

## **DRIP IRRIGATION SYSTEM COST SHARING BY IRRIGATION DISTRICTS FOR WATER CONSERVATION**

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### **ABSTRACT**

Government and irrigation district cost sharing programs have often included financial support for the installation of drip/micro irrigation systems. These programs seek advantages that might include improved crop yield, less applied water, and a reduction in subsurface drainage water and surface tailwater. They may also seek to reduce water consumption. The actual results have been shown to vary by district, hydrology, and crop.

It is true that drip systems in California, on average, have good Distribution Uniformities (DU) of irrigation water – meaning that there are only minor differences between the depths of water received by various plants throughout a field. However, irrigation district cost sharing programs could obtain even better results by requiring specific attributes and equipment in the drip/micro systems that receive financial assistance. Items such as properly placed flow meters, excellent filtration, new system DU, good fertigation systems, efficient pumps, and maximum allowable pressure requirements at the pump are all easy to specify, do not add significant cost, and will improve initial performance and later management options.

### **INTRODUCTION**

Cost sharing programs exist because of perceived benefits. A cost shared item may be presented by different programs as achieving varied objectives. Programs that involve cost sharing with farmers have an additional feature in that they have two tests to pass:

1. Farmers must receive definitive benefits from their investment portions.
2. The district would like to receive benefits.

The goals of the two partners may be quite different. The farmer is interested in benefits and disadvantages as they relate to items such as:

1. Management time
2. Investment cost
3. Fuel expenses
4. Water bills
5. Labor
6. Yield
7. Crop quality
8. Maintenance
9. Net profit/loss

Although in principle the irrigation district is interested in good outcomes that will directly help farmers, the district generally has more interest in various other objectives:

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1. Reduced diversions
2. Reduced high water table problems that may cause regional drainage problems, or which might cause difficulties with drain water disposal due to poor water quality
3. Reduced surface drainage water recycling (that originated from tailwater), and less sediment from that surface water recycling
4. Ability to increase irrigated acreage
5. Checking off a box that some state regulator devised to demonstrate that the district is active in water conservation efforts
6. Reduced groundwater overdraft
7. Reduced irrigation water consumption

This paper addresses three fundamental questions:

1. Which of the farmer expectations, if any, are realistic?
2. Which of the irrigation district expectations, if any, are realistic?
3. How can optimal success of conversion to drip/micro systems (and, as a result, any cost-sharing program that promotes the conversion) be achieved?

### **ARE FARMER EXPECTATIONS REALISTIC?**

In general, drip/micro irrigation has proven to be a very positive investment. This is clear, based on the continued expansion of drip/micro acreage. But it is also very true that there have been catastrophic failures that have generally been caused by farmers expecting extraordinary benefits from marginal investment in capital and time. Grant programs should be designed to help farmers succeed, and therefore it is important to understand what uncertainties exist, with a goal of then minimizing potential problems.

Uncertainties of drip/micro outcomes from the farmer perspective include:

1. The results obtained and the ease of management will depend upon the quality of equipment, the suitability of the design, and existence of certain useful features (which will be explained later). Saying that you have a drip system is like saying "I have a vehicle." It does not reveal very much.
2. There are often unexpected fatal errors in design or management in the early stages of drip/micro in a region. Small details become major headaches. Problems can vary from unexpected iron bacteria problems to varmint nibbling damage, human vandalism, salinity buildup patterns, poor yields due to excess or deficit irrigation, or wasps that plug microsprayers. The list is expansive.



Figure 1. Unexpected leaks in an subsurface drip irrigation (SDI) installation on tomatoes.



Figure 2. Critter cage around valve – but the critters still got in.

3. The more crops that are involved, the more complicated it becomes to design and manage a drip/micro system. Alfalfa, lettuce, processing tomatoes, cotton, pistachios, almonds, table grapes, and wine grapes (as examples) all have unique design and management problems. However, after five to ten years on a specific crop in an area, with progressive farmers and good irrigation dealers who are willing to test and share new information, most of the lessons have been learned. After this break-in period, chances for success on a new field are much greater than for early innovators in an area.

