# ECONOMIC AND ENVIRONMENTAL IMPACTS OF A LARGE SCALE WATER TRANSFER IN THE COLORADO RIVER BASIN

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## ABSTRACT

*The direct economic, and offsite environmental, impacts of a 400,000 acre foot water transfer between irrigators in the Upper Basin of the Colorado River and urban users in the Lower Basin was examined. Results indicated that the transfer would result in considerable offsite benefits, with minimal disruption to local agriculture.*

## INTRODUCTION

Recent legislative actions by Western states are evidence of their "coming to terms" with pressures to use economic criteria in allocating surface waters. California, for instance, opened the door for increased intrastate transfers by allowing individuals access to unused capacity in conveyance facilities (1). The Colorado state legislature imposed a $50 per acre foot tax on water exported from the state in excess of established compacts, despite the fact that such interstate tranfers between individuals are prohibited (2). In addition, the Western Governors Association sponsored research which encouraged orderly voluntary tranfers of existing water rights as an alternative to expensive water development programs (3). Even the traditionally conservative Bureau of Reclamation has promised to "facilitate the transfer of water between willing buyers and sellers" (4).

Two interested parties who could potentially be affected, and possibly benefit, from the above institutional changes are the water users of Southern California and private sector investors attempting to divert excess water from the Upper Colorado River basin to San Diego. Southern California, especially member agencies of the Metropolitan Water District (MWD), is facing the loss of nearly one-half million acre feet due to the Central Arizona Project's (CAP) ability to draw Arizona's full share of the Colorado River for the first time. This situation - plus growing northern California opposition to a cross Delta facility, continued rapid population growth in their service area, and a recent legal setback with diversions from the Mono basin - puts a great deal of pressure upon MWD to find additional economical short and long term water supplies. Hoping to profit from this situation is a consortium of private investors under the name of the Galloway Group Ltd. Their controversial 1984 proposal was to impound from 300,000 to 500,000 acre feet of agricultural and other less perfected water rights from the Upper Colorado basin, particularly Colorado's Yampa and White sub-basins, and lease it to San Diego County Water Authority for an indefinite period (5). Although apparently dead for lack of initial investment (6), the Galloway proposal might have withstood the significant institutional barriers in its path if its backers had been willing

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to wait out the litigation. Among the more notable barriers are the Colorado River Compact, Arizona v. California, the Upper Basin Agreement, state water laws, and Bureau of Reclamation contracts tying water to certain project areas.

Challenging this institutional structure are the above recent state level changes and the well publicized Sporhase decision, which ruled that water is an article of interstate commerce as defined by the Commerce Clause (102 S. Ct. 613, 1982) and states that any legislation or regulation which poses an "impermissable burden" on interstate commerce can be judicially invalidated.

A serious obstacle to the success of the Galloway proposal was the ajudication of the water they claimed rights to. Colorado, like most states employing the prior appropriation doctrine, allows only the consumptive use portion of a water right can be transferred. Much of Galloway's water is suspected of having no history of consumptive use, making it difficult to assess the volume eligible for transfer.

