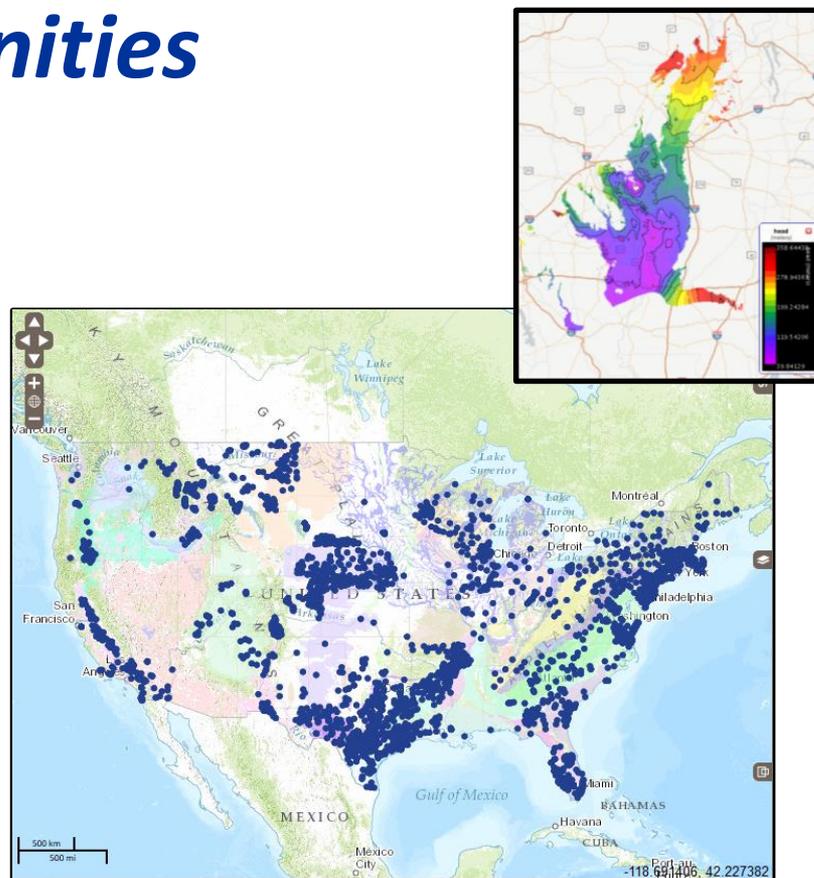


Groundwater Monitoring and Modeling: New Tools and Opportunities

William L. Cunningham
Chief, Office of Groundwater
U.S. Geological Survey

Alabama Department of Environmental Management
16th Annual Groundwater Conference
Montgomery, Alabama
June 8, 2016

U.S. Department of the Interior
U.S. Geological Survey



Presentation Topics

- Monitoring
 - NWISWeb
 - Groundwater Watch
 - Groundwater Quality Trends Mapper
 - National GW Monitoring Network
- Modeling
 - New tools for advective flow simulation, archival, and online viewing
 - New tool for solute transport

USGS Water Data for the Nation

National Water Information System Web (NWISWeb)

National Water Information System: Web Interface

USGS Water Resources Data Category: Home Geographic Area: United States

Click to hide News Bulletins

- Try our new [Mobile-friendly water data site](#) from your mobile device!
- New improved user interface.
- [Full News](#) 

USGS Water Data for the Nation

Search for Sites With Data

Current Conditions Sites with real-time or recent surface-water, groundwater, or water-quality data.

Site Information Descriptive site information for all sites with links to all available water data for individual sites.

 Map of all sites with links to all available water data for individual sites.

Frequent Searches By Data Category

Introduction

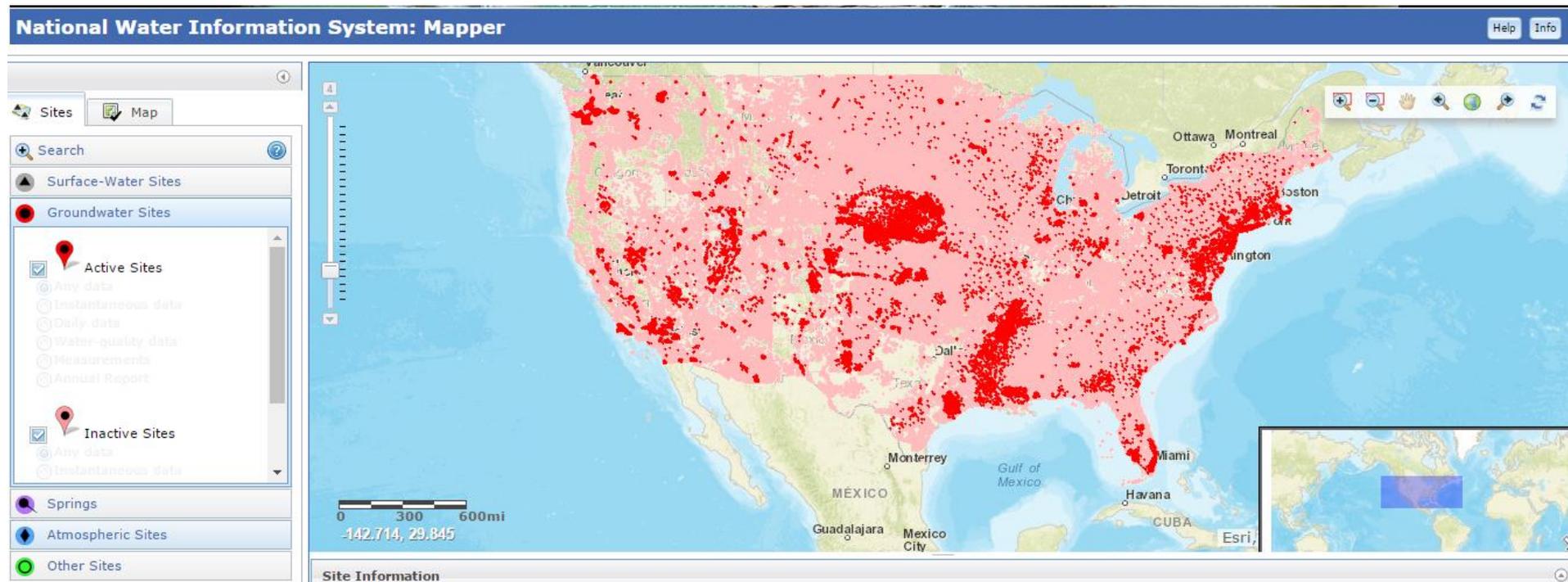
These pages provide access to water-resources data collected at approximately 1.5 million sites in all 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa and the Commonwealth of the Northern Mariana Islands. Online access to this data is organized around the categories listed to the left.

The USGS investigates the occurrence, quantity, quality, distribution, and movement of surface and underground waters and disseminates the data to the public, State and local governments, public and private utilities, and other Federal agencies involved with managing our water resources.

[About Us](#) [Help](#) [Tutorial](#)

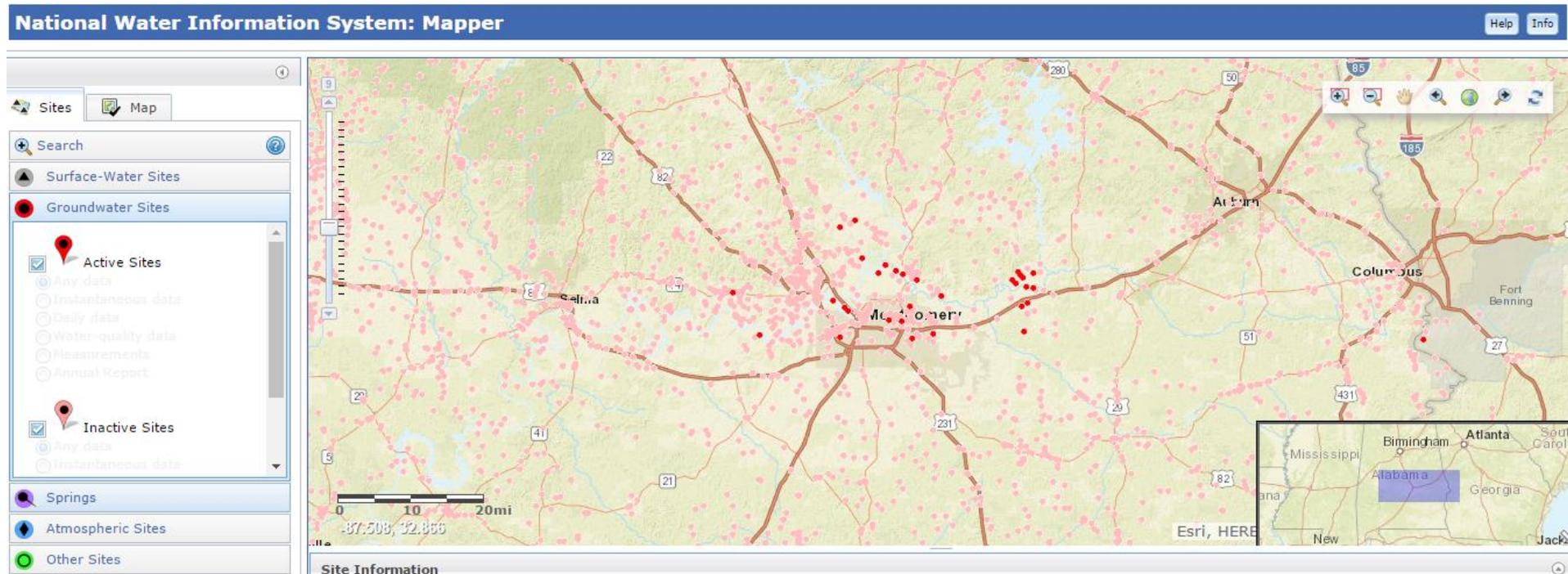
NWISWeb Mapper

850,000 Wells; Measurements 1 to many.

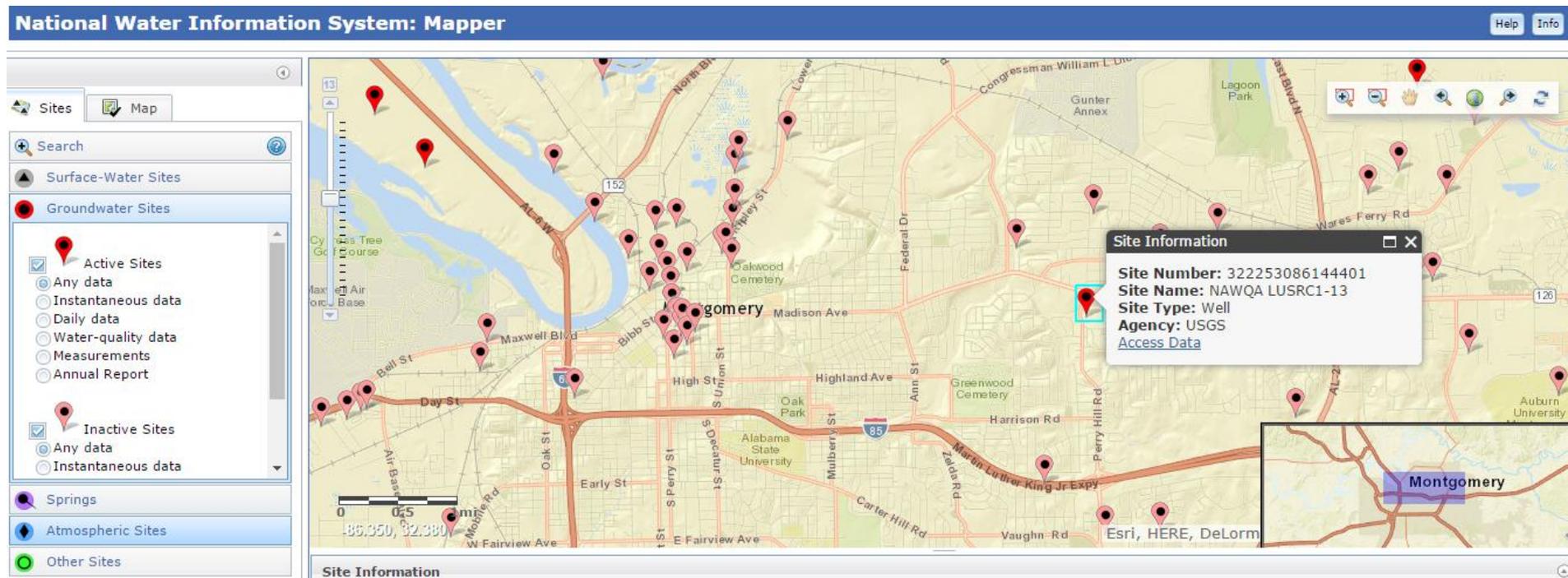


<http://maps.waterdata.usgs.gov/mapper/index.html>

NWISWeb Mapper - Montgomery



Individual Sites



NWISWeb Water Quality Data

USGS 322253086144401 NAWQA LUSRC1-13

Available data for this site

SUMMARY OF ALL AVAILABLE DATA ▾

GO

Well Site

DESCRIPTION:

Latitude 32°22'54.0", Longitude 86°14'42.7" NAD83
Montgomery County, Alabama , Hydrologic Unit 03150201
Well depth: 69.5 feet
Hole depth: 70 feet
Land surface altitude: 260 feet above NGVD29.
Well completed in "Southeastern Coastal Plain aquifer system" (S100SECSLP) national aquifer.
Well completed in "Eutaw Formation" (211EUTW) local aquifer

AVAILABLE DATA:

Data Type	Begin Date	End Date	Count
Field groundwater-level measurements	1999-12-09	1999-12-09	1
Field/Lab water-quality samples	1999-12-09	1999-12-09	1

OPERATION:

Record for this site is maintained by the USGS Alabama Water Science Center
Email questions about this site to [Alabama Water Science Center Water-Data Inquiries](#)

NWISWeb Groundwater Level Data

USGS 333204087324601 (TW5 DRY BRANCH WELL)

Available data for the

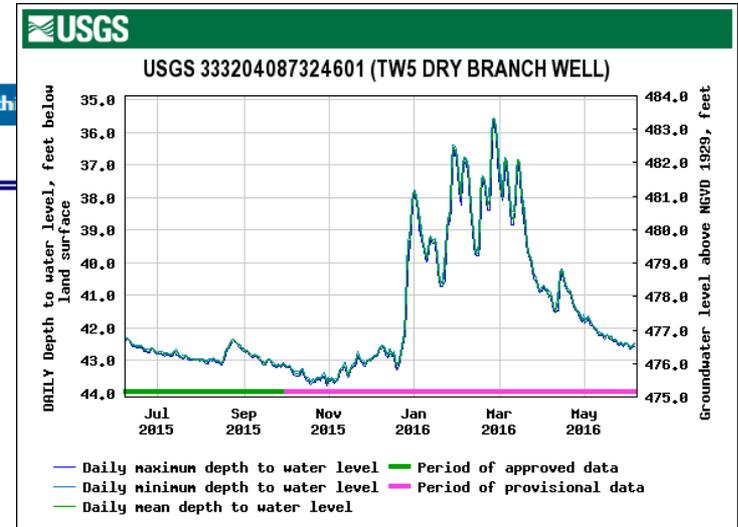
Well Site

DESCRIPTION:

Latitude 33°32'04", Longitude 87°32'46" NAD27
 Tuscaloosa County, Alabama, Hydrologic Unit 03160112
 Well depth: 60 feet
 Hole depth: 60.00 feet
 Land surface altitude: 519.00 feet above NGVD29.
 Well completed in "Pennsylvanian aquifers" (N300PNSLVN) national aquifer.
 Well completed in "Pottsville Formation" (324PSVL) local aquifer

AVAILABLE DATA:

Data Type	Begin Date	End Date	Count
Current / Historical Observations (availability statement)	2007-10-01	2016-06-07	
Daily Data			
Depth to water level, feet below land surface	1979-05-18	2016-06-06	25767
Daily Statistics			
Depth to water level, feet below land surface	1979-05-18	2015-09-30	8341
Monthly Statistics			
Depth to water level, feet below land surface	1979-05	2015-09	
Annual Statistics			
Depth to water level, feet below land surface	1979	2015	
Field groundwater-level measurements	2003-05-06	2016-04-15	105
Field/Lab water-quality samples	1979-03-12	1983-09-27	3
Water-Year Summary	2006	2015	10
Additional Data Sources			
Groundwater Watch **offsite**	1979	2016	8689



Online Groundwater Data Value-Added Products

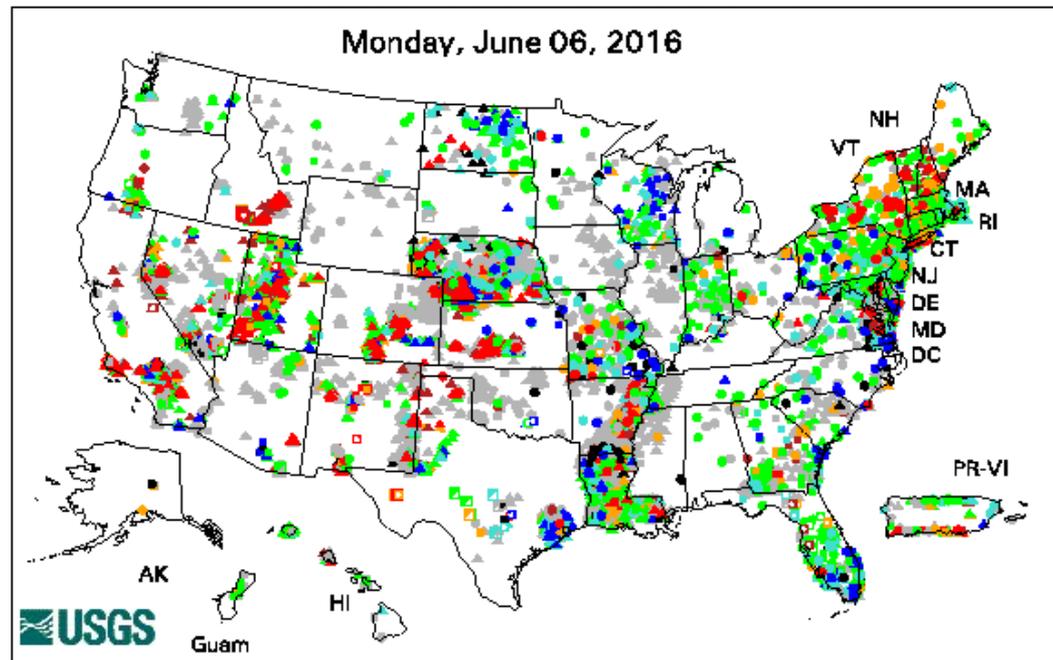
USGS Groundwater Levels

- Groundwater levels and Springs (no quality)
- “Active” = at least 1 measurement in last 13 months
- Real time, continuous, and periodic measurements
- Organized by Network type, State, and County



Active Groundwater Level Network

Monday, June 06, 2016



Explanation - Percentile classes (symbol color based on most recent measurement)								Wells	Springs
●	●	●	●	●	●	●	●	○	■
Low	<10 Much Below Normal	10-24 Below Normal	25-75 Normal	76-90 Above Normal	>90 Much Above Normal	High	Not Ranked	□	▣
								△	▣
									▣
									▣

Active Well Count

Real-Time: 1,497

Daily: 1,192

Periodic: 14,841

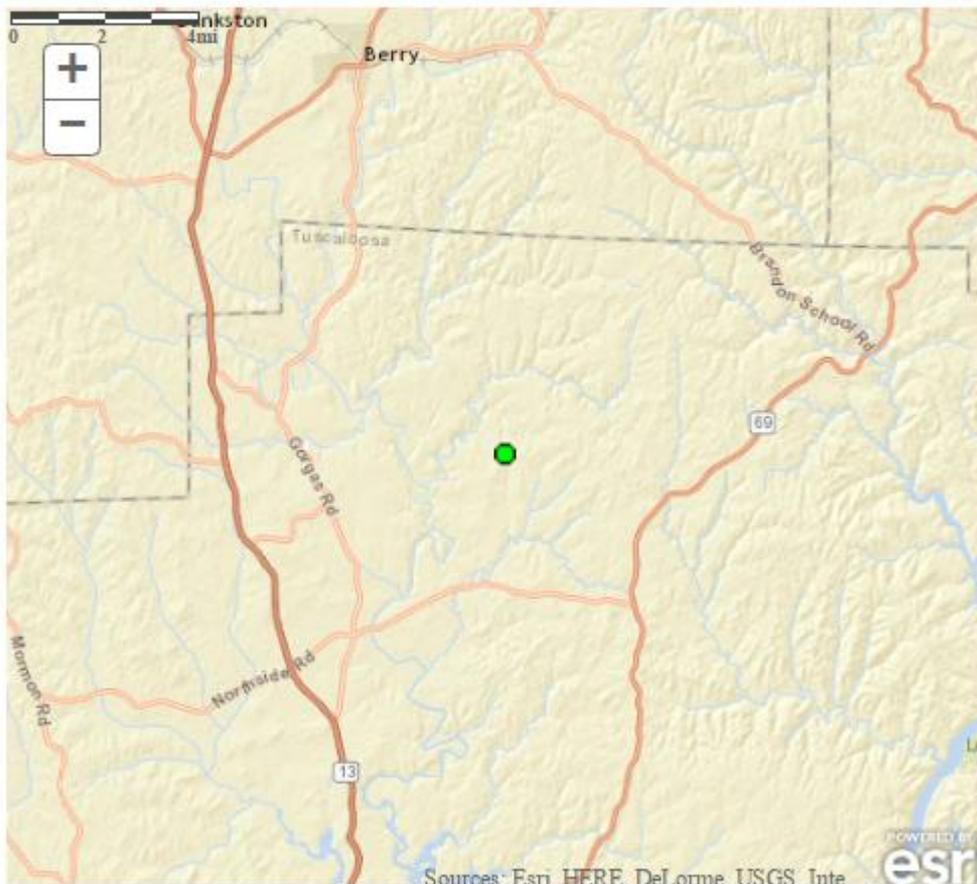
Map generated 6/6/2016 10:36:38 AM

"Site" Webpage

Groundwater Watch

Latest News...

Site Number: 333204087324601 - (TW5 DRY BRANCH WELL)



DESCRIPTION:

Latitude 33°32'04", Longitude 87°32'46" NAD27
 Tuscaloosa County, Alabama, Hydrologic Unit 03160112
 Well depth: 60 feet
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 Land surface altitude: 519.00feet above NGVD29.
 Well completed in "Pennsylvanian aquifers" (N300PNSLVN) national aquifer.
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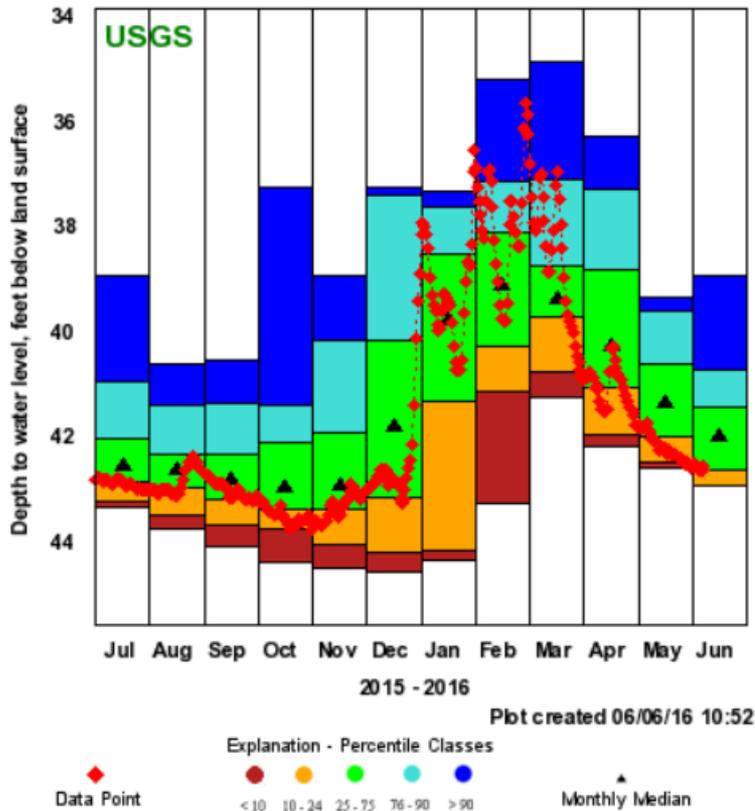
AVAILABLE DATA:

Data Type	Begin Date	End Date	Count
Current / Historical Observations	2007-10-01	2016-06-04	
Daily Data			
Depth to water level, feet below land surface	1979-05-18	2016-06-03	25758
Daily Statistics			
Depth to water level, feet below land surface	1979-05-18	2015-09-30	8341
Monthly Statistics			
Depth to water level, feet below land surface	1979-05	2015-09	
Annual Statistics			
Depth to water level, feet below land surface	1979	2015	
Field groundwater-level measurements	2003-05-06	2016-04-15	105
Field/Lab water-quality samples			
Water-Year Summary	2006	2015	10

Water-Level Statistics, by Well

Site Statistics

333204087324601 - (TW5 DRY BRANCH WELL)



Most recent data value: **42.57** on 6/5/2016

Period of Record Monthly Statistics for 333204087324601

Depth to water level, feet below land surface

All Approved Continuous & Periodic Data Used In Analysis

Note: **Highlighted** values in the table indicate closest statistic to the most recent data value.

