COLORADO STATE UNIVERSITY

COOPERATIVE EXTENSION

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Report To The

USDI-Bureau of Reclamation

GRAND VALLEY DEMONSTRATION PROJECT

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Report to the United States Department of the Interior, Bureau of Reclamation

Cooperative Agreement for Surge Irrigation Research and Development Program, Grand Valley Unit

SUMMARY

As a result of a grant from the USDI, Bureau of Reclamation (# 0-FC-40-09270,) to Colorado State University Cooperative Extension, surge irrigation valves and controllers were supplied to 128 farm sites within the Grand Valley of Colorado.

The purpose of these installations is to test and demonstrate surge technology to area farmers. The equipment also enables irrigators to improve their irrigation efficiency and to reduce the deep percolation and its resultant salt loading of the Colorado River. The valves were installed by the cooperators on fields of corn, alfalfa, small grain, beans, pasture, and orchard crops.

Cooperative Extension personnel studied 149 irrigation events throughout the 1993 irrigation season. Of these 140 provided usable data, and 41 events provided comparisons between conventional and surge. Results of the irrigation evaluations with surge, as well as with conventionally irrigated fields, indicated that the surge irrigations were instrumental in reducing deep percolation of excess irrigation water.

The 41 direct comparison evaluations from the 1993 irrigation season indicated that deep percolation was reduced by 21 acre-inches which translates into a salt load reduction of 28 tons.

Reducing deep percolation losses by 560 acre inches during the 4 irrigation seasons indicates the potential savings due to equipment improvements. The 560 acre inches of deep percolation reduction left over 1,000 tons of salt in place. Additional benefits may be achieved with improved water management.

Projections based on the average salt load reduction over the four year period indicate a total salt saving of 1,617 tons during the 1993 season. This salt reduction of 1,617 tons should continue during the life of the equipment assuming that current water management practices continue.

Report to the USDI, Bureau of Reclamation
from Colorado State University Cooperative Extension

BACKGROUND

Surge irrigation has been recognized for a number of years for its ability to enhance irrigation water advance across a field. The principle involves a valve operated by a motorized controller which switches the irrigation water from one side of the field to the other at prescribed times. The first application advances down a short portion of one side of the set before the water is switched over to the alternate side to advance the water the same distance. It is powered by a solar collector attached to a battery and is relatively maintenance free. The number of cycles of alternating the water from one side to the other is dependent upon the soil type, length of irrigation run and the amount of water available for the irrigation. After the initial alternating times (called "out times") the cycles are decreased in length of time to soaking, or cutback times. At this point, the field should be wetted through to the end and excess water runoff ("tailwater") should be minimized.

Several theories exist as to why surge irrigation works. The most accepted version is that the water may continue to penetrate the soil even after the irrigation water is removed from it; this may result in some soil "sealing" by breaking of some capillary flow and less penetration when the next "surge" of water is applied. Thus, the water may travel further down the furrow with less water applied than if the water had been applied continuously. As a result, vastly improved irrigation efficiencies have been realized by many irrigators and the conclusions have been published in several journals.

THE GRAND VALLEY:

The Grand Valley is situated in west central Colorado. In any given year, about 60,000 acres are irrigated by gravity flow water delivered through mostly unlined canals from the Colorado River. The entire area is underlain by a saline marine formation known as Mancos shale. Since the irrigation water is plentiful and inexpensive, considerable over-irrigation occurs. This over-irrigation coupled with leakage from the unlined canals contributes about 600,000 tons of salt annually from the shale through return flow to the Colorado River drainage. Principal crops are corn for both grain and silage, alfalfa hay, small grains and orchard fruits. Smaller acreages of onions, dry beans and soybeans are scattered throughout the valley. Production on a per-acre basis is good.

THE SURGE PROJECT:

One hundred twenty-eight cooperators were invited to participate in the USBR sponsored surge project over the four year period from 1990 through 1993. The cooperators were given either an in-line surge valve, a gated pipe "T" shaped surge valve or a ported ditch surge gate, together with an appropriate controller. One unit was made available for each farmer selected. After a short workshop on the use of the surge valves, the cooperators installed them in their irrigation systems and began to use them for their first irrigations. The Cooperative Extension team was able to study 149 conventional and surge irrigations throughout the 1993 irrigation season. Both inflow and outflow of a single furrow were measured with v-notch furrow flumes and automated data gathering devices. A furrow that had no wheel traffic upon it was selected for the evaluation. This presented conditions conducive to the greatest amount of deep percolation and least runoff of the applied water (a worst-case scenario). Forty-one of the irrigations produced useable data. The remainder were rendered unusable due to furrow washouts and crossovers and occasional malfunctions of the data gathering equipment. Some of the flumes became silted making the data questionable.

