WASTE DUMPING

HEARINGS

BEFORE THE

SUBCOMMITTEE ON OCEANOGRAPHY

AND THE

SUBCOMMITTEE ON FISHERIES AND WILDLIFE CONSERVATION AND THE ENVIRONMENT

OF THE

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Mr. D'AMOURS. Thank you, Dr. Capuzzo. Dr. Brooks, would you proceed now, please.

Dr. BROOKS. Thank you, Mr. Chairman. I have prepared a presentation, which I think has been circulated to you. I will, however, direct my remarks mainly to what I think your concerns are.

Mr. D'AMOURS. Dr. Brooks, your statement will be entered into the record just as it has been submitted.

Dr. BROOKS. My background is that of an engineer. I am director of the environmental quality laboratory at the California Institute of Technology and professor of environmental and civil engineering.

I have, as a private consultant over the last two and a half decades, worked with many of the larger municipalities on the west coast in developing the designs for ocean outfall systems, and in my work at Cal Tech I have worked on research activities related to the technology of ocean disposal, and, more recently, I have been participating in policy studies.

The written testimony which I presented is actually a shortened version of the final chapter of a book on municipal wastewater discharge to the ocean, which has been sponsored by NOAA, as indicated in the written testimony, footnote on page 2. There are 13 chapters by 13 different authors or coauthors. I have been the author of the final chapter 13—maybe that is an unlucky position to be in—to summarize the alternative strategies for discharge of not only sludge but also effluent. This book is in the final publication process and will be out I believe later this year.

The concept of this book was to try to gather together all of the scientific and engineering information relating to this problem, in a fairly definitive way, for evaluation by responsible and interested parties.

From our written testimony I will read a few of the conclusions that particularly relate to sludge. I might also say that this final chapter reflects only my opinions and those of my coauthor, Professor Krier, professor of law at UCLA, and does not in any way reflect the position of either Cal Tech, where I am employed, or NOAA or any agencies for which I have been a consultant.

Our conclusion No. 4 is that the prohibition of sludge dumping in the ocean is a policy which is not based on scientific, engineering, and economic evaluations of tradeoffs, considering alternative disposal methods impacting the land, fresh waters, and/or the atmosphere.

And No. 5: In general, the highest priority is for better control over the releases of trace toxic chemicals and heavy metals to the ocean—as well as to other environmental media. The only viable strategy is control at the industrial sources to prevent release into the sewers.

I think we have heard earlier today that the problem of toxic chemicals in the sludges is one that is so pervasive, regardless of where you dispose of the sludge that the only strategy is to try to stop the hazardous materials from entering the sewer system in the first place.

No. 9 says:

> Research and demonstration projects should be encouraged to gain more information on effective techniques for management of ocean disposal. An example would

be the deep-water disposal of sewage sludge off Orange County for a trial period of 5 years to observe transport, fates, and effects of the sludge particles, and to improve the methodology for analysis of such discharges in general.

I will come back to that in a few moments.

Finally, skipping to No. 11, the basic elements of good policy for ocean discharge are, in our opinion: *(a)* costs of control which are commensurate with environmental benefits; *(b)* integration with policies for other media; *(c)* flexibility to account for wide variations in the nature of coastal waters; and *(d)* flexibility to adjust control programs on an incremental basis in response to environmental monitoring results or new scientific information.

Now, the role of an engineer in this is to take scientific information on the one hand and policy objectives or legislation and regulations on the other hand and try to forge ideas for the best systems that will accomplish society's goals and get rid of residuals. An engineer—I have been in this role a number of times—has to make judgments about the risks of various actions and be able to adjust to changing policies. But it is obvious that for a municipal waste disposal the failure to decide anything can really lead to very bad consequences. The residuals of man, of urban areas, must be discharged somewhere.

Now, because I have worked on devising improved methods for ocean disposal, I have often been accused of saying, I believe in ocean pollution, I would rather put the stuff there. No, that's not true. I am very much committed to going first class on pollution control by looking at the whole environment; and there are many ways of improving the procedures for discharge of wastes to the ocean that are different from the current practice. It is only through advances of engineering research and exploring of new ideas that one does have a chance to learn and to adjust one's thoughts.

Now, the trouble with a policy that essentially bans ocean dumping, whether by barge, under the jurisdiction of your committee, or by pipeline, under the Committee on Public Works and Transportation, through Federal Water Pollution Control Act amendments of 1977, and the EPA implementation of the laws, is that it denies the engineers an opportunity to consider several of the ocean-disposal alternatives.

You, the committee members, asked earlier about studies in relating discharge in the ocean compared to land discharge, and I would like to tell you a little bit about that.

In 1975, at Cal-Tech's Environmental Quality Laboratory, I initiated some research work on investigation of alternate strategies for sludge disposal in deep ocean basins off southern California, which has led to this report of the Environmental Quality Laboratory, by Jackson, Koh, Brooks, and Morgan, which is cited in the testimony. At the time this was one contribution to a study by the Los Angeles/Orange County metropolitan area regional wastewater solids management program. There was a problem, because there was to be mandatory implementation of secondary treatment, causing the amount of sludge to increase to about a thousand dry tons of solids per day, and the question was what to do with it.

The EPA and the State of California joined with the local agencies to investigate all of the possible means of disposal of sludge, including pyrolysis, incineration, burying in landfill, using it in agriculture; and various contractors and agencies conducted different parts of the overall study (see citation, LA/OMA 1980, in written testimony).

When I proposed to do an assessment of ocean discharge alternatives, EPA and the State of California flatly refused to support it; but with the support of the local agencies, plus some discretionary funds of our own at Cal Tech from the Ford Foundation and the Rockefeller Foundation, we proceeded with this study, which EPA claimed they did not want to have done because it already was their policy not to allow sludge discharge in the ocean.

Now, that seems to me to be contradictory to a rational approach to a multimedium analysis.

This report shows that for southern California the choice of a deep-ocean discharge by pipeline, say to a 1,000-foot depth, in a closely monitored experiment, would probably be found to be a very viable method of disposal.

