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The Performance of Appropriative Water Rights Systems in the Western United States During Drought

I. INTRODUCTION

The systems of water law known as the riparian and the appropriation doctrines differ considerably in their implications for water allocation during periods of water shortage. The western states have generally adopted some form of appropriation doctrine.[1] The West also experiences the lowest average annual precipitation and the most variable seasonal and annual precipitation patterns as compared to other regions. Thus, an understanding of the actual and potential performance of appropriation systems of water rights during periods of water shortage is crucial to improved response to shortages.

The efficiency implications of water rights systems have received relatively little economic analysis. Hartman and Seastone[2] analyzed the conditions necessary for the maximization of total benefits from water use on a river in the presence of return flows. They pointed out that a system allowing unfettered transferability of water rights would not account for impacts on users of return flows and could yield inefficient allocations of water. They further pointed out that the legal procedures established to protect third parties from the effects of changes in uses and/or points of diversion can involve substantial costs and delays, perhaps making transfers unduly difficult and thus inefficient.

Hartman and Seastone also provided a valuable comparative analysis of alternative institutional arrangements for the distribution and reallocation of water. They compared the economic efficiency of the procedures evolved by the Northern Colorado Water Conservancy District (distributor of the Colorado–Big Thompson Project Water) with the economic efficiency of the procedures initially used by the newer Southeastern Colorado Water Conservancy District (distributor of Frying Pan–Arkansas water).

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1. G. RADOSEVICH, K. NOLE, D. ALLARDICE, C. KIRKWOOD, EVOLUTION AND ADMINISTRATION OF COLORADO WATER LAW: 1876–1976 (1976).

2. L. M. HARTMAN, D. SEASTONE, WATER TRANSFERS, ECONOMIC EFFICIENCY, AND ALTERNATIVE INSTITUTIONS (1970).

Callaway[3] has provided an extensive economic efficiency analysis of alternative ways of allocating surface flows among users. His analysis considered quota systems, allocation by marginal value product, "rental markets," and saleable water rights. Callaway's analysis takes into account the timing of flows and return flows as well as the locations of water uses of different economic values and priorities.[4]

Burness and Quirk[5] investigated the possibility of efficient water allocation under appropriation doctrine through competitive market processes. Their analysis represents the only attempt to deal with large numbers of water users and the existence of competitive equilibria in such systems. However, their abstraction from the diversity of water uses, the complexity of return flows, and the sequential nature of the establishment of priorities make generalizations from their results difficult.

A recently completed study by Howe, Alexander, et al,[6] has further illuminated some of the problems encountered under Colorado water law during periods of drought. The study also addresses possibilities for improving the economic efficiency of response to drought.

The next two sections of this paper explain the principles of economically efficient water allocation among users and compare practices under appropriations doctrine with these principles, particularly to identify the sources of inefficiency during drought. The fourth section then describes some of the practices that have developed outside of appropriations doctrine proper to avert some of these inefficiencies. The final section then proposes other fundamental changes in water management institutions to further improve the efficiency of water allocation under the appropriation doctrine.

II. A SIMPLIFIED MODEL OF ECONOMICALLY EFFICIENT ALLOCATION OF RIVER WATER AMONG USERS

The following model is presented simply as a review of the basic principles required for the benefit-maximizing (efficient) allocation of water among users on a river. The model depicts efficient allocation in the short run given the ownership of water rights of various seniorities by the various users. The question of how rights of different seniorities

3. J. CALLAWAY, JR., THE OPTIMAL USE OF SURFACE WATER WITH RETURN FLOWS PRESENT: A THEORETICAL MODEL FOR DESIGNING ALTERNATIVE RISKS (1979).

4. This thesis was awarded the prize for outstanding M.S. thesis by the American Agricultural Economics Association in July, 1980.

