Horsley & Witten, Inc.
Environmental Services

WELLHEAD PROTECTION AREA DELINEATION

Final Report

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WELLHEAD PROTECTION AREA DELINEATION
WOODSTOCK, NEW YORK

INTRODUCTION

Horsley & Witten, Inc. (H&W) has been retained by the Woodstock Environmental Commission to conduct a wellhead protection program for seven existing public supply wells in the Town of Woodstock, New York. This project began with the initial delineation of the aquifer and wellhead protection areas to the wells. The second phase of the project was the confirmation and adjustment of the initial delineation with the installation of test borings and monitoring wells and the undertaking of an aquifer pump test. The remaining work involved the identification of potential contamination sources within the wellhead protection area, and a recommendation of management strategies for the protection of the water quality within this area.

Wellhead protection areas were delineated using the US Environmental Protection Agency's WHPA model version 2.1. Protection areas were mapped according to New York Department of Environmental Conservation requirements.

Physical Setting

The Town of Woodstock obtains its water from seven municipal wells. Two of the wells are located on the north side of the Saw Kill and just east of Dixon Ave. These wells connect to Pump House No. 1. The remaining five wells are located south of Route 212, on the north side of the Saw Kill at the bend in the river.

A review of available literature concerning the aquifer from which water for the Town is pumped was undertaken by H&W. The water supplying this unconsolidated aquifer comes from recharge due to rainfall and from induced infiltration from the Saw Kill, which runs west and south of the town and the public supply wells (Figure 1). Since the Saw Kill is located within 300 yards of the public supply wells, the amount of induced infiltration derived from the Saw Kill is quite high.

HYDROGEOLOGY

Geology

The Town of Woodstock draws water from unconsolidated, stratified sand and gravel, glacial deposits. These deposits were formed during the

Pleistocene Epoch, approximately 20,000 years ago, when a south moving continental ice sheet containing rock fragments and soil began to melt. As the ice receded from the area, the ice-entrained rock and soil fragments were washed out by melt water and deposited as layers of either sands and gravels or silts and clays in valleys throughout Ulster County (Frimpter, 1972).

The glacial outwash deposits in the vicinity of the Town wells range from a few feet to, perhaps, as much as 50 feet thick (Frimpter, 1985). The approximate aerial extent of this water-saturated aquifer is mapped at a scale of 1:48,000 (Frimpter, 1972). Nearly horizontal layers of sedimentary red shale and blue-gray sandstone are underlain by crystalline bedrock of Devonian Age. Borings made by H&W, Inc. to approximately the same depth as the town wells (fifteen to twenty-five feet below land surface) confirm that the town wells are screened in sand and gravel units with cobbles and small boulders located within the units (Appendix A). A reddish clay layer was encountered in all H&W borings at a depth of approximately fifteen feet below land surface.

H&W began installing monitoring wells at 7:30 A.M. on January 11 and all drilling was completed by 7:00 P.M. of that evening. A total of five monitoring wells were installed in the vicinity of the Town well fields. One well was placed at the edge of the soccer field adjacent to Pump House No. 1. A second well was placed near Pump House No. 2. The three remaining wells were placed along Route 212, with one at the intersection of Route 212 and Spear Road, one next to a fire hydrant near the intersection of Route 212 and Dixon Ave., and one on the east side of Overlook Drive near the intersection of Route 212.

The five wells extend to depths from 15 feet to 25 feet and are screened approximately 7 feet below the water table. All wells are constructed with a 10-foot, 2 inch PVC .010 slot screen and 2 inch PVC threaded riser. These wells are capped flush with ground level and are protected with padlocked well caps and 6-inch road boxes. A gravel pack was placed around the screen with a bentonite clay seal above the gravel pack. The road boxes were cemented in place for added protection.

Water Table Map

The monitoring wells were surveyed relative to mean sea level using a level transit. Water levels were then recorded (Table 1) and a water table map of the area was created (Figure 1). With the creation of the water table map, a

Table 1: Water Level Data from Monitoring Wells

WELL I.D.	ELEVATION (FT)	DEPTH TO WATER (FT)	CHALK (FT)	WATER LEVEL (FT)	MEASURING POINT
HW-1	782.14	N/A	N/A	N/A	Top of Casing
HW-2	657.51	14.6	0.64	643.55	Top of Casing
HW-3	662.84	14.5	0.55	648.89	Top of Casing
HW-4	685.76	14.5	0.52	671.78	Top of Casing
HW-5	655.93	10.0	0.33	646.26	Top of Casing

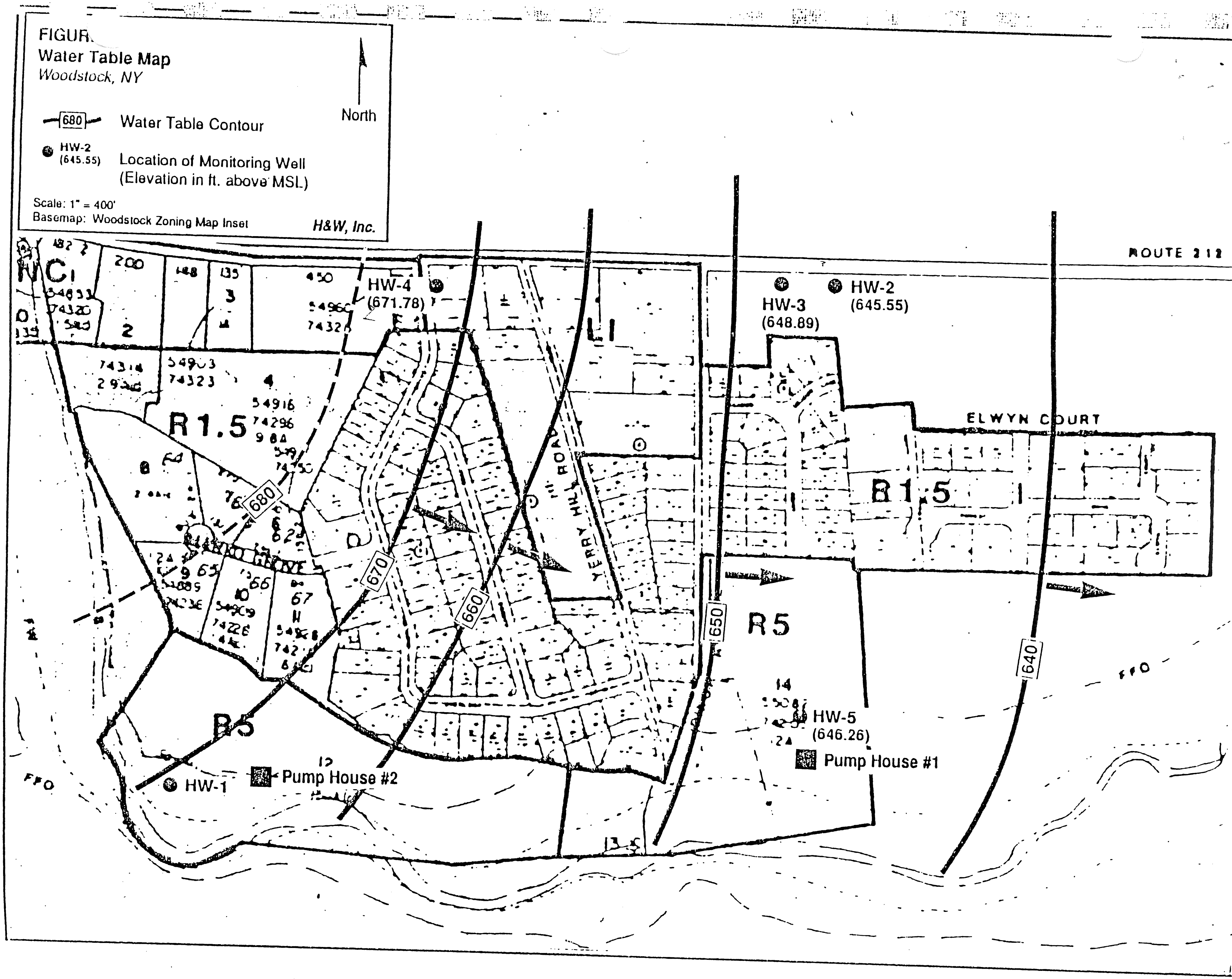
hydraulic gradient was calculated. Water levels vary from 670 feet above Mean Sea Level (MSL) at the bend in the stream west of the town wells, to 640 feet elevation east of the town wells. This change occurs over a distance of 1,579 feet, resulting in a hydraulic gradient of 0.019. The water table map shows that water flows southeasterly and easterly down the valley.