For example, in the San Joaquin Valley of California there are extensive drip/micro systems on crops such as citrus, almonds, pistachios, walnuts, and processing tomatoes. New drip/micro systems on these crops benefit from extensive design and management experience. Specifically, on almonds we know that double line drip or microsprayers are needed, but pistachios do not seem to need an increased wetted soil area. With processing tomatoes, not only is the drip system important, but using the correct tillage equipment is as well. The chance of success of new drip/micro systems greatly improves by building on earlier trial and error and lessons learned.



Figure 3. Almonds with double line drip (R) versus pistachios with single line drip (L). Major differences in wetted soil percentages. Note the two hose ends coming out of the ground on the almonds. An earlier SDI system was abandoned.

- Some crops show major improvements in yield and quality; other crops do not. For example, some of the largest table grape and nectarine farmers in California firmly believe that fruit quality suffers if they use a drip/micro system. The response of many crops such as onions and lettuce will depend upon the crop variety. Cotton requires special care because of its sensitivity to both over-irrigation and under-irrigation, and the timing of both. With other crops such as processing tomatoes, peppers, broccoli, almonds, and varieties of onions, the yield increases have been remarkable when combined with proper fertilizer management. In the last ten years processing tomatoes have moved from about thirty-five tons per acre to double that; average almond yields are now at least double of what was obtained with surface irrigation. Drip on processing tomatoes is especially productive on poor and salty soils.



Figure 4. Cotton on drip that was overirrigated and matured into miniature trees without many bolls.

5. Reduced management time is rare for the first season. In fact, the management time required for unexpected problems can be overwhelming for some farmers. Eventually, unless there are persistent problems (such as coyotes, gophers, etc.) the management time is reduced. What actually happens is that good drip/micro system inherently becomes “more manageable” than other irrigation systems, so the benefits per hour spent can be increased.
6. Reduced labor may or may not occur. If a system is poorly designed, or if there are problems with varmints, insects, or plugging, there can be very large labor requirements to maintain a drip/micro system. Some growers in California have abandoned drip systems because of the high maintenance and labor costs. It is also noteworthy that with over 40 years of drip behind us, the majority of excellent drip/micro systems are not automated – the logic is that people need to be in the field anyway.
7. Drip/micro systems will cost in the \$1000 - \$2500/acre range when all things are considered. Due to the large variability in design requirements for each individual field, costs vary significantly for farmers. But the quality (and therefore, the cost) of irrigation systems proposed by irrigation dealers is highly variable. Farmers have difficulties evaluating the merits of various bid proposals.
8. If a previous irrigation system was very inefficient, and if the new drip/micro system is very efficient, there can be substantial water cost savings if the annual applied irrigation water is a large number. However, that water cost savings is based on those two very big assumptions. In general in California, it is likely that the water applied on orchards and vineyards, especially on variable soil and in small fields, is greater with surface irrigation than with drip. On the other hand, if one examines processing tomatoes, the water volume applied on heavier textured soils during the irrigation season is very similar before (with surface irrigation) and after (with drip).
9. While there are always exceptions, energy consumption, on the average, increases with drip/micro systems. Many farmers convert to well water instead of surface water because of the flexibility and clean water associated with wells, and drip/micro systems are usually designed to need about 40-45 psi at the pump discharge on a flat field. When compared to an entirely gravity supply system on furrows, the energy requirement for pumping is substantially more with a drip/micro system.

### **ARE IRRIGATION DISTRICT EXPECTATIONS REALISTIC?**

Terms such as “irrigation efficiency” and “water conservation” mean something different to almost everyone, regardless of various attempts to carefully define such terms. Furthermore, any program to improve something should first have an excellent notion of the present status.

“Water conservation” programs should ideally follow a 5-step process:

- Step #1. Create a clear definition of the goals.* For example, reduced water consumption may be a goal. Reduced water consumption will technically mean less evapotranspiration, often with the addition of less flow to salt sinks. This can be entirely different from

applying less water to individual fields. In fact, it is well documented, and intuitive, that healthy, unstressed plants with uniform growth across a field will have a higher evapotranspiration (consumption) rate than fields with less healthy plants, stress, and uneven growth.

