Michigan Water Withdrawal Assessment Process and Screening Tool Overview

Southwest Michigan Water Resources Council

January 12, 2012

Overview

- Great Lakes-St. Lawrence River Basin Water Resources Compact, 2008
- State implementation (2008 Public Act 190)
- State Ground Water Conservation Advisory Council

Compact

Section 4.10. Management and Regulation of New or Increased Withdrawals and Consumptive Uses.

1. Within five years of the effective date of this Compact, each Party shall create a program for the management and regulation of New or Increased Withdrawals and Consumptive Uses by adopting and implementing Measures consistent with the Decision-Making Standard. Each Party, through a considered process, shall set and may modify threshold levels for the regulation of New or Increased Withdrawals in order to assure an effective and efficient Water management program that will ensure that uses overall are reasonable, that Withdrawals <u>overall will not result in significant impacts to the Waters and Water Dependent Natural Resources of the Basin, determined on the basis of significant impacts to the physical, chemical, and biological integrity of Source Watersheds</u>, and that all other objectives of the Compact are achieved. Each Party may determine the scope and thresholds of its program, including which New or Increased Withdrawals and Consumptive Uses will be subject to the program.

Ground Water Conservation Advisory Council

- Guiding principals:

http://www.michigan.gov/documents/act148reportlegislature_157533_7.pdf

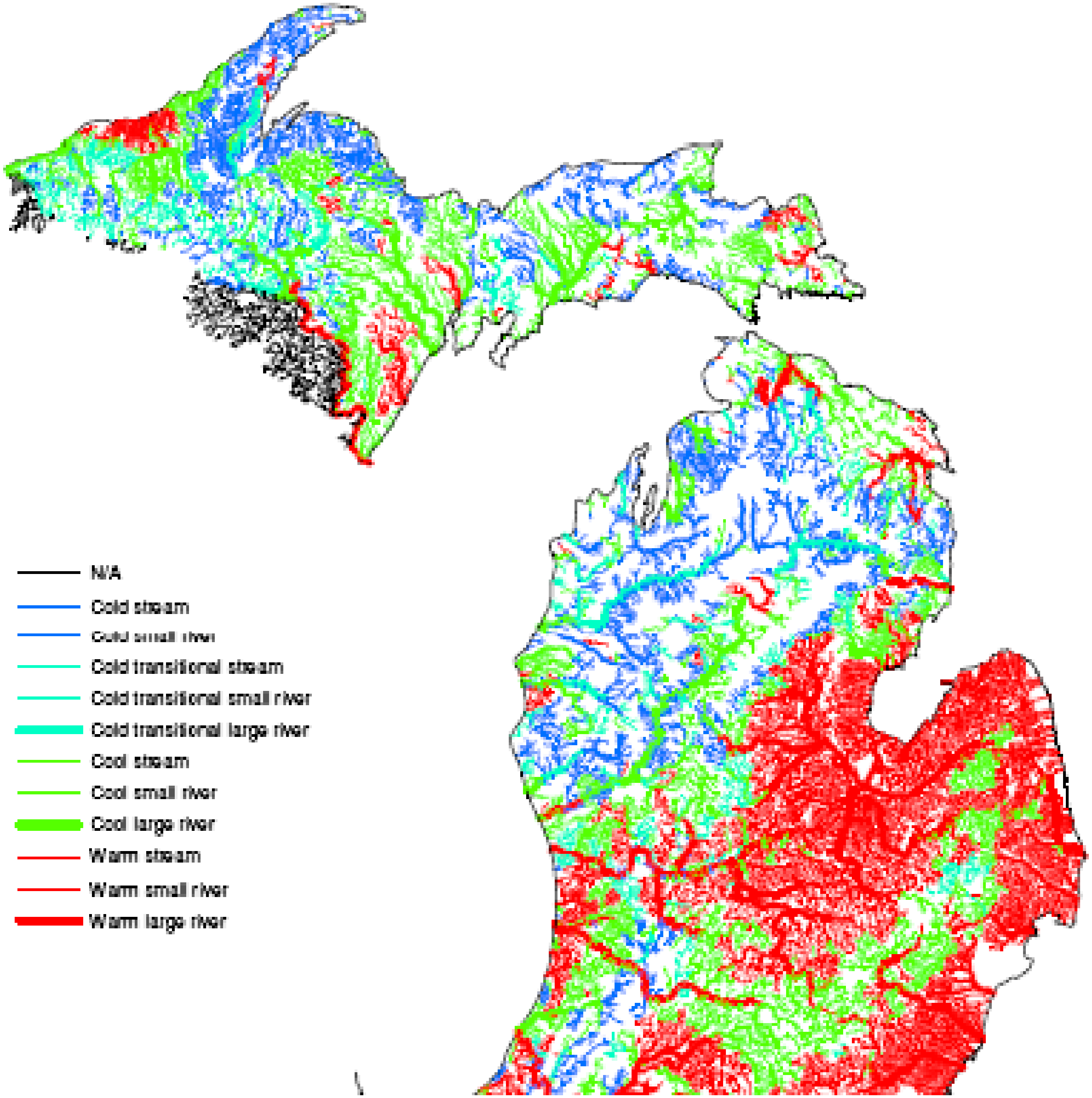
- Discussed implementation language and approaches
- Made recommendations to legislature

New or Increased Withdrawal: Challenges

- Environmental impact from water withdrawal
- How much water can be responsibly removed
- Represent the diversity of streams and aquatic ecosystems
- Account for varied sensitivity to changes in flow and risk of adverse impacts
- Recognize and authorize withdrawals that will likely not have adverse impacts
- Identify potential problems

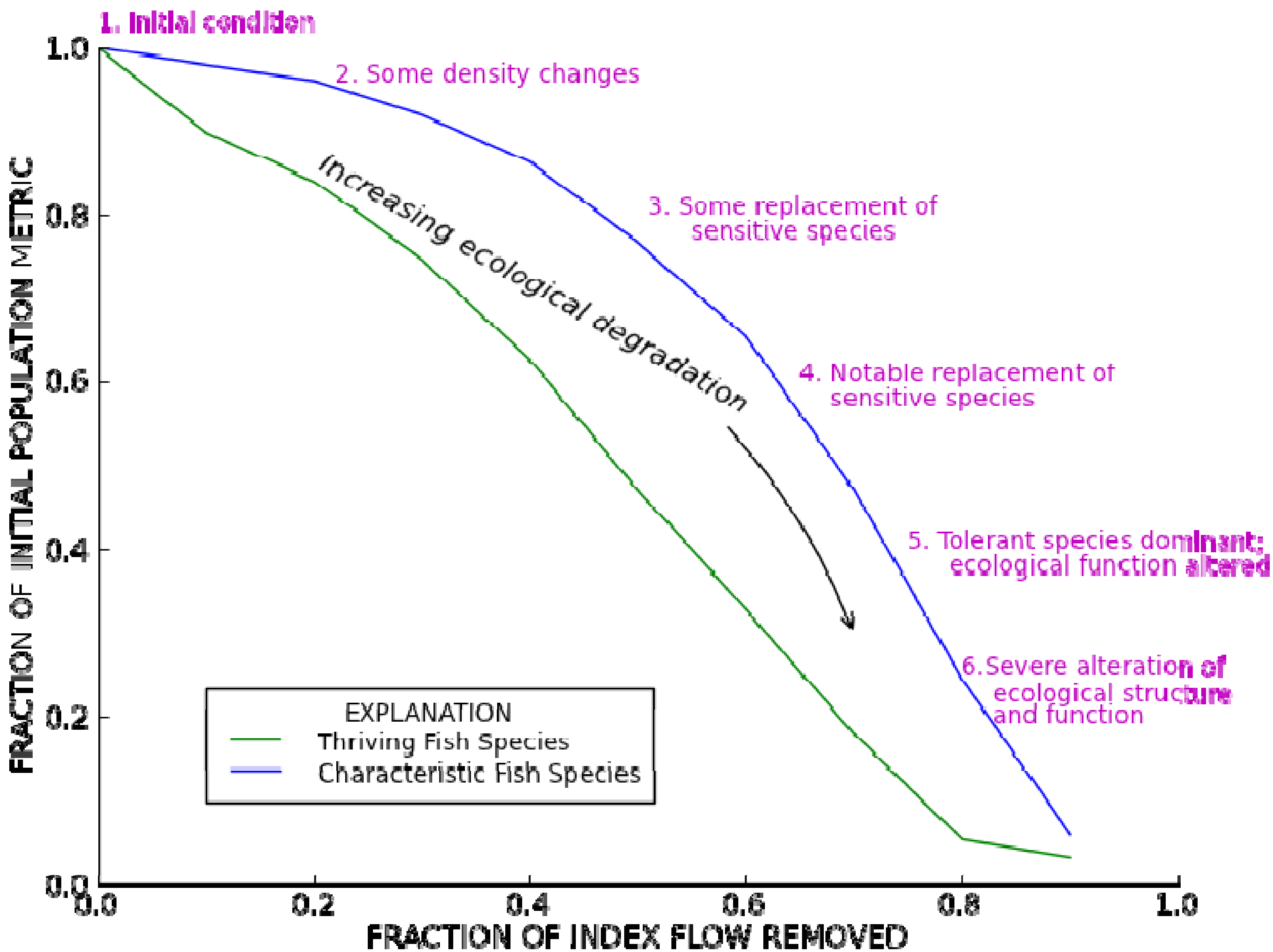
Ecological Response and Stream Classification

- Estimate impacts
- Allow setting of thresholds for removals
- Represents diversity across the state
- Accounts for variation across the state

