FERTIGATION THROUGH SURGE VALVES

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Introduction

The Grand Valley of Colorado is located in the west central portion of the state. In any given year, about 60,000 acres are irrigated by gravity flow from the Colorado River. The valley is underlain by a saline shale formation known as Mancos shale. Since the irrigation water is plentiful and inexpensive, and is delivered to the producers through mainly unlined canals and laterals, deep percolation and seepage dissolve some of the salt from the shale and convey it to the Colorado River. About 600,000 tons of salt are delivered annually to the river via this pathway. As a result, much interest has been generated to improve irrigation efficiencies in the valley to effect a reduction in the salt loading of the river.

The Surge Program

During the summer of 1987 a conventional surge unit was borrowed from Colorado State University for use in the Grand Valley of Colorado. This unit was used for demonstrations on several farms during the next 3 years. The Palic design was used in the Grand Valley as a pattern for construction of surge gates beginning in 1987.

Irrigation system improvements on some fields used level gated pipe for 1 set width with a 6 inch drop to the next set width. When the lower set was being irrigated, the water was flowing through the upper pipe below the gates. This situation lent itself to surge irrigation by an in-line surge valve. An in-line surge unit was constructed during the winter of 1989 and used successfully that crop year.

The results of this study were reported to the American Society of Agricultural Engineers at the 1989 Annual Meeting. As a result, a grant was made available to the Colorado State University Cooperative Extension from the Bureau of Reclamation (USDI) to evaluate and demonstrate surge irrigation to cooperating farmers.

One hundred and twenty-four surge units have been made available to farmers as demonstration units. Irrigation events were recorded using furrow flow recorders at the top and bottom of the fields. Irrigation events on 4 additional fields were recorded by the SCS monitoring team in Grand Junction. Evaluations have indicated a decrease in water use of 25% by surge when compared to adjacent conventionally irrigated fields.

Observations of measured furrow flows on cooperating farmer's fields during the past several years have indicated the opportunity to reduce runoff during the cut-back cycle. Careful adjustment of the gated pipe openings provided the correct amount of water so that all furrows advanced nearly uniformly to the lower end of the field. Adjustment of the cut-back cycle times allowed the operator to reduce tail-water flow to a minimum.

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, and M43 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	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
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

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 surge runoff. Also, reduced set times combined with proper cutback cycle timing should reduce deep percolation.

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. Nearly all of the deep percolation (17.0 inches) from the surge set was during the initial irrigation which indicates an attempt to "black over".

Increased water use on farm M43 reflects the change from corn to alfalfa. During the year of alfalfa establishment a larger amount of water is used to assure seed germination and seedling development. Set times on the surge side are longer than expected on M43.

Salt load reduction estimates were made from the 3 fields that were fully monitored by the SCS monitoring team during the past two irrigation seasons are shown below.

Salt load reduction from selected fields.

(A) Farm	(B) Surge Acres	(C) Water Source	(D) Salt Tons/a.i.	(E) Acre Inch reduction from 1990	(F) Surge 1991	(G) Total	(H) Tons (B)x(D)x(G)
M11	7.5	Orchard Mesa	0.280	8.9	10.9	19.8	41.6
M15	16.6	Mid. Gov't	0.263	10	8.6	18.6	81.2
M43	4.8	Stage 1	0.341	17.5	1.4	18.9	30.9
					Total		153.7

The 153.7 tons of salt saved divided by the 28.9 acres indicates an average salt reduction of 5.3 tons per acre over the two year trial.

It is generally accepted that the downstream dollar value of salt left in place in the Grand Valley is $56.00 per ton. This value times the 153.7 tons saved from these three farms indicates a benefit of $8,607.00 to downstream water users for the two year period.

The cost of the surge equipment used on these three farms purchased under this agreement was $4,257.00.

$8,607 (benefits) divided by $4257 (costs) = 2+.

A survey form was provided to water users that had been supplied with the surge units. Of the 26 respondents, 9 moved the controller to an additional valve on the farm. The 9 moved the controllers to a total of 23 different sites. Also 10 of the cooperators had purchased an additional 39 valves and 5 had purchased an additional 14 controllers. Only 2 of those responding added fertilizer through the surge units.

