United States
Environmental Protection
Agency

Region I
J.F. Kennedy Federal Building
Boston, MA 02203

EPA

Environmental Impact Statement

Final

MDC Proposed Sludge Management Plan, Metropolitan District Commission, Boston, MA.

Part B Volume II

FINAL ENVIRONMENTAL IMPACT STATEMENT

MDC Proposed Sludge Management Plan,
Metropolitan District Commission, Boston, Massachusetts

Lead Agency:	U.S. Environmental Protection Agency Region I JFK Federal Building Boston, Massachusetts 02203
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Abstract:

This Final Environmental Impact Statement (EIS) evaluates a sludge management plan proposed by the Metropolitan District Commission (MDC) and examines other alternative systems; in an attempt to ensure the most environmentally sound and cost effective sludge management plan for the handling and disposal of primary sludge for the MDC system. Although the proposed project would involve 75% federal funding; the ultimate responsibility for implementing the selected sludge management plan lies with the MDC. The various alternatives analyzed and their environmental impacts are discussed in the EIS, and the selected alternative(s) identified.

No Administrative Action will be taken on this project until 30 days after notice of this publication appears in the Federal Register.

VOLUME II - APPENDICES

FINAL

ENVIRONMENTAL IMPACT STATEMENT

MDC PROPOSED SLUDGE MANAGEMENT PLAN,

METROPOLITAN DISTRICT COMMISSION, BOSTON, MASSACHUSETTS

Prepared For

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Jan 8, 1979

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APPENDIX A

IMPACT ASSESSMENT METHODOLOGY

A. General Approach

As indicated in Section I, there are three major areas of investigation in this impact statement: incineration, land disposal and ocean disposal of primary treatment plant sludges. The methods of disposal governed the areas of potential environmental impact. Therefore, it became necessary to define the geographical limits of these potentially impacted areas.

Recalling from Section I that sludge can be disposed of on land by either of two basic methods (direct or indirect), land disposal had the widest possible area of impact, since theoretically any plot of undeveloped land has the potential for accepting sludge. Therefore, digested and prepared sludge could be disposed of any place that is technically, environmentally and economically feasible. In the case of sludges generated in Boston, the entire New England area could be considered for the direct and indirect application of sludge. If sludge were to be applied by the indirect method (i.e. as a dried fertilizer/soil supplement), there is no feasible method of controlling or monitoring the specific sites of application because of the varied users. Therefore, environmental impacts had to be judged or estimated on the basis of the known qualities of the sludge, and not upon the specific receptor sites.

Should it be feasible to dispose of sludge by direct land application to dedicated areas, it becomes necessary (and possible) to identify, monitor, and control these specific sites. Under such circumstance, transportation of these residues in bulk form could also occur throughout New England. However, such a solution carries the implicit need to cross state lines. This, in turn, creates many institutional problems which greatly outweigh the environmental concerns associated with this type of approach. Specifically, the Commonwealth of Massachusetts (in the form of MDC) would not be able to control the final disposal process, since it would be subject to the control of the recipient state. Therefore, in evaluating the technical aspects of direct land application, only the Commonwealth of Massachusetts was considered as a viable disposal area.

In developing the environmental inventory to describe the existing environmental settings, choices must be made as to the depth that each major inventory item will be described. Even though the major geographical limits of the project area have been restricted to the Commonwealth, it would obviously be impossible to describe in minute detail the environmental setting of each community within the State. On the other hand, those areas which had the largest impact from any one alternative were described in detail.

When evaluating the potential impacts resulting from sludge incinerators, it was necessary to describe on a microscale basis the ambient air quality and meteorological conditions for the Boston Metropolitan Area.

Finally, in order that the No-Action alternative could be correctly assessed, the inventory carried a detailed description of the existing conditions in Boston Harbor (water quality, marine ecology, bottom sediments, etc.).

Subsequent to alternative screening and detailed development, the effect of Federal legislation during the period 1975-1978 has been incorporated, eliminating those alternatives not acceptable, as shown in greater detail below.

B. Specific Approach

While the preceding discussion was based on the general approach to be used in evaluating the various alternatives, this section will indicate how each of the environmental areas are to be assessed depending upon the various disposal alternatives.

1. Air Quality

Because of the relative importance of the incineration alternative developed by Havens and Emerson for the MDS, air pollutant emissions, their concentrations in the atmosphere, and their potential impacts on public health are a major area of interest in this Impact Statement. Modeling techniques developed by EPA Region I were used to assess air pollutant loadings and air quality impacts from the proposed sludge incinerator. (Paul Cheremisinoff was the subcontractor for this project responsible for the air quality analyses).

In addition, the examination of impacts on air quality from incineration required our determination of the heat balances as well as an evaluation of these values, prepared by Havens and Emerson, to determine if auxiliary fossil fuel is required.

2. Aquatic and Marine Water Quality

In this area, principal potential water quality impacts arose from ocean disposal or land disposal. While some impacts might arise from atmospheric scrubbing of air pollutants generated by incineration, this is not expected to be a significant area for investigation.

3. Terrestrial, Aquatic and Marine Ecology

Heavy metal and nutrient effects upon the biosphere were addressed for both land and ocean disposal. Specifically, sludge impacts on sediment quality and the potential concentration of metals by trophic level were assessed, as well as the effects of bioconcentration in the terrestrial environment.

In preparing the Final EIS, the determination of land area required for application of sludge was expanded to include proposed Federal legislation. This legislation, part of the Resource Conservation and Recovery Act (P.L. 94-580) had the effect of increasing land area required by a factor of 2.5, from 4,000 to 11,500 acres.

4. Soils and Crops

Impacts on soil and crops would arise from land application of sludge, principally from heavy metals, sodium and nitrogen. The impact of sodium and metal inputs will be long-term, while the nutrient input will be short-term. These considerations were incorporated in the model.

5. Land Use

Impacts of the various alternatives on land use were evaluated, the depth of study depending upon the specific area. For example, the effects of facility construction and operation were evaluated for Quincy, Winthrop and the Harbor Islands. For the land disposal alternative, the impacts on the use of adjacent lands, as well as cropland or other agricultural land uses were evaluated.

6. Energy Sources and Supply

Energy requirements for the alternatives, energy recovery and secondary impacts are a major area of impact. In quantifying these impacts, energy inputs from all sources analyzed were developed for each major alternate. In preparing the Final EIS, the use of energy recovery from incineration, as proposed by the Applicant, was analyzed in detail.

7. Transportation and Noise

Effects on transportation facilities and the resultant noise impacts result from any scheme involving transportation of either sludge or ash, and these impacts were evaluated.

8. Public Health

Public Health impacts stem from several areas of primary impact, such as air quality, rivers, crop uptake of metals, groundwater, surface water, and marine water contamination, etc.

9. Social and Economic Impacts

Impacts in these areas will result from costs of construction and operation of alternative facilities. The two areas of economic impact are: (1) capital and operating costs for each of the various alternatives, and (2) the individual economic benefits (or losses) expected to accrue to any individual segment of society.

10. Aesthetics

The two alternatives expected to have the greatest impact on the aesthetic portion of the environment were land disposal and incineration. This particular quality of the environment is very hard to quantify, but the locale of greatest impact will be the Boston Metropolitan Area. Since aesthetics are a people-related quality of the environment, and because any given adverse aesthetic impact is directly proportional to the number of affected people, the area of highest population density will experience the most significant aesthetic impacts. In preparing the Final EIS, aesthetic impacts of ash disposal were a major factor in selection.

C. Period of Impact

In order to quantify many of the impacts under consideration (air quality, sludge loadings and analyses, land uses, etc.), it is necessary to establish the future year and the worst case for which these effects will be estimated.

As indicated in Section I, this environmental statement assesses the impacts associated with disposal of only primary sewage sludge. The EPA and Massachusetts Division of Water Pollution Control have required the MDC to start construction of primary sludge disposal facilities by June, 1976. Also, the proposed MDC sludge management plan has indicated that the maximum loading for primary-only sludge would occur at about 1985 (Havens and Emerson, 1973).

From an environmental assessment point of view, it is best to pick a "worst case" situation in order that the maximum stress that will be exerted on the environment from any particular alternative will be the basis of comparison between the various alternatives. In other words, choosing the most distant design year practicable for a facility will ensure that the long-term impacts are more proportionately considered. Therefore, for the purposes of this environmental statement, 1985 will be chosen as the year for assessing the maximum, long-term impacts generated by each alternative.

D. Development of Process and Disposal Alternatives

The steps used in developing alternative process sequences and disposal techniques were:

1. Development of Possible Process Sequences

- Definition of available processes for conditioning, dewatering, stabilization and reduction of waste sludge, and available disposal routes.
- Elimination of processes which are not applicable to the MDC situation.
- Selection of the best alternative processes for conditioning, dewatering and reduction (or stabilization) of the MDC primary sludge.
- Combining the chosen processes into flowsheets leading to landfill, ocean disposal or land application.
- Elimination of unfeasible flowsheets.

2. Selection of Process Trains for Further Development

- Comparison of available flowsheets leading to landfill on the basis of environmental, energetic and cost-effectiveness criteria.
- Comparison of available flowsheets leading to ocean disposal on the basis of environmental, energetic and cost-effectiveness criteria.
- Comparison of flowsheets leading to land application based on environmental, energetic and cost-effectiveness criteria (this includes a summary of the evaluation of drying sludge for sale as fertilizer).
- Comparison of land application sites based on environmental, energetic, cost-effectiveness and implementability criteria.

After selection of the most feasible process sequences (including disposal), the following questions were addressed in order to develop in detail the alternatives:

- Location of Processing Facilities
- Location of Land Application and/or Disposal Sites

- Feasibility of Thermal Energy Recovery from Incinerator Off Gas
- Autogenous Operation of Incinerators
- Transportation Routes to Disposal and Application Sites
- Co-incineration
- Disposal of Grit and Screenings

With these descriptions of the alternate systems, it then becomes possible to generate the quality and quantity of liquid and solid effluents, the inputs of labor, energy and materials, and the monetary costs of each option. Before detailed assessment of resource inputs and impacts of feasible alternatives, the eleven alternatives developed in the EIS process were screened for compliance with existing and proposed Federal legislation. As a result of this legislation, those alternatives involving ocean disposal of sludge or ash (Alternatives 3, 4 and 7) and those with land application of sludge (5 and 6) were found to be infeasible.

The quality and quantity of solid and liquid effluent streams will be investigated based on data from several sources. The quantity of these streams under 1985 conditions (previously developed by Havens and Emerson from Federal Water Quality Administration population projections) will be reviewed, as follows. The assumptions used by Havens and Emerson will be examined, the quantities of "minor waste streams" (such as grit and screenings) will be evaluated, and quantities of liquid and solid waste streams projected.

Quality of waste streams were developed from previous work by Havens and Emerson and the Metropolitan District Commission. In addition, there was a split sample analysis of sludge in order to confirm the accuracy of the historical data generated by the MDC laboratories. From these data, quality of the various waste streams were projected. In the process of preparing the Final EIS, sludge and ash from the Deer and Nut Island plants was analyzed in accordance with procedures established by the RCRA. This analysis showed both sludge and ash to be hazardous materials (D. Moon, 1978).

The potential impact of industrial pretreatment for heavy metals removal was also evaluated based on a literature review and experience in other metropolitan areas.

The quality of leachate streams from the disposal of sludge and ash were investigated based on data from Havens and Emerson and from the U. S. EPA.

With process alternatives and quantity and quality of waste streams in hand, the next step was development of the inputs of labor and materials for construction, of labor, materials and energy for operation, and of costs of construction and operation.

APPENDIX B-1

MASSACHUSETTS SALT WATER STANDARDS

[Source: MWRC, 1974]

Class SA - These are waters of the highest quality and are suitable for any high water use including bathing and other water contact activities. These waters are suitable for approved shellfish areas and the taking of shellfish without depuration, have the highest aesthetic value and are an excellent fish and wildlife habitat.

Standards of Quality

Item	Water Quality Criteria
1. Dissolved Oxygen	Not less than 6.5 mg/l at any time.
2. Sludge deposits, solid refuse, floating solids, oil, grease, and scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that will impair any uses specifically assigned to this class.
4. Total Coliform bacteria per 100 ml	Not to exceed a median value of 70 and not more than 10 percent of the samples shall ordinarily exceed 230 during any monthly sampling period.
5. Taste and odor	None allowable.
6. pH	6.8 - 8.5.
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the waters for any other uses.

APPENDIX B-1
MASSACHUSETTS SALT WATER STANDARDS (Contd.)

9. Radioactivity	None in concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class SB - These waters are suitable for bathing and recreational purposes including water contact sports and industrial cooling, have good aesthetic value, are an excellent fish habitat and are suitable for certain shell fisheries with depuration (Restricted Shellfish Areas).

1. Dissolved Oxygen	Not less than 5.0 mg/l at any time.
2. Sludge deposits, solid refuse, floating solids, oil, grease and scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing adequate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3. Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4. Total Coliform bacteria per 100 ml.	Not to exceed an average value of 700 and not more than 1000 in more than 20% of the samples.
5. Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6. pH	6.8 - 8.5.
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the water for any other use.

APPENDIX B-1
MASSACHUSETTS SALT WATER STANDARDS (Contd.)

9.	Radioactivity	None in such concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Class SC - These waters are suitable for aesthetic enjoyments, for recreational boating, as a habitat for wildlife and common food and game fishes indigenous to the region, and are suitable for certian industrial uses.

1.	Dissolved oxygen	Not less than 5 mg/l during at least 16 hours of any 24 hour period nor less than 3 mg/l at any time.
2.	Sludge deposits, solid refuse, floating solids, oil, grease, and scum	None other than of natural origin or those amounts which may result from the discharge from waste treatment facilities providing appropriate treatment. For oil and grease of petroleum origin the maximum allowable concentration is 15 mg/l.
3.	Color and turbidity	None in such concentrations that would impair any uses specifically assigned to this class.
4.	Total coliform bacteria	None in such concentrations that would impair any uses specifically assigned to this class. See Note 2.
5.	Taste and odor	None in such concentrations that would impair any uses specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
6.	pH	6.5 - 8.5.
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive water use.
8.	Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, impair the palatability of same, or impair the water for any other use.

APPENDIX B-1

MASSACHUSETTS SALT WATER STANDARDS (Contd.)

9.	Radioactivity	None in such concentrations or combinations in excess of the limits specified by the United States Public Health Service Drinking Water Standards.

Note 2 - no bacteria limit has been placed on Class "SC" waters because of the urban runoff and combined sewer problems which have not yet been solved. In waters of this class not subject to urban runoff or combined sewer discharges the bacterial quality of the water should be less than an average of 5,000 coliform bacteria/100 ml during any monthly sampling period. It is the objective of the Division to eliminate all point and non-point sources of pollution and to impose bacterial limits on all waters.

APPENDIX B-2

MASSACHUSETTS FRESH WATER STANDARDS

[Source: Massachusetts Water Resources Commission, 1974]

Class A - Waters designated for use as public water supplies· character uniformly excellent.

Item	Water Quality Criteria
1. Dissolved Oxygen	Not less than 75% of saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l at any time.
2. Sludge deposits, solid refuse, floating solids, oil, grease, and scum	None allowable.
3. Color and turbidity	None other than of natural origin.
4. Coliform bacteria per 100 ml	Not to exceed an average value of 50 during any monthly sampling period.
5. Taste and odor	None other than of natural origin.
6. pH	As naturally occurs.
7. Allowable temperature increase	None other than of natural origin.
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to humans, or harmful to animal or aquatic life.
9. Radioactivity	None other than that occurring from natural phenomena.

APPENDIX B-2
MASSACHUSETTS FRESH WATER STANDARDS (Contd.)

Class B - Suitable for bathing and recreational purposes including water contact sports. Acceptable for public water supply with appropriate treatment. Suitable for agricultural and certain industrial cooling and process uses; excellent fish and wildlife habitat; excellent aesthetic value.

Item	Water Quality Criteria
1. Dissolved oxygen	Not less than 75% of saturation during at least 16 hours of any 24-hour period and not less than 5 mg/l at any time.
2. Sludge deposits, solid refuse, floating solids, oils, grease, and scum	None allowable.
3. Color and turbidity	None in such concentrations that would impair any usages specifically to this class.
4. Coliform bacteria per 100 ml	Not to exceed an average value of 1000 during any monthly sampling period nor 2400 in more than 20% of samples examined during such period.
5. Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish.
6. pH	6.5 - 8.0.
7. Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8. Chemical Constituents	None in concentrations or combinations which would be harmful or offensive to human, animal, or aquatic life or any water use specifically assigned to this class.

9. Radioactivity	None in concentrations or combinations which would be harmful to human, animal, or aquatic life for the appropriate water use. None in such concentrations which would result in radio-nuclide concentrations in aquatic life which would exceed the recommended limits for consumption by humans.
10. Total phosphate	Not to exceed an average of 0.05 mg/l as P during any monthly sampling period.
11. Ammonia	Not to exceed an average of 0.05 mg/l as N during any monthly sampling period.
12. Phenols	Shall not exceed 0.001 mg/l at any time.

Class C - Suitable for recreational boating; habitat for wildlife and common food and game fishes indigenous to the region; certain industrial cooling and process uses; under some conditions acceptable for public water supply with appropriate treatment. Suitable for irrigation of crops used for consumption after cooking. Good aesthetic value.

1. Dissolved Oxygen	Not less than 5 mg/l during at least 16 hours of any 24-hour period nor less than 3 mg/l at any time. For seasonal cold water fisheries at least 5 mg/l must be maintained.
2. Sludge deposits, solid refuse, floating solids, oils, grease, and scum	None allowable except those amounts that may result from the discharge from waste treatment facilities providing appropriate treatment.
3. Color and turbidity	None allowable in such concentrations that would impair any usages specifically assigned to this class.
4. Coliform bacteria	None in such concentrations that would impair any usage specifically assigned to this class.

APPENDIX B-2
MASSACHUSETTS FRESH WATER STANDARDS (Contd.)

5. Taste and odor	None in such concentrations that would impair any usage specifically assigned to this class, and none that would cause taste and odor to edible fish.
6. pH	6.0 - 8.5.
7. Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case exceed 83°F in warm water fisheries, and 68°F in cold water fisheries, or in any case raise the normal temperature of the receiving water more than 4°F.
8. Chemical constituents	None in concentrations or combinations which would be harmful or offensive to human or aquatic life or any water use specifically assigned to this class.
9. Radioactivity	None in concentrations or combinations which would be harmful to human, animal, or aquatic life for the appropriate water use. None in such concentrations which would result in radio-nuclide concentrations in aquatic life which exceed the recommended limits for consumption by humans.
10. Total phosphate	Not to exceed an average of 0.05 mg/l as P during any monthly sampling period.
11. Ammonia	Not to exceed an average of 1.0 mg/l as N during any monthly sampling period.
12. Phenols	Not to exceed an average of 0.002 mg/l at any time.

Class D - Suitable for aesthetic enjoyment, power, navigation and certain industrial cooling and process uses. Class D waters will be assigned only where a higher water use class cannot be attained after all appropriate waste treatment methods are utilized.

1. Dissolved oxygen	Not less than 2 mg/l at any time.
2. Sludge, deposits, solid refuse, floating solids, oils, grease, and scum	None allowable except those amounts that may result from the discharge from waste treatment facilities.

APPENDIX B-2
MASSACHUSETTS FRESH WATER STANDARDS (Contd.)

3.	Color and turbidity	None in such concentrations that would impair any usages specifically assigned to this class.
4.	Coliform bacteria	None in such concentrations that would impair any usages specifically assigned to this class.
5.	Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class.
6.	pH	6.0 - 9.0.
7.	Allowable temperature increase	None except where the increase will not exceed the recommended limits on the most sensitive receiving water use and in no case 90°F.
8.	Chemical constituents	None in concentrations or combinations which would be harmful to human, animal, or aquatic life for the designated water use.
9.	Radioactivity	None in such concentrations or combinations which would be harmful to human, animal, or aquatic life for the designated water use. None in such concentrations which will result in radio-nuclide concentration in aquatic life which exceed the recommended limits for consumption by humans.

APPENDIX C
RECOMMENDED PROJECT PLAN (1995)
HAVENS & EMERSON, 1973

RECOMMENDED PROJECT PLAN (1995)

The Recommended Project Plan for sludge management provides the Nut Island and Deer Island plants with facilities to meet the estimated year 1995 secondary treatment loadings. As stated in Chapter I, the average daily wastewater flows estimated for 1995 are 210 mgd for Nut Island and 390 mgd for Deer Island. The sludge facilities are designed to handle raw primary sludge and waste activated sludge for the combined flow of 600 mgd.

The Recommended Project Plan is shown schematically on Figure VII-1.

Nut Island Plant: Raw primary sludge will go direct to sludge storage tanks. Waste activated sludge will be thickened by dissolved air flotation with the thickened sludge being pumped to the sludge storage tanks. The existing anaerobic digestion tanks will be converted to sludge storage tanks; provisions will be made to mix

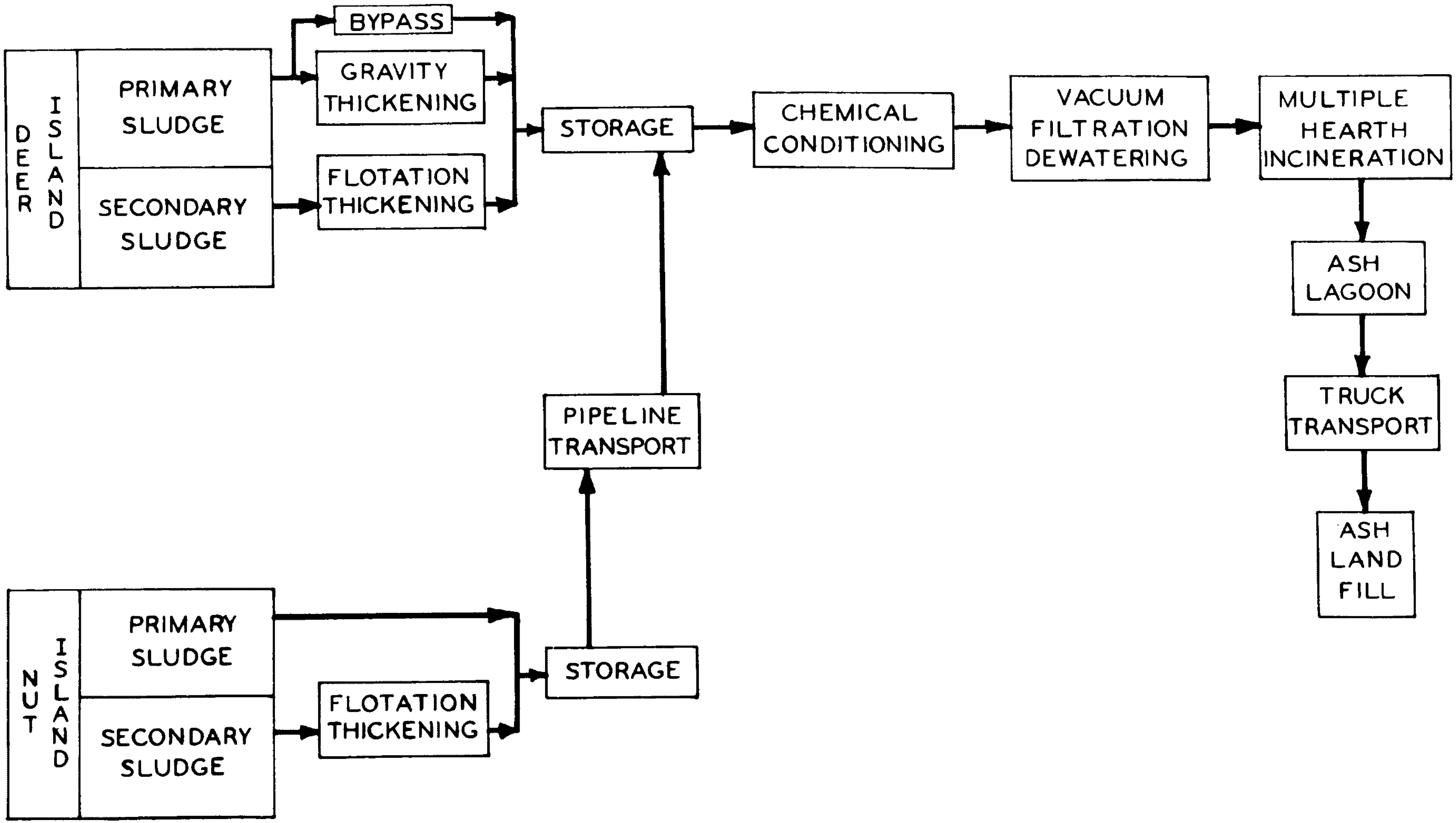

FIGURE VII-1
WASTE SLUDGE MANAGEMENT SCHEMATIC:
RECOMMENDED PROJECT PLAN (1995)

the contents of the storage tanks to provide a homogeneous sludge to pump to Deer Island. An enlarged pumping facility will be provided to pump the mixed sludge to the Deer Island plant. The existing sludge disposal pipeline will be extended to the Deer Island site, and a new parallel sludge force main will be constructed from Nut Island to Deer Island. This parallel facility is required to provide standby capability in case of pipeline outage for repair or cleaning.

Primary effluent will be used as a source of air-charged water for dissolved air flotation, and the liquid effluent from this process will be returned to the head of the plant. The contents of the sludge storage tanks will be mixed and no recycle from these tanks is planned.

Outside electric power will be required when the Nut Island plant is expanded to secondary treatment, and when anaerobic digestion and the recovery of digester gas is abandoned.

Deer Island Plant: Deer Island facilities represent a complete wastewater treatment plant assuming primary and secondary treatment, and sludge disposal. The existing gravity thickeners will provide for thickening of about one-half of the raw primary sludge in the design year. It is recommended that these units be continued in service at optimum loading, but that no new gravity thickeners be constructed. Consequently, about one-half of the primary sludge will go to the sludge storage tanks without thickening. Waste activated sludge will be thickened by dissolved air flotation (similar to the Nut Island), with the thickened sludge going to the sludge storage tanks for mixing with the primary sludges. The combined sludges from both plants will be mixed and be sent to the sludge disposal facilities as a single sludge flow.

The Sludge Disposal Building at Deer Island is the heart of the sludge management system. Sludge will be chemically conditioned with ferric chloride and lime or polymers and delivered to vacuum filters for dewatering. The dewatered cake will be discharged by conveyor into multiple hearth furnaces for incineration. Grit and screenings from the remote sites will be trucked to the Deer Island Sludge Disposal Building for incineration and disposal along with sludge cake. Ash from the incineration process will be pumped in slurry form to on-site ash lagoons for storage and dewatering. Periodically (approximately every two years) ash will be hauled from the site for ultimate disposal of this inert material by sanitary landfill.

Waste heat from the incineration process will be recovered for production of electrical energy. Steam will be produced in waste heat boilers by recovering heat from the incinerator exhaust gases. This steam will be used in turbine generators and is capable of producing approximately one-half of the 1986 power demand for the Deer Island plant. Outside electric power supply should be provided for the remaining load and for standby. (Estimated Deer Island 1995 connected load for primary and secondary treatment with complete sludge processing is about 37 megawatts; average day load with no credit for waste heat recovery is approximately 20 megawatts).

Recycle flows such as filtrate, thickener overflow and ash lagoon supernatant at Deer Island will be returned to the head of plant for treatment.

BASIC DESIGN CRITERIA - RECOMMENDED PLAN

The preliminary basic design criteria for the Recommended Project Plan is listed below. Loadings are for average day conditions in 1995 unless otherwise noted.

Nut Island

1.	Flotation Thickeners	
	No. and Size (length x width)	8 @ 90' x 20'
	Solids loading	9.8 lbs/sf/d
2.	Sludge Storage (Existing Anaerobic Digesters)	
	No. and Size	4 @ 110' diam. x 30' SWD
	Detention	10 days
3.	Sludge Pumping to Deer Island	
	No. and Size	2 @ 1000 gpm
	Average Daily Flow	860,000 gpd (600 gpm)

Deer Island

4.	Gravity Thickeners (Existing)	
	No. and Size	4 @ 55' diam.
	Solids Loading	27.6 lbs/sf/d
5.	Flotation Thickeners	
	No. and Size	16 @ 90' x 20'
	Solids Loading	8.1 lbs/sf/d
6.	Sludge Storage (Existing Anaerobic Digesters)	
	No. and Size	4 @ 108' diam. x 30' SWD
	Detention (Deer Island Flow Only)	6 days
	(Deer & Nut Island Flows)	3 days
7.	Vacuum Filters	
	No. and Size	14 @ 750 sf
	Filter yield, avg. day (10 filters)	4.5 lbs/sf/hr
	max. day (12 filters)	4.9 lbs/sf/hr

8.	Incinerators	
	No. and Size	7 @ 25' diam. x 9 hearth
	Rated capacity, each	410 wet tons/d
	Sludge loading, avg. day (5 units)	8.5 lbs/sf/hr
	max. day (6 units)	9.9 lbs/sf/hr
9.	Turbine Generators	
	No. and Size	4 @ 3400 KW

In order to establish incinerator operating conditions, determine the amount of recoverable heat available, and to establish the operating cost of auxiliary fuel, detailed heat balance computations were prepared. These computations were computerized, and for information of the reader, a typical heat balance computation is presented in Appendix F.

The heat balance shows that under 1995 average day conditions, no auxiliary fuel is required, and that the exit flue gas temperature leaving the furnaces will be about 1136°F. Gas temperature leaving the heat recovery boilers is about 250°F., and at exit from the scrubbers is approximately 105°F.

ESTIMATES OF COST - RECOMMENDED PLAN (1995)

Table VII-2 presents capital costs for the Recommended Project Plan at Deer Island and Nut Island. The costs presented here are based on current price levels. The electrification of raw sewage pumps at Deer Island has been included in this tabulation; earlier in this study it was shown that the operation of raw sewage pump engines was uneconomical, therefore, electrification of these pumps is included.

Table VII-3 presents total annual costs for the recommended plan.

TABLE VII-2

CAPITAL COSTS
RECOMMENDED PROJECT PLAN (1995)

NUT ISLAND	
Flotation Thickeners	$ 1,812,400
Sludge Pump Station and Pipelines to Deer Island	4,852,800
Miscellaneous Facilities[1]	442,000
Total for Nut Island	$ 7,107,200
DEER ISLAND	
Electrification of Raw Sewage Pumps[2]	$ 1,920,000
Flotation Thickeners	3,584,700
Vacuum Filters and Incinerators	24,502,800
Power Generation Station	5,576,400
Miscellaneous Facilities[3]	1,869,000
Ash Lagoons and Landfill	1,642,400
Total for Deer Island	$39,095,300
TOTAL PROJECT COST (Rounded)	$46,202,000

(1) Includes service water, tunnels and yardwork.

(2) After allowance for $180,000 salvage value for 9 engines.

(3) Includes Service Water Facilities, gravity thickener and storage tank odor control, tunnels, and yardwork.

TABLE VII-3

TOTAL ANNUAL COSTS
RECOMMENDED PROJECT PLAN
(Median year 1986)

Total Capital Cost	$46,202,000
Amortized Capital Cost	$ 3,106,500
Annual Operation and Maintenance Costs:	
Fuel and Power	$ 631,700
Chemical Costs	575,000
Maintenance	375,700
Manpower	1,570,500
Total - Oper. & Maint.	$ 3,152,900
Credit for recovered energy	-795,000
TOTAL ANNUAL COST (Rounded)	$ 5,464,000

APPENDIX D

ROCK TYPES OF CONTINENTAL MASSACHUSETTS

Sedimentary Rocks

Conglomerates (Bellingham, Pondville, Roxbury, Dighton and Purgatory, Mount Toby, Howard)

Schists (Brimfield, Oxford, Paxton Quartz, Chiastolite, Boylston, Amherst, Erving Horneblend, Conway, Goshen, Hawley, Savoy, Greylock, Berkshire, Rowe, Hoosac)

Slates (Braintree, Cambridge)

Gneiss (Washington, Hinsdale, Northbridge Granite)

Limestones (Bellowspipe, Stockbridge, Coles Brook)

Quartzites (Oakdale, Westboro, Merrimack, Quabin, Cheshire)

Formations (Marlboro, Nashoba, Wamsutta, Weymouth, Rhode Island, Bernardston, Dalton)

Argillites (Leyden, Braintree)

Worcester Phyllite

Chicopee Shale

Longmeadow Sandstone

Sugarloaf Arkose

Chester Amphibolite

Igneous Rocks

Granites (Middlefield, Pelham, Coys Hill, Fitzwilliam, Hardwick, Hubbardston, Fitchburg, Ayer, Andover, Squam, Quincy, Milford, Westwood)

Granodiorites (Williamsburg, Monson, Dedham)

Diorites (Dana, Dracut, Straw Hollow, Prescott, Newburyport, Quartz, Ironstone Quartz, Lee Quartz)

Granite Gneiss (Northbridge, Becket, Stamford, Sterling)

Syenites (Nephelite, Quartz, Beverly, Sharon)

Tonalites (Belchertown, Wolfpen)

Aplites (New Salem, Titanite-diopside Piorite)

Volcanic Complexes (Lynn, Mettapan, Newbury)

Northfieldite

Pegmatite

Hornblendite

Pyroxenite

Vein Quartz

Blue Hill Granite Porphyry

Salem Gabbro-diorite

. Gabbro at Nahant

Soxonite and Peridotite

APPENDIX E

SEASONAL VARIATIONS IN SURFACE CIRCULATIONS IN THE GULF OF MAINE

[Source: Bumpus, 1973]

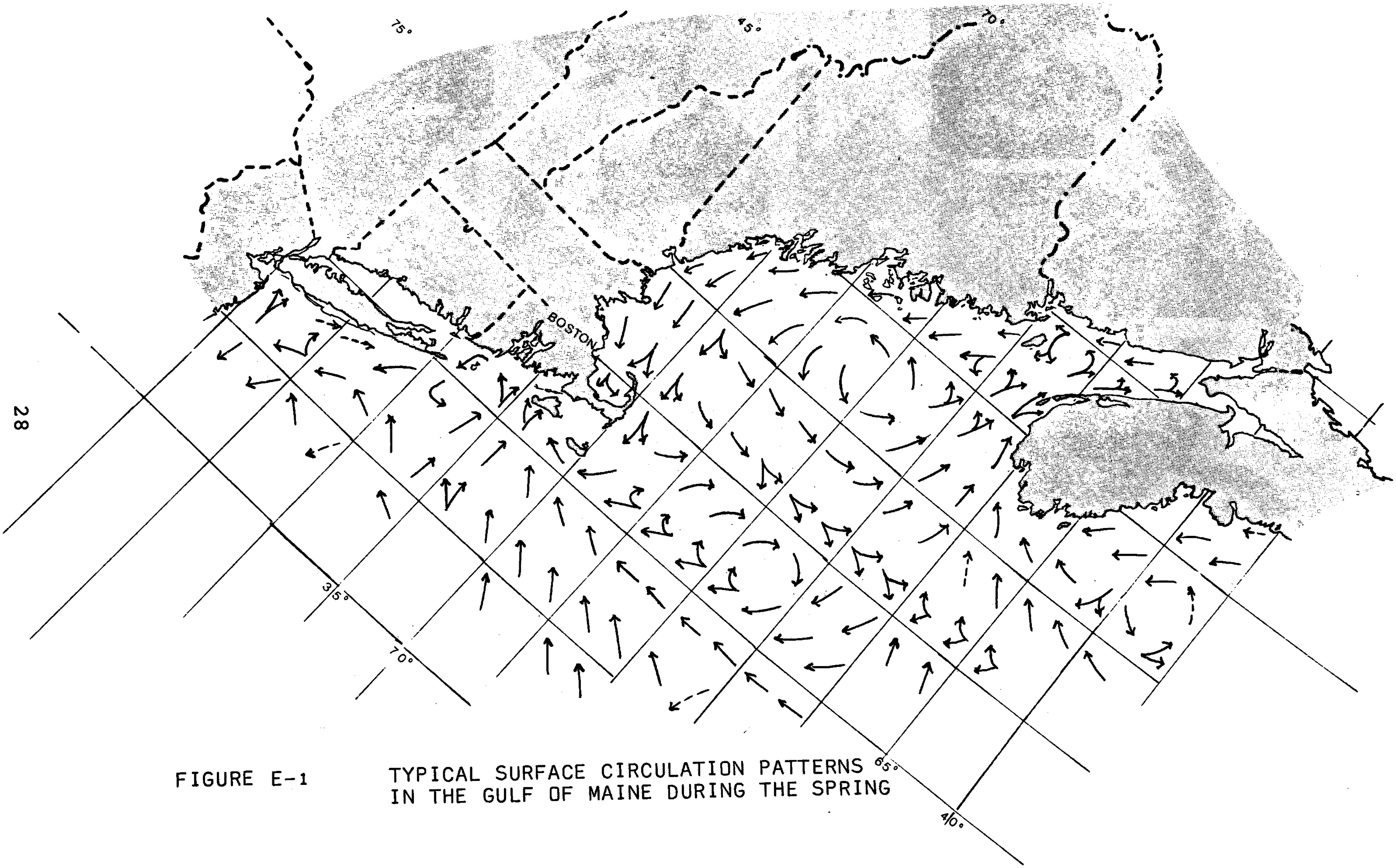

FIGURE E-1 TYPICAL SURFACE CIRCULATION PATTERNS IN THE GULF OF MAINE DURING THE SPRING

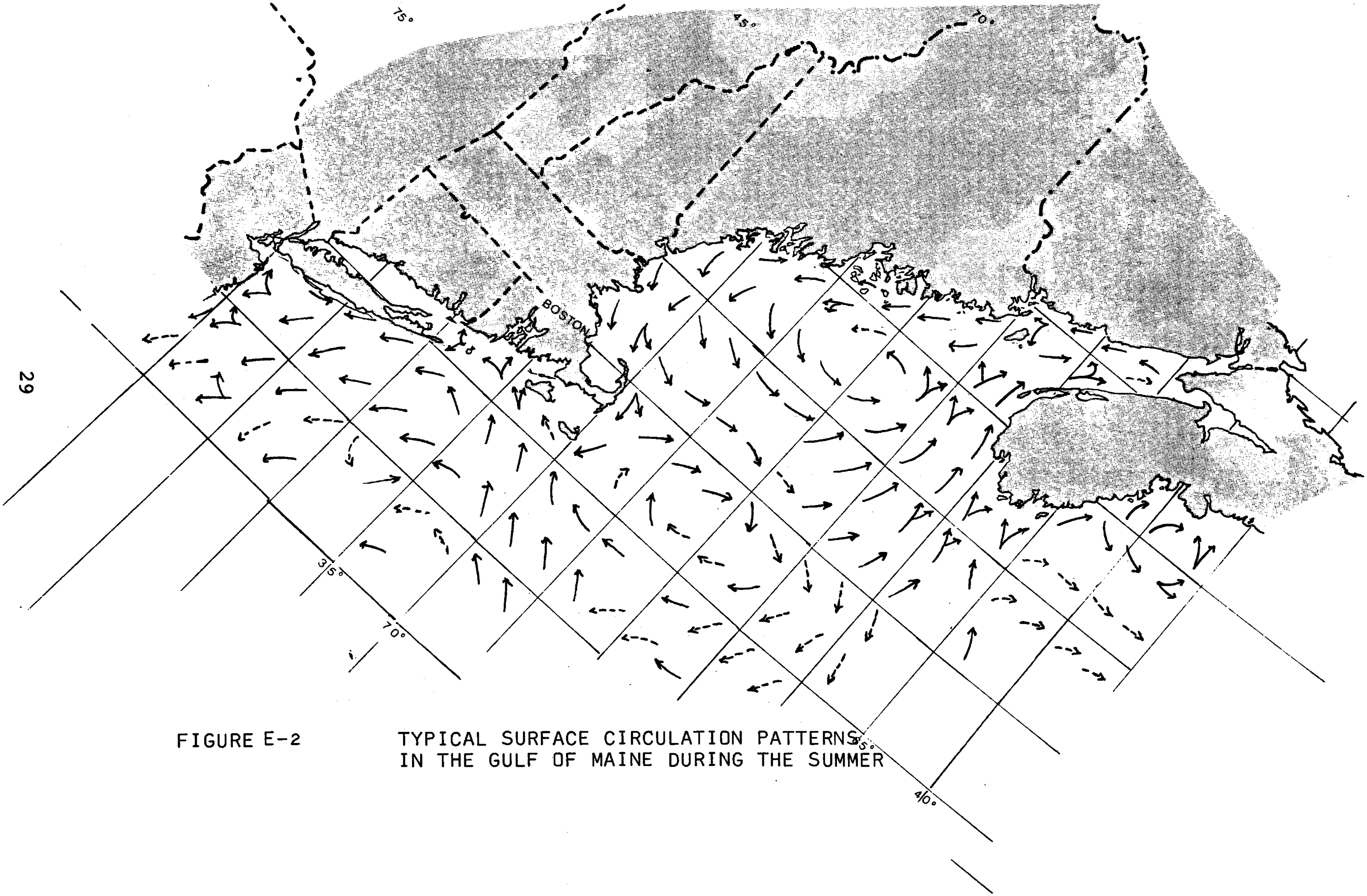

FIGURE E-2 TYPICAL SURFACE CIRCULATION PATTERNS IN THE GULF OF MAINE DURING THE SUMMER

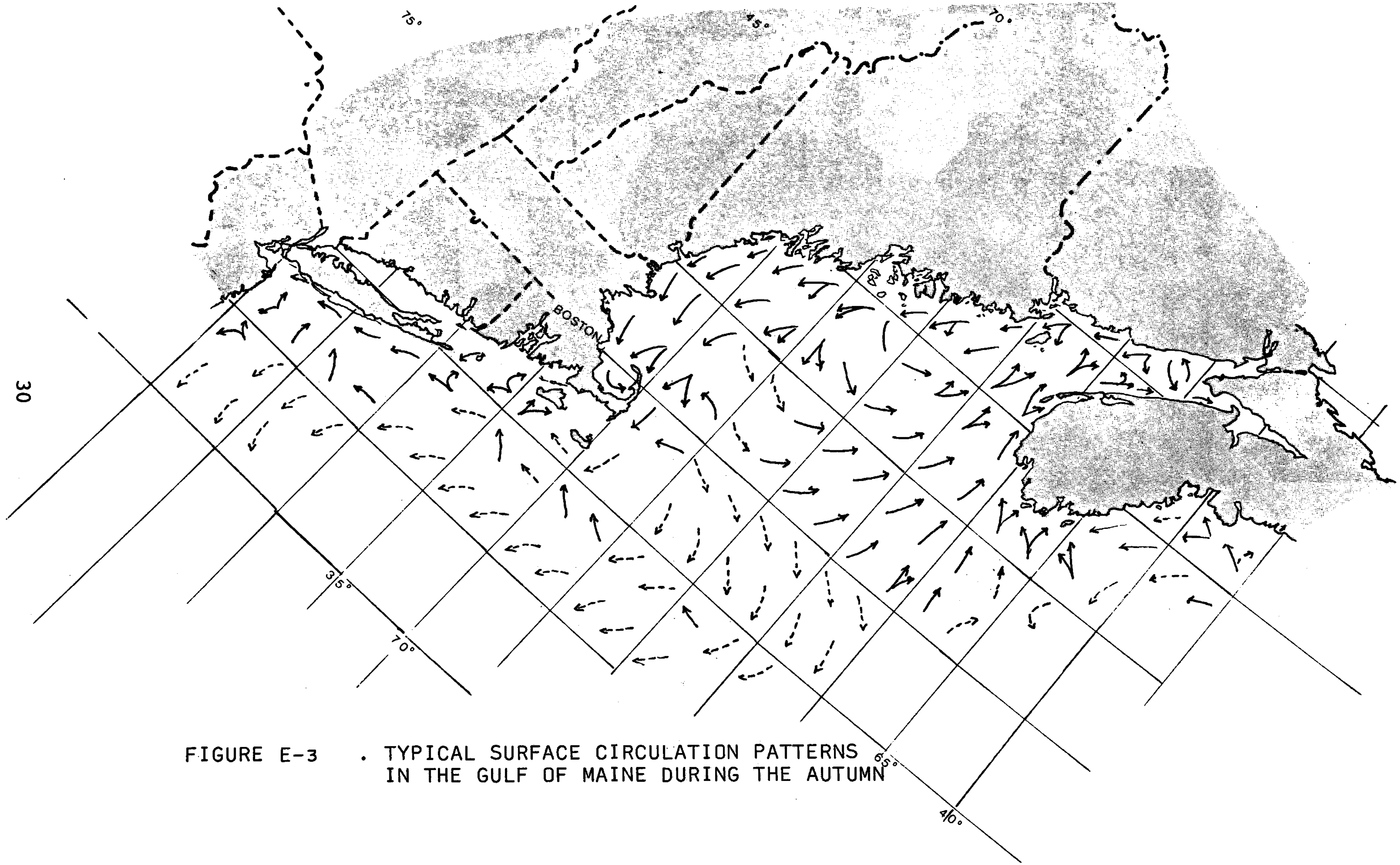

FIGURE E-3 . TYPICAL SURFACE CIRCULATION PATTERNS IN THE GULF OF MAINE DURING THE AUTUMN

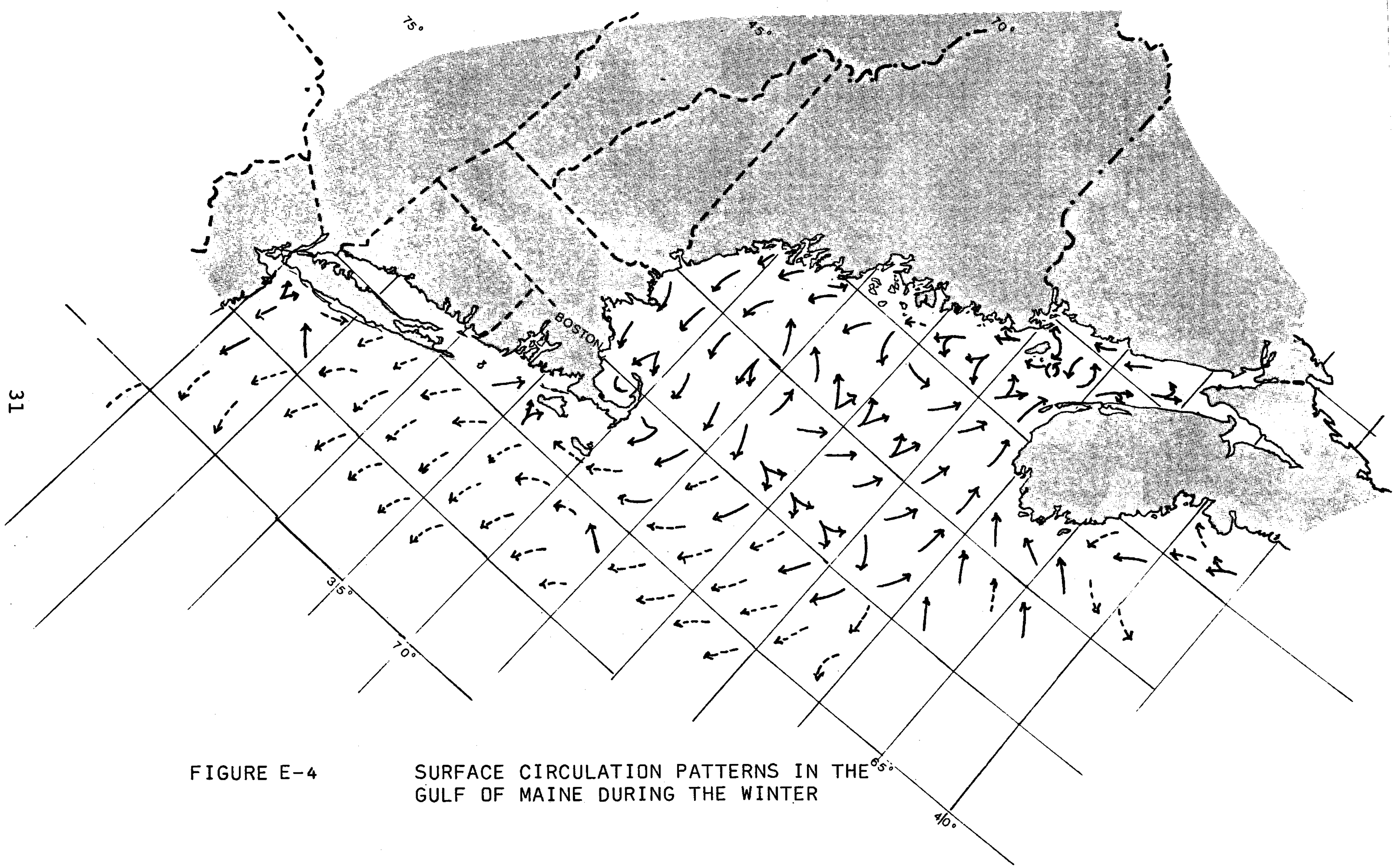

FIGURE E-4 SURFACE CIRCULATION PATTERNS IN THE GULF OF MAINE DURING THE WINTER

APPENDIX F

PROVISIONAL LISTING OF FLORAL SPECIES, COMMONWEALTH OF MASSACHUSETTS

OAK-CHESTNUT FOREST VEGETATION

New Jersey tea
(Ceonothus americanus)
Black huckleberry
(Gaylussacia baccata)
Chokecherry
(Prunus virginiana)
Sumacs
(Rhus copallina,
R. glabra,
R. typhina)
Sweet blueberries
(Vaccinium augustifolium,
V. Vacillans)
Scrub oak
(Quercus ilicifolia)
Chinquapin oak
(Quercus prinoides)
Post oak
(Quercus stellata)
Black oak
(Quercus prinus)
White oak
(Quercus alba)
Red oak
(Quercus borealis var. maxima)
Pignut hickory
(Carya glabra)
Mockernut hickory
(Carya tomentosa)
Shagbark hickory
(Carya ouata)
Red cedar
(Juniperus virginiana)
Tuliptree
(Liriodendron tulipifera)
Red maple
(Acer rubrum)
Sugar maple
(Acer saccharum)
Beech
(Fagus grandifolia)
White ash
(Fraxinus americana)
Black cherry
(Prunus serotina)
Basswood
(Tilia americana)
Hemlock
(Tsuga canadensis)
Flowering dogwood
(Cornus florida)
Sassafras
(Sassafras albidum)
Hornbeam
(Carpinus caroliniana)
Hop Hornbeam
(Ostrya virginiana)
White pine
(Pinus strobus)
Mountain laurel
(Kalmia latifolia)
Witch hazel
(Hamamelis virginiana)
Maple-leaved viburnum
(Viburnum acerifolium)
Butternut
(Juglans cinerea)

HEMLOCK-NORTHERN HARDWOOD VEGETATION

Sugar maple
(Acer saccharum)
American beech
(Fagus grandifolia)
Hemlock
(Tsuga canadensis)
Yellow birch
(Betula alleghaniensis)
Paper birch
(Betula papyrifera)
Northern red oak
(Quercus rubra)
White ash
(Fraxinus americana)
Basswood
(Tilia americana)
Red maple
(Acer rubrum)
Striped maple
(Acer pensylvanicum)
Mountain maple
(Acer spicatum)
Alternate-leaved dogwood
(Cornus alternifolia)
Mountain laurel
(Kalmia latifolia)
Hazelnut
(Corylus americana)
Witch hazel
(Hamamelis virginiana)
Maple-leaved viburnum
(Viburnum acerifolium)
Hobblebush
(Viburnum alnifolium)
Bush honeysuckle
(Diervilla lonicera)
Fly honeysuckle
(Lonicera canadensis)

NORTHERN BOG VEGETATION

Yellow pond lily
(Nuphar variegatum)
Sphagnum moss
(Sphagnum species)
Sedges
(Carex species)
Buckbean
(Menyanthes trifoliata)
Cottongrass
(Eriophorum species)
Cranberry
(Vaccinium macrocarpon, v. oxycoccus)
Leatherleaf
(Chamaedaphne calyculata)
Sheep laurel
(Kalmia angustifolia)
Bog laurel
(Kalmia polifolia)
Bog rosemary
(Andromeda glaucophylla)
Labrador tea
(Ledum groenlandicum)
Sundews
(Drosera species)

Mountain holly
(Nemopanthus mucronata)
Highbush blueberry
(Vaccinium corymbosum)
Red maple
(Acer rubrum)
Balsam fir
(Abies balsamea)
Black ash
(Fraxinus nigra)
Black spruce
(Picea mariana)
Northern white cedar
(Thuja occidentalis)
Tamarack
(Larix laricina)
Red spruce
(Picea rubens)
Dwarf dogwood
(Cornus canadensis)
Speckled alder
(Alnus rugosa)
Pitcher plant
(Sarracenia purpurea)

COAST WHITE CEDAR BOGS

Coastal white cedar
(Chamaecyparis thyoides)
Great laurel
(Rhododendron maximum)
Tamarack
(Larix laricina)
Black spruce
(Picea mariana)
Swamp honeysuckle
(Rhododendron viscosum)
Red maple
(Acer rubrum)
Black gum
(Nyssa sylvatica)

American elm
(Ulmus americana)
Pin oak
(Quercus palustris)
Swamp white oak
(Quercus bicolor)
White ash
(Fraxinus americana)
Sphagnum moss
(Sphagnum species)
Pitcher plant
(Sarracenia purpurea)
Marsh marigold
(Calthus palustris)

SHRUB SWAMP VEGETATION

Speckled alder
(Alnus rugosa)
Mountain holly
(Nemopanthus mucronata)
Swamp holly
(Ilex verticillata)
Maleberry
(Lyonia ligustrina)
Steeplebush
(Spiraea tomentosa)
Meadowsweet
(Spiraea latifolia)
Highbush blueberry
(Vaccinium corymbosum)
Arrowwood
(Viburnum dentatum)
Witherod
(Viburnum cassinoides)
Poison sumac
(Rhus typhina)
Black chokecherry
(Pyrus melanocarpa)
Red maple
(Acer rubrum)
Black ash
(Fraxinus nigra)
American elm
(Ulmus americana)
Balsam poplar
(Populus balsamifera)

PINE BARRENS

Pitch pine
(Pinus rigida)
Black oak
(Quercus velutina)
Bear oak
(Quercus ilicifolia)
Quaking aspen
(Populus tremuloides)
Big-toothed aspen
(Populus grandidentata)
Pin cherry
(Prunus pensylvanica)
White pine
(Pinus strobus)

SALT MARSHES

Marsh elder
(Iva frutescens)
Sea myrtle
(Baccharis halamifolia)
Salt-water cord grass
(Spartina alterniflora)
Salt-meadow grass
(Spartina patens)
Spike-grass
(Distichlis spicata)
Black grass
(Juncus gerardi)
Orach
(Atriplex patula)
Glasswort
(Salicornia europea, S. bigelovii)
Sea blite
Sueda maritima)

Sea lavendar
(Limonium carolinianum)
Salt-marsh gerardia
(Gerardia maritima)
Seaside plantain
(Plantago oliganthos)
Seaside goldenrod
(Solidago sempervirens)
Salt-marsh asters
(Aster subulatus and A. tenuifolius)

FLOODPLAIN FOREST

Red oak
(Quercus borealis var *maxima)*
Chestnut
(Castanea dentata)
Bitternut hickory
(Carya cordiformis)
White ash
(Fraxinus americana)
Butternut
(Juglans cinerea)
Swamp white oak
(Quercus bicolor)
Pin oak
(Quercus palustris)
American elm
(Ulmus americana)
Red maple
(Acer rubrum)
Hornbeam
(Carpinus caroliniana)
Sycamore
(Platanus occidentalis)
Black gum
(Nyssa sylvatica)
Sweet birch
(Betula lenta)
Hackberry
(Celtis species)
Black willow
(Salix nigra)
Swamp cottonwood
(Populus heterophylla)
Slippery elm
(Ulmus rubra)
Silver maple
(Acer saccharinum)
Basswood
(Tilia americana)

Green ash
(Fraxinus pennsylvanica)
Red cedar
(Juniperus virginiana)
Pasture juniper
(Juniperus communis)
Grey birch
(Betula populifolia)
Blueberries
(Vaccinium species)
Sumacs
(Rhus species)
Poison ivy
(Rhus toxicodendron)
Frost grape
(Vitis vulpina)
Woodbine
(Parthenocissus quniquefolia)
Bur-cucumber
(Sicyos angulatus)
Prickly cucumber
(Echinocystis lobata)
Climbing false buckwheat
(Polygonum scandens)
Hogpeanut
(Amphicarpa bracteata)
Morning glory
(Convovulus sepium)
Nightshade
(Solanum dulcamara)
Virgin's bower
(Clemantis virginiana)

APPENDIX G

PROVISIONAL LISTING OF FAUNAL SPECIES, COMMONWEALTH OF MASS.

BIRDS

Common loon
(Gavia imer)
Red-throated loon
(Gavia stellata)
Red-necked grebe
(Podiceps grisegena)
Horned grebe
(Podiceps auritus)
Pied-billed grebe
(Podilymbus podiceps)
Fork-tailed petrel
(Oceanedroma furcata)
Gannet
(Morus bassanus)
Great cormorant
(Phalacrocorax carbo)
Double-crested cormorant
(Phalacrocorax auritus)
Whistling swan
(Olor columbianus)
Canada goose
(Branta canadensis)
Brant
(B. bernicla)
Snow goose
(C. hyperborea)
Mallard
(Anas platyrhynchos)
Black duck
(Anas rubripes)
Pintail
(A. acuta)
Gadwall
(A. strepera)
American widgeon
(Mareca americana)
European widgeon
(Mareca penelope)
Shoveler
(Spatula clypeata)
Blue-winged teal
(Anas discors)
Green-winged teal
(A. carolinensis)
Wood duck
(Aix sponsa)
Redhead
(Aythya americana)
Canvasback
(Aythya valisineria)
Ring-necked duck
(A. collaris)
Greater scaup
(A. marila)
Lesser scaup
(A. affinis)
Common goldeneye
(Bucephala clangula)
Barrow's goldeneye
(Bucephala islandica)
Bufflehead
(B. albeola)
Harlequin duck
(Histrionicus histrionicus)
Common eider
(Somateria mollissima)
King eider
(Somateria spectabilis)
Oldsquaw
(Clangula hyemalis)
Common scoter
(Oidemia nigra)
White-winged scoter
(Melanitta deglandi)
Surf scoter
(Melanitta perspicillata)
Ruddy duck
(Oxyura jamaicensis)
Common merganser
(Mergus merganser
Red-breasted merganser
(M. serrator)
Hooded merganser
(Lophodytes cucullatus)
Turkey vulture
(Cathartes aura)
Goshawk
(Accipiter gentilis)
Cooper's hawk
(A. cooperii)
Sharpshinned hawk
(A. striatus)
Marsh hawk
(Circus cyaneus)
Rough-legged hawk
(Buteo lagopus)
Red-tailed hawk
(B. jamaicensis)
Red-shouldered hawk
(B. lineatus)

BIRDS (Continued)

Broad-winged hawk
(B. platypterus)
Golden eagle
(Aquila chrysaetos)
Bald eagle
(Haliaeetus leucocephalus)
Osprey
(Pandion haliaetus)
Peregrine falcon
(Falco perigrinus)
Pigeon hawk
(F. columbarius)
Sparrow hawk
(F. sparverius)
Turkey
(Meleagris gallopavo)
Ruffed grouse
(Bonasa umbellus)
Bobwhite
(Colinus virginianus)
Ring-necked pheasant
(Phasianus colchicus)
Common egret
(Casmerodius albus)
Cattle egret
(Bulbulcus ibis)
Great blue heron
(Ardea herodias)
Little blue heron
(Florida caerulea)
Louisiana heron
(Hydranassa tricolor)
Green heron
(Butorides virescens)
Black-crowned night heron
(Nycticorax nycticorax)
Yellow-crowned night heron
(Nyctanassa violacea)
American bittern
(Botaurus lentiginosus)
Least bittern
(Ixobrychus exilis)
Glossy ibis
(Plegadis falcinellus)
Virginia rail
(Rallus limicola)
Sora
(Porzana carolina)
Yellow rail
(Coturnicops noveboracnesis)

Black rail
(Laterallus jamaicensis)
King rail
(Rallus elegans)
Common gallinule
(Gallinula chloropus)
American coot
(Fulica americana)
American oystercatcher
(Haematopus palliatus)
Black-bellied plover
(Squatarola squatarola)
American golden plover
(Pluvialis dominica)
Piping plover
(Charadrius melodus)
Semipalmated plover
(Charadrius semipalmatus)
Killdeer
(Charadrius vociferus)
Whimbrel
(Numenius phaeopus)
Marbled godwit
(Limosa fedoa)
Upland plover
(Bartrania longicauda)
Solitary sandpiper
(Tringa solitaria)
Spotted sandpiper
(Actitis macularia)
Willet
(Catoptrophorus semipalmatus)
Greater yellowlegs
(Totanus melanoleucus)
Lesser yellowlegs
(T. flavipes)
Stilt sandpiper
(Micropalama himantopus)
Northern phalarope
(Lobipes lobatus)
American woodcock
(Philohela minor)
Common snipe
(Capella gallinago)
Glaucous gull
(Larus hyperboreus)
Great black-backed gull
(Larus marinus)
Herring gull
(Larus argentatus)

BIRDS (Continued)

Dunlin
(Erolia alpina)
Sanderling
(Crocethia alba)
White-rumped sandpiper
(Erolia fuscicollis)
Baird's sandpiper
(Erolia bairdii)
Least Sandpiper
(Erolia minutilla)
Semipalmated sandpiper
(Ereunetes pusillus)
Western Sandpiper
(Ereunetes mauri)
Red phalarope
(Phalaropus fulicarius)
Iceland gull
(Larus glaucoides)
Ring-billed gull
(L. delewarensis)
Black-legged kittiwake
(Rissa tridactyla)
Laughing gull
(Larus artricilla)
Bonaparte's gull
(Larus philadelphia)
Least tern
(Sterna albifrons)
Common tern
(Sterna hirundo)
Forster's tern
(Sterna hirundo)
Caspian tern
(Hydroprogne caspia)
Black tern
(Chlidonia niger)
Rock dove
(Columbia livia)
Mourning dove
(Zenaidura macroura)
Yellow-billed cuckoo
(Coccyzus americanus)
Black-billed cuckoo
(Coccyzus erythropthalmus)

Barn owl
(Tyto alba)
Snowy owl
(Nyctea scandiaca)
Barred owl
(Strix varia)
Screech owl
(Otus asio)
Great horned owl
(Bubo virginianus)
Long-eared owl
(Asio otus)
Short-eared owl
(A. flammeus)
Saw-whet owl
(Aegolius acadicus)
Whip-poor-will
(Caprimulgus vociferus)
Common nighthawk
(Chordeiles minor)
Chimney swift
(Chaetura pelagica)
Ruby-throated hummingbird
(Archilochus colubris)
Belted kingfisher
(Megaceryle alycon)
Yellow-shafted flicker
(Colaptes auratus)
Pileated woodpecker
(Dryocopus pileatus)
Red-headed woodpecker
(Melanerpes formicivorus)
Yellow bellied sapsucker
(Sphyrapicus varius)
Hairy woodpecker
(Dendrocopos villosus)
Downy woodpecker
(D. pubescens)
Eastern kingbird
(Tyrannus tyrannus)
Great-crested flycatcher
(Myriarchus crinitus)
Eastern phoebe
(Sayornis phoebe)

Solitary vireo
(V. solitarius)
Black & white warbler
(Mniotita varia)
Prothonotary warbler
(Protonotaria citrea)
Worm-eating warbler
(Helmitheros vermivorus)
Blue-winged warbler
(Vermivora pinus)
Golden-winged warbler
(V. chrysoptera)
Nashville warbler
(V. ruficapilla)
Parula warbler
(Parula americana)
Yellow warbler
(Dendroica petechia)
Magnolia warbler
(D. magnolia)
Cape May warbler
(D. tigrina)
Black-throated blue warbler
(D. caerulescens)
Black-throated green warbler
(D. virens)
Myrtle warbler
(D. coronata)
Cerulean warbler
(Dendroica cerulea)
Blackburnian warbler
(D. fusca)
Chestnut-sided warbler
(D. pennsylvanica)
Bay-breasted warbler
(D. castanea)
Blackpoll warbler
(D. striata)
Pine warbler
(D. pinus)
Prairie warbler
(Dendroica discolor)
Palm warbler
(D. palmarum)
Overbird
(Seiurus aurocapillus)
Northern waterthrush
(S. noveboracensis)
Louisiana waterthrush
(S. motacilla)

Yellowthroat
(Geothlypis trichas)
Yellow-breasted chat
(Icteris virens)
Mourning warbler
(Oporornis philadelphia)
Connecticut warbler
(Oporonis agilis)
Hooded warbler
(Wilsonia citrina)
Wilson's warbler
(Wilsonia pusilla)
Canada warbler
(W. canadensis)
American redstart
(Setophaga ruticilla)
House sparrow
(Passer domesticus)
Bobolink
(Dolichonyx oryzivorus)
Eastern meadowlark
(Sturnella magna)
Redwinged blackbird
(Agelaius phoeniceus)
Rusty blackbird
(Euphagus carolinus)
Common grackle
(Quiscalus-quiscala)
Brown-headed cowbird
(Molothrus ater)
Orchard oriole
(Icterus spurius)
Baltimore oriole
(I. galbula)
Scarlet tanager
(Piranga olivacea)
Cardinal
(Richmondena cardinalis)
Rose-breasted grosbeak
(Pheuticus ludovicianus)
Evening grosbeak
(Hesperiphona verpertina)
Indigo bunting
(Passerina cyanea)
Purple finch
(Carpodacus purpureus)
Pine grosbeak
(Pinicola enucleator)
Redpoll
(Acanthis flammea)

Yellow-bellied flycatcher
(Empidonax flaviventris)
Traill's flycatcher
(E. traillii)
Least flycatcher
(E. minimus)
Eastern wood pewee
(Contopus virens)
Olive-sided flycatcher
(Nuttallornis borealis)
Horned lark
(Eremophila alpestris)
Barn swallow
(Hirundo rustica)
Cliff swallow
(Petrochelidon pyrrhonota)
Tree swallow
(Iridoprocne bicolor)
Bank swallow
(Riparia riparia)
Rough-winged swallow
(Stelgidopteryx ruficollis)
Purple martin
(Progne subis)
Blue jay
(Cyanocitta cristata)
Gray jay
(Perisoreus canadensis)
Common raven
(Corvus corax)
Common crow
(Corvus brachyrhynchos)
Fish crow
(Corvus ossifragus)
Black-capped chickadee
(Parus atricapillus)
Carolina chickadee
(Parus carolinensis)
Tufted titmouse
(Parus bicolor)
White-breasted nuthatch
(Sitta carolinensis)
Red-breasted nuthatch
(S. canadensis)
Brown creeper
(Certhia familiaris)
House wren
(Troglodytes aedon)
Winter wren
(T. troglodytes)
Carolina wren
(Thryothorus ludovicianus)
Long-billed marsh wren
(Telmatodytes palustris)
Short-billed marsh wren
(Cistothorus platensis)
Mockingbird
(Mimus polyglottos)
Catbird
(Dumetella carolinensis)
Brown thrasher
(Toxostoma rufum)
Robin
(Turdus migratorius)
Wood thrush
(Hylocichla mustelina)
Hermit thrush
(H. guttata)
Swainson's thrush
(H. ustulata)
Veery
(H. fuscescens)
Gray-cheeked thrush
(H. minima)
Eastern bluebird
(Sialia sialis)
Golden-crowned kinglet
(Regulus satrapa)
Ruby-crowned kinglet
(Regulus calendula)
Water pipit
(Anthus cpinoletta)
Cedar waxwing
(Bombycilla cedorum)
Northern shrike
(Lanius ex cubitor)
Loggerhead shrike
(L. ludovicianus)
Starling
(Sturnus vulgaris)
White-eyed vireo
(Vireo griseus)
Yellow-throated vireo
(V. flavifrons)
Red-eyed vireo
(V. olivaceus)
Philadelphia vireo
(V. philadelphicus)
Warbling vireo
(V. gilvus)

BIRDS (Continued)

Pine siskin
(Spinus pinus)
American goldfinch
(Spinus tristis
Red crosshill
(Loxia curvirostra)
White-winged crossbill
(Loxia leucoptera)
Rufous-sided towhee
(Pipilo erythrophthalmus)
Savannah sparrow
(Passerculus sandwichensis)
Ipswich sparrow
(Passerculus princeps)
Grasshopper sparrow
(Ammodramus savannarum)
Henslow's sparrow
(Passerherbulus henslowii)
Sharp-tailed sparrow
(Ammospiza caudacuta)
Vesper sparrow
(Pooecetes grammeus)
Slate colored junco
(Junco hyemalis)
Tree sparrow
(Spizella arborea)
Chipping sparrow
(S. passerina)
Field sparrow
(S. pusilla)
White-crowned sparrow
(Zonotrichia leucophrys)
White-throated sparrow
(Z. albicollis)
Fox sparrow
(Passerella iliaca)
Lincoln's sparrow
(Melospiza lincolnii)
Song sparrow
(M. melodia)
Swamp sparrow
(M. georgiana)
Snow bunting
(Plectrophenax nivalis)
Lapland longspur
(Calcarius lapponicus)

Short-billed dowitcher
(Limnodromus griseus)
Long-billed dowitcher
(Limnodromus scolopaceus)
Ruddy turnstone
(Arenaria interpres)
Purple sandpiper
(Erolia maritima)
Pectoral sandpiper
(Erolia melanotos)
Knot
(Calidris canutus)

MAMMALS

Little brown bat
(Myotis lucifugus)
Silverhaired bat
(Lasionycteris noctivagans)
Eastern Pipistrel
(Pipistrellus subflauus)
Big brown bat
(Eptesicus fuscus)
Red bat
(Lasiurus borealis)
Hoary bat
(Lasiurus cinereus)
Indiana bat
(Myotis sodalis)
Masked shrew
(Sorex cinereus)
Smokey shrew
(Sorex fumeus)
Longtail shrew
(Sorex dispar)
Northern water shrew
(Sorex palustris)
Least shrew
(Cryptotis parva)
Shorttail shrew
(Blarina brevicauda)
Starnose mole
(Condylura cristata)
Eastern mole
(Scalopus aquaticus)
Hairytail mole
(Parascalopus breweri)
Woodchuck
(Marmota monax)
Eastern chipmunk
(Tamias striatus)
Eastern gray squirrel
(Sciurus carolinensis)
Red squirrel
(Tamiasciurus hudsonicus)
Northern flying squirrel
(Glaucomys sabrinus)
Southern flying squirrel
(Glaucomys volans)
Deer mouse
(Peromyscus maniculatus)
Whitefooted mouse
(Peromyscus leucopus)
Eastern wood rat
(Neotoma floridana)
Redback vole
(Clethrionomys gapperi)
Beach meadow vole
(Microtus breweri)
Meadow vole
(Microtus pennsylvanicus)
Yellownose vole
(Microtus chrotorrhinus)
Pine vole
(Pitymys pinetorum)
Southernbog lemming
(Synaptomys cooperi)
Muskrat
(Ondata zibethica)
Norwary rat
(Rattus norvegicus)
House mouse
(Mus musculus)
Meadow jumping mouse
(Zapus hudsonicus)
Woodland jumping mouse
(Napaeozapus insignis)
Snowshoe hare
(Lepus americanus)
Eastern cottontail
(Sylvilagus flordanus)
New England cottontail
(Sylvilgus transitionalis)
Beaver
(Castor canadensis)
Porcupine
(Erethizon dorsatum)
Whitetail deer
(Odocoileus virginianus)
Oppossum
(Didelphis marsupialis)
Raccoon
(Procyon lotor)
Marten
(Martes americana)
Fisher
(Martes pennanti)

MAMMALS (Contd.)

Shorttail weasel
(Mustela erminea)
Longtail weasel
(Mustela frenata)
Mink
(Mustela vison)
River otter
(Lutra canaderisis)
Striped skunk
(Mephitis mephitis)
Bobcat
(Lynx rufus)
Coyote
(Canis latrans)
Red fox
(Vulpes fulva)
Gray fox
(Urocyon cinereoargenteus)
Eastern cougar
(Felis concolor)
Black bear
(Ursus americanus)

GAME FISH

Brook trout
(Salvelinus fontinalis)
Brown trout
(Salmo trutta)
Rainbow trout
(Salmo gairdnerii)
Largemouth bass
(Micropherus salamoides)
Smallmouth bass
(Micropherus dolomieui)
Chain pickeral
(Esox niger)
White perch
(Morone americana)
Yellow perch
(Perca flavescens)
Calico bass
(Pomoxis nigromaculatus)
Brown bullheads
(Ictalurus nebulosus)

Bluegill sunfish
(Lepomis auritus)
Pumpkinseed sunfish
(Lepomis gibbosus)
Lake trout
(Salvelinus namaycush)
Shad
(Alosa sapidissima)
Carp
(Cyprinus carpio)
White sucker
(Catostomus cammersoni)
Northern pike
(Esox lucius)
Walleye
(Stizostedion vitreum vitreum)
Channel catfish
(Ictalurus punctatus)

<u>REPTILES</u>

Green turtle
(Chelonia mydas)
Ridley turtle
(Lepidochelys kempi)
Loggerhead turtle
(Caretta caretta)
Leatherback turtle
(Dermochelvy coriacea)
Hawksbill turtle
(Eretmochelys imbricata)
Plymouth turtle
(Pseudemys rubriventris bangsi)
Bog turtle
(Clemmys muhlenbergi)
Snapping turtle
(Chelydra serpentina)
Stinkpot
(Sternotherus odoratus)
Mud turtle
(Kinosternon subrubrum)
Spotted turtle
(Clemmys guttata)
Wood turtle
(Clemmys insulpata)
Muhlenberg's turtle
(Clemmy muhlenbergi)
Blanding's turtle
(Emys blandingi)
Box turtle
(Terrapene cardina)
Map turtle
(Graptemys geographicus)
Eastern painted turtle
(Chrysemys picta picka)
Midland painted turtle
(Chrysemys picta marginata)
Red-bellied turtle
(Pseudemys rubrisentris)
Fence lizard
(Sceloporus undulatus)
Five-lined skink
(Eumeces fasciatus)
Worm snake
(Carphophis amoenus)
Black rat snake
(Elaphne obsoleta obsoleta)
Black racer
(Coluber constrictor)
Ring-necked snake
(Diadophis punctatus)
Pilot black snake
(Elaphne obsoleta)
Earth snake
(Haldea valeriae)
Hog-nosed snake
(Heterodon platyrhinos)
Milk snake
(Lampropeltis doliata triangulum)
Common water snake
(Natrix sipedon)
Smooth green snake
(Opheodrys vernalis)
DeKay's snake
(Storeria dekayi)
Red-bellied snake
(Storeria occipitomaculata)
Ribbon snake
(Thamnophis sauritus)
Common garter snake
(Thamnophis sirtalis)
Copperhead
(Ancistrodon contortrix mokeson)
Timber Rattlesnake
(Crotalus horridus)

AMPHIBIANS

Spadefoot toad
(Scaphiopus holbrooki)
American toad
(Bufo americanus)
Fowler's toad
(Bufo woodhousei fowleri)
Cricket frog
(Acris gryllus)
Upland chorus frog
(Pseudacris nigrita)
Spring peeper
(Hyla crucifer)
Gray treefrog
(Hyla versi color)
Bullfrog
(Rana castebiana)
Green frog
(Rana clamitans)
Pickeral frog
(Rana palustris)
Northern leopard frog
(Rana pipiens pipiens)
Wood frog
(Rana sylvatica)
Jefferson salamander
(Ambystoma jeffersonianum)
Blue-spotted salamander
(Ambystoma laterale)

Spotted salamander
(Ambystoma maculatum)
Spring salamander
(Gyrinophilus porphyriticus)
Marbled salamander
(Ambystoma opacum)
Tiger salamander
(Ambystoma tirginum tigrinum)
Red spotted newt
(*Diemictylus viridescens*)
Dusky salamander
(*Desmognathus fuscus*)
Allegheny mountain salamander
(*Desmognathus ochrophaeus*)
Red-backed salamander
(*Plethodov cinereus*)
Slimy salamander
(*P. glutinosus*)
Four-toed salamander
(*Hemidactylium scutatum*)
Purple salamander
(*Gyrinophilus porphyriticus*)
Red salamander
(*Pseudotriton ruber*)
Two-lined salamander
(*Eurycea bislineata*)
Long-tailed salamander
(*Eurycea longicauda*)

APPENDIX H

ENDANGERED SPECIES, COMMONWEALTH OF MASSACHUSETTS

[Source: B. Isgur, Massachusetts State Conservationist; and Massachusetts Audubon Society newsletter, October 1973]

Endangered Birds

Eastern bluebird
(Sialia sialis sialis)
Southern bald eagle*
(Kaliaeetus leucocephalus leucocephalus)
American peregrine falcon*
(Falco peregrinus anatum)
Marsh hawk
(Circus cyaneus hudsonius)
Black crowned night heron
(Nycticorax nycticorax hoactli)
Purple martin
(Progne subis)
Osprey
(Pandion haliaetus carolinensis)
Ipswich sparrow
(Passerculus princeps)
Turkey
(Meleagris gallopavo)

Endangered Mammals

Indiana bat*
(Myotis sodalis)
Eastern cougar*
(Felis concolor cougar)
Northeastern coyote
(Canis latrans thamnos)
Fisher
(Martes pennanti)
Southern bog lemming
(Synaptomys cooperi)
River otter
(Lutra canadensis)
Grey longtail shrew
(Sorex dispar)
Beach meadow vole
(Microtus breweri)
Yellownose vole
(Microtus chrotorrhinus)
Northeastern woodrat
(Neotoma floridana)

Endangered Fish

Black bullhead
(Ictalurus melas)
Burbot
(Lota lota)
Channel catfish
(Ictalurus punctatus)
White catfish
(Ictalurus catus)
Lake chub
(Hybopsis plumbea)
White crappie
(Pomoxis annularis)
Northern redbelly dace
(Chrosomus eos)
Swamp darter
(Etheostoma fusiforme)
American brook lamprey
(Lampetra lamottei)
Fathead minnow
(Pimephales promelas)
Northern pike
(Esox lucius)
Atlantic salmon
(Salmo salar)
Sockeye salmon
(Onocorhynchus nerka)
Emerald shiner
(Notropis atherinoides)

* On U.S. Dept. of Interior's List of Endangered Fauna, 1974

APPENDIX H
ENDANGERED SPECIES (Contd.)

Endangered Fish (Contd.)

Mimic shiner
(Notropis volucellus)
Brook stickleback
(Eucalia inconstans)
Fourspine stickleback
(Apeltes quadracus)
Ninespine stickleback
(Pungitius pungitius)
Threespine stickleback
(Gasterosteus aculeatus)
Atlantic sturgeon
(Acipenser oxyrhynchus)
Shortnose sturgeon*
(Acipenser brevirostris)
Longnose sucker
(Catostomus catostomus)
Longear sunfish
(Lepomis megalotis)
Redbreast sunfish
(Lepomis auritus)
Lake trout
(Salvelinus namaycush)
Trout-perch
(Percopsis omiscomaycus)
Walleye
(Stizostedion vitreum vitreum)

Endangered Amphibians

Blue-spotted salamander
(Ambystoma laterale)
Four-toed salamander
(Hemidactylium scutatum)
Jefferson salamander
(Ambystoma jeffersonianum)
Spring salamander
(Gyrinophilus porphyriticus)

Endangered Reptiles

Copperhead
(Agkistrodon contortrix mokeson)
Timber rattlesnake
(Crotalus horridus horridus)
Five-lined skink
(Eumeces faciatus)
Black rat snake
(Elaphe obsoleta obsoleta)
Eastern worm snake
(Carphophis amoenus amoenus)
Blandings turtle
(Emydoidea blandingi)
Bog turtle
(Clemmys muhlenbergi)
Plymouth turtle
(Pseudemys rubriventris bangsi)
Red bellied turtle
(Pseudemys rubriventris)
Hawksbill turtle*
(Eretmochelys imbricata)
Leatherback turtle*
(Dermochelys coriacea)
Loggerhead turtle
(Caretta caretta)
Ridley turtle*
(Lepidochelys kempi)
Green turtle
(Chelonia mydas)

* On U. S. Dept. of Interior's List of Endangered Fauna, 1974

APPENDIX H
ENDANGERED SPECIES (Contd.)

Endangered Plants

Arethusa
(Arethusa bulbosa)
Bee-balm
(Monarda didyma)
Horned bladderwort
(Utricularia cornuta)
Calopogon
(Calopogon pulchellus)
Three-toothed cinquefoil
(Potentilla tridentata)
Golden club
(Orontium aquaticum)
Broom crowberry
(Corema conradii)
Green dragon
(Arisaema dracontium)
Walking fern
(Camptosorus rhizophyllus)
Stiff gentian
(Gentiana quinquefolia)
Ginseng
(Panax quinquefolia)
Cotton grass
(Eriophorum species)
Harebell
(Campanula rotundifolia)
Trumpet honeysuckle
(Lonicera sempervirens)
Ram's head lady's-slipper**
(Cypripedium arietinum)
Showy lady's-slipper
(Cypripedium reginae)
Yellow lady's-slipper
(Cypripedium calceolus)
Bog laurel
(Kalmia polifolia)
Great lobelia
(Lobelia siphilitica)
American lotus
(Nelumbo lutea)

Marsh-pink
(Sabatia stellaris)
Plymouth gentian marsh-pink
(Sabatia kennedyana)
Blunt-leaf orchis
(Habenaria obtusata)
Green woodland orchis
(Habenaria clavellata)
Large-leaved orchis
(Habeneria macrophylla)
Leafy white orchis
(Habenaria dilatata)
Showy orchis
(Orchis spectabilis)
White fringed orchis
(Habenaria blephariglottis)
Yellow fringed orchis
(Habenaria ciliaris)
Bell-shaped pink
(Sabatia campanulata)
Nodding pogonia
(Triphora trianthophora)
Rose pogonia
(Pogonia ophioglossoides)
Small whorled pogonia**
(Isotria medeoloides)
Whorled pogonia
(Isotria verticillata)
Hill's pondweed
(Potomageton hillii)
Puttyroot
(Aplectrum hyemale)
Great rhododendron
(Rhododendron maximum)
Rhodora
(Rhododendron canadense)
Rose-pink
(Sabatia angularis)
Labrador tea
(Ledum groenlandicum)
Lilia-leaved twayblade
(Liparis lilifolia)

** Federal Register, "Threatened or Endangered Fauna or Flora", July 1, 1975

APPENDIX I

SPECIES LISTINGS, BOSTON HARBOR

DOMINANT PHYTOPLANKTON SPECIES OF THE BOSTON HARBOR-MASSACHUSETTS BAY AREA

[Source: Chesmore et al 1971, USDI-FWPCA and MWRC, 1969, and NEA, unpublished]

Scientific Name	Common Name
DIATOMS	
Asterionella sp.	
Biddulphia aurita	
Chaetoceros decipiens	
Chaetoceros debilis	
Coscinodiscus centralis	
Cylindrotheca closterium	
Detonula confervacea	
Fragilaria sp.	
Gyrosigma sp.	
Melosira sp.	
Nitzschia seriata	
Pediastrum sp.	
Pleurosigma sp.	
Porosira glacialis	
Scenedesmus sp.	
Skeletonema costatum	
Thalassionema nitzschioides	
Thalassiosira decipiens	
Thalassiosira gravida	
Thalassiosira nordenskioldii	
YELLOW-BROWN ALGAE (XANTHOPHYCEAE)	
Vaucheria sp.	
GREEN ALGAE (CHLOROPHYCEAE)	
Chaetomorpha linum	
Enteromorpha erecta	Green Confetti
Enteromorpha intestinalis	
Enteromorpha linza	Green String Lettuce
Enteromorpha prolifera	Silk Confetti
Monostroma oxyspernum	
Rhizoclonium tortuosum	
Ulothrix flacca	
Ulva lactuca	Sea Lettuce
Urospora sp.	

Scientific Name	Common Name
BROWN ALGAE (PHAEOPHYCEAE)	
Agarum cribrosum	Holed Kelp
Ascophyllum nodosum	Rock Weed
Fucus edentatus	Rock Weed
Fucus evanescens	Rock Weed
Fucus spiralis	Rock Weed
Fucus vesiculosus	Rock Weed
Laminaria agardhii	Kelp
Laminaria saccharina	Kelp
Ralfsia fungiformis	
Scytosiphon lomentaria	
RED ALGAE (RHODOPHYCEAE)	
Chondria baileyana	
Chondrus crispus	Irish Moss
Cystoclonium purpureum	
Dumontia incrassata	
Hildenbrandia prototypus	
Lithothamnium lenormandi	
Petrocelis middendorfii	
Porphyra umbilicalis	Red Jabot Laver
Rhodfymenia palmata	Red Kale

CHECK LIST OF FINFISH SPECIES RECORDED IN DORCHESTER, HINGHAM AND QUINCY BAYS

[Source: NEA, unpublished, Chesmore et al, 1971, and Jerome et al, 1966]

Atlantic Silverside
Menidia menidia
Fourspine Stickleback
Apeltes quadracus
Mummichog
Fundulus heteroclitus
Striped Killfish
Fundulus majalis
Threespine Stickleback
Gasterosteus aculeatus
Ninespine Stickleback
Pungitius pungitius
Alewife
Alosa pseudoharengus
American Eel
Anguilla rostrata
Rainbow Smelt
Osmerus mordax
Striped Bass
Morone saxatilis
White Perch
Morone americanus
Winter Flounder
Pseudopleuronectes americanus
Blueback Herring
Alosa aestivalis
Silverhake
Merluccius bilinearis
Atlantic Tomcod
Microgadus tomcod
Northern Pipefish
Syngnathus fuscus
Lumpfish
Cyclopterus lumpus
American Sand Lance
Ammodytes americanus
Spiny Dogfish
Squalus acanthias
Redfin Pickerel
Esox americanus americanus
Atlantic Cod
Gadus morhua
Pollock
Pollachius virens
Red Hake
Urophycis chuss
Grubby
Myoxocephalus aeneus
Ocean Pout
Macrozoarces americanus
Atlantic Mackerel
Scomber scombrus
Windowpane
Scophthalmus aquosus
Smooth Flounder
Liopsetta putnami
Yellow Flounder
Limanda ferruginea

BENTHIC ORGANISMS IDENTIFIED DURING 1968
BOSTON HARBOR SURVEY

[Source: USDI-FWPCA and MWRC, 1969]

MARINE WORMS (POLYCHAETES)

Polydora ligni
Stauronereis rudolphi
Nephtys incisca
Nephtys ingens
Nephtys caeca
Pectinaria gouldii
Capitella capitata
Phyllodoce fragilis
Phyllodoce groenlandica
Phylldoce mucosa
Eumida sanguinea
Eteone lactea
Paranaitis speciosa
Tharyx acutus
Cirratulus grandis
Aricidea jeffreysii
Paraonis sp.
Pherusa plumosa
Nereis virens
Nereis pelagica
Lycastopsis pontica
Harmothoe imbricata
Lepidonotus squamatus
Arabella iricolor
Spirorbis spirillum
Orbinia sp.

SCUDS (AMPHIPODA)

Ampelisca macrocephala
Ampelisea spinipes
Corophium volutator
Letocherius pinguis
Gammarus locusta
Gammarus annulatus
Melita netidia
Melita dentata
Lysianopsis alba
Ampithoe rubricata
Pontogeneia inermis

SOWBUGS (ISOPODA)

Edotea triloba
Edotea montosa
Idotea phopherea

BIVALVES (MOLLUSCA)

Ensis directis
Tellina agilis
Macoma balthica
Mytilus edulis
Lyonsia hyalina
Pandora goulliana

SNAILS (GASTROPODA)

Nassarius sp.
Polinices sp.
Pyramidella fusca
Crepidula formicata

STARFISH (ASTEROIDEA)

Asterias foreesi
Diastylis polita

SHRIMP (DECAPODA)

Spirontocaris pusiola
Caprella linearis

BRITTLE STARS (OPHIOROIDEA)

Ophiopholis aculeata

SEA URCHINS (ENCHINOIDEA)

Strongylocendrotus droeachiensis

CHITONS (AMPHINEURA)

Chaetopleura apriculata
Copepod
Nemaioda

APPENDIX J

SPECIES LISTINGS, NORTHEASTERN CONTINENTAL SHELF INCLUDING THE GULF OF MAINE

MAJOR SPECIES OF PHYTOPLANKTON, NEW ENGLAND TO CAPE HATTERAS

[Source: Watling, Pembroke and Lind, 1975; Bigelow, 1927]

Dinoflagellates

Ceratium tripos
Exuviaella lima
Peridinium trochoideum
Prorocentrum micans

Diatoms

Asterionella japonica
Biddulphia spp.
Chaetoceros compressus
Chaetoceros debilis
Chaetoceros decipiens
Chaetoceros socialis
Corethon hystrix
Coscinodiscus centralis
Coscinodiscus excentricus
Coscinosira sp.
Evcampia sp.
Guinardia flaccida
Lavderia sp.
Leptocylindrus danicus
Leptocylindrus minimus
Melosira sulcata
Nitzschia closterium
Nitzschia seriata
Rhizosolenia alata
Rhizosolenia fragilissima
Rhizosolenia hebetata
Rhizosolenia setigera
Skeletonema costatum
Thalassionema nitzschioides
Thalassiosira decipiens
Thalassiosira gravida
Thalassiosira nordenskioeldii
Thalassiothrix sp.