AQUIFER PUMP TESTS

A series of aquifer pump tests were conducted on 9 March 1994 to determine the hydraulic conductivity, or permeability, of the aquifer. Because the water supply for the Town is derived from seven pumping wells, with wells about 200 feet apart, and also because the water system is configured so that the wells can only be pumped in groups of 2 and 5 wells at a time, pump tests of the water supply wells for determining of aquifer properties was not feasible. With multiple wells pumping, interference of drawdown would occur among the wells, making it difficult to apply standard non-equilibrium analytical equations to calculate hydraulic conductivity. Therefore, H&W conducted single well pump tests on the H&W monitoring wells to determine hydraulic conductivity of the aquifer.

Single well pump tests were conducted on wells HW-2, HW-3, HW-4 and HW-5 (Figure 1). No test was performed on well HW-1 because of ice in the well at the time of the test. Some of the ice was chipped away so that a water level measurement could be taken, but not enough ice could be removed to allow for the pump test. A second attempt was made to test this well on 6 April 1994, but it was still frozen.

The wells were pumped at between 1 and 3 gallons per minute (gpm), and were pumped until the water level in the well reached equilibrium. Once the pump test was complete, the hydraulic conductivity was calculated by using the equation for a single well pump test developed by Hvorslev (1951) and shown below.


FIGUR
Water Table Map
Woodstock, NY
680
Water Table Contour
HW-2
(645.55)
Location of Monitoring Well
(Elevation in ft. above MSL)
North
Scale: 1" = 400'
Basemap: Woodstock Zoning Map Inset
H&W, Inc.
ROUTE 212
ELWYN COURT
YERRY HILL ROAD
HW-4
(671.78)
HW-3
(648.89)
HW-2
(645.55)
HW-5
(646.26)
HW-1
Pump House #1
Pump House #2
R1.5
R1.5
R5
R5
LI
680
670
660
650
640
FFO
FFO

$$K = \frac{Q}{2\Pi L \Delta H} * \ln\left[\frac{L}{D} + \sqrt{1 + \left(\frac{L}{D}\right)^2}\right]$$

where:

K is hydraulic conductivity (ft/day)

Q is pumping rate (cu.ft./day)

D is diameter of the well screen (ft)

L is length of screen in water table at the end of pumping (ft)

Π is a constant (3.14)

ΔH is the change in water level (ft) at equilibrium

The hydraulic conductivity for monitoring wells 2, 4, and 5 was 8.4 ft/day, 8.15 ft/day and 20.19 ft/day respectively. An average value of 12 ft/day was used for all model calculations. No K value was determined for well HW-3 because the well was pumped dry despite using the lowest setting on the pump (1 gpm).

Temperature Data

Estimates of the amounts of ground water and stream water withdrawn by the production wells were made based on temperature measurements. Typical ground water temperature in the Town of Woodstock is 10°C (Todd, 1980). During the months of February and March, 1994, when temperature readings were taken by H&W, the Saw Kill was partly frozen and had a temperature of approximately 1°C. The average water temperatures recorded for the town wells were 8.5°C for Pump House No. 1, and 3°C for Pump House No. 2. With this information, H&W calculated that 83 percent of the water withdrawn at Pump House No. 1 was in the form of ground water, with the remaining 17 percent being derived from the Saw Kill. Pump House No. 2 withdrew 22 percent of its water from ground water, with 78 percent induced from the Saw Kill.

47.3° F 37.4° F

WHPA MODELING

Purpose

The purpose of the modeling was to delineate the wellhead protection areas for the seven wells contributing drinking water to the Town of Woodstock. The model chosen to delineate the well head protection area was the U.S. EPA Wellhead Protection Delineation Model Version 2.1 (WHPA Model). Using image well theory, the RESSQC component of the model simulated the transmissivity, hydraulic conductivity, gradient and pumping rates from the town.

Data Collection

The hydrogeologic data collected to create the numerical model for the Public Supply Well (PSW) included geologic borings (Appendix A), water table mapping (Figure 1), surficial geologic maps and the pump tests. Estimates of the quantity of water induced from the Saw Kill were also calculated based on water temperature data collected by Mr. Malcolm Carnright.

Model Description

Computer modeling was accomplished using the RESSQC component of EPA's WHPA Model so that image well theory could be used. Image well theory is used for aquifers which are bounded on one or more sides by either impermeable boundaries or recharge boundaries such as streams. Since the Woodstock Town wells are bounded to the west and the south by the Saw Kill, the use of image wells (to accurately model the interaction between the wells and the stream) was required.

An 8,000 ft. by 8,000 ft grid was established so that locations of the pumping wells and the image wells could be input into the computer. The two wells located at Pump House No. 1 were combined and modeled as one well, while the five wells at Pump House No. 2 were combined and modeled as two pumping centers. Nine additional imaginary, or image wells, were also established. Three were located on the southern side of the Saw Kill, three on the western side of the stream, and three southwest of the actual pumping wells. The image wells are located the same distance from the stream as the actual pumping wells, and are used to represent interactions between the stream and the ground water.

Assignment of Model Parameters

The WHPA Model was run for 1-year time of travel as well as for steady state conditions. Model inputs include transmissivity, hydraulic gradient, aquifer thickness, discharge rate of the wells, aquifer porosity, and ground water flow direction. Based on boring logs created by H&W, and logs of the seven town wells an aquifer thickness of 20 feet was calculated. A transmissivity of 240 sq. ft/day was calculated by multiplying the hydraulic conductivity (calculated above to be 12 ft/day) by the aquifer thickness. The hydraulic gradient of 0.019, calculated above, and the ground water flow direction, were determined from the water table in Figure 1. An average aquifer porosity of 0.30 was used since it represents a typical value for the type of aquifer material which was encountered during drilling (Todd, 1980).