In my written testimony there are some costs that are estimated—you will find those on page 17, table 2—where the land disposal, which is mandated by EPA, would cost in the order of $80 to $90 per ton, whereas an ocean discharge alternative would be something in the order of $13 to $21 per ton, even including $1 million per year for special research and monitoring.

Now, I don't say what we do should be based on costs, but when this study for Orange County was completed, there appeared to be a general consensus among the technical people that the ocean disposal option looked to be far superior both environmentally and costwise—but the EPA representative simply stated we can't go that way, it's contrary to EPA policy, you will not be eligible for funds, and so on.

In summary, then, a policy which allows an ocean dumping option is not acting in favor of ocean dumping, but is simply saying it should be open as one of the alternatives to be analyzed by the engineers and evaluated on a case-by-case basis.

We have heard from the other panelists here that there is more to be learned in the ocean; but also we have heard from Dr. Spencer that the ocean has an ability to reverse itself fairly well, so that if we commit ourselves to monitoring, paying attention to what's happening, then we can adjust policies as we go along.

To sum up, I think that the policy should specify water quality objectives, land quality objectives, and air quality objectives. Which technology or which choice should be worked out on a case-by-case basis by the engineers, by the sewerage agencies, and by the regulatory agencies. Otherwise, if we stick to a uniform national policy, we are condemning ourselves to do things in some places that simply everybody agrees are not effective and not appropriate for that area.

As engineers, we do have the ability to work from water quality objectives back through the system—we are dealing with an engineering system of pretreatment—or source control, sewers, sewage treatment plants, outfalls, and barges. There are many alternatives which can be studied, and we do have the methodology for making good choices if the policy will stick to the overall objectives and not dictate which kinds of technology you can and cannot use.

I might respond, Mr. Chairman, to your three comments in your opening statement. I think, first of all, you expressed a concern about ocean pollution not only affecting the United States but also other countries. I would say the locations of the coastlines of the United States are by and large such that if there are adverse effects, we will be the first to know them. The circulation in the ocean as a whole is much slower than atmospheric circulation; for example, as in the case of the acid rain problem, the relationship between air quality in Canada and the United States is a much more closely coupled international problem. If we can adopt a wise policy for managing our own shoreline and coastal water quality, I doubt very much that there will be an international problem which would require action over and beyond what we will do for our own case.

Second, you raised a question about the assimilative capacity, and the question of defining unacceptable harm. This is a pervasive problem not only for the ocean, but also for land and the atmosphere. We have heard from other testimony that the types of harm that we are most concerned about in the ocean are due to toxic materials—trace chemicals in the sludge—and I am very strongly in favor of taking whatever measures are possible to capture those materials by pretreatment and source control so they will not be a problem regardless of what we do with the sludge, whether disposal is to ocean, land, or air. I might say, though, that for some of the toxic materials I would feel safer having them in the deep ocean than I would having them sitting in a landfill over a ground water basin, as we have been discussing.

The third reservation I think you expressed was the matter of convenience of ocean dumping—out of sight, out of mind. Now, to me, ocean dumping may be out of sight, but it is very much not out of mind. It is something I have studied for many years. Similarly, emissions to the atmosphere may be considered convenient. However, if the best place turns out to be the ocean for a given situation, for goodness' sake let's not rule it out because it is too convenient or because it is too out of sight!

I will be glad to respond to your questions.

[The following was included for the record:]

ALTERNATIVE STRATEGIES FOR OCEAN DISPOSAL OF MUNICIPAL WASTEWATER AND SLUDGE

By

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I. OVERVIEW

Our knowledge of transport, fates and effects of water pollutants has increased considerably in the last decade and further advances of knowledge are expected. Management of ocean discharges should be directly related to our present understanding of ocean processes, but flexible enough to be adjusted in the light of new research results; in addition, alternate disposal processes to air or land should be evaluated. The ocean disposal option should have technical parity with land and air disposal options.

The technical problems of discharge to the ocean are different from discharges into rivers or inland waters or estuaries. The ocean has great value for assimilation of wastes and the policy governing it should be separate from discharges into other bodies of water. For example, biochemical oxygen demand (BOD) is rarely a problem for ocean discharge, but for discharges to certain inland waters it may be an overwhelming problem that necessitates secondary treatment.

This paper* briefly discusses management alternatives in the context of our current understanding of the needs for controlling ocean pollution from municipal sources.

A. Predictability of Outfall Effects

Effective management of wastewater and sludge discharges to the ocean depends critically on the ability to measure and predict the effects of treatment and outfall systems. The design of new or revised outfall systems is based on certain water quality objectives to be satisfied by the system under design. Fifty years ago outfalls were designed simply as hydraulic pipelines into the sea with the location and length decided either by guessing or by pure judgement, without any scientific analysis of the resulting water quality in the ocean.

In the intervening years, the state of the art has advanced considerably, especially in the physical aspects of design (Fischer et al., 1979). In the design of outfalls we can now do the following predictive analyses quite well:

- initial dilution for a multiport diffuser, taking account of environmental factors such as ambient density stratification and currents

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* This paper is essentially an abridged version of Chapter 13, "Evaluation of Key Issues and Alternatives" by N.H. Brooks, forthcoming in the book The Impact on Estuaries and Coastal Waters of the Ocean Disposal of Municipal Wastewater and its Constituents, Edward P. Myers, editor, sponsored by National Oceanographic and Atmospheric Administration, to be published by the MIT Press. The views expressed herein are solely those of the authors, and do not represent the policies or positions of NOAA.

