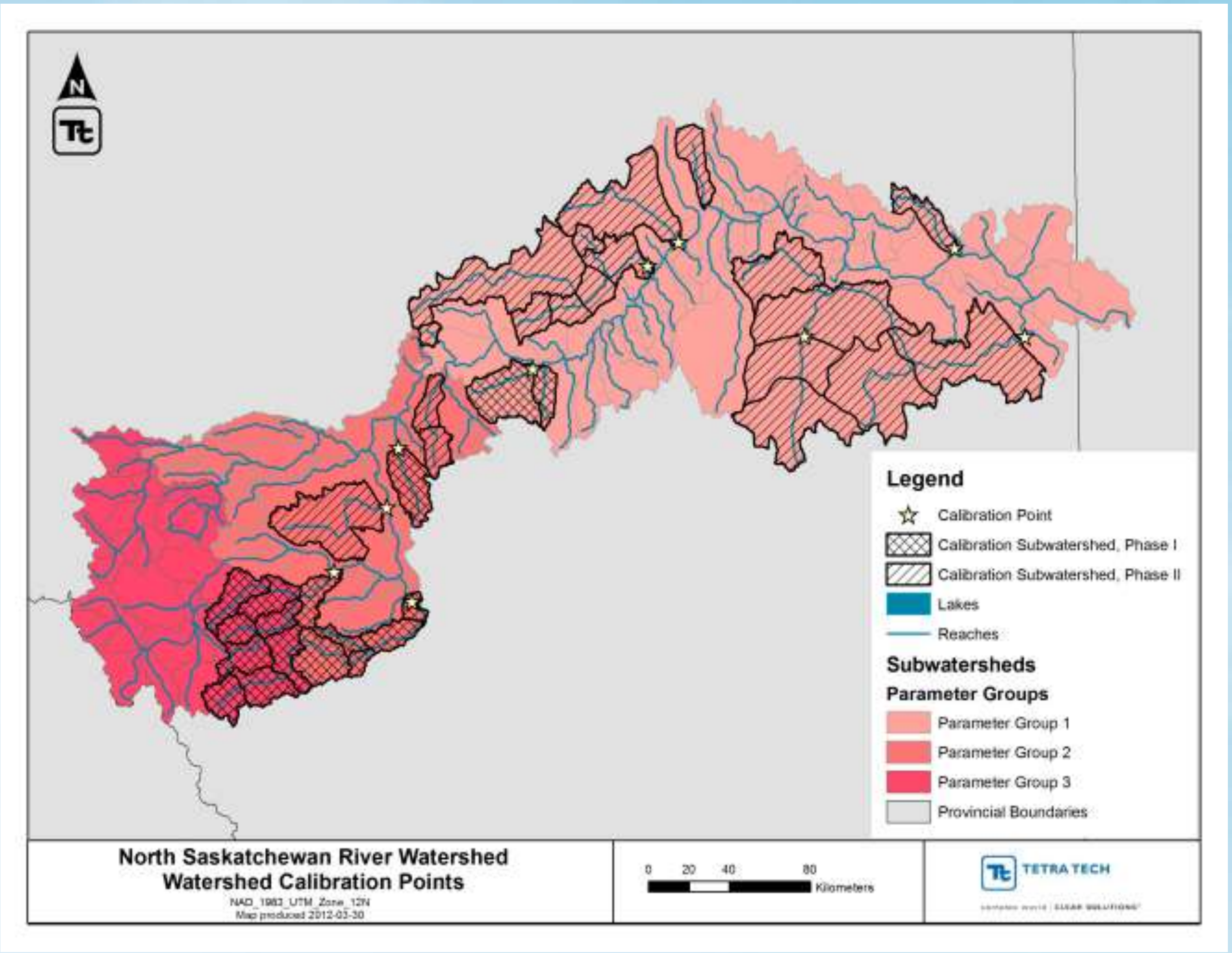
Calibration Locations



Summary of Seasonal Flow Patterns in NSR Basin

NSR Tributary		Average Elevation (m)	Percent NCA	Peak Flow Month	Percent of Observed Annual Flow	
Name	Gage ID				March-**April**-May	May-**June**-July
Ram River	05DC006	1,807	0.0%	June	20%	61%
Clearwater River	05DB006	1,731	0.0%	June	19%	51%
Baptiste River	05DC012	1,106	0.010%	June	30%	58%
Rose Creek	05DE007	974	0.004%	May	49%	62%
Modeste Creek	05DE911	893	0.0%	April	63%	50%
Tomahawk Creek	05DE009	799	0.0%	April	72%	41%
Strawberry Creek	05DF004	798	0.19%	April	71%	47%
Sturgeon River	05EA001	715	27%	April	82%	37%
Vermillion River	05EE009	673	77%	April	84%	41%
Vermillion River	05EE007	666	74%	April	96%	17%
Waskatenau Creek	05EC002	664	37%	April	92%	14%
Redwater River	05EC005	661	26%	April	90%	34%

