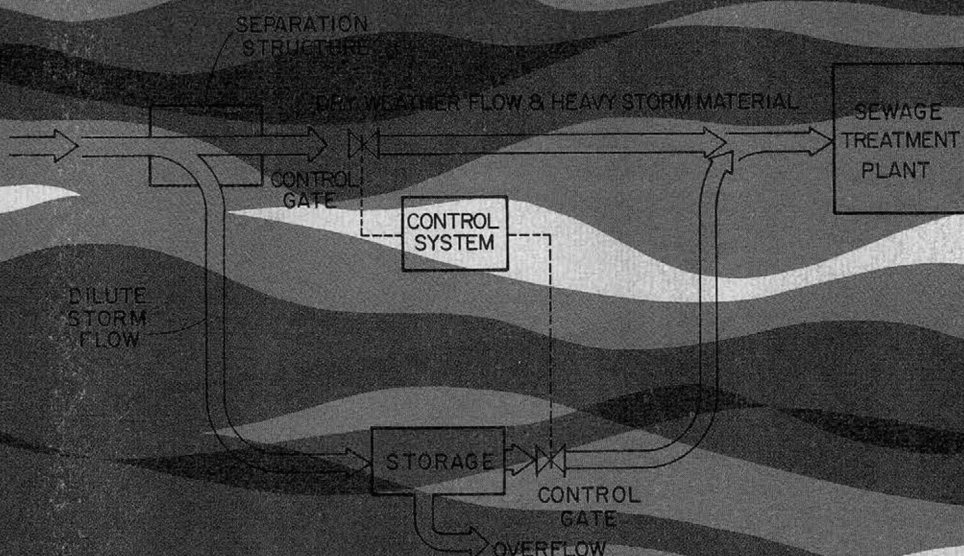
WATER RESOURCE SYSTEMS PROGRAM
Department of Civil Engineering
Colorado State University
Fort Collins, Colorado

PLANNING AND WASTEWATER MANAGEMENT OF A COMBINED SEWER SYSTEM IN SAN FRANCISCO



TR #10 MWIS PROJECT
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PLANNING AND WASTEWATER MANAGEMENT OF A COMBINED SEWER SYSTEM IN SAN FRANCISCO

prepared by

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and

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Metropolitan Water Intelligence Systems

TECHNICAL REPORT NO. 10

Department of Civil Engineering
Colorado State University
Fort Collins, Colorado

FOREWORD

This is one of a series of Technical Reports prepared under a grant by the Office of Water Resources Research which supports a project at Colorado State University entitled "Metropolitan Water Intelligence Systems." The objective of the project is to develop criteria and information for the development of metropolitan water intelligence systems (MWIS). The MWIS is a specialized form of the management information and control system concept which is becoming popular as a tool in industrial applications.

The project consists of three phases, each lasting about one year. This report was prepared during Phase II. Basic objectives for Phase I were to:

1. Investigate and describe modern automation and control systems for the operation of urban water facilities with emphasis on combined sewer systems.
2. Develop criteria for managers, planners, and designers to use in the consideration and development of centralized automation and control systems for the operation of combined sewer systems.
3. Study the feasibility, both technical and social, of automation and control systems for urban water facilities with emphasis on combined sewer systems.

Basic objectives for Phase II are:

1. Formulate a design strategy for the automation and control of combined sewer systems.
2. Develop a model of a real-time automation and control system (RTACS model).
3. Describe the requirements for computer and control equipment for automation and control systems.
4. Describe nontechnical problems associated with the implementation of automation and control systems.

This report is a description of a plan in San Francisco which recommends a control system for their combined sewer system. As such, San Francisco's water quality management problems make an excellent case study for many aspects of this research investigation. The report is essentially a resource paper which abstracts the 3-volume "San Francisco Master Plan for Wastewater Management" prepared in September 1971. Although this Master Plan has not yet been implemented a great deal of the methodology developed and the data produced should be of value to urban water managers who face problems similar to San Francisco's.

The report presents the criteria and procedure used in developing the 1971 Master Plan. It includes skeletal portions of the data used and the descriptive features of the Master Plan itself. The goals of the work envisioned by the Master Plan are to solve three basic problems: water quality impairment by dry weather effluent, by wet weather overflows and drainage problems on city streets. From these goals the report shows the Master Plan procedures within the framework of a systems engineering process. The formulation of objectives, establishment of measures of effectiveness, formulation of alternatives, evaluation of alternatives and recommendation of a basic plan are demonstrated.

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Maurice L. Albertson, George L. Smith and Neil S. Grigg are co-principal investigators.

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The following technical reports were prepared during Phase I of the CSU-OWRR project, Metropolitan Water Intelligence Systems. Copies may be obtained for $3.00 from the National Technical Information Service, U. S. Department of Commerce, Springfield, VA 22151. (When ordering, use the report title and the identifying number noted for each report.)

Technical Report No. 1 - "Existing Automation, Control and Intelligence Systems of Metropolitan Water Facilities" by H. G. Poertner. (PB 214266)

Technical Report No. 2 - "Computer and Control Equipment" by Ken Medearis. (PB 212569)

Technical Report No. 3 - "Control of Combined Sewer Overflows in Minneapolis-St. Paul" by L. S. Tucker. (PB 212903)

Technical Report No. 4 - "Task 3 - Investigation of the Evaluation of Automation and Control Schemes for Combined Sewer Systems" by J. J. Anderson, R. L. Callery, and D. J. Anderson. (PB 212573)

Technical Report No. 5 - "Social and Political Feasibility of Automated Urban Sewer Systems" by D. W. Hill and L. S. Tucker. (PB 212574)

Technical Report No. 6 - "Urban Size and Its Relation to Need for Automation and Control" by Bruce Bradford and D. C. Taylor. (PB 212523)

Technical Report No. 7 - "Model of Real-Time Automation and Control Systems for Combined Sewers" by Warren Bell, C. B. Winn and George L. Smith. (PB 212575)

Technical Report No. 8 - "Guidelines for the Consideration of Automation and Control Systems" by L. S. Tucker and D. W. Hill. (PB 212576)

Technical Report No. 9 - "Research and Development Needs in Automation and Control of Urban Water Systems" by H. G. Poertner. (PB 212577)

Technical Report No. 10 - "Planning and Wastewater Management of a Combined Sewer System in San Francisco" by Neil S. Grigg, William R. Giessner, Robert T. Cockburn, Harold C. Coffee, Jr., Frank H. Moss, Jr. and Mark E. Noonan.

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SECTION I. DEFINITION OF THE PROBLEM

Combined wastewater control and the management of combined sewer overflows historically has been a second priority problem in most water quality management systems. This was true for the City and County of San Francisco until a few years ago when the problem of dry weather treatment was first resolved. With the resolution of the most severe water quality problems attributable to the relatively smaller daily volumes of dry weather sanitary discharges, the attention of regulatory agencies and to some extent the dischargers, has been directed toward the need for control of the relatively massive and highly variable combined sewer overflows. In the late 1960's, the State regulatory agency, California Water Quality Control Board, San Francisco Bay Region, directed that the City develop plans for the management and control of the City's combined overflows.

In recent years the Department of Public Works has been engaged in comprehensive studies leading to the selection of a plan of attack for water quality management. The purpose of this report is to describe these studies and to present a brief outline of a recent document, the 1971 San Francisco Master Plan for Wastewater Management.

With the recognition that water quality problems did exist, the first step in the San Francisco planning process had been taken. This is the first stimulus to the application of systems engineering; that is, the acknowledgment of a problem's existence. Following this step, a commitment to the development of a solution is required. Given this commitment, the basic steps of systems analysis have been started. One listing of the steps that can be followed is:

1. Perception of the problem and commitment to solution
2. Definition of the problem
3. Formulation of objectives for the solution
4. Formulation of measures of effectiveness of alternative solutions
5. Generation of alternative solutions
6. Evaluation of alternative solutions
7. Selection of a plan

One challenge of systems engineering lies in the meaningful application of the method to real problems subject to difficult constraints. In all instances, meaningful application requires real measurements upon the system involved. In many cases, the magnitude and difficulty of the effort in attaining a real understanding of the problem in terms of real data is unlikely to be understood within the confines of a single discipline. Thus, interdisciplinary communication and cooperation must be coupled with the steps listed above. This is particularly true in the area of environmental control.

Problem Description

The City and County of San Francisco (CCSF) operates three wastewater treatment plants with a combined sanitary capacity of 100mgd and an interceptor system of approximately 300mgd to service 43 separate combined sewer districts. The basic objective of the operation of the system is to collect, transport, treat and dispose of the smaller dry weather flows at acceptable cost and nuisance levels, and to handle massive wet weather flows in such a manner that 5-year storm drainage protection is obtained on city streets. It is also the City's responsibility to operate and maintain the system in such a manner to protect the receiving waters from degradation due to wastewater discharges at all times. The phrase "at all times" adds considerable difficulty and expense to the task. The present inadequacy of the smaller dry weather wastewater treatment and disposal system prohibits the effective control, transport, treatment and disposal of the temporally and spatially varying rainfall releases combined with sanitary sewage. The two major system inadequacies are:

1. The dry weather interception, collection treatment and disposal system is grossly inadequate to handle the wet weather flows occurring in the system.
2. Effluent from the City's three chemically augmented treatment plants violates existing standards and cannot meet the quality levels required by present or anticipated State and Federal policy.

Thus, the problem may be defined as a lack of control of the flows from San Francisco's combined sewers during wet weather, and the resulting receiving waters degradation, and a pressing need for improved dry weather treatment and disposal.

One set of effects of the problem can be measured in terms of the receiving water degradation. For example, for up to nine months of the year, the waters may not meet the bacteriological requirements for water contact sports. This may be accompanied by the accumulation of grease and other floatable material of sewage origin on the beaches.

A second set of effects is related to the transport and collection problems and is seen in the nuisance and cost of flooding and of system maintenance. Thus, there are internal and external aspects to the total problem. The objectives for solution of the problems can thus be related to the water quality standards for the waters contiguous to the City and the City goals of flood mitigation and nuisance control.

Water Quality Standards

The water quality objectives for effluents and for receiving waters are presently prescribed by water quality standards. Four levels of government influence these standards. Although many agencies are concerned with water quality the most important regulatory agencies are as follows:

FEDERAL - The Environmental Protection Agency (EPA) establishes and enforces national water quality standards to attain the goals and policies of the Congress.

STATE - The State Water Resources Control Board (SWRCB) develops State Policy and implements the goals set by the Legislature. It operates through regional water quality control boards. In the San Francisco Bay Region the Regional Water Quality Control Board (RWQCB) is the line agency which establishes and enforces effluent and receiving water standards.

REGIONAL - While the RWQCB is a subdivision of a state agency, it effectively operates at the regional level. Also, the Association of Bay Area Governments (ABAG) is concerned with water quality because it is the authorized regional planning agency. It is anticipated that the ABAG role in water quality planning will soon be assumed by the Bay Area Sewerage Services Agency (BASSA).

CITY - There is no direct City regulatory agency, but the Department of Public Works (SFDPW) is responsible for the management and control of wastewater. As such, it can regulate discharges from and levy charges against individual or corporate system users.

The list of agencies above is not all inclusive, for many other agencies are concerned with water quality. A complete list of these, along with their areas of concern is given in the Master Plan[1]. The agencies listed above, however, are essentially in control of the planning for wastewater management.

The basic water quality standards to be met have been prescribed by the RWQCB for discharges from each of the City's three treatment plants. Details of the requirements are also given in the Master Plan[2]. In the past, the standards have been concerned with the usual gross contaminants and with the maintenance of dissolved oxygen levels. More recently, standards have become increasingly stringent, and it is anticipated that they will become more so as levels of knowledge and concern for the environment grow. In addition to the more stringent standards, the quality of storm water discharges may also be subject to some regulation in areas where water quality degradation may be attributed to these discharges. This would be in areas where a significant portion of the watershed runoff is from urban areas.

Problem Scope

The problem of wastewater management and control in the City and County of San Francisco has two facets:

1. Control of the massive and dynamically variable "wet weather" periods of short duration, and
2. Control of the smaller volume of continuous "dry weather" flow.

The dimensions of the problem may be rapidly seen from an examination of Figure 1 where a mass balance of annual flows is given. As shown on this figure, 39 billion gallons (BG) of dry and wet weather flow passes through the treatment plants annually, whereas some 6 BG overflows during

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[1]City and County of San Francisco, Department of Public Works, Master Plan for Wastewater Management, September 15, 1971.

[2]Ibid.

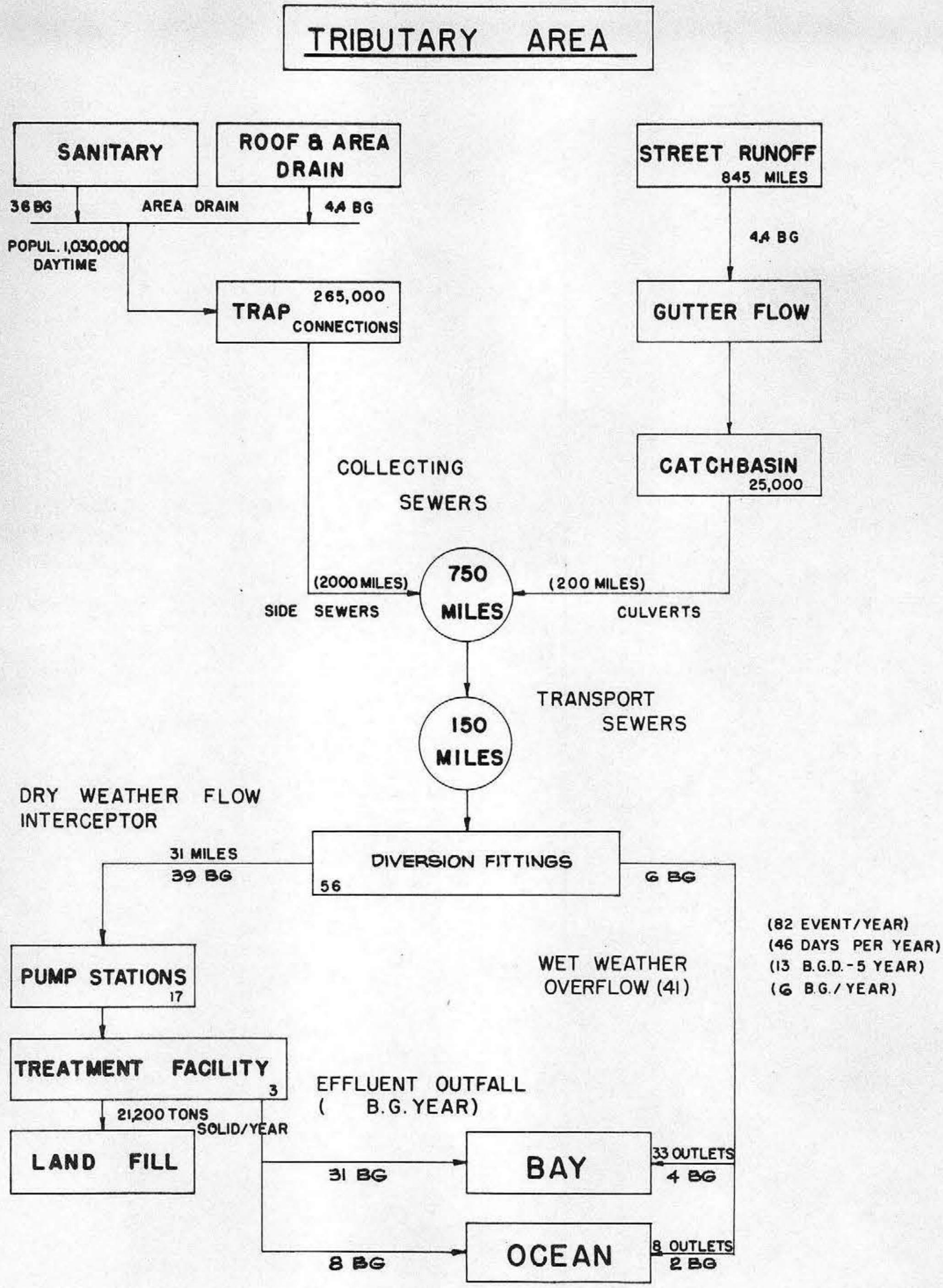

Figure 1. Mass Balance of Wet and Dry Weather Flows (1)

BG... billion gallons

wet weather. Both discharges currently do not meet the established standards. However, significant improvement has been achieved in the dry weather flows by the use of chemical additions at the treatment facilities.