- maximum height of rise of the initial plume in a stratified ocean, i.e. the level at which neutral buoyancy is achieved between the diluted plume and the ambient ocean and and further spreading is done as an internal flow
- frequency of advection toward shore and probable travel times
- coliform die-off and expected coliform counts along the shore
- maximum dissolved oxygen depletion based on dilution
- order of magnitude of regional flushing based on oceanographic variables
- rate of dissolution of particulate forms of metals on sewage particles
- substances likely to be bioaccumulated in the food chain and to require special attention and source control

We have good empirical observations, but less ability to predict, with regard to things like the following:

- settling velocity of particles as a result of flocculation in the ocean
- size and extent of resulting enriched patches on the bottom near outfalls
- detailed ecological effects of wastewater, other than by empirical comparison to existing discharges
- biochemical conversion of trace contaminants to more toxic forms by marine organisms
- rate of degradation of potentially toxic persistent organics.

None of the predictions are exact; there is a degree of uncertainty. (The reliability of the various predictive modeling techniques is described in detail in the forthcoming NOAA book cited in the footnote

above). However, the performance of an outfall is not fixed but follows frequency distributions driven by variations in the ocean environment (the time of the year, storms, tides, etc.). Consequently, when all the factors are considered and conservative assumptions are made, recent design experience has been successful in meeting the prescribed sets of water quality requirements.

In summary, the development of outfall structures to achieve very high dilutions (over 100:1) in locations of good coastal water circulation has been instrumental in achieving good disposal for the conventional pollutants and pathogens. In many locations, secondary treatment is not necessary as part of the system and primary treatment is sufficient.

In recent decades, however, we have failed to predict the effect of trace contaminants such as DDT and PCB's because of their persistence in the environment and bioaccumulation in the food chain. It is now generally agreed that management of this part of the ocean-disposal problem depends not on better outfall designs or more advanced treatment, but rather on controlling the release of hazardous substances into the sewer system in the first place. By measurements of the effluent for trace contaminants it is easy to establish which substances need special attention and source control, and it is easy also to measure an agency's progress toward that goal. What is not within the state of the art, however, is deciding what values of various trace organics can safely be discharged to the ocean. As instrumentation gets better, we expect to find that, for many substances undetected until now, the concentrations are small yet measurable quantities.

Since we do not know how small is small enough, we have to take some risks, but these risks are no different and perhaps less than similar risks we face constantly in all parts of our environment, vis-a-vis trace contaminants.

B. Toxic Substances

One clear point of understanding is that the ocean can safely be used to receive reasonable amounts of wastewater, provided we improve our ability to control the entry of toxic substances into municipal sewer systems. The overriding future risk of ocean discharge of municipal waste is the intentional (or unintentional) introduction of long-lived toxic substances into the marine environment in concentrations which may be damaging to marine ecosystems, or a threat to human health through consumption of seafood. Since similar threats of toxic material exist also in air and on land, the ocean problem is not likely to be solved by a displacement of such substances to another environmental medium. Rather, there is a consensus that the best approach to control of toxic substances is at their sources. There must be a change in the general attitude that sewers are for dumping anything that you want to get rid of.

The concept of source control or pretreatment for municipal sewer systems is to reduce or control the amount of a trace contaminant entering a sewer system from industrial plants or other sources. This is probably the most cost-effective approach — or possibly the only viable approach. To allow hazardous substances to enter the sewer system in excessive quantities creates what appear to be intractable problems of disposal. If the hazardous wastes are captured in sludge by the sewage treatment process, then there is a problem of safe disposal of the sludge. On the other hand, if they pass through to the ocean there may be risks to the ecosystem or human health. In the discussion that follows we assume that good source control or pretreatment is being implemented.

C. Treatment Processes for Ocean Discharge

When conventional secondary treatment (activated sludge) was invented, its main objective was to reduce the biochemical oxygen demand (BOD) of sewage before discharge into fresh water bodies with limited oxygen resources. However, BOD is not generally a problem in the ocean, and the priority of treatment of traditional pollutants is particle removal (i.e., suspended solids removal). Indications are that conventional primary sedimentation may remove about 50 to 60 percent of suspended solids, whereas secondary treatment can be expected to remove 85 percent. However, there are opportunities for intermediate levels of particle removal, called "advanced primary" which are basically enhanced sedimentation processes. The addition of flocculating agents such as polymers, alum, ferric chloride, or lime tend to increase suspended solids removal up to the range of 70 to 80 percent. The cost of advanced primary varies considerably with the coagulating agent used, with polymers being probably the most promising, because of the small amount necessary. If too much flocculant is added there may be a large cost for the chemical (e.g., lime) and substantially increased cost of sludge disposal. For ocean discharge it is recommended that additional research be done on developing cost-effective improved sedimentation processes.

One important advantage of advanced primary over full secondary treatment is the fact that polymers (or other chemicals) can be added with minor modifications to existing primary sedimentation tanks at relatively low cost in structures and land. On the other hand, to upgrade a plant to full secondary treatment requires large new batteries of tanks for in-plant aeration and final clarification in addition to the primary sedimentation tanks; the area of tanks is typically doubled.

Another example of how treatment processes and outfall design have been made specific to ocean discharges is disinfection. It has been found with long ocean outfalls, such as off southern California, that there is a trade-off between outfall length and disinfection, while maintaining the same shoreline bacterial count. For example, in Orange County, when the Orange County Sanitation Districts stopped using the old 7,000-foot outfall and started operating the new 27,400-foot outfall in 1971, effluent chlorination was completely stopped. Previously heavy chlorination was necessary over 50 percent of the time to meet shoreline bacteria standards, which are now easily met by natural processes in the ocean. Not only is the saving in chlorine cost very significant, but also the risk of damage to marine ecosystems and in-plant chlorine hazards to personnel have been avoided.

D. <u>Outfalls vs. Treatment Plants</u> -- <u>Trade-offs</u>

For effluent discharge into the ocean the basic choices and trade-offs involve level of treatment and design of the outfall. For the following discussion we will assume that a good program of source control is being implemented, and thus we focus on such pollutants as organic material, nutrients, and pathogens. The performance of an outfall in diluting and dispersing effluent is characterized by the initial plume dilution over the diffuser, possible plume submergence beneath the pycnocline,* and current patterns. The procedure followed for designing an outfall starts with (1) data on effluent quantity and quality; (2) environmental data for the ocean; and (3) ambient water quality requirements and dilution and submergence objectives. The optimum location of the discharge, the diffuser length and depth, and various port details are then determined so that the requirements are met with the desired margin of safety.

