Building a Water Well Database for GIS Analysis

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OBJECTIVES

The Ohio Department of Natural Resources (ODNR), Division of Water (DOW), is the official repository for all water well records in Ohio. Currently, over 775,000 paper well records are on file at the DOW (Figure 1). The water well records dataset has multiple uses, including requests for homeowner private well information, a usable resource for the water well drilling community, an information source for environmental consultants, and a base for mapping and ground water related research. The DOW is in the process of converting paper well logs to digital data in a database and scanning images of each well record. These data are accessed through a public database. To use these data for more advanced projects, like DOW modeling and potentiometric mapping, it is essential for the data type to be compatible with use of Geographic Information Systems (GIS). Ultimately, the database needs to support the public access activities, while also handling the more advanced GIS functions.

VENDOR

The DOW had three vendors for the data conversion and database construction project. The DOW staff and inmates at an Ohio state penal institution converted the paper well log data into a database. As these labor-intensive steps are costly, the DOW chose to work through a vendor who trained and supervised the inmates on data entry. A separate vendor scanned the well logs as images. Finally, a third vendor redesigned the "front-end" for the database that is used for public data requests. Staff members were responsible for overseeing these operations. A major challenge was quality assurance and quality control.

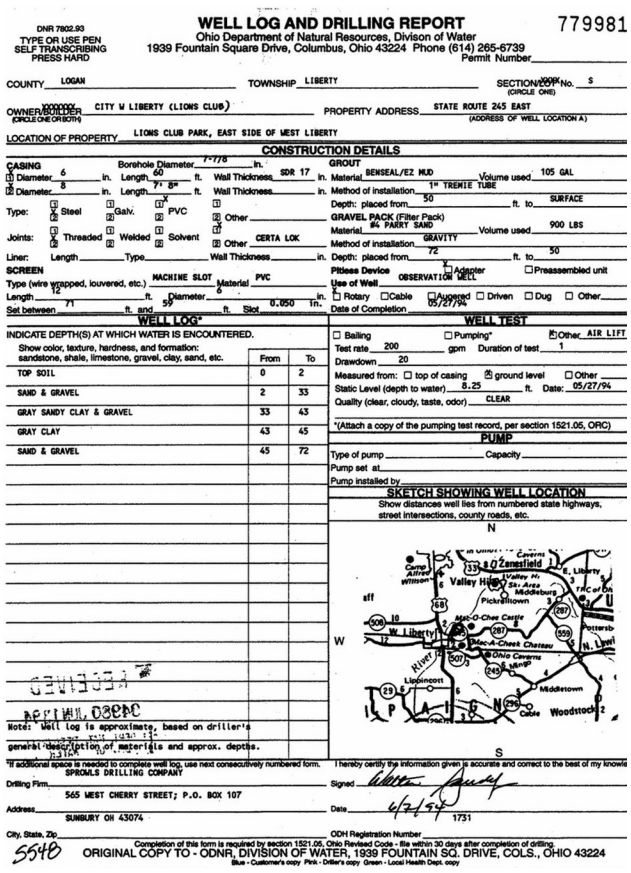
SOFTWARE USED

The well log database is an Oracle 10G Release 1-enterprise database. Oracle, which uses a Unix interface, is administered by the ODNR, Office of Information Technology. As an enterprise system, the DOW has limited write-authority and relies on the administrator to perform updates and maintenance. The DOW purchased from a vendor a custom-built Oracle front-end application called Flotiva from Workiviti version (8-1-6), which is used for data entry, simple string queries, and public service requests (Figures 2 and 3). The Oracle database is accessible to some internal users by using a link through Microsoft Access (2002). No write privileges are associated with this application. Queries and data dumps in Access are saved as tables that are usable in Microsoft Excel (2002). GIS applications are based on the Environmental Systems Research Institute (ESRI) products of Arc Map, Arc Catalog, Arc Toolbox (9.1) (Spatial Analyst, 3-D Analyst), and Arc Workstation (9.1).

WELL LOGS

The DOW began collecting water well records in 1947. Of the 775,000 paper well logs on file, less than 200,000 are located by spatial coordinates. Most of the well log locations are from DOW staff traveling into the field with a topographic map and the well log to plot the location. The field location process was abandoned in the early 1990s due to personnel reductions. Recently, geocoding has been used, with excellent results, for unlocated well log data for three counties.

Water well location maps (Figure 4) were digitized by the vendor and written to CD. The information was organized as an ESRI shapefile for each county in Ohio. To add the spatial coordinates of the wells to the Oracle well log database, a common field between the CD records and the database had to be identified. Each well log has a unique well log number, and therefore, this would have been the logical link between the digitized file and the Oracle database. Unfortunately, the well log locations were digitized using four fields (none of which are the well log number) to tag the locations. These four fields include county code, township code, location map year (the year in which the well logs were located in the field, since many counties



DNR 7802.93
TYPE OR USE PEN
SELF TRANSCRIBING
PRESS HARD

WELL LOG AND DRILLING REPORT 779981
Ohio Department of Natural Resources, Division of Water
1939 Fountain Square Drive, Columbus, Ohio 43224 Phone (614) 265-6739
Permit Number

COUNTY LOGAN TOWNSHIP LIBERTY SECTION/LOT No. 5
OWNER/BUILDER CITY W LIBERTY (LIONS CLUB) PROPERTY ADDRESS STATE ROUTE 245 EAST
LOCATION OF PROPERTY LIONS CLUB PARK, EAST SIDE OF WEST LIBERTY

CONSTRUCTION DETAILS

CASING
1 Diameter 6 in. Length 60 ft. Wall Thickness SDR 17 in.
2 Diameter 8 in. Length 7' 8" ft. Wall Thickness in.
Type: 1 Steel 2 Galv. 3 PVC 4 Other
Joints: 1 Threaded 2 Welded 3 Solvent 4 Other CERTA LOK
Liner: Length Type Wall Thickness in.
Borehole Diameter 7-7/8 in.

