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Solid Waste Disposal and Ocean Dumping

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SOLID WASTE DISPOSAL AND OCEAN DUMPING

by

John William Sellers

Commander

United States Navy

A Research Paper submitted to the University of Rhode Island in partial satisfaction of the requirements for the degree of Master of Marine Affairs.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the University of Rhode Island or any other official organization.

Signature: John William Sellers

16 April 1973

Approved by:

Date: 5/15/73
Abstract of
SOLID WASTE DISPOSAL AND OCEAN DUMPING

A broad-scope overview of the solid waste disposal problem as intensified by legislation against ocean dumping of such wastes. Since the problem of increasing ocean pollution was partly solved by extensive restrictions on ocean dumping, wastes formerly disposed of in the oceans must now be disposed of by other methods. These alternative methods are discussed and cost estimates applied insofar as feasible; effects on the environment and on the conservation of natural resources are also discussed. Some solid wastes can be disposed of in the marine environment with beneficial results and some, in limited amounts, may be processed by the oceans with no significant harm to the environment or marine animals. Efforts should be directed to determine the level of solid waste disposal which would result in beneficial effects or, at the worst, in non-harmful effects on the marine environment. The entire solid waste management problem must be considered as an entity with ocean and land disposal options, capabilities, limitations, and costs carefully evaluated to provide the optimum results to both man and the environment. High level authority will be required to provide the necessary direction in scientific and funding matters and to decide on the best options for the future.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>11</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Pollution in General</td>
<td>1</td>
</tr>
<tr>
<td>Physical/Biological Nature of the Oceans</td>
<td>2</td>
</tr>
<tr>
<td>Background History of Solid Waste Disposal</td>
<td>4</td>
</tr>
<tr>
<td>UNVEILING OF THE NEW PROBLEM</td>
<td>8</td>
</tr>
<tr>
<td>Legislation of Ocean Dumping</td>
<td>8</td>
</tr>
<tr>
<td>Lack of Farsightedness</td>
<td>10</td>
</tr>
<tr>
<td>Nature of the New Problem</td>
<td>11</td>
</tr>
<tr>
<td>Areas of the Problem to Be Considered or Excluded</td>
<td>12</td>
</tr>
<tr>
<td>CONSTRAINTS</td>
<td>13</td>
</tr>
<tr>
<td>Uncertainties</td>
<td>13</td>
</tr>
<tr>
<td>Cumulative Effects</td>
<td>13</td>
</tr>
<tr>
<td>Natural Phenomena</td>
<td>14</td>
</tr>
<tr>
<td>Data Availability</td>
<td>15</td>
</tr>
<tr>
<td>Lack of Records</td>
<td>15</td>
</tr>
<tr>
<td>Past Costs</td>
<td>15</td>
</tr>
<tr>
<td>Future Potential</td>
<td>16</td>
</tr>
<tr>
<td>Recycling</td>
<td>16</td>
</tr>
<tr>
<td>Technology</td>
<td>16</td>
</tr>
<tr>
<td>Requirements</td>
<td>16</td>
</tr>
<tr>
<td>Immeasurables</td>
<td>17</td>
</tr>
<tr>
<td>Problem Perception</td>
<td>17</td>
</tr>
<tr>
<td>Affluence</td>
<td>18</td>
</tr>
<tr>
<td>Influence</td>
<td>19</td>
</tr>
<tr>
<td>ASSUMPTIONS</td>
<td>20</td>
</tr>
<tr>
<td>Continued Increase in the Rate of Solid Waste Production</td>
<td>20</td>
</tr>
<tr>
<td>Continued Interest in Solid Waste and Technological Advances</td>
<td>21</td>
</tr>
<tr>
<td>Continued Importance of Marine Environment</td>
<td>21</td>
</tr>
<tr>
<td>Marine Environment Logical/Feasible Location for Solid Waste</td>
<td>22</td>
</tr>
<tr>
<td>OBJECTIVE</td>
<td>22</td>
</tr>
<tr>
<td>ALTERNATIVES</td>
<td>23</td>
</tr>
<tr>
<td>METHODS OF COMPARISON</td>
<td>24</td>
</tr>
<tr>
<td>Additional Considerations</td>
<td>26</td>
</tr>
</tbody>
</table>
DISCUSSION OF ALTERNATIVES

Recycling
Dredge Spoil
Sewage Sludge
Solid Waste
Industrial Wastes
Construction and Demolition Debris
Explosives and Chemical Munitions
Landfill
Deep-pit or Shallow-Ground Storage
Burning
Burning and Recycling
Composting
Life-Style Change
Combinations of the Alternatives
Dredge Spoil
Sewage Sludge
Solid Waste
Industrial Waste
Construction and Demolition Debris
Explosives and Chemical Munitions

DISCUSSION OF OCEAN DUMPING
General
Constructive Dumping
Artificial Habitats Creation
Artificial Islands
Fertilization
For Consideration
Tectonic Destruction
Mining Platforms

CONCLUSION

NOTES

BIBLIOGRAPHY

APPENDIX I--DETAILED DESCRIPTION OF ALTERNATIVES BY WASTE CATEGORIES

II--TABLES AND FIGURES
Pollution in General.

Pollution of the oceans has occurred to an undetermined extent from various sources divided generally into air pollution, land pollution, and water pollution. "In fact, there is only one pollution because every single thing, every chemical whether in the air or on the land will end up in the oceans." Historically, a great amount of attention has been devoted to the dramatic, visible, publicized pollution from oil and radioactive wastes with subsequent establishment of progressively increasing standards and controls over these pollutants. Similarly, domestic concern and attention has been increasingly focused on air and fresh water pollution as visible, harmful agents; these forms also convey a severe burden of pollutants to the seas and should rightly be stopped.

From a long-term point of view, perhaps, an equal threat is imposed from such sources as are voluntarily injected into the marine environment through direct dumping or ocean outfalls. The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) lists the following as hazardous:

- oil
- radioactive waste
- petrochemicals
- organic chemicals
domestic waste (sewage) organic wastes (including pulp and paper wastes)
pesticides military wastes
inorganic wastes (including heavy metals) heat
detergents solid objects
dredging spoil inert waste

Since the United States is the world's greatest industrial nation, uses a disproportionate amount of the world's natural resources, has the highest standard of living, and contributes materially to the pollution of the world, it is only correct that we should lead in the attempt to correct the problem. In fact, it is extremely doubtful that our society can continue indiscriminately disposing of its products in the marine environment. "Indiscriminately" is the key word, for to legislate and control the quality of the environment does not solve the entire pollution problem. Such legislation and control must be tempered with astute research, planning, analyses, and management of the disposal of the waste products of our society in a manner most beneficial or, at the worst, least harmful to the environment and to man. This paper will examine the solid waste problem in general and will focus on the marine environment as a depository for wastes as compared with alternative methods of disposal.

Physical/Biological Nature of the Oceans.

"Only the fact that so much of the surface of our planet is composed of water makes it habitable." The seas
moderate land temperatures and provide the rains for harvest and cooling; they provide a filtering system where all debris, both mineral and biological, is dissolved, decomposed and transformed into life-supporting substances. They are the universal global sinks, vast septic tanks, providing clean, fresh water by way of evaporation and precipitation. They provide economically feasible trade routes yet serve as a storehouse and covering for vast resources (oil, manganese nodules, tin, sulfur, etc.).

A great source of earth's protein comes from fish in the oceans. Ninety per cent of the living material in the seas obtains life from phytoplankton which, in turn, photosynthesize to produce 70 per cent of earth's oxygen. These same phytoplankton provide the base for the marine food chain and act as a great biological blotter, absorbing nutrients, trace metals and other materials and may successively pass these on to higher organisms. Thus, concentrations of harmful materials not considered high in surrounding waters may result in toxic amounts in higher forms.

There is a delicate balance in the oceans, particularly of the marine food chain, yet the oceans naturally process many of the constituents which are now termed pollutants.
(e.g., mercury, lead, hydrocarbons, radionuclides).* Man, however, is nearly doubling the quantities of these materials present at a rate far in excess of the natural evolutionary process of the oceans, with some future, nearly unknown effect on the biosphere and on the food chain. The seas are not limitless even though they may appear so, and are effective in all natural functions; they are the only portion of our biosphere which have no outlet for refuse. Since all life is interdependent, any change seriously affecting any living system or biochemical cycle can have a major impact on life as a whole. Man is not a spectator but a participant in the cycle. Historically, man has failed to consider himself "involved" in the processing of solid waste.

Background History of Solid Waste Disposal.

Pollution is always present but we make value judgments as to its importance relative to the benefits gained. The stage of a country's development affects the perception of

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*"Estimates made in the mid-sixties suggest that every year, nature, by its own unaided efforts, flushes some 25 million metric tons of iron into the seas and between 300,000 and 400,000 tons of manganese, copper, and zinc. In addition, lead and phosphorus each provide 180,000 tons and mercury 3,000 tons. The point about these last three is their toxic effect. Lead and mercury are lethal poisons; phosphorus contributes to algae blooms. To these natural flows we must now add the vast and accelerated run-off from modern technology...," and deliberate dumping at a time when only one-third of humanity has fully entered the industrial arena. Barbara Ward and Rene Dubos, Only One Earth (New York: Norton, 1972), p. 201.
pollution as a problem and the resources and priority as-signed to it. Factors affecting the magnitude and nature of the pollution problem are: population, rates of production and consumption, and the level and use of technology. Many other facets affect its perception as a problem: legal norms, moral values, and economic, social, political, and cultural considerations and constraints. Most problems are created locally or regionally and could be resolved in these areas should local factors and facets point to the desired solution.

