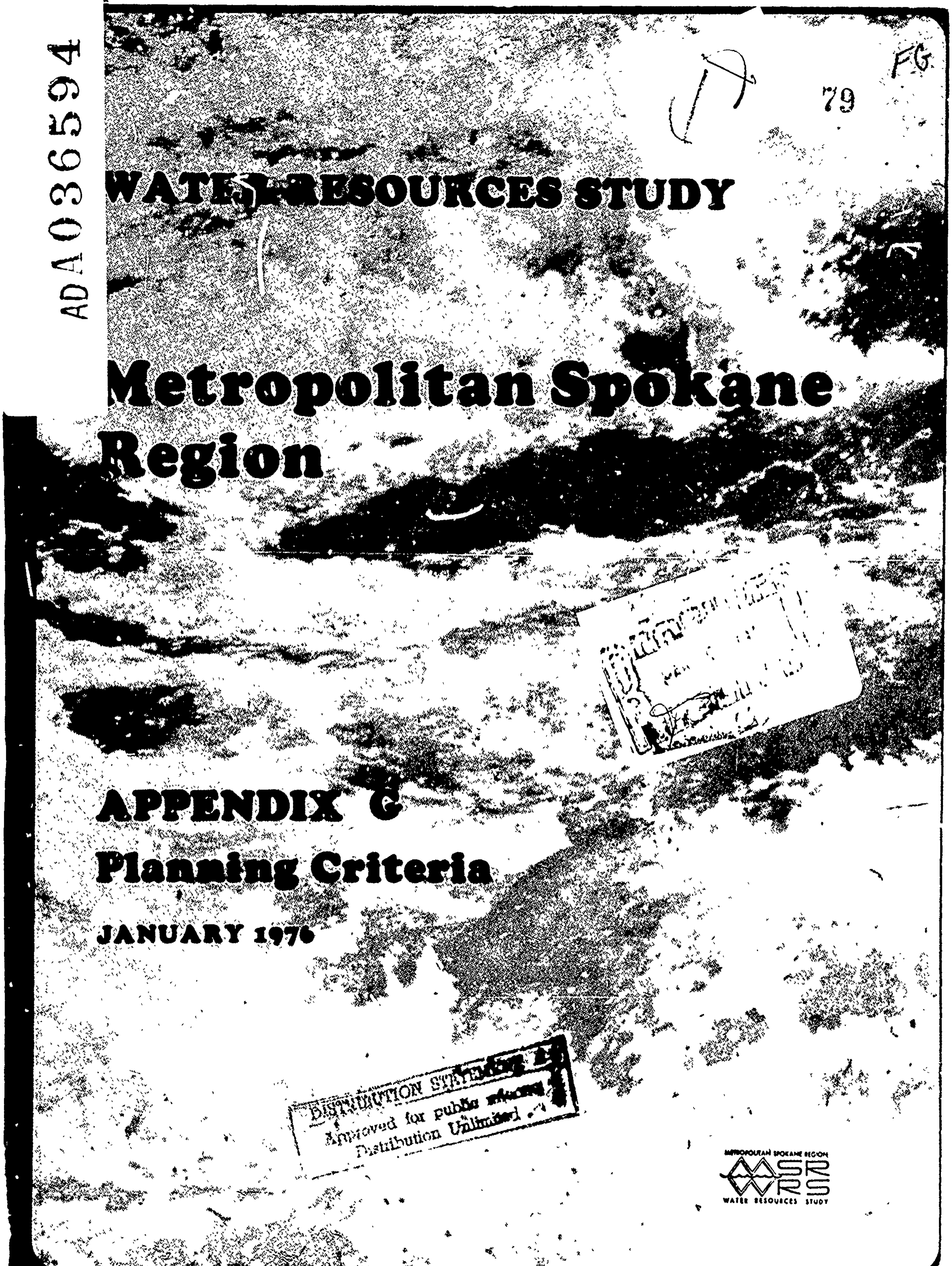

WATER RESOURCES STUDY

Metropolitan Spokane Region

APPENDIX C
Planning Criteria

JANUARY 1976

METROPOLITAN SPOKANE REGION
MSRWRS
WATER RESOURCES STUDY

LIST OF REPORTS AND APPENDICES

REPORTS

Summary Report

Technical Report

APPENDIX	TITLE
A	Surface Water
B	Geology and Groundwater
C	Water Use
D	Wastewater Generation and Treatment
E	Environment and Recreation
F	Demographic and Economic Characteristics
G	**PLANNING CRITERIA**
H (Volume 1)	Plan Formulation and Evaluation
H (Volume 2)	Plan Formulation and Evaluation
I	Institutional Analysis
J	Water Quality Simulation Model

(6)

METROPOLITAN SPOKANE REGION WATER RESOURCES STUDY.

APPENDIX G.

PLANNING CRITERIA.

(12) 426 p.

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Department of the Army
Corps of Engineers, Seattle District

Kennedy-Tudor Consulting Engineers

ACKNOWLEDGEMENTS

The Metropolitan Spokane Region Water Resources study was accomplished by the Seattle District, U.S. Army Corps of Engineers assisted by Kennedy-Tudor Consulting Engineers under sponsorship of the Spokane Regional Planning Conference. Technical guidance was provided by the Spokane River Basin Coordinating Committee, with general guidance from the study's citizens committee. Major cooperating agencies include Spokane City and County, and the Washington State Department of Ecology. The study was coordinated with appropriate Federal and State agencies and with the general public within the metropolitan Spokane area.

The summary report was prepared by the Seattle District Corps of Engineers. The technical report and appendices were prepared for the Seattle District, Corps of Engineers by Kennedy-Tudor Consulting Engineers.

PREFACE

With the enactment of the Federal Water Pollution Control Act Amendment of 1972 (Public Law 92-500), new national goals have been established for the elimination of pollution discharges into our streams and lakes. This appendix is a part of the report prepared to assist local government in satisfying State and Federal Requirements relating to Public Law 92-500. The suggestions contained in this report are for implementation by local interests with available assistance from other local, State and Federal agencies. The study suggests a regional wastewater management plan for the metropolitan Spokane urban area and provides major input to Washington State Department of Ecology Section 303e plans for the Spokane River Basin in Washington State. Also included in the study are planning suggestions for urban runoff and flood control, and the protection of the area's water supply resources.

As listed on the inside front cover, documentation for this study consists of a Summary Report and a Technical Report with supporting Appendices A through J.

The Technical Report summarizes Appendices A through J, which contain 58 individual task section reports prepared during the study. These task sections are listed by title in Attachment I of the Technical Report. Generally, the numbering of appendix task sections reflects the following system:

Study Task Sections	Type of Study Activity
300's	Data Collection
400's	Data Evaluation and Projection
500's	Identification of Unmet Needs
600's	Development of Alternative Plans
700's	Evaluation Comparison and Selection of Plans
800's	Institutional Arrangements

Pages within each appendix are numbered by task section, as illustrated below:

701.2 - 45

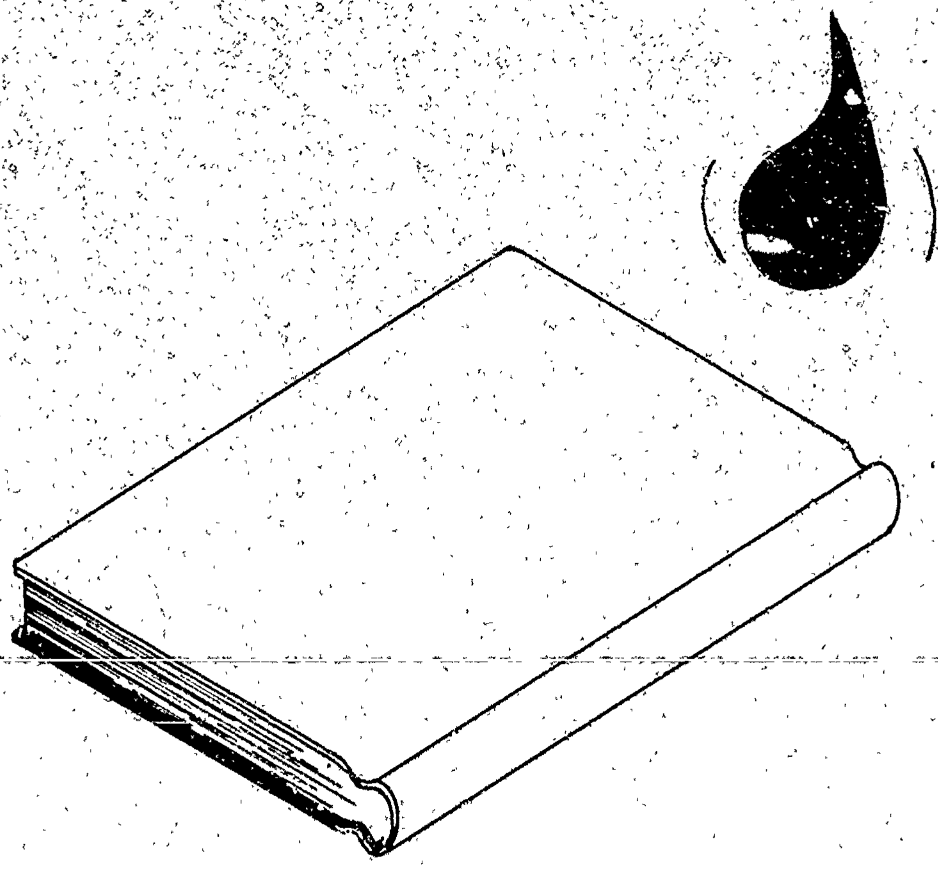
Task section identifier ——/ (701.2)

\\—— Identifies page number, numbered consecutively fro[m] beginning of task section (45)

APPENDIX G - PLANNING CRITERIA

CONTENTS

A detailed index for each task section precedes the respective section text.



SECTION 317

WATER QUALITY STANDARDS AND PLANNING REQUIREMENTS

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 317

WATER QUALITY STANDARDS AND PLANNING REQUIREMENTS

20 May 1974

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

PREFACE NOTE*

This section was completed in draft form 5 February 1974 including Corps comment made and incorporated in the drafting process. Updating of this section does not extend beyond revisions for in-house review through March 1974 and draft comments from DOE dated 16 May 1974.

There has been a subsequent and continuing development of both law and regulation not reflected in this section. Subsequent task report sections have incorporated newer developments as available at the time of their drafting or revision. Reference should be made to the following sections for additional information:

Section 603.1 Disposal Criteria for Public Facilities (Revised 30 September 1975)

Section 603.3 Sludge Treatment and Disposal Criteria (Revised 10 October 1975)

Also refer to Chapter 9 of the Summary and Recommendations for discussion of the implications of the Safe Drinking Water Act, PL 93-523, as applicable to specific study area problems.

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WATER QUALITY STANDARDS AND
PLANNING REQUIREMENTS

INDEX - Continued

WATER QUALITY STANDARDS AND

PLANNING REQUIREMENTS*

Public Law 92-500

The law of the land with respect to water pollution control is The Federal Water Pollution Control Act Amendment of 1972, Public Law 92-500. Although the states are given certain responsibility for implementation of the goals of this federal law, the delegation of authority is subject to extensive and pervasive guidelines and constraints from the federal level. For all practical purposes, the federal law and the interpretive guidelines issued by the federal Environmental Protection Agency (EPA) define activity at the state level. The federal statute has, in addition to the weight of law, the persuasive force implicit in being the source of funds for construction which can be granted only to implement plans developed in conformance with federal planning processes and guidelines.

Federal law 92-500 is the most extensive, complicated piece of legislation developed in this field. The guidelines and strategy being developed by EPA in support of the law are correspondingly extensive and complex. In the following paragraphs, a general abstract of the federal law, supporting guidelines, strategy and derived state law is presented, ending with a summary of the implications to this study with respect to (1) water quality standards and (2) planning requirements.

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*See preface note.

point sources and controllable non-point sources.

2. Preserve existing high water quality while substandard ambient conditions are improved to meet water quality standards.

3. Promote participation of the states.

4. Concentrate on the 1977 water quality goals but lay the groundwork for the future implementation of 1983 goals.

5. Issue discharge permits expeditiously in consonance with the above priorities.

6. Establish an ongoing federal/state management process which integrates planning and program formulation to set milestones and provide reports in terms of these milestones to show whether progress is, in fact, being made toward 1977 and 1983 goals.

7. Institute procedures which assure the public of effective participation in establishing the direction of the water quality program.

Item 4 above is interpreted to mean that every effort is to be made for all point sources to have applied treatment defined as Best Practicable Technology by 1977 and Best Available Technology by 1983. The administrative tool to see that this is being done is the discharge permit system mentioned in item 5.

The structure of PL 92-500 is shown schematically in Figure A. The law is under five titles: I Research Program, II Grants for Construction, III Standards and Enforcement, IV Permits and Licenses and V General Provisions. The elements of the law that are of primary concern to this study are outlined below.

The heart of the implementation of the Federal Water Pollution Control Act, PL 92-500 is the reinforcement of the State's Water Pollution Control and Abatement Program following Federal guidelines and regulations. The State shares the responsibility to implement the Act. Each state must submit a water quality management program annually to the U.S. Environmental Protection Agency for approval (under the requirements of Section 106 of the Act).

The Federal Act, PL 92-500 calls for establishment and implementation of the following major programs by the State.

1. The State must have in operation an approved "continuing planning process" under the requirements of Section 303(a) of the Act which results in the preparation of water quality management plans for all navigable waters (by basins) within the State.

   The purpose of the basin plans is to coordinate and direct the State's water quality management decisions on a river basin scale by identifying problems, determining priorities, scheduling actions, and coordinating other planning activities under Sections 201 and 208, and others.

2. The State must establish and administer a waste discharge permit system under State law as part of National Pollutant Discharge Elimination System, Section 402 of the Act. All collectible direct discharges to navigable waters are subject to NPDES permit and the permit sets forth effluent limitations and other limitations, monitoring requirements, standards of performance and other terms and conditions of discharge.

3. Administration of the construction grant program and development and implementation of municipal waste treatment management plans which are consistent with Section 201 of the Act.

4. Development and implementation of monitoring and surveillance programs, and of training programs for operation and maintenance of municipal waste treatment facilities.

5. The State is required to file with the Administrator of EPA a summary report of the current status of the State Pollution Control Program, as previously described, for his approval and its forthcoming programs for the prevention, reduction, and elimination of pollution under the requirements of Section 106, as well as revised continuing planning process under Section 303(a) and State reports under Section 305 of the Act.

Standards and Enforcement

General. The effluent limitations for point sources are not set out in the law itself. The law requires that the Federal Administrator (EPA) provide guidelines for effluent standards. These guidelines would identify the best practicable control technology for achievement by July 1, 1977 and the best available control technology (BACT) by July 1, 1983 for other than publicly owned treatment works. For publicly owned treatment works the guidelines will identify secondary treatment to be achieved by July 1, 1977 and best practicable waste treatment technology (BPWTT) achieved by July 1, 1983. The stated goal of no discharge of pollutants by 1985 is not a legal requirement at this point.

The law further provides that the federal agency (EPA) promulgate standards for enforcement for all new sources from one year after a list of categories of sources is published. The list of categories of sources shall be published within 90 days after the date of enactment.

The administrator is also required to publish a list of toxic pollutants and effluent limitation for such pollutants including, where appropriate, absolute prohibition of the discharge of such toxic pollutants. The administrator is also required to define requirements for pretreatment standards for industries discharging to a municipal system.

Specific types of pollution are singled out by the law for special mention: oil and hazardous substances (311), marine sanitation (312) and thermal discharges (316).

Establishment of quality standards for lake, river, ground and marine waters remain with the states, subject to federal review. The federal law further provides that each state, for all waters within that state, establish the maximum daily load of pollutants permitted for those waters and, similarly, the maximum heat load to maintain temperature criteria.

Although the authority is given by the law for a federal agency to monitor and enforce conformance with promulgated standards, this authority may be passed on to the states upon approval by the administrator. A part of the enforcement procedure is the continuation of the system of discharge permits (402).

Under Section 304, the federal administrator is required to provide guidelines for establishment of standards. These are discussed below.

Guidelines for Effluent Standards. Effluent limitations shall be the determinative criteria. Water quality standards of the receiving waters shall not be determinative unless the preservation of the quality of the receiving waters requires higher quality effluent than required to meet effluent standards. If the application of effluent limitation to individual dischargers can maintain water quality standards of the receiving water, effluent limitation standards are definitive. Where the water quality standard is not expected to be met even after the application of BPWTT or effluent limitations standards, the dischargers into the water quality limited segments are required to apply BACT or more stringent limitation than promulgated effluent limitations.

Guidelines for the classification of waters into effluent limiting and water quality limiting, although an integral part of standards, are under the planning process. Refer to discussion of State Basin Water Quality Planning, 40 CFR 131.

Guidelines for Secondary Treatment

The following guidelines for the requirements of secondary treatment became effective August 17, 1973. Refer to Federal Register Vol. 38 No. 159, Friday August 17, 1973.

1. The minimum level of effluent quality to be classified as secondary treatment is defined in terms of the following values for parameters in plant effluent:

Parameter	Sampling Period	Maximum Mean* Value Effluent Quality
BOD (5 day)	30 consecutive days	30 milligrams per liter or 15 percent of the mean influent BOD, whichever is smaller
" "	7 consecutive days	45 milligrams per liter
Suspended Solids	30 consecutive days	30 milligrams per liter or 15 percent of the mean influent SS, whichever is smaller
"	7 consecutive days	45 milligrams per liter
Fecal Coliform	30 consecutive days 7 consecutive days	200 per 100 milliliters 400 per 100 milliliters
pH	Continuously	Within the limits 6.5 to 9.0

*Arithmetic mean for BOD and SS, geometric mean for Fecal Coliform.

2. Special consideration is given to treatment plants serving areas with combined sewer and certain industrial waste categories.

    a. Treatment works which receive flows from combined sewers may receive special consideration in the standards to be met while handling wet weather flow on a case by case review basis.

    b. Certain categories of industrial wastes which discharge directly to navigable waters or through a municipal treatment plant to navigable waters are subject to possible effluent quality adjustment for BOD and SS. Where the flow is treated in a municipal plant, it must exceed 10 percent of the total flow to be eligible for consideration.

Guidelines for Best Practicable Waste Treatment Technology (BPWTT). The EPA issued for public comment in March 1974 proposed guidelines under the title "Alternative Waste Management Techniques for Best Practicable Waste Treatment."

The proposed guidelines cover three classes of generally acceptable techniques: (1) land application, (2) treatment and discharge to surface waters, and (3) reuse. The introduction emphasizes that the choice from these three techniques is left to each municipality or regional sanitary district providing it meets cost-effectiveness regulations and general environmental considerations. Through a brief legislative history, however, it points out that Congressional intent is to emphasize the need for consideration of land disposal as an alternative to the traditional surface water disposal. There is also strong emphasis on protection of groundwaters with the intent that this resource remain suitable for drinking water purposes.

Reuse is encouraged but is not really a third alternative since treatment for reuse is defined in terms of the ultimate disposal after reuse. That is, a public facility in offering effluent for reuse must offer it with a quality acceptable for the ultimate disposal to be made even where the user has lower quality needs.

Non-structural reforms in the use of water to reduce total waste flows are also given the status of elements of BPWTT. Among the categories cited are education, pricing policies of water and encouraging the use of new plumbing appliances and fixtures with low water consumption. Reduction of flow through infiltration-inflow control is already a part of current requirements.

BPWTT Applied to Surface Disposal. The goal originally set in the March 1974 proposed guidelines for BPWTT as applied to surface water disposal was to go beyond removal of carbonaceous oxygen demand as accomplished by traditional secondary treatment, to the removal of a significant part of the nitrogenous demand. This proposed mandatory requirement was withdrawn subsequently by EPA in favor of making the determination of such need a responsibility of the states. This proposed change is not formalized in a published document. The minimum requirements of secondary treatment cited above as defined in 40 CFR 133 are continued and are regarded as one of the requirements inherent in achieving BPWTT. Advanced waste treatment, which is defined as nutrient removal, is not required by BPWTT on a national basis. This does not preclude its requirement on a case by case basis.

Thus, except for allowing the States to determine the need for nitrification or nutrient removal on a case by case basis, the proposed guidelines for BPWTT are essentially unchanged from the 1977 milestone requirements for secondary treatment. Acceptable secondary treatment techniques for disposal to surface waters include:

1. Activated sludge process.

2. Trickling filter (or rotating disc or other processes in which the active organisms are fixed rather than free floating).

3. Lagoons with multiple cells and intermittant discharge capabilities at loadings of 20 pounds of BOD_5 per acre and 6 month detention. Continuous discharge lagoons will not meet BPWTT. Equivalent BPWTT performance can be achieved with lesser storage and higher loads by the addition of primary sedimentation pretreatment and mechanical aeration.

4. Physical-chemical processes including at least chemical precipitation followed by filtration.

5. Land application.

In terms of performance, the required effluent quality is required to be as cited above for secondary treatment.

BPWTT for Land Application of Wastewaters

The guidelines specify three acceptable approaches to land application: (1) irrigation, (2) overland flow, and (3) infiltration-percolation. For irrigation, the ultimate disposal may be either to groundwater and evapotranspiration or to surface water. For overland flow the ultimate disposal is usually to surface water. For infiltration-percolation, the ultimate disposal may be either directly to groundwater or via underdrains to surface water. In no case is the quality specified for the wastewater as applied to the land surface either in terms of pollutant concentration or as the output of an acceptable process. The acceptability of land application techniques under EPA guidelines where all or part of the renovated wastewater reaches groundwater is defined in terms of its effect on quality. The effects are unqualified with regard to the degree of stratification or mixing between the leachate and the native groundwater. The guidelines present numerical limits on the resultant quality of the groundwater for certain chemicals, heavy metals, detergents and pesticides. But certain toxic pollutants are not listed since their limiting value are still under consideration. No numerical limits are stated in the guidelines for pathogenic organisms. The reason given is that standard water treatment processes are designed for their removal. Likewise, no numerical values are given for limitations on BOD or solids. The guidelines do state the criteria for BPTWW by land application in general terms as being capable of "reducing chemical and organic pollutants to raw or untreated drinking water supply source levels."

Where the land application technique results in discharge to surface waters, such as underdrained irrigation or ditch collected overland flow, the effluent is required to be as specified for surface water discharge from any other treatment facility.

*** Acceptable irrigation techniques include spray, ridge and furrow and flooding. Acceptable plant cover includes annual and perennial crops, both harvested and unharvested, pasture, landscape, tree farm and forest. The only criteria for acceptability other than the above described effects on groundwater and surface water are the functional adequacy of the combination of application rate, soil type, topography, depth to groundwater and cover material. There are no stated limitations on the character of the wastewater as applied. (It is expected that subsequent guidelines will provide quantity limitations of rates of application addressed to site capabilities.) An hydraulic application rate of 4 inches per week is given for definition purposes to define the upper limit of irrigation as distinguished from infiltration-percolation.

The proposed guidelines indicate that the expected treatment to be achieved by soil as the applied irrigation water passes through the active layer will be as follows, based on the applied waters having had prior secondary treatment:

Parameter	Expected Incremental Removal
BOD and SS	90 - 99%
Nitrogen	85 - 90%
Phosphorus	80 - 99%

Disposal by irrigation on frozen ground is not specifically prohibited by the proposed guidelines. The precautionary statement is made that there is conflicting data.

*** Overland flow land application relies upon treatment achieved on the surface of the vegetation and ground surface rather than within the soil as is the case for irrigation. Percolation to groundwater is usually small or negligible since relatively impermeable soils are usually selected for this purpose. A typical application rate is 4 inches per week applied in cycles of 6 to 8 hours of spraying followed by 6 to 18 hours of drying. The expected incremental removals given in the proposed guidelines are as follows:

Parameter	Expected Incremental Removal
BOD and SS	95 - 99%
Nitrogen	70 - 90%
Phosphorus	50 - 60%

As for irrigation, no criteria are given limiting the quality of wastewater as applied to overland flow treatment. The proposed guidelines indicate that the basis for design is usually a liquid loading rate, as cited above, with the cautionary comment that organic-loading or detention time criteria may be developed in the future. The proposed guidelines indicate that the overland flow method is as yet unproven for use in freezing conditions.

The cover crop for overland flow treatment is necessarily permanent, although it may require periodic cutting, and is not usually a potentially usable crop.

The proposed guidelines classify overland flow as a land application technique. Functionally, it is a polishing treatment for surface water disposal.

*** A suitable site providing an acceptable combination of soil characteristics and depth to groundwater are critical to <u>infiltration-percolation</u> treatment which will satisfy BPWTT. Soils that are too coarse and allow the applied wastewater to pass through the upper layer too quickly to experience the necessary biological and chemical action are not acceptable. Depth to groundwater should be at least 15 feet to insure treatment before the wastewater enters the saturated zone. Soils with inadequate permeability will not support hydraulic loading rates that make the method economically competitive with other land application methods. The normal hydraulic loadings are given in the range 4 to 12 inches per week and the organic loading 3 to 15 tons BOD per acre per year.

As for the other land application methods, the proposed guidelines do not specify any limitation on the quality of the wastewater as applied. The interrelationship between quality applied and maintenance of hydraulic loading capability is pointed out. It is noted that most successful systems for municipal wastewater have applied waters of secondary quality.

Expected incremental removals from applied waste of secondary effluent quality are over 90 percent for BOD, SS and coliforms and 70 to 90 percent for phosphorus. No specific expectations are given in the proposed guidelines for heavy metal, detergent or pesticide removal except to note that removals are poorer than for irrigation. The known significant presence of any of these pollutants in the waste source calls for special removal prior to application. The unreliability of this method for incremental nitrogen removal is noted indirectly in the proposed guidelines.

Infiltration-percolation is considered an operable technique on a year-around basis. The proposed guidelines state that deepwell injection of wastewater is not considered a land treatment alternative under BPWTT. Deepwell injection provides no substantial renovation to the groundwater according to the proposed guidelines. The guidelines indicate that deepwell injection may be considered as an alternative disposal method provided the pretreatment meets the groundwater quality criteria. (This type of disposal of municipal wastes, no matter how well treated, has not gained the support of health authorities where it has been proposed.)

Combined Sewer Control Under BPWTT

The above cited proposed guidelines for BPWTT consider the problem of pollution resulting from combined sewers. These guidelines do not take the form of specific numerical parameters to be met but rather the form of indicating alternative efforts which should be explored to arrive at a cost effective method to reasonably minimize pollution from this source. Absolute elimination of overflows or limitation of overflows to a percent of time or total annual pollution load is not proposed.

The following alternatives are suggested for exploration, with emphasis on the possibility of best cost effectiveness being found in combination of techniques:

1. Sewer separation.
2. Periodic dry weather flushing to prevent buildup of pollutants.
3. Flow routing to maximize capacity of available sewers and treatment.

4. Storage for subsequent treatment.

5. Increased treatment hydraulic capacity with some sacrifice of removals at wet weather flow.

6. Disinfection of overflows.

The alternative methods suggested for direct treatment of overflows are mostly in the experimental or pilot plant stage of development. Acceptable removals or degrees of reliability are not stated.

Urban Runoff Control Under BPWTT

The Federal guidelines do not provide either quantitative criteria or generalized goals with regard to pollution from separated storm drainage from urban areas. PL 92-500 specifically states that EPA is authorized to conduct and assist studies "which will demonstrate a new or improved method of preventing, reducing, and eliminating the discharge into any waters of pollutants from sewers which carry storm water...". To date, the nationwide effort has been devoted largely to characterizing the nature of urban runoff as a pollutant load. Solutions to the problem or standards of control performance have not yet been developed. This situation is summarized in the referenced proposed guidelines by the following quotation:

> "Demonstrated technology to control storm sewer discharges does not exist."

Guidelines for New Sources (Non-point Sources). These guidelines are not available as of December 1973. They are understood to be in the process of development.

Guidelines for Toxic Pollutants. These guidelines are not available as of December 1973. There has, however, been issued a list of toxic pollutants as required by the law. The proposed list is published in Federal Register Vol. 38 No. 129, Friday July 6, 1973.

Toxic pollutants are defined as those which, either directly from the environment or indirectly through food chains, will cause death, disease, behavioral abnormalities, cancer, genetic mutations or physiological malfunctions. The definition is qualified in interpretation to add the requirements that these toxic effects be caused at extremely low concentrations in water and be known to be a significant component of widespread point sources.

The proposed list consists of the following:

1. Aldrin
2. Benzidine and its salts
3. Cadmium and all cadmium compounds
4. Cyanide and all cyanide compounds
5. DDD, DDE and DDT
6. Endrin
7. Mercury and all mercury compounds
8. Polychlorinated biphenyls
9. Toxaphene

Guidelines for Pretreatment. The following guidelines are proposed* by EPA for pretreatment of certain wastes to (1) protect the operation of publicly owned treatment works and (2) prevent the discharge of pollutants which pass through such works inadequately treated. Refer to Federal Register Vol. 38 No. 138, Thursday July 19, 1973.

The proposed standards are covered in two paragraphs, 128.131 and 128.133. Paragraph 128.131 applies to all nondomestic users of publicly owned treatment works. Paragraph 128.133 applies only to major contributing industries, which are defined as those which (a) have a flow of over 50,000 gallons per day; (b) have a flow greater than 5 percent of the flow carried by the municipal system; (c) contain toxic pollutants as defined by the guidelines for toxic pollutants.

Paragraph 128.131, applicable to all nondomestic dischargers, prohibits the discharge to municipal systems of the following:

1. Wastes which create a fire or explosion hazard.
2. Wastes which cause corrosive structural damage to treatment works or having pH lower than 5.0.
3. Solids or viscous substances that would block sewers or interfere with treatment works.
4. Wastewaters at excessive flow rates or pollutant concentrations that would upset treatment.

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*Date for receipt of comments on proposed regulation is September 4, 1973. Presumably, final guidelines will not be issued until sometime after that date.

Paragraph 128.33, applicable to major industrial discharges, required that:

> "the pretreatment standard for incompatible pollutants introduced into a publicly owned treatment works by a major contributing industry shall be best practicable control technology currently available as defined by the Administrator pursuant to section 301(b) of the Act: provided that, if the publicly owned treatment works which receives the pollutants is committed in its NPDES permit to remove a specified percentage of any incompatible pollutant, the pretreatment standard applicable to users of such treatment works shall be correspondingly reduced for that pollutant."

Guidelines for Pollution Abatement from Agriculture and Silviculture. The proposed regulation of discharges from agricultural and silvicultural activities provides for the general exclusion of the numerous small operations on the basis of limited resources application and confines applicability to certain specific exceptions to the general exclusion. Only those activities specifically excepted from the general exclusion shall be subject to the National Pollution Discharge Elimination System requirement. The exceptions from the general exclusion are as follows (refer to Federal Register Vol. 28 No. 128, Thursday July 5, 1973):

1. Animal confinement facilities of the following sizes or larger:

   a. 1000 slaughter and feeder cattle
   b. 700 head or more of dairy cattle
   c. 2500 swine over 55 pounds
   d. 10,000 head of sheep
   e. 55,000 turkeys
   f. 100,000 laying hens or broilers
   g. 30,000 laying hens or broilers with liquid manure handling systems
   h. 5000 ducks
   i. combinations of animals per schedule

2. Fish production facilities.

   a. Fish production with discharges on 30 or more days per year and producing 20,000 pounds per year.
   b. Non-native varieties

3. Irrigation activities with a point source of discharge (that is, a piped system) draining 3000 acres.

4. Identified point sources.

State Classification of Waters in the Study Area

Under section 303e of the Federal Law, the state is required to classify all waters within the planning basin as water quality class segments and/or effluent class segments. These requirements are summarized as follows:

1. Effluent class segment analysis.

   a. An identification of those waters by segment where water quality is better than applicable water quality standards and will continue to be better after the application of Best Practicable Control Technology for industry and Secondary Treatment for municipalities;

   b. An identification of those waters by segment where water quality does not meet applicable standards, but will after the application of Best Practicable Control Technology for industry and Secondary Treatment for municipalities.

2. Water quality class segment analysis.

   a. An identification of those waters by segment where water quality is not expected to meet applicable water quality standards even after the application of the effluent limitations required by sections 301(b)(1)(A) and 301(b)(1)(B) of the Act.

The above classification has been accomplished by the state in a publication titled "Summary of Continuing Planning Process" Sec.

303(E) by Washington State Department of Ecology.

"Segments have been classified according to the following segment definitions:

Effluent Limited - Present quality is above the water quality standards or can be expected to exceed the standards with the application of BPT for all controllable discharges.

-Permits based on best practicable and/or secondary treatment can be issued to all dischargers in the segment. (BPT - Best Practical Treatment)

Water Quality Limited-Point Source - Present quality is below standards and specified criteria is not expected to be achieved with the application of BPT for all controllable dischargers.

-A water quality study will be conducted to assist in establishing permit conditions for individual dischargers, where such a study is required.

-Permits cannot be issued to dischargers (point source and controllable non-point source) until after data is collected and evaluated, where such data is now lacking.

Water Quality-Point Source (Sulfite Waste Liquor) - Present quality is below the standards due to controllable discharges and in some cases, natural conditions. All problems relating to controllable discharges can be corrected with the application of BPT with the exception of SWL.

-A water quality study may be conducted to assist in establishing permit conditions for entities discharging SWL where required.

-Permits based on BPT can be issued immediately to all dischargers in the segment with the exception of SWL where data is adequate to justify permit conditions.

Water Quality-Point Source (Gas) - Present quality is below the standards due to controllable discharges and in some cases, natural conditions. All problems relating to controllable discharges can be corrected with the application of BPT with the exception of total dissolved gas.

-A water quality study may be conducted to assist in establishing permit conditions for entities discharging total dissolved gas where required.

-Permits based on BPT can be issued immediately to all dischargers in the segment with the exception of total dissolved gas where data is adequate to justify permit conditions.

Water Quality-(Natural) - Present quality is below the standards and will remain in violation of the standards due to natural conditions.

-A water quality study will not be conducted in the immediate future.

-Permits based on BPT can be immediately issued to all dischargers in the segment.

Water Quality-Non-Point Sources - Present quality is below the standards and will remain in violation of the standards due to non-point sources.

-A water quality study will be conducted prior to completion of 303 plans.

-Permits based on BPT can be immediately issued to all dischargers in the segment."

The segments designated in the Spokane Basin are as follows:

Segment Number	Segment Name	Class*	Violations
24-54-01	Spokane River mouth to Idaho-Washington Border	WQ-PS	Coli, DO, Temp
24-55-02	Little Spokane River and tributaries	WQ-NPS	Coli
24-56-03	Hangman Creek	WQ-NPS	No Data

*Class Identification Code
WQ = Water Quality Limited
PS = Point Source
NPS = Non Point Source

This same state document under Statewide Assessment of Water Quality Problems contains the following "Special Problems" paragraph applicable to the Study Area.

"The Department (of Ecology) has issued an administrative order to the City of Spokane in the Eastern Region to provide advanced waste treatment by June 1976, and to complete a stage-construction plan to eliminate storm water overflow by October 1973. This project exhibits high priority for FY-1975 funding from allotments to be made available in January 1974."

State Water Quality Standards

On June 19, 1973, the State of Washington Department of Ecology promulgated new Water Quality Standards in response to the requirements of PL 92-500.

The general classification of water is as follows:

1. All surface waters lying within the mountainous regions of the State assigned to national parks, national forests, and/or wilderness areas, are hereby designated Class AA or Lake Class.

2. All lakes and their feeder streams within the State are hereby designated Lake Class and Class AA respectively.

3. All reservoirs with a mean detention time of greater than 15 days are classified Lake Class.

4. All reservoirs with a mean detention time of 15 days or less are classified the same as the river section in which they are located.

5. All reservoirs established on preexisting lakes are classified as Lake Class.

6. All other waters within the State are hereby designated Class A.

In addition to these general classifications, certain waters are singled out for specific designation. In the case of the Study Area, only one specific classification is made, namely for the Spokane River. These standards, as applicable to the Study Area are as follows:

1. By specific designation, the Spokane River from mouth to Idaho Border (River Mile 91) — CLASS A
Special Condition - Temperature - Water temperatures shall not exceed 68°F due in part to measurable (0.5°F) increases resulting from human activities; nor shall such temperature increases, at any time, exceed t=110/(T-15); for purposes hereof, "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

2. Long Lake with storage volume 254,570 has been computed by Soltero (1973) to have a mean exchange rate of approximately 30 days which would place the impoundment in Lake Class based on the definition that all impoundments with mean detention over 15 days are Lake Class. — LAKE CLASS

3. All other impoundments on the Spokane River have mean detention times of much less than 15 days and are therefore classified as same as the river. — CLASS A

4. Streams which feed natural lakes are designated Class AA. These would include West Branch of the Little Spokane above Lake Eloika, the Little Spokane above Chain Lake, Blanchard Creek, Brickett Creek, Fish Creek and Thompson Creek. — CLASS AA

5. All natural lakes are Lake Class. These include but are not limited to Newman Lake, Liberty Lake, Eloika, Horseshoe, Diamond, Chair, Medical, West Medical, Silver, and Clear. — LAKE CLASS

6. All other streams in the Study Area are designated Class A. — CLASS A

The Study Area includes, therefore, Class AA, Class A and Lake Class waters. The water quality characteristics for these three classes are as follows (parts applicable to marine waters have been deleted to clarify for application to the Study Area):

1. <u>Class AA Extraordinary</u>

   a. General Characteristic

      Water quality of this class shall markedly and uniformly exceed the requirements for all or substantially all uses.

   b. Characteristic Uses

      Characteristic uses shall include, but are not limited to the following:

Water supply (domestic, industrial, agricultural)
Wildlife habitat, stock watering
General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating)
General marine recreation and navigation
Fish and shellfish reproduction, rearing and harvest

c. Water Quality Criteria

Total Coliform Organisms shall not exceed median value of 50 with less than 10% of samples exceeding 230 when associated with any fecal source.

Dissolved Oxygen shall exceed 9.5 mg/l

Total Dissolved Gas - The concentration of total dissolved gas shall not exceed 100% of saturation at any point of sample collection.

Temperature - Water temperatures shall not exceed 60°F (FRESH WATER) due in part to measurable (0.5° F) increases resulting from human activities; nor shall such temperature increases, at any time, exceed t = 75/(T-22); for purposes hereof "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

pH shall be within the range of 6.5 to 8.5 with an induced variation of less than 0.1 units.

Turbidity shall not exceed 5 JTU over natural conditions.

Toxic, Radioactive or Deleterious Material Concentrations shall be less than those which may affect public health, the natural aquatic environment, or the desirability of the water for any usage.

Aesthetic Values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

2. Class A Excellent

a. General Characteristic

Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

b. Characteristic Uses

Characteristic uses shall include, but are not limited to, the following:

Water supply (domestic, industrial, agricultural)
Wildlife habitat, stock watering
General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing and boating)
Commerce and navigation
Fish and shellfish reproduction, rearing and harvest

c. Water Quality Criteria

Total Coliform Organisms shall not exceed median value of 240 with less than 20% of samples exceeding 1000 when associated with any fecal sources.

Dissolved Oxygen shall exceed 8.0 mg/l.

Total Dissolved Gas - The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.

Temperature - Water temperature shall not exceed 65°F due in part to measurable (0.5°F) increases resulting from human activities; nor shall such temperature increases, at any time, exceed t = 90/(T-19); for purposes hereof "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.

pH shall be within the range of 6.5 to 8.5 with an induced variation of less than 0.25 units.

Turbidity shall not exceed 5 JTU over natural conditions.

Toxic, Radioactive or Deleterious Material Concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.

Aesthetic Values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

3. Lake Class

a. General Characteristic

Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

b. Characteristic Uses

Characteristic uses shall include, but are not limited to, the following:

Water supply (domestic, industrial, agricultural)
Wildlife habitat, stock watering
General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating)
Fish and shellfish reproduction, rearing and harvest

c. Water Quality Criteria

Total Coliform Organisms shall not exceed median values of 240 with less than 20% of samples exceeding 1,000 when associated with any fecal source.

Dissolved Oxygen - No measurable decrease from natural conditions.

Total Dissolved Gas - The concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.

Temperature - No measurable change from natural conditions.

pH - No measurable change from natural conditions.

Turbidity shall not exceed 5 JTU over natural conditions.

Toxic, Radioactive or Deleterious Material Concentrations shall be less than those which may affect public health, the natural aquatic environment, or the desirability of the water for any usage.

Aesthetic Values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch or taste.

Monitoring and Enforcement

The federal law provides that the primary basis for monitoring and enforcement shall be a system of permits and licenses. The law further provides that this permit and license system may be administered by states which desire to do so and which submit a program that meets the federal requirements for certification. Refer to Section 402 of Law 92-500. The first step in this system is the certification of the state program as adequate to meet federal guidelines. These guidelines are set forth in "State Program Elements Necessary for Participation in the National Pollution Discharge Elimination System" (Title 4, Chapter 1, Part 124, Federal Register December 22, 1972). The requirements for a certifiable program are as outlined below.

1. A state law which prohibits pollution discharge without a permit.

2. Require that all applicants for permits make adequate filings with required data furnished.

3. Provide for adequate interchange of permit data between federal and state agencies to prevent issuance of a permit based on incorrect data.

4. Provide for public participation and public hearings on issue of permits.

The federal regulations provide certain terms and conditions of NPDES permits as follows:

1. Prohibits certain discharges.

2. Provides for application of effluent standards and other water quality standards and requires development of waste load allocations as prerequisite of setting effluent standards under certain conditions.

3. Directs that permits contain specific average and maximum daily quantitative limitations on discharges expressed in terms of weight except for temperature, pH, radiation, and other pollutants not appropriately expressed in weight units.

4. Directs that permits contain time limit for compliance with effluent standards.

5. Provides conditions under which permits can or must be revoked or amended.

6. Requires that copies of all permits be furnished to the Federal Administrator.

7. Provides that permits have a fixed term and be subject to review.

The federal regulations require that states participating in NPDES develop a monitoring system to insure that the permit program is being complied with. The frequency of monitoring and the pollutants to be monitored, in general terms, are specified. Recording and reporting requirements are also specified.

The means of detecting violation or noting whether progress is being made toward compliance are outlined. Provisions for notification of those not in compliance and methods of enforcement are set forth in the guidelines. The federal regulations require that the state provide the necessary personnel and other resources for adequate surveillance and administration.

Certain specific conditions are made part of the criteria for certification. Singled out in this fashion is the requirement that disposal of pollutants into wells be controlled. The state is required to have the ability to prohibit or control this type of disposal through the permit system.

Ocean Disposal (Section 403)

(Not applicable to the Study Area)

Dredge Disposal (Section 404)

(Not directly applicable to the Study Area - but could be indirectly. There are dredge operations in the upper end of Coeur D'Alene that could stir up old deposits containing heavy metals.)

Sewage Sludge Disposal (Section 405)

The federal law provides that additional criteria and a potential additional permit would be required for disposal of sewage sludge into navigable waters.

State Planning Process

The planning requirements set forth by the federal law and regulations include a state continuing planning process, basin water quality management planning, areawide waste treatment management planning, and facility planning.

A state continuing planning process is required by Section 303(e) of the FWPCAA of 1972. The purpose is: "To provide the states with the water quality assessment and program management information necessary to make centralized coordinated water quality management decisions; to provide the strategic guidance for developing the state program submittal under section 106 of the Act; and to encourage water quality objectives which take into account overall state policies and programs, including those for land use and other related natural resources."

The total state planning process is comprised of:

1. The annual state strategy which sets the state's major objectives and priorities for preparing basin plans and its annual program plan.

2. Individual basin plans, which establish specific targets for controlling pollution in individual basins.

3. The annual program plan which establishes the results expected and the resources committed for the State program each year.

4. Reports, which measure program performance in achieving programmed results.

The planning process requires that all of the minor basins identified by EPA shall have a basin water quality management plan prepared by June 30, 1975. The planning process will establish phasing of the basin plans dependent on the classification and ranking of segments and the number of water quality segments in the basin.

The Annual State Strategy includes:

1. An annual statewide assessment of water quality prob-

lems and causes together with a ranking of each segment in a priority order.

2. Schedule of basin plan preparation.

3. A State Municipal Discharge Inventory established by June 30, 1973, and thereafter maintained at least on a yearly basis. The inventory shall rank and categorize significant dischargers.

4. A State Industrial Discharge Inventory established by June 30, 1973 and thereafter maintained at least on a yearly basis. The inventory shall rank and categorize significant dischargers.

A state continuing planning process is required prior to participation in the National Pollutant Discharge System. Also any construction grants awarded after June 30, 1973, must be consistent with applicable planning required by the Act.

The Washington State Department of Ecology in June, 1973, issued a "Summary of the Continuing Planning Process" and a "Summary of the Annual State Strategy." The first mentioned summary contains a map and list of the consolidated basin planning areas, a listing of segments with their classifications and parameters of water quality standards being violated, and a list of basin plans to be completed in Fiscal Year 1974. The Spokane (13-03-#24) Basin is included in this schedule. The Spokane Basin includes the following water quality inventory areas: No. 54 Lower Spokane, No. 55 Little Spokane, No. 56 Hangman, No. 57 Middle Spokane.

Basin Planning

The contents and requirements for basin plans are included in the following documents:

Federal

1. Draft Guidelines, Water Quality Management Plans, Section 303(e) FWPCA Amendment of 1972, EPA, August 1973.

2. State Continuing Planning Process - Interim Regulations - 40 CFR Part 130, Federal Register, March 27, 1973.

3. Water Quality Management Plans Proposed Preparation Guidelines for States 40 CFR Part 131 Federal Register, May 23, 1973.

State

4. Water pollution control planning, Chapter 372-68 WAC and subsequent preparation guidelines (March 1970) and supplemental planning guide, TR-73-031, Washington State Dept. of Ecology.

Following is a brief description of the major requirements.

The objectives of the initial basin water quality management plans are:

1. Establish effluent limitations and compliance schedules or targets abatement dates for point sources.
2. Identify municipal needs.
3. Direct construction grant awards and permit issuance on an abatement priority basis.
4. Identify and schedule further needed actions, including localized planning and additional data collection.

Plans prepared from the present until July 1, 1974, shall have:

1. Management provisions (data assembly, discharge inventories, etc.).
2. Waste load analysis in water quality segments based on existing or readily obtained data.
3. Compliance schedules or target abatement dates.

Plans prepared from the present until January 1, 1975, shall have:

1. All of the above.

2. Nonpoint source analysis and control, as feasible, including state programs under Section 208.

3. Land use controls, if necessary and feasible.

Preparatory classification steps are shown in the flow diagram, Figure 1.

This study, scheduled for completion in August 1975 falls in the last category for content.

Areawide Waste Treatment Management Planning

Management planning for areawide waste treatment is provided for by Section 208 of the Act. This planning is applicable for areas with urban-industrial concentrations having substantial water quality control problems and is contingent upon alternative actions to be taken by declaration of the state governor.

The governor has three options relative to implementation of Section 208: he may designate an area for areawide planning; he may non-designate an area, or he may take no action at all. If the Governor designates the area, then it shall be subject to development of areawide planning under Section 208. If the governor takes no action, the local official within the area may, by agreement, designate the area. If, however, the Governor non-designates the area, he may, at a later date, designate the area but the option of local officials to designate is foreclosed.

The governor has taken no action to date, but has until July 1974 to act before his options are foreclosed.

Probable future action is indicated by the following statement of the Washington State Department of Ecology which explains, in the June 1973 Summary of Annual State Strategy, that:

> "The urban-industrial water quality related problems in the State are not of a magnitude to warrant the implementation of Section 208 planning. The problems are to be addressed through Section 201, Facility Planning for complex areas."

This strategy implies that whatever area or basin wide planning is to be done for the Spokane is to be accomplished under the requirements set forth in Section 303e rather than those of Section 208.

Facility Planning

Sections 201 and 204 of the Act set forth requirements, limitations and conditions to be met for receipt of federal grants for construction of treatment works. EPA has drafted proposed regulations for facilities planning where areawide planning is not applicable that will satisfy Sections 201, 204 and other sections of the Act. Also, facility planning is the first construction step of a three step construction grant program. Following Step (1) preliminary plans and studies (areawide planning or facility planning) are Steps (2) preparation of construction drawings and specifications and (3) fabrication and building of complete and operable treatment works.

As Step (1) of a construction grant program, facility planning is eligible for federal funding or reimbursement. Also, a facilities plan may suffice for a number of related treatment works.

The contents of a facility plan include:

1. An analysis of demographic and geographic factor generating the demand for facilities together with implementation schedules and estimates of capital costs and operations, maintenance and replacement costs.

2. An evaluation of alternative flow and waste reduction measures.

3. An infiltration and inflow analysis.

4. An evaluation including cost comparisons of feasible alternative biological, physical-chemical, and land disposal waste treatment management techniques, and of sludge disposal options compatible with each technique including feasible alternative treatment, transmission and disposal sites.

5. An identification of the best practicable waste treatment technology (identifying regulations to be published).

6. Where required, an assessment of the nature and extent of pollution emanating from separate storm sewer systems and the corresponding effects of such pollution on the pollutant reductions required for the proposed works.

7. An environmental assessment.

8. A cost-effective analysis, including relevant environmental and other impacts, which provides for development of cost-effective treatment works which will meet, as applicable, effluent limitations established under Sections 301 and 302 of the Act.

9. A description and illustration of the flow and waste reduction techniques, facilities, and other measures adopted to meet the requirements of Sections 301 and 302 of the Act within the planning area, including a brief statement demonstrating that the applicant has the necessary legal, financial, institutional, and managerial resources available to insure the construction, operation, and maintenance of the proposed treatment works.

10. Required comments or approvals of relevant state, local and federal agencies.

11. A summary of any public meeting or hearing held.

Other Requirements for Implementation

The subject study is essentially a planning tool and does not extend specifically into the area of detailed construction plans or the application for construction grants. However, certain requirements for construction plans and application for construction grants deserve recognition in the planning phase. These requirements include the following:

Infiltration/Inflow. Refer to Sewer System Evaluations, Environmental Protection Agency, 9/28/73. The federal law requires that all applicants for treatment works grants demonstrate that each sewer system discharging into such treatment works is not subject to excessive infiltration/inflow. The referenced guidelines describe the necessary infiltration/inflow analysis that is required to demonstrate compliance.

Cost Effectiveness. Refer to Proposed Analysis Guidelines for Cost Effectiveness, 40 CFR Part 35, in Federal Register Volume 38, Number 127, July 3, 1973. It is a requirement for both planning and construction that an acceptable methodology of cost effectiveness analysis be applied to the waste treatment management systems and to components of such systems.

The elements of cost effectiveness and analysis that are to be addressed are as follows:

1. Identification, screening and selection of alternatives to arrive at those alternatives which have cost effectiveness potential and which should be analyzed for cost effectiveness in accordance with guidelines.

2. Analysis procedure will recognize elements that can be expressed in monetary value and those that cannot. Those that cannot will be covered by narrative description.

3. Analysis of elements that can be expressed in monetary value will be to determine over the useful life the lowest present worth or lowest equivalent annual value.

4. The planning period for cost effective analysis will be 20 years.

5. Capital costs are to include construction, land, relocations, design engineering, field exploration, engineering inspection during construction, administrative and legal during construction, bond sales costs, start up and operator training, interest during construction and contingency.

6. Annual costs for operation and maintenance are to be included in cost effectiveness analysis.

7. Prices and wage levels are to be as of time of analysis. Inflation is not to be included.

8. The interest rate is to be 7% per annum until revised otherwise.

9. Salvage value will be included.

10. Service lives will be in accordance with a schedule.

User Charges and Industrial Cost Recovery. Refer to proposed rules, 40 CFR 30, User Charges and Industrial Cost Recovery, Grants for Construction of Treatment Works, in Federal Register Vol. 38, No. 98. Tuesday May 22, 1973. The proposed regulations would require that a system of user charges be adopted by all applicants for treatment works construction grants. User charges are payments to a grant applicant by recipients of waste treatment services to offset the cost of operation and maintenance of treatment works provided by the applicant. User charge systems are intended to enable the grantee to be financially self-sufficient with respect to operation and maintenance of treatment works. User charges do not include construction costs.

The proposed regulations would also require that all grantees recover from industrial users that portion of the grant amount allocable to the treatment of wastes from such users. An industrial user's share is to be based on all factors which significantly influence the cost of the treatment works, including strength, volume, and flow characteristics. As a minimum, an industry's share shall be based on its flow versus treatment works capacity except in unusual cases. Industrial cost recovery is directed toward recovery of the share of grant money utilized in building capacity for the industrial user and does not include maintenance and operation costs which are part of the user charges.

Each year, during the recovery period, the industrial user shall pay its share of the grant amount divided by the recovery period which is 30 years or the life of the facility, whichever is less. No interest is charged. The rules contain detailed instructions for calculation of users costs and industries share. There are also provisions for the grantee retaining certain portions of the recovered industrial costs for future expansion and reconstruction.

Environmental Impact Statement. An environmental impact statement is required to be filed, received and approved before construction can begin on any wastewater facility.

State and Local Assistance. The general requirements for obtaining state and local assistance under federal law are contained in 40 CFR Part 35 in Federal Register Volume 38 Number 39, Wednesday February 28, 1973. Those which require recognition in the planning phase are cited above. For further details and requirements which are not necessarily considered at the planning stage, see the referenced material.

Drinking Water Standards

The quality of drinking water for public water supplies is prescribed by State Law WAC 248-54-430. These quality standards adopt the 1962 U.S. Public Health Service Standards including the frequency of tests required for bacteriological samples. These criteria are summarized in Table 1. If the listed substances are present in excess of the listed concentrations, either treatment shall be provided, another supply developed, or other action taken acceptable to the Department of Social and Health Services.

In addition to the standards incorporated in law, the state also makes available a commentary on the various chemical constituents that may occur in drinking water supplies. This commentary provides additional guidance in the evaluation of quality.

Solid Wastes

Solid Waste Management is covered by State law under Chapter 70.95 RCW. The purpose of this legislation is to assign responsibility for adequate solid waste management by local governments to prevent land, air and water pollution resulting from solid waste disposal. The law proposes to accomplish this through requirements for planning, enforcement of standards and technical and financial assistance.

Each county is required to prepare a comprehensive solid waste management plan. These plans are to contain a six year construction and capital acquisition program for solid waste handling and a plan for financing capital cost and operation. The plan must also contain a program for surveillance and control.

A key requirement to enforcement is the requirement for a permit from the jurisdictional health department for operation and maintenance of any solid waste disposal site or facility.

Functional standards for solid waste handling have been promulgated by the State Department of Ecology in Chapter 173-301 WAC, adopted October 24, 1972. Of particular concern to this study are the following quoted provisions relative to pollution control, leachate control and pollution prevention:

> "WAC 173-301-183 --------POLLUTION CONTROL. Adequate pollution control measures shall be provided.
>
> (1) Surface runoff water from around the disposal site and from roof drains shall be intercepted and diverted around or under the disposal site.
>
> (2) Surface runoff from the disposal operation itself shall not cause violation of applicable receiving water standards.
>
> (3) Ground water pollution controls shall be provided as needed. The detailed plans for such controls shall be provided as needed.
>
> (4) Air pollution and dust controls shall be provided as needed.
>
> (5) Open burning is prohibited.
>
> (6) Noise controls shall be provided as needed.
>
> (7) The disposal site shall be maintained in a reasonably clean and sanitary condition.

WAC 173-301-300 SANITARY LANDFILL, LEACHATE CONTROL. Plans for a sanitary landfill shall include provisions for interception and treatment of leachate at all sites where the average annual precipitation is 25 inches or more. Interception and treatment may be required at other sites. A sampling and testing program for the leachate and its treated effluent may be required.

WAC 173-301-301 -------POLLUTION PREVENTION. (1) The distance separating the bottom of a sanitary landfil disposing of readily decomposable organic waste and hazardous wastes shall be determined on a case-by-case basis. Generally, a separation equivalent to four (4) feet of impervious soil shall be the minimum separation between the bottom of the fill and the highest ground water.

(2) Inert materials can be disposed of at landfill sites which affords little or no protection to the ground and surface waters.

(3) Septic tank pumpings and sewage treatment plant sludge disposal shall be determined on a case-by-case basis. generally, a ratio of sludge or pumpings to other solid waste of 1 to 4 or 1 to 5, such that the moisture content does not exceed 40% will give satisfactory disposal results.

(4) The disposal of problem wastes must be determined on a case-by-case basis.

(5) Medical wastes should be deposited above the ground water dependent on a case-by-case basis and covered as soon as possible after deposition.

(6) Odorous materials shall be covered as soon as possible.

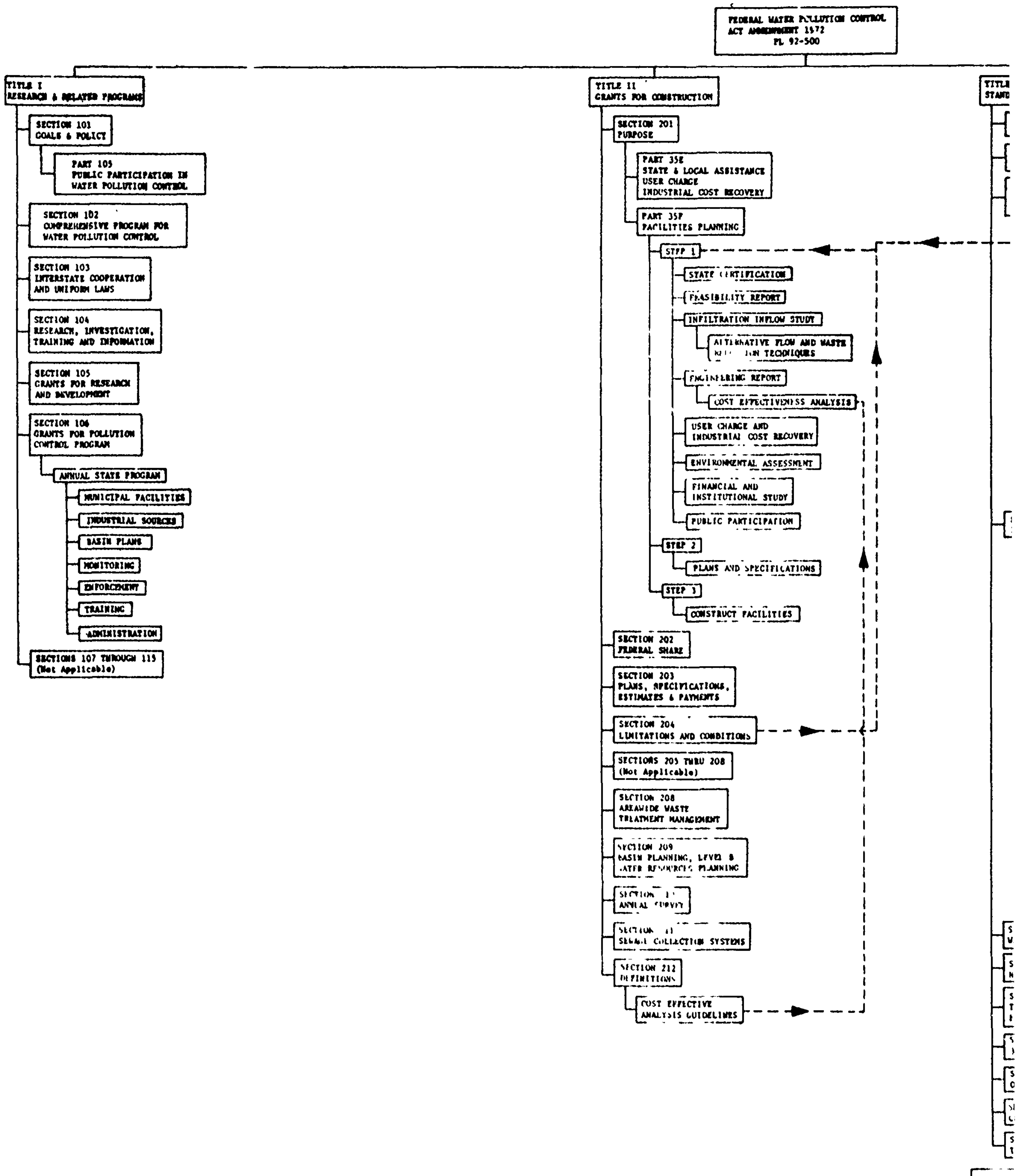
TABLE 1

STATE OF WASHINGTON WATER QUALITY CRITERIA
FOR PUBLIC WATER SUPPLIES

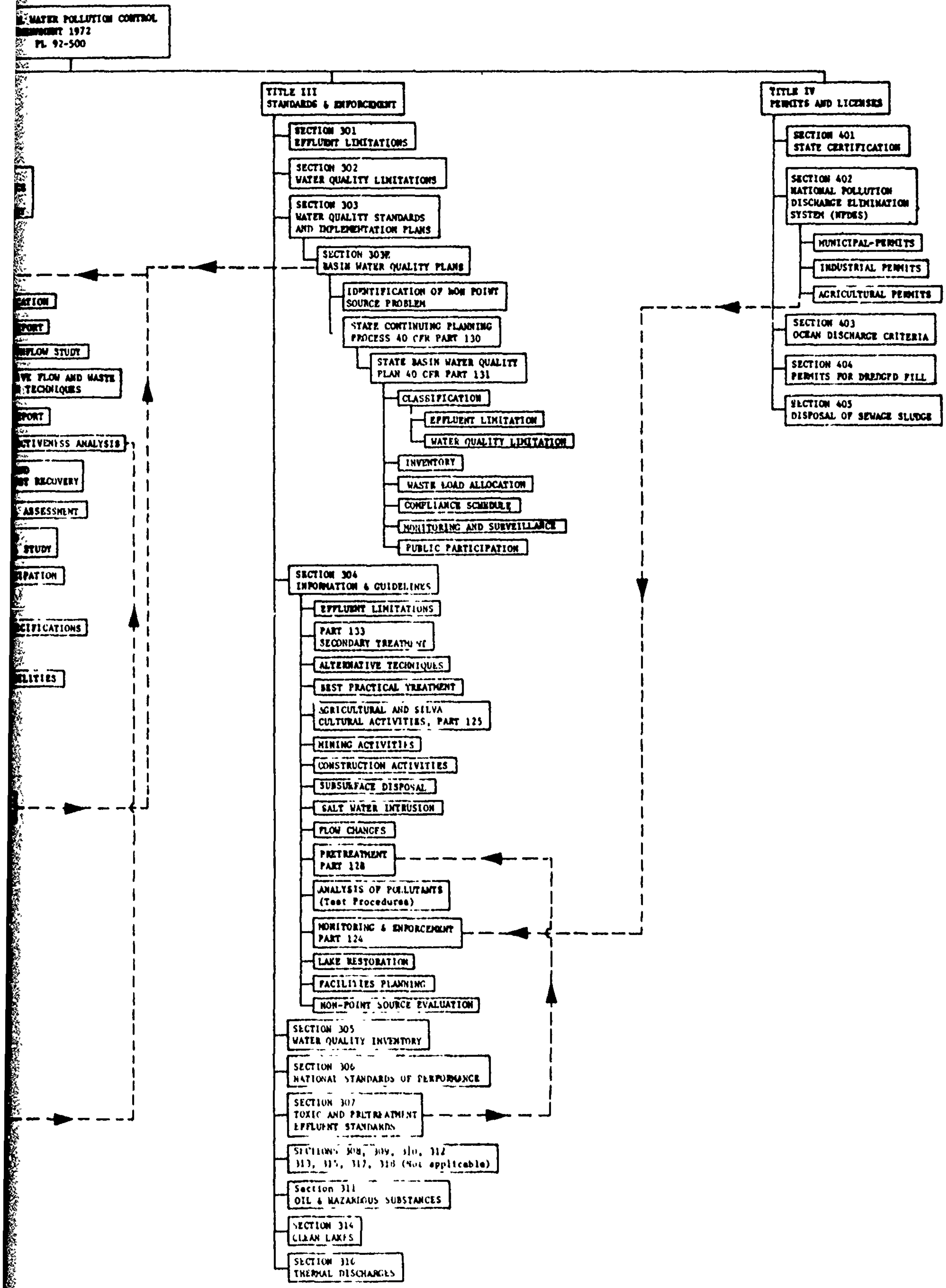
Parameter	Maximum Allowable Value
Turbidity	5 JTU for Unfiltered Water 1 JTU for Filtered Water
Color	15 Units
Threshold Odor Number	3
Arsenic	0.010 mg/liter
Barium	1.000
Boron	1.000
Cadmium	0.010
Carbon Chloroform Extract	0.200
Chloride	250.000
Chromium, Hexavalent	0.050
Copper	1.000
Cyanide	0.010
Methylene Blue Active Substances (Detergents)	0.500
Fluoride	2.000
Iron	0.300
Lead	0.050
Mercury	0.005
Manganese	0.050
Nitrogen (Nitrate plus Nitrite)	10.000
Phenols	0.001
Selenium	0.010
Silver	0.050
Sulfate	250.000
Total Dissolved Solids	500.000
Uranyl Ion	5.000
Zinc	5.000

TABLE 1 (Continued)

Parameter	Maximum Allowable Value
Total Coliforms	When 10 milliliter standard portions are examined, not more than 10% in any month shall show the presence of the coliform group. The presence of the coliform group in three or more 10 milliliter portions of a standard sample shall not be allowable if this occurs: 1. In two consecutive samples; 2. In more than one sample per month when less than 20 are examined per month; or 3. In more than 5% of the samples when 20 or more are examined per month. When the membrane filter technique is used, the arithmetic mean coliform density of all standard samples examined per month shall not exceed 1 per ml. Coliform colonies per standard sample shall not exceed 3/50 ml, 4/100 ml, 7/200 ml, or 13/500 ml in: 1. Two consecutive samples; 2. More than one standard sample when less than 20 are examined per month; or 3. More than 5% of the standard samples when 20 or more are examined per month.
Pesticides	Detected levels of 1 microgram per liter (ppb) requires notification of DSHS to determine remedial action.
Radioactivity	Limits per 1962 USPHS standards or later revision.



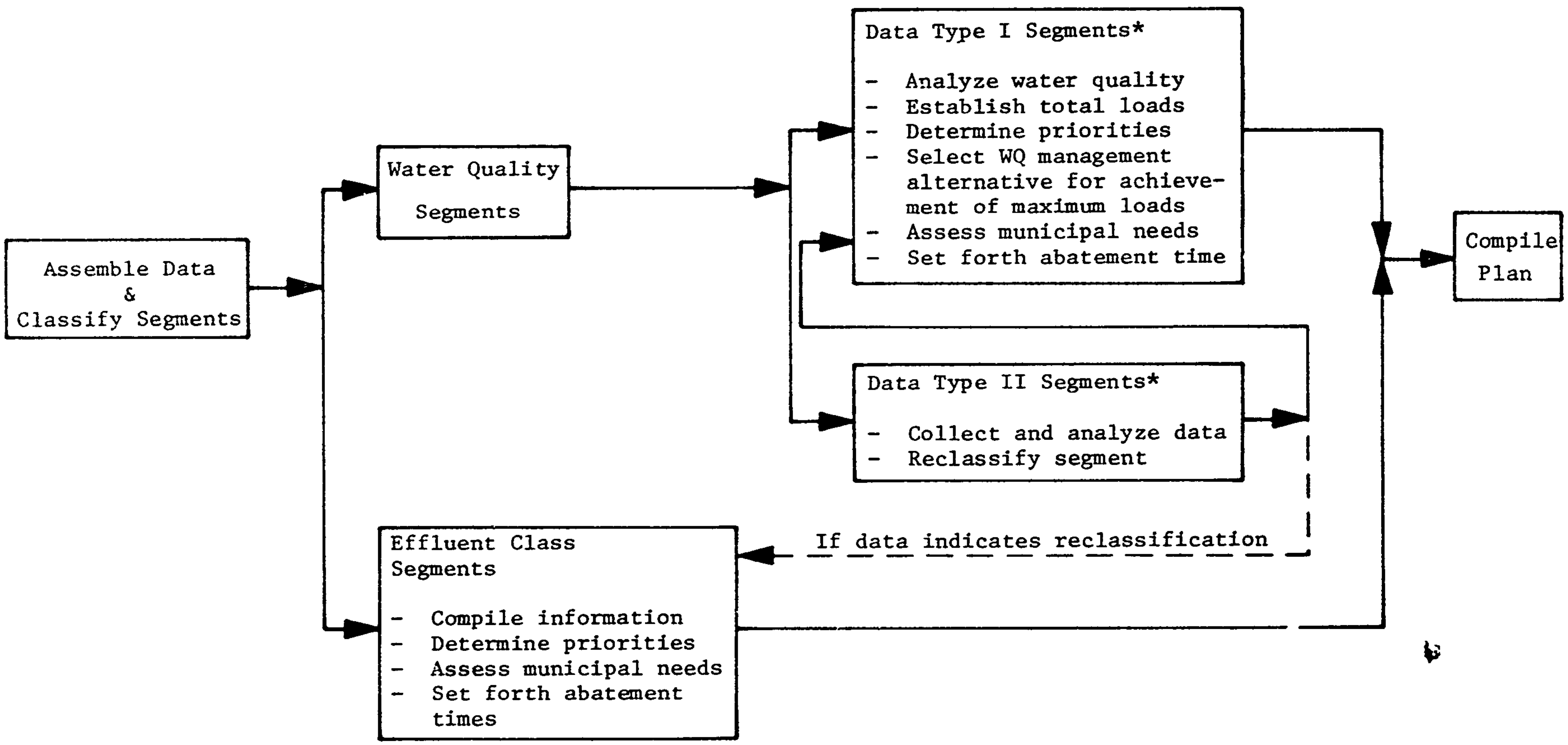
FEDERAL WATER POLLUTION CONTROL ACT AMENDMENT 1972 PL 92-500
TITLE I RESEARCH & RELATED PROGRAMS
SECTION 101 GOALS & POLICY
PART 105 PUBLIC PARTICIPATION IN WATER POLLUTION CONTROL
SECTION 102 COMPREHENSIVE PROGRAM FOR WATER POLLUTION CONTROL
SECTION 103 INTERSTATE COOPERATION AND UNIFORM LAWS
SECTION 104 RESEARCH, INVESTIGATION, TRAINING AND INFORMATION
SECTION 105 GRANTS FOR RESEARCH AND DEVELOPMENT
SECTION 106 GRANTS FOR POLLUTION CONTROL PROGRAM
ANNUAL STATE PROGRAM
MUNICIPAL FACILITIES
INDUSTRIAL SOURCES
BASIN PLANS
MONITORING
ENFORCEMENT
TRAINING
ADMINISTRATION
SECTIONS 107 THROUGH 115 (Not Applicable)
TITLE II GRANTS FOR CONSTRUCTION
SECTION 201 PURPOSE
PART 35E STATE & LOCAL ASSISTANCE USER CHARGE INDUSTRIAL COST RECOVERY
PART 35F FACILITIES PLANNING
STEP 1
STATE CERTIFICATION
FEASIBILITY REPORT
INFILTRATION INFLOW STUDY
ALTERNATIVE FLOW AND WASTE TECHNIQUES
ENGINEERING REPORT
COST EFFECTIVENESS ANALYSIS
USER CHARGE AND INDUSTRIAL COST RECOVERY
ENVIRONMENTAL ASSESSMENT
FINANCIAL AND INSTITUTIONAL STUDY
PUBLIC PARTICIPATION
STEP 2
PLANS AND SPECIFICATIONS
STEP 3
CONSTRUCT FACILITIES
SECTION 202 FEDERAL SHARE
SECTION 203 PLANS, SPECIFICATIONS, ESTIMATES & PAYMENTS
SECTION 204 LIMITATIONS AND CONDITIONS
SECTIONS 205 THRU 208 (Not Applicable)
SECTION 208 AREAWIDE WASTE TREATMENT MANAGEMENT
SECTION 209 BASIN PLANNING, LEVEL B WATER RESOURCES PLANNING
ANNUAL SURVEY
SEWAGE COLLECTION SYSTEMS
SECTION 212 DEFINITIONS
COST EFFECTIVE ANALYSIS GUIDELINES
TITLE



WATER RESOURCES STUDY METROPOLITAN SPOKANE REGIO ' Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	STRUCTURE OF PUBLIC LAW 92-500	FIGURE A

FIGURE B

FLOW DIAGRAM
PREPARATORY CLASSIFICATION FOR BASIN PLANS



*Water Quality Segments - Data Type I - Date sufficient to execute load allocations
- Data Type II - Monitoring needed to acquire sufficient data to classify segment or execute load allocations

WATER RESOURCES STUDY METROPOLITAN SPOKANE REGION Dept. of the Army, Seattle District Corps of Engineers Kennedy - Tudor Consulting Engineers	FLOW DIAGRAM PREPARATORY CLASSIFICATION FOR BASIN PLANS	FIGURE B

List of References

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APPENDIX

PARTIAL LIST OF STATUTE LAWS (RCW) AFFECTING THE DEPARTMENT OF ECOLOGY

RCW TITLE CHAPTER	
15.58	Washington Pesticide Control Act, 1971.
*18.104	Water Well Construction, 1971.
36.93	Local Governments Organization Boundaries-Review Boards, 1967 (AMD-71)
36.94	Sewage-Water Drainage Plans, 1967 (AMD-71).
39.00	New Section: Public Works, Environmental Protection, 1973.
39.34	Inter local Cooperation Act, 1967 (AMD-72).
41.06	State Civil Service Law, (AMD-72).
43.00	New Chapter: Waste Treatment Plants, Operators, 1973.
43.17	Administrative Departments & Agencies - General Provisions, (Reen-71).
43.21	Department of Conservation, (AMD-70).
43.21A	Department of Ecology, 1970, (AMD-73).
*43.21B	Pollution Control Hearings Board, 1970.
*43.21C	State Environmental Policy Act, 1971.
43.27A	Department of Water Resources, 1967. (AMD-70).
43.37	Weather Modification, (AMD-73).
43.52	Power Commission, (AMD-71).
43.83A	Waste Disposal Facilities Bond Issue, 1972.

APPENDIX (continued)

RCW TITLE CHAPTER	
43.83B	Water Supply Facilities Bond Issue, 1972
43.96B	EXPO '74, 1971.
43.99	Marine recreation land - Interagency Committee for Outdoor Recreation. (AMD-72).
46.37	Motor Vehicles - Smoke Control. (AMD-72).
47.04	Highways Environmental Impact, 1971. (Section .110).
53.08	Port Districts - Powers. (AMD-72).
56.02	Sewer Districts - General Provisions, 1971.
57.02	Water Districts - General Provisions, 1971.
70.00	New Chapter: Pollution Control Facilities, Municipal, 1973.
70.05	Local Health Department Boards, 1967. (AMD-69).
*70.93	Litter Control Model Act, 1971.
*70.94	Clean Air Act. (AMD-73).
*70.95	Solid Waste Management, 1969. (AMD-71).
78.52	Oil-Gas Conservation Environmental Impact, 1971.
79.01	Public Lands Act. (AMD-71).
80.50	Thermal Power Plants - Site Location, 1970.
82.34	Pollution Control Facilities - Tax Exemption & Credit, 1967.
85.08	Diking & Drainage - Sewerage Improvement Districts, (AMD-71).
86.04	Flood Control Districts 1935 Act.
86.05	Flood Control Districts 1935 Act, (AMD-70).

