CITY OF PRINCETON
WELLHEAD PROTECTION PLAN
WELLS #1 & #2

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HYDROGEOLOGIC SETTING

Princeton is located along the Upper Fox River in the Town of Princeton, in eastern Green Lake County in the central part of the state. The Fox River meanders from southwest to northeast through the city, eventually emptying into Lake Butte des Morts. The flat topography of the area was created by Late Wisconsin Glaciation. As glaciers advanced over the area, they flattened the landscape. When the glaciers receded and melted, meltwater formed a vast lake known as Glacial Lake Oshkosh. The former lake bed is flatter than surrounding terrain (Schultz, 2004). The glacial lake left deposits of silt clay, and some sand. These fine grained sediments somewhat confine the aquifer, which is best exemplified by the large number of flowing wells constructed along the Fox River (Hooyer & Mode, 2008). As you move away from the Fox River, you move out of the former glacial lake bed onto moraines and drumlins covered by glacial drift (Colgan, 2003 and Hadley & Pelham, 1976). Below the glacial deposits lies Cambrian age sandstone that serves as the city's primary aquifer. Below the sandstone lies Precambrian igneous granite that is considered impermeable. The bedrock layers in the area tilt gently towards the east and the Michigan Basin.

Both wells are cased entirely through the glacial deposits and constructed in the Cambrian sandstone bedrock. Vertical Relationships are shown in the cross section found in Figure 4. Sandstone is capable of producing large well yields. Information gathered from well construction records suggests the thickness of the sandstone aquifer is around 400 ft. As stated earlier, the overlying glacial lake sediment is comprised primarily of less permeable silt and clay that somewhat confine the aquifer. Silt & clay are low hydraulic conductivity materials which help attenuate, retard, or immobilize pollutants and provide protection of the aquifer.

The source of all groundwater is precipitation which infiltrates and recharges the aquifer. The US Geologic Survey has determined an average of 7.3 inches per year of recharge for the region (Neff el. Al., 2005). The rate of groundwater flow in an aquifer is determined by the hydraulic parameters of the aquifer. Important hydraulic parameters are:

- Aquifer Thickness – Vertical thickness of water bearing porous medium.
- Effective Porosity – The ratio of void volume to the total volume of material.
- Hydraulic Gradient – The change in water table elevation (hydraulic head), divided by the change in distance in a given direction.
- Storage Coefficient – The volume of water that an aquifer releases from storage, per unit surface area of the aquifer, per unit change in head (From Schwartz & Zhang, 2003, page 73).
- Transmissivity – The rate at which water is transmitted through a unit width of the aquifer under a unit hydraulic gradient. It is estimated using pump test data, and the "T-Guess" computer solution (Bradbury and Rothschild, 1985).
- Hydraulic Conductivity – The ease with which flow takes place through a porous medium. It is calculated by dividing the transmissivity by the aquifer thickness.

ZONE OF INFLUENCE

The Theis equation is used to calculate the zone of influence (ZOI), which is a circle around each well that represents a cone of depression in the water table defined by a drawdown of 1 ft that would develop after 30 days of continuous pumping at full capacity, with no recharge to the groundwater. It assumes that the aquifer is homogeneous (the aquifer is equally permeable in all places and in all directions), the well fully penetrates the aquifer and drawdown is small compared to the saturated thickness. It simulates theoretical worst-case conditions. This is an important method because it considers the hydraulic parameters of the Aquifer. The aquifer's hydraulic parameters are described previously in the Hydrogeologic Setting section.

<u>Theis Equation</u>:

$$W(\mu) = \frac{sT}{114.6*Q}$$

$$r^2 = \frac{Tt\mu}{1.87S}$$

Where:

$W(\mu)$	= Well Function
s	= Drawdown (1 ft)
Q	= Maximum Pumping Capacity
T	= Transmissivity (gpd/ft)
S	= Storativity
μ	= From lookup table based on $W(\mu)$
t	= 30 days continuous pumping
R	= Radius of the cone of depression

<u>Zone of Influence (ZOI) Calculations</u>:

Well #1

$$W(\mu) = \frac{1 \text{ X } 13{,}566}{114.6 \text{ X } 350} \qquad W(\mu) = 0.2631$$

$$\mu = 0.89$$

$$r = \sqrt{\left(\frac{13{,}566 \text{ X } 30 \text{ X } 0.89}{1.87 \text{ X } 0.01}\right)}$$

ZOI radius= 4,401 feet

Well #2

$$W(\mu) = \frac{1 \text{ X } 20{,}026}{114.6 \text{ X } 490} \qquad W(\mu) = 0.2184$$

$$\mu = 1$$

$$r = \sqrt{\left(\frac{20{,}026 \text{ X } 30 \text{ X } 1}{1.87 \text{ X } 0.01}\right)}$$

ZOI radius= 5,668 feet

The ZOI calculated for both wells are likely artificially large because they do not consider recharge to the aquifer. Additionally, when recharge is considered the ZOI becomes an elliptical shape extending farther upgradient and less downgradient.

municipal water and sewer. Only several residents on outlying streets are served by their own private well and septic systems. There are about 75 recorded private wells in the City, 8 of which are within 1,200 ft of a municipal well. Princeton Utilities keeps an inventory of private wells that is updated when customers provide new information. The City does have a well abandonment ordinance that requires private well owners to apply for a permit and submit a bacteria free water samples to the City every 5 years. The ordinance requires that unused or unsafe private wells are properly abandoned. Currently the well abandonment ordinance is not being actively enforced by the city.

See Appendix C for a comprehensive inventory of potential contaminant sources within ½ mile of each well. Due to the close proximity if Wells #1 & #2 are considered together with a single ½ mile radius around both wells. This inventory should be updated periodically by utility personnel in the space provided.

Well #1 & #2

Wells #1 & #2 are located in downtown Princeton at the city garage. The Fox River flows through the city from south to north less than ¼ mile west of the wells. South and west of the well is dominated by commercial businesses including several auto shops and a medical facility. The land east of the wells is predominately residential neighborhoods with several businesses located more than ½ mile away. Directly north of the wells is several acres of undeveloped lowland, and a piece of property owned by the City.

The wells location near Princeton's historic downtown mean there are is a high number of old leaking underground storage tanks and other contamination cleanup sites near the wells. According to the WDNR's BRRTS website, there are 20 closed remediation investigations and 5 ongoing contamination cleanups within ½ mile of the wells. Despite the close proximity of these contamination sites, there is no history of volatile organic compound (VOC) detections in either well. To reduce the risk of future contamination, it is important to continue managing land use surrounding the well in a way that protects groundwater quality. Potential contaminant sources around Wells #1 & #2 are mapped in Figure 5.

See Appendix C for a comprehensive inventory of potential contaminant sources and distances from the nearest well.

WELLHEAD PROTECTION AREA

This plan establishes a wellhead protection area for both wells (figure 6). The wellhead protection area is established to clearly define the area most critical for protecting the wells from contamination. It should be the primary focus of efforts to protect the City of Princeton's water supply. The wellhead protection area is established based on the 5-year TOT capture zone. 5 years is generally determined to be an adequate amount of time for the geologic formation to degrade or dilute most contaminants, or the contamination could be cleaned up

1. ***Outreach:*** This plan should be made available to the public at City Hall along with educational materials on groundwater protection, including information on disposal of lawn chemicals and common household hazardous materials. Other effective outreach activities include publishing an article in the "Princeton Times" newspaper and the Northwestern newspaper, placing an article on the city's website or distributing information in bill stuffers.
2. ***Education:*** WRWA personnel are available upon request to conduct classroom or group presentations, or assist with other educational activities.
3. ***Point Source Management:*** Princeton Utilities should contact owners of industrial and commercial facilities within the wellhead protection areas that handle potentially hazardous materials. Princeton Utilities should work with these facilities to ensure proper handling and storage of those materials.
4. ***Clean Sweep:*** The City of Princeton should promote the yearly "Clean Sweep" program through Green Lake County. Information on proper disposal of Household Hazardous Waste (HHW) should be made available at City Hall. For more information on the Green Lake County clean sweep, go to http://www.co.green-lake.wi.us
5. ***Road Signs:*** Signs informing people they are in a wellhead protection area placed at the protection area boundary are an effective way to promote awareness.
6. ***Water Conservation:*** Water conservation can reduce the costs of pumping and treatment of both water and wastewater. It can also extend the life of a well and postpone the need for new wells. It conserves a limited resource while minimizing the impacts of groundwater withdrawal. Suggested water conservation measures are as follows
   a. *Water Sense:* The City of Princeton should consider becoming a Water Sense partner through the Wisconsin Public Service Commission and the US EPA to promote water conservation and efficiency. Additionally the City may decide to make water saving fixtures available to residents at cost.
   b. *Water Use Monitoring*: Water bills should be screened for 'spikes' in water use that might be caused by leaking plumbing.
   c. *Leak Detection Surveys:* Princeton Utilities should continue to use leak detection surveys to minimize the amount of water pumped but not sold.
   d. *Water Meter Testing/Exchange:* In compliance with PSC guidelines, Princeton Utilities should test or exchange water meters regularly to assure that meters are accurate and efficient.