5. Burness and Quirk, *Appropriative Water Rights and the Efficient Allocation of Resources*, 69 A.E.R. 25 (1979).

6. C. HOWE & P. ALEXANDER, DROUGHT INDUCED PROBLEMS AND RESPONSES OF SMALL TOWNS AND RURAL WATER ENTITIES IN COLORADO: THE 1976–1978 DROUGHT 524–50 (1980).

are distributed among users of differing characteristics in the long-run presents a vital issue, but it requires more research and will not be addressed here.

The model pictures two users, A upstream and B downstream, having benefit functions $B_a(Q_a)$ and $B_b(Q_b)$ respectively, where B_i might be stated in terms of thousands of dollars per year and Q_i represents the *diversions* of the i^{th} user.[7] Assuming that benefits increase with diversions up to some quantity $\hat{Q}_i$ at which marginal (incremental) benefits fall to zero seems reasonable. Methods of benefit measurement will not be treated here.

For expository purposes, we will attach weights of α to the benefits of A and β to those of B. Such weights could reflect a public policy decision to favor certain uses of water (i.e. agriculture over energy or recreation). The weights can also illustrate the effect that differing seniorities of water rights can have on water allocation. Economic efficiency requires discovering the particular pattern of water allocation that will maximize the net quantifiable benefits resulting from that water use. In simple mathematics, economic efficiency can be stated as: choosing Q_a and Q_b so as to:

$$(1) \quad \text{maximize } \{\alpha B_a(Q_a) + \beta B_b(Q_b)\}$$

subject to

$$(2) \quad Q_a \leq Q \text{ and}$$
$$Q_b \leq Q - cQ_a$$

where Q is the seasonal amount of river flow available at A's headgate and (c) is the consumptive fraction for A. The first constraint simply says that A can't divert more water than is in the river, while the second says that B can divert only what is not consumed by A.

This problem is extremely simple relative to any real-world situations. Yet quite a few different patterns of optimal allocation can result, the correct one depending on the data of the case.[8] For example, if $\hat{Q}_a$ and $\hat{Q}_b$ are the volumes of water use at which marginal benefits to the two users drop to zero, and if $Q > \hat{Q}_b + cQ_a$, there really is *no* allocation problem. That is, if the river flow is great enough to cover A's greatest beneficial consumptive use and B's maximum diversion needs, there really is *no* economic problem. In another case, if A's benefits are high relative to B's benefits, the efficient solution would call for A to divert all the water, leaving only the return flow for B. If B's benefits are the higher,

7. Where B represents the current price of water per acre foot per year and Q, the quantity (volume) of water diverted by each user.

8. *See* Appendix for complete solution.

letting all water by-pass A so that B gets it all may prove to be the best option.

A "more usual" type of solution would involve A and B sharing the total flow Q, with A diverting part of the flow while B uses the non-diverted part plus A's return flow. An efficient allocation of this type occurs only when the (weighted) marginal benefits of A's diversion equal B's (weighted) marginal benefits, both *evaluated from the total system viewpoint.* Mathematically this is stated as:

$$(3) \quad \alpha \cdot \frac{\partial B_a}{\partial Q_a} = \beta \cdot c \cdot \frac{\partial B_b}{\partial Q_b}$$

The expression $c \cdot \frac{\partial B_b}{\partial Q_b}$ represents the opportunity cost of the last acre-foot diverted by A, i.e. the marginal rate at which B is losing benefits because of the consumptive uses out of the last acre-foot diverted by A.

Special cases of (3) would include the one in which the social weights are equal, $\beta = \alpha$, so that A's marginal benefit just equals the benefits being foregone at the margin by B. *Only in the unlikely case that all of A's diversions are consumptive (i.e. $c = 1$) and $\alpha = \beta$ will economic efficiency call for equating the marginal benefits of the two users.*

As an example of the application of the efficiency condition given in (3), suppose that $\alpha = 1$, $\beta = 2$, and $c = 0.6$. Then the efficient allocation of water between A and B will require that marginal benefits for A should be 1.2 times the marginal benefits for B.