Total acres included 32 acres conventionally irrigated and 28 acres irrigated by surge methods during the 1993 irrigation season. All fields are not listed on the attached tables due to data collection problems.

The SCS monitoring team monitored two of the fields, and provided total inflow and outflow water measurements from the fields. Evapotranspiration values for the crops and software for evaluating data were also provided by the monitoring team.

EVALUATION:

Irrigation events were recorded on 149 occasions throughout the 1993 crop year with 140 events yielding useable information. The 2 primary causes of unusable data include water breaking out of the furrows and the "v" notch flumes silting up. In addition, birds pulled the string from the flumes and small animals (skunks and raccoons) disturbed the floats on occasion. The two fields monitored by SCS provided the most reliable data and projections will be made from this information. These fields are identified as M51 and M55 on the data sheet in the farm number column included with this report. The other farm numbers are those where individual furrow flows were measured. See attached data sheets.

Note that some farms have negative numbers in the deep percolation column. This indicates deficit irrigation (the water used by the crop was not replaced totally by the irrigation water) and it increases the efficiency to an unrealistic number. Some fields are believed to be sub-irrigated with water from a higher elevation. The cause of the deficit irrigations on the other fields is unknown. Perhaps the method of calculating evapotranspiration may need to be refined, and some data collection error may have occurred. A crop planted earlier or later than the reference crop, used for evapotranspiration calculations, will use water differently than the reference crop.

Daily evapotranspiration rates provided by the monitoring section of the Soil Conservation Service were used to determine soil moisture deficits between most irrigations. The initial soil moisture deficit prior to irrigation was determined by the hand feel method which was substantiated by a gravimetric evaluation of selected samples.

A comparison of fields identified as M11, M15, M43, M51, and M55 shows a difference in water use between the same crops in different years and a difference in crop use on the same farm (M43).

Field comparisons.

FIELD	ACRE INCH APPLIED/a.		ACRE INCH RUN-OFF/a.		ACRE INCH DEEP PERC./a.	
NUMBER	CONV.	SURGE	CONV.	SURGE	CONV.	SURGE
M11-90	34.6	29.1	4.4	8.8	10.9	2.0
M11-91	51.8	44.3	3.7	11.4	15.9	5.0
M15-90	76.9	49.3	32.5	16.9	20.7	10.7
M15-91	69.5	50.2	24.1	14.8	23.1	14.5
M15-92	67.4	45.6	20.7	6.0	26.5	19.5
M43-90	65.8	50.8	16.2	17.5	31.2	13.7
M43-91	85.2	71.8	36.0	24.7	23.7	22.3
M43-92	61.5	67.0	18.0	14.2	14.2	26.6
M51-91	32.5	22.2	16.3	9.8	4.1	2.1
M51-92	38.1	21.9	15.4	8.0	5.7	0
M51-93	24.5	19.1	8.2	7.4	1.1	0
M55-93	55.5	42.2	12.2	8.7	9.0	1.0

DATA ANALYSIS:

Note the increased water use on farm M11 between 1990 and 1991. This is a well-managed orchard but water management can be improved by adjusting the timing of the cut-back cycles to reduce runoff. Also, reduced set times combined with proper cutback cycle timing should reduce deep percolation. This field was converted to surge irrigation for the 1992 season.

Farm M15 reduced the total amount of water used during the 1991 season when compared to 1990 but set times were about the same so deep percolation was increased during 1991. Seventeen of the 19.5 inches of deep percolation occurred during the initial irrigation of the corn during crop year 1993.

Increased water use on farm M43 reflect the change from corn to alfalfa. During the year of alfalfa establishment -1991- a larger amount of water is used to assure seed germination and seedling development. Examination of set time and furrow flow data, not included here, indicate extended set times during the second and sixth irrigations and reduced furrow flow rates during the second irrigation.

Data obtained from field M51 indicates the operator understands irrigation water management as it pertains to this field.

Field M55 results show improved water management and reduced deep percolation with the surge system.

Comparisons between fields that were full field monitored and fields that were evaluated by single furrow measurements are desirable, but a limited number of fields have total irrigation events available for comparison. Fields that lend themselves to full field evaluations are difficult to find since few have isolated inflows and outflows for accurate flow measurements.

SALT LOAD REDUCTION:

Salt load reduction estimates made from the 5 fields that were fully monitored by the SCS monitoring team during the past four irrigation seasons are shown below.

Salt load reduction from selected fields.

(A)	(B)	(C)	(D)	(E)	(F)		(G)	(H)
			Acre Inch reduction from Surge					
Farm	Surge Acres	Salt Tons/a.i.	1990	1991	1992	1993	Total	Tons (B)x(C)x(G)
M11	7.5	0.280	8.9	10.9			19.8	41.6
M15	16.6	0.263	10	8.6	7.0		25.6	111.8
M43	4.8	0.341	17.5	1.4	-12.4		6.5	10.6
M51	9.6	0.263		2.0	5.7	1.1	8.8	22.2
M55	5.0	0.28				8.0	8.0	11.2
							Total	197.4

The 197.4 tons of salt saved divided by the 43.5 acres indicates an average salt reduction of 4.5 tons per acre over the four year trial from these selected fields.