By this process the treatment plant and the outfall are considered as a system with trade-offs. When the treatment is more extensive (e.g., secondary with disinfection), the outfall can discharge closer to shore with less dilution; but on the other hand, when high outfall performance is easily and economically achieved, then less treatment (e.g., primary without disinfection) may be sufficient.

The trade-offs are not simply a matter of cost. When secondary treatment is used (with an implied shorter outfall) there is an

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* The pycnocline is at the water depth where the water density changes most rapidly; and vertical mixing between the water masses above and below is slow.

additional disposal problem for the increased amounts of digested sludge which may have intangible as well as tangible costs. Another factor is that for secondary treatment a long high-dilution outfall may still be desired for ecological reasons, even if it is not essential for bacterial, dissolved oxygen, or turbidity requirements. Since a large fraction of the original nutrients remain in the secondary effluent, high dilutions are helpful to avoid undue biostimulation.

It is practically impossible to make a generalized economic analysis of the trade-off between outfalls and degree of treatment. It should and must be done on a case-by-case basis. Under the 1972 law this was not permissible, because secondary treatment was mandated regardless of the character of the receiving water or the outfall design; now, with the 1977 amendments, including section 301(h), such a systems approach is possible because it is recognized that the resulting ambient water quality depends on the outfall design and receiving water characteristics as well as the level of treatment.

Experience suggests that the cost trade-off is sensitive to the mean flow of the system. For small flows, perhaps on the order of 1 to 10 MGD (million gallons per day),* the addition of secondary treatment may be cheaper than building a sufficiently long outfall; on the other hand, for very large systems (several hundred MGD) the cost advantage of a long outfall in deep water over secondary treatment may be very large. The reason for this is that the treatment costs tend to be nearly proportional to the flow rate, whereas outfalls exhibit a much larger economy of scale.

* 1 MGD = 1.55 ft^3/s = 0.044 m^3/s.

The cost of an ocean outfall depends not only on water quality requirements, but also on the physical hazards and foundation conditions at the site. Factors which will increase outfall costs significantly are: large ocean waves, shifting bottom profiles, poor foundation conditions, earthquake faults, and hard rock and coral which must be excavated. The cost then is very site specific. The depth profile also enters into the cost significantly in the sense that an outfall is most difficult to build through the shallower surf-zone (typically up to 30 ft depth) and easiest to build in the offshore sections, where burial may not even be required (i.e., the pipe may be simply laid on the bottom with a rock berm to hold it in place).

To get some idea of cost for purposes of comparison with typical secondary treatment costs we may consider the example of the Sand Island Outfall at Honolulu, Hawaii, which was finished in 1975 (Fischer et al., 1979). The design average flow of that outfall is 164 ft^3/s or 106 MGD, roughly equivalent to the flow from a 100 MGD plant. The length of the outfall (7 ft inside diameter) is 13,500 ft including a 3,384-ft diffuser with a terminal depth of 235 ft. The construction cost was $13.6 million (contract awarded in October 1973); in 1980 prices this would probably have been about twice as much, or $27 million. The construction conditions would be considered somewhat more difficult than average because of about 6,000 ft of coral excavation through the surf-zone. Although the <u>average</u> construction cost would be about $2,000/ft, the marginal cost of additional length would be much less. A rough cost formula for an outfall for 100 MGD flow might be

$$C = 5{,}000{,}000 + 2{,}500\ L_s + 1{,}000\ (x - L_s)$$

where C = cost in dollars

L_s = length of the surf zone in feet (requiring trestle construction and trenching)

x = outfall length including diffuser (in feet)

The $5 million constant is the basic fixed cost of mobilization and demobilization. The marginal cost for length is thus estimated to be $1,000 per foot for a 7-foot outfall for 100 MGD for original construction, but not for retrofitting which requires remobilization of heavy equipment.

For a hypothetical example, the required outfall length for primary effluent might be 18,000 feet, but only 12,000 feet for secondary; the surf zone is taken as 4,000 feet. The cost comparisons for two equivalent treatment-outfall combinations are given in Table 1 for a design average flow of 100 MGD. Since the capital costs shown are original project costs, the differences understate the cost of projects to upgrade; i.e., if an outfall to 12,000 ft is already built, then the cost to extend it to 18,000 ft would be much more than $6 million because of the mobilization cost; and if a primary plant already exists, the addition of secondary processes would cost more than the $28 million differential shown.

Although the analysis presented in Table 1 is very generalized and ignores site-specific factors, it does show the nature of the cost

TABLE 1

ESTIMATED TYPICAL COST DIFFERENTIALS OF OUTFALLS AND TREATMENT NEEDED FOR PRIMARY VERSUS SECONDARY OPTIONS (MEAN FLOW = 100 MGD)

Treatment: Outfall Length:	PRIMARY 18,000 ft		SECONDARY 12,000 ft		Difference (Sec. - Prim.)	
	Capital	Annual	Capital	Annual	Capital	Annual
	(Costs in $ Million)					
OUTFALL						
Capital Cost	29		23		-6	
Annual Capital Cost (10.25%, 75 yrs)		3.0		2.4		-0.6
Annual O & M		0.3		0.2		-0.1
Subtotal	29	3.3	23	2.6	-6	-0.7
TREATMENT PLANT						
Capital Cost	41		69		+28	
Annual Capital Cost		5.2		8.8		+3.6
Annual O & M		1.8		4.3		+2.5
Subtotal	41	7.0	69	13.1	+28	+6.1
TOTAL OUTFALL & STP	70	10.3	92	15.7	+22	+5.4

trade-off between a longer outfall and more treatment (presuming that the ocean currents are favorable for flushing highly diluted primary effluent). The savings in annual outfall costs for secondary effluent versus primary effluent would be only approximately $0.7 million for this case; on the other hand, costs of secondary treatment would represent an increment of $6.1 million for a net increase in cost of $5.4 million annually. This represents about a 50 percent increase over the option of primary plus a longer outfall.