## OBJECTIVES

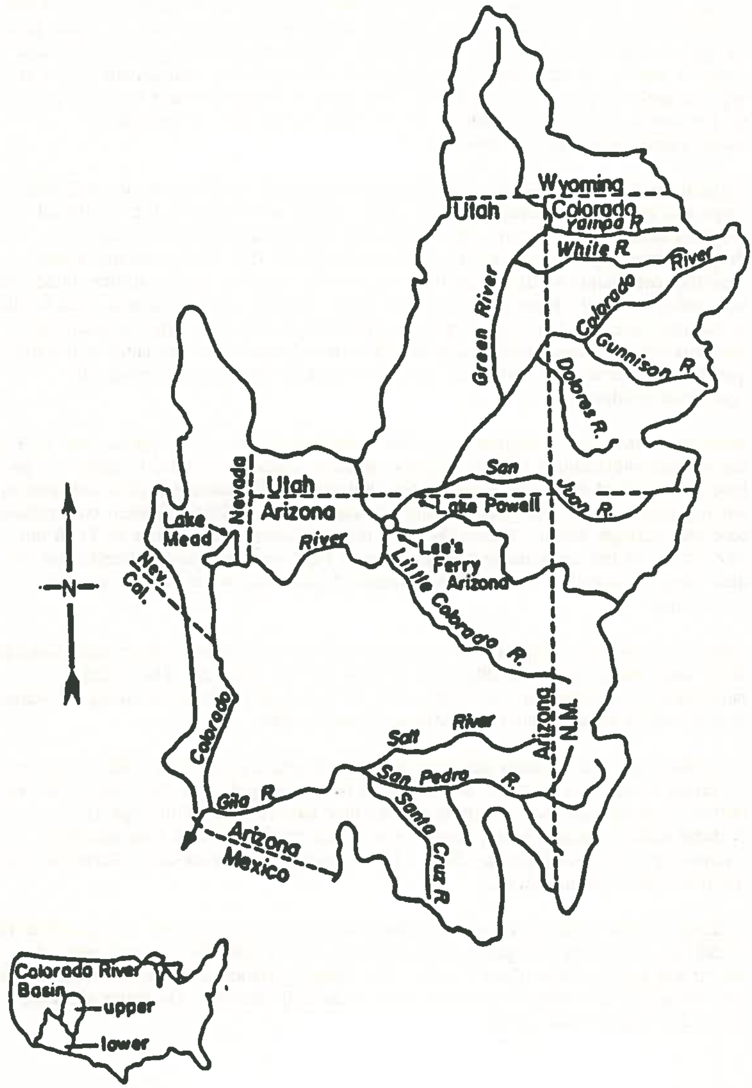
This paper analyzes the direct economic and offsite environmental impacts of the Galloway proposal assuming that the water rights in question come out of one of the lowest valued, quantifiable use in the Upper Basin, namely irrigated agriculture. Specifically, it estimates the marginal value of water for irrigated agriculture to the Upper Basin for the amount involved in the transfer, and estimates the land use, production, agriculture income, and input expenditure changes in the region that result. It also estimates the changes in river quality, as measured by salinity, and changes in the river flow, measured by hydroelectic energy produced at the intervening dam sites, stemming from the transfer. The recipient of this transferred water is presumably San Diego, but the analysis could apply equally to any Lower Basin user.

## METHOD OF ANALYSIS

Three mathematical programming models were developed to measure the value of water to irrigated agriculture, each corresponding to a sub-basin within the Upper Colorado River. The models were originally subsets of the Center for Agricultural and Rural Development (CARD) linear programs of U.S. agricultural production and corresponded to their producing areas (PA's) 82, 83, and 84 (7). PA 82 represents the Green River system, including the Yampa and White Rivers (Figure 1). PA 83 encompasses the Colorado main stem, and the Grand, Dolores, and Gunnison Valleys. The upper and lower San Juan Valleys are represented by PA 84. These PA's correspond to the Water Resource Council's aggregate subareas 1401, 1402, and 1403, respectively. The three models were developed with a profit maximizing criteria, incorporating both dryland and irrigated crop production activities. Irrigated crops include corn grain and silage, wheat, barley, alfalfa, and "other" hay. Wheat and other hay are the dryland crop alternatives. Rotations, rather than single crop alternatives, were considered for this analysis. Both irrigated and dry cropland are divided into 8 groups reflecting qualitative differences in land and corresponding yield differences.

Although land and water are the only constraining resources, other resources and inputs are tracked with accounting rows for insight to the severity of secondary impacts on the local economies. Land contraints for endogenous crops and potential cropland were obtained from the 1982 National Resources Inventory (8). The upper limit on surface

Figure 1. The Colorado River and its tributaries



water supplies is the sum of the consumptive use requirements for the crops times their base year acreages.

The models assume irrigators are price takers through fixed output prices. Land use, output prices, and input costs are based at 1984 levels, the most recent year for which full information is available. Each assumes a fixed technology in the sense that there is no opportunity to move down the production function by practicing deficit irrigation to conserve water. On-farm irrigation application efficiencies are also assumed fixed at approximately 50 percent for each PA. The value of irrigation water implied by the models would have to be considered on the high side in light of the lack of technological substitution possiblities.

Preliminary baseline results indicated implausible specialization in certain profitable crops and virtually no acreage of other crops. As an alternative to the traditional cropland flexibility constraints, the models then incorporated Positive Quadratic Programming (PQP), as put forth by Howitt and Mean (9). This technique avoids flexibility constraints by first calibrating the models with land use constraints intact, and then using the dual values associated with them to derive a quadratic cost term to add to the objective function value of the crop production activities. This quadratic term accounts for the unmeasurable costs of risk, seasonal machinery and labor availability, qualitative differences in soil types, and other unobservable factors inherent in agricultual production.