Model Results and Delineation of the Wellhead Protection Area

The wellhead protection areas were delineated according to the New York DEC regulations with a 200 foot Remedial Action Area, a 1-year time of travel zone, and the complete capture zone under steady state conditions (Figure 2). The delineation under steady state conditions is bordered to the west and south by the Saw Kill, to the north by the mapped extent of the aquifer, and extends to the east almost to Spear Road.

As can be seen in Figure 2, the 1-year time of travel zone for Pump House No. 2 is much smaller than that of Pump House No. 1. This indicates that a greater percentage of stream water is being pumped from Pump House No. 2 than from Pump House No. 1.

The surface runoff watershed which drains into the Wellhead Protection Area was mapped on the basis of topography, and is composed of three sections: the watershed to the entire aquifer, the watershed to the Saw Kill which contributes water to the WHPA, and the watershed to the WHPA itself (Figure 3).

CONTAMINATION ASSESSMENT

Contaminant Source Identification

Once the wellhead protection area had been delineated, an analysis of past, existing, and future potential land uses was conducted in order to formulate an effective protection strategy. A potential threat to ground water quality is elevated nitrate-nitrogen levels, caused primarily by private septic systems. Other potential threats include several small businesses which utilize hazardous materials and may generate hazardous waste, including such varied uses as automotive repair, manufacturing, and agricultural operations. Accidental or inappropriate disposal of hazardous wastes, even in small quantities, may result in ground water contamination exceeding state and federal drinking water standards. For example, many of the drinking water standards for volatile organic compounds are in the low parts-per-billion range. An extensive list of business categories and the hazardous materials associated with them is included here as Table 2. The table is organized in conformance with the Standard Industrial Code (SIC) published by the United States Department of Commerce. This data, along with information regarding hazardous materials handling practices, can be utilized to evaluate the relative risks associated with various commercial/industrial land uses.

H&W ran two nitrogen loading simulations to examine more carefully the potential risk of elevated nitrate-nitrogen levels to Woodstock's water supply(Appendix B). The first simulation was accomplished by identifying

Table 2

COMMERCIAL/INDUSTRIAL LAND USES - HAZARDOUS WASTE GENERATION

Business Category (SIC)*	Hazardous Materials/Wastes/Disposal Practices (if known) Potential Large-Scale Generators
Communications Equipment sludges, Manufacturer (366)	Nitric, hydrochloric, and sulfuric acid wastes, heavy metal copper-contaminated etchant (e.g. ammonium persulfate), cutting oil and degreasing solvent (trichloroethane, Freon, or trichloroethylene), waste oils, corrosive soldering flux, paint sludge, waste plating solution
Electric and Electronic Equipment Manufacturer. (especially circuit boards) (367)	Cyanides, metal sludges, caustics (chromic acid), solvents, oils, alkalis, acids, paints, calcium flouride sludges, methylene chloride, perchloroethylene, trichloroethane, acetone, methanol, toluene, PCBs, paint sludge
Fabricated Metal Products (344)	Paint wastes, acids, heavy metals, metal sludges, plating wastes, oils, solvents, explosive wastes
Machinery (354) = metalworking & machinery (359) = miscellaneous machinery electrical)	(354) - oils, solvents (359) - metals, miscellaneous organics, sludges, oily metal (except shavings Tool & die shops: lubricant & cutting oils, degreasers (TCE), metal marking fluids ("blueing"), mold release agents Oils and solvents may be reclaimed in shop or sold to recyclers, scrap metal sold to dealer
Plastic Materials and Synthetics (282) = plastic materials & synthetics (2821) = plastics, synthetic resins, and nonvulcanized elastomers	(282) - solvents, oils, miscellaneous organics (phenols, resins), paint wastes, inorganics, cyanides, acids, alkalis, wastewater treatment sludges (2821) - organic liquid wastes containing acids and alkalis, cellulose esters, surfactants, glycols, phenols, formaldehyde, peroxides, etc. May be treated on-site or hauled to a hazardous waste facility
Primary Metal Industries (3312) = blast furnaces, steelworks, rolling mills	Heavy metal wastewater treatment sludge, pickling liquor, waste oil, ammonia scrubber liquor, acid tar sludge, alkaline cleaners, degreasing solvents, slag, metal dust
Trucking Terminals or Fleet Vehicles	Fuel tanks, repair shop wastes (chemical substances may be (4231) hauled

NOTE: Up to four digits are used in the SIC codes; codes that contain only two or three digits represent less specific categories and, therefore, should be treated with more caution.

SOURCE: Wellhead Protection Tools for Local Government by Horsley & Witten, Inc. and U.S. Environmental Protection Agency, 1989.

Business Category (SIC)*	Hazardous Materials/Wastes/Disposal Practices (if known) Potential Moderate-Scale Generators
Printing, Publishing, & Allied Industries (27, 731)	Solvents, inks, dyes, oils, miscellaneous organics, photographic chemicals (note that solvents with ink in them may be collected by solvent recovery firms; ink contains heavy metals and may be returned to ink supplier for recovery and reuse; silver in photographic chemicals is recoverable)
Public Utilities (phone, electric power, gas) (481, 491, 492)	PCBs from transformers and capacitors, oils, solvents, sludges, acid solution, metal plating solutions (chromium, nickel, cadmium)
Sawmills and Planing (2421)	Treated wood residue and containers (use copper quinolate, mercury, sodium bazide to control stains and fungus) (use tanner gas to prevent lines from freezing. Paint sludges, solvents, creosote, coating and glueing wastes
Stone, Clay, & Glass Products (32)	Solvents, oils and grease, alkalis, acetic wastes, asbestos, heavy metal sludges, phenolic solids or sludges, metal-finishing sludge
Agriculture (01)	Pesticides (containers and residues), gasoline, motor oil, welding equipment, etc. for farm machinery
Auto Repair (7538)	Waste oils, solvents, acids, paint, waste hydraulic fluids, miscellaneous cutting oils
Local & Interurban Passenger Transit (41)	Waste oil, solvents, miscellaneous wastes, gasoline storage
Gasoline Service Stations (554)	Oils, solvents, miscellaneous wastes (ask if they take back used motor oil and what is done with it)
New and Used Car Dealers (especially those with service departments)	Waste oils, solvents, miscellaneous wastes
Welders (7692)	Oxygen/acetylene tanks
Dry-Cleaning (7216)	Solvents: perchloroethylene, petroleum solvents, Freon-1,1,3 - used in machines in large quantities, distilled solvent, reused spotting chemicals: trichloroethane, methylchloroform, ammonia, peroxides, hydrochloric acid, rust removers, amyl acetate (Residues from distillation put in garbage)
Landfills, Dumps, & Junkyards	Small quantities of chemical wastes, oils, etc. (ask whether the operation has a policy on hazardous wastes if collected by mistake)
Other (Because of information found in inventory)	

