ESTIMATING THE COSTS OF FARM-LEVEL AND DISTRICT

EFFORTS TO ACHIEVE SELENIUM LOAD TARGETS

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ABSTRACT

Seven irrigation and drainage districts in the California's San
Joaquin Valley are participating in a regional program to reduce
the load of selenium entering the San Joaquin River. Farmers have
improved their irrigation methods to reduce surface runoff and
deep percolation, district staff have improved their operations to
support farm-level water management efforts, and a regional
association has been formed to operate regional drainage
facilities and coordinate efforts to achieve monthly and annual
selenium load targets. The costs of these efforts include farm-
level expenditures for new irrigation systems and for increases in
irrigation labor and other water management inputs, district-level
expenditures for new facilities and staff to manage water
deliveries and drainage water reduction efforts more aggressively,
and the fixed and variable costs of operating and maintaining
regional drainage facilities. Empirical estimates of these costs
for the Broadview Water District in 1997 include $93 per acre for
farm-level irrigation improvements, $11 per acre for district-
level efforts, and $14 per acre for supporting regional drainage
activities.

INTRODUCTION

Much of the subsurface drain water collected beneath farmland on
the west side of the San Joaquin Valley contains selenium, boron,
and other elements that occur naturally in local soils and are
leached from the profile during irrigation and drainage activities
(Letey et al., 1986; Deverel and Gallanthine, 1988; Gilliom,
1991). The U.S. Environmental Protection Agency has established a
national water quality criterion for selenium of 5 parts per
billion (ppb), when measured as a 5-day moving average
concentration. The California Regional Water Quality Control
Board for the Central Valley Region has adopted a Basin Plan
Amendment designed to achieve the national selenium concentration
standard, over time.

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That amendment includes a set of monthly and annual selenium load
targets that are expected to generate acceptable selenium
concentrations in the near term, while farm-level and regional
efforts are implemented, over time, to achieve the national water
quality standard.

The Regional Water Quality Control Board has also established a
2-ppb selenium water quality objective for sloughs and channels in
a wetland habitat located between an agricultural production area
and the San Joaquin River. As a result, it became necessary to
remove agricultural drainage water from wetland waterways, as
selenium concentrations in drainage water are often in the range
of 20 to 100 ppb (Deverel et al., 1984; Presser and Barnes, 1985).
Agricultural districts were encouraged by water quality agencies
to form a regional drainage organization and to develop a program
for achieving the selenium load targets and removing drainage
water from the wetland waterways.

Seven irrigation and drainage districts in the region have formed
the Grassland Basin Drainage Activity Agreement to construct and
operate regional drainage facilities and coordinate efforts to
achieve the selenium load targets. The group has constructed a
new channel that carries drainage water from all seven districts
around the wetland area to an existing portion of the San Luis
Drain, which carries the water to a tributary of the San Joaquin
River. That program, known locally as the Grassland Bypass
Project, began operations in September of 1996.

The monthly and annual selenium load targets, which became
effective in October of 1996, are substantially lower than
estimates of selenium discharges in recent years. For example,
the monthly load targets are equivalent to less than 50% of the
estimated discharges from the region during several months of the
1995 and 1996 crop years (please see the figure). The estimated
annual load of selenium discharged in each of those years is
almost twice the annual load target.

The monthly selenium load estimates for 1995 and 1996 reflect
improvements in irrigation practices and drainage water management
efforts that were implemented by farmers and districts in the
early 1990s, when water supplies were reduced due to persistent
drought conditions and changes in public policies regarding the
allocation of water among urban, agricultural, and environmental
uses (Wichelns and Cone, 1992a; Wichelns et al., 1996a). Further
reductions in selenium loads may be possible, but the incremental
cost of achieving those reductions will likely be substantial, as
the most affordable improvements in water management practices
have already been implemented.

FARM-LEVEL COSTS

The potentially restrictive selenium load targets, described above, have caused irrigation and drainage districts to implement additional programs to motivate further improvements in farm-level irrigation practices that will reduce surface runoff and deep percolation, and to increase the blending and re-use of drainage water with fresh water supplies. Innovations in district policies have included tiered water pricing, low-interest loans for purchasing new irrigation systems, and restrictions regarding surface runoff discharged into drainage ditches. Farmers have responded by replacing traditional surface irrigation methods with improved furrow methods, gated pipe, and sprinkler systems. They have also increased the labor and management components of irrigation activities.