	Survey results
Number of respondents	26
Number moving controller	9
Number of sites	23
Respondents purchasing valves	10
Number of valves purchased	39
Respondents purchasing controllers	5
Number of controllers purchased	14

Results of the survey confirm observations that the farmers were moving valves and controllers to where they could be used.

The ten respondents who indicated that they had purchased valves bought nearly 4 valves each and the 5 who bought controllers average 3 per purchaser.

One of the survey questions asked what percent of water savings the user observed when comparing the surged portion of the field with the conventional portion. The percentages observed and the number of respondents are listed below:

Percent water saved	<25	25	30	35	40	45	50	60
Number responding	3	10	4	0	2	2	2	1

The range of water savings reported on the survey was somewhat surprising. Past observations and trials led us to expect a 25 percent water savings, but many cooperators reported more.

The more uniform infiltration made possible by surge irrigation set the stage for developing the "fertigation" concept.

Surge Fertigation

"Fertigation", or adding fertilizer through irrigation water, has been practiced by both sprinkler irrigators and conventional surface irrigators with some success for several years. Depending upon the system and the contour of the land, the fertilizer applications may vary considerably in efficiency. If an irrigator attempts to add fertilizer through a conventional surface irrigation, more runoff of the fertilizer and less uniformity of application may result than if surge fertigation is practiced.

The ability to add fertilizer through the surge valve system is a significant advantage. Liquid forms of fertilizer may be added through the system during the next-to-last cutback cycle. At this point of the surge irrigation, the irrigation set should have been wetted through the entire length of run, and the soaking, or cut-back, cycles should be almost complete. The last cutback cycle should be reserved to flush any excess fertilizer solution out of the system and to move some of the applied fertilizer into the upper portion of the soil profile. If the calculated flow rate of the liquid fertilizer is too great for the capacity of the application system, the "fertigation" application may be split between 2 or more cutback cycles as long as the last one is reserved for flushing the system and moving the fertilizer into the soil.

Since phosphorus does not move readily in the soil, the material may be added at each cutback cycle or at the beginning of the cutback irrigations to maximize any penetration of the phosphorus into the soil profile that may occur. The last cutback cycle must be reserved to flush the system since most phosphorus fertilizer solutions are composed of ammonium polyphosphates.

Advantages to adding the fertilizer through the surge valve are many when the system has been designed and installed properly:

1. The fertilizer is added rapidly and efficiently.
2. Deep percolation losses of nitrogen fertilizer are minimized.
3. Gaseous losses of nitrogen are minimized.

4. No powered equipment is run through the field; fuel is saved.
5. The fertilizer may be added when the crop needs it.

Disadvantages are few:

1. The flow rate of the liquid fertilizer must be calibrated, which is analogous to calibrating a fertilizer spreader.
2. Some "pitting" of the metal components of the delivery system may occur if the last cutback cycle is not saved to flush it; ammonium in liquid fertilizer is able to combine with various salts from the aqueous solution which subsequently corrode metals, particularly aluminum.

There are 2 ways to add liquid fertilizer through the surge valve--the first is to allow it to flow by gravity through a constant head metering valve at some convenient point before the surge valve, such as into an alfalfa valve or an open channel; the second is to employ a powered injector system before the valve; this is necessary when a head of water must be overcome by the fertilizer application.

Several things must be known before applying the fertilizer through the surge valve:

1. How many pounds of the fertilizer are needed per acre?

2. How many gallons of the material are needed?

3. What is the weight per gallon?

4. What is the acreage under the surge valve?

5. How long is the cutback cycle in minutes?

6. What is the application (flow) rate?

The flow rate can be set by using a marked container and a watch with second marking capabilities. By timing the flow and adjusting the discharge valve, the required flow rate can be set closely. If the applicator uses a commercial injector, the flow rate may be simply dialed in.

These principles may be applied to side-roll sprinkler systems as well; the fertilizer may be injected into the sprinkler at some point during the irrigation. Near the conclusion of the irrigation, the injection of the fertilizer should be terminated and the system flushed with the remainder of the irrigation water.

We added liquid nitrogen fertilizer to 3 fields of corn during several irrigations. The summary of these additions is presented in table 1. The liquid fertilizer used in all cases was UAN, 32% N. Since UAN is slightly acidic and the systems were flushed free of fertilizer during the last cutback cycle, no pitting of the metal components was noted.