SECTION II. PLANNING METHODOLOGY

Data Collection

Together with the RWQCB, the CCSF recognized the problem of overflows and became committed to a solution several years ago. In 1968, the San Francisco Board of Supervisors passed a resolution establishing as a policy the goal of control of overflows during wet weather. This recognition of the problem led immediately to a search for background data describing and correlating rainfall and runoff, a necessity to describe the size and mix of a system for control of wet weather flows. The investigation revealed that only first order rainfall data was available from the Federal Office Building rain gauge consisting of 62 years of hourly rainfall amounts. This was obtained and analyzed as described later. About twenty years of hourly records were available at a second order gauge maintained at one of the City's treatment plants. This data was also analyzed.

It was apparent at that point in the analyses process that any further data was going to have to be generated by the City on its own. To accomplish this a computer based rainfall and runoff data acquisition system was designed. The system contains 30 rain gauges (approximately 1 per 850 acres) and 120 flow monitor sites. The rain gauges installed are the tipping bucket type. Each tip (0.01") at each gauge is recorded at the central computer, to the nearest second. Program software allows information retrieval either as rainfall depth or as intensity in inches per hour. The location of the gauges allows a more refined description of storm velocity, intensity, and spatial and temporal variation, all necessary to design control facilities. Total mass of rainfall can also be calculated. Flow monitor stations are installed in the sewer system to measure the runoff in terms of depth of flow in the main sewer at the exits of the monitored districts. Flow levels are recorded every 15 seconds for each monitor station. By using a stage-discharge curve for each station, the runoff at each time period can be obtained and actual rainfall-runoff events for each district can be described. A review of the sewer system noted that there were many interconnections between drainage districts. In order to obtain meaningful rainfall-runoff data the drainage districts were isolated by plugging certain sewers. A known area could then be associated with a particular runoff.

Any number of analyses can be made on the raw data obtained, including the differences in runoff relationships due to storm approach direction, intensity distribution and other variations.

The monitor stations also describe the dry weather flow generation pattern for each district in terms of volume. Correlation of this data with constituent loadings allows determination of the masses of pollutants at any monitor location in the system.

The need for base line data in the receiving waters was recognized, and work was initiated to describe the pollutants discharged during storms, and the effect on receiving waters.

It was anticipated that to provide the proper type of data history, the data acquisition should continue for a minimum of 5 years. Once the data acquisition had been started analysis could begin and goals and objectives set. It must be noted that problem boundary definitions and the assessments of effects have not been completed. However, as the period of data collection extends over such a long time, a critical path approach to the development of a solution can be used. This entails carrying through the steps of the systems engineering approach using available data with refinement as more data becomes available. However, sufficient data must initially be available to allow a first order definition of the problem and its effects.

Establishment of Goals and Objectives

The CCSF is one of many dischargers into the receiving waters of San Francisco Bay and the Pacific Ocean. A recent report by the U. S. Corps of Engineers lists some 165 "major" dischargers of municipal wastewater in the San Francisco Bay - Delta Region[3]. The CCSF cannot, therefore, act independently in setting goals and objectives of water quality. In fact, the objectives to be met are imposed by the State in the form of water quality standards. In addition to changing in time, the standards change in form. New water quality parameters enter the list of those regulated,

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[3]U. S. Army Corps of Engineers, San Francisco District, Public Brochure on Wastewater Management Alternatives for the San Francisco Bay and Sacramento - San Joaquin Delta Water Quality and Waste Disposal Investigation, August 1972.

and the possibility exists that storm waters may become regulated. The achievement of the goals and objectives thus takes on an air of uncertainty as they change. The problem thus becomes one of "decision-making under uncertainty."

Formulation of Measures of Effectiveness

The measures used to evaluate effectiveness of alternatives were:

1. Control
2. Required treatment
3. Operational feasibility
4. Acceptable discharge location
5. Cost

Since the problem is to meet prescribed standards (albeit standards which may change over time), the systems engineering process becomes one of minimizing the cost of a given level of project rather than maximizing the effectiveness for fixed cost. The measures of effectiveness are, therefore, closely connected to the water quality standards.

Measures of effectiveness are needed in the three basic problem areas previously cited; inadequate treatment, excessive overflows, and inadequate drainage capacity.

Inadequate treatment: The effectiveness measures for this category consist principally of the efficiency of removal of contaminants for individual schemes or processes. Typical measures are: survival of test organisms in undiluted waste stream; percent removal of BOD, Nitrogen, Phosphate, suspended solids, and grease.

Overflows: The deleterious effect of overflows in receiving waters is basically characterized by the volume of combined sewage overflowing in a year. This has been related, however, to a more meaningful parameter, the frequency of overflows per year.

Drainage: The effectiveness measure for drainage is the extent to which the system meets the 5-year design criteria.

Generation of Alternatives

Since separation of the sewer system was not considered a viable alternative, plans had to be made to control a large volume of combined sewage. Alternatives for the treatment of dry weather and combined flow consist of different treatment schemes. Alternatives for the overflow problem revolve around combinations of conduit capacity, treatment capacity and storage. For the drainage problem the alternatives consist of increasing pipe size, providing upstream storage, or combinations of both.

Dry Weather and Combined Sewage Treatment: Two basic approaches to this problem are possible. Since the City has three existing treatment plants, the options exist to upgrade them to meet new standards and to expand them to accomodate increased flow rates, or to consolidate all plants into one. To examine these alternatives, three levels of treatment were designated. Table 1 gives explanations of the three levels considered. They basically correspond to advanced primary, secondary and advanced treatment. Table 2 gives a listing of alternatives considered in terms of allocation of capacity to existing plants or to a new plant located at Lake Merced (LM). Also shown on Table 2 are approximate costs associated with the different alternatives.

The Overflow Problem: Overflows occur simply because the rate of flow of combined sewage exceeds existing interceptor capacity and/or treatment capacity at certain points during certain storms. The overflows can occur at outfall locations as shown in Figure 2 and listed on Table 3.

Alternatives for solution of the overflow problem basically fall into three categories:

1. Accept present overflow levels
2. Provide sufficient treatment plant and interceptor capacity to reduce overflows to acceptable levels
3. Provide storage at certain locations to attenuate peaks providing for timed-release of the sewage for later treatment

It is apparent that in a real system such as the San Francisco sewerage system the alternatives considering combinations of the above are quite numerous.

The first alternative listed is not acceptable because it does not meet the standards set by the water quality objectives. Similarly, the second alternative can be rejected *a priori* because it was found financially and technically infeasible. The third class of alternatives really contains a large number of possibilities when all of the combinations of storage opportunities are considered.

Levels of Treatment	Survival in Undiluted Waste Stream	BOD Removal (%)	Nitrogen Removal (%)	Phosphate Removal (%)	Suspended Solids Removal (%)	Grease in Effluent (mg/l)	May Be Accomplished By
I. First Level Treatment (1)	25	40	15	50	75	25	Chemical Treatment using a low Ferric Chloride dosage.
II. Second Level Treatment (2)	40	70	20	85	88	15	Chemical Treatment using a high Lime dosage.
III. Third Level Treatment (3) & (4)	90	94	85	93	98	10	Chemical Treatment utilizing a high Lime dosage treatment **followed by Reclamation Treatment**

Notes:

1) Equivalent removal efficiency described as Advanced Primary Treatment in Bay-Delta Report
2) Equivalent removal efficiency described as Intermediate Treatment in Bay-Delta Report
3) Equivalent removal efficiency described as Tertiary Treatment in Bay-Delta Report
4) The proposed reclamation treatment for Dry Weather flow would consist of the following additional unit processes: Super Chlorination, Dual Media Filtration and Carbon Adsorption.

Table 1. Definitions and Efficiencies of Treatment Levels Considered (1)

	TYPE OF TREATMENT	TREATMENT RATE - MGD				COST MILLIONS		
		R-S	SE	NP	LM	Dry Wea.	Wet Wea.	Total
A. EQUIVALENT LEVELS - ALL PLANTS	I. First Level Treatment							
	a)	70	70	200	660	$ 42	$105	$147
	b)	x	70	200	730	41	103	144
	c)	x	x	200	800	40	101	141
	d)	x	x	x	1000	42	107	149
	II. Second Level Treatment							
	a)	70	70	200	660	66	104	171
	b)	x	70	200	730	69	103	172
	c)	x	x	200	800	73	101	174
	d)	x	x	x	1000	83	107	190
	III. Third Level Treatment							
	a)	70	70	200	660	168	105	273
	b)	x	70	200	730	161	103	264
	c)	x	x	200	800	144	101	245
	d)	x	x	x	1000	130	107	237
B. VARIABLE LEVELS	I. Second Level Treatment at NP, and Ocean Discharge; Third Level at SE							
	a)	70	70	200	660	93	105	198
	b)	x	70	200	730	95	103	199
	c)	x	x	200	800	73	101	174
	d)	x	x	x	1000	83	107	190
	II. Second Level Ocean Discharge; Third Level NP & SE							
	a)	70	70	200	660	147	105	252
	b)	x	70	200	730	150	103	253
	c)	x	x	200	800	127	101	228
	d)	x	x	x	1000	83	107	190

x - Abandoned
R-S: Richmond-Sunset
SE: Southeast
NP: North Point
LM: Lake Merced

Table 2. First Cost Comparison of Expanding
3 Existing Plants vs. 1 New Plant (1)

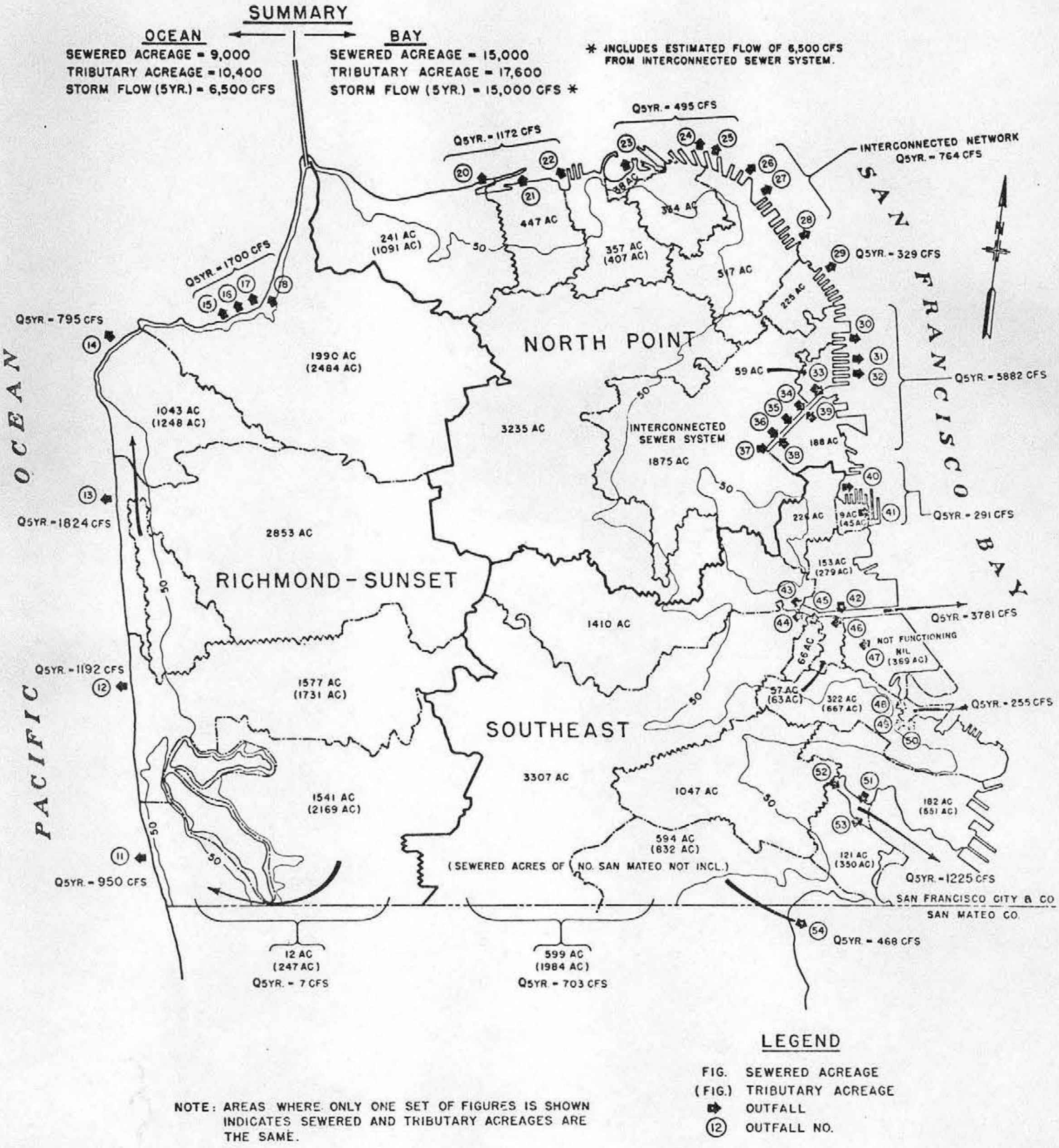

Figure 2. Sewered and Tributary Areas
City & County of San Francisco (1)

