USE AND DESIGN CONSIDERATIONS OF SPRINKLER SYSTEMS IN COLORADO

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CER47-52WEC39

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ABSTRACT

Sprinkling can be used advantageously in Colorado to irrigate rough or uneven lands where surface irrigation would be difficult or unsatisfactory. It is useful on lands that cannot be properly prepared for irrigation because of thin top soils underlain by gravel or hardpan. Most of the hazards of erosion on many of our steep slopes are avoided by sprinkling. A better cover crop can be grown in orchards and root injury by furrowing out tools is eliminated. Light irrigations can be effectively applied by sprinkling and, especially on light textured soil, a considerable saving of water is possible.

Sprinkling offers a very valuable alternative method of applying water but its greatest economic value probably lies in the development of new lands. The high capital cost of equipment can about equal the cost of preparing land for surface irrigation in many cases. Practically no land preparation is necessary under sprinkling. Cost of power is of sufficient importance that it should be given serious consideration in making a choice.

The design of a sprinkler system should not be attempted by the inexperienced. It is an engineering problem in which the engineer should have a knowledge of soils and plants.

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Colorado-Wyoming Academy of Science
Boulder, May 2, 1952

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In a state such as Colorado where we have about 3,000,000 acres under irrigation and have been irrigating for 100 years, sprinkling offers us only an alternative method of applying water. It is a situation quite different from that in the humid areas where irrigation is something new. Here our lands have been prepared through the years as a continuing process to be irrigated by surface methods. Much money has been spent in leveling and smoothing to accomplish this. Water just can't be poured out of a ditch onto raw land and accomplish anything like efficient irrigation. In the East this feature is jumped when sprinkling is used which is proper because it isn't necessary. Our problem is that of choosing something that is better if the older method falls short.

In the case of new lands to be irrigated in Colorado what has been said about Eastern lands holds true but with an additional problem. Whereas only 1 or 2 light irrigations may be required in the East, here we must go through the entire season applying practically all the water required for plant growth. We need therefore to look at sprinkling rather critically; to judge it from all the angles of advantages and disadvantages which it may possess when considered as a replacement of an already established system.

The advantages under Colorado conditions are rather numerous and may not include all that I am about to mention. Probably the most important one and one having reasonably sound aspects is that of applying water to new land. Particularly is this true when the land is topographically difficult for surface irrigation and requiring a complicated distribution system. Land preparation for efficient surface irrigation including ditch building seldom costs less than $20 per acre even with favorable topography. Nothing more than smoothing to permit the movement of farm machinery is sufficient for a sprinkler system. Costs for land preparation therefore can be considered as an offset on sprinkler capital costs. The capital costs in Colorado have been found to range between $30 and $100 per acre averaging about $75. Another type of new land to be considered is that which is boulder strewn or very rough entirely unsuited to surface irrigation but usable as a pasture. The value of such land may be increased from practically nothing to something substantial. There are also those lands with a thin soil covering over gravel or hard pan where leveling may be impossible.

On steep slopes, the danger of erosion is practically eliminated under sprinkling. Erosion under surface irrigation is an ever present menace and a number of orchardists have changed to sprinkling for this reason alone. A favorable condition for a sprinkler is that of the pipes operating down steep slopes. The fall may offset pipe friction and may result in smaller sizes being required. In some situations the fall is sufficient to operate without power. Reverse slopes on lateral lines pose a difficult hydraulic problem.

Sandy soils do not hold as much water per foot of depth as the loams and heavier soils. With surface irrigation much water is lost through deep percolation and furthermore irrigations are necessary. Savings on water by sprinkling may be expected under such conditions.

One other item of advantage and of considerable importance is that of the saving in land area by the elimination of ditches. It is a common situation that as much as 5 percent of farmed area is occupied by ditches. Besides taking up space, ditches are a nuisance in moving farm machinery and are nearly always grown up to weeds to offer a haven to grasshoppers.

