APPENDIX B - ATTACHMENT 2

New Jersey Source Water Assessment Program Surface Water Delineation Methodology

Introduction

The 1996 Amendments to the Federal Safe Drinking Water Act required states to complete Source Water Assessments for all public drinking water sources. New Jersey's Source Water Assessment Program (SWAP) Plan developed in conjunction with the Source Water Assessment Advisory Committee, and approved by USEPA Region 2 on November 1, 1999.

The Source Water Assessment Plan defined an area surrounding each drinking water source and identified the area(s) of source water that a public drinking water system withdraws from the ground or diverts from the surface for treatment and distribution as drinking water. The assessment also inventoried the significant potential sources of contamination, and analyzed how susceptible the drinking water source is to contamination.

The surface water delineations were completed by NJDEP, Bureau of Safe Drinking Water staff in conjunction with Division of Science and Research staff from May 1999 to May 2003. Additional surface water delineations were defined upstream of USGS sampling stations in order to perform susceptibility modeling by USGS in conjunction with Bureau of Safe Drinking Water staff from November 1999 to December 2001 using the same methodology.

Background Information

Source Water Assessment Program Geographic Information System (GIS)

GIS technology was the main tool utilized to accumulate, analyze, transfer, report, and deliver source water assessments in New Jersey. GIS software designed by Environmental Systems Research Institute, Inc.'s (ESRI) ArcView and ArcInfo with migration to ArcGIS vr. 8.x. GIS tools were used to identify source water assessment delineation areas (both groundwater and surface water) based upon certain data layers. Surface water delineations were based on the overland drainage basin for the intake, including all tributaries to their headwaters. The delineation areas then served as the instrument for GIS clipping of the remaining data layers of interest.

GIS Data Sets

The New Jersey SWAP Plan identified two distinct sets of necessary GIS data layers; 1) those required to create the delineation areas, and 2) those required to develop the Potential Contaminant Source Inventory (PCSI) for susceptibility model development and implementation. The New Jersey SWAP Plan, Table 3 pp. 36-37, lists sites/activities of concern, and guided the SWAP when identifying data layers necessary for the PCSI. GIS data-sets were gathered from many sources both within the NJDEP and from other sources (other New Jersey State Agencies, Federal Agencies, and State Agencies outside of New Jersey). All accumulated data for SWAP development were assessed and accepted or rejected based on the accuracy constraints of the data layers. Accuracy constraints included but were not limited to data completeness, positional accuracy, and temporal concerns. Critical data layers, which either did not exist or did not meet necessary accuracy levels were developed by NJDEP staff as needed. The NJDEP/GIS Mapping and Digital Data Standards were followed for any data developed internally by the SWAP.

When assessing GIS data layer's applicability, the SWAP consulted the available metadata. In cases when metadata were unavailable, the data steward(s) were contacted and "pre-metadata" acquired. The SWAP saved all applicable metadata and pre-metadata. GIS data continues to evolve, therefore the SWAP made every effort to keep current with newly released data. This included new data as well as any updates to present data layers. As new data-sets were assessed and accepted, they were incorporated into the SWAP.

Types of Intakes

A drinking water intake is a structure engineered to collect surface water for delivery to a water treatment plant for usage as a potable water supply. Many intakes have controlling structures downstream of the intake, i.e. a dam or a weir, which affect downstream flow. When this occurs SWAP staff delineated the downstream boundary at the controlling structure. When intakes are mentioned in this document, this refers to the intake or controlling structure, when one is present. A drinking water surface water source is any surface water body where water is withdrawn for use as a potable water supply. There are several types of surface water sources in use in New Jersey:

- river,
- reservoir,
- canal,
- groundwater under the direct influence of surface water (GUDI).

For the purposes of SWAP all raw water transfer points are considered a distinct source of surface water. The Source Water Assessment Program delineated all public drinking water surface water sources in New Jersey.

Intake Availability

An intake's status or usage is defined by its availability code found in the Bureau of Safe Drinking Water's New Jersey Public Water System database. Table 1 shows the surface water intakes and GUDI wells and their availability. All intakes/sources except "Not In Use/Discontinued" and "Unknown" were delineated and received susceptibility ratings.

Surface Water Sources/Intakes Inventory

Surface water systems and their sources can be extremely complicated. The following points describe how SWAP staff handled the complexities of delineating surface water intakes.

