Indian Lake Borough Waterworks

PWSID # 4560025

Somerset County, PA

Source Water Protection Plan

Delineation of Source Water Protection Areas

Delineation of Groundwater Protection Areas

A significant purpose of the source water protection program is to delineate protection zones around each water source. For wells, these protection zones are also known as wellhead protection areas. The protection areas for the groundwater sources were determined using a steady-state hydrogeologic flow model consistent with DEP guidance. The summary of the approach and resulting protection areas are described below.

1.0 Description of Water Sources

The Indian Lake Borough Waterworks obtains its water supply from three wells (**Figure 1**). Well 18B, located along Cherokee Lane, is 153 feet deep with 70 feet of 6-inch diameter PVC casing. Well #2, located along West Shore Trail, is 185 feet deep with 80 feet of 4-inch diameter PVC casing. Well 99, located at the base of the Indian Lake dam on the downstream side, is 337 feet deep with 102 feet of 8-inch diameter steel casing. Well 18A, located adjacent to Well 18B, is no longer in service. Well information is provided in **Table 1**.

2.0 Geology

The study area lies within the Allegheny Mountain Section of the Appalachian Plateaus physiographic province and is characterized by wide ridges separated by broad valleys (Sevon, 2000). The geologic structure of the study area resides within the low-amplitude synclinal fold, named the Berlin syncline (Casselberry, 1997). With an axial strike 30 degrees east of north, the Berlin syncline plunges to the southwest (Shaulis, 1997).

The area is underlain by eight geologic formations (Berg et al., 1980; **Figure 2**):

- The Devonian age name Catskill Formation is comprised of sandstone, siltstone, shale, and mudstone.
- The Mississippian and Devonian age Rockwell Formation is comprised of crossbedded, argillaceous sandstone and shale.
- The Mississippian age Burgoon Sandstone is comprised of crossbedded sandstone and includes shale and coal.
- The Mississippian Mauch Chunk Formation is comprised of shale, siltstone, sandstone, and some conglomerate.
- The Pennsylvanian Pottsville Formation is comprised of sandstone and conglomerate as well as thin beds of shale, claystone, limestone, and coal.
- The Pennsylvanian Allegheny Formation is comprised of cyclic sequences of sandstone, shale, limestone, clay, and coal. The upper section of the Allegheny Formation is the producing formation of Well #99.
- The Pennsylvanian Glenshaw Formation is comprised of cyclic sequences of shale, sandstone, red beds, and thin limestone and coal. The middle section of the Glenshaw Formation is the producing formation of Well #2 and Well #18B.
- The Pennsylvanian Casselman Formation is comprised of cyclic sequences of shale, siltstone, sandstone, red beds, thin impure limestone, and thin nonpersistent coal.

The underlying geology of the area, in large part, controls the surface topography and the flow of groundwater through the bedrock aquifers. Therefore, it forms the framework of the hydrogeologic flow model. Because groundwater flow is largely controlled by primary (inter-granular) porosity and secondary (joints and fractures) porosity within the bedrock aquifer, the geologic structure of the aquifers plays a role in shaping the overall groundwater flow regime.

The subsurface aquifer system has varied properties based on the hydraulic properties of the rock formations. Permeability variations are a function of rock composition (lithology, cementation) as it relates to primary porosity and degree of fracturing (as it relates to secondary porosity). This variation in hydraulic permeability results in lateral and vertical heterogeneity in the behavior of the aquifer system on various scales. The shallow system is comprised of unconsolidated material and weathered bedrock. Below this layer is the bedrock aquifer system. The hydraulic properties of the aquifer largely depend on the degree and frequency of fracturing. Overall the degree and volume of water-bearing fracture zones decrease with depth as the lithostatic pressure increases, closing conduits to water flow.

3.0 Conceptual Flow Model

When a well extracts water from an aquifer, it pulls in groundwater from all directions – not just north, south, east, and west, but also from above and below the well. This means that the depth, in addition to the lateral direction, must be considered when evaluating groundwater movement toward a pumping well. The region of the subsurface from which groundwater is pulled into the well is called the capture zone, and is of special interest to the protection of the water source. Even though groundwater is pulled into a well from all three dimensions, the capture zone is usually represented two-dimensionally as an area on the land surface.

