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Subsurface Drip Irrigation (SDI) System Remediation - A Case Study

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Abstract. *Subsurface Drip Irrigation (SDI) has been installed on less than 1 percent of the irrigated field crop areas in Kansas. Although research studies indicated long dripline life is possible, some producer field have serious clogging issues. Clogging of emitters is the primary reason for microirrigation system failure. This paper reviews minimum design recommendations and a case study of remediation efforts on an existing commercial field.*

Keywords. Subsurface drip irrigation, SDI, water quality, remediation, emitter clogging

INTRODUCTION

Subsurface drip irrigation (SDI) systems are currently being used on about 15,000 acres in Kansas. Research studies at the NW Kansas Research and Extension Center of Kansas State University began in 1989 and have indicated that these systems can be efficient, long-lived, and adapted to irrigated corn production in western Kansas. This adaptability is likely extended to any of the deep-rooted irrigated crops grown in the region. Many producers have had successful experiences with SDI systems; however many have experienced at least some minor technical difficulties during the adoption process. Furthermore, a few systems have been abandoned or failed after a short use period due to severe problems associated with either inadequate design, inadequate management or combination of both.

Both research studies and on-farm producer experience indicate SDI systems can result in high yielding crop and water-conserving production practices, but only if the systems are properly designed, installed, operated and maintained. SDI systems in the High Plains must have long life to be economically viable when used to produce the relatively low value field crops common to the region. Design and management are closely linked in a successful SDI system. A system that is not properly designed and installed, will be difficult to operate and maintain and most likely will not achieve high irrigation water application uniformity and efficiency goals. Additionally, a correctly designed and installed SDI system will not perform well, if not properly operated and is destined for early failure without proper maintenance. This paper will review important considerations for a successful SDI system and review a field where re-design and remediation was required.

IMPORTANT SDI SYSTEM CONSIDERATIONS

Design considerations must account for field and soil characteristics, water quality, well capabilities, desired crops, production systems, and producer goals. It is difficult to separate design and management considerations into distinct issues as the system design should consider management restraints and goals. However, there are certain basic features that should be a part of all SDI systems, as shown in Figure 1. Omission of any of these minimum components by a designer should raise a red flag to the producer and will likely seriously undermine the ability of the producer to operate and maintain the system in an efficient manner for a long period of time. Minimum SDI system components should not be sacrificed as a design and installation cost cutting measure. If minimum SDI components cannot be included as part of the system, serious consideration should be given to an alternative type of irrigation system or remaining as a dryland production system.