SCREEN
Type (wire wrapped, louvered, etc.) MACHINE SLOT Material PVC
Length 12 ft. Diameter 6 in.
Set between 71 ft. and 59 ft. Slot 0.050 in.

GROUT
Material BENSEAL/EZ MUD Volume used 105 GAL
Method of installation 1" TREMIE TUBE
Depth: placed from 50 ft. to SURFACE

GRAVEL PACK (Filter Pack)
Material #6 PARRY SAND Volume used 900 LBS
Method of installation GRAVITY
Depth: placed from 72 ft. to 50

Pitless Device ☐ Adapter ☐ Preassembled unit
Use of Well OBSERVATION WELL
☐ Rotary ☐ Cable ☐ Augered ☐ Driven ☐ Dug ☐ Other
Date of Completion 05/27/94

WELL LOG*

INDICATE DEPTH(S) AT WHICH WATER IS ENCOUNTERED.

Show color, texture, hardness, and formation: sandstone, shale, limestone, gravel, clay, sand, etc.	From	To
TOP SOIL	0	2
SAND & GRAVEL	2	33
GRAY SANDY CLAY & GRAVEL	33	43
GRAY CLAY	43	45
SAND & GRAVEL	45	72

Note: Well log is approximate, based on driller's general description of materials and approx. depths.

*If additional space is needed to complete well log, use next consecutively numbered form.

WELL TEST

☐ Bailing ☐ Pumping* ☒ Other AIR LIFT
Test rate 200 gpm Duration of test 1
Drawdown 20
Measured from: ☐ top of casing ☒ ground level ☐ Other
Static Level (depth to water) 8.25 ft. Date: 05/27/94
Quality (clear, cloudy, taste, odor) CLEAR
*(Attach a copy of the pumping test record, per section 1521.05, ORC)

PUMP

Type of pump Capacity
Pump set at
Pump installed by

SKETCH SHOWING WELL LOCATION

Show distances well lies from numbered state highways, street intersections, county roads, etc.

N W S

Zanesfield, E. Liberty, Valley Hi, Ski Area, Middleburg, Pickrelltown, Mac-O-Chee Castle, W Liberty, Mac-A-Cheek Chateau, Ohio Caverns, Logan, Lewistown, Middletown, Woodstock, Cable, Camp Alfred Wilmington

Drilling Firm SPROULS DRILLING COMPANY
Address 565 WEST CHERRY STREET; P.O. BOX 107
City, State, Zip SUNBURY OH 43074

I hereby certify the information given is accurate and correct to the best of my knowle
Signed
Date 6/2/94 1731

ODH Registration Number

Completion of this form is required by section 1521.05, Ohio Revised Code - file within 30 days after completion of drilling.
ORIGINAL COPY TO - ODNR, DIVISION OF WATER, 1939 FOUNTAIN SQ. DRIVE, COLS., OHIO 43224
Blue - Customer's copy Pink - Driller's copy Green - Local Health Dept. copy

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Figure 1. A typical water well log and drilling report.