Although convenient in implementing and defendable in short run applications, PQP has the obvious shortcoming of distorting the objective function in order to achieve a given base level of land use. The objective function value then becomes a poor indicator of net regional income. For example, one PA had a value of $835,000 when constrained to base year acreage levels. Adding the PQP term increased the objective to $13.6 mil. The impact of this undesirable characteristic of PQP was much less noticeable on the dual value of irrigation water, having minimal impact until water became severely constrained.

Offsite environmental impacts were assessed with the Bureau of Reclamation's Colorado River Simulation System (CRSS) (10), adapted for this research. The model is particularly well suited for this analysis due to its regional delineation along sub-basins and the ability to easily alter its institutional constraints.

Historical river and tributary flows are the hydrological inputs to the CRSS which can be varied by the user to match any historical record desired. For this study, a 30 year period of record was used incorporating the flow pattern of 1922 through 1951. Sectoral water demands, return flows, institutional constraints, and river operation criteria are exogenous input to CRSS. The bureau supplied necessary information for the their 1986 baseline values.

Linking the two modeling frameworks was a straight forward process. Output from the CRSS model regarding irrigation water delivery to each sub-basin for each year of record was aggregated to the PA level. The annual variation in these deiveries was then used to adjust the surface water constraint in the PQP models. The latter are then solved for each year of record.

## PROCEDURES

Activities were developed to transfer water to the Lower Basin when it becomes more profitable than its value to irrigation. By parameterizing water's selling (or leasing) price in the PQP models and summing the water transferred at each price across PA's, a normative supply curve for Upper Basin irrigation water can be derived. This supply curve can then be used to observe how much water might be forthcoming from the basin as a whole at given water prices.

The volume of water transferred in this analysis is assumed to be 400,000 acre feet, the mid-range of the Galloway Proposal. The above supply relationship determines where in the basin this amount could be most economically obtained and its marginal value was to irrigation.

Drought years will surely drive up water's marginal value to agriculture. Annual variation in deliveries were observed from the CRSS model over its 30 year period of record and the corresponding change in water value resulting from it can be derived from the supply curves.

Adjusting the CRSS model to reflect the transfer proposal involves allowing an additional 400,000 acre feet in excess of existing compacts to pass through Glen Canyon and Hoover Dams annually to reach the intake of the Colorado River Aqueduct at Lake Havasu. Upper Basin demand and return flow figures are adjusted, based on the results of the previous exercise, to capture the decreased salt loading and increasing flows at certain locations on the river system. Resulting changes in salinity and hydropower production resulting from this were then observed over the period of record and valuated with estimates from other previous studies.

## RESULTS OF THE ANALYSIS

Parameterizing the selling price of water resulted in two normative supply curves depending on how land conversion was handled. Assuming that after the water is sold the formerly irrigated land can revert to dryland production yielded a lower marginal value of water than a no conversion situation (Figures 2 and 3). With conversion possiblities, about 1.8 million acre feet of Upper Basin irrigation water have a marginal value of $40 per acre foot or less. Without conversion, the same volume has a value topping out at $70 per acre foot. Both situations illustrate the low value of irrigation water here and are generally consistent with previous studies by Gisser (11) and Howe (12).

At a transfer level of 400,000 acre feet, with conversion possibilities, a marginal value of $5.05 was derived from Figure 3. Similarly, but without conversion, a value of $9.40 resulted. It is difficult to definitively state whether conversion to dryland production is feasible or not. In some areas of the Upper Basin it would be possible, but in other areas possibly not due to extreme aridity. For brevity, the remainder of the analysis will present only the results for the case with conversion.

Table 1 illustrates changes resulting from the transfer of water use, cropping patterns, production, and other itemized variables from their base levels. Of note in Table 1 is the slight increase in land use in PA 82 resulting from previously idle lands being brought into dryland production. More important, however, is the observation that a 22 percent reduction in total consumptive of irrigation water results in a much less than proportional decrease in the recorded variables.