There may be instances where the comparison will be more striking or less striking. The design of the Barber's Point outfall in Honolulu (a new system) considered the effect of the treatment level on outfall design (see R.M. Towill Corporation, 1974). Although the outfall was officially designed for secondary effluent, the design report indicated that the additional length needed for primary effluent was only 600 ft out of a total length of 10,500 ft, and represented only 2 to 3 percent additional cost. Because of the possibility that secondary treatment might not be built in the future, the designers recommended building this slightly longer outfall (i.e., 10,500 ft) to take advantage of the possibility of not being required to go to full secondary. (The mean design flow for this outfall was 59 MGD; the peak design flow 112 MGD; the depth of discharge 195-200 ft; the length of diffuser 1,750 ft, which could have been 1,150 ft for secondary effluent; and the inside outfall diameter was 78 inches.) One of the reasons the marginal length (and cost) is so low here is the bottom topography; the outfall crosses a long coral shelf and then follows a rather steep decline to a depth of about 195 ft where the diffuser

turns and follows the 200-foot contour. In order to meet the water quality requirements (especially for nutrients), and take advantage of the favorable density structure to achieve plume submergence, it is necessary to go to approximately 200 ft depth for either primary or secondary levels of treatment.

There are other trade-off possibilities. For instance, consider an outfall which is already built and the choice is between lengthening it and adding secondary treatment. In this case, the cost of the incremental length must include the full cost of mobilization of the construction effort; and if the mean flow is small (on the order of 1 to 10 MGD), then installing secondary treatment might be cheaper. On the other hand, if an agency already has an outfall that performs very well with primary treatment, then the secondary treatment requirement may have no trade-off in outfall length (because the outfall is already designed to perform for primary effluent).

In the case of combined sewers, the storage, treatment, and outfall disposal are all relatively expensive because of the large flows, especially considering the fact that combined sewer overflows may be a relatively infrequent occurrence (e.g., only 4 percent of the time at San Francisco). Secondary treatment is not the issue here, but rather the question is whether to provide primary treatment for mixed storm-water sewage; or whether to gradually build a system of separate sewers; or whether to do nothing if it is judged that the damage of occasional overflows to coastal waters is less than the cost of correcting the problem. The federal law at present does not clearly specify how storm water overflows are to be regulated, although the present procedure appears to be to permit it only when a 301(h) waiver is granted (for coastal discharge of less than secondary treated effluent).

E. Sludge Disposal — The Ocean Option

For disposal of digested sludge the ocean option is precluded by current law, but if it were modified the ocean disposal option would be found in some cases to be much cheaper than land disposal or incineration. As an example, the Orange County Sanitation Districts is faced with a program for dewatering sludge and hauling it by truck inland 30 km to landfills in the foothills of the Santa Ana Mountains on the opposite side of the county from the coastal treatment plant. The regional sludge study (LA/OMA, 1980) has estimated the cost of this disposal method as $75 per ton (raw sludge basis) or $9.7 million per year (1977 dollars), if partial secondary treatment is required (planning Phase II). However, a deep water sludge outfall to 300-400 m was suggested as a possible alternate by Jackson et al. (1979), who estimated the cost of a 33,000 ft (10 km) outfall (18 to 24 inches inside diameter) to be between $5 and $10 million.* The environmental impacts of such a system were predicted to be low, although additional

* LA/OMA, 1980, estimated that for the year 2000 with full secondary treatment (planning Phase III) the cost of deep ocean disposal would be $36 per ton (raw sludge basis, 1977 dollars), compared to the landfill disposal cost of $86 per ton for Orange County Sanitation Districts. However, we believe the capital cost estimates used for a marine sludge outfall were much too high.

field research and environmental data were recommended before any project is built.

A comparison between landfill and ocean disposal costs for Orange County Sanitation Districts is presented in Table 2, which includes about one million dollars per year for environmental research and monitoring for the ocean option. Although these numbers must be regarded as preliminary (not official estimates) they do indicate the wide difference in costs between land and ocean disposal (about $11.9 million vs. $2.75 million). The design capacity is 150 tons of sludge solids (dry weight) per day, consisting of mostly primary sludge anaerobically digested and screened to remove any large particles before discharge. It is assumed that under a section 301(h) waiver, full secondary treatment will not be required.

Even if an experimental discharge were permitted for only five years, the savings over landfill disposal could still more than pay for an extensive program of ocean monitoring and fully amortize the outfall pipe in 5 years instead of 30 years. This is an example of a project where an experimental step, if allowed, would be useful, not only for that agency, but as an opportunity to gain valuable information for further developing the methodology for predicting the transport, fates, and effects of sludge introduced into deep water. Since the risk of such an experiment appears to be very low, such research and demonstration projects are recommended.

The ocean disposal option for sewage sludge, of course, includes barging as well as special sludge outfalls. If barging were permitted in the future, there are various disposal strategies that

TABLE 2

ESTIMATED ALTERNATES COSTS OF DIGESTED SLUDGE DISPOSAL FOR ORANGE COUNTY SANITATION DISTRICTS* (150 tons/day)†

	Landfill disposal (by truck)	Ocean disposal (by sludge outfall to to 300m depth)
	$ million	$ million
Capital		
Land	$23-36	
Dewatering, screening	6.0	1.0
Storage	4.5	
Trucking	2.0	
Pipeline		5-10
TOTAL CAPITAL COST	35-48	6-11
Annual costs		
Capital#	4.0-5.3	0.7-1.2
Annual operation and maintenance	6.6	0.25
SUBTOTAL, Capital and O & M.	10.6-11.9	1.0-1.5
Special research and monitoring program	-	0.75-1.25
TOTAL, ALL ANNUAL COSTS ($ million)	10.6-11.9	1.75-2.75
COST PER TON † (dollars)	$82-92	$13-21

*Based on preliminary data for Phase II from Orange County Sanitation Districts, Feb. 1981.

