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COORDINATING HYDROLOGIC AND LEGAL SYSTEMS FOR GROUNDWATER MANAGEMENT

by

Richard C. Peralta, Asst. Professor
Agricultural Engineering Department
University of Arkansas

Ann W. Peralta, Water Law Consultant

Les E. Mack, Director
Arkansas Water Resources Research Center
University of Arkansas

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SUMMARY:

A procedure is presented for developing a hydrologically and legally feasible groundwater management strategy for an area in a "reasonable use" state. Characteristics of the strategy are: Sustained yield, and drought and litigation protection.

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INTRODUCTION

Groundwater levels are declining in many parts of the United States. The Arkansas Grand Prairie is one such area. In Arkansas, persons owning land overlying an aquifer have an unquantified right to make "reasonable use" of the water. When groundwater mining causes wells to go dry, economic hardship results and the spectre of litigation raises its head.

> "Water problems and shortages breed controversy, which often requires court decisions to settle. Past court decisions were frequently controlled by outdated water laws built upon hydrologic assumptions now known to be fallacious or incomplete. Also, many of the past hydrologic studies were narrow in scope and were largely designed by engineers and hydrologists with little knowledge of the social sciences, economics, and law." (Hardt, 1979)

This paper presents a hydrologically and legally feasible method for addressing the groundwater problems of the Arkansas Grand Prairie. (See Figure 1) The method allows a responsive relationship between legal rights and hydrologic realities. It involves calculating the unique sustained yield pumping strategy for a predetermined set of "target" groundwater levels. If a management agency knows the desired levels (i.e. high enough to provide sufficient saturated thicknesses for drought, litigation protection, etc.) it may use this approach to determine the needed pumping rates to maintain those levels. An examination of applicable Arkansas water law is also presented.

THEORY AND EXAMPLE APPLICATION

Theory

The use of groundwater simulation models for prediction is commonplace. In such usage the inputs (i.e. pumping rights or values) are known. The resultant water levels are unknown and solved for. For management purposes it is often important to first determine what water levels are desired, and then to determine the pumping values which will maintain those levels. The following paragraphs describe a means of doing that.

The steady state form of the two dimensional flow equation has previously been used to initialize a linear groundwater simulation model at the proper water levels for the beginning of a time period. (Illangasekare and Morel-Seytoux, 1980; Verdin et al, 1981) For an isotropic heterogeneous aquifer the matrix form of this equation is:

$$[T]\ (S) = (Q)$$

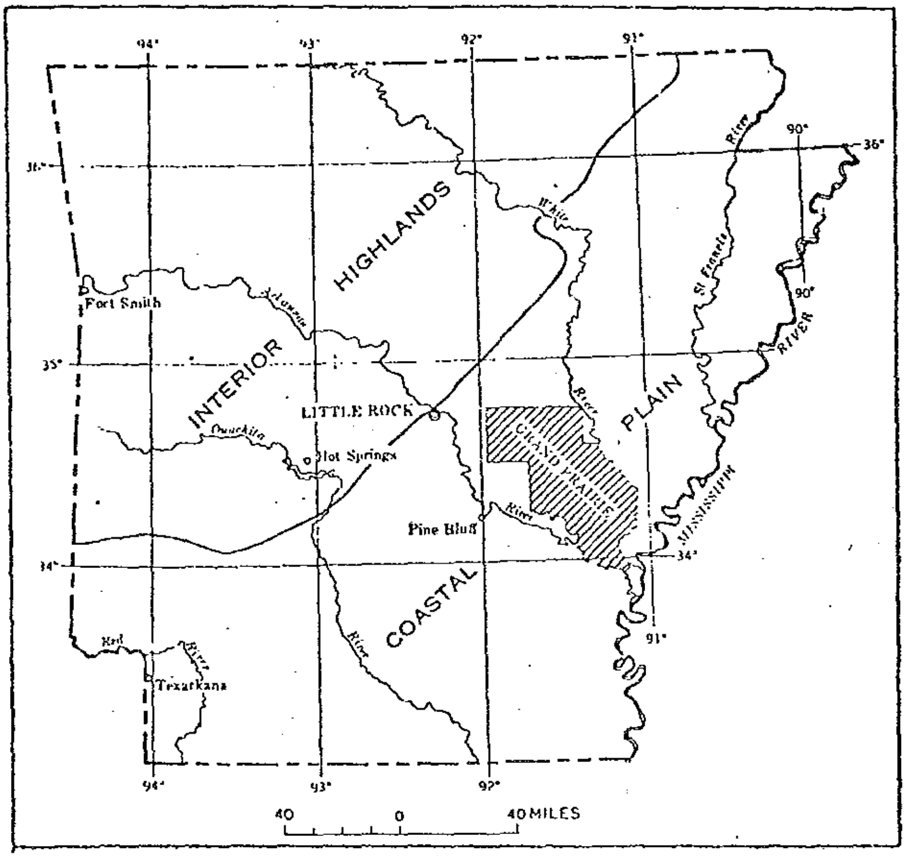

Figure 1. The Arkansas Grand Prairie

where

[T] is a symmetric matrix containing finite difference transmissivity values

(S) is a column vector of the drawdowns in the cells

(Q) is a vector containing the steady state pumping values of all cells

The steady state pumping rate for each cell is simply a linear combination of the transmissivity terms and the appropriate drawdowns. Determination of the pumping in each cell is therefore straightforward.

The steady state pumping strategy can also be utilized as a sustained yield pumping strategy. It is directly applicable in aquifer management if one can assume that the pumping from each cell of the aquifer is the same year after year and if the water levels can be assumed to be approximately the same year after year.

Development of a Sample Pumping Strategy

This section demonstrates the development of a sample sustained yield pumping strategy for the Grand Prairie. There are three steps involved in the development of a pumping strategy: validation of the [T] matrix, creation of the (S) array, and calculation of the (Q) array. The [T] matrix was validated for the Grand Prairie using the model previously referred to under unsteady conditions and using yearly time increments. The study area was limited to that shown in Figure 2. An (S) array was generated using the following procedure.

Observed spring water levels in all the cells were evaluated for the period 1972-1982. A composite water level map ("target map") was prepared utilizing the lowest observed elevation in each cell. This process produced unrealistic discontinuities in elevation between some cells. In such locations, the target levels were adjusted to smooth the synthetic surface somewhat. The final result is shown in Figure 3. Although it is not obvious without calculating gradients, the surface is still unrealistically rough. A more rigorous technique is used in developing a synthetic surface for actual management.

The model was modified to output the sustained yield pumping values for the input water levels. These values represent a cell-by-cell steady state sustained yield pumping strategy for the area being studied. The pumping which will maintain the "target" water levels is shown in Figure 4. Negative values indicate recharge, positive values represent withdrawal. The extreme nonuniformity in pumping between adjacent cells is eliminated by using proper constraints in the surface generation procedure.

