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TECHNICAL REPORT

COSTS OF WASTEWATER TREATMENT BY LAND APPLICATION

June 1976

U.S.Environmental Protection Agency
Office of Water Program Operations
Washington, D.C.20460

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MEMORANDUM FOR USERS OF THIS REPORT

PLEASE TAKE NOTE

For all Stage I curves using effective flow (Figures 7 through 13), do not use the curve for amortized capital cost. Instead, calculate the amortized cost from the capital cost using the appropriate capital recovery factor. For these same figures (7-13), the operation and maintenance cost should be determined using the average annual flow, not the effective flow as shown.

Belford L. Seabrook
Project Officer

NOTE

This Technical Report supplements the Technical Bulletin entitled, EVALUATION OF LAND APPLICATION SYSTEMS, March 1975, No. EPA-430/9-75-001, and should be used in conjunction with the EVALUATION manual.

Additional cost comparison data is presented in the Technical Report, COST-EFFECTIVE COMPARISON OF LAND APPLICATION AND ADVANCED WASTEWATER TREATMENT, November 1975, No. EPA-430/9-75-016.

Methods of estimating costs and evaluating the cost-effectiveness of conventional wastewater treatment works were developed in a separate document entitled, A Guide to the Selection of COST-EFFECTIVE WASTEWATER TREATMENT SYSTEMS, NO. EPA-430/9-75-002, which became available July 1975.

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TECHNICAL REPORT

COSTS OF WASTEWATER TREATMENT BY LAND APPLICATION

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ABSTRACT

Cost information for two stages of planning is presented for alternative land application systems: (1) preliminary cost screening and (2) detailed cost estimates. Cost categories include land, preapplication treatment, transmission, storage, land application, and recovery of renovated water.

For preliminary screening costs (Stage I), curves are presented relating capital, amortized, and operation and maintenance costs to average flowrates ranging from 0.1 to 100 mgd (4.38 to 4,380 l/sec). Cost calculation procedures and an illustrative example are included.

For detailed planning costs (Stage II), curves, tables, and data are presented for 33 individual cost components related to either flowrate or field area. For capital items, total construction costs are shown, and operation and maintenance costs are divided into labor, materials, and power where applicable.

This report is submitted in partial fulfillment of Contract 68-01-0966 by Metcalf & Eddy, Inc., Western Regional Office, under the sponsorship of the Environmental Protection Agency. Work was completed as of May 1975.

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Section 1

INTRODUCTION

PURPOSE

The purpose of this report is to aid the planner and engineer in evaluating the monetary costs and benefits of alternative 1 and application systems for municipal wastewater effluents so that they may be compared in a cost-effectiveness analysis. Procedures documented in the EPA Cost-Effectiveness Analysis Guidelines (40 CFR 35 - Appendix A), which are presented as Appendix F of this report, include requirements to evaluate project costs and benefits in monetary terms where possible and to account for nonmonetary social and environmental factors in descriptive terms. The Technical Bulletin *"Evaluation of Land Application Systems"*, [17] covers these important factors. The Guidelines state that "the most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowert present worth and/or equivalent annual value without overriding adverse nonmonetary costs." The Guidelines further states that the selected alternative shall "realize at least identifical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse and/or land and subsurface disposal."

SCOPE

Cost curves, tables and other data are presented for estimating capital and operation and maintenance costs for land application systems. Information is provided on revenue-producing benefits in Appendix A and nonrevenue-producing benefits in Appendix B. Cost information is presented for two stages of planning that require differing degrees of detail and accuracy. The two stages correspond to alternative evaluation procedures identified in *Guidance for Preparing Facility Plans* [21], preliminary planning cost (Stage I) for screening of alternatives; and detailed planning costs (Stage II) for detailed evaluation of the most feasible alternatives.

Preliminary Planning Costs (Stage I)

Cost information for preliminary screening of alternatives to determine which systems have cost-effective potential is presented in Section 3. A minimum amount of site information is required to use this information. It is expected that the information would be used for preliminary evaluations, as indicated in paragraph c(3) of the Cost-Effectiveness Analysis Guidelines, by planners and engineers when an accuracy of approximately 30 percent is sufficient. It should be noted, however, that for conditions unfavorable to land application, Stage I cost estimates may vary by as much as 50 percent from actual costs.

Detailed Planning Costs (Stage II)

This stage of cost estimation corresponds to paragraph f of the Cost-Effectiveness Analysis Guidelines. Alternatives that have been screened for cost-effective potential and ability to meet federal, state, and local criteria would require economic evaluations based on preliminary designs. Detailed planning costs for this purpose are included in Section 4. It is expected that the accuracy of Stage II information would be within about 15 percent of actual costs. Because of the uniqueness of land application systems, however, the engineer making the estimate will usually need to modify the Stage II information to reflect local conditions in preparing the cost-effectiveness analysis.

Limitations

The cost data cover average plant flowrates between 0.1 and 100 mgd (4.38 to 4,380 l/sec), although they are more applicable for flowrates between 0.5 and 50 mgd (21.9 to 2,190 l/sec). Systems with flowrates above or below these ranges generally require special cost considerations. The types of land application systems identified in Section 2 include irrigation, infiltration-percolation, and overland flow. Other systems, such as subsurface leach fields or deep well disposal, are not included.

With the current level of interest in land application, it is expected that new types of systems and methods of application will be developed and will appear in use. To reflect anticipated changes and improvements, the cost data presented in this report should be revised and updated periodically.

Basis of Costs

All cost data given are for a base date of February 1973 and should be updated to reflect current costs by means of cost indexes. Recommended methods and cost indexes for use in updating the base costs are given in both Sections 3 and 4. Amortized capital costs, which are given in Sections 3, are based on an interest rate of 5-5/8 percent and a period of 20 years.

The costs given in this publication were derived from a variety of sources. Those in Section 3 (Stage I) were derived directly from those in Section 4 (Stage II), which were, in turn, derived from a combination of:

- Previously published information
- Surveys of existing facilities
- Consultation with contractors
- Cost calculations based on typical preliminary designs

For the most part, however, the costs were predominantly built up from typical preliminary designs since very few actual construction cost data are available for existing land application systems. It is hoped that actual costs can be used to a greater degree in future revisions of this report as more data become available.

SECTION 2

LAND APPLICATION SYSTEMS

To provide a background for the development of costs in Sections 3 and 4, three basic concepts of land application will be described:

- Types of systems
- Design components
- Factors other than cost

TYPES OF SYSTEMS

Although there is a wide variety of land application systems, they can generally be classified as (1) irrigation, (2) infiltration-percolation, and (3) overland flow. These three methods are shown schematically in Figure 1, and comparative characteristics are given in Table 1. In the text that follows, each method will be discussed briefly, with emphasis on the ranges of site characteristics and typical loading rates.

Irrigation

Irrigation involves applying wastewater to the land, by spraying or surface spreading, to support plant growth and treat the wastewater. This method is the most popular of land application techniques and is generally the most reliable.

Treatment is accomplished by a combination of physical, chemical, and biological means as the applied wastewater seeps into the soil. Systems may be designed for the following purposes: (1) to avoid surface discharge of nutrients; (2) to obtain economic return from the use of water and nutrients by producing marketable crops; (3) to conserve water by exchange when lawns, parks, or golf courses are irrigated; or (4) to preserve and enlarge greenbelts and open space.

Preapplication treatment is provided for most irrigation systems, and a wide range of treatment requirements are encountered. The bacteriological quality of municipal wastewater is usually limiting where food crops or landscape areas are to be irrigated, or where aerosol generation by sprinkling is of concern. In other cases, reductions in BOD and suspended solids may be necessary to prevent clogging of the distribution system, or to preclude odor problems.

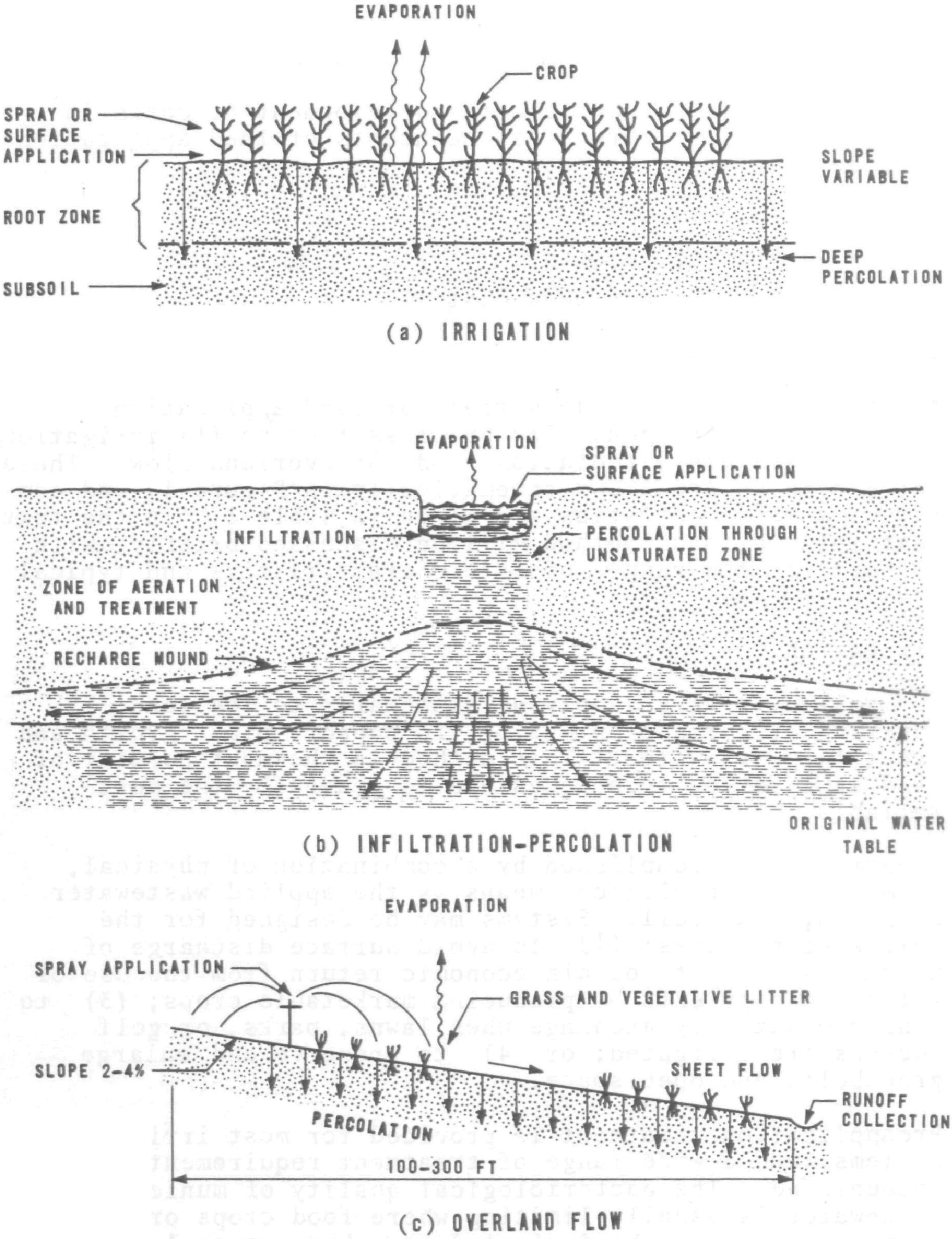


FIGURE 1. METHODS OF LAND APPLICATION

Table 1. COMPARATIVE CHARACTERISTICS OF IRRIGATION, INFILTRATION-PERCOLATION, AND OVERLAND FLOW SYSTEMS FOR MUNICIPAL WASTEWATER

Factor	Irrigation		Infiltration-percolation	Overland flow
	Low-rate	High-rate		
Liquid loading rate, in./wk	0.5 to 1.5	1.5 to 4.0	4 to 120	2 to 9
Annual application, ft/yr	2 to 4	4 to 18	18 to 500	8 to 40
Land required for 1-mgd flowrate, acres[a]	280 to 560	62 to 280	2 to 62	28 to 140
Application techniques	Spray or surface		Usually surface	Usually spray
Vegetation required	Yes	Yes	No	Yes
Crop production	Excellent	Good/fair	Poor/none	Fair/poor
Soils	Moderately permeable soils with good productivity when irrigated		Rapidly permeable soils, such as sands, loamy sands, and sandy loams	Slowly permeable soils, such as clay loams and clays
Climatic constraints	Storage often needed		Reduce loadings in freezing weather	Storage often needed
Wastewater lost to:	Evaporation and percolation		Percolation	Surface runoff and evaporation with some percolation
Expected treatment performance				
BOD and SS removal	98+%		85 to 99%	92+%
Nitrogen removal	85+%[a]		0 to 50%	70 to 90%
Phosphorus removal	80 to 99%		60 to 95%	40 to 80%

a. Dependent on crop uptake.

Metric conversion: in. x 2.54 = cm
ft x 0.305 = m
acre x 0.405 = ha

Site Characteristics. The range of suitable site characteristics for irrigation systems is also wide. The major criteria are as follows:

- Climate — Warm-to-arid climates permit longer season application, but more severe climates are acceptable if adequate storage is provided for wet or freezing conditions.
- Topography — Slopes up to 15 percent for crop irrigation are acceptable if runoff or erosion is controlled.
- Soil type — Loamy soils are preferable, but most soils from sandy loams to clay loams are suitable.
- Soil drainage — Well-drained soil is preferable; however, more poorly drained soils may be suitable if drainage features are included in the design.
- Soil depth — A uniform depth of 5 to 6 feet (1.52 to 1.83 m) or more throughout sites is usually necessary for root development and wastewater renovation.
- Geologic formations — Lack of discontinuities that provide short circuits to the groundwater is necessary.
- Groundwater — A minimum depth of 5 feet (1.52m) to groundwater is normally necessary to maintain aerobic conditions, provide necessary renovation, and prevent surface waterlogging. Control may be obtained by underdrains or groundwater pumping.

Loading Rates. The liquid and nitrogen loading rates are usually the most important for irrigation systems, and in most cases, one of the two will prove to be limiting. Occasionally, however, other loading rates, such as phosphorus and organic matter, or loadings of constituents of abnormally high concentration, may be more critical. To determine the limiting loading rate, balances should be be conducted both for water and for constituents of concern, as shown in *Evaluation of Land Application Systems* [17].

In conducting the water balance, the following factors are considered:

- Wastewater applied
- Precipitation

- Evapotranspiration
- Percolation
- Runoff

The key is to balance, on a monthly or annual basis, the water applied (effluent plus precipitation) with the water losses (evaporation and percolation). Runoff must usually be controlled for irrigation systems. Precipitation and evaporation are determined from an analysis of weather records. Percolation rates used in the design should be determined on the basis of a number of factors, including soil characteristics, underlying geological conditions, groundwater conditions, wastewater characteristics, degree of renovation required, and crop tolerances. In addition to determining the liquid loading rate, the water balance can be used to determine storage requirements. As can be seen in Table 1, the range of liquid loading rates differs for low-rate and high-rate irrigation. Low-rate irrigation systems are normally operated to maximize crop yields, and water is normally applied only during the growing season, and only in quantities required to meet the growth needs of plants. Consequently, very little percolation occurs. On the other hand, high-rate systems are normally operated to optimize the economic treatment of applied wastewater. In this case, the liquid loading is controlled by either hydraulic limitations of the soil or by limiting loading rates of constituents such as nitrogen. With regard to hydraulic limitations, deep sandy or loamy soils usually are not a problem while clayey soils or shallow soil profiles may require application rates of 1.5 in./wk (3.6 cm/wk.) or less.

In conducting the mass balance for nitrogen, the amount of nitrogen applied in the wastewater per year is compared to the amount taken up by a particular crop, and the amount that passes through to the groundwater. Denitrification may amount to 10 to 30 percent of the nitrogen remaining after crop uptake. The amount of nitrogen taken up by crops can be determined from a number of references, including Reference 17. Typical values are about 150 lb/acre/yr (168 kg/ha/yr) for corn and 230 to 400 lb/acre/yr (258 to 443 kg/ha/yr) for Reed canary grass. Allowable amounts of nitrogen passing through to the groundwater can be determined from applicable groundwater standards. The amount of nitrogen applied in the wastewater is a function of concentration and liquid loading rate.

Once the limiting loading rate has been determined, weekly application rates can be calculated over the yearly operating season. Also, the land requirements can be calculated as shown in Sections 3 and 4.

Infiltration-Percolation

In this method, wastewater is applied to the soil by spreading in basins or by spraying and is treated as it travels through the soil matrix. Vegetation is generally not used although grass is grown in some cases. Preapplication treatment is generally provided to reduce the suspended solids content and thereby allow the continuation of high application rates. Biological treatment is often provided prior to spreading or ponding although effluent with only primary treatment has also been used.

Site Characteristics. Because most of the applied effluent percolates through the soil, soil drainage is usually the limiting site characteristic. Other site evaluation criteria include:

- Climate – Infiltration-percolation is applicable in nearly all climates. Loadings may need to be reduced for cold weather conditions.
- Topography – Level terrain is preferable, but rolling terrain is acceptable.
- Soil type – Acceptable soils include sand, sandy loams, loamy sands, and gravels. Soils that are too coarse provide insufficient renovation.
- Soil drainage – Moderate-to-rapid drainage is preferable.
- Soil depth – A uniform depth of 10 to 15 feet (3.1 to 4.6 m) is preferred.
- Geologic formations – Lack of discontinuities is necessary.
- Groundwater – A minimum depth of 15 feet (4.6 m) to the existing water table is necessary; it is not allowed to rise to less than 4 feet (1.2 m) from the ground surface. Control by underdrains may be required.

Loading Rates and Land Requirements. Depending on wastewater characteristics and water quality objectives, loadings of nitrogen, phosphorus, organic, or trace elements may be critical. Although liquid or nitrogen loading is most often limiting, loadings of salt as a result of weathering and soil lime dissolution may be critical in some cases. Loading schedules that include alternating loading and resting periods are required to maintain the infiltration capability of the soil surface and to promote optimum nitrogen removal by nitrification-denitrification.

The water balance is similar to that for irrigation, except that greater amounts of water are lost to percolation. Again, runoff is usually not designed into these systems. The limiting percolation rate should be estimated for saturated soil and adverse climatic conditions. Loading rates of less than 12 in./wk (30.5 cm/wk) are generally required for loams and sandy loams, while higher loading rates usually require the soil to be predominantly sand or gravel.

Where concentrations of nitrogen in either the groundwater or recovered renovated water are limiting, the loading rates and the loading schedule must be selected to maximize denitrification. Some guidance for the determination of the proper loading rates for this purpose is provided in Reference 17 and in papers by Lance [26] and Bouwer [5].

Overland Flow

In this method, wastewater is applied on the upper reaches of sloped terraces of relatively impermeable soils and allowed to flow across the vegetated surface to runoff collection ditches. Renovation is accomplished by physical, chemical, and biological means as the wastewater flows in a sheet through the vegetation and litter. Preapplication treatment should include removal of large solids, grit, and grease which would hamper effective application by sprinkling. Where preapplication treatment includes complete secondary treatment, overland flow can be used for polishing of the effluent and removal of constituents such as nitrogen. The renovation noted in Table 1 has been shown for domestic as well as food processing wastewaters. For domestic wastewater that is not adequately disinfected prior to overland flow treatment, disinfection of the collected runoff may be necessary.

Site Characteristics. Important site characteristics include:

- Climate – Warm climates are preferable, but more severe climates are acceptable if adequate storage is provided for freezing conditions.

- Topography – Rolling terrain is well suited; level terrain can be used to create uniform slopes of 2 to 6 percent, and in some cases as high as 8 percent.

- Soil type – Clays and clay loams are preferable.

- Soil drainage – Poor or slow drainage is necessary.

- Soil depth – Depth must be sufficient to form slopes and maintain vegetative cover.

- Geologic formations – Lack of major discontinuities is necessary.

- Groundwater – Groundwater should not interfere with plant growth.

Loading Rates. Typical loading rates range from 0.25 to 0.75 in./day (0.64 to 1.78 cm/day) for systems applying primary treated wastewater to as high as 0.90 in./day (2.30 cm/day) for systems applying secondary effluent. The water balance should be conducted mainly to determine the amount of expected runoff. The effluent applied plus precipitation should balance the runoff plus evaporation, with a 10 to 30 percent allowance for percolation.

The loading rates mentioned apply to the entire terraced area, which may be composed of 50 to 100 feet (15.2 to 30.5 m) of terrace under the spray diameter, plus 100 to 200 feet (30.5 to 61.0 m) of runoff slope. The required length of runoff terrace will depend on the degree of treatment required, wastewater characteristics, amount of slope, and climate.

DESIGN COMPONENTS

Typically, land application systems are composed of a number of distinct components from the following list of major component categories:

- Preapplication treatment

- Transmission

- Storage

- Distribution

- Recovery of renovated water

The design of land application systems is highly variable and is dependent on many factors relating to site characteristics and project objectives. Some of the major design variables are discussed briefly in the following subsections. Additional references [17, 40] should be consulted for more detailed information.

Preapplication Treatment

The type and level of preapplication treatment will have a significant effect on factors such as:

- The loading rate of various constituents
- The methods of application to be used
- The type of crop or vegetative cover to be grown

Many states have regulations concerning required levels of preapplication treatment. Regulations for California are included as an example in an appendix in Reference 17, and range from requirements for primary treated wastewater for irrigation of fodder, fiber, and seed crops, to requirements for adequately disinfected, oxidized, coagulated, and filtered wastewater for spray irrigation of food crops.

Transmission

Transmission is the conveyance of wastewater from any one portion of the system to another, and may include the conveyance of: (1) wastewater from the collection area to preapplication treatment facilities, (2) treated wastewater from treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point. The three potential methods of conveyance are:

- Gravity pipe
- Open channels
- Force mains

The primary factor to be considered in the selection of the method of conveyance is terrain. Other factors must also be considered, however, particularly in the case of open channels where the possibility of public contact with the wastewater exists. Standard design criteria for each method of conveyance should be used.

Storage

Requirements for storage may range from 1 day of flow to 6 months of flow. The primary considerations in determining storage capacity are the local climate and the design period of operation for the type of system; however, system backup and flow equalization should also be considered.

Storage reservoirs may be required to have impervious linings to eliminate percolation to the groundwater, and asphaltic lining costs have been included in the cost curves in both Sections 3 and 4. Adjustment factors for other types of linings are shown in Section 4.

Distribution

Wastewater may be applied to the land by means of a variety of distribution systems, the most basic of which are discussed in this subsection. These include:

- Solid set spraying (buried)
- Center pivot spraying
- Surface flooding using border strips
- Ridge and furrow application
- Overland flow distribution
- Infiltration basins

Costs are given for each system in both Sections 3 and 4. In Section 3, however, the costs of other basic components have been added to the cost of each basic distribution system, and "Surface Flooding Using Border Strips" and "Ridge and Furrow Application" have been combined into the more general "Surface Flooding."

Solid Set Spraying (Buried). Solid set spraying using buried pipe is used primarily for spray irrigation systems, but it may also be used for infiltration-percolation and overland flow systems. The use of solid set spraying for overland flow is discussed separately in a following subsection. The major design variables include: sprinkler spacing, application rate, nozzle size and pressure, depth of buried pipe, pipe materials, and type of control system. For more detailed information, additional references, such as *Sprinkler Irrigation* [34], should be consulted.

- Sprinkler spacing – May vary from 40 to 60 feet (12.2 by 18.3 m) to 100 by 100 feet (30.5 by 30.5 m) and may be rectangular, square, or triangular. Typical spacings are 60 by 80 feet (18.3 by 24.4 m) and 80 by 100 feet (24.4 by 30.5 m).

- Application rate – May range from 0.10 to 1 in./hr (0.25 to 2.54 cm/hr) or more, with 0.16 to 0.25 in./hr (0.42 to 0.64 cm/hr) being typical. Weekly rates vary with the climate, soil type, and crop requirements over the ranges indicated in Table 1.

- Nozzles – Generally vary in size of openings from 0.25 inch (0.64 cm) to 1 inch (2.54 cm). The discharge per nozzle can vary from 4 to 100 gpm (0.25 to 6.3 l/sec), with a range from 8 to 25 gpm (0.50 to 1.58 l/sec) being typical. Discharge pressures can vary from 30 to 100 psi (2.1 to 7.0 kg/sq cm); with 50 to 60 psi (3.5 to 4.2 kg/sq cm) being typical.

- Depth of buried laterals and mainlines – Depends on the depth of freezing for cold climates. Where the depth of freezing is not a factor, a depth of 18 inches (46 cm) for laterals and 36 inches (91 cm) for mainlines is common [33]. Surface piping, usually of aluminum, may be 40 to 50 percent less costly than buried piping, but it is also less reliable.

- Pipe materials – May be any type used for standard pressure pipe; however, asbestos-cement and plastic (PVC) pipes are most common. Factors that should be considered when selecting type of pipe materials include cost, strength, ease of installation, and reliability.

- Control systems – May be automatic, semiautomatic, or manual. Automatic systems are the most popular for land application systems. Automatic valves may be either hydraulically or electrically operated.

<u>Center Pivot Spraying</u>. Center pivot systems are the most widely used of the moving sprinkling systems. Design variables include size, method of propulsion, pressure, and topography [33].

- Sizes – Systems consist of a lateral that may be 600 to 1,400 feet (183 to 427 m) long. The lateral is suspended by wheel supports and rotates about a point. Areas of 35 to 135 acres (14 to 55 ha) can be irrigated per unit.

- Propulsion — May be by means of either hydraulic or electric drive. One rotation may take from 8 hours to as much as 1 week.

- Pressures — Usually 50 to 60 psi (3.5 to 4.2 kg/sq cm) at the nozzle, which may require 80 to 90 psi (5.6 to 6.3 kg/sq cm) at the pivot. Standard sprinkler nozzles or spray heads directed downward can be used.

- Topography — Systems can be used on rolling terrain with slopes up to 15 to 20 percent.

Surface Flooding Using Border Strips. The major design variables for surface flooding using border strips include strip dimensions, method of distribution, and application rates.

- Strip dimensions — Vary with type of crop, type of soil, and slope. Border widths may range from 20 to 100 feet (6.1 to 30.5 m); widths of 40 to 60 feet (12.2 to 18.3 m) are the most common. Slopes may range from 0 to 0.4 percent. The steeper slopes are required for relatively permeable soils. Strip length may vary from 600 to 1,400 feet (183 to 427 m).

- Method of distribution — May generally be by means of either a concrete-lined ditch with slide gates at the head of each strip, or underground pipe with risers and alfalfa valves.

- Application rates — At the head of each strip, rates will vary primarily with soil type and may range from 10 to 20 gpm per foot (2.1 to 4.1 l/sec per m) width of strip for clay, to 50 to 70 gpm per foot (10.4 to 14.5 l/sec per m) width of strip for sand. The period of application for each strip will vary with strip length and slope.

Additional references, such as *Irrigation* [61], should be consulted for more detailed information.

Ridge and Furrow Application. This method is very similar in concept to surface flooding using border strips, except that the applied water is conveyed down the slope by means of furrows. Row crops, such as corn, are normally grown.

The major design variables are application, topography, and furrow dimensions.

- Application – Usually by gated aluminum pipe. Short runs of pipe (80 to 100 feet) (24 to 30 m) are preferred to minimize pipe diameter and headloss and to provide maximum flexibility. Surface standpipes are used to provide the 3 to 4 feet (0.9 to 1.2 m) of head necessary for even distribution.

- Topography – Method can be used on relatively flat land (less than 1 percent slope) with furrows running down the slope, or on moderately sloped land with furrows running along the contour.

- Dimensions – Furrow lengths usually range from 600 to 1,400 feet (183 to 427 m). Furrows are usually spaced between 20 and 40 inches (51 to 102 cm) apart, depending on the crop.

Overland Flow Distribution. Sprinkling is the most common technique in the United States; however, surface flooding may be practical for effluents relatively low in suspended solids. General practice is as follows:

- Sprinkler application – May be by either fixed sprinklers or rotating boom-type sprays. Moving or portable systems are not practical because a smooth surface must be maintained. Sprinklers are spaced from 60 to 80 feet (18 to 24 m) apart on the laterals.

- Slopes – May range from 2 to 8 percent with 2 to 4 percent preferred for adequate detention time. Lengths of slope may range from 150 to 300 feet (45 to 90 m) with 175 to 250 feet (53 to 76 m) being typical.

- Application cycles – Commonly 6 to 8 hours of wetting and 16 to 18 hours of drying to maintain the microorganisms on the soil surface active.

- Surface application – May be by flooding or by gated pipe. Most suited to wastewater low in organic solids.

Infiltration Basins. This method is the most common for infiltration-percolation systems. The major design variables include: application rate, basin size, height of dikes, and maintenance of basin surfaces.

- Application rates – Can vary from 4 to 120 in./wk (10.2 to 305 cm/wk), with the range of 12 to 24 in./wk (30.5 to 61.0 cm/wk) being most common. Loading cycles generally vary from 9 hours to 2 weeks of wetting and from 1 day to 3 weeks of drying.

- Basin size – Generally a function of design flow and relationship of wetting and drying periods. Basins may range in size from less than 1 acre (0.4 ha) to 10 acres (4 ha) or more. It is usually necessary to include at least two separate basins for even the smallest of systems.

- Height of dikes – Varies with depths of water applied. For depths of 1 to 2 feet (0.30 to 0.61 m), a height of approximately 4 feet (1.22 m) is common.

- Maintenance of basin surface – May be a significant operation and maintenance expense. Many systems require periodic tilling of surface, often annually, while some high-rate systems may required periodic replacement of sand or gravel.

Recovery of Renovated Water

Systems that may be used to recover renovated water include underdrains, runoff collection followed by chlorination and discharge, and recovery wells. Tailwater return is also included in this group, even though the tailwater is usually not completely renovated.

Underdrains. Underdrains may be required in poorly drained soils or when groundwater levels will affect renovation or crop growth. The system normally consists of a network of drainage pipe buried 4 to 10 feet (1.22 to 3.05 m) below the surface and intercepted at one end of the field by a ditch. The pipes normally range in diameter from 4 to 8 inches (10.2 to 20.4 cm). The distance between pipes can range from 100 feet (30.5 m) for clayey soils to 400 feet (122 m) for sandy soils.

Cut-off ditches or open drains can be used in place of buried drain pipes; however, their use is declining and a cost curve is not provided. Such ditches can require from 10 to 30 percent of the field area and are usually not cost effective.

Tailwater Return. A tailwater return system is used with surface irrigation to collect and return excess applied water from the bottom of the strip or furrow. The system normally consists of collection ditches, a small reservoir, a pump, and piping to the nearest distribution line. The system should normally be sized on the basis of the expected amount of return flow, which can range from 10 to 40 percent of the applied flow.

Runoff Collection. The runoff collection systems referred to in this publication are used primarily for overland flow systems and can be followed by chlorination and discharge. The runoff collection ditches are most often unlined and sized to handle the runoff from a specific storm. The chlorination and discharge facilities should include a small reservoir, emergency overflow capabilities, and also should be sized to handle the runoff from a specific storm.

Recovery Wells. Recovery well systems are used primarily with infiltration-percolation systems, but may also be used with high-rate irrigation systems. They may be used for reduction of groundwater levels to ensure treatment effectiveness, or they may be required for further reuse of renovated water or to satisfy water rights considerations. Design variables include well location and spacing, depth, type of packing, and flowrate. Each of these variables is dependent on the geology, soil, and groundwater conditions at the site, application rates, and the desired percentage of the renovated water to be recovered.

Crops

Crops or vegetative cover are normally an integral part of all land application systems, with the exception of most infiltration-percolation systems. Factors that affect the selection of the type of crop to be grown include:

- Water requirement and tolerance
- Nutrient requirements, tolerances, and removal capabilities
- Sensitivity to inorganic ions
- Public health considerations relating to the use of the crop
- Ease of cultivation and harvesting
- Length of growing season
- Value of crop (marketability)

For a more detailed discussion of these factors, Reference 17 should be consulted.

Water Rights

Water rights considerations may be of importance in the cost analysis, particularly in the western states [25]. The return of certain quantities of water to a particular water body may be required. In cases where a change is contemplated in the method of disposal or point of discharge, the state agency or other cognizant authority should be contacted and the status of all existing water rights should be thoroughly investigated.

FACTORS OTHER THAN COST

A number of factors other than direct cost must be considered in the analysis of wastewater alternatives. Among these are:

- Flexibility
- Reliability
- Environmental impact
- Public health considerations
- Social impact
- Economic impact

Each of these factors is briefly discussed with respect to land application systems in the following text. For a more detailed discussion, Reference 17 should be consulted.

Flexibility

The abilities of each alternative wastewater system to operate efficiently under changing conditions, and to be easily modified, should be assessed. Factors related to flexibility that should be considered are:

- Ability to meet changes in treatment requirements
- Ability to meet changes in wastewater characteristics
- Ease of expansion
- Ability to adapt to changing land uses
- Ability to be upgraded as a result of technological advances

Reliability

The reliability and dependability of the system are critical, particularly if the adverse effects of an operational breakdown or poorly operating system may be great. Characteristics relating to reliability that should be considered include:

- Ability to meet or exceed discharge requirements
- Failure rate due to possible operational breakdowns of various components
- Vulnerability to natural disasters
- Adequacy of supplies of required resources
- Factors-of-safety

Environmental Impact

The environmental impact of the selected wastewater alternative will normally be considered in great depth in the later stages of planning when a complete environmental assessment is made. Preliminary assessments should also be made in the earlier stages, however, so that alternatives can be compared on that basis. Generally, the environmental impact of factors unique to land application systems should be assessed with respect to:

- Soil and vegetation
- Groundwater
- Surface water
- Animal and insect life

Public Health Considerations

When evaluating the overall environmental impact of an alternative, special consideration should be given to those effects that relate directly to the public health. Factors that should be considered are:

- Groundwater quality
- Potential for breeding insects and rodents
- Potential runoff from the site

- Aerosols from spray application
- Potential contamination of crops

Social Impact

The overall effects of each alternative should be evaluated in light of their impact on the sociological aspects of the community. Factors that should be considered are:

- Public acceptance
- Relocation of residents
- Aesthetic effects
- Community growth
- Agricultural marketing competition with area farmers

Economic Impact

In many cases a wastewater treatment facility will have indirect economic impacts on the community. Some of the potential impacts are:

- Change in the value of land used and adjacent land
- Loss of tax revenues as a result of governmental purchase of land
- Conservation of resources and energy
- Change in quality of ground or surface waters

Resources Opportunity

The potential benefits that can be derived from the addition or reuse of various resources should be assessed. These may include:

- Availability of a source of water for irrigation
- Recycling of nutrients
- Preservation of open space and greenbelts
- Recreational activities

Section 3

PRELIMINARY PLANNING COSTS (STAGE I)

In this section cost data are presented that will enable the user to quickly estimate the costs of treatment alternatives involving the land application of wastewater for the purpose of preliminary screening. Estimates developed from these data should generally be within 30 percent of actual costs; however, for conditions unfavorable to land application the variance could be more than 50 percent. Such conditions could include large site preparation costs or the need for extensive stormwater control. Consequently, these curves should be used with caution.

COST COMPONENTS AND METHODOLOGY

The costs of land application as presented in this section have been divided into 13 components which are grouped under 7 major categories, as listed in Table 2. Except for land and preapplication treatment, cost curves are presented for each component which relate the capital and operation and maintenance costs to flow in million gallons per day. The relationship among those components for which curves are included is shown in Figure 2. Methods for determining the cost of land and preapplication treatment are discussed in the text.

Once the cost of each component has been computed, the total cost of the system can be determined by adding the component costs. A cost calculation sheet (Table 3) has been included for this purpose at the end of this section. A sample calculation is also included to illustrate the step-by-step procedure (page 54).

Land Costs

The cost of land is often a significant portion of the total system cost. Land may be acquired by an outright purchase, lease, or other means as described in *Evaluation of Land Application Systems* [17]. If the land is to be purchased outright, the cost should be determined by multiplying the estimated total land requirement (acres) by the prevailing market price for land (dollars per acre). The prevailing market price of land should be determined from a local source such as the tax assessor.

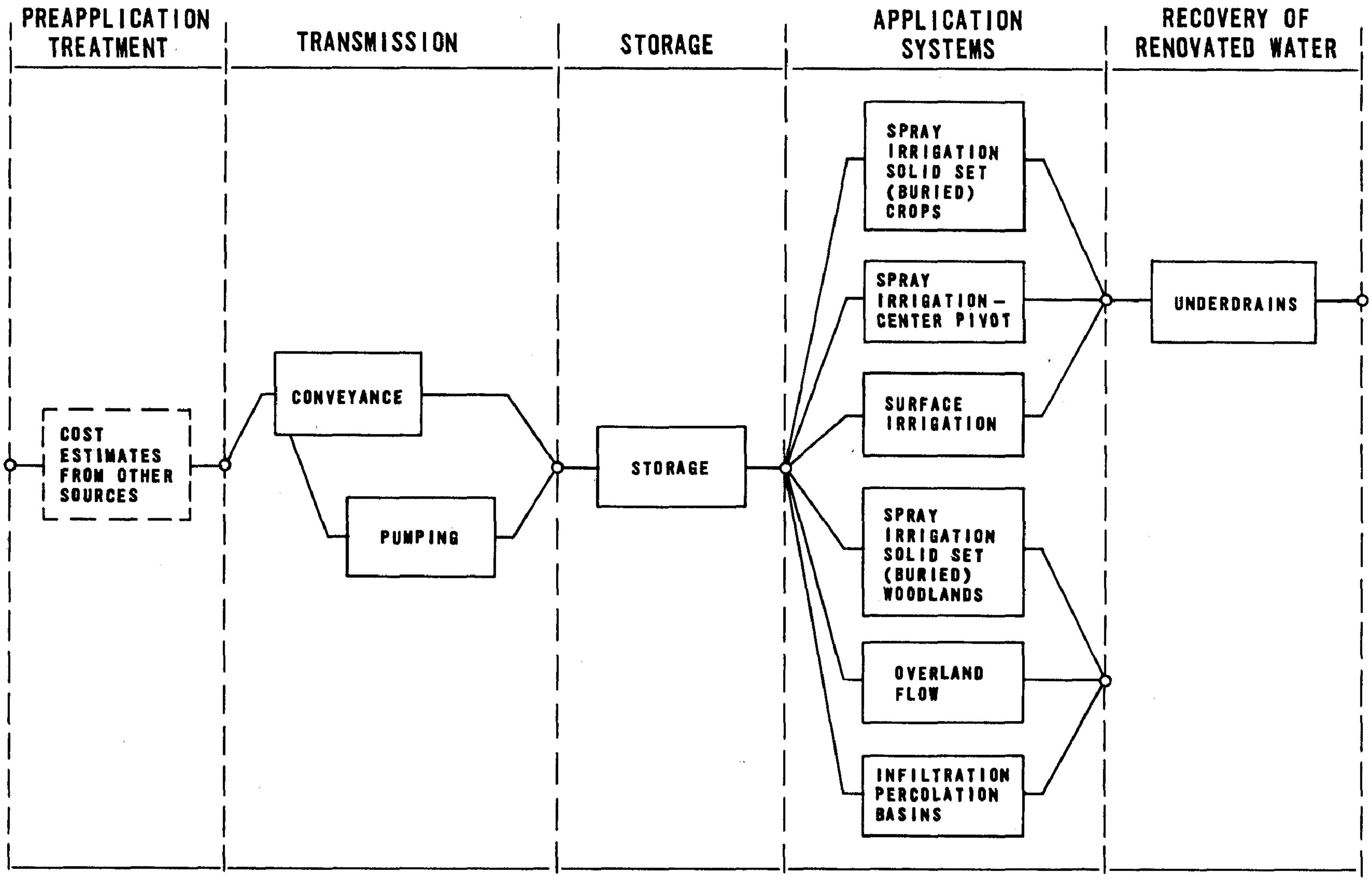


FIGURE 2. RELATIONSHIP OF STAGE I COST CURVES

Table 2. LIST OF STAGE I COST COMPONENTS

Category	Component	Figure No. for curve reference	Page No.
1. Land	• Total area requirement	3[a]	26
2. Preapplication treatment	• Preapplication treatment[b]		
3. Crop revenues	• Crop revenues[c]		
4. Transmission	• Conveyance	4	33
	• Pumping	5	35
5. Storage	• Storage	6	37
6. Application systems	• Spray irrigation, solid set (buried), crops	7	39
	• Spray irrigation, solid set (buried), woodlands	8	41
	• Spray irrigation, center pivot	9	43
	• Surface irrigation	10	45
	• Overland flow	11	47
	• Infiltration-percolation, basins	12	49
7. Recovery of renovated water	• Underdrains	13	51

a. This figure is not a cost curve but a nomograph which relates total area requirement in acres to design flow in mgd, nonoperating time in weeks, and application rate in inches per week.

b. No cost data are provided. See text, page 27.

c. No cost data are provided. See text, page 29.