OUTFALL NO.	NAME	CONDUIT SIZE	CONDUIT X-SEC. AREA (sf)	TRIBUTARY ACRES TOTAL	TRIBUTARY ACRES SEWERED	APPROX. Tc MIN.	APPROX. Tc SEC.	"C"	CA (TOTAL)	5 YR. I	5 YR. Q	10 YR. I	10 YR. Q	25 YR. I	25 YR. Q	50 YR. I	50 YR. Q	100 YR. I	100 YR. Q
11	Lake Merced	10'x11'-3"	95.0	2,169	1,541	30	24	.39	848	1.12	950	1.32	1,119	1.55	1,314	1.72	1,459	1.92	1,628
12	Vicente	2 @ 5'dia.	39.2	1,731	1,577	24	44	.55	946	1.26	1,192	1.50	1,419	1.75	1,656	1.99	1,883	2.20	2,081
13	Lincoln Way	3 @ 6'-6"	106.5	2,853	2,853	24	27	.50	1,425	1.28	1,824	1.51	2,138	1.78	2.537	2.01	2,864	2.22	3,164
14	Mile Rock	9'x11'	80.7	1,154	1,043	24	46	.54	626	1.27	795	1.50	939	1.75	1,095	1.99	1,245	2.20	1,377
15	Sea Cliff P.S. #1	18" dia.	1.8		4	3	0	.70	3	2.59	8	3.01	9	3.51	11	4.00	12	4.16	13
16	Sea Cliff	6' dia.	28.3	2,484	566	17	02	.67	380	1.57	597	1.88	714	2.20	836	2.48	942	2.80	1,064
17	Sea Cliff P.S. #2	12" dia.	0.8		8	4	0	.70	6	2.59	16	3.01	18	3.51	21	4.00	24	4.16	25
18	Baker's Beach	7' dia.	38.5		1,412	20	28	.54	765	1.41	1,071	1.68	1,285	1.99	1,522	2.21	1,691	2.50	1,913
	RICHMOND-SUNSET DISTRICT		390.8	10,391	9,004						6,461		7,641		8,992		10,120		11,265
20	Baker Street	9' dia.	63.4	1,091	241	15	55	.60	145	1.60	232	1.95	283	2.29	332	2.57	373	2.88	418
21	Pierce	8' dia.	50.3	447	447	15	40	.70	313	1.63	510	1.99	623	2.32	726	2.60	814	2.90	908
22	Laguna	6' dia.	28.3	407	357	13	53	.70	250	1.72	430	2.10	525	2.50	625	2.79	698	3.10	775
23	Hyde	24" dia.	3.1	38	38	7	11	.80	30	2.33	70	2.79	84	3.20	96	3.65	110	4.00	120
24	Beach	6'x7'	41.1	314	314	12	52	.75	236	1.80	425	2.19	517	2.56	604	2.88	680	3.19	753
25	Grant (Beach St. Relief)	36" dia.	7.1	20	20			.75	15										
26	Sansome	2 @ 5'-6"x 6'-6"	69.5																
27	Greenwich	6' dia.	28.3	[illegible]	[illegible]	(13	20)	(.83)	(429)	(1.78)	Part of interconnected network.	(2.40)		(2.50)		(2.80)		(3.15)	
28	Jackson	8'x9'-6"	72.3																
29	Howard	7' dia.	38.5	225	225	14	10	.85	191	1.72	329	2.10	401	2.45	468	2.78	531	3.10	592
30	Brannan	7'6"x6'	36.0																
34	North Side Fourth St.	6'-6" dia.	33.2																
35	Fifth Street	7'-9"	47.2	5,110	5,110	(19	00)	(.77)	(3,935)	(1.47)		(1.78)		(2.09)		(2.34)		(2.61)	
36	North Side Sixth St.	6' dia.	28.3								Part of interconnected network.								
37	Seventh & Division	3 @ 8'-3"x 9'-6"	224.2																
31	Townsend	2'x3'	6.0		22	5	38	.75	17	2.55	43	2.98	51	3.47	59	3.88	66	4.11	70
32	Berry	15" dia.	1.2	59	7	5	24	.60	4	2.58	10	3.00	12	3.48	14	3.90	16	4.14	17
33	Third Street	2'-6"x3'-9"	7.3		30	11	41	.75	23	1.90	44	2.28	52	2.65	61	3.00	69	3.35	77
38	South Side Sixth St.	3'-6"x5'-3"	14.0	186	63	10	25	.65	41	2.00	82	2.40	98	2.80	115	3.16	130	3.50	144
39	South Side Fourth St.	2'-6"x3'-9"	7.3		125	15	27	.60	94	1.65	155	2.00	188	2.35	221	2.60	244	2.90	273
	NORTH POINT DISTRICT		372.3	9,416	[illegible]						2,330 (8,879)		2,834 (10,868)		3,321 (12,618)		3,731 (14,139		4,147 (15,768)
40	Mariposa	6' dia.	28.3	226	[illegible]	11	42	.6[illegible]	147	1.90	279	2.28	335	2.65	390	3.00	441	3.35	492
41	20th St. (Beth. Shipyd - Flow Unk.)	24" dia.	3.1	45	9	6	00	.50	5	2.49	12	2.90	15	3.40	17	3.80	19	4.08	20
42	North Side Third St.	3'x6"x5'-3"	14.0	279	153	19	43	.60	92	1.45	133	1.71	157	2.01	185	2.28	210	2.57	236
43	Marin	8'x10'	74.7	1,410	1,410	25	31	.65	917	1.23	1,128	1.48	1,357	1.71	1,568	1.95	1,788	2.15	1,972
44	Selby	3 @ 7'x10'	209.1	3,307	3,307	29	32	.65	2,150	1.12	2.408	1.33	2,860	1.56	3,354	1.76	3,784	1.96	4,214
45	Rankin	5' dia.	19.6	66	66	18	28	.60	40	1.50	60	1.80	72	2.10	84	2.35	94	2.65	106
46	South Side Third St.	2'-6"x3'-9"	7.3	63	57	14	29	.55	31	1.69	52	2.06	64	2.40	74	2.70	84	3.00	93
47	Mendell	4' dia.	12.6	369	nil	8	00	.60											
48	Evans	6' dia.	28.3		260	34	13	.60	156	1.03	161	1.21	189	1.41	220	1.58	246	1.75	273
49	Hudson	30" dia.	4.9	667	43	5	21	.60	27	2.58	70	3.00	81	3.50	95	3.95	107	4.15	112
50	Griffith North	21" dia.	2.4		17	6	40	.60	10	2.39	24	2.81	28	3.29	33	3.69	37	4.02	40
51	Griffith South	5'-6" dia.	23.8	551	182	19	06	.60	109	1.46	159	1.75	191	2.07	226	2.31	252	2.59	283
52	Yosemite	9'x7'-3"	52.9																
		11'-6"x6'-6"	69.6	1,047	1,047	18	28	.60	628	1.50	942	1.80	1,130	2.10	1,319	2.35	1,476	2.65	1,664
53	Fitch	6-9" dia.	35.8	350	121	14	24	.60	73	1.70	124	2.05	75	2.41	176	2.70	197	3.01	220
54	Sunnydale	6-6" dia.	33.2	832	594	19	48	.55	327	1.43	468	1.72	562	2.01	657	2.28	746	2.56	837
	S.E. COLLECTION SYSTEM		619.6	9,212	7,494						6,020		7,116		8,398		9,481		10,562
	GRAND TOTAL		1,882.7	28,019	24,014						14,811 (21,360)		17,591 (25,625)		20,711 (30,008)		23,332 (33,740)		25,974 (37,595)

REMARKS

(1) 12 Ac. of No. San Mateo not incl. Q_{5yr} = 7cfs.
(2) 75 acres to Mile Rock
(3) Incl. 504 acres G.G. Park & 494 acres Presidio.
(4) Incl. Ft. Miley 85 acres & G.G. Park 51 acres.
(5) 5 min. T_c used for computations
(6) Incl. 23 acres from G.G. Park.
(7) 5 min. T_c used for computations.
(8) Incl. 319 acres from G.G. Park.
(9) Incl. 850 acres from Presidio.
(10) (Fig.) = Total Q including estimated flow from interconnected network.
(11) 464 sewered acres of No. San Mateo not incl. Q_{5yr} = 338 cfs.
(12) Undeveloped area - Outlet not functioning.
(13) 135 sewered acres of No. San Mateo not incl. Q_{5yr} = 106 cfs.

Note:
(1) Refers to Outfall #11.
(2) Refers to Outfall #12.
(3) Refers to Outfall #13.
(4) Refers to Outfall #14.
(5) Refers to Outfall #15.
(6) Refers to Outfall #16.
(7) Refers to Outfall #17.
(8) Refers to Outfall #18.
(9) Refers to Outfall #20.
(10) Refers to NP District.
(11) Refers to Outfall #45.
(12) Refers to Outfall #47.
(13) Refers to Outfall #54.

(GRAND TOTAL with Interconnected Network.)

Table 3. Outfall Names, Sizes, Flows and Areas

Drainage Alternatives: The basic problem in the formulation of drainage alternatives is to provide conduit capacity for the design rainfall. Storage and conduit capacities must be considered together to provide the desired drainage service. It is apparent that the drainage problem and overflow problem are closely related.

Description of Alternatives Considered: The alternatives considered are classified as either treatment variations or storage/conduit capacity variations.

1. Treatment variations. These choices are shown in Tables 1 and 2 given earlier. Three levels of treatment and four different combinations of plant capacity allocation are shown. Any number of other combinations are possible.
2. Storage/conduit capacity variations. A number of possibilities exist in this category. Some cities have favored deep tunnel plans while others have favored conduit storage options. San Francisco has developed a unique concept of small detention basins combined with a tunnel, for combination transport - pretreatment and detention storage. The tunnel and the detention basins have been tentatively located as shown in Figure 3. Their sizes may vary to provide different levels of storage. This variation is shown in Table 4.

The Concept of Automatic Control: The conjunctive use of small storage basins, transport, pretreatment and treatment is highly flexible and temporally and spatially responsive to control. Control can vary in degrees of automation from the extreme of no control to the ultimate of total automatic (hands-off) control. One listing of the spectrum of control opportunities includes:

1. No control
2. Data recording
3. Supervisory control
4. Automatic control with manual override
5. Total automatic control

If the capacity of the storage system is small there will be frequent utilization, a high level of cost effectiveness, and a great need for automatic real-time control.

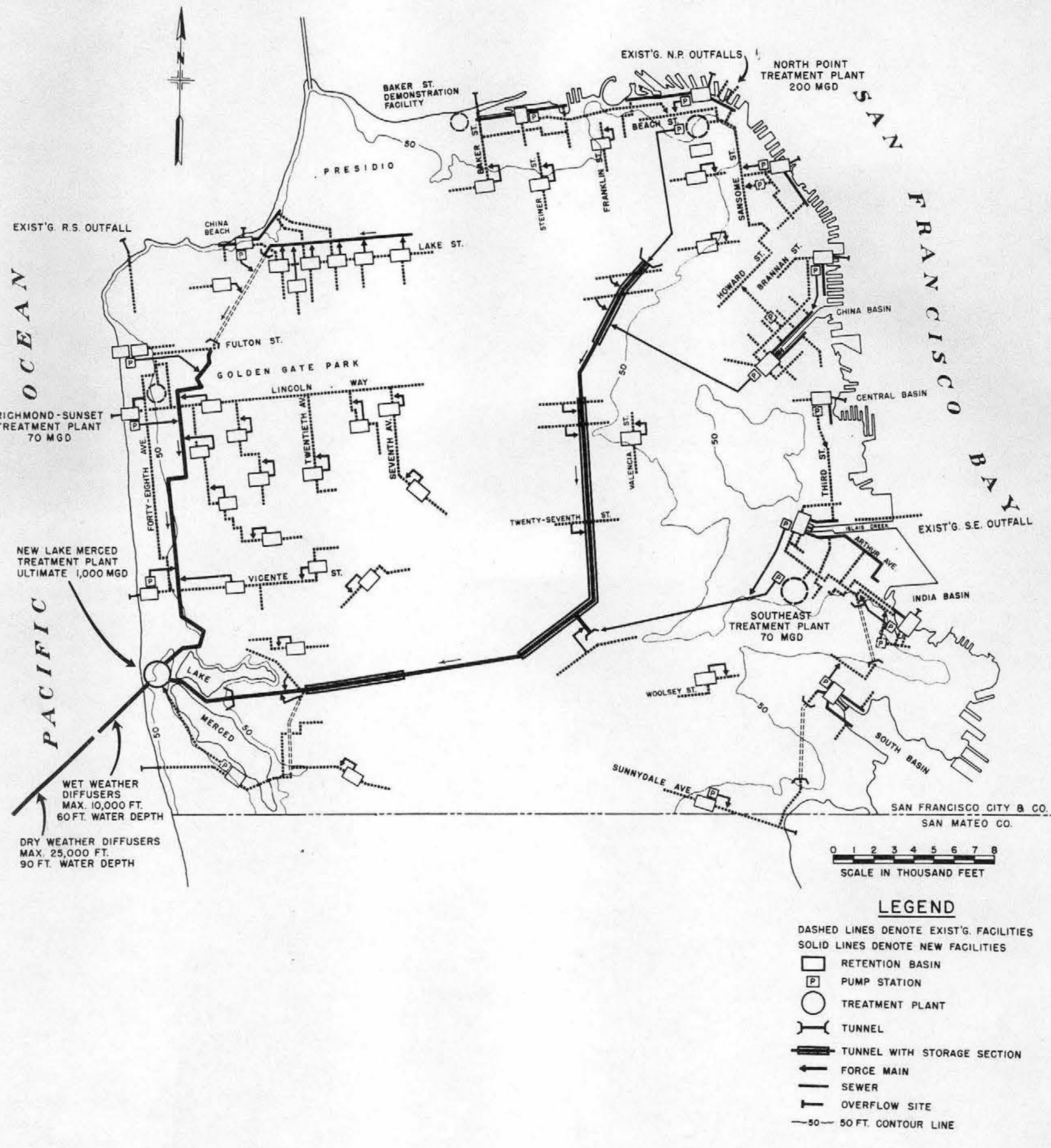

Figure 3. Master Plan for Wet Weather Control (1)

BASIN #	ACRES CONTROLLED	TREATMENT RATE cfs @ 0.10 in/hr.	VOLUME MILLION CUBIC FEET ALTERNATE A (16%)	ALTERNATE B (29%)	ALTERNATE C (61%)	ALTERNATE D (100%)	STAGE
11-1	164	10.8	0.13	0.13	0.23	0.38	7
11-2	182	12.0	-	0.12(T)	0.25(T)	0.41(T)	7
11-3	175	11.6	0.10(T)	0.11(T)	0.25(T)	0.40(T)	7
11-4	761	50.2	0.23(T)	0.51(T)	1.07(T)	1.75(T)	7
11-5	258	17.1	0.10	0.15	0.36	0.59	6
12-1	207	13.7	0.10	0.14	0.30	0.48	6
12-2	715	47.2	0.27	0.48	1.00	1.64	6
12-3	129	8.5	0.10	0.10	0.18	0.30	6
12-4	222	14.5	-	0.15	0.31	0.51	6
12-5	276	18.2	0.10	0.18	0.38	0.63	6
13-1	673	44.5	0.46	0.46	0.95	1.55	6
13-2	186	12.5	-	-	0.26	0.43	6
13-3	122	8.1	0.10	0.11	0.18	0.28	6
13-4	126	8.3	0.10	0.10	0.18	0.29	6
13-5	605	40.0	-	0.40	0.85	1.39	6
13-6	154	10.2	-	0.14	0.21	0.35	6
13-7	101	6.7	0.10	0.10	0.14	0.23	6
13-8	145	9.6	0.10	0.10	0.20	0.33	6
13-9	165	10.9	-	0.11	0.23	0.38	6
13-10	153	10.1	-	0.14	0.21	0.35	6
13-11	387	25.5	0.18	0.26	0.55	0.90	6
14-1	60	4.0	-	-	0.10	0.14	6
14-2	390	25.7	0.16	0.30	0.55	0.90	6
15-1	100	6.6	0.23	0.23	0.23	0.23	4
15-2	88	5.8	0.10	0.10	0.12	0.20	4
15-3	112	7.4	0.10	0.10	0.16	0.26	4
15-4	168	11.1	0.10	0.13	0.24	0.39	4
15-5	413	27.3	-	-	0.58	0.95	4
15-6	456	30.1	0.10	0.30	0.55	1.05	4
15-7	124	8.2	-	0.11	0.18	0.29	4
15-8	189	12.5	-	0.13	0.26	0.43	4
21-1	484	31.9	0.18	0.32	0.68	1.11	1
21-2	109	7.2	0.10	0.10	0.16	0.25	1
21-3	108	7.1	-	0.10	0.16	0.25	1
21-4	229	15.1	0.10	0.15	0.32	0.53	1
24-1	401	26.5	0.22	0.30	0.56	0.92	1
24-2	90	5.9	-	-	0.13	0.21	1
24-3	102	6.7	-	0.10	0.14	0.23	1
28-1	508	33.5	0.19	0.34	0.71	1.17	1
30-1	262	17.3	0.10	0.17	0.37	0.60	13
37-1	2424	160.0	0.89	1.62	3.4	5.58	13
37-2	161	10.6	0.10	0.10	0.23	0.37	13
37-3	303	20.0	0.11	0.20(T)	0.43(T)	0.70(T)	11
37-4	189	12.5	0.10	0.12(T)	0.27(T)	0.44(T)	11
37-5	845	55.8	0.31	0.56(T)	1.18(T)	1.94(T)	11
37-6	80	53.0	-	0.10	0.11	0.18	1
37-7	330	21.8	0.12	0.22(T)	0.46(T)	0.76(T)	14
37-8	271	17.9	0.10	0.18(T)	0.38(T)	0.62(T)	14
37-9	453	29.9	0.17	0.30(T)	0.64(T)	1.04(T)	14
40-1	220	14.5	0.10	0.15	0.31	0.51	14
44-1	2589	170.9	0.98	1.77	3.72	6.10	12
44-2	220	14.5	0.10(T)	0.15(T)	0.31(T)	0.51(T)	12
44-3	469	31.0	0.17(T)	0.32(T)	0.66(T)	1.08(T)	12
44-4	88	5.8	0.10	0.10	0.12	0.20	12
44-5	2753	182.0	1.0(T)	1.83(T)	3.86(T)	6.33(T)	12
48-1	64	4.2	0.10	0.10	0.10	0.15	8
52-1	1239	81.8	0.46	0.83	1.74	2.85	8
52-2	378	24.9	0.14	0.25	0.53	0.87	8
54-1	949	62.6	0.35	0.64	1.33	2.18	8
TOTALS							