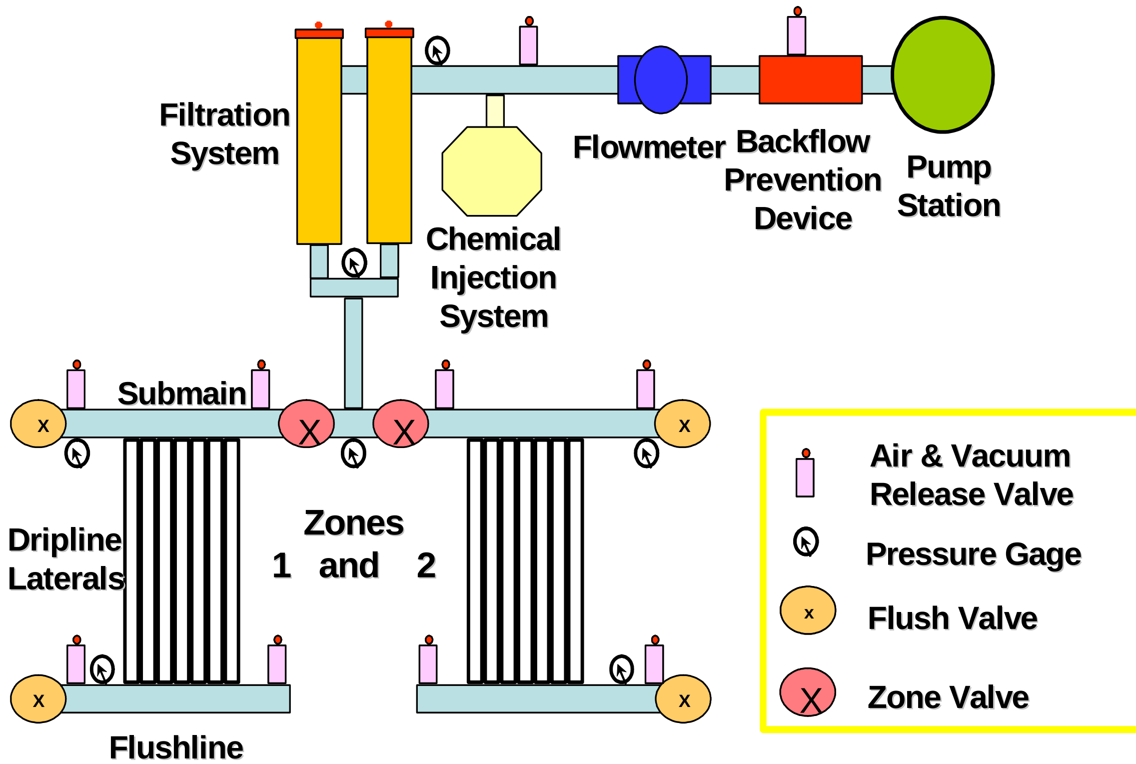

Figure 1. Schematic of Subsurface Drip Irrigation (SDI) System. (Components are not to scale) K-State Research and Extension Bulletin MF-2576, Subsurface Drip Irrigation (SDI) Component: Minimum Requirements

DISTRIBUTION COMPONENTS

The water distribution components of an SDI system include the pumping station, the main, submains and dripline laterals. The size requirements for the mains and submains would be similar to the needs for underground service pipe to center pivots or main pipelines for surface flood systems. Size is determined by the flow rate, elevation changes, and acceptable friction loss within the pipe. In general, the flow rate and acceptable friction loss determines the size (diameter) for a given dripline lateral length. Another factor is the land slope. Theoretically, but totally unwise, a drip system could be only a combination of pumping plant, distribution pipelines and dripline laterals. However, as an underground system, there would be no method to monitor system performance and the system would not have any protection from clogging. Clogging of dripline emitters is the primary reason for SDI system failure.

MANAGEMENT COMPONENTS

The remaining components outlined in Figure 1, those that allow the producers to protect SDI system, monitor its performance, and if desired, provide additional nutrients or chemicals for crop production. The backflow prevention device is a requirement to protect the source water from accidental contamination should a backflow occur.

The flow meter and pressure gauges are essentially the operational feedback cues to the manager. In SDI systems, all water application is underground. In most properly installed and operated systems, no surface wetting occurs during irrigation, so no visual cues are available to the manager concerning the system operating characteristics. The pressure gauge at the control valve in each zone allows the proper entry pressure to dripline laterals to be set. Decreasing flow and/or increasing pressure can indicate clogging is occurring. Increasing flow with decreasing pressure can indicate a major line leak. The pressure gauges at the distal ends of the dripline laterals are especially important in establishing the baseline performance characteristics of the SDI system.

The heart of the protection system for the driplines is the filtration system. The type of filtration system needed will depend on the quality characteristics of the irrigation water. In general, clogging hazards are classified as physical, biological or chemical. The Figure 1 illustration of the filtration system depicts a pair of screen filters. In some cases, the filtration system may be a combination of components. For example, a well that produces a lot of sand may have a sand separator in advance of the main filter. Sand particles in the water would represent a physical clogging hazard. Other types of filters used are sand media and disc filters.

Biological hazards are living organisms or life by-products that can clog emitters. Surface water supplies may require several layers of screen barriers at the intake site to remove large debris and organic matter. Another type of filter is a sand media filter, which is a large tank of specially graded sand and is well suited for surface water sources. Wells that produce high iron content water can also be vulnerable to biological clogging hazards, such as when iron bacteria have infested a well. Control of bacterial growths generally requires water treatment, in addition to filtration.

Chemical clogging hazards are associated with the chemical composition or quality of the irrigation water. As water is pulled from a well and introduced to the distribution system, chemical reactions can occur due to changes in temperature, pressure, air exposure, or the introduction of other materials into the water stream. If precipitants form, they can clog the emitters. Introduction of fertilizers or other agrochemicals into the water may also cause chemical precipitation so always conduct a chemical compatibility test.

