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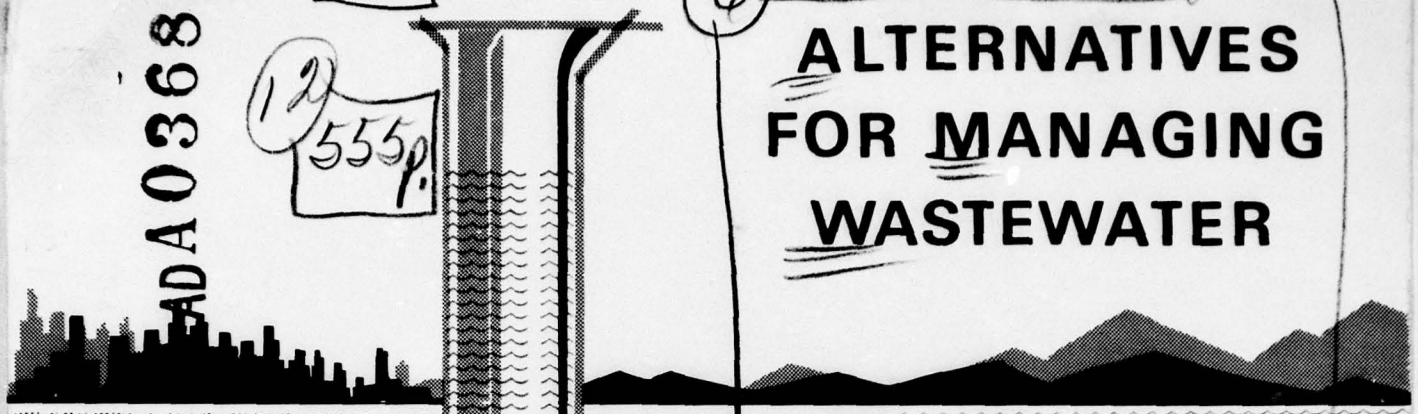

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APPENDIX C - ASSESSMENT OF IMPACTS OF SELECTED ALTERNATIVES

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JULY 1971

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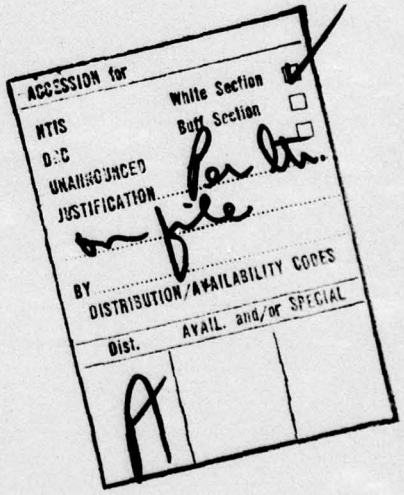
AREA

APPENDIX C

ASSESSMENT OF IMPACTS OF SELECTED ALTERNATIVES



US ARMY ENGINEER DISTRICT, SAN FRANCISCO
CORPS OF ENGINEERS
SAN FRANCISCO, CALIFORNIA

JULY 1971

APPENDIX C

ASSESSMENT OF IMPACTS OF SELECTED ALTERNATIVES

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APPENDIX C

ASSESSMENT OF IMPACTS OF SELECTED ALTERNATIVES

C-1. GENERAL INTRODUCTION

In Appendix B the wastewater management alternatives which best represent each of four waste disposal concepts were selected. Appendix C is concerned with assessing the impacts of alternatives for managing wastewater selected in Appendix B.

Impact assessment identifies the expected changes in the characteristics of the study area resulting from a wastewater management alternative when compared to the situation assumed to prevail without the alternative. The situation assumed to prevail without the alternative is called the base condition. The base condition for the San Francisco Bay and Delta Area which is discussed in Appendix A represents facilities expected to be constructed or under construction before any of the alternatives developed in this study could be implemented. It assumes complete secondary treatment of municipal wastes at consolidated facilities and pretreatment of industrial wastes. These facilities are expected to have sufficient capacity to handle projected 1990 waste flows. It is then further assumed that these facilities would be expanded to handle 2020 waste flows.

Changes in the following characteristics of the study area will be identified:

ECOLOGICAL
SOCIAL WELL-BEING
  AMENITY (AESTHETIC AND RECREATION) AND PUBLIC HEALTH
ECONOMIC

The objectives of impact assessment are to identify or define:

General overall impact of each alternative,
Range of impact within each alternative,
Significant differences in impact between alternatives,
Significant problems associated with each alternative,
Knowledge contraints, and
Need for initiation of more detailed study and/or long-term research.

The definition, scope, criteria (used to identify the changes), and the expected changes in each of the characteristics are contained in subsequent sections of this appendix.

C-2. ECOLOGICAL IMPACTS

a. Hydrosphere.

(1) Introduction. A historical summary of fish and wildlife conditions in the San Francisco Bay and Delta System is presented in Figure C-1. The chart relates to the general decline of economically important species to water quality problems resulting from man's development of the area. More importantly, it illustrates an ecological rationale for wastewater management.

(a) Definition. Ecology, which can be defined as the relations of organisms and their environments, considers the structure and function of nature. Since no living thing exists by itself, ecology examines both the living and non-living components of the biosphere and attempts to relate the presence of living things to their physical surroundings or environment.

The most important unit in the biosphere is the ecosystem. An ecosystem is comprised of a multitude of biological, chemical and physical parameters which interact to determine and regulate the biological sector of the system. In essence, an ecosystem is a dynamic cycling system which transfers energy between living things and their environment.

The ecological analysis of the hydrosphere will be limited to the ecosystems of the central California coastal zone and the San Francisco Bay-Delta estuary.

(b) Scope. The scope of the ecological impact assessment is in part delineated by the National Environmental Policy Act of 1969 (PL 91-190). As such it includes statements on:

1. The environmental impact of the proposed action,

2. any adverse environmental effects which cannot be avoided should the proposal be implemented,

3. the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term, productivity, and,

4. any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

(c) Criteria. For the purposes of this analysis the following definition of criteria, as defined by McKee (1960, pp. 19-20) in his paper "The Need for Water Quality Criteria," has

HISTORICAL SUMMARY BAY
FISH — WILDLIFE — WAT

SPECIES \ EVENT	GOLD RUSH	DELTA RECLAMATION	OIL INDUSTRY
STRIPED BASS	1879: INTRODUCED INTO BAY-DELTA FROM NEW JERSEY	1908: PEAK COMMERCIAL CATCH 1.8 MILLION LBS.	1935 COM FOR
KING SALMON	1880: COMMERCIAL CATCH 10 MILLION LBS.		1926-1943: AVERAGE COMMERCIAL CATCH 1.0 MILLION LBS./YEAR
OYSTERS	1851: FIRST COMMERCIAL OYSTER BEDS IN SOUTH BAY	1899: 2.7 MILLION LBS. OF OYSTER MEAT HARVESTED FROM S.F. BAY	1939: 1,450 L OYSTER MEA FROM S.F BA
MARKET CRAB		1898: CRAB FISHING MOVES FROM THE BAY TO THE OCEAN	1915-1920: AVERAGE COMMERCIAL CATCH 1.3 MILLION LBS.
WATERFOWL		1895-1896: 250 THOUSAND WILD DUCKS SOLD ON CALIFORNIA MARKETS	1915: STATE PROHIBITS "MARKET HUNTING" IN CALIFORNIA
FURBEARERS	1870: FUR SEALS AND SEA OTTERS ELIMINATED FROM THE S.F. BAY AREA		1928: 600 LICENSED TRAPPERS IN THE BAY-DELTA AREA
WATER QUALITY	HEAVY SILT AND MERCURY LOADINGS	FLUCTUATING FRESH WATER FLOWS (SALINITY INCURSION & SILT LOADINGS)	DISCHARGE OF PHENOLS SULFIDES, COD[2], BOD[3] WASTES AND HEATED WATER (ACUTE TOXICITY)

REMARKS:

GOLD RUSH: 1845-1860 HYDRAULIC MINING

DELTA RECLAMATION: 1895-1910 LEVEE BUILDING, WATER DIVERSION, CHANGE TO AGRICULTURAL USE

OIL INDUSTRY: 1920-1943- START OF LARGE SCALE INDUSTRIALIZATION AND URBANIZATION

SHASTA DAM: BEGINNING OF CENTRAL VALLEY WATER PROJECTS

TODAY: 1960-1970

1/ CALIFORNIA DEPARTMENT OF FISH

2/ COD: CHEMICAL OXYGEN DEMAND

3/ BOD: BIOCHEMICAL OXYGEN DEMA

4/ TDS TOTAL DISOLVED SOLIDS

5/ RELATIVE TOXICITY: $\frac{\text{WASTE FLOW}}{TLM_{48}}$

6/ BIOSTIMULATION: UNDESIREABLE GROWTH OF ALGAE

MMARY BAY-DELTA REGION
LIFE — WATER QUALITY

IL INDUSTRY	SHASTA DAM	TODAY	PROJECTIONS
	1935: STATE BANS COMMERCIAL FISHING FOR BASS	1965-1969: 110 THOUSAND BASS KILLED BY POLLUTION	2020: RECREATIONAL USE 10.7 MILLION ANGLER DAYS [1]
-1943: AVERAGE MERCIAL CATCH LLION LBS./YEAR	1957: STATE BANS GILL NETTING IN SUISUN BAY	1968: ESTIMATED 1.0 MILLION ADULT SPAWNERS	2020: RECREATIONAL USE 1.9 MILLION ANGLER DAYS, COMMERCIAL CATCH 8.7 MILLION LBS. (MAX.) [1]
1939: 1,450 LBS. OF OYSTER MEAT HARVESTED FROM S.F BAY	1956: OYSTER HARVESTING PROHIBITED IN BAY BY PUBLIC HEALTH		1980: POTENTIAL FOR 1.7 MILLION GALLONS OF SHUCKED OYSTERS WORTH $5.2 MILLION IF CONTAMINATION WERE ELIMINATED [1]
AVERAGE IAL CATCH N LBS.	1946: CRAB CATCH IN EUREKA (HUMBOLDT COUNTY) EQUALS SAN FRANCISCO'S CATCH	1965-1970: AVERAGE COMMERCIAL CATCH 0.8 MILLION LBS.	UNDER STUDY [1]
TE PROHIBITS HUNTING" ORNIA	1935: WATERFOWL MANAGEMENT BEGINS WITH DISCOVERY OF "FLYWAYS"	1950: GRIZZLY ISL. WILDLIFE AREA ESTABLISHED	1968: ESTIMATED HALF MILLION WINTERING BIRDS	2000: RECREATIONAL USE-270 THOUS. HUNTER DAYS, SUISUN MARSH DUCK "OUTPUT" INCREASED TO ONE MILLION [1]
928: 600 LICENSED TRAPPERS IN THE BAY-DELTA AREA		1950: COMMERCIAL TRAPPING OF MUSKRATS IN THE DELTA	NO PROJECTION
CHARGE OF PHENOLS FIDES, COD [2], BOD [3] TES AND HEATED ER (ACUTE TOXICITY)	REDUCED FRESH WATER INFLOWS, INCREASED NUTRIENTS, TDS [4] AND PESTICIDE LOADS (EUTROPHICATION)	600 MILLION GALLONS OF M&I WASTES DISCHARGED DAILY (RELATIVE TOXICITY [5] AND BIOSTIMULATION [6])	2020: 2,176 MILLION GAL. OF M&I WASTES DISCHARGED DAILY (IMPROVED WATER QUALITY)

IA DEPARTMENT OF FISH & GAME
MICAL OXYGEN DEMAND
CHEMICAL OXYGEN DEMAND
AL DISOLVED SOLIDS
TOXICITY: $\frac{\text{WASTE FLOW}}{TLM_{48}}$
LATION: UNDESIREABLE OF ALGAE

FIGURE C-1

been utilized: A "criterion" designates a means by which anything is tried in forming a correct judgment respecting it. Unlike a standard it carries no connotation of authority other than that of fairness and equity; nor does it imply an ideal condition. When scientific data are being accumulated to serve as yardsticks of water quality, without regard for legal authority, the term "criterion" is most applicable.

In assessing ecological impacts one has to select the environmental criteria which best identify the changes affected by each alternative. The array of physical, chemical and biological criteria which might be used in an assessment is vast. Moreover, all the criteria are interrelated. For example, consider the problem of biostimulation: Phosphate and nitrogen loading stimulates excessive algal growth which in turn causes BOD/DO problems which distresses Opossum Shrimp and/or Striped Bass populations. Obviously one would not use all these criteria to identify this problem. Therefore, the selection of indicator criteria to identify ecological problems is a matter of judgment.

The criteria selected for the ecological assessment were used to measure beneficial and detrimental changes in the hydrosphere resulting from alternative wastewater management plans. Specifically, these criteria are:

1. Nutrients - Chemicals required by plants for growth, e.g. nitrogen and phosphorus.

2. Toxicity - Inorganic substances which have either lethal or sublethal effects on aquatic organisms.

3. Salinity - Total dissolved salts in water.

4. Dissolved Oxygen - Oxygen in water that is usable to aquatic fauna.

5. Persistent Pesticides - Chlorinated hydrocarbons, organo-phosphates and thiocarbamates which are non-biodegradable.

6. Persistent Toxicants - Heavy metals and non-metals which accumulate in increasing amounts in the tissues of aquatic organisms.

(2) Base Condition.

(a) Ocean.

1. Description of the central California coastal zone - The marine environment from Fort Ross to Point Lobos was surveyed by Odemar (1968) to determine whether there were any acceptable

ocean areas which might receive wastes, and to determine the areas (if any) where the least damage to the biota would result from a waste discharge. Included in the survey was an evaluation of the beneficial uses of the marine environment from Bodega Bay to Point Lobos, a collation of biological data pertaining to organisms in the area, a survey of the benthic biota, and a limited collection of oceanographic data.

The summary of that survey provided the following description of the marine environment within the study area:

a. The Fort Ross to Miramontes Point area possesses extensive sport and commercial fisheries. It maintains large populations of important indigenous marine species and provides for necessary spawning and nursery grounds. It is also a pathway of all salmon entering and leaving the Russian and Sacramento-San Joaquin River systems, as well as the smaller streams.

b. The Miramontes Point to Pigeon Point area maintains valuable shore sport fisheries and nearshore party boat sport fisheries, of primarily bottom fish. There is also a commercial shellfish hatchery within the area.

c. The Pigeon Point to Point Lobos area contains important nearshore kelp beds from Pigeon Point to Capitola and from Seaside south. There are extensive commercial and sport fisheries, important nursery grounds and spawning areas, as well as large populations of various marine animals throughout the region. Within the area is Ano Nuevo Island, which is unique because of the number of species of marine mammals utilizing it for rookeries and hauling-out grounds. Sea otters are found among the Monterey kelp beds. In addition to the native central California species, the clear and relatively warmer waters of Monterey Bay support a unique biotic community characteristic of more southern waters.

Also included in the report were detailed analyses of commercial and recreational fish catch data for the years 1962-1966. Much of the data was plotted on grid squares approximately ten miles per side to illustrate where the fishes were caught. Figure C-2, which illustrates the origin of the average annual catch of all species by otter trawlers within the study area, is an example of the plotting technique employed in the survey.

A review of this and similar plots and the supplementary data indicates that, with certain exceptions, the ocean area immediately adjacent to the Golden Gate is one of the least productive within the study area.

A similar conclusion was reached by North (1970), in a review of biological literature on Pacific Coast marine waste disposal as a guide to the prediction of the ecological effects of a submarine outfall in

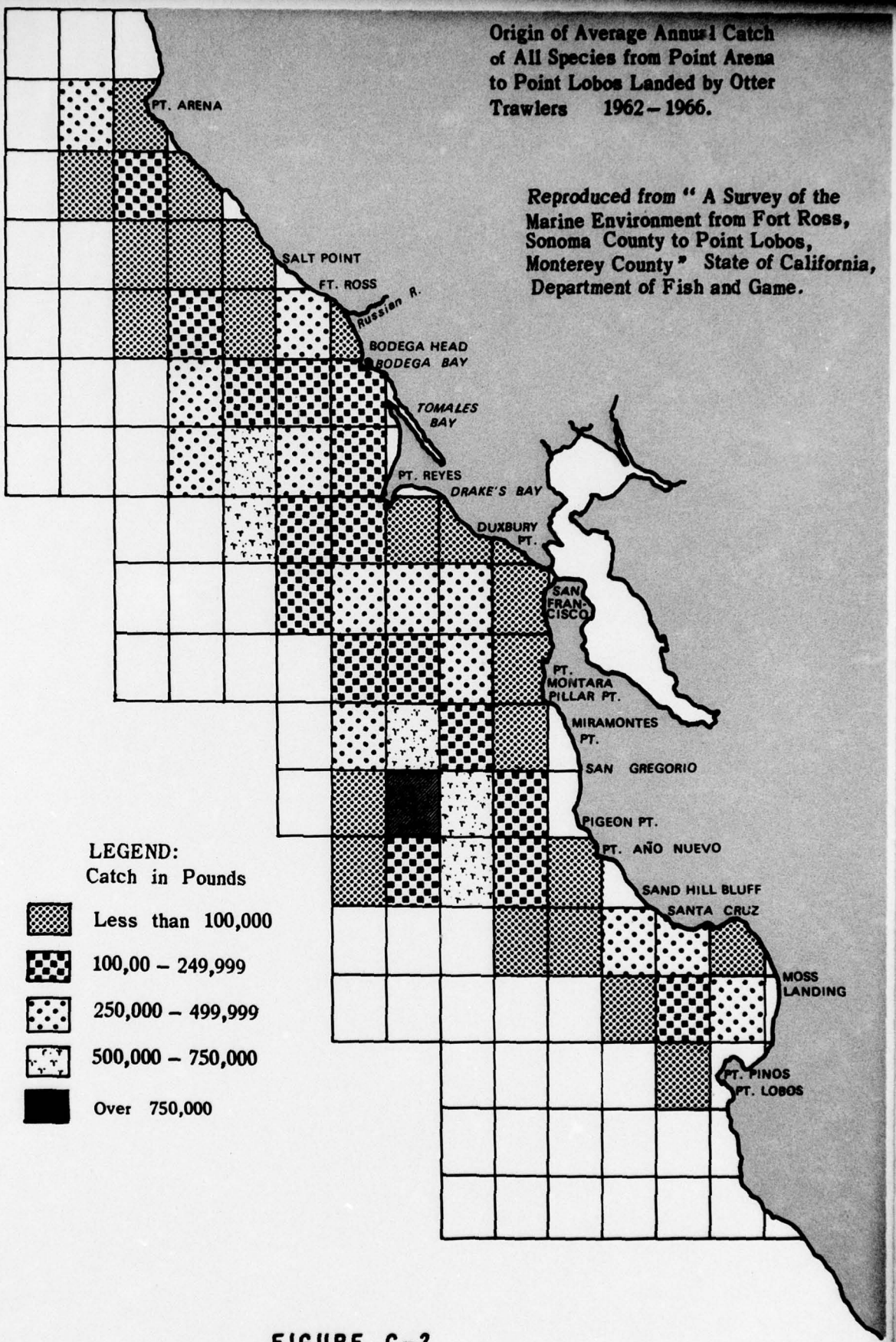

Origin of Average Annual Catch of All Species from Point Arena to Point Lobos Landed by Otter Trawlers 1962 – 1966.
Reproduced from " A Survey of the Marine Environment from Fort Ross, Sonoma County to Point Lobos, Monterey County " State of California, Department of Fish and Game.
PT. ARENA
SALT POINT
FT. ROSS
Russian R.
BODEGA HEAD
BODEGA BAY
TOMALES BAY
PT. REYES
DRAKE'S BAY
DUXBURY PT.
SAN FRAN-CISCO
PT. MONTARA
PILLAR PT.
MIRAMONTES PT.
SAN GREGORIO
PIGEON PT.
PT. AÑO NUEVO
SAND HILL BLUFF
SANTA CRUZ
MOSS LANDING
PT. PINOS
PT. LOBOS
LEGEND:
Catch in Pounds
Less than 100,000
100,00 – 249,999
250,000 – 499,999
500,000 – 750,000
Over 750,000

FIGURE C-2

the Gulf of the Farallons. In this review, he observed that the total commercial fish catches for the San Francisco area had exhibited a long-term decline, dating from 1953 or earlier. The causes for this decline were, decreases among pelagic fish and market crab catches. The decreases among major pelagic fishes were, in his opinion, probably related to broad scale phenomena and not to any local adverse changes in the San Francisco region. Causes of the market crab decline were not as apparent, since the statewide fishery has recently improved. However, there are indications that the crab's planktonic larval stage is being decimated by pollutants originating in the San Francisco estuarine system.

North also analyzed the benthic samples of Yancey (1970) and Ebert and Cordier (1966), and grouped them according to frequency of occurrence and niche. Of the 94 species or groups observed, 24 were classified as Generally Important, 15 as Important at Certain Stations, 53 as Not Important, and two were not classified. Based upon his personal experiences and those of others (Carlisle, 1969; Turner et al, 1966, 1967, 1968), he was able to associate a number of the Generally Important and Important at Certain Stations organisms with the animals common to or frequently seen near outfalls in southern California (Poyorchis, Balanus, Cancer antennarius, C. productus, Modiolus, Odostomia, Olivella, Nassarius Dendraste, Citharichthys, Cymatogaster, Engraulis, Genyonemus, Parophrys, and Rhacolchilus). Many of the other species are not common to southern California and their sensitivity to ocean outfalls has not been assessed. However, many of them (Clinocardium, Macoma, Crago, Clupea, Leptocottus, Microgadus, Psettichthys, Squalus) do occur in San Francisco Bay as evidenced by numerous sampling programs (Aplin, 1966; Kaiser Engineers - Task VII-1b 1968; Filice 1954a, 1954b, 1958, 1959; Storrs, Selleck, and Pearson, 1964, 1965). Therefore, he concluded, a substantial majority (i.e. at least 23 out of 39) of the important species in the Gulf of the Farallons had adapted to or were not sensitive to discharged wastes.

These indications of biotic impoverishment in the marine environment adjacent to the Golden Gate further substantiate the observations of a special faculty committee of the University of California. This committee surveyed the area from Monterey Bay to Stillwater Cove, north of the Russian River, to determine the best site for a U.C. Marine Laboratory. As commented (in Odemar, 1968) by Dr. Cadet Hand, Director of the Bodega Marine Laboratory, "the area between Point Reyes and Pigeon Point clearly showed a faunistic and floristic depression (which we blame on the pollution, silt, etc., that flows out through the Golden Gate)." An appreciable increase in the diversity of marine organisms was noted both north and south of San Francisco. The Association of Bay Area Governments in their Ocean Coastline Study, (1970), also observed that the coastal marine life from south of Bolinas Lagoon to Pigeon Point was relatively poor, presumably as a result of water pollution from the San Francisco Bay.

In summary, the marine environment is characterized by localized biotic impoverishment immediately adjacent to the Golden Gate and generally much richer biological communities to the north and south.

2. Effects of the base condition on the central California coastal zone - As waste discharges are consolidated, upgraded, and centralized to conform with the State's Interim Water Quality Management Plans, there will be a more efficient dispersion of wastes to the marine environment. Such an accelerated dispersion has been demonstrated by the Corps of Engineers hydraulic model studies (Corps of Engineers, 1963), U.S. Geological Survey prototype studies (McCulloch et al, 1970), and the multiple analyses of the San Francisco Bay-Delta Water Quality Control Program. Indeed, it was an interim recommendation of that program to improve the condition of the estuary by accelerating the dispersion of wastes from the estuary into the ocean.

It is assumed that the dispersion of waste discharges into the ocean will continue to follow the existing pattern. That is, wastes will exhibit the highest concentrations in the Gulf of the Farallons and their concentrations will dissipate as they are transported away from the Golden Gate. Tidal activity and internal eddy patterns will tend to retain pollutants in the Gulf. This is especially true of non-conservative waste substances such as heavy metals and pesticides, which are adsorbed to fine sediments and may be biologically magnified in marine organisms.

The multiplicity of the pesticide problem was demonstrated by the special task study on pesticides (Kaiser Engineers - Task IV-3, 1968) of the San Francisco Bay-Delta Water Quality Control Program. In that study, the annual Total Identifable Chlorinated Hydrocarbons (TICH) inflows of municipal and industrial wastes was estimated at about 3,940 pounds, and the total annual TICH runoff, including agricultural and runoff sources as well as municipal and industrial inflows, was estimated at 12,900 pounds. Based upon the mass balance, there was a total TICH influx of 12,900 pounds plus 7,220 pounds (equivalent to unaccounted-for sources of pesticides or reduction in storage) or 20,120 pounds of TICH to the Bay-Delta in 1965. Of this total, it was estimated that tidal exchange accounted for the removal of 12,640 pounds, or 63 percent of the total influx of TICH. All of these pesticides entered the ocean at the Golden Gate, independent of their source. Consequently, the pesticide problem in the ocean environment is most acute in the area immediately adjacent to the Golden Gate. This problem of localized ocean discharge also applies to other non-conservative, persistent toxicants, such as heavy metals. It is possible that this problem is contributed to by current dredge spoil disposal practices, which discharge in the Central Bay or in the Gulf of the Farallons.

This problem of nonconservative pollutants was partially confirmed in Odemar's report in which sediment samples and selected benthos were analyzed for pesticide residues. The data revealed the highest concentrations of pesticides closest to the Golden Gate and decreasing concentrations as the distance from the Golden Gate increased.

It is expected that nutrients will continue to be sufficiently diluted to preclude recurrent algal blooms, such as those reported in the San Diego area, along the central California coastal zone. Moreover, strickland (NAS/NAE, 1969) has observed that in many similar locations, notably the northeast Pacific and off the coast of Peru, comparatively low algal densities are often found in waters which are continually well supplied with nitrate, silicate, and phosphate. Micronutrients are not generally considered to be limiting.

The continual addition of nutrients, especially nitrogen in complex organic compounds, may exert a specificity for certain species with the potentiality of "weed" species to outgrow more normal forms (Ryther, 1954, 1971; Braarud, 1955). The ecological impact of such a shift in community dominance on the life histories of autotrophic forms is not known, but could involve major modifications of existing food webs, species diversity, and species composition (Margalef, 1961, 1967; Hulbert, 1963).

This question of potential changes in species diversity and dominance, specifically that of planktonic forms associated with southern California outfalls, was discussed in the State Bay-Delta Water Quality Control Program Oceanographic Study (Task VII-1a). It was observed that:

> "Based upon the available literature it appears that plankton populations are not influenced by marine discharges. However, the record of data is not sufficiently long to define what might be the long-term effects of gradual enrichment of the environment. There seems to be an inconsistancy between the data published for plankton and the other bio-populations in that there is no particular reason why the former should not be influenced in the same general manner as the latter, e.g., changes in species composition and number of organisms."

Included in North's report (1970) was a limited analysis of the possible interactions between San Francisco fisheries and an ocean outfall in the Gulf of the Farallons. He reviewed the general biology of important species, specifically the King Salmon (Oncorhynchus tshawytscha), the Market Crab (Cancer magister); the Lingcod (Ophiocon elongatus), the English Sole (Parophrys vetulus), the Pacific Albacore (Thunnus alalunga). It was his conclusion that the influences of an ocean outfall, such as that proposed by the City of San Francisco, on those species would probably be small.

In summary, under the base condition the principle impact of discharged wastes on the marine environment will be localized in the Gulf of the Farallons. The impact of sewage wastes will be antagonized by the estuarine discharge of agricultural drainage and surface runoff, as well as ocean dredge spoil disposal and accidental discharges of pollutants (i.e. oil spills). The Gulf, which has been described as biologically depressed, would not be expected to dramatically react to the accelerated discharge of wastes. Nonconservative, persistent pollutants will continue to accumulate there, and will increase the potential for a synergistic reaction with other short-term pollutants. This will heighten the possibility for more subtle long-term changes in the marine environment.

(b) San Francisco Bay & Delta Estuary.

1. Description of the estuarine environment - A study of the ecology of the estuarine system (Kaiser-Engineers - Task VII-1b, 1968) determined the present condition (1968) of the San Francisco Bay through a reduced scale field sampling program and made comparisons between their data and similar data taken during the University of California study (Storrs, Selleck and Pearson, 1963, 1964, 1965). From this comparison, it was concluded that the sediment quality was similar to that of previous years, although benthic animal populations were lower. The principal differences in water quality were in the nutrient levels which had increased significantly during the past few years. It was further concluded that:

-Toxicity exerted a major influence on the health of the biological populations of the Bay,

-nitrogen and phosphate levels were not limiting phytoplankton productivity in the Bay, and

-based upon the traditional measures of pollution (BOD, coliforms, and dissolved oxygen), the conditions in the Bay were improving.

Filice (1954a, 1954b, 1958, 1959) had previously correlated the distribution of bottom invertebrates in San Francisco Bay to discharged wastes, and a California Department of Fish and Game (DFG) report, Fish and Wildlife Resources of San Francisco Bay and Delta: Description, Environmental Requirements, Problems, Opportunities and the Future (1968), issued at the same time stated:

> "Large quantities of toxic materials are being discharged into this estuary and there are occasional visible mortalities of fish from these and from unknown causes. The invisible mortalities that we usually term 'natural' may be greatly influenced by water quality including some of these toxic chemicals. Our studies have led to the belief that increased quantity of toxic discharge and reduced outflows will probably do immense harm to fish populations even though diluted well enough to not directly kill fish."

The same report included the following Table (Table C-1), which lists the principal water quality problems of fish and wildlife in the Bay-Delta System.

TABLE C-1

PRINCIPAL WATER QUALITY PROBLEMS
FACING FISH AND WILDLIFE RESOURCES
OF THE SAN FRANCISCO BAY-DELTA 1/

Problem	Cause	Identifiable Immediate Damage
EUTROPHICATION	Increased nutrient discharges and reduced outflows of fresh water.	Reduced and fluctuating dissolved oxygen levels harmful to Neomysis and to fish.
INCREASES IN TEMPERATURE	Reduced inflow to Delta of Sacramento River water, discharge of cooling water.	Reduced Neomysis populations, interference with normal salmon and steelhead migrations.
TOXICITY	Increased discharge of waste and reduction of freshwater outflow.	Reduced reproduction and growth and survival rates of fishes and their food through numerous ecological mechanisms.
PESTICIDES	Increased use of pesticides in watershed.	Reduced reproduction and growth and survival rates of fishes and their food through numerous ecological mechanisms.
SALINITY INTRUSION	Reduced outflow of fresh water.	Redcced Neomysis populations and striped bass spawning areas in the San Joaquin River.

1/ State San Francisco Bay-Delta Water Quality Control Program, Department of Fish & Game Task VII-1B.

The "problems" listed in that table, with the exception of "Increases in Temperature," are essentially the same as the criteria utilized in this report to assess the ecological impacts of the various alternatives. While this and subsequent discussions of the estuary will concentrate on these principal water quality problems, it must be realized that there are numerous related ecological factors not covered in our discussions.

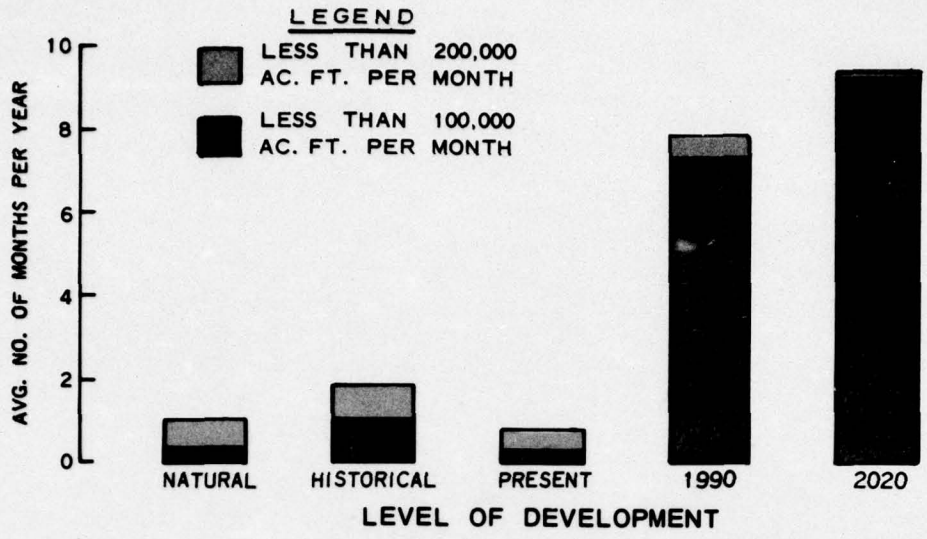
Another complication which will prevail in any discussion of the estuarine system, is the potential development of proposed water projects. These projects could increase Delta water export and agricultural drainage discharge. It is expected that increase water export will reduce the freshwater discharge to the estuarine system; while agricultural drainage will load that discharge, and may introduce deleterious substances to the hydrosphere.

Delta Water Export - The first type of modification (specifically the transport of increased volumes of high quality water out of the estuarine system) will have major impacts on the Sacramento-San Joaquin Delta as indicated by the State Department of Fish and Game (DFG) (Annual Report 1964-65, pg. B-1) in an analysis of the proposed Peripheral Canal:

> "The construction of the Delta water facilities will result in significant changes in the aquatic environment, particularly in the upper estuary, including a new hydraulic flow regimen, variations in water chemistry, and alterations in the biology of the estuary that will be associated with these changes."

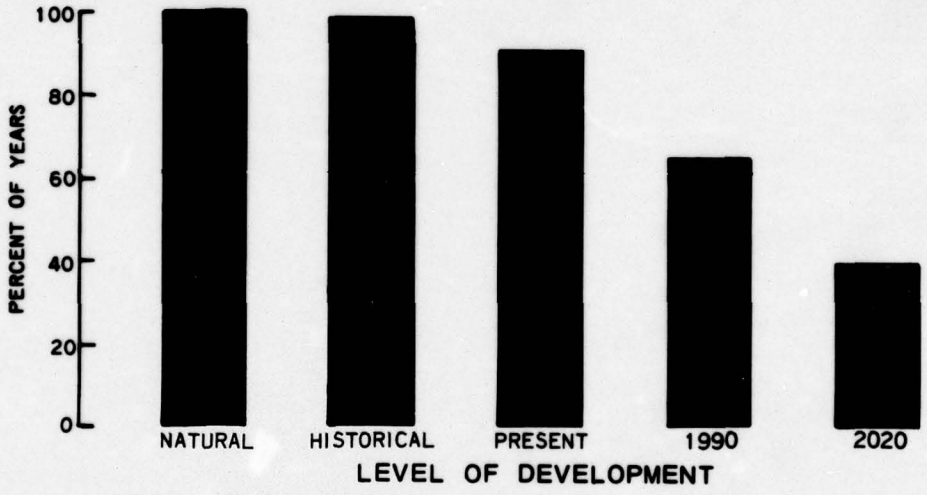
McCarty and Harris, in The Future of an Estuary (1967), discussed some aspects of reduced Delta outflow characteristics which are particularly significant in assessing changes in water quality:

> "The degree of salinity intrusion into the Delta is determined not only by the magnitude of low outflows but by their duration as well. Historically and at the present degree of development, the Delta outflow is estimated to decrease to 100,000 acre-feet per month (about 1,500 cfs) for one month or less each year, on the average (Figure C-3). In the future this low level of outflow is expected to occur more frequently, i.e., seven months during the median year at the 1990 level of development and nine months in 2020. The concentrations of certain waste discharge constitutents during low flow conditions will be strongly influenced by the degree of flushing of the estuary during the previous winter. Analyses performed for this study indicate that at a flow of 25,000 cubic feet per second a very significant transport through the San Francisco Bay system is accomplished in one month and flushing is essentially complete in two months. Using criteria for adequate flushing of 2,000,000 acre-feet outflow in one month, 3,000,000 in two or 4,000,000 in four,



OCCURRENCE OF LOW DELTA OUTFLOW

FIGURE C-3



FREQUENCY OF DELTA OUTFLOWS MEETING THE FLUSHING CRITERIA

FIGURE C-4

REPRODUCED FROM A PAPER BY McCARTY AND HARRIS: "THE FUTURE OF AN ESTUARY," PRESENTED AT THE NATIONAL SYMPOSIUM OF ESTUARINE POLLUTION, STANFORD UNIVERSITY, AUGUST 1967, SPONSORED BY A S C E SANITARY DIVISION.

the frequency with which these criteria will be met was calculated and is shown in Figure C-4. Historically and at the present, adequate flushing and removal of accumulated pollutants have occurred essentially every winter. In 2020 adequate flushing by these criteria will be obtained only one year in three. It appears that at present the annual occurrence of flushing flows prevents the build-up of pollutants to maximum or steady-state concentrations in the receiving water. (In the future, however, low outflows from the Delta will be sustained over longer periods of time and will allow these higher steady-state concentrations to be approached much more frequently."

Future reductions can also be expected to significantly affect the environmental conditions of the southermost portions of the San Francisco Bay-Estuary, as evidenced by the recent report of the U.S. Geological Survey (McCulloch et al, 1970). Part A of that report included the following conclusions:

-The seasonal salinity variations in the South Bay are largely controlled by fresh water from the Sacramento River under present conditions and are nearly unaffected by the comparatively minor discharges of South Bay streams and sewage.

-The observed seasonal changes in phosphate concentration in the South Bay does not appear to be explained by tidal flushing. The changes in phosphate concentration do correspond with seasonal changes in the Sacramento River discharge. This indicates that changes in the net flow of fresh water to the South Bay from the Sacramento River are an important factor in the flushing of the South Bay.

-The apparent relationship between the Sacramento River discharge and flushing suggests that soluble waste materials are removed from South Bay primarily during periods of high river discharge.

Although there is a general agreement that the magnitude of the proposed fresh water exports will be extremely large, there is hardly a concensus of opinion on the relative merit of such projects. In discussing the proposed Peripheral Canal, the Resources Agency (DFG Report No. 7, 1967, pg XI) has stated:

"A joint state-federal Peripheral Canal offers the best opportunity to restore and enhance the Delta's aquatic environment and fishlife."

While, the Contra Costa County Water Agency (1971, pg IV) has countered that:

"The aforementioned drastic changes in hydraulics and hydrology which the Peripheral Canal would entail could (and in all probability would) result in severe degradation, if not devastation, of the ecology of the Bay-Delta ecosystem."

This conflict of opinion, restricts a comprehensive assessment of future water quality conditions in the estuarine system. For the purposes of this report only, it is postulated that future reductions in Delta outflows will relieve negative flows in the southern Delta, but will increase salinity intrusion in more western areas such as Suisun Marsh, improve flushing in localized problem areas, reduce the net waste dispersion potential of the Delta, and render the South Bay more "negative" in terms of its salinity values and flushing potential.

Recently the California Water Resources Control Board ruled (Decision 1379) on water quality conditions required to protect beneficial uses of water in the Sacramento-San Joaquin Delta. Included were required minimum net Delta outflows. The net Delta outflow required depends on the beneficial uses to be protected and the hydrologic condition. In a normal water year the annual net Delta outflow required is 2.4 million acre-feet. The minimum daily net outflow is 1,800 cfs for 125 days to protect agricultural uses. In a critical water year the annual net Delta outflow required is 1.9 million acre-feet. The minimum daily net Delta outflow is 1,300 cfs for 125 days to protect agricultural uses. In addition, a comprehensive monitoring program is required which involves 32 monitoring stations strategically located throughout the Delta at which some or all of 23 water quality parameters will be observed. The impacts of the newly required water quality conditions on existing and proposed water development projects is unknown at this time.

Agricultural Drainage - The potential impact of the other type of proposed water project, that of agricultural drainage, is more readily predictable. As concluded in the Federal Water Pollution Control Administration report, Effects of the San Joaquin Master Drain on Water Quality of the San Francisco and Delta (1967), the planned discharge of the San Joaquin Master Drain to the Delta would not have sigificant adverse effects on the water quality of the estuarine system if adequate pollution control measures are employed. In fact, it should reduce salinity incursion in the Delta. It can also be used to create a positive flow in portions of the estuary that have little or even reverse net outflows.

As indicated in Appendix A of this report, the San Francisco Bay and Sacramento-San Joaquin Delta comprise a vast and complex estuarine system, whose components are interrelated and interdependent. Numerous sampling programs and reports have reiterated the concept that no single component of the estuarine system can be considered as a separate entity.

2. Effects of the base condition on the estuarine environment - In spite of this close relationship, there are hydrological and ecological differences within the estuarine system which account for varying localized responses to wastewater treatment alternatives within the system. Therefore, future discussion of the estuarine base condition and subsequent assesssments of the ecological impacts of the various alternatives on the estuarine system will concentrate on specific problem areas.

The South Bay - There will be no wastewater discharged into the South Bay, below the San Mateo Bridge, once waste discharges are consolidated and centralized. The recent U.S. Geological Survey report (1970) indicated that the relative impact of those discharges on the salinity values of the overall area was minimal. Nevertheless, the elimination of the low salinity effluents could account for localized salinity increases of as much as 8 parts per thousand (ppt) in the extremities of the South Bay, elevating the salinity concentrations to as high as 40 ppt (Kaiser Engineers - Task I-4, 1967). This increase in salinity will preclude the colonization of most estuarine and marine organisms and would deter the reestablishment of an oyster fishery in localized areas.

Complexities in the etiology of algal blooms in South Bay preclude a definitive statement of the base condition as it relates to algal productivity. In the San Francisco Bay-Delta Program (Kaiser Engineers - Task VII-1b-1968) it was found that the addition of nitrogen in chemical form or as activated sludge effluents did not increase growth rates, except in the case of nitrate-nitrogen. From this it was concluded that the required macronutrients are available in unlimiting concentrations in the waters. Therefore, it might be expected that by eliminating all waste discharges in South Bay, the in situ nutrient levels may decrease to the point where they do become a limiting factor.

There are many other aspects, which complicate the problem of algal productivity in South Bay. The above study reported that the ungrading of treatment facilities in the South Bay, apparently, has not resulted in decreased water concentrations of nitrogen and phosphate. Moreover, the high organic content of the bay muds, surface runoff, and sediment tranport are expected to continue to contribute to the nutrient load of the euphotic zone. Toxic industrial wastes, as well as turbidity, have also been suggested as limiting factors. In the case of the former, the elimination of future discharges may actually result in an increase in algal growth rates.

Toxicity, measured as relative toxicity, was observed to depress the benthic animal species diversity below naturally occurring levels in South Bay. Deleterious effects of toxic industrial wastes on intertidal benthic fauna were also observed (Biologic-Ecologic Study, Task VII-1b). Again, these observations are in

agreement with Filice's earlier work (1954a, 1954b, 1958, 1959). Further studies of toxicity are currently being conducted to substantiate these observations. Assuming that toxicity is a limiting factor with benthic fauna, the elimination of waste discharges in South Bay will enable a greater number of species to settle there.

There are sigificant concentrations of mercury in the South Bay sediments (McColloch et al, 1971), as well as other heavy metals and pesticides. These levels are expected to increase from future contributions of surface runoff and agricultural drainage. Sediments transported from Central Bay will also contribute to the accumulated load. No level of sewage treatment can be expected to rapidly improve this condition in the South Bay. Even if no more additions are made to the total volume of persistent pollutants, biological magnification will continue to be a potential problem for an undeterminable number of years.

The B.O.D. in Coyote Creek has decreased considerably from previous levels and there has been an increase in dissolved oxygen levels. Both of these changes are considered to be responses to upgraded treatment at the San Jose plant. It is assumed that these levels will be further improved as future waste effluents are eliminated from the area.

As future Delta freshwater discharges are reduced, problems of salinity concentrations, nutrient loading and flushing are expected to be magnified in this hydrologically negative estuary.

Thus, the elimination of waste discharges in South Bay will antagonize localized problems of high salinity concentrations, reduce the potential for algal blooms, low dissolved oxygen levels and fish kills, enable an increase in the diversity of benthic species, and decrease the rate of accumulation of persistant toxicants in the South Bay.

The Central Bay and San Pablo Bay - The high dilution rates of Central and San Pablo Bays are a function of Delta freshwater discharges and tidal exchange. The centralization of waste discharges will capitalize on this positive estuary effect to disperse the majority of the discharges into the marine environment.

The San Francisco Bay-Delta Program (Kaiser Engineers - Task VII-1b, 1968) indicated an increase in algal growth rates in Central Bay and San Pablo Bay waters by the addition of nitrogen compounds. Therefore, there is a potential for accelerated algal growth in this region. However, a shallow euphotic zone, caused by high turbidity levels, and a limited residence time should preclude major algal blooms in the open waters of these areas.

The Suisun Bay and the Delta - Algal blooms in the restricted tidal areas of Central Bay and the contiguous waters which ring the edges of San Pablo and Suisun Bays are more probable. The Biologic-Ecologic Study (Kaiser Engineers - Task VII-1b, 1968) reported that the minimum summer concentrations of inorganic nitrogen in 1962-63 were five to six times greater than the nitrogen quantities contained in peak phytoplankton populations, and are not now limiting for phytoplankton growth in Suisun Bay. There were, also, relatively high levels of phosphorus and from the growth studies with Navicula, it was concluded that there were probably other factors important in stimulating or inhibiting growth.

Chadwick's studies (1967) suggested that light was a major limiting factor on algal blooms in the Delta and Suisun Bay. Krone (1967) correlated suspended sediment loads to Delta outflow volumes. Therefore, it is quite likely that photosynthetic rates in the Delta and Suisun Bay are and will continue to be a function of the volume of Delta outflows.

The FWPCA (1967) estimated that the predicted increase in nitrogen levels and water transparency, resulting from reduced Delta outflows, would increase summer phytoplankton populations in the western Delta and Suisun Bay from 4 to 10 times over present summer concentrations over the next 25 years.

These increased populations were predicted to create minimum dissolved oxygen concentrations of 1 to 5 mg/l in the western Delta and Suisun Bay during summer periods by 1990. The problem would be especially severe in the deeper channels, as illustrated in Figure C-5. Proposed channel deepening projects may aggravate the problem; this feature requires more detailed study.

The affected area is currently the habitat of the Opossum Shrimp, Neomysis awatschensis. This organism has the highest known dissolved oxygen requirements in the estuary, as illustrated in the following table.

TABLE C-2

DISSOLVED OXYGEN CONCENTRATIONS
NEEDED BY NEOMYSIS AWATSCHENSIS POPULATIONS
AT VARIOUS TEMPERATURES AND SEASONS

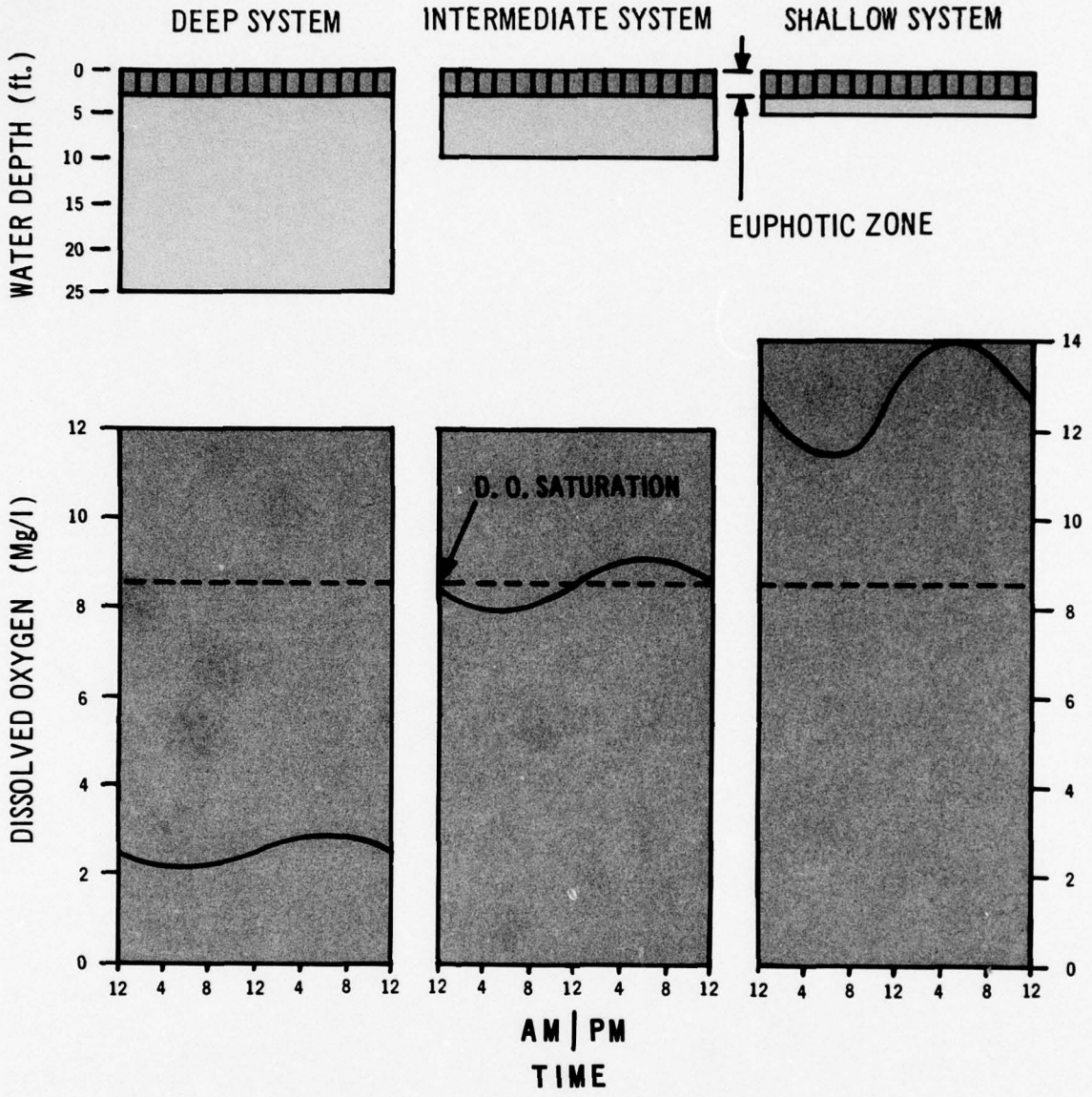
When water temperature is:	Dissolved oxygen must be:	Approximate season:
Greater than 22°C (71.6°F)	No less than 8.0 mg/l	June, July, August
18-22°C (64.4 - 71.6°F)	No less than 6.0 mg/l	September and October, April and May
Less than 18°C (64.4°F)	No less than 5.0 mg/l	November through March

Since Neomysis is generally considered to be a critical component of Delta ecology, the displacement or loss of the species would dramatically alter the ecology of the Bay-Delta system. Striped bass, Roccus saxatilis, which feed during their juvenile stages on Neomysis, would certainly be affected.

Problems associated with salinity incursion will become particularly severe in the western Delta and eastern Suisun Bay. As Delta outflows are reduced there will be an increased stress levied on Suisun Marsh, which is an extremely important feeding area on the Pacific Flyway. The delicate balance of flooding, soil salt concentration and vegetative competition has been recently assessed by Mall (1967). It is predicted that without corrective action, salinity incursion will have accounted for major vegetative changes by 1990. The resultant loss of waterfowl is projected at almost 175,000 birds or about 80 percent of the estimated 224,000 birds annually utilizing the marsh (DFG, Task VII-1B, 1968).

The State Water Resources Control Board (1971) has evaluated the toxicity of the municipal and industrial wastewaters discharged into the Bay and found that almost all of them are toxic to fish in varying degrees. Many of the recent fish kills have been attributed to high concentrations of toxic material, and it is probable that toxicants are contributing, in a synergistic reaction, to all fish kills. An increase in toxic discharges, along with reduced flushing flows, will continue to accelerate already large-scale adverse effects on the estuarine ecology.

COMPUTED DIURNAL DISSOLVED OXYGEN VARIATIONS IN THREE DIFFERENT ENVIRONMENTS



NOTE: All examples based on constant respiration and gross production for 100 ug / l Chlorophyll.

REPRODUCED FROM A PAPER BY BAIN & MINNEHAN: " PREDICTING DIURNAL VARIATIONS IN DISSOLVED OXYGEN BY ALGAE IN ESTUARINE WATERS," PRESENTED AT THE NATIONAL SYMPOSIUM OF ESTUARINE POLLUTION, STANFORD UNIVERSITY, AUGUST 1967, SPONSORED BY ASCE SANITARY DIVISION.

FIGURE C-5

In summary, the San Francisco Bay-Delta estuary and coastal ocean waters, under the base condition, are expected to continue to exhibit the existing environmental problems of algal blooms, fish kills and salinity incursion in the future, as wastewater discharge increases, freshwater inflows decrease and treatment remains at secondary level.

(3) Ocean Disposal Alternatives.

(a) Introduction. Occupying approximately 71 percent of the earth's surface and providing for relatively little direct use by man, the ocean has been promoted as a leading candidate for the disposal of man's wastes.

As the "ultimate sink," the ocean has served as the final repository throughout geological history. This entropic condition has been accelerated by the recent large scale disposal of man's municipal and industrial wastes. For example, approximately 2.8 billion gallons of sewage are discharged daily along the California coastal zone. Except for the 600 million gallons being discharged into the confines of San Francisco Bay, the remainder is directly discharged into the State's coastal waters (Calif. Dept. Fish and Game, 1971).

Approximately one billion gallons of this sewage is discharged daily into the shallow near-shore marine environment in southern California, yet despite the volume of this effluent and its general concentration at four major outfalls (White Point, Hyperion, Point Loma and Orange County) relatively little is known about its ecological effects (Turner, Ebert, and Given, 1966, 1968; California State Water Quality Control Board, 1965; North, 1963).

The present impossibility of quantitatively or even qualitatively assessing the ecological effects of waste disposal in the existing southern outfalls or in proposed outfalls in Central California can be attributed to the following real difficulties.

1. Too little is known of the effects of the total marine environment on chemical processes, and of the effects of chemical form on entry and use in biochemical processes. Extensive bioassay of pesticides and other chemicals has demonstrated that each compound should be fully tested since there is only general prediction value even between related compounds.

2. The biological communities of the continental shelf are not well known, with insufficient comprehension of species composition, energy flow, food chains, and environmental relationships. They vary so greatly around the coasts that generalized prediction is not appropriate.

3. Thousands of species may be involved, and each species is a biochemical and biological entity, sufficiently different from others to make transfer of predictions difficult or unreliable, even between rather closely related species.

4. Within species, response to toxicants has been shown to vary greatly with different stages in the life history, with previous nutrition, with season, and with unknown causes.

5. Toxic effects on single individuals are complex, and may involve different biochemical mechanisms at different concentration levels. Time-exposure-effects curves are frequently non-linear, so that extrapolation may be difficult. (VAS/NAE, 1969). Therefore, with the proceeding difficulties in mind, the potential ecological impacts of the ocean disposal alternatives follow.

(b) Ocean Disposal Alternative - Advanced Treatment.

Estero de San Antonio - The proposed discharge of low salinity wastewater one mile from shore, within the confines of the combined Tomales and Bodega Bays, a region of known restricted circulation, would create a local "estuary" by making the entire region brackish. The transformation of this embayment, presently characterized as a semi-open to protected marine environment, to an estuarine type environment could disrupt or displace all marine communities presently inhabiting the area.

Pillar Point - The discharge site, off Pillar Point, lies in an open coast type of environment. The discharge site, one mile offshore, would be at the transitional boundary between the littoral and neritic zone of circulation. Under such circumstances, the fresh-water discharge would initially mix and form a brackish surface pool, such a pool subsequently spreading shoreward and along the coast. The continuous discharge, brackish pools and plumes would result in chronic exposure of attached algae and associated fauna to somewhat lower salinity conditions, and could change the littoral and near-shore neritic characteristics of the environment.

The discharge of large volumes of fresh-water in both areas could interfere with the migrations of anadromous fish.

(c) Ocean Disposal Alternative - (Secondary Treatment).

In the assessing the ecological impacts of this alternative, it is assumed that all industrial wastes would be pretreated at the source to remove dangerous and noxious materials as well as toxicants. Such an assumption, however, should be treated with extreme caution and it must be assumed that an undetermined fraction of industrial waterborne pollutants would be incorporated in the wastewaters and that secondary treatment is inadequate to remove them.

Uncertainties as to the effectiveness of treatment processes, necessitate that the discharge be located far enough away as to inhibit immediate loading of the shore by detritus and undesirable micro-organisms. Further, a review of the data presented in reports by the State of California Department of Fish and Game (1968) and State Water Resources Control Board (1969), together with recent results from U.S. Geological survey studies (1970), indicate that neither the spatial and temporal variabilities in the stability of the density structure, nor the regime of the shelf circulation, appear adequate to either prevent the sewage field from contaminating the coastline or to keep the field contained around the outfall.

Studies of plankton, benthos, kelp, fish and macroinvertebrate population around southern California outfalls have demonstrated that marine ecosystems do react to the presence of wastewater. Although this alternative will provide a sightly higher degree of treatment than that in southern California, the ecological changes observed in southern California provide a reliable preview of changes that could occur here.

Benthos - The Hancock Foundation found that the average biomass of benthic fauna near Los Angeles City and County outfalls was not significantly different from the average biomass found over the entire southern California mainland shelf (Kaiser Task VII-1a 1968). Studies by the State of California on relative toxicity and biostimulation have indicated that the use of chlorine to disinfect wastewater is causing toxicity problems and benthic species diversity depression around some San Francisco Bay outfalls. This would be a problem in ocean disposal considering the volume of the discharges.

Kelp - Reduction in kelp populations have been experienced in outfall dilution zones due to increased predator (sea urchin) populations and interference with holdfast mechanisms. In areas outside of the dilution zone kelp populations may benefit from sewage discharge due to the presence of additional nutrients.

Fish - During the six-year period (1958-1963), after construction of the Hyperion outfall (1957), the California Department of Fish and Game, in their trawl study found that "the sportfishing catch in Santa Monica Bay showed only small natural fluctuations," indicating no immediate disruption in the fishery. On the other hand, some researchers claim that pollutants from outfalls may be responsible for body lesions and papilloma in fishes.

Plankton - Based on the available literature it appears that plankton populations are not influenced by marine discharges. However, the record of data is not sufficiently long to define what might be the long-term effects of gradual enrichment of the marine ecosystem.

The impacts of ocean disposal would be best documented by the long-term more insidious chronic effects on the environment, if time would allow. Usually overlooked, in this respect, is the enormous ability and capacity of the primary producers (phytoplankton and attached algae) to quickly reconcentrate effluent components, and the successive biological magnification of pollutants in each step of the food chain. The uptake and bioconcentration of pollutants does not, necessarily, adversely affect every step of the food chain, but is most apparent among top carnivores. Long-term, sub-lethal impacts, such as erratic behavior and reproductive failure, are just now becoming apparent in many marine species and predator birds.

(d) Other Aspects of the Ocean Disposal Alternatives. Either ocean disposal alternative would relieve the Gulf of the Farallones from the pollutant load that is would experience under the "base condition." The projected impact on that area is discussed in the estuarine disposal alternative. However, the local current patterns would continue to return some pollutants to the Gulf.

The elimination of all discharges from the estuarine system would reduce the biostimulatory potential and toxicity problems of that system. The impacts would be similar to that of the land disposal alternative with the exception that no flushing flows would be available for Suisun Marsh.

(4) Estuarine Disposal Alternative. Although labeled estuarine disposal, this alternative calls for only partial discharge into the estuary depending on the amount and type of reuse of reclaimed wastewater.

The projected high quality of the effluent would prevent the development of typical zones of active decomposition and degradation. The practically fresh-water discharges would augment Delta outflows and improve the flushing capacity of the entire estuarine system.

(a) The Ocean. The limited discharge of high quality effluent into Central Bay would improve the quality of water moving into the Gulf of the Farallones through tidal action. Essentially, the only pollutants discharged into the ocean environment would be those originating in agricultural drainage and surface runoff.

The reduced pollutant load entering the Gulf would significantly relieve the environmental stress on the organisms inhabiting that area. It is probable that the general health of the existing species would be improved. For example, the planktonic stages of the market crab, Cancer magister, might experience a higher survival rate with a resultant improvement in the standing stock of adult crabs. Additionally, there would be a potential for the establishment of a greater number of species in the area, increasing its species diversity.

The reduced volume of persistent toxicants and pesticides and the diluting capacity of the wastewater discharges would decrease the localized rate of biological magnification that is currently occurring in the Gulf. However, there would continue to be a small fraction of those toxicants in the treated water which would be discharged into the hydrosphere.

Other coastal areas would be preserved and the rate of biological magnification of persistent toxicants and pesticides outside the Gulf would be reduced.

(b) The South Bay. As indicated earlier, the extremities of the South Bay are expected to become more "negative" as low TDS sewage discharges are removed from the area and Delta outflows are reduced (ref. "base condition"). The ensuing hypersalinity and reduced flushing could create severe environmental stresses, in terms of lethal limits, metabolic rates, and osmoregulative capacities, on the organisms in the far reaches of South Bay. A further reduction in species would be expected. The addition of high quality wastewater discharges, on a year-round basis, would effectively superimpose upon all other Delta outflows in regard to their influence on the South Bay. Assuming that the data obtained in the U.S. Geological Survey report, A Preliminary Study of the Effects of Water Circulation in the San Francisco Bay Estuary, 1970, is substantiated by future studies, it can be expected that the additional amounts of low TDS (approximately 1 ppt) effluents would (1) increase the already "large effect on the salinity" in the South Bay during periods of high Sacramento River discharge, and (2) increase the already "strong effect on the absolute salinity valves" of South Bay during periods of low Sacramento discharge.

The limited volume of estuarine discharge, high degree of nutrient removal, and the dispersive capabilities of the upper estuary (to the ocean) would limit the amount of nutrients introduced into South Bay. Its biostimulatory potential would approximate that created by local nutrient loading and surface runoff. As indicated in the base condition, there are significant amounts of nutrients in the South Bay muds which would continue to provide high concentrations of nutrients to the euphotic zone for an extended period of time. The southerly dispersion of sediments observed by Conomos et al (1970) would continue to provide new sources of nutrients to the southernmost reaches of the Bay.

The improved flushing potential, discussed earlier, would be a major factor in the control of algal blooms and low dissolved oxygen levels. (As indicated by McColloch et al, 1970, the flushing rate of South Bay also appears to be a function of Delta discharge volumes.)

The fate of toxicants in South Bay would be similar. Limited discharge, high degree of treatment, and high levels of dispersion would restrict the amount of toxicants entering South Bay. Persistent toxicants, and pesticides, primarily adsorbed to the bay muds, would remain a potential problem due to biological magnification. Flushing flows would further reduce localized problems of high toxicity.

(c) The Delta. High quality wastewater would be discharged into the San Joaquin River to augment the flow regime and improve water quality. The San Joaquin River is already experiencing very low or even reverse flows during critical periods of the summer and fish kills associated with dissolved oxygen sags are common there.

The limited addition of the effluent would contribute to:

1. The maintenance of a long salinity gradient - to permit physiological changes required by anadromous fish in their migrations between fresh water and salt water.

2. The maintenance or creation of a positive net flow toward the sea to prevent flow reverses and pollution blocks.

3. The enhancement of conditions for zooplakton and Opossum Shrimp (Neomysis) populations.

4. The enhancement of estuarine benthic populations.

(These environmental characteristics were originally utilized by the California Department of Fish and Game, 1967, to evaluate the effects of four alternative Delta water plans on the Delta fishery.)

(d) Suisun Marsh. The California Department of Fish and Game in their report to the State Water Resources Control Board (1969) indicated a need for water to flush Suisun Marsh. Seasonal salinity incursion and reduced submergance time, due to reduced Delta outflow, threaten the viability of marsh. The 54,000-acre marsh supports an annual waterfowl population of between 500,000 to 1,300,000 birds. Currently joint studies are underway by the State Departments of Fish and Game and Water Resources to define the amount and quality of water required to maintain the marsh under future salinity conditions. Tentative estimates of the volume required were set at a minimum of 120,000 acre-feet per year. The discharge at Suisun Marsh would meet that demand.

(e) The Central and North Bays. The Suisun Marsh and Delta discharges would improve the flushing potential of the north bays. The freshwater discharges would also contribute to the maintenance of the estuarine system as discussed under the Delta.

As indicated earlier, the Bay Studies Project (Storrs, et. al, 1964, 1965) and the subsequent San Francisco Bay-Delta Water Quality Control Program (Kaiser Engineers - Task VII-1b, 1968) reported levels of macro-nutrients (nitrates and phosphates) to be well above limiting levels in most of the San Francisco Bay. These studies provided added support to the concept of turbidity (i.e. light penetration) as the limiting factor for algal production in the estuarine system. Krone (1966) positively correlated turbidity levels to Delta outflow volumes, indicating that reduced Delta outflows may allow for increased productivity in the upper regions of the estuary.

He observed that the reduced sediment inflows will cause significantly reduced concentrations of suspended solids in the Bay system, particularly during the summer and fall months. One effect of reduced suspended sediment concentrations on water quality would be: "Deeper penetration of light at effective intensities will increase the productivity of photosynthetic organisms. The productivity of a given area of water is inversely proportional to the suspended solids concentration."

The addition of wastewaters with low TSS to the Delta could allow for further reductions of turbidity levels, increasing the potential for algal blooms. It is also feasible that the discharges could induce vertical mixing with a resuspension of bottom sediments, reducing the potential for algal blooms. Of course, the high degree of treatment would reduce the biostimulatory potential of the Bay waters and possibly could become the limiting factor for algal productivity.

Krone also correlated the volume of suspended sediment to the sorbtive capacity of the estuary: "The total sorbtive capacity of the entering sediment will be reduced in proportion to the sediment inflow."

However, since the estuarine discharges would not significantly alter the total sediment inflow, it is not expected that they would alter the estuaries sorbtive capacity. Therefore, problems of toxicity will be largely limited to non-sewage discharges.

(5) Land Disposal Alternative. Under the land disposal alternative, the only treated wastewater discharged into the estuarine system would be 120,000 acre-feet per year to prevent the buildup of salinity concentrations in Suisun Marsh. Theoretically, no other municipal and industrial sewage would be introduced to the hydrosphere.

(a) Impacts on the San Francisco Bay-Delta Estuary. The most obvious area of impact would be Suisun Marsh. This impact has been discussed in the estuarine disposal alternative.

The only sources of pollutants in the estuarine system, other than the finite amount discharged at Suisun Marsh, would be the in situ amounts, contained primarily in the Bay muds, and those discharged as agricultural drainage and surface runoff. The reduced pollutant load would relieve problems of biostimulation and toxicity throughout the estuarine system. However, the elimination of wastewater flushing flows would reduce the dispersion rate and could contribute to localized problems of algal blooms, depressed oxygen levels, and fish kills in the extremities of the estuary. The absence of wastewater flushing flows would also contribute to problems of hypersalinity and sharp salinity gradients in the South Bay and salinity incursion in the north bays and Delta.

(b) The Ocean. The minimum discharge of wastes into the estuary would result in a limited dispersion of pollutants into the ocean. Problems of toxicity and biological magnification would be relieved in the Gulf of the Farallons. The other coastal areas would remain at their present levels of high quality and ocean species would be less subject to problems of persistant toxicants and pesticides.

(6) Combination Disposal Alternative. The combination alternative provides for a discharge into Suisun Marsh or the southern Delta as in the estuarine disposal alternative. Its impacts on the estuary would be similar to that alternative, varying primarily by the order of magnitude.

(a) The Estuary. To meet the projected flushing flow needs of Suisun Marsh, the wastewater discharge under this alternative may need to be supplemented by another fresh-water source. The impacts of the Suisun Marsh discharge have been discussed in the estuarine disposal alternative.

The absence of a Central Bay discharge site, as in the estuarine disposal alternative, would have a minimum impact on the water quality of the estuary. However, it would reduce the net discharge of pollutants into the hydrosphere.

(b) The Ocean. The dispersion of pollutants to the ocean would be intermediate to that of the estuarine and land disposal alternatives. Its effects would, therefore, be intermediate to those two alternatives.

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July 7, 1971

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1. Tables 1 - 22	Tables on Baseline Conditions
2. H. L. Mason	Some definitions and concepts
3. D. R. Storm	Report of ecological and aesthetic impacts of waste disposal to land
4. W. M. Longhurst	Terrestrial ecology in relation to waste disposal to land
5. W. E. Howard	Report on ecological and aesthetic impact of disposing wastewater on land
6. P. R. Day	Report on wastewater reclamation project
7. A. W. Knight	Ecological impact of waste disposal to land
8. C. C. Delwiche	Solid waste disposal as a means for preserving some delta soils
9. R. H. Twiss and J. C. Sorensen	The visual and aesthetic impact of alternative wastewater management plans
10. J. R. Anderson	Potential insect problems associated with the proposed alternative plans of wastewater management
11. R. H. Burgy	Some hydrological considerations in disposal of waste treatment effluent on land sites
12. H. L. Mason	The extension and development of marshes
13. R. B. Krone	Comments on environmental impact studies
14. E. C. Stone	Disposal of wastewater from sewage treatment plants by recycling through the terrestrial phase of the hydrologic cycle
15. R. S. Ayers	Land disposal plan. Comments and evaluation

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SUMMARY

Questions relating to the pros and cons of land disposal of the sewage effluent and sludge of the 12 counties of the San Francisco Region are considered (figure 1). Six potential disposal Areas are evaluated (figure 2). Estimates of certain associated features are given in terms of future needs to 1990 and 2020. The plan calls for the collection of urban sewage for secondary treatment and transfer of effluent and sludge to the appropriate sites within the six Areas for land disposal. Two or three aeration lagoons for 3-day treatment and an equal number of storage reservoirs at each area for winter use only will receive the waste.

Baseline ecological conditions of the Areas are described with special reference to environmental factors important to the counties (Section 4). The potential impact on the Region of an ultimate utilization of the total projected acreage of about 335,000 acres is contemplated. Aesthetic as well as ecological impacts of the land waste disposal plan are described.

Baseline and impact conditions resulting from this particular type of land use are considered in terms of changes brought about at the ground surface and those taking place below the surface.

As signified by Professor Robert Burgy the key hydrologic processes acting in this system are evaporation and transpiration, precipitation, infiltration, drainage systems, and climatic regimes (Exhibit 11). The annual evaporation for Area 1 in San Benito County is about 48 inches. For the other 5 areas, it is from 60 to 70 inches.

The proposal for land disposal envisions about 8 feet of the treated effluent to be applied to the designated land for an 8-month period. An estimated 50 percent will be lost to evaporation leaving about 4 feet for soil percolation and recovery, via extensive underdrain systems.

The study indicates that: (1) site preparation operations for the disposal will affect the carrying capacity of the soil as will the sewage disposal operations themselves*, (2) the presence of such large wet acreage will create potential disease and insect nuisance problems which may possibly be controlled by biological agents (Exhibit 10), (3) increases in the relative humidity and fog frequency may likewise pose problems that are not so readily solved (Exhibit 11), (4) the entire existing ecological relations of the surface areas, which in many instances have not greatly changed from the mid 19th century, will under go drastic alteration, (5) present agricultural practices will give way to new and limited agricultural crops, alfalfa production for example, and specialized silviculture, such as coast redwood production (Exhibit 6 and 14), alterations

* Carlson, C.W. and J.D. Menzies 1971. Utilization of urban wastes in crop production. Bioscience 21:561-564.

of the aesthetic characteristics of the landscape will likewise occur but can be minimized and compensated for by proper planning (Exhibit 9).

Preparatory to considering the waste reclamation problem, it is pointed out that there are three kinds of treatment given sewage in disposal operations. They are primary, secondary, and tertiary treatments. Primary treatment entails the physical separation of solids from effluent whenever and whereever it occurs in the sequence. Secondary treatment entails the biological operations on both effluent and separated sludge fractions. Tertiary treatment entails the chemical additions or operations employed at any point in the sequence. Clearly, the terms are without any specific ordinal connotation. The solids in domestic sludges are composed of the following constituents.

Biologically degradable organics	- 30 percent
Stable organics	- 35 "
Inert material	- 35 "

Secondary sludge differs from primary sludge in that it has a solids content of less than one percent. Primary sludge is much simpler to process, dewater, and stabilize than secondary sludge which decomposes more rapidly presenting odor problems.

According to Dr. P.R. Day, maximum utilization of the soil as an efficient filter system for water reclamation possesses severe limitations over sixty or more percent of the six land disposal Areas due to the presence of fine textured soils, high clay content, and a shallow hardpan. However, Dr. J.D. Teresi, after examining numerous soil maps regards this figure as somewhat high.

As pointed out by Professor Herbert L. Mason in Exhibit 12 there is much non-agricultural land in the Areas that is too alkaline or saline for any current productive use. Much of the land now used for grazing yields a poor return. Those lands would be far more productive if converted into marshland. "Marshes contain plant communities that are the easiest to duplicate artificially of any that exist" (H.L.M.). But here as elsewhere proper water quality must be maintained. An added advantage is that marsh plants also serve as a "living filter" in the sewage disposal operation to further degrade the effluent of phosphates and nitrates and other plant nutrients. Also, the aesthetic qualities of marshes are not to be overlooked.

Another potentially profitable use of waste is to apply the sludge to unproductive land to bring it into rich agricultural production in what might be termed a "waste management-land management program". Under proper management, this type of operation could conceivably fill the present gap caused by taking rich agricultural land out of production and converting it to presumably higher economic uses.

Mr. David R. Storm has evaluated the fertilizer benefits for commercial crops resulting from the availability of the inorgani micro-and macro- nutrients found abundantly in typical domestic wastewaters (Exhibit 3). Quoting literature sources he states, "The values of nitrogen, phosphorus, and potassium are $10, $5, and $2 per acre-foot respectively, or $18 per acre-foot total value.

On the negative side and suggesting caution there are, besid boron which is noted as being extremely detrimental to commercia crops, a number of chemical substances for which phytotoxic properties are known. Those include silica, fluoride, sulphates. chlorides, calcium, magnesium, sodium, manganese, arsenic, copp and lithium.

The water quality effects of large-scale land waste disposal operations depends on the efficiency of the underdrains and the ability of the system to store the waste components during high rainfall months without spillage. The efficiency of the system to exchange ions and filter the effluent is a function of certain critical subsoil properties set forth by Mr. David R. Storm in Exhibit 3, p.7. Chemicals toxic to microorganisms interfere with the cleansing actions of the soil biota. One of the primary land disposal problems will be to maintain a proper micro-biolog chemical balance under the specific soil mechanics characteristi of the proposed land Areas for water disposal. Repeated emphasi has been placed on the importance of recognizing local variation in soil type and hence percolation efficiencies and characterist

Both the marshland development recommendation and the propos to upgrade non-productive agricultural lands embody long-term concepts. By virtue of the increasing magnitude of the disposal problem and the accompanying decrease of fertile soil in California per unit of population, these potential courses of action may prove to be economically feasible. But, again, as Professor Ray B. Krone points out, "The impacts of all of the land disposal methods will depend on the constituents of the wastewaters and sludges when delivered to the disposal sites" (Exhibit 13). He warns against use of the sorptive capacity of the soil for non-degradable toxic compounds.

Overloading of subsurface percolation layers of soil should b guarded against to avoid nuisance problems and sudden failure of the system due perhaps to clogging. This and related considerations prompt the recommendations that wet soils be continuously monitored for any build-up of pathogens and other unwanted organisms and, equally important, that a system of monitoring soils and underlying aquifers be maintained to observe, at an early stage, any build-up of deleterious chemical substances, such as boron and pesticides.

Uppermost in the minds of the system planners must be the conservation and maximum utilization of the potentially valuable components of the system ranging from valuable nutrients, to recoverable wastelands, to reclaimable potable water, and to aesthetic components of the landscape. In this connection, Professor Edward C. Stone discussed a modified terrestrial ecosystem, equivalent to a tertiary treatment plant, that can function in regions where plants can thrive in periodically saturated soils and utilize the chemicals contained in the effluent (Exhibit 14). Interestingly, he builds a practical case for reed canary grass and the coast redwood and states, "It should be possible to produce between 500 and 1000 cubic feet of redwood per acre per year while operating the terrestrial ecosystem as a terminal processing unit" (tertiary treatment)..... "At the present market value of redwood logs and chips, the average net return should be between $125 to $250 per acre per year with a major harvest cut within 20 years after establishment" (Exhibit 14).

The climatological, biological, and agricultural conditions of the project areas, the plans for converting suitable sites within these areas for land disposal of effluents, and the role of soil structure and microorganisms in water reclamation from sewage effluent and sludge utilization have been considered.

Some of the inherent problems of the system may be summarized. A primary consideration is the hazard to aquifers from salination. As indicated by Dr. P. M. McGauhey, a noted authority on irrigation water problems, everything possible should be done to preserve the natural quality of underground aquifers. The question of how to disinfect the sewage and the sludge remains. Commonly used chlorination methods are open to question (Section E-7).

The ecological impact of the spray liquor is important in that resulting fine droplets in the atmosphere will increase the humidity of the site and its adjacent area. Bacterial or viral pathogens trapped in the droplets create a hazard according to Proffessor A. W. knight (Exhibit 7). To possibly overcome this problem, control of droplet size is being tried in Michigan (Muskegan Report, 1971).

The existence of such large areas of wet lands and sewage lagoons and storage reservoirs is certain to cause insect problems. Midges, gnats, and mosquitoes will thrive. Professor John Anderson, who has analyzed this problem critically in Exhibit 10, recommends that biological control methods should be given preference over insecticides whenever possible. A careful entomological monitoring program should accompany any disposal plan of operation.

The possibility of nitrate poisoning of cattle and humans has been stressed. There are instances of such effects now on record. Perhaps no other broad consideration has received more attention

in this study than that of desalination of all waters that may be used directly or indirectly in the system. It is recommended that the question of the economic feasibility of the desalination process be reexamined in light of direct and indirect benefits from many potential uses of waters with improved quality. Nine pertinent advantages of introducing the desalination process into the land disposal system are listed in Section G-1.

A second important consideration is the tremendous water loss, largely from evaporation inherent in the sewage disposal operation. This loss only presents a challenge to the engineer and should not be allowed to detract from the values of the system.

Incineration offers the opportunity to reduce sludge to a sterile, inorganic land-fill and remove offensive odors. However, the resulting particulates can contribute significantly to air pollution. To overcome this problem wet scrubbers of a variety of types are used in preference to centrifugal collectors. The scrubbers have the advantage of absorbing significant amounts of gases including sulphur oxides and odorous organics.

A means for the disposal of sludge in a way to benefit California agriculture has been advanced by Professor Constance Delwiche (Exhibit 8). The plan calls for raising the level of the sinking Delta farmland islands by using sludge and garbage fill and converting the resulting soil complex to rich agricultural land. Professor Delwiche postulates that there is a fifty-year potential disposal site there for solid waste (300,000 acres). By that time the first island to be treated may be reduced sufficiently by attrition (2-3 inches per year now) to warrant beginning another refill cycle.

While the above presentation points out a number of potential problems, it provides opportunity for constructive use of relatively unproductive lands for utilizing economically valuable components of municipal and industrial wastes.

RECOMMENDATIONS

Living systems may approach a steady state with their environment through three well-defined processes, often recognized as environmental imperatives, to guide man's developing activities, namely:

1. Aquisition, storage, and retrieval of information, the ultimate resource of all biological systems;
2. improved re-cycling of materials within the system; and
3. reduction of energy use per unit of supported biota.

These emerging ecological imperatives constitute a basis on which to scientifically assess constructive ecological courses of environmental action. They provide useful criteria on which to measure the components of waste disposal programs in the San Francisco Bay Region. Further, they constitute the basis on which are predicated the recommendations of this report which are a distillate of the most compelling arguments raised by our consultants and ourselves. It is our considered judgment that disposal of treated waste on land is a feasible alternative. The following recommendations are basic to the implemention of this alternative:

1. That wastewater be made as suitable as possible for all human and environmental uses;
2. That sludge be treated and used as effectively as possible to provide agricultural benefits;
3. That a study be undertaken to determine, if possible, methods that are economically sound and hydrologically desirable for applying sludge to unproductive land for agricultural production;
4. That optimum treatment procedures for various reuses of wastewater be determined;
5. That studies be undertaken to evaluate the climatological, ecological, and public health impacts of spray liquor on and near the disposal areas;
6. That wet soils be continuously monitored for any build-up of noxious insects, pathogens, and undesirable micro-organisms;
7. That biological pest control methods take precedence over chemical methods in the abatement of insects from treatment and storage ponds;
8. That a system of monitoring underlying aquifers be initiated to observe any possible build-up of nutrients, salinity, heavy metals and boron, pesticides, and other deleterious substances;
9. That the sorptive capacity of the soils in the waste disposal areas not be used for non-degradable toxic compounds;
10. That soils be monitored to detect any increases in salinity and alkalinity;

11. That changes occurring rapidly should be contrasted with those that are stable and long-lasting; e.g., salt will long continue to be a problem whereas pesticides may be bio-degradable and/or reduced significantly in years to come;
12. That use of spray-treated lands for wildlife support and for grazing be approached with caution because of potential nitrogen accumulation by forage plants;
13. That effects of induced humidity on the occurrence of ground fog be studied;
14. That a study be undertaken to evaluate the extent of hazards from consuming meat products of livestock fed on forage crops grown with waste irrigation water;
15. That evaluation of waste disposal methods give careful consideration to:
    a. the potential of ionizing radiation for use in control of unwanted organisms in appropriate phases of the waste disposal system,
    b. desalination of wastewater by electrodialysis and/or other feasible methods,
    c. Delta Island reclamation,
    d. values inherent in marshland construction with its multipurpose benefits,
    e. an artificial redwood forest and/or other comparable systems as effective sewage treatment units as the subject of a pilot-type study evaluation,
    f. investigating hillside planting of grasses and sedges for a flow-system of effluent treatment; and
    g. the development of multi-stage filtration systems with or without natural systems for large scale water treatment purposes.
16. That waste treatment projects be developed stepwise to permit assessment of each successive stage of development, and in light of new technological, ecological, and aesthetic impacts;
17. That possible benefits of sale of reclaimed water and chemicals be considered;
18. That use of atomic generating plants and other means for recovery of potable water and salt and production be evaluated to relieve, in part, the present need for using extensive land areas of San Francisco Bay for salt production.

A. INTRODUCTION

1. Background information

This study concerns the effects of waste disposal to land on the ecological and aesthetic factors of the environment of the 12-county San Francisco Bay Region (Figure 1). The kinds and quantities of waste for disposal in this region are projected to 1990 and 2020. The baseline conditions of the terrestrial environments of the region are considered to be those prevailing between now and in 1975 when the project disposal plan may be initiated. These conditions include those likely to be affected directly or indirectly by the impact of waste disposal, namely, climate, wildlife, insects,soil organisms, soil mechanics, soil chemistry, water chemistry, water productivity, recreation, and aesthetic factors.

Rainfall is a factor that limits water supply in the 12-counties bordering the San Francisco Bay Area and its principal tributaries (Figure 1). In these counties, the average annual rainfall ranges from as low as 10 inches in San Benito County to 29 inches in Sonoma County (Exhibit 1, Table 1). The average Delta flow to the Bay and ocean is about 18 million acre-feet per year; the months of least flow are June, July, August, and September.

In a broad sense, rainfall is a dominant ecological factor since it modifies to varying degrees the incidence of the major environmental factors receiving the impact of waste deposition. For all six of the project areas significant amounts of monthly precipitation are limited largely to December, January, February, and March. During these months, treated liquid wastes with sludge are, according to plan, to be stored in one or more large reservoirs for each impact area (Figure 2). During the remaining months treated liquid wastes, with up to 10 percent solids, are to be pumped to large aeration lagoons (two or three for each impact area) for three days of aeration, and then pumped to the disposal area for spreading and percolation.

The primary objectives of the study are to:

a. Identify baseline environmental conditions of the six disposal areas giving particular attention to wildlife, vegetation, water quality, soil quality, and soil percolation properties.

b. Describe potential alterations in the natural environmental conditions imposed by waste disposal management.

c. Evaluate the impact of the physical, chemical, and biological changes due to waste disposal on the productivity and aesthetic values of the areas.

d. Identify changes in the effluent required to render it useable.

e. Assess the aesthetic impacts of proposed waste management practices on the ecology of the six disposal areas.

2. Provisions of the National Environmental Policy Act (PL 91-190)

The "National Environmental Policy Act of 1969" was enacted by the 91st Congress:

> "to declare a national policy which will encourage productive and enjoyable harmony between man and his environment;
>
> "to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man;
>
> "to enrich the understanding of the ecological systems and natural resources important to the Nation; and,
>
> "to establish a Council on Environmental Quality."

The Congress declares in the Act that it is the continuing policy of the Federal Government:

> "to use all practicable means and measures. . . . to foster and promote general welfare; and
>
> "to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans."

The Act further states that it is the continuing responsibility of the Federal Government to improve and coordinate Federal plans, functions, programs, and resources to the end that the Nation may:

> "fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
>
> "assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings;

"attain the widest range of beneficial uses of the environment without degradation, risk to health or safety, or other undesirable and unintended consequences;

"preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity and variety of individual choice;

"achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and,

"enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources."

3. Definitions and Concepts

Included here are only such definitions and concepts that differ from some definitions presented in the literature. We hope to bring the definitions into line with modern usage and include that growth of concepts that has resulted from widespread variations and inconsistencies (Exhibit 2).

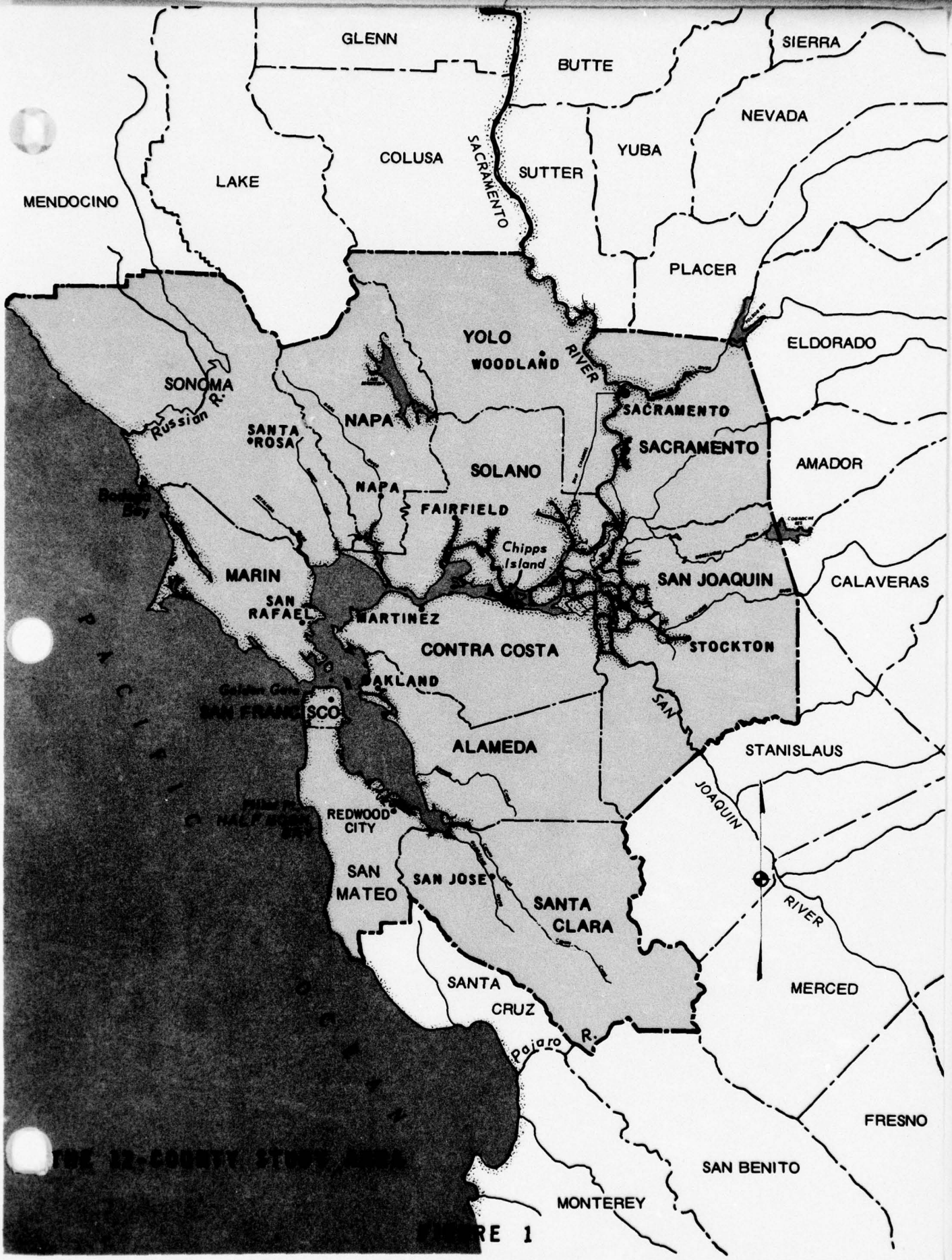
Ecosystem: The pattern on formal relations, holding in data, that concerns the relation of organisms to their environment and that is expressable in the various languages of mathematics.

Ecology: The biological science that seeks to describe the relations holding in the communities of organisms and their environments in the mathematical language of the ecosystem and to explain these relations in the language of the operations of organisms and of the environmental processes.

Primary treatment: The physical separation of effluent and various sludges whenever and wherever it occurs in the treatment sequence.

Secondary treatment: The engineered operations using biological activity for removing objectionable and oxygen demanding substances from a waste water; the resultant biological accumulations (secondary sludges) may be combined with primary treatment solids (primary sludges) and subjected to anaerobic biological digestion, yielding a relatively stable digested sludge which must be disposed of.

Tertiary treatment: The chemical additions and operations employed to remove or facilitate removal or inactivation of substances and dissolved matter from waste materials, as introduced at any point in the treatment sequence.



THE 12-COUNTY STUDY AREA

FIGURE 1

GROSS AREA AVAILABLE FOR LAND DISPOSAL OF WASTEWATER AND SLUDGE

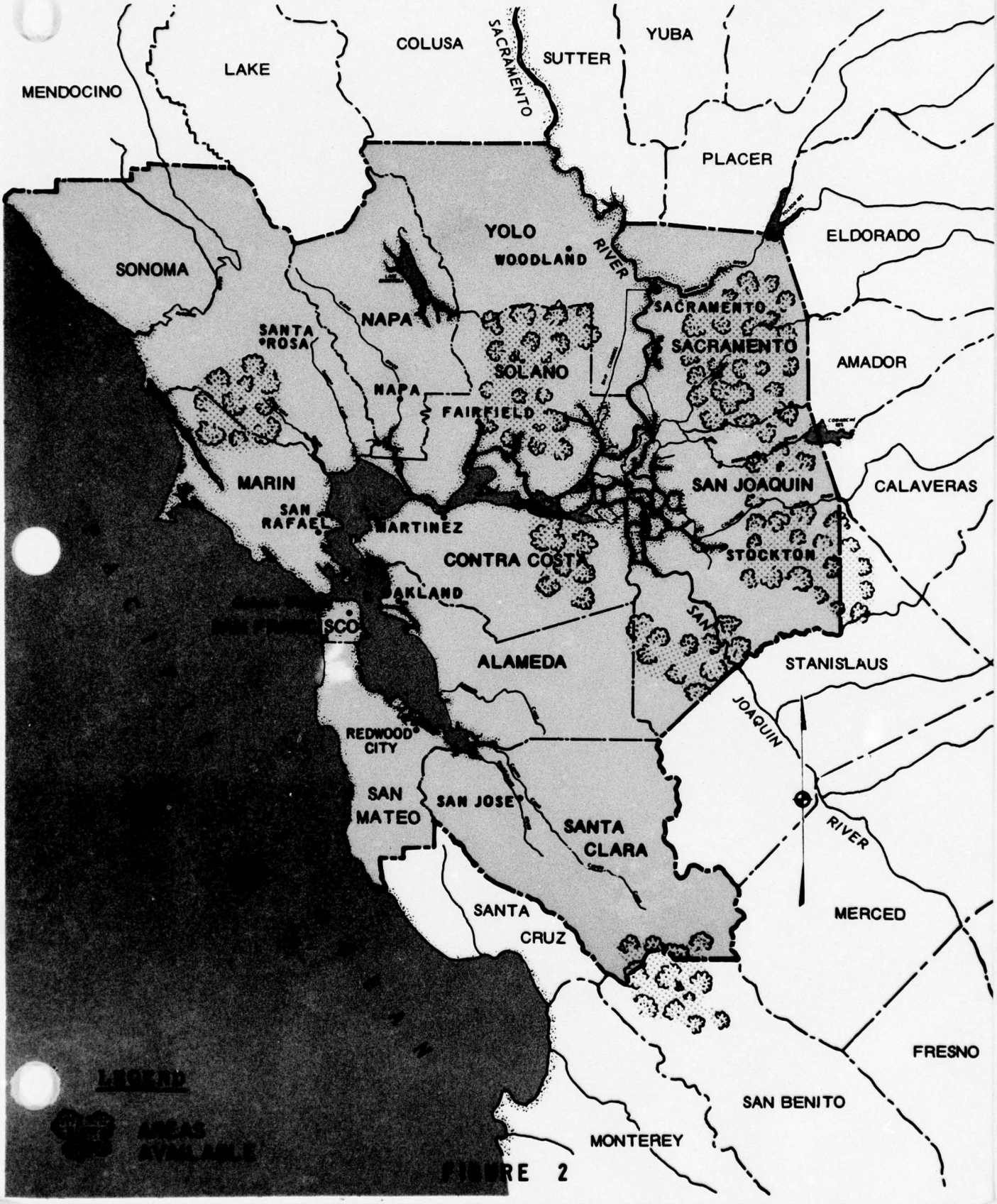


FIGURE 2

B. BASELINE ASSUMPTIONS PERTAINING TO DISPOSABLE WASTES

It is necessary to make certain baseline assumptions pertaining to the disposable wastes because it is impossible to predict these matters meaningfully from day to day, or to foresee conditions that will obtain in 1975 let alone in year 2020. In general, we think such assumptions should be expressed in terms of levels of treatment of sewage rather than any aspect of its specific content. This should take care of a large range of content but we are aware that it might not reflect some drastic and abrupt changes in human habits such as was the shift from a predominant use of soap to that of detergents and the sudden change from hard detergents to the so-called "soft detergents." These shifts caused great changes in the presence of phosphate ions in sewage. We shall assume that:

1. The baseline composition of the waste approximates the values in Tables 6-20 of Exhibit 1. The baseline condition of waste products and water quality are considered in Exhibit 3.

2. The effluent has received at least secondary treatment, largely to accomplish the reduction in biological oxygen demand (BOD). Such treatment will permit greater flexibility in safely meeting any exigencies that may arise in the waste disposal sites (Exhibit 3).

3. The effluent will be biological inert, that is, it will have been disinfected in a way to cause degradation of the disinfectant and removal of other toxins before disposal and thus protect the microflora of the soil.

4. All sludges have been stabilized by anaerobic digestion. Here we are concerned with the decomposition of the putrescibles and breakdown of its structure - the former to minimize BOD and odors at the disposal site and the latter to facilitate mechanical spreading on the land.

5. The sludge liquor has been drained off and given such treatment before disposal as will render it innocuous. The highly toxic character of the sludge liquor demands that it receive further treatment prior to land disposal.

6. The sludge has been washed to remove all traces of the sludge liquor before being placed on the land.

Given all of these treatments the chance of adverse ecological impacts and aesthetic impacts as they pertain to odors will be greatly minimized.