RCW TITLE CHAPTER	
86.08	Flood Control Districts 1937 Act.
86.09	Flood Control Districts 1937 Act, (AMD-70).
86.12	Flood Control by Counties, (AMD-70).
86.13	Flood Control by Counties Jointly.
86.15	Flood Control Zones Districts, (AMD-69)
*86.16	Flood Control Zones by State, 1969 (AMD-73).
86.18	Flood Control Contribution Fund, 1967.
86.24	Flood Control by State in cooperation with federal agencies--
86.26	State participation in flood control maintenance.
87.00	Irrigation Laws. (AMD-71).
89.00	Reclamation-Conservation & Land Settlement. (AMD-72).
89.08	Soil & Water Conservation District Laws. (AMD-67).
89.16	Reclamation by States. (AMD-72).
*	SURFACE AND GROUND WATER LAWS
90.03	Water Code - 1917 Act. (AMD-71).
90.08	Water Code - Stream Patrolman.
90.14	Water Rights - Registration, Waiver & Relinquishment, etc., 1967, (AMD-73).
90.16	Appropriation of Water for Public & Industrial Purposes.
90.22	Minimum Water Flows & Levels, 1969. (available individually)
90.24	Regulations of outflow of lakes. (AMD-71).

RCW TITLE CHAPTER	
90.28	Miscellaneous Rights and Duties.
90.36	Artesian Wells.
90.40	Water Rights of the United States.
90.44	Regulations of Public Ground Waters. (AMD-73).
90.54	Water Resources Act of 1971. (available individually)
90.12	Determination of Water Rights.
90.20	Appropriation Procedures.
*90.22	Minimum Water Flow and Levels, 1967 (AMD-71).
90.32	Crimes Against Water Code.
90.48	Water Pollution Control. (AMD-73).
90.50	Water Pollution Control Facilities - Financing, 1967. (AMD-70)
*90.52	Pollution Disclosure Act, 1971.
*90.54	Water Resources Act, 1971.
*90.58	Shoreline Management Act, 1971. (AMD-73).

*Available from DOE, Olympia, Washington 98504.

The Revised Code of Washington (RCW) is available at State Depository libraries or by purchase from Book Publishing Company, 2518 Western Avenue, Seattle, Washington, Telephone MA3-4221.

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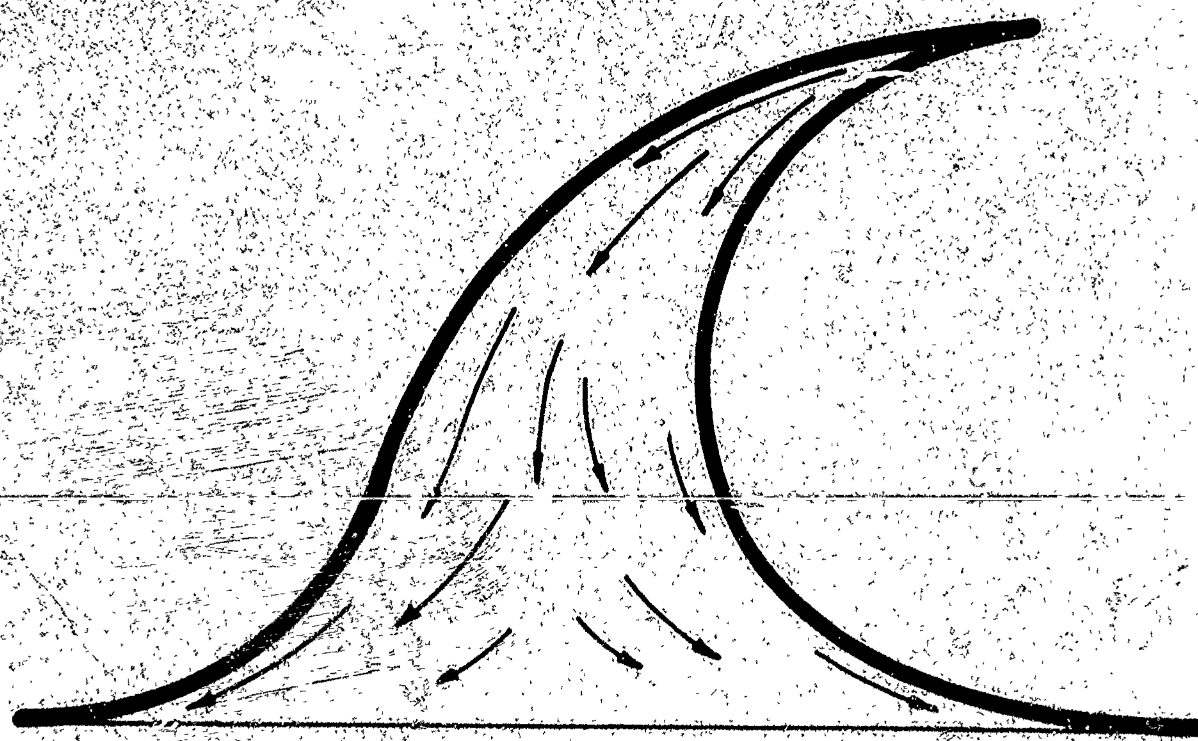

SECTION 603.1

DISPOSAL CRITERIA FOR PUBLIC FACILITIES

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 603.1

DISPOSAL CRITERIA FOR PUBLIC FACILITIES

30 September 1975

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

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SECTION 603.1

DISPOSAL CRITERIA FOR PUBLIC FACILITIES

Introduction and Objectives

The objectives of this section are to specifically state the performance criteria which will have to be met for the disposal of treated wastewaters by structural alternatives proposed in this study. The primary statutory definitions of water quality goals and criteria derive from Public Law 92-500. Administrative interpretation of this law has been under way since its passage and continues as of the date of this report. Basic policy is set in PL 92-500 but enforcement and certain generally additive options in criteria establishment are delegated to the States.

It is assumed that the earliest possible on-line implementation of any major plan for wastewater management resulting from this study will be 1980. Therefore, any facility put into service at that date must anticipate the 1983 milestone requirements of Public Law 92-500.

The 1983 milestone requirements of Public Law 92-500 are the attainment of "best practicable waste treatment technology" (BPWTT) by publicly owned treatment facilities. Specification of BPWTT as a disposal requirement is control through effluent standards rather than on the basis of the assimilative capacity of the receiving waters. The law, however, also provides that certain receiving waters may be classified by the respective states as water quality determinative if degradation would result from discharges meeting effluent standards. In such cases, PL 92-500 provides that more stringent effluent requirements may be determined by the State. The three major streams of the study area, Spokane River, Little Spokane River and Hangman Creek, are classified by the state as water quality determinative.

Administrative guidelines have been issued to define BPWTT. The latest available draft of the proposed guideline, as of this date, is the Environmental Protection Agency (EPA) document titled, "Alternative Waste Management Techniques for Best Practicable Waste Treatment" dated March 1974 and is designated as "Proposed for Public Comment." This document describes methodologies under three general techniques for achieving BPWTT. These techniques are: (1) land application, (2) treatment and discharge to surface waters, and (3) reuse. An objective of this section is to interpret the above proposed guidelines as applicable to the study area.

Public Law 92-500 states as a goal, not as a legal requirement, the achievement of no discharge of pollutants by 1985. The Corps of Engineers policy with respect to protection of the public interest as it may be affected by the uncertainties of the meaning and eventual interpretation and implementation of this goal is stated in "Urban Studies Program, Proposed Policies and Procedures", Federal Register, July 5, 1974. Another objective of this section is to abstract and interpret the Corps policy as it applies to this study.

General Description of the March 1974 Proposed Guidelines

The proposed guidelines cover three classes of generally acceptable techniques: (1) land application, (2) treatment and discharge to surface waters, and (3) reuse. The introduction emphasizes that the choice from these three techniques is left to each municipality or regional sanitary district providing it meets cost-effectiveness regulations and general environmental considerations. Through a brief legislative history, however, it points out that Congressional intent is to emphasize the need for consideration of land disposal as an alternative to the traditional surface water disposal.

There is also strong emphasis on protection of groundwaters with the intent that this resource remain suitable for drinking water purposes.

Reuse is encouraged but is not really a third alternative since treatment for reuse is defined in terms of the ultimate disposal after reuse. That is, a public facility in offering effluent for reuse must offer it with a quality acceptable for the ultimate disposal to be made. The specific reuse may require better quality which would have to be met to satisfy the user, but if the user has lower quality requirements, the quality must nevertheless be provided to meet disposal requirements.

The minimum requirements of secondary treatment as defined in 40 CFR 133 are continued and are regarded as one of the requirements inherent in achieving BPWTT.

The categorical statement is made that advanced waste treatment, which is defined as nutrient removal, is not required by best practicable treatment on a national basis. This does not preclude its requirement on a case by case basis.

PL 92-500 specifically states that EPA is authorized to conduct and assist studies "which will demonstrate a new or improved method of preventing, reducing, and eliminating the discharge into any waters of pollutants from sewers which carry storm water....." To date, the nationwide effort has been devoted largely to characterizing the nature of urban runoff as a pollutant load. Solutions to the problem or standards of control performance have not yet been developed. This situation is summarized in the referenced guidelines by the following quotation:

"Demonstrated technology to control storm sewer discharges does not exist."

The guidelines do address the problem of combined sewer overflows in a qualitative way but without numerical standards.

Non-structural reforms in the use of water to reduce total waste flows are also given the status of elements of BPWTT. Among the categories cited are education, pricing policies of water and encouraging the use of new plumbing appliances and fixtures with low water consumption. Reduction of flow through infiltration-inflow control is already a part of current requirements.

BPWTT Applied to Surface Disposal

The goal originally set in the March 1974 proposed guidelines for BPWTT as applied to surface water disposal was to go beyond removal of carbonaceous oxygen demand as accomplished by traditional secondary treatment, to the removal of a significant part of the nitrogenous demand. This proposed mandatory requirement was withdrawn subsequently by EPA in favor of making the determination of such need a responsibility of the states. This proposed change is not formalized in a published document.

Thus, except for allowing the States to determine the need for nitrification or nutrient removal on a case by case basis, the proposed guidelines for BPWTT are essentially unchanged from the 1977 milestone requirements for secondary treatment. Acceptable secondary treatment techniques for disposal to surface waters include:

1. Activated sludge process.
2. Trickling filter (or rotating disc or other processes in which the active organisms are fixed rather than free floating).
3. Lagoons with multiple cells and intermittant discharge capabilities at loadings of 20 pounds of BOD_5 per acre and 6 month detention. Continuous discharge lagoons will not meet BPWTT. Equivalent BPWTT performance can be achieved with lesser storage and higher loads by the addition of primary sedimentation pretreatment and mechanical aeration.
4. Physical-chemical processes including at least chemical precipitation followed by filtration.
5. Land application.

In terms of performance, the required effluent quality is required to be as shown in Table 1.

As indicated above, the State has designated the Spokane River, Little

Spokane River and Hangman Creek as water quality determinative. It is necessary to examine the specific requirements for each to determine the difference in disposal requirements from those based on the above effluent standards alone.

The classifications and specific deficiencies for each designated water quality determinative segment are as follows.

The Spokane River is specifically cited as being Class A water from mouth to Idaho boundary and has a special proviso with regard to water temperature limits, raising the maximum to 68°F rather than the typical 65°F. Long Lake which is included in this reach of the Spokane River is presumed to be Lake Class since it has a mean detention in excess of 15 days.

All other streams are designated Class A. The definition of Class A and Lake Class waters is shown in Table 2.

The NPDES discharge permit for the City of Spokane sewage treatment plant calls for total phosphorus removal of 85 percent or better. This phosphorus removal criteria is assumed to apply to all other significant discharges to the Spokane River and its tributaries above Long Lake.

In addition to the above cited requirements for surface water disposal in the study area, the State Department of Ecology has policy considerations for dilution. In general a dilution ratio of 1:20 or greater must be provided at 10 year 7 day low flow conditions; if not, treatment level must be "advanced." Advanced treatment is defined as that which will provide the removals indicated in Table 3. Refer to Appendices V and VI for the text of DOE policy on dilution and advanced treatment.

The DOE has not taken a position on the need for nitrogen removal or nitrification except in the case of the advanced treatment requirement for dilutions of 1:20 or less.

Considering the foregoing federal and state requirements, surface water discharges where greater than 1:20 dilution exists require secondary treatment plus 85 percent phosphorus removal. Considering criteria being established elsewhere for ammonia toxicity and the low flow dilution limitations in the Spokane River, a potential need for ammonia removal or denitrification is seen under certain conditions.

In the absence of State guidelines, suggested ammonia toxicity limitation criteria are developed in Appendix I which are summarized as follows, expressed in terms of concentrations in the receiving waters after mixing and at a pH not to exceed 8.0:

1. Not to exceed 0.2 mg/l ammonia as N at mean monthly flow.
2. Not to exceed 0.5 mg/l ammonia as N at minimum mean monthly flow of record.
3. Not to exceed 0.6 mg/l ammonia as N for 7 day 10 year low flow.

The Federal guidelines indicate a number of acceptable alternative processes for consideration in providing nitrification of ammonia or removal of ammonia. In addition to the biological processes of extending the oxidation process beyond the carbonaceous stage the following physical chemical methods are suggested for consideration:

1. Contact with activated carbon to remove ammonia. This method has the ability to remove other organic and inorganic pollutants as well.

2. Ion exchange.

3. Direct air stripping of ammonia to atmosphere.

4. Breakpoint chlorination.

The stated DOE requirement for 85 percent phosphorus removal is on a year around basis. There is no official recognition of a possible alternative which would require phosphorus removal only at such times of the year that it proves to be necessary to limit summer algae growth. This study considers the possibility of seasonal removals as an alternative through simulation modeling and in cost effective analysis.

BPWTT for Land Application of Wastewaters

Introduction. A distinction is made here between wastewaters and the solids or solids slurry (sludge) from wastewaters. Criteria specific to the latter are discussed in a following paragraph.

The EPA guidelines specify three acceptable approaches to land application: (1) irrigation, (2) overland flow, and (3) infiltration-percolation. For irrigation, the ultimate disposal may be either to groundwater and evapotranspiration or to surface water. For overland flow the ultimate disposal is usually to surface water. For infiltration-percolation, the ultimate disposal may be either directly to groundwater or via underdrains to surface water. In no case is the quality specified for the wastewater as applied to the land surface either in terms of pollutant concentration or as the output of an acceptable process. Controls are specified in terms of the quality reaching the ultimate disposal waters. Subsequent guidelines for wastewater solids application to land consider limitations on application determined in terms of the ability or vegetative cover to utilize nutrients. Presumably, revised guidelines for wastewater will include a similar approach.

The State DOE has no official guidelines for land application of wastewater to supplement the federal guidelines. A policy draft was prepared in 1971 as a joint effort of DOE and DSHS* but was never officially adopted. This early draft is considered by current staff to be more restrictive than the present concensus. A copy is included in Appendix II to illustrate one possible viewpoint. Included in Appendix III is a copy of the current California policy which illustrates another viewpoint, possibly closer to current DOE staff viewpoint.

The acceptability of land application techniques under EPA guidelines where all or part of the renovated wastewater reaches groundwater is defined in terms of its effect on quality. The effects are unqualified with regard to the degree of stratification or mixing between the leachate and the native groundwater. Groundwater is defined as that

*State Department of Social and Health Services.

water in the saturated soil zone to differentiate from the unsaturated zone, part of which is utilized as a treatment device in land application techniques. The guidelines present numerical limits on the resultant quality of the groundwater for certain chemicals, heavy metals, detergents and pesticides which are reproduced in Table 4. Certain toxic pollutants are not listed since their limiting values are still under consideration. These toxic substances are covered in the Corps of Engineers recommended standards for urban planning, also shown in Table 4, which are adopted for the purpose of this study.

Until a specific wastewater is being dealt with and the content of such contaminants as pesticides is known, the most important common parameter of concern is total nitrogen with a maximum of 10 mg/1.

No numerical limits are stated in the guidelines for pathogenic organisms. The reason given is that standard water treatment processes are designed for their removal. Likewise, no numerical values are given for limitations on BOD or solids. The guidelines do state the criteria for BPTWW by land application in general terms as being capable of "reducing chemical and organic pollutants to raw or untreated drinking water supply source levels." This is interpreted to mean that the resultant quality of the receiving groundwater would have to be maintained at the levels specified for coliform and nitrates for Class A waters and substantially free of BOD since the DO recovery capability of groundwater under typical circumstances is low.

Where the land application technique results in discharge to surface waters, such as underdrained irrigation or ditch collected overland flow, the effluent is required to be as specified for surface water discharge from any other treatment facility. For discussion of these requirements, see paragraphs above on treatment for surface water discharge.

Specific for Irrigation. Acceptable irrigation techniques include spray, ridge and furrow and flooding. Acceptable plant cover includes annual and perennial crops, both harvested and unharvested, pasture, landscape, tree farm and forest. The only criteria for acceptability other than the above described effects on groundwater and surface water are the functional adequacy of the combination of application rate, soil type, topography, depth to groundwater and cover material. There are no stated limitations on the character of the wastewater as applied. The site selection factors and criteria established by the proposed guidelines are shown in Table 5.

Although the Federal guidelines do not contain specific recommendations, the public health concerns raised by this method of disposal have prompted state level policy drafts. As cited above, the only draft available for the State of Washington has no official status.

This early draft policy is quoted in full in the Appendix II and is probably more restrictive than what may eventually be adopted but is useful in showing the possible public health responses to irrigation with reclaimed wastewater. In summary the proposed policy requires the following:

1. Pretreatment to equivalent of secondary treatment.
2. Disinfection of all irrigation waters.
3. No public access.
4. Application rates controlled to vegetation demands.
5. No application on frozen ground.
6. Fodder crops permitted but crops for human consumption prohibited.

The policy of the State of California, shown in Appendix III, is less restrictive in some cases and probably represents the position that may be adopted in Washington. Its requirements for spray irrigation are summarized as follows:

1. For Produce: Filtered, disinfected reclaimed waters, coliforms not to exceed 2.2 organisms per 100 ml.
2. For fodder, fiber and seed crops: Minimum of primary treated effluent.
3. Processed food, Pasture for milking animals or Landscape Irrigation (including golf courses and playgrounds): Disinfected, oxidized[(1)] reclaimed wastewater, coliforms not to exceed 23 organisms per 100 ml.

In addition, the California requirement prohibits direct public access to areas of reclaimed wastewater irrigation unless the quality is equal to that for produce irrigation cited above. Also, landscape impoundments are restricted in quality to disinfected, oxidized effluent (secondary

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[(1)]Oxidized treatment by definition appears to be equal to or better than secondary treatment.

treatment). These additional requirements are determinative in a practical sense to the very large irrigation projects required to implement land disposal for populations of 170,000 and more. The required irrigated areas are so extensive, 10,000 acres and more, that complete exclusion of the public is virtually impossible. The required impoundments for off season storage are likewise so large that they can be achieved only by open reservoirs created in a dammed canyon, again a facility almost impossible to shut off from unauthorized access. For these reasons and the practical operational considerations of putrescible primary effluent in long pipelines, odor prevention and ease of disinfection, this study conservatively adopts pretreatment to secondary levels with disinfection as a requirement for sprinkler irrigated agricultural use.

For wastewater management alternatives that involve the utilization of the City STP, secondary treatment facilities exist as a sunk cost so that the requirement for secondary treatment has only operation and maintenance costs significance. It is proposed to make at least one cost effectiveness analysis with primary treatment only to evaluate the possible effect on ranking.

It is assumed that the applied irrigation waters would not require treatment for heavy metals and pesticides. Pretreatment by industry will be required to exclude heavy metals so that municipal waste will not usually include levels that would require specific treatment for their removal before disposal to land. Monitoring for heavy metals, pesticides and other exotic pollutants is assumed to be maintained so that unsafe levels are not passed on to land disposal. Specific treatment or other remedial measures are not contemplated except where the specific need is indicated by monitoring. The proposed guidelines are quoted on this subject as follows:

> "Treatment of the wastewater often occurs after passage through the first 2 to 4 feet of soil. As irrigation soils are loamy with considerable organic matter, the heavy metals, phosphorus, and viruses have been found to be nearly completely removed by absorption."

If small amounts of heavy metals are known to exist in a wastewater to be applied as irrigation, it may be necessary to recognize the possible long-term buildup to toxic levels in the usable life of a particular site in a manner similar to that proposed in the guidelines for sludge disposal on land.

The proposed guidelines indicate that the expected treatment to be achieved by soil as the applied irrigation water passes through the active layer will be as follows, based on the applied waters having had prior secondary treatment:

Parameter	Expected Incremental Removal
BOD and SS	90 - 99%
Nitrogen	85 - 90%
Phosphorus	80 - 99%

Short of making a pilot field study of a specific combination of crop, soil, climate and application rate, it must be assumed that secondary treated municipal wastewater disposed by land irrigation will achieve the goals of BPWTT with respect to protection of groundwater and surface water if there is adequate active soil depth and the application rate is not excessive.

Disposal by irrigation on frozen ground is not specifically prohibited by the proposed guidelines. The precautionary statement is made that there is conflicting data. For the purpose of this study, it is assumed that irrigation on frozen ground is not an acceptable form of BPWTT disposal.

An hydraulic application rate of 4 inches per week is given for definition purposes to define the upper limit of irrigation as distinguished from infiltration-percolation. Hydraulic loading rates for irrigation can exceed the evapotranspiration requirements of the plant cover but there is a danger of excessive nitrate loading which sets an upper limit in addition to that set by the necessity to maintain aerobic soil conditions. Application rates should be checked against the ability of the plant cover to utilize and remove nitrogen and prevent its passage through to ultimate disposal in ground or surface waters. The proposed guidelines indicate that the crop nitrogen uptake should be calculated, presumably to set initial loadings. The specific nitrogen limitation given to protect groundwater requires that the field application rate must be adjusted by monitoring.

Specific for Overland Flow. Overland flow relies upon treatment achieved on the surface of the vegetation and ground surface rather than within the soil as is the case for irrigation. Percolation to groundwater is usually small or negligible since relatively impermeable soils are usually selected for this purpose.

The application rates for overland flow disposal are not related to evapotranspiration or percolation but rather to contact time as the flow, in excess of what can be utilized by the cover crop or absorbed by the soil, traverses the surface. The treatment process is more analogous to a trickling filter in that biota on the cover crop and ground surface act similarly to the biota on the media of the filter. A typical application rate is 4 inches per week applied in cycles of 6 to 8 hours of spraying followed by 6 to 18 hours of drying. The expected removals are as follows assuming secondary treatment prior to application:

Parameter	Expected Incremental Removal
BOD and SS	95 - 99%
Nitrogen	70 - 90%
Phosphorus	50 - 60%

Overland flow disposal has significantly lower nitrogen and phosphorus removals than irrigation. The proposed guidelines make no mention of the expected removals of heavy metals, dete gents, pesticides and coliforms. That small part of the applied load which does percolate through the soil would presumably be exposed to the same removal mechanisms which provide the high removals cited for irrigation. Therefore, as far as groundwater is concerned, the expected removals should be equal.

As for irrigation, no criteria are given limiting the quality of wastewater as applied to overland flow treatment. The proposed guidelines indicate that the basis for design is usually a liquid loading rate, as cited above, with the cautionary comment that organic-loading or detention time criteria may be developed in the future.

For the purpose of this study it is assumed that this method is acceptable only on lands from which the public is excluded and that the applied waters would have a minimum of secondary treatment without disinfection. It is further assumed that disinfection would have to be provided for the collected runoff before discharge to surface waters.

The proposed guidelines indicate that the overland flow method is as yet unproven for use in freezing conditions. Therefore, for the purpose of this study, the usable season will be assumed to be the same as the growing season as cited above for irrigation systems.

The cover crop for overland flow treatment is necessarily permanent, although it may require periodic cutting, and is not usually a potentially usable crop.

The proposed guidelines classify overland flow as a land application technique. Functionally, it is a polishing treatment for surface water disposal.

Specific for Infiltration-Percolation. A suitable site providing an acceptable combination of soil characteristics and depth to groundwater are critical to infiltration-percolation treatment which will satisfy

BPWTT. Soils that are too coarse and allow the applied wastewater to pass through the upper layer too quickly to experience the necessary biological and chemical action are not acceptable. Depth to groundwater should be at least 15 feet to insure treatment before the wastewater enters the saturated zone. Soils with inadequate permeability will not support hydraulic loading rates that make the method economically competitive with other land application methods.

As for the other land application methods, the proposed guidelines do not specify any limitation on the quality of the wastewater as applied. The interrelationship between quality applied and maintenance of hydraulic loading capability is pointed out. It is noted that most successful systems for municipal wastewater have applied waters of secondary quality.

The unreliability of this method for incremental nitrogen removal is noted indirectly in the proposed guidelines. The Flushing Meadows experience (Bouwer et al 1974 and Lance and Whisler 1973) indicates that cyclical nitrogen removals may be achieved by periodic loading of beds with a cover crop in the bottom but that spikes of high nitrogen leachate occur when the accumulated nitrified materials are flushed down. This experience is not judged to be adequate to assume that consistent removals could be obtained at the high application rates that would make infiltration-percolation economically attractive in the study area. If there is essentially no nitrogen reduction to applied secondary effluent containing approximately 13 mg/l of nitrogen, the resultant leachate reaching groundwater would, in itself, be a violation of the U.S. PHS limit of 10 mg/l for drinking water sources. The actual concentration drawn from groundwater would depend upon the background concentration in the native groundwater and the degree of mixing between the native groundwater and the leachate. Conservatively one would not plan a system that would use up the entire U.S. PHS limit. Therefore, prudent use of this method where the groundwater is an active domestic supply would require prior nitrogen removal before application.

Since the only practical infiltration-percolation sites in the study area are on the surface of the Spokane Valley aquifer, the application of this technique is necessarily addressed to the specific requirements of this aquifer. Due to the importance of the Spokane Valley aquifer as a public water supply, and the unknown mixing and dilution mechanism that takes place in any aquifer, it is judged to be prudent to require nitrification-denitrification and disinfection in the pretreatment process for all infiltration-percolation proposals upstream from the mouth of the Little Spokane. Since there is relatively minor use of the aquifer downstream from the mouth of the Little Spokane River and access to the aquifer could be controlled, infiltration-percolation disposal in this section is judged not to require nitrification-denitrification or disinfection in the pretreatment process.

Expected incremental removals from applied waste of secondary effluent quality are over 90 percent for BOD, SS and coliforms and 70 to 90 percent for phosphorus. No specific expectations are given in the proposed guidelines for heavy metal, detergent or pesticide removal except to note that removals are poorer than for irrigation. The known significant presence of any of these pollutants in the waste source calls for special removal prior to application.

The normal hydraulic loadings are given in the range 4 to 12 inches per week and the organic loading 3 to 15 tons BOD per acre per year. Only pilot operations can evaluate the true long-term loadings. For the purpose of this study, values to be used are more fully evaluated elsewhere but guidelines suggest criteria in the range 10 inches per week hydraulic and 10 tons per acre per year BOD loading.

The method is considered to be operable on a year-round basis. It should be noted, that in addition to the specific concerns for known drinking water quality parameters, there are reservations in the minds of regulatory bodies for the unknown effects of the use of reclaimed wastewater where ingestion by humans is involved. Refer to Appendix IV, for an example of this concern as expressed in a State of California policy paper. This paper looks with favor on near term plans where the recharge is a small part of the total groundwater basin but does not favor near term recharge that will be a substantial part of the basin budget.

Injection Wells. The proposed guidelines state that deepwell injection of wastewater is not considered a treatment alternative under BPWTT. Deepwell injection provides no substantial renovation to the groundwater according to the proposed guidelines. The guidelines indicate that deepwell injection may be considered as an alternative disposal site provided the pretreatment meets the groundwater quality criteria. This type of disposal of municipal wastes, no matter how well treated, has not gained the support of health authorities where it has been proposed. The State of California has addressed this problem specifically in a policy paper, Appendix IV, titled "Position on Basin Plan Proposals for Reclaimed Water Uses Involving Ingestion." This paper states: "The Department will recommend against injection for groundwater replenishment as a plan element which is to be implemented in the near future (within the next decade). Injection may be considered as a future option, contingent upon the availability of new supportive information and future needs." For the purpose of this study, deepwell injection will not be considered as an alternative disposal method.

Combined Sewer Control

Although no guidelines are proposed for BPWTT with respect to urban runoff as a separate source of pollution, there are guidelines for control of pollution resulting from combined sewers. These guidelines do not take the form of specific numerical parameters to be met but rather the form of indicating alternative efforts which should be explored to arrive at a cost effective method to reasonably minimize pollution from this source. Guidelines do not take the form of absolute elimination of overflows or limiting overflows to a percent of time or total annual pollution load.

The following alternatives are suggested for exploration, with emphasis on the possibility of best cost effectiveness being found in combination of techniques:

1. Sewer Separation.
2. Periodic dry weather flushing to prevent buildup of pollutants.
3. Flow routing to maximize capacity of available sewers and treatment.
4. Storage for subsequent treatment.
5. Increased treatment hydraulic capacity with some sacrifice of removals at wet weather flow.
6. Disinfection of overflows.

The alternative methods suggested for direct treatment of overflows are mostly in the experimental or pilot plant stage of development. Acceptable removals or degrees of reliability are not stated.

The only significant combined sewer system in the study area is the City of Spokane system. The City has submitted to the Department of Ecology a Plan of Study dated September 1974 for "Facilities Planning for the City of Spokane Sewer Upgrading and Overflow Corrections." This plan proposes analysis and solution of the problems associated with the City sewage collection system, most of which arise from the use of combined sewers. The program proposes diversion of the City into nine area to be addressed and corrected over a period extending from 1975 through 1986. The plan proposed consideration of the following alternatives:

1. Storm relief sewers with satellite treatment facilities at

various overflow points to the Spokane River.

2. Storm relief sewers with storage facilities so that all storm water can be conveyed to the sewer treatment plant without requiring any capacity increase in the existing interceptor sewers or the new sewer treatment plant.

3. Storm relief sewers combined with new relief interceptor sewers to the City's sewer treatment plant and further enlargement of the new sewer treatment plant to treat all storm water.

4. Complete storm and sanitary sewer separation with direct discharge of storm waters to the Spokane River.

It is not within the scope of this study to duplicate or parallel the City effort toward solution of these internal sewerage problems. The City program does not extend to the area of evaluation of the need for pollution abatement associated with separated storm drainage or urban runoff. This study, therefore, includes the consideration of potential urban runoff as separated storm drainage.

Urban Runoff Control

As indicated above, the Federal guidelines do not provide either quantitative criteria or generalized goals with regard to pollution from separated storm drainage from urban areas. Refer to Section 604.5 of this study for an approach to both the criteria problem and the probable impact of untreated separated storm water runoff.

Disposal Requirements Beyond 1983

Introduction. The foregoing has discussed disposal requirements based on proposed guidelines for 1983. Facilities contemplated for initial operation in 1980, the earliest date for possible implementation based on this study, would be designed and built to meet the 1983 guidelines. Only two years after 1983, there is the stated goal in PL 92-500 of no discharge of pollutants by 1985. In 1985, the proposed facilities would be only five years old. This leads to the question: Will the facilities completed in 1980 to 1983 standards be compatible with whatever regulation or standard grows out of the stated 1985 goal? The Corps of Engineers has addressed this problem in their formulation of proposed policies and procedures for urban studies planning. This position is abstracted below.

Abstract of Proposed Corps Policy Re: 1985 Goals. The position of the Corps of Engineers with respect to interpretation of the 1985 goal is stated in "Urban Studies Program, Proposed Policies and Procedures" as published in the Federal Register, Friday, July 5, 1974. The Corps position is that Corps planning policy must protect the Federal financial interest (inherent in Federal participation at 75 percent of construction cost under section 201 of PL 92-500) by continuing to consider that the 1985 goal may eventually become policy until such time that the EPA Administrator issues guidelines to the contrary. If the 1985 goal becomes policy, the Corps foresees the potential for significantly different overall costs in plans which call for proceeding from the 1977 requirements to the 1983 requirements without recognition of the next possible step to 1985 goals becoming requirements. To protect the Federal financial interest, the stated Corps policy is to consider through alternatives both possible planning pathways, one to meet 1983 requirements in the most cost-effective manner without consideration of possible future upgrading to 1985 goals as a requirement and the other to meet 1983 requirements in the most cost-effective manner assuming that 1985 goals will become a requirement.

To carry out the Corps policy requires a quantification of the 1985 goal of "no discharge of pollutants." The Corps provides its interpretation in the same referenced Federal Register. The Corps quantification of "no discharge of pollutants" is summarized below and is based on the philosophy of establishing critical levels of constituents above which they are defined as "pollutants" when the water is considered for use as a potable water supply, crop irrigation, livestock watering, full body contact recreation and fish and wildlife habitat. The limits are to be adjusted if necessary to suit specific needs brought out by an environmental scan of the specific location.

1. The following constituents shall be absent from the wastewater discharge.

Arsenic	Copper	Phenols
Barium	Cyanides	Selenium
Boron	Lead	Silver
Cadmium	Pesticides and other synthetic organics	Zinc
Chromium		Mercury

2. The absence of the following constituents is considered desirable but may be permissible at levels no greater than the background as determined by environmental scan:

Antimony	Molybdenum	Tin
Beryllium	Nickle	Titanium
Cobalt	Thallium	

3. The following are maximum permissible levels for the constituents listed, in the absence of natural background from environmental scan:

Constituent	Effluent Level
Total Dissolved Solids	Less than 500 mg/l in "fresh" water.
Biochemical Oxygen Demand/Day	BOD level less than 5 mg/l BOD level equal to or less than dissolved oxygen level.
Heat	The level which assures protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in or on the water into which discharge is made.
Color	Less than 15 color units.
Nitrogen as Nitrate -N and Nitrite -N	Less than 4 mg/l total.
Nitrogen as Ammonia -N	Less than 0.5 mg/l.
Total Nitrogen as N	Less than 8 mg/l.
Phosphorus as Total P	Less than 50 micrograms/liter entering a lake; or 100 micrograms/liter entering a flowing stream.
Oils and Greases	Trace.
Fecal Coliform Organisms	Less than 200/100 ml.
Suspended Solids	Less than 5 mg/l.
Dissolved Oxygen	Greater than 5 mg/l.
Virus	Inactivated, but present at trace levels.
Surfactants	Trace.
Fecal Streptococci	Inactive, but present at trace levels.
Tastes and Odors	None offensive.
Flotables	None.
Settleable Solids	Trace.
Volatile Solids	Trace.
Gamma Radiation	Trace.
Alpha Radiation	Less than one pico curie/liter.
Beta Radiation	Less than 100 pico curies/liter.
Turbidity	Less than five Jackson units.
Chemical Oxygen Demand	Less than 10 mg/l.
pH	Between 6.0 and 8.6.
Alkalinity	Less than 100 to 130 mg/l when pH is between 6.0 and 7.0.
Carbon Dioxide	Less than 25 mg/l.
Sulfates	Less than 100 mg/l.
Calcium	Less than 30 mg/l.
Chlorides	Less than 250 mg/l.
Sodium	Less than 10 mg/l.
Magnesium	Less than 125 mg/l.
Fluorides	Varies from 1.7 mg/l at 10°C to .6 mg/l at 30°C.

Constituent	Effluent Level
Aluminum	Less than 1 mg/l.
Bicarbonates	Less than plus or minus 50 mg/l variation over ambient concentrations.
Manganese	Less than 0.05 mg/l.

In summary, the Corps interpretation of the meaning of "no discharge of pollutants" is that no discharge shall have a quality inferior to the background quality of the receiving waters so that zero reliance is placed on the assimulative capacity, if any, of the receiving water.

Comparison of these 1985 standards with those promulgated in 1972, in Table 1 shows no significant differences.

Commentary on the 1985 Goal. Fundamental to interpretation of what meaning may eventually be given to the stated 1985 goal is the fact that groundwaters and surface waters are related and inseparable elements of the hydrologic cycle. The obvious recognition of the equal importance of protecting groundwater from pollutants is exemplified in the latest revision of the proposed guidelines for 1983 standards. These standards recognize the fact that any so called land disposal is inevitably a disposal to groundwater or surface water or both. Therefore, the "no discharge of pollutants" cannot be interpreted as a mandate for land disposal. Furthermore, since the pollution load in treated wastewater, except for that which becomes stranded in the unsaturated soil, must inevitably reach some element of the hydrologic cycle, it cannot be interpreted as zero discharge.

The Corps interpretation of "no discharge of pollutants" conservatively evaluates it to mean that the treated wastewater must be indistinguishable in quality from the background quality of the receiving water. This is technologically feasible but in the present and foreseeable future is impractical and economically infeasible. The primary impractical element in treating wastewaters to the same quality as the local background is the removal of dissolved salts. Treatment up to that point by a variety of methods is within the realm of economic and resource availability. But demineralization as our overall national policy is judged to be infeasible from the standpoint of costs, resources, energy and the environment.

All known demineralization processes result in a secondary disposal problem for the residual salts and the brines used in the regeneration processes. Unless the ocean is economically within reach and permitted as a disposal site for these brines, brine disposal in the ultimate sense, is impossible. Even evaporation to dry salts leaves a recalcitrant problem for land disposal since they are vulnerable to leaching.

Demineralization as an overall national requirement to match treated wastewater mineral content to background content is judged to be infeasible and not a probable element of any standard growing out of the 1985 goal. There is a place for demineralization in conserving water for reuse and the foregoing opinion is not intended to deny that use. The opinion is limited to application as an overall national requirement comparable to the 1977 requirement for secondary treatment.

In a manner similar to that being used to define BPWTT, the interpretation of 1985 goals being made for this study is in terms of acceptable alternative treatment processes rather than in terms of numerical quality criteria. The degree of treatment of wastewater judged feasible as a realization of the 1985 goal is comparable to one of the following alternatives:

1. For disposal to surface waters, secondary treatment with nutrient removal followed by the equivalent of carbon absorption and sand (or mixed media) filtration, reoxygenation and disinfection with ozone (to avoid the toxicity problems associated with chlorine disinfection).

2. For land disposal

   a. Irrigation with secondary effluent at rates monitored to prevent nitrogen application at ratio in excess of plant uptake.

   b. Overland flow of secondary effluent at monitored rates to prevent nutrient carryover, with the collected overland flow effluent given the equivalent of sand filtration, reoxygenation and disinfection before release to surface waters.

   c. Infiltration-percolation of secondary treated effluent with nitrogen removal.

Implicit in any future requirements as well as those for 1983, is the removal of toxicants and other prohibited substances as listed in Table 4 under Corps requirements.

Also implicit in all future requirements is the fact that where recycle is involved, absolute limits of dissolved salts will have to be met similar to those shown in Table 1 under Corps requirements. Either the number of recycles must be limited to stay within the absolute values or demineralization must be used to restore lower values. It is foreseen that the absolute value concept will prove too inflexible and that a sliding scale related to the background levels and volume must be developed.

In summary, the judged realization of the intent of the 1985 goal will result in probable future requirements, beyond the 1983 level as follows:

1. For surface water disposal: Addition of the equivalent of carbon adsorption, sand filtration and reoxygenation and the substitution of ozone for chlorine disinfection.

2. For land disposal:

   a. No additions to irrigation treatment except that monitoring of the groundwater would be mandatory.

   b. Additions to overland flow, which is really land treatment prior to surface disposal, same as for other surface disposal.

   c. No additions to infiltration-percolation. (Monitoring of groundwater should be mandatory with this technique at 1983 so should not have to be added.)

Recognition of 1985 Goals in this Study. Due to the possible added increment of cost to surface water alternatives as compared with land alternatives, as indicated by the above interpretation of probable requirements toward practical realization of 1985 goals, cost-effectiveness analysis should recognize probable requirements. To do so requires converting probabilities and assumptions into specifics. The following specifics are selected:

1. The upgrading of treatment required beyond 1983 specifications will be as outlined in the preceding paragraph.

2. The upgrading will be put into effect in 1990 and may be accomplished with initial construction or by stage construction as dictated by lowest cost.

Another Corps consultant has addressed the problem of interpretation of 1985 goals. See the reference Monti and Silberman (1974), particularly the concluding article, June 1974. This consultant draws the following conclusion regarding the compatibility of any facility built to meet 1983 standards relative to its continuing utility in meeting projected 1985 standards:

"...we know of no process presently available or foreseeable in the near future to permit the discharge of wastewater to any of the suggested goals of 1985 without employing the existing proven technologies of solids settling (primary treatment), satisfaction of carbonaceous BOD (secondary treatment), and nutrient removal and satisfaction of secondary oxygen demand (advanced treatment).

It will be suggested at this time that perhaps this is not such an unfortunate state of affairs. It allows a rational choice of levels of possible treatment from a treatment facility to be made based upon the determination of water quality conditions existing at a given time and identification of uses and needs for renovated wastewater of any particular quality."

This is judged to be a valid evaluation of the conditions facing decision makers at this time and provides a degree of assurance to proceed without fear that the entire facility may soon be functionally obsolete.

Background Levels

The background quality levels for both groundwater of the primary aquifer and for the Spokane River are also shown on Table 4. Both of these waters are within U.S.P.H.S. and EPA standards except for the coliform counts of the Spokane River. They are both within the Corps effluent standards except for the zinc and oil or grease content of the Spokane River. These pollutants are entering the Spokane River outside the study area. It is assumed that the oil and grease content problem is solvable and will be corrected within the next few years. The zinc problem originates in leaching from old mining operations on the Coeur d'Alene River and is not expected to be easily solved in the near future. For the purpose of this study, the present zinc content of the Spokane River is accepted as a long term feature of background quality.

<u>Wastewater Solids Disposal</u>

Acceptable disposal of wastewater solids can be achieved in four general ways:

1. Sanitary landfill
2. Reduction to an inert ash
3. Conversion to a marketable product
4. Land application

Methods 2 and 3 are not subject to disposal criteria in the sense that 1 and 4 are. Criteria for disposal methods 1 and 4 are provided in proposed EPA guidelines.[1] Method 1 is also covered in State guidelines[2] for solid waste disposal.

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[1] "Acceptable Methods for the Utilization or Disposal of Sludges", U.S. Environmental Protection Agency, November 1974.

[2] WAC 173-301.

The salient requirements for sanitary landfill disposal are as follows:

1. The sludge shall be previously stabilized.
2. The sludge shall contain no free moisture.
3. The groundwater shall be protected from leachate.
4. The sludge materials shall be covered daily and the final cover shall be not less than 2 feet thick.
5. The landfill operation shall be operated in the manner defined for sanitary landfill by State law.

The requirements for land application are as follows:

1. The sludge shall be previously stabilized by the equivalent of anaerobic digestion.
2. Where public access is not positively controlled, pathogen reduction beyond that normally achieved by stabilization shall be provided equal to long term storage (60 days at 20°C or 120 days at 4°C).
3. Application rates are to be limited
   a. By crop capability to utilize nitrogen.
   b. By soil cation exchange capacity (CEC) to protect land resource from heavy metal poisoning.
4. Not to be used on crops eaten raw by humans.
5. Cooked or processed foods or crops used for forage should be negative for pathogens.
6. The entire operation to be checked by an ongoing monitoring system.

TABLE 1
GUIDELINES FOR SECONDARY TREATMENT

The following guidelines for the requirements of secondary treatment became effective August 17, 1973. Refer to Federal Register Vol. 30 No. 159, Friday August 17, 1973.

1. The minimum level of effluent quality to be classified as secondary treatment is defined in terms of the following values for parameters in plant effluent:

Parameter	Sampling Period	Maximum Mean* Value Effluent Quality
BOD (5 day)	30 consecutive days	30 milligrams per liter or 15 percent of the mean influent BOD, whichever is smaller
BOD (5 day)	7 consecutive days	45 milligrams per liter
Settleable Solids	30 consecutive days	30 milligrams per liter or 15 percent of the mean influent SS, whichever is smaller
Solids	7 consecutive days	45 milligrams per liter
Fecal Coliform	30 consecutive days 7 consecutive days	200 per 100 milliliters 400 per 100 milliliters
pH	Continuously	Within the limits 6.0 to 9.0

2. Special consideration is given to treatment plants serving areas with combined sewer and certain industrial waste categories.

   a. Treatment works which receive flows from combined sewers may receive special consideration in the standards to be met while handling wet weather floor on a case-by-case review basis.

   b. Certain categories of industrial wastes which discharge directly to navigable waters or through a municipal treatment plant to navigable waters are subject to possible effluent quality adjustment for BOD and SS. Where the flow is treated in a municipal plant, it must exceed 10 percent of the total flow to be eligible for consideration.

*Arithmetic mean for BOD and SS.
Geometric mean for Fecal Coliform.

TABLE 2
DEFINITION OF STATE WATER QUALITY CLASSES*

2. Class A (Excellent).

a. General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

b. Characteristic uses. Characteristic uses shall include, but are not limited to, the following:

i) Water supply (domestic, industrial, agricultural)
ii) Wildlife habitat, stock watering
iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing and boating
iv) Commerce and navigation
v) Fish and shellfish reproduction, rearing and harvest

c. Water quality criteria

i) Total coliform organisms shall not exceed median value of 240 (fresh water) with less than 20% of samples exceeding 1,000 when associated with any fecal sources or 70 (marine water) with less than 10 percent of samples exceeding 230 when associated with any fecal sources.
ii) Dissolved oxygen shall exceed 8.0 mg/l (fresh water) or 6.0 mg/l (marine water).
iii) Total dissolved gas - the concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.
iv) Temperature - water temperatures shall not exceed 65° F. (fresh water) or 61° F. (marine water) due in part to measurable (0.5° F.) increases resulting from human activities; nor shall such temperature increases, at any time, exceed $t = 90/(T-19)$ (fresh water) or $t = 40/(T-35)$ (marine water); for purposes hereof "t" represents the permissive increase and "T" represents the water temperature due to all causes combined.
v) pH shall be within the range of 6.5 to 8.5 (fresh water) or 7.0 to 8.5 (marine water) with an induced variation of less than 0.25 units.
vi) Turbidity shall not exceed 5 JTU over natural conditions.
vii) Toxic, radioactive, or deleterious material concentrations shall be below those of public health significance, or which may cause acute or chronic toxic conditions to the aquatic biota, or which may adversely affect any water use.
viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

*Source: Washington Administrative Code (WAC) 173-201.

TABLE 2 - Continued
DEFINITION OF STATE WATER QUALITY CLASSES*

5. Lake Class.

a. General characteristic. Water quality of this class shall meet or exceed the requirements for all or substantially all uses.

b. Characteristic uses. Characteristic uses for waters of this class shall include, but are not limited to, the following:

i) Water supply (domestic, industrial, agricultural
ii) Wildlife habitat, stock watering
iii) General recreation and aesthetic enjoyment (picnicking, hiking, fishing, swimming, skiing, and boating)
iv) Fish and shellfish reproduction, rearing, and harvest

c. Water quality criteria

i) Total coliform organisms shall not exceed median values of 240 with less than 20% of samples exceeding 1,000 when associated with any fecal source.
ii) Dissolved oxygen - no measurable decrease from natural conditions.
iii) Total dissolved gas - the concentration of total dissolved gas shall not exceed 110% of saturation at any point of sample collection.
iv) Temperature - no measurable change from natural conditions.
v) pH - no measurable change from natural conditions.
vi) Turbidity shall not exceed 5 JTU over natural conditions.
vii) Toxic, radioactive, or deleterious material concentrations shall be less than those which may affect public health, the natural aquatic environment, or the desirability of the water for any usage.
viii) Aesthetic values shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

TABLE 3
DEFINITION OF ADVANCED TREATMENT

Effluent requirements to meet the definition of advanced treatment as given in Department of Ecology Dilution Zone Guidelines are as follows:

a. 10 mg/l BOD, or 95% removal, whichever results in a better quality effluent.

b. 10 mg/l suspended solids, or 95% removal, whichever results in a better quality effluent.

c. 0.5 mg/l phosphorus, or 95% removal, whichever results in a better quality effluent.

d. 3 mg/l ammonia.

e. Total coliform organisms shall not exceed median values of 50 organisms/100 ml with less than 10% of the samples exceeding 230 organisms/100 ml.

TABLE 4

COMPARISON OF BACKGROUND QUALITY WITH VARIOUS STANDARDS

Category	Constituent	Units	Groundwater Background[1]	Spokane R. Background[2]	U.S.P.H.S. Drinking Water Standards	E.P.A.[3] Groundwater Stds., 1983	Corps Effluent Stds., Planning[4]	Corps Effluent Stds., 1985[5]
STANDARD CHEMICAL	TDS	mg/l	170	41(a)	500		<500	<500
	Suspended	mg/l		8.7(b)			<2	<5
	Volitile S.	mg/l					Trace	Trace
	Turbid	Jackson		1(b)	5		<5	<5
	Color	—			15		<75	<15
	Odor	—			3		None	None
	Carbon Chlor. Ext.	mg/l			0.2	<0.3		
	Alkalinity	mg/l					<100-130 with pH 6.0 - 7.0	<100-130 with pH 6.0 - 7.0
	pH		7.05	6.81-7.34(b)				6.0 - 8.6
	Carbon Dioxide	mg/l	4				< 25	<25
	Sulfate	mg/l	9.6	7.3(b)	250	<250	< 10	<100
	Chloride	mg/l	0.5	0.25(b)	250	<250	<250	<250
	Fluoride	mg/l	0.08		2.0	<1.1	Varies 1.7 @ 10° to 0.8 @ 30°C	Varies 1.7 @ 10°C to 0.8 @ 30°C
	Bicarbonate	mg/l	159				<±50 mg/l over ambient	<±50 mg/l over ambient
	Calcium	mg/l	30	5.8(b)			<30	<30
	Magnesium	mg/l	17	1.9(b)			<125	<125
	Sodium	mg/l	2.8	1.2(b)		<270	<10	<10
	Temprature	°C	10	Annual Range 2° - 24°				
	Hardness	mg/l $CaCO_3$	144					
OXYGEN BALANCE	BOD	mg/l		1.21(a)				<5
	COD	mg/l						<10
	DO	mg/l	8 @ 17°C					>5
NUTRIENTS	Ammonia	mg/l	<.056	0.041(a)			< 0.1	<0.5
	Nitrate	mg/l	1.3	0.064(a)		<10		
	Nitrite	mg/l	<.002	0.003(a)				
	$NO_3 + NO_2$	mg/l	1.3		10.0		<4.0	<4.0
	TKN	mg/l	<.28	0.207(a)				
	Total N.	mg/l		0.208(a)			<10	<8
	Orto P.	mg/l	.030	0.056(a)				
	Total P.	mg/l	.032	0.144(a)			<.050 lake <.100 stream	<.050 lake <.100 stream
PATHOGEN INDICATORS	Total Colif.	#/100ml	< 1					
	Fecal Colif.	#/100ml	< 1				<200	<200
	Fecal Strep.	#/100ml						Inactivated
	Virus	#/100ml				Inactivated		Inactivated
EXOTIC ORGANICS	Surfactants	#/100ml	<.05		0.5	<0.5	Trace	Trace
	Pesticides	µg/l			<1	Varies by kind	None	None
	Phenols	mg/l	<.001		.001		None	None
	Cyanide	mg/l			.01		None	None
METALS	Aluminum	mg/l		< 0.100		<1		< 1
	Manganeue	mg/l	<.010	.020(b)	0.05	<0.05	< 0.5	< 0.05
	Iron	mg/l	<.010	.090(b)	0.3	<0.3		
TOXIC METALS-I	Arsenic	mg/l	<.006		.01	< 0.1(7)	None	None
	Barium	mg/l			1.0	<1.0	None	None
	Boron	mg/l			1.0		None	None
	Cadmium	mg/l	<.005		.01		None	None
	Hex. Chrom	mg/l	<.005		.05	< .05	None	None
	T. Chrom	mg/l			—		None	None
	Copper	mg/l	<.005		1.0	<1.0	None	None
	Lead	mg/l	<.010		.05		None	None
	Mercury	mg/l	<.002	<.0001	.005		None	None
	Selinium	mg/l			.01	<0.01	None	None
	Silver	mg/l		<.001	.05	<0.05	None	None
	Zinc	mg/l	<.005	0.285(a)	5.0	< 5.0	None	None
TOXIC METALS-II	Antimony	mg/l					AD(6)	AD(6)
	Beryllium	mg/l					AD(6)	AD(6)
	Cobalt	mg/l					AD(6)	AD(6)
	Molybdenum	mg/l					AD(6)	AD(6)
	Nickle	mg/l					AD(6)	AD(6)
	Thallium	mg/l					AD(6)	AD(6)
	Tin	mg/l					AD(6)	AD(6)
	Titanium	mg/l					AD(6)	AD(6)
	Uranyllon	mg/l				5.0	AD(6)	AD(6)
OIL AND GREASE		mg/l		5.3(b)			Trace	Trace

(1) Based on Bureau of Rec. Well 5/51 - 28 N near Post Falls, Idaho
(2) (a) = average of available data Post Falls to Liberty Bridge (b) = Sept. 1973 sampling program
(3) From "Alternative Waste Management Techniques for Best Practicable Waste Treatment March 1974
(4) From Corps of Engineers "West Water Management Program, Study Procedure" May 1, 1972
(5) From Federal Regulations July 5, 1974 "Urban Studies Program, Proposed Policies and Procedures"
(6) AD = absence desirable but some level possible based on environmental scan.
(7) Suspect this is a typographical error - .01 intended

TABLE 5

SELECTION FACTORS AND CRITERIA FOR IRRIGATION

Factor	Criterion
Soil type	Loamy soils preferable, but most soils from sands to clays are acceptable
Soil drainability	Well-drained (more than 2 in./day) soil preferred; consult experienced agricultural advisors
Soil depth	Uniformly at least 5 to 6 ft throughout site
Depth to groundwater	Minimum of 5 ft
Groundwater control	May be necessary to ensure treatment if water table is less than 10 ft from surface
Groundwater movement	Velocity and direction must be determined
Slopes	Up to 15% are acceptable with or without terracing
Underground formations	Should be mapped and analyzed with respect to interference with groundwater or percolating water movement
Isolation	Moderate isolation from public preferable, the degree depending on wastewater characteristics, method of application, and crop
Distance from source of wastewater	Economics

Source: Proposed Guidelines, March 1974, "Alternative Waste Management Techniques for Best Practicable Waste Treatment." EPA

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APPENDIX I

DEVELOPMENT OF CRITERIA FOR AMMONIA TOXICITY

The toxicity of ammonia to fresh water organisms is well established and known to be highly dependent upon pH and to a lesser extent on temperature and dissolved oxygen. The toxicity has been shown to be primarily dependent upon the undissociated ammonium hydroxide, the concentration of which is highly pH dependent. (Doudoroff and Katz, 1950.) The toxicity can therefore be expressed in terms of the concentration of undissociated NH_4OH and the corresponding levels of total ammonia N determined for various levels of pH based on known dissociation equilibria. The threshold toxicity of undissociated ammonium hydroxide as determined by bioassay is approximately 0.2 mg/1. The recommended application factors for nonconservative toxicants are of the order 10 to 1 (FWPCA, 1968). The only presently known regulatory application of ammonia toxicity limits is that being currently applied in NPDES permits issued in the San Francisco Bay Area. The stated limit in these permits is 0.025 mg/1 of undissociated ammonium hydroxide. This appears to be in close agreement with the previously described threshold toxicity and application factor.

The following table and Figure A-1 demonstrates the relationship between threshold toxicity, allowable concentration and pH, all at 25°C.

pH	Ratio, Dissociated to Undissociated Ammonium Hydroxide[1]	Threshold Toxicity mg/l as total NH_4OH	as NH_3-N	Allowable Concentration mg/l NH_3-N
9.2	1 to 1	.400	.160	.020
9.0	1.8 to 1	.560	.220	.028
8.3	9.02 to 1	2.00	.80	.100
8.0	18 to 1	3.80	1.52	.190
7.3	90.2 to 1	18.24	7.30	.912
7.0	180 to 1	36.20	14.48	1.810
6.0	1800 to 1	360.2	144.1	18.01

This demonstrates that for the upper limit of allowable pH in Class A waters of 8.5, the threshold toxicity is less than 0.80 mg/l of ammonia as N and that the allowable concentration is therefore less than 0.10 mg/l.

The boundary condition of ammonia concentration as the Spokane River enters the study area is a mean of 0.051 mg/l. Under natural conditions, that is with zero discharge of man generated pollutants, the estimated ammonia level in the Spokane River below the Little Spokane confluence is 0.032 mg/l at 7 day 10 year low flow conditions. The drop in ammonia level is due to the significance of groundwater at low flow. At high flows the downstream concentration would approach the boundary condition. This indicates that the natural background of this parameter is 30 to 50 percent of the allowable limit at maximum pH.

During the Fall of 1973 sampling program, a low flow period, under present conditions of primary treatment by the City, the observed ammonia

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[1] Source, Skoog and West.

concentration at Nine Mile Dam was a mean of 0.589 mg/l and the maximum pH was 7.7. For the pH condition at the time, the allowable ammonia concentration is 0.36 and the threshold toxicity level is 3.0. That is under present loading conditions coincident with low flows, there appears to be a violation of the allowable level of ammonia considering normal application factors.

Under forecast condition at year 2000 for the maximum concentration of surface water disposal, that is for the entire urban planning area waste flows concentrated at the present City STP site and receiving secondary treatment with phosphorus removal, the ammonia increment to the river would be 6500 pounds per day of ammonia as N. This would be equal to 1.2 mg/l when mixed with the 7 day - 10 year low flow of 1000 cfs below the STP (including the municipal and industrial waste volumes upstream). This concentration is approximately equal to the threshold toxicity at a pH of 8.1. Changing the level of treatment to include ammonia stripping would reduce the ammonia increment by a factor of 0.20 so that the resultant receiving water concentration would be 0.24 mg/l corresponding to the allowable loading at pH 7.9. Thus, it can be seen that ammonia toxicity is a matter of potential concern for surface water disposal for both present and future conditions specific to the study area and warrants selection of criteria for evaluation of wastewater management alternatives.

Considering the foregoing, the following is suggested as a reasonable basis for disposal criteria for ammonia toxicity potential in the Spokane River.

1. During the summer months, June 1 through September 30, the maximum allowable pH of the receiving waters should be 8.0 rather than 8.5 as permitted for Class A waters.

2. The maximum allowable ammonia concentration as N, after complete mixing of an effluent, should not exceed 0.6 mg/l at 7 day - 10 year low flow conditions and should not exceed 0.5 mg/l at the long term mean flow for the lowest summer month or 0.2 mg/l for the mean monthly flow throughout the summer.

3. Looking beyond this study to actual monitoring of receiving waters at an effluent, the regulation should allow the above specified concentrations to occur only within 50 feet of the point of discharge or within 25 percent of the stream cross section at the point of discharge, whichever is smaller.

The reason for considering lowering the allowable pH is that this could be a more feasible way to control ammonia toxicity than the extremely restrictive concentrations of ammonia required above pH 8.0. The level of 0.6 mg/l at the rare 7 day low flow condition allows some encroachment on the typical application factor, since to hold to the full application factor at rare occasions is to compound the safety factor. The full application factor is utilized for the criterion at mean flow for lowest month.

Bioassays are recommended for specific fish species and water quality to establish threshold toxicities specific to the study area after the improved City STP has been placed in service and the fishery downstream from the outfall stabilizes to the new conditions.

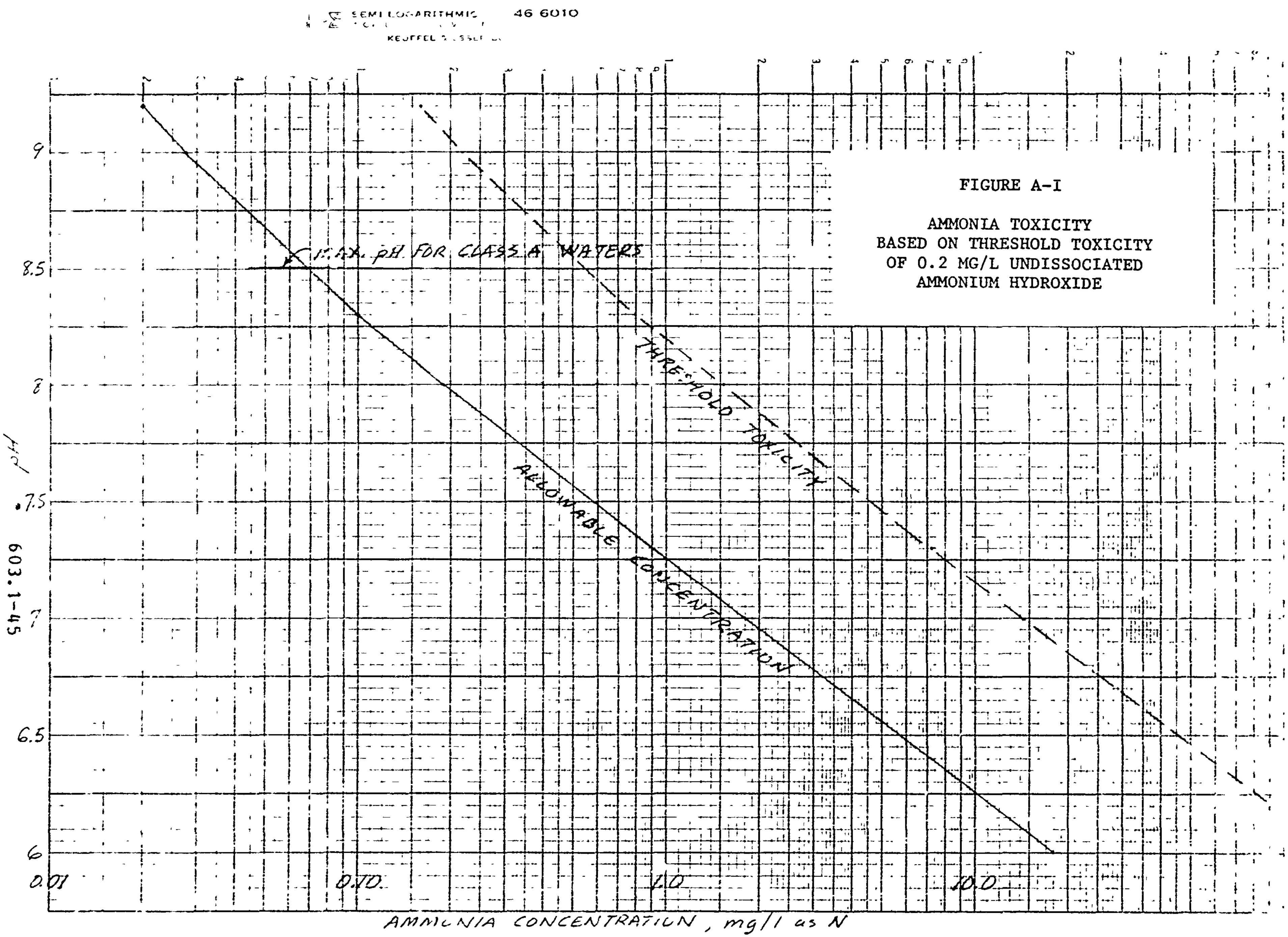

FIGURE A-I

AMMONIA TOXICITY
BASED ON THRESHOLD TOXICITY
OF 0.2 MG/L UNDISSOCIATED
AMMONIUM HYDROXIDE

LIST OF REFERENCES

Federal Water Pollution Control Administration, 1968*. Water Quality Criteria.

Doudoroff, P. and Katz, M., 1950. Critical review of literature on the toxicity of industrial wastes and their components to fish I Alkalies, acids, and inorganic gasses. II Metal as salts. in Sewage and Industrial Wastes.

Skoog and West . Analytical Chemistry.

Sanitary Engineering Research Laboratory, University of California, 1971. Toxicity removal from municipal wastewaters, Volume IV of a study of toxicity and biostimulation in San Francisco Bay Delta Waters.

APPENDIX II

(This document has NO official status and probably does not represent current DOE policy. Inclusion here is to represent a possible conservative viewpoint.)

PROPOSED POLICY FOR LAND DISPOSAL OF TREATED DOMESTIC SEWAGE EFFLUENTS IN EASTERN WASHINGTON

Washington State Department of Ecology
Washington State Department of Social and Health Services

February 1, 1971

For the purposes of this policy, land disposal shall mean the application of treated sewage to the land for the purpose of effluent disposal only.

In many areas of Eastern Washington, adequate streamflow is not available for proper assimilation of treated wastewater. Intermittent streams are common as are isolated basins without surface water drainage. These areas are often faced with extremely difficult problems in providing final disposal of waste waters. The purpose and intent of this policy is to make available an alternative for those areas where conditions prevent utilization of conventional disposal methods. Land disposal will be considered for approval by the state regulatory agencies only after engineering studies have positively developed that other adequate disposal methods are either not available or would be more detrimental to the environment.

The following standards and conditions are intended to be used as guidelines in reviewing proposals for such disposal methods only after the considerations stated in the above paragraph have been satisfied.

1. All effluent shall receive secondary treatment in which a minimum removal of 85% BOD and 90% suspended solids has been attained.

2. All effluent shall be adequately disinfected in accordance with the disinfection policy of the state regulatory agencies.

3. Public trespass shall be restricted at all times by means of adequate fencing and appropriate warning signs.

4. Application rates shall be controlled in order to achieve the following conditions:

    a. There shall be no runoff to land not under the ownership or control of the operating entity.

    b. Operation shall cease when there is a snow cover or frost in the ground.

    c. The effluent shall be disposed of through consumptive use by vegetation and thereby preclude ground saturation or ponding.

    d. An appropriate vegetative ground cover shall be maintained during the growing season.

5. A minimum of sixty days' storage time shall be provided during inclement weather. In areas of more intense snowfall, storage capacities will be increased.

6. The operating entity must have maintenance personnel available at all times the disposal system is operating.

7. Any beneficial use derived from the land disposal operation will be strictly secondary use and must not conflict with the primary purpose of effluent disposal. Fodder type crops may be harvested under such conditions. Crops intended for human consumption are prohibited.

(The regulatory agencies will give special consideration to the beneficial re-use of wastewaters and establish appropriate standards based on the merits of the situation. The controlling criteria in such cases where public contact can be expected will be that the wastewater provide a source of water where other sources are non-existent.)

APPENDIX III
(State of California)
STATEWIDE STANDARDS FOR THE SAFE DIRECT USE OF RECLAIMED WASTEWATER FOR IRRIGATION AND RECREATIONAL IMPOUNDMENTS

Group 12. Statewide Standards for the Safe Direct Use of Reclaimed Waste Water for Irrigation and Recreational Impoundments

Article 1. Intent of Standards

8025. Intent. The intent of these standards is to prescribe levels of waste water constituents which will assure that the practice of directly using reclaimed waste water for the specified purposes does not impose undue risks to public health. Experience indicates that with sufficient treatment of waste waters, their use for the purpose specified is without known health hazard. In order to avoid health hazards, adequate and reliable treatment and distribution facilities, operations, controls, surveillance, and monitoring systems must be included in any operation which uses reclaimed waste water. Precautions must also be taken to avoid direct public contact with reclaimed waste waters which do not meet at least the standards specified in Article 6 for unrestricted recreational impoundments.

NOTE: Authority cited for group 12: Section 102, Health and Safety Code. Reference: Section 13521, Water Code.

History: 1. New Group 12 (Sections 8025 through 8050) filed 5-20-68; effective thirtieth day thereafter (Register 68, No. 20).

Article 2. Definitions

8026. **Reclaimed Waste Water.** Reclaimed waste waters means waters, originating from sewage or other waste, which have been treated or otherwise purified so as to enable direct beneficial reuse or to allow reuse that would not otherwise occur.

8027. **Direct Reuse.** Direct reuse means the use of reclaimed waste water transported from the point of production to the point of use without an intervening discharge to waters of the State.

8028. **Produce.** Produce means any food for human consumption which may be used in its raw or natural state without physical or chemical processing sufficient to destroy pathogenic organisms.

8029. **Spray Irrigation.** Spray irrigation means application of reclaimed waste water from orifices in piping installed above or along the ground.

8030. **Surface Irrigation.** Surface irrigation means application of reclaimed waste water by means other than spraying such that contact between the edible portion of any food crop and reclaimed waste water is prevented.

8031. **Oxidized Waste Water.** Oxidized waste water means waste water in which the organic matter has been stabilized, is nonputrescible, and contains dissolved oxygen.

8032. **Coagulated Waste Water.** Coagulated waste water means oxidized waste water in which finely divided suspended matter has been agglomerated by the addition of a suitable chemical or by an equally effective method.

8033. **Filtered Waste Water.** Filtered waste water means coagulated waste water which has been passed through natural undisturbed soils or filter media, such as sand or diatomaceous earth, so that the final turbidity determined by an approved laboratory method does not exceed ten (10) Turbidity Units.

8034. **Disinfected Waste Water.** Disinfected waste water means waste water in which the pathogenic organisms have been destroyed by chemical, physical, or biological methods.

8035. **Most Probable Number.** Most Probable Number is a statistical expression of the most likely number of bacteria present in a unit volume of sample, and which is determined by an approved laboratory method.

8036. **Primary Effluent.** Primary effluent is the effluent from a sewage treatment process which provides partial removal of sewage solids by physical methods so that it does not contain more than one (1) milliliter per liter of settleable solids as determined by an approved laboratory method.

8037. **Approved Laboratory Methods.** Approved laboratory methods are those specified in "Standard Methods for the Examination of Water and Wastewater," prepared and published jointly by the American Public Health Association, the American Water Works Association, and the Water Pollution Control Federation and which are conducted in laboratories approved by the State Department of Public Health.

8038. **Restricted Recreational Impoundment.** A restricted recreational impoundment is a body of water in which recreation is limited to fishing, boating, and other non-body-contact water sport activities.

8039. **Non-Restricted Recreational Impoundment.** A non-restricted recreational impoundment is a body of water in which no limitations are imposed on body-contact water sport activities.

8040. **Landscape Impoundment.** A landscape impoundment is a body of water which is used for esthetic enjoyment or which serves a function not intended for public contact.

Article 3. Irrigation of Produce

8041. **Spray Irrigation.** Reclaimed waste water used for the spray irrigation of produce shall be at all times an adequately disinfected filtered waste water. The waste water shall be considered adequately disinfected if the median Most Probable Number of coliform organisms in samples collected from the irrigation piping does not exceed two and two-tenths (2.2) per one hundred (100) milliliters. The median value shall be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

8042. **Surface Irrigation.** (a) Reclaimed waste water used for surface irrigation of produce shall be at all times an adequately disinfected oxidized waste water. The waste water shall be considered adequately disinfected if at some point in the treatment process the median Most Probable Number of coliform organisms does not exceed two and two-tenths (2.2) per one hundred (100) milliliters. The median value shall be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

(b) Orchards and vineyards may be surface irrigated with reclaimed waste water that has the quality at least equivalent to that of primary effluent provided that no fruit is harvested that has come in contact with the irrigating water or the ground.

Article 4. Irrigation of Fodder, Fiber, Seed, and Processed Food Crops

8043. **Fodder, Fiber, Seed.** Reclaimed waste water used for the surface or spray irrigation of fodder, fibre, and seed crops shall have the quality at least equivalent to that of primary effluent.

8044. Food Crops. (a) Reclaimed waste water used for the surface irrigation of food for human consumption which will be processed sufficiently by physical or chemical methods to destroy pathogenic organisms shall have the quality at least equivalent to that of primary effluent.

(b) Reclaimed waste water used for the spray irrigation of food for human consumption which will be processed sufficiently by physical or chemical methods to destroy pathogenic organisms shall be at all times an adequately disinfected oxidized waste water. The waste water shall be considered adequately disinfected if at some point in the treatment process the Most Probable Number of coliform organisms of samples collected does not exceed a median of twenty-three (23) per one hundred (100) milliliters. The median value shall be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

8045. Pasture for Milking Animals. Reclaimed waste water used for the irrigation of pasture to which milking cows or goats have access shall have the quality and sampling control program as specified in Article 5, Section 8046.

Article 5. Landscape Irrigation

8046. Landscape Irrigation. Reclaimed waste water used for the irrigation of golf courses, cemeteries, lawns, parks, playgrounds, freeway landscapes, and landscapes in other areas where the public has access shall be at all times an adequately disinfected oxidized waste water. The waste water shall be considered adequately disinfected if at some point in the treatment process the median Most Probable Number of coliform organisms does not exceed twenty-three (23) per one hundred (100) milliliters of sample. The median value will be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

Article 6. Recreational Impoundments

8047. Non-Restricted Recreational Impoundment. Reclaimed waste water used as a source of supply in a non-restricted recreational impoundment shall be at all times an adequately disinfected filtered waste water. The waste water shall be considered adequately disinfected if at some point in the treatment process the median Most Probable Number of coliform organisms does not exceed two and two-tenths (2.2) per one hundred (100) milliliters. The median value shall be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

8048. Restricted Recreational Impoundment. Reclaimed waste water used as a source of supply in a restricted recreational impoundment shall be at all times an adequately disinfected oxidized waste water. The waste water shall be considered adequately disinfected if at some point in the treatment process the median Most Probable Number of coliform organisms does not exceed two and two-tenths (2.2) per one hundred (100) milliliters. The median value shall be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

8049. Landscape Impoundment. Reclaimed waste water used as a source of supply in a landscape impoundment shall be at all times an adequately disinfected oxidized waste water. The waste water shall be considered adequately disinfected if at some point in the treatment process the median Most Probable Number of coliform organisms does not exceed twenty-three (23) per one hundred (100) milliliters. The median value shall be determined from the bacteriological results of the last seven (7) days for which analyses have been completed.

Article 7. Sampling and Analysis

8050. Sampling and Analysis. (a) Samples for analysis shall be collected at least daily and at a time when waste water flow and characteristics are most demanding on the treatment facilities and disinfection procedures.

(b) For uses requiring a quality at least equivalent to primary effluent, a sample shall be analyzed by an approved laboratory method for settleable solids.

(c) For uses requiring an adequately disinfected oxidized waste water, a sample shall be analyzed by an approved laboratory method for coliform bacteria content.

(d) For uses requiring an adequately disinfected filtered waste water, a sample shall be analyzed by approved laboratory methods for turbidity and coliform bacteria content.

APPENDIX IV

(State of California)

POSITION ON BASIN PLAN PROPOSALS
FOR
RECLAIMED WATER USES INVOLVING INGESTION

Introduction

The purpose of the position statement is to provide guidelines for Department of Health review and recommendations on basin plan reclamation components that involve augmentation of a domestic water supply. The Department of Health's responsibility is to represent the best health interests of the State in this matter by assuring protection of the domestic water resource.