Even with a national total of about 62 million tons of solid wastes dumped in the ocean, locally dumped waste is relatively small in terms of total pollutant impact; yet such disposal lends itself more readily to control and coordination than many other forms of pollution. Regardless of recent steps taken towards such control, there is every reason to believe that pressures will mount for increased ocean dumping in the future due primarily to land scarcity and increasing cost as well as to aesthetic interests.

The effects of ocean dumping vary greatly, depending on composition, physical state, method of discharge, affinity of marine organisms for assimilation, and local environmental conditions. Wastes may result in provision of excessive nutrients (nitrates and phosphates) causing over-fertilization resulting in algal blooms and subsequent
de-oxygenation of the water when the blooms die (e.g., the "red tide," the Great Lakes, the Potomac River). Or they may result in bacterial or heavy-metal poisoning. Recent concentrations in 33 of the States and in Canada caused many fishing areas to be closed. On 1 May, 1970, valuable shellfish beds in the New York Bight and off Delaware Bay were closed due to high concentrations of coliform bacteria (though harmless, they are rough indicators of pathogens), 50 to 80 times higher than FDA standards.\textsuperscript{13}

The volume of industrial wastes in the United States — already twice the volume of domestic wastes — is expected to increase seven-fold by 1980.\textsuperscript{14} If biochemical oxygen demand rate (BOD) is used as a measurement, effluents from American industry are estimated to consume three times as much oxygen in the water as the sum of all the effluents from municipalities with reasonable sewage systems. Some 40 per cent of the water treated in municipal sewage plants comes from industry and it has been estimated that over a quarter of a million of these industrial plants produce effluents beyond the handling scope of municipal sewage systems.\textsuperscript{15}

In the main, municipal systems must dispose of both urban and industrial wastes ranging from wet sewage through old, discarded steam engines, broken garden furniture, and the extravagant throw-away items of the modern consumer which
annually include 48 million metal cans (250 per person),
26 billion bottles (135 per person), 65 billion metal and
plastic bottle caps (338 per person), and 7 million junked
autos plus more than $500 million worth of packaging
materials.16

Due to market competition and improved health and safety
standards, the amount of miscellaneous packaging material
used (not consumed) by Americans has rapidly grown: throw­
away bottles, cans, food wrappers, toothpaste tubes, cartons,
boxes, etc., were estimated to be 50 million tons in 1966
and may grow to 75 million tons a year by 1976. These are
not free gifts; in 1970, the American food industry alone
spent more than $24 million for plastic film just to wrap
foodstuffs.17

Of 50 million tons of paper and paper products used in
1967, 80 per cent was used one time and discarded. While
about 10 million tons were reused of the 80 per cent,
30 million tons became solid waste approximating some
35-50 per cent of domestic and commercial waste collections.
Growth of the paper industry is expected to double by 1985.18

It is estimated that in 1968, Americans threw out
7.6 million television sets.19 The list of estimated
"throw-aways" is never-ending.

The volumetric problem of solid waste illustrated above
becomes critical when future projections are made. In 1920,
the average household generated 2.7 pounds of solid waste per day; in 1970, the figure was 5.3 pounds per day. At the present rate of growth, 1980 could see as much as 8 pounds of solid waste generated per household per day. By adding industrial wastes from mines and factories, the per capita figure could be as high as 50 pounds per day — about 5 million tons per day for the nation.20

Although the statistics for industrial wastes are often difficult to obtain, estimates have been fairly accurate for solid waste dumping exclusive of dredge spoils and explosives. There was a four-fold increase in tonnage dumped at sea from 1949 to 1968. In 1959, industrial waste dumped at sea approximated 2.2 million tons; by 1968, the amount had more than doubled to over 4.7 million tons. During the same period, sewage sludge disposed of at sea increased from 2.8 to 4.5 million tons.21

UNVEILING OF THE NEW PROBLEM

Legislation on Ocean Dumping.

Because of increased attention to marine environment pollution and the relative ease of controlling dumping of solid waste as one of the polluting sources, the United States Congress, on 23 October, 1972, passed a comprehensive Act regulating the transportation for dumping, and the dumping, of material into ocean waters. Under this Act,
the Environmental Protection Agency (EPA) administers the
granting of permits required for transportation from United
States territory for dumping and for dumping of anything
from anywhere, inside the United States territorial waters
or contiguous zone. Permits for dumping of dredge spoils
are to be granted by the Secretary of the Army (Corps of
Engineers) in consultation with EPA. In all instances, a
comprehensive environmental impact statement is required and
waivers may be considered. The Act does not regulate dis­
position of any effluent from any outfall structure when
regulated by the other Federal Acts, nor Federal or State
programs for construction of fixed platforms, artificial
islands, or sea-floor devices, nor dumping of oyster shells
and other materials for fishing improvements. 22

The domestic Act summarized above was reinforced by an
International Convention for the Dumping of Wastes at Sea
signed in November, 1972, and expected to become effective
sometime in 1973. 23 The essence of the Convention establishes
an organization for coordination, requires governments to
regulate dumping and to monitor such dumping, and establishes
three categories of dumping material: a "black list" of
prohibited materials (e.g., certain pesticides, persistent
oils, persistent plastics, cadmium, mercury, etc.), a "grey
list" of materials which may be dumped only under special
conditions and requiring special permits (e.g., cyanide and
fluoride wastes, other materials containing heavy metals such as arsenic, lead, and chromium, etc.), and an "all others" category which may be dumped under general permits only. 24

**Lack of Farsightedness.**

On the face of it then, the ocean dumping problem has been solved; control is established and hazardous items are prohibited from being dumped in the marine environment. EPA is currently developing guidelines for implementation of the legislation which will probably result in progressively diminishing limits for dumping of toxic materials in the future. 25 While these actions appear to resolve the present problem of ocean dumping by restricting such dumping or eliminating it altogether, solid waste accumulation and disposal in the future have not been thoroughly considered.

With ocean disposal banned, only land disposal remains. Landfill problems are already becoming acute in some areas because of the scarcity of land and its relatively high price, the aesthetic degradation by way of disposal sites, and the general disinterest of the population. Higher industrial costs are being forced by pollution controls which establish limits for the environment rather than address the problem of what to do with the waste accumulation. Further, there is the anticipated rapid growth in quantity of wastes as technology progresses.
Nature of the New Problem.

The initial legislative steps were probably timely and in the right direction since action on problems such as marine pollution must be taken early enough to prevent the problem from having its fullest impact — and possibly achieving an irreversible state. There are indications that when the oceans' capacity to assimilate pollution is exceeded, environmental deterioration may be rapid and severe, quickly spreading into other ocean areas.

Because of the timely legislation, we have a period of grace in which to perform the research and analysis necessary to determine the constructive uses of the ocean for beneficial or non-harmful waste disposal. Effective research, analysis, and management of the positive environmental aspects of ocean dumping may well contribute to easing other problems created by emphasis on other pollution control measures (e.g., costs for other controls may make the nation less competitive in the international market).

One of the items requiring careful research is that of the continued complete prohibition on pollutants in the ocean which may be counter-productive since the marine environment is capable of recycling some amount of pollutants. Further, what may be detrimental in one location may be beneficial in another, so varied are the oceans. This variance coupled with variable economic considerations
(including social costs) among locales will likewise vary the pressures for ocean dumping. All these variables render benefit-cost analyses exceedingly difficult, particularly when hampered by the emotional biases usually present in ecological considerations. The temptation to dump wastes as landfill into estuarine areas may become great even though these areas have a biological productivity per unit of surface greater than that of agricultural land; but other ocean areas have practically no productivity and may benefit from dumped wastes. This then, is the management problem to be faced. In substance, the marine disposal of pollutants is not simply a matter of good versus evil but a problem of how to turn the evil into good and how to best utilize the marine environment as an integral part of the solution to the solid waste disposal problem.

Areas of the Problem to Be Considered or Excluded.

The solid wastes to be considered in this paper are those unwanted wastes generated by man in solid or liquid-suspension form which may be deliberately disposed of into the seas or estuarine areas. Explicitly excluded from consideration are radioactive wastes (currently adequately controlled), oil pollution, pollution transported by air or agricultural/industrial run-off, and thermal pollution.

Specific waste categories to be considered are:

1. Dredge spoils
2. Sewage Sludge

3. Solid waste (trash, residential, industrial, commercial, institutional and agricultural)

4. Industrial waste (exclusive of occasional waste)

5. Construction and demolition debris

6. Explosives and chemical munitions

A general discussion of these categories will follow under the Discussion of Alternatives section, while detailed benefit-cost analyses where available are to be found in Appendix I.

CONSTRANTS

Uncertainties.

Cumulative Effects. Our knowledge of the marine environment, long-term effects of pollutants introduced, detailed water movements and dispersal, synergistic effects of pollutants and ocean processes, and fish and plant life of the oceans is woefully lacking. "We are profoundly ignorant of much that goes on in the marine environment.... We lack knowledge of fundamental aspects of the physical, chemical, and biological workings of the oceans." Research efforts have been generally directed towards determining deleterious effects of waste disposal rather than beneficial effects. With such uncertain knowledge of total effects in the oceans, determination of costs also become uncertain.
The extensive time required for many effects to be noted in the marine environment also causes uncertainty in making value judgments. The effects of a stranded oil tanker are immediately seen and felt whereas the effects from sewage sludge disposal may take a number of years to be noticed and then only when the limits of ocean endurance are reached.* No one knows what substances have been dumped in the ocean and been forgotten — or ignored — but may yet have some cumulative effect on the marine environment.