C. ECOLOGICAL BASELINE CONDITIONS

California's soil, vegetation, wildlife, and indeed agricultural patterns are subject to the stress of extreme climatological conditions. Rainfall or lack of it produces pronounced seasonal changes in vegetation growth and fluctuations in animal populations. But natural precipitation has over the years failed to keep up with the rapidly increasing demands of a burgeoning population for water. Now, it is clear that either natural water supplies must be conserved for highest priority uses, supplemented by salt water conversion methods, or reused under modern and safe practices of converting substantial fractions of waste effluents to potable water with high standards of water quality.

Our concern here is for the reuse of vast quantities of recoverable water to help meet man's expanding agricultural, recreational, and overall environmental requirements for water. To facilitate water conversion operations and waste management practices now envisaged for the larger population centers of the nation, extensive acreages much be adjusted agriculturally and ecologically to advance the production of potable water. The sites tentatively selected for the San Francisco Bay Region are indicated in figure 2. The biota, agricultural products, soils, and climatic conditions characterizing these sites are briefly described here, with some attention being given to the possible impact on them of the waste disposal operation.

1. The areas for the disposal sites

The general areas in which disposal sites are to be located comprise over 300,000 acres in parts of nine counties. Of the 741,000 acres estimated to be available for waste management purposes, 335,000 will be required by the year 2020 (Table 1 and Figure 2). Since the plan calls for only about 20 or 30 aeration lagoons and storage reservoirs, albeit large ones, the major acreages would be devoted to land spreading of treated liquid effluent and treated sludge. The operational facilities are to be in areas less than 500 feet in altitude and on ground with slopes of less than 10 percent.

TABLE 1

LAND DISPOSAL AREAS

Disposal	Area In Acres Available	Required (By 2020)
1. Santa Clara & San Benito Counties	86,000	60,000
2. Sonoma & Marin Counties	40,000	20,000
3. Solano County	175,000	105,000
4. E. Contra Costa & W. San Joaquin Counties	95,000	75,000
5. S.E. Sacramento County	175,000	50,000
6. E. San Joaquin County	170,000	25,000
Total	741,000	335,000

2. The natural biotic communities

a. General Features

At all sites the primary plant cover of the uncultivated lands is the "California annual type". Native and many introduced species are present. Common genera are given in Exhibit 4, tables 1 and 2. Typically the annual species of both grasses and herbs germinate in the fall of the year after the first rains. They grow in winter, set seed in the spring, die out in early summer, and are replaced in the fall by their seed. A few kinds of plants of the annual type such as Turkey Mullein and Star Thistle reverse the usual pattern of growth, being summer growing species. The common denominator of all the annuals is that they are adapted to a Mediterranean climate typified by moist, cool winters, and dry summers.

Woody vegetation is not abundant on any of the uncultivated lands. Scattered stands of oak, with willows and alders along stream courses occur in Sonoma, Marin, Santa Clara, and San Benito counties. Except for scatterings of blue oaks and a few valley oaks, there is very little native woody vegetation in the remaining disposal areas.

A list of the various crops grown in the counties containing the disposal areas is given in table 3 of Exhibit 4. Most croplands lie in the northern portion of Area 3 and in Area 1.

Particularly pertinent to the waste disposal plan regarding non-agricultural land use are the marsh areas, some of which occur naturally in certain of the six areas and many of which could be successfully developed by the use of reclaimed water. The major natural marsh areas involved is Suisun Marsh, adjacent to Area 3. Such marshland area are in increasingly short supply for waterfowl. An estimated 0.5 to 0.75 million ducks and geese winter in this marsh according to Dr. William Longhurst. They represent about 20 percent of California's wintering population.

In the marshes the types of vegetation depend primarily on salinity and the water control regime.

Salinity in excess of 18-20,000 ppm favors unwanted plants such as pickleweed, Salacornia spp and salt grass, Distichlis spicata which do not provide food for waterfowl. Below this salinity level, especially at a salinity range of 10-12,000 ppm, alkali bulrush, Scirpus robustus, an excellent waterfowl food plant,

grows well. Important marsh plants found in areas 3, 4, and 5 are listed in table 4 of Exhibit 4. Caution must be exercised against habitat modifications, especially salinity increases, that may significatly reduce the waterfowl populations.

The proposed creation of marsh habitats in the six areas has considerable merit. Extensive losses in the famous waterfowl populations of the Bay - Delta due to vast acreages of marshlands being preempted for agricultural purposes have dropped the bird populations to seriously low levels and at great cost to the states economy.

This waste disposal project provides an opportunity for the creation of marshes that can support wildlife and compensate in part for the lost marsh habitats. California is the principal wintering ground for migratory waterfowl on the Pacific Flyway. Out of the original 5 million acres of wetlands in the state, mostly in the Great Central Valley, only about one-half million acres remain according to the U.S. Fish and Wildlife Service (Exhibit 5). According to Professor Walter E. Howard, any increase in waterfowl habitat will provide an additional sancturary in the late fall where waterfowl can be driven should they become an agricultural problem. It is practically impossible to drive waterfowl from agricultural crops unless there is some other suitable habitat available, such as a waterfowl refuge with adequate food and resting places.

As trees, vines and shrubs develop, all six Areas will become more attractive to resident and migrant birds including:

hummingbirds	titmice	bluebirds	blackbirds
woodpeckers	bushtits	solitaires	orioles
flycatchers	chickadees	kinglets	western tanagers
larks	nuthatches	waxwings	finches
swallows	mockingbirds	shrike	sparrows
jays	thrushes	vireos	towhees
magpies	robins	warblers	juncos
crows	starlings		

A few species of grassland birds, such as meadow larks, American pipits, and horned larks, may be expected to decrease in numbers.

Species of furbearers that may increase with the projected waste disposal plan include:

Virginia opossum	Didelphis marsupialis
Racoon	Procyon lotor
Long-tailed weasel	Mustela frenata
Mink	Mustela vision
California striped skunk	Mephitis mephitis
Badger	Taxidea taxus
Red fox	Vulpes fulva
Gray fox	Urocyon cinereorgenteus
Coyote	Canis latrans
Muskrat	Ondatra zibethica
Beaver	Castor canadensis

Few species of big game would benefit from the proposed site. Deer, Odocoileus hemionus californicus are apt to take advantage of the newly created habitats. Margins of the sites treated with effluent, roadways, dams, and adjacent steep habitats will be desirable habitats for quail, pheasants, mourning doves, Audubon cottontails, and other forms of wildlife.

The increased diversity of habitats created by additional water is expected to increase the local diversity of rodents. Species likely to increase in numbers are:

Botta pocket gopher	Thomomys bottas
Western harvest mouse	Reithrodontomys megalotis
Western gray squirrel	Sciurus griseus
Dusky footed woodrat	Neotoma fuscipes
California meadow mouse	Microtus californicus
Muskrat	Ondatra zibethica
Norway rat	Rattus norvegicus
House mouse	Mus musculus

None of the changes in rodent densities are expected to have an adverse effect on adjoining lands. Heavy irrigation will remove current ground squirrel problems, but meadow mice and pocket gophers may create local problems. Conceiveably moles and shrews might increase in numbers and populations of the black-tailed jackrabbit, Lepus californicus might build up in local border areas. Cottontails may also be expected to increase in numbers.

Avian and mammalian predators would probably take advantage of increases in the small mammal fauna.

b. Rare or locally unusual species

According to the list of rare and endangered species of vertebrates published by the Department of Fish and Game on May 29, 1971, it is possible to foresee that some species may be affected either on disposal sites or adjacent areas (Exhibit 4). The following list summarizes the species concerned and the areas likely to be affected:

Endangered list:

American Peregrine Falcon - marsh areas around Suisun Bay and in the Delta

Salt Marsh Harvest Mouse - marshes around Suisun Bay

Rare list:

California Black Rail - Suisun Marshes
California Yellow - billed Cuckoo - Sacramento Valley
Giant Garter Snake - Sacramento Area

The rare and endangered species occurring in the area of the sewage disposal sites are largely species frequenting vernal pools around the periphery of the valley. Here are so-called "hog wallows" containing annual plants that begin their life as aquatics with all of the morphological features of such plants and often end their season as extreme xerophytes living and seemingly flourishing on sun-baked, cracked soil, often themselves showing no visible signs of drought. Some of these kinds of plants are highly local geographically, others less so. In any event it is the special community that should be preserved for educational purposes because they display the operations of natural selection in a highly dramatic way. The communities and their habitats have reached the point of becoming rare as the sites have been disked and landplaned.

A local species that is rare is Lathyrus jepsoni of the Suisun Marsh. It has been reported also along Humboldt Bay but there is question as to the identity of the latter. Whether changes in the Suisun Marsh will militate against the survival of this species is open to question.

There is a form of Laythrum Californicum that occurs in Suisun Marsh. Its habitat is among the Tules in the marsh, a very different habitat from that where L. Californicum is otherwise known and the stems are up to 2 in. tall with correspondingly larger leaves. Its ability to tolerate the summer salinity of these waters is unique. Furthermore, it is subject to the daily tidal overflow prevalent in Suisun Bay.

3. The agricultural communities - plant and animal

a. Nature of the crop

A list of various crops which are grown in the counties involved in the 6 wastewater disposal areas is given in Exhibit 4 table 3. All of these crops are not necessarily grown on the specific disposal areas but it is noted that barley, wheat, alfalfa, oats, and sugarbeets are field crops common to all five counties. San Benito and Santa Clara Counties of Area 1 grow the greatest variety of vegetables including lettuce, carrots, broccoli, cauliflower, artichokes, tomatoes, and onions. Only about half as many varieties are produced in each of the other four counties. The greatest variety of fruits grows in Solano county according to table 3. These include pears, walnuts, apricots, almonds, apples, grapes, and plums.

Most croplands lie in the northern portion of Area 3 and in Area 1. Some cropland is present in Areas 2 and 4 but there is relatively little arable land in the southern portion of Area 3, and in Areas 5 and 6 (Exhibit 4).

b. Water tolerant crops

Crops which are especially tolerant of large amounts of water include a number of kinds of grasses such as rice, sudan grass and cana reed canary grass (Exhibit 4). Unfortunately, all of the proposed disposal sites are insuitable for rice production because their climate is too cold. Sudan grass can utilize large amounts of water during summer months, but it is an annual and does not have a growing season that extends for the desired 8-month application period. Under the conditions of high nutrient application which should pertain with wastewater application, cana reed canary grass should be able to survive water applications to field capacity and provide palatable feed for livestock.

Corn has the ability to utilize large amounts of nutrients, but is notable sensitive to oxygen deficiency associated with high ground water levels. Irrigated pasture also offers a good possibility for high rates of water application and nutrient consumption. For example, on deep soils near Davis irrigated pasture can withstand up to 5 to 6 feet of irrigation water, but in the area west of Dixon in the northwest corner of Area 3, irrigated pasture can only absorb about three inches of water every two weeks after the soil is saturated. In other words, even though the plants used for irrigated pasture can withstand

a considerable amount of water, many soils on the proposed disposal areas provide constraints because of their low permeability and shallow depth. Likewise, livestock use of irrigated pastures, particularly if they are too wet, leads to soil compaction and reduced permeability.

In many respects the formation of additional marshlands with their associated aquatic plants to provide additional waterfowl habitat offers one of the most reasonable possibilities for wastewater disposal. It is somewhat doubtful though that additional waterfowl habitat of the order of magnitude contemplated can be easily assimilated into the economy. Even with marshes managed for waterfowl, if unwanted stands of tule and cattail become too dense, it is necessary to dry them out to allow mechanical control.

4. The soils

Generally speaking, sites that have been found to be most satisfactory as spreading basins for grounwater recharge have been located on coarse sediments, such as gravelly stream beds or flood plains (Exhibit 6). One would expect to use the same types of soil for the present application, or at minimum to use dry soils that are moderately permeable. Some physical and chemical properties of five california soils are shown in Table 21 of Exhibit 1.

Soil surveys of the six Areas indicate that although a large percentage of these areas have adverse conditions (fine texture, presence of hardpan, and presence of adsorbed sodium) a small percentage is suitable by the above criteria.

a. Soil conditions which relate to water spreading

(1) Physical conditions (Exhibit 6)

Soil permeability is a major consideration in water spreading operations. It is affected by the percentage of clay in the soil, the kind of clay, the degree of compaction, and the amount of adsorbed sodium in the soil relative to the total amounts of adsorbed cations. Permeability is affected by the composition of the permeating solution, which exchanges cations with the solid phase of the soil. It is also affected by suspended solids, including sewage sludge.

(2) Chemical properties (Exhibit 6)

The exchangeable cations adsorbed on the surfaces of the soil particles influence soil permeability in accordance with their relative properties in the exchange complex. Permeability becomes exceedingly low when the exchangeable sodium exceeds about 15% of the total population of cations in the exchange complex.

b. Soils of areas for land disposal

(1) Area 1: San Benito County (Exhibit 15)

This disposal area has a very wide range of soils, varying from several thousand acres of very heavy clay now largely in pasture and marginal crops to excellent soils devoted to orchard, vegetable, and seed crops, as well as wine grapes. Very few areas of sand soils exist and infiltration rates probably average less than 0.25 inch per hour.

Under-drainage might be expected to work over much of the area. The pick up of under-drainage water could be accomplished from the Pajaro River or by drains before the drainage flows out of the upper basin down into the lower basin.

Hollister and vicinity (Isgrig 1969)

The soils in this area are classified as belonging to the Sorrento-Yolo-Mocho association and are nearly level to sloping, well-drained, medium-textured soils in flood plains and alluvial fans. This association occupies about 6 percent of San Benito County.

The Sorrento soils make up about 45 percent of the association; Yolo soils, about 20 percent; and Mocho soils about 15 percent. The remaining 20 percent consists of Docas and Metz soils, Riverwash, Sandy alluvial land, and Terrace escarpments.

The dominant Sorrento, Yolo, and Mocho soils are very deep and well drained. The Sorrento soils have a grayish-brown silt loam surface layer underlain by light brownish-gray, calcarous silt loam. The Yolo soils have a brown to grayish-brown loam surface layer of brown loam. The Mocho soils have a surface layer of grayish-brown loam that is underlain by light brownish-gray loam to sandy loam.

In this association are some of the most productive soils in the country. The soils are used for irrigated fruits and nuts, row and field crops, alfalfa, and pasture. They are used for small grain and pasture when dryformed. Except on streambanks, the soils are subject to little or no erosion.

(2) Area 2: Marin Area (Exhibit 15)

Petaluma west.

The soils in this area are not deep and have a limited capacity for accepting water. The area is mostly grassland pasture with clay subsoil. Perhaps this type of grassland pasture and rolling hills would be well suited to an especially adapted method of disposal of rather low amounts of water but would need to be different from that for the San Benito and Petaluma north areas.

These lands are very flat, heavy textured, and poorly drained. Percolation of effluent through these soils will be very slow. A shallow under-drainage system at perhaps three feet and closely spaced (75 feet or less; cf. Exhibit 15) might work but a deep system (8 feet) would not be expected to remove surface applied effluent since percolation rates would be extremely slow. There are extensive grass hillside pasture lands available for effluent disposal, but here again clay subsoils and limited water storage capacity within the shallow rooting zone makes disposal more difficult as to quantity of effluent that can be applied per application and the frequency of application.

(3) Area 3: Solano - Yolo County

The northern and western portions grow a wide variety of crops. Soils in the central and southern portions are heavy textured, poorly drained and utilized for irrigated pastures and dry farmed grassland and cereal grains. There is ample acreage for reduction or aeration ponds and many acres of crop and pasture land that can use the effluent.

Dixon Area (Cosby & Carpenter, 1931)

A large portion of this area is made up of clay or silty clay or a thin soil layer with a hard pan at shallow depths. However, there are 30,000 or so acres of suitable soils (Yolo fine sandy loam, Yolo silt loam, Yolo silty dry loam) which have a depth of 50 inches to 6 feet or more.

(4) Area 4: East Contra Costa, N. Alameda, W. San Joaquin Counties

The Brentwood area has excellent soil and could utilize considerable quantities of effluent on orchards during the winter perhaps at times when much of the other parts of the area are too wet to take much water. Although a large percentage of the area consists of soils with a hard-pan at shallow depths, there are some areas that contain soils that have a uniform texture down to a depth of six feet.

Oakley sand is found in the northeastern part of Contra Costs County where it occupies an area of several square miles. The soil is leachy and porous and extends below a depth of 6 feet (Carpenter & Cosby 1939). Tests of the soil must be made to determine the areas best suited for percolation.

(5) Area 5: SE Sacramento

Two soils dominate this area - San Joaquin and Redding. The San Joaquin is typically a hardpan soil. The Redding is a rocky claypan soil. Neither will accept very much water. The hardpan of the San Joaquin occurs close to the surface at 10 to 40 inches, and is usually impermeable to water except when cracked or shattered. The Redding is on steeper slopes and has a heavy red clay subsoil at 10 to 30 inches below the surface.

Water-holding capacity for crop use or effluent disposal is limited to the depth of hardpan or to the heavy clay subsoil.

Drainage problems will occur - both internal and surface as soon as the soil becomes saturated. This will occur before the first 12 inches of water is applied.

(6) Area 6: SE Sacramento County - E. San Joaquin County (Exhibit 15)

The northern area east of Lockeford is similar in soil conditions to Area 5.

The southern area also is similar to Area 5, but the hardpans and clay pans may be a deeper depths but usually within 40 to 60 inches.

Under-drainage is not possible as normally considered. Some special disposal procedure would need to be worked out.

c. Ground water quality

The quality of ground water is affected by factors that influence the concentration and type of constituents that are carried in solution by ground waters. The principal factors are hydrology and geology, the character of the resident ground water available for mixing, and, in local cases, waste discharges resulting from human activity.

Baseline conditions for ground water quality are presented in a table containing analyses of water from selected wells in typical sites located in the impact areas. The data and the location of wells are presented in Exhibit 1, Table 22. Material in this table and in subsequent water quality evaluations is taken from California Department of Water Resources (1964).

(1) Evaluation of water quality

(a) Gilroy-Hollister Basin - Area 1

This area is largely agricultural and major water use is for irrigation and domestic purposes. Smaller amounts are used for stock watering and for the processing of agricultural products. Pumping for irrigation constitutes about 75 percent of the total ground water withdrawal.

Waste discharges in the area include domestic sewage and wastes from food processing plants. The largest discharge is domestic and industrial sewage from the City of Gilroy which is discharged to Llages Creek after primary treatment. Smaller amounts are discharged by the cities of Hollister and San Juan Bautista, and by food processing plants in the vicinity. The majority of liquid wastes can percolate and reach the underlying ground waters. No evidence is available as yet to indicate that these wastes are degrading the ground water supply.

Ground water in the Gilroy vicinity, while moderate to very hard, is generally of good mineral quality and suitable for most beneficial uses. The water is typically calcium-magnesium or magnesium-calcium bicarbonate type. Ground waters in the vicinity of Hollister are of poor quality, high in total dissolved solids content, and contain boron. These waters also contain high concentrations of chlorides, sulfates, and nitrates.

(b) Petaluma Valley - Area 2.

A great portion of southern Petaluma Valley is at or below sea level, and much of this land has been reclaimed. Only in the upper portion of the valley has the ground water been developed for agricultural and urban use. The major waste discharge consists of domestic and industrial wastes from the City of Petaluma which are discharged to Petaluma Creek after secondary treatment. Domestic wastes from Hamilton Air Force are discharged directly to San Pablo Bay after primary treatment. Neither of these wastes is a present threat to ground water quality.

The water from the younger and older alluvium and the Merced formation is generally of good quality. Water from the shallower wells is of calcium bicarbonate type with deeper wells also producing sodium bicarbonate type. Salt water has intruded the aquifers beneath the tidal marshlands and produced sodium chloride type water which is highly mineralized. Some wells in the southern and central portion of the area, adjacent to Petaluma Creek, produce water high in boron which makes them unsuitable for irrigation of some crops. A few wells in the valley show iron concentrations in excess of those recommended for domestic use. It appears that sea water intrusion in Petaluma Valley is not occurring directly from the Bay by subsurface inflow, but through the downward and lateral movement of surface and near-surface brackish and saline waters.

(c) Suisun-Fairfield Valley - Area 3

The beneficial uses of ground water are municipal, irrigation, industrial, domestic, and stock watering. The two major waste discharges located in this area are domestic wastes from Fairfield-Suisun Sewer District discharged to Suisun Slough after primary treatment, and domestic and industrial wastes from Travis Air Force Base discharged to Union Creek after primary treatment. These discharges are made in the lower end of the basin and to tidal waters. They are not considered a threat to the quality of ground water.

Under natural conditions, ground water moves southward from the margins of the valley towards the tidal marshes. However, in the vicinity of Fairfield a pumping depression has reversed the gradient of the ground water table. This poses a problem of potential encroachment of sea water from the Bay. In addition to the sea water intrusion problem, high concentrations of boron and sodium are found in wells in the southeastern portion of the monitored area. Boron concentrations up to 9 ppm are also found in wells in the vicinity of Fairfield. This level is far above the recommended level of Boron for irrigation waters (Porterfield 1970). Usable ground water is of calcium and sodium bicarbonate type and is generally hard and slightly alkaline.

(d) San Joaquin County - Area 4

Approximately 70 percent of the water pumped is used for irrigation. The remaining portion is used mainly for industrial and domestic purposes. The principal waste discharges in San Joaquin County consist of effluent from sewage treatment plants at or near the Cities of Escalon, Stockton, Lodi, Manteca, Tracy, and Lincoln Village. All the sewage treatment plants dispose of their waste waters to nearby surface waters except for the plant at Escalon which uses percolation ponds for disposal. Waste discharges have no apparent effect on quality of ground waters.

Ground water in the San Joaquin County varies in type and mineral quality depending upon location and depth. Wells less than 1000 feet deep, located east of Stockton, generally yield water suitable for both domestic and agricultural purposes. The water is bicarbonate in type with calcium the predominant cation. Chloride and boron are usually well within the limits for irrigation waters.

Poor quality water underlies the central Delta portion of the county at a depth of less than 100 feet. Impediment of ground water movement due to fine-grained Delta deposits appears to have effectively prevented movement of poor water into the fresh water underlying the eastern portion of the county.

(e) Sacramento County - Area 5

Ground waters in Sacramento County are used primarily for irrigation, domestic, municipal, and industrial purposes. The principal waste discharges consist of effluent from the City of Sacramento, Mather, and McClellan Air Force bases, Aerojet-General Corporation, and Libby, McNeill and Libby plant. Waste from the City of Sacramento and the Air Force bases are discharged to surface waters while wastes from Aerojet-General and Libby are discharged to dredger tailings in the eastern portions of the county.

Ground waters in Sacramento County are primarily calcium-magnesium bicarbonate in type and, although slightly to moderately hard, are of excellent mineral quality. Total dissolved solids are relatively low, seldom exceeding 350 ppm. Boron, chlorides, and nitrates are uniformly low and well within recommended limits.

5. Climatic conditions

Special attention is given to climate since its components alter conditions of existence of the plants and animals of the six areas, the agricultural productivity, and atmospheric qualities affecting population growth and transportation. Rainfall, humidity, and ground fog in their particular zones of interaction with economic and behavioral patterns are prime ecological factors.

a. Rainfall: Annual precipitation in the 6 Areas varied from 10.36 inches at Hollister in Area 1 to 29.04 inches at Sonoma in Sonoma County during 1968 (Exhibit 1, Table 1). No significant precipitation occurred during the months from April to November, inclusive, with the possible exception of October

when the Sonoma monthly average record was 1.98 inches. Most of the rainfall is during four or five winter months of the year, hence the projected sewage land disposal operation is scheduled for the eight months of minimum precipitation.

b. Temperature and evaporation

The mean annual temperatures are about the same for the six Areas, about 60 F, the range for 1968 being from 57.1 F for Vacavile, Solano County to 61.5 F for Folsom Dam in Sacramento County. Temperature extremes reached over 105 F in most of the six Areas in 1968 (Exhibit 1, Table 2 & 3). Evaporation rates were highest in June and July during 1968 (Exhibit 1, Table 4).

D. IMPACT OF SITE PREPARATION ON CARRYING CAPACITY OF THE SOILS

1. The Soil Drainage Operations

It is presumed that the soils of each disposal site are either natural and undisturbed or the surface layers have been disturbed to the extent that commonly happens as a consequence of tillage, overgrazing, sheet erosion, and soil creep. These disturbances are usually limited to the upper layers of the soil profile. The effects of prior operations may entail compaction of the surface layers from the weight of heavy farm equipment moving over them and from the trampling of livestock. It is assumed that the lower levels of the soil profiles have not been greatly disturbed.

Two things stand out in the description of the installation of the receiving beds for the effluent. One is the effect of constructing 8-foot trenches throughout the area to facilitate the surface layers of the soil by heavy equipment in digging the trenches, delivering the tile, and constructing the spray system.

The trenching for drains and for the delivery pipes to the spray system will seriously destroy the natural soil profiles and profoundly affect the porosity and permeability of the soil returned to the trench. The water will percolate much more rapidly than through adjacent soils and the filtering job will, in some instances, depending on the nature of the soil, be rendered incomplete. Since the movement of water in the filter beds must be assumed to be downward with very little lateral transfer, the recovered filtrate will have passed through the disturbed soil of the trenches and not through the natural soil profile, According to Ayers, in the absence of a water table very little of that going through the natural soil profile will find its way to the drains (Exhibit 15). Instead, it may at length find its way to the aquifers. This raises serious questions as to the completeness of the sewage treatment for it threatens the nutrient enrichment of the aquifers and the buildup of their salt content. If no more of the nitrates and chlorides are removed than is contemplated in the Muskegan 1971 report, over the long term in our areas the enrichment of the storage aquifers would present a serious threat. Because of their high nitrogen content, the waters would be rendered unsafe for prolonged human use. The chlorides will increase the salt content. The rate of groundwater contamination will in part depend on how much of these substances have been removed by prior treatment.

The compaction of the soil is another problem with equally serious consequences. A perusal of the agricultural journals of the past few years reveals that "compaction" is the current watchword in the soil management of farms. Farmers are being warned

about the impact of their increasingly heavy farm machinery on the upper three feet of the soil profile. This is the main area of root growth and the area through which the irrigation water must penetrate to become available to the crops. There is growing evidence that compaction impedes root growth and impairs the productivity of the crop. Furthermore, it lessens the percolation capacity of the soil and hence occasions early saturation and much water loss by runoff. Little, Lull & Remson (1959) report that the spraying of 2 inches a day on compacted cultivated fields resulted in saturation and surface runoff, whereas in undisturbed forest soils as much as 150 inches were applied over a 10-day period without noticeable saturation. It should be clear that compacted soils are readily saturated. If the soil is to constitute a filter for effluent, the reduction of its porosity in the upper levels by compaction may demand revised estimates of the speed of the operation and the capacity of the bed to accomplish the task.

Trenching will eliminate any natural vegetation on the surface above and that of adjacent areas may become so damaged by trampling as to initiate lower stages in the ecological succession. However, it may even be a stimulus to crop plants because of the ease with which the roots can penetrate the soil in the trench.

In the constructions of the spray rigs similar problems arise. The conduits of the effluent will probably be buried in trenches. There will be mobile equipment to deliver the supplies to the site. If a track is required to support the spray rig additional disturbance of the soils will occur.

Finally, it would be difficult to discriminate between ecological impacts resulting from the effluent disposal per se from those resulting from the complications in the environment introduced in the construction of the facilities of the site.

E. IMPACT OF SEWAGE DISPOSAL OPERATIONS

In contemplating the ecological and aesthetic impacts of the sewage disposal operation, the spray operation and disposal of the sludge must be considered separately.

1. Spraying of the effluent

Two aspects of the operation are significant, namely, a. amount of water supplied; and b. duration of this cycle of its application.

In considering the total amount of water to be sent to each disposal site, the figure of 8 acre-feet a year has been used. Translated to weather bureau figures this is 96 inches or slightly less than the heaviest annual rainfall recorded in California, namely at Monumental, Del Norte County where it reaches 122 inches

per year. When we consider that in the Del Norte area this rain comes largely in the months - October through May - with a long dry season between, whereas on the disposal sites the water will be cut off during the rainy season, the sites will never be free from the addition of liquid. In other words, the total amount received will be 8-acre-feet plus much of the annual rainfall and, what is very important,it will lack seasonality in its dispersal. Indeed, if one looks over the rainfall records of most every place in California it will be discovered that one can add anywhere from one to two months to the time in which effective spraying can be applied because of minor droughts local in time.

Two potential stresses stand out in attempting to assess the impacts on the ecology: (1) that the soil in the upper layers will be always wet and (2) the surface layers will have to be carefully managed by intermittent spraying and drying to prevent anaerobic conditions in the soil mantle and deterioration of the soil as a medium for root growth. The response of the vegetation to such a water regime, entirely apart from any fertilizer effect, will be a consequence of prolonged optimum moisture conditions for growth; those plants that can tolerate it can be expected to attain abnormally large size. This is the same effect that one sees in the native plants when one moves northward from central California. The red alder has leaves that are progressively larger as one goes northward. By the time we reach Southeastern Alaska, leaf size is enormous. The same holds for the big-leaf maple and many other plants. We can expect any annual plants on the disposal sites to become very large. Add now any fertilizers in the sprayed effluent and the problem is compounded. We can expect any native vegetation to which we apply such amounts of enriched water to undergo a selective response: those able to survive will grow luxuriantly; the rest will succumb. Perennial species will probably come to dominate over drought-adaptive annuals.

This rapid growth is not serious in terms of the objectives of the project, for the increased metabolism of these plants in attaining this size will enhance their value in any <u>living filter</u> operation that might be expected of them. However, annual plants of short duration are to be avoided because of their very short life.

What we say of the native plants holds also for crop plants that we might grow. We can expect gigantism in size and commensurate increase in total biological activity. (Exhibit 4)

Furthermore, there will be site selection of what we can grow and what will not effectively survive. The agriculturist might have data on this but presumeably because of local conditions the most reliable approach is through trial and error. Since alfalfa grows in a wide range of climatic conditions in the United States and does very well in the high rainfall areas of the Pacific

Northwest, we can anticipate that it would be a prime contender for a position in first trials. Various types of clover for hay might also be expected to grow. Some, like red top, are descendants from moist-land, wild ancestors.

The continued wetness of the surface layers of soil cannot be accepted as the working condition of the operation. This is because the rapid increase of soil organisms in the top layers tends to plug the soil and cut down on its permeability and allow the build up of anaerobic conditions, with an attendant growth of blue green algae and certain mosses on the surface. The soil surface must periodically be permitted to drain and the air spaces be permitted to fill with air. This is not only important to the living filter of the soil, it is also necessary for adequate root growth for the living filter of higher plants in the above ground flora. It may well help to control deliterious fungi and other plant pathogens favored by the high moisture level. What this timing interval shall be will depend on the nature of the soil and should result from trial and error. Tillage can correct this problems should their soils become clogged but it would take a prolonged period of sun drying to correct the situation on any wild land type.

Ayers raises serious problems about the amount of water dispensed in terms of percolation capacity, saturation, and consequent runoff and indicates that these matters must be carefully controlled. (Exhibit 15) Furthermore, in some of these areas there is now ample irrigation water that is very cheap and there may be some problem in inducing irrigation districts to use it. However, where the quality of the reclaimed water will exceed that in the natural aquifers, there ought be no problem. These are problems in human and agricultural ecology.

A good review of water tolerant plants both native and crop plants is presented by Dr. Longhurst (Exhibit 4).

2. Ecological impact of the spray liquor

The spray structure, dependent as it is on the hydrostatic head, the character of the spray, and the distance covered, has its own impact on the environment. Potential aerosol effects that increase the amount of fine droplets in the atmosphere will operate to increase the humidity of the site and its adjacent area. Of primary concern is any bacterial or viralcontent trapped in the droplets of the aerosol as pointed out by Professor Knight in Exhibit 7. He discusses the viruses carried in wastewater and states that much speculation exists as to the adequacy of water treatment processes and the coliform tests as a measure of sanitary quality. The treatment of water to control enteric bacteria is not sufficient for the control of viruses which

transmit a significant health hazzard to soil treatment beds receiving this water.

At the Muskegan project (Muskegan Report 1971) it is hoped to control aerosol effects by increasing the droplet size so that they will not go into suspension in the air. A high wind, however, may reek havoc with the best laid plans to produce aerosol spray. The Muskegan group proposes not spraying during high wind. This, it seems, would impose a difficult control regime that is bound at times to get out of hand. Air-induced infection need only happen once. Caution is the watchword in the aerosol problem.

Another effect of the spray on the environment is to increase the humidity. On a hot summer day the cooling effect might be welcome to the nearby human population. However, during periods when Tule fog builds up, the relative number of foggy days might increasingly interfere with both highway and air traffic. The probability is high that this would happen but it needs evaluation by a local climatologist. This could be serious.

Increase in relative humidity in late spring and early summer will tend to increase the amount of mildew and other fungi causing disease in crops. Grapes are especially susceptable to mildew and in the Sonoma and San Benito Areas could be the source of much trouble. The current (1971) late, humid spring in the Bay area witnessed an enormous increase in the occurrence of mildew and rust on roses. The magnitude of the increase in the humidity and of its extension in time is much less than that expected from evaporation from the spray of the disposal sites. This again may greatly reduce the yield of grapes and other fruits and grains subject to fungus diseases.

The maintenance of the "living filter" will be aggravated if the flow of water from the spray saturates the soil and causes run off. The spray must be carefully aligned to the capacity of the soil to absorb it.

There is no doubt that the carrying capacity of the site will be increased by properly applied water for all plants and animals that can survive the high moisture regime. This applies both to wild and crop plants. There is however a distinct danger if too much or improperly applied water. Professor Burgy (Exhibit 11) briefly points out that microclimatic and macroclimatic changes may be expected for long distances downwind from the disposal site.

3. Spreading the sludge

Since the sludge is to be pumped to the disposal site it will, presumeably, be placed on the soil while still wet. It may be piled up or spread over the soil. If it is piled and allowed to rot, the concentration of decomposition products leaching into the soils will sterilize these soils for a long time to come. A preferred alternative is to spread the sludge thinly on the soil and

disk it under and lease the disked land for crop production. It would require a series of such fields to accomodate a cycle of sludge applications. The sludge as treated is not overly rich in nutrients but it has significant amounts. It would be efficacious as a soil conditioner. Such a disposal operation would not only dispose of the sludge in an effective way but it would, without damaging the soils, produce an income to help defray expenses.

There is no question but that the judicious application of sludge will increase the carrying capacity of the soil both for crops and wildlife.

However, Dr. Longhurst questions the advisability of employing the sludge in agriculture since it is so variable and presently contains large residues of pesticides which would build up in the soils. (Exhibit 4) In the current thinking on pesticides, the move is definitely toward biodegradable pesticides and in 10 to 20 years they may present no long-term problems in the soils.

David R. Storm reports that even with deep cultivation there is a finite limit in soils for the assimilation of sludge because of its chemical composition (Exhibit 2). This would suggest that it may be necessary to think in terms of changing to new locations for sludge disposal from time to time.

4. Effects on soils

a Salt accumulation.

(McGauhey, 1968) has pointed out that human cultures dependent upon irrigation in their agriculture have never survived, because of the deliterious build-up of salts and alkali in their soils.

It is expected that application of wastewater to soils will result in a limited build-up of salts. This will affect the quality of the soil, since excess sodium may damage soil structure as colloidal aggregates become de-aggregated, resulting in the clogging of soil pore spaces and a reduction in permeability to water and air (Exhibit 7). As previously pointed out (Section C-4), the exchangeable cations influence the soil permeability; most importantly, the permeability becomes exceedingly low when the exchangeable sodium exceeds about 15% of the total cations in the exchange complex of the soil (Exhibit 6).

The exchange complex of the soil comprises a store of cations which can be released in exchange for an equivalent amount of cations from the permeating solution. Since the total ionic equivalents remain approximately constant, any exchanges of ions of different species between solution and adsorbed phase will affect the relative proportions of the various ions in the adsorption complex. Thus, the adsorbed phase can trap and hold ions from the solution, but only in exchange for less well held ions already there. Since the adsorption capacity is finite

(in the order of 20 milliequivalents of cations per 100 grams of solid), the ability to trap ions from the solution is limited (Exhibit 6). Furthermore, if divalent ions are replaced by sodium (or any other of the monovalent cations, including ammonium), the permeability will be impaired by de-aggregation of the clay colloids. No convenient way of regenerating the ion exchange "column" exists for soils in the field, comparable to the recharging of the ion exchangers used commercially in water softening.

A typical soil contains exchangeable calcium equal to about 0.3 % of the total soil weight, and other cations in smaller percentages. Since an acre-foot of soil weighs about 3,500,000 pounds, the weights of exchangeable ions are considerable, but the trapping ability of the soil is far from inexhaustable, and difficult to reverse (Exhibit 6).

The composition of the exchange complex is sensitive to the composition of the leaching solutions, particularly when leaching is extensive and prolonged. The hazards of indiscriminate watering can be seen in the decline of agricultural economies in many countries in the past. The long-term effects of leaching with waters of controlled composition need to be examined extensively by a systematic research program. The monitoring of cations in the waters both entering and draining the soil processing facility should be made an essential part of any program of water spreading (Exhibit 6).

b Probable soil changes and probable ecological impact

Continuous spreading of water free from suspended solids affects agricultural soils primarily because of oxygen deficiency caused by the metabolism of higher plants and soil micro-organisms. It is well known that soil becomes anaerobic shortly after fields have been flooded, and remains so until after the fields have been drained (Exhibit 6). Most crops, including orchards, will not survive more than a few days under submergence owing to oxygen deficiency in the soil.

Oxygen deficiency has many indirect effects upon soils and plants. Among these effects are denitrification of the soil, loss of iron by reduction to the soluble ferrous state followed by leaching, and mobilization of reduced toxic elements (Exhibit 6). As noted in Section E-4-a above, one would expect a progressive decrease of permeability in the course of time.

Spreading wastewater containing 10% suspended sludge results in the surface accumulation of sludge on the soil, developing a "mat" which causes a great decrease of permeability in the surface layer. Since the rate of decomposition of stabilized sludges is slow, it is necessary to allow resting periods between spreading

cycles to permit decompositions and restructuring of the surface to occur (Exhibit 6).

5. Potentials for salt escape into the aquifers

In order to be effective, the applied wastewater must percolate through the soil to be collected by the under drains for reuse. In many areas, it appears possible that the soil flow may join the natural groundwater and never reach the under drains (Exhibit 7). The potential risk of groundwater contamination appears to be a very real and important consideration.

The surface soils in this area vary from relatively porous sandy loams to the tight adobe clays. The closer one goes to the middle of the valley, the flatter the slope and the less pervious the subsoils. It is not uncommon for sub-surface drainage waters to contain 3 to 10 times as much total soluble salts as the applied wastewater, due to the salt-concentrating effects of evaporation and transpiration (Exhibit 7). Whether this salt-concentrating effect becomes a problem will depend primarily on salt content and composition of the original wastewater , but also upon the soil and vegetation types, and the management procedures employed in spreading. The concentration of certain ions must be given special consideration in evaluating the impact of sewage disposal on land; for example, excess sodium, chloride, and boron can each exert specific adverse effects on plants.

6. Condition and disposal of the filtrate

(a) Filtrate quality and quantity; seasonal changes

McGauhey and Krone (1967) review data covering the changes of water quality resulting from treatment by managed soil systems. Assuming no evaporative or transpirational losses, most equilibrated soil systems show no effect on the concentrations of calcium, magnesium, sodium and chloride ions. In a system actively decomposing residual organic matter the concentrations of sulfate, bicarbonate, and nitrate ions are likely to rise in the drainage water owing to their release from organic compounds and/or oxidation in the soil mantle. Under anaerobic conditions, however, the sulfate and nitrogen components may be reduced (or only partially oxidized) to gaseous forms (N_2 and N_2O; H_2S) and escape to the soil atmosphere and hence to the overlying air. In a similarly variable fashion and depending upon seasonal management practices, the original high ammonium content of a sewage may first be adsorbed as the reduced cation and then oxidized to motile gases or to anions (nitrates and nitrites) which move with the drainage water.

Some soils initially adsorb phosphate effectively in the surface zone, but the capacity to hold phosphate seems limited and can easily be exceeded in a continuing operation. Some

data indicate that soils will decrease the relative potassium concentration, possibly by fulfilling the needs of the vegetation for this essential nutrient; however, the fate of this ion is probably primarily under the control of cation exchange equilibria and consequently largely dependent upon the relative amounts of cations in the applied water and the exchange characteristics of the soil in question. The soil mantle has a well-demonstrated capacity for removal and degradation of linear alkyl-sulfonates and other organic compounds likely to be of concern in municiped waste waters. It should be remembered, however, that "hard pesticides" resist degradation in the mantle and may remain for long periods.

Depending upon evaporative and transpirational losses from the soil system, the concentration of total dissolved substances in an equilibrated drainage may be several times that of the applied water. This reduction of quantity and concommittant increase in concentration of the major dissolved ionic substances by the soil treatment system must be considered one of the primary characteristics of any soil treatment scheme.

Thus, the filtrate would generally be expected to be of higher total dissolved inorganic content than the applied water; it would have relatively higher concentrations of sulfate, bicarbonate, and nitrate, lower concentrations of organic matter, potassium, and ammonium, and about the same relative concentrations of calcium, magnesium, sodium and chloride ions (and possibly phosphate). It should be stressed that these generalities are subject to significant modification with variations in soil system type, water composition and loading rate, and the seasonal management practices. The retention characteristics for heavy metals by soil systems are not well known, but from broad chemical considerations aerobic conditions would be most likely to precipitate these metals in humic complexes or as insoluble oxides and hydroxides.

(b) Effects of the filtrate on beneficial uses of the receiving water: ecological and aesthetic effects

The filtrate may proceed to groundwater; it may be collected for specific agricultural, aquacultural or wildlife management purposes; or it may be discharged directly into a receiving water.

The ecological and aesthetic impacts of filtrate loss to groundwater will depend primarily on the subsequent fate or use of the ground water and will be treated in later paragraphs. Augmentation of ground water salinity and nitrate concentrations appear to be the major concerns in the arid-agricultural West.

If special provision is made for agricultural use of the drainage water, care should be exercised in the selection of salt tolerant plants which can grow at high nutrient levels. Generally, field and vegetable crops show damage above certain well-documented salinity limits, and may have specific ion

tolerances which might be exceeded (Exhibit 4, table 4). The aquacultural use of the drainage water to support managed wildfowl feeding marshes must still contend with problems of high salinity discharge to receiving waters.

Direct discharge of the drainage to receiving waters may have a variety of ecological consequences. Because nitrogen (and phosphorus) are often limiting to the growth of aquatic producers, enriched waters can increase fish production by increasing the growth of algae and other food organisms; however, algal production can also develop into nuisance growths and, if excessive, may result in fish kills due to oxygen depletion caused by algal decomposition (Exhibit 7). The probability is high that significant concentrations of nutrients would occur in the drain water from the proposed wastewater land disposal project (Exhibit 7 & 10).

Damage by salts in the water may result if the drain water enters surface waters. This damage is a function of salt concentration. For example, concentrations somewhat less than 1000 ppm may have little or no effect on fish and wildlife and practically none on recreation (Exhibit 7). Even if the salt content of drain water were somewhat increased (to 3000ppm) it would be unlikely to affect wildlife and it is potentially useable for most purposes; however, water reaching 3000 ppm may cause salt poisoning to young pheasant chicks (Exhibit 7). Drain water containing 3000 to 10,000 ppm of salt may be unpalatable to most upland game species.

7. Chlorination

Recent extensive and continuing studies by Professor David T. Mason[1] and others at the Sanitary Engineering Research Laboratory of the University of California (Richmond), and in the field near the San Leandro outfall, have shown that chlorination of both primary and secondary effluents produces a water much more toxic to fish, to the attached benthic community, and to the phytoplankton community than unchlorinated effluent. Subsequent de-chlorination to chlorine-residual levels of less than 1 ppm reduces this toxicity to approximately the level of the unchlorinated effluent again; however, dechlorination seems to be an effective detoxicant for phytoplankton only at low sewage concentrations in receiving water. Thus the effectiveness of dechlorination of a treated sewage for sprinkling purposes is still clearly in question.

1) Information in this section is based on unpublished material provided by Dr. David Mason.

The metabolic responses of the active soil saprobe populations would probably be as sensitive to residual chlorine as the photosynthetic community of receiving waters. Consequently, a careful study of the levels of acceptable chlorine residual for adequate saprobe populations in the soil mantle ought to be conducted for effective management purposes.

8. Insect control

The presence of ponds and lagoons with open water presents habitats for the propagation of noxious insects especially midges, gnats, and mosquitos with the former especially troublesome in sewage disposal reservoirs. These problems and suggested counter measures for their abatement have been very effectively handled by Professor Anderson who finds that most of them can be abated by stocking the ponds with particular fishes for the particular problems (Exhibit 10). At length if the infection should become too serious insecticides can be employed. The fish, however, are recommended because they constitute a biological control and leave no disturbing residue.

Insects with soil-dwelling larvae might be favored by the high-moisture regime. The sprinkled areas might easily become loci for the dissemination and agriculturally dangerous insects. A careful entomological monitoring program should accompany any disposal plan of operation.

F. Problems raised by the disposal operation

In addition to those problems arising out of the ecological impacts of wastewater disposal as indicated above under these various subjects, there are certain problems that are either definitely not resolved or, to our limited understanding of them, they seem not to be resolved. They are so important that we think they should be isolated from their prior context purely for emphasis. These are as follows:

1. Potential for the escape of salts to the aquifers

McGauhey (1968) points to a prevalent philosophy that cultures dependent upon irrigation in their agriculture never survive because of the build up of salts and alkali in the soils to ruin them. He further states that we now have learned much about handling our soils only to be faced with the prospects of the ruination of our water supply by the salination of the aquifers.

In an arid region such as California this can be very significant and demands that every step possible be taken to insure against lowering the water quality of the aquifers. Already there are several cases reported that indicate encroachment of brine into the aquifers due to depletion of their fresh water by excessive pumping.

Two points stand out. First, everything that can possibly be done should be done to prevent the accumulation of salts in the aquifers from sewage disposal sources. Second, everything should be done that can possibly be done to replenish the aquifers with good water of such quality that it presents no problem to human use.

2. Disinfecting the sewage and soil layers

The problem of disinfecting the sewage and adding disinfectants to the soil especially by chlorination is apt to be especially hazardous to fish in reservoirs where the fish are serving for the control of insects (section E 7).

3. Chemical poisoning hazards

Nitrate poisoning of both cattle and humans is a distinct possibility. With humans it is apt to arise from persistent use of a water supply that has high initial concentrations. With live stock it may come as a consequence of eating plants grown on soils with high nitrate levels. This behoves us to use especial care not to pollute the aquifers with high nitrate levels and to look with suspicion on proposals to permit grazing on lands treated with effluent.

4. Harboring and development of disease agents

Another problem that should be emphasized is that of the potential development of epidemics, epizootics, and plant infestations caused by the build-up of extensive populations of pests and vectors at the disposal site. This subject is discussed in part by Anderson and Knight who describe examples of some probable diseases and their carriers (Exhibits 7 and 10). In addition, it is pointed out that large numbers of mosquitoes and other noxious arthropods interfere with outdoor vocational activities and limited recreational activities such as camping, boating, and fishing. It is anticipated that these problems would increase as additional lands are placed under land disposal of wastewater.

5. Enormous water loss in the disposal operation

Attention should again be called to the enormous water loss anticipated in the sewage disposal operation. Sooner or later this will be significant and we think it important that some thought be given to it now so that the designs of the plant can accommodate any later additions of such a reclamation operation. This water is sorely needed to replenish aquifers now if not for the immediate uses of irrigation.

G. ALTERNATIVE AND ADDITIONAL CONSIDERATIONS

1. Desalination of effluent

The problem of wastewater disposal in Central California is acute. The magnitude of the volume of the effluent available and the cash value of its water content are staggering to contemplate for anyone aware of the needs for water for domestic use, for industry, and for agriculture in the San Francisco Bay area. One is shocked to realize that at least half of this water will be lost in the disposal operation. It is estimated that the volume of effluent available for disposal in the Bay-Area counties and Sacramento and San Joaquin counties will reach nearly 2.5 million acre-feet by the year 2020. This is probably one-sixth of the total storage capacity of all reservoirs in California including Lake Tahoe that are over 5,000 acre-feet capacity (Straus, 1952). The current methods of effluent disposal are inadequate for the reclamation of more than a small part of the water and this both at high cost and not without serious doubt as to its long term deleterious effects upon agricultural soils, ground water, and humans who might be forced to use it constantly.

In the first place it is estimated that at least 50% of the treated water will be lost to the atmosphere by evaporation. The result will be at least a doubling of the concentration of the dissolved substances in what is left. Essentially, pure distilled water will be lost to the atmosphere at the rate of 1.25 million acre-feet per year. The doubling of the load of dissolved content of the remaining effluent greatly increases the salvage problem. At the current highly subsidized cost of irrigation water of 35 dollars an acre-foot this represents a value equivalent to 87.5 million dollars a year involved in water in the sewage effluent of which 45 million dollars will be lost from evaporation alone. What is even more disturbing is that it is a loss of a natural resource of which we are in increasingly short supply. When one considers the cost of the subsidy on irrigation water this figure might run much higher. Probably the cost would be closer to 50 dollars per acre-foot. When one considers the large government subsidy of irrigation systems, no irrigation water may be said to be cheap.

There are also values inherent in the dissolved content of the effluent and in the solid wastes that we shall speak of as their stored energy which can be and should be recycled. The effluent is rich in nitrates and phosphates which are the common components of commercial fertilizers. The sludge contains energy that could be diverted to useful microbial syntheses, or

released as heat if the sludge were dried and incinerated (section G 3). The values of nitrogen, potassium and phosphorus in the wastewater run as high as 18 dollars per acre-foot.

Values of this magnitude demand that some thought be given to their reclamation and recycling. There are at least four sets of values that would accrue if we can accomplish this salvage. First, there is the sanitary disposal of the sewage which is what this project is all about and which can be set at a value of whatever it will cost to accomplish. Secondly, there is the reclaimed water whose value may be placed at the prevailing unsubsidized market value per acre-foot. Thirdly, there is the organic energy which will have a prevailing market value in the chemical industry and as fuel, possibly to be used in the reclamation operation itself. Fourthly, an overall gain to be credited to the salvage operation is the reclamation of the sewage polluted habitats of the area to a healthy ecological condition. Most thinking citizens would gladly share in the cost of accomplishing this reclamation. These values accruing to the people and to be credited to the sewage disposal operation thatundertakes them, enormously broaden parameters of the economic base within which the salvage operation may be studied and hopefully implemented.

Within such a broad economic base the desalination of the effluent might be considered since the costs are not all to be charged to the water reclaimed. Unlike the desalination of sea water the disposal of the raw material, namely the sewage, accrues as a value received in addition to the water. Futhermore, the recycled energy and the salvaged habitats will reduce the cost of the water significantly below that derived from the usual desalination plant.

Over and above the values mentioned there are other advantages of desalination over conventional methods of disposal, namely:

a. the danger of pollution of oceans, estuaries, rivers, aquifers, soils, and air from sewage is eliminated;

b. the speed of eutrophication of affected receiving waters will be greatly reduced, if not stopped or reversed;

c. the danger of building up the salt content and consequently alkalinization of the treated soil is eliminated;

d. the residues of such insecticides, herbicides, and toxic substances not destroyed in the operation can be recovered in the final brine for proper disposal;

e. no elaborate distribution system for the effluent needs to be built;

f. no extensive acreages for land disposal of effluent and sludge will be needed;

g. probably there will be little effect of the operation on the climate;

h. there will be no seasonal constraints on the operation; and

i. the recovered water can go anywhere in the water system without further treatment.

There are several desalination devices now available and others no doubt are on the drawing boards.* Once such devices are placed in operation on a sufficient scale it is to be expected that improvements in design will be developed rapidly and the whole concept of desalination receive the recognition that it merits.

2. Reclamation of the agricultural potential of the Delta Islands of the Sacramento and San Joaquin Rivers

The islands of the Delta at the confluence of the Sacramento and San Joaquin rivers have long been diked and their rich lands " "reclaimed" for agricultural use. Their peat soils are among the most highly productive soils in the United States. Together they approximate about 300,000 acres capable of producing a great diversity of crops.

Being largely organic in composition and occurring in a region of high summer temperatures and with the aid of soil organisms the soils of these islands have been subject to loss by attrition through the oxidation of their organic content. The attrition has been at the rate of about 2 inches of soil a year. Hence, the soil profile has been cut down by this amount by loss at the top. The net result is that not only is the agricultural surface of these islands now below sea level but what was orginally a deposit of about 60 feet of peat has been so reduced as to leave only a relatively few feet with which to face the future. These few feet are underlain by brine presumed to be a remnant of the original Pliocene and early Pleistocene Sea that once occupied the Central Valley. Thus, these peats

* Energy demand for the desalination process could be used to level the power demand curve, thereby decreasing the impact of such a development upon civilization's power needs.

began their history under saltmarsh conditions which shifted to freshwater conditions as the melt of the glaciers in the Sierra Nevada brought in glacial silt to fill in the seas and fresh water to insure the continuity of land building by the marsh. It is estimated that the close of the Pleistocene was 10,000 years ago and that the duration of the Pleistocene was about a million years. It follows that it took Nature anywhere from 10,000 to a million years to build up this valuable natural soil resource, and it took Man only about a 100 years to accomplish its near destruction.

At the present time the thinness of the remaining peat presents such a bleak future to its agricultural potential that when dikes break it no longer is economically feasible to go to the expense of rebuilding them and returning the soil to usefulness. A case in point is what is known as "Franks Tract" a former delta island in the San Joaquin river just above the Antioch bridge. The dikes collapsed during a flood and the land was flooded. The surface of the peat had been carried well below the level of the river by oxidation. When confronted with the cost of rebuilding the dike and the potential duration of the remaining peat it was decided to accept the loss of the agricultural resource.

Professor Constance Delwiche (Exhibit 8) in an outline of a proposed feasibility study at reversing this operation of attrition of the Delta Islands and reclaiming their agricultural potential to the people of California, has presented a novel scheme for correcting this deplorable agricultural situation by providing a synthetic continuity to the formation of peat soils. He notes that common garbage when cleaned of its non-degradable content includes as an organic component residues similar to those which entered into the compostion of peat soils. He also calls attention to the fact that large quantities of domestic wastes are generated each day in the urban areas and in agricultural industries which present difficult disposal problems. Such wastes are accumulated at the rate of 0.3 of a cubic foot per person per day. He further states that these wastes can be stabilized and that this will reduce the gross volume and weight by about two thirds. He would raise the present dikes and fill the resulting basin to the top of the dike and cover it with about 4 feet of peat to be taken from the bottom before the fill was added. He points out that because the area is only very slightly above sea level there would be sufficient hydrostatic head for the delivery of any of the contained mineral elements into the aquifers. Besides the waters below the peat is already high in salts.

Delwiche thinks that there is a fifty-year potential disposal site for solid waste for the Central California area. At least it

would take that long to cover the entire 300,000 acres. By that time the first island to be treated may be reduced sufficiently by attrition to warrant beginning another refill cycle.

In such an operation it might be that sludge could be combined with solid wastes and provide the answer to pressing disposal needs namely, sludge and garbage disposals. Delwiche warns that sooner or later reclamation of solid wastes at the source will prove profitable and we will then not have this volume of material for this special use. It behooves us then to get under way while we have the material to work with. The land being treated could presumably be returned to productive use as soon as it is covered. The solid wastes could be cleaned, shreaded, and stabilized at the place of origin. They could then be placed in a slurry and pumped to the Delta Area.

It is our considered judgment that this is an important workable idea worthy of very serious attention and we recommend its examination for implementation in the sewage disposal project.

3. Sludge incineration

a. Characteristice of sludge

The composition of sewage sludges varies depending on the method of treatment of the sewage. Primary sludges are higher in caloric value than biological sludges because of their high grease content. Undigested solids will have a larger heat content than the solids remaining after digestion treatment of sewage solids. Average characteristics of sewage solids are summarized in Exhibit 1, table 16.

When disposing of sludge by incineration, different types of sludges such as primary, secondary, and digested sludge may be involved.

b. Heat value of sewage sludge

The combustible elements of sewage sludge are carbon, hydrogen, and sulfur. These elements are chemically combined in the organic sludge as grease, carbohydrates, and protein. These combustible portions of sewage sludge have a BTU content about equal to that of lignite coal, (4,000-5,000 BTU/lb). The composition of elements in sewage sludge varies from plant to plant as shown in Exhibit 1, table 17.

c. Air pollution standards and control

Incineration offers the opportunity to reduce sludge to a sterile inorganic land-fill and remove offensive odors, but the resulting particulate matter can be a significant contributor to the air pollution problem in an urban community. The quantity and size of particulate emission leaving the furnace of an incinerator varies widely, depending on such factors as the kind of sludge being fired, operating procedures, and completness of combustion.

Complete combustion to produce the principal end products of CO_2, H_2O, and SO_2 is costly, but too much of SO_2 emission is not permissible due to its toxic and corrosive nature. Incomplete combustion can be disastrous because the intermediate products formed, such as hydrocarbons and carbon monoxide, are more objectionable. Smoke and gases contribute to overall air pollution through reduction in visibility and through their ability to enter into smog-forming photochemical reactions in the air.

The emission standards for particulate matter adopted in California limit emissions to 0.10 - 0.20 grains per standard cubic foot at 50% excess air (0.22 - 0.44 lb. of dust per million BTU fired) for incinerator capacities of 200 lb. per hour and larger.

Most incinerator manufacturers advertise to limit the particulate matter to 0.20 to 0.28 lb. per 1000 lb. of stock gas at 50% excess air. However, in the event of increased air pollution standards, electrostatic precipitation or high efficiency scrubbing may be required.

Particulate matter can be effectively controlled by centrifugal dust collectors or wet scrubbers. Centrifugal collectors remove 75 to 80% fo the particles and are suitable for exhaust gas temperatures of 650 - 750°F.

In general, the nature of the emitted particulate matter from sludge incinerators does not lend itself to centrifugal collection and most systems utilize wet scrubbers of a variety of types including venturi, baffle plate, packed tower, and inpingement models. These scrubbers have the added advantage of absorbing significant amounts of gases including sulphur oxides and odorous organics.

d. Disposal of refuse with sewage sludge

A number of municipalities are reaching the capacity of their land fill areas to receive their refuse. The value of land surrounding municipalities is increasing at a rapid rate for residential and industrial development making new land areas very expensive and often unattainable. Furthermore, people are becoming sensitive to the often unattainable. Likewise, people are becoming sensitive to the existence of a dumping or landfill area in close proximity to the residential areas. These factors are giving impetus to the ever growing popularity of the mixed refuse incinerator for the incineration of sewage sludge and refuse.

Whenever the location of the sewage treatment plant will permit reasonable hauls, the installation of a mixed refuse incinerator at the sewage treatment plant site will permit disposal of the municipal garbage, refuse, and sewage sludge at the same plant site. Such an installation permits drying or incineration of the sewage sludge with no auxiliary fuel requirements due to the heat in the waste gases from the burning of the mixed refuse.

Heat for drying the sewage sludge filter cake is supplied by the mixed refuse incinerator and the flash dried sludge may be marketed as fertilizer or incinerated at will. The dual disposal of mixed

refuse and sewage sludge at the same plant site affects economics in both first cost and operating costs of the disposal equipment. For smaller communities, this system provides modern disposal facilities whereas the first cost or operational cost of the separate disposal facilities will be prohibitive.

The success of burning the sludge with refuse depends on the type of sludge, hauling cost for refuse, etc. However, in all cases, it is important to give consideration to combined use and sludge incineration. This system may be particularly useful in small cities where hauling costs could be reasonable. For larger cities, centrally located refuse collection and sewage treatment could make this system attractive.

4. Potential projects associated with sludge disposal or utilization

a. Sludge utilization in the production of single-cell protein for animal food.

(1) Introduction and background

Microbial or single-cell protein, such as is found in the tissue of microorganisms, has long been used in animal diets. Some of the more recent developments are as follows:

(a) In a study for NASA*, Louisiana State University is converting cellulose waste into high-protein food by fermentation with Cellulomonas and reported an edible end product containing more than 50% protein. In current studies at L.S.U.** chicks and mice are being fed high protein food produced from cellulose waste - including newspaper, computer print-out paper, and cellulose agricultural waste. The food is made in a pilot plant built and operated by L.S.U. personnel at the Mississippi Test Facility of NASA in Bay St. Louis, Mississippi. A mixed culture of the microorganisms Cellulomonas and Alcaligenes is used to prepare animal food of about 75 % protein from cellulose.

(b) British Petroleum will soon supply microbial protein for the Western European animal feed Market.*** By the end of 1971, this oil company plans to produce 20,000 metric tons of protein annually, using controlled fermentation of oil-derived hydrocarbons. The company reports having obtained a product containing 65 % proteins from a continuous process using a single fermenter.

Such products have to compete with established types of protein for the market, e.g., fish meal and soybean extract. British Petroleum believes that its single-cell protein has advantages over fish meal because of extended shelf life and because of the unsteady supply of fish meal. The Journal of Commerce lists the following prices for establishing proteins as of Feb. 2, 1970:

Fishmeal with 60 % protein	$195 per ton
Fishmeal with 65 % protein	200 per ton
Soybean meal	116 per ton

* "Technology", Chemical & Engineering News, Dec. 9, 1968, p.47
** " " " , Jan.18, 1971, p.31
*** "Protein from Oil to go Commercial", Chem. & Eng. News, Feb.2,1970,p.21

(2) Utilization of sludge

It is recommended that research be considered for the purpose of developing processes to use sludge for the production of single-cell protein for animal food.

Possible alternatives

(a) Grow yeast on both pasteurized and non-pasteurized sludge;

(b) Grow yeast on both pasteurized and non-pasteurized mixture of manure and sludge;

(c) Grow yeast on pasteurized and non-pasteurized mixture of cannery waste*, sludge and manure;

(d) Essential amino acid production using proper microorganisms, e.g., production of lysine, methionine, glutamic acid.

b. Thermal utilization from sludge incineration

Various potential projects include:

(1) Power production from thermal energy produced from sludge incineration

Thermal from sludge and garbage and refuse incineration**

(2) Experimentation on beneficial uses of thermal energy in aquaculture and mariculture, e.g., oysters and abalone for which there is a great demand

(3) Thermal energy used in salt production and thereby releasing present salt ponds for other uses

(4) Thermal energy used for increasing evaporation followed by condensation for water recycling from waste waters and sewage.

5. Extension and development of marshes for waterfowl

For the maintenance and development of waterfowl populations in the Bay-Delta Area, there is perhaps no greater single need than for water. Reclamation of agricultural lands from marshes, so needed as wildlife habitat, has progressed at an amazingly fast rate since the turn of the century. Both resident and migratory bird populations have declined. Recreational pursuits have suffered and the monetary loss in hunting license fees alone has been great. Agricultural losses due to the invasion of croplands by large bird populations formerly dependent upon marsh habitats continues to mount.

* Some preliminary studies with encouraging results on growth of yeast on irradiated cannery waste by Mr. W. B. Lane and Dr. J. D. Teresi have been done at SRI in cooperation with The National Canners Association.

** At the end of World War II, power plants utilizing coal and garbage plus refuse were used successfully in Germany. Sunset Scavenger Co. may be interested.

Surplus, treated waters reclaimed from sewage effluent can be used to develop marsh habitats for wildlife (Exhibit 12). There are numerous adequate sites for marsh formation along the Pacific Flyway of the Central Valley. Unproductive land in all six waste disposal Areas can be utilized for marsh development with long-range implications for developing climax situations possessing ecologically balanced relationships and stable patterns of growth and survival of wildlife populations needed for recreational pursuits.

But marsh plants can serve other practical purposes than simply relieving the waterfowl pressure on agricultural crops and providing much needed game for hunters. They constitute a "living filter" to deplete the effluent of phosphates, nitrates, and other plant nutrients. The marsh could serve as a holding pond for sewage effluent until degradation is completed and the water suitable for other uses. Seemingly, the inevitable salinity increase, if serious, could be overcome by treatment processes.

6. Use of disposal sites for silviculture

Professor Stone presents an interesting possibility in the use of coast redwood trees as a "living filter" on soil disposal sites for conditioning of effluent (Exhibit 14). His work on the subject is backed by experimental evidence on the use of the redwood trees for this purpose. He reports a high growth rate with great adaptability to the site on the part of redwood where the water is applied intermittantly. He envisages a crop return in the form of logs and chips after 20 years of from 500 to 1,000 cubic feet of wood per acre per year. Selective logging could maintain forest continuity over the site. Since the coast redwood crown sprouts after harvest and because of its great longevity, only the initial planting would be required in the forseeable future. Trees on such a site would tend to keep the surface soil receptive to the quick acceptance of water. It would seem that a redwood forest would present an enormous surface to photosynthetic activity for the bio-degradation of effluent.

7. Other potential reuses of water

Uses of drain waters in addition to those discussed above are presented in Exhibits 5 and 7. These include such uses as maintenance of parks and golf courses, support of aquaculture of organisms of value to man, establishment of recreational lakes, watering of turf grasses, and for cooling water in nuclear power generators.

H. AESTHETIC IMPACT OF WASTE DISPOSAL

1. Structural components of aesthetic importance.

Natural landscape beauty as manifest in distant hillsides and winding valley floors with characteristic chaparral and grassland vegetation are at stake in the plans for this waste disposal project. The land sites for disposal vary widely in their physical character and visual absorption capacity (Exhibit 9). But they include dominant conservation features of the greatly reduced open space that remains in the San Francisco Bay Region. Eucalyptus windbreaks within attractive ranches with fencing patterns and grazing stock; or large rectilinear crop fields with scenic country lanes leading to large farmstead facilities; or little traveled highways passing within easy reach of charming village centers; or perhaps the disruption of cultural pattern by power pylons or by winding drainage systems of artificial composition; these and other components of the Central California landscape are drawn into sharper focus and recede in broad relief with the changing daylight hours. So variable are the agricultural patterns that, in important respects, the projected physical alterations of the extensive sites for land disposal purposes may not necessarily generate significant visual alterations of the existing agricultural landscape.

An expected change in vegetation character would represent an important impact on the existing site. Conceiveably, orchards and vineyards that attractively characterize many parts of the Hollister Valley, for example, may be replaced by less appealing crops such as alfalfa, sorghum, or soy beans. A change in crop types would appear to affect the Solano and Sacramento sites least since they are planted largely with raw and feed crops.

Site preparations, grading, tree planting, or silviculture in surrounding areas are expected to create considerable disturbance. The creation of lagoons and large holding ponds will tend to alter the present scenic beauties of the landscape but in important respects new and potentially attractive cultural scenes may evolve with their own particular contributions to the beauty of the landscape. The undesirable features of the sludge disposal operation would, in some locations, such as the Marin/Sonoma site, be most apparent from the ridges and slopes.

2. Design and siting criteria.

It is indicated in Exhibit 9 that the aesthetic quality of the six sites cannot be compared against a single ordinal standard. But the sites can be ranked and compared among each other in terms of discrete visual/aesthetic dimensions such as: richness of vegetation variety, degree of openness or evidence of spatial definition, vivid land form features, and pleasing cultural patterns.

Design and siting criteria include:

(a) unattractive disposal operations and facilities should be screened or sited so as to minimize visible impact from the primary observation areas;

(b) roadways, residential and commercial clusters, recreation areas, and vista points should be surveyed to determine the number of observers and frequency of use;

(c) routing of pirelines should insofar as possible conform to natural land contours;

(d) attractive and striking vegetational patterns that are characteristic of the natural landscape should be retained as organizing elements for siting and screening of disposal facilities and operations;

(e) disposal facilities and operations should be designed and constructed to minimize their visual impact;

(f) riparian patterns should not be blocked or removed by disposal operations;

(g) climatological data should be considered in determining the location and operation of waste treatment facilities to minimize undesirable humidity, odors, and hazards to public health (Exhibit 9).

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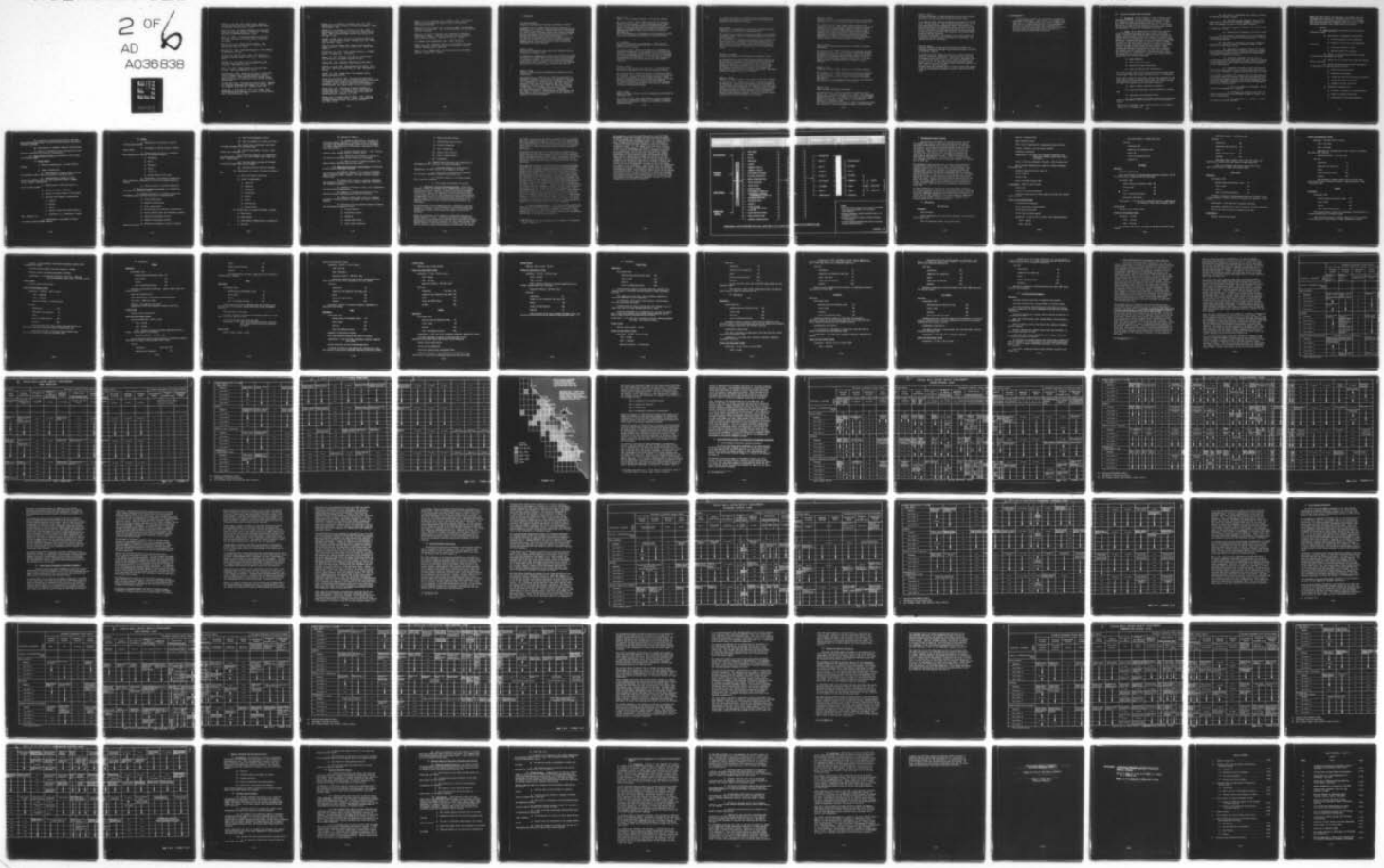

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C-3. SOCIAL WELL-BEING IMPACT ASSESSMENT

a. Definition. For the purposes of these analyses, Social Well-Being is defined to be the condition, existing and desired, of a designated study area and its population expressed in terms of criteria concerning the individual and group quality of life. This quality of life concerns those basic activities, institutions, and inter-relationships of man involved in the maintenance, growth, and development of society and the physical environment.

b. Scope. As an elaboration of the definition, the scope of the Social Well-Being Impact analyses attempts to identify, specify, categorize, and ultimately unify and correlate those individual and interrelated criteria and concepts that could be considered relevant to the equivocal, yet pervasive, concept of social well-being. A generalized scope of social well-being involves those factors of society which concern the physical, material, spatial, psychological, and institutional aspects of a dynamic areal infrastructure in terms of human values, behavior patterns, spatial development systems, and the interaction and evolution of such organizations reflected in governmental, educational, household, and community service organizations, utilities, and activities. For the purposes of classification in this investigation, Social Well-Being criteria to be derived, analyzed, and evaluated will be grouped under the following categories:

(1) Human Betterment

(2) Public Health and Safety

(3) Physical and Spatial Development

(4) Legal and Institutional Considerations

The criteria within each of these categories will be presented later in this report under the section entitled, Criteria to Be Analyzed.

Within each of these four categories, certain basic concepts for comparison and correlation permeate the analyses. The impact of alternative wastewater systems on the social well-being criteria derived will need to be analyzed from the following viewpoints:

(1) Urban, Suburban, and Rural environments

(2) Long term versus short term consequences of development

(3) Beneficial and detrimental effects

(4) The relationship of economic versus social well-being aspects of employment, income, and general growth and development factors.

(Pages C-93 to paragraph d. page C-100 are referred to as pages V-7 through V-16 in Attachment B.)

(5) The concept of determining Value Systems to analyze and evaluate development concepts.

(a) Individual and mass community values and the extent they are articulated in behavior patterns to indicate the degree of acceptance of control in the public interests.

(b) Attitude survey techniques, and investigations of changes in attitude.

(c) Identification of dominant and critical values.

(6) The concept of "economies of scale" for growth and development in relation to improving individual quality of life and overall human betterment.

(7) The concept of developing sociological standards from which to evaluate the impact of alternative plans on the derived social well-being criteria.

(a) Quantitative standards: "scientific" factors such as health and safety criteria, population densities, minimum required income and related factors established by professionals as standards for general well-being.

(b) Comparative standards: factors where no optimum values have been established, but where ranges or boundaries can be established for cross-comparison relating to factors such as education level, per capita income, level of selected employment, land use compatibility.

(c) Independent standards: factors involving the value system within specific areas and groups concerning open space, housing types, residential locations, and desirable public services.

Such a system of standards will primarily help in establishing sets of activities which will optimize stated goals and establish priorities within and among the various types of sociological criteria affected by associated developments in wastewater management systems. Within this framework of measured social criteria and established standards the following occurs:

1. The social impacts of development, whether beneficial or detrimental are analyzed.

2. The impacts are measured in the most definitive quantitative factors derivable in terms of resource conversion or expenditure.

3. The expenditures are compared to present and potential resources available.

Based upon these factors and comparisons, development plans and implementation procedures are determined which reflect the most desirable social well-being goals and objectives to be considered when evaluating wastewater management plans in relation to other Ecological, Economic, Public Health Impact evaluations.

c. Criteria.

(1) Human Betterment (as influenced by and related to alternative plans).

(a) Determination of employment opportunities.

1. Overall increases in job availability

2. Diversity of job choices and supporting activities

3. Long range stability of work

4. Mobility within job categories

(b) Effects on increased opportunities for goods and services for individuals and groups.

(c) Effects on the increased real income for persons, family, and groups.

(d) Factors influencing the equitable distribution of opportunities to deprived groups and areas.

1. Health care and facilities

2. Education and knowledge

3. Leisure time pursuits (including recreation)

4. Income and overall area wealth

5. Community services facilities

(e) Residential considerations.

1. Diversity of choices in location and type

2. Causes for imposed limitations

3. Displacement of existing communities

(f) Alleviation of personal deprivation of specified minority/disadvantaged groups in terms of directed economic and physical development programs.

(g) Determination of community viability considerations.

(h) Effects on increased cultural opportunities in arts awareness, historical and scientific preservations.

(2) Public Health and Safety (as influenced by and related to alternative plans).

(a) Public Health.

1. Physical considerations - see Public Health Analysis

2. Mental considerations

a. Identification of customs, moral attitudes and prejudices, ethnic factors and beliefs of groups and areas

b. Considerations of changes in social structure of dwelling units over time (traditional family, communal living, community reorganization)

c. Identification of needs and wants as a result of value systems

d. Phobias of people to disasters

e. Desires for overall amenity of environment

f. Individual and community considerations

1. Identity

2. Security

3. Dignity

4. Spatial, social and economic mobility

5. Livability, i.e., cleanliness, crowdedness, openness, etc.

g. Establishment of performance standards for privacy, noise abatement, amenity

(b) Safety.

1. Identification of hazardous conditions resulting from systems

2. Development of systems design to maximize public safety

3. Identification and control of hazardous areas susceptible to natural and man-made disasters

a. Earthquakes

b. Fires

c. Explosions

d. Floods

e. Landslides

f. Systems failures (utilities)

4. Establishment of performance standards for space utilization, orientation of internal and external design of systems

5. Security factors of location (dispersion)

(3) Physical and Spactial Development (as influenced by and related to alternative plans).

(a) Possible alternations in theoverall growth and development goals, objectives and plans of influenced areas.

1. State considerations

2. Regional considerations

3. Local considerations

4. Interest group and individual considerations

5. Overall land use plans and development concepts

6. Industrial development patterns

7. Commercial development patterns

8. Residential development patterns, including densities and types

9. Open space development patterns

10. Space requirements for system activities

11. Overall plans, development, and growth of systems throughout the influenced areas

12. Physical requirements (location, right-of-way, size, terminals, etc.

13. Integration capability and compatibility of various utility systems, i.e., water supply, power, waste disposal, transportation

14. Scale and spatial patterns and linkages of activity systems within the environment

15. Recycling potential within all systems

(b) Displacement as a result of growth and development.

1. Direct and indirect influences

2. Types of displacements

a. Industrial

b. Commercial

c. Residential

d. Recreational

e. Cultural

f. Utility

g. Institutional

h. Transportation

(c) Relationship to possible development programs.

1. Model Cities

2. Urban Renewal

3. Redevelopment, Rehabilitation, Conservation

4. New Towns

(d) Desires for amenity.

1. Aesthetic characteristics (placement of structural objects, location of circulation routes, relationship of natural and constructed features, preservation and development of vistas, visual experiences during motion, experiences of openness and enclosure)

2. Sensory perception (visual - color, texture, pattern, shape, rhythm; auditory; odorous; taste)

3. Convenience of facilities in relation to the laction of use areas and the intensity of development

4. Ease of access to recreation/leisure, community service facilities and open space areas.

(4) Legal and Institutional Considerations (as influenced by and related to altenative systems).

(a) Possible changes in the planning, development, and construction procedures, authorities, and structural relationships of national, state, regional, and local political or governmental units.

(b) Desire local autonomy in planning, development, and regulation of public utilities, housing, commercial, industrial, and recreation facilities.

(c) Political activities of labor, civic, professional and institutional organizations.

(d) Desires for "consumer participation" in the decision processes influencing public service activities.

(e) Effects of shifts from a local to a regional government concerning planning, development and control of utility systems.

(f) Existing factors and possible changes in planning and developmental regulatory control.

1. Zoning ordinances

2. Sub-Division control

3. Easements

4. Adopted master plans

5. Public safety ordinances

6. Design codes and criteria

7. Jurisdictional consideration

8. Political boundaries

9. Public acquisition

10. Density control factors

11. Power of eminent domain

12. Condemnation

(g) Changing fiscal conditions and capabilities of governmental units to initiate or sustain development.

1. Long range estimates of local revenues, expenditures, and debt structure of governmental entities

2. Public costs of alternative as reflected in tax rates, compensation payments, bond issues, etc.

3. Possible alteration in tax base of areas due to land use conversion

4. Cost-revenue relationships of land use

d. Constraints on Social Well-Being Analyses. Social Well-Being as a concept for analysis and as a measure with which to assess the impact of proposed regional or subregional wastewater management systems presents many conceptual as well as anlytical and procedural difficulties. However, the importance for such a definitive operational program with which to help assess and evaluate proposals should be emphasized in policy and planning procedures and should, therefore, receive a greater priority in the research and planning effort of agencies responsible for major physical and spatial changes in the environment.

As was discussed in the preceeding sections on definition, scope and criteria for analysis, Social Well-Being is a pervasive concept that attempts to correlate societies' physical, spatial and institutional factors and ultimately relate them to the quality of life of individuals.

Major data limitations and the absence of established operation procedures impede this effort. Unlike many biological and chemical processes that have been analyzed and formulated into established definitive and measurable environmental indicators, and also unlike the many established, accepted, or entrenched theories on economic activity, the concept of Social Well-Being is indefinite and controversial. The great

multitude of human values and needs represented within any localized area, when compounded by regional, state, and national aggregations for establishing public policies, presents a great challenge to those vested with the responsibility to help formulate plans affecting all these levels of social consciousness, human activity, and physical enhancement.

The present embryonic state of the social arts as evidenced by a general lack of established social well-being parameters, indicators, analytical procedures and standards with which to relate definitive policy and planning decisions, demonstrates the necessity for priority efforts in this area of concern if planning agencies are truly to relate and evaluate physical planning efforts in relation to Social Well-Being.

Other immediate constraints restricting the proper Social Well-Being assessment and evaluation of proposed wastewater management systems is the lack of a unified, legally operational policy and planning document which encompasses the twelve study area counties of the San Francisco Bay and Delta area. The lack of an operational overall growth and development plan of these closely related areas concerns not only physical and spatial planning, but social planning as well. The 1990 Region Plan of the Association of Bay Area Governments, the Detailed Plan of the Bay Conservation and Development Commission, the Sacramento Regional Area Planning Commission's Regional General Plan, the Master Plans of San Joaquin County together with other regional and county plans are very useful documents for relating Federal efforts in physical wastewater management planning. However, these documents are inadequate in major areas of concern such as definitive social improvement goals and policies for various population groups regarding major social concerns such as housing, poverty needs, community service, and the general equitable distribution of income, goods, and services - especially among the low income, minority, or disadvantaged groups. As a result, other Federal agencies' efforts in these areas of social concern will be needed to augment the efforts of the Corps of Engineers in seeking to establish the impact of Corps planning proposals on the Social Well-Being of the area's population.

e. Procedures for Analyses.* Within the preceding constraints, Feasibility Study procedures have been established for assessing and evaluating the impact of wastewater management alternatives on the social well-being of the population within the study area. (A major prerequisite for conducting a more detailed study will be the amelioration of many of the preceding constraints.)

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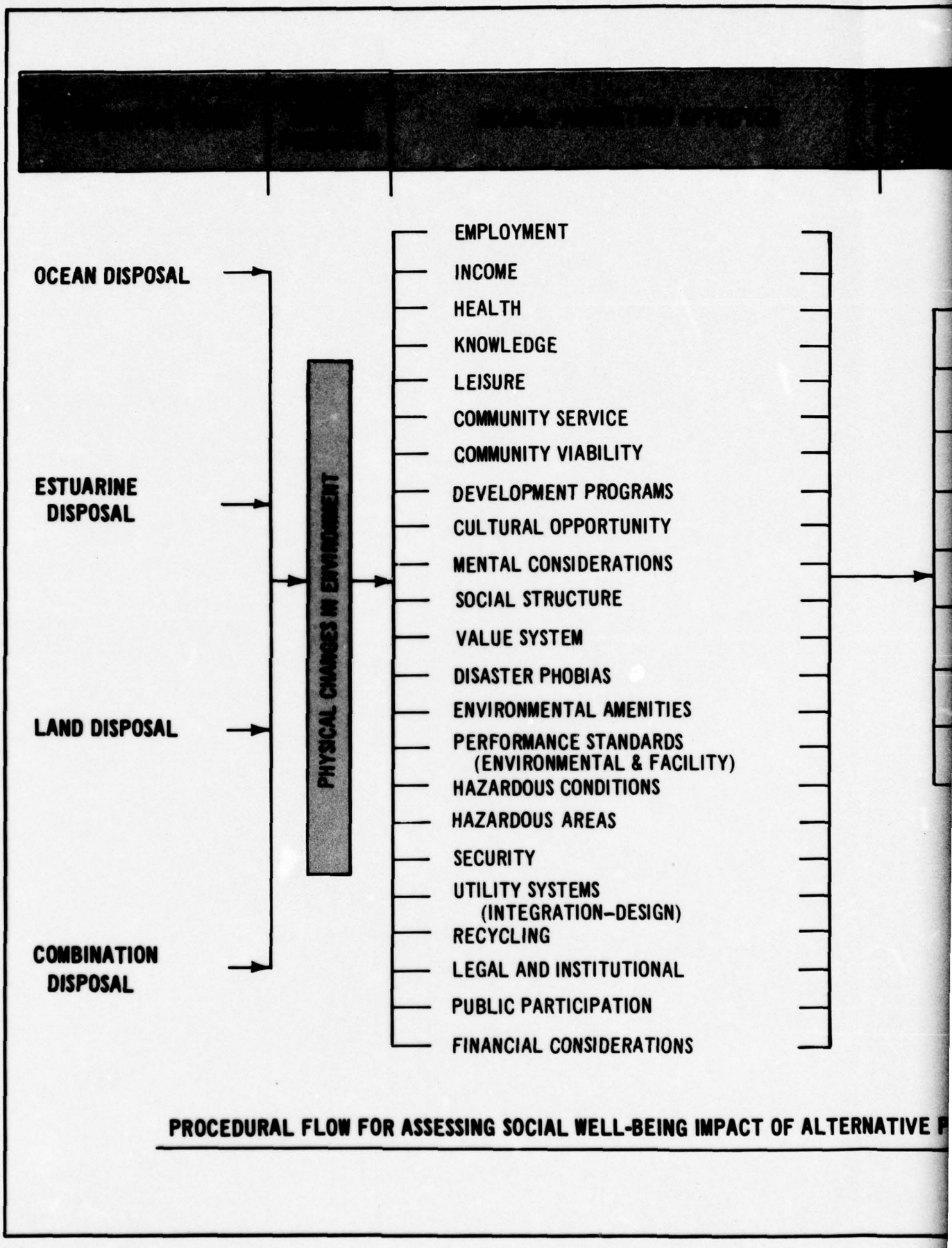
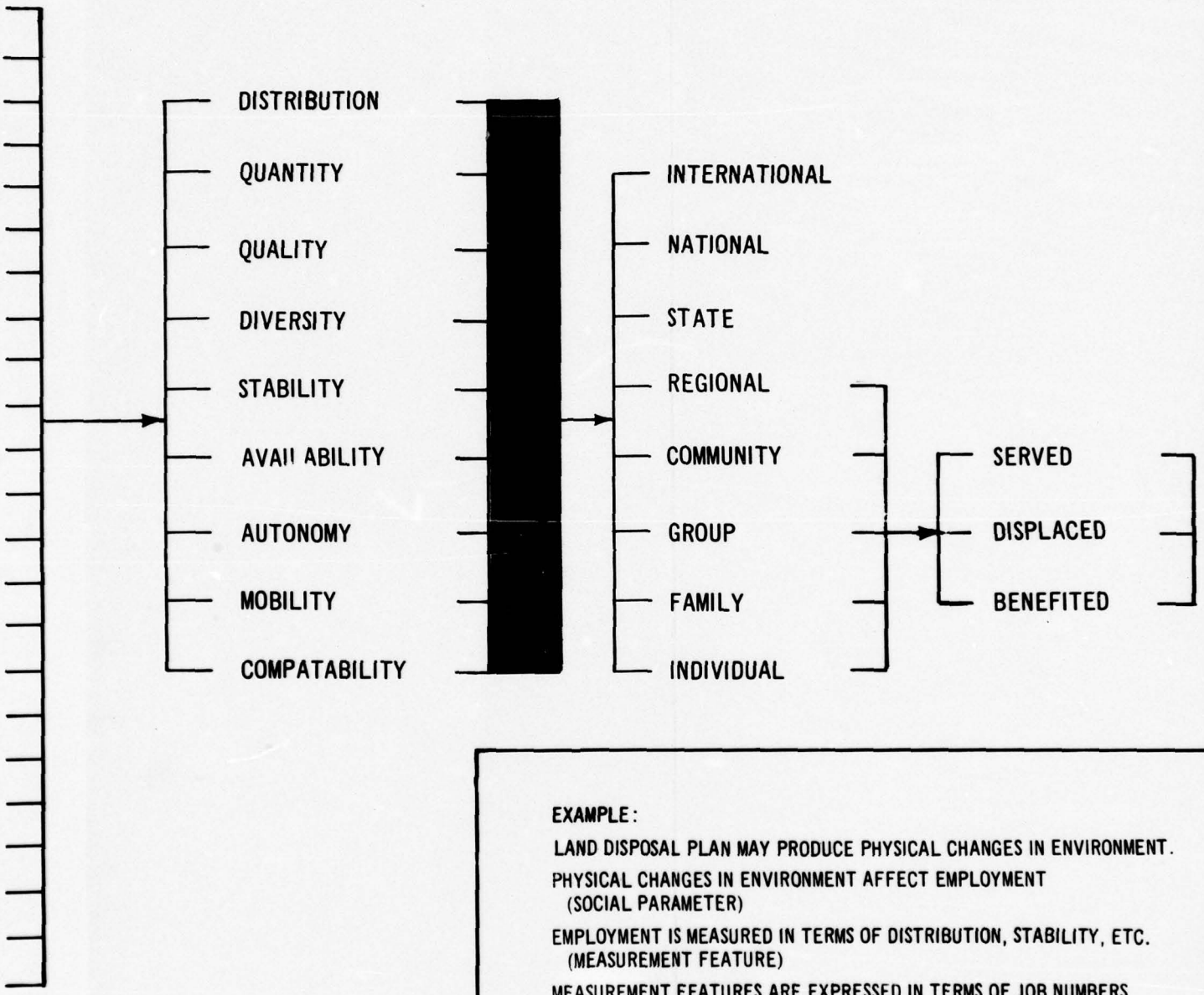
* See Procedural Flow for Assessing Social Well-Being of Alternative Plans. (Figure C-6.)

The assessment of the social well-being impact of the wastewater management alternatives is based initially upon physical changes in the environment that possibly will result from the development of a selected wastewater management system (i.e., Ocean, Estuarine, Land, or Combination Disposal Alternative). The development of a particular alternative would presumably produce two categories of physical change: (1) the change in the constituent resource condition of the hydrogsphere and biosphere as a result of changes in the pollutant constituency and level of wastewater discharged into the environment and (2) the terrestrial physical changes on development patterns and activities as a result of the proposed construction of various physical plants and conveyance systems. These physical changes will be analyzed in relation to an established set of social parameters. The "impacts" on these social parameters are identified as definitely as possible within the constraints of the Feasibility Study and are intended to indicate the possible direction and magnitude of changes in Social Well-Being as a result of each alternative. These changes then are preliminarily evaluated in relation to overall regional goals which are available and generally accepted or postualted by agencies with regional planning responsibilities. Also, objectives which reflect an articulation of national concerns for urban problems and programs and objectives which reflect local concerns and problems will be further developed and correlated because of the probable significant influence of the development of proposed wastewater management systems on individual groups and various population categories.



PROCEDURAL FLOW FOR ASSESSING SOCIAL WELL-BEING IMPACT OF ALTERNATIVE P



TY)

MPACT OF ALTERNATIVE PLANS

EXAMPLE:

LAND DISPOSAL PLAN MAY PRODUCE PHYSICAL CHANGES IN ENVIRONMENT.

PHYSICAL CHANGES IN ENVIRONMENT AFFECT EMPLOYMENT (SOCIAL PARAMETER)

EMPLOYMENT IS MEASURED IN TERMS OF DISTRIBUTION, STABILITY, ETC. (MEASUREMENT FEATURE)

MEASUREMENT FEATURES ARE EXPRESSED IN TERMS OF JOB NUMBERS PER AREA (FACTORS)

FACTORS ARE DISAGGREGATED FROM NATIONAL OR STATE TO REGIONAL AND FINALLY INDIVIDUAL IMPACTS.

FIGURE C-6

f. **Existing Development Patterns**

The pattern of development of the Bay and Delta area can be considered as a band of urban land encircling the Bay proper with modal concentrations near the Delta extremities at Sacramento and Stockton. In the urban band encircling the 9-county Bay area, 80 percent of those counties' population resides and 90 percent are employed. There are 6-1/2 million acres of land within this 12-county area, 4-1/2 million which are usable for agriculture, open space, or urban development. Presently, 80 percent of the usable land is agricultural or vacant. Within the 9-county Bay area there are approximately 4.5 million acres, of which 4 million are undeveloped, but only 1.2 million acres are available for development or urban use.

The population of the 12-county area as a whole can be expected to possibly triple within the next 50 years. Some estimates of the population project over 15 million persons by the year 2020. This regional growth rate is not expected to be uniformly distributed throughout the region, although most projections indicate a trend toward decentralization of industrial development from the presently dominating centers. In the last two decades the rapid rate of employment growth in the San Francisco-Oakland and San Jose metropolitan centers has caused a great residential spread of development into the Santa Clara Valley, southern Marin County, and central Contra Costa County. The development of heavy industrial sites in the Martinez, Pittsburg, Novato areas has resulted in substantial urbanization in these areas.

In order to establish an initial base of socio-economic indicators, the following listing is presented to allow initial general comparisons of the base conditions of the counties and sub-areas influenced by the alternative wastewater management plans (This partial listing does not reflect the 1975 base condition of the overall wastewater management study and is for general reference only and not intended to be a complete listing of all relevent indicators.)

(1) Sub-area A.

San Francisco

Employment

high industrial

service employment more than double employment in manufacturing and wholesale trade

shift of employment growth from central cities

decline in manufacturing

major financial center

40% of total transportation, communications and utilities

finance, insurance, and real estate (69,000)

employment diversified

umemployment = 5.9% (June 1971, seasonally adjusted, combining with Alameda, Contra Costa, Marin, San Mateo)

center of services employment (122,600) = 23% of county total

major regional administrative center for Federal Government

percentages 1965

manufacturing and wholesale trade 19%

retail trade 8%

services 41%

other (including military) 30%

Income Trends - 1968 per capita $5,808

income high

expected to advance moderately

disproportionate shore of older people (12.6% over 65, national figure is 9.1%)

Growth and Development Trends

residential and industrial

little open space, no agricultural

54% privately owned 1950

little room for future growth

population: 74,100 (14.1% of total), little growth expected

1970 = 748,700

1990 = 827,000

population density - 16,391.1/sq. mile

land use

residential 45%

commercial and industrial 16%

public 26%

vacant and agricultural 6%

unusable 3%

San Mateo

Employment

primarily manufacturing

major concentration of transportation employment (airport) (31,200 in transportation, communications and utilities)

percentages 1965

manufacturing and wholesale trade	22%
retail trade	11%
service	35%
other (including military)	29%

employment diversified

unemployment - 5.9% (June 1971, seasonally adjusted, combining with San Francisco, Contra Costa, Alameda, Marin)

Income Trends

1968 per capita income $4,939

Growth and Development Trends

population: 517,050

1970 = 553,700

1990 = 873,000

has increased 50% in past ten years in San Mateo and Santa Clara combined

population density: 1,239.8/sq. mile

land use

residential	16%
commercial and industrial	2%
public	7%
vacant and agricultural	49%
unusable	24%

like Santa Clara, Alameda, Contra Costa and Solano, has agricultural districts which are limited to agricultural use

here and in Alameda, open space zoning extends along most of the shoreline of marsh and reclaimed lands

Santa Clara

Employment

percentages 1965:

manufacturing and wholesale trade	35%
retail trade	12%
service	37%
other (including military)	15%

tremendous increase in manufacturing, especially aerospace (total = 125,000, aerospace = 68,000), electrical equipment and supplies = 46,000 or 37.5%

unemployment = 6.3% (June 1971, seasonally adjusted)

agriculture decreased 25% in last 10 years due to rapid urbanization

third in Bay area in contract construction (21,400)

Income Trends

1968 per capita income $3,949

Growth and Development Trends

population: 872,838 (16.6% of total)

1970 = 1,011,900

1990 = 1,785,000

population has increased 50% in last 10 years in San Mateo and Santa Clara combined

population density: 778.1/sq. mile

land use

residential	7%
commercial and industrial	3%
public	3%
vacant and agricultural	38%
unusable	48%

like San Mateo, Alameda, Contra Costa and Solano, has agricultural districts which are limited to agricultural use - here in selected areas

Alameda

Employment

percentages 1965:

manufacturing and wholesale trade	27%
retail trade	12%
service	34%
other (including military)	25%

light manufacturing, research and development activities have increased substantially in Southern Alameda

rapid population growth in suburban areas has led to an increase in the population serving industry (trade, government, services)

Oakland - food processing, nonelectrical machinery, metals, major transportation center

food and related products (with San Francisco = 55,000)

leads Bay Area in government employment (100,500)

unemployment = 5.9% (seasonally adjusted, June 1971, combining with San Francisco, Contra Costa, San Mateo, Marin)

Income Trends

1968 per capita income $4,285

Growth and Development Trends

population: 1,002,541 (19% of total)

1970 = 1,069,900

1990 = 1,681,000

population density: 1,458.9/sq. mile

land use

residential	12%
commercial and industrial	3%
public	3%
vacant and agricultural	52%
unusable	28%

like San Mateo, Santa Clara, Contra Costa and Solano, has agricultural districts which are limited to agricultural use

here and in San Mateo, open space zoning extends along most of the shoreline of marsh and reclaimed lands

(2) Sub-area B.