Figure 2. A normative supply curve for Upper Basin irrigation water assuming land conversion from irrigated to dryland is feasible

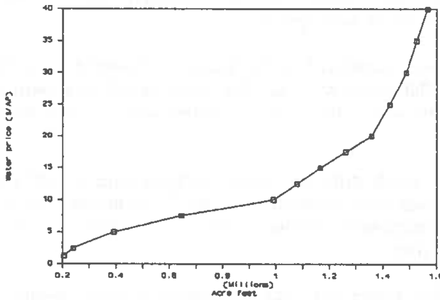



Figure 3. A normative supply curve for Upper Basin irrigation water assuming no land conversion from irrigated to dryland production

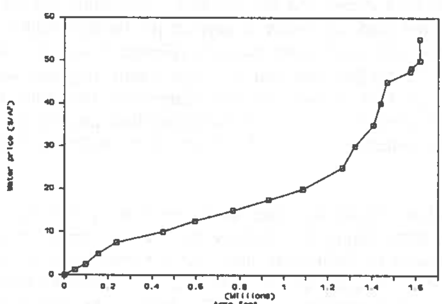


Table 1. Results of reducing Upper Colorado Basin agricultural water use by 400,000 acre–feet, assuming the possibility of land conversion to dryland production

| | Producing area: 82 | 83 | 84 | Total/overall weighted average |
|---|---|---|---|---|
| Reduction in consumptive water use from baseline level (1,000 AF): | 153 | 208 | 47 | 408 |
| Percentage reduction in consumptive water use: | (15) | (36) | (16) | (22) |
| **Percentage change in land use:** | | | | |
| Corn grain | 5 | (8) | 1 | (2) |
| Corn silage | 3 | (38) | (3) | (19) |
| All wheat | 5 | (13) | 1 | (5) |
| Barley | 6 | (3) | 1 | 1 |
| Legume hay | 1 | (18) | (4) | (9) |
| Nonlegume hay | 0 | 31 | 3 | 16 |
| **Percentage change in production:** | | | | |
| Corn grain | 5 | (8) | (2) | (2) |
| Corn silage | 3 | (38) | (3) | (19) |
| All wheat | 16 | (18) | 4 | (3) |
| Barley | 9 | (3) | 1 | 2 |
| Legume hay | 1 | (3) | (5) | (2) |
| Nonlegume hay | (6) | (38) | (31) | (25) |
| **Other percentage changes:**[a] | | | | |
| Soil erosion (water) | (20) | 13 | (1) | (1) |
| Soil erosion (wind) | 7 | 4 | (6) | 5 |
| Machinery expenditures | 1 | (12) | (1) | (6) |
| Pesticide expenditures | 2 | (15) | 22 | (7) |
| Fertilizer expenditures | 2 | (17) | 2 | (8) |
| Labor usage | 1 | (8) | (1) | (4) |
| Reduction in regional net farm income ($1,000): | (489.49) | (101.39) | (27.55) | (618.43) |

With conversion, there are obviously substitution possibilities between crops and between irrigated and dryland production, both of which help to minimize the impacts to regional agriculture despite the loss of 400,000 acre feet. The last item of Table 1, the reduction of agriculturally generated profits, can be subtracted from the total revenues of the water transfer to approximate the producer surplus of the transfer strategy. At $5.05 and 400,000 acre feet, annual revenues would be $2.02 million dollars annually, resulting in an annual producer surplus of $1.4 mil.

The modified CRSS model was simulated over the 30 year period 1986 through 2015, incorporating the historical streamflow records of the period 1922 through 1951. The irrigation water delivery schedule resulting from this was used to adjust the surface water constraints in the agricultural models. These PQP models were then solved for each year of the period 1986-2015. The resulting total annual value of irrigation water is given in the second column of Table 2. Some of the near term values of less than $2.02 mil. ($5.05 x 400,000 AF) reflect that reservoirs were currently near full capacity in 1986 and the likely continued excess deliveries to the Lower Basin until CAP becomes fully operational. Longer run annual values of the 400,000 AF usually exceed $2.02 mil. because regional shortages, particularly in the Green River sub-basin, are explicitly considered in valuing the water. Accounting for the shortages resulted in a long term average value of $5.53 per acre foot. The net present value of irrigation over the 30 year period is given at the bottom of Table 2, using discount rates of 3 and 6 percent.

Of equal interest to policymakers are the transfer's offsite impacts. As seen in the third and fourth columns of Table 2, CRSS estimated long term salinity reductions of about 37 milligrams per liter (mg/l) at Lake Havasu and 43 mg/l at Imperial Dam resulting from the transfer. Using the mid-range of Gardner's estimates of the benefit of salinity reduction to agriculture in the Imperial Valley of $46,000 per milligram per liter yielded the fifth column of Table 2 (13). These benefits are attributable to increased crop yields. It is of interest to note the time lag of 6 to 7 years in realizing the full benefits of salinity reduction. Estimates of the municipal and industrial (M&I) value of reduced river salinity cited in Gardner, with a mid-range of $234,500 per milligram, resulted in the final column. These benefits stem from increased useful life of plumbing fixtures and wastewater facilities. The decreased salinity content of the river results in an economic benefit to Lower Basin water users apparently far in excess of the value of decreased agricultural production in the Upper Basin.

