SEEPAGE RATES FROM IRRIGATIONCANALS

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Roger P. Sonnichsen

June, 1993

OFTR 93-3

Water Resources Program

OPEN-FILE TECHNICAL REPORT

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

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This Open File Technical Report presents the results of a hydrologic investigation by the Water Resources Program, Department of Ecology. It is intended as a working document and has received internal review. This report may be circulated to other Agencies and the Public, but it is not a formal Ecology Publication.

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ABSTRACT

This paper summarizes a literature review of research conducted on seepage losses from irrigation canals. Seepage rate is controlled mainly by the effective hydraulic continuity of the underlying base material and conveyance material, and the hydraulic gradient. The effective hydraulic continuity is measured in feet per day. The hydraulic gradient is measured in feet per feet. The soil type beneath the canal, including any confining layers, controls the water table level. The water table depth in relation to the canal bottom controls the hydraulic gradient. The seepage rate from a canal where the water table is far below the canal bottom is unity. Seepage rate measured through the wetted area of canal has the units feet per day, using the units above. Figure 1 presents average seepage rates found from measurements conducted on canals built from natural materials and typical linings. Typical lining types used include: compacted earth, concrete, plastic membrane, and plastic pipe. The inflow-outflow method or ponding method are recommended for seepage measurement.

INTRODUCTION

Open canals are the common method used to convey water for irrigation in Washington State. Many miles of meandering canals and laterals exist to make use of topography to rely on gravity to provided the needed energy to deliver water to farms. Many canals were built in the underlying soil back at the turn of the century and today much water is lost by seepage through the sides and bottom of these canals. The extensive miles of canals and laterals points to a large amount of seepage loss. Seepage loss from any irrigation system can vary, but Christopher (1981) estimates 25% of any diversion to be an average amount lost to seepage. Controlling seepage loss from canals and laterals is anticipated to create a much needed new source of water, as water uses are expected to increase by nearly 200% by the year 2000 (Erie 1968). This paper is a summary of a literature review into seepage control research in irrigation canals, presenting basic seepage theory, standard methods to measure seepage rates and different seepage rates expected from different lining materials.

SEEPAGE THEORY

Many different empirical equations have been developed to estimate seepage rates from canals (Christopher 1981, Kraatz 1977, USBR 1963, USBR 1967). When calibrated for a given canal and its surrounding conditions these equations have been reported to give good results. However, seepage from canals is a Darcian condition that may be expressed by an equation of the following form:

$$Q=K_e HA \tag{1}$$

Q	=	Seepage rate, ft^3/day
K_e	=	Effective hydraulic conductivity in and under the canal bed, ft/day
H	=	Hydraulic gradient, ft/ft
A	=	Cross-sectional area of seepage flow, ft^2

Seepage losses differ widely because of the varied nature of canal locations and surrounding conditions. The topography, soils, ground water, and conveyance material of any given area vary greatly both individually and in their total effect. Netz (1980) discusses many factors controlling seepage rates from canals. These seepage loss factors can be outlined by how they affect each component of Equation 1. The effective hydraulic conductivity is affected by: surface seal in canal by silt, underlying soil type, entrained air in soil, temperature of water and soil, and canal base material. Hydraulic gradient is affected by: slope of subgrade soil structure, depth of water in canal, atmospheric pressure, capillary attraction, soil and water chemistry, and water table depth. Cross-sectional area of the canal affects the wetted perimeter. Other factors which determine the amount of seepage loss are flow velocity in the canal, phreatophytic vegetation and aquatic weeds which may cause water to become backed up in the canal and increase seepage loss.

The main factors of concern in controlling seepage loss are effective hydraulic conductivity of base material and the depth of the ground water. Effective hydraulic continuity is determined by the conveyance material and base soil underlying the canal, including any confining soil layers. Ground water level will be affected by deep soil layers and their permeability. Wachyan (1987) provides a good analysis of how a deep permeable or impermeable base controls the ground water level and thus changes the seepage rate from a canal. The hydraulic gradient will be unity for very deep water tables. Figure 1 presents typical seepage rates per wetted area for general soil groups based on seepage test results found in the literature.

