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# FURROW IRRIGATION EROSION AND ITS CONTROL

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## INTRODUCTION

Furrow erosion was recognized as a serious problem damaging cropland 40 years ago (Israelson et al., 1946), and attempts to quantify soil loss in relation to furrow stream size and slope were made then and in the following few years (Gardner and Lauritzen, 1946; Mech, 1959). However, little attention was given to these studies, and the furrow erosion problem continued without much effort to correct it for another 25 years. In the early 1970's water quality legislation was directed towards reducing sediment, nutrients and biocides in irrigation return flows. As scientists began to develop methods to improve the quality of irrigation return flows in response to this legislation, some questions were raised about the sources of these pollutants. Brown et al., (1974), and Carter et al., (1974) reported sediment and phosphorus inflows, outflows, and balances for two large irrigation tracts in south central Idaho. They found large quantities of sediment and associated phosphorus were being lost from many irrigated fields. Research has progressed during the life of the STEEP project, and much new information about erosion and sediment loss has been reported both at Kimberly, Idaho, and Prosser, Washington. This paper is a summary of the progress made towards understanding and controlling irrigation erosion and sediment loss.

## FURROW EROSION AND SEDIMENT LOSS

The irrigation furrow serves two purposes. One is to convey water from the top of the field to the bottom to supply water for infiltrating into the soil. The other is to function as the infiltrating surface for water to enter the soil. The stream size needed depends upon the soil infiltration rate, the run length, the furrow slope and factors such as roughness and residue that dissipate energy of flowing water and slow the flow velocity. Some of these factors depend upon others. For example, residue usually increases infiltration which decreases stream size, thereby requiring a larger stream to reach the downslope field end. The stream required for infiltration is small, but that required for transporting water to meet that infiltration need over the entire furrow length is much larger and usually exceeds the erosive stream size on the upslope one-third of the field. Irrigation management, which reflects the irrigator's judgment, is also an important factor. Often stream sizes are too large on steep slopes, and severe erosion occurs.

Berg and Carter (1980) made detailed measurements of sediment losses from furrow erosion with different crops over a slope range of 1.0 to 4.0 percent. From these and other data collected later by these and other researchers, a table of sediment losses has been developed (Table 1). These data illustrate the importance of land slope and crop on sediment losses. The presence and severity of the convex end also has a significant impact on sediment loss. A convex end is an increasing slope into the tailwater ditch over the lower 20 to 60 ft of furrow (Carter and Berg, 1983). The data reported in Table 1 represent average sediment losses under irrigator's management. The actual field observations show wide variation. Much of this variation is associated with wide variation in the furrow stream size applied. The average runoff from all fields was 50 percent of the water applied, indicating that larger streams than needed were applied (Berg and Carter, 1980). Sediment losses are higher where unlined ditches with cut-outs or gated pipe are used because variation in stream is greater.

Table 1.--Estimated seasonal sediment losses in tons/a for different crops irrigated from cement lined ditches with siphon tubes. Run length was 660 ft.

| | Average Field Slope, % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5-1 | | | 1-2 | | | 2-3 | | | >3 | | |
| Convex end | N | M | S | N | M | S | N | M | S | N | M | S |
| Crop | | | | | | | | | | | | |
| Alfalfa | 0.0 | 0.0 | 0.0 | 0.7 | 0.9 | 1.2 | 2.3 | 2.9 | 4.1 | 5.6 | 7.0 | 9.8 |
| Cereal grain or peas | 1.1 | 1.3 | 1.8 | 3.2 | 4.0 | 5.6 | 6.4 | 8.0 | 11.2 | 10.4 | 13.0 | 18.2 |
| Dry beans or corn | 2.5 | 3.1 | 4.4 | 8.7 | 10.9 | 15.3 | 18.4 | 23.0 | 32.2 | 28.0 | 35.0 | 49.0 |
| Sugarbeets | 3.2 | 4.0 | 5.6 | 12.1 | 15.2 | 21.2 | 26.4 | 33.0 | 46.2 | 44.0 | 55.0 | 77.0 |

N = no convex end; M = moderate convex end; S = severe convex end

## CONTROLLING FURROW EROSION AND SEDIMENT LOSS

In response to legislation, the first efforts to improve the quality of irrigation return flows were directed towards removing sediment from drainage waters just before these waters entered streams or rivers. Subsequent research has been directed toward reducing sediment losses from individual farms and fields, and finally to reducing the source of sediment by controlling erosion. Following are brief discussions of control practices developed and evaluated during the life of the STEEP program.