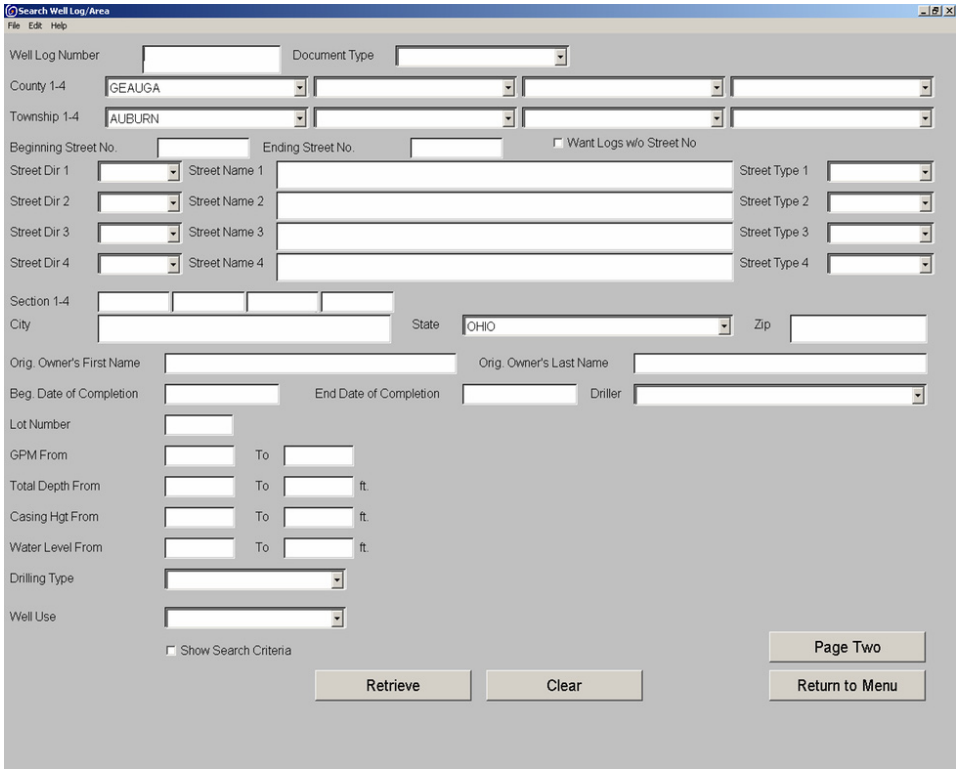


Figure 2. Search well log area screen, from Flotiva Oracle front-end custom application.

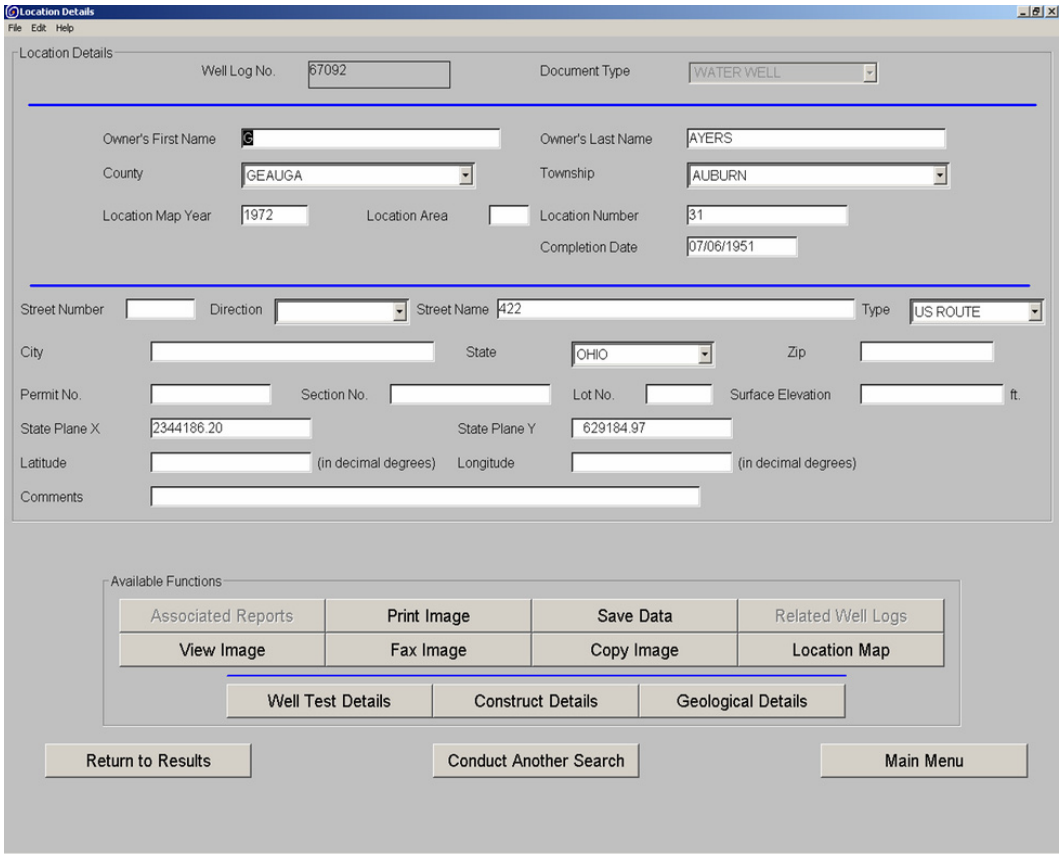


Figure 3. Location details entry screen, from Flotiva Oracle front-end custom application.

