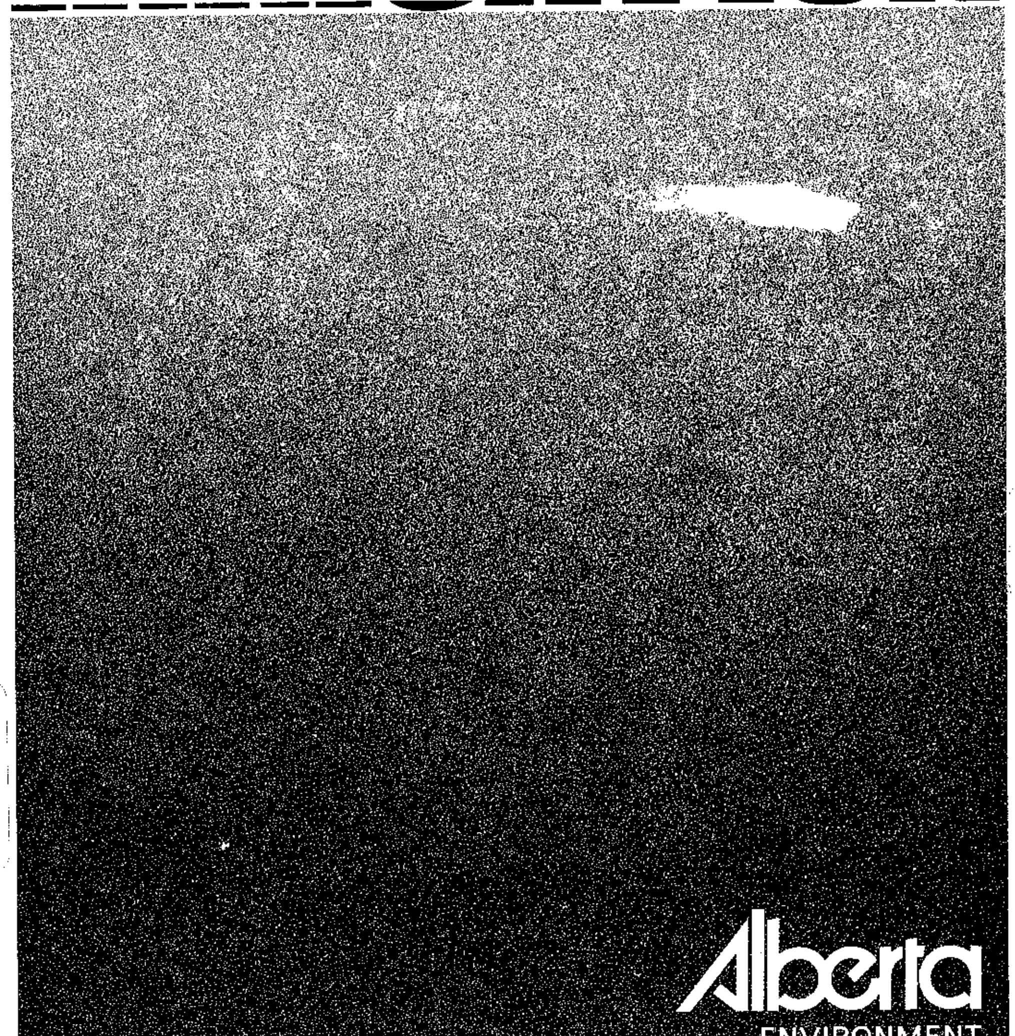
a practical guide to

MUNICIPAL WASTEWATER IRRIGATION



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MUNICIPAL WASTEWATER IRRIGATION

Discussions and Guidelines

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Alberta
ENVIRONMENT
Earth Sciences Division

Preface

This publication is intended for the use of those who are considering irrigation as a method of disposing of wastewater. It contains practical information on whether such irrigation is feasible, indicates what government approvals are necessary and makes reference to where technical assistance can be obtained.

Contents

Introduction

Surface water courses have received municipal sewage effluent for many years. Although sewage treatment standards have been steadily upgraded, the effluents still contain materials considered deleterious to aquatic life. Presently, there are a number of locations in Alberta using all or a good portion of produced municipal effluent to irrigate crops. These projects have been monitored or observed by Alberta Environment and the information so gained has been incorporated in this document. Sewage effluent irrigation schemes, although they are by no means a panacea, do offer a feasible method of waste disposal in areas with net moisture deficiencies if they are properly conceived, designed and operated.