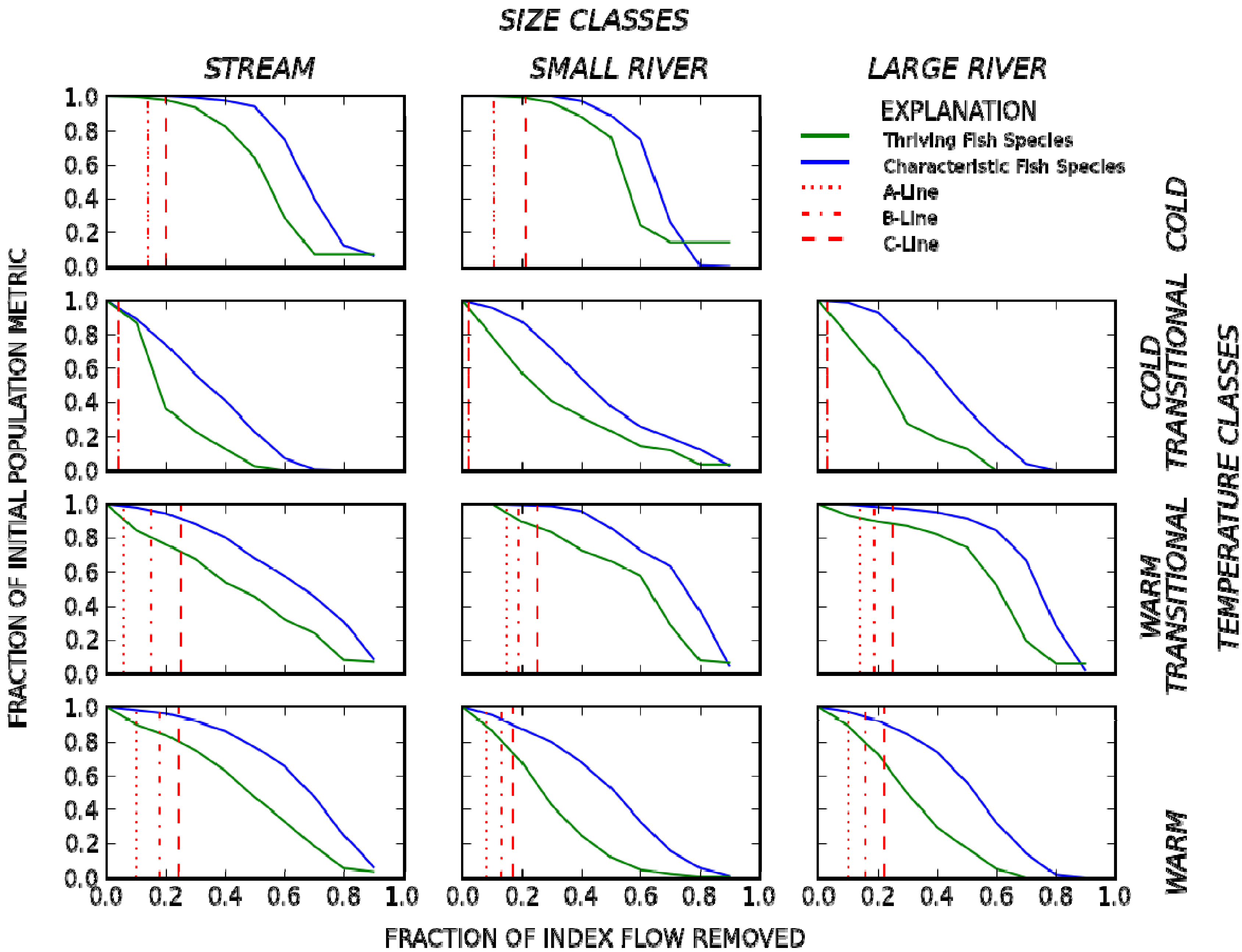

N/A
Cold stream
Cold transitional stream
Cold transitional small river
Cold transitional large river
Cool stream
Cool small river
Cool large river
Warm stream
Warm small river
Warm large river

Adverse Impact

- Response curves were defined using fish data and research relating fish populations to flow and temperature
- Thresholds set through a legislative process



1. Initial condition
2. Some density changes
3. Some replacement of sensitive species
4. Notable replacement of sensitive species
5. Tolerant species dominant; ecological function altered
6. Severe alteration of ecological structure and function
Increasing ecological degradation
EXPLANATION
Thriving Fish Species
Characteristic Fish Species
FRACTION OF INITIAL POPULATION METRIC
FRACTION OF INDEX FLOW REMOVED
0.0
0.2
0.4
0.6
0.8
1.0


SIZE CLASSES
STREAM
SMALL RIVER
LARGE RIVER
EXPLANATION
Thriving Fish Species
Characteristic Fish Species
A-Line
B-Line
C-Line
COLD
COLD TRANSITIONAL
WARM TRANSITIONAL
WARM
TEMPERATURE CLASSES
FRACTION OF INITIAL POPULATION METRIC
FRACTION OF INDEX FLOW REMOVED
0.0
0.2
0.4
0.6
0.8
1.0

Streamflow

- Flow at an ungaged location is typically needed
- Use data from streamgages, individual measurements, and knowledge of setting
- Simplest approach is to choose a gage that represents similar basin characteristics and scale the measured flow at the gage by the ratio of areas of the ungaged location and the gage
- Individual measurements can be used to refine the estimate

Groundwater

- For wells, need to estimate how much a well will interact with a local stream
  - Treat all pumping as if its from local stream
  - Simple to complex models to estimate streamflow depletion

Identify withdrawals less likely to cause adverse resource impacts

- Recognize and authorize withdrawals that will likely not have adverse impacts
- Identify potential problems
- Increase efficiency
- Make system more user driven

Screening Tool: underlying models

- Stream classes and thresholds are the same
- Streamflow
- Groundwater/stream interaction

Streamflow

- Linear regression on streamflow yield (Q/A) to estimate index flow
- Index flow: estimated median flow for the low-flow summer month
- In addition to area:
  - Percent forest from Michigan Resource Information System (1978),
  - Percent A soil from NRCS (low runoff potential, < 10 % clay, > 90% sand or sand/gravel)
  - Percent D soil from NRCS (high runoff potential, > 40% clay, < 50% sand, clayey texture)
  - Percent high transmissivity class from Michigan GWIM
  - Precent low transmissivity class from Michigan GWIM
  - Normal annual precipitation 1970-2000 in inches
- Gage data used in developing the relation: minimum 10 years of record; not appreciably affected by withdrawals, diversions or augmentation; record not significantly impacted by storage in the system. 147 stations were used; record length 11 – 91 years; 88 stations in operation in 2005.
- In screening tool, estimated index flow is cut in half for the initial screening

$$\text{Index flow} = \text{Drainage Area}^{*} \left(-0.55077 + (-0.0014132\ LT) + (0.0019883\ HT) + (0.0039675\ F) + (0.02408\ P) + (0.0023171\ A) + (0.001534\ D)\right)^2$$

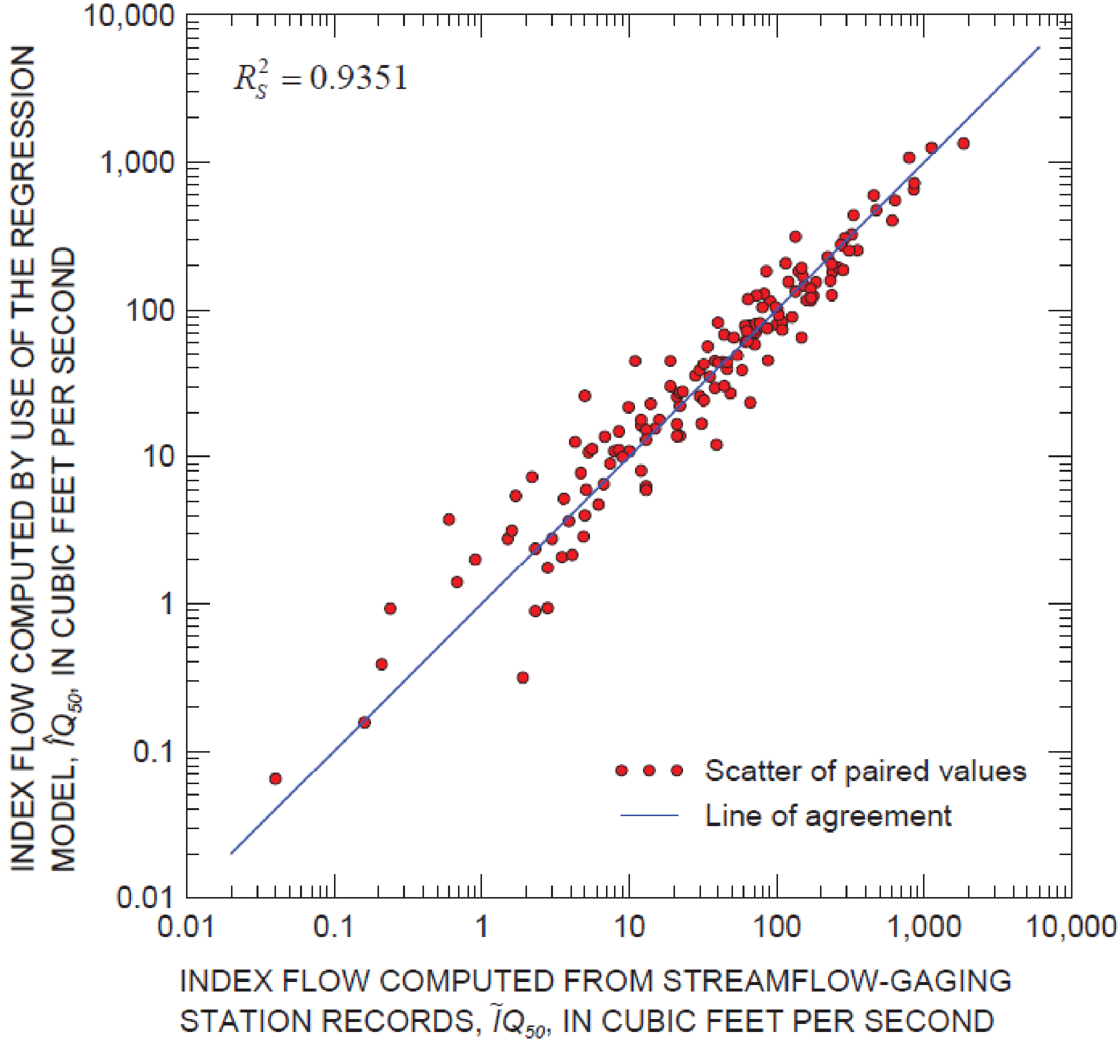


Figure 16. Relation between measured and computed index flows for selected streamflow-gaging stations in Michigan [R_S^2, the Spearman coefficient of determination].