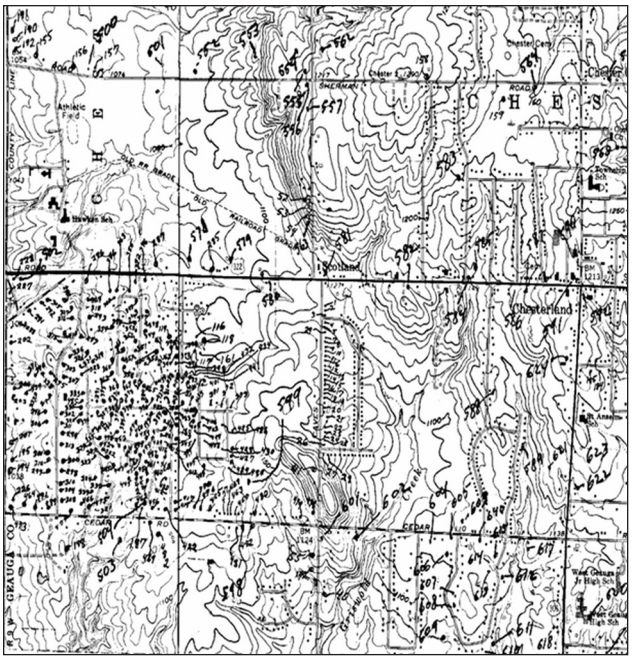
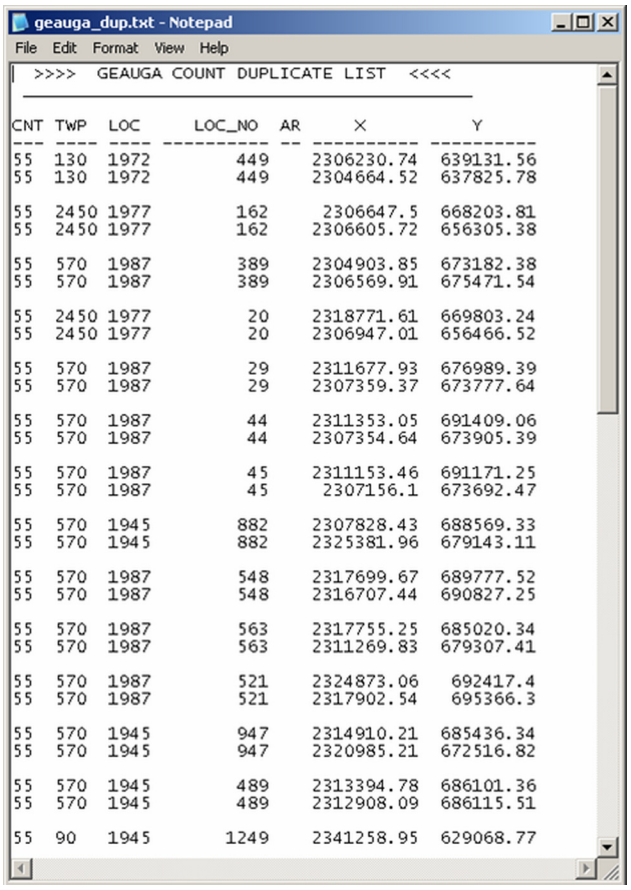


Figure 4. Map showing field-located sites of water well records.

have been field located multiple times), and location area. If these four fields match, then the link is made between the field location map points with spatial coordinates and the data fields in the Oracle database. In addition, paper copies of the well logs were scanned as TIFF type 4 images so they could be linked to the Oracle database.

Errors in linking CD data to the appropriate records in the database can be categorized as either duplicate errors or no-match (Figures 5 and 6). The shapefile of the digitized well locations is sent to the Oracle administrator to be run in a simulation to compare the digitized locations with the records in the Oracle database. The duplicate list shows all of the points with identical coordinates. Often, the errors come from inadvertently clicking the digitizing puck twice on a location. The no-match list contains those points where the four fields of data from the digitized file do not match the records in the well log database. No-match errors are either data entry or missing record errors in the Oracle database.

After error correction is completed, the Oracle administrator performs a finalized update to the Oracle database. Now, the well locations are linked to the database and to the scanned image of the well log.