The cost of the surge equipment purchased under this agreement, used on these five farms, was $6,557.00. This equipment is assigned a 15 year life under the USDA portion of the Colorado River Salinity Control Program.

This equipment cost of $6,557.00, amortized at 8% for the 15 year life of the surge units, divided by 4.5 tons/per acre times 43.5 acres equals $3.91 per ton of salt.

The tons of salt per acre inch of deep percolation, shown in column C, is less than the weighted valley wide average of 0.337 tons per acre inch, shown in Table 1

"EFFECTS OF ONFARM WATER MANAGEMENT". Note that these factors are used on the data sheets as salt tons/ acre inch on the data sheets for 1990, 1991, 1992, and 1993. These numbers have been generated by USBR and USDA for the different areas of the Grand Valley based on measured salt contributions.

The total salt contribution from each field, where data was obtained, has been calculated using the number of acres under surge, the acre inch reduction of deep percolation due to the use of surge irrigation, and the tons of salt produced per acre inch of deep percolation. These numbers and the total are shown in the right column of the data sheets.

Additional, incalculable, salinity benefits can be expected to have occurred in that not all irrigation events on all farms were evaluated each year.

DEEP PERCOLATION REDUCTION:

The amount of deep percolation in acre-inches by conventional and surge irrigation, divided by the acres in each for all years, indicates a deep percolation savings as a result of surge irrigation, as shown below:

Comparison of deep percolation, by system, in acre inches per acre.

Year	Conventional	Surge
1990	5.6	1.5
1991	4.6	1.5
1992	1.1	0.4
1993	0.7	0.03

Several reasons may exist for the declining deep percolation as shown in the above data:

1) Winter moisture and spring rains may have left the soil in the fields in a condition conducive to packing which increased the soil bulk density. Increased bulk density reduces infiltration rates. Weather conditions during the corn planting seasons of 1992 and 1993 were such that they inhibited work in corn fields. This reduced tillage lowered or minimized the loss of stored soil moisture which reduced the amount of early irrigation.

2) The farmers who requested surge units at the start of the program were either the more innovative farmers or the ones with the most serious irrigation problems.

3) The last group of farmers to request surge units were more involved with orchard crops; generally, orchard fields have shorter furrow rows, are easier to manage under conventional irrigation systems and may show less advantage to the surge system. This is supported by the data from field

M11. When this field was conventionally irrigated the run was split in the middle but was successfully irrigated in one run when surge irrigated. Fewer side by side comparisons were possible in the orchards.

4) Cooperative Extension and Soil Conservation Service personnel have actively promoted irrigation water management concepts by personal visits with water users, newsletter articles, workshops, and demonstrations.

The values listed in the table may be questionably low. The numbers may best be used to identify trends that are apparent. During each of the years there is a >3:1 advantage to the surge system applications. Each year there is less deep percolation from either system than during the previous year. These trends indicate improved irrigation water management by the cooperators. Cooperators have also been warned of potential salt build up if adequate leaching water is not used. It is suggested they take soil samples on an annual basis for salinity analysis to be aware of any salt build up in their irrigated fields.

TILLAGE and SURGE:

The bean field on farm E303 was divided into conventional tillage and conservation tillage sectors. In addition to surge and conventional irrigation , evaluations were made of wheel track and non-wheel track furrow flows.

Sediment content of run off waters were made from this field using Imhoff cones.

Conventional irrigation.

Tillage	Furrow type	Inflow	Outflow	Infiltrated	Deep percolation
Conv.	wheel	34.4	10.9	23.7	2.7
Conv.	non-wheel	38.0	8.2	29.8	9.0
Cons.	wheel	35.8	21.8	14.0	-6.9
Cons.	non-wheel	35.1	16.3	18.8	-0.9

Surge irrigation

Tillage	Furrow type	Inflow	Outflow	Infiltrated	Deep percolation
Conv.	wheel	21.3	7.7	13.6	-7.8
Conv.	non-wheel	19.8	3.9	16.0	-4.5
Cons.	wheel	23.7	6.6	17.0	-4.4
Cons.	non-wheel	20.9	7.5	13.4	-8.0

All of the above units are in acre inches per acre. All set times were all 12 hours. This reflects the less water applied to the surge sets where the water was divided into the two surged sets in the 12 hour period.