EMERGENCY CONTACT		PHONE NUMBERS
Local:	Princeton Utilities-Ernie Schmidt	920-299-6038
	Princeton Utilities-Lee Williams	920-299-6037
	Fire Department	911 or 920-295-6561
	Police Department	911 or 920-295-6250
	Ambulance (EMS)	911 or 920-295-6612
	DNR Representative-Jim Schedgick	920-424-7883
County and Regional:		
	Green Lake County Sheriff	911 or 920-294-4000
	Green Lake County Emergency Management	920-361-5416
	Green Lake County Health Department	920-294-4070
	DNR-Regional Spill Coordinator	920-662-5492
	NE Wisconsin Regional Hazmat Team	920-832-5810
State:	DNR-State Spill Response	800-943-0003
	State Lab of Hygiene	608-263-3280

Figure 2 – Regional Groundwater Flow

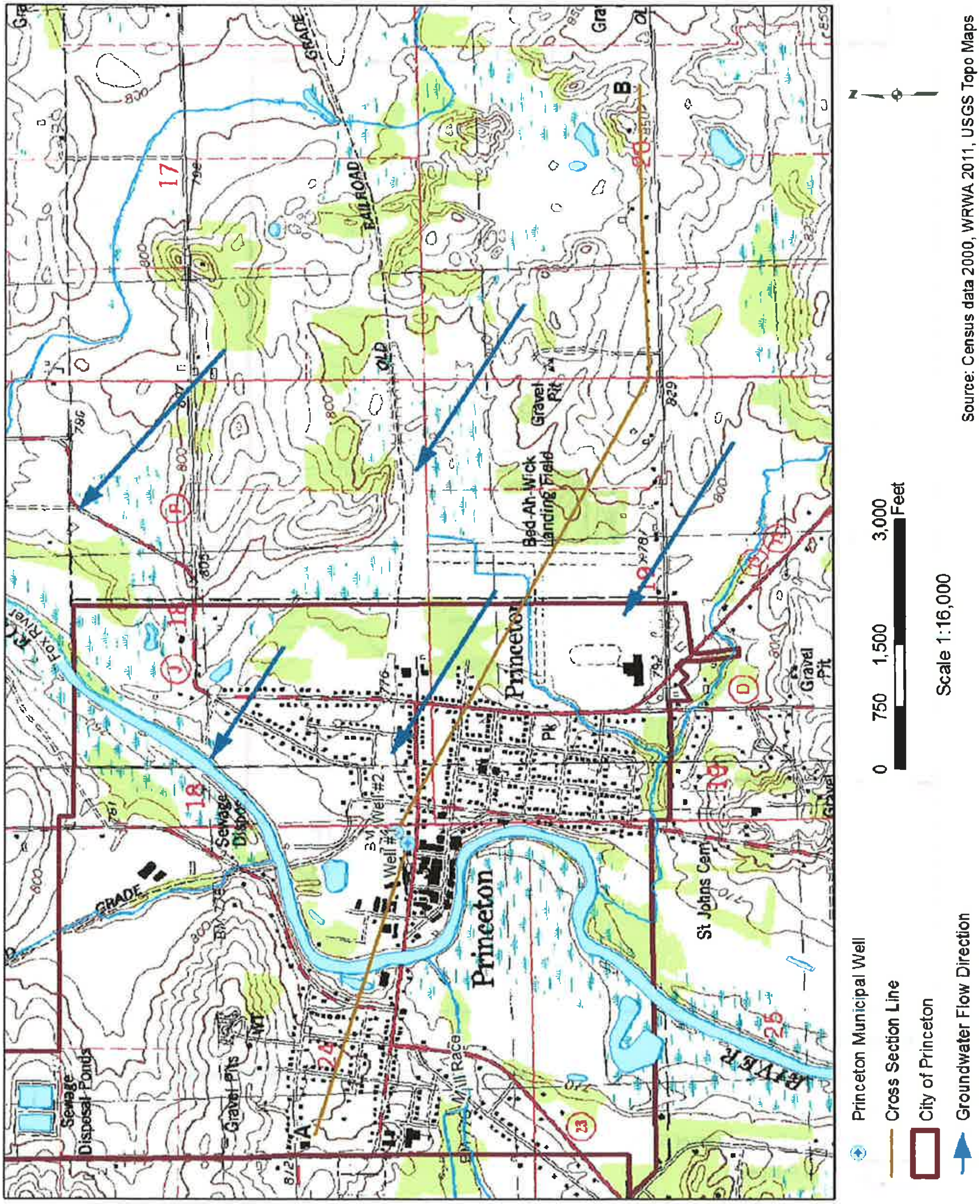


Figure 4 – Vertical Relationships

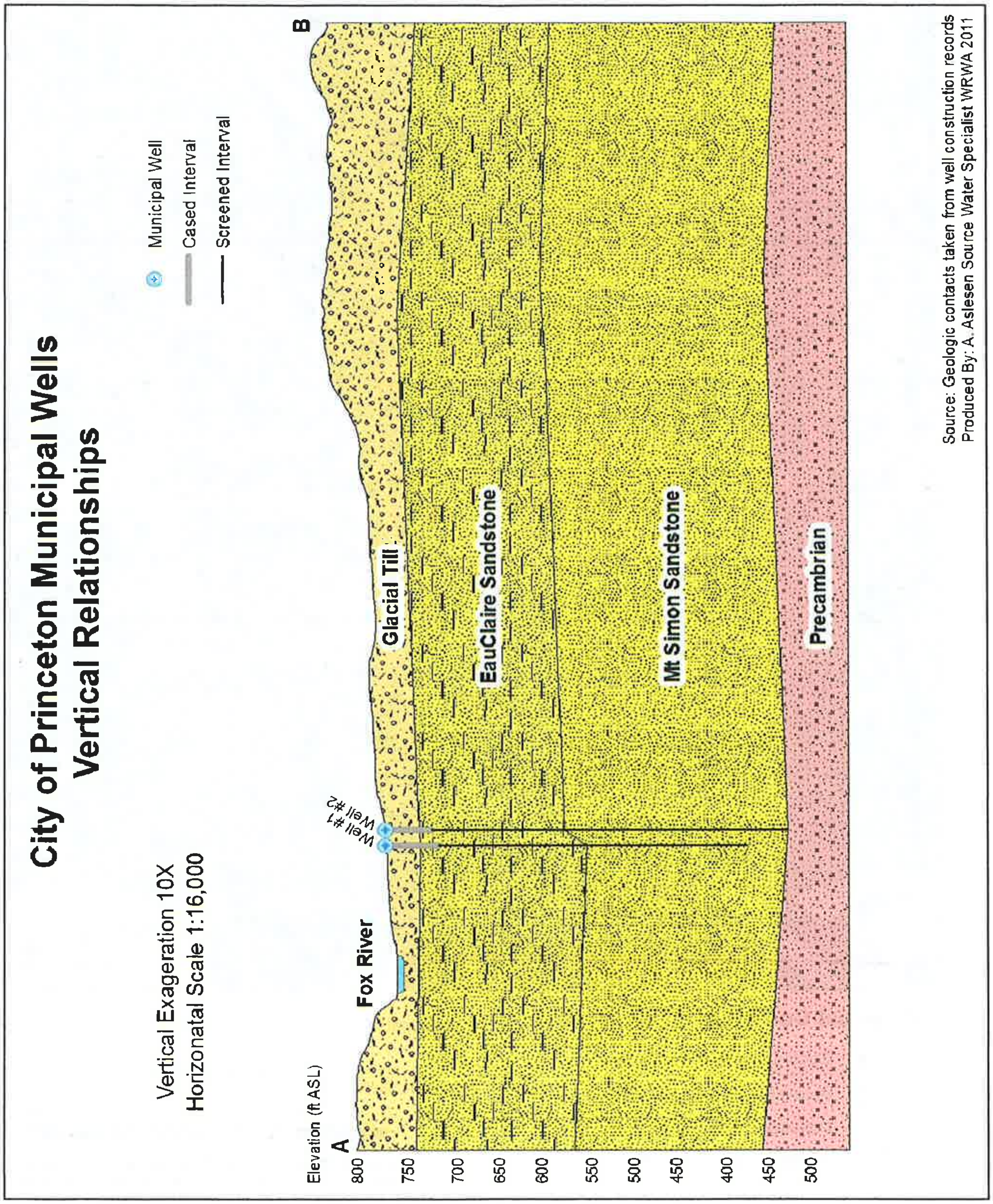
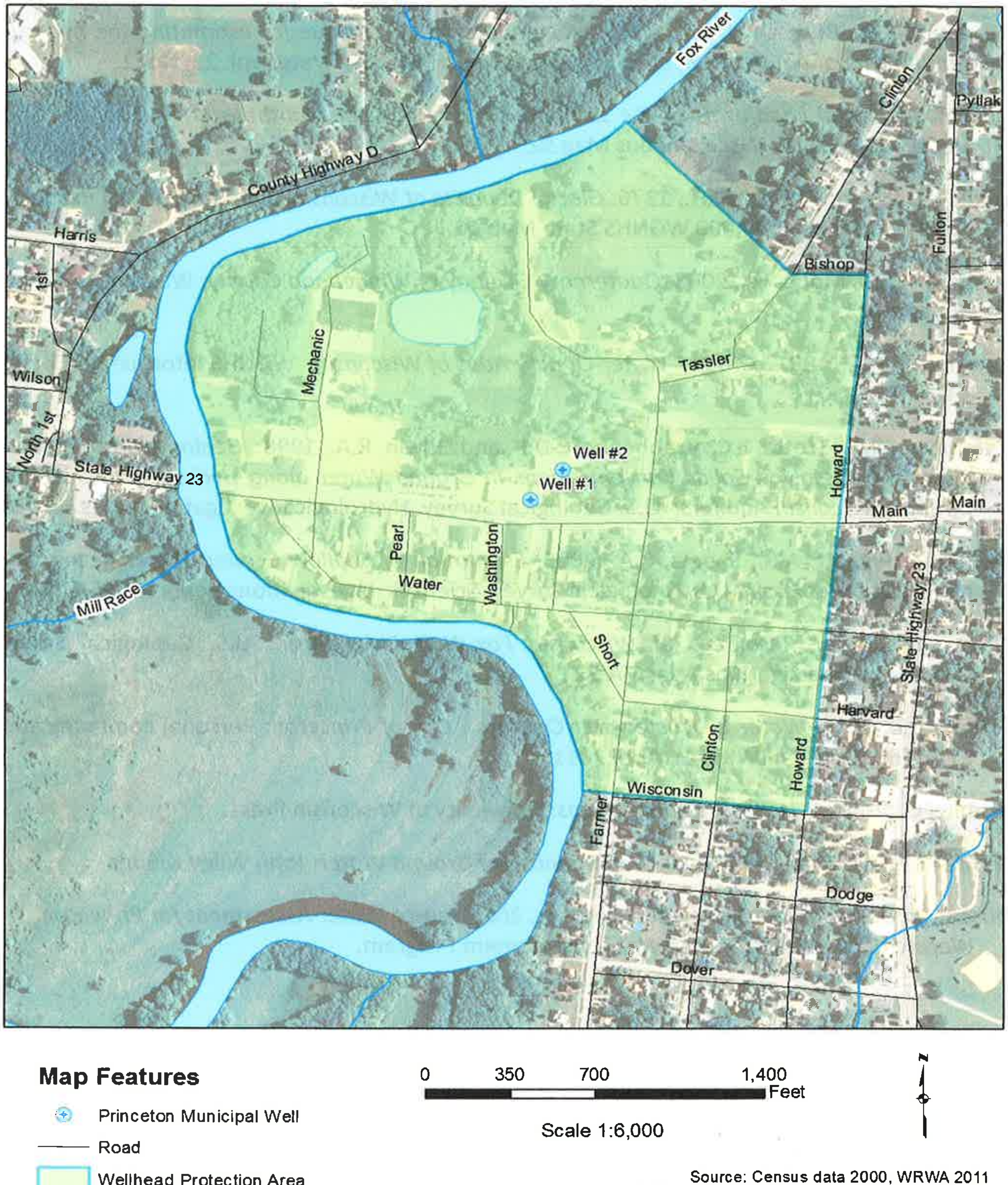


