LOUISIANA DEPARTMENT OF ENVIRONMENTAL QUALITY

Appendix 1

Estimates of Average Ground Water Velocities in Louisiana Aquifers and Delineation of Source Water Protection Areas

Introduction

In order to implement the State Wellhead Protection and Source Water Protection Programs, a protection area must be delineated around each public water supply well or wellfield in the state. Surveys to identify potential sources of contamination will then be conducted within the delineated protection areas. Since these surveys must be completed by the May 6, 2003, the delineated areas need to be small enough to survey within the given time frame and large enough to adequately protect the wells. Systems will be prioritized in the following manner: (1.) Wells shallower than 1000 feet, (2.) Wells deeper than 1000 feet constructed prior to the promulgation of DOTD Construction Standards of November 1985, (3.) Wells deeper than 1000 feet constructed after DOTD Construction Standards, and (4.) Transient Non-community wells. Protection areas will be delineated based on this prioritized ranking. The focus of this study is to provide a rationale for the proposed delineations.

The proposed protection area for wells shallower than 1000 feet is a one-mile radius around the well or wellfield. The proposed protection areas for wells 1000 feet or deeper will be a one-half mile radius for those drilled prior to the promulgation of the DOTD Construction Standards of November 1985, and a 1000 foot radius for those drilled after November of 1985. Wells deeper than 1000 feet are afforded an adequate measure of natural protection from surface and shallow subsurface contaminants by the presence of overlying, confining clay units. The presence of this natural protection is the rationale for using a smaller protection area around deep wells. Aside from any deep abandoned wells that may be present in the area, the most likely path of contaminant migration to deep aquifers would be through the annular space of the well itself, due to improper well construction and deterioration. This is the rationale behind using a larger protection area for wells constructed prior to construction standards.

For transient non-community wells, a 1000-foot radius is proposed. State enforcement records indicate that problems with these systems have been pathogen-related. Furthermore, the problems have been in the distribution systems and not the source water. Research indicates that pathogens have a finite life in the subsurface, estimating their viability to be from 18 months to 2 years (Wireman et al, 1997). A 1000-foot radius should be adequate for protection of such systems from pathogens.

Method

Estimates of ground water velocities in each of the state's aquifers are necessary in order to delineate appropriate wellhead protection areas (or source water protection areas). Ground water velocities in Louisiana vary from less than three feet per year in deep, confined aquifers to over 2,000 feet per year in terrace deposits. The average velocity of ground water movement can be estimated using values of hydraulic conductivity, hydraulic gradient, and effective porosity in the following equation:

$$V = \frac{K\,dh/dl}{N_e}$$

Where:

V = the average velocity of ground water movement in ft/day,

K = the hydraulic conductivity of the aquifer in ft/day,

dh/dl = the hydraulic gradient of the aquifer unit along a flow path (dimensionless), and

N_e = the effective porosity of the aquifer unit as a decimal fraction (dimensionless).

Both hydraulic gradient and hydraulic conductivity show substantial variation within each aquifer. Average values of hydraulic conductivity, hydraulic gradient, and effective porosity were used for each aquifer. Table 2, taken from the Louisiana Recharge Potential Map document, 1989, shows a range of hydraulic conductivities for each aquifer. The average value was used in the velocity calculations. Hydraulic gradients were obtained from available U.S.G.S. potentiometric surface maps for each aquifer. Several gradient measurements were made on each potentiometric surface map and an average value was used in the velocity calculation for each aquifer. Typical effective porosity values reported by the U.S.G.S. for Louisiana aquifers range from 0.20 (20%) to 0.30 (30%). All velocity calculations were made assuming an effective porosity of 0.25 (25%).

Results

Since the proposed protection area radius is one mile for wells shallower than 1000 feet, the time of travel for one mile was calculated for each aquifer. The results are given in Table 1. According to these results, a one-mile radius affords at least a five-year time of travel for all of the aquifers in the state with the exception of the Terrace Aquifers, which is a close 4.5-year time of travel. This allows adequate time for evaluation of effects and relocation of wells should a contamination incident take place within the protection area. The 2-year time of travel was also calculated for each aquifer to determine the suitability of the 1000-foot radius for transient non-community wells. With the exception of wells in the Terrace aquifer, the 1000-foot radius affords at least a 2-year time of travel to transient non-community wells. A half-mile radius will be used for transient non-community wells in the Terrace aquifer to account for the high average ground water velocity and afford a 2-year time of travel protection.

What these Estimates Are and What they Are Not: Important Considerations

The regional average ground water velocities resulting from this study provide reasonable estimates of average ground water flow on which to base protection area delineations. It is important to consider that these estimates are regional estimates. They do not reflect the heterogeneity and anisotropy (variability affecting flow rate and direction) inherent to Louisiana's aquifers. The geology is such that these variations occur over small areas where discontinuous units make predictability extremely difficult. Since these estimates were obtained using average values, they do not take into account localized areas where the hydraulic gradient or conductivity may be higher, or the porosity may be lower. Another consideration is increased ground water velocity in the vicinity of the well due to pumpage. These estimates do not reflect pumping effects such as large cones of depression created by large city wellfields. These considerations should be addressed as part of the susceptibility analysis for each water system. The susceptibility analysis will address the vulnerability of the system based on hydrogeology, age and depth of the wells, and the number and types of potential sources of contamination identified within the protection area.