Month	Lowest Median	10th %ile	25th %ile	50th %ile	75th %ile	90th %ile	Highest Median	Number of Years
Jan	44.36	44.15	41.33	39.79	38.50	37.61	37.31	23
Feb	43.26	41.15	40.28	39.13	38.09	37.12	35.20	23
Mar	41.24	40.78	39.73	39.37	38.73	37.11	34.84	23
Apr	42.19	41.96	41.07	40.28	38.81	37.28	36.26	23
May	42.60	42.50	41.99	41.38	40.63	39.60	39.34	24
Jun	42.95	42.92	42.62	41.99	41.45	40.72	38.94	24
Jul	43.34	43.24	42.86	42.55	42.04	40.96	38.93	24
Aug	43.74	43.50	42.96	42.64	42.34	41.39	40.61	24
Sep	44.10	43.70	43.21	42.83	42.35	41.36	40.54	24
Oct	44.38	43.77	43.38	42.96	42.10	41.39	37.23	24
Nov	44.49	44.06	43.38	42.92	41.94	40.17	38.92	24
Dec	44.59	44.19	43.17	41.80	40.17	37.39	37.26	23

As of 6/3/2016 16:39-2



Statistics Options



View month/year statistics

USGS Groundwater Quality

- 1,511 wells (monitoring wells, domestic wells, PWS wells) with decadal sampling
- Comparing 1998-2001 to 2002-2012.

Inorganics

Arsenic

Boron

Chloride

Fluoride

Iron

Manganese

Molybdenum

Nitrate

Orthophosphate

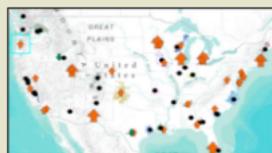
Strontium

ov/Decadal/

the bookmarks bar. [Import bookmarks now...](#)

A Decadal Look at Groundwater Quality

A first of its kind, national assessment of an unseen, valuable resource



About 140 million people—almost one-half of the Nation's population—rely on groundwater for drinking water, and the demand for groundwater for irrigation and agriculture continues to increase.

This mapper shows how concentrations of pesticides, nutrients, metals, and organic contaminants in groundwater are changing during decadal periods across the Nation.

Tracking changes in groundwater quality and investigating the reasons for these changes is crucial for informing management decisions to protect and sustain our valuable groundwater resources.

Learn more
(recommended for
first time users)

Enter the
mapper

Organics

Atrazine

Chloroform

Deethylatrazine

Dieldrin

Methyl tert-butyl ether

Metolachlor

Prometon

Simazine

Tetrachloroethene

Toluene

Decadal Nitrate Trends



Decadal Change in Groundwater Quality

Comparing 1988-2001 to 2002-2012

FAQ

Data

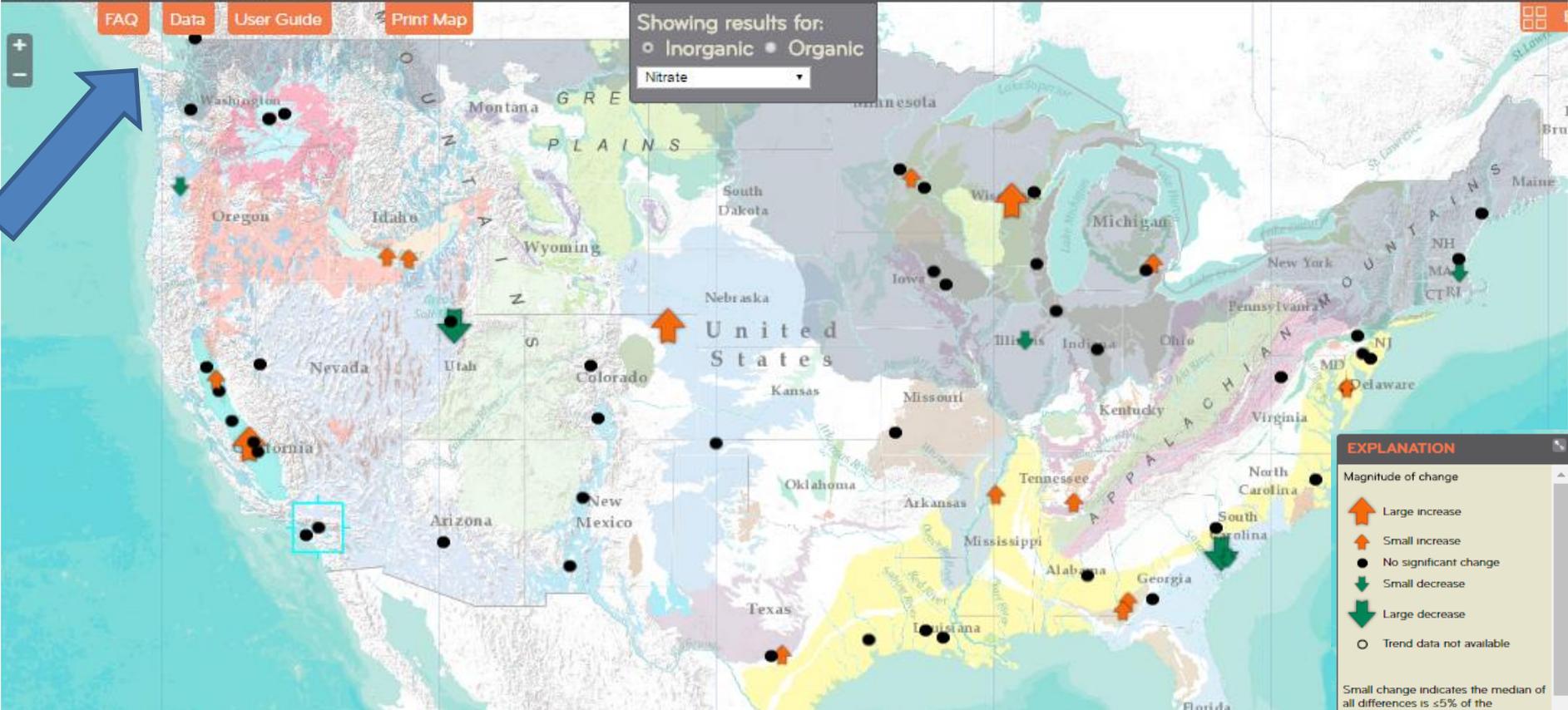
User Guide

Print Map

Showing results for:

Inorganic Organic

Nitrate



EXPLANATION

Magnitude of change

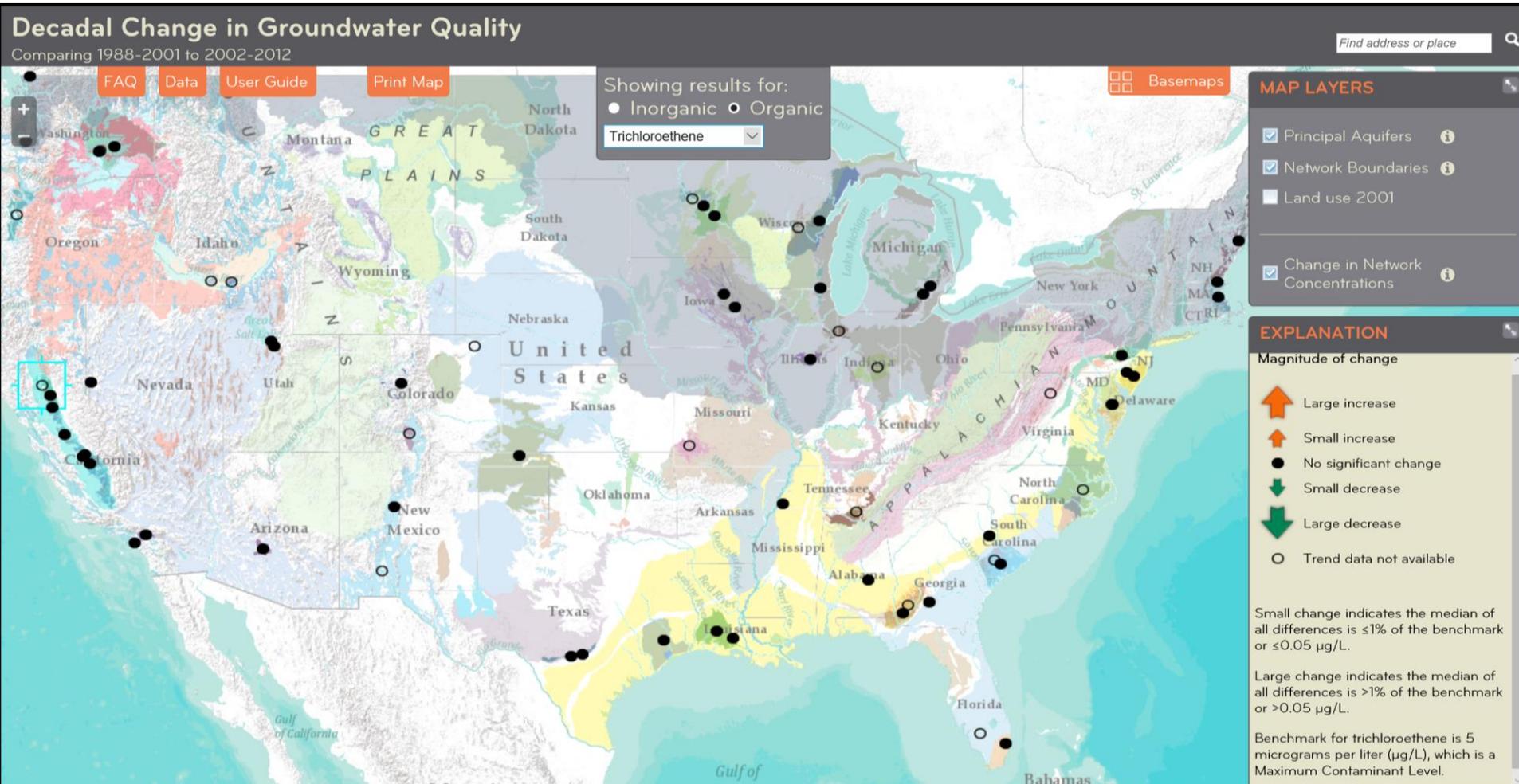
- Large increase
- Small increase
- No significant change
- Small decrease
- Large decrease
- Trend data not available

Small change indicates the median of all differences is $\leq 5\%$ of the benchmark or ≤ 0.5 mg/L.

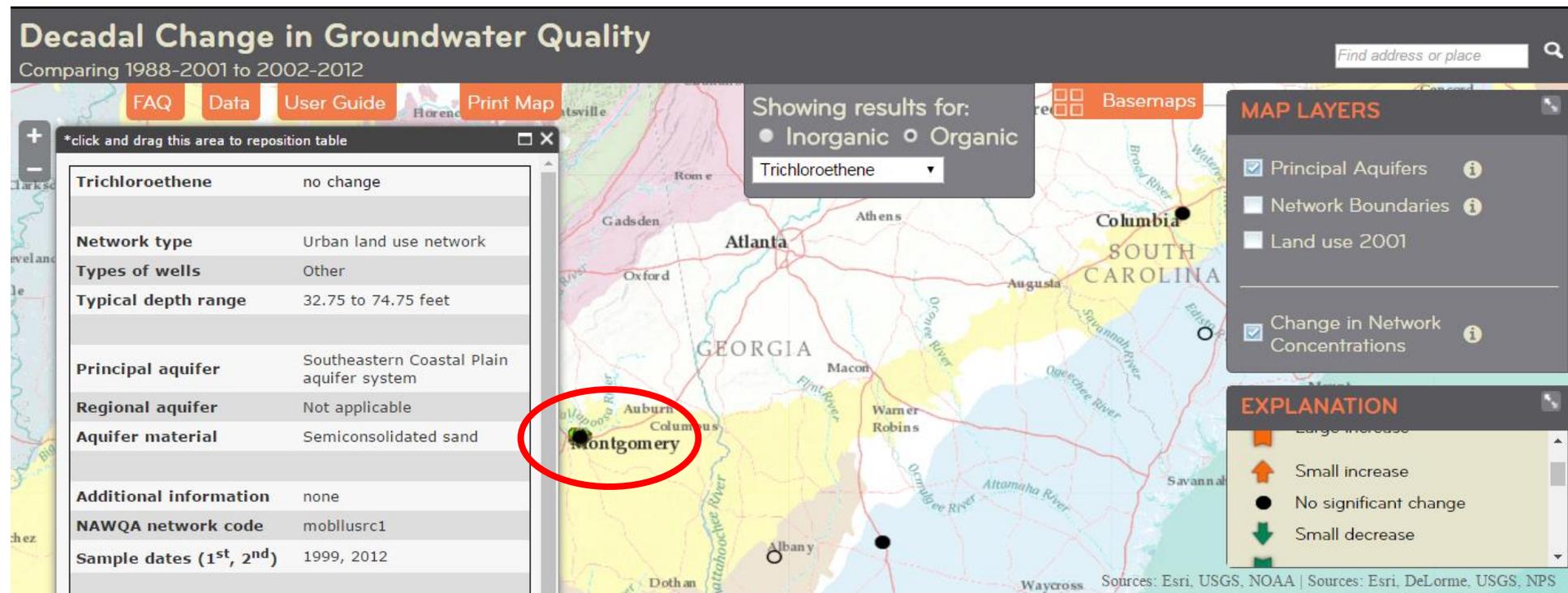
Large change indicates the median of all differences is $> 5\%$ of the benchmark or > 0.5 mg/L.