Assumptions

- Gaged areas and observed flows are representative of conditions across the state
- Variables used in the regression are relevant for flows across the state
- Range of values for regression variables for the gages are consistent with the values for ungaged areas
- Long-term average flows are appropriate for estimating current and future conditions

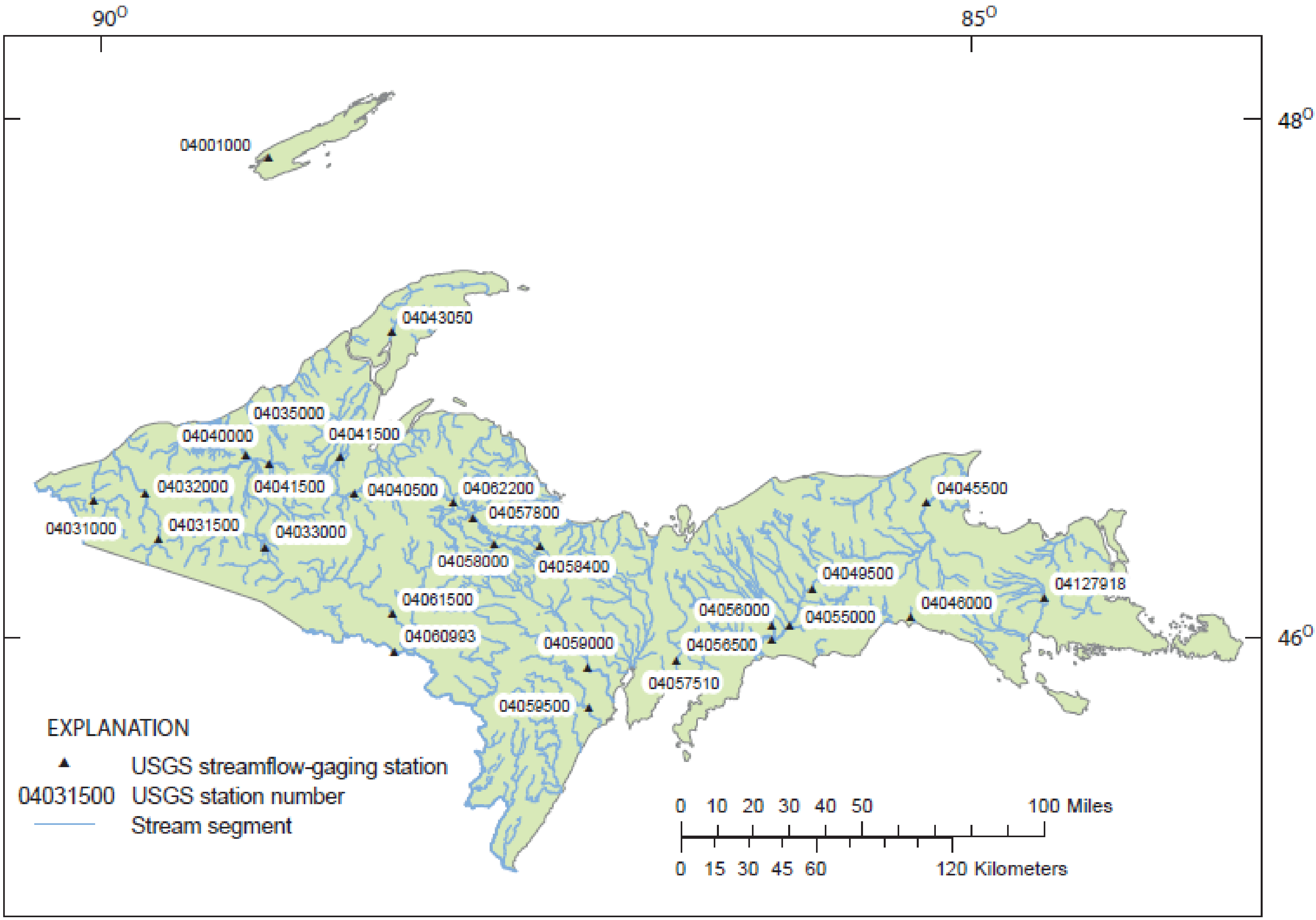


Figure 2. U.S. Geological Survey streamflow-gaging stations in Michigan's Upper Peninsula included in the analyses.

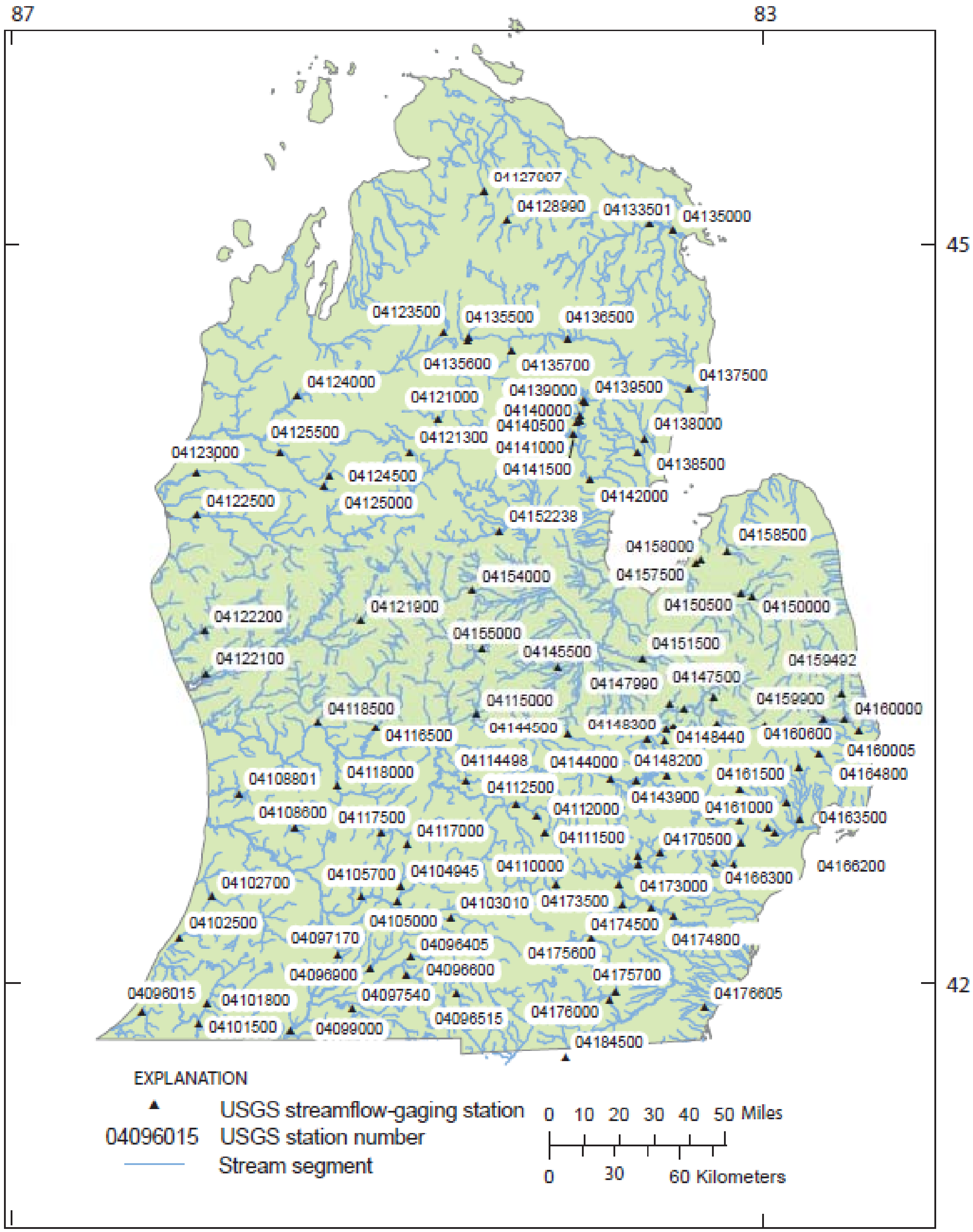


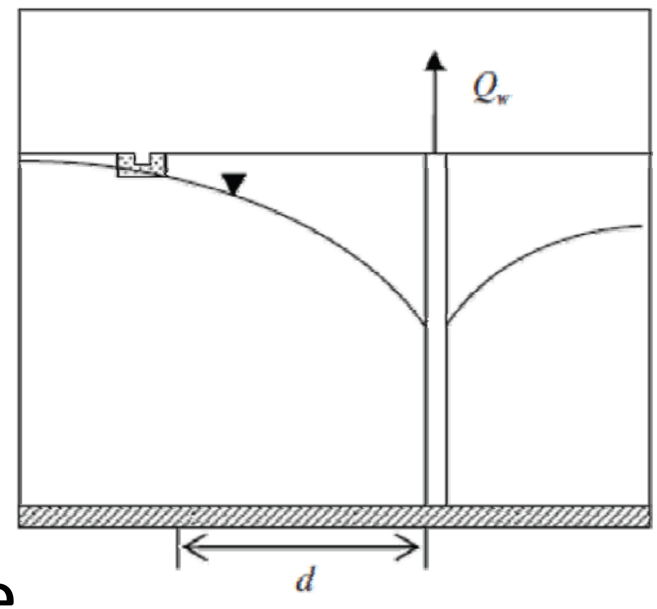
Figure 3. U.S. Geological Survey streamflow-gaging stations in Michigan's Lower Peninsula included in the analyses.

Groundwater

- Analytical equation for stream depletion by a well by Hunt (1999) chosen for the screening tool.
- Drawdown computed by this approach is consistent with methods used in standard aquifer-test analysis.
- Low data requirements and ease of use.
- Simple is solution consistent with screening tool, does not imply more knowledge of the system.

Assumptions

- Aquifer in connection with stream
- Streambed resistance is considered
- Pumping does not change recharge
- No boundaries
- Water to well from storage (drawdown) or stream
- Uniform aquifer properties