COPEPOD SPECIES OCCURRING IN THE REGION MAINE TO CAPE HATTERAS

[Source: Watling, Pembroke and Lind, 1957; Bigelow, 1927]

I. Calanoid

Acartia clausii
Acartia longiremis
Acartia tonsa
Aetidius armatus
Anomalocera ornata
Anomalocera patersonii
Asterocheres boecki
Calanus finmarchicus
Calanus gracilis
Calanus hyperboreus
Calanus minor
Candacia armata
Candacia pachydactyla
Centropages bradyi
Centropages furcatus
Centropages hamatus
Centropages typicus
Dactylopusia thisboides
Dwightia gracilis
Ectinosoma neglectium
Eucalanus attenautus
Eucalanus crassus
Eucalanus elongatus
Eucalanus monarchus
Eucalanus pileatus-subcrassus
Euchaeta marina
Euchaeta media
Euchaeta norregica
Euchaeta spinosa
Eucheirella rostrata
Eurytemora affinis
Eurytemora americana
Eurytemora hirundoides
Gaidius tenuispinis
Heterorhabdus spinifrons
Labidocera acutifrons
Labidocera aestiva
Labidocera wollastroni
Lucicutia grandis
Mecynocera clausi
Metridia longa
Metridia lucens
Nannocalanus minor
Paracalanus crassirostris
Paracalanus parvus
Phyllopus bidentatus
Pontella meadii
Pontella pennata
Pseudocalanus elongatus
Pseudocalanus minutus
Pseudodiaptomus coronatus
Rhincalanus cornutus
Rhincalanus nasutus
Scolecithrix danae
Scolecithricella minor
Temora discaudata
Temora longicornis
Temora stylifera
Temora turbinata
Tortanus discaudatus
Undinula vulgaris
Undevchaeta major
Undevchaeta minor

II. Cyclopoid

Bomolochus eminens
Clytemnestra rostrata
Corycaeus americanus
Corycaeus elongatus
Corycaeus ovalis
Corycaeus speciosus
Corycaeus venustus
Corycella labracis
Cyclops gracilis
Cyclops viridis
Hemicyclops americanus
Olthona brevicornis
Olthona similis
Olthona spinirostris
Oncaea minuta
Oncaea venusta
Sapphirina auronitens
Thalestris gibba

IV. Harpacticoid

Halithalestris croni
Harpacticus littoralis
Harpacticus uniremis
Idya furcata
Metis ignea
Zaus abbreviatus
Zaus spinatus

V. Monstrilloid

Monstrilla anglica
Monstrilla serricornis

ZOOPLANKTON SPECIES, OTHER THAN COPEPODS, KNOWN TO OCCUR IN THE GULF OF MAINE

[Source: Bigelow, 1927]

- Mollusca
  - Pteropods
    - *Limacina retroversa*
    - *L. helicina*
    - *Clione limacina*
- Arthropoda
  - Crustacea
    - Euphausiids
      - *Thysanoessa inermis*
      - *T. longicaudata*
      - *T. gregaria*
      - *T. raschii*
      - *Nematoscelis sp.*
      - *Euphausia krohnii*
      - *Meganyctiphanes norregica*
      - *Thysanopoda acutifrons*
    - Amphipods
      - *Euthemists sp.*
      - *Hyperia sp.*
      - *Hyperoche sp.*
      - *Parathemisto oblivia*
  - Chaetognatha
    - *Sagitta elegans*
    - *S. serratodentata*
    - *S. maxima*
    - *S. lyra*
    - *S. hexaptera*
    - *Eukrohnia hamata*
  - Annelida
    - Tomopterids
      - *Tomopteris catharina*
      - *Tomopteris septentrionatis*
  - Coelenterata
    - *Melicertum campanula*
    - *Staurophora mertensii*
    - *Ptychogena lactea*
    - *Mitrocoma cruciata*
    - *Phialidium languidum*
    - *Aglantha digitale*
    - *Cyanea capillata*
    - *Aurelia aurita*
    - *Stephanomia cara*
    - *Diphyes arctica*
  - Ctenophores
    - *Pleurobrachia pileus*
    - *Mertensia ovum*
    - *Bolinopsis infundibulum*
    - *Beroe cucumis*

A PARTIAL LIST OF BENTHIC INVERTEBRATES KNOWN TO OCCUR FROM MAINE TO CAPE HATTERAS, WHICH COULD BE EXPECTED TO OCCUR IN THE GULF OF MAINE

[Source: Watling, Pembroke and Line, 1975, and Rowe, Polloni and Haedrich, in press]

FORAMINIFERA

Elphidium clavatum
Elphidium subarcticum
Elphidium incertum
Buccella frigida
Ammonia beccarii
Quinqueloculina seminula

SPONGES

Cliona celata
Microciona prolifera
Polymastia
Myrilla

COELENTERATES

Paranthus rapiformis
Astrangia danae
Cerianthus
Gersemia
Paragorgia
Turbularia crocea
Eudendrium
Sertularia
Bouganvillia

NEMERTINEA

Amphiporus sp.

OLIGOCHAETA

Peloscolex intermedius
Peloscolex benedeni
Peloscolex apectinatus
Adelodrilus anisosetosus
Phallodrilus coeloprostatus
Phallodrilus obscurus
Limnodriloides medioporus
Tubifex longipenis

POLYCHAETA

*Lumbrineris latreilli**
*Lumbrineris impatiens**
Lumbrineris tenuis
Lumbrineris acuta
*Dorvilla caeca**

* Species positively identified by Rowe, et. al. (in press)

Nephtys picta
Magelona papillicornis
Macroclymene zonalis
Exogone dispar
Ophelia denticulata
Ophelia sp.
Pherusa affinis
Serpula sp.
Goniadella
Goniadella gracilis
*Scalibregma inflatum**
Nephtys sp.
Nephtys squamosa
Nephtys incisa
Harmothoe sp.
*Onuphis opalina**
Onuphis nebulosa
Lumbrinereis cruzensis
Chaetozone setosa
Notomastus latericeus
Owenia fusiformis
Scolelepis squamata
Exosphaerorus dimunutum
Spirorbis sp.
Sternaspis sp.
Amphitrite sp.
*Leanira tetragona**
*Euchone sp.**
Euchone incolor
Capitella capitata
Spio limicolor
Ninoe nigipes
Asabellides oculata
*Tharyx sp.**
Tharys marioni
Polydora ligni
*Phloe minuta**
Scoloplos armiger
*Paraonis lura**
*Paraonis gracilis**
*Apistobranchus tullbergi**
Aricidea jeffreysii
Aricidea suecia
Prionospio steenstrupi
*Glycera capitata**
Clymenella sp.
*Cossura logochirrata**
Exogone sp.
Exogone verugera
Aricidea quadrilobata
Aricidea cerruti
Parapionosyllis longicirrata
Spiophanes bombyx
*Spiophanes kroyeri**
Palaenotus heteroseta
Pseudeurythoe ambigua
Goniadides n. sp.
Magelona papillicornis
Polydora sp.
*Ceratocephale loveni**
*Ampharete arctica**
*Diplocirrus hirsutus**
*Sphaerosyllis brevifrons**
*Proto dorvillea minuta**
*Eusyllis blomstrandi**
*Nereimyra punctata**
*Amage tumida**
*Antinoella angusta**
*Maldanopsis elongata**
*Terebellides stroemi**
*Paranaitis kosterienisis**
*Antinoella angusta**
*Trochochaeta (Disoma) watsoni**
*Driloneris longa**
*Sigalion sp.**
Owenia fusiformis
Syllides verrilli
*Microphthalmus sp.**
Microphthalmus aberrans
Mediomastus ambiseta
Nereis succinea
Nereis caudata
Streblospio benedicti
Eteone heteropoda
Scoloplos fragilis
Pygospio elegans
*Heteromastus filiformis**
*Paramphinome jeffreysii**
*Ancistrosyllis groenlandica**
*Ophelina abranchiata**

GASTROPODA

Polinices duplicatus
Lunatia heros
*Alvania carinata**
Colus pygmaceus
*Cylichna sp.**
Cylichna gouldi

Cylichna orzyga
Mitrella zonalis
Nassarius trivittatus
Turbonilla interrupta
Crepidula fornicata
Retusa caniculata
Crepidula plana
Olivella adelae
Crepidula plana
Cithna tennella
Adeorbis umbilicatus
Neptunea sp.
Scaphander sp.
Lacuna vincta
Hydrobia minuta
Bittium alternatum
Oliva mutica
Epitonium dallianum

NUDIBRANCHES

Doris sp.
Dendronotus sp.
Dendronotus frondosus
Acanthodoris pilosa
Aeolidia papillosa
Ancula gibbosa
Coryphella verrucosa
Cuthona concinna
Doto coronata
Eubranchus olivaceus
Facelina bostoniensis
Onchidoris fusca
Onchidoris muricata
Polycera dubia
Tergipes tergipes

BIVALVIA

Spisula solidissima
Astarte castanea
Ensis directus
Tellina agilis
Spisula ravenelli
Arctica islandica
Cardita borealis
Astarte sp.
Astarte subequilatera
Astarte undata
Pitar morrhuana
Yoldia sapotilla
Thrasira trisinuata
Placopecten magellanicus
Mulinia lateralis
Nucula proxima
*Nucula delphinodonta**
Nuculana acuta
Cerastoderma pinnulatum
Nucula delphinodonta
Mytilus edulis
Donax variabilis
Anadara transversa
Callocardia morrhuana
Nucula tenuis
Periploma papyracea
Thyasira ovata
*Thyasira equalis**
Venericardie borealis
Gemma gemma
Yoldia (Yoldiella) limatula
*Yoldia (yoldiella) iris**
Solemya velum
Macoma tenta
*Nuculana pernula**
*Bathyarca (Arca) pectunculoides**
*Cuspidaria glacialis**
Chlamys islandia

SCAPHOPODA

*Siphonodentalium sp.**
*Dentalium occidentale**

OSTRACODA

Ostracoda spp.
Actinocythereis dawsoni vineyardensis
Bensonacythere arenicola
Bythocythere sp. A
Cushmanidea seminuda
Cushmanidea ulrichi
Cytheridea sp. A
Cytheropteron pyramidale
Cytherura wardensis
Cytherura pseudostriata
Cytheretta edwardsi
Cytheretta sahnii
Finmarchinella finmarchica
Leptocythere angusta
Loxoconcha impressa sperata
Muellerina canadensis
Neolocophocythere sp. A

Puriana rugipunctata
Eucythere declivis
Murrayina canadensis
Sahnia fasciata
Tringinglymus arenicola
Tringinglymus denticulata
Propontocypris howei
Pontocythere ashermani
Pontocythere turbida
Pontocythere argicola
Microcytherura choctawhatcheensis
Aurila conradi
Loxoconcha granulata

MYSIDACEA

Neomysis americana
Mysis mixta
Mysis stenolepis
Erythrope erythrophthalma
Promysis atlantica
Bowmaniella portoricensis
Meterythrops robusta
Pseudomma affine
Amblyops abbreviata
Mysidopsis bigelowi
Prannus felxosus
Heteromysis formosa

CUMACEANS

Eudorella truncatula
Diastylis quadrispinosa
Diastylis sp.
Eudorella emarginata
Leptocuma sp.
Oxyurostylis smithi
Leucon americanus

ISOPODA

Chiridotea caeca
*Cirolana borealis**
Edotea sp.
Munnopsis typica
Idotea phosphorea
Idotea balthica
Janira alta
Idotea metallica
Sphaeroma quadridentatum
Paracerceis caudata
Idotea tuloba
Ptilanthura tenuis
Chiridotea tuftsi

AMPHIPODA

Uniciola irrorata
Aeginia longicornis
Anomyx lilljeborgi
Anomyx sarsi
Phoxocephalus holbolli
*Ampelisca sp.**
Ampelisca macrocephala
Ampelisca vadorum
Ampelisca compressa
Ampelisca abdita
Ampelisca verrilli
Ampelisca aequicornis
Ampelisca agassizi
Ampelisca eschrichti
Corophium crassicorne
*Casco bigelowi**
Stenopleustes inermis
Caprellid sp.
Caprella linearis
Caprella unica
Caprella penantis
Caprella equilibra
Platyischnopus sp.
Maera sp.
Paraphoxus sp.
Siphonoecetes
Neohaustoris schmitzi
Acanthohaustorius millsi
Haustorius sp.
Gammarus annulatus
Crangonyx richmondensis
Calliopius laeviusculus
Pontogeneia inermis
Hemiaegina minuta
Luconacia incerta
Mayerella limnicola
Platyischnopus
Siphonoecetes maculicornis
Byblis serrata
Byblis gaimardi
Haploops tubicola
Paracaprella tenuis
*Harpinia propinua**
*Erichthonius rubricornis**
*Leptocheirus pinguis**
*Argissa hamatipes**
Hippomedon sp.

OTHER CRUSTACEA

Crangon septemspinosus
Cancer irroratus
Pagurus longicarpus
Dissodactylus mellitae
Emerita talpoida
Dichelopandalus
*Calocaris templemani**
Caeocaris
Geryon
Pandalus
Neopanope texana sayi
Homarus arericanus

SIPUNCULIDA

Golfingia
Phascolion strombi

TARDIGARDA

Stygarctus bradypus
Halechiniscus remanei
Batillipes pennaki

BRYOZOA

Membranipora tenuis
Electra monostachys
Callopora craticula
Amphiblestrum flemingii
Cribrilina punctata
Hippoporina porosa
Hippoporina americana
Hippoporina verrilli
Porella reduplicata
Aetea anguina
Bugula turrita
Bicellariella ciliata
Cellepora avicularis
Discoporella umbrellala depressa
Cupuladria diporosa
Bugula fulva
Bugula stolonifera
Chorizopora brongnianti
Cleidochasma reticulum
Conopeum reticulum
Electra hastingsae
Microporella ciliata
Parasmittina nitida
Schizoporella cornuta
Schizoporella unicornis
Tessaradoma gracile
Turbicellepora dichotoma
Aeverrillia armata
Aeverrillia setigera
Alcyonidium parasiticum
Alcyonidium polyoum
Amathia vidovici
Anguinella palmata
Bowerbankia gracilis
Barentsia timida
Barentsia laxa
Pedicellina cernue
Cupuladria doma
Amphiblestrum septentrionalis
Callopora dumerilli
Cellaria fistulosa
Celleporella hyalina
Cryptosula pallasiana
Electra hastingsae
Electra pilosa
Haplota clavata
Scruparia ambigua
Tegella unicornis
Alcyonidium verrilli
Arachnidium fibrosum
Triticella elongata
Crisia eburnea

ECHINODERMATA

Echinarachnius parma
Strongylocentros drobachiensis
Aricidea lyriformis
Asterias forbesi
Mellita quinquiesperforata
Arbacia puntulata
Solaster sp.
Ophiopholis sp.
Ophiacantha sp.
*Briaster fragiles**
*Ophiura sp.**
Ophiura sarsi
Ophiura robusta
Amphiura otteri
Ctenodiscus crispodus
Amphioplus sp.
Amphilimna sp.
Thyone scabra

ASCIDIANS

Amaroucium
Molgula arenata
Heterostigma
Boltenia
Ascidia
Polycarpa fibrosa

FISHES REPORTED FROM THE GULF OF MAINE

[Source: Bigelow and Schroeder, 1953]

Hagfish
Myxine glutinosa
Sea Lamprey
Petromyzon marinus
Sand Shark
Carcharias taurus
Mackerel Shark
Lamna nasus
Sharp-nosed Mackerel Shark
Isurus oxyrinchus
Maneater, White Shark
Carcharodon carcharias
Basking Shark
Cetorhinus maximus
Thresher
Alopias vulpinus
Chain Dogfish
Scyliorhinus retifer
Smooth Dogfish
Mustelus canis
Tiger Shark
Galeocerdo cuvier
Blue Shark
Prionace glauca
Sharp-nosed Shark
Scoliodon terrae-novae
Dusky Shark
Carcharhinus obscurus
Brown Shark
Carcharhinus milberti
Bonnet Shark, Shovelhead
Sphyrna tiburo
Hammerhead
Sphyrna zygaena
Spiney Dogfish
Squalus acanthias
Black Dogfish
Centroscyllium fabricii
Portuguese Shark
Centroscymnus coelolepis
Greenland Shark
Somniosus microcephalus
Dalatias licha

Bramble Shark
Echinorhinus brucus
Barn-door Skate
Raja laevis
Big Skate
Raja ocellata
Brier Skate
Raja eglanteria
Leopard Skate
Raga garmani
Little Skate
Raja erinacea
Smooth-tailed Skate
Raja senta
Thorny Skate
Raga radiata
Sting Ray
Dasyatis centroura
Cow-nosed Ray
Rhinoptera bonasus
Devil Ray
Manta birostris
Chimaera
Hydrolagus affinis
Sea Sturgeon
Acipenser sturio
Short-nosed Sturgeon
Acipenser Brevirostrum
Ten-pounder
Elops saurus
Tarpon
Tarpon atlanticus
Round Herring
Etrumeus sadina
Herring
Clupea harengus
Hickory Shad
Pomolobus mediocris
Alewife
Pomolobus pseudoharengus
Blueback
Pomolobus aestivalis
Shad
Alosa sapidissima

Thread Herring
Opisthonema oglinum
Menhaden
Brevoortia tyrannus
Anchovy
Anchoa mitchilli
Striped Anchovy
Anchoa hepsetus
Brook Trout
Salvelinus fontinalis
Salmon
Salmo salar
Humpback Salmon
Oncorhynchus gorbuscha
Silver Salmon
Oncorhynchus kisutch
Capelin
Mallotus villosus
Smelt
Osmerus mordax
Argentine
Argentina silus
Headlight-fish
Diaphus effulgens
Lanternfish
Myctophum affine
Pearlsides
Maurolicus pennanti
Viperfish
Chauliodus sloani
Cyclothone
Cyclothone signata
Stomias stomias
Stomioides nicholsi
Trigonolampa miriceps
Silver Hatchet Fish
Argyropelecus aculeatus
Eel
Anguilla rostrata
American conger
Conger oceanica
Slime Eel
Simenchelys parasiticus
Long-nosed Eel
Synaphobranchus pinnatus
Snake Eel
Omochelys cruentifer
Snipe Eel
Nemichthys scolopaceus
Lancetfish
Alepisaurus ferox
Common Mummichog
Fundulus heteroclitus
Striped Mummichog
Fundulus majalis
Sheepshead Minnow
Cyprinodon variegatus
Silver Gar
Tylosurus marinus
Garfish
Ablennes hians
Halfbeak
Hyporhamphus unifasciatus
Needlefish
Scomberesox saurus
Flying Fish
Cypselurus heterurus
Silver Hake
Merluccius bilinearis
Cod
Gadus callarias
Tomcod
Microgadus tomcod
Haddock
Melanogrammus aeglefinus
American Pollock
Pollachius virens
White Hake
Urophycis tenuis
Squirrel Hake
Urophycis chuss
Spotted Hake
Urophycis regius
Long-finned Hake
Urophycis chesteri
Blue Hake
Antimora rostrata
Hakeling
Physiculus fulvus

Four-bearded Rockling
Enchelyopus cimbrius
Cusk
Brosme brosme
Common Grenadier
Macrourus bairdii
Rough-headed Grenadier
Macrourus berglax
Long-nosed Grenadier
Coelorhynchus carminatus
Opah
Lampris regius
Halibut
Hippoglossus hippoglossus
Greenland Halibut
Reinhardtius hippoglossoides
American Dab
Hippoglossoides platessoides
Summer Flounder
Paralichthys dentatus
Four-spotted Flounder
Paralichthys oblongus
Yellow-tail
Limanda ferruginea
Winter Flounder
Pseudopleuronectes americanus
Smooth Flounder
Liopsetts putnami
Witch Flounder
Glyptocephalus cynoglossus
Sand Flounder
Lophopsetta maculata
Gulf Stream Flounder
Citharichthys arctifrons
Hogchoker
Achirus fasciatus
American John Dory
Zenopsis ocellata
Grammicolepid
Xenolepidichthys americanus
Snipe Fish
Macrorhamphosus scolopax
Silverside
Menidia menidia
Waxen Silverside
Menidia beryllina
Mullet
Mugil cephalus
Northern Barracuda
Sphyraena borealis
Nine-spined Stickleback
Pungitius pungitius
Three-spined Stickleback
Gasterosteus aculeatus
Two-spined Stickleback
Gasterosteus wheatlandi
Four-spined Stickleback
Apeltes quadracus
Pipefish
Syngnathus fuscus
Pelagic Pipefish
Syngnathus pelagicus
Sea Horse
Hippocampus hudsonius
Trumpetfish
Fistularia tabacaria
Mackerel
Scomber scombrus
Chub Mackerel
Pneumatophorus colias
Striped Bonito
Euthynnus pelamis
False Albacore
Euthynnus alleteratus
Common Bonito
Sarda sarda
Tuna
Thunnus thynnus
Spanish Mackerel
Scomberomorus maculatus
King Mackerel
Scomberomorus regalis
Cavalla
Scomberomorus cavalla
Escolar
Ruvettus pretiosus
Cutlassfish
Trichiurus lepturus
Swordfish
Xiphias gladius
Blue Marlin
Makaira ampla

White Marlin
Makaira albida
Dolphin
Coryphaena hippurus
Johnson's Sea Bream
Taractes princeps
Butterfish
Poronotus triacanthus
Harvestfish
Peprilus alepidotus
Barrelfish
Palinurichthys perciformis
Black Ruff
Centrolophus niger
Pilotfish
Naucrates ductor
Rudderfish
Seriola zonata
Mackerel Scad
Decapterus macarellus
Crevalle
Caranx hippos
Hardtail
Caranx crysos
Saurel
Trachurus trachurus
Goggle-eyed Scad
Trachurops crumenopthalmus
Moonfish
Vomer setapinnis
Lookdown
Selene vomer
Leatherjacket
Oligoplites saurus
Threadfin
Alectis crinitus
Bluefish
Pomatomus saltatrix
Striped Bass
Roccus saxatilis
White Perch
Morone americana
Sea Bass
Centropristes striatus
Wreckfish
Polyprion americanus
Short Big-eye
Pseudopriacanthus altus
Scup
Stenotomus versicolor
Sheepshead
Atchosargus probatocephalus
Weakfish
Cynoscion regalis
Spot
Leiostomus xanthurus
Kingfish
Menticirrhus saxatilis
Black Drum
Pogonias cromis
Tilefish
Lopholatilus chamaeleonticeps
Rosefish
Sebastes marinus
Black-bellied Rosefish
Helicolenus dactylopterus
Boarfish
Antigonia capros
Hook-eared Sculpin
Artediellus uncinatus
Mailed Sculpin
Triglops ommatistius
Grubby
Myoxocephalus aeneus
Shorthorn Sculpin
Myoxocephalus scorpius
Longhorn Sculpin
Myoxocephalus octodecemspinosus
Staghorn Sculpin
Gymnocanthus tricuspis
Arctic Sculpin
Cottuncolus microps
Sea Raven
Hemitripterus americanus
Alligatorfish
Aspidophoroides monopterygius
Lumpfish
Cyclopterus lumpus
Spiny Lumpfish
Eumicrotremus spinosus
Sea Snail
Neoliparis atlanticus
Striped Sea Snail
Liparis liparis
Common Sea Robin
Prionotus carolinus

Striped Sea Robin
Prionotus evolans
Armored Sea Robin
Peristedion miniatum
Flying Gurnard
Dactylopterus volitans
Cunner
Tautogolabrus adspersus
Tautog
Tautoga onitis
Shark Sucker
Echeneis naucrates
Swordfish Sucker
Remora brachyptera
Remora
Remora remora
Sand Launce
Ammodytes americanus
Rock Eel
Pholis gunnellus
Snake Blenny
Lumpenus lumpretaeformis
Shanny
Leptoclinus maculatus
Arctic Shanny
Stichaeus punctatus
Radiated Shanny
Ulvaria subbifurcata
Wrymouth
Cryptacanthodes maculatus
Wolffish
Anarhichas lupus
Spotted Wolffish
Anarhichas minor
Ocean Pout
Macrozoarces americanus
Wolf Eel
Lycenchelys verrillii
Arctic Eelpout
Lycodes reticulatus
Cusk Eel
Lepophidium cervinum
Toadfish
Opsanus tau
Triggerfish
Balistes carolinensis
Filefish
Monacanthus hispidus
Filefish
Monacanthus ciliatus
Orange Filefish
Alutera schoepfii
Unicornfish
Alutera scripta
Puffer
Sphaeroides maculatus
Burrfish
Chilomycterus schoepfii
Sunfish
Mola mola
Sharp-tailed Sunfish
Masturus lanceolatus
American Goosefish
Lophius americanus
Sargassum Fish
Histrio pictus
Deep Sea Angler
Ceratias hölbolli

A LIST OF OCEAN BIRDS LIKELY TO OCCUR IN THE OPEN WATERS OF THE GULF OF MAINE

[Source: New Hampshire Fish and Game Department, undated]

SHEARWATERS

Cory's Shearwater
Puffinus diomedea borealis
Greater Shearwater
Puffinus gravis
Sooty Shearwater
Puffinus grisevs

STORM PETRELS

Leach's Petrel
Oceanodroma leucorhoa leucorhoa
Wilson's Petrel
Oceanites oceanicus oceanicus

PHALAROPES

Red Phalarope
Phalaropus fulicarius
Northern Phalarope
Lobipes lobatus

JAEGERS

Pomarine Jaeger
Stercorarius pomarinus
Parasitic Jaeger
Stercorarius parasiticus
Gulls & Terns

Black-legger Kittiwake
Rissa tridactyla tridactyla

AUKS, MURRES, PUFFINS

Razorbill
Alca torda torda
Common Murre
Uria aalgae aalgae
Thick-billed Murre
Uria lomvia
Dovekie
Plautus alle alle
Black Guillemot
Cepphus grylle grylle
Common Puffin
Fratercula arctica arctica

MARINE MAMMALS WHICH HAVE OCCURRED OR MAY OCCUR BETWEEN CAPE COD AND CAPE HATTERAS

[Source: Pilson and Goldstein, 1973]

Walrus
Odobenus rosmarus
Common Seal
Phoca vitulina
Gray Seal
Halichoerus grypus
Harp Seal
Pagophilus groenlandicus
Hooded Seal
Cystophora cristata
Manatee
Trichechus manatus
Right Whale
Balaena glacialis
Gray Whale
Eschrichtius gibbosus
Minke Whale
Balaenoptera acutorostrata
Sei Whale
Balaenoptera borealis
Fin Whale
Balaenoptera physalus
Blue Whale
Balaenoptera musculus
Hump-backed whale
Megaptera novaeangliae
Rough-toothed Dolphin
Steno bredanensis
Bottle-nosed Dolphin
Tursiops truncatus
Grampus or Risso's Dolphin
Grampus grisseus
White-beaked Dolphin
Lagenorhynchus albirostris
White-sided Dolphin
Lagenorhynchus acutus
Spotted Dolphin
Stenella dubia
Striped Dolphin
Stenella caeruleoalba
Common Dolphin
Delphinus delphis
False Killer Whale
Pseudorca crassidens
Pilot Whale
Globicephala melaena
Short-finned Pilot Whale
Globicephala macrorhyncha
Killer Whale
Orcinus orca
Harbor Porpoise
Phocoena phocoena
Beluga or White Whale
Delphinapterus leucas
Sperm Whale
Physeter catodon
Pygmy Sperm Whale
Kogia breviceps
Dwarf Sperm Whale
Kogia simus
North Sea Beaked Whale
Mesoplodon bidens
Antillean Beaked Whale
Mesoplodon europeus
True's Beaked Whale
Mesoplodon mirus
Dense-beaked Whale
Mesoplodon densirostris
Goose-beaked Whale
Ziphius cavirostris
North Atlantic Bottle-nosed Whale
Hyperoodon ampullatus

APPENDIX K

DISTRIBUTION OF COMMERCIALLY IMPORTANT FISH OFF THE NEW ENGLAND COAST

U. S. FISH LANDINGS FOR ALL SPECIES FROM SELECTED AREAS OFF THE NEW ENGLAND COAST

Data is in metric tons, live weight and are totals over the 10 years from 1965 to 1974. Numbers at the top of the columns correspond to fisheries statistical areas located on Figure K-1.
[Source: NMFS, Northeast Fisheries Center, 1975A, B]

	513	514	515	521	522
Alewife	4,106	8,780	0	*	*
Goosefish	69	971	<1	*	*
Bluefish	45	171	0	*	*
Butterfish	8	103	0	*	*
Cod	26,136	28,177	1,894	5,893	2,433
Cusk	1,559	2,288	709	*	*
Eels	11	2	0	*	*
Winter Flounder	691	8,448	10	*	*
Fluke	<1	29	<1	*	*
Grey Sole	3,674	3,965	270	*	*
Yellowtail Flounder	638	9,423	23	626	1,492
American Dab	3,312	4,182	177	*	*
Haddock	6,147	12,424	1,300	5,308	5,908
Red Hake	387	1,900	7	*	*
White Hake	5,739	2,302	793	*	*
Halibut	79	167	35	*	*
Herring	49,356	71,843	582	*	*
Mackerel	1,424	12,184	17	*	*
Memhaden	6,945	46,080	0	*	*
Redfish	10,826	2,434	58,401	*	*
Pollock	8,291	9,270	2,336	*	*
Atlantic Salmon	<1	0	0	*	*
Scup	<1	13	0	*	*
Shad	2	232	0	*	*
Shark/Dogfish	513	23	<1	*	*
Skates	138	362	5	*	*
Atlantic Smelt	137	<1	0	*	*
Striped Bass	2	532	0	*	*
Sturgeon	6	5	0	*	*
Swordfish	3	2	0	*	*
Tilefish	19	1	0	*	*
Bluefin Tuna	469	2,738	0	*	*
White Perch	<1	1	0	*	*
Whiting	94,991	39,120	176	*	*
Wolffish	178	736	16	*	*
Billfish	0	2	0	*	*
Bonito	0	<1	0	*	*
Sand Dab	0	<1	0	*	*
Eel Pout	0	333	0	*	*
Sea Bass	0	2	0	*	*
Sea Trout	0	2	0	*	*
Tautog	0	32	0	*	*
Silver Hake	0	0	0	4,097	1,198

	513	514	515	521	522
Other	7,541	28,098	117	*	*
Green Crab	11	0	0	*	*
Rock Crab	1,738	0	0	*	*
Lobster	28,513	4	1	3	21
Shrimp	56,940	7,040	39	*	*
Hard Clam	126	0	0	*	*
Soft Clam	25,605	0	0	*	*
Sea Mussels	1,691	0	0	*	*
Oysters	65	0	0	*	*
Periwinkles	281	0	0	*	*
Sea Scallop	521	0	0	1,639	2,219
Squid	92	0	0	*	*
Sea Urchins	380	0	0	*	*
Sea Moss	4,707	0	0	*	*
Blood Worms	3,234	<1	0	*	*
Sand Worms	637	0	0	*	*

*Note: In areas 521 and 522 data for many species is combined. This information is summarized below.

	521	522
"Other" Flounder[1]	2,202	2,140
"Other" Pelagic[2]	299	3
"Other" Ground[3]	4,689	1,693
"Other" Shellfish[4]	47	0

1 Other flounders

- Winter flounder
- Summer flounder
- Witch flounder
- American Plaice
- Windowpane flounder
- Halibut

2 Other fish (pelagic)

- Bluefin tuna
- Skipjack tuna
- Tuna unclassified
- Tarpon
- Swordfish
- American Shad
- Menhaden
- Atlanttic mackerel
- Argentine

2 (Contd)

- Sea herring
- Bonito
- Bluefish
- Billfish unclassified
- Anchovies
- Alewife
- Butterfish
- Crevalle

3 Other fish (groundfish)

- Monkfish
- Cusk
- Drums
- Eels
- Grenadiers
- Red Hake
- White hake

3 (Contd)

- King mackerel
- Redfish
- Ocean pout
- Pollock
- Sculpins
- Scup
- Sea basses
- Sea robins
- Sea trout
- Sharks
- Dogfishes
- Skates
- Smelt
- Sturgeon
- Tautog
- Tilefish
- Wolffish

4 Other Shellfish

Green crab
Red crab
Rock crab
Jonah crab
Shrimps
Hard clams
Soft clams
Clams unclassified
Conchs
Sea mussels
Oysters
Periwinkles
Squid (*Loligo, Illex*)
Sea urchins

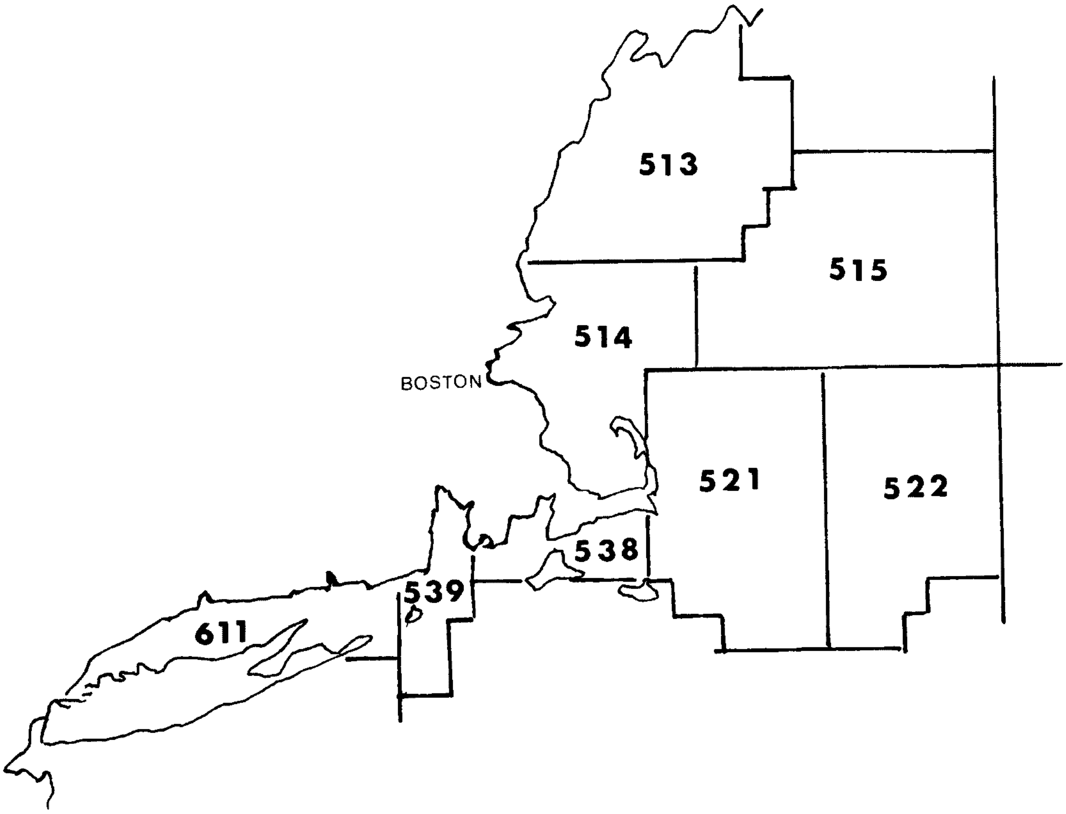

FIGURE K-1 . LOCATION OF FISHERIES STATISTICAL AREAS

SCHEDULE OF THE TWENTY SPECIES OF GROUNDFISH COMMON IN THE GULF OF MAINE

The letters in parentheses correspond to Figure K-2 which indicates the locations and the maximum population densities of these groundfish.

[Source: Fitz, 1965]

Species	Occurrence		
		Depth (M)	Bottom Temperature (°C)
Spiny Dogfish (S) *Squalus acanthias*	Throughout the area - Nova Scotia to Cape May, New Jersey. Abundant north of Cape Cod, off Nova Scotia, and southern New England	30-300	3.9-16.7
Thorny Skate *Raja radiata*	North of 41°00' Latitude. Light concentration on Georges Bank.	50-410	3.9-16.7
Sea herring (H) *Culpea harengus*	North of 41°00' Latitude. Abundant on western side of Georges Bank, north of Cape Cod, south of Nova Scotia, and east of Nantucket.	30-370	4.4-15.0
Argentine (A) *Argentina silus*	In the Gulf of Maine and Between Georges Bank and Browns Bank.	50-410	5.6-13.9
Silver Hake (SH) *Merluccius bilinearis*	Throughout the area - Nova Scotia to New Jersey. Abundant off Cape Cod, western side of Georges Bank, southeastern part of Georges Bank, and south of Cape Cod.	30-410	3.9-19.4
Cod (C) *Gadus marhua*	North of 41°00' Latitude. Abundant off Nantucket, north of Cape Cod, and southeast of Nova Scotia.	30-310	4.4-15.6
Haddock (Ha) *Melanogrammus aeglefinus*	North of 41°00' Latitude. Abundant on the Northern Edge of Georges Bank and on Browns Bank.	30-410	3.9-15.6
American Pollock *Pollachius virens*	North of 41°00' Latitude. Heavy concentrations Near Nova Scotia. Moderate concentrations in the Gulf of Maine and on the western side of Nova Scotia.	30-370	4.4-12.2

Species	Occurrence	
	Depth (M)	Bottom Temperature (°C)
White Hake (W) *Urophycis tenuis*	North of 41°00' Latitude. Abundant along the northern edge of Georges Bank and in the Gulf of Maine.	
	30-410	4.4-15.0
Squirrel Hake *Urophycis chuss*	Throughout the area - Nova Scotia to Cape May, New Jersey. Abundant south of Cape Cod.	
	30-370	4.4-17.8
Longfin Hake (L) *Urophycis chesteri*	In the deep waters of the Gulf of Maine off the Northern edge of Georges Bank.	
	150-410	4.4-10.6
American Dab (D) *Hippoglossoides platessoides*	North of 41°00' Latitude. Abundant along the inshore waters north of Cape Cod and southeast of Nova Scotia.	
	30-330	3.9-16.7
Fourspot Flounder *Paralichthys oblongus*	South of 42°00' Latitude. Abundant from the eastern side of Georges Bank southward to Hudson Canyon.	
	30-130	6.7-19.4
Yellowtail Flounder (F) *Limanda ferruginea*	Along the eastern side of Georges Bank southward to Hudson Canyon and north of Cape Cod. Abundant on Georges Bank, north of Cape Cod, and off southern New England.	
	30-190	5.6-16.7
Witch Flounder (WF) *Glyptocephalus cynoglossus*	North of 41°00' Latitude. Abundant off the coast of Massachusetts and Maine and southeast of Nova Scotia.	
	70-410	3.9-16.1
Butterfish *Poronotus triacanthus*	South of 41°00' Latitude. Abundant south of Cape Cod to Hudson Canyon.	
	30-270	4.4-20.6
Scup *Stenotomus versicolor*	South of 41°00' Latitude. Abundant south of Cape Cod.	
	30-170	8.9-20.6
Redfish (R) *Sebastes marinus*	North of 41°00' Latitude. Abundant in the deep waters of the Gulf of Maine and southeast of Nova Scotia.	
	50-410	4.4-15.6
Longhorn Sculpin *Myoxocephalus octodecimspinosus*	South of 42°00' Latitude. Abundant on Georges Bank and southeast of Cape Cod.	
	30-370	4.4-15.6
American Goosefish *Lophius americanus*	Throughout the area - Nova Scotia to Hudson Canyon. Abundant along the northern edge of Georges Bank.	
	30-310	3.9-15.6

SPECIES		POPULATION DENSITY	
S	Spiny DOG fish	501	or more/18' square
H	Sea herring	201	DO.
A	Argenline	201	DO.
SH	Silver hake	101	DO.
C	Cod	11	DO.
Ha	Haddock	101	DO
P	American pollock	101	DO.
W	White Hake	51	DO.
L	Longfinned hake	301	DO.
D	American dab	51	DO.
F	Yellowtail flounder	13	DO.
WF	Witch flounder	10	DO.
R	Redfish	301	DO.

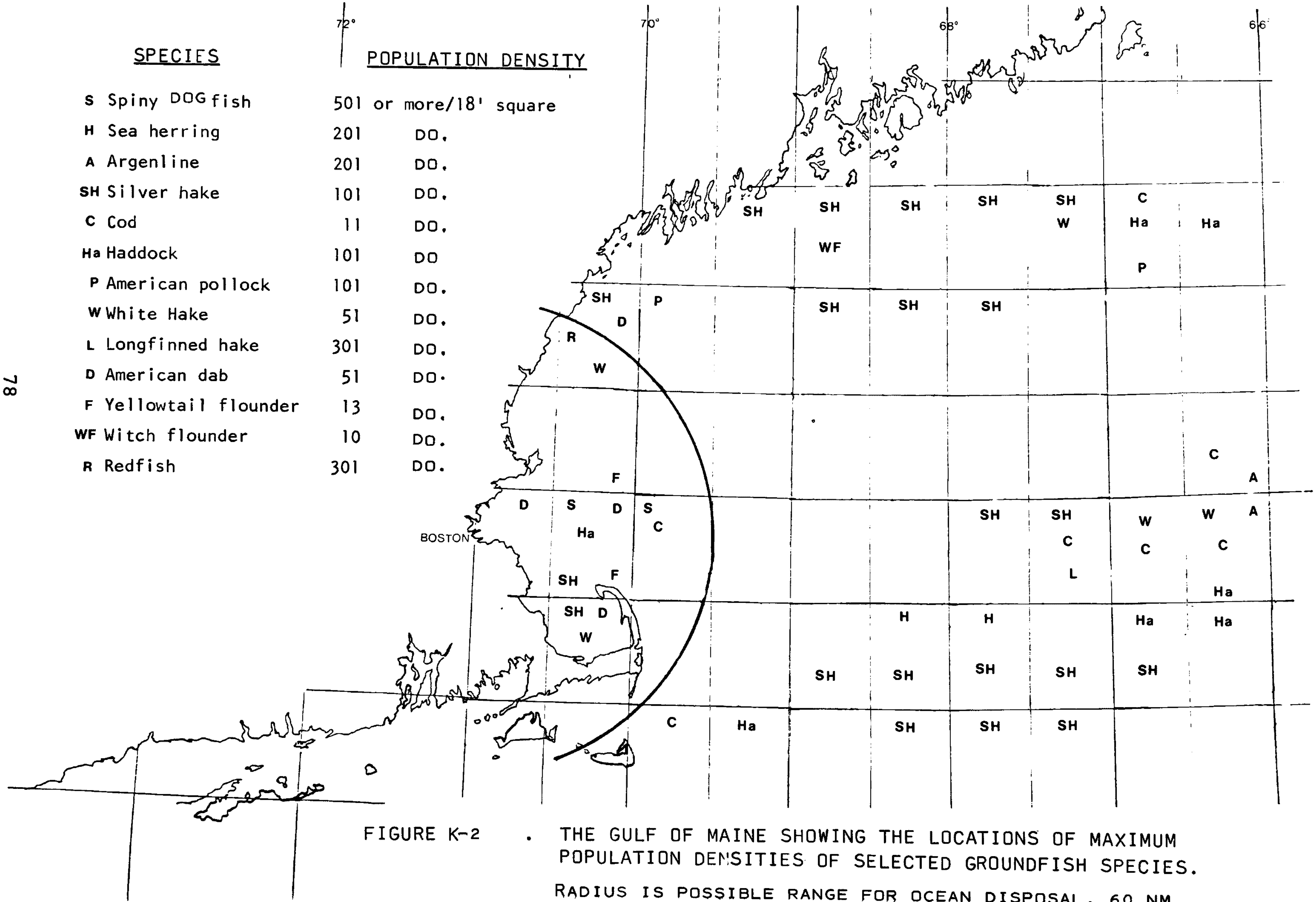

FIGURE K-2 . THE GULF OF MAINE SHOWING THE LOCATIONS OF MAXIMUM POPULATION DENSITIES OF SELECTED GROUNDFISH SPECIES.

RADIUS IS POSSIBLE RANGE FOR OCEAN DISPOSAL, 60 NM

APPENDIX L

DESCRIPTION OF HISTORIC SITES

The following descriptions are keyed to Figure II-12, which locate these historical areas.

(1) Fort Warren, Boston

George's Island; 1834-1863; public. Military engineer Sylvanus Thayer was responsible for the plan and construction of Fort Warren. Built mainly of Quincy granite, the defense work was a bastioned star fort with other walls eight feet thick and six hundred feet long. The Fort was twice modernized after the Civil War (when it was a prison for Confederate leaders). Inside the Fort's wall is a brick magazine and outside is a 2-story late 19th c. hospital. The entire island is forty acres and located in the middle of Boston Harbor.

(2) Fort Independence, Boston

Castle Island; 1634/1705/1741/1809/1851; public. Except for a somewhat earlier defense set up on Fort Hill in the southern end of Boston, Castle Island is the oldest fortified site in the original Massachusetts Bay Colony. Its 328 year history came to an end in 1962, when the Federal government ceded the area of Fort Independence back to the Commonwealth of Massachusetts for use as an historic monument.

(3) Slade Spice Mill, Revere

770 Revere Beach Parkway; 18th-20th c.; private. The Slade Spice Mill is one of the two remaining mills in Massachusetts which were tide powered. It used one of the earliest of the horizontal (turbine) wheels, powered by the release of dammed water dependent on tidal action to turn the mill-stones each day. Some of the original machinery remains and the mill is still used for grinding and mixing spices. The present 3-story frame mill is the fourth on the site, replacing three earlier structures which were destroyed by fire.

(4) Fort Revere, Telegraph Hill

c. 18th; public/private. Fort Revere, named for Paul Revere, is the enlarged and modernized fort which was originally called Fort Independence. It has not been used as a coastal battery since the end of W.W. II when it was sold for development of homes and a school. The French fleet anchored in Nantasket Roads in the fall of 1778 and stationed a detachment of marines at Fort Independence. The view from here of the entire Boston Harbor area quickly reveals the strategic importance of the spot. The presence at the fort of such notables as Heath, du Portail, de Bougainville, de Maresquelle, and others, underscores the significance of Fort Independence. Of the original 77 acre fort, only a 10 acre section comprising the center of the fort remains.

(5) Telegraph Hill

c. 1900; public. As part of the Fort Revere complex, the Water Tower served a three-fold purpose. It was used as an observation tower as well as a water tower by the soldiers stationed there through W.W. II. From the top of this 120' structure, the entire Boston Harbor area can be readily seen. Additionally, the tower has been, and still is, an important navigational landmark enabling both seagoing and airborne pilots to quickly orientate themselves in the Harbor area. It marks the area of the 19th c. telegraph tower and station and the site of the original well at Fort Independence, Fort Revere's predecessor.

(6) Moswetuset Hummock, Quincy

Squantum Street; 17th c.; public. In the early 1600's this hill was the seat of the sachem Chicatabot of the Massachusetts Indians. Shaped like an arrowhead (which in the Indian dialect is mos or mons), the hummock (or wetuset), as slightly altered in pronunciation by the white man, gave rise to the name Massachusetts. Today the hill is still bounded by the sea where the Indians fished, by the marshes that served as a defense, and by the original planting grounds of the tribe.

(7) Adams National Historic Site, Quincy

135 Adams Street; 1730-1731; public. Adams National Historic Site commemorates four generations of the distinguished Adams family, who occupied the house from 1788 to 1927. Here lived John Adams, first Vice President and second President of the United States (1797-1801). His son, John Quincy Adams, was Senator, Congressman, Secretary of State, and President of the United States (1825-1829). His son, Charles Francis Adams, was minister to the Court of St. James (1861-1868). His son, Henry Adams, historian and man of letters, is best known for his autobiography, The Education of Henry Adams. A younger son, Brooks Adams, was the last of the family to occupy the "Old House". A stone library, stable and extensive gardens are other notable features. Included in the Historic American Buildings Survey.

(8) Hull Village Area

Bounded: Nantasket Avenue, Spring and Main Streets; 1682-1882; 8 inventoried properties. Hull Village is the oldest part of Hull where the first settlers came from Plymouth in 1622.

The buildings here represent the oldest buildings in town, some dating back as late as the 17th c. Town meetings were held in this portion of Hull Village from about 1675 to about 1825 when the present Municipal Building was built. It is the oldest part of Hull and still retains the atmosphere and the structures which we revere in American history, because it gives visual reality to the writings of our illustrious historians.

(9) House, Winthrop

97 Washington Avenue; late 19th c.; private. Residence of Joseph P. Kennedy, father of the late President John F. Kennedy.

(10) Deane Winthrop House, Winthrop

40 Shirley Street; 17th c.; private. One of the few surviving good examples of 17th c. architecture. Deane Winthrop, the son of Governor Winthrop, lived here until 1703.

The following locations are part of the Boston National Historical Park. These areas are also keyed to Figure II-12 for location purposes.

A. Faneuil Hall

Boston merchant Peter Faneuil gave this hall to the town of Boston in 1742. It burned in 1761 and was rebuilt 2 years later. The present building is the result of architect Charles Bulfinch's enlargement of the structure in 1806.

Market stalls occupied the first floor, while the hall above was used for Boston town meetings and the discussions that led James Otis to call it the "Cradle of Liberty".

The oldest military company in North America, the Ancient and Honorable Artillery Company, has its armory and museum on the third floor.

B. Paul Revere's House

Built about 1677 after one of the great fires of Boston, this is the oldest frame dwelling left in the city. It was constructed on the original site of Rev. Increase Mather's house and was the home of Paul Revere from 1770 to 1800. Paul Revere, on the night of April 18, 1775, began his famous ride to Lexington from this house.

C. Old North Church

The Old North Church, built in 1723 as a place of worship for non-Puritan Anglicans, was styled after Sir Christopher Wren's churches in 17th-century London.

On the night of April 18, 1775, sexton Robert Newman hung two lanterns in the steeple to signal that the British were leaving Boston by sea. This prearranged signal was intended to give the Charlestown militia warning of the British march toward Lexington and Concord, even if Paul Revere should be captured. This is the oldest church building still standing in Boston.

D. Old State House

The Province of Massachusetts Bay was governed from this building. Here colonial courts met, James Otis argued against Writs of Assistance, and John Hancock and Samuel Adams denounced the tax laws of Parliament. The world's first gallery where the public could watch government in action was established in this building as a result of a motion by James Otis in the Massachusetts House in 1766.

The square in front of the State House was the scene of the famous Boston Massacre on March 5, 1770. In 1776 the Declaration of Independence was read for the first time in Boston from the eastern balcony.

E. Bunker Hill

The Battle of Bunker Hill, June 17, 1775, (actually fought on and around Breed's Hill) was the first significant battle of the Revolutionary War. As Boston was besieged by the Americans, British general Thomas Gage planned to fortify Dorchester Heights to protect the city. On hearing of Gage's plan, the colonial forces decided to occupy Charlestown peninsula and fortify Breed's Hill. Although the British won the ensuing battle, they suffered heavy losses. The Battle of Bunker Hill rallied the colonies and prodded the Continental Congress into organizing an American army.

F. Old South Meeting House

Erected in 1729 as a Congressional meeting house, "Old South" served as the site for Boston's town meetings whenever they became too large for Faneuil Hall.

In this building on the night after the Boston Massacre in March 1770, Bostonians waited until Governor Thomas Hutchinson promised to remove British regiments from Boston. On December 16, 1773, participants in another town meeting dispersed to Griffin's Wharf to carry out the famous Boston Tea Party.

G. Charlestown Navy Yard (Boston Naval Shipyard)

One of the country's first naval shipyards was established in 1800 on "Moulton's Point" in Charlestown. Here in 1833 one of the first two dry docks in the country began operation. The first ship to enter the dock was the U. S. frigate *Constitution*, which now lies at the Navy Yard. This frigate helped drive French privateers from the American coast and the West Indies in the 1790s and became famous for her actions in the War of 1812. "Old Ironsides" is the oldest commissioned ship in the United States Navy.

APPENDIX M

DETAILED DESCRIPTION OF BOSTON HARBOR AREA HIGHWAYS AND HIGHWAY PLANNING

A. Winthrop Regional System

Winthrop is serviced primarily by two regional highway facilities, U.S. Route 1. A regional state highway running in a north-south direction, provides access to the south and Boston proper by means of the Sumner-Callahan Tunnels, as well as access to the northern communities of Saugus, Lynnfield, etc. by means of a varying four-lane/six-lane access highway. Route 1 is also the major highway servicing Logan Airport. Revere Beach Parkway (Route 16)/North Shore Road (Route 1A) is a major arterial running predominantly east-west through Revere, Everett and Medford and traveling north-south through the eastern portion of Revere and continuing through Lynn and Swampscott.

Three major expressway facilities originate in Boston proper and service communities north of Boston. Route 1 is the easterlymost facility, with Interstate 95 and Interstate 93 being the other facilities.

A TOPICS plan was prepared for the Town of Winthrop in September of 1972 by Tippetts-Abbett-McCarthy-Stratton (TAMS).

Both mechanical recorder counts and manual counts were taken during February 1971. The following table, taken from the TAMS report indicates the daily traffic flow on the principal streets within the Town.

	Street	ADT
1.	Main Street	25,000 - 3,000
2.	Revere Street	16,000 - 10,000
3.	Winthrop Parkway	12,000
4.	Pleasant Street	9,000 - 5,000
5.	Pauline Street	8,000 - 3,000
6.	Washington Street	7,000 - 5,000

Winthrop Regional System (Cont'd)

	Street	ADT
7.	Winthrop Street	7,000 - less than 2,000
8.	Crest Avenue	6,000
9.	Shirley Street	6,000 - less than 2,000
10.	Walden Street	4,000 - 3,000
11.	Veterans Road	3,000

The most heavily congested route through the Town is Main Street/Revere Street. Pleasant Street, which is part of the designated truck route, is a narrow two-lane facility with parked vehicles encountered throughout its length. Land use along its entire length is primarily residential.

B. North Shore Regional Plans

The Boston Transportation Planning Review (BTPR) in August 1972 published a Draft Environmental Impact Statement on a variety of possible program options in the north shore area of Revere and Winthrop. That report documented the current transportation deficiencies and addressed a series of program options that might be developed. Of these options, the only one under serious consideration today is the Revere Beach Connector.

Another project directly relating to Winthrop was the Winthrop Connector, which would have provided a third access road servicing Winthrop. However, this project has been terminated.

C. Quincy Regional System

Quincy is serviced by primarily one regional facility, that being the Southeast Expressway (State Route 3). The Southeast Expressway carries approximately 120,000 to 130,000 vehicles per day. It is a six-lane limited access freeway. It is the only major access facility connecting Boston and communities to the south. It operates at

Quincy Regional System (Cont'd)

capacity level during both the morning and afternoon peak periods. The roadway is under constant maintenance and is the most accident-prone roadway in the Boston Metropolitan Area. There are a number of interchanges with the Southeast Expressway located within Quincy, including Neponset Circle, Granite Avenue, Adams Street and Furnace Brook Parkway.

Route 3A is the other primary State number route. State Route 3A traverses the Neponset Bridge, Hancock Street to the Southern Artery. It continues through Quincy, connecting Weymouth, Hingham and other communities to the South. The Hancock Street section of Route 3A functions as a two-lane bi-directional roadway with parking permitted along both sides. Traffic along this route is interrupted with a non-interconnected system of outdated traffic signals. Considerable amounts of bus and truck traffic were observed along Route 3A further disrupting traffic flow through the section. Route 3A continues as the Southern Artery until Washington Street where it follows Washington Street through Quincy. Between Hancock Street and Sea Street, the Southern Artery is designated as a four-lane facility, while between Sea Street and Washington Street it becomes a six-lane roadway.

Land use along the entire section varies. Along Hancock Street, the use is mixed manufacturing, retail and residential. The section of the Southern Artery between Sea Street and Hancock Street is mostly park land, with the remaining section consisting of varies retail use, including drive-in restaurants, gas stations, etc.

A TOPICS plan was prepared for the City in March 1972 by Tippetts-Abbett-McCarthy-Stratton (TAMS). TAMS conducted a series of traffic counts throughout the City which were presented in their report as follows:

Washington Street, The Southern Artery, Sea Street & Quincy Shore Drive	18,000 - 30,000
Quincy Avenue & Hancock Street	10,000 - 30,000
Independence Avenue & Franklin Street	7,000 - 18,000
Willard Street	7,000 - 17,000

Quincy Regional System (Cont'd)

Revere Road & McGrath Highway	10,000 - 16,000
Quarry Street, School Street & Elm Street	10,000 - 14,000
Adams Street	12,000
Newport Avenue & Upland Road	11,000
Coddington Street	10,000
Water Street & Copeland Street	7,000 - 10,000
Furnace Brook Parkway	10,000

The Neponset River Bridge, where Hancock Street and Quincy Shore Drive converge, has an ADT of 60,000.

Contained in the TOPICS report was also a listing of high accident locations throughout the City. The most critical intersection in terms of safety was the Sea Street/ Southern Artery intersection, with 42 accidents reported for the two years studied.

Much of the street network throughout Quincy is in dire need of improvement, as discussed in the TAMS priority package program. The recently completed Upland Street/Newport Avenue widening and the traffic control improvements implemented thereon are witness to the types of improvements that might be realized.

D. South Shore Regional Plans

There are no major regional plans in terms of new roadway in the Quincy vicinity. Various studies are being made concerning ways of improving operations along the Southeast Expressway. Reversible lanes and provision of an additional lane in each direction have been previously discussed. No immediate plans are expected.

APPENDIX N

QUALITY AND QUANTITY OF LIQUID AND SOLID EMISSIONS

In arriving at expected quantities and quality of effluent streams, the following work has been considered: Havens and Emerson (1973), the Metropolitan District Commission (Deer and Nut Island Plant Records 1973-75), in-house analyses of sludge and ash metals concentrations, plus the analyses done during the course of this study by JBF Scientific, Inc. In addition to these sources of data, comparisons have been made with general sludge quality data from other sources. In each of the following sections, the future quantity and quality of treatment plant emissions will be developed. The emissions of solid wastes and liquid effluents will be addressed together because of the interrelationship of these two areas.

A. Quantity of Solid and Liquid Emissions

Development of quality and quantity of sludges and liquid emissions for each of the alternatives will begin with the expected characteristics of sludges entering the process stream. This will be followed by the balance of liquid and solid fractions involved in the dewatering process, with the quantities and concentrations of solid and liquid process streams for each alternative developed as the last point.

The 1985 process stream quantities developed by Havens and Emerson (1973) were the starting point for the development of quality and quantity of process streams. Acceptability of these projections depends on the following considerations:

- Negligible difference in projections of the 1985 population between 1973 and the present. The basis of the projections used by Havens and Emerson was an FWQA study completed in 1970, modified for 1970 Census data. Review of their conclusions in Section II (Environmental Setting) showed a minor difference between the Havens and Emerson and subsequent OBERS projections, with the growth rate used by Havens and Emerson being greater than the more recent estimates.

- Negligible difference in per capita loading assumptions by Havens and Emerson and present expectations. The assumption was made by Havens and Emerson that per capita loadings of solids would increase to the national average over the 20-year period of design (by approximately 20%), with much of this increase occurring in the years 1985-1995. In the absence of concrete information this assumption is conservative.

- Negligible difference in upstream processes, including anaerobic digestion. The Havens and Emerson report included an increase in primary solids recovery at Deer Island with the installation of additional primary settling facilities. This would be necessitated by the increase of plant flows to reach design capacity by 1980. The same increase in efficiency can occur because of elimination of inflow of seawater from existing tide gates. The MDC is pursuing an active program of reconstruction and inspection of these tide gates, so the assumption of increased solids capture is reasonable (although not necessarily for the reasons stated by Havens and Emerson). Additionally, a 10% bypass around existing anaerobic digestion units was assumed. In Section III.B, this assumption is investigated. The conclusion is that bypassing may be unnecessary, but full-scale operational testing is required to confirm this. Accordingly, the 10% bypass assumption must be retained.

- The volume of grit and screenings anticipated to reach the incinerator has not actually been included. This would lead to a lower projection of future sludge quantities.

- At present, inorganic polymers are used in the sludge conditioning process. In the future, organic polymers may be considered. High weight inorganic polymers represent approximately 10% of total solids to incineration. Use of low weight organic polymers would lead to a reduction in projected future sludge quantities.

For these reasons, the projections of sludge quantities for 1985, as developed by Havens and Emerson, are conservative for planning and design.

An area not considered explicitly by the MDC in development of the Phase I project is the question of grit, screenings and skimmings quantities to be processed. Table N-1 includes a summary of data on grit, screenings and skimmings collected during recent years from the Deer Island collection headworks and the Deer and Nut Island treatment plants. The grit quantities from the headworks and from Deer Island are lower in recent periods than formerly, possibly indicating that more care is being taken with sewer system maintenance. It is assumed that the quantities of grit and skimmings are directly proportional to population and population growth. Therefore, increases in population should result in increases in grit and skimmings.

TABLE N-1

QUANTITY OF GRIT, SCREENINGS AND SKIMMINGS

(DAILY AVERAGE)

Source	July-Dec. 1973	Jan.-June 1974	July-Dec. 1974	Jan.-June 1975
Headworks				
Grit, cf/day	203	128	104	88
Screenings, cf/day	254	235	213	256
Deer Island				
Grit, cf/day	189	128	101	88
Skimmings*, lb/day	12,200	11,500	13,500	16,300
Nut Island				
Grit, cf/day	76	101	92	95
Screenings, cf/day	50	27	44	34
Skimmings*, lb/day	15,600	16,700	4,000	2,800

* Withdrawn from digesters

In projecting future sludge quantities, the estimates by Havens and Emerson are shown previously to be conservative for these reasons:

- Actual population growth rates may be lower than estimates by Havens and Emerson.
- Per capita loadings may remain the same.
- Process expansions may not be done.

While these factors tend to cause an overestimation of the 1985 quantities of primary sludge, the differences in estimated waste loadings can be compensated for by including the minor waste streams (grit, screenings and skimmings), which eventually bring the total quantity of wastes up to the levels projected by Havens and Emerson. One exception to this is the quantity of grit screenings, which cannot be disposed of without incineration. There is an existing multiple hearth incinerator at Nut Island (36 tons per day design capacity), which could be used to burn grit and screenings for either the ocean disposal or land application alternatives. Disposal of ash generated in this manner would be via the mechanism chosen for the major sludge disposal alternative. With this addition, the quantities of sludge and ash to be disposed or applied in 1985 should be similar to the quantities estimated by Havens and Emerson, as shown in Table N-2.

B. Quality of Liquid and Solids Waste Streams

Quality of solids and liquid effluent streams is the second question to be addressed in the area of solid and liquid emissions. The basis for stream quality is the Havens and Emerson analyses done in 1973, shown in Table N-3. Table N-4 compares the Havens and Emerson quality data to those developed by the MDC (Deer and Nut Island Plant Records 1973-1975), and by JBF Scientific analyses which were done as a portion of this study. Because sludge quality data are not available for the "minor waste streams" (grit, screenings and skimmings), the solids and liquid quality as developed will be assumed to include these minor streams.

Comparing the sludge quality data developed by Havens and Emerson, the MDC, and JBF Scientific, certain conclusions can be drawn:

- Analyses of solids and nutrients demonstrate similarity, as can be expected from their high concentrations (which are not so sensitive to differences in technique and from the fact that such analyses are frequently performed by the analyst).

TABLE N-2

PROCESS STREAM CHARACTERIZATION
PHASE I PROJECT
MAINTAINING ANAEROBIC DIGESTION AT DEER & NUT ISLAND PLANTS
WITH PRIMARY TREATMENT EXPANSION

[Source: Havens and Emerson, 1973]

Item	AVERAGE DAY					MAXIMUM DAY				
	DSS lb/dy x 10^3	VSS lb/dy x 10^3	%Vol	%Sol	mgd	DSS lb/dy x 10^3	VSS lb/dy x 10^3	%Vol	%Sol	mgd
Primary Solids										
Deer Island	257	179	70	5.0	0.62	450	313	70	4.5	1.20
Nut Island	189	145	77	5.4	0.42	312	239	77	5.0	0.75
Thickened Solids										
Deer Island	250	174	70	7.0	0.43	437	305	70	6.5	0.81
Nut Island			None					None		
Bypassed Solids										
Deer Island	25	17	68	7.0	0.04	43	30	70	6.5	0.08
Nut Island	19	15	79	5.4	0.04	32	25	78	5.0	0.08
Solids to Digester										
Deer Island	225	157	70	7.0	0.39	394	275	70	6.5	0.73
Nut Island	170	130	76	5.4	0.38	280	214	76	5.0	0.67
Solids after Digestion										
Deer Island	137	69	50	4.2	0.39	240	121	50	4.2	0.73
Nut Island	80	40	50	2.5	0.38	132	66	50	2.5	0.67
Solids to Filters										
Deer Island - Total	148	79	53	6.6	0.27	178	98	55	6.1	0.34
Raw	25	17	68	7.0	0.04	43	30	70	6.5	0.08
Digested	123	62	50	6.3	0.23	135	68	50	6.3	0.26
Nut Island - Total	91	51	56	4.0	0.27	111	65	59	4.0	0.33
Raw	19	15	79	5.4	0.04	32	25	78	5.0	0.08
Digested	72	36	50	3.8	0.23	79	40	50	3.8	0.25
Comb. Plants - Total	239	130	54	5.3	0.54	289	163	56	5.2	0.67
Raw	44	32	73	6.6	0.08	75	55	73	5.7	0.16
Digested	195	98	50	5.1	0.46	214	103	50	5.0	0.51
Filter Cake										
Total	255	129	50	30*	0.10*	312	162	52	30*	0.13*
Ash	126	--	--			150	--	--		

* Modified to be in accordance with projected heat balances

TABLE N-3

RAW AND DIGESTED SLUDGE CHARACTERISTICS

[Source: Havens and Emerson, 1973)

Parameter	DEER ISLAND				NUT ISLAND			
	Raw Sludge		Digested		Raw Sludge		Digested	
	Total	Soluble	Total	Soluble	Total	Soluble	Total	Soluble
Total Solids, mg/l	52,000	9,350	35,000	6,800	53,050	3,800	22,000	1,350
Total Volatile Solids, mg/l	36,000	3,450	19,500	1,250	37,500	2,050	12,450	370
Total Phosphorus, mg/l	380	120	275	15	390	125	290	25
Total Kjeldahl Nitrogen, mg/l	1,450	710	1,250	910	1,400	340	1,090	685
Ammonia Nitrogen, mg/l	370	370*	960	535	240	165	650	540
Potassium, mg/l	110	160*	128*	158*	79	98	84	102
Oil & Grease, mg/l	14,000	------	4,150	------	8,150	------	1,150	------
COD	67,500	13,500	29,000	3,035	51,500	9,700	17,600	3,285
BOD_5	22,500	9,500	3,790	2,230	19,000	4,150	3,400	1,050
Chloride	2,450	2,450	3,250	2,935	405	325	455	325
Sulfate, SO_4	870	144	750	51	400	68	171	38.5
Sulfide, $S^=$	24.5	------	30	------	7.5	------	17	------
Sodium, mg/l	------	------	1,725	------	------	------	262.5	------
Boron, mg/l	8	8*	1	1-*	4	4*	4	4*
Cadmium, mg/l	1.55	<.04	0.98	<.04	0.2	<.04	0.19	<.04
Copper, mg/l	34.5	<.16	27	<.04	19.8	<.06	17	<.06
Chromium, mg/l	17.3	<.16	18	<.16	38.5	<.16	4	<.16
Lead, mg/l	4.0	<.001	5.7	<.01	7.3	.10	6.5	<.001
Mercury, mg/l	1.8	------	0.16	------	.09	------	0.15	<.001
Nickel, mg/l	7.7	.35	3.9	<.26	1.24	.26	1.2	<.06
Zinc, mg/l	45.5	<0.13	49.5	<.04	46.5	.28	37	0.06

* Adjusted for Mass Balance Considerations

TABLE N-4

COMPARISON OF DEER AND NUT ISLAND SLUDGE ANALYSES

Constituent	Havens & Emerson 1973		Comparative Analysis September 1975				Half Year Averages of Monthly Data From MDC									
			JBF *		MDC		Jan-June 1973		July-Dec 1973		Jan-June 1974		July-Dec 1974		Jan-June 1975	
	Deer	Nut	Deer	Nut	Deer	Nut	Deer	Nut	Deer	Nut	Deer	Nut	Deer	Nut	Deer	Nut
Total Solids, %	3.5	2.2	6.46	2.45	6.38	2.58	2.77	1.81	4.5	4.8	2.9	1.98	4.1	2.2	2.35	1.74
Volatile Solids, %	56.0	56.6	52.8	51.9	50.8	56.0	47.2	51.6	49.9	57.3	51.1	60.3	51.0	58.2	50.5	56.3
TKN, ppm	1250	1090	2120	1380	2170	1300	848	1074	1055	-	1570	-	2150	1265	1020	1232
Ammonia N, ppm	960	650	302	580	308	550	-	473	-	-	-	-	-	533	-	623
Organic N, ppm	290	440	1817	800	1860	750	-	601	-	-	-	-	-	730	-	608
Total Phosphorus, ppm	275	290	535	302	604	333	112	217	1005	-	358	-	580	316	213	304
Polychlorinated Biphenyl, ppm	-	-	<0.1	<0.1	-	-	-	-	-	-	-	-	-	-	-	-
Arsenic, ppm **	-	-	1.4	4.1	-	-	6.6	7.8	5.1	5.3	9.1	16.0	5.6	10.3	6.5	11.9
Silver, ppm	-	-	85.1	9.39	30	31	45	31	53	31	51	56	57	70	31	18.4
Cadmium, ppm	28.0	8.6	81.2	24	49	23.3	115	66.7	85	48.6	69.2	102	91.2	52.8	50.7	35.2
Chromium, ppm	514	182	1470	265	1787	232	624	179	1040	91	883	285	1576	324	610	213
Copper, ppm	771	772	1705	1060	1923	880	1809	740	1640	630	977	567	1895	862	1690	765
Mercury, ppm	4.6	6.8	3.1	7.3	4.2	4.5	17.7	8.6	8.0	6.2	4.8	6.2	4.9	11.4	8.4	9.4
Nickel, ppm	111	55	248	106	219	310	258	172	219	226	400	483	294	228	475	483
Lead, ppm	163	295	759	510	110	174	630	400	530	390	500	600	340	490	260	290
Zinc, ppm	1414	1682	5260	4290	3041	1736	2210	1580	3760	2000	2280	1260	3480	1600	2360	1170
Beryllium, ppm	-	-	<0.5	<1.2	-	-	-	-	-	-	-	-	-	-	-	-
Boron, ppm	1.0	4.0	0.8	<0.2	-	-	-	-	-	-	-	-	-	-	-	-

* Some JBF data are averages of two replicates

** All metals given as ppm dry weight

- Metals analyses show major variations not only between the three sources, but also with time. The analyses by the MDC, which include a thirty-month period, have variations as great as those between the MDC and JBF or Havens and Emerson. Using an average of 62% of the sludge from Deer Island and 38% from Nut Island, the long-term average metals concentrations would be similar to those shown in Table N-5. The long-term averages shown should be only used as an approximate measure of quality, because of the changes in metals input that may have occurred between 1973 and the present. There are two major areas of difference between JBF and MDC data. The lead concentrations found by JBF are considerably greater than those of the MDC, which is explained by the difference in analytical methods. (Deer Island analytical procedures may be inadvertently precipitating lead by digesting with sulfuric acid). The second major difference is in the zinc concentrations, with JBF data once again in excess of the long-term MDC average. No explanation can be given for this difference. The importance of metals is in the impacts of certain metals on air quality (mercury and lead) and in the impact on acceptability of sludge for land application (zinc, copper, nickel and cadmium.) A comparison of the major metals concentrations that have been determined by the various analysts are presented in Table N-6. These major metals relationships are: (1) mercury and lead emissions; (2) zinc equivalent (see Appendix R on "Chemical Models for Land Application"); and (3) cadmium: zinc ratio. As shown, the differences in the values desired from the metals concentrations are less than the differences in the concentrations themselves.

- Using fiscal year 1976 (July 1975 - June 1976) data, sludge and ash metals concentrations were computed (Table N-13). These figures can be compared to Tables N-7 and N-9 which show metals concentrations in the ash and sludge, respectively, and are based on data in the 1973 Havens and Emerson report, and JBF Scientific analysis. In general, the 1976 concentrations are much larger than 1985 projections, using 1973 data, excepting mercury (near equal) and lead (approximately 40% less). Actual 1985 sludge, and consequently ash, metal concentrations will be dependent upon many factors, one of which being industrial pre-treatment effectiveness.

TABLE N-5

LONG-TERM AVERAGE METALS CONCENTRATIONS

[Source: MDC Analyses , 1973-1975]

Metal	Deer Island (mg/kg)	Nut Island (mg/kg)	Mass Weighted Average * (mg/kg)
Arsenic	6.6	10.3	8.0
Silver	47.4	41.2	45.0
Cadmium	82.2	61.2	74
Chromium	947	218	670
Copper	1600	711	1265
Mercury	8.8	8.4	8.6
Nickel	329	318	325
Lead	452	434	445
Zinc	2818	1522	2325

* Deer Island = 62% of total sludge mass; Nut Island = 38% of total sludge mass.

TABLE N-6

COMPARISON OF MAJOR METALS ANALYSES FOR DIFFERENTIAL IMPACT

Component *	Havens & Emerson 1973	Comparative Analysis, 1975		Half Yearly Averages, MDC Data				
		JBF	MDC	Jan-June 1973	July-Dec 1973	Jan-June 1974	July-Dec 1974	Jan-June 1975
Lead, mg/kg	213	667	134	543	475	540	400	270
Mercury, mg/kg	5.4	6.7	4.3	14.2	7.3	5.3	7.4	8.8
Zinc Equivalent, mg/kg	2790	9160	7550	6380	7175	6790	7720	8210
Cadmium:Zinc	1.36	1.22	1.54	4.9	2.3	4.3	2.77	2.35
Allowable Total Sludge Land Application, (State Average CEC = 14.7 meg/100g) tons per acre	196	59.7	72.3	85.7	76.2	80.5	70.8	66.6

* Based on 62% sludge contribution from Deer Island, 38% sludge contribution from Nut Island

- With the exception of lead and zinc, the differences among metals concentrations are relatively minor. For the purposes of planning the system requirements, the metals analyses developed by Havens and Emerson will be used with the following exceptions:

  - For air quality analyses, the lead concentration developed by JBF and the mercury concentration developed by MDC will be used, assuming that all the metals remain with the solid fraction of the sludge.

  - For analysis of long-term acceptability of sludge, worst-case conditions are assumed for cadmium-to-zinc ratios, and the associated application quantity (50%) will be used. The JBF data indicates that approximately six years of sludge application (at the rate of 10 dry tons per year) will still be within allowable limits as set in the EPA Draft Technical Bulletin (EPA, 1975A).

Quantities and concentrations expected in liquid and solids effluent streams are shown in Table N-7 for the incineration alternatives (Alternatives 1, 2 and 3); in Table N-8 for Alternative 4, ocean disposal of dewatered sludge; in Table N-9 for the two land application alternatives (Alternatives 5 and 6); and in Table N-10 for Alternative 7, No Action. These computations have been based on Havens and Emerson data except as noted, and the concentrations are assumed to apply to the total final mass for disposal or application.

Assumptions made to develop in-plant process stream characteristics include:

- Phosphorus and metals are insoluble upon conditioning, and metals are only sparingly soluble upon digestion.

- Potassium, sodium, chloride and boron are completely soluble.

- Ammonia nitrogen is almost completely soluble.

C. <u>Potential Impact of Pretreatment on Metals Content of Sludge</u>

Because of the importance of heavy metals in both land application and ocean disposal, the levels shown in Tables N-7 through N-10 require some discussion. EPA draft criteria for land application require that cadmium concentration be 1% or less of the zinc concentration, while that shown in Table N-9 is 1.6% of the zinc. The expectation in most situations in

TABLE N-7

EFFLUENT PROCESS STREAMS

ALTERNATIVES 1, 2 & 3; INCINERATION, 1985 CONDITIONS

Constituent	Increase in Plant Effluent Loading, lb/day Nut Island	Increase in Plant Effluent Loading, lb/day Deer Island	Solid Waste Effluent lb/day	Solid Waste Stream mg/kg*
Total Mass	1,251,000	4,839,400	126,000	
Total Suspended Solids	8,000	14,000	126,000	
Volatile Solids	5,140	13,106	-0-	---
Total Phosphorus	134	148	193	1,530
Total Kjeldahl Nitrogen	1,008	4,005	-0-	---
Ammonia Nitrogen	713	2,611	-0-	---
Potassium	127	660	123	980
Oil & Grease	446	2,060	-0-	---
Chemical Oxygen Demand	9,628	32,420	-0-	---
Biochemical Oxygen Demand	2,215	12,130	-0-	---
Chloride	404	9,340	1,507	11,960
Sulfate	99	602	5,175	41,070
Sulfide	7	15	-0-	---
Sodium	326	5,690	940	7,460
Boron	5	12.1	3	23
Cadmium	0.07	0.5	7.5	60
Copper	6.6	13.4	258	2,050
Chromium	1.5	8.9	149	1,180
Lead *	2.5	2.8	168	1,335
Mercury *	0.06	0.1	1.5	12.2
Nickel	0.5	1.9	29.3	233
Zinc	14.3	24.5	491	3,895

* Based on analyses by JBF Scientific

TABLE N-8

EFFLUENT PROCESS STREAMS

ALTERNATIVE 4, OCEAN DISPOSAL, 1985 CONDITIONS

Constituent	Increase in Plant Effluent Loading, lb/day Nut Island	Deer Island	Solid Waste Effluent lb/day	Stream Concentration
Total Mass	1,251,000	4,839,400	1,020,000	---
Total Suspended Solids	8,000	14,000	255,000	---
Volatile Solids	5,140	13,106	130,000	51.0%
Total Phosphorus	134	148	2,465	9670 mg/kg
Total Kjeldahl Nitrogen	1,008	4,005	4,310	1.69%
Ammonia Nitrogen	713	2,611	2,275	8920 mg/kg
Potassium	127	660	98	385 mg/kg
Oil and Grease	446	2,060	33,460	13.1%
Chemical Oxygen Demand	9,628	32,420	214,310	84%
Biochemical Oxygen Demand	2,215	12,130	30,173	11.8%
Chloride	404	9,340	1,196	4960 mg/kg
Sulfate	99	602	4,107	1.6%
Sulfide	7	15	208	815 mg/kg
Sodium	326	5,690	746	2920 mg/kg
Boron	5	12.1	2.3	9 mg/kg
Cadmium	0.07	0.5	6.0	24 mg/kg
Copper	6.6	13.4	205	804 mg/kg
Chromium	1.5	8.9	118	463 mg/kg
Lead	2.5	2.8	133.5	667 mg/kg
Mercury	0.06	0.1	1.2	6.7 mg/kg
Nickel	0.5	1.9	23.3	91.4 mg/kg
Zinc	14.3	24.5	389.5	1530 mg/kg

TABLE N-9

EFFLUENT PROCESS STREAMS
ALTERNATIVES 5 & 6, LAND APPLICATION, 1985 CONDITIONS

Constituent	Increase in Plant Effluent Loading, lb/day		Solid Waste	
	Nut Island	Deer Island	Effluent lb/day	Stream Concentration
Total Mass	1,251,000	4,839,400	1,020,000	---
Total Suspended Solids	8,000	14,000	255,000	---
Volatile Solids	5,140	13,106	130,000	51.0%
Total Phosphorus	134	148	2,465	9670 mg/kg
Total Kjeldahl Nitrogen	1,008	4,005	4,310	1.69%
Ammonia Nitrogen	713	2,611	2,275	8920 mg/kg
Potassium	127	660	98	385 mg/kg
Oil and Grease	446	2,060	33,460	13.1%
Chemical Oxygen Demand	9,628	32,420	214,310	84%
Biochemical Oxygen Demand	2,215	12,130	30,173	11.8%
Chloride	404	9,340	1,196	4690 mg/kg
Sulfate	99	602	4,107	1.6%
Sulfide	7	15	208	815 mg/kg
Sodium	326	5,690	746	2920 mg/kg
Boron	5	12.1	2.3	9 mg/kg
Cadmium	0.07	0.5	6.0	24 mg/kg
Copper	6.6	13.4	205	804 mg/kg
Chromium	1.5	8.9	118	463 mg/kg
Lead	2.5	2.8	133.5	667 mg/kg
Mercury	0.06	0.1	1.2	6.7 mg/kg
Nickel	0.5	1.9	23.3	91.4 mg/kg
Zinc	14.3	24.5	389.5	1530 mg/kg

TABLE N-10

EFFLUENT PROCESS STREAMS
ALTERNATIVE 7, NO ACTION, 1985 CONDITIONS

Constituent	Increase in Plant Effluent Loading, lb/day Nut Island	Deer Island
Total Mass	3,528,000	3,560,000
Total Suspended Solids	99,000	162,000
Volatile Solids	62,315	112,660
Total Phosphorus	1,250	1,947
Kjeldahl Nitrogen	3,071	5,116
Ammonia Nitrogen	2,180	3,419
Potassium	348	537
Oil and Grease	4,770	28,366
Chemical Oxygen Demand	85,025	171,280
Biochemical Oxygen Demand	19,540	25,020
Chloride	1,114	9,820
Sulfate	735	4,025
Sulfide	69	160
Sodium	900	5,860
Boron	13.8	5.6
Cadmium	0.9	5.7
Copper	73.5	151.4
Chromium	30.3	97.9
Lead	27.9	30.1
Mercury	0.6	1.8
Nickel	5.2	20.5
Zinc	161.2	267.1

which heavy metals are excessive is that reductions in concentration will occur with industrial pretreatment. For three cities (New York, Pittsburgh and Muncie), the residential cadmium contribution ranged from 2.9% to 7.6% of the residential zinc contribution (Davis and Jacknow, 1975). Table N-11 compares the influent metals loadings developed by Davis and Jacknow to the total influent metals loadings in the MDC system, based on the effluent metals and the expected removal with settling. The assumed 20% removal rate for cadmium is conservative, because higher assumed rates of removal would yield even lower cadmium loadings. The results indicate that of the metals listed chromium and zinc loadings might be reduced by pretreatment. The principal question with respect to metals is the cadmium concentration, which cannot be expected to be reduced by pretreatment. Cadmium is used in several applications which make it ubiquitous. Pretreatment for zinc removal would be counterproductive, because the removal of zinc would drive the cadmium:zinc ratio further from the desirable 1% level.

Industrial pretreatment can achieve a high percent removal of heavy metals. Pretreatment is employed at the point source (the industry) and with specific pretreatment methods for the heavy metal(s) of concern. Elson T. Killam Associates (1977) shows that when pretreatment was employed for significant metals contributors reductions in the range of 86-100% were achieved. These reductions were of cadmium, chromium, copper, nickel and zinc concentrations; the percent reduction depends on the metal involved and the method of pretreatment employed.

Industrial pretreatment will not remove all metals in the influent. A large portion of metals may be from residential contributions which, due to their nonpoint source nature, is difficult to pretreat. Metal concentrations in the influent may remain high even with industrial pretreatment if nonindustrial contributions of metals are in significant quantities. If, for example, the major portion of cadmium is a result of residential contributions, then industrial pretreatment cannot be expected to effect a significant reduction of cadmium levels in the influent

D. Entry of Metals into Environment

In addition to the absolute quantity of heavy metals and their concentrations in the sludge, a second major consideration is the availability of these substances to enter the food chain, either through higher plants or through bacterial modification (as in the conversion of metallic mercury to methyl mercury in bottom deposits). Havens and Emerson, during their work in 1973, conducted citrate extraction and distilled water extraction tests on both treated sludge and ash. For comparison,

TABLE N-11

COMPARISON OF RESIDENTIAL METALS LOADINGS IN OTHER CITIES, VS. EXPECTED MDC SLUDGE METALS LOADINGS

Metal	Residential Metals Loadings (lb/day/1000 Pop)*	Metals Loading in Sludge, MDC (lb/day/1000)	Expected Removal in Primary Treatment	Calculated Metals Influent in MDC System (lb/day/1000)
Cadmium	0.006-0.016	0.0024	(20% assumed)	0.012
Chromium	0.007-0.080	0.047	33%	0.142
Copper	0.100-0.180	0.032	62%	0.132
Lead	0.062-0.100	0.021	52%	0.040
Nickel	0.012-0.080	0.009	19%	0.047
Zinc	0.17 -0.21	0.156	41%	0.380

* Source: Davis & Jacknow, 1975

** Source: EPA, Fate and Effects of Trace Elements in Sewage Sludge, EPA - 670/2-74-005, January 1974 literature research by the EPA (Page, 1974) included a summary of acid extraction data (0.5N acetic acid) for several wastewater sludges from Wales and England. These data are presented and compared in Table N-12. Generally speaking, these data indicate the reduced availability of heavy metals in the ash. Recent research on release of metals in sea water (Rohatgi and Chen, 1975) indicates that, for digested sludge, releases of heavy metals at equilibrium are: Cd, 93-96%; Cu, 5-9%; Ni, 46-64%; Pb, 35%; and Zn, 18-39%.

While these data are of interest in tracking heavy metals and their effects on biota, the great bulk of research on soils and crops with respect to heavy metals have focused generally on total amounts of metals in the plow layer.

E. Entry of PCB's into Environment

The analysis of MDC sludge from Deer and Nut Islands by JBF Scientific yielded PCB concentrations of less than 0.1 mg/l on a wet weight basis. While this is not the generally accepted lower limit of detectability, the presence of concentrations of oil and grease interferred with PCB detectability below 0.1 mg/l. Vacuum filtration of digested sludge would yield a maximum PCB concentration of 2 mg/l in the filter cake on a dry weight basis, assuming complete capture in the dewatering process.

F. Potential Toxicity of MDC Sludge and Ash

Solid wastes, including ash and sludge from municipal wastewater treatment plants, may be defined as hazardous wastes under the Resources Conservation and Recovery Act of 1976 (RCRA). Some parameters used in this definition include testing the material's flammability, corrosiveness and toxicity. Due to the heavy metals content of the MDC sludge and ash, the sludge and ash may be toxic and be defined as hazardous.

One of the tests to determine a waste's toxicity involves obtaining a representative sample or an elutriate from a "toxicant extraction procedure." If either shows a concentration of a substance, for which an EPA primary drinking water standard exists, greater than or equal to ten times that standard, the waste is considered toxic. (At present, this test is only one of the proposed methods for determining toxicity. Many aspects of RCRA are not yet final and are in the preliminary stages.)

TABLE N-12

AVAILABILITY OF HEAVY METALS

Constituent	Percent Extracted from Original Mass — HAVENS AND EMERSON: Digested Sludge*		HAVENS AND EMERSON: Ash From Digested Sludge*		EPA REVIEW: Digested Sludge	
	Distilled Water Soluble	Citrate Soluble	Distilled Water Soluble	Citrate Soluble	Citric Acid Soluble Minimum	Citric Acid Soluble Maximum
Phosphorus	6%	77%	0.006%	12%	----	----
Cadmium	<0.02%	<0.02%	<0.02%	28%	----	----
Copper	<0.01%	2%	<0.01%	28%	0.5%	31%
Chromium	<0.3%	71%	10%	54%	<0.7%	8.5%
Lead	<2%	<2%	<2%	<2%	0.5%	10%
Nickel	<1.8%	61%	<1.8%	30%	15%	93%
Silver	<1.2%	<1.2%	<1.2%	10%	----	----
Zinc	<0.01%	9%	<0.01%	5%	15%	97%

* Conditioned with lime and ferric chloride

TABLE N-13

METALS ANALYSIS FOR FISCAL YEAR 1976

COMBINED WEIGHTED AVERAGE

[Source: MDC, 1976]

	Sludge (mg/kg)	Ash (mg/kg)
Chromium	1612	2742
Copper	1713	3671
Cadmium	55.42	119.5
Lead	399	859
Nickel	293	622
Zinc	3075	6561
Mercury	5.86	12.65

APPENDIX O

REVIEW OF LEGAL MEASURES AND POLICIES RELEVANT TO OCEAN DISPOSAL OF SLUDGE

In 1970 the Council on Environmental Quality (CEQ) in a report entitled "Ocean Dumping A National Policy" concluded that there was a critical need for a national policy on ocean dumping. The report pointed out the international character of ocean dumping and the lack of legislative authority existing at that time. Regulatory activities were fragmented and authority was largely confined to the territorial sea or to specific classes of pollutants. CEQ recommended a national policy to ban unregulated ocean dumping of all materials and to strictly limit ocean dumping of any materials harmful to the marine environment.

Ocean disposal of sewage sludge may take place through either direct discharge of sludge from barges or ships, or through pipelines which discharge directly to the ocean. The disposal of municipal sewage sludge by barge dumping is prevalent on the east coast on the mid-Atlantic Bight (NAS, 1975). Municipal sludges and effluents are discharged through outfalls on the southern California Bight.

In 1972, Congress passed additional legislation for federal control of water pollution with specific references to ocean disposal of wastes. Sections 102(c) of the Marine Protection, Research and Sanctuaries Act of 1972 (PL 92-532) and 403(c) of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) both require that applications for permits for the dumping or other discharge of any materials into the marine environment be evaluated on the basis of impact of the materials on the marine environment and marine ecosystems, on the present and potential uses of the ocean and on the economic and social factors involved. Permits for outfall discharge of sludge are issued by EPA under the National Pollutant Discharge Elimination System (NPDES) of PL 92-500. Barging for disposal which is also permitted by EPA, falls under the provisions of PL 92-532.

The Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) prohibit the discharges of pollutants into navigable waters, which include the territorial sea and the contiguous zone of 12 miles. The contiguous zone is defined in international law as a zone of limited jurisdiction beyond the territorial sea, measured from the coastal baseline (Ketchum, 1972). Section 402 of PL 92-500 establishes the National Pollution Discharge Elimination System (NPDES) for issuance of permits for discharges including ocean outfalls. The permit system is administered by the Environmental Protection Agency (EPA) or by individual states if authorized and approved by EPA. Section 403 of the Act contains provisions for promulgation of guidelines for determining the degradation of the waters of the territorial seas, the contiguous zone and the oceans due to the effects of pollutants. Section 405 specifically requires a permit issued by the Administrator of EPA for the disposal of sewage sludge in navigable waters.