One of the most active media for decomposition, immobilization, or utilization of wastes is in the root zone of the soil, which supports a great number of diverse micro-organisms, a large and effective surface area for adsorption, and plant roots for the extraction of nutrients. A number of non-biological chemical reactions are also possible in this zone. Although the soil is an excellent treatment medium for waste material, one must be cognizant of the value of this resource and take care not to restrict its potential with respect to food production.

A wide spectrum of designs is available for utilizing the soil as a biological waste-treatment mechanism. At one end of the spectrum is the "living filter" concept, which is usually employed in high-rainfall areas where amounts of liquid, solids and nutrients far in excess of crop requirements are applied to the soil. The soil effectively removes the solids and retains some of the nutrients. A portion of the nutrients may be utilized by growing crops. At the other end of the spectrum is the concept of "maximum utilization" of wastewater and is better adapted to areas having a net moisture deficiency with respect to crops with a high moisture requirement and having large tracts of available land. In this case, the amount of effluent applied is equal to the net moisture deficit plus that amount required for leaching of salts. Although it is possible to design projects encompassing the entire spectrum utilizing varying combinations of the living filter and maximum utilization techniques, Alberta subscribes to the maximum utilization concept.

This guide outlines the major aspects which must be considered in utilizing municipal wastewater, and deals with both the advantages and disadvantages of such a method compared to conventional treatment methods.

It must be stressed that before the system is designed, an extensive investigation must be conducted of both the waste material and the soil to which it is to be applied.

Health Aspects

Many potentially pathogenic micro-organisms are known to exist in domestic sewage (bacteria, viruses, intestinal parasites and amoeba). Certain organisms, e.g., Salmonella spp. are not host specific and are found to be infective to both man and animals. The practice, therefore, of forage production for cattle feed in conjunction with domestic sewage effluent irrigation poses possible health hazards. In this regard, however, one should keep in mind the relative dangers to human health from land application of wastewater versus that from water disposal of the same wastewater to surface water supplies (Oldham, 1975).

The destruction of Salmonella spp. on plant species has been shown to be directly related to time of exposure to bright sunlight and elevated temperatures, and inversely related to humidity. Survival of these organisms also depends upon plant species, i.e., stem and leaf structure (Tannock and Smith, 1971). Recent studies with alfalfa grown in the semi-arid prairie region of Alberta, have shown that adequate protection from Salmonella and interopathogenic E. coli is afforded if at least two sunny days, i.e., 10 hours of bright sunlight, have lapsed between cessation of effluent irrigation and consumption of forage by cattle (Bell, 1975). Alberta embraces several climatic zones and therefore some variation from these findings may be expected even within the province. For domestic sewage effluent partially treated by biological processes, Imhoff (1971) has suggested that one week should lapse before areas irrigated be harvested or used for pasture or forage.

The cutting and collecting of forage cannot be accomplished when the forage or ground is wet. Sufficient drying, resulting in significant die-off of organisms, would therefore occur before harvest.

Although persistent bacterial contamination of vegetative material that has been exposed to the elements is unlikely, the irrigation of crops that could be consumed raw is prohibited.

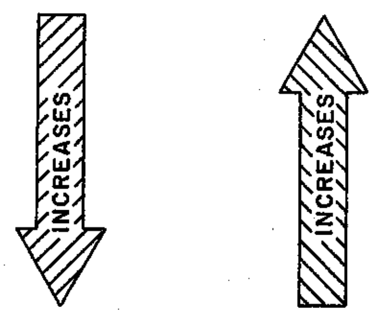
The possibility of assimilation of serious levels of toxic heavy metals in plants irrigated with treated effluent is highly unlikely as most metals are removed from the effluent during treatment.

Contamination of groundwater by effluent irrigation is possible under certain conditions, i.e., very shallow soils over gravel or fractured bedrock. Such sensitive situations require proper instrumentation to establish groundwater flow patterns and to monitor chemical or biological changes in the groundwater.