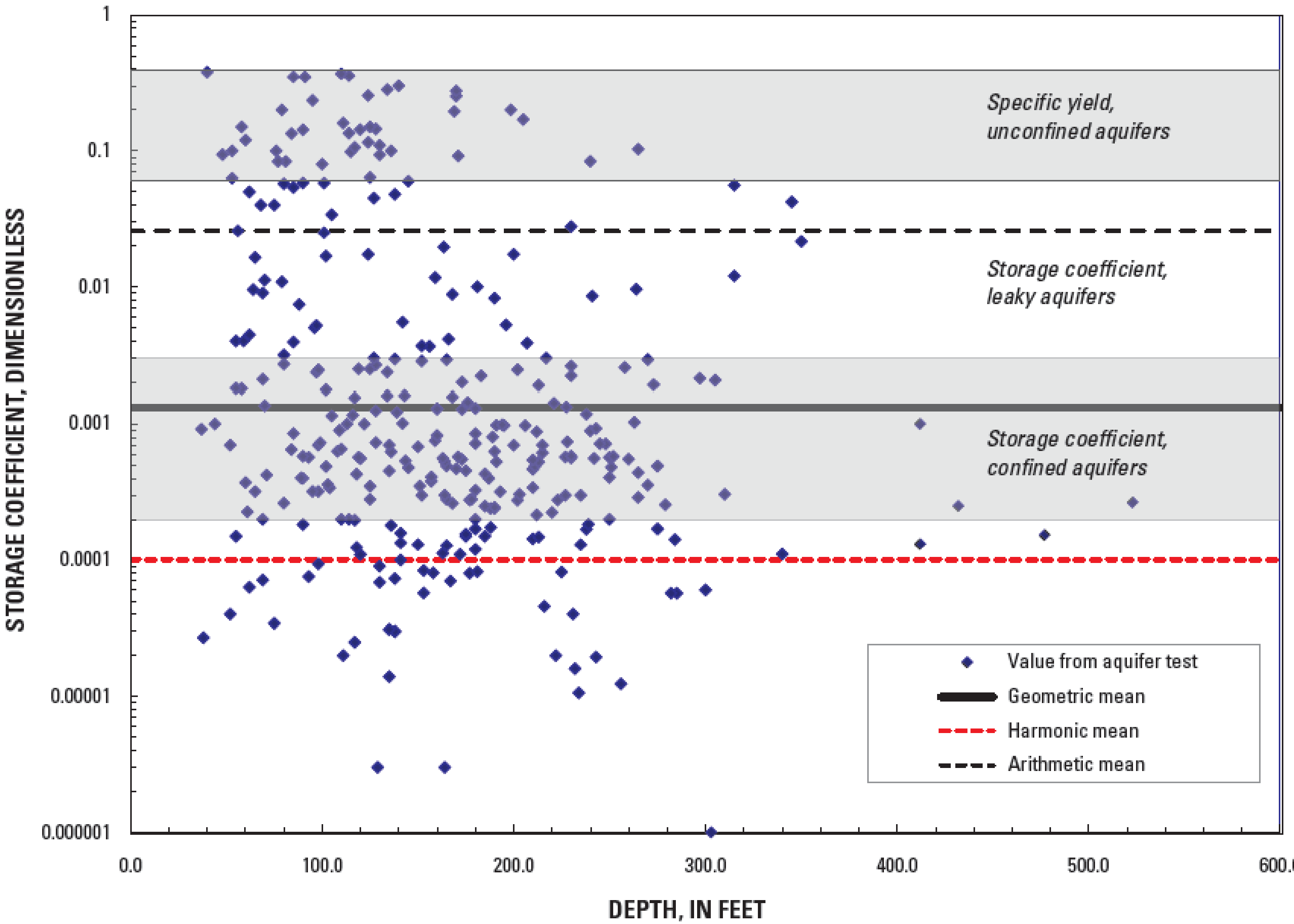


Analytical solution

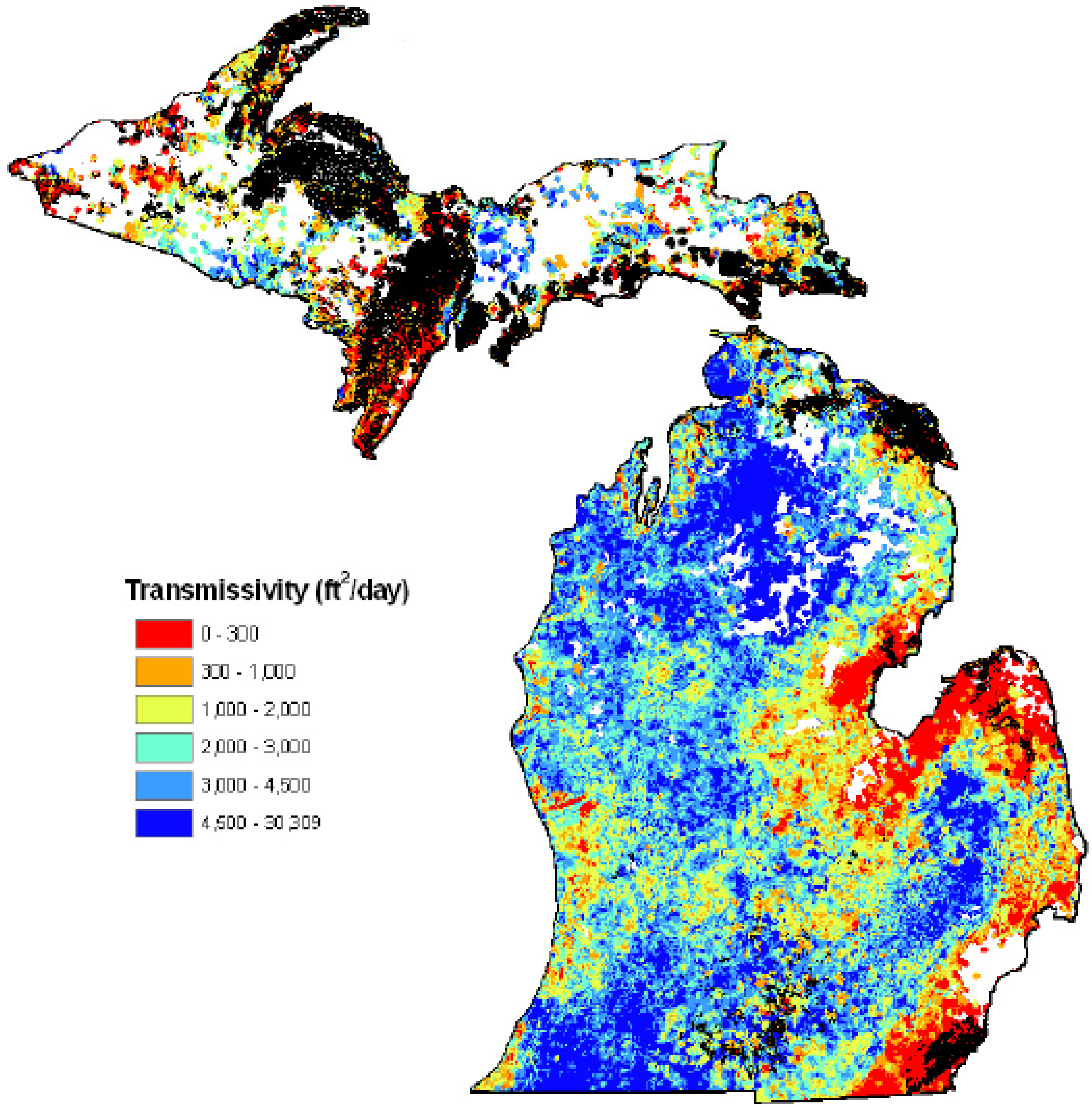
- Requires: distance from well to stream, transmissivity, storativity, streambed conductance.

$$Q_s = Q_w \left[\operatorname{erfc}\left(\sqrt{\frac{d^2 S}{4Tt}} \right) - \exp\left(\frac{\lambda^2 t}{4ST} + \frac{\lambda d}{2T} \right) \operatorname{erfc}\left(\sqrt{\frac{\lambda^2 t}{4ST}} + \sqrt{\frac{d^2 S}{4Tt}} \right) \right]$$

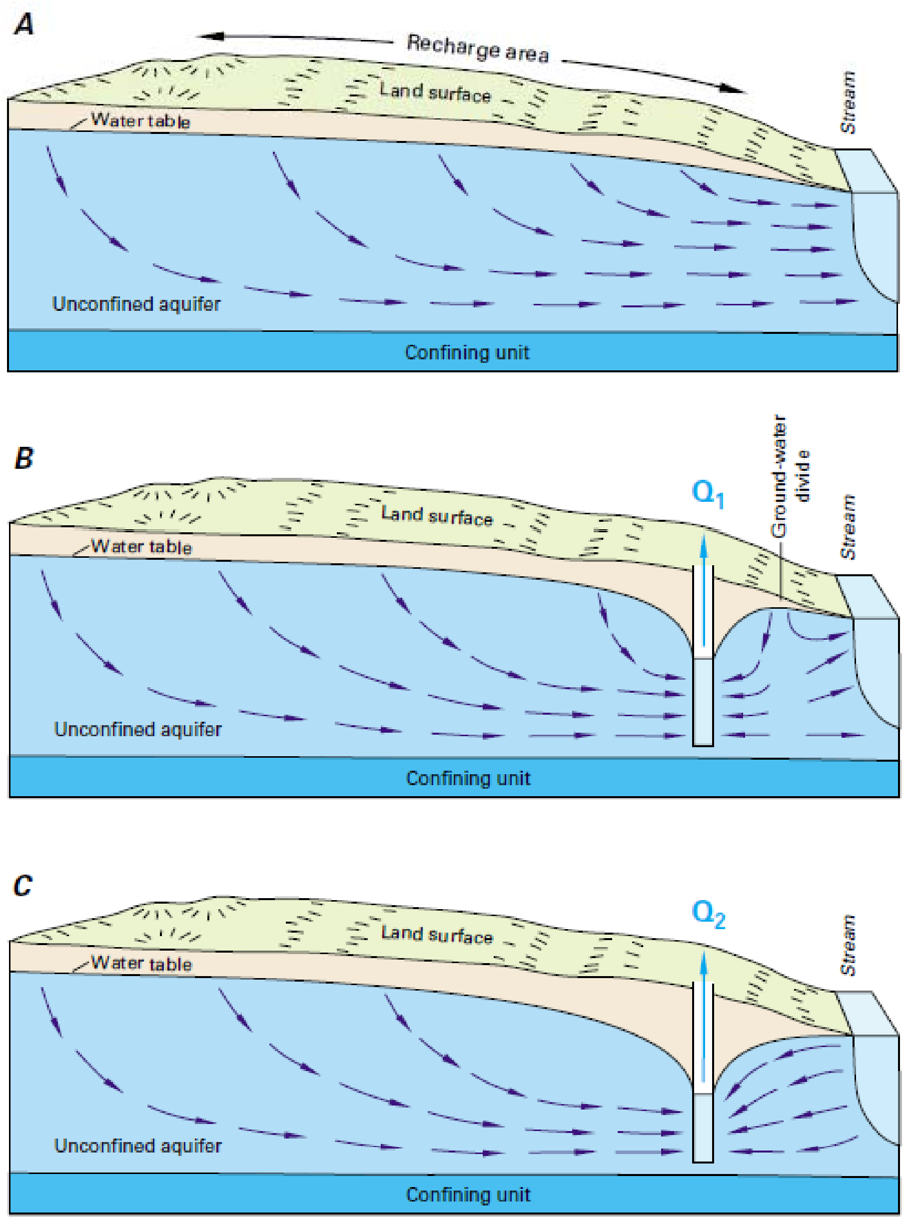
- S -> typical of leaky aquifer, 0.01
- T -> from Michigan Groundwater Inventory and Map. For glacial deposits based on water-well records and glacial landforms, for bedrock based on aquifer-test analysis. Median value from 1000 m grid used for each watershed.
- d -> from web-based mapping tool
- Implementation in screening tool assumes that resistance to vertical flow between top of well screen and streambed dominates and uses an estimate based on aquifer transmissivity, aquifer thickness, and stream width for streambed conductance



STORAGE COEFFICIENT, DIMENSIONLESS
1
0.1
0.01
0.001
0.0001
0.00001
0.000001
0.0
100.0
200.0
300.0
400.0
500.0
600.0
DEPTH, IN FEET
Specific yield, unconfined aquifers
Storage coefficient, leaky aquifers
Storage coefficient, confined aquifers
Value from aquifer test
Geometric mean
Harmonic mean
Arithmetic mean