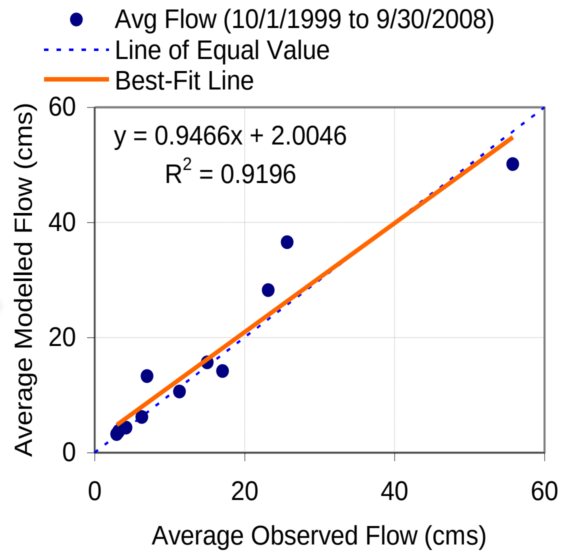
NCA – Evaluation of Physical Processes

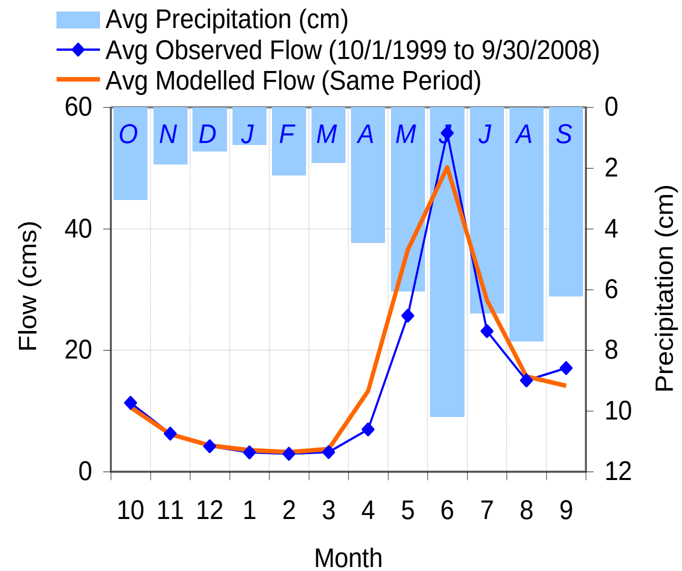
- Frozen Ground
  - Spring: runoff occurs because ground acts impervious
  - Summer: surface depressions contain most runoff when ground thaws
- Deep Aquifer Recharge
  - Summer/fall: baseflow in streams dissipates
  - Performed full mass balance
    - Maximum potential evapotranspiration had little effect
    - Groundwater recharge was most effective

Ram River Gage (05DC006)