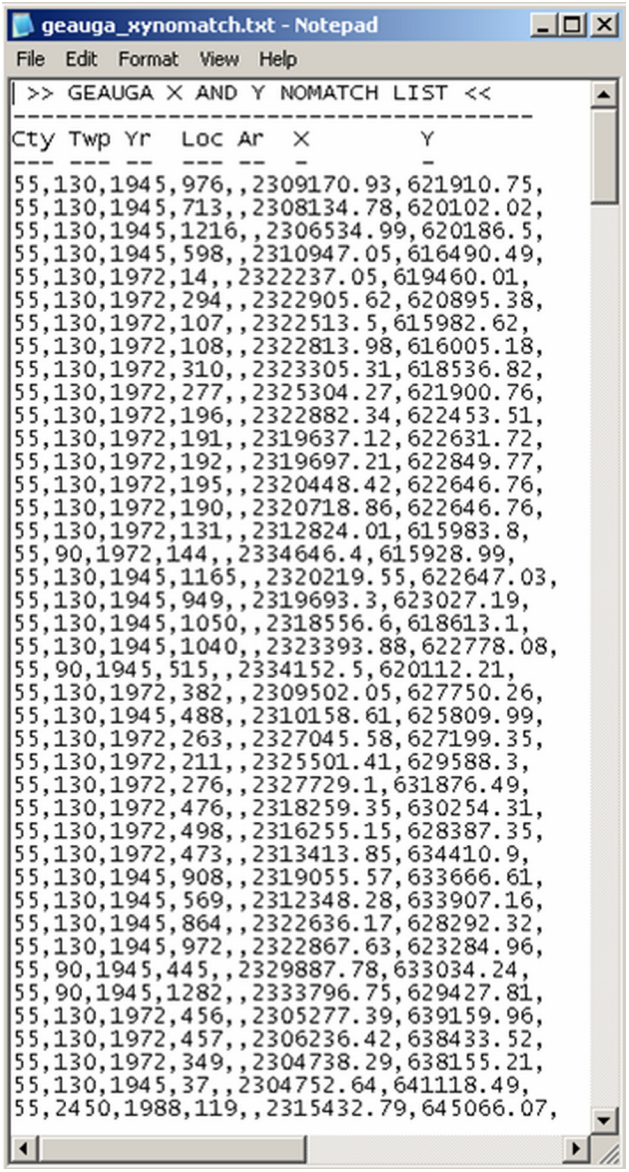
geauga_dup.txt - Notepad

File Edit Format View Help

>>>> GEAUGA COUNT DUPLICATE LIST <<<<

CNT	TWP	LOC	LOC_NO	AR	X	Y
55	130	1972	449		2306230.74	639131.56
55	130	1972	449		2304664.52	637825.78
55	2450	1977	162		2306647.5	668203.81
55	2450	1977	162		2306605.72	656305.38
55	570	1987	389		2304903.85	673182.38
55	570	1987	389		2306569.91	675471.54
55	2450	1977	20		2318771.61	669803.24
55	2450	1977	20		2306947.01	656466.52
55	570	1987	29		2311677.93	676989.39
55	570	1987	29		2307359.37	673777.64
55	570	1987	44		2311353.05	691409.06
55	570	1987	44		2307354.64	673905.39
55	570	1987	45		2311153.46	691171.25
55	570	1987	45		2307156.1	673692.47
55	570	1945	882		2307828.43	688569.33
55	570	1945	882		2325381.96	679143.11
55	570	1987	548		2317699.67	689777.52
55	570	1987	548		2316707.44	690827.25
55	570	1987	563		2317755.25	685020.34
55	570	1987	563		2311269.83	679307.41
55	570	1987	521		2324873.06	692417.4
55	570	1987	521		2317902.54	695366.3
55	570	1945	947		2314910.21	685436.34
55	570	1945	947		2320985.21	672516.82
55	570	1945	489		2313394.78	686101.36
55	570	1945	489		2312908.09	686115.51
55	90	1945	1249		2341258.95	629068.77

Figure 5. List of duplicates, showing matching records with different spatial coordinates.



geauga_xynomatch.txt - Notepad

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>> GEAUGA X AND Y NOMATCH LIST <<

Cty	Twp	Yr	Loc	Ar	X	Y
55	130	1945	976		2309170.93	621910.75
55	130	1945	713		2308134.78	620102.02
55	130	1945	1216		2306534.99	620186.5
55	130	1945	598		2310947.05	616490.49
55	130	1972	14		2322237.05	619460.01
55	130	1972	294		2322905.62	620895.38
55	130	1972	107		2322513.5	615982.62
55	130	1972	108		2322813.98	616005.18
55	130	1972	310		2323305.31	618536.82
55	130	1972	277		2325304.27	621900.76
55	130	1972	196		2322882.34	622453.51
55	130	1972	191		2319637.12	622631.72
55	130	1972	192		2319697.21	622849.77
55	130	1972	195		2320448.42	622646.76
55	130	1972	190		2320718.86	622646.76
55	130	1972	131		2312824.01	615983.8
55	90	1972	144		2334646.4	615928.99
55	130	1945	1165		2320219.55	622647.03
55	130	1945	949		2319693.3	623027.19
55	130	1945	1050		2318556.6	618613.1
55	130	1945	1040		2323393.88	622778.08
55	90	1945	515		2334152.5	620112.21
55	130	1972	382		2309502.05	627750.26
55	130	1945	488		2310158.61	625809.99
55	130	1972	263		2327045.58	627199.35
55	130	1972	211		2325501.41	629588.3
55	130	1972	276		2327729.1	631876.49
55	130	1972	476		2318259.35	630254.31
55	130	1972	498		2316255.15	628387.35
55	130	1972	473		2313413.85	634410.9
55	130	1945	908		2319055.57	633666.61
55	130	1945	569		2312348.28	633907.16
55	130	1945	864		2322636.17	628292.32
55	130	1945	972		2322867.63	623284.96
55	90	1945	445		2329887.78	633034.24
55	90	1945	1282		2333796.75	629427.81
55	130	1972	456		2305277.39	639159.96
55	130	1972	457		2306236.42	638433.52
55	130	1972	349		2304738.29	638155.21
55	130	1945	37		2304752.64	641118.49
55	2450	1988	119		2315432.79	645066.07

Figure 6. The no-match list (well log database records where the actual record is lost).

POTENTIOMETRIC SURFACE MAPPING

Mapping ground water flow directions (potentiometric surface mapping) is extremely important to most hydrogeological studies. The DOW is currently producing potentiometric surface maps for Ohio. Producing electronic datasets to support potentiometric surface mapping from our database is a high priority.

The process of generating a potentiometric surface map begins by downloading the necessary fields from the database using Access (2002). Important fields are well log number, county, township, location map year, location number, static water level, and geologic formation. The data are complied in Excel (2002) and converted into a DBF4 table. The table is imported into ArcView 9.1 as an event theme, then converted into a shapefile. This shapefile is edited to confirm that the well's coordinates lie in the correct county and township (Figure 7).