- Step #2. Implement a scientific examination of the overall potential to reach the goal.* In most cases involving water conservation on an irrigation district level, this means that an excellent water balance must be developed to determine the sources and destinations of water. For example, if there are large amounts of re-circulation of return flows (surface and subsurface) within the district boundaries, there may be little opportunity to truly conserve water. Keep in mind that this discussion deals with irrigation district goals, not farmer goals (which include higher yields).
- Step #3. Closely examine what fraction of the potential conserved water, for example, will be addressed by increasing the acreage irrigated by a drip/micro system.*
- Step #4. Require certain options and performance standards for new drip/micro systems.* For example, requiring a flow meter for each system may seem obvious but it is not necessarily required in some programs. In fact, often very little is required.
- Step #5. Verify results.* Anticipated results may not meet achieved results, and unless installed performance is verified, it is difficult to know if objectives have been met. For example, this past summer the Irrigation Training and Research Center (ITRC) evaluated thirty-five fields in Westlands Water District that had new, grant-related irrigation systems. The fields were evaluated for both Distribution Uniformity and how well the irrigation scheduling matched evapotranspiration (ET) requirements. To illustrate historical variation, Figure 5 below shows approximately 15 years of results of drip/micro irrigation system evaluations using the standardized Cal Poly ITRC evaluation procedures.

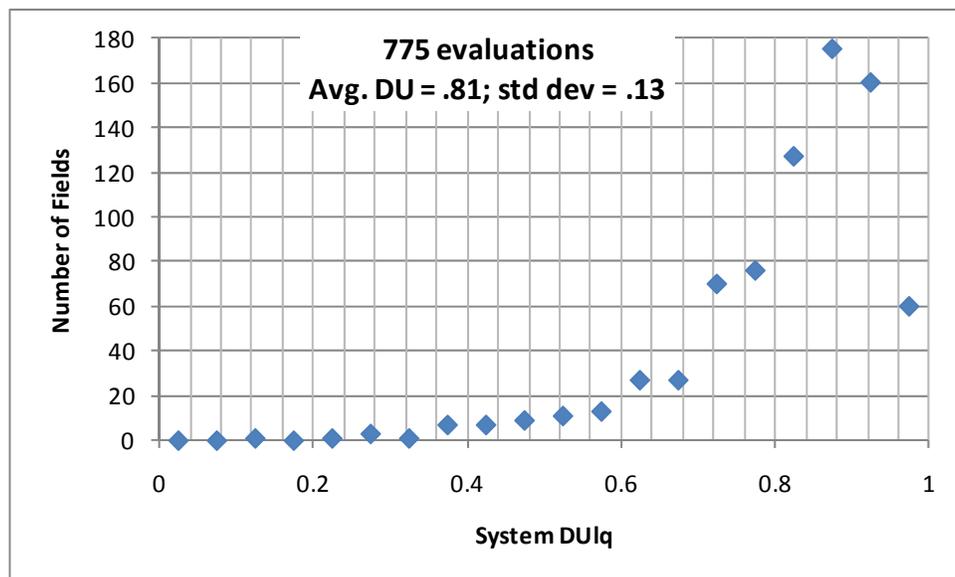


Figure 5. Drip/micro irrigation evaluation results from California

### **ESTIMATING REDUCED APPLICATION VOLUMES**

The term “application” refers to the gross applied water, not the net. The word “reduced” infers that there will be a comparison between the “old” and “new” applications. There is no general rule in terms of a specific percentage. Instead, the following items should be noted:

1. There can be no valid estimate of application reduction unless one first has well documented historical applications on the same crops.
2. The historical applications should be compared against the net requirement (crop ET, plus leaching requirement, minus effective precipitation) to see what the magnitude of application reductions might even be. If the historical application is no more than twenty percent greater than the net requirement, there is likely little change of reduction.