Sonoma

Employment

percentages 1965:

manufacturing and wholesale trade	17%
retail trade	15%
service	42%
other (including military)	25%

lumbering and agriculture important: apples, prunes, dairy and poultry products

major wine producing area

light manufacturing in Santa Rose and Petaluma areas

Santa Rosa - commercial center

Petaluma - "egg basket of the world"
unemployment = 8.7% (not seasonally adjusted, June 1971)

Income Trends

1968 per capita income $3,077

Growth and Development Trends

population: 182,020 (3.5% of total)

1970 = 194,600

1990 = 368,000

2020 = greatest population increases expected here and in Solano - growing rapidly but uniformly

population density: 121.3/sq. mile

in last ten years there has been a growth of scattered low-density development throughout Central Sonoma County (1966)

land use

residential	less than 1/2%
commercial and industrial	2%

public	4%
vacant and agricultural	61%
unstable	33%

only county which still has a large part of its territory unclassified or unzoned

Marin

Employment

percentages 1965:

manufacturing and wholesale trade	9%
retail trade	15%
service	47%
other (including military)	30%

rapid population growth in suburban areas has resulted in employment gains in population serving industries (trade, government, services)

dairy production in NE hills

San Rafael primarily residential and shopping community but has small and growing industrial area

only county without large industrial base
unemployment = 5.9% (June 1971, seasonally adjusted, combining with Alameda, Contra Costa, San Francisco, San Mateo)

Income Trends

1968 per capita income: $4,236

Growth and Development Trends

population: 185,707 (3.5% of total)

1970 = 207,400

1990 = 409,000(?)

population density: 398.6/sq. mile

population centers are east of hills and sheltered from ocean breezes and fogs where temperatures are very equable

land use:

residential	4%
commercial and industrial	less than 1/2%
public	25%
vacant and agricultural	50%
unusable	22%

West Marin: growth of recreation industry, maintenance of agriculture and fishing

Napa

Employment

percentages 1965:

manufacturing and wholesale trade	9%
retail trade	14%
services	50%
other (including military)	27%

primarily an agricultural economy

wine, beef and dairy products main source of income

unemployment = 5.9% (June 1971, seasonally adjusted, combined with Solano)

growing industrial section bordering Napa River

increased efficiency in farm methods has contributed to long term decline in agricultural employment especially here and in Solano

Income Trends

1968 per capita income $3,068

Growth and Development Trends

population: 77,102 (1.5% of total)

1970 = 80,200

1990 = 140,000

population density: 101.8/sq. mile

land use:

residential	less than 1/2%
commercial and industrial	less than 1/2%
public	18%
vacant and agricultural	43%
unusable	38%

Solano

Employment

percentages 1965:

manufacturing and wholesale trade	6%
retail trade	9%
services	26%
other (including military)	59%

unemployment = 5.9% (June 1971, seasonally adjusted, combined with Napa)

government employment accounts for more than 40% of total employment (especially Travis AFB and Mare Island shipyards)

eastern section agricultural

western section industrial

Fairfield is agricultural processing center

increased efficiency in farm methods has contributed to long term decline in agricultural employment especially here and in Napa

Income Trends

1968 per capita income: $3,393

Growth and Development Trends

population: 156,315 (3.0% of total)

1970 = 172,600

1990 = 316,000

2020 = greatest population increases expected here and Sonoma, growing rapidly but uniformly

population density: 209.0/sq. mile

land use:

residential	1%
commercial and industrial	less than 1/2%
public	8%
vacant and agricultural	83%
unstable	7%

like San Mateo, Santa Clara, Alameda and Contra Costa, has agricultural districts which are limited to agricultural uses.

(3) Sub-area C.

Contra Costa

Employment

percentages 1965:

manufacturing and wholesale trade	27%
retail trade	13%
services	33%
other (including military)	26%

rapid population growth in suburban areas has resulted in employment gains in population serving industries (trade, government, services)

like Alameda and Santa Clara, has the highest proportion of industrial employment to total employment

oil refineries, steel mills, heavy chemical, food processing and other production facilities

economic growth in county has been and will continue to be at a higher rate than for either metropolitan area or state

technical development in its industries has cut need for employment so that while manufacturing remains largest employer, rate of growth slowed recently (increased 9% 1958 to 1966)

unemployment = 5.9% (June 1971, seasonally adjusted, combining Alameda, San Mateo, San Francisco, Marin)

Income Trends

1968 per capita income: $3,415

Growth and Development Trends

population: 513,087 (9.7% of total)

1970 = 550,800

1990 = 1,080,000

population density: 751.8/sq mile

land use:

residential	11%
commercial and industrial	3%
public	4%
vacant and agricultural	60%
unusable	22%

in past ten years urban area in Central Contra Costa has been expanded (1966)

like San Mateo, Santa Clara, Alameda and Solano, has agricultural district limited to agricultural use

(4) Sub-area D.

Yolo

Employment

percentages 1965:

manufacturing and wholesale trade	15%
retail trade	8%
services	28%
other (including military)	49%

canneries presently located in urban areas but expected to concentrate closer to raw food sources here and in San Joaquin and Sacramento, due to increasing urbanization and economics involved

predominantly agricultural

over 40% of employment in agriculture, with less than 20% in manufacturing and wholesale trade

unemployment = 6.6% (May 1971, seasonally adjusted, combining Sacramento and Placer)

Growth and Development Trends

population: 82,237 (1.6% of total) (1965)

1990 = 165,000

population of Yolo, Sacramento, and San Joaquin Counties is projected to grow from 4 to 17 times their present size by 2020 as a result of land availability and increasing urbanization

land use:

residential	1%
commercial and industrial less than	1%
public less than	1%
vacant and agricultural	57%
unusable	40%

expected (with Sacramento and San Joaquin) to experience an accelerated growth rate after 1980

Sacramento

Employment

percentages 1965:

manufacturing and wholesale trade	17%
retail trade	13%
services	31%
other (including military)	39%

canneries presently located in urban areas but expected to concentrate closer to raw food sources here and in San Joaquin and Yolo due to increasing urbanization and economics involved

predominantly agricultural

over 40 percent of employment in agriculture, with less than 20 percent in manufacturing and wholesale trade

unemployment = 6.6% (May 1971, seasonally adjusted, combining Yolo, Placer)

Growth and Development Trends

population: 646,759 (12.3% of total) (1965)

1990 = 1,010,000

population (with Yolo and San Joaquin) is projected to grow from 4 to 17 times its present size by 2020 as a result of land availability and increasing urbanization

land use:

residential	10%
commercial and industrial	2%
public	3%
vacant and agricultural	64%
unusable	21%

expected to experience accelerated growth rate after 1980 along with Yolo and San Joaquin

San Joaquin

Employment

percentages 1965:

manufacturing and wholesale trade	22%
retail trade	12%
services	26%
other (including military)	40%

canneries presently located in urban areas but expected to concentrate closer to raw food sources here and Sacramento and Yolo due to increasing urbanization and economics involved

predominantly agricultural

over 40% of employment in agriculture, with less than 20% in manufacturing and wholesale trade

unemployment = 8.9% (May 1971, seasonally adjusted)

Growth and Development Trends

population: 277,489 (5.3% of total)

population of this county (along with Yolo and Sacramento) is projected to grow from 4 to 17 times its present size by 2020 as a result of land availability and increasing urbanization

land use:

residential	2%
commercial and industrial	1%
public	1%
vacant and agricultural	65%
unusable	31%

expected to experience accelerated growth rate after 1980 (along with Yolo and Sacramento)

(5) 12-County Bay-Delta Region.

Employment

forecasts parallel population in magnitude and location

jobs will increase from 2 million (1965) to 6 million (2020)

most from increasing industrialization within region as well as increase in commercial and service employment resulting from expanding urbanization

petroleum refining will increase from 165 million barrels/year to 1,200 million in 2020

paper and allied products will increase 500% to daily production of 12,000 tons

shift in cannery activity from urban to San Joaquin, Sacramento, and Yolo Counties

chemical industry will increase faster here than nationally - 11 fold increase projected for 2020

industrial steel product consumption will increase 4 fold from 2.2 million tons/year to 11 million

San Francisco and Alameda Counties will retain their present positions of leadership in total employment, but trend toward decentralization will result in greater percentage increases in all other counties (2.5 increase)

Yolo, Marin, Sonoma and Solano project greatest increase in percentage (4X)

g. Social Well-being Impact Assessment of Base Condition

The social well-being impact assessment of the base condition is formulated in relation to the established social parameters and the physical impacts of the base condition, in relation to the ocean, estuary and associated land areas. 1/ The social effect of the continued accumulations of hydrospheric pollutants could have a substantial long-term impact on decreasing the stability and altering the future growth of the water-oriented recreation in the entire San Francisco Bay and Delta region. In some localized areas, such as Marin County there is little industrialization, and the development trends are toward the continued growth of recreational activity and the maintenance of agriculture and fishing. These activities constitute the basis for the county's growth and are of prime importance to the viability of the area. Also, continued pollution accumulations, fish kills, and contamination of water species could limit the diversity of long-term employment related to commercial fishing for the entire region. The possible long-term changes to the water-related character of the Bay and Delta area in general could have significant importance by decreasing the visual aesthetics of the Bay and coastal beaches. Also, estuarine and ocean accumulations of pollution could produce substantial changes in the availability, access, and convenience of open space and the associated recreation activities throughout the San Francisco Bay and Delta area.

The possible effects of continued ocean and estuarine pollution on the region and its recreational activity can be demonstrated in relation to a report entitled, A Survey of the Marine Environment From Fort Ross, Sonoma County, to Point Lobos, Monterey County, prepared for the State of California Department of Fish and Game. As can be seen from the Figure C-8, the prime areas for party boat fishing are the San Francisco Bay proper and the immediate coastal waters off the Golden Gate. These nearby fishing areas, when compared with Figure C-2, which shows the areas of highest annual fish catches, are not prime fishing areas or even desirable ones in term of catches. However, their close proximity to the urban population and ease of access make them most desirable in terms of maximum recreation benefit for the greatest number of people. Continued pollutant accumulations in these areas could greatly influence the long-term attractiveness of these areas, not only for boat fishing but for land-side fishing and all other forms of water-oriented recreational activity which is of great importance to the traditional character of the San Francisco Bay region.

1/ See Figure C-7

Within an urban area such as San Francisco, the need for adequate recreational opportunities is important to the mental well-being and physical health of residents as well as visitors. Although the present facilities for activities such as boating are considered to meet present and near term demands, provisions for other recreational activities such as water skiing, picnicking, or swimming are inadequate and do not satisfy existing potential demands. Also the continued reduction in marshland game species as a result of pollutants would not only affect hunting as a recreational activity, but would also affect the overall amenity of a diversified wildlife environment which is a prime aesthetic asset within an urban area.

According to the Kaiser Engineers 1969 study of Present and Future Recreation of the San Francisco Bay and Delta Area, prepared for the San Francisco Bay-Delta Water Quality Control Program, the potential demand for water-oriented recreational use of the San Francisco Bay and Delta area is increasing very rapidly. The study revealed a 750 percent increase in potential demand in participation days of recreation between 1965 and 2020. (One participation day is one person participating in one activity on one occasion.) The 1965 estimate was 38 million participation days. The 2020 total estimate is 264.7 million participation days. Also, the total annual value of the San Francisco Bay and Delta in recreation activity could increase from approximately $63 million in 1965 to over $600 million in 2020. As can be seen the potential dollar loss should water quality deteriorate significantly could produce significant changes in the Bay region economy and especially among those groups whose income is dependent upon or related to water-oriented recreational employment. It is questionable whether the entire projected increase in water related recreation could be realized under the estuarine water quality conditions expected to prevail for the base condition.

Under the base condition, there will probably be an absence of substantial reuse of treated wastewater as a source of future water supply. This factor possibly could have long-term effects on the Bay and Delta in terms of decreasing the level and diversity of regional employment opportunities. The availability of water for industrial and municipal purposes could affect spatial growth and development patterns of industries and the resulting job opportunities and residential developments this growth would stimulate. The impact of the base condition on the general urban, suburban, and rural land use pattern probably would be moderate as a long-term consequence, and the ultimate effects dependent upon many other economic and physical constraints in combination with water quality and overall wastewater plans and operational regulations.

The social well-being impact of the base condition in relation to the concept of "human betterment" indicates that the base condition would have little impact on existing social conditions and would offer little, if any, ameliorative benefits to one of the most significant human betterment concepts - that of the equitable distribution of income goods and community services to individuals and groups within the influenced project areas. Of particular concern in any social analyses should be

	PRELIMINARY HYDROSPHERIC PHYSICAL IMPACTS				
	POLLUTANTS IN OCEAN	POLLUTANTS IN ESTUARY	EUTROPHIC RATE IN ESTUARY	SALINITY IN ESTUARY	
PHYSICAL CHANGE ⇨	CONTINUED ACCUMULATIONS FISH KILLS CONTAMINATION OF SPECIES	CONTINUED ACCUMULATIONS FISH KILLS CONTAMINATION OF SPECIES	NO CHANGE FROM PRESENT CONDITIONS (?)	INCREASING PROBLEM IN DELTA (?)	M
SOCIAL PARAMETERS ⇩					
EMPLOYMENT					
REGIONAL	IMMEDIATE & LONG-TERM DECREASE IN DIVERSITY	IMMEDIATE & LONG-TERM DECREASE IN LEVEL AND DIVERSITY	•	LONG-TERM DECREASE IN DIVERSITY	IM DE DI
SUB-AREA A	IMMEDIATE & LONG-TERM DECREASE IN LEVEL AND DIVERSITY	IMMEDIATE & LONG-TERM DECREASE IN DIVERSITY	•	↓	IM DE
SUB-AREA B	↓	↓	•	↓	
SUB-AREA C	LONG-TERM DECREASE IN DIVERSITY	↓	•	↓	
SUB-AREA D	↓	↓	•	—	
INCOME					
REGIONAL	LONG-TERM DECREASE AMONG CERTAIN CATEGORIES	LONG-TERM DECREASES AMONG CERTAIN CATEGORIES	•	POSSIBLE LONG-TERM DECREASES AMONG CERTAIN CATEGORIES	LO LE
SUB-AREA A	↓	LONG-TERM DECREASES AMONG CERT. CATEGORIES INCREASES IN DISTRIBUTIVE INEQUITY	•	↓	LO RE RE
SUB-AREA B	↓	POSS. LONG-TERM DEC. AMONG CERTAIN CATEGORIES	•	↓	
SUB-AREA C	—	POSS. LONG-TERM DEC. AMONG CERT. CATEGORIES INC. IN DISTRIB. INEQUITY	•	↓	
SUB-AREA D	—	LONG-TERM DECREASE AMONG CERTAIN CATEGORIES	•	↓	
GROWTH AND DEVELOPMENT	POSSIBLE LONG-TERM INCREASE IN DISTRIBUTIVE INEQUITY				
REGIONAL	POSSIBLE DECREASE IN DIVERSITY OF INDUSTRY & COMMERCIAL RECREATION	DECREASE RECREATIONAL, COMMERCIAL, OPEN SPACE LEVEL & DISTRIBUTION	•	DECREASE IN AGRICULTURAL PRODUCTION & FISHING INDUSTRY	DE RE &
SUB-AREA A	LONG-TERM DECREASE IN COMMERCIAL RECREATION	↓	•	—	
SUB-AREA B	↓	↓	•	—	
SUB-AREA C	—	↓	•	—	
SUB-AREA D	—	DECREASE AGRICULTURAL LEVEL & RECREATIONAL OPPORTUNITY	•	DECREASE IN AGRICULTURAL PRODUCTION	

(SEE LEGEND BELOW)

2 SOCIAL WELL-BEING IMPACT ASSESSMENT
BASE CONDITION

ICAL IMPACTS		PRELIMINARY TERRESTRIAL PHYSICAL IMPACTS				
SALINITY IN ESTUARY	SPECIES IN OCEAN & ESTUARY	REUSE POTENTIAL OF WASTE RESIDUALS	GROUND COVER OR SOIL CONDITIONS	SOURCES FOR WATER SUPPLY (POTENTIAL)	GENERAL LAND USE	DISPLACEM OF ACTIVI
			WATER / SLUDGE		URBAN / SUBURBAN / RURAL	
INCREASING PROBLEM IN DELTA (?)	REDUCTION OF MARSHLAND SPECIES (I.E.-BIRDS, GAME, ETC.)	LITTLE REUSE (IF ANY)	NO IMPACT	LITTLE REUSE	MODERATE LONG-TERM IMPACTS	NO IMPAC
LONG-TERM DECREASE IN DIVERSITY	IMMEDIATE AND LONG-TERM DECREASE IN LEVEL AND DIVERSITY	—	NO IMPACT	POSSIBLE LONG-TERM DECREASE IN LEVEL & DIVERSITY	—	NO IMPAC
↓	IMMEDIATE AND LONG-TERM DECREASE IN DIVERSITY	—	↓	↓	—	↓
	↓	—			—	
		—			—	
—		—			—	
POSSIBLE LONG-TERM DECREASES AMONG CERTAIN CATEGORIES	LONG-TERM DECREASES IN LEVEL	—	NO IMPACT	POSSIBLE LONG-TERM DECREASES IN LEVEL	PERSONAL INCOME FROM SOME LAND USES COULD DECREASE	NO IMPA
↓	LONG-TERM DECREASES AS RELATED TO CERTAIN RECREATION ACTIVITIES	—	↓	—	↓	↓
	↓	—		—		
		—		—		
		—		—		
DECREASE IN AGRICULTURAL PRODUCTION & FISHING INDUSTRY	DECREASE IN RECREATIONAL DIVERSITY & DISTRIBUTION	—	NO IMPACT	POSSIBLE ALTERATIONS IN INDUSTRIAL OR RESI-DENTIAL GROWTH PATTERN	POSSIBLE DETRIMENT TO EXISTING LAND USES (OPEN SPACE, RECREATION)	NO IMPA
—	↓	—	↓	↓	↓	↓
—		—				
—		—				
DECREASE IN AGRICULTURAL PRODUCTION	—	—	↓	↓	↓	↓

MATCH LINE TO LOWER PORTION "**BASE CONDITION**"

PHYSICAL IMPACTS				PRELIMINARY REQUIREMENTS FOR SYSTEM DEVELOPMENT		
USE / RURAL	DISPLACEMENT OF ACTIVITIES	ATMOSPHERIC CONDITIONS	TERRESTRIAL SPECIES	LAND ACQUISITION REQUIRED	CONSTRUCTION OF TREATMENT PLANTS	CONSTRUCTION OF CONVEYANCE SYSTEM
-TERM	NO IMPACT	NO IMPACT	NO IMPACT	SOME CONSOLIDATION OF SERVICES CONTINUED LOCAL CONTROL		
	NO IMPACT	NO IMPACT	NO IMPACT	•	•	•
	↓	↓	↓	•	•	•
				•	•	•
				•	•	•
				•	•	•
SOME LAND	NO IMPACT	NO IMPACT	NO IMPACT	•	•	•
	↓	↓	↓	•	•	•
				•	•	•
				•	•	•
				•	•	•
EXISTING E,	NO IMPACT	NO IMPACT	NO IMPACT	•	•	•
	↓	↓	↓	•	•	•
				•	•	•
				•	•	•
				•	•	•

Sheet 1 of 2 FIGURE C-7

PUBLIC HEALTH (MENTAL ATTITUDE)* AND SAFETY				
REGIONAL	LONG-TERM CHANGE ON REGIONAL WATER-RELATED CHARACTER	IMMEDIATE & LONG-TERM DECREASES	•	DECREASE IN TRADITIO BAY RECREATIONAL & COMMERCIAL ACTIVITI
SUB-AREA A	↓	↓	•	↓
SUB-AREA B	↓	↓	•	↓
SUB-AREA C	—	↓	•	↓
SUB-AREA D	—	↓	•	↓
AMENITY				
REGIONAL	LONG-TERM DECREASE IN VISUAL COASTAL AESTHETICS, DECREASE IN COASTAL RECREATION	DECREASE IN AESTHETICS, DECREASE IN CONVENIENCE REC. IN BAY & ESTUARY	•	DECREASE IN AESTHETI DECREASE IN CONVENIE & DIVERSITY OF REC.
SUB-AREA A	↓	↓	•	↓
SUB-AREA B	↓	↓	•	↓
SUB-AREA C	—	↓	•	↓
SUB-AREA D	—	↓	•	↓
REGULATORY CONTROL				
REGIONAL	NEED FOR NATION, STATE AND REGIONAL CONTROL	INCREASE NEED FOR REGIONAL CONTROL & STRICTER STATE REGULATION	•	—
SUB-AREA A	↓	↓	•	—
SUB-AREA B	↓	↓	•	—
SUB-AREA C	—	↓	•	—
SUB-AREA D	—	↓	•	—
FINANCIAL CONSIDERATIONS				
REGIONAL	POSSIBLE POLLUTION CHARGES TO INDUSTRY	INCREASE PUBLIC COSTS FOR CONTROL INCREASE NEED FOR REGIONAL POLLUTION CHARGES	•	—
SUB-AREA A	LONG-TERM INCREASES IN PUBLIC COSTS FOR CORRECTION	↓	•	—
SUB-AREA B	↓	↓	•	—
SUB-AREA C	—	↓	•	—
SUB-AREA D	—	↓	•	—

— INDICATES INDETERMINATE IMPACT

• PRELIMINARY ANALYSIS UNAVAILABLE

* See: HYGIENIC IMPACT FOR PHYSICAL PUBLIC HEALTH

2 1 MATCH LINE TO UPPER PORTION "BASE CONDITION"

DECREASE IN TRADITIONAL BAY RECREATIONAL & COMMERCIAL ACTIVITIES	DECREASE IN TRADITIONAL BAY REC. ACTIVITIES	—	NO IMPACT	POSSIBLE LIMITATIONS ON DISPERSION OF ACTIVITIES	INCREASED NEED FOR CONCERN OVER HAZARDOUS CONDITIONS RELATED TO EARTHQUAKES, SLIDES, FLOODS	N
DECREASE IN AESTHETICS DECREASE IN CONVENIENCE & DIVERSITY OF REC.	DECREASE IN AESTHETICS CONVENIENCE & ACCESS TO DIVERSIFIED RECREATION	—	NO IMPACT	POSSIBLE DECREASE IN OPPORTUNITY FOR FUTURE RECREATION DEVELOPMENT	DECREASE IN VALUE OF AESTHETICS, CONVENIENCE & ACCESS TO OPEN SPACE & RECREATION	N
—	NEED FOR STRONG STATE & REGIONAL REGULATIONS	—	INCREASED NEED FOR SOIL CONSERVATION REGULATIONS AT STATE & REGIONAL LEVEL	INCREASED NEED FOR REGIONAL CONTROL	INCREASED NEED FOR REGIONAL CONTROL	N
—	—	POSSIBLE LONG-TERM INCREASES IN PUBLIC COSTS	NO IMPACT	POSSIBLE LONG-TERM INCREASE IN PUBLIC COSTS FOR WATER	—	

				•	•	•
E IN VALUE OF AESTHETICS, ENCE & ACCESS TO OPEN RECREATION	NO IMPACT	NO IMPACT	NO IMPACT	•	•	•
				•	•	•
				•	•	•
				•	•	•
				•	•	•
ED NEED FOR L CONTROL	NO IMPACT	NO IMPACT	NO IMPACT	PARTIAL REGIONAL CONTROL	PARTIAL REGIONAL CONTROL	PARTIAL REGIONAL CONTROL
—	NO IMPACT	NO IMPACT	NO IMPACT	PARTIAL REGIONAL CONTROL	PARTIAL REGIONAL CONTROL	PARTIAL REGIONAL CONTROL
—						
—						
—						
—						

FIGURE C-

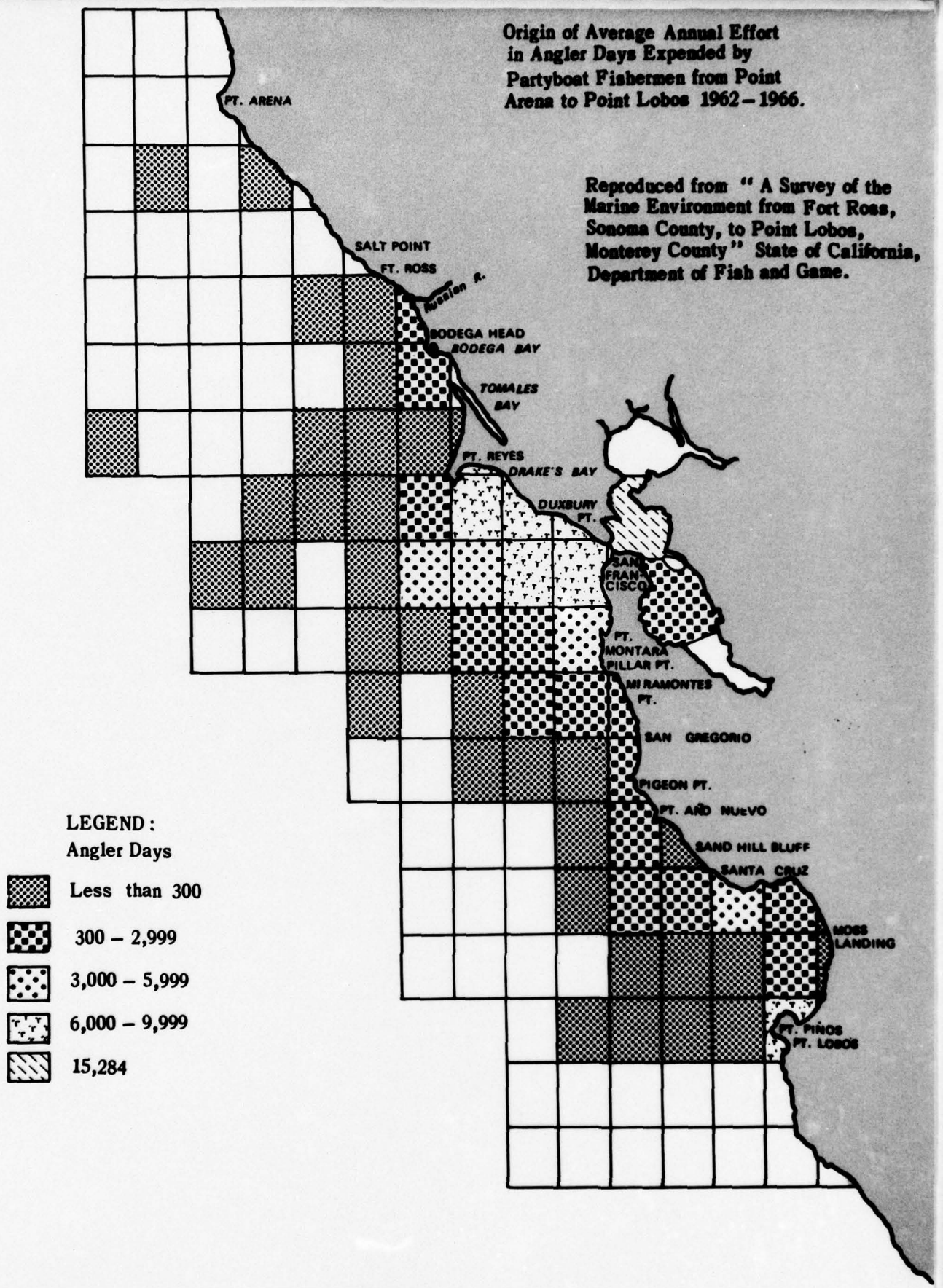

Origin of Average Annual Effort in Angler Days Expended by Partyboat Fishermen from Point Arena to Point Lobos 1962 – 1966.
Reproduced from " A Survey of the Marine Environment from Fort Ross, Sonoma County, to Point Lobos, Monterey County" State of California, Department of Fish and Game.
PT. ARENA
SALT POINT
FT. ROSS
Russian R.
BODEGA HEAD
BODEGA BAY
TOMALES BAY
PT. REYES
DRAKE'S BAY
DUXBURY PT.
SAN FRANCISCO
PT. MONTARA
PILLAR PT.
MI RAMONTES PT.
SAN GREGORIO
PIGEON PT.
PT. AÑO NUEVO
SAND HILL BLUFF
SANTA CRUZ
MOSS LANDING
PT. PIÑOS
PT. LOBOS
LEGEND:
Angler Days
Less than 300
300 – 2,999
3,000 – 5,999
6,000 – 9,999
15,284

FIGURE C-8

the overall plan and project impact on low income groups, minorities, and other disadvantaged groups who are more subject to displacement as a result of living in areas of low property values with inadequate community cohesiveness, and a general lack of representation and participation in planning decisions. In order to honestly address the concept of social well-being, a prime consideration throughout the planning, design, and development of a regional system should be the following concerns:

Who is displaced by the proposed system

Who is adjacently influenced

Who is served, and

Who is economically benefited or detrimented*

Definitive analyses of these population groups should enable policy makers and planners to more adequately establish the distributive consequences of various alternative developments and possibly help establish measures with which to adequately assess and evaluate the social impact of wastewater management proposals.

Finally, the social well-being impact of the base condition possibly could have significant influence toward perpetuating or alleviating existing or future social inequities within the Bay and Delta area. The opportunities to correlate social and environmental enhancement by the distribution of community services such as recreation would greatly decrease with continued Bay and Delta pollution. These conditions in the long term would contribute to the further deterioration of existing bay shore and coastal recreational facilities where socially they are most needed - in close proximity to urban low income areas.

In reference to the need for urban improvement, the Recreation Section in the San Francisco Bay Plan of BCDC states that in relation to accessibility, the easier the recreation facilities are to get to, the more they will be used by people. The report also states that for the Bay area, the greatest percentage of a person's free time (approximately 50 percent) usually is in short intervals such as weekday after work time. Therefore, for maximum advantage for the most persons, recreation facilities should be nearby to gain maximum benefit from them. It is currently estimated that for the San Francisco Bay area approximately two-thirds of the demand for recreation is with one-day round trips. Therefore, the continued accumulation of pollution of the Bay and Delta under the base condition would probably not allow a significant improvement or increase in the amount, quality,

* For greater discussion see p. CB-16 "Review of Feasibility Study on Social Well-Being," by Alonso, Duhl, Krieger and Teitz.

access, or convenience of recreation facilities for the urban residents, especially the poor. These possible distributive considerations in the amount and convenience of recreation facilities could have long-term distributive inequities in relation to social improvement and overall social well-being of large population groups. These distributive implications should be thoroughly analyzed and considered in the final assessment and evaluation of the base condition and in establishing benefits related to wastewater management improvements in general.

Also, according to the Recreation Section of the BCDC plan, the amount of time spent on outdoor recreation and the type of recreation activity chosen is largely dependent upon the income level of the individual families. Persons classified as within the very low income category average approximately 210 hours per year in outdoor recreation. Persons classified in the highest income group average approximately 375 hours of outdoor recreational activity per year. Also, persons of lower income choose activities that cost the least, such as beach and pier fishing, while higher income groups choose activities such as sailing or yachting. As can be inferred from these reports, in order to enable more middle and lower income groups to gain the benefits of outdoor recreation, sites and facilities in close proximity to existing urban poor areas should be developed to allow inexpensive access and travel time convenience. Also, the long-term financial consideration of pollution abatement in relation to public costs should be analyzed in relation to individual equity. The regulatory control aspects of the base condition reflect a need for strong Federal, State, and regional controls of the sources of pollutants, as well as the processes of control and treatment, if social well-being and its necessary equity considerations are serious parameters to be used in the planning and development of wastewater management systems.

h. Social Well-being Impacts of Alternatives for Managing Wastewater

(1) Ocean Disposal Alternative (Advanced Treatment)

The social well-being impact assessment of the Ocean Disposal Alternative with advanced treatment has many of the same social effects on the San Francisco Bay and Delta region as the Ocean Disposal Alternative with secondary treatment presented in the preceding analysis. However, there are several possible changes as a result of the advanced treatment. 1/

The possible long-term decreases in employment diversity and income related to water-oriented activities, expecially ocean fishing would be much less for the coastal areas of the Bay region, and for the region as a whole. The long-term increases in employment and income for the areas bordering the Bay and Delta would remain the same as in the Alternative with secondary treatment.

1/ See Figure C-9

	PRELIMINARY HYDROSPHERIC PHYSICAL IMPACTS									
	POLLUTANTS IN OCEAN		POLLUTANTS IN ESTUARY		EUTROPHIC RATE IN ESTUARY		SALINITY IN ESTUARY			
	SECONDARY TREATMENT	TERTIARY TREATMENT	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.		
PHYSICAL CHANGE ⇨	FISH KILLS CONTAMINATION OF SPECIES	SLIGHT INC. IN LONG-TERM ACCUMULATION	NO PROBLEM		NO CHANGE		INCREASES IN SOUTH BAY			
SOCIAL PARAMETERS ⇩										
EMPLOYMENT										
REGIONAL	IMMEDIATE & LONG-TERM DEC. ON DIVERSITY	POSSIBLE LONG-TERM DECREASE ON DIVERSITY	INCREASED LONG-TERM STABILITY AND DIVERSITY		•	•	LONG-TERM DECREASE IN DIVERSITY			
SUB-AREA A	IMME. & LONG TERM DEC. ON DIVERSITY AND LEVEL	↓	↓	↓	•	•	↓	↓		
SUB-AREA B	↓	↓	↓	↓	•	•	—	—		
SUB-AREA C	LONG-TERM DECREASE ON DIVERSITY	NO IMPACT	↓	↓	•	•	—	—		
SUB-AREA D	↓	↓	↓	↓	•	•	—	—		
INCOME										
REGIONAL	LONG-TERM DECREASE AMONG CERTAIN CATEGORIES	POSSIBLE LONG-TERM DEC. AMONG CERTAIN CATEGORIES	LONG-TERM INCREASES IN CERTAIN CATEGORIES		•	•	POSSIBLE LONG-TER DECREASE AMONG CERTAIN CATEGORIE			
SUB-AREA A	↓	↓	↓	↓	•	•	POSSIBLE LONG-TER DECREASE IN DISTRIBUTIVE EQUIT			
SUB-AREA B	↓	↓	↓	↓	•	•	—	—		
SUB-AREA C	—	NO IMPACT	↓	↓	•	•	—	—		
SUB-AREA D	—	↓	↓	↓	•	•	—	—		
GROWTH AND DEVELOPMENT										
REGIONAL	POSSIBLE DEC. IN DIVERSITY & COMMERCIAL RECREATION	—	INCREASES IN OPPORTUNITY FOR ALL TYPE DEV.		•	•	POSSIBLE LONG-TER DECREASE IN DIVERSITY			
SUB-AREA A	LONG-TERM DEC. IN COMMERCIAL REC.	—	↓	↓	•	•	DECREASE IN RECREATIONAL OPPORTUNITY			
SUB-AREA B	↓	—	↓	↓	•	•	—	—		
SUB-AREA C	—	NO IMPACT	↓	↓	•	•	—	—		
SUB-AREA D	—	↓	↓	↓	•	•	—	—		

(SEE LEGEND BELOW)

2

SOCIAL WELL-BEING IMPACT ASSESSMENT
OCEAN DISPOSAL PLAN

PHYSICAL IMPACTS | PRELIMINARY TERRESTRIAL PHYSICAL IMPA

ATE Y	SALINITY IN ESTUARY		SPECIES IN OCEAN & ESTUARY		REUSE POTENTIAL OF WASTE RESIDUALS		GROUND COVER OR SOIL CONDITIONS				SOURCES FOR WATER SUPPLY (POTENTIAL)		GENERAL LAND USE						DISP OF
							WATER		SLUDGE				URBAN		SUBURBAN		RURAL		
TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC.	TER.	SEC.	TER.	SEC. TREAT.	TER. TREAT.	SEC.	TER.	SEC.	TER.	SEC	TER.	SEC. TRE
E	INCREASES IN SOUTH BAY		LOSS OF SPECIES NEAR OUTFALL	POSSIBLE LOSS OF SPECIES NEAR OUTFALL	NO CHANGE	GREAT INCREASE	NO EFFECT		GREAT EFFECT		NO CHANGE	GREAT INCREASE	LARGE CHANGES		SM. CHAN-GES	MOD. CHAN-GES	SM. CHAN-GES	MOD. CHAN-GES	SMAL CHANG
•	LONG-TERM DECREASE IN DIVERSITY		LONG-TERM DECREASE IN DIVERSITY	POSSIBLE LONG-TERM DECREASE IN DIVERSITY		POSSIBLE LONG-TERM INCREASE IN DIVERSITY	NO IMPACT		LITTLE IMPACT			POSSIBLE LONG-TERM INC. IN DIVERSITY	POSSIBLE SHORT-TERM IMPACT FOR CONSTRUCTION				POSSIBLE LONG-TERM INC. IN DIVERSITY		POSSIBLE DISPLACE SYS. CON
•	↓	↓	↓	↓		↓	↓		NO IMPACT			↓	POSSIBLE LONG-TERM INC. OR DEC. IN CERTAIN LOCAL AREAS				↓		POSSIBLE DISPLACE LOCALIZE
•	—	—	↓	↓		↓	↓		ALTERATIONS OF AGRI. EMPLOY. CATEGORIES			↓	SMALL IMPACT		NO IMPACT		↓		
•	—	—	NO IMPACT				↓		NO IMPACT				POSS. SHORT-TERM INC. FOR CONST.		POSS. SHORT-TERM INC. OR DEC. IN CERT. LOCAL AREAS		↓		
•	—	—	↓	↓			↓		↓				NO IMPACT				↓		
•	POSSIBLE LONG-TERM DECREASE AMONG CERTAIN CATEGORIES		LONG-TERM DECREASE IN LEVEL	POSSIBLE LONG-TERM DECREASE IN LEVEL		POSS. LONG-TERM INC. IN LEVEL	NO IMPACT					POSS. LONG-TERM INC. IN LEVEL	POSSIBLE SHORT-TERM INC. FOR CONST. POSS. FOR GREATER DIST. EQUITY				POSS. LONG TERM INC. IN LEVEL		NO
•	POSSIBLE LONG-TERM DECREASE IN DISTRIBUTIVE EQUITY		LONG-TERM DEC. AMONG CERTAIN CATEGORIES INC. IN DIST. INEQUITY	POSS. LONG-TERM DEC. AMG. CERT. CATEG'S POSS. INC. IN DIST. INEQUITY		POSS. FOR GREATER DIST. EQUITY	↓		↓			POSS. FOR GREATER DIST. EQUITY	↓		NO IMPACT		POSS. FOR GREATER DIST. EQUITY		POSSIBL DIST. EQ IN LOCA
•	—	—	↓	↓		↓			POSS. LONG-TERM INC. IN DISTRIBUTIVE INEQUITY			↓	↓				↓		
•	—	—	NO IMPACT			↓	NO IMPACT					↓	↓		NO IMPACT		↓		
•	—	—	↓	↓		↓	↓		↓				↓						

TRIAL PHYSICAL IMPACTS								PRELIMINARY REQUIREMENTS FOR SYSTEM DEVELOPMENT					
LAND USE			DISPLACEMENT OF ACTIVITIES		ATMOSPHERIC CONDITIONS		TERRESTRIAL SPECIES		LAND ACQUISITION REQUIRED		CONSTRUCTION OF TREATMENT PLANTS		CONSTRUCTION OF CONVEYANCE SYSTEM	
URBAN	RURAL													
TER.	SEC	TER.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.	SEC. TREAT.	TER. TREAT.
MOD. CHAN-GES	SM. CHAN-GES	MOD. CHAN-GES	SMALL CHANGES	MODERATE CHANGES	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE	FOR SLUDGE DISPOSAL CONVEYANCE FACILITIES PLANTS		2 PLANTS REQUIRED: PETALUMA AND REDWOOD CITY		FR. COLLECTORS TO PLANT FROM PLANT TO OUTFALLS AND SLUDGE DISP. FROM SLUDGE DISP. TO PLANT (GREAT WITH TER.) FR. PLANT TO REUSE (TER.)	
-TERM R ON	POSSIBLE LONG-TERM INC. IN DIVERSITY		POSSIBLE SHORT-TERM DISPLACEMENTS DUE TO SYS. CONST.		NO IMPACT		NO IMPACT		NO IMPACT		NO IMPACT		SHORT-TERM INCREASE IN CONSTRUCTION	
ERM INC. RTAIN S			POSSIBLE LONG-TERM DISPLACEMENT IN LOCALIZED PROJECT AREAS											
CT														
SHORT- INC. OR IN CERT. L AREAS											NO IMPACT			
	POSS. LONG TERM INC. IN LEVEL		NO IMPACT		NO IMPACT		NO IMPACT				NO IMPACT		SHORT INCREASE IN LEVEL DUE TO CONSTRUCTION	
CT	POSS. FOR GREATER DIST. EQUITY		POSSIBLE FOR GREATER DIST. EQUITY OR INEQUITY IN LOCALIZED AREAS						POSSIBLE FOR GREATER DISTRIBUTIVE EQUITY OR INEQUITY IN LOCAL AREAS		POSSIBLE FOR GREATER DISTRIBUTIVE EQUITY OR INEQUITY IN LOCAL AREAS		POSSIBLE FOR GREATER DISTRIBUTIVE EQUITY	
CT											NO IMPACT			
TO INC. TROL SPACE	NO IM PACT	INC. IN OPP. FOR ALL DEV.	NO IMPACT		NO IMPACT		NO IMPACT				NO IMPACT		POSSIBLE ALTERATIONS TO REGIONAL GROWTH PATTERN	
BENE-FIT FOR IND. GROWTH			POSSIBLE ALTERATIONS TO COMMUNITY SERVICE FACILITIES IN LOCALIZED AREAS								POSSIBLE TO INCREASE LOCALIZED COMMUNITY SERVICE		POSSIBLE BENEFIT TO OPEN SPACE AND RECREATION DEVELOPMENT	
									NO IMPACT		NO IMPACT			
BENE-FIT FOR IND. GROWTH									POSSIBLE ALSO TO INCREASE COMMUNITY SERVICES		POSSIBLE TO INCREASE LOCALIZED COMMUNITY SERVICE			
									NO IMPACT		NO IMPACT			

Sheet 1 of 2 FIGURE C-9

PUBLIC HEALTH (MENTAL ATTITUDE)* AND SAFETY									
REGIONAL	LONG-TERM ALTERATIONS TO WATER-RELATED CHARACTER	POSSIBLE LONG-TERM ALTERATIONS TO WATER-RELATED CHARACTER	IMMEDIATE AND LONG-TERM INCREASES AND BENEFITS		•	•	POSSIBLE LONG-TERM ALTERATIONS ON WATER-RELATED CHARACTER		—
SUB-AREA A	↓	↓	↓	↓	•	•	↓	↓	DE C
SUB-AREA B	↓	↓			•	•	NO IMPACT		
SUB-AREA C	—	NO IMPACT			•	•	↓	↓	
SUB-AREA D	—	↓	↓	↓	•	•	↓	↓	
AMENITY									
REGIONAL	LONG-TERM DECREASE IN VISUAL COASTAL AESTHETICS	POSSIBLE LONG-TERM DECREASE IN COASTAL AESTHETICS	INCREASES IN AESTHETICS, ACCESS AND CONVENIENCE FOR RECREATION		•	•	POSSIBLE LONG-TERM DECREASE IN CONVENIENCE OF RECREATION		—
SUB-AREA A	↓	↓	↓	↓	•	•	DECREASE IN WATER-RELATED RECREATION & AESTHETICS		CONV
SUB-AREA B	↓	↓			•	•	—	—	
SUB-AREA C	—	NO IMPACT			•	•	—	—	
SUB-AREA D	—	↓	↓	↓	•	•	—	—	
REGULATORY CONTROL									
REGIONAL	NEED FOR COORDINATED FED, STATE & REGIONAL CONTROL		NEED FOR REGIONAL CONTROL		•	•	NEED FOR REGIONAL REGULATION		N
SUB-AREA A	DECREASE LOCAL AUTONOMY		DECREASE LOCAL AUTONOMY		•	•	NEED FOR STRONG SUB-AREA CONTROL		
SUB-AREA B	↓	↓	↓	↓	•	•	NO IMPACT		
SUB-AREA C	↓	↓	↓	↓	•	•	↓	↓	
SUB-AREA D	↓	↓	↓	↓	•	•	↓	↓	
FINANCIAL CONSIDERATIONS									
REGIONAL	POSS INC. IN PUBLIC COSTS	GREAT INC. IN PUBLIC COSTS	POSS. INC. IN PUBLIC COSTS	GREAT INC. IN PUBLIC COSTS	•	•	—	—	POSS INC IN PU COST CONT
	POSS. POLLUTION CHARGES TO INDUSTRY								
SUB-AREA A	↓	↓	↓	↓	•	•	POSSIBLE INCREASE IN PUBLIC COSTS TO CONTROL		P
SUB-AREA B	↓	↓	↓	↓	•	•	NO IMPACT		
SUB-AREA C	↓	↓	↓	↓	•	•	↓	↓	P
SUB-AREA D	↓	↓	↓	↓	•	•	↓	↓	

— INDICATES INDETERMINATE IMPACT

• PRELIMINARY ANALYSIS UNAVAILABLE

* See: HYGIENIC IMPACT FOR PHYSICAL PUBLIC HEALTH

2 / MATCH LINE TO UPPER PORTION **"OCEAN DISPOSAL PLAN"**

POSSIBLE LONG-TERM ALTERATIONS ON WATER-RELATED CHARACTER	—	—	—	POSSIBLE LIMITATION AS A RESULT OF PHOBIAS AND CUSTOMS	NO IMPACT	NO IMPACT	IMPACT DUE TO PHOBIAS & PREJUDICE BENEFIT FOR DISPERSION	IMPACT DUE TO DISASTER. PHOBIAS & HAZARDOUS AREAS		NO IM-PACT	INC. DIS-PER-SION	—
↓	↓	DECREASE IN VALUE OF COASTAL RECREATION	—	↓	↓	↓	↓	↓	↓	↓	↓	—
NO IMPACT		↓	↓	—	POSSIBLE IMPACT RELATED TO PHOBIAS AND CUSTOMS		↓					—
↓	↓	NO IMPACT		—	NO IMPACT		—	↓	↓			—
↓	↓	↓	↓	—	↓	↓	—	—	—	↓	↓	—
POSSIBLE LONG-TERM DECREASE IN CONVENIENCE OF RECREATION	—	—	—	—	NO IMPACT	NO IMPACT	INCREASE & BENEFIT FOR AESTHETICS; ACCESS & CONVENIENCE FOR RECREATION.	POSSIBLE TO INC. ACCESS & CONV. OF REC. & POSSIBLE AESTHETIC DECREASES	POSSIBLE TO INC. ACCESS TO RECREATION POSSIBLE AESTHETIC DECREASES	—	INC. REC.	POSSIBLE INCREA AESTHETICS, CO & ACCESS TO OP SPACE & REC.
DECREASE IN WATER-RELATED RECREATION & AESTHETICS		DECREASE IN CONVENIENCE & DIVERSITY OF RECREATION		—	↓	↓				—		
—	—	↓	↓	—	POSSIBLE DECREASE IN AESTHETIC VALUES	DECREASE IN VISUAL, ODOROUS & AESTHETIC VALUES IN GENERAL	↓	↓	↓	—		
—	—	NO IMPACT		—	NO IMPACT		POSSIBLE BENEFIT FOR RECREATION	POSS. TO INC. ACCESS & CONV. OF REC. POSS AES-THETIC DETR.		—		
—	—	↓	↓	—	↓	↓	↓	↓	↓	—	↓	↓
NEED FOR REGIONAL REGULATION		NEED FOR REGIONAL REGULATION		—	NEED FOR REGIONAL CONTROL	NO IMPACT	NEED FOR REGIONAL CONTROL	NEED FOR REGIONAL COORDINA-TION	NEED FOR REGIONAL CONTROL	NO IM-PACT	NEED FOR REG. CONT.	NEED FOR RE COORDINA
NEED FOR STRONG SUB-AREA CONTROL		NEED FOR STRONG SUB-AREA CONTROL		—	DECREASE LOCAL AUTONOMY	↓	DECREASE LOCAL AUTONOMY	NEED FOR STRONG SUB-AREA CONTROL			DEC. LOC. AU-TON-OMY	NEED FOR ST SUB-AREA CO
NO IMPACT		↓	↓	—	↓	NEED FOR STRONG SUB-AREA CONTROL	↓	↓	↓	↓	↓	↓
↓	↓	NO IMPACT		—	↓	NO IMPACT	↓	↓	↓	↓	↓	↓
↓	↓	↓	↓	—	↓	↓	↓	↓	↓	↓	↓	↓
—	—	POSSIBLE INCREASE IN PUBLIC COSTS TO CONTROL	GREAT INCREASE IN PUBLIC COSTS TO CONTROL	POSSIBLE LONG-TERM INCREASE IN PUBLIC COSTS	POSSIBLE LONG-TERM INC. AND DEC. IN PUBLIC COSTS AND POLLUTION CHARGES.	NO IMPACT	POSSIBLE LONG-TERM INCREASE IN PUBLIC COSTS FOR WATER	PROBABLE LONG-TERM DECREASE IN PUBLIC COSTS FOR WATER	NO IMPACT	—	—	POSS. LONG-TERM DEC. IN PUB. COSTS	—
POSSIBLE INCREASE IN PUBLIC COSTS TO CONTROL		POSSIBLE ADDITIONAL SUB-AREA COSTS				↓				—	—		—
NO IMPACT		↓	↓			POSSIBLE ADDITIONAL SUB-AREA COSTS		↓		—	—	↓	—
↓	↓	POSSIBLE COSTS SHARING AND POLLUTION CHARGES		↓	↓	NO IMPACT	↓	—	↓	—	—	—	—
↓	↓	↓	↓	↓	↓	↓	↓	—	↓	—	—	—	—

ER.	NO IM-PACT	INC. DIS-PER-SION	—	NO IMPACT	NO IMPACT	POSSIBLE TO ENHANCE PUBLIC VALUES	NO IMPACT	POSSIBLE IMPACT DUE TO PHOBIAS POSSIBLE BENEFIT FOR DISPERSON
	↓	↓	—	↓	↓	↓	POSSIBLE DETRIMENT IN LOCALIZED AREAS DUE TO PREJUDICES AND PHOBIAS	↓
			—				↓	
			—				NO IMPACT	↓
			—	↓	↓	↓	↓	—
	—	INC. REC.	POSSIBLE INCREASE IN AESTHETICS, CONVENIENCE & ACCESS TO OPEN SPACE & REC.	NO IMPACT	NO IMPACT	POSSIBLE TO INCREASE AESTHETIC, CONVENIENCE ACCESS	NO IMPACT	POSSIBLE VARIED ALTERATIONS TO ACCESS
	—	↓	↓	↓	↓	↓	NEED FOR GREAT CONTROL OF AESTHETICS IN LOCALIZED AREAS	↓
	—						↓	
	—						NO IMPACT	↓
	—	↓	↓	↓	↓	↓	↓	—
	NO IM-PACT	NEED FOR REG. CONT.	NEED FOR REGIONAL COORDINATION	NO IMPACT	NO IMPACT	NEED FOR REGIONAL CONTROL	—	NEED FOR REGIONAL COORDINATION
	↓	DEC. LOC. AU-TON-OMY	NEED FOR STRONG SUB-AREA CONTROL	↓	↓	↓	—	NEED FOR STRONG SUB-AREA CONTROL
		↓	↓				—	↓
							—	
	↓	↓	↓	↓	↓	↓	—	↓
	—	POSS. LONG-TERM DEC. IN PUB. COSTS	—	NO IMPACT	NO IMPACT	NEED FOR REGIONAL CONTROL TO *DISTRIBUTE* PUBLIC COSTS, FOR ACQUISITION OF LAND	NEED FOR REGIONAL CONTROL TO DISTRIBUTE PUBLIC COSTS	
	—	↓	—	↓	↓	↓	↓	↓
	—		—				—	
	—	—	—	↓	↓	↓	—	↓
	—	—	—			—	—	—

FIGURE C-9

The spatial distribution aspects of commercial water-related activities and recreation will have less restrictions for regional and sub-area growth as a result of less hydrospheric pollution, and the traditional water-related character of these areas should be improved.

The possible suburban and rural changes in land use for agricultural and industrial diversification due to the reuse potential of tertiary treated wastewater could produce regional long-term increases in employment diversity and income level. Also, for the region and particularly for Sub-areas A and B, substantial long-term increases in opportunities for various types of regional growth and spatial distribution patterns should be expected. The possible increased opportunities for land use changes as a result of additional sources of water supply could offer many choices for optimum regional growth dispersion. However, the mental prejudices, customs, and phobias associated with wastewater for agriculture and human consumption must be considered. The need for regional control, particularly the distribution of reclaimed wastewater, will possibly be greater than with the secondary treatment plan. The possible long-term effects on public costs for wastewater management as a result of the reuse potentials of water and other residuals is unresolved but, along with many other factors, would probably be greatly dependent upon the ultimate cost of tertiary level treatment.

The possible distributive inequities in income, community service, employment, housing, or recreational opportunity and benefit would possibly occur as with the development of the secondary treatment process; however, the overall regional gains from water reuse and wastewater pollution abatement could be channeled into activities and programs that addressed the problems of equitably distributing benefits to the poor as well as all other groups.

(2) Ocean Disposal Alternative (Secondary Treatment)

The social well-being impact assessment of the Ocean Disposal Alternative with secondary treatment is formulated within the context of the social criteria established in Part C, and the preliminary physical impact of this alternative on the ocean, estuary, and associated land areas within the San Francisco Bay and Delta region.

The social effect of the possible continuing accumulation of pollutants in the ocean waters of the Bay area could have a substantial long-term impact on decreasing the employment level, diversity, and stability of water-related activities on the coastal sections of Marin and Sonoma Counties (in Sub-area B) and on San Francisco and San Mateo Counties (in Sub-area A). However, in relation to the remainder of the Bay and Delta area, a possible long-term increase in water-related activities

could occur. These activities could increase employment and income within certain categories in the Bay and Delta areas while possibly having an opposite effect on the coastal areas mentioned earlier which are north and south of the Golden Gate. These possible inequities in the distribution of opportunities for employment and associated incomes as a result of the system should be thoroughly considered within the region as a whole. Also, the viability of these coastal counties, such as Marin, in relation to outdoor recreation and water-related activities should be thoroughly investigated. The long-term effect of the pollutant concentrations at the outfall on coastal recreation, commercial fishing, and institutional research could produce great decreases in the local economic base and future development of the areas. The opportunity for varied choices in the spatial distribution of commercial and recreation water-oriented activities possibly would decrease for the region as a whole and especially for the coastal counties previously mentioned.

The abatement of wastewater pollution within the estuary should increase the development potential of all the bordering counties within the region in relation to water-oriented activities. These improved conditions should help re-establish a euphoric attitude toward the traditional water-related character and atmosphere of the Bay proper and should contribute to the overall mental well-being of the major population.

However, the continued pollution of the coastal ocean waters into the future would possibly decrease the overall mental well-being of the region as a long-term condition. Although pollution abatement in the Bay and estuary would undoubtedly increase the aesthetic values enjoyed by the visiting and resident populations, improvements in the access to and convenience of recreational activities are necessary if the reduced pollution is to be of maximum user benefit. As discussed in the proceeding Social Well-Being Impact Assessment of the Base Condition, the existing and potential demand for water-oriented recreation could increase rapidly for the Bay and Delta area. The greatest benefit, however, to be derived from an increase in facilities would only occur if the activities and facilities were developed as close as possible to high density urban centers.

The essential social concern is that the need for adequate recreational opportunities is important to the mental well-being and physical health of urban residents. However, access and convenience are the primary considerations in establishing the true value of any such developments in recreation activity.

In relation to the effectiveness and value of recreation toward developing environmental amenity, the location, siting, and design of wastewater treatment plants and the related network of conveyance

systems could have a substantial impact on the attitudes and physical health and safety of groups in local development areas. The phobias of people in these areas regarding possible landslides, floods, earthquakes and other disasters are compounded by the fear of large scale system failures, especially those designated as "waste" systems. Also, prejudices against "wastewater" systems in general as possibly detrimental to property values for certain land uses, especially high value residential areas, should be given careful analysis.

Another impact of major consequence in the Ocean Disposal Alternative concerns sludge disposal and locations selected. The plans calls for 22,000 acres of land in the valley of Estero San Antonio in Sonoma County and 44,000 acres in San Benito Counties for sludge disposal sites. These two areas have very high cumulative expressions of visible quality factors and use of such areas for sludge disposal would have great long-term impacts. The relatively narrow enclosures of these areas would result in the sludge disposal sites being highly visible from any developments on the surrounding hills. The possible impacts relating to aesthetics and overall existing area character are very significant.

In-depth public information and public participation at the earliest possible date are key factors in establishing the most acceptable solutions for those most affected by the development of the system and for all concerned.

On the positive side of large and small scale system design, proper public information regarding the proposed design and spatial distribution criteria can result in much greater public acceptance and trust in governmental desires to truly enhance the total amenity of the environment. The demonstrated desire and resulting procedural mechanisms necessary to actually obtain and incorporate the desires and values of those directly affected by proposed systems will greatly increase the governmental credibility toward public participation and genuine concern for local desires.

Within the overall concept of Social Well-Being, there are public values regarding concerns such as scenic vistas, open space, and the scale of development with its implications for the "inhumanness" of physical size or the "warmth" of materials. Although each group would possibly express different aesthetic values or concerns, these are expressions regarding individual human needs, not just desires, and are vital concerns in honestly addressing the social well-being impact of wastewater systems.

However, in regard to amenity and the visual and sensory pleasantness of the proposed wastewater management system, the obvious aesthetic values the informed and vocal majority seem to demand should not be assumed the only values or priorities for concern in the planning and design process.

Those served by the proposed facility are not always the persons displaced or disbenefited from its development. The assumed acculturation of the poor in policy and planning decisions can greatly perpetuate the existing distributive inequities while claiming human betterment for all. In reality, the urban poor have little value, or more important, little need for the so-called aesthetic or scenic values of the middle class majority. Those groups deprived of the middle class daily standards of life often considered as "givens" in the physical and economic planning processes are in reality most often concerned with obtaining those basic social and economic "givens" rather than obtaining or voicing concern for aesthetics. For the urban poor, concerns and needs for food, jobs, and a safe playground for children must take precedent over scenic vistas.

Other conditions which can contribute to the decrease in opportunity to benefit from the proposed wastewater management system. In relation to the possible alterations in land use, activity displacements, and land acquisition required, the Ocean Disposal Plan could have significant short-term and long-term impacts on the displacement of employment and housing. Although the generalized area locations of the conveyance system are preliminary and for conceptual analysis only, the general areas indicated along the perimeter of the South Bay and the western Bay side perimeter of Contra Costa County are the most urbanized areas within the entire Bay and Delta region. Therefore, a detailed local analysis of the most appropriate right-of-way would have to consider many inter-related factors. In relation to the social well-being impact of such possible determinations, the processes for selection should insure that social inequities do not occur, especially among those low income and minority groups who already are disadvantaged. In the localized project areas for treatment plant locations near Redwood City and Petaluma, as well as for the localized areas for the regional conveyance systems, there could be strong, obvious economic justifications for acquisition and displacement of certain families or their employment areas. However, economic considerations are only a portion of the overall socail well-being concern. Since prime lands for public acquisition are usually areas of low property value, minority groups and low income families are most often affected. Those not displaced directly are often left with a neighborhood even less amenable than if there was no overall neighborhood improvement. If there was considerable improvement, rents would possibly increase, thus forcing the poor to other depressed areas where rents are low. The adequate consideration and amelioration of such concerns are paramount in any concern for the social well-being impact of developments which possibly would foster such occurrences. Even if the poor cannot be directly benefited by a wastewater management system, the least effort the development should insure is that their condition is made no worse off by it.

Other legal and institutional considerations resulting from the proposed Ocean Disposal Alternative could have significant impact on public expenditures. Because the necessity for physically controlling pollution requires unified regional efforts, great initial and long-term capital investments for a regional solution could result in substantial increases in the public costs for not only pollution control, but

the necessary pollution abatement and environmental enhancement programs as well. Also, the regional aspects of controlling the sources of the Bay and Delta pollution problem indicate a possible need for a regional regulatory control agency with powers not only to regulate and control wastewater, but all forms of environmental pollution. In relation to the Ocean Disposal Alternative for a wastewater management system, the varied physical elements and social considerations previously discussed are only a few of the factors that must be integrated. The local aspects alone present many possible conflicts. The many governmental jurisdictions involved in acquiring right-of-ways and easements for the conveyance systems of the Ocean Disposal Alternative indicate a great need for a regional authority to at least correlate, if not control, the planning and implementation efforts. Questions of zoning, tax rates, compensation payments, bond issues and many others involved in regional solutions to regional problems seem to demand a regionally unified system of overall control of growth and development if the future Bay and Delta area growth is to be environmentally enhancing as well as economically efficient and socially equitable to its inhabitants.

(3) Estuarine Disposal Alternative

The social well-being impact assessment of the Estuarine Disposal Plan is formulated within the context of the social criteria established in Chapter IV and the preliminary physical impacts of this alternative on the ocean, estuary, and associated land areas within the San Francisco Bay and Delta region. 1/

The slight increases in the long-term accumulation of toxicants in the ocean and estuary as resulting from this alternative could possibly produce a long-term decreasing effect on the level, diversity and stability of employment among water-related commercial activities within the Bay and Delta region, particularly those related to commercial fishing. Associated with this possible employment decrease, certain groups could experience a long-term decrease in income level. Those localities within the region, such as Marin County, which are strongly oriented toward the continued growth of outdoor recreation and water-related activities, should be given further in-depth analysis when considering such alternatives. However, possible long-term increases in total growth rates and development potential of water-oriented commercial land-side activities, commercial and sport fishing, and all forms of ocean and estuarine water-related recreation could occur as a result of flow augmentation under this plan. As a result of this dichotomy, a definitive interrelated social as well as economic and environmental analysis must be further established in order to develop a premise from which to formulate policy decisions for subareas as well as regional growth and development.

1/ See Figure C-10.

Although present levels would be reduced, the continued long-term accumulations of hydrospheric pollutants as a result of the Estuarine Disposal Alternative could produce long-term alterations in the water-related character that permeates the Bay and Delta region, especially those areas most densely urbanized. This empirical phenomenon of character, although physchological and individualist in impact, is no less valuable to the region as a major component of its infra-structure than are the financial institutions that bolster the Bay region as a national economic pivot. Also, long-term continued Bay and Delta pollution accumulation could cause substantial decreases in the overall aesthetic value enjoyed by visitors and profited from by residents. The possible long-term degradation of existing recreation sites, and the probable limitations for future such developments in close proximity to the large urban centers, could greatly decrease the general euphoria of present and future urban populations due to limited access of and convenience to recreational areas.

With less pollutants entering the estuary, the resulting maintenance of marshland species should held to maintain and possibly increase the long-term diversity of water-oriented recreational and commercial activities and the related employment and income of associated and dependent groups. Although helping to sustain the diversity of regional recreation development, these activities associated with wildlife communities would not ameliorate the long term impacts on the aesthetics, customs and traditional Bay area character caused by continued long-term pollutant increases.

Sludge disposal on 66,000 acres in portions of six counties could have a significant impact. Sludge disposal in Solano County could have an impact on the already declining agricultural employment in this area. Also, such land alterations could impact on the overall growth and development opportunities of the entire county. Many of these sludge disposal sites in the five other counties would probably be designated permanent open space under agricultural development in the long run. Use of these areas instead for sludge disposal could greatly impact on the associated areas in terms of future development opportunities. Also, possible dramatic alterations of the existing land uses could effect the associated employment and income of many groups dependent upon the maintenance or growth of existing development.

Existing customs regarding environment and the common agricultural uses that possibly would be terminated could cause significant impacts on decreasing the content of residents within the area. Such impacts could accelerate the decreasing agricultural employment and further decrease the income of these groups. The possible distributive inequity results are obvious. Also, prejudices and even phobias of many people against waste materials in general could decrease the area contentment. The impact on area amenity due to the visual (and possibly odorous) effects of sludge and its associated operations could further decrease the desirability and traditional character of the area. These and possibly other impacts taken simultaneously or over an extended period could alter the economic and social structure of the areas, especially certain agricultural income and employment groups. (Note: All the preceding discussions within the plan also relate directly to the social well-being impact of the Combination Disposal Plan.)

	PRELIMINARY HYDROSPHERIC PHYSICAL IMPACTS			
	POLLUTANTS IN OCEAN	POLLUTANTS IN ESTUARY	EUTROPHIC RATE IN ESTUARY	SALINITY IN ESTUARY
PHYSICAL CHANGE ⇨	SLIGHT INCREASE IN LONG TERM ACCUMULATION		REDUCED	REDUCED
SOCIAL PARAMETERS ⇩				
EMPLOYMENT				
REGIONAL	POSSIBLE LONG TERM DECREASE IN DIVERSITY		•	POSSIBLE LONG TERM INCREASE IN DIVERSITY
SUB-AREA A	↓	↓	•	↓
SUB-AREA B	↓	↓	•	↓
SUB-AREA C	NO IMPACT	↓	•	↓
SUB-AREA D	↓	↓	•	↓
INCOME				
REGIONAL	POSSIBLE LONG TERM DECREASE AMONG CERTAIN CATEGORIES		•	POSSIBLE LONG TERM INCREASES AMONG CERTAIN CATEGORIES
SUB-AREA A	POSSIBLE INEQUITIES TO CERTAIN CATEGORIES		•	↓
SUB-AREA B	↓	↓	•	↓
SUB-AREA C	NO IMPACT	↓	•	↓
SUB-AREA D	↓	↓	•	↓
GROWTH AND DEVELOPMENT				
REGIONAL	POSSIBLE LONG TERM IMPACT ON OVERALL GROWTH AND DEVELOPMENT OF WATER RELATED ACTIVITIES	POSSIBLE LONG TERM DECREASE IN OPPORTUNITY FOR RECREATION & OPEN SPACE LEVEL & DISTRIBUTION	•	POSSIBLE LONG TERM INCREASES IN DIVERSTIY OF DEVELOPMENT
SUB-AREA A			•	↓
SUB-AREA B	↓	↓	•	↓
SUB-AREA C		↓	•	↓
SUB-AREA D	↓	—	•	↓

(SEE LEGEND BELOW)

SOCIAL WELL-BEING IMPACT ASSESSMENT
ESTUARINE DISPOSAL PLAN

AL IMPACTS		PRELIMINARY TERRESTRIAL PHYSICAL IMPACTS						
SALINITY IN ESTUARY	SPECIES IN OCEAN & ESTUARY	REUSE POTENTIAL OF WASTE RESIDUALS	GROUND COVER OR SOIL CONDITIONS		SOURCES FOR WATER SUPPLY (POTENTIAL)	GENERAL LAND USE			DISPLACEME OF ACTIVIT
			WATER	SLUDGE		URBAN	SUBURBAN	RURAL	
REDUCED	MAINTAIN MARSH INHABITANTS	SLIGHT IN LOCALIZED AREAS	NO IMPACT	LOCAL-IZED IMPACT	NO CHANGE	SMALL CHANGE	MODERATE CHANGE	SMALL CHANGE	SMALL LOCAL IMPACTS
POSSIBLE LONG TERM INCREASE IN DIVERSITY	POSSIBLE INCREASE IN LONG TERM DIVERSITY	LITTLE IMPACT	NO IMPACT	POSSIBLE IMPACT ON LOCALIZED AGRICULTURE DIVERSITY	POSSIBLE LONG TERM LIMITATIONS ON DIVERSITY	—	—	—	—
					—	POSSIBLE SHORT TERM INCREASE OR DECREASE IN CERTAIN LOCAL AREAS	POSSIBLE SHORT TERM INCREASES IN CERTAIN LOCAL AREAS		POSSIBLE LONG TER DISPLACEMENTS IN LOCALIZED PROJECT
					—				
				NO IMPACT	—				
POSSIBLE LONG TERM INCREASES AMONG CERTAIN CATEGORIES	POSSIBLE LONG TERM INCREASES POSSIBLE FOR GREATER DISTRIBUTIVE EQUITY	LITTLE IMPACT	NO IMPACT	NO IMPACT	POSSIBLE FOR INCREASE IN LONG TERM DISTRIBUTIVE INEQUITY	NO IMPACT	—	NO IMPACT	NO IMPACT
					—	POSSIBLE FOR GREATER DISTRIBU-TIVE EQUITY OR INEQUITY	—		POSSIBLE FOR GREATER DISTR TIVE EQUITY OR INEQUITY IN LOCALIZED PRO AREAS
				POSSIBLE FOR LOCALIZED INCREASE IN DISTRIBUTIVE INEQUITY	—		—	POSS. FOR LOCALIZED INCREASE IN DIST. INEQUITY	
				NO IMPACT	—		—	NO IMPACT	
POSSIBLE LONG TERM INCREASES IN DIVERSTIY OF DEVELOPMENT	INCREASE IN RECREATION DIVERSITY AND DISTRIBUTION	LITTLE IMPACT	NO IMPACT	NO IMPACT	DECREASED OPPORTUNITY FOR VARIED DEVELOPMENT AND SPATIAL DISTRIBUTION	POSSIBLE TO INCREASE OPEN SPACE	POSSIBLE TO INCREASE AND CONTROL OPEN SPACE	INCREASE IN OPPOR-TUNITY FOR ALL DEVEL OPMENT	NO IMPACT
						POSSIBLE TO INCREASE OPEN SPACE AND COMMUNITY SERVICE			POSSIBLE ALTE TO COMMUNITY SERVICE FACIL LOCALIZED ARE
				POSSIBLE ALTERATIONS OF EXISTING AGRICULTURE PATTERN					
				NO IMPACT					

MATCH LINE TO LOWER PORTION "ESTUARINE DISPOSAL PLAN"

L PHYSICAL IMPACTS					PRELIMINARY REQUIREMENTS FOR SYSTEM DEVELOPMENT		
D USE		DISPLACEMENT OF ACTIVITIES	ATMOSPHERIC CONDITIONS	TERRESTRIAL SPECIES	LAND ACQUISITION REQUIRED	CONSTRUCTION OF TREATMENT PLANTS	CONSTRUCTION OF CONVEYANCE SYSTEM
N	RURAL						
TE S	SMALL CHANGE	SMALL LOCALIZED IMPACTS	NO IMPACT		FOR 7 TREATMENT PLANTS FOR SLUDGE DISPOSAL FOR CONVEYENCE	SEVEN PLANTS	FROM COLLECTORS TO PLANTS FROM PLANTS TO DISCHARGE AREAS FROM PLANTS TO SLUDGE DISPOSAL SITES
	—	—	NO IMPACT		NO IMPACT	BENIFIT FOR SHORT TERM EMPLOYMENT IN CONSTRUCTION	
SHORT TERM IN CERTAIN AS		POSSIBLE LONG TERM DISPLACEMENTS IN LOCALIZED PROJECT AREAS					
	NO IMPACT	NO IMPACT	NO IMPACT		—	NO IMPACT	POSSIBLE SLIGHT INCREASE FOR SHORT TIME
		POSSIBLE FOR GREATER DISTRIBU - TIVE EQUITY OR INEQUITY IN LOCALIZED PROJECT AREAS			POSSIBLE FOR GREATER DISTRIBU - TIVE EQUITY OR INEQUITY IN LOCALIZED AREAS	POSSIBLE FOR GREATER DISTRIBU - TIVE EQUITY IN LOCALIZED AREAS	POSSIBLE FOR GREATER DISTRIBU - TIVE EQUITY
	POSS. FOR LOCALIZED INCREASE IN DIST. INEQUITY						
	NO IMPACT						
TO AND E	INCREASE IN OPPOR - TUNITY FOR ALL DEVEL OPMENT	NO IMPACT	NO IMPACT	NO IMPACT	POSSIBLE TO COORDI - NATE DEVELOPMENT, SPACIAL DIST., OPEN SPACE REC.	NO IMPACT	POSSIBLE ALTERA - TIONS TO REGIONA, GROWTH PATTERN
		POSSIBLE ALTERATIONS TO COMMUNITY SERVICE FACILITIES IN LOCALIZED AREAS			POSSIBLE TO INCREASE COMMUNITY SERVICE	POSSIBLE TO INCREASE LOCALIZED COMMUNITY SERVICE	POSSIBLE BENEFIT TO OPEN SPACE AND RECREATION DEVELOPMENT

N "

Sheet 1 of 2 FIGURE C-10

PUBLIC HEALTH (MENTAL ATTITUDE)* AND SAFETY					
REGIONAL	POSSIBLE LONG-TERM ALTERATION OF WATER-RELATED CHARACTER	POSSIBLE LONG-TERM DECREASE TO VALUE OF WATER-RELATED CHARACTER	•	—	INCRE BAY A
SUB-AREA A	↓	↓	•	—	
SUB-AREA B	↓		•	—	
SUB-AREA C	NO IMPACT		•	—	
SUB-AREA D	↓	↓	•	—	
AMENITY					
REGIONAL	POSSIBLE LONG TERM ALTERATIONS ON COASTAL AESTHETICS	POSSIBLE LONG TERM DECREASE IN AESTHETICS, CONVENIENCE & ACCESS TO OPEN SPACE AND REC.	•	POSSIBLE LONG TERM INCREASE IN AESTHETICS CONVENIENCE AND ACCESS TO OPEN SPACE AND REC.	INCREA DIVERS RECREA
SUB-AREA A	↓	↓	•	↓	
SUB-AREA B	↓		•		
SUB-AREA C	NO IMPACT		•		
SUB-AREA D	↓	↓	•	↓	
REGULATORY CONTROL					
REGIONAL	NEED FOR COORDINATED FEDERAL, STATE AND REGIONAL REGULATION	NEED FOR REGIONAL CONTROL	•	—	NEED
SUB-AREA A	↓	↓	•	—	
SUB-AREA B	↓		•	—	
SUB-AREA C	↓		•	—	
SUB-AREA D	—	↓	•	—	
FINANCIAL CONSIDERATIONS					
REGIONAL	POSSIBLE LONG TERM INCREASE IN PUBLIC COSTS FOR CONTROL		•	—	
SUB-AREA A	↓	↓	•	—	
SUB-AREA B	↓		•	—	
SUB-AREA C	↓		•	—	
SUB-AREA D	↓	↓	•	—	

— INDICATES INDETERMINATE IMPACT

• PRELIMINARY ANALYSIS UNAVAILABLE

● See: HYGIENIC IMPACT FOR PHYSICAL PUBLIC HEALTH

2 MATCH LINE TO UPPER PORTION "ESTUARINE DISPOSAL PLAN"

—	INCREASE TRADITIONAL BAY VALUES, CUSTOMS AND ACTIVITIES	LITTLE IMPACT	NO IMPACT	NO IMPACT	NO IMPACT	POSSIBLE IMPACTS DUE TO PREJU - DICES PHOBIAS AND DISASTER AREAS	NO IMPACT	—
—	↓	↓	↓	↓	↓	↓	↓	—
—	↓	↓	↓	POSSIBLE DECREASE DUE TO PHOBIAS AND CUSTOMS	↓	↓	↓	—
—	↓	↓	↓	NO IMPACT	↓	↓	↓	—
—	↓	↓	↓	↓	↓	↓	↓	—
LE LONG TERM ASE IN AESTHETICS NIENCE AND ACCESS IN SPACE AND REC.	INCREASE IN CONVENIENCE, DIVERSITY AND ACCESS TO RECREATION ACTIVITIES	LITTLE IMPACT	NO IMPACT	NO IMPACT	NO IMPACT	INCREASE IN ASTHE- TICS, ACCESS AND CONVENIENCE FOR RECREATION	—	POSSIBLE INCREASE IN AESTHETICS, CONVENIENC AND ACCESS TO OPEN SPA AND REC.
↓	↓	↓	↓	DECREASE IN VISUAL AND ODOROUS AESTHETICS	↓	↓	—	↓
↓	↓	↓	↓	NO IMPACT	↓	↓	—	↓
↓	↓	↓	↓	↓	↓	↓	—	↓
↓	↓	↓	↓	↓	↓	↓	—	↓
—	NEED FOR REGIONAL CONTROL	LITTLE IMPACT	—	NO IMPACT	NEED FOR REGIONAL CONTROL	NEED FOR REGIONAL COORDINATION		NEED FOR REGIONA COORDINATION
—	↓	↓	—	↓	↓	↓		NEED FOR STRONG SUBAREA CONTROL
—	↓	↓	—	NEED FOR STRONG SUB - AREA CONTROL	↓	↓		↓
—	↓	↓	—	NO IMPACT	↓	↓		↓
—	↓	↓	—	↓	↓	↓		↓
—	—	LITTLE IMPACT	—	NO IMPACT	POSSIBLE LONG TERM INCREASES IN PUBLIC COSTS FOR WATER	NO IMPACT		—
—	—	↓	—	↓	↓	↓		—
—	—	↓	—	POSSIBLE ADDITIONAL SUBAREA COSTS	↓	↓		—
—	—	↓	—	NO IMPACT	↓	↓		—
—	—	↓	—	↓	↓	↓		—

ACT	—	NO IMPACT	NO IMPACT	POSSIBLE TO ENHANCE PUBLIC VALUES	NO IMPACT	POSSIBLE ALTERATIONS DUE TO PHOBIAS AND PREJUDICES
	—	↓	↓	↓	POSSIBLE IMPACTS IN LOCALIZED AREAS DUE TO PREJUDICES AND PHOBIAS	↓
	—	↓	↓	↓	↓	↓
	—	↓	↓	↓	↓	↓
—	POSSIBLE INCREASE IN AESTHETICS, CONVENIENCE AND ACCESS TO OPEN SPACE AND REC.	NO IMPACT	NO IMPACT	POSSIBLE TO INCREASE AESTHETICS, CONVENIENCE AND ACCESS TO OPEN SPACE AND REC.	NO IMPACT	POSSIBLE INCREASE OPPORTUNITY FOR ACCESS, AND CONVENIENCE OF REC.
—	↓	↓	↓	↓	NEED FOR GREAT CONTROL OF AESTHETICS IN LOCALIZED AREAS	POSSIBLE DETRIMENT TO AESTHETICS
—	↓	↓	↓	↓	↓	↓
—	↓	↓	↓	↓	↓	↓
L	NEED FOR REGIONAL COORDINATION	NO IMPACT	NO IMPACT	NEED FOR REGIONAL COORDINATION	—	NEED FOR REGIONAL COORDINATION
	NEED FOR STRONG SUBAREA CONTROL	↓	↓	NEED FOR STRONG SUBAREA CONTROL	—	NEED FOR STRONG SUBAREA CONTROL
	↓	↓	↓	↓	—	↓
	↓	↓	↓	↓	—	↓
	↓	↓	↓	↓	—	↓
	↓					
	—	NO IMPACT	NO IMPACT	NEED FOR REGIONAL COORDINATION	—	NEED FOR REGIONAL COORDINATION
	—	↓	↓	NEED FOR REGIONAL AND SUBAREA CONTROL	—	NEED FOR REGIONAL AND SUBAREA CONTROL
	—	↓	↓	↓	—	↓
	—	↓	↓	↓	—	↓
	—	↓	↓	↓	—	↓

Sheet 2 of 2 FIGURE C-10

In the Bay and Delta region as a whole, the Estuarine Disposal Alternative would require the construction of seven wastewater treatment plants. The plant locations would be near Vallejo, Richmond, San Rafael, San Francisco, Oakland, Sacramento, and Antioch. Also, a region-wide network of conveyance lines for wastewater, outfalls, discharges, and sludge disposal would be needed. The physical construction and development of these treatment plant and conveyance systems would result in short-term increases in construction employment in localized areas throughout the Bay and Delta region, and the resultant income level to certain construction categories possibly would increase. The long-term impact of this alternative on the opportunities for more diversified employment, varied patterns of development, or choices for the spatial distribution of activities could be dependent on whether large scale reuse of the reclaimed wastewater is developed. (Note: Most of the preceding discussions regarding the social impact of treatment plants also relates to portions of the Combination Disposal Alternative.)

In relation to the legal and institutional considerations for development of the Estuarine Disposal Alternative, the need for a regional effort in coordinating the various jurisdictional, financial and physical construction processes is obvious. Questions of land acquisitions for treatment plants or conveyance systems, right-of-way, design criteria, zoning, compensation payments, bond issues and many others are regional in nature because the pollution problem and its causes and effects are regional in origin and impact.

Many of the social concerns regarding the distributive equity of income, employment, recreation or displacements and the opportunities and benefits from the development of the system were discussed in the preceding Base Condition and Ocean Disposal Alternative impact assessments. Therefore, the impact of the development of the Estuarine Disposal Alternative on these vital questions is of equal importance and relevance here as with those plans. The questions of who actually benefits and who actually has the opportunity to benefit from the improvements in water quality and the associated recreation increases are vital in addressing the social well-being impact of the Estuarine Disposal Alternative, as well as the others. The honest addressment of these questions and those raised in the preceding plans are a priority if the social well-being of the population and its constituent individuals is truly a consideration. (For example discussions of benefits and distributive equity, see the Social Well-Being Impact of the Base Condition and Ocean Disposal Alternative.)

(4) Land Disposal Alternative

The social well-being impact assessment of the Land Disposal Alternative is formulated within the context of the social criteria established above and the preliminary physical impacts of this alternative on the ocean, estuary, and associated land areas within the San Francisco Bay and Delta region. 1/

The elimination of wastewater discharges into the ocean and estuary of the Bay and Delta region is the primary result of the Land Disposal Alternative. The resultant significant reductions in regional hydrospheric pollution level and future accumulations should have a long-term impact on the basic infrastructure of the region. Ocean and estuary pollutant reductions should greatly help to stabilize and increase employment levels and diversity of water-oriented activities throughout the entire Bay and Delta region, especially for Delta area locations of high pollutant concentrations and certain Bay area localities. In the Bay region, the coastal and bay locations in Sub-areas A and B which are heavily dependent upon water-related commercial and recreation activities should experience long-term employment or income increases within these activities. Increases in the number and quality of habitat for ocean and estuary wildlife species as a result of wastewater pollution abatement and elimination should help to increase a variety of opportunities for regional and local recreation. The overall water-oriented employment and recreation increases should result in regional as well as local income increases for many related employment groups.

Increases in the overall ocean, Bay and Delta water quality of the area should have a long-term impact on enhancing the water-related character associated with the San Francisco Bay region. The value of this character as a tangible impact is evidenced by the tourism industry. Commercial activity within the region should also increase from the recreational opportunities of this water-related character and the expected pollution reductions should greatly enhance the development of these activities. Also, the overall amenity values associated with the Bay urban area should greatly improve if new and improved facilities with greater access and convenience were developed. As stated previously in the Base Condition impact analyses, the locational factors of recreation activity are of prime importance in urban areas when considering the equitable distribution of benefits to the urban resident, especially low income and minority or disadvantaged groups.

(The following social well-being impact discussion is also related to Sub-area D of the Combination Disposal Alternative.)

Within the Land Disposal Alternative, the possibility of a high reuse of residuals from the wastewater treatment process and the high reuse potential of reclaimed water should have a significant long-term impact on the diversity, growth, and stability, not only for agriculture, but for industrial or any other activities dependent upon an abundant, readily accessible water supply. The resulting employment opportunities should benefit the entire region as well as individual sub-areas.

1/ See Figure C-11.

	PRELIMINARY HYDROSPHERIC PHYSICAL IMPACTS			
	POLLUTANTS IN OCEAN	POLLUTANTS IN ESTUARY	EUTROPHIC RATE IN ESTUARY	SALINITY IN ESTUARY
PHYSICAL CHANGE ⇨	NONE	NONE	NO CHANGE	INCREASE IN SOUTH BAY
SOCIAL PARAMETERS ⇩				
EMPLOYMENT				
REGIONAL	LONG-TERM INCREASES IN DIVERSITY AND STABILITY		•	LONG-TERM DECREASE IN DIVERSITY
SUB-AREA A	↓	↓	•	↓
SUB-AREA B	↓	↓	•	↓
SUB-AREA C	—	↓	•	—
SUB-AREA D	—	↓	•	—
INCOME				
REGIONAL	POSSIBLE LONG-TERM INCREASES IN LEVEL OF WATER-RELATED ACTIVITIES	LONG-TERM INCREASES IN LEVEL OF WATER-RELATED ACTIVITIES	•	POSSIBLE LONG-TERM DECREASES AMONG CERTAIN CATEGORIES
SUB-AREA A	↓	↓	•	POSSIBLE LONG-TERM DECREASE IN DISTRIBUTIVE EQUITY
SUB-AREA B	↓	↓	•	—
SUB-AREA C	—	↓	•	—
SUB-AREA D	—	↓	•	—
GROWTH AND DEVELOPMENT				
REGIONAL	LONG-TERM INCREASE IN ALL TYPES OF DEVELOPMENT (ESPECIALLY WATER-RELATED)	LONG-TERM INCREASED OPPORTUNITY FOR ALL TYPE DEV. & DIST.	•	POSSIBLE LONG-TERM DECREASE IN DIVERSITY
SUB-AREA A		INCREASES IN DEVELOPMENT CHOICES POSSIBLE INCREASES IN COMMUNITY SERVICE	•	DECREASE IN RECREATIONAL OPPORTUNITY
SUB-AREA B		↓	•	—
SUB-AREA C	—	↓	•	—
SUB-AREA D	—	↓	•	—

(SEE LEGEND BELOW)

2

SOCIAL WELL-BEING IMPACT ASSESSMENT
LAND DISPOSAL PLAN

AL IMPACTS		PRELIMINARY TERRESTRIAL PHYSICAL IMPACTS						
SALINITY IN ESTUARY	SPECIES IN OCEAN & ESTUARY	REUSE POTENTIAL OF WASTE RESIDUALS	GROUND COVER OR SOIL CONDITIONS		SOURCES FOR WATER SUPPLY (POTENTIAL)	GENERAL LAND USE			DISPLACEM OF ACTIVIT
			WATER	SLUDGE		URBAN	SUBURBAN	RURAL	
INCREASE IN SOUTH BAY	INCREASES	VERY HIGH	GREAT CHANGES		HIGH FOR ALL USES	LITTLE CHANGE	MODERATE CHANGE	VERY GREAT CHANGE	LOW TO MODE IN SOME AR
LONG-TERM DECREASE IN DIVERSITY	POSSIBLE INCREASE IN LONG-TERM DIVERSITY	LONG-TERM INCREASES IN DIVERSITY	IMMEDIATE & LONG-TERM LOCALIZED EFFECTS FROM WATER ON LEVEL & DIVERSITY OF AGRI. EMPLOYMENT POSSIBLE LONG-TERM EFFECT ON INDUSTRY		LONG-TERM INCREASES IN OPPORTUNITY FOR DIVERSITY GROWTH AND STABILITY FOR INDUSTRY & AGRICULTURE	POSSIBLE SHORT-TERM INC. IN CONST. POSS. INC. IN INDUSTRIAL DUE TO SUB-AREA & RURAL LIMITATIONS	SHORT-TERM INC. IN CONST. POSS. ALT. OF INDUSTRIAL PATTERN SHORT-TERM INC. IN CONST. SHORT-TERM INC. IN CONST. SLIGHT ALT. IN IND. SHORT-TERM INC. IN CONST. DEC. IN OPP. FOR IND. DEV. SHORT-TERM INC. IN CONST. POSS. ALT. FOR IND. DEV.	LONG-TERM ALT. OF AGRI. SLIGHT ALT. IN AGRI. POSS. LONG-TERM ALT. IN AGRI. & INDUST. GREAT ALT. IN AGRI.	POSSIBLE LONG-T IMPACT ON AGRI. LEVEL OR DIVERSI LITTLE IMP POSSIBLE LONG-T IMPACT ON EMPL LEVEL OR DIVERS AGRI. OR IND.
POSSIBLE LONG-TERM DECREASES AMONG CERTAIN CATEGORIES	POSS. LONG-TERM INC. IN DIVERSITY & NUMBERS POSS. FOR GREATER DIST. EQUITY	POSSIBLE LONG-TERM INCREASES IN OVERALL LEVEL POSSIBLE FOR GREATER DISTRIBUTIVE EQUITY	LONG-TERM ALTERATION OF SOME INCOME GROUPS POSSIBLE TO INCREASE LEVEL OF AGRI. GROUPS POSS. LONG-TERM EFFECT ON DIST. EQUITY AMONG SEVERAL GROUPS.		POSS. LONG-TERM INC. IN OVERALL LEVEL POSS. FOR GREATER DIST. EQUITY	POSSIBLE SHORT-TERM INC. IN LEVEL	SHORT-TERM INC. DUE TO CONST. POSS. LONG-TERM INC. DUE TO NEW IND. LITTLE IMPACT SHORT-TERM INC. DUE TO CONSTRUCTION POSSIBLE LONG-TERM INC. DUE TO NEW IND.	POSSIBLE SHORT-TERM INC. IN LEVEL DUE TO CONST. POSSIBLE LONG-TERM INC. DUE TO AGRI.	POSSIBLE LONG-T IMPACT ON AGRIC RELATED LEVEL LITTLE IMP POSSIBLE LONG-T IMPACT ON AGRIC LEVEL
POSSIBLE LONG-TERM DECREASE IN DIVERSITY	INCREASE IN RECREATIONAL DIVERSITY & DISTRIBUTION	POSSIBLE GREATER OPPORTUNITY FOR SPATIAL DISTRIBUTION OF ACTIVITIES	LONG-TERM ALTERATIONS ON FUTURE DEVELOPMENT PATTERNS, ESPECIALLY AGRICULTURE.		LONG-TERM INCREASES IN OPPORTUNITY FOR DIVERSIFIED DEVELOPMENT INCREASE COMMUNITY SERVICE		POSSIBLE LIMITATIONS ON INDUSTRIAL LOCATIONS	INCREASED OPP. FOR AGRI. & OPEN SPACE DECREASE OPP. FOR INDUST.	LITTLE IMP
DECREASE IN RECREATIONAL OPPORTUNITY			POSSIBLE SLIGHT ALTERATIONS						POSSIBLE LOCAL IMPACT ON EXIS FUTURE AGRICUL INDUSTRIAL PAT
			SIGNIFICANT LONG-TERM ALTERATIONS ON ALL FUTURE DEV. PATTERNS (ESPECIALLY AGRI.)			POSSIBLE LIMITATIONS ON CHOICE			

MATCH LINE TO LOWER PORTION "LAND DISPOSAL PLAN"

TRIAL PHYSICAL IMPACTS					PRELIMINARY REQUIREMENTS FOR SYSTEM DEVELOPMENT		
LAND USE		DISPLACEMENT OF ACTIVITIES	ATMOSPHERIC CONDITIONS	TERRESTRIAL SPECIES	LAND ACQUISITION REQUIRED	CONSTRUCTION OF TREATMENT PLANTS	CONSTRUCTION OF CONVEYANCE SYSTEM
URBAN	RURAL						
ERATE ANGE	VERY GREAT CHANGE	LOW TO MODERATE IN SOME AREAS	MODERATE IN LOCALIZED AREAS	MODERATE TO GREAT CHANGE	VERY LARGE AREAS FOR SPRAYING AND SLUDGE DISPOSAL STORAGE PONDS AND REUSE RESERVOIRS	CONSTRUCTION OF PUMPING FACILITIES LAGOONS AND RESERVOIRS	FOR COLLECTION TO AERATION LAGOONS TO LAND-DISPOSAL SITES TO REUSE AREA
ORT-TERM INC. IN CONST. ALT. DUSTRIAL ERM	LONG-TERM ALT. OF AGRI.	POSSIBLE LONG-TERM IMPACT ON AGRI. & INDUST. LEVEL OR DIVERSITY	NO IMPACT	—	POSSIBLE SIGNIFICANT IMPACT ON EXISTING AGRI. CATEGORIES	POSSIBLE SHORT-TERM INCREASES IN CONSTRUCTION CATEGORY	POSSIBLE SHORT-TERM INCREASES FOR CONSTRUCTION & LONG-TERM INC. FOR MAINTENANCE
ORT-TERM INC. IN CONST.		LITTLE IMPACT	POSSIBLY COULD AFFECT LONG-TERM AGRICULTURE DIVERSITY IN VALLEY AREAS	—	POSSIBLE LONG-TERM IMPACT ON EXISTING CATEGORIES		
ORT-TERM INC. IN CONST. NT ALT. D.	SLIGHT ALT. IN AGRI.			—	POSS. SIGNIFICANT IMPACT ON AGRI.. POSS. LONG-TERM IMPACTS ON DIVERSITY		
ORT-TERM INC. IN CONST. IN OPP. ND. DEV.	POSS. LONG TERM ALT. IN AGRI. & INDUST.	POSSIBLE LONG-TERM IMPACT ON EMPLOYMENT LEVEL OR DIVERSITY IN AGRI. OR IND.	NO IMPACT	—			
ORT-TERM INC. IN CONST. ALT. ND. DEV.	GREAT ALT. IN AGRI.			—			
T-TERM UE TO . LONG- INC. DUE W IND.	POSSIBLE SHORT-TERM INC. IN LEVEL DUE TO CONST. POSSIBLE LONG-TERM INC. DUE TO AGRI.	POSSIBLE LONG-TERM IMPACT ON AGRICULTURAL-RELATED LEVEL	NO IMPACT	—	POSSIBLE LONG-TERM IMPACTS ON AGRI. GROUPS	POSSIBLE SHORT-TERM INCREASES FOR CONSTRUCTION GROUPS	
TTLE PACT		LITTLE IMPACT	POSSIBLY COULD AFFECT INCOME LEVEL OF GROUPS DEPENDENT UPON EXISTING CONDITIONS	—	POSSIBLE LONG-TERM IMPACTS ON EQUITY FOR CERTAIN GROUPS		
T-TERM DUE TO TRUCTION				—			
IBLE -TERM DUE TO IND.		POSSIBLE LONG-TERM IMPACT ON AGRICULTURAL LEVEL	NO IMPACT	—			
				—			
IBLE TATIONS USTRIAL ATIONS	INCREASED OPP. FOR AGRI. & OPEN SPACE DECREASE OPP. FOR INDUST.	LITTLE IMPACT	NO IMPACT	POSSIBLE IMPACT ON DIVERSITY OF RECREATIONAL DEVELOPMENT	POSSIBLE LONG-TERM IMPACT ON INDUSTRIAL & AGRICULTURAL SPATIAL DISTRIBUTION	POSSIBLE LONG-TERM IMPACT ON DEVELOPMENT & SPATIAL DISTRIBUTION OPPORTUNITIES	SIGNIFICANT IMPACT ON LONG-TERM DEVELOPMENT PATTERN POSSIBLE TO INCREASE AND CONTROL OPEN SPACE IMPACT ON GROWTH PATTERNS POSSIBLE TO INCREASE & CONTROL OPEN SPACE
			POSSIBLE IMPACT ON FUTURE DEVELOPMENT IN LOCALIZED AREAS				
		POSSIBLE LOCALIZED IMPACT ON EXISTING & FUTURE AGRICULTURAL & INDUSTRIAL PATTERNS			POSSIBLE SIGNIFICANT DECREASES ON LOCALIZED OVERALL GROWTH CHOICES & ACTIVITY DISTRIBUTION PATTERNS		
			NO IMPACT				

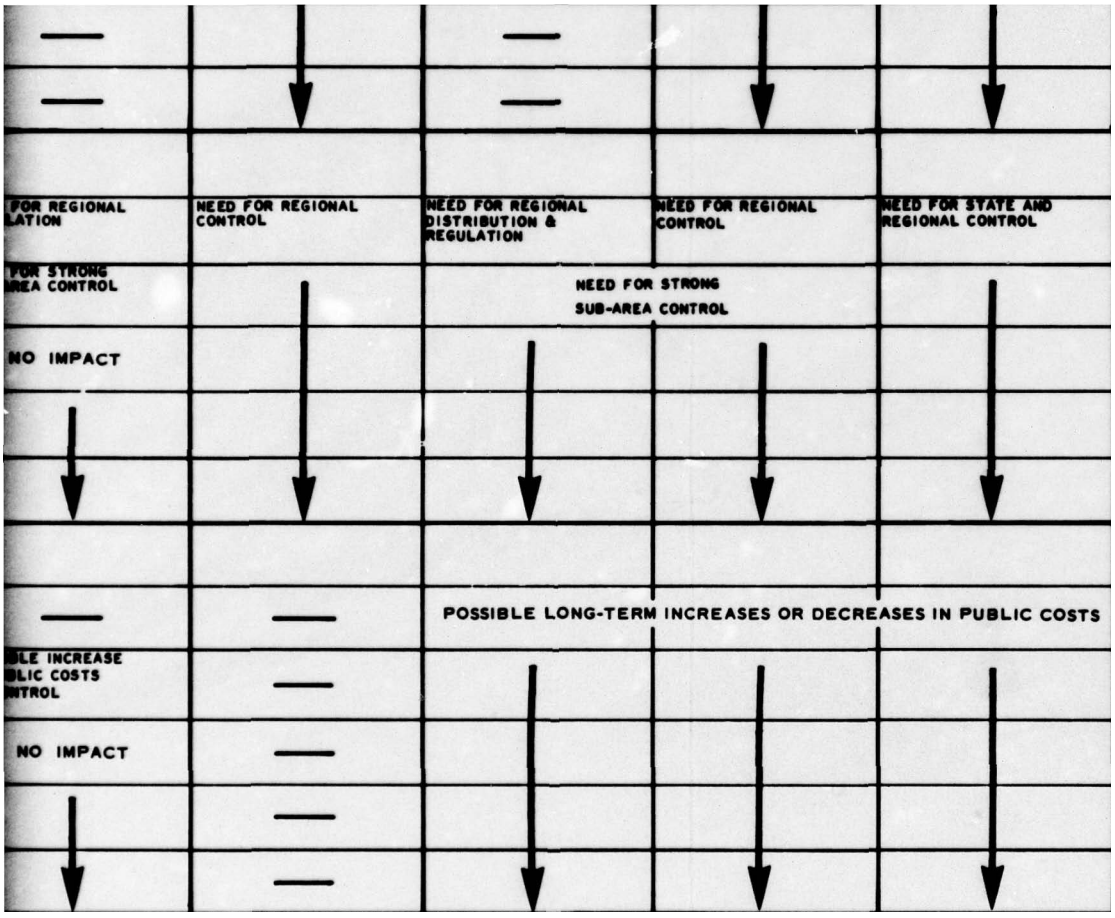
 FIGURE C-11

PUBLIC HEALTH (MENTAL ATTITUDE)* AND SAFETY				
REGIONAL	LONG-TERM INCREASES IN WATER-RELATED CHARACTER	INCREASE IN ALL WATER-RELATED VALUES	•	POSSIBLE LONG-TERM ALTERATIONS IN WATER-RELATED CHARACTER
SUB-AREA A	↓	↓	•	↓
SUB-AREA B	↓	↓	•	NO IMPACT
SUB-AREA C	↓	↓	•	↓
SUB-AREA D	↓	↓	•	↓
AMENITY				
REGIONAL	INCREASES IN OVERALL, AESTHETICS, CONVENIENCE AND ACCESS TO OPEN SPACE AND WATER-RELATED ACTIVITIES		•	POSSIBLE LONG-TERM DECREASE IN CONVENIENCE OF RECREATION DECREASE IN WATER-RELATED RECREATION & AESTHETICS
SUB-AREA A	↓	↓	•	
SUB-AREA B	↓	↓	•	—
SUB-AREA C	—	↓	•	—
SUB-AREA D	—	↓	•	—
REGULATORY CONTROL				
REGIONAL	NEED FOR FEDERAL, STATE AND REGIONAL REGULATION	NEED FOR REGIONAL JURISDICTIONAL CONTROL	•	NEED FOR REGIONAL REGULATION
SUB-AREA A	↓	↓	•	NEED FOR STRONG SUB-AREA CONTROL
SUB-AREA B	↓	↓	•	NO IMPACT
SUB-AREA C	—	↓	•	↓
SUB-AREA D	—	↓	•	↓
FINANCIAL CONSIDERATIONS				
REGIONAL	POSSIBLE LONG-TERM INCREASE IN PUBLIC COSTS FOR CONTROL		•	—
SUB-AREA A	↓	↓	•	POSSIBLE INCREASE IN PUBLIC COSTS TO CONTROL
SUB-AREA B	↓	↓	•	NO IMPACT
SUB-AREA C	—	↓	•	↓
SUB-AREA D	—	↓	•	↓

— INDICATES INDETERMINATE IMPACT

• PRELIMINARY ANALYSIS UNAVAILABLE

* See: HYGIENIC IMPACT FOR PHYSICAL PUBLIC HEALTH


FOR REGIONAL LATION
NEED FOR REGIONAL CONTROL
NEED FOR REGIONAL DISTRIBUTION & REGULATION
NEED FOR REGIONAL CONTROL
NEED FOR STATE AND REGIONAL CONTROL
FOR STRONG REA CONTROL
NEED FOR STRONG SUB-AREA CONTROL
NO IMPACT
POSSIBLE LONG-TERM INCREASES OR DECREASES IN PUBLIC COSTS
LE INCREASE LIC COSTS NTROL
NO IMPACT

POSSIBLE IMPACT DUE TO EXISTING LAND-USE CUSTOMS	IMPACT ON VALUES OR CUSTOMS REGARDING EXISTING ACTIVITIES	LITTLE IMPACT	—	POSSIBLE LONG-TERM IMPACT DUE TO VALUE OF EXISTING LAND-USE CUSTOMS	LITTLE IMPACT	POSSIBLE SIGNIFICANT IMPACT DUE TO CUSTOMS, PHOBIAS OR PREJUDICES FOR LARGE WASTE SYSTEMS
		POSSIBLE DECREASE IN VALUE OF PRESENT CHARACTER OF LOCAL AREAS	POSSIBLE IMPACT ON PRESENT CHARACTER & GROUP VALUES OF EXISTING SPECIES AFFECTED			
		LITTLE IMPACT				
POSSIBLE LONG-TERM VISUAL IMPACTS	POSSIBLE IMPACT ON LONG-TERM AESTHETICS RELATED TO COMPATABILITY OF ACTIVITIES	NO IMPACT	—	—	—	POSSIBLE LONG-TERM IMPACT ON AESTHETICS DUE TO DESIGN CRITERIA POSSIBLE TO INCREASE ACCESS AND CONVENIENCE OF OPEN SPACE
LOCALIZED IMPACTS ON VISTAS		LOCALIZED DECREASE IN AESTHETIC VALUE OF EXISTING CONDITIONS	POSSIBLE LOCALIZED IMPACT ON AESTHETIC VALUE OF ASSOCIATED RECREATION ACTIVITIES	POSSIBLE IMPACT ON LOCAL AESTHETIC VALUE OF EXISTING LAND ACQUIRED	POSSIBLE SHORT-TERM IMPACT ON AESTHETICS DUE TO CONSTRUCTION PROCESSES	
POSSIBLE LARGE LONG-TERM IMPACT ON VISUAL AESTHETICS OF LAND PATTERNS		LITTLE IMPACT				
NEED FOR STRONG REGIONAL CONTROL OF GEN. USE AREAS	LITTLE IMPACT	NO IMPACT	NEED FOR REGIONAL CONTROL	NEED FOR STRONG REGIONAL COORDINATION		NEED FOR STRONG REGIONAL CONTROL
NEED FOR STRONG SUB-AREA CONTROL OF LOC. SITES	NEED FOR STRONG SUB-AREA CONTROL			NEED FOR STRONG SUB-AREA CONTROL		NEED FOR STRONG SUB-AREA COORDINATION
		NO IMPACT				
COMPENSATION ALTERATIONS	IMPACTS DUE TO ALTERATIONS IN TAX BASE, ACQUISITIONS OF LAND, COMPENSATION PAYMENTS	—	—	POSSIBLE GREAT INITIAL AND LONG-TERM PUBLIC EXPENDITURES POSSIBLE LARGE REGIONAL BOND ISSUES AND ALTERATIONS IN LOCAL TAX BASES		
		—	—			
		—	—			
		—	—			
		—	—			

Sheet 2 of 2 FIGURE C-11

The associated personal and family income gains from increased job opportunity could greatly aid in the alleviation of many of the economic problems associated with the poor and disadvantaged. Programs to help direct and distribute the opportunities to those in greatest need of help are a prime measure of the effectiveness of the equitable distribution of benefits. As stated earlier in the assessment of the Base Condition and Ocean and Estuarine Disposal Alternatives, the distributive equity of resultant project benefits should be a prime consideration in addressing the social impact of proposals.