Decadal TCE Trends



Decadal TCE Trends



GW Network Funding Opportunity



National Ground-Water Monitoring Network

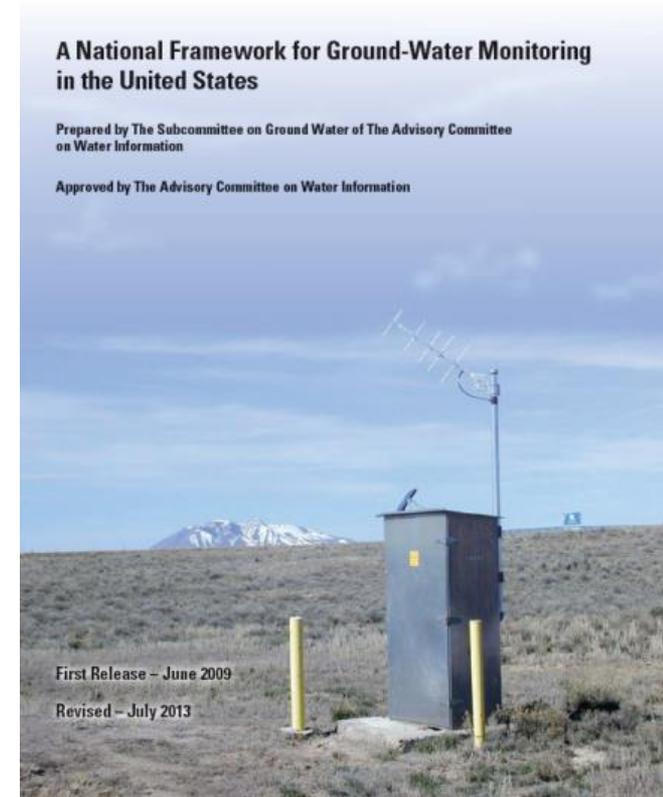
Advisory Committee on Water Information—Subcommittee on Ground Water

Subcommittee on Ground Water and the NGWMN

- The Subcommittee on Ground Water (SOGW) is part of the Advisory Committee on Water Information (ACWI)
- The purpose of the Subcommittee is to develop a National Ground-Water Monitoring Network (“NGWMN”)
- The Subcommittee developed the ‘Framework Document’ which contains the network design and requirements
- Approach was tested in 5 pilots and the ‘Framework Document’ was revised based on findings

NGWMN Framework Document

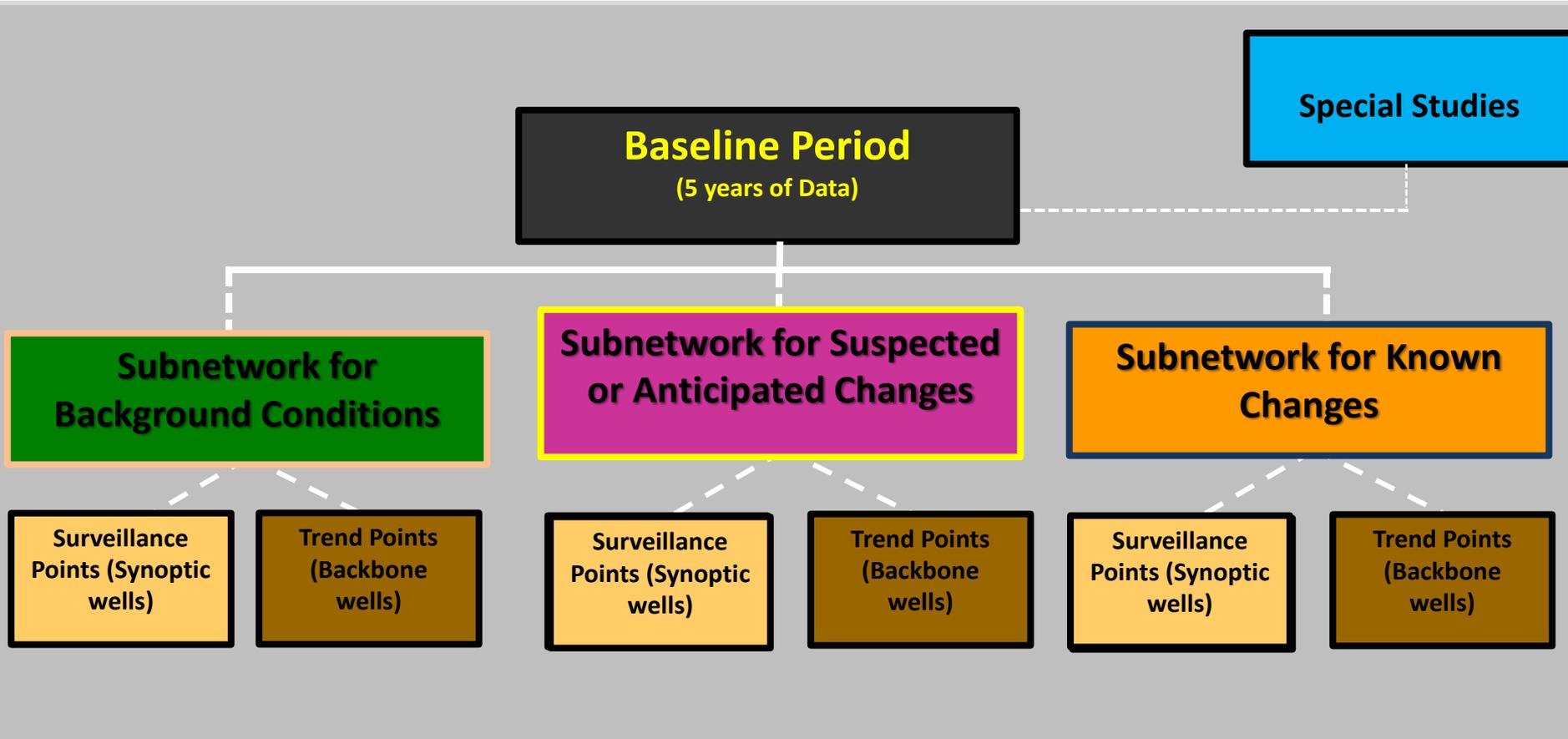
- Design for a collaborative National GW Monitoring Network
- Worked with NGWA to inventory Federal and State monitoring programs
- Guidance for Field Methods
- Guidance for Minimum Data Elements, Standards, & Management
- Implementation Plan and Recommendations
- Initial version in 2009. Revised in 2013 after pilot phase completed
- Factsheet available



NGWMN Design Elements

- Principal and major aquifers
- GW levels and quality, focus on availability
- Priority on sites with long-term data
- Network, not a Warehouse or Master Database
- Willing data providers: State, Federal, Tribes, others
- Sites classified by local experts/data providers, and selected sites become part of the Network
- Data available to all without restriction or cost
- Data provider is the authoritative data source

Network Design: Subnetworks



“Classified” based on water level or water quality change
and on frequency of data collection

NGWMN Data Portal

National Ground-Water Monitoring Network

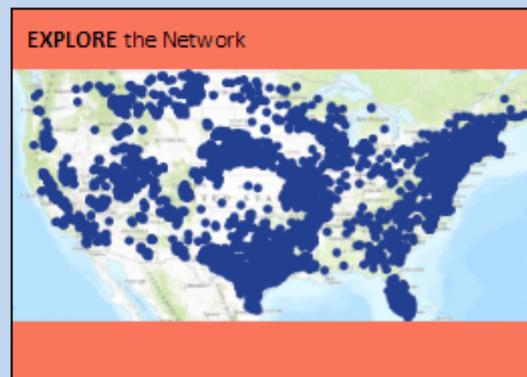
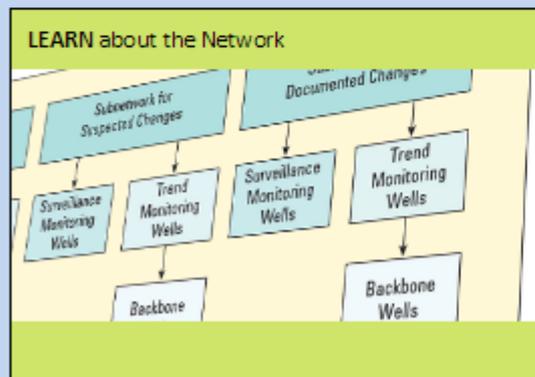
The National Ground-Water Monitoring Network (NGWMN) is a product of the [Subcommittee on Ground Water](#) of the Federal Advisory Committee on Water Information (ACWI). The NGWMN is a compilation of selected groundwater monitoring wells from Federal, State, and local groundwater monitoring networks across the nation.

The [NGWMN Data Portal](#) provides access to groundwater data from multiple, dispersed databases in a web-based mapping application. The portal contains current and historical data including water levels, water quality, lithology, and well construction. The NGWMN is currently in the process of adding new data providers to the Network. Agencies or organizations collecting groundwater data can [find out more about becoming a data provider for the Network](#).

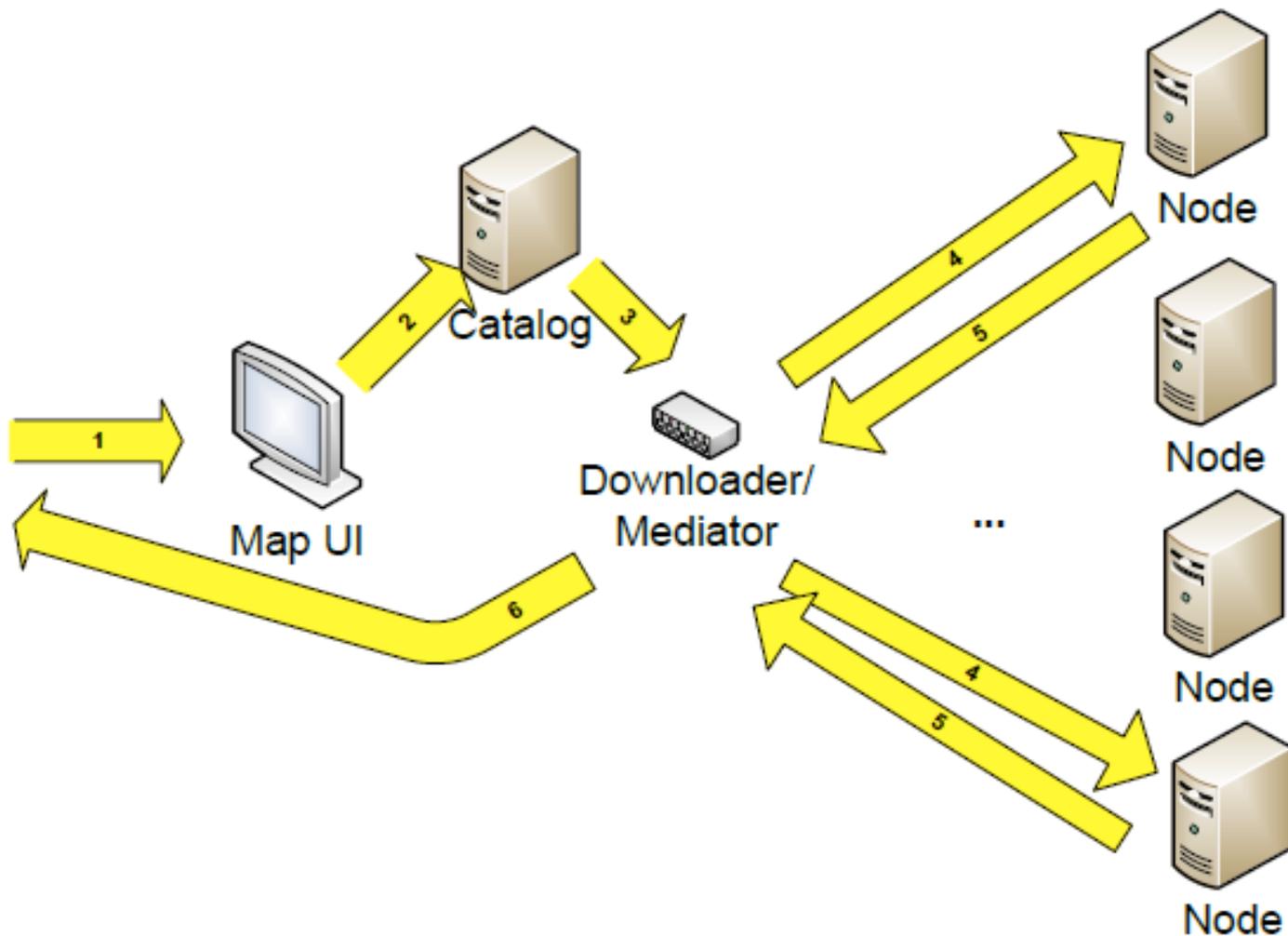
Funding to support data providers to the National Ground-Water Monitoring Network is provided through USGS Cooperative Agreements. Agencies can also find [information about the latest status of the USGS cooperative agreements](#).