Three uses of reclaimed water are considered in the statement:

1. Groundwater recharge by surface spreading.
2. Direct injection into an aquifer suitable for use as a domestic water source, and
3. Direct discharge of reclaimed water for supply augmentation into a domestic water system or storage facility.

Health risks from the use of renovated wastewater may arise from pathogenic organisms and toxic chemicals. The nature of the phenomenon associated with pathogens and heavy-metal toxicants are well enough understood to permit setting limits and creating treatment control systems. This is not the case, however, with regard to some organic constituents of wastewater. In particular, the ingestion of water reclaimed from sewage may produce long-term health effects associated with the stable organic materials which remain after treatment.

This is an area of unknowns--unknowns involving the composition of the organic materials, the types of long-term effects, synergistic effects, metabolite formations, treatment effects, methods of detection and identification, and ultimately, the levels at which long-term health effects are exerted.

The urgent need for knowledge in this area has generated increased calls for answers by health authorities, the water industry, resource managers, and the scientific community. It now appears that the need for research is recognized and there should be action in the near future. As a suggestion of the time frame needed for research activity, it has been estimated that the interval needed before information can be generated through animal feeding experiments (one possible method of study) could range from six to ten years or longer depending on the results that are obtained. The health effects of concern are not immediate or acute. They are related to ingestion over an extended period, measured in years or decades, and may be serious but quite subtle.

In summary, stable organics pose a health question when reclaimed water is used to augment a domestic water s y. This question will not be answered for years, and years of exposure may be involved for the occurrence of adverse effects. It is in this setting that the position statement has been developed.

Uses Involving Ingestion

Three uses of reclaimed water have been identified which involve augmentation of a domestic water supply. These are ranked in ascending order of health significance for the reasons given.

1. Groundwater replenishment by surface spreading. Health protection will depend on treatment, changes or removals which occur during percolation, dilution, and time.

   There are presently four planned recharge systems in operation in California which replenish aquifers used for domestic supply. The largest and one which has operated for more than a decade is the Whittier Narrows recharge operation which involves the recharge of 12,000-18,000 acre-feet of reclaimed water and 160,000 acre-feet of natural surface water annually into a large groundwater basin. The degree of monitoring to determine effects on the organic quality of groundwater from the several planned operations to this time has not been significant.

2. Injection into a groundwater aquifer. Health protection would depend upon treatment and time. There is little assurance that beneficial changes or removals will occur with horizontal movement through a saturated aquifer. Movement will most likely occur as a physical displacement of the natural groundwater with little mixing or dilution.

   Most injection proposals thus far have been for the purpose of saline water repulsion. With mound and trough systems, there is opportunity for partial control of the movement of reclaimed water. The one proposal which has advanced to the construction stage (Orange County Water District) has a number of restrictive provisions and requirements applied to it including "...an alternate source of domestic water supply shall be provided any user whose groundwater is found to be impaired by the injection program." Two other proposals for saline water repulsion are in the development stage in California.

3. Direct discharge into the domestic water system. Health protection would depend on treatment and dilution. Except for extreme situations where the lack of water has been of greater health significance than that associated with use of water reclaimed from wastewater, no responsible authority has embarked on deliberate, direct augmentation by introducing water reclaimed from sewage into the water system. There are proposals for the future.

The Basin Plans

In the Water Quality Control Plans, it is expected that reclaimed water use involving ingestion may be categorized in the following manner:

1. The plan involves an immediate or near-term decision regarding the reclamation element. Funds are to be committed to near-term physical facilities based on the decision and, once the selection has been made, the options are pretty well closed off. This is essentially an immediate "go or no go" decision.

2. The plan involves an immediate or near-term decision regarding the reclamation element, however, there are reasonable options for other reclamation uses or for waste disposal employing the physical facilities. There will be some loss if the intended project is not completed in the proposed manner, however, regardless of eventual health findings the plan does not constitute an unalterable commitment to domestic supply augmentation.

3. The reclamation element is in a latter stage of the plan, 10 or more years in the future, and does not significantly affect earlier stages. A clear decision on health acceptability will be available prior to construction.

There are, of course, many other shadings, but the three categories should suffice for general direction within which reasonable judgment can be applied.

Position on Plans for Direct Discharge into a Water System

A plan which involves direct discharge into a domestic water supply system or storage unit for the near future (within the next decade) is not acceptable because of the uncertain health implications. The Department will recommend against the element of a basin plan which contains such a proposal.

Where a plan requiring a near-term decision involves options or alternatives for the use or disposal of the wastewater, the Department will reject the domestic water reuse alternative and consider the remaining options as the proposals for evaluation.

Direct discharge into a water system may be presented in a plan as a future option which may be appraised as additional information becomes available and future needs and attitudes are clearer.

Position on Plans for Injection for Groundwater Replenishment

The Department will recommend against injection for groundwater replenishment as a plan element which is to be implemented in the near future (within next decade). Injection may be considered as a future option, contingent upon the availability of new supportive information and future needs.

Injection of reclaimed water for saline water repulsion and reclamation of saline aquifers is an acceptable use when accompanied by proper controls. Community domestic water supply may not be drawn from the immediate injection area and preferably, injection should be into the brackish water zone.

Position on Groundwater Recharge by Surface Spreading

Surface spreading appears to have the greatest potential for use of reclaimed water in the basin plans. It is expected that most groundwater recharge will be through this method since surface spreading involves the least cost and has the greatest history of practice.

Although this potential exists, it must be restated that there are no reclamation criteria for domestic use of reclaimed water, information relative to health effects from ingestion is uncertain and the interval involved before conclusive information is available may be considerable. It should also be emphasized that if new information indicated adverse effects are created with substantial recharge, closure of those basins involved would be required with regard to domestic use.

The application of limits on specific percentages of reclaimed water allowable in groundwater would be inappropriate because knowledge of health effects is lacking.

For near-term proposals, plans which involve the recharge of a substantial volume of reclaimed water into a small basin will be recommended against.

If information indicates uncertain or adverse effects are associated with recharge operations of this magnitude, the results would require a costly effort to reclaim the basin or might result in abandonment of the basin for domestic use. The serious implications of this situation, therefore, require the Department of Health to recommend against such a proposal.

Where recharge operations would constitute a small fraction of water in the underground, near-term proposals may be acceptable. Location relative to community wells will be considered as well as the domestic use of the basin waters. By limiting such proposals to operations involving only small percentages of reclaimed water in the groundwater, the corrective action, if required, may be without undue cost or loss of the basin as a domestic source. Near-term plans with available options to surface spreading are desired.

Surface spreading presented as a future option in a plan would be acceptable.

(State of Washington DOE)
Guidelines for the
Establishment of Dilution Zones

The State of Washington water quality regulations directly relating to the establishment of dilution zones is as follows:

"The water quality criteria herein established, except for the aesthetic and acute toxicity values, shall not apply within immediate dilution areas of very limited size adjacent to or surrounding a wastewater discharge. In determining the size of an immediate dilution area, consideration will be given to the quality of the effluent or wastewater discharged and the nature and condition of the receiving waters. No such areas will be established for a waste discharge authorized under a permit unless:

1. The wastewater discharge has been provided with all known, available and reasonable methods of treatment,
2. The wastewater treatment facilities are operated and maintained to the satisfaction of the Department of Ecology and,
3. The treated wastewater is provided with initial diffusion at the point of discharge into the receiving waters to satisfaction of the Department of Ecology."

General Requirements for Dilution Zones

The quality of water outside the dilution zone will be maintained at existing water quality or established water quality standards, whichever is higher.

Dilution zones shall be located in the receiving water in an area where the effluent will have no effect on beneficial uses. These uses include migration of aquatic life, recreational uses, agricultural uses, etc.

The overlapping and interference of two or more dilution zones will not be permitted. No dilution zone will be permitted for new developments or facilities when the dilution ratio of effluent to receiving waters is less than 1:20*.

*10-day low flow statement see bottom of second page

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General Requirements for Dilution Zones (cont.)

No dilution zones will be permitted in lakes with a surface area of less than 1,000 acres. For lakes with surface areas greater than 1,000 acres, a dilution zone will be permitted providing advanced waste treatment is provided to the effluent. The dilution zone location for lakes shall be handled on a case-by-case basis to the satisfaction of the Washington State Department of Ecology.

No exposed discharges will be permitted.

No dilution zones for new sources will be allowed in areas where existing water quality does not meet established receiving water quality criteria.

A. Dilution Zones for Rivers:

1. Dilution zone boundaries shall not encompass more than 15% of the width of a stream or include more than 15% of the volume* of the river flow. The dilution zone boundary in respect to the waterline at low flow* shall begin at a point from the shore which is a minimum of 15% of the stream width, for rivers less than 680 feet in width. For rivers greater than 680 feet in width the dilution zone boundary shall be a minimum of 100 feet out from the waterline at low flow*.

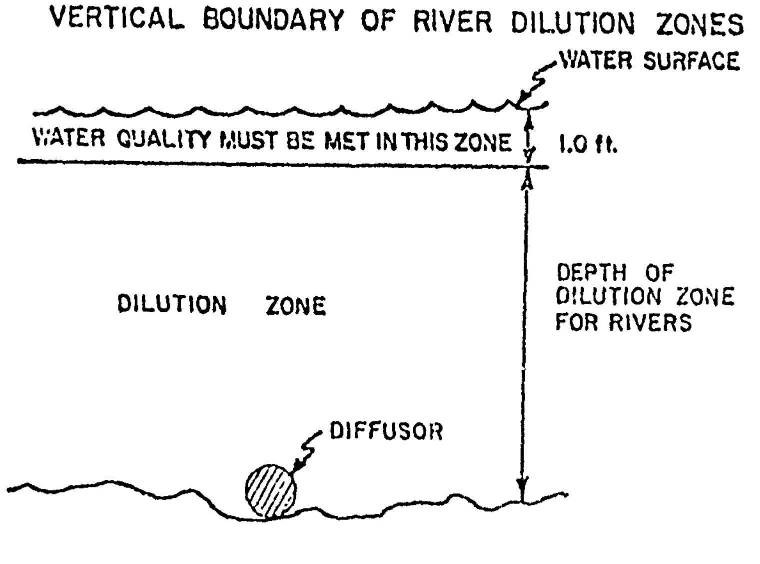


FIGURE 1-A (FOR RIVERS)

2. Dilution Zone Depths, Widths and Lengths

   a. The upper limit of the dilution zone shall be one foot below the surface of the water. (Figure 1-A)

*10-year - 7-day low flow or regulated low flow established by regulation shall be used in the calculations.

b. The length of the dilution zone shall extend laterally to 300 feet from the centerline of the diffusor. (Figure 1-B)

DILUTION ZONES FOR RIVERS (CONT'D.)

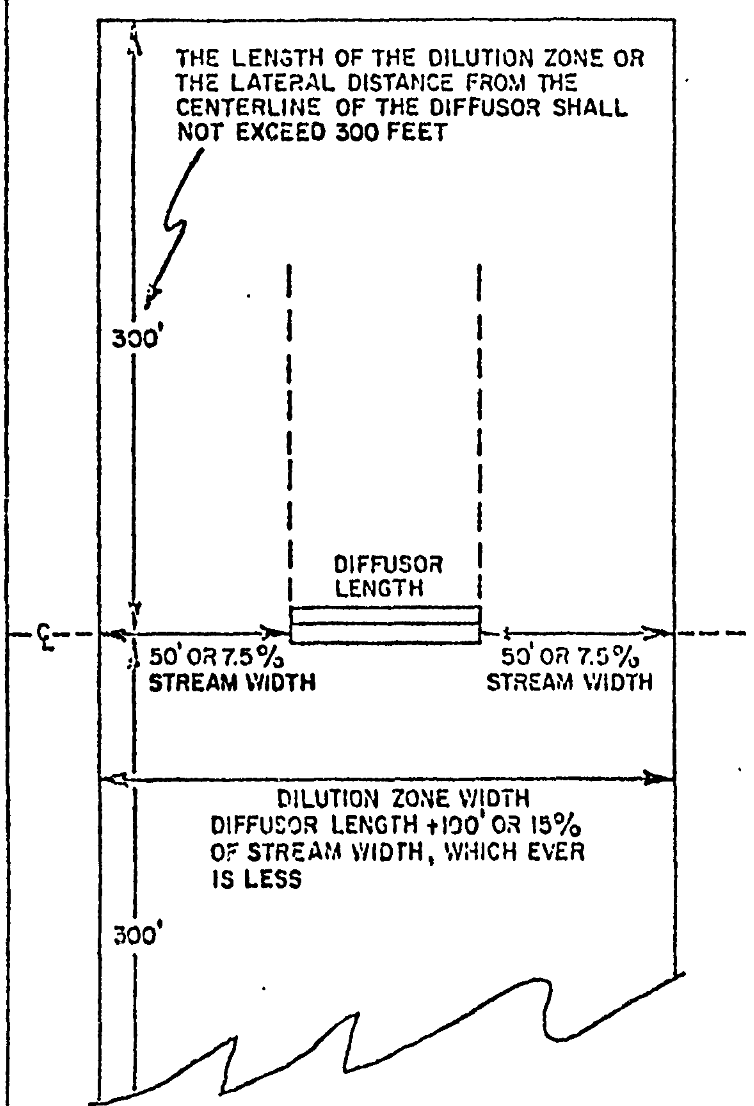


FIGURE 1-B

c. The width of the dilution zone will be the length of the diffusor plus 100 feet or 15% of the width of the stream, whichever is less. This width shall not extend into the shoreline areas. Described in A-1 above.

<u>Pages 4 and 5 of the guidelines on estuarian and marine situations are not included in Appendix V.</u>

APPENDIX VI

DEPARTMENT OF ECOLOGY

DANIEL J. EVANS
GOVERNOR

JOHN A. BIGGS
DIRECTOR

Olympia, Washington 98504

ADVANCED WASTE TREATMENT POLICY

WHERE APPLICABLE

Advanced waste treatment is required for all waste discharges (both proposed and existing) to the following waters:

1. Lakes, whose surface area is greater than 1000 acres, and those rivers tributary to such lakes.

2. Rivers situated in national parks, national forests, and other mountainous recreational areas.

3. Other waters where secondary treatment is not sufficient to maintain the water in accordance with the water quality standards.

NO DISCHARGE PERMITTED

The following stipulation shall take precedence over the foregoing:

No discharge is permitted from a new development or facility wherein:

1. The dilution ratio of minimum stream flow to plant effluent is less than 20 to 1. The stream flow to be used for such a determination shall be the average, for the period of record, of the minimum daily flow which occurs each year. Where a minimum flow has been established by regulation, this value shall be used for the aforementioned determination.

2. Discharge is proposed to a lake whose surface area is less than 1000 acres or to a tributary of such a lake.

3. Other waters where advanced waste treatment is not sufficient to maintain the water in accordance with the water quality standards.

603.1-64

DEFINITION AND APPLICATIONS

Advanced waste treatment is defined as treatment that provides further reduction of BOD, suspended solids, coliform, and/or nutrients than is provided by conventional secondary treatment. More specifically, advanced waste treatment is defined as providing an effluent with the following maximum concentrations:

1. Discharge to lakes, whose surface area is greater than 1000 acres, and those rivers tributary to lakes:

   a. 10 mg/l BOD, or 95% removal, whichever results in a better quality effluent.

   b. 10 mg/l suspended solids, or 95% removal, whichever results in a better quality effluent.

   c. 0.5 mg/l phosphorus, or 95% removal, whichever results in a better quality effluent.

   d. 3 mg/l ammonia.

   e. Total coliform organisms shall not exceed median values of 50 organisms/100 ml with less than 10% of the samples exceeding 230 organisms/100 ml.

2. Discharge to rivers situated in national parks, national forests, and other mountainous recreational areas, but not tributary to a lake. This requirement will apply to situations wherein the dilution ratio of minimum stream flow to plant effluent is greater than 20 to 1.

   a. 10 mg/l BOD, or 95% removal, whichever results in a better quality effluent.

   b. 10 mg/l suspended solids, or 95% removal, whichever results in a better quality effluent.

   c. 3 mg/l ammonia.

   d. Total coliform organisms shall not exceed median values of 50 organisms/100 ml with less than 10% of the samples exceeding 230 organisms/100 ml.

Note: For the department to grant approval of a discharge to rivers situated in national parks, national forests, and other mountainous recreational areas, an applicant must have proven to the department that all possible land disposal methods have been explored and have proven inadequate.

3. Discharge to waters where secondary treatment is not sufficient to maintain the water in accordance with the water quality standards (i.e. the dissolved oxygen concentration of the river would be reduced more than 0.2 mg/l). This requirement will apply to situations wherein the dilution ratio of minimum stream flow to plant effluent is greater than 20 to 1.

   a. 10 mg/l BOD, or 95% removal, whichever results in a better quality effluent.

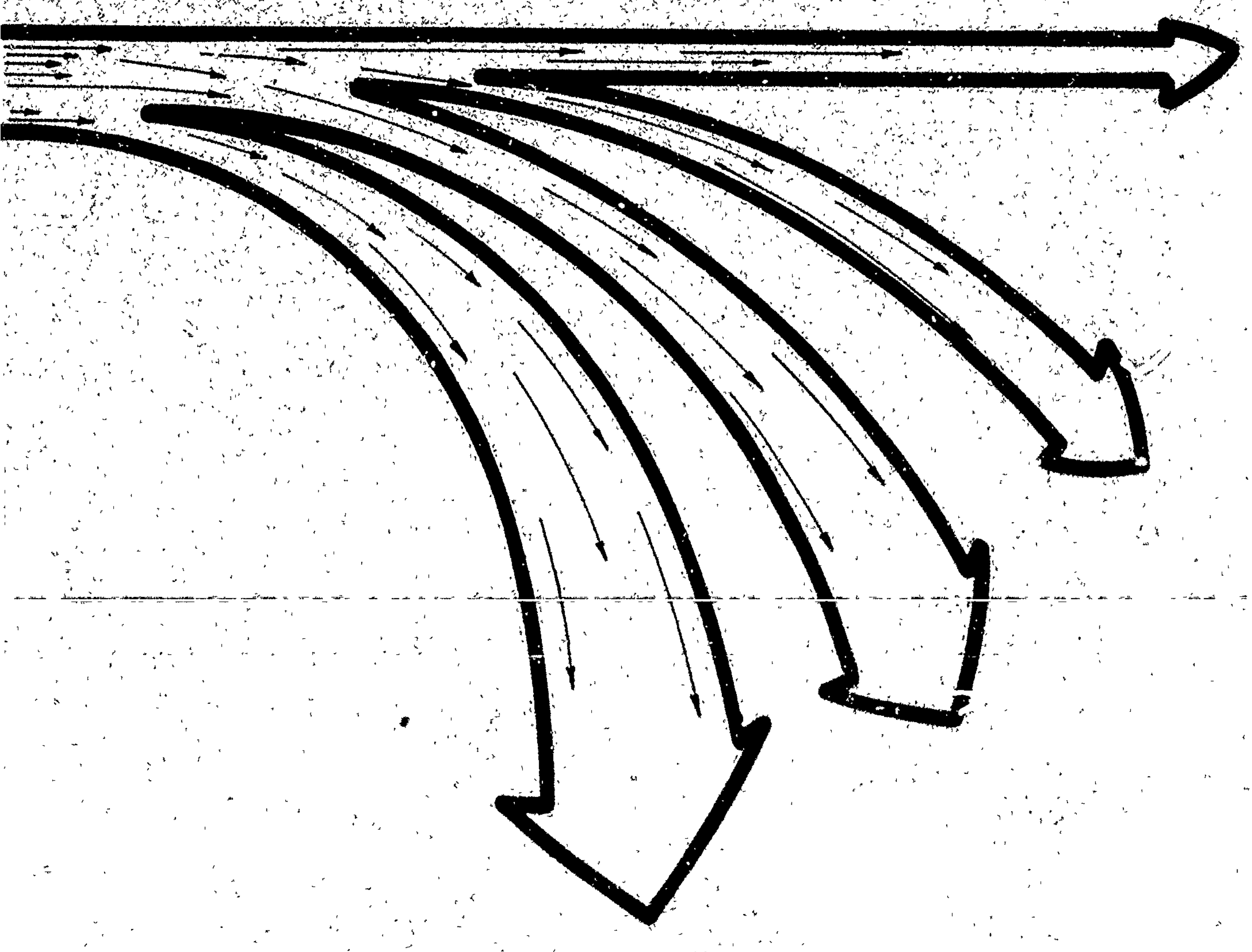
   b. 10 mg/l suspended solids, or 95% removal, whichever results in a better quality effluent.

   c. 3 mg/l ammonia.

   d. Total coliform organisms shall not exceed median values of 50 organisms/100 ml with less than 10% of the samples exceeding 2[illegible]0 organisms/100 ml.

The department may determine that nitrogen is a limiting nutrient in certain lakes and that substantial nitrogen removal from a wastewater discharge is warranted. Moreover, the department may determine that in certain streams, not tributary to a lake, aquatic growths are of such magnitude that substantial phosphorus removal, nitrogen removal, or both, is necessary. Such cases as are described in this paragraph are considered to have infrequent occurrence.

May 12, 1972, supersedes requirements dated October 19, 1970.



SECTION 603.2

TREATMENT CRITERIA FOR PUBLIC FACILITIES

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 603.2

TREATMENT CRITERIA

FOR PUBLIC FACILITIES

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Department of the Army, Seattle District
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Section 603.2

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Objectives

The objectives of this section are to select loading and removal criteria for treatment processes that will meet disposal criteria. The unit loading and removal criteria are the basis for sizing of treatment elements to handle forecast flows and loads.

As a first step, a selection is made of specific treatment processes to provide the following levels of treatment:

1. Secondary
2. Secondary with seasonal or full time phosphorus removal
3. Secondary with seasonal ammonia removal
4. Secondary with full time nitrogen removal
5. Secondary with seasonal or full time phosphorus removal and seasonal ammonia removal
6. Secondary with seasonal or full time phosphorus removal and full time nitrogen removal
7. Other advanced treatment processes

Next, criteria are selected for land treatment techniques, assuming appropriate alternative pretreatment from the foregoing list. The types of land treatment considered are as follows:

1. Irrigation

2. Overlandflow

3. Infiltration-percolation

Finally, the selected processes are described and design criteria established for sizing of the major elements. Expected removals are tabulated to show the extent to which disposal objectives are met.

Solids processing and sludge disposal alternatives and criteria are covered in another section.

Treatment Alternatives

General. For each of the generic treatment types listed above there are a number of specific processes physically capable of achieving the required end result described under Disposal Criteria. To make cost effectiveness comparisons between various wastewater management plans, certain specific processes have clear advantages so it is not necessary or desirable to price out all of the specific processes that could be utilized to achieve a particular treatment objective. A preselection of specific processes to pick an optimal system for each generic type provides a uniform and impartial basis for initial cost effectiveness screening of alternative management plans. This is done with the full awareness of the other available specific alternatives and with the intent of returning to these treatment alternatives for a revaluation after the initial screening and before settling on a final recommended plan.

It is the purpose of the following discussion to identify the candidate specific processes and the method of selection of those processes to be used for initial screening. The selection is not limited to arriving at a single process; alternative processes are included where necessary to explore conditions which involve different possible combinations with land use or where size range indicates the need for a choice of processes.

It will be noted below that a common reason given for selection of a process for this purpose of initial screening is that it is a demonstrated full scale process for which historical cost data are available. This is an important consideration in endeavoring to make impartial cost comparisons because only with the demonstrated processes do we have some assurance that the slope of the cost curve as a function of size is reasonable and that the advantages of scale are neither understated or overstated.

Treatment alternatives are shown in Table 1. Selected treatment systems to meet various treatment objectives are summarized and presented in schematic diagram form in Figure A. Expected removal criteria for the selected systems are summarized in Table 2.

Pretreatment. It is assumed that regulation of industrial wastes at the source will require pretreatment for the exclusion from municipal collection systems of toxic materials* and excessive amounts of oils or greases and for the control of pH and all other waste parameters in quantities that are disruptive to standard biological treatment processes.

* both metals and organics

Preliminary Treatment operations are common to all treatment processes used for both surface water and land disposal. These operations are to remove or reduce large solids and to remove inert mineral solids usually referred to as grit.

The alternatives for removal and reduction of large solids are (1) screening and removal for land disposal, (2) screening and grinding and return to the wastewater stream, and (3) in-stream reduction or comminution. The latter is selected for its operational desirability, as testified by the current widespread acceptance of this method.

Alternatives for grit removal include (1) simple controlled velocity gravity separation (2) aerated tanks and (3) detritus tanks. The aerated tank is selected again for its operational simplicity and widespread acceptance.

Criteria for sizing both elements are hydraulic capacity for PWWF.[1] Aerated grit removal is sized to provide 5 minutes detention at ADWF[2] and not less than 2.5 minutes at PWWF with 0.25 cfm of air per square foot of surface.

A measuring flume is also an essential element of the preliminary treatment fa:ility. The complete preliminary treatment facility is usually sized in anticipation of stage construction.

Primary Treatment is an element of all treatment processes except one version of lagoon treatment. Primary treatment is not an acceptable form

(1) PWWF = Peak Wet Weather Flow
(2) ADWF = Average Dry Weather Flow

of treatment for final disposal. The alternatives for primary treatment are as follows:

1. Plain sedimentation (gravity separation with mechanical sludge removal and skimming)
2. Sedimentation with chemical coagulation
3. Air flotation
4. Upflow clarification
5. Fine screening
6. Plain sedimentation inherent in a lagoon for raw waste

Air flotation and upflow clarification are not competitive on wastes where plain sedimentation will provide satisfactory removal, which is the case for municipal wastes. Air flotation and upflow clarification are not considered further for primary treatment.

Fine screening, long in disfavor because of operational problems, is currently being reexamined by equipment manufacturers who have recently begun marketing of new models. There is, as yet, no experience to justify adoption of this alternative as a fundamental plant element in lieu of the proven plain sedimentation. (The primary target of this new interest is as auxiliary equipment for treatment of combined sewer overflows.)

The other three processes are not truly alternatives. They perform different functions and all three require consideration in combination with certain other processes.

Criteria for sizing sedimentation basins, with or without coagulation, other than as part of a lagoon, are a loading rate of 800** gallons per square foot per day and two hours detention at ADWF and not less than 1.0 hour detention at PWWF. Removal criteria are as follows:

	Removal Percent	
	Without Chemical Coagulation	With Chemical Coagulation
BOD	32	70*
Suspended Solids	55	83*
Phosphorus	9	86*
Nitrogen	12	18
Ammonia	negligible	negligible

* Bovay (1973) for ferric chloride and alum

** Corresponding to 1000 gpsfd at the average of the highest 16 hours of the day

Based on pilot studies reported in Bovay (1973) optimum chemical addition criteria for Spokane wastewater are 97 mg/l of ferric chloride or 123 mg/l of alum plus 0.5 mg/l polymer with both. For further criteria on chemical application see below relative to nitrification and phosphorus removal.

Bovay (1973) also made pilot plant studies of lime addition and found that approximately 480 mg/l were required with 0.5 mg/l polymer but that recarbonation was required to lower pH before primary effluent could be applied to activated sludge. Lime is not considered further here since it will be shown later that for seasonal operation it would be more costly than alum or ferric chloride.

Secondary Treatment. Secondary treatment is defined as meeting the requirements of EPA guidelines, Federal Register Vol. 38 No. 159, Friday August 17, 1973 as follows:

1. The minimum level of effluent quality to be classified as secondary treatment is defined in terms of the following values for parameters in plant effluent:

Parameter	Sampling Period	Maximum Mean* Value Effluent Quality
BOD (5 day)	30 consecutive days	30 milligrams per liter or 15 percent of the mean influent BOD, whichever is smaller
" "	7 consecutive days	45 milligrams per liter
Suspended Solids	30 consecutive days	30 milligrams per liter or 15 percent of the mean influent SS, whichever is smaller
"	7 consecutive days	45 milligrams per liter
Fecal Coliform	30 consecutive days	200 per 100 milliliters
	7 consecutive days	400 per 100 milliliters
pH	Continuously	Within the limits 6.0 to 9.0

2. Special consideration is given to treatment plants serving areas with combined sewer and certain industrial waste categories.

a. Treatment works which receive flows from combined sewers may receive special consideration in the standards to be met while handling wet weather flow on a case-by-case review basis.

b. Certain categories of industrial wastes which discharge directly to navigable waters or through a municipal treatmet plant to navigable waters are subject to possible effluent quality adjustment for BOD and SS. Where the flow is treated in a municipal plant, it must exceed 10 percent of the total flow to be eligible for consideration.

* Arithmetic mean for BOD and SS,
geometric mean for Fecal Coliform.

Secondary Treatment as defined above applied to surface water disposal or pretreatment for land application can be achieved by the following alternative processes:

A. Biological Processes

1. Activated sludge
2. Trickling filter
3. Biodisc
4. Lagoon

B. Physical-Chemical

There are in addition to these broad classifications, many subalternatives to each specific process. Most are not significant to the initial screening process. The subalternatives under lagoon treatment do involve trade-offs with amount of land required and so will be considered.

The lagoon alternatives not only involve land use trade offs among themselves but between them as a group and the other three biological processes as a group and the physical chemical, all of which are concentrated site facilities.

For lagoons to provide secondary treatment three alternative systems are selected, one without mechanical aeration or pretreatment, one with pretreatment only, and one with both. It is necessary to consider all since the most cost effective approach is unknown until combined with land availability and cost.

Lagoons without pretreatment or mechanical aeration are selected to be of the multi-cell type with intermittent discharge. The specification "without pretreatment" as used here means without primary sedimentation. It is proposed that all lagoon influent receive as minimum pretreatment in-stream comminution and removal of large floating materials that cannot be reduced by a comminutor. These lagoons would be of the facultative type with a depth of approximately five feet providing aerobic, facultative and anaerobic conditions at various depths. Selected criteria are 20 pounds of BOD per acre per day and a detention time of 6 months. Sludge removal is assumed to be by dredging or dry excavation for land disposal. The criteria for sludge disposal are discussed in a subsequent section.

Lagoons with pretreatment are selected to treat the effluent from primary sedimentation. The primary sedimentation would have the criteria specified above for plain sedimentation without chemical coagulation. For the lagoons receiving primary effluent, criteria are selected at 50 pounds of BOD per acre per day and detention time of 90 days. Lagoons are again multi-celled intermittent-discharge type and of facultative depth. Sludge disposal from primary sedimentation is as described for other secondary treatment. Sludge disposal from lagoons is by dredging or dry excavation for disposal on land.

Criteria for lagoons with pretreatment by primary sedimentation and equipped with mechanical aerators are selected with a detention time of 30 days of which 10 days are in aerated cells where the applied rate of mechanical aeration is to supply oxygen at a rate of 2.0 times the demand of the applied BOD. The 20 day section is in intermittently discharged facultative cells.

Pond depth is a function of the type of aerator selected. Refer to EPA (1973). Cage aerators can be operated satisfactorily in ponds of standard 5 foot depth. For propeller type aerators deeper ponds or locally deepened areas are required, the actual depth depending upon the horsepower of the unit. Some propeller units are being provided with baffles for installation in 5 foot depth lagooons. Detailed selection of equipment is beyond the scope of this study. For purposes of alternative evaluation a depth of 10 feet is selected for local deepening in cells with aerators and 5 feet for standard cells.

Lagoon performance is highly temperature and sunlight sensitive. Hence, the different removal criteria for summer and winter. Another factor which affects lagoon effluent quality is the algae content. This factor is very difficult to quantify since it depends on many variables including operation, size, wind, etc. The specific requirement for intermittent discharge called out in EPA tentative guidelines for BPWTT is directed toward achieving minimum algae carry over. The requirement for ponds in series is also for this purpose. The EPA tentative guidelines do not mention the possible need for supplemental algae removal in addition to the ponds themselves to meet BPWTT. It is judged that the removal of algae that can be accomplished in ponds alone at the present state of the art will be too unreliable to meet BPWTT for the purpose of discharge to surface waters. For this study, the use of lagoons to provide BPWTT for discharge to surface waters is assumed to require the addition of algae removal facilities equal to autoflotation or dissolved air floatation with alum coagulation. See EPA (1973) for description of systems. Where pond effluent is for subsequent land application, the algae removal step is not required.

Expected removals are as follows:

	Percent Removal			
	w/o Algae Removal		With Algae Removal	
Parameter	Summer	Winter	Summer	Winter
BOD	85	50	97	Not applicable
Suspended Solids	50	50	90	Not applicable
Phosphorus	45	30	65	Not applicable
Ammonia	98	90	98	Not applicable
Nitrogen	65	10	92	Not applicable

The choice between activated sludge process, trickling filters and biodisc involves consideration of scale, stability of operation and energy consumption as well as cost. The biodisc process is one of several fixed media growth reactors similar to the trickling filter concept in which means are sought to increase the available process surface and to improve the contact between the organisms, the wastewater and the air. The biodisc process is essentially untried at full scale so that there is no historical cost data. A 0.5 mgd plant is evaluated as technically successful in Antonie et al (1974). The nature of the equipment, as probably available in early stages of marketing, will not offer scale economies; that is large plants, probably 5 mgd and larger, would utilize multiples of smaller units. For these reasons it is not considered a suitable type for wide size range alternative comparisons. At final evaluation this type deserves reconsideration, especially for small plants due to its stability of operation and low power consumption.

processes with abundant historical cost data. Activated sludge is practical over the entire size range but has high power consumption and is less stable operationally. Trickling filters are more stable and have lower power consumption but are at a cost disadvantage in larger sizes. Criteria are established for both. If cost data indicate no significant difference between the two in smaller size, activated sludge would be used for all sizes for uniformity. Reconsideration would be made after initial screening.

Physical-chemical process for achieving secondary treatment would include primary sedimentation with chemical coagulation followed by carbon adsorption and sand filtration. Note the distinction being made here between physical-chemical methods applied directly to untreated wastewaters and the use of physical-chemical methods as a tertiary process following biological treatment to a secondary level. Significantly higher removals of organics and about 90 percent of the phosphorus are possible with the above described physical-chemical system than with conventional biological secondary. This system, however, has not yet had significant full scale use. Weber et al (1970) describe a successful pilot plant operation and compare potential costs with standard biological secondary. Their forecast costs indicate a total cost, capital recovery plus maintenance and operation, approximately 45 percent higher than conventional biological secondary treatment. Where secondary level of treatment will meet imposed requirements physical-chemical is not a competitive alternative to biological processes. As Weber et al (1970) point out, it is a more appropriate candidate as alternative where the higher levels of treatment are required. Monti and Silberman (1974) reach a similar conclusion and point out the additional advantages in favor of electing biological treatment including ability to incidently remove small amounts of cyanide or hexavalent chromium that might escape industrial pretreatment and the ability to reduce a significant part of the raw ammonia. Culp & Culp (1971) emphasize the problem of combined chemical-biological sludges.

Selected criteria for biological secondary treatment, limited to carbonaceous oxidation, by the activated sludge process are 50 pounds of BOD per day per 1000 cubic feet of aeration tank volume, a detention time of 5.0 hours at ADWF and 2.5 hours at PWWF and an air supply of one cubic foot per gallon. Secondary clarifier loading rate is selected at 650 gallons per square foot per day (gpsfd) at ADWF and not to exceed 1200 gpsfd at PWWF and detentions of 2.5 and 1.0 hours respectively.

Expected total removals for the activated sludge system including primary sedimentation without chemical coagulation are as follows:

Parameter	Percent Removal
BOD	88
Suspended Solids	90
Phosphorus	30
Ammonia Reduction	25
Nitrogen	43

For the trickling filter alternative of secondary treatment, the proposed guidelines for BPWTT of March 1974 called for standard rate loadings of 800 pounds of BOD per day per acre foot. Presumably this low loading rate is specified to achieve the maximum nitrification which was contemplated as a mandatory requirement in the March 1974 draft. With the subsequent change in policy to leave nitrification as a state exercised option, it is assumed that conventional high rate loadings would be acceptable where nitrification was not required. The selected loading criteria for secondary treatment, limited to carbonaceous BOD reduction, is 2000 pounds of BOD per acre foot per day and one to one recirculation.

Expected total removals for the total trickling filter system including primary and secondary sedimentation without chemical coagulation are as follows:

Parameter	Percent Removal
BOD	85
Suspended Solids	90
Phosphorus	30
Ammonia Reduction	25
Nitrogen	43

Secondary Treatment plus phosphorus removal. As indicated above, the expected removals of phosphorus in the normal course of secondary treatment is significant (30%). Where phosphorus removal is specifically required, the level of removal, however, must be 85 percent or more of the level in the raw waste.

Black and Veatch (1971) indicates the scope of choices available for phosphorus removal from trickling filter and activated sludge secondary systems. The methods all involve chemical precipitation and the choices are primarily those of chemical selection and point of application.

For activated sludge process, the indicated options are mineral salts (alum or ferric salts) or lime at a variety of locations including the primary, near the end of the aeration section and in the secondary clarifier. For trickling filter process, the chemical choices are the same but the application choices are limited to primary or secondary clarifier. For both, the advantages of the primary are pointed out as being the incidental improved removal of BOD and SS and the disadvantages as higher dosages and the possibility that a significant part of the phosphate will be in other than ortho form and will not be removed. The secondary clarifier is pointed out as providing better phosphorus removals at lower dosages but requiring closer control. Most phosphorus is converted to ortho form by both activated sludge and trickling filters. A further consideration relative to the choice of point of application of lime is that associated with its recovery from the sludge. In general, required lime doseages are so high that recovery and reuse of a significant part of that applied is necessary to make lime a competitive alternative. There are significant problems to lime recovery from primary sludges which has led to two step lime application, part in the primary and part in the secondary, with the recovery restricted to the secondary sludge. Mineral additions to the primary, although not the object of recovery from primary sludge, change the character of the sludge to such an extent that significant cost additions are involved in thickening and processing for disposal.

Bovay (1973) contains a detailed comparative cost study on the methods of phosphorus removal in connection with the proposed expansion of the City of Spokane sewage treatment plant. These studies are based on pilot plant operations and therefore reflect the specific properties of the actual wastewater flows of the City of Spokane.

Since the entire urban planning area has the same water supply and has a similar pattern of development, all municipal wastewater flows in the urban planning area should have comparable wastewater characteristics, barring the introduction of some exotic contaminant of industrial origin. Therefore, the pilot studies of Bovay deserve considerable weight for being specific to the area as well as the City.

The Bovay study considered the following alternatives for achieving 85 percent phosphorus removal:

1. Adding alum to the raw wastewater
2. Adding alum to the secondary units
3. Adding ferric chloride to the raw wastewater
4. Adding ferric chloride to the secondary units
5. Adding lime to the raw wastewater

These chemical alternatives are evaluated in combination with a broad spectrum of sludge treatment and disposal techniques including elements of thickening, dewatering, incineration and ultimate disposal.

The conclusion reached is that for year-around phosphorus removal, the use of alum or ferric chloride is slightly less costly than lime but that for less than year-around phosphorus removal, the advantage shifts greatly in favor of the alum or ferric chloride useage. Therefore Bovay (1973) recommends the selection of alum or ferric chloride. The cost difference between these latter two chemicals is shown to be insignificant and the physical plant and sludge systems useable with them are interchangeable. They can be regarded as a single alternative designated "mineral" using the nomenclature of Black and Veatch.

With regard to the point of application, Bovay (1973) recommends chemical addition ahead of the secondary clarifier. Reasons cited are (1) sludge with better thickening properties and (2) lower chemical dosage for ferric chloride. The potential advantages of reduced BOD loading through chemical addition to the primary from which reduced activated sludge reactor size might result was also considered and rejected. The cost of chemicals for primary coagulation is not a cost effective alternative to removals of the incremental BOD in an activated sludge reactor. The potential for advantage exists only when the use of chemicals is required for another reason like phosphorus removal. Although the City discharge permit requires year around phosphorus removal, Bovay (1973) considers the possibility good for reduction to seasonal removal. In the eventuality that only seasonal P removal were required, it would be necessary to have full sized activated sludge reactors for the off-season condition in order to avoid excessive chemical cost when phosphorus removal was not required. Bovay (1973) also points out that the increased costs of primary sludge thickening when chemicals are used in the primary largely offsets any potential cost advantage that may accrue from improved removal prior to the activated sludge reactor.

The specific dosages found to be optimum by the Bovay pilot studies to secondary mineral application are 53 mg/1 of ferric chloride or 123 mg/1 of alum.

Having narrowed the method to mineral additions and eliminating lime, the following sludge processing and disposal options are shown by Bovay to be within a narrow range of cost so that final selection can be made on other considerations.

1. Vaccum filtration and landfill
2. Vaccum filtration, incineration and landfill
3. Digestion, vacuum filtration and landfill
4. Digestion - land application

The Bovay (1973) recommendation is for digestion and land application preceded by a pilot study and use of digestion, vacuum filtration and landfill as an interim solution.

It should be reiterated that the Bovay (1973) findings indicated that the mineral addition of coagulants ahead of the secondary clarifier was the lowest cost solution for year around phosphorus removal by a small amount as well as being of much lower cost for seasonal phosphorus removal. Therefore, for the purpose of initial screening of alternatives, the following criteria are selected for both seasonal and year around phosphorus removal: alum dosage at 125 mg/1 and flocculation ahead of the secondary clarifier.

The expected total process removals for activated sludge or trickling filter secondary treatment with phosphorus removal by alum addition ahead of the secondary clarifier are as follows:

Parameter	Removals
BOD	90
Suspended Solids	92
Ammonia	25
Nitrogen	43
Phosphorus	88

For refined consideration in recommended plan formulation it is necessary to reconsider the basic alternatives cited above plus other possibilities such as the proprietary PhoStrip process. The PhoStrip process concentrates the phosphorus content of the wastewater biologically and greatly reduces the size of flow that must be treated chemically in the final step of phosphorus removal. A special cost study by Kennedy Engineers of various refinements of the activated sludge process with various methods of phosphorus removal indicates significant potential cost advantage to the combination of PhoStrip and lime treatment. The process is currently being operated experimentally at approximately 6.0 mgd at Reno, Nevada. Results of successful plant scale PhoStrip operation and estimates of potential cost savings are available in a paper being presented by L. E. Peirano at the Miami Beach conference of the Water Pollution Control Federation, October 7, 1975.

Secondary Treatment plus Seasonal Ammonia Removal. A distinction is made here between ammonia removal and nitrification which is one alternative method of removing ammonia by converting it to the nitrate form. The requirement is for a process that will, in a cost effective manner, remove ammonia or convert it to nitrate during that part of the year when the receiving surface waters are at or above 20°C. The primary goal of this removal is elimination of ammonia toxicity in surface water and secondarily to reduce the long term oxygen demand. Partial removal of nitrogen as a nutrient is not a goal under this heading nor is this process intended as the first step in nitrogen removal in all its forms as contemplated by a nitrification-denitrification system, as discussed under a separate heading below.

The candidate alternative processes for ammonia removal are:

1. Biological Processes
   a. Extend the activated sludge process beyond carbonaceous oxidation to nitrogenous.
   b. Extend trickling filter reaction time beyond carbonaceous oxidation to nitrogenous.
   c. Add a stage of Biodisc treatment to the effluent from either standard activated sludge or trickling filters.
   d. Lagoons in themselves or as an addition to standard secondary processes.
   e. Irrigation at controlled rates with underdrains.
2. Physical-Chemical
   a. Ammonia stripping
   b. Breakpoint chlorination plus dechlorination
   c. Ion exchange

Reference to receiving water temperature data indicates that the length of the season during which receiving waters are at or above 20°C is two months maximum and above 15°C is four months, average.

Of the biological processes, lagoons and irrigation are automatically given consideration separately from processes associated with concentrated site treatment. The Biodisc alternative is not considered for reasons cited under secondary treatment.

Provision of additional biological reactor capacity to achieve nitrification for a two to four month period would not be cost effective when compared with the physical chemical alternatives. The use of chemical coagulation in the primary to "unload" the biological reactor is a cost effective alternative to provide seasonal nitrification compared with physical chemical processes or the addition of a second biological reactor. When the temperature of the waste is near 20°C, nitrification can be achieved in a reactor sized for normal carbonaceous oxidation on the basis of a BOD input of the order 145 mg/l if the BOD loading is reduced to about 65 mg/l or less providing that operating flexibility includes the necessary changes in rate of aeration and control of mean cell residence time. Addition of mineral or lime coagulation to the primary by increasing BOD removal from 32 percent to 70 percent could accomplish the necessary BOD loading for nitrification. In addition to the chemical feed equipment, this would require significant additions to the sludge processing facilities to deal with the larger volume of sludge created by chemical addition and to deal with the more difficult concentration and dewatering problem of the chemical sludge. If seasonal phosphorus removal is also required, the chemical cost can be charged against that requirement, but since phosphorus removal can also be achieved by chemical additions to the secondary, those features of sludge processing which are unique to primary chemical sludges must be charged against this process. For initial alternative screening, the unloading of the biological reactor by addition of seasonal chemical addition to the primary is selected. A subsequent check is proposed against the selected best alternative from the physical-chemical group. Expected removals for this alternative are as follows:

	Percent Removal	
	Seasonal Nitrification	Off Season Operation
BOD	92	88
Suspended Solids	95	90
Ammonia	97	25
Nitrogen	43	43
Phosphorus	86	30

The physical-chemical alternatives for ammonia removal are compared in detail in EPA (1974b). On a year around basis, the ion exchange and breakpoint chlorination alternatives are shown to have costs about double that of ammonia stripping. The primary advantage to ion exchange and breakpoint chlorination is that these methods can be successfully operated in freezing weather whereas conventional* ammonia stripping cannot.

* EPA (1974b) describes a proposed closed cycle stripping system that purports to overcome this disadvantage.

Since the proposed application is seasonal and in non-freezing weather, this potential disadvantage of ammonia stripping is not relevant.

It is necessary to re-evaluate cost effectiveness on a seasonal basis since the ratio of capital cost to operating cost for the three alternatives is different. Ion exchange has higher capital and operating costs than ammonia stripping and therefore could not gain advantage on a seasonal basis. Furthermore, ion exchange is as yet unproven at other than pilot plant level and has a secondary problem in the disposal of regeneration wastes. Therefore ion exchange is considered no further.

In considering ammonia stripping and breakpoint chlorination on a seasonal basis, recognition must be given to the high capital cost of ammonia stripping and the very high operating cost of breakpoint chlorination. Breakpoint chlorination requires chlorine in direct proportion to the amount of ammonia present resulting in very high costs for chlorine. The stoichiometric requirement for the ammonia reaction alone, neglecting other oxidizing demands, is, on a weight basis, 7.6 chlorine to 1 ammonia. Practical rates are of the order of 8 to 1 for secondary effluent. This would make the chlorine requirement for normal secondary effluent about 150 mg/l. At these rates, breakpoint chlorination with its very high operating costs could be competitive for operating periods of 1 to 2 months or less, but becomes rapidly more expensive at such a rate that 4 months operation could cost twice as much as ammonia stripping. For this reason and the fact that chlorine is in short supply and represents a large energy investment, ammonia stripping is selected as the most appropriate physical-chemical process for seasonal ammonia removal.

The ammonia stripping process requires that the pH of the waste be raised to about 11.0. The discharge from the stripper must then be neutralized, by recarbonation with carbon dioxide, to a pH that will meet discharge standards, that is to between 6.0 and 8.6. The lime dosage required to raise the pH to 11 is a function of the alkalinity of the wastewater. Bovay (1973) pilot studies found this to be in the range 300 to 400 mg/l. These lime dosages would provide phosphorus removal in addition to the function of raising pH.

For application in conjunction with the activated sludge process, consideration must be given to the fact that a pH of 11 would be fatal to the process organisms. Therefore, the lime addition to pH = 11 cannot be made ahead of the activated sludge reactor nor in the secondary clarifier from which the activated sludge is recirculated. The lime addition and precipitation are made after the activated sludge clarifier and ahead of the stripping tower. Recarbonation and precipitation of calcium carbonate follow the tower. For seasonal operation not to exceed four months, the capital investment for lime recovery from sludge is probably not justified but should be evaluated in detail at the design stage.

Criteria for sizing ammonia stripping facilities are selected from EPA (1974b) at 2 gallons per minute per square foot, 400 cubic feet of air per minute per gpm and depth of 25 feet. From the same reference, removals of 90 percent at 20°C and 85 percent at 15°C are selected. Chemical feed of lime is assumed for pH adjustment to an optimum value of

11.0 at 400 mg/l. As a byproduct of the lime application, 90 percent phosphorus removal also results during the ammonia removal season.

	Removals	
Parameter	Ammonia Removal Season	Off Season
BOD	90	88
Suspended Solids	92	90
Ammonia	85	25
Nitrogen	80	43
Phosphorus	90	30

The State DOE has published Advanced Waste Treatment Policy* which suggests limiting effluent content of ammonia to 3 mg/l where a need for ammonia reduction has been identified (Approx. equal to 85% removal).

Irrigation criteria are discussed below under land disposal. It is not expected, however, that alternatives will arise in this study in which it is desirable to collect nitrified waste from underdrains in lieu of allowing the excess to percolate.

Secondary Treatment plus Year Around Nitrogen Removal consists of adding to or modifying the secondary process to remove or reduce all forms of nitrogen. The need for this process can occur where there is a requirement to remove or reduce nitrogen as a nutrient or where the requirement is to keep the nitrate level in the receiving water within drinking water standards. There does not appear to be the need for removal as a critical nutrient in this study, a need which could be seasonal. The normal dilution requirements for disposal to surface waters likewise elimi-

* See Appendix VI of Section 603.1

nates the potential need for this process as a means of keeping surface waters within the drinking water standards. (A normal secondary effluent containing 19 mg/l of total N would cause only a 1 mg/l increment to receiving water at minimum dilution of 20 to 1). This likewise could be a seasonal requirement. There is the potential need for protection of groundwaters to drinking water standards or to background standards which is a year around function. Therefore, the selection of a process is based on the need for one most appropriate to year around operation.

The nitrogen content of secondary treated municipal waste is in three forms: ammonia, organic compounds, and nitrate or nitrite. The proportions of these forms in secondary effluent* are .76 ammonia and .24 organics and nitrate. Depending upon the degree of total nitrogen removal required, one or all of the components would have to be acted upon by the process. For example, if a residual of about 8 mg/l total N were acceptable it would be necessary to attack only the ammonia component. Since the drinking water standard is 10 mg/l maximum, the level of removal that could be achieved by attacking the ammonia component only would, in general, be unacceptable as being too large an encroachment on the allowable maximum. Therefore a methodology is required where all forms of nitrogen can be removed or reduced.

* Providing that the biological secondary is controlled to minimize nitrification, which is possible with activated sludge but not practical with trickling filters.

The alternatives for nitrogen removal are as follows:

1. Biological Processes

    a. Aerobic nitrification plus anaerobic reduction of nitrates

    b. Lagoons with algae harvest

    c. Irrigation at controlled rates

2. Physical-Chemical

    a. Ammonia stripping

    b. Breakpoint chlorination

    c. Ion exchange

    d. Packed column reactor (with methanol where available carbon is inadequate)

The first three physical-chemical processes are the same as those discussed under ammonia removal and are capable of removing only that component of the total nitrogen that is in the form of ammonia. The packed column reactor probably should be considered a biological process because it relies on organisms to react with the nitrates and methanol to convert the nitrates to gaseous products. It is essentially a mechanized version of the anaerobic tank reaction discussed below. There is no pilot scale experience for this process. Monti and Silberman (1974) present cost curves for the process that indicate that it is expected to be significantly more costly than complete biological nitrification-denitrification.

There is no full scale experience in the U. S.* for lagoons

* Some experimental work at full scale has been tried in Germany and a proposed system here is described in EPA (1973).

operated with algae harvest for nitrogen removal. Algae removal from the effluent for return to influent ponds is assumed to be required for lagoon discharge to surface waters.

Irrigation at controlled rates with monitoring to insure that the rate of nitrogen application does not exceed plant uptake is a feasible alternative and is developed below under land application.

The remaining alternative that has the capability of removing all forms of nitrogen is the biological nitrification and denitrification system. This system is described in detail in EPA (1974a) and its important features are summarized as follows:

> The activated sludge process is capable of converting ammonia to nitrate after the carbonaceous oxygen demand has been met. A different group of micro-organisms are responsible for the nitrification reaction than are responsible for the carbonaceous reaction. The nitrification reaction is highly dependent upon temperature whereas the carbonaceous reaction is almost independent within the normal ranges encountered. When the activated sludge process is receiving normal primary sedimentation effluent, where 35 percent BOD reduction has been achieved, and the carbonaceous reactions and nitrification reactions are to be carried out over a wide range of temperature, the recommended procedure is to use two reactors in sequence; that is, a normal carbonaceous reactor followed by a clarifier and its sludge recirculation system followed by a second activated sludge

reactor devoted to nitrification followed by its clarifier and sludge recirculation system. The difference in organisms, their required age, oxygen input differences and control stability, where a wide range of temperature is involved, are the primary reasons for requiring a separate reactor of plug flow form rather than simply extending the basic full mixing carbonaceous reactor. Experience to date with this process is meager and indicates the need to take the two step approach at this state of the art.

Where high lime treatment has been provided in the primary providing 65 percent or more BOD removal prior to the activated sludge process (Brown and Caldwell, 1972) there has been pilot operation of single reactor carbonaceous and nitrification reactions. In this case the carbonaceous reaction has been so reduced that the reactor is largely a nitrification reactor. This single reactor method is not considered appropriate to this level of study without specific pilot plant testing.

The criteria for the nitrification process are given in EPA (1974a) from which the following are selected:

1. 10 pounds of ammonia per 1000 cf of reactor at MLVSS of 1500 mg/l for operation at minimum temperature of 12°C.
2. Sedimentation unit 600 gallons per square foot per day at ADWF and not to exceed 1000 gpsfd at PWWF.

Following the complete conversion of ammonia to nitrate in the foregoing process, an anaerobic biological process is capable of reducing the nitrate with the nitrogen being released to the atmosphere in gaseous form. The nitrified waste flow is so short of carbon that a synthetic source of carbon must be introduced on which to base the anaerobic metabolism which performs the denitrifying process. This is described as a single step process in EPA (1974a).

Subsequent pilot plant studies by Horstkotte _et al_ (1974) indicate the need to modify the previously suggested system shown in EPA (1974a). The schematic and parameters developed by Horstkotte _et al_ are adopted for this study as follows.

Methanol would be added to the nitrified effluent to make up the carbon deficiency. Estimated methanol feed rates are 3.3 methanol for each nitrate as N in the waste.

Following methanol addition the denitrification reaction would take place in an open anaerobic reactor with detention of 50 minutes at ADWF. This would be followed by a separate aerated stabilization reactor of the same size, one purpose of which is to oxidize any excess methanol.

Following the stabilization reactor the flow is allowed to refloculate in a short aerated channel before final clarification. Clarifier criteria are as above for secondary clarifier.

The pilot plant was operated at fixed flow. It is not known how variation in detention would react nor how the diurnal variation in methanol demand would be detected and followed. See Flow Equalization below.

The removal of nitrates is expected to approach 100 percent but there will remain some organically bound N that will persist through the processes. The pilot study indicated total N should not exceed 3.7 mg/l. That is, about 80 percent of the approximately 17 to 20 mg/l total N in a typical secondary effluent should be removed.

Total expected removals for the integrated process of secondary plus nitrogen removal are as follows:

Parameter	Removal Percent
BOD	95
Suspended Solids	96
Ammonia	98
Nitrogen	88
Phosphorus	30

Secondary treatment with seasonal and full time phosphorus removal and seasonal ammonia removal. In the foregoing paragraphs treatment systems are selected for these additional processes separately. For biological systems, both seasonal and full time phosphorus removal are by alum coagulation in the secondary clarifier. One alternative for ammonia removal is the ammonia stripping process which, as a by-product to the required pH adjustment, also provides seasonal phosphorus removal. The other alternative for seasonal ammonia removal is by nitrification achieved through unloading of the activated sludge reactor by addition of chemical coagulation to the primary. This would also provide phosphorus removal as a by-product. Both seasonal ammonia removal systems would provide for the combined function of seasonal phosphorus removal without the need for a separate phosphorus removal system.

Where year around phosphorus removal is required in conjunction with seasonal ammonia removal, the above alternative systems can be modified as follows. For the ammonia stripping alternative, year around phosphorus removal can be provided by continuing the lime addition but with the addition of lime recovery equipment. For the nitrification alternative, the mineral coagulation addition can be shifted to the secondary clarifier for the non-nitrification season.

With the ammonia stripping alternative the expected removals are:

	Percent Removal		
		Remainder of Year	
Parameters	During Ammonia and Phosphorus Removal Season	With Phosphorus Removal	Without Phosphorus Removal
BOD	90	90	88
Suspended Solids	92	92	90
Ammonia	85	25	25
Nitrogen	80	43	43
Phosphorus	90	90	30

With the nitrification alternative by unloading the activated sludge reactor, the expected removals are:

Parameters	Percent Removal		
	During Ammonia and Phosphorus Removal Season	Remainder of Year	
		With Phosphorus Removal	Without Phosphorus Removal
BOD	90	90	88
Suspended Solids	92	92	90
Ammonia	97	25	25
Nitrogen	43	43	43
Phosphorus	86	88	30

Lagoon systems provide excellent nitrification and substantial phosphorus removal, of the order of 40 percent. If it is necessary to increase phosphorus removal to the 85 percent level without land disposal, the addition of chemical coagulation is required. Dosage criteria would be as for chemical addition to primary. Expected removals would be as typical for lagoons but with phosphorus removal increased to 85 percent.

Secondary treatment with seasonal or year around phosphorus removal and year around nitrogen removal. Since the same system is selected above for both seasonal and year around phosphorus removal, namely mineral coagulation in the secondary clarifier, this one system supplemented by biological nitrification-denitrification, as selected above, comprises the required system. The two systems are compatible.

Both of the foregoing processes and their criteria have been described above. The expected removals are:

Parameters	Removals, percent	
	Both On Season	Phosphorus Off Season
BOD	95	95
Suspended Solids	96	96
Nitrogen	88	88
Phosphorus	88	30

Disinfection. Secondary treatment processes not followed by sand filtration or a similar polishing process, are capable of removing up to 98 percent of the coliform indicators. With initial raw sewage coliform concentrations in the order of 200,000 organisms per 100 ml, the remaining concentrations of the order 4,000 per 100 ml are too high to meet effluent standards set at 200 organisms per 100 ml. Therefore further treatment is required to either remove or kill these organisms, and, hopefully, the true pathogens including viruses of which these organisms are accepted as an indicator.

A wide variety of chemical agents have been explored but the technical and economic constraints have narrowed the field of candidates to chlorine and ozone. Heat, radiation, acid and alkalies are similarly eliminated on technical and cost grounds.

Chlorine is the most widely used disinfectant in wastewater and water treatment in the U. S. In Europe, there is a significant and growing use of ozone. Chlorine has a number of disadvantages including but not limited to the following:

1. Dangerous to transport and handle
2. When applied to treated wastewater that still contains significant

organics or ammonia, forms compounds with these substances that can be toxic to certain fauna in receiving waters.

3. The possibility of free chlorine residual in the effluent likewise has toxic potential.

The primary disadvantages of ozone are the high capital cost of ozone generating facilities and the high rate of electrical energy consumption. On the other hand, ozone eliminates the transportation on common carrier of a dangerous chemical, chlorine, creates no harmful residual compounds and appears to have a greater kill rate on viruses.

In view of the evaluation of potential 1985 criteria to include the use of ozone in lieu of chlorine, the actual design of initial 1980 installation should consider ozone equipment in anticipation, especially if denitrification is included to reduce ozone demand. In the absence of a body of cost data on ozonation, however, chlorine disinfection is selected for alternative screening.

The guidelines for BPWTT do not address the specifics of disinfection techniques. To achieve the levels of permissible fecal coliform count and required reliability established for secondary treatment, it is judged that superchlorination is required. With high levels of chlorine application, chlorine residuals can be expected to persist into the receiving waters or other point of disposal unless dechlorination technique is applied. To avoid possible toxic effects in receiving waters, it is assumed that all discharges to surface waters will require dechlorination.

Minimum contact time between treated wastewaters and applied chlorine is to be provided at the rate of 30 minutes at PDWF and not less than 15 minutes at PWWF.

Criteria for rates of application are as tabulated below for various types of treatment.

Treatment	Estimated Application Rate mg/1	Installed Capacity Rate mg/1
Secondary without chemical coagulation	5	10
Secondary with ammonia removal	3	8
Secondary with chemical coagulation	4	8
Secondary with chemical coagulation and ammonia removal or nitrogen removal	2	8
Lagoon effluent	2	6
Tertiary effluent	1.5	6

Expected range of fecal coliforms to be found in effluents of various selected treatment systems are shown in Table 2.

Other Advanced Treatment

These processes are to provide additional organic removals beyond that which can be obtained with secondary treatment and are to meet the estimated evaluation of requirements beyond 1983 or for special disposal conditions prior to 1983.

The alternative processes available are as follows:

1. Sand or mixed media filtration
2. Microscreening

3. Carbon adsorption

4. Ozone oxidation

As stated under disposal criteria, it is not anticipated that there will be a general requirement for demineralization. It is anticipated that the requirement for demineralization will be limited to needs generated by recycle. The unusually low mineral content of raw water in the study area would not make demineralization for single pass reuse necessary except for a highly critical purpose. Since no such use is anticipated, no evaluation is made of the alternative demineralization processes which include the following:

1. Ion exchange
2. Osmotic membrane
3. Electrodialysis
4. Distillation
5. Freezing

Filtration and microscreening are not competitive alternatives with carbon adsorption but rather complementary operations. Adsorption is a process for collecting soluble impurities on a suitable interface. The dissolved molecules actually go out of solution by becoming bonded to the solid surface. The adsorbed materials must subsequently be removed from the solid surface to reactivate it for continued operation. Microscreening and, to a large extent, filtration are capable of removing only suspended insoluble matter. Microscreening is likewise not an exact functional alternative to sand or mixed media filtration since microscreening is limited to removal strictly by screening whereas the filter media develop adsorptive capabilities that add to the screening function. Microscreening is a rougher process than filtration with the further disadvantage of higher susceptability to clogging and difficulty in backwashing.

The target for adsorption treatment is the dissolved organic compounds which have escaped breakdown in the preceding biological processes. The only recognized feasible alternative for dealing with these residual dissolved organics is ozone oxidation. Monti and Silberman (1974) indicate that carbon adsorption has a significant cost advantage. Monti and Silberman subsequently recommend ozone oxidation over carbon adsorption followed by chlorine disinfection and reaeration for other reasons. For the purpose of cost effectiveness screening it is desirable to select the lower cost alternative. This does not preclude reconsideration at the design stage.

There are two basic alternative methods of applying the carbon adsorption technique. One is a packed tower or expanded bed granular system. The other is direct application of the powder form followed by settling or filtration. Pilot study data are available on the granular techniques which are selected with loading rate of 6 gpm per square foot at PWWF.

To prevent clogging of the carbon adsorption units, the filtration or screening process usually precedes the carbon adsorption process.

Microstrainers are reported to have slightly lower total cost than sand or mixed media filtration but their removals are lower and they are less adaptable to varying flow. Mixed media filtration is selected with loading criteria of 3 gpm per square foot at ADWF and not to exceed 6 gpm per square foot at PWWF. Refer to EPA (1974c) for a discussion of wastewater filter criteria. Note that flow equalization techniques, discussed in EPA (1974d), are an alternative to excessive peak flows on filter application.

Expected residual BOD following carbon adsorption and mixed media filtration is 5 mg/l when added to secondary treatment and as low as 2 mg/l when added to secondary plus nitrogen removal.

A polishing lagoon is a potential alternative to carbon adsorption and mixed media filtration. Where the polishing lagoon is applied to the effluent from standard biological secondary treatment the loading criteria selected are 30 days detention and loading of 50 pounds of BOD per acre per day. Where lagoons provide the initial as well as the polishing stage, this would be in addition to the requirements already specified for secondary treatment. Lagoons, in their final stages, are in effect lakes with limnological responses that can be as varied and unexpected as those of natural lakes. The final output of a polishing lagoon is subject to these limitations and uncertainties when approaching very high levels of treatment expectation.

Complete Physical-Chemical Advanced Treatment

The foregoing advanced treatment elements can be combined with a basic physical-chemical treatment of the raw wastes as an alternative to being added to secondary biological treatment. Typical of such systems are the following two:

1. Primary treatment followed by mineral precipitation, filtration and carbon adsorption.
2. Primary treatment followed by lime precipitation, ammonia stripping, filtration and carbon adsorption.

The first provides an all physical-chemical alternative to meet a "beyond 1983 level" of treatment where ammonia removal is not required and the second provides the ammonia removal stage. In addition, denitrification can be achieved in packed carbon columns if required. As noted above, the packed carbon column with methanol addition is actually a biological process. To date there is no demonstrated purely physical-chemical process to achieve the function of nitrate removal. Ion exchange removal on an experimental basis by Eliassen & Wyckoff is reported by Culp and Culp (1971).

Integrated Physical-Chemical-Biological Systems

Humenick and Kaufman (1970) have shown the potential for the development of new treatment systems which truly integrate the biological and chemical elements in lieu of stringing known processes in succession to achieve the desired degree of treatment. The cited paper proposes a very short duration (1 hour or less) activated sludge reactor at very high mixed liquor volatile solids (MLVSS in excess of 4000 mg/l) and very high loading (0.5 pounds BOD per day per pound MLVSS) achieved by recycling chemical sludges to the activated sludge reactor from a lime or alum precipitation stage following the activated sludge clarifier. Reported removals are:

Parameter	Percent Removal
BOD	90 - 95
Phosphorus	95
Organic N	70
Ammonia	nil

Where ammonia removal is required, the addition of a stripping operation is proposed if lime is used as a coagulant or ion exchange if alum is used.

The above described process is the equal in performance to the conventional systems selected above for cost-effective analysis in this study. This pilot demonstration is not proposed as a candidate process for this study due to the present lack of more complete demonstration and cost experience. It is cited as a demonstration of the advances in the current art that cannot be fully utilized in a study of this kind but which deserve consideration at the design stage.

Flow Equalization.

Although flow equalization is not a treatment process in itself, it can have a major effect upon the quality of output from many of the foregoing processes. EPA (1974 d) points out the benefits to upgrading conventional processes such as activated sludge and Culp and Culp (1971) indicates that flow equalization is practically a necessity to advanced treatment processes. The elimination of diurnal flow variations can be largely eliminated by storage volume of the order of 20 percent of the average daily flow. For treatment systems which include the following processes, flow equalization storage is proposed as a reasonable cost element: nitrification, denitrification, ammonia stripping, mixed media filtration and carbon adsorption.

There is also a requirement to consider flow equalization storage where long force mains are involved as a means of reducing the costs of providing pump capacity and pipe size for peak flows. These requirements are considered on a case by case basis.

Land Application Alternatives

General. Basic to all land application alternatives is the requirement that the wastewater receive the equivalent of at least secondary treatment* before land application. In some instances there are requirements for additional treatment as follows:

1. Disinfection where disposal involves creation of aerosols.
2. Nitrogen removal to 10 mg/l or less where infiltration-percolation to groundwater is proposed.

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* See discussion in Section 603.1

These treatment facilities may be located either at the wastewater source with treated wastewater conveyed to the land disposal area or raw sewage may be conveyed from the source for treatment at the land disposal site.

The ownership of the land proposed for various types of land disposal or treatment must be given some recognition in the selection of application criteria. For land disposal by infiltration-percolation, the ownership or exclusive use rights must be held by the Wastewater Management Agency (WMA) since there is no potential private enterprise economic return from spreading ponds. The overland flow technique, although having the potential for usable crop production, has low potential for profitable agriculture due to the constraints of collection ditches and maintenance of crop cover. Therefore, overland flow is assumed to be practiced only where the lands are owned or under the exclusive use rights of the WMA. Irrigation, on the other hand, can be carried out on lands owned by the WMA or on lands owned by others. The primary difference in criteria that arises with respect to ownership of lands for wastewater disposal by irrigation are a consequence of the goals to be accomplished.

One goal is to dispose of the largest quantity of water over the longest season on the least amount of land regardless of the economic benefit to be derived from the crops produced by irrigation. The other goal is the production of the most economic gain from the land in the form of crops with utilization of wastewater paced to maximize the production benefit and without regard to the amount disposed. The first goal requires either outright ownership by the WMA or a use contract with WMA that compensates another owner for the profit he would realize from land utilization to maximize beneficial crop production. The second goal could be accomplished under either ownership.

Evaluation of the most beneficial ownership or contractual relation of the WMA is an implementation concern. Resolution of the problem is premature at this point. Criteria, however, must be selected to proceed with cost effectiveness evaluation. To provide criteria that are valid under both kinds of ownership, it is assumed that irrigation use is in response to crop needs rather than to maximize disposal. This is done with the knowledge that subsequent evaluation of the ownership position may require review of these criteria.

Both ownership positions have been addressed with concern and difficulty at other locations. Refer to Postlewaite (1973) for a description of land acquisition at Muskegon, Michigan demonstration project. Refer to the Corps of Engineers position in their report for the San Francisco Bay Area which proposes use contracts in lieu of ownership.

Irrigation. Under disposal criteria it has already been established that irrigation disposal would not involve application on frozen ground and that either storage or alternative disposal would be required to balance availability with demand.

The criteria for selection of possible irrigation disposal sites are as follows:

1. Soil permeability to be adequate for application rates of at least 1-1/2 inches per week on the average or not less than 30 inches per season. Preferably, the capacity should be 2 inches or more per week.
2. No area subject to flooding during the growing season.
3. No area dedicated to public park use.
4. No area forecast to begin urban development before the year 2000.
5. Depth to groundwater not less than 5 feet.
6. Satisfactory existing vegetation or adaptable to an acceptable change in vegetation.

Elevation of the proposed irrigation site is a potential pumping cost constraint. Due to the topography of the study area, it is necessary to consider relatively large pumping lifts on a case by case basis rather than preselecting absolute limits in elevation.

There are no known specific requirements in Washington for the dimensions of a required buffer zone around land under spray irrigation with reclaimed wastewater. A uniform strip 200 feet wide is assumed. (No attempt is made to recognize variations due to prevailing wind direction which would be accounted at final design).

Pilot operations would be required before the design stage to select design application rates. For the purpose of alternative screening the following application rates are selected:

Area & Type	Application Rate inches/wk average	Growing Season Weeks
Spokane Valley-grass seed & pasture	3.0	22
Little Spokane Valley-pasture	2.0	22
Latah soils - wheat	1.0	20
" " - pasture	1.8	24
Pine forest - slopes less than 10%	.5	30
" " " 10 to 40 %	.2	30

Note that nitrogen uptake capability of the plant cover is a limitation as well as hydraulic capacity of soil.

For agricultural irrigation it is assumed that the irrigation would have to be delivered with a pressure of 60 psig measured above the ground elevation of the fields. For forest irrigation the selected pressure is 40 psig.

Underdrains can be applied to lands irrigated with reclaimed wastewater for two reasons. One reason is to help keep the soil sufficiently drained under high application rates to maintain the necessary aerobic soil zone. This implies ultimate surface water disposal of the leachate. The other reason is to recover the leachate for reuse. The leachate is estimated to have the following properties:

Parameter	Range per Michel et al (1974) Concentrations mg/1	Adjusted for this study* Concentrations mg/1
BOD	0.3 - 0.6	0.3
Suspended Solids	0.2 - 0.4	0.2
Total N	1 - 7	3.0
Total P	1 - 2	1.0
Total Dissolved Solid	Twice the applied	

The leachate is obviously of sufficiently high quality for surface disposal and most industrial applications except cooling tower make-up where the high dissolved solids are undesirable. At this point, there is insuffucient data about most local soils and their reaction to various application rates to determine when underdrains would be needed. The Spokane Valley soils have such high permeability that underdrains would not be needed; so much so that the capture efficiency of drains for the purpose of leachate recovery is probably too low to be practical.

If the water which could be recaptured by underdrains is allowed to percolate to groundwater, the wastewater is in effect being recycled for reuse, using the aquifer as the distribution medium rather than a system of underdrains and pipes. The application criteria selected herein are based on estimated soil capacity without underdrains.

Overland Flow. The suggested criteria (Reed and Buzzell 1973) for site

* Michel et al (1974) adjusted per secondary effluent quality expected to be applied here, assuming no additional phosphorus or nitrogen removal systems.

selection are relatively impermeable soils on gentle slopes of from 2 to 6 percent. The required cover is a permanent grass. Application rates are higher but of the same order of magnitude as irrigation.

The required site characteristics and type of cover practically eliminate this alternative from consideration for urban area waste disposal. The only extensive areas within the required slope range are on highly permeable soils. Furthermore, the requirement of a permanent grass crop, suitable only for pasture, but broken up by flow collection ditches makes an unattractive commercial farming enterprise, practically requiring land ownership by the WMA.

Overland flow is essentially a land treatment for surface water disposal rather than a land disposal technique. The expected quality of the water after overland flow treatment is as follows:

Parameter	Range per Michel *et al* (1974) Concentrations mg/1	Adjusted for this study* Concentrations mg/1
BOD	6 - 12	6
Suspended Solids	4 - 8	4
Total Nitrogen	2 - 7	4
Total Phosphorus	2 - 4	2

The phosphorus removal is relatively poor compared with irrigation and might require phosphorus removal by other methods in the secondary

* Michel *et al* (1974) adjusted per secondary effluent quality expected to be applied here, assuming no additional phosphorus or nitrogen removal systems.

process before application. Although this alternative could have a longer annual season of application than regular crop irrigation, there would still be part of the year in which storage or alternative disposal is required. Corps of Engineers (1971) in evaluation of the three land application techniques rates overland flow as the least desirable method for its generally poorer removals in general and of organics, heavy metals and phosphorus in particular. It also has the disadvantage of the largest land requirement since application rates are usually limited to 0.2 inches per day. For these reasons, irrigation and infiltration-percolation are given preferred consideration for formulation of alternatives for initial screening. Unless unusual circumstance should arise where these alternatives cannot be applied, overland flow will not be considered.

Infiltration-Percolation. This land application alternative offers many attractions including lowest potential cost, smallest land area requirement and capability for year around operation.

Site selection criteria are deep, highly permeable soils with at least 15 feet to groundwater. Excessive permeability is undesirable if it allows the treated wastewater to reach groundwater without adequate contact. Expected quality of the percolating water is as follows:

Parameter	Range for Michel *et al* (1974) Concentrations mg/l	Adjusted for this study* Concentrations mg/l
BOD	0.3 - 0.6	0.3
Suspended Solids	0.2 - 0.4	0.2
Total Nitrogen	8 - 33	13
Total Phosphorus	1 - 2	1.0
TDS	As applied plus 10%	

Bouwer (1974) estimates that a maximum of 30 percent of the applied nitrogen is removed by the high rate infiltration-percolation operation of Flushing Meadows, Arizona, where the cycles of flooding and resting have been regulated for maximum removal. Thirty percent removal of 19 mg/l applied in secondary effluent gives almost exact agreement with the 13 mg/l derived above from Michel *et al* (1974).