(T) - Tunnel Storage

Table 4. Required Storage for Different Alternatives

Evaluation of Alternatives

The evaluation of alternative solutions for a set of problems such as those described is a difficult step in the systems engineering process. In simple, deterministic systems, it is often possible to construct a mathematical model to simulate the system in operation. If actual prototype data is available it is, of course, superior to data predicted from a model. Values of performance parameters can then be determined for different system levels and configurations, benefit-cost data can be determined and an array of cost effectiveness parameters can be examined.

The San Francisco wastewater control system is a good example of an urban subsystem that is too complicated for the analysis described above. This is the case with many urban problems. Often, however, assumptions are made which simplify the problem until it can be solved directly. Such an approach was not taken in this case; rather, a systematic analysis and evaluation procedure was undertaken to attack the problem frontally with as much sophistication as technology, economics and practicality would permit.

Groundwork: The studies which led to the Master Plan in its present form were actually started in the late 1960's. A series of consultant reports (see Appendix B) were initiated with the purpose of developing background information and recommendations for various elements of the problem. In 1969 a rain gauge network at the homes of the staff provided the first data on the spatial variation of rainfall in the city. In 1970 the previously described project for real-time data acquisition was initiated. The system has been in the early stages of operation since the end of 1970-71 wet season (March) and reliable data is now becoming available.

Background studies by the Department of Public Works and by consultants fall into the following six categories:

1. Basic data studies
2. Studies of water quality characteristics
3. Ecological studies of the receiving waters
4. Studies of specific treatment processes
5. Prefeasibility studies for alternative structural measures
6. Studies of the existing wastewater control system and modeling studies leading up to the capability to model the system

These studies were incorporated into the thinking and development that went into the Master Plan.

Evaluation of Treatment Concepts: The different levels of treatment were previously defined (Table 1). The most important criterion for the evaluation of a treatment concept is the cost to meet a certain water quality objective. The information in Table 2 gives approximate cost estimates for some of the basic facilities needed for the three levels of treatment considered and summarizes a great deal of analysis on this subject.

Evaluation of Storage-Treatment Combinations: The real heart of the set of alternatives for minimizing overflows is the concept of storage-treatment combinations with a split flow treatment plant. As described previously, the acquisition of sufficient data to formulate a detailed solution to the problem consumes great quantities of time and effort, but a first order definition can be made with sufficient initial data. In determining the appropriate storage-treatment combinations, rainfall periods must be segregated into discrete events or "storms", in order to provide a common denominator to measure the effects. The procedure used in the initial and continuing studies of the Master Plan is as follows:

1. Using available intensity-duration-frequency relationships for rainfall data, select a duration and frequency, for example, a fifteen-year, twenty-four hour storm, thus defining a specific "design rainfall" for containment. The uncertainty is in the selection of an appropriate duration and frequency, and a correct subsequent dry period to allow for dewatering time before the next storm occurs to tax the system.
2. Using available long term rainfall records (generally hourly precipitation data) construct a continuous mass rainfall diagram, to which the various storage and treatment combinations can be applied. Effects can then be determined in terms of overflow quantities and durations. The assumption is made in both this technique and the previous one that the available rainfall record typifies the system under consideration.
3. A refinement of the second technique is the application of appropriate temporally correct diurnal dry weather flow quantities to the rainfall masses for the combined sewer system.
4. Following the above, a more detailed analysis using multiple rain gauges within the system to more closely define the rainfall characteristics and to permit a subsystem-by-subsystem analysis and solution, must be performed within the constraints of the total system.

5. The use of multiple sewer and rain gauging instrumentation for direct measurements of overflows follows the analysis in step 4.

The last two techniques require record durations that are usually nonexistent, and the detailed analysis required for a complete solution of the problem must be preceded by the establishment of detailed histories. A less satisfactory approach would be to use synthetic data sequences for the analysis.

In the case at hand, a first order conceptual solution was arrived at using the technique described under 2 above. It was found that a given overflow frequency could be achieved with any number of combinations of storage and treatment capacities. However, for a given overflow frequency, the larger the treatment rate provided, the less would be the storage capacity required, and, the less would be the resulting average volume overflow. Moreover, rough cost estimates indicated that to achieve a given overflow frequency, the higher treatment rates resulted in a lower overall system cost. The analysis was conducted on the single rain gauge hourly precipitation records for 62 years beginning in 1907. Combinations of treatment and storage were used together with the record data to determine the system response to variations of the two parameters of treatment and storage. The selected treatment plant rate of 1,000 million gallons per day, combined with the appropriate storage capacities to produce desired overflow frequencies, represented a cost effective scheme and is technically feasible.

Having set the treatment plant capacity, storage capacities can be varied to detain any level of runoff quantity, depending on the spacing and volume of detention basins provided. The basic problem can be stated as follows:

Objective: Minimize untreated overflows to receiving waters

Overflows = function (runoff, storage, treatment, space, time)

In evaluating the effectiveness of storage-treatment combinations, both the individual basin and the overall city must be kept in mind. The three objectives of quality of discharge, number and volume of overflows, and drainage within the basins must be considered.

An analysis was made of the frequency of overflows as a function of storage capacity provided (in inches over the entire basin) and of treatment rate (in inches per hour). This is shown in Figure 4.

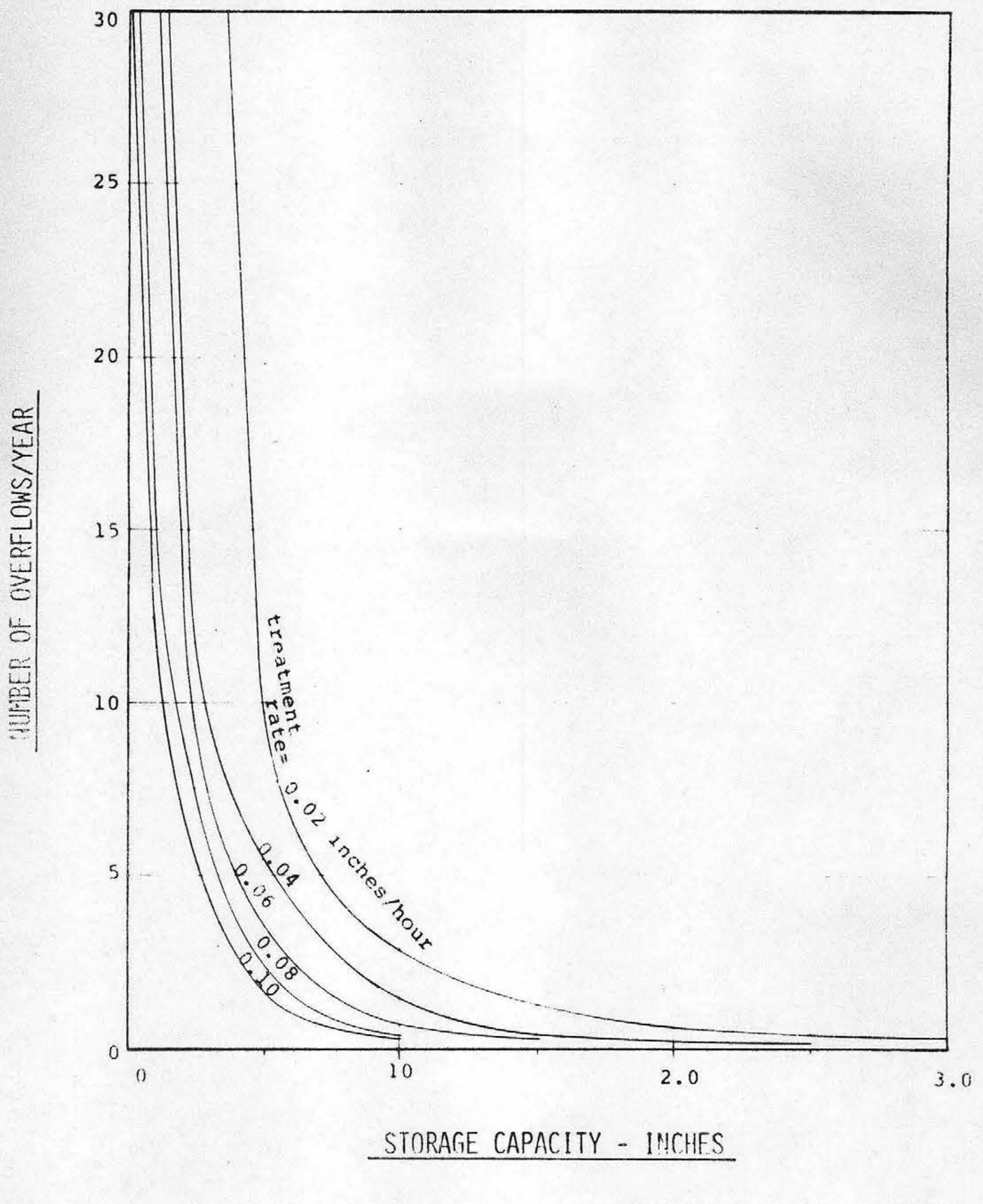

Figure 4. Composite Effects of Various Storage Capacities and Treatment Rate Combinations in Relation to Overflow Occurrences (1)

To set levels of overflow control conditions, several overflow frequencies were considered as objectives for control (Table 5). Table 6 shows the effect on overflow masses of pollutants of the different selections of storage volumes. The number of overflows per year can also be related to the number of days per year of violation of receiving water standards. An example of how this was done for bacteriological standards is shown in Figure 5.

In order to determine the best combinations of storage facilities between shoreline and upstream detention basins and tunnel storage, some approximate unit costs were developed. These are shown in Figures 6 and 7.

The final criteria for evaluation of alternatives is the set of cost information for each alternative considered. For the problem at hand the cost information is presented in tabular form as shown on Table 7. On this table are shown four wet weather control alternatives, three levels of treatment and three combinatorial schemes for treatment plants and effluent disposal. This results in an array of 36 alternatives for the decision makers.

Some of the information in Table 7 is shown graphically on Figures 8 and 9. This demonstrates the increasing marginal cost of achieving higher levels of overflow protection. As in most problems of environmental protection some trade-off point must be selected where the environmental and other benefits associated with a selected project at least equal the costs.

NUMBER OF OVERFLOWS PER YEAR	AVERAGE TOTAL HOURS OF OVERFLOW PER YEAR	PERCENT TIME OVERFLOW OCCURS PER YEAR	PERCENT OF CONTROLLED RUNOFF (2)	PERCENT OF OVERFLOW	VOLUME OF UNCONTROLLED RUNOFF FOR TOTAL CITY ($x10^9$ GALS.)
82	206	2.350	32.0	68.0	6
8	16	0.183	92.5	7.5	0.75
4	8	0.091	95.9	4.1	0.36
1	3	0.034	98.9	1.1	0.09
1/2	1.5	0.017	99.5	0.5	0.04
1/5	0.8	0.009	99.8	0.2	0.02
1/20	-	-	99.95	0.05	0.004

(1) Annual Averages

(2) Based upon Treatment Rate of 0.10 inch per hour of Equivalent Rainfall

Table 5. Percentage Control of Wet Weather Overflow Volumes (1)

Zones	Constituent	EMISSIONS IN POUNDS x 10^3										
		Avg. Dry[1] Weather Day to Treat. Plant	AVERAGE WET WEATHER DAY EMISSIONS[2]									
			TO TREATMENT PLANT					TO OVERFLOW				
			8 of/yr	4 of/yr	1 of/yr	½ of/yr	1/5 of/yr	8 of/yr	4 of/yr	1 of/yr	½ of/yr	1/5 of/yr
NPWPCP	COD	307.0	2531	2537	2542	2543	2543	72.5	76.7	93.1	88.1	100.4
	TSS	89.0	944	954	962	964	965	119.9	130.4	143.0	131.0	134.6
	TN	17.0	140	140	140	140	140	3.8	4.0	4.9	4.6	5.3
	OPP	14.0	111	112	112	112	112	1.6	1.6	2.2	2.2	2.7
	HEM	29.6	244	245	245	245	245	7.0	7.4	9.0	8.5	9.7
	Floatables	1.6	15	15	15	15	15	1.1	1.2	1.3	1.2	1.3
RSWPCP	COD	92.0	815.6	819.4	822.6	823.3	823.7	48.0	51.7	58.7	54.4	58.1
	TSS	30.0	443.5	451.4	458.3	459.7	460.4	100.0	109.1	118.1	107.7	108.9
	TN	6.3	54.2	54.4	54.6	54.6	54.7	2.5	2.7	3.2	2.9	3.2
	OPP	6.0	48.5	48.5	48.6	48.6	48.6	0.8	0.9	1.2	1.1	1.4
	HEM	7.9	71.4	71.7	72.1	72.1	72.1	4.6	5.0	5.6	5.2	5.5
	Floatables	0.5	5.9	5.9	6.0	6.0	6.0	0.9	0.9	1.0	0.9	1.0
SEWPCP	COD	115.0	995.8	999.8	1003	1004	1004	49.0	52.6	60.5	56.3	60.9
	TSS	56.0	645.8	653.6	660.5	661.9	662.6	99.4	108.2	118.0	107.9	110.2
	TN	7.9	67.1	67.3	67.5	67.5	67.6	2.6	2.8	3.3	3.1	3.4
	OPP	4.9	39.7	39.8	39.8	39.9	39.9	0.7	0.8	1.0	1.0	1.2
	HEM	19.7	164.4	164.8	165.2	165.3	165.3	5.4	5.8	6.9	6.5	7.3
	Floatables	0.5	6.0	6.0	6.1	6.1	6.1	0.8	0.9	1.0	0.9	0.9
Total City	COD	514.0	4343	4356	4368	4370	4371	169.5	181.0	212.3	198.8	219.4
	TSS	175.0	2033	2059	2081	2086	2088	319.3	347.7	379.1	346.6	353.7
	TN	31.2	261	262	262	262	262	8.9	9.5	11.4	10.6	11.9
	OPP	24.9	199	200	200	201	201	3.1	3.3	4.4	4.3	5.3
	HEM	57.2	480	482	482	482	482	17.0	18.2	21.5	20.2	22.5
	Floatables	2.6	27	27	27	27	27	2.8	3.0	3.3	3.0	3.2

(1) Average dry weather day emissions is equal to 1/365 of annual dry weather emissions.