Business Category (SIC)*	Hazardous Materials/Wastes/Disposal Practices (if known) Potential Small-Scale Generators
Special Construction Trades (1711) = plumbing, heating, air conditioning (1721) = painting, paper hanging, decorating (1742) = plastering, drywall, acoustical insulation (1751) = carpentry (1752) = flooring (1761) = roofing and sheet metal (1795) = wrecking and demolition (1799) = other special construction trades	(1711) - solvents, asbestos, miscellaneous (empty containers, etc.) (1721) - paints, solvents, glues, miscellaneous 1742) - solvents, adhesives, miscellaneous (waste insulation) (1751) - solvents, lacquers (1752) - paint, glues, miscellaneous (1761) - tars, sealants, miscellaneous (1795) - asbestos, miscellaneous chemicals, miscellaneous (1799) - epoxy waste, solvents, asbestos, miscellaneous
Swimming Pool Cleaning & Maintenance (7399)	Free and combined chlorine, bromine, iodine, algicides (mercury-based, copper-based, or quaternary), cyanuric acid, calcium or sodium hypochlorite, muriatic acid, sodium carbonate
Miscellaneous Repair Service	Solvents, acids, alkalis, paint sludges, metals, organics, miscellaneous chemicals
Medical Facilities (8071)	X-ray developers and fixers (fixers and x-ray film contain reclaimable silver. Developer contains glutaldehyde, hydroquinone, phenedone, potassium bromide, sodium sulfite, sodium carbonate. Fixer has thiosulfates and potassium allum. Infectious wastes, radiological wastes, biological wastes, miscellaneous chemicals, disinfectants, asbestos, beryllium, acids (from dentists)
Veterinary Services	Solvents, infectious materials, vaccines, drugs, disinfectants (0742) (quaternary ammonia, hexachlorophene, peroxides, chlorhexadene chlorox) X-ray developers and fixers (fixers and x-ray film contain reclaimable silver)
Schools (821)	Solvent, chemicals, pesticides, acids, alkalis, waste oils
Furniture & Fixtures (Manufacture & Repair) (2512, 7641)	Paints, sludges, solvents, empty containers, degreasing sludges, solvent recovery sludges
Funeral Services and Crematories (7261)	Formaldehyde is the main preservative used. Also use wetting agents, fumegants, solvents
Government Offices (919)	Machinery/vehicle servicing, gasoline or heating oil tanks
Home Heating Oil (5183)	Underground storage tanks, truck maintenance garage
Photo Processing Laboratory (7333, 7395)	Biosludges, silver sludges, cyanides, miscellaneous sludges

Business Category (SIC)*	Hazardous Materials/Wastes/Disposal Practices (if known) Potential Minor Generators
Apartment and Condominium (6513)	Swimming pool cleaning and maintenance chemicals, landscaping chemicals such as pesticides and fertilizers, on-site sewage treatment plant (hazardous household wastes)
Pharmacies (591)	Spilled and returned products
Hardware Stores (525) & Carpet (5713)	Hazardous chemical products in hardware and parts stores' Stores inventories. Carpet stores use glues and similar adhesives that are hazardous products returned to stores by customers. If forklift is used at lumber, hardware, or carpet store, there may be fuel tank or repair shop. Wood products, if stained or treated on-site, require hazardous chemicals (such as creosote)
Construction Materials (521)	Asbestos
Car Washes (7542)	Miscellaneous chemicals: soap, detergents, waxes
Beauty Shops (723) and Barber Shops (724)	Miscellaneous chemicals in rinses, perm solutions, dyes
Sports Shops (5941) and Hobby Shops (5945)	Gun powder and ammunition, rocket engine and model airplane fuel
Country Clubs (7997)	Pesticides, fertilizers, swimming pool chemicals, vehicle maintenance shops
Bowling Alleys (7933)	Epoxy, urethane-based floor finish
Miscellaneous	

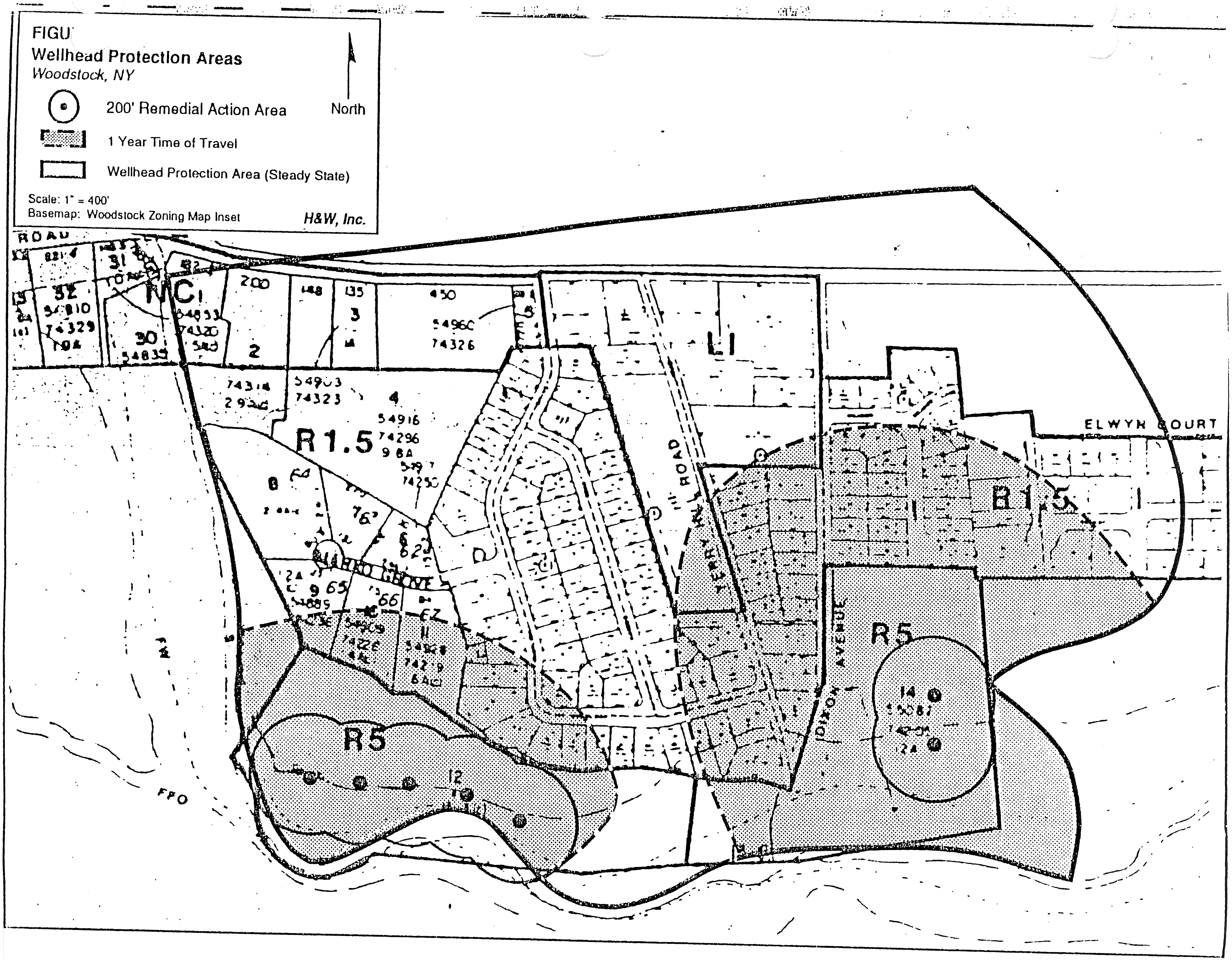
the number of individual homes which are located in the WHPA and assigning an average sewage flow per household. In addition to average sewage flows, an average lawn area of 5,000 sq. ft., an average paved area of 500 sq. ft and an average roof area of 1,500 sq. ft. per house was assigned. Next, the road area in the WHPA was measured and calculated to be 248,000 sq.ft. Finally, an average recharge rate of 18 inches per year was estimated as the average for the area (Frimpter, 1972). With this information nitrogen calculations were run with the assumption of no induced infiltration from the Saw Kill a nitrogen concentration of 4.94 milligrams per liter (mg/l) was calculated (Appendix B). This level is below the EPA recommended limit of 10.00 mg/l. It should be noted that this modeled situation is a worst case scenario. As we have stated previously in this report there is a considerable amount of induced infiltration from the Saw Kill.