1. The simplest situation was when one source water delineation was created for a single intake.
2. Raw water transfers were considered a separate and distinct source of water. When the transfer points were located in a different watershed they received their own distinct delineation area and their own susceptibility ratings. The Oradell reservoir for instance, receives raw water transferred from several locations: the Saddle Brook, the Hirshfeld Brook, the Sparkhill Brook, and the Wanaque Reservoir. These transfer points were delineated and susceptibility models run for each.
3. When intakes or transfer points were within the upstream watershed of a downstream intake, they were not delineated separately. These upstream intakes received the susceptibility ratings of the associated downstream SWA. The Wanaque System exemplifies this situation. Raw water is transferred from several locations to the Wanaque Reservoir, including the Wanaque South, Pompton Lakes, and Point View Reservoir intakes. All of the intakes exist in the same watershed and eventually drain to the Wanaque South intake. All transfer points in the system received the susceptibility ratings for the intake furthest downstream, in this case the Wanaque South intake.
4. In some cases, several intakes were located close to each other and served the same Entry Point To the Distribution System (EPTDS). These also were delineated once, using the furthest downstream intake for the downstream boundary and the furthest upstream intake as the intake location for susceptibility modeling. The upstream intake would be the first to be effected by any contaminants. In this situation all intakes received the susceptibility ratings for the furthest upstream intake.
5. Another unique situation exists with the Wanaque South intake. This intake is located on the Pompton River upstream of the confluence with Passaic River. The intake was engineered so that the intake could draw water from the Passaic River during periods of low flow. This situation does not occur on a continual basis therefore SWAP staff decided to consider the intake as having two separate source water areas. The two source water areas, the Passaic

River and the Pompton River contribution, therefore were delineated separately and received two separate sets of susceptibility ratings.

6. United Water-Franklin Lakes receives raw water from the Wanaque-Oradell aqueduct and received the same susceptibility ratings as the Wanaque South intake.
7. There are five permanent finished water reservoirs in New Jersey, which either do not receive overland drainage or are contained in the SWA delineation from where their water originates. These finished water reservoirs were not delineated and did not receive susceptibility ratings.
8. In some cases more than one GUDI well supplied water to the same EPTDS. One delineation was produced for the multiple wells.

The situations described above created a discrepancy between the number of intakes and the number of delineations as shown in Table 1. The total number of surface water sources is 125 however the total number of delineations is 60.

Table 1: New Jersey Surface Water Sources for Drinking Water
125 total surface water sources (including GUDI)

Surface Water Source Type	Water System Type	Source Availability	Number of Sources	Number of Source Water Areas Delineated
Intakes	Community (67)	Permanent	50	49
		Seasonal	3	
		Interim	2	
		Emergency	6	
		Not In Use / Discontinued	5	
		Unknown	1	
	Non-Community (3)	Permanent	3	
GUDI	Community (30)	Permanent	19	11
		Not In Use / Discontinued	10	
		Monitoring Well	1	
	Other (Duhernal) (25)	Permanent	1	

Note: The Wanaque South intake (permanent) is counted twice (PVWC, NJDWSC).

5 Year Groundwater Time-of-Travel Buffer

The New Jersey Source Water Assessment Program Plan (http://www.state.nj.us/dep/watersupply/swap1.pdf) stated a 5-year groundwater flow zone be added to each delineation to account for base flow to streams in the delineation area. In February 2001 NJDEP asked USGS to examine the utility of the 5-year groundwater buffer zone. The analysis showed that while the concept of a groundwater contribution area was scientifically sound, there was no clear specific benefit associated with the zone for susceptibility rating of surface water intakes. NJDEP also believed that in most cases the 5-year contribution area would be contained within the overland drainage area. Therefore NJDEP decided to forgo the groundwater buffer zones.

Delineation Basic Steps

There are two basic steps to delineate a surface water source:

1. Accurately locate the intake,
2. Delineate the entire drainage area that flows past the intake.

These steps will be discussed in more depth in the following section.

Accurately Locate the Intake

All community and non-community surface water intakes were located and mapped using Global Positioning Systems (GPS) technology. These include permanent, intermittent, and emergency use intakes. The intakes were GPS located by Bureau of Safe Drinking Water (BSDW) personnel, with equipment and procedures which met or exceeded the requirements in "NJDEP GPS Data Collection Standards For GIS Data Development," Bureau of Geographic Information and Analysis Office of Information Resource Management, August 19, 1998. The mapping effort was completed in 2000.

A Geographic Information Systems (GIS) data-set (coverage) with the intakes was developed from the mapping effort. The coverage is maintained and updated annually by BSDW GIS staff. The base coverage for SWAP is the 2002 update.