As an aid for estimating the total land requirement, a nomograph (Figure 3) is included which relates total area in acres, with or without a buffer zone allowance, to design flow in mgd, nonoperating time in weeks, and application rate in inches per week. The nonoperating time is defined as the nubmer of weeks per year during which operation is ceased because of climatic factors. For systems in cold northern states, this would be equal to the storage period. In more temperate climates, the nonoperating time could be considerably greater than the storage period because operation is possible for periods between unfavorable weather.

To use the nomograph, first draw a line through appropriate points on the design flow and application rate axes to the pivot line. Draw a second line from the intersection of the first line with the pivot line through the appropriate point on the nonoperating time axis. The calculated total area is then noted at the intersection of that axis with the second line. This total area includes land for application, roads, storage, and buildings. The total area with

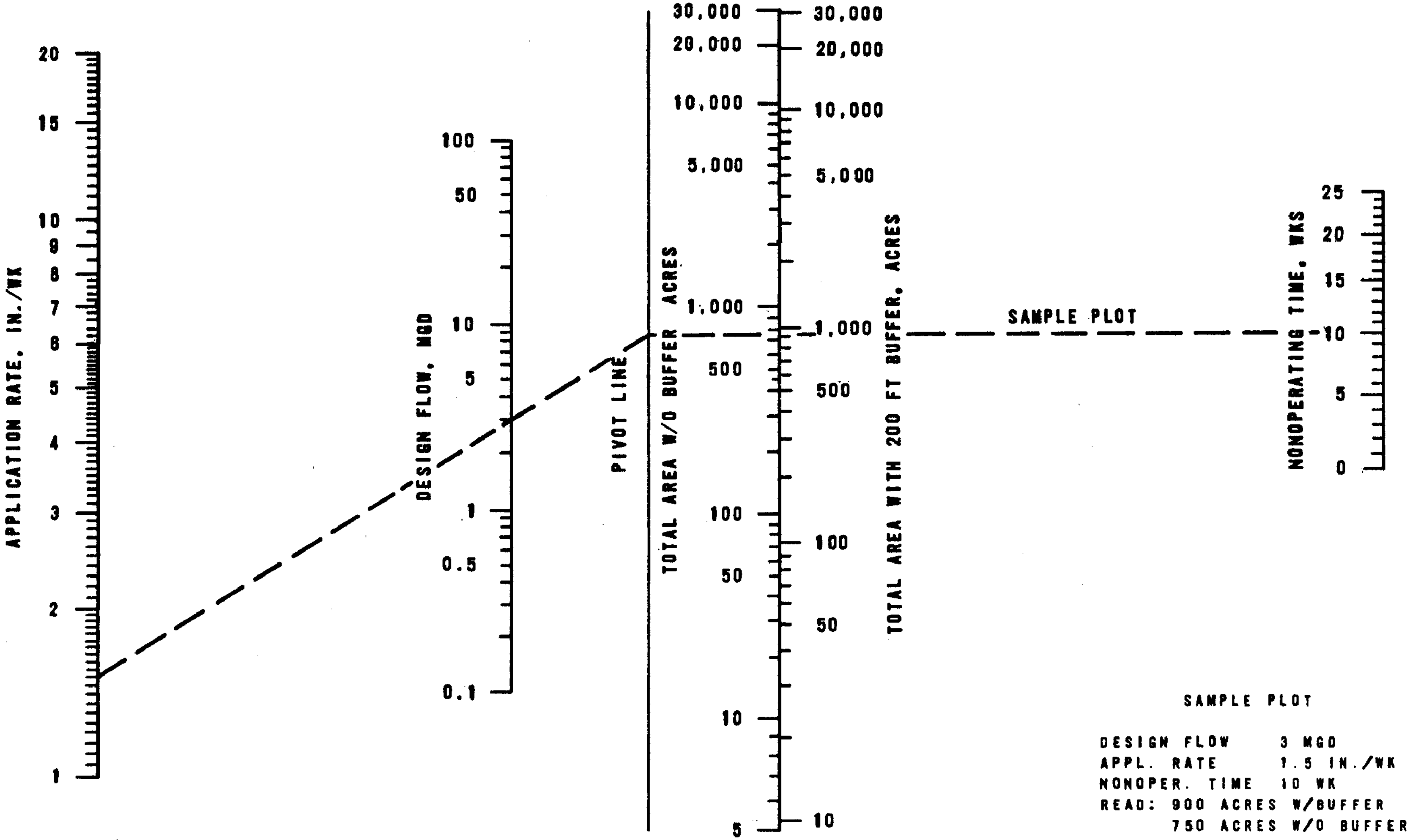


FIGURE 3. TOTAL LAND REQUIREMENT

a 200-foot wide buffer zone allowance is read from the right-hand side of the axis, while the total area without a buffer zone allowance is read from the left-hand side.

Once the total capital cost of land has been calculated, the amortized cost, including an allowance for salvage value, can be determined by the following equation:

$$\text{amortized cost} = 0.0154\ \frac{\text{total capital cost}}{\text{design flow}}$$

where

amortized cost is in ¢/1,000 gal.
total capital cost is in $(thousands)
design flow is in mgd

or in metric units

$$\text{amortized cost} = 0.173\ \frac{\text{total capital cost}}{\text{design flow}}$$

where

amortized cost is in ¢/1,000 1
total capital cost is in $(thousands)
design flow is in 1/sec

Preapplication Treatment

For many systems the cost of preapplication treatment must be included in the total cost of the system. To obtain these costs, other publications that are devoted to the cost of conventional treatment systems should be consulted. *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems* [54], *and Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Systems* [27] are suggested as useful references for this purpose. Special consideration is given to preapplication treatment by aerated lagoons in Stage II because of their common use in conjunction with land application systems, and because of the limited amount of information concerning their costs in other publications. Consequently, a set of cost curves for aerated lagoons (Figure 16) is included in Section 4, page 69.

The level of preapplication treatment required for land application is dependent on a number of factors, including:

- Method of application
- Type of crop grown
- Intended use of crop
- Loading rate of certain constituents
- Equipment limitations

In many states, regulations relating to preapplication treatment exist. For further guidance, Reference 17 should be consulted.

To use preapplication treatment cost data from other sources, the costs should first be trended to the base date of February 1973, using the cost index specified in that source. If a cost index is not specified, the EPA Sewage Treatment Plant Construction Cost Index should be used.

Once the total capital cost has been determined for February 1973, the amortized cost can be determined by the following equation:

$$\text{amortized cost} = 0.0232 \ \frac{\text{total capital cost}}{\text{design flow}}$$

where

amortized cost is in ¢/1,000 gal.
total capital cost is in $(thousands)
design flow is in mgd

or in metric units

$$\text{amortized cost} = 0.268 \ \frac{\text{total capital cost}}{\text{design flow}}$$

where

amortized cost is in ¢/1,000 l
total capital cost is in $(thousands)
design flow is in l/sec

The operation and maintenance cost per volume of treated water may be determined from the annual operation and maintenance cost by the following equation:

$$\text{O\&M cost} = 0.274 \; \frac{\text{annual O\&M cost}}{\text{design flow}}$$

where

O&M cost is in ¢/1,000 gal.
annual O&M cost is in $(thousands)
design flow is in mgd

or in metric units

$$\text{O\&M cost} = 3.17 \; \frac{\text{annual O\&M cost}}{\text{design flow}}$$

where

O&M cost is in ¢/1,000 l
annual O&M cost is in $(thousands)
design flow is in l/sec

Crop Revenues

For many land application systems, the sale of crops grown can help to defray the annual operation and maintenance cost. Consequently, this potential revenue should be included as a credit in the Stage I cost estimate when applicable. Net revenues can normally be expected for irrigation systems (except woodlands irrigation), but infiltration-percolation and overland flow systems offer fewer opportunities for significant revenues.

Because the prices and yields of crops vary considerably with locality, they should be estimated from local sources. A good source for information of this type would be the cooperative extension services at most land grant universities. An example of some typical yields and 1973 prices for crops grown in California is shown in Table 7, page 123.

COST CURVES

The 10 cost curves, which are presented following this discussion, are composed of two-page sets (Figures 4 through 13): the capital and operation and maintenance cost curves are presented on the right-hand pages, and detailed information relating to the curves is summarized on the left-hand pages. Each of the 10 Stage I curves given in this section was derived directly from the Stage II cost curves of Section 4.

Capital Cost Curves

Two curves or groups of curves are presented in each case for capital costs: (1) capital costs, expressed in thousands of dollars, and (2) amortized cost, expressed in cents per thousand gallons. The capital cost is the cost to the owner and includes allowances of 25 to 35 percent for a service and interest factor. This factor includes contingencies; engineering; legal, fiscal, and administrative costs; and interest during construction.

The amortized cost is the total construction cost multiplied by the capital recovery factor for an interest rate of 5-5/8 percent and a period of 20 years (crf = 0.0845), and divided by the design flow for 1 year.

Each of the curves reflects the costs for the base date of February 1973. It is suggested that the costs be trended to reflect current costs by means of the EPA Sewer Construction Cost Index, as explained on page 52.

Operation and Maintenance Cost Curves

An operation and maintenance curve is given for each component. The curve gives the total of all annual labor, power, and materials costs, expressed in cents per thousand gallons. The curves for irrigation systems include the cost of planting and cultivating the crop grown.

The costs are based on an average staff labor rate, including fringe benefits, of $5.00 per hour, and a unit cost of power of $0.02 per kilowatt-hour. Although the costs cannot be readily adjusted for regional or time differences in Stage I, it is suggested that the total operation and maintenance cost be trended by means of the EPA Sewer Construction Cost Index to approximate current costs.

Average Versus Effective Flow

Costs for transmission and storage are related to average flow, which is considered to be the annual average design flow entering the system. In the curves for pumping and conveyance, an allowance for peaking factors has been included.

Costs for application systems and recovery of renovated water are related to effective flow, which is the rate applied to the land during the operating season. For systems operating year-round, the average and effective flows are the same. For systems that cease operation and store incoming flow during a portion of the year, the effective flow will be larger than the average flow in proportion to the number of nonoperating days or weeks. The effective flow can be calculated using the following equation:

$$Q_e = \frac{52}{W} Q$$

where

Q_e = effective flow in mgd or l/sec
Q = average flow in mgd or l/sec
W = number of operating weeks per year

Secondary Variables

A family of curves is included for many of the Stage I components introducing secondary variables, such as storage capacity or application rates. Interpolation between these curves is encouraged for storage capacities and application rates other than those shown. Selection of the proper storage capacity and application rate is specific to the site and application process chosen as indicated in Section 2. It is important to note that each application system represents a separate process or management technique with different site requirements to meet different project objectives. Consequently, the curves under "Application Systems" should not be compared without taking into account these differences.

Detailed Information Relating to Cost Curves

Base Date. The base date for all costs given in this section is February 1973

Costs Included. A summary of the cost items included and the important design assumptions is presented on the left-hand page for each component. The design assumptions generally reflect typical designs of each component with average to moderately favorable conditions.

Metric Conversion. Metric conversion factors are given for those parameters which appear in the cost curves. Additional metric conversion factors are given in Appendix G.

TRANSMISSION

CONVEYANCE

Costs per mile are given for the 3 basic methods of conveyance: (1) gravity pipe, (2) open channels, and (3) force mains.

BASE DATE - FEBRUARY 1973

Assumptions

1. Peaking factor allowance ranges from 3 for systems of 1 mgd (43.8 l/sec) and less average flow, to 2 for systems with greater than 10 mgd (438 l/sec) average flow.

2. Gravity pipe:

   a. 9-ft (2.7 m) depth of cover over crown of pipe
   b. Average slope of 0.002 to 0.005
   c. Average velocity of approximately 3 to 5 fps (0.9 to 1.05 m/sec)
   d. Repaving of road surface required for 10% of distance

3. Open channels:

   a. Concrete-lined, trapezoidal-shaped ditch with 1:1 side slopes
   b. Average slope of 0.004
   c. Minimum average velocity of approximately 2 fps (0.6 m/sec)
   d. Normal freeboard of 1.5 ft (0.5 m)

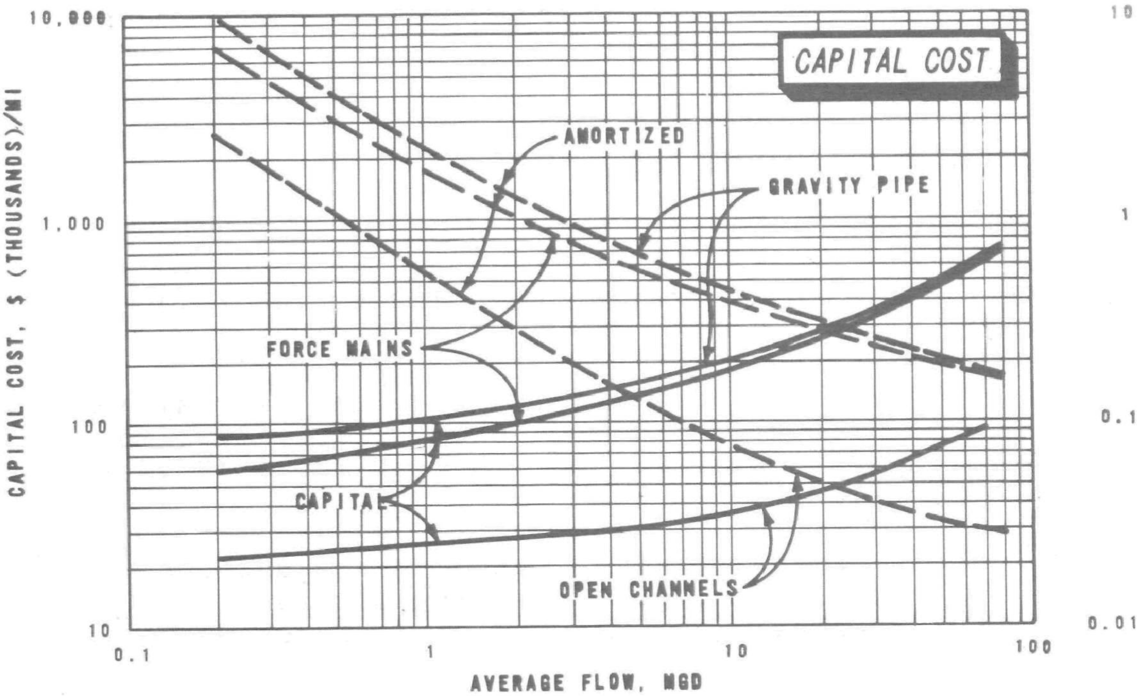
4. Force mains:

   a. 5-ft (1.5 m) depth of cover over crown of pipe
   b. Average velocity of 5 fps (1.5 m/sec)
   c. Repaving of road surface required for 10% of distance

Metric Conversion

1. mgd x 43.8 = l/sec

2. ¢/1,000 gal. x 0.264 = ¢/1,000 l



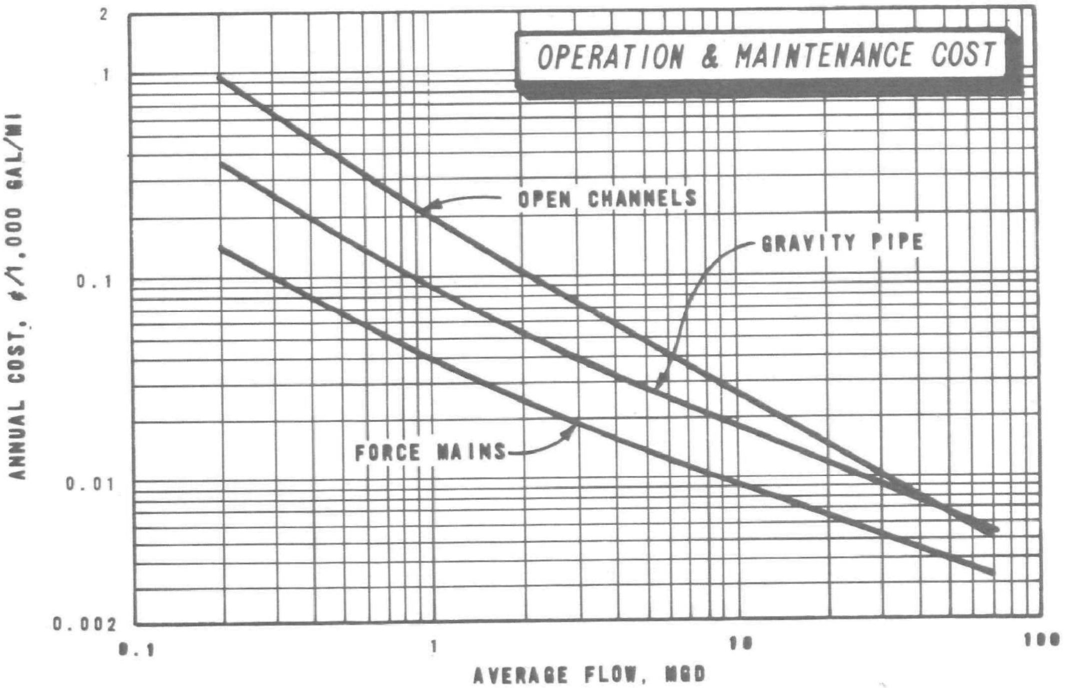


FIGURE 4. TRANSMISSION - CONVEYANCE

TRANSMISSION

PUMPING

BASE DATE - FEBRUARY 1973

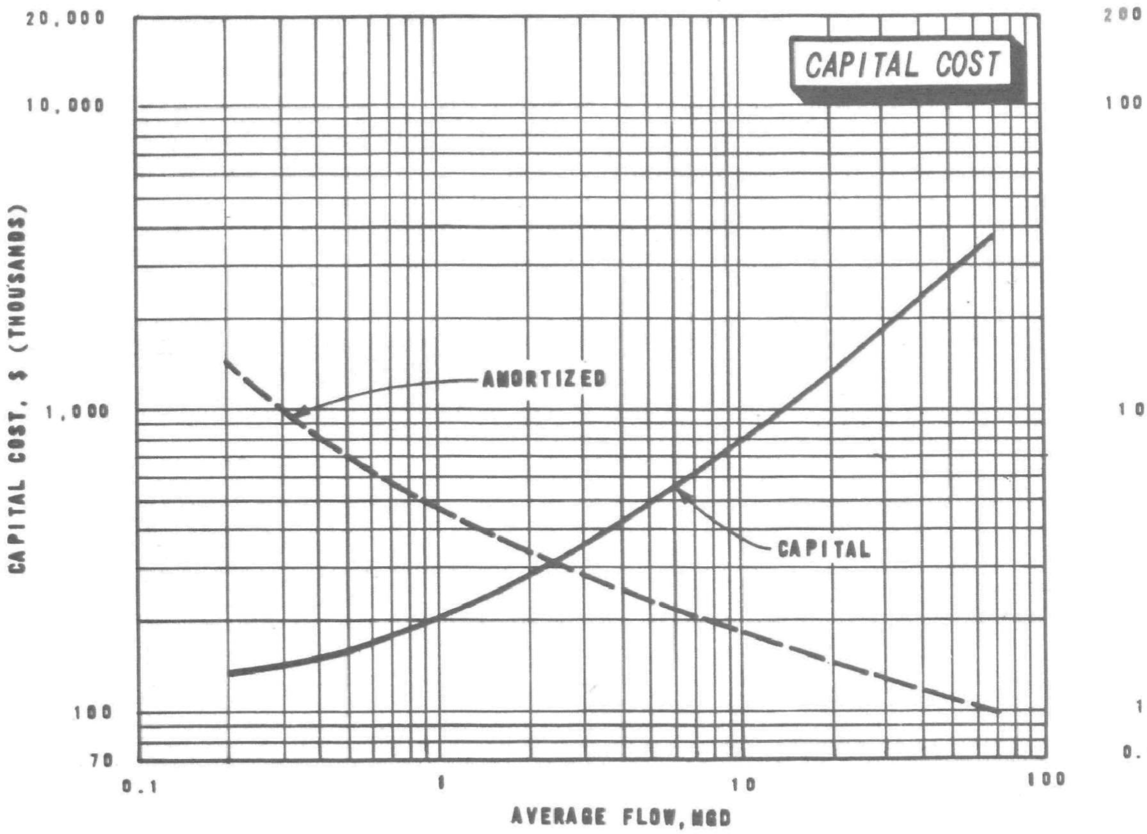
Costs Included

1. Effluent pumping station with 150-ft (45.8 m) total head.
2. Peaking factor allowance ranges from 3 for systems of 1 mgd (43.8 l/sec) and less average flow, to 2 for systems with greater than 10 mgd (438 l/sec) average flow.

Note: These curves should be used in conjunction with those in Figure 4, "Transmission-Conveyance," (see Assumption 4, Force Mains) on the preceding page.

Metric Conversion

1. mgd x 43.8 = l/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 l



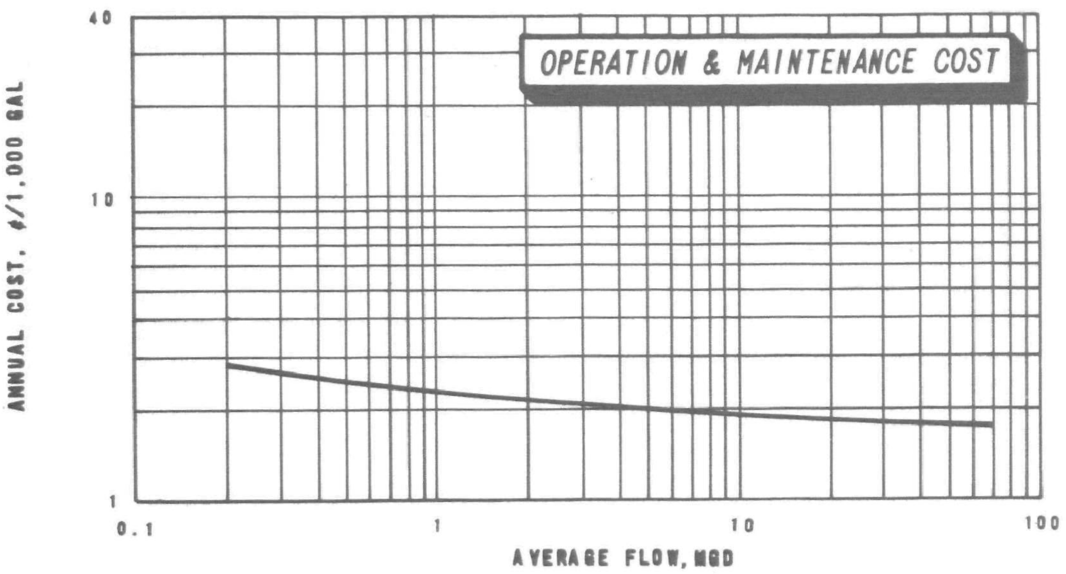


FIGURE 5. TRANSMISSION – PUMPING

STORAGE

Costs are given for various storage capacities as equivalent average flows of 1-, 10-, and 20-week durations.

BASE DATE - FEBRUARY 1973

Costs Included

1. Basic reservoir construction on level ground with dikes formed from native excavated materials.

2. Erosion protection using riprap.

Note: For approximate costs of lined reservoirs, multiply basic cost by a factor of 2.2 for full lining, or 1.6 for half lining.

Metric Conversion

1. mgd x 43.8 = l/sec

2. ¢/1,000 gal. x 0.264 = ¢/1,000 l

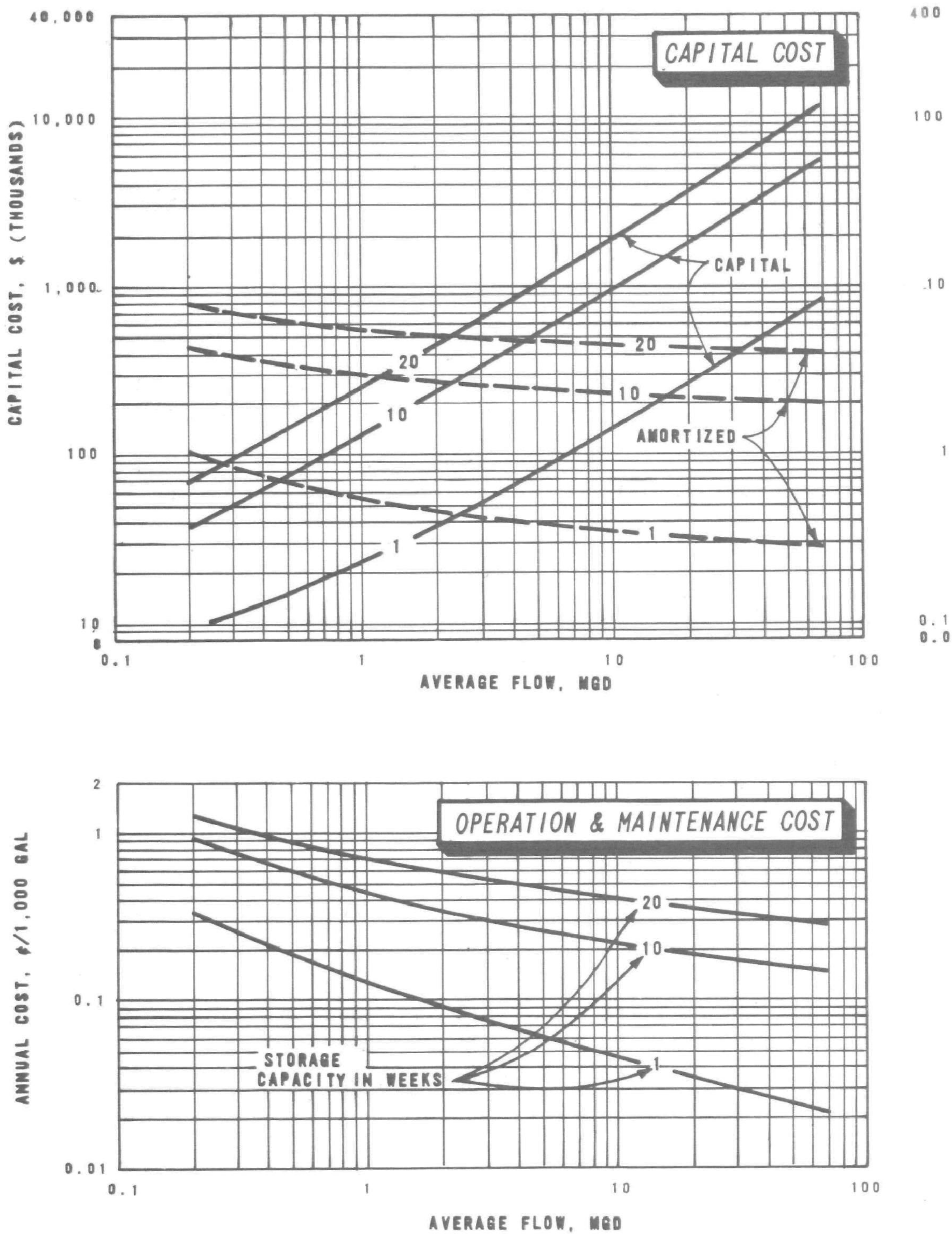


FIGURE 6. STORAGE

APPLICATION SYSTEMS

SPRAY IRRIGATION, SOLID SET (BURIED), CROPS

BASE DATE - FEBRUARY 1973

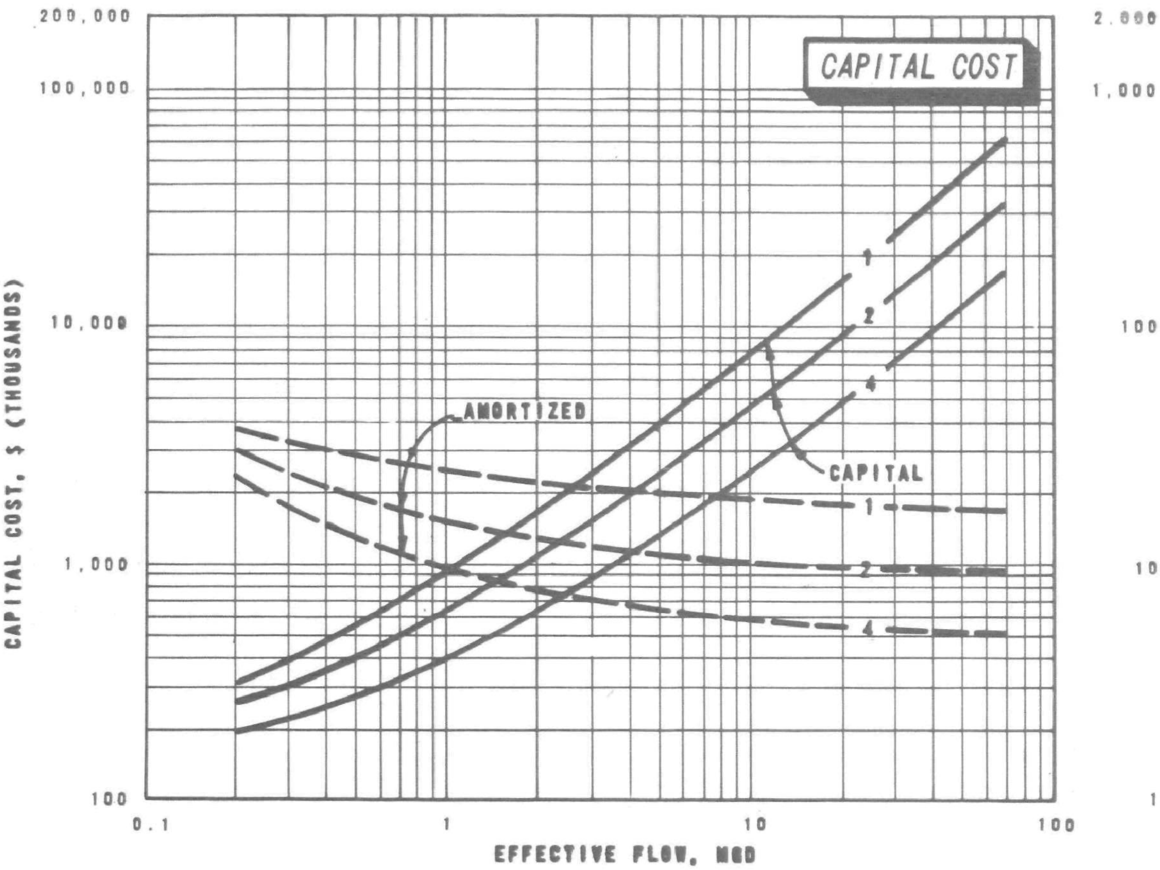
Costs are given for a typical system, for application rates of 1,2, and 4 in./wk.

Costs Included

1. Site clearing of brush and few small trees.
2. Distribution--buried solid-set spray system with automatic controls, 80 x 100 ft (24.4 x 30.5 m) sprinkler spacing.
3. Distribution pumping with 225-ft (68.6 m) total head.
4. Administrative and laboratory facilities.
5. Monitoring wells of 50-ft (15.3 m) depth.
6. Service roads and fencing.
7. Cultivation of corn.

Metric Conversion

1. mgd x 43.8 = l/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 l



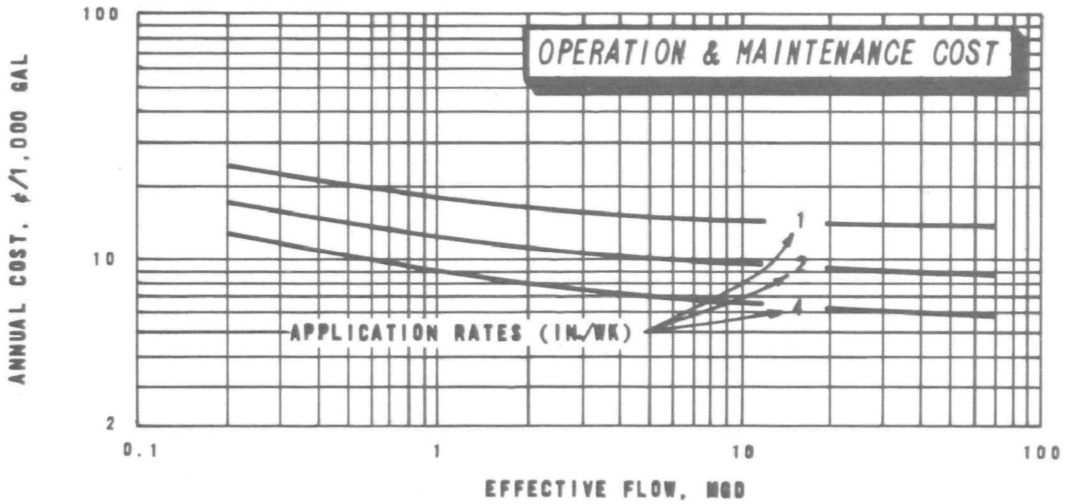


FIGURE 7. APPLICATION SYSTEMS – SPRAY IRRIGATION, SOLID SET (BURIED), CROPS

APPLICATION SYSTEMS

SPRAY IRRIGATION, SOLID SET (BURIED), WOODLANDS

BASE DATE - FEBRUARY 1973

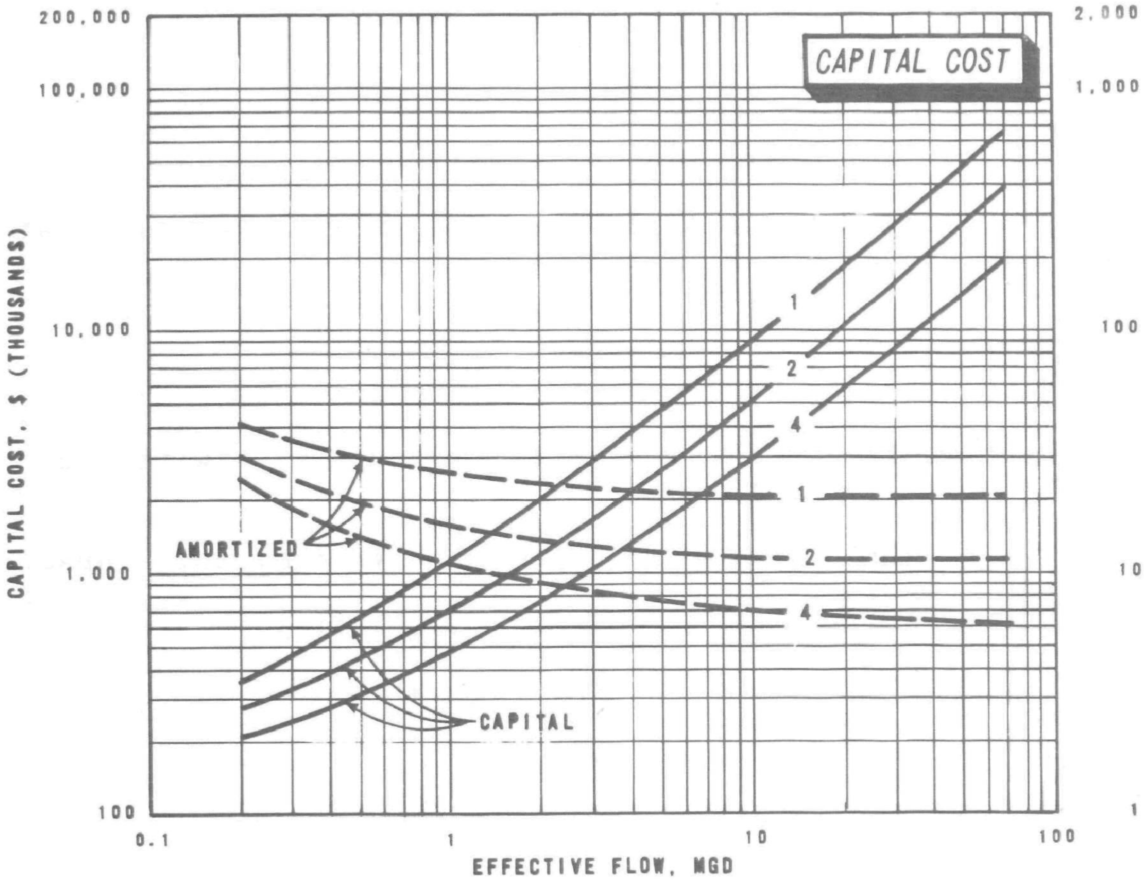
Costs are given for a typical system, for application rates of 1, 2, and 4 in./wk.

<u>Costs Included</u>

1. Site clearing--pathways through wooded area for distribution.
2. Distribution--buried solid-set spray system with automatic controls, 60 x 80 ft (18.3 x 24.4 m) sprinkler spacing.
3. Distribution pumping with 150-ft (45.8 m) total head.
4. Administrative and laboratory facilities.
5. Monitoring wells of 50-ft (15.3 m) depth.
6. Service roads and fencing.

<u>Metric Conversion</u>

1. mgd x 43.8 = l/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 l



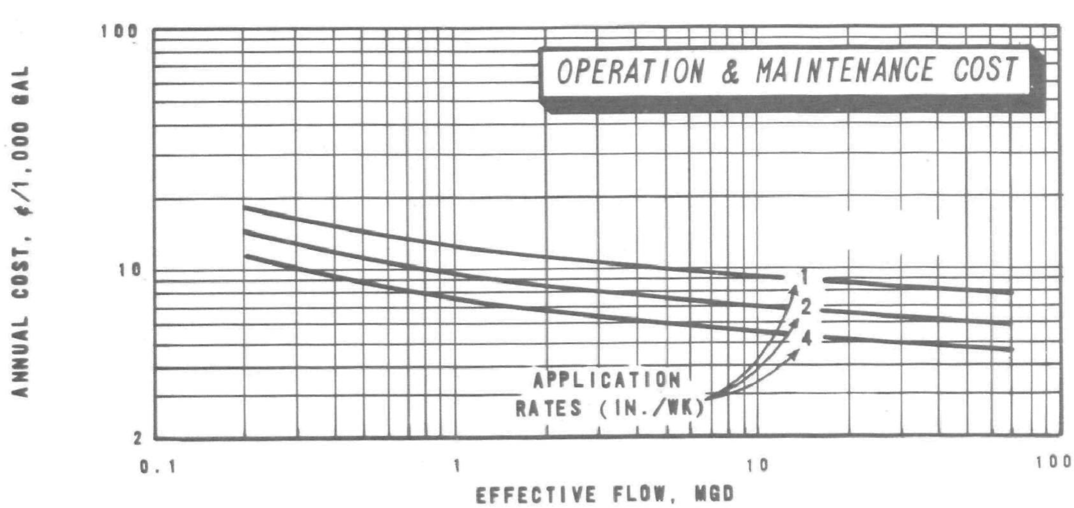


FIGURE 8. APPLICATION SYSTEMS - SPRAY IRRIGATION, SOLID SET (BURIED), WOODLANDS

APPLICATION SYSTEMS

SPRAY IRRIGATION, CENTER PIVOT

BASE DATE - FEBRUARY 1973

Costs are given for a typical system, for application rates of 1, 2, and 4 in./wk.

Costs Included

1. Site clearing--brush with few small trees.
2. Distribution--heavy-duty center pivot rigs with electric drive.
3. Distribution pumping with 150-ft (45.8 m) total head.
4. Administrative and laboratory facilities.
5. Monitoring wells of 50-ft (15.3 m) depth.
6. Service roads and fencing.
7. Cultivation of corn.