The farm-level costs of using improved irrigation methods have been estimated by interviewing farmers in the 9000-acre Broadview Water District. Broadview implemented a tiered water pricing program in 1989 and has adopted additional incentive programs in recent years (Wichelns 1991; Wichelns and Cone 1992a and 1992b; Wichelns et al. 1996a). As a result, Broadview farmers have gained considerable experience in modifying irrigation methods to reduce surface runoff and deep percolation. Farmers have provided detailed estimates of the capital costs and variable costs of operating and maintaining siphon tube, gated pipe, and sprinkler systems (Wichelns et al., 1996b).

We compare the estimated annual costs of alternative irrigation methods for the four major crops grown in Broadview in Table 1. The estimated cost of using traditional siphon tube methods ranges from $148 per acre on seed alfalfa to $200 per acre on cotton, which requires more irrigations per season. Improved siphon tube methods include shorter irrigation run lengths and the use of a night irrigator to manage irrigation events carefully. The costs for gated pipe and sprinkler methods include a capital cost component and a larger labor requirement. Gated pipe must be carried into a field and removed at the end of an irrigation season, while portable sprinkler systems must be moved several times during each irrigation event. Detailed information regarding each cost component is provided in Wichelns et al. (1996b).

Prior to the 1990s, Broadview farmers used traditional siphon tube methods to irrigate most crops. They began improving irrigation methods in the early 1990s, in response to the district's tiered water pricing program and in an effort to maximize the value of surface water supplies that were limited by persistent drought conditions and by changes in public water allocation policies. Farmers have continued to use the improved methods as selenium load targets and uncertainty regarding their water supply have gained importance in recent years. It is unlikely that Broadview farmers will ever resume using traditional siphon tube methods.

We estimate the increased costs of irrigation by comparing the cost of irrigation improvements with the cost of using traditional siphon tube methods. For example, Broadview farmers irrigated 3,877 acres of cotton (63% of the total cotton area) with a combination of sprinklers and siphon tubes in 1997, while using improved siphon tube methods on 1,372 acres (Table 2). The estimated cost of using sprinklers and siphon tubes on those 3,877 acres exceeds the estimated cost of using traditional siphon tube methods by $321,217, while the estimated cost increase for the 1,372 acres irrigated with improved siphon tube methods is $50,193 (Table 3). The estimated increase in irrigation costs for all cotton fields is $494,090, or an average cost of $81 per acre.

Similar analysis of estimated irrigation costs for cantaloupes, processing tomatoes, and seed alfalfa generates a total estimated increase in irrigation costs of $824,566 for the Broadview Water District in 1997, or an average cost of $93 per acre. This result represents the estimated increase in farm-level irrigation costs made necessary by selenium load targets and other public policies regarding agricultural water supplies. While it is not possible to determine the effects of individual policies or water quality programs on farm-level irrigation costs, this estimate provides insight regarding the magnitude of cost increases that have occurred on farms on the west side of the San Joaquin Valley in recent years.

DISTRICT-LEVEL AND REGIONAL COSTS

Irrigation and drainage districts have implemented several programs to support farm-level irrigation improvement efforts. These programs raise the annual cost of district operations, resulting in higher farm-level assessments, service fees, or water prices. For example, several districts have implemented tiered water pricing programs that require more accurate measurement of water deliveries to farm turnouts than were necessary when all water was sold at the same price per unit. Districts have also increased the flexibility with which farmers may begin or terminate water deliveries, to accommodate sprinkler systems and shorter duration irrigation sets. The quality of water deliveries has also been improved to minimize potential problems with clogged sprinkler nozzles.

Most districts in the region have begun or expanded a recycling program to blend commingled drainage water with fresh water supplies, to reduce the volume of drainage water discharged into the regional drainage system. These programs require careful monitoring of delivered water salinity to ensure that crops are not damaged, particularly when farmers are using sprinklers during early-season irrigations. Several districts have modified their water delivery and drainage systems to optimize recycling opportunities. Additional staff have been hired to monitor water

quality at several locations and to manage the blending of
drainage water from many sources within a district.

All districts in the region have implemented water quality
monitoring programs to estimate the loads of salt and selenium in
drainage water at frequent intervals, to improve the information
available to districts regarding short-term blending opportunities
and long-term drainage water reduction strategies. The annual
cost of collecting and analyzing water quality samples has
increased substantially for all districts in the region.

Several districts have taken a leadership role in seeking a method
to remove selenium from drainage water. The cost of innovative
research efforts is often shared by all districts in the region,
using a formula that accounts for each district's size and area
served by subsurface drainage systems. Districts have also shared
the costs of conducting numerous irrigation workshops and field
demonstrations of farm-level techniques for reducing surface
runoff and subsurface drain water.