III. APPROPRIATIVE WATER RIGHTS AND THE EFFICIENT ALLOCATION OF WATER AMONG USERS.

We can interpret a *strict* form of appropriative water rights in terms of condition (3) above. Let us assume that the two parties had filed for rights in the amounts $\hat{Q}_a$ and $\hat{Q}_b$, representing the maximum amounts they can beneficially use, given their land holdings and water demands. Naturally, one or the other parties would own the senior right. If A is the senior, appropriations rules operate *as if* $\beta = 0$, as if no weight is given to B's benefits, and Q_a is determined by letting A divert any quantity up to $\hat{Q}_a$. If B is the senior, the opposite is true. Thus, in the short-run, appropriative water rights clearly violate the conditions needed for economic efficiency (3).

Thus far, we have treated Q (total volume of divertable water) as a known constant. In fact, Q is a random variable which fluctuates over time.

Efficient allocation over time requires that condition (3) hold at *all* points in time. In particular, when periods of low stream flow occur, condition (3) requires a reduction in water use by both A and B. As the severity of water shortage increases, reductions in use by both parties continue in the proportions necessary to maintain condition (3), at least until one use is reduced to zero. Again, a strict priority system would not permit this dynamic adjustment to occur, since the senior would get his or her full decree, $\hat{Q}_i$, before the other party got any.

The extent to which private profit motives affect the model warrants consideration. The profit motive may stimulate short-term exchanges of water that will maintain an efficient allocation among the rights owners. In the case of only two users along a river, the efficiency condition given by (3) would tend to be established by bargaining between the two parties. B would surely see that by borrowing or renting an acre-foot from A (paying A not to divert an acre-foot so it could flow down to B's headgate), he would experience a net gain of only a fraction c of an acre-foot. He therefore would be willing to pay A *at most* the marginal benefits to be gained from using an additional fraction c of an acre-foot $c \cdot \frac{3B_b}{\partial Q_b}$. If the marginal benefits to A are below this amount, he should be willing to rent the water. Thus bargaining should result in an efficient short run allocation.

If more than two users are involved, however, any transaction between two users would ignore the return flow effects on the others. The affect of transactions on return flows presents a case of true externalities, including possible diminished quantity and quality of return flow. Thus, operation of the market alone will yield inefficient short term transfers. While water courts will intervene in permanent water rights transfers that directly impair property rights of third parties, courts generally do not intervene in short term rental arrangements. In addition to ignoring third party effects, the market alone fails to account for both the desire to protect some sectors of the economy (e.g., agriculture) or aesthetic benefits factors denoted by the weights α and β above.

Thus, while privately motivated rentals of water during droughts tend to promote efficiency, the unaided market process may ignore third party effects and various social goals or objectives. The market system cannot yield completely efficient results.

IV. EXISTING PRACTICES THAT INCREASE THE EFFICIENCY OF WATER RIGHTS SYSTEMS DURING DROUGHT

Fortunately, water use patterns need not be as rigid as a strict interpretation of appropriation doctrine would imply. As noted in Section III, rights holders can share or sell some of their water on a short term basis.

Even if the water rental process fails to account for third party effects and various social goals, it greatly improves economic efficiency. This section describes additional practices observed in Colorado which mitigate the effects of drought. This description derives primarily from observations made during the drought of 1976–78.[9] Significantly, many of these actions were *locally* initiated.

A. Cooperative pooling of water within small drainage basins.

Under such pooling arrangements, the rights holders simply agree to share the total water available to them. Such arrangements occurred voluntarily in cases involving no more than 5 or 6 parties. In larger areas involving as many as 15 or 20 rights holders, the local Division Engineer's Staff sometimes negotiated cooperative agreements. Such arrangements, involving no payments to the seniors, were surprisingly prevalent in Colorado during the first year of the drought. They tended to break down after the first year.

These arrangements improve economic efficiency. They allow all users access to some water, instead of permitting the seniors to use water up to the point when its marginal value drops to zero. Also, they encourage the application of water where its marginal value is highest, rather than to small increases in the crops of the seniors.