MEASUREMENT OF SEEPAGE LOSS

Two methods are recommend for evaluation of seepage loss from canals: inflow-outflow method and ponding method. Ponding method is assumed to be the most accurate and dependable method (Kraatz 1977). Christopher (1981) has found that inflow-outflow measurements may vary by 20% from those determined by ponding tests. Inflow-outflow method has the advantage of being performed without affecting the operation of the canal. Either method should include a determination of the ground water level, to assess its control of the seepage rate.

Inflow-outflow method consists of measuring the water that flows into and out of a section of irrigation canal. Seepage being the difference between the quantities of water flowing into and out of the canal section. If seepage losses are small, evaporation and precipitation must also be accounted for. Measurement of flows using the inflow-outflow method should employ current meters or measurement structures.

Current meter measurements require two meters and two people. Measurements are made at the head and tail of each reach. Errors due to personal observations and equipment may be balanced by swapping the observers and instruments between the head and tail measuring sites. Flows in canals are determined by using the two-point method or the six-tenth depth method. The two-point method being used for larger canals and consists of measuring the velocity at 0.2 and then at 0.8 of the depth from the water surface, and the using the average velocity of the two measurements. The six-tenths depth method consists of measuring the velocity at 0.6 of the depth from the water surface.

Measurement structures may include flumes, drops, weirs, or orifices. Properly constructed flumes or sharp-crested weirs equipped with automatic recording gauges provide the most accurate measurement of flow. Observations of flows through such structures at suitable intervals, with proper time lags between observations, are reasonably accurate.

Ponding method consists of measuring the rate of water loss from a pool formed in a canal reach. Two methods are commonly used to determine the seepage rate. The first is to measure the depth of water in a pool over time. The second ponding method involves adding water to the pond to maintain a constant water surface elevation. The accurately measured volume of added water is considered equal to the total losses, and the elapsed time establishes the loss rate. Evaporation and rainfall should be recorded so that the drop in water surface can be corrected accordingly.

The ponding method has the disadvantage of interrupting the normal working of the canal. Building of dams to form the pool may be costly. The ponding method is the most accurate method of seepage loss measurement.

SEEPAGE CONTROL

Common lining structures and material found in use in the United States are soil lining, concrete, plastic membrane, and flumes or pipes. Figure 1 illustrates the ranges of seepage rates encountered from various canal lining types. The USBR standards recommend lining canals that have seepage rates greater than 0.5 ft/day. Worstell (1976) reviewed 765 seepage measurement tests conducted in the western United States finding wide ranges of seepage rates. Kraatz (1977) provides a detailed overview of canal lining research.

Compacted earth lining can reduce seepage to below 0.08 ft/day. An average seepage rate after a few years of service is 0.17 ft/day (Worstell 1976). Earth lining a cost effective method when suitable soil is nearby. Freezing and thawing and alternating wetting and drying are hazards because they loosen the compaction and increase the permeability of the soil. Long term research shows that such hazards may not be such a detriment to performance of canals in controlling seepage (Jones 1987). The expected life of earth lined canals is 20 years.

Unreinforced concrete of 3 inch can reduce seepage to 0.07 ft/day when new. Freezing and thawing of the ground is a hazard which causes cracking in the concrete. An average seepage loss for concrete after a few years of service is 0.24 ft/day (Worstell 1976). The USBR assumes a seepage rate of 0.1 ft/day in designing for flow capacity of concrete canals (Christopher 1981). Slip-form or shot-crete are cost effective methods of lining canals with concrete. Concrete lined canals have a life span of 50 years.

Plastic liners can reduce seepage to near 0.08 ft/day. Exposed plastic liners have a life span of one or two irrigation seasons. Buried plastic liners have a life span of up to 15 years. Recent development of field fabricated synthetic rubber liners are proving to be durable, cost effective, and can reduce seepage below 0.03 ft/day (Westesen 1989).