The chemical injection system can either be a part of the filtration system or could be used as part of the crop production management plan to allow the injection of nutrients or chemicals to enhance plant growth or yield.

The injection system in Figure 1 is depicted as a single injection point, located upstream of the main filter. In many cases, there might be two injection systems. In other cases, there may be a need for an injection point downstream from the filter location.

The injection system, when it is a part of the protection system for the SDI system, can be used to inject a variety of materials to accomplish various goals. The most commonly injected material is chlorine, which helps to disinfect the system and minimizes the risk of clogging associated with biological organisms. Acid can also be injected to affect the chemical characteristic of the irrigation water. For example, high pH water may have a high clogging hazard due to mineral precipitation in the dripline after the filter. The addition of a small amount of acid to lower the pH to slightly acidic might prevent this hazard from occurring.

PRODUCER RESPONSIBILITIES

As with most investments, the decision as to whether the investment would be sound lies with the investor. Good judgments generally require a good understanding of the fundamentals of the particular opportunity and/or the recommendations from a trusted and proven expert. While the microirrigation (drip) industry dates back over 40 years now and its application in Kansas as SDI has been researched since 1989, a network of industry support is still in the early development phase in the High Plains region. Individuals considering SDI should spend time to determine if SDI is a viable systems option for their situation. They might ask themselves:

What things should I consider before I purchase a SDI system?

1. Educate yourself before contacting a service provider or salesperson by
    a. Seeking out university and other educational resources. Good places to start are the K-State SDI website at www.oznet.ksu.edu/sdi and the Microirrigation forum at www.microirrigationforum.com. Read the literature or websites of companies as well.
    b. Review minimum recommended design components as recommended by K-State. http://www.oznet.ksu.edu/sdi/Reports/2003/mf2576.pdf
    c. Visit other producer sites that have installed and used SDI. Most current producers are willing to show them to others.
2. Interview at least two companies.
    a. Ask them for references, credentials (training and experience) and sites (including the names of contacts or references) of other completed systems.
    b. Ask questions about design and operation details. Pay particular attention if the minimum SDI system components are not met. If not, ask why? System longevity is a critical factor for economical use of SDI.
    c. Ask companies to clearly define their role and responsibility in designing, installing and servicing the system. Determine what guarantees are provided.
3. Obtain an independent review of the design by an individual that is not associated with sales. This adds cost but should be minor compared to the total cost of a large SDI system.

Remediation Case Study

A 45-acre SDI system was installed to irrigate a field located in a river alluvial valley in eastern Kansas. The system was used for the first time for corn irrigation in 2002. Before the end of the first irrigation season, uneven crop growth and water stress symptoms were noted by visual observation.

During the winter and early spring of 2002/2003, the producers made contact with K-State Research and Extension personnel. Up until this time, the only operational and maintenance recommendations produced by the designer/installer had been to periodically flush the system. During the initial telephone contacts, verbal generalized information on dripline maintenance procedures, including flushing, chlorination and acidification was provided. SDI bulletins were mailed to the producer. The producer also agreed to have a water quality analysis completed and also removed sample sections of dripline from the visually stressed and non-stressed portions of the field. A cut-away section of the dripline is shown in Figure 2; an orange/yellow paste essentially coated the inner walls of the dripline. The material had slugged off during the handling of the dripline.

Figure 2: Cut-away of case study field dripline showing precipitant accumulation.

Design and/or “as installed” specifications were requested of the producer by the extension specialists, but none had been provided to the producer. A baseline performance test was not conducted by the installer. Although a water meter was installed with the system, it was not properly located and did not provide reliable readings. The producer’s feeling was that about half the original capacity was lost. A new meter installation indicated the system flow rate was about 450 to 480 gpm.

The producer sent the results of the irrigation water quality test. The summary statements indicated good quality irrigation water. However, these recommendations were developed for crop and soil hazards and did not address the potential clogging hazards to SDI systems.

Specific water quality tests and recommendations are further discussed in MF-2575, *SDI Water Quality Assessment Guidelines*. A summary of the clogging hazard ratings for SDI systems is shown in Table 1. The standard irrigation water test does not contain all the recommended tests for a SDI system. The analysis of the water indicates a strong clogging potential. Use of this water is possible but would likely require either some pre-injector treatment or regular post-irrigation treatment to prevent performance deterioration due to clogging.