#Based on 10.25% interest, amortized as follows: Land, interest only: storage tanks and outfall pipe, 30 yrs; pumping, dewatering and screeining equipment, 10 yrs.; trucks, 7 yrs.

†Actual digested sludge discharge is 150 tons/day which is derived from 350 tons/day of raw sludge. For consistency unit costs are given in costs per ton of original raw sludge.

could be analyzed systematically to predict environmental impacts and to estimate the capital and annual costs. Our ability to predict transport, fates, and effects of barge discharges can also be improved through additional research and monitoring.

The practice of barging is significantly different from sludge outfalls in two respects (Jackson et al., 1979): first, the discharge is near the water surface so that it can have more impact on the photic zone (by reducing light transmission) than a bottom discharge; and secondly, the barges can be programmed to dump sludge at various places, as desired, rather than at a fixed point as for an outfall. Environmentally, the first point is a disadvantage, while the latter is an advantage.

The cost of barge disposal may be more or less than sludge disposal by pipeline depending on circumstances. Larger discharges tend to favor pipelines because continuous pipeline transport is cheaper than batch transport. Higher dilutions and submerged plumes can be more readily achieved. On the other hand, long distances and/or difficult outfall construction conditions favor barge disposal, especially for small or moderate sludge volumes.

In summary, our predictive ability for engineered systems of sludge discharge to the ocean (by pipeline or by barge) has advanced considerably in recent years and will continue to improve as more research is done. For the Southern California Bight, Jackson et al. (1979) developed various predictive models and applied them to analyze the environmental impacts of various alternative methods of sludge disposal in deep water. For this area they recommended outfall pipelines to about 1000 ft depth as the best new method for further engineering evaluation. Additional research needs were also identified.

F. Monitoring

An important part of the ocean option for disposal of sewage or sludge (when permitted) is an adequate monitoring program to identify any trends in environmental effects or to discover any new problems. Monitoring is typically required of the discharge agency by the regulatory agency. The discharger either does its own monitoring or else contracts the work out, and reports to the regulatory body.

There are basically two kinds of monitoring: (1) measurements of the chemical quality of the effluent and the flow rate, and (2) measurements of ambient water quality in the vicinity of the discharge and along the nearby shoreline. For large discharges the required monitoring stations may be scattered over 10 kilometers in each direction.

The main purpose of monitoring efforts, it appears, is to determine compliance with the regulations rather than for research. For example, measurement of numerous water quality parameters may be required once a week (or more often), but no current data, density profiles, or other information is required even though it might be useful to understanding synoptic conditions at the time the water quality samples are taken. If a discharge is found to be out of compliance at a particular time of sampling, there is nothing that can be done in "real time" (because the offending plumes have already been discharged into the ocean). The fastest response is to start or stop chlorination, or

adjust the dose of chlorine, or any other chemical that may be added as part of the treatment process (such as polymers to enhance sedimentation).

Unpermitted doses of toxic pollutants cannot be quickly detected in the effluent nor can the source of them be readily found without extensive investigations. Therefore, it appears that too much money and effort is spent on routine monitoring which could be better spent on research-oriented tasks and looking for new problems. This point is well illustrated by the industrial discharge of waste DDT (until 1970) through the sewer system of the Los Angeles County Sanitation Districts and the outfalls off Palos Verdes. The extensive adverse effects of this discharge were not uncovered by routine monitoring (DDT was not on the list of regulated substances then), but rather it was found through a special series of measurements and studies stimulated by the publication of research findings linking nesting problems of marine birds to bioaccumulation of DDT in the marine food chain.

The discharges of toxic pollutants from municipal sewer systems are very unlikely to accumulate to acutely toxic levels. The question is whether existing levels may be chronically toxic. Thus, the best strategy for monitoring the environment is to use tests which are integrative in nature, such as measuring at regular intervals (like a year) the accumulations of trace contaminants in bottom sediments, or in particular indicator shellfish at designated locations (Goldberg's "mussel watch"). Such long-term monitoring will be required of any discharger who gets a section 301(h) waiver.

However, the control of short term problems, such as infection by pathogens, must be measured by instantaneous point samples of receiving water at some regular short interval depending on the size of the discharge, the intensity of beach use, and the rapidity with which prevailing currents or stratification may change. Measurement intervals are typically in the range of daily to weekly.

The cost of monitoring programs is difficult to determine. However, a good indication is given by an analysis by the EPA of the cost of providing the necessary information and monitoring in the discussion of the proposed ocean discharge criteria (45 FR 9548). For a large POTW discharging 360 MGD, the incremental user charge is estimated to be only $0.06 per month; however, that would rise to $0.80 per month for POTWs of 5 MGD capacity and to just over three dollars per month for plants of 0.5 to 1 MGD. The sharply rising unit costs per user as the plant size decreases indicates that monitoring cost is a variable which decreases much more slowly than the discharge. For small discharges especially, it is highly doubtful that the value of the information obtained is commensurate with the costs incurred, simply because small discharges to the ocean represent very small threats in most cases.

In the past, the design of monitoring programs has included an excess of routine measurements, but insufficient research aimed at identifying new relationships or problems. A notable example of a forward-looking monitoring and research effort was the establishment of the Southern California Coastal Water Research Project (SCCWRP) in 1969, by the County Sanitation Districts of Los Angeles and Orange

Counties, the Cities of San Diego and Los Angeles, and Ventura County. Organizationally it is separate from the severage agencies and under an independent board. The scientific work is guided by a director and a special board of consultants. Although the funding has come primarily from the discharge agencies, additional support has come in recent years from various other research funding agencies. SCCWRP issues comprehensive biennial reports summarizing results of numerous special studies (see SCCWRP, 1979-80, for the latest report), and occasional special publications, as well as publishing papers in the technical literature.