A conceptual model was created to describe the components of the aquifer system surrounding the Indian Lake Borough Waterworks wells (**Figure 3**). The conceptual model distills the essential hydrogeologic information into a simplified set of assumptions. Based on a review of published geologic and hydrologic data for the area, the following assumptions were used:

- The water budget for study area is defined as a closed system, where inflow equals outflow.
- The groundwater basin supplying water to the wells encompasses the Stoneycreek River watershed subbasins, creating an overall regional groundwater flow from the headwaters towards the stream valleys.
- The majority of recharge to the aquifer system occurs in the up-dip outcrop areas on the flanks of the Berlin Syncline. Secondary recharge occurs through vertical leakage.
- Groundwater flow, on the order of one foot per day, is generally perpendicular to bedrock strike in a down-dip direction.
- The Stoneycreek River, to the west of the wells, is a regional discharge point of the groundwater system. The average elevation of the river coincides with the elevation of the groundwater table.
- The wells produce water from a highly layered confined aquifer system comprised of cyclic sequences no larger than tens of feet thick creating a hydraulic condition where horizontal conductivity is much greater than the vertical conductivity with limited degree of hydraulic interconnection between layers.
- Each stratigraphic interval exhibits a discrete hydraulic head.
- The bedrock fractures are bedding-parallel with vertical fractures common in valley floor. The bedrock fracture density is greater in the valley floors than in the upland areas.

- Based on well water level elevation data, the lake does not appear to contribute to the underlying confined aquifer system.
- The aquifer contains primary porosity within the sandstone formation and secondary porosity controlled by bedding orientation and fracture features.

The average groundwater flow system can be approximated using a steady-state model that ignores daily and seasonal variations in the water table in favor of long-term, average flow conditions. The groundwater system described in the conceptual model is a three-dimensional phenomenon; groundwater flows from high elevation at the recharge area to low elevation at the discharge area. The flow paths are influenced not only by the geological orientation of the aquifer system, but also the vertical changes in hydraulic properties within the aquifer. For this reason, a three-dimensional modeling approach was used to describe the groundwater flow movements through the system. To account for the variation of hydraulic properties for the various stratigraphic units, the hydrogeologic model is created as a six layer system.

4.0 Numeric Model

SSM personnel constructed and calibrated a steady-state hydrogeologic computer model to assess the groundwater flow system in the study area. In addition to delineating the source water protection areas, the model can be used as a planning tool for water resource issues.

A hydrogeologic flow model numerically simulates groundwater flow using mathematical equations. The model takes a complicated natural system and simplifies it to its basic components. Although the model is constructed from real-world data (*e.g.*, ground surface elevation, stream location, and underlying geology), the model assumes ideal and uniform local conditions that rarely occur in real systems. Therefore, the hydrogeologic flow model provides an approximation (as opposed to a direct measurement) of the groundwater flow regime that can be used to understand the overall hydrogeologic system.

SSM delineated the source water protection areas from the results generated by the hydrogeologic flow model (presented in **Section 8**). The hydrogeologic model was created using US Department of Defense Groundwater Modeling System (GMS) Version 7.0 GMS is an industry-recognized groundwater flow software that couples a model design system and graphical analysis tools with MODFLOW (A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model), PEST (Model-Independent Parameter Estimation), and MODPATH (a particle tracking post-processing program) program codes (BYU, 2009). Detailed descriptions of the program codes are provided on the Data Package CD included with this report.

5.0 Model Inputs

Hydrogeologic model construction requires geographic, geologic, and hydrologic data to produce a realistic flow model. The input data used to construct the model were derived from various published data as well as collected field data within the project area. The following is a discussion of the input data parameters.