The CRSS model indicated an approximate 450 gigawatt hour increase in annual hydroelectric production from increased river flows associated with the transfer. Valuing this at a wholesale rate of $.015 per kilowatt hour yields the third column of Table 3. The value of the increased power production, even when valued at such a conservative rate, dominates the value of both agriculture and salinity changes. The remainder of Table 3 examines the value of increased power production for alternative power rates. It is worth noting that the additional power is "firm" since the CRSS model explicitly considers turbine capacity of the power system. However, it does not consider any additional transmission capabilities that may be needed as a result.

## CONCLUSIONS

This analysis, like many before, illustrates the low marginal value of water in crop irrigation. This is not suggesting, however, the wholesale dismantling of the institutional structure allocating its use. Rather, it suggests that state or Federal

Table 2. Value of transferred water in terms of net farm income and reduced salinity benefits

| Year | Value of water in crop production ($1,000) | Salinity reduction /1 | | Value of salinity reduction | |
|---|---|---|---|---|---|
| | | Lake Havasu mg/l | Imperial Dam mg/l | Imperial Valley /2 ($1,000) | M&I /3 ($1,000) |
| 1986 | 1,571 | 0 | 0 | 0 | 0 |
| 1987 | 1,656 | 1 | 4 | 184 | 235 |
| 1988 | 1,742 | 6 | 7 | 322 | 1,407 |
| 1989 | 1,951 | 10 | 12 | 552 | 2,345 |
| 1990 | 2,016 | 13 | 15 | 690 | 3,049 |
| 1991 | 2,001 | 19 | 23 | 1,058 | 4,456 |
| 1992 | 1,914 | 22 | 28 | 1,288 | 5,159 |
| 1993 | 1,914 | 25 | 29 | 1,334 | 5,863 |
| 1994 | 1,986 | 28 | 31 | 1,426 | 6,566 |
| 1995 | 2,244 | 29 | 35 | 1,610 | 6,801 |
| 1996 | 1,986 | 29 | 32 | 1,472 | 6,801 |
| 1997 | 2,122 | 30 | 33 | 1,518 | 7,035 |
| 1998 | 3,813 | 33 | 37 | 1,702 | 7,739 |
| 1999 | 2,145 | 35 | 41 | 1,886 | 8,208 |
| 2000 | 2,128 | 42 | 48 | 2,208 | 9,849 |
| 2001 | 2,096 | 46 | 56 | 2,576 | 10,787 |
| 2002 | 2,136 | 50 | 59 | 2,714 | 11,725 |
| 2003 | 2,272 | 53 | 62 | 2,852 | 12,429 |
| 2004 | 2,416 | 51 | 60 | 2,760 | 11,960 |
| 2005 | 2,100 | 55 | 64 | 2,944 | 12,898 |
| 2006 | 2,116 | 56 | 66 | 3,036 | 13,132 |
| 2007 | 2,184 | 56 | 65 | 2,990 | 13,132 |
| 2008 | 2,120 | 51 | 61 | 2,806 | 11,960 |
| 2009 | 2,180 | 51 | 59 | 2,714 | 11,960 |
| 2010 | 2,264 | 50 | 59 | 2,714 | 11,725 |
| 2011 | 2,064 | 51 | 60 | 2,760 | 11,960 |
| 2012 | 2,272 | 53 | 60 | 2,760 | 12,429 |
| 2013 | 2,020 | 53 | 59 | 2,714 | 12,429 |
| 2014 | 2,052 | 53 | 60 | 2,760 | 12,429 |
| 2015 | 2,196 | 52 | 57 | 2,622 | 12,194 |
| Annual avg. | 2,123 | 37 | 43 | 1,966 | 8,622 |
| Avg. $/AF | 5.31 | | | 4.91 | 21.55 |
| Net present value: | | | | | |
| @ 3% | 41,008 | | | 34,114 | 149,137 |
| @ 6% | 28,307 | | | 20,940 | 91,213 |

1/ Source: Colorado River Simulation System (CRSS)
2/ Based on Gardner, 1983
3/ Based on Kleinman and Brown, 1980