**Natural Phenomena.** Natural phenomena, not completely understood, often lead to confusion, uncertainty, and incorrect judgments. Fishery populations increase and decrease for unknown reasons. The infamous "red tide" appears but is not fully explained. Ocean currents and temperatures sometimes change for no known reason. Yet we are quick to blame the observation of change on man-made phenomena if a suitable rationality can be developed. In short, we are still shamefully ignorant of the biosphere around us.

*In the New York Bight waste disposal area, where sludge has been dumped for 43 years, the oxygen concentration as a percent of saturation declined from 63 per cent in 1943 to 59 per cent in 1964 (4 points in 21 years). By 1969, it had dropped to 29 per cent (30 points in 5 years), and was as low as 10 per cent in the center of the dump. This may indicate that a threshold had been reached followed by rapid deterioration of water quality. The threshold is uncertain as is the recovery time — if any exists at all. Council on Environmental Quality, *Ocean Dumping: A National Policy*, (Washington: U.S. Govt. Print. Off., October, 1970), p. 14.
Data Availability.

Lack_of_Records. Poor records of dumping, both quantitative and qualitative, prevailed until the past few years, for ocean dumping was generally considered a routine right of all men. A review of several high level solid waste management studies originated between 1965 and 1970 reveals a fairly broad spectrum of estimates of costs, quantities, and relevant benefits. This may, in part, be the result of a lack of common terminology and definition both among study groups and regions studied. Also, the fragmented nature of the study groups themselves undoubtedly contributed to the differences. Estimates used in this paper are representative.

Past_Costs. Past costs, even with retrogressive analysis, are bound to be uncertain, as is the perception of the costs. To an oysterman, the loss of his oyster bed is incomparable, but to the city dumping sewage into his oyster bed, the cost of any other disposal form may well be prohibitive. Which is more preferable: DDT which may contaminate a fishery but subdue malaria in an area, or malaria? In industry, there was no requirement to worry about pollution, therefore, the simplest and possibly cheapest method of disposing of unwanted by-products was used — ocean dumping.
**Future Potential.**  

**Recycling.** Recycling of our already scarce resources appears to be a ready answer to many of our problems. In a general sense, matter can neither be created nor destroyed; man processes and uses matter and may change its chemical composition or basic form, but in some combination of solids, liquids or gases, all of the original matter of planet Earth continues to be a part of the world around us. However, recycling of all waste material may not be desirable let alone practical or economical. There may well be items or categories of waste which should best be left to nature's recycling schedule. Benefit-cost analyses have not been conducted in this area of interest as yet, and it is not known at this time what degree of recycling is desirable from all aspects.

**Technology.** Future technological developments in pollution control and devices are uncertain, depending for the most part on the qualitative and quantitative efforts devoted to them. In turn, this depends on the perceived requirements for such controls, be they to stop pollution or to efficiently and economically dispose of wastes. In the former case, more wastes, though possibly of different composition, will ensure augmenting another portion of the pollution problem.

**Requirements.** Future need for artificial islands or for separate storage of the potential resources contained in
waste is unknown. Artificial islands may themselves serve as storage, but later reclamation might create special problems. Also, such islands would present interesting legal problems on both the domestic and international levels. It may be feasible and desirable to "store" segregated wastes in areas pending future technological development of efficient reclamation methods. This process depends in great part on the determined need felt by governments and individuals for preservation or retention of natural resources for future re-use (note that a high percentage of the minerals "thrown-away" were imported in the first place and import demands may be expected to increase).

**Immeasurables.**

Problem Perception. The perception by government and individuals of the magnitude and far-reaching consequences of the problem may be expected to increase — but only if objective realization of the problem is achieved. Since 1965, the Federal government has instigated several studies and programs intended to reduce specific types of pollution and has had moderate success in some areas through legislation (Federal water quality control, clean air, automobile anti-pollution features). A great many individuals are eager to help assuage pollution but with reluctance to pay the costs. Basic inertia appears to have been overcome and environmental improvement programs appear to be gathering...
momentum. Whether this momentum will continue when it collides with the out-of-pocket costs for the individual, is questionable.

Where solid waste is concerned, the general perception of individuals has been one of short-term interest: take it away from where it is not wanted, but do not worry about it after that ("out-of-sight, out-of-mind").

**Affluence.** The American standard of living — the Age of Affluence — has contributed to the development of a peculiar social standard reflected by the "throw-away" society. Few people now save and return bottles or cans, metallic foil, or even major appliances. The garbage grinder has freed the housewife from the malodorous garbage can and the burden of preparing "left-overs". Urban renewal projects have actually increased the solid waste accumulation of construction and demolition debris. Repairs are out, throw-away and replace is in. Keep up with the Joneses. New cars every year. Junk mail proliferates, quickly scanned and discarded. The Age of Affluence with its easy credit, easy financing, and easy money appears to be firmly ensconced as a social norm. Nearly everyone, except the very poor, finds it "easier" to buy a case of canned beverage rather than of returnable bottles of the same brand though the refund on the bottles is 30¢. The effort to save and return the bottles is not worth the 30¢ and may be socially unacceptable. Programmed
obsolescence may have been cause or effect of this social attitude, but regardless, it contributes heavily to the increase in solid wastes. That there will continue to be strong pressures for an even easier, higher standard of living is certain but a change of social mores in the direction of individual resources conservation is questionable. The Age of Affluence might well be called the Era of Effluents.39

Influence. The influences and future attitudes of various special interest groups are in doubt inasmuch as they may well reflect the future perceptions of government and individuals as well as any derived social change which may occur. Ecologists may exert stronger pressures in the future or they may become less dedicated. Industry, in general, appears not so much concerned with ecology as with its own image and the drive for profits. Labor, as a group, appears to be similarly disposed. Fishermen and certain scientists may be expected to continue striving for a clean environment at least insofar as their direct areas of interest are considered. Scrap dealers may plead for government assistance as salvage costs increase. As a byproduct, there appears to be developing a pollution control industry which may well speak with increased authority in the future.

Social and political forces will be at work, perhaps at counter-purposes. Local political forces may have to yield
influence to regional, State, or even Federal controls. Legal problems and influences are bound to be felt throughout the arena of environmental control, for such controls may be interpreted as restricting human rights — specifically the right to despoil without being held responsible. It is just as feasible that the growing energy, natural resources, food supply, and disposal crises will cause pressure groups — and technology — to measure and resolve these crises. At this time, the direction and effect of the various pressure groups is uncertain.

ASSUMPTIONS

With the continued need for solid waste disposal established as fact, a number of assumptions need to be logically made for any analysis of the continuing problem.

**Continued Increase in the Rate of Solid Waste Production.**

The high rate of increase in amounts of solid waste has been caused by a number of factors: increased production of time and labor-saving devices; rising affluence within nearly the entirety of the population causing increased demand for items other than purely subsistence ones; rising population; built-in obsolescence; the drive for urban renewal, new construction, new roads, etc.; and, related to all the foregoing, the change in social mores that accompany a "heavenly-bestowed" society. Zero population
growth will not result in a stable population until the next century. Old construction will continue to age and new construction, never built to last long, will age even faster. It would require a major effort or phenomena to halt even built-in obsolescence let alone reduce the drive for more luxury items and the "better life". It therefore appears sound to assume that there will continue to be an increase in the amount of solid waste produced in this country, although the rate of increase may decline.

**Continued Interest in Solid Waste and Technological Advances.**

It is assumed that government (both Federal and local) will continue its efforts to reduce pollution of our biosphere and that the EPA will continue with increased responsibilities. As a result, more effort — and funds — will be applied to technology by way of developing specialized efficient methods of controlling not only pollution but the wastes from the control methods themselves. Even as advancing technology produces the problem, technology will be capable of correcting it.

**Continued Importance of Marine Environment.**

As world population continues to increase, the resources of the oceans will assume even greater importance. As a major source of protein, the fisheries of the world will become of even greater concern to man while the continental
shelves and estuarine areas will ascribe to more research and protective activity. Efforts to resolve pollution problems of the oceans will become greater due to their increased importance. This will cause direct confrontation with the following assumption.

**Marine Environment Logical/Feasible Location for Solid Waste.**

Technology and acceptance of it may not develop rapidly enough to provide early efficient disposal of solid waste (and this will not occur until the perception of the problem increases materially). In this case, the increasing cost of land, transportation, and labor concomitant with the increasing marginal disutility of the waste disposal function as employment and with the individual and political disapproval of having a "dump" for a neighbor, will logically increase the need — and pressure — for disposal in the marine environment. In spite of counter-pressures from science and law, the urgency for finding locations for waste disposal less objectionable to the majority of people than nearby land areas, will dictate increased dumping in the oceans and, perhaps, estuarine landfill.

**OBJECTIVE**

This study of solid waste disposal relates directly to the problem of how best to utilize the marine environment constructively as part of the solution to the disposal
problem, if this is necessary or required. In order to determine the need for utilizing the oceans for waste disposal, it is necessary to determine the utility of all disposal methods with their costs, both quantitative and qualitative. Therefore, the objective is to determine if the marine environment will be required for solid waste disposal in view of practicality, costs and benefits of other alternatives. Results may indicate the need for further analyses to determine the maximum acceptable extent of ocean dumping.

ALTERNATIVES

Alternatives to ocean dumping of solid wastes appear numerous. Each is considered separately, although there are significant interrelationships. A summary of alternatives available now, in the near-term, or within technological achievement is listed below with a preliminary, brief statement of major advantages and disadvantages.

1. Recycling - conserves selected natural resources by returning them to stockpile or production; expensive.

2. Landfill - applicable to nearly all solid waste and relatively simple; becoming increasingly expensive, limited land available, and resources lost (or hard to recover).