Obviously there are always extreme cases, but they can be identified by following the two points listed above. Perhaps cost sharing programs should only target extreme cases. But in California, with crops such as processing tomatoes that are often grown on “heavy” textured soils in areas with limited water supply, ITRC has documented that typical average reductions in application are in the neighborhood of 10%. It must be emphasized that if the district program goal is to have major differences in application depth (without considering net reduction), this is important. There has been widespread acceptance and support of these programs by farmers, but their goals are different than district goals.

### **ENSURING EXCELLENT PERFORMANCE**

USDA/NRCS has certain requirements for its cost sharing programs but those could be improved. Irrigation district cost sharing programs in California seem to have few requirements regarding specific performance measures or equipment, which means the programs are often relatively unregulated and the results can be questionable. The cost sharing programs typically just pay some percentage of the cost, up to some dollar maximum, of a new irrigation system - no questions asked except that it be placed on land within the irrigation district.

There is an existing tool that could be used as the first step in improving these programs. In 1994, the Cal Poly ITRC worked with various utilities and irrigation groups to develop the “Irrigation Consumer Bill of Rights” (ICBR), which was in fact two Bills: one covering general irrigation and the other dealing with drip/micro irrigation. These Bills, which include simple lists of questions regarding irrigation system design and performance, can be found at <http://www.itrc.org/reports/icbr/icbr.pdf>. Additional information on the Bills can be found in other ITRC reports (use the search engine at [www.itrc.org](http://www.itrc.org)).

The original idea was that irrigation dealers would sit down with customers and review the questions provided in the Bills, in order for both customers and dealers to reach a common understanding of desired performance and technical issues. The customer would know what was being purchased, and the dealer would have a well-informed customer. The intended result was less hassle and better performance. In reality, only a few irrigation dealerships utilize the ICBR. It remains a valuable, if underutilized, tool that can also be helpful for cost-sharing programs.

The Bills could be tailored with district-specific questions and answers (which the ICBR did not include) for any given program. Discussion and recommendations for some key parameters are outlined below.

Distribution Uniformity (DU). The concepts and computations of a global, system distribution uniformity ( $DU_{lq}$ ) for a drip system are well established (Burt, 2004 and Burt et al, 1997). The word “system” is emphasized because the DU must account for variations across a whole field, not just along a single hose. New drip/micro irrigation systems should be guaranteed to have a system  $DU_{lq}$  of better than 0.92 (1.0 being perfect), to include all variations in emitter pressure (friction, elevation change, pressure regulator valve variations) and emitter manufacturing variation.

Field Flow Rates. Some programs recommend specific flow rates for a given crop and area. However, the flow rate requirement issue is not so simple.

A huge component of the decision involves selecting the proper “down time” of the system. If a pump only operates for half the time (as compared to 100% operating time), the system flow rate must be doubled. That, in turn, requires twice the horsepower (HP) (but the same HP-hours per year), larger filters, and larger mainline pipe. There are excellent reasons for operating less-than-100% of the time during the period of peak irrigation water demand. These include:

- *Electric utility time-of-use rates*. Farmers may be able to obtain substantially lower dollar per kilowatt hour rates if they agree to not pump for certain hours of the week.
- *Cultural operations*. There may be a need for certain tractor or spraying activities that are not compatible with irrigating at the same time.
- *Safety factor*. It’s not a question of if things will break – it’s only a question of when.

A second question involves the net depth of water required per day or week or month. It is common to use average monthly ET values, and divide by the number of days in the month (for example, thirty-one days for July). By definition, however, an average value is not big enough to cover the month during an unusually hot year, and dividing by thirty-one days per month assumes that the ET for each day is the same, which is untrue. On the other hand, designers know that if they design for the hottest day of the hottest month, the cost will be outlandish. Essentially, this is a question that the grower must answer: How much of a gamble is the grower willing to take when balancing cost and adequate irrigation? Different growers will have different answers; there is no single correct answer. For example, a grower who only has one year to pay off a loan cannot invest as much in a system as another grower might. What is important, and what the ICBR attempts to promote, is that both grower and designer are clear on expectations.