CURRENT NETWORK:

4035 water-level wells
1316 water-quality wells
10 subnetworks
10 contributing agencies
51 states
57 principal aquifers



Network Portal Data Model



NGWMN NETWORKS

Water level: ?

Subnetwork: **All** ?

- Background
- Suspected Changes
- Known Changes

Monitoring Category: **All** ?

- Surveillance
- Trend
- Special

Water quality: ?

Subnetwork: **All** ?

- Background
- Suspected Changes
- Known Changes

Monitoring Category: **All** ?

- Surveillance
- Trend
- Special

FILTER MAP DATA

Principal Aquifer

Available Data

Water Level **Water Quality** **Well Log**

TIPPECANOE 17 (TC 17)

SUMMARY WELL LOG WATER LEVELS WATER QUALITY

Agency: U.S. Geological Survey (National Water Information System)

Site Name: TIPPECANOE 17 (TC 17)

Site #: 402734087033401

Lat/Long(WGS84): 40.4595, -87.0595

Well Depth: 212.54 ft

Local Aquifer Name: Outwash

National Aquifer Name: Sand and gravel aquifers (glaciated regions)

Water Level Network: Surveillance - Background

Water Quality Network: Unknown - Unknown

INDIANA DEPARTMENT OF NATURAL RESOURCES

SELECT FOR DOWNLOAD

BIG SPRING FISH HATCHERY - WELL FWPL-06

SUMMARY WELL LOG WATER LEVELS

Depth of water level (feet below land surface)

Month/Year

SELECT FOR DOWNLOAD

SMITH AL

SUMMARY WELL LOG WATER LEVELS

Longitude: 47.3237

Latitude: -106.9149

Elevation: 2638.00 ft.

Well Depth: 145.00 ft.

140.00'	CLAY
130.00'	SAND
120.00'	SHALE
110.00'	COAL
100.00'	ROCK
90.00'	SAND

Depth From (ft)	Depth To (ft)	Lithology	Description
140.00	145.00	CLAY	CLAY
110.00	140.00	SAND	SAND
20.00	110.00	SHALE	SHALE
15.00	20.00	COAL	COAL
12.00	15.00	ROCK	ROCK
0.00	12.00	SAND	SAND

SELECT FOR DOWNLOAD

Site Selection

Site Name	Agency	WL	WQ	Log
GREAT NORTHERN RAILWAY COMPA...	MBMG	●	●	●
PIA-2000A Cisco	ISWS	●	●	●
TWDB-7764401	TWDB	●	●	●
250790-- lmaystown MW1	USGS	●	●	●
GRANT 10 (GT 10)	USGS	●	●	●
66018	MN DNR	●	●	●
MPCA Ambient Network Site 1152	MPCA	●		

7 sites selected.

REMOVE SELECTED DOWNLOAD

CURRENT STATUS

3022 Sites mapped

2806 Water-level network wells

<http://cida.usgs.gov/ngwmn/>



Cooperative funding agreements to support NGWMN data providers (CFDA 15.980)

- Authority under SECURE Water Act of 2009
- Funding opportunity available to State or Local groundwater resource agencies
 - Federal agencies, Tribes, Institutions, and Companies may contribute data, but are not eligible for funding
- Round 1 funding closed in January 2016 (14 state agencies)
- Round 2 funding application period open Mar31-May31, 2016
- Round 3 funding will be in federal FY2017
- Requires cost sharing in the form of in-kind services

Round 2 Proposals: Eligible Activities

1. Support persistent data service from existing data providers (*maintain flow of data*)
2. Support to become a new data provider (*well selection; set up web services*)
3. Filling gaps in information at NGWMN sites
4. Well Maintenance
5. Well Drilling

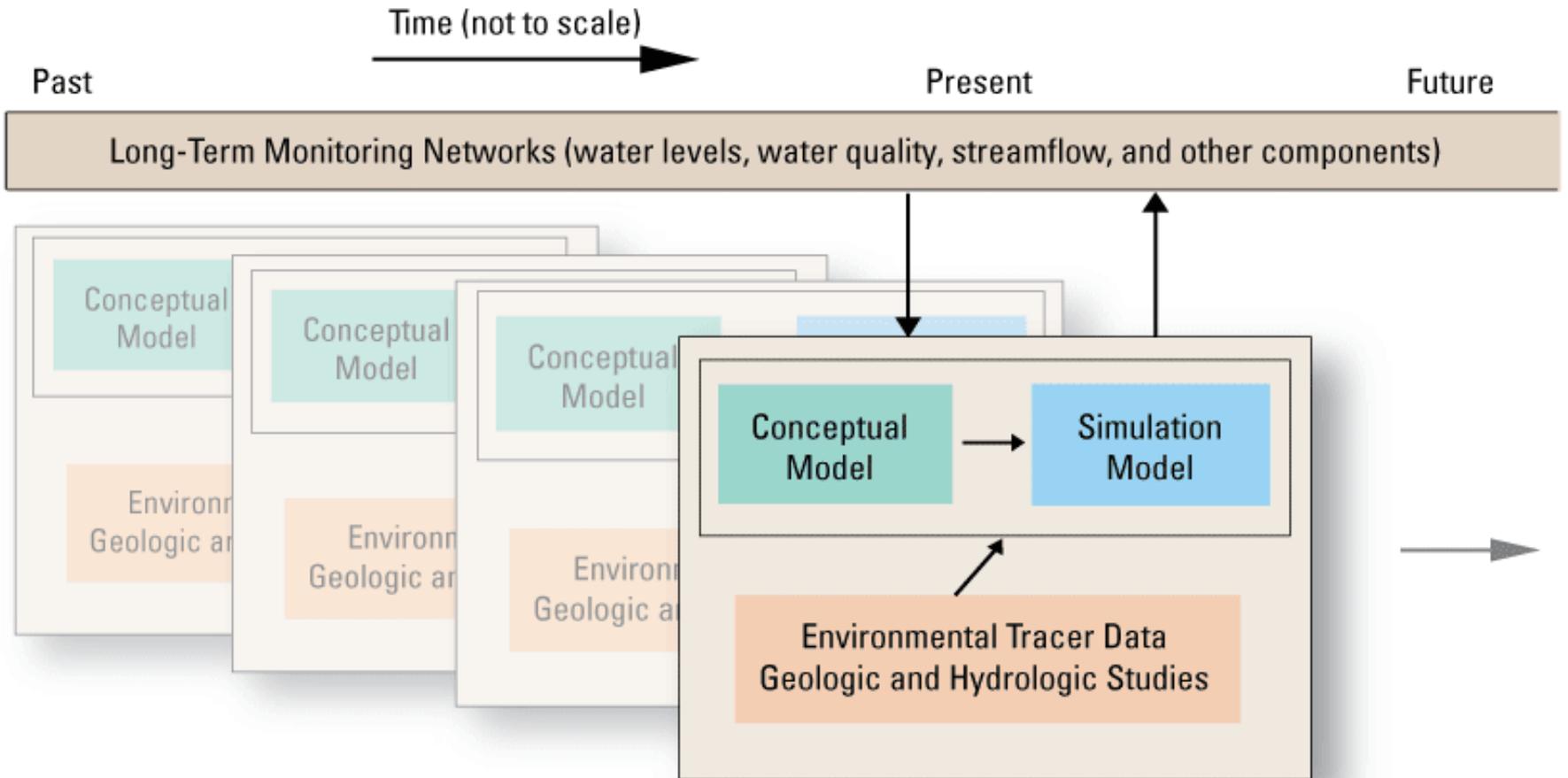
In-kind services match

No match requirement for IT services

Work done by an agency to collect data at NGWMN sites can be used as the agency match for in-kind services

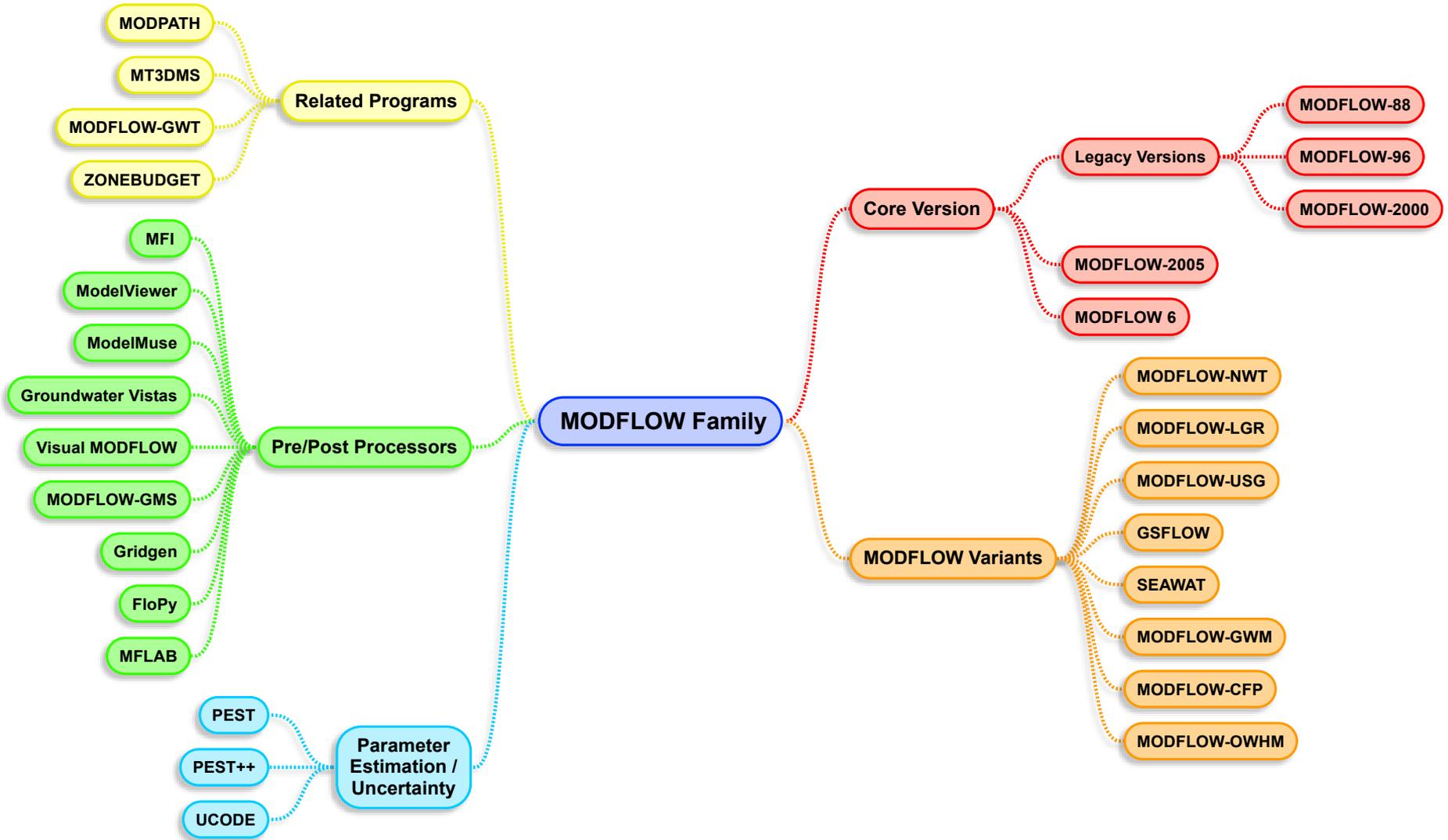
Funding up to \$110K for 2-year award.

