Hooker + Alexander

- Like Ayer + Hoyt, derives demand for water by calibrating a production function and then solving profit maximization to obtain the uncondition input demand for water

- Unlike Ayer + Hoyt, it incorporates choice of cropp pattern and choice of irrigation technology. But, this is not based on observed choice by farmer. It is based on presumed maximizati of profit by the researcher.

- Adjusts for irrigation efficiency

- Essentially ignores non water inputs (like Ayer +

PRODUCTION FUNCTION FOR GIVEN CROP

$$y = f[(a_1 + a_2), i, q, c] \qquad (1)$$

where a_1 and a_2 are quantities of surface and ground water in hectare-centimeters, respectively; i is a technology index (with higher numbers corresponding to increasingly capital intensive and efficient technologies); q is a measure of water quality; and c is weather (measured in volume of pan evaporation). Fertilizer and other inputs are assumed to be applied at (independently derived) optimum levels.

The crop-water production functions, converted to yield in tons, are then

$$Y_T = -100.3 + 3.0445(i*AW) - 0.0119(i*AW)^2$$
$$- 4.08(EC_i) - 0.085(EC_i)^2 - 0.0054(i*AW)(EC_i) \qquad (2)$$

for tomatoes, . Finally, i enters as the multiplicative factor adjusting AW. Since furrow irrigation is the baseline in the production functions and has irrigation efficiency 0.6 (Caswell *et al.*, 1990), $i = 1$ for that case. The irrigation efficiencies for shortened furrow, sprinkler, and drip are .7, .8, and .95; so for these technologies i = .7/.6, .8/.6, and .95/.6, respectively. If the production function generates crop yields above the physical maximum for a set of inputs, it is truncated to that maximum.

EC measures water salinity (which is bad)

From the production function, a profit function for crop i using irrigation technology j is obtained by multiplying the crop's price by f and subtracting variable and fixed costs:

$$\pi_{ij} = \max_{a_1,a_2}\Big\{P_j * f_j\big[(a_1+a_2),i,q,c\big] - w_1a_1 - w_2a_2$$
$$- V_{ij}(a_1,a_2,f) - k_i - k_j\Big\} \qquad (5)$$

where P_j is the price of the crop j; w_1 and w_2 are the prices of surface and ground water, respectively; $V(\ )$ is a crop-and technology-specific function giving costs of production as a function of water inputs and crop output; and k_i and k_j are the fixed costs associated with technology i and crop j. The first cost term, w_1a_1, is simply the price of surface water that farmers must pay multiplied by the quantity taken. The specification here assumes a constant cost per unit, so it abstracts from alternative arrangements like tiered pricing. The second cost term is the associated ground water cost, where price is determined by the farmer's

pumping cost

DEMAND SCHEDULES FOR SURFACE DELIVERY OF IRRIGATION WATER

If one is willing to assume that the farmers' optimization problems are solved at interior maxima, that

for each surface water price in the relevant range. Within each pumping depth-price combination, farmers may use any quantities of surface and ground water with any of four irrigation methods and three crops. We compute the highest-profit irrigation strategy for each technology-crop combination, and then the maximum profit across each of these 12 possibilities.

TABLE 1. Price and Cost Data for Irrigation and Crop Production.

A. Irrigation Costs

Technology	Pumping	Maintenance and Capital	Labor
Furrow	0	$51.60/ha	$0.55/ha-cm
Short Furrow	0	$125.48/ha	$0.83/ha-cm
Sprinkler	$1.8543/ha-cm	$290.05/ha	$0.69/ha-cm
Drip	$1.3120/ha-cm	$1106.04/ha	$0.14/ha-cm

B. Non-Water-Related Prices and Costs

Crop	Price	Land Maintenance Cost	Harvest Cost
Alfalfa	$90/ton	$835/ha	$19/ton
Cotton	$1665/ton	$1150/ha	$230/ton
Tomatoes	$50/ton	$871/ha	$18/ton

C. Ground Water Costs (pumping)

Lift = 200 ft.: $1.89/ha-cm
Lift = 400 ft.: $3.78/ha-cm
Lift = 600 ft.: $5.67/ha-cm
Lift = 800 ft.: $7.56/ha-cm

D. Administrative Costs for Professional Irrigation Scheduling

$39.54/ha (constant for all technologies and crops)

Sources: Irrigation costs; prices, maintenance and harvest costs for tomatoes and cotton; and administrative costs are from Casterline *et al.* (1989). Groundwater costs are from Gohring *et al.* (1991). Alfalfa data are from U.C. Cooperative Extension (1992).

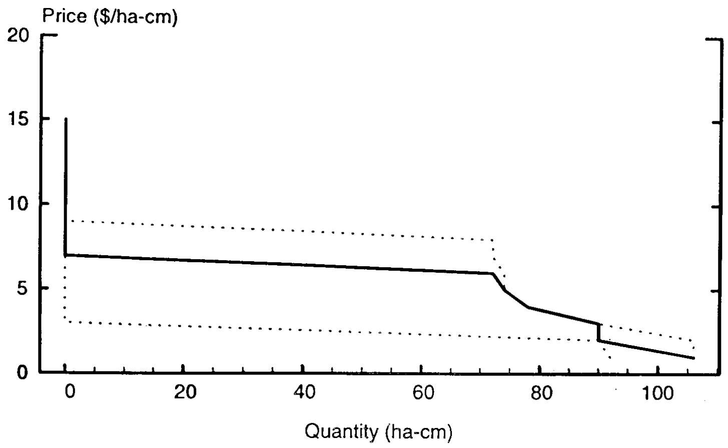

Figure 1a. Demand Schedule for Surface Water at 200 ft. Lift.