3. Deep-pit or shallow-ground storage - conserves selected resources for future technology; limited storage volume; expensive.
4. Burning - inexpensive and simple; lose resources and cause other pollutants.

5. Burning and recycling - conserves some resources; more expensive than straight burning and still causes other pollutants.

6. Composting (recycling) - sanitary processing with consequent direct closing of a natural process cycle; lack of demand for product due ready availability of substitute fertilizers.

7. Life-style change - reduce amount of disposable waste, render recycling less expensive; retrogression in the process of attaining standard-of-living improvements, contrary to human desires.

8. Various combinations of foregoing - may provide best trade-off possibilities; expensive; requires extensive research and development.

METHODS OF COMPARISON

For comparison of alternatives to ocean dumping, a simplified measure of effectiveness is used, namely, tons of waste disposed. Similarly, a simplified measure of cost is applied as the estimated dollar cost per ton of waste disposed. This necessarily includes other measurable quantitative costs where appropriate and available; e.g., transportation, resale of recycled waste material. Incomensurables
have already been described in some detail, as have the cost figures impossible to obtain at this writing.

Establishing a suitable criterion that reflects the objective is difficult in this instance inasmuch as the decision rule most appealing is to dispose of the most solid waste at the least cost — obviously unacceptable. The overall problem of solid waste disposal involves disposal of all wastes (fixed level) at minimum cost. Considering the assumptions, it appears feasible that some or all solid waste might be disposed of by means other than dumping in the marine environment but probably at some elevated expense. Ocean dumping is attractive for coastal areas, and most large cities are either on the coast or have ready access to it. Therefore, it appears that one consideration is whether ocean dumping is, or will be, required at all, and if so, under what acceptability standards. The marine environment must be protected, but to what extent is uncertain. However, not all is uncertain, for there is every indication that some types of waste are not harmful, some are helpful, and limited amounts of some others may be processed in the marine environment. Hence a useful criterion is to determine the tons of waste which can be disposed of at a given cost ($/ton). Then we should be better able to determine the maximum amount of solid waste which can be dumped in the marine environment with no significant long- or short-term damage (fixed level), at minimum cost.
Additional Considerations.

In addition to the major criterion, other aspects are relevant. For example, the amount of each type of solid waste absorbable by the marine environment with no lasting harmful effects must be determined. The cumulative effects, if any, of the various types of solid wastes must also be determined. These two determinations constitute the decisive elements of solid waste control, but are unknown at this time. A strict dollar costing is questionable in that placing a dollar value on amenities, political effects, and social as well as psychological needs is extremely difficult if not impossible.

Economic effects of expensive pollution control measures may hinder competition in the world as well as domestic market, for increased production costs will surely result. Therefore, it appears imperative that production costs be held down wherever possible by realistic, efficient pollution control and solid waste disposal measures. Where ocean dumping looks most attractive from an economic viewpoint, the situation must be carefully analyzed in accordance with the objective to ensure no significant damage to the marine environment. To enable better comparisons, the discussion of alternatives will concentrate on methods exclusive of the marine environment insofar as feasible.
DISCUSSION OF ALTERNATIVES

Each alternative to ocean dumping will be discussed briefly. Except where noted, data is from 1968. General information pertaining to each waste category will be discussed under recycling; for detailed information, see Appendix I which, together with this section, serves as the basis for Table I and for the discussion of combinations of the alternatives.

Recycling.

Recycling holds great potential as a solid waste disposal method in that it preserves scarce natural resources on a selected basis. Further, through the process of returning resources to useful life, the quantity of waste requiring ultimate disposal is reduced.

**Dredge Spoil.** Dredge spoil constitutes about 80% of all tonnage dumped in the marine environment. Of this, about 35% is polluted and the remainder totally acceptable for sea or land disposal. As fresh water quality control standards gradually take effect, the percentage of polluted spoil should decline. Because of the nature and variety of dredging, even in new projects, spoil has not generally been considered worthy of recycling. Landfill with diked spoil has been conducted often in port areas and can be considered a type of recycling although at increased cost over the
normal range of 20 to 55 cents per ton.\(^2\) Costs per ton to dispose of dredge spoil varies widely throughout the country due to labor, volume, type of dredge, distance to dumping area, testing required, etc. Several types of recycling uses for dredge spoil are currently being researched, but cost estimates are not yet available (though it is anticipated that costs per ton could increase by as much as 100%). Recycling projects under development include: subsidence and erosion control, agricultural land improvement, land reclamation of marginal land for pasture land (saline spoil acceptable), and production of bricks or construction materials.\(^3\) Results of research for recycling to the marine environment would generally cost the same as present disposal; these include: creation of marshland refuges and spoil islands for artificial habitats, creation of shellfish habitats, and pre-planned use for landfill in waterfront or island parks and recreation areas.

**Sewage Sludge.** EPA is now working on measures to implement the 1972 Federal Waters Act requiring secondary treatment of all sewage sludge by 1977.\(^4\) The range of costs for at sea dumping of sewage sludge was $0.80-$1.20 per ton which included undigested sewage.\(^5\) This cost can increase to $5/ton for digested sludge thickened and dumped nearshore and to $40/ton for digested sludge dumped several hundred miles offshore. Pipeline disposal of treated sludge to the
Solid Waste. Recycling of solid wastes is a complex management problem in itself. The 1970 annual national direct cost for collection, transport, processing, and disposal of "refuse" approximated $4.5 billion with some 337 thousand people directly employed in the industry. It is notable that only 20% of the total expenditure was devoted to salvage and disposal. Yet the annual disposal of 25 million tons of paper and paper products, 14 million tons of glass, 12 million tons of assorted metals (excluding junked automobiles), and 2.2 million tons of rubber constitutes a significant portion of our national material wealth. At this time, recovery of paper and paper products and of
certain metals is feasible, but glass, rubber, plastics, and many others need the development of recovery techniques and a general public acceptance for the need. 51

The two major problems with salvage of solid waste materials are the requirements for individual cooperation and the general failure to look at the waste problem as one complete system. In-plant recycling is common and this reduction at the source recycles some half of the generated waste; another 25% is disposed of by the generator directly, leaving about 45 million tons of refuse to be disposed of by private contractors or municipalities. 52 An indeterminate amount of this 45 million tons is capable of being salvaged and reused were the demand great enough and raw materials not readily and cheaply available. As it is, the salvage business is estimated to be a $5-$7 billion enterprise in the United States even though plagued by problems. 53 Rubber has been salvaged for more than 100 years; waste rubber brings $7.50-$14.00/ton at the plant and, after reclamation, is worth $200-$250/ton. On the other end of the scale, fly ash from power plants and incinerators can be used in cinder block, as road ballast, etc., but only 10% is so used at present. The remainder must be dumped somewhere for a cost of $0.40-$2.00/ton. 54 Possibly all could be used were it not for other readily available raw materials.

For product unity, most composting plants employ
magnetic separation to remove tin cans from the waste; eleven municipal and two private contractors are also so equipped. Salvaged tin cans are sold for between $10-$20/ton. Estimates for a Washington, D.C., incinerator plant for a can-metal recovery system, including operating and amortization charges, disclosed a cost of $13.60/ton to recover the material; since shipping charges would be added to this cost, the plan was not considered economical.\textsuperscript{55} It is estimated, however, that if all incinerated refuse were properly burned, the residue might contain 10 million tons of iron; 1 million tons of aluminum, copper, lead, zinc, and tin; 1.4 million tons of glass; and smaller quantities of nonmetals and precious metals.\textsuperscript{56}

Automobile recycling is a national problem posing many difficulties. Copper is normally salvaged because of its high price, but transportation and processing costs inhibit salvage of the bulk ferrous materials. In 1966, six million scrapped cars were processed and sold for reuse but estimated additions to the scrap file were from 10-20 million cars scattered throughout the country. In 1968, 43,000 cars were abandoned in New York City and 24,000 in Chicago; nationwide, over half a million are abandoned annually and the figure is climbing.\textsuperscript{57} In spite of high transportation costs (between $10-$12/ton for barge or ocean transport and $0.04-$1.00/ton-mile for truck transport), about 68 million
tons of scrap metal were salvaged in the United States for reuse in 1965. Due to the high capital cost of metal shredding, stripping, and compacting plants, no estimates of salvage value per ton are available.

Composting and incineration as recycling measures will be discussed later.

**Industrial Wastes.** Recycling of industrial wastes appears to be necessary in most cases for, although the wastes vary widely, they usually contain nutrients, heavy metals and other toxic substances which may remain toxic in any environment. Wastes normally considered are waste acids, paper mill wastes, chemical wastes, oil drilling wastes, and waste oil. Previous ocean disposal costs ranged from $0.60-$9.50/ton for bulk wastes (99.5% of those disposed) to $5-$130/ton for containerized wastes. There are ongoing research projects for recycling of industrial wastes but no cost data is presently available. The burden is upon technology; however, changes in industrial processes and recycling can be effective as evidenced by the fact that average waste from modern sulfate plants is only 7% of wastes in the older sulfite plants. This remaining waste will still require treatment, processing, or disposal, perhaps by storage ashore in containers, and any of these methods will be significantly costly.
Construction and Demolition Debris. About 6.5 million tons of generally dense and inert waste material is generated each year, most of which comes from demolition. There is very little waste material from construction and most of that is reused. In fact, much of the demolition is also reused. Generally, this category of waste is in demand for stable landfill. No research efforts are known to be in progress towards recycling of all or selected types of construction and demolition wastes, but they are not believed to be toxic or harmful except insofar as they cover other material when dumped. Hauling costs are the only known expense at about $0.30/ton-mile.