Linking Monitoring and Modeling



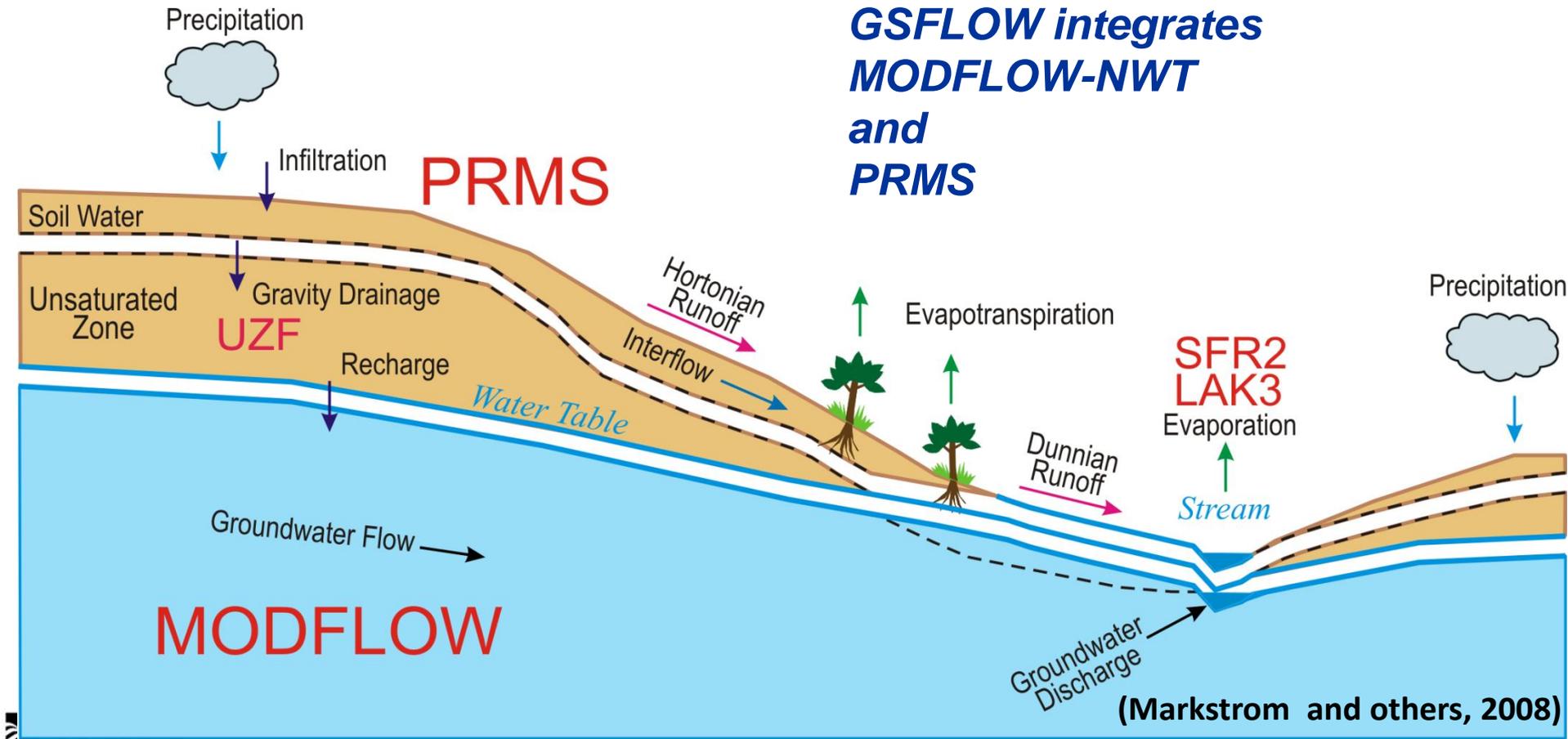
(Reilly and others, 2008)

Status 2016: MODFLOW Family



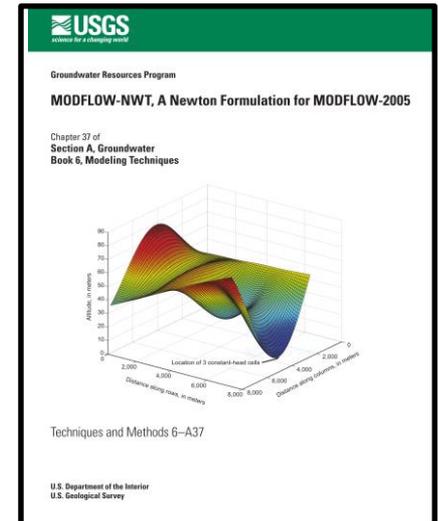
GSFLOW—Simulation Of All Major Hydrologic Processes

*GSFLOW integrates
MODFLOW-NWT
and
PRMS*



MODFLOW-NWT

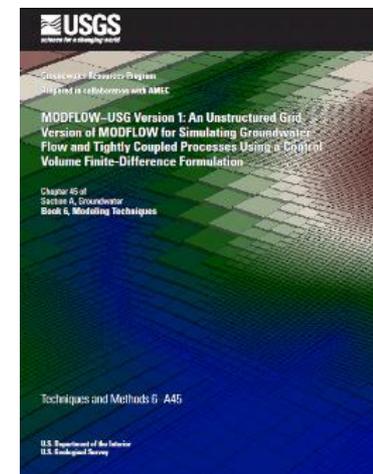
- MODFLOW originally developed for groundwater flow problems with standard boundary conditions to solve linear (confined) to weakly non-linear problems.
- 3D unconfined applications and many new packages can create additional nonlinearities.
- MODFLOW-NWT developed to provide a more robust nonlinear solution approach – addresses “wet-dry” nonlinearity



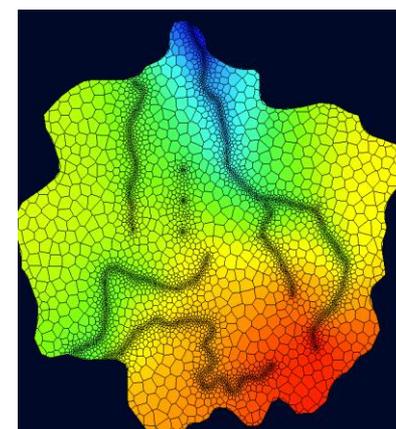
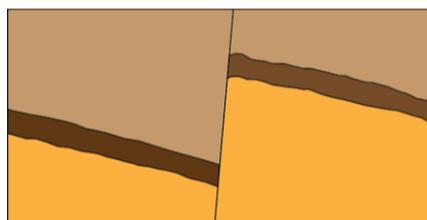
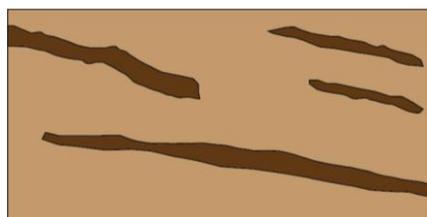
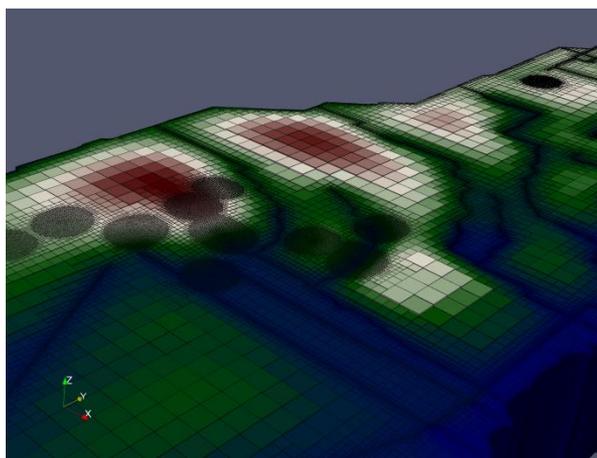
(Niswonger and others, 2011)

MODFLOW-USG

- Increase flexibility in grid design
 - Add resolution where needed
 - Handle pinched layers and fault offsets
- Efficiently solve tightly coupled hydrologic processes
- Retain MODFLOW concepts and finite-difference approach

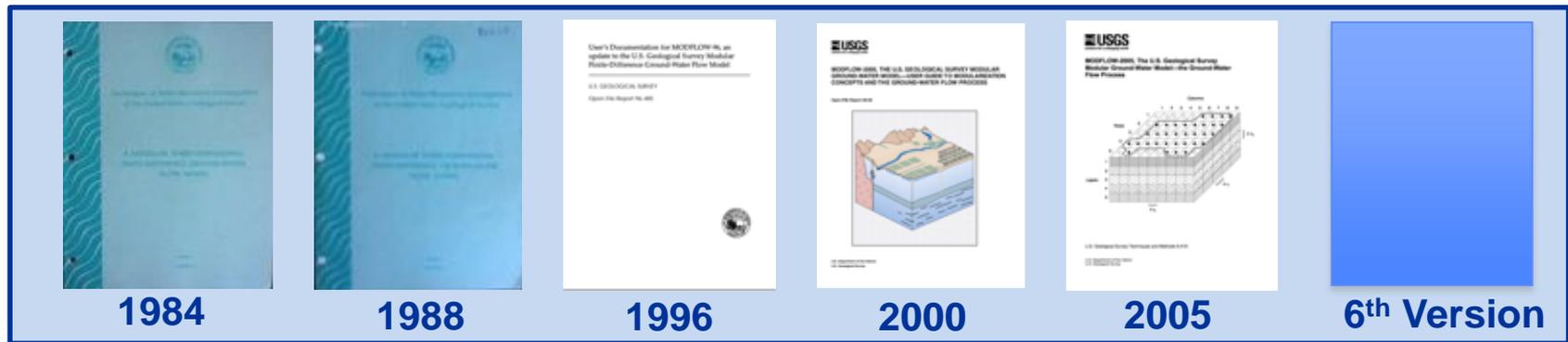


(Panday and others, 2015)