The Marine Protection, Research and Sanctuaries Act of 1972 requires permits for dumping wastes anywhere in ocean waters. The purpose of the Act is to regulate the transportation of material from the United States for dumping into ocean waters, and the dumping of material, transported from outside the United States, if the dumping occurs in ocean waters over which the United States has jurisdiction or control under accepted principles of international law. Title I of the Act delineates prohibited acts, permit requirements and criteria for evaluating permit applications. The Administrator of EPA is given the authority to issue permits. EPA has delegated responsibility for permit review and approval to its ten regional offices. Title II of the Act contains provisions for the initiation of a comprehensive, continuing program of monitoring and research regarding the effects of dumping of materials into the ocean waters, coastal waters where tidal flow takes place, or the Great Lakes and their connecting waters.

Since MDC is not now presently considered an ocean dumper, the type of permits that might be allowed are either of the "special" or "emergency" type. Emergency permits are only available where a situation of urgency exists and cannot be considered as a feasible long-term solution to the sludge disposal problem. Special permits are available (with expiration dates specified as no later than three years after issuance) if the dumped material meets certain criteria with regard to trace contaminants and environmental impact. The allowable levels of these materials may not exceed the following (40 CFR, Subchapter H):

<u>Mercury and its compounds</u>

Solid phase - not greater than 0.75 mg/kg
Liquid phase - not greater than 1.5 mg/kg

<u>Cadmium and its compounds</u>

Solid phase - not greater than 0.6 mg/kg
Liquid phase - not greater than 3.0 mg/kg

Organohalogens:

Not to exceed 0.01 of a concentration shown to be toxic to appropriate sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures after reasonable allowance for initial mixing in the mixing zone or; 0.01 of a concentration of a waste material or chemical constituent otherwise shown to be detrimental to the marine environment.

Oils and greases:

Not to produce a visible surface sheen in an undisturbed water sample when added at a rate of one part of waste material to 100 parts of water.

If these materials are harmless or are rapidly rendered harmless by physical, chemical or biological processes at sea, will not, if dumped, make edible marine organisms unpalatable or will not, if dumped, endanger human health or that of domestic animals, fish, shellfish and wildlife the above limitations do not apply. Wastes containing one or more of the following materials shall be treated as requiring special care:

1. The elements, ions, and compounds of:

   Arsenic
   Lead
   Copper
   Zinc
   Selenium
   Vanadium
   Beryllium
   Chromium
   Nickel

2. Organosilicon compounds and compounds which may form such substances in the marine environment.

3. Inorganic processing wastes, including cyanides, fluorides, titanium dioxide wastes, and chlorine.

4. Petrochemicals, organic chemicals, and organic processing wastes, including, but not limited to:

   Aliphatic solvents
   Phenols
   Plastic intermediates and byproducts
   Plastics
   Amines
   Polycyclic aromatics
   Phthalate esters
   Detergents

5. Biocides not prohibited elsewhere, including, but not limited to:

   Organophosphorus compounds
   Carbamate
   Carbamate compounds
   Herbicides
   Insecticides

6. Oxygen-consuming and/or biodegradable organic matter.

7. Radioactive wastes not otherwise prohibited. As a general policy, the containment of radioactive materials is indicated rather than their direct dispersion and dilution in ocean waters.

8. Materials on any list of toxic pollutants published under section 307(a) of PL 92-500, and materials designated as hazardous substances under section 311(b)(2)(A) of PL 92-500, unless more strictly regulated under §227.2.

9. Materials that are immiscible with seawater, such as gasoline, carbon disulfide, toluene.

These materials may be dumped if the applicant can demonstrate that the sludge proposed for disposal meets the limiting permissible concentrations of total pollutants described for organohalogens considering both the concentration of pollutants in the waste material itself and the total mixing zone available for initial dilution and dispersion.

Amendments to the existing legislation (both PL 92-500 and PL 92-532) and finalization of rules and regulations regarding criteria and permit procedures for ocean dumping of sewage sludge have clarified the positions of both Congress and EPA on the ocean dumping question.

- In January 1977, EPA published final revisions of regulations and criteria for ocean dumping (FR 42 #7, part VI).
- In November 1977, Congress passed amendments to the Marine Protection, Research and Sanctuaries Act of 1972 (PL 95-153).
- In December 1977, Congress passed amendments to the Clean Water Act (PL 95-12).

These actions serve to further specify the conditions under which sewage sludge (among other materials) may be dumped into the ocean.

The most important statements of policy are contained in the 1977 amendments to the Marine Protection, Research and Sanctuaries Act of 1972 as follows:

Sec. 4(a). The Administrator of the Environmental Protection Agency shall end the dumping of sewage sludge into ocean waters,...., as soon as possible...., but in no case may the Administrator issue any permit ...., which authorizes any such dumping after December 31, 1981.

Sec. 4(b). ....the term "sewage sludge" means any solid, semisolid, or liquid waste generated by a municipal wastewater treatment plant the ocean dumping of which may unreasonably degrade or endanger human health, welfare, amenities, or the marine environment, ecological systems or economic potentialities.

The United States is also bound by international law to control ocean dumping of potential pollutants. An international conference entitled, "Convention on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter", was held in London during October and November 1972. The London Convention prohibits the dumping of some materials (except as trace materials), requires special care for the dumping of other identified substances, and provides for a general permit for others (NAS, 1975). The Convention was ratified by the United States on August 3, 1973. On October 15, 1973, ocean dumping regulations pursuant to PL 92-532 were adopted and subsequently amended (PL 92-254) in March 1974 to incorporate provisions of the London Convention, which were not included in the original legislation. The London Convention recently became international law following ratification by fifteen consulting nations.

Summary

The basis for determining the level of degradation outlined in paragraph (b) above remains those criteria governing the issuance of permits (CFR 40, Subchapter H) or bioassay procedures which have yet to be approved. On these bases, the MDC sludge would not be approvable for ocean dumping in the foreseeable future, since the level of trace contaminants far exceed those in the criteria.

The nature of the sludge, at present, the remote likelihood of improvement in the near future, the possibility of other alternatives, and the stated policies of the federal government regarding ocean dumping, makes this alternative infeasible.

APPENDIX P

LAND APPLICATION OF SLUDGE - STATE OF THE ART

The primary treatment of wastewater produces approximately 0.1 pounds per capita per day of sludge, the solids which settle out during primary sedimentation. Dick (1973) and Reed (1973) have given descriptions of sludge disposal, which will be summarized here along with data from other sources.

Presently there are two different forms of land application for sanitary waters: WWTP effluents, and treatment plant sludges. Raw sewage is not generally applied to land in the United States, principally for reasons of public health. In this discussion, methods for disposal of dried and liquid sludge will be addressed.

A. Forms of Applied Sludge

Sludge is presently applied to land in one of three concentrations: as liquid sludge, as a dewatered cake, or as a dry fertilizer.

1. Dewatered Sludge

When sludge is dewatered it commonly has 60-75% moisture remaining (Singh, et. el. 1975; C.E.Q. 1974). The resulting cake is generally transported using trucks for ultimate disposal at landfills or as a soil conditioner and/or fertilizer. Costs for dewatering the sludge are about $25 per ton of dry solids (Dick, 1973) plus the cost of transporting the dry sludge to the disposal site, while drying sludge costs about $100 per ton (Alter, 1975).

When dewatered sludge is used for a nutrient source and soil conditioner, the cake is spread on the ground by manure spreaders, bulldozers or tractors, then the field is plowed to mix the sludge into the active soil layer. As the sludge becomes assimilated by the soil, it changes the pore size of clay soils resulting in better aeration. As a result of sludge incorporation, sandy soils have improved soil aggregation (tilth), increased chenical reaction sites for nutrient exchanges, and increased binding capacity (Kirkham, 1974).

Application of 30 tons per acre of sludge at 18% moisture has been shown to double the yields of corn per acre compared to plots that have not been fertilized (Singh, et. al. 1975). While zinc concentrations increase to almost double the amount found in the vegetative portions of plants grown on soils not fertilized with sludge, the amounts were shown to remain below toxic levels (Singh, et. al. 1975).

Dried sludge (5% moisture) has the advantage of being transported in dump trucks without special precautions to avoid leakage. But dried sludge is harder to incorporate into the soil than other forms of sludge. Odors and pathogens are not a problem with this material, since the drying process is unfavorable for pathogens and reduces the volatile materials which cause odors.

2. Liquid Sludge

Liquid sludge has been applied to the soil in the past, but without special consideration for its nutrient value. With costs of chemical fertilizers rising, use of sludge as a fertilizer and soil conditioner is being more closely studied for its advantages and disadvantages (Kirkham, 1974; Walter, 1975; Singh, et. al. 1975). Liquid sludge acts as a soil conditioner in much the same manner as dried sludge. Sludge contains 1-7% nitrogen (Walter, 1975), and based on samples from two plants, about 3% phosphorus and 1% potassium (kirkham, 1974). The sludge is applied as a slurry, containing generally 3-5% solids (Dalton and Murphy, 1973; Hinesly and Sosewitz, 1969). In the United States, this method of disposal is presently used for Chicago, Illinois, Martinsville, Virginia, and Denver, Colorado (Hinesly and Sosewitz, 1969; Dalton and Murphy, 1973; Hatcher, 1974; Wolf, 1975). In the United Kingdom, reports describe the use of land application in West Hertfordshire (Wood and Ferris, 1972), Slough (Claydon et. al 1973), Blackburn (Rawcliffe and Saul, 1974), Letchworth (Taylor, 1974), Peterborough (Spotswood and Raymer, 1973), East Calder and Newbridge (Brownlie and Akers, 1973).

The amount of sludge applied to the soils depends on the type of soil and its use. Between 10 and 30 tons of dry solids per acre per year have been applied to agricultural land with no apparent problems (Singh, et. al. 1975; Allen, 1973; Dean, 1973). When used to condition a sand landfill, 100 tons of dry solids per acre per year has been used successfully, while 1 ton dry solids per acre per year has been used to fertilize publicly owned grasslands (Hinesly and Sosewitz, 1969).

Although the infiltration rate of the soil determine how much liquid sludge can be applied at one time, the total amount that may be applied is generally determined by the cation exchange capacity of the soil and the concentrations of zinc, copper and nickel in the sludge (Walker, 1975). As a guideline until research shows differently, the Environmental Protection Agency has proposed a formula for determining the total tons of sludge that can be applied to the soil (Walker, 1975). The EPA also recommends that sludge not be applied to cropland if the cadmium level is greater than 1% of the zinc content, since cadmium is toxic at a much lower concentration than zinc (Walker, 1975).

Spreading of liquid sludge is generally less complex than is spreading of dried sludge. Three methods are commonly used: Spray irrigation, ridge and furrow infiltration, and spreading from tank trucks. Spray irrigation utilizes large-nozzled sprayers to distribute the liquid evenly over the soil surface. Ridge and furrow infiltration depends on basins or canals to allow infiltration of the liquid into the soil. Infiltration may be capable of handling a larger volume than the other methods, although spray irrigation is more efficient for nutrient removal (Hinesly and Sosewitz, 1969).

Considering only domestic sludge, spray irrigation in a forest has been used from June until December, and handled 0.2 inches per day per acre of liquid at a nutrient removal efficiency of 80%. The ridge and furrow method has been used for 230 days, handling an average of 1.52 inches of sludge per day per acre, with a 65% nutrient removal efficiency (Reed, 1973). Similar data is not available for tank truck spreading procedures.

Two of the difficulties associated with these methods are their dependence on climatic and soil conditions for proper operation. During periods of rain or snow these techniques are not effective, thus requiring storage facilities for the sludge. Care must be taken that organic and nitrogen contamination of groundwater does not occur.

Odors from the sludge may be disagreeable to neighboring populations (Reed, 1975). In order to contain odor problems in Denver, it was found necessary to work the sludge into the ground soon after application (Wolf, 1975).

Although the transport and distribution of liquid sludge is a more complex process than that of dry sludge, data show that based on a population of one million people, the cost for treating and then transporting sludge 140 miles, is about $25 per ton of dry solids. This is about the cost of dewatering the sludge alone (Riddel and McCormack, 1968).

3. Fertilizer from Sludge

By air-drying sludge, a granular fertilizer can be produced, which can either be processed further or distributed in that form. The Metropolitan Sanitary District (MSD) of Chicago has three methods of disposing of sludge: liquid sludge applied to strip mines; heat-dried sludge which is sold to a contractor who then sells it to citrus growers; and an air-dried sludge which is distributed free of charge. A major difference between these methods is their cost. For heat drying the sludge, the cost is about $100 per dry ton, while processing and transporting liquid sludge results in a cost of between $50-150 per dry ton. Using the Imhoff method, the cost of granular air-dried sludge is about $8 per ton dry solids. Approximately 2% to 6% of MSD's sludge is handled in this matter, or 12 tons of dry solids per day from the MSD;s 1.4 billion gallons of sewage per day.

Winston-Salem, North Carolina, also air-dries its sludge to produce a granular fertilizer containing 10% moisture, 3% nitrogen, 3% phosphoric acid and less than 0.2% potash, at a cost of about $10-12 per dry ton. When distribution of the sludge became a problem, a fertilizer producer was contacted and an arrangement made where the contractor supplements the nutrient content and then markets the sludge (Styers, 1973). Winston-Salem disposes of approximately 10 tons of dry solids per day in this manner.

B. Transportation of Sludge Prior to Land Application

Transportation sludge from a waste treatment plant to the final disposal site may be accomplished by utilizing any one or any combination of several modes of transportation, including tank truck, barge, railroad and pipeline. In developing a system of transporting sludge for ultimate disposal at a utilization site or landfill, three factors should be considered:

- the mode of transportation and its corresponding energy intensiveness,
- sludge characteristics such as volume, density, and applicability, and
- land availability and distance to the disposal site.

The transported sludge may be in the form of a liquid, thickend sludge, dewatered cake, compost product or dried powder. The various forms of sludge or sludge products which remain after dewatering or drying exhibit different physical characteristics. These characteristics will impose some limitations in selecting modes of transportation which are capable of handling the type of sludge being considered for transport.

Sludge may be transported by truck, rail, barge or pipeline. However, there is considerable variation in energy intensiveness (which is defined as BTU per ton-mile of transported material).

1. Truck Transportation Energy Costs

Using work by Ashtakla (1975), the energy costs of truck transportation of sludge can be calculated. A diesel powered truck with a 20-ton (18.1 mt) payload and a 29-ton (26.3 mt) gross vehicle weight has an average fuel cost of 1,770 BTU per ton-mile one way. This assumes that the truck returns empty. As an example, if the transport distance one way is 20 miles, the fuel energy required is 20 x 1,770 or 35,400 BTU per ton. A second approach is to use the BTU per ton-mile versus gross vehicle weight curve presented by Ashtakala with an average payload both ways of 10 tons (9.05 mt) resulting in a fuel energy use of 1,940 BTU per ton-mile. As a conservative figure, allowing for waiting time at loading and unloading facilities, 2,000 BTU per ton-mile may be used.

For transportation of sludge or compost, the BTU per ton-mile measure must generally be converted to BTU per dry ton-mile. For sludge dewatered to 25% dry solids, the transport energy cost would be 8,000 BTU per dry ton-mile.

2. Rail, Barge and Pipeline Transport Energy Costs

Using data presented by Hirst (1973) for energy costs of rail transport, barge and pipeline, sludge transport energy costs have been developed. For transport of sewage sludge or compost, two modifications are necessary. The moisture content of the sludge and the energy cost of returning the empty vehicle must be considered. Modifying the energy cost by considering the vehicle weight equal to one-third of the gross weight, the following energy costs can be calculated:

TABLE P-1

Mode of Transport	Basic Total Energy Cost (Hirst, 1973)	Net Weight Energy Cost Modified for One-Way Haul
Rail	670 BTU/T-M	1340 BTU/T-M
Barge	680 BTU/T-M	1660 BTU/T-M
Pipeline	450 BTU/T-M	450 BTU/T-M

With respect to the relative solids concentrations, these three methods will require a solids concentration of 8% or less. Using 8% solids, the net weight energy costs per dry ton-mile.

As noted, a correlation between the present solids of the sludge and the energy required to transport a ton of dry solids can be derived. From the data presented in Table P-1, and the truck transport energy cost of 2,000 BTU/T-M, datum points for each mode of transportation were derived by computing the total amount of sludge (in tons) at various solids concentration, which had an equivalent dry weight of 1 ton. The energy intensiveness required to transport these quantities were then calculated for each mode of transportation. Figure P-1 is a graphical presentation of this correlation. For simplicity, percent solids was used to depict the total weight of the sludge. For example, a sludge with a solids concentration of 10% requires 10 tons of sludge to produce 1 ton of dry solids.

It is apparent from the graph in Figure P-1 that truck transport is significantly more energy intensive than barge, rail or pipeline transport.

However, trucks offer flexibility in the selection of a disposal site and for this reason have been widely used to haul and apply sludge. Small to medium size tank trucks with capacities of 1,500-2,000 gallons can serve the needs of small communities where space and accessibility are sufficient to accommodate truck traffic with minimal adverse impacts on traffic. Large tank trucks which are capable of transporting approximately 3,000 gallons of sludge are usually too cumbersome for applying sludge directly to disposal sites and result in more adverse impacts on traffic in urban areas.

Railroad transport is less energy intensive than truck transportation of sludge or sludge products, but requires a rail head of switching yard near the plant for efficient operation of this transport system. Pumping is required from the treatment plant to the rail head which in turn may impose limitations in cases where rail service is not readily accessible.

Barge or waterway transportation of sludge is practical in cases where water access is readily available. Loading of barges is accomplished by pumping directly from the digesters at the treatment plant.

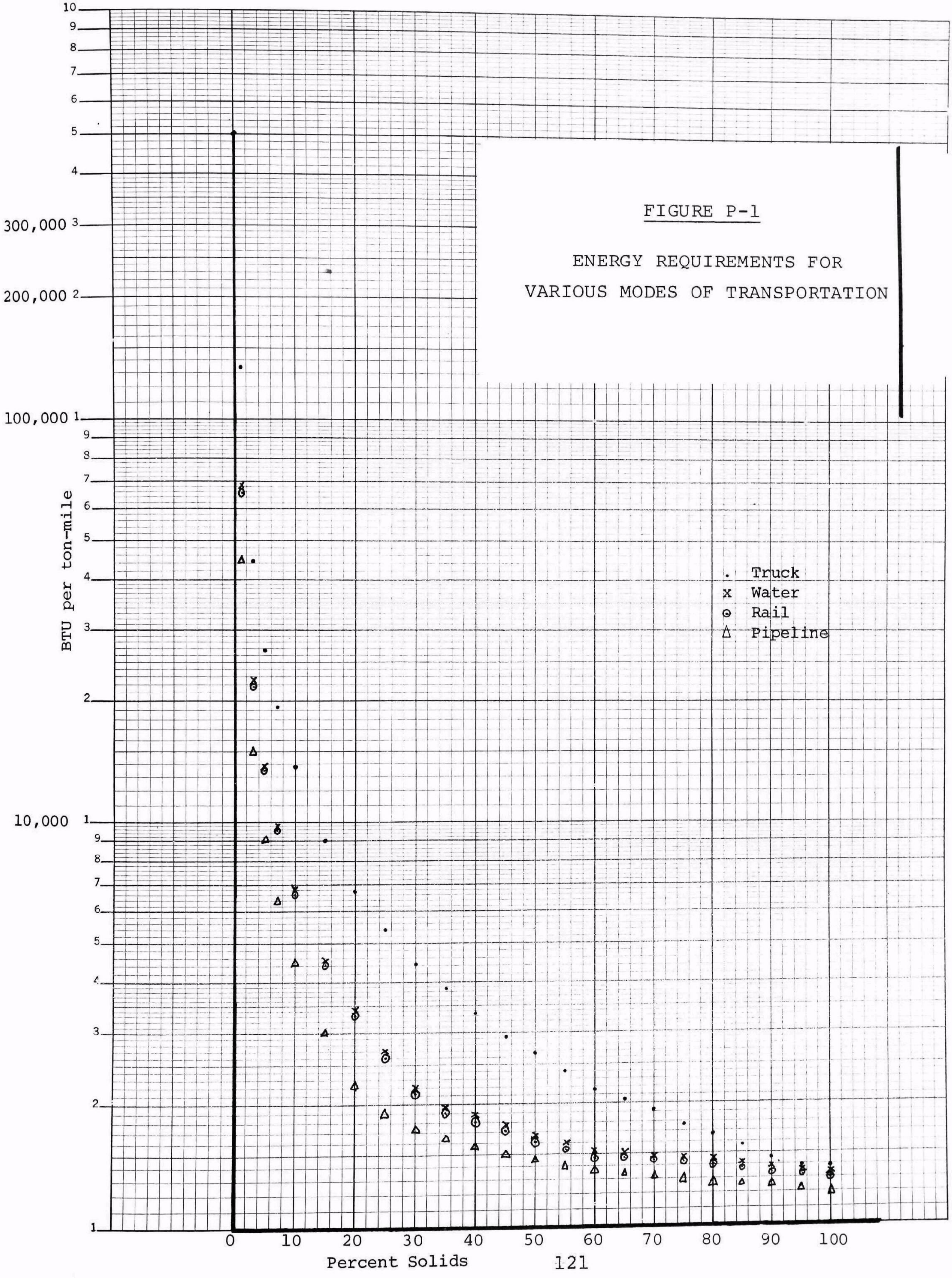
FIGURE P-1
ENERGY REQUIREMENTS FOR VARIOUS MODES OF TRANSPORTATION
300,000
200,000
100,000
10,000
BTU per ton-mile
Percent Solids
0
10
20
30
40
50
60
70
80
90
100
. Truck
x Water
⊙ Rail
Δ Pipeline

Pipeline transport can be utilized only when solids concentrations are approximately 7 percent or less. This mode of transportation offers the least flexibility. In order for a pipeline transport system to be effective for the Boston situation, the ultimate land disposal site would have to have sufficient land availability to insure an efficient useful life of approximately 40 years.

C. Crop Production

Liquid sludge has been used for fertilizing corn, wheat, soybean and grain sorghum crops as well as pasture land and public grassland (Hatcher, 1974; Singh, et. al. 1975; Hinesly and Sosewitz, 1969; Walker, 1975; and Wold, 1975). Corn grown on a prison farm has been fertilized by sludge from Martinsville, Virginia, and has shown better color and growth than corn grown on unfertilized plots (Hatcher, 1974). Denver has been applying sludge to 2,000 acres of Federal land which is rented to a private concern for use as pasture. Applications of 450 dry tons per acre have shown no detrimental effects on the wheat or Sudan grass that is grown, and cattle pastured on the land are healthy and heavier than cattle raised on unfertilized pastures (Wolf, 1975).

Research by Singh, Keefer and Horvath (1975) on two types of soil shows different results. On a loamy soil the yield of corn per acre more than doubled compared to unfertilized plots. However, in a sandy soil the plants were stunted compared to the crop grown on unfertilized plots. They theorize that the excessive drainage of the soil resulted in leaching of nutrients, as well as a possible plant toxicity from heavy metals.

Since primary digested sludge is generally used as agricultural land, contamination of foodstuffs and spreading of pathogens is of concern. An additional problem associated with sludge fertilization is heavy metal uptake by crops, resulting in toxicity of the plants or concentration of heavy metals in consumers. While application of 30 tons of dry solids per acre has resulted in an increase in zinc concentration in foliage from 48 ppm to 88 ppm, this level is well below the accepted toxicity concentration of 200 ppm (Singh, et. al. 1975). Monitoring of a yield utilizing 137 dry tons/acre over a span of five years showed no toxicity from heavy metals, outbreaks of pathogen related diseases of groundwater contimination (Kirkham, 1974), In addition publicly owned grassland fertilized with sludge has resulted in the grass growth rate improving 100%. No health problems or toxicity problems were reported (Hinesly and Sosewitz, 1969) and the crops grown on sludge fertilized land have generally been healthy and produce large yields.

D. Problems With Land Application of Sludge

1. Public Acceptability

So far the greatest problem in land disposal of sludge has been public acceptability. The idea of using sludge to fertilize crops and recreational areas is repugnant to many people. As with marketing sludge fertilizers, marketing of agricultural products grown in sludge fertilized fields has been difficult at times. Fears of disease and odors are the common complaint, and can be reduced by the distribution of information on the techniques used and how any problems will be contained (Alter, 1975; Kirkham, 1974). But an additional complicating factor are various local laws restricting the transport of sludge or the sale of municipal "property;" such restrictions have at times caused more problems than the actual marketing (Styers, 1973).

The type of sludge being applied and the method of application also influence the pathogens and odors present. Dry sludge in the fertilizer form has little problem with pathogens or odors due to the method of preparation. Liquid and dewatered sludges need care in handling to control possible odors and pathogen populations.

2. Heavy Metals

Excessive heavy metal concentrations are a problem in all forms of sludge that are land applied. Certain elements found in sewage sludge, although often necessary for plants and animals in low concentrations, can cause toxic reactions in high concentrations. Included in this group of elements are: zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), nickel (Ni), mercury (Hg), and molybdenum (Mo). Table P-2 indicates background soil metal concentrations and concentrations found in different sludge samples. Although higher concentrations of these elements are found in industrial wastes, concentrations in municipal wastes alone can be high enough to present toxicity problems when applied to agricultural land (Page, 1974).

The solubility and availability to plants of heavy metals is affected by the form of metal added (i. e. sulfide, hydroxide, carbonate, phosphate, etc.), the soil cation exchange capacity, clay sorption other than by the CEC, the organic content of the soil and pH. Elements considered for plant toxicity include cadmium, copper, lead, zinc, chromium, mercury and nickel. These metals have been found to increase most drastically with sludge application. Phytotoxicity, in decreasing order, occurs most frequently with: copper, nickel, zinc, cadmium, lead, mercury, and chromium (Ryan, 1977).

TABLE P-2

SELECTED METALS CONCENTRATIONS

[Source: Ryan, 1977]

Metal	Range in Soils (mg/kg)	Concentration in Sludge (mg/kg)			Potential Toxicity	
		Median	Mean	Range	Plant	Animal
Boron	2-100	36	97	12-760	Not determined	Not determined
Cadmium	.01-7	16	106	3- 3,400	Moderate	High
Chromium	5-3,000	1,350	2,070	24-28,800	Low	Low
Copper	2-100	1,000	1,420	85-10,100	High	Slight to moderate
Lead	2-200	540	1,640	58-19,730	Low	Low to high
Manganese	100-4,000	280	400	58- 7,100	Not determined	Not determined
Molybdenum	.2-5	30	29	24-30	Low	Moderate to high
Nickel	10-1,000	85	400	2- 3,520	High	Low to moderate
Mercury	Not determined	5	1,100	.5-10,600	Low	Low to high
Zinc	10-300	1,890	3,380	108-27,800	Moderate	Low

Organic matter can chelate toxic materials and make them less available for plant uptake. This is a common occurrence for copper and nickel, while phosphate has been shown to reduce zinc insoluble salts of lead and mercury in the soil, thus restricting their movement. Zinc, cadmium, copper and nickel are held either as salts or by the cation exchange capacity of the soil, although some is available for plant uptake. Iron, manganese, calcium, magnesium and potassium are abundant in most soils, indicating that amounts added by sludge should not affect plant balances (Lindsay, 1973). Extractable concentrations of cadmium and zinc have been shown to decrease with the depth of soil (Kirkham, 1975). This indicates that once plant roots extend past the surface layer of soil less metals come in contact with the plant roots, resulting in less uptake.

Field studies involving plant toxicity generally raised the soil pH to 6.5. This condition has been shown to limit metals solubility and plant uptake. Chaney, et al (1977) reported investigations on the effect of a pH decrease. During normal farming operations farmers often do not lime to the extent recommended by agricultural extension agents, resulting in a lower than desirable soil pH. Chaney found no toxicity responses at a pH of 6.5, but at 5.5 snapbeans and soybeans showed a severe toxic reaction (Chaney, et al, 1977). Other crops also suffered severe yield reductions, yet no single foliage metal content was at a level that would be considered toxic. Still other crops show no toxic responses. This indicates that crop tolerances vary considerably and soil pH is important. Ordinary foliar metals diagnois was difficult due to the complex conditions presented by the sludge (Chaney, et al, 1977).

Of concern with sludge application is that the major source for cadmium in the public's diet is from food. Unlike most other metals, cadmium uptake is not as restricted in plants. This is particularly important where the soil pH drops below 6.5. In one field experiment, where the soil pH was initially near 6.5, liming was necessary after sludge application to raise the pH to acceptable levels. Later in the season liming was again required. Apparently, mineralization and oxidation of sludge nitrogen and sulfide resulted in acidification of the soil. This indicates that, even with proper conditions at the beginning of the growing season, unless constant monitoring occurs conditions that allow increased cadmium uptake may occur later in the season (Chaney, et al, 1977).

In addition to different crops having different responses to metal concentrations, it was found that different cultivars react differently. Using various corn cultivars, the cadmium concentration in the foliage was found to vary from 2.5 to 62.9 ppm, with the same sludge rate applied (Chaney, et al, 1977). This necessitates selection of crops to be grown on sludge-amended soils down to the cultivar level. As the information is not currently available, this indicates that extensive study is necessary in order to limit the potential impacts on people from heavy metals.

Most studies looked at sludge application over several years to determine their impacts on plants. Chaney, et al (1977) also studied a one-time application of different rates of sludge, all equivalent to rates used in other studies. Four years after this single application, significant cadmium was still found to be extractable from the soil.

In addition to plant studies, the effects of ingesting metals contained in plants by animals has been studied. Using laboratory animals and swiss chard for feed, it was found that at sludge application rates of 25, 50 and 100 tons per acre that the metals concentrations increased significantly in various tissues of their bodies. It was found that liver and kidney tissues had the greatest increase in metals concentrations (Lisk, 1978). Selenium in excess of 4-5 μg/g (Allaway, 1968), molybdenus in excess of 5 μg/g if copper concentrations are low (Allaway, 1968), and cadmium when the zinc-cadmium ratio exceeds 299 (Chaney, 1973) may cause toxic reactions in animals from ingestion of plant materials. Lead has shown toxicity when ingested directly. However, plants do not take up significant amounts of lead, and toxicity to animals would primarily occur from surface contamination by the sludge (Page, 1974).

Pathogen content of sludge is considered a potential health hazard at land application sites. Although no disease outbreaks have been traced to irrigation with secondary effluent, pathogens have been shown to survive for a considerable period of time on plants or in the soil and surface waters. Pathogenic bacteria have been found to survive from a few days to a few weeks on fruits or vegetables, although they are seldom detected unless sludge particles are present. Fecal coliforms applied to grass crops have been shown to require 20-50 hours of bright sunshine to be eliminated. Bacteria pathogens have been found to survive in the soil from a few days to a few months, and viruses that were absorbed to clay particles were still infectious. Human enteroviruses survived in pond water from 84 to 91 days. This indicates that although land application has not been shown to be a health hazard at this time the potential exists (Lance, 1978).

LAND APPLICATION OF COMPOST

A. Regulations

Land application of sewage sludge is regulated by the U. S. EPA with stabilization recommended in all cases (U. S. EPA, 1977, 1978). This is necessary to reduce public health problems and nuisance odors. This is most readily accomplished by complete composting although pastuerization, high pH treatment, long term storage of liquid sludge at 20°C for 60 days, and radiation treatment are possible (U. S. EPA, 1977).

The amount of stabilization that is required depends on the application method to be used and the use of the disposal site. Crops that can only accept sludge as a surface dressing would need the most stable substance. For pastures or hay, additional stabilization is necessary to reduce pathogen levels in order to prevent health problems to foragers. Where the sludge can be plowed into the soil after application, a less stabilized sludge can be applied. Crops used directly for human consumption, such as vegetables, are not recommended for growth on soils that have received sludge within the previous three years (Jelinek & Braude, 1977). This would apply with even the most highly stabilized sludge, as a residual pathogen population is often present.

In addition to stabilization requirements, site restrictions and restrictions on crop practices are given in Tables P-3 and P-4.

B. Stabilization Methods

Stabilization of sludge can occur by several means: aerobic or anaerobic digestion; high lime treatment; and composting. The digestion methods and high lime treatment occur in the process train of a treatment plant, while composting occurs after the plant processes. Although composting is not a new concept, a great amount of research with sewage sludge has been ongoing in recent years.

Composting has been used as both a single and an additional stabilization step. The research done by the USDA at the Beltsville, Maryland, Agricultural Research Center provides the most extensive study available on the effectiveness of composting in pathogen reduction and the bulking materials that can be used (Willson, Epstein & Parr, 1977). Beltsville uses an aerated pile method, with a bulking agent required to allow proper air circulation. The ratio of bulking to sludge and types of agents used vary, with woodchips at a 2:1 volume ratio being the most common. When used as a single step stabilization process,

TABLE P-3

SITE RESTRICTIONS

Soil	Restriction	Reference
	Medium texture	Hall, Wilding & Erickson, 1976
	Tested for CEC	US EPA, 1976
	High pH	US EPA, 1976 H, W&E, 1976
	Testing for background heavy metals	US EPA, 1976
	Depth of ≥ 3 ft.	H, W&E, 1976
	High infiltration	H, W&E, 1976
	Moderate permeability	H, W&E, 1976
Drainage	Closed or modified-closed	H, W&E, 1976
Bedrock	> 3-4 ft. below surface	H, W&E, 1976
Slope	< 4%	H, W&E, 1976
Groundwater	Monitor if rate > 10 T/A/yr. sludge	US EPA, 1976
Public Access	Restricted by remoteness or by fencing	US EPA, 1976

TABLE P-4

RESTRICTIONS ON CROP PRACTICES

	Restriction	Reference
Sludge quality	< 1,000 mg/kg Pb < 20 mg/kg Cd < 10 mg/kg PCG	Jelenik & Braude, 1977
Total metals applied (with CEC of 5-15 meq/100 g soils)	0.005 T/A 0.011 Mt/hectare) Cd 0.5 T/A (1.12 Mt/ hectare) Pb	Jelenik & Braude, 1977
Crops eaten raw	< 3 years since last sludge application	Jelenik & Braude, 1977
Growing crops	Not applied	Jelenik & Braude
Timing	Not applied during rainfall	Miller, 1976
	2-3 weeks prior to planting	Miller, 1976
Cadmium application when applied to land used for the production of food chain crops*		US EPA, 1978
A. Maximum annual application		
1. Present to 12/31/81	2.0 kg/ha	
2. 1/1/82 to 12/31/85	1.25 kg/ha	
3. Beginning 1/1/86	0.5 kg/ha	
B. Maximum cumulative additions		
1. Soil CEC <5	5 kg/ha	
2. Soil CEC of 5-15	10 kg/ha	
3. Soil CEC >15	20 kg/ha	
C. Sludge quality	≤ 25 mg/kg Cd	
D. pH of sludge/soil mixture	≥ 6.5	

*This is one method proposed by the US EPA. Another method proposed includes a comparison of crops and meats grown on the sludge amended land to crops and meats produced on local non-sludge amended land, with respect to cadmium concentrations, to determine acceptable levels.

dewatered raw sludge is combined with the bulking agent, piled in windrows over an air circulation system and covered by a layer of screened compost. The screened compost cover helps restrict odor problems, although they may still occur if raw sludge is used. Dewatered digested sludge, composted in the same manner, exhibits less odor and fewer problems. In either case, the high sustained temperatures necessary for pathogen reduction are attained by the composting process. Screening after composting returns most of the woodchips for reuse, after which the compost is cured for 30 days. The resulting material is relatively odor and pathogen free, with a moisture content of 40-45 percent (Willson, Epstein and Parr, 1977).

When determining the bulking agents to be used, availability, volume required, amount recyclable, costs and the quality and quantity of resulting compost must be taken into consideration. Materials tested at Beltsville include (Willson, Epstein and Parr, 1977):

- woodchips
- paper cubes
- auto salvage
- licorice root
- leaves
- leaves combined with woodchips

Woodchips are the most frequently used bulking material. The size is about 1 cubic inch and they are used in a volume ratio of 2-2.5 parts woodchips to 1 part sludge. During screening about 80 percent of the woodchips may be recovered. Cost depends on source and seasonal demand (Willson, Epstein and Parr, 1977).

Paper cubes are formed by putting waste paper through a die-cutting machine. Used at a volume of 3:1, there is no recovery of the bulking material. Although a recycling program may be able to supply the needs of a composting facility at a negligible cost, there is no guarantee that the entire supply would be met. Specialized machinery to make the cubes would be necessary (Willson, Epstein and Parr, 1977).

Materials used from auto salvage are fabrics, foam and plastics. Glass and metal would be sorted out. A volume ratio of 1:12 has been used successfully. This was possible as the material absorbed a large quantity of liquid from the sludge. However, recovery of all the bulking material was difficult and some plastics, foam and fabric were left in the finished compost. This affects its desirability for land application. The costs of the salvage material would partially depend on the amount of sorting that is necessary and the haul distance (Willson, Epstein and Parr, 1977).

Licorice root is a fibrous residue from extraction processes and was used at a volume ratio of 2.5:1. No recycling of the bulking material was possible, but other fibrous residues, such as peanut shells, may be used. A problem with using this type of material is the identification of a supply source (Willson, Epstein and Parr, 1977).

Leaves have been used both as a sole source of bulking and in combination with woodchips. Using 100 percent leaves, a volume ratio of 2:1 is successful. A mixture of 60 percent leaves and 40 percent woodchips can use a 2.5:1 volume ratio. With the latter, 32 percent recycle is possible, reducing the amount of material to be obtained for each process. Problems with this system include the increased volume to be disposed of and the supply of an adequate amount of leaves throughout the composting process. A benefit is a disposal mechanism for leaves and reduced costs for bulking materials (Willson, Epstein and Parr, 1977).

At present, research as to the feasibility of disinfecting municipal sludge is being conducted at the MDC Deer Island treatment plant. The results so far indicate that adequate bacterial and viral disinfection is possible. There is evidence that other useful effects, such as improved dewatering characteristics, breakdown of toxic chemicals and de-infestation of pathogenic parasites, are also produced (Trump, 1977).

C. Application Sites and Management

Application can be done on two general area types: non-food and food crops. Crop lands are preferred for land application as they are disturbed areas and can return a cost benefit from the fertilizer value of the sludge. Although many forests are nutrient deficient, application of compost is difficult unless the area has been logged, at which point it is a disturbed area.

Application to non-food crops depends on the management techniques used at each site. Sod farmers may prefer to apply compost after removing the sod and prior to seeding. Tree farmers may prefer to use a top dressing of compost on young trees, or to add it to the land after trees are removed for sale. Orchards would primarily require a top-dressing. Surface application of sludge or compost has a greater potential for being carried by surface runoff than if it had been incorporated into the soil. Also, better nutrient utilization is possible with incorporation. Disturbed areas, such as strip mines or quarries, can use sludge or compost, either incorporated or as a top-dressing. These areas are nutrient and organic material deficient and would readily respond to sludge or compost application. Problems associated with application to non-food crops include: scheduling of application; production of treatment plant versus limited need of crops; possibility of surface water impacts from surface runoff of top-dressed compost; and a low fertilizer credit. Advantages of application to non-food crops over food crops include: less possibility of heavy metals entering the human food chain; less monitoring of crop quality required; and a source of material to rehabilitate disturbed areas (such as strip mines).

Food crops considered for application include: grains (corn, wheat, oats and barley); hay feed to domestic animals; and pastures utilized by grazing animals. As previously discussed, vegetable crops should not be grown on land application sites. The nature of grain crops makes application during the growing season difficult. To obtain the most benefit from the sludge, application should occur prior to planting and after harvesting. Climate and timing of farm operations will affect the efficiency of application. Early planting and late harvesting of a crop restricts the possible periods of application and, should the possible times occur during winter when the soil is frozen or covered with snow, application is also restricted.

Application to pasture and hay crops is recommended: prior to spring growth; after plant domancy; and immediately after cutting but before significant new growth has occurred (Miller, 1976). Although 2 to 3 weeks are recommended before animals are allowed on the field, it has been found that a significant amount of sludge remains on the grass even after numerous rainfalls. The sludge is then ingested by the foragers and the heavy metals would concentrate in their kidneys and liver (Kienholz, et al, 1977). Dairy cows are of less concern than those used for meat, as the metals do not occur in the milk. Concerns with application of sludge or compost to food crops include: bio-concentration of heavy metals; phytotoxicity if the soil pH drops; and pathogen transfer potential. Advantages include: nutrient source; trace element source; fertilizer cost benefit to farmers; improvement of soil condition from organic material addition; and increase of soil pH during application.

As described, application to crop lands depends on when the soil is available for machinery movement. Table P-5 presents a general guideline for southern New York. The table identifies the months that dewatered sludge or compost may be applied, as compared to planting and harvesting schedules. These are general times and will vary yearly and by region. Under corn, compost application during October and November will occur if harvesting occurred earlier. December and January are not used for application, as the ground is generally frozen and the potential for runoff increased. Application in February is possible after the ground has thawed.

TABLE P-5

GENERAL APPLICATION PERIODS

Month	Corn	Hay	Barley	Soybeans	Oats
January	-	-	-	-	-
February	Compost	Compost	-	Compost	Compost
March	Sludge	Compost	-	Sludge	-
April	-	Compost	-	-	Plant
May	Plant	-	-	Plant	-
June	Plant	Harvest	Harvest	Plant	-
July	-	Harvest	Harvest	-	Harvest
August	-	Harvest	Sludge	-	Compost
September	Harvest	Compost	-	-	Compost
October	Harvest (compost)	Compost	Plant	-	Compost
November	Harvest (compost)	Compost	-	Harvest	Compost
December	-	-	-	-	-

Distribution of the sludge or compost from the treatment plant site to the application area may be accomplished in many ways. A system where the user picks up the sludge or compost at the plant is used in some areas. This is feasible for small quantities, but is not reliable for most large treatment plants. Distribution to large scale users, such as farmers or nurserymen, would require a management system operated by a municipal agency. Although many combinations and systems are possible, two basic alternatives exist: storage on municipal property with distribution to users according to their schedules and needs, with application by the agency to ensure that all requirements are met; or distribution to the user with short-term storage on the user's property, with a legal agreement that the user will apply according to regulations. The latter system allows for distribution planning by the agency, while giving the user flexibility of application times. However, where the user is responsible for application, careful management is necessary to ensure that sludge or compost is only placed on suitable areas at acceptable rates.

APPENDIX Q

CONCLUSIONS AND RECOMMENDATIONS FROM "MARKET SURVEY AND FEASIBILITY OF SLUDGE FERTILIZERS"

[Source: Development Planning and Research Associates, Inc. 1975]

VI. ALTERNATIVE STRATEGIES AND RECOMMENDATIONS

The alternative strategies for producing and marketing dried sludge fertilizer at Deer Island presented in this chapter meet the production characteristics presented by Havens and Emerson in the "Environmental Assessment Statement" dated October, 1974 1/. These conditions are as follows:

- The processing of dried sludge from primary treatment [with a]
- 2-2-0 analysis (N-P_2O_5-K_2O) [at a]
- Cost of $94.50 per ton of dried sludge (5% moisture), delivered to a storage facility at Deer Island [and with]
- 45,000 to 50,000 tons (dry basis) of annual production.

Our review of other sludge fertilizer programs indicates that the established operations with successful marketing programs are those which dry activated sludge from secondary treatment processes. These operations market their products with 5 to 6 percent (or more) nitrogen, an analysis which gives the products greater marketability. While it is not the purpose of this study to evaluate the MDC sewage treatment plan, it must be recognized that the secondary treatment necessary to produce an activated sludge is an alternative which might be considered in any plant to produce fertilizer at Deer Island. (The limitations of the present study precluded any attempt to examine the financial aspects of such secondary treatment.)

Few operations have successfully marketed significant amounts of dried primary sludge. On the other hand, the MDC might have an option of

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1/ "Environmental Assessment Statement for A Plan for Sludge Management," Commonwealth of Massachusetts and Metropolital District Commission, Boston, October 1974.

giving away a dried sludge (analyzing 2-2-0). However, no study has been made to determine the feasibility of a give-away program. How much could be disposed of in such a manner and at what cost to the MDC are questions which would require a separate feasibility study. As a minimum, the MDC would have to pay the $94.50 per ton drying cost, plus transportation and promotion costs of $20 to $25 per ton. It is possible that alternative drying techniques, such as the potential process owned by Organic Recycling, Inc., might result in lower drying costs; specific data are not available on this process.

Therefore, this chapter's evaluation of strategies must be based on the system presented by the MDC to EPA. The alternatives which follow are compatible with the conditions cited at the beginning of this section.

A. Framework for Evaluating Alternative Strategies

The following framework has been utilized to identify and evaluate alternative strategies for producing and marketing a dried primary sludge fertilizer at Deer Island.

	Alternatives	
	A	B
1. Treatment process	Primary	Secondary
2. End-product	Fortified	Unfortified
3. End-uses	Lawn and garden/golf courses	Farm
4. Fortified analysis	6-2-4	Other grades
5. Form	Unsized	Compacted, Pelletized or Extruded

	Alternatives (Con'd) A	B
6. Packaging	Bulk	Bagged
7. Shipping mode	Rail	Truck
8. Marketing organization	Outside organization	In-house
9. Distribution channel	Lawn and garden retailers	Direct
10. Price	Competitive	Premium
11. Geographic market	Local/regional	National

The best alternative is stated in the headings and its selection is discussed in the text.

1. <u>Treatment process: PRIMARY</u>

Although there are advantages in utilizing a secondary treatment, the conditions specified in the project preclude this alternative. Primary treatment has been specified and becomes a key determinant in selecting other alternatives.

2. <u>End-product: FORTIFIED</u>

The 45,000 to 50,000 tons of dried primary sludge to be produced annually at the proposed Deer Island site is a low analysis material, averaging 2-2-0 ($N-P_2O_5-K_2O$). Such a product has value primarily as a soil conditioner and, if sold, would compete with peat moss, dried manure, bark mulch and composts. Unfortified dried primary sludge would have a relatively low unit value and, if sold, would have a relatively restricted geographic market because of its transportation costs.

These facts lead first to the conclusion that fortification would be a more desirable alternative. In order to market any sizeable volume of material, the product must be made more attractive to potential users. Some degree of fortification should be achieved through mixing with inorganic chemical fertilizers. A second and less desirable alternative would be to produce 2-2-0 for low-priced bulk disposal.

3. End-uses: LAWNS AND GOLF COURSES

Fundamental to the question of fortification is the intended use of the final product. The survey of the market for dried sludge fertilizers clearly shows that the home lawn and golf course markets are most promising. There could be a limited farm market in Massachusetts and nearby states, but economic considerations argue that it is not promising.

Farmers purchase fertilizers for specific and varying crop and land needs. Although a single grade fertilizer could suffice for many crop applications, it would not conform to the best agronomic and farming practice. Fertilizers, also, are generally priced on a nutrient content basis with the chemical fertilizers determining the price at which sludge fertilizers can be sold. The costs of transporting and spreading a low-analysis, bulky product mitigate against any widespread use of dried sludge in conventional farming operations. Furthermore, there are serious questions about the heavy metals in sludge which must be resolved before MDC should attempt to sell to the farm market.

On the other hand, an organic fertilizer such as Milorganite (6-2-0.5) has gained wide acceptance as a turf fertilizer. It is actually preferred by many turf specialists and is highly recommended for lawns and golf greens. Its slow release of nutrients and non-burning qualities make it superior to many chemical fertilizers. The number of homes and golf courses provide a much larger market than do the relatively small number of farms which might be reached. The heavy metals problem is not present in lawn use, but dried sludge is not acceptable for vegetable gardens. Therefore, the home lawn and golf course market is the most desirable end-use alternative.

4. Fortified Analysis: 6-2-4

An endless variety of fertilizer grades are currently used on lawns, gardens and golf greens. Very high analysis products such as 23-7-7 are marketed in the Boston area. As noted earlier, Milorganite (6-2-0.5) is popular among turf growers. Corenco sells a 5-5-0 dried activated sludge product. A common lawn grade is 10-6-4 with varying percentages of the total N expressed as organic (natural or chemical).

An excellent grade of New England turf fertilizer would contain about 6 percent nitrogen and 4 percent potash (K_2O). The P_2O_5 content is not as critical and could be as low as 2 percent.

Given the analysis of MDC sludge (2-2-0), the addition of appropriate amounts of urea, diammonium phosphate and sulfate of potash would convently produce a 6-2-4 grade.

5. Form: UNSIZED

The proposed MDC plant will produce a dried sludge with irregular sized particles, ranging from dust to 14-mesh size. The product might be upgraded through compacting, pelletizing or extruding to make it more like Milorganite which is evenly sized; however, given the nature of the MDC material, conventional equipment cannot be adapted to producing a uniformly sized product. The Organic Recycling patented process might be utilized, but as a proprietary process, it is not possible to assess its viability in this project. With these limitations, an unsized material is the only viable alternative.

6. Packaging: BULK AND BAGGED

The end-product, 6-2-4, can be distributed in bulk or in bags. If the product is sold to fertilizer manufacturers for bagging and/or re-formulation, it could move in bulk form from the Deer Island plant. If the product is marketed through distributors (jobbers and/or wholeslaers), it would have to be bagged at the treatment plant.

There is no clearly preferable alternative strategy discernible between bulk and bagged distribution. From a cost viewpoint, it is preferable to distribute the bulk product to eliminate bagging and handling costs. If the entire production could be sold to manufacturers, no bagging facility would be required at Deer Island.

On the other hand, it appears that sales through distributors to retailers are necessary for some part of the output. Provision should be made for packaging some or all of the product in 50-pound bags. Storage facilities for bulk or bagged products do not vary significantly.

The most desirable alternative is to provide for both bulk and bagged distribution.

7. Shipping Mode: TRUCK

The product can move either by truck or rail. Rail rates are somewhat lower than truck rates and would be especially advantageous for longer distances (over 100 miles). However, motor carriers have two inherent advantages: route flexibility, even for longer hauls, and loading/unloading convenience. Truck hauling can be arranged through a common carrier at posted ICC rates, through a carrier at negotiated private rates, or through an MDC-owned or leased fleet. Either of the latter alternatives appears to be the most feasible and worthy of future study. Because a number of distributors and/or wholesalers would prefer to pick up the product at Deer Island, the need for truck loading facilities should be emphasized.

Another important consideration is the availability of shipping facilities at Deer Island. Since there is no rail spur to the treatment plant site, the product would have to be transported by truck or barge to a rail siding and reloaded onto rail cars; the cost of rehandling the product would partially or entirely offset the advantages of lower rail rates. Of course, the alternative of constructing a rail siding to the Deer Island plant is one which should be considered. No feasibility study has been conducted on such a project. Barging is a possibility if the market is to be in coastal states; however, this was not considered a viable alternative at present and established barge shipping rates, therefore, were not calculated.

On balance, truck transportation appears to be more desirable in the absence of rail handling facilities. Certainly, MDC should give serious consideration to the alternative of building a rail siding to Deer Island and to the method of operating trucks.

8. Marketing Organization: OUTSIDE ORGANIZATION

MDC has an option of establishing its own marketing organization or of contracting the marketing to an outside organization. Milwaukee has its own intensive marketing and advertising program for Milorganite, while Houston and Chicago operate through brokers who have extensive programs. Either method could be used.

The complexities and expense of establishing a marketing organization make that alternative less attractive especially for marketing a bulk product. Houston's arrangement -- the city contracts with one firm to take its entire output -- appears more economical for selling bulk material over a wide area. Houston pays a 6 percent commission on its f.o.b. plant price and incurs no other marketing expense; the marketing cost per ton is about $1.50. Our estimates for a marketing program, operated by MDC, are many times that amount. An in-house sales and marketing staff might develop more effective sales programs, especially when aimed at local markets. The in-house marketing personnel could also serve as public relations specialists. However, it takes much time and effort to develop an effective marketing organization.

In view of the uncertainty of extensive markets, an outside organization with an established reputation as a distributor is a more desirable alternative.

9. Distribution Channels: WHOLESALE/RETAIL

The MDC product could be sold directly to end-users, especially to golf courses or to farmers, or MDC could rely primarily on lawn and garden retail outlets. The final choice will depend largely upon the decision made in the marketing system discussed under section 8 above. If MDC were to market through its own organization, it could conceivably sell some product directly to users. If MDC uses an outside organization, the choice of distribution channels would be left to the outside firm.

In view of the number and type of established retail outlets in the Northeastern U.S., it would appear most cost effective to use that channel for the distribution of a bagged product. This would be true whether or not MDC uses an outside firm for marketing. Lawn and garden retailers have the clientele and the expertise in selling the product to the final user, making their use advantageous.

Selling to golf courses could best be achieved through a distributor (jobber or wholesaler) or through one of the established fertilizer manufacturers/formulators. Again, these firms have the experience and technical knowledge to deal with greens superintendents and course managers.

10. Price: $65.00 PER TON F.O.B.

In arriving at a sale price, MDC could consider the alternatives of competitive or premium pricing. Premium pricing could be advantageous if MDC's product is recognizably differentiated from other lawn fertilizers and if it is successfully marketed as a superior turf fertilizer. These requirements are reasonable; therefore, MDC's product can be priced slightly higher than other turf fertilizers.

11. Geographic Market: 150-MILE RADIUS

The marketing area in which MDC sludge as 6-2-4 fertilizer may be sold is largely a function of the existing and potential number of final users, existing and potential competitive products and transportation costs. Markets may be categorized as follows:

- Local -- 50-mile radius
- New England -- 150-mile radius (through zone 6)
- Boston - Pittsburgh - Washington triangle -- 500-mile radius
- National

A critical factor in evaluating these alternative markets is the annual volume of product to be sold. If MDC has no alternative disposal methods for its sewage sludge, then its market must extend far enough to sell approximately 49,000 tons of 6-2-4 annually (equivalent to 40,000 tons of 2-2-0). Based on the analysis of existing markets for sludge fertilizers, the 6-2-4 product would have to be offered nationally to move 49,000 tons in today's market. There are, of course, potential users who do not now use sludge-type products and who might be "educated" to their use. The expected population growth by 1980 doubtless may increase the use of the product. These potential users are not likely to become customers without a massive promotion campaign or some user-incentive program.

Competitive sources must also be considered. Milwaukee and Chicago have marketed their products for over 40 years and will not be easily replaced as suppliers in the Northeast. Other producers have more recently entered the market, with mounting evidence that a great many more communities and private firms will be entering the market in the near future. As this occurs, the geographic market for a Boston-based product will shrink and will be ultimately limited to the Boston area.

The most desirable alternative under existing conditions is the 150-mile New England market, simply because that large a territory is necessary to market, ultimately, 16,200 tons of 6-2-4 (equivalent to 13,235 tons of 2-2-0). Should lesser amounts be marketed, economic considerations would make it advantageous to market over smaller areas, with the local territory around Boston offering the best alternative for 9,250 tons annually.

As distribution extends from Boston outward toward the 150-mile radius, transportation costs increase but plant net-back also increases; beyond 150 miles, the net cost of distributing a larger volume of product increases on a unit basis as the distance increases. Since the product must be sold at a loss in all markets, the least cost alternative (rather than the highest net gain) becomes the most desirable.

On this basis, the 150-mile radius offers the most attractive alternative. Unfortunately, this territory at present does not offer a large enough market for MDC's total output of sludge as 6-2-4. As new producers enter the competitive picture, the potential for 1980 may be even less.

It becomes obvious, then, that it appears to be impossible to sell 6-2-4 nationwide and that, if the entire output of MDC sludge were to be dried, some of it (about 34,000 TPY) would have to be disposed of as 2-2-0. The reasons why this would be difficult on a sales basis have been stated. The only alternative would be to distribute it at zero or nominal cost to the homeowner. Such a program would result in the spreading of 2-2-0 on one lawn in ten in Massachusetts every year.

B. Recommendations

From a purely financial point of view, MDC should not attempt to produce and sell a fertilizer product. Only a small amount of a 2-2-0 product can be sold (about 5,000 tons per year), making the investment in drying facilities uneconomic. A fortified product (6-2-4) can be sold in larger quantities (up to 16,400 tons of sludge per year), but the additional costs of fortification would not quite be recovered and the financial returns would contribute nothing toward the cost of drying. Two-thirds of the sludge output would still have to be disposed of as a 2-2-0 soil conditioner. Given the concern over heavy metals there is small likelihood that the 2-2-0 product could be sold at more than a nominal price.

On the other hand, if there is no disposal alternative (such as incineration or ocean disposal) or if MDC and EPA select the fertilizer alternative for sludge disposal, then the alternatives examined above can be stated as a set of recommendations as follows:

1. Produce 16,200 tons per year of a fortified, 6-2-4 unsized fertilizer material, equivalent to 13,235 tons of dried primary sludge.
2. Market through an outside organization, primarily to lawn and garden retail outlets for home lawn and golf course use.
3. Distribute in 50-pound bags or in bulk form where possible.
4. Ship by truck but investigate the construction of a rail siding to Deer Island.
5. Offer this competitively priced product within a 150-mile radius of Boston.
6. Attempt to distribute the remainder of the dried 2-2-0 sludge locally at little or no cost to homeowners.

APPENDIX R

CHEMICAL MODELS FOR SLUDGE APPLICATION

Introduction

The two constituents of sewage sludge which most often limit its application to croplands are nitrogen and heavy metals. Excessive quantities of nitrogen can cause nitrate contamination of groundwater, while high concentrations of heavy metals in the soil can result in their entering the food chain. However, if these two constituents are properly controlled, land application can be a safe, environmentally sound method of sludge disposal.

Sodium (from salt water infiltration into the Deer Island system) could also be a factor influencing the rate and duration of application. This is discussed at the end of the Appendix, as it appears that the sodium concentration in the sludge will be low and subsequently will not hinder the application program.

This Appendix presents a simple model which can be used to calculate the minimum amount of land which is required for conducting a sludge application program. This will allow preliminary determinations to be made of the feasibility and cost-effectiveness of land application alternatives for sludge disposal.

Nitrogen

Nitrogen is present in sewage sludge in both the organic and inorganic forms. Typical digested sewage sludge contains from 1 to 5 percent organic nitrogen by dry weight and from 1 to 3 percent inorganic nitrogen (Sommers et al., 1976).

Nitrogen is a nonconservative substance in soils and is constantly changing form. Biological activity will break down organic nitrogen into the inorganic form where it will oxidize to nitrate, which is utilized by vegetation as a nutrient. Numerous other reactions, such as nitrogen fixation, also occur, and some nitrogen is contained in rainfall.

Soil contains 400 to 10,000 kg/ha of nitrogen (Haith, 1973), mostly in the organic form. From 2 to 10 percent of the soil organic nitrogen will mineralize each year.

When sludge is applied to land, the inorganic nitrogen fraction is readily available for uptake by crops. Sommers et al. (1976) estimates that 15 percent of the sludge's organic nitrogen will become available the first year, with

3 percent of the remainder becoming available for at least three succeeding years. Other researchers (King, 1975) have used slightly different assumptions, such as 10 percent the first year and 5 percent each succeeding year.

Uptake by crops is a major mechanism for nitrogen removal from soil. Sommers et al. (1976) presented estimates of the nitrogen requirements of typical crops. Removal of nitrogen by crop uptake assumes that the crop is removed from the site by harvesting.

Leaching is soluble nitrate nitrogen to groundwater is another removal mechanism. Any inorganic nitrogen in excess of that needed for crop uptake can potentially leach into the groundwater. The USEPA drinking water standards fro nitrate nitrogen is 10 mg/l.

Taking sources and sinks into account, an annual nitrogen mass balance can be expressed as:

Soil nitrogen which is mineralized
\+ Sludge organic nitrogen which is mineralized
\+ Sludge inorganic nitrogen
\+ Other nitrogen additions, such as rainfall
\- Nitrogen uptake of crops
\- Nitrogen lost in leachate
= 0

This mass balance can be expressed mathematically by assuming that a fraction of the sludge organic nitrogen mineralizes the first year and that the remainder becomes part of the soil organic nitrogen; the soil organic nitrogen also mineralizes, but not necessarily at the same rate as the sludge organic nitrogen.

$$b\,N_s\,(n) + a\,F_o\,A\,(n) + F_i\,A\,(n) + R - U - G = 0 \qquad \text{Equation 1}$$

where

- N_s (n) = Soil organic nitrogen, kg/ha, at the start of year n
- A)n) = Amount of sludge applied, kg/ha, in year n
- a = Fraction of the sludge organic nitrogen which is mineralized in the first year the sludge is applied, $year^{-1}$
- b = Fraction of the soil organic nitrogen which is mineralized each year, $year^{-1}$
- F_o = Fraction of organic nitrogen in the sludge
- F_i = Fraction or inorganic nitrogen in the sludge
- R = Additions of nitrogen from rainfall or commercial fertilizer applications, kg/ha/yr
- U = Uptake of inorganic nitrogen by crops, kg/ha/yr
- G = Inorganic nitrogen lost in leachate, kg/ha/yr

Rearranging equation 1 gives the maximum amount of sludge that can be applied in any year, based on nitrogen limitations:

$$Amax\ (n) = \frac{Gmax + U - R - b\ N_s\ (n)}{a\ F_o + F_i}$$

where

Amax(n) = Maximum amount of sludge, kg/ha, which can be applied in year n

Gmax = Maximum allowable loss of nitrogen through leaching, based on water quality standards for groundwater

The soil organic nitrogen will be augmented by the part of the sludge organic nitrogen which is not mineralized in the first year:

$$N_s\ (n + 1) = [1-b]\ N_s\ (n) + [1-a]\ F_o\ An \qquad \text{Equation 3}$$

By using equations 2 and 3, it is possible to calculate the maximum sludge application rate for each successive year of land application. This technique will be demonstrated after limitations on heavy metals are discussed.

Heavy Metals

Unlike nitrogen, heavy metals behave as conservative substances. That is, once placed in the soil, they will tend to remain in place and accumulate. Concentrations must not be allowed to become excessive and the soil pH must remain sufficiently high to avoid solubilization of heavy metals. Thus, while nitrogen limits annual sludge application rates, heavy mentals limit the total amount of sludge which can be applied to a given plot of land.

Table 1 shows the concentrations of heavy metals in sludge from Deer and Nut Island Treatment Plants compared to ranges of concentrations found in other sludges. Table 2 shows the total amounts of sludge metals allowed on agricultural lands; other limits may be appropriate for non-agricultural lands or if supported by a monitoring program for heavy metals.

TABLE 1

TRACE ELEMENT CONCENTRATIONS IN SEWAGE SLUDGE [Source: "Ohio Guide for Land Application of Sewage Sludge," Ohio Agricultural Research and Development Center, Ohio Cooperative Extension Service, July, 1975]

Element	Range (ppm*, dry wt.)	Median**	Boston***
Boron	6-1000	50	9
Cadmium	1-1500	10	24
Chromium	20-40,600	200	463
Cobalt	2-260	10	-
Copper	52-11,700	500	804
Nickel	10-5300	50	91.4
Manganese	60-3900	500	-
Mercury	0.1-56	5	6.7
Molybdenum	2-1000	5	-
Lead	15-26,000	500	667
Zinc	72-49,000	2000	1530

* Parts per million
** The mediam is that value for which 50 percent of the observations, when arranged in the order of magnitude, lie on each side.
*** Raw dewatered sludge

TABLE 2

MAXIMUM AMOUNTS OF SLUDGE METALS ALLOWED ON AGRICULTURAL LAND
[Source: Sommers et al., 1976]

	Soil Cation Exchange Capacity (meg/100 g)*		
Metal	0-5	5-15	> 15
	Maximum Amount of Metal (lb./Acre)		
Pb	500	1000	2000
Zn	250	500	1000
Cu	125	250	500
Ni	50	100	200
Cd	5	10	20

* Determined by the ph 7 ammonium acetate procedure

The maximum total of sludge which can be applied is:

$$A_H = \text{Min} \begin{cases} 2.27 \times 10^9/F_{Pb} \\ 1.12 \times 10^9/F_{Zm} \\ 5.60 \times 10^8/F_{Cu} \\ 2.24 \times 10^8/F_{Ni} \\ 2.24 \times 10^7/F_{C/d} \end{cases} \quad \text{Equation 4}$$

where

A_H = Maximum amount of sludge, kg/ha, which can be applied, based on heavy metals limitations

F_{Pb}, F_{Zm}, F_{Cu}, F_{Ni}, F_{Cd} = Fractions (dry weight) of lead, zinc, copper, nickel and cadmium, respectively, in the sludge, ppm

Note: Equation 4 assumes a soil with a cation exchange capacity greater than 15 meg/100 g. For soils with a CEC of 5 to 15 meg/100 g, the rates shown should be halved; for CEC less than 5 meg/100 g, the allowable rates are one quarter those shown.

One further heavy metals limitation which must be considered is the need to limit cadmium according to a new EPA schedule of maximum allowable yearly soil application rates (40 CFR 257). By this schedule the standards for cadmium will become increasingly stringent until the ultimate maximum allowable application rate of 0.5 kg/ha.y is acheived in 1986. Thus, the following limitation results.

$$A_{max} \leq \begin{cases} 2.0 \times 10^6/F_{Cd} \text{ until December 31, 1981} \\ 1.25 \times 10^6/F_{Cd} \text{ until December 31, 1985} \\ 0.5 \times 10^6/F_{Cd} \text{ after January 1, 1986} \end{cases} \quad \text{Equation 5}$$

Maximum Sludge Application Rates

The maximum amount of sludge which can be applied to a parcel of land can be calculated by alternately solving equations 2 and 3 (or 5 and 3, if Cadmium limits), as the flow diagram in Figure 1 shows. Sludge applications must cease when A_H is reached.

Maximum application rates for sludge from the Deer and Nut Island Plants were calculated, using the assumptions shown in Table 3.

Land Requirements

The minimum amount of land required for a sludge application program can be calculated by assuming that each parcel of land will be used to the greatest extent possible before acquiring any new land. As shown previously, the capacity of land to accept sludge decreases each year as orginic nitrogen is added to the soil, and applications must eventually cease when the heavy metals limit is attained. Thus, even if the quantity of sludge produced were to remain constant, additional land would be needed each year to allow for this decreasing capacity to accept sludge.

In the first year of application, the maximum amount of sludge which can be applied to a parcel of land of a given size is described by Equation by 6a. In the second year of application, this first parcel of land has a smaller ability to accept sludge, so more land is needed as shown in Equation 6b. This process continues for each year:

$$S(1) = L(1)\,A(1) \qquad \text{[Equation 6a]}$$

$$S(2) = L(1)\,A(2) + L(2)\,A(1) \qquad \text{[Equation 6b]}$$

$$S(3) = L(1)\,A(3) + L(2) + L(3)\,A(1) \qquad \text{[Equation 6c]}$$

$$S(n) = L(1)\,A(n) + L(2)\,(n-1) \ldots L(n)\,A(1) \qquad \text{[Equation 6b]}$$

where

$S(n)$ = Amount of sludge, kg, applied in year n
$L(n)$ = Amount of land, ha, for which sludge applications start in year n
$A(n)$ = Sludge application rate kg/ha.yr, after n years of applications, defined in previous sections

Equation 6a through 6d can be solved successively to find the amount of land needed to be added each year.

TABLE 3

EXAMPLE OF CALCULATING MAXIMUM RATES OF APPLICATION

Data and Assumptions

Type of Sludge:

Characteristics:

Organic Nitrogen	= 0.99%
Inorganic Nitrogen	= 0.14%
Copper	= 804 ppm
Nickel	= 91.4 ppm
Zinc	= 1530 ppm
Cadmium	= 24 ppm
Lead	= 667 ppm
Mercury	= 6.7 ppm

Initial Soil Organic Nitrogen, N_S (1)	= 3400 kg/ha
Crop Nitrogen Uptake, U	= 220 kg/ha.y
Rainfall Nitrogen Input, R	= 7 kg/ha.y
Nitrogen Leaching, G	= 2 kg/ha.y
Mineralization, first year, a	= 0.15
Mineralization, succeeding years, b	= 0.03

Calculations:

Maximum Total Application, A_H	= 326,900 kg/ha (based on copper)
Maximum Yearly Application, based on cadmium	= 11,166 kg/ha.y

Year	Rate of Application kg/ha	Limitation
1	11,166	Nitrogen
2	11,243	Nitrogen
3	11,316	Nitrogen
4	11,386	Nitrogen
5	11,453	Nitrogen
6	11,516	Nitrogen
7	9,025	Cadmium
8	9,025	Cadmium
9	9,025	Cadmium
10	9,025	Cadmium
11	9,025	Cadmium

$L(1) = S(1)/A(1)$

$L(2) = [S(2) - L(1) A(2)]/A(1)$ [Equation 7a]

$L(3) = [S(3) - L(1) A(3) - L(2) A(2)]/A(1)$ [Equation 6b]

$L(n) = S(n) - \sum_{i=1}^{n-1} L(n-i) A(i+1) /A(1)$ [Equation 7d]

For the application of dewatered sludge from the MDC plants, the total area required would be 4671 hectares (11540 ac).

Sodium Balance

The amount of sodium that may safely enter the soil can be found by using the Sodium Absorption Ratio (Froth and Turk, 1972):

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

where: Na = ppm sodium entering the soil;
Mg = ppm magnesium entering or already in the soil;
Ca = ppm calcium entering the soil or already there.

In determining the sodium balance of sludge at 25% solids, is was assumed that Deer Island received most of the saltwater intrusion, and the sodium ion concentrations at Nut Island would be about normal for sludge without saltwater intrusion. Using the concentrations presently found at the treatment plants, the levels of sodium were 674 ppm from Deer Island and 300 ppm from Nut Island. The average sodium concentration of combined Deer and Nut Island sludges would be 532 ppm. This value is derived as follows: (62% total sludge mas)(674 ppm) + (38% total sludge mas) (300 ppm) = 532 ppm.

It is assumed that the sodium ions are found only in the liquid fraction of the sludge (because of its high solubility), the concentration of sodium found in the dewatered sludge (75% liquid) is calculated as follows: 532 ppm mg/l x .75 = 399 mg/l in total mass.

Most of the background calcium and magnesium that is in the sludge is also assumed to come from saltwater intrusion, resulting in approximately 46 ppm Mg and 15 ppm Ca at the Deer Island plant, with a negligible amount of each from the Nut Island plant. However, the amount of lime added in the treatment process would result in about 15,000 ppm calcium in the sludge.

Putting these amounts in the equation, the result is:

$$SAR \frac{400}{\sqrt{\frac{15,015 + 46}{2}}} = \frac{400}{86.78} = 4.61$$

Since the maximum SAR value that is acceptable for soil application is 9 (Foth and Turk, 1972), the amount of saltwater that is lime that is added in the process. A general guidelines for applying sludge that contains saltwater is that the total sludge volume should contain no more than 1% (Satterwhite, 1975). This is based on estimated soil conditions and does not take into account the calcium added in sludge conditioning. Using 300 mg/l as the normal sodium concentration in wastewater, the Nut Island sludge has little or no seawater content. Based on a normal seawater sodium concentration of 30,400 gm/l (Reid, 1961), the Deer Island sludge, containing 627 mg/l of sodium, is composed of 1.23% seawater (627-300/30,400). Although the saltwater in the sludge is presently at 1.23% of the total sludge volume at Deer Island, lime added during conditioning and further anticipated reductions in seawater intrusion in the collection system served by Deer Island will compensate for the difference. In the event of substitution of polymers for lime in the conditioning process, the SAR would be above 72, limiting application of sludge unless sludge is wasted (elutriated) with low sodium water.

Conclusions

The ability of land to accept sludge without adverse environmental impacts will vary from year to year, depending upon previous applications of sludge. This variation will affect the size of a sludge application program, equipment requirements and annual costs. Because allowable annual sludge loadings will vary, a strong management system is recommended for any land application program in order to avoid adverse impacts. Because of provisions of the Resource Conservation and Recovery Act, the application of a sludge deemed hazardous, as are the sludges from both Deer and Nut Island, would require under draining and leachate recovery. For the 4,671 hectares required over 20 years, and with 25.4 cm per year of leachate, and average treatment capacity of 32,500 m3/day (8.6 mgd) would be required, effectively eliminating land application.

APPENDIX S

EVALUATION OF EXISTING MULTIPLE HEARTH SEWAGE SLUDGE INCINERATORS

A. Introduction

Incineration of dewatered sludge using a multiple hearth incinerator is part of the system for disposal of sludge proposed by the Metropolitan District Commission (MDC). An important question regarding incinerators is the question of autogenous burning. Autogenous operation means that the thermal energy required in incineration is supplied entirely by the heat value of the sludge. A review of several existing multiple hearth incinerators throughout the United States showed that an average of 50 gallons of fuel oil (or its equivalent) was required for auxiliary heat to incinerate one ton of sludge (Olexsey, 1975). Therefore, the question of operation without this auxiliary energy input must be answered before proceeding with comparison of system costs, energy requirements and environmental effects.

Theoretical calculations indicate that the MDC sludge, like many other sludges, can burn autogenously without the aid of auxiliary fuel. Experience, however, has shown that the day-to-day operations of a treatment plant do not always perform as planned.

This appendix was prepared to answer the following questions:

- Can the proposed incineration system for MDC sludge operate autogenously (without auxiliary fuel)?
- If the proposed system is capable of operating autogenously, what measures must be taken to insure full-time autogenous operation?

Incineration can be thought of as a process in which the heat of burning sludge (and other fuel) is used to evaporate the water portion of the sludge. Therefore, by examining existing incinerator facilities, these questions can be answered:

- What are the prevailing operating constraints and conditions at these plants, compared with that proposed for the MDC facility?
- Based on heat balance computations from incinerator records, what are the efficiencies of existing incinerators?
- What effect would design and operating differences have on autogenous operation of the proposed MDC facility?

B. Operation of Existing Incinerator Installations

1. Installations Evaluated

To answer our questions on operation of existing incinerators, it was necessary to collect and analyze long term records for installations similar to those proposed by the MDC. Figure S-1 is a diagram of a typical multiple hearth incinerator, similar in design concept to the equipment proposed by the MDC. The installations visited were selected based on the following criteria:

- Comparable in size to the MDC facility.
- Incinerating primary sludge.
- Of either recent design and construction or recently renovated.
- Originally designed for autogenous operation.
- Well-kept operational records for quantities of sludge incinerated and fuel used.

The plants selected all had primary treatment only, without digestion. The method used in heat balance calculations was based on the actual concentration of volatile solids, so that the results would be applicable to facilities either with or without anaerobic digestion of sludge. (Digestion reduces the volatile solids content of sludges.)

Field trips were made to observe incinerators in operation and to talk with the operators. Topics of discussion included control procedures, fuel economy, maintenance problems and variations from the engineers' original designs. The facilities visited were:

a. Bissell Point Treatment Plant, St. Louis, Missouri:

This is a large primary treatment plant. The facility has five 11-hearth multiple hearth incinerators, which are 23'3" in diameter, and each of which has a capacity of 250 tons per day of wet sludge. Sludge from the primary settling tanks is conditioned with lime, dewatered on vacuum filters and incinerated. The sludge solids content after conditioning and dewatering averages about 30 percent. Since sludge storage facilities have only about four days capacity, the dewatered sludge is sent immediately to the incinerators.

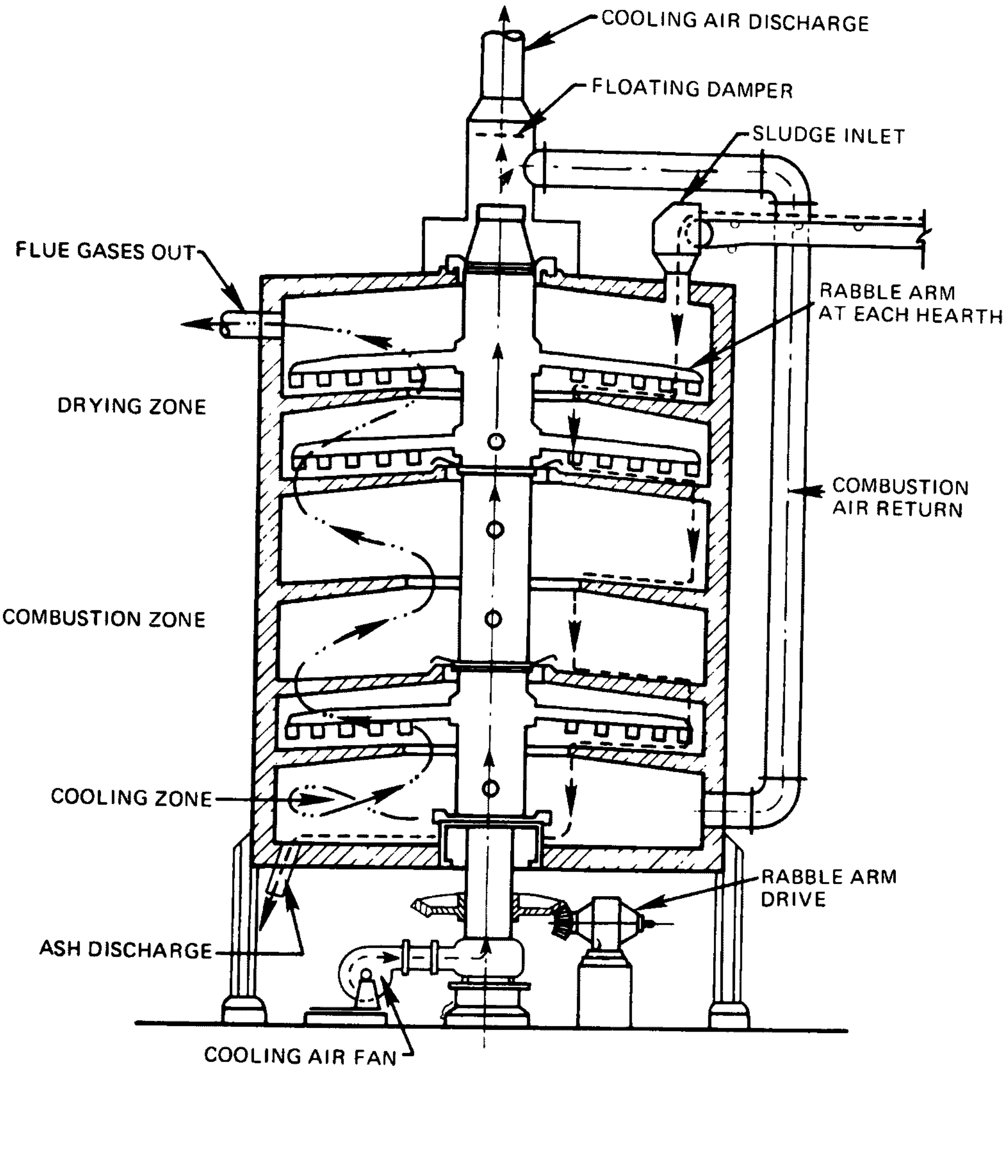


FIGURE S-1

CROSS SECTION OF A TYPICAL MULTIPLE HEARTH INCINERATOR

Additional data was also obtained for the Lemay Treatment Plant, St. Louis, Missouri, which is very similar to the Bissell Point Plant, except it has only three incinerators and conditions the sludge with a polyelectrolyte.

b. City of Detroit Wastewater Treatment Plant, Detroit, Michigan: This huge 1.4 billion gallons per day (bgd) treatment plant is being upgraded to secondary treatment. Approximately one-third of its total capacity is now operating as an activated sludge facility. Raw sludge is treated with polymers and vacuum filtered to 30 percent solids content, however there is no sludge storage. The Detroit incinerators are grouped in two complexes. "Complex 2" contains the newer units, six 12-hearth, 25'9" diameter multiple hearth incinerators, each with a capacity of 437 wet tons per day. (Two additional units had been installed but were not in operation at the time of the plant visit.) "Complex 1" has the older units, some of which date back to 1939. However, these old units have been maintained and updated and presently process the bulk of the plant's sludge.

c. Jersey City Sewage Authority, Jersey City, New Jersey: This primary treatment plant has a single 10-hearth multiple hearth incinerator, which is 22'3" in diameter, and has a capacity of 246 wet tons per day. Sludge from the primary settling tanks is conditioned with polyelectrolyte and ferrous chloride, then vacuum filtered. Solids content of the dewatered sludge averages about 30 percent. Incinerator operation is intermittent, usually during the day shift only.

2. Present Operating Practice

The day-to-day operation of large incinerators requires the skills of both a mechanic and an engineer. Not only must complex machinery be kept running, but operations must be optimized to keep costs, including auxiliary fuel costs, under control. The objectives, control methods and problems of sludge incineration, as seen by the operators, were examined.

a. Objectives of Operation: In discussions with the operators, the following objectives were identified:

- Fuel economy - The rising cost of auxiliary fuel has made this one of the most important concerns.
- Good mechanical operation - Breakdowns can be expensive and disruptive. All operators took considerable care to see that machinery was run properly.

- Air pollution control - All installations were under some pressure to control emissions as best they could, and this was reflected in their operating procedures.

b. Combustion Control: A basic principle of incineration control is to set the temperature of each hearth at a given value. This establishes zones of drying, burning and cooling. Each installation has established a desired temperature pattern for one or more loading conditions, and shift operators were expected to see that the actual operating temperatures came reasonably close to these values.

The control panels displayed the temperatures of most or all hearths, as well as cooling air and flue gas temperatures. Indicators displayed the status of fans, burners, etc. Burning could be observed through peepholes in the hearth doors. Some plants used closed circuit television to observe the stack gases from the control room.

Hearth temperatures were controlled by adding either combustion air or auxiliary fuel, as necessary. In some plants, control was automatic, but others preferred manual control.

Operators did not have control (other than on and off) over the induced draft fan or the rabble arm speed. Thus, there was essentially no control over the total amount of combustion air supplied or the residence time of the sludge in the incinerator. In addition, the minimal amounts of available sludge storage capacity allowed little control over the loading rate.

C. Energy Efficiency of Existing Incinerators

1. Definition

The sludge incineration process is highly sensitive to both the water content and the volatile solids content of the sludge. Thus, auxiliary fuel consumption may depend more on the dewatering processes than on the incinerator design itself. In order to establish a common basis for evaluating incinerator performance (apart from the preparatory dewatering steps), it is necessary to consider a simple definition of efficiency as "useful" work divided by the work input.

Sludge incineration is essentially a drying process, so the "useful" work performed by a sludge incinerator is to convert the liquid water content of the sludge to a gas. This is theoretically equal to heat of vaporization, 1059.9 BTU per pound of water at 60°F. If lime has been used to remove phosphates or to condition the sludge, the heat required for recalcining should also be considered "useful" work according to the overall reaction:

$$CaCO_3 \rightarrow CaO + CO_2 \qquad \Delta H = 1367 \text{ BTU/lb CaO} \qquad \text{(Eq.1)}$$

The work input includes both the heat value of the volatile solids in the sludge plus the heat value of any auxiliary fuel used. The difference between work input and useful work represents heat losses in the stack gas, unburned fuel, cooling air, heat radiation and other losses. An efficient incinerator will minimize these losses. Incinerator manufacturers' acceptance tests for performance guarantees employ a similar concept of efficiency. The incinerator manufacturer usually guarantees to achieve a specified fuel consumption rate for a sludge of assumed characteristics. The actual sludge characteristics are measured during the test, and the heat balance is recalculated to account for any differences.

In summary then, the efficiency of a sludge incinerator can be defined as:

$$\text{Thermal Efficiency} = \frac{1059.9 \times \text{lb.water} + 1367 \times \text{lb.lime recalcined}}{\text{BTU volatile solids} + \text{BTU fuel}} \qquad \text{(Eq.2)}$$

2. Data for Incinerators Evaluated

Using the definition of efficiency in Equation 2, the operating records of existing incinerators were reviewed. Monthly average efficiencies for four installations are shown in Table S-1. These represent gross monthly totals and include effects of any operational events such as startups or malfunctions. The average monthly thermal efficiency for all four installations was 35.5%, with a range of 33.6% to 37.4%.

TABLE S-1

MONTHLY AVERAGE EFFICIENCIES

Plant	Period of Record	Efficiency Average	Efficiency Range
Bissell Point	6 months	35.5	31-37
Lemay	6 months	35.3	32-38
Detroit (Complex 2)	4 months	33.6	27-40
Jersey City	7 months	37.4	35-39

To study the more-or-less routine operation of an incinerator installation, the daily records of the Bissell Point Plant in St. Louis were examined. (Bissell Point was selected because its records provided information on the sludge feed rate to each incinerator.) Days with incinerator startups or shutdowns, or any other unusual occurrences were eliminated from consideration. The average* efficiency on this basis was 35.4% with a daily range of 22.6% to 58.1%.

3. Analysis of Data for Existing Incinerators

a. Capacity vs. Actual Loading: The incinerators of the Bissell Point Plant are designed to incinerate 250 tons per day each of wet sludge, along with some grease and scum. Sludge storage is limited, however, and the incinerators must operate at loading rates ranging from 40 to 100 percent of their capacity. For each day of routine operation, the loading rate (expressed as percentage of full capacity, depending on the number of incinerators in operation) was plotted against the efficiency; this correlation is shown in Figure S-2.

There is a clear trend towards lower thermal efficiency at lower loadings. According to a best-fit straight line, the efficiency drops from 41.5% at full capacity to 29.5% at half capacity. Thus, on the average, an incinerator at half capacity is only 71% as efficient as one at full capacity. This lower thermal efficiency represents the need for an additional 1040 BTU of heat input for each pound of water that must be evaporated.

The reason for the direct correlation between lower loading rates and reduced thermal efficiency can be found by further examination of this data. There are two common features for each one of those facilities that were investigated. First, the induced draft mechanism provided a constant volume of combustion air under all sludge load conditions. Second, the rabble arms which move the sludge downward through the incinerator rotate at a constant speed under all conditions.

The losses of thermal energy in heating up the excess combustion air and its associated moisture content were not included in the calculations of efficiency discussed above. The heat requirement of the excess combustion air, at 0.01 lb. water vapor per lb. of air, is about 300 BTU per pound. Using a value of 50% excess air over that required for combustion, about 70% of the loss of efficiency can be explained by the extra heat necessary to heat the excess air to the sludge's burning point. If the

* Weighted for amount of sludge processed each day

FIGURE 1

EFFICIENCY VERSUS LOADING _ BISSELL POINT PLANT

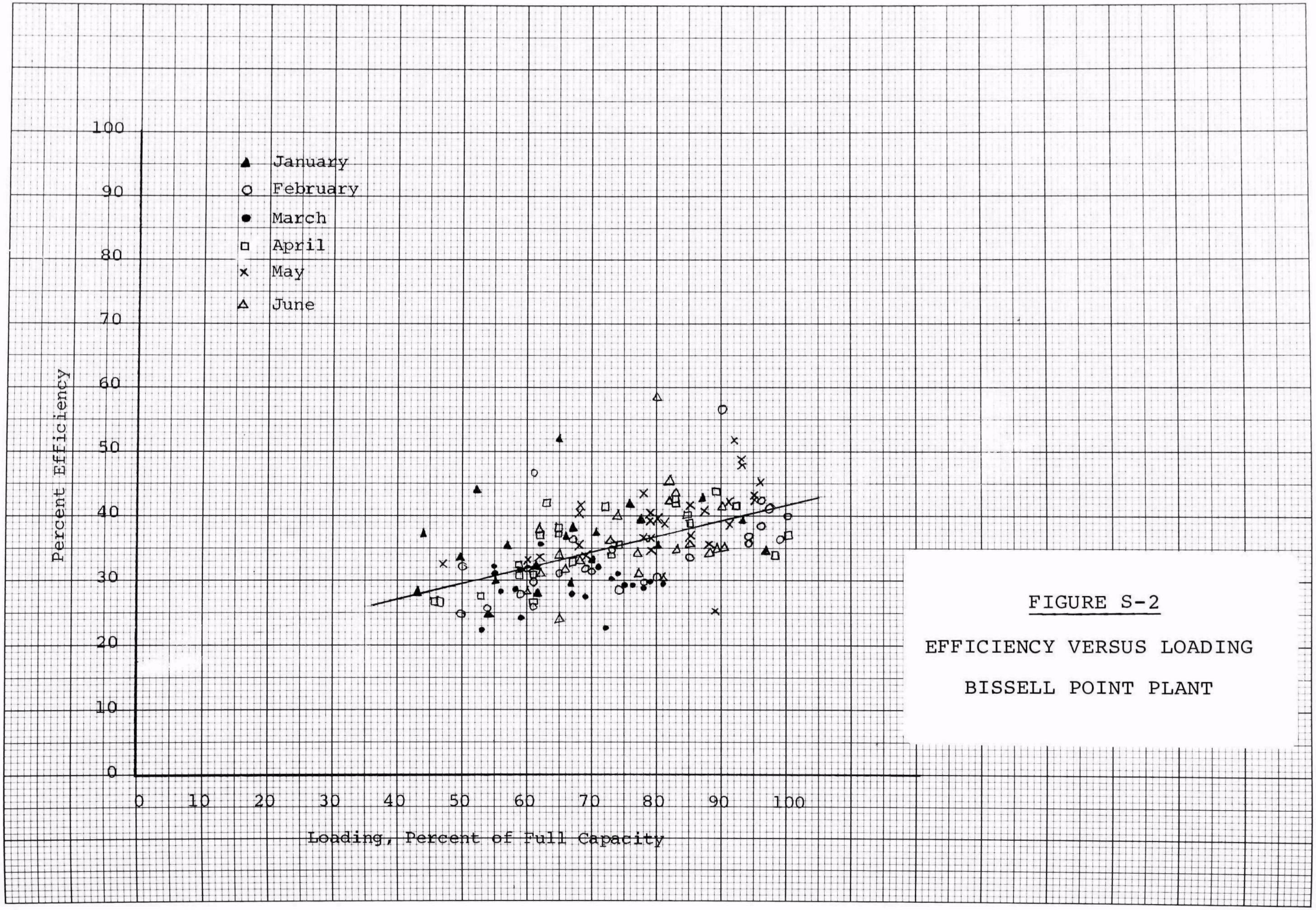


FIGURE S-2

EFFICIENCY VERSUS LOADING

BISSELL POINT PLANT

excess air inputs were near zero, the efficiency would increase by more than 10%. While a reduction to zero excess air is not feasible, this exercise illustrates the importance of combustion air control.