Figure 6 – Wellhead Protection Area



Source: Census data 2000, WRWA 2011
Wellhead Protection Area Established by WRWA

Appendix A – Lithologic Logs and Well Construction Details

WISCONSIN UNIQUE WELL NUMBER BF928
Source: SWAP PROJECT KEYED

State of Wi-Private Water Systems-DG/2
Department Of Natural Resources, Box 7921
Madison, WI 53707
Form 3300-77A (Rev 02/02)bw

Property Owner: PRINCETON, CITY OF
Telephone Number: 414-295-6612
Mailing Address: 438 W MAIN ST
City: PRINCETON State: WI Zip Code: 54968
County of Well Location: 24 GREEN LAKE
Co Well Permit No: W
Well Completion Date: January 1, 1984

Depth 404 FT

1. Well Location
T=Town C=City V=Village: C of PRINCETON
Fire#
Street Address or Road Name and Number: 438 W MAIN ST #1
Subdivision Name / Lot# / Block #
Gov't Lot or SE 1/4 of SE 1/4 of Section 24 T 16 N;R 11 E
Latitude Deg. 43 Min. 51.0676
Longitude Deg 89 Min. 7.7222

Well Constructor: AE MCMAHON ENG CO License #
Address
City State Zip Code
Facility ID (Public): 424021950
Public Well Plan Approval#
Date Of Approval: 04/02/1934
Hicap Permanent Well #: 79269
Common Well #: 001
Specific Capacity: 6.8 gpm/ft

2. Well Type 3 (See item 12 below) 1=New 2=Replacement 3=Reconstruction
of previous unique well # ______ constructed in 0
Lat/Long Method: GPS004
Reason for replaced or reconstructed Well?
1 1=Drilled 2=Driven Point 3=Jetted 4=Other

3. Well Serves # of homes and or M (eg: barn, restaurant, church, school, industry, etc.)
M=Munic O=OTM N=NonCom P=Private Z=Other X=NonPot A=Anode L=Loop H=Drillhole
High Capacity: Well? Property?

4. Is the well located upslope or sideslope and not downslope from any contamination sources, including those on neighboring properties?
Well located in floodplain?
Distance in feet from well to nearest: (including proposed)

1. Landfill
2. Building Overhang
3. 1=Septic 2=Holding Tank
4. Sewage Absorption Unit
5. Nonconforming Pit
6. Buried Home Heating Oil Tank
7. Buried Petroleum Tank
8. 1=Shoreline 2=Swimming Pool
9. Downspout/Yard Hydrant
10. Privy
11. Foundation Drain to Clearwater
12. Foundation Drain to Sewer
13. Building Drain 1=Cast Iron or Plastic 2=Other
14. Building Sewer 1=Gravity 2=Pressure 1=Cast Iron or Plastic 2=Other
15. Collector Sewer: ___ units ___ in. diam.
16. Clearwater Sump
17. Wastewater Sump
18. Paved Animal Barn Pen
19. Animal Yard or Shelter
20. Silo
21. Barn Gutter
22. Manure Pipe 1=Gravity 2=Pressure 1=Cast iron or Plastic 2=Other
23. Other manure Storage
24. Ditch
25. Other NR 812 Waste Source