The second nitrogen simulation took induced infiltration into account. This simulation used all of the data from the first simulation, but also assumed 444,888 gallons per day (gpd) of induced infiltration from the Saw Kill. The nitrogen concentration calculated in this simulation was 0.70 mg/l, well within the EPA's recommended limit.

These simulations showed that the threat of contamination from elevated nitrogen levels is not a problem at the present. However, if the amount of induced infiltration from the Saw Kill is ever reduced, as it is during the summer months, or if it is ever cut off, as in the case of a severe drought, the Town's water quality could be dramatically impacted in a relatively short period of time.

H&W also identified several specific businesses and land uses in the Town of Woodstock as potential sources of contamination to the aquifer. These included private underground storage tanks (USTs) used for home heating oil, an automotive repair facility, and a manufacturing facility (Simulaids Figure 4). The largest threat is from the USTs. Since these are underground, they are out of sight, and determining if a leak exists can be very difficult. If a leak does exist, it might continue for some time before it was discovered, and it would not take much heating oil to contaminate the water supply. Special care should be taken in their monitoring, and every homeowner should be informed about the potential threat from these tanks and how they should be monitored.

The information contained above is intended to serve as a starting point for the Town of Woodstock in its task of identifying potential sources of contamination to the seven PSWs. It should be noted that sources of potential contamination may lie outside of the 50-year time-of-travel zone. Since the town wells draw much of their water from the Saw Kill, the dumping or spilling of hazardous materials into the Saw Kill upgradient from the town wells could drain into the Saw Kill and travel down stream


FIGU
Wellhead Protection Areas
Woodstock, NY
200' Remedial Action Area
North
1 Year Time of Travel
Wellhead Protection Area (Steady State)
Scale: 1" = 400'
Basemap: Woodstock Zoning Map Inset
H&W, Inc.
ROAD
ELWYN COURT
DIXON AVENUE
R1.5
R5
R5
B1.5
LI
NC1
FPO
FW

where it might contaminate the town's water supply .

As can be seen from the preceding data, there are a variety of businesses, as well as several land use practices, which use and/or generate hazardous materials. It is obvious that a potential threat to the town's drinking water does exist, and proper precautions should be taken to ensure clean drinking water now and in the future.

Water Quality Management Strategies

Management approaches to wellhead protection can include both regulatory and non-regulatory measures. Regulatory resources include zoning, subdivision, and health ordinances. Non-regulatory measures include monitoring and public education. Table 3 provides a summary of potential wellhead protection measures.

One major regulatory tool is a wellhead protection area ordinance, often referred to as an overlay regulation. This regulation restricts certain businesses and land uses within the wellhead protection area, and can be expanded to include the entire aquifer rather than just the part which contributes to the town wells. This could be used to insure good ground water quality for the future development of new ground water sources within the aquifer.

Several non-regulatory tools may be appropriate for the Town of Woodstock's wellhead protection program. Many of the potential contamination sources identified in the preceding sections of this report could be further evaluated (and possibly managed) with techniques such as public education and monitoring. It will be important to educate business owners within the delineated WHPA who utilize hazardous materials that even small quantities of these materials must be handled carefully. Stormwater management activities related to the major highways in the area should be coordinated between the town and the State of New York, with the objectives of water quality protection within the WHPA.

Finally, public involvement can be a key element of the management component. Public meetings and workshops designed to educate citizens should be formulated and held on a regular basis, with agenda items including water quality monitoring data and review of proposed development projects. Another public education tool is that of signage. "Entering a Wellhead Protection Area" signs along major roads serve to alert truck drivers carrying hazardous cargo, and also provides a constant reminder to all citizens of the community that they are entering a sensitive environmental area. Helping everyone realize that we are living, working, and playing on top of our drinking water supply may prove to be among the most powerful tools of all in protecting the ground water resources.

Table 3. SUMMARY OF WELLHEAD PROTECTION TOOLS

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Regulatory: Zoning				
Overlay GW Protection Districts	Used to map WHPA's. Provides for identification of sensitive areas for protection. Used in conjunction with other tools that follow.	Community identifies WHPA's on practical base/zoning map.	Well accepted method of identifying sensitive areas. May face legal challenges if WHPA boundaries are based solely on artibrary delineation.	Requires staff to develop overlay map. Inherent nature of zoning provides "grandfather" protection to pre-existing uses and structures
Prohibition of Various Land Uses	Used within mapped WHPA's to prohibit known ground-water contaminants and uses that generate contaminants.	Commuity adopts prohibited uses list within their zoning ordinance.	Well recognized function of zoning. Appropriate technique to protect natural resources from contamination.	Requires amendment to zoning ordinance. Requires enforcement by both visual inspection and on-site investigations.
Special Permitting	Used to restrict uses within WHPA's that may cause ground-water contamination if left unregulated.	Community adopts special permit "thresholds" for various uses and structures within WHPA's. Community grants special permits for "threshold" uses only if ground water quality will not be compromised.	Well recognized method of segregating land uses within critical resource areas such as WHPA's. Requires case-by-case analysis to ensure equal treatment of applicants.	Requires detailed understanding of WHPA sensitivity by local permit granting authority. Requires enforcement of special permit requirements and on-site investigations.
Large-Lot Zoning	Used to reduce impacts of residential development by limiting numbers of units within WHPA's.	Community "down zones" to increase minimum acreage needed for residential development.	Well recognized perogative of local government. Requires rational connection between minimum lot size selected and resource protection goals. Arbitrary large lot zones have been struck down without logical connection to Master Plan or WHPA program.	Requires amendment to zoning ordinance.
Transfer of Development Rights	Used to transfer development from WHPA's to locations outside WHPA's.	Community offers transfer option within zoning ordinance. Community identifies areas where development is to be transferred "from" and "to".	Accepted land use planning tool.	Cumbersome administrative requirements. Not well suited for small communities without significant administrative resources.