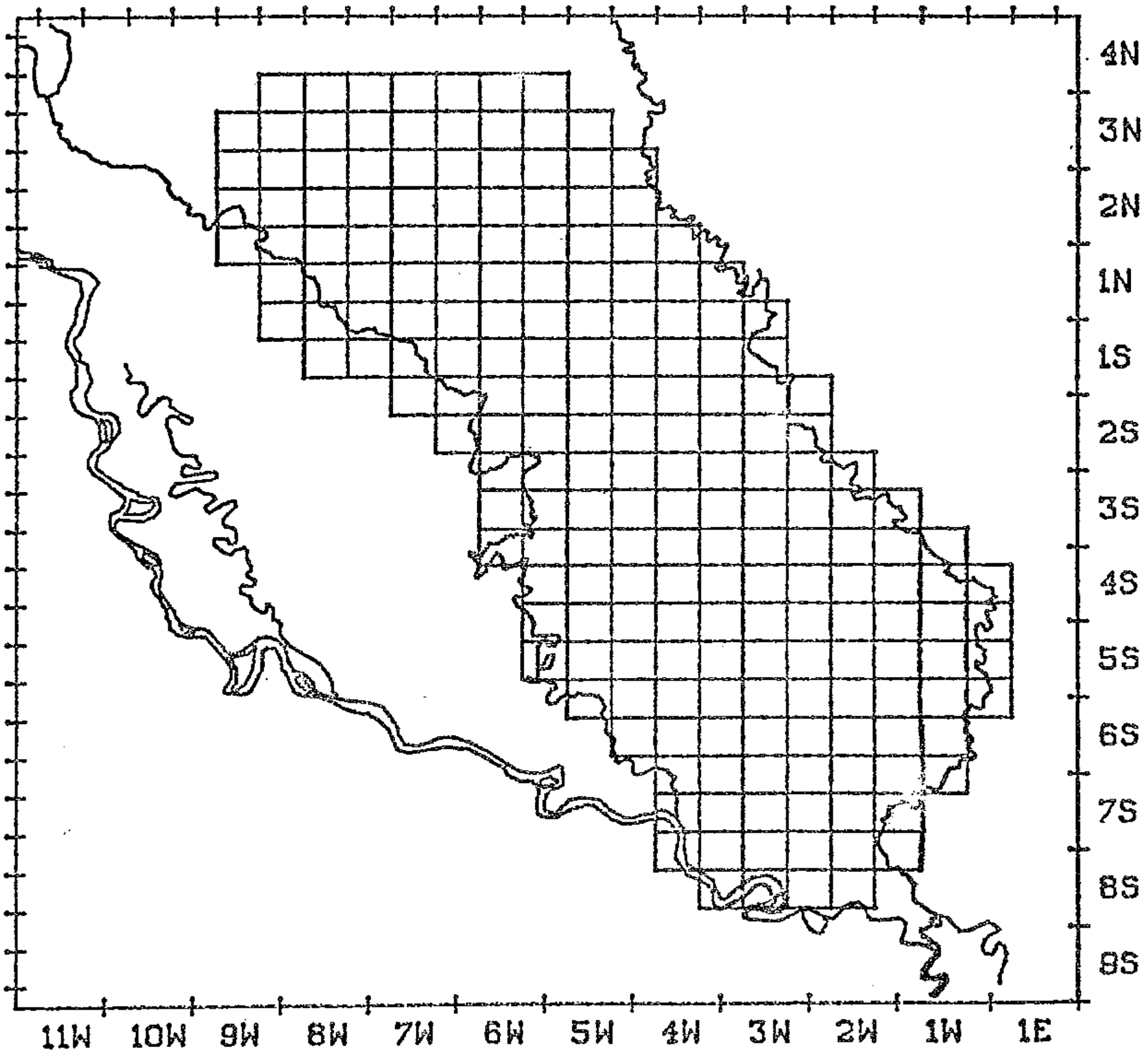

Figure 2. The Simulation Study Area

	194.9	179.6	173.0	159.3	152.5	150.9	147.3										
191.0	170.6	161.8	155.7	147.3	140.7	139.1	144.3	150.1									
167.6	153.3	148.6	141.8	132.8	127.9	132.2	138.7	145.7	154.4								
164.3	147.6	141.0	134.1	124.5	119.9	122.9	129.7	137.0	146.9								
172.0	141.0	137.4	129.6	122.6	119.9	119.8	118.8	124.8	135.6	144.1							
	152.6	139.1	128.4	124.0	121.6	118.2	115.1	117.8	125.8	136.3	147.4						
	158.4	145.6	134.9	126.9	124.1	118.4	114.1	111.3	119.1	130.0	139.1	151.7					
		158.8	149.8	138.6	131.0	126.2	115.2	107.3	110.2	122.0	134.1	146.9					
				153.9	142.6	132.5	118.1	102.7	104.9	115.5	127.5	138.4	149.0				
					150.7	137.8	121.2	105.8	106.3	110.3	121.5	131.8	142.9				
						143.9	125.8	109.7	103.8	108.0	115.7	125.6	134.1	142.4			
						147.0	130.8	111.9	102.7	105.2	109.9	119.4	127.6	135.0	142.8		
						153.7	138.8	117.3	101.8	100.1	106.1	115.5	122.3	129.2	134.9	138.8	
							145.9	129.1	107.7	101.5	104.2	112.8	119.8	125.5	130.5	133.5	138.0
							155.7	135.4	114.8	108.5	109.1	113.7	118.6	123.3	127.9	131.4	136.7
							163.5	145.0	127.3	116.3	114.1	116.1	119.4	122.6	125.7	128.3	133.1
								156.7	136.4	125.2	120.8	120.1	121.8	123.7	125.0	127.8	132.6
									148.2	131.2	126.9	124.9	125.1	125.8	126.8	130.5	
										142.7	132.7	129.6	128.5	128.0	128.0	131.3	
										145.7	139.6	135.6	132.4	130.3	129.9		
										144.2	142.5	139.8	135.8	131.8	131.5		
											152.1	147.1	139.2	133.5			