The total nitrogen of the leachate itself is expected to exceed the limit of 10 mg/l set in Public Health Service drinking water standards. Dilution by the native groundwater could bring the mixture below PHS standards. Whether possible dilution is acceptable or not is a disposal criterion which may differ for various locations. There will be no attempt to resolve this problem at this point. The resolution of this point will determine whether or not nitrogen removal should or should not be an addition to the secondary process prior to land application for infiltration-percolation. For this study, disinfection is adopted as a requirement

* Michel *et al* (1974) adjusted per secondary effluent quality expected to be applied here, assuming no additional phosphorus or nitrogen removal systems.

before application to protect groundwater especially where highly permeable soils occur.

As for other land disposal techniques, pilot studies are required to determine application criteria for actual design. For the purpose of alternative screening the following criteria are adopted:

		Cycle Loading		
		Loading		Resting
Location	Net Annual Rate, Feet	Ft/Day	Time Days	Time Days
Spokane Valley	180	1.5	10	20
North Spokane	119	1.0	7	14
Other	83	.7	7	14

These compare with actual rates of 250 feet per year reported for Flushing Meadows and 72 feet per year for Ft. Devens (Reed & Buzzell 1973).

Development of Treatment Systems

The foregoing describes selected alternative systems to meet the generalized treatment objectives listed in the opening paragraph of this section. Many systems in meeting one objective also, incidently, meet other objectives. To summarize the available systems and enumerate their capabilities for meeting treatment objectives, Figure A provides a compilation of integrated systems and the objectives met by each. Figure A also introduces a system identifier, symbols for ready reference to each system, and provides a schematic diagram of each to display the treatment elements included and their inter-relation. The system identifiers provide reference to system performance data which are summarized in Table 2.

Note that in Figure A, the systems are shown including certain additions that may be required under specific applications such as re-aeration and disinfection. When applying these systems to specific structural alternatives it is necessary to not only specify the system identifier but whether these optional additions are or are not included.

TABLE 1

TREATMENT ALTERNATIVES

Treatment Type	Functions	Alternatives
PRETREATMENT	Removal of toxic metals and organics	1. Treatment, removal or elimination at the source
PRELIMINARY	Removal of gross solids	1. Screening and removal 2. Screening and grinding 3. In-stream comminution
	Removal of mineral grit	1. Selective sedimentation a. Gravity grit channel b. Aerated grit tank 2. Detritus tank
PRIMARY	Removal of settleable solids and skimming	1. Sedimentation a. Plain with mechanical sludge collection and skimming b. With chemical coagulation 2. Air flotation 3. Upflow clarification 4. Fine screening 5. Lagoon
SECONDARY	Reduction of BOD and suspended solids	1. Biological a. Activated sludge b. Trickling filter c. Biodisc d. Lagoon (1) Plain (2) Aerated 2. Physical-Chemical a. Coagulation sedimentation plus carbon adsorption and filtration

TABLE 1 (continued)

Treatment Type	Functions	Alternatives
NITRIFICATION	Removal of ammonia or conversion to nitrate nitrogen	1. Biological a. Activated sludge b. Trickling filter or Biodisc c. Lagoon d. Irrigation 2. Physical-Chemical a. Ammonia stripping b. Breakpoint chlorination c. Ion exchange
DENITRIFICATION	Removal of all forms of nitrogen	1. Biological a. Anaerobic sludge b. Lagoon with algae harvest c. Irrigation* 2. Physical-Chemical a. Ammonia stripping b. Breakpoint chlorination c. Ion exchange d. Packed carbon column
PHOSPHORUS REMOVAL	Removal of all forms of phosphorus	1. Chemical precipitation 2. Biological concentration and chemical precipitation (PhoStrip process) 3. Infiltration-percolation through soil 4. Crop irrigation
DISINFECTION	Inactivation of pathogenic organisms	1. Chlorination 2. Ozone 3. Heat 4. Ultraviolet irradiation 5. Acid or alkali
TERTIARY	Removal to a high degree of BOD and SS after maximum possible by secondary	1. Land application 2. Filtration, sand or mixed media 3. Microscreening 4. Carbon adsorption 5. Ozone oxidation
DEMINERALIZATION	Removal of soluble inorganic salts	1. Ion exchange 2. Osmotic membrane 3. Electrodialysis 4. Distillation 5. Freezing

* Including intermittent flooding of planted infiltration ponds

TABLE 2

REMOVAL CRITERIA SUMMARY

Treatment System Ident.	Description	BOD Removal %	BOD Eff conc mg/l	Sus. Sol. Removal %	Sus. Sol. Eff conc mg/l	Ammonia Removal %	Ammonia Eff conc mg/l	Total N Removal %	Total N Eff conc mg/l	Total P Removal %	Total P Eff conc mg/l	Fecal Col. after disinfection No./100 ml
	Raw municipal waste as typified by forecast Average quality at year 2000		212		203		19.5		33.6		11.5	NA
	Primary Sed. without chemical coagulation	32	144	55	91	neg.	19.5	12	29.6	9	10.5	NA
	Primary Sed. with chemical coagulation	70	64	83	35	neg.	19.5	18	27.6	86	1.6	NA
S-1	Activated Sludge ST w/o chem. add. to Primary	88	25	90	20	25	14.6	43	19.2	30	8.0	200 - 500
S-2	Trickling Filter ST w/o " " " "	85	32	90	20	25	14.6	43	19.2	30	8.0	100 - 400
S-3	Lagoon as secondary Tr., Summer w/o algae removal	85	32	50	102	70	5.8	65	11.8	45	6.3	50 - 200
SX-4 and SPX-4	" " " ", " with " "	97	6	90	20	98	0.4	92	2.7	86	1.6	20 - 100
SP-1 and SP-2	ST with seasonal or year around phosphorus removal by chemical add. ahead of secondary clarifier (ON SEASON)	90	21	92	16	25	14.6	43	19.2	88	1.4	50 - 200
	(OFF SEASON) SP-1	88	25	90	20	25	14.6	43	19.2	30	8.0	100 - 400
	" " SP-2	85	32	90	20	25	14.6	43	19.2	30	8.0	100 - 400
SX-1	ST with seasonal nitrification by reduced load to standard carbonaceous reactors through chemical add. to primary (ON SEASON)	92	17	95	10	97	0.6	43	19.2	86	1.6	100 - 400
	(OFF SEASON)	88	25	90	20	25	14.6	43	19.2	30	8.0	100 - 400
SX-2	ST with seasonal nitrification by ammonia stripping (ON SEASON)	90	21	92	16	85	2.9	80	6.7	90	1.2	50 - 200
	(OFF SEASON)	88	25	90	20	25	14.6	43	19.2	30	8.0	200 - 500
SX-3	ST with full time nitrification by trickling filter operation at low loading to achieve maximum nitrification	88	25	90	20	65	6.3	43	19.2	30	8.0	50 - 200
SN-1	ST with nitrogen removal through bio. nitrif. and denitrif., two step, w/o chem. coag.	95	11	96	8	58	0.4	88	4.0	30	8.0	20 - 100
SPX-1S	ST with seasonal phosphorus removal and seasonal ammonia removal by alum coag. in primary to reduce load to Act. Sl. reactor and precipitate phosphorus (ON SEASON)	90	21	92	16	97	0.6	43	19.2	86	1.6	50 - 200
	(OFF SEASON)	88	25	90	20	25	14.6	43	19.2	30	8.0	50 - 200
SPX-2S	ST with seasonal phosphorus removal and seasonal ammonia removal by lime coag. to remove phosphorus and ammonia stripping (ON SEASON)	90	21	92	16	85	2.9	80	6.7	90	1.2	50 - 200
	(OFF SEASON)	88	25	90	20	25	14.6	43	19.2	30	8.0	50 - 200

TABLE 2 (Cont.)

REMOVAL CRITERIA SUMMARY

Treat-ment System Ident.	Description	BOD Removal %	BOD Eff conc mg/1	Sus. Sol. Removal %	Sus. Sol. Eff conc mg/1	Ammonia Removal %	Ammonia Eff conc mg/1	Total N Removal %	Total N Eff conc mg/1	Total P Removal %	Total P Eff conc mg/1	Fecal Col. after disinfection No./100 ml
SPX-3	ST with full time nitrification and seasonal or full time phosphorus removal using trickling filter at low load for maximum nitrification and with alum coagulation in secondary (ON SEASON)	90	21	92	16	65	6.8	43	19.2	88	1.4	50 - 200
	for phosphorus removal (OFF SEASON)	88	25	90	20	65	6.8	43	19.2	30	8.0	50 - 200
SPX-1 Y	ST with year around phosphorus removal and seasonal ammonia removal, using alum coag. in primary to reduce load to Act. Sl. reactor for on season ammonia removal and alum coag. in secondary off season to continue (ON SEASON)	90	21	92	16	97	0.6	43	19.2	86	1.6	50 - 200
	phosphorus removal (OFF SEASON)	90	21	92	16	25	14.6	43	19.2	88	1.4	50 - 200
SPX-2 Y	ST with year around phosphorus removal and seasonal ammonia removal using lime coag. and ammonia stripping on season and lime coag. w/o ammonia stripping off season, (ON SEASON)	90	21	92	16	85	2.9	80	6.7	90	1.2	50 - 200
	and with lime recovery (OFF SEASON)	90	21	92	16	25	14.6	43	19.2	90	1.2	50 - 200
SPN-1	ST with year around nitrogen removal and seasonal or year around phosphorus removal using biological nitrification-denitrification and chem. add to secondary (BOTH YEAR AROUND AND SEASONAL)	95	11	96	8	98	0.4	88	4.0	86	1.6	20 - 500
	(OFF SEASON RE PHOSPHORUS)	95	11	96	8	98	0.4	88	4.0	30	8.0	50 - 200
BT-1, 2, and 3	Advanced addition of carbon adsorption plus mixed media filtration plus reaeration to biological ST	NA	5	NA	3	(1)	(1)	(1)	(1)	(1)	(1)	2 - 5
PCT-1,2 & 3	All physical-chemical systems to provide advanced treatment. PCT-3 at all times and PCT-2 (ON SEASON)	NA	5	NA	3	85	2.9	80	6.7	92	0.9	2 - 5
	PCT-1 at all times and PCT-2 (OFF SEASON)	NA	5	NA	3	neg.	19.5	18	27.6	86	1.6	2 - 5
BT-4	Addition of lagoon treatment with algae [illegible]oval to ST effluent to achieve advanced treat[illegible]t	97	7	90	20	98	0.4	92	2.7	65(6) 92(7)	4.0 0.9	2 - 5

Notes: (1) Removals for all listed parameters except BOD and Suspended Solids are unchanged by addition of tertiary process to any given biological secondary process

(6) Without chemical removal of P in ST
(7) With chemical removal of P in ST

TABLE 2 (Cont.)

REMOVAL CRITERIA SUMMARY

Treat-ment System Ident.	Description	BOD Removal %	BOD Eff conc mg/1	Sus. Sol. Removal %	Sus. Sol. Eff conc mg/1	Ammonia Removal %	Ammonia Eff conc mg/1	Total N Removal %	Total N Eff conc mg/1	Total P Removal %	Total P Eff conc mg/1	Fecal Col. see notes (4) & (5) No./100 ml
LA-1	Land application by crop irrigation using alternative pretreatment to secondary effluent standards. (2)		0.3		0.2		neg.		3.0		1.0	>2-5 (4)
LA-2	Land treatment by overland flow on permanent cover using alternative pretreatment to secondary effluent standards. (3)		6.0		4.0		neg.		4.0		2.0	10-100 (4)
LA-3	Land application by percolation-infiltration using alternative pretreatment to secondary standards (2)		0.3		0.2		ND		13.0		1.0	2-5 (4) 2-100+ (5)
LA-4	Same as LA-3 except pretreatment alternatives include year around nitrogen removal in addition to secondary treatment. (2)		0.3		0.2		>0.4		>4.0		1.0	2-5 (4) 2-100+ (5)

Notes: (2) Effluent quality of land application techniques refers to the quality of the leachate expected to percolate toward groundwater or gathered by underdrains.

(3) Effluent quality of overland flow effluent refers to quality leaving in collection ditches.

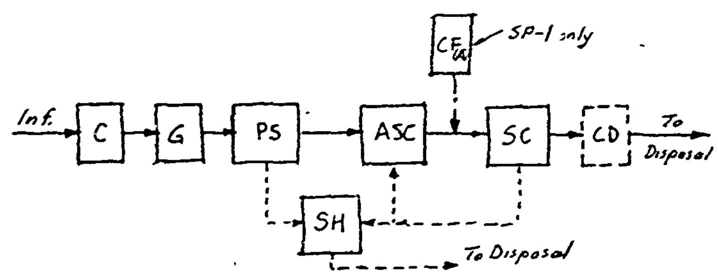
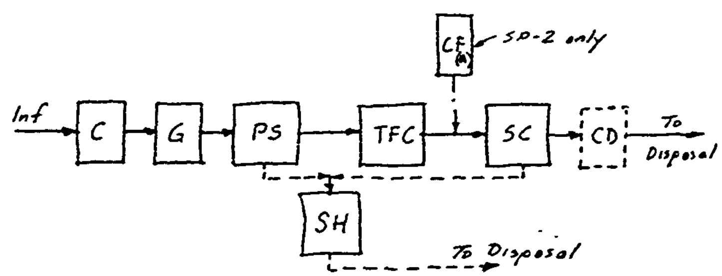
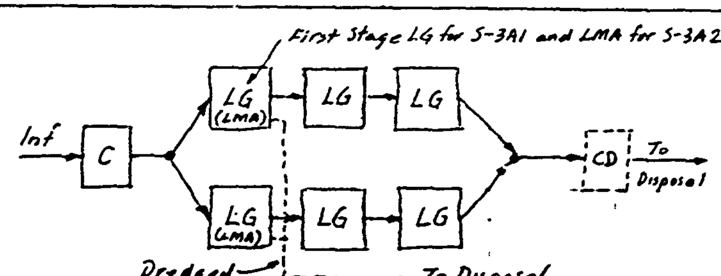
(4) Estimated range assuming disinfection prior to land application.

(5) " " without prior disinfection (Bouwer et al 1974).

TUDOR ENGINEERING COMPANY

BY E.M. DATE 15 Dec '74 SUBJECT WPS SPOKANE SHEET NO. 57 OF
CHKD BY DATE FIGURE A JOB NO. 603.2

TREATMENT SYSTEM SCHEMATICS

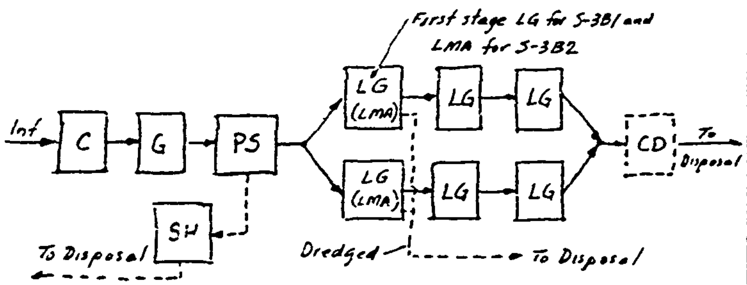
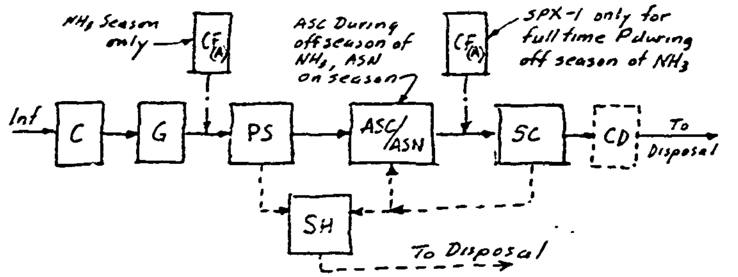
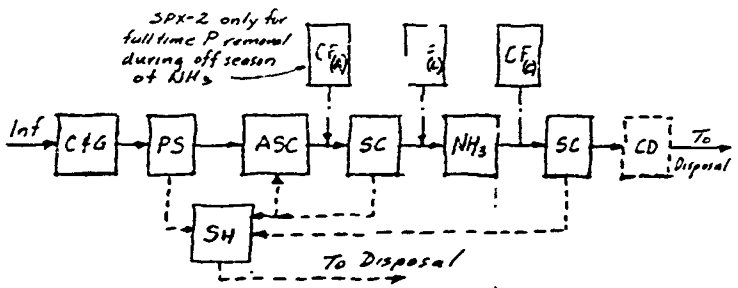
System Identifier	Treatment Objectives (2): Secondary	P Remov. Seasonal	P Remov. Full Time	NH3 Remov. Seasonal	NH3 Remov. Full Time	N Remov. Seasonal	N Remov. Full Time	Adv. BOD SS Red	Reaeration	Disinfection	Schematic Diagram (1)	Description
S-1	/									O		S-1 Secondary treatment using activated sludge process.
SP-1	/	A	A							O		SP-1 Same as S-1 except provision made for seasonal or year around phosphorus removal by alum precipitation in the secondary.
S-2	X									O		S-2 Secondary treatment using trickling filter process, high rate, restricting removal to carbonaceous.
SP-2	X	A	A							O		SP-2 Same as S-2 expect provision made for seasonal or year around phosphorus removal by alum precipitation in the secondary
S-3A1&2	X									O		S-3A Secondary treatment suitible for subsequent land application provided by complete lagoon treatment. S-3A1 utilizes plain lagoons, S-3A2 utilizes mechanical aerators in first stage lagoons.

For Notes See Page 63

TUDOR ENGINEERING COMPANY

BY E. K. DATE [illegible] SUBJECT WRS SPOKANE SHEET NO. 58 OF
CHKD BY DATE FIGURE A JOB NO. 603.2

TREATMENT SYSTEM SCHEMATICS

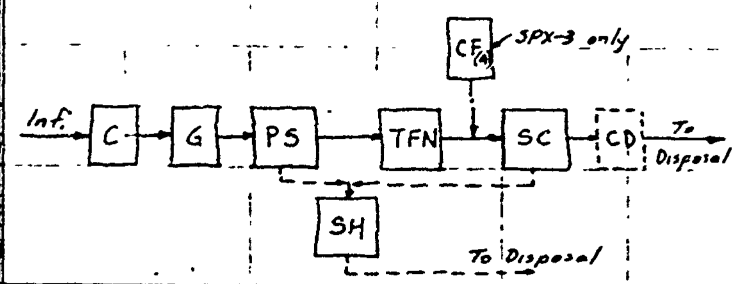
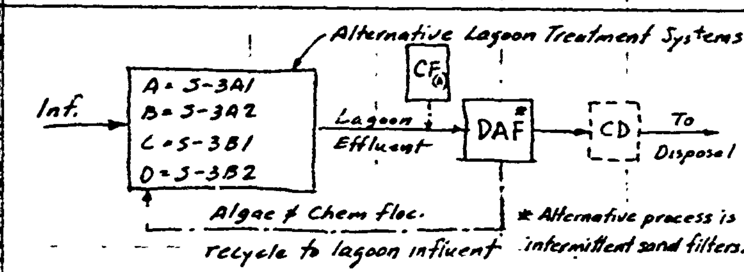
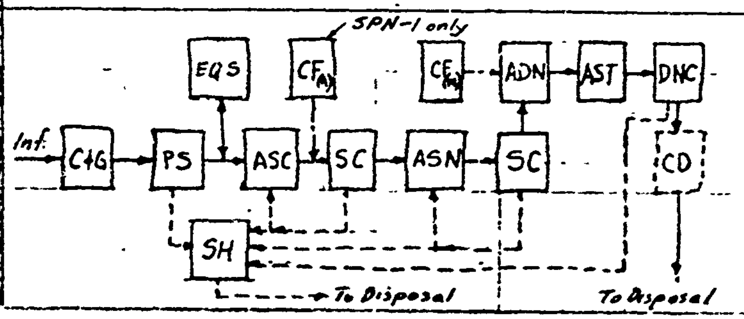
System Identifier	Secondary	P Removal Seasonal	P Removal Full time	NH_3 Removal Seasonal	NH_3 Removal Full time	N Removal Seasonal	N Removal Full time	Adv BOD & SS Red	Reaeration	Disinfection	Schematic Diagram (1)	Description
S-3B1 & 2	/									O		S-3B Secondary treatment suitable for subsequent land application provided by lagoon treatment of primary settled wastewater. S-3B1 utilizes plain lagoons, S-3B2 utilizes mechanical aeration in first stage lagoons.
SX-1	/	/		/						O		SX-1 Secondary treatment with seasonal nitrification and phosphorus removal provided by activated sludge process with seasonal unloading of the AS reactor through increased primary removal by alum coagulation.
SPX-1	/	/	X	X						O		SPX-1 Same as SX-1 but with provision to extend phosphorus removal to year around by adding alum coagulation to secondary off season.
SX-2	/	X		X						O		SX-2 Secondary treatment with seasonal ammonia and phosphorus removal provided by activated sludge process followed by ammonia stripping using lime for pH adjustment and P removal.
SPX-2	/	X	X	X						O		SPX-2 Same as SX-2 but with provision to extend phosphorus removal to year around by adding alum coagulation to secondary off season (Subalt - continue lime addition w/o operation of stripper).

For Notes See Page 63

TUDOR ENGINEERING COMPANY

BY E.N. DATE 15 Dec '74 SUBJECT WRS SPOKANE SHEET NO. 59 OF ____
CHKD BY ____ DATE ____ FIGURE A JOB NO. 603.2

TREATMENT SYSTEM SCHEMATICS

System Identifier	Treatment Objectives (2): Secondary	P Remove: Seasonal	P Remove: Full time	NH_3 Remove: Seasonal	NH_3 Remove: Full time	N Remove: Seasonal	N Remove: Full time	Add BOD & SS Red	Reaeration	Disinfection	Schematic Diagram (1)	Description
SX-3	X			X	X					O		SX-3 Secondary treatment with year around nitrification provided by trickling filters operated at low loading to provide maximum nitrification.
SPX-3	X	A	A	X	X					O		SPX-3 Secondary treatment with year around nitrification provided by trickling filters at low load and seasonal or year around phosphorus removal accomplished by alum precipitation in secondary.
SX-4A&D	X	X		X		X		A	A	O		SX-4 Seasonal advanced level BOD, SS, N and P removal provided by complete lagoon treatment followed by seasonally operated alum coagulation and dissolved air floatation for algae removal.
SPX-4A&D	X		X		X		X	X	X	O		SPX-4 Same as SX-4 except operation of DAF is year around.
SN-1	X				X		X			O		SN-1 Complete biological secondary treatment including year around nitrification and denitrification using the activated sludge process.
SPN-1	X	A	A		X		X			O		SPN-1 Same as SN-1 except seasonal or year around phosphorus removal added by alum precipitation in secondary.

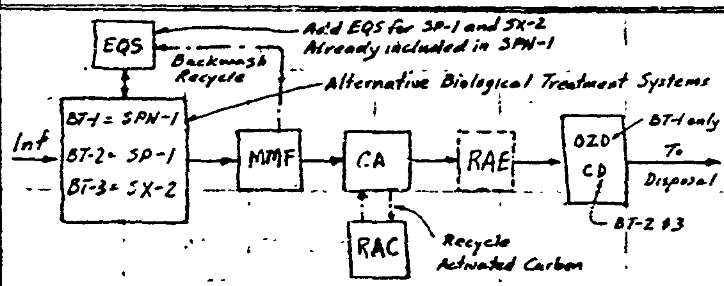
For Notes See Page 63

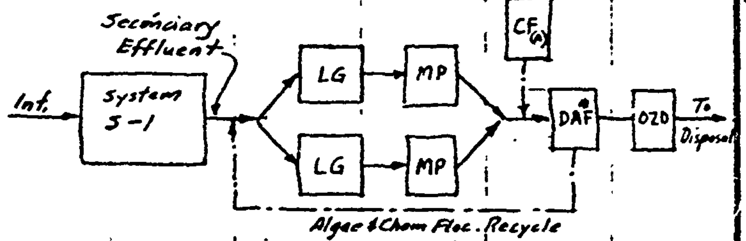
TREATMENT SYSTEM SCHEMATICS

System Identifier	Secondary	P Remove Seasonal	P Remove Full Time	NH3 Remove Seasonal	NH3 Remove Full Time	N Remove Seasonal	N Remove Full Time	Adv. BOD&SS Rem.	Recreation	Disinfection
BT-1	X	A	A		X		X	X	O	X
BT-2	X	A	A					X	O	X
BT-3	X	X		X				X	O	X
BT-4	X		X		X		X	X	X	X

Treatment Objectives (

Schematic Diagram (1)





* Alternative process is intermittent sand filters.

Description

BT-1 Advanced levels of BOD, SS, P and N removal accomplished by adding multi-media filtration and carbon adsorption to complete biological system including nitrification and denitrification.

BT-2 Advanced levels of BOD, SS and P removal achieved by adding MMF and CA to biological secondary including phosphorus removal.

BT-3 Advanced levels of BOD, SS and P removal plus seasonal ammonia removal by adding MMF and CA to biological sec. with seasonal ammonia and P removal.

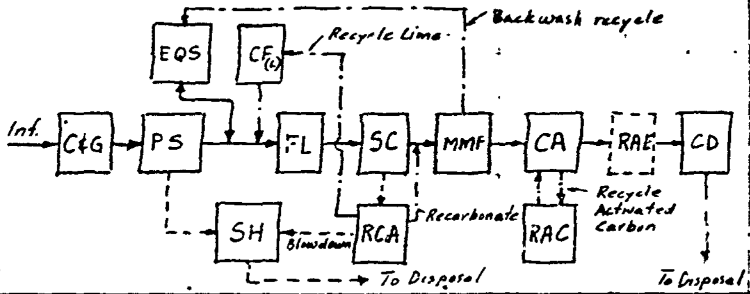
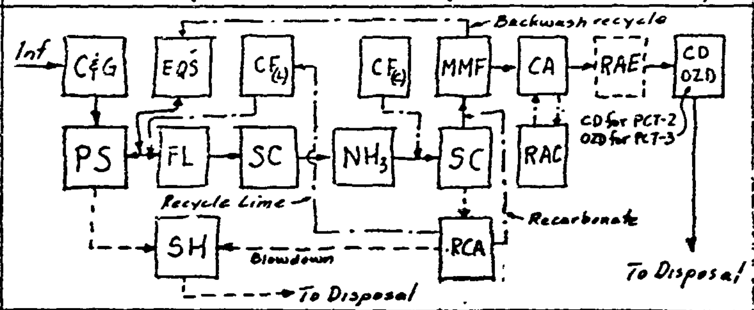
BT-4 Advanced levels of BOD, SS, P and N removal achieved by adding lagoon treatment with flotation algae removal to biological secondary.

For Notes See Page 63

TUDOR ENGINEERING COMPANY

BY EJM DATE 15 Dec 74 SUBJECT WRS SPOKANE SHEET NO. 61 OF ____
CHKD BY ____ DATE ____ FIGURE A JOB NO. 603.2

TREATMENT SYSTEM SCHEMATICS

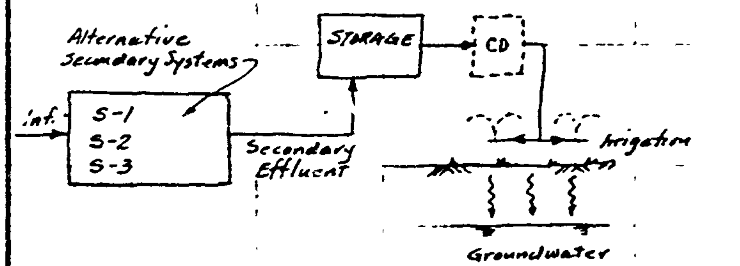
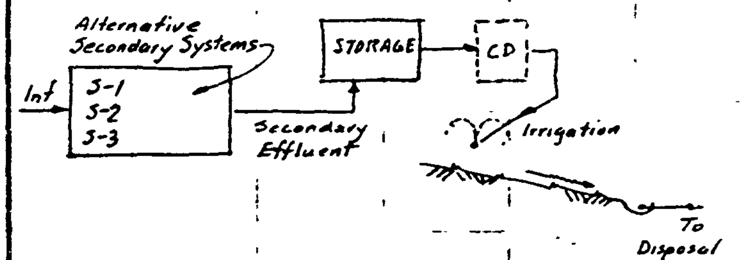
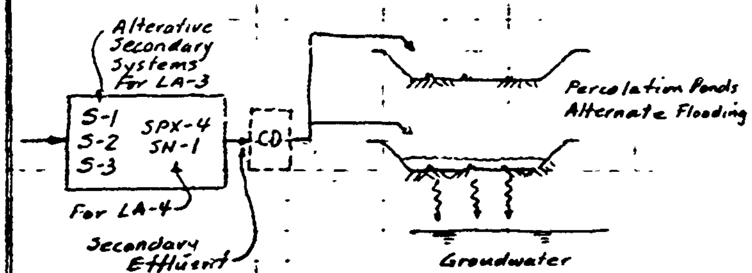
System Identifier	Treatment Objectives: Secondary	P Remove: Seasonal	P Remove: Full Time	NH3 Remove: Seasonal	NH3 Remove: Full Time	N Remove: Seasonal	N Remove: Full Time	Adv BOD&SS Red.	Reaeration	Disinfection	Schematic Diagram (1)	Description
PCT-1	X		X					X	O	X		PCT-1 Physical-chemical treatment to advanced levels of BOD, SS and P removal using sedimentation with chemical floculation, multi-media filtration and carbon adsorption. (This system does not provide any significant removal of ammonia. OZD is not an economical alternative to CD for this system)
PCT-2	X		X	X				X	O	X		PCT-2 Physical-chemical treatment to advanced levels of BOD, SS and P removal plus seasonal ammonia removal using sedimentation with chemical floculation, conventional ammonia stripping, multi-media filtration and carbon adsorption
PCT-3	X		X		X			X	U	X		PCT-3 Same as PCT-2 except that the ammonia stripping process is a closed circuit type for year around operation

For Notes See Page 63

TUDOR ENGINEERING COMPANY

BY E-M DATE 15 Dec '7_ SUBJECT WRS SPOKANE SHEET NO. 62 OF ____
CHKD. BY ____ DATE ____ FIGURE A JOB NO. 603.2

TREATMENT SYSTEM SCHEMATICS

System identifier	Treatment Objectives: Secondary	P Remove: Seasonal	P Remove: Full Time	NH3 Remove: Seasonal	NH3 Remove: Full Time	N Remove: Seasonal	N Remove: Full Time	Adv BOD & SS Red	Reaeration	Disinfection	Schematic Diagram (1)	Description
LA-1	X	X		X		X		X		O		LA-1 Land application by crop irrigation using alternative pretreatment to secondary effluent standards.
LA-2	X	X		X		X		X		O		LA-2 Land tr...tment by overland flow on permanent cover using alternative pretreatment to secondary effluent standards.
LA-3	X		X					X		O		LA-3 Land application by percolation-infiltration using alternative pretreatment to secondary standards.
LA-4	X		X				X	X		O		LA-4 Same as LA-3 except pretretment alternatives include year around nitrogen removal in addition to secondary treatment.

For Notes See Page 63

NOTES FOR FIGURE A

1. Process Elements in Schematic Diagrams are identified as follows:

   ——→ Wastewater process sequence
   - - → Sludge process flows
   —·→ Other process flows as noted

ADN	Anoxic denitrification
ASC	Activated sludge, carbonaceous oxidation
ASN	Activated sludge, nitrification
AST	Aeration stabilization of nitrified effluent
C	Coarse screening and in-stream comminution
CA	Carbon adsorption
CD	Chlorine disinfection including contact chamber
$CF_{( )}$	Chemical feed, as noted
	$CF_{(A)}$ alum $CF_{(c)}$ carbon dioxide
	$CF_{(L)}$ lime $CF_{(M)}$ methanol
DAF	Dissolved air flotation
DNC	Denitrification clarifier
EQS	Equalizing storage
FL	Floculation
G	Grit removal
LG	Lagoon, plain, facultative
LMA	Lagoon with mechanical aeration
MMF	Multi-media filtration
MP	Maturation lagoon
NH3	Ammonia stripping
OZD	Ozone disinfection
PS	Primary sedimentation
RAC	Reactivation furnace, activated carbon
RAE	Reaeration basin
RCA	Recalcining furnace, lime
SC	Secondary clarifier
SPS	Solids processing systems
TFC	Trickling filter, carbonaceous loading
TFN	Trickling filter, nitrification loading

2. Treatment objectives met by the process are indicated by "X". Objectives which may be met by exercising of operation options are indicated by "A". Objectives which are not a part of the basic system but which can be added as compatible options are indicated by "O".

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APPENDIX I
AERATION RATE FOR MECHANICALLY
AERATED LAGOONS

The power level assumed for aeration is that required to provide an oxygen supply at approximately 2.0 pounds of O_2 per **pound** of BOD. Oxygen transfer efficiency is assumed at 1.8 pounds of oxygen per horsepower hour or 43.2 pounds per day making the horsepower to BOD loading 0.0463 horsepower per pound of BOD per day.

Assuming that the raw sewage contains 212 mg/l of BOD, equals 1766 pounds per million gallons, 50 percent will be removed in the primary pre-treatment lagoon ahead of the areated lagoon. Assuming further that a final effluent of 50 mg/l quality is desired, equal 417 pounds per mg, the overall reduction between primary and final is (.50 x 1766) - 417 = 466 pounds per day. To remove all of this in the aerated lagoon would require a horsepower input of 0.0463 x 466 = 21.6 hp per mgd throughput.

For a ten foot deep aeration lagoon with 0.1 hp per 1,000 cf (13.3 hp per mg) given by Metcalf and Eddy as the threshold for significant mixing, the 21.6 hp per mgd throughout would require a detention of 1.62 days. Complete mixing is not required. Select 5 days detention in aeration equal to 0.03 hp/1,000 cf (4 hp per mg of basin volume) or 25 hp per mgd throughput for treatment comparable to secondary pretreatment for land application. Hold horsepower requirement per mgd of throughput for other levels of treatment but vary detention in aeration section.

APPENDIX II
COMPARABLE CRITERIA FOR
VARIOUS LAGOON TREATMENT SYSTEMS

Group A - To produce a highly polished effluent comparable to JPWTT secondary for surface water disposal.

	System	Criteria
A-1	Plain Facultative Lagoons	180 days detention & 20 lbs. BOD/Ac/Day
A-2	Primary Pretreatment Plus Plain Facultative Lagoons	90 days detention & 50 lbs. BOD/Ac/Day
A-3	Primary Pretreatment Plus Aerated Lagoons	30 days of which 10 are in aerated section at 25 hp per million gallons
A-4	Lagoon Primary Plus Aerated Lagoons	20 day primary, 10 day aerated at 25 hp per mgd throughput, 20 day polish.

Group B - To produce a secondary effluent suitable for irrigation that would not tend to go septic in distribution or storage and could be satisfactorily disinfected.

B-1	Plain Facultative	90 days detention & 50 lbs. BOD/Ac/Day
B-2	Lagoon Primary Plus Aerated Lagoons	20 day primary, 5 day aerated at 25 hp per mgd throughput, 15 day polish
B-3	Primary Plus Plain	60 days detention & 70 lbs. BOD/Ac/Day
B-4	Primary Plus Aerated	5 day aerated at 25 hp per mgd throughput, 15 day polish

Group C - To produce an effluent comparable to primary suitable for irrigation and with the same limitations.

C-1	Plain Facultative	30 days detention
C-2	Lagoon Primary Plus Aeration	7 day primary plus 3 day aeration @ .03 hp per mg volume and 7 day polish

APPENDIX III
COST COMPARISON OF GROUP B
LAGOON ALTERNATIVES

Alternative B-1 Plain Facultative

Volume at 5' depth for 1 mgd at 90 days detention

$$\frac{90 \times 3.068}{5} = 35.3 \text{ acres}$$

Volume for 212 mg/1 BOD influent at 50#/Ac/Day

$$\frac{212 \times 8.33}{50} = 35.3 \text{ acres}$$

Time governs Cost/mg @ $7500*/Ac = $412,500/mg at both 1 & 10 mg points

Alternative B-2 Lagoon Primary Plus Mechanical Aeration

Volume of 5' section @ 35 days detention

$$\frac{35 \times 3.068}{5} = 21.5 \text{ acres @ \$7500*/Ac.} = \$161,300$$

Volume of 10' section @ 5 days detention

$$\frac{5 \times 3.068}{10} = 1.53 \text{ acres @ \$12,000*/Ac.} = 18,400$$

HP required at 25/mg of throughput

25 x $800*/hp = 20,000

Subtotal per mg at both 1 & 10 mgd points = $199,700

* Refer to Section 401.2 for cost criteria.

APPENDIX III
(Continued)

Alternative B-3 Structural Primary Plus Lagoon

Volume @ 5' deep at 60 days detention

$$\frac{60 \times 3.068}{5} = 36.8 \text{ acres}$$

Volume @ 70 #BOD/Ac/day

$$\frac{212 \times 8.33}{70} = 25.2 \text{ acres}$$

Time governs 36.8 Ac @ $7500*/Ac = $276,000

Structural Primary from curve @ 1 mg per mg = 440,000*

Total @ 1 mgd = $716,000/mg

Structural Primary from curve @ 10 mgd = $240,000/mg

Total @ 10 mgd = $516,000/mg

Alternative B-4 Structural Primary Plus Mechanical Aerated Lagoon

Volume at 10' deep for 5 days detention

$$\frac{5 \times 3.068}{10} = 1.53 \text{ acres @ \$12,000* = \$18,400}$$

Aeration at 25 hp/mg @ $800/hp = $20,000

Volume at 5' deep for 15 days detention

$$\frac{15 \times 3.068}{5} = 9.20 \text{ acres @ \$7500* = \$69,000}$$

Subtotal w/o primary = $107,400/mg

Primary for 1 mgd = 440,000*/mg

Total @ 1 mgd = $547,400/mg

Primary for 10 mgd = 240,000*/mg

Total @ 10 mgd = #347,400/mg

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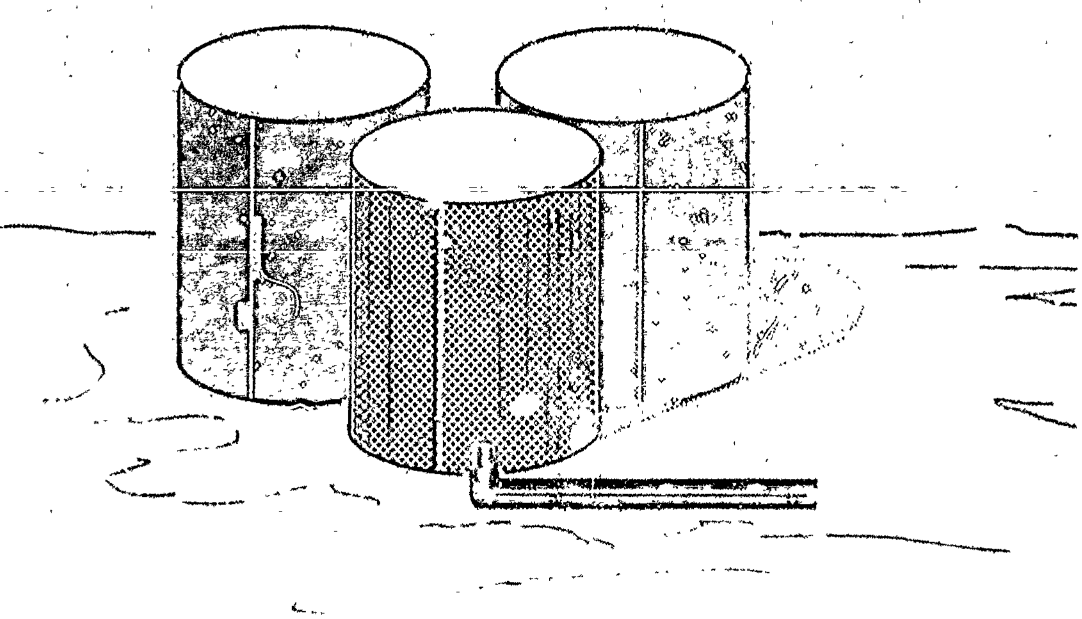
* Refer to Section 401.2 for cost criteria.

APPENDIX III
(Continued)

Summary

	Alternative	Capital Cost Per Mg For 1 mgd	For 10 mgd
B-1	Plain Facultative	$412,500	$412,500
B-2	Lagoon Primary Plus Mechanical Aeration	199,700	199,700
B-3	Structural Primary Plus Plain Lagoon	716,000	516,000
B-4	Structural Primary Plus Mechanical Aerated Lagoon	547,400	347,400

Lagoon Primary Plus Mechanical Aeration has lowest capital cost for both 1 mgd and 10 mgd plant size by large margin. Where space is available select as lowest cost secondary pretreatment for land application alternatives.



SECTION 603.3

SLUDGE TREATMENT AND DISPOSAL CRITERIA

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 603.3

SLUDGE TREATMENT
AND DISPOSAL CRITERIA

10 October 1975

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

INDEX

SECTION 603.3

TREATMENT CRITERIA FOR
SLUDGE PROCESSING

Objectives

The objectives of this section are as follows:

1. Establishment of criteria for evaluating the solids loads expected from the alternative wastewater treatment systems
2. Selection of alternative sludge processing systems compatible with alternative wastewater treatment systems
3. Selection of loading criteria for sizing of sludge processing elements
4. Establishment of criteria for evaluating the solids and volume reduction achieved by alternative sludge processing systems
5. Identification of alternative ultimate disposal methods for stabilized or reduced waste solids.

Representative wastewater treatment processes for initial screening of alternatives are selected in another section. This section addresses the selection of sludge processing systems to meet these specific needs from the widest possible array of candidate treatment and disposal methods. This section develops criteria for computation of the solids loads to be expected from these specific wastewater processes handling raw waste flows of the quality projected for the study area.

Sludge Quantities

The specific wastewater treatment categories to be addressed for determination of sludge production quantities are shown in Table 1. The projected wastewater concentrations of BOD and suspended solids for the various planning units throughout the entire planning period, 1980 to 2020, are developed in Section 406.2. The removal criteria for various treatment processes and chemical dosages are developed in Section 603.1. The interaction of the projected concentrations and the removal criteria and chemical dosages are calculated to determine the solids content of sludges from the various treatment processes, results of which are summarized in Table 1.

(Subsequent to the earlier drafts of this task report section, the report by Bovay for the Department of Ecology on land application for sludge from the City of Spokane treatment plant was made available. The sludge quantities for the waste activated component developed in this report from experimental work are significantly different than the literature values in Table 1. Since it becomes desirable to utilize the results of the Bovay report in task report Section 701.3, the Bovay values for sludge quantities are utilized for city alternatives in Section 701.3 rather than the original values in Table 1. Thus all comparison of alternatives in Section 701.3 including Bovay results are on a uniform basis for comparison. Table 1 values are used uniformly for initial screening in Section 701.2 where all sludge systems are held the same. Refer to Section 701.3 for the specific criteria used therein.)

The variation in projected wastewater concentrations between planning areas and with time during the cost effectiveness planning period, 1980 - 2000, are less than 12 percent above and below a central value. Therefore the year 2000 values of BOD at 212 mg/l and suspended solids at 203 mg/l are selected as representative for all solids loads estimations. These values, developed to be representative of the study area, with its high water use and relatively small industrial component, are similar to typical literature values of 250 mg/l BOD and 200 mg/l of suspended solids. Therefore, as would be expected from this relationship, the specific calculated solids loads in Table 1 are approximately equal to the values given in EPA 625/1-74-006.

Chemical sludge quantities associated with alum addition for phosphorus removal are estimated based on previously selected alum dosage of 125 mg/l. The estimated production of alum sludge, a mixture of aluminum phosphate and aluminum hydroxide, is 350 pounds per million gallons of wastewater treated.

In addition to the solids expected in raw sludge for each process, Table 1 also shows the expected proportion as volatile solids and the concentration for each component as drawn from the process. The concentration is the basis for the calculation of the volume of sludge in gallons per million gallons, also shown in Table 1. The very low concentrations normally experienced with waste activated sludge usually require thickening before it is economical to perform subsequent operations. Biodegradable fractions are assumed to be 75 percent for primary sludge, 80 percent for biological sludges, and zero percent for alum sludges. Although alum sludges contain a finite volatile fraction, none of this is biodegradable. Columns 8 and 9 on Table 1 show the expected concentrations to be achieved by the thickening processes, described below, and the resultant thickened volume.

The use of Table 1 through column 9 is demonstrated by the following example: Assume a 10 mgd wastewater treatment facility to provide secondary treatment plus seasonal phosphorus removal utilizing the activated sludge process with alum coagulation in the secondary clarifier for phosphorus removal. During the phosphorus removal season, the indicated sludge production is 930 pounds per mg of dry solids from the primary at a concentration of 5 percent plus 800 pounds per mg of dry solids from waste activated sludge and chemical treatment at 1 percent concentration. During the season when phosphorus removal was not being practiced, the primary sludge production rate would be the same but the secondary sludge would be reduced to 450 pounds per mg of waste activated sludge at a concentration of 0.8 percent. Thus at 10 mgd rate with phosphorus removal, the daily amount of combined raw sludges would contain 17,300 pounds of dry solids and the volume would be 118,370 gallons. With thickening provided for the waste activated sludge portion to increase its solids content to 3.5 percent, the daily volume is reduced to 49,770 gallons. In the same manner, during the season of no phosphorus removal, the daily raw solids are 13,800 pounds in a volume of 89,860 gallons before thickening of the waste activated sludge and 37,760 gallons after.

Integration of Sludge Processing With Wastewater Disposal

It is recognized that the selection of a complete wastewater management plan must compare complete integrated systems including both the wastewater treatment and disposal element and the sludge processing and disposal elements. For each wastewater treatment system there are a number of alternative sludge treatment and disposal systems. The cost of sludge processing and disposal usually represents 30 to 50 percent of the total cost associated with the complete wastewater treatment (Bernard, 1974). Therefore, the sludge disposal system selected for combination with a particular wastewater treatment process can significantly affect its overall cost and its position in cost effectiveness analysis. The number of candidate wastewater disposal alternatives is large without consideration of the permutations and combinations that result from simultaneous consideration of sludge processing alternatives. The unwieldy number of combinations suggests a two step screening process, recognizing the need to exercise care to not bias the final selection by premature exclusions.

All disposal alternatives involve the equivalent of a minimum of secondary treatment prior to surface water disposal or land application. There are two basic methods of providing secondary treatment, either concentrated site facilities such as activated sludge process, or lagoon treatment. If a single type of sludge processing or disposal is selected for the concentrated site facilities and another single method for lagoon treatment, the wastewater systems can be given an initial screening which will emphasize the relative advantages without the complication of various sludge processing alternatives. Having made such an initial screening, the more promising candidates can be compared again with alternative sludge disposal systems which are site and system specific.

The goal of this section is to identify those sludge processing and disposal systems which are compatible with the concentrated wastes produced by the various wastewater treatment systems and to make some initial screening with regard to cost and functional capability. The field of candidate sludge processes and disposal or resource recovery methods are summarized in Table 2.

Sludge Disposal Criteria

For this study area, the ultimate disposal of waste solids is limited to the following:

1. Landfill with the object of disposing of the wastes but with no intent to benefit from the resources in the waste solids.
2. Land application with the object of reaping the benefits of soil improvement and fertilization.
3. Conversion to a marketable product
4. Maximizing reduction by incineration or wet oxidation with ash disposal by landfill or pyrolysis with activated carbon residual for reuse or disposal.

The primary criteria for landfill disposal are avoidance of nuisance, protection of health, and protection of ground and surface waters from degradation due to leaching. These criteria are in part met by the proper selection of the landfill site and the operation of the landfill in a manner conforming to state regulations covering sanitary landfill. See Section 312.5 of this report and refer to WAC 173-301-183, WAC 173-301-301 through 306. Specific reference is made to disposal of sewage sludge in WAC 173-301-301 requiring limitation of in place moisture content, obtained by mixing with other solid wastes, of not over 40 percent. The net effect of the foregoing requirements is that sludge for landfill disposal must be a stabilized material, with moisture content reduced to approximately 75 percent or less. Stabilization is defined as application of any of the alternatives listed under this process in Table 2. The average landfill is assumed to be capable of accommodating 4700* cubic yards of sludge cake per active acre or 3100* cubic yards per acre of gross site including buffer.

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*Refer to page 45 of Section 401.2 for detailed development.

Basic criteria for land application are as stated above for landfill, namely avoidance of nuisance, protection of health, and protection of ground and surface waters. Prior to the initial drafts of this task report section, specific guidelines for land application of sludge were not available and the following criteria were selected and adapted from EPA 625/1-74-006.

1. Moisture content is not a limitation; the sludge may be applied over the entire range from dried cake to liquid as drawn from digesters to diluted sludge with treated wastewater. The primary limitation is an hydraulic one in that the rate of application should not result in free runoff. As will be noted below, the limitation with respect to nitrogen application will, in general, automatically control. In general, slopes of over 6 percent are not suitable due to inability to control runoff either of sludge or rain. Similarly, application should not be made on frozen ground due to the inability to control runoff due either to precipitation or melting.
2. Rate of application of sludge solids should not provide nitrogen in excess of plant ability to utilize it so that excess nitrogen is free to percolate to groundwater. The relationship to crop needs is discussed in detail below under the heading Resource Recovery. In summary, an application rate of 4 tons of dry solids per year is selected as a guideline in the absence of more specific data.
3. Pathogen control to minimize the hazard of direct contact in

handling and application require that the pathogen content of the sludge be reduced through application of one of the stabilization techniques. Satisfaction of this requirement also achieves control of nuisance by minimizing odor.

Reduction of pathogens does not achieve elimination, which is not feasible economically. Therefore, there will be pathogens in and on the soil for an indefinite period. The general recommendation in the EPA reference is that sludge not be applied to root crops or above ground crops intended for human consumption in raw form.

4. Heavy metals in sludge can also constitute a limit to rate of application or duration. Spokane sewage has a low heavy metal content, at present, so that this limitation is not expected to be controlling. It would, of course, be monitored at the implementation stage.

Subsequently, proposed guidelines became available in draft form under the title "Acceptable Methods for the Utilization or Disposal of Sludges" proposed for public comment in November 1974 as EPA document 430/9-75-XXX. These guidelines are in general agreement with the foregoing interim selections but have additional specific provisions which are summarized as follows:

1. Stabilization must provide not less than a 40 percent reduction in volatile solids and 97 percent reduction in fecal coliforms.

2. Pathogen content must be further attenuated by the equivalent of:

   a. Pasturization for 30 minutes at 70°C

   b. High pH lime treatment for 3 hours at pH 12

   c. Long term storage of 60 days at 20°C or 120 days at 4°C.

3. Heavy metals not to be applied beyond 5% of soil cation exchange capacity (CEC) and cadmium to zinc ratio not to exceed 0.005

4. Impact on groundwater quality to be governed by:

   a. Not to degrade below drinking water standards

   b. Protected from possible nitrogen enrichment by application of nitrogen balance techniques in determining nutrient application rate to crops.

5. Sludge application rate (the following quotes directly from EPA 430/9-75-XXX).

   "The sludge application rate per acre must be managed to ensure that environmental requirements are met. It is not possible to give a rate, or even an upper limit, which would be universally applicable, since the limit varies widely and must be determined for each site. Application rates can be estimated based on experience, site exploration data, or test plot data.

   "Nitrogenous substances usually limit annual application rates. The rate of sludge application to agricultural land must be consistent with the use of N by agronomic crops to prevent contamination of groundwater with nitrate. The information required to establish a sludge application rate includes: (1) total and inorganic N content of sludge, (2) N, P, and K requirement of crop grown, and (3) soil test for available P and K. Supplemental fertilizer, especially K, may be needed to optimize crop production. Sludge rate should be such that the total amount of plant available N added is no greater than twice the N requirement of the crop grown. Plant available N includes that mineralized from the soil and the inorganic sludge N (ammonium and nitrate) plus a mineralization rate of 15 to 20% of the sludge organic N for the first growing season and 3% of the residual sludge N for three subsequent growing seasons. Volatilization of NH_3 from surface applied sludge should be taken into account; experience has shown that about 50% of this N may be lost if the material is not immediately incorporated.

"Each prospective land application should be assessed on an individual basis, with consideration given to both sludge characteristics and soil characteristics."

6. A monitoring plan must be implemented for each land application site, where the application rate will exceed 5 dry tons/acre/year for liquid digested sludge, or 50 dry tons/acre over a three year period for dried or dewatered sludge.

   The site monitoring must be specifically designed for applicable local conditions, and is to include consideration of:

   a. Heavy metals, persistent organics, pathogens, and nitrates in groundwater, surface water, sludge, and soils.

   b. Heavy metals, persistent organics, and pathogens for human food chain products grown in sludge-aided soil.

Site specific considerations for land application are discussed in Section 701.3.

Criteria for conversion to a marketable product fall into two categories, one for a general public market and one for a special contract buyer. For a general marketable product, the material must be rendered completely stable and non-noxious and be dried to a very low moisture content so that it can be shipped economically. Other criteria include having a worthwhile and constant nutrient content and freedom from stringy materials and grease. To meet these criteria for a general marketable product requires limitation to utilizing waste activated sludge, without primary sludge (Garrett 1974), drying to moisture content of approximately 5 percent and probably supplemental additions of nutrients. For a special contract sale, the usual basis of costing is nitrogen content and the form of the product is flexible but stabilization is a minimum requirement.

Disposal of ash from incineration is limited to landfill operation criteria.

Sludge Processing Alternatives

General. The constraints for selection of sludge processes are established by the foregoing paragraphs including the wastewater treatment systems to be served and the ultimate disposal criteria to be met with the waste solids. The field of sludge processing elements comprising the candidates for alternative systems is shown in Table 2.

Categories of sludge types. The concentrated site wastewater treatment systems listed in Table 1 produce seven basic types of sludge. These are:

1. Primary sludge without chemical addition
2. Primary sludge with alum coagulation
3. Trickling filter secondary sludge without chemical addition
4. Trickling filter secondary with alum coagulation
5. Waste activated sludge (W.A.S.) without chemical addition
6. W.A.S. with alum coagulation
7. Lime sludge from secondary effluent treated for phosphorus removal and ammonia stripping.

Primary sludge and trickling filter secondary sludge, both without chemical additions, produce a sludge with sufficiently high solids content so that they can be processed without thickening. W.A.S. and all sludges with alum coagulation are drawn from the process at such low solids concentrations that it is most cost effective to thicken them before proceeding to other processes. There are other characteristics that follow the same division as that which forms the two categories relative to the need for thickening. These characteristics are associated with the relative ease of dewatering. All of the foregoing sludges, except lime sludge, can be mixed for and are amenable to the various stabilization processes. Thus, the first six types of sludge can be consolidated into fewer categories for consideration of various processes and can, with minor variations, be applied to all. Lime sludges have unique properties and are discussed separately.

Thickening. As indicated above, the following types of sludges are so dilute as drawn from the basic wastewater treatment process that an increase in concentration is required to obtain more economical utilization of subsequent processes.

1. Primary sludge with alum coagulation
2. Trickling filter secondary sludge with alum coagulation
3. W.A.S. with and without alum coagulation

The alternatives as indicated in Table 2 are simple gravity thickening, flotation and centrifugation. Gravity thickening, although the simplest, is not particularly effective except with excessive detention times and consequent cost. Centrifugation is effective but costly being a process capable of higher degrees of concentration than usually necessary for the thickening function. Flotation is more effective than gravity and less costly than centrifugation and is the process with widest acceptance in current practice for this function. The dissolved air flotation (DAF) process is selected for all systems requiring the thickening function for raw sludge.

Alum sludge can be effectively thickened as either surface or under flow from a flotation thickener with the proper selection of conditioning polyelectrolytes and air quantities. Alum sludge occuring as a mixture with primary sludge is mixed with waste activated sludge prior to thickening.

Selected design criteria for dissolved air flotation thickeners are

0.6 lbs. solids per hour per square foot and 0.8 gpm per square foot (Ref. EPA 625/1-74-006, 4.3.5).

Stabilization. All methods of ultimate disposal except those which involve prior reduction to ash require stabilization as an intermediate process. All of the sludges and their mixtures, except lime sludges, thickened where required, are amenable to all of the alternative stabilization processes shown in Table 2 and below.

1. Anaerobic digestion
2. Aerobic digestion
3. Heat treatment
4. Chemical treatment
    a. Lime
    b. Chlorine oxidation

The selection of the appropriate stabilization process depends upon the size of the facility, the proposed ultimate disposal and the site specific economics of chemicals and fuel. Aerobic digestion, heat treatment and chemical treatment all require significantly higher energy input directly or in the form of manufacture of chemicals than anaerobic digestion. Aerobic digestion is usually economically competitive with anaerobic digestion only for plants below 4 mgd. The high cost of chlorine oxidation and the decreasing availability of this chemical make this alternative unattractive for general long term application. For the application of liquid sludge to land surfaces, heat treatment and lime treatment have had limited application. The most widely used stabilization process and the one which is compatible with dewatering processes and all disposal process is anaerobic digestion.

Anaerobic digestion is selected as the basic stabilization process for initial screening. Criteria selected for all types of sludge are 0.08 pounds of volatile solids per cubic foot of digester and 25 days detention. Expected performance is 45 percent reduction in volatile solids. These criteria are more conservative than the criteria given in EPA 625/1-74-006. The criteria in this reference are believed to be excessively optimistic for sizing heated mixed digestion tanks in particular. A more conservative basis for sizing is considered appropriate for planning studies. Expected concentrations of sludges drawn from anaerobic digestion are 4-1/2 percent solids for primary and trickling filter sludges without chemical coagulation and from 2.5 to 3.0 percent solids for all WAS and chemical coagulation sludges.

For refined evaluation of alternative stabilization processes of heat treatment and lime treatment the following criteria are selected. For heat treatment, the sludge is raised to a temperature of 70-75°C for a period of not less than one hour to effectively pasteurize the sludge (EPA 625/1-74-006). For lime treatment, dosages for the various types of sludge are selected as follows, based on Table 5-17 of EPA 625/1-74-006, to provide a pH greater than 11 for at least 14 days.

Type of sludge	Pounds of Hydrated Lime per ton of dry solids
Primary	250
Biological	800
Mixed primary and biological with chemical coagulation	700

Dewatering. The dewatering alternatives as shown in Table 2 are listed below:

1. Vacuum Filtration
2. Pressure Filtration
3. Centrifugation
4. Vibrating Screens
5. Evaporation
   a. Fueled
   b. Natural bed drying

The first four alternatives are, at the level of regional planning, matters of equipment selection and should be addressed in detail only at the design level. For alternative screening at the regional planning level the important decision is whether to have mechanical dewatering or not. Without prejudice to the ultimate selection process at design level, vacuum filtration is selected as the basis for price data for mechanical dewatering since, at this date, it has been most widely used and has the better cost data. The selected criteria are 3.5 pounds per square foot per hour with 4.5 percent solids feed and 1.5 pounds per square foot per hour for 2.7 percent solids feed and producing cake of 20 percent solids and 18 percent solids respectively.

The evaporation alternatives represent a basic choice from the mechanical dewatering alternatives. Fueled dewatering to the equivalent of vacuum filter cake level is not economically competitive. The competitive alternative is natural evaporation when land area is available. This is a site specific application. Criteria selected are 15 pounds of solids per square foot per year at 8 inch fill depth. Bed dry cake is expected to have a solids content of 30 percent.

Conditioning. Conditioning processes are those carried out not as an end in themselves but as means of facilitating a subsequent process. The processes most frequently requiring prior conditioning are the various mechanical dewatering processes. Again, like the mechanical dewatering processes, the actual selection of the appropriate process is more properly a design consideration. The primary objective for this study is to recognize the need for conditioning for certain sludges so that an appropriate cost is included. The conditioning alternatives as listed in Table 2 are chemical, heat and elutriation. Frequently, a combination of processes is required.

For the purpose of initial screening where anaerobic digestion is selected as the stabilization process to be followed by mechanical dewatering, a combination of elutriation and chemical treatment is selected as the appropriate conditioning process. Stabilized sludges from primary sedimentation without chemical coagulation and from trickling filter secondary are expected to have concentrations and properties that would make elutriation conditioning unnecessary. All other sludges or mixtures which include the other sludges are expected to benefit significantly by elutriation conditioning.

In addition to reducing the quantities of conditioning chemical required by "washing" the sludge, elutriation produces a more concentrated sludge. It is estimated that elutriation will concentrate 2-1/2% solids to 4-1/2% solids. Elutriation tanks are sized based on 25 gallons of digested sludge slurry per sqaure foot per day. This loading rate is based on information furnished by Genter, who developed the two stage, counter flow elutriation process.

Reduction. All of the reduction processes are oxidation (or partial oxidation in the case of pyrolysis) processes designed to minimize the remaining organic content to the point where the residual is primarily ash. These processes have been used, in general, only where land disposal of the unreduced liquid or dewatered cake is no longer feasible within a reasonable distance. Note that land disposal of the ash from reduction processes is likewise required as the ultimate disposal step but at a greatly reduced scale due to the smaller volume. For example, a 10 mgd flow through an activated sludge plant produces raw sludge containing 13,800 pounds per day of dry solids. As a stabilized and dewatered vacuum filter cake of 18 percent solids the disposal required is 45,000 pounds per day or approximately 25* cubic yards. As ash from a multiple hearth incineration the

* At truck loaded density of 65 pounds per cubic foot for filter cake.

required disposal is approximately 3,200 pounds per day with a volume of 2.4 * cubic yards. The cost of achieving this approximately 10 to 1 reduction in ultimate disposal requirements is more than the larger ultimate disposal costs for the unreduced sludge where land is available nearby. For the purpose of this study, initial screening is on the basis of land disposal of unreduced sludges. Following initial screening the selected site specific conditions are then tested against reduction alternatives.

For this purpose it is necessary to make an initial survey of reduction alternatives to select a most appropriate type for testing against the site specific unreduced disposal. If the reduction alternative in general appears favorable from either a cost effectiveness, functional or environmental standpoint it may then be necessary to make a revaluation of all of the reduction alternatives. If a reduction process appears to be the best solution, the actual selection of a particular reduction process is a design consideration.

The reduction alternatives as listed in Table 2 are as follows:

1. Incineration
    a. Multiple Hearth
    b. Flash Drying
    c. Fluidized bed
    d. Cyclonic

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* At truck loaded density of 50 pounds per cubic foot for ash

2. Incineration in combination with municipal solid waste disposal

3. Wet oxydation

4. Pyrolysis

Incineration. All of the incineration sub-alternatives require prior dewatering by either vacuum filtration or centrifugation to reduce the moisture content to a point where the fuel content of the sludge is near that required for a self-sustained process. Prior stabilization is not required nor is it desirable since it reduces the fuel content. Supplemental fuel requirements are a function of the kind of process, moisture content, volatile solids content and excess air. There is also a significant supplemental fuel requirement for warm-up when the process is not operated continuously. Not counting warm-up, typical supplemental fuel requirements for an activated sludge plant with filter cake of 18 percent solids and 70 percent volatile solids is given as over 800 cubic feet of natural gas per ton of wet cake. If moisture content of the cake can be reduced to 23 percent solids the theoretical supplemental fuel requirement can be reduced to zero (From Figure 8-2 of EPA 625/1-74-006).

Heat treatment conditioning prior to vacuum filtration is capable of producing a sludge cake that can be dewatered to 35 to 40 percent solids, but heat treatment itself is fuel consumptive and has high capital costs. This is another possible consideration at design level.

All of the incineration processes create an air pollution threat. It is the opinion of the EPA Sewage Sludge Incineration Task Force that it has been adequately demonstrated that existing well-designed and operated municipal wastewater sludge incinerators are capable of meeting the most stringent particulate emission control regulation existing in any state or local control agency. This observation coupled with the fact that the newly promulgated federal standards are based on demonstrated performance of an operating facility indicates that use of proper emission controls and proper operation of the incineration system will enable a facility to meet all existing air pollution regulations.

The foregoing opinion indicates that incineration as an alternative should not be eliminated on a nationwide scale from consideration because of its air pollution threat since there is strong evidence that it is controllable. The present critical unresolved air pollution problem in Spokane must be recognized as a strong negative factor in consideration of any incineration alternative specifically for this area. Although this specific condition in Spokane seems to preclude any further consideration of incineration, it is prudent to make an initial cost effectiveness evaluation to determine its status from that point of view. It is essential that the capital and operating costs of air pollution control be adequately covered in any evaluation of the process.

There are existing full scale installations of multiple hearth, flash drying and fluidized bed incinerators. The multiple hearth type is the most widely used to date. Each has certain functional advantages and disadvantages which should be weighed at the design stage. For the process of comparison with other alternatives, the multiple hearth unit is selected for its greater experience and availability of cost data. The cyclonic type is available as presently developed for very small systems serving 5000 persons or less which is not applicable to urban planning area alternatives.

Incineration in combination with municipal solid waste disposal. This method provides a means of using another municipal waste to provide the supplemental fuel requirement. The implementation of this alternative is dependent upon the resolution of the region's solid waste problem. The development of a need to recover the heat value in the solid wastes is foreseen as a possible stimulus to future consideration of municipal incineration.

This alternative, if available, would be very attractive from a cost effectiveness standpoint since the incremental cost chargeable to adding sludge incineration to general municipal solid waste incineration would be small. Although continuation of landfill operations for both City and County are favored in the Coordinated Comprehensive Solid Waste Management Plan, the possibility of incineration is not precluded. See Section 312.5. The present critical unresolved air pollution situation in Spokane, however, places even more severe constraints on this method, as mentioned above for incineration of sludge alone, due to the larger volumes of emissions involved. This method is not given further consideration for this reason.

Wet oxidation. Wet oxidation of sewage sludge by air at moderate temperatures and high pressures is commercially available as the patented Zimpro process. This process does not require prior dewatering as incineration but does require a degree of thickening or concentration for best efficiency. The process takes place at temperatures of about 500° F and at pressures necessary to keep water from flashing to steam at these temperatures, namely 1000 to 1750 psi. Directly used fuel is not required except for startup heating but power costs are high for compression of air to the process pressure. Although dewatering is not required before the process, a corresponding operation is required after the process to separate the ash from the liquid. Also, the liquid fraction, high in organics, phosphorus and nitrogen, requires recycling to the wastewater treatment process. A considerable body of plant scale experience has been obtained on this process at Chicago before it was shut down in favor of land reclamation. The primary advantage of the wet oxidation process is the minimizing of air pollution problems. The disadvantages are the need for complex high pressure equipment with their attendant safety, maintenance and reliability problems and the recycle liquid which requires further treatment.

Pyrolysis. Pyrolysis is basically an incineration process with a starved air supply. The objectives are reduction in volume, sterilization and by-product recovery. One of the potential by-products is activated carbon for use in advanced treatment processes. There are no full scale facilities to date and consequently no corresponding cost data.

Reduction Process Evaluation. As indicated above, the primary concern of a study of this level is to determine whether a reduction process has merit when compared with other alternatives. It is not the concern of a study of this level to seek final selection from among all reduction alternatives and subalternatives. From review of the available processes to date, multiple hearth incineration with adequate air pollution control is selected as being both favorably representative of the group and well documented by plant scale operation. Selected criteria are that sludge feed will be dewatered by the equivalent of vacuum filtration, supplementary fuel requirement is estimated at 500 cubic feet of gas per wet ton, and resulting in an output with complete removal of the volatile component to an ash with bulk density of 50 pounds per cubic foot.

Resource Recovery

The opportunities for resource recovery as listed in Table 2 fall in the following categories.

1. Gas production from anaerobic digestion
2. Heat production from incineration of dry solids
3. Fertilizer chemicals by land application or by incorporation into compost.
4. Soil conditioner (humus) by land application or incorporation into compost.
5. Activated carbon by pyrolysis

Gas production from anaerobic digestion will normally produce approximately 11 cubic feet of gas of heat content 566 Btu per cubic foot from each pound of volatile solids consumed (EPA 625/1-74-006). For a typical secondary plant in this study, Table 1 indicates the destruction of 424 pounds of volatile solids per million gallons. Therefore, the gas heat availability per million gallons is 424 x 11 x 566 = 2.65×10^6 Btu. In terms of electrical energy generation at 3.5 cf of gas per kwh, 1330 kwh are available per million gallons. The recovery of this energy resource is commonly included in existing plants in the larger sizes where economically feasible in the form of digestion tank heating, space heating, powering of aeration blowers and electrical energy production. Therefore capital and operating cost data from historical sources recognizes this aspect of resource recovery. This resource is not utilized when alternative stabilization processes such as aerobic digestion, lime treatment and chlorination are utilized.

The net heat available from incineration of solids is low or even negative as indicated above in the discussion of incineration. Although the sludge solids themselves have a heat content of about 10,000 Btu per pound of volatile solids, the dewatering processes and evaporation of residual moisture leave little net available at best and, in most circumstances, requires energy input. Note that gas production captures about one-fourth of this potential (45% volatile solids reduction at 6200 Btu/ pound reduced equals 2800 Btu/ pound total volatile). Therefore gas production appears to be the better method of energy recovery.

The nutrient content of sludge depends upon the method by which it has been processed prior to land application. The nutrient content will differ for raw, digested, liquid, dewatered and heat dried. Almost half of the nitrogen and potassium in digested sludge is in the liquid phase, so drying or dewatering can decrease these nutrients significantly (EPA-625/1-74-006). An analysis of digested municipal sewage sludge given by Hinesly and Sosewitz (1969) indicates a nutrient content as follows, expressed as percent of total dry solids.

Nutrient			Percent Dry Solids
Total Nitrogen	as	N	5.5
Phosphorus	as	P	2.5
Potassium	as	K	0.4

Typical crop nutrient uptakes are as indicated below (USDA Miscl. Publ. #369):

		Plant Food Uptake, Pound per Acre per Year				
Crop	Annual Yield per Acre	Nitrogen N*	Phosphate P_2O_5*	P	Potassium K_2O*	K
Wheat	40 bu.	50	25	5.4	15	6
Alfalfa	4 tons	180	40	8.6	180	75
Timothy	2.5 tons	60	25	5.4	95	40
Apples	500 bu.	30	10	2.2	45	19

Comparison of crop needs with typical sludge content indicates that if nitrogen demand is met, phosphorus is oversupplied and potassium is undersupplied.

Since potassium content is low in proportion to plant needs and phosphorus is bound to soil particles, the limiting constitutent is nitrogen. If the rate of nitrogen application exceeds plant needs there is the danger that the excess will be leached to ground or surface waters. The EPA interim guidelines for BPWT (March 1974) indicates that application rates of 5 tons of total dry solids or less per acre per year have been

* It is the practice of the fertilizer industry to express nitrogen as N, phosphate as P_2O_5 and potassium as K_2O and to designate fertilizer content in that order by percent: for example a 25-10-10 fertilizer is 25% N, 10% P_2O_5 and 10% K_2O.

successful. This is equal to 550 pounds of nitrogen per acre which appears to be high compared with crop needs which range from 200 to 500 pounds per year. A rate of 4 tons of total dry solids per acre per year is selected for this study.

Application rates in terms of the various moisture contents of sludges is given below to apply 4 tons of dry solids per acre per year.

Type of Sludge	Solids content percent	Tons of Sludge to contain 4 tons dry solids	Volume of Sludge per acre per year: as liquid gallons	Volume of Sludge per acre per year: as semi-solid cubic yards
Raw Primary(1)	5	80	19,200	
Raw Secondary(1) (2)	4.4	92	22,000	
Digested Primary	4.5	89	21,400	
Digested Secondary(3)	2.9	138	33,000	
Vacuum Filter Cake	20	20		17.6
Flash Dried	90	4.55		6.7

(1) Stabilized by lime treatment or chlorination. Lime solids not included in loading criteria

(2) Activated sludge with thickening of WAS

(3) No thickening after drawoff from digesters

A limitation on sludge land application rates and duration is the heavy metal content. This is a characteristic of the individual community and of its industrial waste component. A monitoring program is required to protect against this contingency.

Utilization of sludge as a source of nutrients on land far from the source must be compared with the lower shipping costs of concentrated chemical fertilizers. Note that even dried sludge with a solids content of 90 percent contains approximately one-fifth of the nitrogen per ton as does anhydrous ammonia, the most commonly used chemical fertilizer in the study area.

The relatively low nutrient content of sewage sludge is not without some benefit since the remaining constituents are humus-like organic materials which are beneficial in improving the physical properties of the soil. This soil conditioning benefit is provided through sludge application to agricultural land, either for itself or as incidental to the nutrient properties. The humus content can be increased further through composting of the sludge with other organic wastes.

Composting provides a means of dewatering sludge and putting it into a form that can be handled easily for land application without objectionable aesthetic or health problems. It is essentially a digestion process of sludge combined with other organic material. The high temperatures developed in the digestion process provide a pasteurizing action. The other combined organic material can be, among others, sawdust, municipal solid wastes, paper, leaves, etc. Both raw and digested sludges have been used. The process can be carried out in a variety of methods from simple windrows to highly mechanized reactors. The history of composting in the U. S. has indicated that the process is generally not economically attractive due to lack of a market for the product to offset process costs

(EPA 625/1-74-006). Therefore, this alternative is not considered further.

Pyrolysis or starved air incineration provides a potential for converting sludge to activated carbon. The carbon content of the sludge is a relatively low value resource compared with other sources and its salvage is regarded not as an end in itself, but rather as a by-product of the disposal process to be considered where there is the opportunity for on-site utilization where carbon adsorption is used in the treatment process.

Special Sludge Processes

Lime Sludges. Two wastewater processes alternatives will produce lime sludges. One is from lime application to secondary treated wastewaters to provide the dual functions of phosphorus removal and pH adjustment for subsequent ammonia stripping. The only significant plant scale experience to date with this type of sludge is at South Lake Tahoe (EPA 625/1-74-006). Culp and Culp (1971) point out the need to process this sludge separately from the primary and WAS sludges. The process used at South Lake Tahoe consists of a lime sludge thickener, centrifuge dewatering and lime recalcining furance. Thickener criteria are 1000 gpd/sq. ft. and 2000 pounds per day solids per square foot resulting in output of 8-20 percent solids. For seasonal operation, the recalcining operation may not be necessary since it may be more economical to waste the dewatered lime to ultimate disposal with the biological sludges. The Tahoe experience is 28 percent reclaimed lime. The incinerator used is a multiple hearth type.

The other type of lime sludge is a mixture of lime sludge and sewage produced by high lime treatment of raw sewage as the first step in all physical-chemical advanced treatment. Since this would be year around operation, recalcining would be essential. There is little plant scale experience with this type of sludge but all indications are that it will be extremely difficult to dewater and to separate the lime from the biological component of the sludge. For the purpose of this study, the system planned for the Contra Costa (California) plant is selected as a representative system. This system utilizes wet classification by series centrifugation prior to the recalcining furnace and by classification after.