The orchardist finds other advantages. The usual practice these days is the growing of ground cover between the trees. Ordinarily furrows are used which must be cl aned out several times during the season thereby preventing but little growth in them. The middles between the furrows, especially those furrows adjacent to the trees, often do not receive sufficient water to support growth. A large proportion of the surface therefore - perhaps 40 percent, is without cover. Another drawback with furrows is the root injury caused by the implements used to make them. Tree roots grow very close to the surface to feed on the fertilizer placed there. Sprinkling encourages growth over the entire surface and further since furrows are eliminated, traffic with spray rigs and harvesting truck can be in any direction and damage to vehicles is greatly reduced.

The approach to the desired amount of water to apply by sprinkling is theoretically the same as with any other method. However no other method quite reaches the perfection of water control as does the sprinkler and therefore much can be done from an engineering-agronomy standpoint to attain these ends. In this a knowledge of soils is valuable, in fact necessary to bring about satisfactory results.

Several things must be taken into consideration almost simultaneously in the design of a sprinkler system. Part of them are agronomic and part depend on the farmer's labor situation. Once these are determined, the problem is ready for engineering analysis.

It is necessary first to consider the crop to be watered, because of the great variation in root habits of plants. The grasses for instance have a shallow root system, 6 to 18 inches, while alfalfa and trees have a much deeper system, 4 to 6 feet. The object of irrigation of course is to place moisture where the roots will make the best use of it. Water placed beyond roots is lost and generally thought of as being wasted. Water applied in insufficient quantity thereby not providing moisture in the feeding zone limits plant growth by not providing a sufficient volume of earth to feed upon. It also entails replenishment at more frequent intervals. There is then the problem of placing water in the soil to predetermined depths. The various soil types have varying capacities for holding water available for plant use. This is not the place to go into any great detail about soil moisture characteristics, however, some attention must be given to it. The amount of water held by capillarity against gravity is called its field capacity. This occurs a day or so after irrigation depending on the soil type. Plants are unable to withdraw all the moisture held in the soil. A certain amount is firmly held against the power of the roots to extract it. The amount of water between these two limits is called the plant available moisture.

Moisture available to plants varies from 1 inch in sandy soil to 2½ inches in heavy loams per foot of depth. This is the reservoir that the plant draws upon between irrigations. The object of the irrigator then is to fill this reservoir to the proper depth and as a manager, never allow it to be fully exhausted. We know approximately the rate at which plants consume water. It varies with the crop, the stage of maturity and rate of growth and ranges from 0.1 to 0.25 inch per day. Now with the amount of water required to bring the soil reservoir up to capacity and the use rate per day known we can determine the amount of water to put into it and how long it will last.

The unfortunate thing about all this is that only the soil scientist, with his tools and knowledge, can determine all the factors involved. For instance a soil moisture test would be the only means of discovering how much moisture the soil contains at any given time. The farmer does not have these scientific aids. He cannot know the water holding capacity of his soil but science has provided him with an approximation from the soil type. He also does not know the rate of use by the plant but again he knows it approximately. His soil auger will tell him how far wrong he might be and he can adjust his program accordingly. And if he does not take advantage of these aids he can watch his crop for symptoms of distress - not always a good method. He dares not wait for severe symptoms to develop because he knows that further damage will occur before he can get the entire field irrigated.

With the approximate data gained by reviewing the items thus far discussed, the engineer can start his design of a sprinkler system. He needs first of all to know the limit of rate of application which must not be exceeded. Probably the next important consideration is the desire of the operator as to how long he wishes a sprinkler line to be left in one position. Opinions vary considerably in respect to this point. Some farmers may wish to manage the equipment themselves while others will use hired labor. Some will not want to irrigate at night. Thus from the labor standpoint, times of set will be from 3 or 4 hours to 12 or even 24 hours. One of the most common plans chosen consists of 2 moves per day for a maximum irrigation. Of course not all the times yield the same efficiency. The shorter the period of set and the higher the rate of application, the greater the efficiency will be.