B. Water rental or water banking practices wherein groups of juniors paid seniors for the use of water

These arrangements were frequent and tended to continue through the drought. The practice involved agriculture-to-agriculture sales, agriculture-to-town sales, and town-to-agriculture sales. The Bureau of Reclamation's "water bank" money was intended to stimulate such arrangements, although in practice these funds often simply substituted for private money already being used in such arrangements. The efficiency-increasing effects here parallel those attributable to cooperative pooling arrangements.

C. Cooperative storage of water

In rural irrigation districts where physical layout of the reservoir and canal systems permitted, water users consolidated storage of the smaller volume of available water in the larger, tighter reservoirs. Storage consolidation minimized evaporative and seepage losses.

The Conejos Water Conservancy District provides another example of a cooperative storage strategy. This District acts as the contracting agency with the United States for the repayment of the irrigators' portion of the

9. HOWE & ALEXANDER, *supra* note 6, at 43–53.

cost of construction of Platoro Reservoir, high on the Conejos River in southern Colorado. Certain provisions of the Rio Grande Compact prevent the District in recent years from storing water under its reservoir storage right. In 1980, by voluntary agreement of the irrigators, with the cooperation of the Rio Grande Compact Commission, and under the leadership of the Colorado State Engineer, direct flow irrigation rights were stored in Platoro Reservoir and subsequently released to the irrigators throughout the growing season. Direct flow rights usually cannot be stored legally, but storing some of these flows earlier in the season meant more water for everyone in the District. The experiment proved successful and could be widely imitated.

Both of these storage arrangements promote efficiency. The first reduces the volumes of water lost through reservoir evaporation and seepage and can facilitate water rentals over a wider area if the larger reservoir has a larger command area. The second type, exemplified by the Conejos District storage strategy, permits the conversion of non-usable direct flow rights into an inventory of water available for use during the entire season.

D. "Futile calls" on deliveries to certain seniors

Under Colorado law, the Division Engineer can declare certain deliveries "futile," or physically impossible to accomplish. Situations involving futile calls arise during periods of very low flow and where a senior is located far downstream. Strict priority would deny diversions to upstream juniors, but the water would never reach the senior, thus being wasted—at least for immediate uses. The Division Engineer makes futile call declarations sparingly, and the senior may seek legal recourse by getting the water court to set aside the ruling. The reasonableness of such rulings in the past, however, has made such challenges rare. The extent of discretion that should be granted the District Engineer in this matter presents an interesting question.

V. CONCLUSIONS AND RECOMMENDATIONS REGARDING EFFICIENCY-INCREASING CHANGES IN WATER MANAGEMENT INSTITUTIONS

Present use patterns emphasize the importance of efficient utilization of water supplies in the West. We now use about 90 percent of our water for agricultural purposes and the remaining 10 percent is consumed in all municipal, domestic, and industrial uses. If agricultural efficiency could be increased by only 10 percent, the quantity of water available for municipal, domestic, and industrial uses would be doubled.

The study by Howe, Alexander, *et al* pointed out the great variability in climatic and hydrologic conditions that existed within one state during the 1976–78 drought.[10] The study also pointed out many steps that can be taken at the local level to mitigate the adverse effects of drought (e.g. by reducing water losses and improving the allocation of water among users). Thus, *local initiative* in establishing local climate patterns, identifying available local actions, and acting in a timely fashion comprises an important component of a successful drought mitigation strategy. Statewide and federal drought programs have a role to pay in mitigation plans. Unfortunately, these programs frequently serve to discourage rather than stimulate local initiative.[11]

Some other fundamental institutional reforms that would facilitate the short-term and long-term flexibility and efficiency of water allocation include the following possibilities:

1. *More flexible water ownership rules.* The establishment of an agency that files for (or buys) water rights under state laws and then sells the water produced to another entity can avert the inflexibilities imposed by state water laws. The Bureau of Reclamation's sale of Colorado–Big Thompson water to the Northern Colorado Water Conservancy District provides an extremely effective example of such an arrangement. Federal, state, or private storage and transport systems all require that appropriate state water rights be owned before storage can begin. The Colorado–Big Thompson Project in Colorado (a Bureau of Reclamation Project of the late 1930s and early post-war period) filed for junior storage rights on the Upper Colorado River in the 1930s. The Bureau then sold water by contract to the Northern Colorado Water Conservancy District which distributes the water to its members. The members hold title to the water under the regulations of the District, free of considerations of state water law. Owners of water allotments in the District are permitted to sell their allotments freely to any party within the District boundaries (subject to approval of the Board of Directors, mostly to protect against pure speculation in water) or to rent any part of it short-term. The high degree of hydraulic control achieved by the canal and reservoir system and the retention of ownership of return flows in the District provides protection of District members from adverse return-flow effects.

The results of this great flexibility in water allocation include (1) very high efficiency in on-farm irrigation application, and (2) a ready source of water for new industries or towns established within the District's boundaries. Congress should encourage the Bureau of Reclamation to write similar contracts on current projects.

2. *Acquisition and Administration of Water Rights by Conservancy Districts.* In areas served by traditional water rights only, the acquisition

10. *Id.* at 1–23.
11. *Id.* at 69–79.

by water conservancy districts of all or a substantial part of the water rights in a basin would permit the reallocation of those rights on a competitive contract basis. Control of these rights could be acquired by contract with the owner, or title could be obtained through purchase or condemnation. Conservancy districts, organized under the general conservancy district act[12] or under specific legislature authorization[13] not only have authority to purchase water rights, but also the "power of eminent domain and dominant eminent domain . . ." (i.e. the authority to condemn rights held by other public entities).

Annual charges against water users would permit recovery of the cost of acquisition and contracts could be structured so as to reduce, if not eliminate, waste. Total control by a conservancy district could either prevent or accelerate the transfer of water for agriculture to municipal use, depending on the policy of the governing board of the district. Various conservation measures such as ditch lining, sprinkler or trickle irrigation and other water-saving practices could be made a condition precedent to the granting of a water contract. This practice would result in less frequent curtailment of use in times of drought, and, in normal times, would make water available for new uses which could not be served before.

The Southeast Colorado Water Conservancy District provides an example of the use of this type of contract by a conservancy district. Annual contracts approved by the Board of Directors of the District govern distribution of water from the federal Fryingpan–Arkansas Project. These contracts need not be renewed and therefore potentially permit great flexibility in the allocation of water. However, such short term contracts are likely to inhibit longer term investments dependent on water. The contract period could be extended.

Most contract arrangements involve a common problem. Some "board" must decide who gets the contracts. The information requirements for such a board decision are tremendous, since the board must select from the changing set of economic actors the party deserving a contract. These varied information requirements suggest that conservancy districts, having acquired the water rights or having contracted with the Bureau of Reclamation for water, should be allowed to establish saleable shares and facilitate the working of a market in these shares. Then the informed business calculations of different users would determine who would buy the rights and who would use the water. Such a system would eliminate the need to establish requirements for canal lining or other conservation techniques, since the marketability of water would motivate such steps whenever the value of water warranted them.

12. 37 COLO. REV. STAT. §45 (1973).
13. 37 COLO. REV. STAT. §§46–48 (1973).

A system of administrative acquisition and distribution of water rights certainly entails the potential for making all parties better off. Such a system could also encourage water quantity safeguards and yield handsome monetary compensation for the owners of the acquired rights. Unfortunately, the concept of such pooling has long been anathema to the holders of senior water rights and is probably politically infeasible at present. Emotions still overrule reason often in western water affairs.

3. *The establishment of a state or interstate agency that would "make a market" in water rights.* Such an agency would stand ready to buy rights at a known schedule of prices and to sell rights to new users. The existence of such a program would inform water users of the value of water and would facilitate the transfer of rights to new, evolving or more efficient uses. The agency would have to provide compensation for injured third parties. The creation of a new agency (especially an interstate agency) with such powers is probably politically impossible at this time because of state sensitivity to infringements on their controls over water. However, the success of the processes outlined in paragraphs 1 and 2 above would logically extend to such an expanded program.