Filter backwash wastes result from backwashing of multimedia or sand filtration applied as part of advanced treatment. This flow is typically 2 to 5 percent of the plant throughput (Culp & Culp 1971) but occurs at high rates and requires a storage volume for holding prior to further processing. Rather than attempting to separate the solids from the backwash flow, which is usually accomplished in drying ponds at water treatment plants, the proposed method in wastewater treatment is to recycle the backwash water slowly into the main wastewater treatment stream. Selected criteria is provision of a backwash surge tank with a volume of 1.0 percent of the plant daily throughput.

Carbon recovery is an economic requirement of the activated carbon adsorption process. A plant scale system has been developed for regeneration of granular carbon as used in a packed tower. A plant scale process has not yet been demonstrated for powdered carbon. The South Lake Tahoe system for granular carbon consists of dewatering tanks, a multiple hearth furnace and a dry process to remove fines from the regenerated product(Culp & Culp 1971). A system similar to the South Lake Tahoe process is included in the capital and operating cost data for the basic wastewater treatment carbon adsorption systems in this study. The regeneration is not in this case handled as a separate "solids processing" operation.

Summary of Processing Quantities

As indicated above, first level screening of wastewater treatment processes is to be on the basis of comparing all with anaerobic digestion and vacuum filtration to produce sludge cake for landfill disposal. The second level screening i to consider in a site specific manner the alternatives involving other types of sludge application to land either as filter cake or as stabilized liquid. The quantities involved in these alternatives are summarized in Table 1 in columns 10 through 19. Following the same example cited above for the demonstration of Table 1 in columns 1 through 9, the quantitities available from Table 1 in columns 10 through 19 are demonstrated. For a 10 mgd secondary activated sludge plant with seasonal phosphorus removal, Table 1 shows that 49,770 gallons per day of sludge (column 9)containing 11,220 pounds of volatile solids (column 3) are being sent to digestion during the phosphorus removal season. Column 10 shows that the governing criteria in this case is holding time and that the required volume is 165,900 cubic feet. The phosphorus removal season which produces 49,770 gpd governs over the off season which produces 37,760 gpd. Column 11 shows that 5050 pounds of volatile solids are destroyed and that 49,770 gpd containing 12,250 pounds of solids (column 12) at 3 percent solids concentration (column 13) require dewatering. To condition for dewatering, column 15 shows that an elutriation tank of area 1990 square feet is required and that the conditioned sludge volume is reduced to 32,680 gpd (column 16) at 4.5 percent solids (Notes for column 16). Column 17 shows that 205 square feet of vacuum filter surface are required and that 61,250 pounds per day (column 18) of wet cake are produced having a volume of 34.9 cubic yards per day (column 19). The amount of sludge during the off season, when alum precipitation is not used, is available opposite the heading secondary w/o chemical coagulation at 45,200 pounds per day (column 18) and 25.8 cubic yards (column 19).

For sludge disposal alternatives involving liquid sludge, the volumes are available from column 6 for unthickened sludge or from column 9 for thickened sludge both assuming stabilization by heat or lime treatment and from column 14 where stabilization by digestion is assumed. Continuing the example, disposal of unthickened sludge with heat or lime stabilization involves the transport of 118,370 gallons per day (column 6) during the phosphorus removal season.

TABLE 1

SLUDGE QUANTITIES
PER MILLION GALLONS OF WASTEWATER

Wastewater Treatment Objectives	Wastewater Treatment Process	Sludge Type	Raw Sludge Characteristics Per Million Gallons of Wastewater: Total Dry Solids Pounds (1)	Percent Volatile (2)	Component Solids: Volatile Pounds (3)	Component Solids: Inert Pounds (4)	Consistency as Drawn from WW Process: Percent Solids (5)	Consistency as Drawn from WW Process: Volume Gallons (6)
Primary Pretreatment for Lagoon Alternatives	Primary Settling	Primary	930	75	698	232	5.0	2,233
Secondary w/o Chemical Coagulation	Trickling Filter	Primary	930	75	698	232	5.0	2,233
		T.F. Second.	425	80	340	85	3.0	1,701
		Total	1,355	77	1,038	317	4.1	3,934
	Activated Sludge	Primary	930	75	698	232	5.0	2,233
		W.A.S.	450	80	360	90	0.8	6,753
		Total	1,380	77	1,058	322	1.8	8,986
Secondary with Phosphorus Removal	Trickling Filter with Alum Coagulation in Secondary	Primary	930	75	698	232	5.0	2,233
		T.F.-Alum Sec.	775	52	403	372	1.2	7,753
		Total	1,705	65	1,101	604	2.0	9,986
	Activated Sludge with Alum Coagulation in Secondary	Primary	930	75	698	232	5.0	2,233
		W.A.S. - Alum	800	53	424	376	1.0	9,604
		Total	1,730	65	1,122	608	1.8	11,837
	Physical-Chemical System with Lime Coagulation Secondary	Primary	930	75	698	232	5.0	2,233
		Lime Sludge	5,700	5	300	5,400	2.0	38,000
Secondary with Seasonal Ammonia Removal (and Seasonal Phosphorus Removal Inherent in Both Alternatives)	Activated Sludge, Single Reactor Nitrification, with Alum Coagulation Primary	Primary-Alum	1,730	64	1,107	623	1.5	13,846
		W.A.S.	165	80	132	33	0.8	2,476
		Total	1,895	65	1,239	656	1.4	16,322
	Activated Sludge Followed by Ammonia Stripping	Primary / W.A.S. / Total	Same as Activated Sludge Secondary w/o Chemical Coagulation					
		Lime Sludge	5,400	-	-	5,400	2.0	32,400
Secondary with Full Time Nitrogen Removal	Activated Sludge, Three Reactor-with Nitrification & Denitrification	Primary / W.A.S. / Total	Same as Activated Sludge Secondary w/o Chemical Coagulation					
Secondary with Full Time Nitrogen & Phosphorus Removal	Activated Sludge, Three Reactor-with Nitrification & Denitrification Plus Alum Coag. Second.	Primary / W.A.S.-Alum / Total	Same as Activated Sludge Secondary with Chemical Coagulation					

Column Heading	Notes
(7)	Criteria: (a) 0.6 pounds total solids per hour per square foot; (b) 0.8 gpm per square foot (a) =[Col. (1) ÷ 24] ÷ 0.6 (b) =[Col. (6) ÷ 1440] ÷ 0.8 Largest result governs
(10)	Criteria: (a) 0.08 pounds volatile solids per day per cubic foot; (b) 25 days detention of incoming volume (a) = Col. (3) ÷ 0.08 (b) = [Col. (6) or Col. (9) as applicable] x 25 ÷ 7.5 Largest result governs
(11)	Criterion: 45 percent reduction of volatile solids (11) = Col. (3) x 0.45
(12)	Col. (1) - Col. (11)
(13) & (14)	Criteria: (a) For primary alone or primary plus trickling filter assume stratification and decant of supernatant with underflow at 4.5 percent solids, Col.(13) = 4.5; calculate volume (14) = [Col.(12) ÷ 0.045] ÷ 8.33 (b) For all other assume mixing and no decant so that volume in equals volume out Col.(14) = Col.(9); calculate concentration (13) = Col.(12) ÷ [Col.(9) x 8.33]
(15)	Criterion: 25 gallons of digested sludge slurry per day per square foot of surface (15) = Col.(14) ÷ 25
(16)	Criterion: Elutriation will concentrate to 4.5 percent solids (16) = [Col.(12) ÷ 0.045] ÷ 8.33

Column Heading	No[tes]
(17)	Criteria: (a) 3.5 pou[...] foot at [...] (b) 1.5 pou[...] foot at [...] Pro rate lin[...] Assume 120 h[...] load (a) = [Col.(12) x 7 ÷ 1[...] (b) = [Col.(12) x 7 ÷ 1[...]
(18)	Criteria: (a) 20 perc[...] percent (b) 18 perc[...] percent (a) = Col.(12) ÷ 0.20 (b) = Col.(12) ÷ 0.18
(19)	Criterion: Bulk densit[...] foot. (19) (Sludge cak[...] density 73[...]
(20a)	Sludge Quantities from[...] ment. For a system similar t[...] Section 603.2 the appr[...] follows: (a) Primary sludge wou[...] treatment with 930 percent volatile.

...ter ...nsistency as ...from WW Process ...ent ...s ...(5)	Volume Gallons (6)	Dissolved Air Flotation Thickening Required Surface per mg sq. ft. (7)	Consistency After Thickening Percent Solids (8)	Consistency After Thickening Volume Gallons/mg. (9)	Anaerobic Digestion Required Volume per mg of w.w. cubic feet (10)	Volatile Solids Reduction Pounds per mg (11)	Remaining T. Solids Pounds per mg (12)	Digested Sludge Percent Solids (13)	Digested Sludge Volume Gallons per mg (14)	Elutriation Required Surface sq. ft. per mg (15)	Leaving Volume Gallons per mg (16)	Vacuum Filtratio... Required Area per mg sq. ft. (17)	Cake Product... Wet Cake Weight Pounds (18)	We... Vo... Cu...
	2,233	-	-	-	8,725(a)	314	616	4.5	1,643	-	-	10.27	3,080	
	2,233 1,701 3,934	-	-	-	13,133(b)	467	888	4.5	2,369	-	-	14.80	4,440	
	2,233 6,753 8,986	- 31.2(a) -	- 3.5 4.4	2,233 1,543 3,776	13,225(a)	476	904	2.9	3,776	151	2,411	29.30 15.10	5,022 4,520	
	2,233 7,753 9,986	- 53.8(a) -	- 3.5 4.2	2,233 2,658 4,881	16,270(b)	495	1,210	3.0	4,881	195	3,228	37.15 20.21	6,722 6,050	
	2,233 9,604 11,837	- 55.6(a) -	- 3.5 4.2	2,233 2,744 4,977	16,590(b)	505	1,225	3.0	4,977	199	3,268	37.61 20.46	6,806 6,125	
	2,233 38,000	- -	- -	- -	8,725(a)	314	616	4.5	1,643	-	-	10.27	3,080	
	13,846 2,476 16,322	- 131.6(a)	- 3.5	- 6,500	21,666(b)	558	1,337	2.5	6,500	260	3,566	51.99 22.33	7,428 6,685	
...ical	Coagulation 32,400													
...ical	Coagulation													
...ical	Coagulation													

Notes

...: (a) 3.5 pounds of solids per hour per square foot at 4.5 percent solids feed
(b) 1.5 pounds of solids per hour per square foot at 2.7 percent solids feed
Pro rate linear between feed concentrations.
Assume 120 hours per week operation at design load
...Col.(12) x 7 ÷ 120] ÷ 3.5
...Col.(12) x 7 ÷ 120] ÷ (1.5 or pro rate value as applicable)

...: (a) 20 percent solids in cake from 4.5 percent feed
(b) 18 percent solids in cake from 2.7 percent feed
...l.(12) ÷ 0.20
...l.(12) ÷ 0.18

...on: Bulk density of filter cake 65 pounds per cubic foot. (19) = Col.(18) ÷ (27 x 65)
(Sludge cake compressed without voids has density 73 pounds per cubic foot)

... Quantities from Physical-Chemical Secondary Treat-...

...system similar to PCT-1 as shown in Figure A of ... 603.2 the approximate sludge quantities are as ...:

...imary sludge would be same as shown for primary ...eatment with 930 pounds of dry solids per mg, 75 ...rcent volatile.

Column Heading	Notes
(20a)	(b) Lime sludge for a dosage of 480 mg/l of 70 percent pure calcium hydroxide (Bovay 1973) as drawn from secondary clarifier, approximately 5400 pounds per mg of calcium compounds and 300 pounds per mg of biological sludges. Assuming wet classification, approximately 85 percent of the calcium compounds, mostly calcium carbonate, could be separated as a cake recycle by recalcining. The remaining 15 percent of the calcium compounds, 810 pounds per mg, mostly calcium sulfate, plus practically all of the organics, 300 pounds per mg, totaling 1110 pounds per mg would be in the centrate at approximately 2 percent solids.
	(c) The centrate (blowdown) is usually dewatered directly without digestion by a second stage of centrifugation or by vacuum filtration. A sludge cake of 20% solids can usually be produced, making 5550 pounds of cake per mg for landfill disposal, equal to 2.94 cubic yards per mg at 70 pounds per cubic foot bulk density.
	(d) Total ultimate disposal requirements are 3080 pounds/mg from primary (1.76 cy) plus 5550 pounds/mg from blowdown (2.94 cy) for a total of 8630 pounds/mg (4.70 cy).
	(e) Lime make-up computed at 20 percent is equal to 96 mg/l or 800 pounds per mg.

C...
H...

(2...

...ed Sludge	Elutriation		Vacuum Filtration			
Volume Gallons per mg (14)	Required Surface sq. ft. per mg (15)	Leaving Volume Gallons per mg (16)	Required Area per mg sq. ft. (17)	Cake Production per mg: Wet Cake Weight Pounds (18)	Cake Production per mg: Wet Cake Volume Cubic Yards (19)	Remarks (20)
1,643	-	-	10.27	3,080	1.76	
2,369	-	-	14.80	4,440	2.53	
3,776	151	2,411	29.30 15.10	5,022 4,520	2.86 2.58	W/o elutriation With elutriation
4,881	195	3,228	37.15 20.21	6,722 6,050	3.83 3.45	W/o elutriation With elutriation
4,977	199	3,268	37.61 20.46	6,806 6,125	3.88 3.49	W/o elutriation With elutriation
1,643	-	-	10.27	3,080	1.76	See Note (20a) for Lime Sludge.
6,500	260	3,566	51.99 22.33	7,428 6,685	4.23 3.81	Off season same as Secondary w/o Chemical Coag. W/o elutriation With elutriation
						See Note (20b) for Lime Sludge.

Notes

...for a dosage of 480 mg/l of 70 percent ... hydroxide (Bovay 1973) as drawn from ...arifier, approximately 5400 pounds per mg ...compounds and 300 pounds per mg of biolo...s. Assuming wet classification, approxi...ercent of the calcium compounds, mostly ...bonate, could be separated as a cake ...recalcining. The remaining 15 percent of ...compounds, 810 pounds per mg, mostly ...fate, plus practically all of the organics, ...er mg, totaling 1110 pounds per mg would ...ntrate at approximately 2 percent solids.

... (blowdown) is usually dewatered directly ...ation by a second stage of centrifugation ... filtration. A sludge cake of 20% solids ...be produced, making 5550 pounds of cake ...landfill disposal, equal to 2.94 cubic ... at 70 pounds per cubic foot bulk density.

...te disposal requirements are 3080 pounds/...ary (1.76 cy) plus 5550 pounds/mg from ...94 cy) for a total of 8630 pounds/mg

... computed at 20 percent is equal to 96 pounds per mg.

Column Heading	Notes
(20b)	Lime sludge quantities for ammonia stripping.

The quantity of lime sludge for 480 mg/l dosage would be approximately 5400 pounds per mg of calcium compounds with negligible organic sludge after activated sludge treatment. Quantities to recovery by recalcining and to waste by blowdown would be as calculated in note (20a) without the minor organic component. Total to recalcining is approximately 4590 pounds per mg in 9180 pounds of 50% solids cake. Blowdown cake after dewatering is approximately 4050 pounds per mg (2.14 cy) of 20 percent cake. Adding this to sludge from prior elements in the process at 4520 pounds per mg (2.58 cy) the total process disposal is 8570 pounds per mg (4.72 cy).

For short season operation it may be desirable to waste the entire lime sludge and purchase carbon dioxide for recarbonation. In this case the total sludge weight to disposal would be 6,304 pounds of dry solids per mg in approximately 17,750 pounds of cake.

TABLE 2

CANDIDATE ALTERNATIVES FOR SOLIDS PROCESSING

Process	Process Objective	Alternatives
THICKENING	Increase solids concentration to reduce volume	1. Gravity 2. Flotation 3. Centrifugation
CONDITIONING	Modify properties to increase efficiency of subsequent processes	1. Chemical additions 2. Heat treatment 3. Elutriation
STABILIZATION	Reduce the odor, putrefaction and infections potential of raw sludge	1. Anaerobic digestion 2. Aerobic digestion 3. Heat treatment 4. Chemical treatment a. Lime b. Chlorine oxidation 5. Composting
DEWATERING	Removal or reduction of the water content of the sludge	1. Vacuum filtration 2. Pressure filtration 3. Centrifugation 4. Vibrating Screens 5. Evaporation a. Fueled b. Natural bed drying
REDUCTION	To reduce the volume of the waste product to the minimum prior to final disposal	1. Incineration a. Multiple hearth b. Flash drying c. Fluidized bed 2. Incineration in combination with municipal solid waste disposal 3. Wet oxidation 4. Pyrolysis

TABLE 2 (Continued)

Process	Process Objective	Alternatives
DISPOSAL	Permanent disposition of the process waste	1. Landfill a. Sanitary b. Land reclamation 2. Land spreading a. Liquid (1) Concentrated (2) Mixed with treated effluent b. Solid or semi-solid (1) Surface application (2) Trench application
RESOURCE RECOVERY	To obtain beneficial use of the thermal or chemical constituents of the sludge	1. Gas production from anaerobic digestion 2. Heat production from incineration of dry solids 3. Fertilizer chemicals by land spreading 4. Soil conditioner from stabilized organics by a. Composting b. Land spreading 5. Activated carbon and other chemicals from pyrolysis

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*Cited as EPA 625/1-74-006.

SECTION 401.1

CRITERIA FOR COST-EFFECTIVENESS ANALYSIS

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 401.1

CRITERIA FOR COST-EFFECTIVENESS ANALYSIS

27 January 1975

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

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SECTION 401.1

CRITERIA FOR

COST-EFFECTIVENESS ANALYSIS

Objectives

The objectives of this section are to prepare criteria and methodology for cost-effectiveness analyses of alternative wastewater management plans.

The cost-effectiveness analyses are to be prepared to criteria which will permit such analyses to be made in conformance with the guidelines establishing requirements for making Federal assistance available for facilities construction. For cost-effectiveness analysis both capital costs and operation and maintenance costs are considered. The most essential element is a uniform technique for assembling these cost elements that, when applied to various alternatives, will result in an unbiased and true comparative cost evaluation. It is not essential that the costs used in cost-effective analysis attempt to estimate the probable absolute costs which will obtain at some future date, a consideration that is recognized in Federal guidelines which state that it is the implied assumption that all prices involved will tend to change over time by approximately the same percentage and that the result of cost-effective analysis will not be affected by changes in the general level of prices.

Criteria for Cost-Effective Analysis

The basic criteria for cost-effective analysis where Federal construction assistance is contemplated are stated in the Federal Register at Volume 38 No. 174, September 10, 1973. These data are elaborated and interpreted by sample calculation in Chapter 4 of the EPA publication "Guidance for Facilities Planning", January 1974. These criteria are summarized below as applicable to this study.

** Price Level. The price level is specified as being that which is current at the time that the cost effectiveness analysis is made. In this case, these criteria are being developed in mid-1974. The cost indices as of June 1974 are as follows:

ENR Seattle Construction Cost	1955
Sewage Treatment Plant and Sewer Construction Cost Index	
Seattle Plant Index WPC-STP	202
Seattle Sewer Index WPC-S	216

Therefore, a rounded value of ENR at 2000 is selected as the cost level for pricing.

The cost of land is at the corresponding calendar date of June 1974.

** Cost Comparison Period. The planning period for cost-effective analysis is specified to be 20 years and the beginning date as the date of initial operation of the system. The estimated earliest possible operation date of any facilities recommended in this study is estimated to be 1980. Therefore, the planning period for cost effective analysis is 1980 to the year 2000.

Forecast flows and loads to the year 2020 are developed and the facilities selected for the 1980-2000 planning period are evaluated in the context of ongoing requirements, particularly in the acquisition of facilities sites and sizing of interceptor sewers and force mains. All facilities except sewers and force mains are sized, in stages where required, to an ultimate capacity to serve the year 2000 forecast waste load. Sewers and force mains are sized to serve the forecast waste flows for the year 2020.

** Staged development. Consideration of the staged construction is specified as an essential element. Each alternative management plan is examined for optimum staging of construction in a micro cost-effective study before comparison with all other alternative management plans. That is, each alternative is examined to see if the minimum cost is obtained by constructing all the required year 2000 capacity at 1980 or whether this capacity should be provided in one or more incremental phases.

** Sunk costs. The capital costs of existing facilities whether used in an alternative management plan or not, are not an element in cost-effective analysis. Facilities which are committed to construction are also regarded as existing facilities. Of specific concern in this study is the enlargement and improvement of the City of Spokane sewage treatment plant under DOE directive. This facility is regarded as existing and its cost as a sunk cost. Operation and maintenance costs for the facility are included in cost-effective analysis as are any enlargements or improvements subsequent to the initial construction.

** Basis for comparison. Cost-effectiveness comparisons are specified to be made on the basis of present worth or equivalent annual value computed from the total of capital costs, including major replacement, adjusted for salvage value, and annual operation and maintenance costs. The present worth or equivalent annual value are to be computed recognizing the time value of money at the specified interest rate.

** Interest Rate. An interest rate of 7 percent is specified in the above referenced guidelines which refer to the concurrently issued (FR 10 Sept. '73 Vol. 38 No. 174) "Proposed Principles and Standards for Planning Water and Related Land Resources" for further guidance. As of January 6, 1974, the Seattle office of EPA interprets these guidelines to indicate that 7 percent is appropriate for current studies to be used in satisfying EPA planning requirements. Therefore, the 7 percent rate is adopted for this study.

** Elements of Capital Costs. Capital costs include not only the construction costs of facilities and the lands on which the facilities are located, but the costs attendant to design, construction, startup and land acquisition. These elements are enumerated as follows from Chapter 4 of "Guidance for facilities planning".

a. The estimated contract construction costs of all system components including:

   1. Those for collection, treatment and disposal of wastewater.

   2. Modifications required for existing facilities.

   3. Components for treatment and disposal of residual wastes, including conveyance to disposal sites.

   4. Components for storage and recycling of wastewater including land disposal.

5. Integral flow and waste reduction measures.

6. (See discussion below).

7. Storage or control measures for control of domestic wastes and combined sewer overflows.

8. Any interim facilities needed while more permanent facilities are deferred or under construction plus incremental operation and maintenance costs of the temporary facilities compared with costs of the old facilities.

b. Costs for detailed engineering and design services, field exploration studies, and engineering services during construction.

c. Costs for legal and administrative services associated with implementation of the facilities plan.

d. Costs of all lands, including capitalized costs of leased lands (including publicly-owned lands), rights-of-way, and easements based on appraised market values.

e. Startup costs such as operator training.

f. Interest foregone during facilities construction.

g. Contingency allowances as appropriate to the level of complexity and detail used.

Guidance for facilities planning include as item a-6 above the private costs of pretreatment facilities for industrial wastes. These costs, in general, are the same for all alternatives and therefore do not influence the relative cost of alternative plans. For this reason, these costs are not evaluated in the comparison of alternative plans.

** Elements of Major Replacement Costs are defined as capital outlay for periodic replacements of auxiliary equipment not covered by capital recovery allowances for normal depreciation. For example, if it is necessary to replace certain equipment before the end of its service life, the project must be charged with the discounted cost of the new equipment less the accrued depreciation and salvage of the old. Equipment whose service life expires before the end of the planning period fall in this category.

Major replacement costs also include any probable initial major replacements costs required to fully utilize existing facilities.

** Element of Operation and Maintenance Costs are defined in general terms as the ongoing operation and maintenance costs of the wastewater management system to insure effective and dependable facility operation at designed capacity and level. Specific elements are as follows:

a. Administration
b. Operating labor
c. Power
d. Chemicals
e. Supplies
f. Replacement parts*
g. Repairs
h. Laboratory labor
i. Laboratory supplies
j. Non-fixed equipment#
k. Training programs

Recognition is given to elements which are essentially fixed and those which are dependent upon the flow or pollutant volume processed.

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* Exclusive of major replacements which are accounted for under depreciation.

Examples are trucks for general plant operation or sludge haul and equipment for maintenance of land disposal.

** Service life and salvage value. Depreciation of the facilities purchased through capital outlay is recognized through the assignment of a finite service life.

Land and rights-of-way are assumed to suffer no depreciation and therefore have no assigned service life and have salvage value at the end of the study period equal to the original price. When the salvage value is discounted to present worth and subtracted from the original cost, the effect is that the cost of land use is equal to the interest on the capital invested in it.

Guidelines for the service lives of structural elements are given in the cost effectiveness guidelines as follows:

Structures.. 30 - 50 years

(includes plant buildings, concrete process tankage, basins, etc.; sewage collection and conveyance pipelines; lift station structures; tunnels; outfalls)

Process equipment.................................... 15 - 30 years

(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)

Auxiliary equipment .... 10 - 15 years

(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)

For this study the following service lives are adopted:

Sewage conveyance facilities such as sewers, force mains and tunnels ....40 years

Treatment plant buildings, concrete
process tanks and pump stations .... 30 years

Process equipment .... 20 years
(as defined above)

Auxiliary equipment .... 10 years
(as defined above plus irrigation facilities)

The salvage value for all structural facilities at the end of their respective service lives is adopted as zero. For all except conveyance structures, the zero salvage is in recognition of the high rate of technological obsolescence in this field which will give these facilities negligible salvage even when physically sound. For conveyance facilities, the long life renders the salvage value less significant, but here functional obsolescence is the probable cause of ultimate loss of utility.

Salvage value at the end of the planning period is specified to be determined on a straightline basis from the initial cost to the ultimate salvage value over the service life. This, in effect, assumes that there is a continuing use for the facilities beyond the end of the planning period which should be a valid assumption for wastewater mangement facilities.

Interest Relationships

Certain mathematical relationships involving the specified interest rate of 7 percent are required repeatedly throughout cost-effectiveness analysis. It is the purpose of this paragraph to summarize the most frequently used of these relationships for quick reference. Refer to Table 2 for complete sets of factors referred to below.

** To convert a lump sum (single payment) at a future date to present worth, multiply the lump sum by the Present Worth Factor (PWF) for the n years in the future at which the expense takes place. Example: For lump sum expense 10 years hence, the PWF is 0.5083. For 20 years hence, the PWF is 0.2584.

In round numbers, this means that at 7% interest an amount spent 10 years in the future has a present worth of 50% and at 20 years in the future, 25%.

** To convert a uniform series of annual expenses to present worth, multiply the annual expense by the Series Present Worth Factor (SPWF) for the n number of years over which the series extends from the base present worth date. Example: For a 20 year annual series SPWF is 10.594.

If the uniform series begins at a date other than the base present worth date, the present worth of the series as calculated above must be further discounted as described above for a single payment present worth calculations.

** To convert a linearly variable series of annual expenses to present worth, divide the annual expense into two components, a uniform series and the equal amount by which the expense increases each year. Treat the uniform component as above. Multiply the equal annual increase by the

Gradient Present Worth Factor (GPWF) for the n number of years of the series. Example: For a 10 year annual series varying linearly from $10,000 per year to $20,000 per year, separate into a uniform series of $10,000 per year and a gradient series of $1,000 per year increments. For the gradient series, the GPWF for 10 years is 27.72.

** To convert a lump sum expended at present to an equivalent uniform annual series of expenditures, multiply the lump sum by the Capital Recovery Factor (CRF) for the n number of years over which the series is to run. Example: The CFR for 10 year series is 0.1424 and for the 20 year series is 0.0944.

Construction Cost Indices

The price level was defined above in terms of two cost criteria. The ENR and the Sewage Treatment Plant and Sewer Construction Cost indices. The ENR is the Engineering News Record Construction Cost which is compiled and kept up to date by the Engineering News Record Magazine. The construction cost is based on 1913=100 and is for general engineered construction. The ENR publishes the index in terms of a national average and a number of regional indices, including Seattle.

The Sewage Treatment Plant and Sewer Construction Cost Indices were started by the Public Health Service in 1963 and first published in their publication no. 1069. These PHS indices were subsequently adopted by the

FWPCA in 1967 and is carried on by its successor EPA. These indices are herein referred to as the WPC-STP index and the WPC-S index for treatment plants and sewers respectively.

Both of these indices are used by various citations from the literature. It is necessary, therefore, to have a history of both to adjust data to a common basis.

Smith (1968) and Carelli (1971) both consider the WPC indices a more valid means of trending wastewater facilities than the more general ENR. Where it is necessary to trend data, this study adopts the WPC indices.

Table 1 shows the history of both the ENR and WPC indices.

Methodology for Analysis

Tables 3 and 4 are presented showing the methodology for processing the capital and operation and maintenance costs respectively of alternative plans. Sample computations are included. Details of the operations carried out in each table are described below by reference to column numbers.

Table 3 - Capital Cost Work Sheets

Col. 1 Is to identify the basic cost category

- L = land and rights of way
- CV = conveyance structures
- TR = structural treatment facilities
- LA = land application facilities including irrigation distribution, spray irrigation, and percolation ponds
- ST = storage reservoirs

Col. 2 Description of the specific cost element

Col. 3 The predominant size or capacity characteristic of the cost element

Col. 4 Construction cost of structural elements and acquisition costs of lands and rights-of-way without engineering or administrative costs and without contingencies. All costs at 1974 level.

Col. 5 Total capital cost at time of construction or acquisition including engineering and administrative costs and contingencies.

For categories CV, TR, ST and LA the engineering and administrative costs are assumed to total 25 percent composed as follows:

Engineering -	planning and preliminary	2
	surveys	1
	design	6
	construction supervision	6
		15
Legal and administrative		5
Sales tax		5
		25

And for CV, TR, ST and LA, contingencies are evaluated at 15 percent, making the total factor from construction cost to total cost 1.40 for these categories.

For category L, the engineering and administrative costs are assumed to total 15 percent composed as follows:

Engineering - planning and preliminary surveys	2
	5
	7
Legal and Administrative	8
	15

The contingency allowance assumed for category L is 10 percent making the total factor from acquisition to total cost 1.25 for this category.

Col. 6 Records the year when the facility is required to go into service. Rather than make a separate computation for interest during construction or interest on land acquisition ahead of land utilization, these cost elements are included as a preliminary step prior to application of the Present Worth Factor (PWF). For categories CV, TR, ST and LA, it is assumed that the equivalent interest during construction is 6 months interest at 7% per annum or 3-1/2 percent. For category L, it is assumed that the land would have to be acquired 1-1/2 years in advance of need to allow for construction, or 10-1/2 percent. A factor identified as IDC (interest during construction) is inserted in Column 8 as the basis for an operation to include interest during construction in a step prior to multiplying by the PWF.

Col. 7 The difference in years between the date at which the facility is required and the base year for valuation, 1980.

This number of years determines present worth factor in Col. 8.

Col. 8 The interest during construction (IDC) factor, as described above under Col. 6, and the present worth factor (PWF), as read from Table 2, to be applied by successively multiplying each times Col. 5.

Col. 9 Present worth of the capital cost in Col. 5 reduced to base year 1980 including correction for interest lost prior to year of Col. 6.

Col. 10 Service life in years for the entire facility or its component parts per the following table.

Category	Component	Service Life, Years
L	all	Infinite
CV	sewers and force mains	40
	pump structures	30
	pump equipment	20
TR	structures	30
	equipment	20
	lagoon earthwork	40
	lagoon equipment	10
LA	distribution mains	40
	spray equipment	15
	pond embankments	40
ST	all	40

Col. 11 Year last used during the cost effectiveness study period

1980 to 2000; that is the year at which salvage value, if any, is realized.

Col. 12 Age of the facility at year in Col. 11; that is, the number of years of service life expended for facilities already existing prior to this study, a footnote to years shown in Col. 12 should state year of construction of facility. For facilities proposed in these alternatives, the age in Col. 12 is the difference between dates in Col. 11 and Col. 6.

Col. 13 Salvage value determined as follows. For all land and rights of way, the salvage value is the original cost at 1974 price level. For all cases where the land is assumed to continue for wastewater management use the original cost is taken from Col. 5 including engineering, administration and contingency additions. For cases where the land is assumed to no longer continue in wastewater management use, the salvage value is taken from Col. 4, the base acquisition cost without engineering, administration and contingency. Note that this applies to lands or R/W acquired both before, after, and at the study base date of 1980.

For all physical improvements that continue to have utility in the waste management system, the salvage value is the depreciated value determined on a straight line base from original cost at 1974 level to last date of use. For physical improvements that are taken out of service because they are being replaced or abandoned and no longer have utility in the waste management system, the salvage value is zero (this assumes there is no alternative use for structures and negligible scrap value for equipment).

Col. 14 The difference between last date of use and the base year 1980 (Col. 12 less 1980). This is the number of years for selection of the PWF to return the salvage value to worth at the base year.

Col. 15 Present Worth Factor from Table 2 for the number of years in Col. 14.

Col. 16 Present worth at base year, 1980, of the salvage value computed as the product of Col. 13 times Col. 15.

Col. 17 The net present worth at base year 1980 of the capital cost less salvage value, Col. 9 less Col. 16.

Table 4 - Operation and Maintenance Work Sheets

Computation of operation and maintenance costs is broken into two elements, costs that are uniform year by year and costs that change year by year. Variable costs are simplified to the extent that variation is assumed to be straight line. Where annual costs are a mixture of uniform and variable components, the two components are separated into a uniform component equal to the lowest annual cost and a variable component changing linearaly from zero to a maximum value. This breakdown lends itself to reducing these two kinds of annual series by the Series Present Worth Factor (SPWF) and the Gradient Series Present Worth Factor (GPWF) respectively.

Col. 1, 2 and 3 - Refer to descriptions for Table 3.

Col. 4 and 5 - Beginning and ending years of a uniform annual cost series. If there is a step change in the series, two lines are to be used.

Col. 6 The uniform annual cost component between the years shown in Cols. 4 and 5.

Col. 7 The Series Present Worth Factor (SPWF) for the number of years difference between Cols. 4 and 5.

Col. 8 Present work of the uniform series of annual costs of Col. 6 for the period Cols. 4 to Col. 5, reduced to the date of Col. 4. If the date of Col. 4 is also the base year 1980, the value in Col. 8 is also the present worth at base year and should be entered in Col. 10.

Col. 9 The single payment present worth factor (PWF) for the number of years difference between the beginning year of Col. 4 and the base year 1980, if any. This factor is to bring the series present worth to the base year level where the initial year and the base year are not the same.

Col. 10 Present worth of the uniform series reduced to the base year 1980, Col. 9 times Col. 8.

Col. 11 and 12 Beginning and ending years of the gradient annual series.

Col. 13 Incremental annual cost which makes up the straight line gradient annual series. This is the amount by which the annual cost increases each year. For example, an annual increment of $1,000 per year would indicate a series in which each annual cost was $1,000 more than the previous year beginning at zero in the first year to n thousand dollars per year in the nth year.

Col. 14 The Gradient Series Present Worth Factor (GPWF) from Table 2 for the number of years indicated by the difference between columns 11 and 12.

Col. 15 The present worth to the beginning year of the gradient series, that is, to the year of Col. 11. If Col. 11 date is also the base year 1980, the value in Col. 15 is also the present worth at the base year and should be entered in Col. 17.

Col. 16 The single payment present worth factor (PWF) for the number of years difference between the beginning year of Col. 11 and the base year 1980, if any. This factor is to bring the gradient series present worth to the base year level where the initial year and the base year are not the same.

Col. 17 The present worth of the gradient series reduced to the base year 1980, Col. 16 times Col. 15.

Col. 18 The present worth at base year of both the uniform and variable components of annual operation and maintenance costs, Col. 10 plus Col. 17.

TABLE 1

COST INDICES

Year	WPC-STP INDEX (1)		WPC-S INDEX (1)		ENR-CCI INDEX (2)	
	Seattle	National	Seattle	National	Seattle	National
1957	100.88	98.04	102.43	96.80	746	724
1958	105.57	101.50	111.59	100.42	802	759
1959	107.86	103.65	116.98	104.78	836	797
1960	109.29	104.96	117.18	106.22	859	824
1961	111.63	105.83	120.85	108.19	893	847
1962	112.49	106.99	122.55	109.72	915	872
1963	115.08	108.52	125.14	113.07	961	901
1964	116.58	110.54	129.31	115.10	983	936
1965	118.99	112.57	131.30	117.31	1028	971
1966	124.50	116.92	139.14	121.18	1084	1019
1967 Aug.	130.51	120.28	141.70	125.36	1130	1070
1968 Apr.	131	122	145	127	1254	1155
1969 Apr.	141	130	155	137	1333	1269
1970 Apr.	147	139	162	146	1413	1386
1971 Aug.	164	165	173	170	1571	1581
1972 Aug.	171	173	183	187	1763	1753
1973 March	181	180	195	196	1763	1859
June	181	183	192	200	1763	1896
Sept.	184	185	196	202	1842	1929
Dec.	187	186	199	206	1844	1939
1974 March	191	191	205	210	1853	1940
June	202	203	216	225	1887	1994

(1) Values 1957 through 1967 are for August of each year from FWPA (1967)
Values 1968 through 1970 are for April of each year from Carelli (1971)
Values 1971 & 1972 are August each year, Source EPA Library

(2) From Engineering News Record Magazine, March 21, 1974 and June 20, 1974

TABLE 2

PRESENT WORTH AND COST RECOVERY FACTORS

AT 7 PERCENT INTEREST

n	PWF	SPWF	GPWF	CRF	n
1	0.9346	0.9346	0.00	1.0700	1
2	0.8734	1.8080	0.87	0.5531	2
3	0.8163	2.6243	2.50	0.3811	3
4	0.7629	3.3872	4.80	0.2952	4
5	0.7130	4.1002	7.65	0.2439	5
6	0.6663	4.7665	10.97	0.2098	6
7	0.6227	5.3893	14.72	0.1856	7
8	0.5820	5.9713	18.79	0.1675	8
9	0.5439	6.5152	23.14	0.1535	9
10	0.5083	7.0236	27.72	0.1424	10
11	0.4751	7.4987	32.47	0.1334	11
12	0.4440	7.9427	37.35	0.1259	12
13	0.4150	8.3576	42.33	0.1197	13
14	0.3878	8.7455	47.37	0.1143	14
15	0.3624	9.1079	52.44	0.1098	15
16	0.3387	9.4466	57.53	0.1059	16
17	0.3166	9.7632	62.59	0.1024	17
18	0.2959	10.0591	67.62	0.0994	18
19	0.2765	10.3356	72.60	0.0968	19
20	0.2584	10.5940	77.51	0.0944	20

PWF = Present Worth Factor for a single payment
SPWF = Series Present Worth Factor for a uniform series
GPWF = Gradient Present Worth Factor for a series increasing by uniform increments
CRF = Cost Recovery Factor
n = Number of Years

TUDOR ENGINEERING COMPANY

BY ______ DATE ______ SUBJECT WRS SPOKANE SHEET NO. ______ OF ______
CHKD BY ______ DATE ______ JOB NO. 604

TABLE 3
CAPITAL COST WORK SHEET

Alternative. SAMPLE

			CAPITAL COST						SALVAGE VALUE							NET PW,
CATEGORY	DESCRIPTION	SIZE	Construction or Acquis. Cost Dollars	Including Conting & Engineer Dollars	When Required Year	Base to Req. Yr. Years	IDC and PWF	PW at Base Year Dollars	Service Life Years	Last Use in Study Year	Age at Last Use Years	Salvage Value Dollars	Last Use To Base Years	PWF	PW of Salvage Dollars	CAPITAL LESS SALVAGE Dollars
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
CV	Trunk Sewer from Point of Conc. to Treatment Site 12,000 LF open R/W	48"	480,000	672,000 (1.40)	1980	0	1.035 x 1.000	695,520	40	2000	20	336,000	20	.2584	86,822	608,698
L	R/W for portion of Trunk not in Public Ways 5,000 LF 15' wide		7,500	9,375 (1.25)	1980	0	1.105 x 1.000	10,359	∞			9,375	20	.2584	2,422	7937
TP	First Stage Secondary Treat. with Primary	10 mgd	5,300,000	7,420,000 (1.40)	1980	0	1.035 x 1.000	7,679,700	50% 30 50% 20	2000	20 20	1,236,667 None	20	.2584	319,555 —	7,360,145
TR	Second Stage Treat. Plant Enlargement Yr. 1990	Add 5 mgd	2,400,000	3,360,000 (1.40)	1990	10	1.035 x 0.5083	1,767,664	50% 30 50% 20	2000	10 10	1,120,000 840,000	20 20	.2584 .2584	289,408 217,056	1,261,200
L	Treatment Plant Site for Ult. Year 2020 size 20 mgd	15 Ac.	45,000	56,250 (1.25)	1980	0	1.105 x 1.000	62,156	∞			56,250	20	.2584	14,535	47,621

NOTES:

TUDOR ENGINEERING COMPANY

BY ______ DATE ______ SUBJECT WRS SPOKANE SHEET NO ______ OF ______

CHKD BY ______ DATE ______ JOB NO. 604

TABLE 4

OPERATION AND MAINTENANCE WORK SHEET

Alternative: SAMPLE

			UNIFORM ANNUAL COST							VARIABLE ANNUAL COSTS							TOTAL PW
CATE-GORY	DESCRIPTION	SIZE	Begin Year	End Year	Unit Annual Cost Dollars	SPWF	PW of U Series at Beg Yr Dollars	PWF	PW of U. Series at Base Yr. Dollars	Begin Year	End Year	Incremental Annual Cost at ~~End Yr~~ Dollars	GFIIF	PW of G. Series at Beg. Yr Dollars	PWF	PW of G. Series at Base Yr Dollars	OF ANNUAL O&M COSTS Dollars
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
CV	Trunk Sewer, 12,000 cf	48"	1980	2000	10,000	n=20 10.5940	105,940	—	105,940								105,940
TR	First Stage Treatment Flow increasing 5 mgd to 10 mgd from 1980 to 1990	10 mgd	1980	1990	160,000	n=10 7.0236	1,123,776	—	1,123,776	1980	1990	4,000	27.72	110,880	—	110,880	1,234,656
TR	Enlarged Treatment Plant Flow increasing 10 mgd to 15 mgd from 1990 to 2000	15 mgd	1990	2000	208,000	n=10 7.0236	1,460,909	.5083	742,580	1990	2000	5,200	27.72	144,144	.5083	73,268	815,848

List of References

Federal Register, Vol. 38 No. 174, Monday September 10, 1973. Cost-effectiveness Analysis.

U.S. Environmental Protection Agency, 1974. Guidance for Facilities Planning.

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SECTION 401.2

COST DATA

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 401.2

COST DATA

20 June 1975

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

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INDEX - Continued

FIGURE INDEX

FIGURE INDEX - Continued

SECTION 401.2
COST DATA

Objective

The objective of this section is the compilation of a cost data basis to be applied to alternative plans for their evaluation by cost effectiveness analysis. Criteria for cost effectiveness analysis are developed in Section 401.1 including the price level. The cost data developed herein are in conformance with the requirements in Section 401.1

Price Level

All costs data are to be for the price level of mid-1974 as represented by the following cost indices.

Name	Index Level
Engineering News Record	
Seattle Construction Cost	2000
Sewage Treatment Plant and Sewer Construction Indices	
Seattle Plant Index WPC-STP	202
Seattle Sewer Index WPC-S	216

For a discussion of these cost indices and a historical record of their index levels, refer to Section 401.[1]

Costs Included

Two kinds of costs are developed, capital costs and the costs of operation and maintenance. The capital costs developed herein are the cost of construction in the case of structural facilities or the market price in the case of land or other acquisitions. The costs for engineering, legal, interest during construction, owner's overhead and contingencies are not included herein but are considered subsequently in the process of cost effectiveness analysis.

Operation and maintenance costs include labor, materials and supplies for the day to day operation and maintenance plus the averaged cost of longer term recurring maintenance. Replacements are not included except for parts that are regarded as maintenance.

Sources of Data

All sources canvassed and evaluated for cost data are shown in the List of References. A specific listing and evaluation of data sources is given for each type of facility or operation.

In the process of evaluating and comparing data sources, all costs are adjusted to the price level of this study as defined above using either the WPC-STP index or the WPC-S index as appropriate. The historical values used to create adjustment factors is shown in Appendix I which is a duplication of Table 1 from Section 401.1. Many sources include engineering, contingencies and other costs above the actual construction cost. These identifiable factors are also accounted for in reduction to a common basis.

Gravity Sewers and Force Mains

Capital costs developed for gravity sewers and force mains are shown in Figures B-1 and B-2 respectively. Sewer and force main costs are shown for two surface conditions, developed areas and undeveloped areas. Developed areas are defined as those requiring cutting, removal and restoration of pavement, traffic control and protection of other crossing underground utilities. Undeveloped areas are defined as those without pavement, traffic or interfering underground utilities. All sewer and force main costs include trench excavation and backfill, pipe materials, pipe installation and testing. In developed areas, costs of pavement removal, restoration, traffic control and protection of other utilities are also included as well as the effect on rate of underground construction caused by working in a developed area.

Gravity sewers include the cost of manholes allocated to each foot of sewer based on spacing and depth appropriate to each pipe size. Since definitive design profiles are inappropriate to this study, excavation and backfill costs are developed for typical trench depths as a function of pipe size ranging from 10 feet for 8 inch size to 18 feet for sizes 36 inch and larger. Gravity sewer pipe material prices are based on manufacturer's quotations.

Force main costs are developed for three working pressures, 100 psig, 150 psig and 200 psig, in anticipation of the range of heads to be encountered in plan alternatives. Pipe material costs are from manufacturer's quotations for each pressure rating, utilizing concrete mortar lined and coated steel cylinder pipe with rubber ring gasketed joints. There are no manholes on force mains, but costs include an allowance for cleanouts, air vents and thrust blocks. Depth of trench for force mains is to provide four feet of cover over the pipe.

For both gravity sewers and force mains, complete installed costs are developed from work elements based on Puget Sound Area contractor experience in glacial outwash soils similar to those of the study area. The costs are for average conditions and do not reflect excessively wet conditions, rock or large boulder conditions. The calculated results shown in Figures B-1 and B-2 are in substantial agreement with three literature sources, not specific to the study area conditions. When corrected to a common price level and depth of trench, gravity sewer costs from Carelli (1971) are found to be lower than Brown and Caldwell (1972) in sizes below 48 inch but in agreement above

48 inch. Costs in Table B-1 developed herein are found to be between these two references, approaching the lower up to 30 inch and approaching the higher above 30 inch. Force main costs in developed areas are found to be in agreement with Brown and Caldwell (1972) and those in undeveloped areas with those developed by the consultant for the USCE Merrimack (1971).

River crossings by force mains where there is an existing bridge are priced as for in the ground in developed areas. Where a crossing is required and there is no existing bridge a cost of $300 per foot plus pipe materials is adopted based on typical underwater construction costs for midsized pipe, 36 to 66 inch.

The selected basis for computation of operation and maintenance costs for sewers and force mains in 0.5 percent per year of capital cost. USCE-Merrimack (1971) uses 1 percent of capital cost, OTC (1973) uses 0.5 percent and Brown and Caldwell (1972) uses 0.3 percent. There are expected to be real differences between experience with force mains and gravity sewers and between raw sewage and treated effluent as well as differences specific to size and location. The mid-range value is selected a mean for all exposures. This value would not apply to collection system sewers where costs are significantly higher.

Pump Stations

Capital costs developed for various types of pumping facilities are shown in Figure B-3. Data are presented for three categories:

1. Raw Sewage Pump Stations

2. Treated Effluent Pump Stations

3. Irrigation Distribution Pump Stations

Sizes are in terms of firm capacity, that is with one unit out of service. Raw sewage pumping stations include provision of a standby power source to provide the necessary degree of reliability. Raw and treated sewage pump station costs include earthwork, concrete underground and superstructure, pumping equipment, piping, electrical work and controls and standby power facilities where applicable. Irrigation distribution pump stations are in-the-line type and do not include underground wet wells.

Costs are developed from evaluation of the following literature sources:

Carelli (1971)
Patterson and Banker (1971)
USCE-Merrimack (1971)
USCE-CSLEM (1973)
Nute _et al_ (1972)
Office of Technical Coordination (1973)
Brown and Caldwell (1972)

Carelli (1971) and Patterson and Banker (1971) are in substantial agreement throughout the size range 1 mgd to 60 mgd. These sources are both based on historical data and are judged to inadequately reflect new requirements for system reliability and the need to eliminate by-pass of raw wastes to the environment. The newer sources based on synthesis of designs to include reliability features are significantly higher, particularly in the 1 mgd to 10 mgd size range. The adopted curve for this study for raw sewage pump stations gives greater weight to these newer curves, particularly that for Office of Technical Coordination (1973).

The curve for treated effluent pumping is evolved from the adopted raw sewage pump station curve by a ratio developed from the same sources listed above, where available. The adopted factor is 0.60.

The curve for irrigation pumping is in turn derived from the treated effluent curve by elimination of most of the underground structure elements, using a factor of 0.70. The costs for irrigation conveyance pumping shown in Pound et al (1974) exceed adjusted historical costs for raw sewage pumping from both Carelli (1971) and Patterson and Banker (1971) and are judged to be excessively high and inappropriate for this study.

Operation and maintenance costs for pump stations are considered in two elements, electrical energy costs and all other operation and maintenance costs. Operation and maintenance costs other than electrical energy are shown in the selected curve in Figure G-2 and are based on evaluation of the same sources listed above for capital costs. Greatest weight is given to Patterson and Banker (1971) with increased labor unit costs and less size advantage in the 1.0 to 10.0 mgd range. The resultant curve also agrees with OTC (1973) for sizes 10 mgd and larger, the range of interest in this study. A single curve is selected for all types of pump stations although it is recognized that there are differences for raw and treated sewage (for which different capital cost curves are developed).

Electrical energy costs are computed from the calculated annual energy consumption of each specific pump station in kilowatt hours (kwh). Total pumping head is determined as the sum of static and dynamic heads.

Power requirements are computed on a wire to water efficiency of 62 percent for raw sewage and 71 percent for treated effluent. Costs of electrical power in dollars per kwh are computed on the basis of unit costs developed herein under the paragraph Electrical Energy Costs and summarized in Figure G-3.

Electrical Energy Costs

Electrical energy costs for the study area are based on Washington Water Power Company rates which were effective to December 31, 1974. The following rate schedules were analyzed for power use in the range from 50 kva* to 10,000 kva demand, all at a load factor of 60 percent. Refer to Appendix II for rate schedules.

Rate	Designation
12	General Service
21	Large Service
22	Extra Large Service
35	Pumping

The analysis indicates that Rate 35 provide the lowest cost through a demand of 3000 kva and Rate 22 for demands of 5000 kva and larger. Washington Water Power confirms that Rate 35 would be applicable to wastewater pumping although it was developed specifically for irrigation.

Electrical energy costs are summarized in Figure G-3.

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* kva = 1000 volt ampers

Equalizing Storage

Adopted capital costs for equalizing storage are shown in Figure B-4. The data source is USEPA Tech Transfer (1974). The selected construction for use in conveyance systems is an earthen basin with plastic liner on a sand bed, floating aerator and concrete scour pad. Pumping is not included since pumping facilities are being priced separately. The price curve is extrapolated beyond 2.4 mg basin size given ir the citation based on the assumption of a moderate cost advantage with size increase. Sizing for use in conveyance systems is equal to 50 percent of ADWF for raw sewage and 20 percent of ADWF for treated effluent.

For use in conjunction with advanced waste treatment processes where the equalizing storage is in the treatment plant site, concrete construction similar to other plant elements is selected. Sizing for use in advanced treatment is 20 percent of ADWF.

The selected basis for operation and maintenance costs for equalizing storage is 1 percent per year of capital cost for treated effluent storage and 5 percent for raw sewage.

Secondary Treatment

The capital costs of the elements of standard secondary treatment exclusive of solids handling disposal are shown in Figure C-1. Since the evaluation of alternative solids handling and disposal systems is an objective of this study it is desirable to develop these costs separately from the basic wastewater processing system. It is also desirable to separate the primary part of the plant from the secondary elements. Therefore, there are two additive curves shown in Figure C-1 to make up complete secondary treatment. The curve for the primary element includes all of the basic headworks elements including screening, grinding, measurement, and grit removal as well as the basic office, laboratory, parking, driveways, fencing and landscaping. The curve for the secondary element includes the biological reactor units and secondary sedimentation tanks, including inter-unit piping, aeration equipment and ancilliary facilities related to these elements.

Data sources evaluated in arriving at the adopted values shown in Figure C-1 are as follows:

Public Health Service (1964)*
Butts and Evans (1970)*
Shah and Reid (1970)*
U.S.C.E. Merrimack (1971)*
U.S.C.E. CSELM (1973)*
Nute _et al_ (1973)*
Smith (1968)*
Carelli (1971)*
Weber _et al_ (1970)*
Brown and Caldwell (1972)
Battelle (1974)
Culp and Culp (1971)
Office of Technical Coordination (1973)

The majority (marked with asterisk) of these data sources do not separate solids handling nor do they separate primary from biological secondary. Also, activiated sludge type secondary is common to all. Therefore to have the widest possible base for evaluation, the overall cost of activated sludge secondary including solids handling is adopted for screening.

It should be recognized that Smith (1968) is basic to most subsequent sources which quote and incorporate Smith data. Smith in turn relies on six sources which predated his study. This interrelationship is demonstrated in the following matrix.

Data Sources	Summary Reports which Utilize the Various Sources		
	Smith (1968)	Carelli (1971)	Brown & Caldwell (1972)
Velz (1948)	X	(X)*	(X)*
Diachishin (1957)	X	(X)	(X)
Rowan (1961)	X	(X)	(X)
Logan (1962)	X	(X)	(X)
Public Health Service (1964)	X	(X)	(X)
Swanson (1966)	X	(X)	(X)
Dorr-Oliver (1968)#			X
Smith & McMichael (1969)#		X	X
Michel et al (1969)#		X	
Shah and Reid (1970)		X	

As indicated above, nine sources have data in the form for the total process without separation of solids handling. The other sources with separate elements can be put in this same form. With all sources on a common basis and with data reduced to a common price index, the following evaluation is made.

The resultant cost curves have two characteristics which must be compared, their slope and their absolute value. Smith (1968) is a source common to all and is in turn dominated by Public Health Service (1964). Smith (1968) and Public Health Service (1964) have the same

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* (X) indicates use of these sources indirectly through use of Smith (1968).

Operation and Maintenance cost references.

slope, as would be expected, but Smith (1968) is approximately 14 percent higher, probably reflecting the other sources that were averaged in.

Shah and Reid (1970), which makes use of an entirely different and more recent sampling base, has a flatter slope than Smith (1968) or PHS (1964). This was recognized by Shah and Reid and pointed out in their report as being significant. Shah and Reid's data show that the newer plants of small size had proportionately higher costs and the larger size lower costs. Shah and Reid indicate that it is to be expected that, as the technology becomes more complex, the advantages of scale increase. At 1.0 mgd Shah and Reid is equal to PHS (1964) but at 10 mgd Shah and Reid is about 10 percent lower.

Carelli (1971) who uses both Smith (1968) and Shah and Reid (1970) has a slope almost equal to that of Shah and Reid (1970) indicating that significant weight was given to the latter source. Carelli (1971), however, is about 27 percent higher than Shah and Reid (1970) at 10 mgd but about equal to Smith (1968) at 10 mgd. That is, Carelli (1970) has the slope of Shah and Reid (1970) passing through the absolute value of Smith (1968) at 10 mgd.

Brown and Caldwell (1972) and OTC (1973) who do not use Shah and Reid (1970) are found to have a slope substantially steeper than Smith (1968). The absolute value at 10 mgd is about 37 percent higher than Carelli (1971). At 1 mgd, however, the difference is only about 6 percent but at 100 mgd the spread increases to 75 percent. In adjusting literature data Brown and Caldwell appear to be using ENR construction cost index rather than WPC-STP. This would account for some of the difference in absolute value. For example, the adjustment of Smith (1968) which is in terms of June 1967 price level takes a factor of 1.8 to bring to 1974 by ENR and a factor of 1.7 to bring to 1974 by WPC-STP. The major difference in absolute value is probably due to recognition of the more sophisticated plants being built currently compared with the older plants which made up the samples in the literature. The steeper slope which gives less recognition to the advantages of scale does not appear to be in keeping with this increase in complexity at all levels of size.

Alternatives in the urban planning area could consider treatment facilities in the size range from approximately 2 mgd ADWF to 50 mgd ADWF. The absolute values are therefore of primary interest in that range. As a check in this range, the following actual known projects where activated sludge plants are built in one step are also considered after adjustment to the common price level and also adjusted for known unusual features such as pile foundations.

Project	Design Flow mgd	Year Built	Historical Cost	Remarks
Reno-Sparks	20	1965	$4,874,000	
Oro Loma	20	1967	6,593,000	All on pile foundation
U. C. Davis	3	1969	1,442,000	Without solids processing
S.F. Int. Airport	3	1970	2,430,000	Pile foundation
Carmel	4	1971	2,525,000	Part pile foundation and without solids processing
Vancouver	12	1971	4,813,000	

The above specific examples indicate that the absolute value from the updated Carelli curve is too low in the size range of interest by at least 15 percent but that the slope of the curve is satisfactory. Compared with Brown and Caldwell and OTC, the absolute value from these sources at mid-range appears to be about 15 percent high and the slope too steep.

Thus, the analysis to this point leads to the selection of a curve passing through $5,200,000 at 10 mgd with a slope of 0.74 as most representative of currently constructed complete activated sludge secondary treatment plants, including solids processing. It is estimated that comparable plants built in 1980 with the control and refinements necessary to achieve BPWTT will cost approximately 10 percent more, at a given price level, than preexisting plants. Making an upward adjustment of 10 percent but maintaining the selected slope, the projected basic cost curve becomes one of slope 0.74 (on log-log) through $5.8 million dollars at 10 mgd average dry weather flow (ADWF).

Figure C-1 is derived from this basic curve by first deducting solids processing costs and then dividing into primary treatment and biological secondary elements. The comparable point without solids processing at 10 mgd is $4.7 million dollars. Refer to the appropriate paragraph below for derivation of solids processing costs. The solids processing elements removed correspond to those included in the data sources, namely anaerobic digestion and vacuum filtration.

Division between primary and secondary elements is based on Battelle (1974), OTC (1973) and cost breakdown data on individual plants in the mid-size range such as Reno-Sparks cited above. The resultant selected values at the 10 mgd point are 2.45 million dollars or 52 percent in primary, including all influent and site work, and 2.25 million dollars or 48 percent for biological secondary. It is assumed that the advantages due to size are the same for both plant elements, resulting in parallel curves with the same slope as the basic total plant curve.

The costs developed above are for standard design criteria and are representative of costs associated with the specific criteria developed for this study as follows:

> Primary: Hydraulic loading of 800 gallons per square foot per day, 2.0 hours detention at ADWF and not less than 1.0 hours at PWWF.
>
> Secondary: Reactor loading 50 pounds of BOD per 1000 cubic feet of aeration tank volume, detention time of 5 hours at ADWF and 2.5 hours at PWWF and an air supply of one cubic foot per gallon. Secondary clarifier loading 650 gallons per square foot per day at ADWF and not to exceed 1200 gallons per square foot per day at PWWF with a detention time of 2.5 and 1.0 hours respectively.

The selected operation and maintenance cost curve for biological secondary treatment is shown in Figure H-1. The data sources evaluated in preparing the selected curve are included in the listing for capital cost source above. Sources in general include primary treatment and solids processing. Taking the 20 mgd size as a checkpoint, Smith (1968) and Carelli (1971) give $400,000 per year. Michel et al (1969), USCE-CSELM (1973), USCE-Merrimack (1971), Battelle (1974) and Brown and Caldwell (1972) are in the range, $550,000 to $650,000 at the same size. Weber et al (1970) indicates costs in excess of

$1,200,000 at 20 mgd. Specific plant data indicate costs of $550,000 plus dollars per year. These data are evaluated to indicate a selection point for combined primary-biological secondary including solids processing of $600,000 per year at 20 mgd. There is a general concensus that the slope of the curve in recognition of size advantage is as originally established by Smith (1968). The breakdown into separate components is based on Battelle (1974) and OTC (1973) at 47 percent to primary, 38 percent to secondary and 15 percent to solids processing. It should be recognized that such a breakdown necessarily contains arbitrary allocations of many costs elements. The above basis leads to selected points of $280,000 per year for primary and $230,000 per year for biological secondary at 20 mgd and a slope of 0.76. Specific solids processing O&M costs are developed below considering the foregoing and other data sources.

Nitrification-Denitrification

The capital costs of nitrification and denitrification processes as additions to activated sludge secondary are shown in Figure C-1. The data sources considered in development of these selected values are as follows:

Battelle (1974)
OTC (1973)
Nute et al (1972)
Brown and Caldwell (1972)
Environmental Quality Systems (1973)
USCE Merrimack (1971)
USCE-CSELM (1973)

There are no data for actual full scale plants employing biological techniques for these processes. All data sources are based on projections. The nitrification part of the system is an extension of activated sludge oxidation from the carbonaceous into the nitrogenous phase so that it is the least speculative of the two processes. There is not yet full agreement as to the methodology for denitrification. This study is assuming the modifications proposed by Horstkotte et al (1974).

At the 10 mgd point, the cited sources give widely varying costs for the complete nitrification-denitrification system. The costs range from a low of 1.6 million dollars for common wall construction per Environmental Quality Systems (1973) to 4.8 million dollars selected by the consultants for USCE Merrimack (1971). The common wall assumption is judged to be too optimistic for planning. Also the process does not recognize the addition of an aerated stabilization reactor following the anaerobic reactor as recommended by Horstkotte. For these reasons a higher cost level is selected based on a 10 percent addition to figures developed by Battelle (1974) resulting in a value of 3.1 million dollars at 10 mgd. The relative advantage of size is selected to be as for similar basic plant units developed from extensive historical data above at slope of 0.74.

The selected curve for operation and maintenance cost of complete biological nitrification-denitrification facilities is shown in Figure H-1. Data sources evaluated are included in the above listing for capital cost data. Battelle (1974), OTC (1973) and Environmental

Quality Systems (1973) are in substantial agreement in the 10 to 30 mgd range. USCE-CSELM (1973) and USCE-Merrimack (1971) are approximately 20 percent lower. Since these costs, like the capital costs, are highly speculative due to the lack of full scale experience, a comparison is made with related basic processes and to evaluate the chemical costs, which are included in the referenced data. At a typical methanol dosage of 50 mg/1*, the annual cost of chemicals for a 20 mgd plant are in the range $220,000 per year at a methanol cost of $0.50 per gallon in large quantities. For the range shown by cited references, this leaves a remainder ranging from $160,000 to $260,000 per year for the non-chemical costs of operation and maintenance. The historically substantiated operation and maintenance cost of the activated sludge reactor including aeration equipment and clarifier is $230,000 per year at 20 mgd size. Since the nitrification-denitrification operation is incremental to the basic activated sludge process, the operation component of the incremental O&M would be expected to be less. The higher capital cost for the nitrification-denitrification elements would be expected to increase the maintenance component. The selected value represents chemical cost plus maintenance at 2-1/2 percent of capital cost and one additional operator shift. The net result is a total including chemical cost of $380,000 at 20 mgd, substantially equal to the value used by USCE-CSELM (1973). The slope selected is parallel to other biological elements.

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* Equal to ratio 3.0 methanol to 1.0 nitrogen per Horstkotte (1974).

Phosphorus Removal

The phosphorus removal methodology selected in the development of treatment criteria is by addition of alum to the secondary clarifier following the activated sludge reactor. Neglecting the solids handling consequences, the capital cost addition for phosphorus removal is that associated with the storage and feeding of alum. Also, at design stage there may be modifications to criteria for precise sizing of the secondary clarifier. In general, these added costs, again emphasizing neglect of solids handling, are so small in proportion to the total plant that they are not worth identifying by a separate cost curve.

The large costs for chemical is recognized under operation and maintenance costs. The resultant significant increase in sludge volume and difficulty in processing is recognized under both the capital cost and operation and maintenance costs for solids handling. The cost of alum is developed from supplier's quotation, including freight. For selected dosage rate for phosphorus removal of 123 mg/l, the cost becomes $18,425 per full year per million gallons of flow shown graphically in Figure H-1.

Seasonal Nitrification

The potential need for a short season of nitrification operation is identified under development of disposal criteria in connection with avoidance of ammonia toxicity in surface waters. This need is within the season concurrent with phosphorus removal. As indicated under treatment criteria, one alternative method of providing nitrification under these conditions is to move all or part of the chemical coagulation process for phosphorus removal from the secondary into the primary where the resultant increased removal of BOD in the primary may be utilized to unload a normally carbonaceous reactor to operate in the nitrification range. This usually requires an augmented air supply in the activated sludge reactor. A capital cost increment of 7.5 percent of the activated sludge process cost curve in Figure 5-C is added to provide the augmented air supply where this alternative is exercised.

Chemical coagulation in the primary introduces revised sludge quantities and characteristics which are recognized in sizing and selection of solids handing process elements. Refer to chemical costs for phosphorus removal.

Ammonia Stripping

The selected capital cost curve for ammonia stripping is shown in Figure C-2. The sources evaluated in selection are as follows:

Carelli (1971)
Smith and McMichael (1969)
Culp and Culp (1971)
OTC (1973)
Smith (1968)
Brown and Caldwell (1972)

Culp and Culp (1971) provide only one point at 3.75 mgd but that is the only full scale experience to date (Lake Tahoe). The Smith and McMichael (1969) curve passes directly through the Culp and Culp data point. Carelli (1971) is exactly the same as Smith and McMichael.

All the others are at levels from .75 to .50 of Smith and McMichael.

The Culp and Culp (1971) supported Smith and McMichael line is adopted except that below the available data point size advantage does not appear to be adequately stated and the adopted curve is given flatter slope.

The selected sizing criteria are 2 gpm per square foot, 400 cfm of air per gpm and depth of 25 feet.

The selected curve for operation and maintenance costs for ammonia stripping on a four month per year basis is shown in Figure H-2. As was the case for capital costs, the Smith and Michael (1969) curve based on Lake Tahoe experience is given greatest weight.

Multi-Media Filtration

The selected capital cost curve for multi-media filtration is shown in Figure C-2. Sources evaluated in the selection process are:

Smith (1968)
Smith and McMichael (1969)
Weber et al (1970)
Carelli (1971)
OTC (1973)
Brown and Caldwell (1972)
USCE-Merrimack (1971)
USCE-CSELM (1973)
Environmental Quality Systems (1973)

Smith (1968), Smith and McMichael (1969), Weber et al (1970) and Carelli (1971) appear to be identical and probably all derive from Smith (1968). USCE-Merrimack (1971) is likewise so close to the above as to be identical. Environmental Quality Systems (1973) and Brown and

Caldwell (1972) are approximately 23 percent higher than the five which appear to be identical and USCE-CSELM (1973) and OTC (1973) are 50 percent cent higher. The values developed by Environmental Quality Systems (1973) for the Corps of Engineers are adopted over the range 1 to 10 mgd. Above 10 mgd, the advantage of size for this type of facility is judged to be less and the curve steepened to reflect this, but not to the extent by Brown and Caldwell.

The higher figure is selected to allow for backwash storage which is not included in the basic figures.

Sizing criteria are selected at 3-4 gpm per square foot at ADWF corresponding to the selected cost source.

Multi-media filtration, although new to wastewater treatment, has extensive experience in water treatment. Therefore it is not surprising that the various sources were in close agreement. As an advanced treatment method, multi-media filtration costs are less speculative than those with no full scale experience.

The selected operation and maintenance cost curve for multi-media filtration is shown in Figure H-2. As for capital costs, the source given greatest weight in the selection is Environmental Quality Systems (1973). The O&M costs from the same sources cited above, which were closely grouped relative to capital costs, are more scattered.

Carbon Adsorption

The selected capital cost curve for carbon adsorption is shown in Figure C-2. This is a methodology without a backlog of full scale experience. Despite this there is an extensive list of sources which present projected costs for evaluation. These sources are as follows:

Smith (1968)
Smith and McMichael (1969)
Weber et al (1970)
Carelli (1971)
OTC (1973)
Brown and Caldwell (1972)
USCE-Merrimack (1971)
USCE-CSELM (1973)
Battelle (1974)
EPA Tech Transfer (1973)
Environmental Quality Systems (1973)

When reduced to a common price level all of the above sources except the last two give substantially the same result in the 1 to 10 mgd range, with a slight fanning out above 10 mgd depending upon the degree to which size advantage is credited or discounted. The data from EPA Tech Transfer (1973) do not contain the cost of regeneration equipment, which accounts for its low position.

The values selected are from the consensus from 1 to 10 mgd. Above 10 mgd the slope is steepened to join the high side of the group in recognition of the fact that size advantage decreases with absolute size since multiple units are required.

The selected operation and maintenance curve for carbon adsorption is shown in Figure H-2. The Smith and McMichael (1969) data are given greatest weight. This source is on the higher side of the general concensus of the sources which is judged appropriate considering that some of the lower are known to not include carbon regeneration.

Treatment Plant Site Requirements

Site areas required for various types of treatment plants as a function of design capacity are shown in Figure E-1. Data sources evaluated in the course of development of the selected curves include the following:

Smith (1968)
Patterson and Banker (1971)
Battelle (1974)
USCE-CSELM (1973)

The literature sources exhibit wide variation that cannot be explained. Therefore a synthetic approach is used, checked against known individual plants.

The site areas shown in Figure E-1 include space for solids processing including anaerobic digestion and vacuum filtration. Space is not included for sludge drying beds. The site areas also include a nominal buffer strip ranging from 50 feet in small sizes to 100 feet in larger sizes. As a check, note that the proposed upgraded City STP with layout to expand to 60 mgd biological secondary is being placed on a 28 acre site in an unusually compact configuration. The adopted curve calls for a 33 acre site.

Completion of the synthetic approach when rechecked against the above cited data sources shows substantial agreement of the secondary facility curve with that shown by Patterson and Banker (1971) for minimum site. When it comes to actual acquisition, Patterson and Banker recommend areas up to double the minimum to cover unforseen needs. For the purpose of cost effectiveness analysis, the foreseen needs only are selected as appropriate.

Chlorination

The selected capital cost curve for chlorination facilities is shown in Figure C-3. The costs are shown for a complete system and its two primary components, the chlorine storage and application equipment including shelter and the contact chamber. For certain alternative plans where there is available a pipeline of adequate length to perform the contact function (incidental to conveyance), the storage and application element alone is used and the pipeline is priced as conveyance structure.

Cost sources evaluated include the following:

Smith (1968)
Weber et al (1970)
Carelli (1971)
Patterson and Banker (1971)
USCE-CSELM (1973)

Again, Smith (1968), Weber et al (1970) and Carelli (1971) are essentially identical. Patterson and Banker is about 10 percent lower at 10 mgd and gives large credit to size advantage for higher flow. USCE-CSELM (1973) is about 15 percent higher at 10 mgd and parallel to Patterson and Banker. The effect of size by the later sources is judged to better represent this type of facility and becomes the basis for selected slope. The absolute value selection point at 10 mgd is approximately 10 percent above the Smith value to allow for inclusion of more sophisticated closed circuit control than was in general use historically. The final selected curve in effect is close to USCE-CSELM (1973).

The cost curve is expressed in terms of ADWF and a dosage of 5 mg/l. The separation of the system total into its components is based on an evaluation that the contact chamber ranges from 33 percent at 1 mgd, to 42 percent at 10 mgd and 51 percent at 100 mgd.

Operation and maintenance of chlorination facilities is considered in two components. The chemical costs and the costs of operation and maintenance of the equipment. Most sources consider the cost of chemical only, presumably on the basis that other O&M costs are incidental to basic treatment plant operation. Smith (1968) and those derived directly from Smith like Carelli (1971) do present data on the non chemical phases of chlorination O&M. The selected curve shown in Figure H-3 is derived from Smith (1968). Chlorine chemical costs are based on delivered costs from suppliers and are also shown in Figure H-3. Two prices for chlorine are presented, one for use in quantities of less than 500 pounds per day and one for use over 500 pounds per day to recognize the price break in quantity purchase.

Ozonation

The selected capital cost curve for complete system for disinfection with ozone is shown in Figure C-3. Although ozone has been extensively used for water treatment in Europe and to a lesser extent in this country, cost data are scarce. The basic problem is the lack of a developed industry manufacturing a standard equipment package. The total equipment package is complex if the system is to produce ozone from air and electricity alone rather than from previously prepared and dried pure oxygen. The costs herein are for a complete system using air. The two data sources used are Diaper (1972) and Harris (1974). These two sources are in substantial agreement and the adopted curve is taken directly from Diaper (1972) and includes all mechanical, electrical and application equipment.

Operation and maintenance costs are considered in two components, electrical energy costs and all other costs. Electrical energy is computed from Diaper (1972) based on 28 watt hours per gram of ozone (equal 12.7 kwh per pound, which agrees with Harris (1974) range of 10 to 13 kwh per pound). The non-energy component is based on selection of 5 percent per year of capital cost in small sizes, 10 mgd and less, and 2 percent of capital cost above 10 mgd. Selected O&M cost curves are shown in Figure H-4. (Note that the above described electrical energy criterion is equal to a continuous demand of approximately 220 kilowatts for a 10 mgd plant, about the same order of magnitude as the power demand for activated sludge aeration.)

Pretreatment for Lagoons

Facilities to screen, grind and measure raw sewage before actual lagoon treatment are priced separately from the lagoons themselves. The selected capital cost curve for the pretreatment element is shown in Figure C-4 and is derived primarily from Patterson and

Banker (1971). The Patterson and Banker data which are in terms of maximum flow and include grit removal are modified to be in terms of average flow and exclude grit removal.

Operation and maintenance costs for the pretreatment element is incorporated into the cost for the entire lagoon complex. As a check, the data from Patterson and Banker (1971) were compared with the overall cost.

Lagoon Construction

Costs are developed for lagoons based on a quantity take off for typical construction in 10 to 15 acre cells in 100 acre blocks for both 5 foot deep facilities and 10 foot deep aerated units. The unit costs considered include inlet and outlet header piping, earthwork, gravel road surface on dike tops, slope protection on dike faces, internal piping and valves and site fencing. An average site slope of one percent is assumed for earthwork evaluation.

The developed costs for 5 foot deep cells are in close agreement with the historical construction costs of the Ligerwood lagoons adjusted to 1974 price level which come to $8,200 per acre for four 6.2 acre cells. The developed costs are approximately 10 percent lower as should be expected for larger cells in larger groups. Pound et al (1974) and Patterson and Banker (1971) also provide substantiation of the developed lagoon costs.

Selected costs are:

Five feet deep - $7,500 per net acre
Ten feet deep - $12,000 per net acre

To convert net area to gross land requirement including space occupied by dikes and boundary strip 30 feet to fence all around, multiply by 1.34.

Lagoon capital cost data are summarized in Figure C-5.