It is interesting to note that more runoff and less infiltration occurred on the conservation tillage side of the conventionally irrigated portion of the field than on the conventionally tilled portion. One would have expected the opposite to occur upon visual inspection of the field; great amounts of residue left from the previous crop of corn in the furrows created a very rough furrow structure which should have led to impeded flows and less runoff. A possible explanation to this phenomenon is that no tillage was performed on this side of the field; rather, the original furrows and beds were simply re-shaped. Some packing of the surface soil may have occurred during the re-shaping process which may have reduced infiltration of the irrigation water.

The fact that surge irrigation negated the effect of tillage or no tillage on infiltration and runoff amounts is also of interest. This result has significant implications regarding future procedures of crop residue handling and surface irrigation and should be studied in detail. Surge irrigation may offer a significant advantage when conservation tillage procedures are applied to a surface irrigated field.

The forty percent reduction in water use obtained by surge irrigation as compared to conventional irrigation on the field is of great significance. Explanations for this occurrence have been elicited elsewhere.

Several reasons may exist for the apparent large negative deep percolation values. This field site is located about 8.5 miles from the weather station that was used to generate the evapotranspiration data used to estimate soil moisture deficits. There is the possibility of a micro-climate change between the two sites. ET estimates as used in the Grand Valley may be higher than needed. A water table condition may exist on this site which would modify the ET estimates for the field.

FOLLOWUP:

Attempts were made to contact each surge unit recipient to determine their acceptance of the surge concept. A questionnaire was used to document the responses. A copy is included. Responses are summarized as follows:

Acres in surge sets ranged from 2 to 8, while conventional, companion sets ranged from 0.5 to 6.4 acres.

Time to start a conventional set ranged from 0.5 minutes to 120 minutes with surge start time ranging from 1 to 120 minutes.

The various crops listed include: alfalfa, corn small grains, orchard, and pastures.

The fertigation concept is most useful on annual grass crops such as corn and 11 % of the farmers used this method.

Yield differences were not noticed by the cooperating farmers.

Fields were probed by 76% of the farmers during irrigation events.

Various methods were used to determine when to irrigate. Many farmers are on a rotation system so they must irrigate when the have a turn at the water. These water users indicated that they can complete their irrigation in less time due to the use of the surge system.

Additional surge equipment was purchased by 23% of the farmers.

Most farmers (83%) were comfortable using the surge systems.

Most of the problems listed by the respondents were of a minor nature such as the outmost cover of the solar collector peeling off. Several (3) had premature battery problems.

Some of the comments by users are included here:

"Great system"

"Some field slopes and soil types on Orchard Mesa make the use of surge more complex than it would if the fields had a uniform slope and soil type"

"Wished I could afford to convert whole farm to surge"

"Runoff decreased, better irrigation of hard to irrigate areas, first irrigation of season on newly plowed fields much more efficient"

"Surge is an excellent system, should be used on all areas"

"Works good"

"A real work and water saver"

"Surge computer needed repair"

"I would recommend the surge system to be used more"

"I think it is great"

"While I haven't noticed any difference in yields, a definite improvement can be seen in the trees at the end of the season. I attribute this to better infiltration due to the surge system and especially the information on the computer readout"

"I would like to know how to gradually set gates open more as the elevation increases from the end cap to the surge valve. This is a real problem with time getting a field to irrigate properly until the summer is over"

"We have only had the opportunity to use surge one year. Due to soil conditions (shale) and length of experience with crop rotation we had no comparison to crop yields"

"I really like using the surge as it doesn't leave a lot of tail water and over soaking on part of the field"

"The surge system has helped put a more uniform irrigation. Much easier and a great time saver for me"

"Seems very efficient"

"The surge system has cut the time and water use in half, and am pleased with more uniform tree growth"

"Surge set requires additional time, as more area is getting irrigated throws off irrigation schedule"

"Still trying to use my fields irrigation with surge"

"The surge system saves me water and is also more efficient, as opposed to the traditional methods of irrigation"

"We have been extending the run on the surge side because we were not getting enough infiltration"

"Saves water & time"

"Works good! Uses 1/2 the water as compared with conventional system or 2 times the ground with same amount of water"

"Saves water"

"Works good. Saves time and water"

"Controller will not shut off valve completely"

"Excellent system - saves lots of time and expense"

"Have trouble keeping unit charged"

"Believe that the block that surge sets has not been correctly leveled making the surge erratic. At end of irrigation must go back and manually override system and irrigate missed creases"

"If the system is managed properly it is very efficient. If not it can cause many problems"

"I work with sloping land and the surge seems to work very well for me. It has saved me time, and uses less water to do the same job"

"Overall efficiency is great - less time to water and use less water probably only 1/3 as much. Deep percolation eliminated - not much run off"

" I feel it works better on shorter field than long runs"

"Trying to use the quick-connect set screws we found the hole did not line up, consequently the set screws were destroyed. Being unstable, the unit moved enough to break the main gear in the controller. Had to send it to Texas for repair"

"Couldn't use this summer because of a stuck valve"

"Need individual help programming surge valve"

SURVEY SUMMARY:

Information from the survey sheets was compiled and it is projected that equipment purchased by these grant funds is used on 1040 acres of alfalfa, 560 acres of corn, 300 acres of small grains and beans, 150 acres of orchard crops, and on 50 acres of other crops including pasture.