Table 3. Estimate of increased power production due to the transfer, and the value of the power at alternative power rates, assuming a 1922-1951 period of record

| Year | Additional energy production /1 (GWH) | $.015/kwh ($1,000) | $.025/kwh ($1,000) | $.05/kwh ($1,000) | $.08/kwh ($1,000) |
|---|---|---|---|---|---|
| 1986 | 478 | 7,170 | 11,950 | 23,900 | 38,240 |
| 1987 | 479 | 7,185 | 11,975 | 23,950 | 38,320 |
| 1988 | 478 | 7,170 | 11,950 | 23,900 | 38,240 |
| 1989 | 502 | 7,530 | 12,550 | 25,100 | 40,160 |
| 1990 | 629 | 9,435 | 15,725 | 31,450 | 50,320 |
| 1991 | 348 | 5,220 | 8,700 | 17,400 | 27,840 |
| 1992 | 496 | 7,440 | 12,400 | 24,800 | 39,680 |
| 1993 | 527 | 7,905 | 13,175 | 26,350 | 42,160 |
| 1994 | 502 | 7,530 | 12,550 | 25,100 | 40,160 |
| 1995 | 491 | 7,365 | 12,275 | 24,550 | 39,280 |
| 1996 | 439 | 6,585 | 10,975 | 21,950 | 35,120 |
| 1997 | 385 | 5,775 | 9,625 | 19,250 | 30,800 |
| 1998 | 452 | 6,780 | 11,300 | 22,600 | 36,160 |
| 1999 | 437 | 6,555 | 10,925 | 21,850 | 34,960 |
| 2000 | 474 | 7,110 | 11,850 | 23,700 | 37,920 |
| 2001 | 411 | 6,165 | 10,275 | 20,550 | 32,880 |
| 2002 | 455 | 6,825 | 11,375 | 22,750 | 36,400 |
| 2003 | 454 | 6,810 | 11,350 | 22,700 | 36,320 |
| 2004 | 428 | 6,420 | 10,700 | 21,400 | 34,240 |
| 2005 | 439 | 6,585 | 10,975 | 21,950 | 35,120 |
| 2006 | 468 | 7,020 | 11,700 | 23,400 | 37,440 |
| 2007 | 483 | 7,245 | 12,075 | 24,150 | 38,640 |
| 2008 | 458 | 6,870 | 11,450 | 22,900 | 36,640 |
| 2009 | 475 | 7,125 | 11,875 | 23,750 | 38,000 |
| 2010 | 461 | 6,915 | 11,525 | 23,050 | 36,880 |
| 2011 | 467 | 7,005 | 11,675 | 23,350 | 37,360 |
| 2012 | 444 | 6,660 | 11,100 | 22,200 | 35,520 |
| 2013 | 471 | 7,065 | 11,775 | 23,550 | 37,680 |
| 2014 | 474 | 7,110 | 11,850 | 23,700 | 37,920 |
| 2015 | 489 | 7,335 | 12,225 | 24,450 | 39,120 |
| Annual average | 466 | 6,997 | 11,662 | 23,323 | 37,317 |
| Annual avg. $/AF | | 17.49 | 29.15 | 58.31 | 93.29 |
| Net present value: | | | | | |
| @ 3% | | 137,854 | 229,757 | 459,513 | 735,221 |
| @ 6% | | 97,394 | 162,324 | 324,647 | 519,435 |

1/ Source: Colorado River Simulation System (CRSS) policymakers should be aware of the direct and offsite impacts of individual transfer proposals before reacting with legislation. For a transfer similar to that proposed by Galloway, substitution among crops and dryland conversion opportunities can minimize the adverse secondary impacts. In Radosevich's words, states should not "cut off their nose to spite their face" by categorically prohibiting such transfers (14). There is also the obvious benefit of increased income accruing to the basin, although there is no assurance that its recipients will remain there to spend it. The main cost of such a plan is the long term sacrifice of an important resource such as water, whose ability to draw an emotional response is hard to understate. Future research may discover that more flexible transfer plans, such as a lease option by the urban user during dry years, may furthur reduce these adverse impacts.

The offsite impacts of changes in river salinity and hydropower production appear to overshadow the agricultural impacts, from an economic standpoint. Although evaluated here in a rather "back of the envelop" fashion, these impacts are significant and should be considered in evaluating transfers.

Whether Southern California interests, such as San Diego, will continue to attempt to gain use of Upper Basin agricultural water depends on the economic and political feasiblity of their other alternatives. However, it appears there are possibilities of net gains to both parties involved in a transfer of 400,000 acre feet of agricultural water to Lower Basin urban uses.

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