Aeration Equipment for Lagoons

Aeration equipment for lagoons is priced on a unit cost per installed horsepower. Floating propeller type aeration units are assumed. Costs include in addition to the electric motor driven aerator all structural, mechanical and electrical installation features.

Cost data are based on actual installation from Burns et al (1970) at power intensity comparable to selected criteria but in small units. Adjusted to 1974 levels the selected cost per installed hp is $800. This is in substantial agreement with Patterson and Banker (1971) for large impeller aerators. For the selected combination of plain and aerated lagoon, the applied power by surface aerators is 16.3 hp per acre or 25 hp per mgd of throughput.

Lagoon Operation and Maintenance

In general, literature sources for operation and maintenance of lagoons are in terms of flow without correlation to loading criteria and are for experience with small installations without pretreatment or mechanical aeration. The following sources are of this type:

Michel (1970)
Michel, Perlmoter and Palange (1969)
Battelle (1974)
Patterson and Banker (1971)

Due to the wide variety of lagoon loading criteria and the subalternatives including mechanical aeration, estimation of operation and maintenance costs based on flow alone are judged to be inapplicable to this study. For this reason, operation and maintenance costs are developed in terms of the specific combinations of pretreatment, plain lagoon area and mechanically aerated area. The cost elements included are:

(1) Normal day to day attendance to monitor overall performance, mechanical screening and grinding and mechanical aeration.

(2) Periodic routine maintenance including weed control and mechanical equipment.

(3) Electrical energy (primarily for mechanical aeration).

(4) Long term maintenance including upkeep of embankments, slope protection and dike-top roads.

These costs are developed based on the following criteria:

(1) Normal attendance--up to 150 acres, 2 man years/year and 1 vehicle; 150 to 300 acres, 3 man years/year and 1-1/2 vehicles; over 300 acres 4 man years/year and 2 vehicles. (Size range is 65 to 360 acres for study alternatives.)

(2) Routine maintenance, weed control, $300 per acre of dike slope, every other year.

(3) Electrical energy per Figure G-3.

(4) Long term maintenance in terms of percent of capital cost at 1 percent for pretreatment, 5 percent for aeration equipment and 0.2 percent for earthwork.

Application of the foregoing results in the curve shown in Figure H-5 where converted to average flow in mgd. The 10 mgd point on this curve is in substantial agreement with Patterson and Banker (1971). These costs for mechanically aerated lagoons are approximately 50 percent of the costs for primary treatment excluding solids handling, giving a reasonable overall check.

Refer to the section on solids processing for the cost of periodic removal of sludge accumulation in lagoons.

Irrigation Distribution

A distribution pipe network is required to convey irrigation water from the terminal storage reservoir to the point at which it is picked up by the individual field sprinkler systems. It is customary for an irrigation water purveyor to make a point of connection available for each 40 acre plot (a square with 1320 foot sides). The cost of distribution within the 40 acre plot is a part of the sprinkler system cost. The conveyance to each 40 acre plot is herein designated irrigation distribution.

An irrigation distribution price is developed based on the layout of a unit network of 1000 acres sized to deliver a peak flow of 5.5 feet per month or approximately one half inch per day. Distribution piping is sized at 4.5 feet per second (fps) in 30 inch and larger, 4.0 fps in 12 through 24 inch and 3.0 fps in 12 inch and smaller. The resultant piping system is priced at the rates developed elsewhere for force mains rated 100 psi.

To test the validity of the layout it is compared with data given in the U.S. Bureau of Reclamation Report for the East Greenacres

Unit which indicates that a typical layout should require approximately 40 feet of main per acre served and in sizes up to 30 inch. These criteria check the unit layout. As a further check, the overall price obtained at $800 per acre served is checked against data in Michel, Gilbert and Creed (1974) which gives a range of $580 to $725 per acre at 1974 levels.

Operation and maintenance costs for irrigation distribution are selected at 1 percent per year of capital cost. Sources considered include Michel, Gilbert and Creed (1974), and Pound et al (1974), with greatest weight given to the former.

Irrigation Sprinkler Systems

Distribution within each 40 acre plot of irrigated land and the sprinkler equipment itself is included in the cost of sprinkler systems. Conveyance from the edge of the irrigated area through a network capable of reaching a point on each 40 acre plot is included under costs for irrigation distribution.

A cost of $1,700 per acre is selected for sprinkler systems based on distributor's quotation for solid set systems complete, installed in the Pacific Northwest. This cost is generally substantiated by data given in Pound et al (1974) ranging from $1,630 to $2,011 depending upon total area.

The operation and maintenance costs of sprinkler systems are selected at $48 per acre per year. Sources considered include Michel, Gilbert and Creed (1974) and Pound et al (1974). These two sources are in substantial agreement. The selected figure is adjusted to exclude pumping costs which are handled separately in this study.

Storage Reservoirs

The cost of storage reservoirs for seasonal storage of treated effluent prior to irrigation application is determined on an individual basis for each storage site based on determination of the approximate earthwork volume and other physical quantities applied to selected unit costs. The cost elements include the following:

Clearing
Dam embankment
Outlet pipe and structure
Spillway earthwork
Spillway concrete

A geological reconnaissance of the sites, reported in the Appendix to Section 701.2, provides the basis for construction conditions at each site. Reservoir volume as a function of depth is developed from area-capacity curves constructed for each site. Gross reservoir volumes are determined as the sum of dead storage, active storage of treated wastewater and an allowance for storage of local runoff to prevent spills. Spillway capacity is provided for the estimated 1000 year flood.

The lack of subsurface exploration at each site requires the assumption of criteria based on judgment applied to the surface reconnaissance. It is assumed that the top 10 feet of each site will have to be removed for dam embankment foundation and that a cut off key with depth equal to 25 percent of the embankment height is required.

Unless otherwise indicated in the geologic reconnaissance for a specific site, the dam embankment volumes are based on a 3 horizontal to 1 vertical upstream face and a 2-1/2 horizontal to 1 vertical downstream face, with 20 foot wide crest.

Included in the cost of dam embankment are excavation, haul and compaction of the embankment itself, adjusted to recognize local differences in estimated haul distance, plus other items such as slope protection, drilling and grouting.

Operation and maintenance costs are developed from consideration of basic cost elements as follows:

(1) Weed and brush control.

(2) Long term maintenance of outlet works.

(3) Periodic inspection and monitoring of the embankment for safety.

(4) Routine check of outlet works.

Developed costs covering these work items range from $33.50 per site acre per year for the smaller reservoirs to $22.00 for the larger reservoirs as summarized in Figure H-7. Data for a small Bureau of Reclamation dam and reservoir (Touchet near Walla Walla) at $17,000 per year, confirm the developed level for the larger sizes of interest in this study.

Crop Revenue

Since it is assumed for the purpose of cost effectiveness analysis that the wastewater management agency owns and operates the land used for irrigation treatment, it is necessary to credit the plan with the net income of crop production; that is, the total sale price of the crop less the cultivating, planting, harvesting and marketing costs. First, it is necessary to select the appropriate crop and second, determine the average net income for that crop.

Common crops in the Spokane vicinity are typified by wheat, peas and lentils, grass seed, alfalfa and pasture. Of these crops, only alfalfa is capable of tolerating and using the high application rates necessary to justify the expense of distribution and sprinkler systems and minimize land use. Wheat needs a supplement of only about 12 inches of irrigation per season and the incremental value added over dry farming is small. Grass seed has a short irrigation season of 6 to 8 weeks with practically none after July 1. Alfalfa can use in excess of 36 inches of irrigation per season, provides a permanent cover to prevent erosion, can utilize high rates of nutrient application (important if sludge application to land is to be considered), has moderately high value and is readily marketable in the Spokane area.

The net yield for wheat at current high price, $3.80 per bushel, is approximately $100 per acre by dry farming. Addition of irrigation could raise the net to $150 per acre. At long term average of $2.80 per bushel, the yields are $74 and $110 respectively. Irrigated alfalfa has an average yield of $120 per acre.* To dispose of the same quantity of wastewater would require 3 times as much land for

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*Net yield data are from discussions with Agricultural Extension Service.

wheat as for alfalfa and an investment in three times as much irrigation distribution and sprinkler work. For cost effective analysis, alfalfa is selected as the basis for crop revenue valuation except where limited by soil moisture capacity.

Where the soil mantle is thin and has low moisture holding capacity as in the Airways Heights-Fairchild area, a maximum feasible application rate is selected at 24 inches of water per year. The low soil moisture holding capacity would require very frequent water applications for crops with a high rate of uptake like alfalfa. Irrigated pasture appears to be a more feasible application if 24 inches of water are to be used. Wheat is also a possibility but water application would be reduced and irrigated yield would be less than cited above for present wheat lands. To dispose of 12 inches of water to irrigated wheat is estimated to yield less than $100 per acre net. To dispose of 24 inches of water to pasture should yield around $75 per acre net. The latter is selected for cost effectiveness evaluation.

Crop revenue rates are summarized in Figure F-1.

Infiltration-Percolation Facilities

Costs are developed based on quantity take-off for a pond system based on the following site assumptions and design criteria.

(1) Natural ground slope not to exceed 2 percent.

(2) Top 1 foot of natural soils unsuitable for infiltration-percolation.

(3) Flooding depth 16 inches.

(4) Application cycle 10 days flooded, 10 days to 20 days resting.

(5) Cell size 10 acres each.

The cost elements included are clearing and grubbing, earthwork, cell constant head inlet and outlet structures, distribution piping and valving, equalizing storage, circulation pumping, paving, fencing, garage for cell maintenance equipment.

Developed cost per net acre of active pond surface is $18,267. The ratio of net active pond to total site requirement is 1.25. Data are summarized in Figure C-6.

Selected operation and maintenance costs for infiltration-percolation ponds are shown in Figure H-8. The selected costs are synthesized from unit operations and are then checked against literature data. Primary reliance is not placed on literature data since the physical conditions represented are varied and not typical of study conditions. The range in size of interest in this study is from approximately 40 to 500 acres of net active pond area.

The operation and maintenance costs are evaluated as consisting of the following basic elements:

(1) Day to day routine operation, primarily concerned with controlling the flooding and resting cycles of the individual cells and seeing that ponds are taking water at the expected rates. Quality monitoring is also included.

(2) Regular operations which occur each year concerned with maintaining the surface of the ponds such as planting vegetation, cutting overgrown vegetation and restoring percolative capacity of the surface layer.

(3) Long term overall maintenance of the basic physical plant including the distribution piping, control weirs and flumes, circulation pumping and dike and road surfaces.

The results of applying unit costs to the above element are summarized in Figure H-8. Reduced to an equivalent cost per 1000 gallons, the range is found to be equal to 3.7 cents for a 40 acres unit to 2.0 cents for a 500 acre unit. These values are in agreement with data given in Pound and Crites (1973) which range from 3.5 cents per 1000 gallons for their synthesis of a small pond to 2.4 cents and 2.7 cents for historical operations at Flushing Meadows, Arizona and Whittier Narrows, California, respectively.

Dissolved Air Flotation

The selected capital cost curve for liquid sludge thickening by dissolved air flotation is shown in Figure D-1. The costs are for a complete system and include pressurizing pumps, air compressors, thickening tanks and all necessary interconnecting piping and mechanical and electrical work. Costs are expressed in terms of dollars per square foot of surface area of thickening tank. Area requirements for this study are established elsewhere at 14.4 pounds of dry solids per square foot per hour or a hydraulic loading of 0.8 gpm per square foot, whichever is larger.

The data sources evaluated are the USEPA Tech Transfer document on sludge treatment and disposal and OTC (1973). The Tech Transfer data are judged to give excessive credit to the advantage of size resulting in low costs for the larger size range. OTC (1973) and Tech Transfer are in substantial agreement in the range of 100 square foot units. The adopted curve follows a normal size advantage slope of 0.58 to 500 square feet steepening to 0.83 where multiple units are expected.

The selected operation and maintenance cost curve for dissolved air flotation is shown in Figure I-1. The O&M costs include day to day operation, power, conditioning chemicals and maintenance and repair parts. The basis for selection is compatible with the capital cost data source.

Elutriation

The selected capital cost curve for digested sludge conditioning and thickening by elutriation, combining washing and gravity thickening features, is shown on Figure D-1. The primary data source is Smith (1968) for specific reference to elutriation. Back up is available from other sources by recognizing that, on a square foot of tank basis, the costs are similar to gravity thickening plus additional circulation piping and baffles. Application criteria developed elsewhere in this study are 25 gallons of digested sludge slurry per day per square foot plus adjustable wash water (treated effluent) at rates up to 450 gallons per square foot per day.

The selected operation and maintenance cost curve for elutriation is shown in Figure I-1. No data sources for O&M specific to elutriation were found. Selected costs are estimated based on gravity thickening and primary sedimentation.

Anaerobic Digestion

The selected capital cost curve for complete anaerobic sludge digestion is shown in Figure D-2. The costs covered include digestion tanks with floating covers, internal gas mixing equipment control building, sludge heaters, sludge piping and recirculation pumping. Selected application criteria are 0.08 pounds of volatile solids per day per cubic foot or 25 days detention time, whichever gives the larger volume. Costs are expressed in dollars per cubic foot of volume.

Data sources evaluated include the following:

Smith (1968)
Patterson and Banker (1971)
USEPA Tech Transfer-Sludge (1974)
Battelle (1974)
USCE-Merrimack (1971)
Brown and Caldwell (1972)
DiGregorio (1968)
OTC (1973)

Within the size range 100,000 to 500,000 cubic feet there is very close agreement between Smith (1968), USEPA Tech Trans Sludge (1973), Patterson and Banker (1971) and Battelle (1974). The absolute value appears to be identical at the 500,000 cubic foot size. The differences below this size are in degree of recognition of size advantage, Smith showing essentially none and the others showing significant size advantage. Those that extend beyond 500,000 cubic feet agree that there is little size advantage in this range since it becomes a matter of building multiple units.

Recent individual project data with separable digestion costs indicate that the above described concensus is 10 to 30 percent low. The selected curve is given the shape of the concensus but is raised in absolute value to recognize these recent projects.

The other data sources considered were evaluated as being unrealistic. As with practically all data from DiGregorio, it is excessively low. OTC (1973) is about 78 percent above check points. USCE-Merrimack (1971) is 2-1/2 to 3 times higher than check points.

The selected operation and maintenance cost curve for anaerobic digestion is shown in Figure I-2. Data sources evaluated are more limited than available for capital cost. Of those representing a concensus on capital cost, the following also have O&M cost data:

USEPA Tech Trans. Sludge (1973)
Patterson and Banker (1971)
OTC (1973)
USCE-Merrimack (1971)

Another indirect source is the data on overall plant operation including solids processing discussed above under basic biological treatment element.

Patterson and Banker data are expressed in manhours for operation and maintenance separately plus maintenance materials. Application of an appropriate labor cost brings the total into substantial agreement with the total O&M curve presented by USEPA Tech Trans. Sludge. The Tech Trans. data at the 500,000 cf size give $48,000 per year at study price level compared with capital cost item of $1,550,000; that is, gross operation and maintenance equal to approximately 3 percent of capital cost. USCE Merrimack (1971) states as their criterion 3 percent of capital cost, but given the extremely high capital cost used by USCE-Merrimack the absolute cost in dollars at $111,000 per year for 500,000 cf digestion capacity is approximately double that reported by Tech Trans. and Patterson and Banker. The solids processing component developed from overall plant operation and maintenance costs corresponding to 500,000 cf digestion capacity are of the order $150,000 per year. OTC (1973) data which is expressed in terms of solids processed rather than in terms of physical plant size results in annual costs of the order $110,000 per year for the corresponding solids load but smaller physical facilities.

The Patterson and Banker and Tech Trans. data are evaluated as excessively low considering the high maintenance on sludge piping, heating and circulation equipment and on floating covers and mixers. Greater weight in selection of the adopted curve is given to the other sources, particularly the component of overall cost.

Vacuum Filtration

The selected capital cost curve for vacuum filtration dewatering of conditioned sludge is shown in Figure D-3. The costs include, in addition to the vacuum filter and its auxiliary pumps, vacuum pumps, etc., and the necessary building space to house the equipment and connecting piping and conveyors. Costs are expressed in dollars per square foot of filter drum. Selected application criteria are a loading of 3.5 pounds of dry solids per square foot per hour of slurry fed at 4.5 percent solids and 1.5 pounds of dry solids per square foot per hour of slurry at 2.7 percent solids. Unless otherwise noted a working cycle of 120 hours per week is assumed.

Data sources evaluated include the following:

Smith (1968)
Patterson and Banker (1971)
DiGregorio (1968)
OTC (1973)
Brown and Caldwell (1972)
Battelle (1974)

For this element of solids processing, the USEPA-Tech Trans. Sludge (1974) does not give usable data.

At size 500 square feet, there is substantial agreement in absolute cost between Patterson and Banker (1971), Battelle (1974), OTC (1973) and Brown and Caldwell (1972) with Smith (1968) being 15 to 20 percent lower. At size 100 square feet there is a substantial divergence due to differences in recognition size advantage. Beyond 500 square feet there is agreement that there is relatively little size advantage due to the requirement for multiple units. The selected curve is in general conformance with the upper level of the concensus as represented by Patterson and Banker (1971).

DiGregorio and USCE-Merrimack appear to be irrelevant, being lower than the concensus by a factor of 3.

The selected curve for operation and maintenance cost for vacuum filtration is shown in Figure I-3. The selected curve is based on Patterson and Banker (1971), which is the same source given greatest weight for capital cost. The selected curve is based on 120 hours per week operation at rated loading of 3.5 pounds of dry solids per square foot per hour. In applying the total O&M curve, recognition may be given to its breakdown into components as follows: maintenance labor and supplies 0.27, operating labor 0.34 and chemicals and power 0.39.

Centrifugation

The selected capital cost curve for sludge dewatering by centrifugation is shown in Figure D-4. The selected costs are derived from Patterson and Banker (1971) for comparative purposes with vacuum filtration costs predominantly from the same source. The centrifugation costs are expressed in dollars per capacity units in gallons per minute. The vacuum filtration and centrifugation curves cannot be compared directly due to the different pricing units without assumption of loading criteria for each. When this is done, assuming both units processing plain activated sludge, and filter feed at 3.5 pounds of dry solids per square foot of 4.5 percent solids, the capital costs of vacuum filters are found to be equal to the centrifuge in small sizes but approximately 100 percent higher at the largest size considered in this study.

The costs for the centrifuge installation in Figure D-4 represents a complete system including pumps, piping, cake conveyors, electrical facilities and the structure housing the equipment.

Operation and maintenance costs for a complete centrifugation system as shown in Figure I-5 are likewise from Patterson and Banker (1971). These costs include operating labor, average conditioning chemicals and electrical power as well as maintenance labor and repair parts. Again a comparison is made with vacuum filtration costs as described above for capital costs. The results are substantially equal costs over the range of sizes of concern.

Land Requirements for Sludge Sanitary Landfill

Selected criterion for disposal of dewatered sludge cake to sanitary landfill is 0.00032 acres per cubic yard of cake. This value is developed based on an operational procedure of placement on a ramp surface in layers 6 inches deep covered with 6 inches of earth each day to a total cell depth of 8 feet, including 2 feet of earth final cover. This results in a net of 3 cubic yards per square yard of active fill. To allow for a buffer zone it is assumed that only two-thirds of the site is active fill, resulting in the above stated criterion. Refer to state solid waste disposal criteria for confirmation of the adopted operational procedure.

Sanitary Landfill Operation

Operation costs of sanitary landfill of sludge cake disposal are developed in two categories, truck haul from the treatment plant to the site and spreading and covering at the site.

Truck haul costs are rates established by the tariff rates of the state Utilities and Transportation Commission. Rates are taken from Tariff No. 4-A for the Eastern Area. For initial screening without specific site selection a round trip distance of 15 miles is assumed using rates for 10 cubic yard units at $19.09 per hour including fuel and equipment fully operated and maintained. For alternatives generating in excess of 100 cubic yards per day, 20 cubic yard units at $25.80 per hour are assumed. For initial screening assumptions of haul, these criteria result in costs of $1.91 per cubic yard up to 100 cy per day tapering to $1.30 per cubic yard at 500 cy per day.

For site specific alternatives, these costs are converted to a ton mile basis as follows.

Hauls up to 10 miles one way and less than 100 cy per day, use $0.30 per ton mile.

Hauls up to 10 miles one way and over 100 cy per day use $0.18 per ton mile.

Hauls over 10 miles one way and less than 100 cy per day, use $0.20 per ton mile.

Hauls over 10 miles one way and over 100 cy per day use $0.11 per ton mile.

Truck haul costs are summarized on Figure I-5.

For operation of the sanitary landfill itself, Battelle (1974) and USEPA Tech Trans. Sludge (1974a) are evaluated. The validity of such costs, especially for small operations, is highly dependent upon being able to make efficient use of manpower and equipment at a parallel solids waste disposal operation as opposed to a completely separate operation. These references do not make clear what assumptions are used in this connection. The value from USEPA Tech Transfer at 100 cubic yards per day rate is equal to $356 per calendar day or $520 per work day. Since 100 cubic yards of cake represents about 200 cubic yards of total work, these costs appear to represent an independent operation in which the entire day's charges for operator and equipment are charged to sludge disposal, including idle time. The data from Battelle at 100 cubic yards per day is approximately one-third of that from USEPA Tech Trans. These values appear to more closely match the machine and manpower demands without excessive idle time. Since solid waste disposal in the study area is by sanitary landfill it is appropriate to consider joint operations for this analysis. The selected cost curve shown in Figure I-5 is a modification of the Battelle data reflecting this consideration.

Lagoon Sludge Disposal

Accumulated solids are removed from wastewater treatment lagoons at the end of each ten year period of operation. It is estimated that the quantity to be removed is equal to one half of the dry solids equivalent of primary digested sludge at a consistency of 25 percent solids.

Removal cost is selected at $1.70 per cubic yard including move-on and move-off costs, excavation and removal to a nearby site for landfill disposal. Landfill disposal cost is selected at $1.22 per cubic yard based on data developed in Figure I-5.

Incineration

The most abundant historical cost data is for multiple hearth type incineration which is selected as the basis for evaluation. The selected capital cost curve is shown in Figure D-5 and operation and maintenance costs in Figure I-7.

Data sources evaluated include the following:

USEPA Tech. Transfer Sludge (1974)
Patterson and Banker (1971)
Battelle (1974)
Brown and Caldwell (1972)
USCE-Merrimack (1971)

In general, all sources assume a solids content of feed of 25 percent minimum which requires either vacuum filtration or centrifugation dewatering as a preliminary step.

For capital costs, the first three of the above cited references are in substantial agreement throughout a range of 10 to 300 tons of dry solids per day. When compared with current information from incineration manufacturers, however, this historical consensus is found to be approximately 35 percent low, undoubtedly reflecting the more stringent current emission standards. The selected cost curve reflects adjustment for current conditions.

There is less agreement between sources on operation and maintenance costs. Two of those forming a consensus of capital costs are in substantial agreement at 30 tons per day capacity, namely Tech. Trans. Sludge and Patterson and Banker. These data are adjusted upward approximately 15 percent to reflect increased costs associated with current emission control. Supplemental fuel cost requirements do not appear to be adequately covered in the Patterson and Banker or EPA Tech. Trans. Sludge data. Specific experience indicates that typical supplemental fuel requirements are approximately nine million btu per ton of dry solids from raw sludge and twelve million btu per ton of dry solids from digested sludge. Fuel costs are based on Washington Water

Power rate schedule number 122 for natural gas which has a cost of $1.25 per million btu. The supplemental fuel costs on this basis are additive to the operation and maintenance costs from Patterson and Banker and EPA Tech. Trans. Sludge. The basic operation and maintenance curve and two supplemental fuel cost curves are shown in Figure I-7.

Ash disposal cost is based on a density of 50 pounds per cubic foot and truck haul and sanitary landfill costs as developed for sludge cake.

Wet Oxidation

The earliest installations of this process were of the high pressure type designed to provide reduction in solids volume of 70 percent to be competative with incineration. The literature data cited by EPA Tech. Trans. Sludge (1974) including McKinley (1965) and Harding and Griffin (1965) are for this type of installation. Current application shows greater emphasis on intermediate and low pressure systems. The low pressure system provides essentially no reduction in volume and is an alternative sterilization and conditioning process. The intermediate pressure system provides about 40 percent reduction and is an alternative to anaerobic digestion . To provide comparable costs data on all three systems as currently proposed, it is necessary to rely on equipment manufacturers data. The selected capital cost data are shown in Figure D-6 and include the cost of an enclosing structure but do not include subsequent processing such as solids separation from the liquid phase. Selected operation and maintenance costs as shown in Figure I-8 are also based on manufacturers data but are adjusted to include costs associated with the structure and to increase the allowance for long term heavy maintenance.

Air Drying Beds

Selected capital costs and operation and maintenance costs for uncovered air drying beds are shown in Figures D-7 and I-9, respectively. These data are taken from Patterson and Banker (1971). The construction costs include earthwork, sand beds, gravel and pipe for underdrainage collection. Maintenance and operation includes excavation and loading of dried sludge into trucks and maintenance and replacement of sand bedding.

Sludge Force Mains

Sludge force main costs are developed using methodology similar to that described above for wastewater force mains. To facilitate maintenance and provide continuity of service, all sludge force mains are assumed to consist of parallel runs of pipe laid in a common trench. Pipe materials are assumed to be cement mortar lined ductile iron. Depth of cover is assumed to be four feet. The developed capital costs are shown in Figure D-8. Operation and maintenance costs are selected at 2 percent of capital costs per year to reflect expected higher costs to keep clear and clean as compared with regular wastewater lines which are at one half percent per year.

Land Application Elements

Storage Basins. Sludge storage in the vicinity of application sites is provided for seasonal, operational and disinfection reasons. The facilities are assumed to be earth diked lagoons consisting of four cells and provided with liners to prevent infiltration to groundwaters. Construction is priced on a unit price basis for earthwork, dike top surfacing, inlet piping, liner and site fencing. Cells are assumed to be ten feet deep and to conform with DOE requirement for storage embankments less than 15 feet high. Developed capital cost basis, dollars per acre foot of storage, is shown in Figure D-9. Operation and maintenance costs, exclusive of sludge withdrawal machinery as discussed below, is taken as three percent of construction cost per year.

Dredge. A small floating dredge is selected as the mechanism for withdrawal of stored sludge from storage basins. The sludge is expected to be stored for periods of up to 300 days and is expected to have settled and densified over the extensive basin bottom. A winch controlled dredge is selected to achieve removal of these stored materials. Capital costs are shown in Figure D-10 and are based on quotations from manufacturers.

Operation and maintenance costs are developed from consideration of labor and fuel for operation plus five percent of cost per year for long-term maintenance. Developed criteria are shown in Figure I-4.

Sludge Storage Tank. To provide flexibility in pumping from the treatment plant site to the storage basins at remote locations, additional storage is necessary at the treatement site. This capacity could be provided in the digestion tanks themselves or in separate tanks. For costing of alternatives separate tanks are selected. Capital cost is selected as the same as equalizing storage structures as shown in Figure B-4. Maintenance and operation costs are selected as twenty-five percent higher than when handling wastewater.

Distribution Piping. To apply sludge to fields it is assumed that a circulating distribution network is required to provide 750 gpm hydrants not more than 1,000 feet from any point in the service area.

Cost estimates are developed on an individual basis to suit size of area required with pipe materials priced per Figure B-2 and with operation and maintenance costs at two percent of capital cost for sludge rather than 0.5 percent for wastewater. Systems are sized for 8 hours per day 90 days per year to deliver the entire year's sludge production.

Field Application. A wide variety of field application techniques for liquid sludge are examined in Bovay (1975) ranging from fixed sprinkler systems through specialized mobile units. Bovay (1975) develops a cost of approximately $15 per ton of dry solids if considered as a subcontract operation including capital recovery, as well as operation and maintenance for specialized mobile equipment, tractor drawn. To test the validity of this cost, a similar calculation is made utilizing off highway type sprinkler trucks. Again as a fully operated subcontract, the cost is found to be approximately $20 per ton of dry solids. The criteria used are an application rate of two tons of dry solids per acre per year in sludge of 3 percent solids and 7,500 gallon vehicles at $30 per hour fully operated by subcontract.

The cost of $15 per ton of dry solids is adopted for large areas and used with a complete distribution system. The cost of $20 per ton of dry solids is adopted for small areas that can be served by direct haul from the storage basin or a skeleton distribution system.

Land

The cost of land is based on the market value in 1974 developed from assessed valuation for specific sites. A list of specific sites was furnished to Spokane County with a request for typical assessed valuations at the indicated sites. The nominal ratio of market to assessed value is 1.25 to 1.00. A further judgmental adjustment was made to the nominal market price to arrive at an estimated actual market price. Figure E-3 tabulates land cost data and Figure E-4 maps the specific locations referred to in Figure E-3.

FIGURE A-1

INDEX TO COST DATA

Cost Element	Figure Reference: Capital	Figure Reference: Operation and Maintenance
CONVEYANCE FACILITIES		
Gravity Sewers	B-1	G-1
Force Mains	B-2	G-1
Pumping Facilities	B-3	G-2 and G-3
Equalizing Storage	B-4	G-1
WASTEWATER TREATMENT		
Primary	C-1	H-1
Activated Sludge Secondary	C-1	H-1
Phosphorus Removal	-	H-1
Biological Nitrification	C-1	-
Biological Nitrification-Denitrification	C-1	H-1
Ammonia Stripping	C-2	H-2
Multi-media Filtration	C-2	H-2
Carbon Adsorption	C-2	H-2
Chlorination	C-3	H-3
Ozonation	C-3	H-4
Pretreatment for Lagoons	C-4	H-5
Lagoons	C-5	H-5
Irrigation Distribution	C-6	H-6
Irrigation Sprinklers	C-6	H-6

FIGURE A-1
(Continued)

Cost Element	Capital	Operation and Maintenance
Storage Reservoirs	(1)	H-7
Infiltration-Percolation Ponds	C-6	H-8
SOLID WASTES PROCESSING		
Dissolved Air Flotation	D-1	I-1
Anaerobic Digestion	D-2	I-2
Elutriation	D-1	I-1
Vacuum Filtration	D-3	I-3
Truck Haul of Sludge Cake	(2)	I-4
Sanitary Landfill	(3)	I-5
Centrifugation	D-4	I-6
Incineration	D-5	I-7
Lagoon Sludge Disposal	---	I-4
Wet Oxidation	D-6	I-8
Air Drying Beds	D-7	I-9
Sludge Force Mains	D-8	I-4
Land Application Elements		
Sludge Storage Basins	D-9	I-4
Sludge Dredges	D-10	I-4
Distribution Piping	(1)	See Text
Field Application	(2)	I-4
LAND REQUIREMENTS		
Areas for Miscellaneous Facilities	E-1	---
Area for Treatment Plants	E-2	---
Land Costs	E-3 and E-4	---
REVENUE		
Crop Revenue	---	F-1

(1) Priced on individual quantity take-off and selected unit prices on site specific basis.

(2) No capital cost. Priced as subcontract in which subcontract cost includes complete operation, maintenance and ownership costs.

(3) No capital cost except site covered under land.

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC-S INDEX - 216

FIGURE B-1
CAPITAL COSTS

GRAVITY SEWERS

Pipe Size Inches Diameter	Total Installed Cost Dollars Per Foot*	
	Undeveloped Areas	Developed Areas
8	12.97	21.50
12	14.98	23.74
15	18.64	28.13
18	19.72	29.31
21	22.22	32.08
24	28.48	39.37
27	36.24	49.12
30	40.36	53.69
36	52.76	74.01
42	67.83	86.85
48	78.16	97.80
54	89.84	111.59
60	108.42	132.86
66	123.30	148.89
72	141.15	169.33
78	160.00	188.00
84	180.00	207.00
90	202.50	
96	216.00	

*Includes costs of manholes.

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
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FIGURE B-2
CAPITAL COSTS

FORCE MAINS

Total Installed Cost, Dollars Per Foot

Pipe Size Inches Diameter	Undeveloped Areas			Developed Areas		
	100 psig Class	150 psig Class	200 psig Class	100 psig Class	150 psig Class	200 psig Class
8				22.00	22.00	22.00
12	17.89	17.89	17.89	25.96	25.96	25.96
14	19.50	19.50	19.50	27.71	27.71	27.71
16	21.59	21.59	22.29	29.92	29.92	30.62
18	23.95	23.95	25.15	32.42	32.42	33.62
20	25.86	25.86	27.41	34.47	34.47	36.02
21	27.13	27.33	29.18	36.17	36.37	38.22
24	30.42	31.22	33.87	39.67	40.47	43.12
27	35.71	37.06	40.21	46.32	47.67	50.82
30	40.23	42.43	46.23	51.17	53.37	57.17
33	44.57	47.47	51.67	55.72	58.62	62.82
36	49.58	55.13	59.78	62.20	67.75	72.40
39	56.32	60.47	66.37	69.15	73.30	79.20
42	63.50	68.30	75.70	77.85	82.65	90.05
45	71.79	77.34	85.19	86.35	91.90	99.75
48	78.85	85.35	94.60	94.97	101.47	110.72
51	83.64	91.69	102.09	99.97	108.02	118.42
54	100.03	109.33	121.23	117.90	127.20	139.10
57	104.32	116.17	129.72	122.40	134.25	147.80
60	111.64	125.34	140.74	131.47	145.17	160.57
66	125.95	142.70	159.40	146.37	163.12	179.82
72	146.97	163.82	183.82	170.53	187.38	207.38
78	169.30	186.80	209.20	202.50	211.30	237.50
84	196.00					
90	227.00					
96	263.00					

PRICE LEVEL:
MID-1974, PACIFIC NORTHWES
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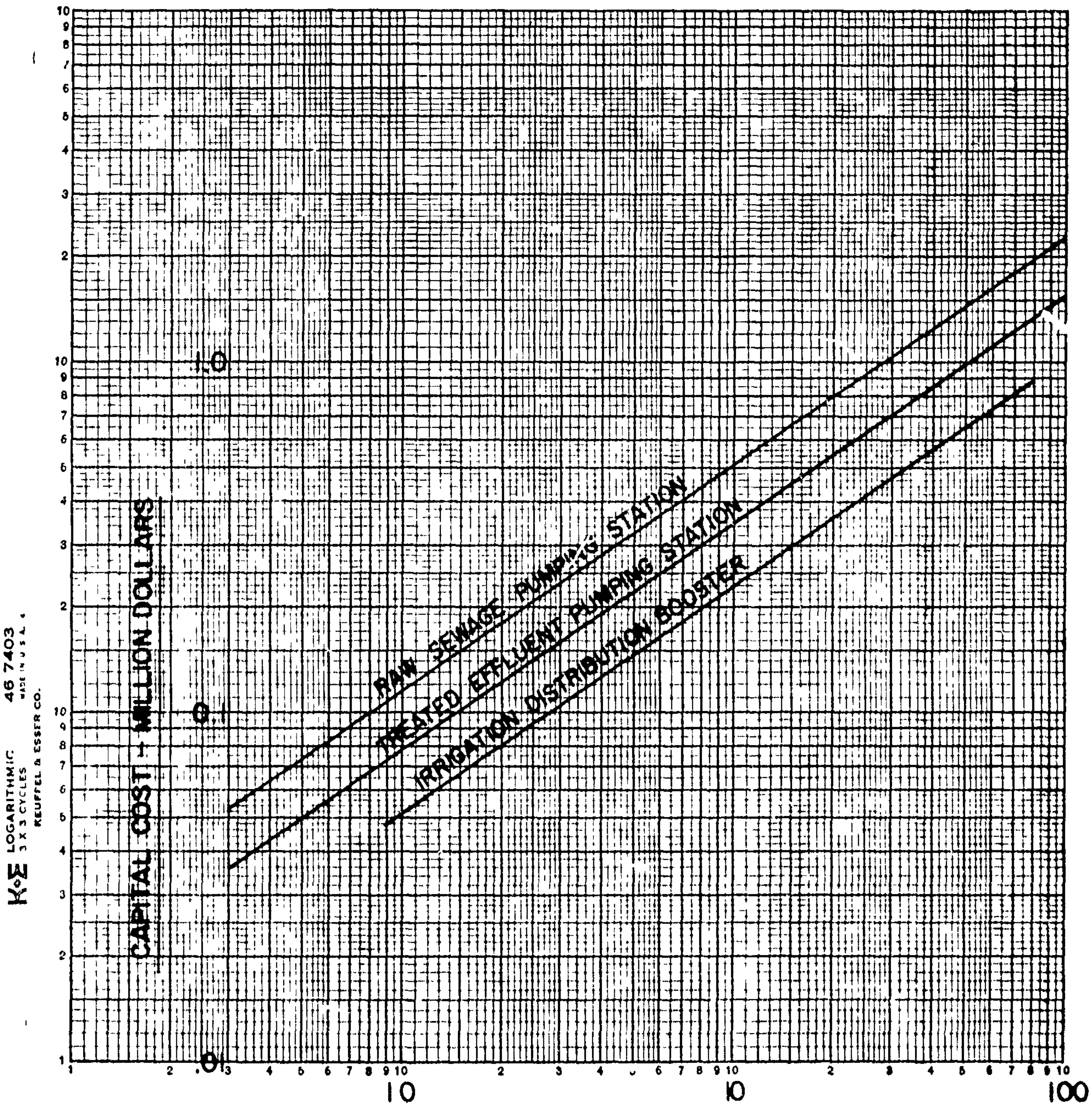
WPC STP INDEX - 202

FIGURE B-3
CA[illegible]

PUMPING FACILITIES

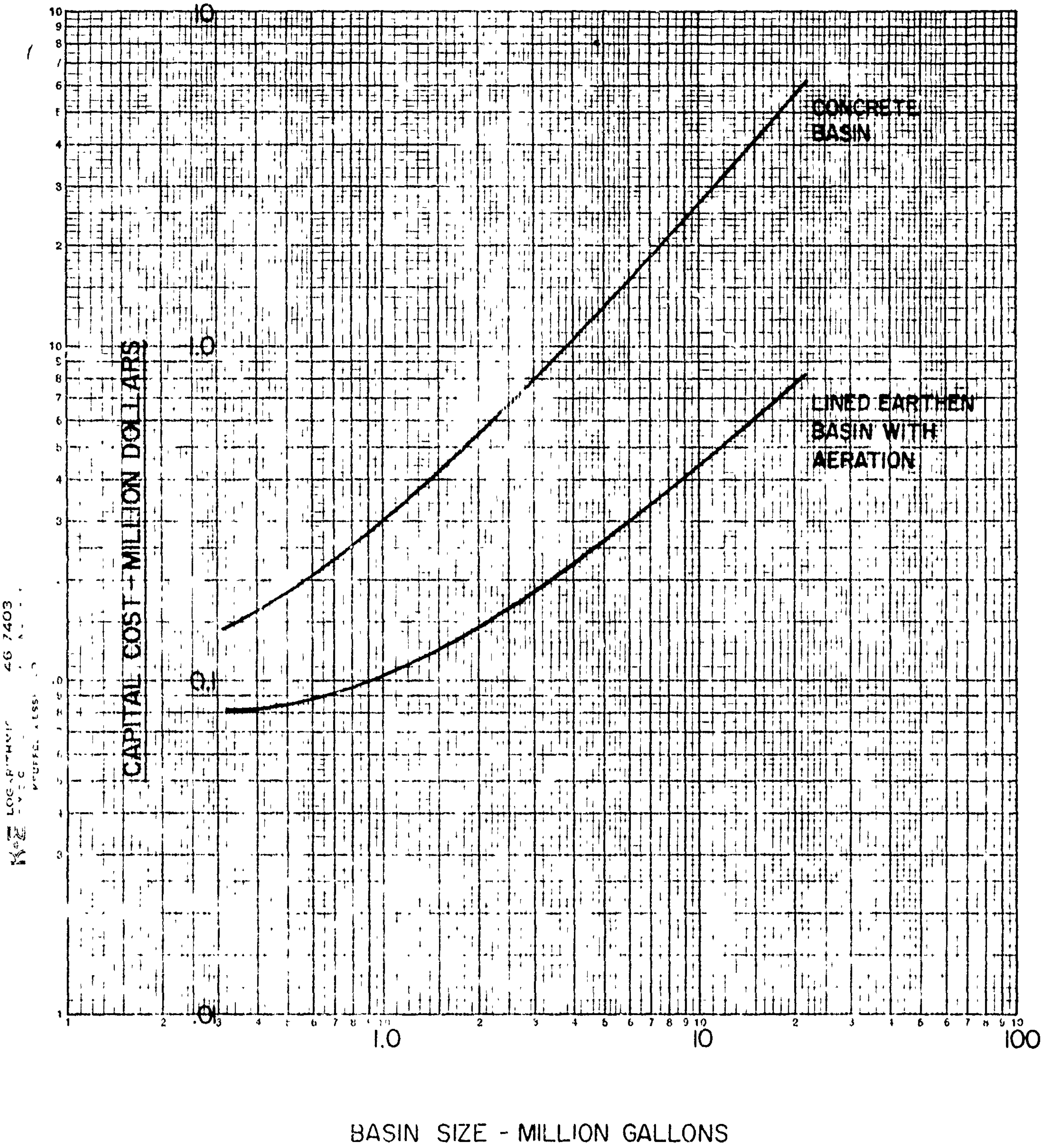


FIRM PUMPING CAPACITY - MGD

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

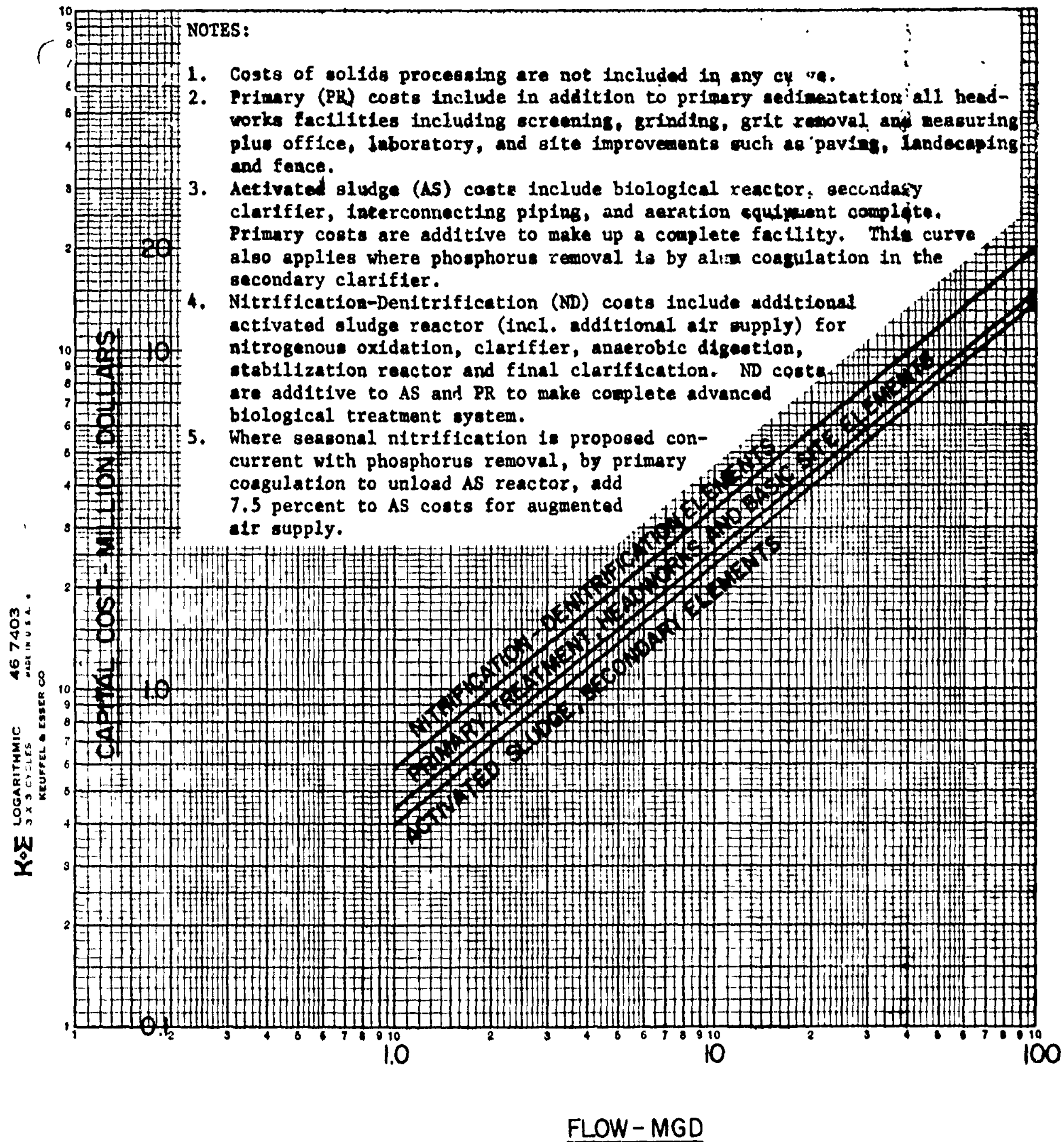
FIGURE B-4
CAPITAL COSTS

EQUALIZING STORAGE



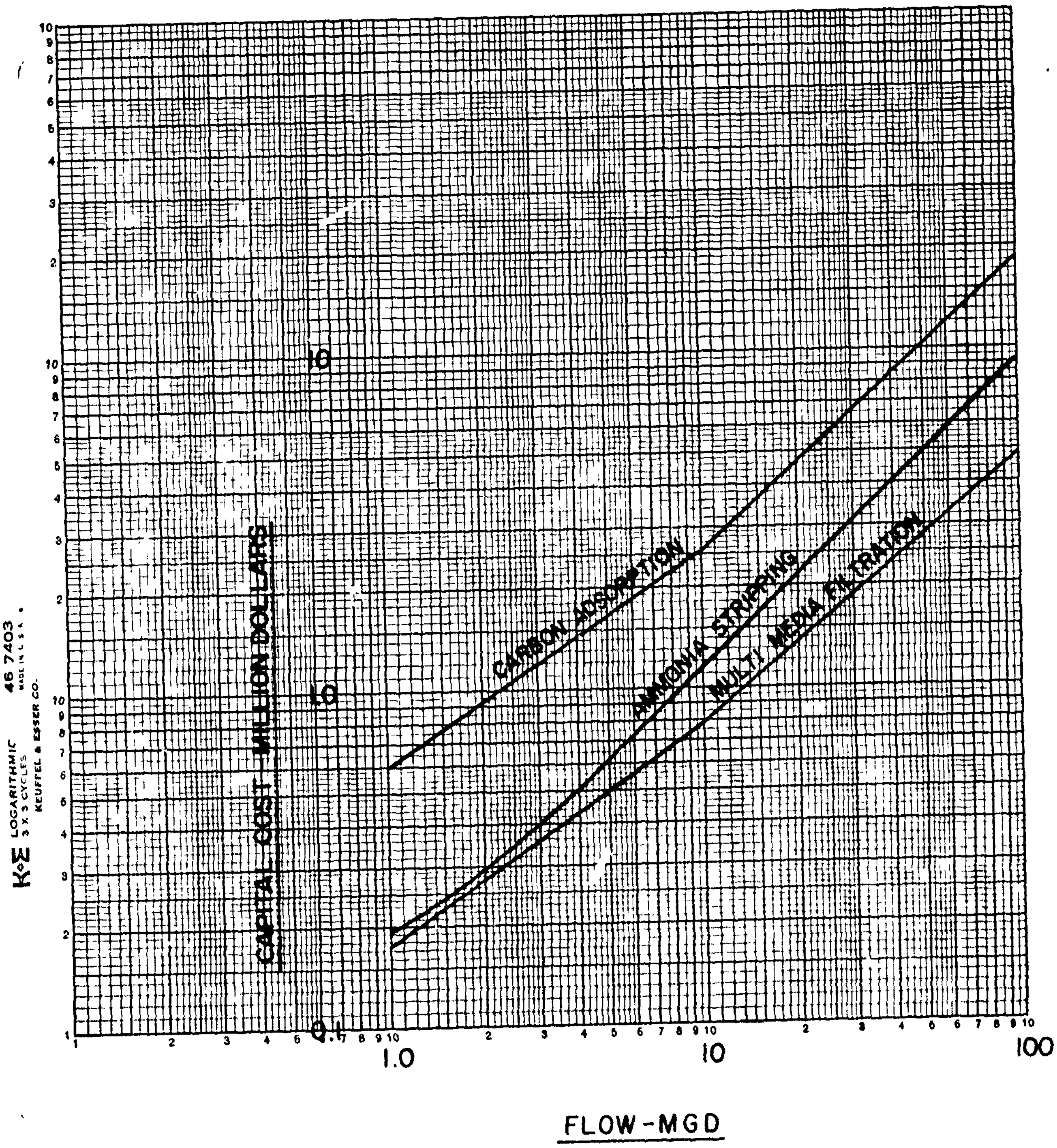
PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE C-1
CAPITAL COSTS
PRIMARY AND BIOLOGICAL TREATMENT
ELEMENTS



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

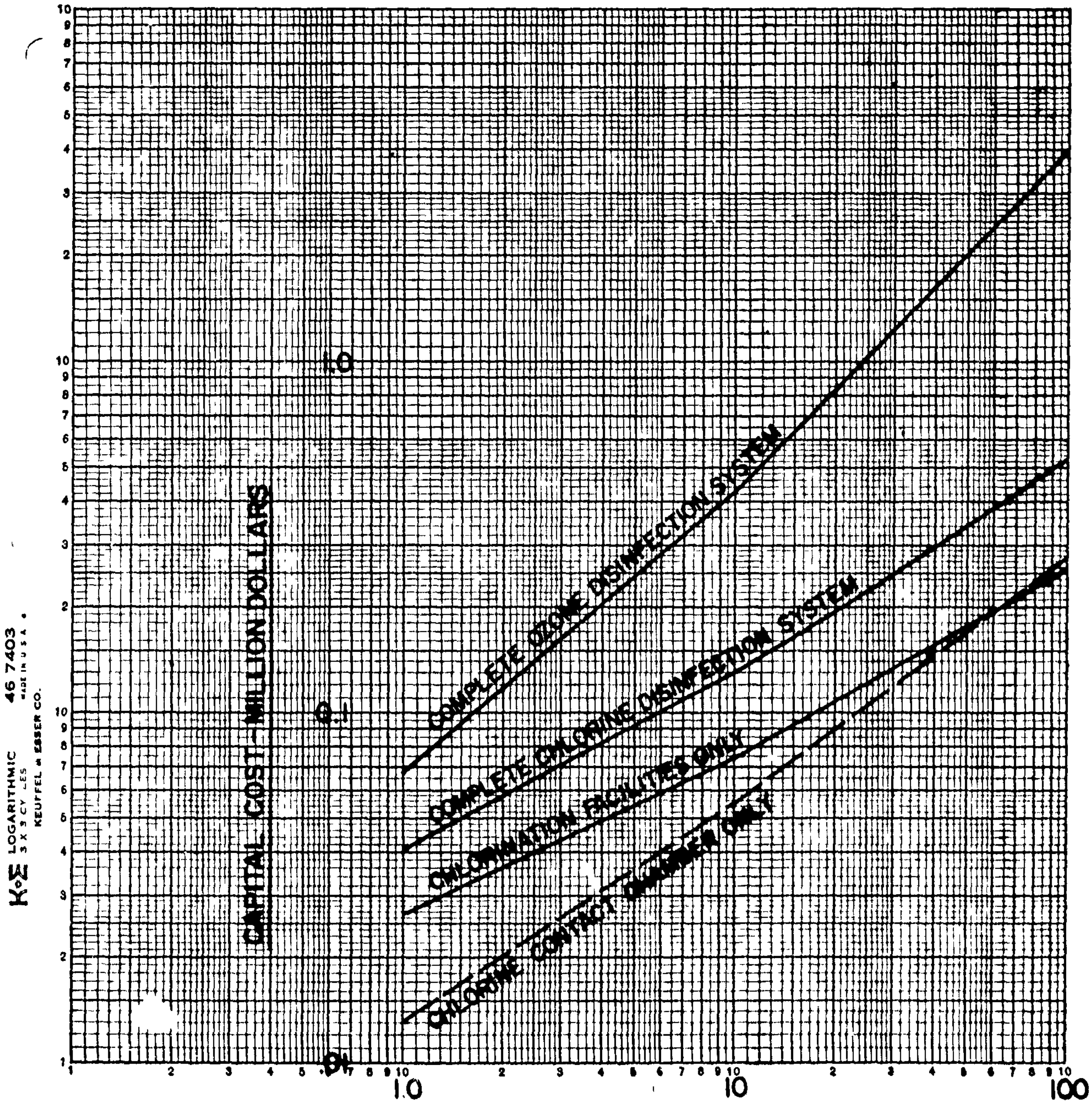
FIGURE C-2
CAPITAL COSTS
ADVANCED PHYSICAL-CHEMICAL
ELEMENTS



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE C-3
CAPITAL COSTS

DISINFECTION FACILITIES

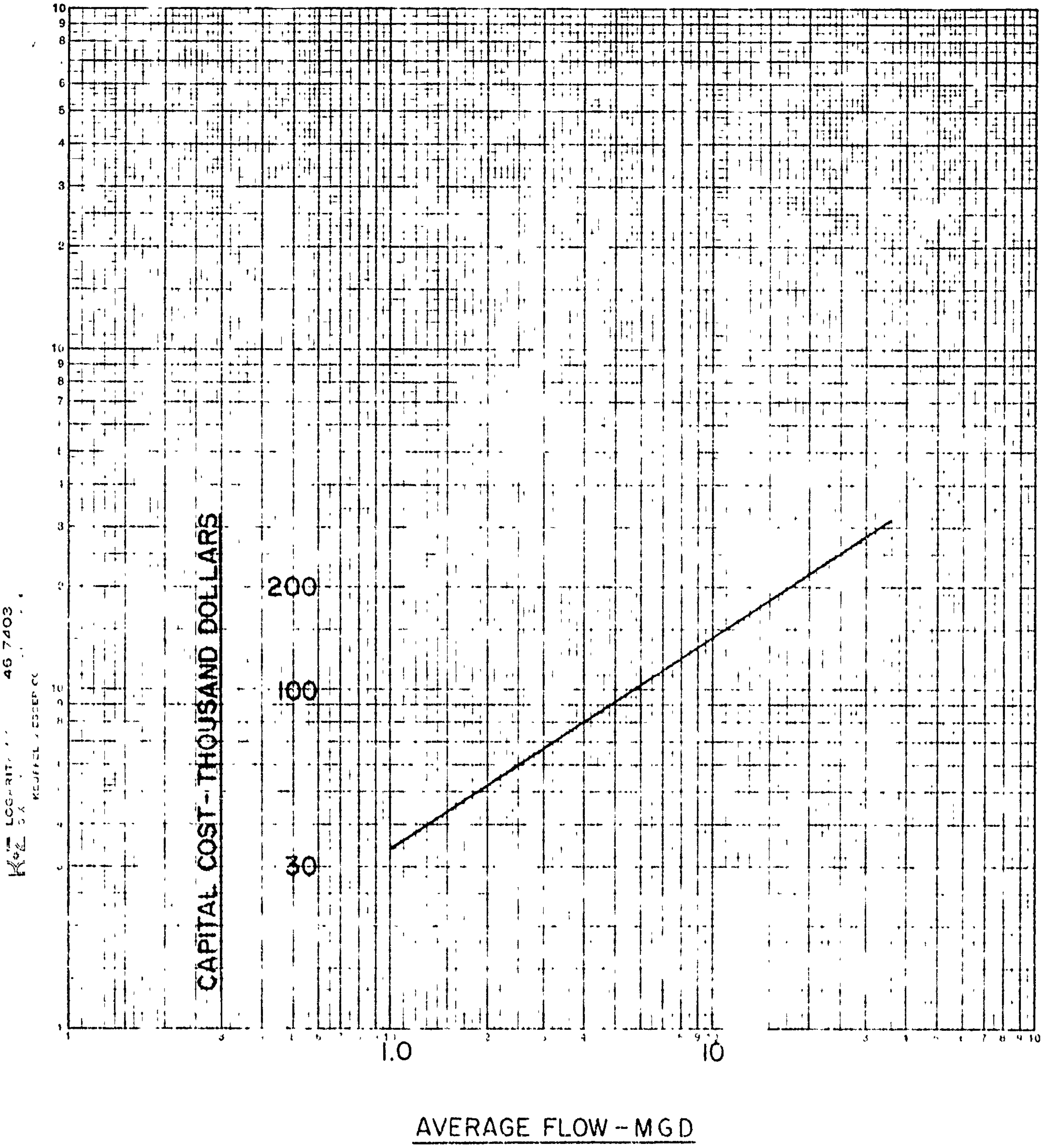


FLOW - MGD

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE C-4
CAPITAL COSTS

PRETREATMENT FOR LAGOONS



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE C-5
CAPITAL COSTS

LAGOONS

Earth dike lagoons in cells of 10 to 15 acres complete including earthwork, interconnecting piping, slope protection, dike top road paving, and fence.

	Lagoon Construction	
	Unit Cost, Dollars per Acre(3)	
Type	Based on Net Active Area	Based on Gross Site Area(1)
Five foot deep facultative	7,500	5,600
Ten foot deep aerated	12,000(2)	9,000(2)

(1) Gross area is 1.34 times active area.

(2) Not including aeration equipment. Floating propeller type electric motor driven aeration units priced at $800 per horsepower installed including all mechanical, electrical and structural work.

(3) Not including pretreatment elements of screening/grinding and measurement. For these elements see Figure C-4.

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
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FIGURE C-6
CAPITAL COSTS

LAND APPLICATION ELEMENTS

IRRIGATION

Distribution piping throughout the irrigation area from source point to a service point on each 40 acre subunit.	$800 per acre
Sprinkler piping and sprinklers within a 40 acre subunit based on solid set system.	$1700 per acre
Pumping to provide head necessary for distribution and residual at sprinkler head.	See Figure B-3
Storage reservoirs, including earth dam, outlet works and spillway.	Individual quantity and unit cost basis.

INFILTRATION-PERCOLATION

Complete ponds including site work, dikes, distribution and recirculation manifolds, pumping, inlet and outlet structures.	$18,267 per acre

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
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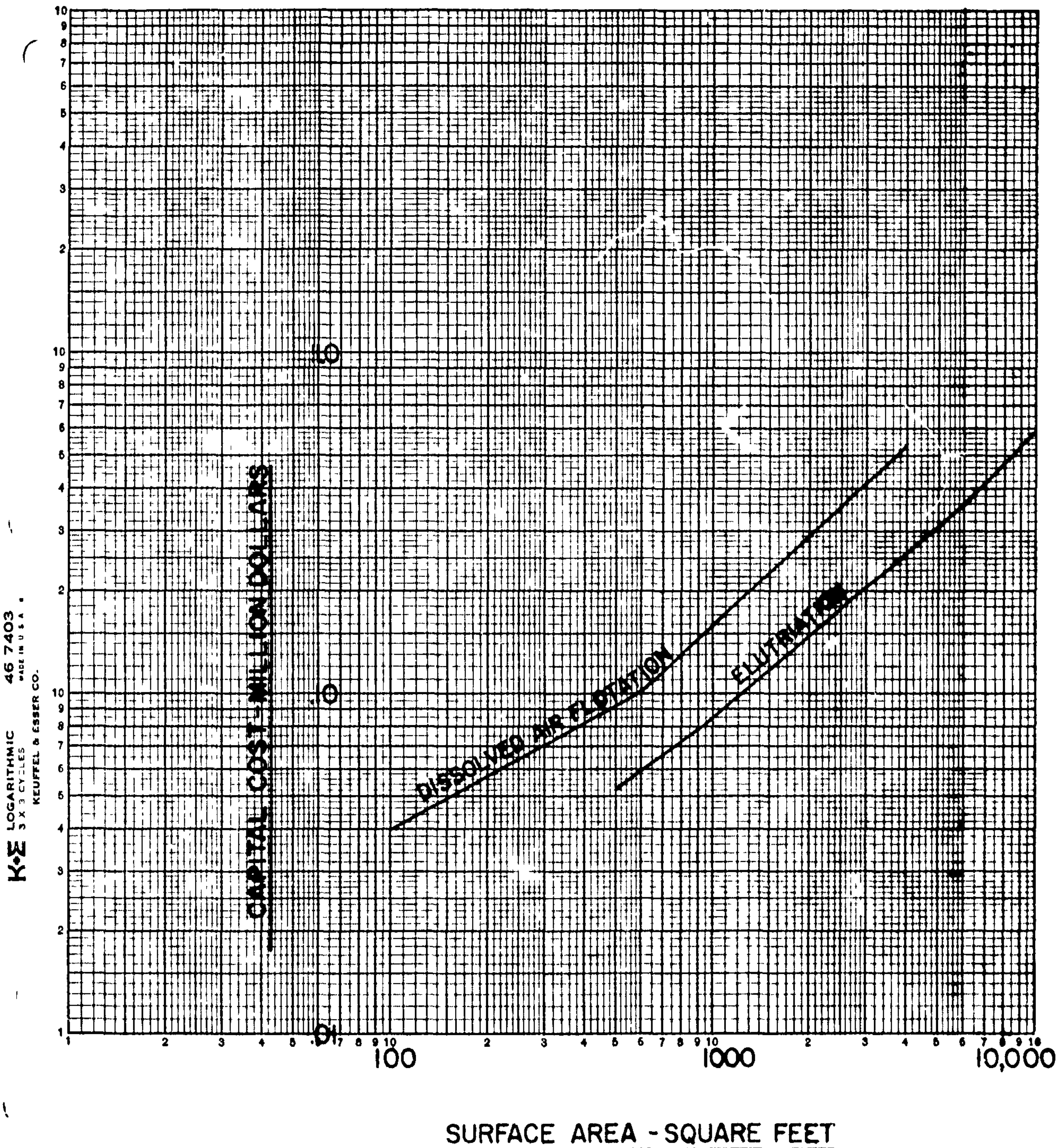
FIGURE D-1
CAPITAL COSTS

LIQUID SLUDGE CONCENTRATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
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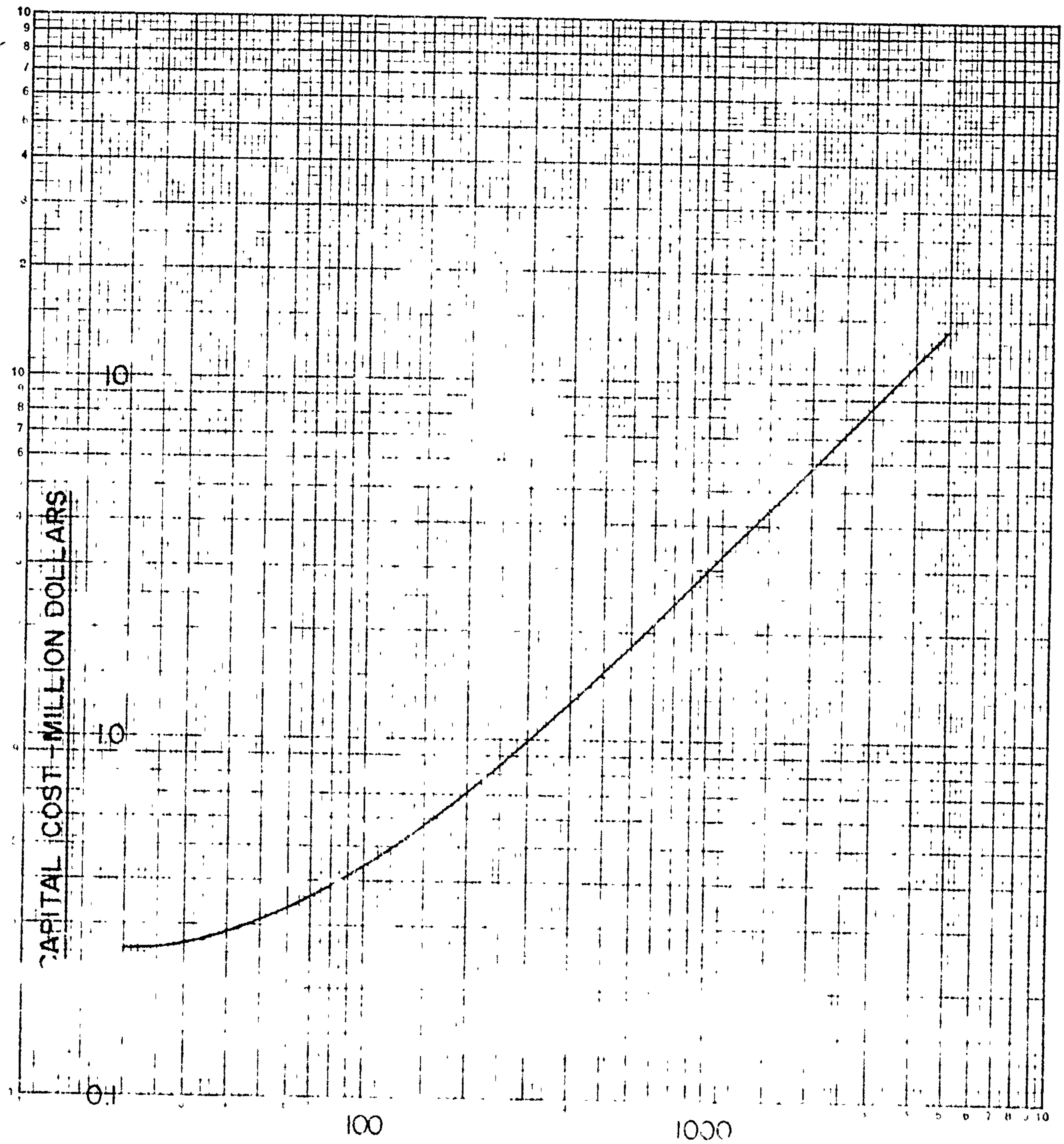
WPC STP INDEX - 202

FIGURE D-2
CAPITAL COSTS

ANAEROBIC DIGESTION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
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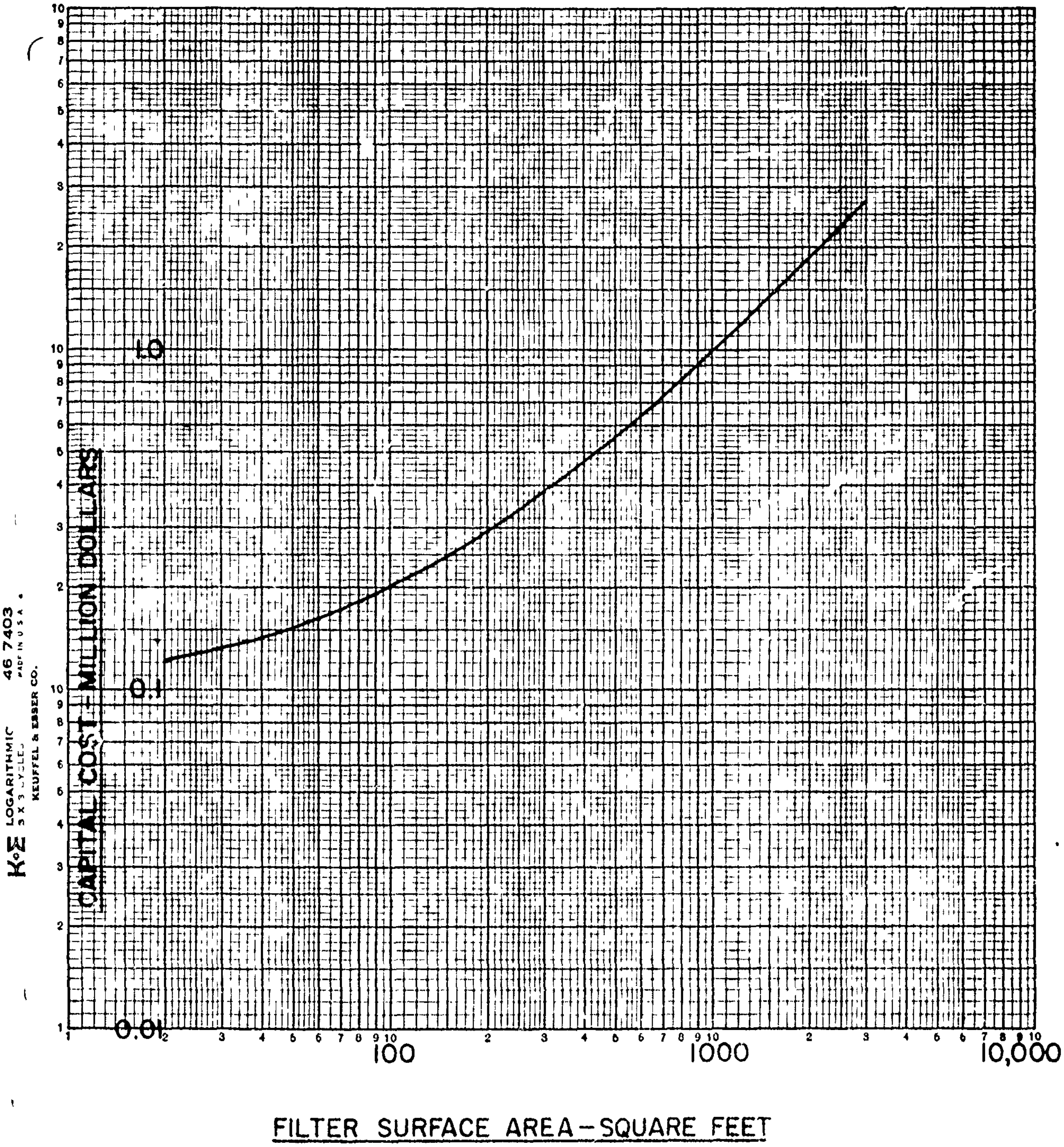
FIGURE D-3
CAPITAL COSTS

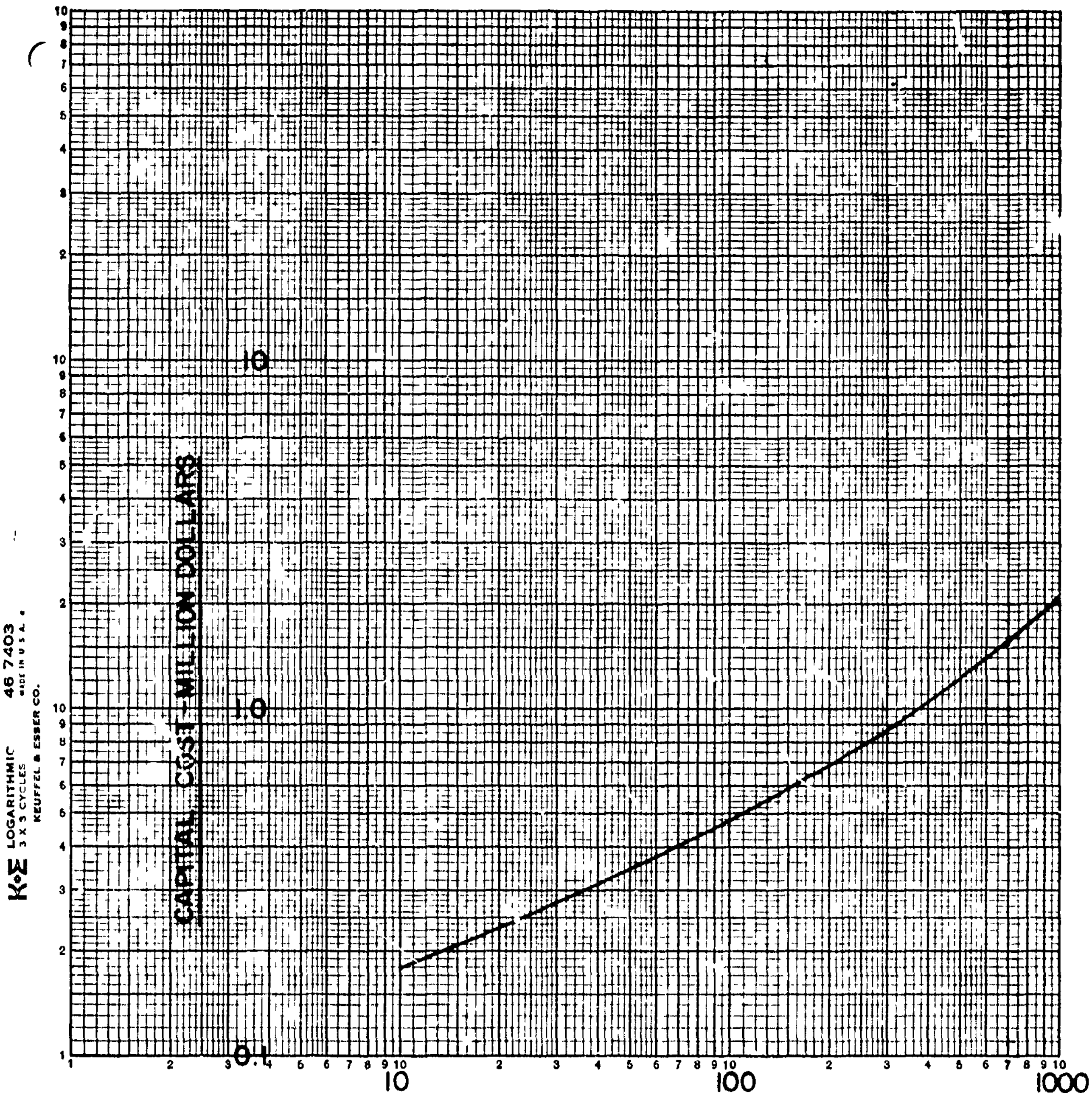
VACUUM FILTRATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE D-4
CAPITAL COSTS