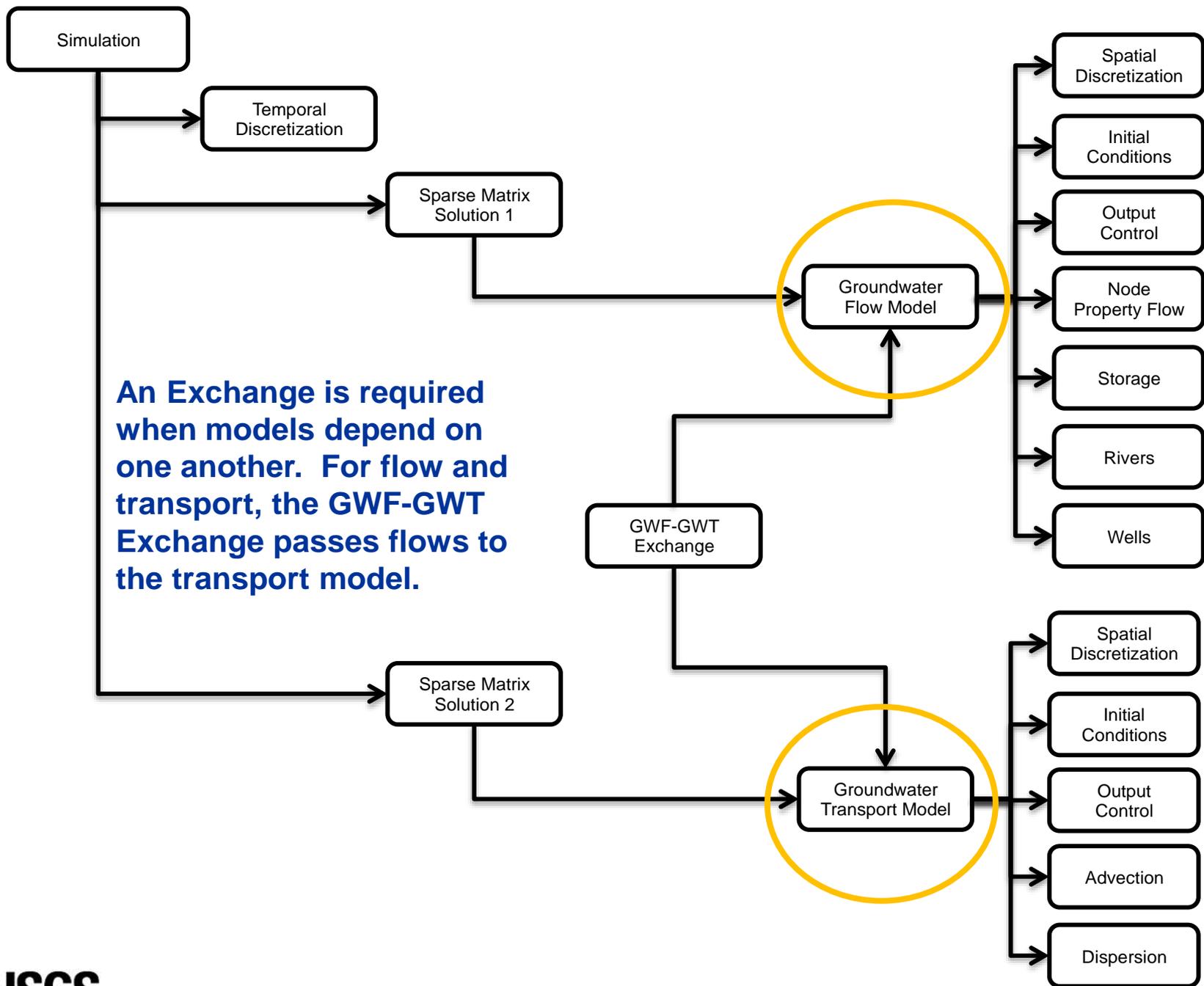
Coming Soon: *MODFLOW6*

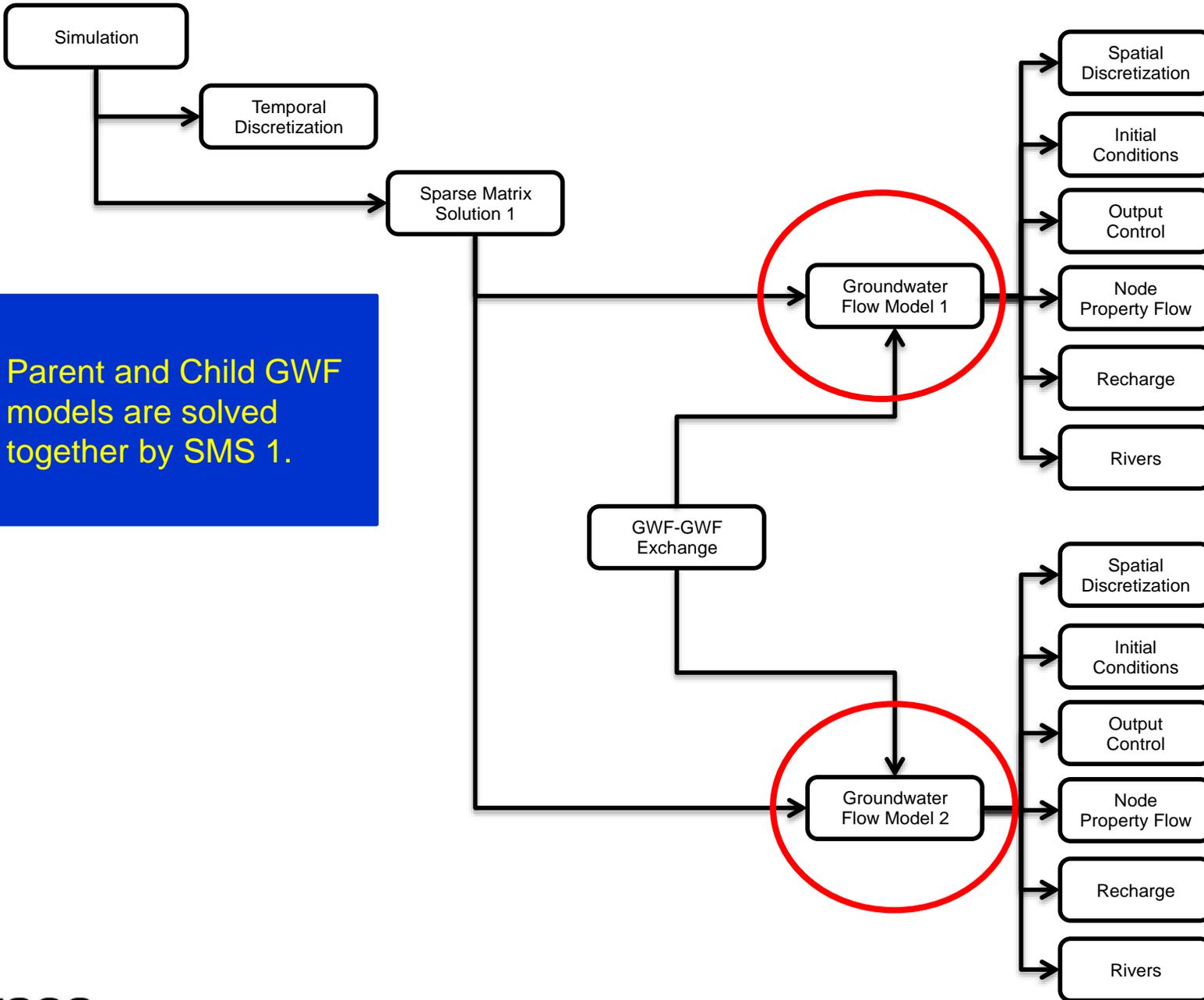
- GW issues becoming more complex
- Proliferation of new versions and packages
- Increase in package complexity
- Loss of package independence
- Incompatibilities
- Difficult to add other process models to MODFLOW; same grid required for all packages and processes



MODFLOW6 Overview

- Combined capabilities from:
 - MODFLOW-2005
 - MODFLOW-NWT
 - MODFLOW-USG
 - MODFLOW-LGR
- Internal flow
 - Flow package
 - Storage package
- Boundary packages
 - CHD, WEL, DRN, GHB, RIV, RCH, EVT
- Advanced packages
 - Multi-Aquifer Well (MNW1, MNW2)
 - Stream-Flow Routing (STR, SFR1, SFR2)
 - Lake Package (LAK)
 - Unsaturated Zone Flow (UZF)
 - Water Mover (MVR)





Parent and Child GWF models are solved together by SMS 1.

New Product: Model Archive/"Data Release"

Search Data.Gov

DATA TOPICS ▾ IMPACT APPLICATIONS DEVELOPERS CONTACT

DATA CATALOG / Datasets Organizations ?

Home / Organizations / U.S. Geological Survey, ... Report Data Issue

USGS
science for a changing world
Federal

U.S. Geological Survey,
Department of the
Interior

<http://www.usgs.gov> The USGS is a federal science agency that provides impartial information on the health of our ecosystems and environment, the natural hazards that... read more

Contact
jdhughes@usgs.gov

Share on Social Sites
Google+
Twitter
Facebook

Dataset extent

Map data © OpenStreetMap contributors
Tiles by MapQuest

SEAWAT model used to evaluate the potential effects of alterations to the hydrologic system on the distribution of salinity in the Biscayne aquifer in Broward County, Florida: U.S. Geological Survey Data Release

Metadata Updated: Mar 30, 2016

A three-dimensional, variable-density solute-transport model (SEAWAT) was developed to examine causes of saltwater intrusion and predict the effects of future alterations to the hydrologic system on salinity distribution in eastern Broward County, Florida. The model was calibrated to conditions from 1970 to 2012, the period for which data are most complete and reliable, and was used to simulate historical conditions from 1950 to 2012. The model was used to (1) evaluate the sensitivity of the salinity distribution in groundwater to sea-level rise and groundwater pumping, and (2) simulate the potential effects of increases in pumping, variable rates of sea-level rise, movement of a salinity control structure, and use of drainage recharge wells on the future distribution of salinity in the aquifer. This USGS data release contains all of the input and output files for the simulations described in the associated model documentation report (<http://dx.doi.org/10.3133/sir20165022>). This data release also includes (1) preprocessing python scripts and associated input data files for creating the sensitivity and scenarios runs, (2) flopy source code, and (3) SEAWAT (v4) source code.

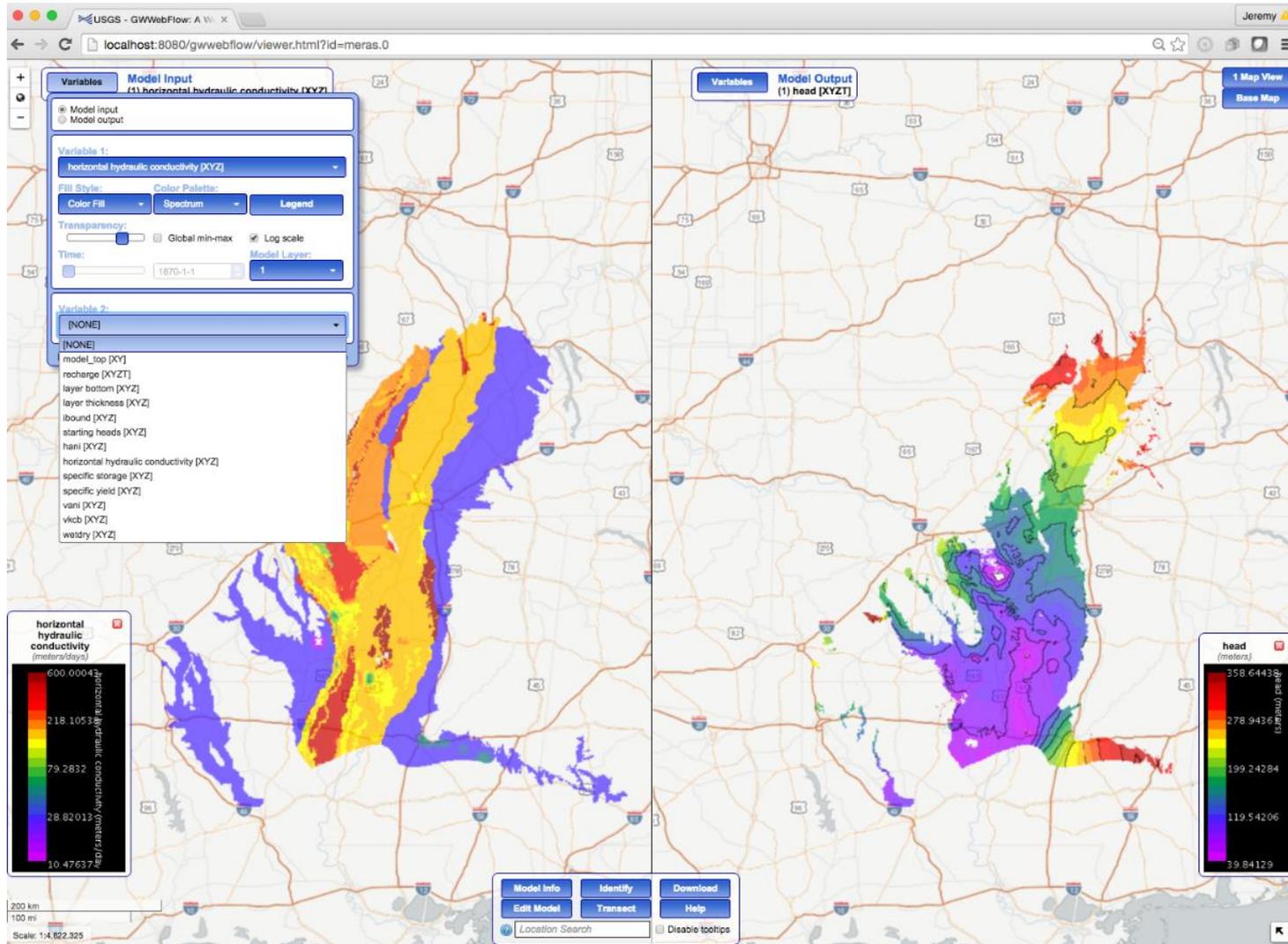
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Downloads & Resources