A third question regarding flow rates is how “Irrigation Efficiency” or “DU” are used to obtain a gross flow rate from a net requirement (just looking at ET and hours). If one goes back to the original development of the  $DU_{lq}$  concept, that value was intended to be used for irrigation scheduling as follows:

$$\text{Gross to apply} = \frac{\text{Net Required}}{DU_{lq} \times \left(1 - \frac{\% \text{ surface losses}}{100}\right)} \quad (1)$$

The focus was to avoid under-irrigation. By using the “low quarter” (lq) concept for DU in this equation, only one-eighth of the field would be underirrigated and the underirrigation on that small part of the field would be minimal. The argument was that it was not worth it to adequately irrigate the entire field, and that slight under-irrigation of one-eighth of the field was much more economical.

However, there is another way to view this computation. This scenario guarantees that there will be deep percolation on seven-eighths of the field. The question for an irrigation district that is trying to minimize high water table problems is simple: Is this a desirable goal? Or should the  $DU_{lq}$  be eliminated from the equation above? If it is eliminated, half of the field will have deep percolation, and half will have under-irrigation. It is an interesting discussion item. It is important to point out, however, that if the DU is very good, it does not really make much difference. For drip/micro systems, the gross should be very similar to the net required. So why do cost sharing programs not require a guaranteed high new DU, plus the proper filtration and chemigation equipment, to help ensure that the DU will remain high over time?

Many customers and dealers focus on the flow rate of the emitters or tape. That flow rate number should not directly enter into this conversation. The numbers of interest are (i) the flow rate of the pump, and (ii) the total acreage irrigated by that pump.

As a general guideline, the following specification provides for time-of-use electrical demand and reasonable results :

- Design a drip/micro system for 17 hours of operation per day during peak ET period.
- For the peak ET, use the published average peak monthly ET value, multiplied by 1.05
- For the  $DU_{lq}$ , use a value of 0.82. This assumes eventual deterioration of performance (from the 0.92 at the start).
- Assume no surface losses, as extra evaporation should be built into the peak ET number.

**Chemical Injection.** Both nutrient and maintenance chemicals need to be injected through drip systems. Well informed farmers have numerous chemical tanks at the filter site, while those with less knowledge about the subject have one or none.

There are two common, significant problems with many common installations in regard to chemical injection:

1. Not enough injection points or injection pumps are supplied. Every chemical needs a different pump and meter and injection point because:
  - a. Mixing chemicals often creates compatibility problems (i.e., things plug up)
  - b. Different chemicals have entirely different flow rate requirements (e.g., nitrogen will be injected at a higher rate than a special polymer to inhibit iron problems)
  - c. Chemicals can't be spoonfed if only one chemical can be injected at once.

2. Many chemicals are injected downstream of filters rather than upstream. This requires that the designer and farmer address several issues:
  - a. The system must be designed to stop chemical injection during filter backflushing, or else the backflush water (minus the dirt) needs to be recirculated. Commercial equipment is readily available for both solutions.
  - b. A common complaint is that the filters backflush all the time, so it is impossible to stop chemical injection during filter backflush. This means something is wrong with the filter system.
  - c. Some growers damage their filters by injecting high dosages of strong acids. In most cases, however, strong acids are not necessary. In many soils, it is very easy to drop the pH but almost impossible to raise it again. And hoping that strong acids will adequately dissolve carbonate precipitation on emitters is a bit of a gamble.
  - d. The big exception to the upstream injection recommendation, of course, is pesticides. Those should always be injected downstream.

Basic recommendations are as follows:

- Install an approved backflow prevention valve before any injection points, if the water supply is a well or the source water could be contaminated by backflow.
- Install four injection points upstream of the filter, and two downstream.
- Install five outdoor receptacles that can power injector pumps with 20 amps each, 110 V.

Flow meter. Use a full spool flow meter with a pulse or 4-20 mA output that can be connected to fertilizer injector for proportional injection. The flow meter must be installed with upstream and downstream dimensions that conform to manufacturer requirements.