In the installations examined, the fixed combustion air input had a major impact on efficiency at less than full capacity operation. For example, when an incinerator with 50% excess combustion air feed is operated at half capacity, the actual excess air becomes 200% of that required.

b. Starting and Stopping: Three of the four plants examined operate incinerators continuously. The Jersey City incinerator, however, operates only about 7 hours per day, 5 days per week. Intermittent operation might be expected to be less efficient than continuous operation, but Table S-1 does not support this conclusion: Jersey City actually operated slightly more efficiently than the others. Although it must use auxiliary fuel for starting, Jersey City prossibly makes up for the loss by running at a higher capacity, thereby gaining thermal efficiency. At the Bissell Point plant, incinerator startups occurred about every 11 to 12 days during the first six months of 1975.

D. Proposed Installation at Deer Island

1. Description

The proposed incinerators, to be located at Deer Island, would burn anaerobically digested and raw primary sludge. There will be three multiple hearth incinerators, each with a capacity of 410 tons per day wet sludge. Air pollution control devices will include a venturi scrubber and four impingement trays and afterburners which can be used if needed.

Sludge would be dewatered by vacuum filters or by filter presses. The quantity and characteristics of the sludge have been estimated and are shown in Table S-2.

TABLE S-2

SLUDGE QUANTITY AND CHARACTERISTICS *

	1980		1985	
	Average	Peak	Average	Peak
Dry solids, lb/day x 10^3	228	280	255	312
Dry volatile solids, lb/day x 10^3	110	138	129	162
Ash, lb/day x 10^3	118	142	126	150
Percent volatile solids	48	51	50	52
Moisture percent	70	70	70	70
Heat value of volatile solids, BTU/lb.	11,030	11,065	11,080	11,120

* From calculations by Havens & Emerson, Ltd., Consulting Engineers

2. Heat Balance

Using the values in Table S-2, heat balances were computed for the proposed incinerators. These indicated that, as designed, the incinerators will burn sludge autogenously under steady state conditions, i. e. without using auxiliary fuel. The heat balances under equilibrium conditions (as determined by computer) are summarized in Table S-3 (Havens & Emerson, 1973).

The next step was to compute the efficiency of incineration, as defined in Equation 2: this is shown in Table S-4.

TABLE S-4

PROPOSED INCINERATORS, EFFICIENCY VS. LOADING

	1980		1985	
	Average	Peak	Average	Peak
Loading, percent of full capacity	94	58	53	65
Efficiency, percent	46.8	45.7	45.1	45.1
BTU required to evaporate 1 lb. water	2260	2320	2350	2350

It is apparent that the proposed incinerator is assumed to achieve an efficiency only slightly higher than that achieved by installations now operating. Furthermore, there is very little decrease in efficiency at lower loadings. The reasons for this improved performance will be examined in the next section.

3. Engineering Improvements

a. Control of Combustion Air: The proposed incinerators will offer improved process air control by the following means:

- A variable speed induced draft fan to allow control of the total amount of combustion air.
- Adjustment of the combustion air according to the oxygen content of the stack gasses.

TABLE S-3

HEAT BALANCE AT EQUILIBRIUM CONDITIONS (SUMMARY)*

	1980		1985	
	Average	Peak	Average	Peak
Wet feed, lb/hr (each unit)	31,600	19,400	17,700	21,700
Number of incinerators in operation	1	2	2	2
Moisture content of feed, %	70	70	70	70
Base temperature of feed, °F	60	60	60	60
Base temperature of air, °F	60	60	60	60
Moisture in air, lb/lb.	0.01	0.01	0.01	0.01
Temperature of flue gas at exit, °F	911	912	938	995
Temperature of ash at exit, °F	600	600	600	600
Excess air, % of theoretical air	50	50	50	50
Total air required for combustion, lb/hr.	54,567	34,195	32,022	40,426
Cooling air lost to atmosphere, %	50	50	50	50
Radiation loss, $BTU/ft^2/hr$.	130	130	130	130
Total heat in flue gases above 60 °F, BTU/hr. (includes vapor)	48,574	30,047	28,048	35,802
Fuel oil required (143,000 BTU/gal), gal/hr.	0	0	0	0

* From calculations by Havens and Emerson, Ltd., Consulting Engineers (1973)

The effects of these improvements can be seen by looking at the heat balance. At 53% loading, (1985 - Avg.) the incinerator would, without control of the total combustion air, have 185% excess air instead of 50%, or about 29,000 pounds per hour more than necessary. To heat this air would require auxiliary fuel which would waste about 9.1×10^6 BTU per hour (about 740 BTU per pound of water evaporated), and would cause the thermal efficiency to drop to about 34%. Thus, without this improvement, the proposed incinerator would have an efficiency similar to existing installations.

The 50% excess air condition would occur only under steady-state conditions. Under transient conditions of underloading, the excess air quantity could rise to 75%. Accordingly, the fuel requirement to heat 75% excess air was compared with the fuel requirement under 50% excess air conditions. This requirement is based on 0.29 additional pounds of air (at 0.01 lb moisture per lb air), per wet pound of sludge and 316 BTU required to heat one pound of air. This calculation yields an auxiliary fuel requirement of 4.4 gallons of oil per dry ton of sludge if no excess heat is available from the burning sludge. However, this volume of auxiliary fuel would be reduced because of two other considerations.

First, the thermal efficiency required operating with 75% air and autogenous conditions would be only about 50%; this compares favorably with the 45% to 46% thermal efficiency predicted in the steady state heat balances done by Havens and Emerson. Second, the auxiliary fuel requirement, if any, would not be necessary under steady state conditions (50% excess air). Independent calculations (Olexsey, 1975) have indicated that incineration may be autogenous even with 75% excess air, indicating that the higher efficiency may be achieved.

b. Control of Residence Time in Incinerator: In addition to control of excess air, the residence time of sludge in the incinerator can be controlled by varying rabble arm rotational speed and by introducing sludge at several different points in the incinerator. With these modifications to standard design, the sludge residence time can be varied to obtain optimum contact in each hearth. During underloading conditions with fixed arm speed and single feed, the drying and burning occur only in upper hearths, distilling volatile components out, thus generating odors. With variable arm speed and multiple feed points, the use of afterburners can be reduced if not eliminated.

c. Heat Recovery: The proposed incinerator will have a heat recovery unit to convert heat contained in the stack gases to electrical energy. It is estimated by Havens & Emerson that as much as 38% of the flue gas heat can be recovered. Although heat recovery has not been included in the previous efficiency calculations, it could represent a very substantial energy savings, even at lower recovery rates, and raise overall efficiency to as high as 60% to 75%. Three facts should be noted, however:

- Although heat recovery from flue gases is common in the chemical processing industry, heat recovery from sludge incinerators remains to be proven in long-term operation.

- It will definitely not be energy-efficient to burn and recover heat from excess auxiliary fuel, i.e. to operate the incinerator as a power boiler. In this mode, the sludge incinerator would have a net efficiency of only 23 percent compared to 38 percent for commercial power boilers.

- Another study (ISC, 1975) has recommended that gases exit the power boiler at 500°F to prevent deposition on the boiler tubes. This would halve the available thermal energy and would double the cost of such power.

Because of these reasons, the question of thermal energy recovery has been separated from the incineration alternatives.

d. Sludge Storage: The anaerobic digesters give Deer Island a large amount of sludge storage. They also serve to insulate the incinerators from day-to-day variations in settled sludge characteristics. With control of the feed rate, and with near-constant sludge quality, the operators will be able to adjust the incinerators for efficient burning and maintain this condition for long periods of time. Thus, the large daily variations in efficiency noted at Bissell Point can be avoided in Boston.

E. Conclusions

After comparing the proposed incineration to existing installations, the following is concluded:

1. Boston incinerators would be able to operate significantly more efficiently in burning sludge than the existing installations studied for this evaluation. This is principally due to (a) improved control of the total combustion air; (b) the variable speed of the rabble arms (both of which result in better efficiencies at partial loadings); and (c) the large amount of sludge storage, which allows for more constant operating conditions.

2. Given the improved efficiency described above, it is likely that sludge from the Deer Island and Nut Island plants will burn autogenously.

3. If practical, heat recovery from flue gases offers potentially substantial energy savings, but there are significant questions as to whether or not it is feasible. However, whether or not it is feasible will not have a substantial

impact on the selection of incineration as a total concept over the other possible courses of action. The issue of heat recovery for electrical generation is a final design question that needs to be addressed in detail by MDC only if incineration as a total program is chosen. However, should energy recovery be feasible, the incinerators should not be used to burn excess auxiliary fuel for power production.

4. Based on the Bissell Point startup interval of 11-12 days, the proposed MDC facility would experience a startup approximately every 10 days. Because each startup requires 4,000 gallons of fuel, the daily average startup fuel requirement would be 400 gallons per day.

F. Measures to be Taken to Insure Autogenous Operation

While the conclusion has been drawn that the incinerators contemplated by the MDC could operate autogenously under variable load conditions, there is still some question as to whether or not this would be the case during actual operation. Should incineration be chosen as the best method for MDC sludge handling and disposal, the following conditions could be included in the contract documents:

- Incinerator acceptance testing should be done at several levels of loading to the incinerator. Commonly, specifications only require autogenous operation at 100% loading. Because the system is arranged to operate without auxiliary fuel over a wider loading range, this should be so specified.

- The incinerator supplier should be required to perform not only startup but also operator training and preparation of operating guidance.

- Using the proposed oxygen sensor in the offgas system the supplier should determine the best combinations of combustion air feed rate and rabble arm speed for several conditions of dry solids loading, volatile solids loading, and sludge moisture content. With these relationships, the operator would not be dependent upon continuous operation of the oxygen sensor to maintain autogeny.

With these specifications and using the improvements developed by Havens and Emerson, the proposed sludge incineration system can operate autogenously a large percentage of the time.

APPENDIX T

PROCESS AND TRANSPORTATION INPUTS OF LABOR, MATERIAL, ENERGY AND MONETARY COSTS

Inputs of materials and energy are a major question in focusing on the best alternative for sludge management. In addition to their dollar costs, these inputs can have major impacts in their own right. For example, the construction and operation labor for a given alternative will have some impact on employment, on government operating budgets, and on regional balances between export and local employment. Accordingly, sources of data for the various process inputs are developed below, followed by a tabulation of inputs of labor, materials, energy and cost for each of the alternatives.

A. Sources and Methodology Used to Compute Input Quantities

Within each of the major categories of input (labor, energy, materials, dollars), some information sources were used to a greater extent than were others. Energy inputs for transportation (Hirst, 1973; Ashtakala, 1975 are used throughout the report and have considerable impact on the energy intensiveness of a given alternative. The sources and methodologies used in this analysis were as shown in succeeding paragraphs.

1. On-Site Processes

On-site process inputs were developed from the original Havens and Emerson work for the MDC (Havens and Emerson, 1973 and 1974) and from general process data developed by the U. S. EPA (Smith, 1973 and CEQ, 1974). The electrical energy inputs for dewatering and incineration were developed from EPA Research Reports (Smith, 1973, and CEQ, 1974) and were converted to diesel fuel equivalents expressed in gallons of #2 diesel fuel per day. The basis for this calculation was the size of the process facilities as developed by Havens and Emerson. Electrical energy inputs were converted to equivalent fuel inputs assuming 32.5% efficiency of power production. The fuel value used for #2 diesel fuel was 143,000 BTU per gallon.

Fuel requirements for incineration are based on Havens and Emerson calculations (H&E, 1973) for pilot fuel and start-up fuel requirements, assuming one start every ten days (Appendix S).

Chemical inputs for sludge conditioning consist of 7% lime (CaO) and 2.5% ferric chloride ($FeCl_3$) as a fraction of the dry solids for the conditioning of sludge prior to dewatering. Daily requirements for lime and ferric chloride were based on projected quantities of sludge for the year 1985. Manpower requirements for the operation and maintenance of each on-site process were based on data presented in existing EPA manuals (CEQ, 1974) or reasonable man-hour estimates.

Operation and maintenance costs for on-site processes are calculated from the inputs based on these same reference sources. The value of electrical energy used in computing annual credit for thermal energy recovery was $0.045 per kwh, which was also used in analyzing the cost effectiveness of energy recovery. Operating and maintenance labor costs were, in turn, based on manhour requirements assuming an hourly wage rate of $5.70 (Havens & Emerson, 1973) + 20% fringe benefits for a wage rate of $6.84/hour. These costs were compared to present hourly rates and found to be within 1% (MDC, 1978). Maintenance supply costs are assumed to be approximately 2 to 4% of the equipment cost for each year of operation. Current costs for chemicals are approximately $40 per ton for lime and approximately $120 per ton for ferric chloride (ENR, 1978).

Capital inputs and costs of on-site process facilities were developed based on the Havens & Emerson Phase I (1985) costs (H&E, 1974) with only sludge process-related costs used. Items included were dewatering and incineration facilities and the sludge pump station and force main. Calculations for the alternatives not incorporating incineration (alternatives 4, 5 and 6) were done by subtracting incinerator costs (developed from EPA cost curves) from the costs of dewatering and incineration facilities. Annual capital costs were developed using 6.625% interest for 20 years, assuming no salvage value. The July 1973 EPA Construction Index for the Boston area was 188.63. The April 1975 Index for the Boston area is 240.30. The costs developed by Havens & Emerson were scaled up by a factor of 1.27 for current conditions. In going from Draft to Final EIS, an additional increment of 1.14 times the 1975 costs is required by the increase of the new EPA LSAT Index for Boston from 135 to 154 in the intervening period.

The manpower for construction was developed from the Sewer and Sewage Treatment Plant Construction Cost Index documentation (FWPCA, 1964). The hypothetical "1 mgd trickling filter plant in Kansas City" used 33,970 manhours and $368,834 for construction. Based on manhours per capital dollar scaled back to 1962 conditions (EPA index base year), this yields 0.0921 manhours per base year capital dollar or 0.0383 manhours per capital dollar at the present Boston area index of 154 (1973 National Average = 100). This was converted to 16.1 manyears per million dollars of capital cost.

Capital inputs of concrete and steel are estimated from the CEQ-EPA document, Municipal Sewage Treatment, A Comparison of Alternatives (CEQ, 1974), using a range of process costs and inputs to develop a log-linear relationship.

2. Transportation, Storage and Application Facilities

From the on-site processes, the product is to be transported to landfill, either on or off Deer Island. Because of the impacts on Winthrop residents from sludge or ash transport through Winthrop, barging to a dedicated terminal was made the initial linkage in Alternative 1. Barge capacities for 1 and 9 were based on sizing to smooth the operation of further transport linkages, with small (300 DWT) barges being used.

Transport to storage or fill would be done with 40,000-pound capacity trailers. The estimated number of tractors and trailers for each alternative is based on amount transported and turnaround time.

Operation and maintenance costs for the transport, storage and disposal of ash are based on the $6.84 hourly wage rate previously identified. The cost of transport fuel for landfill is based on $2.70 per million BTU of energy ($0.38 per gallon of diesel fuel). Mileage costs of $0.10 per mile of truck transport reflect the costs of maintenance and other minor costs associated with vehicle operation. Barge transport mileage costs are $0.003 per ton mile (Hirst, 1973) and are assumed to include the two costs. The costs of landfilling of ash range from $8.00 to $10.00 per ton, so $10.00 per ton was used (St. Hilaire, 1978). Estimated cost for transfer of trailers at the barging facility is $50.00 per trailer (total both directions), assuming roll-on-roll-off facilities.

Capital costs of transport and application equipment and facilities include costs of container-trailers (Meyrick, 1975), and tractors (Havens & Emerson, 1973, checked by Ecol Sciences, 1975). Barge costs were based on actual 1975 prices for ferry-type barges (surplus LST). For vehicles other then barges, replacement at 10 years was assumed, with no salvage value after 10 years.

To determine cost effectiveness of thermal energy conversions to electrical energy, thermal energy recoverable by a 500°F temperature drop (1000°F to 500°F) was calculated. The electrical energy needs of the dewatering and incineration units were then subtracted, and the remaining available electrical energy of about 9.9×10^6 kwh per year was multiplied by $0.045 per kwh to yield an annual credit of $444,000 per year for a 20-year present value of $4,844,000. Incorporating this credit, the present worth energy cost without thermal energy recovery of $2,695,300 is greater than the net cost of $2,540,000 with energy recovery.

B. Calculation of Alternative Inputs

In Table T-1, the calculations and inputs of capital, labor, energy and chemicals are presented for dewatering, incineration and energy recovery, based on the data from Section A above and from Appendix N, "Quantity and Quality of Solid and Liquid Emissions."

In Table T-2, the calculations of transport and disposal inputs and costs are presented showing differential inputs of the feasible alternatives.

It should be noted that the credit shown for electrical energy recovery is actually money that will be saved on other energy use within the MDE Deer Island Plant. For example, conversions of existing diesel pumps to electrical operation will require 100,000 to 200,000 kwh per day. Incorporation of the energy cost of lime and ferric chloride was done by using 5.5×10^6 BTU/ton of lime and 21,000 BTU/pound of chlorine (Argo & Wesner, 1976). The total energy cost of chemicals then becomes about 50×10^9 BTU per year, and the net energy production with thermal energy recovery becomes $52\text{-}54 \times 10^9$ BTU per year.

TABLE T-1

RESOURCES AND COSTS
ON-SITE PROCESSES

Capital Costs (1978) and Inputs

Inputs:	Labor	480 manyears	
	Concrete	2,000 CY	
	Steel	1,500 Tons	
Costs:	Dewatering & Incineration		$ 25,652,500
	Thermal Energy Recovery		4,213,600
	Total Cost		$ 29,866,100
	Annual Capital Cost		$ 2,737,500

Operating Resource Costs and Inputs

Inputs:	Labor	113,900 manhr/year	
	Electrical Energy	5.49×10^6 kwh/year	
	Fuel, Pilot & Auxiliary	147,800 gallons/year	
	Chemicals: CaO	3,250 tons/year	
	$FeCl_3$	1,170 tons/year	
Costs:	Labor		$ 779,100/year
	Electrical Energy		247,000/year
	Fuel		56,160/year
	Chemicals: CaO		130,000/year
	$FeCl_3$		140,400/year
	Maintenance: 2.5% of Dewatering & Incineration		641,300/year
	10% of Energy Recovery Equipment		148,500/year
	Annual O & M Costs		$ 2,142,460

Total Annual Costs	$ 4,879,960
Annual Credit for Electricity	$ 441,000
Net Annual Cost	$ 4,438,960
Net Annual On-Site Energy Production	54×10^9 BTU/year

TABLE T-2

RESOURCES AND COSTS

TRANSPORTATION AND ULTIMATE DISPOSAL

	ALTERNATIVE					
	1	2	8	9	10	11
Operating Resources						
Barge Link, Miles	6.3	-	-	5.5	-	-
Ton Mi/Year	1.45×10^6	-	-	1.27×10^5	-	-
BTU/Year	1.63×10^8	-	-	1.42×10^8	-	-
Annual Fuel Use, Gallons	1,160	-	-	1,000	-	-
Annual Labor, Hours	6,240	-	-	6,240	-	-
Truck Link, Miles	30	0.4	1.0	0.2	0.2	1.0
Ton Mi/Year	689,800	9,200	23,000	4,600	4,600	23,000
BTU/Year	1.39×10^9	1.84×10^7	4.6×10^7	9.2×10^6	9.2×10^6	4.6×10^7
Annual Fuel Use, Gallons	9,650	130	320	65	65	320
Annual Labor, Hours	10,400	6,240	6,240	6,240	6,240	6,240
Disposal Operation						
Tons/Year	23,000	23,000	23,000	23,000	23,000	23,000
Cubic Yards/Year	34,100	34,100	34,100	34,100	34,100	34,100
Area Reqd., 15' Depth, Acres	1.41	-	1.41	1.41	-	1.41
30' Depth, Acres	-	0.70	-	-	0.70	-
Labor	-	2,080	2,080	2,080	2,080	2,080
Capital Resources						
Barge Link						
Roll-on Facilities	2 @ $100,000	-	-	1 @ $100,000	-	-
Barge-Ferry	1 @ $300,000	-	-	1 @ $300,000	-	-
Truck Link						
Tractors	9 @ $ 35,000	2 @ $35,000	2 @ $35,000	4 @ $ 35,000	2 @ $ 35,000	2 @ $ 35,000
Trailers	19 @ $ 22,000	3 @ $22,000	3 @ $22,000	6 @ $ 22,000	3 @ $ 22,000	3 @ $ 22,000

TABLE T-2 (Cont'd.)

RESOURCES AND COSTS

TRANSPORTATION AND ULTIMATE DISPOSAL

	ALTERNATIVE					
	1	2	8	9	10	11
Capital Resources (Cont'd.)						
Disposal Site Prep.						
Cofferdam	-	7ac @ $685,700	-	-	7 @ $685,700	-
Lining and Recycle	-	-	15 @ $39,000	15 @ $39,000	$22,000	15 @ $39,000
Leachate Treatment	-	-	-		-	-
Monitoring Wells	-	-	2 @ $ 2,000	-	-	2 @ $ 2,000
Total Annual Operating Resources						
Fuel, Gallons/Year	10,720	130	320	1,065	65	320
Labor, Hours/Year	16,640	8,320	8,320	8,320	8,320	8,320
Land, Acre/Year	1.41	0.70	1.41	1.41	0.70	1.41
Equivalent Energy, BTU/Year	1.53×10^9	1.53×10^9	4.58×10^7	1.52×10^8	9.3×10^6	4.58×10^7
Total Annual Costs						
Capital Costs						
Barge	$300,000	-	-	$300,000	-	-
Roll-on Facilities	$200,000	-	-	$100,000	-	-
Tractors & Trailers *	$733,000	$136,000	$136,000	$272,000	$ 136,000	$136,000
Disposal Site Prep.	-	$4,800,000	$589,000	$595,000	$4,822,000	$589,000
Annual Capital Costs, 6-5/8%	$148,400	$459,000	$ 73,000	$ 90,770	$ 461,000	$ 73,000
Annual Operating Costs						
Fuel @ $0.38/gallon	$ 4,075	$ 50	$ 120	$ 405	$ 25	$ 120
Labor @ $6.84/hour	$113,820	$ 56,910	$ 56,910	$ 56,910	$ 56,910	$ 56,910
Transfer Fees, $/Year	$ 60,000	-	-	-	-	-
Landfill Fees, $/Year	$230,000	-	-	-	-	-
Maintenance	$103,300	$ 13,600	$ 13,600	$ 57,200	$ 13,600	$ 13,600
Total Operating Costs	$511,195	$ 70,560	$ 70,630	$114,515	$ 70,535	$ 70,630
Total Annual Costs, without Grant	$659,595	$529,560	$143,630	$209,865	$531,535	$143,630
with Grant	$574,825	$187,115	$ 90,690	$149,970	$187,620	$ 90,690

*Using 10-year equipment life for trucks and trailers.

TABLE T-2 (Cont'd.)

RESOURCES AND COSTS

TRANSPORTATION AND ULTIMATE DISPOSAL

	ALTERNATIVE					
	1	2	8	9	10	11
Totals Including Dewatering, Incineration, and Energy Recovery						
Total Annual Costs Including Incinerator,						
without Grant	$5,089,555	$4,959,320	$4,573,420	$4,635,245	$4,961,495	$4,573,420
with Grant	2,960,660	2,572,950	2,476,525	2,535,805	2,573,455	2,476,525
Total Annual Net Energy Production, BTU x 10^9	52	54	54	54	54	54

APPENDIX U

ANALYSIS OF EXISTING SLUDGE DUMPING ACTIVITIES AND THE KNOWN ENVIRONMENTAL EFFECTS

A. Introduction

This appendix contains a discussion of the environmental effects on the ocean resulting from sludge disposal operations of the New York Metropolitan Area, and (to a lesser extent) the City of Philadelphia. Both operations have been studied in detail and provide a preliminary basis for predicting the potential effects of sludge disposal in the ocean. The discussion centers on both the particular experiences at these sludge disposal sites and general information about ocean processes which affect, or are impacted by, sludge disposal. The discussion is broken into subject topics such as biota or trace metals so that discussions of New York's or Philadelphia's dumping are accompanied (where possible) by an explanation of the processes responsible for the observed effect.

B. Current Dumping Activities

Sewage sludge is dumped into the ocean by both the New York Metropolitan Area and the City of Philadelphia. New York dumps 4.1 million wet tons of sludge per year into the New York Bight, into water approximately 90 feet deep. The City of Philadelphia dumps 0.6 million wet tons of sewage sludge per year into the Chesapeake Bight at a dumpsite about 40 miles east of Ocean City, Maryland (USDC, 1975B). New York dumps sludge containing five percent solids while Philadelphia dumps sludge containing 14 percent solids (NAS, 1975).

C. Physical and Chemical Effects of Sludge Dumping

1. Composition of Sludge

Sewage sludge contains large amounts of organic matter and traces of other substances including heavy metals, organohalogens, pathogens, floatables, oils, greases and plant nutrients. Sewage sludge is composed primarily of fine particulate matter (NAS, 1975). The solids portion of sewage sludge consists of two distinct fractions. These fractions are: (1) the heavier solids which sink rapidly to the bottom; and (2) dissolved solids, suspended solids and floatable materials. Organic portions include mostly amorphous aggregates which may have some identifiable material such as seeds, hair and cellulose (USDC, 1975B). When sludge is discharged into the ocean it undergoes physical fractionation and chemical and biological changes. Microbial species composition changes, biological degradation begins, and differential settling takes place.

2. Physical Dispersion of Solids

The dispersion of sludge particles on the bottom and in the water column is dependent upon the density, shape and size of the particles and the current activity in the vicinity of the discharge. Fine-grained and/or low density particles will stay in suspension for a longer time than coarser, denser particles. A portion of sewage sludge solids are likely to remain in suspension after being dumped. The suspended materials are likely to be transported out of the dump area by any existing currents.

The average sedimentation rate of the New York Bight sludge dumpsite was 4 mm/year over an area of 36 km^2 between 1964 and 1968 (NAS, 1975). According to Pararas-Caryannis (NAS, 1975), the apparent absence of thick coastal deposits at the New York Bight sludge dumpsite indicates either that the organic matter is rapidly degraded or that a transport mechanism is removing both organic and inorganic sediments. Although sludge dumping in the New York Bight does not appear to have altered bathymetry, fine particles have had an effect on the grain size distribution of bottom sediments in an area north of the sludge dumpsite (USDC, 1975A).

Concentrations of suspended solids in the bottom one third of the water column overlying and immediately surrounding the New York sludge dumpsite are 30 to 50 percent greater than at locations in the same area not used for dumping (USDC, 1974). Turbidity currents appear to play an important role in the removal of waste sediment from the New York Bight (Pararas - Caryannis, 1973). Slicks of organic matter on the surface have also been observed at the New York Bight sludge dumpsite (NAS, 1975). In the Philadelphia sludge dumpsite, turbidity clouds have been observed to dissipate from 104 ppm to 10 ppm within two hours time (NAS, 1975).

3. Turbidity

Turbidity may produce significant environmental effects upon biota. Potential indirect effects of turbidity and siltation upon marine organisms include clogged gills and impaired respiratory exchange in fish and poor survival of larval stages of fish and shellfish (NAS, 1975). Other potential indirect effects include (NAS, 1975):

a. Reduction in light penetration and reduced photosynthesis.

b. Reduction of visibility to some feeding organisms.

c. Destruction of spawning areas.

d. Reduction of food supplies.

e. Reduction of vegetational cover.

f. Trapping of organic matter, resulting in anaerobic bottom conditioning.

g. Flocculation of planktonic algae.

h. Absorpution or adsorption of organic matter or inorganic ions.

i. Adsorption of oil.

Crabs taken down current from the New York Bight are reported to have their gills fouled with granular materials. The fouling may have resulted from the pollution load rather than from the sediment itself (NAS, 1975).

4. Dissolved Oxygen

The bulk of sewage wastes consist of biodegradable matter of natural origin. After the sludge is dumped, degradation of organic matter consumes oxygen. In the New York Bight dumpsite the rate of oxygen consumption is between 16 and 330 g/kg at the surface of the waste deposits (NAS, 1975). The oxygen content of the bottom water is, on the average, two to three mg/l lower than that at the same depth in areas outside of the dump (NAS, 1975). The most severe bottom water oxygen depletion occurs between July and October when the thermocline limits natural mixing. Oxygen levels of 2 mg/l, which are too low to support many marine forms may be reached during the summer (NAS, 1975). However, oxygen deficient waters are restored to near saturation values during seasons of vertical mixing.

5. Bacteria and Pathogens

Bacterial contamination has also occurred as a result of ocean disposal of sludge on the New York Bight. Shellfish near the dumpsites contain high concentrations of coliform bacteria (USDC, 1975B). Coliform counts exceeding FDA's standards have been found in surf clams collected 8 kilometers from the center of the dumpsite (NAS, 1975). As a result, FDA has closed the area with 10 miles of the center of the site to fisheries.

Coliform contamination may be used as an indicator of the potential presence of pathogenic bacteria and viruses. However, the survival of pathogenic species in ocean water may not be the same as that of the coliform group. In fact, sea water is bactericidial to coliform bacteria (Ketchum, 1951). The die-off rate of coliform in ocean water is very rapid making the use of coliforms as indicators of bacterial contamination effective only in the vicinity of the discharge. The National Academy of Sciences (1975) was unable to find a study on the New York Bight which isolated and identified pathogenic bacteria from sewage sludge but referenced studies which indicate that *Salmonella*, which is often present in sewage sludge, is concentrated by clams in other areas.

6. Heavy Metals

Sludge typically contains concentrations of heavy metals much greater than those naturally occurring in marine sediments. Very little is known about the physical and chemical state of metals in sewage sludge. In anoxic environments, heavy metals react with sulfide ions to form highly insoluble sulfides (NAS, 1975). Heavy metals are present in oxygen rich waters in soluble forms. In seasonally stratified waters with anoxic zones near the bottom, oxidized metals are generally present in the surface layers. During the winter when storms mix and aerate the water, they will occur in deeper waters (NAS, 1975).

Concentrations of copper, chromium, lead, and nickel in superficial sediments in the New York Bight are ten to a hundred times greater near waste disposal areas than in uncontaminated sediments (Carmody, et. al., 1973). Table U-1 compares the concentrations of heavy metals found in both contaminated and uncontaminated sediments in the New York Bight.

TABLE U-1

TRACE METALS IN NEW YORK BIGHT SEDIMENTS
[Source: Carmody, et. al., 1973]

Trace Metal	Average Concentration (ppm dry sediment)	
	uncontaminated sediments	center of sewage sludge dump area
Chromium	6	105
Copper	3-5	141
Lead	12-14	170
Nickel	3-8	24
Zinc	18-20	254

The metals concentrations decrease with distance from the central area of the disposal site. Broad tongues of contaminated sediment stretching from the disposal site may indicate that some dispersal by water currents is taking place (Carmody, et. al., 1973). Accumulation of metals has been noted in Artico islandico (mahogany clam) and Placopectan magellancus (scallop) on the Chesapeake Bight near the Philadelphia dumpsite (USDC, A). Ketchum (NAS, 1975) has suggested that microbial processes may be inhibited by heavy metals in the sediments. Reduced microbial activity would decrease the rate of waste degradation if it contained significant concentrations of heavy metals. Central areas of high metal concentration in the New York Bight correlate well with areas which show greatly lowered populations of benthic fauna (Carmody, et.al., 1973).

7. <u>Toxic Materials</u>

Marine ecosystems may be stressed by the introduction of certain synthetic hydrocarbons. Many synthetic hydrocarbons resist chemical and biological degradation and persist in the marine environment. Chief toxicants in this category include pesticides, herbicides and industrial compounds. Bioassays indicate the polychlorinated biphenyls (PCBS) are concentrated by marine organisms to levels exceeding 100,000 times the amount in their environment. Many organisms exposed to PCBS then become extremely sensitive to disease and changes in environmental conditions. Concentration of PCBS equal to greater than 100 parts per trillion may be lethal to certain shrimp and fishes (USDC, 1975C).

D. <u>Impacts on Marine Life Forms</u>

1. <u>Benthos</u>

Benthic organisms are usually in contact with polluted sediments and overlying water for long periods of time, and therefore are good indicators of chronic pollution. Benthic organisms form an important link in the marine food chain. They are important food sources for many sport and food fishes. They also accumulate contaminants such as trace metals, petrochemicals and organic pollutants (NAS, 1975). In areas of the New York Bight which are covered with sewage sludge, the macrobenthos appear to be inhibited by the intermittent organic overload and the low oxygen stress (Rowe, 1971). Microfauna occur in even the most polluted areas (NAS, 1975). Species diversity and total number of individuals is reduced for both macrofauna and microfauna (NAS, 1975). Benthic communities are less severely impacted immediately outside of the dump area (NAS, 1975).

2. <u>Plankton</u>

Studies of phytoplankton nutrients and productivity indicate that the effects of dumping on planktonic composition in the New York Bight are localized and almost imperceptible (USDC, 1975A). The annual production of the Inner Bight which is comparable to that of very productive upwelling systems (USDC, 1975B) is caused by the influx of nutrient rich water from the estuaries which flow into the Bight.

Amoeba and ciliated protozoa are important components of the plankton and benthos. A predominance of ciliates which feed upon bacteria in the water above the sewage dump site has been noted in the New York Bight (USDC, 1975B). The ciliates <u>Uronema nigrocans</u>, and <u>Cyclidium polyschizonucleatum</u> have been found in close association with the sewage dump site either in the sediments or in the water overlying the dumpsite (USDC, 1975B).

3. Finfish

Stomach content analysis of fish collected from the vicinity of the sludge dumps indicate that the fish mainly eat benthic organisms, but also ingest debris associated with the sludge (NAS, 1975). This poses the question of whether or not the fish are also ingesting pathogenic organisms and other contaminants such as heavy metals. A higher than normal incidence of fin rot disease is found in the New York Bight (USDC, 1975A). Twenty-two species have fin rot, with the winter flounder being the most susceptible (USDA, 1975A). However, researchers from the USDC Stony Brook Lab have been unable to conclusively demonstrate any relationship between fin rot and dumping practices.

E. Update on EPA Activity Related to Ocean Dumping in the New York Bight

The most recent conclusions of EPA regarding the dumping activities in the New York Bight are contained in a Draft Environmental Impact Statement (U.S.EPA 1976). While the proposed action called for the designation of another dump site farther out in the Bight, EPA decided, based on the most recent studies, not to go ahead with that plan. Rather, it was decided that the best course of action would be to continue use of the existing site and continue to explore land-based alternatives. The reasoning behind this decision involved the facts that the existing site was already degraded, and further dumping would aggravate the situation there only slightly, while the proposed action would significantly degrade the immediate area of any new dump site, and adversely affect marine resources located there.

APPENDIX V

AIR QUALITY IMPACT ANALYSIS

A. Introduction

The air quality impact analysis for this study consists of two parts. The first part is the emission burden analysis. For each alternative, the principal pollutant sources are identified, the emission factors for each pollutant of concern are estimated, and the total amount of emissions are calculated. This emission burden analysis is intended to serve as a basis for comparing air pollutant emissions among the action alternatives. The analysis results can also be used as a basis for evaluating the effects of the proposed alternatives on regional air pollutant emissions. The methodology and assumptions used for this analysis and the analysis results are discussed in section B of this Appendix.

The second part of the analysis is the detailed microscale air quality analysis for the alternatives of concern. The project-generated air pollutant concentrations will be calculated and compared with the standards set in the regulation for Prevention of Significant Deterioration of AirQuality as established in the Clean Air Act Amendments of August 7, 1977. Then, the total ambient air quality will be estimated by superimposing the project-generated concentrations on the projected background air quality concentration. The total ambient air quality concentrations will be assessed in terms of meeting the Federal and Massachusetts ambient air quality standards. The microscale air quality analysis is discussed in Section C of this appendix.

B. Emission Burden Analysis

1. The Incineration Alternatives

Potential pollutant sources resulting from this alternative and the various ash disposal options are: (a) incinerator; (b) trucks to transport; (c) barge operation; and (d) pilot fuel use.

a. The Incinerator: The major pollutants which may be emitted from the proposed incinerators are particulate matter, sulfur dioxide, and nitrogen oxides. The U.S. EPA's promulated New Source Performance Standards for municipal sludge incinerators limit the discharge of particulate matter to a maximum of 1.30 lbs. per ton of dry sludge input (U.S. EPA, 1971A). Since the proposed incincerators will be required to meet this standard, the 1.30 lbs. per ton of dry sludge per stack was used as the particulate emission rate for the proposed incinerator.

There is no effluent standard for sulfur dioxide discharge from sewage sludge incinerators. The average emission factor for sulfur dioxide is estimated to be approximately 2 lbs. per ton of dry sludge per stack. Based on the dry sludge loading of 2.655 tons per hours per unit, the daily emissions for particulates and sulfur dioxide are calculated to be 75.2 and 115.8 kgs per day, respectively. Average SO_2 emission from pilot and startup fuel is 5.5 kg/day.

The other pollutants which may be emitted from the incinerators include nitrogen oxides, hydrocarbons, carbon monoxide, and heavy metals (such as mercury, lead, beryllium and vanadium). The emission factors for nitrogen oxides and hydrocarbons, obtained from "Compilation of Air Pollutant Emission Factors" (U.S. EPA, 1975C), are 5, and 1 lbs. per ton of dry sludge per unit, respectively.

There is a hazardous pollutant standard limiting the atmospheric discharge of mercury from incineration to a maximum of 3,200 grams per day (40 CFR 61). For the period January-June 1973, the Deer Island WWTP and the Nut Island WWTP sludges contained an average mercury concentration of 14.2 mg per kg on a mass weighted basis. The removal rate of mercury through scrubbers installed on the incinerator at Livermore, California, was found 90.2 percent (Sebastian, 1975). Using a more conservative 60% removal in the scrubber, the average amount of mercury discharge from the proposed facility would be 657 grams per day in 1985. The maximum mercury emission may reach 800 grams per day during peak sludge burning conditions. It can be seen that the proposed mercury emission standard will not be exceeded under 1985 conditions.

Analyses performed on Deer and Nut Island sludges during this study indicate that the average lead concentration in the total sludge mass is approximately 655 mg per kg of sludge. Based on the lead removal efficiency of 99.15 percent found at the Livermore incinerator (Sebastian, 1975), expected average lead emission rate for the proposed project would be 653 grams per day, with a maximum of 797 grams per day.

There is also a regulation limiting the maximum beryllium emission to 10 grams over a 24 hour period (40 CFR 61). The maximum beryllium concentration in the sludge is assumed to be 0.77 mg per kg of dry sludge. Kaakinen (1975) has shown that most of the beryllium in coal fired power plants remains in the ash. Assuming that beryllium in sludges will act in a similar manner, the average beryllium emission is estimated to be 0.12 grams per day, which is well below the proposed beryllium emission standard. And finally, the maximum vanadium emission rate is estimated to be approximately 2.4 grams per day, based on the sludge analyses performed for this study.

There is also the potential for discharge of stable organic compounds because of the content of pesticides and other persistent organic compounds in the municipal sludge. In a randon selection of sludges, EPA reported the following levels of organic compounds present in raw sludges (U.S. EPA, 1975D):

Compound	Range (parts per million)
Aldrin	16 (in one sludge only)
Dieldrin	0.08 to 2.0
Chlordane	3.0 to 32
DDD	Not detected to 0.5
DDT	Not detected to 1.1
PCB's	Not detected to 105

Among these persistent organics, PCB's (polychlorinated-biphenyls) are the most thermally stable component. It has been reported that complete destruction of pure PCB's occurs at 2400°F in 2.5 seconds, with 99% destruction at 1600-1800°F in 2.0 seconds. In combined incineration with municipal sludge, total destruction was obtained at an exit temperature of 1100°F, with 95% destruction at 700°F. The proposed incinerator system will have an average top hearth temperature of around 960°F and a maximum temperature of 1400-1700°F. Thus, it can be assumed that most organic compounds will be destroyed by incineration or remain as ash or vapors in the water-scrubbed gas stream. The emission of the stable organics will be minimal. Based on the above discussion, the daily pollutant emissions from the incinerators under 1985 conditions are summarized in Table V-1.

The other potential air pollutant sources associated with the incineration alternative include truck transportation of ash, barge transportation of ash, and the burning of pilot fuel.

b. Truck Transportation: It is assumed that 1980 model diesel powered trucks with gross vehicle weights of 60,000 lbs. could be used for transporting incinerator ash. The EPA's emission factors for 1980 model heavy duty diesel trucks in 1985 calendar year are listed below (U.S. EPA, 1975C):

1985 Calendar Year Emission Factors

Pollutant	Emission Factor (g/mi)
Carbon monoxide	28.7
Hydrocarbons	4.6
Nitrogen oxides	18.1
Particulates	1.3
Sulfur dioxide	2.8

Based on these emission factors and the estimated daily travel miles, the truck emissions are calcualted as shown in Table 1.

c. Barge Travel: The average fuel consumption rate of diesel-powered barges was estimated at 8.73 gallons per mile. Based on emission factors for diesel fuel (U.S. EPA, 1975C), the daily emissions from barge travel were calculated, and are also shown in Table 1.

d. Burning of Pilot and Startup Fuel: The incinerator will burn approximately 405 gallons of no. 2 diesel pilot and startup fuel. This will produce small amounts of pollutants, as shown in Table V-1.

2. Comparison of the Total Emissions from the Basic Alternatives

Table V-1 shows the partial emissions from each pollutant source, and the total emissions from all sources for each alternative. The majority of pollutant emissions for the incineration alternative will be from the incinerators. The estimated daily emission will be highest nitrogen dioxide, followed by sulfur dioxide, and then particulates and hydrocarbons. The mercury and lead emissions will be 0.657 and 0.797 kilograms per day, respectively.

C. Microscale Air Quality Analysis

1. Analysis of the Incinerator Emissions of 1985

As discussed in the previous section, the major pollutant sources for the incinceration alternative include the incinerators, truck transportation, barge travel, and the burning of pilot fuel. The incinerators account for more than 95% of the total emissions for each pollutant of concern. Thus, the air quality analysis for the incineration alternative will concentrate on the impacts resulting from the incinerator emissions, as shown in Table V-2.

The principal pollutants emitted from the incinerators include particulate matter, sulfur dioxide, hydrocarbons, nitrogen oxides, and heavy metals. Since the estimated total heavy metal emissions will not exceed the proposed hazardous pollutant effluent standards for mercury and beryllium, and because there is no established air quality standard for other heavy metals, the ambient heavy metal concentrations

TABLE V-1

AIR POLLUTION EMISSIONS, 1985 CONDITIONS (kgs/dy)

Alternative 1

	TSP	SO_2	CO	HC	NO_x	Hg	Pb	Be	Va	Organics
2 incinerators	75.2	115.8	neg.	57.8	289.0	0.122	0.797	0.00012	0.0026	neg.
Truck transportation (189 miles/day)	0.25	0.50	5.42	0.88	3.4	neg	neg.	N/A	N/A	neg.
Pilot and startup fuel, 405 gal/day	2.03	5.5	0.58	0.29	8.11	N/A	N/A	N/A	N/A	N/A
Barge Travel (6.3 miles/day)	3.03	2.27	1.82	1.36	2.12	N/A	N/A	N/A	N/A	N/A
Total	80.51	124.07	7.82	60.33	302.63	0.122	0.797	0.00012	0.0026	neg.

TABLE V-1 (Cont'd.)

Alternative 2

	TSP	SO_2	CO	HC	NO_x	Hg	Pb	Be	Va	Organics
2 incinerators	75.2	115.8	neg.	57.8	289.0	0.122	0.797	0.00012	0.0026	neg.
Truck transportation (2.5 miles/day)	0.00	0.01	0.07	0.01	0.05	neg.	neg	N/A	N/A	neg.
Pilot and startup fuel, 405 gal/day	2.03	5.5	0.58	0.29	8.11	N/A	N/A	N/A	N/A	N/A
Barge Travel (0 miles/day)	-	-	-	-	-	-	-	-	-	-
Total	77.23	121.4	0.65	59.10	297.16	0.122	0.797	0.00012	0.0026	neg.

TABLE V-1 (Cont'd.)

Alternative 8

	TSP	SO_2	CO	HC	NO_x	Hg	Pb	Be	Va	Organics
2 incinerators	75.2	115.8	neg.	57.8	289.0	0.122	0.797	0.00012	0.0026	neg
Truck transportation (6.3 miles/day)	0.01	0.01	0.18	0.03	0.11	neg.	neg.	N/A	N/A	N/A
Pilot and startup fuel, 405 gal/day	2.03	5.5	0.58	0.29	8.11	N/A	N/A	N/A	N/A	N/A
Barge Travel (0.0 miles/day)	-	-	-	-	-	-	-	-	-	-
Total	77.24	121.4	0.76	58.12	297.22	0.122	0.797	0.00012	0.0026	neg

TABLE V-1 (Cont'd.)

Alternative 9

	TSP	SO_2	CO	HC	NO_x	Hg	Pb	Be	Va	Organics
2 incinerators	75.2	115.8	neg.	57.8	289.0	0.122	0.797	0.00012	0.0026	neg.
Truck transportation (1.3 miles/day)	0.00	0.00	0.04	0.01	0.02	neg	neg	N/A	N/A	neg
Pilot and startup fuel, 405 gal/day	2.03	5.5	0.58	0.29	8.11	N/A	N/A	N/A	N/A	N/A
Barge Travel (5.5 miles/day)	2.65	1.98	1.59	1.19	1.87	N/A	N/A	N/A	N/A	N/A
Total	79.88	123.28	2.21	59.29	299.0	0.122	0.797	0.00012	0.0026	neg.

TABLE V-1 (Cont'd.)

Alternative 10

	TSP	SO_2	CO	HC	NO_x	Hg	Pb	Be	Va	Organics
2 incinerators	75.2	115.8	neg.	57.8	289.0	0.122	0.797	0.00012	0.0026	neg.
Truck transportation (1.3 miles/day)	0.00	0.00	0.04	0.01	0.02	neg	neg	N/A	N/A	neg
Pilot and startup fuel, 405 gal/day	2.03	5.5	0.58	0.29	8.11	N/A	N/A	N/A	N/A	N/A
Barge travel (0 miles/day)	-	-	-	-	-	-	-	-	-	-
Total	77.23	121.30	0.62	58.10	297.13	0.122	0.797	0.00012	0.0026	neg

TABLE V-1 (Cont'd.)

Alternative 11

	TSP	SO_2	CO	HC	NO_x	Hg	Pb	Be	Va	Organics
2 incinerators	75.2	115.8	neg.	57.8	289.0	0.122	0.797	0.00012	0.0026	neg.
Truck transportation (6.3 miles/day)	0.01	0.01	0.18	0.03	0.11	neg	neg	N/A	N/A	neg.
Pilot and startup fuel, 405 gal/day	2.03	5.5	0.58	0.29	8.11	N/A	N/A	N/A	N/A	N/A
Barge Travel (0.0 miles/day)	-	-	-	-	-	-	-	-	-	-
Total	77.24	121.31	0.76	58.12	297.22	0.122	0.797	0.00012	0.0026	neg.

TABLE V-2

INCINERATOR FACILITY EMISSIONS

Proposed Incinerator Facilities on Deer Island

Number of units in operation	- 2
Number of stacks	- 1 per unit
Dry sludge loading	- 2.655 tons/hr/unit
Total suspended particle (TSP) emissions:	
Sludge emission factor	- 1.3 lb/ton dry sludge
**Average emission rate	- 0.434 gm/sec/unit
*Peak emission rate (at peak sludge burning condition)	- 0.532 gm/sec/unit
Sulfur dioxide emissions:	
Sludge emission factor	- 2 lb/ton dry sludge
**Average emission rate (excluding auxiliary fuel emissions)	- 0.67 gm/sec/unit
Peak emission rate (at peak sludge burning condition)	- 0.82 gm/sec/unit
Emission factor with afterburner (sludge and fuel emission)	- 3.6 lb/ton dry sludge
Emission rate with afterburner	- 1.205 gm/sec/unit
Avg. fuel emission rate	- 0.031 gm/sec/unit
**Avg. total emission rate (sludge and auxiliary fuel emission)	- 0.701 gm/sec/unit
Emission factor at startup condition (sludge and fuel emission	- 3.98 lb/ton dry sludge
*Emission rate at startup condition	- 1.333 gm/sec/unit
Location of stacks	- 40 feet center-to-center
Height of stacks	- 110 feet above grade, 140 feet above mean sea level
Stack gas exit temperature	- 120°F
Ambient air temperature	- 60°F
Stack gas exit velocity	- 10 meters/sec
Stack effluent gas flow	- 32,118 cubic feet per minute per unit at 938°F
or	- 6.29 cubic meters per sec/unit at 120°F
Stack inside diameter	- 0.8949 meter

* These peak emission rates are used for analyzing short-term (3 hour and 24 hour) air quality impacts.

**These average emission rates are used for analyzing annual air quality concentrations.

and their distribution will not be analyzed in the same detail as for SO_2 and particulates. In addition, the state of the art is not currently advanced enough to estimate impact on the long-term concentration of nitrogen dioxide and hydrocarbons from a single source (i.e photochemical oxidants). Thus, the emphasis of the air quality analysis will be placed on particulate, sulfur dioxide, and nitrogen oxides analysis.

For the ambient air quality analysis, the concentrations resulting from the proposed projects are estimated and compared with the allowable incremental concentrations established in the August 7, 1977 Clean Air Act Amendments' section Prevention of Significant Deterioration of Air Quality. Then these project-generated concentrations are added to the projected background concentrations in order to get the total ambient air quality concentrations. Thus, the estimated total air pollutant concentrations can be compared with the natural and state ambient air quality standards. The following sections discuss the input data, methodology, and assumptions used in the analysis of the incinerator-generated concentrations for the study year, 1985.

a. Incinerator Parameters: The inputs of the incinerators characteristics used for the air pollution calculation are listed below.

It should be noted that consideration has been given in determining these incinerators parameters in order to minimize the possibility of aerodynamic downwash of pollutants emitting from the stack. In general, a stack height of 2.5 times the highest building adjacent to the stack will overcome the influence of aerodynamic turbulence around the building. In addition, an effluent gas velocity of 1.5 times the prevailing wind speed will prevent the downwash in the wake of the stack. For the proposed incinerator, the highest adjacnet building height is approximately 50 feet. The proposed stack height of 110 feet plus the plume rise resulting from the high exit gas velocity will minimize the effect of building obstruction. The effluent gas velocity of 10 meters per second (22.37 miles per hour) will prevent downwash in the wake of the stack during normal meteorological conditions.

b. Worst Case Analysis: The national and Massachusetts ambient air quality standards are defined such that they may not be exceeded more than once a year (except for annual average concentrations). Therefore, to compare the possible future ambient air quality to the standards, the worst case must be considered.

In general, the ground level concentrations resulting from stacks are a function of meteorological conditions such as stability of the atmosphere, wind speed and direction, atmosphere mixing height and ambient air temperature, stack parameters such as height and inside diameter, exit gas speed and temperature, and other factors. Based on the peak emission rates and other stack parameters defined in the previous paragraph, the PTMAX model, developed by the U. S. EPA, was used to determine the worst meteorological conditions at which the maximum ground level concentrations will occur. A detailed description of this model is given in this report.

The analysis results of the maximum hourly concentrations of particulates and sulfur dioxide resulting from a single stack are presented in Tables V-3 and V-4. The corresponding wind speed and downwind distance of maximum concentration for each condition of stability are also in those tables.

However, these analysis results represent the concentrations resulting from a single stack only. There are two proposed stacks located approximately 40 feet apart on Deer Island. The total maximum ground level concentrations from both stacks must be determined. The following sections discuss the analysis for the concentrations resulting from two incinerators.

c. Calculation of the Maximum Short-Term Concentrations Resulting from Two Stacks: The U.S. EPA's computer model PTMTP was used to calculate the maximum hourly concentrations resulting from both stacks. This model is capable of calculating the partial concentration from each stack and the total concentration from multiple stacks at a given meteorological condition.

As shown in Tables V-3, V-4 and V-5, the maximum ground concentration is different for each condition of stability, and so is the corresponding wind speed. Stability 1 will have the highest maximum ground concentration, followed by stability 2, and then stabilities 3, 4, 5, and 6. According to the historical meteorological data collected at Logan Airport, the frequency of occurrence for stabilities 1, 2 or 3 is much less than that of stability 4. Thus stability 4, with a wind speed

TABLE V-3

ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED: PARTICULATES

*Maximum Predicted Ground Level Concentration At Designated Stability (1 Hour)

Stability	Wind Speed (m/sec)	Max. Conc. (g/cu m)	Dist. of Max. (km)	Plume Height (m)
1	0.5	2.8588 E-05 *	0.445	105.9
1	0.8	2.8411 E-05	0.362	78.8
1	1.0	2.7615 E-05	0.331	69.7
1	1.5	2.5312 E-05	0.281	57.7
1	2.0	2.2846 E-05	0.255	51.6
1	2.5	2.0748 E-05	0.239	48.0
1	3.0	1.-978 E-05	0.228	45.6
2	0.5	2.3295 E-05	0.740	105.9
2	0.8	2.4936 E-05 *	0.565	78.8
2	1.0	2.4914 E-05	0.505	69.7
2	1.5	2.3591 E-05	0.416	57.7
2	2.0	2.1698 E-05	0.372	51.6
2	2.5	1.9914 E-05	0.345	48.0
2	3.0	1.8322 E-05	0.328	45.6
2	4.0	15.6704 E-06	0.306	42.6
2	5.0	13.6264 E-06	0.292	40.8
3	2.0	2.1842 E-05 *	0.569	51.6
3	2.5	2.0209 E-05	0.525	48.0
3	3.0	1.8673 E-05	0.496	45.6
3	4.0	1.6061 E-05	0.460	42.6
3	5.0	14.0158 E-06	0.439	40.8
3	7.0	11.1110 E-06	0.415	38.7
3	10.0	8.4413 E-06	0.397	37.1
3	12.0	7.2688 E-06	0.390	36.5
3	15.0	6.0120 E-06	0.383	35.9
4	0.5	11.8494 E-06	3.243	105.9
4	0.8	15.1679 E-06	2.037	78.8
4	1.0	1.6275 E-05	1.684	69.7
4	1.5	1.7158 E-05 *	1.253	57.7
4	2.0	1.6801 E-05	1.055	51.6
4	2.5	1.5851 E-05	0.961	48.0
4	3.0	14.7545 E-06	0.908	45.6
4	4.0	12.8169 E-06	0.843	42.6
4	5.0	11.2553 E-06	0.805	40.8
4	7.0	8.9900 E-06	0.760	38.7
4	10.0	6.8704 E-06	0.727	37.1
4	12.0	5.9302 E-06	0.715	36.5
4	15.0	4.9167 E-06	0.702	35.9
4	20.0	3.8239 E-06	0.689	35.3
5	2.0	8.2978 E-06 *	2.543	60.9
5	2.5	7.2182 E-06	2.415	58.9
5	3.0	6.4246 E-06	2.319	57.4
5	4.0	5.3212 E-06	2.181	55.3
5	5.0	4.5798 E-06	2.085	53.7

TABLE V-3 CONT'D

Stability	Wind Speed (m/sec)	Max. Conc. (g/cu m)	Dist. of Max. (km)	Plume Height (m)
6	2.0	6.9735 E-06 *	4.498	56.2
6	2.5	6.0814 E-06	4.239	54.6
6	3.0	5.4226 E-06	4.046	53.4
6	4.0	4.5016 E-06	3.773	51.6
6	5.0	3.8800 E-06	3.584	50.3

*Maximum Ground Level Concentration

Note: E-05 = 10^{-5}

TABLE V-4

ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED: SULFUR OXIDES

*Maximum Predicted Ground Level Concentration (1 Hour)

Stability	Wind Speed (m/sec)	Max Conc. (g/cu m)	Dist. of Max. (km)	Plume Height (m)
1	0.5	8.4440 E-05 *	0.445	105.9
1	0.8	8.3918 E-05	0.362	78.8
1	1.0	8.1571 E-05	0.331	69.7
1	1.5	7.4766 E-05	0.281	57.7
1	2.0	6.7481 E-05	0.255	51.6
1	2.5	6.1284 E-05	0.239	48.0
1	3.0	5.6057 E-05	0.228	45.6
2	0.5	6.8808 E-05	0.740	105.9
2	0.8	7.3653 E-05 *	0.565	78.8
2	1.0	7.3588 E-05	0.505	69.7
2	1.5	6.9679 E-05	0.416	57.7
2	2.0	6.4092 E-05	0.372	51.6
2	2.5	5.8820 E-05	0.345	48.0
2	3.0	5.4116 E-05	0.328	45.6
2	4.0	4.6287 E-05	0.306	42.6
2	5.0	4.0248 E-05	0.292	40.8
3	2.0	6.4515 E-05 *	0.569	51.6
3	2.5	5.9694 E-05	0.525	48.0
3	3.0	5.5155 E-05	0.496	45.6
3	4.0	4.7439 E-05	0.460	42.6
3	5.0	4.1399 E-05	0.439	40.8
3	7.0	3.2820 E-05	0.415	38.7
3	10.0	2.4939 E-05	0.397	37.1
3	12.0	2.1470 E-05	0.390	36.5
3	15.0	17.7580 E-06	0.383	35.9
4	0.5	3.5001 E-05	3.243	105.9
4	0.8	4.4801 E-05	2.037	78.8
4	1.0	4.8069 E-05	1.684	69.7
4	1.5	5.0682 E-05 *	1.253	57.7
4	2.0	4.9627 E-05	1.055	51.6
4	2.5	4.6818 E-05	0.961	48.0
4	3.0	4.3582 E-05	0.908	45.6
4	4.0	3.7857 E-05	0.843	42.6
4	5.0	3.3245 E-05	0.805	40.8
4	7.0	2.6554 E-05	0.760	38.7
4	10.0	2.0294 E-05	0.727	37.1
4	12.0	17.5160 E-06	0.715	36.5
4	15.0	14.5224 E-06	0.702	35.9
4	20.0	11.2947 E-06	0.689	35.3
5	2.0	2.4509 E-05 *	2.543	60.9
5	2.5	2.1321 E-05	2.415	58.9
5	3.0	1.8976 E-05	2.319	57.4
5	4.0	15.7174 E-06	2.181	55.3
5	5.0	13.5277 E-06	2.085	53.7

TABLE V-4 CONT'D

Stability	Wind Speed (m/sec)	Max. Conc. (g/cu m)	Dist. of Max. (km)	Plume Height (m)
6	2.0	2.0598 E-05	4.498	56.2
6	2.5	17.9630 E-06 *	4.239	54.6
6	3.0	16.0164 E-06	4.046	53.4
6	4.0	13.2965 E-06	3.773	51.6
6	5.0	11.4605 E-06	3.584	50.3

*Maximum Ground Level Concentration

Note: E-05 = 10^{-5}

TABLE V-5

ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED: NITROGEN OXIDES (1 HOUR)

*Maximum Predicted Ground Level Concentration

Stability	Wind Speed (m/sec)	Max. Conc. (g/cu m)	Dist. of Max. (km)	Plume Height (m)
1	0.5	13.5919 E-05 *	0.445	105.9
1	0.8	13.5079 E-05	0.362	78.8
1	1.0	13.1301 E-05	0.331	69.7
1	1.5	12.0348 E-05	0.281	57.7
1	2.0	10.8621 E-05	0.255	51.6
1	2.5	9.8647 E-05	0.239	48.0
1	3.0	9.0233 E-05	0.228	45.6
2	0.5	11.0758 E-05	0.740	105.9
2	0.8	11.8557 E-05 *	0.565	78.8
2	1.0	11.8452 E-05	0.505	69.7
2	1.5	11.2159 E-05	0.416	57.7
2	2.0	10.3166 E-05	0.372	51.6
2	2.5	9.4680 E-05	0.345	48.0
2	3.0	8.7109 E-05	0.328	45.6
2	4.0	7.4506 E-05	0.306	42.6
2	5.0	6.4786 E-05	0.292	40.8
3	2.0	10.3847 E-05 *	0.569	51.6
3	2.5	9.6087 E-05	0.525	48.0
3	3.0	8.8780 E-05	0.496	45.6
3	4.0	7.6360 E-05	0.460	42.6
3	5.0	6.6638 E-05	0.439	40.8
3	7.0	5.2828 E-05	0.415	38.7
3	10.0	4.0135 E-05	0.397	37.1
3	12.0	3.4560 E-05	0.390	36.5
3	15.0	28.5884 E-06	0.383	35.9
4	0.5	5.6339 E-05	3.243	105.9
4	0.8	7.2114 E-05	2.037	78.8
4	1.0	7.7374 E-05	1.684	69.7
4	1.5	8.1581 E-05 *	1.253	57.7
4	2.0	7.9883 E-05	1.055	51.6
4	2.5	7.5361 E-05	0.961	48.0
4	3.0	7.0152 E-05	0.908	45.6
4	4.0	6.0936 E-05	0.843	42.6
4	5.0	5.3512 E-05	0.805	40.8
4	7.0	4.2743 E-05	0.760	38.7
4	10.0	3.2666 E-05	0.727	37.1
4	12.0	28.1947 E-06	0.715	36.5
4	15.0	23.3761 E-06	0.702	35.9
4	20.0	18.1806 E-06	0.689	35.3
5	2.0	3.9451 E-05 *	2.543	60.9
5	2.5	3.4320 E-05	2.415	58.9
5	3.0	3.0545 E-05	2.319	57.4
5	4.0	25.2996 E-06	2.181	55.3
5	5.0	21.7749 E-06	2.085	53.7

TABLE V-5 CONT'D

Stability	Wind Speed (m/sec)	Max. Conc. (g/cu m)	Dist. of Max. (km)	Plume Height (m)
6	2.0	3.3155 E-05	4.498	56.2
6	2.5	28.9143 E-06 *	4.239	54.6
6	3.0	25.7809 E-06	4.046	53.4
6	4.0	21.4029 E-06	3.773	51.6
6	5.0	18.4474 E-06	3.584	50.3

*Maximum Ground Level Concentration

Note: E-05 = 10^{-5}

E-06 = 10^{-6}

of 1.5 meters per second, was used as the worst meteorological condition for the analysis of the air quality impacts.

This selected worst meteorological condition and the parameters of the two proposed stacks were input into the PTMTP model to calculate the maximum hourly ground level condition. The partial concentrations from each stack and the total concentration from both stacks were calculated at 27 selected receptor sites. The results are shown in Tables V-6, V-7, and V-8. The receptor sites were selected so that they correspond to the locations of maximum concentration determined by the PTMAX. It can be seen that the maximum hourly ground level concentration resulting from both stacks will be 34, 102, and 164 micrograms per cubic meter for particulates, sulfur dioxide, and nitrogen oxides, respectively. The corresponding distance of this maximum concentration is approximately 1.25 kilometer downwind from the stacks.

As indicated in the air quality summary, there are 24-hour and annual average air quality standards for particulates; there are 3-hour, 24-hour, and annual average standards for sulfur dioxide, and there is an annual average stand for nitrogen oxides. In addition, the hourly standard of the World Health Organization for nitrogen oxides is considered in this report. In order to calculate the maximum ground level concentration for time periods longer than 1 hour, meteorlogical variations must considered. The maximum concentrations for 3-hour and 24-hour time periods were obtained by multiplying the hourly concentration by the applicable meteorlogical persistance factors listed below.

Sampling Time	Meteorological Persistance Factor
1 hour	1
3 hours	0.84 *
24 hours	0.25 **

* Suggested in Turner's <u>Workbook</u>, U.S. EPA publication AP-26.

** Suggested by Warren Peters, Region I EPA.

Thus, the maximum ground level concentrations resulting from the proposed incinerator units are calculated as shown below:

TABLE V-6

MULTIPLE SOURCE MODEL: PARTICULATES

Model CBT51

* * * S O U R C E S * * *

NO	Q (G/SEC)	HP (M)	TS (DEG K)	VS (M/SEC)	D (M)	VF (M**3/SEC)	R (KM)	S (KM)
1	0.84	33.5	322.0			6.3	0.0	0.0
2	0.84	33.5	322.0			6.3	0.012	0.0

* * * R E C E P T O R S * * *

NO	RREC (KM)	SREC (KM)	Z (M)
1	0.006	0.0	0.0
2	0.500	0.0	0.0
3	0.700	0.0	0.0
4	0.900	0.0	0.0
5	1.000	0.0	0.0
6	1.100	0.0	0.0
7	1.200	0.0	0.0
8	1.253	0.0	0.0
9	1.280	0.0	0.0
10	1.300	0.0	0.0
11	1.400	0.0	0.0
12	1.500	0.0	0.0
13	1.600	0.0	0.0
14	1.700	0.0	0.0
15	2.000	0.0	0.0
16	2.500	0.0	0.0
17	4.000	0.0	0.0
18	6.000	0.0	0.0
19	10.000	0.0	0.0
20	15.000	0.0	0.0

* * * M E T E O R O L O G Y * * *

NO	THETA (DEG)	U (M/SEC)	KST	HL (M)	T (DEG K)
1	270.0	1.5	4	609.	289.

TABLE V-6 CONT'D

AVERAGE PARTICULATE CONCENTRATIONS FOR 1 HOUR

RECEPTOR NUMBER - PARTIAL CONCENTRATIONS

Stacks	1	2	3	4	5	6
1	0	1.8812 E-06	8.4922 E-06	14.4250 E-06	1.6251 E-05	1.6883 E-05
2	0	1.6030 E-06	8.0559 E-06	14.1484 E-06	1.6061 E-05	1.6820 E-05
Total Concentration	0	3.4842 E-06	1.6581 E-05	2.8581 E-05	3.2312 E-05	3.3703 E-05

S	7	8 *	9	10	11	12
1	1.7152 E-05	1.7184 E-05	1.7184 E-05	1.7168 E-05	1.6994 E-05	1.6678 E-05
2	1.7136 E-05	1.7184 E-05	1.7184 E-05	1.7184 E-05	1.7026 E-05	1.6725 E-05
Total Concentration	3.4229 E-05	3.4383 E-05	3.4368 E-05	3.4336 E-05	3.4004 E-05	3.3419 E-05

S	13	14	15	16	17	18
1	1.6298 E-05	1.5840 E-05	14.3618 E-06	11.9874 E-06	7.2955 E-06	4.4168 E-06
2	1.6346 E-05	1.5903 E-05	14.4219 E-06	12.0412 E-06	7.3224 E-06	4.4279 E-06
Total Concentration	3,2628 E-05	3.1743 E-05	2.8787 E-05	2.4029 E-05	14.6179 E-06	8.8431 E-06

S	19	20
1	2.2211 E-06	12.7399 E-07
2	2.2258 E-06	12.7541 E-07
Total Concentration	4.4469 E-06	2.5499 E-06

*Maximum Ground Level Concentration

Note: E-05 = 10^{-5}

TABLE V-7

MULTIPLE SOURCE MODEL: SULFUR OXIDES

* * * S O U R C E S * * *

NC	Q (G/SEC)	HP (M)	TS (DEG K)	VS (M/SEC)	D (M)	VF (M**3/SEC)	R (KM)	S (KM)
1	2.48	33.5	322.0			6.3	0.0	0.0
2	2.48	33.5	322.0			6.3	0.012	0.0

* * * R E C E P T O R S * * *

NO	RREC (KM)	SREC (KM)	Z (M)
1	0.006	0.0	0.0
2	0.500	0.0	0.0
3	0.700	0.0	0.0
4	0.900	0.0	0.0
5	1.000	0.0	0.0
6	1.100	0.0	0.0
7	1.200	0.0	0.0
8	1.253	0.0	0.0
9	1.280	0.0	0.0
10	1.300	0.0	0.0
11	1.400	0.0	0.0
12	1.500	0.0	0.0
13	1.600	0.0	0.0
14	1.700	0.0	0.0
15	2.000	0.0	0.0
16	2.500	0.0	0.0
17	4.000	0.0	0.0
18	6.000	0.0	0.0
19	10.000	0.0	0.0
20	15.000	0.0	0.0

TABLE V-7 CONT'D

AVERAGE SULFUR DIOXIDE CONCENTRATIONS FOR 1 HOUR

RECEPTOR NUMBER - PARTIAL CONCENTRATION

Stacks	1	2	3	4	5	6
1	0.	5.5610 E-06	2.5092 E-05	4.2616 E-05	4.8022 E-05	4.9886E-0
2	0.	4.7370 E-06	2.3806 E-05	4.1814 E-05	4.7481 E-05	4.9719E-0
Total Concentration	0.0	10.2960 E-06	4.8898 E-05	8.4430 E-05	9.5485 E-05	9.9605E-0

S	7	8 *	9	10	11	12
1	5.0688 E-05	5.0800 E-05	5.0763 E-05	5.0725 E-05	5.0203 E-05	4.9290E-0
2	5.0632 E-05	5.0781 E-05	5.0781 E-05	5.0763 E-05	5.0297 E-05	4.9420E-0
Total Concentration	10.1339 E-05	10.1581 E-05	10.1544 E-05	10.1469 E-05	10.0500 E-05	9.8729E-0

S	13	14	15	16	17	18
1	4.8134 E-05	4.6810 E-05	4.2430 E-05	3.5420 E-05	2.1588 E-05	13.0495E-0
2	4.8283 E-05	4.6978 E-05	4.2616 E-05	3.5588 E-05	2.1644 E-05	13.0831E-0
Total Concentration	9.6436 E-05	9.3789 E-05	8.5046 E-05	7.1008 E-05	4.3194 E-05	2.6136E-0

S	19	20
1	6.5639 E-06	3.7639 E-06
2	6.5751 E-06	3.7694 E-06
Total Concentration	13,1371 E-06	7.5333 E-06

*Maximum Ground Level Concentration

Note: E-05 = 10^{-5}

TABLE V-8

MULTIPLE SOURCE MODEL: NITROGEN OXIDES

* * * S O U R C E S * * *

NO	Q (G/SEC)	HP (M)	TS (DEG K)	VS (M/SEC)	D (M)	VF (M**3/SEC)	R (KM)	S (KM)
1	4.00	33.5	322.0			6.3	0.0	0.0
2	4.00	33.5	322.0			6.3	0.012	0.0

* * * R E C E P T O R S * * *

NO	RREC (KM)	SREC (KM)	Z (M)
1	0.000	0.0	0.0
2	0.500	0.0	0.0
3	0.700	0.0	0.0
4	0.900	0.0	0.0
5	1.000	0.0	0.0
6	1.100	0.0	0.0
7	1.200	0.0	0.0
8	1.250	0.0	0.0
9	1.280	0.0	0.0
10	1.300	0.0	0.0
11	1.400	0.0	0.0
12	1.500	0.0	0.0
13	1.600	0.0	0.0
14	1.700	0.0	0.0
15	2.000	0.0	0.0
16	2.500	0.0	0.0
17	4.000	0.0	0.0
18	6.000	0.0	0.0
19	10.000	0.0	0.0
20	15.000	0.0	0.0

TABLE V-8 CONT'D

AVERAGE NITROGEN OXIDE CONCENTRATION FOR 1 HOUR

RECEPTOR NUMBER - PARTIAL CONCENTRATION

Stacks	1	2	3	4	5	6
1	0	8.9512 E-06	4.0390 E-05	6.8597 E-05	7.7299 E-05	8.0300 E-05
2	0	7.6249 E-06	3.8320 E-05	6.7307 E-05	7.6429 E-05	8.0030 E-05
Total Concentration						
	0	16.5731 E-06	7.8710 E-05	13.5904 E-05	15.3698 E-05	16.6330 E-05

S	7	8 *	9	10	11	12
1	8.1590 E-05	8.1770 E-05	8.1710 E-05	8.1650 E-05	8.0810 E-05	7.9340 E-05
2	8.1500 E-05	8.1740 E-05	8.1740 E-05	8.1710 E-05	8.0960 E-05	7.9550 E-05
Total Concentration						
	16.3121 E-05	16.3511 E-05	16.3451 E-05	16.3331 E-05	16.1770 E-05	15.8920 E-05

S	13	14	15	16	17	18
1	7.7479 E-05	7.5349 E-05	6.8297 E-05	5.7014 E-05	3.4749 E-05	21.0053 E-06
2	7.7719 E-05	7.5619 E-05	6.8597 E-05	5.7284 E-05	3.4-39 E-05	21.0593 E-06
Total Concentration						
	15.5229 E-05	15.0968 E-05	13.6894 E-05	11.4299 E-05	6.9527 E-05	4.2071 E-05

S	19	20
1	10.5656 E-06	6.0585 E-06
2	10.5836 E-06	6.0675 E-06
Total Concentration		
	21.1463 E-06	12.1260 E-06

*Maximum Ground Level Concentration

Note: E-05 = 10^{-5}

TABLE V-9 REVISED

MAXIMUM PREDICTED GROUND LEVEL CONCENTRATIONS (GLC) FOR INCINCERATOR POLLUTANTS

Pollutant	Time Period	GLC_{max} µg/m³	Distance of Max. Concentration (M)
Particulate	1	34.4	1253
	24	8.6	1253
Sulfur dioxide	1	101.6	1253
	3	85.3	1253
		25.4	1253
Nitrogen oxides	1	163.5	1253

It should be pointed out that the ground level concentra tions resulting from the incinerators at any other locations will be less than these maximum concentrations. The graphical presentation of the ground level concentration as a function of downwind distance from the incinerators is shown in Figure V-1.

d. Calculation of the Annual Average Concentrations: It is inappropriate to extrapolate the one-hour concentrations to time periods longer than 24 hours. Therefore, the U.S. EPA's Climatological Dispersion Model was used to calculate the annual average concentrations resulting from the proposed incinerators. The input data required by this model include incinerator parameters and the joint frequency distribution of wind direction, wind speed, and the stability for the period of consideration. The detailed description of this model may be found in Appendix W. Table V-10 presents the calculated annual concentration for particulates, sulfur dioxide, and nitrogen oxides at the selected receptor sites. The location of the receptors are shown in Figure V-2. It should be noted that the receptor sites 1, 2, 18, 19, 21, 22, 23, 24, 26 and 27 are located near the places where the short-term maximum concentrations would occur (approximately 1.253 kilometer downwind from the incinerator). The maximum annual concentration was found to occur at Receptor Site 21 on Deer Island. The corresponding maximum annual concentrations of particulates,

TABLE V-10

BOSTON SLUDGE ANNUAL CONCENTRATION CDM PROGRAM
(Micrograms Per Cubic Meter)

Coordinates		Receptor Site	Particulates	Sulfur Dioxides	Nitrogen Oxides
7.33	10.50	0.01	0.354 E-01	0.546 E-01	1.3274 E-01
6.50	10.33	0.02	0.357 E-01	0.549 E-01	1.3347 E-01
6.66	11.84	0.03	0.140 E-01	0.215 E-01	.5227 E-01
6.33	13.50	0.04	0.752 E-02	0.116 E-01	.2820 E-01
4.50	10.84	0.05	0.193 E-01	0.297 E-01	.7221 E-01
3.17	9.17	0.06	0.164 E-01	0.252 E-01	.6127 E-01
4.00	7.84	0.07	0.116 E-01	0.179 E-01	.4352 E-01
3.17	6.84	0.08	0.807 E-02	0.124 E-01	.3015 E-01
4.66	4.50	0.09	0.758 E-02	0.117 E-01	.2845 E-01
6.17	2.33	0.10	0.534 E-02	0.822 E-02	1.9985 E-02
9.00	1.66	0.11	0.110 E-01	0.170 E-01	.4133 E-01
11.50	5.84	0.12	0.214 E-01	0.329 E-01	.7999 E-01
10.00	3.33	0.13	0.102 E-01	0.156 E-01	.3793 E-01
8.00	3.00	0.14	0.149 E-01	0.230 E-01	.5592 E-01
8.66	4.66	0.15	0.241 E-01	0.371 E-01	.9020 E-01
9.50	5.50	0.16	0.199 E-01	0.307 E-01	.7464 E-01
9.66	6.84	0.17	0.483 E-01	0.744 E-01	1.8088 E-01
8.00	7.17	0.18	0.845 E-01	0.130 E-00	.3161 E-00
6.50	7.17	0.19	0.265 E-01	0.408 E-01	.9919 E-01
5.50	6.50	0.20	0.147 E-01	0.226 E-01	.5495 E-01
7.66	9.16	0.21	0.365 E-00	0.562 E-00	1.3663 E-00
7.50	9.50	0.22	0.138 E-00	0.212 E-00	.5154 E-00
7.50	10.00	0.23	0.586 E-01	0.902 E-01	2.1930 E-01
7.00	11.50	0.24	0.174 E-01	0.268 E-01	.6516 E-01
9.00	7.32	0.25	0.536 E-01	0.826 E-01	2.0082 E-01
7.50	6.50	0.26	0.234 E-01	0.360 E-01	.8752 E-01
7.66	6.84	0.27	0.667 E-01	0.103 E-00	.2504 E-00

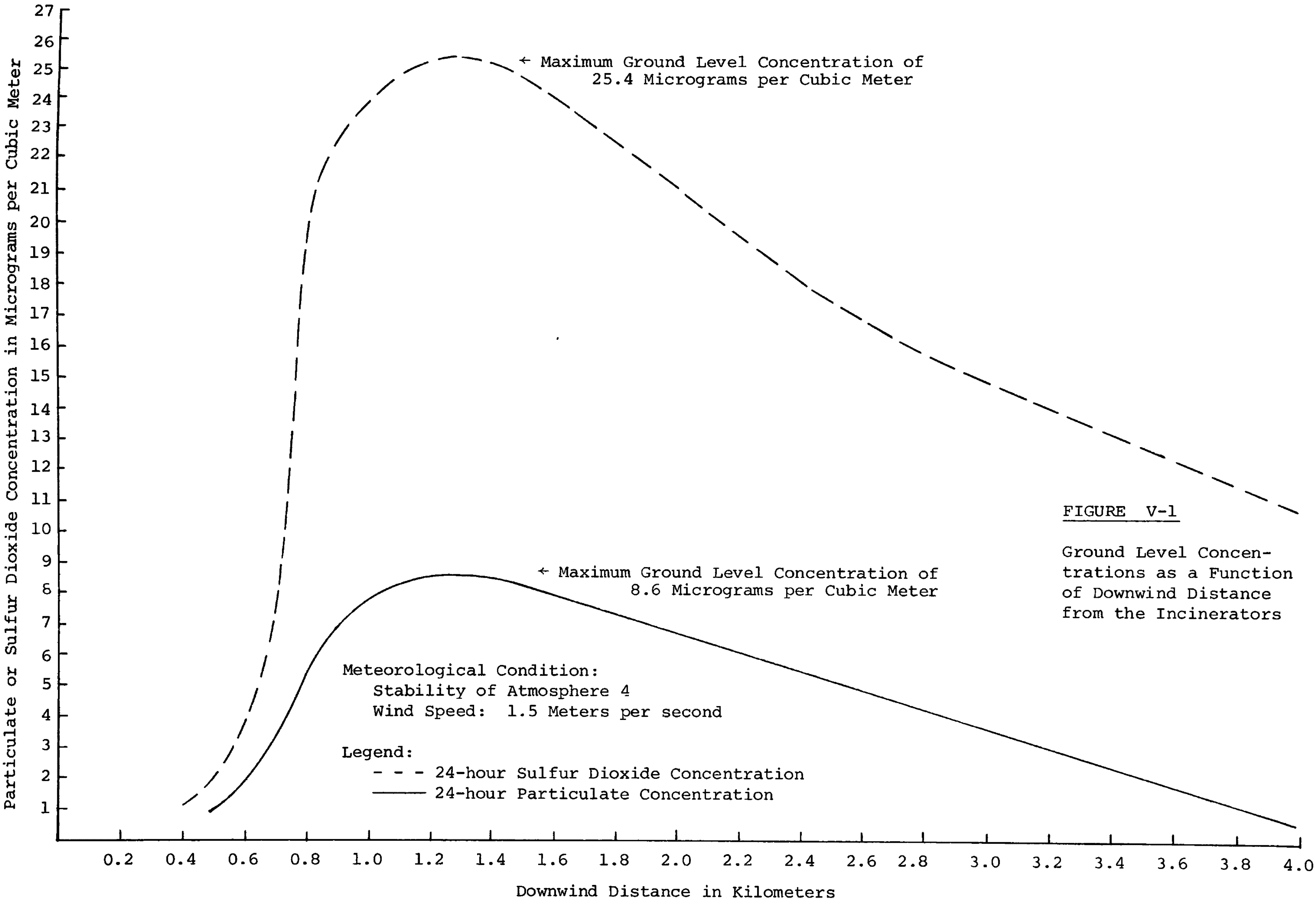


FIGURE V-1

Ground Level Concentrations as a Function of Downwind Distance from the Incinerators

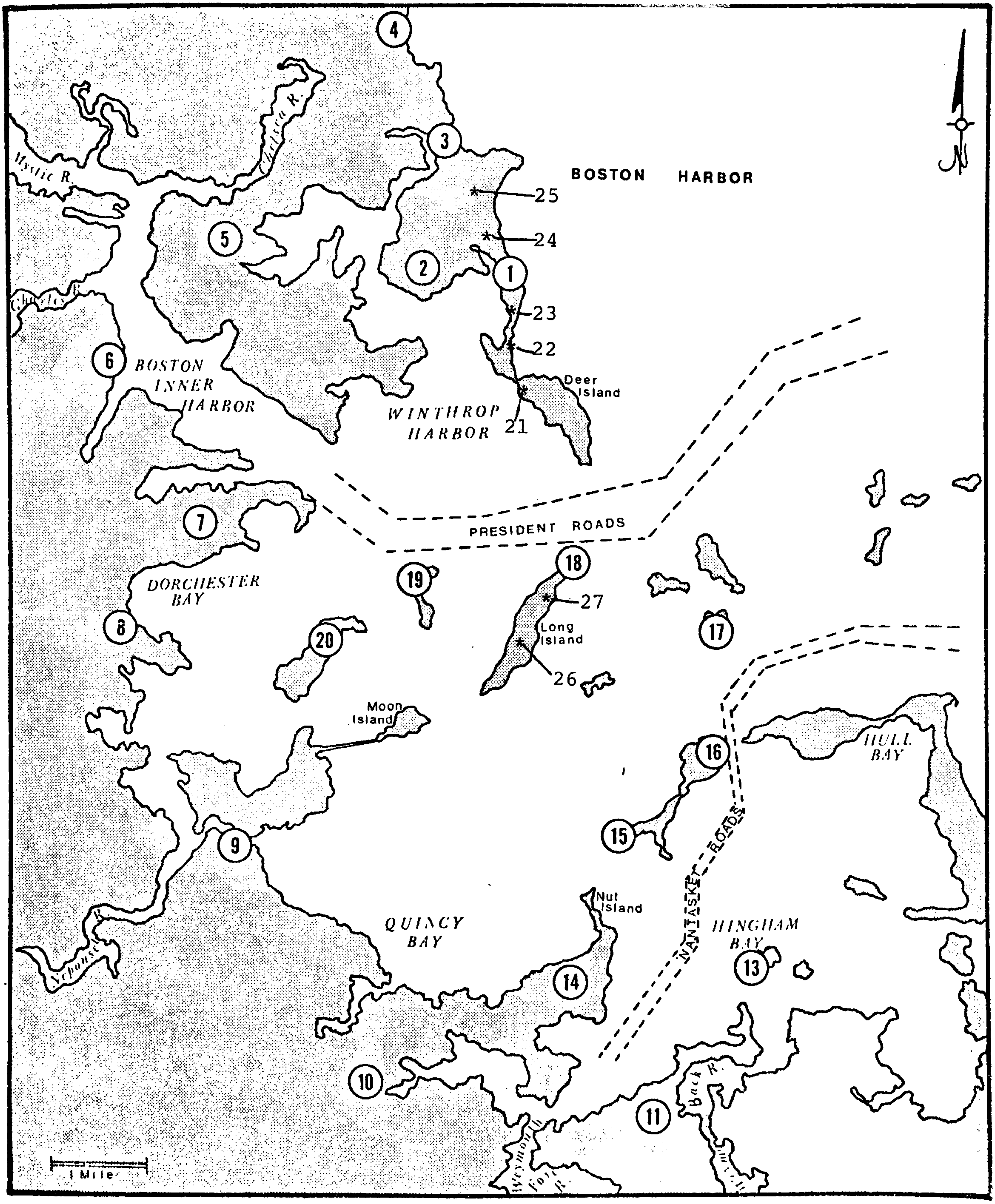


FIGURE V-2
LOCATIONS OF RECEPTOR SITES

sulfur dioxide and nitrogen oxides were found to be 0.37, 0.56, and 1.36 $\mu g/m^3$, respectively. The contours of annual particulate, sulfur dioxide, and nitrogen oxides concentrations are shown in Figures V-3, V-4 and V-5. As can be seen, the groundlevel concentrations decrease rapidly as the distance from the incinerators increase.

2. Projection of Background Concentrations in 1985

A proportional method was used to estimate 1985 background concentration of particulates and sulfur dioxide based on the 1974-1975 air quality monitoring data. The equation used in the calculation is:

$$C_{i1985} = C_{i1975} \times (1 + D_i E_i)$$

where: C_{i1985} = 1985 maximum background concentration

C_{i1975} = 1975 maximum monitoring air quality concentration

D_i = Growth rate of emissions between 1975 and 1985 for source category i

E_i = Emission reduction factor for source category i due to the emission control regulations

a. Existing Air Quality Monitoring Data: The following describes the inputs and assumptions used in the proportional method analysis. In the metropolitan Boston region, there are a number of air quality monitoring stations, none of which are located within the three-mile radium of the proposed incinerators. The closest monitoring station to Deer Island is located at Garfield Junior High School, Revere. The monitoring data is available for the period of January through December 1977. The number of observations for particulates and sulfur dioxide 24 hour concentrations at this site are 44 and 33 respectively. Although only 2 observations of 24 hour concentrations for nitrogen oxides were made at this site during 1977, the data has been considered. However, conclusions are made with reservations of the statistical meaning. The summary of the monitoring data is shown below.

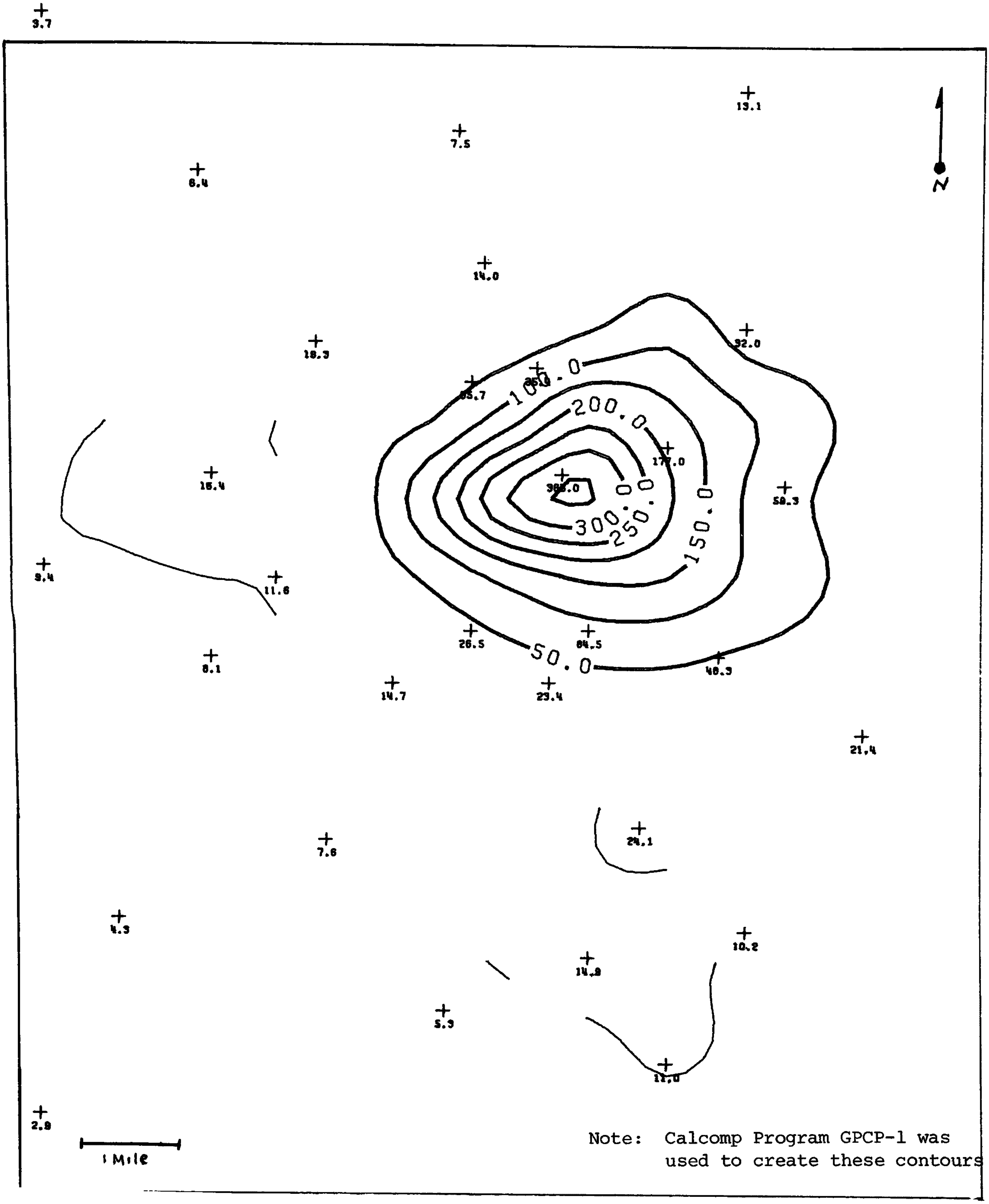
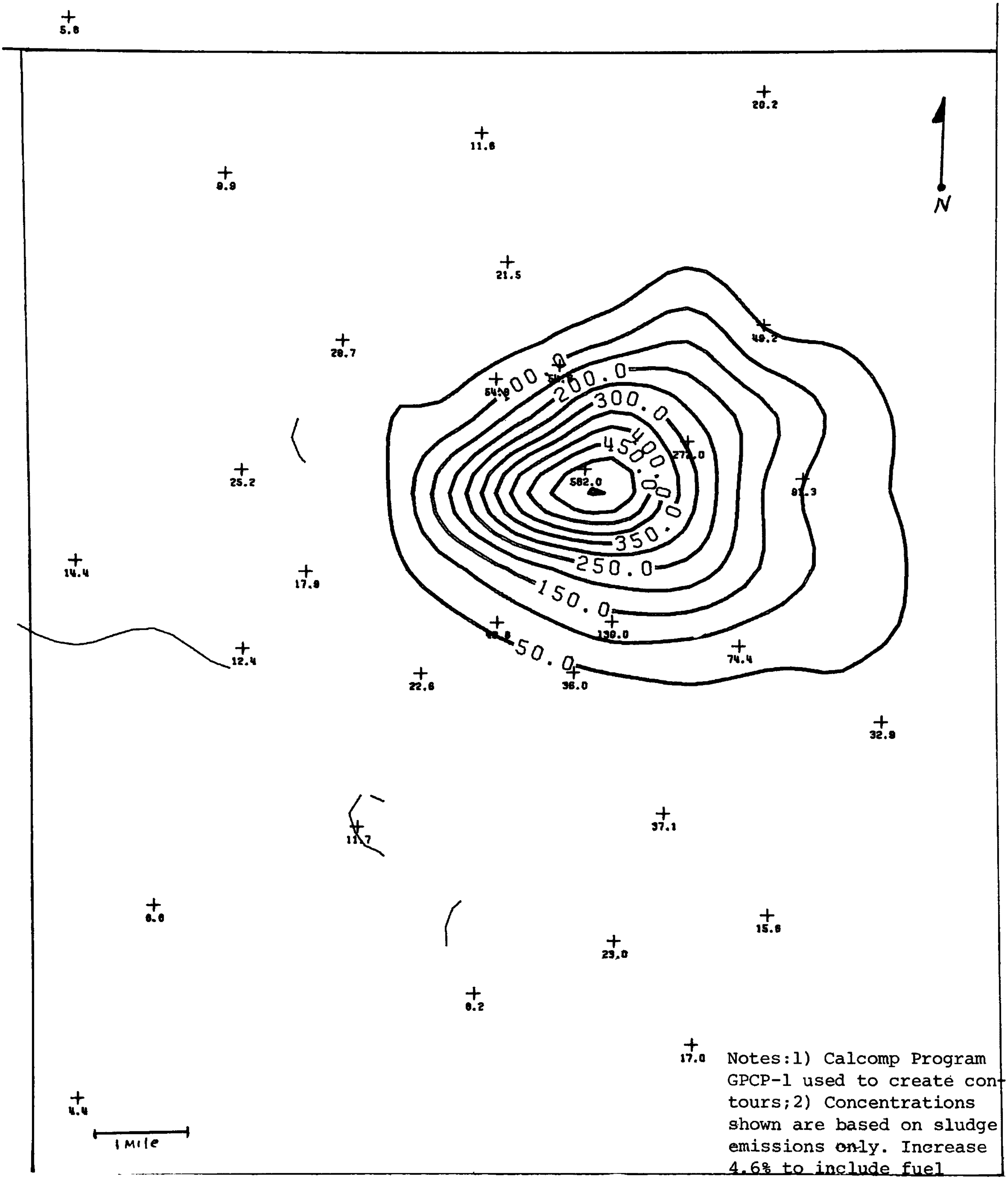


FIGURE V-3
CONTOURS OF ANNUAL PARTICULATE CONCENTRATIONS
($x10^{-3}$ MICROGRAMS PER CUBIC METER)



Notes: 1) Calcomp Program GPCP-1 used to create contours; 2) Concentrations shown are based on sludge emissions ~~only~~. Increase 4.6% to include fuel emissions.