Metric Conversion

1. mgd x 43.8 = l/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 l

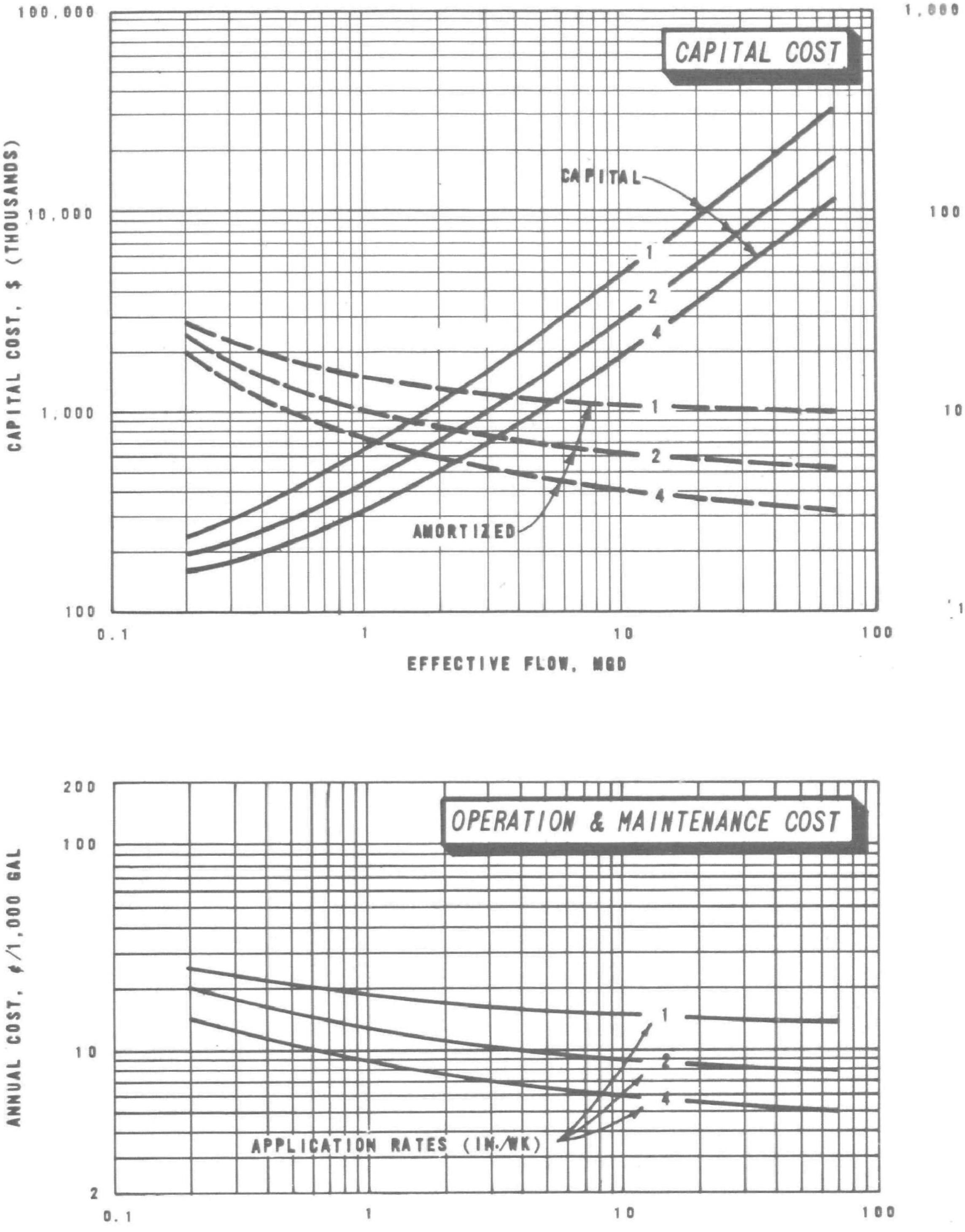


FIGURE 9. APPLICATION SYSTEMS – SPRAY IRRIGATION, CENTER PIVOT

APPLICATION SYSTEMS

SURFACE IRRIGATION

Costs are given as an average of costs for ridge and furrow application, and surface flooding using border strips, for application rates of 1, 2, and 4 in./wk.

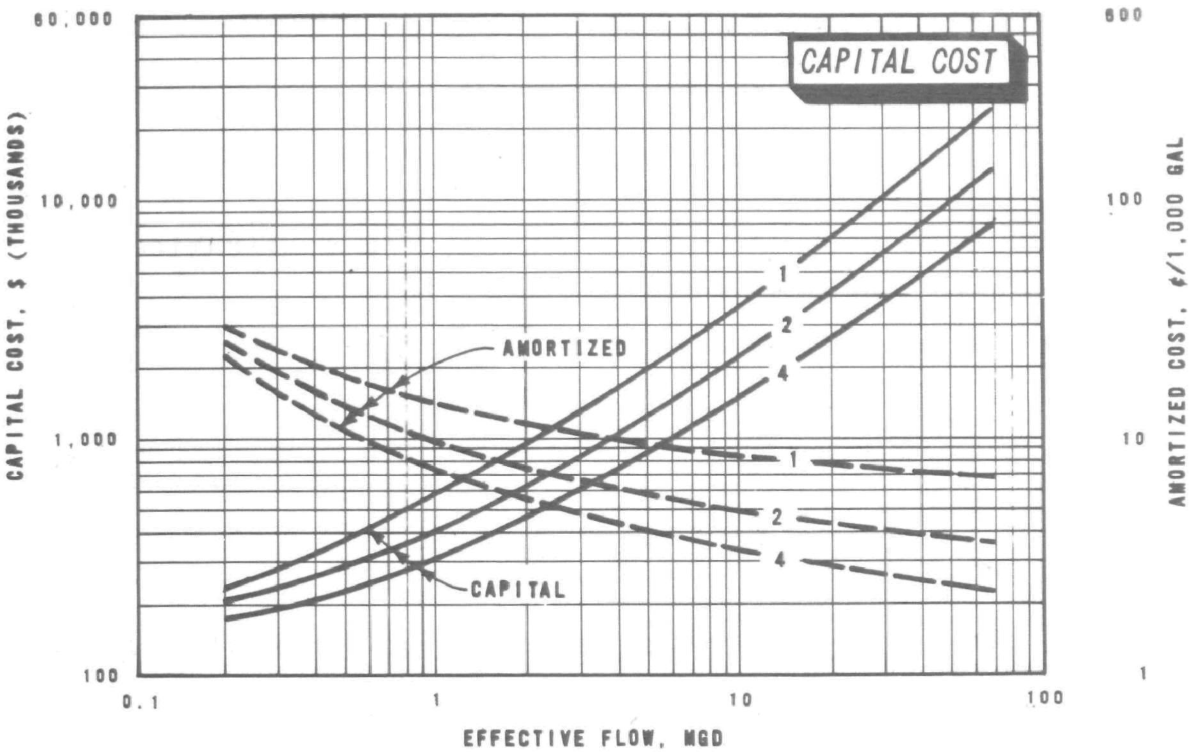
BASE DATE - FEBRUARY 1973

Costs Included

1. Site clearing--brush with few small trees.
2. Land leveling--500 cy/acre (945 cu m/ha).
3. Distribution--average of ridge and furrow application, and surface flooding using border strips.
4. Distribution pumping with 15-ft (4.6 m) total head.
5. Tailwater return--25% of applied flow is returned.
6. Administrative and laboratory facilities.
7. Monitoring wells of 50-ft (15.3 m) depth.
8. Service roads and fencing.
9. Average of cultivation of corn and alfalfa.

Metric Conversion

1. mgd x 43.8 = 1/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 1



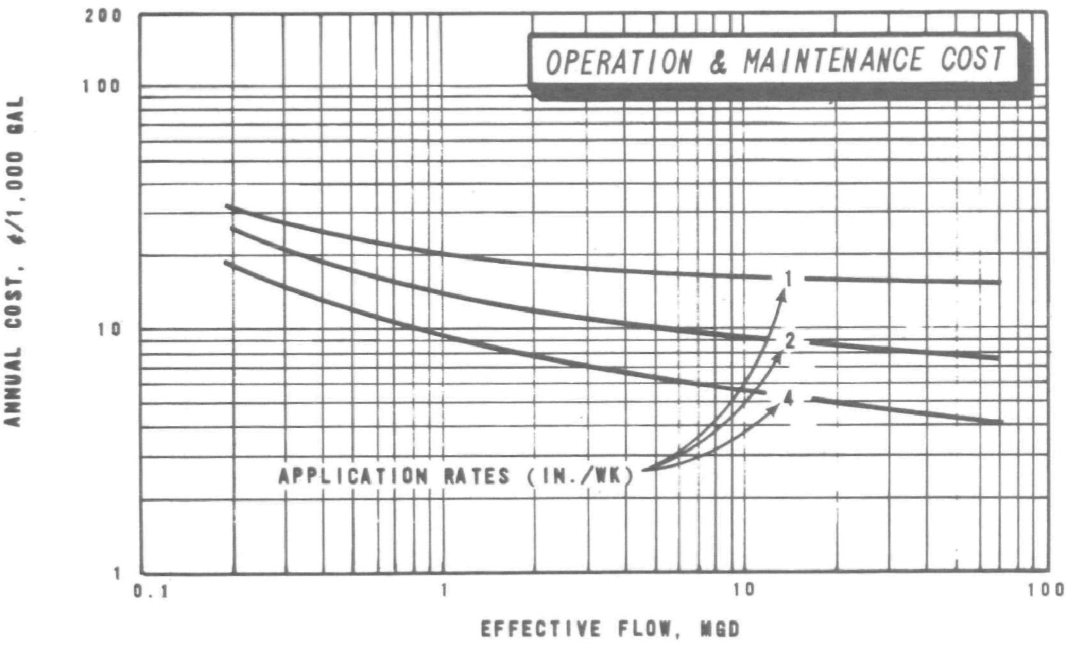


FIGURE 10. APPLICATION SYSTEMS – SURFACE IRRIGATION

APPLICATION SYSTEMS

OVERLAND FLOW

BASE DATE - FEBRUARY 1973

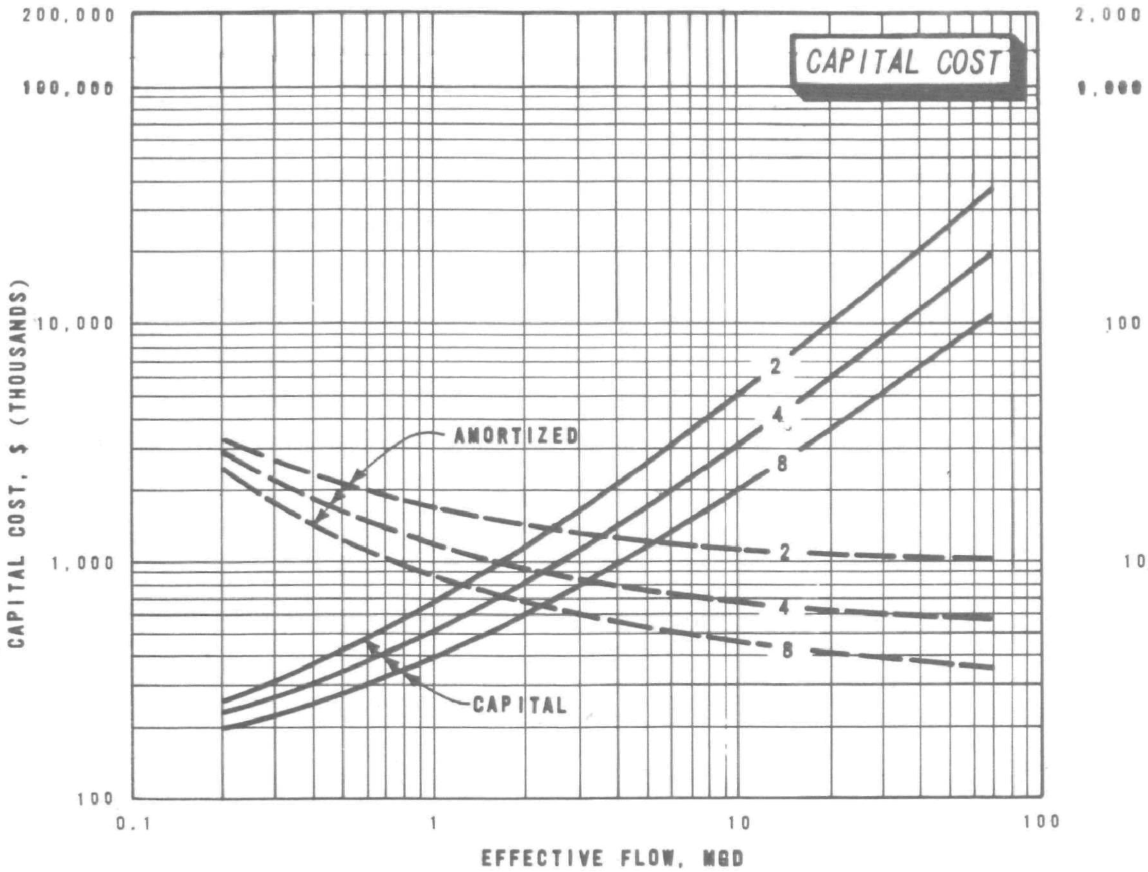
Costs are given for a typical system, for application rates of 2, 4, and 8 in./wk.

Costs Included

1. Site clearing--brush with few small trees.
2. Overland flow terrace construction--1,400 cy/acre (2,650 cu m/ha).
3. Distribution--terrace width of 250 ft (76.3 m).
4. Distribution pumping with 225-ft (66.8 m) total head.
5. Runoff collection using open ditches.
6. Chlorination and discharge--average flow of recovered water equal to 75% of applied flow.
7. Administrative and laboratory facilities.
8. Service roads and fencing.
9. Planting of grass.

Metric Conversion

1. mgd x 43.8 = 1/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 1



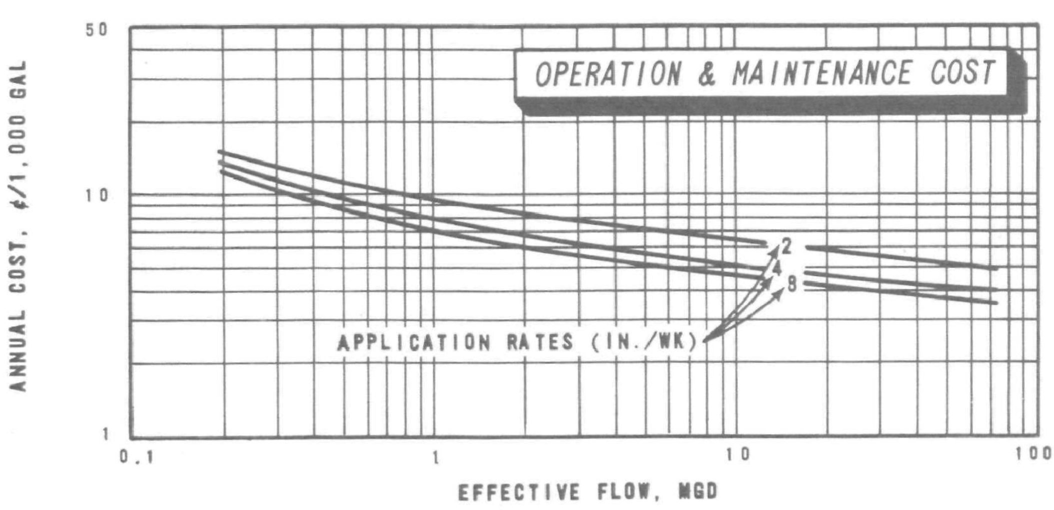


FIGURE 11. APPLICATION SYSTEMS - OVERLAND FLOW

APPLICATION SYSTEMS

INFILTRATION-PERCOLATION, BASINS

BASE DATE - FEBRUARY 1973

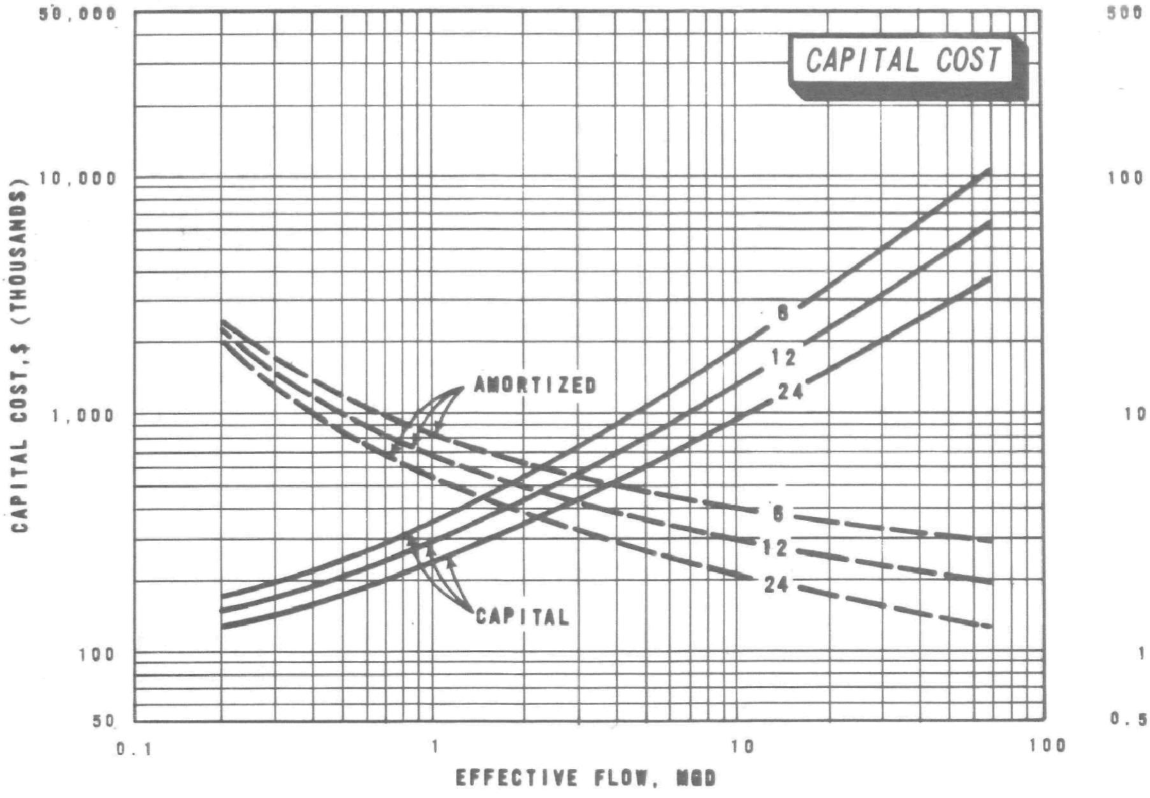
Costs are given for a typical system, for application rates of 6, 12, and 24 in./wk.

<u>Cost Included</u>

1. Site clearing--brush with few small trees.
2. Distribution--multiple unit infiltration basins with 4-ft (1.2 m) dikes.
3. Distribution pumping with 15-ft (4.6 m) total head.
4. Recovery wells--50-ft (15.3 m) depth, flow of recovered water equal to 75% of applied flow.
5. Monitoring wells of 50-ft (15.3 m) depth.
6. Administrative and laboratory facilities.
7. Service roads and fencing.

<u>Metric Conversion</u>

1. mgd x 43.8 = l/sec
2. ¢/1,000 gal. x 0.264 = ¢/1,000 l



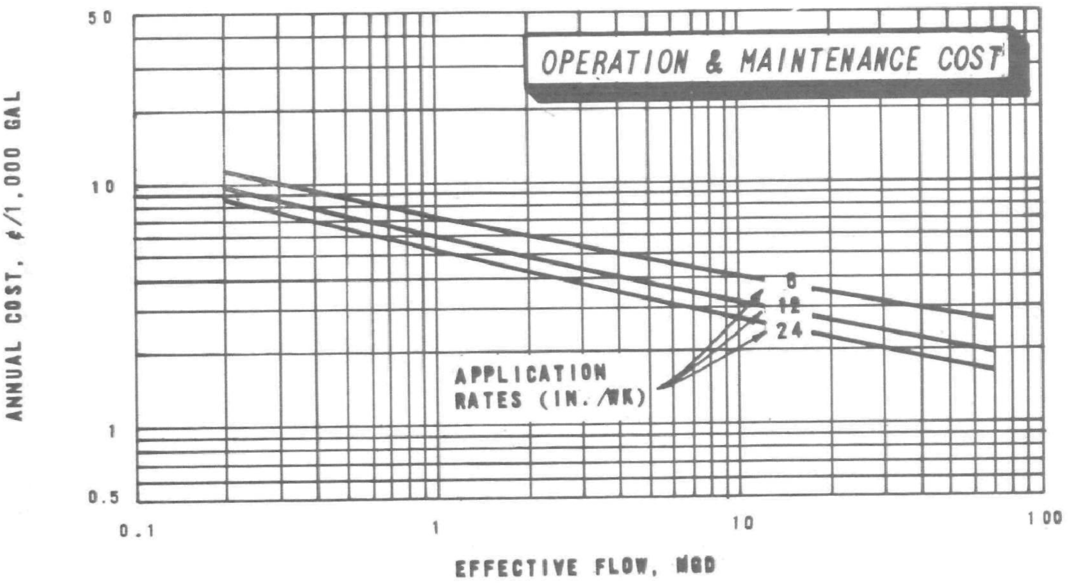


FIGURE 12. APPLICATION SYSTEMS–
INFILTRATION–PERCOLATION, BASINS

RECOVERY OF RENOVATED WATER

UNDERDRAINS

BASE DATE - FEBRUARY 1973

Costs are given for typical underdrain system for irrigation application rates of 1, 2, and 4 in./wk.

Cost Included

1. Drain pipes buried 6 to 8 ft (1.8 to 2.4 m), with a spacing of 200 ft (61 m).

2. Interception ditch along one side of the field.

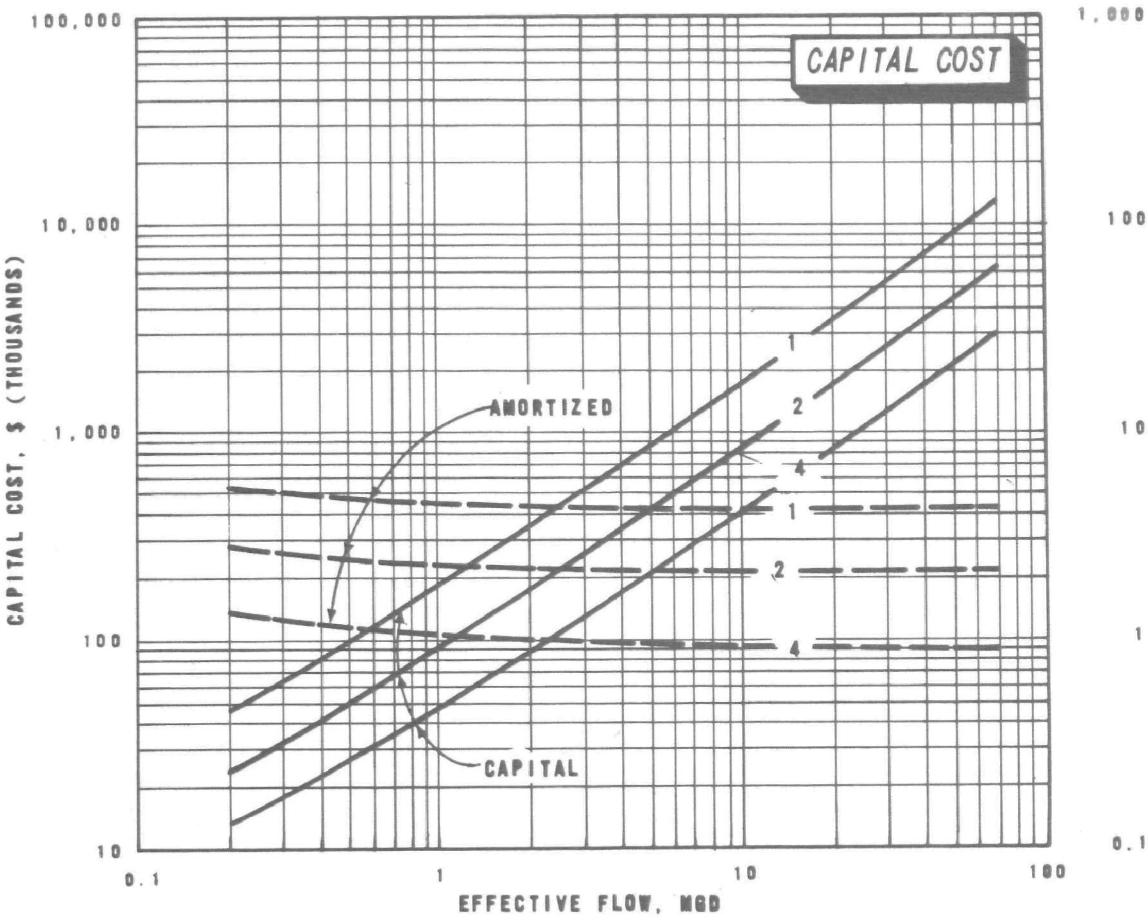
3. Weir for control of discharge.

Note: These curves should be used in conjunction with those in Figures 7, 9, or 10, "Application Systems."

Metric Conversion

1. mgd x 43.8 = 1/sec

2. ¢/1,000 gal. x 0.264 = ¢/1,000 1



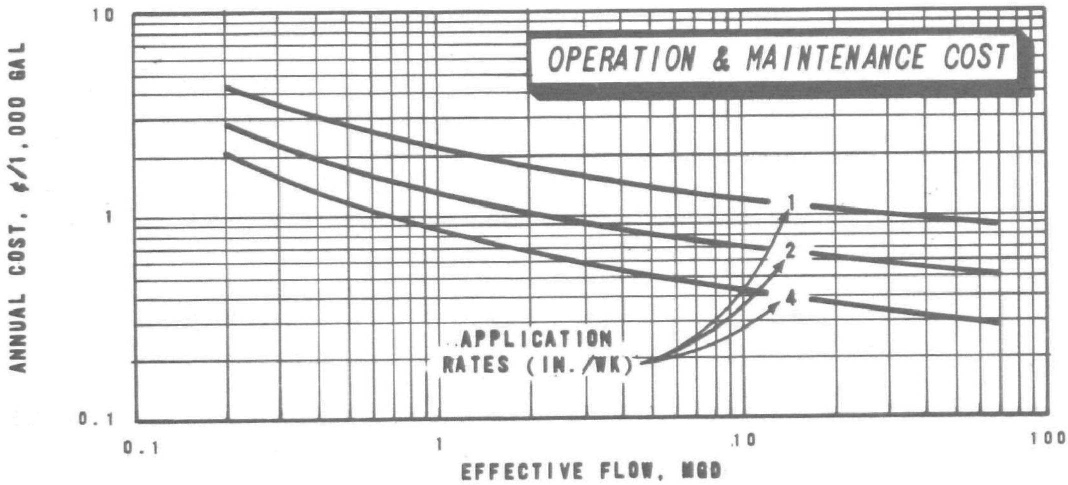


FIGURE 13. RECOVERY OF RENOVATED WATER - UNDERDRAINS

COST CALCULATION PROCEDURE

To facilitate the use of the cost data presented for Stage I, a sample cost calculation sheet has been developed (Table 3). For each alternative to be analyzed, a similar calculation sheet could be used.

The procedure for calculating Stage I costs is as follows:

1. Determine appropriate storage capacity and application rate (see discussion in Section 2).

2. Determine effective flow from number of operating weeks per year by method described on page 30.

3. Determine total capital cost, amortized capital cost, and operation and maintenance cost from cost curves for each applicable component.

4. Enter costs in appropriate columns on cost calculation sheet.

5. Add amortized capital cost and operations and maintenance cost to determine total cost for each component.

6. Add each column to determine subtotal for base date of February 1973.

7. Determine trend factor from EPA Sewer Construction Cost Index for analysis date at appropriate location.

8. Multiply subtotal for base date by trend factor to determine subtotal for analysis date.

9. Determine total and amortized capital land costs by method described on page 27 and enter under appropriate columns.

10. Determine net revenue from sale of crops, if applicable, and enter under appropriate columns.

11. Subtract crop revenues from subtotal to determine total operation and maintenance cost.

12. Add land costs to subtotal to determine total capital cost.

Table 3. SAMPLE STAGE I COST CALCULATION SHEET

Alternative No.__________ Average flow __________ mgd
Type of system__________ Analysis date __________

Cost component	Total capital cost, $	Amortized capital cost, ¢/1,000 gal.	O&M cost, ¢/1,000 gal.	Total cost, ¢/1,000 gal.
Preapplication treatment				
________	______	______	______	______
________	______	______	______	______
________	______	______	______	______
Transmission - conveyance ______, ______ mi	______	______	______	______
Transmission - pumping	______	______	______	______
Storage period ______ wks	______	______	______	______
Application systems ______ @ ______ in./wk	______	______	______	______
Underdrains	______	______	______	______
SUBTOTAL, BASE DATE[a]	______	______	______	______
Trend factor[b]	______	______	______	______
SUBTOTAL, ANALYSIS DATE	______	______	______	______
Crop revenues			(______)	(______)
Land cost	______	______	______	______
TOTAL COST	______	______	______	______

a. February 1973.
b. Trend factor = EPA Sewer Construction Cost Index for analysis date at appropriate location ÷ 194.2.

EXAMPLE

The use of the cost curves and cost calculation sheet is illustrated in the following example. A hypothetical 3-mgd (131 l/sec) surface irrigation system, to be constructed as part of a new wastewater treatment system in the San Francisco area, is used in this example. The analysis date is July 1974, and the EPA Sewer Construction Cost Index for that date for San Francisco is 242.0. The example is meant to illustrate all facets of the cost curves and cost calculation sheet, and the total costs should not be compared with other hypothetical cost estimates.

Assumptions

1. Preapplication treatment is to consist of preliminary treatment (screening, grit removal, and flow measurement) and aerated lagoons.

2. The distance from the preapplication treatment plant to the potential land application site is approximately 2 miles (3.2 km) and is of sufficient slope as to allow transmission by gravity pipe.

3. The storage requirement is approximately 10 weeks of detention. Lining of reservoir is not required.

4. The normal operating season is to be 42 wk/yr.

5. The land is essentially flat and covered with brush and small trees.

6. The application rate is to be approximately 1.5 in./wk (3.8 cm/wk).

7. A buffer zone is not required.

Solution

The determination of costs is shown on a sample cost calculation sheet (Table 4, page 58) and is discussed for each item. Total capital costs are given to the nearest thousand dollars, while amortized capital costs, operation and maintenance costs, and total costs are all given to the nearest tenth of a cent per thousand gallons.

The total cost in cents per thousand gallons is the sum of the amortized and operation and maintenance costs, and is not included in the discussion.

From the equation given on page 31, the effective flow is determined to be 3.7 mgd (163 l/sec).

Preapplication Treatment - Includes preliminary treatment and aerated lagoon.

1. Preliminary treatment - Based on maximum flow of 6 mgd (263 l/sec). Costs determined from reference [37] are:

Total capital cost	$ 94,000
Amortized capital cost (¢/1,000 gal.) - $0.0232 \times \frac{\$94 \text{ (thousand)}}{3 \text{ mgd}}$	0.7¢
Operation and maintenance cost - Annual cost is found to be $9,500. The cost in ¢/1,000 gal. is then $0.274 \times \frac{\$9.5 \text{ (thousand)}}{3 \text{ mgd}}$	0.8¢

2. Aerated lagoon - Costs determined from Stage II cost curve (Figure 16) are:

Total capital cost	$140,000
Amortized capital cost (¢/1,000 gal.) - $0.0232 \times \frac{\$140 \text{ (thousand)}}{3 \text{ mgd}}$	1.1¢
Operation and maintenance cost - Annual cost is found to be $8,240/mgd. The cost in ¢/1,000 gal. is then 0.274 x $8.24 (thousand)/mgd	2.3¢

Transmission - Conveyance - From Figure 4, the costs for gravity pipe are:

Total capital cost - 2 mi x $140,000	$280,000
Amortized capital cost (¢/1,000 gal.) - 2 mi x 1.0¢	2.0¢
Operation and maintenance cost (¢/1,000 gal.) - 2 mi x 0.04¢	0.1¢

Storage - From Figure 6, the costs for storage for 10 weeks detention are:

Total capital cost -	$ 350,000
Amortized capital cost (¢/1,000 gal.) -	2.6¢
Operation and maintenance cost (¢/1,000 gal.) -	0.3¢

Application System - Surface Irrigation - From Figure 10, the costs for surface irrigation for an effective flow of 3.7 mgd are:

Total capital cost -	$1,300,000
Amortized capital cost (¢/1,000 gal.) -	8.0¢
Operation and maintenance cost (¢/1,000 gal.) -	14.0¢

Subtotal, Base Date - The subtotals of costs for each column for the base date of February 1973 are:

Total capital cost -	$2,164,000
Amortized capital cost (¢/1,000 gal.) -	14.4¢
Operation and maintenance cost (¢/1,000 gal.) -	17.5¢

Trend Factor - The EPA Sewer Construction Cost Index for the analysis date of 242.0 divided by the index for the base date of 194.2 is: 1.25

Subtotal, Analysis Date - The subtotals of costs for each column for the analysis date of July 1974 are:

Total capital cost - 1.25 x $2,164,000	$2,700,000
Amortized capital cost (¢/1,000 gal.) 1.25 x 14.4¢	18.0¢
Operation and maintenance costs (¢/1,000 gal.) 1.25 x 17.5¢	21.9¢

Crop Revenues - A conservative yield of corn silage of 20 tons per acre and a price of $15 per ton are determined from Table 7 in Section 4. Corn is assumed to be grown on 500 acres of the total area. The estimated negative cost from the sale of corn is:

Operation and maintenance cost - Annual revenue is determined to be $50,000/mgd. The revenue in ¢/1,000 gal. is then 0.274 x $50.0 (thousand)/mgd.	(13.7¢)

Land Cost - From Figure 3, the total land requirement is determined to be 750 acres. The cost of land, determined from local sources, is approximately $1,000 per acre. Land costs are then:

Total capital cost - 750 acres x $1,000/acre	$ 750,000
Amortized capital cost (¢/1,000 gal.) $0.0154 \times \frac{\$750 \text{ (thousand)}}{3 \text{ mgd}}$	3.9¢

Total Cost - The subtotals for the analysis date plus land costs are:

Total capital cost	$3,450,000
Amortized capital cost (¢/1,000 gal.)	21.9¢
Operation and maintenance cost (¢/1,000 gal.)	8.2¢

Table 4. EXAMPLE OF COMPLETED STAGE I COST CALCULATION SHEET

Alternative No. 1   Average flow 3 mgd
Type of system SURFACE IRRIGATION   Analysis date JUL '74

Cost component	Total capital cost, $	Amortized capital cost, ¢/1,000 gal.	O&M cost, ¢/1,000 gal.	Total cost ¢/1,000 gal.
Preapplication treatment				
PRELIMINARY	94,000	0.7	0.8	1.5
AERATED LAGOON	140,000	1.1	2.3	3.4
Transmission - conveyance GRAVITY PIPE, 2 mi	280,000	2.0	0.1	2.1
Transmission - pumping	--	--	--	--
Storage period 10 wks	350,000	2.6	0.3	2.9
Application systems SURFACE IRRIGATION @ 1.5 in./wk	1,300,000	8.0	14.0	22.0
Underdrains	--	--	--	--
SUBTOTAL, BASE DATE[a]	2,164,000	14.4	17.5	31.9
Trend factor[b]	1.25	1.25	1.25	1.25
SUBTOTAL, ANALYSIS DATE	2,700,000	18.0	21.9	39.9
Crop revenues			(13.7)	(13.7)
Land cost	750,000	3.9	--	3.9
TOTAL COST	3,450,000	21.9	8.2	30.1

a. February 1973.
b. Trend factor = EPA Sewer Construction Cost Index for analysis date at appropriate location ÷ 194.2.

Section 4

DETAILED PLANNING COSTS (STAGE II)

In this section cost data of a more detailed nature are presented that will enable the user to estimate the cost of a land application system more accurately than in Stage I. It is anticipated that these estimates will be used in the evaluation of selected wastewater treatment alternatives that are considered to be feasible.

The major differences between Stage I and Stage II are that in Stage II: (1) costs are developed for more individual system components, (2) costs are presented for each particular component in relation to the most applicable parameter, and (3) costs can be more easily adjusted to reflect local and current conditions. To utilize Stage II cost data properly, a greater amount of specific information, including a preliminary design layout, will usually be required.

Stage II cost estimates developed from the data in this section should be within about 15 percent of actual costs. It is anticipated that the engineer will build on the cost curves presented here and modify the numbers to arrive at his final cost-effectiveness analysis and cost estimate.

COST COMPONENTS AND METHODOLOGY

The costs of land application systems have been divided into 33 components which are grouped under 8 major categories as listed in Table 5. For 26 components, cost curves are presented which relate the capital and operation and maintenance costs of the component to the most applicable parameter, such as storage volume, flowrate, or field area. The relationship between those components for which cost curves are included is shown in Figure 14. The figure shows only a typical relationship; in actual practice, combinations of components other than those shown are possible.

Once the cost of each component has been estimated, the total cost of the system can be determined by adding the component costs. Cost calculation sheets for both capital costs (Table 8, page 124) and operation and maintenance costs (Table 9, page 125) have been included for this purpose at the end of this section. They are arranged so that each component and its cost can be written under the appropriate component category. A column for computing amortized cost from the capital cost is provided in Table 8. A sample calculation is also included to illustrate the step-by-step procedure (page 127).

Table 5. LIST OF STAGE II COST COMPONENTS

Category	Component	Figure number for curve reference	Page number
1. Land	a. Field area requirement[a]	15[a]	63
2. Preapplication treatment[b]	a. Aerated lagoons	16	69
	b. Chlorination	17	71
3. Transmission	a. Gravity pipe	18	73
	b. Open channels	19	75
	c. Force main	20	77
	d. Effluent pumping	21	79
4. Storage	a. 0.05-10 million gallons	22	81
	b. 10-5,000 million gallons	23	83
5. Field preparation	a. Site clearing	24	85
	b. Land leveling for surface irrigation	25	87
	c. Overland flow terrace construction	26	89
6. Distribution	a. Solid set spraying (buried)	27	91
	b. Center pivot spraying	28	93
	c. Surface flooding using border strips	29	95
	d. Ridge and furrow application	30	97
	e. Overland flow	31	99
	f. Infiltration basins	32	101
	g. Distribution pumping	33	103
7. Recovery of renovated water	a. Underdrains	34	105
	b. Tailwater return	35	107
	c. Runoff collection for overland flow	36	109
	d. Chlorination and discharge for overland flow	37	111
	e. Recovery wells	38	113
8. Additional costs	a. Administrative and laboratory facilities	39	115
	b. Monitoring wells	40	117
	c. Service roads and fencing	41	119
	d. Planting, cultivation, and harvesting	--[c]	120
	e. Yardwork	--	120
	f. Relocation of residents	--	120
	g. Purchase of water rights	--	122
	h. Service and interest factor	--	122

a. This figure is not a cost curve but a nomograph which relates field area in acres to design flow in mgd, nonoperating time in weeks, and application rate in inches per week.

b. See text, page 64 for other methods.

c. No cost curves are provided; see discussion on referenced pages.

