An Economic Model of Water Transfer Analysis for the Central Valley Project Improvement Act

Bin Zhang, Steve Hatchett and Roger Mann

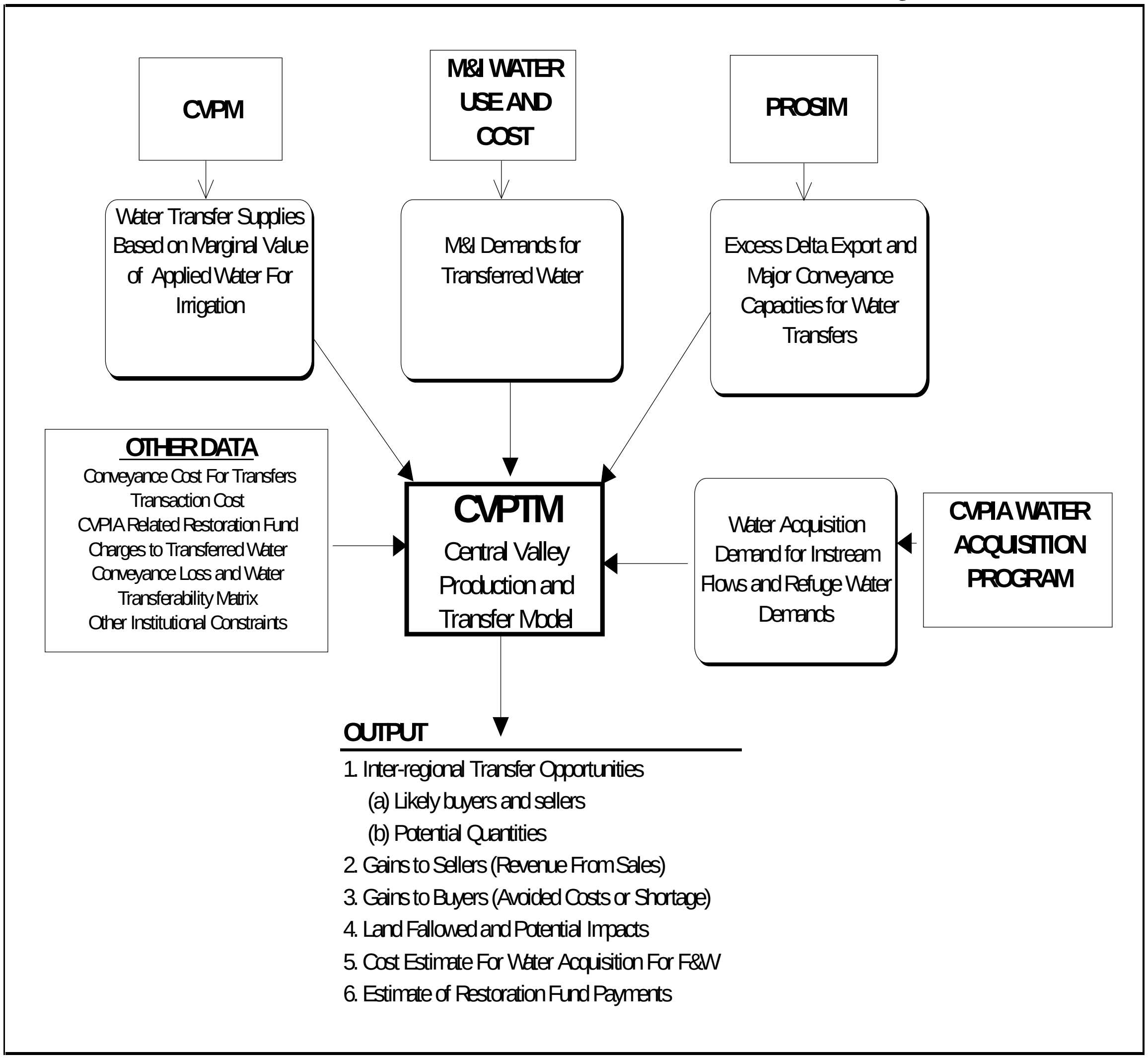
CH2M HILL
2485 Natomas Park Drive
Suite 600
Sacramento, CA 95833-2937