The Digital Line Graphs (DLG) hypsography layer for each quadrangle is downloaded from the Center for Mapping at the Ohio State University (Figure 8). The DLGs are projected to State Plane South NAD27 coordinate system. The hypsography (elevation contours) layer is recoded to display the "elevation" item using code written in arc macro language (AML). The resulting surficial elevation from the hypsography layer is used to construct a Triangular Integrated Network (TIN) model (Figure 9). A TIN model is a 3-dimensional surface of the X, Y, and Z values interpolated at locations between data points. The ArcInfo Workstation command Tinspot selects the elevation at the spatial location of each point in the coverage and picks the elevation from the TIN model. This elevation item will be significantly more accurate than selecting the elevation from a DEM surface, where the cell size can skew the value returned. The static water level is subtracted from the surface elevation at each point to get the elevation of the water table. USGS 1:24,000

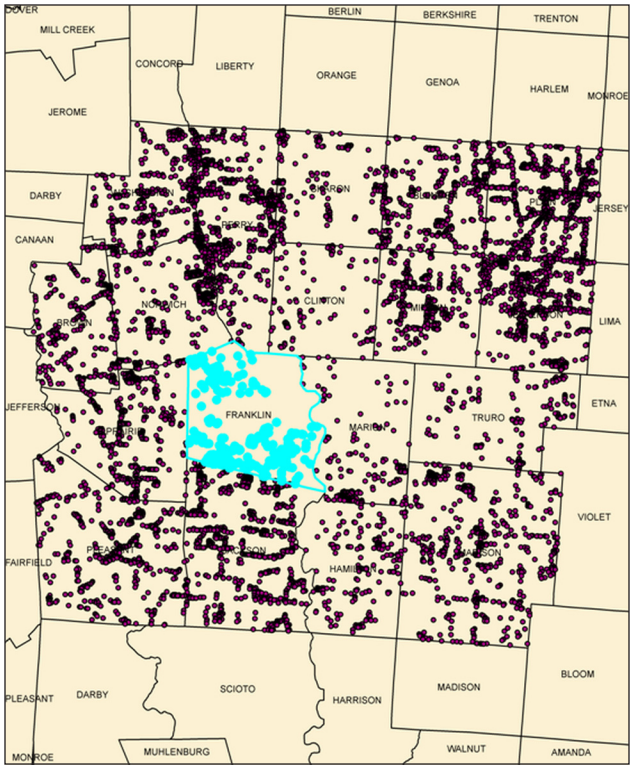

Figure 7. Water well location map. Franklin County wells highlighted in light gray (light blue in online version).

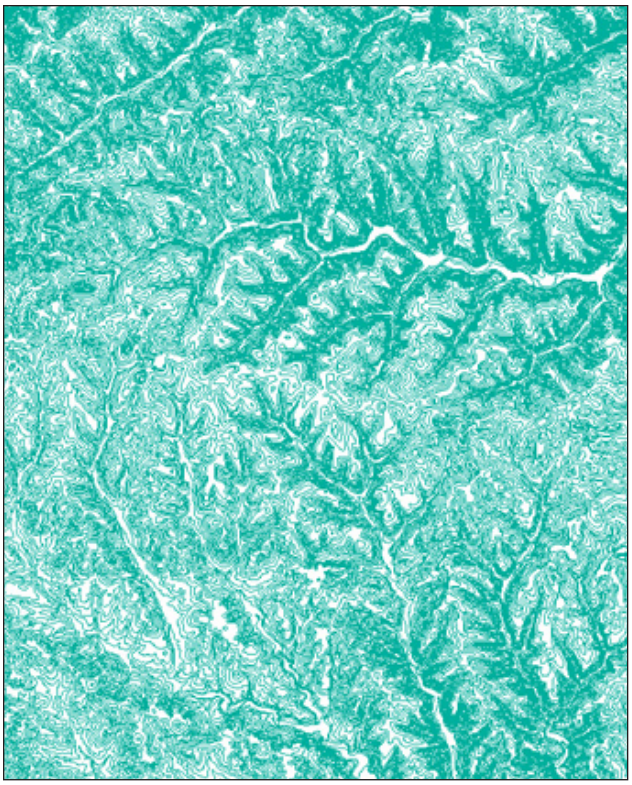

Figure 8. A typical Digital Line Graph (digitized topographic elevation contours).