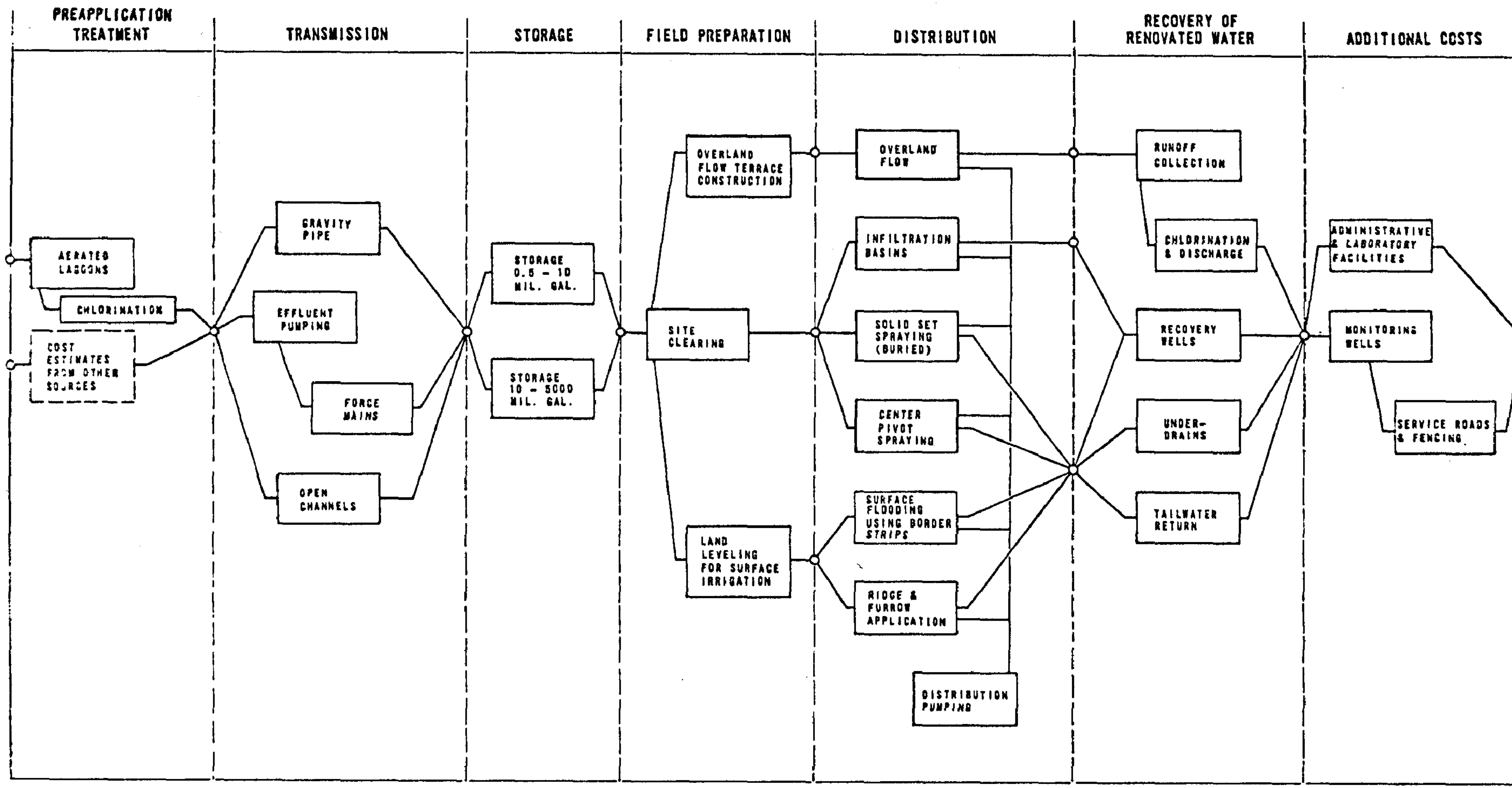


FIGURE 14. RELATIONSHIP OF STAGE II COST CURVES

Land

In many cases, the cost of land, either as an outright purchase or a lease, will be a significant portion of the total cost of the system. In Stage II this cost should be determined for a specific plot of land, based on a preliminary layout. An important first step in this process is the determination of the field area requirement. This is the area of land in which the actual treatment process takes place. The field area requirement is also an important design parameter to which the costs of many of the components in Stage II are related.

Field Area Requirements. As an aid to the determination of field area requirements, a nomograph (Figure 15) is included which relates field area in acres to design flow in mgd, nonoperating time in weeks, and application rate in inches per week. To use the nomograph, first draw a line between appropriate points on the design flow and nonoperating time axes. Draw a second line from the intersection of the first line with the pivot line and the appropriate point on the application rate axis. The calculated field area is then noted at the intersection of that axis with the second line. In some cases it may be necessary to increase this figure by a use factor to account for inefficiencies of land utilization. The use of the nomograph is further illustrated by means of a sample plot.

Land Costs. Once the field area has been calculated, the total land requirements can be determined. This should be done by means of a preliminary layout for a specific site. Included in the layout should be an adequate amount of land for each of the following items, if they are required:

- Field area
- Buffer zones
- Storage
- Buildings, roads, and ditches
- Future expansion or emergencies

The land costs should then be determined by multiplying the estimated total land requirement (acres) by the prevailing market price for land (dollars per acre). The prevailing market price for land should be determined from a local source such as the tax assessor.

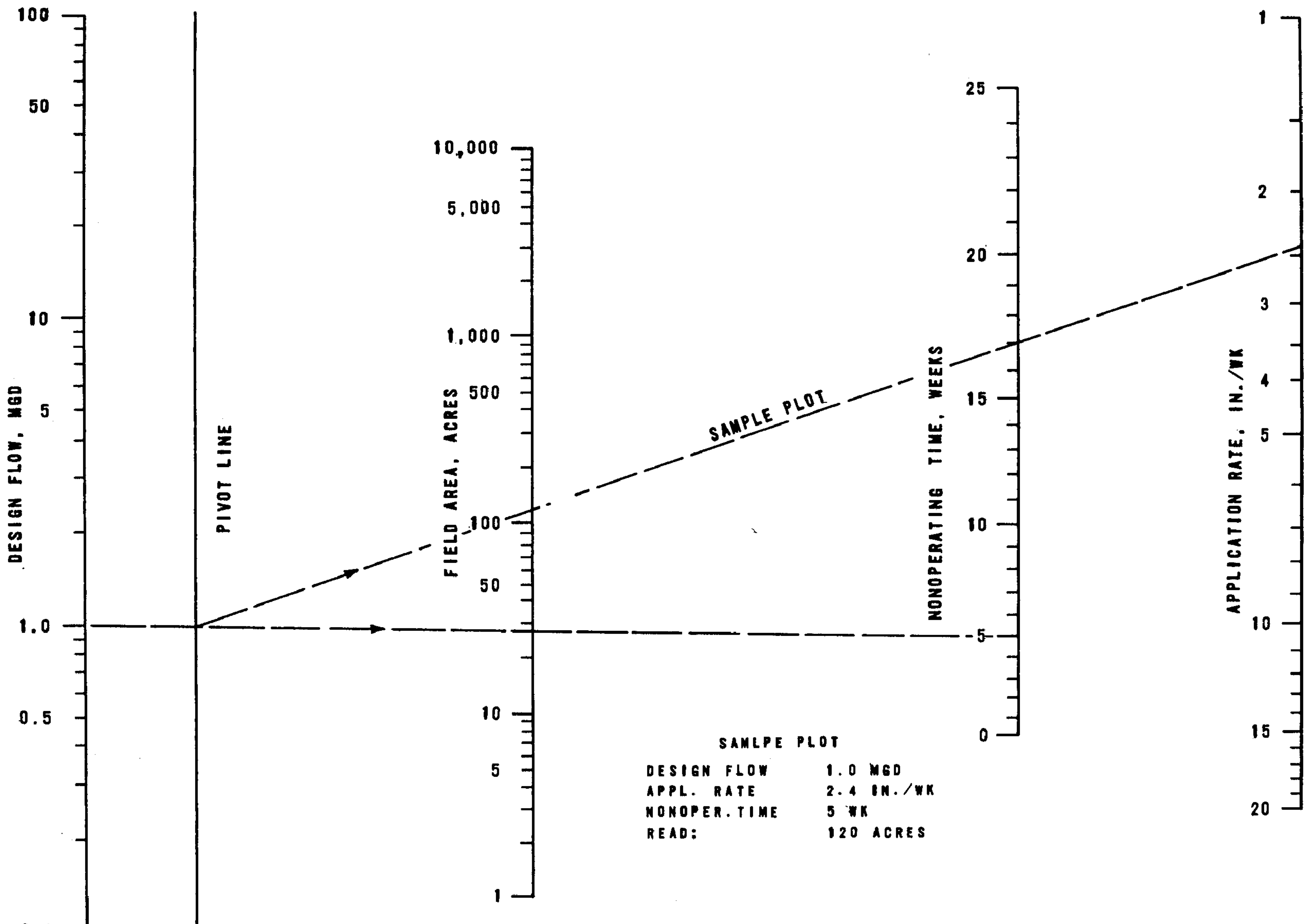


FIGURE 15. FIELD AREA REQUIREMENT

In accordance with the Federal Regulations on Cost Effectiveness Analysis (40 CFR 35), land shall be assumed to have a salvage value at the end of the planning period equal to its prevailing market value at the time of the analysis. This fact is reflected in the format for calculating the amortized cost of land as described on page 126.

Preapplication Treatment

For many systems the cost of preapplication treatment must be included in the total cost of the system. To obtain these costs, other publications that are devoted to the cost of conventional treatment systems should be consulted. *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems* [54], and *Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Systems* [37] are suggested as useful references for this purpose. Special consideration is given to preapplication treatment by aerated lagoons because of their common use in conjunction with land application systems, and because of the limited amount of information concerning their costs in other publications. In addition, the cost of chlorination for preapplication treatment is given in Figure 17.

The level of preapplication treatment required for land application is dependent on a number of factors, including:

- Method of application
- Type of crop grown
- Intended use of crop
- Loading rate of certain constituents
- Equipment limitations

In many states, regulations relating to preapplication treatment exist. For further guidance, the technical bulletin, *Evaluation of Land Application Systems* [17] should be consulted.

Additional Costs

The category of "Additional Costs" consists of 8 components, and cost curves are presented for 3 of these. The costs for the remaining components are not readily presented by means of curves; therefore, other methods of cost computation are described in the text that follows the curves.

COST CURVES

The 26 cost curves, which are presented following this discussion, are composed of two-page sets (Figures 16 through 41): the capital and operation and maintenance cost curves are shown on the right-hand pages, and detailed information relating to the curves is summarized on left-hand pages.

Capital Cost Curves

A curve or group of curves is presented for each component which represents the total capital cost to the owner, including the contractor's overhead and profit. The curves do not include allowances for contingencies, administration, or engineering, however.

Each of the costs is related to either the "EPA Sewer Construction Cost Index" or the "EPA Sewage Treatment Plant Construction Cost Index" for February 1973. For many components, neither of these indexes directly applies, in which case the index used is the one which is considered to be the most applicable. Capital costs read from the curves should be trended by means of the specified index or other method to reflect current costs for a particular locality. Current values for both indexes are published monthly in the Journal of the Water Pollution Control Federation, and quarterly in the Engineering News Record.

For some components, a group of curves is presented that shows a range of costs for some secondary parameter. For example, a group of curves corresponding to a range of depths of cover is included for "Gravity Pipe" (Figure 18). In several other cases, additional curves are included for significant subcomponents or auxiliary costs, as in the case of "Force Mains" (Figure 20), where an additional curve is included for the cost of repaving.

Operation and Maintenance Cost Curves

Operation and maintenance costs are divided, where applicable, into three curves or groups of curves: labor, power, and materials. They are each expressed in terms of dollars per unit per year.

The labor cost is the estimated annual cost for operating and maintaining that component by members of the staff, and includes administration and supervision. It is based on an average staff labor rate, including fringe benefits, of $5.00 per hour and may be adjusted to reflect actual average rates when significant differences exist.

The power cost is the estimated annual cost for electrical power required to operate the particular component based on a unit cost of $0.02 per kilowatt-hour. It may be adjusted to reflect actual unit costs when significant differences exist. For several components a group of power cost curves are shown for a range of pumping heads.

The materials cost is the estimated annual cost for normal supplies, repair parts, and contracted repair or maintenance services. An equivalent annual cost based on the sinking fund factor for an interest rate of 5-5/8 percent is included for those materials costs which are not incurred annually.

Wholesale Price Index. The Wholesale Price Index for Industrial Comodities, which may be used for trending the materials cost, was 120.0 for February 1973.

Detailed Information Relating to Cost Curves

Basis of Costs. A summary of the bases of costs for which the curves were derived is included on the upper portion of the left-hand page for each component. These bases normally include: (1) the selected construction cost index for February 1973, (2) the average labor rate, and (3) the power cost.

Assumptions. A list of assumptions concerning basic design features, and items included and not included in the cost curves, is presented on the left-hand page for each component. Generally it reflects typical designs of each component with average conditions. In many cases adjustment factors are included for assumptions involving important design parameters that are highly variable.

Adjustment Factors. Adjustment factors are included for many components to account for significant variations in designs. These factors should be multiplied by the cost from the indicated curve to obtain the adjusted cost. For example, if the adjustment factor for labor costs were 1.1, and the labor cost for a given field area were $1,000 per acre per year, then adjusted labor cost would be $1,100 per acre per year.

Metric Conversion. Metric conversion factors are given for those parameters which appear in the cost curves. Additional metric conversion factors are given in Appendix G.

Sources. The various sources of information from which the curves were derived are listed along with reference numbers (in brackets). References are presented in Appendix C.

PREAPPLICATION TREATMENT

AERATED LAGOONS

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Average detention time 7 days.
2. 15-ft (4.6 m) water depth.
3. Horsepower requirement based on meeting oxygen demand.
4. Small impeller floating aerators.
5. Capital cost includes:
    a. Excavation, embankment, and seeding of lagoons
    b. Service road and fencing
    c. Riprap embankment protection
    d. Hydraulic control works
    e. Aeration equipment and electrical equipment

Metric Conversion

1. mgd x 43.8 = 1/sec

Sources

Derived from previously published information [37].

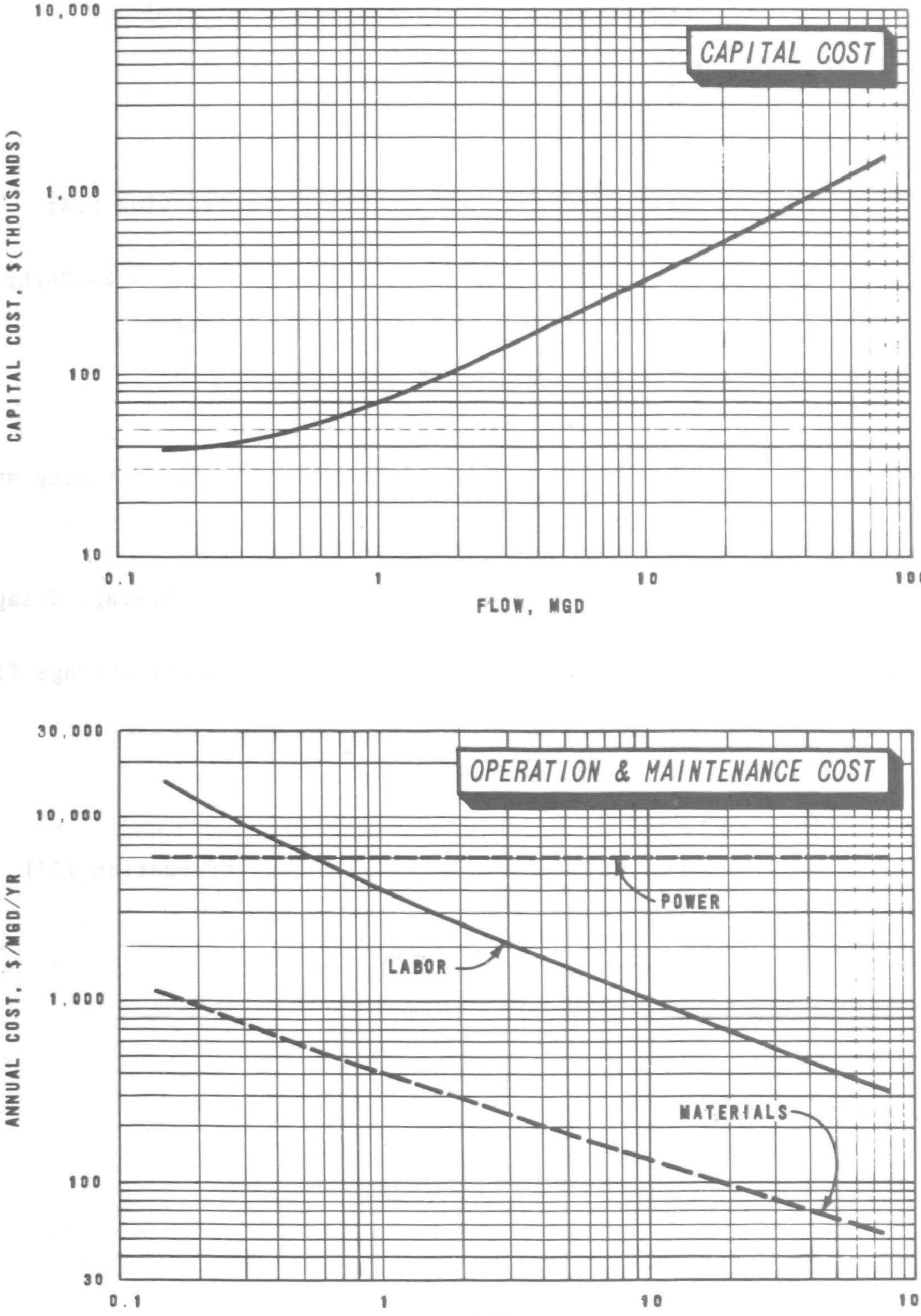


FIGURE 16. PREAPPLICATION TREATMENT - AERATED LAGOONS

PREAPPLICATION TREATMENT

CHLORINATION

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.

2. Labor rate including fringe benefits = $5.00/hr.

3. Chlorine cost = $0.05/lb ($0.023/kg).

Assumptions

1. Capital cost includes:

    a. Chlorination facilities with flash mixing and contact basin
    b. Chlorine storage
    c. Flow measuring device

2. Maximum dosage capacity, 10 mg/l. Average dosage, 5 mg/l.

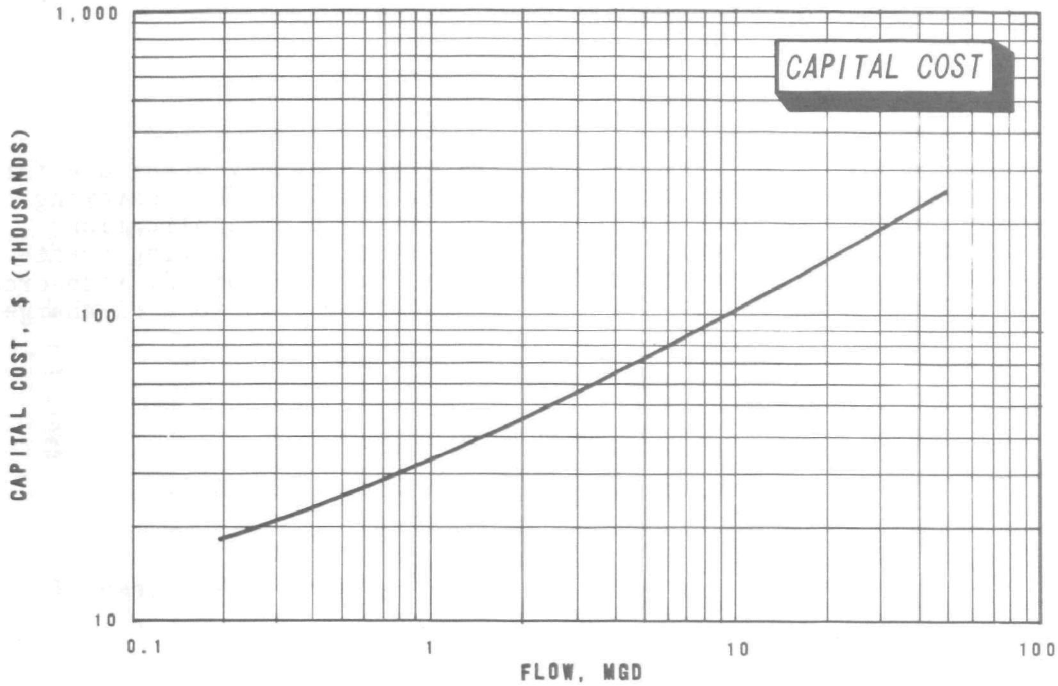
3. Chlorination contact time, 30 min for average flows.

Metric Conversion

1. mgd x 43.8 = l/sec

Sources

Derived from previously published information [37].



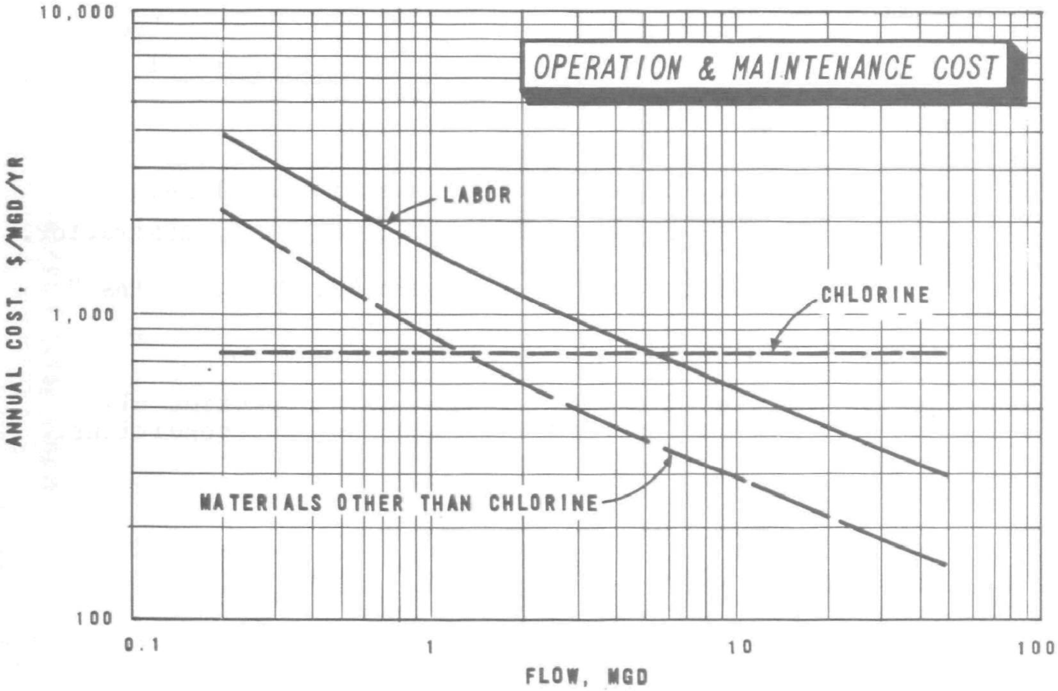


FIGURE 17. PREAPPLICATION TREATMENT - CHLORINATION

TRANSMISSION

GRAVITY PIPE

Cost curves are given for gravity pipe that may be of use for any applicable segment of the system, such as for conveying (1) wastewater from the collection area to preapplication treatment facilities, (2) treated water from existing treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Curves given for various depths of cover over crown of pipe in feet.
2. Moderately wet soil conditions.
3. All excavation in earth.
4. Capital cost includes:
   a. Pipe and fittings
   b. Excavation
   c. Laying and jointing
   d. Select imported bedding and initial backfill
   e. Subsequent backfill of native material
   f. Manholes
   g. Testing and cleanup
5. Labor cost includes periodic inspection of line.
6. Materials cost includes periodic cleaning by contractor.

Note: For cost of repaving see Figure 20, "Force Mains."

Adjustment Factor

1. Soil conditions (capital cost): From approximately 0.80 for dry to approximately 1.20 for wet conditions.

Metric Conversion

1. in. x 2.54 = cm
2. ft x 0.305 = m

Sources

Derived from previously published information [6].

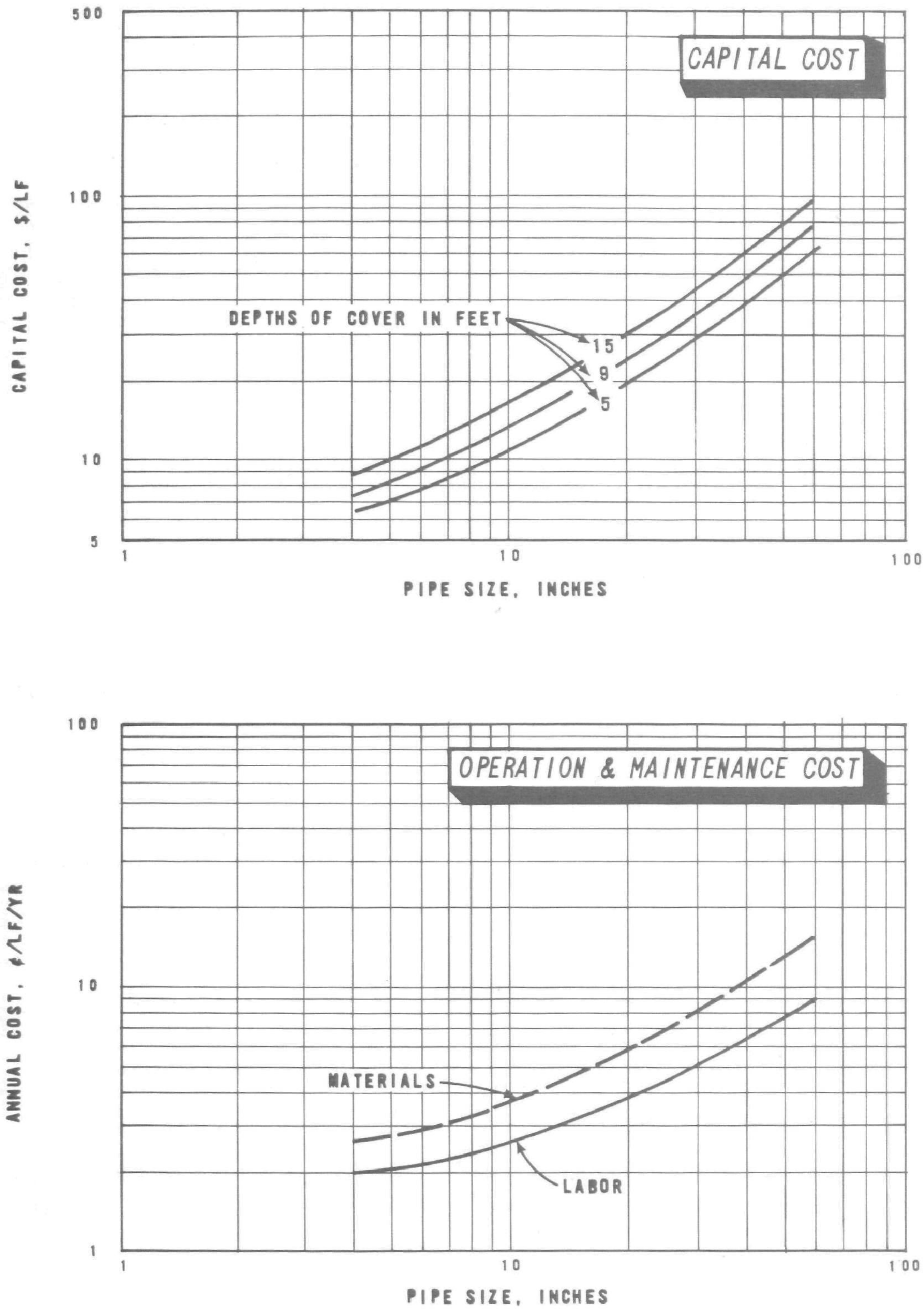


FIGURE 18. TRANSMISSION – GRAVITY PIPE

TRANSMISSION

OPEN CHANNELS

Cost curves are given for open channels that may be of use for any applicable segment of the system, such as for conveying (1) wastewater from the collection area to preapplication treatment facilities, (2) treated water from existing treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Stable soil, predominantly flat terrain.
2. Capital cost includes:
   a. Slip-formed concrete-lined trapezoidal ditches with 1:1 side slopes
   b. Earth berm
   c. Simple drop structure every 1/2 mile (805 m)
3. Labor cost includes periodic inspection, cleaning, and minor repair work.
4. Materials cost includes major repair or ditch relining after 10 yr by contractor.

Adjustment Factor

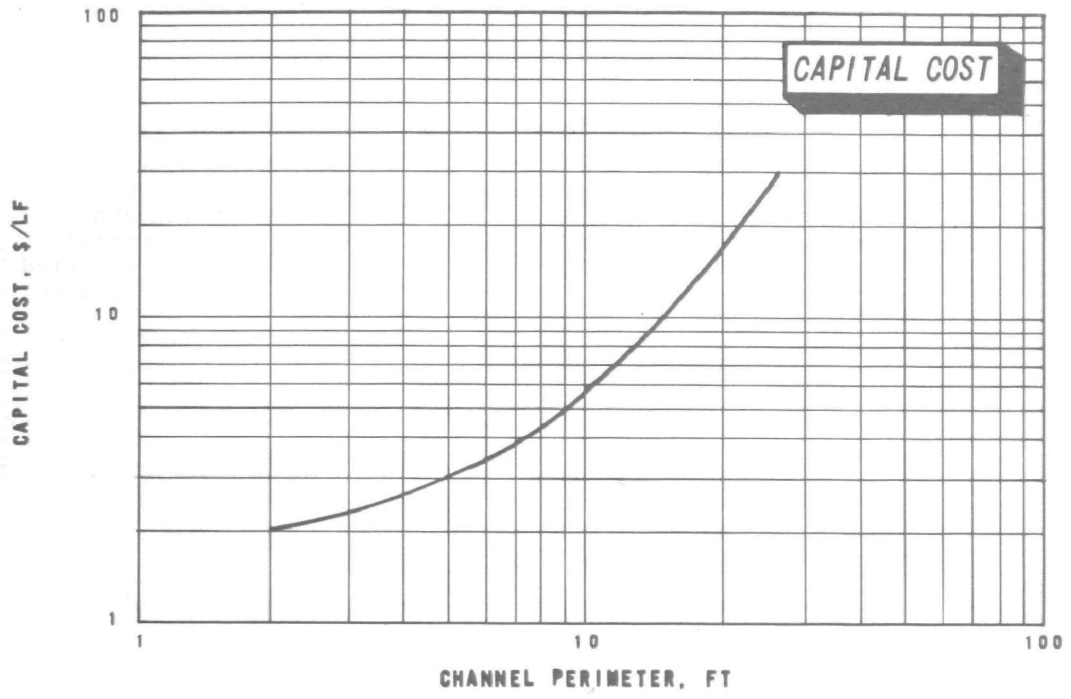
1. Irregular terrain (capital cost): 1.10 to 1.40.

Metric Conversion

1. ft x 0.305 = m

Sources

Derived from cost calculations based on a series of typical designs. Unit costs based on price quotes from an irrigation contractor.



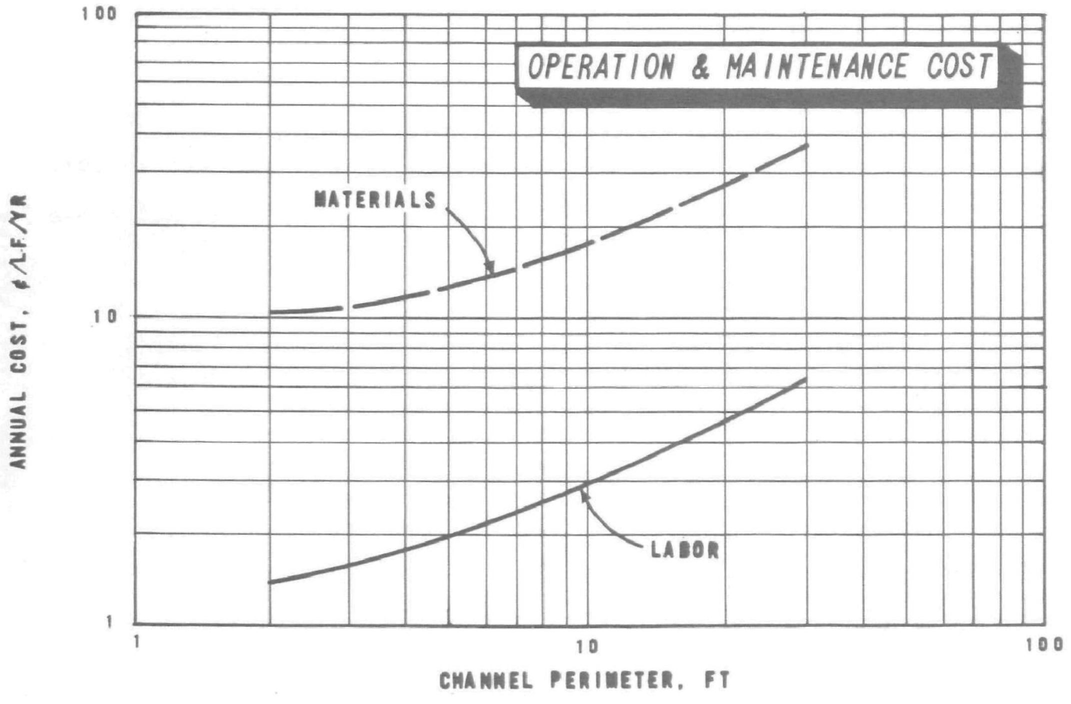


FIGURE 19. TRANSMISSION – OPEN CHANNELS

TRANSMISSION

FORCE MAINS

Cost curves are given for force mains that may be of use for any applicable segment of the system, such as for conveying (1) wastewater from the collection area to preapplication treatment facilities, (2) treated water from existing treatment facilities to the land application site, or (3) recovered renovated water from the land application site to a discharge point.

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Depth of cover over crown of pipe, 4 to 5 ft (1.2 to 1.5 m).
2. Moderately wet soil conditions.
3. All excavation in earth.
4. Capital cost includes:
   a. Pipe and fittings
   b. Excavation
   c. Laying and jointing
   d. Select imported bedding and initial backfill
   e. Subsequent backfill of native material
   f. Testing and cleanup
5. Repaving cost included as separate curve.
6. Materials cost includes periodic cleaning by contractor.

Note: These curves should be used in conjunction with those in Figure 21, "Transmission-Effluent Pumping."

Adjustment Factor

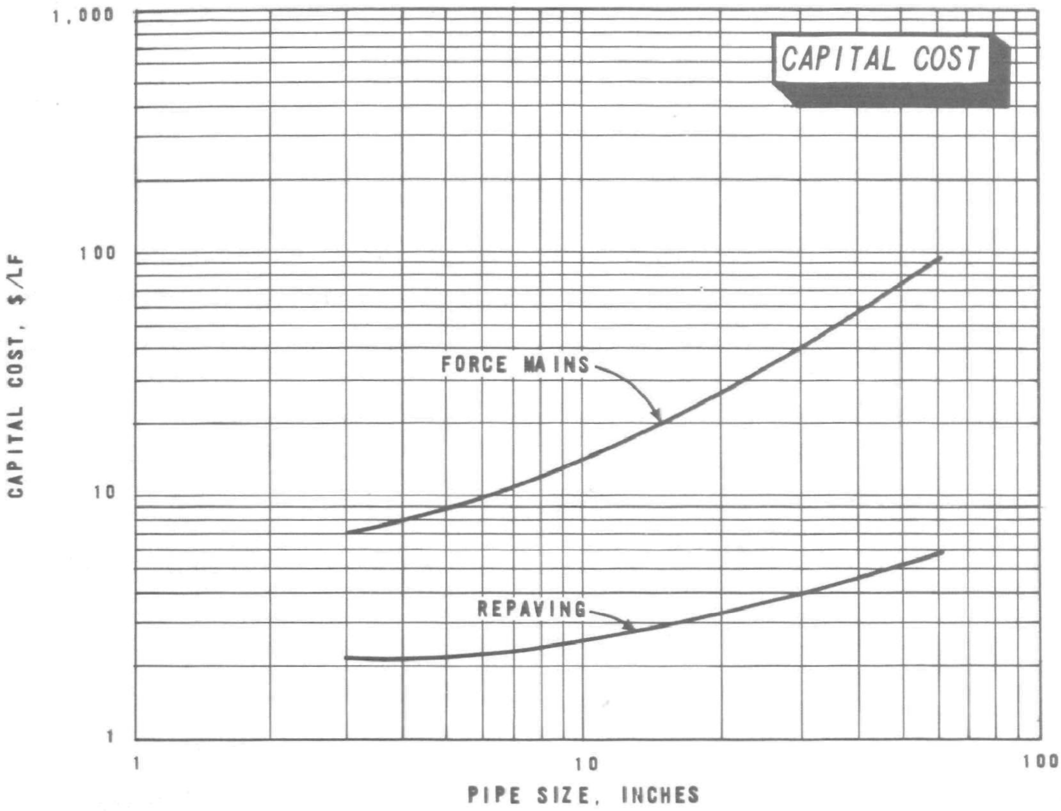
1. Soil conditions (capital cost): From approximately 0.80 for dry to approximately 1.20 for wet conditions.

Metric Conversion

1. in. x 2.54 = cm
2. ft. x 0.305 = m

Sources

Derived from previously published information [6].



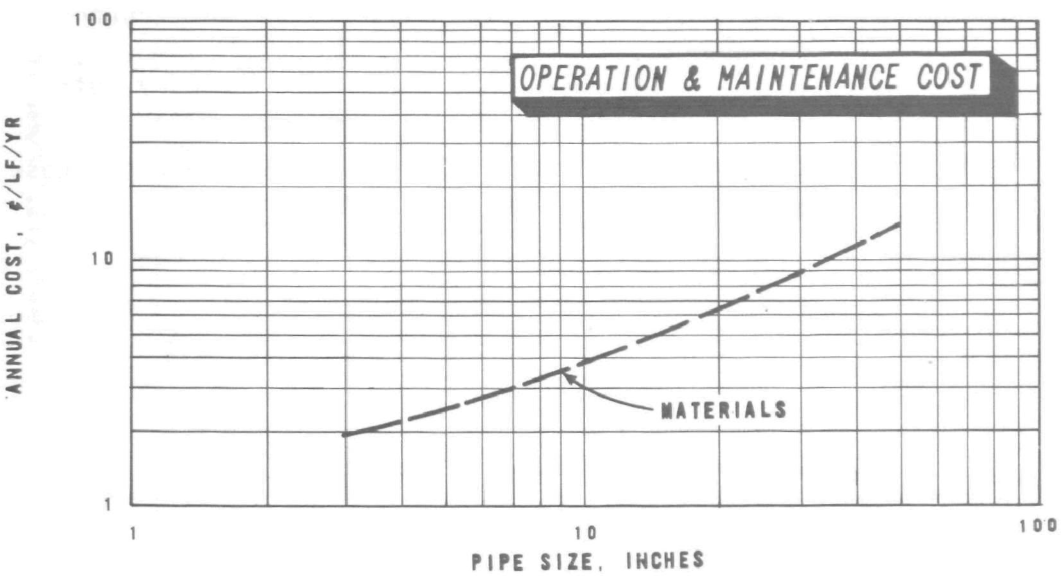


FIGURE 20. TRANSMISSION - FORCE MAINS

TRANSMISSION

EFFLUENT PUMPING

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Capital and power cost curves given for various total heads in feet.
2. Capital costs are related to peak flow in mgd. Operation and maintenance costs are related to average flow.
3. Capital cost includes:
   a. Fully enclosed wet well/dry well type structure
   b. Pumping equipment with standby facilities
   c. Piping and valves within structure
   d. Controls and electrical work
4. Labor cost includes operation, preventive maintenance, and minor repairs.
5. Materials cost includes repair work performed by outside contractor and replacement of parts.

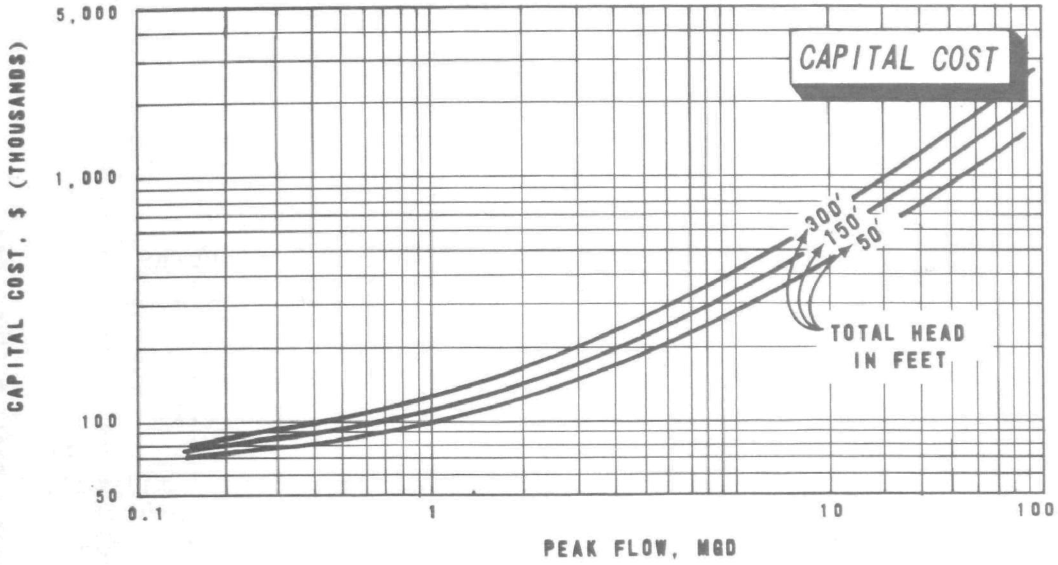
Note: These curves should be used in conjunction with those in Figure 20, "Transmission-Force Mains."