Table 1. Clogging Potential of Water Quality for the Case Example SDI system. Clogging ratings are from KSU Bulletin MF-2575.

Water Quality Constituent	Clogging Hazard Rating
Ph (measure of acidity)	Medium
Ca (Calcium)	High
Mg (Magnesium)	Medium
SO_4 (Sulfate-Sulfur)	High
N_a (sodium)	High
K (Potassium)	High
Fe (Iron)	Medium
HCO_3 (Bicarbonate)	High
($pH – pH_c$) (precipitant indicator)	Positive: C_aCO_3 and Mg CO_3 precipitates can form

Since the system was already severely clogged, the immediate concern was whether remediation was possible. The producer was willing to try an aggressive acid treatment, especially since the winter (2002/03) maintenance chlorination and flushing did not improve performance.

A site inspection was conducted in the early summer of 2003. At this time, the existing soybean crop was also showing water stress in the upper one-third of the field. The system design failed to meet many of the minimum SDI design recommendations that were discussed previously. It was recommended that improvements be made. A new contractor reconstructed the filtration, injection and control valves at the pumping station. The irrigation zone (the field is irrigated as one unit) was also split into two flushing zones. This would allow for higher water flow velocities in the driplines during flushing. Improvements also included addition of air relief vents on the high points of the system, piping and valves to allow direct water bypass from the well, should well treatment be required, and improved placement of the flow meter (Figure 3a and 3b).

Figure 3a: Original pumping plant and filtration configuration of the case study SDI system.

Figure 3b. Improved pumping plant and filtration configuration of the case study SDI system.

The field configuration is rectangular with approximately 1300- foot length of run for the driplines. One design issue that was not addressed in the reconstruction was the addition of driplines that extended into the dryland corner of an adjoining center pivot irrigated field. These driplines were directly connected to the flushline serving the bottom portion of the main field. The driplines ended when the center pivot irrigated area was reached.

An analysis of the precipitant clogging the dripline confirmed it was primarily calcium bicarbonate, colored by the associated iron. The sample length of dripline was tested for flow and found to be almost entirely clogged. The producer indicated he had access to a economically priced sulfuric acid source, however muratic acid was successfully used in the lab test to see if remediation was possible. Sulfuric acid is highly corrosive and may not be the safest and best acid for farmstead use.

A water sample from the well was tested (titrated) to determine effect of a known amount of sulfuric acid on the pH of a known volume of water (Table 2). A 5-foot sample (4 emitters) section of the SDI system had been sent to K-State by the farmer. This sample section was treated by recycling water from a small stock tank of water that had been acidized to a pH level of approximately 2. The tank water was Manhattan tap water, which is of similar chemical composition as the SDI site water, however it was treated with muratic acid.

Water was pumped through the test dripline section for an hour and then shut off for a rest period of 4 hours. This cycle was repeated several times. The four emitters were initially severely clogged with almost no flow from any of the emitters. All emitters recovered to a large degree. However, one emitter recovered quickly and then partially re-clogged and never recovered to the same level as the other three. The results of the cleaning treatment are shown in Table 3. At 9:45, essentially no flow was observed from any of the 4 emitters in the test section. After 1 hour of injection, emitter 3 and emitter 4, to a lesser degree, had recovered some flow. Periodic injection and rest periods continued throughout day 1. The acid treatment was then left in the lines overnight. The next flow measurement showed all four emitters with recovered flow rates of similar values. The treated water continued to be injected during day 2 to observe if any additional flow rate increase would occur. It was during this period that emitter 3 re-clogged. The system was allowed to rest for an additional 4 hours and then retested. Emitter 3 still remained clogged. It was suspected some other particle, rather than the original chemical precipitant had entered the number 3 emitter pathway.

The main recovery in emitter flow appeared to occur during the rest periods. Therefore, during the field remediation trial, acid was injected until the entire system was treated with the low pH water and then left in the system overnight.

The SDI system had been flushed prior to the acid treatment. The system was started and the treatment began. The water was tested using a pH test strip downstream of the injection site and was found to be near the treatment goal of approximately 2 pH.