FIGURE V-4
CONTOURS OF ANNUAL SULFUR DIOXIDE CONCENTRATIONS
($X10^{-3}$ MICROGRAMS PER CUBIC METER)

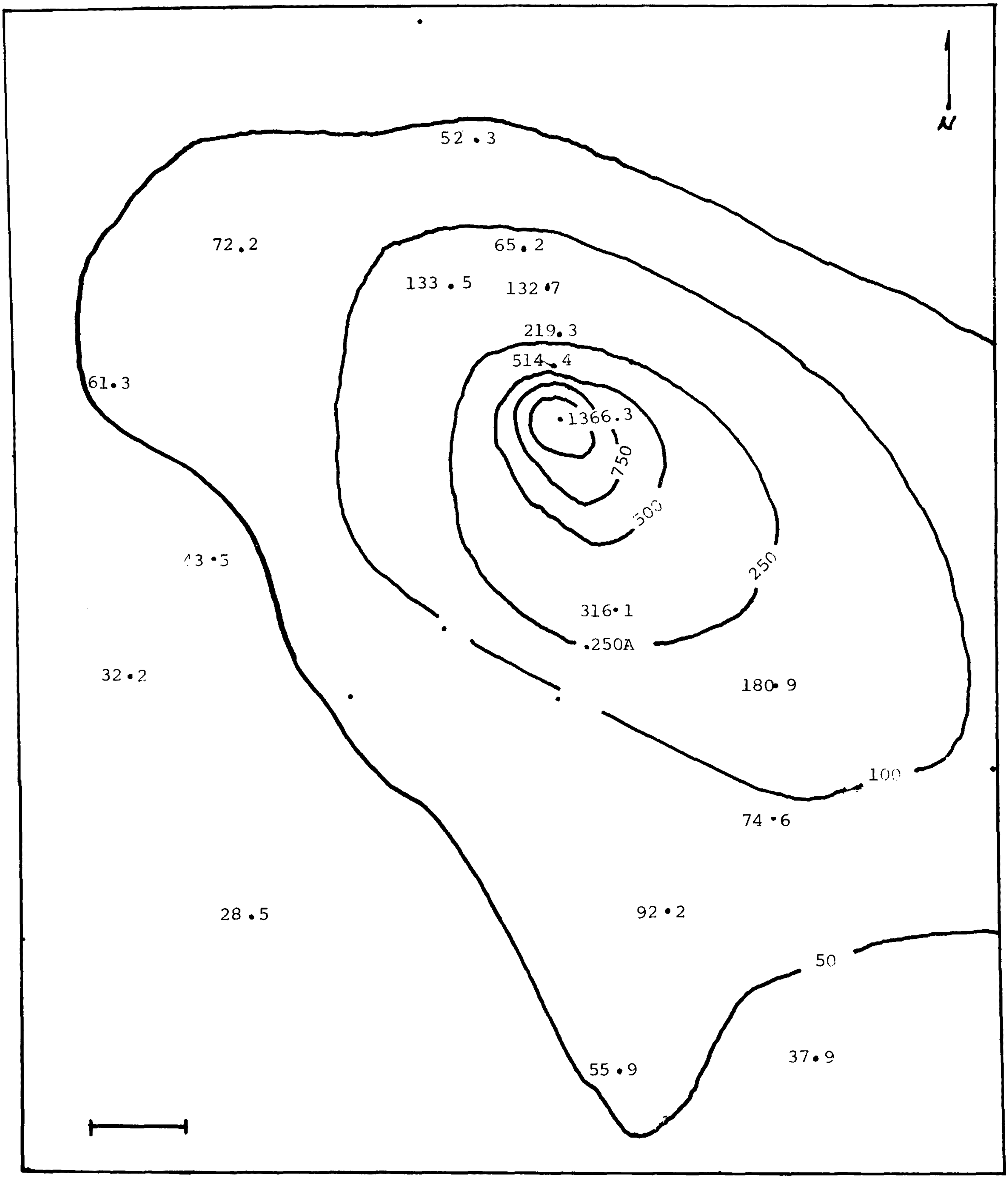


FIGURE V-5
CONTOURS OF ANNUAL NITROGEN OXIDE
CONCENTRATION ($\times 10^{-3}$ PER CUBIC METER)

SUMMARY OF MONITORING AIR QUALITY CONCENTRATIONS AT GARFIELD JR. HIGH SCHOOL, REVERE

24 Hour Concentration (Micrograms Per Cubic Meter

		Particulates		Sulfur Dioxide	Nitrogen Oxides
Number of observations		44		33	2
Minimum		23		1	15
Maximum		107		35	18
2nd Maximum		101		27	15
Arithmetic mean		51		10	17
Arithmetic standard deviation		22		9	2
Geometric Mean		47		6	16
Geometric standard deviation		1.51		2.93	1.14
Number of observations greater than	180	0	105	0	
	260	0	140	0	
	150	0	100	0	

Based on these noncontinuous sampling data the Larsen Mathematical Model (Larsen, 1971) was used to determine the maximum and second highest concentration for continuous sampling data.

The estimated maximum 24-hour concentration for TSP would be 157.9 $\mu g/m^3$ and the second highest would be 139 $\mu g/m^3$. The estimated maximum 24-hour concentration for sulfur dioxide would be 141.5 $\mu g/m^3$ and the second highest would be 102 $\mu g/m^3$. By similar analysis the estimated maximum 24-hour concentration for nitrogen oxides would be 23.5 $\mu g/m^3$ and the second highest would be 22.5 $\mu g/m^3$.

The accuracy of Larsen's model analysis is dependent on the number and the adequacy of samples collected. The results obtained with noncontinuous sampling (in this case 44, 33, and 2 for TSP, SO_2, and NO_x respectively) will not be as accurate as that obtained with continuous sampling.

b. Growth Rate of Emissions Between 1975 and 1985: According to the "Guidelines for Air Quality Maintenance Planning and Analysis" (U.S. EPA, 1974F), the growth rate of emissions for each source category can be estimated based on the parameters shown below:

Category	Projection Parameter
Fuel Combustion (excluding power plant)	Total earnings
Industrial processes	Manufacturing earnings
Solid waste	Population
Transportation	Population
Miscellaneous	Total earnings

Based on the information provided by the State Bureau of Air Quality Control (Parks, 1975), and the composite growth factors in the City of Boston between 1975 and 1985 are shown below:

Population growth	0.93
Total employment growth	1.19
Manufacturing employment growth	1.15
Non-manufacturing employment growth	1.19

It should be noted that the gorwth factors in the Boston suburd areas may be different from those of Boston City.

c. Emission Reduction Factor: For industrial process, a reduction factor of 0.4 would generally be used to account for control between 1975 and 1985 due to forthcoming new source performance standards.

d. Overall Emission Growth from 1975 to 1985: Following the "Guidelines for Air Quality Maintenance and Analysis" (U.S. EPA, 1974), the composite growth factors particulate matter and sulfur dioxide are calculated to be 1.092 and 1.159 respectively. The detailed calculation is shown in Table V-11.

e. 1985 Maximum Background Concentrations: Based on the measured baseline air quality concentrations, Larsen's Model of the estimated growth factor, and the emission adjustment factor, the maximum 24-hour background particulate, sulfur dioxide, and nitrogen oxides concentrations in 1985 are estimated as follows:

TABLE V-11

CALCULATION OF EMISSION GROWTH FROM 1975 TO 1985
(in Boston Area)

Source Category	Projection Parameter	Growth Factor of the Parameter* (D)	Reduction Factor Due to Emission Control Regulations (E)	Adjusted Growth Factor Δ	Fraction of Total Emission**		Weighted Emission Growth Factor+	
					Particulate	Sulfur Dioxide	Particulate	Sulfur Dioxide
Fuel Combustion	Total Earnings	0.19	1	1.19	0.30	0.77	0.357	0.916
Industrial Processes	Manufacturing Earnings	0.15	0.4	1.06	0.56	0.20	0.594	0.212
Solid Waste	Population	-0.07	1	0.93	0.03	0	0.028	0
Transportation	Population	-0.07	1	0.93	0.07	0.02	0.065	0.019
Miscellaneous	Total Earnings	0.19	1	1.19	0.04	0.01	0.048	0.012
				Composite Growth Factor			1.092	1.159

* These are the growth factors projected for the City of Boston, provided by the State Air Pollution Control Commission.

** Based on 1974 nationwide emissions data, obtained from U.S. EPA, National Air Data Branch, Research Triangle Park, North Carolina

\+ Weighted growth factor = adjusted growth factor x fraction of total emission for each source.

Δ Adjusted Growth Factor = 1 + Growth Factor, D x Reduction Factor (E).

	Maximum Background Concentration		Second Highest Background Concentration	
	1977	1985	1977	1985
24-hr. particulate concentration ($\mu g/m^3$)	157.9	172.4	139	151.8
24-hr. sulfur dioxide concentration ($\mu g/m^3$)	141.5	164	102	118.2
24-hr nitrogen oxides concentration ($\mu g/m^3$)	23.5	27.2	22.5	26.1

Again using the Larsen Model, the maximum second highest concentration for other averaging times are estimated based on these 24-hour concentrations. These results are given below:

Pollutant ($\mu g/m^3$)	Averaging Time	1985 Maximum Background Concentration	1985 Second Highest Background Concentration
Particulates	24 hour	172.4	151.8
	annual	52.5	52.5
Sulfur dioxide	24 hour	164.0	118.2
	3 hours	418.4	301.6
	annual	11.6	11.6
Nitrogen oxides	1-hour	32.6	31.2
	annual	19.7	19.7

3. Assessment of the Air Quality Impact of Incineration Alternatives

The air quality impact can be assessed in terms of whether or not the proposed project will comply with the Clean Air Act Amendment's of August 17, 1977 section Prevention of Significant Deterioration of Air Quality., as well as meet the Federal and Massachusetts Air Quality Standards. The following section discusses the air quality impact of the proposed incineration alternatives.

a. Complying with the Regulations for the Prevention of Significant Deterioration of Air Quality: Requirements in the Clean Air Act Amendments of 1977 provide for the Prevention of Significant Deterioration (PSD) of ambient air quality. Under these provisions ambient concentrations for the five pollutants for which National Ambient Air Quality Standards (NAAQS) were set under the Clean Air Act of 1970 are compared to the NAAQS. Based on these results air quality designations are assigned.

1. Attainment Area - Ambient air concentrations of the specific pollutant for a given region are less that the established NAAQS for the pollutant.

2. Non-Attainment Area- Ambient air concentrations of the specified pollutant for a given region exceed the NAAQS for that pollutant.

The PSD program has also established regional air quality classes and air quality standards for the degradation of air quality.

Class I - Areas in which practically any incremental change in air quality would not be allowed.

Class II - Areas in which deterioration normally accompanying moderate well-controlled growth would be allowed.

Class III- Areas in which larger incremental deterioration of air quality would be allowed.

Incremental increase in pollutant levels should not exceed NAAQS. Further, those areas designated as non-attainment would be required to reduce a pollutant's emission equal to or greater than proposed emissions before a major expansion or new major source would be allowed.

Presently, PSD class standard (incremental allowances) exist for sulfur dioxide and particulates. Within two years of August 7, 1977, class standards will be promulgated for nitrogen oxides, carbon monoxide, and hydrocarbons.

The study area has been designated as an attainment area and also a Class II area. Table V-12 gives the maximum allowable incremental increases in pollutant concentrations over baseline air quality concentration for each area designation. Table V-13 compares impact with the standard.

TABLE V-12

PREVENTION OF SIGNIFICANT DETERIORATION OF AIR QUALITY CLASS INCREMENTS

Pollutant	Maximum Allowable Increase ($\mu g/m^3$) Class I	Class II	Class III
Particulate Matter			
Annual Geometric Mean	5	19	37
24-hour maximum	10	37	75
Sulfur Dioxide			
Annual Arithmetic Mean	2	20	40
24-hour maximum	5	91	182
3-hour maximum	25	512	700

TABLE V-13

PREVENTION OF SIGNIFICANT DETERIORATION OF AIR QUALITY. COMPARISON OF MAXIMUM PROJECT-GENERATED CONCENTRATIONS WITH THE ALLOWABLE INCREMENTAL CONCENTRATION

Pollutant	Allowable Class II Deterioration	Maximum Incremental Concentration Resulting from the Incinerators
Particulate Matter		
Annual Geometric Mean	19	0.36
24-hour maximum	37	8.4
Sulfur Dioxide		
Annual Arithmetic Mean	20	0.56
24-hour maximum	91	25.4
3-hour maximum	512	85.3

b. Meeting the Federal and Massachusetts Ambient Air Quality Standards: Except for the annual average concentrations, the Federal and Massachusetts Air Quality Standards are defined such that they may not be exceeded more than once a year. Thus, in the case of 1, 3, and 24-hour concentration, an analysis was made to determine whether the second highest ambient concentrations (project-generated plus background) will exceed the standards. The second highest ambient concentrations are obtained by superimposing the maximum project-generated concentrations on top of the projected second highest 1985 background concentrations. The calculated results are shown and compared with the air quality standards in Table V-14.

TABLE V-14

COMPARISON OF THE PROJECTED 1985 GROUND LEVEL CONCENTRATIONS WITH AMBIENT AIR QUALITY STANDATDS AT A DISTANCE OF 1.25KILOMETERS DOWNWIND FROM THE INCINERATOR

Pollutant	Averaging Time	Maximum Incinerator - Generated Concentration	Second Highest 1985 Background Concentration	Second Highest Total Concentration	Federal Standards[1] Primary	Federal Standards[1] Secondary	Massachusetts Standards[1] Primary	Massachusetts Standards[1] Secondary
Particulates	24-hr	8.4[2]	151.8	160.2	260	150	260	150
μg/m^3)	annual	0.36[2]	52.5	52.86	75	60	75	60
Sulfur Dioxide	3-hr	85.3[2]	301.6	386.9	-	1,300	-	1,300
μg/m^3)	24-hr	25.4[2]	118.2	143.6	365	-	365	-
	annual	0.56[3]	11.6	12.16	80	-	80	-
Nitrogen	1-hr	163.5	31.2	194.7	200	-	-	-
Oxides (μg/m^3)	annual	1.37	19.7	21.07	100	100	100	100

[1]Other than annual average may not be exceeded more than once a year.

[2]The locations of maximum ground level concentration are a a distance of 1.253 kilometer downwind from the incinerators. These may include Winthrop, Shirley Point, and the northern part of Long Island. Because no monitoring data are available at these locations, the etimated concentration based on air quality sampling data at the Revere site were used. The actual background concentration at these locations may be less than at Revere because of the lower level of land use activity at these locations.

[3]The locations of maximum concentration are at receptor 21 on Deer Island (see Figure 2). Maximum annual average ground level concentration includes SO_2 from pilot and startup fuel.

[4]World Health Organization Standard-not a federal or state standard.

Since the annual average standards are never to be exceeded, the maximum annual concentrations resulting from the project were calculated. The results are compared with the standards in Table V-14.

As shown in Table V-14, none of the promulgated Federal of Massachusetts Ambient Air Quality Standards for particulates, nitrogen oxides, or sulfur dioxide will be exceeded in the study year except for the 24-hour particulate secondary standard. It should be noted that the background concentration is responsible for violation of the secondary 24-hour particulate standard at these locations, 1.25 km downwind of the incinerators. The incinerator-generated concentration accounts for 8.4 $\mu g/m^3$ compared to the 151.8 $\mu g/m^3$ background level. The nitrogen oxides 1-hour World Health Organization standard was not exceeded. As noted previously, these locations 1.25 km downwind may include the northern par of Long Island, Winthrop and Point Shirley. As no measured air quality data were available at these locations, the estimated background concentrations based on monitoring data at Revere were used. The actual background at these locations may be expected to be less than at Revere because the level of polluting land use activities is less than at Revere. Another assumption used in projecting the 1985 background concentration is the assumption of no reduction of existing source emissions in the 1977-1985 period. This is a conservative assumption because the existing stationary source emissions are expected to be reduced through the State Implementation Plan requirement for emission limitations on existing sources and the State Attainment Plan for secondary standards. These are presently being revised as per the 1977 Clean Air Act Amendment.

As the proposed incinerators will comply with the New Source Performance Standards for particulates and the violation of the 24-hour particulate secondary standard will not be the direct result of the incinerators, the potential mitigating measures should emphasize the control of background concentration through the Air Quality Attainment and Maintenance Plan. As the State Attainment Plan for secondary standards is presently under way, it is suggested that the proposed incinerators be considered in that plan.

c. Air Quality Analysis for the Areas where Violations of the 24-hour TSP Standard Occur: In addition to impacts of incineration on the air quality at Revere, the existing sampling site with greatest impact, there will be some impact on those sites presently exceeding ambient air quality standards in 1974-75. Based on the Regional Administrator's Annual Report "Environmental Quality in New England" (U.S. EPA, 1975E), those sites which exceed the 24-hour standards for TSP are:

Boston, Kenmore Square
Cambridge, Science Park
Medford, Fire Headquarters
Medford, Wellington Circle
Qunicy, Fore River

The 1977 24-hour sampling data collected at the five sites under consideration are given in Tables V-15, V-16, and V-17. Based on these noncontinuous sampling data, the maximum and second highest concentrations were estimated for continuous sampling data using Larsen's Model. The 1985 maximum and second highest concentrations for TSP were projected by using the proportional model; the TSP composite emission growth factor of 1.092 was used in the calculation. The results are given in Table V-18.

The incremental TSP concentrations resulting at the five monitoring sites under consideration from the proposed incinerators were estimated, based on the outputs of previous PTMTP and CDM analyses. The results are presented in Table V-19. These incremental TSP concentrations resulting from the incinerators are compared to Table V-20 with the maximum allowable incremental concentrations set forth in the Class II increments were considered in this analysis because this area has been designated Class II. Based on the assumptions made, none of the incremental concentrations will exceed the standards.

The second highest ambient TSP concentrations are obtained by superimposing the maximum project-generated concentrations on the projected second highest 1985 background concentrations. The results are shown in Table V-21. It can be seen that the 24-hour and annual primary secondary standards will be exceeded at Kenmore Square. The 24-hour annual secondary standards will be exceeded at all five locations. Also, the primary 24-hour standard at Science Park and Wellington Circle will be exceeded. None of the violations of standards at these locations are the direct result of the incremental concentrations, but are due to high background concentrations.

TABLE V-15

1974 24-HOUR TSP DATA FOR FIVE SELECTED SITES

[Source: EPA, Region I]

Monitoring Site	Kenmore Square (Boston)	Science Park (Cambridge)	Fire Station (Medford)	Wellington Circle (Medford)	Fore River (Quincy)
Number of Observations	39	48	47	36	44
Minimum reading ($\mu g/m^3$)	31	1	22	1	26
Maximum reading ($\mu g/m^3$)	305	116	145	161	119
2nd maximum ($\mu g/m^3$)	270	115	131	111	114
Arithmetic Mean ($\mu g/m^3$)	97	68	60	62	65
Arithmetic Standard Deviation ($\mu g/m^3$)	64	23	27	26	26
Geometric Mean ($\mu g/m^3$)	82	61	55	54	59
Geometric Mean Deviation ($\mu g/m^3$)	1.72	1.97	1.51	2.13	1.53

TABLE V-16

1977 24-HOUR SO_2 DATA FOR FIVE SELECTED SITES

Monitoring Sites	Kenmore Square (Boston)	Science Park (Cambridge)	Fire Station (Medford)	Wellington Circle (Medford)	Fore River (Quincy)
Number of Observations	31	38	29	34	36
Minimum Reading (g/m^3)	1	1	1	1	1
Maximum Reading (g/m^3)	45	45	24	23	49
2nd Maximum (g/m^3)	33	26	22	19	
Arithmetic Mean (g/m^3)	13	11	8	8	9
Arithmetic Standard Deviation (g/m^3)	10	9	7	6	10
Geometric Mean (g/m^3)	10	8	5	6	5
Geometric Standard Deviation (g/m^3)	2.44	2.45	2.98	2.31	2.99

TABLE V-17

1977 24-HOUR NO_X DATA FOR FIVE SELECTED SITES

Monitoring Site	Kenmore Square (Boston	Science Park (Cambridge)	Fire Station (Medford)	Wellington Circle (Medford)	Fore River (Quincy)
Number of Observations	42	44	1	43	44
Minimum Reading ($\mu g/m^3$)	21	14	15	1	1
Maximum Reading ($\mu g/m^3$)	62	61	15	77	69
2nd Maximum ($\mu g/m^3$)	61	53	-	50	46
Arithmetic Mean ($\mu g/m^3$)	44	33	15	32	25
Arithmetic Standard Deviation ($\mu g/m^3$)	9	10	0	14	11
Geometric Mean ($\mu g/m^3$)	42	31	15	26	22
Geometric Standard Deviation ($\mu g/m^3$)	1.26	1.37	1.0	2.53	1.89

TABLE V-18

PROJECTED PARTICULATE MATTER TSP CONCENTRATIONS ($\mu g/m^3$)
(Background Data)

Monitoring Site	Maximum Concentration 1977	Maximum Concentration 1985	2nd Highest Conc. 1977	2nd Highest Conc. 1985	Geometric Mean 1977	Geometric Mean 1985	Annual Mean (Arithmetic) 1977	Annual Mean (Arithmetic) 1985
Kenmore Square (Boston)	403.9	441.1	343	374.6	82	90	97	106
Science Park (Cambridge)	447.8	489.0	365	398.6	61	67	68	74
Fire Station (Medford)	184	200.9	163	178.0	55	60	60	66
Wellington Circle (Medford)	498	543.8	397	433.5	54	60	62	68
Fore River (Quincy)	206.0	225.0	181.3	198.0	59	64	65	71

TABLE V-19

INCREMENTAL TSP CONCENTRATIONS

Monitoring Site	Distance from the Incinerators*	Maximum Incremental Concentrations** 24-Hour	Annual
Kenmore Square (Boston)	11.7 km	.92 μg/m³	0.005 μg/m³
Science Park (Cambridge)	9.7 km	1.14 μg/m³	0.006 μg/m³
Medford (Fire Station)	14.7 km	.65 μg/m³	0.003 μg/m³
Medford (Wellington Circle)	15.0 km	.62 μg/m³	0.003 μg/m³
Quincy (Fore River)	11.0 km	.95 μg/m³	0.005 μg/m³

* Approximate distances obtained from map, scale 1" = 1.6 mi.
** Based on model data shown in Table V-4

TABLE V-20

INCREMENTAL CONCENTRATIONS COMPARED TO NON-DEGRADATION LIMITS

Monitoring Site	24-Hour TSP (μg/m³) Maximum Allowable Incremental Concentration Limit = 30 **	Annual TSP (μg/m³) Maximum Allowable Incremental Concentration Limit = 10 **
Kenmore Square (Boston)	.92	0.005
Science Park (Cambridge)	1.14	0.008
Fire Station (Medford)	.65	0.003
Wellington Circle (Medford)	.62	0.003
Fore River (Quincy)	.95	0.007

* Source: Table V-15
** Source: 40 CFR 52

TABLE V-21

AIR QUALITY ANALYSIS FOR THE AREAS WHERE VIOLATIONS OF THE 24-HOUR STANDARD OCCUR

Monitoring Site	Averaging Time	Maximum Incinerator Generated Conc.	1985 Background Concentration	Second Highest Total Concentration	Federal Standard Primary	Federal Standard Secondary	Mass. Standard Primary	Mass. Standard Secondary
Kenmore Square (Boston)	24-hour	.91	374.6	375.52	260	150	260	150
	Annual	.005	106	106.005	75	60	75	60
Science Park (Cambridge)	24-hour	1.14	398.6	399.74	260	150	260	150
	Annual	.008	74	74.008	75	60	75	60
Fire Station (Medford)	24-hour	.65	178.0	178.65	260	150	260	150
	Annual	.003	68	66.003	75	60	75	60
Wellington Circle (Medford)	24-hour	.62	433.5	434.12	260	150	260	150
	Annual	.003	68	68.003	75	60	75	60
Fore River (Quincy)	24-hour	.95	198.0	198.95	260	150	260	150
	Annual	.007	71	71.007	75	60	75	60

Units = $\mu g/m^3$

APPENDIX W

MODELS FOR AIR QUALITY PREDICTIONS

The three air quality models used in this study are presented in detail below. These models are PTMAX, PTMTP, and the Climatological Dispersion Model (CDM).

A. PTMAX Model

The following discussion of the PTMAX model, written by D. B. Turner, is excerpted from the author's draft User's Guides (Turner and Busse, 1973).

The PTMAX model calculates the maximum hourly ground level concentration resulting from a single stack as the function of wind speed and stability class. The input data required for the computer program includes stack parameters, such as stack height, inside diameter, effluent gas velocity and temperature, and emission rate; ambient air temperature; and atmospheric pressure. The printed output includes effective height of emissions, maximum ground level concentration, and distance of maximum concentration for each condition of stability and wind speed. The input data used for each particular calculation are also printed.

This model is based primarily on the steady-state Gaussian plume model; that is, the concentration of pollutants within the plume generated by the stack are distributed normally in both the cross-wind and vertical directions. The method suggested by Briggs (1971) is used to determine the rise of the plume above the stack. The Briggs plume rise formula is:

$$\Delta h = 1.6F^{1/3}U^{-1}\rho^{2/3} \qquad \rho \leq 3.5X^*$$

and

$$\Delta h = 1.6F^{1/3}U^{-1}(3.5X^*)^{2/3} \qquad \rho > 3.5X^*$$

$$X^* = 14F^{5/8} \text{ if } F < 55$$
$$X^* = 34F^{2/5} \text{ if } F \geq 55$$

where
- Δh = plume rise, meters
- $F = gV_sR_s^2 \; [(T_s - T_a)/T_s]$
- g = acceleration due to gravity, m/sec^2
- V_s = average exit velocity of gases of plume, m/sec
- R_s = inner radius of stack, meters
- T_s = average temperature of gases in plume, °K
- T_a = ambient air temperature, °K
- U = wind speed at stack height, m/sec
- ρ = distance from source to receptor, meters

As suggested by Briggs, ρ/X^* was not allowed to exceed the limiting value of 3.5.

The effective height, i.e., the sum of the physical stack height and the rise of the plume, is used to determine the maximum ground level concentration. If the effective heights of emissions were the same under all stability classes, the maximum ground level concentration from a given stack would occur with the lightest winds. However, as shown in Briggs' equation, the plume rise is an inverse function of wind speed. The maximum ground level concentration generally occurs at some intermediate wind speed, at which a balance is reached between dilution due to wind speed and the effect of emission height. The procedures to determine the maximum ground level concentration, the distance to the maximum concentration, and the corresponding wind speed are the same as those discussed in the report entitled "Workbook of Atmospheric Dispersion Estimates." The principal assumptions or limitations of this model are listed below:

- Does not account for aerodynamic effects of buildings or other topographic obstructions on the diffusion of the plume emitted from the stack.
- The emission rate and wind speed are assumed to be constant for the time period considered, i.e., one hour.
- This model is capable of predicting the maximum concentrations from a single point source only. In the case of multiple stacks, this model can be applied to each individual stack; however, it cannot give the maximum combined concentrations of the stacks.

B. PTMTP Model

This model is also written by D. B. Turner. The User's Guide to PTMTP, prepared by D. B. Turner and A. D. Busse, is excerpted below.

Users' Guide to PTMTP (The Interactive Version of DBT 51)

Program Abstract

PTMTP produces hourly concentrations at up to 30 receptors whose locations are specified from up to 25 point sources. A Gaussian plume model is used. Inputs to the program consist of the number of sources to be considered, and for each source the emission rate, physical height, stack gas temperature, volume flow, or stack gas velocity and diameter, the location, in coordinates. The number of receptors, the coordinates of each and the height above ground of each receptor are also required. Concentrations for a number of hours up to 24 can be estimated, and an average concentration over this time period is calculated. For each hour the meteorological information required is: wind direction, wind speed, stability class, mixing height, and ambient air temperature.

The assumptions that are made in this model follow: Meteorological conditions are steady-state for each hour and a Gaussian plume model is applicable to determine ground level concentrations. Computations can be performed according to the "Workbook of Atmospheric Dispersion Estimates." The dispersion parameter values used for the horizontal dispersion coefficient, sigma y, and the vertical dispersion coefficient, sigma z, are those given in Figures 3-2 and 3-3 of the Workbook. The sources and receptors exist in either flat or gently rolling terrain, and the stacks are tall enough to be free from building turbulence so that no aerodynamic downwash occurs. The wind speed and wind direction apply from the shortest to the tallest plume height. No wind direction shear or wind speed shear occurs. The given stability exists from ground-level to well above the top of the plume.

Calculations for each hour are made by considering each source-receptor pair. Plume rise is calculated according to Briggs' plume rise estimates. For each source-receptor pair, the downwind and crosswind distances are determined. If the downwind distance is closer than the distance to final rise, the plume rise for this distance is calculated. The concentration from this source upon this receptor is determined using these distances by the Gaussian model.

The use of the interactive version of the program is relatively straightforward. First, an alphanumeric title to identify the output is entered. Next, the number of sources to be considered is given. The source strength, physical height, stack gas temperature, and volume flow is entered for each stack. If the volume flow is not known the stack gas velocity and diameter are required. The coordinates based on a coordinate system having units of one kilometer are required for each source. Next, the number of receptors to be processed, the coordinates of each and the height above ground for each are entered. The meteorological information includes the number of hours to be averaged up to 24, the wind direction, wind speed, stability class, mixing height, and ambient air temperature are entered for each hour. An option exists to print the partial concentrations, that is, the concentration from each source at each receptor. Also, an option exists to print the hourly concentrations.

The output is quite simple, consisting of title followed by input information on the sources, receptors, and meteorology. This is followed by hour by hour partial concentrations if desired and total concentrations. If partial concentrations are printed the final plume height for that hour for each source is also printed. Then average concentrations for the time period are printed including partial concentrations if desired. When the output is complete, the user is offered the option of ending the run or entering at 3 different points. He may go back to enter new sources or he may keep the same sources and enter new receptors or he may keep both the same sources and receptors and enter only different meteorological conditions.

C. The Climatological Dispersion Model

The Climatological Dispersion Model (CDM), developed by the U.S. EPA (Busse and Zimmerman) calculates long-term quasi-stable pollutant concentrations at any ground level receptor using average emission rates from point and area sources and a joint frequency distribution of wind direction, wind speed, and stability for the same period.

This model uses primarily the Gaussian dispersion model to calculate the ground level concentrations from point and area sources. For the elevated point sources, Briggs' plume rise formula and an assumed power law increase in wind speed with height are used to calculate the effective height of the elevated sources. Figure W-1 defines the concentration formulas for the CDM model. The detailed description of the model and its assumptions and application may be found in the U.S. EPA publication entitled User's Guide for the Climatological Dispersion Model.

For this study, the stack emission rates as given in the text, and the frequency distribution of wind data for Logan Airport as shown in Table W-1, were input to the model to estimate annual average concentrations of TSP and SO_2. The receptor sites for calculation of concentrations are discussed in the text. The points were selected to be representative of the sludge incinerator impact area. The calculated annual concentrations of TSP and SO_2 are also shown in the text. It should be pointed out that the model was not calibrated because no appropriate observation data were available. Thus, in the text the total concentrations are the same as the calibrated concentrations.

FIGURE W-1

CDM Concentration Formulas

The average concentration $\overline{C}_A$ due to area sources at a particular receptor is given by

$$\overline{C}_A = \frac{16}{2\pi} \int_0^{\infty} \left[\sum_{k=1}^{16} q_k(\rho) \sum_{\ell=1}^{6} \sum_{m=1}^{6} \phi(k,\ell,m) S(\rho, z; U_\ell, P_m) \right] d\rho \qquad (1)$$

where

k = index identifying wind direction sector

$q_k(\rho) = \int Q(\rho,\theta)\, d\theta$ for the k sector

$Q(\rho,\theta)$ = emission rate of the area source per unit area and unit time

ρ = distance from the receptor to an infinitesimal area source

θ = angle relative to polar coordinates centered on the receptor

ℓ = index identifying the wind speed class

m = index identifying the class of the Pasquill stability category

$\phi(k,\ell,m)$ = joint frequency function

$S(\rho, z; U_\ell, P_m)$ = dispersion function defined in Equations 3 and 4

z = height of receptor above ground level

U_ℓ = representative wind speed

P_m = Pasquill stability category

For point sources, the average concentration $\overline{C}_p$ due to n point sources is given by

$$\overline{C}_p = \frac{16}{2\pi} \sum_{n=1}^{n} \sum_{\ell=1}^{6} \sum_{m=1}^{6} \frac{\phi(k_n,\ell,m) G_n S(\rho_n, z; U_\ell, P_m)}{\rho_n} \qquad (2)$$

where

k_n = wind sector appropriate to the n^{th} point source

G_n = emission rate of the n^{th} point source

ρ_n = distance from the receptor to the n^{th} point source

If the receptor is presumed to be at ground level, that is, $z = 0$, then the functional form of $S(\rho, z; U_\ell, P_m)$ will be

$$S(\rho, 0; U_\ell, P_m) = \frac{2}{\sqrt{2\pi}\, U_\ell\, \sigma_z(\rho)} \exp\left[-\frac{1}{2}\left(\frac{h}{\sigma_z(\rho)}\right)^2\right] \exp\left(\frac{-0.692\rho}{U_\ell T_{\frac{1}{2}}}\right) \qquad (3)$$

if $\sigma_z(\rho) \leq 0.8$ L and

$$S(\rho, 0; U_\ell, P_m) = \frac{1}{U_\ell L} \exp\left(\frac{-0.692\rho}{U_\ell T_{\frac{1}{2}}}\right) \qquad (4)$$

if $\sigma_z(\rho) > 0.8$ L. New terms in Equations 3 and 4 are defined as follows:

$\sigma_z(\rho)$ = vertical dispersion function, i.e., the standard deviation of the pollution concentration in the vertical plane

h = effective stack height of source distribution, i.e., the average height of area source emissions in the k^{th} wind direction sector at radial distance ρ from the receptor

L = the afternoon mixing height

$T_{\frac{1}{2}}$ = assumed half life of pollutant, hours

The possibility of pollutant removal by physical or chemical processes is included in the program by the decay expression $\exp(-0.692\rho / U_\ell T_{\frac{1}{2}})$.

The total concentration for the averaging period is the sum of concentrations of the point and area sources for that averaging period.

TABLE W-1

THE JOINT FREQUENCY FUNCTION FOR STABILITY CLASS 1

	0-3 knots	4-6 knots	7-10 knots	11-16 knots	17-21	≥21 knots
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0
5	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
6	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
7	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
8	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
9	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
10	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0
12	0.900000E-04	0.700000E-04	0.0	0.0	0.0	0.0
13	0.100000E-04	0.700000E-04	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0

Fogenbaum Data

THE JOINT FREQUENCY FUNCTION FOR STABILITY CLASS 2

1	0.370000E-03	0.140000E-03	0.210000E-03	0.0	0.0	0.0
2	0.150000E-03	0.0	0.140000E-03	0.0	0.0	0.0
3	0.700000E-04	0.0	0.0	0.0	0.0	0.0
4	0.100000E-04	0.210000E-03	0.480000E-03	0.0	0.0	0.0
5	0.310000E-03	0.410000E-03	0.960000E-03	0.0	0.0	0.0
6	0.170000E-03	0.410000E-03	0.820000E-03	0.0	0.0	0.0
7	0.210000E-03	0.103000E-02	0.171000E-02	0.0	0.0	0.0
8	0.800000E-04	0.140000E-03	0.210000E-03	0.0	0.0	0.0
9	0.230000E-03	0.140000E-03	0.620000E-03	0.0	0.0	0.0
10	0.100000E-04	0.140000E-03	0.0	0.0	0.0	0.0
11	0.100000E-03	0.410000E-03	0.410000E-03	0.0	0.0	0.0
12	0.180000E-03	0.550000E-03	0.820000E-03	0.0	0.0	0.0
13	0.410000E-03	0.750000E-03	0.137000E-02	0.0	0.0	0.0
14	0.140000E-03	0.210000E-03	0.410000E-03	0.0	0.0	0.0
15	0.800000E-04	0.210000E-03	0.340000E-03	0.0	0.0	0.0
16	0.100000E-04	0.140000E-03	0.270000E-03	0.0	0.0	0.0

THE JOINT FREQUENCY FUNCTION FOR STABILITY CLASS 3

1	0.800000E-04	0.960000E-03	0.247000E-02	0.140000E-03	0.0	0.0
2	0.300000E-04	0.550000E-03	0.480000E-03	0.0	0.0	0.0
3	0.150000E-03	0.750000E-03	0.620000E-03	0.0	0.0	0.700000E-04
4	0.0	0.410000E-03	0.257000E-02	0.480000E-03	0.700000E-04	0.0
5	0.700000E-04	0.480000E-03	0.592000E-02	0.397000E-02	0.140000E-03	0.0
6	0.220000E-03	0.820000E-03	0.589000E-02	0.247000E-02	0.270000E-03	0.0
7	0.100000E-04	0.890000E-03	0.548000E-02	0.116000E-02	0.0	0.0
8	0.100000E-04	0.890000E-03	0.103000E-02	0.270000E-03	0.0	0.0
9	[illegible]	0.820000E-03	0.253000E-02	0.410000E-03	0.700000E-04	0.700000E-04
10	0.0	0.340000E-03	0.144000E-02	0.620000E-03	0.270000E-03	0.0
11	0.700000E-04	0.480000E-03	0.151000E-02	0.960000E-03	0.140000E-03	0.0
12	0.100000E-04	0.137000E-02	0.418000E-02	0.205000E-02	0.550000E-03	0.700000E-04
13	0.800000E-04	0.103000E-02	0.541000E-02	0.233000E-02	0.480000E-03	0.0
14	0.100000E-04	0.680000E-03	0.295000E-02	0.110000E-02	0.700000E-04	0.700000E-04
15	0.800000E-04	0.680000E-03	0.384000E-02	0.103000E-02	0.140000E-03	0.0
16	0.150000E-03	0.620000E-03	0.199000E-02	0.270000E-03	0.0	0.0

SECTOR

THE JOINT FREQUENCY FUNCTION FOR STABILITY CLASS 4

1	0.220000E-03	0.287500E-02	0.921000E-02	0.113000E-01	0.277500E-02	0.925000E-03
2	0.235000E-03	0.168000E-02	0.342500E-02	0.459000E-02	0.137000E-02	0.685000E-03
3	0.135000E-03	0.123500E-02	0.452000E-02	0.531000E-02	0.181500E-02	0.130000E-02
4	0.335000E-03	0.120000E-02	0.438500E-02	0.537500E-02	0.174500E-02	0.580000E-03
5	0.450000E-03	0.195000E-02	0.794500E-02	0.109250E-01	0.185000E-02	0.890000E-03
6	0.215000E-03	0.233000E-02	0.602500E-02	0.890500E-02	0.168000E-02	0.340000E-03
7	0.200000E-03	0.150500E-02	0.414500E-02	0.305000E-02	0.170000E-03	0.350000E-04
8	0.195000E-03	0.116500E-02	0.376500E-02	0.209000E-02	0.135000E-03	0.0
9	0.390000E-03	0.246500E-02	0.118850E-01	0.972500E-02	0.140500E-02	0.445000E-03
10	0.115000E-03	0.720000E-03	0.650500E-02	0.132200E-01	0.359500E-02	0.550000E-03
11	0.850000E-04	0.790000E-03	0.520500E-02	0.138700E-01	0.294500E-02	0.720000E-03
12	0.150000E-03	0.755000E-03	0.794500E-02	0.200700E-01	0.373500E-02	0.790000E-03
13	0.150000E-03	0.550000E-03	0.534000E-02	0.254100E-01	0.859500E-02	0.349500E-02
14	0.500000E-04	0.615000E-03	0.568500E-02	0.243150E-01	0.887000E-02	0.315000E-02
15	0.155000E-03	0.925000E-03	0.592500E-02	0.200000E-01	0.596000E-02	0.120000E-02
16	0.850000E-04	0.995000E-03	0.507000E-02	0.119500E-01	0.219000E-02	0.205000E-03

THE JOINT FREQUENCY FUNCTION FOR STABILITY CLASS 5

1	0.220000E-03	0.287500E-02	0.921000E-02	0.113000E-01	0.277500E-02	0.925000E-03
2	0.235000E-03	0.168000E-02	0.342500E-02	0.459000E-02	0.137000E-02	0.685000E-03
3	0.135000E-03	0.123500E-02	0.452000E-02	0.531000E-02	0.181500E-02	0.130000E-02
4	0.335000E-03	0.120000E-02	0.438500E-02	0.537500E-02	0.174500E-02	0.580000E-03
5	0.450000E-03	0.195000E-02	0.794500E-02	0.109250E-01	0.185000E-02	0.890000E-03
6	0.215000E-03	0.233000E-02	0.602500E-02	0.890500E-02	0.168000E-02	0.340000E-03
7	0.200000E-03	0.150500E-02	0.414500E-02	0.305000E-02	0.170000E-03	0.350000E-04
8	0.195000E-03	0.116500E-02	0.376500E-02	0.209000E-02	0.135000E-03	0.0
9	0.390000E-03	0.246500E-02	0.118850E-01	0.972500E-02	0.140500E-02	0.445000E-03
10	0.115000E-03	0.720000E-03	0.650500E-02	0.132200E-01	0.359500E-02	0.550000E-03
11	0.850000E-04	0.790000E-03	0.520500E-02	0.138700E-01	0.294500E-02	0.720000E-03
12	0.150000E-03	0.755000E-03	0.794500E-02	0.200700E-01	0.373500E-02	0.790000E-03
13	0.150000E-03	0.550000E-03	0.534000E-02	0.254100E-01	0.859500E-02	0.349500E-02
14	0.500000E-04	0.615000E-03	0.568500E-02	0.243150E-01	0.887000E-02	0.315000E-02
15	0.155000E-03	0.925000E-03	0.592500E-02	0.200000E-01	0.596000E-02	0.120000E-02
16	0.850000E-04	0.995000E-03	0.507000E-02	0.119500E-01	0.219000E-02	0.205000E-03

THE JOINT FREQUENCY FUNCTION FOR STABILITY CLASS 6

1	0.910000E-03	0.534000E-02	0.822000E-02	0.0	0.0	0.0
2	0.960000E-03	0.247000E-02	0.178000E-02	0.0	0.0	0.0
3	0.109000E-02	0.116000E-02	0.137000E-02	0.0	0.0	0.0
4	0.610000E-03	0.164000E-02	0.103000E-02	0.0	0.0	0.0
5	0.850000E-03	0.295000E-02	0.199000E-02	0.0	0.0	0.0
6	0.850000E-03	0.286000E-02	0.205000E-02	0.0	0.0	0.0
7	0.100000E-02	0.342000E-02	0.171000E-02	0.0	0.0	0.0
8	0.430000E-03	0.308000E-02	0.192000E-02	0.0	0.0	0.0
9	0.134000E-02	0.705000E-02	0.500000E-02	0.0	0.0	0.0
10	0.820000E-03	0.432000E-02	0.418000E-02	0.0	0.0	0.0
11	0.740000E-03	0.404000E-02	0.411000E-02	0.0	0.0	0.0
12	0.470000E-03	0.466000E-02	0.111000E-01	0.0	0.0	0.0
13	0.660000E-03	0.356000E-02	0.664000E-02	0.0	0.0	0.0
14	0.650000E-03	0.349000E-02	0.102100E-01	0.0	0.0	0.0
15	0.440000E-03	0.349000E-02	0.119200E-01	0.0	0.0	0.0
16	0.510000E-03	0.322000E-02	0.740000E-02	0.0	0.0	0.0

APPENDIX X

NOISE IMPACT ANALYSIS

A. Introduction

Noise pollution, commonly defined as unwanted sound, has a receptor-oriented/site specific impact. Characteristics of sites that are generally susceptible to noise impacts include:

- Sites on which churches, hospitals, housing for the elderly, schools, or residences are located.
- Sites requiring serenity, e.g., parks.
- Densely populated sites.
- Sites on which wood frame structures or structures with little or no insulation are located.

Implementation of a sludge management plant requires that two possible categories of noise-generating activities take place, activities which, if in close proximity to susceptible receptor sites (and without the benefit of mitigative techniques), will generate impacts. Specifically, these activities can be identified as: (1) actions associated with the construction of a sludge treatment facility and (2) the truck hauling of ash from operational facilities. It should be noted that construction activities include the use of construction equipment on the site, the transportation of construction equipment and materials to the site, and the transportation of workers to the site.

B. Identification of Potential Impact Areas

The following criteria were developed to identify potential noise-impacted areas:

- Areas within a 1,000 foot radius of sludge treatment facility construction site.
- Areas within a 4,000 foot radius of Deer Island (Alternatives 2 and 10).
- Residential areas adjacent to nongrade separated arterial and local roadways designated to be used to transport construction equipment, supplies and materials, and workers to and from the construction site.

- Residential areas adjacent to nongrade separated arterial and local roadways designated to be used as a route by trucks hauling ash and returning to the treatment facility.

The results of the application of these criteria are illustrated in Table X-1. During the construction phase, areas located within 200 feet of the plant sites on Deer Island and Nut Island are potential noise impact areas. Neighborhoods in Winthrop, East Boston, and Quincy, identified as potential noise impact areas, are residential areas through which routes for the transport of construction equipment, supplies, materials, and personnel have been designated. (See Figures X-1 and X-2 and Tables X-2 and X-3.)

Areas potentially impacted by noise during the operation phase are those through which truck-haul routes have been designated. These areas include neighborhoods in Charlestown and residences in Plainville, Randolph or Amesbury. (See Figures X-3 and X-4.) For Alternatives 2 and 10 potential impact areas lie within 4,000 feet and 2,000 feet respectively.

C. Impacts During the Construction Phase

Projected facility requirements indicate that the extent and nature of construction activity will vary with each alternative. Specifically, the alternatives will require the construction of three stacks and related facilities on Deer Island Alternatives 2 and 10 also include construction of a cofferdam at Deer Island. In addition, there will be some construction based at Nut Island, relative to the sludge transfer pipeline.

With respect to the generation of noise, it is anticipated that for all alternatives cranes, bulldozers and other earth-moving equipment, as well as cement mixers, will be required. It is also projected that the heavy pieces of equipment will be transported to the construction site by barges. Thus, noise impacts will result from the operation of heavy equipment at the site and the movement of cement mixers to and from the site. Table X-4 illustrates the range of noise levels generated by construction equipment at a distance of 50 feet.

Cofferdam construction will require the use of a pile driver. Resultant noise peaks will be 105 dB at 15 m (50 feet) (Magrab, 1975). For Alternatives 2 and 10, the distance to homes in Point Shirley is 1,220 m (4,000 feet) and 760 m (2,500 feet) respectively. Under adverse meteorological conditions, impulse noise levels at Point Shirley would be 80 dB for Alternative 2 and 90 dB for Alternative 10. This assumes a sound dissipation of 20 dB/km and does not include the effect of other construction equipment.

TABLE X-1

POTENTIAL NOISE IMPACT AREAS

Alternative	Potential Noise Impact Areas	
	Construction Phase	Operation Phase
Land fill of incinerator ash Deer Island plant	• Deer Island site • Point Shirley • Winthrop (specific neighbor-hoods) • East Boston (specific neigh-borhoods	• Charlestown (specific neighborhoods) • Plainville, Randolph or Amesbury vicinity
Land fill of incinerator ash Deer and Nut Island plants	• Deer Island • Nut Island • Winthrop (specific neighborhoods) • East Boston (specific neighborhoods) • Quincy (specific neighborhoods)	• Charlestown (specific neighborhoods) • Quincy (specific neighborhoods) • Plainville, Randolph or Amesbury vicinity

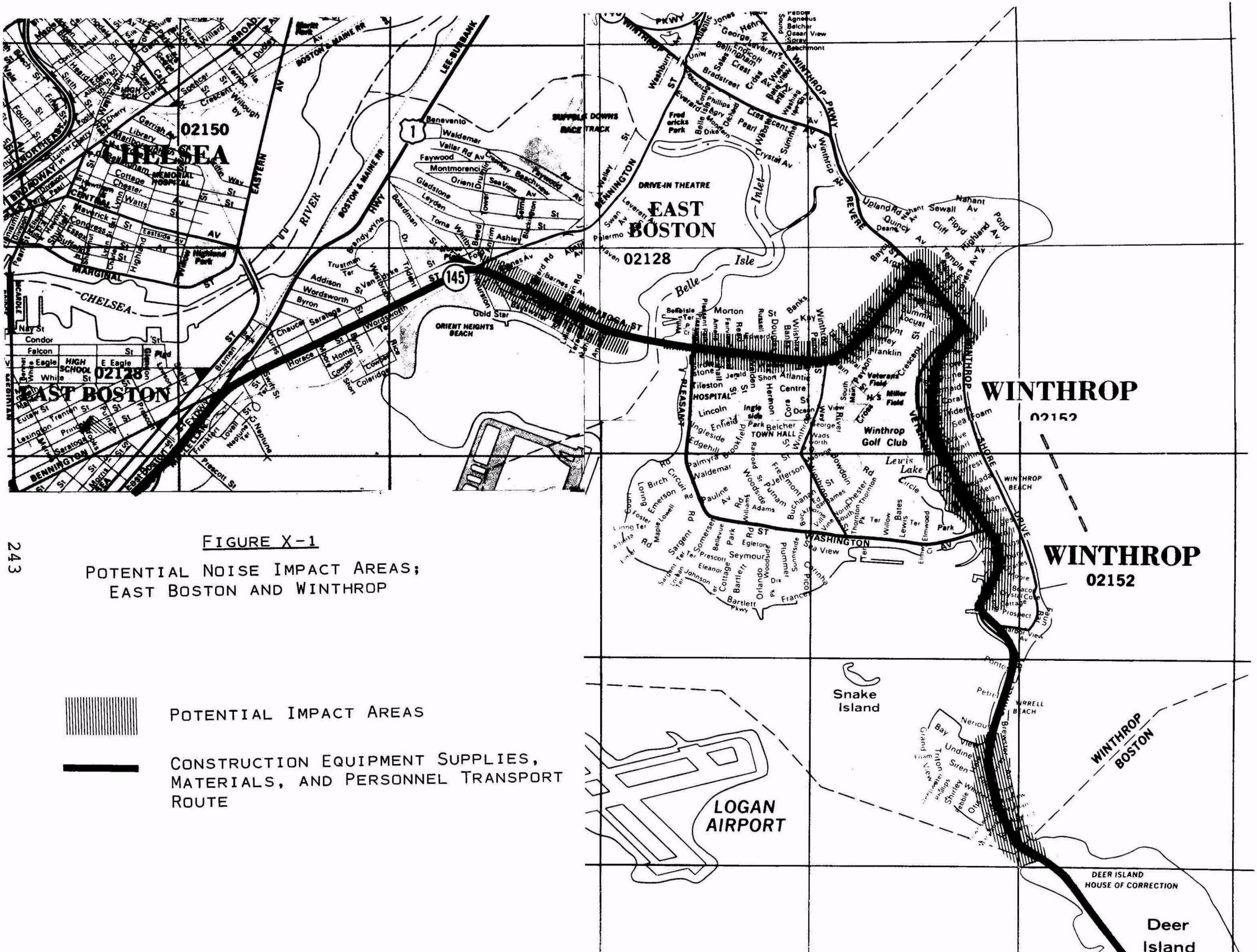


FIGURE X-1

POTENTIAL NOISE IMPACT AREAS; EAST BOSTON AND WINTHROP

POTENTIAL IMPACT AREAS

CONSTRUCTION EQUIPMENT SUPPLIES, MATERIALS, AND PERSONNEL TRANSPORT ROUTE

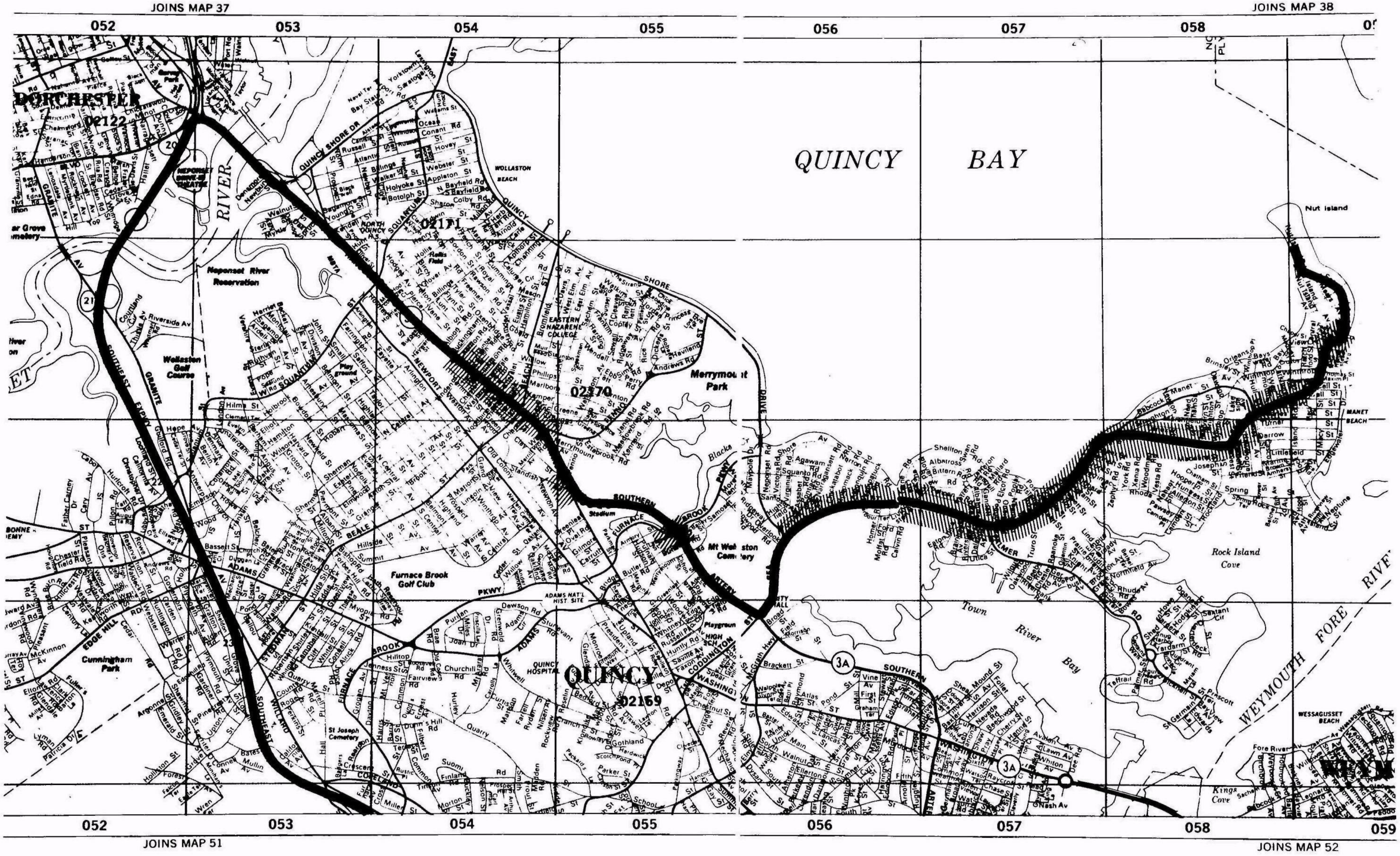


FIGURE X-2   POTENTIAL NOISE IMPACT AREAS: QUINCY

POTENTIAL IMPACT AREA

DESIGNATED TRUCK ROUTE

TABLE X-2

SUSCEPTIBLE RECEPTOR INDICATORS

[Source: 1970 U. S. Census Boston SMSA]

Place	Affected Census Tracts	Percent Housing Units Over 30 Years Old	Percent Multi-Family Units	Percent Elderly (Over 65)
Charlestown	0401	99	76	12
	0402	73	89	9
East Boston	0509	99	92	11
	0510	74	81	11
	0511	70	85	14
Quincy	4176	80	51	15
	4177	70	64	20
	4178	58	33	8
Winthrop	1801	68	73	12
	1802	73	64	12
	1805	84	70	14

TABLE X-3

INVENTORY OF SENSITIVE RECEPTORS

Charlestown	East Boston	Quincy	Winthrop
• Vine Street residences	• Orient Heights Beach	• Sea Street residences	• Yierel Beach
• Hunter Street residences	• Church and school on Moore Street near Bennington Street	• Atherton Hough School	• Taft Street residence
• School on Hunter Street	• Saratoga Street residences	• Merrymount Park	• Shirely Street residence
• Lowney Street residences		• Hancock Street residences	• School at Irwin and Shirely
• Chelsea Street residences		• Playground at Young Street and Hancock Street	• Synagogues on Shirely Street
			• Crest Avenue residences
			• Revere Street residences
			• Main Street residences

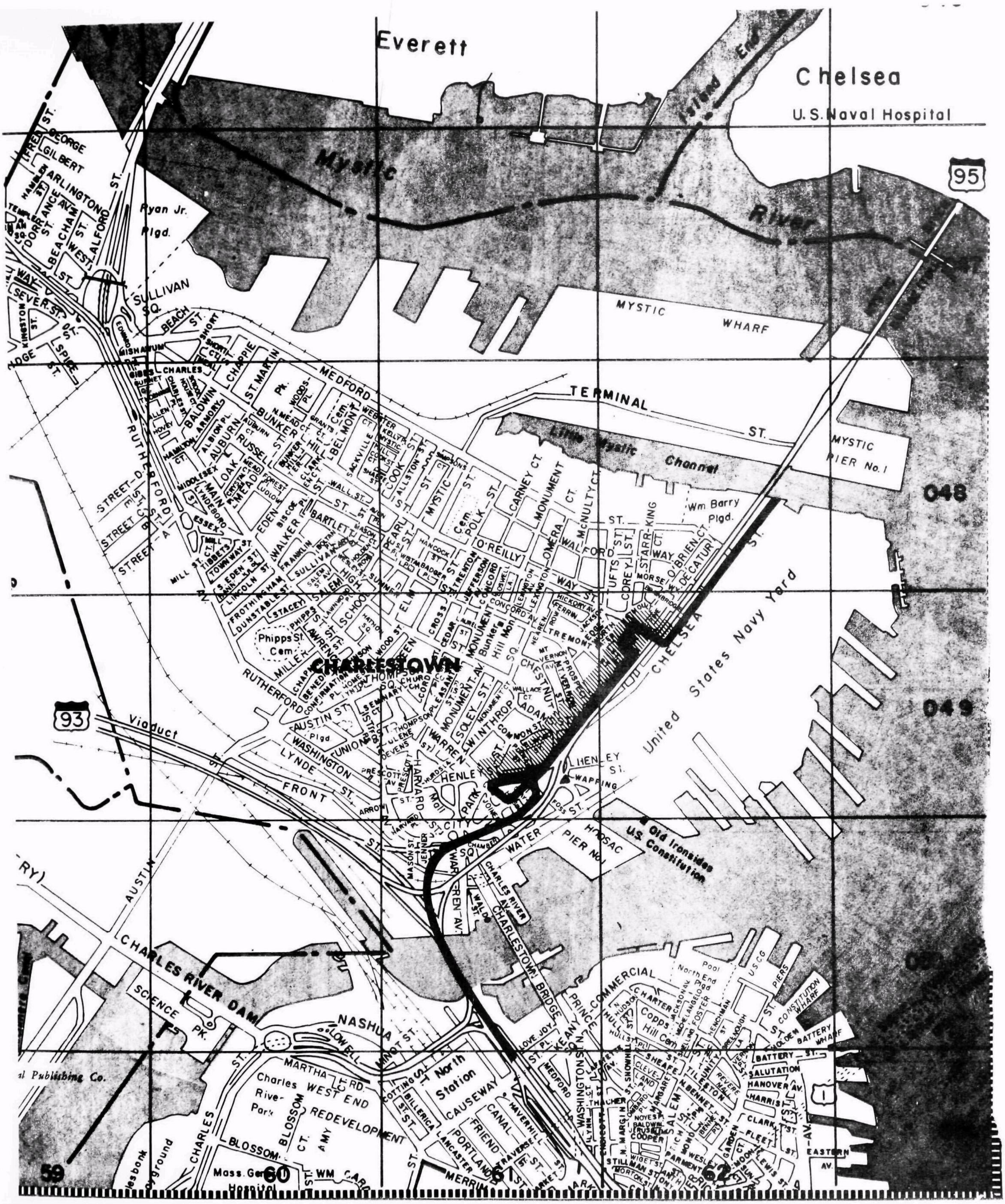


FIGURE X -3

POTENTIAL NOISE IMPACT AREAS: CHARLESTOWN

POTENTIAL IMPACT AREAS

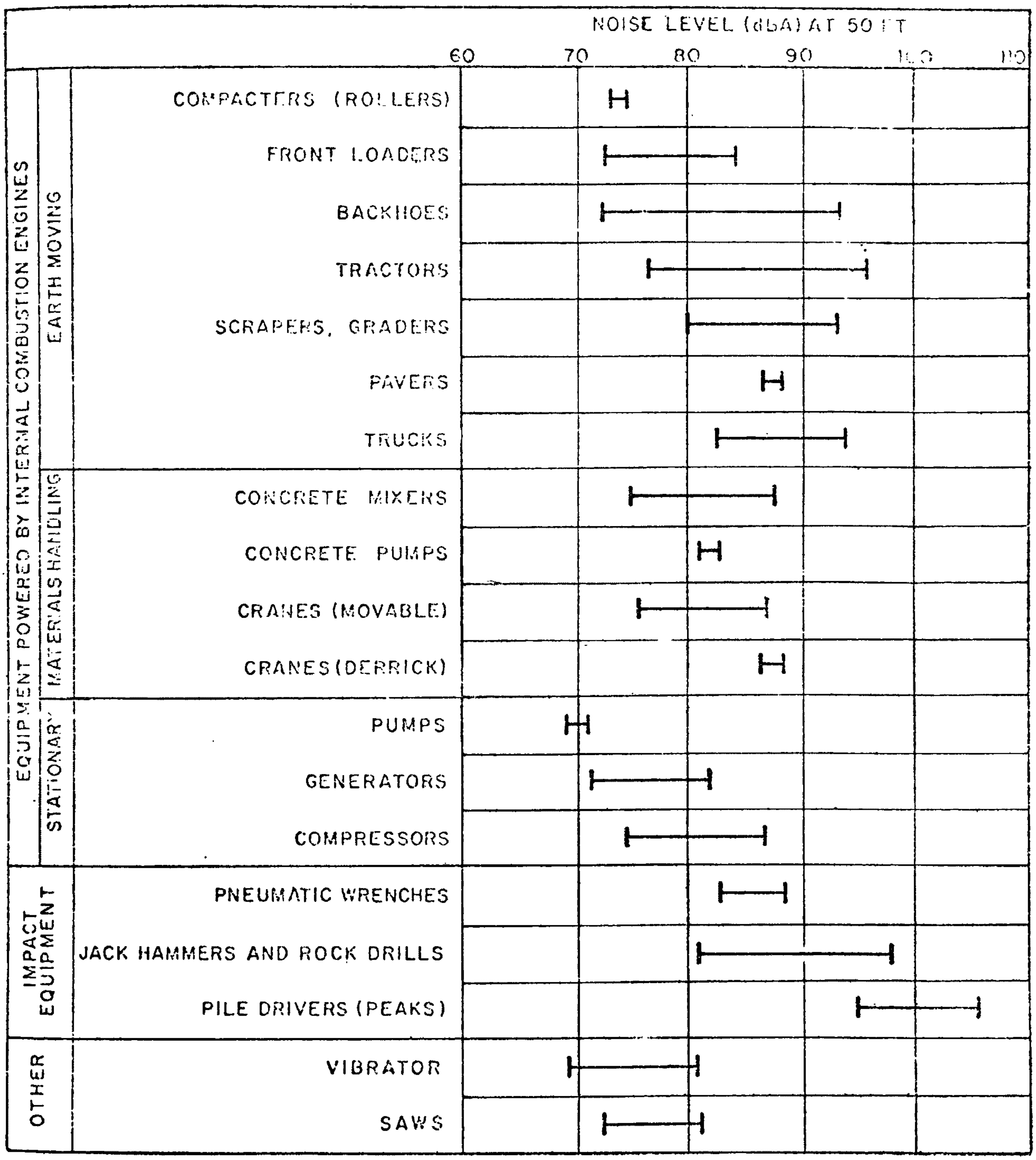
DESIGNATED TRUCK ROUTE

Randolph Site
Amesbury Site
Scale 1" = 10 mi.
Plainville Site
Designated Haul Rte.

FIGURE X-4 POTENTIAL LANDFILL SITES

TABLE X-4

CONSTRUCTION EQUIPMENT NOISE RANGES



Note: Based on Limited Available Data Samples

Source: Bolt, Beranek and Newman, Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances, U.S. Environmental Protection Agency, Washington, D.C., December 31, 1971, p. 11.

Table X-5 summarizes the probable noise impacts associated with the construction phase for each alternative. It is projected for each alternative that the use of construction equipment will significantly impact areas within 50 feet of the source, and in most cases this would expose construction workers and employees at the existing treatment plant.

With respect to the transport of construction materials to the site, particularly the movement of cement mixers, it is estimated that the frequency of trips (no more than 3 per day over a six month period) will generate negligible increases in the overall noise levels in surrounding neighborhoods; however, the 75 dB - 85 dB range generated by these trucks can possibly be intrusive to residences with shallow setbacks on a periodic basis.

D. Impacts During the Operational Phase

The sole source of neighborhood noise impact during the operation for each of the alternatives will be noise levels generated in local neighborhoods by 20 ton diesel trucks laden with approximately 20 tons of ash. Table X-6 indicates that the projected noise level increment in urban neighborhoods in Charlestown will be negilgible for each alternative. However, these minor increments are applied to Charlestown's background levels which already exceed EPA guidelines.

TABLE X-6

PROJECTED TRUCK-INDUCED NOISE IMPACTS DURING OPERATIONAL PHASE

Alternative	Noise Impact Area	Projected Noise Level Increment*	Projected Noise Level, L_{eq}
Landfill of incinerator ash/Deer Island incinerator (3 stacks)	Charlestown	0.14 dBA	74.14 dBA
	Plainville	3.14 dBA	63.14 dBA
	Randolph	3.14 dBA	63.14 dBA
	Amesbury	3.14 dBA	63.14 dBA

* It was assumed in making calculations that:

- Receptor was 50 feet from truck, and
- Time duration of truck noise was 30 minutes.

TABLE X-5

PROJECTED NOISE IMPACTS DURING CONSTRUCTION PHASE

Alternative	Noise Impact Area	Construction Equipment Use	Construction Related Transport
Deer Island incineration	Deer Island Site	Impact construction workers and employees of existing treatment plant	-
	Point Shirley	Impulse noise peaks at Point Shirley	-
	Winthrop	None	Overall noise level increment will be negligible, periodic cement mixer trips will be intrusive
	East Boston	None	Overall noise level increment will be negligible, periodic cement mixer trips will be intrusive

The most significant noise impacts take place at sites where the ash landfill may be located. While projected noise levels in all of these areas do not exceed EPA guidelines, increments in the 3 to 7 dBA range indicate substantial changes which could be clearly perceivable by local residents in the vicinity of the designated truck haul routes.

It should also be noted that while trucks carrying ash may not produce noise emission levels that can be considered harmful to most people in quantified terms, they may be perceived as a disturbance or nuisance. One aspect of this is that the cargo carried by the trucks will be known to be a product of wastewater treatment and may cause the trucks to be considered undesirable, even though there is no serious quantifiable impact.

The local noise impacts from on-site operation of dewatering equipment and incinerators should be negligible because of the separation from sensitive receptors.

APPENDIX Y

TRAFFIC IMPACT ANALYSIS

A. Introduction

The incineration alternative with inland fill at an existing fill will require the use of some truck transport within the region. The assumptions used in preparing the traffic impact analysis are as follows:

1. Routing - Alternative 1

   a. Landfill of incinerator ash from Deer Island:

      - Barge from Deer Island to terminal.

        (1) Amesbury Site:

        - Route 92 North to Route 495 West.
        - To a site South of Route 495 on Hunt Road in Amesbury.

        (2) Randolph Site:

        - South on the Southeast Expressway (Route 95) to Route 128 to Route 24 South.
        - To a site approximately one mile Southeast of the Route 128 and Route 24 intersection on the Randolph border.

        (3) Plainville Site:

        - South on the Southeast Expressway (Route 95) to Route 128 to I-95.
        - West on Route 495 to a site in the Northeast quadrangle of the intersection of Route 295 and U. S. Route 1, near Plainville.

   b. Landfill of incinerator ash from Nut Island:

      - Truck from Nut Island through the Town of Quincy on Hancock and Sea Streets, to I-95.
      - Continued as for trucks from terminal to ultimate disposal site for Deer Island.

2. Truck Characteristics

a. Truck size - gross vehicle weight = 60,000 lbs. (40,000 lbs. net weight).

b. Diesel fuel.

c. 1980 vehicle standards for noise and air pollutant emissions (vehicles purchased in 1980 assumed to be operational in 1985).

3. Frequency and Timing of Transportation

a. Landfilling of incinerator ash:

- Five (5) truck vehicle loads per day outbound from Terminal (Deer Island).

  (1) Amesbury Site:

  - Vehicle miles - 500 miles/day (250 in empty, 250 out loaded) of truck travel plus 6.5 miles/day of barge travel.

  (2) Randolph Site:

  - Vehicle miles - 150 miles/day (75 in empty, 75 out loaded) of truck travel plus 6.5 miles/day of barge travel.

  (3) Plainville Site:

  - Vehicle miles - 400 miles/day (220 in empty, 220 out loaded) of truck travel plus 6.5 miles/day of barge travel.

b. Truck speed is thirty miles per hour.

B. Transportation Impact

1. Operation Impacts

Alternative 1 is the only alternative that includes transport over public streets during operation. With use of a terminal in the Inner or Outer harbor, not owned by MASSPORT, a total of ten trips per day will not create a detectable impact in the area. Once the ash trucks reach a major highway, such as the Southeast Expressway, no impact on traffic will occur.

All other incineration alternatives with land disposal involve no use of public streets and therefore no operational impact on traffic.

2. Construction Impacts

Alternatives 1, 2, 8, 9, 10 and 11 all have similar construction inputs for onsite processes and hence similar impacts. For each of these, the daily traffic increase during construction will include 240 automobile trips per day and less than one truck trip per day for materials. The impact of automobile traffic will be minor, and the impact of truck traffic will be negligible.

For the alternatives with cofferdam construction (2 and 10), an additional increase in automobile and truck traffic will occur. While these impacts will be negligible, they will be greater than construction impacts for 1, 8, 9 and 11.

APPENDIX Z

CORRESPONDENCE

The Commonwealth of Massachusetts

Department of Environmental Quality Engineering
~~Department of Public Health~~

600 Washington Street

Boston 02111

David Standley
XXXXXXXXXXXXXXXXXXXXXXXX
COMMISSIONER

26 November 1975

Mr. James E. Shirk, P.E.
EcolSciences, Inc.
Environmental Consulting Services
20 Union Street
Rockaway, New Jersey 07866

RE: PLAINVILLE - Solid Wastes -
Clean Communities Landfill

Dear Srr:

The Department of Environmental Quality Engineering hereby acknowledges receipt of your letter of 13 November 1975 relative to the possible disposal of sewage residues at the above referenced facility.

Please be advised that this facility has been approved by the Department for the disposal of 750 tons per day as stated in the approval letter of 30 April 1975.

The Department would consider the disposal of dewatered sewage residue at the site provided that the amount does not exceed fifteen percent of the solid wastes by volume. Further, any residue would have to be mixed in with the refuse and could not be utilized as cover material.

Prior to the disposal of any sewage residues at the site, the Department must be notified as to what kind of residue is to be disposed of. This is necessary in order to ascertain if any pertinent hazardous waste regulations would be applicable.

If you have any further questions in this matter, please refer all correspondence to Mr. Vartkes K. Karaian, Associate Sanitary Engineer, Department of Environmental Quality Engineering, Division of General Environmental Control, 600 Washington Street, Room 320, Boston, Ma. 02111, Telephone (617) 727-2655.

Very truly yours,
For the Commissioner

Paul T. Anderson

Paul T. Anderson, P.E.
Director
Division of General Environmental Control

PTA/sc

cc: Board of Health
Plainville, Ma. 02676

cc: Clean Communities Corp.
1 Newbury Street
Peabody, Ma. 01960

cc: Bureau of Solid Waste Disposal
Leverett Saltonstall Building
100 Cambridge Street
Boston, Ma. 02202

cc: Camp, Dresser & McKee, Inc.
One Center Plaza
Boston, Ma. 02108

CITY OF BOSTON CONSERVATION COMMISSION / ROOM 911 / CITY HALL / BOSTON, MASSACHUSETTS / 02201

November 10, 1975

Mr. Peter Spinney
Ecolsciences, Inc.
20 Union Street
Rockaway, New Jersey

RE: Incinerator Ash Landfill for MDC Sludge Facility

Dear Mr. Spinney:

As we discussed by telephone last week, the Boston Conservation Commission is strongly opposed to any alternative for the handling of sludge at the MDC's Deer Island treatment plant which proposes landfilling of incinerator ash residue in the harbor.

As you know, the Conservation Commission, under the authority of the Wetlands Protection Act (Ch. 131, s. 40 of the General Laws), would review such a proposal. As a matter of policy, it is quite unlikely that the Commission would approve the necessary permit for any filling of any portion of Boston Harbor for the purpose of waste disposal.

As a matter of principle, it seems absurd to attempt to solve a harbor pollution problem by destroying a portion of the harbor itself.

The potential leachate from the ash landfill, which is sure to be highly contaminated, represents in effect a concentrating and localizing of the environmental costs and impacts of the treatment plant wastes. The feasibility of using an impermeable membrane to contain leachates is dubious, and, it seems to us, presents an unacceptable risk.

The proposed site of the landfill, on the western side of Deer Island, is adjacent to or near extensive areas of intertidal flats which support important shellfish populations, and is at the doorway of a vital part of the harbor, containing salt marsh, beaches, and boating facilities. The risk of leaching and the reduction of from 8 to 20 acres of water area may well have severe impacts on the already marginal water quality and viability of marine life and vegetation in this area of the harbor. Furthermore, filling in this area may result in undesirable changes in tidal currents and flows.

I have not discussed other sludge handling alternatives, which would not require harbor landfill. It is hoped that the environmental impact statement process, with which you are presently engaged, will emphasize and focus on those alternatives.

Very truly yours,

Eugenie Beal
Environmental Affairs Coordinator

EB/dd

APPENDIX AA

U. S. ENVIRONMENTAL PROTECTION AGENCY

FINAL REGULATIONS FOR THE PREPARATION OF

ENVIRONMENTAL IMPACT STATEMENTS

(40 CFR Part 6)

federal register

MONDAY, APRIL 14, 1975
WASHINGTON, D.C.

Volume 40 ■ Number 72

PART III

ENVIRONMENTAL PROTECTION AGENCY

Preparation of Environmental Impact Statements

■

Final Regulations

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

[FRL 327-5]

PART 6—PREPARATION OF ENVIRONMENTAL IMPACT STATEMENTS

Final Regulation

The National Environmental Policy Act of 1969 (NEPA), implemented by Executive Order 11514 of March 5, 1970, and the Council on Environmental Quality's (CEQ's) Guidelines of August 1, 1973, requires that all agencies of the Federal Government prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. NEPA requires that agencies include in their decision-making process an appropriate and careful consideration of all environmental aspects of proposed actions, an explanation of potential environmental effects of proposed actions and their alternatives for public understanding, a discussion of ways to avoid or minimize adverse effects of proposed actions and a discussion of how to restore or enhance environmental quality as much as possible.

On January 17, 1973, the Environmental Protection Agency (EPA) published a new Part 6 in interim form in the FEDERAL REGISTER (38 FR 1696), establishing EPA policy and procedures for the identification and analysis of environmental impacts and the preparation of environmental impact statements (EIS's) when significant impacts on the environment are anticipated.

On July 17, 1974, EPA published a notice of proposed rulemaking the FEDERAL REGISTER (39 FR 26254). The rulemaking provided detailed procedures for applying NEPA to EPA's nonregulatory programs only. A separate notice of administrative procedure published in the October 21, 1974, FEDERAL REGISTER (39 FR 37419) gave EPA's procedures for voluntarily preparing EIS's on certain regulatory activities. EIS procedures for another regulatory activity, issuing National Pollutant Discharge Elimination System (NPDES) discharge permits to new sources, will appear in 40 CFR 6. Associated amendments to the NPDES operating regulations, covering permits to new sources, will appear in 40 CFR 125.

The proposed regulation on the preparation of EIS's for nonregulatory programs was published for public review and comment. EPA received comments on this proposed regulation from environmental groups; Federal, State and local governmental agencies; industry; and private individuals. As a result of the comments received, the following changes have been made:

(1) Coastal zones, wild and scenic rivers, prime agricultural land and wildlife habitat were included in the criteria to be considered during the environmental review.

The Coastal Zone Management Act and the Wild and Scenic Rivers Act are intended to protect these environmentally sensitive areas; therefore, EPA should consider the effects of its projects on these areas. Protection of prime agricultural lands and wildlife habitat has become an important concern as a result of the need to further increase food production from domestic sources as well as commercial harvesting of fish and other wildlife resources and from the continuing need to preserve the diversity of natural resources for future generations.

(2) Consideration of the use of floodplains as required by Executive Order 11296 was added to the environmental review process.

Executive Order 11296 requires agencies to consider project alternatives which will preclude the uneconomic, hazardous or unnecessary use of floodplains to minimize the exposure of facilities to potential flood damage, lessen the need for future Federal expenditures for flood protection and flood disaster relief and preserve the unique and significant public value of the floodplain as an environmental resource.

(3) Statutory definitions of coastal zones and wild and scenic rivers were added to § 6.214(b).

These statutes define sensitive areas and require states to designate areas which must be protected.

(4) The review and comment period for negative declarations was extended from 15 days to 15 working days.

Requests for negative declarations and comments on negative declarations are not acted on during weekends and on holidays. In addition, mail requests often take two or three days to reach the appropriate office and several more days for action and delivery of response. Therefore, the new time frame for review and response to a negative declaration is more realistic without adding too much delay to a project.

(5) Requirements for more data in the negative declaration to clarify the proposed action were added in § 6.212(b).

Requiring a summary of the impacts of a project and other data to support the negative declaration in this document improves its usefulness as a tool to review the decision not to prepare a full EIS on a project.

(6) The definitions of primary and secondary impacts in § 6.304 were clarified.

The definitions were made more specific, especially in the issue areas of induced growth and growth rates, to reduce subjectivity in deciding whether an impact is primary or secondary.

(7) Procedures for EPA public hearings in Subpart D were clarified.

Language was added to this subpart to distinguish EPA public hearings from applicant hearings required by statute or regulation, such as the facilities plan hearings.

(8) The discussion of retroactive application (§ 6.504) was clarified and abbreviated.

The new language retains flexibility in decision making for the Regional Administrator while eliminating the ambiguity of the langauge in the interim regulation.

(9) The criteria for writing an EIS if wetlands may be affected were modified in § 6.510(b).

The new language still requires an EIS on a project which will be located on wetlands but limits the requirements for an EIS on secondary wetland effects to those which are significant and adverse.

(10) A more detailed explanation of the data required in environmental assessments (§ 6.512) was added.

Requiring more specific data in several areas, including energy production and consumption as well as land use trends and population projections, from the applicant will provide a more complete data base for the environmental review. Documentation of the applicant's data will allow EPA to evaluate the validity of this data.

(11) Subpart F, Guidelines for Compliance with NEPA in Research and Development Programs and Activities, was revised.

ORD simplified this subpart by removing the internal procedures and assignments of responsibility for circulation in internal memoranda. Only the general application of this regulation to ORD programs was retained.

(12) The discussions of responsibilities and document distribution procedures were moved to appendices attached to the regulations.

These sections were removed from the regulatory language to improve the readability of the regulation and because these discussions are more explanatory and do not need to have the legal force of regulatory language.

(13) Consideration of the Endangered Species Act of 1973 was incorporated into the regulation.

EPA recognizes its responsibility to assist with implementing legislation which will help preserve or improve our natural resources.

The major issues raised on this regulation were on new and proposed criteria for determining when to prepare an EIS and the retroactive application of the criteria to projects started before July 1, 1975. In addition to the new criteria which were added, CEQ requested the addition of several quantitative criteria for which parameters have not been set. These new criteria are being discussed with CEQ and may be added to the regulation at a future date. Changes in the discussion of retroactive application of the criteria are described in item 8 above.

EPA believes that Agency compliance with the regulations of Part 6 will enhance the present quality of human life without endangering the quality of the natural environment for future generations.

Effective date: This regulation will become effective April 14, 1975.

Dated: April 3, 1975.

RUSSELL E. TRAIN,
Administrator.

Authority: Secs. 102, 103 of 83 Stat. 854 (42 U.S.C. 4321 et seq.)

Subpart A—General

§ 6.100 Purpose and policy.

(a) The National Environmental Policy Act (NEPA) of 1969, implemented by Executive Order 11514 and the Council on Environmental Quality's (CEQ's) Guidelines of August 1, 1973 (38 FR 20550), requires that all agencies of the Federal Government prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. NEPA requires that agencies include in the decision-making process appropriate and careful consideration of all environmental effects of proposed actions, explain potential environmental effects of proposed actions and their alternatives for public understanding, avoid or minimize adverse effects of proposed actions and restore or enhance environmental quality as much as possible.

(b) This part establishes Environmental Protection Agency (EPA) policy and procedures for the identification and analysis of the environmental impacts of EPA nonregulatory actions and the preparation and processing of environmental impact statements (EIS's) when significant impacts on the environment are anticipated.

§ 6.102 Definitions.

(a) "Environmental assessment" is a written analysis submitted to EPA by its grantees or contractors describing the environmental impacts of proposed actions undertaken with the financial support of EPA. For facilities or section 208 plans as defined in § 6.102 (j) and (k), the assessment must be an integral, though identifiable, part of the plan submitted to EPA for review.

(b) "Environmental review" is a formal evaluation undertaken by EPA to determine whether a proposed EPA action may have a significant impact on the environment. The environmental assessment is one of the major sources of information used in this review.

(c) "Notice of intent" is a memorandum, prepared after the environmental review, announcing to Federal, regional, State, and local agencies, and to interested persons, that a draft EIS will be prepared.

(d) "Environmental impact statement" is a report, prepared by EPA, which identifies and analyzes in detail the environmental impacts of a proposed EPA action and feasible alternatives.

(e) "Negative declaration" is a written announcement, prepared after the environmental review, which states that EPA has decided not to prepare an EIS and summarizes the environmental impact appraisal.

(f) "Environmental impact appraisal" is based on an environmental review and supports a negative declaration. It describes a proposed EPA action, its expected environmental impact, and the basis for the conclusion that no significant impact is anticipated.

(g) "NEPA-associated documents" are any one or combination of: notices of intent, negative declarations, exemption certifications, environmental impact appraisals, news releases, EIS's, and environmental assessments.

(h) "Responsible official" is an Assistant Administrator, Deputy Assistant Administartor, Regional Administrator or their designee.

(i) "Interested persons" are individuals, citizen groups, conservation organizations, corporations, or other nongovernmental units, including applicants for EPA contracts or grants, who may be interested in, affected by, or technically competent to comment on the environmental impacts of the proposed EPA action.

(j) "Section 208 plan" is an areawide waste treatment management plan prepared under section 208 of the Federal Water Pollution Control Act (FWPCA), as amended, under 40 CFR Part 126 and 40 CFR Part 35, Subpart F.

(k) "Facilities plan" is a preliminary plan prepared as the basis for construction of publicly owned waste treatment works under Title II of FWPCA, as amended, under 40 CFR 35.917.

(l) "Intramural project" is an in-house project undertaken by EPA personnel.

(m) "Extramural project" is a project undertaken by grant or contract.

§ 6.104 Summary of procedures for implementing NEPA.

(a) *Responsible official.* The responsible official shall utilize a systematic, interdisciplinary approach to integrate natural and social sciences as well as environmental design arts in planning programs and making decisions which are subject to NEPA review. His staff may be supplemented by professionals from other agencies, universities or consultants whenever in-house capabilities are insufficiently interdisciplinary.

(b) *Environmental assessment.* Environmental assessments must be submitted to EPA by its grantees and contractors, as required in Subparts E, F, G, and H of this part. The assessment is used by EPA to decide if an EIS is required and to prepare one if necessary.

(c) *Environmental review.* Environmental reviews shall be made of proposed and certain ongoing EPA actions as required in § 6.106(c). This process shall consist of a study of the action to identify and evaluate the environmental impacts of the action. Types of grants, contracts and other actions requiring study are listed in the subparts following

Subpart D. The process shall include a review of any environmental assessment received to determine whether any significant impacts are anticipated, whether any changes can be made in the proposed action to eliminate significant adverse impacts, and whether an EIS is required. EPA has overall responsibility for this review, although its grantees and contractors will contribute to the review through their environmental assessments.

(d) *Notice of intent and EIS's.* When an environmental review indicates that a significant environmental impact may occur and the significant adverse impacts cannot be eliminated by making changes in the project, a notice of intent shall be published, and a draft EIS shall be prepared and distributed. After external coordination and evaluation of the comments received, a final EIS shall be prepared and distributed. EIS's should be prepared first on those proposed actions with the most adverse effects which are scheduled for earliest implementation and on other proposed actions according to priorities assigned by the responsible official.

(e) *Negative declaration and environmental impact appraisal.* When the environmental review indicates no significant impacts are anticipated or when the project is changed to eliminate the significant adverse impacts, a negative declaration shall be issued. For the cases in Subparts E, F, G, and H of this part, an environmental impact appraisal shall be prepared which summaries the impacts, alternatives and reasons an EIS was not prepared. It shall remain on file and be available for public inspection.

§ 6.106 Applicability.

