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USE AND DESIGN CONSIDERATIONS OF SPRINKLER SYSTEMS IN COLORADO

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ENGINEERING RESEARCH

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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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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

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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 strewm 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 claned out several times during the season thereby preventing

but little growth in them. The middles between the furrows, especially those Constitute for helding water amiliable for plant was. This is not had place furrows adjacent to the trees, often do not receive sufficient water to support to er into the same acoust to all north roth roth the colorists beside in a receipt bear growth. A large proportion of the surface therefore - perhaps 40 percent, is Estention constor at fea to lith the arrant of water nets by Expillintly by extinguing 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 defeadles on the well byper then to are untile to rising yer all the adjacent held on the fertilizer placed there. Sprinkling encourages growth over the entire is the suit. A certain accept to introduct against the power of the mode to surface and further since furrows are eliminated, traffic with spray rigs and existing its The ampairt of value ecopern that a test lights to be the black harvesting truck can be in any direction and damage to vehicles is greatly arai asbir, sacartara, d 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

With the approximate data gained by reviewing the items thus far discussed. capacities for holding water available for plant use. This is not the place liler syster. He needs fires of all to to go into any great detail about soil moisture characteristics, however, some brow the limit of rate of application which west not be presented. Typhobly the next attention must be given to it. The amount of water held by capillarity against Appendent consideration is the decire of the operator of to how long he wishes a gravity is called its field capacity. This occurs a day or so after irrigation periodics line to be left in our conttion. Opinions very considerably in Yearsest depending on the soil type. Plants are unable to withdraw all the moisture held to mis rotat. Sime for era may with to remove the contract themselves while in the soil. A certain amount is firmly held against the power of the roots to others will upo hired later. Some will not want to irrigets at night. Jun from extract it. The amount of water between these two limits is called the plant the knowledge of other of out will be from 3 or A hours to 13 or orea 200 available moisture.

Dan of the love could blone chosen consists of 3 mayer per day for a Moisture available to plants varies from 1 inch in sandy soil to 2 inches werested trainition. Of course not all the close yield the game officiousy. The in heavy loams per foot of depth. This is the reservoir that the plant draws shapter the period of rol and the nigher the rate of application, the greater the upon between irrigations. The object of the irrigator then is to fill this efficiency will be. reservoir to the proper depth and as a manager, never allow it to be fully have any camp aids available to the caginoss in the way of tables and exhausted. We know approximately the rate at which plants consume water. It distring weigh obviews leborious ocapulations in proparing a design. Mastinesumers varies with the crop, the stage of maturity and rate of growth and ranges from exection data on the alterrage and diacolor of appeal of their sprinkly 0.1 to 0.25 inch per day. Now with the amount of water required to bring the various presentes. They do not begrever autory date on the character of colleges soil reservoir up to capacity and the use rate per day known we can determine the developed by their a ringlers. This charges with prospure and stadly attenamount of water to put into it and how long it will last.
Tables are available that provide the average precipitation per hour for washing

The unfortunate thing about all this is that only the soil scientist, with product 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 darss 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 first quantity for entermination is that of providing the national the engineer can start his design of a sprinkler system. He needs first of all to whof weather averies came; the thosen ported of lateral placements. Stringist know the limit of rate of application which must not be exceeded. Probably the next herethe will be caused or throughly and that he a multiple of his or in feet as important consideration is the desire of the operator as to how long he wishes a these are the equation wire lengths: Senatur falls into I call burggetten a sho sprinkler line to be left in one position. Opinions vary considerably in respect PAN AMPRICAGO AND STORY FOR FIRELY WASTE. OFFICER SOUTIES TO MORALLY BY TO AN to this point. Some farmers may wish to manage the equipment themselves while there has not be addicated to wit bir they rule, Samming man be about because to others will use hired labor. Some will not want to irrigate at night. Thus from the The series low defective articlery egglerate. The lot stop equipment buy Vine the labor standpoint, times of set will be from 3 or 4 hours to 12 or even 24 northweath white state and we have a weather decisions. Can employed hours. One of the most common plans chosen consists of 2 moves per day for a are some for all the subject of the contract of maximum irrigation. Of course not all the times yield the same efficiency. The an in the feath, then the constant to Chap To you all stating may be so said as shorter the period of set and the higher the rate of application, the greater the et as de fore. The restrict profession that I a chiefal withit to a see the bloc efficiency will be.