Transmissivity (ft²/day)
0 - 300
300 - 1,000
1,000 - 2,000
2,000 - 3,000
3,000 - 4,500
4,500 - 30,309

From USGS Circular 1186



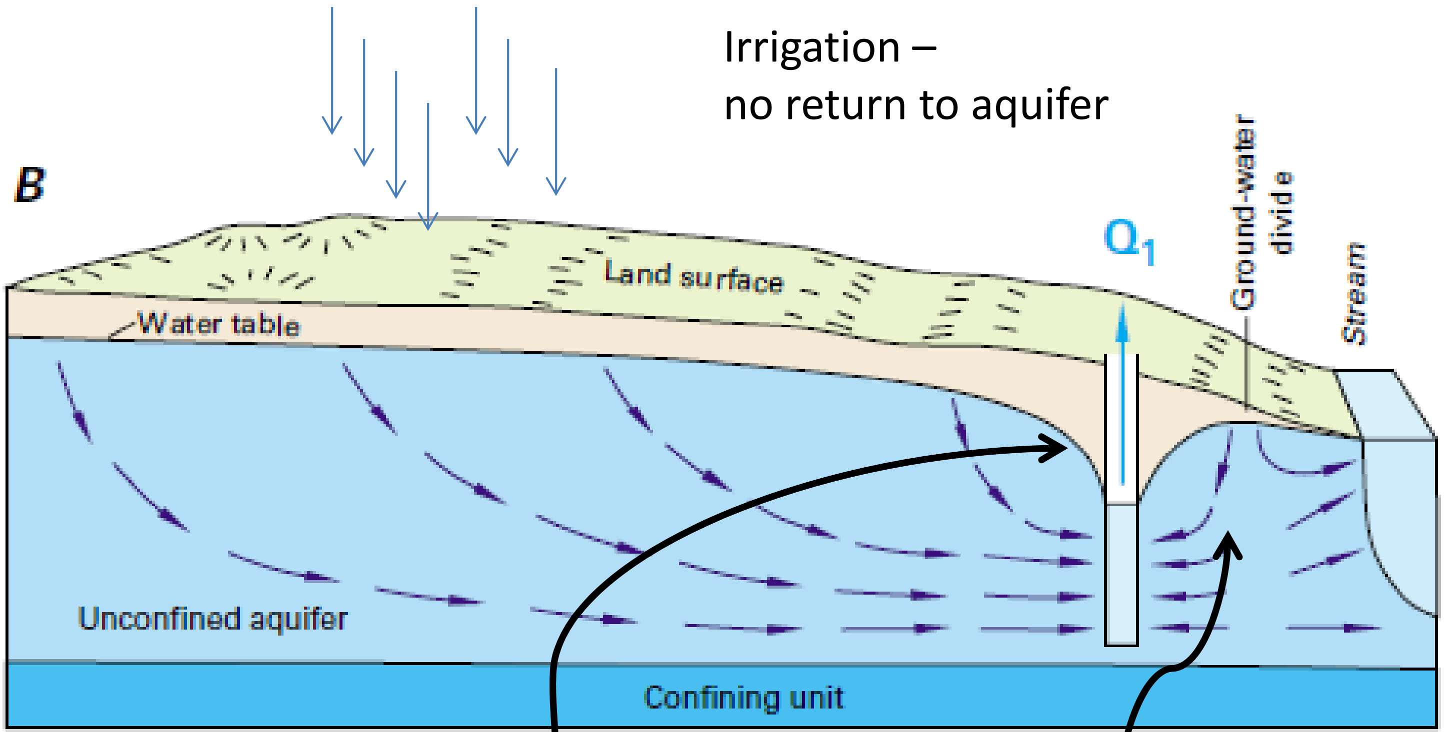
Capture water that would have discharged to the stream

Induce flow from the stream to the well

Figure 13. Effects of pumping from a hypothetical ground-water system that discharges to a stream. (Modified from Heath, 1983.)

Recharge unchanged by pumping

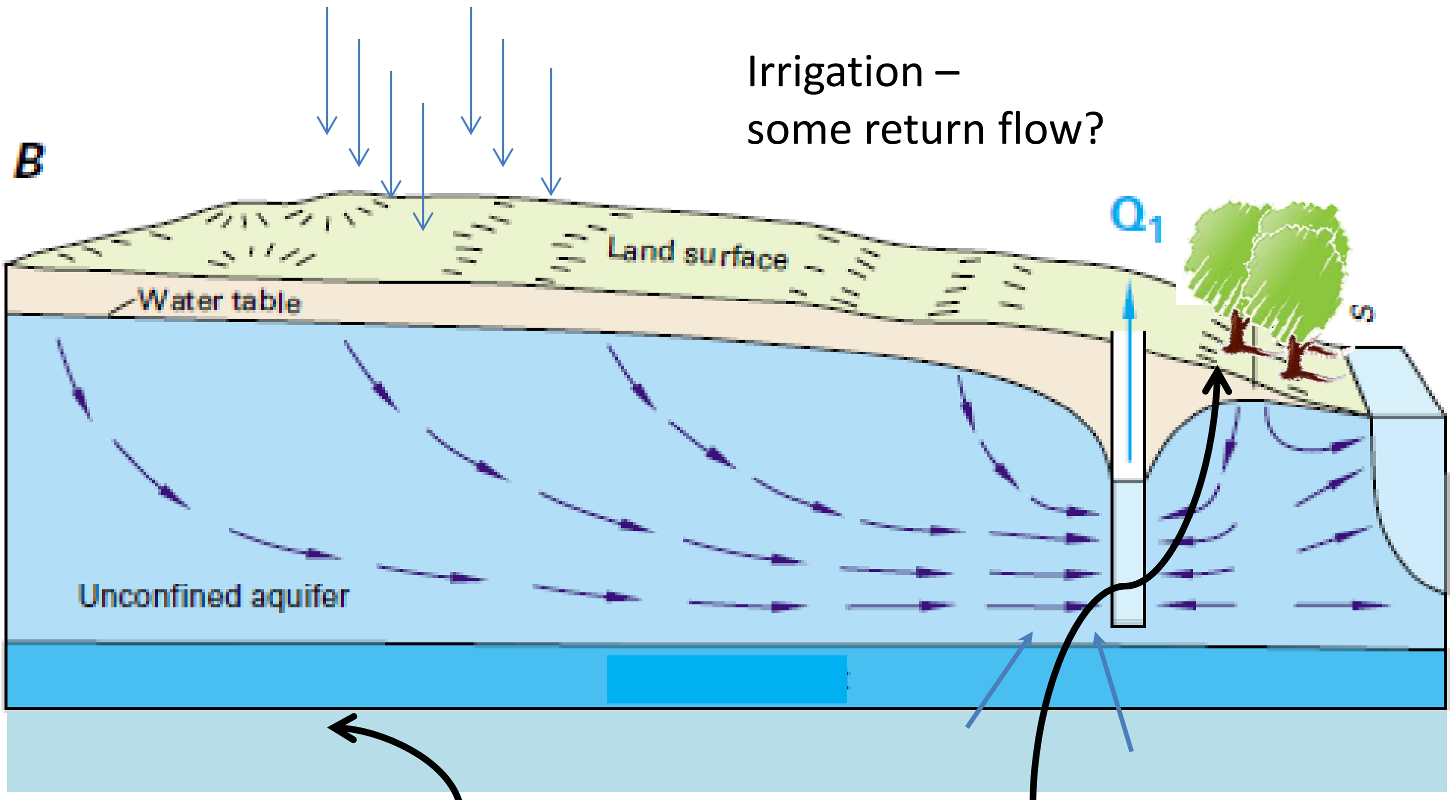
Irrigation –
no return to aquifer



Water from storage or from stream, either capture of water that would have discharged to stream or induced flow.

Recharge changed by pumping, irrigation changes to soil moisture, changes in water table depth, etc.

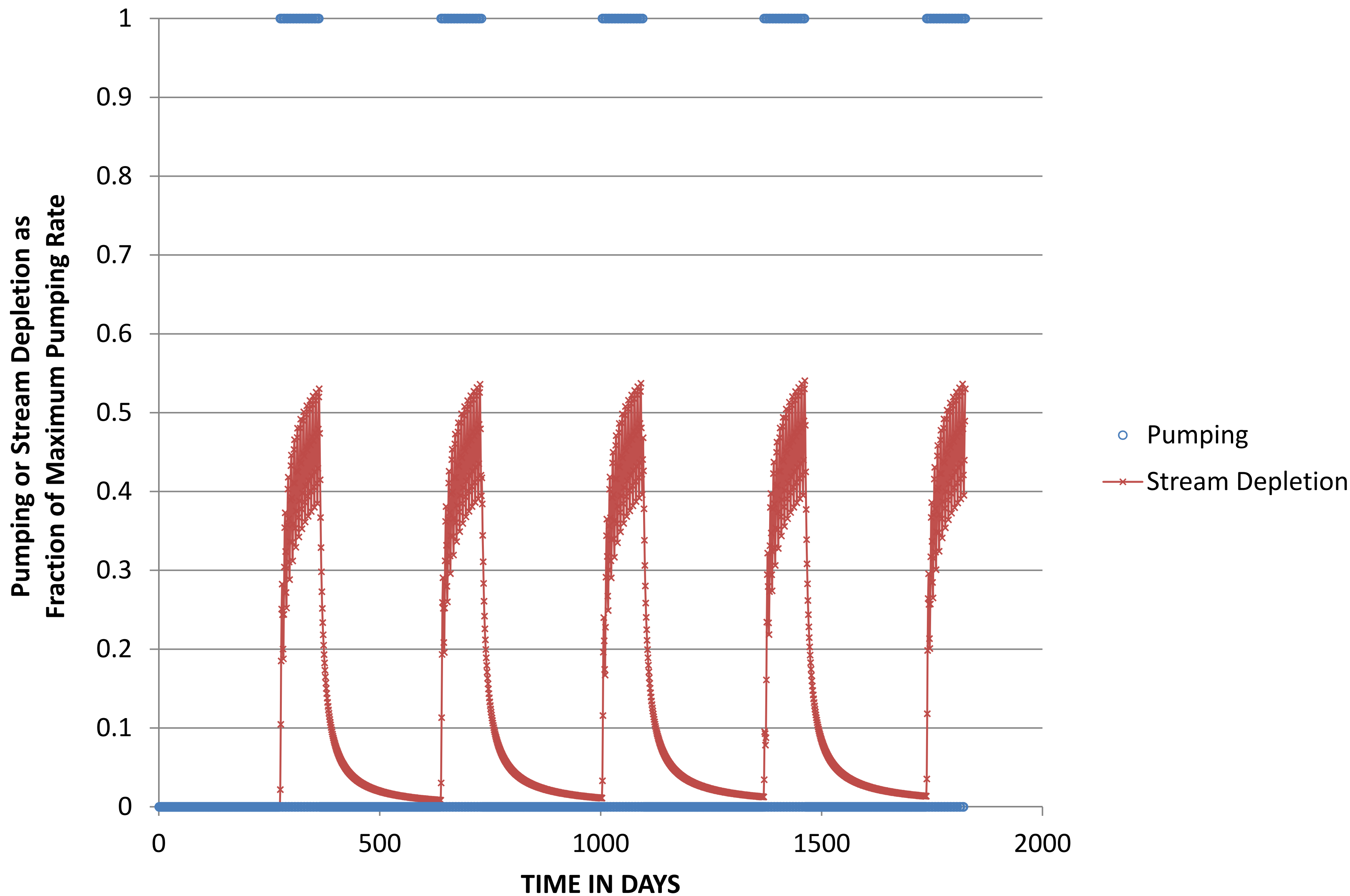
Irrigation –
some return flow?