This reuse of residuals and wastewater for certain uses, however, could have substantial impacts on public attitudes and overall community identity in the sub-areas. Many people hold prejudices and even phobias regarding the use of "waste" products and their uses in agriculture or in water supply for human consumption. These possible attitudes should be thoroughly understood, documented, analyzed and dealt with through public information, education and participation early in the planning effort.

The overall impacts of general land use changes and the possible displacement of activities as a result of the Land Disposal alternative could have a significant influence upon the existing activities and overall growth and development of the Bay and Delta area. The impact upon certain localities within the sub-areas could be even more significant.

Urban, suburban, and rural land use and activity changes as a result of this alternative and its associated impacts possibly would increase construction employment for a short time in the entire region. In suburban and rural areas the land use alterations could produce long-term impacts on the existing agricultural patterns. The large areas needed for spraying, sludge disposal, storage ponds, and reuse reservoirs in Contra Costa, Sacramento, Solano, and San Benito counties could decrease the future development choice of these areas, especially since these land areas are of less than 10 percent slope and suitable also for possible industrial development in the future. Even assuming these areas should remain agricultural, existing crop patterns could be greatly altered. Persons or groups also dependent upon continued employment and income from existing agricultural use could be affected.

The overall community or area identity in relation to attitudes and values of local residents in the Marin/Solano and Santa Clara/San Benito areas could be significantly affected due to the conversion of prime valley lands into "waste" treatment areas. Their prejudices, customs, or even phobias regarding "waste" in general should receive careful consideration. Also, the impact on compatibility of land uses and the alteration in the traditional agricultural character of the localities must be thoroughly understood.

In the Marin/Sonoma and Santa Clara/San Benito areas the local disposal sites could have very significant aesthetic impacts due to their distinct visibility from the surrounding hills. Also, the visual character could alter drastically as a result of humidity increases from spraying possibly trapped by the encircling valley enclosures. These conditions could produce impacts of significant magnitude.

The physical requirements for the construction and development of the Land Disposal Alternative involve many factors such as land acquisition, reservoir and lagoon sitings, and conveyance system construction. The regional and local employment and income impacts of these activities could have significant long-term influence on the growth and development patterns in the site locations as well as for the entire region.

The design and construction criteria used would greatly determine the probable aesthetic impact due to the magnitude of this system's overall scale and the formulation of these criteria is of paramount importance. Significant local participation and consultation with the allied design professions of architecture, landscape architecture, and urban and regional planning are vital.

The legal and institutional considerations as a result of this alternative are extensive. The regulatory control needed to construct the systems, with the large land acquisitions, right-of-ways, and jurisdictional boundaries to be considered, indicate a great need for a strong regional organization with powers to acquire land, issue bonds, collect revenues, zone, establish design, construction and performance standards, acquire easements, and perform othersuch duties as necessary to adequately plan, design, construct and maintain a region-wide wastewater management system. Local control of existing systems and duties possibly would continue with strong coordination and correlation with the regional agency. The possible long-term increases in public costs for pollution abatement and control indicate a great need for maximum efficiency, and the associated economies of scale a regionally developed system would allow is an important consideration.

The social impact concerns of distributive equity in relation to the Land Disposal Alternative are similar to those addressed in the preceding Base Condition, Ocean Disposal, and Estuarine Disposal Alternatives, and are no less applicable here. Concerns for convenience and access regarding the urban poor and the actual recreational benefit they have opportunities to use are crucial social impact concerns. Also, the actual value to the disadvantaged of some aesthetic benefits are very questionable, especially when the concerns of the poor are often far

more basic needs such as a job, more food, or a safe place for a child to play. Therefore, the social well-being impact of the Land Disposal Alternative, like the previous alternatives, will greatly affect the lives of all the people, but in a variety of ways to a variety of different people with different needs. (For example discussions of benefit and distribution, see the Social Well-Being Impact of the Base Condition and Ocean Disposal Alternative.)

(5) Combination Disposal Alternative.

The social well-being impact assessment of the Combination Disposal Plan is formulated within the context of the social criteria established above and the preliminary physical impacts of this alternative on the ocean, estuary, and associated land areas within the San Francisco Bay and Delta region. 1/

The preliminary hydrospheric physical impacts for the Combination Disposal Alternative are essentially the same as those hydrospheric physical impacts of the Estuarine Disposal Alternative. As a result, the social well-being impact from continued accumulations of ocean and estuary pollutants on the region and sub-areas would be essentially the same. Also, the impacts regarding eutrophication, salinity, species propagation, and sludge disposal would produce similar social impacts for the region and sub-areas under both the Combination and Estuarine Disposal Alternatives. The impact of the construction and development of wastewater treatment plants also would be the same for both plans, except 7 plants would be needed for the Estuarine Alternative and only 3 for the Combination Disposal Alternative.

As previously stated, the Combination Disposal Alternative has similar physical and social well-being impacts on sub-areas A and C as the Estuarine Disposal Alternative. However, the physical and social impacts on the counties in sub-areas B and D are similar to the impacts on those areas under the Land Disposal Alternative, with the exception of not impacting certain areas as discussed below.

The physical and resulting social well-being impacts of the Combination Disposal Alternative will include the possibility of long-term accumulation of wastewater pollutants in the ocean and estuary. Though significantly reduced compared to the Estuarine Disposal Alternative the social well-being impact on employment, income, and recreational activity should continue at a reduced level. Within the land disposal portion, the reuse potentials of residuals from the wastewater treatment processes and the potential for large scale reuse of water should possibly increase opportunities for employment, income levels, industrial development, and spatial distribution choices. These possible long-term impacts however, would not be so great for the region as compared with the total possible impact under the Land Disposal Alternative.

1/ See Figure C-12

The Sub-areas A and C not directly involved and influenced by the land disposal operations of the Combination Disposal Alternative possibly would not receive the potential reuse impacts previously mentioned unless there were regional control and distribution regulations in effect. However, San Benito County, although not included as part of sub-area A, would not be physically or socially impacted as a result of this alternative. Also, the impacts associated with the development of the land disposal conveyance system would not influence Sub-areas A and C in the Combination Disposal Alternative.

Many important social well-being impacts from this alternative like the other alternatives, are concerned with the equitable distribution of income, community services, and the opportunities for all persons to benefit from environmental improvements and increases in the national wealth. Problems such as displacement, convenience and access to recreation, job opportunities, and the actual benefits low income groups are able to receive from project development and environmental enhancement are crucial to the assessment of the social well-being impact. These considerations within the Combination Disposal Alternative as well as the other alternatives, are of primary importance. (For example discussions of benefits and distribution, see the Social Well-Being Impact of the Base Condition, and Ocean Disposal Alternative.)

	PRELIMINARY HYDROSPHERIC PHYSICAL IMPACTS			
	POLLUTANTS IN OCEAN	POLLUTANTS IN ESTUARY	EUTROPHIC RATE IN ESTUARY	SALINITY IN ESTUARY
PHYSICAL CHANGE ⇨	SLIGHT INCREASE IN LONG-TERM ACCUMULATION	SLIGHT INCREASE IN LONG-TERM ACCUMULATION	REDUCED	REDUCED
SOCIAL PARAMETERS ⇩				
EMPLOYMENT				
REGIONAL	POSSIBLE LONG-TERM DECREASE IN DIVERSITY	POSSIBLE LONG-TERM DECREASE IN DIVERSITY	•	POSSIBLE LONG-TE INCREASE IN DIVER
SUB-AREA A	↓	↓	•	↓
SUB-AREA B	↓		•	
SUB-AREA C	NO IMPACT		•	
SUB-AREA D	↓	↓	•	↓
INCOME				
REGIONAL	POSSIBLE LONG-TERM DECREASE AMONG CERTAIN CATEGORIES	POSSIBLE LONG-TERM DECREASE AMONG CERTAIN CATEGORIES	•	POSSIBLE LONG-TER INCREASE AMONG CERTAIN CATEGORIE
SUB-AREA A	POSSIBLE INEQUITIES TO CERTAIN CATEGORIES	POSSIBLE INEQUITIES TO CERTAIN CATEGORIES	•	↓
SUB-AREA B	↓	↓	•	
SUB-AREA C	NO IMPACT		•	
SUB-AREA D	↓	↓	•	↓
GROWTH AND DEVELOPMENT				
REGIONAL	POSSIBLE LONG-TERM IMPACT ON OVERALL GROWTH & DEVELOPMENT OF WATER-RELATED ACTIVITIES	POSSIBLE LONG-TERM DECREASE IN OPPORTUNITY FOR RECREATION AND OPEN SPACE LEVEL & DISTRIBUTION	•	POSSIBLE LONG-TE INCREASE IN DIVER OF DEVELOPMENT
SUB-AREA A	↓		•	↓
SUB-AREA B	↓	↓	•	
SUB-AREA C	NO IMPACT		•	
SUB-AREA D	↓	—	•	↓

(SEE LEGEND BELOW)

2

SOCIAL WELL-BEING IMPACT ASSESSMENT
COMBINATION DISPOSAL PLAN

SICAL IMPACTS		PRELIMINARY TERRESTRIAL PHYSICAL IMPACTS						
SALINITY IN ESTUARY	SPECIES IN OCEAN & ESTUARY	REUSE POTENTIAL OF WASTE RESIDUALS	GROUND COVER OR SOIL CONDITIONS		SOURCES FOR WATER SUPPLY (POTENTIAL)	GENERAL LAND USE			DISPLAC OF ACT
			WATER	SLUDGE		URBAN	SUBURBAN	RURAL	
REDUCED	MAINTAIN MARSH INHABITANT	HIGH	MODERATE CHANGES		HIGH FOR CERTAIN AREAS AND USES	LITTLE CHANGE	SLIGHT TO MODERATE CHANGE	MODERATE TO GREAT CHANGE	LOW TO MO IN SOME
POSSIBLE LONG-TERM INCREASE IN DIVERSITY	POSSIBLE INCREASE IN LONG-TERM DIVERSITY	LOCALIZED LONG-TERM INCREASES IN DIVERSITY	LOCALIZED IMME & LONG-TERM EFFECT ON LEVEL & DIVERSITY OF AGRI. EMPLOYMENT ● POSS. LONG-TERM EFFECT ON IND.		POSSIBLE LONG-TERM LOCALIZED INC. FOR GROWTH & STABILITY OF AGRI. & IND.	POSSIBLE SHORT-TERM INC. DUE TO CONST.	POSSIBLE AREA SHORT-TERM INC. DUE TO CONST.		POSSIBLE LON IMPACT ON AG & INDUSTRIAL OR DIVERSITY
		NO IMPACT	NO IMPACT		NO IMPACT		NO IMPACT	NO IMPACT	LITTLE I
		POSSIBLE INCREASE IN LONG-TERM DIVERSITY	POSSIBLE LONG-TERM EFFECT ON LEVEL & DIVERSITY OF AGRI. EMPLOYMENT		POSSIBLE LONG-TERM INCREASES FOR GROWTH & DEV. FOR AGRI. OR IND.		POSS. SHORT-TERM INC. DUE TO CONST. POSS. LONG-TERM INC. IN IN IND. OR AGRI.		POSS. LONG-T ON EMPLOY. L DIVERSITY IN
		NO IMPACT	NO IMPACT						
		POSSIBLE INCREASES IN DIVERSITY	POSSIBLE LONG-TERM EFFECT ON LEVEL & DIVERSITY OF AGRI. EMPLOYMENT						
POSSIBLE LONG-TERM INCREASE AMONG CERTAIN CATEGORIES	POSSIBLE LONG-TERM INCREASES POSSIBLE FOR GREATER DISTRIBUTIVE EQUITY	POSSIBLE LOCALIZED LONG-TERM INCREASES IN OVERALL LEVEL	LOCALIZED LONG-TERM ALTERATION OF SOME INCOME GROUPS POSSIBLE TO INCREASE LEVEL OF AGRI. GROUPS		POSSIBLE LOCALIZED LONG-TERM INCREASES FOR AGRI. OR IND. GROUPS	POSSIBLE SHORT-TERM INCREASE IN LEVEL	AREA SHORT-TERM INC. IN CONST. LONG-TERM INC. IN AGRI. OR IND.		POSSIBLE L IMPACT ON A
		NO IMPACT	NO IMPACT		NO IMPACT		NO IMPACT	NO IMPACT	LITTLE
		POSSIBLE LONG-TERM INCREASES AND GREATER DISTRIBUTIVE EQUITY	POSSIBLE LONG-TERM EFFECT ON AGRI. GROUPS POSSIBLE TO INC. DIST. EQUITY.		POSSIBLE LONG-TERM INC. FOR IND. OR AGRI. GROUPS POSSIBLE FOR GREATER DIST. EQUITY.		SHORT-TERM INCREASE IN CONST. LONG-TERM INCREASE IN AGRI. OR IND.		POSS. LONG- ON AGRI. LE
		NO IMPACT	NO IMPACT						
		POSSIBLE LONG-TERM INCREASES AND GREATER DISTRIBUTIVE EQUITY.	POSSIBLE LONG-TERM EFFECT ON AGRI. GROUPS POSSIBLE TO INC. DIST. EQUITY.						
POSSIBLE LONG-TERM INCREASE IN DIVERSITY OF DEVELOPMENT	INCREASE IN RECREATION DIVERSITY & SPATIAL DISTRIBUTION	POSSIBLE GREATER LOCALIZED OPPORTUNITY FOR SPATIAL DISTRIBUTION OF ACTIVITIES	LONG-TERM LOCALIZED ALTERATIONS ON FUTURE DEVELOPMENT PATTERNS, ESPECIALLY AGRICULTURE		LONG-TERM LOCALIZED OPP. FOR SPATIAL DIST. CHOICES FOR IND. & AGRI.	POSSIBLE TO ENHANCE OPEN SPACE DEV.	OPPORTUNITY FOR SPATIAL DISTRIBUTION CHOICES		LITTLE
		NO IMPACT	NO IMPACT		NO IMPACT		NO IMPACT	NO IMPACT	NO I
		POSSIBLE FOR GREATER SPATIAL DISTRIBUTION CHOICES	LONG-TERM LOCALIZED EFFECTS ON AGRICULTURE DEVELOPMENT PATTERNS		LONG-TERM OPP. FOR CHOICES IN SPATIAL DISTRIBUTION OF IND. & AGRI.		OPPORTUNITY FOR SPATIAL DISTRIBUTION CHOICES		POSS. LOCA ON EXISTIN AGRI. & IN
		NO IMPACT	NO IMPACT						
		POSSIBLE FOR GREATER SPATIAL DISTRIBUTION	LONG-TERM LOCALIZED EFFECTS ON AGRICULTURE DEVELOPMENT PATTERNS						

MATCH LINE TO LOWER PORTION "COMBINATION DISPOSAL PLAN"

RESTRIAL PHYSICAL IMPACTS					PRELIMINARY REQUIREMENTS FOR SYSTEM DEVELOPMENT		
RAL LAND USE		DISPLACEMENT OF ACTIVITIES	ATMOSPHERIC CONDITIONS	TERRESTRIAL SPECIES	LAND ACQUISITION REQUIRED	CONSTRUCTION OF TREATMENT PLANTS	CONSTRUCTION OF CONVEYANCE SYSTEM
UBURBAN	RURAL						
SLIGHT TO MODERATE CHANGE	MODERATE TO GREAT CHANGE	LOW TO MODERATE IN SOME AREAS	MODERATE TO HIGH IN CERTAIN LOCALIZED AREAS	MODERATE CHANGE IN LOCALIZED AREAS	LARGE AREAS FOR SPRAYING AND SLUDGE DISPOSAL, STORAGE PONDS AND REUSE RESERVOIRS AREA FOR THREE PLANTS	THREE PLANTS PUMPING FACILITIES, LAGOONS AND RESERVOIRS	FOR COLLECTION TO TREATMENT PLANT TO AERATION LAGOONS TO LAND DISPOSAL SITES REUSE AREAS
POSSIBLE AREA SHORT-TERM INC. DUE TO CONST.		POSSIBLE LONG-TERM IMPACT ON AGRICULTURAL & INDUSTRIAL LEVEL OR DIVERSITY	NO IMPACT	—	POSSIBLE IMPACT ON EXISTING AGRICULTURAL CATEGORIES	POSSIBLE SHORT-TERM INCREASE IN CONSTRUCTION	POSSIBLE SHORT-TERM INCREASE FOR CONST. & LONG-TERM INC. FOR MAINT.
NO IMPACT	NO IMPACT	LITTLE IMPACT	↓	NO IMPACT	LITTLE IMPACT	↓	↓
SS. SHORT-TERM INC. E TO CONST. OSS. LONG-TERM INC. IN N IND. OR AGRI.		POSS. LONG-TERM IMPACT ON EMPLOY. LEVEL OR DIVERSITY IN AGRI. OR IND.	POSSIBLY COULD AFFECT LONG-TERM AGRI. IN VALLEY AREAS	—	POSSIBLE SMALL IMPACT ON EXISTING CATEGORIES POSSIBLE LONG-TERM ON DIVERSITY		
↓	↓	↓	NO IMPACT	—	↓	↓	↓
↓	↓	↓	↓	—	↓	↓	↓
AREA SHORT-TERM INC. IN CONST. LONG-TERM INC. IN AGRI. OR IND.		POSSIBLE LONG-TERM IMPACT ON AGRI. LEVEL	NO IMPACT	—	POSSIBLE LONG-TERM IMPACT ON CERTAIN CATEGORIES	POSSIBLE SHORT- TERM INCREASES FOR CONSTRUCTION GROUPS	
NO IMPACT	NO IMPACT	LITTLE IMPACT	↓	NO IMPACT	LITTLE IMPACT	↓	↓
HORT-TERM NCREASE IN CONST. ONG-TERM INCREASE N AGRI. OR IND.		POSS. LONG-TERM IMPACT ON AGRI. LEVEL	POSSIBLY COULD AFFECT INCOME LEVEL OF GROUPS DEPENDENT UPON EXISTING CONDITIONS	—	POSSIBLE LONG-TERM IMPACTS ON EQUITY FOR CERTAIN GROUPS		
↓	↓	↓	NO IMPACT	—	↓	↓	↓
↓	↓	↓	↓	—	↓	↓	↓
OPPORTUNITY FOR SPATIAL DISTRIBUTION CHOICES		LITTLE IMPACT	NO IMPACT	—	POSSIBLE LONG-TERM IMPACT ON IND. & AGRI. SPATIAL DIST.	POSSIBLE LONG-TERM IMPACT ON DEVELOPMENT & SPATIAL DISTRIBUTION OPPORTUNITIES	SIGNIFICANT IMPACTS ON REGIONAL OPEN SPACE & OVERALL SPATIAL DISTRIBUTION PATTERNS
NO IMPACT	NO IMPACT	NO IMPACT	POSSIBLE IMPACT ON FUTURE DEVELOPMENT IN LOCALIZED AREAS	NO IMPACT	POSSIBLE IMPACT ON URBAN OPEN SPACE PATTERNS	LITTLE IMPACT	POSSIBLE IMPACT ON URBAN OPEN SPACE PATTERNS
OPPORTUNITY FOR SPATIAL DISTRIBUTION CHOICES		POSS. LOCALIZED IMPACT ON EXISTING & FUTURE AGRI. & IND. PATTERNS	NO IMPACT	PROBABLE IMPACT ON DIVERSITY OF REC. DEV.	POSSIBLE LONG-TERM IMPACT ON SPATIAL DISTRIBUTION CHOICES	POSSIBLE LONG-TERM IMPACT ON OVERALL DEVELOPMENT PATTERNS	SIGNIFICANT IMPACTS ON REGIONAL OPEN SPACE & OVERALL SPATIAL DISTRIBUTION PATTERNS
↓	↓	↓	↓	↓	↓	↓	↓
↓	↓	↓	↓	↓	↓	↓	↓

L PLAN"

Sheet 1 of 2 FIGURE C-12

PUBLIC HEALTH (MENTAL ATTITUDE)* AND SAFETY					
REGIONAL	POSSIBLE LONG-TERM ALTERATIONS OF WATER-RELATED CHARACTER	POSSIBLE LONG-TERM DECREASE TO VALUE OF WATER-RELATED CHARACTER	•	—	INCR VA
SUB-AREA A	↓	↓	•	—	
SUB-AREA B	↓	↓	•	—	
SUB-AREA C	NO IMPACT	↓	•	—	
SUB-AREA D	↓	↓	•	—	
AMENITY					
REGIONAL	POSSIBLE LONG-TERM ALTERATIONS ON COASTAL AESTHETICS	POSSIBE LONG-TERM DECREASE IN AESTHETICS, CONVENIENCE AND ACCESS TO OPEN SPACE & RECREATION	•	POSSIBLE LONG-TERM DECREASE IN AESTHETICS, CONVENIENCE AND ACCESS TO OPEN SPACE AND RECREATION	INCR DIVE TO R
SUB-AREA A	↓	↓	•	↓	
SUB-AREA B	↓	↓	•	↓	
SUB-AREA C	NO IMPACT	↓	•	↓	
SUB-AREA D	↓	↓	•	↓	
REGULATORY CONTROL					
REGIONAL	NEED FOR COORDINATED FEDERAL, STATE AND REGIONAL REGULATION	NEED FOR REGIONAL CONTROL	•	—	
SUB-AREA A	↓	↓	•	—	
SUB-AREA B	↓	↓	•	—	
SUB-AREA C	↓	↓	•	—	
SUB-AREA D	—	↓	•	—	
FINANCIAL CONSIDERATIONS					
REGIONAL	POSSIBLE LONG-TERM INCREASE IN PUBLIC COSTS TO CONTROL		•	—	
SUB-AREA A	↓	↓	•	—	
SUB-AREA B	↓	↓	•	—	
SUB-AREA C	↓	↓	•	—	
SUB-AREA D	↓	↓	•	—	

— INDICATES INDETERMINATE IMPACT

• PRELIMINARY ANALYSIS UNAVAILABLE

* See: HYGIENIC IMPACT FOR PHYSICAL PUBLIC HEALTH

2

MATCH LINE TO UPPER PORTION "COMBINATION DISPOSAL PLAN"

—	INCREASE TRADITIONAL BAY VALUES, CUSTOMS AND ACTIVITIES	POSSIBLE LOCALIZED LIMITATIONS ON USE AS A RESULT OF PREJUDICES, PHOBIAS OR CUSTOMS RE-GARDING WASTE MATERIALS	LOCALIZED IMPACT ON CUSTOMS OR PREJUDICES REGARDING TREATED WASTE MATERIAL USES	POSSIBLE SUB-AREA IMPACTS ON OPPORTUNITIES OF DISPERSION	POSS. IM-PACT DUE TO PHOBIAS OF SYS. FAILURE			IMPACT ON VALUES CUSTOMS REGARDI EXISTING ACTIVIT
—	↓	NO IMPACT	NO IMPACT	NO IMPACT	↓	LITTLE IMPACT	NO IMPACT	NO IMPACT
—	↓	POSSIBLE USE LIMITATIONS DUE TO PREJUDICES AGAINST WASTE MATERIAL REUSE	IMPACT ON CUSTOMS OR PREJUDICES REGARDING TREATED WASTE MATERIAL USES	POSSIBLE INCREASED OPPORTUNITIES FOR DISPERSION	↓	POSSIBLE IMPACT ON COMMUNITY IDENTITY	POSSIBLE IMPACT DUE TO TRADI-TIONAL LAND-USE CUSTOMS	IMPACT ON VALUES CUSTOMS REGARDI EXISTING ACTIVITI
—	↓	NO IMPACT	NO IMPACT	↓	↓	↓	↓	↓
—	↓	POSSIBLE USE LIMITATIONS DUE TO PREJUDICES AGAINST WASTE MATERIAL REUSE	IMPACT ON CUSTOMS OR PREJUDICES REGARDING TREATED WASTE MATERIAL USES	↓	↓	↓	↓	↓
SSIBLE LONG-TERM CREASE IN AESTHETICS, NVENIENCE AND ACCESS OPEN SPACE AND CREATION	INCREASE IN CONVENIENCE, DIVERSITY AND ACCESS TO RECREATION ACTIVITIES	—	LOCALIZED ALTERATIONS ON EXISTING AESTHETIC CHARACTERISTICS	POSSIBLE INCREASE IN AESTHETIC DIVERSITY FOR SUB-AREAS	POSS. SHORT & LONG-TERM IM-PACT ON VISUAL AES-THETICS	POSSIBLE LONG-TERM IMPACT ON VISUAL AESTHETICS		POSSIBLE IMPACT ON LONG-TERM AESTHETI RELATED TO COMPATA
↓	↓	—	NO IMPACT	NO IMPACT	↓	NO IMPACT		IMPACT ON URB AESTHETICS BY SY
↓	↓	—	LONG-TERM IMPACT ON EXISTING AESTHETIC CHARACTERISTICS	POSSIBLE LONG-TERM INCREASE IN AESTHETIC DIVERSITY FOR WATER-RELATED ACTIVITIES	↓	POSSIBLE LONG-TERM IMPACT ON VISUAL AESTHETICS		POSSIBLE SESTHETIC DUE TO COMPATABILI OF ACTIVITIES IMPACT ON URBAN AESTHETICS BY SYST
↓	↓	—	NO IMPACT	↓	↓	↓	↓	↓
↓	↓	—	LONG-TERM IMPACT ON EXISTING AESTHETIC CHARACTERISTICS	↓	↓	↓	↓	↓
—	NEED FOR REGIONAL CONTROL	NEED FOR REGIONAL DISTRIBUTION AND CONTROL	NEED FOR REGIONAL COORDINATION	NEED FOR REGIONAL	NEED FOR REGIONAL COOR. SYSTEM DESIGN	NEED FOR SUB-AREAS A & C AND SUB-AREAS B & D INTEGRATION AND CONTROL		NEED FOR STRON SUB-AREA CONTR
—	↓	NO IMPACT	NO IMPACT	↓	↓	↓	↓	↓
—	↓	NEED FOR SUB-AREA CONTROL	NEED FOR STRONG SUB-AREA CONTROL	↓	↓	↓	↓	↓
—	↓	NO IMPACT	NO IMPACT	↓	↓	↓	↓	↓
—	↓	NEED FOR SUB-AREA CONTROL	SUB-AREA	↓	↓	↓	↓	↓
—	—	POSSIBLE LONG-TERM INCREASES OR DECREASES IN PUBLIC COSTS	POSSIBLE TO HELP AMELIORATE NEED FOR INCREASES IN PUBLIC COSTS		NEED FOR REGIONAL COOR-DINATION	POSSIBLE COMPENSATION PAYMENTS POSSIBLE ALTERATIONS IN TAX BASE		IMPACTS DUE TO ALTERATIONS IN TA ACQUISITIONS OF LA COMPENSATION PAY
—	—	↓	↓	↓	↓	POSSIBLE COMPENSATION PAYMENTS		↓
—	—	↓	↓	↓	↓	POSSIBLE COMPENSATION PAYMENTS POSSIBLE ALTERATIONS IN TAX BASE		↓
—	—	↓	↓	↓	↓	↓	↓	↓

	IMPACT ON VALUES ON CUSTOMS REGARDING EXISTING ACTIVITIES	NO IMPACT	—	POSSIBLE LONG-TERM IMPACT DUE TO VALUE OF EXISTING LAND-USE CUSTOMS	LITTLE IMPACT	POSSIBLE SIGNIFICANT IMPACTS DUE TO CUSTOMS, PHOBIAS OR PREJUDICES FOR LARGE WASTEWATER SYSTEMS
NO IMPACT	NO IMPACT	↓	NO IMPACT	↓	↓	↓
SSIBLE IPACT UE TO RADI- TIONAL LAND-USE USTOMS	IMPACT ON VALUES ON CUSTOMS REGARDING EXISTING ACTIVITIES	POSSIBLE DECREASE IN VALUE OF PRESENT CHARACTER OF LOCAL AREAS	POSSIBLE IMPACT ON PRESENT VALUE OF EXISTING SPECIES AFFECTED	↓	↓	↓
↓	↓	↓	↓	↓	↓	↓
LONG- CT S	POSSIBLE IMPACT ON LONG-TERM AESTHETICS RELATED TO COMPATABILITY	NO IMPACT	NO IMPACT	—	—	POSSIBLE LONG-TERM IMPACT ON AESTHETICS DUE TO DESIGN CRITERIA POSSIBLE TO INCREASE ACCESS & CONVENIENCE OF OPEN SPACE
ACT	IMPACT ON URBAN AESTHETICS BY SYSTEM	↓	↓	LITTLE IMPACT	LITTLE IMPACT	↓
LONG- ACT CS	POSSIBLE SESTHETIC IMPACT DUE TO COMPATABILITY OF ACTIVITIES IMPACT ON URBAN AESTHETICS BY SYSTEM	LOCALIZED DECREASE IN AESTHETIC VALUE OF EXISTING CONDITIONS	POSSIBLE LOCALIZED IMPACT ON AESTHETIC VALUE OF ASSOCIATED RECREATION ACTIVITIES	POSSIBLE IMPACT ON LOCAL AESTHETIC VALUE OF EXISTING LAND ACQUIRED	POSSIBLE SHORT-TERM IMPACT ON AESTHETICS DUE TO CONSTRUCTION PROCESS	↓
↓	↓	↓	↓	↓	↓	↓
A & C EAS RATION DL	NEED FOR STRONG SUB-AREA CONTROL	NO IMPACT	NEED FOR REGIONAL CONTROL	NEED FOR SUB-AREAS A & C AND SUB-AREAS B & D INTEGRATION AND CONTROL		NEED FOR REGIONAL COORDINATION
↓	↓	↓	NEED FOR STRONG SUB-AREA CONTROL	↓	↓	↓
↓	↓	NEED FOR STRONG LOCAL CONTROL	↓	↓	↓	↓
↓	↓	↓	↓	↓	↓	↓
PENSATION ERATIONS	IMPACTS DUE TO ALTERATIONS IN TAX BASE, ACQUISITIONS OF LAND, COMPENSATION PAYMENTS	—	—	POSSIBLE LARGE INITIAL AND LONG-TERM PUBLIC EXPENDITURES POSSIBLE LARGE REGIONAL BOND ISSUES AND ALTERATIONS IN TAX BASES		
PENSATION	↓	—	—	↓	↓	↓
PENSATION ERATIONS	↓	—	—	↓	↓	↓
↓	↓	—	—	↓	↓	↓
↓	↓	—	—	↓	↓	↓

Sheet 2 of 2 FIGURE C-12

i. Amenity (Aesthetic and Recreation) Impacts

(1) Introduction. The existence of wastewater management facilities can be considered as being aesthetic if the following two requirements are met. First, the wastewater treatment facilities must be pleasing to man's five physical senses; second, they must contribute to the improvement of man's environment. The proposed alternatives selected in Appendix B consist of a series of distinct elements:

(a) Pipelines

(b) Treatment plants, buildings, and lagoons

(c) Storage reservoirs

(d) Lands for wastewater and sludge disposal

(e) Outfalls for Ocean and Estuary disposal

Each of these elements has unique recreational and aesthetic impacts which can be either adverse or favorable.

(2) Potential Adverse Impacts

(a) Pipeline easements with widths of up to 200 feet and extending in long linear corridors could potentially disrupt neighborhoods and communities by acting as barriers to social interchange. The impact of construction on the existing environment would probably be adverse. All of these impacts can be minimized through proper planning.

(b) Treatment plants can be physically hidden through landscaping but adverse odors present a potential problem.

(c) The aesthetic and recreational appeal of wastewater contained in storage reservoirs is directly dependent upon the level and efficiency of treatment. If, for any reason, the quality of water present will not permit fishing and water contact sports, most recreational impacts will be adverse regardless of landscaping or other attempts to make the area visually pleasing. People will understand restrictions around treatment plants but will not accept similar restrictions for a reservoir.

As with reservoirs, the level of treatment will determine the aesthetic and recreational values of the areas designated for land disposal of wastewater and sludge.

(d) Outfalls have the following potential adverse effects.

1. The increase in pests where floating debris and slicks wash onto shore.

2. A discoloration and/or turbidity of the water down current from the outfall.

3. The possibility of fish kill from toxicants contained in the effluent should the plant operate at less than design efficiency.

4. The presence of odor producing material.

5. The receiving waters may become unfit for human contact or accidental ingestion.

(3) Potential Favorable Impacts

(a) Pipelines would create long linear open spaces and could serve as access corridors with extensive recreational potential by providing trails for walking, bicycling, horseback riding, and motorbike riding. Areas designated for picnics, playgrounds, and other similar activities could be developed. In terms of aesthetics, landscaping will mitigate the adverse impacts of construction.

The pipelines can further be used as a device for preserving vistas of such desirable areas as salt marshes by routing the pipelines along their peripheries and protecting them from development. The pipelines can also create access to areas such as bayshores where none would otherwise exist.

(b) Treatment plants will tend to be an obvious feature of the landscape. These plants will most likely be physically isolated through landscaping and siting. From a distance, buildings and oxidation ponds can be made visually pleasing. In situations where obtrusive structures must be built, distance would generally mitigate most adverse visual impacts with proper control. Recreational benefits might be anticipated from the lands adjacent to treatment plants.

(c) With suitable water quality, storage reservoirs will potentially provide for activities with high aesthetic and recreational values such as walking, hiking, boating, sightseeing, fishing, and swimming. The Santee project in San Diego and the project at Lake Tahoe have clearly shown that people are interested in the quality and usability of the water more than they are interested in the sources of the water. Both projects have created recreation areas utilizing treated and reclaimed wastewater.

(d) If reclaimed water is used to create lakes and ponds, they could have favorable recreational and aesthetic impacts. If "new" croplands are established, impacts would have to be assessed on an individual basis. The concepts of large areas of fodder crops, redwood trees, marshes etc., as outlined by Dr. Newcombe in Appendix C must be examined more closely before a proper assessment and evaluation may be made of the aesthetic and recreational impacts. Similar studies should be made upon impacts of sludge disposal.

(e) There are potentially favorable impacts of outfalls. These will depend upon their structural components. One example would be providing fishing access on the outfall piers. Other benefits will have to be assessed during design.

(4) Expected Impacts of Wastewater Management Alternatives

(a) Ocean and Estuarine Disposal. The primary factors affecting aesthetics resulting from disposing wastewater in the ocean or estuary will be the residual floatables and oils. Specific items of concern in both ocean and estuarine disposal are:

1. The increase in pests where floating debris and slicks wash onto shore.

2. A discoloration and/or turbidity of the water down current from the outfall.

3. The possibility of fish kill from toxicants contained in the effluent.

4. The presence of odor producing material.

5. The receiving waters may become unfit for human contact or accidental ingestion.

(b) Land Disposal. Land disposal of water will have little effect upon presently irrigated lands, however, newly irrigated lands will be changed dramatically. Regardless of their present usage, disposal lands would be converted into "wet land" farming fodder crops, marshlands, or redwood silviculture. The recreational and aesthetic impacts will be directly dependent upon extent type and efficiency of wastewater treatment. Specific impacts which are expected in the location of areas for land disposal are as follows:

1. The existing vegetative pattern will be altered.

2. Vegetative growth will be coated and possibly discolored.

3. In order to facilitate water disposal the terrain must be altered.

4. Insect and animal pests can be expected to be present.

5. Existing wildlife in the area may be eliminated or decreased.

6. Odors may occur.

7. Humidity can be expected to rise, while temperatures will decrease downwind from the area, with a probable increase in fog during the appropriate season.

8. Crop patterns would be established in some barren locations.

9. Some wildlife would be attracted to the area as new growth or crops provide food and shelter.

(c) Sludge Disposal. Sludge disposal on land is a feature common to all plans. It is a complex problem with many potential solutions including upgrading grazing lands, soil conditioners, fertilizers, reclamation of Delta islands, building materials, and related topics. The results of such actions must be studied further before any indication of potential impacts may be assessed and evaluated.

Specific expected impacts on aesthetic and recreational conditions are as follows:

1. Existing views could be blocked by screening efforts.

2. Existing pastoral setting of cropping or grazing would be altered over a wide area.

3. There will be a disturbance of the existing terrain and vegetative pattern.

4. Existing wildlife presently enjoyed by residents or visitors could be eliminated or reduced in number.

5. A crust of sludge residue might develop which would be aesthetically displeasing.

6. The attraction of a variety of insect pests may become a problem.

7. Noxious odors are anticipated as the sludge disintegrates.

8. Should the sludge be cultivated into the soil it is anticipated that particulate matter will become windborne.

(5) Opportunities for Enhancement of Recreational and Aesthetic Values.

(a) Aesthetics. A project of this magnitude will result in a number of major construction features. This work has the potential for beneficial, or adverse, visual or aesthetic impacts. Specific items that should be reviewed to assure aesthetic consideration are grading requirements; location of dikes, levees, dams; pipeline location; ponds, lagoons and reservoir sites; wastewater spray irrigation sites; powerlines, corporate yards, administration facilities and treatment plants. In most cases all of these components can be brought into being with a minimal disturbance to the aesthetic quality of the region if adequate planning for this purpose is initiated at the beginning of the planning stage and is actively continued through design con struction and operation of the system.

Natural landscape beauty as manifest in distant hillsides and winding valley floors with characteristic chaparral and grassland vegetation are at stake in the plans for land disposal of wastewater. Although the land sites for disposal vary widely in their physical character and visual absorption capacity, as indicated in Exhibit 9, of this Appendix, they include dominant conservation features of the open space remaining in the San Francisco Bay Region such as: eucalyptus windbreaks within attractive ranches with fencing patterns and grazing stock; or large rectilinear crop fields with scenic country lanes leading to large farmstead facilities; or little traveled highways passing within easy reach of village centers; or perhaps the disruption of cultural pattern by power pylons or winding drainage systems of artificial composition. So variable are these agricultural patterns that the projected physical alterations of the extensive sites for land disposal purposes may not generate significant visual alterations of the existing agricultural landscape.

An expected change in vegetation character would represent an important impact on the existing sites. Conceivably, orchards and vineyards that attractively characterize many parts of the Hollister Valley, for example, may be replaced by less appealing crops such as alfalfa, sorghum, or soy beans. A change in crop types would appear to affect the Solano and Sacramento sites least since they are planted largely with row and feed crops.

Site preparations, grading, tree planting, or silviculture in surrounding areas can be expected to create considerable disturbance. The creation of lagoons and large holding ponds will tend to alter the present scenic beauties of the landscape but in important respects new and potentially attractive cultural scenes may evolve with their own particular contributions to such beauty of the landscape. The undesirable features of the sludge disposal operation would, in some locations, such as the Marin/Sonoma site, be most apparent from the ridges and slopes.

As indicated in Exhibit 9, of the Appendix, the aesthetic quality of the six land disposal sites cannot be compared against a single standard. The sites can be ranked and compared among each other, however, in terms of discrete visual/aesthetic dimensions such as: richness of vegetation variety, degree of openness or evidence of spatial definition, vivid land form features, and pleasing cultural patterns. The following are some important points to be considered for design and siting criteria:

1. Existing roadways, residential and commercial clusters, recreation areas and vista points should be surveyed to determine the number of observers and frequency of use and consideration given to similar developments proposed for the future.

2. Disposal facilities and related operational activities should be designed, constructed, sited and/or screened to minimize their visible impact from observation areas.

3. Attractive and striking vegetational patterns that are characteristic of the natural-landscape should be retained as organizing elements for siting and screening of disposal facilities and operations.

4. Climatological data should be considered in determining the location and operation of waste treatment facilities to minimize undesirable humidity, odors and hazards to public health.

5. Routing of pipelines should, where possible, conform to natural land contours and above ground utility lines routed off the skyline.

6. Riparian patterns should not be blocked or removed by disposal operations.

7. Construction scars should be obliterated upon completion of the work through the judicious use of plant material to retain or improve the natural flavor of the area. Much may be done in certain instances to recapture that which has been lost in the past.

All alternative proposals will result in the need to dispose of sludge. It is assumed that sludge disposal will generate a far more adverse visual impact than wastewater disposal. Therefore, it is important that a site, or sites be selected on the basis of its visual impact after application. Areas that provide wide-level sites would permit a more effective use of view screening methods (windbreaks, grading, fencing, walls) to conceal the sludge disposal operations. Conversely sludge disposal within comparatively narrow enclosures would be difficult to screen from developments on the surrounding ridges and slopes.

(b) Recreation. Many national studies, during the past decade, have pointed out that there is a desperate need for open space and recreation facilities in close proximity to the general public. Very few urban areas have sufficient open space parks (neighborhood and city) or recreation facilities to provide for this growing social need. The wastewater program envisioned in this study offers the potential for alleviating a portion of this urban problem and will be particularly important where the pipeline right-of-way goes through or is adjacent to urban lower income areas. In addition to long linear open space corridors which such rights-of-way will provide, this land can provide for many types of public access including trails for riding, hiking and biking.

The pipeline rights-of-way could be developed into a series of mini parks connected by landscaped paths. This could provide an ideal natural artery within a neighborhood as a link to schools and shopping centers as well as between neighborhoods. Further expansion of such a system could progress to undeveloped land and remaining open space, by creating riding, hiking, and biking trails that connect with other regional systems and provide ultimate access to the Bay area beaches, marshes, and tidal flats.

Urban areas which are in need of this type of open space and recreation development include all of the larger urban communities situated adjacent to the Bay proper such as Berkeley, Oakland, Alameda, San Leandro and south to Fremont on the east and from San Francisco to San Jose on the west. Other equally important but not as populous areas would be the more crowded areas near Sacramento and Stockton as well as a growing congestion potential for Marin County in the north and the Monterey Bay region of Watsonville, Hollister and Salinas to the south.

Open space areas provided by storage reservoirs, ponds, and lagoons, required to satisfy operational needs of the program, do not offer the same opportunities for intensive recreation use. This is due to their distance from population centers, potential health problems, and extensive land requirements.

The primary concerns expressed by Dr. Cooper in the Public Health Impact, Appendix C, are (1) the presence or absence of infectious or toxic agents, (2) the concentration of these agents, (3) the response of susceptible population and (4) the nature and probability of human contact with these materials. The number of variables and unknowns relating to these conditions abound. A major difficulty is predicting the consequences of new techniques, either technical or managerial, upon the health of the human population. Additionally, there is a problem of residual pathogens, virus or toxicants that would be detrimental to the establishment and growth of a permanent population of fish and possibly wildlife.

Assuming that sufficient monies and knowledge becomes available to eliminate inherent adverse health hazards there is a potential for water based recreation use for these waters. The primary human use of such bodies of water are envisioned as fishing and boating. Because of the distance from centers of population there must be access roads and parking areas, plus sanitary and water facilities.

PUBLIC HEALTH IMPACTS OF ALTERNATIVE WASTE WATER MANAGEMENT CONCEPTS

A Report for the U.S. Army Corps of Engineers

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ALTERNATIVES FOR MANAGING WASTEWATER IN THE SAN FRANCISCO BAY A--ETC(U)
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1. GENERAL INTRODUCTION

At the present time more than 660 million gallons of wastewater are discharged into San Francisco Bay and its tributaries. This volume is discharged after various degrees of treatment by 155 cities, sanitary districts, or other public agencies located in the 12 counties involved.

We have reached a level, or even beyond, wherein this situation cannot be allowed to continue. This is particularly so when one considers the population estimates for this area in the near future. It is projected that by 2020, 16 million people will reside in the Bay Area and will produce an estimated 2 billion gallons of sewage every day.

The United States Army Corps of Engineers, by authority of the Refuse Act of 1899 and by Presidential directive, is interested in the study and evaluation of alternate wastewater treatment schemes which may be appropriate for the anticipated situation in the year 2020.

These schemes are based primarily upon the collection of all the liquid wastes of the 12 Bay-Delta counties, treating to the level required, and discharging directly into the hydrosphere, onto the land or a combination of the two. Discharge into the hydrosphere would be either into the northern extreme of the estuary or into the Pacific Ocean. Land disposal would be accomplished by spreading with consequent evapotranspiration and percolation. All solids produced are to be placed on the land or incinerated.

The impact of these various schemes upon man and his environment are being considered in terms of their ecological, hygienic, aesthetic, social and economic characteristics.

The purpose of this report is to examine the hygienic aspects of the various wastewater disposal plans. The document is limited to potential effect upon human health which, for the purposes of this report, is limited to the presence or absence of clinical disease.

It is impossible to make unequivocal statements concerning the disease hazard involved when any specific disposal scheme is under consideration. This is particularly so with chronic diseases that may be involved. Because of these difficulties, it was felt necessary to review as concisely as time permitted what is presently known concerning wastewater and disease agents, both animate and inanimate. This is presented in terms of what agents, appropriate to this study, are known to exist, how they are transmitted or associated with water and what is known concerning the effectiveness

of various treatment processes in either their removal or potentiation. With this background in hand, inferences can be drawn concerning the various proposed treatment schemes and their impact on human health.

2. POTENTIAL PUBLIC HEALTH HAZARDS OF WASTEWATER: BIOLOGICAL AGENTS

2.1 Introduction

Since the beginning of recorded history, man has been afflicted with intestinal disorders that are transmittable via water and wastewater. The agents of primary concern have been bacterial, including such diseases as cholera, typhoid fever and other salmonella etiologies; diseases such as amoebic dysentary, caused by protozoan parasites; and, more recently recognized or suspected diseases of viral origin.

The history of any of these diseases is intimately associated with the development of civilization. As long as people lived widely apart, in small groups, often travelling nomads, epidemic dysenteric disorders were relatively rare. When man found it more and more necessary to group together for mutual protection, he also became more apt to contract these diseases. The advent of the wastewater carriage system (sewerage) exacerbated previous problems because it exposed any number of people to everyone's waste discharge. To wit, Oliver Wendell Holmes stated in 1862: "The bills of mortality are more obviously affected by drainage than by this or that method of (medical) practice."

Of equal importance in man's history of water development has been the effect upon vector-borne diseases, the most serious of which are malaria, filariasis, yellow fever, and especially in California, equine encephalitis. These diseases, while not always a direct result of man's activity, have often been enhanced by his misuse of water resources, particularly irrigation.

No list of important water-borne diseases would be complete without reference to the various forms of trematodes or flukes which range from the catastrophe of bilharzia to the annoyance of swimmer's itch. In all cases, the common factors are water, the various intermediate hosts (snails, fish, water plants and crustaceans) and the contamination of water with infected feces of the host animal.

It was not until the 1960's, [1] with the well-documented case of pesticide accumulation in the food web of the biota of Clear Lake, California, that environmentalists began to be aware of the potential problem of biomagnification of toxic agents. This is a phenomena, well-known to ecologists, wherein materials are accumulated at a low trophic level and continuously concentrated as they pass to the highest level. In the case of Clear Lake, the highest levels were fish and aquatic birds in which DDD applied to the Lake at a concentration of about 0.01 ppm to control gnats was magnified to as much as 2600 ppm in the fat of higher trophic level fish. In the realm of human health, this kind of situation has most certainly been brought to focus with the discovery of the accumulation of mercury in fish. [2] In this instance, evidence points to a process of biomagnification and the indirect transmission of a toxic agent through water and its resident biota.

It is clear that it is of the utmost importance that both the direct and indirect transmission of disease be carefully considered when grand designs are being developed for the handling of the tremendous volumes of wastewater produced by the 12 Bay-Delta counties.

2.2 Water Borne Infectious Diseases

Bacteria of the genus Salmonella contain a wide variety of species pathogenic for man and animals. These bacterial agents are transmitted from man to man by means of personal contact, contaminated food and contaminated water. There are three chemically distinct forms of Salmonellosis in man: enteric fevers, septicemias and acute gastroenteritis. Typhoid fever caused by Salmonella typhic is the prototype, and the most severe of enteric fever form of Salmonellosis, and for which man is the only host. At the turn of this century, death rates of more than 50 per 100,000 persons were not uncommon in cities of the United States. The death rate for the entire country in 1900 was 31.3 per 100,000; however, at present it is practically non-existent. Over the last seventy years, the morbidity has also shown significant change; for example, the U.S. morbidity for typhoid fever in 1930 was 12.6 per 100,000 and in 1971 there were less than 0.2 isolations of S. typhi per 100,000 population of which less than half were clinical cases. [3] The morbidity is getting so low that epidemiologists are beginning to speak in terms of eradication. [4] At this point in time in the United States, water is not a significant vehicle for the transmission of this disease.

The Salmonella septicemias are characterized by bacteremia, high remittent fever usually without involvement of the gastrointestinal tract. These are most commonly caused by S. choleraesuis and are relatively rare. Because the G.I. tract is not normally involved, this clinical type is not usually associated with water and wastewater. Salmonella choleraesuis has a predilection for swine and is not particularly common in the human populations.

The third form of salmonellosis, acute gastroenteritus, is the form in which the Salmonella are most commonly encountered. In excess of 1400 serotypes have been identified and most, in contrast to S. typhi, are not host specific. The reported isolation rates from hummans in California is between 8.0 and 11.9 per 100,000 and is increasing. The incidence is higher in the Southern portion of the State than in the North. This isolation rate is about the average for the United States as a whole and most health authorities agree is probably much lower than the actual total incidence. An accurate assessment of the number of deaths attributed to Salmonella is not possible but of the recorded cases between 1962 and 1969 the case fatality rate was 0.28 percent, mostly very young and very old.

The most common non-human source of these organisms is food and overwhelmingly poultry products. Water, while an important source, contributes only a little more than two percent of the total (Table I). The most common form of Salmonella isolated from either human or non-human sources in the United States is S. typhimurium. Although the incidence of water-borne salmonellosis is very low, there are a number of occurrences, verified and suspected, in which large numbers of persons infected by this route. One of the most documented is the outbreak in Riverside, California, in 1965, in which 18,000 people were infected with S. typhimurium. (5) The bacterium was isolated from 100 different stool specimens and from 5 samples of the drinking water. This report is clear evidence that Salmonella can be transmitted via a municipal water supply.

Bacteria of the genus Shigella produce an intestinal disease in man and higher apes known as bacillary dysentary. The disease spreads rapidly under conditions of overcrowding and improper sanitation. The mode of transmission is primarily from person to person and through contaminated food. Because

TABLE I: Salamonella Isolations from Non-Human Sources by Number Percentage. United States, 1963-1967 (Adapted from Aserkoff et al.) (4)

SOURCE	NUMBER OF ISOLATES	PERCENT OF TOTAL
Fowl	16,172	46.43
Swine	2,791	8.01
Cattle	2,306	6.62
Other Animals	2,474	7.10
Eggs	2,117	6.08
Dried Milk	846	2.43
Other Foods	1,406	4.04
Animal Feed	3,703	10.63
Water	746	2.14
Miscellaneous	1,660	4.77
Unknown	609	1.75
TOTAL	34,830	100

these organisms are sensitive to environmental conditions, the water route does not seem to be too important but certainly should not be overlooked. Recently, [6] there have been two reports of water-borne outbreaks of Shigellosis in small communities on the East and West Coasts. Both instances involved small common, unchlorinated wells which were obviously contaminated with sewage. Shigella sonnei was isolated in both instances.

The isolation rate in the United States is approximately 15 per 1,000,000 population. Of the six species commonly pathogenic for man, S. sonnei and S. flexneri are most commonly isolated, the former 60.3 percent of the time and the latter 38.2 percent of the time from the various States in the Union.

Cholera is a serious disease of great historical and current interest. It is similar in many respects to typhoid fever but more rapid in onset, more virulent, and more often fatal. Death rates of 25 to 85 percent of the cases are commonly reported. The disease has been endemic in India for centuries and was unknown in the western world until 1817, at which time an epidemic originating in India became pandemic. The United States was not spared; a number of epidemics occurred between 1826 and 1896 and were closely associated with the movement of European migrants to this country. Except for occasional cases at seaports, there has been no cholera in the United States since the turn of the century. [7]

The etiologic agent of this disease is the small, curved, gram negative, mobile, non-spore-forming rod, Vibrio commona. Man is the only host and since a carrier state is unknown, the disease must be maintained by an unbroken chain of mild inapparent infections. Infected water is the frequent mode of transmission.

Cholera is not now a problem in the western world. The most persistent endemic focus is in India and East Pakistan. The most recent large epidemics outside of India were in Egypt in 1948, causing the loss of more than ten thousand lives. Interestingly, Egypt had been free of the disease since 1902. Since 1961, El Tor Cholera (a variety of V. commona) has continued to spread from Indonesia. [8] In 1970, it advanced into previously uninfected areas of the USSR, the Middle East, and Africa. As of January 15, 1971, the State of Niger has reported the occurrence of the disease.

Other bacteria of less suspected importance in domestic waste water would include the Tubercle bacillus, Leptospira, and "non-pathogenic" bacteria.

Mycobacterium tuberculosis [9] has been isolated from sewage, particularly where an institution treating tuberculosis patients is involved or where industries such as dairies and slaughter houses handling tuberculosis animals may be expected to discharge their wastes. Human cases associated with waste water usually involve swimmers in highly contaminated water, who aspirate water into their lungs.

There have been a number of reports of swimmers contacting leptospirosis. [10] In these instances they have been swimming in ponds or slow moving streams in which cattle and swine have access. Forty cases were reported from Iowa in 1959 and 15 in 1964. Fifty cases have been reported from New York in 1951. In all these instances Leptospira ponoma or L. grypotyphosa were involved. Most common species of leptospiris are infectious for both man and an mal and gain access to water via animal urine. There is one leptospire, L. biflexa, that is not pathogenic, but common to water. This latter form does have a common generic antigen and could possibly be confused with the other, pathogenic forms when isolations are made from water.

There are many reports of water-borne gastroenteritis of unknown etiology in which bacterial infections are suspected. It is important, therefore, to mention certain gram negative bacteria normally considered nonpathogenic as potential sources for these disturbances. Both enteropathogenic Escherichia coli and certain strains of Pseudomonas are often mentioned, particularly in the new born. [11] Both genera are universally found in waste water.

From the preceding discussions, it would appear that at the present time in the United States the bacterial agents of most concern are the Salmonella sp. responsible for acute gastroenteritis and perhaps the suspected "non-pathogenic gran negatives". Cholera is not present and the agents of tuberculosis and leptospirosis although important do not, from an epidemiological point of view, appear significant in municipal waste water.

Sanitary scientists are extremely interested in the control of these diseases and desire to detect the presence of any of these agents in water and waste water. None of these microbes are readily isolated from water and, more importantly, they are not readily enumerated. Because of the difficulty in determining directly the presence of these microorganisms, the environmentalist must rely upon indicator microroganisms whose presence can be readily determined, whose number can be estimated,

whose presence is indicative of fecal contamination, and whose survival characteristics are similar to the disease producing organisms expected to be present. The most universal of these indicators is a group of microorganisms unofficially classified as coliforms. The presence of these organisms in water is thought to be indicative of fecal contamination since they are common in large numbers in the intestinal tract of man and animals. During the last 70 years a great deal of effort has been expended in developing and improving methods for their isolation and quantitation. Unfortunately, they are not limited to the intestines of man and other animals but are also found in soil and on plants. Because of this, the interpretation of this sanitary significance in a given situation often proves difficult. More recently, methods have been developed and proved for the isolation and enumeration of coliforms of fecal origin which will enable health workers to make more meaningful decisions. In regards to this present report, these bacteria are important because often the effectiveness of waste water and water treatment process is reported in terms of these indicator organisms rather than in terms of specific pathogens. In actual practice, the presence of these organisms in water indicates the potential presence of hazardous microorganisms.

Parasitical Diseases. There are a myriad diseases of protozoan and metazoan etiology which are transmitted from man to environment to man in fecal material; therefore, many would be associated with water. An exhaustive list of these parasites would not be appropriate in this report and only the most important or potentially important organisms will be mentioned.

In the United States perhaps the most important parasitical disease to be associated with waste water is amoebic dysentary. The etiology of this disease is Entamoeba histolytica, a protozoan, which can infect the human colon causing erosion of the superficial mucous membranes. It may eventually invade the tissue with consequent ulceration. In certain severe cases, the parasite may metastasize to other body organs. The amoeba has the ability to form heavy walled cysts and transmission occurs when mature cysts are excreted with feces into water or food. Infection begins with the ingestion of cysts which germinate in the gut to become vegetative amoeba which multiply and may become invasive. The cysts are most important from an epidemiologic point of view because they are resistent to environmental forces. The vegetative forms do not survive outside the gut. The disease is world-wide and normally occurs an inapparent infections. The incidence of infection in the United States is not well established because of the non-clinical infestations; it is most probably of considerable magnitude.

Human schistosomiasis is an important disease in many parts of the world, including South America, Africa and the Orient. Fortunately, this disease does not occur in North America; however, "swimmers' itch" is a problem in many parts of the country. This is a schistosomiasis whose primary hosts are water fowl. Man is accidentally infected by the cercariae and because he is not a natural host they cannot develop any further, resulting in local irritation and itching, which can be quite severe.

Other helminthic parasites which may be present in municipal waste waters could include the eggs of Ascaris lumbricoides (Giant round worm) whose host and reservoir is man and various cestodes (tapeworms) Taneia sp. In this latter instance, cestode eggs would be transmitted to the intermediate host, swine or cattle and man would be infected by eating their meat. This is of the most importance when sewage sludge is spread in agricultural areas.

Viruses in Water and Waste Water. The role of water and waste water in the transmission of animal viruses has not yet been fully evaluated. It is well established that viruses are present in human and animal feces, sewage, polluted waters and even public water supplies. Because of increasing water pollution and the need for expanded reuse and reclamation of our water resources, the potential hazard of viruses in water must be evaluated to insure that the demand for adequate and safe supplies of drinking, recreational and irrigational water will be met.

At the present time the viruses considered to be of major importance in waste water are primarily of human origin. These fall into four main groups, the enteroviruses, the adenoviruses, the reoviruses, and the agent of infectious hepatitis. These major groups and their subdivisions are shown in Table II.

All of the enteric viruses are capable of producing clinically obvious diseases; however, with the exception of infectious hepatitis, these manifestations are relatively in frequent complications of otherwise trivial infections.

The amounts of enteric viruses in sewage have not been precisely established because of the insensitivity and inaccuracy of present detection methods and the variability in the amounts and types of viruses which may be present under different conditions. The enteric virus concentration in domestic sewage reaches a peak during the later summer and early fall and varies with the social-economic level of the population. (12)

Experimental investigations on the concentrations of enteric viruses in raw sewage indicate that the enteric virus density may range from a few infectious units per 100 ml in cold weather to several hundred in warm weather. (13) Enteric viruses have been isolated from contaminated waters such as marine and estuarine waters, lakes, reservoirs, ground waters, swimming pools and public water supplies.

Table II: Viruses Found in Animal Feces and Waste Water

Biologic Group	Antigenic Type	Associated Disease Syndrome
Enteroviruses		
Polioviruses	3	Poliomyelitis, aseptic meningitis
Coxsackie Virus Group A	24	Hepangina, aseptic meningitis, exanthem
Coxsackie Virus Group B	6	Asepticmeninfitis, myocarditis, percarditis
Echoviruses	33	Asepticmeningitis, exanthem, gastroenteritis
Adenoviruses	31	Upper respiratory illness pharyngitis, conjunctivitis
Reoviruses		Upper respiratory illness, diarrhea, exanthem
Infectious Hepatitis Virus (es)	1?	Infectious hepatitis

Infectious hepatitis is the enteric virus disease of most importance in waste water. Although the agent of infectious hepatitis has not yet been propagated in the laboratory, many outbreaks have been attributed to contaminated water on the basis of epidemiologic evidence. Ten outbreaks have been documented in the United States. (14) Most of the outbreaks involved gross contamination of small supplies. It has been suggested that there may be many unrecognized infectious hepatitis epidemics. (15) Although it is a distinct possibility that some of these unrecognized outbreaks are water-borne, the water route still only accounts for less than one percent of the total outbreaks in the United States.

The water route of transmission has been implicated in several outbreaks of Poliomyelitis. Outbreaks in Edmonton, Alberta, Canada, and Huskerville, Nebraska, were attributed to contaminated water but the evidence is by no means conclusive. (16, 17) Most authorities agree that in the developed countries poliomyelitis should be considered a disease in which water transmission is, at best, a rare occurrence. In underdeveloped coutries where sanitation is poor, the transmission of poliomyelitis and other enteric virus diseases may be a common occurrence.

Three outbreaks of pharyngoconjunctivitis caused by adenovirus type 3 have been attributed to contaminated swimming pools. (18, 19, 20) Isolation of the virus from the pool water was either unsuccessful or not attempted, and the water route of transmission was implicated only on the basis of epidemiologic evidence.

A number of outbreaks of infectious hepatitis due to the ingestion of raw or steamed shellfish taken from sewage polluted waters have been reported. (15) In the feeding process shellfish take viruses into their digestive systems from the surrounding water. The amount of virus in the shellfish is related to the concentration of virus in the surrounding water, and virus-containing shellfish can be decontaminated by depuration in uncontaminated water. Although no outbreaks of shellfish-associated disease have been attributed to other members of the enteric virus group, several outbreaks of shellfish-associated "gastroenteritis" have been reported. (21, 22)

No other enteric viruses have been specifically implicated as causative agents in documented outbreaks of water-borne viral disease, but it is not certain that serious attempts are being made in this direction. In relation to this point is the fact that for many outbreaks of gastroenteritis and diarrhea, no agent can be specifically incriminated. The cause of such

outbreaks is often listed as "viral" in nature. For the years 1946 through 1960, 142 epidemics of waterborne gastroenteritis and diarrhea involving 18,790 cases were reported in the United States. (23) In terms of magnitude, gastroenteritis and diarrhea are the most important diseases transmitted by water. The possibility that enteric viruses are the causative agents of such episodes cannot be dismissed.

In addition to the possible role of water-borne viruses in epidemics, it has been suggested that the major problem with well managed water supplies is the possibility of low-level transmission of viral infections resulting in sporadic clinical cases rather than explosive outbreaks. (24) The study of low-level transmission or endemic occurrence of water-borne virus diseases has been virtually ignored for several reasons: (a) present virus detection methods are not sensitive enough to accurately detect low concentrations of viruses in large volumes of water; (b) enteric virus infections are often inapparent, thus making it difficult to establish the endemicity of such infections; (c) once introduced into a population, person-to-person contact would become a major mode of transmission of an enteric virus, thereby obscuring the role of water in its transmission.

On the basis of existing evidence, it must be concluded that viral infection resulting from the use of properly treated public water supplies appears to be unlikely at present. A risk of infectious hepatitis arises from the consumption of shellfish taken from sewage-polluted waters. The possibility, however, of either gross viral contamination of raw water sources or the absence or breakdown of reliable treatment procedures at local water treatment plants, poses a constant threat of viruses not being reduced below infectious levels in municipal water supplies.

2.3 Vectorborne Diseases

Indirect transmission. Any waste water management strategy that proposes to increase surface water, through the construction of holding ponds and the restoration of water for irrigational purposes, must consider the potential indirect disease problems that will result from expected increases in populations of arthropod vectors and wildlife hosts of diseases transmittable to man. Most of the diseases referred to here are zoonotic diseases that are endemic in California and are maintained in wildlife host-to-wildlife host or wildlife host-to-arthropod vector-to-wildlife host transmission cycles. Man and his domestic vertebrates are aberrant hosts and become involved tangentially in the transmission cycles. This is particularly so when man alters his

environment for recreational and agricultural purposes, creating an environment that supports or augments the vectors and wildlife hosts. Nowhere is this better exemplified than in the Central Valley of California where man has transformed a desert into rich agricultural lands and, in so doing, has greatly enhanced his exposure to the mosquito-borne viral encephalitides. (25)

Numerous factors influence epidemics of zoonotic diseases. Most important, however, is the abundance of arthropod vectors and wildlife vertebrate hosts. It is only when vector populations reach sufficiently high levels that there will be a "spillover" of the disease agent to man. Large populations of young and susceptible vertebrates are needed to allow rapid build-ups of high infection rates in the vector populations. These points have been well documented with mosquito-borne encephalitides in California. (26, 27, 28) Since there is no effective vaccine available for most zoonotic diseases that occur in California, control must rely on the elimination or reduction of vector and/or host populations. Thus, a waste water management proposal that would increase vector or host populations would potentially increase the exposure of man to certain zoonotic diseases.

Any increase in surface water availability in the Central Valley of California will undoubtedly result in a concurrent increase in certain arthropods that breed in water or in the mud along the edges of ponds. Of public health importance are the blood-sucking arthropods that are either pests or vectors of disease. These would include numerous species of Culicine and Anopheline mosquitoes, which lay their eggs on surface water, and biting midges of the Culicoides variipennis complex. (29)

Culex tarsalis is probably the most important Culcine mosquito because it is the primary vector of western equine and St. Louis encephalitis viruses, which frequently produce widespread disease in man, horses, or wildlife. (25, 30) Table III, IV, and V show human and horse cases of encephalitis in California for the years 1952 through 1968. These viruses are maintained in nature during the summer epidemic season by a transmission cycle involving C. tarsalis and numerous species of wild birds. Culex tarsalis breeds in a variety of habitats, including rice fields, irrigation tailwaters, tules along edges of ponds and streams, etc. Since nutriment of the larva depends in part on the amount of organic matter in the water, sewage water is a very excellent medium for the breeding of this species. For example, farms located south of Bakersfield in Kern County, California, are irrigated with treated sewage water. Aside from duck ponds, this probably constitutes the most

Table III

HUMAN CASES OF ST. LOUIS ENCEPHALITIS IN CALIFORNIA, 1952-1968

LOCATION	NUMBER OF CASES BY YEAR																
	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Sacramento Valley	(3)	(3)	(22)	(1)	(3)	(15)	(4)	(26)	(3)		(8)		(1)	(1)	(2)	(3)	(2)
Butte			9	1	1	2	2	1			2					2	
Colusa					1	1		2	1								
Glenn		1	1					1						1		1	
Placer								1			1						
Sacramento	1	1	1		1	3		5	1		1				1		1
Shasta																	
Sutter			4			5		2									
Tehama	1		1			1		3			1		1				1
Yolo	1	1	2			1	1	5	1		3				1		
Yuba			4			2		5									
Unknown Sac. V.							1	1									
San Joaquin Valley	(38)	(11)	(73)		(2)	(6)	(7)	(10)	(7)	No data		No data				(3)	(1)
Fresno	11	4	24			2		4	4							1	
Kern	16	4	10				2										1
Kings			2			2											
Madera	4		4		1		1	3	1							1	
Merced	1		3			1											
San Joaquin	3	1	12				1	2								1	
Stanislaus		1	14				1										
Tulare	3	1	4		1	1	2		1								
Unknown S. J. V.								1	1								
Other Northern			2		1	1	1	3			2				2	1	1
Other Southern	2	8	1		1		4	1	2				1				
Other/Unknown	2		1	2		1											
TOTAL	45	22	99	3	7	23	16	40	12		10		2	1	4	7	4

Table IV

HUMAN CASES OF WESTERN EQUINE ENCEPHALITIS IN CALIFORNIA, 1952-1968

LOCATION	NUMBER OF CASES BY YEAR																
	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Sacramento Valley	(63)	(7)	(1)	(2)	(3)		(11)						(8)	(5)	(4)	(5)	(2)
Butte	4		1		1		3						1			2	
Colusa	2	1															
Glenn																2	
Placer																	
Sacramento	38	1					2						1	1	3		
Shasta														1	1		
Sutter	4	2		1			2						1	1			
Tehama		2					1						1	1			
Yolo	11	1		1	1		3						3	1		1	2
Yuba	4				1								1				
San Joaquin Valley	(296)	(3)	(21)	(4)	(10)	(1)	(24)	(1)		No data		No data		(3)	(4)		(4)
Fresno	64	1	11	2	3		5							1			
Kern	100	2	5		3	1	15										2
Kings	13				1		2										
Madera	5		1	1	1												
Merced	12						1								1		1
San Joaquin	48		1		1			1						1	2		1
Stanislaus	27		2	1	1										1		
Tulare	27		1				1							1			
Other Northern	9	2			1		2	1					2		1		3
Other Southern	2	2				1			1								
Other/Unknown	5					1								1			
TOTAL	375	14	22	6	14	3	37	2	1		0		10	9	9	5	9

Table V

EQUINE ENCEPHALITIS IN CALIFORNIA, 1952-1968

LOCATION	NUMBER OF CASES BY YEAR																
	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Sacramento Valley					(1)	(2)					(7)		(20)	(17)		(19)	(7)
Butte											1		8	2		5	1
Colusa													1				
Glenn											2		1				
						1							1	2			
Sacramento					1	1					1		6	8		6	3
Shasta											2		1			2	
Sutter													2	2		2[a]	1[a]
Tehama											1			1		2	1
Yolo														2		2	1
Yuba																2[a]	1[a]
San Joaquin Valley				(1)		(1)					(8)		(8)	(33)		(6)	(11)
Fresno						1					3		1	14			5
Kern	1													8			
Kings																	
Madera														1			
Merced											3		1	2			1
San Joaquin				1							1		4	3		5	5
Stanislaus											1		2	3		1	
Tulare														2			
Other Northern				2	1	1							1	7		9	10
Other Southern					4						2			2		1	4
Other/Unknown																	
TOTAL			4	3	6	4					17		29	59	21	35	32

No data — No other data — No data on number per county — No data on number per county

[a] Counted as Sutter-Yuba.

important production source of C. tarsalis in Kern County and is a constant trouble spot for the Kern County Mosquito Abatement District. (31)

Anopheles freeborni is the most important Anopheline mosquito species found in California today. This species is found in high numbers in the Sacramento Valley where it breeds primarily in rice fields, duck ponds and marshy areas. The only effective means of controlling this mosquito is the elimination of breeding sites. These mosquitoes frequently bite man and domestic mammals and are considered an important pest mosquito. It is not known to be a vector of any viral disease in California but is a very efficient vector of the protozoan parasite that causes malaria in man. A malaria epidemic is a constant threat in California today because this parasite is being reintroduced into California at an alarming rate, primarily by veterans returning from Southeast Asia. This is further complicated by the needle-sharing habits of drug addicts. For example, over 50 cases of malaria occurred last winter in Bakersfield when a malaria-infected veteran shared a needle with the local drug addicts. Thus, if a similar event occurred at the right time and place where A. freborni populations were high, we would very likely have a widespread epidemic of malaria.

The potential threat of mosquito-borne diseases in California has increased in recent years because control measures for mosquitoes are rapidly deteriorating. The two factors accounting for this are the development of pesticide-resistent mosquito populations. (32) and the rapid expansion of irrigated farming and other water impoundments outside the boundaries of established mosquito abatement districts. New methods, probably other than chemical, will have to be developed for mosquito control in order to combat this problem.

The biting medge, Culicoides variipennis, is the vector of four viruses in California, (30) including bluetongue virus, which produces disease in sheep and cattle and Main Drain virus, which probably produces disease in horses. Jackrabbits are the primary hosts of these viruses.

Culicoides larva usually develop several inches under the soil and the adults emerge through cracks in the soil. However, in Kern County Culicoides variipennis breeds in massive numbers in the mud around the edges of ponds in the desert used for disposal of water from oil wells. A similar situation might occur around the edges of the proposed holding ponds for restoration of sewage water.

Unless designed and maintained correctly, the undeveloped land at the edge and in between storage ponds will provide a haven for certain species of rodents, leporids and birds. For example, dense tules will develop around the edges of ponds and in any areas where seepage might occur. This is a favored nesting and roosting site for blackbirds, which can serve as hosts of encephalitis viruses. Populations of ground squirrels, jackrabbits and small burrowing rodents will increase rapidly as vegetation develops and provides food and cover. These animals are natural hosts of plague, (33) tularemia (34) and leptospirosis. (35) Thus, unless properly controlled, increased vertebrate population around storage ponds could become focal points for the maintenance and dissemination of certain zoonotic diseases in California.

2.4 Airborne Infectious Diseases

Louis Pasteur was the first scientist to demonstrate unequivocally that microbes were present in air, although prior to that time many prominent investigators had theorized that disease and food spoilage were associated with airborne substances. We now know that the air is an important vehicle in the dispersion of microbes, and that air is probably the only means of transmission for some diseases.

There are two arbitrary classes of airborne disease action; the first is associated with "contact infection," where one person is close enough to another person to receive direct droplet contact from a cough or sneeze--and is not important to this discussion; the other is true airborne infectivity associated with droplets so small that they essentially follow wind currents, even drafts of unusually small magnitude. (36)

Distribution and Sources. Bacteria, viruses, and certain fungal spores can exist in the air in particles as small as 0.5 micrometers (μm) in diameter. Since these particles fall as a result of gravitational forces at rates between 1×10^{-2} and 1×10^{-4} cm/sec, then upward air motion of equal velocity will support such particles, and they can be distributed for long distances by normal wind motion. One might suppose that such particles would never be removed from air and that the concentration of airborne microbes would constantly increase, but wind currents blow downward as well as upward, and the average concentration of particles in a horizontal, turbulent, moving air mass will decrease (decay) as if the flow were ideally laminar; the greater the height of the moving air, however, the slower the rate of decay.

Also, airborne particles usually originate from a "point source," so they will diffuse at right angles to the direction of motion, and will diffuse upward, thus greatly reducing the concentration per unit volume. Eventually all airborne particles "settle out."

Sources of airborne microbes are varied. In dry weather, agricultural activities such as plowing and harvesting produce clouds of dust (aerosols) containing fungal and bacterial spores. Wind blowing across infected grain will transmit the disease for many miles.

Almost any human activity produces small amounts of aerosols. Some individuals "shed" more than others, a situation that has caused epidemics in hospital wards; bed-making and laundry are particularly productive activities. (37)

Any industrial activity that uses liquid associated with living substances may produce aerosols, and these usually are made of particles so small (0.5 to 5 μm) that the cloud is not visible. Included are activities such as sewage disposal and the washing of plant or animal products. For example, Q-fever was transmitted downwind for a distance of ten miles in Oakland, California, as a result of the scrubbing of sheep hides in a tanning company. (38) Coliform organisms have been isolated from air 0.8 miles downwind from a trickle filter associated with a sewage disposal plant. (39) Brucellosis was found in the air of a packing plant. (40) (For a more detailed review, the reader should refer to references 41, 42.)

Factors involved in spread of airborne disease. The question of whether airborne microbes are hazardous to man is best answered with qualifications. On the one hand, most microbes do not cause disease, even if breathed in large numbers. On the other hand, the species causing tularemia (rabbit fever) is so contagious that a single microbe (about 0.9 μm in diameter) will produce an infection. (43) Between these extremes there is a range of infectious potentials. For example, the common cold or tuberculosis are moderately contagious airborne diseases.

Other, equally important factors are involved in the question. First, to be infectious via the respiratory route the particle containing a pathogen must be able to reach the innermost parts of the lung, i.e., the alveoli. Only particles in the size range 0.2 μm to 10 μm, at most, can reach and be retained in the alveoli in appreciable numbers. Particles smaller than 0.2 μm are breathed out; particles larger than 10 μm are stopped in the nares (nose structure) and are eventually swallowed. (44)

Secondly, bacteria do not survive in the airborne state indefinitely. Air, moisture, and sunlight kill airborne cells. However, the process is complex, and whereas some species are very hardy, other species are differentially sensitive to each of the three aforementioned environmental conditions. Within a given species, the rate of death of airborne microbes also varies with the originating environment; i.e., age of the cells, growth factors, prior treatment, etc. The only general "rule of thumb" that might be stated is that a mid-day, sunny atmosphere at a relative humidity of about 50% is lethal to most microbes whereas a cool dark night and a relative humidity of 70% or greater would allow the greatest number of microbes to remain alive for the longest time. This phenomenon is complicated by the fact that under experimental conditions the death rate and the change of infectious potential are not always equal. (43)

Another factor, and one that is elusive in terms of both assay of potential hazard (sampling) and of actual harmfulness (measured infectivity) is the probability of breathing an individual microbe in a unit air volume. Unlike gases, infectious microbial aerosols do not become so diffuse that no disease will result. A viable pathogenic cell is a "package," and if breathed by the right person at the right time will produce an infection. Fortunately, that probability is normally very small. The average adult human breathes 9 liters of air per minute (roughly 1/3 ft^3). A concentration of ten microbes per ft^3 is a reasonable <u>average</u> value for most living spaces, although the number can be as high as 10^7 for short intervals. On a statistical basis, therefore, a person breathes, and likely retains, three to four microbes per minute. If one in every three to four hundred thousand airborne cells or viruses are "pathogenic," then the probability that a given person will be exposed is 10^{-5}/minute, a value hardly worth consideration.

Finally, individuals vary in susceptability, in terms of inherited factors and as a function of their general health. Stated another way, all individuals in a given sample of a population may receive an "equal" exposure to an "infectious" aerosol, but not all will become infected; the more intense the exposure, either in terms of time or concentration per interval, the greater the number of persons infected.

In summary, because of the great number of variables, the health hazard of airborne microbes can be evaluated only on a statistical basis within an indefinite confidence interval; during the lifetime of an octogenarian the probability of serious infection has been near zero--for the TB patient it has been 100 percent. The common cold is an economically

important airborne disease, but control efforts have been directed almost universally toward testing medical treatments (immunization) rather than toward vehicle control, as contrasted to efforts to control water and insect-borne diseases.

3. POTENTIAL PUBLIC HEALTH HAZARDS OF WASTE WATER: CHEMICAL AGENTS

3.1 Introduction

Permissible levels for a number of chemicals in public water supplies have been reviewed in the Report of the Committee on Water Quality Criteria [45] and Public Health Service Drinking Water Standards. [46] Some representative criteria are shown in Table VI. The scientific basis for the permissible levels will not be repeated in this report. We will discuss instead a) the current trend of toxicological evaluations and the resulting implications for the revision of present criteria and the establishment of new criteria for hitherto uninvestigated chemicals, b) some recent developments in the study of toxic chemicals in water, and c) toxic chemicals with the greatest potential for becoming human health hazards in the future.

Adverse health effects of toxic chemicals in water can result either from direct contact through drinking of the contaminated water or indirectly via consumption of foods harvested from contaminated waters. Adverse health effects may be either acute or chronic. Acute reactions appear shortly, e.g., less than a week, after exposure and usually follow ingestion of a large dose of the chemical. Acute reactions from drinking water seldom occur because of the high concentrations of chemicals necessary to produce acute reactions. Special circumstances accompany episodes of acute poisoning from drinking water: for example, copper poisoning from water channelled through copper pipes, [47] lead poisoning from lead-soldered pipes in a soft water region, [48] or infant methemoglobinemia from well-water with a high nitrate content. [49]

The close temporal association between cause and effect is such that acute health reactions to toxic chemicals in drinking water are usually rapidly recognized and controlled. Less reassuring, from the viewpoint of control, are the chronic long-term health effects that may arise from the consumption of small quantities of toxic chemicals in drinking water.

TABLE VI: Drinking Water Standards (1962) for Some Chemicals in Water

Substance	Rejection of Supply conc. (mg/L)
Arsenic	0.05
Cadmium	0.01
Lead	0.05
Recommended Control Limits	
Arsenic	0.01
Copper	1.00
Carbon Chloroform Extract	0.02
Nitrate	45.00
Phenols	0.001
Zinc	5.00

Chronic toxicity from chemicals is generally defined as adverse health effects secondary to the intake of small amounts of chemicals over a long period of time or, when carcinogenesis, mutagenesis, and teratogenesis are considered, diseases which appear long after exposure, i.e., diseases with a long incubation period. Chronic degenerative diseases of unknown etiology currently account for over 80 percent of the mortality and morbidity of man. (50)

Experiments in animals have repeatedly shown that low doses of toxic chemicals will produce degenerative diseases which mimic the chronic degenerative diseases of man. (51,52) These experiments, some valid, others questionable, but all widely publicized, have induced a state of chemophobia in the public and in public health officials. The resulting attitude which prevails is that toxic chemicals in air, food, and water should be allowed only at zero or at near zero levels whenever possible. Recent events which reinforce this attitude are incidents of poisoning from cadmium in water (53,54) and methylmercury in fish. (55,56) The following paragraphs describe what we envision as the potential health hazard of toxic chemicals in wastewater.

3.2 Direct Toxicity from Chemicals in Water

Heavy Metals. The most recent example of direct toxicity from drinking water is the Itai-Itai disease observed in the Jintsu River region of Japa. (53,54) This disease, known as the "ouch-ouch" disease, because of the pain experienced by the victims, is due to excess quantities of cadmium in the water supply. The source of cadmium was the wastewater discharge from a mine which produced zinc, lead, and cadmium. Treatment of the wastewater resulted in a diminished number of reported cases, but, of the 200 known victims, about 100 died.

"Itai-Itai" disease is clinically characterized by bonewasting. X-rays show a uniform decrease of radioapaque substance in bone. The disease appears to selectively affect middle-aged women and causes extreme pain. Similar bonewasting pathology was produced in rats fed river water from the contaminated area. Effective antidotal therapy has not yet been developed.

Cadmium is a contaminant of zinc ore, and consequently sources of cadmium pollution in water are waste discharges from zinc smelting and refining and from processes using zinc ore for making galvanized steel. Cadmium is also used for electroplating and discharge from electroplating processes has been reported to contaminate ground water. (57) Kobayashi(54) has surveyed the environment around the largest zinc refinery in

Japan and shown widespread elevation of cadmium levels in vegetation, soil and water. Increased exposure in man was evidenced by elevated fecal cadmium levels in samples collected in the neighborhood of the refinery. It is fortunate that there are no large zinc refineries in the Bay Area. We do, however, have cadmium electroplating industries and manufacturers of galvanized steel.

Schroeder [58,59] has amassed evidence showing a relationship between body levels of cadmium and circulatory disorders. Hypertension and cerebrovascular accidents were closely correlated to tissue levels of cadmium in man. Subsequent studies in man and experimental animals have substantiated this hypothesis.

Low levels of cadmimum in drinking water (5 ppm) decreased longevity of rats and mice. [60] The renal tissue levels of cadmium necessary to produce decreased longevity approximate the levels present in man. Inhaled cadmium fumes produces in man an acute chemical pneumonitis followed sometimes by emphysema and bronchitis.[61] Renal necrosis and death have also been reported following inhalation of cadmium.

In summary, it may be stated that we are increasingly aware of the adverse public health effects of cadmium pollution. The permissible level for cadmium in drinking water (.01 mg/l) was not established in the United States until 1962. [46] Recognition of other sources of cadmium intake or further epidemiological studies of the effects of cadmium on human health may necessitate further revision of this standard. It appears that complete control should be established over cadmium discharge into wastewater.

Other metals of toxicological concern are lead, arsenic, barium, and copper. Criteria for these metals have been established and are extensively discussed in the Public Health Service Drinking Water Standards. [46] The advance of technology is such that different sources of contamination and newer pollutants will constantly necessitate revision and establishment of new criteria. For example, the contemplated use of plastic pipes for transporting potable water has aroused concern over the possible leaching of metal plasticizers into the drinking water.[52] The problem of aerial fallout of beryllium, nickel, lead, and cadmium onto surface water, while not germane to this discussion, is receiving attention by others.[62]

Potentiation of metal toxicity can also occur when absorption of the metal is facilitated by a carrier. Standard pharmacology textbooks advise against the oral administration of calcium ethylenediaminetetraacetic acid (EDTA) for childhood lead poisoning because EDTA may increase the amount of lead absorbed through the gut. British-Antilewisite (BAL) may also facilitate the entry of phenylmercuric acetate into the brain.(63) Therefore, it is not surprising to discover that nitrilotriacetic acid (NTA), a chelating agent used in detergents, will potentiate heavy metal toxicity in the fetus.(64) It should be noted, however, that EDTA is an accepted food preservative.(65)

Carcinogens and Teratogens. Trace quantities (1 - 10 ug/m^3) of carcinogenic polyaromatic hydrocarbons have been found in wastewater effluents.(66) These quantities of carcinogens should be contrasted to 8 ug/kg of benzo (a) pyrene present in a well-done charcoal-broiled steak.(67) Organic extracts of river water were not carcinogenic to mice.(68) However, a preliminary experiment(69) showed tumors, a lymphoma and a fibrosarcoma, in 2 out of 10 rats given wastewater to drink for 18 weeks. The difficulties inherent in interpreting tests on a substance that is not completely characterized chemically, and the duration and expense of evaluating carcinogenic activity, prescience future controversies over the carcinogenicity of wastewater.

Nitrites and 2,3,7,8-tetrachlorodibenzo-p-dioxin (the latter referred to subsequently as dioxin) are prominent candidates for designation of the title: "newly identified environmental carcinogens."

Nitrites react with secondary amines to form carcinogenic nitrosamines.(70) It is well-known that infants can convert nitrates to nitrites in the small intestine. If it is established that intestinal bacteria of infants convert, in vivo, nitrates to carcinogenic nitrosamines, then drinking water standards for nitrates should be drastically reappraised (for other aspects of nitrate toxicity, see section III, Miscellaneous Compounds).

Goldberg (51) and others (71) have summarized the teratogenic potential of the herbicides 2,4D and 2,4,5T and the trace contaminant dioxin. Dioxin are potent teratogens; threshold toxicity to the rat fetus being observed at doses of 0.125 ug/kg/day. The current permissible criteria for chlorinated phenol herbicides (0.1 mg/l) does not take into account the trace amounts of dioxin added to water or the possible conversion, in the aquatic environment, of chlorinated phenol herbicides to dioxins. The discovery (72) that soil fungi can synthetize 2,4 dichlorophenol suggests that natural sources of chlorinated phenols exist in the environment. Since

microorganisms have aromatic dehalogenating enzymes, consideration should be given to the possible synthesis of dioxin under different conditions of wastewater treatment.

Paraquat. Under present permissible criteria, direct poisoning from exposure to halogenated hydrocarbon and organophosphate insecticides in water may be dismissed as beyond reasonable likelihood. Permissible criteria, however, have not been established for some newer compounds which have appeared on the market. One example is paraquat.