The fertilizer was applied with a gravity-fed constant head metering device at the Rooks and the Colorado State University (CSU) farms. The fertilizer was applied with a small, inexpensive 12 volt powered injector pump at the Barbee farm.

Table 1a. Fertilizer Additions, Rooks

Irrigation Method	lbs. N/A	Time
Surge	40	Pre-Plant
	64	3rd Irrigation
	84	4th Irrigation
Conventional	40	Pre-Plant
	130	Lay-By

Table 1b. Fertilizer Additions, Barbee

Irrigation Method	lbs. N/A	Time
Surge	44	Pre-Plant
	50	2nd Irrigation
	50	3rd Irrigation
	50	4th Irrigation
Conventional	44	Pre-Plant
	150	Lay-By

Table 1c. Fertilizer Additions, CSU

Irrigation Method	lbs. N/A	Time
Surge	44	Pre-Plant
	120	Lay-By
	80	6th Irrigation
Conventional	44	Pre-Plant
	200	Lay-By

At the Rooks and the Barbee farms, the fourth irrigation took place just before tasseling of the corn, and the sixth irrigation at the Colorado State University farm occurred just before tasseling.

Yield comparisons from the Rooks and Barbee farms are presented in table 2. No yield data was available from the CSU farm.

Table 2. Yield Comparisons.

Farm	Silage Yield, Tons/Acre Conventional	Surge
Rooks	15.6	20.0
Barbee	27.2	31.0

Since a slightly greater amount of N was applied through the surge system than under conventional irrigation at the Rooks farm, yields were calculated as pounds of silage per pound of N applied. Table 2a presents this data:

Table 2a. Pounds of silage per pound of N applied, Rooks.

Irrigation Method	lbs. Silage/lb. N Applied
Conventional	183.5
Surge	210.0

The yields indicate that a greater efficiency of nitrogen use occurred under surge fertigation and irrigation than under conventional irrigation.

In addition, soil samples were taken from the Rooks farm after the growing season. Each data point represents the average of 4 sample points. The data is shown in table 3.

Table 3. Residual Nitrate Nitrogen, Rooks.

Method of Irrigation	Feet, Depth Of Sample	Mg/Kg Nitrate Nitrogen
Surge	0-1	14.0
	1-2	8.3
Conventional	0-1	5.5
	1-2	5.8

The surge irrigated and fertigated side of the field contained more residual nitrogen in the upper part of the soil profile than did the conventionally irrigated and fertilized field.

The fertigation that was practiced on the CSU farm occurred during the 6th irrigation. Approximately 80 pounds per acre of nitrogen were applied to the corn during the next-to-last cutback cycle of the surge irrigation. Five days after the irrigation, samples were taken at the 1/4, 2/4, and 3/4 distance of the length of run. The field length was 740 feet. The samples were analyzed shortly thereafter for nitrate nitrogen contents. The data is presented in table 4.

Table 4. Nitrate Nitrogen, CSU Farm

		Mg/Kg Nitrate Nitrogen	
Distance	Depth	Surge	Conventional
1/4	0'-1'	26.8	13.8
	1'-2'	13.0	15.2
2/4	0'-1'	24.3	14.2
	1'-2'	15.7	14.0
3/4	0'-1'	24.0	18.2
	1'-2'	14.2	18.8

The data indicated that more nitrate nitrogen was available in the soil for the corn's use as a result of the fertigation. Since we measured only nitrate nitrogen, the total amount of nitrogen present was not apparent, probably because the ammoniacal form of nitrogen had not undergone biological oxidation before soil sampling and determination of the nitrate nitrogen were performed.

Figure 1 is a graphic representation of the fertigation inflow as monitored by small 60° trapezoidal V-notch furrow flumes and automated data gathering devices. The irrigation water flow was measured on and off of the field in 4 furrows. The data agreed quite well between the furrows in terms of total flow. Figure 2 shows the discharge from the field during the irrigation. The next-to-last peak on the graphs indicates the point of the irrigation that the fertigation took place, and the last peak represents the flushing cycle. Approximately 0.74 gallons per minute per furrow flowed from the field for about 17 minutes during the fertigation cycle, which represents a loss of about 0.11 pounds of N per furrow. Since the UAN is a mixture of urea and ammonium nitrate, most of this nitrogen loss would be in the ammonium form.