Explosives and Chemical Munitions. Recycling of ammunition has long been common practice where feasible; only about 10% of "waste" ammunition has been dumped in the ocean for an average of 2840 tons per year at a cost ranging between $15-$90/ton (average of $15). Since ocean dumping of explosives and chemical munitions was banned on 24 February 1971, an extensive research and development program has gone forward on projects to safely and efficiently dispose of ammunition not reclaimable and to increase the types to be reclaimed. However, funding for the projects has been slow. Estimates for the reclamation or destruction of the previously unreclaimable ammunition range from $40-$800/ton for safe disposal in the future. No data is available for chemical munitions but recycling appears technologically feasible.
Landfill.

Currently a common type of disposal means for many types of operations, landfill is heavily dependent upon the existing land-use plans at a time when materials are readily available. Land use planning seldom includes solid waste disposal. Landfill is widely used for reclamation and may represent a stockpiling of material until contained values become sufficiently important to justify segregating and reprocessing.

The major problems with landfill lie in siting, increasing land costs and scarcity, and public acceptance. Of 90,000 more or less recognized land-disposal sites, about 19,000 were planned and only about 12,000 were subject to a degree of local control that identifies them as "sanitary." Only about 1680 sites enjoy any degree of local acceptance and only about a third of these actually meet the requirements for sanitary landfills. EPA is forcing the former open dumps to either close or convert to sanitary operations, but the shift is slow and expensive (e.g., in California, sanitary landfills constitute 9% of the sites yet employ 38% of the manpower in the industry). Sanitary or controlled landfill costs approximate $3/ton while uncontrolled open dumps cost between $0.15-$0.70/ton exclusive of land costs. Compaction is normally done on site by tractor to reduce volume requirements.
Landfill sites convenient to urban centers are becoming scarce; however, well planned and controlled sanitary sites are capable of preserving amenities and actually providing increased land values (e.g., golf course landfill in Hollywood, California, Mount Trashmore near Chicago, Mount Trashmore near Virginia Beach). An indeterminate number of potential landfill sites exist in the United States including all the unreclaimed land resulting from mining of ores, sand, gravel, rock, etc. Shipping costs of about $0.30/ton-mile will have to be considered in such planned landfills and may significantly increase disposal costs; pre-compaction may reduce these costs somewhat. Nearly all waste categories are amenable to disposal by landfill.

Deep-Pit or Shallow-Ground Storage.

This alternative appears to have high future potential if carefully planned, managed, and controlled. Selective separation of waste products could be applied and segregated storage made in areas not foreseen as having future potential for other uses. Such a method provides time for determination of future critical material needs and for technology to develop retrieval means. As in the previous methods, suitable sites appear to be ready made in abandoned mine-shafts and in surface-mined areas. "Resource savings banks" could well be established in this manner.

A less desirable method would be to "store" selected...
waste types such as junked autos without prior separation of desired materials. In any event, compaction or reduction prior to storage would be required. Major costs would include hauling, compaction, segregation, and land acquisition.\textsuperscript{73}

**Burning.**

Destruction of waste materials by burning has long been common in the United States. Recent anti-pollution controls have eliminated town dumps as burning sites and have required air pollution controls on municipal and industrial incinerators as well. Municipal and industrial incinerators account for 30-50 per cent of the total trash disposal in the United States, but under complicated circumstances such as the wide variety of materials submitted for burning (from wet garbage with a heating value of 2,000 BTU/pound to polystyrene with 19,000 BTU/pound and to scrap metal with zero).\textsuperscript{74} Other complications include the toxic gases frequently resulting from burning of plastics, nonburnable material control, and fly ash precipitation and removal. There are many different sizes and types of incinerators and their costs are most often calculated in dollars per ton of rated 24-hour capacity. Capital costs vary between $3,000-$6,000/ton capacity depending on the type of material handled, degree of mechanization, and air pollution and other health standards to be met. These plus housekeeping costs and quantity of waste also
affect ultimate operating cost which may range between $2.50-$7.50/ton (costs are from 1959). Operating costs for fly-ash precipitators were estimated to be about $4,000/precipitator/year. 75

One method of making incinerators less costly is through design and use of waste-heat recovery systems which constructively use the heat generated by combustion of wastes for steam production. This method has been used exclusively in Europe but not in the United States. Capital and operating costs vary considerably with locale. Representative of the method is the Salvage Fuel Boiler Plant at Norfolk, Virginia. This plant operates one boiler per week on a five day, 24-hour/day schedule. Of approximately 140 tons per day incinerated, 20 tons of residue remains requiring further disposal as landfill. The original capital investment was $2,200,000 in 1967 and improvements are now planned at a cost of $1,700,000 in order to correct deficiencies, improve metal recovery systems, and comply with air pollution requirements. Operating and maintenance costs for 1969 were $10.65/ton while cost credit for steam generated was $5.75/ton yielding an incinerator cost of $4.90/ton excluding capital costs (amortized for 6 years to $10.16/ton) but including residue removal and disposal. 76 Certain economies of scale may be assumed for larger capacity plants in capital costs; e.g., an 800 ton/day capacity plant may have a capital cost of
between $3.5-$6.0 million but may expect operating costs to decrease by a factor of 2-6. Given an urban area with a sufficient amount of waste for consistent operation, it is feasible that applied technology could develop a power-producing plant fueled primarily by solid wastes.

**Burning and Recycling.**

This alternative actually varies but little from burning except insofar as some costs may be recovered through sale of recycled materials. While it is advantageous to remove metal, large objects, and noncombustibles from waste prior to burning, salvage experience in the United States has generally been unprofitable. Recycling and burning both have been thoroughly discussed as individual processes and the major effects of combining them intelligently would be to preserve resources while simultaneously disposing of solid wastes not considered recoverable. In point of fact, with waste-heat recovery for power production, even more resources would be conserved while constructively disposing of solid wastes. Unfortunately, most of the readily-burned wastes are also capable of being recycled (e.g., paper products, wood, digested sewage). On the other hand, many non-burnables are capable of recycling before or after a burning process (e.g., metals, glass, rubber). It is possible that, as resource availability decreases and prices rise, the demand for recycled material will increase.
For funding reasons, municipalities prefer to build incinerators at low cost and suffer higher operating costs.79 This same funding principle reduces the plant's capability for efficient recycling of salvageable material.

Composting.

Though widely used in Europe, composting has met with little success in the United States probably because reuse has been more expensive than manufacture of a new material. Composting has been looked on as a business rather than as a means of solid waste disposal, and as a business it was expected to generate profits thereby adding a burden not experienced by the other alternatives. Basically, composting is a biological process by which organic wastes are naturally transformed by decomposition into a stable, humuslike substance. Completely automatic systems have been developed using refuse as an input, removal of metal particles by magnetic separation, removal of nonmagnetic metals, moisture addition, continuous low pressure air addition with thorough mixing and granulation, natural aerobic microorganisms decomposing the material at spontaneous temperatures lethal to pathogenic organisms, ultimate separation of durable matter from the compost, and final removal of glass shards, etc. Some 60-70% of the refuse can be converted to a useful fertilizer in this manner.80 The non-decomposables can be recycled or disposed of as landfill.
Cost estimates on composting plants range from $2.50-$20.00/ton of refuse processed but included so many variables as to make the cost data unreliable (variables include plant size, method of operation, wage scale and complement, number of shifts, land cost, final disposal, accounting systems, and financing details). Capital investment costs range from $6.15/ton for a 50 ton/day plant to $2.01/ton for a 200 ton/day plant. A small but overly-sophisticated plant in Tennessee operated at reduced capacity with a yearly capital investment cost of $12.98/ton; at design capacity, costs would have been $6.88/ton of refuse processed including capital investment. With less gold-plating of building construction, costs would have been lower. It should be noted that these costs include equipment and processing of sewage sludge; such sludge adds the moisture necessary for processing as well as a significant amount of organic material. Cost per ton would be reduced by 11-14 per cent were sewage sludge disposal not provided. Estimated investment costs for windrowing plants are $0.47/ton versus $0.75/ton for enclosed plants, for a 150-ton per day capacity plant.

Operating costs of a windrowing plant may vary between $8.70/ton to $13.65/ton. Nearly 80% of this cost is labor. To this must be added recycling costs (or savings) or sanitary landfill costs between $0.75-$2.00/ton of noncompostable material. Estimated costs per ton of refuse processed range from $3.85-$20.65.
Sale of salvageable material and compost can reduce overall costs. Savings to a municipality may also result from integrating sewage with other waste disposal into composting plants. Revenue from sale of compost may approximate $1.50-$3.50/ton of raw refuse processed; however, the possibility exists that all or part of the compost may not be sold. Revenue from the sale of salvaged materials (paper, metal, rags, glass) is subject to many variables but is estimated to range from $1.00-$3.50/ton of refuse received. Credit from integration of sewage sludge is estimated to range from $0-$1/ton of refuse processed, perhaps greater for plants using high-rate enclosed digesting systems.

Even when used as landfill, compost provides benefits in that it approximates a 50% volume reduction, is less noxious and offensive to people, is less attractive to rodents and insects, requires less cover, and provides good land reclamation qualities. The net cost of composting, considering all factors, could range from $2.45-$18.65/ton of refuse processed.

**Life-Style Change.**

Any discussion of this alternative tends towards the qualitative rather than quantitative approach. The obvious extreme of this alternative is to solve the waste disposal problem by reducing the wastes to some absolute minimum. Such an effort would require significant changes in the life
of every individual, abandonment of some products and industries, establishment of other products and industries, and, probably, increased costs in some areas. Additionally, local interests would give way to regional or national interests for waste disposal, thus augmenting political as well as economic problems. Savings in the environment and in natural resources are not easily quantifiable in comparison with a change in the style of living. True management coordination would be required to obtain immeasurable benefits. The 'out-of-sight, out-of-mind' attitude towards throw-away items would have to be eliminated. Value judgments will be required making disposal minimal but at least harm to the environment.