There are many aids available to the engineer in the way of tables and diagrams which obviate laborious computations in preparing a design. Manufacturers provide data on the discharge and diameter of spread of their sprinklers at various pressures. They do not however supply data on the character or pattern developed by their sprinklers. This changes with pressure and nozzle size. Tables are available that provide the average precipitation per hour for various ordinary spacings between sprinklers for given discharges per sprinkler. Since sprinkler discharge is simply controlled by nozzle size, any reasonable desired discharge is attainable. For a given sprinkler type, there is a fairly wide assortment of nozzle sizes that may be used. In choosing a nozzle size the designer must keep in mind its association with pressure. Too small a nozzle with a high pressure will break up the stream into a mist and low pressure with a large nozzle causes excessively large drops of water. The first condition results in a mist which suffers much loss in immediate evaporation in the air and an excessive wind drift loss. The second condition of large drops causes unwanted compaction of the soil surface and is usually attended with a very poor precipitation pattern.

The first quantity for determination is that of providing the maximum precipitation required during the chosen period of lateral placement. Sprinkler spacing will be chosen arbitrarily and must be a multiple of 20 or 30 feet as these are the standard pipe lengths. Spacing falls into 2 main categories - one for orchards and the other for field crops. Orchard spacing is usually 20 by 20 feet but may be adjusted to fit the tree rows. Spacing must be short because of the low angle, low capacity sprinklers employed. Field crop spacing may vary considerably but ordinarily there are but 2 main divisions. One employs a pressure of about 35 psi and the spacing will automatically be 30 by 60 feet or 40 by 60 feet. When the pressure is 60 or 70 psi the spacing may be as much as 60 by 80 feet. The required precipitation that I mentioned which is based on the spacing and discharge per sprinkler is that actually entering the soil. Since part of the moisture is lost by evaporation of the streams in the air and a much larger part from wetting plant foliage, adjustment must be made for such losses. The number of sprinklers on a lateral in a symetrical design is known from its length, hence multiplying the average discharge per sprinkler by the number of sprinklers one arrives at the total quantity of water necessary to convey in pipes.

Systems may be composed of one or more laterals. It is common for a completely portable system to consist of but one lateral and a very short main line. Other systems consist of rather long portable main lines and 2 laterals or the main lines may be permanent and laid underground. Main lines are usually of one size from end to end but laterals may consist of several sizes. The pipe size for a main line is most frequently chosen by a rule of thumb on the basis of reasonable friction loss. For precise determination of size the annual cost of the pipe line would be balanced against the annual cost of power. The design of the lateral line is more complicated because of water being discharged at intervals along its entire length. Here again the engineer is assisted by specific diagrams which greatly simplify the computations especially where it is desirable to use several sizes of pipe. I might say here that it has been found from experience that it is highly undesirable for lateral lines to exceed 1300 feet in length. The selection of pipe sizes is a cut-and-try process in which the design is tested for pressure drop. A limit has been agreed upon of 20 percent between the first and last sprinkler which results in an approximately 10 percent variation in discharge. Frequently there are as many 3-pipe sizes involved and several trials may be necessary before the cheapest line providing the proper losses is found. Should a lateral line be running uphill, this must be taken into account in combination with friction loss. Sometimes in such cases, smaller capacity sprinklers are necessary at the beginning of the line.

The final item of design is the pumping plant. It should be carefully chosen so that it will operate at maximum efficiency. A pump driven by an internal combustion engine has some flexibility as to speed and hence capacity. This cannot be changed greatly for both pressure and capacity are affected. The speed of an electric motor cannot be changed hence a pump so driven particularly must be carefully selected. The completely portable system will have a pumping unit mounted on wheels and will be engine driven. It would require a water supply in a ditch and would be moved for every set or, with a short feeder line, every 3 sets. This is about the cheapest type of sprinkler system. Another type with the water supply at one edge of a farm could consist of a long mainline, 2 or more laterals and a permanent pumping station. With a central water supply the mainline would be only half as long and perhaps of smaller pipe. In this pipe would be taken off on one side of the pump to be added onto the line running in the opposite direction. A third type would contain a permanent buried mainline.