We sampled the corn ear leaves from the Barbee and Rooks farms when they were apparent and analyzed them for total nitrogen. As part of another study, corn ear leaves were taken for analysis from 3 other conventionally irrigated farms. The samples were taken when silking was completed, the ears were well-formed, and the kernels were in the early milk stage. This data is shown in table 5. The ear leaves taken from the corn that was surge fertigated (Barbee and Rooks farms) contained the most nitrogen within the plant.

Table 5. Corn Ear Leaf Nitrogen.

Farm Name	Irrigation System	% Total Nitrogen
Barbee East	Surge	2.55
Barbee West	Surge	2.62
Bernal	Conv.	2.40
Cloud	Conv.	2.42
Downer	Conv.	2.24
Rooks	Surge	2.66

In conclusion, if the surge irrigator practices fertigation under a high level of management, he may expect to see rapid, efficient fertilizer additions which may result in increased fertilizer use efficiencies and, ultimately, in greater yields. Also, significantly less nitrate nitrogen may be leached into ground and surface waters with surge fertigation than would be under conventionally fertilized and irrigated operations. However, caution as well as a high degree of management must be applied, since improper cutback cycle settings could cause a significant loss of nitrogen to surface waters.

References:

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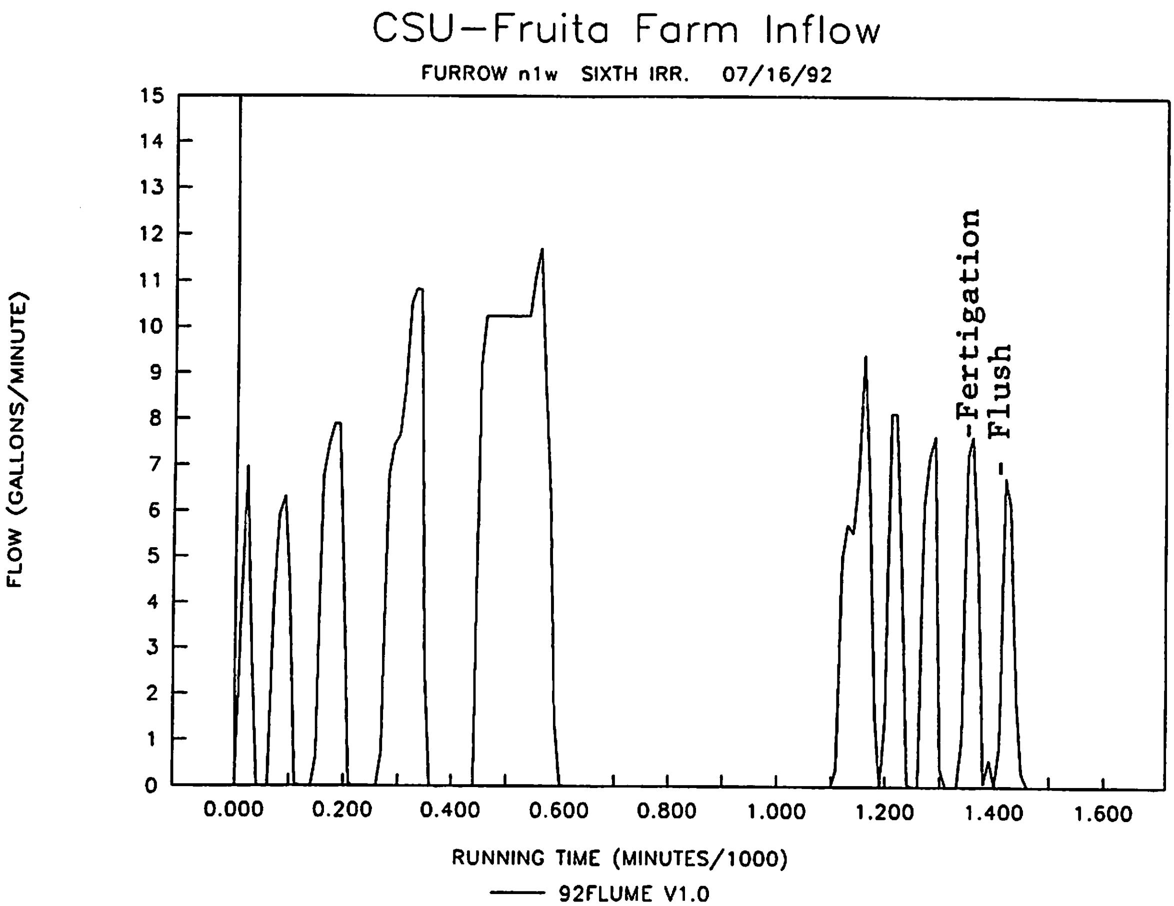