We have estimated the annual district-level costs of these
programs using data collected from the Broadview Water District.
The estimated annual cost of the district manager's time in
performing administrative tasks and attending meetings regarding
district-level and regional drainage issues is $23,000. The
estimated cost of staff time required to manage the district's 25
subsurface drainage systems, operate the drainage water recycling
system, and monitor progress regarding monthly and annual selenium
load targets is $44,000 per year. The estimated annual cost of
collecting and analyzing water quality samples is $24,000.
Broadview and other water districts contribute funds each year to
support regional research projects regarding selenium removal from
drainage water. The average annual contribution from Broadview is
$10,000. The estimated total cost of these activities is $101,000
per year, or an average cost of $11 per acre (Table 4).

Broadview is one of seven irrigation and drainage districts
participating in the Grassland Basin Drainage Activity Agreement,
the regional authority that operates and maintains drainage
facilities serving an area of 94,000 acres. The authority
coordinates district-level efforts to achieve monthly and annual
selenium load targets. It also conducts a regional water quality
and toxicity monitoring program, and interacts frequently with
state and federal agency staff regarding compliance with water
quality objectives. The annual budget of the drainage authority
is $865,575 or an average cost of about $9 per acre, though the
average cost for each district varies according to the area served
by drainage systems and other district characteristics.

SUMMARY

All of the expenditures required to improve water management practices and achieve regional water quality objectives are eventually paid by farmers in the region, either directly or through district fees and assessments. A summary of the estimated annual costs of these efforts for farmers in the Broadview Water District is presented in Table 5. The estimated annual cost of irrigation improvements in Broadview is $824,566, or an average cost of $93 per acre. Farmers in the six other districts participating in the Grassland Bypass Project have implemented similar improvements in irrigation practices. Therefore, an estimate of the regional cost of irrigation improvements is obtained by multiplying the average cost of $93 per acre in Broadview by the 94,000 acres in the region. This generates an estimated regional cost of irrigation improvements of $8.7 million per year (Table 5).

The estimated annual cost of district efforts to reduce drainage water volume and selenium loads is determined by multiplying the average cost of $11 per acre in Broadview by the 94,000 acres in the region, resulting in an estimated regional cost of $1,054,680 (Table 5). The annual budget of the regional drainage authority is $865,575, resulting in a estimated total regional cost of farm-level, district, and regional efforts of $10.6 million (Table 5), or an average cost of about $113 per acre.

The district-level and regional costs appearing in Table 5 are largely attributable to efforts to reduce drainage water volume and selenium loads, in response to the imposition of monthly and annual selenium load targets. However, some of the farm-level costs of irrigation improvements would likely be observed even in the absence of selenium load targets. Farmers in Broadview and other districts have improved irrigation practices for several reasons in the 1990s including drainage water reduction efforts, greater uncertainty regarding water supplies, and efforts to improve the efficiency of water use.

Many farmers in the San Joaquin Valley have developed innovative combinations of irrigation methods that generate better crop yields, while reducing the volume of water delivered to farm turnouts. The farm-level cost of irrigation has increased as a result of these improvements, while the yield per unit of water delivered has increased. Given the outlook for future water demand and supply in California, it is likely that farmers will continue using improved irrigation methods, provided that water supplies are sufficient to sustain profitable crop production activities and to maintain salt balance in the soil profile.

The estimated costs presented in Table 5 pertain to current activities implemented by farmers and districts to improve water management practices and achieve selenium load targets. A portion

of those costs can be attributed to general irrigation improvement efforts made necessary by the changing allocation of water among competing uses in California. However, most of the improvements in irrigation practices and district operations are helpful in reducing surface runoff, deep percolation, and the load of selenium discharged to the San Joaquin River.

Estimates of long-term costs that may result from changes in irrigation and drainage management practices are not included in Table 5. For example, all of the participating districts have increased their recycling of saline drainage water to reduce the volume discharged into the regional drainage system. As a result, the average salinity of water deliveries has increased in the region, resulting in greater loads of salt deposited on farm fields. Soil salinity and boron concentrations will increase, over time, if farmers are unable to leach their fields with a frequency and volume sufficient to maintain salt balance.

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Table 1.   Estimated annual irrigation costs for selected crops in California's San Joaquin Valley

Irrigation Method	Cotton	Cantaloupes	Processing Tomatoes	Seed Alfalfa
	(Dollars per Acre)			
Siphon tubes, traditional	200	162	189	148
Siphon tubes, improved	237	178	226	162
Gated pipe	310	255	301	225
Sprinklers and siphon tubes	283	223	332	204
Sprinklers and gated pipe	342	285	399	255
Sprinklers	370	n/a	n/a	n/a

Source: Wichelns, et al., 1996b. Original cost data have been converted from 1993 dollars to 1997 dollars using the producer price index for intermediate materials excluding foods. The appropriate conversion factor is 1.076.