Water from storage, stream, capture from riparian vegetation, wetlands, ponds, other aquifers…

Intermittent Pumping

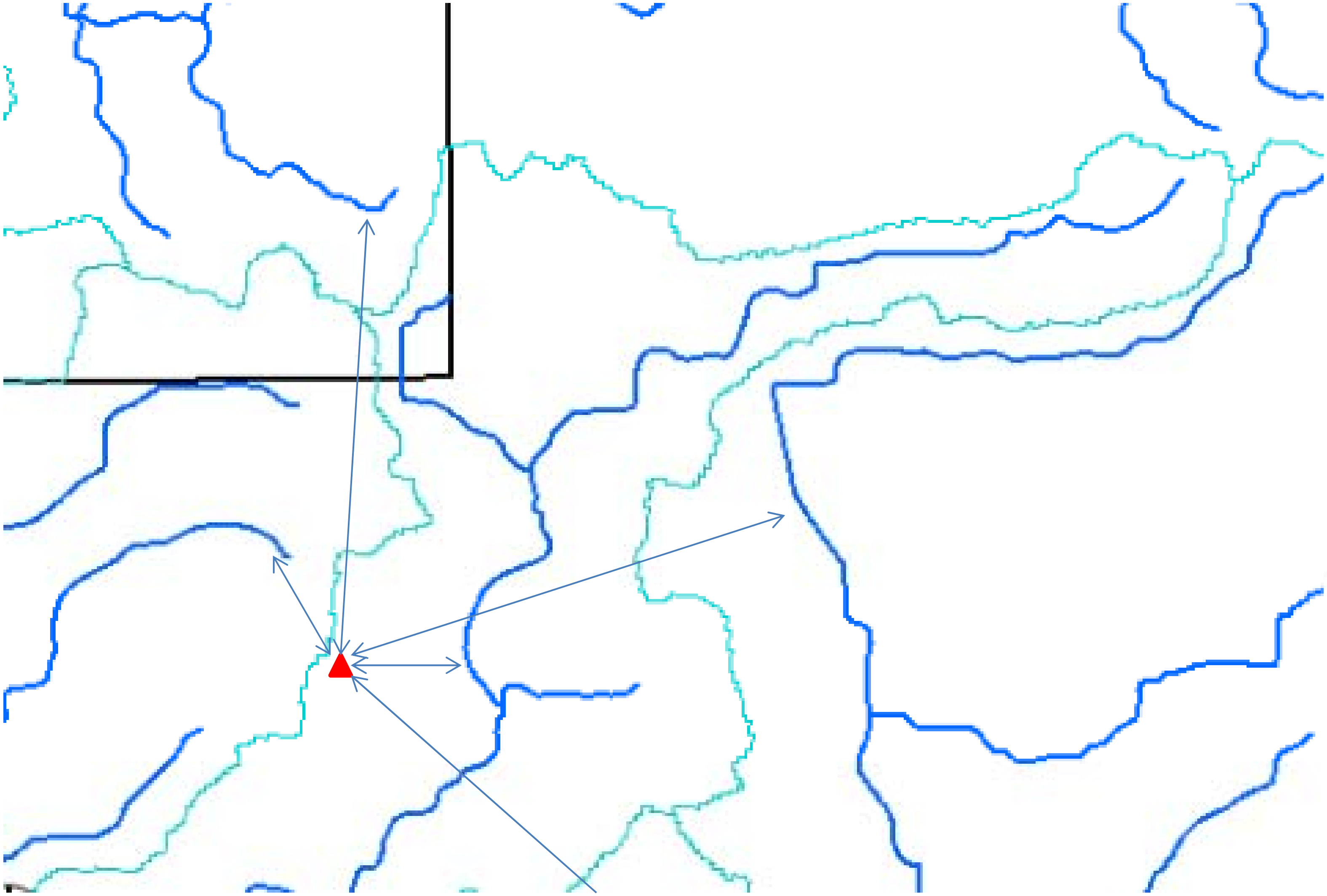
- Approach accounts for seasonal pumping and damping effect of storage on streamflow depletion



Well 500 ft from stream

Multiple streams

- In the on-line screening tool, pumping is distributed to multiple streams by inverse-distance weighting: streams closer to well provide more water to the well
- Total pumping is split between the watershed containing the well and all watersheds that share a boundary. The closest stream is found in each watershed and this distance is used in the analytical solution for each watershed.
- The T, S, and streambed conductance from the home watershed is used for all the evaluations
- In the screening, neighbors with depletions < ½ maximum depletion of all watersheds are not considered



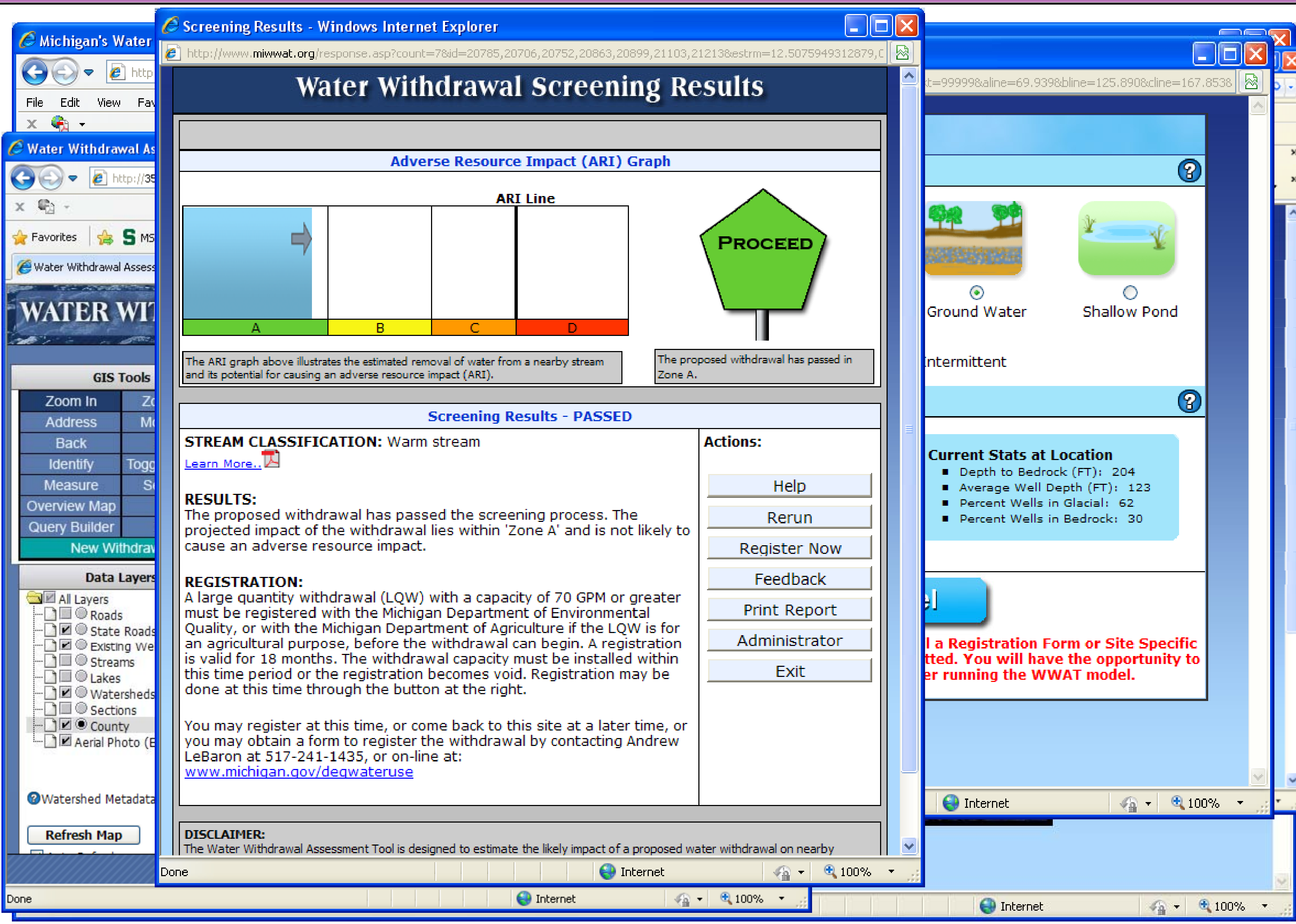
Accounting: cumulative impacts

- Accounting database and registration database were built around screening tool and embedded registration process