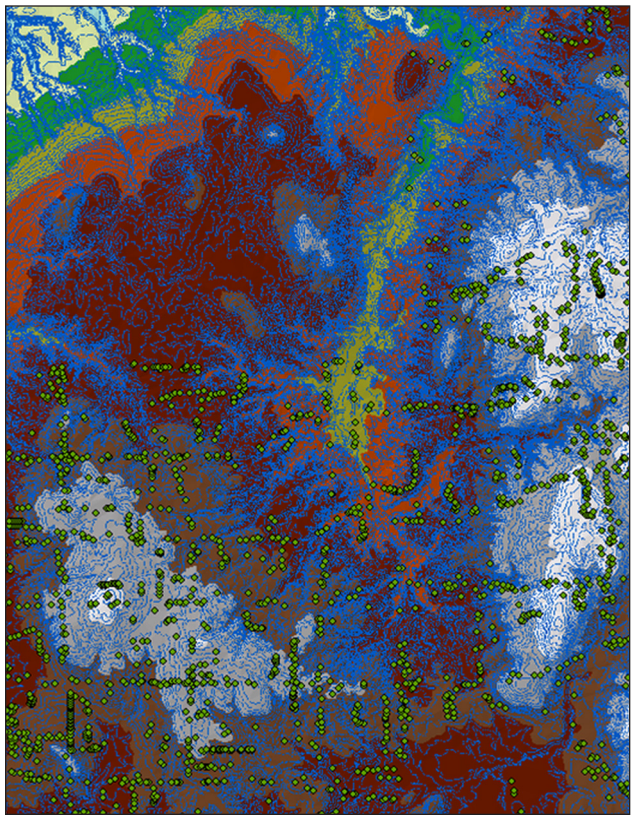

Figure 9. The 3-D TIN (Triangular Irregular Network) model constructed from Digital Line Graph file, then shaded by elevation. Well log points also are shown.

quadrangle plots of the water elevation point data are printed on Mylar for mapping hydrogeologists to interpret and map ground water flow direction. After mapping is completed, the contours drawn on the Mylar sheets are digitized to create a final layout (Figure 10).

USING GIS TO CREATE AND ANALYZE POTENTIOMETRIC SURFACE

In our latest effort with the digital database, the data points from the well log database were plotted to create sand and gravel and a bedrock aquifer potentiometric surface map near Darby Creek in Western Franklin County, Ohio. These potentiometric surface maps were combined to show where groundwater is flowing. The shapefiles were turned into TIN models, which were turned into grids. Using grid subtraction in ArcMap, Spatial Analyst, a raster difference map was generated from the potentiometric surface map data. On the Difference Map, negative values (blues) show areas where water can move downward from the sand and gravel to the bedrock aquifers. Positive values (reds) show areas where the bedrock aquifer has a net upward effect, which means that water moves from the bedrock into the sand and gravel. For more information on this technique, please view the PDF of this work as a poster session from the DMT 06 conference, http://ngmdb.usgs.gov/Info/dmt/docs/angle06.pdf.

APPLICATIONS FOR DIGITAL DATA

The DOW receives many requests for our digital water well log database. The requests may be for an area, county, watershed, or localized site. Using the capacities of GIS to clip the data to the desired configuration has made completing those requests easier. Some requests (often from environmental consulting companies) are for an area within a given radius from a natural feature or

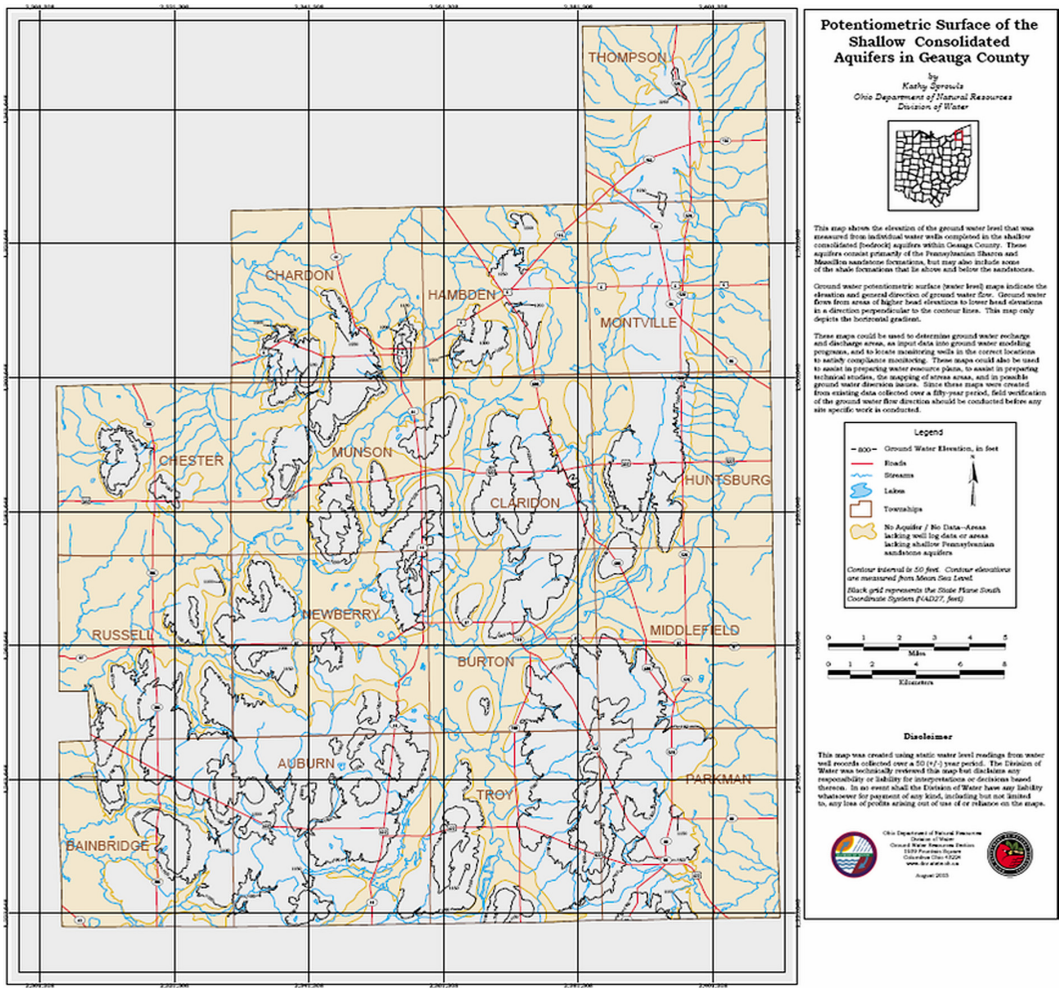

Figure 10. Potentiometric surface map (contour map of water table elevation) of shallow consolidated aquifers in Geauga County, Ohio.