Delineate the entire drainage area that flows past the intake

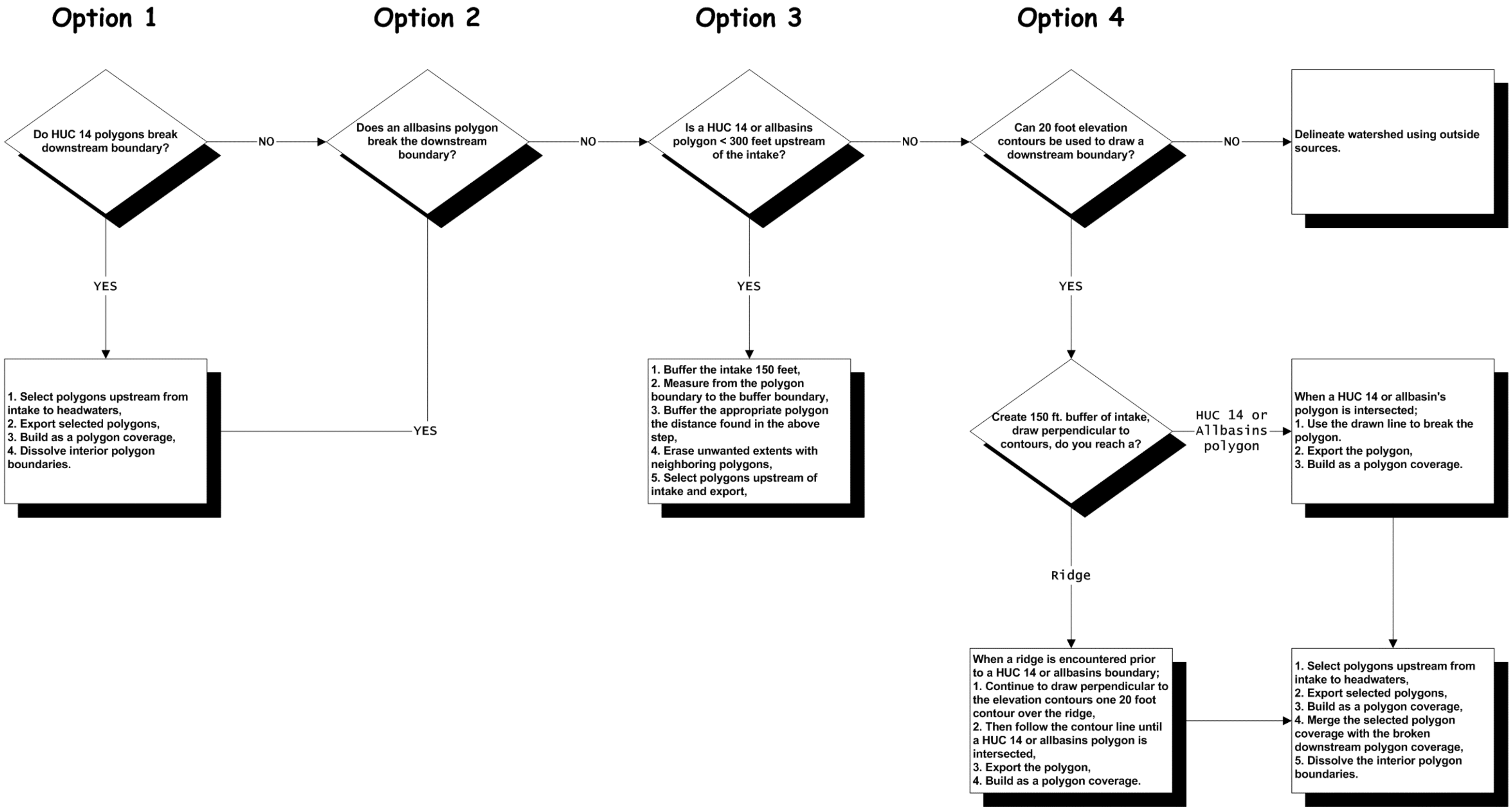
The source water assessment area contains the entire drainage area that flows past the intake, including all tributaries to their headwaters. The delineation methodology is as follows:

Base data used:

a. NJDEP HUC 14 polygon coverage,
b. USGS allbasins coverage (sub HUC 14 watersheds),
c. NJDEP streams coverage,
d. NJDEP lakes coverage,
e. WMSA reservoirs coverage,
f. BSDW surface water intakes coverage.

The Hydrologic Unit Code (HUC) 14s polygon coverage was used as the base coverage for defining the upstream source water area. The simplest method is to use GIS tools to reselect the upstream HUC14s until the headwaters are reached. The HUC14 coverage was not created with Source Water Assessment in mind therefore many situations occurred where an intake is not located at the drainage point for the HUC14. The following flowchart and discussion shows how these and other unique situations were handled.