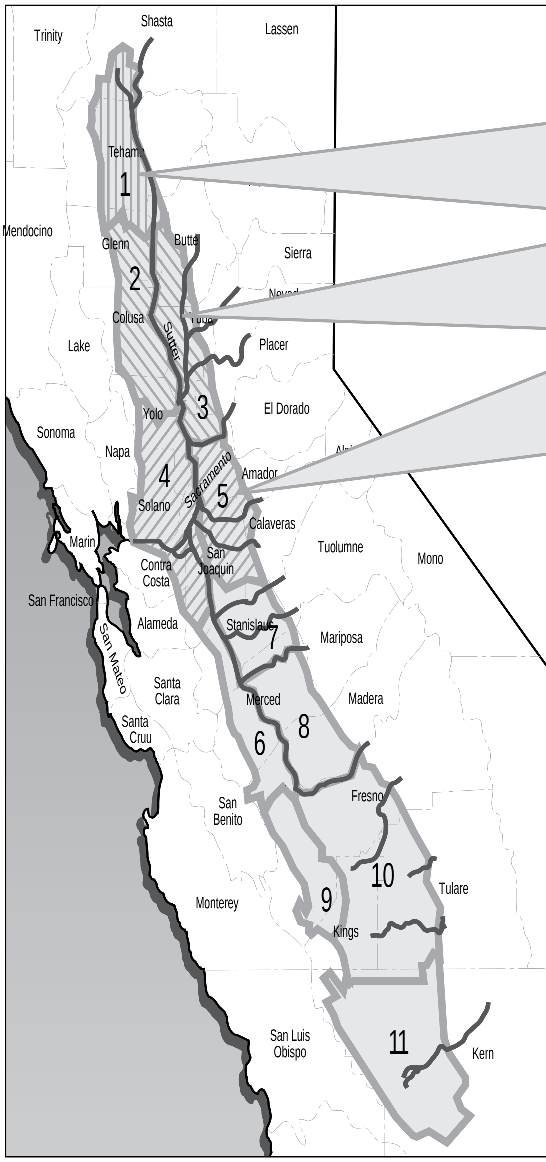
An Economic Model of Water Transfer Analysis
for the Central Valley Project Improvement Act

Abstract

This paper describes the Central Valley Production and Transfer Model developed for the analysis of CVPIA alternatives. While some general results are discussed, this paper focuses on modeling methods and results of a model confirmation run to simulate the 1991 California Drought Water Bank.

FIGURE 1
CVPTM INTERACTION WITH CVPM, M&I ECONOMICS, PROSIM, AND WATER ACQUISITION PROGRAM





ACTUAL 1991	CVPTM Predicted
15.0 TAF	25.2
31.5	61.1
333.5	227.7
380	314

FIGURE 2

SIMULATION OF 1991 STATE DROUGHT BANK
ACTUAL vs CVPTM PREDICTED WATER SOLD FROM FALLOWING

An Economic Model of Water Transfer Analysis for the Central Valley Project Improvement Act

INTRODUCTION

Water transfers play several different, but related, roles within the Central Valley Project Improvement Act of 1992. First, the Act states that CVP users may transfer all or a portion of the water to any other California water user or water agency for beneficial use. Second, water purchases are one vehicle by which the water acquisition program can obtain additional supplies of water for fish and wildlife purposes. An economic model of water transfer analysis- the Central Valley Production and Transfer Model (CVPTM)- was developed and used to assess the impacts of a water transfer market on municipal water supply costs, agricultural economics, and cost of the water acquisition program. The purpose of the water transfer analysis is not to predict the movement of water or who the exact sellers would be. Rather, the purpose is to:

- identify opportunities for water transfers and show how these opportunities change with alternative plans for implementation of the CVPIA;
- indicate likely buying and selling regions and estimate relative price ranges for water sales in different regions;
- estimate the change in water use, the amount of land fallowing, and the change in agricultural net revenue resulting from transfers;
- estimate the cost of water acquired for fish and wildlife purposes.