(2) Average wet weather day emissions to:
Overflow is equal to annual combined sewer overflow portion ÷ no. of overflow per year
Treatment plant is equal to 1/46 of (total raw emissions - combined sewer overflow portion)

Table 6. Comparison of Daily Average Mass Emissions Under Controlled Conditions (1)

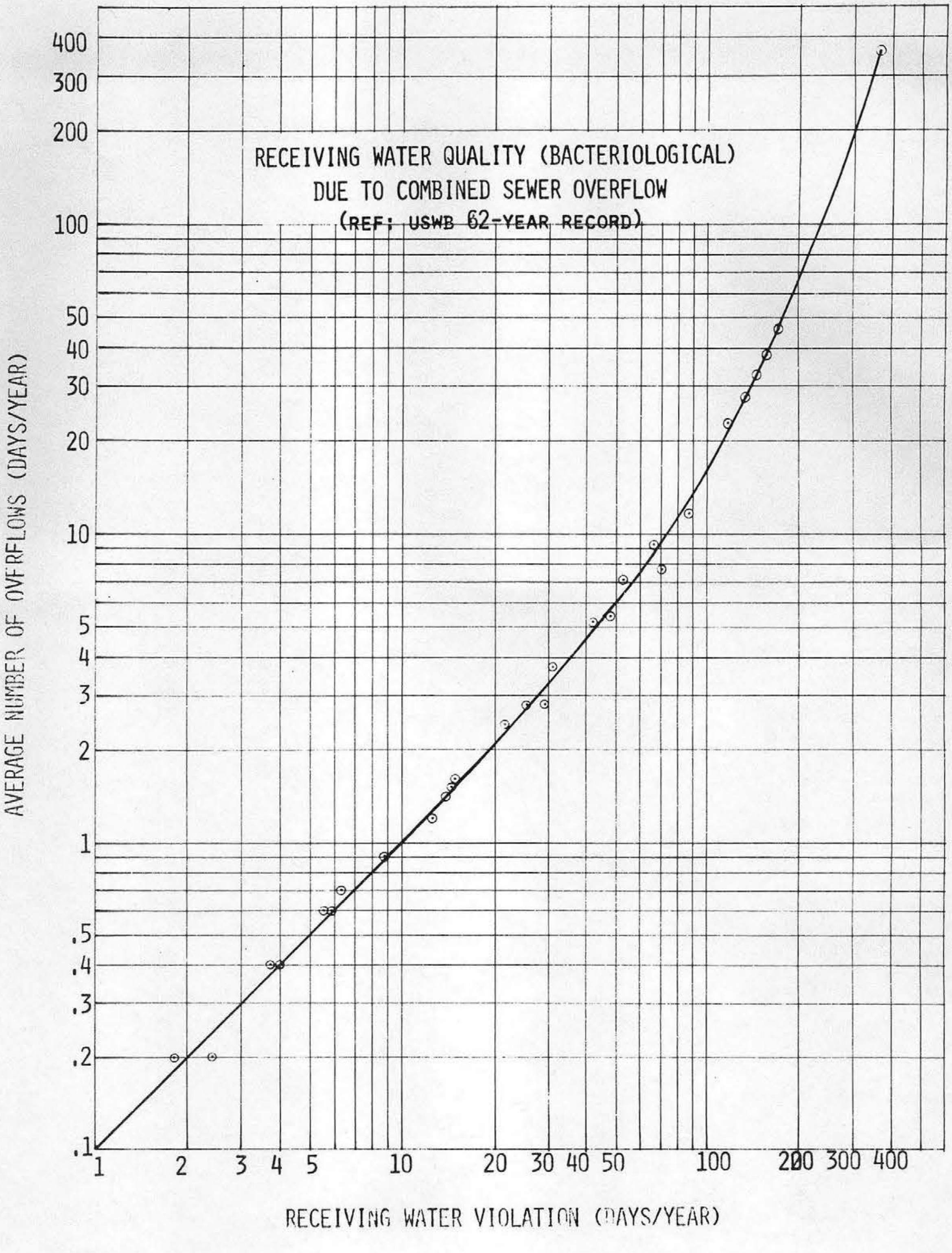

Figure 5. Receiving Water Quality (Bacteriological)
Due to Combined Sewer Overflow (1)
(Ref: USWB 62-Year Record)

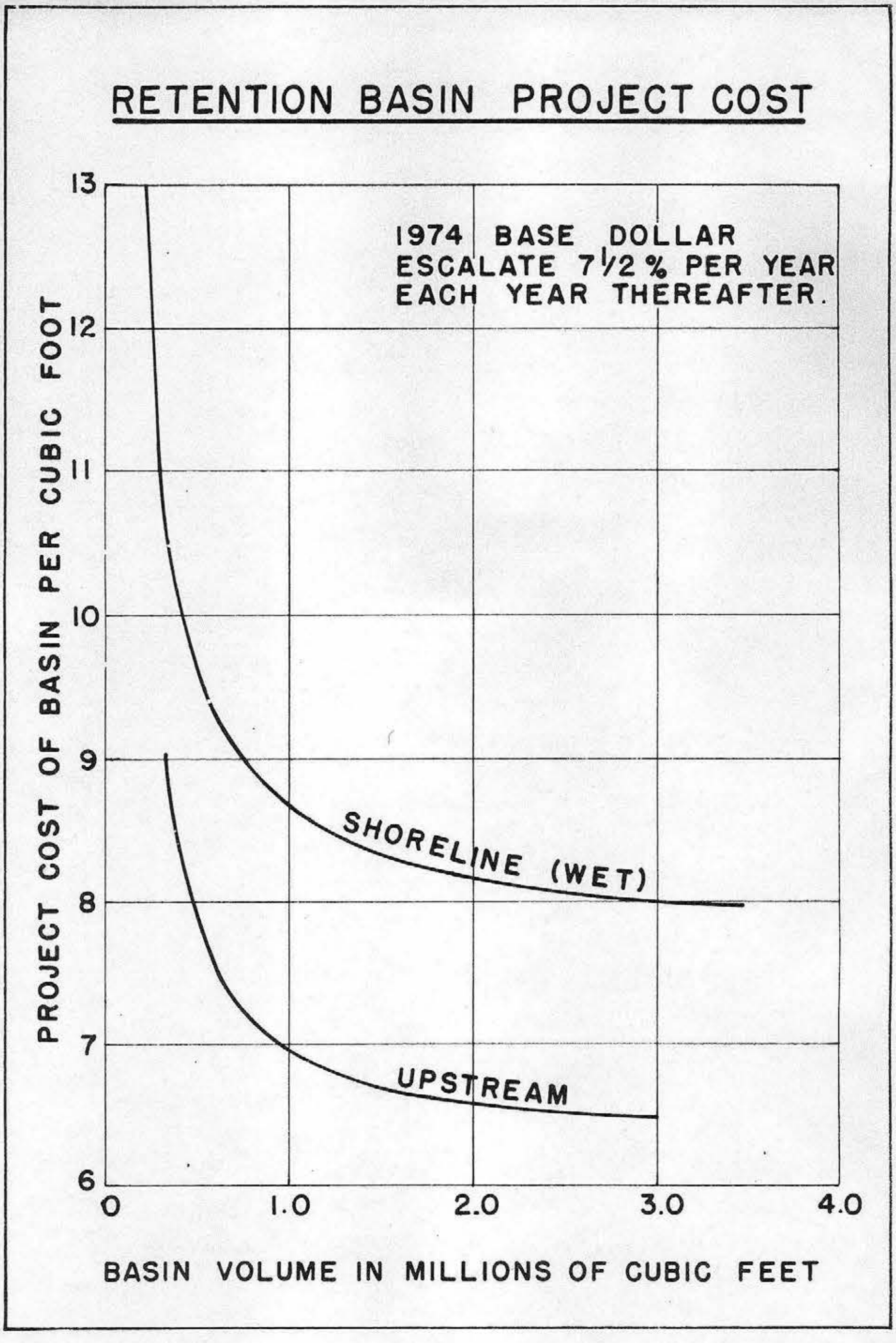

Figure 6. Retention Basin Project Cost (1)

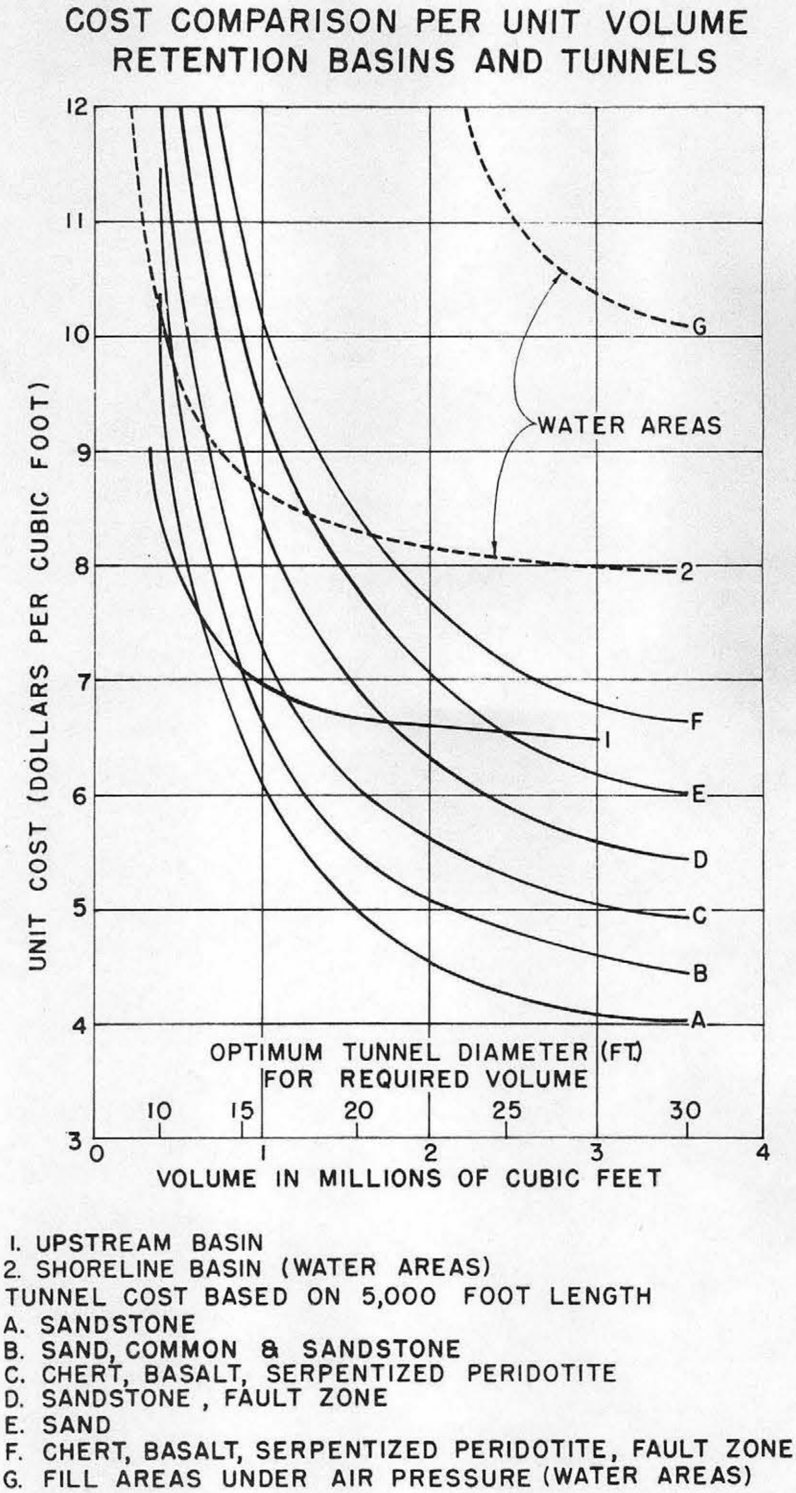

Figure 7. Cost Comparison Per Unit Volume
Retention Basins and Tunnels (1)

	WET WEATHER ALTERNATIVES			
	A	B	C	D
WET WEATHER COSTS	$ 333	$ 396	$ 522	$ 665

COMBINED DRY-WET WEATHER COSTS

DRY WEATHER PROGRAM	LEVEL OF TREATMENT	WET WEATHER ALTERNATIVES			
		A	B	C	D
SCHEME I (Most economical)*	1	$375	$438	$564	$707
	2	416	479	605	748
	3	463	526	652	795
SCHEME II (S.E. effluent to ocean)	1	406	469	595	738
	2	458	521	647	790
	3	505	568	694	837
SCHEME III (S.E. & N.P. effluent to ocean)	1	417	480	606	749
	2	469	532	658	801
	3	516	579	705	848

* "Most economical" means - Optimized staging of facilities to meet wet weather requirements with least duplication of dry weather costs.