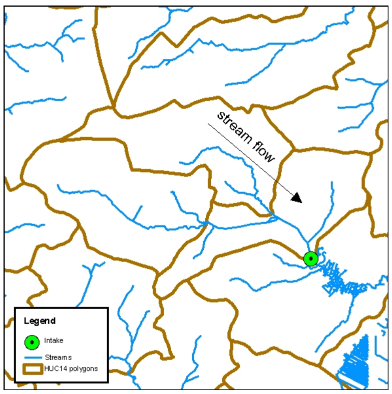
Surface Water Delineation Flowchart

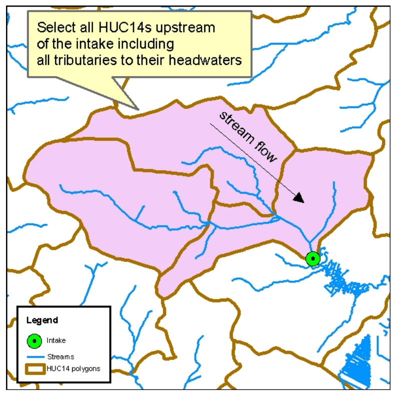


Delineation Options

Option 1

1. Locate the intake of interest and identify stream flow,
2. Select the HUC 14 polygons which define the drainage area upstream of the intake to the headwaters,
3. Export the selected polygons to a shapefile,
4. Create and build a polygon coverage from the shapefile, and
5. Dissolve the inner HUC boundaries.

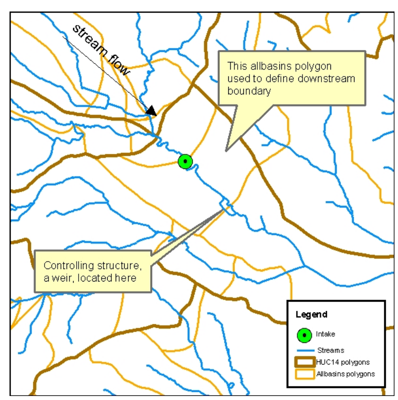




Option 2

Many times the HUC 14 boundary does not coincide with the intake (the intake may be located in the middle of the HUC 14). When this occurs, the allbasins polygon coverage is loaded. If this data-set contains a pre-defined sub-HUC 14 polygon which allows the user to determine the downstream boundary the following procedures were followed:

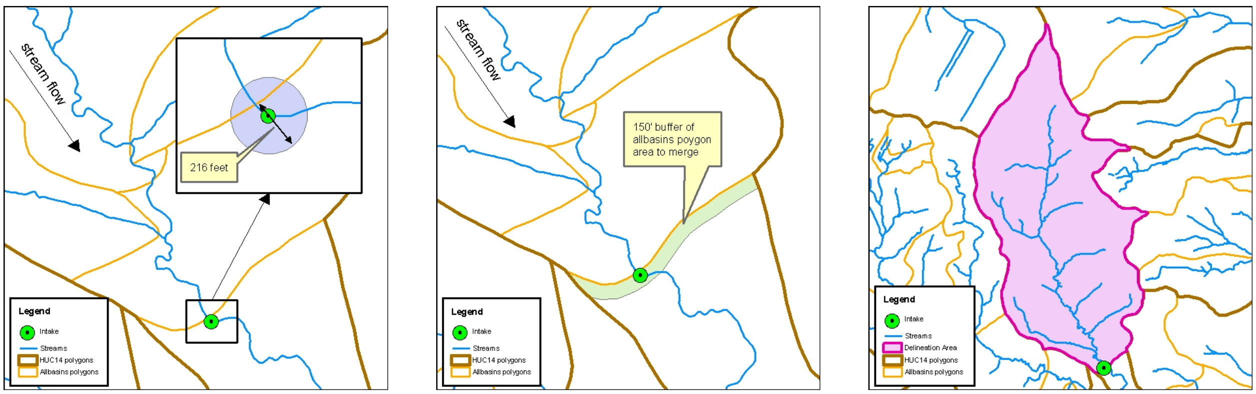
1. Locate the intake of interest and identify stream flow,
2. When possible use the allbasins polygon coverage to define the downstream boundary. Select the HUC 14 polygons which define the drainage area upstream of the intake to the headwaters, while omitting the polygon which needs to be broken.
3. Export the selected polygons to a shapefile,
4. Create and build a polygon coverage from the shapefile,
5. Dissolve the inner HUC boundaries,
6. Select the polygon from the allbasins polygon coverage which defines the downstream boundary of the drainage basin,
7. Export the selected polygons to a shapefile,
8. Create and build a polygon coverage from the shapefile, and
9. Dissolve the inner HUC boundaries, merge the coverages to create the final delineation polygon coverage.



Option 3

If the intake is 0-300 feet downstream of a HUC 14 polygon or an allbasins polygon, then the following the procedures were used:

1. Locate the intake of interest and identify stream flow,
2. Create a 150 foot buffer for the intake,
3. Use the measuring tool, ascertain the distance from the polygon to the downstream boundary of the buffer intake,
4. Buffer the polygon using the distance found in the preceding step,
5. Use the neighboring polygons to erase the unwanted portions of the polygon buffer, (upstream and lateral polygons), and
6. Merge the erased, buffered polygon to the selected upstream HUC 14 polygons as described earlier.