CENTRIFUGATION

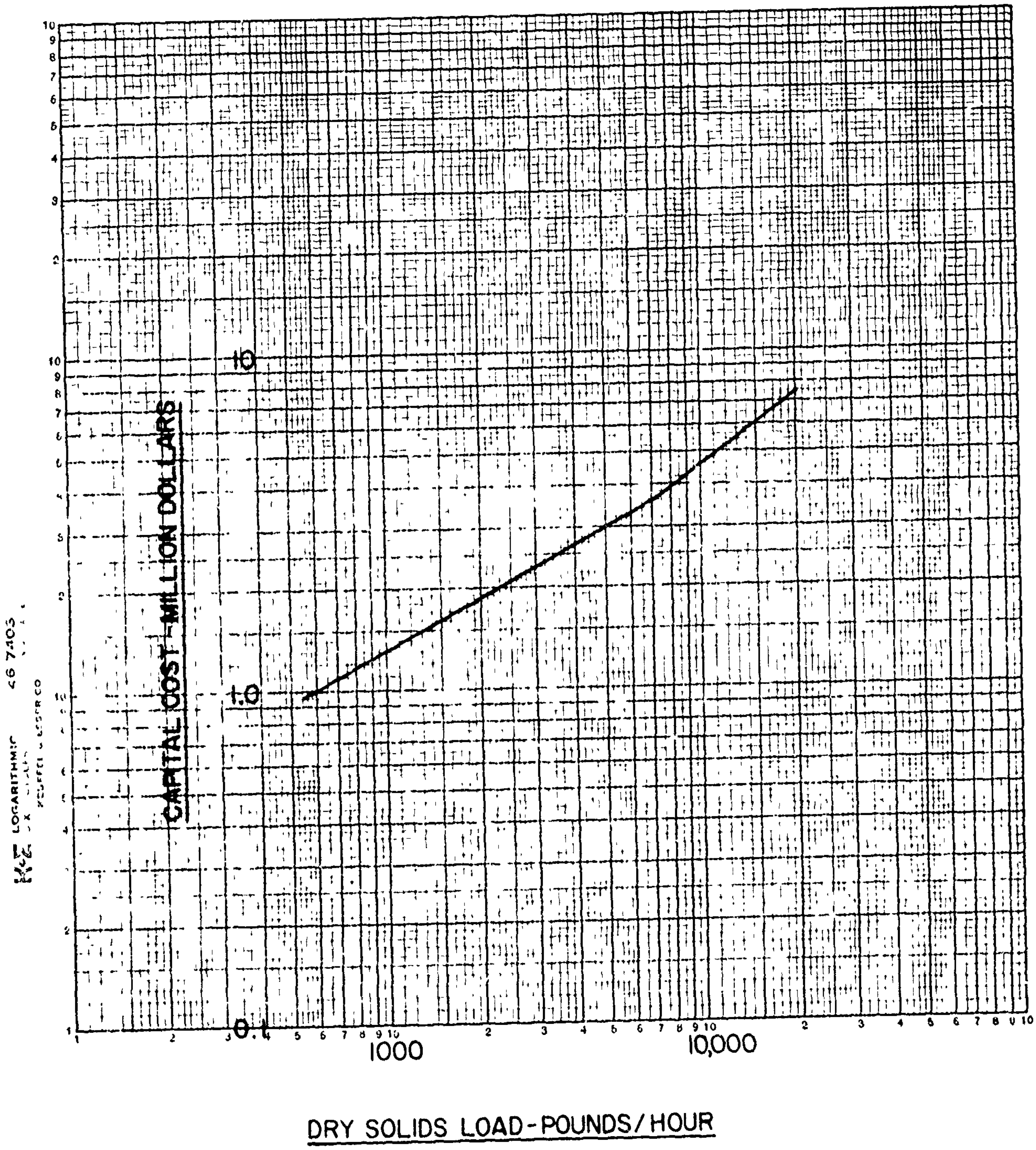


FIRM CAPACITY - GPM

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE D-5
CAPITAL COSTS

MULTIPLE HEARTH INCINERATION

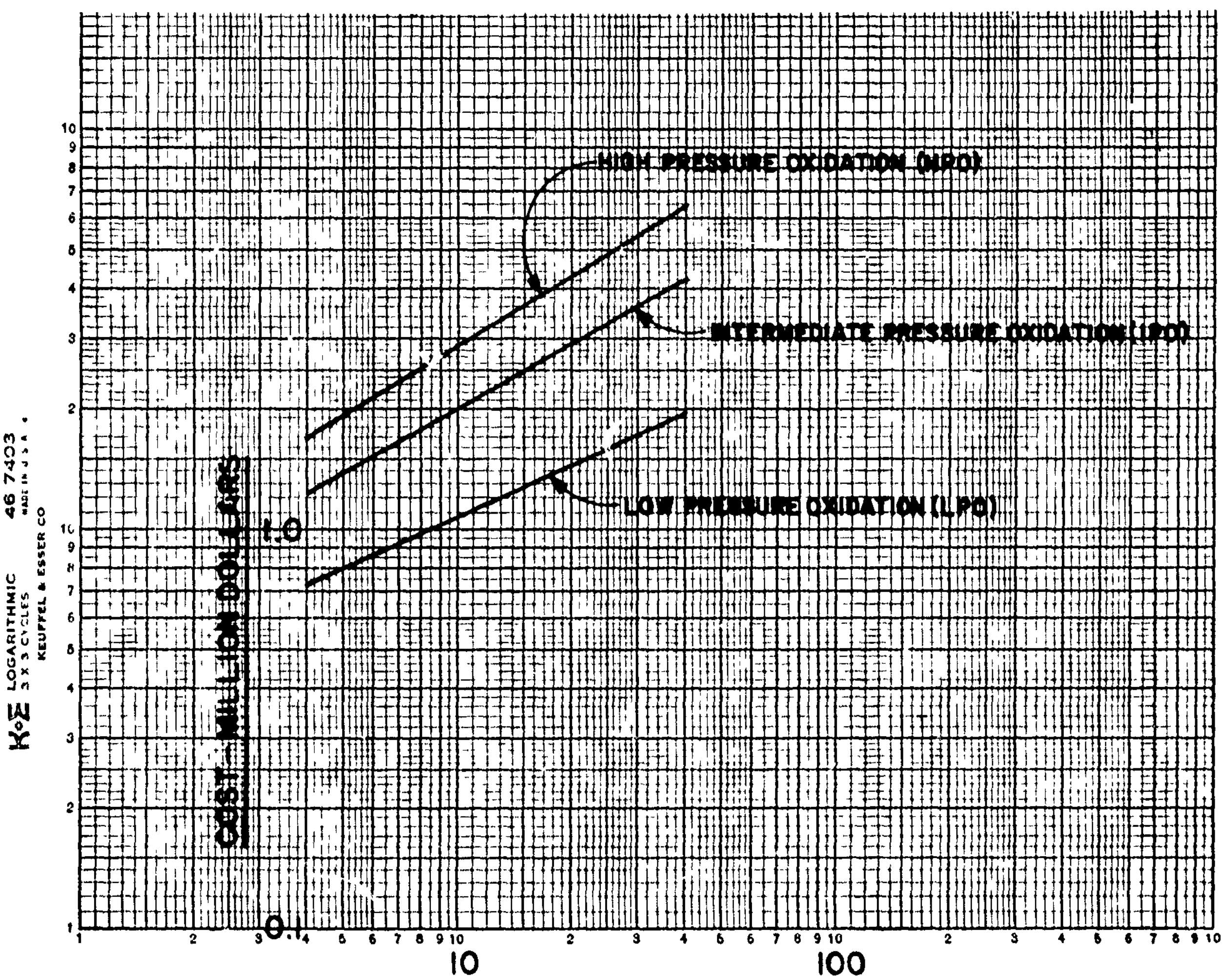


PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE D-6
CAPITAL COSTS
WET OXIDATION OF SLUDGE

NOTES:

1) for 4% feed of sludge with 75% volatiles
2) includes enclosing building
3) does not include separation of solids from effluent
4) LPO essentially no solids reduction, IPO 40% reduction, HPO 70% reduction



DRY SOLIDS - TONS/DAY

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
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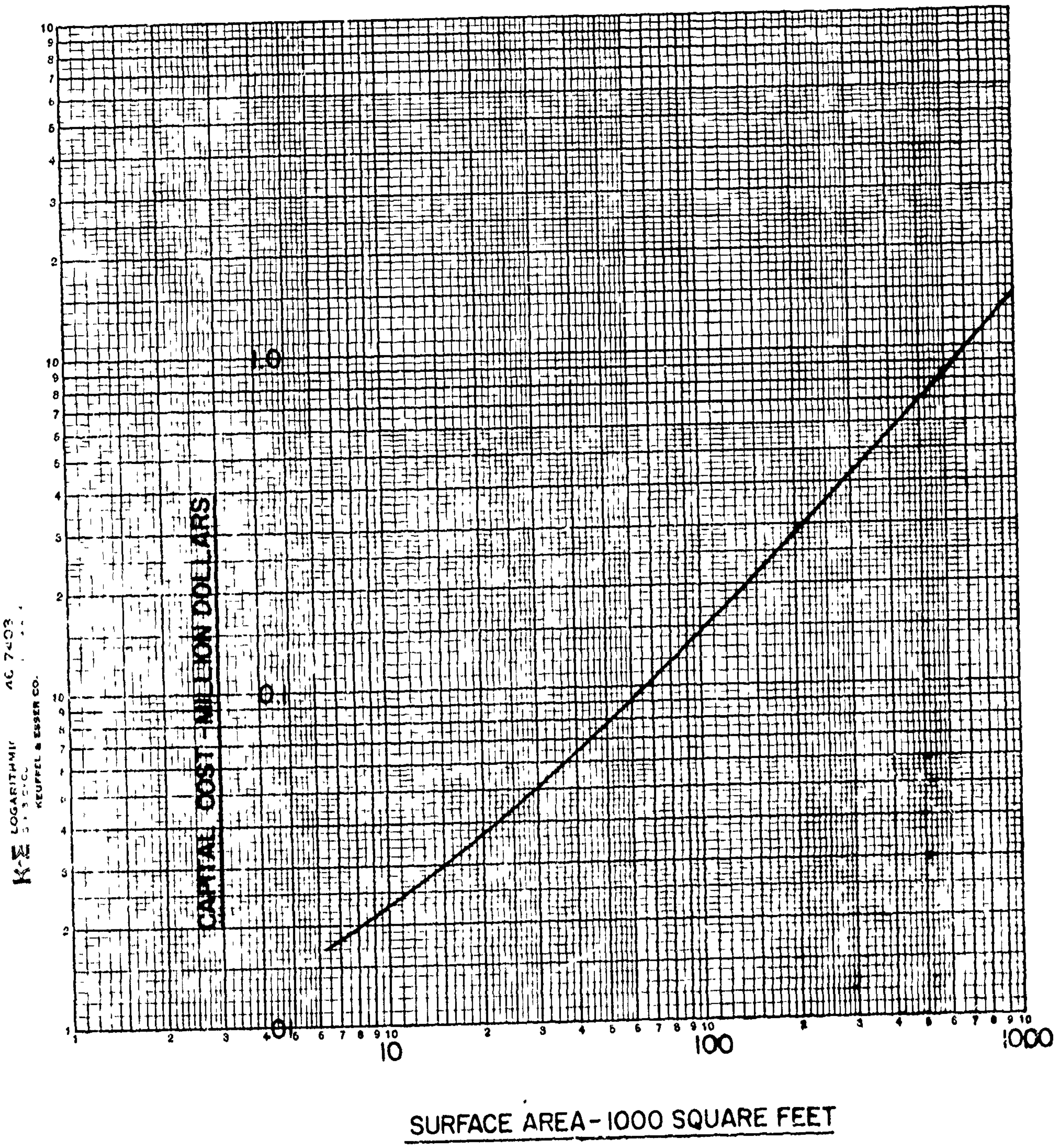
FIGURE D-7
CAPITAL COSTS
AIR DRYING BEDS



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX 2000
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FIGURE D-8
CAPITAL COSTS
SLUDGE FORCE MAINS

Pipe Size (Inches)	Number	Installed Cost, Dollars per Foot	
		Undeveloped Areas	Developed Areas
6	Single	7.33	12.21
6	Double	13.35	20.14
8	Single	10.44	16.17
8	Double	19.32	26.53
10	Single	13.42	19.41
10	Double	23.99	31.44

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
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WPC - S INDEX - 216

FIGURE D-9
CAPITAL COSTS
LAND APPLICATION ELEMENTS

Element	Capital Cost Basis
SLUDGE STORAGE BASINS Earth diked, lined, 10' deep	$4,100 per acre foot
DREDGE Self contained floating dredge, diesel powered, winch controlled	Refer to Figure D-10
SLUDGE STORAGE TANKS Concrete, open, at STP sites	Price as concrete equaling storage without pumping Figure B-4
DISTRIBUTION PIPING	Refer to Figure B-2
FIELD APPLICATION	No capital costs. Considered as a subcontract where O & M includes ownership costs to the subcontractor. Refer to Figure I-4

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
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CURVE [illegible]-10
CAPITAL COSTS
SLUDGE DREDGES

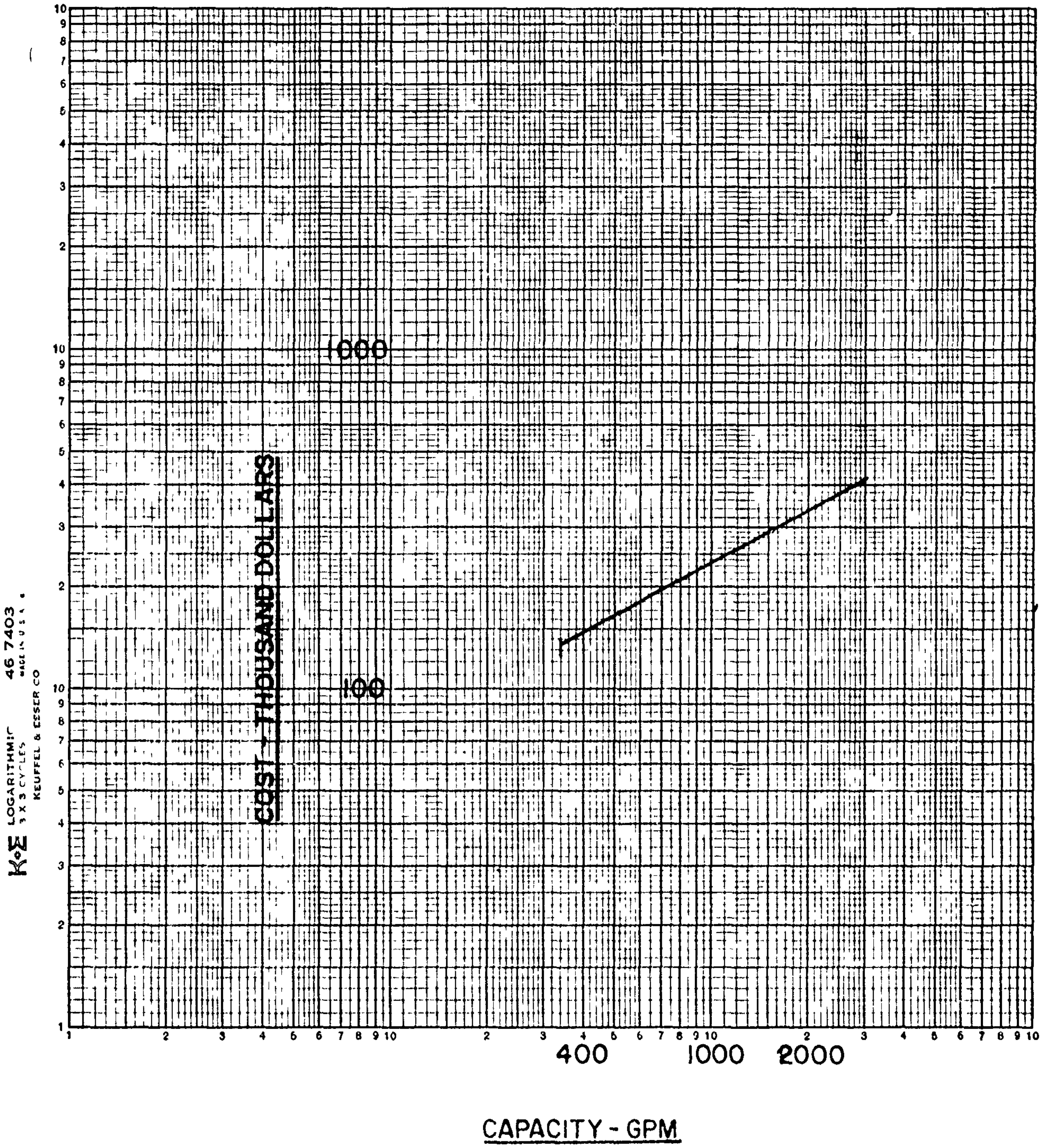


FIGURE E-1

LAND AREA REQUIREMENT FOR MISCELLANEOUS FACILITIES

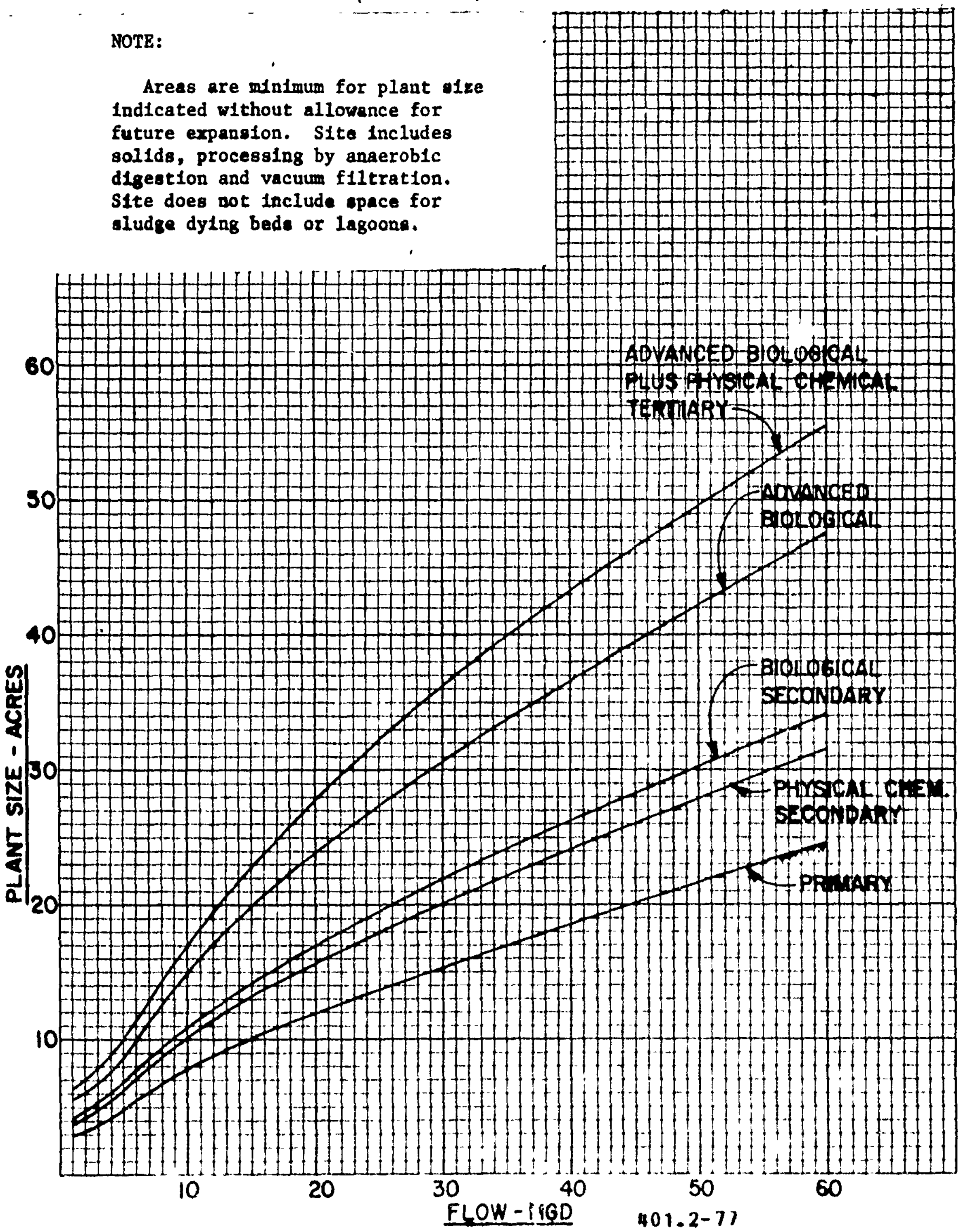
Element	Basis for Site Requirement
PUMPING FACILITIES	
Plants 10 mgd and less	2500 sq. feet
Plants over 10 mgd	2500 sf. plus 100 sf per mgd over 10
EQUALIZING STORAGE	0.3 acres per mg
TREATMENT FACILITIES	See Figure E-2
LAGOONS	Net area x 1.34
IRRIGATED LAND	Net area x 1.15
DAMS	Area at dam crest for year 2020 requirements x 1.05
INFILTRATION-PERCOLATION PONDS	Net area x 1.25
SANITARY LANDFILL	.00032 acres per cubic yard of sludge cake

FIGURE E-2
LAND AREA REQUIREMENTS

FOR TRF TMENT FACILITIES

NOTE:

Areas are minimum for plant size indicated without allowance for future expansion. Site includes solids, processing by anaerobic digestion and vacuum filtration. Site does not include space for sludge dying beds or lagoons.



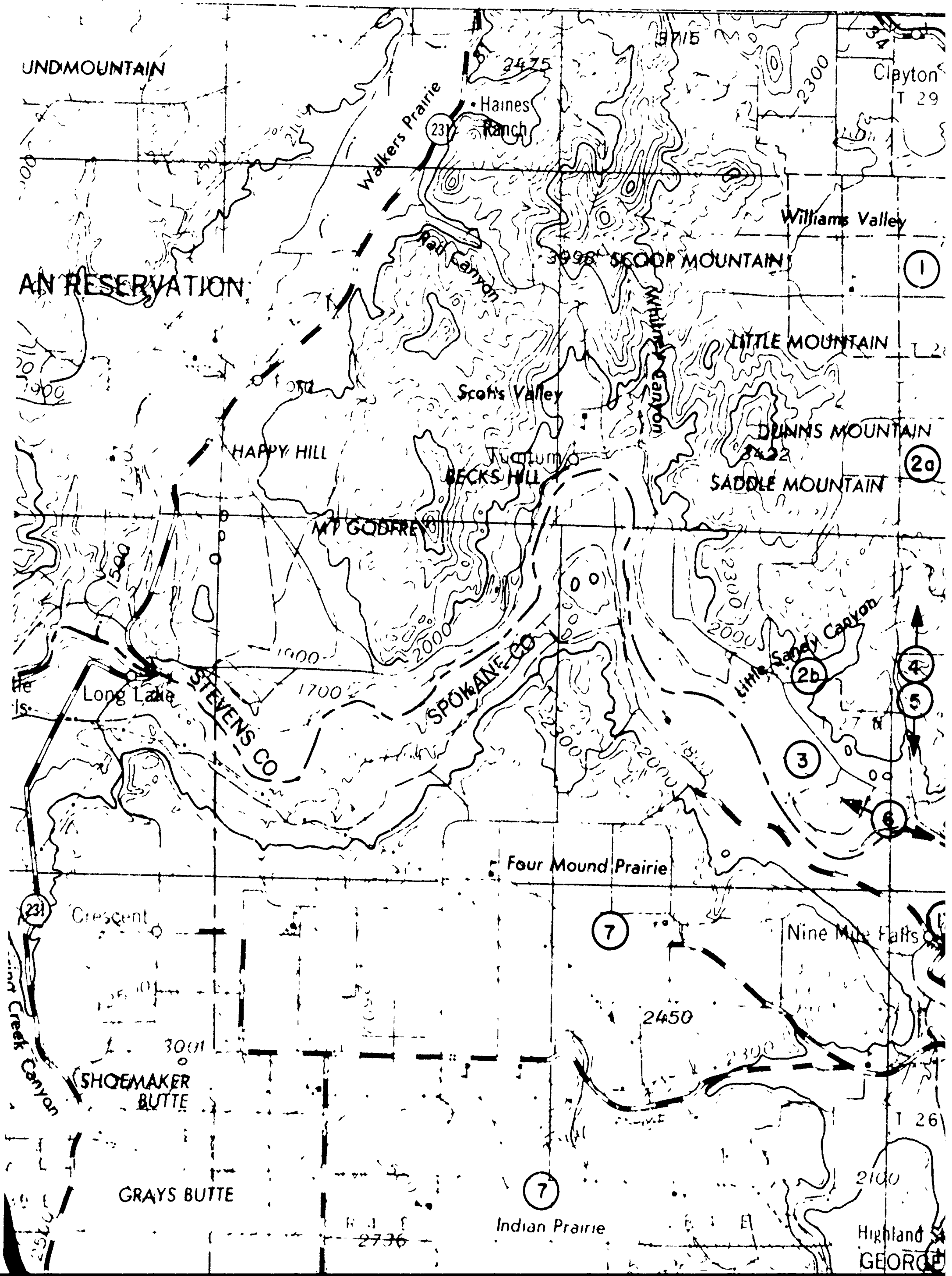
401.2-77

PRICE LEVEL:
MID 1974

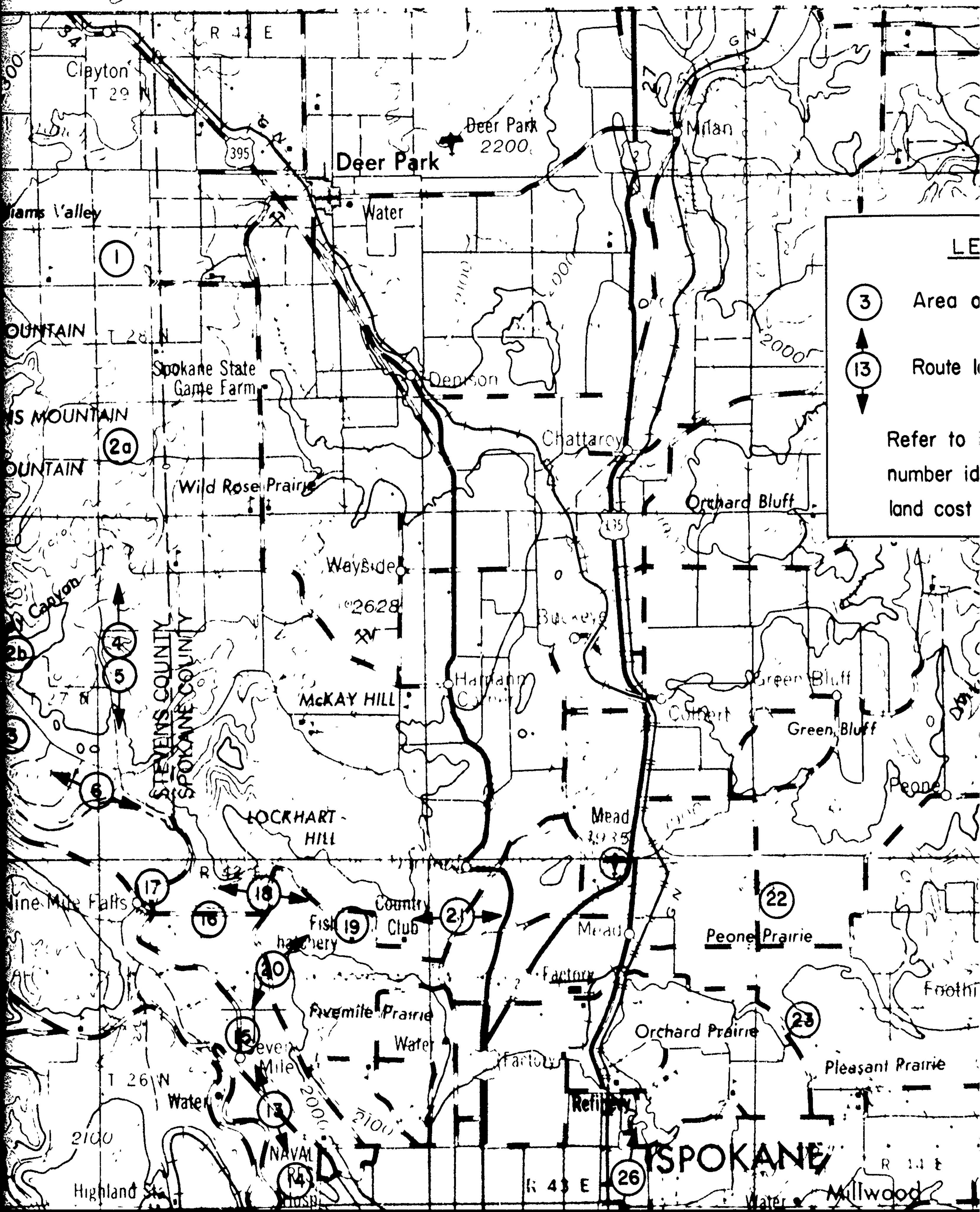
FIGURE E-3
LAND COSTS

Map Symbol (4)	Location	Potential Wastewater Function	Average Assessed Value	Nominal Market Value	Estimated Actual Market Price
1	Williams Valley	Irrigation	$300/Ac.	$375/Ac.	$ 700/Ac.
2a	Dunns Mountain	Reservoir	300/Ac.	375/Ac.	300/Ac.
2b	Sandy Canyon	Reservoir	300/Ac.	375/Ac.	300/Ac.
3	Terrace-North Shore of Long Lake	Infiltration	300/Ac.	375/Ac.	2,000/Ac.
4	Route-Mouth of L.S.R. to 2a	Pipe R/W(1)	3/Rod	3.75/Rod	3.75/Rod
5	Along Route of 4	Pump Sta(2)	600/Site	750/Site	750/Site
6	Route-Mouth of L.S.R. to 2b or 3	Pipe R/W	3/Rod	3.75/Rod	4.00/Rod
7	Indian Prairie & Espanola	Irrigation	250/Ac.	313/Ac.	1,000/Ac.
8	Any channeled scablands	Sludge Disp(3)	50/Ac.	63/Ac.	60/Ac.
9	North of Airway Heights	Irrigation	200/Ac.	250/Ac.	250/Ac.
10	Between Fairchild AFB & Spokane Int.	Irrigation	125/Ac.	156/Ac.	250/Ac.
11	Old Trails Road Canyon	Reservoir	240/Ac.	300/Ac.	300/Ac.
12	Route-City STP to Old Trails	Pipe R/W	3/Rod	3.75/Rod	5/Rod
13	Route-City STP to Mouth L.S.R.	Pipe R/W	3/Rod	3.75/Rod	6/Rod
14	Southwest of Nine Mile Road at Francis	P.S. & E.S.(5)	60/Ac.	75/Ac.	2,000/Ac.
15	West of Nine Mile Road at Seven Mile	P.S. & E.S.(5)	320/Ac.	400/Ac.	2,000/Ac.
16	Rutter Parkway between Indian Trail & Nine Mile	Infiltration	200/Ac.	250/Ac.	2,000/Ac.
17	Hwy 291 at Little Spokane River	Pump Sta	500/Ac.	625/Ac.	1,500/Ac.
18	Route-Fairwood Lagoon to Mouth L.S.R.	Pipe R/W	6/Rod	7.50/Rod	7.50/Rod
19	Fish Hatchery Vicinity	Treatment	500/Ac.	625/Ac.	4,000/Ac.
20	Route-Fish Hatchery to Nine Mile	Pipe R/W	6/Rod	7.50/Rod	7.50/Rod
21	Route-Fish Hatchery to Peone Prairie	Pipe R/W	3/Rod	3.75/Rod	4.00/Rod
22	Peone Prairie	Irrigation	250/Ac.	313/Ac.	500/Ac.
23	Bruce Road Canyon	Reservoir	300/Ac.	375/Ac.	1,000/Ac.
24a	Mission at Upriver Drive	Pump Sta	360/lot	450/lot	450/lot
24b	Greene Street at Marshall	Pump Sta	200/lot	250/lot	1,500/lot
25	Felts Field, NE corner	Treatment	40/Ac.	50/Ac.	2,000/Ac.
26	Route through Emeralda Golf	Pipe R/W	6/Rod	7.50/Rod	7.50/Rod
27	Canfield Gulch	Reservoir	400/Ac.	500/Ac.	1,000/Ac.
28	Saltese Flats	Reservoir	100/Ac.	125/Ac.	500/Ac.
29	East Valley	Irrigation	750/Ac.	938/Ac.	1,000/Ac.

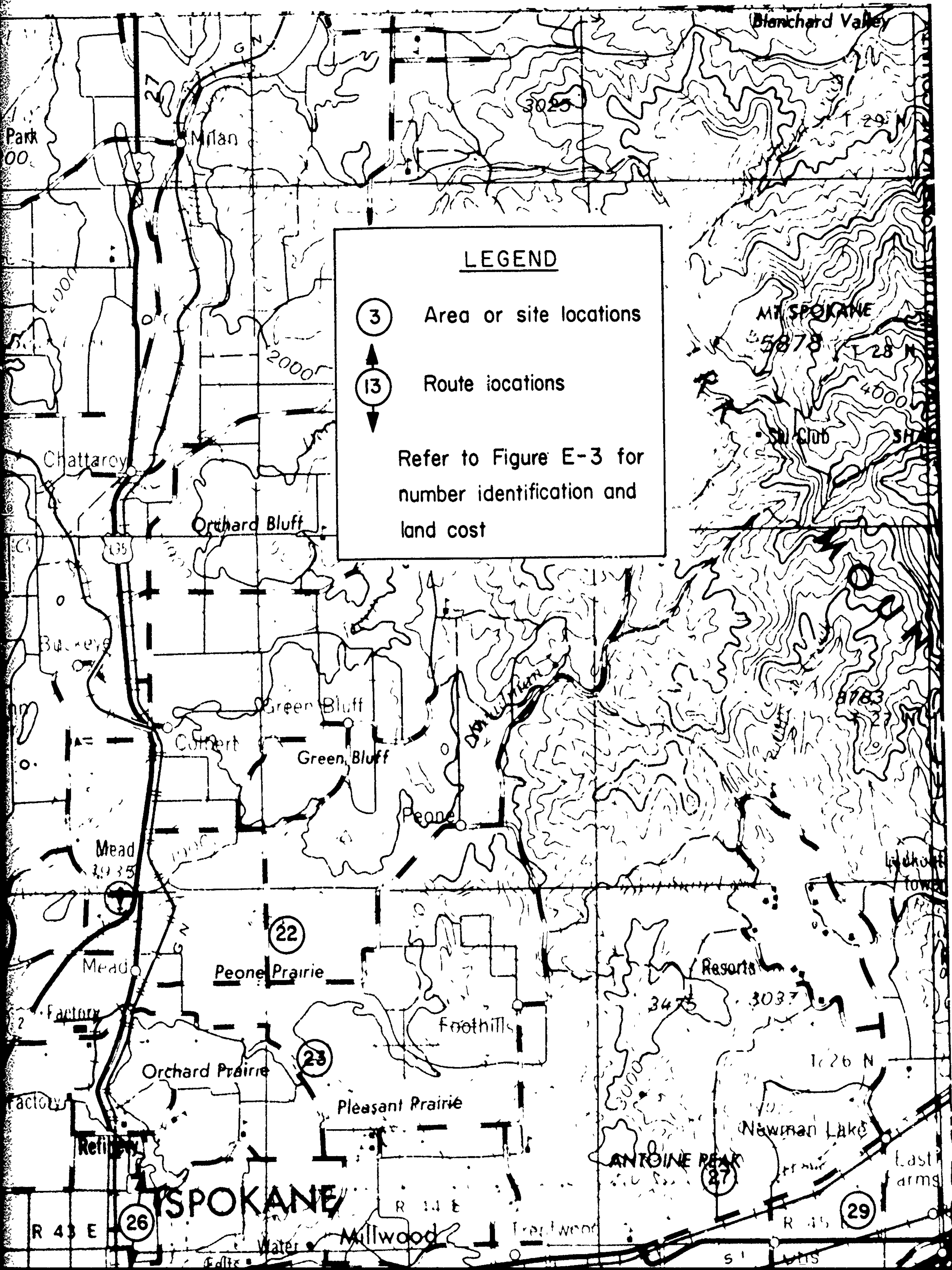
(1) Pipe R/W - Right-of-way for pipeline where not in a public road. One Rod = 16.5 feet.
(2) Pump Sta. - A small parcel of land appropriate for a pump station site which would not be purchased on acreage basis.
(3) Sludge Disposal - As liquid or dried cake.
(4) Refer to Figure E-4 for locations.
(5) Site for pump station and equalizing storage.

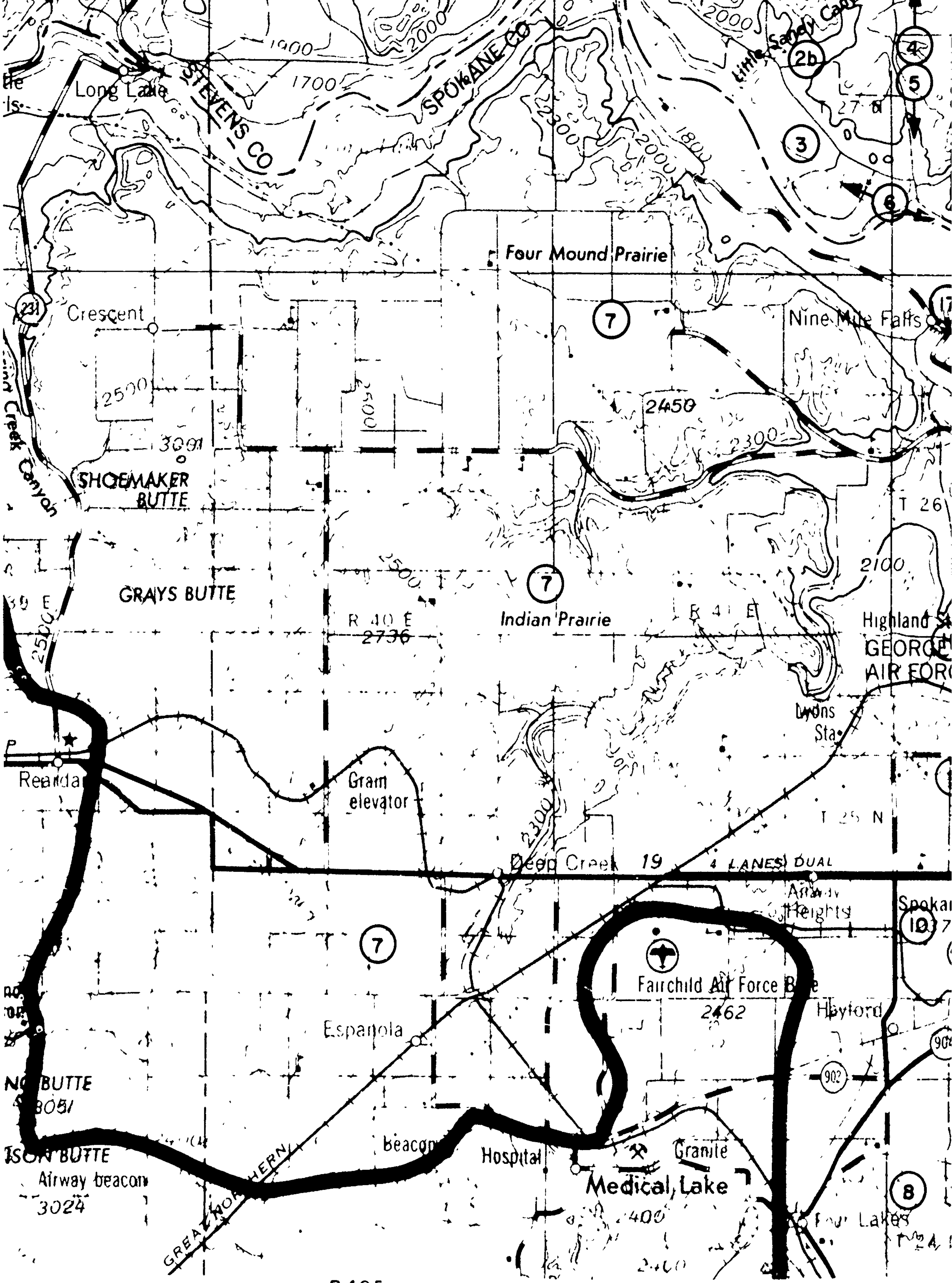


UNDMOUNTAIN
Walkers Prairie
Haines Ranch
231
3715
2475
2300
Clayton
T 29
Williams Valley
AN RESERVATION
Rail Canyon
3998
SCOOP MOUNTAIN
1
LITTLE MOUNTAIN
Scotts Valley
HAPPY HILL
DUNNS MOUNTAIN
BECKS HILL
SADDLE MOUNTAIN
2a
MT GODFREY
1500
2000
1900
1700
Little Sandy Canyon
2b
4
5
3
6
Long Lake
STEVENS CO
SPOKANE CO
Four Mound Prairie
7
Crescent
Nine Mile Falls
2450
SHOEMAKER BUTTE
T 26
2100
GRAYS BUTTE
Indian Prairie
2736
Highland



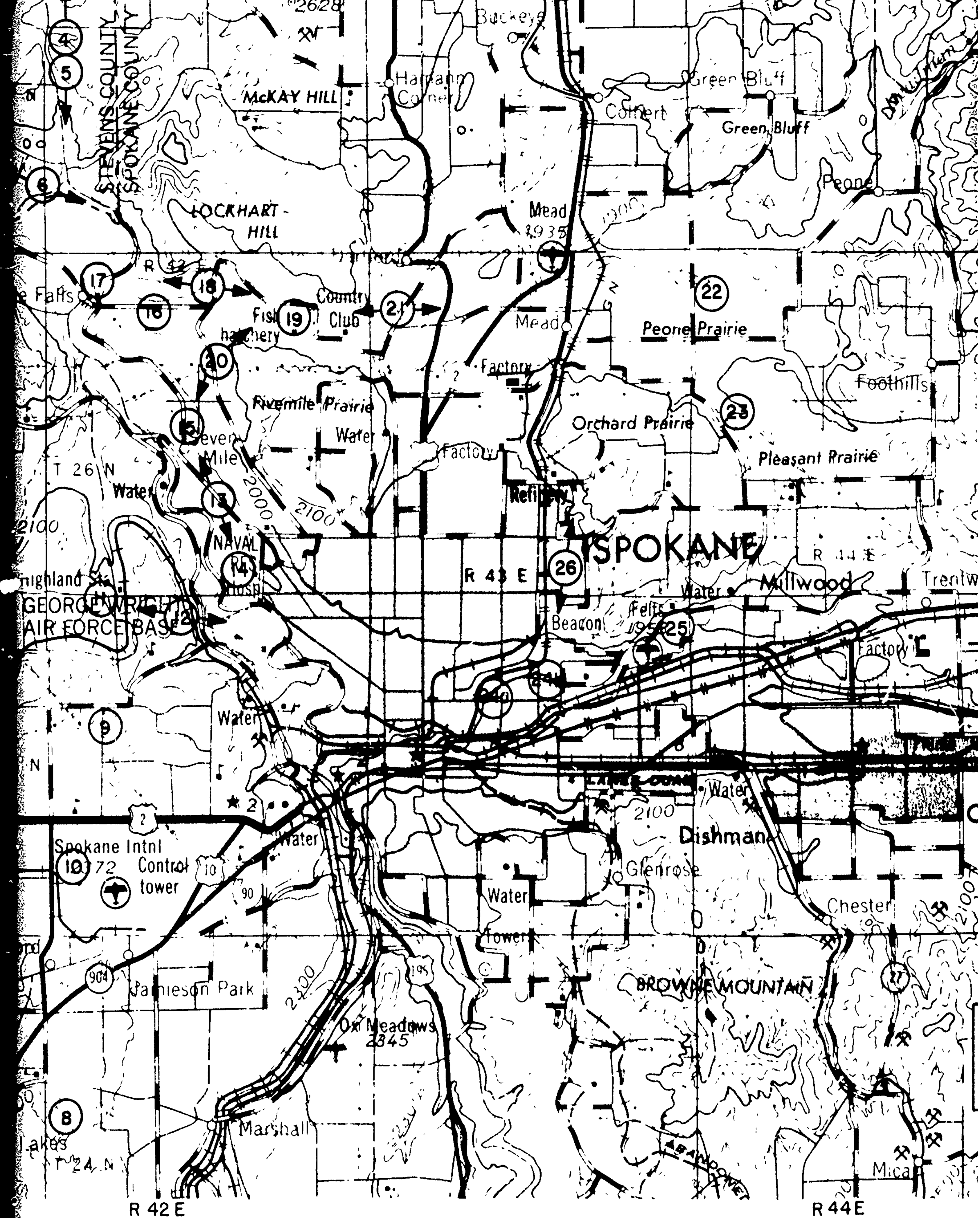
R 42 E
Clayton
T 29 N
395
Deer Park
Deer Park
2200
Milan
Water
LE
Area o
Route l
Refer to
number id
land cost
MOUNTAIN
T 28 N
Spokane State
Game Farm
Denison
2000
MOUNTAIN
MOUNTAIN
Chattaroy
Wild Rose Prairie
Orchard Bluff
Wayside
2628
Buckeye
Canyon
STEVENS COUNTY
SPOKANE COUNTY
T 27 N
McKAY HILL
Colbert
Green Bluff
Green Bluff
Peone
LOCKHART
HILL
Mead
1935
Nine Mile Falls
Country
Club
Fish
hatchery
Mead
Peone Prairie
Factory
Fivemile Prairie
Water
Orchard Prairie
Foothi
Seven
Mile
Pleasant Prairie
T 26 N
Water
Refinery
2100
2100
2000
NAVAL
SPOKANE
Highland
R 43 E
R 44 E
Water
Millwood
1
2a
2b
3
4
5
6
13
14
15
16
17
18
19
20
21
22
23
26


LEGEND
3 Area or site locations
13 Route locations
Refer to Figure E-3 for number identification and land cost
Blanchard Valley
Milan
T 29 N
MT SPOKANE
5878
T 28 N
Ski Club
Chattaroy
Orchard Bluff
Buckeye
Green Bluff
Colbert
Peone
Mead
22
Peone Prairie
Foothills
Resorts
3475
3037
23
Orchard Prairie
Pleasant Prairie
Factory
Refinery
T 26 N
Newman Lake
ANTOINE PEAK
27
29
SPOKANE
26
R 43 E
Millwood
Water



Long Lake
STEVENS CO
SPOKANE CO
Little Sandy Canyon
1900
2000
1700
1800
2b
4
5
3
6
Four Mound Prairie
Crescent
231
7
Nine Mile Falls
2500
2450
2300
3001
SHOEMAKER BUTTE
T 26
2100
GRAYS BUTTE
R 40 E
2736
Indian Prairie
R 41 E
Highland
Lyons Sta
Reardan
Grain elevator
T 25 N
Deep Creek
19
4 LANES DUAL
Airway Heights
Spokane
10
Fairchild Air Force Base
2462
Espanola
Hayford
902
904
BUTTE
3051
BUTTE
Airway beacon
3024
Beacon
Hospital
Granite
Medical Lake
8
Four Lakes
GREAT NORTHERN

R40E



STEVENS COUNTY
SPOKANE COUNTY
McKAY HILL
LOCKHART HILL
Buckeye
Hamann Corner
Colbert
Green Bluff
Peone
Mead
1935
Falls
Country Club
Fish hatchery
Peone Prairie
Foothills
Factory
Fivemile Prairie
Water
Orchard Prairie
Pleasant Prairie
Seven Mile
T 26 N
2100
2000
Refinery
NAVAL
SPOKANE
R 43 E
R 44 E
Millwood
Trentw
Highland
GEORGE WRIGHT AIR FORCE BASE
Beacon
Felts
Dishman
Glenrose
Chester
Spokane Intnl
Control tower
Tower
BROWNE MOUNTAIN
Jamieson Park
Ox Meadows
2345
2300
Marshall
Lakes
T 24 N
Mica
R 42E
R 44E

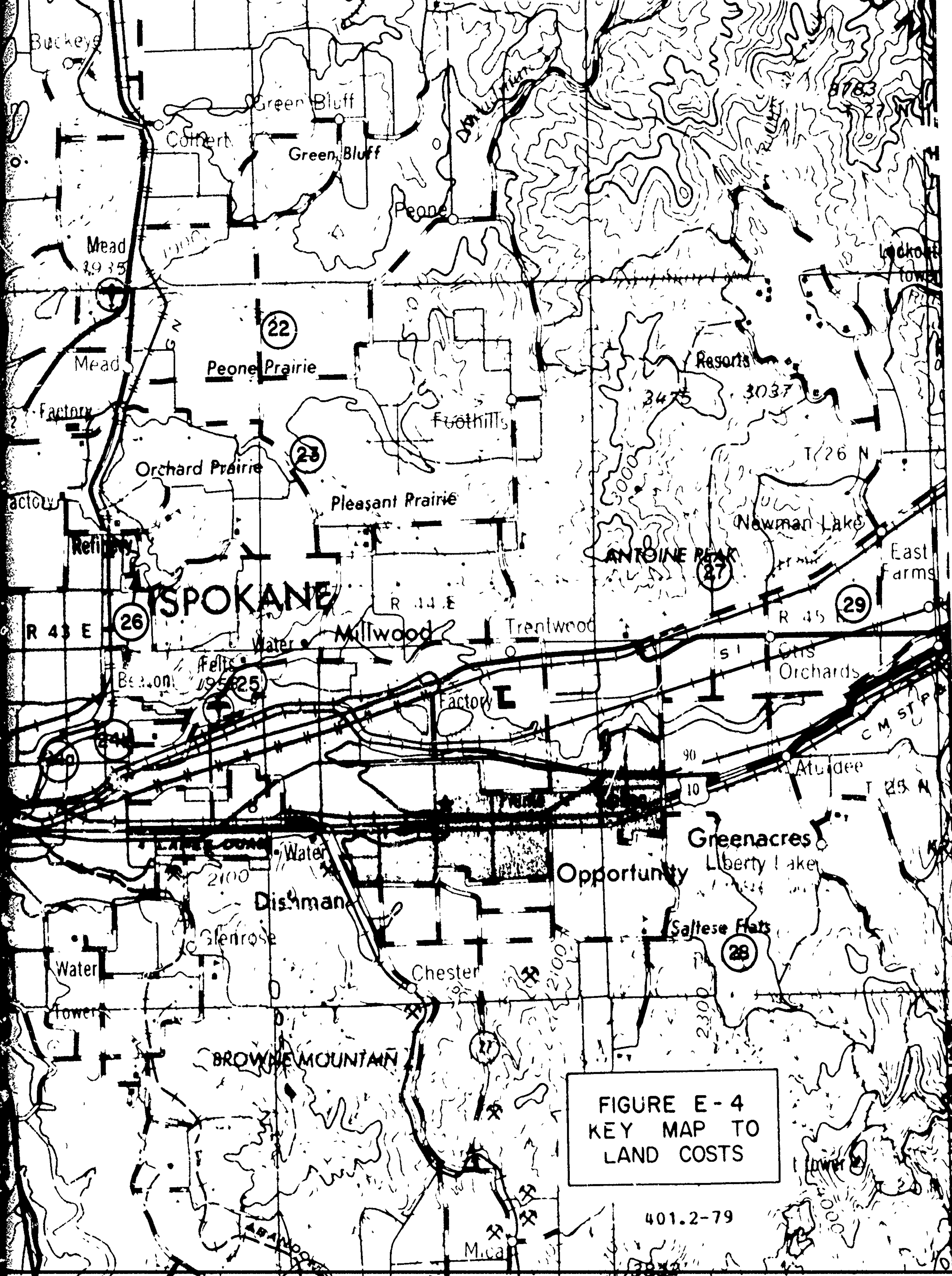


FIGURE E-4
KEY MAP TO
LAND COSTS

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MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

CAPITAL COSTS

LIQUID SLUDGE CONCENTRATION

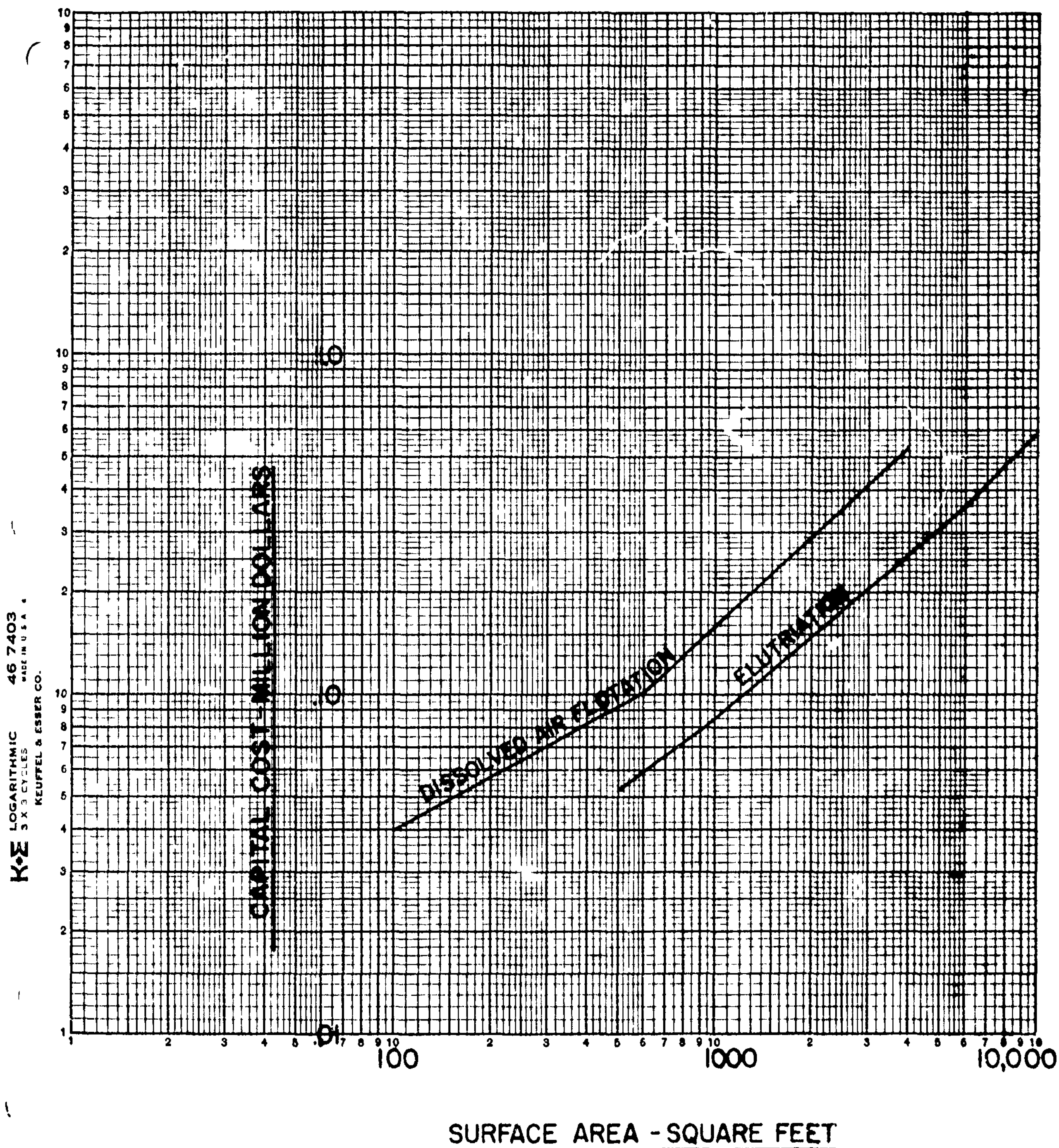

FIGURE G-1
OPERATION AND MAINTENANCE COSTS

CONVEYANCE FACILITIES

Element	Annual O&M Cost Basis
GRAVITY SEWERS AND FORCE MAINS	0.5 percent of capital cost
PUMP STATIONS	
For other than electrical energy component	Figure G-2
For electrical energy component	Figure G-3
EQUALIZING STORAGE	
For raw sewage storage	5 percent of capital cost
For treated effluent storage	1 percent of capital cost

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR LEVEL - 2000
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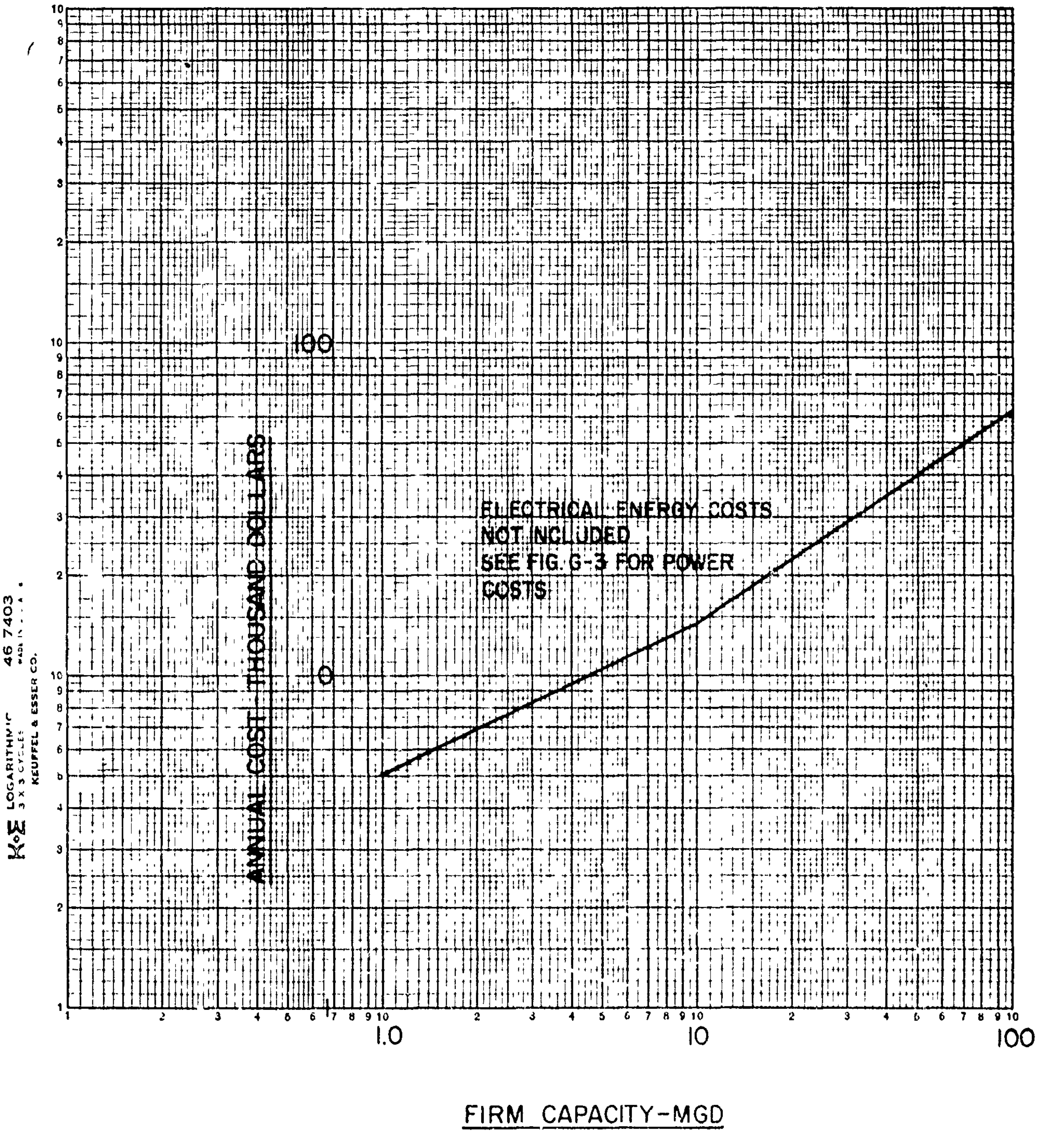
FIGURE G-2
OPERATION AND MAINTENANCE COSTS

PUMP STATIONS



PRICE LEVEL:
MID 1974

FIGURE G-3
OPERATING COSTS

ELECTRICAL ENERGY FOR PUMPING

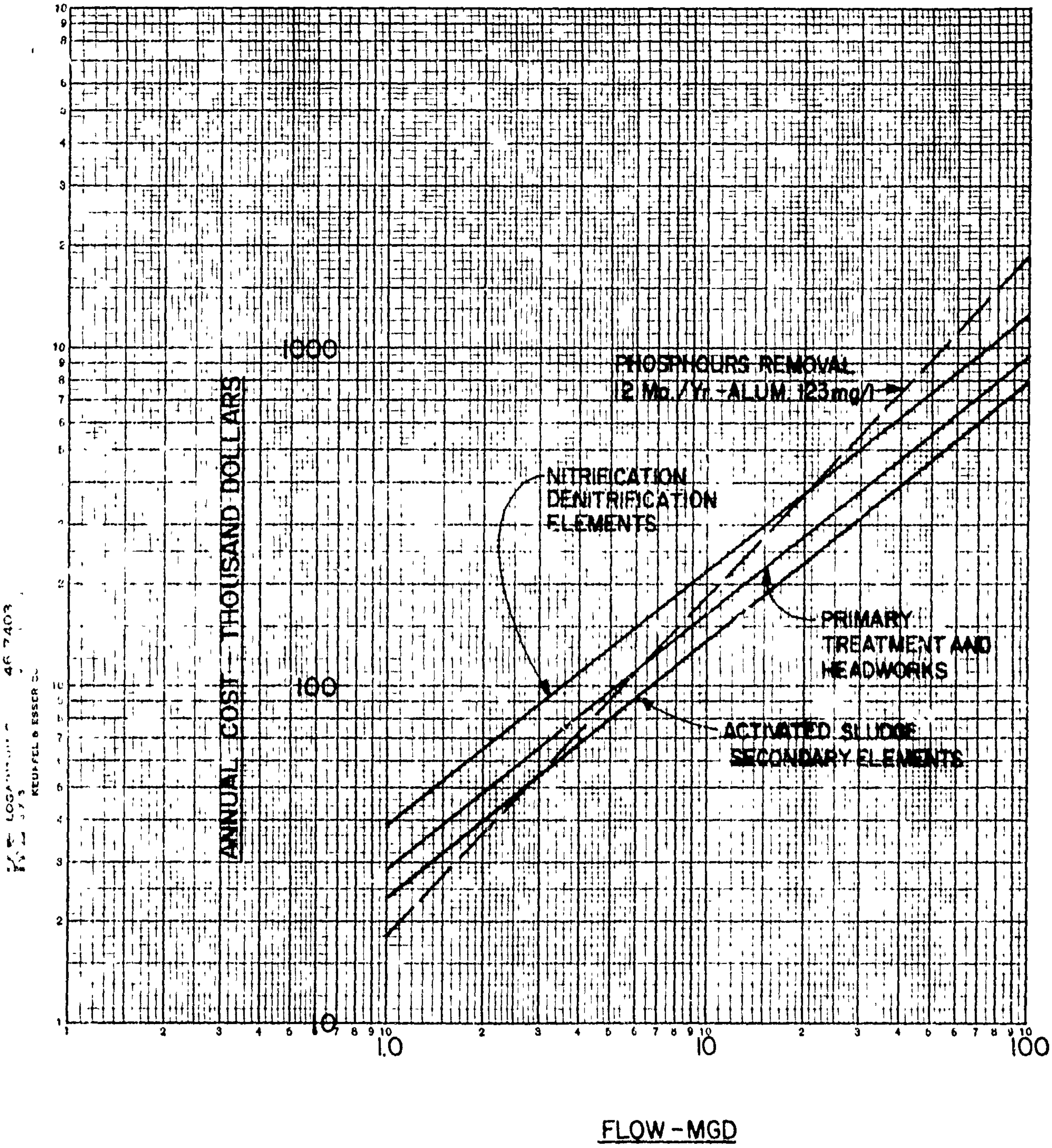
Annual Use Range 10^6 kwh	Energy Cost--Dollars per kwh
0 to 0.300	0.010*
Over 0.3 to 0.6	0.008*
Over 0.6 to 20.0	0.007*
Over 20.0	0.006**

*Based on Washington Water Power Schedule No. 35, effective to December 31, 1974, and a load factor of 60 percent.

**Based on Washington Water Power Schedule No. 22, effective to December 31, 1974 and a load factor of 60 percent.

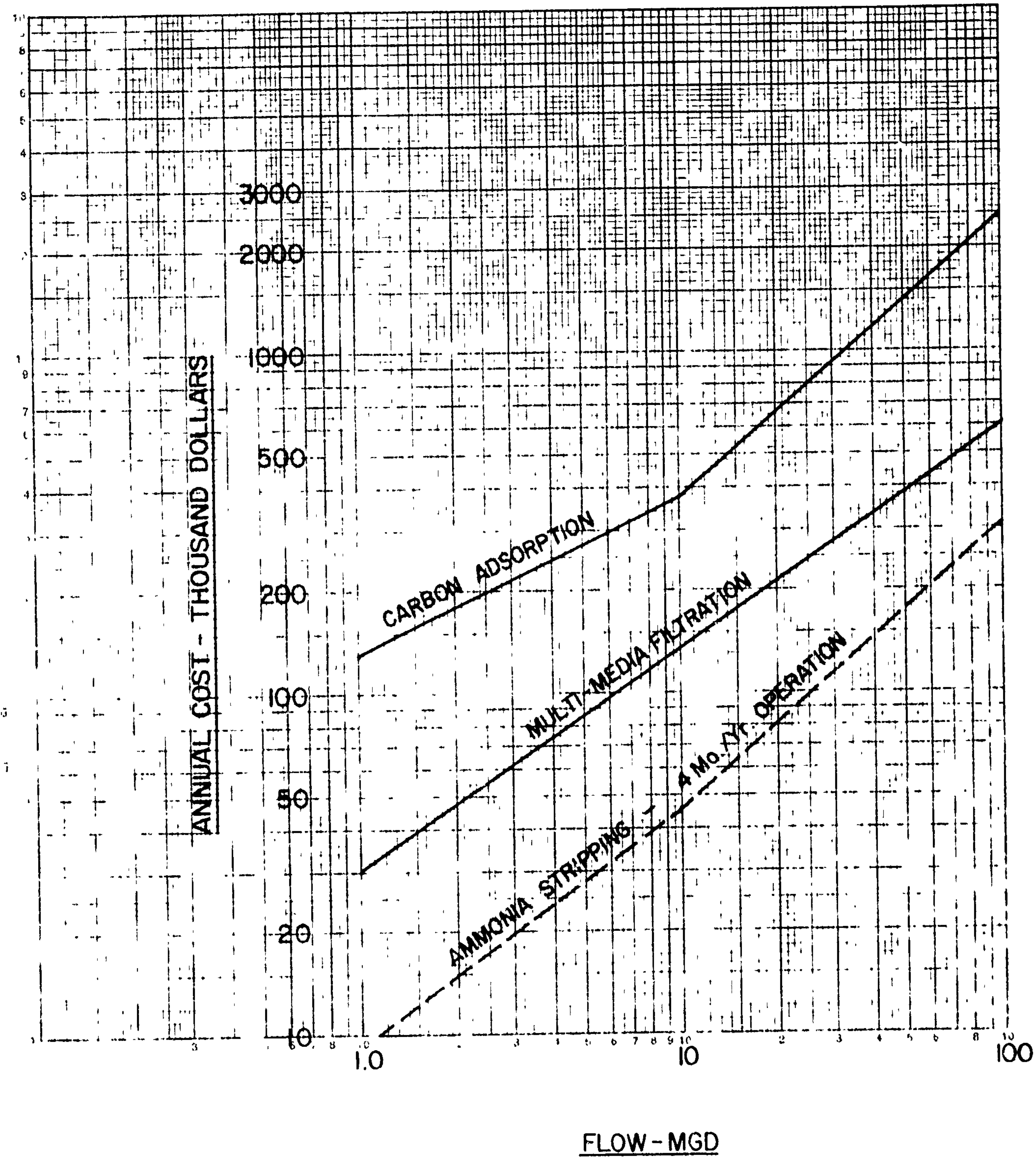
PRICE LEVEL:
MID-1974, PAC .IC ORTHWES
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE H-1
OPERATION AND MAINTENANCE COSTS
PRIMARY AND BIOLOGICAL
TREATMENT ELEMENTS



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

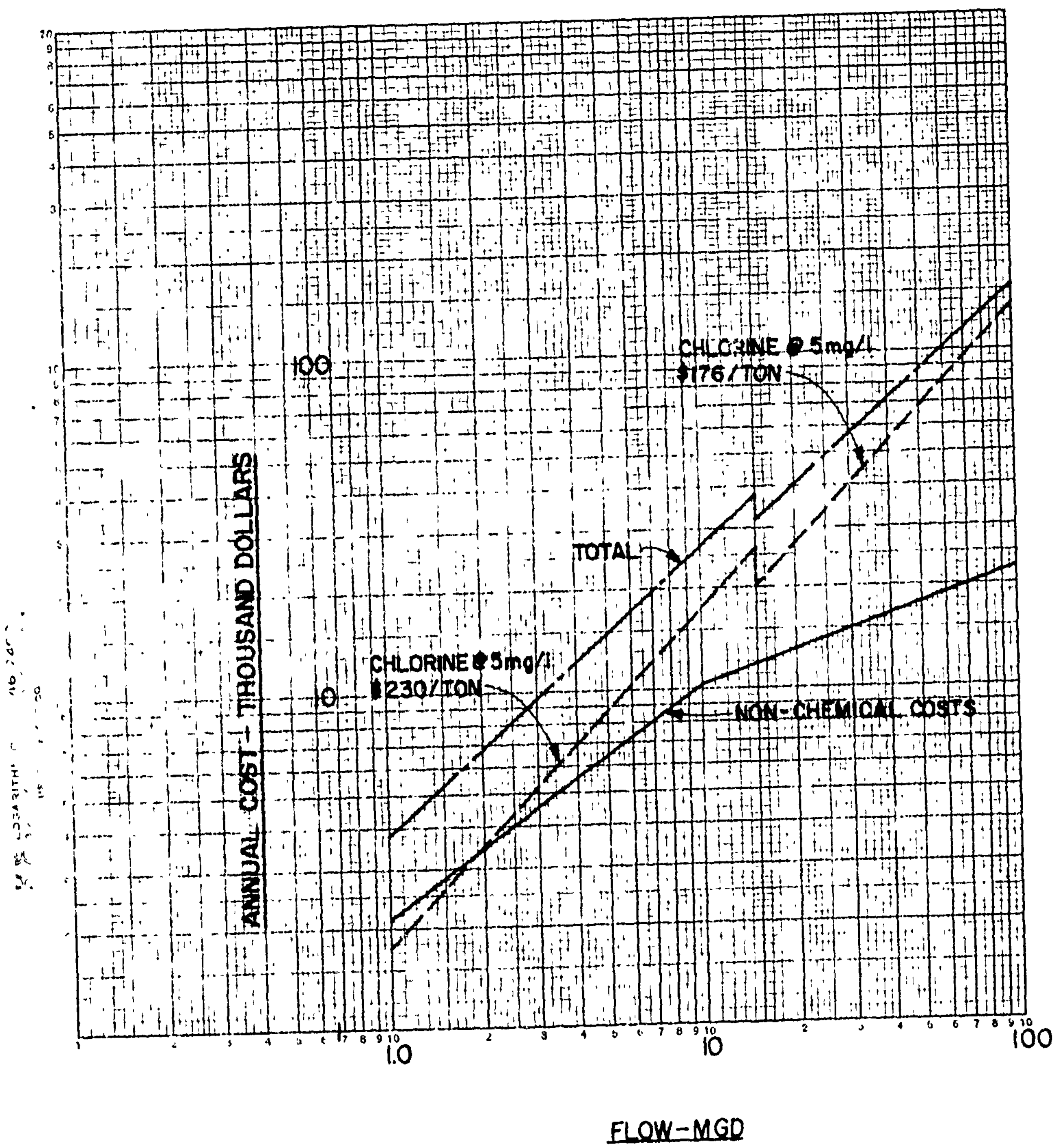
FIGURE H-2
OPERATION AND MAINTENANCE COSTS
ADVANCED PHYSICAL-CHEMICAL
ELEMENTS



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE H-3
OPERATION AND MAINTENANCE COSTS

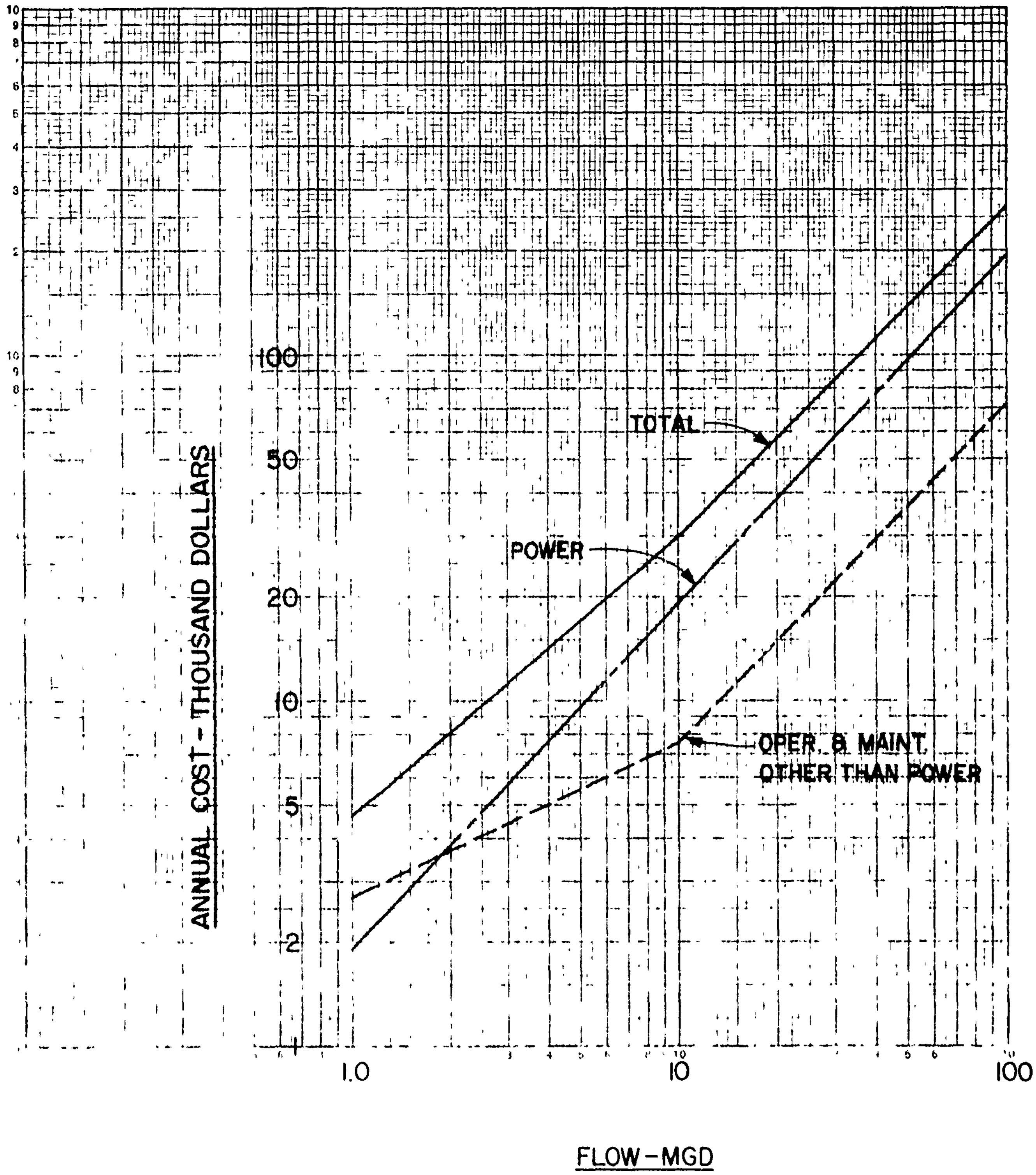
CHLORINATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE H-4
OPERATION AND MAINTENANCE COSTS

