MAGNET Data Network

BIG DATA from the TOP-DOWN

(Under continuous development and expansion)

Table: Pre-processed Big Data live-linked to the MAGNET modeling platform (current status)

Parameter		Resolution	Coverage	Data Source
Digital Elevation Models		90m	Global	ASTER Global DEM from USA NASA LP DAAC
		30m	USA	National Elevation Dataset, NED USGS (2006)
		10m	USA	
		3m	USA (some locations)	LiDAR datasets
		1m	USA (some locations)	
Watersheds		2 digit (large) – 12 digit (small)	USA	National Hydrography Dataset NHD USGS (2010)
Streams		Order 1 (small) – Order 10 (large)	USA (lower 48 states)	National Hydrography Dataset NHD USGS (2010)
Lakes		Size 1 (< 3,000 m^2) – Size 5 (> 500,000 m^2)	USA (lower 48 states)	National Hydrography Dataset NHD USGS (2010)
Soil		90m	USA (lower 48 states)	USDA SSURGO, SSS NRCS (2016)
Root Zone Depth		90m	USA	USDA SSURGO, SSS NRCS (2016)
Land Use and Land Cover		30m	USA	USGS LULC Dataset, Fry et al. (2011)
Climate	Precipitation	8000m (Daily and Monthly);	USA	PRISM Climate Group, PRISM (2004)
	Max. Temp.	400m (1981 – 2010 30-year Normal)		
	Min. Temp.			
	Mean Temp.			
Hydraulic Conductivity (shallow surficial & deeper surificial/rock deposits)		540m	State of Michigan	GWIM Project, State of Michigan (2006)
		Polgons (mean size: ~90 km^2)	Global	GLHYMPS 2.0, Huscroft et al. (2018)
Long-term average Recharge		1609m	State of Michigan	GWIM Project, State of Michigan 2006
		1˚ x 1˚ (roughly 111 km x 111 km)	Global	Pokhrel et al. 2015
Bottom surface, surficial aquifer		500m	State of Michigan	Interpolated from Wellogic
		1000m	Global	ORNL DAAC Soil Collections archive, Pelletier et al. (2016)
USGS water sensor data		Discrete locations (GW monitoring wells and stream gages)	USA	United States Geological Survey
Static Water Levels (SWLs)		Variable (tens or hundreds of thousands, e.g., Michigan: 560,000+)	*See Figure 1* : Arizona, British Columbia (Canada), California, Colorado, Idaho, Indiana, Kansas, Kentucky Massachusetts, Maine, Michigan, Missouri, New York, North Dakota, Nova Scotia (Canada), Ohio, Oklahoma, Pennsylvania, Ontario (Canada), Texas, Vermont	State/Provincial Enviromental Agencies or Natural Resources DepartmentsA1:E27

At the heart of MAGNET is a wide-ranging data storehouse of pre-processed "BIG" spatial framework data needed to conceptualize and calibrate numerical groundwater flow and transport models. The MAGNET modeling tools are built on / integrated with / live-linked to the preprocessed BIG DATA to allow almost instant modeling of groundwater conditions in the *surficial* aquifer layer critical to water resources and groundwater-dependent ecosystems.

This initial "instant" model 'closes the loop' but is not meant to be final or complete. In other words, it allows users to model site-specifically, anywhere on earth, using the best available global datasets, while providing the freedom to easily customize, refine and extend the model based on the study objectives, user experience and expertise, and any available local data.

The following subsections provide details regarding how different parts of an aquifer system are modeled / parameterized using BIG DATA in MAGNET.

Aquifer Top

The top surface of a surficial aquifer model in MAGNET is the spatially variable land surface, represented by preprocessed Digital Elevation Models (DEMs). A 90 m resolution data layer is available globally from ASTER Global DEM, and 30 or 10 m also available for United States from USGS NED. In some areas (e.g., west-central Michigan), 1m (or less) LiDAR data are available for representing land surface topography.