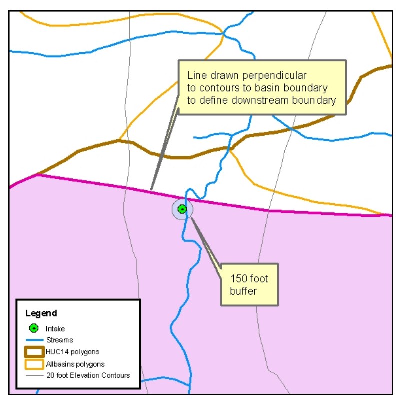


Option 4

If the intake location is greater than 300 feet downstream of the HUC 14 polygon or allbasins polygon, a downstream boundary needed to be created. The technician used the 150 foot intake buffer as a break off point, and drew a downstream boundary perpendicular to existing 20 foot elevation contours using the following procedures:

A) When a HUC 14 or allbasins polygon is reached prior to a ridge or stream,

1. Locate the intake of interest and identify stream flow,
2. Create a 150 foot buffer for the intake,
3. Draw a line perpendicular to the contour elevations from the downstream boundary of the 150 foot buffer, until a HUC 14 or allbasins boundary is met,
4. Use the drawn line to break the dowstream polygon,
5. Select the appropriate upstream polygons as described earlier, export, and
6. Merge the selected polygons with the downstream polygon, create a coverage and dissolve the interior boundaries.



B) If a ridge is reached prior to a HUC 14 or allbasins polygon,

1. Draw a line perpendicular to the contour elevations from the downstream boundary of the 150 foot buffer, continue past the ridge to the first 20 foot contour line past the ridge,
2. Follow the contour line upstream until a HUC 14 or allbasins polygon is intersected, use the drawn line to break the downstream polygon,
3. Select the appropriate upstream polygons as described earlier, export, and
4. Merge the selected polygons with the downstream polygon, create a coverage and dissolve the interior boundaries.

Delaware River Intakes

The sheer size of the Delaware River drainage basin combined with large portions in the neighboring states of New York and Pennsylvania, compelled SWAP to break the basin into a more manageable size for the susceptibility models. It was felt any density type variables would be skewed with such a large area. There also existed an uncertainty as to what data might be available and the compatibility of that data from the surrounding states. For these reasons SWAP investigated ways to attain more meaningful results. SWAP reviewed many states' Source Water Assessment Plans including California, Georgia, North Carolina, Ohio, and Philadelphia Water Department. All of the plans broke the delineations of large watersheds into more manageable zones either defined by "time of travel" or "fixed distance." The SWAP was especially interested in Philadelphia Water Department's plan since New Jersey shares the Delaware River as a surface water source. Philadelphia Water Department's plan contains three zones based on time of travel:

Zone A – 5 hour time of travel with a one quarter mile buffer, which receives a detailed inventory,
Zone B – 25 hour time of travel with a 2 mile buffer, which receives a less detailed inventory,
Zone C – The remainder of the watershed, with no inventory.

NJ SWAP decided for intakes whose source is the Delaware River, the entire drainage area will be considered the Source Water Area. For the susceptibility modeling a 25 Hour Time of Travel zone would be utilized. This zone includes all HUC boundaries to the headwaters for any tributaries which drain to the main stem of the Delaware River in the 25 Hour Zone.

In order to identify the 25-Hour Time of Travel zone SWAP utilized the U.S. Geological Survey Open-File Report 99-248, "Source-Area Characteristics of Large Public Surface-Water Supplies in the Conterminous United States: An Information Resource for Source-Water Assessment," USGS and EPA, 1999. The report contains digital data-sets based on the Environmental Protection Agency's River Reach File 1 (1996) with time of travel information for large Public Water Systems in the United States. Two intakes from New Jersey and on the Delaware River can be found in the report, the New Jersey American-Delran intake, and the Trenton Water Department intake.

New Jersey American-Delran Intake & Trenton Water Department Intake

For the New Jersey American-Delran intake and the Trenton Water Department intake delineation of the Source Water Susceptibility Area was completed by the following method:

1. The appropriate data-set was obtained from the report compact disc,
2. The data-set was projected into NJ State Plane, US survey Feet, NAD83.,
3. Stream reaches were reselected based on the CTOT attribute field which contains cumulative time of travel data to the intake in days (CTOT <= 1.041667, one day plus one hour or .041667 days),
4. The base data-set for the Delaware River intakes is the Hydrologic Unit Code (HUC) 11 from the Delaware River Basin Commission,
5. Pennsylvania stream digital data-sets were also obtained from the Delaware River Basin Commission,
6. All HUC11s which intersect and are upstream of the RF1 stream reaches were selected, also all HUC11s for any tributaries to the mainstream of the Delaware River were selected to their headwaters,
7. Downstream boundaries were determined as described earlier, except the downstream portion of the stream reach was used instead of the intake to account for any tidal concerns built into the time of travel data. If the downstream portion of the stream reach did not coincide with a downstream HUC11 boundary the process described earlier was used to define the downstream boundary of the source water area. There were some modifications to this process however:
    - on the New Jersey side of the Delaware River the HUC14s were used first, then the allbasins coverage, then digital USGS topographic quadrangles were used for elevation information and the process described in the flowchart earlier was followed. The USGS topographic quadrangles were used to remain consistent with the Pennsylvania side of the Delaware River where elevation contours were not available.