5. Drillhole Dimensions and Construction Method

Dia.(in.)	From (ft)	To (ft)
12.0	surface	404

Upper Enlarged Drillhole / Lower Open Bedrock
-- 1. Rotary - Mud Circulation
-- 2. Rotary - Air
-- 3. Rotary - Air and Foam
-- 4. Drill-Through Casing Hammer
-- 5. Reverse Rotary
-- 6. Cable-tool Bit in. dia
-- 7. Temp. Outer Casing in. dia. ___ depth ft. Removed ?
Other

8. Geology

Geology Codes	Type, Caving/Noncaving, Color, Hardness, etc	From (ft.)	To (ft.)
_TS	TILL	0	25
_NG_	GRAVEL	25	37.5
I_N_	SANDSTONE EAU CLAIRE	37.5	225
I_N_	SANDSTONE MT SIMON	225	404

6. Casing Liner Screen

Dia. (in.)	Material, Weight, Specification Manufacturer & Method of Assembly	From (ft.)	To (ft.)
12.0		surface	39
10.0	LINER (1984)	0	60

Dia.(in.)	Screen type, material & slot size	From	To

7. Grout or Other Sealing Material

Method / Kind of Sealing Material	From (ft.)	To (ft.)	# Sacks Cement
GROUT (1984)	surface	60.0	

9. Static Water Level 6.1 feet A ground surface A=Above B=Below

10. Pump Test Pumping level 45.0 ft. below surface
Pumping at 350.0 GPM 0.0 Hrs

11. Well Is: 0 in. Grade A=Above B=Below
Developed? Disinfected? Capped?

12. Did you notify the owner of the need to permanently abandon and fill all unused wells on this property?
If no, explain

13. Initials of Well Constructor or Supervisory Driller Date Signed
Initials of Drill Rig Operator (Mandatory unless same as above) Date Signed

Additonal Comments? Variance Issued?
Owner Sent Label? Y More Geology?
Batch 555

Appendix B – Hydraulic Gradient Calculation

http://www.epa.gov/athens/learn2model/part-two/onsite/gradient4plus-ns.html

EPA United States Environmental Protection Agency

Ecosystems Research Division

EPA On-line Tools for Site Assessment Calculation

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Hydraulic Gradient

Gradient Calculation from fitting a plane to as many as fifteen points

$$a\,x_1 + b\,y_1 + c = h_1$$
$$a\,x_2 + b\,y_2 + c = h_2$$
$$a\,x_3 + b\,y_3 + c = h_3$$
$$\ldots$$
$$a\,x_{15} + b\,y_{15} + c = h_{15}$$

where (x_i,y_i) are the coordinates of the well and h_i is the head

i = 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15

The coefficients a, b, and c are calculated by a least-squares fitting of the the data to a plane

The gradient is calculated from the square root of $(a^2 + b^2)$ and the angle from the arctangent of a/b or b/a depending on the quadrant

Example Data Set 1 Example Data Set 2 Calculate Clear

Save Data Recall Data Go Back

Site Name City of Princeton

Date 4/22/2011 Current Date

Calculation basis Head

Coordinates m

I.D.	x-coordinate	y-coordinate	head ft
BF928	590029.978	375705.427	770
CC986	590614.735	374791.674	780
DS437	590959.092	374652.443	780
EO479	590774.254	376478.009	770
EL789	591712.644	374891.083	789

Number of Points Used in Calculation	5
Max. Difference Between Head Values	5.791
Gradient Magnitude (i)	0.003
Flow direction as degrees from North (positive y axis)	307.2
Coefficient of Determination (R^2)	0.975

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35	BFT	Petroleum Storage	1,260	N		
36	GFB	Fuel Storage Tank-Below Ground	1,260	N		
37	WWO	Wastewater Discharge to Surface	1,400	N		
38	WRP	ERRP Site	1,640	W	224543451	Closed
39	WLS	Leaking Underground Storage Tank	1,650	W	324002454	Closed
40	CVR	Motor Vehicle Repair Shop	1,780	W		
41	CSS	Gass Service Station	1,850	SE		
42	WRP	ERRP Site	2,300	E	224169281	Closed
43	WLS	Leaking Underground Storage Tank	2,340	W	324002765	Closed
44	CSS	Gass Service Station	2,340	W		
45	WRP	ERRP Site	2,440	E	224001347	Closed
46	WLS	Leaking Underground Storage Tank	2,600	SE	324096733	Closed
47	WRP	ERRP Site	2,620	SE	224553536	Closed