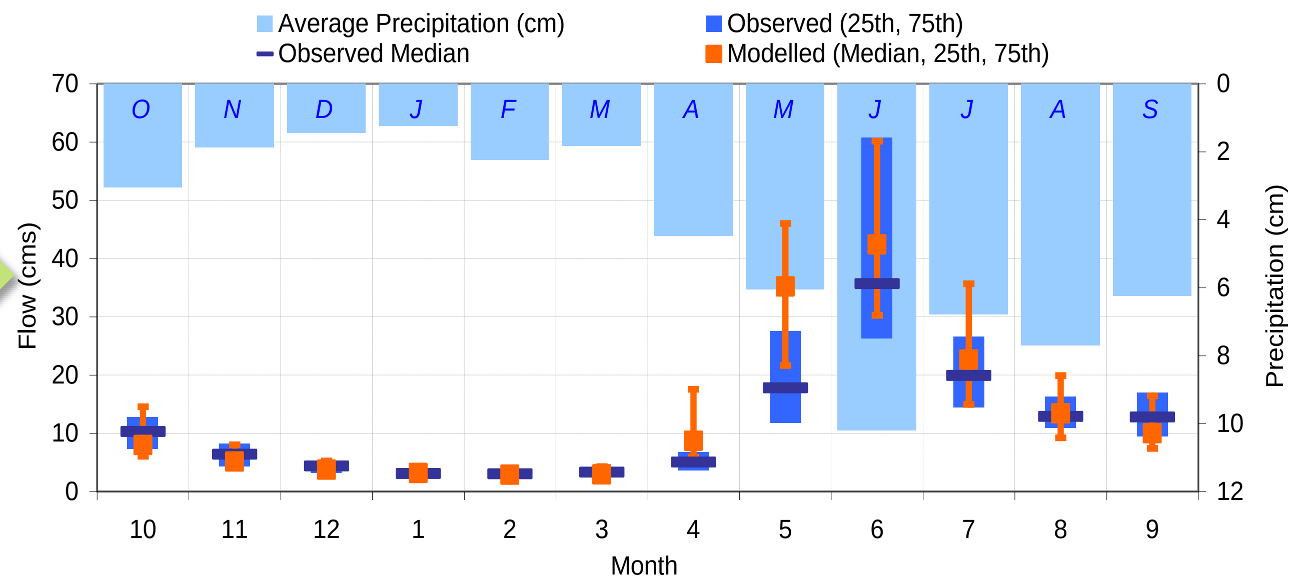
Streamflow Observed vs. Modelled

seasonal / monthly flow





quartile variation



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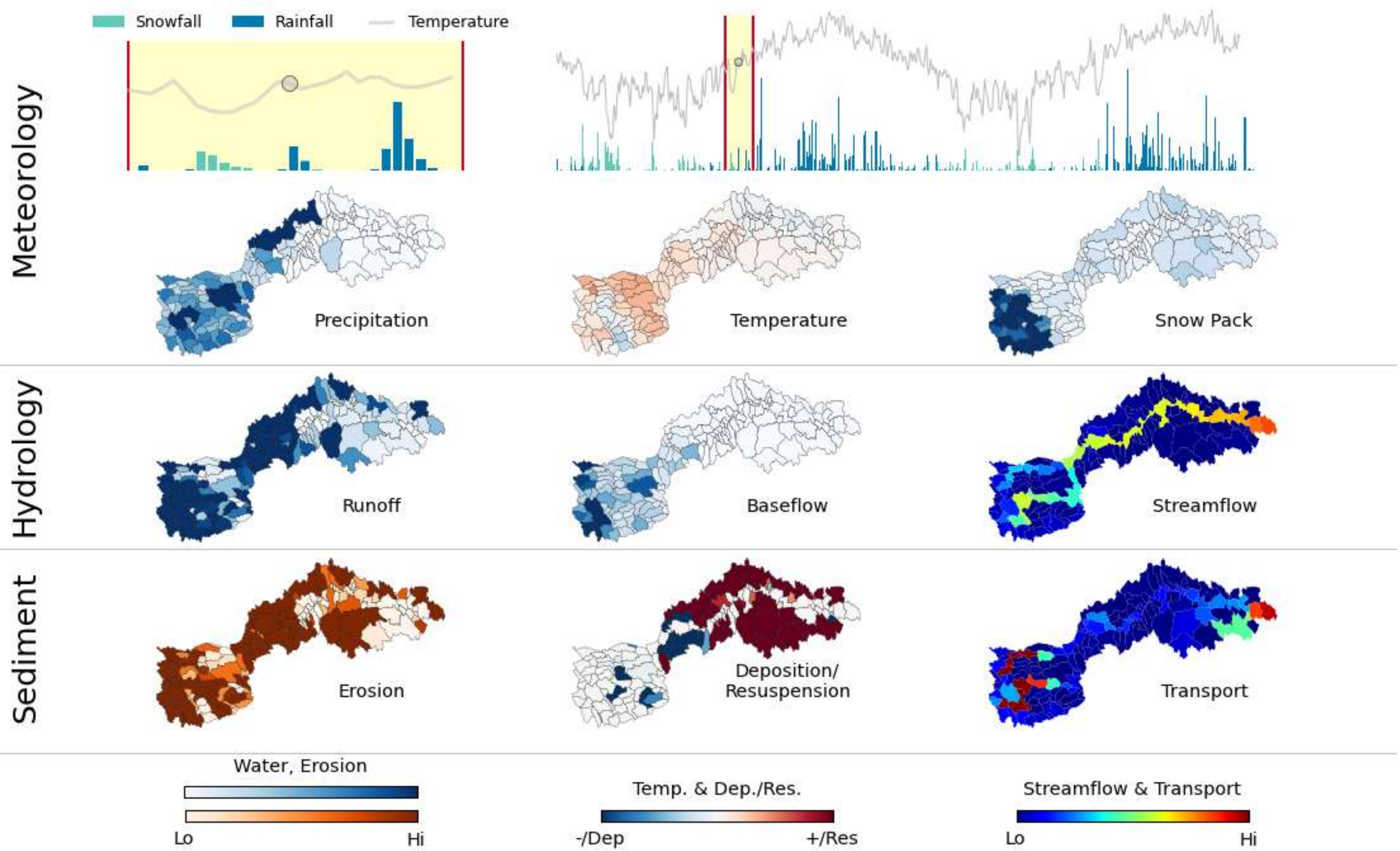
Error Statistics: Ram River (LSPC)