Figure 3. Example "Target" Elevations (Ft)

	-6710.	-1544.	-2774.	-179.	-492.	-978.	13.										
-7195.	3165.	1616.	137.	28.	172.	924.	13.	-1297.									
1103.	3544.	657.	625.	1086.	1118.	26.	30.	44.	-2933.								
-464.	1012.	212.	192.	1674.	1761.	559.	186.	431.	-2510.								
-6255.	7558.	100.	924.	1253.	682.	16.	1376.	1985.	150.	-3063.							
	-3640.	1723.	2998.	594.	157.	178.	836.	1377.	1835.	562.	-3853.						
	-4323.	2385.	2571.	3013.	566.	1228.	188.	804.	852.	265.	1917.	-3838.					
		-5156.	-3435.	1710.	1943.	103.	295.	525.	1277.	892.	653.	-3340.					
				-5528.	38.	15.	429.	1749.	1347.	917.	192.	601.	-3281.				
					-3054.	23.	47.	1882.	115.	2071.	209.	73.	-2276.				
						-2112.	393.	653.	816.	511.	1390.	208.	583.	-3184.			
						-966.	162.	614.	909.	36.	982.	594.	257.	586.	-3196.		
						-1653.	237.	683.	1126.	1193.	957.	18.	620.	175.	442.	-2163.	
							-1480.	41.	1814.	1237.	1373.	677.	243.	407.	62.	1126.	-1367
							-2606.	1247.	1347.	703.	490.	604.	227.	336.	43.	354.	-1648
							-3566.	866.	525.	863.	499.	574.	187.	340.	256.	966.	-265.
								-2911.	1216.	283.	326.	433.	311.	144.	826.	1123.	-896.
									-3025.	1586.	234.	249.	72.	184.	521.	-1270.	
										-1129.	511.	205.	58.	91.	936.	-961.	
										-1454.	186.	37.	15.	58.	9.		
										-87.	1130.	828.	244.	883.	-296.		
											-3117.	-2533.	-193.	905.			

Figure 4. An Example Sustained Yield Pumping Strategy. (Ac-Ft/ year)

FUTURE APPLICATION AND LEGAL FEASIBILITY

Objective of the Grand Prairie Water Supply Project

An objective of the Grand Prairie Water Supply Project is to have sufficient saturated thickness in all parts of the Prairie that wells will not go dry even during an extremely dry growing season. This requires the creation of a different synthetic surface than that described above. Reasonable assumptions can again be made for the levels in the constant head cells. The target levels for the other cells must also be determined. One method is to simulate (using weekly or monthly time steps) the response of the aquifer to pumping during a dry season. The results, combined with a knowledge of the actual wells, can be used to determine what the groundwater levels should be in the Spring to insure that wells do not go dry. These levels represent a "target" map for drought protection. A steady state pumping strategy can then be calculated which will maintain these target levels once they are reached.

It will take a number of years of management to achieve the target levels. During that period, and during the sustained yield era, pumping in some parts of the Prairie would need to be less than present pumping. To insure the continued availability of adequate water to meet water requirements, surface water will need to be diverted to those areas. Fortunately there are adequate surface water resources nearby to provide the supplemental water.

The Legal Setting

No matter how desirable a particular outcome is or how efficient an engineering solution to a water problem is, legal constraints must be considered. A basic understanding of Arkansas groundwater law is necessary to evaluate the utility of the strategy described above.