While some general results from water transfer analyses for the CVPIA will be discussed[1], this paper focuses on modeling methods and results of a model confirmation run to simulate the 1991 California Drought Water Bank.

THE MODEL

Model Linkages

The CVPTM is linked with several other aspects of the impact analysis, including agricultural economic analysis, municipal and industrial (M&I) economic analysis, and hydrologic simulation. Figure 1 shows the interactions between CVPTM and the Central Valley Production Model (CVPM), the M&I Water Use and Cost Analysis, the Project Simulation Model (PROSIM), and the Water Acquisition Program.

CVPTM is an augmented version of CVPM with water transfers. CVPM is amulti-regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers in the Central Valley of California. The model includes 22 crop production regions and 26 categories of crops. Without water transfers, CVPM estimates an implicit water value by region which is the marginal increase in agricultural net revenues from an additional unit of water supply. CVPTM uses these implicit water values to describe a supply function for transferred water. It includes 11 agricultural regions (aggregated from the 22 regions), which are either potential buyers or sellers, and 10 M&I regions that are potential buyers

[1] Results of the water transfer analysis for the PEIS are currently in the administrative review stage and are not publicly available. The results will be presented at the WAEA summer meetings.

Objective Function

CVPTM objective function can be simplified as

$$OBJECT = \sum_R \sum_C \left[YLD_{R,C} \bullet P_C - IRCST_{R,C} - OTCST_{R,C} \right] \bullet XN_{R,C} - \sum_R \sum_W WP_{R,W} \bullet WAT_{R,W}$$
$$+ \sum_R \sum_C CS(XN_{R,C})$$

$$- \sum_R \sum_Q \sum_W TRCOST_{R,Q,W} \bullet WTRAN_{R,Q,W} \ | AT_{R,Q}$$
$$+ \sum_D \sum_Q \sum_W TRFRAC_{D,Q} \bullet WTRAN_{D,Q,W} \ | AT_{R,Q} \bullet \left[WPRI_D - TRCOST_{D,Q,W} \right]$$
$$+ \sum_D MICS(TRFRAC_{D,Q} \bullet WTRAN_{D,Q,W})$$

where

R, Q	= Central Valley agricultural production regions
C	= crops
W	= water sources, including CVP contract water, CVP water rights water, State Water Project water, local surface water, and groundwater
YLD, P	= crop yields and output prices
IRCST	= annualized irrigation system cost
OTCST	= other production costs
XN	= irrigated acres
D	= M&I regions
WP	= water cost per acre-foot
WAT	= applied irrigation water
CS	= consumer surplus for agricultural product users
TRCOST	= conveyance cost and other transfer cost per acre-foot of transferred water
WTRAN	= the amount of water transferred out of the selling region
AT	= water transfer feasibility matrix
TRFRAC	= ratio of sold water to received water
WPRI	= price of transferred water received by M&I users
MICS	= consumer surplus for M&I water users

The objective function consists of two parts. The first part (the first two lines) is a simplified representation ofCVPM’s objective function. It is the sum of producer’s surplus (measured as net revenue from irrigated crop production) and consumer surplus

CS.[2] The second part extends the CVPM's objective function by including water transfers. It first subtracts the total conveyance costs for transfers between agricultural regions, then, for water sold to M&I regions, it adds seller's net revenue received from water sold and buyer's gains from water bought. Seller's net revenue received equals the gross revenue received minus transfer costs. Buyer's gains are defined as consumer surplus for M&I (MICS).[3] CVPTM solves for the water price, crop mix, amount of irrigated land, and level of water transfers that maximize the sum of net revenue and consumer surplus for both agricultural production and water transfers.