Aquifer Bottom

The bottom boundary is represented with a spatially variable surface representing the top of the bedrock unit underlying the unconsolidated sediments. Both a 500m data layer and a 1 km data layer is available for the State of Michigan and globally, respectively – see Table 1. These layers are somewhat coarse for site-scale analysis, but they are a useful as a first-order approximation of surficial aquifer thickness, which can be improved upon with local data collection.

The bottom model boundary is treated as "no flow" (no groundwater flux across the boundary), but users can easily add additional aquifer layers beneath the surficial aquifer layer, if needed.

Hydraulic Conductivity

The ease with which groundwater flows through the subsurface (hydraulic conductivity) can be represented with a spatially variable 2D data-layer available on the MAGNET server. The quality/resolution of this layer depends on location, e.g., for the State of Michigan a high resolution conductivity raster is available for use, generated by interpolating estimates of K from records in the *Wellogic* database, public water supply and U.S. Geological Society aquifer-tests, and aquifer properties reported in literature. (Similar data layers will be available for other states/provinces soon.) Globally, lower resolution/quality data layers are available for both the surficial aquifer layer and the underlying rock. Although the global K layers are somewhat crude/low resolution, they provide a useful starting point for model development.

Soon, it will be possible to produce detailed characterizations of intra-aquifer geologic variability using MAGNET. Specifically, it will be possible to produce Transition Probability (Markov chain) geostatistical simulations built from detailed lithology borehole records compiled state-by-state or province-by-province (see, e.g., Weissmann and Fogg 1999, Liao et al. 2019).

Aquifer Recharge

Infiltration of precipitation to the water table (groundwater recharge) is represented with a spatially variable 2D recharge input to the top-most cells in the groundwater model. Similar to hydraulic conductivity, the quality/resolution of the recharge layer depends on location. For the State of Michigan, a recharge raster layer is available (1609 m resolution), generated following empirical methods presented in Holtschlag (1997) involving observed stream flow hydrographs and information related to land use, soil conditions, and watershed characteristics.

Soon, two other MAGNET modules will be available for estimating aquifer recharge (actually, the entire land surface water budget): 1) MAGNET SWAT, a web-based, real time interactive version of the sub-catchment-based Soil and Water Assessment Tool (SWAT) for watershed simulation (water quantity and quality); and 2) a semi-processed based modeling tool following the procedures used in the USGS INFIL 3.0 - a grid-based, distributed-parameter watershed model by USGS (USGS, 2008). These new tools will make critical use of the pre-processed climate data, soil / root zone data, and land use / land cover data available on the MAGNET server.

Surface Sources / Sinks of Water

In instances where the groundwater head exceeds the land surface elevation, groundwater can leave the aquifer as a sink of water (i.e., groundwater is lost as surface seepage). This approach automatically captures the exchange of groundwater to surface water bodies as part of the robust solution process, as the surface water stages (elevations) are embedded in the high-resolution DEM datasets available on the MAGNET server.

MAGNET also includes an Import Shapefile tool to add explicitly streams/rivers, lakes and wetland features as prescribed head or flux boundaries within a model. (*Warning*: prescribing boundary conditions of this nature requires careful application by the user, without which significant errors in the regional water balance can occur (even though the flow patterns may be correct). Currently under development is an interface that will allow users to automatically extract NHD surface water features and add them as conceptual features to the model. (Eventually, we will include lakes, streams and wetlands on a *global* basis.)

Model Calibration

A somewhat "universal" source of physical groundwater data (water levels) available in MAGNET are Static Water Level (SWL) measurements available from water well records (universal in the sense that water wells exist wherever groundwater is being produced for societal needs). Digitization and compilation of huge numbers of SWL measurements into statewide / provincial databases is becoming increasingly common in the US and elsewhere. We are currently in the process of integrating large SWL datasets to the MAGNET platform (see Figure 1 for a depiction of current SWL data coverage).