The agencies which founded SCCWRP discharge about 1 billion gallons per day of effluent to the Southern California Bight. Although they maintain their own routine monitoring effort involving frequent sampling of the shoreline and offshore waters for compliance with the requirements, they wisely established the special organization to conduct ongoing and long-term special studies of the effects. Some of the best results in the literature come from this effort. The costs of such research efforts, in the total context of wastewater disposal costs, are small and well worthwhile.

G. Summary of Management Alternatives

A well-designed program of disposal of municipal wastewater and sludge to the ocean, as we have seen, includes a mixture of source control, sewage treatment and sludge processing, appropriate outfalls (or barging operations), and monitoring and research efforts commensurate with the scale of the discharge and the risks. The level of activity in each category is clearly related to each of the others, and the engineer-manager should seek an optimum combination of efforts. For example, good monitoring measurements of the accumulation of metals in sediments or in the food chain will provide the basis for rational discussions on how much source control effort is needed for particular substances. With monitoring and research information we can focus the attention on substances which are believed to be most important in the environment and avoid excessive efforts on nonproblems.

Overlying all of the foregoing should be a program of geographically varying "management standards"; i.e., requirements for waste management which are set on a regional or case-by-case basis in sensible time steps, with the flexibility to adjust each control program in response to the ocean observations of the effects of a particular discharge. The compliance schedule would allow enough time and flexibility to study the effects of different actions as the basis for any further tightening of the requirements. It is not necessary, nor economically efficient, to tighten the requirements in one step to the most demanding level that might possibly be necessary, because in most instances we are not dealing with a water quality crisis but rather with some long-range concerns. The ability to make wise and cost-effective decisions is greatly improved by having time for feedback loops.

Another reason for using management standards is to achieve better integration of marine disposal options with air and land disposal. For example, time could be provided for incremental

implementation of alternative disposal systems to land or air. Thus, if it is believed that it is better to dispose of sludge on land rather than to the ocean, it might be wise to establish such an operation for a minor fraction of the sludge (such as 10 percent) to fully investigate the feasibility and environmental effects of the alternate disposal procedure before making a full-blown commitment to switch.

Heretofore, federal legislation and regulations have not permitted enough flexibility in management alternatives. The rigidity of the regulations does not encourage innovation in developing new cost-effective measures. Government policy so far has been relatively unresponsive to new technological approaches or to new environmental research results because of the lack of flexibility or regionalization of the regulations.

II. POLICY ALTERNATIVES AND ADMINISTRATION

The previous section gave an overview of the key technical components of management alternatives which could improve ocean disposal practices for municipal wastewater. This section treats general policy elements of a sensible strategy.

A. Balancing the Effects and Risks of Ocean Discharge Against the Costs of Avoidance.

It is an obvious proposition that discharge of pollutants into the nation's waters imposes costs — whether through adverse effects on humans and their environment, or through the threat of such effects. It is an equally obvious proposition that avoiding these costs can itself be very expensive. The need for trade-offs, for weighing one category of costs against the other with an eye to achieving a reasonable balance, is quite clearly posed. Yet, by and large, present federal policy disdains such a balancing approach. Put differently, present policy reflects a very conservative (in the sense of risk-averse) attitude: high (and costly) levels of control are required, without much regard to resulting benefits. Put still differently, the benefits of demanding controls are presumed to be very large.

A conservative approach is not by any means a necessarily bad approach. Quite to the contrary, for example, it seems clearly justified in the case of toxic pollutants. Whether it is justified with

regard to disposal of more conventional pollutants into ocean waters is, insofar as this volume is concerned, an open question. It is clear to us, however, that in the limited instance of ocean disposal of conventional municipal wastes, the conservatism of present policy — a general (minimum) requirement of secondary treatment for POTW effluent — is, on balance, unwarranted.

Several considerations support this conclusion. First, a requirement of secondary treatment for POTWs discharging into ocean waters entails very substantial costs — not just direct capital, operating, and maintenance costs, but also, for example, increased costs of sludge disposal. Second, alternative technologies — much less expensive than secondary treatment, but satisfactory because they take advantage of the oceans' enormous assimilative capacities — exist and are in fact in use. Third, and assuming effective source-control programs, secondary treatment, for all its costs, may yield negligible benefits. Conventional POTW pollutants — e.g., BOD and suspended solids — simply do not pose large risks for ocean waters when subjected to primary treatment and discharged by well-designed means. Even cautious calculations, then, suggest the wisdom of a more balanced approach in the case of ocean waters.

Congress, it appears, endorsed this conclusion in the Clean Water Act of 1977. Section 301(h) of that legislation provides for modifications of secondary treatment requirements in the case of some ocean discharges. While the modification provisions are welcome, they are not without shortcomings. They apply only to existing discharges, only for a limited time, and (probably) only to limited coastal regions; they cannot result in imposition of additional controls on other sources; they are rigidly constrained by water quality standards; they entail difficult, expensive, and time-consuming application procedures (the possible adverse effects of secondary treatment have never received the scrutiny to which proposed modifications are subjected). All in all, it is too early to tell whether section 301(h) will reflect the balanced attention to costs and benefits so important to sound ocean discharge policy. It is clear, though, that the section does neglect a second important policy component, considered next.

B. Relating Ocean Discharge Policy to Other Disposal Options

1. Alternatives to Ocean Discharge. Federal law for ocean discharge is written with the underlying premise that land disposal of effluent and sludge may often be environmentally superior to ocean discharge. For example, the Ocean Dumping Act, by virtue of the ban on ocean dumping after 1981, presumes *a priori* that land disposal must be better than ocean disposal for digested sludge and other solid wastes. The multi-media choices and trade-offs for sewage sludge disposal have been discussed in detail in National Academy of Sciences (1978).

Since the basic laws were formulated in the early 1970s, there has been greatly increased awareness and measurement of groundwater contamination by toxic pollutants. There are apparently greater risks than heretofore realized for contamination of groundwater by surface disposal of both solid and liquid wastes, followed by rainfall percolation and leaching of contaminants to the groundwater supplies. Because

groundwater is a major source of drinking water, the direct public health risks of land disposal for a given effluent with trace contaminants (and nitrates) are generally much greater than for marine disposal. Not only does the ocean provide much greater dilution (on the order of several hundred to one for a good outfall), but also the ocean is not a source of drinking water.