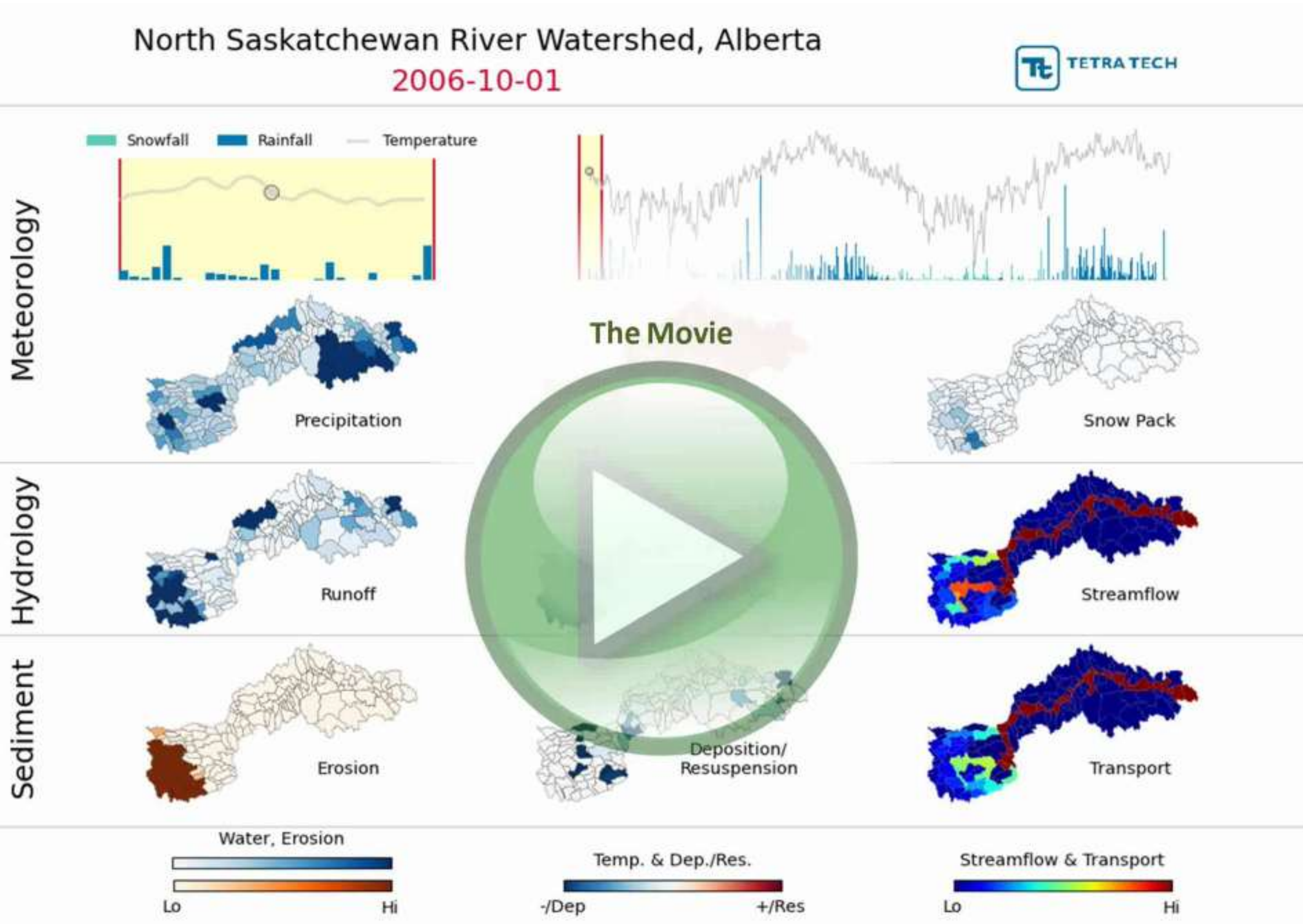
Hydrologic Indicator	Observed (cm/year)	Simulated (cm/year)	Error Statistics	
			Error (%)	Goal (%)
Total In-stream Flow:	24.34	26.43	8.60	±10
Total of lowest 50% flows:	3.35	3.60	7.51	±10
Total of highest 10% flows:	10.90	10.41	-4.55	±15
Summer (months 7-9):	7.75	8.16	5.31	±30
Fall (months 10-12):	3.06	2.96	-3.21	±30
Winter (months 1-3):	1.29	1.45	12.50	±30
Spring (months 4-6):	12.24	13.86	13.22	±30
Total Storm Volume:	5.18	4.56	-11.89	±20
Summer Storm Volume (7-9):	1.16	1.20	3.43	±50
Nash-Sutcliffe Coefficient of Efficiency, E:		0.54	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':		0.44	as E or E' approaches 1.0	

Metrics: HSPEXP, Nash-Sutcliffe, Garrick

North Saskatchewan River Watershed, Alberta

2007-04-09




North Saskatchewan River Watershed, Alberta
2006-10-01
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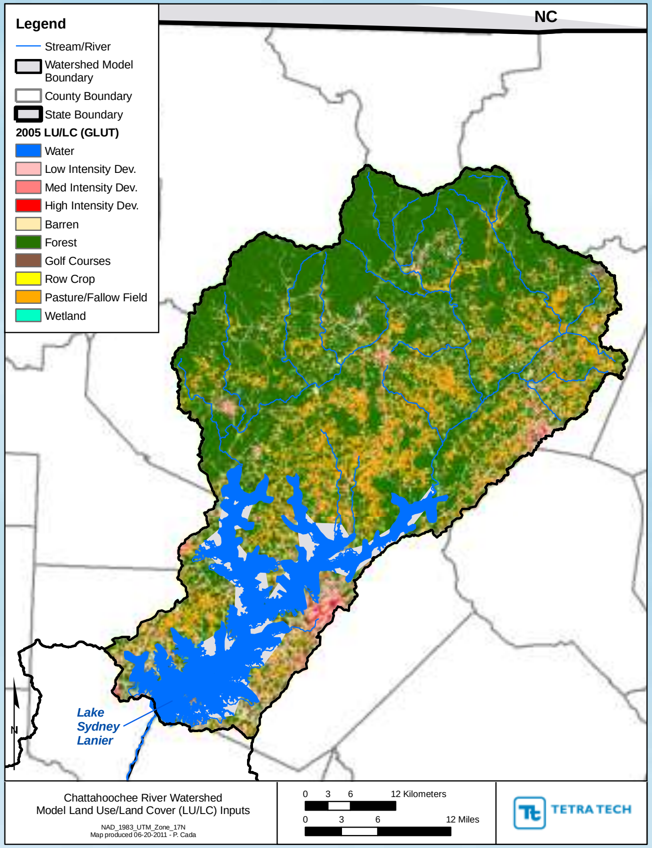
Snowfall
Rainfall
Temperature
Meteorology
Hydrology
Sediment
The Movie
Precipitation
Snow Pack
Runoff
Streamflow
Erosion
Deposition/
Resuspension
Transport
Water, Erosion
Lo
Hi
Temp. & Dep./Res.
-/Dep
+/Res
Streamflow & Transport
Lo
Hi

Lake Lanier

LSPC → EFDC

- ▶ Multi-purpose application
- ▶ Reservoir operations (Army Corps of Engineers)
- ▶ TMDL and wasteload allocations (Georgia EPD and USEPA)
- ▶ Landuse management for development