Something should be said about the attitude of people with respect to labor in handling a sprinkler system. In this there is a considerable diversity of opinion. Some men detest the business of moving pipe wholeheartedly. Others praise it to the skies. Much depends on what they are used to and what kind of soil and crops are involved. Moving pipe for a row crop in muddy heavy soil is very arduous work. With pasture or alfalfa in light, quick draining soils, the work is relatively easy but in either case much walking is involved. Rubber boots are necessary and if a plugged sprinkler is being worked upon, the operator usually gets pretty wet. So often hired labor is inexperienced and requires close supervision with surface irrigation. It can be said that sprinkling requires less experience and intelligence for satisfactory results. Once a sprinkler program is determined, little or no judgment is required after becoming acquainted with the mechanics of the equipment. On sets involving such long periods as 11 hours, labor can be utilized part time in other manners.

Comparison of efficiencies are always interesting. Irrigation efficiencies also can be compared. Some sprinkler manufacturers are guilty of making claims not entirely correct in this regard. On the lighter, permeable soils with surface irrigation, much water is lost through deep percolation at the upper ends of long runs to properly irrigate the lower ends. On heavy soils loss from deep percolation is not so much of a problem but more water may be lost as runoff at the lower ends. Investigations of farm consumptive use of water indicate that an efficiency of 70 percent can be considered quite high but attainable under careful management. A fair average would be near 50 percent. Not much work has been done along this line with sprinklers but the indications are that 2 to 4 percent of the water is evaporated from the streams in the air. Water drenches all the foliage of field crops as well as all the ground surface. The total surface area from which evaporation is taking place therefore is very great. Estimates based on some experimental work indicate that combined losses may be 25 or 30 percent on a moderately hot day with a light wind. Under very hot, arid conditions and fair winds the losses may reach 40 percent or more. Thus we find that sprinkling can be no more ~~expensive~~ efficient than good surface irrigation. However because sprinkling most likely would be used under conditions where surface irrigation would be difficult and efficiency low we can honestly conclude that it frequently would be more economical of water. This would be particularly true where only light irrigations are wanted.

Uniformity of application is often stressed by sprinkler agents. In a way uniformity as an average for an entire area can be good but local distribution can be very poor. The circles of wetted areas feather out to zero precipitation at the edges of course. The fact that these circles of coverage overlap is not sufficient. They must overlap properly in depth and about the only way to determine uniformity is through the construction of a diagram using the pattern from one sprinkler repeated as necessary until a rectangle is completed between 4 sprinklers. By dividing this rectangle into numerous squares and computing the precipitation for each square, one obtains a comparison between the high and low application areas. Many arrangements will show a variation of as much as 50 percent. The more extreme variations will become apparent in the condition of the crop. Examples of uneven heights of plants are common in fields of grain and alfalfa. Examination of the soil with an auger will corroborate the observations. These conditions may exist because of an inherent pattern defect of the individual sprinkler, for a given spacing. Or it may be because of wind, one of the sprinklers worst enemies. A corrective remedy can be employed by shifting the lines laterally on succeeding irrigations to prevent permanent dry spots.

In summing up, it will be seen from what has been said that in sprinkling we have a specialized tool that can be very useful under conditions where surface irrigation would fail or the results be very poor. It offers a scientific approach to irrigation because of the close control over the water. By taking advantage of known rooting habits of a crop, penetration can be limited to a desired depth. It probably will be more costly initially than the preparation of land well suited to surface irrigation. It may or may not save labor but it does make it possible to manage by the clock once the time of application is determined. Operating costs will probably be greater. It can be more efficient in the use of water but not necessarily so when compared with efficient surface irrigation. It may or may not provide reasonable uniformity of water application. In a situation where sprinkling is considered as a replacement of surface irrigation, the change with its added costs should be given very serious thought.