Economics

The place of irrigation in the wastewater treatment picture in respect to construction costs and land area required is portrayed as follows:

Method	Construction Cost	Land Area Required
Spray Irrigation (with lagoon storage)		
Lagoons		
Aerated Lagoons		
Rotating Biological Contactor (RBC)		
Activated Sludge Processes		
Physical/Chemical Processes		



The fact that irrigation is not possible during the winter in Alberta dictates that storage must be provided for a minimum of seven to nine months depending on the length of the irrigation season, and a lagoon system must therefore be included as a part of the wastewater irrigation system. Probably the major cost of such a system is land purchase. However, it must be realized that land will probably appreciate in value, whereas mechanical treatment plants will depreciate.

Due to the great variety of situations in Alberta, and due to insufficient actual data, the net operation costs of wastewater irrigation are difficult to obtain. Methods for estimating costs of wastewater treatment by land application are available from the U.S. Environmental Protection Agency (1975). The opinion of those associated with such projects in Alberta is that the crop production obtained will cover the cost of operation under average conditions. Projects in areas with a high frequency of moisture-deficient years will probably experience a net profit over operating costs.

An environmental and economic advantage of land treatment is the potential for a high degree of nutrient recycling through crops. There is also the possibility of increasing soil organic matter if the waste material itself contains the necessary substrates.

Treatment Efficiencies

Land treatment is an efficient method for the removal of organic materials, suspended solids, plant nutrients (N, P and K), and to some degree some metals from liquid wastes. Sewage effluent contains macronutrients in forms readily available to growing plants (e.g., NO_3-N, NH_4, orthophosphates, K, SO_4-S, Ca and Mg). Furthermore, organically-bound nitrogen, phosphorus and sulphur are subject to mineralization and other soil processes which can convert them to plant-available forms.

It must be realized, however, that many of the so-called "common salts" present in effluent such as Ca, Mg, Na, Cl, HCO_3 and SO_4 may be only partially and selectively removed by cropping, and must either accumulate in the soil or be leached down into the groundwater system, eventually reaching a surface drainage system. As the latter alternative is required to maintain the system, it follows that some of the constituents will eventually reach the goundwater. This aspect is covered in more detail under the section on water quality for irrigation.

Soil column studies in Alberta (4) showed that a variety of soils removed 90% or more of K, P, NH_3 and BOD from domestic sewage in the top 140 cm of soil. Additional removal through the remaining soil proved difficult to establish due to variability in the results. The removal of nutrients was accompanied with an increase in hardness in the leachate water and a slight increase in soil salinity and SAR. Greenhouse yield of barley was 40% higher when irrigated with sewage than when irrigated with tap water.

A field project using supernatant liquor for irrigation at Calgary (5) showed a removal of 90% of the N and 85% of the P in the first year of operation and 95% and 99% respectively, during the second year.

Six years of irrigation in a project in Alberta resulted in the application of over 250 cm of domestic sewage effluent on land (3). Frequent analysis of the groundwater has shown no apparent change in groundwater chemistry.

Wastewater Chemisty

Sewage must undergo the equivalent of primary treatment followed by storage, prior to use for irrigation. The type of process acceptable for this treatment is determined by Alberta Environment. This treatment is required to remove large particles and objects which cause mechanical problems during irrigation. A higher level of sewage treatment is required when the municipality does not own or control the land which is to be irrigated. In such cases the level of treatment required will be as per Alberta Environment's "Recommended Standards for Water Supply and Sewerage".

Disinfection of sewage effluent prior to irrigation may be required where warranted by public health concerns e.g., golf courses, parks and vegetable crops.

The major characteristic of sewage effluent as compared to good-quality water is the higher concentration of living and non-living organic material, nitrogen and phosphorus. Low concentrations of grease, oil, detergents and some metals may also be present. The major characteristics are usually expressed as units of COD, BOD, bacterial counts, total nitrogen and total phosphorus. The magnitude of the numbers associated with these parameters is extremely variable among the types of systems and times of the year. However, analysis of effluent from standard lagoons during the irrigation season (1) in Alberta indicates that the general range of values for these parameters are:

COD	75-150 mg/L or 20-40 lbs. per acre inch
Kjeldahl N	15-20 mg/L or 4-6 lbs. per acre inch
NH_4-N	10-20 mg/L or 2-2 1/2 lbs. per acre inch
Total P	4-8 mg/L or 1-2 lbs. per acre inch
NO_3-N	0-1 mg/L or less than 1/4 lb. per acre inch

Factors Affecting the Feasibility of Land Treatment of Waste Waters

Land Availability

Sufficient land to handle the anticipated flows must be obtained. Alberta subscribes to an almost complete utilization of nutrients and about 85% utilization of water. The remaining 15% is required for leaching.