The salt reduction from all acres due to the use of the surge equipment is projected to be 1,617 tons in 1993. This reflects the averaged salinity reduction over the period of the study and the averaged value of the salt contributions from the 13 salinity contributing areas in the Grand Valley.

Local benefits include reduced irrigation applications, fertilizer savings, and the surge equipment in place.

Total expenditures for surge equipment, evaluation equipment, seasonal labor for evaluations, mileage, and reporting costs total about $260,000.

At the end of FY93, 243 surge units had been requested by cooperators in the Grand Valley Unit as part of the cost-share approach of the Colorado River Salinity Control Program. An additional number of units, not readily quantifiable, have been purchased by area farmers using their own funds. Nearly all of these units are in place because of the surge demonstrations in the area made possible through this grant and other Extension activities.

IMPLICATIONS:

The benefit to downstream water users is the 560 acre inches that was not percolated through the soil profile on the surge irrigated portions of the fields and the resultant salt loading reductions as shown by the combined data. This is the measured total from the farms irrigation systems evaluated over the four year period. See column 12 of the attached data sheets under the heading of acre inch reduction of deep percolation. This value is different than the projected value calculated if all farms were measured at all irrigations. Note that 1,000 tons were measured during the course of the study but that 1,617 tons were projected during the 1993 irrigation season. This difference is partially due to not having the equipment available to measure each irrigation event during the season on all farms and the necessity of averaging salt load reduction values.

Improved irrigation water management by irrigators and/or reduced application rates due to irrigation equipment hardware changes do not save water on basin-wide basis. Those who expect to harvest this "saved" water do not understand the hydrological cycle.

Water that is deep percolated past the root system in the Grand Valley is eventually returned to the Colorado River for use downstream. This time period is variable but based on observations of the various drainages in the valley the quantity of water deep percolated from irrigations is back in the river by April of the following year. This water is degraded in quality but the quantity has not been significantly reduced. The purpose of the Colorado River Salinity Control Program is to address water quality, not quantity. If less water is diverted because of better irrigation water management the flow will be available downstream at an earlier date but there will not be more flow available. While the water is underground in the irrigated areas it is subject to less evaporation than while in the major reservoirs downstream; this concept is often overlooked.

Deep percolation reduction made possible by surge units purchased with cost-share and private funds is beyond the scope of this study, but will be included as part of the total USDA salinity reduction report.

Water crossing over from one irrigated furrow to another prevented accurate flow measurements on some fields. This implies poor irrigation water management. More frequent and/or deeper furrowing by the farmer may remedy this problem.

An additional solution may be leveling on grade by laser or by conventionally controlled equipment.

Silting of the flow measuring flumes may be indicative of excess furrow flows, a steep grade, poor furrow compaction, high silt load in the irrigation water, and/or recently cultivated ground. Future studies should consider identifying the cause and quantifying the amount of silting. Adequate manpower and equipment to measure the sediment content of the water during an irrigation are needed.

1994 PLANS:

The grant from Bureau of Reclamation, USDI, has been used for this demonstration and evaluation program and has been terminated after 1993. Evaluation equipment will be available for use and continued irrigation evaluations will be made using Cooperative Extension funds.

Plans for the 1994 crop year include continued furrow flow evaluation, immediate processing of data and quick return of the information to the farmer, and increased emphasis on improved water management by the cooperators.

Comparison of nitrate nitrogen,sediment and phosphorous contents of the tail water of the surge sets and conventional sets will be made when funding is available.

Results of the surge fertigation program as noted in a previous report and irrigation water management concepts as determined by the surge demonstration and evaluation program will be stressed at meetings and

INTERVIEW SHEET

How many acres are in the surge sets?

How many acres are in the conventional set?

How much time does it take to start a conventional set?

How much time does it take to start the surge sets?

Crop?

Have you used the fertigation concept to apply nitrogen fertilizer?

Have you noticed any difference in yields between the surge and conventional systems?

Do you probe the top and bottom of the fields during or after irrigation?

How do you determine when to irrigate?

Have you purchased additional surge equipment?

Are you comfortable adjusting advance and cutback (soak) cycles?

Have you experienced any problems with the surge equipment?

COMMENTS BY USER

Table 1

EFFECTS OF ONFARM WATER MANAGEMENT

The hydro-salinity model shows that deep percolation is 11 inches per year from 60,000 acres. This equals 660,000 acre-inches (55,000 acre-feet) of deep percolation. The associated salt load is 168,100 tons per year.