Table 7. Program Costs (1974 Million Dollars) For Combined Dry - Wet Weather Programs

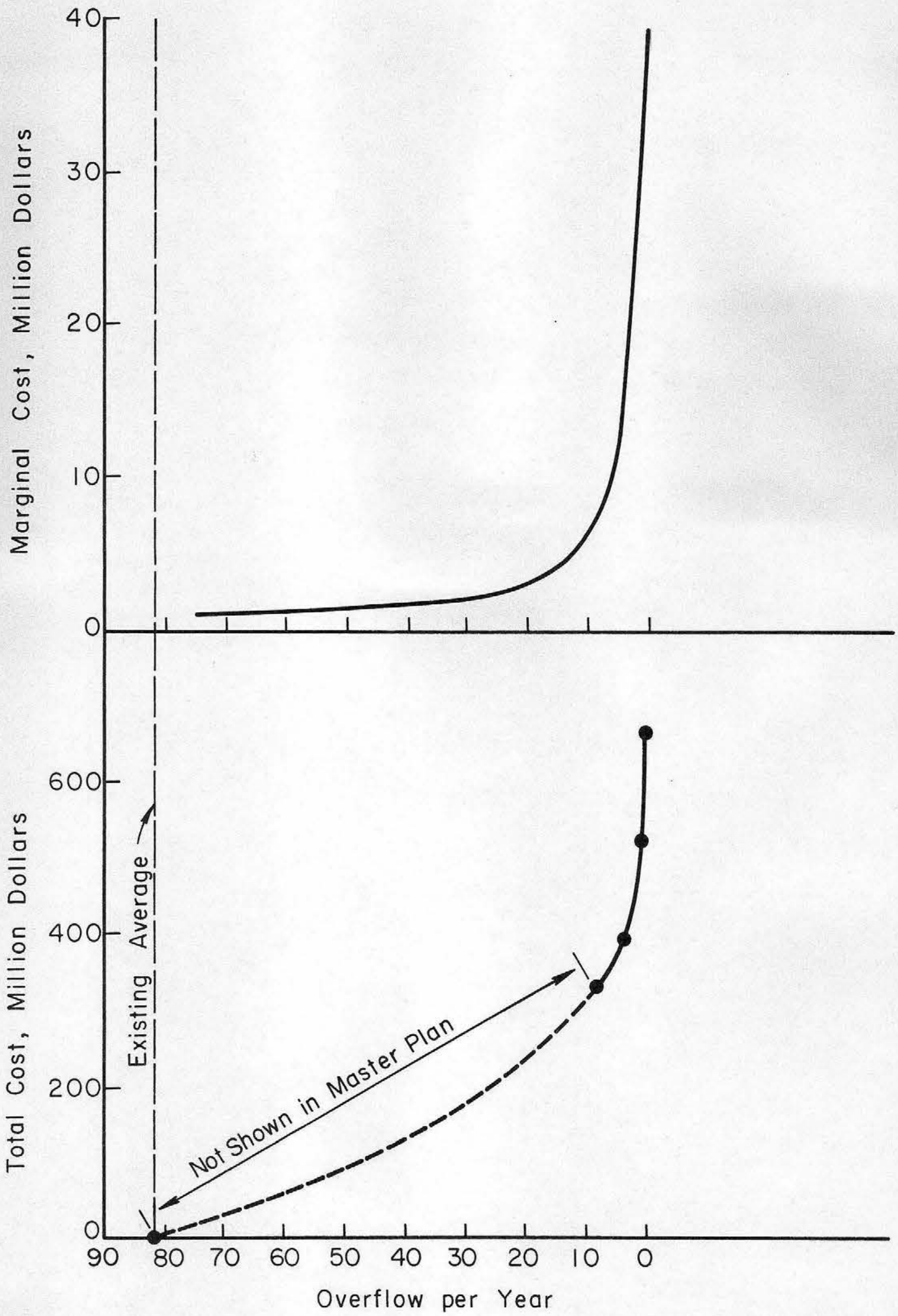

Figure 8. Costs of Wet Weather Alternatives

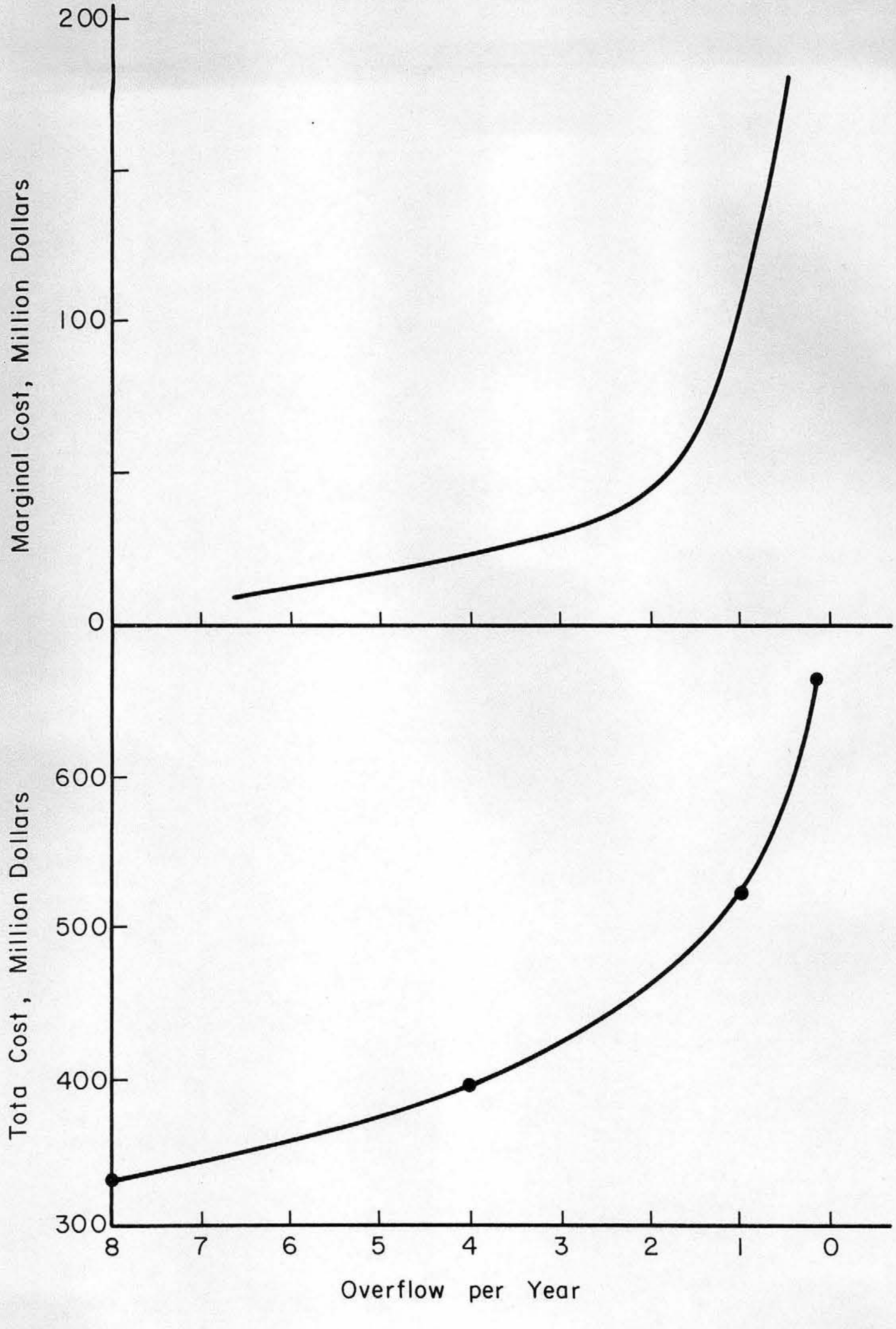

Figure 9. Costs of Wet Weather Alternatives

SECTION III. SUMMARY AND CONCLUSIONS OF THE MASTER PLAN

The methodology employed by the authors of the Master Plan established a logical sequence that led to certain conclusions and recommendations of the Master Plan.

The Plan is a program for management and upgrading of the wastewater triad, namely, collection, treatment, and disposal of San Francisco's combined sewage and rainfall runoff. It is addressed to both existing and anticipated future conditions.

San Francisco's sewerage system consists of underground conduits for the collection and transport of wastewaters and runoff, treatment plants and disposal and reuse systems. It is a combined system which transports and processes both storm runoff and dry weather sewage through a single system of pipes to the treatment plants. Basically, the deficiencies of the existing system can be described as follows:

1. Transport and collection. Many of the sewer mains are too small to transport the combined sewage and runoff during wet weather and flooding is a result. Based on recent experience, over a ten-year span, approximately 16% of the system is structurally inadequate, requiring replacement.
2. Treatment. The treatment system as it exists has only 1/50th of the capacity of the transport system. During rainstorms which have intensities above that of a light rain, the existing treatment plants by-pass combined sewage flow without treatment.
3. Level of treatment. Existing sewage treatment plants (North Point, Southeast, and Richmond-Sunset) do not consistently comply with discharge requirements and certainly will violate any more stringent new requirements.

In developing a solution to these deficiencies, three basic sets of factors were considered. These are factors which cannot be modified, those which can be influenced by policy decisions and finally, ecological factors and considerations.

The following factors represent elements which cannot be controlled or modified to effect a solution:

1. Rainfall, amount, and spatial and temporal variation
2. Area tributary to the City's combined sewer system
3. Land usage
4. Topography
5. Receiving water ecosystems

Factors considered to be subject to modification by means readily available to the City are:

1. Sewer system characteristics
2. Treatment processes utilized
3. Location of wastewater discharge

A final set of factors relate the receiving water ecosystems to the quality of the wastewater and the location of discharge. These are the ecological criteria for the disposal of wastewater effluents. These criteria were developed based upon chlorinated primary effluent and the acute response of selected organisms. It must be noted that the criteria are presently questioned by the California Department of Fish and Game. These criteria are:

1. Dilutions in shallow shoreline waters are not to be less than 1,000:1.
2. The dilutions at the benthos shall not be less than 500:1.
3. Main water body dilutions shall not be less than 100:1 in any 24 hour period and no less than 200:1 over a longer term.

After weighing all of the above factors and considering the measured data, the following recommendations were formulated:

1. Retain the combined sewer system; add storage and enlarge treatment to reduce overflows. This will provide a higher level of water quality protection than providing separate storm and sanitary systems.
2. The quality of water contiguous to the City's shoreline is affected by discharges other than from the City.
3. Meaningful reductions of pollutant discharges will result if Plan A, eight overflows per year, is implemented (90% control).

4. Persistent toxicants are best controlled at their source. Chemical treatment may be effective in some cases.
5. The range of cost-effectiveness ratios indicates that the 90% control level, eight overflows per year, represents a reasonable limit of control to start from.
6. The impact of one overflow per year will be no greater than that of one every five years.
7. Continuing measurement of the constraint parameters is necessary to furnish design data and to insure minimum system costs.
8. To protect the benthos and shoreline, all discharges should be offshore and a surface field provided during wet weather.
9. Any wet weather discharge south of the Bay Bridge will likely not meet the discharge criteria.
10. Treatment of wet weather discharges must provide substantially complete removal of settleable and floatable materials, plus sufficient removals of turbidity, oil and grease, to eliminate nuisance.

The following recommendations of the SFMPWWM are based upon the need to adequately protect the beneficial uses of the receiving waters contiguous to the City from impairment:

1. The concept of constructing combined sewers within the City and County of San Francisco should be retained. The combined system, with control, represents the most secure system of water pollution control that can be reasonably built.
2. Control facilities should be constructed to provide sufficient storage and treatment capacity so that no more than 8 overflows will occur in each year. This design point represents the control of up to 90% of annual combined sewer overflow discharges.
3. All discharges of combined flow should be given a level of treatment sufficient to protect the most stringent beneficial uses now recognized. In particular, persistent toxicants and floatable materials must be eliminated and pathogenic organisms must be reduced.

4. The recommended plan for implementation as described in the SFMPWWM will best attain the following criteria:
   a. Treated wastewater shall be discharged through properly designed outfalls so as to have no adverse effect on the marine ecosystem, the water, or beaches.
   b. The treatment rate should be variable to meet special flow or available dilution changes.
   c. There shall be flexibility to meet changing water quality requirements and needs for reclaimed wastewater and treatment shall be based on a "building block" concept to meet these needs.
   d. The direction of the City and State wastewater management planning should be reflected to avoid adverse effects on the future development of San Francisco, particularly waterfront or water areas and the use of valuable property for treatment facilities should be avoided.
   e. Valuable land, such as that used by the FSWPCP in Golden Gate park and the NPWPCP in the north waterfront area, should be released from sewage treatment use as replacement facilities with multi-use potential are constructed in more appropriate locations.
   f. The financing plan should be feasible, recognizing that Federal and State funding may decrease the time span for implementation.
   g. A cost-benefit relationship should be included so that policy on the degree of wet weather treatment can be established.
   h. Immediate upgrading of the effluents should be undertaken.
   i. Substantial reduction in flooding of City streets should be obtained.
   j. The degradation of receiving waters by combined overflows must be substantially reduced.
   k. A viable industrial waste program should be provided to control toxic discharges at their source with supplemental treatment as necessary as technically feasible.

l. There should be a long range capability for the consolidation of the three treatment plants into one plant.

m. If possible, an investment in facilities should not be abandoned if it proves necessary to prohibit all discharges into the Bay.

n. There should be the capability to effectuate an agreement for San Francisco to accept effluent from agencies in northern San Mateo County to facilitate a subregional consolidation plan.

o. There should be compatibility with the anticipated Bay Area Regional Sewerage Plan.

p. There should exist the capability of conversion to rail transport of solids (dried sludge) in the event a local or regional rail haul (or other means) plan for solid wastes is implemented.

q. Advantage should be taken of the City's hilly topography for underground storm storage.

r. There should be direction toward a central control system, so that dry weather flow, wet weather flow and street drainage can be managed with high speed decisions on assignments of flow increments to transport and treatment facilities to make the maximum use of available capacity with changing storm patterns.

5. The City should provide capacity to collect the runoff from all areas within its bounds with appropriate reimbursement from beneficiaries for the costs incurred in the collection of runoff from Federal and State lands. Agencies outside of the City's bounds should also be allowed to purchase capacity within the City's system.

6. A program for the collection of all minor runoff outlets on the City's periphery should be completed.

7. The existing treatment capacity deficit should be alleviated through the construction of a major facility at a site in the vicinity of Lake Merced. This plant would provide for a minimum of chemical treatment for dry weather flows and provide split flow options for wet weather flows consistent with required effluent quality. Subject to further cost

studies, this site is favorable for ocean disposal, wastewater reclamation via irrigation, groundwater recharge, or discharge to Lake Merced for recycling, as well as for subregional consolidation with smaller coastal facilities in San Mateo County.

The above factors, conclusions and recommendations are products of the Master Plan described herein. The realities of certain factors will persist and need to be addressed when examining alternatives of size, process, and method of disposal now or in the future. All alternatives must be evaluated on the same scale, to provide a realistic comparison.

APPENDIX A

Description of the Master Plan

The Master Plan for Wastewater Management presents a basic strategy to reduce wet weather overflows and to upgrade the quality of effluents discharged from San Francisco. It recommends a building block concept of components, creating the ability to meet different levels of water quality objectives for different levels of construction costs. The plan allows for staged construction over a period of years.

The basic structural elements of the plan are (see Figure 3):

1. A new one-billion-gallon-per-day split flow treatment plant which would consolidate all wastewater treatment at one location. The 250 MGD dry weather portion of the plant could be constructed at the same location with alternative levels of treatment in a split flow configuration. The treatment facilities could therefore blend effluent treated to a high degree by dry weather processes, with the excessive wet weather flows which receive only a high rate physical-chemical treatment. This concept is shown on Figure A-1.
2. A new, dual-compartment ocean outfall for final disposal of the effluent from the new treatment plant. For the protection of the marine ecosystem, the smaller dry weather flow would be discharged five miles offshore in a subsurface, maximum dilution field. The larger wet weather flow would be discharged two miles offshore in a surface field of much lower initial dilution.
3. A crosstown transport-storage tunnel which allows for the interception, detention or transport of wastewater. Virtually all present Bay discharge would be re-routed to the ocean.
4. A series of small upstream and shoreline detention basins which could temporarily detain and store combined sewage for later release to the treatment plant.