The amount of land required is dependent upon the consumptive use of water by plants, the natural precipitation from April 1 to September 30, an efficiency factor, the soil moisture stored in the root zone, and the leaching requirement. The last two factors are opposite in sign and approximately equal in magnitude, and are therefore omitted.

The actual annual moisture deficiency for a high-yielding grass mix in the Province is shown in Fig. 1 (Steed, 1971). The gross amount of effluent to be applied is calculated by the following equation:

$$D = \frac{M}{0.80} \quad (1)$$

in which D is the annual amount pumped in inches, M is the moisture deficiency in inches (Fig. 1) and 0.80 is the efficiency factor.

D values for other crops can be determined by multiplying D by the following appropriate conversion factor:

Alfalfa	1.2
Soft Wheat	0.80
Hard Wheat	0.75
Oats & Barley	0.65

The land area required is calculated by:

$$A = \frac{(V)}{23200\ (D)}$$

in which A is the acres of land, V is the annual volume of wastewater in gallons, and D is derived from the preceding equation.

In most cases forage crops are advantageous due to their greater consumptive use of water which results in a lower land requirement, and their longer growing period which lengthens the irrigation season, thus lowering storage capacity.

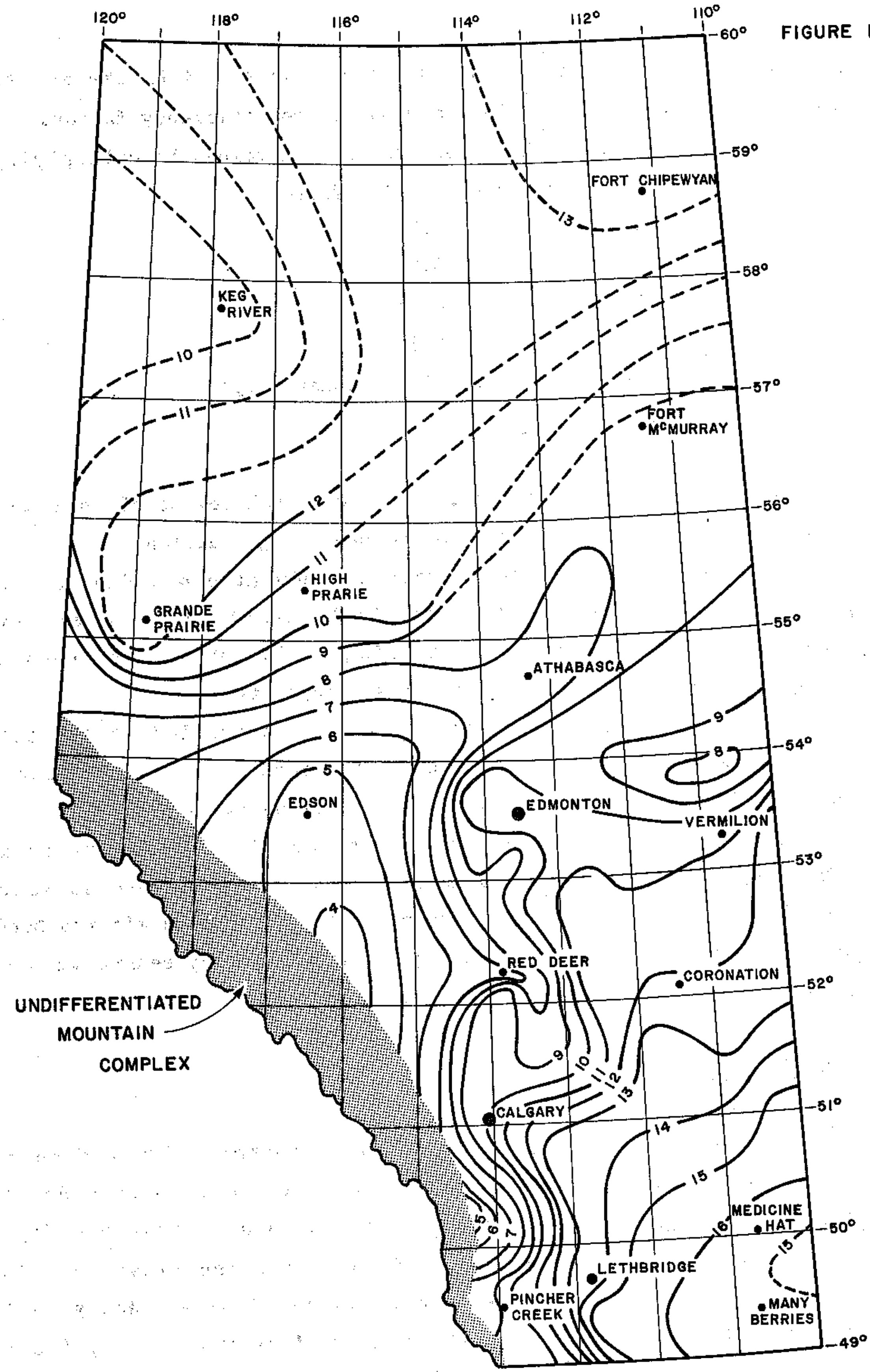
These calculations can of course be overruled if the total nitrogen applied per year exceeds 200 pounds per acre, which is unlikely in the case of municipal sewage effluent.