Resources

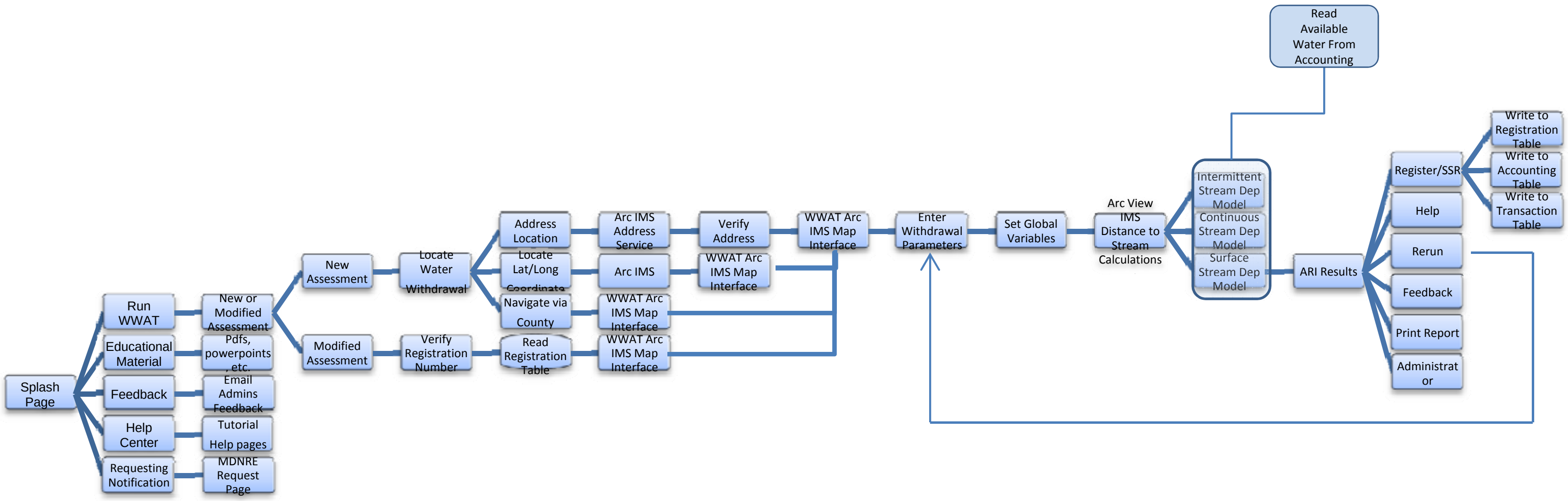
- Alley, W.M., Reilly, T.E., and Franke, O.L., 1999, Sustainability of ground-water resources: U.S. Geological Survey Circular 1186, 79 p.
- Hamilton, D. A., and Seelbach, P.W., 2011. Michigan's Water Withdrawal Assessment Process and Internet Screening Tool: Michigan Department of Natural Resources, Fisheries Special Report 55, 37 p.
- Hamilton, D.A., Sorrell, R.C., and Holtschlag, D.J., 2008, A regression model for computing index flows describing the median flow for the summer month of lowest flow in Michigan: U.S. Geological Survey Scientific Investigations Report 2008–5096, 43 p.
- Reeves, H.W., Hamilton, D.A., Seelbach, P.W., and Asher, Jeremiah, 2009, Ground-water-withdrawal component of the Michigan water-withdrawal screening tool: U.S. Geological Survey Scientific Investigations Report 2009-5003, 36 p.
- Reeves, H.W., 2008, STRMDEPL08—An Extended Version of STRMDEPL with Additional Analytical Solutions to Calculate Streamflow Depletion by Nearby Pumping Wells: U.S. Geological Survey Open-File Report 2008–1166, 22 p.
- Zorn, T. G., Seelbach, P. W., Rutherford, E. S., Wills, T. C., Cheng, Su-Ting, and Wiley, M. J., 2008, A landscape-scale habitat suitability model to assess effects of flow reduction on fish assemblages in Michigan streams: State of Michigan, Department of Natural Resources, Fisheries Research Report 2089, 46 p.

WWAT Screening Tool Interface

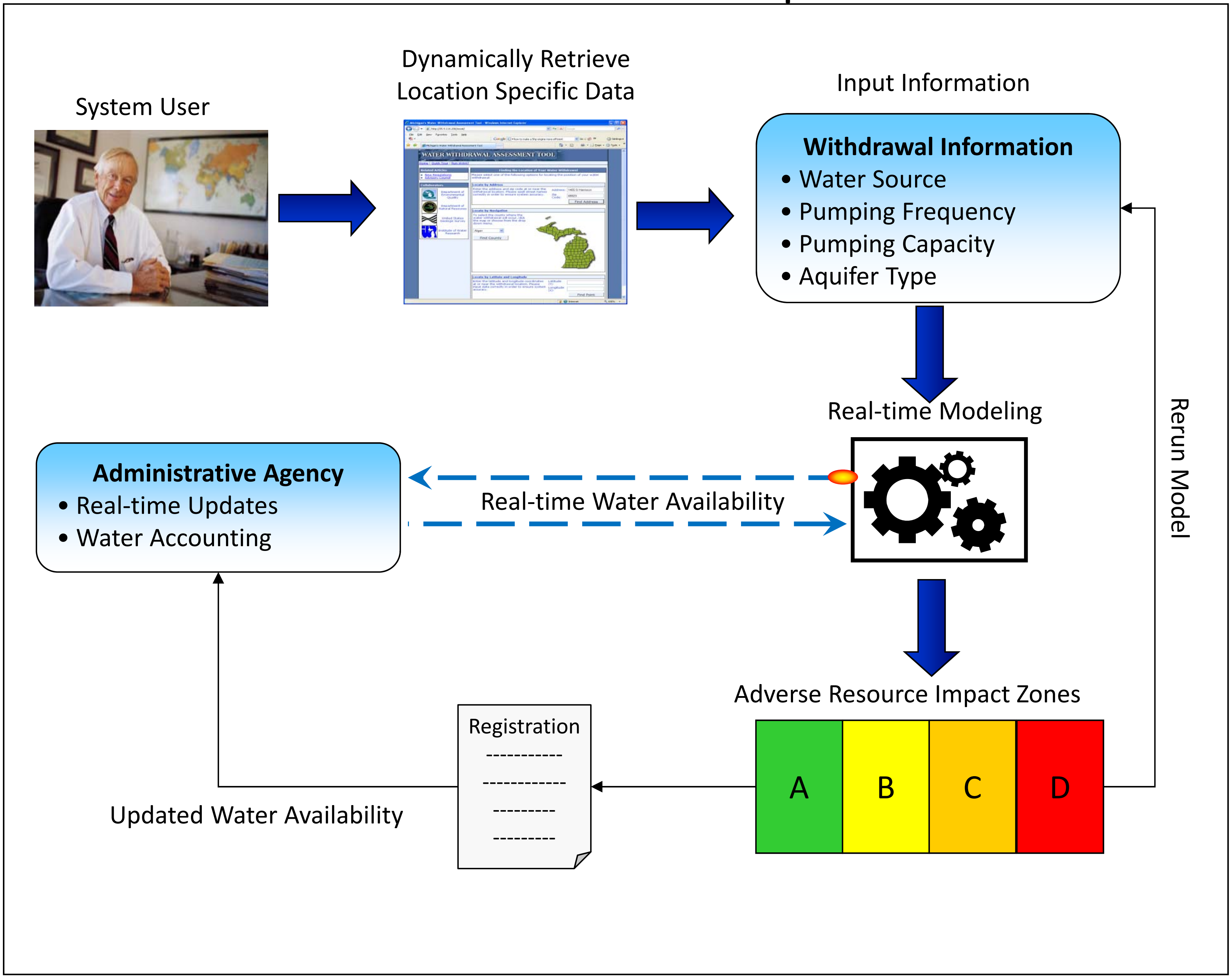


Design Diagram

Project: Water Withdrawal Assessment Tool
Name: Webpage Layout

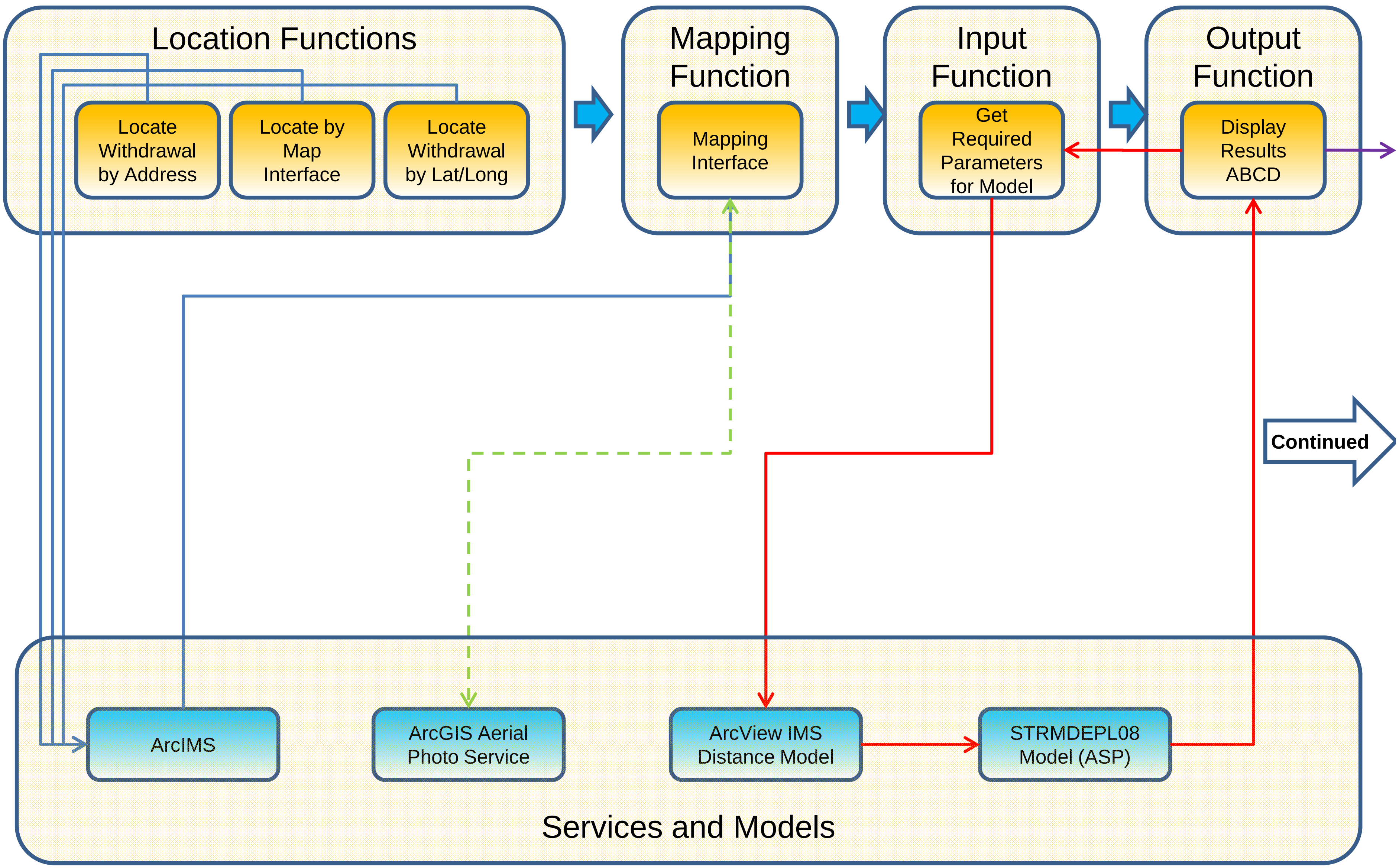


Water Withdrawal Assessment Tool Conceptual Model



Design Diagram

Project: Water Withdrawal Assessment Tool
Name: Major System Functions and Services