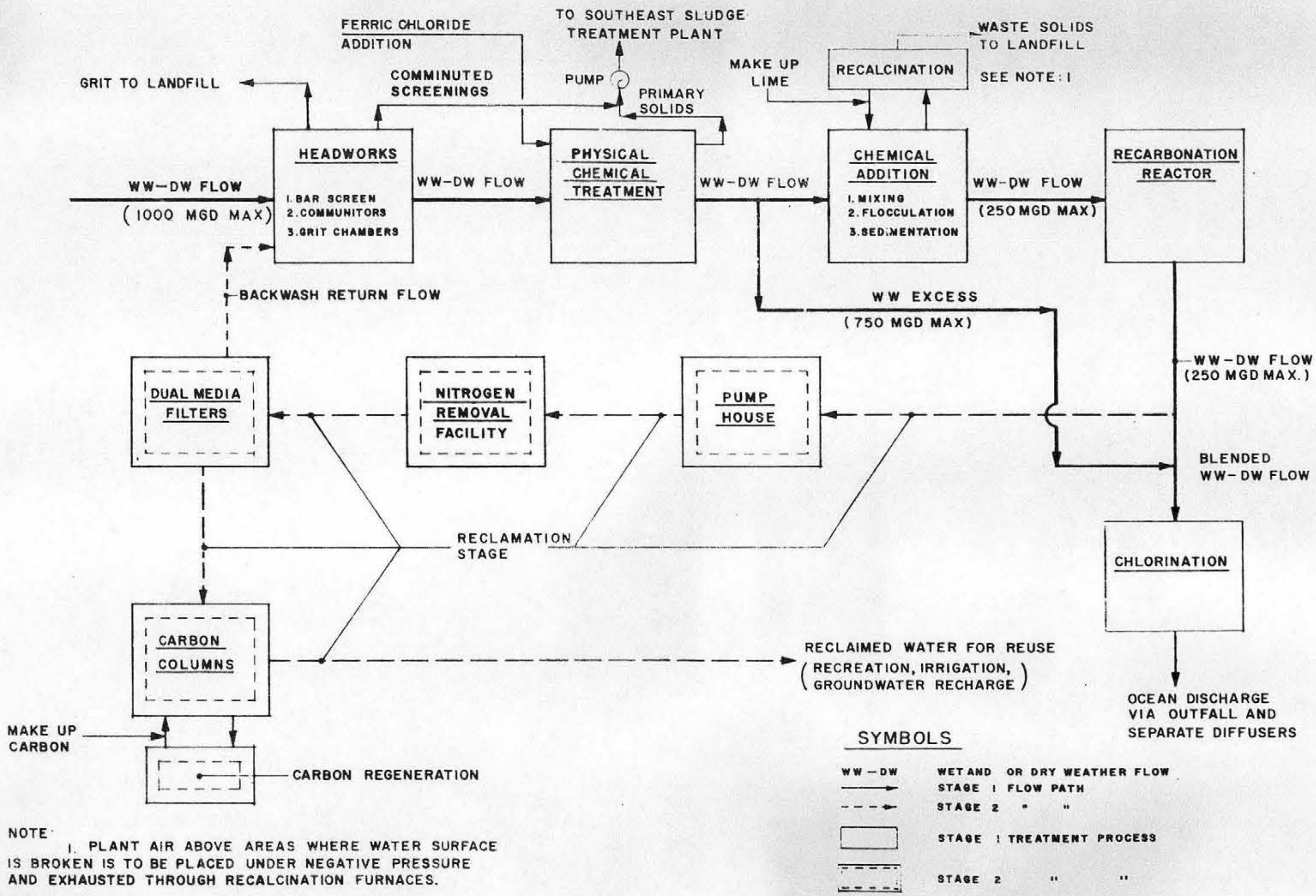

Figure A-1. Proposed Lake Merced Water Pollution Control Plant Conceptual Flow Diagram:

5. A central intelligence and control system which would eventually allow for the total automatic control of the system in such a manner to insure optimum use of storage and treatment facilities to result in minimum overflows.

Control System

The control system envisioned for the wastewater management facilities will be built in stages. Its functional arrangement will be as shown in Figure A-2. The first stage is already in operation. It consists of a set of flow and rain gauges which have been installed to build a data base upon which the control logic can eventually be developed. This system will later serve as the sensing elements shown in Figure A-2. The development of control logic is planned for the future after an adequate data base has been prepared.

The eventual operation of the control system will be as follows:

1. As a storm begins over the area, the "intelligence system", consisting of flow gauges and rain gauges transmits data to the computer center.
2. By reference to a data history bank, the computer assigns, by mass balance techniques, rainfall-runoff to either storage or treatment, or both. Based upon the above, positioning of regulators (valves, pumps, gates) in the system is executed. Updating of data occurs as rainfall proceeds, and adjustments are made from feedback status reports.
3. The computer signals the regulators to assume certain positions which are calculated to minimize overflows from the interceptors.
4. New signals come in from the intelligence system which starts another repetition of the process described above. The process is repeated according to a preset, recursion time interval for the duration of the storm.

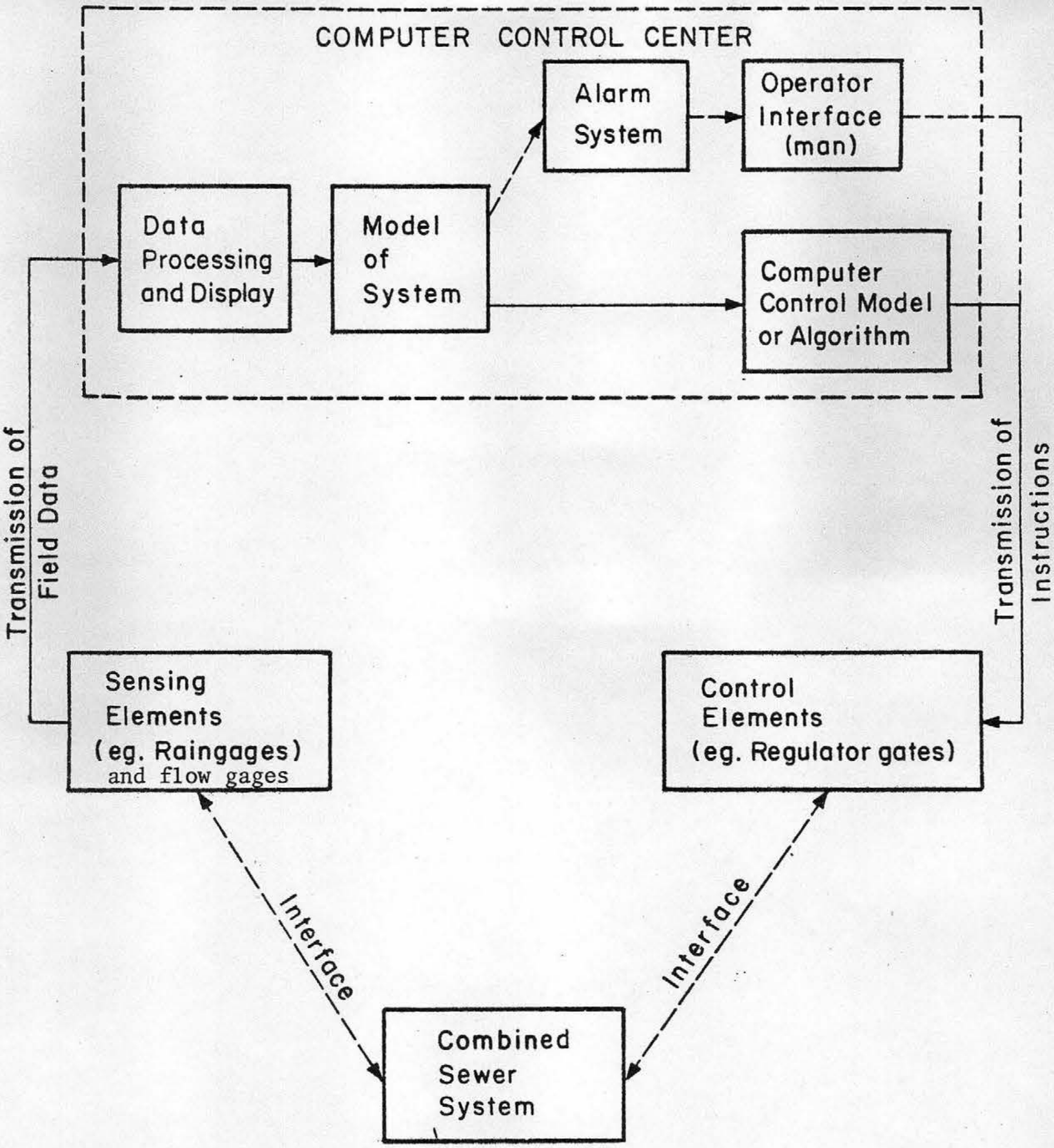

Figure A-2. Components and Control Cycle for Automatic Mode

Treatment Plant

A flow chart for the proposed Lake Merced Treatment Plant was given in Figure A-1. The plant shown includes all components which fall into the category previously described as Level One treatment. There is provision for a reclamation stage and for the split flow configuration. In effect, there are two treatment plants. One smaller (250 MGD) high level plant will function at all times. Excess flow amounts (greater than 250 MGD) are routed to Level One tanks.

The new treatment plant would thus have the capacity of providing first level treatment for up to one billion gallons per day during wet weather. It would provide split flow treatment options such that there will be 1000 MGD capacity for first level treatment of all flow and the capability of providing 250 MGD capacity of second and third level facilities. This split flow system provides a flexible capability for upgrading treatment to meet the needs and demands of the future. This is also a realistic method for treating combined flows. During dry weather periods, the excess split flow capacity of 750 MGD, required for wet weather treatment, also provides backup facilities to protect against mechanical breakdown of the dry weather plant.

The recommended location of the plant was partially determined by the requirements for receiving waters. The Lake Merced location allows for disposal to the south and west of the San Francisco Bar. (See Figure A-3). This was proposed after a careful study of alternate disposal locations. (Consultant Report No. 4) The advantages of this location are:

1. The area is biologically relatively barren.
2. The depths available are sufficient for required dilution factors.
3. The shoreline is afforded maximum protection because of the dilution obtained and the low probability of effluents being returned to the shore.
4. The background pollution present in San Francisco Bay is not a factor in selecting treatment levels as a function of desired receiving water quality.

Alternative Levels of Treatment

The Master Plan suggests that higher than Level One treatment for all flow and higher levels for the dry weather flow and standby are presently

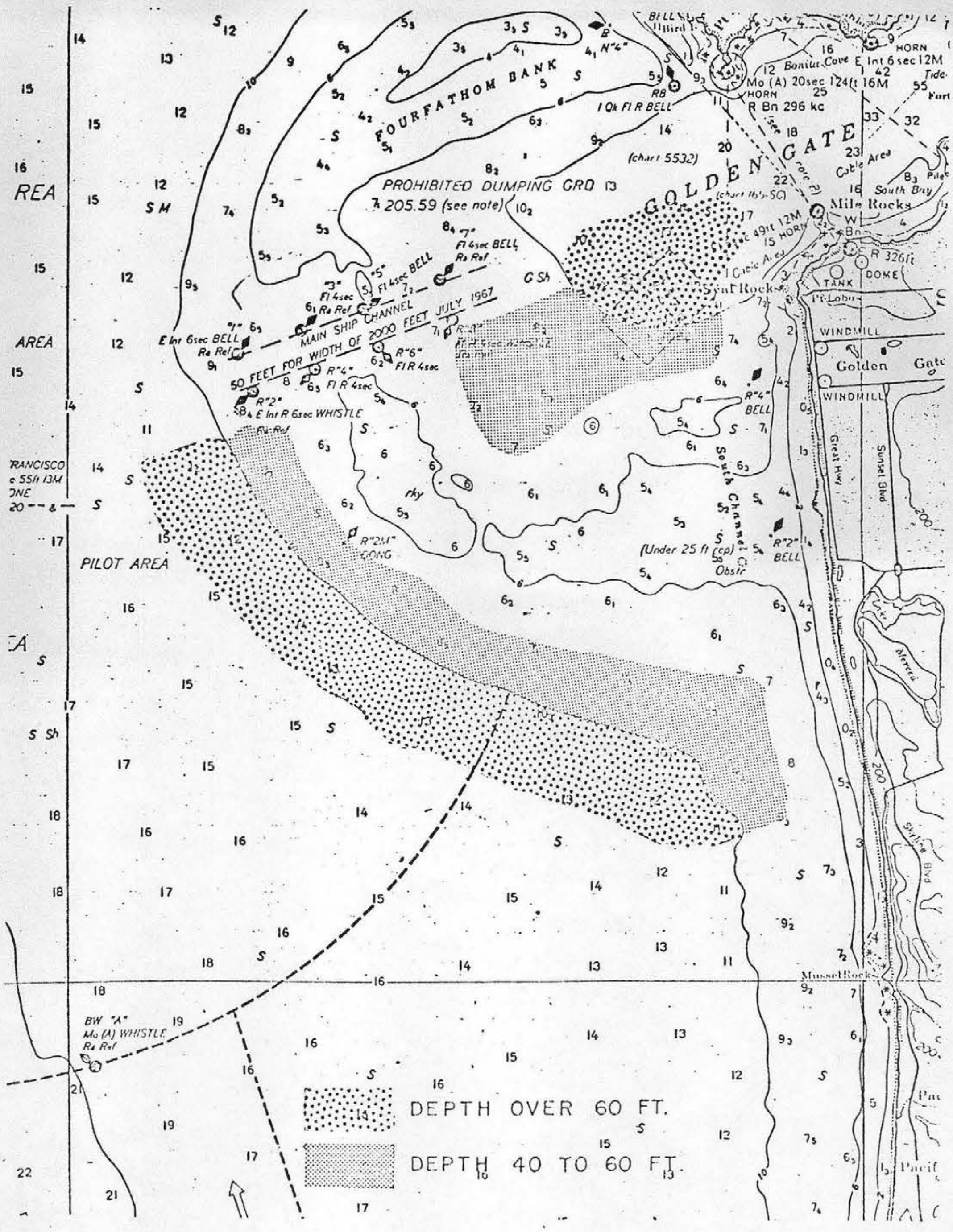

Figure A-3. Suitable Disposal Areas

unnecessary and impractical. Provisions in the design of the new treatment plant provide the potential for upgrading the treatment for the split flow in the future. Three alternative levels of chemical and physical treatment are considered, each a progressive level to provide a higher degree of pollutant removals. The following table illustrates the choices:

Table A-1 Efficiencies of Treatment Combinations

Level of Treatment	BOD Removal (%)	Nitrogen Removal (%)	Phosphate Removal (%)	Suspended Solids Removal (%)	Grease Removal (%)
1	40	15	50	75	55
1-2 Split	59	20	84	84	83
2	60	20	85	88	85
1-2-3 Split	87	81	92	93	88
3	90	85	93	98	90

At present, further work and study is underway to determine which combination of treatment processes should be used to achieve the desired level of treatment. Building block design is again of prime concern in order that higher levels of treatment can be reached by modular addition of processes, the overall compatibility of which will have been demonstrated and measured in pilot scale.

Storage Components

The storage components selected for recommendation fall into three categories: shoreline and inland detention basins, and tunnel storage. The detention basins are to be constructed of reinforced concrete, and contain separation structures to separate gross floatables and settleables for express transport to the treatment plant. It is planned to use gravity flow for discharge from the detention basins where possible, and to use pumping in other cases. The use of gravity to empty basins results in reduced energy requirements. Descriptive drawings of the detention basin concept and the storage/transport tunnel are shown in Figures A-4 and A-5. The control concept for the storage transport option is shown in Figure A-6.

