Appendix O Results of Groundwater Modeling Study Shallow Groundwater Source Fox River & Vernon Marsh Area Waukesha Water Utility

RESULTS OF GROUNDWATER MODELING STUDY SHALLOW GROUNDWATER SOURCE FOX RIVER & VERNON MARSH AREA WAUKESHA WATER UTILITY Prepared by RJN Environmental Services, LLC April 2010

Objective

The Troy Bedrock Valley Aquifer Model ("model" – Southeastern Wisconsin Regional Planning Commission Memorandum Report Number 188) was utilized to simulate various shallow aquifer pumping scenarios for the Waukesha Water Utility. The objective of this work was to assess the potential impact to surface waters and wetlands, as well as private wells, of groundwater extraction from the sand and gravel aquifer in the vicinity of Vernon Marsh, Waukesha County, Wisconsin.

Model Description

The construction and calibration of the model was funded by the City of Muskego, the Villages of Mukwonago and East Troy, and the Waukesha Water Utility to be used as a tool for the development of new water resources in the Troy Bedrock Valley. The model is a three-dimensional finite difference model (MODFLOW – United States Geological Survey). It consists of five layers, simulating the unconfined, unconsolidated deposits in the Troy Bedrock Valley. This model was rigorously reviewed by experts at the Wisconsin Geological and Natural History Survey, and is therefore considered to accurately simulate the groundwater flow within the model domain.

MODFLOW consists of a series of mathematic "modules," with each simulating an aspect of groundwater flow. With respect to groundwater interaction with surface waters, two modules were used. "Drains" are features into which groundwater discharges. In the event that the simulated aquifer level drops below the user-selected elevation of a drain, the drain goes dry. "Rivers" are similar to drains except that they can discharge water to the aquifer if the aquifer level drops below the user-defined elevation of the river. Unlike drains, river cells do not go dry, and can therefore act as a source of water.

The model itself covers a large portion of Waukesha and Walworth Counties. The area of concern is the northern portion of Vernon Marsh, including reaches of the Fox River, Pebble Brook and Mill Brook, all located in the central area of the model. Consequently, simulated impacts of wells are not influenced by model boundary conditions. Surface waters of the model are simulated as rivers, and wetlands are simulated as drains. In the river option, surface waters can receive groundwater from the aquifer, or lose water to the aquifer. Drains can only receive water from the aquifer.

Additionally, the model used simulates steady-state conditions. That is, the model assumes that simulated wells are operating all the time, with the simulated flow rate being spread over a 24-hour period.

Typically, the most productive layer of the unconfined aquifer in the Troy Bedrock Valley is at the base of the unconsolidated deposits. Consequently, pumping wells were simulated in layers 4 and 5 of the model, which is consistent with the layers utilized by existing wells that were placed in the model during its construction.

Modeling Approach

For this work, two primary impacts were evaluated: A reduction in the baseflow to streams and wetlands, caused by the wells, and the number of private wells potentially impacted by the wells. Although private wells are not plotted, the figures show the number of private wells on record at the Wisconsin Department of Natural Resources in each Section. Baseflow reduction was estimated by calculating the changes in cell-to-cell flow, and relating that to the base run, in which no wells are simulated in this area.

Based on projected needs, two groups of scenarios were simulated. In the first, a total of 6.5 million gallons per day (MGD) were simulated from shallow wells, assuming that this water would be blended with 4.4 MGD from deep wells, for a total desired amount of 10.9 MGD. Two scenarios which are representative of the results of this group are presented.

Tables 1 and 2 summarize the wells simulated in each of the presented model runs, as well as the simulated pumping rates. Simulated well locations were based on various considerations. Wells 11, 12 and 13 are existing Waukesha Water Utility wells. The "Lather" wells are potential well locations that have already been located by Waukesha. "Troy" wells refer to potential wells in the Troy Bedrock Valley. These well locations were selected in an attempt to minimize the impacts to sensitive surface water features and private wells, and based on the potential availability of well sites.

Results

Figure 1 shows the drawdown simulated by Scenario 1-1. This scenario produced a maximum drawdown of 105 feet. This scenario places the stress directly in the area of the Fox River, resulting in a 240 percent reduction in baseflow (see Table 3), meaning that no groundwater is being discharged to the river in this area, and the aquifer is drawing a significant amount of water out of the river.

Scenario 1-2 spreads the stress in the areas of the Fox River and Pebble Brook. Figure 2 shows the simulated drawdown from this scenario. Although the maximum drawdown is significantly reduced in this scenario (50 feet), the reductions in baseflow are still high. As Table 3 shows, the baseflow reduction in the Fox River is still over 100 percent; however, the reduction in Pebble Brook is 61 percent. Because Pebble Brook is a trout stream, it is given special protections by Wisconsin water laws.

Two sets of results are also presented to represent the second group of scenarios, in which the projected daily need of 10.9 MGD is drawn entirely from the unconfined aquifer of the Troy Bedrock Valley. In the first scenario, the stress is again concentrated on the Fox River area. Figure 3 shows the simulated drawdown resulting from this model run. Although more wells are utilized in this run than in Scenario 1-1, the maximum drawdown is still 105 feet, with a baseflow reduction in the Fox River of 346 percent. Additionally, the flow reduction to Pebble Brook, which is some distance from the simulated wells, is 58 percent, and the marsh and Mill Brook are also significantly impacted.