spicing and discrenge ver corrector is the actually extending the soil. Comme There are many aids available to the engineer in the way of tables and es of the destricted as they be engineed by the object in this air this air the about diagrams which obviate laborious computations in preparing a design. Manufacturers the same free from westigg which full are adjusted about it also for area identity. provide data on the discharge and diameter of spread of their sprinklers at The antier of springion on a control in a speciment issist is known from the various pressures. They do not however supply data on the character or pattern age of the contract to the contract to a restrict of the contract of the contract of developed by their sprinklers. This changes with pressure and nozzle size. with blaze are attitude to this total quantity of which operating to comment Tables are available that provide the average precipitation per hour for various Distant the his concess of the armore laverals, at an comment of the property ordinary spacings between sprinklers for given discharges per sprinkler. Since by workers we ten to proceed as bot one lateral and a very story rate to be sprinkler discharge is simply controlled by nozzle size, any reasonable desired there correspond a marior of victims loss operable main lime and 2 listens of the discharge is attainable. For a given sprinkler type, there is a fairly wide As Agriculture to be permitted and laid amin'ny but. Heir lines are vessily of eas assortment of nozzle sizes that may be used. In choosing a nozzle size the with them and he and the history is may consist of screenil cises. The pair with designer must keep in mind its association with pressure. Too small a nozzle for his line is not incoming the an by a chie of those on the water of with a high pressure will break up the stream into a mist and low pressure with a were many to the first that There is no show the critical first to the the best to the the large nozzle causes excessively large drops of water. The first condition results and the West world be bullered actions the about 1 cost of works. The realist in a mist which suffers much loss in immediate evaporation in the air and an As the transfer that to more our likewish booten of with bring what and wi excessive wind drift loss. The second condition of large drops causes unwanted configure atoms for only bought. Were shift the anglines to anglicul of compaction of the soil surface and is usually attended with a very poor a serve of the contract of the ground of the contract of the c precipitation pattern. is desirable to use coveral class of page. I about may kare that it has been

found from expectance that it is highly and eliable for leteral true to expect The first quantity for determination is that of providing the maximum 1300 feet in length. The edjection of pinestness in a culture wager consens t precipitation required during the chosen period of lateral placement. Sprinkler which the carles is there for presente drop. A limit has been agreed work of spacing will be chosen arbitrarily and must be a multiple of 20 or 30 feet as persons between the first and last oprickler with receive is an empreciansely these are the standard pipe lengths. Spacing falls into 2 main categories - one ly passent variation is discharge. Fromensky there are as many 3-pine after for orchards and the other for field crops. Orchard spacing is usually 20 by 20 involved and several trials may be nonescary before the cheapest line provising feet but may be adjusted to fit the tree rows. Spacing must be short because of e project lises. In a wall, facult a lateral lise he remains uphill, ship was the low angle, low capacity sprinklers employed. Field crop spacing may vary se talkenture account la consination with friction line. Besetting in nucli cases, considerably but ordinarily there are but 2 main divisions. One employs a success signification envious or a section of the fire become of the fire pressure of about 35 psi and the spacing will automatically be 30 by 60 feet or id final item of design is the province as at. It should be constaint 40 by 60 feet. When the pressure is 60 or 70 psi the spacing may be as much as derived by that it will operate of markets acrimisancy. A many drived by an intermal 60 by 80 feet. The required precipitation that I mentioned which is based on the controlling angine the contribution of the contribution of the contribution of spacing and discharge per sprinkler is that actually entering the soil. Since in the seal greatly for boil process, and disposity are allested part of the moisture is lost by evaporation of the streams in the air and a much Court has al classic with an out in charact bende a pure so delver eart larger part from wetting plant foliage, adjustment must be made for such losses. mint an expectly relacted. The populately postable areas will have a rewards The number of sprinklers on a lateral in a symetrical design is known from its whit we said on whoch and will be engled driven. It would require a p length, hence multiplying the average discharge per sprinkler by the number of supply the sociation and would be seed for every set or, with a short feeder sprinklers one arrives at the total quantity of water necessary to convey in pipes. erosy a colon, fain is about the changes type of nerintles grates. Another to

Systems may be composed of one or more laterals. It is common for a completewith the motor capply at one same of a fami could consist of a long mainline, I ly portable system to consist of but one lateral and a very short main line. er wire interels and a perment purples station. With a control water grante Other systems consist of rather long portable main lines and 2 laterals or the the columne would be only but as long and perhaps of another time. In this promain lines may be permanent and laid underground. Main lines are usually of one would be large cition as a size of the roup to be added onto the line remains size from end to end but laterals may consist of several sizes. The pipe size in the appreciate direction. A third type would profe a personnel beriefe for a main line is most frequently chosen by a mile of thumb on the basis of reasonable friction loss. For precise determination of size the annual cost of Something should be east about the citibate of poople with more only the pipe line would be balanced against the annual cost of power. The design to labor lactanding a sprinter arrion. To this there is a consideralis of the lateral line is more complicated because of water being discharged at diversity of upinion. Some man detect the business of noving pipe the letter being. intervals along its entire length. Here again the engineer is assisted by Othern proise it to the elies. And depends on what they are used to and west specific diagrams which greatly simplify the computations especially where it kind of soil and crops are involved. Sering pipe for a reversor in mady beauty is desirable to use several sizes of pipe. I might say here that it has been avil is very ardnous work. With proture or alfalfa in light, quick draining

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. 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 offon one side of the pump to be added onto the line running in the opposite direction. A third type would contain a permanent buried k. Inconspicing Issaela. At geodelich die einer Tella selfica elekt greinering der die Ind 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

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 dranches 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 etticient more expensive 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 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 equares 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.