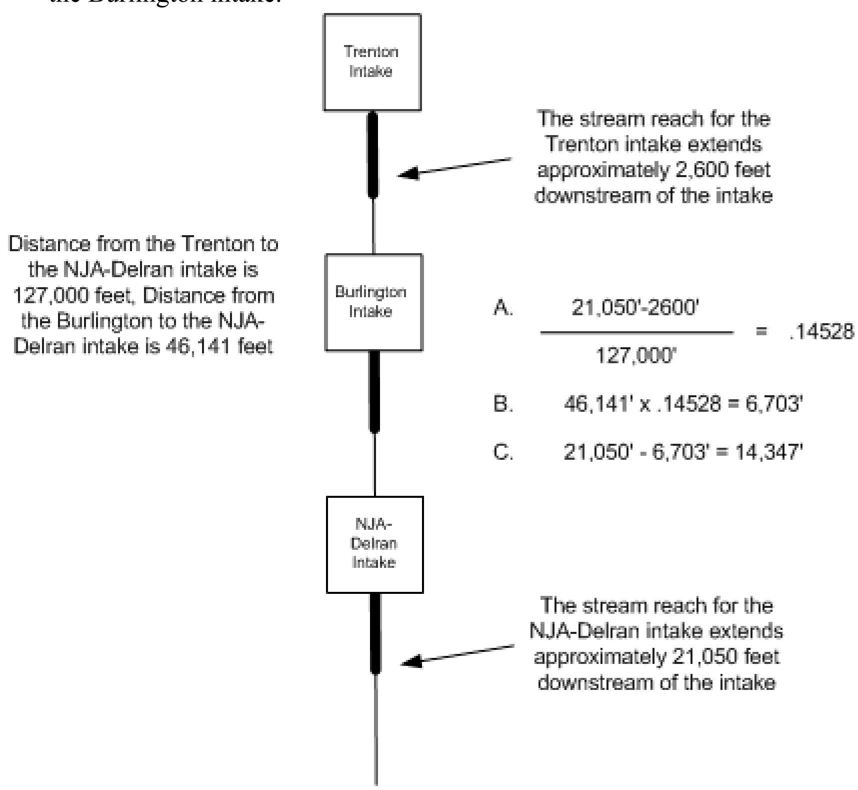
- on the Pennsylvania side of the Delaware River the USGS topographic quadrangles were used to determine elevation and create the downstream boundary.

8. The selected areas were exported, merged, and interior boundaries dissolved.

Burlington City Water Department Intake

The Burlington City intake did not have specific reach data in the USGS open file report, so the river reach was modified as follows:

1. The New Jersey American-Delran intake is downstream of the Burlington City intake, therefore the river reach data for the NJA-Delran intake was exported and used.
2. To find the distance of tidal influence for the Burlington intake:
   A. The downstream distance of the NJA-Delran intake is subtracted from the downstream distance of the Trenton intake and then divided by the distance from the NJA-Delran and the Trenton intakes.
   B. This rate of change is then applied to the distance between the NJA-Delran and the Burlington intakes.
   C. The change in tidal influence is then subtracted from the distance between the NJA-Delran and the Burlington intake producing the length downstream of tidal influence for the Burlington intake.



3. Once the river reach starting point is found the time of travel in days is recalculated to attain the ending point of the river reach segment.
4. The rest of the process is the same as done for the New Jersey American-Delran and Trenton intakes.

Hoffman Laroche & BASF Intakes

These intakes are located upstream of the Trenton Water Department intake and are delineated using the same process described earlier for the Burlington City Water Department intake except the starting point for the stream reach was where the intake was located, since no tidal influence was present.