Water Transfer Balance Equation

$$SOURCET(R,W)\ldots WAT_{R,W} + \sum_{QD} WTRAN_{QD,R,W} \quad |AT$$
$$\leq BWATER_{R,W} + \sum_{Q} TRFRAC * WTRAN_{R,Q,W} \quad |AT$$

The water balance equation for each selling region R states that water used for crop production plus gross transfer out of the region must be less than or equal to water sources available plus net transfers into the region. Net transfer (TRFRAC*WTRAN) is measured at the destination. It equals the gross transfer measured at the selling region minus transfer conveyance losses and Delta outflow requirements for cross Delta transfers. The 1994 Bay-Delta Plan Accord generally restricts exports to be no greater than 35% of Delta inflow between February and June and no greater than 65% of Delta inflow between July and January. For the CVPIA analysis, CVPTM assumed that cross-Delta transfers would occur in the July through January period only.

[2] CS depends on the demand functions used. For simplicity, we use a general term here.
[3] We use a general term here for simplicity.

Delta Export Capacity Available for Water Transfers

$$DELTPUMP\ldots\sum_{RDS}\sum_{QN}\sum_{SW} TRFRAC_{RDS,QN} \bullet WTRAN_{RDS,QN,SW} \ \ |AT \leq DELTALIM$$

Water transfers from the north of Delta (QN) to the south of Delta (RDS) are subject to the Delta export capacities available for water transfers (DELTALIM). For example, the California Department of Water Resources (1994) reports that the total of CVP and SWP export capacities available for water transfers are estimated to be about 0.6 millionaf in an average year condition and 1.4 millionaf in a dry year condition. CVPTM obtains the estimates of Delta export capacities for water transfers from PROSIM. For example, under the PEIS No-Action Alternative, PROSIM estimates that the available Delta export capacities for water transfers are 1.32 millionaf for average years and 2.1 millionaf for dry years.

M&I Water Transfer Demand Functions

$$PRICE(D)\ldots.\sum_{Q}\sum_{W} TRFRAC_{D,Q} \bullet WTRAN_{D,Q,W} \ \ |AT = MIINT_{D} - MSLP_{D} \bullet WPRI_{D}$$

CVPTM includes water transfer demand functions for 10 major groups of M&I providers who may participate in Central Valley water markets. The demand functions are developed based on water shortage estimates, capacity limitations, costs of alternative supplies, and costs of shortages. The price and quantity of M&I water is measured at the treatment plant. Hence the price of M&I water purchased (WPRI) includes seller's price plus transfer costs, and the quantity is the net water received (TRFRAC*WTRAN).

Water Transfer Demand by Fish and Wildlife

There are two options in modeling water acquisition for fish and wildlife restoration. One would be to include a set of demand functions for instream fish flow requirements and refuge water needs. These demand functions would be treated just like M&I demand functions such that the demands can be met either by local sources or by water transfers from other locations. In this option, CVPTM could group various fish and wildlife management areas into several demand regions based on similarity of geographical location and potential supply sources within the Central Valley. The second option would be to treat instream flows and refuge demands as physical constraints on water available to other users in regions in which the streams or refuge sites are located. In other words, these demands would be supplied during the hydrological simulations, reducing water available for other users, so no specific demand functions would be included in CVPTM. In the second option, average unit cost estimates for acquired water would be based on the water transfer results for a given alternative so that competition from M&I and other water buyers would be included.

Transfer Feasibility Matrix and Conveyance Cost

A water transfer feasibility matrix (AT) represents the physical possibility to move water from one location to another. It is a matrix of ones or zeros, where one represents a feasible water transfer and zero represents non-feasibility. CVPTM allows two types of transfers: direct and exchange. In a direct transfer, water that would have moved to the seller is instead moved to the buyer. There are only two parties to the transfer. In an exchange transfer, there are at least three parties to the transfer, and the buyer may not directly obtain the seller's water. In an exchange, the seller provides more water to a third party, and the buyer provides less water to the third party or takes more water from the third party such that the third party is made whole. Exchanges are not uncommon in California, and are often used to facilitate physical storage or conveyance. For example, Arvin-Edison Water Storage District receives CVP water through the Cross Valley Canal in exchange for Friant-Kern water used to satisfy other demands in the Friant-Kern service area.