The unit factors for evaluating salt load reduction resulting from reduced deep percolation are:

Canal - Water Source		tons/ac. in.	tons/ac. ft.
1. East End	Gov't Highline	0.474	5.69
2. Middle	Gov't Highline	0.263	3.16
3. Stage 1	Gov't Highline	0.341	4.09
4. West End	Gov't Highline	0.234	2.81
5. Grand Valley Canal		0.475	5.70
6. Grand Valley Highline		0.263	3.16
7. Grand Valley Mainline		0.258	3.09
8. Independent Ranchman's		0.270	3.24
9. Kiefer Extension		0.350	4.20
10. Price Ditch		0.592	7.10
11. Stub Ditch		0.592	7.10
12. Orchard Mesa No. 1		0.280	3.36
13. Orchard Mesa No. 2		0.280	3.36
Weighted Average-Valley Wide		0.337	4.05

SURGE IRRIGATION RESEARCH, DEVELOPMENT, AND DEMONSTRATION - 1990

FARM NUMBER	CROP	NUMBE of IRRG.	ACRES CONV.	SURGE	ACRE INCH APPLIED/a. CONV.	SURGE	ACRE INCH RUN-OFF/a. CONV.	SURGE	ACRE INCH DEEP PERC./a. CONV	SURGE	ACRE INCH REDUCTION OF DEEP PERC. by SURGE	SALT TON/A.I.	SALT LOAD REDUCTION
M11	ORCHAR	4	4.3	7.5	34.6	29.1	4.4	8.8	10.9	2.0	8.9	0.28	18.7
M15	CORN	8	18.9	16.6	76.9	49.3	32.5	16.9	20.7	10.7	10	0.263	43.7
M43	CORN	5	2.4	4.8	65.8	50.8	16.2	17.5	31.2	13.7	17.5	0.341	28.6
M45	SM. GRAI	5	5.6	11.3	60.7	39.2	28.2	12.1	16.8	11.2	5.6	0.341	21.6
12	ALFALFA	4	4.0	6.0	66.4	44.2	12.4	5.6	31.6	16.2	15.48	0.234	21.7
14	BEANS	2	4.58	11.5	26.8	20.1	11.5	6.2	9.1	7.7	1.4	0.234	3.8
24	CORN	1	4.34	8.1	28.6	14.2	8.7	1.7	15.2	7.8	7.4	0.234	14.0
26	BEANS	6	0.57	6.64	63.4	35.8	6.6	8.2	48.2	19	29.2	0.341	66.1
28	ALFALFA	1	4.48	8.95	10.5	10.5	0.4	2.3	7.4	5.5	1.9	0.258	4.4
32	CORN	3	0.19	1.74	89.6	63.2	13.5	8.8	65.7	43.6	22.1	0.263	10.1
34	ALFALFA	3	1	2.5	30.5	19.6	9.7	5.5	5.9	0	5.9	0.28	4.1
40	ORCHAR	1	0.67	5.22	29.6	21.9	13.1	11.3	11.2	5.4	5.8	0.28	8.5
42	SM. GRAI	2	2.9	5.9	18.1	7.8	8.2	1.6	4 6	0.7	3.9	0.341	7.8
44	BEANS	1	3.95	8	38	24.7	8.6	9	26.2	12.4	13.8	0.341	37.6
50	PASTURE	2	1.9	3.8	13.5	12.5	3.6	2.8	0.5	0.2	0.3	0.263	0.3
56	ORCHAR	2	0.6	1.4	45.1	21	21.9	2.1	13.5	9.2	4.3	0.28	1.7
58	ALFALFA	1	2.11	2.11	30	12	19.4	4	7.6	4.9	2.7	0.263	1.5
62	GRASS	3	1.86	4.81	18	13.7	5.2	1.6	-1.1	-1.8	0.7	0.341	1.1
68	ORCHAR	1	0.53	1.32	8.4	8.9	1.6	3	-1.1	-2	0.9	0.28	0.3
70	ORCHAR	3	1.6	3.3	79.2	51.5	36.5	28.3	22.9	3.8	19.1	0.28	17.6
74	ALFALFA	1	1.26	2.27	38.5	17.3	0.9	1.52	32.4	10.6	21.8	0.263	13.0
76	BEANS	1	3.18	6.68	24.2	13	3.2	0	16.6	8.6	8	0.28	15 0
80	ORCHAR	2	0.58	1.16	13.8	11.7	5.3	1.1	2.2	1.4	0.8	0.28	0.3
		62	71.5	131.6	910.24	592.04	271.58	159.92	400.44	194.58	207.48		341.67