Groundwater rights in Arkansas are governed by "reasonable use". Ownership of land overlying an aquifer carries with it the right to use the groundwater therein. The water right is part and parcel of the land, and like other property rights, is protected by constitutional due process. The overlying landowner may use the amount of groundwater "necessary for some reasonable beneficial purpose in connection with his land," (Hutchins, 1974) as long as it does not interfere with the "reasonable use" of other overlying landowners. The determination of which uses are "reasonable" and which are "unreasonable" is made by the courts on a case by case basis as conflicts arise.

If the supply is insufficient, two modifications of the reasonable use rule apply. The Arkansas Supreme Court has favorably recognized the California correlative rights doctrine. (Jones vs. Oz-Ark-Val Poultry Co., 228 Ark. 76, 306 S.W., 2d, 111, 1957) Under correlative rights an overlying landowner is entitled only to his proportionate or pro-rated share of the available supply. An Arkansas statutory provision delineates priority of use during times of scarcity as: first, sustaining life, then maintaining health, and finally, increasing wealth. (Ark. Stat. sec. 21-1308) Accordingly, the Arkansas Supreme Court has ruled that "the use of a substantial quantity of groundwater for an industrial purpose which caused wells on adjoining land to go dry, and thus deprived landowners of water for domestic purposes was unreasonable." (Dewsnup and Jensen, 1973)

Agriculture, like industry, must yield to the priority given to domestic use. As groundwater levels on the Grand Prairie continue to fall, agricultural users will become increasingly vulnerable to litigation. Agricultural pumping may well be ruled "unreasonable" if the use of domestic wells is disrupted. In fact, some wells have gone dry and the water level under parts of the Grand Prairie has been dropping one foot per year for the last fifty years. A recent report confirms that groundwater sources cannot sustain the present level of use indefinitely. (Arce, 1982)

The drought of 1980 focused attention on potential and existing water problems in Arkansas. To protect the long term availability of the water resources, and to minimize conflict, consideration is being given to modifying present Arkansas water laws. A recent study by one of the authors suggests that moderate adjustments of the present legal system are more likely to gain popular acceptance and less likely to create constitutional conflict than are sweeping changes. (Peralta, A., 1982) The pumping strategy described insures protection of the groundwater resources of the Grand Prairie and provides an understandable and equitable definition of "reasonable use". Present groundwater rights would not have to undergo radical revision to accomodate the strategy. Nor would the state be required to create a massive water bureaucracy to utilize this method. A legal modification to allow some non-riparian use of supplemental surface water would be required. As long as no harm to present riparian users occurs, this should not present a major obstacle. For example, provision applying to a Grand Prairie water management district allowing the district to distribute surface water to its non-riparian users (as municipalities have long done) would be adequate.

SUMMARY AND CONCLUSIONS

One of the major weaknesses of existing water law in the United States is the tendency of legislators and judges to fashion water law without sufficient consideration for the characteristics of the hydrologic system. In the past, Arkansas waters have been plentiful enough to forestall most conflicts over water supply. This is no longer true in the Grand Prairie where demand for groundwater has increased dramatically and supplies have steadily decreased. Too often in such cases, a purely regulatory approach is taken (i.e. a rigid permitting system) which looks tidy on paper but which is out of synch with Mother Nature. Regulation is only one of the tools available to water managers and cannot be effective when used alone. (Crane, 1969)

The objectives of water management on the Grand Prairie are:

- to provide adequate water to users
- to provide drought protection
- to minimize litigation

Using a mathematical simulation model, a pumping strategy can be developed to help accomplish all three of these objectives. Before management of the resource is possible, its responses and limits must be understood and defined. The model calculates the response of groundwater levels to pumping. It also calculates sustained yield pumping rates that will produce predetermined saturated thicknesses. These saturated thicknesses can be selected to provide adequate groundwater reserves to keep domestic wells from going dry and to provide for times of drought. A technical/workable definition of "reasonable use" is that use compatible with the achievement of the three objectives listed above. If accepted by the courts, such a definition of reasonable use could make efficient and equitable water management on the Arkansas Grand Prairie a reality.

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