Water transfer conveyance cost (TRCOST) depends on source, destination, type of water, and conveyance facility used. Water transfers conveyed through CVP facilities pay the CVP cost-of-service rate. In general, a transfer to a part of the CVP with higher capital costs would require an increased payment for capital. Transfers to areas with lower capital costs do not result in a reduction (credit) in capital costs because Reclamation's transfer rules require that the transfer bear the greater of the two transfer capital costs. The energy costs may also be higher for transfers that use additional pumping (e.g., transfers into the San Felipe Division). If a water transfer results in less use of energy, then there is a credit for the unused energy. Water transfers wheeled through State Water Project facilities do not require additional payments for capital. All of these principles are incorporated into the transfer cost matrix. In addition, TRCOST includes other transfer related costs such as transactions costs and CVPIA Restoration Fund charges. For example, if CVP agricultural water is transferred to a non-CVP M&I users, then a $25 per acre-foot CVPIA Restoration Fund charge is added to the cost.

Other major assumptions or constraints included in the CVPTM are:

- CVP water service contract and exchange water cannot be transferred without CVPIA authorization;
- no groundwater transfer or substitution of groundwater for transferred water is allowed;
- savings from irrigation improvements are not transferable, to assure that “real water” is being transferred;
- cumulative transfers from a region are restricted to 20% of the surface water supply, to limit third party impacts; and
- only ET of applied water or other irrecoverable losses may be transferred.

TESTING THE MODEL AGAINST THE 1991 DROUGHT WATER BANK

In 1991, the State instituted a drought water bank which included a significant land fallowing component. The State offered farmers a fixed price of $125 per net acre-foot of water made available by fallowing land. According to a report prepared by the State (Howitt, et al., 1992), approximately 166,000 acres of farmland were fallowed, yielding about 380,000 acre-feet of water. Fallowing occurred from Shasta County to as far south as San Joaquin County.

In order to test the reasonableness of the CVPTM's estimates, the State water bank was simulated using the model. The State's land fallowing offer was simulated by creating a water transfer demand at the Delta, with a very elastic demand function at the $125 per acre-foot price. Specifically, a linear demand function with an elasticity of 25 was used that passed through the observed level of 380,000 acre-feet at $125 per acre-foot. With the high elasticity, this is roughly equivalent to offering $125/af for any quantity of water. CVPTM was then solved subject to 1991 hydrologic conditions.

Results of the simulation were quite reasonable, and somewhat conservative. The net water sold into the simulated water bank was 314,000 acre-feet at just over $126 per acre-feet. The locations of water sold were also roughly consistent with those observed during the bank, reported by county in Howitt et al. (1992). The model's hydrologic regions do not correspond well with county lines so a direct comparison is difficult. Regions predicted to sell water were Region 1(25,000 af), Region 3(61,000 af), Region 4(156,000 af), and Region 5(72,000 acre-feet). Figure II-2 presents the comparisons.

CONCLUSIONS

This paper describes the Central Valley Production and Transfer Model (CVPTM) developed for the analysis of CVPIA alternatives. The paper focuses onCVPTM's structures and its linkages to other economic and hydrologic models. Results from a model confirmation run are also presented. The results from water transfer analysis for the CVPIA are currently in the administrative review stage and are not publicly available. The general results indicate that the CVPIA water transfer provision - allowing CVP water service contract and exchange water to be transferred - would significantly affect water transfer market in California. The transfer demands by both M&I and agricultural buyers are expected to increase due to the greater availability of less expensive CVP water closer to buying regions. Central and South Coast M&I users are expected to be the largest buyers under all the alternatives, followed by the M&I users in San Francisco Bay Area.

REFERENCES

California Department of Water Resources, *California Water Plan Update*, Volume 1, Bulletin 160-93, October 1994.

California Department of Water Resources, *Program Environmental Impact Report, State Drought Water Bank*, DWR, California, 1993.

Howitt, Richard; N. Moore and R. K. Smith. 1992. "A Retrospective on California's 1991 Emergency Drought Water Bank." A Report Prepared for the California Department of Water Resources.

Zilberman, D, D. Sunding, R. Howitt, A. Dinar, and N MacDougall, "Water for California Agriculture: Lessons From the Drought and New Water Market Reform," Choice, Fourth Quarter, 1994.