(a) *Administrative actions covered.* This part applies to the administrative actions listed below. The subpart referenced with each action lists the detailed NEPA procedures associated with the action. Administrative actions are:

(1) Development of EPA legislative proposals;

(2) Development of favorable reports on legislation initiated elsewhere and not accompanied by an EIS, when they relate to or affect matters within EPA's primary areas of responsibility;

(3) For the programs under Title II of FWPCA, as amended, those administrative actions in § 6.504;

(4) For the Office of Research and Development, those administrative actions in § 6.604;

(5) For the Office of Solid Waste Management Programs, those administrative actions in § 6.702;

(6) For construction of special purpose facilities and facility renovations, those administrative actions in § 6.804; and

(7) Development of an EPA project in conjunction with or located near a project or complex of projects started by one or more Federal agencies when the cumulative effects of all the projects will be major allocations of resources or foreclosures of future land use options.

(b) *Administrative actions excluded.* The requirements of this part do not apply to environmentally protective regulatory activities undertaken by EPA, nor to projects exempted in § 6.504, § 6.604, and § 6.702.

(c) *Application to ongoing actions.* This regulation shall apply to uncompleted and continuing EPA actions initiated before the promulgation of these procedures when modifications of or alternatives to the EPA action are still available, except for the Title II construction grants program. Specific application for the construction grants program is in § 6.504(c). An EIS shall be prepared for each project found to have significant environmental effects as described in § 6.200.

(d) *Application to legislative proposals.* (1) As noted in paragraphs (a) (1) and (2) of this section, EIS's or negative declarations shall be prepared for legislative proposals or favorable reports relating to legislation which may significantly affect the environment. Because of the nature of the legislative process, EIS's for legislation must be prepared and reviewed according to the procedures followed in the development and review of the legislative matter. These procedures are described in Office of Management and Budget (OMB) Circular No. A–19.

(2) A working draft EIS shall be prepared by the EPA office responsible for preparing the legislative proposal or report on legislation. It shall be prepared concurrently with the development of the legislative proposal or report and shall contain the information required in § 6.304. The EIS shall be circulated for internal EPA review with the legislative proposal or report and other supporting documentation. The working draft EIS shall be modified to correspond with changes made in the proposal or report during the internal review. All major alternatives developed during the formulation and review of the proposal or report should be retained in the working draft EIS.

(i) The working draft EIS shall accompany the legislative proposal or report to OMB. EPA shall revise the working draft EIS to respond to comments from OMB and other Federal agencies.

(ii) Upon transmittal of the legislative proposal or report to Congress, the working draft EIS will be forwarded to CEQ and the Congress as a formal legislative EIS. Copies will be distributed according to procedures described in Appendix C.

(iii) Comments received by EPA on the legislative EIS shall be forwarded to the appropriate Congressional Committees. EPA also may respond to specific comments and forward its responses with the comments. Because legislation undergoes continuous changes in Congress beyond the control of EPA, no final EIS need be prepared by EPA.

§ 6.108 Completion of NEPA procedures before starting administrative action.

(a) No administrative action shall be taken until the environmental review process, resulting in an EIS or a negative declaration with environmental appraisal, has been completed.

(b) *When an EIS will be prepared.* Except when requested by the responsible official in writing and approved by CEQ, no administrative action shall be taken sooner than ninety (90) calendar days after a draft EIS has been distributed or sooner than thirty (30) calendar days after the final EIS has been made public. If the final text of an EIS is filed within ninety (90) days after a draft EIS has been circulated for comment, furnished to CEQ and made public, the minimum thirty (30) day period and the ninety (90) day period may run concurrently if they overlap. The minimum periods for review and advance availability of EIS's shall begin on the date CEQ publishes the notice of receipt of the EIS in the FEDERAL REGISTER. In addition, the proposed action should be modified to conform with any changes EPA considers necessary before the final EIS is published.

(c) *When an EIS will not be prepared.* If EPA decides not to prepare an EIS on any action listed in this part for which a negative declaration with environmental appraisal has been prepared, no administrative action shall be taken for at least fifteen (15) working days after the negative declaration is issued to allow public review of the decision. If significant environmental issues are raised during the review period, the decision may be changed and a new environmental appraisal or an EIS may be prepared.

§ 6.110 Responsibilities.

See Appendix B for responsibilities of this part.

Subpart B—Procedures

§ 6.200 Criteria for determining when to prepare an EIS.

The following general criteria shall be used when reviewing a proposed EPA action to determine if it will have a significant impact on the environment and therefore require an EIS:

(a) *Significant environmental effects.* (1) An action with both beneficial and detrimental effects should be classified as having significant effects on the environment, even if EPA believes that the net effect will be beneficial. However, preference should be given to preparing EIS's on proposed actions which, on balance, have adverse effects.

(2) When determining the significance of a proposed action's impacts, the responsible official shall consider both its short term and long term effects as well as its primary and secondary effects as defined in § 6.304(c). Particular attention should be given to changes in land use patterns; changes in energy supply and demand; increased development in floodplains; significant changes in ambient air and water quality or noise levels; potential violations of air quality, water quality and noise level standards; significant changes in surface or groundwater quality or quantity; and encroach-

ments on wetlands, coatstal zones, or fish and wildlife habitat, especially when threatened or endangered species may be affected.

(3) Minor actions which may set a precedent for future major actions with significant adverse impacts or a number of actions with individually insignificant but cumulatively significant adverse impacts shall be classified as having significant environmental impacts. If EPA is taking a number of minor, environmentally insignificant actions that are similar in execution and purpose, during a limited time span and in the same general geographic area, the cumulative environmental impact of all of these actions shall be evaluated.

(4) In determining the significance of a proposed action's impact, the unique characteristics of the project area should be carefully considered. For example, proximity to historic sites, parklands or wild and scenic rivers may make the impact significant. A project discharging into a drinking water aquifier may make the impact significant.

(5) A proposed EPA action which will have direct and significant adverse effects on a property listed in or eligible for listing in the National Register of Historic Places or will cause irreparable loss or destruction of significant scientific, prehistoric, historic or archaeological data shall be classified as having significant environmental impacts.

(b) *Controversial actions.* An EIS shall be prepared when the environmental impact of a proposed EPA action is likely to be highly controversial.

(c) *Additional criteria for specific programs.* Additional criteria for various EPA programs are in Subpart E (Title II Wastewater Treatment Works Construction Grants Program), Subpart F (Research and Development Programs), Subpart G (Solid Waste Management Programs) and Subpart H (Construction of Special Facilities and Facility Renovations).

§ 6.202 Environmental assessment.

Environmental assessments must be submitted to EPA by its grantees and contractors as required in Subparts E, F, G, and H of this part. The assessment is to ensure that the applicant considers the environmental impacts of the proposed action at the earliest possible point in his planning process. The assessment and other relevant information are used by EPA to decide if an EIS is required. While EPA is responsible for ensuring that EIS's are factual and comprehensive, it expects assessments and other data submitted by grantees and contractors to be accurate and complete. The responsible official may request additional data and analyses from grantees or other sources any time he determines they are needed to comply adequately with NEPA.

§ 6.204 Environmental review.

Proposed EPA actions, as well as ongoing EPA actions listed in § 6.106(c), shall be subjected to an environmental review. This review shall be a continuing one, starting at the earliest possible point in the development of the project. It shall consist of a study of the proposed action, including a review of any environmental assessments received, to identify and evaluate the environmental impacts of the proposed action and feasible alternatives. The review will determine whether significant impacts are anticipated from the proposed action, whether any feasible alternatives can be adopted or changes can be made in project design to eliminate significant adverse impacts, and whether an EIS or a negative declaration is required. The responsible official shall determine the proper scope of the environmental review. The responsible official may delay approval of related projects until the proposals can be reviewed together to allow EPA to properly evaluate their cumulative impacts.

§ 6.206 Notice of intent.

(a) *General.* (1) When an environmental review indicates a significant impact may occur and significant adverse impacts cannot be eliminated by making changes in the project, a notice of intent, announcing the preparation of a draft EIS, shall be issued by the responsible official. The notice shall briefly describe the EPA action, its location, and the issues involved (Exhibit 1).

(2) The purpose of a notice of intent is to involve other government agencies and interested persons as early as possible in the planning and evaluation of EPA actions which may have significant environmental impacts. This notice should encourage agency and public input to a draft EIS and assure that environmental values will be identified and weighed from the outset rather than accommodated by adjustments at the end of the decision-making process.

(b) *Specific actions.* The specific actions to be taken by the responsible official on notices of intent are:

(1) When the review process indicates a significant impact may occur and significant adverse impacts cannot be eliminated by making changes in the project, prepare a notice of intent immediately after the environmental review.

(2) Distribute copies of the notice of intent as required in Appendix C.

(3) Publish in a local newspaper, with adequate circulation to cover the area affected by the project, a brief public notice stating that an EIS will be prepared on a particular project, and the public may participate in preparing the EIS (Exhibit 2). News releases also may be submitted to other media.

(c) *Regional office assistance to program offices.* Regional offices will provide assistance to program offices in taking these specific actions when the EIS originates in a program office.

§ 6.208 Draft EIS's.

(a) *General.* (1) The responsible official shall assure that a draft EIS is prepared as soon as possible after the release of the notice of intent. Before releasing the draft EIS to CEQ, a preliminary version may be circulated for review to other offices within EPA with interest in or technical expertise related to the action. Then the draft EIS shall be sent to CEQ and circulated to Federal, State, regional and local agencies with special expertise or jurisdiction by law, and to interested persons. If the responsible official determines that a public hearing on the proposed action is warranted, the hearing will be held after the draft EIS is prepared, according to the requirements of § 6.402.

(2) Draft EIS's should be prepared at the earliest possible point in the project development. If the project involves a grant applicant or potential contractor, he must submit any data EPA requests for preparing the EIS. Where a plan or program has been developed by EPA or submitted to EPA for approval, the relationship between the plan and the later projects encompassed by its shall be evaluated to determine the best time to prepare an EIS. Whenever possible, an EIS will be drafted for the total program at the initial planning stage. Then later component projects included in the plan will not require individual EIS's unless they differ substantially from the plan, or unless the overall plan did not provide enough detail to fully assess significant impacts of individual projects. Plans shall be reevaluated by the responsible official to monitor the cumulative impact of the component projects and to preclude the plans' obsolescence.

(b) *Specific actions.* The specific actions to be taken by the responsible official on draft EIS's are:

(1) Distribute the draft EIS according to the procedures in Appendix C.

(2) Inform the agencies to reply directly to the originating EPA office. Commenting agencies shall have at least forty-five (45) calendar days to reply, starting from the date of publication in the FEDERAL REGISTER of lists of statements received by CEQ. If no comments are received during the reply period and no time extension has been requested, it shall be presumed that the agency has no comment to make. EPA may grant extensions of fifteen (15) or more calendar days. The time limits for review and extensions for State and local agencies; State, regional, and metropolitan clearinghouses; and interested persons shall be the same as those available to Federal agencies.

(3) Publish a notice in local newspapers stating that the draft EIS is available for comment and listing where copies may be obtained (Exhibit 2), and submit news releases to other media.

(4) Include in the draft EIS a notice stating that only those Federal, State, regional, and local agencies and interested persons who make substantive comments on the draft EIS or request a copy of the final EIS will be sent a copy.

(c) *Regional office assistance to program office.* If requested, regional offices will provide assistance to program offices in taking these specific actions when the EIS originates in a program office.

§ 6.210 Final EIS's.

(a) Final EIS's shall respond to all substantive comments raised through the review of the draft EIS. Special care should be taken to respond fully to comments disagreeing with EPA's position. (See also § 6.304(g).)

(b) Distribution and other specific actions are described in Appendix C. If there is an applicant, he shall be sent a copy. When the number of comments on the draft EIS is so large that distribution of the final EIS to all commenting entities appears impractical, the program or regional office preparing the EIS shall consult with OFA, which will consult with CEQ about alternative arrangements for distribution of the EIS.

§ 6.212 Negative declaration and environmental impact appraisals.

(a) *General.* When an environmental review indicates there will be no significant impact or significant adverse impacts have been eliminated by making changes in the project, the responsible official shall prepare a negative declaration to allow public review of his decision before it becomes final. The negative declaration and news release must state that interested persons disagreeing with the decision may submit comments for consideration by EPA. EPA shall not take administrative action on the project for at least fifteen (15) working days after release of the negative declaration and may allow more time for response. The responsible official shall have an environmental impact appraisal supporting the negative declaration available for public review when the negative declaration is released for those cases given in Subparts E, F, G, and H.

(b) *Specific actions.* The responsible official shall take the following specific actions on those projects for which both a negative declaration and an impact appraisal will be prepared:

(1) *Negative declaration.* (i) Prepare a negative declaration immediately after the environmental review. This document shall briefly summarize the purpose of the project, its location, the nature and extent of the land use changes related to the project, and the major primary and secondary impacts of the project. It shall describe how the more detailed environmental impact appraisal may be obtained at cost. (See Exhibit 3.)

(ii) Distribute the negative declaration according to procedures in Appendix C. In addition, submit to local newspapers and other appropriate media a brief news release with a negative declaration attached, informing the public that a decision not to prepare an EIS has been made and a negative declaration and environmental impact appraisal are available for public review and comment (Exhibit 2).

(2) *Environmental impact appraisal.* (i) Prepare an environmental impact appraisal concurrently with the negative declaration. This document shall briefly describe the proposed action and feasible alternatives, environmental impacts of the proposed action, unavoidable adverse impacts of the proposed action, the relationship between short term uses of man's environment and the maintenance and enhancement of long term productivity, steps to minimize harm to the environment, irreversible and irretrievable commitments of resources to implement the action, comments and consultations on the project, and reasons for concluding there will be no significant impacts. (See Exhibit 4.)

(ii) Distribute the environmental impact appraisal according to procedures in Appendix C.

§ 6.214 Additional procedures.

(a) *Historical and archaeological sites.* EPA is subject to the requirements of section 106 of the National Historic Preservation Act of 1966, 16 U.S.C. 470 *et seq.*, Executive Order 11593, the Archaeological and Historic Preservation Act of 1974, 16 U.S.C. 469 *et seq.*, and the regulations promulgated under this legislation. These statutes and regulations establish environmental review procedures which are independent of NEPA requirements.

(1) If an EPA action may affect properties with historic, architectural, archaeological or cultural value which are listed in the National Register of Historic Places (published in the FEDERAL REGISTER each February with supplements on the first Tuesday of each month), the responsible official shall comply with the procedures of the Advisory Council on Historic Preservation (36 CFR 800), including determining the need for a Memorandum of Agreement among EPA, the State Historic Preservation Officer and the Advisory Council. If a Memordandum of Agreement is executed, it shall be included in an EIS whenever one is prepared on a proposed action. See § 6.512(c) of this part for additional procedures for the construction grants program under Title II of the FWPCA, as amended.

(2) If an EPA action may cause irreparable loss or destruction of significant scientific, prehistoric, historic or archaeological data, the responsible official shall consult with the State Historic Preservation Officer in compliance with the Archaeological and Historic Preservation Act (P.L. 93-291).

(b) *Wetlands, floodplains, coastal zones, wild and scenic rivers, fish and wildlife.* The following procedures shall be applied to all EPA administrative actions covered by this part that may affect these environmentally sensitive resources.

(1) If an EPA action may affect wetlands, the responsible official shall consult with the appropriate offices of the Department of the Interior, Department of Commerce, and the U.S. Army Corps of Engineers during the environmental review to determine the probable impact of the action on the pertinent fish and wildlife resources and land use of these areas.

(2) If an EPA action may directly cause or induce the construction of buildings or other facilities in a floodplain, the responsible official shall evaluate flood hazards in connection with these facilities as required by Executive Order 11296 and shall, as far as practicable, consider alternatives to preclude the uneconomic, hazardous or unnecessary use of floodplains to minimize the exposure of facilities to potential flood damage, lessen the need for future Federal expenditures for flood protection and flood disaster relief and preserve the unique and significant public value of the floodplain as an environmental resource.

(3) If an EPA action may affect coastal zones or coastal waters as defined in Title III of the Costal Zone Management Act of 1972 (Pub. L. 92-583), the responsible official shall consult with the appropriate State offices and with the appropriate office of the Department of Commerce during the environmental review to determine the probable impact of the action on coastal zone or coastal water resources.

(4) If an EPA action may affect portions of rivers designated wild and scenic or being considered for this designation under the Wild and Scenic Rivers Act (Pub. L. 90-542), the responsible official shall consult with appropriate State offices and with the Secretary of the Interior or, where national forest lands are involved, with the Secretary of Agriculture during the environmental review to determine the status of an affected river and the probable impact of the action on eligible rivers.

(5) If an EPA action will result in the control or structural modification of any stream or other body of water for any purpose, including navigation and drainage, the responsible official shall consult with the United States Fish and Wildlife Service (Department of the Interior), the National Marine Fisheries Service of the National Oceanic and Atmospheric Administration (Department of Commerce), the U.S. Army Corps of Engineers and the head of the agency administering the wildlife resources of the particular State in which the action will take place with a view to the conservation of wildlife resources. This consultation shall follow the procedures in the Fish and Wildlife Coordination Act (Pub. L. 85-624) and shall occur during the environmental review of an action.

(6) If an EPA action may affect threatened or endangered species defined under section 4 of the Endangered Species Act of 1973 (Pub. L. 93-205), the responsible official shall consult with the Secretary of the Interior or the Secretary of Commerce, according to the procedures in section 7 of that act.

(7) Requests for consultation and the results of consultation shall be documented in writing. In all cases where consultation has occurred, the agencies consulted should receive copies of either the notice of intent and EIS or the negative declaration and environmental appraisal prepared on the proposed action. If a decision has already been made to prepare an EIS on a project and wetlands, floodplains, coastal zones, wild

and scenic rivers, fish or wildlife may be affected, the required consultation may be deferred until the preparation of the draft EIS.

§ 6.216 Availability of documents.

(a) EPA will print copies of draft and final EIS's for agency and public distribution. A nominal fee may be charged for copies requested by the public.

(b) When EPA no longer has copies of an EIS to distribute, copies shall be made available for public inspection at regional and headquarters Offices of Public Affairs. Interested persons also should be advised of the availability (at cost) of the EIS from the Environmental Law Institute, 1356 Connecticut Avenue NW., Washington, D.C. 20036.

(c) Lists of EIS's prepared or under preparation and lists of negative declarations prepared will be available at both the regional and headquarters Offices of Public Affairs.

Subpart C—Content of Environmental Impact Statements

§ 6.300 Cover sheet.

The cover sheet shall indicate the type of EIS (draft or final), the official project name and number, the responsible EPA office, the date, and the signature of the responsible official. The format is shown in Exhibit 5.

§ 6.302 Summary sheet

The summary sheet shall conform to the format in Exhibit 6, based on Appendix I of the August 1, 1973, CEQ Guidelines, or the latest revision of the CEQ Guidelines.

§ 6.304 Body of EIS.

The body of the EIS shall identify, develop, and analyze the pertinent issues discussed in the seven sections below; each section need not be a separate chapter. This analysis should include, but not be limited to, consideration of the impacts of the proposed project on the environmental areas listed in Appendix A which are relevant to the project. The EIS shall serve as a means for the responsible official and the public to assess the environmental impacts of a proposed EPA action, rather than as a justification for decisions already made. It shall be prepared using a systematic, interdisciplinary approach and shall incorporate all relevant analytical disciplines to provide meaningful and factual data, information, and analyses. The presentation of data should be clear and concise, yet include all facts necessary to permit independent evaluation and appraisal of the beneficial and adverse environmental effects of alternative actions. The amount of detail provided should be commensurate with the extent and expected impact of the action and the amount of information required at the particular level of decision making. To the extent possible, an EIS shall not be drafted in a style which requires extensive scientific or technical expertise to comprehend and evaluate the environmental impact of a proposed EPA action.

(a) *Background and description of the proposed action.* The EIS shall describe the recommended or proposed action, its purpose, where it is located and its time setting. When a decision has been made not to favor an alternative until public comments on a proposed action have been received, the draft EIS may treat all feasible alternatives at similar levels of detail; the final EIS should focus on the alternative the draft EIS and public comments indicate is the best. The relationship of the proposed action to other projects and proposals directly affected by or stemming from it shall be discussed, including not only other EPA activities, but also those of other governmental and private organizations. Land use patterns and population trends in the project area and the assumptions on which they are based also shall be included. Available maps, photos, and artists' sketches should be incorporated when they help depict the environmental setting.

(b) *Alternatives to the proposed action.* The EIS shall develop, describe, and objectively weigh feasible alternatives to any proposed action, including the options of taking no action or postponing action. The analysis should be detailed enough to show EPA's comparative evaluation of the environmental impacts, commitments of resources, costs, and risks of the proposed action and each feasible alternative. For projects involving construction, alternative sites must be analyzed in enough detail for reviewers independently to judge the relative desirability of each site. For alternatives involving regionalization, the effects of varying degrees of regionalization should be addressed. If a cost-benefit analysis is prepared, it should be appended to the EIS and referenced in the body of the EIS. In addition, the reasons why the proposed action is believed by EPA to be the best course of action shall be explained.

(c) *Environmental impacts of the proposed action.* (1) The positive and negative effects of the proposed action as it affects both the national and international environment should be assessed. The attention given to different environmental factors will vary according to the nature, scale, and location of proposed actions. Primary attention should be given to those factors most evidently affected by the proposed action. The factors shall include, where appropriate, the proposed action's effects on the resource base, including land, water quality and quantity, air quality, public services and energy supply. The EIS shall describe primary and secondary environmental impacts, both beneficial and adverse, anticipated from the action. The description shall include short term and long term impacts on both the natural and human environments.

(2) Primary impacts are those that can be attributed directly to the proposed action. If the action is a field experiment, materials introduced into the environment which might damage certain plant communities or wildlife species would be a primary impact. If the action involves construction of a facility, such as a sewage treatment works, an office building or a laboratory, the primary impacts of the action would include the environmental impacts related to construction and operation of the facility and land use changes at the facility site.

(3) Secondary impacts are indirect or induced changes. If the action involves construction of a facility, the secondary impacts would include the environmental impacts related to:

(i) induced changes in the pattern of land use, population density and related effects on air and water quality or other natural resources;

(ii) increased growth at a faster rate than planned for or above the total level planned by the existing community.

(4) A discussion of how socioeconomic activities and land use changes related to the proposed action conform or conflict with the goals and objectives of approved or proposed Federal, regional, State and local land use plans, policies and controls for the project area should be included in the EIS. If a conflict appears to be unresolved in the EIS, EPA should explain why it has decided to proceed without full reconciliation.

(d) *Adverse impacts which cannot be avoided should the proposal be implemented and steps to minimize harm to the environment.* The EIS shall describe the kinds and magnitudes of adverse impacts which cannot be reduced in severity or which can be reduced to an acceptable level but not eliminated. These may include water or air pollution, undesirable land use patterns, damage to fish and wildlife habitats, urban congestion, threats to human health or other consequences adverse to the environmental goals in section 101(b) of NEPA. Protective and mitigative measures to be taken as part of the proposed action shall be identified. These measures to reduce or compensate for any environmentally detrimental aspect of the proposed action may include those of EPA, its contractors and grantees and others involved in the action.

(e) *Relationship betwen local short term uses of man's environment and the maintenance and enhancement of long term productivity.* The EIS shall describe the extent to which the proposed action involves tradeoffs between short term environmental gains at the expense of long term gains or vice-versa and the extent to which the proposed action forecloses future options. Special attention shall be given to effects which narrow the range of future uses of land and water resources or pose long term risks to health or safety. Consideration should be given to windfall gains or significant decreases in current property values from implementing the proposed action. In addition, the reasons the proposed action is believed by EPA to be justified now, rather than reserving a long term option for other alternatives, including no action, shall be explained.

(f) *Irreversible and irretrievable commitments of resources to the proposed action should it be implemented.* The EIS shall describe the extent to which the proposed action requires commitment of construction materials, person-hours and funds to design and implement the project, as well as curtails the range of future uses of land and water resources. For example, induced growth in undeveloped areas may curtail alternative uses of that land. Also, irreversible environmental damage can result from equipment malfunctions or industrial accidents at the project site. Therefore, the need for any irretrievable and significant commitments of resources shall be explained fully.

(g) *Problems and objections raised by other Federal, State and local agencies and by interested persons in the review process.* Final EIS's (and draft EIS's if appropriate) shall summarize the comments and suggestions made by reviewing organizations and shall describe the disposition of issues raised, e.g., revisions to the proposed action to mitigate anticipated impacts or objections. In particular, the EIS shall address the major issues raised when the EPA position differs from most recommendations and explain the factors of overriding importance overruling the adoption of suggestions. Reviewer's statements should be set forth in a "comment" and discussed in a "response." In addition, the source of all comments should be clearly identified, and copies of the comments should be attached to the final EIS. Summaries of comments should be attached when a response has been exceptionally long or the same comments were received from many reviewers.

§ 6.306 Documentation.

All books, research reports, field study reports, correspondence and other documents which provided the data base for evaluating the proposed action and alternatives discussed in the EIS shall be used as references in the body of the EIS and shall be included in a bibliography attached to the EIS.

Subpart D—EPA Public Hearings on EIS's

§ 6.400 General.

While EPA is not required by statute to hold public hearings on EIS's, the responsible official should hold a public hearing on a draft EIS whenever a hearing may facilitate the resolution of conflicts or significant public controversy. This hearing may be in addition to public hearings held on facilities plans or section 209 plans. The responsible official may take special measures to involve interested persons through personal contact.

§ 6.402 Public hearing process.

(a) When public hearings are to be held, EPA shall inform the public of the hearing, for example, with a notice in the draft EIS. The notice should follow the summary sheet at the beginning of the EIS. The draft EIS shall be available for public review at least thirty (30) days before the public hearing. Public notice shall be given at least fifteen (15) working days before the public hearing and shall include:

(1) Publication of a public notice in a newspaper which covers the project area, identifying the project, announcing the date, time and place of the hearing and announcing the availability of detailed information on the proposed action for public inspection at one or more locations in the area in which the project will be located. "Detailed information" shall include a copy of the project application and the draft EIS.

(2) Notification of appropriate State and local agencies and appropriate State, regional and metropolitan clearinghouses.

(3) Notification of interested persons.

(b) A written record of the hearing shall be made. A stenographer may be used to record the hearing. As a minimum, the record shall contain a list of witnesses with the text of each presentation. A summary of the record, including the issues raised, conflicts resolved and unresolved, and any other significant portions of the record, shall be appended to the final EIS.

(c) When a public hearing has been held by another Federal, State, or local agency on an EPA action, additional hearings are not necessary. The responsible official shall decide if additional hearings are needed.

(d) When a program office is the originating office, the appropriate regional office will provide assistance to the originating office in holding any public hearing if assistance is requested.

Subpart E—Guidelines for Compliance With NEPA in the Title II Wastewater Treatment Works Construction Grants Program and the Areawide Waste Treatment Management Planning Program

§ 6.500 Purpose.

This subpart amplifies the general EPA policies and procedures described in Subparts A through D with detailed procedures for compliance with NEPA in the wastewater treatment works construction grants program and the areawide waste treatment management planning program.

§ 6.502 Definitions.

(a) "Step 1 grant." A grant for preparation of a facilities plan as described in 40 CFR 35.930-1.

(b) "Step 2 grant." A grant for preparation of construction drawings and specifications as described in 40 CFR 35.930-1.

(c) "Step 3 grant." A grant for fabrication and building of a publicly owned treatment works as described in 40 CFR 35.930-1

§ 6.504 Applicability.

(a) *Administrative actions covered.* This subpart applies to the administrative actions listed below:

(1) Approval of all section 208 plans according to procedures in 40 CFR 35.1067-2;

(2) Approval of all facilities plans except those listed in paragraph (a)(5) of this section;

(3) Award of step 2 and step 3 grants, if an approved facilities plan was not required;

(4) Award of a step 2 or step 3 grant when either the project or its impact has changed significantly from that described in the approved facilities plan, except when the situation in paragraph (a)(5) of this section exists;

(5) Consultation during the NEPA review process. When there are overriding considerations of cost or impaired program effectiveness, the Regional Administrator may award a step 2 or a step 3 grant for a discrete segment of the project plans or construction before the NEPA review is completed if this project segment is noncontroversial. The remaining portion of the project shall be evaluated to determine if an EIS is required. In applying the criteria for this determination, the entire project shall be considered, including those parts permitted to proceed. In no case may these types of step 2 or step 3 grants be awarded unless both the Office of Federal Activities and CEQ have been consulted, a negative declaration has been issued on the segments permitted to proceed, and the grant award contains a specific agreement prohibiting action on the segment of planning or construction for which the NEPA review is not complete. Examples of consultation during the NEPA review process are: award of a step 2 grant for preparation of plans and specifications for a large treatment plant, when the only unresolved NEPA issue is where to locate the sludge disposal site; or award of a step 3 grant for site clearance for a large treatment plant, when the unresolved NEPA issue is whether sludge from the plant should be incinerated at the site or disposed of elsewhere by other means.

(b) *Administrative actions excluded.* The actions listed below are not subject to the requirements of this part:

(1) Approval of State priority lists;

(2) Award of a step 1 grant;

(3) Award of a section 208 planning grant;

(4) Award of a step 2 or step 3 grant when no significant changes in the facilities plan have occurred;

(5) Approval of issuing an invitation for bid or awarding a construction contract;

(6) Actual physical commencement of building or fabrication;

(7) Award of a section 206 grant for reimbursement;

(8) Award of grant increases whenever § 6.504(a)(4) does not apply;

(9) Awards of training assistance under FWPCA, as amended, section 109(b).

(c) *Retroactive application.* The new criteria in § 6.510 of this subpart do not apply to step 2 or step 3 grants awarded before July 1, 1975. However, the Regional Administrator may apply the new criteria of this subpart when he considers it appropriate. Any negative declarations issued before the effective date of this regulation shall remain in effect.

§ 6.506 Completion of NEPA procedures before start of administrative actions.

See § 6.108 and § 6.504.

§ 6.510 Criteria for preparation of environmental impact statements.

In addition to considering the criteria in § 6.200, the Regional Administrator shall assure that an EIS will be prepared on a treatment works facilities plan, 208 plan or other appropriate water quality management plan when:

(a) The treatment works or plan will induce significant changes (either absolute changes or increases in the rate of change) in industrial, commercial, agricultural, or residential land use concentrations or distributions. Factors that should be considered in determining if these changes are significant include but are not limited to: the vacant land subject to increased development pressure as a result of the treatment works; the increases in population which may be induced; the faster rate of change of population; changes in population density; the potential for overloading sewage treatment works; the extent to which landowners may benefit from the areas subject to increased development; the nature of land use regulations in the affected area and their potential effects on development; and deleterious changes in the availability or demand for energy.

(b) Any major part of the treatment works will be located on productive wetlands or will have significant adverse effects on wetlands, including secondary effects.

(c) Any major part of the treatment works will be located on or significantly affect the habitat of wildlife on the Department of Interior's threatened and endangered species lists.

(d) Implementation of the treatment works or plan may directly cause or induce changes that significantly:

(1) Displace population;

(2) Deface an existing residential area; or

(3) Adversely affect significant amounts of prime agricultural land or agricultural operations on this land.

(e) The treatment works or plan will have significant adverse effects on parklands, other public lands or areas of recognized scenic, recreational, archaeological or historic value.

(f) The works or plan may directly or through induced development have a significant adverse effect upon local ambient air quality, local ambient noise levels, surface or groundwater quantity or quality, fish, wildlife, and their natural habitats.

(g) The treated effluent is being discharged into a body of water where the present classification is too lenient or is being challenged as too low to protect present or recent uses, and the effluent will not be of sufficient quality to meet the requirements of these uses.

§ 6.512 Procedures for implementing NEPA.

(a) *Environmental assessment.* An adequate environmental assessment must be an integral, though identifiable, part of any facilities or section 208 plan submitted to EPA. (See § 6.202 for a general description.) The information in the facilities plan, particularly the environmental assessment, will provide the substance of an EIS and shall be submitted by the applicant. The analyses that constitute an adequate environmental assessment shall include:

(1) *Description of the existing environment without the project.* This shall include for the delineated planning area a description of the present environmental conditions relevant to the analysis of alternatives or determinations of the environmental impacts of the proposed action. The description shall include, but not be limited to, discussions of whichever areas are applicable to a particular study: surface and groundwater quality; water supply and use; general hydrology; air quality; noise levels, energy production and consumption; land use trends; population projections, wetlands, floodplains, coastal zones and other environmentally sensitive areas; historic and archaeological sites; other related Federal or State projects in the area; and plant and animal communities which may be affected, especially those containing threatened or endangered species.

(2) *Description of the future environment without the project.* The future environmental conditions with the no project alternative shall be forecast, covering the same areas listed in § 6.512 (a)(1).

(3) *Documentation.* Sources of information used to describe the existing environment and to assess future environmental impacts should be documented. These sources should include regional, State and Federal agencies with responsibility or interest in the types of impacts listed in § 6.512(a)(1). In particular, the following agencies should be consulted:

(i) Local and regional land use planning agencies for assessments of land use trends and population projections, especially those affecting size, timing, and location of facilities, and planning activities funded under section 701 of the Housing and Community Development Act of 1974 (Pub. L. 93-383);

(ii) The HUD Regional Office if a project involves a flood risk area identified under the Flood Disaster Protection Act of 1973 (Pub. L. 93-234);

(iii) The State coastal zone management agency, if a coastal zone is affected;

(iv) The Secretary of the Interior or Secretary of Agriculture, if a wild and scenic river is affected;

(v) The Secretary of the Interior or Secretary of Commerce, if a threatened or endangered species is affected;

(vi) The Fish and Wildlife Service (Department of Interior), the Department of Commerce, and the U.S. Army Corps of Engineers, if a wetland is affected.

(4) *Evaluation of alternatives.* This discussion shall include a comparative analysis of feasible options and a systematic development of wastewater treatment alternatives. The alternatives shall be screened with respect to capital and operating costs; significant primary and secondary environmental effects; physical, legal or institutional constraints; and whether or not they meet regulatory requirements. Special attention should be given to long term impacts, irreversible impacts and induced impacts such as development. The reasons for rejecting any alternatives shall be presented in addition to any significant environmental benefits precluded by rejection of an alternative. The analysis should consider, when relevant to the project:

(i) Flow and waste reduction measures, including infiltration/inflow reduction;

(ii) Alternative locations, capacities, and construction phasing of facilities;

(iii) Alternative waste management techniques, includign treatment and discharge, wastewater reuse and land application;

(iv) Alternative methods for disposal of sludge and other residual waste, including process options and final disposal options;

(v) Improving effluent quality through more efficient operation and maintenance;

(vi) For assessments associated with section 208 plans, the analysis of options shall include in addition:

(A) Land use and other regulatory controls, fiscal controls, non-point source controls, and institutional arrangements; and

(B) Land management practices.

(5) *Environmental impacts of the proposed action.* Primary and secondary impacts of the proposed action shall be described, giving special attention to unavoidable impacts, steps to mitigate adverse impacts, any irreversible or irretrievable commitments of resources to the project and the relationship between local short term uses of the environment and the maintenance and enhancement of long term productivity. See § 6.304 (c), (d), (e), and (f) for an explanation of these terms and examples. The significance of land use impacts shall be evaluated, based on current population of the planning area; design year population for the service area; percentage of the service area currently vacant; and plans for staging facilities. Special attention should be given to induced changes in population patterns and growth, particularly if a project involves some degree of regionalization. In addition to these items, the Regional Administrator may require that other analyses and data, which he determines are needed to comply with NEPA, be included with the facilities or section 208 plan. Such requirements should be discussed during preapplication conferences. The Regional Administrator also may require submission of supplementary information either before or after a step 2 grant or before a step 3 grant award if he determines it is needed for compliance with NEPA. Requests for supplementary information shall be made in writing.

(6) *Steps to minimize adverse effects.* This section shall describe structural and

nonstructural measures, if any, in the facilities plan to mitigate or eliminate significant adverse effects on the human and natural environments. Structural provisions include changes in facility design, size, and location; nonstructural provisions include staging facilities as well as developing and enforcing land use regulations and environmentally protective regulations.

(b) *Public hearing.* The applicant shall hold at least one public hearing before a facilities plan is adopted, unless waived by the Regional Administrator before completion of the facilities plan according to § 35.917-5 of the Title II construction grants regulations. Hearings should be held on section 208 plans. A copy of the environmental assessment should be available for public review before the hearing and at the hearing, since these hearings provide an opportunity to accept public input on the environmental issues associated with the facilities plan or the 208 water quality management strategy. In addition, a Regional Administrator may elect to hold an EPA hearing if environmental issues remain unresolved. EPA hearings shall be held according to procedures in § 6.402.

(c) *Environmental review.* An environmental review of a facilities plan or section 208 plan shall be conducted according to the procedures in § 6.204 and applying the criteria of § 6.510. If deficiencies exist in the environmental assessment, they shall be identified in writing by the Regional Administrator and must be corrected before the plan can be approved.

(d) *Additional procedures.* (1) Historic and archaeological sites. If a facilities or section 208 plan may affect properties with historic, architectural, archaeological or cultural value which are listed in or eligible for listing in the National Register of Historic Places or may cause irreparable loss or destruction of significant scientific, prehistoric, historic or archaeological data, the applicant shall follow the procedures in § 6.214(a).

(2) If the facilities or section 208 plan may affect wetlands, floodplains, coastal zones, wild and scenic rivers, fish or wildlife, the Regional Administrator shall follow the appropriate procedures described in § 6.214(b).

(e) *Notice of intent.* The notice of intent on a facilities plan or section 208 plan shall be issued according to § 6.206.

(f) *Scope of EIS.* It is the Regional Administrator's responsibility to determine the scope of the EIS. He should determine if an EIS should be prepared on a facilities plan(s) or section 208 plan and which environmental areas should be discussed in greatest detail in the EIS. Once an EIS has been prepared for the designated section 208 area, another need not be prepared unless the significant impacts of individual facilities or other plan elements were not adequately treated in the EIS. The Regional Administrator should document his decision not to prepare an EIS on individual facilities.

(g) *Negative declaration.* A negative declaration on a facilities plan or section 208 plan shall be prepared according to § 6.212. Once a negative declaration and environmental appraisal have been prepared for the facilities plan for a certain area, grant awards may proceed without preparation of additional negative declarations, unless the project has changed significantly from that described in the facilities plan.

§ 6.514 Content of environmental impact statements.

EIS's for treatment works or plans shall be prepared according to § 6.304.

Subpart F—Guidelines for Compliance With NEPA in Research and Development Programs and Activities

§ 6.600 Purpose.

This subpart amplifies the general EPA policies and procedures described in Subparts A through D by providing procedures for compliance with NEPA on actions undertaken by the Office of Research and Development (ORD).

§ 6.602 Definitions.

(a) "Work plan." A document which defines and schedules all projects required to fulfill the objectives of the program plan.

(b) "Program plan." An overall planning document for a major research area which describes one or more research objectives, including outputs and target completion dates, as well as person-year and dollar resources.

(c) "Appropriate program official." The official at each decision level within ORD to whom the Assistant Administrator delegates responsibility for NEPA compliance.

(d) "Exemption certification." A certified statement delineating those actions specifically exempted from NEPA compliance by existing legislation.

§ 6.604 Applicability.

The requirements of this subpart are applicable to administrative actions undertaken to approve program plans, work plans, and projects, except those plans and projects excluded by existing legislation. However, no administrative actions are excluded from the additonal procedures in § 6.214 of this part concerning historic sites, wetlands, coastal zones, wild and scenic rivers, floodplains or fish and wildlife.

§ 6.608 Criteria for determining when to prepare EIS's.

(a) An EIS shall be prepared by ORD when any of the criteria in § 6.200 apply or when:

(1) The action will have significant adverse impacts on public parks, wetlands, floodplains, coastal zones, wildlife habitats, or areas of recognized scenic or recreational value.

(2) The action will significantly deface an existing residential area.

(3) The action may directly or through induced development have a significant adverse effect upon local ambient air quality, local ambient noise levels, surface or groundwater quality; and fish, wildlife or their natural habitats.

(4) The treated effluent is being discharged into a body of water where the present classification is being challenged as too low to protect present or recent uses, and the effluent will not be of sufficient quality to meet the requirements of these uses.

(5) The project consists of field tests involving the introduction of significant quantities of: toxic or polluting agricultural chemicals, animal wastes, pesticides, radioactive materials, or other hazardous substances into the environment by ORD, its grantees or its contractors.

(6) The action may involve the introduction of species or subspecies not indigenous to an area.

(7) There is a high probability of an action ultimately being implemented on a large scale, and this implementation may result in significant environmental impacts.

(8) The project involves commitment to a new technology which is significant and may restrict future viable alternatives.

(b) An EIS will not usually be needed when:

(1) The project is conducted completely within a laboratory or other facility, and external environmental effects have been minimized by methods for disposal of laboratory wastes and safeguards to prevent hazardous materials entering the environment accidentally; or

(2) The project is a relatively small experiment or investigation that is part of a non-Federally funded activity of the private sector, and it makes no significant new or additional contribution to existing pollution.

§ 6.610 Procedures for compliance with NEPA.

EIS related activities for compliance with NEPA will be integrated into the decision levels of ORD's research planning system to assure managerial control. This control includes those administrative actions which do not come under the applicability of this subpart by assuring that they are made the subject of an exemption certification and filed with the Office of Public Affairs (OPA). ORD's internal procedures provide details for NEPA compliance.

(a) *Environmental assessment.* (1) Environmental assessments shall be submitted with all grant applications and all unsolicited contract proposals. The assessment shall contain the same information required for EIS's in § 6.304. Copies of § 6.304 (or more detailed guidance when available) and a notice of the requirement for assessment shall be included in all grant application kits and attached to letters concerning the submission of unsolicited proposals.

(2) In the case of competitive contracts, assessments need not be submitted by potential contractors since the NEPA procedures must be completed before a request for proposal (RFP) is issued. If there is a question concerning

the need for an assessment, the potential contractor should contact the official responsible for the contract.

(b) *Environmental review.* (1) At the start of the planning year, an environmental review will be performed for each program plan with its supporting substructures (work plans and projects) before incorporating them into the ORD program planning system, unless they are excluded from review by existing legislation. This review is an evaluation of the potentially adverse environmental effects of the efforts required by the program plan. The criteria in § 6.608 shall be used in conducting this review. Each program plan with its supporting substructures which does not have significant adverse impacts may be dismissed from further current year environmental considerations with a single negative declaration. Any supporting substructures of a program plan which cannot be dismissed with the parent plan shall be reviewed at the appropriate subordinate levels of the planning system for NEPA compliance.

(i) All continuing program plans and supporting substructures, including those previously dismissed from consideration, will be reevaluted annually for NEPA compliance. An environmental review will coincide with the annual planning cycle and whenever a major redirection of a parent plan is undertaken. All NEPA-associated documents will be updated as appropriate.

(ii) All approved program plans and supporting substructures, less budgetary data, will be filed in the OPA with a notice of intent or negative declaration and environmental appraisal.

(iii) Later plans and/or projects, added to fulfill the mission objectives but not identified at the time the program plans were approved, will be subjected to the same NEPA requirements for environmental assessments and/or reviews.

(iv) Those projects subjected to environmental assessments as outlined in paragraph (a) of this section and not exempt under existing legislation also shall undergo an environmental review before work begins.

(c) *Notice of intent and EIS.*

(1) If the reviews conducted according to paragraph (b) of this section reveal a potentially significant adverse effect on the environment and the adverse impact cannot be eliminated by replanning, the appropriate program official shall, after making sure the project is to be funded, issue a notice of intent according to § 6.206, and through proper organizational channels, shall request the Regional Administrator to assist him in the preparation and distribution of the EIS.

(2) As soon as possible after release of the notice of intent, the appropriate program official shall prepare a draft EIS using the criteria in Subpart B, § 6.208 and Subpart C. Through proper organizational channels, he shall request the Regional Administrator to assist him in the preparation and distribution of the draft EIS.

(3) The appropriate program official shall prepare final EIS's according to criteria in Subpart B, § 6.210 and Subpart C.

(4) All draft and final EIS's shall be sent through the proper organizational channels to the Assistant Administrator for ORD for approval. The approved statements then will be distributed according to the procedures in Appendix C.

(d) *Negative declaration and environmental impact appraisal.* If an environmental review conducted according to paragraph (b) of this section reveals that proposed actions will not have significant adverse environmental impacts, the appropriate program official shall prepare a negative declaration and environmental impact appraisal according to Subpart B, § 6.212. Upon assurance that the program will be funded, the appropriate program official shall distribute the negative declaration as described in § 6.212 and make copies of the negative declaration and appraisal available in the OPA.

(e) *Project start.* As required by § 6.108, a contract or grant shall not be awarded for an extramural project, nor for continuation of what was previously an intramural project, until at least fifteen (15) working days after a negative declaration has been issued or thirty (30) days after forwarding the final EIS to the Council on Environmental Quality.

Subpart G—Guidelines for Compliance With NEPA in Solid Waste Management Activities

§ 6.700 Purpose.

This subpart amplifies the general policies and procedures described in Subparts A through D by providing additional procedures for compliance with NEPA on actions undertaken by the Office of Solid Waste Management Programs (OSWMP).

§ 6.702 Criteria for the preparation of environmental assessments and EIS's.

(a) *Assessment preparation criteria.* An environmental assessment need not be submitted with all grant applications and contract proposals. Studies and investigations do not require assessments. The following sections describe when an assessment is or is not required for other actions:

(1) *Grants.* (i) *Demonstration projects.* Environmental assessments must be submitted with all applications for demonstration grants that will involve construction, land use (temporary or permanent), transport, sea disposal, any discharges into the air or water, or any other activity having any direct or indirect effects on the environment external to the facility in which the work will be conducted. Preapplication proposals for these grants will not require environmental assessments.

(ii) *Training.* Grant applications for training of personnel will not require assessments.

(iii) *Plans.* Grant applications for the development of comprehensive State, interstate, or local solid waste management plans will not require environmental assessments. A detailed analysis of environmental problems and effects should be part of the planning process, however.

(2) *Contracts.* (i) *Sole-source contract proposals.* Before a sole-source contract can be awarded, an environmental assessment must be submitted with a bid proposal for a contract which will involve construction, land use (temporary or permanent), sea disposal, any discharges into the air or water, or any other activity that will directly or indirectly affect the environment external to the facility in which the work will be performed.

(ii) *Competitive contract proposals.* Assessments generally will not be required on competitive contract proposals.

(b) *EIS preparation criteria.* The responsible official shall conduct an environmental review on those OSWMP projects on which an assesment is required or which may have effects on the environment external to the facility in which the work will be performed. The criteria in § 6.200 shall be utilized in determining whether an EIS need be prepared.

§ 6.704 Procedures for compliance with NEPA.

(a) *Environmental assessment.* (1) Environmental assessments shall be submitted to EPA according to procedures in § 6.702. If there is a question concerning the need for an assessment, the potential contractor or grantee should consult with the appropriate project officer for the grant or contract.

(2) The assessment shall contain the same sections specified for EIS's in § 6.304. Copies of § 6.304 (or more detailed guidance when available) and a notice alerting potential grantees and contractors of the assessment requirements in § 6.702 shall be included in all grant application kits, attached to letters concerning the submission of unsolicited proposals, and included with all RFP's.

(b) *Environmental review.* An environmental review will be conducted on all projects which require assessments or which will affect the environment external to the facility in which the work will be performed. This review must be conducted before a grant or contract award is made on an extramural project or before an intramural project begins. The guidelines in § 6.200 will be used to determine if the project will have any significant environmental effects. This review will include an evaluation of the assessment by both the responsible official and the appropriate Regional Administrator. The Regional Administrator's comments will include his recommendations on the need for an EIS. No detailed review or documentation is required on projects for which assessments are not required and which will not affect the environment external to a facility.

(c) *Notice of intent and EIS.* If any of the criteria in § 6.200 apply, the responsible official will assure that a notice of intent and a draft EIS are prepared. The responsible official may request the appropriate Regional Administrator to assist him in the distribution of the NEPA-associated documents. Distribution procedures are listed in Appendix C.

(d) *Negative declaration and environmental impact appraisal.* If the environmental review indicated no significant environmental impacts, the responsible official will assure that a negative declaration and environmental appraisal are prepared. These documents need not be prepared for projects not requiring an environmental review.

(e) The EIS process for the Office of Solid Waste Management Programs is shown graphically in Exhibit 7.

Subpart H—Guidelines for Compliance With NEPA in Construction of Special Purpose Facilities and Facility Renovations

§ 6.800 Purpose.

This subpart amplifies general EPA policies and procedures described in Subparts A through D by providing detailed procedures for the preparation of EIS's on construction and renovation of special purpose facilities.

§ 6.802 Definitions.

(a) "Special purpose facility." A building or space, including land incidental to its use, which is wholly or predominantly utilized for the special purpose of an agency and not generally suitable for other uses, as determined by the General Services Administration.

(b) "Program of requirements." A comprehensive document (booklet) describing program activities to be accomplished in the new special purpose facility or improvement. It includes architectural, mechanical, structural, and space requirements.

(c) "Scope of work." A document similar in content to the program of requirements but substantially abbreviated. It is usually prepared for small-scale projects.

§ 6.804 Applicability.

(a) *Actions covered.* These guidelines apply to all new special purpose facility construction, activities related to this construction (e.g., site acquisition and clearing), and any improvements or modifications to facilities having potential environmental effects external to the facility, including new construction and improvements undertaken and funded by the Facilities Management Branch, Facilities and Support Services Division, Office of Administration; by a regional office; or by a National Environmental Research Center.

(b) *Actions excluded.* This subpart does not apply to those activities of the Facilities Management Branch, Facilities and Support Services Division, for which the branch does not have full fiscal responsibility for the entire project. This includes pilot plant construction, land acquisition, site clearing and access road construction where the Facilities Management Branch's activity is only supporting a project financed by a program office. Responsibility for considering the environmental impacts of such projects rests with the office managing and funding the entire project. Other subparts of this regulation apply depending on the nature of the project.

§ 6.808 Criteria for the preparation of environmental assessments and EIS's.

(a) *Assessment preparation criteria.* The responsible official shall request an environmental assessment from a construction contractor or consulting architect/engineer employed by EPA if he is involved in the planning, construction or modification of special purpose facilities when his activities have potential environmental effects external to the facility. Such modifications include but are not limited to: facility additions, changes in central heating systems or wastewater treatment systems, and land clearing for access roads and parking lots.

(b) *EIS preparation criteria.* The responsible official shall conduct an environmental review of all actions involving construction of special purpose facilities and improvements to these facilities. The guidelines in § 6.200 shall be used to determine whether an EIS shall be prepared.

§ 6.810 Procedures for compliance with NEPA.

(a) *Environmental review and assessment.* (1) An environmental review shall be conducted when the program of requirements or scope of work has been completed for the construction, improvement, or modification of special purpose facilities. For special purpose facility construction, the Chief, Facilities Management Branch, shall request the assistance of the appropriate program office and Regional Administrator in the review. For modifications and improvements, the appropriate responsible official shall request assistance in making the review from other cognizant EPA offices.

(2) Any assessments requested shall contain the same sections listed for EIS's in § 6.304. Contractors and consultants shall be notified in contractual documents when an assessment must be prepared.

(b) *Notice of intent, EIS, and negative declaration.* The responsible official shall decide at the completion of the environmental review whether there may be any significant environmental impacts. If there could be significant environmental impacts, a notice of intent and an EIS shall be prepared according to the procedures in § 6.206. If there may not be any significant environmental impacts, a negative declaration and environmental impact appraisal shall be prepared according to the procedures in § 6.212.

(c) *Project start.* As required by § 6.108, a contract shall not be awarded or construction-related activities begun until at least fifteen (15) working days after release of a negative declaration, or until thirty (30) days after forwarding the final EIS to the Council on Environmental Quality.

EXHIBIT 1

NOTICE OF INTENT TRANSMITTAL MEMORANDUM SUGGESTED FORMAT

(Date)

ENVIRONMENTAL PROTECTION AGENCY

(Appropriate Office)

(Address, City, State, Zip Code)

To All Interested Government Agencies and Public Groups:

As required by guidelines for the preparation of environmental impact statements (EIS's), attached is a notice of intent to prepare an EIS for the proposed EPA action described below:

(Official Project Name and Number)

(City, State)

If your organization needs additional information or wishes to participate in the preparation of the draft EIS, please advise the (appropriate office, city, State).

Very truly yours,

(Appropriate EPA Official)

(List Federal, State, and local agencies to be solicited for comment.)
(List public action groups to be solicited for comment.)

NOTICE OF INTENT SUGGESTED FORMAT

NOTICE OF INTENT—ENVIRONMENTAL PROTECTION AGENCY

1. Project location:
   City -------------------
   County -------------------
   State -------------------
2. Proposed EPA action:

   ----
3. Issues involved:

   ----
4. Estimated project costs:
   Federal Share (total) ---------- $-----
   Contract $---- Grant $---- Other $-----
   Applicant share (if any):
   (Name) ---------- $-----
   Other (specify) ---------- $-----
   Total ---------- $-----
5. Period covered by project:
   Start date:----- -------------------
   (Original date, if project covers more than one year)
   Dates of different project phases: --------
   Approximate end date: --------
6. Estimated application filing date: --------

EXHIBIT 2

PUBLIC NOTICE AND NEWS RELEASE SUGGESTED FORMAT

PUBLIC NOTICE

The Environmental Protection Agency (originating office) (will prepare, will not prepare, has prepared) a (draft, final) environmental impact statement on the following project:

(Official Project Name and Number)

(Purpose of Project)

(Project Location, City, County, State)

(Where EIS or negative declaration and environmental impact appraisal can be obtained)

This notice is to implement EPA's policy of encouraging public participation in the decision-making process on proposed EPA actions. Comments on this document may be submitted to (full address of originating office).

EXHIBIT 3

NEGATIVE DECLARATION SUGGESTED FORMAT

(Date)

ENVIRONMENTAL PROTECTION AGENCY

(Appropriate Office)

(Address, City, State, Zip Code)

To All Interested Government Agencies and Public Groups:

As required by guidelines for the preparation of environmental impact statements (EIS's), an environmental review has been performed on the proposed EPA action below:

(Official Project Name and Number)

(Potential Agency Financial Share)

(Project Location: City, County, State)

(Other Funds Included)

PROJECT DESCRIPTION, ORIGINATOR, AND PURPOSE

(Include a map of the project area and a brief narrative summarizing the growth the project will serve, the percent of vacant land the project will serve, major primary and secondary impacts of the project, and the purpose of the project.)

The review process did not indicate significant environmental impacts would result from the proposed action or significant adverse impacts have been eliminated by making changes in the project. Consequently, a preliminary decision not to prepare an EIS has been made.

This action is taken on the basis of a careful review of the engineering report, environmental impact assessment, and other supporting data, which are on file in the above office with the environmental impact appraisal and are available for public scrutiny upon request. Copies of the environmental impact appraisal will be sent at cost on your request.

Comments supporting or disagreeing with this decision may be submitted for consideration by EPA. After evaluating the comments received, the Agency will make a final decision; however, no administrative action will be taken on the project for at least fifteen (15) working days after release of the negative declaration.

Sincerely,

(Appropriate EPA Official)

EXHIBIT 4

ENVIRONMENTAL IMPACT APPRAISAL SUGGESTED FORMAT

A. Identify Project.
Name of Applicant: ------------------
Address: ------------------
Project Number: ------------------

B. Summarize Assessment.
1. Brief description of project: ------------------
2. Probable impact of the project on the environment: ------------------
3. Any probable adverse environmental effects which cannot be avoided: ------------------
4. Alternatives considered with evaluation of each: ------------------
5. Relationship between local short-term uses of man's environment and maintenance and enhancement of long-term productivity: ------------------
6. Steps to minimize harm to the environment: ------------------
7. Any irreversible and irretrievable commitment of resources: ------------------
8. Public objections to project, if any, and their resolution: ------------------
9. Agencies consulted about the project: ------------------
State representative's name: ----------
Local representative's name: ----------
Other: ------------------

C. Reasons for concluding there will be no significant impacts.

(Signature of appropriate official)
(Date)

EXHIBIT 5

COVER SHEET FORMAT FOR ENVIRONMENTAL IMPACT STATEMENTS

(Draft, Final)

ENVIRONMENTAL IMPACT STATEMENT

(Describe title of project plan and give identifying number)

Prepared by: ------------------
(Responsible Agency Office)

Approved by: ------------------
(Responsible Agency Official)

(Date)

EXHIBIT 6

SUMMARY SHEET FORMAT FOR ENVIRONMENTAL IMPACT STATEMENTS

(Check One)
( ) Draft
( ) Final

ENVIRONMENTAL PROTECTION AGENCY

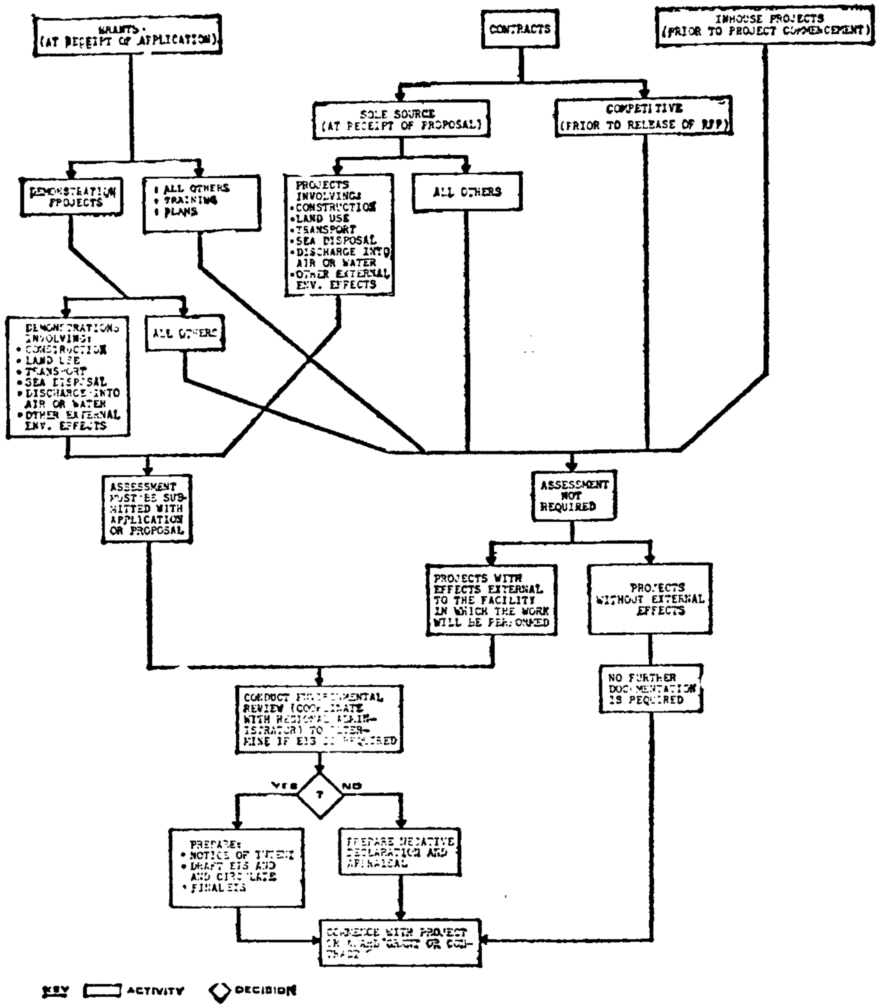
(Responsible Agency Office)

1. Name of action. (Check one)
   ( ) Administrative action.
   ( ) Legislative action.
2. Brief description of action indicating what States (and counties) are particularly affected.
3. Summary of environmental impact and adverse environmental effects.
4. List alternatives considered.
5. a. (for draft statements) List all Federal State, and local agencies and other comments have been requested.
   b. (for final statements) List all Federal Ctate, and local agencies and other sources from which written comments have been received.
6. Dates draft statement and final statement made available to Council on Environmental Quality and public.

EXHIBIT 7

FLOWCHART FOR OSWMP

PROCEDURES FOR DETERMINING IF AN EIS IS REQUIRED ON OSWMP PROJECTS



APPENDIX A

CHECKLIST FOR ENVIRONMENTAL REVIEWS

Areas to be considered, when appropriate, during an environmental review include, but are not limited to, the items on this checklist, based on Appendix II of the CEQ guidelines for the preparation of environmental impact statements which appeared in the FEDERAL REGISTER August 1, 1973. The classification of items is not mandatory.

I. *Natural environment.* Consider the impacts of a proposed action on air quality water supply and quality, soil conservation and hydrology, fish, and wildlife populations, fish and wildlife habitats, solid waste disposal, noise levels, radiation, and hazardous substances use and disposal.

II. *Land use planning and management.* Consider the impacts of a proposed action on energy supply and natural resources development; protection of environmentally critical areas, such as floodplains, wetlands, beaches and dunes, unstable soils, steep slopes and aquifer recharge areas, coastal area land use; and redevelopment and construction in built-up areas.

III. *Socioeconomic environment.* Consider the impacts of a proposed action on population density changes, congestion mitigation, neighborhood character and cohesion, low income populations, outdoor recreation, industrial/commercial/residential development and tax ratables, and historic, architectural and archaeological preservation.

APPENDIX B

RESPONSIBILITIES

I. *General responsibilities.* (a) *Responsible official.* (1) Requires contractors and grantees to submit environmental assessments and related documents needed to comply with NEPA, and assures environmental reviews are conducted on proposed EPA projects at the earliest possible point in EPA's decision-making process.

(2) When required, assures that draft EIS's are prepared and distributed at the earliest possible point in EPA's decision-making process, their internal and external review is coordinated, and final EIS's are prepared and distributed.

(3) When an EIS is not prepared, assures that negative declarations and environmental appraisals are prepared and distributed for those actions requiring them.

(4) Consults with appropriate officials identified in § 6.214 of this part.

(5) Consults with the Office of Federal Activities on actions involving unresolved conflicts with other Federal agencies.

(b) *Office of Federal Activities.* (1) Provides EPA with policy guidance and assures that EPA offices establish and maintain adequate administrative procedures to comply with this part.

(2) Monitors the overall timeliness and quality of the EPA effort to comply with this part.

(3) Provides assistance to responsible officials as required.

(4) Coordinates the training of personnel involved in the review and preparation of EIS's and other NEPA-associated documents.

(5) Acts as EPA liaison with the Council on Environmental Quality and other Federal and State entities on matters of EPA policy and administrative mechanisms to facilitate external review of EIS's, to determine lead agency and to improve the uniformity of the NEPA procedures of Federal agencies.

(6) Advises the Administrator and Deputy Administrator on projects which involve more than one EPA office, are controversial, are nationally significant, or "pioneer" EPA policy, when these projects have had or should have an EIS prepared on them.

(c) *Office of Public Inquiries.* Assists the Office of Federal Activities and responsible officials by answering the public's queries on the EIS process and on specific EIS's and by directing requests for copies of specific documents to the appropriate regional office or program.

(d) *Office of Public Affairs.* Analyzes the present procedures for public participation, and develops and recommends to the Office of Federal Activities a program to improve those procedures and increase public participation.

(e) *Regional Office Division of Public Affairs.* (1) Assists the responsible official or his designee on matters pertaining to negative declarations, notices of intent, press releases, and other public notification procedures.

(2) Assists the responsible official or his designee by answering the public's queries on the EIS process and on specific EIS's, and by filling requests for copies of specific documents.

(f) *Offices of the Assistant Administrators and Regional Administrators.* (1) Provides specific policy guidance to their respective offices and assures that those offices establish and maintain adequate administrative procedures to comply with this part.

(2) Monitors the overall timeliness and quality of their respective offices efforts to comply with this part.

(3) Acts as liaison between their offices and the Office of Federal Activities and between their offices and other Assistant Administrators or Regional Administrators on matters of agencywide policy and procedures.

(4) Advises the Administrator and Deputy Administrator through the Office of Federal Activities on projects or activities within their respective areas of responsibilities which involve more than one EPA office, are controversial, are nationally significant, or "pioneer" EPA policy, when these projects have had or should have an EIS prepared on them.

(g) *The Office of Legislation.* (1) Provides the necessary liaison with Congress.

(2) Coordinates the preparation of EIS's required on reports on legislation originating outside EPA. (See § 6.106(d)).

(h) *The Office of Planning and Evaluation.* Coordinates the preparation of EIS's required on EPA legislative proposals. (See § 6.106 (d)).

II. *Responsibilities for Title II Construction Grants Program (Subpart E).* (a) *Responsible official.* The responsible official for EPA actions covered by this subpart is the Regional Administrator. The responsibilities of the Regional Administrator in addition to those in Appendix B.I. are to:

(1) Assist the Office of Federal Activities in coordinating the training of personnel involved in the review and preparation of NEPA-associated documents.

(2) Require grant applicants and those who have submitted plans for approval to provide the information the regional office requires to comply with these guidelines.

(3) Consult with the Office of Federal Activities concerning works or plans which significantly affect more than one regional office, are controversial, are of national significance or "pioneer" EPA policy, when these works have had or should have had an EIS prepared on them.

(b) *Assistant Administrator.* The responsibilities of the Office of the Assistant Administrator, as described in Appendix B.I, shall be assumed by the Assistant Administrator for Water and Hazardous Materials for EPA actions covered by this subpart.

(c) Oil and Special Materials Control Division, Office of Water Program Operations, coordinates all activities and responsibilities of the Office of Water Program Operations concerned with preparation and review of EIS's. This includes providing technical assistance to the Regional Administrators on EIS's and assisting the Office of Federal Activities in coordinating the training of personnel involved in the review and preparation of NEPA-associated documents.

(d) *Public Affairs Division, Regional Offices.* The responsibilities of the regions' Public Affairs Divisions, in addition to those in Appendix B.I, are to:

(1) Assist the Regional Administrator in the preparation and dissemination of NEPA-associated documents.

(2) Collaborate with the Headquarters Office of Public Affairs to analyze procedures in the regions for public participation and to develop and recommend to the Office of Federal Activities a program to improve those procedures.

III. *Responsibilities for Research and Development Programs (Subpart F).* The Assistant Administrator for Research and Development, in addition to those responsibilities outlined in Appendix B.I(a), will also assume the responsibilities described in Appendix B.I(f).

IV. *Responsibilities for Solid Waste Management Programs (Subpart G).* (a) *Responsible Official.* The responsible official for EPA actions covered by this subpart is the Deputy Assistant Administrator for Solid Waste Management Programs. The responsibilities of this official, in addition to those in Appendix B.I(a), are to:

(1) Assist the Office of Federal Activities in coordinating the training of personnel involved in the review and preparation of all NEPA-associated documents.

(2) Advise the Assistant Administrator for Air and Waste Management concerning projects which significantly affect more than one regional office, are controversial, are nationally significant, or "pioneer" EPA policy.

V. *Responsibilities for Special Purpose Facilities and Facility Renovation Programs (Subpart H).*

(a) *Responsible official.* The responsible official for new construction and modification of special purpose facilities is as follows:

(1) The Chief, Facilities Management Branch, Data and Support Systems Division, shall be the responsible official on all new construction of special purpose facilities and on all improvement and modification projects for which the Facilities Management Branch has received a funding allowance.

(2) The Regional Administrator shall be the responsible official on all improvement and modification projects for which the regional office has received the funding allowance.

(3) The Center Directors shall be the responsible officials on all improvement and modification projects for which the National Environmental Research Centers have received the funding allowance.

(b) The responsibilities of the responsible officials, in addition to those in Appendix B.I, are to:

(1) Ensure that environmental assessments are submitted when requested, that environmental reviews are conducted on all projects, and EIS's are prepared and circulated when there will be significant impacts.

(2) Assist the Office of Federal Activities in coordinating the training of personnel involved in the review and preparation of NEPA-associated documents.

APPENDIX C

DISTRIBUTION AND AVAILABILITY OF DOCUMENTS

I. *Negative Declaration.* (a) The responsible official shall distribute two copies of each negative declaration to:

(1) The appropriate Federal, State and local agencies and to the appropriate State and areawide clearinghouses.

(2) The Office of Legislation, the Office of Public Affairs and the Office of Federal Activities.

(3) The headquarters EIS coordinator for the program office originating the document. When the originating office is a regional office and the action is related to water quality management, one copy should be forwarded to the Oil and Special Materials Control Division, Office of Water Program Operations.

(b) The responsible official shall distribute one copy of each negative declaration to:

(1) Local newspapers and other local mass media.

(2) *Interested persons on request.* If it is not practical to send copies to all interested persons, make the document available through local libraries or post offices, and notify individuals that this action has been taken.

(c) The responsible official shall have a copy of the negative declaration and any documents supporting the negative declaration available for public review at the originating office.

II. *Environmental Impact Appraisal.* (a) The responsible official shall have the environmental impact appraisal available when the negative declaration is distributed and shall forward one copy to the headquarters EIS coordinator for the program office originating the document and to any other Federal or State agency which requests a copy.

(b) The responsible official shall have a copy of the environmental impact appraisal available for public review at the originating office and shall provide copies at cost to persons who request them.

III. *Notice of Intent.* (a) The responsible official shall forward one copy of the notice of intent to:

(1) The appropriate Federal, State and local agencies and to the appropriate State, regional and metropolitan clearing houses.

(2) Potentially interested persons.

(3) The Offices of Federal Activities, Public Affairs and Legislation.

(4) The headquarters Grants Administration Division, Grants Information Branch.

(5) The headquarters EIS coordinator for the program office originating the notice. When the originating office is a regional office and the action is related to water quality management, one copy should be forwarded to the Oil and Special Materials Control Division, Office of Water Program Operations.

IV. *Draft EIS's.* (a) The responsible official shall send two copies of the draft EIS to:

(1) The Office of Federal Activities.

(2) The headquarters EIS coordinator for the program office originating the document. When the originating office is a regional office and the project is related to water quality management, send two copies to the Oil and Special Materials Control Division, Office of Water Program Operations.

(b) If none of the above offices requests any changes within ten (10) working days after notification, the responsible official shall:

(1) Send five copies of the draft EIS to CEQ.

(2) Send two copies of the draft EIS to the Office of Public Affairs and to the Office of Legislation.

(3) Send two copies of the draft EIS to the appropriate offices of reviewing Federal agencies that have special expertise or jurisdiction by law with respect to any impacts involved. CEQ's guidelines (40 CFR 1500.9 and Appendices II and III) list those agencies to which draft EIS's will be sent for official review and comment.

(4) Send two copies of the draft EIS to the appropriate Federal, State, regional and metropolitan clearinghouses.

(5) Send one copy of the draft EIS to public libraries in the project area and interested persons. Post offices, city halls or courthouses may be used as distribution points if public library facilities are not available.

(c) The responsible official shall make a copy of the draft EIS available for public review at the originating office and at the Office of Public Affairs.

V. *Final EIS.* (a) The responsible official shall distribute the final EIS to the following offices, agencies and interested persons:

(1) Five copies to CEQ.

(2) Two copies to the Office of Public Affairs, Legislation and Federal Activities.

(3) Two copies to the headquarters EIS coordinator for the program office originating the document.

(4) One copy to Federal, State and local agencies and interested persons who made substantive comments on the draft EIS or requested a copy of the final EIS.

(5) One copy to a grant applicant.

(b) The responsible official shall make a copy of the final EIS available for public review at the originating office and at the Office of Public Affairs.

VI. *Legislative EIS.* Copies of the legislative EIS shall be distributed by the responsible official according to the procedures in section IV(b) of this appendix. In addition, the responsible official shall send two copies of the EIS to the Office of Federal Activities and the EIS coordinator of the originating office.

[FR Doc.75-9553 Filed 4-11-75;8:45 am]

APPENDIX BB

INFORMATIONAL HANDOUTS DISTRIBUTED

AT THE TWO PUBLIC WORKSHOPS

HELD TO DISCUSS THE EIS FOR THE

BOSTON SLUDGE MANAGEMENT PLAN

FIRST PUBLIC WORKSHOP

relating to the

ENVIRONMENTAL IMPACT STATEMENT

for the

PROPOSED BOSTON HARBOR

SLUDGE MANAGEMENT PLAN

Sponsored by:

U. S. Environmental Protection Agency, Region I
J. F. Kennedy Federal Building
Boston, Massachusetts

September 4, 1975

In order that the present proceedings may be put into the perspective of sludge management planning for Boston Harbor, a brief history and chronology of related activities will be presented first. This history is outlined schematically in the accompanying figure.

The planning for the disposal of sewage sludge generated in the Metropolitan Boston area had its genesis in May, 1968. At that time, the Federal Water Pollution Control Administration convened an enforcement conference to discuss with the State of Massachusetts the adverse economic and public health impacts that wastewater was having on the shellfishing areas of Boston Harbor. In addition, the conference addressed the total impacts on the water quality of Boston Harbor.

Approximately one year later, in April, 1969, the enforcement proceeding was reconvened, and is referred to as the Second Enforcement Conference. This conference was called to discuss the progress made on the recommendations that were put forth in the First Conference. But most importantly, it made the following recommendations:

a) that a "consulting firm be retained" to evaluate the tidal and current patterns and the dispersion characteristics of Boston Harbor, particularly as it effects the Deer Island and Nut Island treatment plants. Evaluation would include....the determination of mixing zones and recommendations for sludge disposal and chlorination practices.

b) "Provide an evaluation and recommendation as to the most practical and economical solution to the....effects of tributary streams and combined sewer overflows."

In implementing the first recommendation, the Massachusetts Division of Water Pollution Control (DWPC) retained the firm of Hydro Science, Inc., to describe the hydrographic conditions of Boston Harbor. That hydrographic model reached the following conclusion: "that the present practice of discharging sludge for the first three hours of ebbing tide results in the deposition of approximately 15 to 20 percent of the sewage sludge solids in the portion of the harbor west of Deer Island."

The results of the Hydro Science model prompted the DWPC and the Metropolitan District Commission (MDC), operator of the Deer and Nut Island facilities, to sign a Memorandum of Agreement on October 1, 1971. This memorandum, supported by the EPA, stated that the MDC would:

1) "Study alternative methods for the disposal of sludge from the Nut Island and Deer Island Treatment Plants and file a report on alternative methods with the Secretary of Environmental Affairs and the Division on or before April 1, 1972;

2) "Prepare a preliminary engineering report indicated by the results of the above study for submission to the Secretary of Environmental Affairs and the Division by April 1, 1973..."

The Memorandum of Agreement was signed one week prior to the Third Enforcement Conference, which convened on October 7, 1971. At that third conference, representatives of the DWPC stated "that the sludge disposal practices at these facilities (Deer and Nut Islands) are not suitable to meet water quality standards", those standards being class "SB". And that "alternate methods of sludge disposal by the MDC are required to increase the overall efficiency of the treatment plants..." The DWPC presented to the conferees a list of proposed recommendations which were essentially incorporated as the recommendations of the Third Conference. Those that dealt with the sludge management problems stated that:

> The MDC should complete a study of the alternative methods for the disposal of sludge from its Nut Island and Deer Island treatment plants by April 1, 1972; and a specific solution chosen and construction implementation schedule to be prepared by July 1, 1972.

As a result of both the Memorandum of Agreement and the Third Enforcement Conference, the MDC established a Boston Harbor Pollution Task Force. In April, 1972, the Task Force presented its recommendations; their original mandate was to screen on a preliminary basis all possible sludge management schemes; and to come up with those alternatives which it considered feasible for detailed engineering and environmental analysis. The Task Force recommended that three major sludge handling and disposal methodologies be evaluated in detail:

1) wet air oxidation,
2) land application, and
3) incineration.

Just prior to the completion of the Task Force report, the MDC, DWPC, and the EPA were preparing a tripartite agreement which essentially set up a detailed implementation schedule for wastewater management in the Eastern Massachusetts Metropolitan Area. Two major courses of action were set in motion as the result of this Three Party Agreement (finally signed in July, 1972): First, the EMMA Study for the long-range management of wastewater in Eastern Massachusetts was initiated; and second, the final steps in the early planning for the sludge management problem were completed.

In August, 1973, MDC's consultant, Havens & Emerson, Inc. of Cleveland, Ohio, completed the Proposed Sludge Management Plan for the MDC. The completion of this plan satisfied the requirements of the Three Party Agreement, and was the logical follow-on to the Task Force recommendations. Havens & Emerson was mandated by MDC to investigate the three alternative sludge handling and disposal techniques recommended by the Task Force.

In its most essential form, the sludge management plan proposed by MDC consisted of the following:

> Digested sludge from Nut Island would be pumped across the Harbor to Deer Island. There it would be combined with the digested sludge at Deer Island, and burned in several multiple hearth incinerators.

Since MDC was intending to apply for Federal funding on this project, it was required to prepare an environmental assessment stating the anticipated environmental impacts that would result from the proposed project. The environmental assessment statement was completed in April, 1975, and the required public hearing was held in May, 1975.

Partly as a result of that hearing, and partly because of prior knowledge of the public controversy that was rising around the proposed plan, the Environmental Protection Agency issued a "notice of intent" whereby it gave public notice that a formal environmental impact statement would be prepared in accordance with the National Environmental Policy Act of 1969, and 40CFR Part 6 (April 14, 1975 Federal Register).

In June, 1975, EPA, Region I contracted with the environmental consulting firm of EcolSciences to assist the Region in preparing the Environmental Impact Statement. Their responsibility is to investigate in detail the following four major alternatives for the handling and disposal of primary sludge, and to determine the most environmentally acceptable and cost effective method of treating the sludge:

1) Sludge incineration
2) Land application
3) Ocean disposal
4) No action

Since the EMMA Study is presently underway, and an implementation schedule for secondary treatment at the MDC facilities has not yet been finalized, it was felt that the disposal of primary sludge (through the near future) represented the most concrete set of operating conditions which could be projected, and still address the main issue.

Within the three "action" categories, there are numerous sub-alternatives which are being developed as well. Specifically, they are:

1. Sludge Incineration
    a. Incineration of digested sludge
    b. Incineration of raw sludge
    c. Ash disposal
        - Landfilling
        - Lagooning on wetlands (proposed plan)
        - Deep ocean disposal

2. Land Application
    a. Direct land application
        - Dedicated single sites, land spreading
        - Farmlands application, multisites
        - Landfilling

    b. Indirect land application
        - Conversion of the sludge to a soil conditioner and/or fertilizer

3. Ocean Disposal
    a. Extended outfall to the vicinity of the Graves
    b. Deep ocean dumping by barge

The entire gamut of environmental costs, monetary costs, engineering feasibility and institutional ramifications are being taken into account in these evaluations.

At the present time, the environmental inventory necessary to assess the impacts from the alternatives has been completed. And the evaluations of the various alternatives and their sub-alternatives has commenced. The general approach that is being taken in this evaluation process is the following:

Separate teams have been set up to screen the various sub-alternatives in each major category. This will produce the best disposal technique for each of the three basic alternatives. These "best" systems for land disposal, incineration, and ocean disposal will then be compared against each other, as well as compared with the no-action alternative. Of these four, the most desirable sludge disposal solution will be chosen on the basis of environmental, economic, engineering, and institutional considerations.

In the most desirable of circumstances, all of the above factors (environmental, costs, etc.) are in mutual agreement, and the choice of alternate becomes relatively simple. However, on a project this size, one or more of those considerations may be at odds with the remainder. In such an instance, it will become necessary to consider the trade-offs required to produce the solution with the least combined adverse impact. For example, environmental costs, engineering feasibility, and monetary costs may be in essential agreement, yet the prospects for institutional acceptance are remote. Therefore, tradeoffs between environment, cost, or engineering reliability will have to be made to produce a plan with institutional acceptability.

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September 4, 1975

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Second Public Workshop
relating to the

Environmental Impact Statement
for the

Proposed Boston Harbor
Sludge Management Plan

Sponsored by:
U. S. Environmental Protection Agency, Region I
J. F. Kennedy Federal Building
Boston, Massachusetts

November 10, 1975

A. Introduction

On September 4, 1975, the first of two public workshops were held to present and discuss the plan of study relating to this environmental impact statement (EIS). While there was some discussion on the issues of the proposed plan, the audience could not put forth concrete criticisms or counter-proposals, since no detailed, definitive plans were available at that time. However, the intent of this workshop is to present for public consideration a series of detailed proposals that can be discussed with a view towards getting significant input for the decision-making process.

We will present in this handout a review of the First Public Workshop, as well as a brief summary of each of the five feasible alternatives that have received detailed analyses. In addition to the mechanical description of the alternates, several significant impacts for each one will be presented. These impact areas will cover: (1) environment; (2) monetary costs; and (3) energy costs. Each of these areas have been developed in greater detail during the preparation of this EIS.

The five feasible alternatives that have resulted from the preliminary and detailed analyses are as follows:

Alternate 1-A: Incineration with onshore landfilling of ash
Alternate 1-B: Incineration with deep ocean disposal of ash
Alternate 2: Land application of the entire sludge load
Alternate 3: Deep ocean disposal of the sludge
Alternate 4: Land application and landfilling of sludge.

The analyses which have been performed have separated the above alternates into two broad categories:

Environmentally Unacceptable - Alternates 1-B and 3; those having ocean disposal as an integral component;

Environmentally Acceptable - Alternates 1-A, 2, and 4; incineration, land application, and the hybrid land disposal system.

At the present time, we have judged the "Acceptable" plans to be approximately equal in their overall environmental impact, although there are significant differences in some of the other areas of evaluation. However, neither the EPA nor its consultants, EcolSciences, inc., have made a selection of the most preferable plan. It is the intent of this workshop to put forth to the public the major advantages and disadvantages of these potential solutions. This public input will, in large measure, give the clearest picture of the implementability of each of these alternatives, because in the end, it is society and its representatives which must make the tradeoffs and judge the relative importance of conflicting issues.

B. Review

In its most essential form, the sludge management plan proposed by the Metropolitan District Commission (MDC) consists of the following:

Digested sludge from Nut Island would be pumped across the Harbor to Deer Island. There it would be combined with the digested sludge at Deer Island, and burned in several multiple hearth incinerators.

In June, 1975, EPA, Region I contracted with the environmental consulting firm of EcolSciences to assist the Region in preparing the Environmental Impact Statement. Their responsibility was to investigate in detail the following four major alternatives for the handling and disposal of primary sludge, and to determine the most environmentally acceptable and cost effective method of treating the sludge:

1) Sludge incineration
2) Land application
3) Ocean disposal
4) No action

The above list was used as the departure point from which various detailed disposal systems were generated. In evaluating the four basic alternates, the most attention was given to the "action" solutions. From the three action alternatives came the five feasible systems which were described earlier.

Since the EMMA Study is presently underway, and an implementation schedule for secondary treatment at the MDC facilities has not yet been finalized, it was felt that the management of primary sludge (through the near future) represented the most concrete set of operating conditions which could be projected, and still address the main issue.

C. Description and Evaluation of Feasible Sludge Management Systems

The attached figure indicates the relationship of the common sludge handling processes and the five alternative disposal systems. In all cases, the sludge will be digested in anaerobic digesters. At the present time, the MDC proposal states that by 1985, the digester capacity at both Deer and Nut Islands will be exceeded by 10%, thus resulting in a mixture of raw (20%) and digested (80%) sludge being passed on for further disposal steps. This is predicated on continuing present digester operation techniques. However, there are indications that with modifications in digester operation, the entire sludge load generated in 1985 could be handled in the existing facilities.

In all cases, sludge would be transferred from Nut Island to Deer Island via force main under Boston Harbor. The sludge would then be

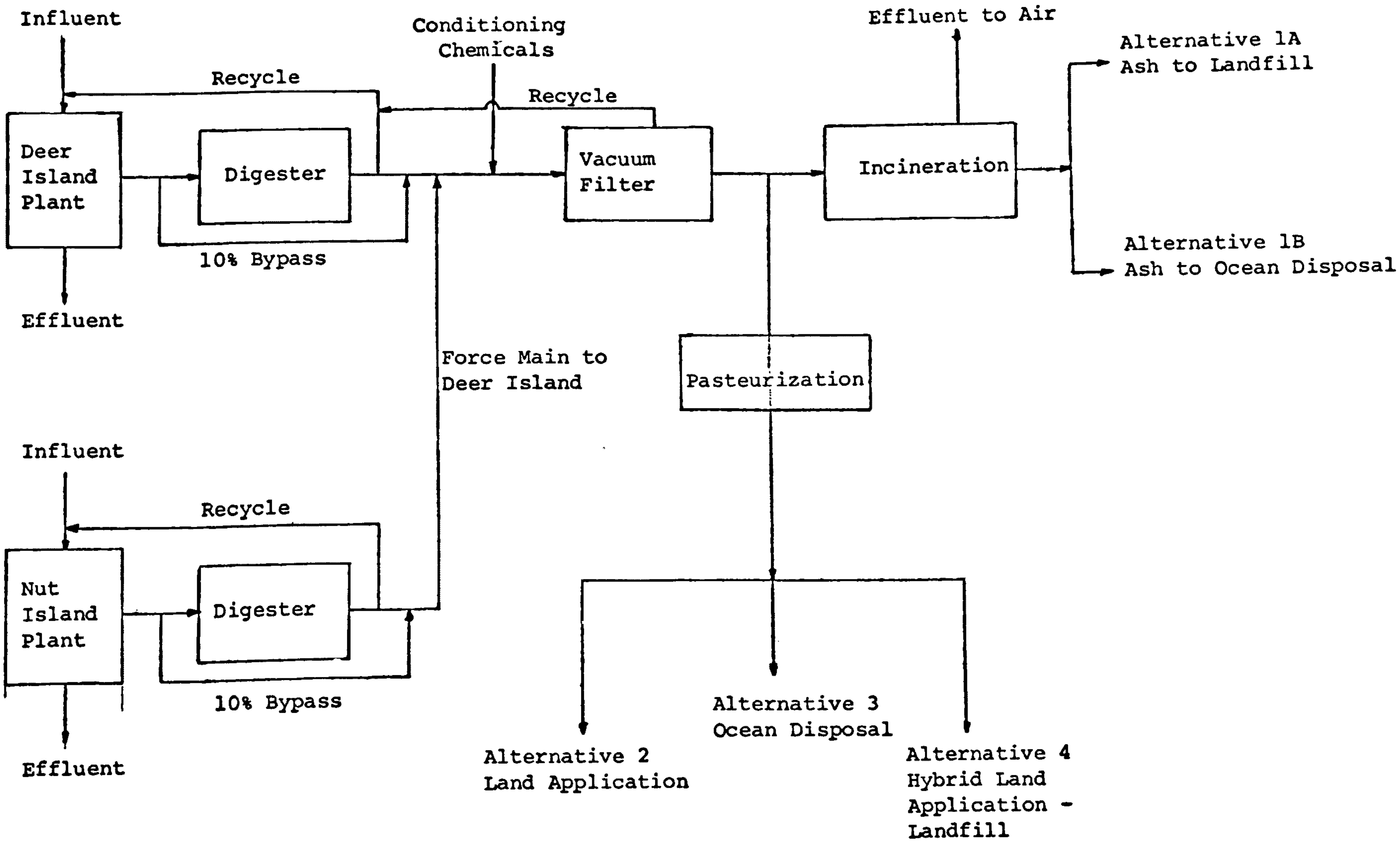


FIGURE V-1 PROCESS FLOWSHEET - ALL ALTERNATIVES conditioned with ferric chloride and lime at Deer Island, then dewatered to 25% solids using vacuum filtration. Once the sludge has been dewatered, then it would pass onto one of the five disposal routes.

As can be seen from the figure, incineration has been considered as an additional process step and not a disposal alternative per se. While some mass is lost to the atmosphere through incineration (and thus becomes a "disposal" area), there is still a residue which must ultimately be disposed. Therefore, the fate of the incinerator ash is considered the ultimate disposal route.