Notes: Total annual costs include annual capital and maintenance costs, labor, and the cost of water and energy. Traditional siphon tube irrigation includes 1/2-mile furrows (cotton, seed alfalfa, and tomatoes) or 1/4-mile furrows (cantaloupes), with no night irrigator. Improved siphon tube irrigation includes 1/4-mile furrows (cotton and seed alfalfa) or 1/6-mile furrows (cantaloupes and tomatoes) and a night irrigator.

Labor costs are estimated using $7.80 per hour for irrigators and $26 per line for line movers, including wages and payroll taxes. The cost of water is $40 per acre-foot and the cost of energy is $10 per acre-foot of water delivered.

Sprinklers cannot be used throughout the season on cantaloupes, tomatoes, or seed alfalfa.

Table 2.   Summary of irrigation methods used by farmers in the
            Broadview Water District, 1997

Irrigation Method	Cotton	Cantaloupes	Processing Tomatoes	Seed Alfalfa
(Acres)				
Siphon tubes, improved	1,372	303	0	313
Gated pipe	150	146	0	150
Sprinklers and siphon tubes	3,877	0	73	0
Sprinklers and gated pipe	524	760	799	237
Sprinklers	187	0	0	0
Total Area	6,110	1,209	872	700

Notes: Combinations of irrigation systems are used in sequence.
         For example, farmers use sprinklers for early irrigations
         of cotton and tomatoes, before switching to siphon tubes
         or gated pipe for later irrigations. In addition, many
         farmers who use sprinklers to pre-irrigate cantaloupe and
         cotton fields will use surface methods for seasonal
         irrigations.

Table 3. Estimated increases in the annual costs of irrigation,
          by crop and irrigation method, in the Broadview Water
          District, 1997

Irrigation Method	Cotton	Cantaloupes	Processing Tomatoes	Seed Alfalfa
		(Dollars)		
Siphon tubes, improved	50,193	4,564	0	4,378
Gated pipe	16,463	13,510	0	11,459
Sprinklers and siphon tubes	321,217	0	10,447	0
Sprinklers and gated pipe	74,425	93,225	167,646	25,246
Sprinklers	31,791	0	0	0
Total Increase	494,090	111,299	178,093	41,084

Notes: Cost increases are estimated by subtracting the annual,
        per-acre cost of using siphon tubes, traditional (Table 1)
        from the annual per-acre cost of using each alternative
        irrigation method (Table 1), and multiplying the per-acre
        difference by the number of acres planted in each crop
        (Table 2). The sum of estimated total costs for these
        four crops is $824,566, or an average of $92.74 per acre.

Table 4. Estimated annual costs of district efforts to reduce
          selenium loads in the Broadview Water District, 1997

Item	Description	Estimated Annual Cost
		(Dollars)
Manager's time	Administrative tasks regarding drainage issues	23,000
Staff time	Re-design and operation of sumps and recycling system	44,000
Water Quality Program	Frequent sample collection and laboratory analysis	24,000
Selenium Removal Research Support	Contributions to regional research program	10,000
Total Cost		101,000

Notes: The estimated cost of support for regional research
        projects varies, over time and among districts, with
        changes in the research program.

Table 5. Summary of estimated annual farm-level, district, and
          regional costs to reduce selenium loads entering the San
          Joaquin River, 1997

Item	Broadview Water District		Grassland Bypass Project Area
	Total Cost	Average	
	(Dollars)	($/Acre)	(Dollars)
Farm-level irrigation improvements	824,566	92.74	8,717,560
District efforts	101,000	11.22	1,054,680
Regional Drainage Authority	124,338	13.82	865,575
Total Cost	1,049,904	117.78	10,637,815

Notes: Estimated annual costs of farm-level and district efforts
        in the Grassland Bypass Project area are determined by
        multiplying the estimated average annual cost for
        Broadview Water District by the 94,000 acres participating
        in the Bypass Project. The estimated cost of the Regional
        Drainage Authority is obtained from the annual budget of
        that organization. The Broadview portion of that budget
        is determined by a formula that allocates costs among the
        seven participating districts according to the drainage
        characteristics of each district.

Estimated Selenium Loads and Targets in The Grassland Area, 1995 and 1996

Pounds of Selenium

October 1994 through September 1996

☐ Est. Loads ━■━ Targets