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Regulatory: Health Regulations				
Underground Fuel Storage Systems	Used to prohibit underground fuel storage systems (UST) within WHPA's. Used to regulate UST's within WHPA's.	Community adopts health/zoning ordinance prohibiting UST's within WHPA's Community adopts special permit or performance standards for use of UST's within WHPA's.	Well accepted regulatory option for local government.	Prohibition of UST's require little administrative support. Regulating UST's require moderate amounts of administrative support for inspection follow-up and enforcement.
Privately-Owned Wastewater Treatment Plants (Small Sewage Treatment Plants)	Used to prohibit Small Sewage Treatment Plants (SSTP) within WHPA's.	Community adopts health/zoning ordinance prohibiting SSTP's within WHPA's. Community adopts special permit or performance standards for use of SSTP's within WHPA's.	Well accepted regulatory option for local government.	Prohibition of SSTP's require little administrative support. Regulating SSTP's require moderate amount of administrative support for inspection followup and enforcement.
Septic Cleaner Ban	Used to prohibit the application of certain solvent septic cleaners within WHPA's, a known ground water contaminant.	Community adopts health/zoning ordinance prohibiting the use of septic cleaners containing 1,1,1-Trichloroethane or other solvent compounds within WHPA's.	Well accepted method of protecting ground water quality.	Difficult regulation to enforce even with sufficient administrative support.
Septic System Upgrades	Used to require periodic inspection and upgrading of septic systems.	Community adopts health/zoning ordinance requiring inspection and, if necessary, upgrading of septic systems on a time basis (i.e. every 2 years) or upon title/property transfer.	Well accepted purview of government to ensure protection of ground water.	Significant administrative resources required for this option to be successful.
Toxic and Hazardous Materials Handling Regulations	Used to ensure proper handling and disposal of toxic materials/waste.	Community adopts health/zoning ordinance requiring registration and inspection of all businesses within WHPA using toxic/hazardous materials above certain quantities.	Well accepted purview of government to ensure protection of ground water.	Requires administrative support and on-site inspections.

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Private Well Protection	Used to protect private on-site water supply wells.	Community adopts health/zoning ordinance to require permits for new private wells and to ensure appropriate well to septic system setbacks. Also requires pump and water quality testing.	Well accepted purview of government to ensure protection of ground water.	Requires administrative support and review of applications.
Non-Regulatory: Land Transfer and Voluntary Restrictions				
Sale/Donation	Land acquired by a community within WHPA's, either by purchase or donation. Provides broad protection to the ground water supply.	As non-regulatory technique, communities generally work in partnership with non-profit land conservation organizations.	There are many legal consequences of accepting land for donation or sale from the private sector, mostly involving liability.	There are few administrative requirements involved in accepting donations or sales of land from the private sector. Administrative requirements for maintenance of land accepted or purchased may be substantial, particularly if the community does not have a program for open space maintenance.
Conservation Easements	Can be used to limit development within WHPA's.	Similar to sales/donations, conservation easements are generally obtained with the assistance of non-profit land conservation organization.	Same as above.	Same as above.
Limited Development	As the title implies, this technique limits development to portions of a land parcel outside of WHPA's.	Land developers work with community as part of a cluster/PUD to develop limited portions of a site and restrict other portions, particularly those within WHPA's.	Similar to those noted in cluster/PUD under zoning.	Similar to those noted in cluster/PUD under zoning.
Non-Regulatory: Monitoring	Used to monitor ground water quality within WHPA's.	Communities establish ground water monitoring program within WHPA. Communities require developers within WHPA's to monitor ground water quality downgradient from their development.	Accepted method of ensuring ground water quality.	Requires moderate administrative staffing to ensure routine sampling and response if sampling indicates contamination.

	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Cluster/PUD Design	Used to guide residential development outside of WHPA's. Allows for "point source" discharges that are more easily monitored.	Community offers cluster/PUD as development option within zoning ordinance. Community identifies areas where cluster/PUD is allowed (i.e. within WHPA's).	Well accepted option for residential land development.	Slightly more complicated to administer than traditional "grid" subdivision. Enforcement/inspection requirements are similar to "grid" subdivision.
Growth Controls/Timing	Used to time the occurence of development within WHPA's. Allows communities the opportunity to plan for wellhead delineation and protection.	Community imposes growth controls in the form of building caps, subdivision phasing or other limitation tied to planning concerns.	Well accepted option for communities facing development pressures within sensitive resource areas. Growth controls may be challenged if they are imposed without a rational connection to the resource being protected.	Generally complicated administrative process. Requires administrative staff to issue permits and enforcement growth control ordinances.
Performance Standards	Used to regulate development within WHPA's by enforcing predetermined standards for water quality. Allows for aggressive protection of WHPA's by limiting development within WHPA's to an accepted level.	Community identifies WHPA's and establishes "thresholds" for water quality.	Adoption of specific WHPA performance standards requires sound technical support. Performance standards must be enforced on a case-by-case basis.	Complex administrative requirements to evaluate impacts of land development within WHPA's.
Regulatory: Subdivision Control				
Drainage Requirements	Used to ensure that subdivision road drainage is directed outside of WHPA's. Used to employ advanced engineering designs of subdivision roads within WHPA's.	Community adopts stringent subdivision rules and regulations to regulate road drainage/runoff in subdivisions within WHPA's.	Well accepted purpose of subdivision control.	Requires moderate level of inspection and enforcement by administrative staff.

Regulatory: Health Regulations	Applicability to Wellhead Protection	Land Use Practice	Legal Considerations	Administrative Considerations
Underground Fuel Storage Systems	Used to prohibit underground fuel storage systems (UST) within WHPA's. Used to regulate UST's within WHPA's.	Community adopts health/zoning ordinance prohibiting UST's within WHPA's Community adopts special permit or performance standards for use of UST's within WHPA's.	Well accepted regulatory option for local government.	Prohibition of UST's require little administrative support. Regulating UST's require moderate amounts of administrative support for inspection follow-up and enforcement.
Privately-Owned Wastewater Treatment Plants (Small Sewage Treatment Plants)	Used to prohibit Small Sewage Treatment Plants (SSTP) within WHPA's.	Community adopts health/zoning ordinance prohibiting SSTP's within WHPA's. Community adopts special permit or performance standards for use of SSTP's within WHPA's.	Well accepted regulatory option for local government.	Prohibition of SSTP's require little administrative support. Regulating SSTP's require moderate amount of administrative support for inspection followup and enforcement.
Septic Cleaner Ban	Used to prohibit the application of certain solvent septic cleaners within WHPA's, a known ground water contaminant.	Community adopts health/zoning ordinance prohibiting the use of septic cleaners containing 1,1,1-Trichloroethane or other solvent compounds within WHPA's.	Well accepted method of protecting ground water quality.	Difficult regulation to enforce even with sufficient administrative support.
Septic System Upgrades	Used to require periodic inspection and upgrading of septic systems.	Community adopts health/zoning ordinance requiring inspection and, if necessary, upgrading of septic systems on a time basis (i.e. every 2 years) or upon title/property transfer.	Well accepted purview of government to ensure protection of ground water.	Significant administrative resources required for this option to be successful.
Toxic and Hazardous Materials Handling Regulations	Used to ensure proper handling and disposal of toxic materials/waste.	Community adopts health/zoning ordinance requiring registration and inspection of all businesses within WHPA using toxic/hazardous materials above certain quantities.	Well accepted purview of government to ensure protection of ground water.	Requires administrative support and on-site inspections.

SUMMARY AND CONCLUSIONS

The Town of Woodstock is blessed with an abundance of clean water to utilize for drinking water supplies. The work conducted as part of this project confirmed this fact, and provides a foundation for the town to base further efforts to protect this supply.

H&W delineated wellhead protection areas to the seven wells. Up to 80 percent of the water pumped by the wells comes from the Saw Kill, highlighting the fact that protection of the water supply will involve proper management of both the aquifer area supplying water to the wells, and the surface watershed supplying overland runoff to the Saw Kill that ultimately enters the wells..