1. Alternative 1-A: Incineration with Onshore Landfilling

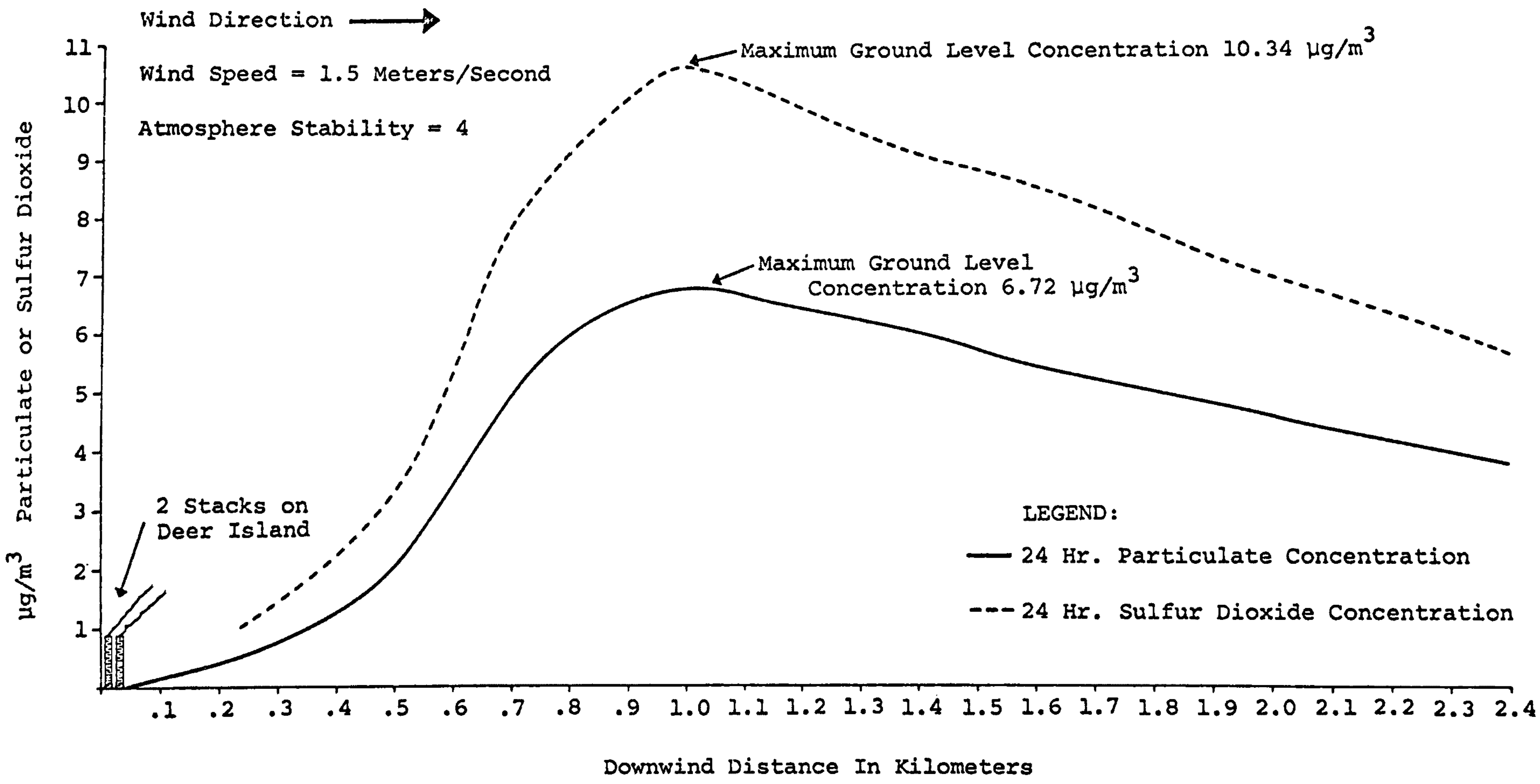
a. System Description: In this alternative, the process steps after digestion are conditioning, vacuum filtration and multiple hearth incineration. The incineration step is followed by scrubbing of the gas stream to prevent escape of excess air pollutants. The ash from the incineration step, combined with the fly ash from the scrubber system, is to be trucked to a landfill site, approximately 30 miles from Deer Island, and probably located in Plainville, Massachusetts. To avoid adverse impacts of truck travel in Winthrop, which does not have a street system adequate to handle large numbers of trucks, ash will be transported in detached trailers by barge to the Mystic terminal, and from there by truck to the final disposal point. Upon arrival at the landfill site, disposal of ash would be in layers, as in a standard landfill. With the exception of the ash disposal system, this alternative is similar to the Phase I system developed by Havens and Emerson in their 1973 and 1974 work.

b. Environmental Impacts: The most significant portion of the environment affected by either incineration impact is air quality. Based upon sludge characteristics, fuel oil requirements, emissions control facilities, and meterological conditions, the maximum 24-hour groundlevel concentration of sulfur dioxide would be 10.34 $\mu g/m^3$ (3 hour maximum of 35 $\mu g/m^3$); and the maximum 24-hour groundlevel concentration of total suspended particulates would be 6.72 $\mu g/m^3$. These maximum concentrations would occur at approximately 1 kilometer downwind of the stacks located on Deer Island. The next figure gives a graphic representation of these values.

The Federal and Commonwealth 1985 secondary standards for particulates, for the Boston Air Quality Control Region, is 150 $\mu g/m^3$ for 24 hours. The secondary standard for SO_2 is 1,300 $\mu g/m^3$ for 3 hours. Estimations of the 1985 ambient air quality for Boston without the incinerator indicate that the levels for particulates and SO_2 will be on the order of 139 $\mu g/m^3$ and 426 $\mu g/m^3$, respectively.

FIGURE 1

THE GROUND LEVEL CONCENTRATIONS AS A FUNCTION OF DOWNWIND DISTANCE FROM THE INCINERATORS



If the emissions burden described earlier were added to this 1985 ambient air quality, the resulting values would be 146 $\mu g/m^3$ for particulates and 461 $\mu g/m^3$ for SO_2. In comparing the projected air quality against the secondary standards, it can be seen that while the particulate concentrations would approach the limits, it would not exceed them. And SO_2 concentrations would be well under the limits.

The area most affected by the emissions from these incinerators would be the northern tip of Long Island. Long Island is the site of the Long Island Chronic Disease Hospital, with 900 beds and a staff of 400.

The other pollutants which may be emitted from the incinerators include nitrogen oxides, hydrocarbons, carbon monoxide, and heavy metals such as mercury and lead. There is a proposed hazardous pollutant standard limiting the atmospheric discharge of mercury from incineration to a maximum of 3,200 grams per day. Assuming a worst case situation, i.e. that all mercury in the combined sludge would be vaporized, the mercury emission would be approximately 2,294 grams per day in 1985. Assuming a similar situation for lead, the total lead emissions would be approximately 23,800 grams (23.8 kilograms) per day.

With landfilling of the ash at an approved shorebased sanitary landfill, the balance of the environmental impacts should be minimal.

In addition to impacts on air quality, the transportation and landfilling of 126,000 pounds of ash per day would have some impacts. Transportation traffic and noise impacts would be negligible, with an average of five (5) truckloads per day being transported to a State-approved landfill site which has been identified.

c. Monetary Costs: The monetary costs associated with this alternative are summarized below. This alternative has the second lowest annual cost.

Total Annual Costs (20 years @ 6-1/8% interest)	\$3,810,800
Total Annual Costs, MDC Share	

d. Energy Costs: Tne energetics of this alternative are shown below, in terms of the total energy requirements expressed as millions of BTU per day. Also, all possible energy recoveries, including byproducts, are listed.

Energy Required	98×10^6 BTU/day
Possible Gross Recovery	255×10^6 BTU/day
Possible Net Recovery	157×10^6 BTU/day

2. Alternative 1-B: Incineration with Deep Ocean Disposal of the Ash

a. System Description: This alternative is similar to Alternative 1-A in regards to on-site processes. The difference lies in the transporting of the ash to deep ocean disposal. The barge system to be used is a large (1,500 ton capacity) vessel to be unloaded in deep (depth in excess of 100 meters) water. The haul distance under this alternative is approximately 70 miles from the Deer Island plant site, to be dumped in the Murray-Wilkinson Basin, in the Gulf of Maine. The next figure indicates the possible area for such a dump site. (The development of the possible location of this dump site was done in conjunction with the deep ocean disposal of sludge alternative. However, the mechanical aspects of either alternative would be identical.)

b. Environmental Impacts: All of the adverse air quality impacts associated with Alternative 1-A would be identical to this system. The major additional area of impact would be associated with effects on the marine environment. (A more detailed development of those impacts will be given in relation to the ocean disposal alternative.)

Since ash would not have the organic and pathogen contamination problems associated with the ocean disposal of sludge, many of these adverse impacts would be significantly reduced. However, the heavy metal oxides which would still be in the residue (except mercury and lead) might be more accessible to the marine environment than would the highly insoluble metal sulfides associated with anoxic sludge deposits. In addition, the general lack of knowledge about the impact of pollutants on the marine environment poses significant problems in determining the magnitude of any long term effects.

It is general EPA and Federal policy to restrict and/or eliminate ocean disposal of wastes, unless no other feasible alternative can be found.

c. Monetary Costs: Because of the inexpensiveness of the sludge hauling (barge transport), this alternative has a lower annual cost than landfilling of the ash.

Total Annual Costs (20 years @ 6-1/8% interest)	$3,718,500
Total Annual Costs, MDC Share	$1,799,600

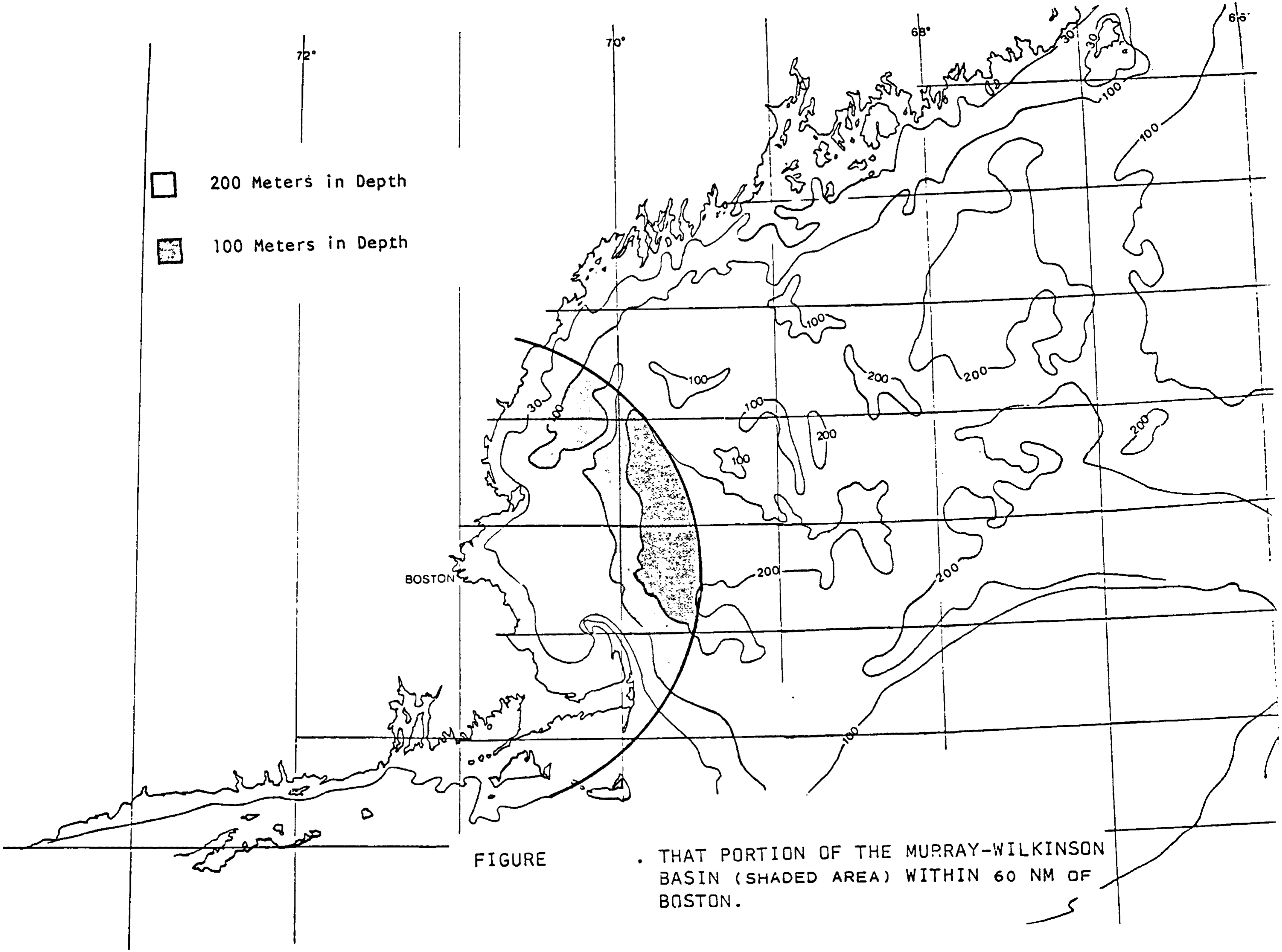


FIGURE . THAT PORTION OF THE MURRAY-WILKINSON BASIN (SHADED AREA) WITHIN 60 NM OF BOSTON.

d. Energy Costs: The alternative has the best energetics of all the feasible alternates.

Total Energy Requirement	93×10^6 BTU/day
Possible Gross Recovery	255×10^6 BTU/day
Possible Net Recovery	163×10^6 BTU/day

The large energy recovery from incineration, coupled with the low BTU/ton mile for ash transport, give this a favorable energetic balance.

3. Alternative 2: Land Application of Dewatered, Pasteurized Sludge

a. System Description: This system begins with lime and ferric chloride conditioning and vacuum filtration, as in the two previous alternatives, followed by pasteurization to 170°F for 30 minutes on site. Transportation to storage would be by 20-ton self-dumping trailers (barged to Mystic Terminal as in Alternative 1-A), with further transport to one of approximately five storage sites in the Bridgewater area, the Westport area, and the Connecticut River valley. Storage at these sites would be for six months. To prevent either degradation of runoff quality or increasing sludge moisture content, the windrows of limed pasteurized sludge would be covered with a plastic moisture barrier. During March and October, the sludge would be removed by frontend loader, trucked to the final farm application site, and spread by modified manure spreader. Following this application by dedicated equipment, the individual farm operator would be responsible for incorporation into the soil. The site selection for land application was based on tilled land identified in the 1971 Massachusetts Land Use Survey by the University of Massachusetts at Amherst. The purchase of cropland for this project is not contemplated, but rather, a marketing effort is planned to encourage use by private and institutional farm operators. For planning purposes, land requirements are based on nitrogen and metals concentrations developed on a Statewide basis, but the actual analysis of sludge and the soil nitrogen and cation exchange capacity of the site will dictate the actual sludge loading in dry tons per acre. The general conditions for applying sludge to tilled land would be the following: Ten (10) dry-weight tons per acre per year, for 6-1/2 years. After this period of time the cation exchange capacity of the soil would reach the upper safe limits for heavy metals concentration. Then other areas would be used.

The tilled farmland areas which have been tentatively identified as being adequate for land application purposes are shown on the next figure.

The proposed land application system must include monitoring of sludge, soil and water for nutrients and trace metals. This monitoring cost is included in the system costs.

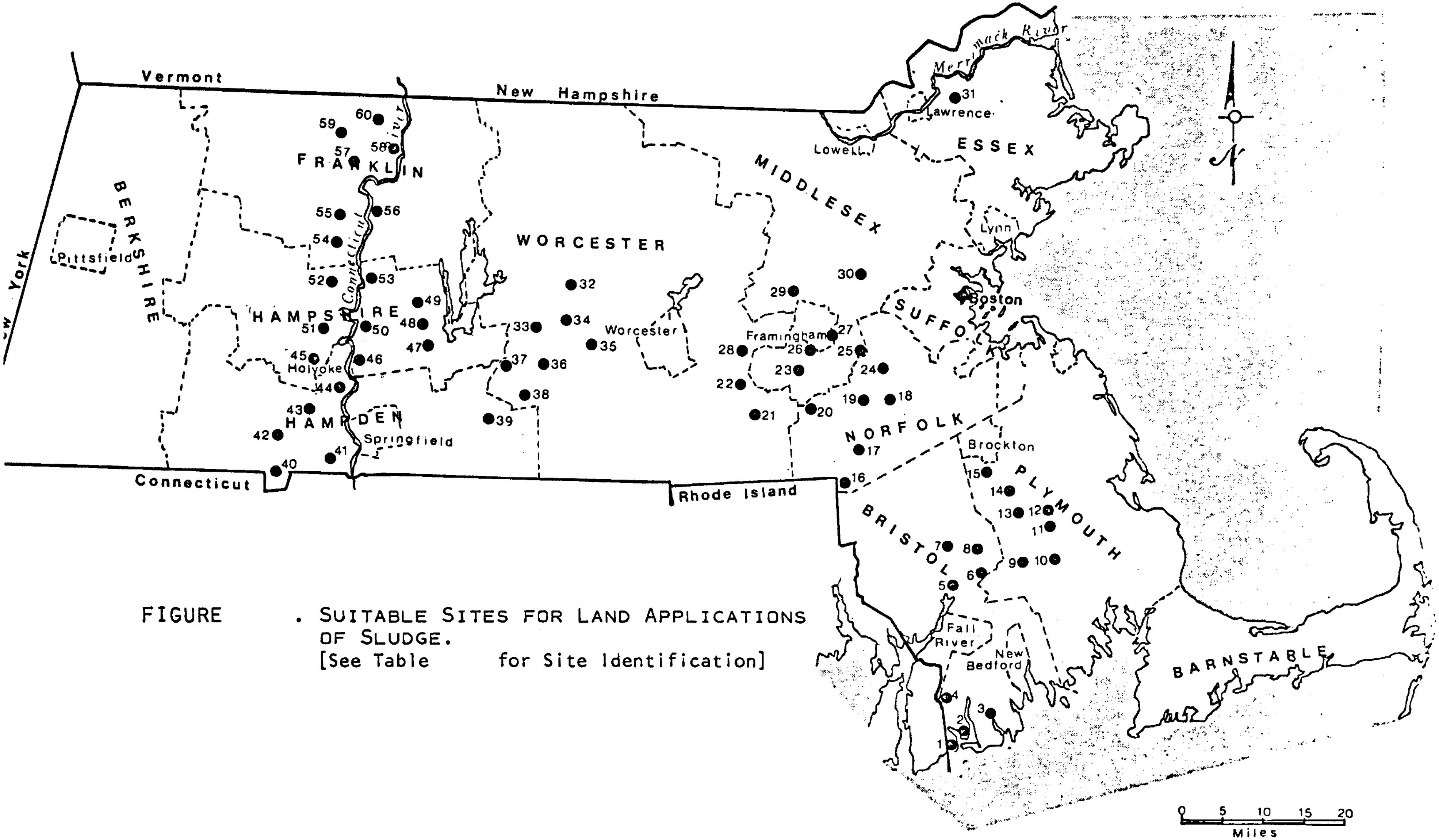


FIGURE . SUITABLE SITES FOR LAND APPLICATIONS OF SLUDGE.
[See Table for Site Identification]

b. Environmental Impacts: In assessing the relative environmental impacts of the feasible solutions, it has been determined that the land application alternatives impact on a great many more portions of the environment than the incinerator/landfill option. While the incinerator/landfill alternative does have a significant, concentrated impact on air quality when compared to land application, this is its major area of impact. Incineration, of course, also has other adverse impacts, but the area and scope of impact is limited to one major component of the environment. The impacts on the biotic community are generally limited in scope to the area immediately adjacent to the incinerator site.

The land application systems have many more beneficial environmental impacts as compared to the incineration alternatives. For example, the fertilizer and lime value of the sludge and the resultant economic benefits directly experienced by farmers; reduction in food costs; direct encouragement of Massachusetts agriculture; etc. While the number of beneficial impacts are greater, the land application alternatives also have a much broader range of adverse environmental impacts. Two major areas have considerably more range of adverse impact: biotic communities, and public health. Since heavy metals have been identified as being the component of the sludge which has the most adverse impact, the spreading of this material on open land opens up several avenues for plant, animal, and human contamination. But the magnitude of impact in any one area would not be as great as the single impact which the Boston air quality would receive.

This system has one significant constraint. Because of the extremely high levels of heavy metals in the Deer Island treatment plant sludges, this solution could be implemented only if pretreatment, or some other program were instituted to reduce the metals concentrations to the point where the sludge could safely be applied.

c. Monetary Costs: The annual costs associated with the operation of a land application system makes it the most costly of the five alternates. However, in addition to its large out-of-pocket expenses, there is an offsetting monetary credit to the Commonwealth's economy that is realized in the agricultural value of the sludge which is applied to the land. While applying this credit to expenses of this system tends to make it more cost-competitive with the other alternates, it does not reflect a net decrease in MDC's expenses, unless the Commonwealth would be willing to give the MDC directly, a cash credit for the agricultural value of the sludge.

Total Annual Costs (20 yeara @ 6-1/8% interest)	$6,318,300
Total Annual Costs, MDC Share	$4,508,800

Annual Value to Agriculture	$1,355,000
Net Resources Cost, Expressed as $	$4,963,300

d. Energy Costs: The land application system (applying 100% of the sludge) would also be the most costly in terms of energetics, even though credit is taken for the nitrogen and phosphorous as fertilizers.

Total Energy Required	459 x 10^6 BTU/day
Possible Gross Recovery	395 x 10^6 BTU/day
Possible Net Recovery	(64) x 10^6 BTU/day

4. Alternative 3: Ocean Disposal of Dewatered Pasteurized Sludge

a. System Description: The sludge preparation is similar to the land application alternative, including conditioning, vacuum filtration and pasteurization as on-site processes, with deep ocean (>100 meters depth) disposal of the sludge. The potential site selected for dumping is in the Murray-Wilkinson Basin, approximately 70 miles east of Deer Island in the Gulf of Maine. The dumping site would be demarcated with navigational aids to prevent fishing activity.

In order to insure that mixing of the sludge into the water column is held to a minimum, it should not be discharged into the wake of the barge, as is now generally done, but released all at once through bottom doors in the barge. In addition, the sludge should be as concentrated as possible, but still moist, to insure rapid settling and minimal mixing. Sludge should not be dumped across any appreciable vertical current patterns. It should not be dumped in upwelling areas, or in areas where turbulent bottom water turnover is known to occur frequently. The dump site would have to be well marked by a permanent buoy, and barges should remain within a specified distance during dumping. The limits of the dump site should be as small as possible. Continuous monitoring of toxic metals, toxic organic compounds, organic matter, nutrient salts, floatables, and bacterial and viral levels, and oxygen levels in the sediments and in the water column would be mandatory. In addition, benthic and pelagic biota would have to be monitored for any indication of detrimental effects. These measurements must include sampling outside of the spoil area.

b. Environmental Impacts: The following effects will be noticed as the result of deep ocean disposal of digested sludge. Reduced dissolved oxygen levels will occur in the water overlying the sludge dumpsite. Nutrient levels will increase in the water column. The effect of this cannot be accurately judged since increase in phytoplankton activity may be beneficial as well as adverse. Heavy metals will increase in concentration, and will be bioconcentrated in fish. Turbidity might increase in the dumpsite since it is apparently an area of considerable hydrographic activity. Increases in bottom sediment heavy metals and toxic organics, with resultant bioconcentration in bottom feeders, and further contamination up the food chain may occur. Sediments will become anoxic, thus changing biological communities. Species diversity and composition will decrease. Filter-feeding organisms may be adversely affected by fine-grained particles.

c. Monetary Costs: Because ocean disposal uses the most efficient method of hauling and does not have large investments in capital equipment, this alternate has the lowest monetary costs of the feasible solutions.

Total Annual Costs (20 years @ 6-1/8% interest)	$2,947,700
Total Annual Costs, MDC Share	$1,598,800

d. Energy Costs: Even though this system utilizes the most efficient method of sludge transport, it is still fairly costly in energy since the sludge would still have to be pasteurized prior to dumping.

Total Energy	212×10^6 BTU/day
Possible Gross Recovery	255×10^6 BTU/day
Possible Net Recovery	325×10^6 BTU/day

5. Alternative 4: Partial Land Application of Dewatered Pasteurized Sludge (Hybrid System)

a. System Description: This system is similar to the complete land application alternative (Alternative 2), including conditioning, vacuum filtration, and pasteurization of the portion to be land applied (estimated as 50% in 1985) and conditioning, vacuum filtration and landfill of that sludge which cannot be land applied because of heavy metals or other quality constraints. Landfilling of dewatered sludge would be in accordance with the criteria of the Massachusetts Department of Environmental Quality Engineering.

After a considerable amount of development work had been done on the land application alternate, it was found that the entire system could not be put into operation unless the heavy metals concentration were significantly reduced in the Deer Island sludges. There is evidence that some heavy metals, e.g. cadmium, have become a pervasive part of the environment and that these constituents might not be removed sufficiently even with a pretreatment campaign. Therefore, in order to have a land application system that could be implemented under existing sludge conditions, the hybrid solution was developed. The hybrid system was specifically set up to accommodate this problem by: (a) land applying that portion of the sludge which is acceptable (Nut Island's, plus approximately 10% of Deer Island's); and (b) by landfilling (burying) the remaining highly contaminated portion.

b. Environmental Impacts: Since the hybrid system uses a major component of the land application system, the types of impacts are similar; but since only about half the land area would be affected by this system, the adverse impacts (as well as the beneficial) are concomittantly reduced. The landfilling operation would require considerably more land than for disposal of ash (130 acres vs. 300 acres, over a 10 year period), and the leachate characteristics would be worse. However, the sanitary landfill in Plainville (recently approved by the Commonwealth) has provisions for leachate collection and treatment.

Therefore, in the overall assessment of environmental impact, the hybrid system ranks better than the pure land application alternative, and only slightly more adverse than the incineration option.

c. Monetary Costs: As with the land application alternate, there is a non-cash, monetary credit that is realized because of the fertilizer benefits of the sludge. Since such a large portion of the sludge is landfilled, operating costs are reduced significantly.

Total Annual Costs (20 years @ 6-1/8% interest)	\$4,918,900
Total Annual Costs, MDC Share	\$3,258,200
Annual Value to Agriculture	\$ 678,000
Net Resources Cost, Expressed as \$	\$4,240,900

d. Energy Costs: Because of the necessity for pasteurization and large transport energetics, the hybrid system is highly unfavorable in this category.

Total Energy Required	301×10^6 BTU/day
Possible Gross Recovery	325×10^6 BTU/day
Possible Net Recovery	25×10^6 BTU/day

WORKSHOP - MDC SLUDGE HANDLING FACILITY

MONDAY NOVEMBER 10, 1975

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APPENDIX CC

REFERENCES

APPENDIX CC

REFERENCES

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APPENDIX DD

NATIONAL REGISTER OF HISTORIC PLACES

federal register

TUESDAY, FEBRUARY 7, 1978
PART II

DEPARTMENT OF THE INTERIOR

Heritage Conservation And Recreation Service

■

NATIONAL REGISTER OF HISTORIC PLACES

Annual Listing of Historic Properties

st. marys county

Beauvue vicinity. *MULBERRY FIELDS*, About 4.5 mi. SE of Beauvue off MD 244, (3-14-73) HABS.

Bushwood vicinity. *OCEAN HALL*, Bushwood Rd. off MD 239 at Bushwood Wharf, (10-25-73)

Chaptico. *BACHELOR'S HOPE*, Off MD 238, (11-7-72)

Chaptico vicinity. *DEEP FALLS*, 1 mi. SE of Chaptico on N side of MD 234, (5-12-75)

Colton vicinity. *ST. CLEMENT'S ISLAND HISTORIC DISTRICT*, S of Colton Point on the Potomac River, (4-10-72)

Compton. *ST. FRANCIS XAVIER CHURCH AND NEWTOWN MANOR HOUSE*, S of Compton on MD 243, (11-9-72)

Drayden. *PORTO BELLO*, MD 244 E of Drayden, (4-26-72)

Drayden vicinity. *WEST ST. MARY'S MANOR*, About 1 mi. E of Drayden on the St. Mary's River, (4-15-70) NHL; HABS.

Hollywood vicinity. *RESURRECTION MANOR*, 4 mi. E of Hollywood, (4-15-70) NHL; HABS.

Hollywood vicinity. *SOTTERLEY (BOWLES SEPARATION)*, E of jct. of MD 245 and Vista Rd., (11-9-72)

Hughesville vicinity. *CHARLOTTE HALL HISTORIC DISTRICT*, S of Hughesville at jct. of MD 5 and 6, (5-2-75)

Leonardtown. *TUDOR HALL (AMERICA FELIX SECUNDUS)*, Tudor Hall Rd., (4-26-73)

Leonardtown vicinity. *ST. ANDREW'S CHURCH*, 5 mi. E of Leonardtown on St. Andrew's Church Rd., (3-14-73)

Oakley vicinity. *THE RIVER VIEW*, SE of Oakley on Burch Rd., (5-4-76)

Piney Point vicinity. *PINEY POINT COAST GUARD LIGHT STATION*, W of Piney Point on MD 498, (6-16-76)

Ridge vicinity. *BARD'S FIELD*, 1.2 mi. W of Ridge off Curleys Rd., (11-7-76)

St. Inigoes vicinity. *ST. IGNATIUS ROMAN CATHOLIC CHURCH*, W of St. Inigoes on Villa Rd., (11-3-75)

St. Marys City. *ST. MARYS CITY HISTORIC DISTRICT*, (8-4-69) NHL; HABS.

St. Marys City vicinity. *MARY W. SOMERS* (Chesapeake Bay skipjack), SE of St. Marys City at St. Inigoes Creek, (10-8-76)

Valley Lee vicinity. *ST. GEORGE'S PROTESTANT EPISCOPAL CHURCH (POPLAR HILL)*, W of Valley Lee, off MD 249 on MD 244, (10-3-73)

talbot county

Easton. *MYRTLE GROVE*, Goldsborough Neck Rd., (8-13-74)

Easton vicinity. *ANCHORAGE, THE*, NW of Easton off MD 370, (7-30-74)

Easton vicinity. *DONCASTER TOWN SITE*, NW of Easton, (9-5-75)

Easton vicinity. *ST. JOHN'S CHAPEL OF ST. MICHAEL'S PARISH*, 3 mi. W of Easton on MD 370, (3-30-73)

Easton vicinity. *TROTH'S FORTUNE*, 3.25 mi. E of Easton on MD 331, (4-24-75) HABS.

Easton vicinity. *WYE HOUSE*, 7 mi. NW of Easton on Miles Neck River, (4-15-70) NHL.

St. Michaels. *CROOKED INTENTION*, W of MD 33, (7-24-74)

St. Michaels vicinity. *SHERWOOD MANOR*, 4 mi. N of St. Michaels on MD 451, (4-5-77)

St. Michaels vicinity. *VICTORIAN CORN CRIBS*, 6.8 mi. E of St. Michaels off MD, (1-11-76)

Tilghman. *RELIANCE* (CHESAPEAKE BAY SKIPJACK), Knapps Narrows off MD 33, (7-30-76)

Trappe vicinity. *COMPTON*, W of Trappe on Howell Point Rd., (7-25-74)

Trappe vicinity. *WILDERNESS, THE*, SW of Trappe on Island Neck Rd., (7-25-74)

washington county

CHESAPEAKE AND OHIO CANAL NATIONAL HISTORICAL PARK, *Reference—see Allegany County*

HARPERS FERRY NATIONAL HISTORICAL PARK, *Reference—see Jefferson County, WV*

OLD NATIONAL PIKE MILESTONES, *Reference—see Allegany County*

Antietam and vicinity. *ANTIETAM IRON FURNACE SITE AND ANTIETAM VILLAGE*, Confluence of Antietam Creek and Potomac River, (6-26-75)

Big Pool vicinity. *FORT FREDERICK STATE PARK*, SE of Big Pool near jct. of MD 56 and 44, (11-7-73) NHL.

Boonsboro. *BOWMAN HOUSE*, 323 N. Main St., (4-29-77)

Boonsboro vicinity. *KEEDY HOUSE*, NW of Boonsboro off U.S. 40A on Barnes Rd., (7-25-74)

Boonsboro vicinity. *WASHINGTON MONUMENT*, Washington Monument State Park, (11-3-72)

Cavetown vicinity. *WILLOWS, THE*, SW of Cavetown on MD 66, (2-23-73)

Hagerstown. *ELLIOT-BESTER HOUSE*, 205–207 S. Potomac St., (5-2-75)

Hagerstown. *HAGER HOUSE*, 19 Key St., (11-5-74) HABS.

Hagerstown. *HOUSES AT 16–22 EAST LEE STREET*, 16–22 E. Lee St., (11-25-77)

Hagerstown. *MARYLAND THEATRE*, 21–23 S. Potomac St., (11-13-76)

Hagerstown. *PRICE-MILLER HOUSE*, 131–135 W. Washington St., (5-24-76)

Hagerstown. *WASHINGTON COUNTY COURTHOUSE*, W. Washington St. and Summit Ave., (12-24-74)

Hagerstown. *WESTERN MARYLAND RAILWAY STATION*, Burhans Blvd., (4-22-76)

Hagerstown vicinity. *BRIGHTWOOD*, N of Hagerstown off MD 60, (7-30-74)

Hagerstown vicinity. *DITTO KNOLLS*, E of Hagerstown on Landis Rd., (7-12-76)

Hagerstown vicinity. *MCCAULEY, HENRY, FARM*, E of Hagerstown on Mt. Eatna Rd., (6-29-76)

Hagerstown vicinity. *TROVINGER MILL*, 3 mi. E of Hagerstown on Trovinger Mill Rd. and Antietam Creek, (4-21-75)

Hagerstown vicinity. *VALENTIA*, S of Hagerstown on Poffenberger Rd. off MD 65, (6-27-74)

Keedysville vicinity. *B & O BRIDGE*, NW of Keedysville over Antietam Creek, (11-23-77)

Keedysville vicinity. *GEETING FARM*, S of Keedysville at Geeting and Dog Rds., (11-25-77)

Knoxville vicinity. *MAGNOLIA PLANTATION (BOTELER-HOLDER FARM)*, NW of Knoxville off Sandy Hook Rd., (6-18-75)

Samples Manor. *JOHN BROWN'S HEADQUARTERS (KENNEDY FARM)*, Chestnut Grove Rd., (11-7-73) NHL; HABS; G.

Sharpsburg. *ANTIETAM NATIONAL BATTLEFIELD SITE*, N of Sharpsburg off MD 45, (10-15-66) HABS.

Sharpsburg. *CHAPLINE, WILLIAM, HOUSE*, 109 W. Main St., (10-8-76)

Smithsburg vicinity. *MAPLES, THE*, 2 mi. SW of Smithsburg on MD 66, (2-24-75)

Williamsport. *SPRINGFIELD FARM*, S of U.S. 11, (7-30-74)

Williamsport vicinity. *ROSE HILL*, 0.5 mi. S of Williamsport on MD 63, (4-11-73)

wicomico county

Allen vicinity. *BENNETT'S ADVENTURE (BRYAN'S MANOR)*, 3 mi. W of Allen on Clifford Cooper Rd., (11-20-75)

Hebron vicinity. *SPRING HILL CHURCH (ST. PAUL'S EPISCOPAL CHURCH)*, 1 mi. NE of Hebron at jct. of U.S. 50 and MD 347, (10-22-76)

Quantico. *ST. BARTHOLOMEW'S EPISCOPAL CHURCH*, Green Hill Church Rd., (6-5-75)

Salisbury. *GILLIS-GRIER HOUSE*, 401 N. Division St., (10-31-72) G.

Salisbury. *JACKSON, SEN. WILLIAM P., HOUSE*, 514 Camden Ave., (9-28-76)

Salisbury. *PEMBERTON HALL*, Pemberton Rd., (2-18-71) G.

Salisbury. *PERRY-COOPER HOUSE*, 200 E. William St., (11-17-77)

Salisbury. *POPLAR HILL MANSION*, 117 Elizabeth St., (10-7-71) G.

Wetipquin vicinity. *LONG HILL*, Wetipquin Ferry Rd; 1 mi. SE of Wetipquin, (12-31-74)

worcester county

Berlin. *BURLEY MANOR*, 3 S. Main St., (7-7-74)

Berlin vicinity. *BUCKINGHAM ARCHEOLOGICAL SITE*, 4 mi. S of Berlin, (2-24-75)

Berlin vicinity. *CALEB'S DISCOVERY*, 2 mi. W of Berlin on U.S. 50, (5-27-75)

Berlin vicinity. *GENESAR*, SE of Berlin on MD 611 off U.S. 50, (9-17-71) HABS; G.

Ocean City vicinity. *SANDY POINT SITE*, SW of Ocean City, (4-28-75)

Pocomoke. *COSTEN HOUSE*, 206 Market St., (12-6-75)

Pocomoke City vicinity. *BEVERLY*, 4.5 mi. SW of Pocomoke City off Cedarhall Rd., (10-29-75)

Showell vicinity. *ST. MARTINS CHURCH*, 1 mi. S of Showell at jct. of U.S. 113 and MD 589, (4-13-77)

Snow Hill vicinity. *NASSAWANGO IRON FURNACE SITE*, NW of Snow Hill off MD 12 on Old Furnace Rd., (10-31-75)

MASSACHUSETTS

barnstable county

Barnstable. *OLD JAIL*, Main St. and Old Jail Lane, (7-2-71) G.

Barnstable. *U.S. CUSTOMSHOUSE*, Cobbs Hill, MA 6A, (11-12-75)

Brewster. *OLD HIGGINS FARM WINDMILL*, Off Lower Rd., (6-10-75)

Brewster vicinity. *DILLINGHAM HOUSE*, W of Brewster on MA 6A, (4-30-76)

Chatham. *BRANDEIS, LOUIS, HOUSE*, Neck Lane, off Cedar St., 8 mi. SW of Stage Harbor Rd. intersection, (11-28-72)
SCG Station, MA NHL.

Chatham vicinity. *OLD HARBOR U.S. LIFE SAVING STATION (USCG STATION)*, NE of Chatham on Nauset Beach, (8-18-75)

Dennis. *DENNIS, JOSIAH, HOUSE*, Nobscusset Rd. at Whig St., (2-15-74)

Dennis. *WEST SCHOOLHOUSE*, Nobscusset Rd. at Whig St., (4-24-75)

East Sandwich. *WING FORT HOUSE*, Spring Hill Road, (6-3-76)

Eastham vicinity. *PENNIMAN, EDWARD, HOUSE AND BARN*, S of Eastham at Fort Hill and Governor Prence Rds., (5-28-76) HABS.
Harwich. *HARWICH HISTORIC DISTRICT*, Irregular pattern on both sides of Main St., W to Forest St. and E to jct. of Rte. 39 and Chatham Rd., (2-24-75)
Hyannis Port. *KENNEDY COMPOUND*, Irving and Marchant Aves., (11-28-72) NHL.
North Eastham vicinity. *FRENCH CABLE HUT*, E of North Eastham at jct. of Cable Rd. and Ocean View Dr., (4-22-76)
Orleans. *FRENCH CABLE STATION*, SE corner of Cove Rd. and MA 28, (4-11-72)
Provincetown. *CENTER METHODIST CHURCH*, 356 Commercial St., (10-31-75) G.
Provincetown. *FIRST UNIVERSALIST CHURCH*, 236 Commercial St., (2-23-72) G.
Provincetown. *PROVINCETOWN PUBLIC LIBRARY*, 330 Commercial St., (4-21-75)
Sandwich. *TOWN HALL SQUARE HISTORIC DISTRICT*, Irregular pattern centered around town square includes both sides of Main, Grove, and Water Sts., and Tupper Rd. from Beale Ave. to MA 6a., (10-31-75)
South Wellfleet. *MARCONI WIRELESS STATION SITE*, 1 mi. NE of Cape Cod National Seashore, (5-2-75)
Truro. *HIGHLAND HOUSE*, Off U.S. 6 on Cape Cod National Seashore, (6-5-75)
Wellfleet vicinity. *ATWOOD, THOMAS, HOUSE*, NW of Wellfleet on Bound Brook Island, (7-30-76)
Wellfleet vicinity. *SMITH, SAMUEL, TAVERN SITE*, SW of Wellfleet on Great Island, (11-11-77)

berkshire county

Adams. *QUAKER MEETINGHOUSE*, Maple St. Cemetery, (8-17-76) HABS.
Ashley Falls vicinity. *ASHLEY, COL. JOHN, HOUSE*, W of Ashley Falls on Cooper Hill Rd., (2-10-75) G.
Florida and Savoy vicinity. *MOHAWK TRAIL*, Along the bank of the Cold River, (4-3-73) (also in Franklin County)
Great Barrington. *DU BOIS, WILLIAM E. B., BOYHOOD HOMESITES*, MA 23, (5-11-76) NHL.
Great Barrington. *DWIGHT–HENDERSON HOUSE*, Main St., (3-26-76) HABS.
Great Barrington vicinity. *RISING PAPER MILL*, N of Great Barrington on MA 183 at Risingdale, (8-11-75)
Hancock. *HANCOCK TOWN HALL*, MA 43, (9-26-75) G.
Interlaken. *CITIZENS HALL*, Off U.S. 90, (6-19-72) G.
Lanesborough. *ST. LUKE'S EPISCOPAL CHURCH*, U.S. 7, (2-23-72) G.
Lee. *HYDE HOUSE*, 144 W. Park St., (11-21-76)
Lee. *LEE LOWER MAIN STREET HISTORIC DISTRICT*, Main and Park Sts., (3-26-76)
Lenox. *LENOX LIBRARY*, 18 Main St., (4-3-73)
Lenox vicinity. *MOUNT, THE (EDITH WHARTON ESTATE)*, S of Lenox on U.S. 7, (11-11-71) NHL; G.
North Adams. *BEAVER MILL*, Beaver St., (5-11-73) HAER.
North Adams. *FREIGHT YARD HISTORIC DISTRICT*, W of the Hadley Overpass and SW of the Hoosac River, (6-13-72)
North Adams. *HOOSAC TUNNEL*, From North Adams on the W to the Deerfield River on the E, (11-2-73) HAER.
North Adams. *MONUMENT SQUARE–EAGLE STREET HISTORIC DISTRICT*, Monument Square and environs, at E end of Main St., (6-19-72)
North Adams. *WINDSOR PRINT WORKS*, 121 Union St., (5-17-73)
Pittsfield. *MELVILLE, HERMAN, HOUSE (ARROWHEAD)*, Holmes Rd., (10-15-66) NHL; HABS; G.
Pittsfield. *OLD CENTRAL FIRE STATION*, 66 Allen St., (11-2-77)
Pittsfield. *OLD TOWN HALL*, 32 East St., corner of Allen St., (4-26-72)
Pittsfield. *PARK SQUARE HISTORIC DISTRICT*, At jct. of North, South, East, and West Sts., (7-24-75)
Pittsfield vicinity. *HANCOCK SHAKER VILLAGE*, 5 mi. S of Pittsfield on U.S. 20, Hancock Tpke., (11-24-68) NHL; HABS; G.
Pittsfield vicinity. *SOUTH MOUNTAIN CONCERT HALL*, New South Mountain Rd., (8-14-73)
South Lee. *MERRELL TAVERN*, MA 102, (2-23-72) HABS.
Stockbridge. *MISSION HOUSE*, Main St., (11-24-68) NHL.
Stockbridge. *NAUMKEAG (JOSEPH HODGES CHOATE HOUSE)*, Prospect St., (11-3-75)
Stockbridge. *STOCKBRIDGE CASINO (BERKSHIRE PLAYHOUSE)*, E. Main St. at Yale Hill Rd., (8-27-76)
Stockbridge vicinity. *CHESTERWOOD (DANIEL CHESTER FRENCH HOUSE AND STUDIO)*, 2 mi. W of Stockbridge, (10-15-66) NHL; G.
Stockbridge vicinity. *OLD CURTISVILLE HISTORIC DISTRICT*, N of Stockbridge on MA 183, (10-29-76)

bristol county

Dighton vicinity. *DIGHTON ROCK*, Across the Taunton River from Dighton in Dighton Rock State Park, (7-1-70)
Easton. *BAY ROAD*, 416-535 Bay Rd. (Foundry St. to the Norton town line), (5-5-72)
Easton. *NORTH EASTON HISTORIC DISTRICT*, Section of town N of and including both sides of Main/Lincoln St., (11-3-72) G.
Fairhaven. *FORT PHOENIX*, S of U.S. 6 in Fort Phoenix Park, (11-9-72)
Fall River. *ACADEMY BUILDING*, S. Main St., (7-2-73)
Fall River. *U.S.S. JOSEPH P. KENNEDY JR.*, Battleship Cove, (9-30-76)
Fall River. *U.S.S. LIONFISH*, Battleship Cove, (9-30-76)
Fall River. *U.S.S. MASSACHUSETTS*, Battleship Cove, (9-30-76) G.
New Bedford. *CARNEY, SGT. WILLIAM H., HOUSE*, 128 Mill St., (4-21-75)
New Bedford. *COUNTY STREET HISTORIC DISTRICT*, Roughly bounded by Acushnet, Page, Middle, and Bedford Sts. (includes both sides), (8-11-76)
New Bedford. *FIRE STATION NO. 4*, 79 S. 6th St., (7-24-75)
New Bedford. *FIRST BAPTIST CHURCH*, 149 William St., (4-21-75) G.
New Bedford. *FORT TABER DISTRICT (FORT AT CLARK'S POINT)*, Wharf Rd. within Fort Rodman Military Reservation, (2-8-73) G.
New Bedford. *MERRILL'S WHARF HISTORIC DISTRICT*, MacArthur Dr., (11-11-77)
New Bedford. *NEW BEDFORD HISTORIC DISTRICT*, Bounded by Front St. on E, Elm St. on N, Acushnet Ave. on W, and Commercial St. on S, (11-13-66) NHL; HABS.
New Bedford. *OLD THIRD DISTRICT COURTHOUSE*, 2nd and William Sts., (9-28-71) HABS.
New Bedford. *U.S. CUSTOMHOUSE*, SW corner of 2nd and Williams Sts., (12-30-70) NHL; HABS.
North Attleborough vicinity. *ANGLE TREE STONE*, W of North Attleborough off High St., (1-1-76) (also in Norfolk County)
North Easton. *NORTH EASTON RAILROAD STATION*, Off Oliver St. on railroad right-of-way, (4-11-72) HABS; G.
Norton. *CLARKE, PITT, HOUSE*, 42 Mansfield Ave., (7-13-76) HABS.
Norton. *NORTON CENTER HISTORIC DISTRICT*, MA 123, (12-23-77)
Norton. *OLD BAY ROAD*, From Easton Town Line to Taunton Town Line, (11-8-74)
Seekonk. *MARTIN HOUSE*, 940 Court St., (5-2-74) HABS.
Taunton. *CHURCH GREEN*, U.S. 44 and MA 140, (12-16-77)
Westport. *CUFFE, PAUL, FARM*, 1504 Drift Rd., (5-30-74) NHL.

dukes county

Vineyard Haven. *RITTER HOUSE (JIREH LUCE HOUSE)*, Beach St., (12-6-77)

essex county

Amesbury. *ROCKY HILL MEETINGHOUSE AND PARSONAGE*, Portsmouth Rd. and Elm St., (4-11-72) HABS; G.
Amesbury. *WHITTIER, JOHN GREENLEAF, HOUSE*, 86 Friend St., (10-15-66) NHL.
Andover. *ABBOT, BENJAMIN, HOUSE*, 9 Andover St., (2-24-75) G.
Beverly. *BALCH, JOHN, HOUSE*, 448 Cabot St., (2-23-73)
Beverly. *CABOT, CAPT. JOHN, HOUSE*, 117 Cabot St., (4-16-75) G.
Beverly. *FISH FLAKE HILL (FRONT STREET) HISTORIC DISTRICT*, N and S sides of Front St. from Cabot to Bartlett Sts., (10-26-71) G.
Beverly. *HALE, REVEREND JOHN, HOUSE*, 39 Hale St., (10-9-74)
Beverly. *HOLMES, OLIVER WENDELL, HOUSE*, 868 Hale St. (Beverly Farms), (11-28-72) NHL.
Boxford. *BOXFORD VILLAGE HISTORIC DISTRICT*, Middleton and Topsfield Rds. and Main and Elm Sts., (4-11-73)
Boxford. *HOLYOKE-FRENCH HOUSE*, Elm St. and Topsfield Rd., (4-26-72) G.
Boxford. *SPOFFORD-BARNES HOUSE*, Kelsey Rd., (9-6-74)
Boxford vicinity. *HOWE VILLAGE HISTORIC DISTRICT*, NE of Boxford on MA 97, (4-3-73)
Danvers. *DERBY SUMMERHOUSE*, Glen Magna Estate, Ingersoll St., (11-24-68) NHL; HABS.
Danvers. *PUTNAM, GEN. ISRAEL, HOUSE*, 431 Maple St., (4-30-76) HABS.
Danvers. *SALEM VILLAGE HISTORIC DISTRICT*, Irregular pattern along Centre, Hobart, Ingersoll, and Collins Sts., as far N as Brentwood Circle, and S to Mello Pkwy., (1-31-75) G.
Danversport. *FOWLER HOUSE*, 166 High St., (9-17-74)
Gloucester. *FRONT STREET BLOCK (WEST END BUILDINGS)*, West End, 55-71 Main St., (5-8-74)
Gloucester. *GLOUCESTER CITY HALL*, Dale Ave., (5-8-73) G.
Gloucester. *HAMMOND CASTLE*, 80 Hesperus Ave., (5-8-73)
Gloucester. *LANE, FITZ HUGH, HOUSE*, Harbor side of Rogers St., (7-1-70)

Gloucester. *OAK GROVE CEMETERY*, Bounded by Derby, Washington, and Grove Sts., and Maplewood Ave., (4-3-75)
Gloucester. *PURITAN HOUSE*, 3 Washington St. and 2 Main St., (5-28-76)
Gloucester vicinity. *BEAUPORT*, Eastern Point Blvd., (4-26-76) G.
Hamilton. *HAMILTON HISTORIC DISTRICT*, 540–700 and 563–641 Bay Rd., (4-13-73)
Haverhill. *BRADFORD COMMON HISTORIC DISTRICT*, S. Main St., (9-14-77)
Haverhill. *WASHINGTON STREET SHOE DISTRICT*, Washington, Wingate, Emerson Sts., Railroad, and Washington squares, (10-14-76)
Haverhill vicinity. *ROCKS VILLAGE HISTORIC DISTRICT*, NE of Haverhill at Merrimack River, (12-12-76)
Haverhill vicinity. *WHITTIER, JOHN GREENLEAF, HOMESTEAD*, 4 mi. E of Haverhill at 105 Whittier Rd., (7-30-75) G.
Ipswich. *CHOATE BRIDGE*, MA 133/1A over the Ipswich River (S. Main St.), (8-21-72)
Ipswich. *WHIPPLE, JOHN, HOUSE*, 53 S. Main St., (10-15-66) NHL; HABS; G.
Ipswich vicinity. *CASTLE HILL*, E of Ipswich on Argilla Rd., (12-2-77)
Lawrence. *ESSEX COUNTY MACHINE SHOP*, Union St., (11-9-72) HABS.
Lawrence. *GRACE EPISCOPAL CHURCH*, Common and Jackson Sts., (11-7-76)
Lawrence. *GREAT STONE DAM*, Merrimack River and MA 28, (4-13-77)
Lawrence. *MECHANICS BLOCK HISTORIC DISTRICT*, 107–139 Garden St., 6–38 Orchard St., (4-3-73) G.
Lawrence. *NORTH CANAL*, Parallel to Canal St., (7-29-75)
Lynnfield. *MEETINGHOUSE COMMON DISTRICT*, Summer, S. Common, and Main Sts., (11-21-76)
Manchester vicinity. *THE NEW HAMPSHIRE*, SE of Manchester off Graves Island, (10-29-76)
Marble Road. *HOOPER, ROBERT "KING," MANSION*, 8 Hooper St., (5-12-76) HABS.
Marblehead. *ABBOT HALL*, Washington Sq., (9-6-74)
Marblehead. *FORT SEWALL*, Fort Sewall promontory, (4-14-75)
Marblehead. *GERRY, ELBRIDGE, HOUSE*, 44 Washington St., (7-2-73)
Marblehead. *GLOVER, GEN. JOHN, HOUSE*, 11 Glover St., (11-28-72) NHL.
Marblehead. *LEE, JEREMIAH, HOUSE*, Washington St., (10-15-66) NHL; HABS; G.
Marblehead. *OLD TOWN HOUSE*, Town House Sq., (8-13-76) HABS.
Marblehead. *ST. MICHAEL'S CHURCH*, 26 Pleasant St., (6-18-73) G.
Nahant. *LODGE, HENRY CABOT, HOUSE*, 5 Cliff St., (12-8-76) NHL.
Newbury. *NEWBURY HISTORIC DISTRICT*, Irregular pattern along High Rd., Green and Hanover Sts., (5-24-76) HABS.
Newbury. *SPENCER-PIERCE-LITTLE HOUSE*, At the end of Little's Lane on the E side of U.S. 1A, (11-24-68) NHL; G.
Newburyport. *BROWN SQUARE HOUSE*, 11 Brown Sq., (3-7-75)
Newburyport. *CUSHING, CALEB, HOUSE*, 98 High St., (11-7-73) NHL; HABS.
Newburyport. *FIRST RELIGIOUS SOCIETY CHURCH AND PARISH HALL*, 26 Pleasant St., (4-2-76) HABS.
Newburyport. *MARKET SQUARE HISTORIC DISTRICT*, Market Sq. and properties fronting on State, Merrimac, Liberty, and Water Sts., (2-25-71) G.
Newburyport. *SUPERIOR COURTHOUSE AND BARTLETT MALL*, Bounded by High, Pond, Auburn, and Greenleaf Sts., (4-30-76)
Newburyport. *U.S. CUSTOMHOUSE*, 25 Water St., (2-25-71)
North Andover. *BARNARD, PARSON, HOUSE*, 179 Osgood St., (9-6-74) G.
North Andover. *KITTREDGE MANSION*, 56 Academy Rd., (12-12-76)
North Andover. *OSGOOD, SAMUEL, HOUSE*, 440 Osgood St., (12-30-74)
North Andover vicinity. *KUNHARDT, GEORGE, ESTATE (CHAMPION HALL)*, 1518 Great Pond Rd., (4-22-76)
Peabody. *FOSTER, GEN. GIDEON, HOUSE*, 35 Washington St., (6-23-76)
Peabody. *PEABODY CITY HALL*, 24 Lowell St., (6-27-72) G.
Peabody. *PEABODY INSTITUTE LIBRARY*, Main St., (6-4-73)
Rockport. *ROCKPORT DOWNTOWN MAIN STREET HISTORIC DISTRICT*, Portions of Main, Cleaves, Jewett, and School Sts., (5-28-76)
Salem. *BOWDITCH, NATHANIEL, HOUSE*, North St., (10-15-66) NHL.
Salem. *CHARTER STREET HISTORIC DISTRICT*, Bounded by Liberty, Derby, Central, and Charter Sts., (3-10-75)
Salem. *CHESTNUT STREET DISTRICT*, Bounded roughly by Broad, Flint, Federal, and Summer Sts., (8-28-73)
Salem. *CITY HALL*, 93 Washington St., (4-3-73)
Salem. *DERBY WATERFRONT DISTRICT*, Derby St. from Herbert St. to Block House Sq., waterfront Sts. between Kosciusko and Blaney Sts., (5-17-76) HABS.
Salem. *ESSEX COUNTY COURT BUILDINGS*, 32 Federal St., (5-17-76)
Salem. *ESSEX INSTITUTE HISTORIC DISTRICT*, (6-22-72) HABS; G.
Salem. *FORT PICKERING (FORT WILLIAM, FORT ANNE)*, Winter Island, (2-8-73)
Salem. *GARDNER-PINGREE HOUSE*, 128 Essex St., (12-30-70) NHL; HABS.
Salem. *GEDNEY AND COX HOUSES*, 19 and 21 High St., (10-1-74)
Salem. *HAMILTON HALL*, 9 Cambridge St., (12-30-70) NHL; HABS.
Salem. *HOUSE OF SEVEN GABLES HISTORIC DISTRICT*, Turner, Derby, and Hardy Sts., (5-8-73)
Salem. *OLD TOWN HALL HISTORIC DISTRICT*, Derby Sq. and 215–231 Essex, 121–145 Washington, and 6–34 Front Sts., (12-4-72)
Salem. *PEABODY MUSEUM OF SALEM*, 161 Essex St., (10-15-66) NHL; HABS.
Salem. *PEIRCE-NICHOLS HOUSE*, 80 Federal St., (11-24-68) NHL.
Salem. *SALEM COMMON HISTORIC DISTRICT*, Bounded roughly by St. Peter's, Bridge, and Derby Sts. and Collins Cove, (5-12-76) HABS.
Salem. *SALEM MARITIME NATIONAL HISTORIC SITE*, Derby St., (10-15-66) HABS.
Salem. *STORY, JOSEPH, HOUSE*, 26 Winter St., (11-7-73) NHL.
Salem. *WARD, JOHN, HOUSE*, 132 Essex St., (11-24-68) NHL.
Salem. *WOODBRIDGE, THOMAS MARCH, HOUSE*, 48 Bridge St., (3-31-75) G.
Salem vicinity. *BAKERS ISLAND LIGHT STATION*, E of Salem on Bakers Island, (11-21-76)
Saugus. *BOARDMAN HOUSE*, Howard St., (10-15-66) NHL.
Saugus. *SAUGUS IRONWORKS NATIONAL HISTORIC SITE*, Off U.S. 1, (10-15-66)
Swampscott. *THOMSON, ELIHU, HOUSE*, 33 Elmwood Ave., (1-7-76) NHL.
Thacher's Island. *TWIN LIGHTS HISTORIC DISTRICT*, 1 mi. off the coast, E of Rockport, (10-7-71)
Topsfield. *CAPEN, PARSON, HOUSE*, Howlett St., (10-15-66) NHL.
Topsfield. *TOPSFIELD TOWN COMMON DISTRICT*, High and Main Sts., (6-7-76) HABS.
Wenham. *CLAFLIN-RICHARDS HOUSE*, 132 Main St., (4-3-73)
Wenham. *WENHAM HISTORIC DISTRICT*, Both sides of Main St. between Beverly and Hamilton city lines, (4-13-73)

franklin county

MOHAWK TRAIL, Reference—see Berkshire County
Buckland. *GRISWOLD, MAJ. JOSEPH, HOUSE*, Upper St., (2-23-72) G.
Deerfield. *OLD DEERFIELD VILLAGE HISTORIC DISTRICT*, (10-15-66) NHL; HABS; G.
Greenfield vicinity. *RIVERSIDE ARCHEOLOGICAL DISTRICT*, NE of Greenfield on MA 2, (7-9-75)
New Salem. *WHITAKER-CLARY HOUSE*, Elm St., (6-18-75)

hampden county

Agawam. *LEONARD, CAPT. CHARLES, HOUSE*, 663 Main St., (3-10-75)
Chicopee. *CITY HALL*, Market Sq., (7-30-74)
Chicopee. *DWIGHT MANUFACTURING COMPANY HOUSING DISTRICT*, Front, Depot, Dwight, Exchange, Chestnut Sts., (6-3-77)
Chicopee Falls. *BELLAMY, EDWARD, HOUSE*, 91-93 Church St., (11-11-71) NHL; G.
East Longmeadow. *BURT, ELIJAH, HOUSE*, 201 Chestnut St., (4-26-76)
Holyoke. *HADLEY FALLS COMPANY HOUSING DISTRICT*, Center, N. Canal, Grover, and Lyman Sts., (11-9-72) G.
Holyoke. *HOLYOKE CITY HALL*, 536 Dwight St., (12-6-75)
Holyoke. *WISTARIAHURST*, 238 Cabot St., (4-23-73)
Sprinfield. *MAPLE-UNION CORNERS*, 77, 83, 76–78, 80–84 Maple St., (4-26-76)
Springfield. *AMES HILL/CRESCENT HILL DISTRICT*, Bounded by section of Central, Maple, Mill, and Pine Sts., Crescent Hill, Ames Hill, and Maple Ct., (5-1-74)
Springfield. *COURT SQUARE HISTORIC DISTRICT*, Bounded by Main, State, Broadway, Pynchon Sts. and City Hall Pl., (5-2-74) HABS; G.
Springfield. *FIRST CHURCH OF CHRIST, CONGREGATIONAL*, 50 Elm St., (2-1-72) G.
Springfield. *HAMPDEN COUNTY COURTHOUSE*, Elm St., (2-1-72)
Springfield. *MCKNIGHT DISTRICT*, Roughly bounded by Penn Central, State St., the Armory, and includes both sides of Campus Pl., and Dartmouth St., (4-26-76)
Springfield. *MEMORIAL SQUARE DISTRICT*, Main and Plainfield Sts., (8-29-77)
Springfield. *MILLS-STEBBINS VILLA*, 3 Crescent Hill, (10-15-73) HABS.
Springfield. *QUADRANGLE-MATTOON STREET HISTORIC DISTRICT*, Bounded by Chestnut St. to the W, State St. to the S, and includes properties on Mattoon, Salem, Edwards, and Elliot Sts., (5-8-74) G.
Springfield. *SOUTH CONGREGATIONAL CHURCH*, 45 Maple St., (4-30-76)

Springfield. *SPRINGFIELD ARMORY NATIONAL HISTORIC SITE*, Armory Sq., (10-26-74)
Springfield. *STATE ARMORY*, 29 Howard St., (5-3-76)
Springfield. *1767 MILESTONES*, Between Boston and Springfield along Old Post Rd., (4-7-71) (also in Middlesex, Norfolk, Suffolk, and Worcester counties)
West Springfield. *DAY, JOSIAH, HOUSE*, 70 Park St., (4-16-75) G.

hampshire county

Amherst. *DICKINSON, EMILY, HOUSE*, 280 Main St., (10-15-66) NHL.
Amherst. *DICKINSON HISTORIC DISTRICT*, Kellogg Ave., Main, Gray, and Lessey Sts., (8-16-77)
Cummington vicinity. *BRYANT, WILLIAM CULLEN, HOMESTEAD*, 2 mi. from Cummington on side rd., (10-15-66) NHL.
Hadley. *HADLEY CENTER HISTORIC DISTRICT*, Middle and Russell Sts., (12-2-77)
Hadley. *PORTER-PHELPS-HUNTINGTON HOUSE*, 130 River Dr., (3-26-73)
Haydenville. *HAYDENVILLE HISTORIC DISTRICT*, Main and High Sts., and Kingsley Ave., (3-26-76)
Northampton. *COOLIDGE, CALVIN, HOUSE*, 19–21 Massasoit St., (12-12-76)
Northampton. *NORTHAMPTON DOWNTOWN HISTORIC DISTRICT*, Roughly bounded by Hampton, Pearl, Strong, Bedford, Elm, MA 66, and railroad tracks, (5-17-76)
Northampton. *SMITH ALUMNAE GYMNASIUM*, Smith College campus, Green St., (4-30-76)
Northampton. *THE MANSE*, 54 Prospect St., (10-14-76)
Pelham. *PELHAM TOWN HALL HISTORIC DISTRICT*, Amherst Rd. at the corner of Daniel Shays Hwy., (11-23-71) G.

middlesex county

ISAAC DAVIS TRAIL (ACTON'S TRAIL), Running E-W between towns of Acton and Concord, (4-11-72)
MIDDLESEX CANAL, Running SE between towns of Lowell and Woburn, (8-21-72) G.
1767 MILESTONES, Reference—see Hampden County
Acton. *FAULKNER HOMESTEAD*, High St., (12-16-71) HABS; G.
Arlington. *ARLINGTON TOWN CENTER DISTRICT*, Bounded by Massachusetts Ave. and Academy, Pleasant, and Maple Sts., (7-18-74)
Arlington. *FOWLE-REED-WYMAN HOUSE*, 64 Old Mystic St., (4-14-75) G.
Arlington. *OLD SCHWAMB MILL*, 17 Mill Lane and 29 Lowell St., (10-7-71) G.
Arlington. *RUSSELL, JASON, HOUSE*, 7 Jason St., (10-9-74)
Bedford. *BEDFORD CENTER HISTORIC DISTRICT*, Irregular pattern along Great Rd. from Bacon to Concord and North Rds., (11-17-77)
Bedford. *LANE, JOB, HOUSE*, 295 North St., (5-8-73) G.
Bedford vicinity. *BACON–GLEASON–BLODGETT HOMESTEAD*, 118 Wilson Rd., (4-14-77)
Belmont. *RED TOP (WILLIAM DEAN HOWELLS HOUSE)*, 90 Somerset St., (11-11-71) NHL.
Billerica. *BILLERICA TOWN COMMON DISTRICT*, Bounded by Cummings St., Concord Rd., and Boston Rd., (8-14-73)
Billerica. *SABBATH DAY HOUSE*, 20 Andover Rd., (8-14-73)
Burlington. *WYMAN, FRANCIS, HOUSE*, Francis Wyman St., (3-13-75) HABS; G.
Cambridge. *AUSTIN HALL*, Harvard University campus, (4-19-72)
Cambridge. *BALDWIN, MARIA, HOUSE*, 196 Prospect St., (5-11-76) NHL.
Cambridge. *BIRKHOFF, GEORGE D., HOUSE*, 22 Craigie, (5-15-75) NHL.
Cambridge. *BRATTLE, WILLIAM, HOUSE*, 42 Brattle St., (5-8-73) HABS.
Cambridge. *BRIDGMAN, PERCY, HOUSE*, 10 Buckingham Pl., (5-15-75) NHL.
Cambridge. *CAMBRIDGE COMMON HISTORIC DISTRICT*, Garden, Waterhouse, Cambridge, and Peabody Sts., and Massachusetts Ave., (4-13-73) HABS; G.
Cambridge. *CHRIST CHURCH*, Garden St., (10-15-66) NHL; HABS.
Cambridge. *COOPER-FROST-AUSTIN HOUSE*, 21 Linnaean St., (9-22-72)
Cambridge. *DALY, REGINALD A., HOUSE*, 23 Hawthorn St., (1-7-76) NHL.
Cambridge. *DAVIS, WILLIAM MORRIS, HOUSE*, 17 Francis St., (1-7-76) NHL.
Cambridge. *ELMWOOD (JAMES RUSSELL LOWELL HOUSE)*, 33 Elmwood Ave., (10-15-66) NHL.
Cambridge. *FIRST BAPTIST CHURCH*, Magazine and River Sts., (4-14-75) HABS; G.
Cambridge. *FORT WASHINGTON*, 95 Waverly St., (4-3-73) HABS; G.
Cambridge. *FULLER, MARGARET, HOUSE*, 71 Cherry St., (7-2-71) NHL.
Cambridge. *GRAY, ASA, HOUSE*, 88 Garden St., (10-15-66) NHL.
Cambridge. *HASTINGS, OLIVER, HOUSE*, 101 Brattle St., (12-30-70) NHL.
Cambridge. *LITTLE, ARTHUR D., INC. BUILDING*, Memorial Dr., (12-8-76) NHL.
Cambridge. *LONGFELLOW NATIONAL HISTORIC SITE*, 105 Brattle St., (10-15-66) HABS.
Cambridge. *MASSACHUSETTS HALL, HARVARD UNIVERSITY*, Harvard University Yard, (10-15-66) NHL.
Cambridge. *MEMORIAL HALL, HARVARD UNIVERSITY*, Cambridge and Quincy Sts., Harvard University campus, (12-30-70) NHL.
Cambridge. *MOUNT AUBURN CEMETERY*, 580 Mount Auburn St., (4-21-75) G.
Cambridge. *OLD HARVARD YARD*, Massachusetts Ave. and Cambridge St., (2-6-73)
Cambridge. *PRATT, DEXTER, HOUSE*, 54 Brattle St., (5-8-73)
Cambridge. *RICHARDS, THEODORE W., HOUSE*, 15 Follen St., (1-7-76) NHL.
Cambridge. *SANDS, HIRAM, HOUSE*, 22 Putnam Ave., (4-30-76)
Cambridge. *SEVER HALL, HARVARD UNIVERSITY*, Harvard Yard, (12-30-70) NHL.
Cambridge. *UNIVERSITY HALL, HARVARD UNIVERSITY*, Harvard Yard, (12-30-70) NHL.
Chelmsford. *OLD CHELMSFORD GARRISON HOUSE COMPLEX*, 105 Garrison Rd., (5-8-73) G.
Chelmsford Center. *FISKE HOUSE*, 1 Billerica Rd., (12-9-77)
Concord. *ALCOTT, LOUISA MAY, HOUSE (ORCHARD HOUSE)*, Lexington Rd., (10-15-66) NHL; HABS.
Concord. *BARRETT, COL. JAMES, FARM*, 448 Barrett's Mill Rd., (11-15-73)
Concord. *CONCORD MONUMENT SQUARE–LEXINGTON ROAD HISTORIC DISTRICT*, MA 2A, (9-13-77)
Concord. *EMERSON, RALPH WALDO, HOUSE*, Lexington Rd. and Cambridge Tpke., (10-15-66) NHL.
Concord. *OLD MANSE*, Monument St., (10-15-66) NHL; HABS.
Concord. *PEST HOUSE*, 153 Fairhaven Rd., (4-18-77)
Concord. *THOREAU-ALCOTT HOUSE*, 255 Main St., (7-12-76)
Concord. *WRIGHT'S TAVERN*, Lexington Rd. opposite the Burying Ground, (10-15-66) NHL; HABS; G.
Concord-Lexington vicinity. *MINUTE MAN NATIONAL HISTORICAL PARK*, From Concord to Lexington on MA 2A, (10-15-66) HABS.
Concord vicinity. *BROOKS, DANIEL, HOUSE*, Brooks Rd. E., (10-25-73) HABS.
Concord vicinity. *CUMING, DR. JOHN, HOUSE*, W of Concord at Barretts Mill Rd. and Reformatory Circle, (11-11-77)
Concord vicinity. *WALDEN POND*, 1.5 mi. S of Concord, (10-15-66) NHL.
Framingham. *FRAMINGHAM RAILROAD STATION*, 417 Waverly St., (1-17-75)
Groton. *GROTON INN*, Main St., (8-3-76)
Hudson. *GOODALE HOMESTEAD*, 100 Chestnut St., (1-21-75)
Lexington. *BUCKMAN TAVERN*, Hancock St., on the E side of Lexington Green, (10-15-66) NHL; HABS.
Lexington. *CHANDLER, GEN. SAMUEL, HOUSE*, 8 Goodwin Rd., (4-13-77)
Lexington. *FOLLEN COMMUNITY CHURCH*, 755 Massachusetts Ave., (4-30-76) HABS.
Lexington. *HANCOCK-CLARKE HOUSE*, 35 Hancock St., (7-17-71) NHL; HABS; G.
Lexington. *HANCOCK SCHOOL*, 33 Forest St., (8-22-75)
Lexington. *LEXINGTON GREEN*, Massachusetts and Hancock Sts., (10-15-66) NHL.
Lexington. *LEXINGTON GREEN HISTORIC DISTRICT*, Bounded by Massachusetts Ave., Bedford St., and Harrington Rd., (4-30-76) HABS.
Lexington. *SANDERSON HOUSE AND MUNROE TAVERN*, 1314 and 1332 Massachusetts Ave., (4-26-76) HABS.
Lexington. *SHERBURNE, WARREN E., HOUSE*, 11 Percy Rd., (12-2-77)
Lexington. *SIMONDS TAVERN*, 331 Bedford St., (10-14-76)
Lexington. *STONE BUILDING*, 735 Massachusetts Ave., (4-30-76) HABS.
Lincoln. *GRANGE, THE*, Codman Rd., (4-18-74) G.
Lincoln. *HOAR TAVERN*, NE of Lincoln on MA 2, (7-23-73)
Lowell. *BOWERS, JONATHAN, HOUSE (ROUND HOUSE)*, 58 Wannalancit St., (6-18-76)
Lowell. *CHELMSFORD GLASS WORKS' LONG HOUSE*, 139–141 Baldwin St., (1-25-73) HABS.
Lowell. *CITY HALL HISTORIC DISTRICT*, Roughly area between Broadway and French Sts., Colburn St. and both sides of Kirk St., (4-21-75)
Lowell. *HOLY TRINITY GREEK ORTHODOX CHURCH*, Lewis St., (4-13-77)
Lowell. *LOWELL LOCKS AND CANALS HISTORIC DISTRICT*, Between Middlesex St. and the Merrimack River, (8-13-76) HAER.
Malden. *OLD CITY HALL*, Main St., (10-8-76)
Medford. *ALBREE-HALL-LAWRENCE HOUSE*, 353 Lawrence Rd., (4-30-76) HABS.
Medford. *ANGIER, JOHN B., HOUSE*, 129 High St., (4-23-75)

Medford. *BIGELOW BLOCK*, NE corner of Forest and Salem Sts., (2-24-75)
Medford. *BROOKS, CHARLES, HOUSE*, 309 High St., (6-18-75) G.
Medford. *BROOKS, JONATHAN, HOUSE*, 2 Woburn St., (6-26-75) HABS.
Medford. *BROOKS, SHEPHERD, ESTATE*, 275 Grove St., (4-21-75)
Medford. *CURTIS, PAUL, HOUSE*, 114 South St., (5-6-75)
Medford. *FERNALD, GEORGE P., HOUSE*, 12 Rock Hill St., (4-30-76)
Medford. *FLETCHER, JONATHAN, HOUSE*, 283 High St., (6-23-75)
Medford. *GRACE EPISCOPAL CHURCH*, 160 High St., (11-3-72) G.
Medford. *HALL, ISAAC, HOUSE*, 43 High St., (4-16-75) HABS.
Medford. *HILLSIDE AVENUE HISTORIC DISTRICT*, Property on both sides of Hillside and Grand View Aves., (4-21-75)
Medford. *LAWRENCE LIGHT GUARD ARMORY*, 90 High St., (3-10-75)
Medford. *OLD SHIP STREET HISTORIC DISTRICT*, Both sides of Pleasant St. from Riverside Ave. to Park St., (4-14-75)
Medford. *PARK STREET RAILROAD STATION*, 20 Magoun Ave., (4-21-75)
Medford. *ROYALL, ISAAC, HOUSE*, 15 George St., (10-15-66) NHL; HABS.
Medford. *TUFTS, PETER, HOUSE*, 350 Riverside Ave., (11-24-68) NHL.
Medford. *UNITARIAN UNIVERSALIST CHURCH AND PARSONAGE*, 141 and 147 High St., (4-21-75) HABS.
Medford. *WADE, JOHN, HOUSE*, 253 High St., (6-18-75)
Medford. *WADE, JONATHAN, HOUSE*, 13 Bradlea Rd., (4-21-75)
Natick. *NATICK CENTER HISTORIC DISTRICT*, North Ave., Main, Central, and Summer Sts., (12-16-77)
Natick. *PARSONAGE, THE (HORATIO ALGER HOUSE)*, 16 Pleasant St., (11-11-71) NHL.
Newton. *BIGELOW, Dr. HENRY JACOB, HOUSE*, 742 Dedham St., (1-1-76)
Newton. *DURANT, CAPT. EDWARD, HOUSE*, 286 Waverly Ave., (5-13-76) HABS.
Newton. *FESSENDEN, REGINALD A., HOUSE*, 45 Waban Hill Rd., (1-7-76) NHL.
Newton. *JACKSON HOMESTEAD*, 527 Washington St., (6-4-73)
Newton. *WOODLAND, NEWTON HIGHLANDS, AND NEWTON CENTRE RAILROAD STATIONS, BAGGAGE AND EXPRESS BUILDING*, 1897 Washington Sts., 18 Station Ave., 80 and 50 Union St., (6-3-76)
Reading. *PARKER TAVERN*, 103 Washington St., (8-19-75)
Shirley vicinity. *SHIRLEY SHAKER VILLAGE*, S of Shirley on Harvard Rd., (5-24-76) (also in Worchester County)
Somerville. *BOW STREET HISTORIC DISTRICT*, Boy St., (3-26-76)
Somerville. *POWDER HOUSE PARK*, Powder House Circle, (4-21-75)
Sudbury. *SUDBURY CENTER HISTORIC DISTRICT*, Concord and Old Sudbury Rds., (7-14-76)
Sudbury. *WAYSIDE INN HISTORIC DISTRICT*, Old Boston Post Rd., (4-23-73) HABS.
Tyngsboro vicinity. *TYNG, COL. JONATHAN, HOUSE*, 80 Tyng Rd., (8-19-77) HABS.
Waltham. *GORE PLACE*, 52 Gore St., (12-30-70) NHL; HABS; G.
Waltham. *PAINE, ROBERT TREAT JR., HOUSE*, 577 Beaver St., (10-7-75)
Waltham. *VALE, THE (THEODORE LYMAN ESTATE)*, Lyman and Beaver Sts., (12-30-70) NHL; HABS; G.
Watertown. *COMMANDING OFFICER'S QUARTERS, WATERTOWN ARSENAL*, 443 Arsenal St., (1-30-76)
Watertown. *FOWLE, EDMUND, HOUSE*, 26–28 Marshall St., (11-11-77)
Wayland. *WAYLAND CENTER HISTORIC DISTRICT*, Irregular pattern along both sides of U.S. 20 and MA 27, (9-6-74) G.
Wayland vicinity. *OLD TOWN BRIDGE*, N of Wayland on MA 27, (5-2-75)
Weston. *GOLDEN BALL TAVERN*, 662 Boston Post Rd., (9-28-72) G.
Weston. *HARRINGTON HOUSE*, 555 Wellesley St., (6-22-76)
Weston. *WOODWARD, REV. SAMUEL, HOUSE*, 19 Concord Rd., (10-8-76)
Weston vicinity. *TRAIN, SAMUEL, HOUSE*, 342 Winter St., (12-12-76)
Wilmington. *HARNDEN TAVERN*, 430 Salem St., (4-8-75)
Woburn. *BALDWIN, LOAMMI, MANSION*, 2 Alfred St., (10-7-71) HABS; G.
Woburn. *COUNT RUMFORD BIRTHPLACE*, 90 Elm St., (5-15-75) NHL.
Woburn. *WOBURN PUBLIC LIBRARY*, Pleasant St., (11-13-76)
Woburn. *1790 HOUSE*, 827 Main St., (10-9-74)

nantucket county

Nantucket. *COFFIN, JETHRO, HOUSE*, Sunset Hill, (11-24-68) NHL; G.
Nantucket. *NANTUCKET HISTORIC DISTRICT*, Nantucket Island, (11-13-66) NHL; HABS.

norfolk county

1767 MILESTONES, Reference—see Hampden County
Braintree. *THAYER, GEN. SYLVANUS, HOUSE*, 786 Washington St., (12-3-74)
Brookline. *JOHN FITZGERALD KENNEDY NATIONAL HISTORIC SITE*, 83 Beals St., (5-26-67) HABS.
Brookline. *MINOT, GEORGE R., HOUSE*, 71 Sears Rd., (1-7-76) NHL.
Brookline. *OLMSTED, FREDERICK LAW, HOUSE*, 99 Warren St., (10-15-66) NHL.
Brookline. *OLMSTED PARK SYSTEM*, Encompassing the Back Bay Fens, Muddy River, Olmsted (Leverett Park), Jamaica Park, Arborway, and Franklin Park, (12-8-71) G. (also in Suffolk County)
Brookline. *PILL HILL HISTORIC DISTRICT*, Roughly bounded by Boylston St., Pond Ave., Acron, Oakland and Highland Rds., (12-16-77)
Brookline. *ST. MARK'S METHODIST CHURCH*, 90 Park St., (12-17-76)
Cohasset. *LOTHROP, CALEB HOUSE*, 14 Summer St., (5-3-76)
Dedham. *FAIRBANKS HOUSE*, Eastern Ave. and East St., (10-15-66) NHL; HABS; G.
Dedham. *NORFOLK COUNTY COURTHOUSE*, 650 High St., (11-28-72) NHL.
Franklin. *DEAN JUNIOR COLLEGE HISTORIC DISTRICT*, Dean Junior College campus, (4-23-75)
Franklin. *RED BRICK SCHOOL*, 2 Lincoln St., (1-1-76)
Medfield. *FIRST PARISH UNITARIAN CHURCH*, North St., (4-18-74)
Medfield. *PEAK HOUSE*, 347 Main St., (9-5-75)
Millis. *PARTRIDGE, JOHN, HOUSE*, 315 Exchange St., (10-15-74)
Milton. *FORBES, CAPT. ROBERT B., HOUSE*, 215 Adams St., (11-13-66) NHL.
Milton. *HOLBROOK, DR. AMOS, HOUSE*, 203 Adams St., (4-18-74) G.
Milton. *HUTCHINSON, GOV. THOMAS, HA-HA*, 100, 112 Randolph Ave., (2-13-75)
Milton. *PAUL'S BRIDGE*, Neponset Valley Pkwy., over the Neponset River, (12-11-72) (also in Suffolk County)
Milton. *SUFFOLK RESOLVES HOUSE (DANIEL VOSE RESIDENCE)*, 1370 Canton Ave., (7-23-73) HABS.
Norfolk vicinity. *WARELANDS*, N of Norfolk at 103 Boardman St., (11-10-77)
North Attleborough vicinity. *ANGLE TREE STONE, Reference—see Bristol County*
Norwood. *DAY, FRED HOLLAND, HOUSE*, 93 Day St., (4-18-77)
Quincy. *ADAMS ACADEMY*, 8 Adams St., (9-6-74)
Quincy. *ADAMS, JOHN, BIRTHPLACE*, 133 Franklin St., (10-15-66) NHL; HABS; G.
Quincy. *ADAMS, JOHN QUINCY, BIRTHPLACE*, 141 Franklin St., (10-15-66) NHL; HABS; G.
Quincy. *ADAMS NATIONAL HISTORIC SITE*, 135 Adams St., (10-15-66)
Quincy. *MOSWETUSET HUMMOCK*, Squantum St., near jct. with Morrissey Rd., (7-1-70)
Quincy. *QUINCY GRANITE RAILWAY*, Bunker Hill Lane, (10-15-73)
Quincy. *QUINCY GRANITE RAILWAY INCLINE*, Mullin Ave., (6-19-73)
Quincy. *QUINCY HOMESTEAD*, 34 Butler St., (7-1-70) G.
Quincy. *QUINCY, JOSIAH, HOUSE*, 20 Muirhead St., (5-28-76) HABS; G.
Quincy. *THOMAS CRANE PUBLIC LIBRARY*, 40 Washington St., (10-18-72)
Quincy. *UNITED FIRST PARISH CHURCH (UNITARIAN) OF QUINCY*, 1266 Hancock St., (12-30-70) NHL; HABS.
Quincy. *WINTHROP, JOHN, JR., IRON FURNACE SITE*, Crescent St., (9-20-77)
Randolph. *BELCHER, JONATHAN, HOUSE*, 360 N. Main St., (4-30-76)
Sharon. *COBB'S TAVERN*, 41 Bay Rd., (8-7-74)
Sharon. *SHARON HISTORIC DISTRICT*, Both sides of N. Main St. from Post Office Sq. to School St., (8-22-75)
Stoughton. *STOUGHTON RAILROAD STATION*, 53 Wyman St., (1-21-74)
Walpole. *LEWIS, DEACON WILLARD, HOUSE*, 33 West St., (10-29-75)
Wellesley. *EATON-MOULTON MILL*, 37 Walnut St., (5-13-76)
Wellesley. *WELLESLEY TOWN HALL*, 525 Washington St., (4-30-76)

plymouth county

Brockton. *BROCKTON CITY HALL*, 45 School St., (3-26-76)
Brockton. *CENTRAL FIRE STATION*, 40 Pleasant St., (7-25-77)
Brockton. *KINGMAN, GARDNER J., HOUSE*, 309 Main St., (7-25-77)
Brockton. *SNOW FOUNTAIN AND CLOCK*, N. Main and E. Main Sts., (7-25-77)
Cohasset vicinity. *CUSHING HOMESTEAD*, W of Cohasset on MA 128, (6-4-73)
Duxbury vicinity. *PLYMOUTH LIGHT STATION*, SE of Duxbury at Gurnet Point, (3-8-77)
Hingham. *LINCOLN, GEN. BENJAMIN, HOUSE*, 181 North St., (11-28-72) NHL; HABS.
Hingham. *OLD SHIP MEETINGHOUSE*, Main St., (10-15-66) NHL; HABS; G.
Hull. *TELEGRAPH HILL*, (7-12-76)
Lakeville. *TOWN HALL*, Bedford St., (10-22-76)

Marshfield. *WEBSTER, DANIEL, LAW OFFICE AND LIBRARY*, Careswell and Webster Sts., (5-30-74) NHL.
Mattapoisett. *THIRD MEETINGHOUSE*, 1 Fairhaven Rd., (1-2-76)
Middleboro. *PEIRCE, PETER, STORE*, N. Main and Jackson Sts., (4-30-76)
Middleboro vicinity. *WAMPANOAG ROYAL CEMETERY*, S of Middleboro off MA 105, (11-11-75)
Middleboro vicinity. *WAPANUCKET SITE*, SW of Middleboro of MA 25, (6-4-73)
North Abington. *NORTH ABINGTON DEPOT*, Railroad St., (5-13-76)
Norwell. *BRYANT-CUSHING HOUSE*, 768 Main St., (3-26-76)
Plymouth. *BARTLETT-RUSSELL-HEDGE HOUSE*, 32 Court St., (4-30-76)
Plymouth. *COLE'S HILL*, Carver St., (10-15-66) NHL.
Plymouth. *HARLOW OLD FORT HOUSE*, 119 Sandwich St., (12-27-74)
Plymouth. *HILLSIDE*, 230 Summer St., (9-18-75)
Plymouth. *HOWLAND, JABEZ, HOUSE*, 33 Sandwich St., (10-9-74) G.
Plymouth. *NATIONAL MONUMENT TO THE FOREFATHERS*, Allerton St., (8-30-74)
Plymouth. *OLD COUNTY COURTHOUSE*, Leyden and Market Sts., (2-23-72)
Plymouth. *PILGRIM HALL*, 75 Court St., (4-11-72) G.
Plymouth. *PLYMOUTH ANTIQUARIAN HOUSE*, 126 Water St., (12-27-74)
Plymouth. *PLYMOUTH ROCK*, Water St., (7-1-70)
Plymouth. *SPARROW, RICHARD, HOUSE*, 42 Summer St., (10-9-74) G.
Scituate Center. *LAWSON TOWER*, Off First Parish Rd., (9-28-76)
Wareham. *TREMONT NAIL FACTORY DISTRICT*, 21 Elm St., (10-22-76)

suffolk county

OLMSTED PARK SYSTEM, Reference—see Norfolk County
PAUL'S BRIDGE, Reference—see Norfolk County
1767 MILESTONES, Reference—see Hampden County

Boston. *AFRICAN MEETINGHOUSE*, 8 Smith St., (10-7-71) NHL; HABS; G.
Boston. *AMES BUILDING*, 1 Court St., (4-26-74)
Boston. *ARLINGTON STREET CHURCH*, Arlington and Boylston Sts., (5-4-73) HABS; G.
Boston. *ARMORY OF THE FIRST CORPS OF CADETS*, 97–105 Arlington St. and 130 Columbus Ave., (5-22-73)
Boston. *ARNOLD ARBORETUM*, 22 Divinity Ave., (10-15-66) NHL.
Boston. *BACK BAY HISTORIC DISTRICT*, (8-14-73) G.
Boston. *BEACON HILL HISTORIC DISTRICT*, Bounded roughly by Beacon St. on the S, the Charles River embankment on the W, Pinckney and Revere Sts. on the N, and Hancock St. on the E, (10-15-66) NHL; HABS; G.
Boston. *BLACKSTONE BLOCK HISTORIC DISTRICT*, Area bound by Union, Hanover, Blackstone, and North Sts., (5-26-73) HABS.
Boston. *BOSTON ATHENAEUM*, 10 1/2 Beacon St., (10-15-66) NHL; G.
Boston. *BOSTON COMMON AND PUBLIC GARDEN*, Beacon, Park, Tremont, Boylston, and Arlington Sts., (7-12-72)
Boston. *BOSTON LIGHT*, Little Brewster Island, Boston Harbor, (10-15-66) NHL.
Boston. *BOSTON NATIONAL HISTORICAL PARK*, Inner harbor at mouth of Charles River, (10-26-74)
Boston. *BOSTON NAVAL SHIPYARD*, E of Chelsea St., Charlestown, (11-15-66) NHL.
Boston. *BOSTON PUBLIC LIBRARY*, Copley Sq., (5-6-73)
Boston. *BUNKER HILL MONUMENT*, Breed's Hill, (10-15-66) NHL.
Boston. *COPP'S HILL BURIAL GROUND*, Charter, Snowhill, and Hull Sts., (4-18-74)
Boston. *CROWNINSHIELD HOUSE*, 164 Marlborough St., (2-23-72)
Boston. *CUSTOMHOUSE DISTRICT*, Between J.F.K. Expwy. and Kirby St. and S. Market and High Sts., (5-11-73) HABS.
Boston. *CYCLORAMA BUILDING*, 543–547 Tremont St., (4-13-73)
Boston. *DORCHESTER HEIGHTS NATIONAL HISTORIC SITE*, South Boston, (10-15-66)
Boston. *ELIOT BURYING GROUND*, Eustis and Washington Sts., (6-25-74) G.
Boston. *ETHER DOME, MASSACHUSETTS GENERAL HOSPITAL*, Fruit St., (10-15-66) NHL.
Boston. *FANEUIL HALL*, Dock Sq., (10-15-66) NHL.
Boston. *FIRST BAPTIST CHURCH*, Commonwealth Ave. and Clarendon St., (2-23-72)
Boston. *FULTON-COMMERCIAL STREETS DISTRICT*, Fulton, Commercial, Mercantile, Lewis, and Richmond Sts., (3-21-73)
Boston. *HARDING, CHESTER, HOUSE*, 16 Beacon St., (10-15-66) NHL.
Boston. *HEADQUARTERS HOUSE*, 55 Beacon St., (10-15-66) NHL.
Boston. *HOWE, SAMUEL GRIDLEY AND JULIA WARD, HOUSE*, 13 Chestnut St., (9-13-74) NHL.
Boston. *KING'S CHAPEL*, Tremont and School Sts., (5-2-74) NHL.
Boston. *KING'S CHAPEL BURYING GROUND*, Tremont St., (5-2-74)
Boston. *LONG WHARF AND CUSTOMHOUSE BLOCK*, Foot of State St., (11-13-66) NHL.
Boston. *MASSACHUSETTS GENERAL HOSPITAL*, Fruit St., (12-30-70) NHL; HABS.
Boston. *MASSACHUSETTS HISTORICAL SOCIETY BUILDING*, 1154 Boylston St., (10-15-66) NHL.
Boston. *MASSACHUSETTS STATEHOUSE*, Beacon Hill, (10-15-66) NHL; HABS.
Boston. *NELL, WILLIAM C., HOUSE*, 3 Smith Court, (5-11-76) NHL.
Boston. *OLD CITY HALL*, School and Providence Sts., (12-30-70) HABS; NHL.
Boston. *OLD CORNER BOOKSTORE*, NW corner of Washington and School Sts., (4-11-73)
Boston. *OLD NORTH CHURCH, (CHRIST CHURCH EPISCOPAL)*, 193 Salem St., (10-15-66) NHL; HABS; G.
Boston. *OLD SOUTH CHURCH IN BOSTON*, 645 Boylston St., (12-30-70) NHL.
Boston. *OLD SOUTH MEETINGHOUSE*, Milk and Washington Sts., (10-15-66) NHL; HABS; G.
Boston. *OLD STATEHOUSE*, Washington and State Sts., (10-15-66) NHL.
Boston. *OLD WEST CHURCH*, 131 Cambridge St., (12-30-70) NHL; HABS.
Boston. *OTIS, (FIRST) HARRISON GRAY, HOUSE*, 141 Cambridge St., (12-30-70) NHL; HABS.
Boston. *OTIS, (SECOND) HARRISON GRAY, HOUSE*, 85 Mt. Vernon St., (7-27-73) HABS.
Boston. *PARK STREET DISTRICT*, Tremont, Park, and Beacon Sts., (5-1-74)
Boston. *PARKMAN, FRANCIS, HOUSE*, 50 Chestnut St., (10-15-66) NHL.
Boston. *PIERCE-HICHBORN HOUSE*, 29 North Sq., (11-24-68) NHL; HABS.
Boston. *QUINCY MARKET*, S. Market St., (11-13-66) NHL.
Boston. *REVERE, PAUL, HOUSE*, 19 North Sq., (10-15-66) NHL.
Boston. *SEARS, DAVID, HOUSE*, 42 Beacon St., (12-30-70) NHL.
Boston. *SOUTH END DISTRICT*, South Bay area between Huntington and Harrison Aves., (5-8-73) G.
Boston. *SOUTH STATION HEADHOUSE*, Atlantic Ave. and Summer St., (2-13-75)
Boston. *ST. PAUL'S CHURCH*, 136 Tremont St., (12-30-70) NHL.
Boston. *ST. STEPHEN'S CHURCH*, Hanover St. between Clark and Harris Sts., (4-14-75)
Boston. *SUFFOLK COUNTY COURTHOUSE*, Pemberton Sq., (5-8-74)
Boston. *SUMNER, CHARLES, HOUSE*, 20 Hancock St., (11-7-73) NHL.
Boston. *SYMPHONY AND HORTICULTURAL HALLS*, Massachusetts and Huntington Aves., (5-30-75) G.
Boston. *TREMONT STREET SUBWAY*, Beneath Tremont, Boylston, and Washington Sts., (10-15-66) NHL.
Boston. *TRINITY CHURCH*, Copley Sq., (7-1-74) NHL.
Boston. *TRINITY RECTORY*, Clarendon and Newbury Sts., (2-23-72)
Boston. *U.S.S. CONSTITUTION (OLD IRONSIDES)*, Boston Naval Shipyard, (10-15-66) NHL.
Boston. *WINTHROP BUILDING*, 7 Water St., (4-18-74)
Boston. *YOUTH'S COMPANION BUILDING (SAWYER BUILDING)*, 209 Columbus Ave., (5-2-74)
Boston Harbor. *FORT WARREN*, Georges Island, (8-29-70) NHL.
Boston (Roxbury). *HALE, EDWARD EVERETT, HOUSE*, 12 Morley St., (5-8-73) HABS.
Boston vicinity. *FORT INDEPENDENCE (FORT WILLIAM)*, Castle Island, (10-15-70) G.
Charlestown. *PHIPPS STREET BURYING GROUND*, Phipps St., (5-15-74)
Charlestown. *TOWN HILL DISTRICT*, Bounded roughly by Rutherford Ave. and Main and Warren Sts., (5-11-73) HABS.
Chelsea. *BELLINGHAM-CARY HOUSE*, 34 Parker St., (9-6-74)
Chelsea. *NAVAL HOSPITAL BOSTON HISTORIC DISTRICT*, 1 Broadway, (8-14-73)
Dorchester. *BLAKE, JAMES, HOUSE*, 735 Columbia Rd., (10-15-66) HABS.
Dorchester. *CLAPP HOUSES*, 199 and 195 Boston St., (5-2-74) HABS; G.
Dorchester. *DORCHESTER NORTH BURYING GROUND*, Stoughton St. and Columbia Rd., (4-18-74)
Dorchester. *PIERCE HOUSE*, 24 Oakton Ave., (4-26-74) HABS.
Dorchester. *TROTTER, WILLIAM MONROE, HOUSE*, 97 Sawyer Ave., (5-11-76) NHL.
Jamaica Plain. *LORING-GREENOUGH HOUSE*, 12 South St., (4-26-72) G.
Revere. *SLADE SPICE MILL*, 770 Revere Beach Pkwy., (6-30-72)
Roxbury. *GARRISON, WILLIAM LLOYD, HOUSE*, 125 Highland St., (10-15-66) NHL.
Roxbury. *JOHN ELIOT SQUARE DISTRICT*, John Eliot Sq., (4-23-73) HABS.