These estimates are of ground water velocity, or rate of ground water movement within the aquifer. Likewise, they provide an estimate of the rate of movement of **dissolved** contaminants through the aquifer. These are contaminants that are dissolved in the ground water and therefore move with the ground water. Velocity estimates say nothing about the migration of non-dissolved contaminants such as LNAPLS (ÃƒÂ¢Ã¢â€šÂ¬Ã…â€œfloatersÃƒÂ¢Ã¢â€šÂ¬Ã‚Â) and DNAPLS (ÃƒÂ¢Ã¢â€šÂ¬Ã…â€œsinkersÃƒÂ¢Ã¢â€šÂ¬Ã‚Â). Site specific, detailed contaminant transport modeling which takes into account the aquifer properties, dispersion, advection, and the contaminant properties would be necessary to attempt to predict their potential path of migration. Such a study is well beyond the scope of statewide ground water protection activities.

One final point to consider is that the potential contamination sources located in closest proximity to the wells will pose the greatest threat. The greater the distance the less chance of contamination, because dilution, sorption, and degradation increase with distance (Knox et al, 1993). Most public water supply contamination incidents in the State of Louisiana have resulted from either leaking underground storage tanks or surface spills of gasoline in the vicinity of the wells. These plumes usually do not move beyond 1000 feet as natural bacteria in the soil usually breaks down the gasoline through natural degradation processes (Cherry, 1994).

References

Buono, Anthony. 1983. The Southern Hills Regional Aquifer System of Southeastern Louisiana and Southwestern Mississippi. Water Resources Investigations Report 83-4189. U.S. Geological Survey. Baton Rouge, LA. 38pp.

Cherry, John A. 1994. Ground Water Foundation Conference Presentation Summary. Infiltration. Vol. 3, No. 2. p. 3.

Dial, Don C. and Chabot Kilburn. 1980. Ground Water Resources of the Gramercy Area, Louisiana. Water Resources Technical Report No. 24. U.S. Geological Survey. Baton Rouge, LA 39 pp.

Knox, Robert C., David A. Sabatini,, and Larry W. Canter. 1993. Subsurface Transport and Fate Processes. Lewis Publishers. Boca Raton, FL. 430pp.

Louisiana Department of Environmental Quality. 1989. Recharge Potential of Louisiana Aquifers. Prepared by the Louisiana Geological Survey. Baton Rouge, LA. 50pp.

Nyman, Dale J. and Larry D. Fayard. 1978. Ground Water Resources of Tangipahoa and St. Tammany Parishes, Southeastern Louisiana. Water Resources Technical Report No. 15. U.S. Geological Survey. Baton Rouge, LA. 76 pp.

Rogers, J.E., and A.J. Calandro. 1965. Water Resources of Vernon Parish, Louisiana. Water Resources Bulletin No. 6. LA Dept. of Conservation, LA Geological Survey and LA Dept. of Public Works. Baton Rouge, LA. 104 pp.

Seanor, Ronald C. and Charles W. Smoot. 1995. Louisiana Ground-Water Map No. 8: Potentiometric Surface, 1991, of the Carrizo-Wilcox Aquifer in Northwestern Louisiana. Water Resources Investigations Report 95-4176. U.S. Geological Survey. Baton Rouge, LA.

-----. 1995. Louisiana Ground-Water Map No. 6: Potentiometric Surface, 1990, and Water Level Changes, 1974-90, of the Mississippi River Alluvial Aquifer in Northeastern Louisiana.

Smoot, Charles, W. and Angel Martin, Jr. 1991. Generalized Potentiometric Surfaces of the Red River Alluvial Aquifer, Pool 1, Red River Waterway Area, Central Louisiana. Water Resources Investigations Report 91-4109. U.S. Geological Survey. Baton Rouge, LA.

Smoot, Charles W. and Ronald C. Seanor. 1991. Louisiana Ground Water Map No. 3: Potentiometric Surface, 1989, and Water Level Changes, 1980-98, of the Sparta Aquifer in North-Central Louisiana. Water Resources Investigations Report 90-4183. U.S. Geological Survey. Baton Rouge, LA.

-----. 1992. Louisiana Ground-Water Map No. 4: Potentiometric Surface, 1989, and Water Level Changes, 1984-89, of the Jasper Aquifer System in West-Central Louisiana. Water Resources Investigations Report 91-4137. U.S. Geological Survey. Baton Rouge, LA.

Snider, J.L.. 1983. Ground-Water Resources of the Filmore-Haughton-Red Chute area, Bossier and Webster Parishes, Louisiana. Water Resources Technical Report No. 32. U.S. Geological Survey. Baton Rouge, LA. 21pp.

Snider, J.L. and T.H. Sanford, Jr. 1981. Water Resources of the Terrace Aquifers, Central Louisiana. Water Resources Technical Report No. 25. U.S. Geological Survey. Baton Rouge, LA. 48pp.

