DRAINAGE SYSTEMS; PRINCIPLES, MATERIALS, AND RESULTS

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INTRODUCTION

Alfalfa is a deep rooted crop that does poorly when the water table rises into the root zone, drowning the roots, and allowing the accumulation of harmful salts and alkali. A subsurface drainage system, consisting of perforated drain tubing, can control the water table and allow the salts and alkali to be leached from the root zone. In this paper, I would like to discuss the following aspects of drainage systems:

A. Evaluating where subsurface drainage is needed.

B. Benefits

C. Various type drainage systems.

D. Design procedures.

E. Envelope materials

F Installation equipment.

G. Economics.

EVALUATING WHERE SUBSURFACE DRAINAGE IS NEEDED

The first indication of a drainage problem is, of course, poor alfalfa growth and production. When the water table is non-saline, then a shallow water table does not kill the alfalfa outright. It merely shortens the stand life, reduces tonnage, and allows water loving weeds such as bermuda grass and johnson grass to invade the field.

Where the water table is saline, such as occurs on most of the west side of the San Joaquin Valley, then the problem of drowned roots is aggravated by salt accumulation. The saline water wicks to the ground surface causing a reduction in yield. As salts and alkali accumulate in the root zone, bald spots appear and eventually the soil becomes so toxic that alfalfa will no longer germinate or grow.

When the soil testing lab reports that the soil has a high pH, high sodium levels, high electrical conductivity, and occassionally high boron levels, that is strong evidence of poor drainage.

A subsurface drainage system is not a magic cure-all. Other common solutions to a soil with poor internal drainage are deep ripping, deep plowing, or merely eliminating the application of excess irrigation water. Where these other methods are applicable, they are generally cheaper, and work better.

However, where the drainage problem is caused by a restrictive stratum in the soil profile (such as clay pans, hard pans, or bedrock) at a depth of 4 feet or deeper, then a subsurface drainage system is the most practical solution. This paper is directed at the situations where drainage systems are needed.

BENEFITS

Alfalfa struggling to produce in the presence of a high water table, responds well when a drainage system is installed. The major benefits are:

A. Increased alfalfa production and quality.
Deep healthy roots support healthy plants.

B. Longer stand life.

C. Increased growing season. Well drained soils are warmer in the spring.

D. Soil aeration. Roots and bacteria need air to function properly.

E. Increased fertility - A deep root zone provides more soil volume for nutrient extraction.

Increased water holding capacity and drought resistance. A deep root zone provides more soil volume for moisture extraction.

TYPES OF SYSTEMS

There are two basic types of drainage systems: interception and relief. Frequently a combination of both a relief system and an interception system is needed to solve the drainage problem.

Interception systems are effective when the water causing the problem is coming horizontally from outside the field boundaries, and the ground slope is fairly steep. Generally the source of water is a leaking canal or irrigation on fields higher up the slope. Water will not flow laterally unless there is a shallow restrictive layer that prevents the downward movement of water. Water accumulates on this layer and then moves sideways into adjacent fields downslope. To be most effective, the interceptor drain line should be placed just above the restrictive layer. Often one interceptor drain line along the high side of the field will completely solve the problem.

Relief systems are needed when the land surface and the water table are both fairly flat. Then one drain line alone, no matter how it was oriented, would not solve the problem. A relief drainage system consists of a network of drain lines which work together to lower the water table in the field. Alfalfa is generally grown on flat, deep soils in alluvial valleys, and so relief system are by far the type most commonly needed by alfalfa growers.

DESIGN PROCEDURES

The first item we look for is an acceptable outlet. And by acceptable we don't mean merely a ditch deep enough or with enough capacity to carry the drainage flow. These problems are easily solved. By acceptable we mean a legal outlet to a salt sink, or to some other disposal area undamaging to the environment. In some cases the drainage water is of good enough quality to be reused for irrigation, recreation, wildlife or some other beneficial use. However, in most cases the water is so salty nobody wants it.

Some irrigated regions have formal drainage districts that provide this legal outlet to the ocean, large evaporation basins, or to some other salt sink. Unfortunately, much of California does not have such good outlets. The individual farmer must then take a large portion of his land out of production for an evaporation basin or not drain.

Once we have determined we have an acceptable outlet, we check the fields on aerial photos. Conventional black and white photos available at the local U.S.D.A. Soil Conservation Service office often show crop damage, wet areas, or old stream channels. Another very useful tool we use is infrared aerial photos.

The high altitude NASA photos available to us are on such a small scale they are not of much use. In the beginning we hired a professional photographer, experienced with infrared, to take photos of an area where we were designing some drainage systems. After observing how simple the procedure is (all that is needed is a good 35mm camera, infrared film, and an infrared filter), we have started taking our own infrared photos with good success.

In spite of our hopes that infrared photography would revolutionize drainage design our primary use of them is to determine where to dig the test holes. Rather than stick to a grid system of test holes, we use random hole locations based on our interpretation of the aerial photo.

It isn't necessary to be particularly adept at infrared photo interpretation. All that is needed is to identify different areas, streaks, and color changes, and then go to the field and drill holes to find out why they are different. Aerial photos are useful, but when it comes to evaluating soils and determining what is causing the drainage problem, nothing beats having a soil scientist dig a hole 10 feet deep.