If a salt build-up occurs, an occasional fall irrigation with good quality water may be necessary to leach the excess salts. Additional land may have to be purchased to allow for a minimum buffer strip of 200 feet between the irrigated field and any sensitive areas such as residences, schools, domestic wells, etc.

Land Suitability

Soil classification will be required. This requires investigation to approximately 20 feet or to bedrock with drilled holes being logged as to geological material and water table depth. Soil survey reports would be an aid in this classification. Soil samples should be taken at one to two foot intervals and analyzed for soluble salts (Ca, Mg and Na), pH and electrical conductivity (as per USDA Handbook 60). Soils with SAR values over 12 are considered to be non-irrigable.

FIGURE I



CONSUMPTIVE USE LESS PRECIPITATION (INCHES)

(PASTURE)

Saline soils should not be irrigated except where artifical drainage is provided. Some measurement of subsurface drainage characteristics is required.

Land Control

Two situations exist with respect to government requirements on land control for irrigation projects.

1. If wastewater irrigation is considered part of the waste treatment process, the municipality should either own or have a firm, long-term lease on the land used for irrigation.
2. If a private landowner desires to utilize wastewater that is already adequately treated and can be used for irrigation in an approved manner, land control is not critical. However, the landowner should have a written agreement with the municipality regarding use and access to the wastewater.

Approval Procedures

For both situations described under Land Control, a Permit to Construct is required prior to commencement of any construction. A letter of application, appropriate plans and a feasibility report must be submitted to the Municipal Engineering Branch, Standards and Approvals Division, Alberta Environment, Edmonton. Once the project has been approved and constructed, a Licence to Operate or Letter of Permission is required before operation can proceed. The Licence or Letter of Permission will spell out operating conditions and requirements for the system.

The municipality must be responsible for the proper operation of the irrigation project, even if someone other than the municipality is actually operating the system.

Water Quality for Irrigation Suitability

Because an equilibrium exists between the soil and the soil water, irrigation with wastewater with unsatisfactory chemistry will result in an unacceptable change in soil chemistry. An effluent with an SAR of over eight is considered unsatisfactory while an EC of 250 millisiemens per metre (mS/M) or greater should be considered unsuitable unless the soil is very well drained.

Small projects with an effluent which has a high SAR and a low EC can possibly be made suitable by modifying the water quality with the addition of calcium salts such as gypsum.

Complete retention of all wastewater constituents in the soil is possible, however, many of the salts cannot be retained in the soil without making it unproductive. Excess Na, Ca, Mg, Cl, SO_4 and HCO_3 salts must be removed from the soil by leaching. These salts eventually enter streams either through groundwater flow or possibly directly through open or tile drains. Water or wastewater in excess of that being used by plants must be applied to move accumulating salts out of the root zone. This additional application is called the "leaching requirement".