Metric Conversion

1. ft x 0.305 = m
2. mgd x 43.8 = l/sec

Sources

Derived from various sources [6, 37].



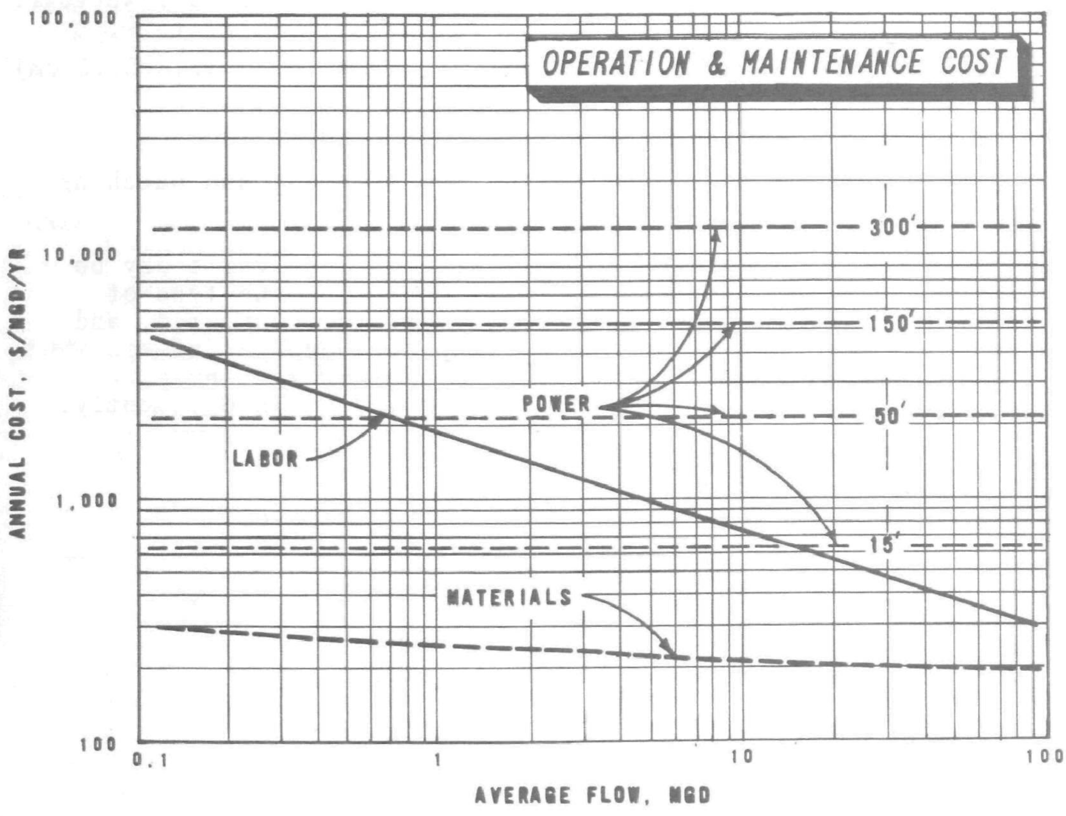


FIGURE 21. TRANSMISSION - EFFLUENT PUMPING

STORAGE

STORAGE (0.05-10 MILLION GALLONS)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Dikes formed from native excavated material.
2. Inside slope of dike, 3:1; outside slope, 2:1. 12-ft (3.7 m) wide dike crest.
3. 5-ft (1.5 m) depth of reservoirs less than 1 mil gal. (3,790 cu m), increasing to 12-ft (3.7 m) depth of reservoirs greater than 10 mil gal. (37,900 cu m).
4. 3-ft (0.9 m) freeboard.
5. Rectangular reservoir on level ground.
6. Cost of lining given for asphaltic lining of entire inside area of reservoir. Must be added to reservoir construction curve to obtain cost of a lined reservoir. For other types of lining see adjustment factors.
7. Cost of embankment protection given for 9 in. (22.8 cm) of riprap on inside slope of dike.
8. Labor cost includes maintenance of dike.
9. Materials cost includes bottom scraping and patching of lining by contractor after 10 yr.

Note: The design and cost of storage reservoirs may be highly variable and will depend on the type of terrain, type of earth material encountered, and other factors. If the expected design differs significantly from the one summarized above, a cost estimate should be arrived at independently.

Adjustment Factor

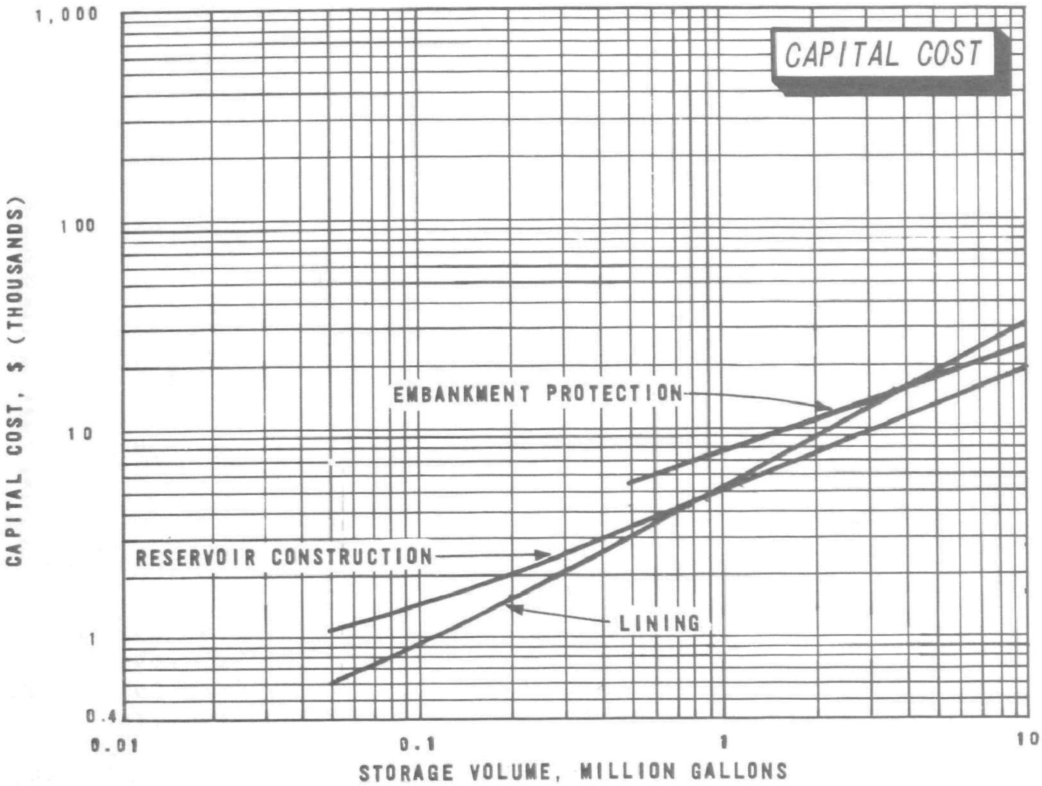
1. For linings other than asphaltic membrane:
    a. Bentonite - 0.86
    b. PVC (10 mil) with soil blanket - 1.21
    c. Soil cement - 1.21
    d. Petromat - 1.24
    e. Butyl neoprene (30 mil) - 1.97

Metric Conversion

1. mil gal. x 3,790 = cu m

Sources

Derived from cost calculations based on a series of typical designs.



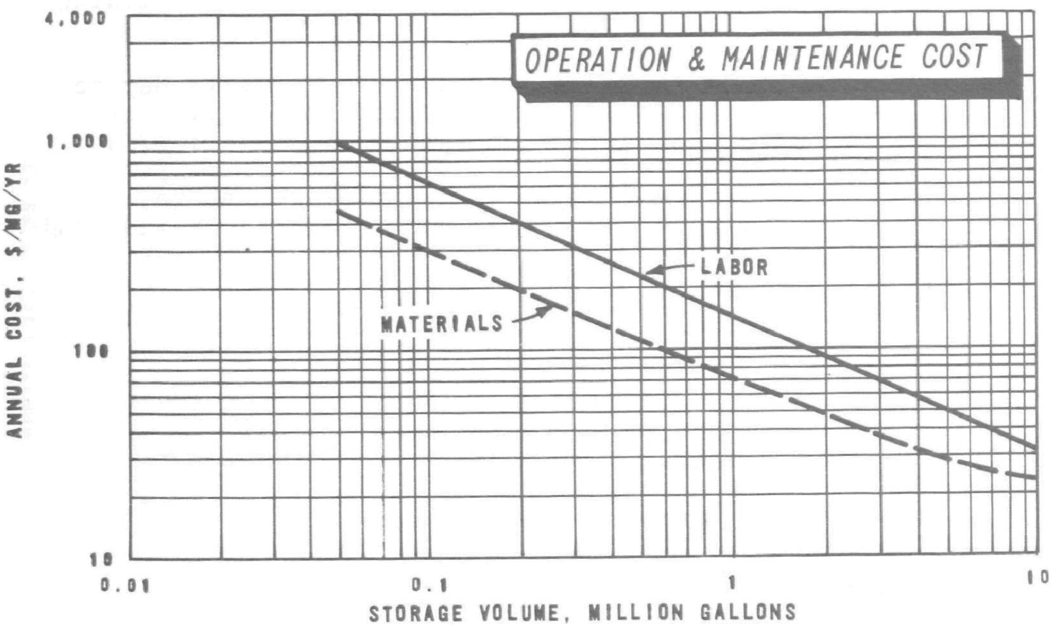


FIGURE 22. STORAGE (0.05–10 MILLION GALLONS)

STORAGE

STORAGE (10-5,000 MILLION GALLONS)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Dikes formed from native excavated material.
2. Inside slope of dike, 3:1; outside slope, 2:1. 12-ft (3.7 m) wide dike crest.
3. 12-ft (3.7 m) depth of reservoir with 3-ft (0.9 m) freeboard.
4. Rectangular reservoir on level ground.
5. Reservoirs greater than 50 acres (20 ha) divided into multiple cells.
6. Cost of lining given for asphaltic lining of entire inside area of reservoir. Must be added to reservoir construction curve to obtain cost of a lined reservoir. For other types of lining see adjustment factors.
7. Cost of embankment protection given for 9 in. (22.8 cm) of riprap on inside slope of dike.
8. Labor cost includes maintenance of dike.
9. Materials cost includes bottom scraping and patching of lining by contractor after 10 yr.

Note: The design and cost of storage reservoirs may be highly variable and will depend on the type of terrain, type of earth material encountered, and other factors. If the expected design differs significantly from the one summarized above, a cost estimate must normally be arrived at independently.

Adjustment Factor

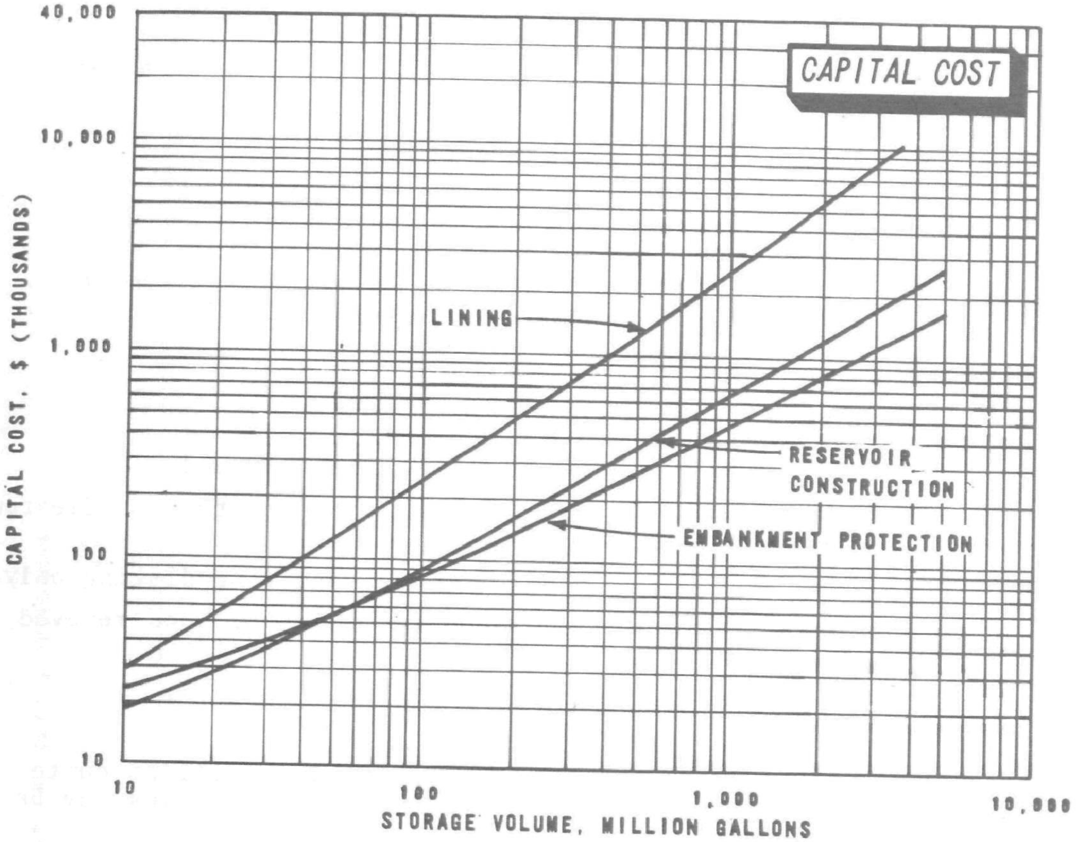
1. For linings other than asphaltic membrane:
   a. Bentonite - 0.86
   b. PVC (10 mil) with soil blanket - 1.21
   c. Soil cement - 1.21
   d. Petromat - 1.24
   e. Butyl neoprene (30 mil) - 1.97

Metric Conversion

1. mil gal. x 3,790 = cu m

Sources

Derived from cost calculations based on a series of typical designs.



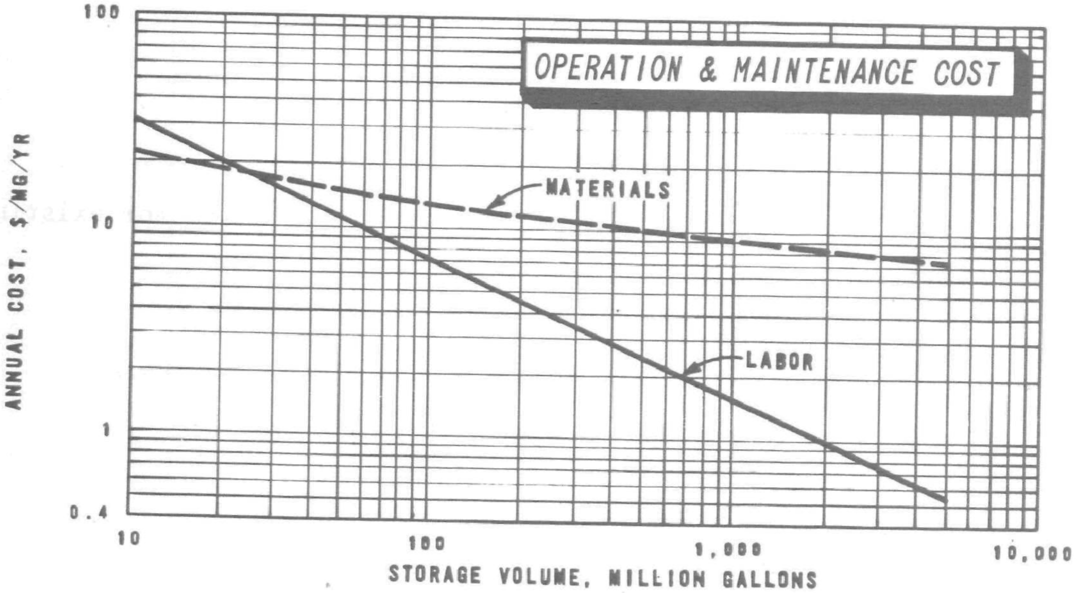


FIGURE 23. STORAGE (10–5,000 MILLIONS GALLONS)

FIELD PREPARATION

SITE CLEARING

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Heavily wooded--fields cleared and grubbed.
2. Brush and trees--mostly brush with few trees. Cleared using bulldozer-type equipment.
3. Grass only--abandoned farmland requiring disking only.
4. No capital return included for value of wood removed from site.
5. All debris disposed of onsite.

Note: In actual practice site conditions will be quite variable, and interpolation between curves may be required.

Adjustment Factor

1. Debris disposed offsite: 1.8 to 2.2.

Metric Conversion

1. acre x 0.405 = ha

Sources

Based on a survey of actual construction costs for existing systems.

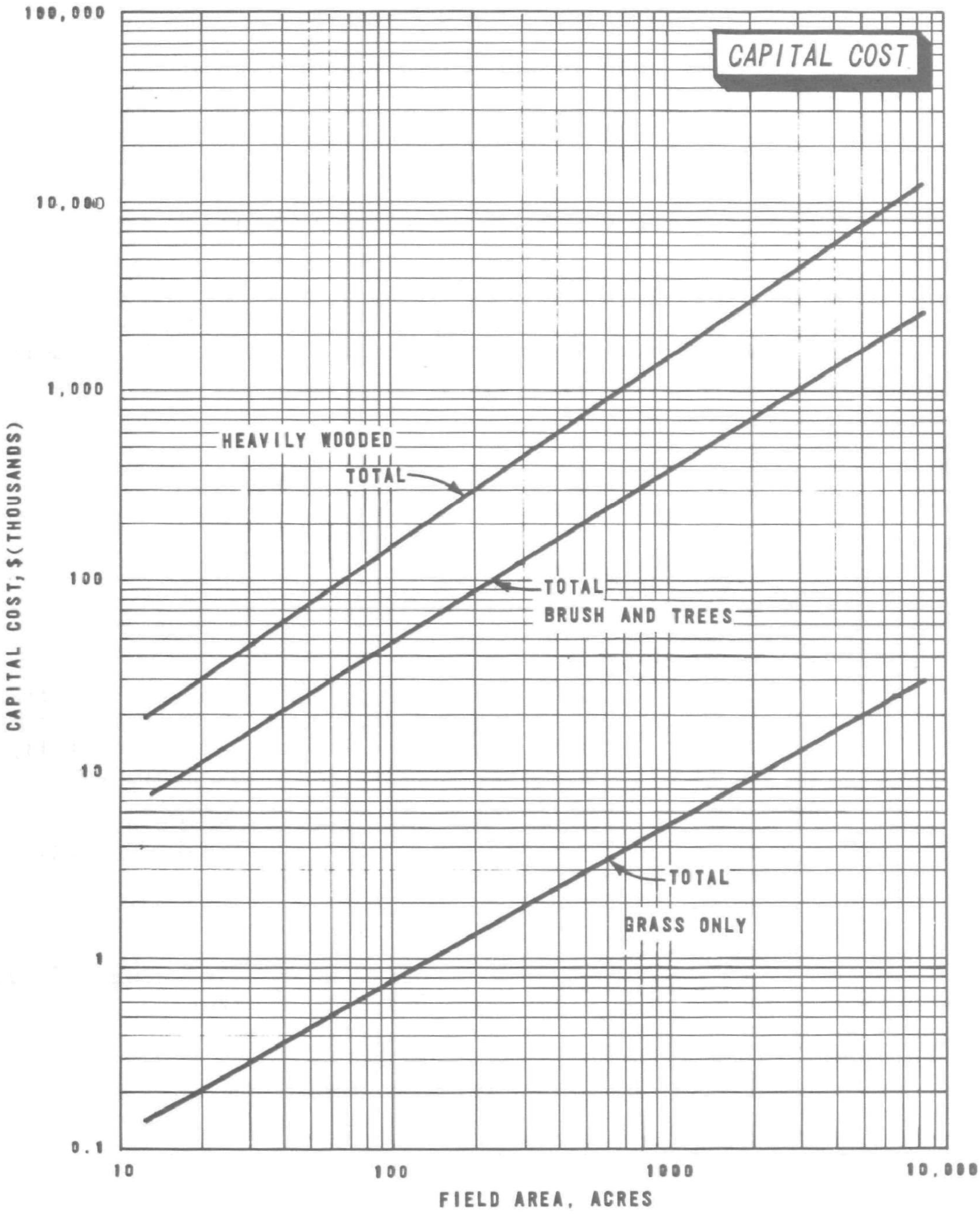


FIGURE 24. FIELD PREPARATION - SITE CLEARING

FIELD PREPARATION

LAND LEVELING FOR SURFACE IRRIGATION

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Land previously cleared and rough leveled.
2. Curves given for volumes of cut of 500 and 750 cy/acre (945 and 1,418 cu m/ha).
3. Costs include:
   a. Surveying
   b. Earthmoving
   c. Finish grading
   d. Ripping two ways
   e. Disking
   f. Landplaning
   g. Equipment mobilization
4. Clay loam soil.

Note: In many cases, 500 cy/acre is sufficient, while the curve for 750 represents conditions requiring considerable earthmoving. The curves should generally be used in conjunction with those in Figure 24, "Field Preparation-Site Clearing," and either Figure 29, "Distribution-Surface Flooding Using Border Strips," or Figure 30, "Distribution-Ridge and Furrow Application."

Adjustment Factor

1. Volumes of cut: 0.2 + 0.0016C where C = volume of cut, cy/acre. Cost based on 500 cy/acre curve.

Metric Conversion

1. acre x 0.405 = ha
2. cy/acre x 1.89 = cu m/ha

Sources

Derived from cost calculations based on a series of typical designs and consultation with the California Agricultural Extension Service.

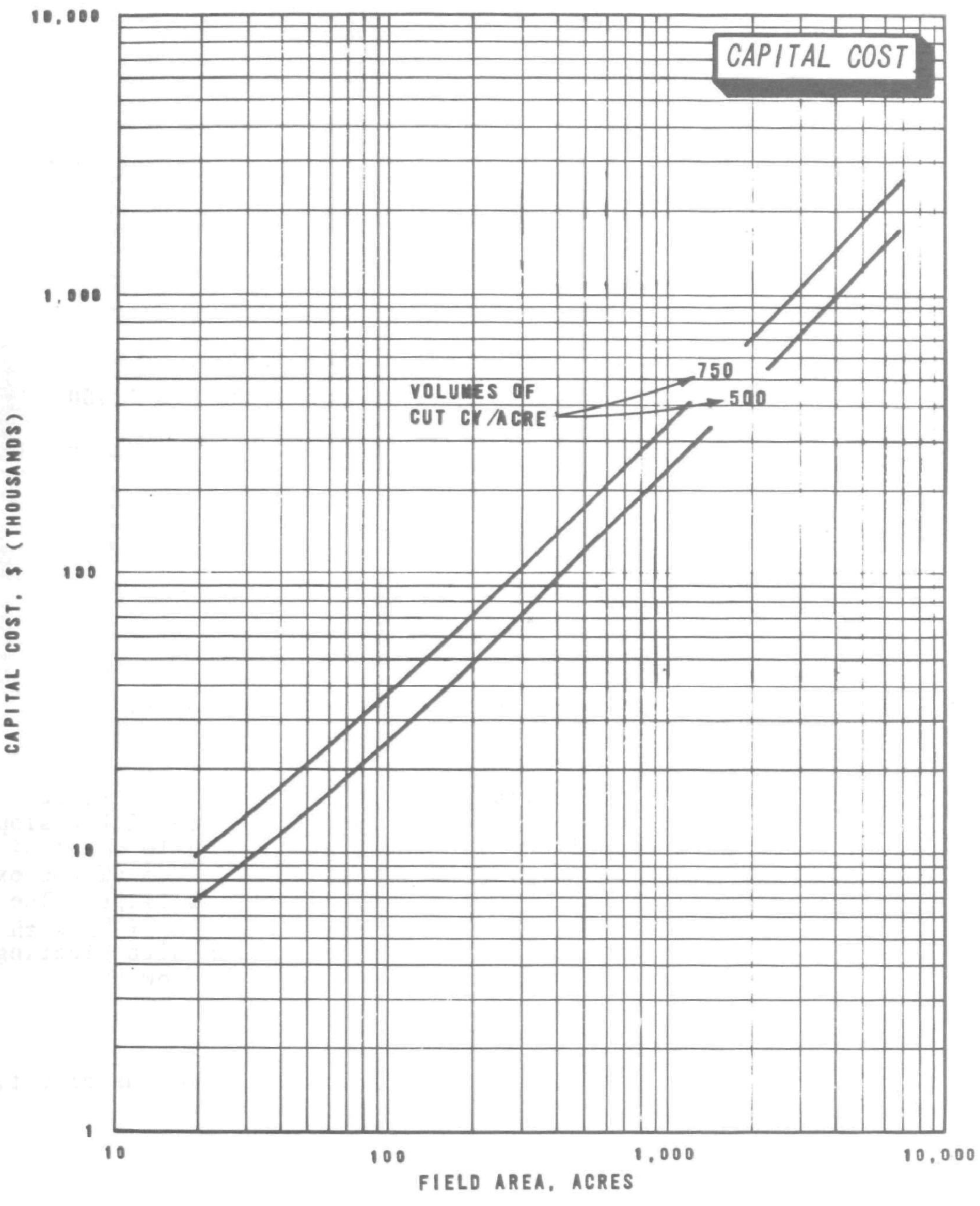


FIGURE 25. FIELD PREPARATION – LAND LEVELING FOR SURFACE IRRIGATION

FIELD PREPARATION

OVERLAND FLOW TERRACE CONSTRUCTION

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

1. Land previously cleared and rough leveled.
2. Curves given for volumes of cut of 1,000 and 1,400 cy/acre (1,890 and 2,646 cu m/ha).
3. Costs include:
   a. Surveying
   b. Earthmoving
   c. Finish grading
   d. Ripping two ways
   e. Disking
   f. Landplaning
   g. Equipment mobilization
4. Clay soil with only nominal amount of hardpan.
5. Final slopes of 2.5%.

Note: A cut of 1,000 cy/acre would correspond to terraces of approximately 175-foot (53.4 m) width with a slope of 2.5% from initially level ground, while a cut of 1,400 cy/acre would correspond to terraces of approximately 250-foot (76.2 m) width and 2.5% slope. The curves should generally be used in conjunction with those in Figure 24, "Field Preparation-Site Clearing," and Figure 31, "Distribution-Overland Flow."

Adjustment Factor

1. Volumes of cut: 0.2 + 0.0008C where C = volume of cut, cy/acre. Cost based on 1,000 cy/acre curve.

Metric Conversion

1. acre x 0.405 = ha
2. cy/acre x 1.89 = cu m/ha

Sources

Derived from cost calculations based on a series of typical designs.

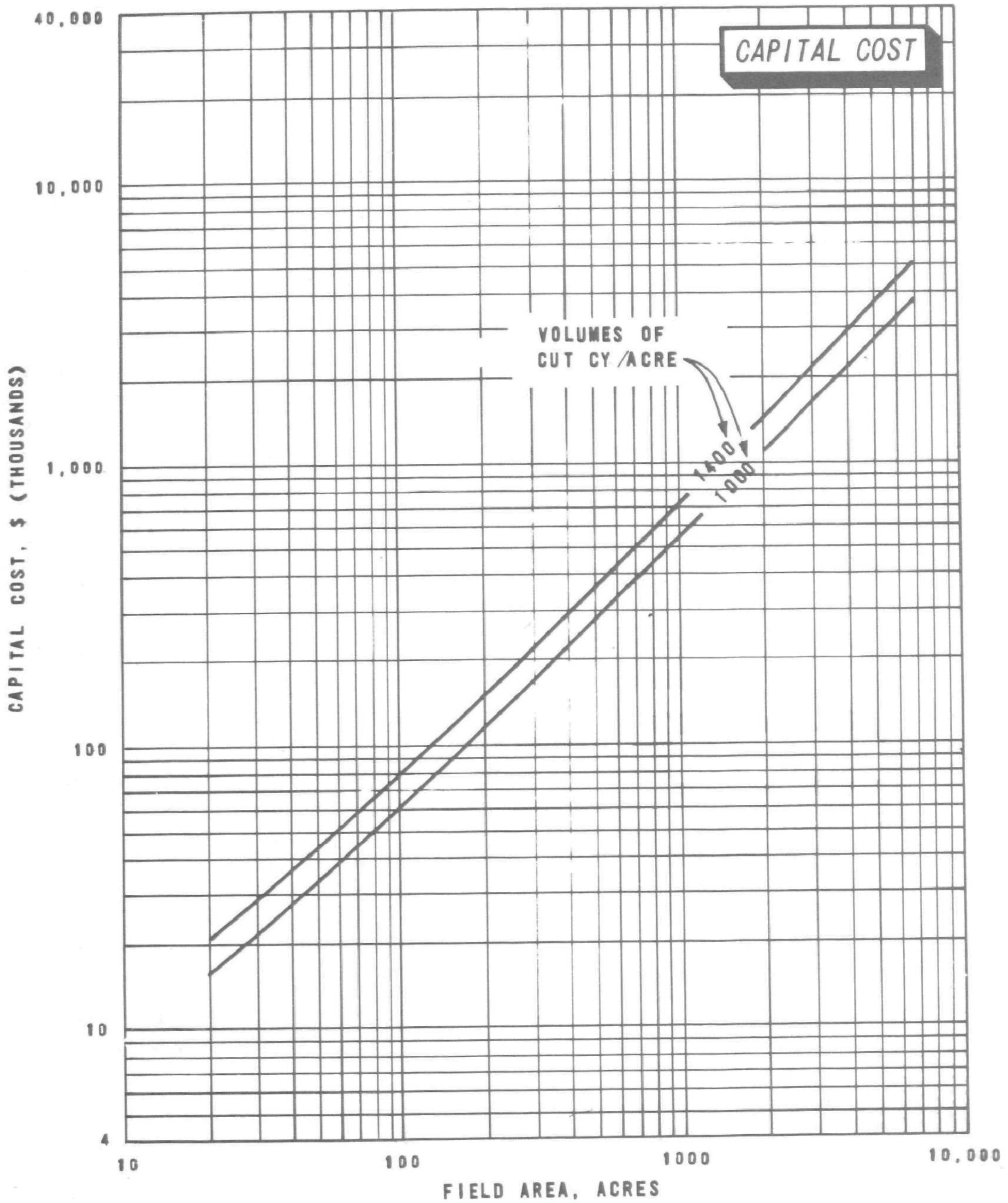


FIGURE 26. FIELD PREPARATION –
OVERLAND FLOW TERRACE CONSTRUCTION

DISTRIBUTION

SOLID SET SPRAYING (BURIED)

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Lateral spacing, 100 ft (30.5 m). Sprinkler spacing, 80 ft (24.4 m) along laterals. 5.4 sprinklers/acre (2.2 sprinklers/ha).
2. Application rate 0.20 in./hr (0.51 cm/hr).
3. 16.5 gpm (1.04 l/sec) flow to sprinklers at 70 psi (4.9 kg/sq cm).
4. Flow to laterals controlled by hydraulically operated automatic valves.
5. Laterals buried 18 in. (46 cm). Mainlines buried 36 in. (91 cm).
6. All pipe 4 in. (10 cm) diam and smaller is PVC. All larger pipe is asbestos cement.
7. Materials cost includes replacement of sprinklers and air compressors for valve controls after 10 yr.

Adjustment Factors

Item	Capital cost	Labor	Materials
1. Irregular-shaped fields	1.15 to 1.30	--	--
2. Sprinkler spacing	0.68 + 0.06S	0.65 + 0.065S	0.1 + 0.17S

Note: S = sprinklers/acre.

Metric Conversion

1. acre x 0.405 = ha
2. in. x 2.54 = cm

Sources

Derived from a survey of existing systems and cost calculations based on a series of typical designs.

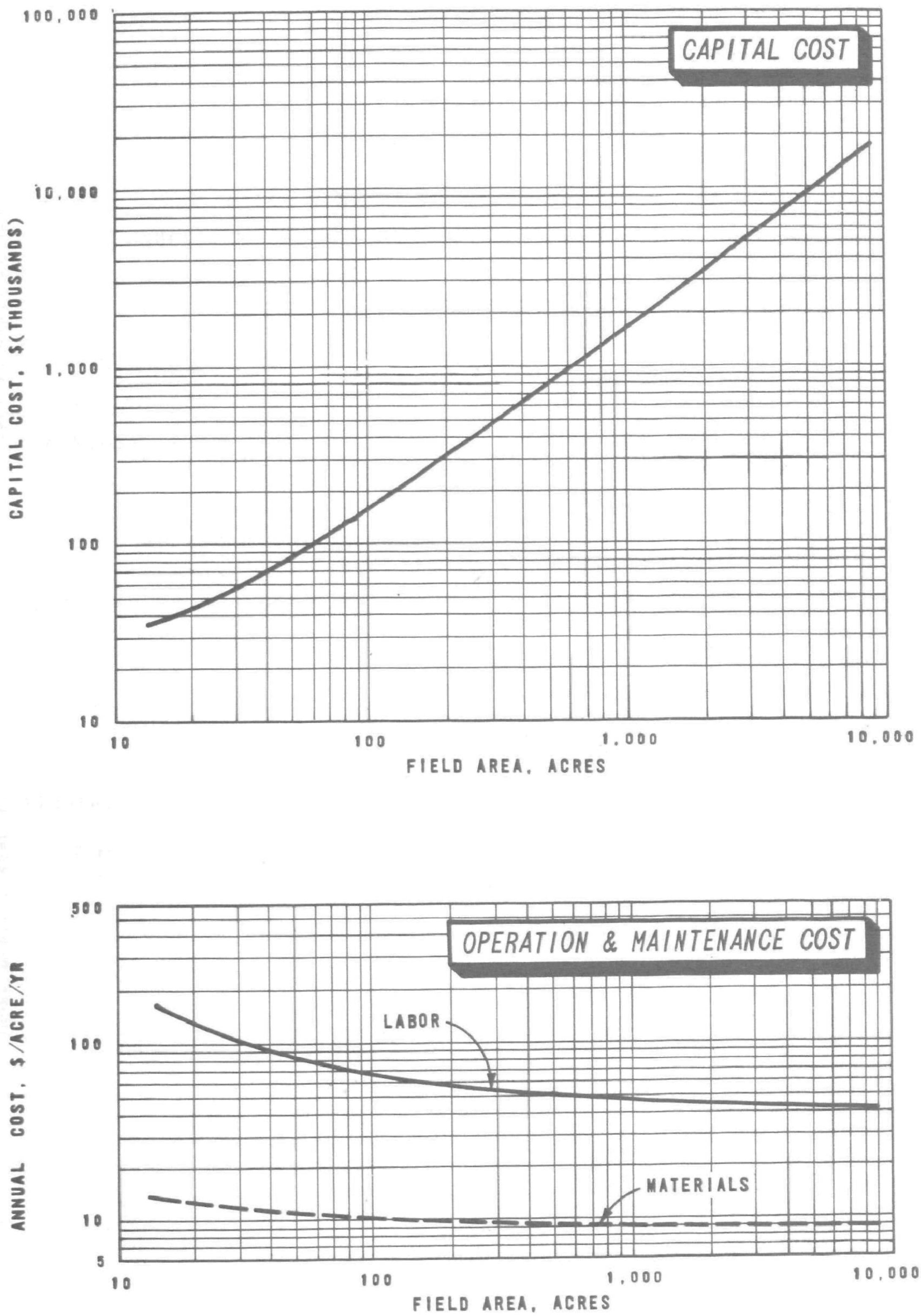


FIGURE 27. DISTRIBUTION - SOLID SET SPRAYING (BURIED)

DISTRIBUTION

CENTER PIVOT SPRAYING

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

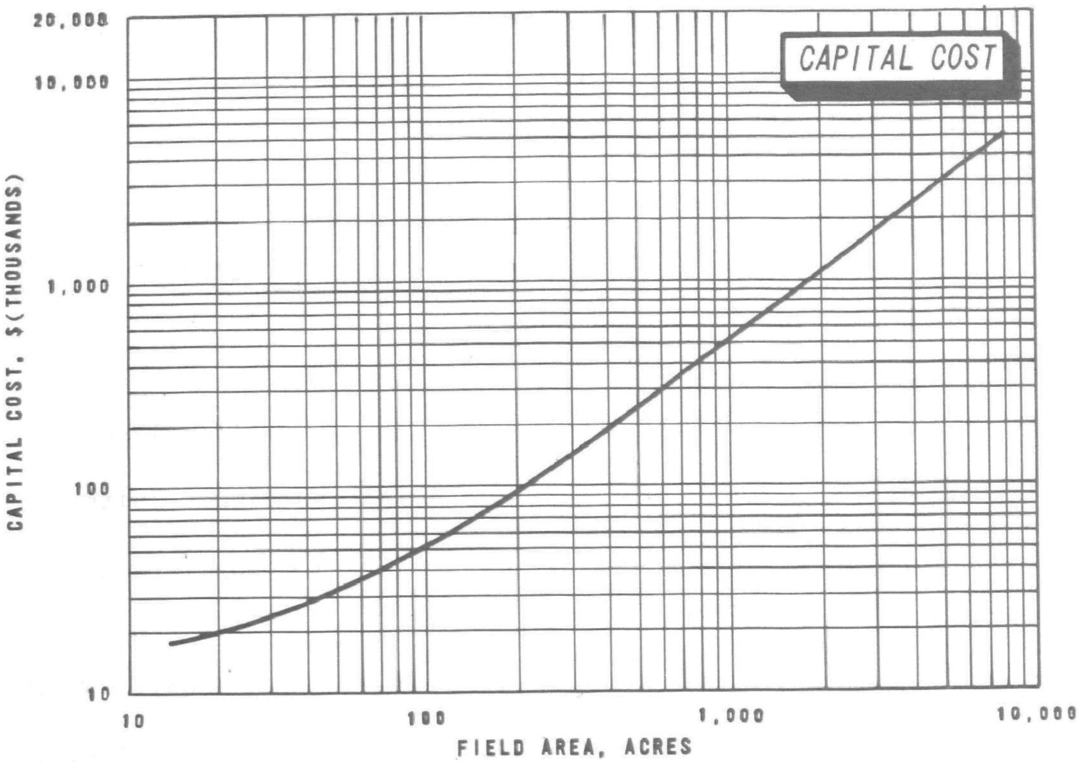
1. Heavy-duty center pivot rig with electric drive.
2. Multiple units for field areas over 40 acres (16.2 ha). Maximum area per unit, 132 acres (53.4 ha).
3. Distribution pipe buried 36 in. (91 cm).
4. Materials cost includes minor repair parts and major overhaul of center pivot rigs after 10 yr.
5. Power cost based on 3.5 days/wk operation of each rig.

Metric Conversion

1. acre x 0.405 = ha

Sources

Derived from a survey of existing systems and cost calculations based on a series of typical designs.



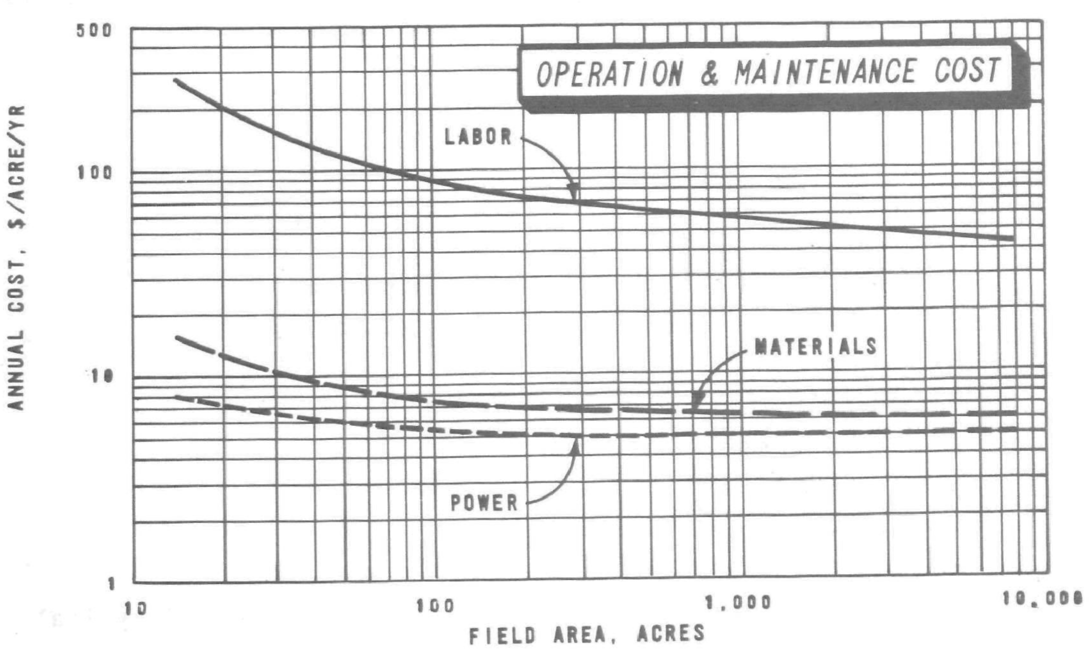


FIGURE 28. DISTRIBUTION – CENTER PIVOT SPRAYING

SURFACE FLOODING USING BORDER STRIPS

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Border strips 40 ft (12 m) wide and 1,150 ft (350 m) long.
2. Concrete-lined trapezoidal distribution ditches with 2 slide gates per strip.
3. Rectangular-shaped fields previously leveled to a slope of approximately 0.4%.
4. Clay loam soil.
5. Continuous operation for large systems and 5 days/wk for systems smaller than 50 acres (20 ha).
6. Materials cost includes rebordering every 2 yr and major relining of ditches after 10 yr.