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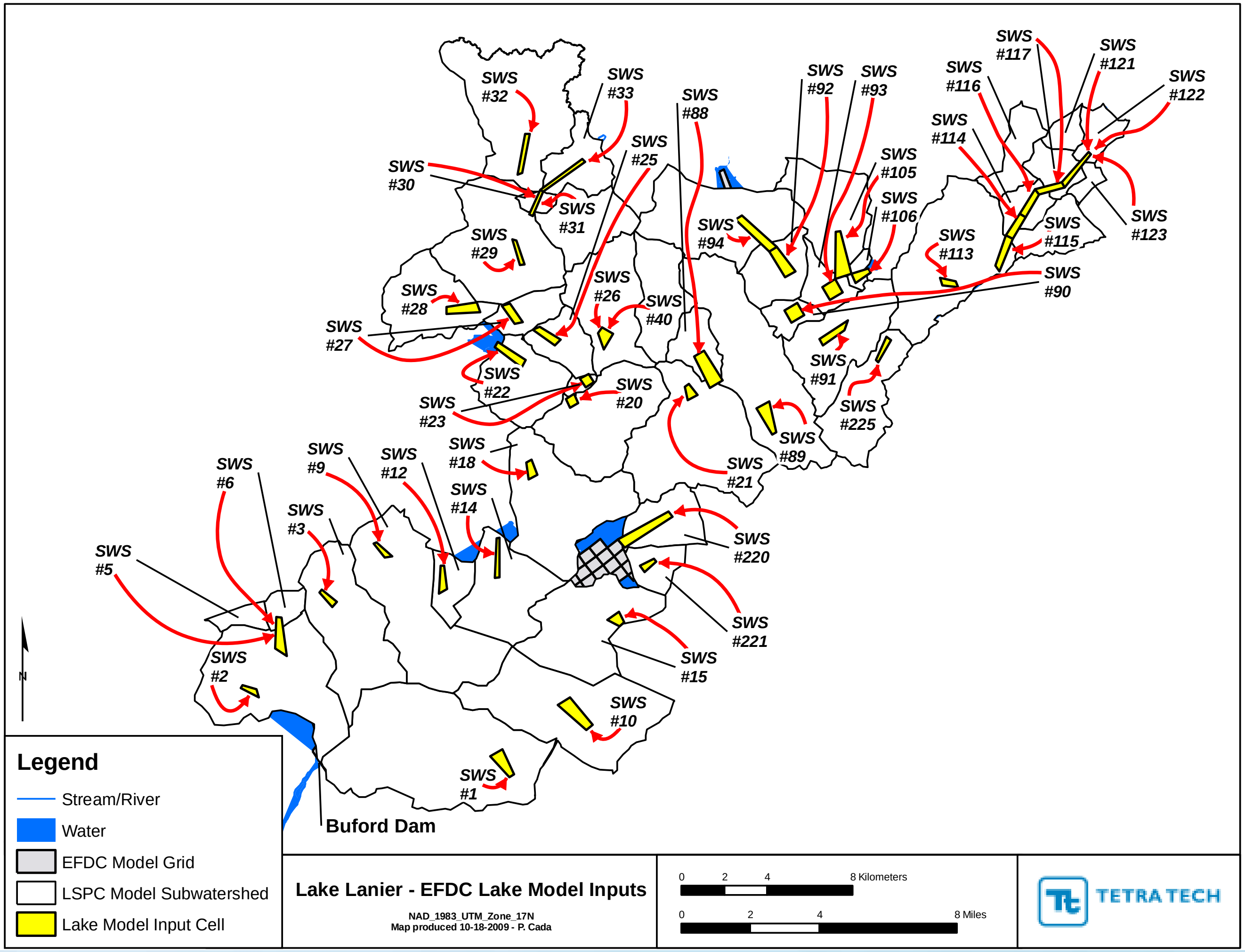
Concentrations:
Chl-a, TN, NH_3, NOx, OrgN, TP, PO_4, OrgP, BOD, DO, Temp, TSS, Fecal

LSPC

Flows
Temperatures
Concentrations

EFDC

Lake/Harbor – Water Surface
River/Lakes – Temperatures
River/Lake/Harbor Concentrations:
(Chl-a, TN, NH_3, NOx, OrgN, TP, PO_4, OrgP, BOD, DO, Temp)



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Scenarios

- Historical and current conditions
- Current conditions with allowable permits
- Current conditions w/ point sources/withdrawals removed
- All forested/natural
- Future land use full build-out
- Future land use w/ point sources/withdrawals removed
- Nonpoint source management practices
- TMDL to meet water quality criteria
  - Landuse and point source-specific reductions
- Reservoir operational changes