Delaware and Raritan Canal Intakes

The Source Water Area for the D&R Canal was delineated as follows:

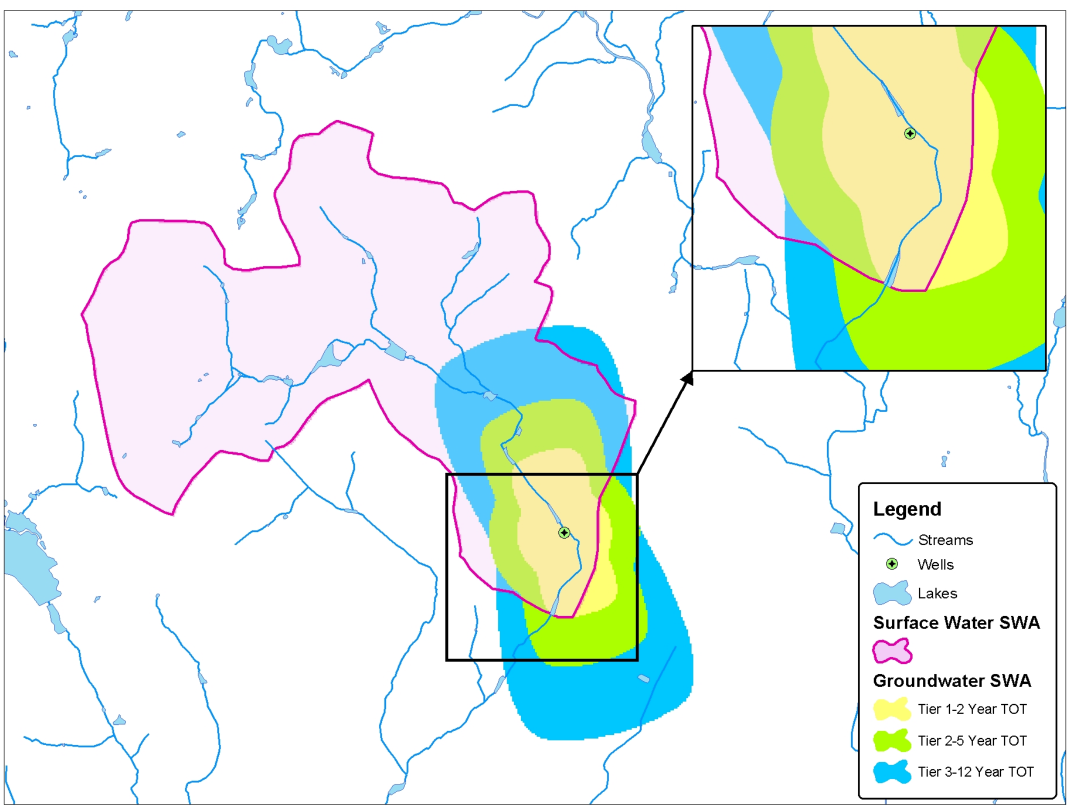
1. Influent drainage basins were identified and mapped for the following report, "Water Quality of the Delaware And Raritan Canal, New Jersey, 1998-99 / Water-Resources Investigations Report 01-4072," by Jacob Gibs, Bonnie Gray, Donald E. Rice, Steven Tessler, and Thomas H. Barringer of the USGS in cooperation with the New Jersey Water Supply Authority 2001.
2. The above mentioned report also found the time of travel for the canal is 8-10 days, so the length of the canal was used rather than including any drainage area from the Delaware River,
3. The downstream boundary was delineated at each intake,
4. SWAP added a 300 foot buffer on both sides of the canal to account for any local runoff, and
5. The influent drainage basins were merged to the buffer area and the interior boundaries dissolved.

Groundwater Under the Direct Influence of Surface Water (GUDI)

The GUDI wells have a conjunctive delineation with both a surface water and groundwater delineation. The groundwater delineations were completed by the New Jersey Geological Society. The surface water component was delineated by the earlier described methods with a few modifications discussed below.

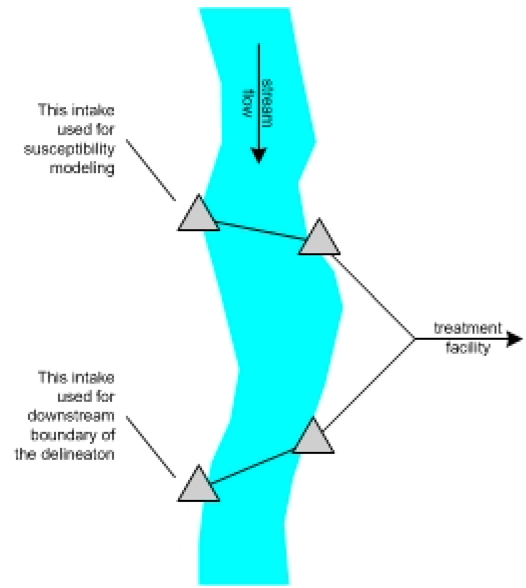
- The downstream boundary was determined by where the 2 year time of travel groundwater zone intersects the stream. If the influencing surface water body was a lake or reservoir the controlling structure was delineated as the downstream boundary.
- If there was not a defined influencing surface water body or the GUDI well was located on a watershed divide the 12 year time of travel groundwater zone was used as the surface water source water area.