The groundwater example illustrates an obvious but often overlooked point. Decisions involving waste discharge into the ocean must compare the costs and risks of ocean disposal with those of other methods of disposal. If we had only to minimize the impact on the ocean without regard to any other environmental media, then the answer would be very simple: zero discharge to the ocean. Do anything else with the wastewater at any cost but do not put any of it into the ocean! Plainly, though, such an attitude is unrealistic. As long as people choose to live in urban areas along the seacoast, there is no way to avoid some impacts on the quality of coastal waters not only from sewage, but also from stormwater overflows, street runoff, aerial fallout, ship pollution, and so on. Only in rare instances will land disposal be a viable alternative to ocean disposal. Factors favoring land disposal might include an arid climate with a high evaporation rate, a big demand for reclaimed water, abundant land, the location of land disposal sites at places where there is no groundwater threat, small wastewater flows, and unfavorable oceanographic conditions for an outfall. In addition, if the source of the wastewater becomes a significant distance inland from the coast, then land or stream disposal becomes relatively more attractive because of the conveyance cost to the ocean. At the present, one of the longest transit distances for municipal severage systems from origin to ocean discharge is about 100 kilometers (e.g. Los Angeles County Sanitation Districts system).

2. Policy. Efforts to protect ocean waters without regard to effects on other resources — land and air — could well result in net social losses. Constraints limiting waste disposal on land or in the air, without regard to their implications for ocean disposal policy, could quite easily yield a situation where all disposal options have been made infeasible. Even with programs to limit the production of wastes and to promote recycling, there will still be residuals which must go somewhere, and the only alternatives are air, land, and water, or some mix of these receiving media.

In light of these considerations, it is evident that a sound approach would: (1) promote feasible source control, including reduction in waste production, pretreatment, conservation, and reuse; (2) direct disposal of remaining residuals, under proper controls, to those media that can best tolerate them. The effort, in short, should be to minimize the sum of all relevant costs, taking all media into account.

As sensible as such an approach is, it does not represent present policy. Quite to the contrary, the present approach constrains disposal from all sides, and without much regard to the interrelated effects of doing so. In our particular case, ocean disposal of municipal waste, matters are in fact worse than this. Chief reliance on secondary treatment results in increased sludge production, yet opportunities for sludge disposal are severely limited. Section 301(h)

modifications can have a positive effect here, but an unduly narrow one. Modification procedures should include a searching analysis of alternative disposal options, but it appears they do not. The impact on ocean waters of granting a modification is considered with great care; the impact on land and air of denying a modification is virtually ignored. Thus, for example, the limited assimilative capacity of some ocean waters of the East Coast is a matter of major concern, while similarly limited air and land capacity are more or less overlooked.

In short, federal controls are far less integrated than they should be and could be; a more systematic approach is both necessary and possible. This is not to say that trade-offs must be made with fine-tuned precision — more rough-and-ready calculations would be a satisfactory beginning. Nor should our comments suggest an instant need for a completely integrated approach to environmental management. Rather we recommend a more modest program, limited to ocean disposal of municipal waste and sensitive simply to the most obvious trade-offs among air, land, and water as disposal sites. Given a relatively small number of sources and a relatively good understanding of the options and constraints they face, such a more integrated approach to the municipal waste-ocean disposal problem would appear to be manageable.

C. Approaching Policy on a Regional Basis.

If the interrelated effects — costs and benefits — of alternative management strategies are to be considered in formulating controls on ocean discharge of municipal waste, then this means almost necessarily that policy must be developed on a regional not a national basis. Land, air, and water resources differ significantly from place to place, and controls that make sense for one area will not suit another. Ocean waters are regionally variable, for example — some provide greater assimilative capacity than others, some have more sensitive ecosystems than others, some are subjected to more effluent input than others. Variations like these should be taken into account; standards and controls should be regional. Section 301(h) adopts such an approach in part by taking careful account of differences among ocean waters. As mentioned above, however, the modification provisions tend to ignore areal differences among air and land resources; the tendency is a product of the unsystematic approach of present environmental controls. In other words, the need for the ocean disposal option (as for sludge) depends heavily on the impacts of not using the ocean, which may vary considerably among regions.

Developing policy on a regional basis implies not only different controls for different areas, but different timetables as well. For example, a phase-out of ocean dumping by a specified date may well prove to be appropriate for one set of cases in one region, but a different set may need a different schedule.

Present environmental policy in general displays undue amounts of national uniformity, and the job of revamping existing controls in order to take account of regional variability will be a big one. But that is not the concern here. Ocean disposal of municipal waste

presents a discrete set of problems and can be dealt with accordingly, without having to address larger reforms.

D. Adjusting Policy in Response to New Information

Another important aspect of ocean discharge policy should be flexibility to respond to new information of all kinds: research on transport, fates, and effects of pollutants in coastal waters; monitoring results near outfalls; technological advances (in all aspects of source control, treatment plants, and outfall construction); impacts on other media related to ocean discharge policies; changing costs (both capital and O&M). Many present requirements are so rigidly prescribed (in legislation or regulations) that changes may take years to get through the "system". Individual POTWs can respond with more innovation and pollution control for the money if regulatory agencies have enough flexibility to adjust standards on a timely case-by-case basis. (See also the discussion of management standards in Sec. I-G above.)

Severage agencies should also be encouraged and supported to undertake research and demonstration projects to improve overall environmental management. A good example is the use of deepwater special outfalls for sludge disposal off Southern California as suggested by Jackson et al. (1979). However, current policy prohibits such a project, probably even as a research and development activity. With good source control of contaminants such a project would not be risky on a trial basis to observe the impacts.

Without flexibility, we deny ourselves the opportunity to profit by our experience — both good and bad.