Note: A flatter slope or more permeable soil condition would require a reduction in strip length.

Adjustment Factors

Item	Capital cost	Labor and materials
1. Irregular-shaped fields	1.15 to 1.30	1.10 to 1.20
2. Strip length	2.4 - 0.0012L	1.8 - 0.0007L

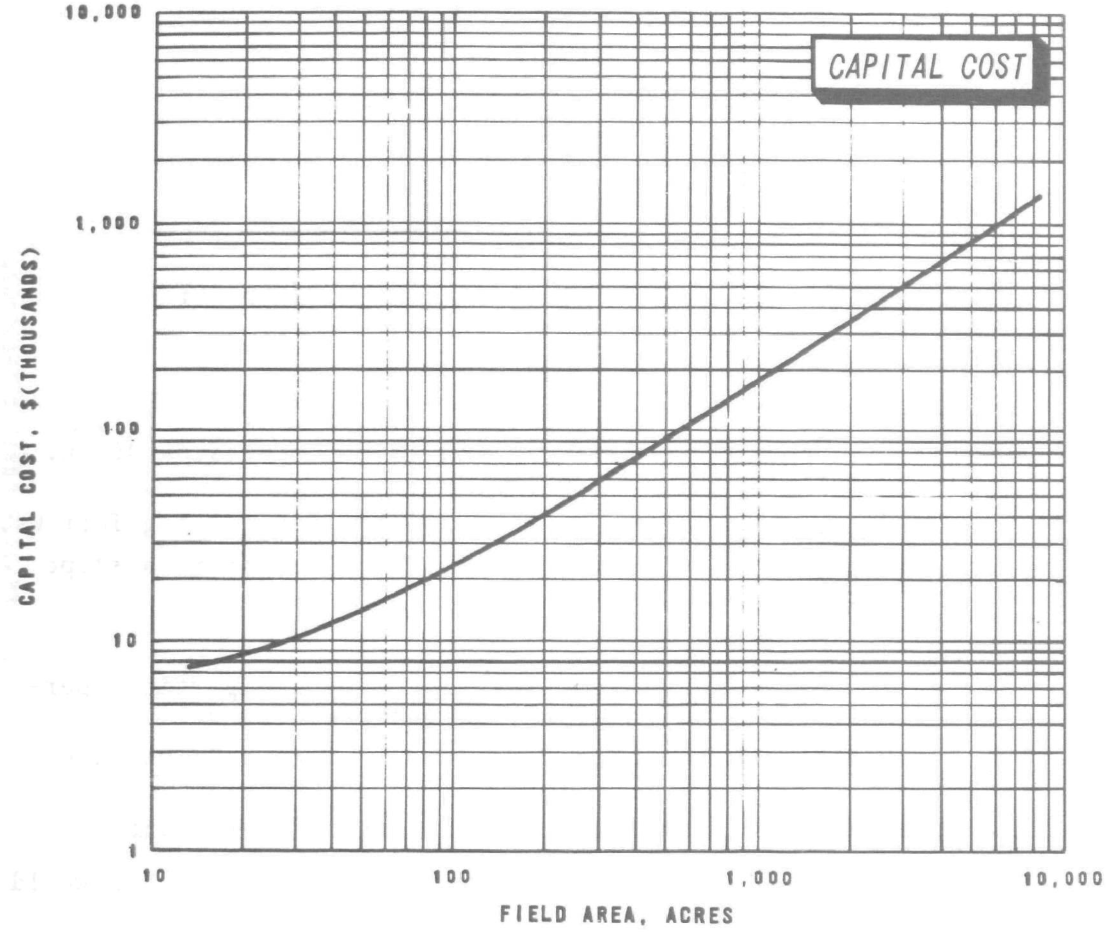
Note: L = length of border strip, ft.

Metric Conversion

1. acre x 0.405 = ha
2. ft x 0.305 = m

Sources

Derived from cost calculations based on a series of typical designs.



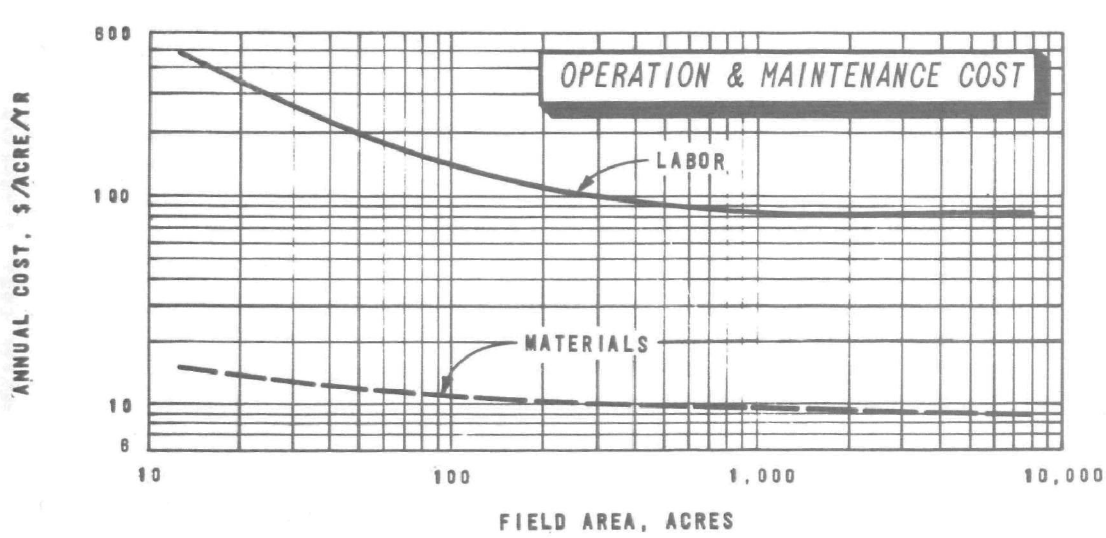


FIGURE 29. DISTRIBUTION – SURFACE FLOODING USING BORDER STRIPS

DISTRIBUTION

RIDGE AND FURROW APPLICATION

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Gated aluminum pipe distribution with outlets on 40-in. (102 cm) centers.
2. Gated pipe spacing based on 1,200-ft (366 m) long furrows.
3. Rectangular-shaped fields previously leveled to a slope of approximately 0.3%.
4. Loam soil.
5. Continuous operation for large systems and partial operation for systems smaller than 50 acres (20 ha).
6. Materials cost includes replacement of gated pipe after 10 yr.
7. Cost of furrows included in planting and harvesting.

Note: A flatter slope or more permeable soil condition would require a reduction in furrow length.

Adjustment Factors

Item	Capital cost	Labor and materials
1. Irregular-shaped fields	1.10 to 1.25	1.10 to 1.20
2. Furrow length	2.2 - 0.001L	2.44 - 0.0012L

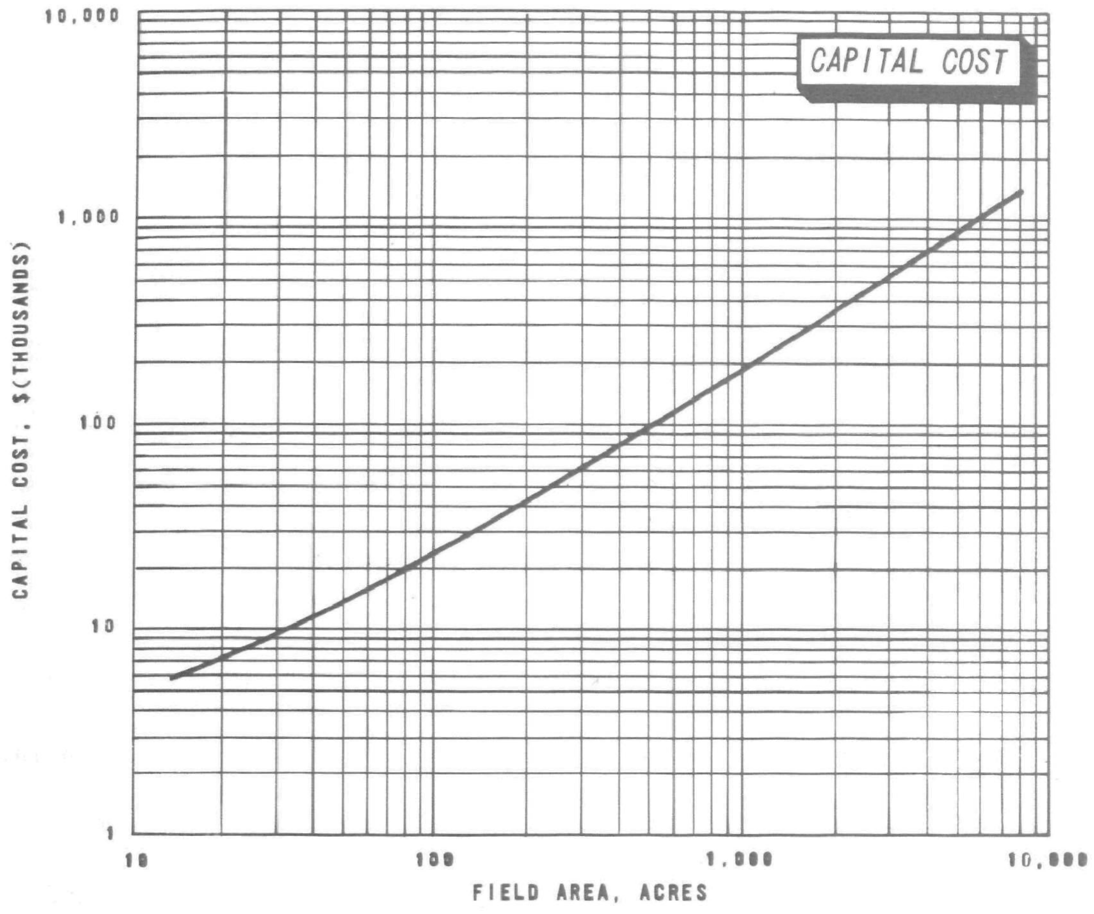
Note: L = length of furrow, ft.

Metric Conversion

1. acre x 0.405 = ha
2. ft x 0.305 = m

Sources

Derived from cost calculations based on a series of typical designs.



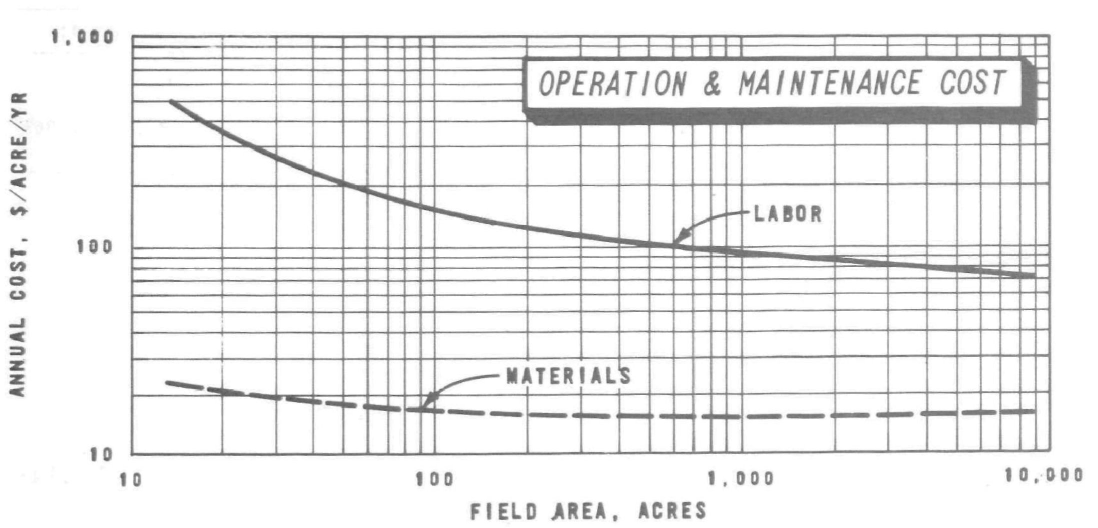


FIGURE 30. DISTRIBUTION - RIDGE AND FURROW APPLICATION

DISTRIBUTION

OVERLAND FLOW

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Terraces 250 ft (760 m) wide and previously leveled to 2.5% slope.
2. Application rate over field area 0.064 in./hr (0.16 cm/hr).
3. 13-gpm (0.83 l/sec) flow to sprinklers at 50 psi (3.5 kg/sq cm).
4. Laterals 70 ft (21.3 m) from top of terrace.
5. Flow to laterals controlled by hydraulically operated automatic valves.
6. Laterals buried 18 in. (46 cm). Mainlines buried 36 in. (91 cm).
7. All pipe 4-in. (10 cm) diam and smaller is PVC. All larger pipe is asbestos cement.
8. Materials cost includes replacement of sprinklers and air compressors for valve controls after 10 yr.

Adjustment Factors

Item	Capital cost	Labor	Materials
1. Irregular-shaped fields	1.15 to 1.30	--	--
2. Terrace width	1.5 - 0.002T	1.75 - 0.003T	2.5 - 0.006T

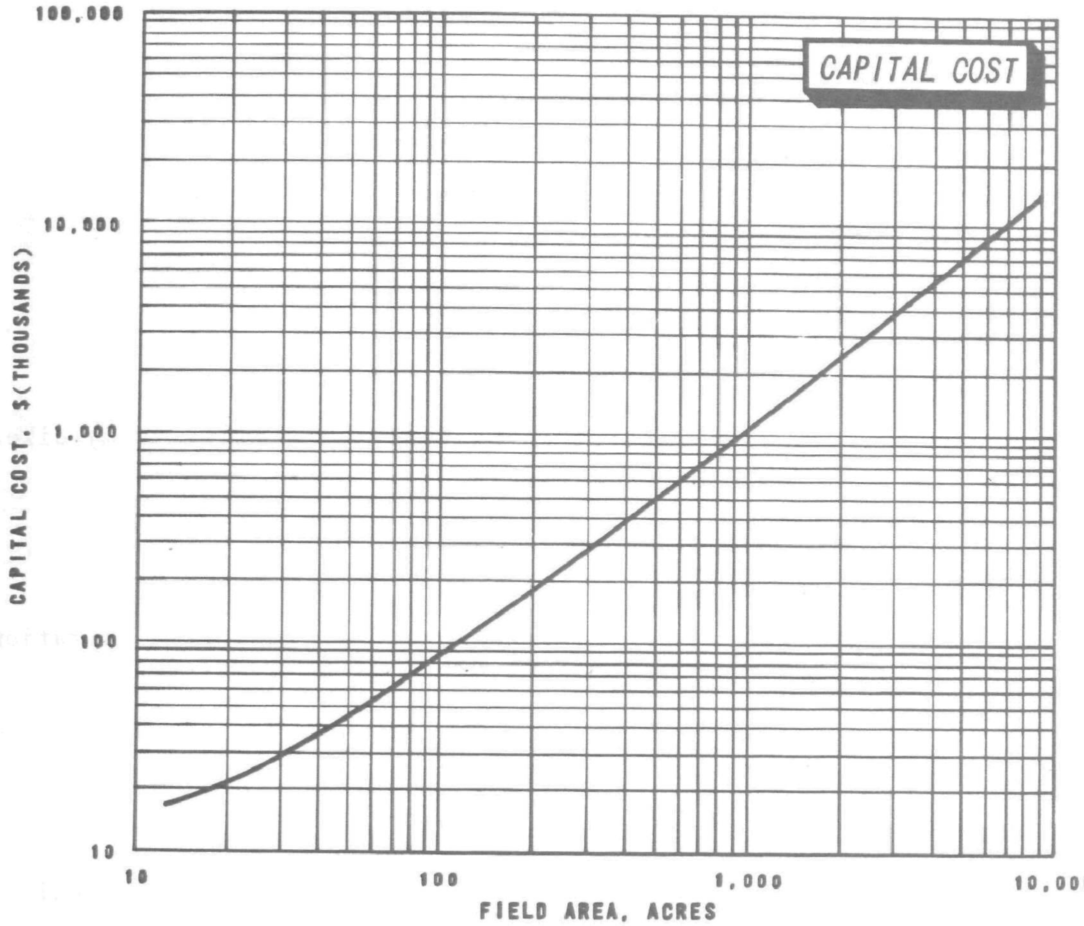
Note: T = terrace width, ft.

Metric Conversion

1. acre x 0.405 = ha
2. ft x 0.305 = m

Sources

Derived from a survey of existing systems and cost calculations based on a series of typical designs.



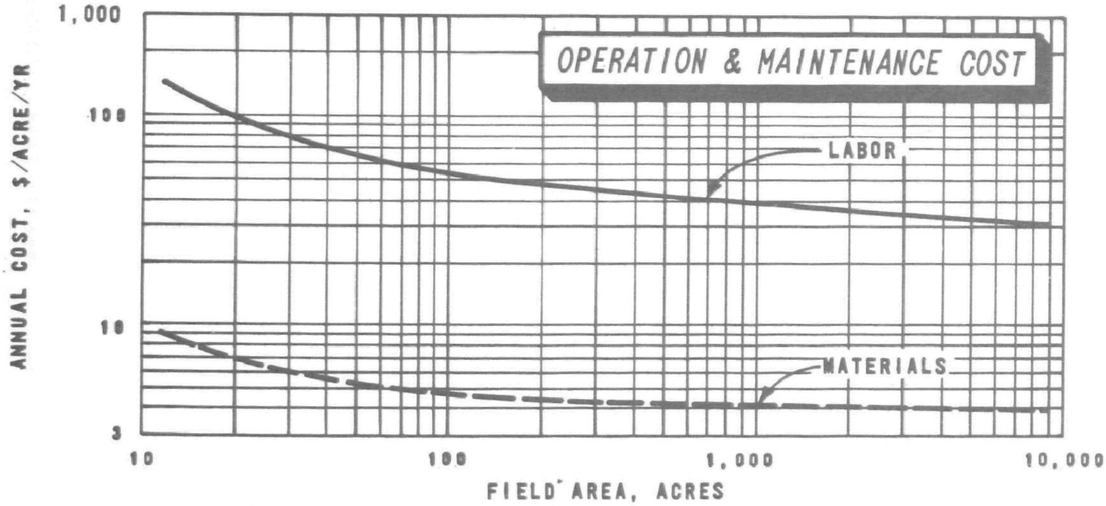


FIGURE 31. DISTRIBUTION – OVERLAND FLOW

DISTRIBUTION

INFILTRATION BASINS

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

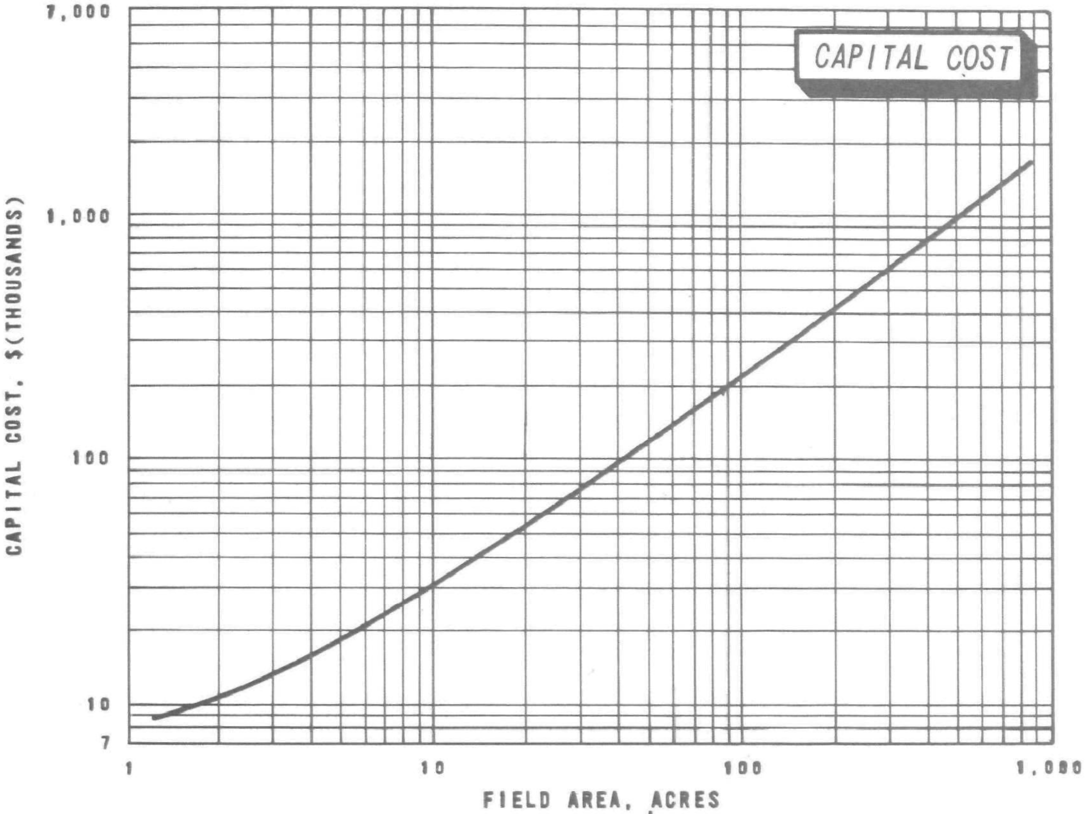
1. Multiple unit infiltration basins with 4-ft (1.22 m) dike.
2. Dikes formed from native excavated material.
3. Inside slope of dike 3:1; outside slope, 2:1. 6-ft (1.83 m) wide dike crest.
4. Deep sandy soil.
5. Materials cost includes annual rototilling of infiltration surface and major repair of dikes after 10 yr.

Metric Conversion

1. acre x 0.405 = ha

Sources

Derived from cost calculations based on a series of typical designs.



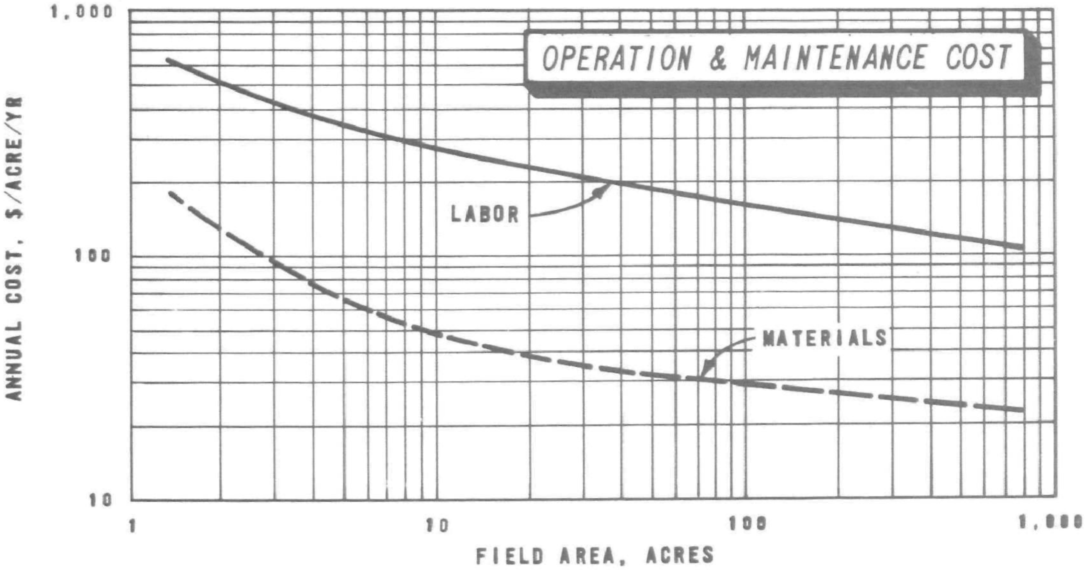


FIGURE 32. DISTRIBUTION - INFILTRATION BASINS

DISTRIBUTION

DISTRIBUTION PUMPING

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Capital and power cost curves given for various total heads in feet.
2. Capital costs are related to peak flow in mgd. Operation and manitenance costs are related average flow.
3. Capital cost includes:
   a. Structure built into dike of storage reservoir
   b. Continuously cleaned water screens
   c. Pumping equipment with normal standby facilities
   d. Piping and valves within structure
   e. Controls and electrical work
4. Labor cost includes operation, preventive maintenance, and minor repairs.
5. Materials cost includes repair work performed by outside contractor and replacement of parts.

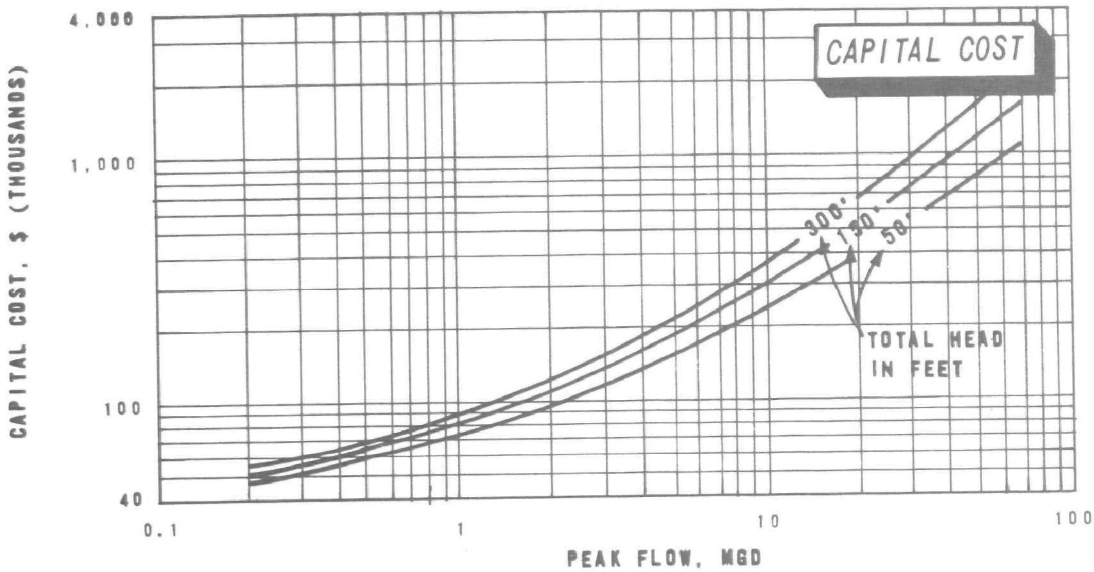
Note: The curves should generally be used in conjunction with curves for a particular method of distribution.

Metric Conversion

1. ft x 0.305 = m
2. mgd x 43.8 = l/sec

Sources

Derived from a series of typical designs and various cost data [6, 37].



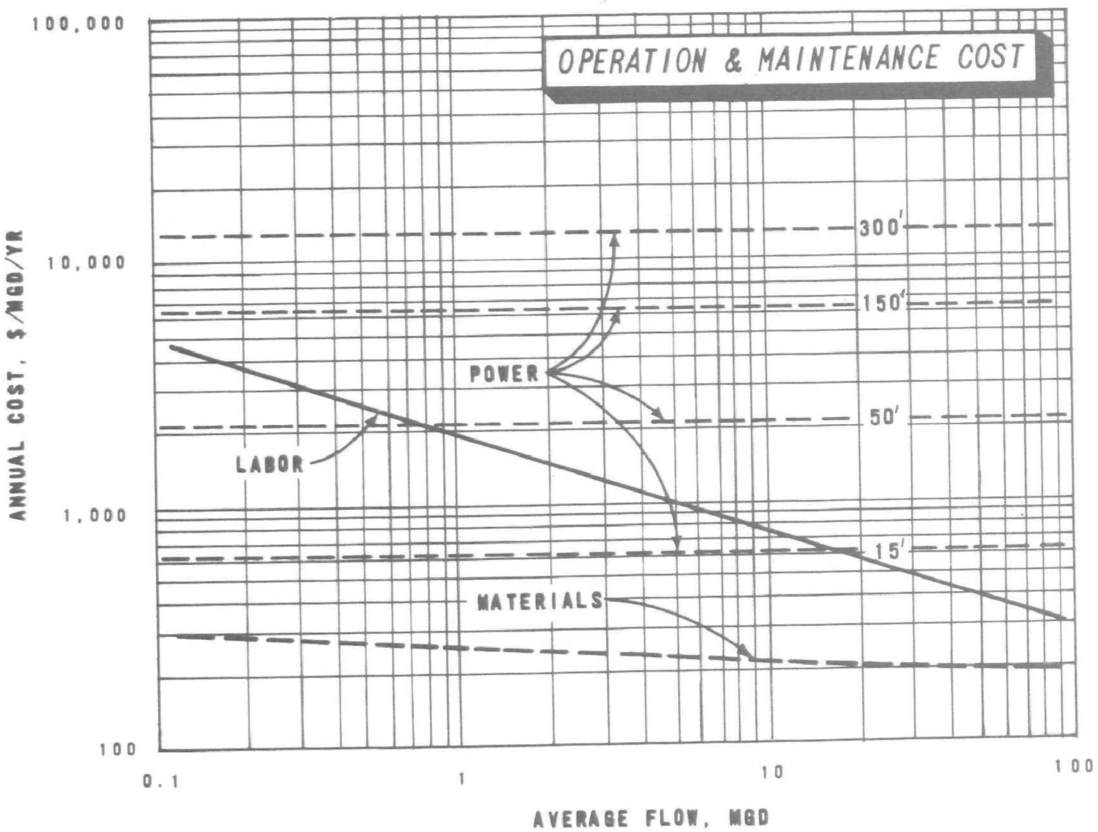


FIGURE 33. DISTRIBUTION - DISTRIBUTION PUMPING

RECOVERY OF RENOVATED WATER

UNDERDRAINS

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Costs given for spacings of 100 and 400 ft (30 and 122 m) between drain pipes.
2. Capital cost includes:
   a. Drain pipes buried 6 to 8 ft (1.8 to 2.4 m).
   b. Interception ditch along length of field
   c. Weir for control of discharge
3. Labor cost includes inspection and unclogging of drain pipes at outlets.
4. Materials cost includes high pressure jet cleaning of drain pipes every 5 yr, annual cleaning of interceptor ditch, and major repair of ditches after 10 yr.

Note: Spacings as small as 100 ft may be required for clayey soils; a 400-ft spacing is typical for sandy soil conditions [23].

Metric Conversion

1. ft x 0.305 = m
2. mgd x 43.8 = l/sec

Sources

Derived from cost calculations based on a series of typical designs.

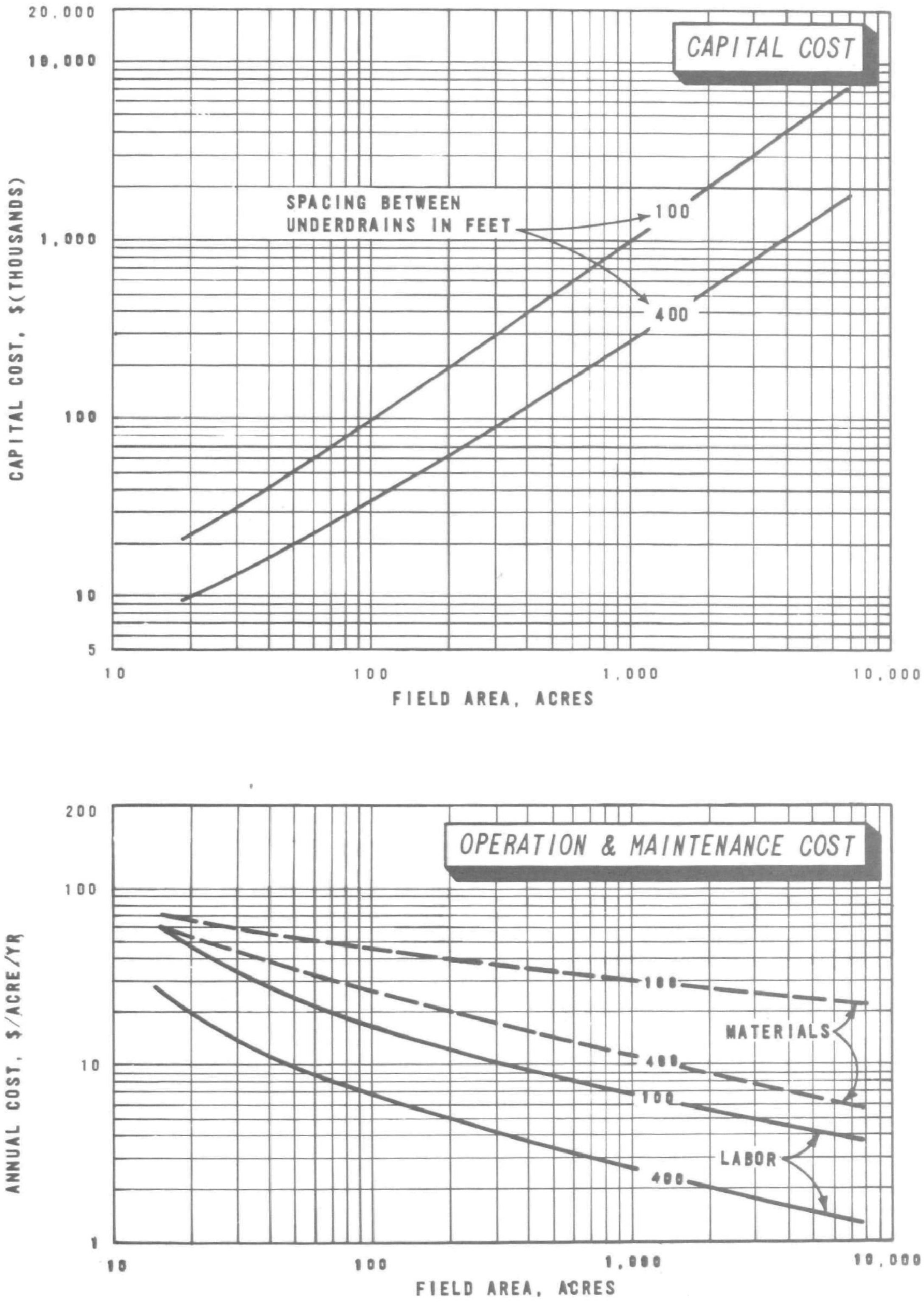


FIGURE 34. RECOVERY OF RENOVATED WATER - UNDERDRAINS

RECOVERY OF RENOVATED WATER

TAILWATER RETURN

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Costs are given versus flow of recovered water.
2. Capital cost includes:
   a. Drainage collection ditches
   b. Pumping station forebay, 1/3 acre (0.14 ha).
   c. Pumping station with shelter and multiple pumps
   d. Piping to nearest point of distribution mainline (200 ft or 61 m)
3. Materials cost includes major repair of pumping station after 10 yr.

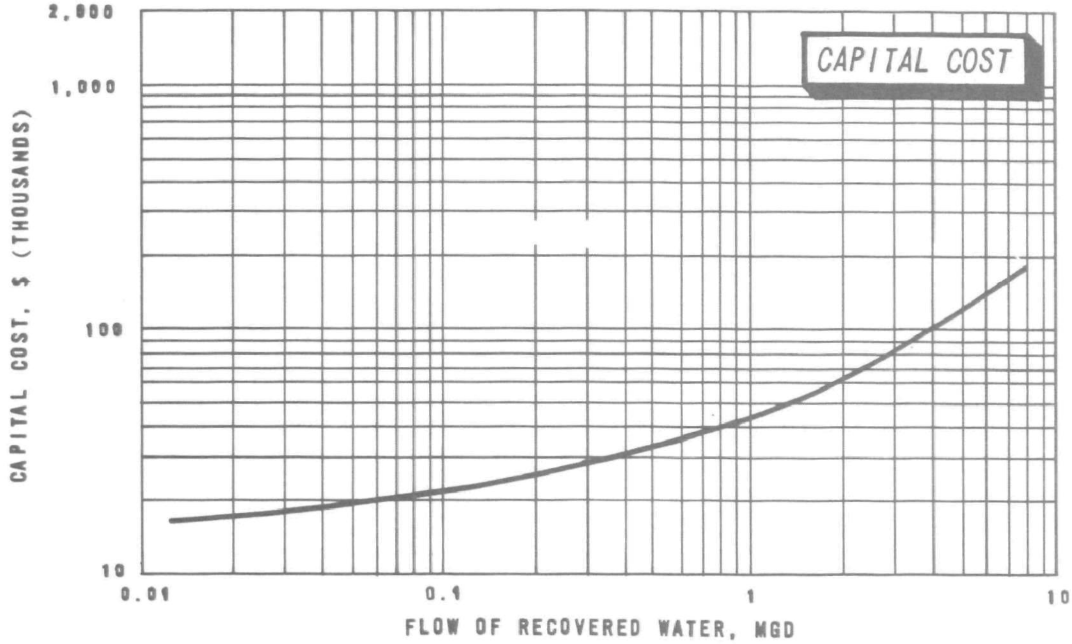
Note: Generally, the flow of recovered water can be expected to be 10 to 40 percent (an average would be 20 percent) of the flow of applied water, depending on soil conditions, application rate, slope, and type of crop or vegetation. This range is based on irrigation practice where water is plentiful and soil-water quality conditions may dictate excess water application. Should return piping lengths be significantly more than 200 ft (61 m), to the nearest distribution main, the additional costs could be obtained from Figure 20, "Transmission-Force Mains."

Metric Conversion

1. mgd x 43.8 = l/sec

Sources

Derived from cost calculations based on a series of typical designs.



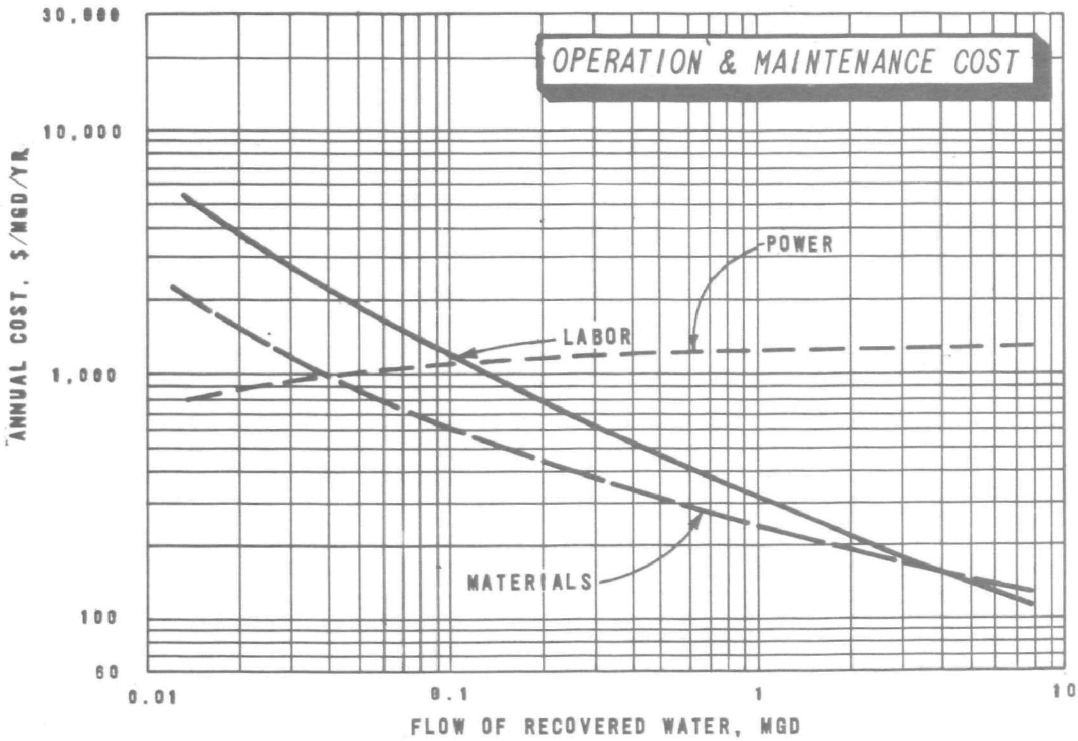


FIGURE 35. RECOVERY OF RENOVATED WATER—
TAILWATER RETURN

RECOVERY OF RENOVATED WATER

RUNOFF COLLECTION FOR OVERLAND FLOW

Costs are given for overland flow runoff collection by both open ditch and gravity pipe. The curves may be used in conjunction with those in Figure 37, "Recovery of Renovated Water-Chlorination and Discharge for Overland Flow."