Design Diagram

Project: Water Withdrawal Assessment Tool
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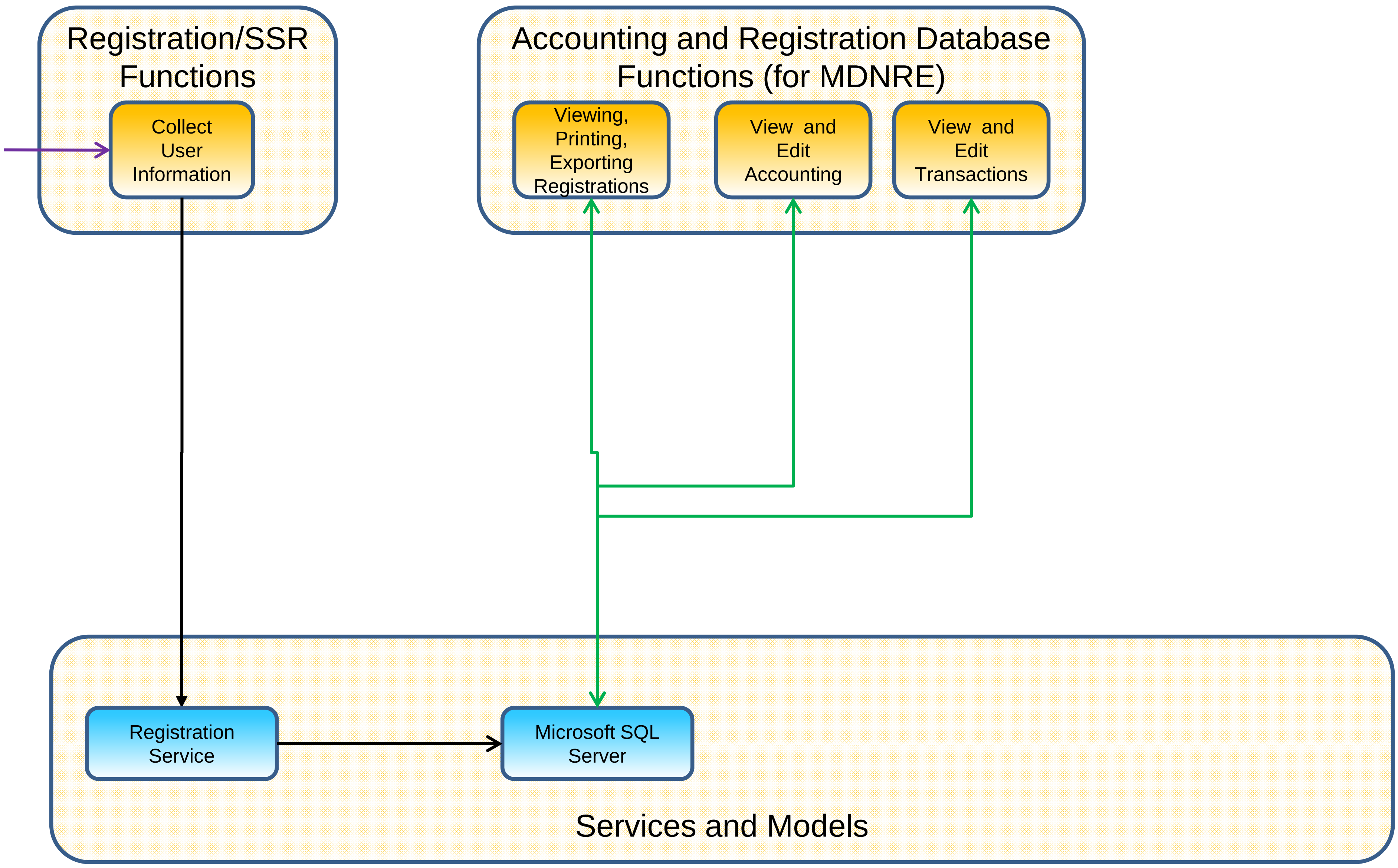
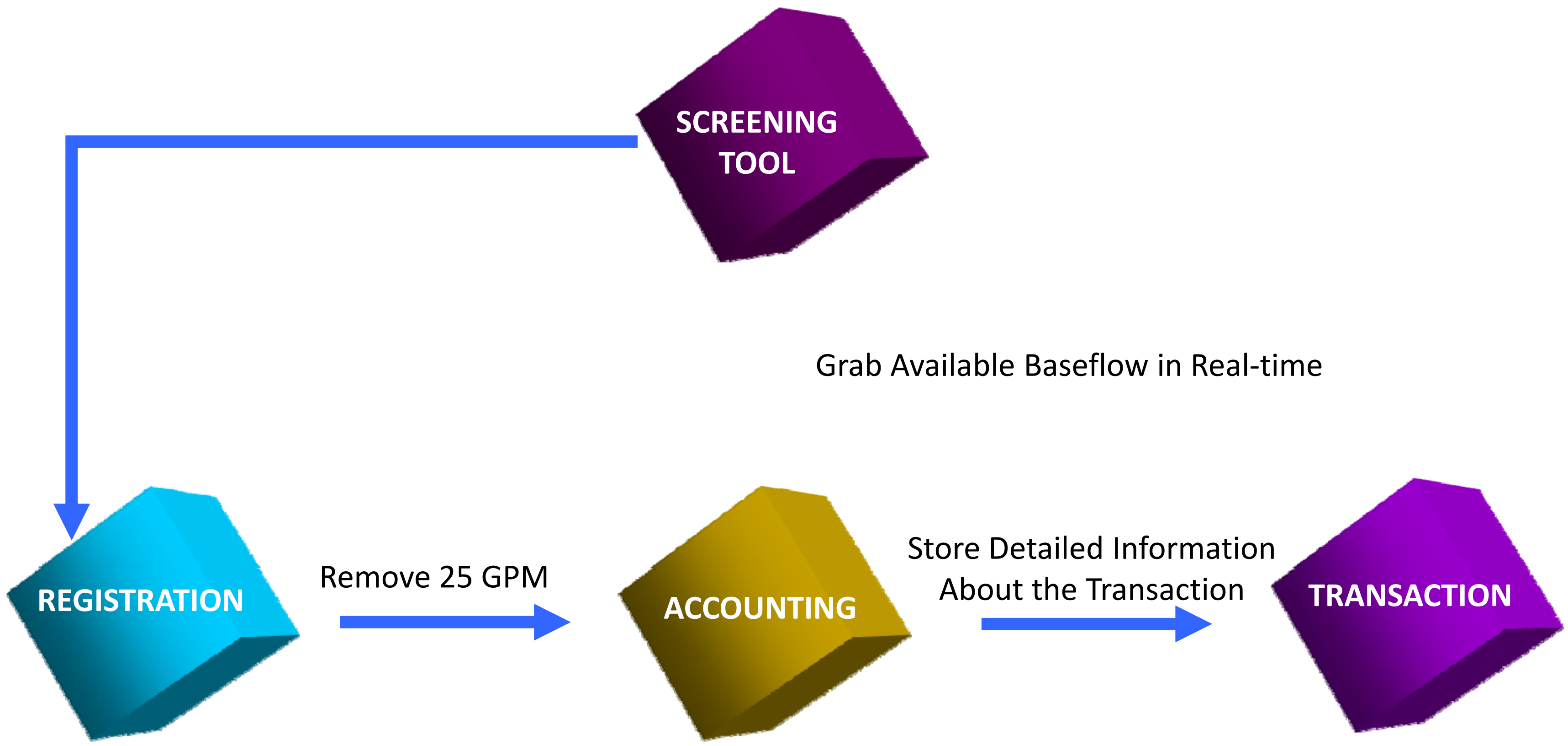


WWAT Account Transactions Information Flow



The Accounting Table

http://www.miwwat.org/db/ - Windows Internet Explorer

WWAT - Accounting and Registration Database

Home | Login | Registrations | Accounting | Transactions

View Accounting

View All

View Modified

Find Watershed:

ACCOUNTING TABLE - (Showing records with changes made to available water)

Modify	Watershed ID	Index Flow	Stream Type	A/B Zone Break	B/C Zone Break	C/D Zone Break	A/B Adjusted Break	B/C Adjusted Break	C/D Adjusted Break	Cold Mod Flag
Edit	78	13.8	Cold stream	435	435	621	435	435	621	
Edit	625	168.1	Cool large river	5280	7166	9429	5248	7134	9397	
Edit	681	2.9	Cold stream	93	93	132	81	81	120	
Edit	724	0.4	Cold stream	13	13	19	5	5	11	
Edit	759	4.2	Cold stream	133	133	190	-56	-56	1	
Edit	775	1.3	Cold stream	41	41	58	87	87	195	
Edit	776	1.6	Cold stream	51	51	73	33	33	55	
Edit	777	2.2	Cold stream	69	69	99	-21	-21	8	
Edit	790	1.2	Cold stream	36	36	52	22	22	38	
Edit	801	224.5	Cool large river	7054	9573	12596	7048	9567	12590	
Edit	815	1.8	Cold stream	55	55	79	27	27	51	
Edit	1545	1.4	Cool stream	19	48	80	12	41	73	
Edit	2623	2.1	Cool stream	29	72	120	29	72	120	

The Transaction Table

WWAT - Accounting and Registration Database

Home | Login | Registrations | Accounting | Transactions

View Transactions

View All

View Manual Entry

View Auto Entry

TRANSACTION TABLE - (Showing all transactions)

	ID	Reg ID	Wellogic ID	Watershed ID	Transaction Date	Amount (GPM)	Transaction Code	Transaction Type	Home/Neighbor	Status	Status Change	Created By	Flag	Notes
Edit	80	497		12515	4/21/2009 2:57:46 PM	37	Reg	WD	H	Open		Auto		
Edit	81	498		12515	4/21/2009 3:02:22 PM	35	Reg	WD	H	Open		Auto		
Edit	82			191	4/21/2009 3:18:31 PM	200	SSRC	DP	H	Closed		Jeremiah Asher		Added water due to stream measurements
Edit	83	499		27	4/21/2009 3:22:46 PM	441	SSR	WD	H	Closed	4/21/2009 3:28:06 PM	Auto		Closed by: Jeremiah Asher. Transaction logged in using ID: 84
Edit	84	499		27	4/21/2009 3:28:06 PM	50	SSRC	DP	H	Closed	4/21/2009 3:49:02 PM	Jeremiah Asher		Closed by: Andy LeBaron. Transaction logged in using ID: 87
Edit	85	500		27	4/21/2009 3:38:12 PM	55	SSR	WD	H	Open		Auto		
Edit	86	501		12515	4/21/2009 3:42:01 PM	62	Reg	WD	H	Open		Auto		
Edit	87	499	1251712	27	4/21/2009 3:49:02 PM	0	RegVer	WD	H	Closed		Andy LeBaron		
Edit	88	502		14970	4/28/2009 12:50:42 PM	55	Reg	WD	H	Open		Auto		
Edit	89	503		19448	4/30/2009 11:29:50 AM	170	Reg	WD	H	Open		Auto		

Questions or Comments

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