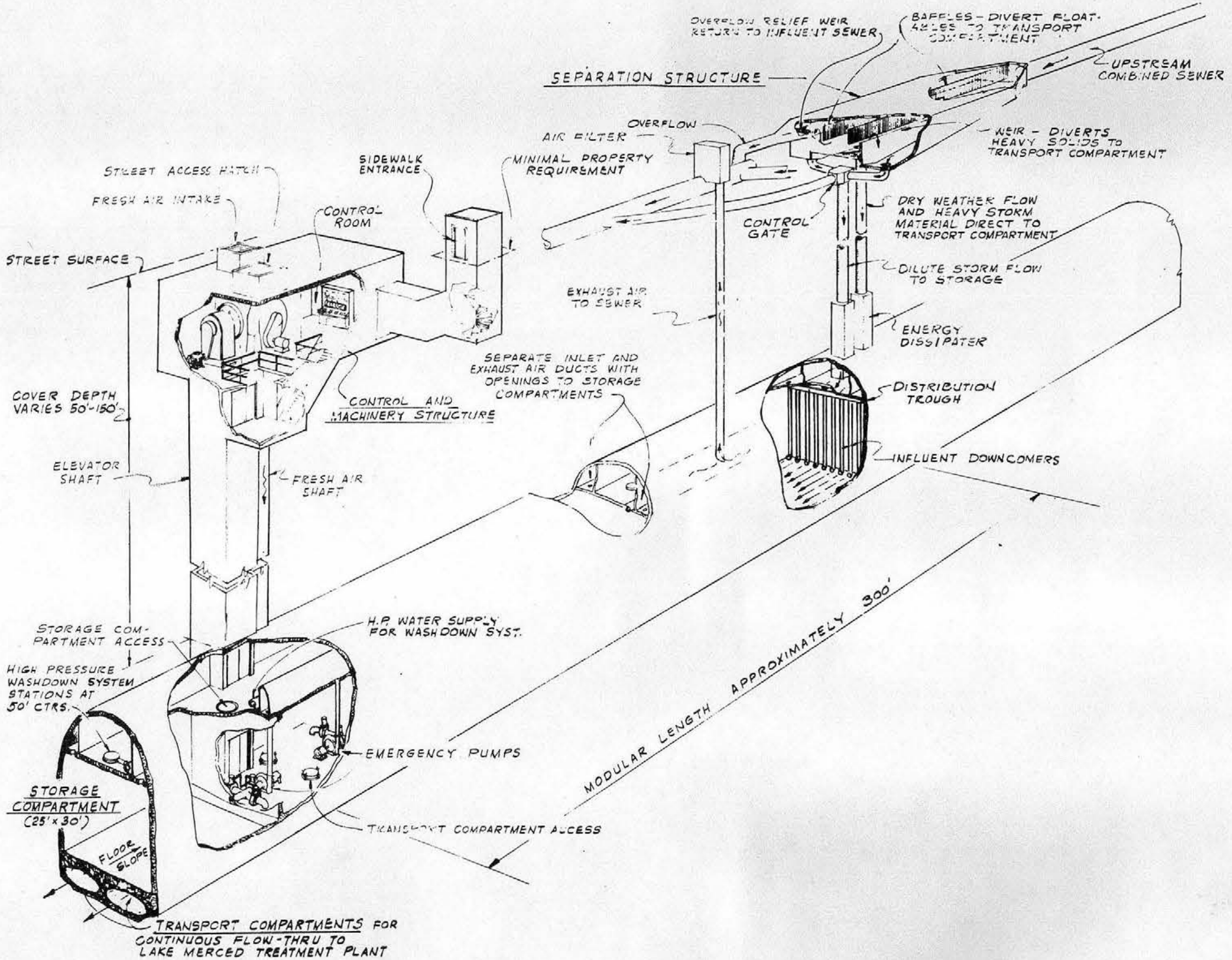

Figure A-4. Tunnel Perspective

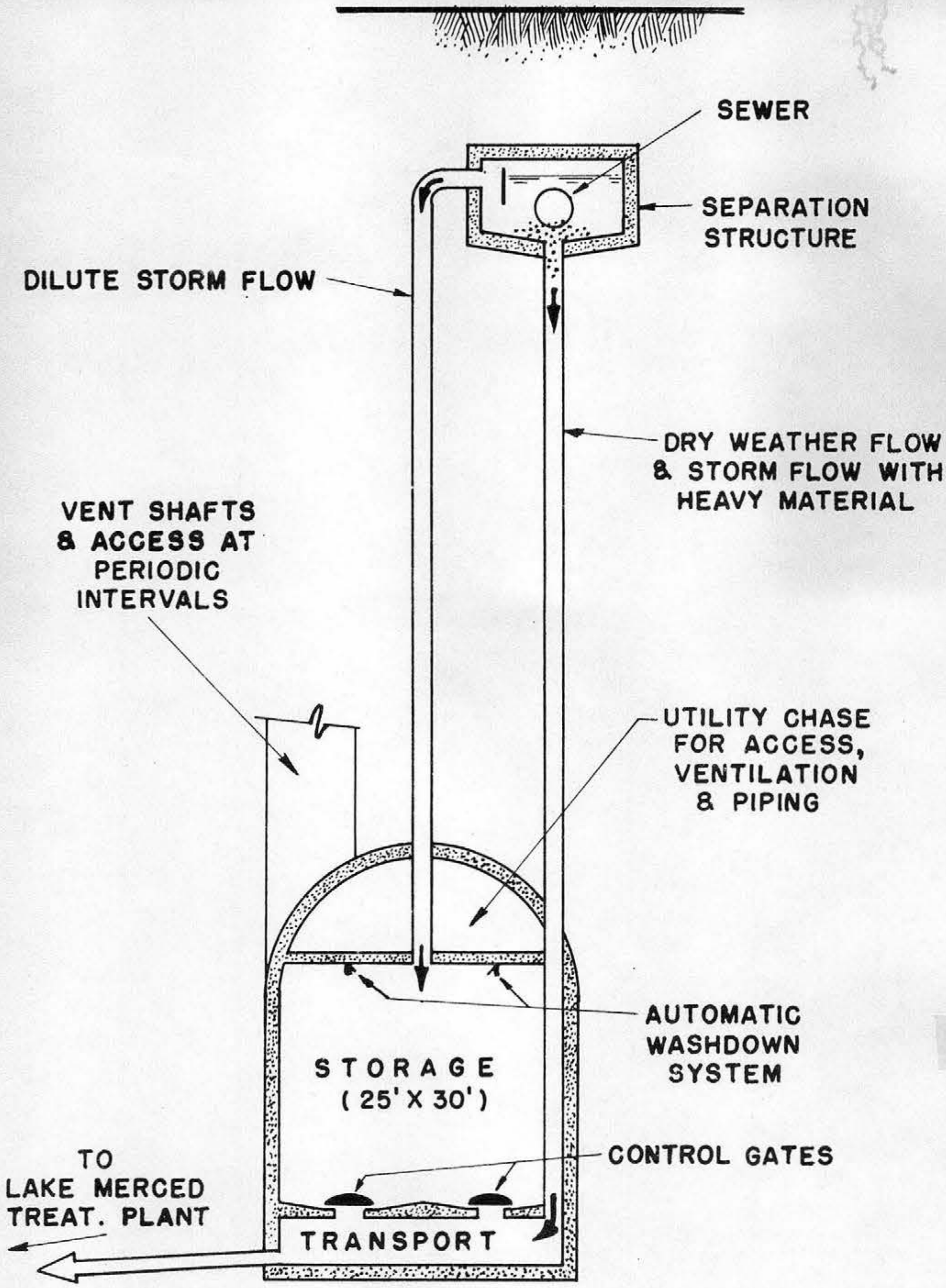

Figure A-5. Schematic Section of Tunnel

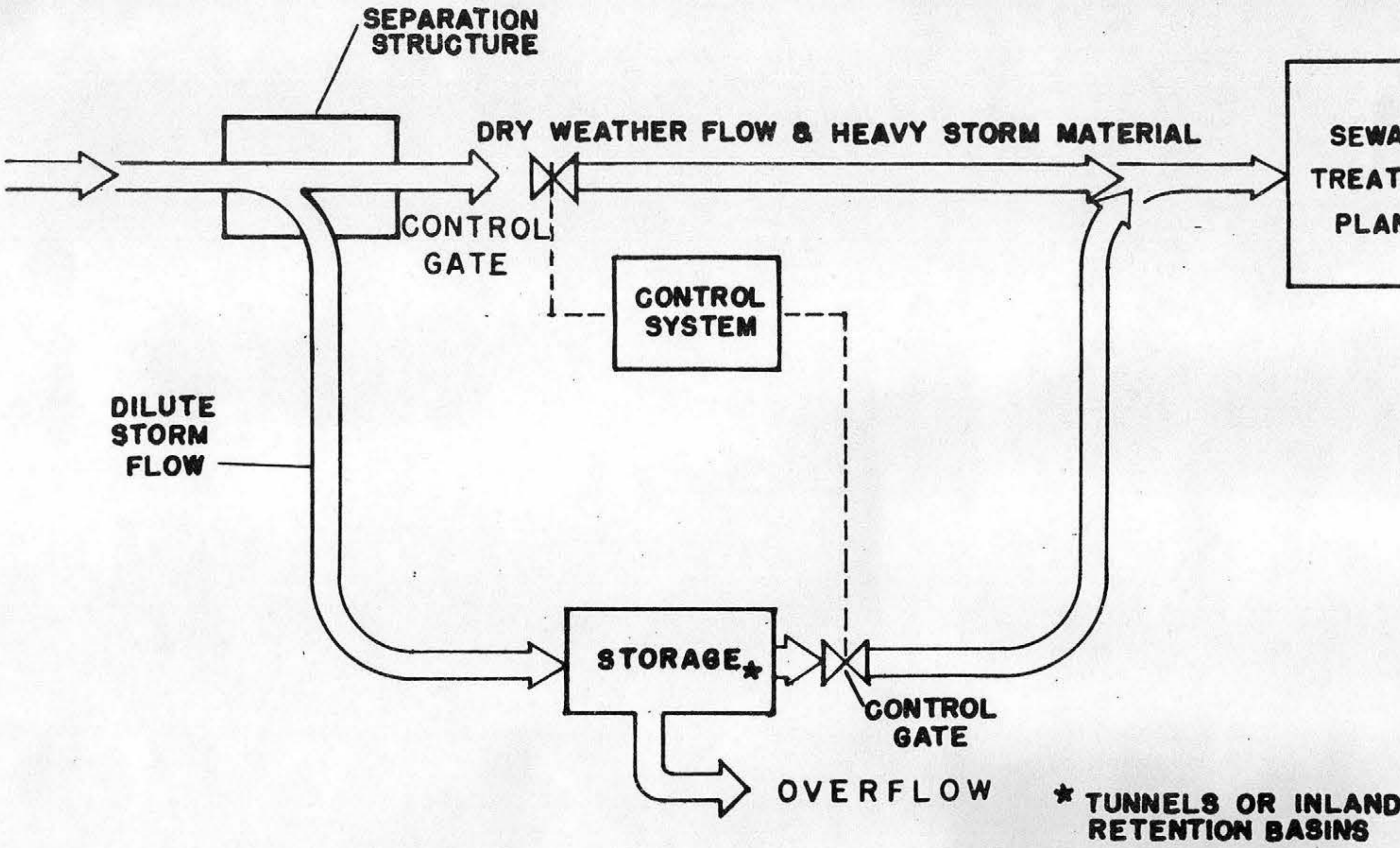

Figure A-6. Schematic Diagram of Wet Weather Control

Outfall

The proposed location of the new outfall is shown in Figure 3. This location and basic concept was selected from oceanographic investigations. The investigations included consideration of physical and marine oceanography as affected by the physical characteristics of the systems studied and the quality of the wastewaters discharged to the receiving waters. Additional work will be undertaken to further identify marine biota resident in the area and level of treatment necessary to adequately protect them at all times.

APPENDIX B

SUPPLEMENTARY REPORTS

Ref. No.	Title	Date	Prepared By
1	San Francisco Comprehensive Master Plan Report - Text (preliminary)	9/71	(1)
2	San Francisco Comprehensive Master Plan Report - Book of Plates (preliminary)	9/71	(1)
3	Characterization and Treatment of Combined Sewer Overflows	11/67	(2)
4	Alternate Methods of Effluent Disposal	2/69	(3)
5	Prefeasibility Study - Sewer Tunnel Project for the City of San Francisco	5/70	(4)
6	Chlorination Study - Southeast Plant Dry Weather Flow	9/70	(5)
7	Review of Biological, Literature on Pacific Coast Marine Waste Disposal as a Guide to Prediction of Ecological Effects of a Submarine Outfall in the Gulf of the Farallones (This is printed as part of Reference No. 24)	12/70	(6)
8	Watershed Model and Sewer Model	4/71	(7)
9	Water Quality Transport Model	5/71	(7)
10	Dissolved Air Flotation Project Report	7/71	(2)
11	Dissolved Air Flotation - Appendix A - Pre-construction Studies on Quality and Quantity Relationships of Combined Sewage Flows and Receiving Water Studies at Outer Marina Beach	7/71	(2)
12	Dissolved Air Flotation - Appendix B - Technical Objectives for Field Demonstration of Baker Street Dissolved Air Flotation Facility	7/71	(2)

SUPPLEMENTARY REPORTS (Cont.)

Ref. No.	Title	Date	Prepared By
13	Dissolved Air Flotation - Appendix C - Treatment of and Dilute Raw Sewage with the Dissolved Air Flotation Process - A Pilot Plant Study	7/71	(2)
14	Dissolved Air Flotation - Appendix D - Design Factors for Baker Street Dissolved Air Flotation Facility	7/71	(2)
15	Dissolved Air Flotation - Appendix E - Cost for Dissolved Air Flotation Facilities	7/71	(2)
16	Dissolved Air Flotation - Appendix F - Characterization of the Receiving Water	7/71	(2)
17	Dissolved Air Flotation - Appendix G - Performance Evaluation of Baker Street Facility with Raw Sewage	7/71	(2)
18	Report on Water Pollution Control Plants - Report 1 - Phase I - Existing Operations and Plant Performance	9/71	(3)
19	Report on Water Pollution Control Plants - Report 1 - Phase II - Alternative Treatment Processes for Reductions of Turbidity, Color, Floatables, Grease and Settleable Matter	9/71	(3)
20	Report on Water Pollution Control Plants - Report 2 - Phase I - Reductions Required for Turbidity, Color, Floatables, Grease and Settleable Matter	9/71	(3)
21	Report on Water Pollution Control Plants - Report 2 - Phase II - Alternative Treatment Processes for Reductions of Toxicity and Biostimulants	9/71	(3)
22	Report on Water Pollution Control Plants - Report 3 - Phase I - Reductions Required for Toxicity and Biostimulants	9/71	(3)

SUPPLEMENTARY REPORTS (Cont.)

Ref. No.	Title	Date	Prepared By
23	(Not used)		
24	City & County of San Francisco, A Predesign Report of Marine Waste Disposal, Oceanographic and Base Data Acquisition and Evaluation of Alternate Locations	9/71	(3)
25	Survival of Dungeness Crab Larvae in Two Concentrations of San Francisco Sewage Effluent (This is printed as part of Reference No. 24)	2/70	(8)
26	Interim Water Quality Control Plan, San Francisco Bay Basin	6/71	(9)
27	San Francisco Bay Delta Water Quality Control Program, Final Report	6/69	(10)
28	City and County of San Francisco Sewerage System - Basic Data Development (Land Use and Population)	6/71	(1)

(1) San Francisco Department of Public Works

(2) Engineering-Science Incorporated

(3) Brown and Caldwell

(4) Bechtel Incorporated

(5) URS Research Company

(6) Dr. Wheeler J. North

(7) Water Resources Engineers, Incorporated

(8) Dr. George Schuman, Marine Associates

(9) California Regional Water Quality Control Board San Francisco Bay Region

(10) Kaiser Engineers

APPENDIX C

References

1. City and County of San Francisco, Department of Public Works, Master Plan for Wastewater Management, September 15, 1971. (Consists of 3 volumes and a technical appendix. The 3 volumes are the Preliminary Summary Report, the Preliminary Comprehensive Report and the Book of Plates.)

2. U. S. Army Corps of Engineers, San Francisco District, Public Brochure on Wastewater Management Alternatives for the San Francisco Bay and Sacramento - San Joaquin Delta Water Quality and Waste Disposal Investigation, August 1972.