Lake Sidney Lanier, Georgia

2005-10-01

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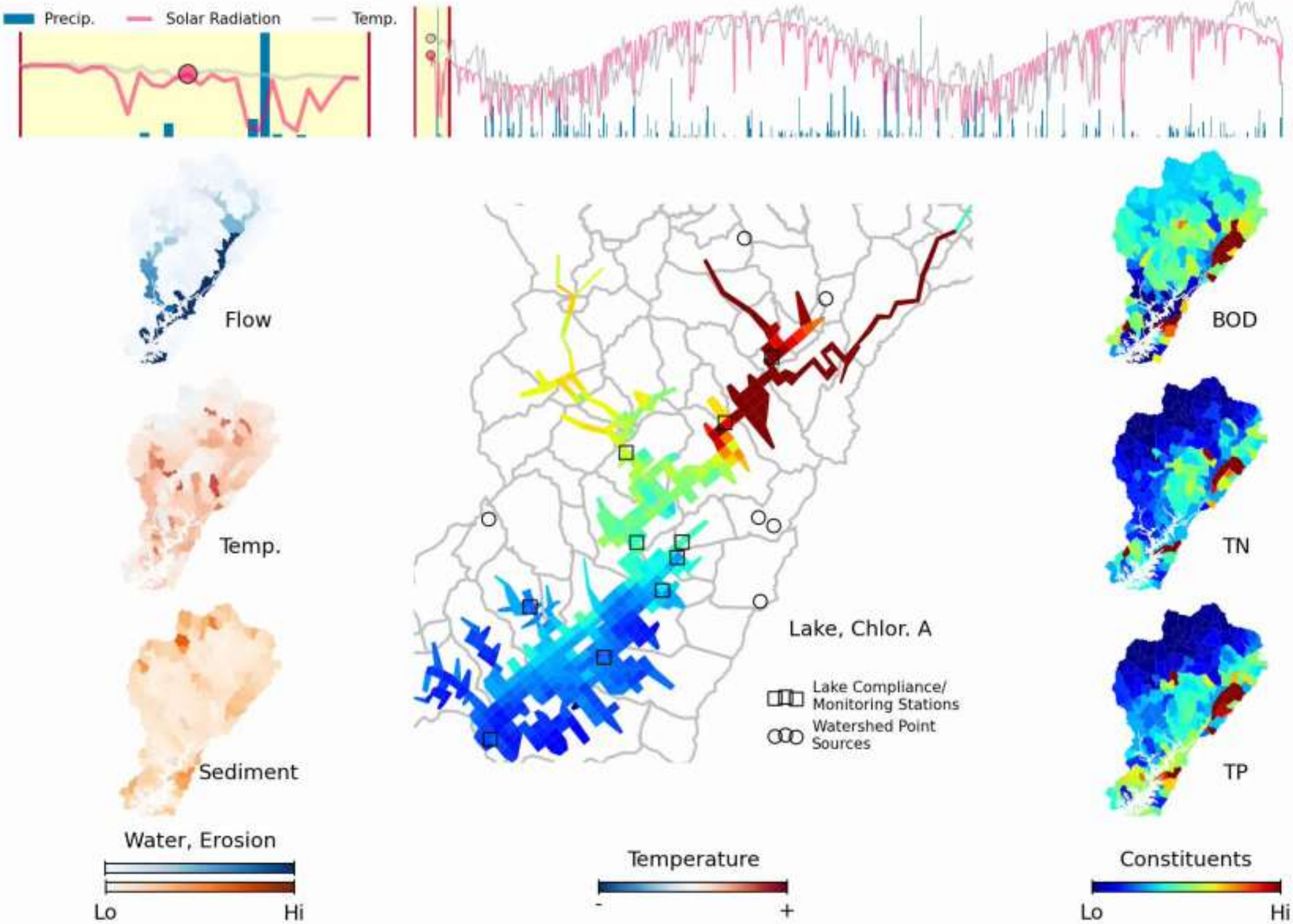

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Milwaukee Metropolitan Sewer District

LSPC → SUSTAIN

- Explored ability of green infrastructure to reduce combined sewer overflows
- Benefits measured by:
  - Environmental outcomes (pollution reductions)
  - Economic and social outcomes (triple bottom line)
- Applied SUSTAIN linked to LSPC

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Potential Types and Locations