SURGE IRRIGATION RESEARCH, DEVELOPMENT, AND DEMONSTRATION – 1991

FARM NUMBER	CROP	NUMBE of IRRG.	ACRES CONV.	SURGE	ACRE INCH APPLIED/a. CONV.	SURGE	ACRE INCH RUN–OFF/a. CONV.	SURGE	ACRE INCH DEEP PERC./a. CONV	SURGE	ACRE INCH REDUCTION OF DEEP PERC. by SURGE	SALT TON/A.I.	SALT LOAD REDUCTION
M11	ORCHAR	5	4.3	7.5	51.8	44.3	3.7	11.4	15.9	5.0	10.9	0.28	22.9
M15	CORN	6	18.9	16.6	69.5	50.2	24.1	14.8	23.1	14.5	8.6	0.263	37.5
M43	ALFALFA	6	2.4	4.8	85.2	71.8	36.0	24.7	23.7	22.3	1.4	0.341	2.3
M51	CORN	6	19.0	9.6	32.5	22.2	16.3	9.8	4.1	2.1	2	0.341	6.5
E11	CORN	1	5.4	9.1	16	8.18	4.07	3.59	4.64	-2.72	7.36	0.234	15.7
E12	ALFALFA	5	4.0	6.0	90.5	48.6	14.1	3.7	39.2	7.6	31.6	0.234	44.4
E14	BEANS	2	4.58	11.5	26.5	22.9	8.9	12.8	7.6	-4.9	12.5	0.234	33.6
E17	SM. GRAI	1	3.4	6.8	23	14.4	0.2	1.4	20.1	10.3	9.8	0.234	15.6
E18	CORN	2	6.6	6.6	33.1	30.8	0.9	3.1	19.6	14.6	5	0.28	9.2
E19	ORCHAR	3	1.58	2.2	73	106	24.4	48.8	26.3	35.5	-9.2	0.28	-5.7
E20	SM. GRAI	3	0.36	1.38	73.8	69.8	41.3	41.5	18.4	14.1	4.3	0.35	2.1
E26	BEANS	6	0.57	6.64	47.9	37.8	8.8	4.4	18.1	12.4	5.7	0.341	12.9
E27	CORN	6	2.5	5.6	45.6	37.7	10	6.5	13.3	8.8	4.5	0.263	8.6
E29	SM. GRAI	2	0.96	12.5	18.8	9.5	2.2	0.7	8.9	1.1	7.8	0.263	25.6
E32	CORN	3	0.19	1.74	39.9	39.3	7.5	6.6	16.9	17.3	-0.4	0.263	-0.2
E34	ALFALFA	2	1	2.5	19.4	14.8	10.9	6.6	-9.9	-10.2	0.3	0.28	0.2
E36	ALFALFA	1	3.3	2	27.2	12.6	8.7	6.4	7.7	-4.6	12.3	0.28	6.9
E50	PASTURE	3	1.9	3.8	68.7	57	13.1	5.9	39.7	35.2	4.5	0.263	4.5
E55	SM. GRAI	1	7.1	16	10.1	8.3	0	3	-1.8	-3.4	1.6	0.258	6.6
E57	ORCHAR	2	1.8	3.6	11.4	5.2	2.3	1.1	0.17	-5.9	6.07	0.28	6.1
E58	ALFALFA	3	2.11	2.11	54.1	39.3	21.5	11.5	12.3	7.5	4.8	0.263	2.7
E62	GRASS	6	1.86	4.81	47.7	37.9	0.5	1	17	6.6	10.4	0.341	17.1
E68	ORCHAR	2	0.53	1.32	25.3	22.5	3.3	6.8	9.1	2.7	6.4	0.28	2.4
E72	CORN	1	6.6	6.6	28.1	30.3	3.2	17.9	19.5	6.95	12.55	0.28	23.2
E73	CORN	1	6.7	11.6	6.7	2.9	1.1	0.67	1.73	-0.5	2.23	0.234	6.1
E75	SM. GRAI	1	4.98	9.96	19.1	9.9	1.6	4	13.5	1.8	11.7	0.234	27.3
E77	SM. GRAI	5	2.6	2.97	58.1	46.2	23.4	14.9	12.1	8.6	3.5	0.234	2.4
E80	ORCHAR	5	0.58	1.16	71	45.5	3	11.1	38	4.4	33.6	0.28	10.9
E81	PASTURE	2	2.9	5.8	46.2	23.5	24.1	7.5	5.1	-1.1	6.2	0.234	8.4
E83	ORCHAR	11	0.96	1.7	122	58.1	52.5	17.5	55.8	26.9	28.9	0.592	29.1
E85	CORN	2	2.5	3.5	60.5	41.3	6.1	2.8	32.9	33.2	-0.3	0.341	-0.4
E95	ALFALFA	4	2.48	4.8	59.7	39.3	13.7	15.9	23.5	1.1	22.4	0.341	36.7
		90	115.8	176.99	1174	945.88	295.07	284.62	536.24	267.23	269.01		419.26