Combinations of the Alternatives.

From a practical point of view, various combinations of the foregoing alternatives appear to be desirable in order to provide better response to the variables of locale, volume and types of waste, and local needs. As with most of this discussion, combinations will be highly dependent upon such intangibles as perception of the problem, need for resources, and financing ability. Long-term combinations may vary from the short-term ones; economic considerations may be over-riding. Discussion of this alternative will consider two conditions: cost and environmental/resource change keeping in mind the approximations involved and the
paucity of usable data. Considerations are based on discussion of the foregoing alternatives. Appendix I, and Table I, page 77, which summarizes the known and estimated data.

**Dredge_Spoil.** Costs: diked spoil costs the least ($0.20-$0.55) with newer methods of recycling and near landfill a close second ($0.40-$1.10). Environment/resource change: newer methods of recycling hold the greatest chance for bettering both the environment and resource conservation.

**Sewage_Sludge.** Cost: composting appears least costly though within a wide range ($2.45-$18.65) whereas landfill is attractive ($5) with no range and burning is attractive with a smaller range ($2.50-$7.50). Environment/resource change: composting stands out as most beneficial by completing a natural earth cycle.

**Solid_Waste.** Cost: sanitary landfill is least costly ($3) but composting is attractive within a broad range ($2.45-$18.65) while burning and recycling is also attractive ($2.50-$20.00) under waste-heat recovery conditions. Environment/resource change: composting again stands out as most beneficial, but waste-heat burning and recycling as well as landfill also tend to complete a natural earth cycle.

**Industrial_Waste.** Cost: data is very incomplete but
burning appears least costly ($1.50-$5) with recycling of toxic wastes to be done by industry. Environment/resource change: composting of the non-toxics appears most beneficial with non-organic wastes to be recycled by industry.

**Construction and Demolition Debris.** Cost and environment/resource change: landfill is most attractive and really has no alternatives at this time.

**Explosives and Chemical Munitions.** As with construction and demolition debris, no other true alternatives are extant at this time to recycling and burning currently performed.

**DISCUSSION OF OCEAN DUMPING**

**General.**

The dollar costs of ocean dumping are well documented in the literature (See Tables II and III, pages 78, 79). Also well documented — and publicized — are the harmful effects of ocean dumping. However, there have been few instances of attention being given to beneficial or even non-harmful effects of ocean dumping. While it must be acknowledged that pollution of the marine environment must be at least reduced if not stopped entirely, the cessation of all solid-waste disposal in the marine environment regardless of effect must also be considered an overreaction and,
perhaps, counter-productive. Various analyses have been conducted of dredge spoil disposal, for example, demonstrating little effect on the environment. In some instances, beneficial fringe results were shown. At least one estuarine sewage disposal study has demonstrated mixed blessings from estuarine dumping of sewage. Continuing thorough analysis of explosive dumping sites has shown little observable short-term damage and no long-term damage to the environment. Between 1948-1957 industrial acid-iron waste disposal operations in the New York Bight had minimal adverse effects and, on the contrary, may have contributed to a concentration of bluefish near the disposal area. While these examples are certainly not conclusive, they do indicate that a more positive outlook towards constructive ocean dumping of solid wastes should be observed.

Constructive Dumping.

Artificial Habitats Creation. Since the late 1950's, several States (California and Florida predominately), private organizations, municipalities, and individuals have participated in substantive artificial marine habitat ("artificial reef") creation with surprisingly good results. Marine populations are attracted to these habitats even when of small height (five feet or less) and located in previously "barren" coastal areas. For example, the Fire Island Ocean Reef, New York, was built of 16,500 cubic yards of rubble in
a previously very poor fishing area. Within one year the "reef" area was abounding with marine life of many types. 94 Similar results were obtained in California experiments using comparative "reefs" of old streetcars, auto bodies, quarry rock, and concrete shelters. Although the experiment is incomplete, analysis over a one year period indicated a slight preference of the fish for concrete shelters — but the other materials also achieved significant populations. 95

Almost any solid waste that is sinkable and stable on the bottom can be used. Among the best items are old rubber tires set in concrete for ballast; unit cost is only $2.75-$3.00 each to build plus transportation to the reef site. 96 Transportation costs vary widely with location and distance; an estimated range would be $700-$2300 per day for one tug, one barge, crane, and crew. 97 Auto bodies deteriorate within 4-5 years and are expensive to handle and transport, but other metal objects or wood-metal combinations have a much longer useful life as reefs (e.g., old wrecks are still prominent and serve as stable havens for marine life).

Artificial habitats can be well-designed, pre-planned, and coordinated as in the case of the two artificial reefs being constructed off Virginia Beach using 166 surplus Navy LCM's. Though constructed 15 and 30 miles off the coast, they are not expected to have any significant adverse
environmental effects, but should attract pelagic and big
game fish respectively.\textsuperscript{98} Cost data is unavailable for this
project. Known artificial reefs as of 1968 are shown in
Figures 1, 2, and 3, pages 80, 81, and 82.

\textbf{Artificial Islands.} As is the case with artificial
habitats, artificial islands can be constructed predominately
of solid waste, including dredge spoil, in previously unpro-
ductive ocean areas in order to attract and enhance marine
life; currently, offshore oil well platforms and oil islands
perform this function as an observed spillover benefit.\textsuperscript{99}
With increased pressures for offshore ports, airports, and
other installations, use of solid waste for solid island
construction is feasible and would accomplish three purposes:
build the platform, increase the marine population, and dis­
pose of solid waste in a beneficial manner. Many management
and legal problems can be foreseen but should not prevent
thorough analysis of this method of solid waste disposal.

\textbf{Fertilization.} Use of dredge spoil for marsh creation
in otherwise unproductive areas has been mentioned. Similarly,
it is feasible to consider fertilization of otherwise unpro-
ductive marine areas by the dumping of organic wastes coupled
with some aeration process. It appears that this could pro-
duce a type of aquaculture in certain ocean and estuarine
areas while simultaneously providing for solid waste disposal.
For Consideration.

Imagination and technology together with sound scientific research should be able to produce other positive uses of the marine environment for ocean dumping of solid wastes. Two theoretical examples are given.

**Tectonic Destruction.** Undesired and unmanageable solid wastes (explosives, containerized industrial wastes) may be capable of ocean disposal in deep trenches of the subductive tectonic plates.\(^{100}\) In a very slow process, the wastes would be covered with silt and eventually drawn deep into the earth's mantle where pressures and temperature would return the basic elements of the waste to the earth from which they came.\(^{101}\)

**Mining Platforms.** As with artificial islands, mining platform bases could be built to support the eventual mineral resource exploitation of the ocean floor. Since these would be in relatively deep water, a large amount of solid waste would be required over a significant period of time. The "nation of Minerva" project wherein a private corporation plans to create a new nation from landfill on a small reef in the Pacific Ocean, could become a practical project if sound management and government were to be employed. It is conceivable that the United Nations might sponsor just such a project as an international one with profits to be shared
by developing countries. Farfetched though it may seem, this could provide a depository for solid wastes, a haven for marine life, a base for nodule mining, and an international source of income to developing countries.

CONCLUSIONS

No conclusive decision can be made as the result of this brief analysis. One thing is markedly clear, however, from a purely dollar costing point of view: ocean dumping is generally less expensive than other methods, sometimes significantly so. The negative aspects of ocean dumping have been foremost in the minds of many, although there are several ways in which ocean dumping would or could actually benefit the environment and man. Data on alternatives is fragmented and incomplete in most cases and this can easily lead to incorrect conclusions.

General indications from this study are that it might well be disadvantageous to terminate ocean dumping altogether; however, other indications point to some alternatives for disposal of solid waste as having potential advantages, given the required conditions. Since nearly all solid waste will remain above, on, or in the Earth and its oceans, the grand question remains: where do we want it to be and what do we want it to do?

It is known that ocean dumping of some wastes is
beneficial while others are harmful, but the actual level of dumping at which the marine environment will not suffer significant damage is unknown. Serious research should be devoted to determining the permissible level of ocean dumping. Subject to this determination, high level management must consider the entire solid waste disposal problem as an entity involving national requirements for resources conservation, economic, social, and psychological needs, and environmental goals. This consideration should then — and only then — result in a decision concerning the disposal of solid waste by ocean dumping, both qualitative and quantitative.
NOTES


8. Ward and Dobos, p. 197.


10. Ibid., p. 3-4.


15. Ward and Dobos, p. 68.
16. Ibid., p. 80.
20. Ward and Dubos, p. 79.

52

31. Ibid., p. 22.

32. Ibid., p. 5-7.


34. Schachter and Serwer, p. 19.

35. Ibid., p. 1.


38. Small, p. 5.

39. Ibid., p. 18.


44. Interview with Mr. Fitzhugh Green, Environmental Protection Agency, at University of Rhode Island, Kingston, Rhode Island: 20 March, 1973.

45. Smith and Brown, p. 10.

47. Small, p. 63-66.


49. Ibid., p. 16.

50. Ibid., p. 27.

51. Ibid., p. 36.


53. Ibid., p. 56.

54. Ibid., p. 57-59.


57. Ibid., p. 38.


60. Smith and Brown, p. 27.

61. Ibid., p. 21.


63. Small, p. 27-31.


68. Ibid., p. 35.


70. Ibid., p. VI-36.

71. Ibid., p. VI-5 - VI-8.


77. Drobory, p. 71.

78. Engdahl, p. 21.

79. Ibid., p. 16.

80. Lund, p. 7-43 - 7-44.

82. Ibid., p. 61.
83. Ibid., p. 63.
84. Ibid., p. 64-67.
85. Ibid., p. 68-72.
86. Ibid., p. 73-75.
92. Smith and Brown, p. 27-29.
94. Ibid., p. 48-52.