intersection. The buffer function in ArcMap makes these requests straightforward (Figure 11). For example, if you were looking for ground water/surface water interaction, you can easily create a query that returns all of the water wells within a 1-mile radius of a major stream. A further refinement of the query might be to return only the sand and gravel wells with a total depth of less than 50 feet and a static water level of less that 20 feet. Consulting firms often request a 1-mile radius around a site (Figure 12). GIS capacity allows for quick fulfillment of these requests.

FINAL PRODUCTS FOR DIGITAL DATA

Templates are developed in ArcMap for all of our mapping projects. This allows for a standard design to all maps of the same series. The templates require the input of new data and some minor modifications and the map is published on-line as a PDF. Examples of these maps can be viewed on-line at http://www.dnr.state.oh.us/water/gwpsurface/County_List/tabid/3621/Default.aspx and http://www.dnr.state.oh.us/water/gwppmaps/default/tabid/3541/Default.aspx.

SOFTWARE CITED

ESRI, ARCGIS – Environmental Systems Research Institute, Inc., 380 New York St., Redlands, CA 92373-8100 USA, (909) 793-2853, http://www.esri.com

Flotiva-Workiviti, Document Imaging Solutions, 8529 N. Dixie Drive, Dayton, Ohio 45414 USA, 1-937-890-5135, http://www.disolutions.com

Microsoft, Microsoft Office 2002 – Microsoft Corporation, One Microsoft Way, Redmond, WA 98052-6399 USA, 1-800-642-7676, http://www.microsoft.com

Oracle, Oracle 10G Release 1 – Oracle Corporate Headquarters 500 Oracle Parkway, Redwood Shores, CA 94065 USA, 1-650-506-0024, http://www.oracle.com

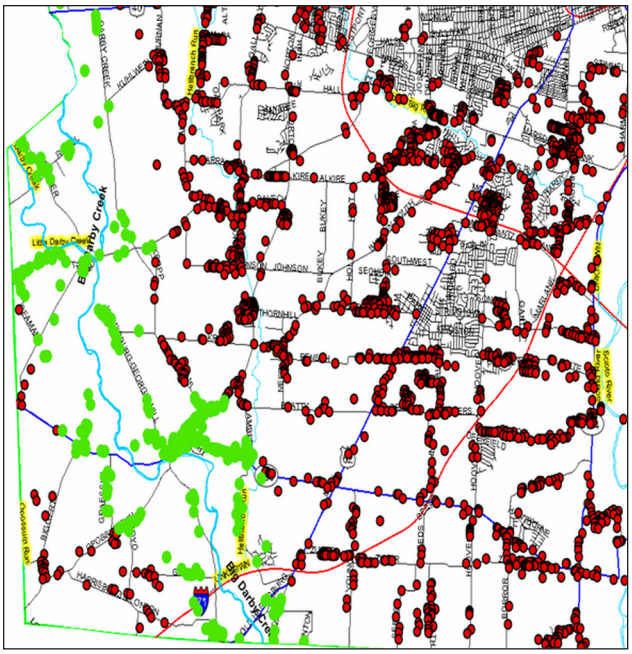

Figure 11. Water wells within one-mile buffer around Big Darby Creek in Franklin County, Ohio. Wells within buffer are highlighted in light gray (green in online version).

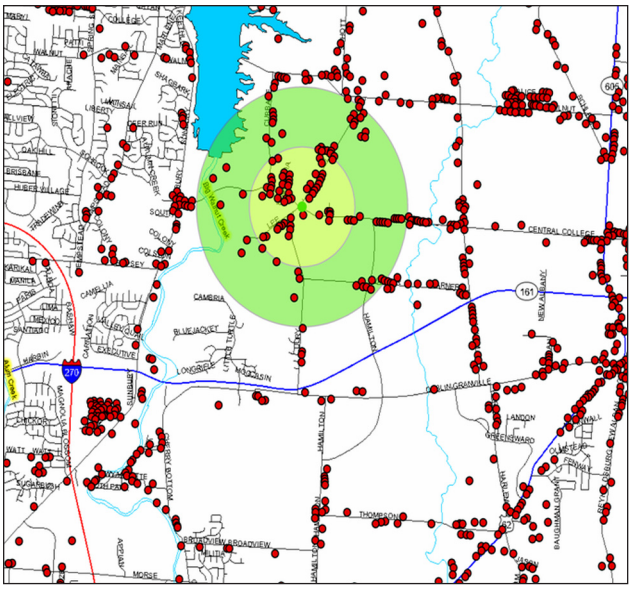

Figure 12. One-mile search radius centered on a road intersection, indicating water wells within the search area.