5.1 Model Boundaries

The 50.7-square mile modeled area, shown in **Figure 4**, includes eight watershed subbasins (ERRI, 1997). The lateral boundaries of the model coincide with the surface water divides and/or hydrogeologic boundaries. At the model boundaries, it is assumed that surface water divides and groundwater divides are coincident. Consequently, all of the model boundaries are considered "no-flow" boundaries. The top boundary of the model coincides with the surface topography within the project area. A digital elevation model (DEM) was used to determine the elevation of the model's top boundary (**Figure 5**). The data used in the modeling effort was derived from the U.S. Geological Survey (USGS) National Elevation Dataset DEM coincident with the Berlin, Central City, New Baltimore, and Stoystown 7.5-minute US Geological Survey quadrangles (USGS, 2014a). The basal boundary of the model is coincident with the base of the Pottsville Group. The basal model depth was chosen based on the maximum well depths reported in the study area (DCNR, 2014).

The modeled aquifer system is comprised of a mixture of unconfined and confined aquifers based on the resultant potentiometric head configuration. For example, a shallow well may draw water from a shallow, unconfined aquifer while a deeper, neighboring well may draw from a deep, confined aquifer.

5.2 Geographic Data

The locations of surface water and other geographic features are also required for construction of the hydrogeologic model. Stream locations were imported to the model from the National Hydrography Dataset (NHD; USGS, 2014b). Elevations of the streams were derived from the digital elevation model. The hydrogeologic model treats streams as either perennial (existing year-round) or ephemeral (drying up during some periods of the year). From a modeling standpoint, the only distinction between the two types of stream is that perennial streams can either receive groundwater as base flow or contribute water to the groundwater system, whereas ephemeral streams can only receive groundwater. For modeling purposes, the streams in the study area were determined to be perennial or ephemeral based on the stream order. Perennial streams are comprised of stream reaches with a stream order greater than or equal to three.[1] Stream reaches with a stream order less than three are deemed to be ephemeral (**Figure 4**).

5.3 Field Data

To calibrate the hydrogeologic model, stream flow and well water level data were incorporated into the model. The process involved varying estimated parameters (such as hydraulic conductivity) to match model outputs (like groundwater table elevation) with observed data.

The water level data used in the model calibration were derived from the water well inventory (WWI) and the ground-water site inventory (GWSI) of the Pennsylvania Ground Water Information System (PAGWIS; DCNR, 2014), and the Pennsylvania Drinking Water Information System (PADWIS; DEP, 2013) (**Figure 6**). The data in PAGWIS come from several governmental agencies and private well drillers who submit data to the Pennsylvania Geological Survey. The USGS maintains the National Water Inventory System (NWIS) which contains comprehensive information for wells and streams located across the country (NWIS; USGS, 2014c). The GWSI database, a subset of the NWIS inventory, is an inventory of USGS monitoring wells. The Pennsylvania Department of Environmental Protection maintains an inventory of permitted drinking water sources (PADWIS) within the Commonwealth in accordance with Pennsylvania's Safe Drinking Water Act. Water level data from 42 wells were used in the modeling effort.

The groundwater table (and hence the water level within the wells) fluctuates both daily and seasonally. The hydrogeologic model is a steady-state model that ignores short-term variations in favor of an average long-term condition. To calibrate the model based on the observed water level data, a single groundwater table elevation (or head) value is assigned to each observation well, along with a range of elevation values within which the water level would be expected to fall or rise. Ground surface elevation data at each well was obtained from the DEM.

5.4 Groundwater Recharge

Groundwater recharge is the rate at which precipitation infiltrates to the bedrock to supply water to the groundwater system. It is a function of average precipitation, land use, morphology and the underlying geologic formation. Groundwater recharge rates are estimated for a particular area by measuring the base flow of the area streams because, in theory, the discharge rate of groundwater to

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[1] Based on the Strahler Stream Order hydrology algorithm.

the stream is directly proportional to the rate at which groundwater is being recharged. Estimates of groundwater recharge were based on streamflow-hydrograph analysis of the Stoneycreek River (Roland and Stuckey, 2008; Stuckey, 2006; USGS, 2014d). Direct precipitation, stormwater runoff, and evapotranspiration are assumed components of the groundwater recharge estimates. The recharge units were derived from the average precipitation (SCAS OSU, 2000), soil characteristics and land surface slope (USDA, 2008), land use (PSU, 2007), and underlying geology (DCNR, 2001; **Figure 7**). The resulting rate has a mean value of 0.417 million gallons per day per square mile (8.75 inches per year). Recharge is applied to the shallowest layer of the model. Water moves in a vertical direction to the underlying layers in accordance with the hydraulic conductivity of the layer.