Although there are a number of sources of error and variability embedded in SWL datasets (e.g., approximate well locations, measurement uncertainty due to QA/QC variabilities from well driller to well driller, and physically impossible data due to procedural error), our recent research shows systematic processing and critical evaluation of SWLs yields important insights into groundwater systems. In particular, large SWL datasets are especially useful for calibrating regional (long-term average) groundwater conditions, which provides the proper context (boundary conditions) for local-scale modeling of flow and transport.

Soon, MAGNET will be live-linked to spatially distributed sensor networks through web-based data repositories, providing crucial information needed for characterizing temporal trends and calibrating groundwater models, namely: historic and present-day groundwater levels; surface water stages; and stream/reservoir flows.

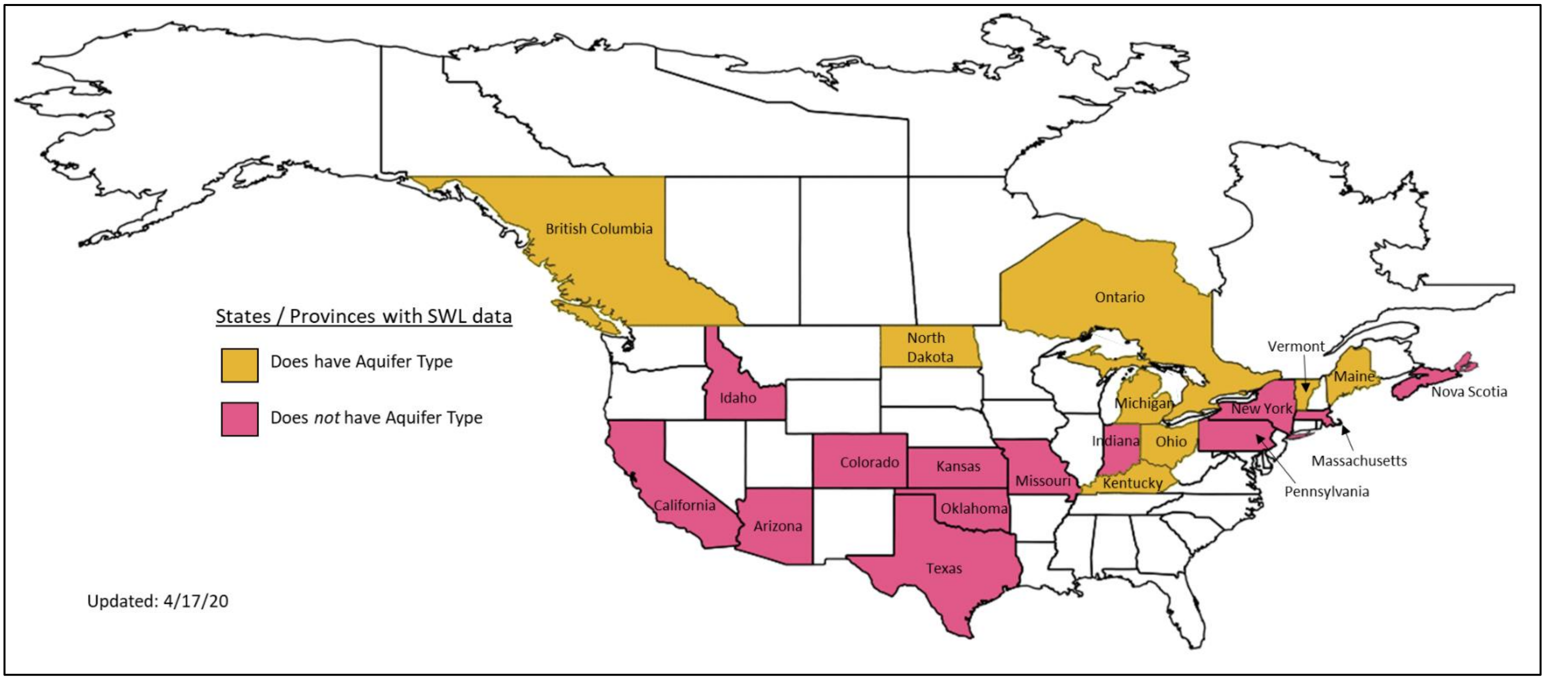

Figure 1: States/provinces for which water level data are available from statewide water well databases.