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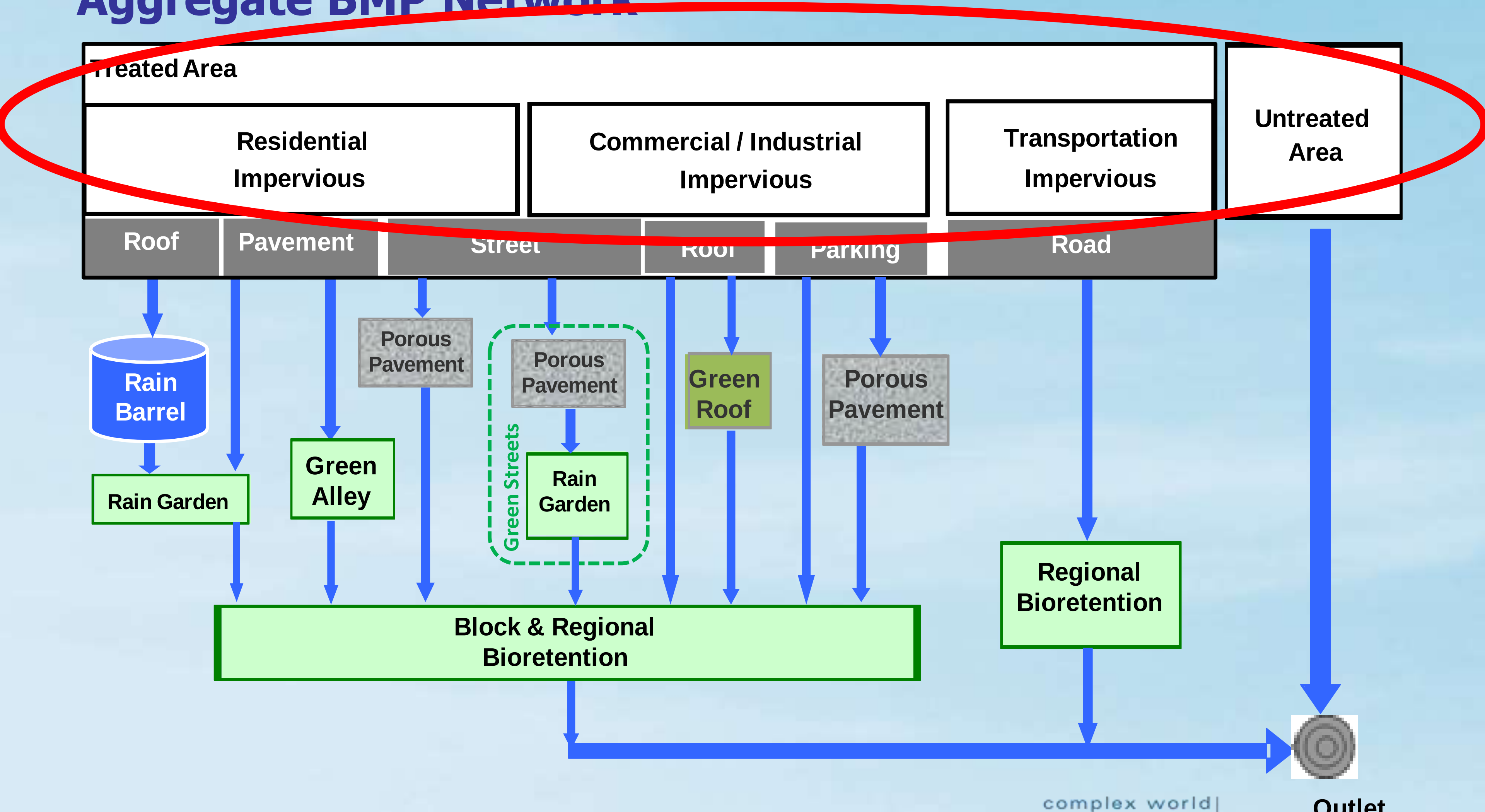
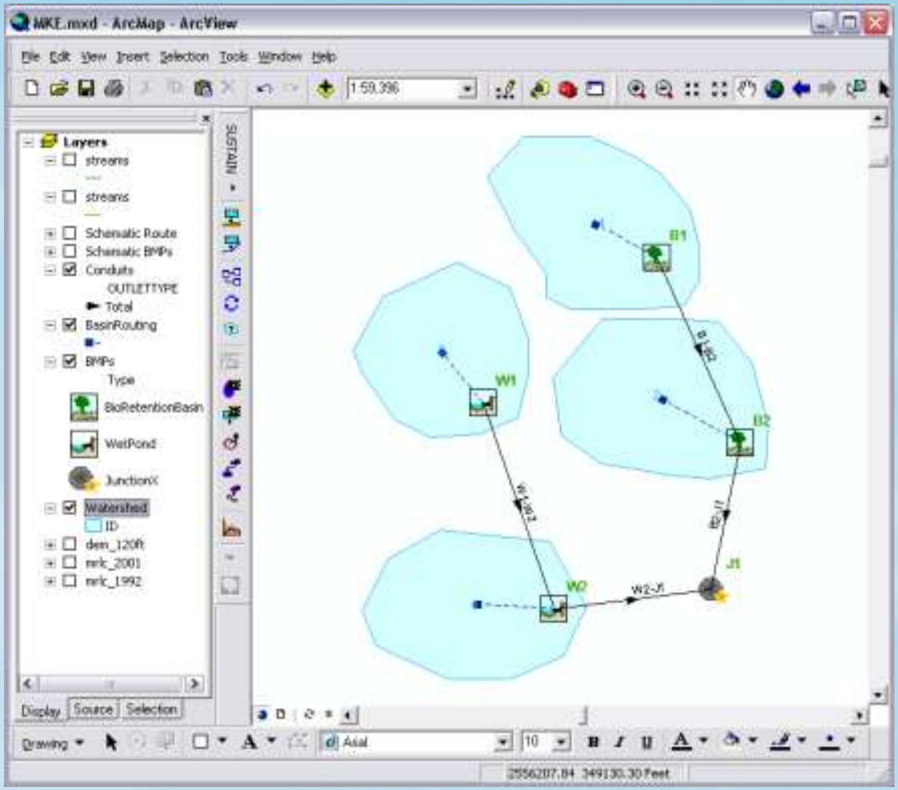
BMP Configuration:
Aggregate BMP Network