Paraquat is a herbicide that has been used for the control of aquatic weeds. The pathology produced by accidental paraquat poisoning in man is that of progressive lung fibrosis and proliferation of cells in the lung alveoli.[73] Although paraquat is thought to be inactivated by adsorption to bottom mud when applied, the degradation kinetics for this substance in water is not clear.[74] Sixth thousand pounds of paraquat was used in California agriculture during the first six months of 1970.[75] Since paraquat is extremely toxic to all living organisms, it would be advisable that careful evaluation precede its application to the aquatic environment.

Miscellaneous Compounds: Nitrates. Nitrates may find their way into ground waters from various sources, including contamination by nitrate containing fertilizers, intrustion of sewerage and leaching from naturally occurring nitrogenous formations.

Nitrates, when ingested, may be reduced to nitrite within the digestive tract of infants. When absorbed from the digestive tract, the nitrites react with hemoglobin to form methemoglobin, a form of hemoglobin which is incapable of efficiently transporting oxygen to the tissues.[76] When large amounts of methemoglobin are present in infants, their skin and mucous membranes take on a dusky or bluish appearance and they may become acutely or, on rare occasions, fatally ill. The recommended Public Health Service Drinking Water Standard for nitrates is 45 mg/l.

In terms of liquid waste management strategies, the potential for creation of a human health hazard from nitrates would be significant with only one alternative: land disposal with consequent contamination of ground waters with high nitrate content.

Beneficial Chemicals. On the positive side, the fortuitous presence of some trace chemicals in water may benefit health. The example of fluoride and dental caries is well-known.(77) Recent investigations suggest that excess fluoride may result in the decreased deposition of cholesterol plaques in the aorta.(78) The hardness of water is inversely correlated to sudden ischemic heart death. (79) From rather far-fetched extrapolations of biochemical phenomenon, one researcher has suggested that the addition of copper, zinc, and vanadium to drinking water could possibly reduce the incidence of cardiovascular disease.(80)

3.3 Indirect Toxicity from Chemicals in Water

The term indirect toxicity as used here involves the phenomenon of biomagnification, which is the process where certain foreign substances enter the aquatic environment; are taken up by the marine "biomass" or living material; and are transferred through the food chain from lower to higher trophic levels undergoing increasing concentration as they pass from lower organism to higher.

Organometallic Compounds. Organometallic compounds are the class of chemicals with the structure R-M+, where R is an organic radical and M+ is a metal ion. For short-chained alkylmetallic compounds, toxicity is exceptionally high because of the lipid solubility of these compounds and the consequent prolonged retention in nervous tissue. Examples of organometallic compounds which have caused fatal nervous disorders in man are: methylmercury and ethylmercury,(56) tetraethyl- and tetramethyllead, triethyltin, and cyclopentadienylmanganese.(81)

The recent discovery by Swedish workers of bacterial conversion of inorganic mercury to methylmercury has raised serious concern about the possible synthesis by microorganisms of other toxic organometallic compounds from metals in the environment.(82) From fragmentary and exploratory initial experiments, it now appears that arsenic is converted to dimethylarsine but that lead is not converted to the tetramethyl form.

Mercury is the metal which has received most attention as a organometallic compound capable of undergoing biomagnification.(83) Discharge of mercury into the aquatic environment in either its organic or inorganic form is followed by a buildup of mercury in the bottom sediments. Here it is methylated by microorganisms and enters the aquatic food chain where it undergoes biomagnification as it is passed from lower to higher life forms. Through this mechanism, methylmercury, among the most toxic of all forms of mercury, finds its way in potentially dangerous quantities into marine organisms which serve as food for man. Although no recognized case of human poisoning has been attributed to the phenomenon of biomagnification in this country, several such episodes have occurred in Japan with tragic consequences.(56)

Insecticides. Currently used synthetic organic insecticides can be classified generally into three groups: the organochlorines, the organophosphates and the carbamates. It is highly unlikely that sufficient quantities of any of these agents would be present in domestic wastewater to create a potential for direct injury to human health. This statement would hold for any of the alternative management strategies contemplated. If ocean or estaurine disposal is selected, however, the potential for indirect toxicity through the phenomenon of biomagnification should be considered. Fortunately, however, of the three groups of pesticides listed above, only the organochlorines appear to participate in this phenomenon. DDT, for example, has been shown to concentrate over 1,000 times as it travels up the marine food chain from plankton to carnivorous birds.(84) Insofar as human health hazard is concerned, concentrations of DDT-derived materials have been found in game fish taken in the vicinity of wastewater outfalls which have been far in excess of those permitted in fish sold in the marketplace for human consumption. Other organochlorine insecticides have not been identified as major food chain concentrators, however, they and often be found in marine inhabitants and their potential for creating significant biomagnification problems must be born in mind.

Pentachlorophenol is a widely used fungicide used in the tannning industry. This compound has caused fish kills and in the Napa Valley significant quantities of pentachlorophenol are found in fish. Fatal poisoning have been reported in man ingesting large quantities(85) and in infants poisoned by diapers contaminated with pentachlorophenol.(86) No standards have been set for pentachlorophenol discharge into wastewater. The present permissible criteria for "phenols" is based on taste and is aimed at controlling the aerosols and xylenols. The herbicides 2,4,5T and 2,4D have different permissible criteria (.1 mg/l). The possible conversion, in the wastewater process, of chlorinated phenol herbicides to more toxic compounds such as dioxins should be investigated.

Polychlorinated Biphenyls (PCB). There are approximately 200 different compounds and isomeric configurations which can be classified as PCB. PCB are stable, are not hydrolized by water and are resistant to alkalais and acids. They are soluble in hydrocarbons and insoluble in water. Volatility is low and decreases with increasing chlorination.

Interest in residues of PCB has been in two broad areas: (1) their potential for interference in the determination of organochlorine pesticides, particularly DDT and its analogs; and (2) their significance as residues in animal tissues and foods. It is the second area which is germane to this discussion; the first area being the province of the analytical chemist.

PCB's enter the ecosystem in many ways, including incineration of products containing them, such as carbonless reproducing paper, plastics, paints, etc. Another source is industrial wastes from plants which manufacture PCB's and from plants where PCB are utilized in manufacturing processes. They can escape through the plant ventilation system into the atmosphere and through its waste treatment system into sewers or directly into waterways.

PCB's have been found in brown seals off the coast of Scotland, white tailed eagles in Sweden, cod in the Baltic Sea, mussels in the Netherlands, penguin eggs in the Antartica, brown pelican eggs in Panama, shrimp in Florida, river water in Japan, waters of the Great Lakes, and in human hair and adipose tissue.(87)

The physical properties of PCB and the available residue data indicate clearly that these materials are capable of biological magnification in food chains. The most detailed studies currently available are those of Jensen et al.(86,88) These investigators reported an average of 14,000 ppm PCB in the pectoral muscle of White-tailed Eagle. Creatures lower in the food web, such as mussels and herring contained an average of about 5 ppm PCB. Eggs of sea birds collected in the San Francisco Bay region contain up to 805 micrograms of PCB.(89)

4. EFFECTIVENESS OF PROPOSED TREATMENT METHODS

4.1 Removal of Infectious Agents by the Proposed Treatment Methods

The proposed treatment methods include conventional treatment (primary and secondary), advanced treatment which includes chemical precipitation, ponding, filtration and disinfection. It is of interest to know how well these various methods remove or destroy bacterial, parasitical and viral agents. Prior to the 1960's, very little was known concerning the fate of viruses in waste water treatment systems; however, the fate of other pathogenic organisms was well document.

Bacterial and Parasitical Disease Agents

In 1959, Kabler(90) wrote an extensive review article concerning the removal of pathogenic microorganisms by sewage treatment processes including activated sludge and trickling filter methods, anaerobic digestion, and chlorination. In this review he points out trickling filter treatment reduces the total number of bacteria and coliforms from 70 to 95 percent; salmonella from 84 to 99 percent; and the tubercle bacillus by 66 percent. The activated sludge procedure reduced the total count by 90 to 98 percent, the coliform, salmonella, cholera and shigella by 91 to 99 percent and M. tuberculosis by 88 percent. Anaerobic digestion removes 25 to 93 percent of the salmonella and 90 to 96 percent of the tubercle bacillus. Chlorination is usually 93 to 99 percent effective.

The same processes removed tape worm ova, amoebic cysts, hookworm ova, and ova and aquatic stages of schistosomes with a wide range of efficiencies. These vary from 20 to 100 percent most probably depending upon operational parameters in effect at the time of the original report.

The basic mechanisms of purification in operation in waste stabilization ponds is thought not to differ greatly from that in other treatment methods. Total bacterial counts in the effluent usually are less than one percent of the original concentration and coliforms are reduced by 59 to 99.9 percent. In one study salmonella were isolated from all phases of an oxidation pond process.(91)

Virus Removal

Removal and Inactivation of Enteric Viruses in Sewage Treatment Process. Although many investigations on enteric virus survival in conventional sewage treatment processes have been reported, many serious gaps still exist in our knowledge of this problem.

Storage. As with water treatment, substantial reductions in the enteric virus density of wastewater are achieved only if long storage times are employed.(92)

Primary Sedimentation. Results of both laboratory and field investigations indicate that primary sedimentation is capable of only slight reductions in enteric virus density. Removals of enteric viruses are generally no more than 40 or 50 percent.(93,94)

Trickling Filters. There have been no laboratory studies and few field studies on virus reductions in trickling filtration. The few field studies reported indicate that virus removals are not more than 40 or 50 percent.(94,95,96)

Activated Sludge. Activated sludge has been shown to be the most effective conventional sewage treatment process for reducing the enteric virus density of wastewater. Removals of 90 percent or more have been achieved. From the results of laboratory studies, some investigators have suggested that virus removal in activated sludge is an adsorption process involving the formation of a stable virus-sludge complex.(93) Other investigators have suggested that virus destruction may be due to a two-step process involving aeration in the presence of sludge floc and nutrients followed by settling of the floc.(94) Kelly and her co-workers also reported that biological antagonism in the sludge may play a role because they were able to isolate several bacteria from activated sludge which had antiviral activity. These authors also concluded that virus removal in activated sludge is probably by adsorption on the sludge particles. Biological factors were also believed to play a role in virus removal. The subsequent fate of sludge-associated virus was not determined. In several field studies on virus survival in activated sludge, it was found that enteric viruses were present 4 to 10 times less frequently in the activated sludge effluent than in the influent.(97,98,99)

Stabilization Ponds. Only a few studies on enteric virus removal in stabilization ponds have been reported. Virus reduction in a stabilization pond has been studied at the Santee Water Reclamation Project in Southern California, where sewage is treated to a high degree and the reclaimed water is used for recreational lakes.(100) One of the stages in the reclamation process is a facultative stabilization pond with a 30-day detention time. From July 1962, to October 1965, virus studies were conducted and a summary of the findings indicates that the percentage of samples positive for virus was 97 percent in the pond influent and 19 percent in the pond effluent.

Malherbe and Strickland-Cholmley(96) did extensive studies on virus removal in both pilot and full-scale ponds. Poliovirus type 2 was seeded over a period of 20 days into a one-half acre model stabilization pond system treating raw sewage and consisting of 4 ponds in series. In samples taken 20 times over a period of 56 days, no appreciable reduction of virus was observed beyond that expected from dilution. Studies with full-scale ponds utilized two different municipal pond systems. In one pond system where virus survival was studied for a period of 6 months, the percent of samples positive for virus was 4.3 percent in the pond influent (trickling filter effluent) and 3.8 percent in the pond effluent. In another pond system the percent of samples positive for virus was 49 percent in the pond influent (trickling filter effluent) and 2.5 percent in the effluent over a 9-month period.

The removal of poliovirus type 3 in a pilot pond and in effluent taken from a full-scale municipal pond has been studied by Christie.(101) In batch experiments the pilot pond water was capable of reducing the virus concentration by nearly 5 orders of magnitude in 96 hours. The pilot pond experiments are difficult to interpret because the virus added to the pond influent could not always be accounted for, suggesting that virus was destroyed before it reached the pond. Municipal pond effluents were capable of reducing the concentration of added poliovirus by more than 2 orders of magnitude in 72 hours.

The survival of enteric bacteria and viruses has recently been studied in three different stabilization pond systems in New Hampshire.(102) Enteric viruses were isolated from a majority of the pond effluents tested during all seasons of the year. Insufficient data was collected to determine if virus reductions occurred in the ponds.

The effect of waste ponding upon enteric viruses has been studied at the Windhoek Wastewater Reclamation Plant in Southwest Africa.[103] The reclamation system includes a series of nine maturation ponds with a detention period of 14 days. In a 48-hour study on virus removal at each stage of the reclamation process, the reduction of enteric virus concentration in the maturation pond series was at least 95 percent.

On the basis of the above mentioned studies, it would appear that algal-bacterial treatment systems are capable of reducing the concentrations of enteric viruses in sewage. However, these studies do not provide sufficient quantitative information to generalize about the efficiency of virus removal in these systems.

Removal of Infectious Agents by Advanced Treatment

The two most prominent activities in which advanced waste treatment processes are being employed are the Santee Water Reclamation Project in Southern California and the Windhoek Wastewater Reclamation Plant in Southwest Africa. In the former case, wastewater is being reclaimed for recreational use, while in the latter, for domestic use.

The Santee Project consists of primary sedimentation, activated sludge, oxidation ponding, percolation through a natural sand and gravel layer, and chlorination. The final effluent is used for a series of recreational lakes. Bacterial removal by the conventional treatment methods was between 96 and 99 percent effective (see Table VII).

TABLE VII: Bacterial Removal in Preliminary Waste Treatment Process, Santee, California.[100]

	% Removal of Influent	
EFFLUENT	COLIFORM	FECAL COLIFORM
Primary	0	35
Activated Sludge	89	80
Oxidation Pond	96	99

Although the percent removal was quite good, a large number of bacteria still remained and the water from the oxidation pond was not acceptable for bathing. Infiltration through the gravel layers was still not enough and chlorination prior to discharge was necessary. Results of the bacterial analyses for a six-month period are given in Table VIII.

The bacteriological quality of the influent to the recreational lake is well within the desirable raw surface water quality criteria for public drinking water supplies. Both the lake inlet and outlet quality were acceptable for primary (swimming) human contact.(45)

TABLE VIII: Removal of Coliform and Fecal Coliform During Tertiary Treatment Santee, California - 1963-1964

Station	Coliform		Fecal Coliform	
	MPN*>	%2>	MPN	%
Pre Inflitration	330,000	0	130,000	0
Post Infiltration	3,300	99.00	>8	99.94
Lake Inlet (Post Chlorination)	4.5	99.99	<2	---
Lake Outlet	200	99.94	8	99.94

1> MPN per 100 ml

2> % Removal

The Santee Project was also evaluated for virus removal efficiency. Using the gauze pad method of virus sampling, it was observed that the percentage of samples being positive for virus was 100 percent after primary treatment, 97 percent after activated sludge, 19 percent after detention in an oxidation pond, less than 10 percent after chlorination of pond effluent, 2 percent after percolation, and 0 percent in the recreational lakes over a 33-month period.

The Windhoek Wastewater Reclamation Plant consists of primary sedimentation, trickling filtration, secondary sedimentation, maturation in a series of 9 oxidation ponds, aluminum sulfate flocculation/flotation, foam fractionation, secondary lime/aluminum sulfate flocculation, breakpoint chlorination, sand filtration, and activated carbon filtration.

This operation is able to produce a water of acceptable bacteriological quality after breakpoint chlorination is applied. The total bacterial count is significantly reduced by chlorination but increases after the activated carbon filtration, most probably because of bacterial growth in the carbon filters. (104)

At the South African site, initial investigations on the removal of added poliovirus in a pilot scale system showed that reductions of greater than 90 percent could be achieved in each unit process studied and that no virus could be detected at any stage after flocculation/flotation. Using either the polymer 2-phase method or the ultrafiltration method of virus concentration, substantial virus reductions in the full-scale reclamation system were found. (103) Although 18 percent of the virus in the influent sewage remained after secondary settling, a further reduction of 95 percent was achieved in the maturation ponds, and no virus could be detected after foam fractionation or any later treatment step. With the concentration methods used, however, only 1 liter aliquots of wastewater effluent samples could be tested for virus.

A number of laboratory studies have been conducted to evaluate the removal of viruses by various coagulation methods to be used in advanced wastewater treatment. Removal of viruses from wastewater effluents by coagulation and flocculation has been studied in the laboratory by Brunner and Sproul. (105) They found that phosphate precipitation from wastewater effluent by calcium and aluminum removed 90 percent or more of added poliovirus. However, Chaudhuri and Engelbrecht found that aluminum sulfate coagulation of bacteriophages T4 and MS2 in wastewater effluents removed only about 60 percent and 10 percent respectively of the added virus in laboratory studies. The authors concluded that high virus removal efficiency would not be achieved by coagulation and flocculation of wastewater effluent due to the presence of interfering organic matter.

The removal of poliovirus from secondary effluents by lime flocculation and rapid sand filtration has been studied in the laboratory by Berg et al. (106) Lime flocculation removed 70 to 99.86 percent of poliovirus, the degree of removal depending upon the concentration of lime and the pH level attained. Virus removal by filtration through 8 inches of sand ranged from 82 to greater than 99.8 percent. When lime flocculation was followed by sand filtration, the overall virus removal ranged from 98.6 to greater than 99.997 percent.

Sproul et al (107) reported low removals of poliovirus in laboratory studies with activated carbon. Poor virus removal was attributed to competition for adsorption sites by organic material in the sewage.

The Soil Mantle

The soil mantle is quite efficient in the removal and inactivation of microbial pathogens. Because sewage spreading is a method of promise in the reclamation of wastewater, it is important to measure its purification capability. Great numbers of bacteria are removed by percolation through a few feet of fine sand by the process of mechanical and biological filtration and by the antagonistic effect of soil organisms. Excellent bacteria removals have been reported by passage through a minimum of three to seven feet, even though the soil is quite coarse. This latter studies, which included the spreading of raw sewage, a travel depth of twelve feet was required to effect 99.99 percent coliform removal. (108) In all instances of bacterial removal, it is notable that the most pronounced activity is in the top 0.5 to 1.0 cm of soil and that often there is a secondary limiting zone appearing 50 to 60 cm below the surface. (109) The soil texture of the soil involved also has an effect on the ability to remove bacteria as is shown in Table IX.

TABLE IX: Soil Texture and Coliform Count at a Depth of Three Feet for Five California Soils (110)

NAME	EFFECTIVE SIZE (cm)	FLOW RATE (ft/day)	COLIFORM (MPN/ml)
Hesperia Sandy Loam	0.0020	0.2	45
Hanford Sandy Loam	0.0056	0.3	45
Columbia Sandy Loam	0.0034	0.3	45
Yolo Sandy Loam	0.0016	0.3	24,000
Oakley Sand	0.0150	0.1	2,400

Initial coliform count 1.9×10^8 coliform per 100 ml.

The work done at Santee, California, wherein secondary effluent was infiltrated latterly through 1,500 feet of sand and gravel indicated most of the removal of bacteria occurred in the first 200 feet. Little further removal was seen in the next 1,300 feet of percolation bed. These data indicate impressive removal of bacteria even by a very coarse medium and also indicate an optimum depth beyond which one obtains diminishing returns in bacterial removal.

A number of laboratory and field studies on virus removal from water and wastewater in various types of soil systems have reported. In a pilot scale study Robeck (111) reported that 2 feet of packed sand removed poliovirus from relatively clean water flowing at rates up to 4 feet per day, but the virus breakthrough occurred when the flow rate was increased. In a laboratory study Hori et al. (112) found that at least 97 percent of the poliovirus applied to some Oahu soils was removed at soil thicknesses of 1.5, 2.5 and 6 inches. Other Oahu soil types were considerably less effective in removing virus. Carlson (113) reported that bacteriophage T2 and poliovirus were effectively removed from aqueous salt solutions by adsorption to clay particles. The virus removal efficiency was lower in experiments with natural river waters. Drewry and Eliassen (114) studied bacteriophage removal in both soil columns and batch soil suspensions in salt solutions. They found that virus was removed from the water by adsorption to the soil particles, and they obtained virus removals of greater than 99 percent in 16 to 20-inch soil columns. At the Santee Water Reclamation

Project, oxidation pond effluent was percolated through a 1,500 foot long bed of sand and gravel having a depth of 10 to 12 feet. During a 10-month period the percentage of samples positive for virus was 9 percent in the percolation bed influent and 2 percent in the effluent. When the percolation bed was challenged with a single dose of about 3.6 x 10 PFU of poliovirus, no virus could be detected in the percolated water after 200 or more feet of travel. In a recent review of bacteria and virus movement through porous media, Romero (110) concluded that soil uniformly composed of fine sand with a high clay content is the best aquifer material for removing biological contaminants and that such contaminants would travel a maximum of 100 feet in this environment.

Disinfection. Chlorine is most commonly used for the disinfection of water and waste water. When used properly, it is extremely effective in destroying bacteria, parasites and viruses. The chemical may be added to water either in the form of chlorine gas or as a hypochlorite. In either case, it is felt that the unionized HOCl is the most effective disinfectant and therefore a pH that favors the existence of this species is desirable. Chlorine also reacts with nitrogenous compounds in such a way that its germicidal effectiveness is greatly reduced. Therefore, it is important in water disinfection to chlorinate beyond the breakpoint. In all cases, therefore, the effectiveness of disinfection will be effected by pH, contact time, temperature and water quality.

Viruses are, as a rule, more resistant to chlorination than are bacteria; therefore, using coliforms as an index of efficiency of chlorination is open to some question. It has been indicated (95) that at pH 6 to 8 a concentration of 0.3 mg/l free available chlorine for 30 minutes is required to remove 99.9 percent of the viruses present in water and combined chlorine residual of 10 mg/l for more than an hour would be required to cause a similar result. Normally, municipal water supplies are chlorinated in a range of 0.1 to 0.2 mg/l free available chlorine which may not be sufficient for virus removal.

Bauman and Ludwig (115) compiled data from the literature concerning the chlorination of small public supplies of water. They developed a number of death curves for various bacteria, viruses and protozoans as they react to different concentrations of free available chlorine. The slope of these curves was approximately one and from which these authors gave the following "rule of thumb" formula for water disinfection:

$$C^{-n}t = K$$

where C is the chlorine concentrations in mg per liter; t is the time required to remove 99 to 100 percent of the organisms present; n is the slope of the death curve and K is a constant. Since n approximates one, the relationship Ct = K would hold in which the product of any concentration of chlorine and contact time in minutes that equals K would be an effective dose. They developed the useful K values shown in Table X.

TABLE X: Value of Disinfection Constant K for Various Important Water-Borne Microorganisms - Temp 20-29°C

K Value	Microorganisms
2-4	E. coli pH 7.0 - 8.5
	Salmonella pH 7.0
6	Poliovirus pH 6.8 - 9.3
	Coxsackie A pH 7-9
10	Hepatitis pH 6.4
50-125	E. histolytica pH 7-8

It can be readily seen that there is a considerable range of differences depending upon the organism of interest. The agent of amoebic dysentary is extremely resistant to disinfection; however, filtration is an effective means of its removal.

Discharge to the Marine Environment. Discharge of wastewater into the aquatic or marine environment is a method of treatment or at least the final sink for treated and untreated wastewater. It is appropriate, therefore, that a statement concerning the survival of infectious agents in receiving waters be made.

All living things are faced with the problem of survival, which becomes acute in an unfavorable environment. Receiving waters are normally unfavorable to infectious agents in that they normally do not multiply. The important aspect is the

rate at which they are inactivated in this milieu. This rate depends upon a large number of factors including some that are inherent in the organism itself (structure, enzyme constitution, etc.), the previous recent history of the organism and, of course, such environmental factors as temperature, pH, antibiotics, predators, and nutrients.

There has been particular interest in the survival of bacteria in seawater because since the 1880's microbiologists were aware that bacterial death rates were greater in seawater than in fresh water. Generally, it can be concluded that bacteria not natural to seawater die away very rapidly and this includes coliforms.[116] The rate of die-away is seasonal, being greater in summer than in spring, and in the laboratory this generally exceeds 90 percent in one to three days. The die-away is logarithmic and the consensus is that bacterial pathogens die more quickly than coliforms. Ketchum et al[117] evaluated the effect of dilution, predation and antibiosis upon the survival of bacteria in a tidal estuary and concluded that the bacteriocidal effect of estuarine water was 26 to 35 times more important in inactivation than either dilution or predation. The antibiotic effect has not been adequately elucidated.

Seawater is also more virucidal than fresh water. McLean and Brown[118] demonstrated that poliovirus persist in undiluted titre for 12 days at 4°C, while in seawater at 4°C the infectivity declined 100 fold and at 25°C was undetectable in five days. A non-biological agent lethal to viruses has been postulated. It must be remembered that even though seawater inactivates viruses (and bacteria), these agents have been isolated in shellfish from estuarine and freshwaters and are a potential hazard.

4.2 The Removal of Non-infectious Disease Agents from Liquid Waste

The identified agents in wastewater of potential public health concern are the heavy metals, pesticides, and polyaromatic carcinogens. The major contributor of these compounds to municipal sewage is industry. Control of industrial wastes can best be effected by control at the source of entry into the municipal system. However, regardless of how well managed and enforced, industrial wastes will find their way into the system whether it be by accidental spills or negligence.

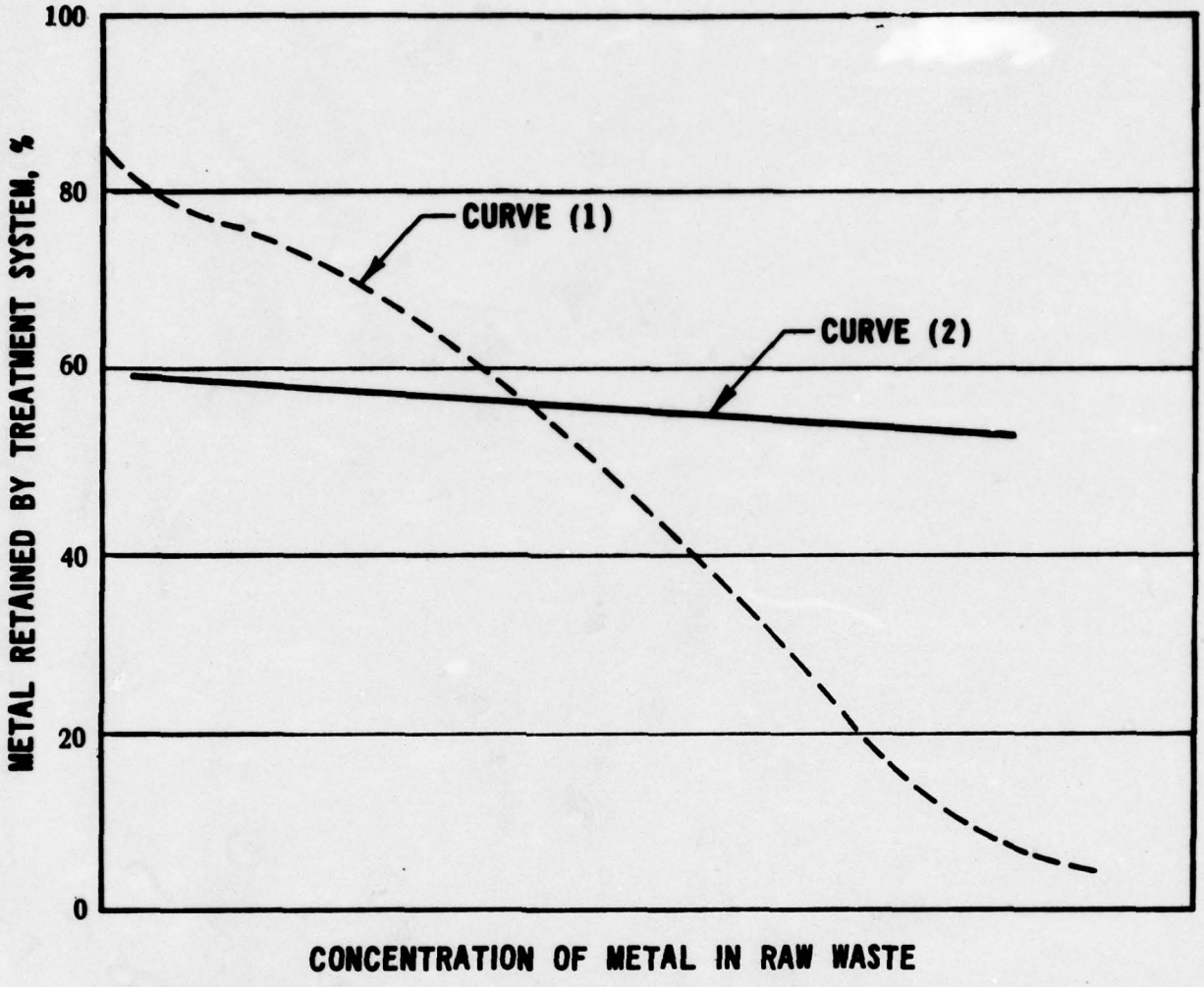
Even if industrial contributions are eliminated, phenomena such as corrosion, run off, aerial fallout, additives used in water treatment, and poor raw water will add agents of public health concern. Some sources may be very unexpected. For example, a major source of mercury in the Los Angeles sewage

system originates from baby diaper services using phenylmercuric acetate as a diaper disinfectant. [119] Kopp, in examining over 1,500 raw water supplies in the United States, found 177 violations of the limits set for metals by the Water Quality Criteria for Public Water Supplies. Manganese was first with 71 violations, followed by arsenic with 41, lead with 27, and iron with 25. Cadmium and hexavalent chromium made up another 10. In the 380 finished waters examined, iron, manganese, lead, copper, and cadmium exceeded the Drinking Water Standards on occasion. The presence of trace elements in finished water is directly related to the trace element levels in the raw supply, as treatment processes generally do not remove these trace elements. [120]

The removal of heavy metals can be accomplished by precipitation, adsorption onto colloidal surfaces, or by formation of insoluble sulfides. [121] Nilsson [122] showed that with lime at a pH of 9.5 or aluminum sulfate, 100 mg/1, 90 percent of Lead (II), Copper (II), Cadmium (II), Arsenic (V), Zinc (II), and mercury was removed from mechanically treated municipal sewage. Initial metal concentrations averaged 3 mg/1 and the average concentrations after treatment were fractions of a mg/1. Lime treatment had lower final concentrations than aluminum sulfate and efficiencies of removal varied for each metal. The chromium concentration was not significantly reduced. Allaway [123] predicts that any selenium in a waste stream would be in the effluent waters as selenates as it goes through aerobic processes operating at alkaline conditions. Under anaerobic conditions, selenium would be converted to elemental Se or to $Fe(OH)_3 - SeO_3$ complexes. These forms are insoluble and would remain in the sludge. In extended aeration plants, all the metal is transported to the receiving water unless sludge removal is practiced.

A group at the Robert Taft Engineering Center [124] have determined retention percentages by municipal primary and secondary sewage treatment of various metals. Their results are shown in Figure 1.

Type 1 Curve is the response of chromium introduced as chromate. The inefficient reduction of hexavalent chromium in the system causes the behavior shown. Type 2 Curve is the response by most other metals.



PATTERNS OF HEAVY METAL RETENTION BY TREATMENT SYSTEMS

FIGURE 1

It must be noted that removal efficiencies may differ for different metals. Table XI gives the results for hexavalent chromium, copper, nickel and zinc.

TABLE XI: Distribution of Metals Through the Activated Sludge Process [124]

	Percent of Metal Fed			
	Cr (VI) 15 mg/1*	Cu 10 mg/1*	Ni 10 mg/1*	Zn 10 mg/1*
Primary sludge	2.4	9	2.5	14
Excess activated sludge	27	55	15	63
Final effluent	56	25	72	11
Metal unaccounted for	15	15	11	12
Average efficiency of process in removing metal	44	75	28	89
Range of observation	18-58	50-80	12-76	74-97

*Influent Dose

It has been shown by various workers [125,126] that chlorinated hydrocarbons show strong sorption onto particulate matter. Subsequent settling in the sewage treatment process would reduce their concentration in the effluent, but they would appear in the sludge. Degradation of chlorinated hydrocarbon pesticide has been investigated under both activated and anaerobic sludge process. [125] Degradation of most chlorinated hydrocarbon pesticides was more rapid under anaerobic conditions. Some pesticides such as dieldrin and heptachlor epoxide were, however, persistent. Metabolism, adsorption and absorption into the lipid bacterial components probably account for the mechanism or removal. It should be noted, however, that degradation can frequently result in the formation of more toxic biological substances so that the disappearance of the parent compound cannot be interpreted as the removal of biotoxicity.

The other major class of insecticides, the organophosphates, are readily hydrolyzed in aqueous solution. Slight alkalinity (approximately pH 8) increases the hydrolysis rate of these phosphate esters.[127] It is doubtful that the finding of some anticholinesterase activity in organic micro-pollutants of water has any significant physiological meaning.[128] Before there are clinical symptoms of excess cholinergic nerve transmission, 99 percent of the mammalian true cholinesterase activity has to be inhibited.[129] Concentrations found in sewage are not sufficient to accomplish this.

Carcinogenic organic substances are resistant to oxidative degradation in the activated sludge process and removal depends mostly on sorption to organic material.[130] These organic compounds probably originate from petroleum refinery wastes and associated chemical industries. The actual carcinogenic hazard posed by human intake of these chemicals via water, however, may be several-fold lower than the intake from other sources, such as charcol-broiled foods and cigarette smoking. Dose response relationships between polyaromatic hydrocarbons and cnacer in man are still poorly quantified.

The fate of heavy metals in the sea for final disposal has been investigated by Krauskopf.[131] The concentrations of these elements are less than saturation level with respect to any of the 13 metals investigated even where pH and temperature have extreme values. Adsorption onto various absorbants with their respective effectiveness is shown in Table XII.

TABLE XII: Adsorption of Heavy Metals by Various Adsorbates[131]

Metal	Hydrated Fe_2O_3	Hydrated MnO_2	Apatite	Clay	Plankton	Peatmoss
Zn	95		86	99	40 (48)	99
Cu	96	96	77	94	54	
Pb	86		96	≈96		>96
Ni	33 (94)	99	8 (69)	10	8	
Co	35 (91)	93 (94)	15 (82)	18	8	
Hg	50 (>95)		<5 (25)	96	98	99
Ag	22 (20)	(8)	23 (6)	20	49 (96)	54
Cr	10 (49)	94	12	8	10	
Mo	25 (56)	50 (74?)	10	35	15	53?
W	80	99	5		8	
V^{iv}	>96		19	27	16	
V^{v}	96	23 (40)	17	33	3	

--Conc. of adsorbate: 0.6 - 2.5 ppm for first 7 elements, 2-10 ppm for last 5. A second # in parenthesis is the % adsorption for lower conc. of adsorbate, in the range 0.1 - 0.7 ppm.

--Conc. of adsorbent: for Fe_2O_3, MnO_2 and apatite 0.02 - 0.1 gm/l except for underlined figures which have 0.3 - 0.7 gm/l, for clay and peatmoss 7-20 g/l, for plankton not measured.

--All values are given as percent of metal adsorbed.

--Temp. 18° - 23°C, pH 7.7 - 8.2.

The factors which affect desorption, therefore, will be of major import to the ultimate fate of the sorbed metals. In general, the fate of pesticides in the water component upon discharge to the sea will parallel that of the metals.

It should be noted that the opportunity for biomagnification exists with toxicants sorbed onto particles especially for filter feeders such as shellfish.

Engineered soil systems that are without vegetation are quite limited for the removal of chemicals. Chromate, phenols and other chemicals have been observed to travel many miles. (109) For this reason, they have not been employed for industrial treatment. Observation on pesticide movement through soils have been made.(132) Pesticides and their residues have been observed to move very slowly and in trace quantities. Compounds with increasing water solubility tend to move more rapidly.

If vegetation is present, volitalization and recycling can occur. For example, selenium accumulator species have frequently contained concentrations of over 200 ppm while their parent soil contained less than 10 ppm of total selenium. Other species of food or feed plants can accumulate selenium in concentrations potentially toxic to animals and may represent an indirect human hazard.(123) Similar statements can be made of the other heavy metals.

5. SLUDGE DISPOSAL

In addition to the liquid effluent from waste water treatment plants, by-product slurries or sludges are produced. The public health hazards associated with disposal of this material depend first on its composition, and second, on the likelihood of any toxic or pathogenic constituents reaching man as a result of the disposal or processing methods employed.

In general, the constituents of sludge that are of concern are pathogenic organisms and toxic chemicals, both of which are found in raw sewage. In conventional waste treatment systems, primary sludge is produced by allowing the solids to settle out of the influent wastewater. If plain sedimentation is employed, roughly 60% of the suspended solids are removed. If chemical coagulation is used, the fresh sludge will be comprised of the precipitated chemicals and form 70 to 90 percent of the suspended solids. In either case, digestion

modifies the solids in much the same way.(133) Further, the presence of the chemical precipitates from phosphate removal processes should not interfere with anaerobic digestion. (134)

Secondary wastewater treatment processes convert soluble organic matter and suspended solids to settlable material which is readily collected and stablilized. Conversion efficiencies are approximately 60 percent in the trickling filter process and 80-90 percent in the activated sludge process.

The raw sludge is principally composed of lignin, cellulose, hemicellulose, protein, protein-diamines, organic N - intermediates, bacteria, viruses, inorganic minerals and a variety of metallic elements depending upon the nature of the service area. (135) Table XIII shows a digest of the results of spectrographic analyses of sludges sampled from 12 treatment plants in Oklahoma.(136) Although mercury and cadmium are conspicuously absent from these analyses, the data seems to be the most comprehensive currently available on metals of significance to human health.

TABLE XIII: Metals Content of Air Dries Sludge
(as % of air dried sludge (136))

	PERCENTAGE	
ELEMENT	RANGE	MEAN
Copper	0.08 - 0.60	0.24
Nickel	0.01 - 0.30	0.05
Zinc	0.30 - 0.70	0.52
Beryllium	trace	--

The removal of heavy metals by various treatment processes has been studied by a number of investigators. (124) It appears that most heavy metals generally end up in sludge, but under certain conditions appreciable quantities will be present in the final effluent. Calcium, magnesium, strontium, barium, aluminum, trivalent chromium, manganese, iron, cobalt, nickel and copper can be removed by lime clarification. Zinc, cadmium, arsenic, antimony, mercury, tin and lead may be removed by adsorption in the process of lime precipitation.

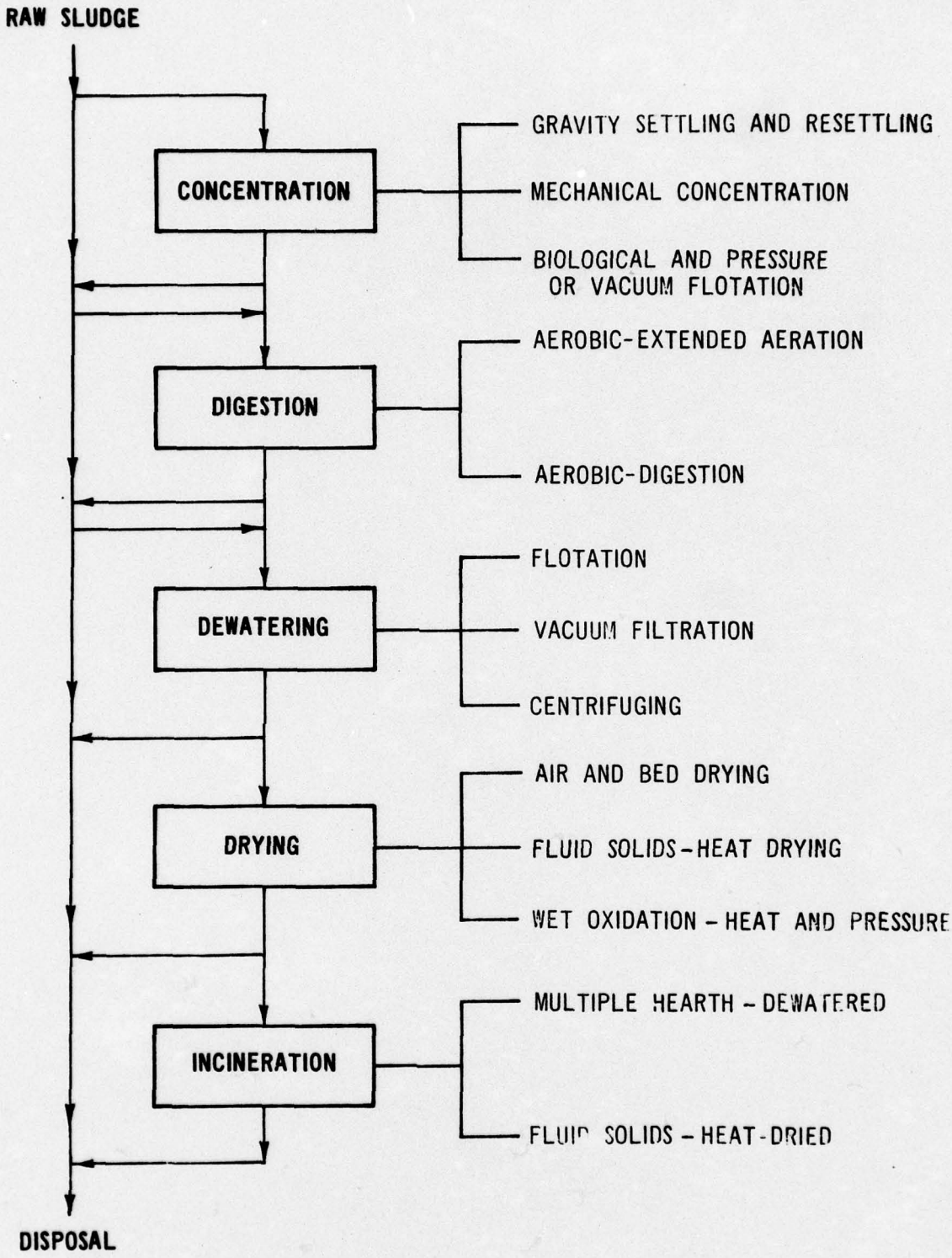
Mercury, cadmium and zinc are strongly adsorbed on organic matter and are found in primary and secondary sludges. Hexavalent chromates are not removed in primary and secondary treatment processes. (121)

In general, it can be assumed that metals present in the influent will appear in sludge solids. A similar comment applies to persistent pesticides. In particular, a significant percentage of influent chlorinated hydrocarbons is likely to be found associated with the lipid fraction of the sludge.

Up to 90% of the pathogenic organisms present in the influent waste water will be found in primary sludge. (137) This figure pertains particularly to bacteria and larger parasites. However, a lesser percentage of viral particles is likely to be removed by primary sedimentation. On the other hand, preliminary data indicate that 95 to 99% of viral particles are removed in the activated sludge process, which suggests that the combined sludge contains a very large fraction of the total virus population. Hence, the species of pathogenic organisms found in the raw sludge can be assumed to be identical with that of the influent waste water and, in addition, the numbers may be only slightly diminished.

Disposal Alternatives

Figure 2 shows a flow chart for solids handling applicable to conventional treatment processes. At the completion of any of these unit processes, it is possible to consider the product material a candidate for ultimate disposal.



FLOW CHART FOR SOLIDS HANDLING
Arrows Indicate Possible Flow Paths

FIGURE 2

The direct disposal of the raw sludge, or concentrated raw sludge, is possible, but attractive only from an economic view. The introduction into the environment of large numbers of pathogenic organisms seems unwise, however, well managed. In addition, numerous cases of domestic livestock infection resulting from being pastured on sludge treated fields are known. (138) Salmonella, Mycobacterium, tuberculosis and parasites have been transmitted in this fashion. Further, the potential for groundwater contamination increases as the concentration of pathogenic organisms increases due to continuous application. At the very least, the odor and pest problems, which to a greater or lesser degree accompany the transport and spreading of raw sludge, will present a public nuisance.

Stabilization of raw sludge is conventionally accomplished by extended aeration or by anaerobic digestion. Anaerobic digestion is the method of choice in the United States. Table XIV gives the properties of digested sludge. (139)

In more detail, the chemical composition of digested sludge includes: cellulose, hemicellulose, lignin, pectic derivatives of protein, and fats, amino acids, carbosyl, phenolics, sulfonates, protein, nitrogen products of partial oxidation of organic nitrogenous compounds, nitrites, nitrates, sulfides, phosphates, bicarbonates and the various heavy metals. (135) Clearly, heavy metal contaminants present in the raw sludge will emerge in the digested sludge.

The disposal of wet digested sludge on land presents a somewhat more attractive alternative than that of raw sludge from a public health viewpoint. However, for either the digester effluent of the dewatered sludge, at about 10% solids, pathogenic organisms are still of concern. Anaerobic digestion has been found to remove 25 to 92% of tuberclebacilli, 95% of tape worm ova and 45% of ascarids ova. (90) These removal fractions depend heavily on the particular species involved and the operating parameters of the digester. For example, 90% of samples taken from the sludge after 4 weeks of digestion were contaminated with salmonella, whereas only 45% of samples from the raw sludge were contaminated. (138) This does not imply growth of pathogenic organisms in sludge, but indicates the relative concentrating effect of the process. There seems to be scant data in the literature concerning virus survival in anaerobic digestion.

TABLE XIV: Properties of Digested Sludge [139]

Color	Blackish
Physical State	Amorphous, non-plastic heterogenic mixture
pH	6.5 - 8.0
% solids	3.0 - 8.0
Carbon-Nitrogen Ratio	14.0 - 22.0
Density (gm/ml)	1.050 - 1.200
Cation exchange cap. meg/100gm solids	300 - 450
O - R potential	-400 to -420
Chem. Elements found	K, Cr, Zn, Sn, Mn, Fe, Cu, Ca, Mg, Si, etc.
Major Contents	Humus like and lignin like material
Other Contents	Phosphates, sulfides, ammonium, bicarbonates, carbonates, organic acids, polyuronides, alcohols, etc.

The application of digested sludge to crop land has been discussed extensively in the literature. Hinesly and Soeswitz [140] report no problems with odors or flies in their field studies. However, four 20 ft. deep test wells showed high counts of total coliform, fecal coliform and fecal strep after a heavy rainfall. They attribute these counts to surface water leakage into the well casings. They also report higher concentrations of Cr, Cu, Pb, Mn, Ni, and Zn in the soils of sludge treated lysimeters. Zn, Mn, and Mg concentrations were also higher in the leachates from sludge treated lysimeters, as was the nitrate concentrations. Anderson [141] reports that sludge applied at the same rate as manure, in Sweden, results in a buildup of 30-290 g Hg/hectare over the normal background of 245 g Hg/hectare.

The Metropolitan Sanitary District of Greater Chicago has actively pursued research in the land disposal of digested sludge. In a paper describing the work at Chicago, Dalton et al [142] cite a number of domestic and foreign examples of the use of digested sludge in agriculture. They seem to infer that health problems, or other deleterious effects, have not been noted at these sites. However, Dean [121] cites a paper by Rohde which recounts a loss of fertility in sludge treated soils associated with heavy metal contamination of the sludge.

The application of wet sludge to land disposal areas presents a particular groundwater contamination problem if the disposal site is located on fractured rock or if the water travels in fissured strata. German practice, for example, forbids disposal of sludge in areas where seepage to groundwater is likely. [143] In California, regulations concerning land disposal of digested sludge were deleted from the Health and Safety Code in 1968. At present the land and water disposal of sludge is regulated by the Regional Water Quality Control Boards. They consider sludge solids to be a class 2 material in common with municipal refuse.

There is considerable data on pathogen survival in percolation beds and groundwater recharge systems. The question of pesticide transport through soil systems has also been studied. In the former case, the situation with respect to sludge application may be expected to parallel that with water-borne pathogens. However, the transport of sludge-borne chemicals may differ considerably since the various metals and/or pesticides may be associated with large particles which will clog the soil structure and impede transport. For this reason, heavy metal contamination of groundwater is not thought to be a problem.

Recently, studies on nitrate leaching from sludge-treated soils have been carried out at the University of Illinois. (145) The results of these studies have not yet appeared, but the question of high nitrates in groundwaters is a concern due to the potential of methemoglobinemia in infants. In 1967, the Public Health Service limit for nitrates in drinking water was set at 10 mg/l NO_3-N to protect against this disease. If nitrate levels exceed this value, the area from which groundwater can be withdrawn is effectively reduced.

With reference to Figure 1, the next step in solids processing is drying of the dewatered sludge. The dried sludge can be used either as a soil conditioner in landfills or incinerated. Turning first to agriculture or land fill uses of the dried sludge, the principal point of note is that proper drying procedures can result in a material essentially free of pathogens. Dried sludge has been sold commercially as a fertilizer. However, an extensive market has not developed for the product either in this country or in Europe.

It must be recognized, however, that any heat drying process will make mercury in sludge an air-borne pollutant. The Stickney sewage treatment plant in Chicago emits a minimum level of 0.079 ppm Hg measured at the stack. The estimated total annual output is 570 pounds. (146)

The first sludge incinerators in this country began operation in 1934. In 1968, 125 multiple hearth furnaces were in use in the United States with an additional 35 under construction. In some cases lime build-up has been a problem, but recently Albertson and Sherwood (147) found that combustion of the precipitate formed by removal of phosphates with lime was practical and lime could be recovered from the ash.

The principal health problems associated with sludge incineration do not differ appreciably from those associated with incineration of other municipal wastes. For example, incineration of sludges containing ferrous sulfide release oxides of sulfur as an air pollutant. Sludges can be as bad as many grades of coal from the standpoint of sulfur oxides. (121) Nitrogen oxides are also emitted in sludge incinerators. However, the new fluidized bed incinerators are said to emit less nitrogen oxides than multiple hearth furnaces due to lower combustion temperature. (144) In addition, unburned hydrocarbons are absent from the stack gases due to the fact that combustion occurs before appreciable distillation products are lost. Blanc and Maulaz (148) describe a fluidized bed system that has been used in Lausanne, Switzerland, for several years. An analysis of the ash content of the stack gases is shown in Table XV.

TABLE XV: Ash Content Analysis of Stack Gases for Fluidized Bed Incineration (148)

Soluble in H_2O	16.6% by wt.
Soluble in HCl	71.1%
Unsoluble in HCl	12.3%
$Fe_2O_3 + Al_2O_3$	30.3%
$Ca(OH)_2$	39.3%
Quartz & silicates	11.7%

Cross et al (149) investigated the particulate and metal emissions from incinerators burning both sludge and municipal waste. They report emissions from both sludge and refuse exceeded those of refuse alone by a factor of 1.7. Cadmium emissions averaged .007 lbs/hr with refuse alone or with refuse and sludge. Copper emissions, on the other hand, averaged 0.38 lbs/hr for refuse alone and 0.69 lbs/hr for refuse plus sludge. Cross and his colleagues conclude that metal emissions may be a significant emission component in municipal incinerators, particularly in industrial areas.

In conclusion, it appears that the incineration of sewage sludge presents no health hazards that are not common to general municipal or industrial incineration practice. In order to achieve a stack emission quality acceptable to air pollution control agencies may be expensive, but it would not appear to require technology different from that applicable to many other gaseous waste streams.

Industrial Hygiene. In a regional treatment facility, a large number of employees would be in close contact with the wastewater and treatment products. Their work environment may differ from that of present treatment facilities in scale only. Dixon and McCabe (150) attempted to determine if exposures to pathogens in existing facilities led to a higher incidence of disease amongst plant employees. Although the data was scanty, they found no clear-cut indication that a higher incidence of work related diseases occurred. Unless treatment processes should change in some unforeseen manner, it seems unlikely that any appreciable industrial hygiene problem will exist among plant employees. However, if large acreages of quiescent water were utilized in the treatment process, a vector-borne disease problem might arise which would be expected to affect those men working in the area to a greater degree than the general population.

6. OCEAN DISPOSAL OF TREATED SEWAGE LIQUID WASTES

Public health and beneficial uses protection in the receiving environment are the major considerations when treated sewage liquid wastes are discharged into nearshore ocean waters. The factors and parameters of concern are: 1) mass-emission of waste products, 2) allowable receiving water time-concentration of nutrients, waste products, or infectious agents, 3) rate of effluent dilution, 4) decay rates of discharged agents, 5) transport of agents by receiving water, 6) emission of tract level toxic products that are concentrated at the air-water interface and/or accumulated in the surf zone and on the beach.

The type of waste treatment and the design of the outfall facility are selected to optimize conditions for control or utilization of the above considerations. The conditions which control those considerations that are affected primarily by location of outfall are discussed below.

Experience in the discharge of large volume, treated sewage wastes into California Coastal waters has shown the need to release the effluent at depths of 200 feet or greater to achieve significant initial dilution for satisfactory nearshore water quality. (151,152) Discharges of large flows, >100 mdg at 60 feet depth or approximately one mile offshore for much of the California Coast will result in a surface plume of effluent from which the net onshore transport of waste can occur at 0.3 knots during an average summer day. (151, 153) This condition could result in beach contact within 3 hours. The same discharge located three to five miles offshore would not contact the shore during a complete tidal cycle. This time delay is of importance so that normal decay processess and eddy diffusion can act and have time to reduce waste product concentration as well as bacterial concentration to an acceptable level.

The discharge of a large flow of fresh water into the ocean above the thermocline will result in the immediate surfacing of fresh water unless an extensive diffuser system is employed. (154,155) The scope of such a system is indicated by the fact that a secondary treated waste effluent discharged several miles offshore will require a diffuser system that utilizes the receiving capacity represented by 150 feet of shoreline or more per mgd of effluent. (151) However, if such a diffuser system that involves the discharge of several hundred million gallons of waste effluent per day were to be located one mile offshore the waste products would tend to concentrate in the surf zone. (156,157) In addition, the surface active materials and flotage from the effluent released this close to shore would concentrate at the air-water surface and be quickly transported to the beach, where they would constitute an aesthetic pproblem, if not a health hazard, from bacteria associated with this flotage.

Available treatment methods for large flows do not at present result in a quality of waste effluent satisfactory for discharge into nearshore waters. (151) Until such treatment becomes feasible, it appears desirable to release treated waste effluent offshore at sufficient depth to achieve maximum initial dilution and provide for at least 24 to 48 hours time for dilution and biologic activity to occur prior to human contact with the waste-sea-water mixture.

7. PUBLIC HEALTH IMPLICATIONS OF ALTERNATIVE WASTE WATER MANAGEMENT STRATEGIES

7.1 Introduction

In order to produce diseases of exogenic origin, two prime requisites must be met: a susceptible host, and the presence of an infectious or toxic agent to which the host is vulnerable. Neither of these requisite factors are clear-cut, which adds to the difficulty of defining the boundaries of a public health problem. Susceptibility of a host is a probability based upon a myriad of factors. Some are known, such as age, previous experience, general health conditions and the like. Others are completely unknown and intangible.

The effectiveness of the disease agent, exclusive of host related factors, depends upon the concentration and the time of exposure. In the case of animate agents, there are varying degrees of pathogenicity even among members of the same species of organism.

The response of the susceptible host to a disease agent may be either acute or chronic, depending upon all the aforementioned factors or because of the host's accumulating toxic doses over a long period of time. The acute response is relatively easy to deal with because there is an obvious clinical reaction soon after exposure to the noxious agent. In this situation one recognizes a problem soon after the cause has been applied. Chronic responses are orders of magnitude more difficult to deal with because the time lag between application and response can be a matter of years. In this latter instance a great deal of damage can be done before the health worker is aware of the situation. Such was the recent case with mercury in Japan.

Of equal importance with the two prime requisites of diseases of exogenous origin is the vehicle by which the host and the agent are brought in contact, principally water, air, food and vectors. All of these vehicles are of greater or less importance to the various proposed strategies for wastewater management. The uses to which this reclaimed water might be put, i.e., the intimacy of the contact, will become a prime consideration.

In regards to the problem at hand, it can be concluded that domestic wastewater does contain infectious and toxic agents and that within the twelve Bay-Delta counties reside susceptible hosts. The problem narrows down to (1) the ability of the treatment process to remove or reduce disease agents present in the waste stream; (2) the dose response, for example, the number of infectious organisms required to cause disease; and (3) the probability of human contact either direct or indirect.

Regardless of the means of ultimate disposal of water into the hydrosphere or onto land, there will be comparable pretreatment process using primary, secondary, or perhaps advanced treatment processess. The public health quality of the water ultimately discharged depends to a large degree upon these preliminary treatment processess.

Primary treatment, i.e., settling of raw sewage, will remove forty percent or more of the enteric bacterial pathogens and large parasites present in raw sewage. This stage of treatment is not too effective in the removal of viruses. Important heavy metals such as mercury, cadmium, zinc, and lead, are not effectively removed with the raw primary sludge; however, chlorinated hydrocarbons and other organics will be adsorbed on the solids present and will be removed to a significant degree.

The raw sludge thus collected will normally be digested under anaerobic conditions. Bacterial and larger parasitic pathogens can be expected to be reduced but certainly not eliminated during this process. As previously mentioned, there is a concentration process occurring simultaneously with the death process and investigators have been able to isolate pathogens more frequently in digested than in raw sludge. The heavy metals present will most probably be reduced and concentrated. Chlorinated hydrocarbon pesticides will be degraded slowly and often the degradation products will be potentially toxic.

The primary effluent is normally treated in a secondary stage which employs some aerobic process, either activated sludge or trickling filter. Both processes will reduce infectious and toxic agents; however, there is much more information available concerning the former than the latter. Activated sludge treatment is very effective in the removal of the remaining pathogenic microorganisms. Up to 90 and 99 percent inactivation can be anticipated in a well-operated plant. Chlorinated hydrocarbon pesticides are not effectively changed by the process; however, the organophosphate types will be readily hydrolized. Heavy metals are removed with fair efficiency during this process. Data available indicates 75 percent removal of copper, 89 percent of zinc, while hexavalent chromium and nickel, for example, are removed with much less efficiency. The result of these aerobic processes is to produce sludges which can be readily separated from the treated stream. The sludge will contain most of microorganisms and, of course, all of the heavy metals removed by the process. This sludge will be further treated by anaerobic digestion along with the primary sludge.

The ultimate effect of the primary and secondary treatment process is to reduce the concentration of toxic and infectious agents in the liquid fraction by concentrating them in the sludge fraction.

The effectiveness of advanced treatment (usually chemical precipitation, with or without subsequent biological treatment, followed by filtration) in the removal of these agents is still under study. At present, there would be no reason to feel that they would be any less effective than conventional treatment. Actually, much evidence points to their superiority. The result of these processes will also be sludges in which much of the materials under consideration will be concentrated and further treated by anaerobic digestion.

The result then of the pretreatment will be a significant inactivation of bacterial, viral, and larger pathogens and a translocation of much of the hazardous materials to the sludge phase. The output of the anaerobic digester will therefore be an extremely important material. How this digested sludge is further handled will be critical. The aqueous phase will, no matter how effective the operation, still contain numbers of pathogens depending upon the initial concentration. Even when removals are 99 percent effective, 10,000 units would still remain if the initial concentration were in the range of one million. In terms of bacteria, this is not a remote possibility. In all cases where human contact will occur, some form of effective disinfection will be necessary to insure safety.

The dose response aspect of the problem is not a simple one to resolve. Again, this is particularly difficult when chronic effects are involved. How few pathogenic microo-organisms can a susceptible host ingest or inhale in order to produce a clinical disease? In the case of typhoid fever, this appears to be a rather large number, something like 100,000 bacteria to produce disease in 25 percent of those exposed. In the case of tularemia, only a few organisms are necessary for a high case rate among those exposed.

The situation regarding chemical agents is equally as difficult to evaluate. The state of the art in toxicological research is such that few conclusions can be made about chronic human toxicity resulting from exposure to environmental chemicals. It is a logical impossibility to prove that a certain dose of chemical is safe. A positive toxicological experiment demonstrates toxicity, but a negative result does not exclude other possibilities. As newer and more sensitive tests are developed, older chemicals previously considered safe may be found to be selectively toxic to sensitive organisms. The dose response characteristics of the general population require that organismic, environmental and synergistic variables be evaluated individually and in combination. Due to the large number of chemicals and biological parameters that need to be evaluated it appears unlikely that complete toxicological studies will precede the entry of a chemical into the environment. Human toxicity will probably be found in retrospective epidemiological studies, since successful control measures for prevention will require considerable foresight. At present one can either make dire predictions or conclude that there will be minimal health effects from chemicals in drinking water. Optimal concentrations for chemicals in water have yet to be defined.

What this means is that using various waste treatment processes, we can reduce the potential dose of various environmental agents, but we still are never certain of the response, particularly in the area of chronic toxicity.

The third aspect of the problem is that of human contact. As stated before, this will be of the utmost importance in defining the public health aspect of the various wastewater disposal methods. The contact would be direct and intimate if the resulting water were used for drinking, less intimate if used for recreation. The contact can also be indirect in those situations which involve biomagnification of chemical and biological agents in food webs where man is the ultimate consumer. The contact contact can even be quite remote as would be the case in vector-borne disease, wherein the water management process would enhance vector and disease reservoir

development. Obviously, if human contact is kept to a minimum, the risk of host-agent interaction will also be reduced to a minimum.

7.2 Effluent Returned to Hydrosphere

The parameters for evaluation of the alternatives are primarily further dose reduction after preliminary treatment, the probability of human contact either direct or indirect, and biomagnification.

Ocean Disposal. In this instance dose reduction will be accomplished primarily by dilution provided the material is discharged via a properly designed and placed outfall. The antagonism of this hostile environment will normally insure that die-away of disease agents is continuous and often more rapid than when discharged to fresh water. One note of caution is necessary; it has been observed that regrowth of coliforms does occur on occasion. Such a phenomena has been reported in river and in brackish water. There are limited observations of this in seawater. The sanitary significance of such regrowth is uncertain; however, we must be aware of its potential occurrence.

Toxic agents, heavy metals, pesticides, etc., will react with the suspended material in the receiving water. In this instance one cannot determine their fate based upon known physical constants such as solubility equilibria, but may well have to make direct measurements for specific receiving areas. The adsorption to particulate matter can act to reduce the dose by removal, but it can also facilitate biomagnification in those situations wherein particulate material is fed upon by members of the human food web.

Human contact with the final dose present in the ocean situation is relatively limited. The most intimate contact, from a disease standpoint, would be drinking relatively large volumes of contaminated water, a situation which is not apt to happen in a saltwater environment. Other more casual contacts are recreational which would include swimming, boating, and fishing. In these cases the degree of contact will be prinicipally a function of how much of the discharged material reaches shore. The outfalls, as proposed in the Corps of Engineers' feasibility plan, would not allow for sufficient diffusion and contaminants could find their way to the beach in a matter of hours.

Human contact with potentially contaminated water may also be of an indirect nature. If disease vectors and reservoirs are potentiated by the wastewater management scheme, then the chances of human contact would increase. At the present state

of our knowledge, there would seem to be no problem of this kind with ocean discharge. One possible problem of an indirect nature would be if the discharge affected the local environment in such a way that toxic algal blooms such as those of the "red tide" were encouraged. In this latter case, these organisms will be concentrated by certain mollusks which are consumed by man, who in turn becomes intoxicated.

As far as airborne microbes are concerned, there is only one hazardous situation which might occur as a result of waste discharge into the ocean. Spindrift from waves produces aerosols. If the local marine environment were disturbed in a manner which caused a pathogenic species of microbe to increase greatly in numbers, then that species could be carried inland with unpredictable consequences. There is no evidence that any oceanic microbe is infectious to man via the respiratory route. The possibility of any problem in this regard seems most remote.

Biomagnification of toxic material discharged to the ocean is a problem of unknown magnitude. The situation with mercury and pesticides is well documented, although the kinetics of such biomagnification are still vague. As the offshore waters become more important as a food source, such biomagnification will grow in public health significance.

The concentration of infectious material by shellfish has been recognized for many years. There have been numerous outbreaks of shellfish-borne typhoid, hepatitis, and gastroenteritis. These mollusks are also known to concentrate heavy metals, radionuclides and pesticides. The discharge of waste waters into the marine or estuarine environment must be such that shellfish growing areas are not contaminated with infectious or toxic materials. At present the Public Health Service will approve areas in which the medium coliform MPN does not exceed 70/100 ml. (158) This regulatory agency feels that this number would represent a dilution ratio of approximately 8 million cubic feet of coliform free water per day for the fecal material of each person contributing sewage to the area.

Estuarine Disposal. As an alternative management scheme, the ultimate disposal of waste water into the estuarine environment presents much the same situation as ocean disposal. Dose reduction will be brought about by dilution and environmental antagonism. In the estuarine situation dilution may not be as great as that of ocean discharge and therefore dose reduction would not be of the same magnitude. The average annual Sacramento-San Joaquin Delta discharge is 18 million acre feet. The total waste discharge in 2020 is estimated to be almost 2.25 million acre feet or about 11 percent of the total annual flow. With complete mixing and no seasonal variation, this would be a 1.9 dilution. In actuality, the river flow is seasonal, total mixing may be difficult, and dilution would be relatively small.

The probability of human contact with estuarine waters is of a higher order than ocean water, particularly on the Northern California coast. Swimming, fishing and boating are an important aspect of the San Francisco Bay-Delta economy.

The concentration of infectious and toxic agents by shellfish may be of more significance in the estuary where growing areas are more productive. At present shellfishing in the Bay-Delta is not particularly popular or productive, but it has been in the past and may very well become so in the future. In the latter event, it could become an important contact between humans and toxic agents in wastewater discharge.

7.3 Land Disposal

Engineered soil systems offer many attractive possibilities for the disposal of wastewater. Biological agents seem to be effectively removed depending upon infiltration rate, soil particle size, and soil composition. Travel through from 3 to 12 feet of soil can be up to 99.99 percent effective in the removal of bacteria, parasites and viruses. These agents are removed by straining, sedimentation entrapment and adsorption, with the top few cm being the most effective. The intestinal pathogens remain viable for up to 2 months, depending upon the organic matter present. In summary, it can be said that proper land disposal of treated wastewater will be an added treatment that removes microorganisms and parasites.

The ability of soil percolation to remove chemical agents from wastewater appears limited. Biodegradable material will be removed by the soil biota in the upper zones of the earth. The efficiency will be a function of the contact time required for the microorganisms to carry out the metabolic operations involved in reducing organic compounds to more stable forms. Chlorides, nitrates, sulfates move freely through the percolation bed and in the case of nitrates may contaminate the local groundwater. Chemicals of an industrial origin such as picric acid, gasoline, phenols, etc., are ineffectively removed by percolation. The fate of heavy metals when percolated through soil is not well documented. Some work with a radionuclide of indicated up to 95 percent removal in laboratory soil columns; however, certain other isotopes studied were not removed. (109)

In the process of land disposal, dose reduction is primarily carried out by further treatment in the soil column, i.e., bio-oxidation, filtration, ion exchange and environmental antagonism. The reduction of dose by significant dilution does not take place as it does either in ocean or estuarine disposal. Many chemicals of a potentially toxic nature are not removed and will find their way into the groundwater or into drainage water.

Unless carefully monitored, human contact with waste water spread on the land will range from using the groundwater produced for drinking to the more casual recreational contacts of fishing and boating.

This method of wastewater management could potentially increase the exposure of Californians to malaria and several zoonotic diseases through a build up in arthropod vector and vertebrate host populations around storage reservoirs. However, proper design and maintenance of reservoirs would minimize this public health hazard. For example, mosquitoes will not breed in large numbers in open water. If the reservoirs had impervious banks and the water level was maintained above the unsealed earth, then this essentially eliminates the growth of tules and the breeding of mosquitoes and Culicoides around the edge of the ponds. Gambusia fish could also be planted in the ponds to control mosquito breeding provided that they could survive.

Biomagnification is much of an unknown parameter when considering the land disposal alternative. The translocation of selenium is known to occur in plants grown in soils containing the element. Lead will either be collected or concentrated in the grasses of fields exposed to exogenous sources of the element. Animal diseases have been perpetuated on fields in which sewage has been spread and there is the possibility of the transmission of tape worm and trichinosis to humans from animals raised on such fields.

The extent of the hazard from the air due to inland sewage disposal can only be approximated. Adams and Spendlove [39] found as many as 900 airborne, viable coliform cells per cubic meter 40 yards downward from sewage treatment plants processing 6×10^6 to 25×10^6 gallons per day; the number dropped to 4 coliform cells per cubic meter at 1500 yards. Numbers of unclassified bacteria downwind often exceeded the upwind numbers by 2-to 100-fold and were as high as 200 per cubic meter at 1500 yards downwind.

The rate of change of the coliforms (from 900 coliforms/meter^3 at 40 yards to 4 at 1500 yards) included all factors such as settling-out, loss of viability, change of sampling efficiency as a function of aerosol "age", as well as varied wind, humidity, and temperature conditions and the significant process of lateral and vertical diffusion. From epidemiological evidence to date, this situation does not appear hazardous.

Sludge Disposal. All processes involved in the proposed treatment of wastewater will produce considerable amounts of solids. Because it was common to all alternatives, sludge disposal alternatives were discussed in Section 5 of this report. As was pointed out, the great majority of the toxic materials present in the original waste will find their way to the digested sludge. Drying will inactivate most pathogens; however, this process will have little effect on toxic chemicals. Spreading treated sludge on land is of uncertain value. The experience at Chicago has been acceptable while others have voiced concern over the loss of soil fertility due to the accumulation of heavy metals. The fate in soil of toxic agents and pathogenic organisms present in the sludges should be the same as discussed in the land disposal section above. This kind of treatment will tend to concentrate the original dose and certainly there will not be much dilution when added to the land. Human contact and biomagnification factors would be the same as discussed in the land disposal section.

Incineration methods will tend to concentrate certain toxic materials but will certainly destroy pathogens. Therefore, the dose will be increased and perhaps, unless carefully controlled, some toxicants will change from the aquatic-ground phase to the air phase. If good stack effluent control, perhaps integrated with recovery of important materials, is maintained, there would be a minimum of human contact.

7.4 Summary

Table XVI represents a summary of the public health implications of the alternative wastewater management strategies. The values given are relative based upon the foregoing discussions. A value of 1 would be of a low magnitude, while 5 would be correspondingly high. In the case of dose reduction, ocean disposal would outweigh the other alternatives because of the potential of large dilution. The other factors involved in dose reductions, i.e., ancillary treatment or environmental antagonism, would be somewhat similar for the various alternatives. The chance for both direct and indirect human contact with materials discharged into the ocean are more limited than in either of the other alternatives. Estuarine disposal would probably be less of a risk in this respect than land disposal.

Biomagnification factors are, at this time, very difficult to rank. Disposal on land may be the best alternative in this regard. Overall, then, it would seem that strictly in terms of

human disease transmission the order of choice of alternatives would be ocean disposal first, estuarine second, and land last. It should be emphasized here that this choice is relative, somewhat subjective and made without regard to economic or ecologic considerations. Either of these latter impacts may in an overall evaluation far outweigh certain health risks involved with any of the alternatives.

TABLE XVI: Relative Magnitude* of Public Health Implications of Alternative Wastewater Management Strategies

Value Parameter	Disposal Alternative		
	Ocean	Estuary	Land
Dose Reduction:			
Dilution	5	3	1
Ancillary Treatment	2	2	3
Environmental Antagonism	5	4	4
Human Contact:			
Direct-Intimate	1	2	3
Direct-Casual	2	5	5
Indirect	2	3	5
Biomagnification	3	3	2

*Value parameter of 1 through 5 is equivalent to a range of low to high.

8. PROBLEM AREAS AND FUTURE OBJECTIVES

The evaluation of the public health aspect of a large scale engineering project such as those herein considered is frought with difficulty. The problem may most conveniently be reduced to (1) the presence or absence of infectious or toxic agents in the resulting wastewater, (2) the concentration of these agents, (3) the response of a susceptible population to these agents, and (4) the nature and probability of human contact with these materials. The number of variables and unknows relating to these conditions abound.

The measurement for the presence or absence of disease agents and their concentration in the waste stream is an area of continuing endeavor. Monitoring of the various waste components as well as the final effluent will be of considerable importance in environmental

control. Much work is needed in order to develop criteria about what to monitor, when to monitor and how to integrate this monitoring into a realistic control system. For example, the coliforms have been used for years to monitor wastewater for the presence of pathogens; however, we are coming to realize their limitations, particularly as regards the presence of viruses.

Probably the most crucial information required concerning the impact of wastewaters and sludges on human health is in the area of dose-response. What are the chronic and/or accumulative effects of many of the agents involved? We know relatively little about the continued exposure of man to low levels of heavy metals and other toxic chemicals. What of the many new chemicals which are being constantly introduced by our rapidly developing technology? We also know very little concerning the potential of chronic or delayed disease such as may be brought about by yet unknown viruses.

Finally, what of the future nature of human contact with the dose? One of the major difficulties in the environmental health field is that of predicting the consequences of new techniques, either technical or managerial, upon the health of the human population. For example, there is a potential, in the not-too-distant future, of building high-rise animal feed lots in our urban centers, whose waste would contribute to the total community waste. What is the chance, in a situation such as this, that an epizootic of a disease, such as brucellosis, to which man is also susceptible might occur? This could add exceptionally high numbers of pathogens to the wastewater stream. Depending upon the degree of contact, this could prove very hazardous to the local population of both man and animals.

Consideration should also be given to the potential for natural disasters and the impact such phenomena would have on the wastewater system. How would man's probability of increased contact with hazardous agents be affected in this instance? In this situation, which of the alternatives would be most acceptable?

It is evident that there are many questions to ask concerning the health impact of any system designed to treat the waste of a very large population. It would seem of little value here to continue the list of appropriate questions. The ultimate use of treated wastewater will obviously be the key to the human health impact of such water discharge. Any use which increases human contact also increases the potential for adverse public health. When one considers the value of water, it seems inevitable that human contact with wastewater will increase. It behooves us, therefore, to continue to develop our knowledge concerning the health hazards of this potential increased contact.

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C-4. ECONOMIC IMPACTS

a. Introduction. A complex network of economic activity is interwoven with water quality and quantity in the San Francisco Bay-Delta area. In order to evaluate the ocean, estuarine, land application, and combination alternatives, it is necessary to assess their respective impacts.

(1) Definition. Economic impact is defined as changes in net income (or "value added" as used in national income accounting) and is primarily related to the objective of national economic development.

This concept is concerned with production costs and resultant income gained by the region and the nation. However, the contribution of one wastewater management system or another to the production of income, and, in turn, economic well-being is only one of several objectives that must be considered. Intangible objectives such as aesthetics, health and environmental amenities may weigh equally significant in decision-making. No judgment is made concerning the requirements for economic growth, or distribution of the additional income. Pending the formulation of regional development goals by appropriate institutions, it is merely assumed that an aggregate increase in regional income is beneficial. National and regional objectives are discussed further in Appendix D.

(2) Scope. The study area extends from the foothills of the Central Valley to the Pacific Ocean and consists of 12 counties surrounding the San Francisco Bay and the Delta. Three predominantly agricultural counties (Yolo, Sacramento, and San Joaquin) and part of Contra Costa County bound the Delta area. The other eight counties (Alameda, San Francisco , San Mateo, Santa Clara, Marin, Napa, Solano and Sonoma) and part of Contra Costa are adjacent to San Francisco Bay. Together these counties comprise a highly developed complex of manufacturing, commercial, governmental and agricultural activities, which are linked in many ways to the waters of San Francisco Bay and the Delta.

The structure of the economic base exhibits an interdependence so that a reaction by one sector to changes in water quality management may have an impact throughout the regional economy. The present investigation screens significant initial impacts on various economic sectors. It is proposed that water-related inter-industry impacts will be investigated in a subsequent survey scope study.

The framework of this study consists of an analysis of the impact of four wastewater management alternatives on four sub-areas. These are compared with base conditions. Impacts are shown in an economic

assessment chart for each plan. Potential reuse of water is indicated for irrigation, industrial use and recreation. Reuse for domestic purposes is considered a potential opportunity in the long-run. The degree of treatment selected will be that necessary to satisfy public health standards and limitations imposed by public attitudes. In assessing each alternative, impact on the overall growth and development of the Bay-Delta area is considered along with impact on income changes and how this differs from what would prevail under the base condition.

(3) Criteria. The principal economic criterion is concerned with increases in income in the region resulting from improvements in water quality. Impacts on the sub-areas are first assessed in this appendix. Potential income changes directly related to water quality are evaluated in Appendix D on the basis of available data. As noted, this criterion does not exclude from consideration important, less tangible, areas of concern affecting the quality of life and economic well-being. The wastewater management alternatives will cause varying changes in the quality and quantity of water throughout the region. Specific changes, and their probable impacts, are shown on the economic assessment charts developed for each alternative. Also shown in the tables are the economic criteria used to indicate or measure the results.

b. Assessment of Base Condition. The base condition assumes facilities to be construced by 1975. These facilities are assumed to be consolidated secondary treatment plants with capacity to handle projected 1990 waste flows. For purposes of comparison with the selected alternatives, it is further assumed that base condition facilities would be expanded to handle projected 2020 waste flows in 1990.

These facilities are primarily designed to overcome severe pollution problems in the extremities of the San Francisco Bay. To the extent pollutant loads are not reduced and remain to be dispersed in the hydrosphere they will impact adversely on the aquatic and land environment and hence on the economy of the region.

An assessment of the base condition upon the Bay and Delta, ocean waters and land areas, follows:

(1) San Francisco Bay and Delta. Pollutants dispersed in the estuary under base conditions would result in certain economic losses. Some losses, e.g., aesthetic values and health hazards, are not readily quantifiable in economic terms. However, fish and shellfish which are killed or rendered inedible by pollutants constitute a measurable loss. Many sport and commercial fishes depend on the estuarine environment of the Bay-Delta system for habitat, food, spawning and nursery areas. Under the base condition, the discharge of non-degradable wastes will have

the impact of damaging aquatic life unique to the estuarine environment. An indication of the potential adverse economic impact under base conditions is evident from historic trends. In the mid-1930's the annual commercial harvest of shellfish ranged from 100,000 to 300,000 pounds. Commercial shellfish production has virtually disappeared. Clam digging is prohibited throughout the estuary because of pollution. Similarly, shrimp fishery landings were as high as 6.5 million pounds in the 1930's, whereas landings at present are approximately 10,000 pounds or less. Significant advances in the field of aquaculture indicate that the historic decline in income from shellfish catches could conceivably be reversed given an upgrading of Bay-Delta water quality.

The San Francisco Bay and Delta area is noted for its sport fishing. While no precise values in dollar terms are assigned to this activity, official warnings given by State and Federal agencies that fish caught in the estuarine waters should not be consumed in substantial quantities has had an impact on sport fishing in this region. Under the base condition the amelioration of these circumstances is not envisioned.

Nutrients entering the Bay can cause algal blooms which impair the aesthetic value of the Bay. These in turn, can have an adverse impact on land values. Throughout the Bay, public beach use and water contact sports are generally limited. Again, no attempt is made to quantify these economic losses but they are considered substantial.

Pesticides in the Bay system originate from municipal storm sewer and sanitary sewage systems, urban runoff and drainage, and mostly from vast agricultural lands in the Central Valley. An estimated pesticide load of about 12,000 pounds per year is carried into the Bay system. A significant amount is carried to the Pacific Ocean, however, much is retained in sediments of the Bay. Resultant pesticide concentrations in the food chain can also cause economic losses similar to those described above. If degradable pesticides are brought into use agricultural production could continue unaffected. However, if this is not the case, agricultural production could be affected adversely by restrictions on waste discharges.

(2) Ocean Waters. The dispersion of waste constituents by tidal flushing into the ocean under the base conditions would result in adverse effects on coastal waters and adjacent land areas. There is evidence that marine life in coastal waters near San Francisco Bay may be threatened by toxic elements from industrial wastes and pathogens associated with domestic sewage discharges. Contamination by all forms of chlorinated hydrocarbons and heavy metals have rendered several species of fish unfit for human consumption. Even in such cases where pollutant levels do not prevent consumption, fish may be discolored or tainted. The commercial value of fish landings at present is approximately $2,000,000 annually. Continued degradation of water quality could result in a decline in the value of commercial fish landings.

(3) Land Areas. Under the base condition, the interior valley and the land area on the periphery of the bay are likely to experience sustained economic growth which would generate an increasing volume and concentration of agricultural, municipal and industrial wastes into waters which have a finite assimilative capacity.

The base condition would continue to erode the quality of Bay waters and the adjacent land resource is also likely to deteriorate. San Francisco and the Bay area are tourist attractions of world-wide significance; part of their attraction is based on the quality of the water resource. At many points in the city or in the Bay area the visitor can step to the water's edge. Or, the visitor can ride a harbor ferry, an excursion boat, or a deep-sea fishing craft. The attractiveness of these activities is based largely on the quality of the water. As quality of the Bay waters declines, those aspects of the local economy based on tourism and outdoor recreation are also likely to decline.

Other sectors of the area's economic base can also be affected if Bay water quality deteriorates or is of low quality. Many manufacturing processes make demands on Bay waters for cooling and processing. As Bay water quality deteriorates these firms must pay more to obtain water in sufficient quantity and quality for their use.

Some Bay area water quality problems appear related to land development patterns. The base condition, with its fragmented development, approaches these problems in a minimum manner. Regional disposal alternatives would require more attention to development patterns and their effects on waste loadings. Environmental constraints may necessitate more selective agricultural and industrial production and careful consideration of urban densities.

An important negative impact affecting land areas under the base condition is the fragmented manner in which municipalities and sanitary districts can plan capital improvements. Facilities planned by local agencies are often limited in area extent and size because of local financial limitations and hence are unrelated to long range area-wide plans.

The prevailing base condition trend of more stringent regulation of waste discharges is likely to continue under joint Federal-State standards. Water pollution problems generated in various sub-regions have already resulted in orders to cease and desist connecting new construction to inadequate sewage facilities. Financial constraints could then force developing sub-regions with outmoded plants to invest in the gradual improvement of existing systems at present sites. This procedure could preclude the use of wastewater management to implement an economically advantageous pattern of regional development based on environmental constraints.

c. Assessment of Alternatives for Managing Wastewater. The anticipated economic impacts of four alternatives: Ocean, Estuarine, Land and Combination, are shown in Figures C-13 through 16. Figure C-17 is a summary identifying sub-areas in which a direct impact will occur under the various alternatives. In varying degree each alternative would reverse the detrimental impacts associated with the base condition.

Projected expansion of population and industry points to large future demands on Bay-Delta waters to receive, assimilate and transport wastes. Although the relationship between the cost of improving water quality and the economic base of the region is not well understood, the location and growth of certain industries which use large quantities of process water could be affected by increased costs. These include canning, petroleum, meat, dairy, steel, chemical manufacturing and pulp and paper. Agricultural production is another important sector which would be affected.

An assessment of economic impact of each of the alternatives follows:

(1) Ocean Disposal Alternative. The economic impact assessment of the Ocean Disposal Alternative is shown in Figure C-13. The plan would have an adverse effect on the ocean resource in the "mixing" zone, although the amount of harm would depend upon whether secondary or tertiary treatment practices were employed. The immediate adverse economic effect would be a reduction in the value of commercial fishing. The economic impact of the Ocean Disposal Alternative on Bay-Delta waters would be beneficial, mainly because they would no longer be burdened with the physical problems of pollution. Salinity changes in the eastern portion of the Bay and Delta estuary could be adverse. Land resources related to enjoyment of the Bay would also benefit.

(2) Estuarine Disposal Alternative. The economic impact assessment of the Estuarine Disposal Alternative is shown in Figure C-14. Compared with the base condition, it would help protect the ocean resource from adverse ecological effects which might endanger species of commercial fishes. To the extent it resulted in cleaning up the waters of the Bay, it would aid those portions of the economy based on use of the Bay. Land uses adjacent to the Bay would also benefit. A potential economic advantage of estuarine disposal over the other alternatives is its possible impact on the quality of ground-water supplies. Although major urban areas in the Bay-Delta region import surface supplies from the Sierras, a large portion of agricultural, industrial and domestic water requirements in Delta areas are still met by ground-water. Discharge of treated wastewater into the estuary might reduce sea water incursion and benefit industries, farms and communities.

(3) Land Disposal Alternative. The economic impact assessment of the Land Disposal Alternative is shown in Figure C-15. It would protect those sectors of the area's economy based on ocean and Bay-Delta

waters, although it would not help prevent the problem of salt water incursion. In a sense, it may shift the burden of pollution inland. In this investigation, it was not possible to fully assess the long-term impact of large volumes of reclaimed water made available for irrigation. Market analyses of the types of crops that can be grown safely are needed. It appears that the acreages to be irrigated are so large that some readjustments in the area's agricultural economy would occur. Also, patterns of future settlement will be affected.

(4) Combination Alternative. The fourth alternative, the Combination Plan, combines the estuarine disposal and land disposal plans. The economic impact assessment is shown in Figure C-16. Approximately 35 percent of the waste load would be placed onto the land. Therefore, the impacts of the Land Disposal portion of this alternative would be less than under the land disposal alternative since only about one-third as many acres will be irrigated.

One advantage the Combination Alternative has over the Land Disposal Alternative is that over time, as the economy requires, or can use, more treated wastewater, the combination system presumably could be altered to supply it. Also, more highly treated effluents could be placed in the estuary to offset other water sources required for salt water repulsion in the Delta. The Combination Alternative thus is a compromise between the Estuarine and Land Disposal Alternatives and that may yield its most important long-run economic contribution -- the ability to shift treated wastewater between two reuses. Figure C-17 summarizes the economic impacts on sub-areas in the San Francisco Bay-Delta region resulting from wastewater management alternatives.

ECONOMIC IMPACT ASSESSMENT OF ALTERNATIVE WASTEWATER MANAGEMENT PLANS ON SUBAREAS IN THE SAN FRANCISCO BAY – DELTA REGION

OCEAN DISPOSAL PLAN

ECONOMIC IMPACT CRITERIA			IMPACT ON SUBAREAS			
ANTICIPATED CHANGE IN PHYSICAL RESOURCE	PROBABLE IMPACT	PROBABLE EVALUATION FACTOR	SUBAREA A COUNTIES Alameda, San Francisco, San Mateo, & Santa Clara	SUBAREA B COUNTIES Marin, Napa, Solano & Sonoma	SUBAREA C COUNTIES Contra Costa	SUBAREA D COUNTIES Sacramento, San Joaquin & Yolo
OCEAN WATERS						
Change in quality	Change in quantity of commercially valuable fish life.	Value of catch.	Value of commercial catch will decline. Most of fishing fleet is based in this Subarea.	→	→	→
	Effect on other species of marine life and aquatic growth.	Potential economic effects of breakdown in ecologic chain.	Initial ecologic-economic impact of ocean disposal will be on coastal areas.			
BAY & DELTA WATERS						
Change in quality	Change in desirable species of fish and wildlife.	Visitor or recreation days, and value of commercial catch.	Quantity of sport fish and game in Bay will increase; main benefit will be to subarea residents who fish or hunt; conceivably commercial clam fisheries within Bay will be restored.			
	Changes in public access, and change in other water-related recreation.	Visitor-days.	Boating, swimming, sight-seeing, nature hiking, sunbathing, photography, etc., will increase, benefiting both residents and visitors.			
	Change in commercial establishments based on "enjoyment" of Bay.	Income from services.	Harbor tours, marinas, waterfront restaurants, and other "tourist-oriented" services will benefit from increased patronage.			
	Change in property values near Bay because of aesthetics.	Changes in value.	Main increase would be in value of properties adjacent to surface waters.			
	Change in water temperatures.	Changed pumping costs for industrial cooling.	Estuary temperatures would be lowered so less pumping would be required. However, salt water incursion may change chemical content of water being pumped.			
LAND RESOURCE						
Re-use of water	Agricultural and forestry production.	Value of output.	→	→	→	→
	Soil erosion control.	Reduced maintenance dredging costs.	→	→	→	→
	Change in "green" municipal parks and golf courses.	Visitor days.	→	→	→	→
	Change in demands in other sources of irrigation water.	Cost savings.	→	→	→	→
	Groundwater replenishment.	Pumping costs; Alternative surface water costs.	→	→	→	
	Change in salt water incursion.	Differing "life" of fresh water wells and associated costs.	Salt water incursion will increase, decreasing usefulness of "fresh" water wells. Fresh water will have to be supplied from other sources.			
	Change in land subsidence.	Cost of surface repairs, or of protection from flooding.	→	→	→	→
	Water available for cooling.	Price at which it could be sold.	→	→	→	→
Re-use of residual solids	Potential increased agricultural production.	Value of products.	Potential for soil melioration; reclamation of constituents.			
	Fertilizer, land-fill, mulch-compost or fill; recycling of waste constituents.	Price at which it could be sold.	→	→	→	→
INSTITUTIONAL CHANGES						
CHANGE IN LAND-USE PATTERNS	Control over patterns of settlement.	Costs of providing government services.	→	→	→	→
	Change in cost/revenue patterns of local governments.	Ability of government to provide necessary services.	→	→	→	→
IMPEDIMENTS TO POLLUTERS						
	Costs to users of sewage system.	Change in value of industrial production.	→	→	→	→
		Change in rate of regional growth.	→	→	→	→
	Restrictions on bypassing public system; i.e., against direct discharge.	Change in value of industrial production.	Stricter controls on discharging into estuary may raise production costs for certain industries.			

NOTE: → Denotes IMPACT PROBABLE

FIGURE C-13

ECONOMIC IMPACT ASSESSMENT OF ALTERNATIVE WASTEWATER MANAGEMENT PLANS
ON SUBAREAS IN THE SAN FRANCISCO BAY – DELTA REGION

ESTUARINE DISPOSAL PLAN

ANTICIPATED CHANGE IN PHYSICAL RESOURCE	ECONOMIC IMPACT CRITERIA: PROBABLE IMPACT	ECONOMIC IMPACT CRITERIA: PROBABLE EVALUATION FACTOR	IMPACT ON SUBAREAS: SUBAREA A COUNTIES Alameda, San Francisco, San Mateo, & Santa Clara	SUBAREA B COUNTIES Marin, Napa, Solano & Sonoma	SUBAREA C COUNTIES Contra Costa	SUBAREA D COUNTIES Sacramento, San Joaquin & Yolo
OCEAN WATERS						
Change in quality	Change in quantity of commercially valuable fish life.	Value of catch.	Protection of ocean water quality will help fishing fleet based in this subarea.	→	→	→
	Effect on other species of marine life and aquatic growth.	Potential economic effects of breakdown in ecologic chain.				
BAY & DELTA WATERS						
Change in quality	Change in desirable species of fish and wildlife.	Visitor or recreation days, and value of commercial catch.	Quantity of sport fish and game in Bay will increase somewhat; benefits will accrue to subarea residents and visitors.			
	Changes in public access, and change in other water-related recreation.	Visitor-days.	Water-related recreation will increase as changes in Bay water quality become noticeable. Provision of sewage transport and treatment facilities may increase opportunities for public access to subarea water courses.			
	Change in commercial establishments based on "enjoyment" of Bay.	Income from services.	→	→	→	→
	Change in property values near Bay because of aesthetics.	Changes in value.	→	→	→	→
	Change in water temperatures.	Changed pumping costs for industrial cooling.	→	→	→	→
LAND RESOURCE						
Re-use of water	Agricultural and forestry production.	Value of output.	→	→	→	→
	Soil erosion control.	Reduced maintenance dredging costs.	→	→	→	→
	Change in "green" municipal parks and golf courses.	Visitor days.	→	→	→	→
	Change in demands in other sources of irrigation water.	Cost savings.	→	→	→	→
	Groundwater replenishment.	Pumping costs; Alternative surface water costs.	→	→	→	→
	Change in salt water incursion.	Differing "life" of fresh water wells and associated costs.	→	→	→	→
	Change in land subsidence.	Cost of surface repairs, or of protection from flooding.	→	→	→	→
	Water available for cooling.	Price at which it could be sold.	→	→	→	→
Re-use of residual solids	Potential increased agricultural production.	Value of products.	Potential for soil melioration; reclamation of constituents.			
	Fertilizer, land-fill, mulch-compost or fill; recycling of waste constituents.	Price at which it could be sold.				
INSTITUTIONAL CHANGES						
CHANGE IN LAND-USE PATTERNS						
	Control over patterns of settlement.	Costs of providing government services.	→	→	→	→
	Change in cost/revenue patterns of local governments.	Ability of government to provide necessary services.	→	→	→	→
IMPEDIMENTS TO POLLUTERS						
	Costs to users of sewage system.	Change in value of industrial production.	→	→	→	→
		Change in rate of regional growth.	→	→	→	→
	Restrictions on bypassing public system; i.e., against direct discharge.	Change in value of industrial production.	Stricter controls on discharging into estuary may raise production costs for certain industries.			