The potential for contamination of the supply is different for sources affecting ground water within the WHPA versus those that affect the Saw Kill directly. Subsurface sources of contamination within the wellhead protection area, including underground storage tanks and septic systems, can directly affect the quality of ground water pumped by the well. If a leak occurs in an underground tank, the contamination can readily migrate to the well, and identification and remediation of the problem can be costly.

In contrast, subsurface sources of contamination in the surface watershed to the Saw Kill pose less of a threat to the water supply. For contamination to affect the wells from a such a source, it must first migrate through ground water, across the stream bed into the Saw Kill. It must then flow in the surface water to the vicinity of the wells where it is then induced back into the ground water system and enters the wells. The potential for attenuation and dilution of the contamination is therefore much greater than for a subsurface source discharging directly into the aquifer. However, contamination sources affecting the quality of overland runoff in the watershed can pose a threat to drinking water quality. Sources such as road salts and fertilizers can readily wash into the Saw Kill, and could negatively impact the wells.

The town should be concerned about all sources of contamination that could adversely affect the water supply. Given the information developed as part of the contamination source inventory, the greatest potential threat to the water supply is most likely from subsurface sources of contamination within the steady state wellhead protection area shown on Figure 4. Obviously sources closer to the wells are a greater threat than those farther away because there is less time to identify and remediate a spill. Within the surface watershed areas mapped by H&W, the sources affecting surface runoff water quality are more of a threat than subsurface sources of contamination.

REFERENCES

Frimpter, M. H., 1972, Ground-Water Resources of Orange and Ulster Counties, New York: US Geological Survey, Water Supply Paper 1985, 80 p.

Todd, 1980, Groundwater Hydrology, 2nd ed., John Wiley & Sons, New York, 535 p.

Hvorslev, J. M., 1951, Time Lag and Soil Permeability in Ground-Water Observations: US Army Corp. of Engineers, Bulletin No. 36.

APPENDIX A

HORSLEY & WITTEN, INC
NITROGEN LOADING CALCULATIONS

Recharge area:	TOWN OF WOODSTOCK
Model Run:	Induced Infiltration Included

INPUT FACTORS

Number of Residential units	133
Sewage flow per house (gal/day)	165
N-conc. in effluent (mg/l)	40
Lawn area per house (square feet)	5000
Pavement per house (square feet)	500
Road area (square feet)	248000
Roof area per house (square feet)	1500
Total recharge area (acres)	139
Recharge rate for pervious area (in/yr)	18
Recharge rate for impervious area (in/yr)	40
Induced Infiltration From Stream (gal/day)	444888

INPUT	CALCULATIONS	RESULTS
Sewage (gal/day)		CALCULATED LOADING (LBS/YR)
21,945	x N-conc (mg/l) x 3.785 l/gal x 365 days/yr ÷ 454000 mg/lb	2671
Lawn area (sq ft)		
665,000	x 0.0009 lb N/sq ft	599
Pavement area (sq ft)		
314,500	x 0.00031 lb N/sq ft	97
Roof area (sq ft)		
199,500	x 0.00015 lb N/sq ft	30
Natural area (acres)		
112	x 43560 sq ft/acre x 0.000005 lb N/sq ft	24
Induced infiltration (gal/day)	x 3.7851/gal x 365 days x 0.5 mg/l	676.90
444,888		
	TOTAL NITROGEN LOADING (LBS/YR)	4098
		TOTAL RECHARGE (MG/YR)
Recharge from sewage (gal/day)		
21,945	x 365 days/yr : 1,000,000 gal/million gal	8.01
Total pervious area (sq ft)		
5,540,840	x 18 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	62.17
Total impervious area (sq ft)		
514,000	x 40 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	12.82
Induced Infiltration (gal/day)		
444,888	x 3.785 l/gal x 365 days/yr ÷ 1,000,000 gal/million gal	614.62
	TOTAL RECHARGE (MGAL/YR)	697.62
TOTAL NITROGEN LOAD/TOTAL RECHARGE X 454,000 MG/LB : 3,785,000 L/MGAL		
	=RECHARGE NITROGEN CONCENTRATION (mg/l or ppm)	0.70

PREPARED BY HORSLEY & WITTEN, INC.

HORSLEY & WITTEN, INC
NITROGEN LOADING CALCULATIONS

Recharge Area:	TOWN OF WOODSTOCK
Model Run	No Induced Infiltration

INPUT FACTORS

No. Residential units	133
Sewage flow per house (gal/day)	165
N-conc. in effluent (mg/l)	40
Lawn area per house (square feet)	5000
Pavement per house (square feet)	500
Road area (square feet)	248000
Roof area per house (square feet)	1500
Total recharge area (acres)	139
Recharge rate for pervious area (in/yr)	18
Recharge rate for impervious area (in/yr)	40

INPUT	CALCULATIONS	RESULTS
Sewage (gal/day)		CALCULATED LOADING (LBS/YR)
21,945	x N-conc (mg/l) x 3.785 l/gal x 365 days/yr : 454000 mg/lb	2671
Lawn area (sq ft)		
665,000	x 0.0009 lb N/sq ft	599
Pavement area (sq ft)		
314,500	x 0.00042 lb N/sq ft	97
Roof area (sq ft)		
199,500	x 0.00015 lb N/sq ft	30
Natural area (acres)		
112	x 43560 sq ft/acre x 0.000005 lb N/sq ft	24
	TOTAL NITROGEN LOADING (LBS/YR)	3421
		TOTAL RECHARGE (MG/YR)
Recharge from sewage (gal/day)		
21,945	x 365 days/yr : 1,000,000 gal/million gal	8.01
Total pervious area (sq ft)		
5,540,840	x 18 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	62.17
Total impervious area (sq ft)		
514,000	x 40 in/yr /12 in/ft x 7.48 gal/cu ft : 1,000,000 gal/million gal	12.82
	TOTAL RECHARGE (MGAL/YR)	82.99
TOTAL NITROGEN LOAD/TOTAL RECHARGE X 454,000 MG/LB : 3,785,000 L/MGAL		
	=RECHARGE NITROGEN CONCENTRATION (mg/l or ppm)	4.94

APPENDIX B

BORING LOG

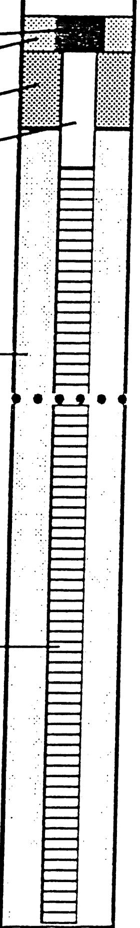
Boring No. HW-1
Sheet 1 of 1

Project: Town of Woodstock, NY
Client: Town of Woodstock, NY
Boring Contractor: American Drilling Services, Inc.
Boring Equipment: Hollow Stem Auger
Ground Water:

Date	Depth, ft.
11 January 1994	5 Below Land Surface

Date: 11 January 1994
Completion Depth: 12 ft.
Elevation: N/A
Inspector: H. Frank