### Sediment Retention Basins

Several types of sediment retention basins ranging from 1.0 acre or more located on a main drain to mini-basins receiving runoff from only four or five furrows have been evaluated. All are effective and each has an effective application. Large sediment basins are often created by constructing an earthen dam across a natural drainage at a suitable site and installing a proper outlet. These large basins have sediment removal efficiencies of 65 to 95 percent, depending upon the sediment concentration in the inflow and the time required for water to pass through the basin (Brown et al., 1981). Medium sized basins are often excavations receiving runoff water from one or more fields. Their sediment removal efficiencies range from 75 to 95 percent. Mini-basins are formed by excavating a sequence of small basins along the lower end of a field or by placing earthen checks across the tailwater drainage ditch and extending them across the convex end where present. If controlled outlets into a separate drainage ditch are placed in each mini-basin, the sediment removed efficiencies range from 85 to 95 percent. If water is allowed to pass from one basin to the next, efficiencies are only 40 to 70 percent, and often flow volumes destroy the basins by washing out the earthen checks (Brown et al., 1981; Carter and Berg, 1983).

Another type of mini-basin is the "I-slot" or "T-slot", constructed by excavating a 6 to 10 ft section in the shape of an "I" or "T". A series of these slots are constructed along the tailwater ditch. Efficiencies of these basins are about the same as for other mini-basins where the water flows from one to the other, or about 40 to 70 percent. These slots, however, because they are below the level of the ditch bottom, are not susceptible to being destroyed by the drainage stream.

Sediment basins are costly to maintain because they need cleaning and the removed sediment must be transported. We recommend that where possible, basins be located in naturally low areas that can be farmed as part of an adjacent field once they are filled with sediment.

The Soil Conservation Service and the Extension Service in Idaho, Oregon, and Washington can provide information on the design and appropriate type of sediment basins to use for various field and farm situations. Cost share funds may be available under several programs in many irrigated areas within these states.

<u>Buried Pipe Runoff and Sediment Control System</u>

In an attempt to correct convex end problems on many fields, Carter and Berg (1983) developed a system comprised of a buried drain pipe along the lower end of a field in place of the drainage ditch. Vertical inlets at intervals along the pipe allow drainage water to enter. An earthen dam is constructed immediately downslope from each inlet, and the top of the inlet is placed at the elevation to eliminate the convex end once the area between the dam fills to the top of the inlet pipe with sediment. The first season this system functions much the same as mini-basins with separate outlets and is 85 to 95 percent efficient for removing sediment. After the convex end is corrected, the efficiency decreases to 75 to 90 percent, but the incoming sediment load is much smaller because the convex end no longer exists and the high erosion rate along the convex end has been eliminated. The area once barren as a convex end can be farmed adding to crop production, and tailwater ditches that could not be crossed with equipment are eliminated. Weed control problems along the lower field end are also reduced.

The initial cost of the buried pipe runoff and sediment control system is higher than that of some other practices, but it has the potential of paying for itself in 4 to 8 years by correcting convex end and tailwater control problems and adding productive area to fields. This increased production increases the net income from the field. This system requires little or no maintenance after the convex end is corrected.

## Vegetative Filter Strips

Strips of cereal grain, grass or alfalfa seeded along the lower ends of fields can reduce sediment losses by 40 to 60 percent, depending upon the sediment load in the runoff water, placement of the vegetation filter strip and how far furrows are made into the strip. These vegetative filter strips can be harvested for some return from the land, but yields per unit area are usually 50 to 70 percent of field yields. Such filter strips can also be placed along upper ends of fields or on particularly steep segments where the furrow streams exceed erosive size. Vegetative filter strips must be properly installed and managed if they are to be effective. They are a relatively low cost alternative, but their effectiveness is less than that of some other erosion and sediment loss control alternatives.

## Use of Crop Residues to Control Furrow Erosion

The proper use of crop residues is a valuable tool to control soil erosion under natural precipitation (Larson et al., 1978). Similar benefits should occur with sprinkler irrigation. Crop residues also effectively reduce erosion during furrow irrigation. At Prosser, Washington, Aarstad and Miller (1981) found that relatively small amounts of straw (500 to 1000 lbs/a of furrow area) almost eliminated furrow erosion and the sediment load in the outflow water. Brown (1985) obtained similar results at Kimberly, Idaho. Miller and Aarstad (1983) observed that with corn or wheat residue from the previous year's crop, limited tillage could be performed for seed bed preparation and herbicide incorporation with enough residue remaining in the furrows to effectively reduce erosion.

An important problem with furrow irrigation is the non-uniformity of wetting along the furrows, especially when the soil is loose and the infiltration rate is high, such as during the first irrigation of the season or after cultivation. By the time the furrow stream advances to the bottom end of a field, the upper end may be overirrigated. All of the above studies have shown that residues in the furrows increase infiltration rates by 50% or more, further aggravating the non-uniformity of wetting.

Surge flow refers to an irrigation system in which the furrow stream is alternately ON and OFF for the desired period of time - 0.5 hr ON and 0.5 hr OFF, for example (Stringham and Keller, 1979; Bishop et al., 1981). It has been found that furrow streams advance as fast or faster with surging than with continuous flow. Inasmuch as the total amount of water applied by surge flow is only one-half that used in continuous flow (water is applied to the furrow only one-half of the time in surge flow) the uniformity of wetting along the furrow when outflow begins is much better with surge than with continuous flow (Evans et al., 1985).