100. Smith, p. 6-7, F2-F-3.


Appendix I.


57


11. Ibid., p. F-5.


13. Ibid., p. 220.


15. Ibid., p. 22-23.

16. Ibid., p. 21.


19. Smith, p. 6-7, F2-F3.

20. Drobory, p. 87.
BIBLIOGRAPHY

Articles


Books and Published Reports


Schaefer, Milner E. "The Resources of the Seabed and Prospective Rates of Development as a Basis of Planning for International Management." Institute of Marine Resources. La Jolla, Calif.: University of California at San Diego, 16 June 1970.


Government Documents and Published Reports


Unpublished Material


Interview with Mr. Fitzhugh Green, Environmental Protection Agency, at University of Rhode Island, Kingston, Rhode Island: 20 March 1973.
APPENDIX I

DETAILED DISCRIPITION OF
ALTERNATIVES BY WASTE CATEGORIES
APPENDIX I

Detailed Description of Alternatives by Waste Categories

Landfill.

Dredge_Spoil. As in recycling, disposal by landfill is feasible in most cases and cost estimates will be generally the same as for recycling since this may be considered the same as recycling. Polluted spoil would require processing to protect the water table. Considerable planning and coordinating would be necessary to ensure spoil availability at regular intervals as with maintenance dredging. However, most maintenance spoil is too low in quality for good landfill. ¹

Sewage_Sludge. The same principles and costs apply as in recycling with treated sludge and hauling costs considered.

Solid_Waste. Landfill is currently a common method of disposal of solid wastes with a cost range of $0.75-$2.00/ton plus hauling costs where applicable with the increase to $3/ton or more probable as the shift to all sanitary, planned landfills occurs. ²

Industrial_Waste. Although definitive data is not available, the toxic nature of the majority of industrial wastes would appear to preclude disposal by landfill due
to projected environmental damage. Technological developments in treatment and processing may render industrial waste disposal by landfill feasible but at a high expense.3

**Construction_and_Demolition Debris.** Commonly desired for landfill and so disposed of at hauling costs (occasionally reimbursed by the user). Cost is approximately $0.30/ton-mile exclusive of land-costs where appropriate.

**Explosives_and_Chemical Munitions.** Because of the inherent danger and some toxicity, disposal of explosives and chemical munitions even by burying is not considered acceptable.4

**Deep-Pit or Shallow-Ground Storage.**

**Dredge_Spoil.** Recent systems analysis revealed that bulk transport of dredge spoil by pipeline is technically and economically feasible for distances of 100 miles. However, deep-pit and strip mines within the range of such pipelines are only extant in the Great Lakes area for the most part. Only a very small number of locations are available within 100 miles of the ocean-coastal major dredging operations; due to the nature and utilization of shallow aquifers and recharge characteristics in these regions, dredge spoil disposal may be untenable.5 In any event, piping up to 100 miles may cost as much as $40-$60/ton.6 Prior treatment and hauling at $0.30/ton-mile would appear more
attractive except for the added cost and time (in retention basins) for the drying operation. Dredge spoil does not appear to be a valuable commodity for storage against future needs.

**Sewage Sludge.** Like dredge spoil, sewage sludge does not appear to be a valuable commodity for storage, although deep-pits and shallow-ground storage are generally available closer to the source since sewage is generated in all populated areas. Rail and truck routes to storage areas are generally available, though they may have been abandoned for some time. Costs for major urban areas would vary as the distance from the disposal sites in a manner similar to that for recycling and land reclamation. Since all sewage will be digested in the future, it would appear more advantageous to use the digested sludge immediately as fertilizer rather than conserve it for the future, using artificial fertilizers in the interim.

**Solid Waste.** Storage against future technology appears to have excellent potential for solid waste, particularly of the types containing mineral resources not in abundance in the United States. The same principles apply as were discussed under recycling; there is a need to conserve scarce resources (indeed, perhaps all resources). Separation and segregation with removal of toxic and hazardous substances
would be a significant part of the cost for storage disposal and would, therefore, increase cost over those for landfill possibly to as much as $15-$20/ton exclusive of transportation costs. Of course, these costs could vary even more widely were the degree of separation limited to given categories (e.g., automobiles, heavy iron objects) and excluding other categories such as biodegradables or non-biodegradables. These determinations would require separate analyses.

**Industrial Waste.** Although potentially hazardous because of toxicity and high BOD and COD requirements, industrial waste could be disposed of by storage provided containerization were effected. Such containerization costs about $24/ton; to this would be added transportation costs. Non-toxic wastes with high BOD or COD requirements could be disposed of separately over land by carefully controlled aerating sprays (as is already done with some paper industry waste) thus reducing the amount of containerization required.

**Construction and Demolition Debris.** Presently there is no foreseen need to conserve materials from construction and demolition debris other than those already conserved and reused. Should such a future need be foreseen, the principles and costs applicable would be similar to those for solid wastes.
**Explosives and Chemical Munitions.** Carefully controlled underground storage is a normal practice at Department of Defense (DOD) sites. It is quite feasible that additional underground storage of explosives may be desired to provide against a critical shortage of materials not basic to a peacetime economy. Relatively inexpensive, large, remote sites could be developed on DOD land for increased storage against future requirements. It is interesting to note that TNT appears to be biodegradable by microorganisms; studies are underway to ascertain if other munitions are also susceptible. No costing data is available for projected underground storage.

**Burning.**

**Dredge_Spoil.** The solid portions of dredge spoil can be separated out from the liquid portions and, frequently, result in sludge similar to sewage sludge. Fine particulate matter may accompany the sludge and increase the amount of residue after incineration. Further, the vast amounts of dredge spoil and the lack of scheduled regularity would impose burdens upon any incineration facility. High temperature incineration costs range between $4-$11/ton exclusive of processing and transportation costs.

**Sewage_Sludge.** Digested sludge will be in solid form and very amenable to incineration. Although high-temperature
incineration of undigested sewage sludge costs between $35-$50/ton, digested sludge incineration should cost approximately the same as solid waste, between $2.50-$7.50/ton. Practically speaking, were incinerators employed extensively, most municipal incinerators would be located conveniently for sewage sludge incineration thereby obviating extensive transportation costs.

**Solid Waste.** A significant amount of solid waste is being disposed of by incineration at between $2.50-$7.50/ton. With the additional cost of significant residue removal and disposal, costs may approximate $10.00/ton. The CPU-400 incinerator under development is expected to burn shredded and dried refuse for power generation; projections show a 400 ton/day unit producing 15,000 KW of electric power at an annual cost of between $4.27-$5.99/ton of waste disposed. If this development is successful, it will be economically sound and contribute to waste control simultaneously with fuel conservation.

**Industrial Waste.** It is feasible to burn a significant amount of industrial wastes after treatment and under carefully managed conditions. Cost for the food industry varies between $5/ton during amortization to about $1.50/ton for operating costs. Costs for other industries, particularly those with toxic waste problems, will probably be significantly higher.
Construction_and_Demolition Debris. Generally, that portion of construction waste and demolition debris which is burnable and not salvaged is burned as solid waste. There appears to be no need for further consideration of incineration.

Explosives_and_Chemical_Munitions. All open-burning of munitions is being halted. Approximately 2000 tons annually of explosive residues or unprocessable explosives will be incinerated in especially designed plants at initial capital cost estimates to be $4 million with processing costs $100/ton. Research is ongoing for safe incineration of other stocks; capital investment of at least $1.5 million is expected with processing costs of $400/ton.19

Burning and Recycling.

Dredge_Spoil. As discussed, dredge spoil can be recycled or burned. It may be advantageous to burn the toxic spoil and recycle the non-toxic; because of the volume of dredge spoil and the requirement for thorough analysis prior to disposal, this split appears feasible (though as spoils become less toxic, the ratio of toxic to non-toxic will decrease from the present 1:2). Recycling of the non-toxic two-thirds is estimated to range between $0.40-$1.10/ton, while the toxic one-third might cost $2.50-$7.50/ton to burn (as might all solid waste). These estimates are exclusive of processing and transportation costs.
Sewage Sludge. Digested sewage sludge is burnable at $2.50-$7.50/ton but could also provide excellent fertilizer or land-reclamation fill at $35-$50/ton.

Solid Waste. Approximately 85% is burnable at $2.50-$7.50/ton with disposal of the residue and unburned portions required at additional cost. Salvage of unburnables is relatively simple after burning; salvage prior to burning is within the scope of technology but at higher cost either at the incinerator or nearer the waste sources (e.g., households, stores, factories). Depending upon sale of salvaged material, burning and recycling could cost from $2.50-$20.00/ton.

Industrial Waste. Recycling of industrial wastes at the incinerator does not appear technologically feasible at this time. Generally, the treatment required prior to incineration closely parallels the treatment required for recycling, costing $1.50-$5.00/ton to burn. No data is available for recycling which will vary considerably with the type of waste.

Construction and Demolition Debris. This waste has already been considered under this alternative and is so normally applied.

Explosives and Chemical Munitions. This waste has
already been considered under this alternative and is so normally applied.

Composting.

Dredge_Spoil. While no data is currently available for processing dredge spoil by composting, it appears technologically feasible to compost the solid portions of spoil. Problems may ensue due to the great volume of spoil and the transportation costs to a composting plant. However, the applicability should be analyzed.