Using aerial photography as a guide, we generally drill at least one hole every 10 acres. The holes are drilled 10 feet deep, a few holes are dug to 15 feet to determine where the barrier actually is. If we do not find the barrier within 15 feet we give up and say the barrier is at infinity. We use conventional 4 inch hand augers equipped with standard, mud or sand buckets. Also we use an Oakfield soil probe. This probe is the only tool we have found that allows the soil scientist to continue the hole in sandy stratas. Anyone who has tried augering a hole in non-cohesive soils with a high water table is familiar with the problem of the hole caving in as fast as it is excavated. By vibrating the soil probe, sandy stratas can be penetrated to the restrictive layers below. The various soil stratas, depth to barrier, depth to water table, and other pertinent data are logged at each hole.

To determine topography of the fields, we have gone completely to laser surveying equipment. The biggest advantage they have is that one man alone can do the complete survey, and do it faster than a two man survey with conventional telescopic equipment. Normally we drain established, leveled agricultural fields, and a shot every 500 feet (153 m) is sufficient for design. Of course, in undeveloped areas on rolling terrain a complete topograpic map is prepared.

Once we have collected the data it is organized onto a working base map. On this base map of the fields we plot: ground elevations, soil logs, depth to groundwater, and depth to barrier. From this working map we can evaluate whether the problem is relief, interception or both.

The depth of the drain lines is a very controversial and emotionally charged subject. The contractor wants them as shallow as possible, and as close as possible. He can install lots of tubing and do it as easily as possible. The farmer wants them as far apart as possible so he can keep the costs down. He particularly wants them wide if his neighbor down the road has wide spacings that appear to be doing the job. It is sometimes lost on him that the wide spacings also invariably mean deeper depths with a high cost per lateral, or that in his soil he may not be able to go that deep without placing the lines in a dense clay barrier. In between these two is the designer trying to rationally come up with the lowest cost per acre to drain the fields. Here is what we are taking into account:

1. Contractor's equipment and its capabilities.
2. Contractor's price differences for various depths.
3. Soil textures and soil stratas.
4. Depth to barrier or restrictive layer.
5. Salinity of groundwater.
6. Alfalfa root zone requirements.

Our first consideration is providing an adequate root zone for alfalfa. This adequate root zone becomes the minimum drawdown for solution of the drain line spacings. We have generalized using the following root zone requirements:

ROOT ZONE DEPTHS - ARID IRRIGATED AREAS

SOIL TEXTURE	MIN. DEPTH OF WATER TABLE BETWEEN DRAINS	
	Saline water table	Non-saline water table
Sandy loam or coarser	4 ft.	3.5 ft.
Loam or finer	5 ft.	3.5 ft

Notice the deeper depth required when the water table is saline. This deeper depth is required to offset the tendency for salts to wick up into the root zone by capillary action. Also soils of loam or heavier textured have a higher capillary pull and need a little deeper depth to water table to provide assurance that the root zone needed by the crop will stay free of high salt levels.

Of course, to provide the minimum root zone depth, the drain tubing must be placed deeper. If there are sandy soil stratas we attempt to place the lines at that depth. Placing the lines in a sand strata markedly improves the performance of the drainage system. Placing the drain lines below a restrictive layer or barrier is avoided. Where the soils are fairly uniform and deep, the ideal depth appears to be 6 - 7 feet. Any deeper than that, the contractor significantly raises the price per foot to the farmer. This depth also results in reasonabl wide lateral spacings. These "ideal depths" are based on trenching equipment currently being used throughout California. As new equipment such as high speed plows become more widely used, these "ideal depths" may change.

ENVELOPE MATERIALS

In the alluvial soils of California's valleys, an envelope material placed around the drain tubes is essential to prevent soil particles from entering the drain lines and plugging them. Graded sand-gravel envelopes are still the most common. However, on about 40% of the systems we now design, we are specifying a synthetic envelope material. The tubing manufacturer places the synthetic envelope around the drain tube like a sock. The tubing, with the sock already in place, is then delivered to the field.

There are over 100 of these manufactured envelopes that have been developed and tried in various parts of the world, with varying degrees of success. There have been failures with some of these artificial envelopes. The one we have had the most success with is a nylon spun-bonded material called "Drain Guard" manufactured by Monsanto.

We use considerable caution when recommending synthetic envelopes. We know they function well in sandy soils and clay soils. However, we avoid the non-cohesive soils that have more than 40% silts, especially where the drains are going to be installed below a water table. Apparently the problem is the construction process. The trenching equipment creates a slurry in the trench, and then the hydraulic head from the water table moves enough fine silt particles to the drain tube to coat the tube and reduce its effectiveness.

INSTALLATION EQUIPMENT

Traditionally, the majority of drainage systems in California were installed with a trenching machine. In the past few years drainage plows have become increasingly popular. These new plows install tubing over 3 times faster than a conventional trencher, with smaller crews and less support equipment. Drainage plows can install both synthetic and gravel envelopes, and the performance of the drain lines appear to be just as good as those installed with a trencher. Drainage plows have been very influential in keeping the cost of drainage systems stable over the past 4 years.

ECONOMICS

People always want to know how much drainage systems cost. Obviously there can be no fixed answer because of variations in project size, drain depth, spacing, soil conditions, etc. A range of prices is probably the fairest way to answer the question. In 1979, the least expensive relief systems cost about $300 per acre, while the more expensive systems cost about $500 per acre.

An economic evaluation of drainage systems in alfalfa fields generally show very strong benefit/cost ratios. Benefit/cost ratios in excess of 3/1 are common. Merely increasing the production by one ton per acre will pay for most drainage systems over a 5 - 10 year period.

CONCLUSION

Again, drainage is not a cure-all, but where needed it can be the key to successfully growing alfalfa. If a drainage problem is suspected, get the soils analyzed and determine where the water table is. If drainage is needed, proceed on with getting a drainage system designed, and having an experienced contractor install it. Alfalfa responds well to drainage, and farming today requires top production from each and every acre.