Updates to Wells #1&2 potential contaminant source list

Date	Updated By	Abbreviation	Potential Contaminant Sources	Distance (ft)	Direction

	manufacturing		paints, methylene chloride, tetrachloroethylene, trichloroethane, acetone, toluene, PCBs
IES	Electroplating / metal finishing facility		Acids, alkaline solutions, cyanide, metallic salts, solvents, cyanide, heavy metal contaminated wastewater
IFM	Furniture or wood manufacturing / refinishing / stripping		Paints, solvents (toluene, methylene chloride), degreasing sludges
IFW	Foundry / smelting plant		Cyanides, sulfides
IGS	Gravel and Sand pits		Spills, miscellaneous chemicals, bacteria
IMQ	Mining / Mine waste		Cyanide, sulfides, metals, acids drainage
IPC	Plastics manufacturer / molder		Solvents, oils, organics and inorganics, paint wastes, cyanides, acids, alkalis, sludges, esters, surfactants, glycols, phenols, formaldehyde, peroxides
IPM	Paper mill		Metals, acids, minerals, sulfides, chemicals, sludges, chlorine, hypochlorite, chlorine dioxide, hydrogen peroxide
IPP	Pipeline (petro./chem.)		Petroleum, chemicals
ISQ	Stone quarries		Spills, miscellaneous chemicals, potential conduit, bacteria
ITP	Textile / polyester manufacturer		Chemicals
IWT	Wood preserving facility		Treated wood residue, preservatives (pentachlorophenol, chromate, copper arsenate,), tanner gas, paint sludges, solvents, creosote, coating wastes
MFT	Fire training facility		Chemicals
MGC	Golf course		Fertilizers, herbicides, pesticides for controlling mosquitoes, ticks, ants, gypsy moths, and other pests., automotive wastes
MGP	Manufactured gas plant / gasification plant		Petroleum VOCs, Benzo(a)pyrene, PAHs, cyanide
MLA	Laboratory (college, medical, school, private, etc.)		Biological wastes, disinfectants, acids, formaldehyde, miscellaneous chemicals
MMI	Military installation		
MMP	Medical Installation (e.g. Hospital)		X-ray developers and fixers, infectious wastes, radiological wastes, biological wastes, disinfectants, asbestos, beryllium, acids, formaldehyde, miscellaneous chemicals
MOT	Other (specify) ______________		
WDR	Class V injection well	Any well, drilled or dug hole, used to inject fluids into the subsoil	Chlorides, pathogens, petroleum products, pesticides
WHS	Hazardous waste generator (SARA Title III) / RCRA authority clean-ups	Any facility listed on the SARA Title III list thought to pose a threat to the well / RCRA clean-ups	Hazardous waste
WIN	Incinerator (municipal)		Metals, combustion by-products
WLA	Landfill	Solid and hazardous waste sites listed in the DNR "Registry of Waste Disposal Sites in Wisconsin"	Leachate
WLS	Leaking underground storage tank (LUST)	LUST Sites included in the DNR "Leaking Underground Storage Tank List"	Gasoline, diesel fuel, other petroleum products
WRF	Recycling facility		Petroleum products, chemicals
WRP	ERRP Site	Sites on the DNR "Emergency and Remedial Response" list	Spills
WSI	Wastewater Spray Irrigation		Coliform bacteria, nitrate, chloride, pathogens, viruses
WSS	Sludge spreading	Municipal wastewater sludge, paper mill sludge	Viruses, coliform bacteria, heavy metals, dioxins
WSW	Storm water retention pond		Metals, petroleum products
WTS	Solid waste transfer station		Miscellaneous chemicals
WUC	Superfund site	Sites listed in the DNR "Superfund Sites in Wisconsin"	Miscellaneous contaminants
WWL	Wastewater lagoon	Treatment and/or storage lagoons	Coliform bacteria, viruses
WWO	Wastewater discharge to surface water	Surface water outfall	Coliform bacteria, viruses
WWP	Wastewater treatment plant		
WWS	Wastewater discharge to groundwater	Absorption and seepage cells, spray irrigation, subsurface systems, etc.	Coliform bacteria, viruses