Depth (feet)	Description	Sample Number	Penetra./ Recovery	Blow Count	Comments	Well Details
0						
1					Lock Box; Cement Seal	
2					1 ft. Bentonite; 2 ft. PVC Riser	
3	F-M-C sand, gravel, So cobbles					
4						
5					Gavel Pack	
5	••• Water Level •••				Water Level	
6						
7	F-M-C sand, So VF sand and brown silt and clay					
8					10 ft. of 2 in. .010 slot threaded PVC screen	
9						
10						
11						
12	Bottom of Hole				Bottom of Hole	



Proportions used:

trace (tr)	0-10%
little (li)	10-20%
some (so)	20-35%

Abbreviations:

f = fine	f/c = fine to coarse
m = medium	v = very
c = coarse	+ = more

H & W, Inc

BORING LOG

Boring No. HW-2
Sheet 1 of 1

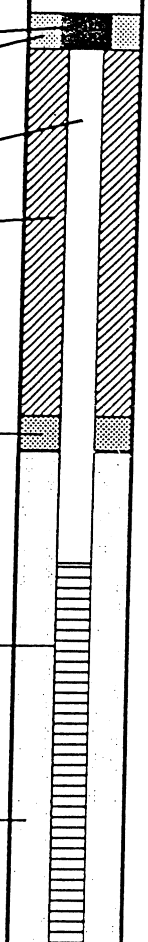
Project: Town of Woodstock, NY
Client: Town of Woodstock, NY
Boring Contractor: American Drilling Services, Inc.
Boring Equipment: Hollow Stem Auger
Ground Water:

Date	Depth, ft.
11 January 1994	

Date: 11 January 1994
Completion Depth: 24.5 ft.
Elevation: N/A
Inspector: H. Frank

Depth (feet)	Description	Sample Number	Penetra./ Recovery	Blow Count	Comments
0–24.5	F-M-C sand, gravel, So cobbles, So red silt				Lock Box; Cement Seal; 14 ft. PVC Riser; Backfill; 1 ft. Bentonite Seal
	F-M sand, so VF sand and brown silt and clay				10 ft. of 2 in. .010 slot threaded PVC screen; 12 ft. Gavel Pack
24.5	Bottom of Hole				Bottom of Hole

Well Details



Proportions used:

trace (tr)	0-10%
little (li)	10-20%
some (so)	20-35%

Abbreviations:

f = fine
m = medium
c = coarse

f/c = fine to coarse
v = very
\+ = more

H & W, Inc

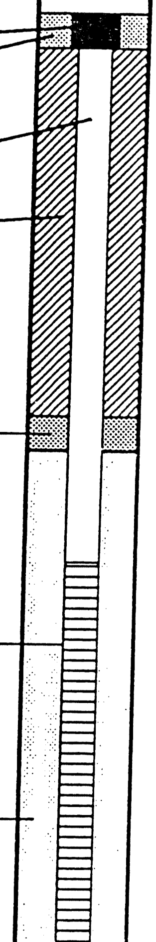
BORING LOG

Boring No. HW-3
Sheet 1 of 1

Project: Town of Woodstock, NY
Client: Town of Woodstock, NY
Boring Contractor: American Drilling Services, Inc.
Boring Equipment: Hollow Stem Auger
Ground Water:

Date	Depth, ft.
11 January 1994	

Date: 11 January 1994
Completion Depth: 24.5 ft.
Elevation: N/A
Inspector: H. Frank

Depth (feet)	Description	Sample Number	Penetra./ Recovery	Blow Count	Comments	Well Details
0						
					Lock Box	
2					Cement Seal	
4					14 ft. PVC Riser	
6					Backfill	
8	F-M-C sand, gravel, So cobbles, So red sitl					
10						
12					1 ft. Bentonite Seal	
14						
16					10 ft. of 2 in. .010 slot threaded PVC screen	
18						
20	VF-F sand, So brown and red silt and clay					
22					12 ft. Gavel Pack	
24						
	Bottom of Hole				Bottom of Hole	
26						

Proportions used:

trace (tr)	0-10%
little (li)	10-20%
some (so)	20-35%

Abbreviations:

f = fine	f/c = fine to coarse
m = medium	v = very
c = coarse	+ = more

H & W, Inc

BORING LOG

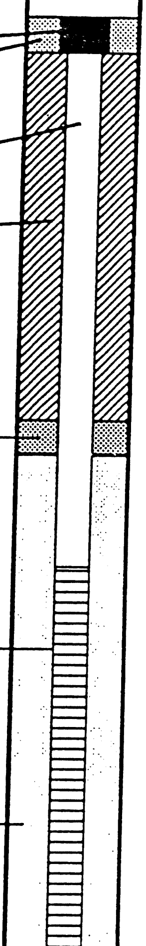
Boring No. HW-4
Sheet 1 of 1

Project: Town of Woodstock, NY
Client: Town of Woodstock, NY
Boring Contractor: American Drilling Services, Inc.
Boring Equipment: Hollow Stem Auger
Ground Water:

Date	Depth, ft.
11 January 1994	

Date: 11 January 1994
Completion Depth: 24.5 ft.
Elevation: N/A
Inspector: H. Frank

Depth (feet)	Description	Sample Number	Penetra./ Recovery	Blow Count	Comments	Well Details
0						
2					Lock Box Cement Seal	
4					14 ft. PVC Riser	
6					Backfill	
8	F-M-C sand, gravel, So cobbles					
10						
12					1 ft. Bentonite Seal	
14						
16					10 ft. of 2 in. .010 slot threaded PVC screen	
18	F-M-C brown/red sand					
20						
22					12 ft. Gavel Pack	
24						
	Bottom of Hole				Bottom of Hole	
26						



Proportions used:

trace (tr)	0-10%
little (li)	10-20%
some (so)	20-35%

Abbreviations:

f = fine
m = medium
c = coarse

f/c = fine to coarse
v = very
\+ = more

H & W, Inc

BORING LOG

Boring No. HW-5
Sheet 1 of 1

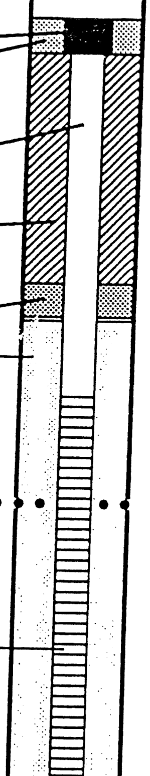
Project: Town of Woodstock, NY
Client: Town of Woodstock, NY
Boring Contractor: American Drilling Services, Inc.
Boring Equipment: Hollow Stem Auger
Ground Water:

Date	Depth, ft.
11 January 1994	13 Below Land Surface

Date: 11 January 1994
Completion Depth: 20 ft.
Elevation: N/A
Inspector: H. Frank

Depth (feet)	Description	Sample Number	Penetra./ Recovery	Blow Count	Comments
0					
2					Lock Box; Cement Seal
4					10 ft. PVC Riser
6					Backfill
8					1 ft. Bentonite Seal
10	F-M-C sand, So gravel				12 ft. GavelPack
12					Water Level
14	F-M-C sand, So VF sand and brown silt and clay				
16					10 ft. of 2 in. .010 slot threaded PVC screen
18					
20	Bottom of Hole				Bottom of Hole

Well Details



Proportions used:

trace (tr)	0-10%
little (li)	10-20%
some (so)	20-35%

Abbreviations:

f = fine
m = medium
c = coarse
f/c = fine to coarse
v = very
+ = more

H & W, Inc