5.5 Hydraulic Conductivity

Hydraulic conductivity is the measure of the ease with which water flows through an aquifer, and can be calculated through aquifer tests (*i.e.*, pump tests) on wells. Because hydraulic conductivity within a regional aquifer system can vary greatly, a single conductivity value cannot be applied uniformly to the modeled area. The hydrogeologic model was calibrated with a parameter estimation program to conform to the observed values of groundwater head (*i.e.*, well water level). The calibration process was conducted by varying the hydraulic conductivity input for each geologic formation and model layer, as well as horizontal and vertical anisotropy factors, until the resulting groundwater flow model predicted head values that fit the set of observed water level data.

Through the parameter estimation process, hydraulic conductivity values for the modeled area were estimated to be between 0.001 and 94 feet per day. Given the various layer thicknesses, the hydraulic conductivity range equates to a transmissivity range of 0.2 to 16,000 square feet per day (**Table 2**). Further, it was found from the calibration process that the bedrock aquifers exhibit a high degree of anisotropy in the vertical conductivity field. This means that the flow of groundwater is easier (higher conductivity) in a horizontal (bed-parallel) direction than in a vertical direction. The ratio of horizontal conductivity to vertical conductivity ranges from 1.1 to 790, with a median ratio of 53.

6.0 Groundwater Withdrawal

To simulate the groundwater conditions during operation of the water supply wells, groundwater is extracted from the model at the location of each source. The rates are based on the withdrawal permit for each source (**Table 1**).

To address the impact of well interference, groundwater is extracted from other public water supply wells (DEP, 2013), and wells registered under the DEP Water Use Planning program (DEP, 2010), (**Figure 4**). Twenty-one water supply wells were identified within the modeled area, totaling one million gallons per day of permitted and/or registered groundwater withdrawal from the study area.

7.0 Model Results

The calibrated model produces a volumetric flow budget and predicted groundwater table elevations (*i.e.*, head values) during operation of the water system. **Figure 8** displays the predicted groundwater elevation contours on a potentiometric surface map of the study area.

7.1 Residual Analysis

Model validation is performed to determine how well the model results fit the observed data. The predicted head values are compared to the observed water levels to assess the model confidence using a residual analysis. A model is considered to fit the data if the residuals appear to behave randomly (USDC, 2006) and the magnitudes of the residual errors are acceptably small (BYU, 2009). The model calibration results were determined to fit the observation data. The predicted and observed head values used in the residual analysis are found in the data package of this report.

7.2 Volumetric Flow Budget

The hydrogeologic model is constructed on the assumption of a steady-state, closed system, where inflow equals outflow. A volumetric flow budget was developed for the project area that accounts for all of the simulated groundwater as it passes between model elements. Data tables accounting for the flow rate of groundwater that moves through the modeled area are contained in the model output files (**Data Package CD**). The hydrogeologic flow model accounts for several sources of groundwater inflow and outflow such as inflow from recharge derived from meteoric waters and surface water features and outflow to wells, springs and stream baseflow.

Groundwater inflow to the model from recharge is the water added to the groundwater system through groundwater recharge which is ultimately derived from precipitation. The inflow from streams is the water added to the groundwater system through losing stream reaches. Inflow from lakes and ponds is the water added to the groundwater system through leakage through the base of a lake, pond or other water impoundment.

Groundwater outflow to wells is the water extracted by registered water withdrawal wells. The outflow to lakes and ponds is the water that enters a lake, pond or other water impoundment through groundwater springs. Outflow to streams is the water lost from the groundwater system to maintain baseflow in gaining streams. Outflow to springs and ephemeral streams is the water lost to discharge to naturally flowing springs and ephemeral streams. From a modeling standpoint, springs and ephemeral streams are treated the same because they only flow if the groundwater table is high enough to support the discharge. If the potentiometric surface is below the discharge point, the spring does not discharge groundwater.

Another source of groundwater withdrawal is the extraction of groundwater from private wells and springs for onsite use, such as for a rural home. In areas without public sanitary sewers, most of the water extracted from the well is returned to the groundwater via an on-lot septic system, forming a localized loop of water withdrawal and discharge. For this reason, the groundwater withdrawal due to private, on-lot water systems was not included in the hydrogeologic model.