Scenario 2-2 presents an extreme condition, in which stress is removed from the Fox River, and many wells are added. Most of the new wells were placed a distance from Pebble Brook (e.g., a mile or more), in an effort to reduce the impact to the brook, while at the same time minimize, to the extent possible, the significant well and distribution system costs. As Figure 4 shows, the maximum drawdown in this scenario is reduced to 55 feet; however, the reductions in baseflow are still very high. The aquifer continues to draw water from the Fox River, with a baseflow reduction of 156 percent. Reductions in baseflow to Pebble Brook and Mill Brook are 82 and 94 percent, respectively, and there is a 51 percent reduction to the sensitive environments of Vernon Marsh.

Summary

Numerous model runs were completed in an effort to develop a scenario by which the Waukesha Water Utility can obtain sufficient water from the unconfined aquifer of the Troy Bedrock Valley. Although this is a very productive aquifer, it is also the home to some very sensitive environmental features, such as the Vernon Marsh and Pebble Brook. Because the marsh relies a great deal on input from the Fox River, this stream is also an important environmental feature.

The first group of scenarios was run to consider the possibility of blending the water from the shallow aquifer with bedrock aquifer water, which is of a poorer quality. Not only did these scenarios reduce the baseflow of water to the Fox River, they actually showed the wells drawing water from the River. Although the direct baseflow reductions to the Vernon Marsh was relatively low (6 to 7 percent), the loss of surface water from the Fox River means that the impact to the marsh would be much greater than that.

The impacts from the second group of scenarios are much larger, even with the addition of numerous wells. The resulting reductions in baseflow to the Fox River range from 156 to 346 percent, compounding the simulated reduced baseflow to the Vernon Marsh of 17 to 51 percent. The reduction in flow to Pebble Brook is also significant, ranging from 58 to 82 percent.

Conclusions

Because the Fox River, Pebble Brook and Mill Brook converge on Vernon Marsh from the north and northeast, the groundwater discharge from the small area between these streams is split between them. Consequently, most of the base flow to this section of the Fox River comes from the west, while base flow to Pebble Brook and Mill Brook comes primarily from the east. As a result, even the placement of wells thousands of feet east of the Pebble Brook results in the interception of much of its baseflow.

Although by spreading the impact to the aquifer to more wells than were simulated in this effort, it may be possible to obtain acceptable baseflow reductions, it is clear from these analyses that many wells would be required, spaced over a very large area.

TABLES

TABLE 1 SIMULATED WELLS AND PUMPING RATES GROUP 1 - DEEP AND SHALLOW WAUKESHA WATER UTILITY

	PUMPING							
VVELL	RATE (MGD)							
SCENARIO 1-1								
11	0.6							
12	0.6							
13	1.1							
Lather 1	0.82							
Lather 2	0.82							
Lather 3	0.82							
Lather 4	0.82							
Lather 5	0.82							
Total	6.4							
SCENARIO 1-2								
11	0.376							
12	0.376							
13	0.376							
Lather 1	0.376							
Lather 2	0.376							
Lather 3	0.376							
Lather 4	0.376							
Lather 5	0.376							
Troy 1	0.376							
Troy 2	0.376							
Troy 3	0.376							
Troy 4	0.376							
Troy 5	0.376							
Troy 6	0.376							
Troy 7	0.376							
Troy 8	0.376							
Troy 9	0.376							
Total	6.4							

TABLE 2 SIMULATED WELLS AND PUMPING RATES GROUP2 - SHALLOW WELLS WAUKESHA WATER UTILITY

h							
WELL							
	RATE (MGD)						
SCENARIO 2-1							
11	0.6						
13	0.6						
Lather 1	1						
Lather 3	1						
Lather 5	1						
Troy 2	0.55						
Troy 3	0.55						
Troy 5	0.55						
Troy 6	0.55						
Fox 1	1.5						
Fox 3	1.5						
Fox 4	1.5						
TOTAL	10.9						
10	0.369						
12	0.369						
I Jothor 1	0.389						
Lather 1	0.389						
Lather 2	0.389						
Lather 3	0.389						
Lather 4	0.389						
Lather 5	0.389						
Troy 1	0.389						
I roy 2	0.389						
I roy 3	0.389						
Troy 4	0.389						
Troy 5	0.389						
Troy 6	0.389						
Troy 7	0.389						
Troy 8	0.389						
Troy 9	0.389						
Troy 10	0.389						
Troy 11	0.389						
Troy 12	0.389						
Troy 13	0.389						
Troy 14	0.389						
Troy 15	0.389						
Troy 16	0.389						
Troy 17	0.389						
Troy 18	0.389						
Troy 19	0.389						
Troy 20	0.389						
Total:	10.9						

TABLE 3 WAUKESHA WATER UTILITY SUMMARY OF FLOWS

RESOURCE	BASEFLOWS									
	BASE SCENARIO	SCENARIO 1-1		SCENARIO 1-2		SCENARIO 2-1		SCENARIO 2-2		
	GPD	GPD	PERCENT	GPD	PERCENT	GPD	PERCENT	GPD	PERCENT	
			REDUCTION		REDUCTION		REDUCTION		REDUCTION	
FOX RIVER	1,702,810	-2,384,868	240	-716,304	142	-4,188,052	346	-960,338	156	
PEBBLE BROOK	3,399,693	2,969,633	13	1,328,516	61	1,443,515	58	617,102	82	
VERNON MARSH	2,817,027	2,660,343	6	2,633,676	7	2,326,537	17	1,373,475	51	
MILL BROOK	687,910	615,123	11	488,956	29	483,495	30	42,239	94	
PEBBLE CREEK	553,948	440,009	21	503,946	9	424,346	23	501,104	10	

FIGURES