The flush valves at the ends of the submain were opened to allow any material to be flushed and then closed when the pH reading approached the target level.

A flush valve at the lower end of the system was then opened and tested until the pH dropped. This was repeated at the other outside edge of the SDI system=s flush valve. Injection was continued for another 15 to 20 minutes before shut down. Because the recovery in the test sample seemed to occur due to the long period of contact, rather than due to continuous injection, the SDI system was shut down, saving a great deal of treatment expense.

The injected treatment was left in the system until the next morning. The system was completely flushed the next morning and retreated and left to rest again for approximately 24 hours and flushed again. The field was then irrigated. After three treatments, the system recovered from a flow rate of approximately 480 gpm to 720 gpm.

It was recommended that each irrigation cycle end with approximately 15 minutes of acid injection to lower the pH to approximately 4 to continue recovery and as a preventative maintenance treatment for the remainder of the 2003 irrigation season. However, a 4 pH level did not seem to be sufficient for additional recovery.

No additional tests on samples have been conducted during the off-season, although dripline sampling and site re-evaluation are planned for the 2004 irrigation season. The current recovery to 720 gpm is still estimated to be only a partial recovery of an estimated design capacity of 1000 gpm.

Table 2. Titration test results for the case study SDI site.

	ml acid / L H_2O	ml acid / L H_2O	System Acid Requirememt gal / hr
pH	24% H2SO4	96% H2SO4	gal 96%/hour/500 gpm
6.959	0	0	0
6.162	0.3	0.075	2.25
5.713	0.5	0.125	3.75
5.047	0.75	0.1875	5.625
2.7	1	0.25	7.5
2.343	1.5	0.375	11.25
2.162	1.75	0.4375	13.125
2.114	2	0.5	15

Table 3. Lab Cleaning Tests for the case study SDI site, injected water treated to 2.1 pH.

				Emitter Flow (L/h)			
Date	Status	Time	Elapsed Contact Time (hr)	1	2	3	4
6-03	on off	9:45:00 10:45:00	1	0 0	0 0	0 0.35	0 0.15
	on off	13:30:00 14:35:00	1	0	0.43	0.61	0.52
	on off	15:45:00 16:45:00	1	0	0.58	0	0.58
6-26	on off	8:50:00 12:00:00 16:45:00	8	0.57 0.6 0.65	0.58 0.62 0.63	0.6 0.4 0.19	0.58 0.56 0.59
6-27	on off	8:25:00 13:00:00	4.5	0.62 0.6	0.62 0.57	0.17 0.09	0.59 0.56

CONCLUSIONS

SDI can be a viable irrigation system option, but should be carefully considered and researched by producers before any financial investment is made. This case study indicates proper design and management is needed to prevent SDI failures. Recovery of clogged SDI system may be possible but can be time consuming and expensive.

OTHER AVAILABLE INFORMATION

The above discussion is a very brief summary from materials available through K-State. The SDI related bulletins and irrigation related websites are listed below.

MF-2361 *Filtration and Maintenance Considerations for Subsurface Drip Irrigation (SDI) Systems* *http://www.oznet.ksu.edu/sdi/Reports/2003/mf2361.pdf*

MF-2576 *Subsurface Drip Irrigation (SDI) Components: Minimum Requirements* *http://www.oznet.ksu.edu/sdi/Reports/2003/mf2576.pdf*

MF-2578 *Design Considerations for Subsurface Drip Irrigation* *http://www.oznet.ksu.edu/sdi/Reports/2003/mf2578.pdf*

MF-2590 *Management Consideration for Operating a Subsurface Drip Irrigation System*
http://www.oznet.ksu.edu/sdi/Reports/2003/MF2590.pdf

MF-2575 *Water Quality Assessment Guidelines for Subsurface Drip Irrigation*
http://www.oznet.ksu.edu/sdi/Reports/2003/mf2575.pdf

MF 2589 *Shock Chlorination Treatment for Irrigation Wells*
http://www.oznet.ksu.edu/sdi/Reports/2003/mf2589.pdf

Related K-State Research and Extension Irrigation Websites:

Subsurface Drip Irrigation
www.oznet.ksu.edu/sdi

General Irrigation
www.oznet.ksu.edu/irrigate

Mobile Irrigation Lab
www.oznet.ksu.edu/mil

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