Adequate Filtration. The first truth about filtration of surface water is that there is rarely enough attention paid to “prefiltration”. Almost all drip/micro filters (disc, sand media, screen) are polishing filters. They are incapable of adequately handling large particles and very heavy dirt loads. That is the task for settling ponds, rotating screens upstream of the pump, etc., known as prefiltration. Additionally, for well pumps, starting a pump slowly with a variable frequency drive controller works exceptionally well to minimize the large amounts of sand and dirt that can show up when a typical well pump starts up. For canal deliveries, irrigation districts should investigate the most applicable pre-filtration devices, and then specify those as requirements.

The author of this paper has personal preferences for the "polishing" filtration. For simple sand problems, the best option can be a screen filter with internal rotating wands. For almost anything else, the author recommends media tanks. Still, there are huge differences in the quality, ease of maintenance, and ease of operation of various models and brands. ITRC recently published a report on sand media filters that points out recent improvements in sand media filtration (<http://www.itrc.org/reports/mediafilters.htm>).

Once the required prefiltration and the correct type of filter are present, there must be standards or guidelines for the proper size or number of filters. The filter number and size are highly dependent on water quality as well as the size/type of emitter in the field. Without adequate guidelines, farmers are faced with multiple vendors selling multiple sizes of filters for the same

flow rate and water quality. The ITRC recommendations for media tank sizing are shown in Table 1.

Table 1. Recommended sand media tank sizing (Burt and Styles, 2011)

<u>Irrig. System Flow Rate, GPM</u>		<u>Number and Size</u>
<u>Moderate Dirt Load</u>	<u>Moderately Heavy Dirt Load</u>	<u>(Dia) of Tanks</u>
50	35	2 - 18"
100	70	3 - 18"
150	105	3 - 24"
175 – 275	122 – 192	3 - 30"
276 – 425	193 – 299	4 - 30"
426 – 575	300 – 399	4 - 36"
576 – 775	400- 539	3 - 48"
776-1025	540 – 719	4 - 48"
1026-1275	720 – 899	5 - 48"
1275 – 1525	900 – 1069	6 - 48"
1526 – 1675	1070 – 1170	7 - 48"

Pump Efficiency and Power. This is important because of ongoing operation expenses. There are three major items to highlight:

1. It is almost impossible to perfectly match one pump to all of the various flow rate and pressure combinations that one encounters in a drip system when considering various backflush flows, different block sizes, different block elevations, etc. The simple solution is to select a good large pump and use a variable frequency drive controller to avoid excess power consumption when it is not needed.
2. The minimum acceptable pumping plant efficiency should be specified. Recommended new pumping plant efficiencies should be 72% or better.
3. Even with an excellent efficiency, a pumping plant might still be pumping much more pressure than necessary. Typical wastes of energy in drip/micro systems are:
  - a. Valves that require large (e.g., 20 psi) pressures just to open, even though the manufacturers report only 1-3 psi friction at the design flow rate (without mentioning that the valve will not open at low pressures). This is an important consideration for drip tape systems. If drip tape systems are cost-shared, the valves should be specified to have no more than a 4 psi loss while delivering the desired discharge pressure.
  - b. Designers under-design the backflush piping on drip systems, and think that media tanks need 35 psi to backflush properly, which is not true. However, other filters actually require 35 psi, minimum, to operate properly.
  - c. Poor designs have very long hoses (albeit with pressure compensating emitters) and small pipes and small valves, plus a conservative “10 psi” or so added as a buffer amount.

On flat ground, the system should be designed for a total inlet pressure to the system of less than 35 psi.

## CONCLUSION

It is easy to set up a simple cost sharing program for drip/micro irrigation systems, but programs must be carefully structured to maximize all benefits that are achievable. Growers and districts must recognize that their goals may be different, and any program must be tailored accordingly.

Additionally, proper education regarding drip system design is vital in order to ensure that any program encouraging the switch to drip/micro irrigation will succeed.

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