Full References for Data Sources

Global DEM:

NASA LP DAAC (2015), ASTER Level 1 Precision Terrain Corrected Registered At-Sensor Radiance. Version 3. NASA EOSDIS Land Processes DAAC, USGS Earth Resources Observation and Science (EROS) Center, Sioux Falls, South Dakota (https://lpdaac.usgs.gov), accessed January 1, 2016, at http://dx.doi.org/10.5067/ASTER/AST_L1T.003.

USA DEM*:*

NED USGS. (2006). National Elevation Dataset. US Department of Interior: United States Geological Survey, http://ned.usgs.gov/Ned/about.asp.

USA Hydrography*:*

NHD USGS. (2010). USGS: National Hydrography Dataset. US Department of Interior: United States Geological Survey, http://nhd.usgs.gov/index.html.

USA Soil and Root Zone Depth:

Soil Survey Staff (SSS), Natural Resources Conservation Service (NRCS), United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for west-central southern Michigan. Available online at https://gdg.sc.egov.usda.gov/. Accessed October 10, 2016.

USA Land Use / Land Cover*:*

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J. 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

USA Climate Data:

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004.

USGS Sensor Data

USGS (2016). U.S. Geological Survey National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [September 11, 2018], at https://nwis.waterdata.usgs.gov/nwis/inventory/?site_no=04137500&agency_cd=USGS.

State of Michigan Hydraulic Conductivity (shallow surficial deposits)*:*

State of Michigan. (2006). Public Act 148—Groundwater inventory and map project (GWIM), executive summary, Michigan State Univ., East Lansing, MI.

Global Hydraulic Conductivity (shallow surficial layer and deeper/rock layer)*:*

Huscroft, J., Gleeson, T., Hartmann, J. and Börker, J. (2018). Compiling and Mapping Global Permeability of the Unconsolidated and Consolidated Earth: GLobal HYdrogeology MaPS 2.0 (GLHYMPS 2.0), *Geophysical Research Letters*, 45, 4, (1897-1904).

State of Michigan Long-term Average Recharge*:*

State of Michigan. (2006). Public Act 148—Groundwater inventory and map project (GWIM), executive summary, Michigan State Univ., East Lansing, MI.

Global Long-term Average Recharge*:*

Pokhrel, Y.N., Koirala, S., Yeh, P.J.F., Hanasaki, N., Longuevergne, L., Kanae, S. and Oki, T., 2015. Incorporation of groundwater pumping in a global L and Surface Model with the representation of human impacts. Water Resources Research, 51(1), pp.78-96.

State of Michigan Surficial Aquifer Bottom Surface*:*

MDEQ (2015). Michigan Department of Environmental Quality. *Wellogic* System (periodically updated). Available at https://secure1.state.mi.us/wellogic/

Global Surficial Aquifer Bottom Surface*:*

Pelletier, J.D., P.D. Broxton, P. Hazenberg, X. Zeng, P.A. Troch, G. Niu, Z.C. Williams, M.A. Brunke, and D. Gochis. (2016). Global 1-km Gridded Thickness of Soil, Regolith, and Sedimentary Deposit Layers. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1304

Other work cited*:*

Holtschlag, D.J. (1997). A generalized estimate of ground-water-recharge rates in the Lower Peninsula of Michigan (No. 2437). US Geological Survey; Information Services [distributor],.

Liao, H.S., Curtis, Z.K., Sampath, P.V. and Li, S.G., 2019. Simulation of Flow in a Complex Aquifer System Subjected to Long-Term Well Network Growth. Groundwater.

U.S. Geological Survey (USGS) 2008. Documentation of computer program INFIL3.0-A distributed-parameter watershed model to estimate net infiltration below the root zone: U.S. Geological Survey Scientific Investigations Report 20085006. https://water.usgs.gov/nrp/gwsoftware/Infil/Infil.html (accessed May 1, 2017).

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