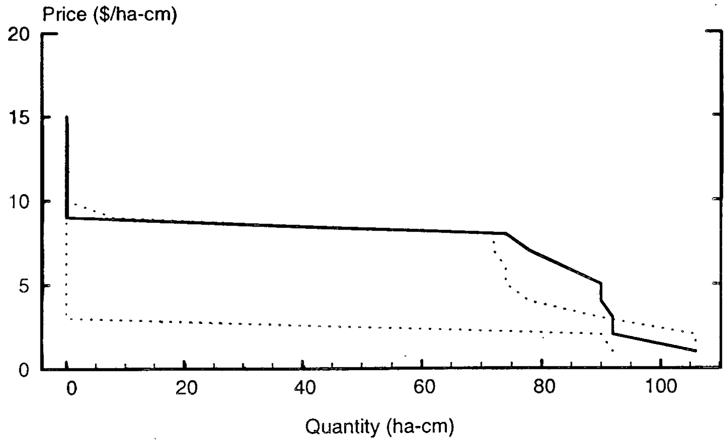

Figure 1b. Demand Schedule for Surface Water at 400 ft. Lift.

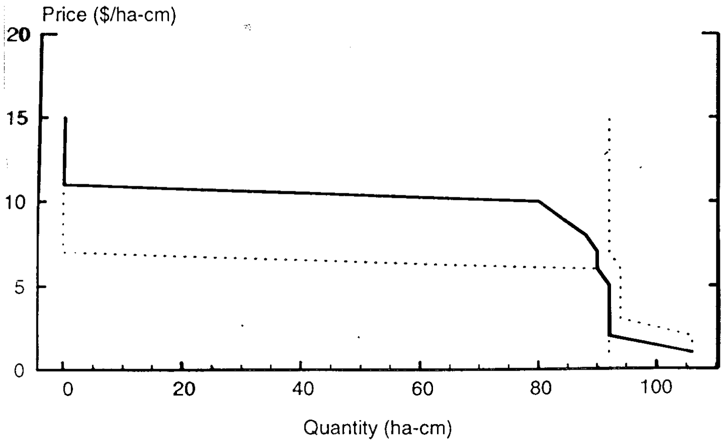

Figure 1c. Demand Schedule for Surface Water at 600 ft. Lift.

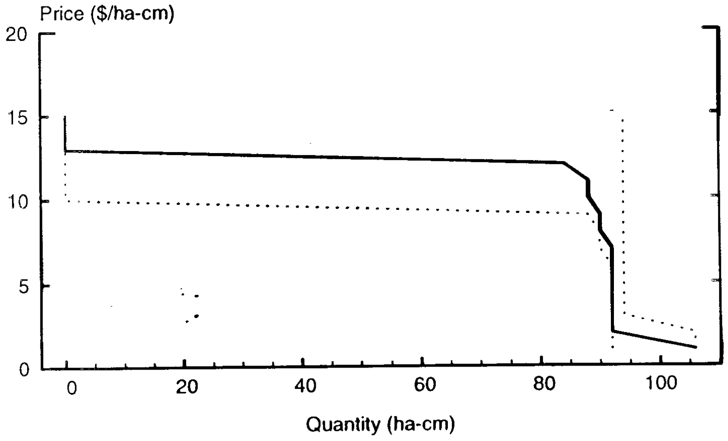

Figure 1d. **Demand Schedule for Surface Water at 800 ft. Lift.**

The inelastic demand results that we obtain (at low surface water prices) are consistent with the low elasticities typically estimated in the econometric literature. The results are also consistent with the finding of Moore *et al.* (1994) that the effects of increases in water price (although for ground water in their study) impact crop choice, irrigation technology, and land allocation decisions more than volume of water in a given application. However, our findings of high elasticities at higher prices suggest caution in extrapolating low-elasticity estimates to higher water prices and for larger changes in prices. The threshold behavior that we find may also partly explain the apparent contradiction between econometric estimates of low elasticity, and programming estimates (which often consider larger price changes than have historically occurred) of higher elasticities.

Our results suggest that the move currently underway in California and the Western U.S. towards a greater role for markets in allocating water has the potential for making large amounts of water available to urban users, and generating increased ground water mining, and thus a lower water table and reduced drainage runoff. However, it may also involve major changes in cropping patterns and irrigation methods. A market system will also affect different farmers very differently; those who can cheaply substitute to pumped ground water will be the best off.

Question: To what extent do the demand functions simulated by the authors match the actual behavior of farmers?

The two main techniques for computing demand elasticities are econometric estimation and optimization models describing profit-maximizing farmer behavior. The general character of the results is that econometric studies tend to find inelastic demand, while optimization studies find demand to be much more sensitive to price changes [see Ogg and Gollehon (1989) for econometric estimates and some discussion of the literature].

A drawback to econometric studies is that the estimates are somewhat unreliable, particularly for assessing the effects of prices far away from those observed in the sample (prices paid by some municipalities in California are more than ten times the prices paid by farmers). This is because there has been so little fluctuation in historical prices for water and in many cases prices have been so low. Indeed, elasticities are often calculated using price changes of 10 percent or less, or by imposing a functional form like log-log on the demand curve which restricts the elasticity to be equal at all prices. The main limitation of optimization studies is that many aspects of the farmer's problem must be ignored or simplified to make the problem tractable.