NOTE: → Denotes IMPACT PROBABLE

FIGURE C-14

ECONOMIC IMPACT ASSESSMENT OF ALTERNATIVE WASTEWATER MANAGEMENT PLANS ON SUBAREAS IN THE SAN FRANCISCO BAY – DELTA REGION

LAND DISPOSAL PLAN

ANTICIPATED CHANGE IN PHYSICAL RESOURCE	ECONOMIC IMPACT CRITERIA: PROBABLE IMPACT	ECONOMIC IMPACT CRITERIA: PROBABLE EVALUATION FACTOR	IMPACT ON SUBAREAS: SUBAREA A COUNTIES Alameda, San Francisco, San Mateo, & Santa Clara	SUBAREA B COUNTIES Marin, Napa, Solano & Sonoma	SUBAREA C COUNTIES Contra Costa	SUBAREA D COUNTIES Sacramento, San Joaquin & Yolo
OCEAN WATERS						
Change in quality	Change in quantity of commercially valuable fish life.	Value of catch.	Protection of ocean water quality will help fishing fleet based in this subarea.	→	→	→
	Effect on other species of marine life and aquatic growth.	Potential economic effects of breakdown in ecologic chain.	→	→	→	→
BAY & DELTA WATERS						
Change in quality	Change in desirable species of fish and wildlife.	Visitor or recreation days, and value of commercial catch.	Bay waters would be of higher quality but there would also be more salt-water incursion. Combined effect is unknown.			Wildlife in irrigated areas may be affected with decline in species which require dry habitat.
	Changes in public access, and change in other water-related recreation.	Visitor-days.	Bay waters would be visibly cleaner and more attractive to tourists.		→	→
	Change in commercial establishments based on "enjoyment" of Bay.	Income from services.	Harbor tours, marinas, waterfront restaurants, and other "tourist-oriented" establishments will benefit from increased patronage.			→
	Change in property values near Bay because of aesthetics.	Changes in value.	Property values adjacent to cleaner waters will increase; in areas where salt water incursion causes difficulties, this may not hold.			→
	Change in water temperatures.	Changed pumping costs for industrial cooling.	Temperatures in parts of Bay would decrease as fewer discharges were allowed; however they would increase if there were no low flow augmentation in some months.			→
LAND RESOURCE						
Re-use of water	Agricultural and forestry production.	Value of output.	Up to 60,000 acres will be irrigated, including acres in San Benito county.	Up to 125,000 acres will be irrigated.	Up to 40,000 acres will be irrigated.	Up to 110,000 acres will be irrigated.
	Soil erosion control.	Reduced maintenance dredging costs.	Reduced public and private maintenance dredging in north end of S.F. Bay and in Sacramento River and San Joaquin River.			
	Change in "green" municipal parks and golf courses.	Visitor days.	Limited amounts of effluent will be used for irrigating golf courses and parks, and for creating recreational lakes. Recreational use, and adjoining property values, will increase.			
	Change in demands in other sources of irrigation water.	Cost savings.	Availability of effluent for irrigation will reduce demand for other sources of irrigation water; and may prolong their useful life.			
	Groundwater replenishment.	Pumping costs; Alternative surface water costs.	→	→	→	→
	Change in salt water incursion.	Differing "life" of fresh water wells and associated costs.	Salt water incursion will increase; this will have adverse effects on some users of surface and ground waters.			→
	Change in land subsidence.	Cost of surface repairs, or of protection from flooding.	Land subsidence is a problem in this subarea and could be arrested.			→
	Water available for cooling.	Price at which it could be sold.	Effluent could be used for industrial cooling purposes, especially in warm areas.			
Re-use of residual solids	Potential increased agricultural production.	Value of products.	Potential for soil melioration; reclamation of constituents.			
	Fertilizer, land-fill, mulch-compost or fill; recycling of waste constituents.	Price at which it could be sold.	→	→	→	→
INSTITUTIONAL CHANGES						
CHANGE IN LAND-USE PATTERNS	Control over patterns of settlement.	Costs of providing government services.	Because of planning controls necessary to implement the land disposal concept, less scattered development will occur.			
	Change in cost/revenue patterns of local governments.	Ability of government to provide necessary services.	Tax base of agricultural lands will increase; however, it will be difficult to change them to more developed uses.			
IMPEDIMENTS TO POLLUTERS						
	Costs to users of sewage system.	Change in value of industrial production.				
		Change in rate of regional growth.	→	→	→	Rate of growth will increase because of additional irrigated acreage.
	Restrictions on bypassing public system; i.e., against direct discharge.	Change in value of industrial production.	Stricter controls on discharging into estuary may raise production costs for certain industries.			→

NOTE: → Denotes IMPACT PROBABLE

FIGURE C-15

ECONOMIC IMPACT ASSESSMENT OF ALTERNATIVE WASTEWATER MANAGEMENT PLANS ON SUBAREAS IN THE SAN FRANCISCO BAY – DELTA REGION

COMBINATION DISPOSAL PLAN

ECONOMIC IMPACT CRITERIA			IMPACT ON SUBAREAS			
ANTICIPATED CHANGE IN PHYSICAL RESOURCE	PROBABLE IMPACT	PROBABLE EVALUATION FACTOR	SUBAREA A COUNTIES Alameda, San Francisco, San Mateo, & Santa Clara	SUBAREA B COUNTIES Marin, Napa, Solano & Sonoma	SUBAREA C COUNTIES Contra Costa	SUBAREA D COUNTIES Sacramento, San Joaquin & Yolo
OCEAN WATERS						
Change in quality	Change in quantity of commercially valuable fish life.	Value of catch.	Protection of ocean water quality will help fishing fleet based in this subarea.	→	→	→
	Effect on other species of marine life and aquatic growth.	Potential economic effects of breakdown in ecologic chain.	→	→	→	→
BAY & DELTA WATERS						
Change in quality	Change in desirable species of fish and wildlife.	Visitor or recreation days, and value of commercial catch.	Quantity of sport fish and game in Bay will increase; benefits will accrue to residents of subareas and visitors.			
	Changes in public access, and change in other water-related recreation.	Visitor-days.	Water-related recreation will increase with changes in Bay water quality.			→
	Change in commercial establishments based on "enjoyment" of Bay.	*Income from services.*	→	→	→	
	Change in property values near Bay because of aesthetics.	Changes in value.	→	→	→	
	Change in water temperatures.	Changed pumping costs for industrial cooling.	→		→	→
LAND RESOURCE						
Re-use of water	Agricultural and forestry production.	Value of output.	→	Up to 60,000 acres will be irrigated.	→	Up to 60,000 acres will be irrigated.
	Soil erosion control.	Reduced maintenance dredging costs.	→	→	→	→
	Change in "green" municipal parks and golf courses.	Visitor days.	Some effluent may be used to irrigate golf courses, parks, and to create recreational ponds.			
	Change in demands in other sources of irrigation water.	*Cost savings.*	Demands on other sources of irrigation water will reduced.			
	Groundwater replenishment.	Pumping costs; Alternative surface water costs.	→	→	→	→
	Change in salt water incursion.	Differing "life" of fresh water wells and associated costs.	→	→	→	→
	Change in land subsidence.	Cost of surface repairs, or of protection from flooding.	→	→	→	→
	Water available for cooling.	Price at which it could be sold.				
Re-use of residual solids	Potential increased agricultural production.	Value of products.	Potential for soil melioration; reclamation of constituents.			
	Fertilizer, land-fill, mulch-compost or fill; recycling of waste constituents.	Price at which it could be sold.	→	→	→	→
INSTITUTIONAL CHANGES						
CHANGE IN LAND-USE PATTERNS	Control over patterns of settlement.	Costs of providing government services.	Because of planning controls necessary to implement the land disposal concept, less scattered development will occur.			
	Change in cost/revenue patterns of local governments.	Ability of government to provide necessary services.	Tax base of agricultural lands will increase.			
IMPEDIMENTS TO POLLUTERS						
	Costs to users of sewage system.	Change in value of industrial production.	→	→	→	→
		Change in rate of regional growth.	→	→	→	Rate of growth will increase because of additional irrigated acreage.
	Restrictions on bypassing public system; i.e., against direct discharge.	Change in value of industrial production.	Stricter controls on discharging into estuary may raise production costs for certain industries.			→

NOTE: → Denotes IMPACT PROBABLE

FIGURE C-16

IDENTIFICATION OF ECONOMIC IMPACTS ON SUBAREAS IN THE SAN FRANCISCO BAY – DELTA REGION RESULTING FROM ALTERNATIVE WASTEWATER MANAGEMENT PLANS

(✓) Means subarea will experience direct impact

ANTICIPATED CHANGE IN PHYSICAL RESOURCE	PROBABLE IMPACT	PROBABLE EVALUATION FACTOR	SUBAREA A COUNTIES Alameda, S.F., San Mateo, Santa Clara				SUBAREA B COUNTIES Marin, Napa, Solano, & Sonoma				SUBAREA C COUNTIES Contra Costa				SUBAREA D COUNTIES Sacramento, San Joaquin & Yolo			
			OCEAN	EST	LAND	COMB.	OCEAN	EST.	LAND	COMB.	OCEAN	EST.	LAND	COMB.	OCEAN	EST.	LAND	COMB.
OCEAN WATERS																		
Change in quality	Change in quantity of commercially valuable fish life.	Value of catch.	✓	✓	✓	✓												
	Effect on other species of marine life and aquatic growth.	Potential economic effects of breakdown in ecologic chain.	✓				✓											
BAY & DELTA WATERS																		
Change in quality	Change in desirable species of fish and wildlife.	Visitor or recreation days, and value of commercial catch.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	
	Changes in public access, and change in other water-related recreation.	Visitor-days.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓				
	Change in commercial establishments based on "enjoyment" of Bay.	Income from services.	✓		✓		✓		✓		✓		✓					
	Change in property values near Bay because of aesthetics.	Changes in value.	✓		✓		✓		✓		✓		✓					
	Change in water temperatures.	Changed pumping costs for industrial cooling.	✓		✓		✓		✓		✓		✓					
LAND RESOURCE																		
Re-use of water	Agricultural and forestry production.	Value of output.			✓				✓	✓			✓				✓	✓
	Soil erosion control.	Reduced maintenance dredging costs.							✓				✓				✓	
	Change in "green" municipal parks and golf courses.	Visitor days.			✓				✓	✓			✓				✓	✓
	Change in demands in other sources of irrigation water.	Cost savings.			✓				✓	✓			✓				✓	✓
	Groundwater replenishment.	Pumping costs; Alternative surface water costs.			✓								✓					
	Change in salt water incursion.	Differing "life" of fresh water wells and associated costs.	✓		✓		✓		✓		✓		✓					
	Change in land subsidence.	Cost of surface repairs, or of protection from flooding.			✓													
	Water available for cooling.	Price at which it could be sold.															✓	
Re-use of residual solids	Potential increased agricultural production.	Value of products.					✓	✓	✓	✓		✓				✓	✓	✓
	Fertilizer, land-fill, mulch-compost or fill; recycling of waste constituents.	Price at which it could be sold.																
INSTITUTIONAL CHANGES																		
CHANGE IN LAND-USE PATTERNS																		
	Control over patterns of settlement.	Costs of providing government services.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Change in cost/revenue patterns of local governments.	Ability of government to provide necessary services.							✓	✓							✓	✓
IMPEDIMENTS TO POLLUTERS																		
	Costs to users of sewage system.	Change in value of industrial production.																
		Change in rate of regional growth.															✓	✓
	Restrictions on bypassing public system; i.e., against direct discharge.	Change in value of industrial production.	✓	✓		✓	✓	✓		✓	✓	✓		✓				

NOTE: ⟶ Denotes IMPACT PROBABLE

FIGURE C-17

ATTACHMENT A

EXHIBITS 1 THROUGH 15 OF A
"REPORT ON ECOLOGICAL
AND AESTHETIC IMPACTS
OF WASTE DISPOSAL TO LAND"

TABLE OF CONTENTS

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ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-
San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT I

DESCRIPTION OF BASELINE CLIMATOLOGICAL CONDITIONS

EXHIBIT 1

TABLE 1 - 5. DESCRIPTION OF BASELINE CLIMATOLOGICAL CONDITIONS

The baseline climatological conditions are represented by the 1968 data of the U. S. Weather Bureau for California and are shown in Tables 1 - 5 for total temperature, temperature extremes, total precipitation, evaporation and wind movement, and drainage and elevation, respectively. These data are comparable with those appearing in the Yearbook of Agriculture, 1941 and Soil Survey of San Benito County 1969 for Hollister. The stations listed in the tables are the available ones listed by the U. S. Weather Bureau which best correspond to the selected impact areas for this study, namely Hollister for disposal area no. 1 - Santa Clara and San Benito Counties; Sonoma and/or Knight's Valley for area no. 2 - Sonoma and Marin Counties; Vacaville for area no. 3 - Solano County; Tracy Carbona and/or Tracy Pumping Station for area no. 4 - E. Contra Costa and W. San Joaquin Counties; Folsom Dam for area no. 5 - S. E. Sacramento County; and Manteca for area no. 6 - E. San Joaquin County.

TABLE 1. BASWLINE CLIMATOLOGICAL CONDITIONS-1968. PRECIPITATION RECORDS.
(From U.S. Weather Bureau Climatological Data, California, 1968)

TOTAL PRECIPITATION (Inches)

Station	County	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Sonoma	Sonoma	7.34	3.69	3.92	.27	.47	.00	.00	.27	.00	1.98	3.15	7.95	29.04
Folsom Dam	Sacramento	4.15	3.11	2.76	.47	.79	.31	.00	.25	.00	.92	4.06	4.11	20.93
Vacaville	Solano	5.58	3.03	3.04	.26	.25	.00	.00	.15	.00	.87	3.35	4.49	21.02
Hollister ISW	San Benito	1.51	1.20	2.62	.41	.22	.00	.00	.00	.00	.28	1.74	2.38	10.36
Manteca	San Joaquin	3.63	1.41	2.59	.36	.20	.00	.00	.07	.00	.50	2.39	3.12	14.27
Tracy Carbona	San Joaquin	2.90	1.09	1.91	.70	.31	.00	.00	2.49	.00	.78	1.87	2.26	14.31

TABLE 2. BASELINE CLIMATOLOGICAL CONDITIONS-1968. TEMPERATURE RECORDS.
(From U. S. Weather Bureau Climatological Data, California, 1968)

AVERAGE TEMPERATURES (°F)

Station	County	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Sonoma	Sonoma	43.7	54.6	54.1	57.6	59.9	67.6	70.1	68.9	68.6	60.2	52.6	44.7	58.6
Folsom Dam	Sacramento	44.4	54.4	55.8	59.6	64.0	74.7	77.6	73.4	72.8	63.6	52.7	49.9	61.5
Vacaville	Solano	43.5	54.3	54.7	59.5	62.9	72.7	75.8	72.5	71.1	60.8	52.4	43.3	60.3
Hollister ISW	San Benito	45.8	55.3	53.1	54.7	58.1M	64.1	65.7	65.8	64.6	59.4	53.2	45.2	57.1
Manteca	San Joaquin	42.0	53.6	55.8	59.7	64.3	73.2	75.3	71.3	70.1	61.4	52.8	44.1	60.3
Tracy Carbona	San Joaquin	42.7	53.7	57.0	63.6	64.7	74.1	76.2	71.7	71.2	62.7	53.4	43.9	61.2

TABLE 3. BASELINE CLIMATOLOGICAL CONDITIONS-1968. TEMPERATURE EXTREMES.

TEMPERATURE EXTREMES (°F)

Station	County	Maximum	Date	Minimum	Date
Sonoma	Sonoma	106	8-29	20	12-21
Folsom Dam	Sacramento	105	7-6+	25	12-21
Vacaville	Solano	107	7-19	22	1-5
Hollister ISW	San Benito	103	8-29	18	12-21
Manteca	San Joaquin	106	7-6+	23	1-6
Tracy Carbona	San Joaquin	106	7-6	24	1-6

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ALTERNATIVES FOR MANAGING WASTEWATER IN THE SAN FRANCISCO BAY A--ETC(U)
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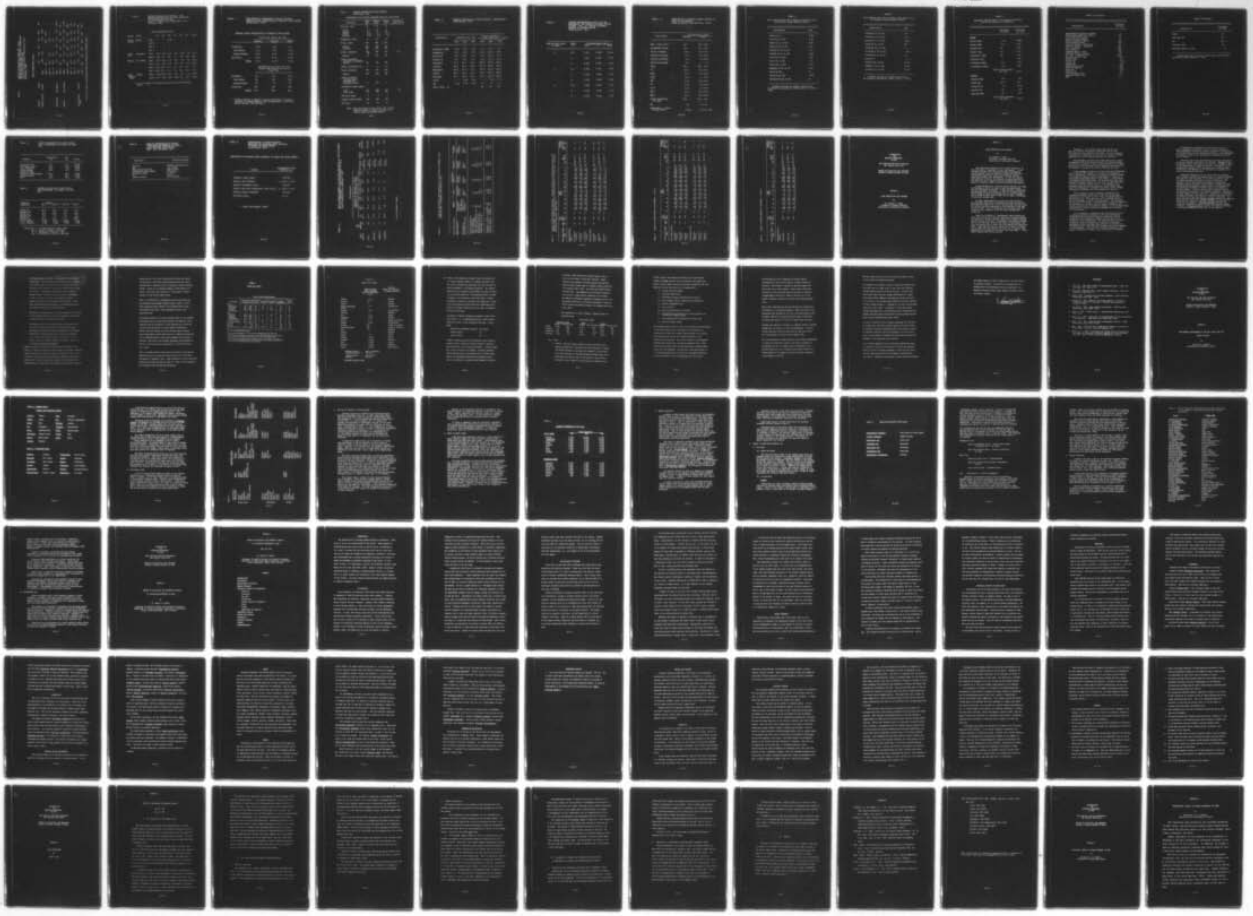

TABLE 4. BASELINE CLIMATOLOGICAL CONDITIONS - 1968.
EVAPORATION RECORDS UNDER INDICATED TEMPERATURES (°F) AND WIND VELOCITIES (mph)
(From U.S. Weather Bureau Climatological Data, California, 1968)

TOTAL EVAPORATION (Inches)

Station	County		Jan.	Feb.	Mar.	Apr.	May.	Jun.
Knights Valley	Sonoma	Evap.	1.26*	3.05	-	5.44	5.61*	-
		Wind V.	812	-	-	1169	995*	-
		Max. T.	52.2	63.5	-	79.3	-	-
		Min. T.	38.9	43.5	-	46.7	-	-
Folsom Dam	Sacramento	Evap.	1.10	1.37	3.42	6.42	7.84	10.49
		Wind V.	823	631	578	652	366	244
Manteca	San Joaquin	Evap.	0.92	1.11	3.19	7.13	9.05	11.89
		Wind V.	1031	732	1306	1721	1916	2196
		Max. T.	46.2	60.0	65.1	75.0	81.4	89.9
		Min. T.	37.4	47.9	46.4	48.9	52.4	57.9
Tracy Pumping Plant	Alameda	Evap.	1.34	1.87*	5.22	9.92	12.61	1707
		Wind V.	1914	1864	3047	4230	6184	6479

* Pan is of copper, and painted inside and outside with aluminum paint.

TABLE 5. BASELINE CLIMATOLOGICAL CONDITIONS - 1968. EVAPORATION RECORDS UNDER INDICATED TEMPERATURES (°F) AND WIND VELOCITIES (mph) (From U.S. Weather Bureau Climatological Data, California, 1968)

TOTAL EVAPORATION (Inches)

Station	County		Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Knights Valley	Sonoma	Evap.	-	-	4.82*	-	-	-	-
		Wind V.	-	-	-	-	-	-	-
		Max. T.	-	-	-	-	-	-	-
		Min. T.	-	-	-	-	-	-	-
Folsom Dam	Sacramento	Evap.	11.62	9.03	8.03	4.05	1.68*	.82	65.87
		Wind V.	209	273	280	247	198	586	5087
Manteca	San Joaquin	Evap.	11.62	8.59	6.31	3.59	1.66	1.16	66.22
		Wind V.	1931	1827	1626	1162	1325	1770	18543
		Max. T.	91.6	86.2	78.6	70.5	59.3	48.5	71.0
		Min. T.	59.8	58.5	55.5	50.2	46.4	38.4	50.0
Tracy Pumping Plant	Alameda	Evap.	16.96	13.02	10.97	6.06	2.50	1.41	98.95
		Wind V.	6177	5559	4954	3079*	823	613	44923

* Pan is of copper, and painted inside and outside with aluminum paint.

TABLE 6. SOME PHYSICAL PROPERTIES OF WASTE PRODUCTS; AVERAGE SOLIDS COMPOSITION OF DOMESTIC WASTE WATER, (From Gates, 1967)

AVERAGE SOLIDS COMPOSITION OF DOMESTIC WASTE WATER

	Pounds per capita per day		
	Mineral	Organic	Total
Suspended	0.05	0.15	0.2
Settleable	0.03	0.09	0.12
Nonsettleable	0.02	0.06	0.08
Dissolved	0.18	0.18	0.36
TOTAL	0.23	0.33 *	0.56
	Milligrams per liter for 100 gallons per capita per day of water use		
Suspended	65	170	235
Settleable	40	100	140
Nonsettleable	25	70	95
Dissolved	210	210	420
TOTAL	275	380	655

* Organic matter in domestic waste (exclusive of ground garbage) is approximately 50% carbohydrates, 40% nitrogenous matter, and 10% fats.

TABLE 7. CHEMICAL PROPERTIES OF WASTE PRODUCTS.
(From Gates, 1967)

CHARACTERISTICS OF TYPICAL UNTREATED MUNICIPAL WASTE WATER

Constituent	Weak, mg/l	Medium, mg/l	Strong, mg/l	Pounds per capita per day
Nitrogen, total	13	28	40	
Organic	8.5	15	18	
Ammonia	4	12	20	
Nitrite	0.05	1.1	0.2	
Nitrate	0.45	0.9	1.8	
Phosphorus, total	2	15	40	
Solids, total	430	600	1230	
Organic	240	420	810	
Inorganic	190	180	420	
Solids, suspended	98	200	370	0.2
Organic	72	140	220	
Solids, settleable (included in suspended solids)	60	120	200	
Solids, settleable, ml l	4	8	12	
Solids, dissolved	330	400	860	
Organic	170	280	590	
Solids, colloidal (divided between suspended and dissolved solids)	---	120	---	
Biochemical oxygen demand				
5-day	95	210	410	0.2
First stage	130	290	545	
Dissolved oxygen	0	0	0	
Chemical oxygen demand	150	400	650	
Chlorides	20	40	80	

NOTE: These data apply to most cities with "normal" amounts and types of industrial wastes and limited numbers of garbage grinders.

TABLE 8. CHEMICAL PROPERTIES OF WASTE PRODUCTS, PENNSYLVANIA. (From Kardos, 1967)

Constituent	Concentration, mg/l			Amount Applied at 2-in.-per-week level, lb/acre		
	1963	1964	1965	1963	1964	1965
Surfactant (ABS)	3.23	1.82	0.74	35.2	27.2	9.7
Phosphorus	9.70	8.95	6.60	105.6	133.8	86.8
Nitrate N	5.8	13.8	5.5	63.4	206.6	72.3
Organic N	6.9	4.4	2.6	75.4	65.2	34.2
Potassium	17.3	16.0	19.2	188.2	239.2	252.5
Calcium	31.5	30.1	28.8	342.8	450.2	378.7
Magnesium	18.6	15.8	15.3	202.4	236.4	201.2
Sodium	46.7	32.9	34.6	358.0	492.2	455.0
Chloride	43.5	42.3	43.2	473.2	632.8	568.1
Boron	--	0.40	0.32	--	6.0	4.2
pH	7.26	7.20	7.60	--	--	--
Waste water, in.				48	66	58

TABLE 9. AVERAGE CONCENTRATION (mg/l) OF ABS, PHOSPHORUS, AND NITRATE NITROGEN DURING OCTOBER, 1965, IN SUCTION LYSIMETER SAMPLES AT SEVERAL DEPTHS. (From Kardos, 1967)

Application Level, in./week	Depth ft.	Concentration, mg/l		
		ABS	P	NO_3N
0	0.5	0.035	0.058	10.06
	2	0.015	0.033	9.15
	4	0.007	0.030	6.26
1	0.5	0.040	0.057	0.83
	2	0.018	0.018	2.73
	4	0.016	0.018	5.20
2	0.5	0.063	0.183	3.03
	2	0.043	0.043	3.79
	4	0.034	0.036	5.97

TABLE 10. COMPOSITION OF SETTLED SEWAGE APPLIED TO SOILS IN LYSIMETERS.
(From Greenberg, and McGauhey, 1955)

Constituent	Concentration (ppm)	
	Average	Range
BOD, 5-day, 20 C.	187	90 - 322
Suspended solids	135	44 - 324
Total nitrogen	40.8	32.7-55.9
Ammonia-nitrogen	31.3	17.2-50.4
Organic-nitrogen	9.0	4.3-18.4
Nitrate-nitrogen	0.5	0 - 1.8
HCO_3^-	256	146 - 366
Cl^-	44.5	22.1-56.0
$SO_4^{=}$	42.1	23.1-64.0
$PO_4^{\equiv}$	15.9	0 - 28.6
Na^+	53.8	25.0-80.0
K^+	11.9	8.0-14.9
Ca^{++}	13.6	6.2-34.0
Mg^{++}	23.2	14.2-34.8
NH_4^+	40.2	22.1-64.9
Total Alkalinity ($Ca\ CO_3$)	209	120 - 300
pH	7.4	7.1-7.9
Monovalent - total cation ratio	0.641	0.523-0.760

TABLE 11

Water Analysis Report for a Composit from Three City of San Francisco Sewage Treatment Plants*

Determination	mg/1
Arsenic as As	0.006
Iron as Fe, by AAS	0.52
Cooper as Cu, by AAS	0.19
Nickel as Ni, by AAS	0.01
Chromium as Cr, by AAS	0.2
Aluminum as Al, by AAS	0.28
Lead as Pb, by AAS	0.34
Tin as Sn, by AAS	0.2
Zinc as Zn, by AAS	0.25
Manganese as Mn, by AAS	0.12
Silica as SiO_2	18
Silver as Ag, AAS	0.005
Magnesium as Mg, by AAS	32

*Prepared by Brown and Caldwell Laboratories, San Francisco; Analysis No. 10959; Analyst: S. Kirby, A. Jeong.

TABLE 12

Water Analysis Report for a Composite from Three City of San Francisco Sewage Treatment Plants*

Determination	mg/l
Calcium as Ca, by AAS	29
Titanium as Ti, by AAS	<0.1
Bismuth as Bi, by AAS	<0.05
Sodium as Na, by AAS	258
Potassium as K, by AAS	9
Strontium as Sr, by AAS	0.31
Zirconium as Zr, by AAS	<5
Boron as B	1.1
Barium as Ba, by AAS	<0.05
Cadmium as Cd, by AAS	<0.01
Lithium as Li, by AAS	<0.05

*Prepared by Brown and Caldwell Laboratories, San Francisco; Analysis No. 10959; Analyst: A. Jeong.

TABLE 13

Wastewater Analysis Report for a Composite from Three City of San Francisco STP Effluents*

	Milligrams per liter	Milliequiv. per liter
Anions		
Nitrite (NO_2)	0.39	0.008
Nitrate (NO_3)	19.9	0.32
Chloride (Cl)	425	11.99
Sulfate (SO_4)	114	2.37
Bicarbonate (HCO_3)	150	2.46
Carbonate (CO_3)	0	0.00
H Phosphate (HPO_4)	11.1	0.23
H_2 Phosphate (H_2PO_4)	8.9	0.09
	Total milliequivalents per liter	17.47
Cations		
Ammonium (NH_4)	19.4	1.07
Sodium (Na)	248	11.2
Potassium (K)	7.3	0.19
Calcium (Ca)	29	1.45
Magnesium (Mg)	32	2.63
	Total milliequivalents per liter	16.64

TABLE 13 (Continued)

Determination	Milligrams per liter
Phenolphthalein Alkalinity ($CaCO_3$)	0
Methyl Orange Alkalinity ($CaCO_3$)	129
Free Carbon Dioxide (CO_2)	---
Calcium Hardness ($CaCO_3$)	72
Magnesium Hardness ($CaCO_3$)	132
Total Hardness ($CaCO_3$)	204
Dissolved Residue - Calculated	---
Dissolved Residue - Evaporated	1100
Loss on Ignition	697
Fixed Residue	403
Suspended Matter, total	180
Suspended Matter, volatile	35
Sp. Cond. - Micromhos 25 C	1886
Hydrogen Ion Conc. (pH)	6.9
Silica (SiO_2)	12
Nitrite (N)	0.12
Nitrate (N)	4.5
Ammonia (N)	16.0
Organic Nitrogen (N)	28.2
Total Nitrogen (N)	48.8
Boron (B)	0.8
Fluoride (F)	0.9
Total Phosphate (PO_4)	20
Chlorine Residual (Cl)	---
MBAS	---

TABLE 13 (Continued)

Determination	Milligrams per liter
Grease	30
5-day BOD, 20C	178
COD	385
Turbidity (JTU)	75
Settleable Matter, ml/l/hr	1.5

*Prepared by Brown and Caldwell Laboratories, San Francisco; Analysis No. 10959; Analyst: A. Jeong.

TABLE 14

Spectrographic Analysis (Semi-quantitative) of the Residue of a Composite from Three City of San Francisco Sewage Treatment Plants*

Determination	Per Cent
Iron	0.15
Cooper	0.02
Nickel	<0.001
Chromium	0.03
Aluminum	0.08
Lead	0.003
Tin	0.001
Zinc	0.02
Cobalt	<0.001
Manganese	0.015
Molybdenum	<0.001
Silicon	1.00
Silver	0.002
Vanadium	<0.001
Magnesium	5.00
Calcium	7.00
Titanium	0.004
Bismuth	<0.001
Sodium	Major
Potassium	2.00
Strontium	0.04
Zirconium	<0.005
Boron	0.20
Barium	<0.01

*Prepared by Metallurgical Laboratories, Inc., San Francisco.

TABLE 15

Chlorinated Hydrocarbon Pesticides Found in a Composite from Three City of San Francisco Sewage Treatment Plants*

Chlordane	2.0 ppb
Aldrin	0.4 ppb
pp DDE	0.2 ppb
Methyl Parathion	2.0 ppb

*Prepared by Morse Laboratories, Sacramento, California.

TABLE 16. AVERAGE CHARACTERISTICS OF SEWAGE SLUDGE. FROM: BALAKRISHNAN, WILLIAMSON, AND O'KEY 1970.

Material	Combustibles (%)	Ash (%)	BTU/lb.
Grease and scum	88.5	11.5	16,750
Raw sewage solids	74.0	26.0	10.285
Fine screenings	86.4	13.6	8,990
Ground garbage	84.8	15.2	8,245
Digested sewage Solids and ground garbage	49.6	50.4	8,020
Digested sludge	59.6	40.4	5,290
Grit	30.2	69.8	4,000

TABLE 17. ELEMENTAL COMPOSITION OF SEWAGE SLUDGE. FROM BALAKRISHNAN, WILLIAMSON, AND O'KEY, 1970.

Elemental Composition	Source* No. 1	No. 2	No. 3	No. 4
Carbon (%)	64.3	65.6	55.0	51.8
Hydrogen (%)	8.2	9.0	7.4	7.2
Oxygen (%)	21.0	20.9	33.4	38.0
Nitrogen (%)	4.3	3.4	3.1	3.0
Sulfur (%)	2.2	1.1	1.1	Trace
Volatile (%)	47.9	72.5	51.4	82.0
V.S.S. (BTU/lb.)	12,840	12,510	10,940	8,990
T.S.S. (BTU/lb.)	6,160	9,080	5,620	7,380

*Source No. 1 - Cleveland Southerly Plant, 1955
No. 2 - Detroit, Michigan, 1955-1956
No. 3 - Minneapolis, Minnesota, 1955
No. 4 - New Rochelle, New York, 1960-1962

TABLE 18. RANGE IN CONCENTRATIONS OF SELECTED CONSTITUENTS AND PROPERTIES OF DENVER SEWAGE-TREATMENT PLANT EFFLUENT. FROM: PAGE AND WAYMAN, 1966

Constituent	Concetration Range
Bacteria	100,000-4,000,000 per ml
ABS	2.8-7.5 ppm
Total dissolved solids	440-1,030 ppm
Biochemical oxygen demand	125-250 ppm
Dissolved oxygen	0-5.0 ppm
pH	6.2-8.1
Surface tension	50-62 dynes/cm

TABLE 19. MICROBIOLOGY OF WASTE PRODUCTS.
DENSITIES OF COLIFORM GROUP BACTERIA
IN WATER AND WASTE WATER*
(From Gates, 1967)

DENSITIES OF COLIFORM GROUP BACTERIA IN WATER AND WASTE WATER*

Liquid	Approximate range MPN/100 ml.
Domestic waste water	10^8-10^9
Septic tank effluent	3×10^7-3×10^8
Aerobic household units	10^6-10^7
Septic tank plus subsurface sand filter	3×10^4-3×10^5
Bathing water standards	10^2-10^3
Drinking water	0.1-1

* Data from Thomas (1960)

TABLE 20. MOST PROBABLE NUMBERS OF COLIFORM ORGANISMS IN THE EFFLUENTS OF SOIL LYSIMETERS - THREE-FOOT DEPTH OF SOIL. (From Greenberg and McGauhey, 1955)

Soil	No. of Samples	Distribution: Percent of Samples in Which MPN*/100 ml was greater than: 10	100	1000	10,000	100,000	1,000,000	Range	Median	Mean
Oakley	70	96.1	92.2	73.7	44.8	35.5	17.1	2.3-11,000,000	2400	556,500
Yolo	78	92.3	77.0	38.5	24.4	12.8	5.1	2.3-2,400,000	240	145,000
Hanford	77	54.6	45.5	23.4	7.8	2.6	0	2.3-240,000	23	8,070
Hesperia	73	37.0	26.1	4.1	1.4	0	0	2.3-24,000	3.6	575
Columbia	77	28.6	7.8	3.9	1.3	0	0	2.3-24,000	2.3	396

* Most probable number

TABLE 21. PHYSICAL AND CHEMICAL CHARACTERISTICS OF FIVE PERVIOUS CALIFORNIA SOILS. (MODIFIED FROM: GREENBERG, AND McGAUHEY, 1955)

Soil Characteristic	Soil Types				
	Oakley	Yolo	Hanford	Hesperia	Columbia
Parent Material	Sandy mixed Alluvium Wind modified	Sedimentary Alluvium	Granitic Alluvium	Gramitic Alluvium	mixed Alluvium
Soil Reaction	Slightly acid	neutral	neutral	neutral	neutral
Sub-surface drainage	Excessive	good	good	good	good
Particle Size-percent					
Clay <0.002 mm	5	3	6	8	10
Silt 0.002-0.05mm	9	19	21	30	24
Very fine sand 0.05-0.1 mm	15	20	16	12.5	18
Fine sand 0.1-0.2 mm	26	33	25	17.5	29.5
Medium sand 0.2-0.5 mm	42	24.5	29	27.5	11
Coarse sand >0.5 mm	3	0.5	3	4.5	7.5
Monovalent cations - me/100g	0.24	0.43	0.72	0.89	0.51
Divalent cations - me/100g	2.79	13.98	5.66	8.02	5.67
Exchange capacity - me/100g	3.03	14.41	6.38	8.91	6.18

TABLE 22 QUALITY OF GROUND WATERS IN CALIFORNIA. SELECTED ANALYSES OF GROUND WATER FOR EACH OF THE DISPOSAL AREAS. (From Department of Water Resources Bulletin No. 66-62, Part 1, Northern and Central California, August 1964).

State Well Number Date	Temp °F	Sp. Cond. Micro Mhos.	pH	PPM / EQ.PM. Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	TDS PPM	% Na	Hardness as $CaCO_3$ Total PPM	N.C. PPM
Gilroy-Hollister Basin																			
10 S/3E-26J1	64	411	7.6	33	22	15	0.4	0	162	20	22	23	0.2	0.08	39	255	16	174	41
6-13-62				1.65	1.83	0.65	0.01	0.00	2.66	0.42	0.62	0.37	0.01						
11 S/4E-3L2	71	480	8.2	40	19	34	1.3	0	242	28	16	3.8	0.2	0.14	25	286	29	178	0
6-13-62				2.00	1.56	1.48	0.03	0.00	397	0.58	0.45	0.06	0.01						
12 S/4E-34P2	64	1880	7.5	217	68	133	2.3	0	483	381	206	27	0.6	0.8	26	1300	26	822	426
6-13-62				10.83	5.59	5.78	0.06	0.00	7.92	7.93	5.81	0.44	0.03						
Petaluma Valley																			
3N/6W-1SMI	56	538	7.4	46	19	33	1.9	0	110	61	69	8	0.4	0.02	7	365	27	195	105
4-3-62				2.30	1.60	1.46	0.05	0.00	1.80	1.27	1.96	0.14	0.02						
4N/6W-33R1		4070	7.6	164	202	382	19	0	561	0	1124	10	0	0.42	28	2660	40	1242	782
4-62				8.20	16.64	16.60	0.50	0.00	9.20	0.00	31.65	0.17	0.00						
SM/7W-8D3		1100	8.3	68	28	87	4	0	252	38	177	0	0	0	21	905	40	285	78
4-62				3.38	2.52	3.80	0.10	0.00	4.15	0.81	4.97	0.00	0.00						

TABLE 22 QUALITY OF GROUND WATERS IN CALIFORNIA. (Cont'd)

State Well Number Date	Temp °F	Sp. Cond. Micro Mhos.	pH	PPM EQ.PM. Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	TDS PPM	% Na	Hardness as $CaCO_3$ Total PPM	N.C. PPM
San Joaquin County																			
4N/4E-14C1 7-19-62	68	990	8.3	17 0.85	5.6 0.46	200 8.70	1.3 0.03	3.0 0.10	221 3.62	20 0.42	204 5.75	0.0 0.00	0.2 0.01	1.6	28	588	87	66	0
1S/4E-14M1 7-20-62	66	1450	8.4	22 1.12	13 1.14	290 1260	0.9 0.02	9.0 0.30	241 3.95	264 5.50	174 4.90	0.0 0.00	0.1 0.00	1.6	24	916	85	113	0
3S/5E-861 7-27-62	75	820	7.8	58 2.88	26 2.07	78 3.40	2.5 0.06	6.0 0.00	152 2.50	89 1.87	98 2.75	64 1.03	0.2 0.01	0.8	40	531	40	248	123
Sacramento County																			
6N/8E-1SJ1 8-30-62	72	160	8.2	13 0.66	4.4 0.36	8.8 0.38	2.8 0.07	0.0 0.00	57 0.93	1.9 0.04	7.1 0.20	11 0.18	0.2 0.01	0.0	66	143	26	51	5
9N/4E-27F1 10-5-62	61	720	8.2	41 2.07	17 1.41	85 3.70	2.0 0.05	0.0 0.00	223 3.65	0.0 0.00	122 3.42	0.0 0.00	0.1 0.00	0.5	40	417	51	174	0
10N/6E-27L 10-9-62	72	340	8.7	29 1.46	13 1.08	21 0.90	1.4 0.04	4.5 0.15	146 2.47	0.1 0.01	26 0.73	0.0 0.00	0.1 0.00	0.1	62	230	26	127	0

TABLE 22 QUALITY OF GROUND WATERS IN CALIFORNIA. (Cont'd)

State Well Number / Date	Temp °F	Sp. Cond. Micro Mhos.	pH	PPM EQ.PM. Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	NO_3	F	B	SiO_2	TDS PPM	% Na	Hardness as $CaCO_3$ Total PPM	N.C. PPM
Suisun-Fairfield Valley																			
3N/1E-22F3		1890	8.2	40	31	350	5	0	523	80	301	28	0.7	3.36	20	1340	76	114	0
				2.00	2.56	15.20	0.12	0.00	8.58	1.66	8.48	0.45	0.04						
4N/1W-33A1		3600	8.1	56	55	713	8	0	624	162	864	1	0.4	14	22	2500	80	366	0
				2.80	4.52	31.00	0.20	0.00	1024	3.39	2433	0.02	0.02						
5N/2W-34N1		2010	7.7	96	91	248	1	0	704	293	183	19	0.5	2.14	16	1520	46	613	36
				4.78	9.47	10.80	0.20	0.00	1153	6.10	5.14	0.30	0.02						

ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 2

SOME DEFINITIONS AND CONCEPTS

by

Dr. Herbert L. Mason
Professor of Botany, Emeritus
University of California, Berkeley

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The traditional definition of "ecology" defines it as the 'relations of organisms to their environment'. To an informed ecologist this implies that many environmental factors impinge upon the organism by means of which the environmental relations, which the definition implies constitute ecology, are implemented. It will not require much analysis to reveal that whereas the above definition may leave one with a vague feeling of comprehension of the subject it does not leave him with much useful information.

A good definition of a science should indicate the range of knowledge in which the subject lies and should state how that knowledge is pursued. I shall propose a definition that generalizes on the nature of what the ecologist does in constructing the body of knowledge that he calls "ecology" and in doing so shall gain an idea of the range of knowledge in which the science lies.

At least theoretically but often in actual practice, the ecologist intuitively contemplates his body of data and discovers that some of it is in a certain order and that there are certain obvious connections in the relations of the data he has in hand. Thus, he discovers that in their order and connection the relations in his data have mathematical properties.

Order is a relation of 'betweenness' which requires at least three terms for it to hold such that one may be between the other two. We may, however, speak of an ordered relation between any two such terms. Furthermore, the relation giving rise to an order must be such that when it holds between the first and second term it must also hold between the second and third. When this is true of a given set of terms it follows that it must also hold between the first and the third. Good examples are the relations 'preceeds' and 'less than '. Order always implies some kind of series.

'Connection' is a relation such that when one fact preceeds, another necessarily follows and is such that the converse of the relation never holds. Not all connected relations are necessarily in series but all serial relations generated by a valid ordering relation are connected.

Theoretically, the next step of the operation is purely mathematical and should never be trusted to intuition alone. It entails the pursuit of implications generated by the formal properties of the relations and the design and description of the pattern or system of the formal relations that hold.

System belongs to that part of the structure of knowledge that is called "description". It entails the language of formal description. We describe the formal relations holding by a simple or complex logical or mathematical model or a complex multidimensional grid of such models. The ecosystem is probably of the latter type. We havedescribed only a few elemental connected systems but do not as yet know how these fit into an overall system or grid. The language of the system may take the form of equations, formal definitions, algebraic expressions, coordinates and their curves, ordinal correlators, diagrams, and other mathematical devices.

In the pursuit of these ecological systematics the ecologist constantly refers back to his data at each new implication he discovers to see if what is implied holds for the data as well. This operation in the construction of a body of knowledge is called "interpretation". He interprets his data into the system. Interpretation is always an operation of correlation of the data into the system in terms of the formal properties of the relations holding. In the interpretation, biological data appear connected by mathematical relations and correlations.

It is important to understand that ecosystem as such is a thoroughly mediated intellectual construct entailing an extensive array of other intellectual constructs such as coordinates, and dimensions, numbers and the like, each a fabrication of the human mind. The ecosystem does not occur in Nature. What is in Nature is an array of uncollected uninterpreted facts awaiting some collector or observer to incorporate them in his data and interpret them in the language of the ecosystem. Thus the term "ecosystem" belongs to the realm of theoretical ecology, not to the reality of Nature.

No systematic interpretation of the data is ever of itself completely satisfying. What is required further is some explanation of how the relations we discover and describe in our data arose via the operations of Nature. The explanation is always in terms of the operations of organisms and of the laws of Nature.

With this very brief and admittedly incomplete background we may now attempt a definition of "ecology". Ecology is the biological science that seeks to describe the relations holding in the communities of organisms and their environments in the mathematical language of the ecosystem and to explain these relations in the language of the operations of organisms and of the environmental processes.

Regarding definitions of the three kinds of treatment given sewage in disposal operations there is confusion stemming from the fact that the names of the three treatments imply an ordinal sequence which may not occur in practice. For example, some of the biological operations of secondary treatment can and do occur during primary treatment and some primary physical separation takes place as a consequence of the effects of secondary treatment such as the removal of certain sludges. In fact, some tertiary operations may be introduced at any place in the treatment sequence. Therefore, we shall employ the words "primary", "secondary", and"tertiary" as names relating to the agency of treatment that takes place; the terms are without any specific ordinal connotation. We shall therefore hold that primary treatment entails the physical separation of solids from effluent whenever and whereever it occurs in the sequence. Secondary treatment entails the biological operations on both effluent and separated sludge fractions. Tertiary treatment entails the chemical additions or operations employed at any point in the sequence.

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REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 3

CONDITION OF WASTE PRODUCTS

by

David R. Storm

EXHIBIT 3

STORM ENGINEERING • DESIGN

WATER AND WASTE MANAGEMENT

June 26, 1971

Dr. C. L. Newcombe
Director
San Francisco Bay
Marine Research Center
8 Middle Road
Lafayette, California 94599

Subject: Contribution of D. R. Storm to "Report of Ecological and Aesthetic Impacts of Waste Disposal to Land".

Dear Dr. Newcombe:

The following paragraphs are identified by appropriate Roman numeral and letter designation as contained in your report outline, dated June 14, 1971.

III.B. Condition of the waste products.

1. Physical properties

a.) Waste water and/or effluent - The secondary waste effluent will be generally innoccuous to the casual observer and if entirely domestic in origin will carry an odor best described as "earthy" and sometimes lightly scented by soaps and detergents. Residual chlorine from disinfection processes may mask both the "earthy" and "soapy" odors. Primary effluent on the other hand can be malodorous as can be the supernatant liquor, or the moisture component remaining after solids separation, through sedimentation or surface leaching, of solids and carrying water. The general appearance of the effluent will be clear and free of suspended solids or

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floating materials and scums, if treatment is satisfactorily accomplished. Any dissolved solids remaining in the effluent after good secondary treatment will be of such concentration that during most seasons of the year reasonable clarity should be expected. Algae population densities will be high and emergent aquatic vegetation will proliferate on the margins of open conveyance structures and storage works where abundant nutrients and other edaphic factors permit. Waste water temperatures will be variable, fluctuating with season and available quantities of solar radiation.

The physical characterization of industrial wastes is a function of the industry and process and can be assumed to be extremely variable and beyond the scope of this study.

The aggregate impact of the obvious physical characteristics of waste on the general public and in particular to those individuals and communities which lie adjacent to the proposed treatment and disposal areas, must be carefully considered. It is believed that public acceptance and support of such a massive land waste disposal scheme would depend in great part on "how it looks and how it smells".

2. Chemical properties - The chemical constituency of domestic waste water is a complex arrangement (stable) organic and inorganic compounds resulting directly and indirectly from the activities of man. There are hourly, daily and seasonal variations in chemical constituency of waste waters. Diet, economic level, numbers of contributing sink garbage grinders, ground water infiltration into the sewage collection

system are but a few of the factors which influence the quality of waste water. Hill 1963, reported average annual per capita contributions of chemical salts of 70 pounds for typical sewerage systems. Because of the seasonal changes in both quantity and quality it has been found convenient to distinguish a separate category for wet and dry weather flows.

Table I is illustrative of average waste water constituency for six (6) Marin County sewage treatment plants, several of which would discharge treated effluent ot the Northern Marin County land disposal area under a land confinement of waste water alternative plan.

Of principal interest in the waste effluent under the land confinement scheme will be the fertilizer benefits for commercial crops resulting from the availability of the inorganic micro and macro-nutrients found abundantly in typical domestic wastewaters. Hirsch, 1969, has reported the plant nutrient value of typical waste waters based on 1969 retail prices for commercial fertilizers such as ammonium nitrate, triple super phosphate, and potassium chloride. The value of the nitrogen, phosphorus and potassium are $10, $5, and $3 per acre-foot respectively, or $18 per acre-foot total value.

Boron, an element which is found occuring naturally in most western ground waters and on occasion in surface waters, can be extremely detrimental to commercial crops. Other substances for which phytotoxic properties are known are shown in Table II. Many of these substances are frequently found in minicipal wastewaters.

TABLE I

(After Anon 1967)

Chemical Analyses of Sewage Effluents

Determination	Marin County sewage effluents[a]			Water supply average	Normal mineral pick-up[b]	Calculated effluent quality[c]	Las Gallinas effluent June, 1961
	Average	Maximum	Minimum				
Cations							
Calcium (Ca)	42	114	16	19	-4	15	16
Magnesium (Mg)	84	288	25	12	+4	16	28
Sodium (Na)	556	2,230	74	9	+63	72	98
Potassium (K)	30	92	13	< 1	+10.7	12	14
Ammonium (NH_4)	32	45	19			32	29
Anions							
Sulfate (SO_4)	144	562	40	14	+28	42	40
Chloride (Cl)	990	4,090	85	15	+41	56	102
Nitrate (NO_3)	8.5	58	0.2			8	0.9
Phosphate (PO_4)	24	32	5			24	
Bicarbonate (HCO_3)	256	314	78	81	+189	270	296
Total hardness ($CaCO_3$)	450	1,470	154	98	+13	111	154
Silica (SiO_2)	19	23	15			19	21
Boron (B)	0.6	1.4	0.4		+0.5	0.6	0.4
Fluoride (F)	1.6	3.2	0.2	0.12		1.6	1.0
Total dissolved solids	2,010	7,600	467	135	+293	428	467
pH		7.8	6.6			7.4	7.8

All results are expressed as mg/l except pH.

[a] Source of data: DWR Bulletin No. 68-62 12 analyses at 6 different plants from 1956 to 1961.

[b] Normal change in concentration after domestic use. Source: DWR "Residential Unit Water Use Survey, Monterey Hills Tract, Los Angeles County, for March 1962 - March 1964" February, 1966.

[c] Obtained by adding normal mineral pickup to average concentration in water supply. Where data are lacking on water supply or mineral pickup, values are average for Marin County sewage effluents. Not applicable in areas where salt water infiltration is anticipated.

Table II

(After Wilcox 1963)

	USPHS Drinking Water Standards Max. Desirable Limit (mg/L)	Relative Degree of Toxicity in Irrigation Water*
Arsenic	0.01	Extreme
Chloride	250	Slight
Copper	1	Extreme
Carbon chloroform extract	0.2	Unclassified
Cyanide	0.01	Unclassified
Fluoride	--	Moderate
Iron	0.03	Slight
Manganese	0.05	Extreme
Nitrate	45	Slight to nontoxic
Phenols	0.001	Unclassified
Sulfate	250	Slight to nontoxic
Dissolved Solids	500	Slight to nontoxic
Zinc	5	Moderate
Lithium	--	Extreme
Barium	1**	Slight
Cadmium	0.01**	Slight
Chromium	0.05**	Moderate
Lead	0.05**	Slight
Selenium	0.01**	Moderate
Silver	0.05**	Unclassified

*Extreme toxicity : 2mg/L permissible
Moderate toxicity : 2-25 mg/L "
Slight toxicity : 25-250 mg/L "
Nontoxic : 250 mg/L "

**Maximum allowable limit

a.) Sludge - The fundamental principal behind the operation of all sewage treatment plants is to separate the water from the solids (suspended and dissolved) such that the water is restored somewhat to its original condition. The chemical salts which are retained in the effluent have been described in the previous subsection. The separated solids or sludge is usually a thick mixture of water and solids. Several processes are employed to stabilize the sludge and to reduce it to an inoffensive product which after dewatering can be buried, incinerated, disposed of in the ocean, or employed as a soil conditioner.

The solids in domestic sludges are composed of three prime constituents, i.e., biodegradable material, stable organic matter and inerts. in the following proportions: (Levin, 1968)

Biologically degradable organics	- 30 percent
Stable organics	- 35 "
Inert material	- 35 "

Primary treatment generally by sedimentation and screening produces primary sludge and in most plants this represents some 100 percent of the total solids removal. Primary sludge has a solids content of 1-4 percent. Secondary treatment removes 60-95 percent of the solids while a tertiary plant removes the remaining solids which are generally wasted back to the primary or secondary plant elements for removal.

Secondary sludge differs from primary sludge in that it has a solids content of less than 1 percent. Primary sludge is much simpler to process, dewater and stabilize while secondary sludge tends to decompose rapidly presenting odor problems (Ibid. 1968). The solids have high bacterial concentrations. Some segments of the bacterial assemblage are utilized in stabilization (digestion) of the sludge. The numbers of pathogenic organisms in sludge decrease during the sludge stabilization process with thermophilic digestion (125°F) having the greatest potential for pathogen destruction (Ibid. 1968).

The components of a typical domestic, digested sludge are tabulated below:

(After Bacon 1967)

	Digested Sludge		=	Water	+	Solids	
	(grams)	(lb/acre inch)		(grams)	(lb/acre inch)	(grams)	(lb/acre inch)
Solids	28.90	6560		0.98	222	27.92	6338
Nitrogen	1.45	329		0.35	79	1.10	250
Phosphorus	0.87	202		0.06	13.8	0.83	188
Potassium	0.167	38		0.155	35	0.012	3

IV.A. Water

1. Quality - The water quality effects of large scale land waste disposal schemes which incorporate both the application of sludge and treated effluent to land areas will depend to a large extent on (1) the efficiency of proposed underdrain systems during the 9-month application period, and (2) the ability to store without spillage the waste components during the winter rainfall period.

Further, much of the potential efficiency of the land disposal system to exchange ions and filter the effluent will depend upon certain critical subsoil properties and their variability with time. Among the critical soil factors to be considered are:

a.) porosity and perviousness

b.) capillary conductivity

c.) infiltration capacity and percolative capacity

d.) base exchange capacity (adsorptive and desorptive)

e.) percent exchangeable ions

f.) pore saturation

g.) grain size destribution in profile

h.) concentration and production of ferrous sulfide as an interstitial clogging element

i.) clay swelling from the adsorption of sodium ions

j.) dissolved oxygen content

The concentrations of specific ions in the effluent after percolation to the drain fields at the 8 foot depth will be difficult to predict and will vary with eventual operating mode at the various land disposal sites and the soil chemistry kinetics of the particular soils involved. Some ions are likely to be permanently adsorbed while others will be eluted by subsequent flows. Some reactions in the soils with the waste water will be chemical while others will be biochemical. The toxicity of some waste waters to soil bacteria populations will have to be thoroughly understood so that the benefits of the microorganisms will not be lost.

Both nitrogen and sulfur compounds will deserve special consideration as they are both subject to ready oxidation or reduction. The presence or absence of dissolved oxygen will govern the fate of these elements. Under aerobic conditions, especially in the percolating waters of the zone of aeration, nitrogen might be expected to remain as nitrate, but in the absence of oxygen a reduction to nitrite and nitrogen gas might occur.

Baars, 1961, indicated that nitrates decreased in concentration with depth in a low oxygen environment. Baars also found in the Netherlands that although the soil has a purifying capacity under favorable conditions, overloads and shock loads of pollutants can exceed the capacity of the soil to render waste innoccuous.

Similarly the reduction of sulfates to elemental sulfur or sulfides depends upon the presence of sulfur microorganisms. It has not clearly been shown that such reductions can take place in the soil in the absence of sulfur bacteria (McKee, 1961).

The areas designated as sludge disposal sites although underdrained to capture the supernatant leachate will have the problems of maintaining the soil in a useable state as described for the effluent sites above, but in addition will be more difficult to manage because of the sludge mat which will rapidly accummulate on the surface of the plot.

Even with deep cultivation the soil areas would appear to have a finite limit for assimilating sludge.

The problems of wet weather storage of sludge and effluent have been dealt with on a small scale in other land waste disposal systems at a north-central California latitude. A study of the winter waste water hold-over storage requirements for a small Contra Costa County community indicated that storage in excess of 34 percent of the average annual sewage flow would be required (20 inch average rainfall). Presumably in wet years some spillage would occur (Anon. 1963). An analysis of winter waste water storage requirements for a Lake Berryessa resort subdivision land disposal sewerage system indicated that holdover storage requirements had been underestimated (Storm, 1970).

It can be concluded from the foregoing paragraphs that the effect of a large scale land waste disposal system on the water quality of adjacent streams and underlying ground water resources, should be approached carefully with full knowledge of the soil, waste, water, microbiological, biochemical and geochemical functions and processes of the system which are involved.

It is strongly suggested that well-monitored demonstration plots be installed as soon as is practicable to acquire the necessary data for a useful technology assessment; so that not only short-term but long-term effects may be recognized, identified and anticipated. Likewise the experiences in large scale waste effluent

and sludge disposal on land in other parts of the world should be carefully reviewed. In particular the systems should be examined where soil improvement has been accomplished, i.e., Melbourne, Australia; Maple Lodge, England; Jerusalem, Israel; and Leipzig, Germany.

David R. Storm

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ALTERNATIVES
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REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 4

THE NATURAL ENVIRONMENT OF THE LAND AREAS USED FOR WASTE DISPOSAL

by

William M. Longhurst
University of California, Davis

EXHIBIT 4

TERRESTRIAL ECOLOGY IN RELATION TO WASTE DISPOSAL TO LAND

by

William M. Longhurst
University of California, Davis

The Natural Environment of the Land Areas used for Waste Disposal

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EXHIBIT 4

TERRESTRIAL ECOLOGY IN RELATION TO WASTE DISPOSAL TO LAND

by

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1. Surface Vegetation

a. Uncultivated lands

The primary cover on the bulk of the uncultivated lands on all of the proposed application sites is the so-called "California annual type." Annual grasses and broad leafed herbs predominate in this plant association with a multitude of species being represented. Some perennial plants are included. Both native and introduced species are present. In some cases 80 percent or more of the vegetation may be introduced forms from the Mediterranean area.

The complexity of this vegetational type varies greatly and in some situations 50 species may be found on a single 100-foot square plot. Species composition also is related to such factors as season, slope exposure, soil type and elevation. Tables 1 and 2 show common genera involved.

This kind of grassland can also occur as an understory in open stands of oak trees or other woody vegetation. Typically the annual species of both grasses and herbs germinate in the fall of the year after the first rains which usually come in October or November. They continue to grow through the winter and mature and set seed in the spring as the soil dries out, generally from late April to June depending upon locality. They die and are replaced the following fall by the seed they have produced. However, not all seed may germinate during any one year and significant reserves may be built up in the soil. This "hard seed" condition is more typical of herbs than grasses.

Table 1. Common genera

Grasses and grasslike plants

Festuca	Fescue	Aira	Airgrass
Bromus	Brome	Ely	Wildrye, Medusahead
Avena	Oats	Hordeum	Foxtail
Poa	Bluegrass	Sitanion	Squirreltail
Briza	Quaking grass	Stipa	Needle grass
Cynosurus	Dogtail grass	Juncus	Rush
Melica	Medic grass	Carex	Sedge
Cynodon	Bermuda		

Table 2. Broadleaf herbs

Erodium	Filaree	Orthocarpus	Owl's clover
Medicago	Bur clover	Galium	Bedstraw
Trifoluim	True clover	Baeria	Goldfields
Lupinus	Lupine	Centaurea	Star thistle
Eremocarpus	Mullein	Carduus	Italian Thistle
Plagiobothrys	Popcorn flower	Haemizonia	Tar weed

A few kinds of plants found in the annual type such as Turkey Mullein, Star Thistle, and Tar Weed reverse the usual pattern of growth and are summer growing species. They germinate in the spring, grow through the summer, and mature in late summer or early fall. Generally these are deep rooted plants which can tap water in the lower soil layers.

Perennial grasses belonging to such genera as Sitanion, Elymus, and Stipa do not die when the soil dries out in the spring, but go into a dormant state with only their above ground parts dying. When rains come in the fall, they sprout again. As a rule these perennials tend to stay green longer in the spring and start to grow earlier in the fall than do annual species.

The common denominator of all of these plants found in the annual type is that they are adapted to a Mediterranean climate typified by moist, cool winters and dry summers.

Woody vegetation is not abundant on any of these uncultivated lands. Scattered stands of oaks occur in Sonoma and Marin Counties. Along some of the stream courses in this area some willows and alders are also found and bay trees grow on a few of the north slopes. Some groves of eucalyptus trees have been planted for windbreaks west of Petaluma.

The Santa Clara-San Benito County area has some scattered oak trees particularly along water courses intermixed with willows and sycamores. Very little native woody vegetation is found on any of the other areas except for scatterings of blue oaks along the east side of areas 5 and 6 and the west side of area 4. Some valley white oaks are found also along the stream courses in area 4. A few groves of eucalyptus have likewise been planted for windbreaks in parts of area 3.

b. Cultivated lands

A list of various crops which are grown in the counties involved in the 6 wastewater disposal areas are shown in table 3; however, all of these crops are not necessarily grown on the specific disposal areas. Actually, most croplands lie in the northern portion of area 3 and in area 1. Some cropland is involved in area 2 and 4, but there is relatively little arable land in the southern portion of area 3 and in areas 5 and 6. From the data available it was not possible to define the precise areas cultivated or the crops grown there.

Table 3.

CULTIVATED CROPS

	San Benito & Santa Clara	Marin	Solano	Sacramento	San Joaquin
FIELD CROPS	Barley	Barley	Rice Barley	Rice	Rice
	Wheat	Wheat	Wheat	Barley	Barley
	Alfalfa	Oats	Oats	Wheat	Wheat
	Sugarbeets	Alfalfa	Alfalfa	Oats	Oats
	Corn	Sugarbeets	Irrigated pasture	Corn	Corn
	Sorghum	Wild & grain hay	Corn	Grain sorghum	Grain sorghum
	Irrigated pasture		Safflower	Alfalfa	Alfalfa
			Wild & grain hay	Irrigated pasture	Irrigated pasture
			Sugarbeets	Red kidney beans	Red kidney beans
				Sugarbeets	Sugarbeets
				Safflower	Safflower
VEGETABLES	Lettuce		Tomatoes	Tomatoes	Tomatoes
	Carrots		Melons	Onions	Sweet corn
	Broccoli		Lettuce	Carrots	Cantaloup
	Cauliflower		Dry beans	Melons	Watermelons
	Artichokes		Peas		Pumpkins
	Tomatoes				Onions
	Sweet corn				
	Celery				
	Onions				
	Melons				
FRUITS	Grapes	Grapes	Pears	Almonds	Peaches
	Apricots	Apples	Walnuts	Walnuts	Apricots
	Prunes		Apricots	Cherries	Walnuts
	Strawberries		Almonds	Grapes	Almonds
	Pears		Apples	Olives	Grapes
	Walnuts		Cherries	Plums	Cherries
			Grapes	Pears	Strawberries
			Peaches	Strawberries	
			Plums		
			Prunes		

c. The use of crops as a filter system

Certain crops may be feasible for filtering purposes. The basic advantages would be: 1) that they would remove some of the nutrients such as nitrates and phosphates from the wastewater; 2) would improve and maintain permeability of the soil; 3) reduce erosion; and 4) improve the economic relationships of wastewater disposal if they yield marketable products or produce food for livestock or wildlife. Disadvantages include: 1) the transpiration of large amounts of water which serves to further concentrate undesirable chemicals contained in wastewater; 2) the potential for introducing additional pesticides into ecosystems; and 3) the limited capacity of most crops to withstand the impact of large amounts of wastewater and its associated chemicals.

If wastewater applications can be balanced to various crop tolerances, it may be feasible to grow a number of different things in certain parts of the proposed disposal areas. However, if the stated rates of wastewater application namely eight feet per year over an eight month period, are adhered to, then very few if any, crops can be commercially grown.

The three principal factors that preclude the feasibility of this rate of wastewater application are in addition to the water and salinity limitations stated above, the low permeability of many of the soils involved. In many of the proposed disposal sites soils are shallow (1-3 ft.) with an impermeable hardpan layer below which precludes effective subsurface drainage. Likewise, in many areas the high clay content of the soil reduces permeability. With excess water application above field capacities, waterlogging and surface runoff will result. Also, because of the shallow soil depth the proposed subsurface drainage system at a depth of eight feet is not feasible.

With excess water a number of plant tolerance factors may be exceeded. These include an oxygen deficit, excess carbon dioxide which results when ground water levels are too high or the soil becomes waterlogged. These effects may be directly on the plants or indirectly on soil microbes, especially those which fix nitrogen. The time of germination seems to be a particularly sensitive period for plants to be subjected to water excesses.

Because of the dissolved chemicals in wastewater, the potential exists for exceeding salinity tolerances of certain crops. Table 4 indicates the tolerance levels of a number of field and vegetable crops. In all probability, however, water tolerances are apt to be exceeded before salinity tolerances.

If field or vegetable crops are eventually considered with an appropriately reduced water application schedule, it is probable that some pesticide applications will be needed in order to produce marketable products. If these are persistent, they will produce effects on the ecosystem.

d. Water tolerant crops

Crops which are especially tolerant of large amounts of water include a number of kinds of grasses such as rice, sudan grass and cana reed canary grass. Unfortunately, none of the proposed disposal sites are suitable for rice production because their climate is too cold. Sudan grass can utilize large amounts of water during summer months, but it is an annual and does not have a growing season that extends for the desired 8-month application period. Under the conditions of high nutrient application which should pertain with wastewater application, cana reed canary grass should be able to survive water applications to field capacity and provide palatable feed for livestock.

Corn has the ability to utilize large amounts of nutrients, but is notably sensitive to oxygen deficiency associated with high ground water levels. Irrigated pasture also offers a good possibility for high rates of water application and nutrient consumption. For example, on deep soils near Davis irrigated pasture can withstand up to 5 to 6 feet of irrigation water, but in the area west of Dixon in the northwest corner of area 3, irrigated pasture can only absorb about three inches of water every two weeks after the soil is saturated. In other words, even the plants used for irrigated pasture can withstand a considerable amount of water, many soils on the proposed disposal areas provide constraints because of their low permeability and shallow depth. Likewise, livestock use of irrigated pastures, particularly if they are too wet, leads to soil compaction and reduced permeability.

Table 4.

SALINITY TOLERANCE AT 25° C ppm

	Yield Reduction		
FIELD CROPS	**10%**	**25%**	**50%**
Barley	7,680	10,240	11,520
Sugarbeets	6,400	8,320	10,240
Safflower	4,480	7,040	8,960
Wheat	4,480	6,400	8,960
Sorghum	3,840	5,760	7,680
Rice	3,200	3,840	5,120
Corn	3,200	3,840	4,480
Beans	960	1,280	1,920
Alfalfa	1,920	3,200	5,120
VEGETABLE CROPS			
Spinach	3,520	4,480	5,120
Tomatoes	2,560	4,320	5,120
Broccoli	2,560	3,840	5,120
Sweet corn	1,600	2,560	3,840
Lettuce	1,280	1,920	3,200
Onions	1,280	1,920	2,560
Carrots	960	1,600	2,560
Beans	960	1,280	1,920

e. Marsh vegetation

A number of marsh areas are either within the wastewater disposal areas or are in the immediate vicinity where they are apt to be affected by drainage waters. The major marsh area which would be involved is the Suisun marsh which lies adjacent to area 3. This is essentially a tidal area intersected by a number of sloughs which are connected to Suisun Bay. The bulk of the islands lying between these sloughs as well as the surrounding low-lying lands have been dyked for water control and are used for waterfowl hunting almost exclusively. Most of these marshes are privately owned, but one state-owned waterfowl refuge on Grizzley and Joyce Islands is also included. An estimated 1/2-3/4 million ducks and geese winter in this marshland comprising about 20% of California's wintering population.

The kinds of vegetation growing in particular situations throughout this extensive marsh area depend primarily upon salinity and the water control regime. During the summer months some of these islands are dried up to control undesirable growth of tules (Scripus acutus) and cattails (Typha spp.), whereas others are kept flooded year-round. If salinity exceeds 18-20,000 ppm, vegetation tends more toward unwanted species such as pickleweed (Salacornia spp.)and salt grass (Distichlis spicata) which do not provide food for waterfowl. Below this salinity level alkali bulrush (Scripus robustus), an excellent waterfowl food plant, grows well. It is especially favored in the range of 10-12,000 ppm salinity. Another food plant much favored by waterfowl managers is watergrass or wild millet (Echinochloa crusgalli), but its growth is restricted over about 3,000 ppm salinity.

The northern portion of area 3 is largely in irrigated cropland and much of the present wastewater drains eastward through a series of small marshes or Putah Creek into the Sacramento River. A number of these marshes are used seasonally for waterfowl hunting.

A similar situation is found with drainage waters and natural runoff from the northern portion of area 5. These waters collect in a series of small marshes west of area 5 before draining into the Sacramento River and the Delta waterways.

Drainage from area 5 also feeds into the Delta. Although the bulk of the land in the Delta is intensively farmed and waterways have been dredged and levees constructed, the area still supports a rich population of wildlife and added wastewater could have an important bearing on the ecosystem.

Other marsh plants in these areas which are valuable waterfowl food are listed in table 5.

Characteristics of the water regime which determine the kind of marsh vegetation which will grow in a particular area are salinity as mentioned earlier, permanency, and whether it is standing or flowing. The nutrient regime which is available to marsh plants will depend upon soil characteristics and the chemical contents of the waters involved. The amount of nutrients available will determine the vigor and amount of growth vegetation will achieve.

2. Impact of Land Waste Disposal on:

a. The biota

(1) Flora and fauna

The existing flora on most of the upland areas within the disposal sites will predictably change significantly in terms of both species and density. Consequent changes in the birds and mammals which are dependent upon and attuned to the present floras can likewise be forseen. The drier sites can be expected to show greatest changes whereas changes along stream courses and in marsh areas will be least. Rapidity of changes should follow this same pattern. Without more precise evaluation of local areas, predicting the magnitude of these changes is risky, but surely the impact of adding 8 feet of water to any of these ecosystems will initiate some major shifts.

(2) Productivity

Plants

Productivity in terms of biomass, should increase through reduction of seasonal water deficiencies and an enriched nutrient regime. However, even though a greater mass of vegetation will be produced, there is some doubt as to whether a greater biomass of

Table 5. Important Waterfowl Food Plants

Echinochloa crusgalli	wild millet or water grass
Scirpus robustus	alkali bulrush
Eleocharis spp	spike rush
Polygonum spp	smartweed
Sagittaria spp	arrowhead
Potamogeton spp	pond weed
Echinodorus cordifolius	burhead

herbivorous animals can be supported. Quality of forage does not always increase commensurate with quantity. An example is that with some species applications of commercial nitrogen fertilizer increases volume of growth but actually may reduce protein content, apparently by a dilution process. Also, the kinds of plants which may grow on uncultivated lands will not necessarily be as usable by livestock and wildlife as existing vegetation. Production of planted crops should increase if tolerances for amount and quality of applied water are observed.

(3) According to the list of rare and endangered species of vertebrates published by the Department of Fish and Game on May 29, 1971, it is possible to foresee that some species may be affected either on disposal sites or adjacent areas. The following list summarizes the species concerned and the areas likely to be affected:

Endangered list:

American peregrine falcon - marsh areas around Suisun Bay and in the Delta

Salt Marsh Harvest Mouse - Marshes around Suisun Bay

Rare list:

California Black Rail - Suisun Marshes

California Yellow-billed Cuckoo- Sacramento valley

Giant Garter Snake - Sacramento area

(4) Conservation - wildlife management

Waterfowl and pheasants should thrive on wastewater disposal areas if suitable vegetation can be grown to meet their needs. Marsh vegetation requirements were discussed in Section III, A2. Pheasants can utilize these areas as well, provided they are not completely inundated. Both waterfowl and pheasants will benefit from seed grain crops as well, but these crops will not withstand the proposed 8 feet of applied wastewater.

Likewise, many of the soils involved are not suitable for raising grain. Also,"clean" farming which is desirable for the production of many crops from the standpoint of weed and pest control, does not leave adequate cover for either pheasants or waterfowl.

Both doves and quail may be benefitted in areas adjacent to disposal areas but these species thrive best in much drier situations than will pertain with the application of 8 feet of water. Likewise, both of these birds utilize woody vegetation advantageously for cover and roosting sites. Doves can nest either on the ground or in trees or bushes but they seem to prefer to nest off the ground. Quail nest on the ground but do not tolerate excessively wet sites.

Deer exist in some numbers in the vicinity of areas 1 and 2 but are generally scarce or lacking on the other disposal sites except along the western edge of area 4 and possibly there may be a few along the eastern side of areas 5 and 6. As a rule deer require woody vegetation for cover and forage and may thrive best around the margins of areas 1 and 2. Certainly some of the vegetation and crops that may be grown on these areas will prove to be usable deer forage. Likewise, improving the soil fertility level should raise forage quality of some plants, particularly the ones which can use phosphorus.

b. Animal husbandry

Livestock can play a part in the wastewater disposal program but there are certain limitations to their use. While it is technically feasible to pasture livestock on pastures irrigated with wastewater, the aesthetics and acceptability of meat from such animals are not fully resolved. Some animal products such as wool, hides, etc., are acceptable, but a livestock industry cannot survive without the sale of meat.

As mentioned earlier, soil compaction on irrigated pastures poses problems so that rotational irrigation becomes necessary between periods of grazing. If there are persistent pesticides or other chemicals in wastewater that can be accumulated by grazing animals, meat and dairy products may not be acceptable. Heavy metals should be scrutinized in this regard as well.

Nitrate poisoning of livestock is a distinct possibility on areas irrigated with wastewater containing its usual high concentration of nitrates. Table 6 lists a number of plants which occur in central California which are known accumulators of nitrate.

Table 6. Plants which have been involved in nitrate poisioning or are capable of accumulating appreciable amounts of nitrate.

PLANT	COMMON NAME
Amaranthus blitoides	Prostrate pigweed
A. graecizans	Tumbling pigweed
A. retroflexus	Rough pigweed
Amsinckia douglasiana	Douglas' fiddleneck
A. intermedia	Common fiddleneck
Apium graveolens	Celery
Avena sativa	Oats
Beta vulgaris	Sugar Beet
Bidens frondosa	Beggar-ticks
Bromus catharticus	Rescue grass
Chenopodium album	Lamb's-quarters
C. californicum	Soap plant
C. murale	Nettle-leaf goosefoot
Conium maculatum	Poison hemlock
Convolvulus arvensis	Wild morning-glory
Cucumis sativa	Cucumber
Daucus carota	Carrot
Eleusine indica	Goose grass
Gnaphalium purpureum	Purple cudweed
Helianthus annuus	Common sunflower
Helianthus tuberosus	Jerusalem artichoke
Hordeum volgare	Barley
Lactuca sativa	Lettuce
L. scariola	Prickly lettuce
Linum usitatissimum	Flax
Malva parviflora	Cheeseweed
Medicago sativa	Alfalfa
Melilotus officinalis	Yellow sweet clover
Montia perfoliata	Miner's lettuce
Panicum capillare	Witch grass
Plagiobothrus	Popcorn flower
Rafinesquia californica	Calfornia chicory
Salsola kali	Russian thistle
Secale cereale	Rye
Silybum marianum	Mile thistle
Solanum carolinense	Carolina horse nettle
S. nigrum	European black nightshade
Sonchus asper	Prickly sow-thistle
S. oleraceus	Common sow thistle
Sorghum halepense	Johnson grass
S. sudanense	Sudan grass
S. vulgare	Sorghum
Thelypodium lasiophyllum	California mustard
Tribulus terrestris	Puncture vine
Triticum aestivum	Wheat
Zea mays	Corn

An understanding of the relationships involved in nitrate poisoning is necessary to evalute this problem. Most plants normally have some nitrate present, however, this is below the toxic level. On the other hand, over 60 plants, many of which are commonly used for feed, have been incriminated in poisoning due to excessive levels of nitrate. Many factors determine the level of nitrate in a plant, and it is not possible to predict where or when toxic levels may occur. Some of the factors involved are as follows: Nitrate must be available in the soil, and fertilization level may affect the level in the plant. An adequate moisture supply tends to promote soil nitrate formation and plant absorption of nitrate. However, it has also been shown that some plants have a higher level of nitrate under drought conditions than in well-watered conditions. The acidity of the soil and the presence of other minerals may affect nitrate accumulation. Low temperature results in a decrease in the utilization but not in absorption, and hence the net effect is the accumulation of nitrate. The amount of light and length of day have been shown to affect nitrate accumulation. When one includes the variables between plants, soils, climate and moisture--all of which affect nitrate accumulation--one can appreciate the difficulty in predicting when toxic levels will occur. The fact that they do occur on rare occasions in commonly used forage plants, such as sudan grass, makes predicting poisoning from this element difficult.

Ruminant animals, particularly cattle, convert nitrate to nitrite in their rumens. The nitrate is absorbed through the rumen wall into the blood stream where it combines with hemoglobin. Nitrite converts hemoglobin (which normally carries oxygen from the lungs to the body tissues) to methemoglobin (a substance that will not function in oxygen transport). When 70-90% of the hemoglobin is converted to methemoglobin the oxygen transport capacity of the blood is below the level that will sustain life. As the methemoglobin level increases, it is essentially the same as depriving the animal of its oxygen supply, and it begins to respond by breathing rapidly and becoming cyanotic. As the metheglobin level increases beyond the critical point, the animal dies of oxygen deprivation. Methemoglobin has a brownish color. The oxygen deprivation on the animal results in cyanotic mucous membranes. This reaction in the blood can take place very rapidly and if nitrite is introduced directly into the bloodstream, death can occur in a matter of few minutes. Nitrite can be absorbed rapidly from the rumen and it is a common occurrence that death from ingestion of nitrate occurs within a few hours after ingestion.

Sheep are apparently less susceptible to nitrate poisoning than cattle, but even monogastric species such as swine and horses sometimes succumb to this type of poisoning. Careful management

of livestock will be necessary to avoid this problem.

Continued grazing on irrigated pastures during summer months also sets the stage for nematode parasitic infections in livestock. Most of the harmful nematodes, stomach, intestinal and lung worms, have a direct life cycle. The adult worms live in the host animal and produce large number of eggs which pass out with fecal material. After a few days under suitable conditions of moisture and temperature the eggs hatch into minute larvae which crawl up onto green vegetation. The next grazing animal to ingest this vegetation also ingests the larvae which develop into adult worms, therby completing one life cycle which in total takes about a month. Besides causing severe irritation to tissues of the digestive tract or lungs, many of these worms also are blood suckers from the mucosal tissues and in severe infections cause significant anemia. Morbidity and frequent mortality can result, particularly in young animals.

c. Recreation

Golf courses and city parks offer possibilities for effluent disposal, but few if any are included within the proposed disposal sites. Aesthetic relationships of such programs should be investigated.

Hunting, particularly in waterfowl marshes, is one distinct possibility and there may be some chance of improving habitat for upland game and even deer in limited areas. However, before a meaningful appraisal of the effects on such species as quail, pheasants, doves and deer can be made, a more detailed assessment of vegetaional changes will be necessary. With hunting, as with the golf courses and parks, aesthetic acceptance of use of these areas need appraisal.

3. Summary

With proposed application of 8 feet of sewage effluent over a period of 8 months each year, it is doubtful that much of the present vegetation on the uncultivated lands of disposal sites will survive. Few planted crops now being produced in these areas are adapted to this amount of water and its contained chemicals.

Shallow soils with low permeability over much of these areas also preclude application of this amount of water if

surface flows of effluent are to be avoided. Subsurface drains at the proposed level of 8 feet are not practical in shallow soils. Unless water applications are balanced to plant tolerances, few crops can be successfully grown. However, irrigated pasture and waterfowl marsh development offer possibilities.

Salinity, nutrients, pesticides and heavy metals contained in wastewaters may all pose problems if they exceed plant tolerances or are involved in bioaccumulation patterns.

Crops have some advantages as a filter system but few can be raised which will meet requirements. Forage crops can be raised to feed livestock if wastwater application rates do not exceed their tolerances. Utilization of meat products needs evaluation. Other constraints to livestock use of such forage include possible nitrate poisoning and disease problems.

Productivity of disposal sites will probably be increased in terms of plant biomass, but improvements for utilization by herbivorous animals may not be commensurate.

Recreational possibilities are somewhat limited but with judicious management, habitat especially for pheasants and waterfowl not severely threatened, several forms exist in affected areas and consideration should be given to their requirements. Consequences of land disposal of sludge should be carefully evaluated before mounting a program.

4. Recommendations

Before proceeding with a land disposal program of either wastwater or sludge, a much more careful evaluation of site conditions and ecological consequences should be carried out. Without onsite appraisal of conditions it is impossible to make more than generalized predictions.

The economics of alternative strategies need thorough comparison and should include tertiary treatment and onsite treatment of industrial wastes. Benefits of sale of reclaimed water and chemicals need consideration. Possible inclusion of atomic energy generating plants such as Rancho Seco, should be explored. Likewise, if sufficient salt can be recovered from tertiary treatment plants, it might relieve the need to devote large areas of valuable land to salt production at the north and south ends of San Francisco Bay.

Final decisions and planning on a waste disposal program should not rest with the Army Engineers because of their vested interests. An objective approach is needed.

ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-
San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 5

REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF DISPOSING WASTEWATER ON LAND

by

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REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF DISPOSING WASTEWATER ON LAND

June 28, 1971

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INTRODUCTION

New approaches for recycling sewage effluent are essential. Fresh water is one of the serious needs of this nation. Today mankind is removing ground water about twice as fast as nature is replacing it. It is easy to foresee the time when people will have put every drop that can be caught and channeled into municipal, industrial, electrical, and recreational use, so future populations are going to be forced to depend increasingly on intensive recycling of used water. At this point in time, it is impossible to predict how economical tertiary treatments will be in the year 1990 or 2020. However, without the present economical means of completely recycling sewage effluent, it is desirable to at least evaluate the feasibility of the land disposal designs of this Project. Any water salvage program deserves the highest priority in today's reclamation effort.

AN OVERVIEW

As an ecologist, my overview of this Project may differ from that of engineers or those who know more about waste disposal. I believe that eventually all municipal, industrial, and agricultural wastewater should be given tertiary treatment. However, until complete recycling of water becomes feasible, I view this Project as having considerable potential for recycling many nutrients and water, and of benefiting wildlife. In time, this Project would also provide some desirable and aesthetically pleasant unspoiled countryside. I fully realize that none of the six areas will be returned to their pristine state, but the presence of essentially unlimited amounts of water can do tremendous things to the environment in terms of different crops and ditches, canals, marshes, ponds, and reservoirs, all with lush growth of riparian

vegetation to assist in removing nutrients from the water. This situation will provide many new types of wildlife habitats, far more than were in these locations originally. There will also be various stages of plant succession in a wide variety of biological communities. The suitability of the habitat is what determines which species will be present, and with so many different kinds of suitable wildlife habitats being produced, the Project should have a profound beneficial effect on most species of wildlife. It will establish a much richer fauna and flora in all six Areas.

I assume that this Project is primarily concerned with domestic wastes, and that any special, unique industrial waste problem will be dealt with separately. I agree completely with the thesis that mankind must develop means of recycling his wastes and reclaiming the water, even if there is no way of making his wastes totally innocuous to the environment. We can no longer operate in a "throughput open system," and must pay the price and develop the technology necessary to remove the undesirable elements from our sewage, salvage the nutrients, and reclaim the water. Economically, we cannot afford not to achieve these goals, even if government must provide economic incentives and increase its water pollution abatement activities to make water conservation a reality. Perhaps the price of water needs to be raised to provide further incentives for conserving water in homes, agriculture and industry, and to raise the funds required to give it tertiary treatment. Aquatic systems have borne the brunt of man-made environmental insults too long; it is high time this practice be discontinued. Until cities, industries, and agriculture are forced to recycle their own effluent, it will be difficult to keep them from continuing to dump wastes into rivers and oceans. Perhaps the growing water shortage will focus more

attention toward even more "radical" solutions to the problem. Someday households may have to use two kinds of water, one for drinking and the less pure water for toilets and gardens. This is even more likely to come about if, in recycling, difficulty is experienced in achieving effective disinfection, i.e., the removal of all the bacteriological and viral agents.

APPLICATION OF EFFLUENT

Until there is much more public awareness and concern about over-population and pollution problems, I doubt very much that the people living within Areas 1 to 6 will be interested in this Project, unless they can realize a substantial monetary benefit. Most of these rural Areas are already fairly heavily populated, but by 1990 and 2020 it is anyone's guess how much more settled these sites will be, with the consequent increased socio-political problems of gaining approval of this type of program.

Before the effluent is sprayed on private land, it will first have to be disinfected, because of airborne enteric bacteria and aerosol transport of other pathogens associated with sewage. Just how the land should be prepared will not be considered here other than raising the points of need for terracing and perhaps deep plowing where the existing hardpan soil may be too shallow to trap many nutrients. The primary objective is removal of nutrients, not the evaporation of a scarce commodity like water. Water is a scarce resource and it would seem to me that where possible evaporation should be kept to a minimum, but I do not know enough about waste disposal to say how this can best be done.

If the undesirable constituents can be removed from the effluent, the remaining nutrients would then be of value to many agricultural crops. Unfortunately, in this instance, orchards and most crops can easily be overirrigated. In most, but not all, of the Areas, the soil is too shallow for deep-rooted plants like alfalfa, so where large amounts of water must be sprayed or otherwise applied, species like sudan grass, orchard grass, or ladino clover may have to be used, unless deep plowing can overcome the problem. It would be fortunate if a hydrophytic plant like rice could be grown in some of the Areas. Rice is also a prime waterfowl and pheasant food.

As far as wildlife species are concerned, they will benefit by the addition of waterfowl plants in the marsh areas, stripcropping of any fields, pasture development, planting of hedges, and the presence of more trees. Riparian vegetation is beneficial to fish as shade and as a source of insect foods. It is good habitat for fur animals, woodducks, and many kinds of song birds.

I wonder if there is some way this effluent problem might become associated with the nuclear reactor water problems. Effluent free of nutrients, but still possessing perhaps some undesirable elements, could be used to cool reactors. On the other hand, perhaps the effluent of reactors, which would be low in nutrients, could be used to further dilute the sewage effluent or to warm the water to enhance algae blooms where it was being produced as animal feed.

Whenever the degree of wetness is provided that is contemplated by this project, mosquitoes and other vectors create public health problems like anthrax and encephalitus. Maintaining a good flow of water will tend to reduce these problems in the ponds and marshes and also help prevent avian botulism from developing. Botulism is a common problem associated in sewage ponds of canneries in the Sacramento Valley.

It would seem that the gross land application rates of the effluent should not exceed the net evaporation from the airborne spray and the rate of evapotranspiration of the irrigated areas. Even though such areas would not be sprayed during the wet winter season, winter rains will still probably transport some of the accumulated nutrients and stable materials to oxygenation lagoons and collection impoundments. Here, further biodegrading will take place in the aquatic food chains.

When additional nutrients are needed, some effluent could run directly into the first ponds. It is here that the biomagnification in the trophic pyramid will occur with toxic heavy metals, some pesticides, and other obnoxious substances in the effluent needing removal, such as nitrates, sulphates, boron, etc. Hopefully, those not removed by plants will end up in fish or be degraded by bacteria. Experience and research will be needed to determine how many nutrients can be accommodated in each pond and what are the most effective species of fish to use in the series of ponds. The first ponds do not necessarily need to include game fish, but will need herbivorous fish and species adapted to low amounts of oxygen. The ponds will have to be watched closely to insure that they are not overloaded. When the soil begins to plug and water runs overland, the amount sprayed on them will need to be drastically reduced for a while.

SEWAGE TREATMENT

Unfortunately, when perhaps half of the water input is to be evaporated or transpired, the undesirable elements in the water which are not biodegraded or taken up by the plants or fish will be further concentrated just as in agriculture, where the accumulation of salts and other nutrients is a result of water loss through evapotranspiration.

It seems likely that natural biological breakdown processes may not be able to assimilate and decompose all the material. In these instances some additional recycling through the fields and ponds may be indicated to further disperse and degrade the unwanted materials.

Most sewage treatment today, as I understand it, is little more than the settling out of the heavier particles (primary treatment) followed by microbial treatment (secondary) to change organic material to inorganic nutrients. These conventional primary and secondary treatments do little for the refractory wastes and nothing for the removal of the nutrients. Subsequent filtration and chlorination of such waters often will not render them again suitable for domestic use.

The nutrients from such effluents promote rapid algae growth, or eutrophication. The decomposition of dead algae by microorganisms may then deplete the oxygen supply (biological oxygen demand is high following algae blooms), even making it impossible for fish to live. More research is needed to determine which species of plants and animals are best adapted to remove these nutrients and to concentrate the various other noxious elements that need to be removed from the effluent to improve its quality before it enters rivers or is used by a municipality, industry, or agriculture.

In waste reclamation the aerobic process means growing algae at maximum rate, often adding a carbon source. This method requires large land areas. The algae can be harvested for use as a soil supplement or for conversion into animal feed for chickens or other species. More research is needed, but this approach might well be incorporated as part of this Project.

Anaerobic denitrification is the removal of nitrates as nitrogen gas. The treatment involves the addition of a carbon source, such as

methanol, ethanol, acetone, or acetic acid, and an aerobic environment for the denitrifying bacteria. Amonia stripping can be accomplished by raising the pH of the water to 9 and agitating the water in presence of air. This process requires high temperatures to function properly, and some of the nitrogen may be returned whenever it rains. Lime can be used to precipitate out phosphates. Soluble organics can be removed by activate carbon, but when the carbon is regenerated by incineration, the problem may become one of air pollution rather than water pollution. Obviously, much more research is needed. Perhaps by the year 1990 or 2020, tertiary treatment will become more feasible economically and the basic principles of sedimentation, disposal of solids, aerobic, and anaerobic digestion, microstraining, microfiltering, and purification will be such that the reclaimed water can even be used domestically.

ECOLOGICAL IMPACTS OF WASTE WATER

Since nearly all of the Areas proposed to be used by this Project are now developed row-crop or grazing agricultural land, the terrestrial wildlife currently present is somewhat limited. The same is true of the aquatic species. The land-dwelling wildlife, including amphibians, reptiles, birds, and mammals, are of little economic significance. The birds have aesthetic value, whereas most of the rodents and rabbits are more pestiferous than desirable. When more water is applied to these regions, a great number of additional habitats will be provided, thus greatly enriching the variety and density of the terrestrial and aquatic fauna that will be present. This will have an economically beneficial short- and long-term effect.

Man must insure the protection of other species and the diversity of environments that nuture life on this planet. He must do this to

succeed in attaining an ecologically optimum, man-made environment, which civilization can sustain.

Waterfowl

This Project provides an opportunity for the creation of sizeable areas of ponds and marshlands. These new wet areas will partly replace the vast marshes of the Sacramento and San Joaquin Valleys lost by agricultural drainage and diking. The marsh habitats will not be the same as the original habitats; nevertheless, they will be very beneficial to many forms of wildlife, in particular, to waterfowl. California is the principal wintering ground for migratory waterfowl on the Pacific Flyway. From about 8 to 15 million ducks and one million geese winter there.

About 300,000 ducks and 25,000 Canada geese are produced in California each year, mostly in the northeastern part. In the Central Valley, mallards make up most of the nesting birds. This Project could increase the breeding area for waterfowl in the Sacramento and San Joaquin Valleys. This would be invaluable to the species and also of economic importance.

It is estimated that at the time of the first Spanish explorers, there were 5,000,000 acres of wetlands in the state, mostly in the Central Valley. In 1906 a U.S. Department of Agriculture land inventory showed there to be 3,420,000 acres of wetlands; but that by 1922, due to agriculture, industry, and urbanization, these wetlands had dwindled to 1,179,000 acres. The U.S. Fish and Wildlife Service showed that by 1954 the wetlands had shrunk to 559,000 acres. Presently, there are less than 500,000 acres remaining, of which 175,000 are in privately owned duck clubs. Most of the remaining are on state and federal waterfowl refuges.

Any increase in waterfowl habitat will provide an additional sanctuary in the late fall where waterfowl can be driven should they become an agricultural problem. It is practically impossible to drive waterfowl from agricultural crops unless there is some other suitable habitat available, such as a waterfowl refuge, in which they can find adequate food and resting places. The increased waterfowl habitat will be most beneficial to the species and economically important in hunting.

Furbearers

Furbearers that might be affected by the project are several.

Virginia opossum (Didelphis marsupialis): This species was introduced near San Jose in 1900, and is now in the Sacramento and San Joaquin Valleys and along the coast. Their fur is of little value, but their numbers will probably increase with any increase in marsh habitat. They are of no economic importance.

Raccoon (Procyon lotor): This nocturnal animal is very much associated with water and would probably increase in all Areas of the Project. The fur is of little value but coon hunting at night is a popular sport. They are of no economic importance.

Long-tailed weasel (Mustela frenata): Where small rodents increase, weasels may also increase, although they seldom become very abundant. They are of no economic significance.

Mink (Mustela vision): As marshland is increased, this prized furbearer may also increase, but it is doubtful if they would become sufficiently numerous to be either an economic asset or liability.

California striped skunk (Mephitis mephitis): Furs of this animal are no longer in fashion, but their numbers are sure to increase

along the many ditches and banks of ponds which this Project will develop. Their fondness for eggs, in addition to insects and rodents, has led to some control where ground nesting birds are being managed intensively. They are of no economic significance.

California spotted skunk (Spilogale gracilis): Sometimes called "civet cat." This smaller skunk will probably become less common as the areas become wetter. It has no economic value.

Badger (Taxidea taxus): Since they are not common now in any of the proposed treatment areas, there will be little effect. Increased wetness probably will not benefit the badgers, but this is desirable since they dig sizeable burrows into levee systems. Its fur is of little value. It has no economic importance.

Red fox (Vulpes fulva): A small population of red foxes of unknown origin is extending its range in the Sacramento Valley. This fox lives in close proximity to ranches and cultivated lands. Their numbers might increase if areas of sizeable wetland were developed. They have an attractive fur, but it is currently of little value. It is doubtful that they would become a pest. They are of no economic value.

Gray fox (Urocyon cinereorgenteus): This common fox would undoubtedly increase some in areas that become good habitat for increased numbers of birds and rodents, but it is doubtful if they would become a pest. The fur is of little value. They are of no economic value.

Coyote (Canis latrans): The proposed sites are not large enough to encourage many coyotes, which are mostly confined to wilder areas. However, a few are now found in existing wildlife refuges and occasionally in all of the proposed areas. It is doubtful if their numbers would increase very much, so there is no potential predator problem to livestock and they are of no economic significance.

Bobcat (Lynx rufus): This carnivore prefers brushy hillsides and is not likely to increase in any of the six Areas. It is not common now in these places, so its status will not be changed. They are of no economic importance.

Muskrat (Ondatra zibethica): This rodent is the most abundant furbearer taken in California. It was introduced into Northern California in the late 1920s for fur farming, and due to escapes they now inhabit the Sacramento-San Joaquin Valleys. It is California's most important furbearer, because of the number taken and the durability of its fur. With any development of ditches and impoundments, especially marsh conditions, the number of this species will greatly increase. They can also be a pest by burrowing around headgates and into small levees, which offsets the value of the fur. They would not spread to surrounding areas, so are of little economic importance.

Beaver (Castor canadensis): This valuable furbearer might find some of the new wetlands desirable habitat; however, they probably would be promptly removed because they would become a nuisance where water flow must be maintained. They are not economically important.

Furbearers that would not be affected, because they do not occur in the proposed sites include: ringtail cat (Bassariscus astutus), pine marten (Martes caurina), fisher (Martes pennanti), ermine (Mustela ermines), wolverine (Gulo luscus), river otter (Lutra canadensis), Sierra red fox (Vulpes fulva), kit fox (Vulpes macrotis), and mountain lion (Felis concolor).

Big Game

At one time California grizzly bear, black bear, pronghorn antelope, tule elk, California mule deer, and Columbia black-tailed deer occupied

some of the proposed sites, but should the new wet situations be created, only the deer (Odocoileus hemionus californicus and O. h. columbianus) are apt to take advantage of these new habitats. Their numbers would not be great, however, so no real economic value, positive or negative, is likely to occur. European wild pigs are not found in any of the sites and it is unlikely that feral domestic pigs will become common; although they are a popular game animal in other areas. None of these will be important economically.

Upland Game

Most of our wildlife are grown and harvested on private land used for cultivated crops, livestock, or wood products. Since all of the land projected to be treated with the effluent will, in reality, not be sprayed or flooded, the untreated margins, roadways, dams, steep portions, etc., will be very desirable as habitat for quail, pheasants, mourning doves, Audubon cottontails, and other wildlife.

The Audubon cottontail (Sylvilagus audubonii) would benefit very much by this proposal wherever riparian vegetation or other cover occurs. There would be some hunting benefits, and no apparent disadvantages to their presence. The riparian vegetation would also provide desirable cover for California quail (Lophortyx californica), ring-necked pheasant (Zenaidura macroura). The increase in these three birds could be considered an economic benefit. The success of pheasants will depend entirely on the types of crops planted, and they may be expected to do best in Areas 3 and 5.