<u>Basis of Costs</u>

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

<u>Assumptions</u>

1. Cost of lateral collection ditches along bottom of terrace in included in Figure 26 - "Field Preparation-Overland Flow Terrace Construction".
2. Open Ditches:
   a. Network of unlined interception ditches sized for a 2-in./hr storm
   b. Culverts under service roads
   c. Concrete drop structures at 1,000-ft (305 m) intervals
   d. Materials cost includes biannual cleaning of ditches with major repair after 10 yr
3. Gravity Pipe:
   a. Network of gravity pipe interceptors with inlet/manholes every 250 ft (76.3 m) along submains
   b. Storm runoff is allowed to pond at inlets
   c. Each inlet/manhole serves 1,000 (305 m) of collection ditch
   d. Manholes every 500 ft along interceptor mains.
   e. Operation and maintenance cost includes periodic cleaning of inlets and normal maintenance of gravity pipe

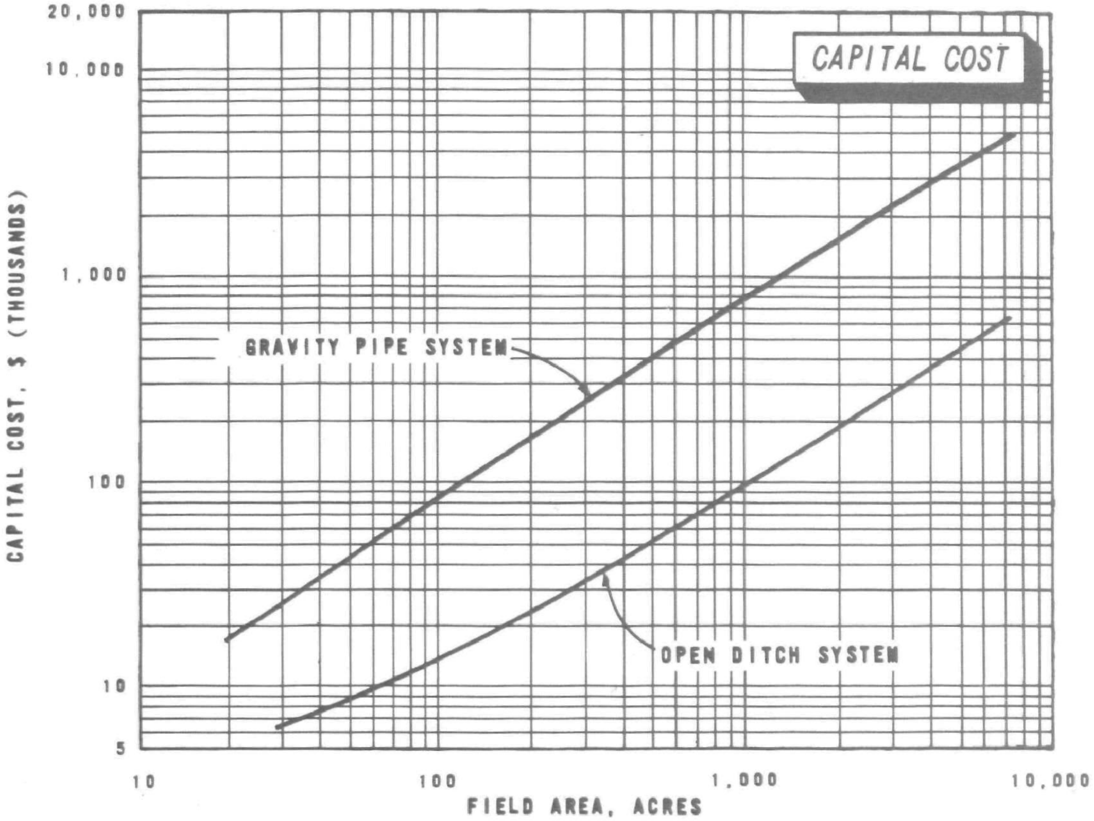
Note: Open ditches should be used where possible. Gravity pipe systems may be required when unstable soil conditions are encountered, or when flow velocities are erosive.

<u>Metric Conversion</u>

1. acre x 0.405 = ha

<u>Sources</u>

Derived from cost calculations based on a series of typical designs.



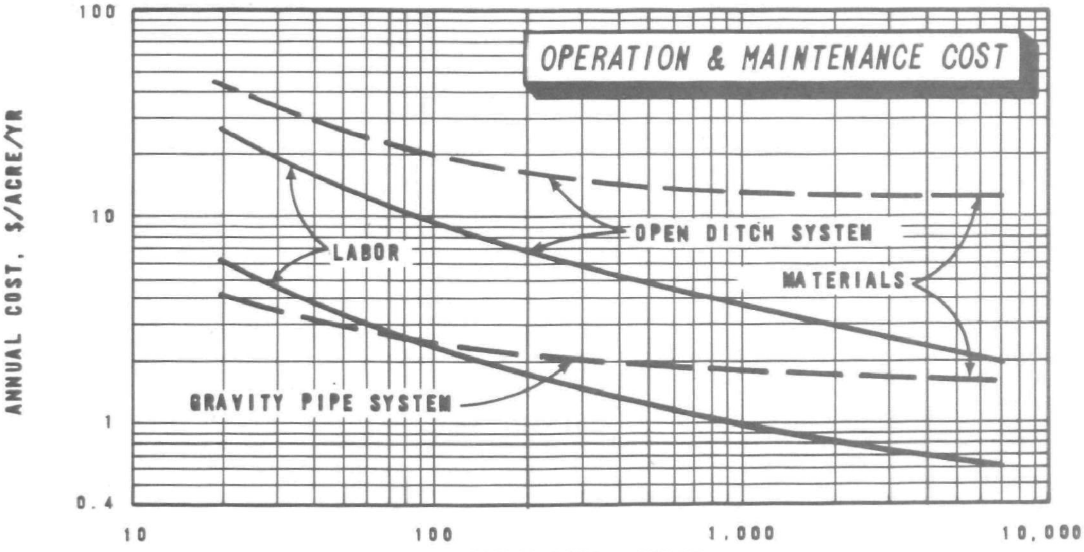


FIGURE 36. RECOVERY OF RENOVATED WATER – RUNOFF COLLECTION FOR OVERLAND FLOW

RECOVERY OF RENOVATED WATER

CHLORINATION AND DISCHARGE FOR OVERLAND FLOW

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.
3. Chlorine cost = $0.05/lb ($0.023/kg).

Assumptions

1. Capital cost includes:
   a. Chlorination facilities with flash mixing and contact basin
   b. Chlorine storage
   c. Flow measuring device
   d. Stormwater overflow structure
2. Maximum dosage capability, 10 mg/l. Average dosage, 5 mg/l.
3. Chlorination contact time, 30 min.

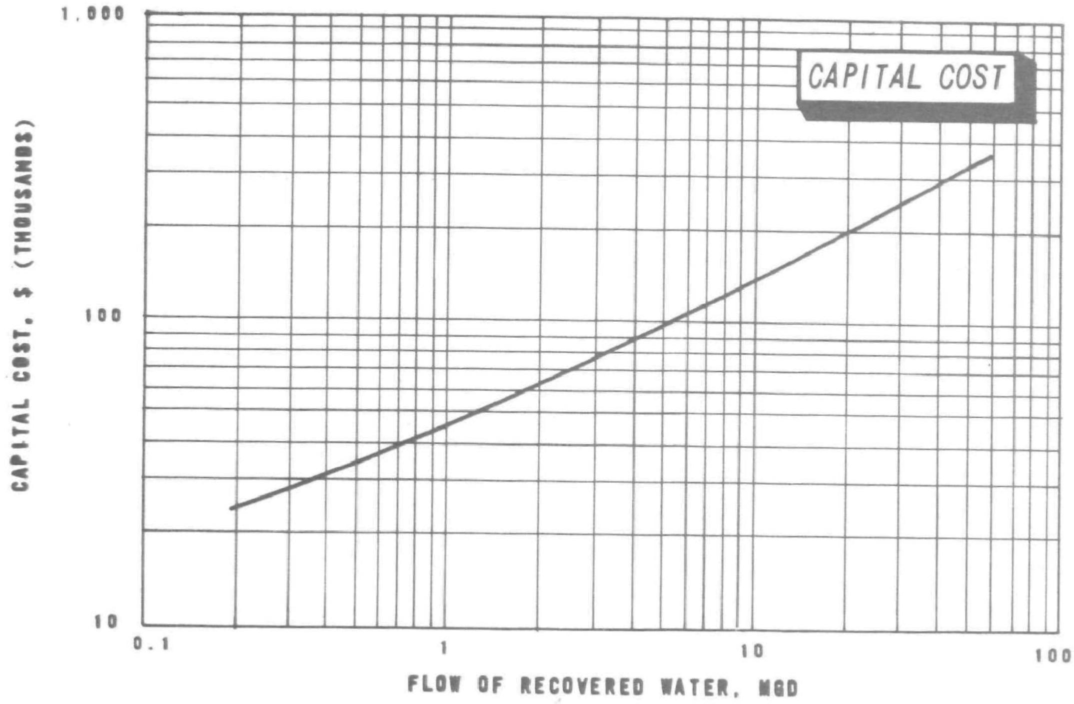
Note: The curves should be used in conjunction with those in Figure 36, "Recovery of Renovated Water-Runoff Collection for Overland Flow."

Metric Conversion

1. mgd x 43.8 = l/sec

Sources

Derived from previously published information [27], and cost calculations based on a series of typical designs.



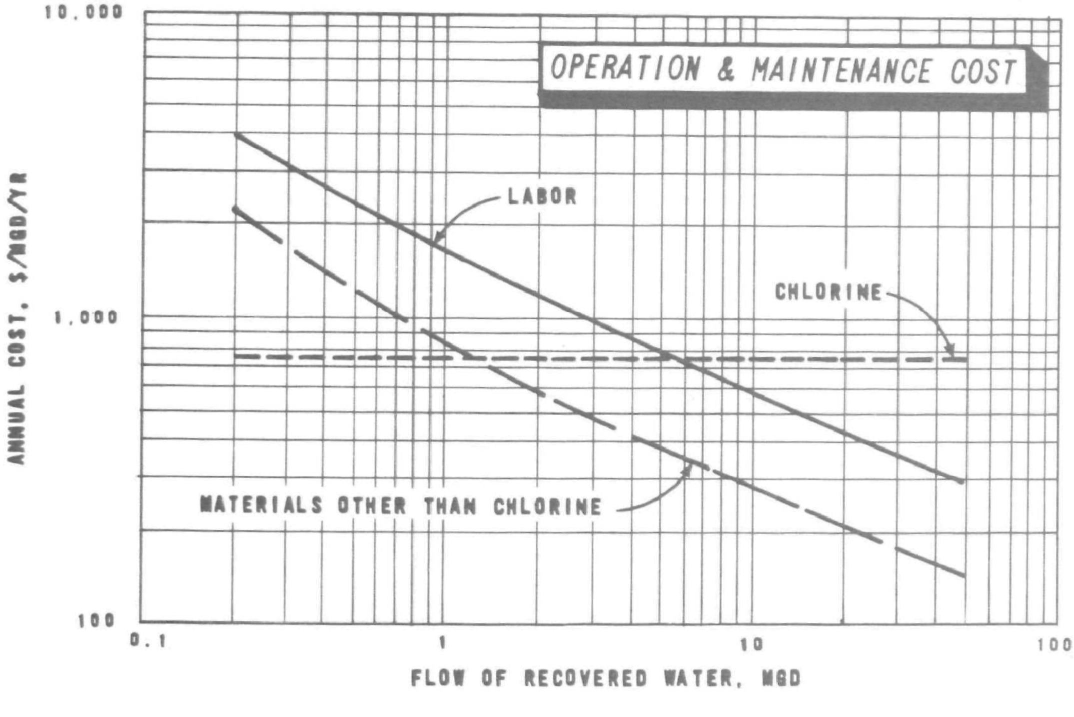


FIGURE 37. RECOVERY OF RENOVATED WATER – CHLORINATION AND DISCHARGE FOR OVERLAND FLOW

RECOVERY OF RENOVATED WATER

RECOVERY WELLS

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.
3. Electrical power cost = $0.02/kwh.

Assumptions

1. Capital and power cost curves given for well depths of 50 and 100 ft (15 and 30 m).
2. Total head equal to well depth.
3. Capital cost includes:
   a. Gravel-packed wells
   b. Vertical turbine pumps
   c. Simple shelter over each well
   d. Controls and electrical work
4. Labor cost includes operation, preventive maintenance, and minor repairs.
5. Materials cost includes repair work performed by outside contractor and replacement of parts.

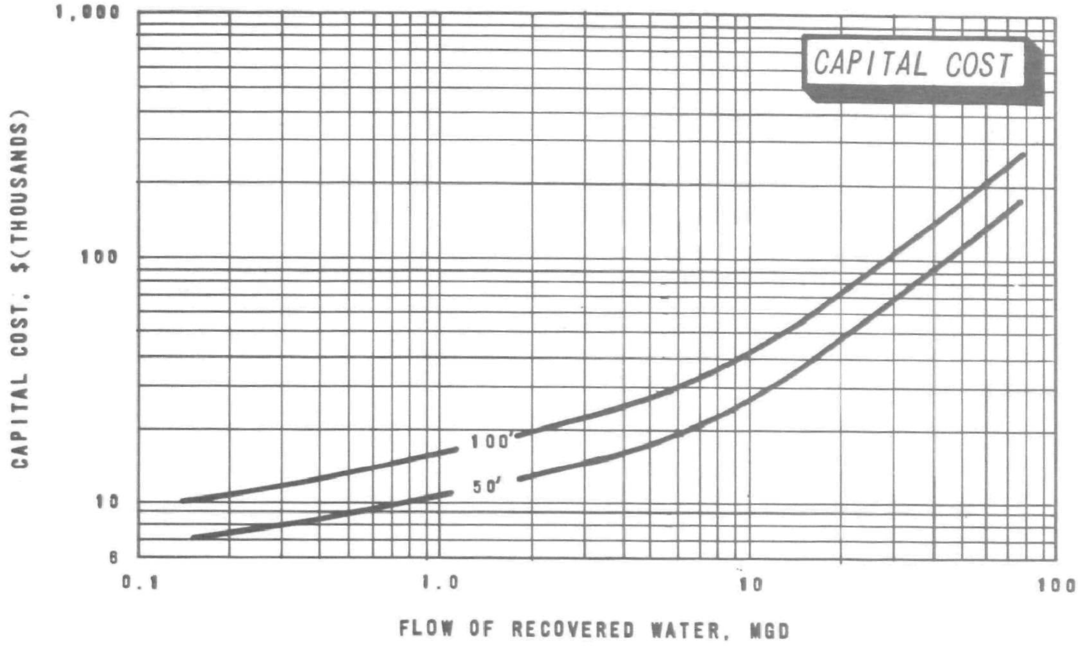
Note: The costs do not include any piping away from the well. The cost of discharge piping can be obtained from Figure 20, "Transmission-Force Mains."

Metric Conversion

1. ft x 0.305 = m
2. mgd x 43.8 = l/sec

Sources

Derived from previously published information [8].



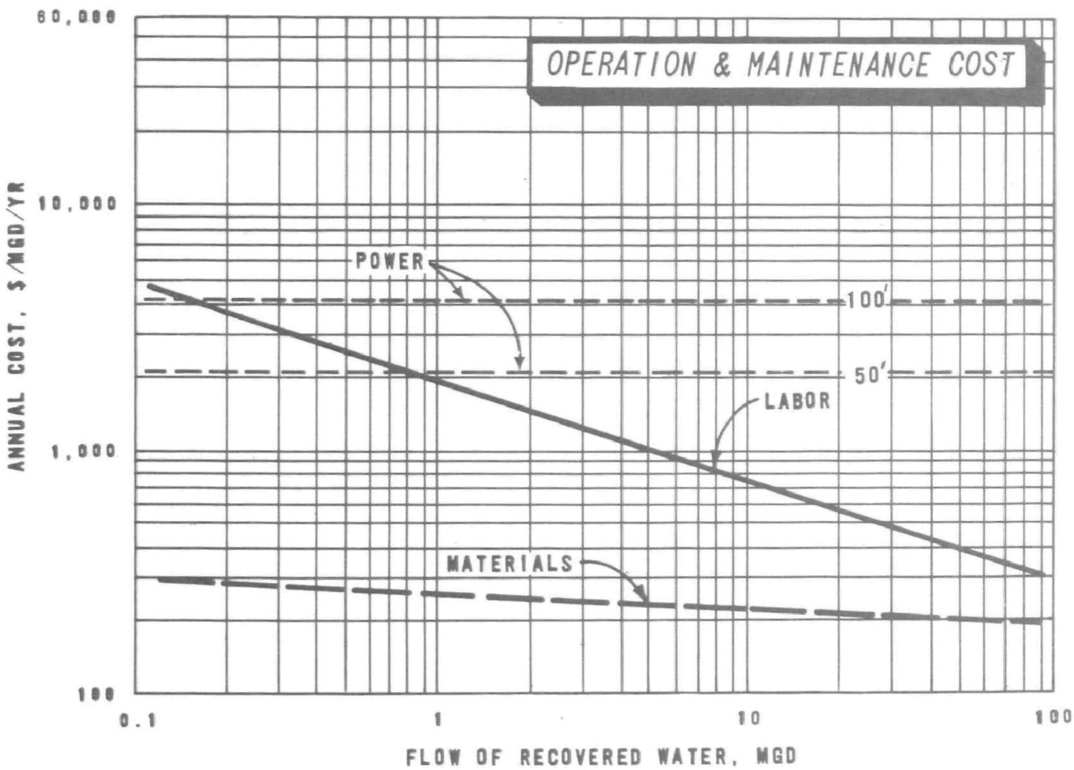


FIGURE 38. RECOVERY OF RENOVATED WATER – RECOVERY WELLS

ADDITIONAL COSTS

ADMINISTRATIVE AND LABORATORY FACILITIES

Basis of Costs

1. EPA Sewage Treatment Plant Construction Cost Index = 177.5.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

1. Capital cost includes:
   a. Administration and laboratory building
   b. Laboratory equipment
   c. Garage and shop facilities
2. Labor cost includes:
   a. Laboratory analyses and reporting
   b. Collection of samples
   c. Maintenance of buildings
3. Labor cost does not include administrative supervision. Labor for supervision included under individual components.
4. Materials cost includes:
   a. Chemicals and laboratory supplies
   b. General administrative supply items

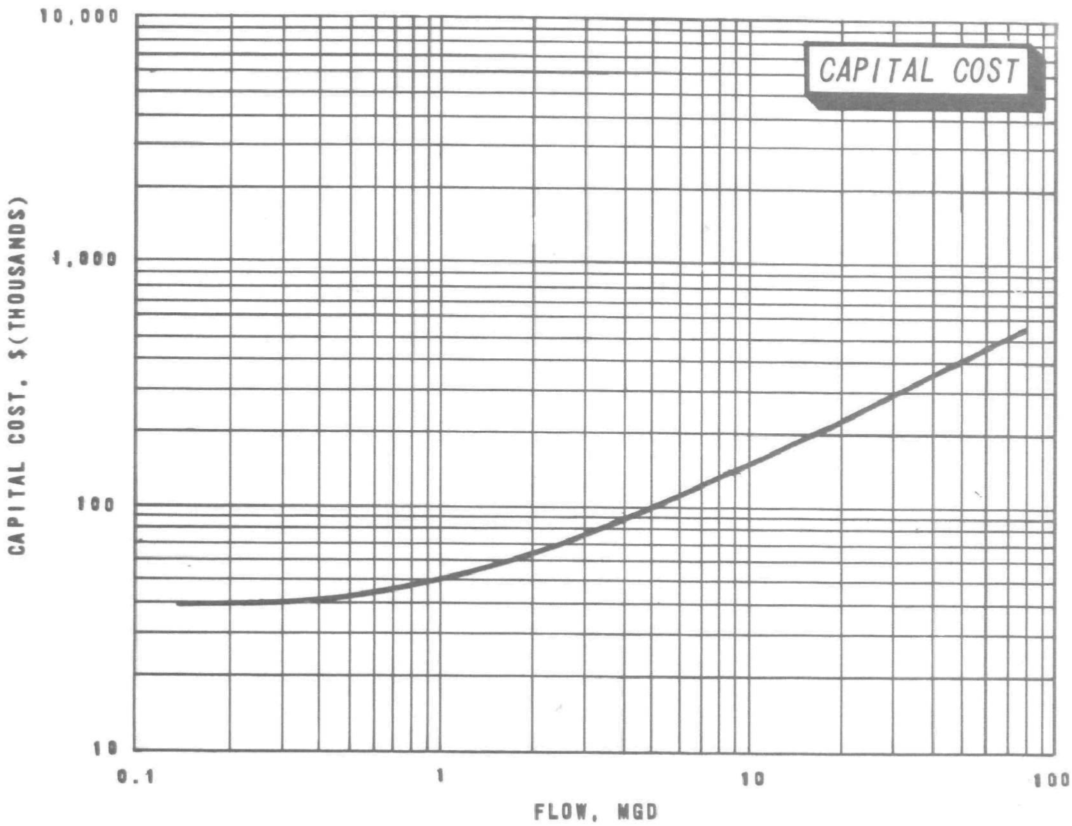
Note: When the land application system is to be an addition to an already existing conventional treatment system, complete facilities (as described here) are not required, and the costs given should be reduced accordingly.

Metric Conversion

1. mgd x 43.8 = l/sec

Sources

Derived from previously published cost information [37].



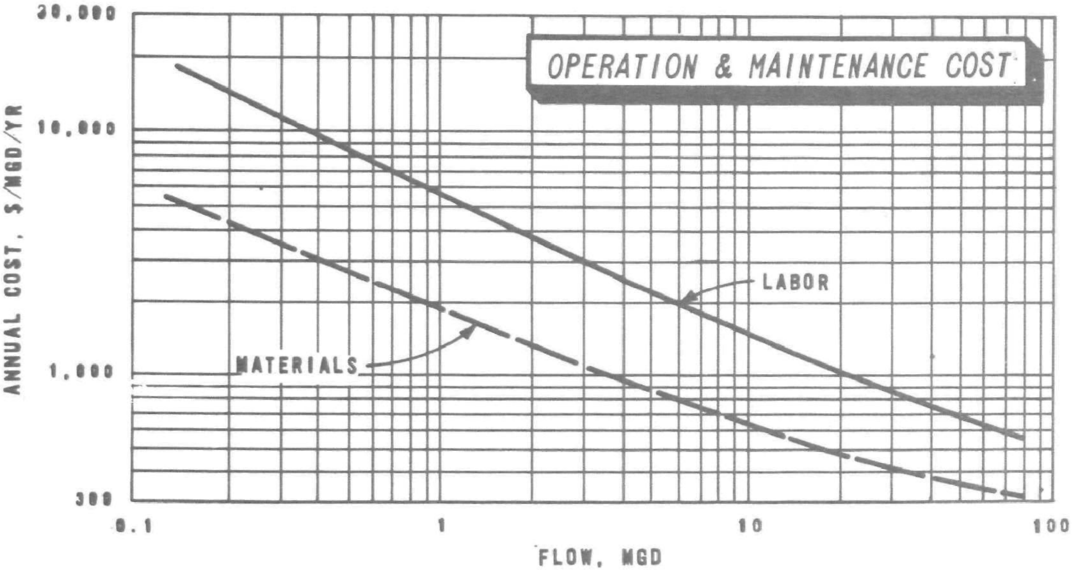


FIGURE 39. ADDITIONAL COSTS—
ADMINISTRATIVE AND LABORATORY FACILITIES

ADDITIONAL COSTS

MONITORING WELLS

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.
2. Labor rate including fringe benefits = $5.00/hr.

Assumptions

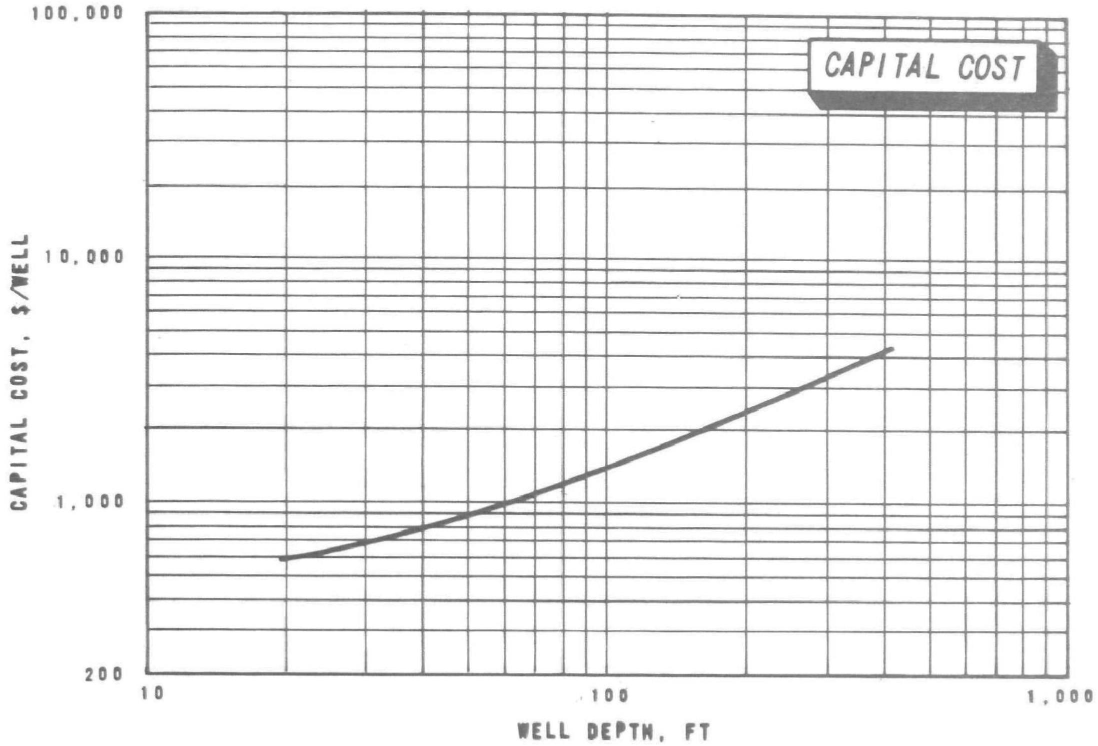
1. Capital cost includes:
   a. 4-in. (10 cm) diam drilled wells
   b. Vertical turbine pump, 10 gpm (0.63 l/sec)
   c. Controls and electrical work
2. Labor cost includes preventive maintenance and minor repairs by staff. Labor costs for sampling included in Figure 39, "Additional Costs-Administrative and Laboratory Facilities."
3. Materials cost includes repair work performed by outside contractor and replacement of parts.

Metric Conversion

1. ft x 0.305 = m

Sources

Derived from previously published cost information [8].



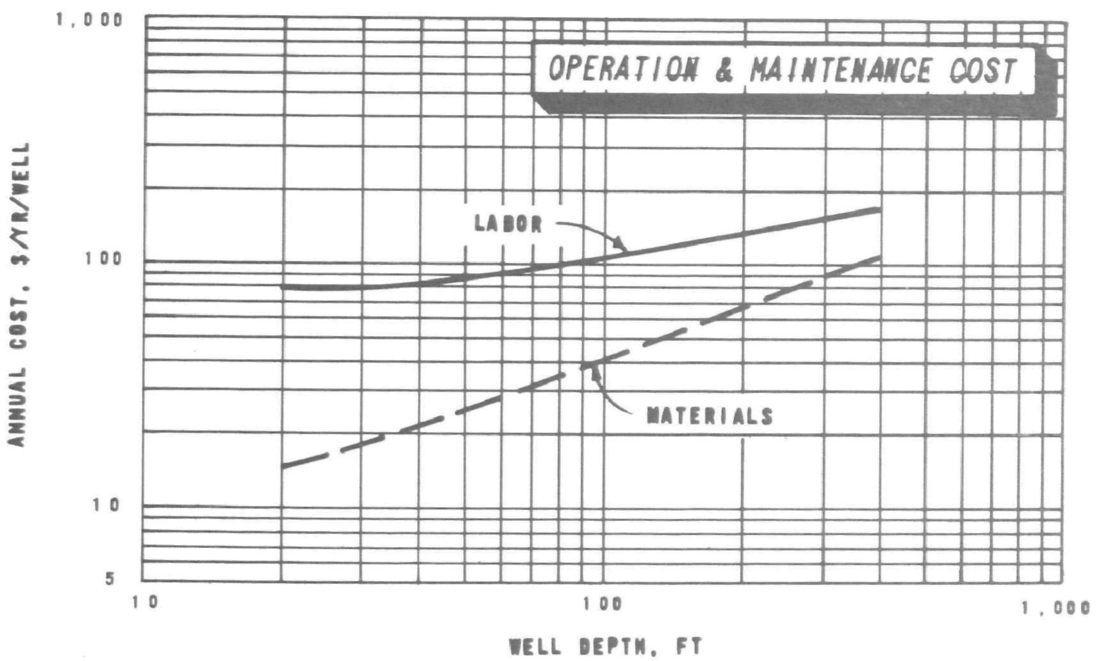


FIGURE 40. ADDITIONAL COSTS - MONITORING WELLS

ADDITIONAL COSTS

SERVICE ROADS AND FENCING

Basis of Costs

1. EPA Sewer Construction Cost Index = 194.2.

Assumptions

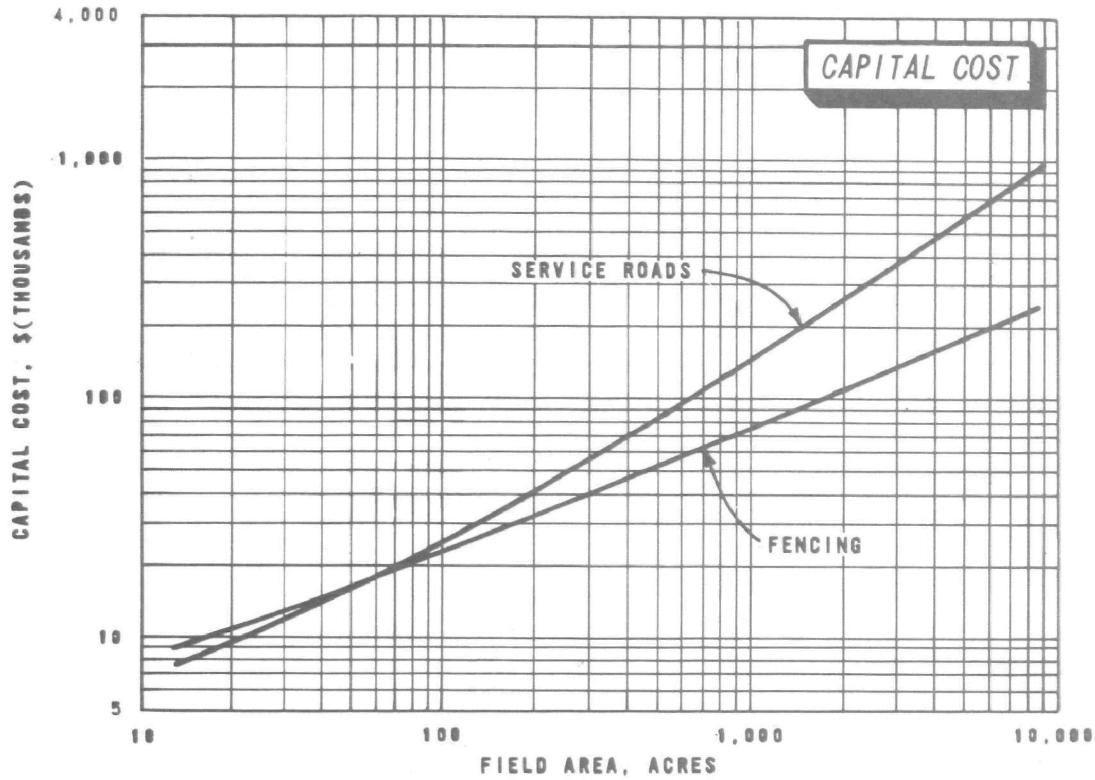
1. Costs of service roads and fencing given versus field area based on typical system layouts.
2. 12-ft (3.67 m) service roads, with gravel surface, around perimeter of area and within larger fields.
3. 4-ft (1.22 m) stock fence around perimeter of area.
4. Materials costs includes major repair after 10 yr.

Metric Conversion

1. acre x 0.405 = ha

Sources

Derived from cost calculations based on a series of typical designs.



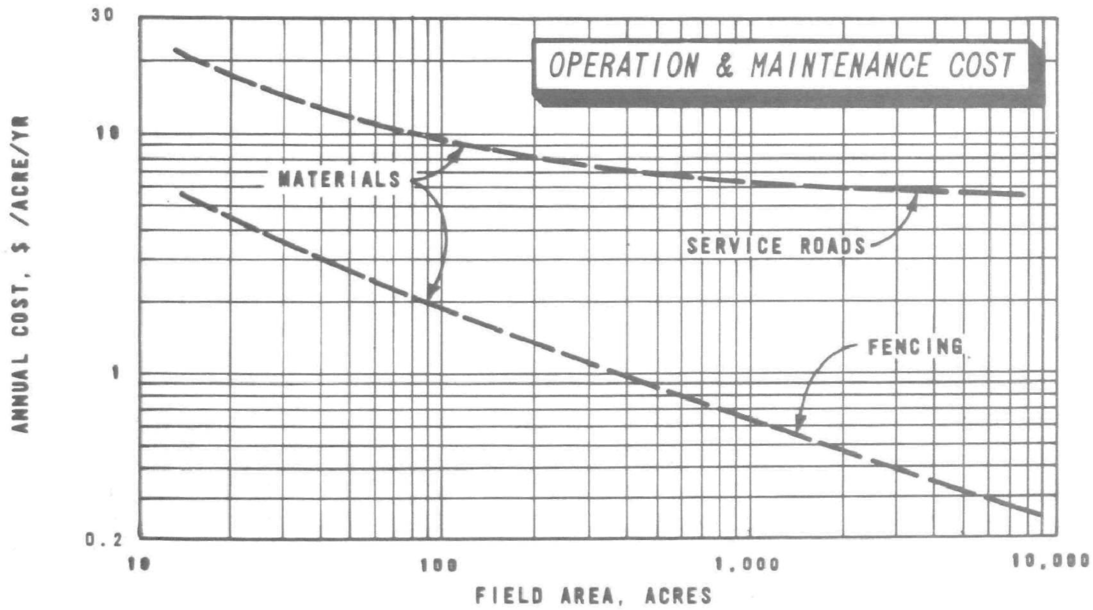


FIGURE 41. ADDITIONAL COSTS - SERVICE ROADS AND FENCING

ADDITIONAL COSTS

The following components are not readily presented by means of curves. Alternative means of cost estimation are therefore discussed.

Planting, Cultivation, and Harvesting

Annual agricultural costs will generally be quite variable, depending on the type of crop or vegetation grown and various local conditions. Costs should normally be determined from local sources; however, as an aid, sample costs to produce crops in California are given in Table 6 [42]. Similar cost information is available in most states through cooperative extension services at land grant universities.

Yardwork

Yardwork includes a variety of miscellaneous items. For conventional treatment systems, these items would generally include: general site clearing and grading, intercomponent piping, wiring, lighting, control structures, conduits, manholes, parking, sidewalk and road paving, landscaping, and local fencing. The suggested costs for these items are [37]: (1) capital cost, 14 percent of total construction cost; and (2) annual operation and maintenance cost, $1,500 to $4,000 per mgd for labor and $80 to $400 per mgd for materials. These cost allowances are suggested for land application systems if applied only to the cost of preapplication treatment components.

When applied to the cost of a land application system as a whole, the proportion of costs for yardwork would be considerably less because the costs of many of the items are included in the cost of other components.

Relocation of Residents

The purchases of large quantities of land will often require that some residents be relocated. If the project is to be federally funded, this must be conducted in accordance with the Uniform Relocation Assistance and Land Acquisition Policies Act of 1970. The cost of relocation, which can be significant, should be estimated on the basis of local conditions. Assistence in estimating this cost can often be obtained from agencies which must frequently deal with this problem, such as the U.S. Army, Corps of Engineers, and state highway agencies.

Table 6. SAMPLE COSTS TO PRODUCE CROPS IN CALIFORNIA [42]

Crop	Expected yield, per acre	Cost, $/acre: Cultural cost: Labor	Fuel and repairs	Materials	Equipment overhead	Harvest	Cash over-head	Rent	Manage-ment	Total	Cost per unit of yield, $
Perennials											
Alfalfa, green chop	36 tons	42	9	69	106[a]	55	18	125	26	450	12.50
Alfalfa hay	8 tons	26	2	70	39[a]	63	7	100	23	330	41.40
Alfafa, seed	310 lb	5	19[b]	51	--	17	20	50	8	170	0.55
Clover, seed	4 cwt[c]	18	3	90	40[a]	47	6	50	12	266	66.50
Pasture	12 aum[d]	5	1	46	6	--	4	94	4	160	13.33
Annuals											
Barley	2.5 tons	9	23[b]	34	--	19	19	60	12	176	3.52
Corn, silage	25 tons	32	10	43	31	57	10	98	80	361	14.44
Cotton	8 cwt (lint)	46	24	87	25	115	20	115	24	370	46.00
Grain sorghum	65 cwt	26	15	58	23	10	10	65	13	220	3.38

Note: Expected yield - Yields attainable under good management. Usually above average for the major producing area.

Labor cost - Includes wages, transportation, housing, and fringe benefits for farm workers.

Fuel and repairs - Includes fuel, oil, lubrication plus repairs (parts and labor) of farm equipment.

Material - Includes seed, fertilizer, water or power, spray, machine work hired, and other costs not included in labor or fuel and repairs.

Equipment overhead - Depreciation, interest, property taxes.

Harvest - Total cost of harvest up to receiving payment for product.

Cash overhead - Office, accounting, legal, interest on operating capital, and other costs of management.

Rent - Actual rent or cost of taxes, interest on investment, and depreciation of fixed facilities if land is owned.

Management - Usually calculated at 5 percent of the gross income.

a. Includes crop stand.

b. Custom operations.

c. cwt = 100 lb.

d. aum = animal unit months or forage eaten by one 1,000-lb cow in one month.

Metric conversion: lb x 2.2 = kg
acres x 0.405 = ha

Purchase of Water Rights

In many cases, particularly in the western states, the consumptive use of water may require the purchase of water rights. This may be either a capital or annual cost and should generally be determined on the basis of prevailing local practices.

Service and Interest Factor

A service and interest factor must be applied to the capital cost of the system to account for the additional cost of items such as:

- Contingencies
- Engineering
- Legal, fiscal, and administrative
- Interest during construction

Generally, the cost for these items ranges from about 35 percent of the nonland total construction cost for $50,000 projects, to about 25 percent for $100 million projects.

BENEFITS (NEGATIVE COSTS)

Benefits that may apply to land application systems range from the sale of crops grown or renovated water recovered to the leasing of land for secondary uses such as recreation. Monetary or revenue-producing benefits are discussed more fully in Appendix A, and possible nonrevenue producing benefits (social or environmental factors) are described in Appendix B.

Typically, an irrigation or overland flow treatment system would have an economic benefit from the sale of the crop grown.

Prices and yields will vary with the locality and should be determined from local sources. As an aid, however, typical yields and prices for some feed and fiber crops grown in California for 1973 are given in Table 7 [42]. Similar information is available in most states through cooperative extension services at land grand universities. The data for Reed canary grass are from a University of Missouri publication [2] where the Missouri price range is $15 to $30 per ton.