Figure 1. Inflow hydrograph from CSU farm, 6th irrigation and fertigation.

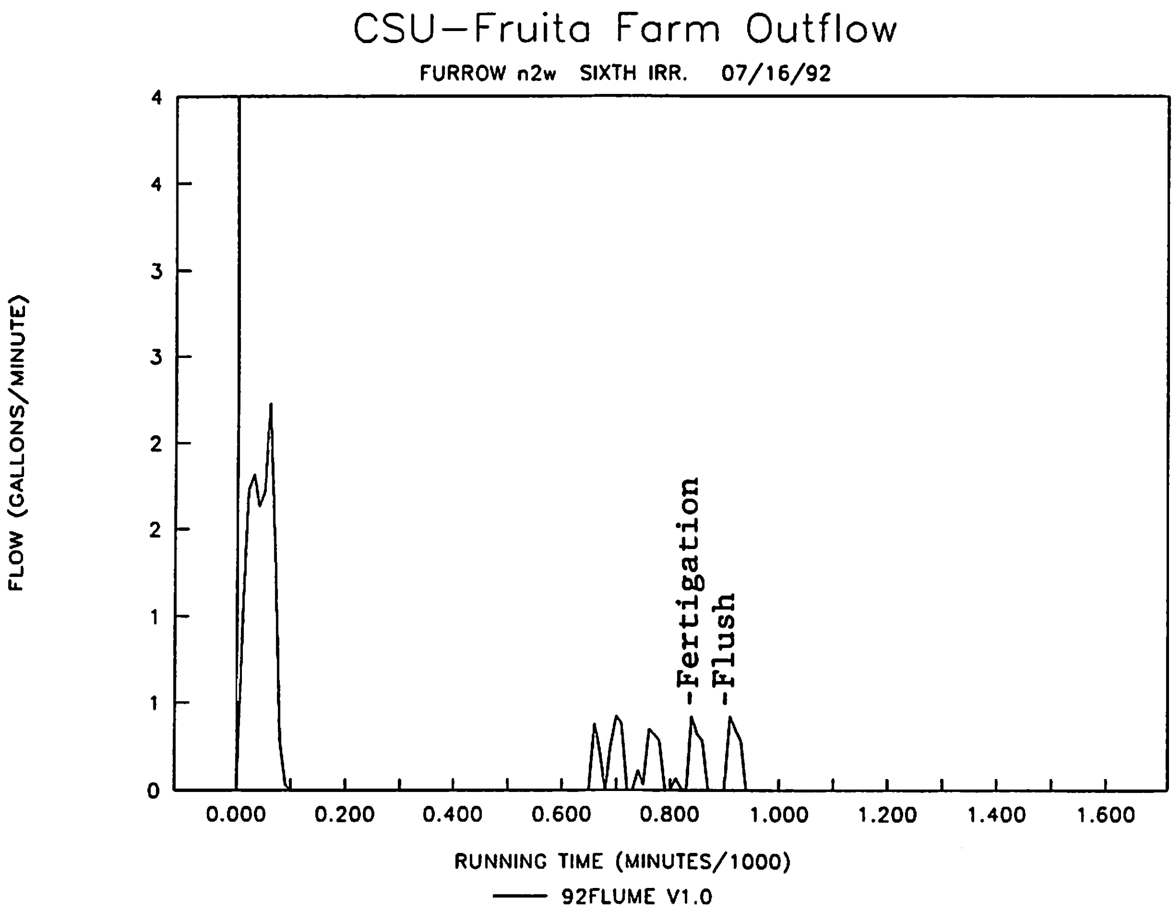

Figure 2. Runoff hydrograph from CSU farm, 6th irrigation and fertigation.