Sewage_Sludge. Normal sewage sludge has value as an input to composting plants and is itself particularly subject to composting and natural removal of pathogens. Since composting plants usually include sewage sludge as inputs, separate cost data is difficult to ascertain.

Solid_Waste. The major bulk of inputs to composting plants consists of solid waste. Processing costs and salvage revenues have been previously discussed and are integrated with sewage sludge costs.

Industrial_Waste. Food and paper processing wastes as well as some others appear to be amenable to composting inasmuch as they are subject to aerobic decomposition. Other toxic wastes and acids, however, will have to be disposed of by other methods. No data is available for composting of industrial waste.
Construction_and_Demolition Debris. These wastes seldom contain materials subject to composting and will therefore have to be disposed of by other methods.

Explosives_and_Chemical Munitions. These wastes are considered unsafe for composting as a means of disposal.

Life-Style Change.

Dredge_Soil. Rivers and harbors will continue to require dredging and subsequent spoil disposal. Close management of both new dredging and spoil deposit will be required to ensure maximum benefit or least harm.

Sewage_Sludge. As a natural function, sewage will continue to be produced but only unusable items should be inputs to the waste disposal systems, and even these should be processed for benefit to both environment and to man where feasible.

Solid Waste. As with sewage, only unusable items should be inputs to the system. Bottles, cans, rags, metals, and paper should be saved and separately collected for recycling. Technology could provide means of reclaiming many other items normally discarded. Individuals would return to the days of string, foil, tin can, bottle, and paper-saving.

Industrial Waste. Industry will have to reduce the amount of waste produced, recycle its own waste where feasible,
and coordinate waste treatment and processing to provide environmental benefits or least harm as applicable. Effective, planned reclamation would be required at all mining sites in coordination with the appropriate management authority.

*Construction and Demolition Debris.* Little change is foreseen in this category except that efforts be directed towards minimizing spillover costs at work sites (e.g., crushed foliage, removal of excess topsoil, confining work site to minimum area).

*Explosives and Chemical Munitions.* Extensive research should be done to ensure ease of demilitarization, recovery, and reuse.
APPENDIX II

TABLES AND FIGURES
<table>
<thead>
<tr>
<th>DREDGE SPOIL</th>
<th>SEWAGE SLUDGE</th>
<th>SOLID WASTE</th>
<th>INDUSTRIAL WASTE</th>
<th>CONSTRUCTION &amp; DEMOLITION DEBRIS</th>
<th>EXPLOSIVE &amp; CHEMICAL MUNITIONS</th>
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<td>cost ($)</td>
<td>effect env/res ($)</td>
<td>cost ($)</td>
<td>effect env/res ($)</td>
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<td></td>
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<td>2.50-20.00</td>
<td>G/E</td>
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<td>G/NC</td>
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<td>5.00</td>
<td>G/NC</td>
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<td>no data</td>
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<td>G/NC</td>
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<td>NC/P</td>
<td>35-50.00</td>
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<td>G/G</td>
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<td>G/NC</td>
<td>15-20.00</td>
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<td>50-80.00</td>
<td>G/NC</td>
<td>25-50.00</td>
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<td>G/G</td>
<td>35-50.00</td>
<td>G/NC</td>
<td>15-20.00</td>
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<td>COMPOSTING</td>
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<td>2.45-18.65</td>
<td>E/E</td>
<td>2.45-13.65</td>
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**TABLE I: SUMMARY OF COSTS PER TON AND ENVIRONMENTAL/RESOURCE CONSERVATION EFFECT OF VARIOUS ALTERNATIVES TO OCEAN DUMPING (1968)**

**Notes:**
Life-Cycle Alternative omitted since not quantitative
# 100 mile for dredge spoil, 50 mile for sewage
+ sanitary landfill and digested sewage requirement
  + few landfills are now sanitary or preserve resources
  + containerized storage only
= high temperature incineration (high moisture)
% all waste either burned or recycled except dredge spoil and solid waste (85% burnable, rest salvage)

Value judgments applied to environmental/resource column: general overall effect of type of disposal indicating by answering question, "How does this change the environment, does it conserve or waste resources?" Answers indicate amount and direction of change; E-excellent, G-good, NC-no change, P-poor. A change for the betterment of environment or conservation of resources is E or G.
## TABLE 3
### SUMMARY OF TYPE, AMOUNT AND ESTIMATED COSTS OF WASTES DISPOSED OF IN PACIFIC, ATLANTIC, AND GULF COAST WATERS FOR THE YEAR 1968 *

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Pacific Coast</th>
<th>Atlantic Coast</th>
<th>Gulf Coast</th>
<th>Total</th>
<th>Total</th>
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<tr>
<td></td>
<td>Annual</td>
<td>Annual</td>
<td>Annual</td>
<td>Annual</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td>tonnage</td>
<td>tonnage</td>
<td>tonnage</td>
<td>tonnage</td>
<td>Tonnage</td>
</tr>
<tr>
<td>Dredging spoils</td>
<td>8,320,000</td>
<td>30,880,000(a)</td>
<td>13,000,000</td>
<td>52,200,000</td>
<td>23,646,000</td>
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<td>Industrial wastes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bulk</td>
<td>981,000</td>
<td>3,011,000</td>
<td>690,000</td>
<td>4,682,000</td>
<td>204,000</td>
</tr>
<tr>
<td>Containerized</td>
<td>300,000</td>
<td>2,000</td>
<td>6,000</td>
<td>8,500</td>
<td>26,000</td>
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<tr>
<td>Refuse, garbage(b)</td>
<td>26,000</td>
<td>4,477,000</td>
<td>4,477,000</td>
<td>26,000</td>
<td>392,000</td>
</tr>
<tr>
<td>Sewage sludge(c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>200</td>
<td>4,433,000</td>
<td>4,433,000</td>
<td></td>
<td></td>
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<tr>
<td>Construction and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>demolition debris</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$74,000</td>
<td>430,000</td>
<td>574,000</td>
<td></td>
<td>1</td>
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<tr>
<td>Explosives</td>
<td>15,200</td>
<td>235,000</td>
<td>15,200</td>
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<td>Total, all wastes(d)</td>
<td>9,327,500</td>
<td>38,959,400</td>
<td>4,991,000</td>
<td>61,982,900</td>
<td>37,332,000</td>
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</table>

(a) Includes 200,000 tons of fly ash.
(b) At San Diego 4700 tons vessel garbage at $280,000 per year were discontinued in November 1968.
(c) Tonnage on wet basis. Assuming average 4.5 percent dry solids, this amounts to approximately 200,000 tons dry solids per year being barged to sea.
(d) Radioactive wastes omitted. There were no dumps during 1968. Average Annual disposal in 1969–1970 was 4.2 tons.
(e) Estimated costs were increased proportionately for each area from the original Tonnage/cost data.

* Revised and updated by James L. Verber, FDA.

Note: Sewage costs increased to $5.00 per ton as secondary treatment is required; applies to digested sludge dumped into nearshore waters.

OVER FOR
FIGURES 11-2 AND
PAGES 80-81
Figure 2. Sewage sludge disposal sites were only found on the Atlantic Coast, where most radioactive waste disposal sites were also located.
Corps of Engineers tankers are discharging an amount of industrial waste presently dredged up through designated disposal sites in the deep waters off the coast of Mexico. Most industrial waste disposal operations in the Gulf of Mexico are conducted beyond the 400-fathom line (2,400 feet), which off Galveston requires disposal about 125 miles off the coast.
DEPARTMENT OF THE ARMY  
NEW ENGLAND DIVISION, CORPS OF ENGINEERS  
424 TRAPELO ROAD  
WALTHAM, MASSACHUSETTS 02154

IN REPLY REFER TO:  
NEDOC-1

Commander J. W. Sellers  
College of Naval Warfare  
Naval War College  
Newport, Rhode Island 02840

26 October 1972

Dear Commander Sellers:

Pursuant to our telephone discussion we are forwarding herewith information relating to dredging and ocean disposal of dredged materials. The following documents are among the inclosures:

a. A preliminary working draft, dated May, 1972, of a study of the disposal of dredged spoil prepared by a team from the U. S. Army Engineer Waterways Experiment Station at Vicksburg, Mississippi. Since this is a preliminary draft which has not been published, it would appear that any information used from it ought to be credited, not to the study, but to the applicable sources indicated in the references and bibliographies included as part of the study.


e. A list of established ocean disposal areas in New England waters.

Additional sources are an article titled "Real or Imaginary Dilemma" on pages 17-22 of the Spring 1972 edition of Water Spectrum, a Corps of Engineers publication, and a paper relating to the "Ecological Effects of Dredged Borrow Pits" by Joel F. Gustafson, Ph.D., in the September, 1972 edition of World Dredging & Marine Construction.
Control over dredging and ocean disposal of dredged material by non-federal interests has been exercised through the provisions of Title 33 United States Code, Sections 403, 407 and 419, and dumping ground regulations are contained in 33 Code of Federal Regulations, Section 205. A discussion of the problems involved in dumping dredged material in New York Bight is set out in New York v. Department of the Army, a case decided January 12, 1972, by the United States District Court for the Southern District of New York and reported in 3 Environmental Reporter Cases 1947.

It is our understanding that amendments dated October 13, 1972, to the Federal Water Pollution Control Act now make the Environmental Protection Agency responsible for the issuance of permits heretofore governed by 33 United States Code Section 407. The effect of these amendments on present policies and procedures of the Corps of Engineers is not known.

With best wishes in your assignment, I am

Sincerely yours,

Raymond C. McCulloch
Division Counsel

Incl as stated