Table 7. TYPICAL YIELDS AND PRICES FOR CROPS IN CALIFORNIA FOR 1973 [42]

Crop	Unit	Price, $ per unit	Yield, units per acre
Perennials			
Alfalfa, hay	ton	49.00	8.0
Alfalfa, seed[a]	cwt[b]	42.00	3.1
Clover, seed[a]	cwt	62.50	4.0
Reed canary grass hay,[c]	ton	20.00	4.5
Annuals			
Barley	cwt	4.58	50.0
Corn, silage[d]	ton	15.00	25.0
Cotton, lint	cwt	47.00	8.0
Grain hay	ton	--	1.8
Grain sorghum	cwt	5.11	65

Note: Prices reflect seasonal averages received by farmers at the first delivery point.
a. For 1972.
b. cwt = 100 lb.
c. For Missouri, reference [2].
d. From reference [10].
Metric conversion: lb x 2.2 = kg
acres x 0.405 = ha

COST CALCULATION PROCEDURE

To facilitate the use of the cost data presented for Stage II sample cost calculation sheets have been developed and are shown as Tables 8 and 9. For each alternative to be analyzed, a similar calculation sheet could be used.

The procedure for calculating State II costs is as follows:

1. Enter the cost curve or table for the applicable cost components and read off the cost.

2. For operation and maintenance costs, multiply the resultant annual costs per unit by the appropriate units to yield the cost in dollars per year.

Table 8. STAGE II CALCULATION SHEET FOR CAPITAL COSTS

Alternative No. ______________ Average flow ______ mgd
Type of system ______________ Analysis date ______

Cost component	Total cost, $	Amortized cost, $/yr
Preapplication treatment		
______________	______	
______________	______	
Transmission		
______________	______	
______________	______	
Storage ______ mil gal.	______	
Field preparation		
______________	______	
______________	______	
Distribution		
______________	______	
______________	______	
Recovery		
______________	______	
______________	______	
Additional costs		
______________	______	
______________	______	
______________	______	
______________	______	
SUBTOTAL	______	
Service and interest factor @ ______ %	______	
SUBTOTAL	______	______
Land @ ______ /acre	______	______
TOTAL	______	______

Amortization:

i = ______%, n = ______yr, CRF = ______, PWF = ______

Table 9. STAGE II CALCULATION SHEET FOR OPERATION AND MAINTENANCE COSTS

Alternative No. ______ Type of system ______		Average flow ______ mgd Analysis date ______		
	Annual cost, $/yr			
	Labor	Power	Material	Total
Preapplication treatment				
______	____	____	____	____
______	____	____	____	____
Transmission				
______	____	____	____	____
______	____	____	____	____
Storage ______ mil gal.	____	____	____	____
Distribution				
______	____	____	____	____
______	____	____	____	____
Recovery				
______	____	____	____	____
______	____	____	____	____
Additional costs				
______	____	____	____	____
______	____	____	____	____
______	____	____	____	____
______	____	____	____	____
______	____	____	____	____
Benefits				
______	____	____	____	____
______	____	____	____	____
TOTALS	____	____	____	____

3. Adjust the costs for different cost indexes or wage or power rates.

4. Multiply the costs by an appropriate adjustment factor, if necessary.

5. Enter the resultant costs on the calculation sheet for that cost component.

For operation and maintenance costs, the total annual costs in dollars per year for labor, power, and materials, can now be found by summing the appropriate columns. For capital costs and amortized capital costs, however, several additional steps are necessary before totals can be determined. To obtain the total capital cost in dollars:

1. Increase the nonland subtotal of the costs of all components by the appropriate service and interest factor.

2. Add to this subtotal the cost of land.

To obtain the amortized cost in dollars per year:

1. Determine the capital recovery and present worth factors for the appropriate interest rate and period from Appendix E.

2. Multiply the nonland subtotal cost including the service and interest factor by the capital recovery factor to obtain the amortized nonland subtotal.

3. Determine the present worth of the salvage value of land by multiplying the initial cost of land by the appropriate present worth factor.

4. Subtract this value from the initial cost of land and multiply by the appropriate capital recovery factor to obtain the amortized cost of land.

5. Add the amortized nonland subtotal and the amortized cost of land.

EXAMPLE

The use of the cost curves, adjustment factors, and cost calculation sheets is illustrated in the following example. A hypothetical 1-mgd (43.8 l/sec) spray irrigation system to be constructed as part of a new wastewater treatment system in the Baltimore area, is used in this example. The example is meant to illustrate all facets of the cost curves, adjustment factors, and calculation sheets, and the total costs should not be compared with other hypothetical cost estimates.

Basis of Costs

1. The analysis date is July 1974. The EPA Construction Cost Indexes for that date are 204.7 for sewage treatment plants and 226.0 for sewers.

2. The labor rate including fringe benefits is $7.50/hr.

3. The electrical power cost is $0.02/kwh.

4. The materials cost is assumed to be equal to February 1973 cost.

5. Amortization at 7% is for 20 yr (capital recovery factor = 0.0944, present worth factor = 0.2584).

Assumptions

1. Preapplication treatment is to consist of preliminary treatment (screening, grit removal, and flow measurement), aerated lagoons, and chlorination.

2. The distance from the preapplication treatment plant to the land application site is 2 miles (3.2 km).

3. From a water balance calculation, the storage requirement is 35 days of detention.

4. The land terrain is essentially flat and covered with brush and trees. Debris can be disposed of onsite.

5. The application rate is to be 2.4 in./wk (6.1 cm/wk).

6. The soil is a loam underlain by clay.

7. Perennial grass is to be harvested by the staff twice a year, with a yield of 5 tons/acre/yr (11.2 metric ton/ha/yr).

8. The buffer zone requirement is 150 feet (45 m) around the irrigated area.

Solution (Total Capital Cost)

The determination of total capital cost is shown on a sample cost calculation sheet (Table 10, page 132), and is discussed for each line item. Additional minor assumption and adjustments are included to illustrate the range of applicability of the cost curves. All costs are given to the nearest thousand dollars.

Each of the costs determined from cost curves is updated, or trended to the analysis date by means of the indicated EPA Construction Cost Index, as follows:

1. For costs keyed to EPA Sewer Construction Cost Index

$$\text{updated cost} = \text{cost} \times \frac{204.7}{177.6}$$

2. For costs keyed to EPA Sewage Treatment Plant Construction Cost Index

$$\text{updated cost} = \text{cost} \times \frac{226.0}{194.2}$$

Land - From Figure 15, for a flow of 1 mgd (43.8 l/sec), a nonoperating time of 5 weeks, and an application rate of 2.4 in./wk (6.1 cm/wk).

field area requirement = 120 acres (48.6 ha)

Total land requirements based on a preliminary layout are:

	acres	ha
Field area	120	48.6
Buffer zone	33	13.4
Roads	3	1.2
Storage	9	3.6
Preapplication treatment	10	4.1
Total	175	70.9

Preapplication Treatment - Includes preliminary treatment, aerated lagoon, and chlorination.

1. Preliminary treatment - Based on maximum flow of 2.5 mgd (109 l/sec), updated cost from reference [37]	$ 63,000*
2. Aerated lagoon - Updated cost from Figure 16	$ 80,000
Chlorination - Updated cost from Figure 17	$ 40,000
	$120,000*

Transmission - Includes force main, repaving, right-or-way and easement acquisition, special crossings, and effluent pumping station.

1. Force main - From Figure 19, updated cost for 10-in. (25.4 cm) pipe is $14.50/lf	$153,000
Repaving - 1,000 ft (305 m). From Figure 19, updated cost of repaving for 10-in. pipe is $2.80/lf	$ 3,000
Right-of-way and easement acquisition- 4,000 ft (1,220 m). From local sources, cost is determined to be $2.00/lf	$ 8,000
Special crossings - 2 streets. Cost determined from local sources	$ 12,000
	$176,000*
2. Effluent pumping - From Figure 21, for total head of 150 ft (45.7 m)	$133,000*

Storage - From Figure 23, updated storage costs for required storage volume of 35 mil gal. (133,000 cu m) are:

reservoir construction	$ 46,000
lining	$103,000
riprap	$ 50,000
	$199,000*

* Number entered on Table 10, page 132.

Field Preparation - From Figure 24, updated cost or clearing site of brush and few trees	$ 62,000*
Distribution - Includes solid set spraying (buried) distribution system and distribution pumping.	
1. Solid set spraying (buried) - Updated cost from Figure 27	$ 201,000
Adjustment factor for 80 ft by 80 ft (24.4 m by 24.4 m) sprinkler spacing, or 6.8 sprinklers/acre	x 1.09
	$ 219,000*
2. Distribution pumping - From Figure 33, for total head of 150 ft (45.7 m)	$ 93,000*
Recovery of Renovated Water - 50 acres of underdrains with spacing of 100 ft. Updated cost from Figure 34	$ 58,000*
Additional Costs - Includes administrative and laboratory facilities, monitoring wells, and service roads and fencing.	
1. Administrative and laboratory facilities - Updated cost from Figure 39	$ 58,000*
2. Monitoring wells - Four wells of 20-ft depth. Updated cost from Figure 40	$ 3,000*
3. Service roads and fencing - Updated cost from Figure 41	$ 58,000*
First Subtotal - Total of numbers*	$1,242,000*
Service and Interest Factor - 30 percent of first subtotal	$ 372,000*
Second Subtotal - First subtotal plus service and interest factors	$1,615,000*
Land - Cost of $1,000/acre ($2,470/ha) determined from local sources	$ 175,000*
Total - The total capital cost is determined to be	$1,790.000*

* Number entered on Table 10, page 132.

Solution (Amortized Capital Cost)

The determination of the amortized capital cost is shown in the right-hand column of Table 10. First the nonland subtotal is amortized by multiplying it by the capital recovery factor of 0.0944. The resulting amortized cost of $152,000 per year is entered in the appropriate space.

A salvage value of zero at the end of the 20-year planning period is assumed for all components except land. For land, the salvage value after 20 years is assumed to be the present market value of $175,000. The present worth of the salvage value at 7 percent interest is $45,000, which is determined by multiplying the present market value by the present worth factor of 0.2584. The difference between the two values of $130,000 is multiplied by the capital recovery factor 0.0944 to obtain the amortized cost of land of $12,300 per year.

Solution (Operation and Maintenance Cost)

The determination of annual operation and maintenance costs is shown on a sample cost caluclation sheet (Table 11). The method for determining the costs of each individual component from cost curves is similar to that used for total capital costs; consequently, a discussion of that method for each line item is not included. Two items which are discussed because of their unique nature are cultivation and harvesting costs, and the benefits from crop sale.

Cultivation and Harvesting - From Table 6, the estimated labor and materials costs for alfalfa hay are:

1. Labor - Total total from labor and harvest columns of $89/acre ($36/ha)	$ 10,700
2. Materials - The total from the materials column less the estimated costs of water and fertilizer, or $60/acre ($24.3/ha)	$ 7,200

Benefits - From Table 7, the estimated negative materials cost from the sale of alfalfa hay, assuming a conservative yield of 5 tons/acre (11.2 metric tons/ha) and a price of $40/ton ($44/metric ton), is $200/acre ($494/ha).	($ 24,000)

Table 10. EXAMPLE OF COMPLETED STAGE II COST CALCULATION SHEET FOR CAPITAL COSTS

Alternative No. 1 Average flow 1 mgd
Type of system SPRAY IRR. Analysis date JUL '74

Cost component	Total cost, $	Amortized cost, $/yr
Preapplication treatment		
PRELIMINARY TREATMENT	63,000	
AERATED LAGOON AND CHLORINATION	120,000	
Transmission		
FORCE MAIN	176,000	
EFFLUENT PUMPING	133,000	
Storage 35 mil gal.	199,000	
Field preparation		
SITE CLEARING	62,000	
Distribution		
SOLID SET SPRAYING (BURIED)	219,000	
DISTRIBUTION PUMPING	93,000	
Recovery		
UNDERDRAINS	58,000	
Additional costs		
ADMIN & LAB FACILITIES	58,000	
MONITORING WELLS	3,000	
SERVICE ROADS & FENCING	58,000	
SUBTOTAL	1,242,000	
Service and interest factor @ 30 %	372,000	
SUBTOTAL	1,615,000	152,500
Land @ $1,000 /acre	175,000	12,300
TOTAL	1,790,000	164,800

Amortization:

i = 7 %, n = 20, CRF = 0.0944, PWF = 0.2584

Table 11. EXAMPLE OF COMPLETED STAGE II COST CALCULATION SHEET FOR OPERATION AND MAINTENANCE COSTS

Alternative No. 1 — Average flow 1 mgd
Type of system SPRAY IRR. — Analysis date JUL '74

	Annual cost, $/yr			
	Labor	Power	Material	Total
Preapplication treatment				
PRELIMINARY TREATMENT	7,100	--	1,500	8,600
AERATED LAGOON AND CHLORINATION	8,600	6,000	2,000	16,600
Transmission				
FORCE MAIN	--	--	500	500
EFFLUENT PUMPING	2,900	6,500	300	9,700
Storage 35 mil gal.	800	--	600	1,400
Distribution				
SOLID SET SPRAYING (BURIED)	12,300	--	1,500	13,800
DISTRIBUTION PUMPING	2,900	6,500	300	9,700
Recovery				
UNDERDRAINS	1,800	--	2,600	4,400
Additional costs				
ADMIN & LAB FACILITIES	8,600	--	1,900	10,500
MONITORING WELLS	500	--	100	600
SERVICE ROADS & FENCING	--	--	1,400	1,400
CULTIVATION & HARVESTING	10,700	--	7,200	17,900
Benefits				
SALE OF CROP	--	--	(24,000)	(24,000)
TOTALS	56,200	19,000	(4,100)	71,100

APPENDIX A

REVENUE-PRODUCING BENEFITS

Revenue-producing benefits should be incorporated into the cost-effectiveness analysis procedure as negative operation and maintenance costs. Possible monetary benefits include (1) sale of crop grown, (2) sale of renovated water recovered, (3) sale of surplus effluent to adjacent farmers or industries, (4) lease of purchased land back to farmers for the purpose of land application, and (5) lease of purchased lands to groups or individuals for secondary purposes, such as seasonal recreation. Additional benefits may arise in a specific locality if secondary uses of the water or land are practical. If recreational or other social or environmental benefits can be quantified, they should be incorporated into the monetary portion of the cost-effectiveness analysis.

SALE OF CROP GROWN

Data on cash returns from crops grown using effluents for irrigation are relatively scarce. Some information is included in Sullivan [50] and Pound and Crites [40]. Generally, the return from the sale of crops will offset only a portion of the total operation and maintenance cost. The cost of planting, cultivation, soil amendments (if necessary), and harvesting should be offset by the crop sale for a well-operated system. The relative costs and benefits of crop production will depend on local farming practice, the local economy, and the type of irrigation system. Referring back to Table 7, the returns from the sale of annual crops, especially where two or more crops can be raised in a year, are generally higher than for perennials. On the other hand, operating costs are usually higher and the needed degree of farming expertise may also be greater.

For overland flow systems, the economic returns generally amount to a small fraction of the operating costs [52, 18].

SALE OF RENOVATED WATER RECOVERED

This benefit is most applicable to overland flow and infiltration-percolation systems. The return will depend on the economic value of water in the area and the restrictions, if any, placed on the use of the water. This type of benefit has been incorporated into management plans for Bakersfield, California, and Phoenix, Arizona.

SALE OF SURPLUS EFFLUENT

This has been practiced at many existing land application sites in Texas and California to reduce storage costs, raise revenue, or, in one case, to satisfy a lawsuit. In Pomona, California, effluent is purchased from the Los Angeles County Sanitation Districts at $7 per acre-foot ($0.006 per cu m) and sold to various users at $5 to $22 per acre-foot ($0.004 to 0.018 per cu m) [40].

LEASE OF LAND FOR IRRIGATION

As an alternative to the conduct of farming operations by cities or sanitary districts, the land owned by the city or sanitary district is leased to a local farmer. Such leases are prevalent in the western states. Variations exist on the length of the lease, the requirements for storing or applying effluent, and the responsibility for maintenance of distribution facilities.

LEASE OF LAND FOR RECREATION

This type of benefit has been realized at Woodland, California, where land that is leased to a farmer for $23 per acre ($57 per ha) for irrigation in the summer is leased to a duck club for $6 per acre ($15 per ha) during the late fall for hunting privileges [40]. Other recreational benefits may be feasible at other locations.

APPENDIX B

NONREVENUE-PRODUCING BENEFITS

Nonrevenue-producing benefits including social and environmental benefits must be accounted for descriptively in the cost-effectiveness analysis to determine their significance and impact. Social benefits may include recreational activities, creation of greenbelts, or preservation of open space. Environmental factors may include reclamation of sterile soils or repulsion of saline water intrusion into aquifers by groundwater recharge.

SOCIAL BENEFITS

Recreational benefits should be included in the descriptive analysis, especially where parks or golf courses are to be irrigated. The creation of greenbelts and the preservation of open space are planning concepts specifically encouraged in P.L. 92-500 for wastewater management systems.

Where the social benefits identified can also be quantified, they should be incorporated into the monetary portion of the cost-effectiveness analysis.

ENVIRONMENTAL BENEFITS

Claims of environmental benefit for recycling of nutrients should be scrutinized closely to determine whether nutrients are being recycled, or whether nutrient problems are only being transferred from one area to another. Energy savings resulting from use of fertilizing agents in effluents in lieu of commercial fertilizer should be evaluated on the basis of actual fertilizer value of the effluent and local fertilizing practice.

Reclamation of sterile or strip-mined soil by applications of wastewater is an environmental benefit that is difficult to quantify. Similarly, groundwater recharge to reduce salinity intrusion is a qualitative benefit. The environmental benefits that can be achieved through a specific wastewater management alternative should be enumerated and evaluated to determine their significance.

APPENDIX C

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APPENDIX D

EPA SEWAGE TREATMENT PLANT AND SEWER CONSTRUCTION COST INDEXES
(1957-1959=100)

Table D-1. SEWAGE TREATMENT PLANT CONSTRUCTION COST INDEX

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual index
1957													98.04
1958													101.50
1959													103.65
1960													104.96
1961													105.83
1962									107.19	107.20	107.03	106.84	106.99
1963	106.80	107.05	107.08	107.11	107.22	107.78	108.07	108.52	108.58	109.54	109.51	109.60	108.52
1964	109.64	109.45	109.53	109.57	109.70	109.99	110.24	110.54	110.63	110.69	110.73	110.68	110.11
1965	110.82	111.04	111.07	111.12	111.15	111.83	112.31	112.57	112.70	112.82	112.87	113.09	111.95
1966	114.05	114.60	114.77	115.08	115.34	116.05	116.82	116.92	117.11	117.51	117.46	117.48	116.10
1967	117.76	118.08	118.11	118.22	118.34	119.11	119.63	120.28	120.59	120.89	120.91	121.01	119.41
1968	121.10	121.20	121.21	121.55	121.71	122.49	123.39	123.69	124.53	126.80	127.24	127.71	123.55
1969	128.68	129.50	129.84	130.03	130.03	131.11	132.44	135.34	135.46	135.85	136.61	136.86	132.65
1970	137.63	137.87	138.15	138.49	141.18	143.03	146.25	146.70	147.45	148.07	149.28	149.63	143.64
1971	150.60	150.89	153.34	155.41	157.29	158.62	160.58	165.07	166.30	166.25	166.44	167.19	159.83
1972	167.73	168.66	169.16	169.88	171.41	172.18	172.31	173.11	173.78	174.45	175.47	175.68	171.98
1973	176.14	177.49	180.38	181.62	182.56	182.86	183.68	183.87	184.51	184.97	185.79	187.51	182.62
1974	188.13	190.21	190.97	196.10	197.76	202.53	212.15						

a. Source: EPA, Office of Water Program Operations

Table D-2. SEWER CONSTRUCTION COST INDEX

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual index
1957													96.80
1958													100.42
1959													104.78
1960													106.22
1961													108.19
1962													109.72
1963													113.07
1964				114.50	114.42	114.69	115.19	115.10	115.26	115.20	115.03	115.01	114.72
1965	115.32	115.60	115.65	115.72	115.72	116.50	117.03	117.31	117.32	117.57	117.61	117.93	116.61
1966	118.19	118.68	119.02	119.68	119.97	120.40	121.39	121.18	121.44	121.93	122.20	122.16	120.52
1967	122.72	122.98	122.83	123.01	123.36	124.23	124.74	125.36	125.71	126.00	126.17	126.24	124.45
1968	126.31	126.94	127.04	127.40	127.90	128.80	129.90	130.31	131.12	132.39	133.33	133.44	129.57
1969	135.01	135.73	136.10	136.57	136.36	137.00	139.32	141.48	141.24	141.49	141.98	142.61	138.74
1970	143.29	144.00	144.60	145.74	146.81	149.15	152.57	152.62	153.48	154.38	154.82	155.94	149.78
1971	157.39	157.78	159.17	161.01	164.25	166.76	168.38	169.89	172.00	173.25	177.29	178.99	167.18
1972	179.56	180.42	181.50	181.99	184.79	185.67	186.23	187.53	188.73	189.27	190.44	191.06	185.60
1973	192.83	194.22	195.78	196.54	198.93	199.63	200.97	201.34	202.02	202.83	203.69	206.01	199.57
1974	206.68	208.40	210.49	214.20	217.48	224.62	229.68						

a. Source: EPA, Office of Water Program Operation.

Appendix E

PRESENT WORTH AND CAPITAL RECOVERY FACTORS

Table E-1. PRESENT WORTH FACTOR, PWF = $\frac{1}{(1 + i)^n}$

i = interest rate, %	N = period, yr				
	10	15	20	25	30
5.000	0.6139	0.4810	0.3769	0.2953	0.2313
5.125	0.6067	0.4725	0.3680	0.2866	0.2233
5.250	0.5995	0.4642	0.3594	0.2783	0.2154
5.375	0.5924	0.4560	0.3510	0.2701	0.2079
5.500	0.5854	0.4479	0.3427	0.2622	0.2006
5.625	0.5785	0.4400	0.3347	0.2546	0.1936
5.750	0.5717	0.4323	0.3269	0.2477	0.1869
5.875	0.5650	0.4247	0.3193	0.2400	0.1804
6.000	0.5584	0.4172	0.3118	0.2330	0.1741
6.125	0.5519	0.4100	0.3045	0.2262	0.1681
6.250	0.5454	0.4028	0.2975	0.2197	0.1622
6.375	0.5390	0.3957	0.2905	0.2133	0.1566
6.500	0.5327	0.3888	0.2838	0.2071	0.1512
6.625	0.5265	0.3280	0.2772	0.2012	0.1460
6.750	0.5204	0.3754	0.2708	0.1953	0.1409
6.875	0.5143	0.3689	0.2645	0.1897	0.1361
7.000	0.5083	0.3624	0.2584	0.1842	0.1314
7.125	0.5024	0.3562	0.2525	0.1789	0.1268
7.250	0.4966	0.3500	0.2466	0.1738	0.1225
7.375	0.4909	0.3439	0.2410	0.1688	0.1183
7.500	0.4852	0.3380	0.2354	0.1640	0.1142
7.625	0.4796	0.3321	0.2300	0.1593	0.1103
7.750	0.4741	0.3264	0.2247	0.1547	0.1065
7.875	0.4686	0.3208	0.2196	0.1503	0.1029
8.000	0.4632	0.3152	0.2145	0.1460	0.0994

Table E-2. CAPITAL RECOVERY FACTOR, CRF = $\frac{i(1 + i)^n}{(1 + i)^n - 1}$

i = interest rate, %	N = period, years				
	10	15	20	25	30
5.000	0.1295	0.0963	0.0802	0.0709	0.0650
5.125	0.1303	0.0972	0.0811	0.0718	0.0660
5.250	0.1310	0.0980	0.0820	0.0727	0.0670
5.375	0.1319	0.0988	0.0828	0.0736	0.0679
5.500	0.1326	0.0996	0.0837	0.0745	0.0688
5.625	0.1335	0.1005	0.0845	0.0755	0.0698
5.750	0.1343	0.1013	0.0854	0.0764	0.0707
5.875	0.1351	0.1021	0.0863	0.0773	0.0717
6.000	0.1359	0.1030	0.0872	0.0782	0.0726
6.125	0.1367	0.1038	0.0881	0.0792	0.0736
6.250	0.1375	0.1047	0.0890	0.0801	0.0746
6.375	0.1383	0.1055	0.0899	0.0810	0.0756
6.500	0.1391	0.1064	0.0908	0.0820	0.0766
6.625	0.1399	0.1072	0.0917	0.0829	0.0776
6.750	0.1407	0.1081	0.0926	0.0839	0.0786
6.875	0.1416	0.1089	0.0935	0.0848	0.0796
7.000	0.1424	0.1098	0.0944	0.0858	0.0806
7.125	0.1432	0.1107	0.0953	0.0868	0.0816
7.250	0.1440	0.1115	0.0962	0.0878	0.0826
7.375	0.1449	0.1124	0.0972	0.0887	0.0836
7.500	0.1457	0.1133	0.0981	0.0897	0.0847
7.625	0.1465	0.1142	0.0990	0.0907	0.0857
7.750	0.1474	0.1151	0.1000	0.0917	0.0867
7.875	0.1482	0.1159	0.1009	1.0927	0.0878
8.000	0.1490	0.1168	0.1019	0.0937	0.0888

APPENDIX F

COST-EFFECTIVENESS ANALYSIS GUIDELINES

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—GRANTS

PART 35—STATE AND LOCAL ASSISTANCE

Appendix A—Cost-Effectiveness Analysis

On July 3, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing guidelines on cost-effectiveness analysis pursuant to section 212(2)(c) of the Federal Water Pollution Act Amendments of 1972 (the Act) to be published as appendix A to 40 CFR part 35.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. No changes were made in the guidelines as earlier proposed. All written comments are on file with the agency.

Effective date.—These regulations shall become effective October 10, 1973.

Dated September 4, 1973.

JOHN QUARLES,
Acting Administrator.

APPENDIX A

COST EFFECTIVENESS ANALYSIS GUIDELINES

a. *Purpose.*—These guidelines provide a basic methodology for determining the most cost-effective waste treatment management system or the most cost-effective component part of any waste treatment management system.

b. *Authority.*—The guidelines contained herein are provided pursuant to section 212 (2)(C) of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

c. *Applicability.*—These guidelines apply to the development of plans for and the selection of component parts of a waste treatment management system for which a Federal grant is awarded under 40 CFR, Part 35.

d. *Definitions.*—Definitions of terms used in these guidelines are as follows:

(1) *Waste treatment management system.*—A system used to restore the integrity of the Nation's waters. Waste treatment management system is used synonymously with "treatment works" as defined in 40 CFR, Part 35.905-15.

(2) *Cost-effectiveness analysis.*—An analysis performed to determine which waste treatment management system or component part thereof will result in the minimum total resources costs over time to meet the Federal, State or local requirements.

(3) *Planning period.*—The period over which a waste treatment management system is evaluated for cost-effectiveness. The planning period commences with the initial operation of the system.

(4) *Service life.*—The period of time during which a component of a waste treatment management system will be capable of performing a function.

(5) *Useful life.*—The period of time during which a component of a waste treatment management system will be required to perform a function which is necessary to the system's operation.

e. *Identification, selection and screening of alternatives*—(1) *Identification of alternatives.*—All feasible alternative waste management systems shall be initially identified. These alternatives should include systems discharging to receiving waters, systems using land or subsurface disposal techniques, and systems employing the reuse of wastewater. In identifying alternatives, the possibility of staged development of the system shall be considered.

(2) *Screening of alternatives.*—The identified alternatives shall be systematically screened to define those capable of meeting the applicable Federal, State, and local criteria.

(3) *Selection of alternatives.*—The screened alternatives shall be initially analyzed to determine which systems have cost-effective potential and which should be fully evaluated according to the cost-effectiveness analysis procedures established in these guidelines.

(4) *Extent of effort.*—The extent of effort and the level of sophistication used in the cost-effectiveness analysis should reflect the size and importance of the project.

f. *Cost-Effective analysis procedures*—(1) *Method of Analysis.*—The resources costs shall be evaluated through the use of opportunity costs. For those resources that can be expressed in monetary terms, the interest (discount) rate established in section (f)(5) will be used. Monetary costs shall be calculated in terms of present worth values or equivalent annual values over the planning period as defined in section (f)(2). Non-monetary factors (e.g., social and environmental) shall be accounted for descriptively in the analysis in order to determine their significance and impact.

The most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse nonmonetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse and/or land and subsurface disposal.

(2) *Planning period.*—The planning period for the cost-effectiveness analysis shall be 20 years.

(3) *Elements of cost.*—The costs to be considered shall include the total values of the resources attributable to the waste treatment management system or to one of its component parts. To determine these values, all monies necessary for capital construction costs and operation and maintenance costs shall be identified.

Capital construction costs used in a cost-effectiveness analysis shall include all contractors' costs of construction including overhead and profit; costs of land, relocation, and right-of-way and easement acquisition; design engineering, field exploration, and engineering services during construction; administrative and legal services including costs of bond sales; startup costs such as operator training; and interest during construction. Contingency allowances consistent with the level of complexity and detail of the cost estimates shall be included.

Annual costs for operation and maintenance (including routine replacement of equipment and equipment parts) shall be included in the cost-effectiveness analysis. These costs shall be adequate to ensure effective and dependable operation during the planning period for the system. Annual costs shall be divided between fixed annual costs and costs which would be dependent on the annual quantity of wastewater collected and treated.

(4) *Prices.*—The various components of cost shall be calculated on the basis of market prices prevailing at the time of the cost-effectiveness analysis. Inflation of wages and prices shall not be considered in the analysis. The implied assumption is that all prices involved will tend to change over time by approximately the same percentage. Thus, the results of the cost effectiveness analysis will not be affected by changes in the general level of prices.

Exceptions to the foregoing can be made if their is justification for expecting significant changes in the relative prices of certain items during the planning period. If such cases are identified, the expected change in these prices should be made to reflect their future relative deviation from the general price level.

(5) *Interest (discount) rate.*—A rate of 7 percent per year will be used for the cost-effectiveness analysis until the promulgation of the Water Resources Council's "Proposed Principles and Standards for Planning Water and Related Land Resources." After promulgation of the above regulation, the rate established for water resource projects shall be used for the cost-effectiveness analysis.

(6) *Interest during construction.*—In cases where capital expenditures can be expected to be fairly uniform during the construction period, interest during construction may be calculated as $I \times \frac{1}{2} P \times C$ where:

I=the interest (discount) rate in Section f(5).
P=the construction period in years.
C=the total capital expenditures.

In cases when expenditures will not be uniform, or when the construction period will be greater than three years, interest during construction shall be calculated on a year-by-year basis.

(7) *Service life.*—The service life of treatment works for a cost-effectiveness analysis shall be as follows:

Land	Permanent
Structures (includes plant buildings, concrete process tankage, basins, etc.; sewage collection and conveyance pipelines; lift station structures; tunnels; outfalls)	30–50 years
Process equipment (includes major process equipment such as clarifier mechanism, vacuum filters, etc.; steel process tankage and chemical storage facilities; electrical generating facilities on standby service only).	15–30 years
Auxiliary equipment (includes instruments and control facilities; sewage pumps and electric motors; mechanical equipment such as compressors, aeration systems, centrifuges, chlorinators, etc.; electrical generating facilities on regular service).	10–15 years

Other service life periods will be acceptable when sufficient justification can be provided.

Where a system or a component is for interim service and the anticipated useful life is less than the service life, the useful life shall be substituted for the service life of the facility in the analysis.

(8) *Salvage value.*—Land for treatment works, including land used as part of the treatment process or for ultimate disposal of residues, shall be assumed to have a salvage value at the end of the planning period equal to its prevailing market value at the time of the analysis. Right-of-way easements shall be considered to have a salvage value not greater than the prevailing market value at the time of the analysis.

Structures will be assumed to have a salvage value if there is a use for such structures at the end of the planning period. In this case, salvage value shall be estimated using straightline depreciation during the service life of the treatment works.

For phased additions of process equipment and auxiliary equipment, salvage value at the end of the planning period may be estimated under the same conditions and on the same basis as described above for structures.

When the anticipated useful life of a facility is less than 20 years (for analysis of interim facilities), salvage value can be claimed for equipment where it can be clearly demonstrated that a specific market or reuse opportunity will exist.

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Appendix G

GLOSSARY OF TERMS, ABBREVIATIONS, AND CONVERSION FACTORS

TERMS

Aerosol - A suspension of fine solid or liquid particles in air or gas.

Application rate - The rate at which a liquid is dosed to the land (in./hr, ft/yr, etc.).

Aquifer - A geologic formation or stratum that contains water and transmits it from one point to another in quantities sufficient to permit economic development.

Border strip method - Application of water over the surface of the soil. Water is applied at the upper end of the long, relatively narrow strip.

Contour check method - Surface application by flooding. Dikes constructed at contour intervals to hold the water.

Cost-effectiveness analysis - The procedure for economic evaluation of wastewater treatment alternatives given in the guidelines as 40 CFR 35-Appendix A.

Conventional wastewater treatment - Reduction of pollutant concentrations in wastewater by physical, chemical, or biological means.

Drainability - Ability of the soil system to accept and transmit water by infiltration and percolation.

Evapotranspiration - The unit amount of water used on a given area in transpiration, building of plant tissue, and evaporation from adjacent soil, snow, or intercepted precipitation in any specified time.

Field area - Total area of treatment for a land-application system including the wetted area.

Flooding - A method of surface application of water which includes border strip, contour check, and spreading methods.

Grass filtration - See overland flow.

Groundwater - The body of water that is retained in the saturated zone which tends to move by hydraulic gradient to lower levels.

Groundwater table - The free surface elevation of the groundwater; this level will rise and fall with additions or withdrawals.

Infiltration - The entrance of applied water into the soil through the soil-water interface.

Infiltration-percolation - An approach to land application in which large volumes of wastewater are applied to the land, infiltrate the surface, and percolate through the soil pores.

Irrigation - Application of water to the land to meet the growth needs of plants.

Land application - The discharge of wastewater onto the soil for treatment or reuse.

Loading rate - The average amount of liquid or solids applied to the land over a fixed time period, taking into account periodic resting.

Overland flow - Wastewater treatment by spray-runoff (also known as "grass filtration" and "spray runoff") in which wastewater is sprayed onto gently sloping, relatively impermeable soil that has been planted to vegetation. Biological oxidation occurs as the wastewater flows over the ground and contacts the biota in the vegetative litter.

Pathogenic organisms - Microorganisms that can transmit diseases.

Percolation - The movement of water beneath the ground surface both vertically and horizontally, but above the groundwater table.

Permeability - The ability of a substance (soil) to allow appreciable movement of water through it when saturated and actuated by a hydrostatic pressure.

Primary effluent - Wastewater that has been treated by screening and sedimentation.

Ridge and furrow method - The surface application of water to the land through formed furrows; wastewater flows down the furrows and plants may be grown on the ridges.

Secondary treatment - Treatment of wastewater which meets the standards set forth in 40 CFR 133.

Sewage farming - Originally involved the transporting of sewage to rural areas for land disposal. Later practice included reusing the water for irrigation and fertilization of crops.

Soil texture - The relative proportions of the various soil separates--sand, silt, and clay.

Soil water - That water present in the soil pores in an unsaturated zone above the groundwater table.

Spraying - Application of water to the land by means of stationary or moving sprinklers.

Spray-runoff - See overland flow.

Transpiration - The net quantity of water absorbed through plant roots that is used directly in building plant tissue, or given off to the atmosphere.

Viruses - Submicroscopic biological structures containing all the information necessary for their own reproduction.

Wetted area - Area within the spray diameter of the sprinklers.

ABBREVIATIONS

acre-ft	-	acre-foot
ASCE	-	American Society of Civil Engineers
BPT	-	best practicable treatment technology
crf	-	capital recovery factor
cm	-	centimeter
cu m	-	cubic meter
cy	-	cubic yard
diam	-	diameter
EPA	-	Environmental Protection Agency
ENRCC	-	*Engineering News-Record* construction cost (index)
fps	-	feet per second
ft	-	foot
gal.	-	gallon
gpm	-	gallons per minute
ha	-	hectare
hr	-	hour
in.	-	inch
kg	-	kilogram
kg/sq cm	-	kilograms per square centimeter
km	-	kilometer
kwh	-	kilowatt-hour
l	-	liter
lb	-	pound
lf	-	linear feet
m	-	meter
mil gal.	-	million gallons
mgd	-	million gallons per day
mg/l	-	milligrams per liter
ml	-	milliliter
mm	-	millimeter
O&M	-	operations and maintenance

ppm	-	parts per million
perim	-	perimeter
psi	-	pounds per square inch
PVC	-	polyvinylchloride
pwf	-	present worth factor
Q	-	flow
Q_e	-	effective flow
SCS	-	Soil Conservation Service
sec	-	second
sff	-	sinking fund factor
sq cm	-	square centimeter
sq ft	-	square foot
STPCC	-	sewage treatment plant construction cost (index)
wk	-	week
yr	-	year

CONVERSION FACTORS

million gallons x 3.06 = acre-feet
acre-inch x 27,154 = gallons
mg/l x ft/yr x 2.7 = lb/acre/yr

CONVERSION FACTORS
English to Metric

English unit	Abbreviation	Multiplier	Abbreviation	Metric unit
acre	acre	0.405	ha	hectare
acre-foot	acre-ft	1,233.5	cu m	cubic meter
cents per thousand gallons	¢/1,000 gal.	0.264	¢/1,000 l	cents per thousand liters
cubic foot	cf	28.32	l	liter
cubic feet per second	cfs	28.32	l/sec	liters per second
cubic inch	cu in.	16.39 0.0164	cu cm l	cubic centimeter liter
cubic yard	cy	0.765 764.6	cu m l	cubic meter liter
cubic yards per acre	cy/acre	1.89	cu m/ha	cubic meters per hectare
degree Fahrenheit	deg F	0.555 (°F-32)	deg C	degree Celsius
feet per second	fps	0.305	m/sec	meters per second
feet per year	ft/yr	0.305	m/yr	meters per year
foot (feet)	ft	0.305	m	meter(s)
gallon(s)	gal.	3.785	l	liter(s)
gallons per acre per day	gad	9.353	l/day/ha	liters per day per hectare
gallons per capita per day	gcd	3.785	l/capita/day	liters per capita per day
gallons per day	gpd	4.381×10^{-5}	l/sec	liters per second
gallons per day per square foot	gpd/sq ft	1.698×10^{-5} 0.283	cu m/hr/sq m cu m/min/ha	cubic meters per hour per square meter cubic meters per minute per hectare
gallons per minute	gpm	0.0631	l/sec	liters per second
gallons per minute per square foot	gpm/sq ft	2.445 0.679	cu m/hr/sq m l/sec/sq m	cubic meters per hour per square meter liters per second per square meter
horsepower	hp	0.746	kw	kilowatts
inch(es)	in.	2.54	cm	centimeter
inches per day	in./day	2.54	cm/day	centimeters per day
inches per hour	in./hr	2.54	cm/hr	centimeters per hour
inches per week	in./wk	2.54	cm/wk	centimeters per week
million gallons	mil gal.	3.785 3,785.0	Ml cu m	megaliters (liters x 10^6) cubic meters
million gallons per acre per day	mgad	0.039	cu m/hr/sq m	cubic meters per hour per square meter
million gallons per day	mgd	43.808 0.0438	l/sec cu m/sec	liters per second cubic meters per second
mile	mi	1.609 1,609	km m	kilometer meter
parts per million	ppm	1.0	mg/l	milligrams per liter
pound(s)	lb	0.454 453.6	kg g	kilogram grams
pounds per acre	lb/acre	1.121	kg/ha	kilograms per hectare
pounds per day per acre	lb/day/acre	1.121	kg/day/ha	kilograms per day per hectare
pounds per million gallons	lb/mil gal.	0.120	mg/l	milligrams per liter
pounds per square inch	psi	0.0703	kg/sq cm	kilograms per square centimeter
square foot	sq ft	0.0929	sq m	square meter
square inch	sq in.	6.452	sq cm	square centimeter
square mile	sq mi	2.590	sq km	square kilometer
square yard	sq yd	0.836	sq m	square meter
ton (short)	ton	907.2 0.907	kg metric ton	kilogram metric ton
tons per acre	tons/acre	0.3674	metric tons/ha	metric tons per hectare
yard	yd	0.914	m	meter

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