A survey of industries discharging wastewater into the sewage system is necessary to assist in the identification of any toxic materials which may be present. The concentration of these possible toxic elements must be determined.

Assistance

Technical assistance for feasibility of wastewater utilization on land can be obtained from the Earth Sciences Division of Alberta Environment (Edmonton, Calgary or Lethbridge).

Financial assistance may be available to municipalities through the Alberta Municipal Grant Program administered by the Alberta Department of Utilities and Telecommunications.

Individuals wishing to irrigate with effluent may receive assistance from the Regional Office of the Prairie Farm Rehabilitation Administration.

Design

If feasibility factors such as effluent quality, land availability and quality are considered adequate, the next step is design.

Lagoons

The land requirement as outlined earlier is a result of average consumptive use and rainfall. As climatic variations are of considerable magnitude in Alberta, some allowance should be made in the design of the system for these variations.

There are three alternatives for abnormal years:

1. A land area greater than that calculated for an average year can be obtained, along with the required additional irrigation equipment. Some project lands will only be irrigated occasionally with a resultant reduction in yield.
2. Larger wastewater applications can be applied, thus increasing the risk of an unwanted water-table buildup.
3. The storage reservoir can be designed with a safety factor, which will allow storage from a wet year to be applied during a dry year.

The latter alternative is recommended and the safety factor suggested is 25%.

Sprinkler Systems

If sprinkler irrigation is chosen, it is recommended that assistance be obtained either from a reputable supplier or Alberta Agriculture. However, a few guidelines are included in this presentation.

Systems such as the conventional hand-move, the side roll or pivot system should be operated at a pressure of about 55 psi. The terminal sprinkler should operate at about 45 psi. The normal spacing of sprinkler heads is 40 feet and will require from 8 to 14 gpm per head, depending on the infiltration rate of the soil. Problems of foreign materials plugging sprinkler nozzles appear to be similar to those encountered when irrigating with normal irrigation water.

The large diameter volume guns require pressures in the range of 100 psi and are more subject to problems caused by strong winds than the closely-spaced lower pressure sprinklers.

Automatic centre pivot systems are recommended for soils with low moisture-holding capacities (coarse textured). These soils require frequent, light applications which could result in continuous irrigation during dry periods. The high labour costs associated with non-automatic systems should be considered when deciding on the type of system to purchase.

Surface Irrigation

Surface methods include level basin, border dike, border ditch, corrugations, and furrows. Supply can be obtained by open ditch or by piping. Surface methods are most appropriate on medium textured soils.

The major disadvantage of surface methods is that the liquid must run over the bottom end of the field for a considerable length of time in order to achieve adequate infiltration at that point. This tail water must be collected and then pumped to the top of the field.

Although surface runoff may occur with sprinklers, it is much easier to control and less volume of water is involved.

Assistance for surface irrigation design is available from Alberta Agriculture, Irrigation and Conservation Division.

Operation

Proper operation of the system is essential for longevity of the system, for a high degree of treatment and for high production. Although crop production is not the prime objective of this type of system, a vigorous crop is essential for utilization of water and nutrients. To achieve high production, the crop should be protected from moisture stress. This requires the maintenance of the soil moisture content near field capacity.

Due to the great variation in waste concentration, soils and climate, no attempt will be made to elaborate on irrigation management. The operational requirements will be stated in either the Licence to Operate or Letter of Permission.

The installation of groundwater observation wells in or immediately downhill from the irrigated field is recommended for operational guidance.

Summary of Advantages and Disadvantages of Wastewater Irrigation

Advantages

1. Construction costs are low.
2. Storage lagoons are less sensitive to extreme variations in flow and concentrations than conventional sewage treatment systems.
3. Operating costs are lower; possible profits can result.
4. The land will probably appreciate over time.
5. Nutrients are recycled.
6. It offers the most complete treatment.
7. It increases food production.

Disadvantages

1. Possible odour from lagoons or the storage reservoir can occur.
2. Land purchase or availability is required.
3. It is not suitable in all areas because of quality of land and effluent restrictions.
4. New industries releasing materials toxic to crops in low concentrations must be avoided.
5. It causes a restriction on the types of crops grown.
6. Groundwater monitoring is recommended.
7. Effects on groundwater must be considered and the effect of any changes in the groundwater must be assessed.

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