From LSPC model



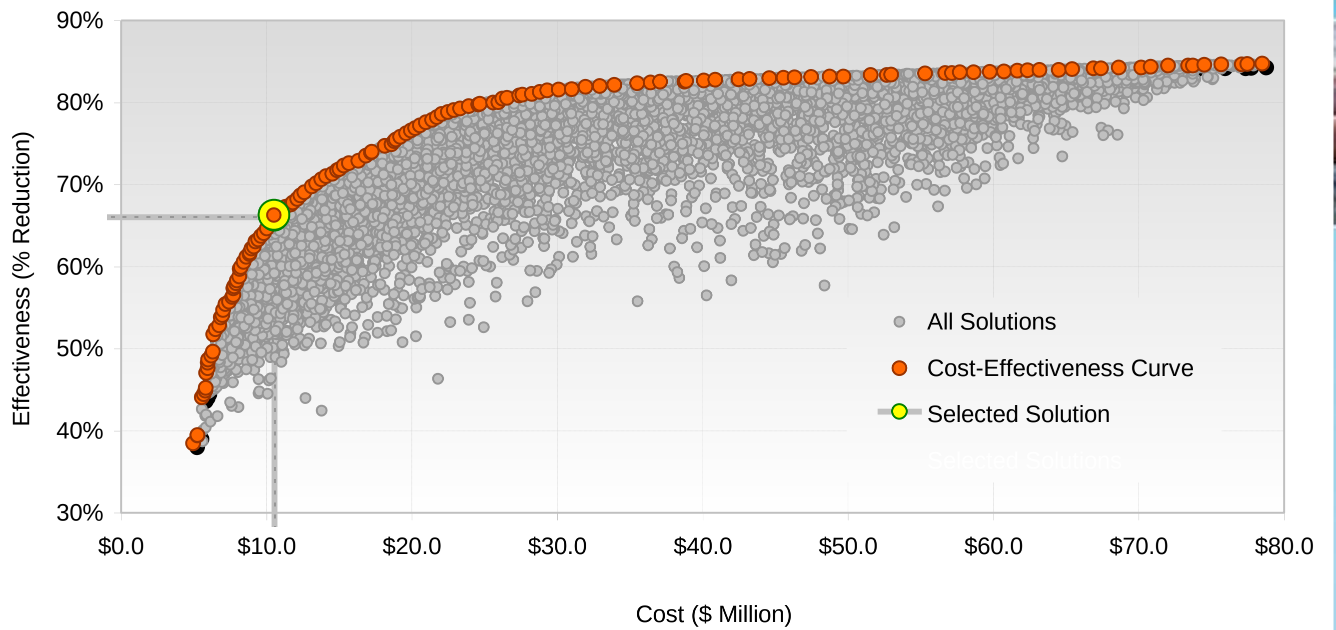
Selection and Placement Optimization

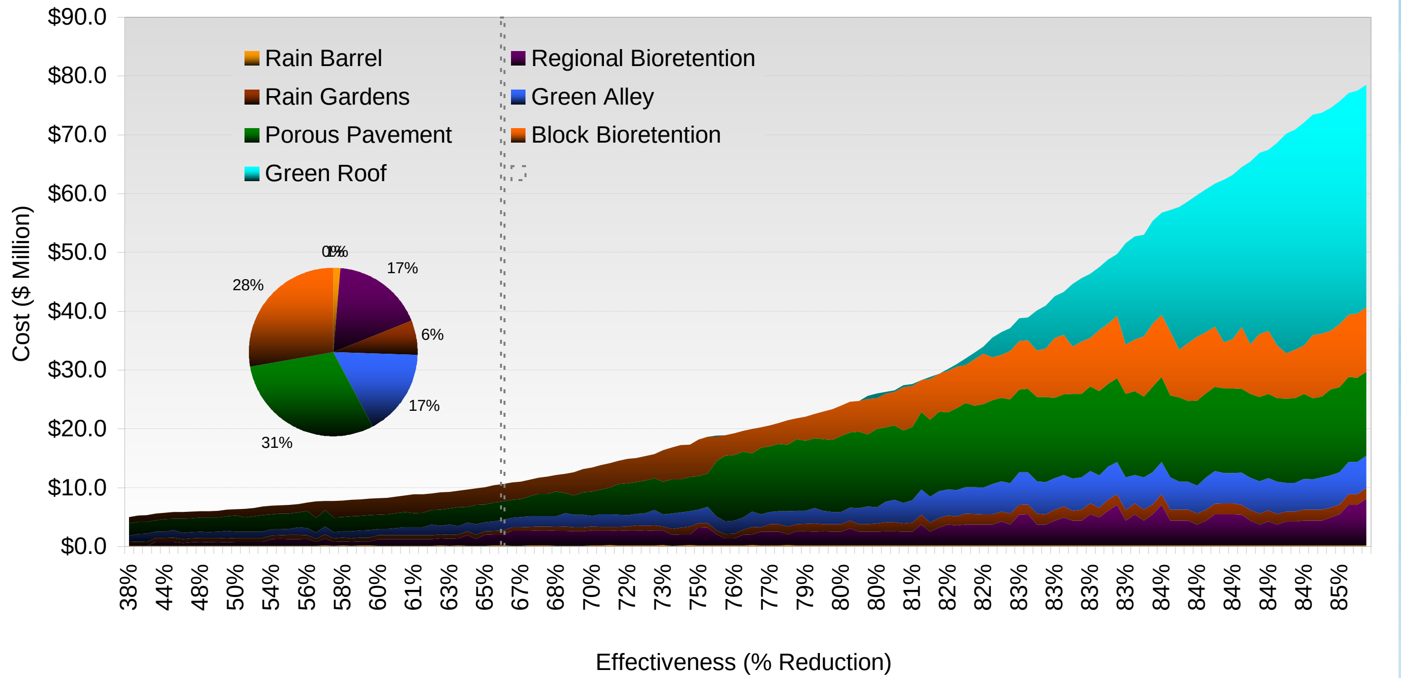
- ► BMP Configuration
  - Map all potential locations
  - Typical routing configuration
  - Unit cost (scalable)
- ► Decision Variables
  - BMP Size (0 to maximum)
  - BMP Location (on or off)
- ► Objectives
  - Minimize Cost
  - Maximize Volume Reduction



Cost-effective Solutions

- Reduction:
  66.0%
- Cost:
  $10.6 Mil





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Thank you!

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