Rodents, Moles, and Rabbits

The increased diversity of habitats resulting from the additional water will increase the local diversity of rodents present. In the

heavily irrigated protions, the following species will decline in numbers: California ground squirrels (Spermophilus beecheyi), Heermann kangaroo rat (Dipodomys heermanni), and deermice (Peromyscus spp.). Species of rodents which are likely to increase as a consequence of the irrigated crops and growth of trees include Botta pocket gopher (Thomomys bottae), Western gray squirrel (Sciurus griseus), Western harvest mouse (Reithrodontomys megalotis), dusky-footed woodrat (Neotoma fuscipes), California meadow mouse (Microtus californicus), muskrat (Ondatra zibethica), Norway rat (Rattus norvegicus), and house mouse (Mus musculus).

None of these changes in rodent densities will have an adverse effect in adjoining lands. With the extensive irrigation proposed by this Project, the usual ground squirrel problems will disappear and, depending upon the crop, meadow mice and pocket gophers may create local problems.

Of the Order Insectivora, the now uncommon ornate shrew (Sorex ornatus) would probably increase along waterways, and in Areas 1 and 2 the broad-handed mole (Scapanus latimanus) might become more common. Neither would be of economic importance.

The black-tailed jackrabbit or hare (Lepus californicus) might increase in numbers if sufficient nonirrigated borders and other fairly dry habitat were also available. Any changes in density of jackrabbits would be localized, some increasing and some decreasing depending upon crops. They would not become of much economic concern.

As mentioned under Upland Game, cottontails can be expected to increase.

Birds

Generally speaking, birds should benefit from the increased variety of habitats that will be produced by this Project. It should make all six Areas attractive to more species than are present now. The species that will benefit most will be those associated with impounded water, riparian vegetation, and marshland. They are loons, grebes, bitterns, egret, herons, swans, many kinds of ducks and geese, rails, gallinules, coots, plovers, snipe, sandpipers, avocets, stilts, and black tern. With the increased fauna present, the numbers of vultures, hawks, and owls will also increase. As trees, vines, and shrubs develop, all Areas will become more attractive to resisdent and migrant hummingbirds, woodpeckers, flycatchers, larks, swallows, jays, magpies, crow, titmice, bushtits, chickadees, nuthatches, wren-tit, wrens, mockingbird, thrushes, robin, bluebird, solitaire, kinglet, waxwing, shrike, starling, vireos, warblers, blackbirds, orioles, western tanager, finches, sparrows, towhees, and juncos. There could be a decrease in birds that are more associated with grasslands, such as meadow larks and, in winter, American pipits and horned larks. There is no question but that the Project would be very beneficial to birds.

Fishes

Aquaculture is the growing of food resources such as algae and fish in nutrient-laden waters to provide high-quality protein and at the same time clean up the water. This type of a biological system of removing the excess nutrients from the effluent is desirable because of its efficiency and low cost. Where the effluent is richest in nutrients, such as the reservoirs where it is to be stored during the

winter months, the oxygen supply may become low. In this case, fish such as carp and catfish, which can survive in water low in oxygen, will be needed to prevent further eutrophication. In the future there will probably be artificial fisheries with genetically-altered fish feeding upon the flora and fauna of sewage-enriched waters. Such fish will probably be harvested mechanically. Much more research is needed for this and other types of fish farming that might be incorporated in all six Areas.

All impoundments, ditches, and marsh areas established by the Project will provide good habitats for a number of introduced species of warmwater game fish. In addition to the great sporting value of the game fish, all of them will be important in helping to remove the surplus nutrients from the water and in helping to degrade toxic materials that may be in the effluent. Fish are efficient converters of plants and lower forms of animals into useable protein, thus fish will have a beneficial economic effect.

The principal types of game fish include largemouth bass (Micropterus salmoides), which are in all impounded water. Small-mouth bass (Micropterus dolomieui) prefer lower temperatures (about 70°F in contrast to about 80°F for large-mouth bass), so might do well in some of the canals and streams. The bluegill (Lepomis macrochirus) will abound in all ponds and perhaps some of the canals. Black crappie (Pomoxis nigromaculatus) do well in warm ponds and reservoirs. These are the main predaceous fish located high up on the trophic food chain.

About 95 percent of all the catfish caught in the Sacramento-San Joaquin Delta are white catfish (Ictalurus catus), and they may increase in the larger rivers which drain the treated areas. The catfish,

most likely to be common in all the ponds and reservoirs, is the brown bullhead (Ictalurus nebulosus). Whether or not trout will be feasible in some of the reservoirs and ponds will depend on water temperatures, which are not now known.

A number of minnows and forage fish will do well in all canals, ponds, reservoirs, and marshes. They all help maintain a more balanced ecosystem and range from the mosquitofish (Gambusia affinis), to control mosquitoes, to a more recently introduced forage fish, the threadfin shad (Dorosoma petenense), and carp (Cyprinus carpio). Even though carp are considered the worst fish pest, in some situations they may be important participants because they also eat a large amount of plant material.

Suckers and minnows comprise the largest group of freshwater nongame fish. Some of the ones to be favored by this project will be suckers (Catostomus spp.), goldfish (Carassius auratus), golden shiner (Notemigonus crysolucas), which thrives in heavy growths of aquatic vegetation, and Sacramento blackfish (Orthodon microlepidotus).

Amphibians and Reptiles

Bullfrogs will be favored by the many ditches and impoundments, thus providing much "frogging" sport. Other changes in amphibians and reptiles will be of no economic significance, those species favored by the new habitat conditions increasing. It is doubtful if any species will be locally eliminated, because most of these species have a small home range. In general, the increased diversity of habitat should provide a richer fauna.

ENDANGERED SPECIES

In no way would this Project threaten any species. The fact that it would create many new habitats and replace some of the original wetland conditions, insures its beneficial effect on all groups of native vertebrates. By providing more waterfowl habitat, it would be advantageous to the endangered tule white-fronted goose (*Anser albifrons gambeli*).

HUNTING AND FISHING

A distinct economic advantage to the Project is the potential hunting that could be provided, especially in Areas 3, 4, 5, and 6, if suitable waterfowl habitat were also provided. Depending upon ownership and interest, there would also be a good opportunity for establishing shooting preserves, where pen-raised birds could be released. Shooting preserves need cover for the species being sought, but food plants are of little importance since most of the released birds will be taken by hunters. The Project will increase hunting opportunities for such species as waterfowl, pheasant, quail, mourning dove, and cottontail. Bow hunting for rabbits and carp is also a common sport.

Fishing would be an important recreational benefit of the Project, and quite a variety of fish could be made available in the resulting marshes, ditches, canals, ponds, and reserviors. Sport fishing is a very popular form of recreation.

RECREATION

It is important for families to be able to find outdoor recreation opportunities within comfortable commuting distance of home. We are in a new age of leisure, which is sure to expand in the near future as working hours become less. Water is the principal ingredient of most forms of recreation. It is essential for the creation of attractive wildlife habitats, aesthetically pleasing environments, and the many water-oriented activities. With proper planning, the lure of water can be made irresistable.

In the larger ponds and reservoirs, opportunities could be provided for canoeing, sailing, and boating. Other types of recreation that this Project could profitably create in each of the six Areas are places for

picnicing, nature walking, bird watching, horseback riding, cycling, archery, and golf courses. These can all go hand in hand with commerical crops and livestock operations, if planned properly, further increasing the economic return from the venture.

AESTHETIC IMPACTS

The following remarks about aesthetics are also related to recreation. The only potential undesirable aesthetic effect of the Project would be odor, if some of the effluent is only given secondary treatment. I assume others who are better qualified will analyze this aspect.

Every human activity has its effect on wildlife habitat. In the past, many of these have had detrimental effects on fish and wildlife values; but man's activities, in what is now a completely man-disturbed environment in all six Areas, can be more beneficial than detrimental. The main disadvantage of the previous farming and urbanization activities has been the great reduction in the variety of habitats that were formally present. This has mainly been brought about by such means as leveling, channeling, paving, single cropping, clearing, and draining. Once the habitat is made unsuitable, wildlife species suffer, and the current impact of development and other uses of resources do not provide an encouraging picture for wildlife in the future. For these reasons, the ecological impacts of this Project are most beneficial to wildlife. They will also be beneficial, for the most part, to introduced species of fish. California had few native freshwater or anadromous fish, other than some species of trout, steelhead, sturgeon, and a now uncommon Sacramento perch. Practically all others, including striped bass, large and smallmouth bass, shad, catfish, bluegills, crappie, carp, etc., have been introduced.

Until recently, fish and wildlife were primarily recognized as a resource to be managed for individual use, with the emphasis on the animal as the desired product. Now that it is apparent that the wildlife resource is not inexhaustible, there is a growing demand for its protection. Other users, however, seek their recreation in hunting or fishing or derive their enjoyment from looking at and listening to wildlife and having them available for photography and study. These recreational uses of fish and wildlife will continue to increase, with even greater values being given to the more obscure nongame species. This means there will be high consumer demand for the fish and wildlife resource which the six Areas will create, especially since they are all relatively close to high populations of people.

There are many opportunities for providing better quality and increased diversity in the wildlife resource on the six Areas with proper planning. Many agencies and organizations are ready and willing to suggest means of enhancing the fish and wildlife resource through proper planning. Before this proposed Project is activated, it would be desirable to develop a comprehensive fish and wildlife natural resource plan. It would provide the private ownerships involved with alternatives that would insure future maintenance and wise use of the fish and wildlife resource. Such comprehensive area plans would not merely consider the development and use of the natural resources, but would account for all the uses that the people might make of the areas, including housing, transportation (cars, bicycles, and horses), agriculture, and industry. Future demands for use-opportunities for fish, wildlife, and outdoor recreation will increase both in magnitude and variety. Much planning is required to prevent large numbers of urban visitors to a fine landscape from having a devastatingly severe impact upon it.

Contemporary man's immense impact on the natural environment is one of the most impressive manifestations of his activities. Throughout the ages, man has certainly made alterations to the landscape, but never to the extent and with the speed he does today. The rapid social, economic, and technical developments of our age, as well as the growing tendency to a uniform way of life, cause immense repercussions on the landscape.

The discipline of ecology in the context of the modification and development of large areas of landscape is rather a matter of understanding and acknowledging natural forces than a matter of identifying a pattern of different plant communities. Yet, because man has now reached a stage when he can dominate the local landscape to a degree well beyond his previous abilities, it is necessary to consider whether this domination can be great enough to show mastery over regional landscapes, or whether he should still work with, rather than against, natural forces. With the amount of water and nutrients to be utilized in this Project, considerable planning will be necessary to keep each Area a cohesive unit over the long term.

To establish new marshes and wetlands is to conserve all the species associated with wetlands. It is a moral, aesthetic, scientific, and economic necessity to provide such areas. Wetlands are a natural resource, a part of our heritage which provides much pleasure to vast numbers of people. They are rich in opportunities for research and education, and would be utilized extensively by school children. Wetlands are a natural resource, comparable to forests and farmlands, and essential to many activities. They are a resource, so valuable, and now so scarce, that every effort must be made to preserve what still remains and recreate as many as possible of those that have been lost to civilization.

Man alone has the power to change his environment to suit his needs, and this imposes a moral responsibility. Ethically, we are answerable to future generations for what we do to the natural world around us. Why develop marsh areas? Scientifically, wetlands provide an almost unlimited field for education and research. Included in their special characteristics, fitting them for natural laboratories, are the wide diversity of plants and animals, the complex relationship between communities, the high rate of productivity, the rapid changes in natural succession, and the subtle differences which result from the interplay of physical factors.

SUMMARY

1. The ultimate objective must be to provide tertiary treatment to all sewage, so that the water can be recycled for domestic, industrial, and agricultural uses, and so that the nutrient and other materials present in the effluent can be recaptured.
2. Until better technology and socio-political conditions are available on how to economically recycle sewage, the objectives of this Project deserve serious consideration.
3. Considerable financial incentive and favorable publicity are probably going to be required before most of the landowners in all six Areas will be likely to go along with this Project. The Areas are already fairly heavily settled, and have a large number of owners.
4. The basic plan of utilization of nutrients and of conserving much of the water, is a commendable one. This puts these materials to a productive use rather than creating additional adverse effects in the Delta, San Francisco Bay, and the Pacific Ocean.

5. From a long range viewpoint, it would seem more desirable to deal with any subsequent accumulation of dangerous forms of heavy metals or hydrocarbons on land rather than in the Delta or ocean.
6. The short and long term ecological impacts of this Project are predominantly favorable; the main disadvantages are the possible localized odor problems and the public health aspects resulting from increased mosquitoes and other vectors.
7. The increase in waterfowl habitat, especially in Areas 4 to 6, will be most beneficial to the great flocks of winter migrants and to the summer nesting mallard ducks. Also, with additional places for waterfowl to find food and resting sites, it will be easier to frighten them from nearby unharvested crops.
8. Most furbearers will find the new habitats beneficial; and no problems are anticipated.
9. There may be additional Columbia black-tailed deer in Areas 1, 2, and 4, and possibly, a few California mule deer attracted to Areas 5 and 6, if sufficient trees are planted to provide suitable cover.
10. Upland game hunting of quail, mourning doves, cottontails, and pheasants will be improved.
11. The Project Areas will not create vertebrate pests in the surrounding areas. When new crops, such as alfalfa are grown, they may develop pest populations of, for example, pocket gophers and meadow mice.
12. The increased variety of suitable habitats will have favorable effects with most species of wild birds.
13. The increased amounts of water will be most beneficial to fish, and aquaculture may prove feasible in oxygenation lagoons and nutrient-rich ponds.
14. Most of the amphibians and reptiles will benefit.

15. No endangered species will be affected, and the availability of the diverse habitats may even help some species from becoming endangered.

16. Hunting and, especially, fishing should be enhanced in all Areas. If proper waterfowl habitats are developed, they could be a major economic benefit.

17. Depending on how the various Areas develop, canoeing, sailing, boating, nature walking, cycling, archery, horseback riding, and golf courses could all provide needed available recreation.

18. The potential aesthetic and recreational values of creating ditches, marshes, canals, ponds, and reservoirs is exceptional. The increase in trees, shrubs, and agricultural crops should make all Areas far more attractive.

19. The great variety of habitats and biological communities produced will have great aesthetic value and benefit a large number of kinds of fish and wildlife.

20. Before any development of the Project occurs, comprehensive area-wide and detailed landscaping plans should be completed. They should integrate all the uses people might make of each Area.

21. The lack of knowledge about many aspects of this Project indicate there is a need for additional research.

RECOMMENDATIONS

1. This Project should not be considered as a solution to the domestic wastewater problem, but only as a suitable alternative until better tertiary treatments are developed. However, it is a better alternative than dumping the nutrient-rich effluent into either the San Francisco Bay -- Delta area, or the Pacific Ocean.

2. Much research is needed to determine both the short and the long term relationships of the soil-vegetation-water-effluent materials. (This subject will be covered more thoroughly by others who are better qualified.)
3. Keep water application rates low enough on most of the Areas to accomodate productive agriculture. Divert all "useable" water to other areas for agricultural use to keep the amount of land taken out of productive agriculture to a minimum.
4. Much research is needed in the aquaculture aspects of the Project to provide better understanding of the trophic structure upon which fish production is based.
5. Should this scheme be approved, then, a large task of detailed planning lies ahead to take full advantage of the potential aesthetic, recreational, hunting and fishing, and wildlife values of this Project.
6. After alternative designs on how best to develop this Project in each Area are completed, much public relations work should then be undertaken at the community level so that the landowners involved will clearly understand the benefits to them of implementing the program.
7. One small portion of one of the six Areas should be selected for preliminary research on all aspects of this Project.
8. It seems to me that someday it should be technologically and economically feasible to use the peripheral canals, California aquaduct, and the Delta-Mendota Canal as places for further purifying previously used domestic, industrial and agricultural waters, and consideration should be given to the methodology of achieving this goal.

ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-
San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 6

SOIL CONDITIONS

by

Paul R. Day

EXHIBIT 6

REPORT ON WASTEWATER RECLAMATION PROJECT

Paul R. Day

June 29, 1971

I. Soil Conditions at the Impact Sites

The land disposal plan proposes the transportation of treated sewage effluent to various disposal sites, where the water will be percolated through eight feet of soil, and the excess will be collected by field drains and returned to the processing plant for reuse. The plan clearly intends to utilize sites which have at least an eight-foot depth of permeable soil.

Generally speaking, sites that have been found to be most satisfactory as spreading basins for groundwater recharge have been located on coarse sediments, such as gravelly stream beds or flood plains (Stone and Garber, 1951; Gotaas, 1952; Parkhurst, 1969). One would expect to use the same types of soil for the present application, or at minimum to use deep soils that have moderately high values of hydraulic conductivity (II.A.).

A preliminary study of the soil survey reports of the particular areas indicates that only a small percentage of these areas is suitable by the above criteria. The following adverse conditions are found: fine texture (clays and silty clays), presence of hardpan (indurated horizons), presence of compact horizons (non-indurated), and presence of adsorbed sodium in the soil (solic soils). These conditions can be corrected only by expensive or prolonged ameliorative procedures.

The Hollister area (San Benito County) provides a good example of the situation described above. In the region northwest of Hollister there are approximately 25 square miles of fine-textured soils, many of which are affected by salt. These soils are similar in some of their characteristics to the soils of the middle Sacramento Valley where rice is grown. One advantage of fine-textured soils for rice production is their low permeability, which permits submergence of the land during the growing period without excessive loss of water by deep percolation. Although the portion of the Hollister area referred to above might conceivably be suited to rice, this area would not be a suitable water spreading ground because of low permeability. The area northeast of Hollister, representing about 10 square miles, is generally fine textured, with some claypan soils, and probably unsuited to the intended use for the same reason. The only likely parts of the Hollister area, from the standpoint of water spreading operations, are the flood plains of the San Benito River south of town, and Pacheco Creek on the northern boundary with Santa Clara County.

II. Soil Conditions Which Relate to Water Spreading

A. Physical conditions

Soil permeability is a major consideration in water spreading operations. It is represented quantitatively by the permeability coefficient K, or hydraulic conductivity, defined as the rate of flow per unit hydraulic gradient. Soil permeability is affected by the percentage of clay in the

soil, the kind of clay, the degree of compaction, and the amount of adsorbed sodium in the soil relative to the total amounts of adsorbed cations. However, K is a variable quantity, and is affected by the composition of the permeating solution, which exchanges cations with the solid phase of the soil. K is also affected by suspended solids, including sewage sludge (see III.B.).

After a soil has been saturated with water, and subjected to leaching by continued additions of water, its permeability decreases rapidly with time, as a result of bacterial activity and dispersion of soil aggregates (SERL, 1955a). For this reason, designs of water spreading installations should take into account the likelihood that the permeabilities will decline markedly with time.

Coarse soils (gravels and sands) are preferred to fine textures (clays and silty clays) for water spreading because they are generally more permeable (SERL, 1955b). However, factors other than texture are also important, as indicated above.

Lysimeter studies of proposed soil types should precede actual field installations, to determine their permeabilities and the rates of decline of permeability (SERL 1955a, 1955b).

The application of water to the soil surface by flooding requires that the land be nearly level. Sprinkling (spray irrigation) is adapted to sloping land if the water is supplied at a rate less than the maximum infiltration capacity of the soil.

B. Chemical properties

The cations adsorbed on the surfaces of the soil particles (the exchange complex) play an important role in water spreading for at least two reasons.

1. The exchangeable cations influence the soil permeability in accordance with their relative proportions in the exchange complex. The most important single application of this in the present context is the fact that the permeability becomes exceedingly low when the exchangeable sodium exceeds about 15% of the total population of cations in the exchange complex. Such soils are called sodic soils.

2. The exchange complex comprises a store of cations which can be released in exchange for an equivalent number of cations from the permeating solution. Since their total number remains approximately constant, any exchanges of ions of different species between solution and adsorbed phase affect the relative proportions of the various ions in the adsorption complex. Thus, the adsorbed phase can trap ions from the solution, but only in exchange for ions already there. Since the adsorption capacity is finite (in the order of 20 milliequivalents of cations per 100 grams of solid), the ability to trap ions from solution is limited. Furthermore, if the ion which is captured in this manner is sodium (or any other of the monovalent cations, including NH_4^+), the permeability will be impaired as stated above in 1. No convenient way of regenerating the ion exchange "column" exists for soils in the field, comparable to the recharging of the ion exchangers used commercially in water softening.

The quantitative amount of cations can be seen in perspective by noting that a normal soil has an amount of exchangeable calcium equal to about 0.3% of the total soil weight, and other ions in smaller percentages. Since an acre-foot of soil weighs about 3,500,000 pounds, the weights of exchangeable ions are considerable, but the trapping ability of the soil is far from inexhaustable, and exceedingly difficult to reverse.

The composition of the exchange complex is sensitive to the composition of the leaching solutions, particularly when leaching is extensive and prolonged. The hazards of indiscriminate watering can be seen in the decline of agricultural economies in many countries in the past. The long-time effects of leaching with waters of controlled composition need to be examined more extensively by a systematic research program (SERL, 1955a; Fireman and Bodman, 1939). The monitoring of the effluent from the processing facility should be made an essential part of any program of water spreading.

III. Assessment of Probable Soil Changes under Application of Wastewater and Sludge, and Probable Ecological Impact

A. Continuous water spreading, with water free of suspended solids.

Agricultural soils are profoundly affected by continuous flooding, primarily because of oxygen deficiency caused by the metabolism of higher plants and soil microorganisms. In the rice growing area of the Sacramento Valley, it is well known that the soil becomes anaerobic shortly after the

fields have been flooded, and remains so until after the fields have been drained in preparation for the harvest. Rice is unique among economic crops in its ability to adapt well to anaerobic soil conditions; most crops, including orchards, will not survive more than a few days under submergence owing to oxygen deficiency in the soil.

Oxygen deficiency has many indirect effects upon soils and plants. Among these effects are denitrification of the soil, loss of iron by reduction to the ferrous state followed by leaching, and mobilization of toxic elements.

As noted in II.A., one would expect a progressive decrease of permeability in the course of time.

B. Application of wastewater containing 10% of suspended sludge

Sludge accumulates on the surface of the soil without penetrating more than a few millimeters, develops a "mat," and causes a great decrease of permeability in the surface layer (Gotaas, 1953; SERL, 1955b). The rate of accumulation in pounds per square foot per day is given by $q(w/V)$, where q is the flux of water in feet per day and w/V is the concentration of suspended solids in pounds per cubic foot of suspension. Thus, if the flux is 0.3 foot per day and w/V is 0.10, the weight of solid residue left on the surface will be 0.03 pounds per square foot per day. However, the rate of decomposition of sludge is slow, and it is necessary to allow resting periods between spreading cycles to allow decomposition and restructuring of the surface to occur (Gotaas, 1953).

Although digested sewage sludge is rather low in fertility value (Vlamis and Williams, 1961) it nevertheless contributes modest amounts of nitrogen, phosphorus, potassium and sulfur, together with the principal micronutrients.

Although the use of sludge may be beneficial from a fertility standpoint, it is a disadvantage with respect to technique of application and with respect to maintaining the infiltration rates of water at satisfactory levels.

IV. Summary

The plan of returning and reusing some of the transport water does not appear to be suitable for the majority of soils that are found in the various impact areas. Furthermore, prolonged and continuous submergence is incompatable with the simultaneous growth of economic crops on the sites. A more normal irrigation practice, with intermittency of application of water, would take advantage of the greater area of land which might become available and would permit a normal growth of agricultural crops. The frequent drying of the soil in such a management regime would tend to maintain higher infiltration rates than in a continuous program of water application.

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ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 7

ECOLOGICAL IMPACT OF WASTE DISPOSAL TO LAND

by

Professor A. W. Knight
University of California, Davis

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The increasing human population and increased production of food, fiber, and manufactured products have created wastes that exceed the diluting capacity of the natural streams, lakes, rivers, estuaries, and ocean.

Impact assessment of land disposal as an alternative to advanced or tertiary treatment for wastewater disposal is the major objective of this statement. In addition, an attempt is made to identify potential problems that would likely be associated with land disposal of wastewater.

The use of soil as a method of renovation by spreading wastewaters over the soil and utilizing natural processes such as filtering, biological action in the soil, the uptake of chemical nutrients by plants resulting in water fit for further use has been under evaluation for some time. Sewage effluent, for example, has been used for irrigation for over 100 years in some parts of the world (Mitchel, 1931). Glass and Jenkins (1964) reported 361 municipal waste treatment plants in the 17 western states applied their discharge water to the land in 1962.

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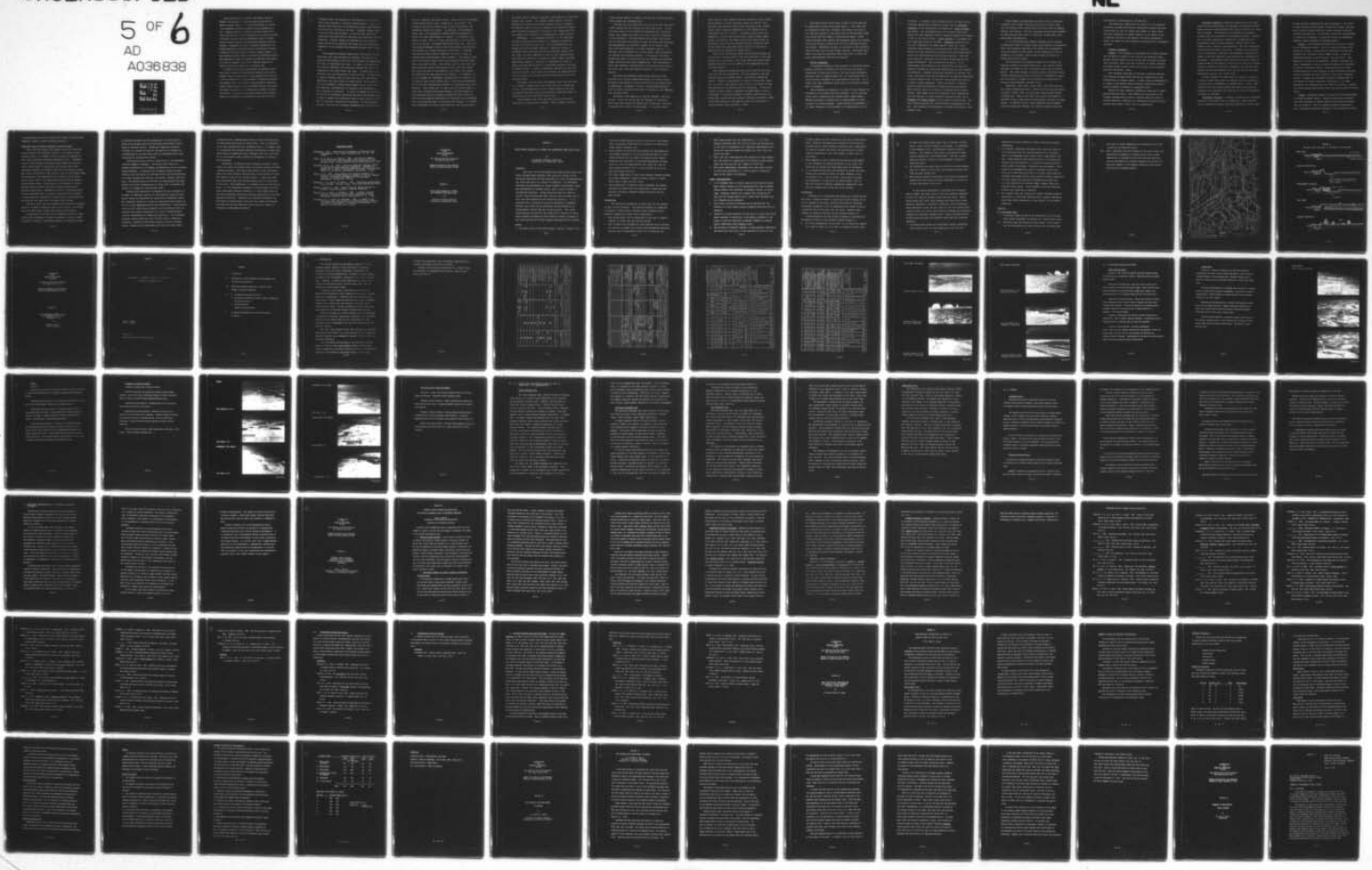

Soils have been shown to provide a high degree of physical, chemical, and biological treatment for organic wastes when the system is properly designed. If industrial wastewater is included in the wastewater land disposal program, serious problems may result. Industrial wastewater presents an extensive range of materials as to defy even a broad classification in this brief assessment. In the past, reuse of industrial wastewater has been an in-house practice, usually resulting from restrictions imposed by regulatory agencies. Considerable treatment of industrial wastewater by such advanced processes as demineralization or de-ionization is required in addition to processes applied to domestic sewage treatment. In many instances economic methods do not exist for effectively treating many components of industrial wastewater and therefore land disposal as a means of reclamation and reuse of industrial wastes do not appear to be the best alternative at the present time.

In addition to the above considerations, the problem of heavy-metal salts in industrial wastewater may constitute a very serious problem if reuse is contemplated. Living organisms have the ability to take up elements from a solution against a concentration gradient and accumulate them. This ability of some organisms to concentrate elements above the levels in their environment and pass them through the aquatic food chain may thus concentrate the element in spectacular fashion. Since numerous heavy metals already occur in varying amounts in the potential receiving waters in the area of the land

disposal areas, the presence of such materials in the wastewater would represent a potential health hazard. Despite its demonstrated efficiency in assimilating wastes, land disposal has never been extensively utilized. Although various industries have used land disposal, it has not been generally appreciated and exploited by sanitation and pollution control officials. Several reasons are apparent for the practice having failed to be used more and these will be evaluated in reference to the proposed land disposal program under evaluation.

The proposed wastewater application rate may be suitable where the soil type and depth are optimal, but much of the proposed land disposal sites will not tolerate the application of 8 feet of wastewater per year. In order to be effective, the applied wastewater must percolate through the soil to be collected by the under drains for reuse. In many areas, the available soil for percolation is far too thin. In many areas, it appears possible that the soil flow may join the natural groundwater and never reach the under drains. The potential risk of groundwater contamination appears to be a very real and important consideration in evaluation the feasibility of land disposal of wastewater. In order to dispose of the large quantities of wastewater envisioned for the land disposal sites, it doesn't appear that sufficient time or space will be available to allow for intermittent irrigation. If the wastewater disposal sites are not irrigated intermittently, they will not

dry out, reaerate, and remain sweet. Tight soils and overloaded fields become septic, sour, sewage-sick, and useless. The alternate wetting and drying cycle is also required for the ecological control of insects. In addition, the problems of algae, odor, and groundwater mounding would be improved by moving the water from subarea to subarea. If sprinkler irrigation is used, there is a need, particularly in the arid and semi-arid regions, of keeping application rates low. Soils in the proposed disposal sites are far from uniform, particularly with respect to vertical hydraulic conductivity. Considerable non-uniformity must be expected, far more in areas of discontinuous stratification than elsewhere. The steeper lands near the foothills tend to have more permeable subsoils which drain into gravel strata. The surface soils in this area vary from relatively porous sandy loams to the tight adobe clays. The closer one goes to the middle of the valley, the flatter the slope and the less pervious the subsoils. In addition, it is not uncommon for subsurface drainage waters to contain 3 to 10 times as much total soluble salts as the applied wastewater, due to the salt-concentrating effects of evaporation and transpiration. Even though this is some cause for concern when reusing water produced from land disposal, drainage waters of this type may still be reusable provided the salt content of the originally applied wastewater is relatively low or provided that a good quality water is available for dilution. In evaluating wastewaters for their reuse potential, the concentration

of certain ions is equally important a consideration as the total soluble salt content. For example, excess sodium, chloride, and boron can each exert specific adverse affects on plants. In addition, excess sodium may damage soil structure as aggregates become de-aggregated, resulting in the clogging of soil pore spaces and a reduction in permeability to water and air.

Wastewater --- if improperly applied --- will flow over the soil, picking up and carrying in suspension quantities of fine clay particles and silt. This suspended matter can damage fish and fish food organisms. Excessive amounts of suspended matter entering lakes and streams may smother fish fry, eggs, and food organisms as well as cover spawning beds. The resultant turbidity in streams and lakes reduces sunlight penetration, making it difficult or impossible for fish to locate food and may decrease or retard photosynthetic activity by aquatic plants. Runoff of wastewater flowing over the land may pick up plant stains which also reduces the penetration of light in water, thus further reducing the productivity of the receiving water.

Wastewater draining from land disposal sites may also pick up or contain organic matter and carry this into streams and rivers. The decomposition of this organic material may lead to reduced dissolved oxygen concentrations which may result in destruction of fish and other aquatic life.

Land disposal drain water may also pick up pesticides, fungicides, or weed killer residues. These residues can have

a very serious effect on aquatic life and may ultimately affect other animals and ultimately man.

Problems are also associated with the water that would percolate through the soil profile and into tile drains. If the tile drain water is not reused but discharged into receiving waters, the soluble nutrients of the soil would be discharged in the wastewater. Enriched waters can increase fish production by increasing the growth of algae and other food organisms. The phytoplankton is the basic element in the aquatic food chain and fish production is largely dependent upon it. If nutrients are introduced into surface waters, algae production can develop into nuisance growths. If excessive, the algal growths may result in fish kills due to insufficient dissolved oxygen resulting from algal decomposition. The likelihood is great that excessive concentrations of nutrients would occur in the drain water from the proposed wastewater land disposal project.

Sylvester and Seabloom (1962) found indications that nutrients were rapidly assimilated during the growing season by aquatic vegetation in return drains and in the Yakima River in Washington. Pondweeds, cattails, and bulrushes might be used to collect excessive nutrients in portions of the proposed land disposal sites.

Wastewater, when applied to land for disposal, may pick up heat. Since the use of land for disposal of wastewater would take place during the warmer part of the year, the water so applied would tend to become warmer. If surface runoff

water from the land disposal area was allowed to enter surface water systems, it might seriously affect the aquatic life. Sylvester and Seabloom (1962) found indications that surface return water raised the temperature of the Yakima River in Washington about 4°C. (7°F.). In surface waters where the temperature is near the critical point (upper lethal temperature), the addition of warmer runoff water might result in unsuitable conditions for desirable species of aquatic life. On the other hand, many warm water species of fish may be benefited by the addition of warmer water.

Water from tile drains, which has percolated through the soil profile, usually loses to the soil mass most of the head picked up at the surface. Such water from tile drains would probably have little or no effect on the temperature of the receiving waters.

Land disposal systems may carry salts from the soil profile into the tile underdrains. If the wastewater from the underdrains enters surface waters, considerable damage may result. Limited concentrations of salts in drain water (somewhat less than 1,000 ppm) may have little or no effect on fish and wildlife and practically none on recreation. If the salt content of drain water is somewhat increased (about 1,000 to 3,000 ppm), it would be unlikely to effect wildlife and it is potentially usable for most purposes (Swenson and Baldwin, 1965). Drain water reaching 3,000 ppm may cause salt poisoning to young pheasant chicks (Griffith, 1963).

Moderately saline drain water (3,000 to 10,000 ppm) may be unpalatable to most upland game species. Game fish such as largemouth black bass, bluegill, and others are known to live and grow rapidly in the lower half of this salinity range even though they are unable to successfully spawn. Leach (1960) indicates that catfish and Sacramento perch can tolerate drain water having a salinity of at least 9,504 ppm and carp, even higher. Waterfowl are able to use water of this salinity range and even water of much higher salinity. Waterfowl food plants can tolerate salinities from fresh water to above sea water concentrations (varies with species).

Vector Assessment

A successful program of land disposal of wastewater would produce conditions favorable for the build-up of extensive populations of pests and vectors. Not only would wastewater spreading lead to standing water but it's anticipated that it would continue throughout the warm months of the year. It is likely that such conditions would allow for potential development of epidemics.

Heavy breeding of mosquitoes in areas of land disposal of wastewater will present difficult problems. Of all existing insect pests, mosquitoes are usually Public Enemy Number 1. Mosquito breeding is usually due to mismanagement of water intended for useful purposes. Land disposal of wastewater --- if proper drainage is not provided or if application rate is

excessive --- produces ideal breeding places for many vectors. Increased populations of malaria vectors such as Anopheles freeborni or the transmitter of encephalitis, Culex tarsalis may result. The arthropod-borne viral encephalitides have become the most important group of mosquito-transmitted diseases of man in the United States. Culex tarsalis is considered the most important vector in the West. Anopheles mosquitoes are the sole transmitters of human malaria, which was a very important human disease in the United States until recently. Malaria has been essentially eradicated from the United States except for reintroduction from foreign countries. This mosquito would be a potential health hazard should malaria ever become established. The distribution of malaria, if re-established, would depend on the availability of water for mosquito breeding and associated imperfections in land disposal of wastewater. Improper wastewater spreading or improper irrigation with drain water may be productive of numerous mosquitoes. Irrigated pasture land, if used for land disposal may also be a source of many mosquitoes. Where irrigation is properly practical with due attention to good agricultural practice, there need be little or no threat of mosquito-borne disease. However, when swampy areas are produced or small depressions are water-filled, an ideal breeding situation results for A. freeborni and Culex tarsalis in the western United States. The land disposal program will surely produce waterlogging of the soil, thus producing an enhancement of mosquito breeding in the disposal area.

Large numbers of mosquitoes and other noxious arthropods interfere with outdoor vocational activities in many areas, and also greatly limit recreational activities such as camping, boating, and fishing. The mere annoyance which enormous numbers of them cause by their bite is sufficient to make some areas practically uninhabitable.

It is anticipated that mosquito problems would increase as additional lands are placed under land disposal of wastewater. Since the biological reservoirs and vectors for encephalitis virus are present in the region, future outbreaks as well as epidemics are possible, constituting a definite threat to human health in this basin.

The envisioned land disposal program will increase the habitats suitable for midge populations. The effect of mass emergence of midges is one of nuisance rather than of health hazard. The adults become a nuisance around residential areas. Further investigation would be in order to determine the possible involvement of midges in the mechanical transmission of bacteria from wastewater disposal areas.

Horseflies, deer flies, snipe flies, and black flies are all avidly bloodsucking flies. These flies are notorious pests of horses, cattle, deer, and many other warm-blooded animals, including man. Many of the flies that attack man abound in favorable areas in the western United States, breeding in soggy ground. In addition to the severe annoyance and discomfort resulting from their feeding, the disease tularemia has been

attributed to transmission by the deer fly.

Increased water applied to the land due to the proposed wastewater program would produce additional breeding and developing areas as well as enhance the numbers of these flies, but much information is needed relative to the effect of environmental factors on the immature and adult populations before the effect of land disposal of wastewater can be properly assessed.

Disease Assessment

Anthrax - Land disposal of wastewater will likely increase the incidence of anthrax in the area of the disposal sites. Because anthrax spores are one of the most resistant of pathogenic bacteria, there have been instances of animal infection of anthrax areas 25 years after the original case of disease (Merchant and Packer, 1961).

The increased likelihood of flooding resulting from the land disposal program would increase the probability of the dissemination of anthrax spores. A major mode of dissemination of spores is by surface waters flooding contaminated ground, causing transfer of spores to widespread areas.

Animals are most commonly infected by ingestion of contaminated food and water. The flooding as visualized in the disposal program would present a greater potential risk of anthrax infection, especially in contaminated districts where surface water plays a major role in transmission.

Pathogenic Bacteria - Bacterial diseases that have been transmitted to human beings or livestock by contaminated water remain potential health hazards when land is utilized for wastewater disposal. The potential for transmission increases markedly when the wastewater is deliberately reused. Diseases that have been reported as transmitted to human beings by contaminated water include dysentery, typhoid fever, paratyphoid fevers, cholera, gastroenteritis, and less frequently, leptospirosis and other infections. Diseases such as brucellosis, tuberculosis, tularemia, and salmonella infections are common to man and therefore conceivably may be transmitted in wastewater. Considerable effort should be directed toward an understanding of the factors involved in the spread of disease by water, because of the greater demand on the limited water supplies within the disposal sites and the need to draw upon questionable sources for various uses.

Protests against the application of sewage to ground as a spray in areas where bees are numerous has been entered by an association of beekeepers in Germany (Anon., 1955). They indicate that bees flying through the spray may become contaminated with pathogens and these may in turn be transmitted to humans by stinging.

Pathogenic Protozoa - A number of protozoa are intestinal parasites of man and a few are pathogenic. These protozoa may be regarded as primary polluting substances and the cysts

of many are well recognized for their durability. The cysts of some protozoa survive months in water and sewage, and pass quite readily through biological sewage treatment processes including chlorination. If the water treated by land disposal is reused for irrigation, a potential exists for waterborne epidemics among consumers of uncooked produce.

Viruses - The problems associated with viruses in waters are of increasing concern. Over 76 viruses are known to be pathogenic to man. Viruses found in wastewater include the adenoviruses, coxsackie viruses, ECHO viruses, viruses of infectious hepatitis, polio viruses, and reoviruses. Only hepatitis is known to be waterborne. However, evidence for water transmission of polio viruses and adenovirus infections by water is relatively strong. Much speculation has been advanced relative to the adequacy of water treatment processes and the coliform tests as a measure of the water's sanitary quality. Because the treatment generally afforded water in the control of enteric bacterial infections is, at times, apparently not sufficient for the control of viruses, a potential health hazard would likely exist with land disposal of wastewater.

Fungus - Pathogenic species of fungi have been encountered in sewage treatment plants. Limited studies have indicated that the resistance of fungal spores to chlorination exceeds that of bacteria. Prior to intensive reuse of wastewater, more information should be obtained on the prevalence of fungi

in wastewaters and on the resistance of spores and other developmental stages to waste treatment processes.

Potential Reuse of Water Produced by Land Disposal

Waste and drain waters may support life that could have direct economic and aesthetic appeal in the disposal areas. Drainage water is a valuable source of water for ponding at duck clubs and public waterfowl management areas. Considerable use could be made of drainage water pumped into natural water courses where it would mix with natural waters and controlled releases to produce substantial recreational areas. Many areas in California and the West, such as the Klamath Basin and Stillwater, have benefited from irrigation drain water. Return water, even if of rather poor quality, may be usable for waterfowl areas. Suisun Marsh is an example of a multi-million-dollar wildlife recreation industry based on the brackish tidal water. Thousands of acres of waterfowl marsh, with an estimated value in excess of twenty-million dollars, is based upon the utilization of water that is unsuitable for agricultural use other than low grade cattle forage.

The drain water from the proposed land wastewater disposal could be utilized to maintain parks, golf courses, or provide water for duck ponds, upland game areas and fish ponds.

A potential use of some of the wastewater exists in aquaculture (the husbandry of aquatic organisms of value to man). If properly treated, considerable amounts of wastewater could

be rendered suitable for the propagation of a high quality edible fish protein while utilizing many constituents considered as societal wastes. Wastewater components would be utilized as a source of food for the species of interest as intermediates in its food chain and the reclaimed water could ultimately be recycled and reused.

Recreational lakes could be established if the wastewater received adequate treatment. The Santee Lake Project in southern California is an example of deliberate use of reclaimed sewage effluent. A tertiary soil treatment system has been effective for the control of nutrient levels and the production of a water suitable for boating, picnicking, fishing, and swimming. The Santee Recreation Project has demonstrated the feasibility and social acceptability of using water reclaimed from sewage as a supply for recreational lakes.

Studies have been made to determine the salt tolerance of a number of important species of floricultural crops and ornamental shrubs as potentials for agricultural wastewater reuse. The ornamental shrubs as a group are considered poor choices on which to reuse degraded agricultural wastewaters. Floricultural crops are not sufficiently tolerant to total soluble salts to consider this group satisfactory for reuse of degraded agricultural wastewaters for commercial production. For landscape purposes, where yields are less critical than in commercial production, several of the flower species would be suitable. Similar research with turfgrasses has shown that many repre-

sentatives have a demonstrated ability to grow satisfactorily at relatively high levels of total salts. Thus, turfgrasses offer good possibilities for wastewater reuse. It appears that as irrigation waters become degraded sufficiently to make them unsuitable for commercial crops, perhaps their best use would be on recreational areas planted to turfgrasses of superior salt tolerance.

Wastewater, if given suitable advanced treatment, could serve as a source of cooling water for nuclear electrical power generating plants. The Rancho Seco Nuclear Power generating plant near Ione utilizes approximately 12,000 gallons of water per minute in each of its cooling towers. I have been told that ultimately four such cooling towers will be constructed at the site. This represents a tremendous loss of high quality water. If the wastewater produced in the Sacramento area was given additional tertiary treatment, it could supply much of the water presently lost during cooling operations at the power generating facility. Substituting renovated wastewater for high quality natural water would not only reduce the degradation and loss of such water but would serve as a means of disposing of renovated wastewater.

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REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 8

SOLID WASTE DISPOSAL AS A MEANS FOR PRESERVING SOME DELTA SOILS

by

Professor Constance Delwiche
University of California, Davis

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ABSTRACT:

Peat soils of the Sacramento-San Joaquin Delta which were built through recent geologic time since the retreat of the Wisconsin glaciation are now subsiding at a rate of approximately two inches per year as a result of oxidation. As subsidence continues the maintenance of levees becomes increasingly costly and reclamation of flooded islands when a levee is broken is economically marginal. Unless positive steps are taken to correct these difficulties about 300,000 acres of land will be lost from food production and recreation potential. It is proposed that a feasibility study be conducted to determine whether these lands can be protected and maintained by re-establishment through the use of solid wastes. This would simultaneously provide for the constructive solution of solid waste disposal problems of urban centers located on waters of San Francisco Bay and the San Joaquin-Sacramento River systems.

FACTS:

1. The peat soils of the Delta region, varying in depth to 60

feet were formed during the past 10,000 years from vegetation on annually flooded plains as glacial ice melted and ocean levels gradually rose.

2. Since islands of the Delta were drained and developed oxygen became available to soil microorganisms which in turn slowly oxidized the top layers of organic matter (peat).
3. Oxidation has resulted in a continual subsidence of these soils at a rate of approximately two inches per year so that present surfaces are at varying depths up to 15 or more feet below sea level.
4. The gross composition of most solid domestic wastes includes, as a major component, organic residues similar to those which went to make the peat soils.
5. Large quantities of domestic wastes (garbage) are generated daily in urban areas and agricultural industries and provide a difficult disposal problem which has not yet been solved.

ASSUMPTIONS:

The following assumptions are made only for the purpose of this initial analysis. Any detailed analysis as suggested in Proposal I below should reexamine these assumptions and consider feasibility without their constraints.

1. That solid wastes will be generated at the rate of approximately 0.3 cubic feet per day per person.
2. That suitable and economically sound methods can be devised for sorting to remove and recover non-decomposable materials leaving only bio-degradable wastes for reclamation use.

3. That these wastes will be stabilized by a 3- to 5-day aerobic digestion near the site of origin and the material to be used in reclamation will represent approximately one-third the starting volume and weight (0.1 cubic foot per person per day).
4. That with this stabilization and allowing for some compaction, the waste of a population of 10 million would require about one acre per day for a depth of 25-40 feet.
5. That after emplacement subsidence will take place rapidly at first but eventually at a rate of about 2 inches per year as the result of oxidation.

OTHER CONSIDERATIONS:

1. It is probable that in future years (a half century hence) many organic wastes will be reprocessed for their valuable energy content and converted to products similar to petroleum. Economic factors will require this frugality not only for the energy factor but in order that valuable mineral elements may be recycled.
2. Until more constructive methods can be devised for the handling of these wastes interim disposal practices must be employed.
3. Disposal of these materials in the sea or in most land areas poses problems of pollution, with organic residues in the ocean or with the delivery of mineral elements to ground waters underlying land disposal sites.
4. The delivery of mineral elements to deep aquifers underlying the Delta will not occur if the restoration level is only

slightly above sea level because of the lack of hydrostatic head. Moreover the deep waters underlying the Delta are already high in salts probably resulting from a combination of ancient residual sea waters and the delivery of salts from the watershed of the river system to plant life in the Delta.

5. There appears to be no elaborate engineering requirements in the transport of stabilized wastes to the scene, but processes of sorting and stabilizing must be developed.
6. It is essential that both the handling of wastes and their disposition provide no insult to other elements of the environment; e.g., that no salts, particularly nitrates and phosphates, be delivered to ground waters, that no odor be created to disturb neighboring communities, and that the composition of the bay not be altered.

DISCUSSION:

Although it is envisioned that during the interim period that such a disposal method is practiced (a half century or so) entire islands of the Delta could be protected or reclaimed, the present proposal is for an immediate pilot study involving a selected area of not more than 100 acres. Typical Delta islands are shown on the map section attached (Figure 1).

A selected parcel of land could be leased or purchased and developed as shown in the attached diagram (Figure 2).

A. An initial preparation of the site would involve the removal of a layer of peat (5 to 10 feet in thickness) which would

be used to increase levee height and to provide a buffer zone to limit lateral movement of drainage. If necessary a thin membrane (e.g., polyethylene) could be used as barrier. The purpose of this step is primarily to make initial disposition of excavated peat. The peat itself does not provide a barrier to the movement of water or dissolved salts.

B. The excavated area would then be filled with solid organic waste to a depth of 20-40 feet and covered with peat soil from the next borrow area.

C. This process would be continued in the usual cut-and-fill method until the entire area was reclaimed to a level 10 or more feet above river level.

As the process described is continued and reclaimed land is added, the water level in the soil would be expected to rise to a natural eustatic point near sea level. Solid wastes below this level (and probably well above this level) would be subjected to anaerobic conditions and the processes which operated to form the peat soils in the first place would rapidly convert the solid waste material through the biological sequences of anaerobic decomposition. These processes cannot be described precisely but probably would take the following sequence:

1. Initially there would be considerable aerobic metabolism which would result in some temperature rise with the

possiblity of local tendencies toward limited spontaneous combustion.

2. As anaerobic conditions developed there would be fermentative reactions with the limited production of volatiles, amines, and depending upon protein level, some ammonia and H_2S. There would be some denitrification if nitrates were present with the formation of nitrogen and possibly N_2O or other oxides of nitrogen. Depending upon management, these products of decomposition would be absorbed in the overlying soil layer and reoxidized to nitrates (from ammonia), sulfates (from H_2S) and CO_2 (from volatile organic compounds).
3. In later stages this anaerobic decomposition would slow with the possibility of methane (CH_4), ammonia (NH_3) and hydrogen being formed. These probably would be reoxidized without ever surfacing in quantity.
4. As a steady state was reached the organic residues would be converted to a peat-like substance and a gradual subsidence would take place approaching a rate similar to the present condition.

PROPOSAL:

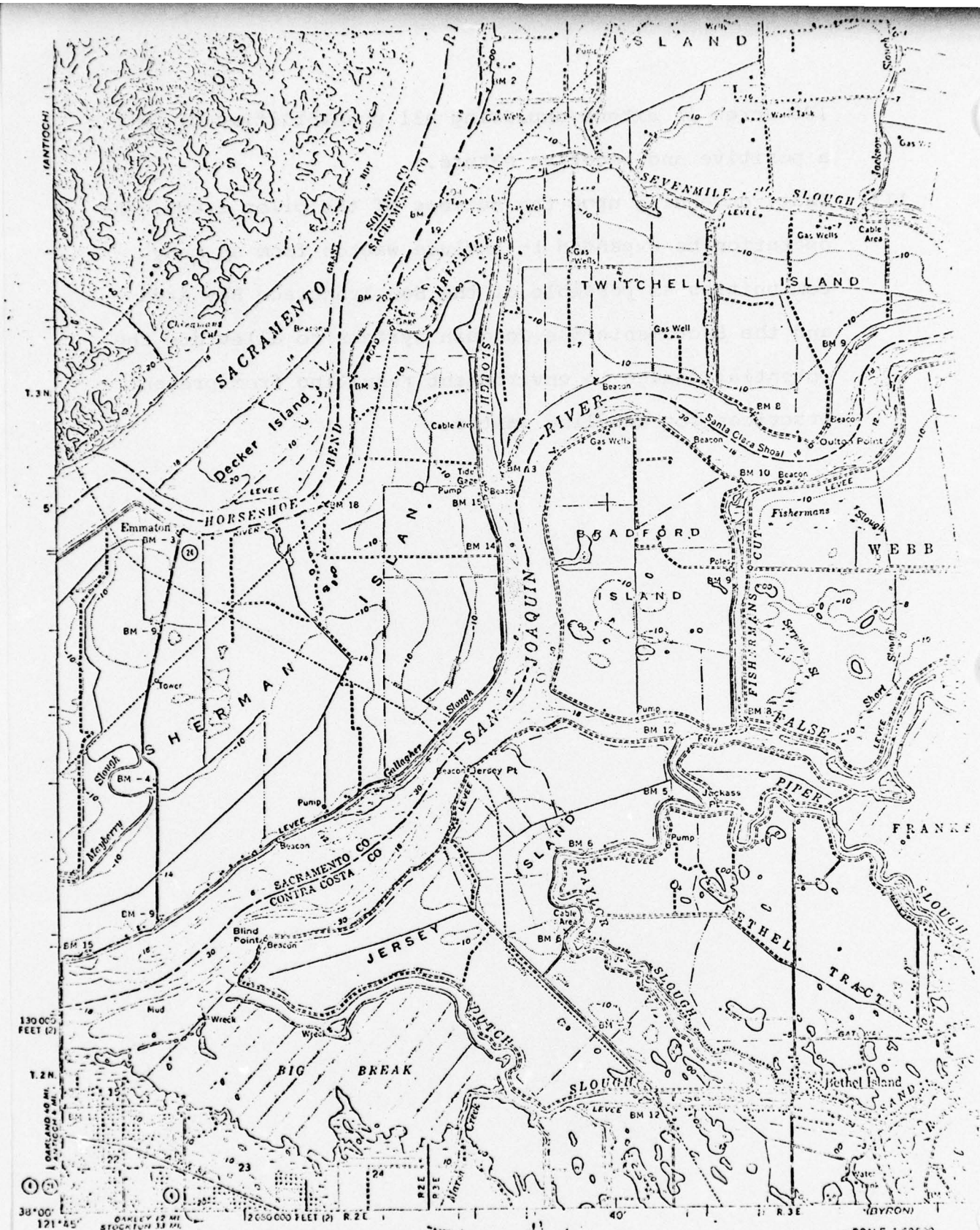
It is proposed that:

I. A detailed study be made of the feasibility of utilizing solid wastes (garbage) to maintain or reclaim Delta soils.

II. Depending upon the outcome of this study, a pilot operation be initiated on an area of Delta soil not more than

100 acres in extent exploring all possibilities of both a positive and negative nature.

III. That, depending upon the success of the pilot study, the operation be expanded to include wastes from as many communities as possible of the San Francisco Bay Area and the Sacramento-San Joaquin systems to alleviate the potential damage to environment resulting from present practices for handling wastes.



Mapped, edited, and published by the Geological Survey

Control by USGS, USC&GS, and USCE

Compiled in 1958 from 1:21 000 scale maps of the Isleton, Rio Vista, Jersey Island, and Poulton Island quadrangles, surveyed in 1952-1953

Culture and drainage by USC&GS from aerial photographs taken 1931

SCALE 1:62500

FIGURE 1

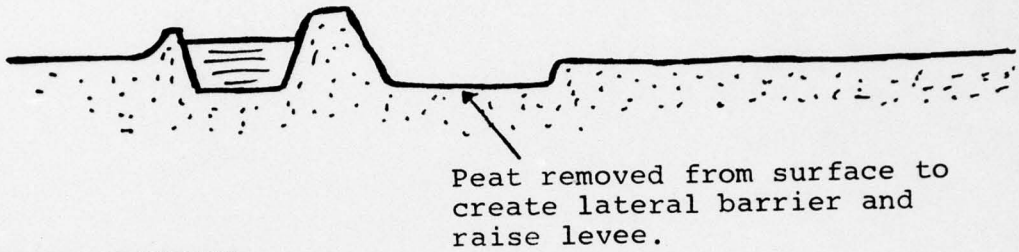
CA-8-8

FIGURE 2

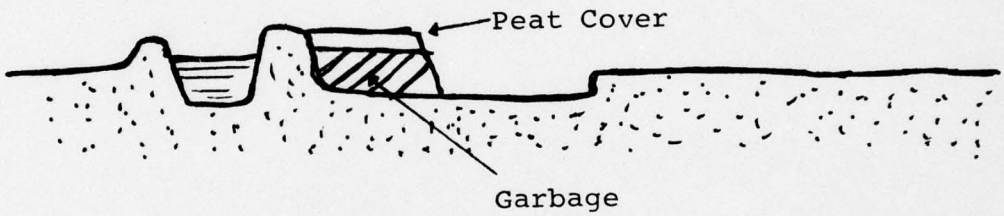
TYPICAL CROSS SECTIONS OF SEQUENTIAL DEVELOPMENT

TIME ZERO

INITIAL PREPARATION

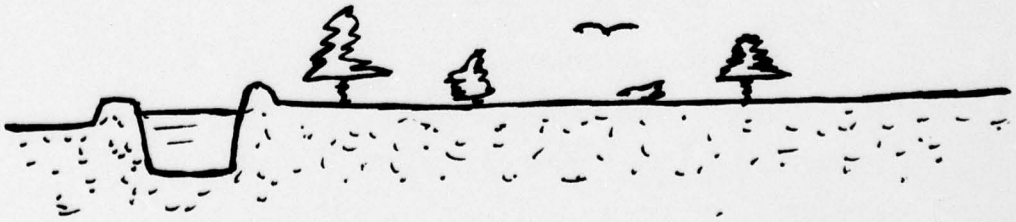


DEVELOPMENT SEQUENCE



USE STAGE

MATURE CONDITION



ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-
San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 9

THE VISUAL AND AESTHETIC IMPACT OF ALTERNATIVE WASTEWATER MANAGEMENT PLANS

by

Robert H. Twiss
Jens C. Sorensen

EXHIBIT 9

June 28, 1971

THE VISUAL AND AESTHETIC IMPACT OF ALTERNATIVE WASTEWATER MANAGEMENT PLANS

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Jens C. Sorensen

A Report To:

San Francisco Bay Marine Research Center

CONTENTS

I Introduction

II Relationship of Plan Alternatives and Requirements for Operations and Facilities.

III Relationship Between Operations -- Facilities and Changes in Aesthetic Condition

IV A. Preliminary Description of Sites.

B. Preliminary Evaluation of Plans in Terms of Comparative Site Characteristics.

C. Planning Criteria

Design and Siting Criteria

V Concluding Recommendations for Further Evaluation of Impacts

I. INTRODUCTION

This report presents a preliminary assessment of the visual/aesthetic impacts of four alternative wastewater management plans and their concomitant requirements for facilities and land modification. Findings are based almost entirely on the information contained in the Project Description. However, a cursory field examination was made of the Santa Clara/San Benito site, and four other sites were examined from low-altitude flight.

In general, this report demonstrates that while the plans differ markedly in their impacts, all have very serious potential consequences. Similarly the land disposal sites vary widely in their physical character and visual absorbtion capacity; but several are key features of the Bay Area's remaining open space. Further planning for these sites must be accompanied by detailed design and behavioral studies.

Since the project is a rather complex set of combinations of potential facilities, operations, locations, and land uses, Part II of this report lays out the relationship of plan alternatives and requirements for land and facilities in the form of a matrix.

Part III, also in matrix form, then portrays the relationship between facilities (e.g. aeration lagoons) and visual and aesthetic impacts (e.g. breaking of present lines of sight or increased humidity).

Part IV presents an overview of the potential disposal sites in terms of their physiographic characteristics and visual composition, and then evaluates the plan alternatives's principle relationship to particular sites. Given these

problems and potentials, very preliminary suggestions for planning and design criteria are offered.

Because this study was necessarily of a limited scope and duration, recommendations for further study are presented, as Part V.

PART II

FACILITIES-OPERATIONS	DISPOSAL PLANS			
	OCEAN	ESTUARINE	LAND	COMBINATION
▲TREATMENT SYSTEM				
PLANTS	2 ADVANCED SEWAGE	1 ADVANCED SEWAGE		1 ADVANCED SEWAGE
LOCATIONS	REDWOOD CITY PETALUMA	ANTIOCH		ANTIOCH
▲TRANSPORTATION SYSTEM				
PIPELINES				
COUNTY FLOWS TO TREATMENT PLANT		●		
TREATMENT PLANT TO DISPOSAL AREA	1990 2020 1.6 3.8 (MGD) SONOMA 4.4 7.5 SAN BENITO	1990 2020 6.0 11.3 (MGD)	●	●
TREATMENT PLANT TO OUTFALL	●	●		1990 2020 4.4 7.5 (MGD)
TREATMENT PLANT TO AERATION LAGOON			●	●
AERATION LAGOON TO STORAGE PONDS			●	●
AERATION LAGOON TO DISPOSAL AREA			1990 2020 5.0 9.7 (MGD)	1990 2020 5.2 9.4 (MGD)
AERATION LAGOON OR STORAGE PONDS TO DIGESTER			●	
DIGESTER TO DISPOSAL AREA			●	●
STORAGE PONDS TO DISPOSAL AREA			●	●
DRAINAGE SYSTEM TO REUSE RESERVOIR/TREATMENT	1990 2020 4 3.3 (MGD) SONOMA 3.8 6.5 SAN BENITO	1990 2020 5.2 9.8 (MGD)	●	●
REUSE RESERVOIR TO TREATMENT PLANT	●			●
TREATMENT PLANT TO OUTFALL (RECLAIMED)		1990 2020 106 106 (MGD) SAC 810 1,550 SAC 275 520 SJ		

CA-9-5

PART II (CONT.)

FACILITIES - OPERATIONS	DISPOSAL PLANS			
	OCEAN	ESTUARINE	LAND	COMBINATION
▲ DISPOSAL SYSTEM				
WASTEWATER				
OUTFALL	2 OUTFALLS	4 OUTFALLS		1 OUTFALL
LOCATIONS	PESCADERO PT. REYES	CHIPS ISLAND SUISUN MARSH SAC. RIVER S.J. RIVER		ANTIOCH
DISTRIBUTION AREAS			6 LOCATIONS	4 LOCATIONS
ACERAGE			1990 189,000 2020 335,000	1990 60,000 2020 130,000
LOCATIONS			1. SAN C - SAN B 5. SAC 2. SOL - MAR. 6. SJ. 3. SOL. - YOLO 4. CC - ALA - SJ.	1. SONOMA - MARIN 2. SOLANO - YOLO 3. SACRAMENTO 4 SAN JOAQUIN
AERATION LAGOON			6 LOCATIONS	4 LOCATIONS
ACERAGE			1990 2020 2,250 6200	
STORAGE PONDS			6 LOCATIONS	4 LOCATIONS
ACERAGE			1990 2020 8900 16,100	1990 2020 2,700 5,900
SLUDGE	2 LOCATIONS	1 LOCATION	6 LOCATIONS	4 LOCATIONS
ACERAGE	24,000 42,000	66,000	INCLUDED IN WASTEWATER	
LOCATIONS	SONOMA SAN BENITO	SOLANO	SAME AS 6 WASTEWATER LOCATIONS	1. SONOMA - MARIN 2. SOLANO - YOLO 3. SACRAMENTO 4 SAN JOAQUIN
APPLICATION	SPRAY OR OTHER IRRIGATION METHODS			
▲ RECLAMATION SYSTEM				
REUSE RESERVOIR			6 LOCATIONS	4 LOCATIONS
ACERAGE			1990 2020 670,000 1,220,000	1990 2020 195,000 445,000
LOCATIONS			1. SAL-S JD 4. MARTINEZ 2. SR 5. ESP 3. SUI-NAPA 6 ESP	SAME AS 4 SLUDGE DISPOSAL LOCATIONS
▲ AUXILIARY FACILITIES				
ROADS				
POWERLINES				
CORPORATION YARDS				
ADMINISTRATIVE FACILITIES				
GRADING				
FENCING - LANDSCAPING				
SIGNS				

ABBREVIATIONS: ALA - ALAMEDA CC - CONTRA COSTA ESP - EASTSIDE PROJECT SJ - SAN JOAQUIN S JO - SAN JOSE SR - SANTA ROSA SAC - SACRAMENTO SAL - SALINAS SOL - SOLANO SON - SONOMA SUI - SUISUN SAN B - SAN BENITO SAN C - SANTA CLARA

PART III

FACILITIES – OPERATIONS

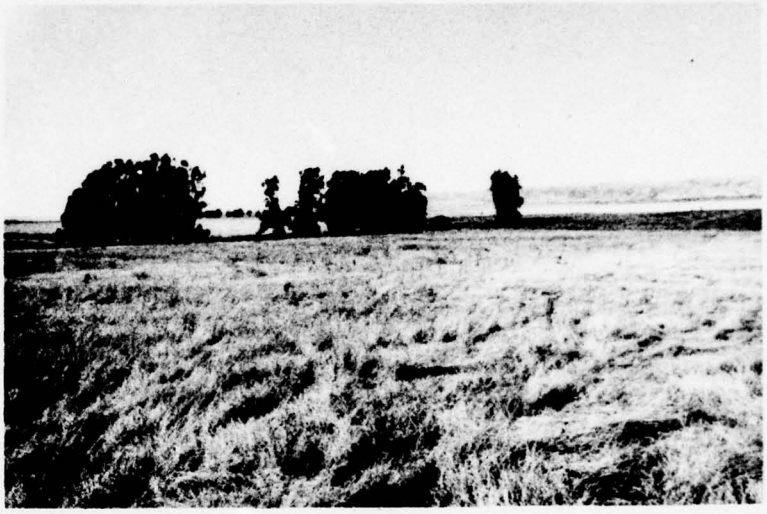
CHANGES IN AESTHETIC CONDITION	▲ ADVERSE	■ LAND	BLOCK VIEW LINES	INTRUSION ON PASTORAL SETTING	GRADING SCARS	DISTURBANCE OF VEGETATIONAL PATTERN	DISTURBANCE OF TERRAIN PATTERN	SLUDGE RESIDUE CRUST	DEAD-DISEASED VEGETATION	DISCOLORED-COATED VEGETATION	ATTRACTION OF PESTS	ELIMINATE-DECREASE PLEASING WILDLIFE	SKYLINE INTRUSION	■ WATER	DISCOLORATION-TURBIDITY	FLOATING DEBRIS-SLICKS	FISH-BIOTA KILLS	ATTRACTION OF PESTS	NOXIOUS ODORS	CONTAMINATED FOR CONTACT & INGESTION	ALGAL BLOOMS
TREATMENT PLANTS			●	●	●								●								
PIPELINES			●	●	●	●	●														
OCEAN-ESTUARINE OUTFALLS											●				●	●	●	●	●	●	●
WASTE WATER SPRAY IRRIGATION						●	●		●	●	●	●						●	●		
AERATION LAGOONS			●	●	●	●	●		●	●	●	●						●	●		
STORAGE PONDS			●	●	●	●	●				●	●						●	●		
SLUDGE APPLICATION			●	●	●	●	●	●	●		●	●									
REUSE RESERVOIR			●	●	●	●	●				●	●						●	●		
ROADS				●	●	●	●														
POWERLINES				●		●	●						●								
CORPORATION YARDS				●	●	●	●														
ADMINISTRATIVE FACILITIES			●	●	●	●	●														
GRADING			●		●	●	●														
FENCING			●			●	●														
LANDSCAPING			●		●	●	●						●								
SIGNS			●			●							●								

PART III (CONT.)

CHANGES IN AESTHETIC CONDITION	TREATMENT PLANTS	PIPELINES	OCEAN-ESTUARINE OUTFALLS	WASTE WATER SPRAY IRRIGATION	AERATION LAGOONS	STORAGE PONDS	SLUDGE APPLICATION	REUSE RESERVOIR	ROADS	POWERLINES	CORPORATION YARDS	ADMINISTRATIVE FACILITIES	GRADING	FENCING	LANDSCAPING	SIGNS
FACILITIES - OPERATIONS																
▲ADVERSE (CONT.)																
■AIR																
NOXIOUS ODORS	●			●	●	●	●	●								
INCREASED HUMIDITY				●	●	●		●								
PARTICULATE MATTER				●			●		●				●			
SMOKE-HAZE-SMOG	●										●					
DISTURBING NOISE	●			●	●						●					
DECREASE TEMPERATURE				●	●			●								
■ACCESS																
BLOCK CROSS ACCESS	●	●		●	●	●	●	●	●		●	●	●	●	●	
CONGEST THROUGH ACCESS		●		●										●		
▲COMPATIBLE																
■LAND																
PRESERVE OPEN SPACE					●	●										
PLEASING CROP PATTERN				●												
ATTRACTIVE SCREENING AND EARTH FORMS													●		●	
ATTRACTION OF WILDLIFE								●								
■WATER																
VIVID SPRAY FEATURE				●	●											
ATTRACTION OF WILDLIFE				●												
IMPROVE WATER APPEARANCE			●													
■ACCESS																
PROVIDE PUBLIC ACCESS	●			●					●							

SANTA CLARA- SAN BENITO

Hollister Valley- to SW.



Hollister Valley- to E.
Eucalyptus windbreaks

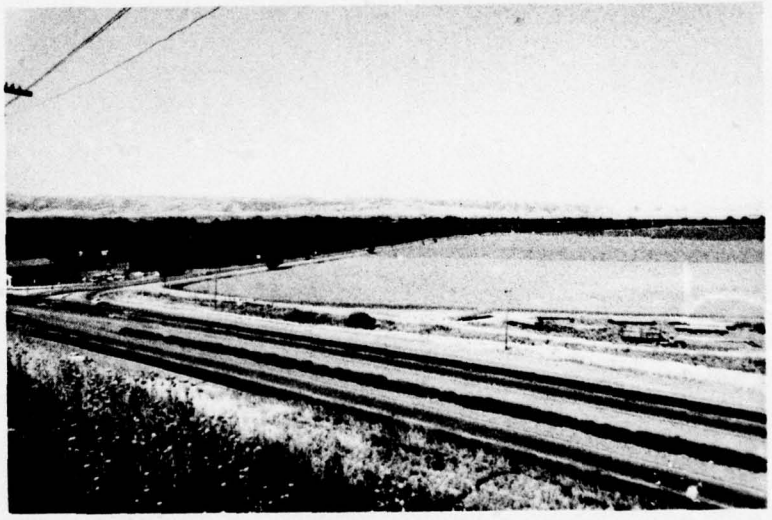
Hollister Valley- to NE.
Tomato field & farmstead.

Fig CA-9-1

SANTA CLARA- SAN BENITO

Hollister Valley- to NE
Garlic field & barn.

San Juan Valley- to W
Vineyard in foreground.



Hollister Valley- to NE
Orchards south of Gilroy.

Fig CA-9-2

IV. A PRELIMINARY DESCRIPTIONS OF SITES

Santa Clara/San Benito

Enclosure - Well defined by Gabilan and Diablo Ranges forming the broad San Juan and Hollister Valleys. Moderately well-articulated sense of place.

Land form pattern/Features - Open flat valley contrasts with vertical thrust of foothill and mountain range. Gentle foothill forms serve as harmonious transition between rugged peak, pinnacle, and outcrop features of the enclosing ranges and the flat valley floor.

Vegetational patterns/Features - Grided crop patterns on valley floor (consisting of well tended fields of vegetable and feed crops, vineyards and orchards). Foothills of grass cover in grazing pattern. Pleasing, transition from field pattern to grass foothills to Chaparrel - Oak Woodland Ranges.

Eucalyptus windbreaks vivid features and space definitions on valley floor. Weak or absent riparian definition. Clustering of exotic vegetation defines farmsteads amid the open field expanses.

Cultural patterns/Features - Attractive Farmsteads - Scenic - Well traveled highways between Gilroy and Hollister, Gilroy and Pacheco Pass, Hollister and San Juan Bautista, and Hollister and Pinnacles National Monument. Concentration of tourism at San Juan Bautista Mission and surrounding historical reconstruction.

Marin/Sonoma

Enclosure - Composite configuration of small sub-enclosures branching off the narrow valley of Estero San Antonio. Valley enclosure strongly defined by low undulating hills. Strongly defined sense of place with intimate scale relationship between hill enclosure and valley floor.

Land form pattern/Features - Grassland cover reveals soft, pleasing contours of gentle hill curvature and mounding. Floor plain of narrow to moderate width. Notable absence of landform point and linear features. (Pinnacles, out crops, ridges).

Vegetational patterns/Features - Strongly characterized by grassland cover and grazing patterns. Dramatic eucalyptus windbreaks and small scale riparian skim provide only breaks to grassland dominance. Occasional fields of feed crops on valley floor.

Culture patterns/ Features - Attractive ranches, fencing patterns and presence of grazing stock. Scenic corridor for recreational travel between upper Bay Area and Marin Sonoma Coast. (Including Pt. Reyes National Park).

MARIN-SONOMA

Estero San Antonio Valley

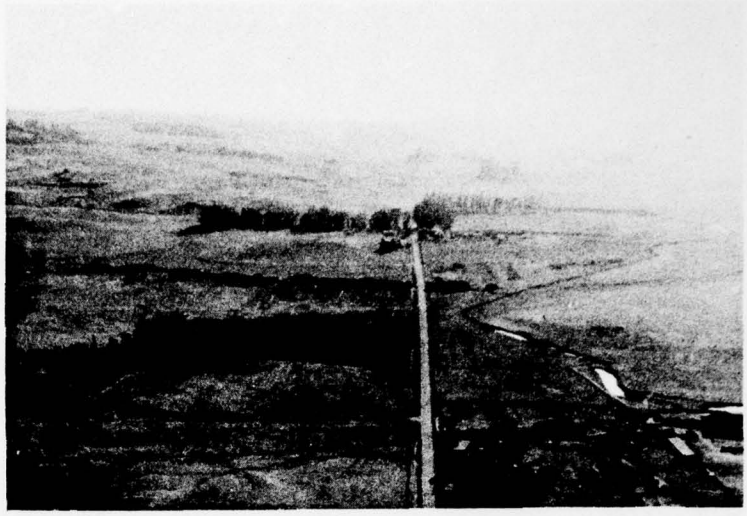


Fig CA-9-3

Solano

Enclosure:

Completely open and flat with only very distant enclosure references at Vacaville and Montezuma Hills. Feeling of immense space extending to horizon.

Landform pattern/ Features - only breaks on the vividly flat terrain are the low field perimeter mounds and the roadway grades.

Vegetational patterns/ Features - Strikingly characterized by large rectilinear crop fields. Strong checker board pattern defined by fields of low crops. Pleasing contrasts in color and texture among fields. Few windbreaks, riparian definition absent.

Culture patterns/ Features - Interstate 80, the Sacramento-Bay Area thoroughfare, and Central Valley's Interstate 5 bisect the site. Scenic country lanes crisscross the site, separating the larger tracts. Large farmstead facilities. Utility pylons march across the horizon in several directions. Only sizeable break in crop patterns are small towns (as Dixon) and interstate highways with attendant services.

Sacramento and East San Joaquin

(combined in flight plan to single overview)

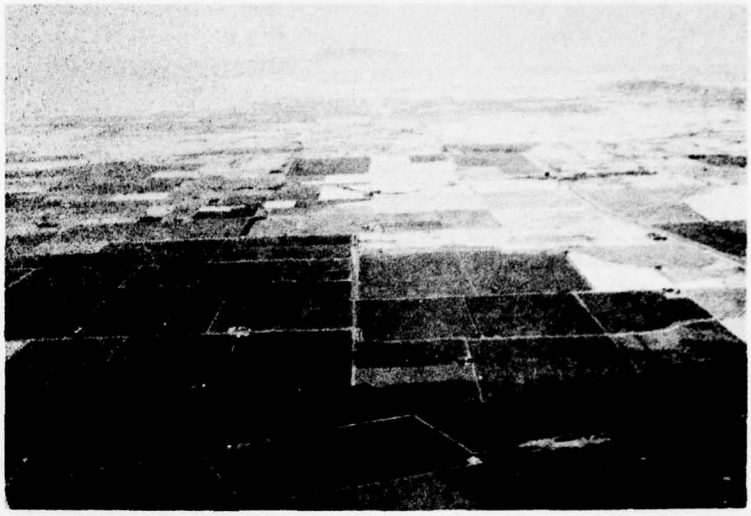
Enclosure-open with very slight hill enclosure along drainage networks. Small scale spatial definition formed by riparian vegetation. Distant reference to Sierra Nevada foothills-mountain range.

Landform Patterns/ Features - Drainage swales and cuts appear to be only relief across the flat terrain.

Vegetational Patterns/ Features - Medium scale field size in mixture of crop and grass cover, composing irregular geometric patterns. Field patterns oriented to drainage network - area not intensively cultivated. Strongly defined riparian association as major vertical definition.

Cultural Patterns/ Features - Small agricultural settlements. Power pylons. No major highways through sites.

SOLANO



near Vacaville- to S.

near Davis- to S.

SACRAMENTO- SAN JOAQUIN

near Galt- to E.

Fig CA-9-4

SACRAMENTO- SAN JOAQUIN

Near Galt- to SE.

CONTRA COSTA- SAN JOAQUIN

near Oakley-to S.

near Oakley - to S.

Fig CA-9-5

East Contra Costa - West San Joaquin

Enclosure - Single sided enclosure formed on West by Mt. Diablo Range and Foothills. Confined by Delta drainage on East.

Landform Patterns/ Features - Sharp contrast between undulating hills and flat Delta plain. Occasional breaks in Delta plain by gentle hill features.

Vegetation Pattern/ Features - Strong contrast between geometric orchard pattern on plain and grass covered foothills. Orchards in moderately sized tracts are dominant cover pattern of Contra Costa site.

Cultural Patterns/ Features - No major scenic highways through site. Several power pylon paths across site - major railroad line bisects location.

IV. B. PRELIMINARY EVALUATION OF PLANS IN TERMS OF COMPARATIVE SITE CHARACTERISTICS

Ocean Disposal Plan

The Ocean Disposal Plan, like the Estuarine Disposal Plan, offers the obvious visual advantage of not requiring any wastewater disposal sites. However, the Plan does require two sludge disposal areas - totaling 66,000 acres. The two locations selected - Santa Clara/San Benito Counties and the valley of Estero San Antonio in Sonoma - have very apparent and strongly refined aesthetic qualities. It appears that a thorough comparative analysis with the other four possible disposal sites, would indicate that these two sites would have the highest cumulative expression of visual quality factors. The analysis should indicate that if location were based on minimizing the loss of aesthetic qualities, these two locations would be the last choice for disposal purposes. The comparatively narrow enclosure of both the Sonoma and Santa Clara/San Benito locations would mean that virtually any sludge disposal site would be visible from developments on the surrounding ridges and slopes. However, the four Central Valley sites are spaciously open with only a distant single-sided enclosure. Sludge areas could be located at such a distance from the side slopes that they would not be highly visible.

We assume that the sludge disposal will generate a far more vivid visual impact than wastewater disposal. This assumption is based on the hypothesis that sludge application, unlike wastewater, irrigation, will replace all existing

cover with an unappealing crust of residue. Sludge disposal areas, if compared to all other methods involved in wastewater management, may be classed as most usually objectionable or aesthetically displeasing. Therefore, the Ocean Disposal Plan appears to indicate that the sites possibly representing the highest aesthetic values are selected for locating the more visually objectionable operations in wastewater management.

Estuarine Disposal Plan

The Estuarine Disposal Plan, while similar to the Ocean Plan (most noticably in not requiring wastewater disposal sites), offers several visual impact advantages.

A sludge disposal area of the same acreage is still required, however the location is limited to one site, and site characteristics appear to be more suitable for the purpose. The Solano Plan's wide-level terrain avoids the problem of visual impact on surrounding slopes, inherent in the Hollister and San Antonio Valley sites. The wide-level site also permits a more effective use of view screening methods (windbreaks, grading, fencing, walls) to conceal the sludge disposal operation.

It may be argued that concentration of the sludge disposal operation in one site instead of dispersal to two sites would produce less total visual impact to the population at large. Concentration may also result in economics of scale, whereby savings in operation might be applied to a greater design effort to minimize the adverse visual impacts. One possible disadvantage of the Solano location is the bisection of the site by Interstate 80, and the concomitant exposure of

the site to the regional and nation-wide "audience".

Consideration should be given to the potentially adverse visual effects of sewage introduction on the Estuarine system. Impacts such as discoloration of water, dead and dying biota, algae blooms and offensive odors, are more likely to occur in a relatively closed Estuarine system than an open ocean condition.

Land Disposal Plan

The Land Disposal Plan, with its requirement for six locations, totaling 335,000 acres (by 2020) for wastewater and sludge disposal areas, will obviously have considerably greater magnitude of areal impact than either the Ocean or Estuarine Plans. In addition to the vast areas for wastewater disposal, the land disposal system requires several facilities for wastewater treatment (not components of the Ocean and Estuarine Plans). Specifically, these facilities include storage ponds, aeration lagoons and re-use reservoirs that, presumably, would be highly visible features in the landscape.

The spraying of wastewater on disposal sites, although requiring vast acreage, may not generate a significant visual alteration of the existing agricultural landscape if the wastewater could be used for irrigation for crop farming as suggested. The majority of the total disposal site would remain in agricultural patterns. However, while retaining the overall cultivation pattern, the vegetation character of the composite fields may be expected to change if wastewater application necessitates a change in crop selection. Orchards and vineyards that attractively characterize many

parts of the Hollister Valley and east Contra Costa may be replaced by less appealing crops - such as alfalfa, sorghum, soy beans, sugar beets. A change in crop types would appear to effect the Solano and Sacramento sites least, since they already are strongly characterized by row and feed crops.

The wastewater irrigation will probably produce the most significant visual change on the Marin County site. The dominant visual pattern is pasturage for beef and dairy cattle. Fields of feed crops are only occasionally seen. The introduction of crops would produce a profound visual change from the existing grazing patterns.

Wastewater disposal, because of the scale of operations, may necessitate an enlargement or redefinition of existing field patterns. Large geometric fields would be most easily accommodated on the Solano site, presently characterized by a large, open tract pattern. The Sacramento/San Joaquin, Contra Costa/San Joaquin, and Santa Clara/San Benito sites are in smaller, less geometric tracts. Considerable disturbance to the field pattern by grading and border rearrangement may be necessary.

The spraying of wastewater into the air should significantly increase the relative humidity of the ambient air over the site. The Santa Clara/San Benito and Marin/Sonoma sites, because of their encircling valley enclosure, might be expected to trap and hold significantly higher amounts of humidity than the other four relatively open Central Valley sites.

Combination Plan

The Combination Plan offers a two-thirds reduction (2020) of wastewater disposal acreage and two less sights (4) than the Land Disposal Plan. Three of the sights selected, Solano, S.E. Sacramento and East San Joaquin are presently in crop irrigation and appear to be visually adaptable to wastewater application if the scale of operation remains consistent with the existing tract patterns. However, irrigation and crop culture on the Marin/Sonoma site would represent a radical visual departure from the existing grazing patterns.

As in the Land Disposal Plan, each of the wasteland disposal sites will require a storage pond, re-use reservoir, and aeration lagoons. The site of these facilities indicates that they may stand out as vivid features from the surrounding agricultural setting. We assume that all three facilities will require extensive site preparation and regrading of existing contours into earth walls and dikes. View of these features and the sludge disposal operation would be most apparent from the ridges and slopes bounding against the Marin/Sonoma site. The three Central Valley locations have a spatial configuration that does not permit close overview of the site from surrounding slopes and ridges.

IV. C CRITERIA

Planning Criteria

Operations and facilities should be placed where the least aesthetic quality would be foregone. This criteria applies in both the regional location process and specific sites within the region.

The aesthetic quality of the six sites cannot be compared against a single ordinal standard, but sites could be ranked and compared among each other in terms of certain discrete visual/aesthetic dimensions such as: richness of vegetation variety, degree of openness or evidence, of spatial definition, vivid land form features, and pleasing cultural patterns-features.

No one criterion of concentration or dispersion of operations will suffice. Rather, a strategy for the total plan should be built up from the detailed analysis of the site conditions. Then, within each site- a detailed plan for clustering or generally distributing facilities and operations should be designed.

Design and Siting Criteria

- Unattractive disposal operations and facilities should be sited or screened so as to minimize visible impact from the primary observation areas.

Roadways, residential and commercial clusters, recreation areas, and vista points should be surveyed to determine the number of observers,

the sequence and intensity of their observation and the landscape visible.

The major roadways through the disposal locations and public viewing areas will be of particular importance to the formation of a landscape impression. A view from the road analysis should be conducted to factor the landscape into units of visibility - invisibility and character description. Units that are highly visible and/or possess noteworthy landscape characteristics either should be left undisturbed, or very sensitively modified to respect the unit's qualities.

Those facilities and operations that are considered to be the most visually objectionable (such as sludge areas and storage ponds) should be located in those units that are least visible and have the least quality landscape characteristics. However, operations and facilities with low locational flexibility may necessitate the relocation or a road or existing development out of the perimeter of immediate visibility.

- The routing of pipelines will require special consideration. So far as possible, the routing should conform to the longitudinal lay of the land and not straight cut across the contours in a contrasting zig-zag path.

- The attractive and striking vegetational patterns that are strongly characteristic of agricultural landscapes should be retained as organizing elements for siting and screening of disposal facilities and operations.

The prominent vertical features of eucalyptus windbreaks and riparian vegetation should serve as the basis for outlining a screening perimeter around the more unsightly disposal operations. Where new

screening is required, additional eucalyptus windbreaks or extensions of the riparian pattern should be established. The continued or deliberate cultivation of tall-dense crops along roadways or around observation areas could serve both as a screening device and symbolic representation of good husbandry of productive land.

Landscaping of facilities and operations should conform and blend with the indigenous vegetation and not stand out as an isolated and exotic cosmetic feature.

- Disposal facilities and operations should be designed and constructed to minimize their visual impact.

Interdisciplinary design teams (engineers, architects, landscape architects) should be organized at the pre-planning stage of project development. Most of the facilities and operations appear to require treatments that would make them as inconspicuous as possible (low visual profile). It appears that the major design objectives would be to blend, camoflage or recede the facility-operation into the existing landscape fabric. Treatments to accomplish this would include: excavation and undergrounding, earth berming according to contour patterns, screens consisting of indigenous vegetation, low profile structures, and organically colored and textured surfaces.

However, some facilities and operations such as spraying or administrative structures may be attractive features and highlight treatment may be desireable in these special cases.

- Natural landform and drainage patterns that break the agricultural

plain should be retained as spatial and compositional definitions.

● Riparian patterns should not be blocked or removed by disposal operations. Pipelines and reclamation drains, particularly, may desire location in riparian courses. Extensive grading or construction of earthen pikes-walls for ponds, reservoirs, lagoons, and sludge containment may create a new and strikingly artificial landform pattern of clashing contrast with the natural terrain patterns.

● Siting of facilities and practices and the manner and scheduling of their operation should be based on the climatological capabilities so as to minimize the impact of noxious odors and humidity.

Climatological analysis should reveal where and when the release of spors and humidity from disposal operations will produce the least discomfort to the surrounding public. Nocturnal spraying of wastewater while nearly invisible may produce a greater lingering humidity in the ambient air. Operations with the more noxious odors, such as storage ponds and aeration lagoons should not be located upwind from population concentrations or public thoroughfares.

V. CONCLUDING RECOMMENDATIONS FOR FURTHER EVALUATION OF IMPACTS

Should this project progress to the point where a formal impact study is prepared (for Section 102 of the National Environmental Policy Act), the following steps should be included in the further evaluation of visual/aesthetic effects.

First, the basic need for the project as a whole should be clearly stated so as to question the population projections for 1990 and 2020. Steps are being taken in the region to limit and control population growth and distribution, and these might be reflected either in adjustment of overall project scale, or in the form of alternatives. Measures for reducing water use and waste production per capita should also be considered and evaluated. Given the magnitude of visual and aesthetic impact suggested by the nature of the plan alternatives, it will be important to demonstrate a high level of demand for the project.

Similarly the particular set of technologies emphasized should be further justified. Both the Land and Combination alternatives display a rather cavalier attitude toward land and open space. The Marin/Sonoma, Santa Clara/San Benito sites especially are likely to be part of a region-wide open-space system and are, as such, representative of values which go beyond that represented by current market value. Alternatives which are more parsimonious in the use of

land (e.g. urban recycling, advanced treatment plus irrigation, etc.) should be fully considered. The positive beneficial uses of wastewater byproducts should also be elaborated upon, because to the layman, the advantages of dissipation to the atmosphere of valuable water will not be readily apparent.

Detailed studies of the physiographic and visual setting of each site would necessarily need to be performed. These studies should include evaluation of "seen areas" and critical views from activity nodes and travel routes. Each site should also be considered in relation to its surrounding locale and region, so as to identify and preserve unique features insofar as possible. Studies of the impact of project on access and through travel should also be conducted. Similarly, the critical link between visual/aesthetic aspects of the physical environment, and the perceptions and attitudes of the inhabitants and users of the region should be made.

Although not central to the purpose of this portion of the report, the problem of climate and air quality is germane insofar as it affects human comfort and well being. Especially in the Marin and San Benito areas, spray-induced humidity could adversely effect local residents. In the Marin area, the potential for spraying to influence the severity of summer fogs should be investigated.

In all cases, the wind patterns and potential downstream effects of odor and humidity deserve the most

careful consideration. The impact of noise from tractors (clearing sludge), trucks (any sludge hauling operation) and plants must also be taken into account in subsequent work.

Further studies of an inter-disciplinary nature should definitely include the services of professional landscape architects and related design professionals. It is imperative that environmental design considerations be included early and continuously in this study, evaluation, and design process. It is also clear that a comprehensive synthesis of visual/aesthetic, engineering, agricultural, and behavioral aspects must be accomplished, to the end that the project is not only technically and economically possible, but of net social benefit to the region.

ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-
San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 10

POTENTIAL INSECT PROBLEMS ASSOCIATED WITH THE PROPOSED ALTERNATIVE PLANS OF WASTEWATER MANAGEMENT

by

John R. Anderson
Department of Entomology and Parasitology
University of California, Berkeley

EXHIBIT 10

POTENTIAL INSECT PROBLEMS ASSOCIATED WITH THE PROPOSED ALTERNATIVE PLANS OF WASTEWATER MANAGEMENT

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Potential insect problems may occur in association with the establishment of lagoons, and with the land disposal of wastewater and sludge in all proposed geographical areas.

A. Potential Lagoon Problems. A wide variety of insects are known to inhabit, and develop in, sewage lagoons in California (Usinger and Kellen 1955, Usinger 1956) and elsewhere (e.g., Smith and Enns 1969), but only the production of non-biting midges (Diptera: Chironomidae) and mosquitoes (Diptera: Culicidae) seems to constitute a serious potential problem. Aquatic beetles (Coleoptera), bugs (Hemiptera), and dragonflies (Odonata), and such bloodsucking flies as no-see-ums (Ceratopogonidae) and horse flies (Tabanidae), have not generally occurred in annoying numbers, and because most people seem to admire the beauty and aerodynamics of dragonflies, these insects could be regarded as an aesthetic asset around reservoirs of water.

I. Non-biting "midges" and "gnats" (Diptera: Chironomidae and Chaoboridae).

Of the potential inhabitants of sewage lagoons these insects are the most likely to cause serious problems. Hordes of adult chironomids and chaoborids have long been a problem at certain lakes (e.g., Burrill 1913, Bonnell and Mote 1942, Cook 1965, Miller 1951), but they have colonized and caused serious nuisance problems around various kinds of artificial bodies of water about as rapidly as

man constructs the latter. In most instances it has been the smaller chironomid midges that have caused most of the problems. Cook (1963) discussed the relationship of gnat abundance with respect to the ratio of surface area to shoreline when analyzing nuisance levels. However, he later (1967) indicated that this relationship did not always indicate a "problem threshold", when he stated, "Residents of Clear Lake, accustomed to 10,000 gnats swarming around a patio light bulb, might consider a 90% reduction as a noticable relief. However, a city-dweller moving to a suburban development with some gnat-producing ponds may consider 10 gnats per light bulb annoying and 100 gnats intolerable. Thus gnats need not occur in the densities previously found at Clear Lake in order to present serious annoyance problems". The words of Cook's last sentence certainly are borne out by the many recent midge and gnat nuisance problems encountered in California, and the increasing frequency with which local Mosquito Abatement Districts have been dealing with such problems (see references in next paragraph).

Because these mosquito-like insects do not bite, they become troublesome only when they occur in unusually large numbers. However, such dense, non-tolerant population densities have been occurring with regular frequency throughout California with the establishment of sewage lagoons, oxidation ponds and other kinds of water reservoirs (Anderson, et al. 1964, 1965, Bay 1964, Bay and Anderson 1965, 1966, Bay, et al. 1965, 1966, Brumbaugh, et al. 1969, Cook 1967, Grodhaus 1963a, 1963b, 1967, 1968, Hazeleur 1970, Kimball 1968, Lusk and Willis 1970, Mezger 1967, Whitsel, et al. 1963). Similar problems also have occurred in many other geographical areas (e.g., James and Harwood 1969, Mundie 1956, 1957, Spiller 1965).

Although these insects occasionally affect the health of man by causing allergy problems (e.g., Shulman 1967, Weil 1940), they more commonly adversely affect man by occurring in dense hordes. Under the latter conditions they restrict normal outdoor activities, are inhaled and get into people's eyes. Among other things (Grodhaus 1963b) they have been recorded creating traffic hazzards, ruining paint on buildings, fouling adjacent swimming pools, etc, increasing the density of spiders and webs on houses, and leading to unpleasant odors when piles of dead midges begin to rot. Intolerable numbers of chaoborid gnats originating from new sewage lagoons for the city of Redding led to threatened lawsuits and the city spending nearly $200,000 to purchase surrounding property (Hazeleur 1970, Lusk and Willis 1970).

Almost all of the above cited papers referring to midge problems in California deal with species originating from sewage lagoons. Grodhaus (1967) has pointed out that of the more than 150 species occurring in California, there are 16 species most apt to create a nuisance problem. Although intolerable numbers of midges are most likely to originate from lagoons during the first 1-4 years of their use, there are instances of yearly problems (e.g., Bay 1964, Brumbaugh et al. 1969, Grodhaus 1963b).

Like mosquitoes, the life stages of midges include the egg, four larval instars, pupa and adult. The adults live only about a week, but because larval development and emergence is not entirely synchronous, nuisance problems with adults may continue for several weeks. Eggs are laid on the water surface and the larvae develop in organically enriched media at the bottom of ponds and lakes. Usinger and Kellen (1955) stated that the larvae benefitted the sewage purification process by allowing

oxygen to penetrate the bottom material through their burrowing and body undulations. The new adults, of course, remove a certain biomass when they emerge and fly away, but this constitutes the problem. A more detailed account of the biology of chironomids can be found in Grodhaus (1963a, 1963b) and Oliver (1971).

Recommended Methods of Abatement. Midges and gnats developing in the bottom strata of sewage lagoons and other bodies of impounded water can be abated by the use of insecticides in their immature or adult stages (e.g., Anderson, et al. 1964, 1965, Bay, et al. 1965, Brumbaugh, et al. 1969, Hazeltine 1963, Mezger 1967, McFarland, et al. 1962, Spiller 1965, Whitsel, et al. 1963), or in the larval stage by bottom feeding fish such as carp, bullheads and goldfish (Anderson, et al. 1964, 1965, Bay 1964, Bay and Anderson 1965, Bay, et al. 1965, Cook 1964, 1965, Cook and Moore 1966, Grodhaus 1968, Kimball 1968, Mezger 1967). The mosquitofish, Gambusia affinis, is not effective in reducing midge populations (Bay and Anderson 1966) nor are fathead minnows, Pimephales promelas or sunfish (Anderson, et al. 1964).