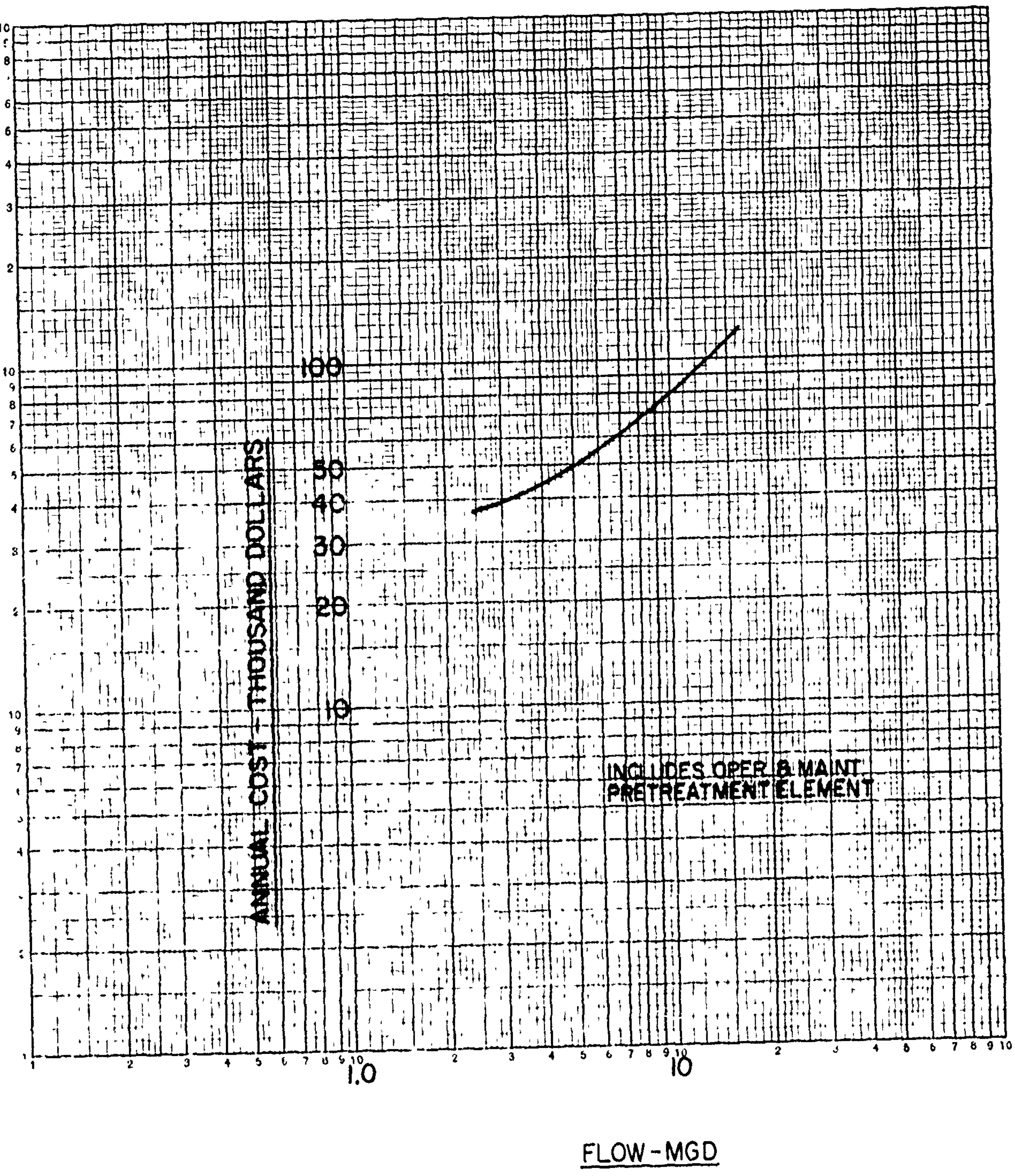
OZONATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE H-5
OPERATION AND MAINTENANCE COSTS

LAGOONS WITH MECHANICAL AERATION



PRICE LEVEL:
MID 1974

FIGURE H-6
OPERATION AND MAINTENANCE COSTS

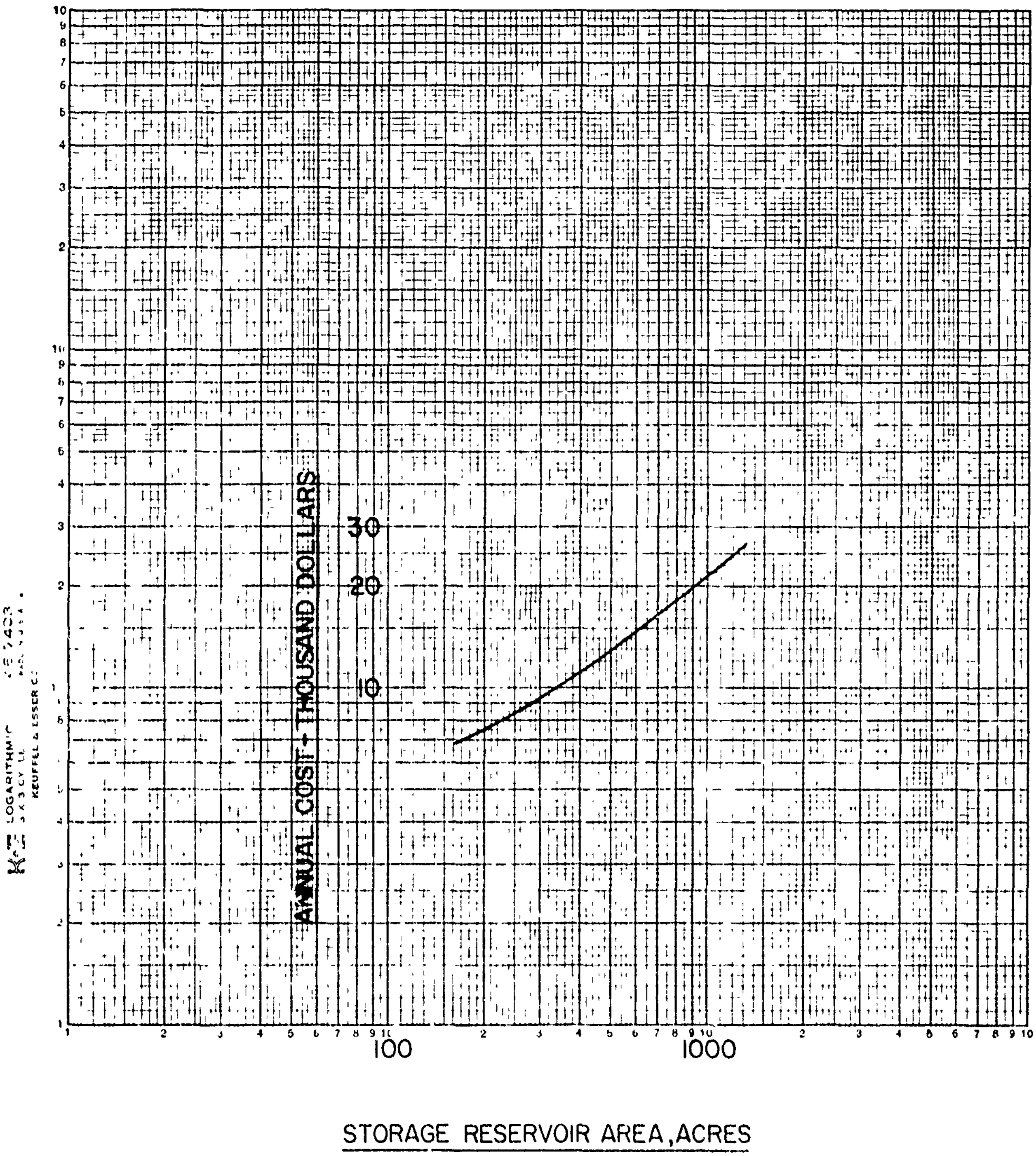
LAND APPLICATION ELEMENTS

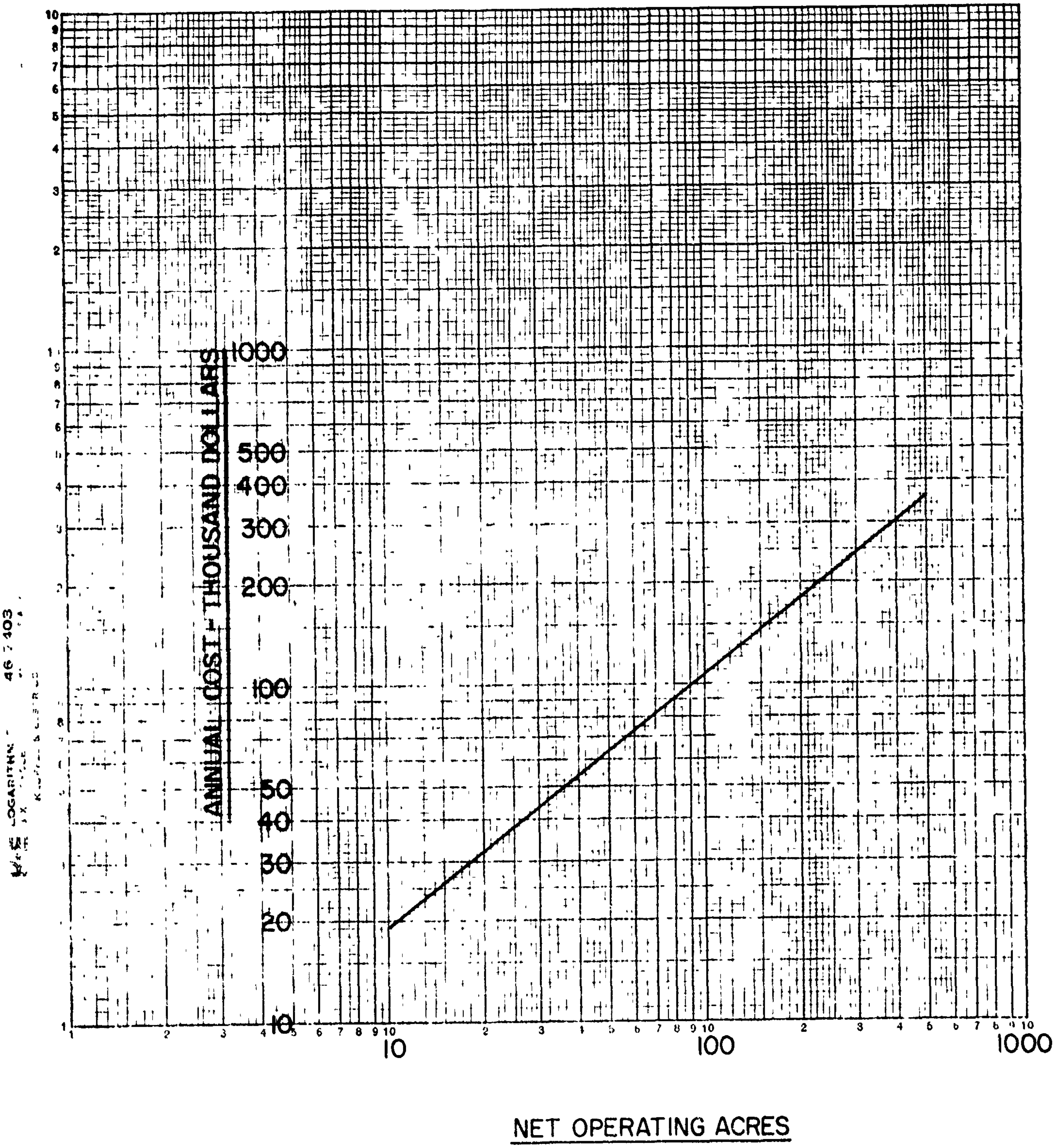
Element	Annual O&M Cost Basis
IRRIGATION	
Pumping	Figures G-2 and G-3
Distribution	1 percent of capital cost of distribution
Sprinkler Systems	$48 per acre
Storage Reservoirs	Figure H-7
INFILTRATION-PERCOLATION	Figure H-8

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE H-7
OPERATION AND MAINTENANCE COSTS

STORAGE RESERVOIRS

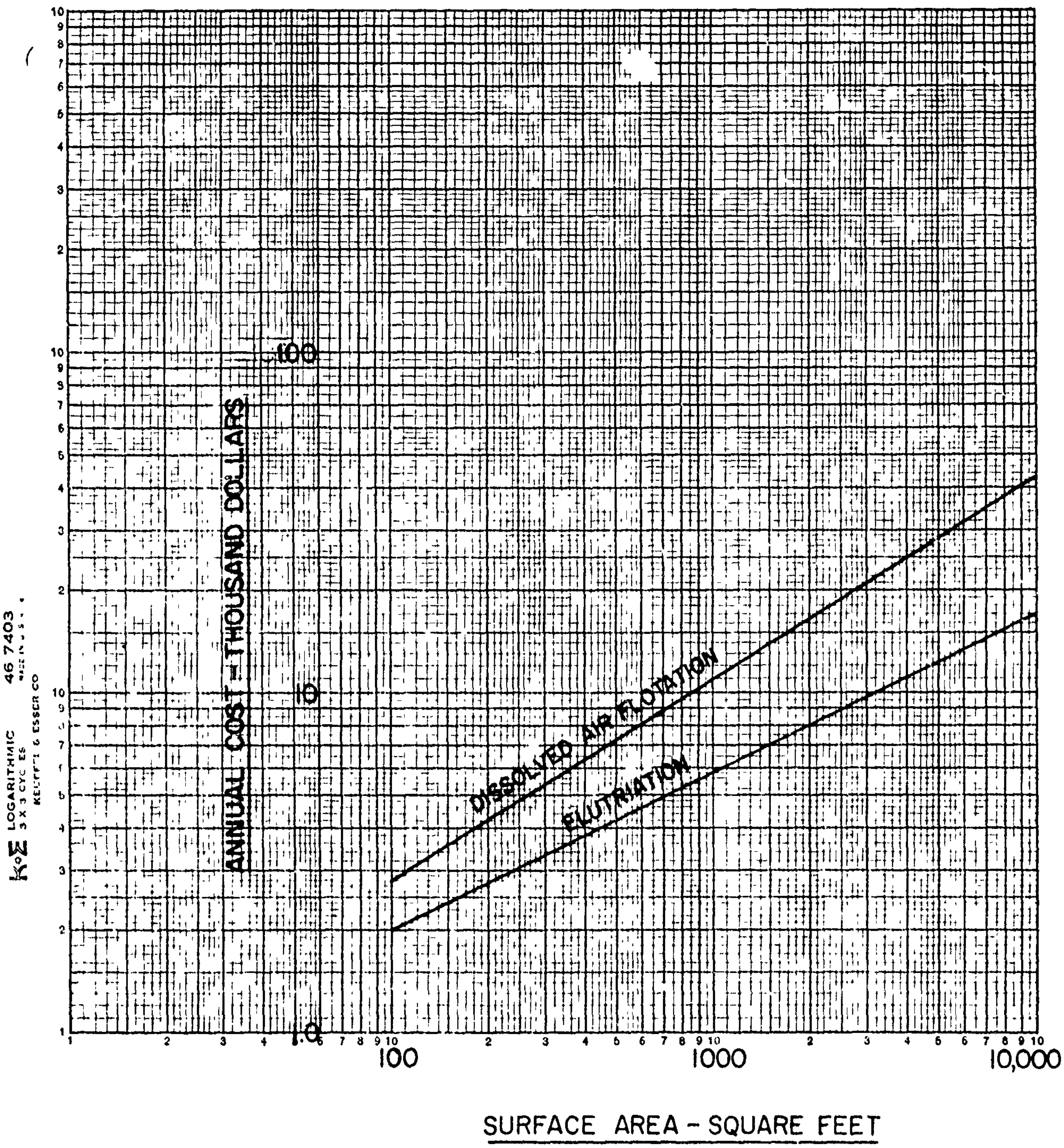



ANNUAL COST - THOUSAND DOLLARS
1000
500
400
300
200
100
50
40
30
20
10
10
100
1000
NET OPERATING ACRES

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-1
OPERATION AND MAINTENANCE COSTS

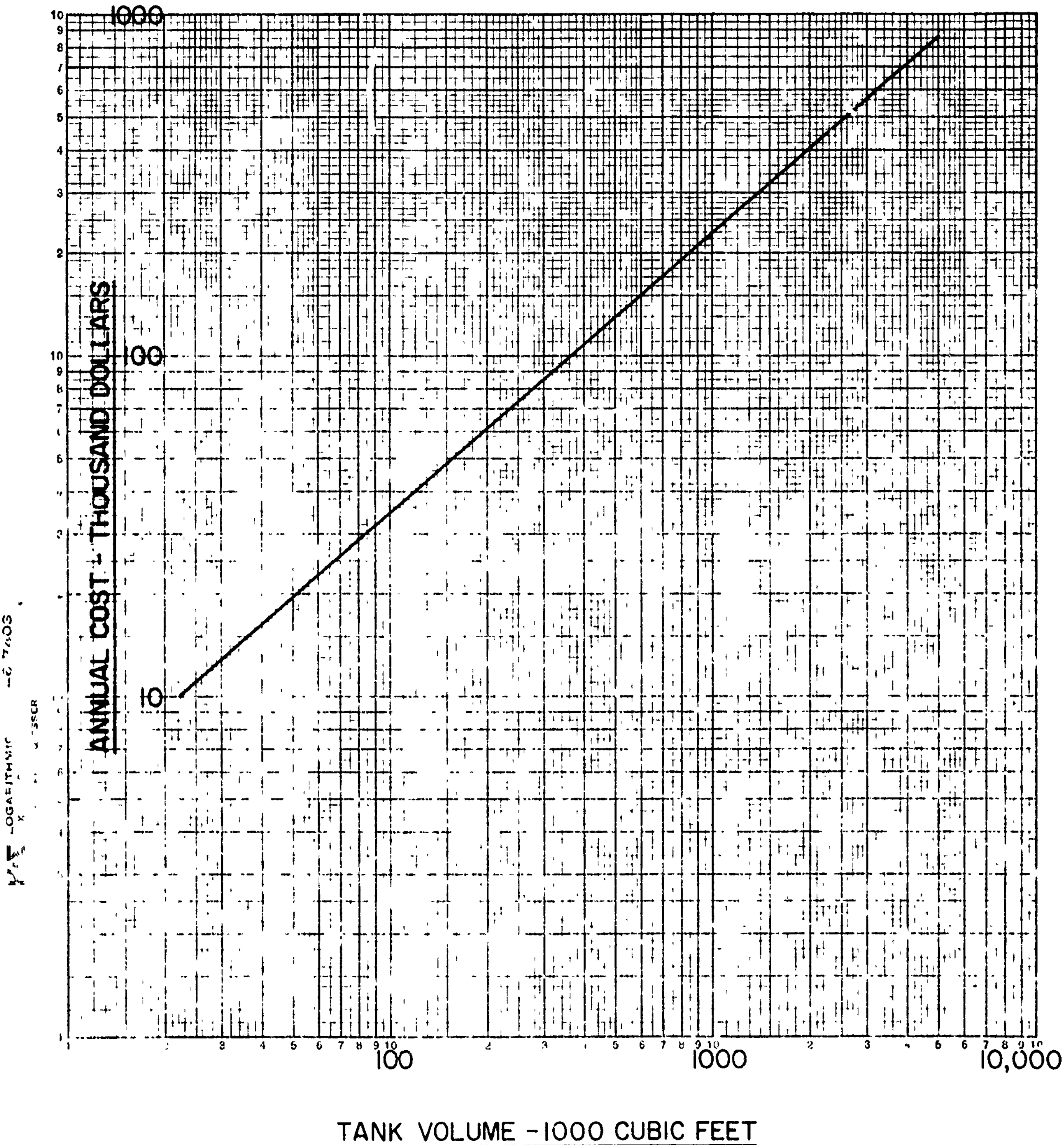
LIQUID SLUDGE CONCENTRATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-2
OPERATION AND MAINTENANCE COSTS

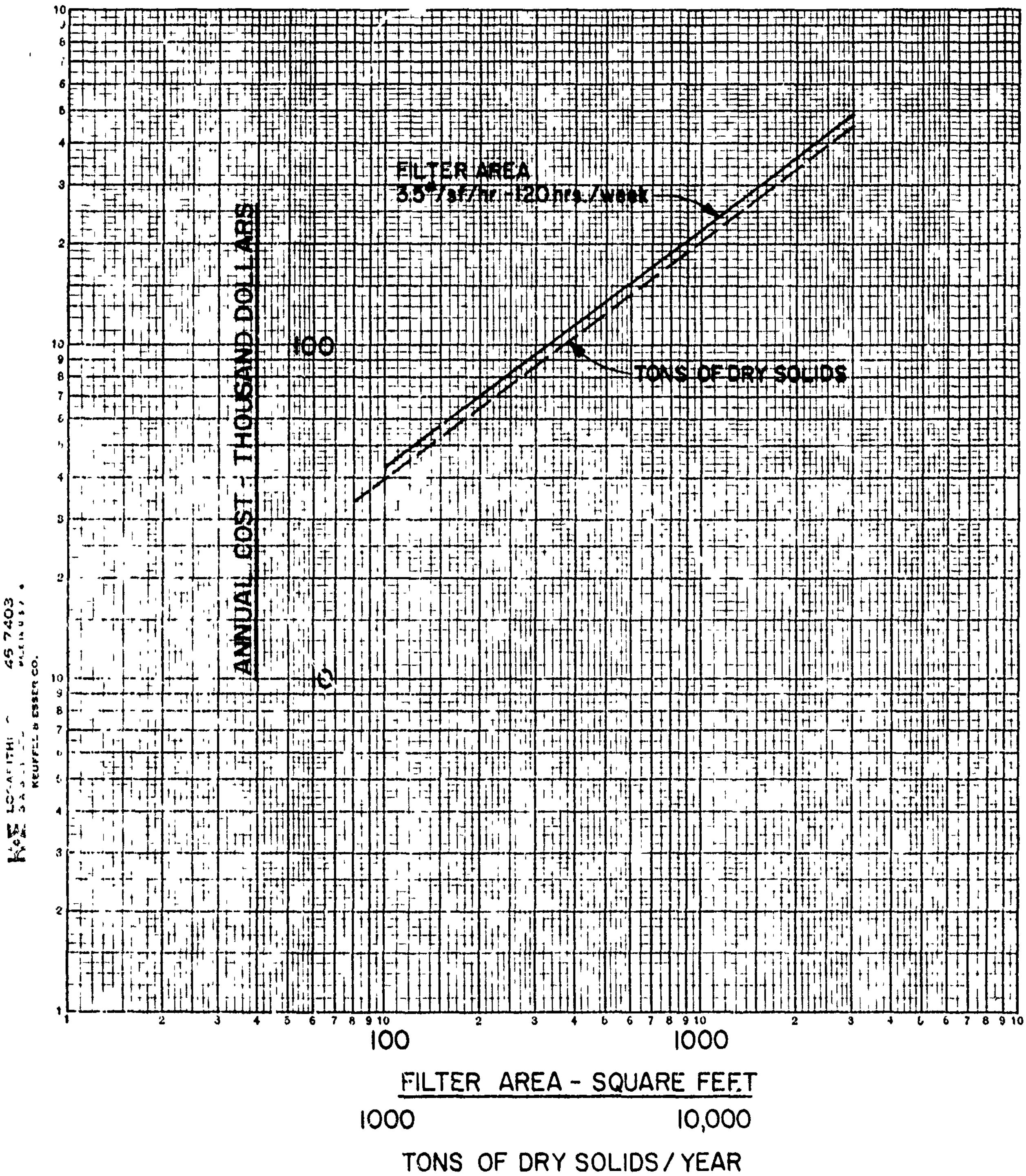
ANAEROBIC DIGESTION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-3
OPERATION AND MAINTENANCE COSTS

VACUUM FILTRATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST,
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-4
OPERATION AND MAINTENANCE COSTS

MISCELLANEOUS SLUDGE OPERATIONS

Element	Annual O&M Cost Basis
TRUCK HAUL OF SLUDGE CAKE	
Non-site Specific	
For 15 mile round trip <100 cy/day	$1.91/cy (or Figure I-5)
For 15 mile round trip >100 cy/day	$1.30/cy (or Figure I-5)
Site Specific	
Up to 10 miles one way <100 cy/day	$0.30/ton mile
Up to 10 miles one way >100 cy/day	$0.18/ton mile
Over 10 miles one way <100 cy/day	$0.20/ton mile
Over 10 miles one way >100 cy/day	$0.11/ton mile
REMOVAL OF SLUDGE FROM LAGOONS	
Removal, including move-on and move-off, excavation and removal to landfill disposal site*	$1.70/cy
Incorporation into sanitary landfill	$1.22/cy

OPERATION OF SLUDGE FORCE MAINS

Two percent of capital cost per year.

OPERATION OF SLUDGE STORAGE BASINS

Three percent of capital cost per year.

OPERATION OF SLUDGE DREDGES

Sum of labor, fuel and long-term maintenance as follows:
Labor @ $3,000/month during dredge season; Fuel @ $31 per mg;
Long-term maintenance at 5 percent of capital cost per year.

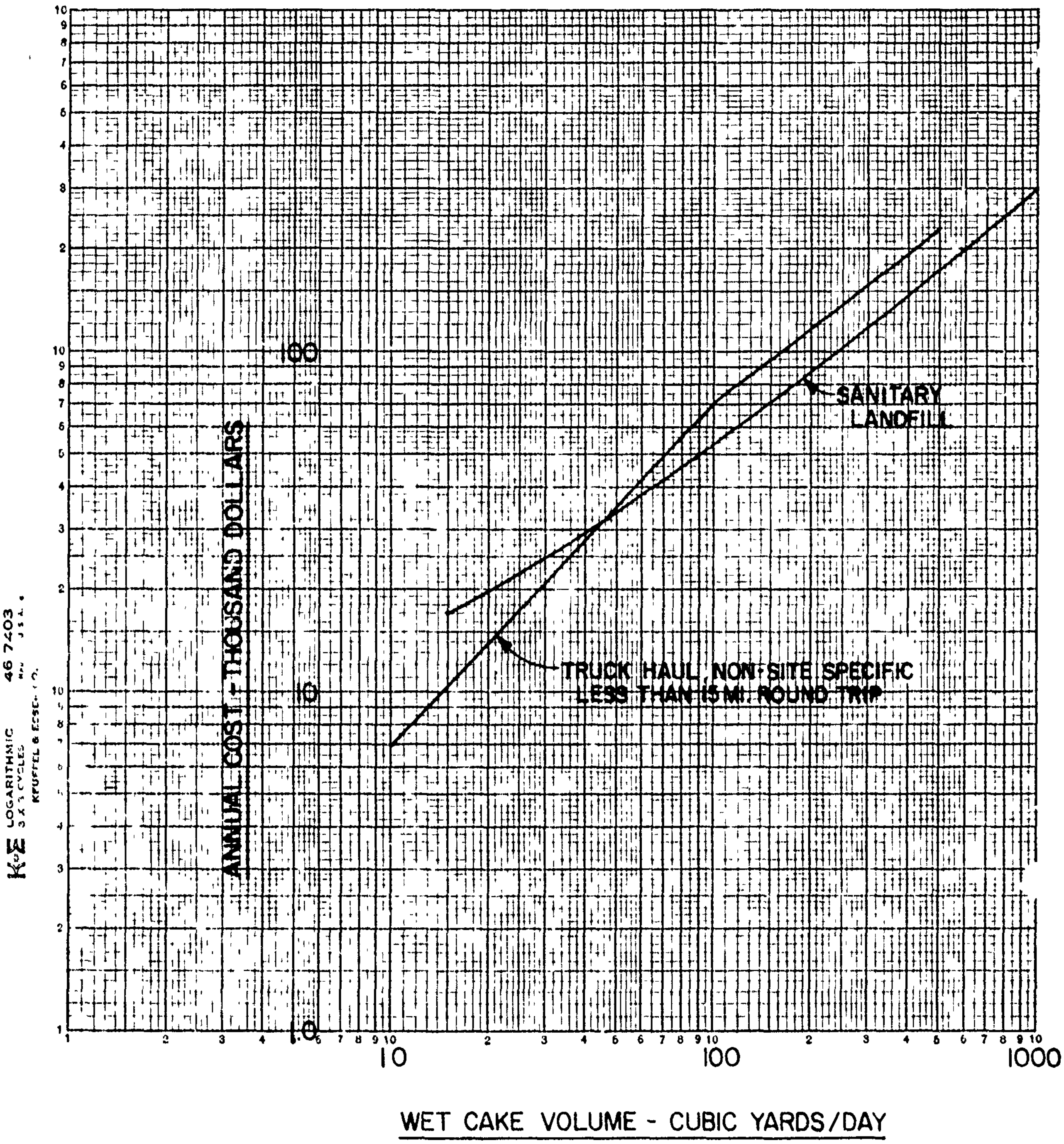
FIELD APPLICATION OF LIQUID SLUDGE

As subcontracts including ownership costs
By tractor-drawn injector, $15 per ton of dry solids
By off-highway sprinkler truck, $20 per ton of dry solids

* Periodic operation once per ten years

PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

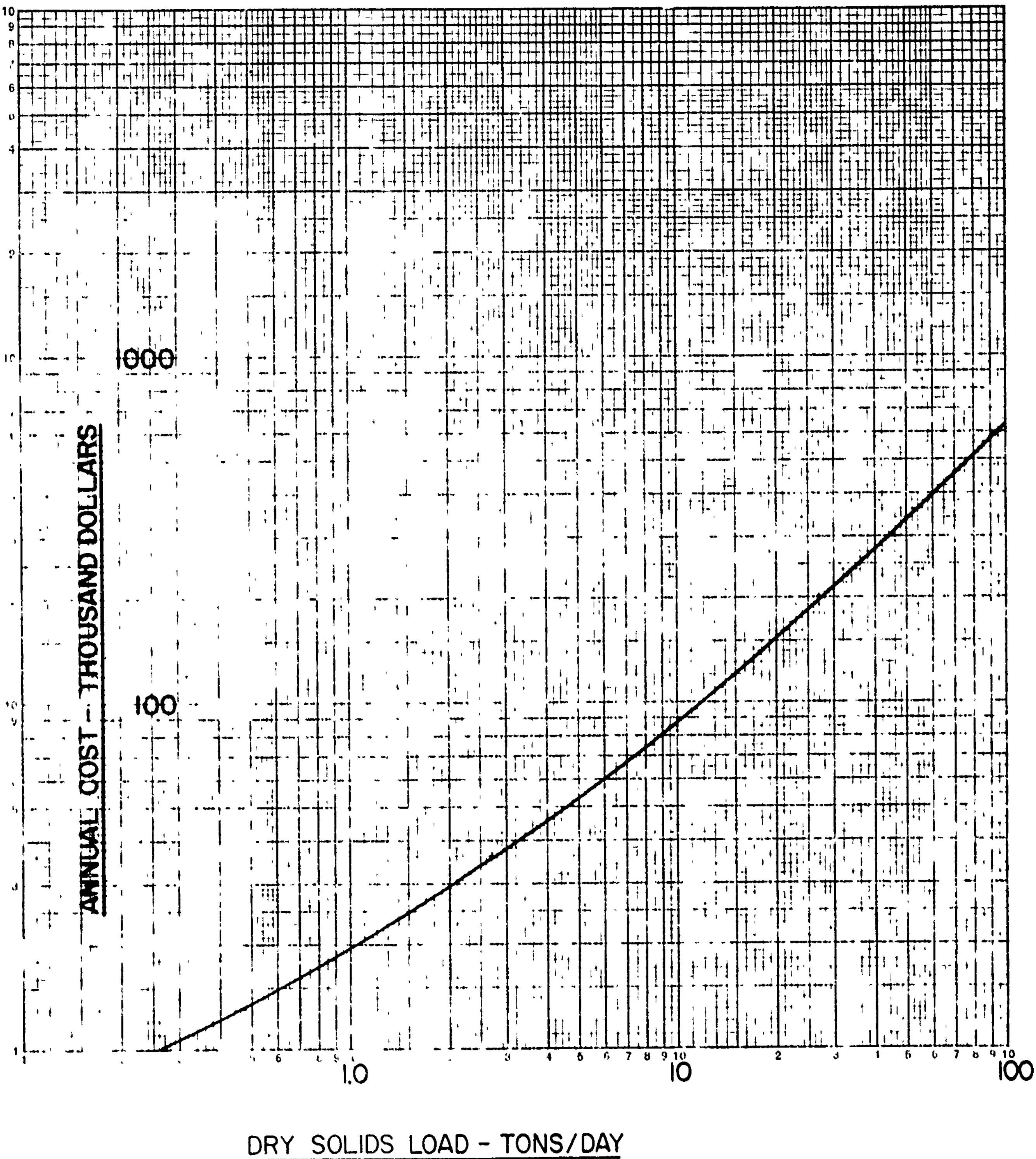
FIGURE I-5
OPERATION AND MAINTENANCE COSTS
SLUDGE DISPOSAL TO SANITARY
LANDFILL



PRICE LEVEL.
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-6
OPERATION AND MAINTENANCE COSTS

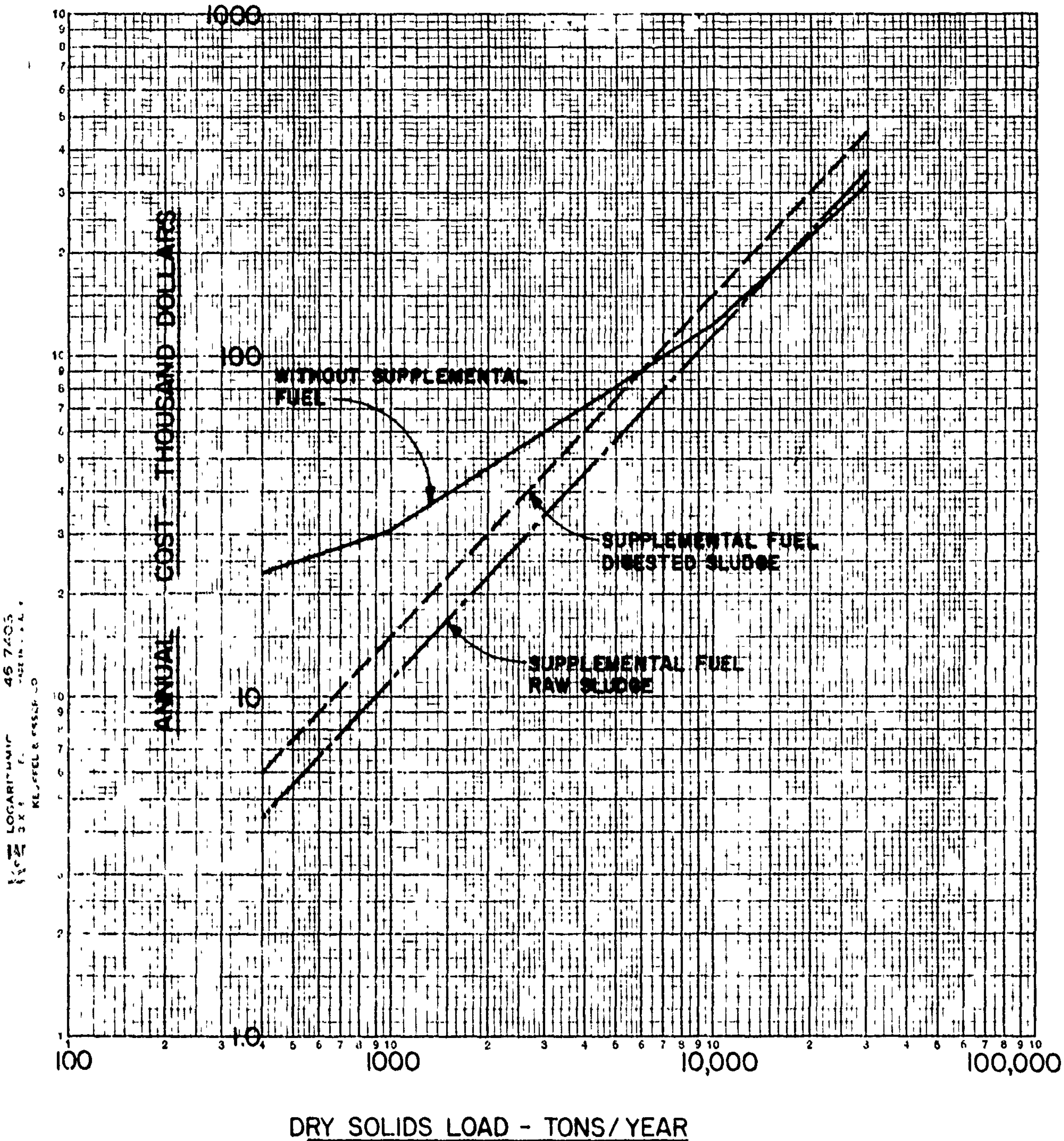
CENTRIFUGATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

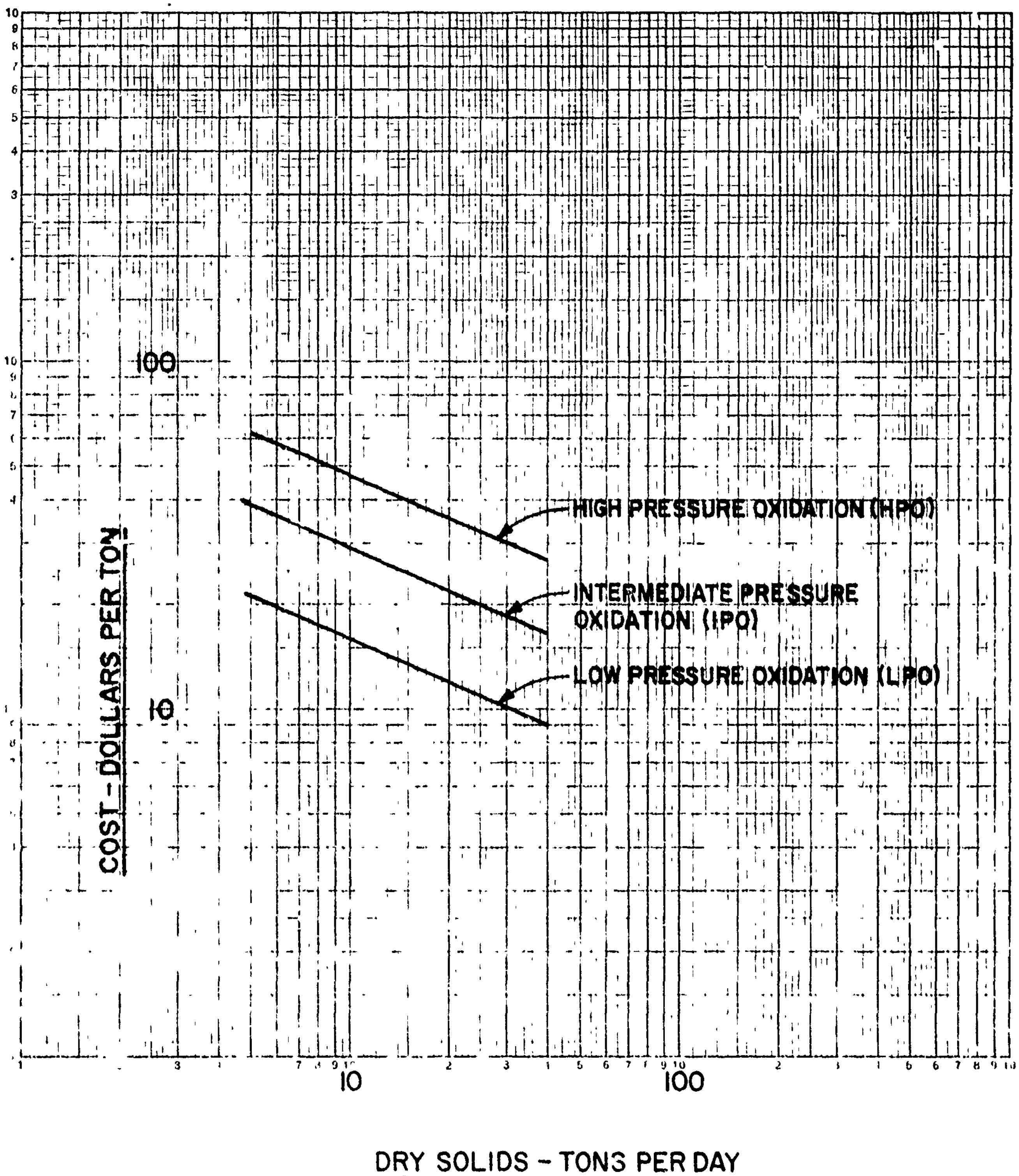
FIGURE I-7
OPERATION AND MAINTENANCE COSTS

MULTIPLE HEARTH INCINERATION



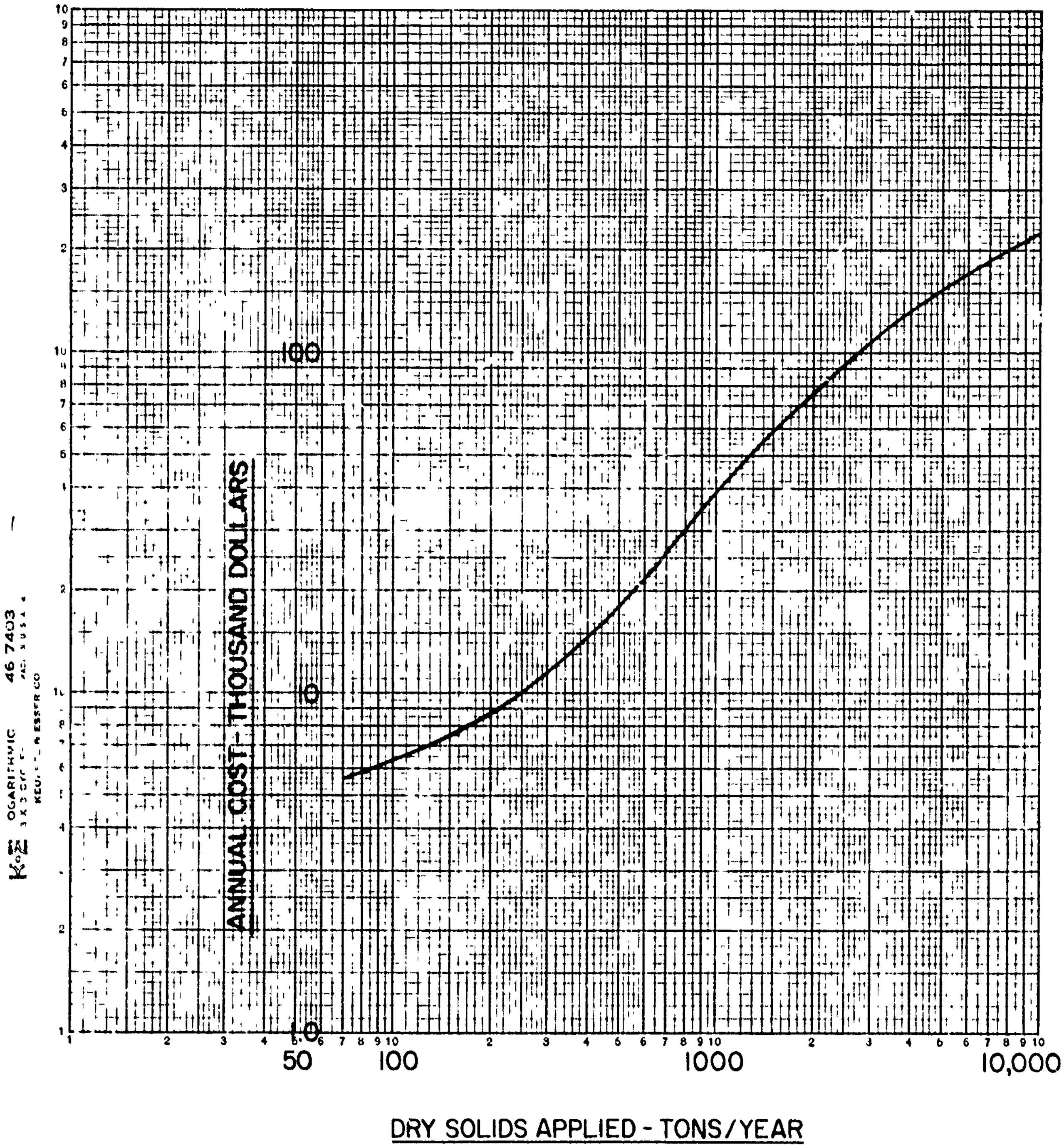
PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-8
OPERATION AND MAINTENANCE COSTS
WET OXIDATION



PRICE LEVEL:
MID-1974, PACIFIC NORTHWEST
ENR INDEX - 2000
WPC STP INDEX - 202

FIGURE I-9
OPERATION AND MAINTENANCE COSTS
AIR DRYING BEDS



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APPENDIX I

COST INDICES

Year	WPC-STP INDEX (1)		WPC-S INDEX (1)		ENR-CCI INDEX (2)	
	Seattle	National	Seattle	National	Seattle	National
1957	100.88	98.04	102.43	96.80	746	724
1958	105.57	101.50	111.59	100.42	802	759
1959	107.86	103.65	116.98	104.78	836	797
1960	109.29	104.96	117.18	106.22	859	824
1961	111.63	105.83	120.85	108.19	893	847
1962	112.49	106.99	122.55	109.72	915	872
1963	115.08	108.52	125.14	113.07	961	901
1964	116.58	110.54	129.31	115.10	983	936
1965	118.99	112.57	131.30	117.31	1028	971
1966	124.50	116.92	139.14	121.18	1084	1019
1967 Aug.	130.51	120.28	141.70	125.36	1130	1070
1968 Apr.	131	122	145	127	1254	1155
1969 Apr.	141	130	155	137	1333	1269
1970 Apr.	147	139	162	146	1413	1386
1971 Aug.	164	165	173	170	1571	1581
1972 Aug.	171	173	183	187	1763	1753
1973 March	181	180	195	196	1763	1859
June	181	183	192	200	1763	1896
Sept.	184	185	196	202	1842	1929
Dec.	187	186	199	206	1844	1939
1974 March	191	191	205	210	1853	1940
June	202	203	216	225	1887	1994

(1) Values 1957 through 1967 are for August of each year from FWPA (1967)
Values 1968 through 1970 are for April of each year from Carelli (1971)
Values 1971 & 1972 are August each year, Source EPA Library

(2) From Engineering News Record Magazine, March 21, 1974 and June 20, 1974

APPENDIX II

ELECTRICAL ENERGY RATE SCHEDULES[1]

SCHEDULE 12 - GENERAL SERVICES

Applicable

To general service supplied for lighting and power purposes when all such service taken on the premises is supplied through one kilowatt-hour meter, except that water heating service may be supplied separately under applicable water heating rate.

Monthly Rate

The sum of the following demand and energy charges:

Energy Charge:

First	200 Kwh	4.00c per Kwh
Next	300 Kwh	2.60c per Kwh
Next	2,500 Kwh	1.60c per Kwh
Next	15,000 Kwh	1.20c per Kwh
All over	18,000 Kwh	.80c per Kwh

Demand Charge:

No charge for the first 10 kw of demand. $1.15 per kw for each additional kw of demand.[2]

Minimum:

The demand charge but not less than $2.40 for single phase service and $3.00 for three phase service; unless a higher minimum is required under contract to cover special conditions.

SCHEDULE 21 - LARGE GENERAL SERVICE

Applicable

To general service supplied for all power requirements when all such

---

(1) All schedules are Washington Water Power Company rates that were effective in 1974 to December 30.

(2) Demand is defined as the average kw supplied during the 15 minute period of maximum use during the month as determined by a demand meter.

service taken on the premises is supplied through one meter installation for a demand of not less than 50 kw. Customer shall provide and maintain all transformers and other necessary equipment on his side of the point of delivery and enter into a written contract for five (5) years or longer.

Monthly Rate

The sum of the following demand and energy charges:

Energy Charge:

First	18,000 Kwh	1.11c per Kwh
Next	40,000 Kwh	0.81c per Kwh
All over	58,000 Kwh	0.51c per Kwh

Demand Charge:

$62.50 for the first 50 kw of demand or less. $1.00 per kw for each additional kw of demand.

Primary Voltage Discount:

If Customer takes service at 11 kv (wye grounded) or higher, he will be allowed a primary voltage discount of 10c per kw of demand per month.

Minimum:

The demand charge unless a higher minimum is required under contract to cover special conditions.

Annual Minimum

The current 12-month billing including any charges for power factor correction shall be not less than $10.00 per kw of the highest demand established during the current 12-month period provided that such highest demand shall be adjusted by the elimination of any demand occasioned by an operation totally abandoned during such 12-month period.

SCHEDULE 22 - EXTRA LARGE GENERAL SERVICE

Applicable

To general service supplied for all power requirements when all such service taken on the premises is supplied through one meter installation for a demand of not less than 3000 kva. Customer shall provide and maintain all transformers and other necessary equipment on his side of the point of delivery and enter into a written contract for five (5) years or longer.

Monthly Rate

First 200 Kwh per kva of demand but not less than 1,000,000 Kwh	0.80c per Kwh
All additional Kwh	0.43c per Kwh

Primary Voltage Discount:

If Customer takes service at 11 kv (wye grounded) or higher, he will be allowed a primary voltage discount of 10c per kva of demand per month.

Minimum:

$8,000 per month.

Annual Minimum

The current 12-month billing shall not be less than $10.00 per kva of the highest demand established during said 12-month period.

SCHEDULE 35 - PUMPING SERVICE

Applicable

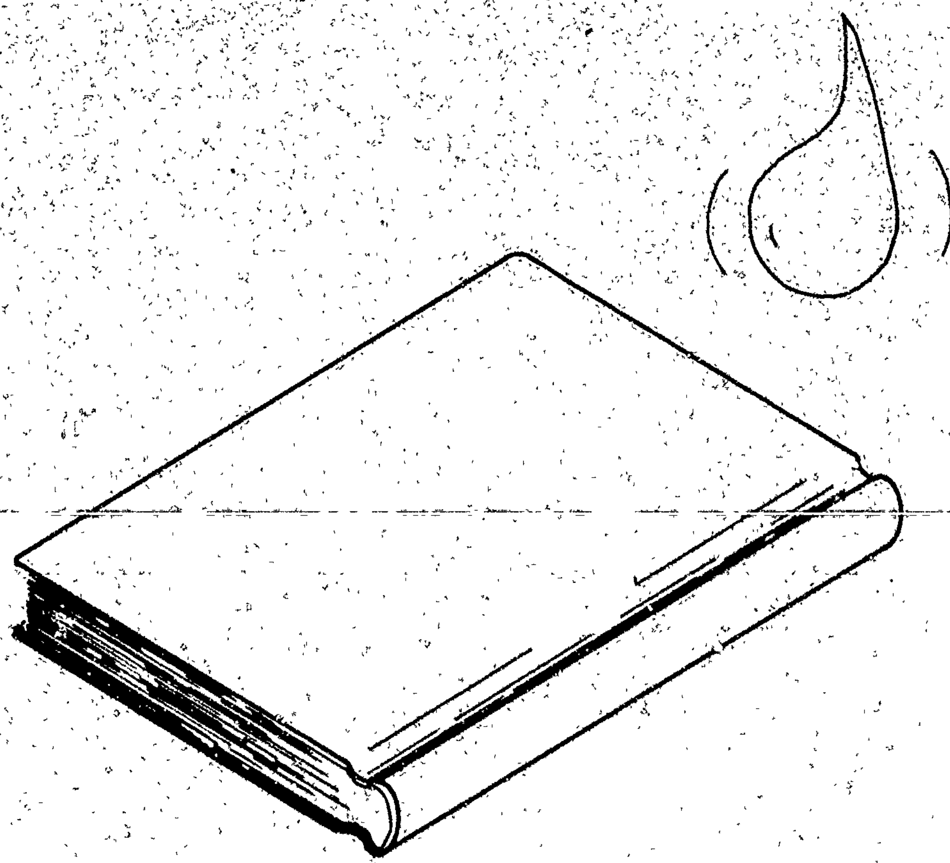
To service through one meter for pumping water, including incidental power used for other equipment and lighting essential to the pumping operation. For such incidental service, Customer will furnish any transformers and other necessary equipment. Customer will enter into a written contract for five (5) years or longer and will have service available on a continuous basis unless there is a change in ownership or control of property served.

Monthly Rate

First	85 Kwh per kw of demand	2.01c per Kwh
Next	80 Kwh per kw of demand but not more than 3,000 Kwh	1.51c per Kwh
Next	12,000 Kwh	0.51c per Kwh
All additional	Kwh	0.31c per Kwn

Annual Minimum

$6.00 per kw of the highest demand established in the current year ending with the November billing cycle. If no demand occurred in the current year the annual minimum will be based on the highest demand in the latest previous year having a demand.



SECTION 401.3

CRITERIA FOR EVALUATION OF WASTEWATER MANAGEMENT PLANS

WATER RESOURCES STUDY

METROPOLITAN SPOKANE REGION

SECTION 401.3

CRITERIA FOR EVALUATION OF

WASTEWATER MANAGEMENT PLANS

17 October 1975

Department of the Army, Seattle District
Corps of Engineers
Kennedy-Tudor Consulting Engineers

INDEX

SECTION 401.3

CRITERIA FOR EVALUATION OF
WASTEWATER MANAGEMENT PLANS

Scope and Objectives

The objective of this section is to establish the criteria by which candidate plan alternatives are to be evaluated, judged and finally selected for recommendation to the citizens of the study area. The very process of establishing criteria is in itself the result of an evaluation process; that is, the process of selecting from the wide spectrum of qualities that can be effected by a wastewater management system those qualities which deserve consideration. It is impossible that this selection process be purely objective since there is such diversity of viewpoint on goals and no one can lay claim to a knowledge of the average man's opinion. To make the selection of criteria as objective as possible it is desirable to start from as broad a base of concerns as possible. On the other hand, the more numerous the criteria are, the more difficult it becomes for a meaningful basis for decision to emerge from their application and rating.

As a first objective this section proposes to prepare a comprehensive listing of concerns arranged by broad categories. It is intended that these categories will form a basis for rating that is of manageable size and that the comprehensive list behind each category will provide a check list from which the most significant impacts for each alternative will be selected for evaluation.

In addition to the concerns themselves, a basis for comparison is the next most important criterion for evaluation. That is, when each concern is held up and examined for the probable impact of a particular alternative, what is the base condition against which it is being measured? Should it be the present condition, some specific past condition or some ideal condition?

It is an objective of this section to establish base line conditions for the various evaluation categories.

The final objective of this section is to develop an evaluation matrix to display the results of alternative plan evaluation in summary form that reveals a meaningful basis for decision.

General

The approach taken is first to compile a comprehensive list of concerns by categories. This list should provide a positive answer to the question, "Have all significant concerns which could be impacted by a wastewater management plan been considered in the decision making process?"

The basic categories selected are as follows:

(1) Cost Effectiveness
(2) Economic
(3) Social
(4) Environmental
(5) Energy and resource utilization
(6) Performance and reliability
(7) Flexibility
(8) Institutional

A narrative discussion of the elements in each category is provided as the basis for reducing the many facets to definitive subcategories. At this point recognition is given to the fact that the nature of wastewater management systems defines the areas of significant impact and permits some reduction in the mass of detail. That is, the list of concerns is made specific to wastewater management eliminating, for example, concerns which would only be significant to a proposed rapid transit plan.

Cost Effectiveness

Cost effectiveness analysis seeks to determine on a uniform comparative basis the total direct capital and operation and maintenance costs for facilities to implement the plan. This is the only evaluation element which is subject to quantification in recognized terms and under developed guidelines. These guidelines are established by EPA in Federal Register, Vol. 38 No. 174, September 1973. Criteria for specific application to this project are developed in Section 401.1,"Criteria for Cost Effectiveness Analysis." Dollar amounts for candidate alternative plans are developed in the Section 701.1,"Initial Cost Effectiveness Screening of Wastewater Management Alternatives."

Cost effectiveness does not consider other economic impacts. These other areas of economic impacts are developed below.

Economic

Those concerns of an economic nature other than the direct capital, operation and maintenance costs of the wastewater management facilities can be divided into three fundamental subcategories: primary, secondary and transient.

Primary concerns are those which are a direct consequence of the direct capital, operation and maintenance costs. Among these are the following:

(1) The effect of the capital expenditure on total bonding capacity and its affect on the community's ability to provide capital funds for other community needs.

(2) The effect of repayment of the capital expenditures, together with the financing charges and depreciation reserves, on utility charges and/or tax rates.

(3) The effect of operation and maintenance costs on utility charges and/or taxes.

(4) The direct effect on employment from operation of the wastewater management facility and of displacements of employment caused by construction of wastewater management facilities.

(5) The direct effect on tax income caused by displacements to construct wastewater management facilities.

(6) Any direct loss of community income due to displacement to construct wastewater management facilities.

All of the above are of significant importance and are selected for inclusion in the rating matrix.

Secondary concerns are those which are an indirect consequence of the impact of the wastewater management facility on the economy of the areas. Among these concerns are the specific impacts upon the following:

(1) Employment

(2) Commercial activity

(3) Industrial productivity

(4) Agricultural productivity

(5) Property values

(6) Tax income

(7) Economic development incentive

The specific identification and evaluation of each of the above items for most wastewater management alternatives is difficult. The first six items are actually consequences of item 7, economic development incentive. In general, it will be sufficient to determine whether a plan tends to improve the general economic climate of the community in which case positive impacts can be expected on the broad economic indicators of improved economic development incentive, property values and tax income. These later three items are selected for inclusion in the rating matrix with the understanding that refinements represented by items 1 through 4 can be discussed specifically where applicable.

Transient concerns are those which are a consequence of the various construction phases involved in implementing the physical plant for a wastewater management alternative. These concerns are in general of short-term nature but can have permanent long-term consequences. Included among the transient concerns are the following:

(1) Employment

(2) Local materials market

(3) Disruption of circulation and commercial activities

The impact of employment demands relating to implementation of plan alternatives and the demands for locally produced products and construction materials will be significant local transient economic impacts, particularly in consideration of the probable financing support of wastewater project construction from federal and state grant funds. The impact of disruption to circulation as a result of project construction is a transient impact of serious concern which should be evaluated for its economic impact but which should also be regarded as a significant influence with regard to the final selection of pipeline alignments and other critically located facilities.

Social

Social concerns can be categorized into those which effect the community as a whole and those which have their primary impact on people as individuals.

Among the community concerns are the following:

(1) General level of public health and safety

(2) Employment patterns

(3) Residential patterns

(4) Circulation patterns

(5) Cultural opportunities

(6) Educational opportunities

(7) Recreational opportunities

(8) Land use and planning

(9) Aesthetics

(10) Dislocation of established community patterns

The primary interest in items 2 through 6 above are the possible negative impacts which can be caused by major dislocations that could be a consequence of a wastewater management plan.

Individual sociological concerns may be broadly expressed in a single category defined as "life style" which may be influenced by numerous sociological elements. Of the varied elements influencing individual life style, which include the community factors previously stated, the following are considered to be of primary importance and will be the basic elements used in evaluating "life style" impact of alternatives:

(1) Individual place and kind of employment and mobility within employment categories.

(2) Quality of individual home and immediate environment

(3) Transportation and individual mobility

(4) Cultural and educational involvement

(5) Recreational activity

The impact to individual life style and well being would be severely impacted by dislocation of the individual and for this reason will be identified as a separate evaluation factor in the summary matrix.

Environmental

Environmental concerns are the primary target of the wastewater management plan and as such deserve the most detailed response and evaluation. The basic environmental categories in this context are: (1) surface water quality and quantity, (2) groundwater quality and quantity, (3) lands quality and (4) a[illegible] quality. Under each of these categories, the concerns are those which preserve or enhance the capacity of the environment to support that variety of functions which make up its beneficial uses. These concerns are listed below under each basic category all of which are included in the rating matrix.

(1) Surface water quality and quantity

(a) As fish habitat

(b) As public drinking water supply

(c) As industrial water supply

(d) As agricultural water supply

(e) As a recreation focus

(f) As an aesthetic element

(g) As an element in wildlife habitat

(2) Groundwater quality and quantity

(a) As surface water low flow augmentation and/or temperature

(b) As public drinking water supply

(c) As industrial water supply

(d) As agricultural water supply

(3) Lands quality

(a) As a wildlife habitat

(b) As open space

(c) As repository of natural vegative cover

(d) As space for recreation

(e) As an aesthetic element

(f) As agricultural reserve

(4) Air quality

(a) As a healthful medium for man, plants and animals

(b) As an aesthetic environmental element, free from objectionable odors, discoloration or particulate matter.

(5) Ambient noise level

Behind each of the functional uses enumerated above are the many physical and chemical parameters which are used to measure suitability such as dissolved oxygen, fecal coliform count, temperature, etc. Since a minimum condition for all conditions is compliance with 1983 standards, most of these parameters will be at satisfactory levels in any case under future conditions. Satisfaction of these detail parameters is not a goal in itself, it is the sum total of all factors as they relate to satisfying the above listed functions that are the prime concern of the decision maker. Therefore, these detailed parameters of quality are not listed in the rating matrix, but rather the interpreted total effect in the form of qualification to perform a desired function.

Energy and Resource Utilization

National and even world wide concern for use of energy and non-renewable resources is second only to the environment as a serious contemporary concern and growing public awareness. The serious implications and long-range realities of these concerns insure that they are not any more a fad than the concern for the environment. Although energy and resource utilization could rightly be considered as elements under either economic, social or environmental categories, they are set out separately as deserving of the attention, particularly since wastewater management alternatives strongly impact these concerns and at an accelerated rate as the treatment standards increase. These concerns are considered in three categories: (1) energy as it is used locally in the wastewater management process, (2) use of chemicals, perhaps manufactured elsewhere, that represent an input of energy at their place of manufacture and further represent a resource of limited supply that is in demand nationally for similar purposes and (3) the potential for salvage of energy or resources in the processed wastewater flows.

The concerns in this area are listed by categories below:

(1) Energy utilization

- (a) Electrical energy consumption
- (b) Thermal energy consumption
- (c) Indirect energy consumption for chemical manufacture and delivery

(2) Chemical resource consumption

- (a) Chlorine
- (b) Coagulants
- (c) Activated carbon
- (d) Miscellaneous (including methanol, etc.)

(3) Salvage of resources in waste flows

- (a) Energy
- (b) Fertilizer chemicals
- (c) Soil conditioning organics

All subcategories under (1) are included in the rating matrix but only the category headings for (2) and (3) are included. Where applicable, the deleted detail may be added by reference or supplemental notes.

Performance and Reliability

Performance and reliability are important evaluation criteria included in the categories described previously, but which also deserves special attention. The importance of these factors is emphasized by the way in which the 1983 water quality standards are stated, calling for certain levels of performance with stated specific degrees of reliability. It is not a function of a planning report to delve into the details of a particular plant design to determine the degree of redundancy and standby capacity to meet detailed performance and reliability requirements. These concerns are recognized in the cost estimates used in the cost-effectiveness evaluation, where standby power is included for pumping and equalizing storage is included in advanced treatment to insure reliable performance. The kind of performance and reliability to be evaluated here involves recognition of the differences that are inherent in various systems, assuming that they are all equally well designed within the limitations of the system.

Two categories are selected with no listing of specific subheadings. These categories are : (1) performance and (2) reliability. Under performance it is intended to evaluate such items as:

(a) Whether the process used is a proven one of long standing or whether it is a process that has only been used at pilot scale under research conditions.

(b) Whether the process depends on precise control for effective achievement or whether it is largely self-regulatory.

Under reliability the intended evaluation items include:

(a) Whether the consequences to a system i [illegible] re are serious or not to the receiving water.

(b) Whether storage or some intervening process provides a buffer capacity for short-term failure.

(c) The relative complexity of the process and its inherent vulnerability to failure.

Flexibility

Since neither future growth, needs, regulations or goals can be precisely foreseen, an important consideration in the evaluation of any plan is its flexibility in adapting to meet changes in these significant areas. The following specific concerns are selected for evaluation.

(a) Flexibility of the plan to adjust to changes in the amount of and location of population growth.

(b) Flexibility of the plan to adjust to changes in water quality criteria and goals.

(c) Flexibility to adapt and utilize future technological advances.

Institutional

There are usually several alternative institutional arrangements by which any given management plan can be implemented. Each legally feasible institutional arrangement has its advantages and disadvantages from the standpoints of public and political acceptance and financing capability. The elements of public and political acceptability are frought with prejudice and it is for this reason that current planning guidelines emphasize suppression of this historical bias by eliminating institutional acceptability from the initial screening process for management alternatives. This procedure is to insure that the selected institutional arrangements are responsive to the most beneficial management plan rather than that the selection of the management plan be subservient to existing institutions or existing bias relative to institutions. This does not eliminate the need to eventually evaluate the institutional requirements of a management plan, but rather the sequence of its consideration.

Institutional considerations are therefore not an item in the initial screening process. Institutional alternatives are explored in Section 801.3 and the associated financing capability in Section 801.4, both addressed to the most favored candidates from the initial screening process.

The primary evaluation concern for institutional arrangements are financing capability and ability to equitably allocate costs. If these concerns can be answered favorably, public and political acceptance become matters of education. The ability to utilize existing institutions rather than form new bodies is also a significant concern not only to avoid the proliferation of agencies but the attendant cost and delay of formation.

Compliance with Guidelines

The foregoing development of evaluation criteria specific to wastewater management including sludge handling and disposal requires checking for completeness against guidelines. The following comprises a check of coverage as proposed herein against items which have a mandatory requirement for consideration under Corps of Engineers guidelines* responsive to Section 122 of Public Law 91-611.

Guideline Concern	Where Covered By Concerns per Tables 1 & 2
Social Categories	
Noise	10c
Displacement of People	5b and 6a
Aesthetic Values	Primarily 9b, also 5c and 10b
Community Cohesion	5b and 6a, also 4c
(Desirable) Community Growth	See Note (1)

* ER 1105-2-105 Guidelines for Assessment of Economic, Social and Environmental Effects of Civil Works Projects, 15 December 1972.

Guideline Concerns	Where Covered By Concerns per Tables 1 & 2
Economic Categories	
Tax revenues	2a, 2b, and 2d
Property Value	See Note (2)
Public Facilities	4c, 5c, 5d, 9c
Public Services	4c, 5a, 5b, 5c, 6a
(Desirable) Regional Growth	See Note (1)
Employment/Labor Force	2c, 3a, 4a, 9c
Business and Industrial Activity	3a
Displacement of Farms	9c and 6a
Environmental Categories	
Man-made Resources	4c, 5b, 9c, 11a, 11b, 13a, b, c
Natural Resources	7a, 8a, 9a, 9b, 10a, 10b, 11a, 11b
Air	10a, 10b
Water	7a, 8a

NOTES:

(1) This study does not concern itself with the issue of whether growth is desirable or not. In general, favorable impacts on all social and economic concerns make the community a more attractive place to live and hence favor growth. Concerns most strongly involved are 2c, 2d, 3a, 5a, 5c, 5d, 9b, 9c, 10a, 10b and 10c.

(2) In the same way that general favorable social and environment impacts favor growth as discussed in note (1) they would also favor preservation or increase in property values. Concerns most strongly involved are as listed in note (1).

Evaluation Process

Two evaluation tools are proposed. The first involves a narrative response to the applicable items to record the basis for evaluation. Since most items other than cost-effectiveness do not have recognized means of quantification, these narrative statements provide the necessary description of evaluation. The second is a summary matrix that provides a quick visual comparison of the relative impacts of plans on the items of concern. In the summary matrix, the initial evaluation is proposed to be a relative ranking between the alternative plans being considered. Subsequent steps in the evaluation process are built on the narrative evaluations and the relative ranking so developed.

A sample form of the narrative response is shown in Table 2 and the sample form for the summary matrix is shown in Table 1.

TABLE 1
SUMMARY RANKING OF CANDIDATE PLANS

CHARACTERISTICS AND CONCERNS	Ranking of Candidate Plans							
	A	B	C	D	E	F	G	H
1. COST EFFECTIVENESS								
a. Present worth of the sum of capital and operation and maintenance costs								
b. Is most cost effective								
2. DIRECT ECONOMIC CONCERNS								
a. Has lowest requirement for capital								
b. Has lowest annual O&M cost								
c. Causes minimum loss of employment and real income due to displacement								
d. Causes minimum loss of tax revenue due to displacement								
3. INDIRECT ECONOMIC CONCERNS								
a. Has maximum favorable impact on attractiveness to business and rise in level of economic activity								
4. TRANSIENT ECONOMIC CONCERNS								
a. Has maximum potential for local employment increase during construction								
b. Has maximum potential for increase in local manufacture and supply activity during construction								
c. Will cause minimum disruption of circulation and business activity during construction								
5. SOCIAL CONCERNS FOR THE COMMUNITY								
a. Has most favorable impact on health, welfare and safety								
b. Causes the least disruption to existing community living patterns								
c. Has the most beneficial impact on availability of recreation								
d. Introduces the least constraints to land use and land use planning								
6. SOCIAL CONCERNS FOR THE INDIVIDUAL								
a. Causes the least dislocation of individuals from their homes, employment and general pattern of cultural activity								
7. CONCERNS FOR GROUNDWATER								
a. Provides maximum protection of groundwater quality								

CHARACTERISTICS AND CONCERNS	Ranking of Candidate Plans							
	A	B	C	D	E	F	G	H
8. CONCERNS FOR SURFACE WATER								
a. Provides maximum protection or enhancement of surface water quality for all concerns								
9. CONCERNS FOR LAND USE								
a. Preserves or increases land available for wildlife habitat, natural vegetation and open space								
b. Preserves or enhances the aesthetic value of the landscape								
c. Creates least interference with other beneficial uses of land								
10. CONCERNS FOR AIR QUALITY AND NOISE								
a. Provides maximum protection of public health aspects of air quality								
b. Provides minimum potential for offensive odors								
c. Provides minimum noise impact								
11. CONCERNS FOR ENERGY AND RESOURCES								
a. Requires minimum input of 10^6 kwh electrical energy								
b. Requires minimum input of chemicals								
c. Provides the maximum opportunity for energy and resource recovery								
d. Has lowest net energy requirement considering recovery								
12. PERFORMANCE EVALUATION								
a. Provides best technical performance in wastewater renovation								
b. Provides highest degree of reliability								
13. FLEXIBILITY								
a. Has maximum flexibility to meet unanticipated changes in growth								
b. Has maximum flexibility in adapting to changes in disposal criteria								
c. Has maximum flexibility to incorporate changes in technology of wastewater treatment								

TABLE 2

NARRATIVE EVALUATION

ALTERNATIVE PLAN:

DESCRIPTION:

1. COST-EFFECTIVENESS EVALUATION

   a. Capitalized Cost Basis

      Planning period facilities cost expressed as present worth, millions of dollars.

      1) Total Cost, capital plus operation & maintenance ________

      2) Capital costs only, including land ________

      3) Operation and maintenance costs only ________

   b. Annualized Cost Basis

      Planning period facilities cost expressed as equivalent equal annual cost, dollars per year.

      1) Total, including capital and O and M ________

      2) Capital costs only, including land ________

      3) Operation and maintenance costs only ________

   c. Capitalized cost of this project is ________ million dollars more than the most cost effective project.

2. DIRECT ECONOMIC CONCERNS

   a. What relative impact will the capital funding of this plan alternative have on the total supply and availability of capital funds to meet other community needs?

   b. What will be the relative impact of operation and maintenance costs of this plan alternative on utility rates and/or tax rates?

c. What relative impact will any displacements caused by this plan alternative have on employment and community real income?

d. What relative impact will any displacements caused by this plan alternative have on tax income of the community?

3. INDIRECT ECONOMIC CONCERNS

a. What relative impact will this plan alternative have on the general desirability of this area as a place to operate a business which will be reflected in the rate of economic development of the area? What relative impact will this plan alternative have on the general level of economic activity of the area which will be reflected in property values and tax income of the community?

4. TRANSIENT ECONOMIC CONCERNS

a. What will be the relative impact of project construction on local employment during the construction period based on this plan alternative?

b. What relative impact will the construction of this plan alternative have on local manufacturing and materials supply business?

c. What relative impact will the construction of this plan alternative have on temporary disruptions of circulation and/or business activity that will result in reduced employment or other economic loss?

5. SOCIAL CONCERNS FOR THE COMMUNITY

a. What relative impact will this plan alternative have on the health, welfare and safety of the community?

b. Will the implementation of this plan alternative cause disruptions of existing community living patterns such as location, quality and character of residential communities, locations and kinds of employment and general cultural activities?

c. What relative impact will this plan alternative have on the recreation patterns of the community?

d. What relative impact will this plan alternative have on land use and land planning?

6. SOCIAL CONCERNS FOR THE INDIVIDUAL

a. Will the implementation of this plan alternative cause dislocations which will effect the place of residence, employment, business mobility and general cultural activity of a significant number of individuals?

b. To what extent will the implementation of this plan impact individual life style?

7. CONCERN FOR GROUNDWATER QUALITY

a. What is the relative potential of this plan for impact on groundwater quality?

8. CONCERN FOR SURFACE WATER QUALITY

a. What is the relative potential of this plan for impact on surface water quality?

9. CONCERNS FOR LAND USE

What are the land use requirements of this candidate plan?

a. What relative impact will this plan have on the quantity or quality of land available for wildlife habitat, natural vegetation and open space?

b. What relative impact will this plan have on the aesthetic quality of the landscape?

c. What constraints will this plan place on other beneficial uses of land?

10. CONCERNS FOR AIR QUALITY AND NOISE

a. What effect will the implementation of this plan alternative have on the public health aspects of air quality?

b. What effect will the implementation of this plan alternative have on the aesthetic aspects of air quality?

c. What will be the relative impact of this plan alternative with respect to noise.

11. CONCERNS FOR ENERGY AND RESOURCES

a. How does this project compare with other plan alternatives with respect to the need for:

(1) Electrical energy input?

(2) Thermal energy input?

b. How does this plan alternative compare with other alternatives with respect to need for consumption of chemicals or other consumable resources which may be in short supply?

c. What positive aspects does this plan alternative have with respect to salvage of energy or reusable chemical resources?

d. How does this plan compare with other plan alternatives in net energy requirements after considering credits for resource recovery potential?

12. PERFORMANCE EVALUATION

a. How does this plan alternative compare with others in technical performance toward releasing to the environment the highest quality renovated wastewater?

b. How does this plan alternative compare with others in reliability of technical performance?

13. FLEXIBILITY

a. How does this plan alternative rate for its flexibility in being adaptable to unanticipated changes in rate and location of growth?

b. How does this plan alternative rate for its flexibility in adapting to possible changes in water quality criteria and goals?

c. How does this plan alternative rate for flexibility in being able to utilize future changes in technology of wastewater treatment?

14. INSTITUTIONAL JURISDICTION

a. How does institutional jurisdiction influence the acceptability and implementability of this plan alternative?

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