4. *Development of climate information and forecasting programs specific to substate areas.* Such a program would define certain sets of conditions that would aid in the determination of certain "alert" and "trigger" levels of key climate variables for each substate region so that local initiatives can be taken in a timely fashion. Such a program would also facilitate the rational coordination of state and federal programs.[14]

5. *Extension training and information programs.* Such programs teach the individual irrigator how and when to apply water more efficiently. The Bureau of Reclamation has already undertaken initial steps in this type of program. The Bureau has conducted programs to demonstrate the appropriate time to apply water in order to maximize benefits and minimize waste. These experiments, in Western Nebraska and in the Grand Valley area of Colorado, indicate not only water saving potential, but also a reduction in salinity in return flows from irrigation.

All of these steps warrant serious policy consideration and further study. Improvements can be made *within the existing framework of appropriative water law* to enhance the efficiency of water allocation, in both the short and long terms. The changes proposed here would encourage short-term rentals and facilitate long-term transfers of rights, and would consequently promote greater flexibility in the appropriative system. Greater flexibility thus appears to be the key to improving the performance of the appropriative water rights system.

14. HOWE & ALEXANDER, *supra* note 6, at 77–79.

APPENDIX

DERIVATION OF THE NECESSARY CONDITIONS FOR EFFICIENT WATER ALLOCATION

The Lagrangean function for the problem described by equations (1) and (2) in the text is:

$$(4)\quad L(Q_a, Q_b, \lambda_1, \lambda_2) = \alpha \cdot B_a(Q_a) + \beta \cdot B_b(Q_b) + \lambda_1(Q - Q_a) + \lambda_2(Q - cQ_a - Q_b)$$

The necessary (Kuhn-Tucker) conditions for a maximum are:

$$(5)\quad \frac{\partial L}{\partial Q_a} = \alpha \cdot \frac{\partial B_a}{\partial Q_a} - \lambda_1 - c\lambda_2 \leq 0 \text{ and } \frac{\partial L}{\partial Q_a} \cdot Q_a = 0$$

$$(6)\quad \frac{\partial L}{\partial Q_b} = \beta \cdot \frac{\partial B_b}{\partial Q_b} - \lambda_2 \leq 0 \text{ and } \frac{\partial L}{\partial Q_b} \cdot Q_b = 0$$

$$(7)\quad \frac{\partial L}{\partial \lambda_1} = Q - Q_a \geq 0 \text{ and } \frac{\partial L}{\partial \lambda_1} \cdot \lambda_1 = 0$$

$$(8)\quad \frac{\partial L}{\partial \lambda_2} = Q - c \cdot Q_a - Q_b \geq 0 \text{ and } \frac{\partial L}{\partial \lambda_2} \cdot \lambda_2 = 0$$

In the cases where neither constraint is binding at the optimum, $\lambda_1^* = \lambda_2^* = 0$ and $Q_a^* = \hat{Q}_a$ and $Q_b^* = \hat{Q}_b$.

In the cases where the first constraint is binding at the optimum (and assuming $\lambda_1^* > 0$), it follows that $Q_a^* = Q$ and $Q_b^* = (1 - c)Q$ or $\hat{Q}_b$, whichever is smaller.

Finally, if only the second constraint is binding (and $\lambda_2^* > 0$), conditions (5) and (6) combine to give the condition:

$$(9)\quad \frac{\partial B_a}{\partial Q_a} \leq \left(\frac{\beta}{\alpha}\right) \cdot c \cdot \frac{\partial B_b}{\partial Q_b}$$

If the inequality holds strictly, then $Q_a^* = 0$ and $Q_b^* = Q$. If (9) is an equality, then A diverts some amount $Q^* < Q$ such that the equality holds.