7.3 Groundwater Flow Model

In addition to the volumetric flow budget, the hydrogeologic model also generates groundwater flow vectors that identify paths along which groundwater flows. Because groundwater flows from high to low piezometric areas, it typically moves perpendicular to surface contour lines under isotropic conditions. It exits the model through stream discharge and withdrawals from wells and springs. Using a particle tracking algorithm, the flow paths can be traced from a point of origin (*e.g.*, recharge area) to a discharge point (*e.g.*, well). The groundwater contours wrap around the production well in response to groundwater withdrawal. As the water level drops in response to pumping, a cone of depression forms around the well. Water within the cone of depression will flow towards the well to be withdrawn by the pump. By running the groundwater flow model backwards, the source of the extracted groundwater can be determined. These extrapolated flow traces then form the basis of the source water protection areas as described below. A groundwater flow path map, illustrating the interpreted paths groundwater takes to the discharge point, is presented in **Figure 9**.

8.0 Source Water Protection Area Delineations

The source water protection area calculations and delineations are based on well information, groundwater flow patterns and watershed configuration. The delineated zones for each of the groundwater supply sources are shown in **Figure 10**.

8.1 Source Water Protection Zone I

The source water protection Zone I is the smallest of the three zones and is also the most stringent from a protection standpoint. Zone I is a circle around the well with a radius between 100 and 400 feet depending on well and aquifer characteristics. The management goal for Zone I is maintaining it in a natural state, under control of the water supplier, with no potential sources of contamination.

The Zone I areas for the public water supply wells have been established using the DEP "Recommended Wellhead Protection Area Zone I Delineation Methodology" (DEP, 2005). The methodology requires three pieces of information to determine the Zone I radius: porosity of the producing formation, the open borehole interval, and the groundwater withdrawal rate. **Table 3** presents the well information and Zone I radius for each of the public water supply wells.

For all wells permitted after October 9, 1995, the water supplier is required to own or substantially control the Zone I wellhead protection area to prohibit activities within the Zone that may have a potential adverse impact on source quality or quantity. To determine the regulatory requirements for ownership or control of the specified buffer area around the wellhead, the Water Supply Permit should be consulted.

8.2 Source Water Protection Zone II

The land that contributes groundwater to a pumping well is referred to as the capture zone, or the zone of diversion. Zone II is the surface representation of the capture zone. This area is delineated by a volume of water, in an aquifer, contributing to a well. The Zone II delineations shown in **Figure 10** represent the volume of water entering the sources in a 10-year time-of-travel. In other words, groundwater that resides below the area identified as Zone II has a high probability of reaching the corresponding source in fewer than ten years. The Zone II area for all of the water sources occupies an area of 1.63 square miles. The surface area of the capture zones for each of the water sources are listed in **Table 3**.

The Zone II area for Well #18B is elongated to the east, following the primary groundwater flow from the up-dip outcrop recharge area located to the east and northeast of the well. The Zone II area for Well #2 extends to the north in response the primary groundwater flow from the up-dip outcrop recharge area located to the north and northwest of the well. The Zone II area for Well #99 extends to the north and east following the primary groundwater flow in a structurally down-dip direction.

8.3 Source Water Protection Zone III

Zone III is the land area beyond Zone II that contributes recharge to the aquifer within the first two areas via surface water or groundwater. Collectively, Zones II and III constitute the contributing area of a well. Zone III is determined through a particle tracking algorithm with the groundwater flow model. The tracking algorithm determines the extent of a recharge area by tracing the groundwater flow paths that enter a well backwards to the point of origin. The groundwater that enters the wells from the up-dip outcrop recharge areas. Since the strategraphic sequences play a major role in controlling the groundwater flow through the aquifer, the areas where the strategraphic intervals penetrated by the wells outcrop to the surface form critical aquifer recharge areas (**Figure 10**). The Zone III is the up-gradient drainage area that contributes recharge to the aquifer recharge areas. The Zone III for all of the wells occupies an area of 16.9 square miles.

9.0 References

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