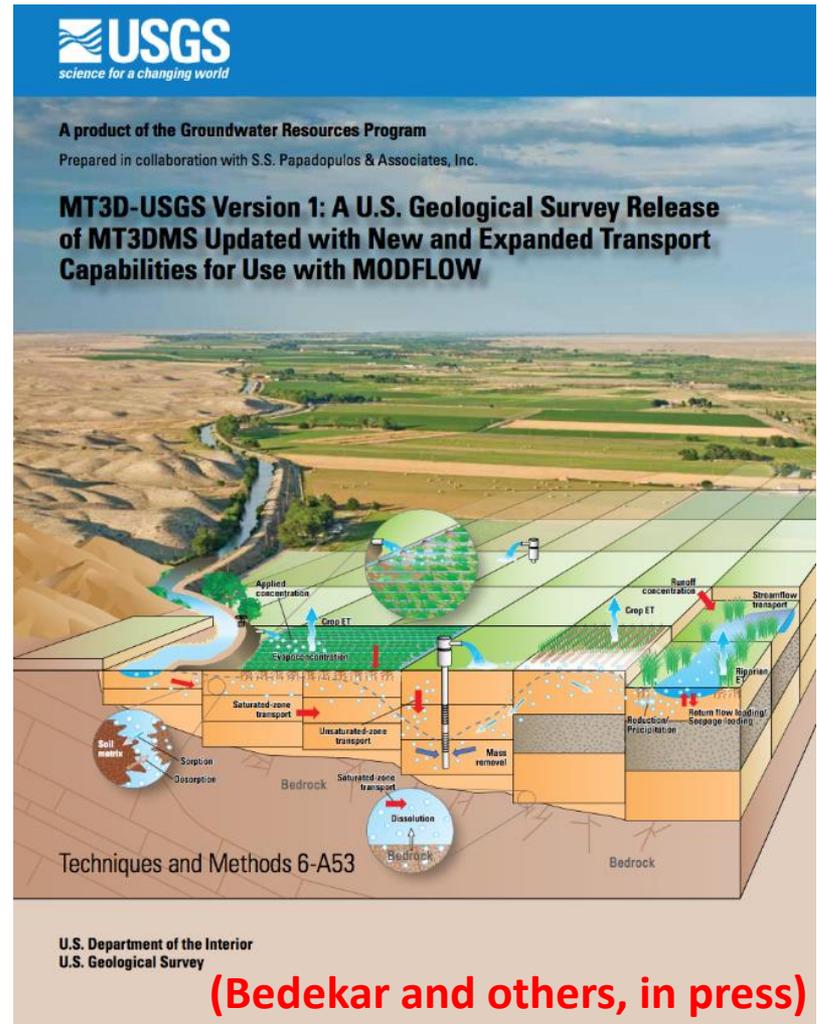
readme.txt	This ASCII text file describes the model data release. This file also...	Download
modelgeoref.txt	This ASCII text file defines the four corners of the model domain. Model data...	Download
ancillary.zip	This ZIP file contains ancillary data including directories with python...	Download

Coming Soon: Online Viewing of Models

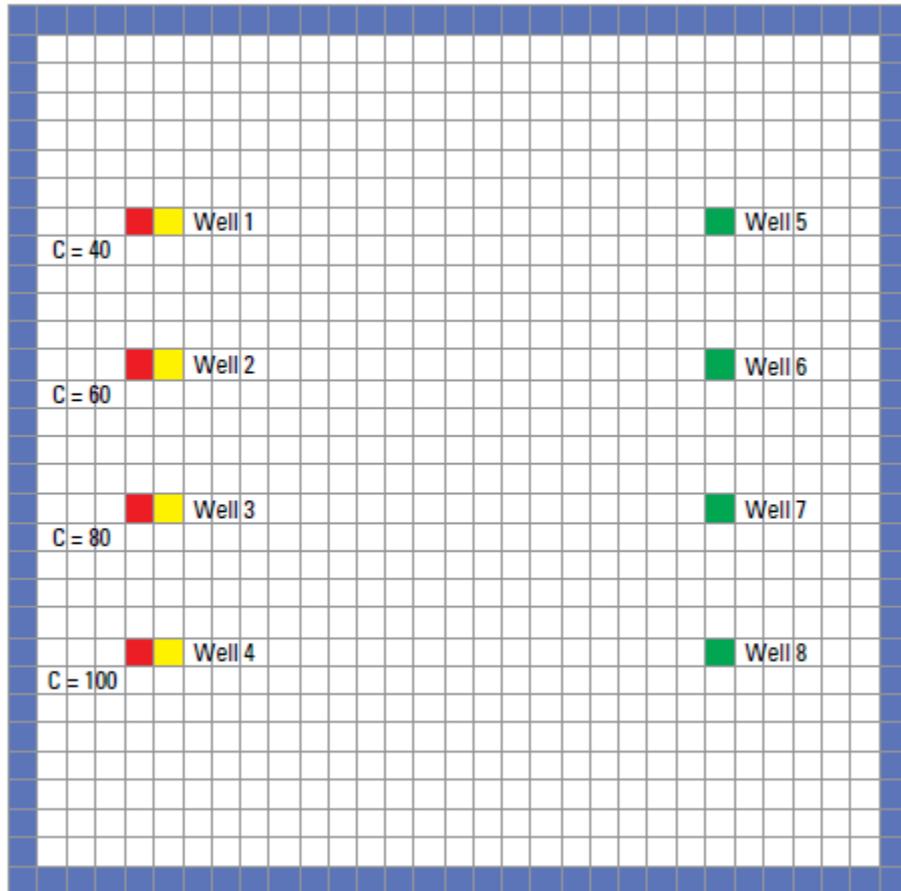


Coming Soon: Flow and Transport: MT3D-USGS

- Updated version of MT3D with support for
 - MODFLOW-NWT
 - Unsaturated Zone Flow (UZF) Package
 - Stream-Flow Routing (SFR) Package
 - Lake (LAK) Package
 - Contaminant Treatment System (CTS) Package
- Report is in press



New Capability: Contaminant Treatment System (CTS) Package



EXPLANATION

- Prescribed concentration
- Extraction well
- Injection well
- Constant-head boundary

C = 40, concentration is 40 milligrams per liter (mg/L);
C = 60, 60 mg/L;
C = 80, 80 mg/L;
C = 100, 100 mg/L

- Simulates pump and treat remediation

(Bedekar and others, in press)

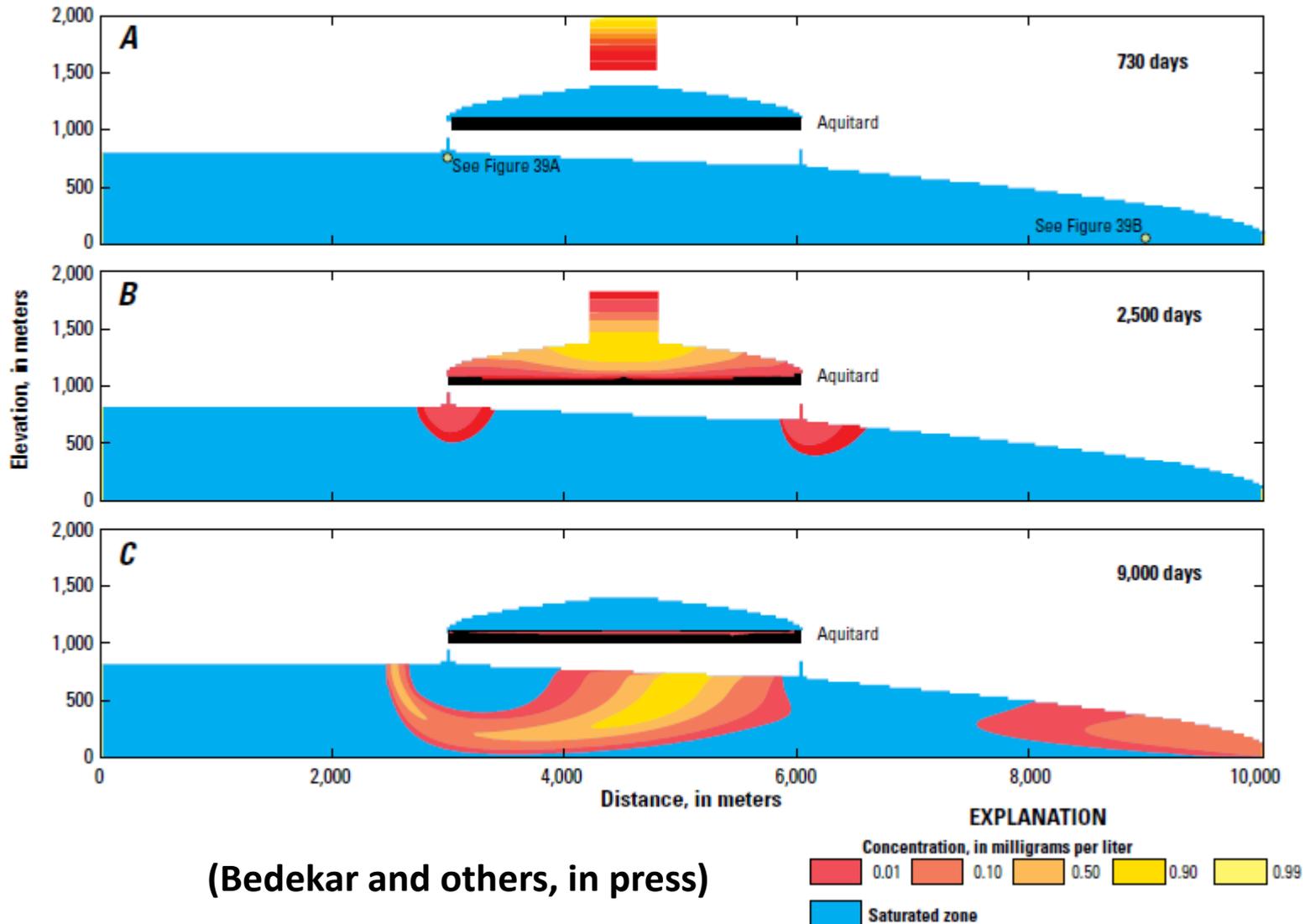
New Capability: Unsaturated Zone Transport (UZT)

-- Regional aquifer example

-- Mass routed through dry cells.

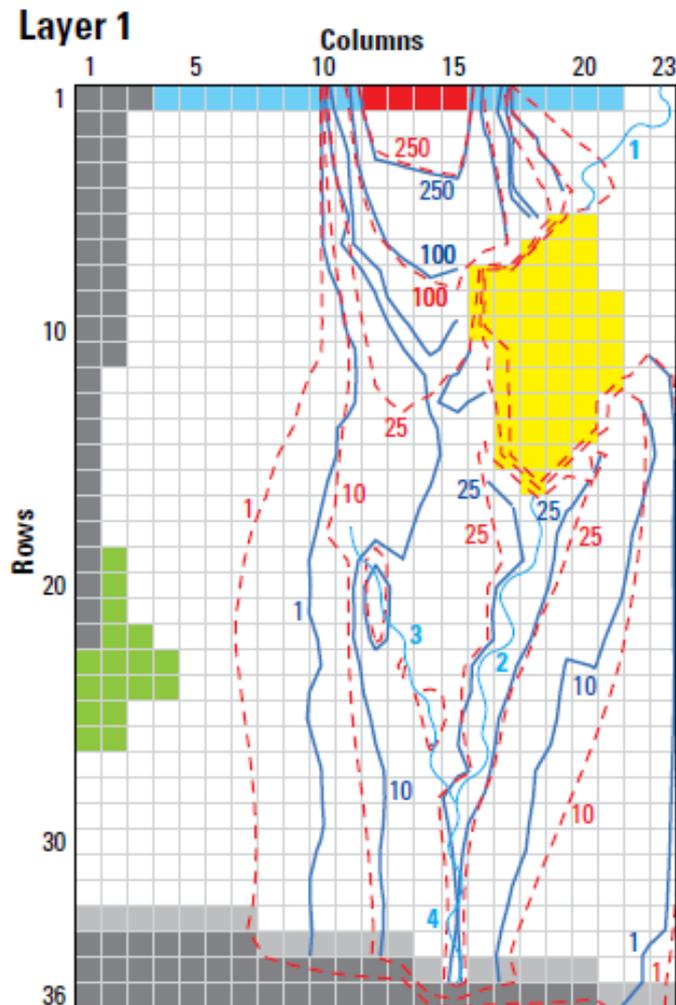
-- UZ transport only to first saturated cell.

-- But mass moved through UZ below confining unit



(Bedekar and others, in press)

New Capability: Streamflow Transport (SFT); Lake Transport (LKT)



EXPLANATION

- Inactive cells
- Constant head at 50.0 feet, and concentration in fluid source is zero
- Constant head from 50.10 to 50.15 feet, and constant concentration in fluid source of 500 micrograms per liter
- Constant head at 28.0 feet
- Lake 1
- Lake 2
- 4 Stream and segment number
- 1 Isoconcentration contour lines as calculated by the software GWT and number, in grams per liter
- 100- Isoconcentration contour lines as calculated by MT3D-USGS and number, in grams per liter
- No-flow boundary (frame around cell grid)

- 1D transport in stream
- Instantaneous mixing in lake

Contact:

Bill Cunningham

U.S. Geological Survey

Office of Groundwater

411 National Center

Reston, VA 20192

703-648-5005

wcunning@usgs.gov

Code availability:

<http://water.usgs.gov/ogw/modflow/>