SURGE IRRIGATION RESEARCH, DEVELOPMENT, AND DEMONSTRATION - 1992

FARM NUMBER	CROP	NUMBE of IRRG.	ACRES CONV.	SURGE	ACRE INCH APPLIED/a. CONV.	SURGE	ACRE INCH RUN-OFF/a. CONV.	SURGE	ACRE INCH DEEP PERC./a. CONV	SURGE	ACRE INCH REDUCTION OF DEEP PERC.	SALT TON/A.I.	SALT LOAD REDUCTION
M15	CORN	6	18.9	16.6	67.4	45.6	20.7	6.0	26.5	19.5	7.0	0.263	30.6
M43	ALFALFA	6	2.4	4.8	61.5	67.0	18.0	10.3	14.2	26.6	-12.4	0.341	-20.3
M45	ALFALFA	5	5.6	11.3	60.0	54.9	13.2	12.8	22.6	17.3	5.3	0.341	20.4
M51	CORN	8	17.6	9.6	38.1	21.9	15.4	8.0	5.7	0.0	5.7	0.341	18.7
E19	ORCHAR	1	1.6	2.2	25.6	11.4	13.8	3.3	6.1	2.8	3.3	0.28	2.0
E27	CORN	2	1.3	12.7	3.5	8.7	0.0	1.7	-0.1	-0.6	0.5	0.258	1.6
E71	CORN	3	1.5	12	18.5	19.1	8.5	10.7	5.1	0.4	4.7	0.263	14.7
E73	CORN	1	3.7	10.3	14.6	7.2	4.6	0.7	6.1	2.6	3.5	0.234	8.5
E77	GRASS-A	1	12.5	7.5	10.0	12.6	0.2	3.1	7.8	7.7	0.2	0.234	0.3
E81	ALFALFA	1	28.3	8.7	13.0	7.9	2.2	0.9	4.8	1.0	3.8	0.234	7.7
E83	ORCHAR	6	0.3	0.8	25.1	23.0	8.7	7.0	8.2	7.9	0.3	0.592	0.2
E85	ALFALFA	4	3.6	10.4	28.4	31.8	7.9	10.3	-1.0	-0.1	-0.9	0.341	-3.3
E201	CORN	6	6.9	13.8	36.4	33.0	6.2	13.3	12.8	1.4	11.5	0.341	54.1
E203	ORCHAR	3	1.8	1.8	4.8	10.8	0.3	2.3	0.8	-5.0	5.8	0.281	2.9
E210	ORCHAR	3	0.9	1.9	30.6	17.8	4.9	3.4	8.9	-2.9	11.8	0.592	13.3
E212	ALFALFA	2	1.8	33	4.1	1.7	1.1	1.0	0.0	-4.8	4.8	0.263	41.6
E217	GRASS P	3	2.1	4.3	19.0	20.5	11.0	9.8	5.8	1.2	4.6	0.475	9.5
E235	CORN	4	2.2	7	25.0	19.7	3.2	2.7	9.9	5.3	4.6	0.28	8.9
		65	113.0	168.7	485.7	414.6	140.0	107.3	144.1	80.2	63.9		211.3

SURGE IRRIGATION RESEARCH, DEVELOPMENT, AND DEMONSTRATION - 1993

FARM NUMBER	CROP	NUMB of IRRG.	ACRES CONV.	SURGE	ACRE INCH APPLIED/a. CONV.	SURGE	ACRE INCH RUN-OFF/a. CONV.	SURGE	ACRE INCH DEEP PERC./a. CONV	SURGE	ACRE INCH REDUCTION OF DEEP PERC.	SALT TON/A.I.	SALT LOAD REDUCTION
M51	CORN	7.0	16.9	9.6	24.5	19.1	8.2	7.4	1.1	0.0	1.1	0.341	3.6
M55	ORCHAR	8.0	5.0	5.0	55.5	42.2	12.2	8.7	9.0	1.0	8.0	0.280	11.2
E201	CORN	6.0	6.0	6.9	39.1	24.0	2.1	1.5	2.8	1.6	1.2	0.592	4.9
E210	ORCHAR	6.0	0.7	1.4	69.3	55.3	4.1	1.1	1.1	0.3	0.8	0.280	0.3
E235	BEANS	6.0	0.4	0.8	43.3	39.1	1.7	1.0	1.6	1.4	0.2	0.280	0.0
E303	BEANS	7.0	0.9	0.9	35.8	21.4	2.1	0.9	0.1	-0.9	1.0	0.350	0.3
E311	CORN	1.0	1.3	2.6	7.4	3.1	1.8	2.4	5.9	-2.5	8.4	0.350	7.6
		41.0	31.2	27.2	274.9	204.2	32.2	23.0	21.6	0.9	20.7		28.0