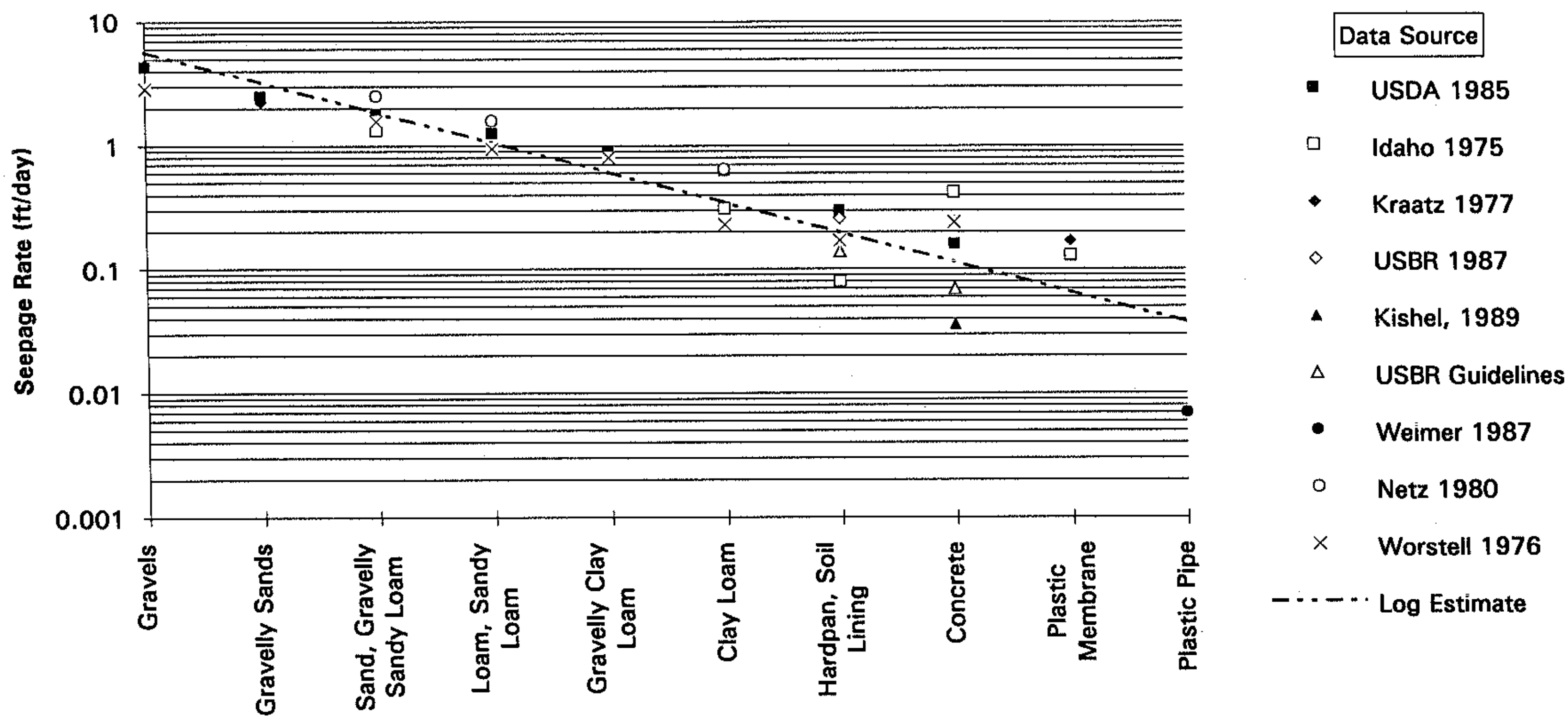
Flumes and pipes made of either concrete or plastic provide very low seepage rates. Concrete pipe is expensive. Plastic pipe is shown to be economical for small canals and laterals. Research by Weimer (1987) has shown that plastic pipe can reduce seepage rates to 0.007 ft/day.

CONCLUSION

A summary of literature presenting research on canal seepage losses, measurements, and lining types was presented. Figure 1 shows average seepage rates found from measurements of unlined canals and typical linings. The inflow-outflow method and ponding method are recommend for seepage measurement. The ponding method is assumed to by the most accurate.

Figure 1

Seepage Rates from Unlined Canals and Typical Linings



Canal lining recommended if seepage rate greater than 0.5 ft/day.

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