Stuart, C.G., Darwin Knochenmus, and Benton D. McGee. 1994. Guide to Louisiana's Ground-Water Resources. Water Resources Investigations Report 94-4085. U.S. Geological Survey. Baton Rouge, LA. 55pp.

Walters, David J. 1995. Louisiana Ground-Water Map No. 11: Potentiometric Surface, Spring 1993, and Water Level Changes, 1987-93, of the Gonzales-New Orleans Aquifer in Southeastern Louisiana. Water Resources Investigations Report 95-4169 U.S. Geological Survey. Baton Rouge, LA.

-----. 1996. Louisiana Ground-Water Map No. 10: Potentiometric Surface, 1991, and Water Level Changes, 1985-91, of the Chicot Aquifer System in Southwestern Louisiana. Water Resources Investigations Report 954044. U.S. Geological Survey. Baton Rouge, LA.

Wireman, Mike, et al. 1997. Draft Strawman for Assessment of Hydrogeologic/Source Barrier for Purposes of Implementing the Ground Water Disinfection Rule, U.S. EPA.

Table 1. Average Ground Water Velocity Estimates & Approximate 1 Mile Radius TOT

AQUIFER	dh/dl	K	Ne	V (ft/yr)	1 MILE TOT	2 Year TOT (ft)
Miss Rr Alluvial	0.00032	270 ft/d	0.25	126.1	41.9 yrs	252.2
Red Rr Alluvial	0.00047	270 ft/d	0.25	185.3	28.5 yrs	370.6

Terrace	0.00379	210ft/d	0.25	1162	4.5 yrs	2324
Chicot						
Upper Sand	0.00068	130 ft/d	0.25	129	40.9 yrs	258
500 Ft. Sand	0.00047	130 ft/d	0.25	89.2	59.2 yrs	178.4
Southern Hills						
600 Ft Sand (BR)	0.00126	105 ft/d	0.25	165.6	31.9 yrs	331.2

Gramercy	0.00022	105 ft/d	0.25	33.7	156.7 yrs	67.4
Gonzales-N.O.	0.00076	105 ft/d	0.25	116.1	45.5 yrs	232.2
Pontchatoula	0.00035	105 ft/d	0.25	53.8	98.1 yrs	107.6
1500 Ft Sand (BR)	0.00095	105 ft/d	0.25	145.2	36.4 yrs	290.4
Abita & Kentwood	0.00032	105 ft/d	0.25	48.4	109.1 yrs	96.8
2000 Ft Sand (BR)	0.00105	105 ft/d	0.25	161.3	32.7 yrs	322.6
Covington/Slidell	0.00047	105 ft/d	0.25	72.6	72.7 yrs	145.2
Hammond	0.00038	105 ft/d	0.25	58.1	90.9 yrs	116.2
Amite	0.00047	105 ft/d	0.25	72.6	72.7 yrs	145.2

Evangeline	0.00152	100 ft/d	0.25	222	23.8 yrs	444
Jasper (Miocene)						
Williamson Creek	0.00189	140 ft/d	0.25	386.3	13.7 yrs	772.6
Carnahan Bayou	0.00237	140 ft/d	0.25	484.4	10.9 yrs	968.8
Cockfield	0.00095	63 ft/d	0.25	87.1	60.6 yrs	174.2

Sparta	0.00108	63 ft/d	0.25	99.3	53.2 yrs	198.6
Carrizo-Wilcox	0.00101	21 ft/d	0.25	31	170.3 yrs	62

Table 2. Hydraulic Characteristics of the Aquifers in Louisiana

AQUIFER SYSTEM	**RANGE OF THICKNESS OF FRESHWATER INTERVAL (feet)**	**RANGE OF WELL DEPTHS (feet)**	**TYPICAL WELL YIELDS (gal/min)**	**HYDRAULIC CONDUCTIVITY (feet/day)**	**SPECIFIC CAPACITY (gal/min/ft of drawdown)**

ALLUVIAL	20 - 500	30 - 500	<500 - 4000	10 - 530	5 - 90
TERRACE of central and north Louisiana	20 - 150	40 - 150	40 - 400	150 - 270	1 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 50
CHICOT	50 - 1050	50 - 800	500 - 2500	40 - 220	2 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 35
SOUTHEAST LOUISIANA	50 - 600	<100 - 3300	100 - 2100	10 - 200	10 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 200
EVANGELINE	50 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 1900	200 - 2200	200 - 1000	20 - 180	2 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 38
MIOCENE of central Louisiana	50 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 1250	200 - 2200	50 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 1200	20 - 60	2 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 30
COCKFIELD	50 - 600	200 - 900	100 - 1800	25 - 100	1.5 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 75
SPARTA	50 - 700	200 - 900	100 - 1800	25 - 100	1.5 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 7.5

CARRIZO-WILCOX	50 - 850	100 - 600	30 - 300	2 - 40	0.5 ÃƒÂ¢Ã¢â€šÂ¬Ã¢â‚¬Å“ 4

From *Recharge Potential of Louisiana Aquifers*, prepared by the Louisiana Geological Society for the Louisiana Department of Environmental Quality, 1989.