In recent years Evans et al. (1985) at Prosser have been evaluating the combination of residues in furrows and surge flow irrigation to control erosion and increase wetting uniformity. The residues allow large furrow streams and rapid advance without excessive erosion, and surge flow increases uniformity of wetting. This work has shown that large furrow streams can be used without excessive erosion, if the furrows contain residues, whether the residues are hand-placed or grown on site (Table 2). The furrow stream of 8.0 gal/min is very high for this soil and slope, 3.0 gal/min would be more usual. Even with

Table 2.--Instantaneous rate of sediment discharge from furrows as affected by straw placed in the furrows (1983) or wheat and corn residues grown *in situ* (1985). Measurements were made soon after outflow began with a furrow inflow of 8.0 gal/min. After the measurements, the furrow stream was reduced to just maintain outflow. In 1985, only surge flow was used during the advance phase.

| Straw rates† | 1983 Surge | 1983 Continuous | 1985 Residue‡ | 1985 Surge |
|---|---|---|---|---|
| | Ton $a^{-1}/day^{-1}$ | | | Ton $a^{-1}/day^{-1}$ |
| Ton/a | | | | |
| 0 | 78.8 | 63.3 | 0 | 53.7 |
| 1 | 0.8 | 0.2 | wheat | 0.6 |
| 2 | 0.2 | 0.1 | corn | 0.4 |

†Hand-placed in furrows
‡Grown *in situ*

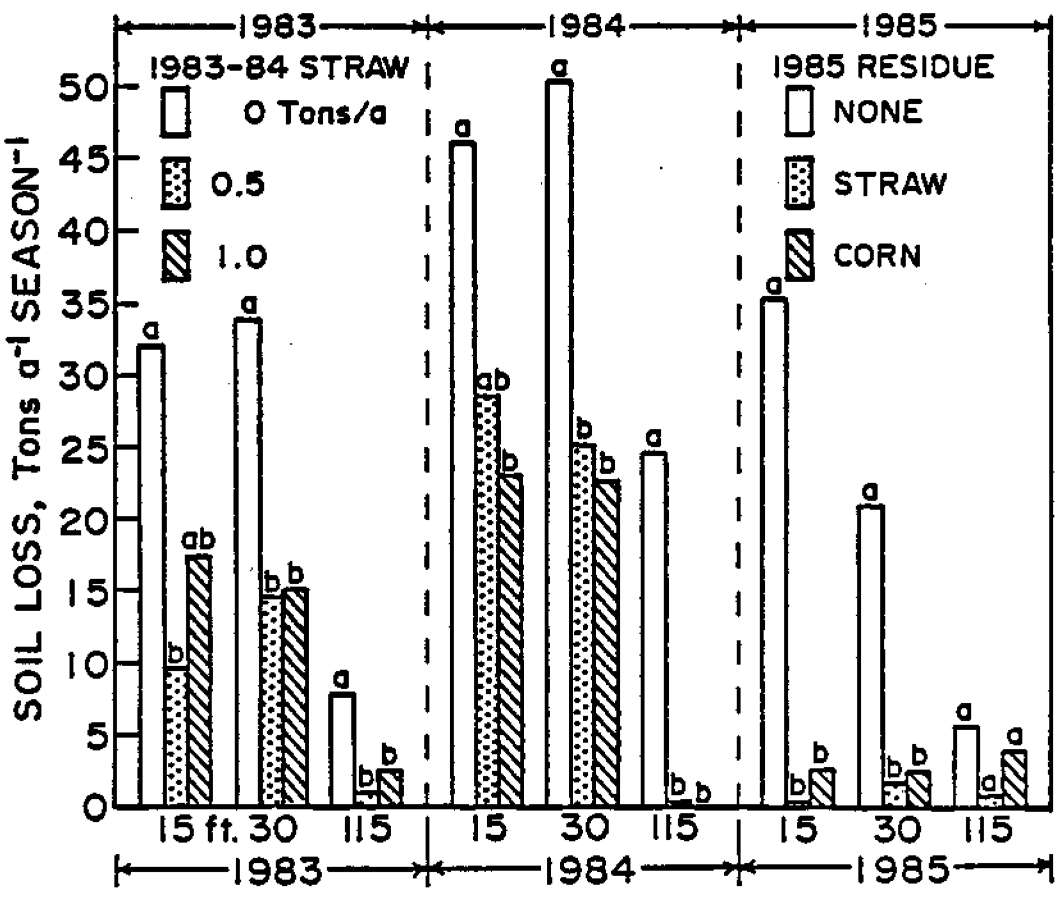


Fig. 1.--Seasonal furrow erosion at three distances from the upper end of the furrows as affected by residues in the furrows. Bars within each group of three with different letters represent significantly different values of P=0.05 or less.

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