Example GUDI Delineation



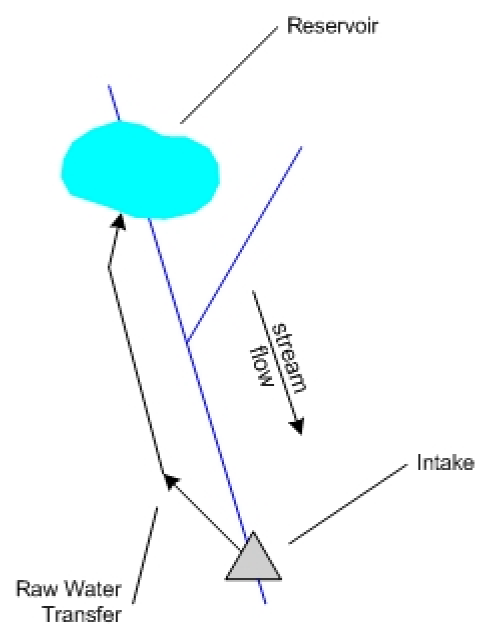
Elizabethtown Water Company Intakes

Elizabethtown Water Company operates 4 intakes on the Raritan River in close proximity to each other. The intakes also merge and supply surface water to the same treatment facility. The furthest downstream intake defined the downstream boundary for the single surface water source water area delineation created for the four intakes. The intake furthest upstream was chosen to be used as the intake point for susceptibility modeling. This point would be the first to be impacted by any potential contaminants in the Raritan River.



New Jersey Water Supply Authority-Manasquan System Intakes

There are two intakes used by this water system: one on the Manasquan River and one on the Manasquan Reservoir. The reservoir is upstream of the river intake. Water draining from the reservoir flows naturally overland past the river intake. In addition the river intake pumps raw water back to the reservoir. With the movement of raw water from the river intake to the reservoir any potential contaminants which impact the river intake will also impact the reservoir. Since the reservoir is upstream and in the same watershed as the river intake, one source water area was created for the river intake. This source water area was used for the susceptibility models for both intakes.



New Jersey American Water Company-Glendola Reservoir Intakes

The Glendola Reservoir receives minimal overland runoff as recharge. The reservoir receives most its water from raw water transfers from the New Jersey American Shark River intake and the New Jersey Water Supply Authority Manasquan System (NJWSA can transfer raw water from either the Manasquan River or the Manasquan Reservoir intakes). The Glendola Reservoir was delineated as if it has two sources of water. The Shark River and Manasquan System are reported as surface water sources for New Jersey American Water Company-Monmouth along with their susceptibility rankings.

North Jersey District Water Supply Commission Intakes

Multiple reservoirs and raw water transfers are the Commission's sources of surface water. All of the components are in the same watershed and eventually drain to the Wanaque South pump station. This pump station transfers raw water to the Wanaque Reservoir (NJDWSC's main source of water) which drains naturally to the pump station. The same procedure as in the Manasquan System was used, where the furthest downstream component was delineated. The susceptibility ratings for that point/delineation were then applied to the other components of the water system. Unique to the Wanaque South pump station however is the ability of the station to draw water upstream from the Passaic River at times of low-flow. This situation is not the norm, therefore the Passaic River is treated as a separate surface water source. The Passaic River received a separate delineation with the confluence of the Pompton and Passaic Rivers as the downstream boundary.

USGS Sampling Stations

In order to develop the surface water models, DEP and USGS delineated the area supplying water to USGS sample sites, a standard GIS hydrologic watershed analysis. Watershed analyses determine the elevation based boundary line that controls the direction of flow of a raindrop falling on the land surface. These boundaries are called drainage divides. The general process is described below, with the technical terms in parentheses.

A very regular grid of elevation data, called a DEM (digital elevation model), was used. Processed DEM's break up an area into many thousands of small square grid cells (raster grid). Every one of the thousands of cells contains a unique elevation value. Following some initial data preparation (filling grid), the elevation in a target cell was compared to the elevation of all of its "neighbor" cells, then the steepest slope is calculated. The aspect (<u>cardinal direction</u> of slope, or flow direction) was also calculated by comparing the elevation of each cell to its neighbors. This entire process was repeated for each and every cell in the entire grid. Once slope and flow direction are known, it becomes possible to determine which cell, from among its neighbors, a given cell must flow into. This was determined for each and every cell in the grid. Next, the number of cells flowing into each individual cell was summed. Because it is a cumulative sum, some cells "accumulate" many cells from distant "upgradient" areas. Cells with the very highest "accumulation values" become the streams and mouths of watersheds. At this point, cells that flow into any single cell, such as the cell location containing a sample site (or pour point) can be identified. Fundamentally, water flows downhill, so using the elevation data we are able to model the area that flows to a given point, and the area that flows elsewhere.