Although many currently available insecticides are highly effective in controlling gnats and midges (Loc. cit.), these probably should best be planned for use as "emergency" control materials. As carp and other bottom feeding fish have proved effective in abating nuisance populations of these flies because of their ability to dislodge larvae from mud (Loc. cit.), the stocking of lagoons and reservoirs with these fish should receive high priority (previously cited papers discuss stocking rates). Because most species of gnats and midges inhabit comparatively shallow bodies of water, the proposed 50-foot depth of the storage reservoirs

may prevent their development if this depth is uniform throughout. If the depth is sloped to a maximum of 50 feet, I would anticipate larval development in shallower areas. The constant spraying of water into the air in aeration lagoons, thus creating a continual disturbance of the water surface, may prevent oviposition and development of mosquitoes, but it is more difficult to guess at its affect on gnats and midges as wave action on lakes and large water reservoirs has not resulted in their elimination. Since the affect of a 50-foot depth in storage reservoirs and continual disturbance of the water surface by spraying appear to be unknown factors, small scale pilot experiments to test these factors would seem in order. However, instead of waiting until a problem develops it would seem advisable to consider stocking both mosquito fish (see next section) and carp (and other bottom feeders) in the lagoons as they go into operation.

II. Mosquitoes (Diptera: Culicidae).

Mosquitoes of the genus Culex, particularly C. tarsalis, C. pipiens pipiens, C. pipiens quinquefasciatus, and Culex peus have been most commonly found breeding in sewage lagoons in California (e.g., Mulla, et al. 1970a, 1970b, Sjogren 1968, Spiller 1968) and elsewhere (e.g., Beadle and Rowe 1960, Curtis 1963, Rapp 1960, Smith and Enns 1967, Smith 1969). Although the latter species feeds on mammals and birds but not man, both Western Equine Encephalitis and St. Louis Encephalitis viruses have been isolated from field-captured specimens (e.g., Loc. cit., James and Harwood 1969, Spiller 1968, Steelman, et al. 1967). The other species all feed on man and are well known vectors of the above viruses to man and animals. In all cases mosquito problems in sewage lagoons have been

associated with the presence of vegetation in and around the edges of ponds (Loc. cit.).

Recommended Methods of Abatement. Mosquito breeding in lagoons can be eliminated or abated by habitat management (e.g., Bickley and Mallack 1961, James and Harwood 1969, Kimball 1965, Silveira 1960), introduction of "pollution tolerant" populations of such fish predators as the mosquito fish, Gambusia affinis and other species (e.g., Bay 1967, 1969, 1970, Hart 1970, Kimball 1965), and by insecticides (e.g., Mulla, et al. 1970a, 1970b, Schaefer and Dupras 1969, 1970, Steelman, et al. 1967). Habitat management includes steep, weed-free banks, weed-free waters and roads along banks to accommodate motorized equipment. Larger lagoons have greater wave action and consequently no or minimal numbers of larvae.

If water in the aeration lagoons is continually sprayed up into the air, and thus constantly creating a disturbance of the water surface, I would anticipate no problems with mosquito breeding if the water surface also is kept free of vegetation. But as recommended for midges and gnats, pilot experiments would seem in order. In any event, as mosquito fish are known to thrive in a variety of types of sewage lagoons (Loc. cit. and Gerberich and Laird 1966, Russel 1970, Stains 1970), it would seem desirable to routinely stock and rear such fish in the proposed lagoons. Recent research has shown that mosquito fish are very effective in controlling mosquitoes in sewage oxidation lagoons (Loc. cit.), rice fields (Hoy and Reed 1970), etc, but that there is only a limited quantity of fish available to local mosquito abatement districts (Hoy, J. B., pers. communication). Thus it would seem that the stocking and rearing of these fish in the proposed lagoons could prove an economical asset. The fish could be sold or donated to mosquito abatement districts as a public service, and thus be-

come more widely used as a biological means of mosquito suppression, particularly in view of the current widespread resistance of mosquitoes to insecticides in California (e.g., Schaefer 1970 and pers. communication).

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III. Miscellaneous Bloodsucking Insects.

Larvae of both horse and deer flies (Diptera: Tabanidae) and biting midges or no-see-ums (Diptera: Ceratopogonidae) have been found developing in muck and mud around reservoirs of water, as well as in polluted areas (e.g., Gingrich and Hoffman 1967, Jamnback 1965, Jones 1961, Smith and Enns 1969, Teskey 1969, Wirth 1952). However, the rareness of reports of their breeding in association with the bodies of waters similar to those proposed indicates that these insects probably will be of no significance.

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IV. Miscellaneous Potential Problems.

A potential problem that could indirectly affect insect populations in surrounding bodies of waters is that of their absorbing ammonia liberated from lagoons, and thereby leading to accelerated eutrophication (Annonymous 1970).

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B. Potential Problems Associated with Sludge. The house fly, Musca domestica, of course, as well as several other common species of "filth flies", is known to breed in sewage sludge and related organic debris (e.g., Kramer, et al. 1962, Markos, et al. 1963, Scott and Littig 1962, West 1951, Von Zuben, et al. 1952, Wolf 1955) but the proposed methods of handling sludge indicates that production of "filth flies" will not be a problem, or only a minor one. The extent of this potential problem will depend on how thoroughly the sludge is digested before being sprayed or pumped onto land disposal areas, how much sprayed sludge accumulates on the land each day, and how soon pumped sludge is covered with earth. If the sludge is thoroughly digested, there should be no breeding of filth flies (e.g., Wolf 1955), and since the effluent should be odorless, no flies should be attracted. In other similar sewage disposal systems, in which the treated effluent is sprayed onto land, there have been no reported insect problems (e.g., Kardos 1967, 1970, Meyers 1966). This also seems to be the case when liquid manures from domestic animals are sprayed or spread on the land (e.g., Dale, et al. 1969, Dobson and Kutz 1970, Vanderholm and Beer 1970, and author's pers. experience). However, the continuous spraying of land with effluent could lead eventually to soil saturation and/or ponding of water in lower areas. This in turn could result in breeding sites for such previously mentioned potential pests as midges, gnats, mosquitoes, horse and deer flies and biting gnats (see previous references). These areas should be anticipated and corrected by filling or leveling, looked for early in the operation of spraying systems, and long-range surveillance plans should include inspection for such potential troublesome sites.

To avoid problems with terrestrial, plant-feeding insects, large areas of monocultures should be avoided. Belts of different kinds of crops, along

with yearly strip rotation would alleviate problems associated with these insects (e.g., Kardos 1970, Smith and Reynolds 1966, Smith and van den Bosch 1967).

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ALTERNATIVES
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REPORT ON ECOLOGICAL AND AESTHETIC
IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 11

SOME HYDROLOGICAL CONSIDERATIONS IN DISPOSAL OF WASTE TREATMENT EFFLUENT ON LAND SITES

by

Professor Robert H. Burgy

EXHIBIT 11

Some Hydrologic Considerations in Disposal of Waste Treatment Effluent on Land Sites

Prof. Robert H. Burgy

This assessment deals with one of four alternative methods of management of waste effluent waters and by-products by land disposal. A combination alternative also includes partial land disposal.

The investigative results presented here are based on a very brief review of the subject proposal made by the U. S. Corps of Engineers in a preliminary feasibility study. The data base for the analysis consists of short descriptive sections supplied with a map of the general locations proposed for land waste disposal, in the San Frandisco Bay and Delta Region of California. Estimates of land areas required on six sites together with estimates of capacities of certain associated features are given in terms of future needs to 1990 and 2020.

Land Disposal Plan

As perceived herein, the concept involves the collection of urban sewage to regional centers for processing through secondary treatment phases. Effluent and byproduct sludge will be transferred to sites for disposal on land. At certain locations, existing facilities will be utilized for the pretreatment. The remainder of the waste will be given on-site equivalent secondary treatment by lagooning and aeration. Evaporative loss of about half the volume is envisioned, the balance to be recovered via extensive underdrain systems and returned to specified natural receiving water bodies for reuse.

Climatic conditions require the storage of wastes for about 4 months each year during the winter rainy season. Reservoirs for this purpose are included. During 8 months of the year the processed effluent will be handled by short detention in lagoons equipped for aeration and then applied to disposal lands by appropriate distribution facilities. These lands are to be equipped with underdrains to preclude deep percolation to groundwater and the flows so collected are to be conducted to nearby waterways. Theoretically the balance of the volume applied would be reconditioned to a quality suitable for certain uses presently undetermined, thereby constituting a reclaimed (recycled) water supply.

The team assessment of the feasibility of these concepts for accomplishment, considers many facets of the problem, with particular emphasis on the ecological and environmental aspects of this regional land waste disposal plan. Detailed discussions of system components including the soils, waste water composition, treatment requirements and related items are covered in other reports. Hydrological factors and relationships to atmospheric and climatic elements and to the environment are considered herein.

Summary of Plans for Hydrologic Interpretation

The Land Disposal Plan for effluent water is based on the reduction of volume of water by evaporation and transpiration through spreading over large areas of land.

Criteria for land area needed is based on an assumed application of about 8 feet of depth of water in an 8 month period, representing the continuing inflow volume of waste plus the portion of stored waste water accumulated in four months of the winter period.

Conditions, locations and assumed volumes are summarized from the Appendix data, as shown in the table following.

Distribution of effluent water to the lands will be on a programmed basis at each site, the applications made in a sequence somewhat analogous to agricultural irrigation, that is, to apply an increment to successive blocks. Due to inherent difference in the soil and conditions at each site, it is presumed the incremental "irrigations" will vary among the 6 locations.

Underdrains are to be installed in the disposal areas to recover the percolate for return to waterways or for alternative reuse.

This restatement of the plan and preliminary design concepts is the basis for interpretation of the hydrologic impact.

Hydrologic Assessment

Analysis of the outlined plans may be based on the examination of several hydrologic processes acting in this type of system. Key processes in the plan include:

Evaporation and transpiration

Precipitation

Infiltration

Drainage systems

Climatic Regimes

Evaporative Processes

The general evaporative conditions prevailing at the six sites have been reviewed and condensed as shown in the tabulation, using published evaporation records.

Site No.	Ave.Ann. Evap. In.	Ft.	80%E.	Precip.Range
1	48	4	3	20
2	60	5	4	20-30
3	60	5	4	10-20
4	70	6	5	10-20
5	65	5	4	10-20
6	70	6	5	10-20

These are annual amounts. The plan calls for disposal during 8 months assumed to be approximately (March-April) through (Oct.-Nov.). Review of seasonal distribution of evaporation indicates about 80% of the loss occurs during these months. Therefore the annual amounts

to the 80% value recorded above.

Evaporation pan data is an effective indicator of the evaporative potential of the atmosphere at a given place. It is obvious the effective amounts of water which may be expected to dissipate from the disposal lands on 4 of the 6 sites is at capacity. Only by increasing the energy input to the sites would it be possible to increase this amount. Since the fact of applying water requires time during which the lower atmospheric layer becomes nearly saturated, the effect of creating vast areas of wetted surfaces acts to reduce the potential and tends to lower evaporative loss, at least a portion of the time.

Precipitation

Annual rainfall in the six sites is distributed over about 6 months. Approximately three fourths of the annual rain occurs during the prime winter months. Variations produce wide ranges in seasonal distribution as well as in the totals. Early and late rainfall in fall and spring may occur in substantial amounts, acting to reduce evaporation at those times. From these considerations the contention that evaporative losses in this design approach maximum possible values seems to be justified.

Infiltration

Many factors influence infiltration of water into soils. Among these of importance here are long periods of wetting, water quality factors and the additions of fine suspended materials that tend to act as retardents by blocking soil pores. The soils of the disposal sites are discussed in detail by others, however, it is worth while to note here the relative nature of infiltration as a

hydrologic parameter and to recognize the limitations which must be imposed on the design values.

To maintain optimum infiltration rates in soils of the disposal sites will require surface manipulations or vegetation of a type which maintains the surface condition. It is difficult to devise a management scheme for cropping which will involve regular surface tillage and yet maintain the vegetation which is essential to the concept of cycling of water and nutrients on a disposal site. Regular agricultural practices and crops might be adapted if the complications associated with sewage effluent can be worked out.

Drainage Systems

The disposal sites are generally situated on lands where soils are marginal for agricultural production, being shallow and poorly drained. The specifications indicate land slopes less than 10% and elevations below 500 feet. These conditions are compounded by the need for an underdrain network to recover the percolating water and prevent recharge to ground water. All the sites have an inherent problem in that it is virtually impossible to produce a drainage design that will insure complete isolation of surface applications in the system to prevent deep penetration. Short of full sealings of the bottom surfaces of the plots, no underdrain design can be devised to guarantee this kind of operation.

Climatic Considerations

Atmospheric factors such as wind flow, vapor content and energy levels are important in the evaporative process. Concurrently, the wind regime and moisture levels may produce undesirable downwind effects.

Summary

The plan for disposal of waste water effluent on land produces a number of questions which need resolution. The data base for these interpretations has not been fully developed due to inavailability and shortage of time. The time constraints preclude in-depth analysis of all aspects. Certain important factors related to the hydrology of the disposal sites are reviewed.

Beneficial Aspects

1. The regional concept of planning of areawide waste disposal is considered good.
2. The concept of disposal of waste water and byproducts by the most beneficial method with least impact on the environment is essential.
3. The concept of salvage and reuse of water for suitable purposes may be an essential future consideration. To ascertain the optimum treatment procedures for various reuses of waste water will require careful assessment and should be the subject of intensive ongoing study and research.
4. The value of water which may be recharged to the atmosphere could be beneficial by adding to the precipitable water vapor in the atmosphere. With the high orographic barrier to the east (Sierra Nevada Mountains) a synergistic effect may be achieved, i.e. more vapor transported to mountains may produce increased precipitation and consequent increased runoff for water supply.

Potential Environmental Consequences

1. The plan envisioned for evaporation of water in this system is at maximum limit of potential evaporation on most of the sites. The factors of early and late season precipitation together with variations of climate combine to approach the limit of potential evapotranspiration. The design value of 4 feet loss planned, is seemingly somewhat optimistic. Increased area for the disposal sites is the only solution to maintain the balance of loss versus recycling. Added to the extensive land commitment already planned increasing the disposal area requirements may not be justified on many bases.

2. Microclimatic and macroclimatic changes should be expected. Lowering of temperatures and increases in humidity will result for large distances downwind of the sites. Increased costs for humidity control and air conditioning may result.

3. Vegetative species and vegetation management to maintain the effectiveness of the disposal sites for evaporative and infiltration requirements need indepth study and research.

4. Additions of chemical constituents, sediment as well as nutrients need further analysis with regard to infiltration problems.

5. In cycling the plots for efficient production, drying will be needed. The potential for dispersal of particulate matter to the air must be considered.

6. Development of odors and gases from lagoons and reservoirs poses a problem.

7. Overall there seem to be a significant number of uncertainties relating to extensive land waste disposal, making it expedient to seek a technology assessment of this proposed plan. Many ramifications of the concept would emerge as the various alternatives were explored for their full impact and cost.

Disposal Area	Reservoirs (Vol.-Ac.ft.)		Land Area-Acres	
	1990	2020	1990	2020
	(in Thousands)			
1. Santa Clara-San Benito	100	150	40	60
2. Sonoma-Marin	20	45	10	20
3. Solano-Yolo	145	250	60	105
4. Alameda-Contra Costa-San Joaquin	95	185	40	75
5. Sacramento	60	120	25	50
6. E. San Joaquin	25	55	10	25
Total	445	805	185	335

Additional Area Needed For Lagoons

Site No.	Surface Area- Acres	
1.	500	800
2.	100	250
3.	700	1300
4.	500	900
5.	300	600
6.	150	300

Lagoon Depth--15 ft.
Detention -- 3 days with aeration

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Soil Survey Records-- USDA, SCS Records

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EXHIBIT 12

THE EXTENSION AND DEVELOPMENT

OF MARSHES

by

Dr. Herbert L. Mason

Professor of Botany, Emeritus
University of California, Berkeley

EXHIBIT 12

THE EXTENSION AND DEVELOPMENT OF MARSHES

Dr. Herbert L. Mason
Professor of Botany, Emeritus
University of California, Berkeley

In the early history of California the entire Delta area and much of the overflow lands and lower reaches of the San Joaquin and Sacramento rivers as the approached and converged in the Delta were occupied by extensive marshes. This was also true of all of the major tributaries of the Valley rivers. The agricultural lands of the island Delta and those of most of the peripheral area have been reclaimed by dyking and the disposal of excess water. The Delta and the San Joaquin Valley at least as far south as Dos Palos, because of extensive marshes presented problems to early travelers, especially those with horses, because of the insecure footing in marshlands.

These marshes, being along the main Pacific Flyway for waterfowl, provided resting sites and food for the millions of migrating birds that pass through each year, and in addition provide nesting sites and a secluded place to rear the young, for resident birds (Mason, H.L. 1957).

Everywhere man has controlled the overflow of rivers and estuaries by dykes reclaiming thousands of acres of rich agricultural lands that once were marsh. The result was an enormous reduction of available habitat for resident and migratory birds. The carrying capacity of what remained, being much reduced, produced fewer resident birds. Among these are the mallards prized by the hunter. The

reduced carrying capacity also caused an overcrowding of migratory birds so they move on to the Gulf of California. The result is fewer birds available for the local hunters.

When the rice industry was introduced into California, here were extensive acreages of artificial marshes tempting the hords of migratory birds at harvest time to the consternation of our farmers. Likewise these enormous flocks of migratory birds will land in grain fields and trample them beyond salvage. As a consequence of inadequate marsh habitats to which these birds would naturally go, we are suffering serious crop damage.

The answer to the problem does not rest in returning our rich agricultural lands back into marshes. Rather there is much non-agricultural land that is too alkaline or saline, and much that is so poor productively that it would be far more productive if it were converted into marsh to produce fish and waterfowl. Much of this land is now employed for grazing yielding a very poor return. It has proved many times that stall feeding of such stock is far more economical.

Marshes contain plant communities that are the easiest to duplicate artificially of any that exist. The basic problem of irrigation ditches is keeping the marsh plants out as weeds. They are essentially weedy plants wherever there is wet ground or shallow water. All that is required is to provide a shallow basin, fill it with water and let Nature do the rest. Migratory birds will bring in seed to supply diversity to the flora. Within a single season much of the shoreline will be occupied by marsh plants that will gradually extend

the populations out from the shore so that in two or three years the project will be well on its way (Exhibit 5).

It would be well to allow some small islands for nesting and resting. These present no great engineering problems in their construction and need be no higher than a foot above water level. They too will soon be surrounded by a marsh flora.

In many game management areas crops for bird feed are grown. These are largely to entice the birds away from nearby agricultural crops. They would not be necessary in the type of marshes here suggested.

It would seem that with all of the surplus water available from sewage disposal as well as the agricultural wastewater from the San Luis drain, extensive marshes could be developed in the alkaline lands boardering the San Joaquin river. There are many sites peripheral to the agricultural lands of the valley and especially at the north end of the valley to the west of the agricultural lands where soils are so poor as to render the land not productive. These are all in the flyway. It would be less productive, but not unproductive to develop marshes in valleys away from the flyways because they would not attract the hords of migratory birds. However, they would attract a population of resident birds that would increase to the level of the carrying capacity of the marsh.

The duck hunting avocation is a multimillion dollar operation in the economy of the state. In addition, there are many kinds of

edible fish that live in marshes that would greatly enhance the sport fishing potential as well as supply as easy source of food to migratory human workers and other unfortunate people. However, the quality of this wastewater must meet sanitary levels for this purpose.

In terms of the objectives of the sewage disposal operation these marsh plants would constitute a living filter to further degrade the effluent of phosphates and nitrates and other nutrients important to the plants. Possibly residues such as pesticides would be absorbed. The marsh could serve as holding ponds until the degradation is completed and the water then sent on to other uses.

There is a 25,000 acre area of subsaline soil northeast of Hollister now used for grazing. The soil is so dense that it is almost impermeable to water. There would be very little lost to the aquifers in such an area. In view of the fact that the San Benito area under consideration is of questionable value for disposal of the effluent because of soil depth, this area across the Hollister valley might be substituted, employing the living filter of marsh plants instead of the soil to accomplish the job. The marsh water would also develop a population of algae. The formation of unsightly algal scum might be discouraged by planting Eichornia (water hyacinth) which would soon cover the surface and shade it. There would still be sufficient light for large populations of micro-organisms that would help in the degrading operation.

In the area under consideration on the eastern flanks of the Sacramento valley soils are so thin as to render these sites inadequate to the purpose for which they are being considered. In addition, the hardpan ranges from a few inches to twenty-five feet in thickness and is now rock. Here, too, one might find large areas along the flyway that could be converted into marsh employing the living filter of marsh plants rather than soil for the task of reducing the effluent. Over the long term, such marshes will construct a soil and may require raising the dykes to permit this soil thickness to grow and render the area too valuable to continue as a marsh, since marsh construction is relatively low cost construction this is economically sound. The sale of the soil covered land should more than pay the costs of developing a new area of marsh. We can thus evisage an eventual increase in the amount of arable land as a consequence of converting the area to marsh.

Professor Burgy (Exhibit 11) in his discussion of the impact of the proposed sewage disposal operation on the hydrological cycle calls attention to the fact that the proposal was overly optimistic on evaporation potentials and that a much larger evaporation surface would be required. He considers this adversability of employing the topographic features of California for carrying this moisture upward against the Sierra Nevada for precipitation and return it as natural waters to the streams and reservoirs. Marshes could contribute this water surface for additional

evaporation especially in the Central valley.

Marshes have aesthetic qualities of their own. To bear this out one only visit the great museums of art and note how many times artists have painted these scenes with their plant and bird life. There is an exciting charm to a marsh with its very busy bird life. That they have an appeal to many people is born out by the number of cartons of photographic film one sees where a marsh is accessible to a road. This only records the visitors who had to change film at the point.

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EXHIBIT 13

COMMENTS ON ENVIRONMENAL

IMPACT STUDIES

by

Dr. Ray B. Krone
Consultant

EXHIBIT 13

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June 21, 1971

Dr. Curtis L. Newcombe, Director
San Francisco Bay Marine Research Center
8 Middle Road
Lafayette, California 94549

COMMENTS ON ENVIRONMENTAL IMPACT STUDIES.

Dear Dr. Newcombe:

This letter was prepared in response to your request for "top of the head" comments on the kinds of environmental impact that should be anticipated during consideration of land disposal of Bay area waste waters and waste sludges. Such a nebulous assignment leaves me uneasy; I prepared the following remarks to meet your needs as I understand them.

Land disposal of waste waters can be accomplished in several ways, each with different environmental effects. Surface disposal methods range from spray, furrow, or flood irrigation of crops to evaporation basins or evaporation from land surfaces where dissolved and suspended residues are accumulated from evaporating waste waters. Subsurface disposal can include charging of under ground waterbearing formations via recharge wells, leaching fields, or surface infiltration facilities. The suitability of each disposal method depends on the character of the soil and subsurface formation, the climate, the location with regard to other land uses, the public health, and costs and benefits, as well as the aesthetic and biological impacts of each method. The former factors will be considered in the engineering studies that will necessarily be made at each location before the feasibility of the several methods can be assessed. These comments will be confined to identification of changes from a base condition associated with land disposal of wastewaters and sludge.

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The impacts of all of the land disposal methods will depend on the constituents of the waste waters and sludges when delivered to the disposal site. If the water is upgraded so that it compares with California Water Project water, for example, its impact will be comparable to that planned for the lands supplied by that project. Generally the effects will be less desirable as the constituents are more nearly those of untreated municipal and industrial used waters, and the effects of the individual constituents will be of concern.

Crops have been irrigated successfully with conventionally treated M & I waters for years, and procedures for assuring safety of the public health are well established. If surface drainage of applied waste waters to water courses is prevented and subsurface drainage is provided, and if over irrigation is avoided, useful filtering and biological decomposition of organic materials in the waste waters are provided by the soil. The increased salt concentration in the drainage water must be managed as for irrigated agriculture generally, however. The sorptive capacity of the soil for non-degradable toxic compounds should be used sparingly or not at all. This method of disposal is really "reuse" and produces a crop.

Evaporation of water and accumulation of dissolved and suspended constituents on the land surface requires nearly irreversible dedication of land to such activities, but may be appropriate on soils having poor subsurface drainage. Arid lands can become saline ponds or surfaces: The impact is the steady increase in salt residue left as water evaporates. This impact can be less than that of salts let into a water course having a reduced flow.

Subsurface disposal into water bearing formations can affect the constituents of the groundwater in significant ways. If the surface soil is used for filtration and bio-decomposition of waste water constituents, then the waters reaching the waterbearing formation will be changed by that treatment. Otherwise the dissolved constituents of the charged waste waters will gradually prevail in the groundwater. Waters should not be

put into waterbearing formations that would be undesirable in a water pumped from that formation.

Obvious but easily overlooked changes from the base condition that accompany land disposal of water on arid lands are the changes that accompany the presence of water. Increased humidity, multiplication of flying insects, the occasional presence of waterfowl, and changes in the number of people and kinds of activity in the locality if recreational or agricultural benefits accompany the operations should be included among ecological impacts.

Land disposal of sludges can be accomplished by burial or by incorporating the sludge in the soil. Burial is really a means of storing sludge. The environmental impacts might include contamination of ground waters by leaching runoff waters, drainage from the base of the fill, and slumping and otherwise undesirable changes in the land surface at the burial site. Gases from decomposition might result from partially stabilized sludge. These are problems now encountered in sanitary land fills for other solid wastes.

Incorporation of treated sludge in soil has been practiced for years in Golden Gate Park and other places. Possible disease transmission might result from this practice if applied to soils used for produce such as lettuce, carrots, broccoli, etc. Research on disease transmission would be needed before indiscriminate application of sludge to agricultural soils could safely be practiced.

There are more general remarks that should be made in considering waste disposal on land. These are:

1. Every site is different. The characteristics of the soils, subsoils, and underground formations must be determined before planning a land disposal operation at a prospective site. Environmental impacts at each site should be evaluated separately.

2. The capacity of a land disposal system to provide nuisance free, usually aerobic, disposal should not be exceeded. Overloading

can produce sudden failure. Adequate land, and suitable storage and treatment facilities are essential to a nuisance free operation.

3. Land disposal really does not eliminate undesirable constituents. They are either stored on the land or move with the portion of water that penetrates the soil, or are lost to the atmosphere. It is important that the fate of waste water constituents over long periods be anticipated when selecting a disposal system. Land disposal does not eliminate the need for treatment of the waste waters.

4. Undesirable constituents, such as toxic materials should be kept out of waste waters or removed by appropraite treatment for land disposal except when evaporation and accumulation of constituents is planned.

I hope that you find these remarks useful. Please send me a copy of your report.

Sincerely

Ray B. Krone

RAY B. KRONE
Consultant

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EXHIBIT 14

DISPOSAL OF WASTE WATER FROM SEWAGE TREATMENT PLANTS BY RECYCLING THROUGH THE TERRESTRIAL PHASE OF THE HYDROLOGIC CYCLE

by

Edward C. Stone

Professor of Forest Ecology
School of Forestry and Conservation
University of California, Berkeley

EXHIBIT 14

DISPOSAL OF WASTE WATER FROM SEWAGE TREATMENT PLANTS BY RECYCLING THROUGH THE TERRESTRIAL PHASE OF THE HYDROLOGIC CYCLE

Edward C. Stone[1]/

Disposal of water and sludge is the terminal step in the sewage treatment system -- a system of "black boxes" or processing units through which the sewage passes and within each of which organic matter is progressively removed. The number of processing units and their contents differ, of course, depending on the specific treatment system employed. In this brief review I want to focus on the terminal process unit in the system through which the water must pass before it can be safely released into the terrestrial phase of the hydrologic cycle. This unit can be either a tertiary treatment plant or a modified terrestrial ecosystem, and it is the latter that I want to consider here.

Use of a terrestrial ecosystem to carry out the terminal processing has been most widely employed in connection with septic tanks

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[1]/ Vegetation management consultant and Professor of Forest Ecology, School of Forestry and Conservation, University of California, Berkeley.

installed to serve single-family dwellings.[2] But it has been employed both experimentally and operationally on a much larger scale. Recently, for example, it was used in the Tahoe Basin by the South Tahoe Public Utility District as an interim measure while a tertiary treatment plant was under construction. It was not properly employed by them, however, and serves as an example, par excellence, of the difficulties encountered when the complexities of the terrestrial ecosystem employed are not fully appreciated by the design engineer. The temporary nature of the installation, apparently, was sufficient justification for exceeding the processing capacity of the first of two terrestrial ecosystems employed and thereby causing its destruction.

To be a successful processing unit the ecosystem must have the capacity to: (1) absorb the effluent at the rate applied, (2) hold the effluent in the soil long enough for the microflora to destroy bacterial and other disease organisms that it might still contain, and (3) reduce the chemical content to an acceptable level. In addition, the vegetative cover in the system, whether it be trees, shrubs, grasses, herbs or some combination thereof, must be kept alive and healthy.

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[2] On this subject the literature is truly voluminous, but not very helpful in dealing with the subject at hand.

The first area employed by the South Tahoe Public Utility District was located on National Forest land. It was much too small and its absorption capacity was quickly exceeded. By the third year of operation, surface flow of effluent from the area was extensive and, depending on the time of year, as little as 30 percent of the nitrogen and the phosphorus contained in the effluent was retained in the soil.[3/] The vegetative cover began to show signs of injury during the third year and after six years all the trees on the area were dead or sufficiently damaged to require their removal.

After the vegetation on the first area was destroyed, the operation was moved to private land. The area was considerably larger and the water-spreading system employed allowed for an improved rotational system of periodic soil saturation and drying. There was some overland flow of effluent, during the winter months when the infiltration rates were greatly reduced. How much of the nitrogen and phosphorus was retained in the soil is not a matter of public record and may not have been measured. Some flooding occurred where clay and impervious layers in the parent material intersected the slope surface, and in one of these areas a large number of the trees died during the second year of operation. I believe

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[3/] Foster, H. B., P. C. Ward, and A. A. Prucha. 1965. Nutrient removal by effluent spraying. J. Sanitary Engr. Divis. ASCE, Vol. 91, Proceed. paper 4556.

many more would have died had the operation continued for more than another year.

Difficulty with the two terrestrial ecosystems employed as terminal processing units should not be accepted as evidence that such processing units are impractical. Properly designed, they can be completely effective and inexpensive to operate and, in some areas, should be able to produce at the same time a saleable crop to reduce the cost of operation. Had vegetation management specialists been consulted, they could have predicted many of the difficulties encountered by the Tahoe operation, because the tree species involved cannot tolerate saturated soils during the growing season for any extended period of time. There are several tree species in the Tahoe Basin that could conceivably be used to develop a suitable processing unit there. But, except for willow, these trees are relatively slow growing and ten years or more could be required to establish an effective "processing" ecosystem. Management, however, would be complicated, because without exception these species are highly susceptible to insect or pathogen attack.

In practical terms, the use of terrestrial ecosystems for terminal processing units is limited to regions in which plants that can thrive in periodically saturated soils and can utilize the chemicals contained in the effluent can be readily established and maintained.

In California there are a number of agricultural crops that could probably be employed. Reed canary grass (Phalaris arundinacea),

for example, grows well in California and has been used successfully in Texas for this purpose, where the effluent was generated in a Campbell Soup Company cannery. On the other hand, if trees are to be used, there is only one species that I can currently recommend with confidence for this purpose in California. This is the coast redwood (Sequoia sempervirens) which tolerates flooding, can more than double its growth when irrigated with sewage effluent, and can be grown at low elevations throughout much of the state.

Many tree species are able to tolerate flooding for short periods of time but, unlike the redwood, few can do so without suffering a significant depression in growth rate. Also, most of these species are killed by prolonged flooding during the growing season. This difference in tolerance to flooding has a physiological basis, which we recently examined in redwood and Douglas-fir (Pseudotsuga menziesii) in terms of photosynthesis, respiration, transpiration and internal moisture stress.[4/]

Two-year-old seedlings grown in gallon cans in a fertile sandy clay loam soil were used. Half of the seedlings were flooded with tap water for six weeks, after which the study was terminated, while the other half were watered just enough every 3 or 4 days to maintain

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4/ Stone, E. C. and R. B. Vasey. Annual Report for 1967 on Redwood Ecology Study for California Division of Beaches and Parks. Wildland Research Center, University of California, Berkeley.

soil moisture close to field capacity, i.e., water held against gravity by a freely drained soil not subject to evaporative stress.

Redwood and Douglas-fir differed considerably in their response to flooding. All the redwood seedlings survived, although both their growth rate and overall appearance were affected. Seventy-five percent of the Douglas-fir seedlings died during the first three weeks and only one was alive after six weeks.

Apparent photosynthesis of the redwood seedlings after a short sharp initial decline dropped slowly following flooding and after six weeks was still approximately 60 percent of normal (Figure 1). In Douglas-fir it dropped off sharply following flooding and then continued to decline until the seedlings were dead (Figure 1).

Respiration of the redwood seedlings (tops) following flooding closely paralleled the changes recorded in apparent photosynthesis. There was a sharp initial drop during the first 24 hours followed by a general decline; after 6 weeks it was still approximately 70 percent of normal (Figure 2). In Douglas-fir, respiration changes did not parallel apparent photosynthesis. During the first 48 hours it did not change significantly; during the next 5 days it dropped sharply; and then during the next 6 days it increased sharply after which it again dropped off rapidly just prior to death (Figure 2).

Changes in daily net photosynthesis (apparent photosynthesis minus respiration) reflect changes in food reserves in the seedling following flooding. It was little affected in redwood during the first week following flooding; then it dropped sharply after which

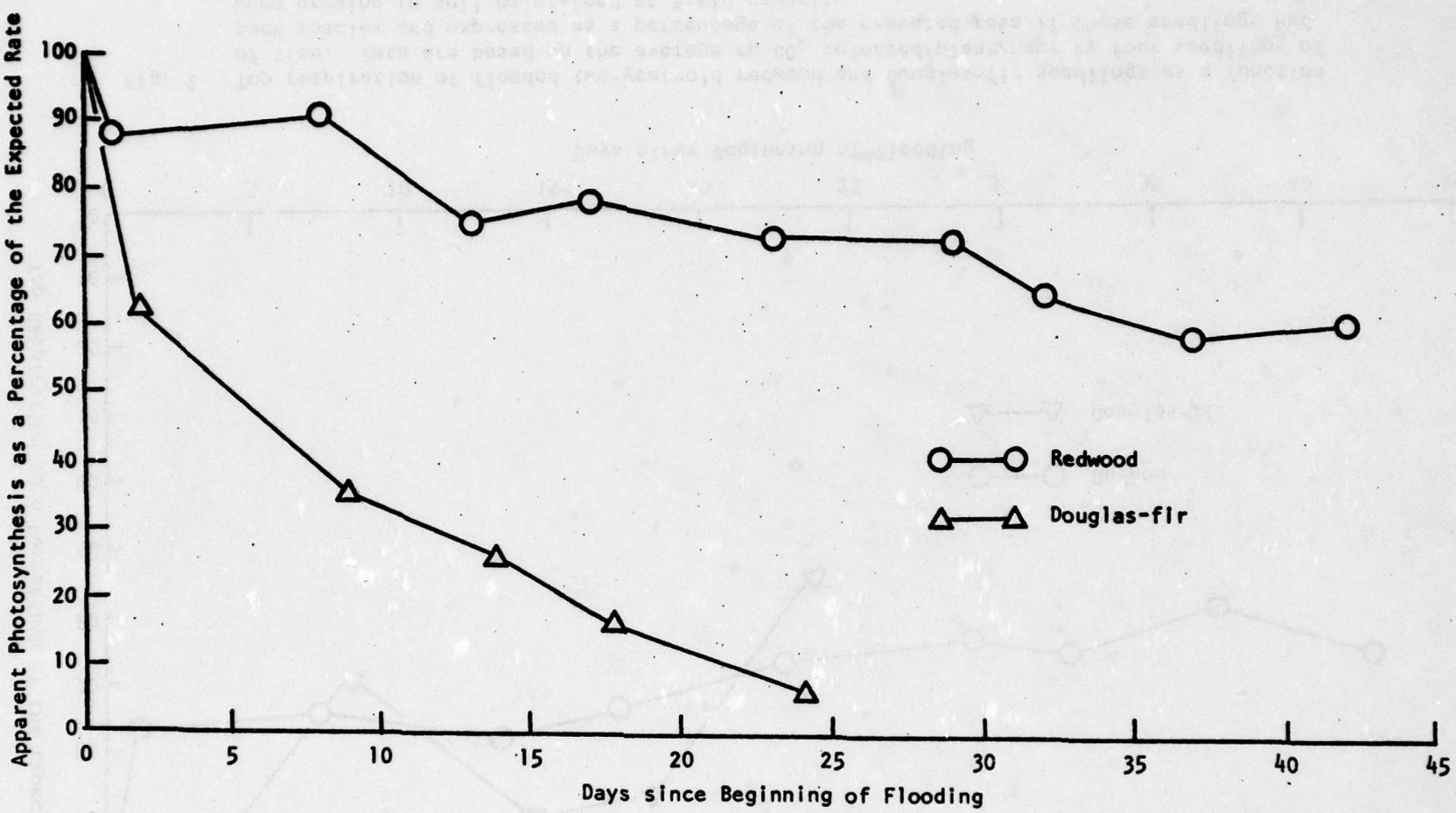

Fig. 1 Apparent photosynthesis of flooded two-year-old redwood and Douglas-fir seedlings as a function of time. Data are based on the average mg CO_2 fixed/plant/hour by four seedlings of each species and expressed as a percentage of the expected rate if those seedlings had been growing in soil maintained at field capacity.

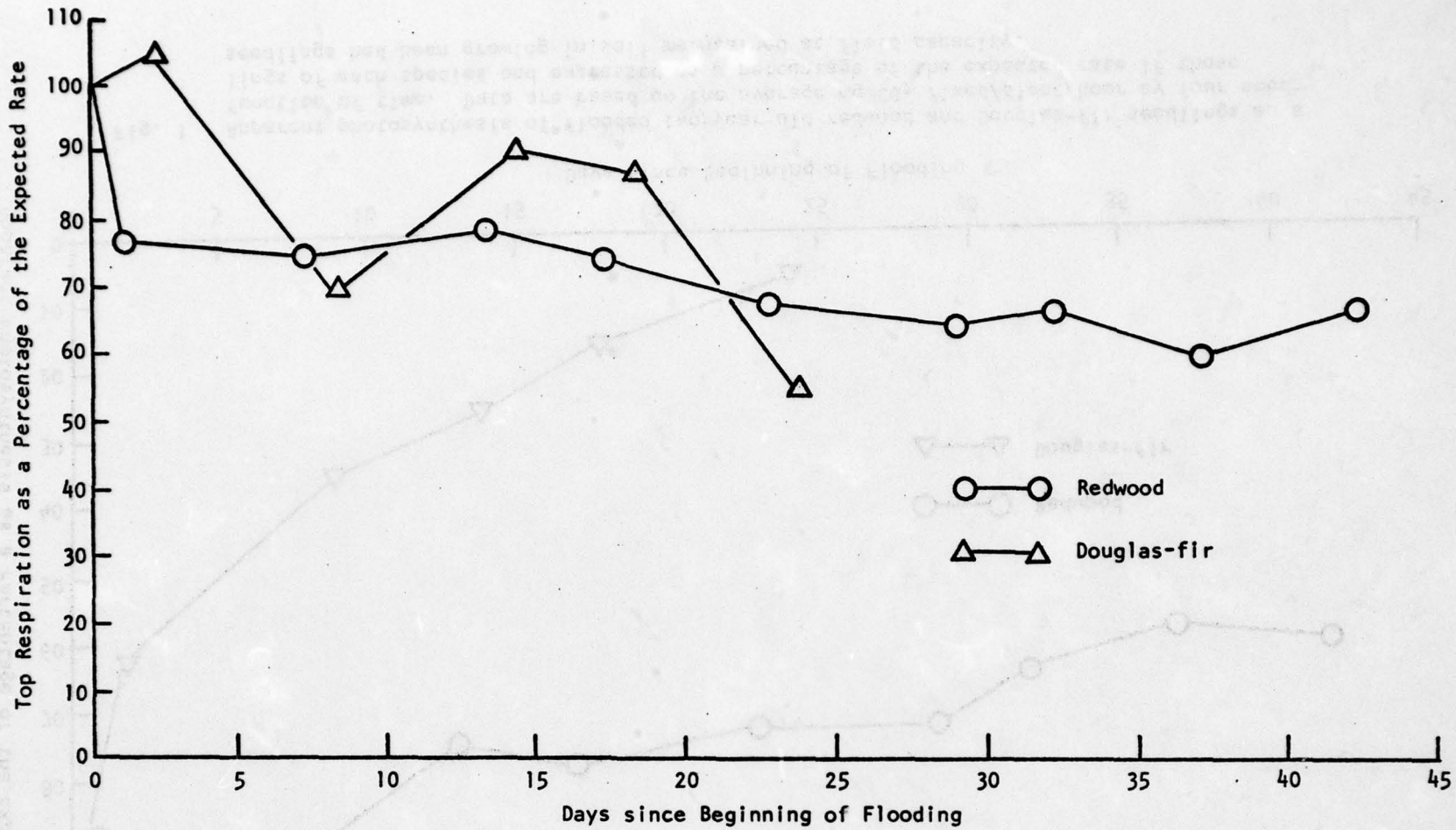

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Fig. 2 Top respiration of flooded two-year-old redwood and Douglas-fir seedlings as a function of time. Data are based on the average mg CO_2 released/plant/hour by four seedlings of each species and expressed as a percentage of the expected rate if those seedlings had been growing in soil maintained at field capacity.

it slowly decreased (Figure 3). In Douglas-fir it began to drop immediately and reached zero after 10 days. Thereafter it continued to drop until the net loss exceeded the normal net gain by approximately 30 percent (Figure 3).

Transpiration was also affected by flooding. In redwood it remained normal during the first 48 hours, then shot up to above normal after which it dropped slowly, finally falling below normal some 3 weeks later. After 6 weeks it was still 86 percent of normal (Figure 4). In Douglas-fir there was an initial drop following flooding followed in turn by a sharp increase and from then on by a steady decline. After only 3 weeks it was down to 30 percent of normal (Figure 4).

At weekly intervals throughout the study a number of seedling root systems were washed free of the soil mass and examined. Unflooded seedlings showed extensive new growth. Many of the redwood roots were killed by flooding, but even after six weeks of flooding there were still numerous white root tips present, indicating that some of the roots had continued to grow in spite of flooding. In the case of Douglas-fir, flooding killed all the roots during the six-week study period, except in the case of one seedling. That seedling had developed a small root system adventitiously from the stem just above the soil surface.

Recently, as a first step in a project for determining the feasibility of using a redwood forest ecosystem as a tertiary sewage treatment unit, while producing at the same time a supply of redwood

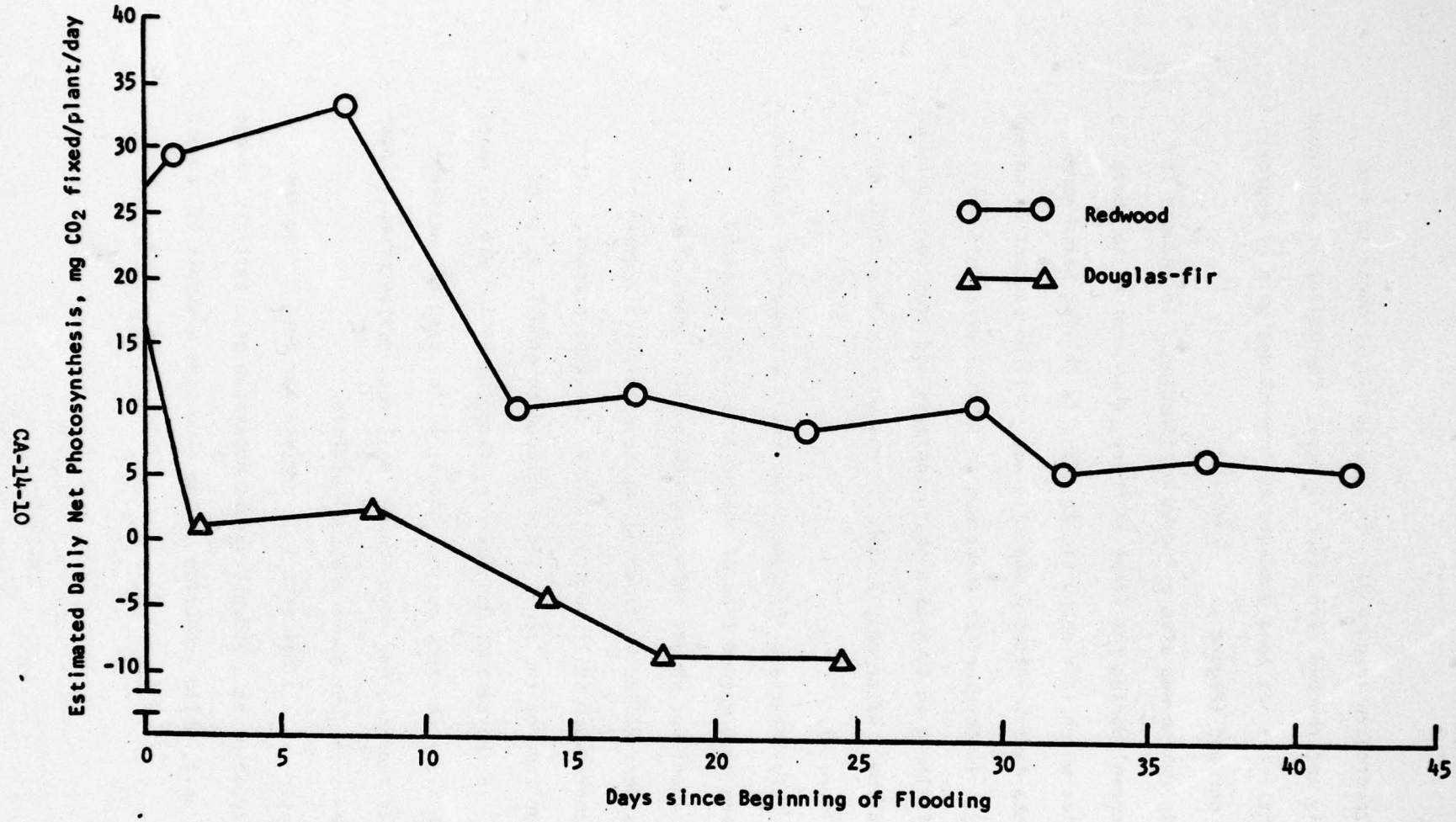
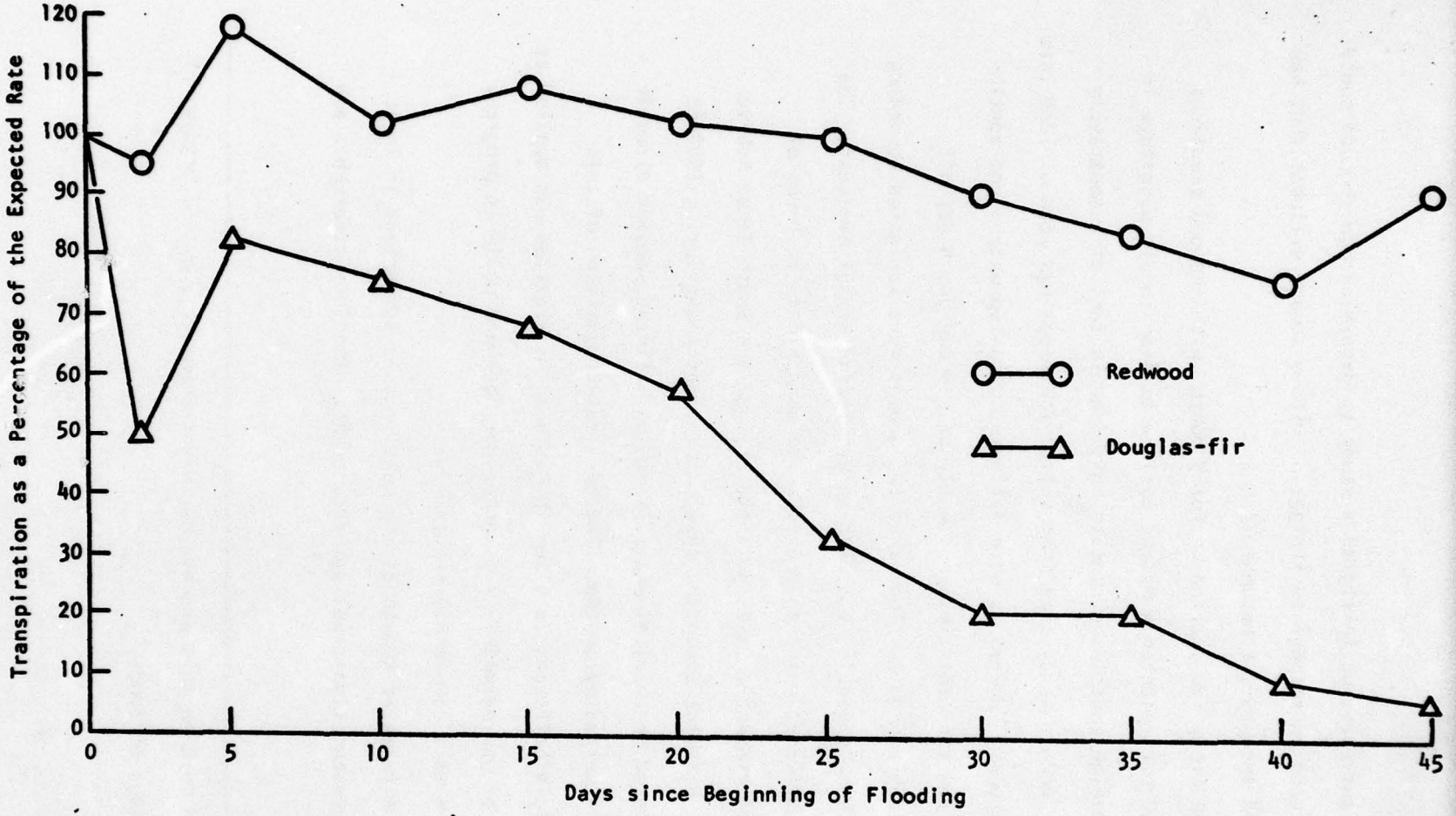


Fig. 3 Estimated daily net photosynthesis of flooded two-year-old redwood and Douglas-fir seedlings as a function of time. Data are based on the average net mg CO_2 fixed/plant/day by four seedlings of each species.



CA-14-11

Fig. 4 Transpiration of flooded two-year-old redwood and Douglas-fir seedlings as a function of time. Data are based on the average gm H_2O transpired/plant/day by eight seedlings of each species and expressed as a percentage of the expected rate if those seedlings had been growing in soil maintained at field capacity.

lumber and pulp, we initiated a study to determine how redwood could be expected to respond to irrigation with a sewage effluent that had received secondary treatment.[5/]

The study was carried on for 9 months with redwood seedlings that had been planted 4 months earlier as 8-month-old seedlings in 14-inch-high containers containing .25 cubic feet of a moderately fertile forest sandy clay loam soil. The seedlings were divided into four groups. Two groups were irrigated with tap water, one continuously and the other intermittently on a 3 day on, 4 day off irrigation schedule. The other two groups were irrigated according to the same schedule, but with an "artificial" sewage effluent. The sewage effluent was prepared so as to approximate in terms of chemical content an average effluent from the South Tahoe Public Utility District secondary sewage treatment plant during 1968-69. It is based on chemical analysis run on effluent sampled directly from the spreading system. The chemical composition of this "artificial" effluent is given in Table 1. Irrigation was applied at a rate of approximately 1.5 inches per hour and while in progress kept the soil completely saturated.

The relative growth of the seedlings is summarized in Table 2 and representative seedlings from each of the four treatments are

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[5/] Work on this project has been temporarily halted because of a shortage of funds.

TABLE 1.

Chemical content of the artificial sewage effluent employed.

Ion	PPM	Ion	PPM	Total	PPM
CL^-	61.7	Na^+	88.1	N	27.0
$SO_4^=$	89.7	K^+	19.6	P	14.2
$BO_3^{\equiv}$	2.5	Ca^{++}	23.7		
		Mg^{++}	4.6		

TABLE 2.

Growth of redwood receiving continuous and intermittent irrigation with tap water and sewage effluent.

Treatment	Height (cm)	Top Weight (gms)	Root Weight (gms)
Intermittent irrigation with tap water	46	28	62
Continuous irrigation with tap water	50	27	57
Intermittent irrigation with sewage effluent	124	248	137
Continuous irrigation with sewage effluent	73	63	34

shown in Figure 5. Irrigation with the sewage effluent greatly increased the growth of redwood, but was most effective when applied intermittently, increasing height growth by 150 percent and top dry weight by 900 percent.

Based on this response and extensive field studies of redwood in its natural environment,[6/] I believe artificially established redwood stands can be used as highly effective tertiary sewage treatment units where a suitable combination of climate, soils and land area are available. What is needed now is a series of pilot-type evaluations carried out on a variety of soil types and at various locations in the state. This, of course, involves not only the establishment of redwood, but a characterization of the mineral cycle that can be expected to function following its establishment and maintenance with sewage effluent. Of particular interest will be the relative capacity of the soils that could be involved to fix phosphorus.

[6/] Stone, E. C. and R. B. Vasey. Annual Reports for 1960, 1961, 1962, 1964, 1966 and 1967 on Redwood Ecology Study for California Division of Beaches and Parks. Wildland Research Center, University of California, Berkeley. Also: Stone, E. C. and R. B. Vasey. 1968. Preservation of coast redwood on alluvial flats. Science 159: 157-161.

Figure 5. One-year-old redwood seedlings after continuous (C) and intermittent (I) irrigation for 9 months with tap water (T) and artificial sewage effluent (E). (Scale: 1 mm = 1 cm)

Based on the growth response of redwood to irrigation with sewage effluent, it should be possible to produce between 500 and 1,000 cubic feet of redwood per acre per year while operating the terrestrial ecosystem as a terminal processing unit. Productivity, of course, would be dependent on the type of soil present and the length of the growing season. At the present market value of redwood logs and chips, the average net return should be between $125 and $250 per acre per year with a major harvest cut within 20 years after establishment.

Provided a proper landscape plan is implemented, and the vegetative cover on the terrestrial ecosystem processing unit is redwood, the aesthetic qualities of an area need not be lowered by the installation of a sewage treatment system and, in some areas, might even be improved. Harvesting could be on a selective basis so that a continuous forest cover could be maintained over the entire operation. Border areas could even be developed for picnic sites and, if reservoirs are to be used to trap the water after it has passed through the terrestrial ecosystem, a major recreational complex could be developed. Considering the "sex-appeal" redwood possesses in the field of conservation, I can visualize all kinds of public support and enthusiasm for such a plan -- sewage reclaimed, a redwood forest established, an appreciable part or perhaps all the maintenance costs covered by the sale of redwood logs and chips, and a recreational park within the redwood forest complete with lakes, boating and fishing.

Aesthetic values would be a great deal more difficult to maintain and/or enhance if some other vegetative cover is used. In a farming community, where the vegetative cover could be handled as a farming operation, e.g., the terrestrial ecosystem planted to reed canary grass and harvested regularly for hay, there should be relatively little negative input on the surrounding area. But as we know from recent experience, in California no area can be considered safe from subdivisions and, should such development occur, the presence of a sewage disposal system with an agricultural-type vegetative cover could materially affect the aesthetic quality of the surrounding area. However, even here, if the agricultural-type vegetative cover were broken up with a matrix of redwood plantings, the aesthetic quality of the area might be enhanced.

One quick word about sludge disposal. It can be incinerated, used for sanitary land fill or for soil conditioning. My guess is that once a large, cheap or perhaps even free source of sludge is available, most if not all of it could be disposed of as a soil conditioner. Even so, an incinerator capable of disposing of 25 percent of the sludge produced when the processing plant reaches full operating capacity should be included, at least on a tentative basis, in the initial plans.

ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-San Joaquin Delta Area

REPORT ON ECOLOGICAL AND AESTHETIC IMPACTS OF WASTE DISPOSAL TO LAND

EXHIBIT 15

LAND DISPOSAL PLAN

COMMENTS and EVALUATION

by

R. S. Ayers

EXHIBIT 15

R. S. Ayers

Land Disposal Plan

Comments and Evaluation

The time available for study of the impact of land disposal of sewage wastes-effluent and sludge- does not allow me to do more than offer a few comments based on my own experiences and judgment in water quality related primarily to agricultural requirements and tolerances.

Land disposal to crop land is being used in about 29 counties in California with very few reports of problems. The sewage effluent from the secondary treatment plant is used directly on certain crops or is diluted by adding to the irrigation stream as from a well or canal. One of the primary problems in the present use is caused by the daily and continuing need for utilization or disposal of the sewage effluent. It keeps coming - rain or shine, good weather and bad. Regardles of whether the crop needs the water or not, the irrigation may have to be made as a disposal measure.

In the winter, when soils are wet by rains, the soil reservoir becomes filled, infiltration rates decrease, and problems of having adequate acreage that can accept the effluent are multiplied. At such times an alternate disposal system to surface drains may be acceptable due to volume of winter run-off and the dilution capability.

The possibility of utilization or reclamation of sewage effluent offers great possibilities and could aid in water conservation, however, its use for agriculture as a disposal alternative may need considerable subsidization or encouragement since water supplies to agriculture are not expected to be severely limited in the foreseeable future except in perhaps a few areas.

Areas for Land Disposal

Area 1:

San Benito County

This disposal area lies in the Pajaro River drainage and flows to Monterey Bay west of Watsonville. Monterey Bay is a pollution sensitive area.

The proposed disposal area has a very wide range of soils, varying from several thousand acres of very heavy clay now largely in pasture and marginal crops to very excellent soils devoted to orchard, vegetable, and seed crops, as well as wine grapes.

Population is not great but closely tied to agriculture and agri-business. In the general area a high water table exists over perhaps 50% of the bottom lands. Surface and sub-surface gradients are less than 1% and in many areas very nearly flat. Very few areas of sand soils exist and infiltration rates probably average less than 0.25 inch per hour.

The acreage of heavy soils could be utilized for reduction and aeration ponds and the good crop soils used for disposal of treated effluent and could replace present irrigation water.

Under-drainage might be expected to work over much of the area. The pick up of under-drainage water could be accomplished from the Pajaro River or drains before reaching the river before the drainage flows out of the upper basin down into the lower basin. Further treatment, if it becomes necessary, could then be given and water used in the Pajaro Valley downstream.

Water from the San Luis Reservoir (State Water Plan) is available for recharge of deeper underground water and its use is already planned by San Benito County for recharge of its underground water supplies.

Disposal to this area removes the nutrients, etc., from the San Francisco Bay and transfers them to Monterey Bay via the Pajaro drainage.

Twenty-three hundred acres of heavy clay soils are presently under 7-year lease for disposal of cannery wastes by an association of Santa Clara County Canneries (CEI). This is to be a dry disposal of waste as a slurry, spread and disked as needed to eliminate fly and odor problems.

Present well water supplies are of rather poor quality (EC = 0.75 to 2.00 millimhos) and boron is a problem in several areas. The Pajaro River has water quality not greatly different than the well waters except during periods of heavy winter run-off.

Municipal water supplies from the Bay area for whom this land disposal is planned for, will probably average a very much better quality water than the present water supplies of this San Benito area. Even with the usual 300 ppm rise in salts and proportional rise in which boron is added by municipalities, the sewage effluent should be equal to or better than the quality of the existing ground water basin of this San Benito area.

This area seems well suited to land disposal. There are problems, of course, but I am fairly well aquainted with the area and can see some real possibilities for disposal here.

Area 2:

Marin Area - Petaluma west

The bulk of the area west of Petaluma is in rather poorly defined drainage basins that would appear to be very difficult to regulate or control for general agricultural use of reclaimed water. Disposal to this area would need to be either concentrated with very careful control or very widely spread, using rather low amounts of water applied to rolling hill lands and let natural under-drainage concentrate flows to the narrow valley floor to points of easy collection.

The topography does not lend itself to controlled tile drainage except in the narrow valley bottoms. Rainfall is rather high, climate is cool reducing crop needs, and soils are not deep and have a limited capacity for accepting water. The area is mostly grassland pasture with clay subsoil areas. Perhaps this type of grassland pasture and rolling hills would be well suited to an especially adapted method of disposal but would need to be very different than for the San Benito area.

The quality of the present water supplies in this area are variable but range up to extremely poor and in some instances indicate presence of high nitrates (above 90 ppm NO_3).

There are no real streams, only short drainages, but winter run-off down the many small drainages may be considerable.

Marin Area - Petaluma north

These lands are very flat, heavy textured, and poorly drained. Percolation of effluent through these soils will be very slow. A shallow under-drainage system at perhaps three feet and closely spaced (75 feet or less) might work but a deep system (8 feet) would not be expected to be removing surface applied effluent since percolation rates would be extremely slow.

Slow surface flow through or over a dense cover of Reeds Canary grass, rushes, sedges, etc., might greatly reclaim the effluent and allow nutrient reduction to take place. I understand this type of disposal or reclamation of effluent is being successfully used in Germany.

The underground water quality of this Petaluma-north area is much better than the Petaluma-west area. There is a definite good surface drainage through Petaluma Creek but flow is back to the Bay. There are extensive grass hillside pasture lands available for effluent disposal but here again clay subsoils and

limited water storage capacity within the shallow rooting zone makes disposal more difficult as to quantity of effluent that can be applied per application and the frequency of application.

In general the Marin area, in my judgment would be satisfactory, if very carefully operated with very specialized methods of effluent dispersal. Winter-time disposal might be next to impossible without real problems of run-off and all the problems accompanying run-off.

Area 3:

Solano-Yolo County

This area offers mostly flat lands adapted mostly to field, vegetable, and seed crops. The northern and western portions now grow a wide variety of crops such as tomatoes, sugar beets, beans, and a few orchards in the more favorable locations.

Soils in the central and southern portions are heavy textured, poorly drained and utilized for irrigated pastures and dry farmed grasslands and cereal grains.

There is ample acreage for reduction or aeration ponds and many acres of crop and pasture land that can use the effluent.

Present water supplies are either Sacramento River water, Lake Berryessa water, or well water and relatively low cost. Quality is excellent and perhaps too pure for good water penetration. Some improved water penetration into these heavy soils might be expected by switching to effluent.

Underground water supplies are not of very good quality - moderately high salts and often with some boron. If the excellent quality surface waters were reserved for people and the effluent and poorer waters were reserved for agriculture, there might be some all around benefits.

All underground escapement of drainage waters drain back to the Bay-Delta area. Water tables now exist in part of the area. With adequate extensive drains, water tables could be controlled and water recovered could be reclaimed if necessary. Present perched water tables are generally of acceptable quality for use on pasture grasses.

Area 4:

East Contra Costa, N. Alameda, W. San Joaquin Counties

The comments for the Solano-Yolo area apply equally well to this area.

There are not so many acres available, nor is the present surface water supply as ample or of as excellent a quality.

Return flows and underground drainage would be to the San Joaquin river portion of the delta and this is presently a poor quality water. Effluent if coming from the Bay area should be of better quality than much of the water now available in this area.

The Brentwood area has excellent soils, a good climate and could utilize considerable quantities of effluent on orchards during the winter perhaps at times much of the other parts of the area are too wet to take much water.

Area 5:

SE Sacramento County

Two soils dominate the area - San Joaquin and Redding. The San Joaquin is typically a hard pan soil. The Redding is a rocky clay pan soil. Neither will accept very much water. The hard pan of the San Joaquin occurs close to the surface, at 10 to 40 inches, and is usually impermeable to water except where cracked or shattered. The Redding is on steeper slopes and has a heavy red clay subsoil at 10 to 30 inches below the surface.

Water holding capacity for crop use or effluent disposal is limited to the depth to hard pan or to the heavy clay subsoil.

Drainage problems will occur - both internal and surface as soon as the soils become saturated. This will occur before the first 12 inches of water are applied. This will preclude any attempt at disposal through the soil.

However, the slope of land might lend itself to surface flow for reclamation as done by Campbell Soup Company and reported on in various environmental publications. For this sort of disposal, the area might be ideal. Certainly no percolation or contamination of underground water basin is to be expected. And there are probably sufficient acres of crop land in adjacent areas that could utilize the reclaimed effluent.

Area 6:

<u>SE Sacramento County</u> - <u>E. San Joaquin County</u>

The northern area east of Lockeford is similar in soil conditions to the Area 5.

The southern area also is similar to Area 5 but the hard pans and clay pans may be at deeper depths but usually within 40 to 60 inches.

Under-drainage is not possible as normally considered. Some special disposal procedures would need to be worked out.

There is considerable acreage downslope that could utilize any reclaimed effluent but again present costs of water are not excessive and some inducement might be needed to get acceptance.

General Comments on Land Disposal
of Waste Water and Sludge

General -

1) Under-drainage systems for collecting carriage water can only work if water tables are present. If no water table exists or is formed during disposal and within depths of tile placement, no water recovery by under-drainage is possible.

2) Spray disposal is practical on a continuing basis and utilization of the land as a filter, only if the application rate is lower than soil infiltration rate - otherwise the disposal is simply flood irrigation by spray application and what then is the benefit over surface flooding? Drainage is essential.

3) Calculations from assumptions presented on page 7 under G. Reuse Facilities indicate an expected disposal of a 7.5 to 8 ft. depth of water annually over the areas under consideration. This seems extreme if any cropping is to be done. A 4 to 6 ft. depth of applied water might be accomodated under best conditions and still grow some adapted crops with the 4 foot depth more realistic than the 6 foot.

4) For a "permanent" solution to the disposal problem a basin or watershed balance must be achieved - nitrogen, salts, boron, etc. Additions of nutrients or constituents to a watershed must be balanced against losses from the watershed. There is little indication in the plan outline as to quantities involved in inputs or expected outflows. Such balances are difficult to construct and more difficult to evaluate since there are so many unknowns. Attempts however, must be made in order to get some idea as to long term effects. For the most part, the disposal areas considered are still within the Bay-Delta basin and we haven't disposed of a thing.

Even though land disposal may be possible and feasible, what are we accomplishing over the long haul unless we really look at what we are putting in the Bay-Delta basin and what and where is it going to come out? At some time or place inputs and outputs must be equal. I see no indication that special treatments are planned to bring nitrogen into balance, or total salts, or boron etc.

I believe land disposal may be possible, but we are only moving the problem around. We are not solving it. Why not more complete treatment of the effluent to remove or reduce the objectionable constituents to an acceptable level then utilize the effluent for the highest use possible.

ATTACHMENT B

REVIEW OF THE FEASIBILITY STUDY

ON

SOCIAL WELL-BEING

By

Martin H. Krieger

CB

ALTERNATIVES
FOR
MANAGING WASTEWATER
IN THE

San Francisco Bay and Sacramento-San Joaquin Delta Area

REVIEW OF THE FEASIBILITY STUDY

ON

SOCIAL WELL BEING

by
Martin H. Krieger

REVIEW OF THE FEASIBILITY STUDY ON SOCIAL WELL-BEING

Martin H. Krieger*

with

William Alonso
Leonard J. Duhl, M.D.
Michael B. Teitz

*This review was authored by Martin H. Krieger with the aid of William Alonso, Leonard J. Duhl, and Michael B. Teitz. Though we have some differences with respect to questions of emphasis, we are in agreement on the general conclusions.

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SUMMARY

The efforts of the U.S. Army Corps of Engineers to explicitly include social well-being effects in evaluating alternative waste water management projects are a proper response to changing national sentiment and policy concerning environmental improvement. Many, but not all, social well-being considerations can be operationally included in the decision process by using currently available methods of measurement and consumer participation. These approaches represent a natural extension of methods currently in use by the Corps.

Distributive Equity as an Objective

Though social well-being is a very broad concept spanning material, social, and psychological factors, one value, that of distributive equity, is of paramount importance and most easily incorporated into current Corps procedures.

The criterion of distributive equity concerns the incidence of costs and benefits on different populations. In a narrow interpretation it deals with material costs and benefits; in a broader one, it deals with the incidence of aesthetic, psychological, and community effects.

A number of versions of the criterion are in use. Conventionally, the results of an activity are equitable if those who are made worse off as a result are compensated in some form for their loss. Distributive equity, on the other hand, as understood in much of current Federal and local policy, is a criterion which suggests that as a result of an action

greater weight be given to benefits for those in the greatest need and who have the smallest resources. At the least, the projects should not make the lot of the poor any worse. We note that traditional conflicts in Corps projects involved differences between middle and upper class interests -- development vs. conservation. The current conflicts are broader in their implications.

We shall be concerned with material, regional, and political distributive equity. In evaluating projects, the effects on the material well-being, i.e. personal income and wealth, of the poorest should receive primary attention. The intra-regional distributional effects must similarly be taken into account. Finally, it is necessary that those who are most left out of the decisional process today be actively incorporated into it.

Procedures for Evaluation

Present Corps evaluation procedures of economic and ecological consequences of alternative schemes could reasonably be extended by specifying which groups receive what costs and what benefits. The identification of the relative groups should receive priority. A tentative listing of these would include those served by the facility, those displaced or otherwise affected on the site and immediate neighborhood, citizens as tourists, citizens as consumers, and various producer groups such as manufacturing, farming, service establishments, and maritime industries.

Governance and Consumer Participation

However, many considerations of social well-being cannot be covered by such technical analysis, and to incorporate these the evaluation of alternatives should include the active participation of citizen and producer groups, of local and regional governments, and of such concerned Federal agencies as the Departments of Housing and Urban Development and Health, Education and Welfare. The involvement with other Federal departments reflects a realization of the broad impacts of programs and the overlapping responsibilities among governmental divisions.

Effluent Charges and the Set of Alternatives

From the point of view of social well-being, the set of waste water management alternatives currently being considered is incomplete. Present alternatives take projections of the amount of waste as given, and propose technical means for its disposal. Further alternatives which consider the production of effluents as a variable sensitive to policy, by such means as the taxation of effluents, need greater emphasis than they receive in the current study. The policy-sensitive aspects of population change also need attention. Such alternatives involve substantial questions of equity and other forms of social well-being, since they would not only reduce the quantities of effluents, but also, by causing the internalizing of social costs by the producers of wastes, they would reduce negative and inequitable effects through the operation of the market. The Corps itself cannot put such a tax structure into effect, but given the strong prospects for such policies at all levels

of government, consideration of these alternatives would enhance the realism of the analysis. The potential use of the Refuse Act of 1899 for regulation is yet to be played out. Further, since the Corps is probably the most technically knowledgeable and experienced agency in this general field, its analysis of such alternatives would greatly assist in clarifying the issues involved, and thus assist in the formulation of these policies by national, state and local governments.

The Study Itself

We have made a detailed review of the Social Well-Being element of the Study. As a preliminary effort it is especially valuable. It incorporates a concern for most if not all of the major values associated with social well-being. However, its lack of focus and priorities should make it difficult to implement in its current form. This reflects, to a large extent, the current state-of-the-art in most measurement-oriented "quality of life" research. Still, it is possible to implement means of articulating social well-being values. Our discussion of major priorities suggests a somewhat shorter set of evaluative issues that should be operational.

I. INTRODUCTION: BACKGROUND OF THIS REVIEW

We have been asked to review the Social Well-Being element (pp. V-7 to V-16) of the Draft (3 June 1971) Feasibility Study of the San Francisco Bay and Sacramento-San Joaquin Delta Waste Water Management Investigation. We want to examine the conception of social well-being and suggest how it may be realized in the practice of making decisions on alternative waste water management projects. We will also examine the nature of the set of alternatives being considered, although it is not our task to do a systematic analysis of the social well-being impacts of the alternatives.

The Corps' interest in explicitly including the social well-being impacts of its efforts is part of a larger national movement. This has most recently come under the rubric of "social indicators." These are statistics that relate social action to the state of the society. Currently, a great deal of research effort, in and out of government, is being devoted to developing such indicators. Much of the research is concerned with factors describing positive, rather than ameliorative, aspects of society - indicators of the quality of life. We strongly endorse the Corps' efforts to include these factors in evaluating projects.

The urgency for doing so will be especially great in the case of waste water management. Most residents of urbanized areas view such an issue as a utility, something for which they pay but about which they do not worry. Of late, many utilities, notably electric power, have come to the attention of the population as the systems for supplying

the service have broken down. These breakdowns are the result of complex sequences, often originating in conflicts over land use. Rather than using systemic failure as a way of raising the issues of waste water management in the public's eye, those who must develop waste water management systems will need to involve the affected publics in the early stages of their design and choice. The Corps' experience in waterways and harbors should be helpful. In this manner support for the massive allocation of resources for waste water management will be developed.

How the "waste water management problem" comes to be defined has major implications for the social well-being impact of waste water management. The Bay Area population is unusually aware of the environmental impact of projects. More than most other places in the country, it is aware that some sort of recycling system is necessary (at least ecologically). Waste water management, besides dealing with wastes, has something to do with the production of drinking water and of fish and shellfish from the oceans, estuaries, and bays.

The Set of Alternatives

Although the current set of four alternatives is responsive to these aspects of social well-being, they are too limited. The manner that the question is posed, i.e., the social well-being impacts of alternative waste water management projects, ignores the primacy of certain nationally articulated social values. Rather the question that should be asked is, "What kinds of social values are considered to be nationally significant and how can we design waste water management

procedures that will reinforce these values and effectively deal with wastes?"

If we take our question in this form and, as we argue later, take equity as a major value, then the set of alternatives for waste water management may need some expansion and alteration. By assuming "all things being equal," especially waste production per person and population growth, we may be ignoring equity considerations.

Taxes and effluent charges are likely to have some effect on waste production. It seems fair and equitable to charge those who produce wastes, the costs of cleaning them up. As a result of market processes, this will encourage many waste producers to reduce the amount of wastes they discharge. The magnitude and resulting form of waste water management procedures may be altered dramatically.

To summarize, though the Corps seems to be well aware of the importance of systematization and recycling, the current set of alternatives do not seem sufficiently responsive to certain policy instruments, especially effluent charges, that will affect discharge levels. Further emphasis is needed here. These have substantial social well-being implications through equity considerations.

Our Procedure

After examining the concept of social well-being, we shall discuss the Social Well-Being element itself. We then suggest what the major objectives would be and how they may be used analytically. These objectives of material equity, regional quality, and equitable

governance are then examined in further detail. We conclude with some methodological notes. An Appendix discusses the contents of the element in greater detail.

II. WHAT IS "SOCIAL WELL-BEING?"

The concept of "social well-being" has no precise definition or one that is embodied within a single profession's practice. In that sense, it is very different from "economic efficiency" or "ecological survival." Yet it is obviously a genuinely significant value to which certain professions are committed -- medicine, law, planning and design, among others. Politicians have always tried to address themselves to it. Still, efforts to systematically include social well-being in decisional processes seem to require an explicit definition.

The one proposed in the Feasibility Study (p. V-7) seems to be as good as any. Our concern is mainly with the quality of group, family and individual life. The dimensions that seem most significant include material equity (and implicitly the quality of jobs and schools), psychological well-being, physical health, democratic participation in governmental processes, and aesthetic factors. In order for these to have meaning, certain regional structures, governmental and physical, must exist.

When a concept is not well defined, certain procedures can insure that the latent aspects of the definition are included and that public action is at least partially responsive to the values associated with

the concept. A fairly straightforward element of social well-being, likely to find wide acceptance, is distributive equity. In order that the other aspects of the definition be included in the process of decision making, a broad representative group, outside of the engineering and design professions, needs to be included. These will comprise local residents, public officials, and specialists from fields concerned with social well-being. The latter may consist of social planners, certain economists, psychiatrists and lawyers, among others.

The Social and Psychological Character of the Problem

The lack of an "objective" definition of social well-being is not peculiar to this concept alone.

"Pollution" is also a cultural artifact. Of course, it is known from physical and medical sciences that the ingestion of certain substances will have toxic effects. Calling such substances "pollutants" is the result of a social evaluation of the significance of such toxic effects compared to the (presumably existent) beneficial effects. The levels of risk we accept are socially, and not scientifically, determined. A pollutant in one society will be considered either neutral or beneficial in another, yet the physical effects in both may be roughly the same.

With respect to waste water management this is especially clear. Currently, the idea of drinking purified waste waters may seem abhorrent to some people (even though this is what "nature" does already), independent of physical health hazards. Similarly, the spraying of partially

purified waters onto the land, and perhaps growing crops on the same land, is likely to suffer social suspicions associated with pollutants. Yet people can be convinced of the purity of mechanically recycled water, as many examples in effect today show.

We conclude from this discussion that the ways in which we manage and define waste water treatment systems must be responsive to psychological and cultural factors not well represented by quantitative data. Yet the associated values and sentiments are genuine and often of great significance in determining the acceptability of projects.

III: DISCUSSION OF THE SOCIAL WELL-BEING ELEMENT

In this section we shall make some brief remarks on the Social Well-Being element (pp. V-7 to V-16) of the Feasibility Study. A detailed discussion is to be found in the Appendix.

There is no generally accepted set of criterion values for social well-being. Various values are emphasized in different contexts. These variations in emphasis tend to reflect professional biases, the utility of certain values for specific areas of concern, and the national politics of the moment.

The element we have examined adequately reflects the spectrum of relevant values to waste water management alternatives. It serves as the basis for the priorities that we recommend further on.

The difficulties associated with this element are: (1) lack of focus of priorities, and (2) problems of measurement. In part, this is due to the preliminary draft nature. Priorities are needed since we have

limited attention and time and only a small number of values can be effectively used in choosing among alternatives. In this sense, the element is not useable in present form. A second problem is that the statistics or indicators that would be needed often do not exist. We must find indicators that are already gathered or can be easily gathered (within the ongoing processes) if we are to successfully incorporate them into actual choices. Finally, goals, procedures, statistics and events are confused in the listing. This makes it difficult to figure out what to do with some of the considerations.

On the other hand, the emphasis on material equity, consumer participation, and regional development choices represent significant initiatives on the part of the Corps. They are likely to lead to waste water management alternatives significantly more responsive to social well-being considerations than previous procedures.

We encourage the Corps to continue research associated with making these values more easily implemented in its evaluation procedures. It should be possible to develop measurement and decisional methods incorporating these values. The effort involved is not small, but could be easily developed for the waste water management alternatives study.

IV: MAJOR OBJECTIVES FOR SOCIAL WELL-BEING

Social well-being objectives consist of both normatively oriented impacts and processes by which the decision among alternatives is made. The latter are especially important. The social well-being of certain groups crucially depends on the manner in which problems come to be

defined and subsequently worked on. The chosen solution to the problem is important, but the method by which it is chosen may be of equal importance.

Distributive Equity

The one objective that characterizes all of the concerns we shall articulate below is that of distributive equity -- of material goods, of regional quality, and of decisional power.

A number of versions of the objective are in use. Conventionally, the results of an activity are equitable if those who are made worse off as a result are compensated in some form for their losses. Distributive equity, on the other hand, as understood in much of current Federal and local policy, is a criterion which suggests that as a result of an action greater weight be given to benefits for those in the greatest need and who have the smallest resources. The kinds of goods people desire as benefits needs to be taken into account. At the least, the projects should not make the lot of the poor any worse.

Evaluation Procedures

In many cases, as we discuss below, current Corps practices provide a basis for evaluating potential equity effects.

The existing economic and ecological impact analyses (Section V of the Study) provide a starting point for articulating the social well-being aspects of each alternative project.

The economic analysis focusses on issues of project efficiency

while the ecological analysis evaluates various impacts with respect to an objective which might be called survival. They seem to consider many of the events or impacts that would result from the alternatives. These same impacts should be evaluated, as well, according to the social well-being objective and sub-objectives within it. The general concept is shown diagrammatically in Table 1. (This is reminiscent of conventional tables; its purpose here is schematic.) On the vertical scale are listed the various impacts identified by the economic and the ecological analysis. There will be a certain number of other impacts, such as psychological or aesthetic ones, not considered in these two analyses, and therefore this listing would be somewhat longer.

Across the Table are the various relevant objectives. While the impacts identified in the economic section are those assessed from the point of view of economic efficiency, or their contribution to national product, each of these should also be evaluated with respect to the other objectives, recognizing that for some impacts and some objectives the consequences will be nil. Thus, a given economic impact, which in the efficiency criterion is evaluated in terms of its aggregate national effects, would be considered within the material equity column in terms of its impacts for each of several groups. For instance, a total benefit of 1000 might represent a benefit of 500 for each of two groups and nil effect for other groups. Or a benefit of 1000 might represent a benefit of 2000 for one group and a cost of 1000 to another. Separate accounts are needed for each public.

Each of the various impacts should be evaluated by each of the criteria, and each of these effects should be disaggregated or unfolded for each of the groups affected. Thus a particular impact might be economically efficient, ecologically nil, negative from the point of view of equity, positive but inequitable from an aesthetic point of view and so forth.

The particular objectives listed under Social Well-Being are illustrative. They include a consensual but tentative listing of material or income equity, mental health or psychological criteria, aesthetic criteria, regional patterns from the perspective of efficiency and amenity, and governance.

To recapitulate: it is our recommendation that the listing of impacts be extended somewhat to include further impacts not presently included in the economic or ecological sections. That each of the impacts, regardless of the list in which it originally appears be assessed by each of the criteria. And that, within the social well-being criterion, for each of the sub-criteria, the consequences of each impact be specified by the group affected. Complex sequences of effects (economic, ecological and social) occur before the incidence of a project's impact can be assessed. For some of the more substantial effects, these sequences or flows will have to be disentangled.

A. Material Equity

Different waste water management alternatives will affect the material well-being of sectors of the population in different ways.

TABLE 1

Objective / Impacts	Efficiency for "X"	Survival for "X"	Social Well-Being of Public "X"*			
			Income Equity	Regional Amenity	Psychological Effects	Governance
Economic Impacts _____ _____ . . .	CA	P	P	P	P	P
Ecologic Impacts _____ _____ . . .	P	CA	P	P	P	P
Impacts Particular to Social Well-Being	P	P	P	P	P	P

CA: Currently Assessed P: Proposed

*A separate accounting is needed for each Public

We believe that the differential effects of projects on real family income should be primary evaluative criterion in choosing among projects.

Differential Effects of Project

Alternative projects affect income by changing the mix of jobs, the costs and character of access to work, the kinds of (non-priced but valuable) recreation available, and the tax structure of a community. These effects are manifested through the project as an investment in the area (mainly during construction) and as a result of the operations of the facility. For example, one of the investment effects of the recent downtown building boom in San Francisco and the construction of the Bay Area Rapid Transit System has been a strong demand for construction workers. Even here the problem is not straightforward. Worker migration from outside the region may be substantial. Similar effects will attend the development of large waste water management projects.

Publics

A number of publics may be identified as being affected differentially by alternative projects. We may make a cut along the rich-poor dimension. This will be especially important when we consider distributive equity. We also want to look at publics from the impact perspective. We may distinguish, among others:

a. population served by the facility;

b. population displaced or severely impacted by the physical facility (pipelines, lagoons, etc.);

c. population neighboring the physical facilities;

d. population otherwise affected by physical facilities (e.g., aesthetics of intra-regional recreation);

e. population benefited by foregoing alternatives to the facility;

f. economic groups affected by the facility (farmers, fishermen, tourist industry, etc.);

g. effects on the rest of the nation (e.g., long distance travel of effluents).

A detailed socio-economic study of groups b, c, and f, as well as the distribution on the rich-poor continuum, should be done. The study shoud should include numbers, race, income, family structure, opportunities for residential or economic readjustment, among other variables.

Such an analysis should contribute materially to clarifying the distributional consequences of alternatives.

A person may belong to a number of the publics suggested above. His attitude towards a project may be very different depending on which of his publics he identifies with at any one time. A technical consequence of this is that we cannot simply total all of the public accounts to get an aggregate accounting.

The Differences in the Preference of Different Public

In any case, it is quite clear that the environmental preferences of the rich and the poor are substantially different. The rich view environmental quality in terms of amenity, while the poor are concerned with escaping from dirt and deprivation. The attention of the rich may be on the beauty of the wilderness, while the urban poor may be most concerned with the security and cleanliness of their apartments. Thus the impacts of different projects will be valued differently by the different income groups.

Also, it seems likely that the distribution of environmental pollutants and disamenity is inequitable and that people who are income and wealth poor suffer disproportionately from a poverty of environment. They often live near the sources of greatest disamenity (powerhouses and sanitation plants) and cannot escape from them.

What is perhaps most disturbing is that very deliberate effort is needed to make sure that environmental improvements aimed at helping the poor do not end up benefitting the well-to-do at the expense of the poor. An example will make this clear. Say that poor people end up living near a sanitation plant. We propose to develop a regional system which will enable us to eliminate this plant and thereby improve the local neighborhood. We suspect that we have improved the lot of the poor. But this may not be the case. The sanitation plant, which kept rents low in a neighborhood, is no longer present. What is to prevent the neighborhood from becoming attractive to the non-poor, have rents bid up, forcing the renting poor to move and thereby taking away their better environment. This effect characterizes much of urban redevelopment work of the past decades.

We note in a discussion of the Muskegon experiment on land disposal a seeming positive feeling that the dollar value of homes displaced is low. From the perspective of equity considerations, we would want to have an opposite attitude.

In order to understand how these unintended effects occur, detailed tracing of the flows of incidence should be done. Not every impact need

or can be traced, but some, especially those related to displacement in the work or residence of poorer people, have high priority.

B. Regional Quality

Even though a regional waste water management system would be a very large investment, this project in any of its various proposed forms is unlikely to influence the rate of development of the region significantly. If it were not built, then there might be a substantial effect, but we must consider that a good part of that would be offset by ad hoc investment by localities.

The limited effects on aggregate growth have two main sources. Regional growth is highly dependent on outside forces related to migration and the national demand for the region's products. Secondly, these latter effects are only partially dependent on the quality and cost of waste water management alternatives. On the other hand, the differential effects (probably canceled out in the aggregate) may be substantial for specific industries. These will need emphasis.

Inter-Regional Distribution

Rather than affect the overall levels of population growth or economic development of the area, the main consequence of the system would be socially distributive: who gains and who loses, and geographically distributive: directing urban or agricultural growth in some directions or discouraging or pre-empting it in others. Consequently the time stream of development in sub-areas will be affected. These sub-areal growth effects may need justification under Sec. 102c of the National Environmental Policy Act. An equitable distribution of these effects is a useful and appropriate objective.

Such distributional effects can be substantial. A land disposal system could: a. Impact large amounts of rural land for the spraying and purification process; b. provide contracts for high technology contractors likely to be based in San Francisco; and, c. provide opportunities for growth in the suburbs of San Francisco without local costs of waste water disposal systems. Other systems would have disaggregated effects of similar magnitude.

Effects on Differential Growth

The way in which the project is administered will have strong regional distributive effects. If waste water treatment services are available to any community in the region at no direct cost, then constraints that may exist on the development of large scale areas will be loosened. Depending on the alternative system used, different amounts of local treatment will result in different constraints. This availability of waste water systems will have very definite effect on regional development. It is not policy neutral. A reduction in constraints to development is an implicit development policy, the consequences of which need to be spelled out and evaluated. An example is provided by the practices of the Metropolitan Water District of Southern California.

The Muskegon experiment mentions a "service area concept" which encourages communities to explicitly predict their demands for waste water treatment facilities. This would be responsive to the pleas above. But it is not clear that a regional system built by the Corps will easily incorporate such a concept.

Another differential effect of different alternatives will be their intrusion on poor people's homes and on public recreation areas. The low- or non-priced aspects of these must underestimate their values to the people involved. The costs of replacement may be much higher than the prices of the property. Also the dislocation effects may have undesirable short and long run consequences.

It seems to us that the only way in which alternative projects' effects on regional distribution can be evaluated is by disaggregated analysis of them. Rather than concentrating on regional growth, differential effects of different alternatives ought to be emphasized. Different subregions will be impacted by the investment, by the benefits from it, and by the dis-benefits. These must be made clear for each project. A first step is in this direction is in Section IV of Feasibility Study.

Finally a word about the effects of scale of a region-wide system. While there may economies of scale, it is likely that the physical aspects of region wide systems will be much more grand than those of local systems. At the same time, the physical apparatus will be localized in some single area. So a region's waste water management machinery will exist in a locality. The local aesthetic, health, and economic effects, as well as social well-being effects, will have to be taken into account.

C. Equity in Governance

There is a long tradition of local participation in the development and advocacy of Corps projects. As the Corps becomes more deeply involved with waste water management, and thereby the problems of urban populations, this experience will serve it in good stead. What is needed is an enlargement of the arena of legitimate actors in the process of designing and choosing projects. In this manner the Corps' professional expertise will be supplemented by intimate contact with those affected by its efforts. The result should be the choice and design of projects that will have substantial and wide support within the region.

Consumer Participation

The preferences and interests of the poor and the rich, the consumers and the farmers and manufacturers and the Blacks and the Whites are different. Yet each will be affected by a large wastewater management system. Each is legitimately desirous of influencing the kinds of projects that constructed.

We might try to develop a technique for recording the values of various interested groups and develop relative weights for them. This process has deep theoretical as well as practical difficulties. It seems much better, from recent experience, that the conflicting groups come together to consider alternatives as live representatives of their interests.

Social well-being is fostered in two ways by such an effort. The acts of participation themselves help in building community and individual competence. The process of participation brings certain social well being values, not easily explicitly measured (even qualitatively), to the attention of the community and the Corps.

Considerations of equity suggest that groups that have traditionally been left out of the design and choice process be actively included, kept well informed, and be given substantial power. These will include groups representative of the poor, the end point consumer, and the racial minorities.

Local participation is no cure-all. It is likely that cries of cooptation and feelings of resentment and disaffection will set in. These are not to be avoided but are natural concomitants. The value of incorporating the perspectives of those who tend to be left-out, and of developing an informed community, are too great to let these difficulties become hindrances.

As a result of such efforts, the Corps is likely to find a well-informed citizenry, representative of the whole population, capable of aiding it in its work. It is essential that the various groups be involved <u>early</u> in the process, that the difficulties of their maintaining interest over the many years between conception and construction be recognized, and that participants are actually a

part of the process. It is incumbent on the Corps to adequately explain the character of the alternative projects with good visual and descriptive aids. The complexity of these projects requires this for intelligent formation of opinions.

The Corps' experience in doing this is a basis for more effective efforts. The innovative aspects of the breakwater project in the Seattle District are of some merit.

Other Governmental Units

The concern for social well-being is distributed throughout government. The problems associated with wastewater management are legislatively distributed to several of the Departments, notably Housing and Urban Development and Health, Education, and Welfare, as well as the Corps among others. (The Environmental Protection Administration is already involved.)

Each governmental unit represents certain concerns as its primary ones. It would be impossible for any one unit to incorporate all such concerns as primary ones at any one time. In order that the social well-being objective be met, active participation in the choice and design process by these various Departments will be needed. There is no lack of commitment to deal with wastewater problems, so that it is likely that the various units (including those of the State) should be anxious to participate.

Since we are concerned with regional wastewater management systems, which sometimes may even cut across state lines, we will constantly face questions of centralization vs. decentralization. Should the development of the system take place in local governments, in national units (such as the Corps), or in communities? Clearly the answer is "yes" to all three. Each level of government will be able to do some jobs best. This does not mean that it has total control over the area in which it is most competent. Local efforts will have to be responsive to regional system wide effects and, similarly, regional plans and designs must take cognizance of important local values. If some piece of land is locally significant for parks, formal or informal, then the system plans cannot just readily sacrfice such land.

Regional Government

Finally, we wish to say something about the effects of a regional system on regional government. Different alternatives will have profoundly different effects with respect to the viability of regional government. There is much to be said for such governments when the region seems genuine to most people and certain problems (such as transport and wastewaters) are regional in effect. If the Corps were to set up a system without involving local governments, then a prime opportunity around which regional government can be encouraged would be lost.

Besides the efforts at local participation, one vehicle for encouraging regional governments would be the arrogation of the operation of the regional system to such a government. The operations involved would be substantial and would provide a base for further development. In the Bay area, such operations could give even further legitimacy to any one of a number of organizations. These include among others, the Regional Water Quality Control Board, the Open Space Commission, the Bay Conservation and Development Commission, and the Association of Bay Area Governments.

V. A NOTE ON METHODOLOGY

Systematic inclusion of social well-being factors in the choice process is receiving much attention these days. It is clear that these factors are important, yet even qualitative methods for use are still in the formative stage. Except for some notable exceptions, such as income equity, quantitative measures are not available.

Yet it seems possible to develop practical and usable proxies for more sophisticated measures. One procedure that will be of great value is various participation efforts. Latent but significant sentiments will be expressed better than current methods of measurement would allow. Another, will be the use of those social indicators that are being developed, so that base lines may be set and examinations of suspected trends may be performed.

A most salutary effect of some of the difficulties will be that we will be wary of setting premature standards. It is well known that standards are sourced in social as well as "scientific" procedures and it is important that we not get stuck with them too early. By enlarging the meaning of standards to include standard procedures (for participation, for example), social well-being can be effectively included in studies.

Social well-being impacts are describable and capable of being incorporated in Corps practices. It is not likely that they will be incorporated in the same fashion that physical and economic impacts are.

VI. CONCLUSION

By including social well-being impacts in wastewater management studies, the Corps is facing issues concerning urban areas in a proper fashion. By emphasizing differential equity effects of alternative projects, a major portion of this impact will be encompassed. Enlarging participation in the choice and design process will improve the capability of perceiving these impacts.

What is needed now is an enlargement of the alternatives to include the potential for effluent charges and thereby include a profound equity and social well-being effect as a result of wastewater management.

APPENDIX

We now want to review, in a detailed fashion, the contents of the Social Well-Being discussion (pp. V-7 to V-16) of the Feasibility Study. More general comments are to be found in the main text of our review.

1. "Definition"-As mentioned in the text, the definition is a reasonable one to which we have no particular objections. Greater emphasis on human growth values might be worth adding.

2. "Scope" --The listing of the scope is sufficiently broad to include social well-being concerns. The set of four divisions is adequate. In both the definition and scope the very large number of factors listed does not mean that all are of equal significance or relevance to alternative wastewater management systems. Our text emphasize the most significant in our view.

3. "Impacts" (pp. V-8, V-9). - 1,2,3. All of these need to be supplemented by distributive questions. Who receives what and how is it valued by him? Also, we note that the time preferences of rich and poor are substantially different and this is reflected in the choice of discount rate.

(4) has received the most attention in our text. As for (5) we believe that, though it is possible to learn of attitudes by "scientific" procedures, use of participation efforts are more efficient and effective. (6) does not seem meaningful. (7) talks in terms of standards that characterize physical properties. Most social well-being properties are not so describable. See text.

4. The emphasis on p. V-10 on quantitative factors should not cause the ignoring of less precise data.

5. Human Betterment Criteria (pp. V-11, 12) - Though all of the various factors are important, and most are measureable, a small number seem most sensitive to alternative wastewater management projects. These would be A, B, C, and E. These may be proxied by income data. For specific projects, F is likely to be very significant. The other values are of lesser importance.

6. Public Health and Safety (p. V-12, 13) - There exist formal procedures for incorporating these factors into practice already. Those concerned with public health, landscape and urban design, and safety engineering will represent these interests. The important factor likely to receive insufficent attention will be g.

7. Physical and Spatial Development. (pp. V-13, 14, 15)-(A) The practice of regional planning incorporates these values. No single one of the fifteen listed factors is unimportant, and the judgment of these professionals is likely to be a good source for integrating the various values. (B) The most important displacement, largely because they lack sufficient resources to bounce back, will be marginal businesses, poor families, and the elderly . (C) Discussed in text. (D) Discussed in text. We want to emphasize the importance of realizing that different groups have different preferences for amenity. Though some professions will have distinctive ideas of what amenity is, they do not represent the values of many groups.

8. Legal and Institutional Considerations (p. V-16) - (A, B, D, E) are discussed in the test. (C) is really related to involving people in the Corps procedures so that they may articulate their sentiments about alternatives. (F) involves local procedures and will naturally come up in each case.

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