Roxbury. *KITTREDGE, ALVAH, HOUSE*, 12 Linwood St., (5-8-73)
Roxbury. *ROXBURY HIGH FORT (HIGHLAND PARK)*, Beech Glen St. at Fort Ave., (4-23-73)
Roxbury. *SHIRLEY-EUSTIS HOUSE*, 31-37 Shirley St., (10-15-66) NHL; HABS.
West Roxbury. *BROOK FARM*, 670 Baker St., (10-15-66) NHL.

worcester county

SHIRLEY SHAKER VILLAGE, Reference—see Middlesex County
1767 MILESTONES, Reference—see Hampden County
Auburn vicinity. *GODDARD ROCKET LAUNCHING SITE*, Ninth fairway, Pakachoag Golf Course, Pakachoag Rd., (11-13-66) NHL.
Barre. *BARRE COMMON DISTRICT*, Bounded roughly by South, Exchange, Main, Pleasant, Broad, School, and Grove Sts., (5-4-76)
Boylston. *GOUGH, JOHN B., HOUSE*, 215 Main St., (3-19-74) NHL.
Charlton. *NORTHSIDE VILLAGE HISTORIC DISTRICT*, Stafford St., Northside and Cemetery Rds., (10-5-77)
Charlton. *SPURR, JOHN, HOUSE*, Main St., (4-26-76)
Charlton vicinity. *RIDER TAVERN*, NE of Charlton on Stafford St., off U.S. 90, (5-19-76) G.
Harvard. *FRUITLANDS*, Prospect Hill, (3-19-74) NHL.
Holden. *HOLDEN CENTER HISTORIC DISTRICT*, Main, Maple, Highland, and Reservoir Sts., (12-22-77)
Lancaster. *CENTER VILLAGE DISTRICT*, Irregular pattern along Main St., (9-15-77)
Lancaster. *FIRST CHURCH OF CHRIST, LANCASTER*, Facing the Common, (12-30-70) NHL; HABS; G.
Lancaster. *NORTH VILLAGE HISTORIC DISTRICT*, (11-23-77)
Lancaster. *THAYER, NATHANIEL, ESTATE*, 438 S. Main St., (7-6-76)
Lancaster vicinity. *LANCASTER INDUSTRIAL SCHOOL FOR GIRLS*, SE of Lancaster on Old Common Rd., (10-8-76)
Lancaster vicinity. *LANE, ANTHONY, HOUSE*, NE of Lancaster on Seven Bridge Rd., (11-7-76)
Milford. *MILFORD TOWN HALL*, 52 Main St., (9-22-77)
North Brookfield vicinity. *MATTHEWS FULLING MILL SITE*, NW of North Brookfield off Murphy Rd., (11-12-75)
North Uxbridge. *ROGERSON'S VILLAGE HISTORIC DISTRICT*, N and S sides of Hartford Ave., (11-23-71) G.
Northborough. *NORTHBOROUGH TOWN HALL*, NE corner of W. Main and Blake St., (2-23-72)
Northbridge and vicinity. *BLACKSTONE CANAL*, E of MA 122 between Northbridge and Uxbridge, (2-6-73)
Oxford. *BARTON, CLARA, HOMESTEAD*, 3 mi. W of Oxford on Clara Barton Rd., (9-22-77)
Petersham vicinity. *GAY FARM (NEGUS HILL)*, S of Petersham off Nichewaug Rd., (9-22-77)
Royalston. *ROYALSTON COMMON HISTORIC DISTRICT*, Main St., Frye Hill Rd., and Athul Rd., (12-12-76)
Rutland. *PUTNAM, GEN. RUFUS, HOUSE*, 344 Main St., (11-28-72) NHL; HABS.
Shrewsbury. *SHREWSBURY HISTORIC DISTRICT*, Church Rd., Main, Prospect, Boylston, and Grafton Sts., (10-8-76)
Shrewsbury. *WARD, GENERAL ARTEMAS, HOMESTEAD*, Main St., opposite Dean Park, (5-4-76)
South Lancaster. *SOUTH LANCASTER ENGINE HOUSE*, 283 S. Main St., (10-22-76)
Sturbridge. *STURBRIDGE COMMON HISTORIC DISTRICT*, Main St. between Hall Rd. and I-86, (11-9-77)
Uxbridge vicinity. *FRIENDS MEETINGHOUSE*, S of Uxbridge on MA 146, (1-24-74)
West Boylston. *OLD STONE CHURCH*, Off MA 140, (4-13-73)
West Brookfield vicinity. *WHITE HOMESTEAD*, NW of West Brookfield on Ware Rd. (MA 9), (4-14-75)
Worcester. *AMERICAN ANTIQUARIAN SOCIETY*, 185 Salisbury St., (11-24-68) NHL.
Worcester. *ELM PARK*, (7-1-70)
Worcester. *G.A.R. HALL*, 55 Pearl St., (3-13-75) G.
Worcester. *GREENDALE VILLAGE IMPROVEMENT SOCIETY BUILDING*, 480 W. Boylston St., (11-7-76)
Worcester. *LIBERTY FARM*, 116 Mower St., (9-13-74) NHL.
Worcester. *MASSACHUSETTS AVENUE HISTORIC DISTRICT*, Between Salisbury St. and Drury Lane, (12-16-71)
Worcester. *MECHANICS HALL*, 321 Main St., (11-9-72) G.
Worcester. *OXFORD-CROWN HISTORIC DISTRICT*, Roughly bounded by Chatham, Congress, Crown, Pleasant, Oxford Sts. and Oxford Pl., (5-6-76)
Worcester. *PAINE, TIMOTHY, HOUSE*, 140 Lincoln St., (4-30-76)
Worcester. *SALISBURY HOUSE*, 61 Harvard St., (6-10-75)
Worcester. *SALISBURY MANSION AND STORE*, 30, 40 Highland St., (5-30-75) G.
Worcester. *WHITCOMB HOUSE*, 51 Harvard St., (11-9-77)

MICHIGAN

alger county

AuTrain vicinity. *PAULSON HOUSE*, S of AuTrain on USFS Rd. 2278 in Hiawatha National Forest, (11-9-72)
Christmas vicinity. *BAY FURNACE*, NW of Christmas off MI 28 in Hiawatha National Forest, (9-31-71)
Munising. *LOBB HOUSE*, 203 W. Onota St., (10-8-76)
Munising vicinity. *SCHOOLCRAFT FURNACE SITE*, NE of Munising off MI 94, (12-28-77)

allegan county

HACKLANDER SITE, NW Allegan County, (7-27-73)

antrim county

HOLTZ SITE, Central Antrim County, (6-19-73)
Elk Rapids. *ELK RAPIDS TOWNSHIP HALL*, River St., (9-22-77)
Elk Rapids. *HUGHES HOUSE*, 19 Elm St., (5-6-76)

baraga county

SAND POINT SITE, Northern Baraga County, (6-19-73)
Assinins. *ASSININS*, U.S. 41, (5-19-72)

barry county

Hastings. *STRIKER, DANIEL, HOUSE*, 321 S. Jefferson St., (1-13-72)

bay county

FLETCHER SITE, Late Archaic, Early and Late Woodland, Hopewell, and Middle Historic, (4-16-71)
Bay City. *CITY HALL*, 301 Washington St., (7-18-75)
Bay City. *TROMBLE HOUSE*, 114, 116, 118 Webster St., (1-25-73)

benzie county

Benzonia. *MILLS COMMUNITY HOUSE (MILLS COTTAGE)*, 891 Michigan Ave., (8-21-72)

berrien county

SANDBURG HOUSE, (4-14-72)
Benton Harbor. *SHILOH HOUSE*, Britain Rd., (9-29-72)
Berrien Springs. *BERRIEN SPRINGS COURTHOUSE*, Corner of Union and Cass Sts., (2-16-70) G.
Buchanan vicinity. *MOCCASIN BLUFF SITE*, (4-13-77)
Niles. *FORT ST. JOSEPH SITE*, Off S. Bond St., (5-24-73)
Niles. *LARDNER, RING, HOUSE*, 519 Bond St., (5-16-72)
Niles. *PAINE BANK*, 1008 Oak St., (5-8-73) HABS.
Three Oaks. *UNION MEAT MARKET*, 14 S. Elm St., (9-22-72)

branch county

Coldwater. *EAST CHICAGO STREET HISTORIC DISTRICT*, Chicago St. from Wright St. to Division St. including parks, (5-12-75)
Coldwater. *WING HOUSE*, 27 S. Jefferson St., (2-24-75)

calhoun county

Albion. *GARDNER HOUSE*, 509 S. Superior St., (5-6-71)
Athens vicinity. *PINE CREEK POTAWATOMI RESERVATION (NOTTAWASIPPE RESERVATION)*, 1 mi. W of Athens, (3-30-73)
Battle Creek. *BATTLE CREEK POST OFFICE*, 67 E. Michigan St., (8-21-72)
Battle Creek. *FEDERAL CENTER (BATTLE CREEK SANITARIUM)*, 74 N. Washington St., (7-30-74)
Battle Creek. *PENN CENTRAL RAILWAY STATION (NEW YORK CENTRAL AND MICHIGAN CENTRAL RAILWAY STATION)*, W. Van Buren, (4-16-71) HABS.
Marshall. *BROOKS, HAROLD C., HOUSE (JABEZ S. FITCH HOUSE)*, 310 N. Kalamazoo Ave., (7-8-70) HABS.
Marshall. *CAPITOL HILL SCHOOL*, 603 Washington St., (3-16-72) G.
Marshall. *GOVERNOR'S MANSION*, 621 S. Marshall Ave., (1-8-75)
Marshall. *HONOLULU HOUSE (ABNER PRATT HOUSE)*, 107 N. Kalamazoo St., (7-8-70) HABS; G.
Marshall. *JOY HOUSE*, 224 N. Kalamazoo Ave., (4-19-72)
Marshall. *OAKHILL*, 410 N. Eagle St., (12-31-74)
Marshall. *STONEHALL (ANDREW L. HAYES HOUSE)*, 303 N. Kalamazoo St., (6-28-72)
Marshall. *WAGNER'S BLOCK*, 143 W. Michigan Ave., (10-7-71) G.
Marshall. *WRIGHT-BROOKS HOUSE (DANIEL PRATT HOUSE)*, 122 N. High St., (3-16-72) HABS.

charlevoix county

O'NEILL SITE, (5-27-71) G.
PEWANGOING QUARRY, Western Charlevoix County, (6-20-72)

APPENDIX EE

DEVELOPMENT OF ALTERNATIVES

Developing alternatives requires that an integrated sequence of processes be organized. This is necessary because several different methods can be used for each of the following steps encountered in the handling and disposal of sludge:

- Stabilization
- Conditioning and Dewatering
- Volume Reduction
- Disposal

Each one of the first three major steps may not be necessary in every possible sequence of processing steps. For example, in an agricultural area where land application of sludge can be practiced, sludge dewatering may be unnecessary.

Development of feasible alternative handling and disposal systems will be done as follows:

- Description of available processes
- Elimination of infeasible process steps
- Organization of feasible process steps into process trains
- Elimination of infeasible process trains

The rationale behind this sequence is that certain individual processes are inappropriate, given the particular circumstances of an alternative. Their elimination will reduce confusion in generating "process trains." Process trains, or process flowsheets, are the sequences of processes which start with the removal of sludge from the wastewater and follow through to the final disposal of the sludge.

1. Description of Process Steps and Disposal Methods

The processing and disposal steps listed above can be further described as follows:

- Stabilization (Optional Step)
  - Anaerobic digestion is the use of anaerobic bacteria (living in the absence of free oxygen) to break down biodegradeable solids, thus producing methane gas and more bacteria. The sludge to be digested is normally 70% volatile (biodegradeable). During digestion, half of the volatile solids are broken down, resulting in a final mixture which contains 65% of the initial mass, of which about 50% is volatile solids.

- Aerobic digestion is a process using oxygen (or air addition) to biologically oxidize a portion of the solids before processing further. The percentage of volatile solids reduction can range from 40% to 45%. This process operates best with digestion of waste secondary or combined sludges.

- The Purifax process uses high doses of chlorine (<2000 mg/l) to chemically oxidize part of the volatile fraction of solids.

- Conditioning and Dewatering

  - Conditioning

    - Chemical conditioning is a process using a multivalent metal ion such as aluminum or iron to enable the sludge particles to coalesce or flocculate. In addition to the multivalent metal ions, lime is usually added to assist in vacuum filtration (or dewatering). Organic polymers have been developed which perform the same function. The polymers are used in lower concentration.

    - Thermal conditioning is the heating of sludge, which has been pressurized to prevent boiling. This heating destroys a portion of the solids and releases the bound water in the solid mass.

  - Dewatering

    - Vacuum filtration uses the self-filtering ability of the sludge to remove moisture. The sludge cake is formed by vacuum on a moving cloth or wire medium, followed by washing and vacuum dewatering.

    - Filter pressing involves mechanical compression of conditioned sludge inside flexible, porous cloth bags to press out the free water. Typically, large doses of coagulants or of fly ash are necessary for proper operation. Bulking material is often necessary.

    - Centrifugation uses a cylinder, rotating at high speed, to separate the solid fraction at high gravities. The centrifuge usually requires use of organic polymers for conditioning, and typically returns more solids to the plant than do vacuum filters or filter presses.

- Belt filter presses dewater sludge through sedimentation and compression under a pressure equal to and subsequently greater than gravity. A belt and roller system is employed; and when pressure is applied, the filtrate is squeezed from the sludge solids. Chemical conditioning, usually polymers, are used for high filtrate quality.

- <u>Volume Reduction (Optional Step)</u>

  - Incineration is the volume reduction process most commonly used, in which dewatered sludge is burned using the heat content of the volatile solids to drive off the moisture. Typical maximum temperatures are 1400-1700°F in the furnace. If the heat content of the sludge is sufficient and the incinerators properly designed and operated, the burning process can become self-sustaining or "autogenous."

  - Pyrolysis is a process using heat and controlled feeding of oxygen to break down complex volatile organic components to gases and oils (which in turn can be used as fuels) along with a solid "char" which contains some heat value. Once the process is initiated using an outside heat source, it may be maintained with recycle of a portion of the product oils or by varying the oyxgen feed rate. In pyrolyzing sewage sludge, the fuel value is totally used in combustion.

  - Wet air oxidation is similar to pyrolysis in that it is done under pressure, but excess air (oxygen) is added to allow nearly complete oxidation. After wet air oxidation, the remaining solids are separated out and the liquid portion is returned to treatment.

  - Heat drying can also be regarded as a volume reduction step because of the removal of moisture. In this process, fuel is used to heat the sludge up to 700-1000°F, driving off most of the moisture.

- <u>Disposal</u>

  - Landfill is the burial of the final product (dewatered sludge, char, incinerator ash) in a designated disposa site. In this process, the product is placed in one to two foot layers, covered with earth daily, and upon completion of the fill, is sealed with more earth and planted with suitable cover crops. Use of landfill is controlled by the Resource Conservation and Recovery Act of 1976 (P.L. 94-580).

- Land Application is the application of liquid sludge, sludge cake or dried sludge to land. This can either be principally a disposal method at high (> 44 metric tons per hectare) loading or a nutrient recovery process at lower loadings. The land can be either publicly or privately owned, and food or non-food crops grown. Use of land application is controlled by the Resource Conservation and Recovery Act of 1976 (P.L. 94-580).

2. Elimination of Infeasible Processes

Of the processes described above, those discussed below are not considered feasible, either intrinsically or in comparison to the three major alternatives under consideration for the proposed project:

- Stabilization (Optional Step)

  - Aerobic digestion can be eliminated because of its high energy demand for aeration and because the sludge which is to be stabilized at the MDC facilities does not include waste secondary sludge. Also, anaerobic digestion capacity is presently available.

  - The Purifax process can be eliminated because of the large amounts of chlorine required, because of questions concerning the generation of chlorinated hydrocarbons, and because of the existing anaerobic digestion capacity at the MDC plants.

- Conditioning and Dewatering

  - Thermal conditioning can be eliminated because of the absence of secondary treatment. The thermal conditioning process produces a high strength liquid residue which requires biological (secondary) treatment.

  - Centrifuging can be eliminated because of the relatively poor solids capture in the process. In comparing this method and the two filtration options, centrifuging may return as much as ten times the solids to the treatment process. These solids, when returned to a secondary plant, may be captured in biological treatment, but will not be captured in a primary facility.

- <u>Volume Reduction (Optional Step)</u>

  - Pyrolysis as a volume reduction step can be eliminated for several reasons. As with thermal conditioning, pyrolysis is subject to similar problems with the quality of liquid sidestreams resulting from distillate separation. For an experimental acid-pyrolysis system in California (Fassell, 1974) a total of approximately 420 pounds/ton of water-soluble short-chain organic compounds (principally acetic and propionic acids) were produced as a system byproduct. Byproduct use of this carbon source for denitrification was suggested, but in the Phase I system which will lack biological treatment this 420 pounds/ton of organics would be released in the effluent. Aerobic biological treatment of this quantity of organic material would require approximately 1.8 x 10^6 BTU of energy for aeration. For the experimental system considered by Fassell, this is twice the energy value of recovered "fuel." If anaerobic digestion is used for treatment of the water soluble acids generated by pyrolysis, more energy recovery might be possible, but the comparatively low concentrations of soluble organics militate against this system. A bench-scale pyrolysis system in California was used to evaluate the total energetics of pyrolysis (Folks, 1975). The results indicated that no net energy would be available at less than 43% solids, not including any energy necessary for biological treatment of any residual organics.

    Pyrolysis of sewage sludge with the starved air incineration process uses a normal multiple hearth furnace which has been sealed to prevent extraneous air entry to heat the feed in an oxygen starved atmosphere. Under these conditions the organic material is driven from the solids in the form of combustible pyrolysis gas of about 60 BTU per cubic foot. Heat is provided by combustion of a portion of this pyrolysis gas within the furnace, and the remainder is burned in an external combustion chamber. Assuming a sufficiently dry feed, and a normal municipal biological sludge, a pyrolysis furnace will require fuel only for warm-up. The feed is reduced to an inert, sterile ash (Neptune & Nichols, 1976).

The fuel usage of a pyrolysis furnace is related to the fuel value of the sludge. The process is not such that it is self-generating or totally self-perpetuating. An energy input is required. In this process all of the energy is used in thermal reduction and afterburning. While the energy input for startup and for maintenance of furnace temperatures may be less than a nonstarved air multiple hearth furnace, any furnace processing sewage sludge will not generate an amount of fuel over the amount of fuel that is put in.

- High temperature wet air oxidation can be eliminated for the same reasons as thermal conditioning, i.e., the liquid residue would contain high concentrations of oxygen demanding organics.

  A certain extent of metals recovery, utilizing a wet air oxidation process in mild acid conditions, may be possible. The process of wet oxidation alone does not completely solubilize all metals, but with economically practical levels of sulfuric acid additions, copper, zinc and cadmium are solubilized while lead and silver remain in the insoluble residue or ash (Fassell, 1974).

  The soluble metals can be removed as precipitated sulfides which can be shipped to the smelter. The lead, silver and perhaps gold in the ash may be amenable to chlorinated brine leaching. This precipitate would then also go to the smelter (Fassell, 1974).

  It may be possible, using this process, to render the ash nonhazardous and recover some costs by the sale of the removed metals. The technology, however, remains unproven. The removal of metals may never be enough to render the ash nonhazardous, and it remains doubtful that a profit, or even a significant return of costs, could be realized through sale of the recovered metals.

3. Development of Feasible Process Trains

By eliminating the infeasible processes from consideration, the remaining processes can be organized into process trains leading from primary sedimentation to final disposal.

Before developing these process trains, two process choices should be discussed for their applicability to all flowsheets. Anaerobic digestion is currently practiced at both Deer and Nut Island facilities, and is a stabilization process of choice in this EIS for several reasons including:

- Stabilization and reduction of sludge volume,
- Reduction of pathogen content, and
- Recovery of energy as gas.

In addition to these advantages, there are certain disadvantages, including the rather high capital and operating costs and the relatively high land area requirement. Also, compared with raw sludge, digested sludge has a reduced organic nitrogen content. This, in turn, may reduce the total system efficiency in terms of dollars and energy required to deliver a given quantity of nitrogen to soil for a land application system. The reduction of volatile solids through digestion also can reduce the possibility of autogenous incineration (not requiring additions of fossil fuels). The Phase I system developed by Havens and Emerson includes bypassing of a portion of the raw primary solids (10% of both Deer Island and Nut Island) under 1985 conditions. Inclusion of these bypassed quantities into digestion results in volatile solids loadings (0.15 pounds VSS/cf/day at Deer Island and 0.12 pounds/cf/day at Nut Island) which are below the loadings specified for high-rate digestion of 0.15-0.40 pounds VSS/cf/day (EPA, 1974C). Therefore, upgrading of existing digester capacity to 1985 conditions may be possible. For the purpose of this study, the 1985 sludge quantities and qualities developed by Havens and Emerson (1973) will be used. Appendix N develops in detail the rationale behind this decision. In the final process flowsheets for both land application and ocean disposal, there are sufficient methods for pathogen control, such that construction of additional digester capacity is not required. For these reasons, anaerobic digestion will continue in use on all flowsheets (process trains).

The three remaining dewatering alternatives, vacuum filters, filter presses, and horizontal belt filters (HBF), have been examined with respect to differential impacts. The principal difference is that filter pressing will require more conditioning chemicals and HBF requires organic polymer additions to produce a sludge of less moisture content. In terms of cost, energy use, and solids content, all processes are comparable. Horizontal belt filters offer an advantage over plate and frame presses in that they have fewer operational difficulties. Actual comparative evaluation and process selection between vacuum filter and HBF will be done during Step II design (Weiss, 1978).

A basic premise that has been put forward in the proposed plan is that the incineration process will be autogenous. And since the production of an autogenous sludge depends upon several considerations, detailed analysis will be necessary before selecting a final system for dewatering. Because of the similarity of process inputs except for conditioning chemicals, horizontal belt filtration can be substituted for vacuum filtration (depending upon pilot testing) at the time of final design.

With these questions resolved, the following process alternatives remain:

- Stabilization - anaerobic digestion
- Conditioning and dewatering (optional); chemical conditioning and vacuum filtration or horizontal belt filtration
- Volume reduction (optional)
  - Incineration
  - Heat Dyring
- Disposal
  - Landfill
  - Ocean disposal (eliminated by P.L. 92-500 and P.L. 92-532)
  - Pathogen reduction and land application for resource recovery

Using these options and because dewatering must precede volume reduction, twelve possible rocess trains can be developed, as summarized in Table EE-1. Of these twelve systems for processing and disposal, four can be eliminated as infeasible on a preliminary basis. This infeasibility results from the basic incompatibility of the final disposal method and the prior handling steps. An example of this basic infeasibility would be the large amounts of unrecoverable energy required for heat drying, followed by ocean disposal (process E). The feasible processing and disposal systems which remain after this preliminary screen are:

- Process Train A: Dewatering - Incineration - Landfill
- Process Train B: Dewatering - Incineration - Ocean Disposal
- Process Train F: Dewatering - Heat Drying - Land Application
- Process Train G: Dewatering - Landfill
- Process Train H: Dewatering - Ocean Disposal
- Process Train I: Dewatering - Land Application
- Process Train K: Direct Ocean Disposal
- Process Train L: Direct Land Application

At this point, these flowsheets are feasible because they are composed of feasible process components, because they are internally consistent, and because the final disposal method is consistent with the processes used.

TABLE EE-1

Process Trains Developed From Feasible Processes

Process Trains	Stabilization Process	Conditioning-Dewatering Process	Volume Reduction Process	Disposal	Feasible System (Yes or No)
A	Digestion	Chemical-Vacuum Filter	Incineration	Landfill	Yes
B	"	"	"	Ocean Disposal	Yes
C	"	"	"	Land Application	No
D	"	"	Heat Drying	Landfill	No
E	"	"	"	Ocean Disposal	No
F	"	"	"	Land Application	Yes
G	"	"	None	Landfill	Yes
H	"	"	"	Ocean Disposal	Yes
I	"	"	"	Land Application	Yes
J	"	None	"	Landfill	No
K	"	"	"	Ocean Disposal	Yes
L	"	"	"	Land Application	Yes

3. Selection of Process Trains for Further Development

Because of the effort necessary to develop and analyze in detail any of these alternatives, it is desirable to further reduce the number of feasible systems for consideration. This reduction involves removing complete systems at this point, much as the four infeasible systems were removed in the previous step. The objectives of this further elimination are:

- To elicit the best system for each mode of ultimate disposal, i. e. landfill, ocean disposal, and land application.
- To retain those systems which (while not the best at first investigation) still have some promise.

For the final selection, the process flowsheets can be reorganized according to their final disposal options:

- Landfill Options
    - Process Train A: Dewatering - Incineration - Landfill
    - Process Train G: Dewatering - Landfill
- Ocean Disposal Options
    - Process Train B: Dewatering - Incineration - Ocean Disposal
    - Process Train H: Dewatering - Ocean Disposal
    - Process Train K: Direct Ocean Disposal
- Land Application Options
    - Process Train F: Dewatering - Heat Drying - Land Application
    - Process Train I: Dewatering - Land Application
    - Process Train L: Direct Land Application

The selection of the systems for further analysis will be done according to these major disposal areas. There are several process related questions which will be considered in the last section.

- Selection of Landfill Alternatives

Landfilling of waste sludge, as described previously, can be done either with dewatered sludge or with the ash from incineration. The choice between the two can be made on the following major criteria:

- Impact of air emissions resulting from incineration
- Relative capital and operation costs, including landfilling costs

- Impact of transportation to landfill and of leaching from landfill
- Availability of land for landfill use

Of the criteria listed above, availability of land for filling, cost of filling of sludge, and impacts of leachate are the three major concerns which tend to eliminate landfilling of the total dewatered mass as a long term option. The landfilling of ash is also subject to consideration under provisions of the Resource Conservation Recovery Act of 1976 (RCRA). Under the act, ash must be determined to be either a hazardous or nonhazardous solid waste. The management of ash will vary depending upon this determination. The activities of generation, transportation and disposal of hazardous wastes are subject to more stringent regulations than nonhazardous wastes.

Certain RCRA provisions concerning hazardous wastes are not yet final. The determination criterion for hazardous waste is one such provision. Therefore, ash landfilling, both as a hazardous waste or nonhazardous waste, had to be evaluated and alternatives provided.

These alternatives (Numbers 1 and 2 and 8 through 11, added in preparing the FEIS) include consideration of various landfill sites for ultimate disposal. Nonhazardous ash landfill sites considered are: Plainville, Randolph and Amesbury sanitary landfills (Alternative 1); a harbor fill at Deer Island (Alternative 2); a Deer Island landfill (Alternative 8); and a Spectacle Island landfill (Alternative 9). At present, no hazardous wastes landfill exists in Massachusetts. Two possible locations for hazardous waste landfills were proposed and include the Deer Island harbor fill (Alternative 10) and a Deer Island inland location (Alternative 11).

Ultimately, four landfill alternatives have been proposed for ash as a nonhazardous waste:

- Alternative 1: Digestion - Dewatering - Incineration - Landfill at Plainville, Randolph or Amesbury
- Alternative 2: Digestion - Dewatering - Incineration - Deer Island Harbor Fill
- Alternative 8: Digestion - Dewatering - Incineration - Deer Island Inland Fill
- Alternative 9: Digestion - Dewatering - Incineration - Spectable Island Landfill

Two landfill alternatives have been proposed for ash as a hazardous waste:

- Alternative 10: Digestion - Dewatering - Incineration - Deer Island Harbor Fill
- Alternative 11: Digestion - Dewatering - Incineration - Deer Island Inland Fill

There remains an additional factor to be considered regarding ash toxicity. The ash when tested may be deemed hazardous due to heavy metals concentrations. If these metals can be fixed or immobilized in the ash, the ash could be rendered nontoxic and become a nonhazardous solid waste. The final decision on the landfill site chosen will remain until after procedures and methods for treating the ash (if it is hazardous) are evaluated in regard to their effectiveness and costs. Evaluation of chemical fixation is presently being done by the EPA Environmental Research Laboratory-Cincinnati (Eralp, 1978). Once detailed data are available, the use of fixation and normal waste handling can be compared to use of hazardous waste handling based on economic and environmental costs.

- <u>Selection of Ocean Disposal Alternatives</u>

Ocean disposal can be done with digested sludge via barge or pipeline, with dewatered sludge via barge, or with ash from incineration of sludge. There are two choices here, the first between incinerator ash disposal and dewatered sludge disposal, and the second in the degree of dewatering of sludge to be done. The elements of the first choice are:

- Air quality impacts of incineration
- Impacts of sludge or sludge ash on marine biota
- Relative capital and operating costs

Without more detailed study, none of these elements of choice can be resolved. If the adverse impacts of oxygen-demanding elements are an order of magnitude greater than heavy metals impacts, the choice might be incineration or, if the impact of incineration on air quality is unacceptable, the sludge might be more properly carried to disposal in the dewatered form. At this level, neither alternative can be rejected.

In order to determine the answer to the second question, disposal area distance and depth criteria will be necessary. If the disposal site selected is close inshore, direct transport of sludge via pipeline may be best. If a site further offshore is selected, dewatering prior to transportation may be desirable. This is subject to the provision that no major differential impacts will result from dewatered versus liquid sludge, a safe assumption in that the solids captured in dewatering would be about 99%.

Ocean disposal through outfalls has several disadvantages. First, a substantial capital investment is required to construct the outfall. Required depth or length may add significantly to the cost of construction. Second, flexibility is lost. Construction of an outfall at any particular site implies a long-term commitment to dump at that site. If monitoring subsequent to disposal reveals significant detrimental effects upon the marine environment that dictate that the outfall must be abandoned, a significant capital investment is lost. In addition, it concentrates wastes in shallow, inshore areas where the greatest possibility for contact with the sludge exists. For these reasons, outfall disposal is not considered to be a viable alternative for Boston's sludge.

Barge disposal requires a smaller initial capital cost and eliminates the commitment to a single site or group of sites. If shallow water spreading is desired, the sludge can be discharged at, or very close to, the surface through shorter hoses while the barge traverses a large area. Ideally, direct deep water disposal would be attained through the use of a long discharge hose through which sludge is pumped for disposal. Although this method of disposal appears to be technically feasible, it is in the research and development stage and is not presented as an implementable alternative. At this time, it is proposed that disposal into deep water would be attained by relying on the rapid settling characteristics of most constituents of the sludge. The sludge would be discharged at a single point dump by release through the bottom hopper of a barge.

To choose between deep water containment and shallow water spreading, available information on current dumping activities and the work of an international study group were consulted. The two disposal methods represent substantially different philosophies of waste disposal. The objective of deep water disposal is to minimize dispersion of the sludge by placing it in an area where both current activity and biological activity are low. Shallow water disposal by spreading accomplishes dispersion of the sludge throughout the water column because of differential settling and current activity. The choice between the two disposal methods involves careful consideration of the ultimate fate of the sludge in the marine environment. Unfortunately, at this time the decision is based on incomplete knowledge of many of the processes which will affect its fate.

The working group on the scientific basis for disposal of waste into the sea of the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) held a conference in Copenhagen during October 1974. The work resulting from that session is entitled, "Scientific Criteria for the Selection of Sites for Dumping of Wastes Into the Sea." The purpose of the report is to consider how the effects of waste disposal can be assessed and reduced to a minimum and what scientific principles are involved in the selection of sites for dumping. According to GESAMP (1975), "Ideally, the only ultimate method of eliminating waste disposal is recovery and reutilization of the materials presently considered to be wastes; other disposal operations merely remove material from one part of our environment to another." The report generally states that maximum physical dispersion should be a primary objective of waste disposal in the marine environment to minimize the environmental impacts of the wastes. It also states that only materials that should be dumped are those that meet the criteria of the London Convention. Appendix O explains the London Convention, as well as other ocean dumping policies.

The alternative of spreading the MDC sludge over a large area of open ocean to maximize dispersion was also considered. It was rejected at this time for a number of reasons, although ultimately, dispersion of sludge over a large area of ocean might prove to be an acceptable alternative. For example, such a system would require that contaminants such as heavy metals or pathogens be removed, destroyed or rendered inactive, or that allowable maximum concentrations be quantitatively determined in terms of effects upon the marine environment and that these levels would not be exceeded.

There are two main reasons for rejecting ocean spreading. Analysis of the MDC sludge indicates the criteria for allowable metals concentrations are exceeded. Therefore, unless industrial pretreatment could effectively eliminate these metals by the time that ocean disposal is eliminated, MDC's sludge would be dumped under an interim permit. Spreading would disperse the contaminants over a large area. A detailed monitoring program would have to be set up over a large area. Spreading might degrade the water quality or contaminate fisheries over an area in the tens of square miles. Analysis for compliance with other ocean dumping criteria (40 CFR 220-227) such as oil and greases and organohalogens has not been performed to date. A comparison of the mercury and cadmium content of the MDC sludge with allowable concentrations is presented below:

	Concentration (mg/kg, dry wt. basis)	
	Allowable*	MDC Sludge
Mercury	0.75	5-9
Cadmium	0.6	20-30

* 40 CFR 227

A second reason for rejecting ocean spreading is that there is very little quantitative information about the toxicity to, or accumulation of, contaminants by biota. There is even less information relating concentrations of contaminants in the water column to concentrations observed in biota. Virtually all of the ocean area within practicable barging distance from Boston supports important fisheries, as shown in the Environmental Setting (Section I). Potential contamination of a large area of ocean could ultimately have significant health and socioeconomic impacts. Constituents of the sludge might be toxic to, or be accumulated by, marine organisms which are part of the food chain of commercially valuable species. Subtle modifications of habitat might alter natural species composition over a large area and disrupt food chain relationships.

Based on existing knowledge of the fate of sludge in the ocean, disposal by barge to a deep-water area where minimal dispersion is expected is the most feasible ocean disposal alternative. Total containment of the sludge is technically very difficult to achieve. However, by limiting the dispersion of the sludge as much as possible, the effects of dumping upon the marine environment can be minimized. Actual site selection should be made to minimize the influence of sludge dumping on present and potential uses of the sea.

Although containment provides the best short-term ocean disposal option, it does have several disadvantages. Anoxic conditions are likely to be produced by continuous dumping of any particular deep-water site. Anoxic conditions will be accompanied by production of hydrogen sulfide which is toxic to many marine organisms, but trace metals combine with hydrogen sulfide under anoxic conditions to form insoluble metal sulfides. This, in turn, will limit the extent of trace metal contamination.

Microbial activity is reduced in deep-water (Jannasch, 1971) and the sludge may be degraded more slowly than it would be in shallow water. Accumulation of sludges may bury benthic communities, but they are likely to be recolonized rapidly by pollution tolerant species. Deep-water benthic communities have evolved in a relatively stable environment as compared to shallow water communities and may be extrememly sensitive to environmental stresses. Although restricting fisheries in a small area of dumping would not produce severe socioeconomic impacts, migratory species might feed at the sites and become contaminated.

In summary, although sludge disposal by barge to deep ocean sites has a number of disadvantages, it offers the best ocean disposal method for Boston based on current knowledge. And of the possible ocean disposal system, it also offers the most easily implemented and controlled monitoring program. A system of sampling points can be set up in and around the periphery of the dump site at various depths in the water column and in the sediments. If the amount of materials which are being dumped are known, changes in concentration of materials in the marine environment in the vicinity of the dump can be studied in relation to the amounts dumped.

The conclusions reached in the preceding discussion generally apply also to ash disposal. Although the constituents of ash and expected environmental impacts are significantly different from those in sludge, the same method of ocean disposal, i.e., barge to deep-water, maximum containment, is chosen for ash.

With the most environmentally desirable form of ocean disposal being deep-water dumping, the best form of sludge for disposal can be resolved. To achieve the desirable depth (greater than 100 meters), a haul distance of approximately 60-70 NM is required. At this distance, pipeline transport is not practical, leaving barging as the method of transportation. In deciding between liquid and dewatered sludge, the energy cost to transport the liquid by barge is 1.8 times greater than the energy necessary to vacuum filter and transport the dewatered sludge over the same distance. The disposal distance beyond which dewatering is practical in terms of energy varies between 20 NM (dewatering to 35% solids) and 22.5 NM (dewatering to 25% solids).

The final alternatives selected for ocean disposal are:

- Alternative 3: Dewatering - Incineration - Ocean Disposal of Ash
- Alternative 4: Dewatering - Ocean Disposal of Sludge

As outlined in Appendix O, a permit to allow the ocean dumping of sludge and ash would be necessary. The MDC sludge and ash would not be approvable for ocean dumping in the foreseeable future, since the level of trace contaminants far exceed those in the criteria governing the issuance of permits. The nature of the sludge, at present, the remote likelihood of improvement in the near future, the possibility of other alternatives, and the stated policies of the federal government regarding ocean dumping, makes Alternatives 3 and 4 infeasible.

- <u>Selection of Land Application Alternative</u>

Recall that the feasible land application alternatives are:

- Process Train F: Dewatering - Heat Drying - Land Application
- Process Train I: Dewatering - Land Application
- Process Train L: Direct Land Application of Liquid Sludge

Selection of the best alternative from among these systems can be done on several criteria, including:

- Least amount of pathogen and heavy metals contamination
- Greatest nutrient value recovery
- Greatest positive agricultural economic impact
- Least net energy cost
- Least capital and operating cost

Because these systems have significant differences in terms of processing, transportation and storage requirements, environmental impacts, and suitable types of application sites, it is necessary to summarize system characteristics for each process train. These summarizations are presented in Tables EE-2, EE-3, and EE-4. Further discussion of land application techniques is given in Appendix P, "Land Application of Sludge - State of the Art."

The first process comparison to follow is: (a) between dried sludge (Process Train F) and dewatered sludge (Process Train I); and the second comparison will be (b) between dewatered sludge (Process Train I) and direct application of liquid sludge (Process Train L).

a. <u>Evaluation of Dried vs. Dewatered Sludge</u>

The experiences of Milwaukee and Houston regarding the sale of heat-dried sludge and the interest expressed in the potential for selling MDC sludge as fertilizer led to a Region I sponsored sludge fertilizer marketing survey (Development Planning and Research Associates, 1975). Appendix Q is a reproduction of the recommendations and conclusions of that market study. The purpose of the survey was to determine the potential for the sale of heat-dried sludge as fertilizer and/or soil conditioner.

TABLE EE-2

CHARACTERISTICS OF LAND APPLICATION PROCESS TRAIN F

DEWATERING - HEAT DRYING - LAND APPLICATION

(95% SOLIDS)

Processing: Capital and operating costs high
Energy costs high (12.3 to 17.9 million BTU/ton)

Transportation: Capital costs low
Operating costs low
Energy costs low (approx. 2100 BTU/ton mile)

Storage: Capital costs low
Operating costs low

Application: Low cost, low energy, through normal distribution channels

Suitable Application Sales: Farmland, open fields, home gardens landscaped areas

Advantages: Lack of odor
Sterility (drying at 700^{o}-$1100^{o}F$)
Ease of handling
May be economically self-supporting

Disadvantages: High dollar and energy costs
Loss of nitrogen in drying
Lack of flexibility
Air pollution effects of fuel use

TABLE EE-3

CHARACTERISTICS OF LAND APPLICATION PROCESS TRAIN I

DEWATERING - LAND APPLICATION

(25% SOLIDS)

Processing: Capital and operating costs - moderate
Energy costs - moderate (414,000 BTU/ton)

Transportation: Capital and operating costs - moderate
Energy costs - moderate (8000 BTU/ton mile)

Storage: Capital and operating costs moderate
Land requirements moderate

Application: Capital and operating costs high
Separate system required

Suitable Application Sites: Farmland

Advantages: Moderate total energy costs
Flexibility of transportation
Flexibility of application areas
Reduced sodium to soil
Flexibility of disposal method

Disadvantages: Potential odor problems from storage
Loss of ammonia nitrogen in storage
High costs of transportation and application
Little possibility of recovery of dollar value
Potential groundwater impacts
Potential conflict with adjacent land uses

TABLE EE-4

CHARACTERISTICS OF LAND APPLICATION PROCESS TRAIN L

DIRECT LAND APPLICATION

(5% SOLIDS)

Processing:	Capital and operating costs - negligible Energy costs - negligible
Transportation:	
Pipeline -	Capital costs - high Operating costs - moderate Energy costs - moderate (13400 BTU/ton mile)
Truck or Rail -	Capital costs - high Operating costs - high Energy costs - high (4000 BTU/ton mile - truck) (20,400 BTU/ton mile - rail)
Storage:	Capital and operating costs - high Land requirements - high
Application:	Capital and operating costs - high
Suitable Application Sites:	Forests, farmlands (dedicated areas required with pipeline transport)
Advantages:	Greatest delivery of nitrogen to soil
Disadvantages:	High capital costs for either truck or pipeline delivery. High capital costs for application. Large storage volume required. Inflexibility of application site. May require dedicated area. Odors from storage and application. Long-term commitment. Potential for groundwater contamination. Potential conflict with adjacent land use.

Questions that were answered by the survey were:

- Present and historical sales of inorganic fertilizer in Massachusetts and the other New England states
- Present and historic use of organic fertilizers and soil conditioners in Massachusetts and the other New England states
- Market prices of inorganic and organic fertilizers in the region
- Sales potential of a fortified or unfortified agricultural product made from dried sewage sludge
- Dollar return (or dollar cost) to the MDC from sale of such products, and the quantity which could be sold

Two possible products were analyzed: (1) a dried sludge (2-2-0) containing 2% nitrogen and 2% phosphorus (as P_2O_5); and (2) a fortified dried sludge (6-2-4) containing 6% nitrogen, 2% P_2O_5 and 4% potassium oxide. These two products were analyzed for marketability to farm operators, fertilizer formulators, and to home owners and golf courses.

The market researchers concluded that there was effectively no market for an unfortified dried sewage sludge (2-2-0), either to homeowners, to farm operators or to fertilizer formulators. This lack of market occurs because the 2-2-0 product would compete with sludges of higher nutrient concentration that are produced from activiated sludge. The fortification of MDC sludge to 6-2-4 would increase its value by more than the cost of bulk-fortifying chemicals. Taking liberal estimates of overall market growth and MDC's capture of that market, the potential sales of bagged fortified sludge could be as much as 16,400 tons of sludge (20,000 total product tons) per year to the home and garden market. The profit to MDC would be $3.29, sold at home and garden prices. The maximum home and garden sale of 16,400 tons of sludge per year leaves 29,600 tons per year to be sold through the farming market. For sale to the farm market, the MDC would lose $16.68 per ton of sludge sold because of the lower value to farm operators. Therefore, the added cost to MDC of sludge disposal as dried sludge for fertilizer would be the average, or a cost to MDC of $9.56 per ton of sludge. In their 1974 assessment statement, Havens and Emerson estimated a production cost of $94.50 per ton of dried sludge, thus yielding a total cost of $104.06 per ton of sludge which is dried, fortified and sold for land application. For comparison, the estimated cost of incineration per ton of sludge, discounting the recovery of thermal energy, was $65.06 per ton (including ash disposal) at the 1974 cost index.

Beyond the question of cost-effectiveness, the questions of environmental impacts and energy requirements must also be examined to determine if important benefits might be lost with rejection of the heat drying option. The environmental characteristics that differentiate heat drying versus application of dewatered sludge are:

- Decreased odor problems at the site of application
- Decreased pathogens
- Decreased potential groundwater quality problems
- Increased dried sludge loading for a given nitrogen requirement, leading to increased metals impacts
- Lack of control over sales, uses and environmental impacts of use
- Air pollution impacts from fuel use in drying.

The balance between these beneficial and adverse impacts is close enough that no significant environmental benefits would be gained by sludge drying.

Energetically, the costs of drying sludge are high compared to the energy costs of processing and transporting dewatered sludge. The haul distance at which total energy requirements become equal for dewatered and dried sludge is about 1,500 miles. For a 100 mile haul, the heat drying and transport would require ten times as much energy per ton compared to dewatering and transportation energy requirements. An additional comparison of energy requirements can be made between dried sludge and inorganic fertilizer. With the 2% nitrogen and 2% P_2O_5 nutrients content of dried sludge, drying alone would require about ten times as much energy as producing an equivalent amount of inorganic fertilizer.

- <u>Evaluation of Dewatered Sludge Vs. Liquid Sludge</u>

The second comparison to be made is between the application of dewatered sludge and the direct application of liquid sludge. The greatest single difference between the two is the type of land area which is most suitable for each type of sludge. In addition, the transportation mode that is most effective will have a major impact on the final design of the application system. The application system characteristics suitable for each type of sludge are:

- Dewatered sludge
  - Truck or rail transport
  - Decentralized storage
  - Application by modified manure spreader
  - Application on either privately owned farms or purchased farms or fields
  - Application to either small farms or large farms
- Liquid sludge - direct application
  - Rail or pipeline transport
  - Centralized storage
  - Application by tank truck or by sprayer
  - Application on purchased or private farms, fields or forests
  - Application on large areas

With these differences, we will first determine the best type of application site; then, second, determine which option (dewatered vs. liquid) is better for that site.

Land Site Characteristics: An important question is whether or not a government operated farm should compete with private farmers, and whether dedicated tracts of land should be used at all. Recently, Chicago, Philadelphia and several cities in Ohio have had difficulty in purchasing or otherwise obtaining dedicated tracts of land for land application of sludge. The Commonwealth of Massachusetts has among its goals the expansion of agriculture in Massachusetts, and the growing for sale of crops by a subsidized farm might tend to drive small private farmers out of business. If presently operating farms were purchased, this would also be in conflict with state goals.

Purchase of land outside the MDC service area for sludge application could be seen as being principally a "disposal" tactic, and based on Philadelphia's experience, it would be resisted vigorously by the local population. Purchase of land would also commit that area to long-term use for land application. This, in turn, would result in heavy metals problems. However, should private farmland be used, long-term commitments for use of that land would not be necessary. Thus, for the following reasons, application of sludge to large dedicated tracts is not feasible:

- Potential problems with obtaining sufficient land

- Adverse effects of competition with private farm owners

- Potential adverse heavy metals effects from long term disposal (eliminated by use of limiting metal concept to control total application)

If the concept of using dedicated lands is abandoned, the next question is the type of lands to be used for application. The choices are farmlands, pasturelands, or forests. The problems associated with each type of application area are:

- Farmlands

    - Potential metals uptake by crops
    - Potential pathogen contacts
    - Potential loss of nitrogen in seepage and runoff

- Pasturelands

    - Direct pathogen contact with animals
    - Greater metals uptake by grasses
    - Odor problems caused by non-incorporation of sludge into soil
    - Loss of nitrogen to air
    - Less recovery of nutrients

- Forests

    - Direct pathogen contact with animals
    - Greater loss of nitrogen to runoff and leaching
    - Potential aesthetic impacts
    - Odor problems
    - Little recovery of nutrients
    - Adverse impact of new access roads required for sludge distribution

Of the above possible types of application sites, crop farmlands offer the fewest negative impacts and the greatest recovery of nutrients. Because of this recovery of nutrients, application to privately owned farmlands will be more acceptable to farm owners and will yield an economic advantage to the owners and to the Commonwealth. Therefore, the most desirable method of land application is to distribute the sludge to private farmlands which are used for crop production. It should be recognized that the Guidelines for Municipal Sludge Management (EPA, 1975) favor use of dedicated lands, but the above considerations outweigh the control difficulties.

With this choice made, the dewatered sludge option is the better of the two systems because the private farmlands of Massachusetts are small and dispersed (although principally found in the Connecticut Valley and in the Bridgewater-Westport area). An important benefit of using dewatered chemically conditioned sludge is the lime content which mitigates adverse impacts of metals and also improves soil fertility.

<u>Transportation Modes</u>: The energy cost comparison between applying liquid and dewatered sludge shows that rail transportation for the liquid sludge requires 20,000 BTU/ton-mile (Hirst, 1973), and truck transportation requires 8,000 BTU/ton-mile for the dewatered sludge and 40,000 BTU/ton-mile for liquid sludge (Ashtakala, 1975). However, the energy cost for dewatering is approximately 414,000 BTU/ton. Using these values, a loss of soluble nitrogen with dewatering of 1 percent, and assuming 10-mile truck load required for liquid sludge, the distance at which transport of dewatered sludge becomes more practical than liquid sludge is approximately 50 miles.

<u>Selection and Development of Land Application Systems</u>: For the above reasons, the application of dewatered sludge to privately owned farmland (Process Train I) is the preferred land application option. This becomes a land application alternative:

- Alternative 5: Dewatering and Land Application of Sludge

This alternative as originally proposed used the cadmium to zinc ratio as a factor to determine the amounts of sludge applied. The latest EPA guidelines use sludge cadmium concentrations to determine the amounts of sludge to be land applied, both annual and total. These guidelines (see Appendix R) would allow application of the total amount of MDC sludge, although at a much lower rate than previously assumed, using the cadmium to zinc ratio. The guidelines are presented as maximum annual and maximum cumulative amounts of cadmium applied.

Industrial pretreatment may reduce the cadmium and other heavy metals amounts to reach the treatment plants. It is possible that the application rate may be increased; or, alternatively, the total land area needed for application could be reduced.

- Alternative 6: Dewatering - Land Application and Landfill

This is a hybrid alternative developed for the Draft EIS when it was determined that only 50 percent of the blended sludge of Deer and Nut Islands could be land applied. This amount was obtained using the cadmium to zinc ratio which no longer represents the state of the art in regard to the ability of the soil to accept heavy metals.

The use of two ultimate disposal schemes as originally proposed would lead to higher energy costs and monetary cost. Also, there is a loss of potential resource recovery with respect to the land applied sludge. These facts, coupled with the current situation regarding soil cadmium additions, lead to the conclusion that this alternative may not be practical, and it may be removed from further consideration.

- <u>Detailed Development of Alternatives</u>

Since the basic alternative systems have been established, it now becomes possible to complete the detailed development of those alternatives in order to be able to assess their impacts. In preparing detailed descriptions of the alternatives, several broad questions must be asked of each alternative. In addition, there are other specific issues which are unique to particular alternates. These issues of general and unique interest are summarized below and will be discussed in detail in the remainder of this section.

- Location of processing facilities
- Location of disposal/application sites
- Feasibility of recovering thermal energy
- Autogenous incineration (operation without auxiliary fuel)
- Transportation routes to disposal/application sites
- Coincineration
- Grit and screenings
- Pasteurization of sludges to be land applied
- Long-term availability of landfill capacity

The development of answers to these questions will permit the complete definition of the alternatives.

- Location of Process Facilities

Since dewatering has been included as a major step in all of the alternatives chosen, processing should not be planned at sites other than present treatment plant sites, because liquid recycle streams will require treatment. Thus the question becomes whether to centralize processing at Deer Island or to construct facilities at both plants. Considerations include the following advantages and disadvantages for single-site facilities at Deer Island:

- Advantages
  - Reduced total land area required
  - Availability of land at Deer Island
  - Decreased capital costs because of economy of scale
  - Decreased requirements for standby equipment
  - Reduced impact of air pollution (incineration alternatives) on sensitive receptors because of the population of Hull being in the downwind path of the prevailing wind over Nut Island
- Disadvantages
  - Possibility of rupture of sludge transfer line
  - Possibility of one sludge being incompatible with disposal route chosen (e.g., heavy metals concentrations too high for land application)
  - Construction impacts of sludge force main across Boston Harbor

Of the disadvantages shown above, the one most subject to quantification is the impact of rupture of the force main. Assuming 12 inch diameter for each of two lines and 30,000 feet length, rupture of one line would result in loss of 58,800 pounds of sludge, provided the system is equipped with some means of detecting breakage. The second disadvantage is mitigated in the hybrid system, Alternative 6, and in fact, Alternative 6 requires a centralized system in order to mix the two sludges in proper proportions. The third disadvantage involves underwater construction of approximately 18,000 feet of pipeline, of which

10,000 feet would be laid on the mud flats of Long Island. This construction would parallel previously disturbed areas. Providing satisfactory pipeline construction methods and providing that air quality criteria are satisfied, the single plant scheme is the preferable alternative.

- Location of Disposal and Application Sites

The location of disposal and land application sites has been developed for landfill, ocean disposal, and land application alternatives. With passage of the Resource Conservation and Recovery Act of 1976 and promulgation of draft guidelines for landfilling of residues, the differences between landfills for hazardous and nonhazardous wastes can be tabulated as shown in Table EE-5.

a. Landfill Sites

- Alternatives 2 and 10

The ash would be disposed of by filling in a man-made lagoon on the east side (ocean) for nonhazardous ash and on the western edge (harbor side) of Deer Island for hazardous ash. The lagoon would be created by walling off an eight acre portion of the harbor with a cofferdam. Then ash would be pumped into the lagoon, gradually displacing the water inside.

If the ash is determined to be hazardous, additional measures to insure that no environmental damage occurs must be undertaken. These measures are provided by the Resource Conservation and Recovery Act of 1976 (RCRA).

- Alternative 9

Spectacle Island has been used as a dump for approximately fifty years. In 1960, after the dump was abandoned, fire, probably from spontaneous combustion, broke out and continues to the present (MAPC, 1962). The island is 97 acres in size and could accommodate the expected nonhazardous ash volumes. While use of harbor islands for landfilling is specifically forbidden by state law, nonhazardous ash may be used for regrading to restore aesthetic quality.

- Alternatives 8 and 11

Ash would be disposed of at an inland site on Deer Island. A sanitary landfill or hazardous wastes landfill would be constructed near the plant site. The regulations for operation and maintenance of the landfill, as provided by RCRA, would be complied with.

TABLE EE-5

COMPARISON OF LANDFILLS FOR
HAZARDOUS AND NONHAZARDOUS MATERIALS

Characteristic	Hazardous Fill Site	Nonhazardous Fill Site
Leachate control	Recover and treat	No criteria except groundwater protection
Liner	Natural material (7 ft. of material with permeability of 10^{-5} cm/sec)	Either natural or plastic material membrane
Controlling agency	USEPA	State Solid Wastes Agency or subagency
Monitoring wells	Quality data sent to USEPA	Quality data to state agency

For nonhazardous ash, the ultimate disposal may include beneficial reuse for site regrading. For hazardous ash, a fill site has been assigned at the lower end of Deer Island as shown in Figure EE-1. This site has been provided as part of the planning for secondary facilities at the Deer Island wastewater treatment plant (EPA, 1978). The total area available is 7.3 ha (18.0 ac). Allowing for select fill for berm and liner, a fill depth of 12.2 m (40 ft) will yield a fill service life of 20 years with a bulk ash density of 800 kg/m^3 (50 lb/ft^3).

- Alternative 1

Ash would be disposed of at one of three possible sites. This alternative deals with ash as a nonhazardous material. The sites are sanitary landfills, approved for nonhazardous waste disposal.

- Plainville Site - The site is located near the Interstate Route 495 and U. S. Route 1 intersection. The area of the site approved for operation is 107 acres. An approved leachate control and recovery system exists on site (Kennedy, 1975). At present, no special wastes (as defined by the state) are accepted (Russ, 1978). Recent information shows this site is now closed (Leighton, 1978).

- Amesbury Site - The site is located on Hunt Road approximately 5 miles west of Route 95. The site area approved at present is 24 acres. At the moment they are encountering difficulties with their plans for expansion (St. Hilaire, 1978).

- Randolph Site - Located off Canton Street, near the Route 24 and Route 128 intersection. This site is the closest to the treatment plants. The landfill is currently unapproved for it is under order to correct an existing leachate problem and is experiencing difficulties with proposed expansion plans (St. Hilaire, 1978).

- Ocean Disposal Sites: Based on the discussion, barging sludge to deep water is the most feasible and environmentally sound ocean disposal alternative for both ash and dewatered sludge. Three potential dump sites were discussed by Pratt, Saila, Gaines and Grout (1973). They were: Stellwagen Basin, 25 miles from Boston; Jeffreys Basin, 15 miles from Portsmouth, New Hampshire; and the Murray Wilkinson Basin, about 60 miles from Boston. They felt the latter was of particular interest because of its great depth. It is closed below 200 meters and has extensive area below 260 meters. Two of these, Stellwagen Basin and Jeffreys Basin, appear unsuitable. Both are shallow in comparison to the open basin of the Gulf, and both are relatively close to shore. All three are located in important fishery areas. Fisheries data indicates that the deepest areas

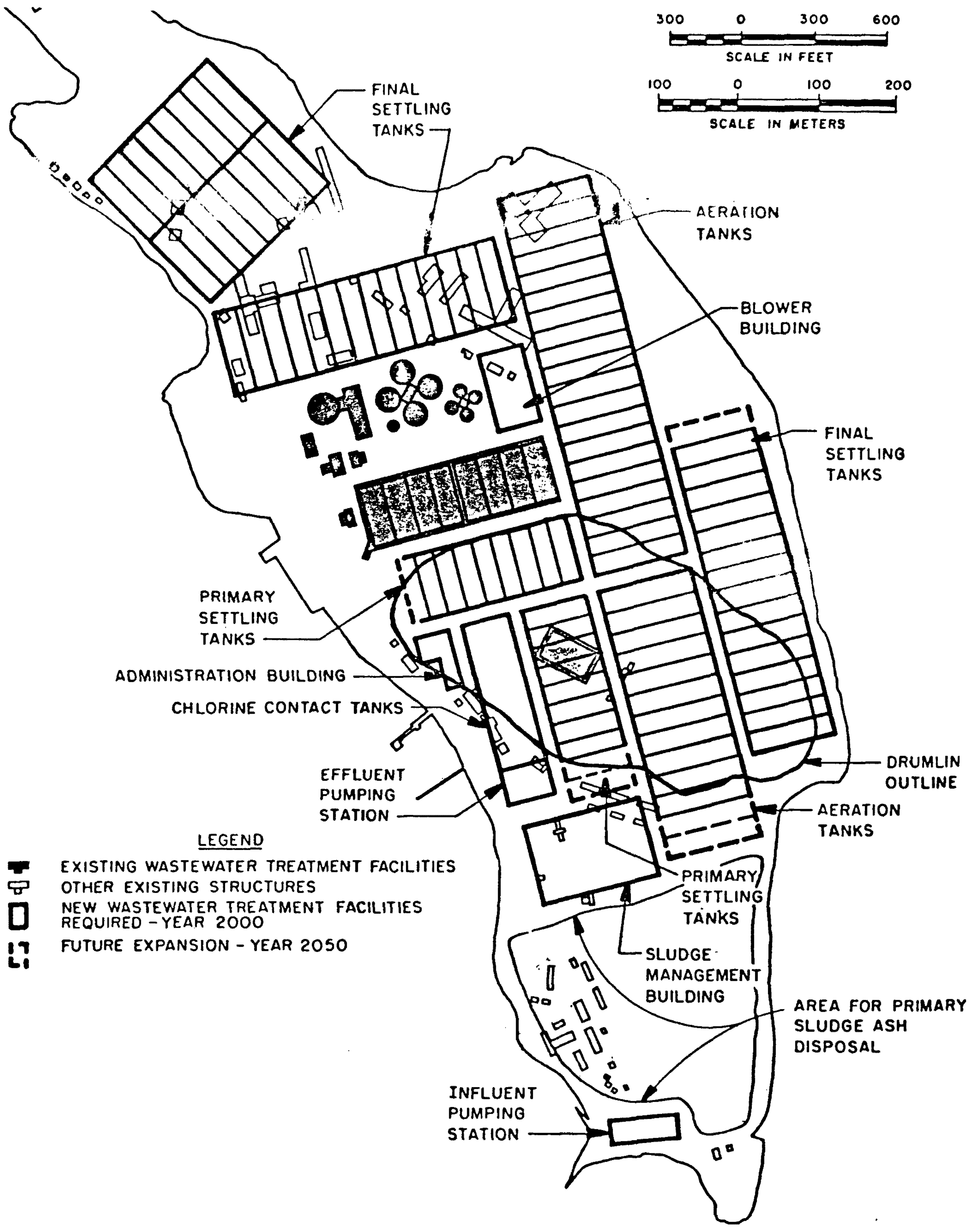

FIGURE II-1 DISPOSAL SITE FOR HAZARDOUS ASH, ALTERNATIVE 11
[SOURCE: EPA, 1978]

of the Gulf of Maine provide lower fisheries yields than do intermediate depths or the banks along the seaward edge. Of the three, the Murray-Wilkinson Basin is the deepest, is the furthest removed from shore, and is likely to support the most restricted biota. Figure shows the area of the Murray-Wilkinson Basin within 60 NM of Boston. Depths greater than 100 and 200 M are contoured. It is recommended that any dumping be restricted to a portion of this area, preferably at a site where the depth exceeds 200 meters. However, site specific surveys would have to be completed prior to any selection. Such a survey should stress hydrographic conditions, particularly water movements and sediment conditions, and an extensive biological survey of the area. Dumping must be confined to a well marked area where continuous monitoring of the sludge can be reasonably conducted.

c. Land Application Sites: Land requirements for land application alternatives include sites for storage of sludge and farmland for the actual application. The site locations for possible storage area are presently the object of discussion within the Commonwealth of Massachusetts and have not yet been identified. Conditions most favorable for land application of sludge are generally also those most suited for farming. Soils should have a moderately rapid permeability, with the optimum rate between 0.63 and 6.3 inches per hour. A rapid permeability of greater than 6.3 inches per hour may result in leaching, and a slow permeability of less than 0.2 inches per hour does not allow extensive plant growth. The texture of the soil should be between fine sandy loams to silt loams, although other soil types may be used if the quantity of sludge is monitored to keep the soil from remaining saturated. Application of sludge should not result in the rising of the water table, and the root zone should remain unsaturated to permit acceptable growing conditions for plants.

Initial examination of land use data from the Massachusetts May Down (1971) revealed sufficient tilled land for application of sludge on a long-term basis. The criteria used in this selection were:

- that the land is presently (1971) used for row crops;
- that the slopes of the land are less than 10 percent;
- that tract sizes of less than 40 acres were not considered.

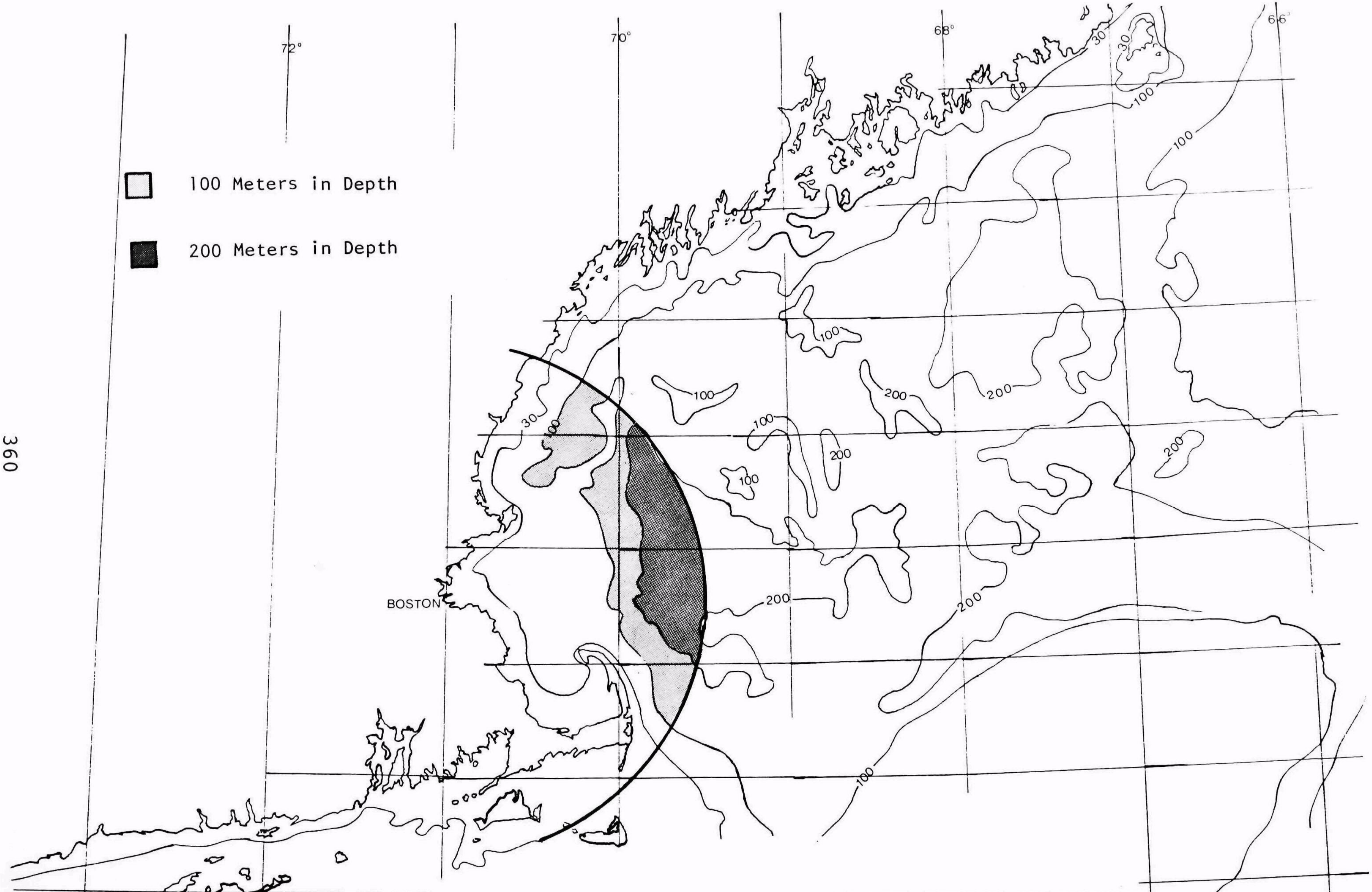

FIGURE . THAT PORTION OF THE MURRAY-WILKINSON BASIN (SHADED AREA) WITHIN 60 NM OF BOSTON.

Site selection based on these criteria results in a key assumption: that the land presently under cultivation for crops has the proper characteristics for land application. This is important because there is a lack of published data on the soil characteristics of Massachusetts counties. Therefore, the use of active farming areas as a predictive tool to locate land of proper quality for land application is a reasonable substitution for the lack of adequate soil data because land that is only marginal for farming would be the first land allowed to revert to "old field" status. Also, lands subject to development pressure and concomitant high taxation would revert to nonfarm uses more rapidly, and any remaining tracts would be small.

Figure indicates the location of possible suitable land application sites. Table describes the amount of land available and the distance the site is from the Deer Island treatment plant. The weighted average distance from Boston is 69.9 miles. Adding 25 miles for handling and storage yields an average of 95 miles of transportation.

Application rates of the sludge are limited by the crop to be grown. Appendix R indicates the methodology used to determine the amount of sludge that may be applied to a field if the field is to be used for a corn crop.

- <u>Energy Recovery from Incinerator Off-Gas</u>

In their work on the MDC project, Havens and Emerson, Ltd., have included energy recovery from the hot off-gasses of incineration. In the system envisioned by Havens and Emerson, the efficiency was predicted at 38%, based on the fact that the loss of efficiency (about 15%) in fuel burning normally used in power boiler computations need not be included. The best efficiency of a complete system in the power industry is approximately 38% which, with the 85% fuel efficiency, yields a boiler efficiency of 45% in comparison to the 38% from Havens and Emerson.

In a similar study for the New York-New Jersey Metropolitan Area (ISC, 1975) the feasibility of heat recovery was investigated, with the conclusion that it was infeasible, except when after-burners were operating. The reason for this feasibility was that a boiler exit temperature of 500°F was recommended in order to prevent fouling of the boiler tubes.

In a similar study by EPA Region V for Columbus, Ohio, the question of feasibility of energy recovery was also addressed (U.S. EPA, 1978A), using a boiler exit temperature of about 500°F. Under these conditions and with a daily incinerator loading comparable to 1985 conditions at Deer Island (90-100 tons per day vs. 127.5 tons per day), the estimated cost of electricity produced was $0.03/KWH. Comparing this to the $0.045/KWH cost of commercial electrical power (Boston Edison, 1978) shows that energy recovery is economically feasible. This is evaluated in more detail in Appendix T.

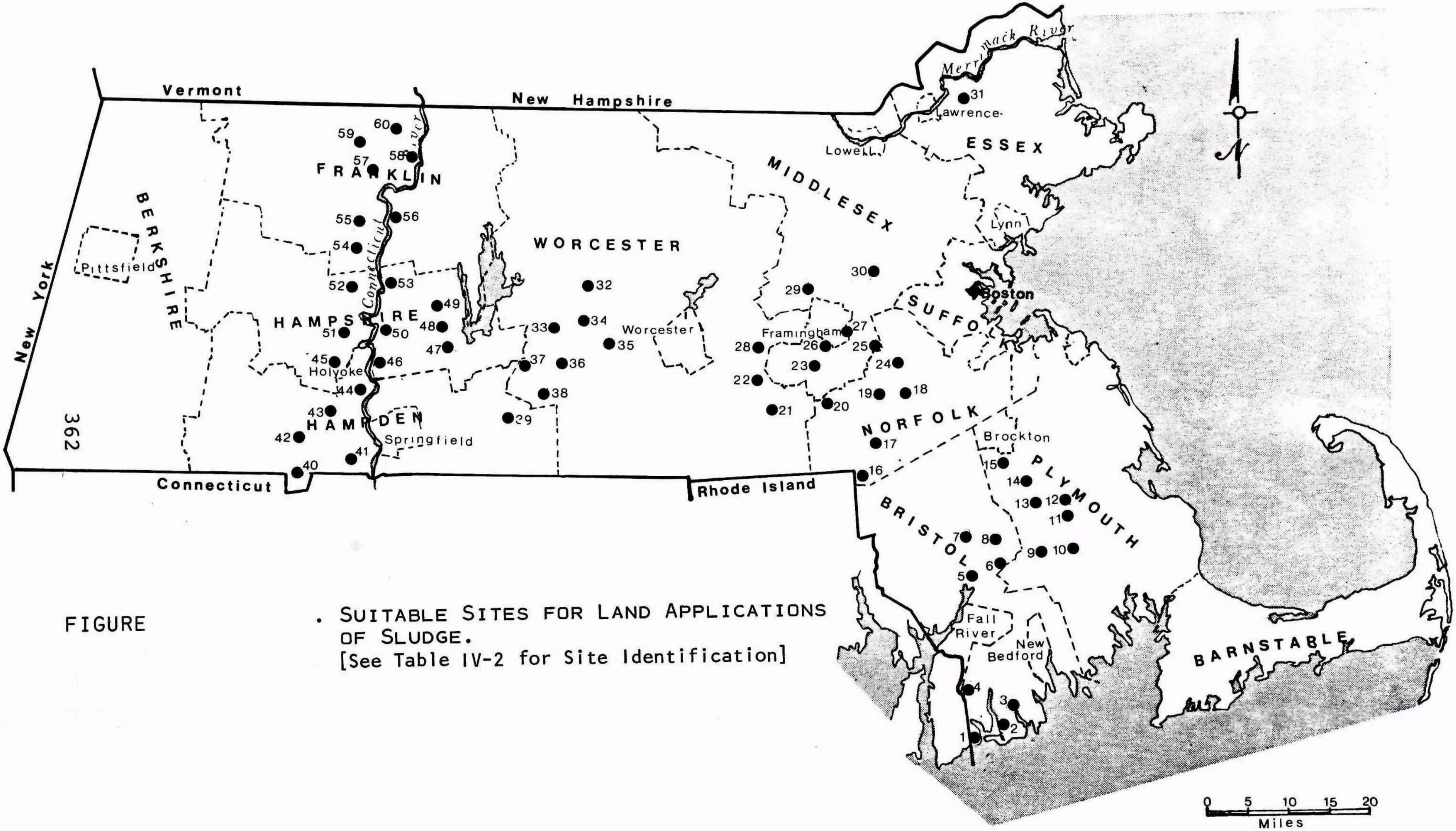

FIGURE . SUITABLE SITES FOR LAND APPLICATIONS OF SLUDGE.
[See Table IV-2 for Site Identification]

TABLE

SUITABLE SITES FOR LAND APPLICATION

Site Number	Topographic Sheets	Acres	Miles From Boston
1	Westport	125	56
2	Westport	218	54
3	Westport	1,839	52
4	Westport	845	50
5	Assonet	288	36
6	Assonet	45	35
7	Assonet	148	33
8	Assonet	48	32
9	Assawompset Pond	400	33
10	Assawompset Pond	60	34
11	Bridgewater	380	29
12	Bridgewater	778	26
13	Bridgewater	250	26
14	Bridgewater	290	23
15	Whitman	690	21
16	Wrentham	106	29
17	Wrentham	333	25
18	Medfield	150	18
19	Medfield	247	23
20	Holliston	180	27
21	Milford	136	34
22	Milford	276	34
23	Holliston	45	26

TABLE III-10(Contd.)

SUITABLE SITES FOR LAND APPLICATION

Site Number	Topographic Sheets	Acres	Miles From Boston
24	Medfield	296	17
25	Natick	109	19
26	Holliston	45	31
27	Framingham	125	22
28	Milford	45	32
29	Framingham	342	25
30	Natick	26	24
31	South Groveland	530	25
32	Barre	883	53
33	Ware	1,389	59
34	North Brookfield	781	54
35	North Brookfield	1,498	51
36	Warren	378	59
37	Warren	160	62
38	Warren	422	60
39	Warren	90	65
40	Southwick	518	91
41	West Springfield	3,658	86
42	Southwick	826	91
43	Mount Tom	634	87
44	Mount Tom	160	83
45	Mount Tom	774	85
46	Mount Holyoke	1,062	79
47	Belchertown	883	71

TABLE III-10(Contd.)

SUITABLE SITES FOR LAND APPLICATION

Site Number	Topographic Sheets	Acres	Miles From Boston
48	Belchertown	397	73
49	Belchertown	154	73
50	Mt. Holyoke	6,938	79
51	Easthampton	2,304	83
52	Williamsburg	339	83
53	Mount Toby	10,585	77
54	Williamsburg	1,587	82
55	Greenfield	2,022	83
56	Greenfield	1,702	78
57	Bernardston	1,978	81
58	Northfield	2,784	77
59	Bernardston	198	83
60	Bernardston	499	81
	TOTAL	54,998 ac.	
		22,257 ha.	

• Autogenous Operation (Operation without Auxiliary Fuel)

Appendix S on the state of the art of multiple hearth incineration addresses the question of operation of the incinerators without fossil fuel inputs. In the incineration system as proposed by the MDC, autogenous operation is theotetically possible. The principal reason that additional fossil fuels are required for incinceratos (based on analysis of records from existing plants) the combustion air feed is fixed, usually at 150% of the volume required. As Appendix S points out, the effect of this fixed quantity of air is that when the incincerator is running at 50% of capacity, the air supply is 300% of that required or 200% esxess air. Because the thermal energy required to heat the incoming air is about 300 BTU/pound of air, this exerts a powerful impact on fuel requirements.

For every 1% reduction in thermal efficiency below that calculated for autogeny in 1985, the daily fuel requirement would be approximately 100 gallons per day (@ 143,000 BTU per gallon). Because the question of energy input is so important the MDC's consultant has developed an incineration system in which the combustion air input is variable, depending on the oxygen requirement and the percentage of incinerator capacity used. Appendix S recommends several additional measures that could be taken by the MDC to further insure autogenous operation. In addition to auxiliary fuel use, start-up fuel will be required. Each start-up will require 4000 gallons of fuel (H&E, 1973), and based on existing plant data (Appendix S), the start-up frequency will be one start every ten days. On this basis, the average daily auxiliary fuel requirement will be 400 gallons.

• Transportation Modes and Routes for Final Disposal or Application

For the ash and sludge disposal and land application alternatives, there are only a few choices of transportation modes or routes. Basically, the transportation modes are dictated by access to the Deer Island plant and the available intrastate system for Massachusetts.

The Deer Island site in Winthrop has only limited access roadway alternatives. In this community, truck travel is excluded along Shore Road fronting the beach area.

The Deer Island site would appear to have three optional routes, all of which traverse narrow roads fronting on residential areas.

• Option 1 - Tafts Avenue - Shirley Street - Washington Street - Pleasant Street - Main Street - Saratoga Street - Bennington Street - Route 1

- Option 2 - Tafts Avenue - Shirley Street - Revere Street - Main Street - Saratoga Street - Bennington Street - Route 1

- Option 3 - Tafts Avenue - Shirley Street - Crest Avenue - Revere Street - Main Street - Saratoga Street - Bennington Street - Route 1

The primary problem with each of these options is not related to capacity, but that the street system within Winthrop was not designed to accommodate heavy truck travel.

Those alternatives which require daily transport of ash or sludge (Alternatives 1, 5, 6, 8, 9, and 11) have the option of passage through Winthrop or transport by barge (in container trailers) to a dedicated terminal with roll-on, roll-off facilities which would permit subsequent transfer of trailers to the highway system. Advantages and disadvantages of each of these options are:

- Advantages of transport through Winthrop
  - Fewer transfers of trailers
  - Reduced capital and operating costs
  - No channel dredging impact (required for barging scheme)

- Advantages of transport via barge
  - No impact on Winthrop streets or on residents
  - Reduced energy costs
  - Increased storage capacity

Although the relatively low volume of ash transported under Alternative 1 would reduce the impacts on the Winthrop residents, the lower cost disadvantage for cross-harbor barging would not outweigh the benefits to the community. Therefore, the barge transfer link between Deer Island and the terminal will be included in all land oriented disposal or application alternatives.

The second topic under transportation is the choice between rail and truck transportation of sludge for land application. (Use of rail for daily ash transportation to disposal was not considered because of the small quantity involved). Rail transport would be ideal for several reasons including reduced energy demand and reduced highway traffic impacts. A method was developed for transporting either sludge or ash in trailers which could be "piggy-backed" on to flatcars. Then the costs of flatcar transport was investigated in discussions with Boston and Maine Railroad (Hanrahan, 1975). The rail transport costs between the terminal and the East Cambridge yards, and between East Cambridge and

Fitchburg would be about $2 million per year to accommodate 1985 sludge volume conditions. In addition, truck tractors for transport from the railhead to the storage site would still be required. For these reasons rail transport as an option was abandoned. The system of truck transportation adopted does not preclude periodic review of transport cost and energy effectiveness should the Conrail reorganization radically change rail rates in the northeast.

Given the above development, the transportation scheme for each alternative can be summarized in Table III-11.

- <u>Coincineration</u>

This section considers the possibility of incineration sewage sludge from Deer and Nut Islands, along with municipal solid refuse in a steam generating facility. Proposed systems include coincineration with the solid waste from Boston in a new facility, at the RESCO facility in Saugus, or at the West Suburban Project facility in Stoughton.

In November of 1976, the Metropolitan District Commission released this feasibility study for an integrated waste management system for the Boston, Massachusetts area, prepared by Stone & Webster. The purpose of the study was to evaluate the technical, environmental, and financial feasibility of cotreatment of solid waste and municipal sewage sludge in the Boston Metropolitan Area. Final disposal of the ash would be the same as for separate incineration, except that the two ashes would be mixed. From an air pollution standpoint, total emissions would be the same for either case, but coincineration would result in higher peak concentrations because of the single large point source.

The City of Boston's Public Works Department (PWD) is responsible for collection and disposal of solid waste from domestic sources. The PWD has the option of collection and disposal of commercial and industrial refuse for a fee, but so far has not exercised this option. Because the city-owned incinerator at South Bay has been shut down by court order due to air pollution problems, the PWD has been forced to contract private disposal companies to replace the disposal capacity of the incinerator. The city plans to have a new incineration facility constructed and operated for a period of 20-plus years by a private corporation. Therefore, the two monotreatment plans (sludge and solid waste) and a cotreatment plan were examined in the feasibility study.

TABLE

TRANSPORTATION SCHEMES FOR THE TEN ACTION ALTERNATIVES

Alternative 1	Barge transport of ash in containerized trailers to a dedicated on-shore terminal; then truck transport to chosen landfill site
Alternative 2	On-site disposal; no transport
Alternatives 3 & 4	Barge transport to Murray-Wilkinson Basin
Alternative 5	Barge transport to an on-shore terminal; truck transport to dispersed storage sites
Alternative 6	Barge transport to a terminal; truck transport to dispersed storage sites (50%) or to the chosen landfill site (50%)
Alternative 8	Truck transport to Deer Island site
Alternative 9	Barge transport to Spectacle Island
Alternative 10	On-site disposal; no transport
Alternative 11	Truck transport to Deer Island site

The approach which was used to evaluate the feasibility of cotreatment was to first examine several alternative cotreatment processes, select the optimum plan, and then compare that plan to the separate treatment plans developed by MDC and PWD. The alternatives selected for consideration were composting, pyrolysis, and incineration. Solid waste and sludge pretreatment processes necessary for pyrolysis or incineration as well as several types of incineration were examined. Each cotreatment alternative was evaluated on the basis of waste pretreatment needs, the treatment process itself, environmental impacts and markets for services and by-products. Additionaly, the possibility of providing an initial incineration process which would eventually be convertible to a pyrolytic operation was considered throughout the various evaluations.

Composting was rejected as a feasible alternative because (1) the land area required is not available, (2) the adequacy of the market for the compost product and the acceptability of the product in terms of heavy metal toxicity are questionable, and (3) the cost of the process was relatively high. Pyrolysis was considered infeasible as an initial alternative because (1) it is a relatively new technology and (2) the cost estimates indicate both high capital and annual operating costs. Several types of incineration (water wall, dry wall, multiple hearth, and fluid bed) were examined with the main objective being that of finding a low risk system capable of cotreating Boston's solid waste and the MDC sludge. Each process type has its advantages and disadvantages with respect to process adaptability, successful operating history, and by-product generation. The selected system consists of a water wall boiler with separate dry sludge and solid waste entrance points, dry quenching of ash and magnetic ferrous material separation from the residue. The capital and operating costs for this basic system installed at either of two possible locations, South Bay and Deer Island, were analyzed to determine the optimum site/system alternative. Facilities at the South Bay site would consist of two boilers, each having a capacity of 850 TPD, sludge drying equipment, electrostatic precipitators, ferrous recovery and residue conveyors, and an underground steam connection. The Deer Island site would incorporate the same basic systems except that steam would be piped to two 20,000 KW turbogenerators for power production instead of being piped into the existing Boston Edison district heating system. The South Bay facility would require delivery of solid waste to the site via packer truck and transportation of dewatered sludge via truck and barge from the sewage treatment plants. The Deer Island site would necessitate truck-barging of solid waste and sludge from

Nut Island to Deer Island. A comparison of the capital costs for the two site locations with and without grants is given below. The cost of a privately-owned facility at South Bay is also included below (Stone & Webster, 1976).

	Capital Cost	
	South Bay	Deer Island
Without Grants	$45,781,000	$60,419,000
With Grants	39,428,000	52,561,000
Privately Owned	51,327,000	-

By-product markets and revenues for each facility site were estimated on the basis of a 1,500 TPD facility. The cost of operation and estimated revenues from the sale of by-products were used to establish an estimated net cost of operation for each facility with and without grants. The resulting operating costs are shown below.

	Annual Operating Cost	
	South Bay	Deer Island
Without Grants	$ 8,836,000	$10,475,000
With Grants	8,294,000	9,805,000
Private Operations		
With Private Financing	10,127,000	-
With Tax Exempt Financing	9,309,000	-

On the basis of capital and operating cost estimates the South Bay site with grants would be selected as the most economical. Additionally, an analysis of the regional costs generated by a cotreatment system was conducted and the results are given below.

	Regional Costs	
	South Bay	Deer Island
Without Grants	$5,053,000	$6,618,000
With Grants	4,177,000	5,622,000

Again it would appear that the South Bay with grants option would be the optimum plan. However, a serious problem with this plan is that the annual cost to the MDC would be approximately $1,000,000 more if the South Bay site were selected.

The higher cost is largely due to sludge hauling costs. The resulting dilemma is that although the region would benefit by cotreating at South Bay, that benefit would be at the expense of a state agency, the MDC.

In assessing the environmental impacts of a cotreatment system located at the South Bay or Deer Island site, air quality, noise, socioeconomic, terrestrial ecology, water quality and energy consumption were all taken into account. The most adverse environmental effects of cotreatment were found to be in connection with air quality. However, due to the present air quality conditions, neither site could be considered preferable. The following table gives the environmental analysis results showing the preferred site marked by an (X).

	Neither	South Bay	Deer Island
Air Quality	X		
Noise		X	
Socioeconomic		X	
Water Quality	X		
Terrestrial Ecology		X	
Energy Consumption		X	

From the above table, it can be seen that the South Bay site would also be preferable on an overall environmental basis. Therefore, in consideration of capital, operating and regional costs, and environmental impacts, the South Bay Cotreatment Facility Plan is considered the optimum plan to be compared with the two monotreatment plans.

In comparing the optimum cotreatment plan with the two monotreatment plans, a multi-case comparison of capital and operating cost was conducted with the following results:

	Capital Costs (Public Ownership)	
	Without Grants	With Grants
Coincineration (Optimum Case)		
South Bay	$45,781,000	$39,428,000
Sludge Dewatering	7,600,000	760,000
Total	$53,381,000	$40,188,000
Monotreatment (Separate Plants)		
South Bay	$39,555,000	$39,555,000
Deer Island	32,230,000	3,223,000
Total	$71,785,000	$42,778,000

	Operating Costs (Public Ownership)	
	Without Grants	With Grants
South Bay Coincineration	$ 8,836,000	$ 8,294,000
Sludge Dewatering at Deer Island	1,628,000	1,080,000
Sludge Hauling to South Bay	1,551,000	1,551,000
Total	$12,015,000	$10,924,000
Monotreatment at South Bay	$ 7,910,000	$ 7,910,000
Monotreatment at Deer Island	4,209,000	1,883,000
Total	$12,119,000	$ 9,793,000

Fron the preceding cost information, it can be seen that on a capital cost basis, each monotreatment plan is less costly than the optimum cotreatment plan. However, the total cost of monotreatment to the Boston community as a whole would be greater than cotreatment at South Bay. On an annual operating cost basis the monotreatment plans with grants would be the least costly.

Several conclusions have been drawn from this coincineration feasibility study as evaluated by Stone & Webster Management Consultants, Inc.:

(1) Cotreatment (coincineration) is technically and environmentally feasible.

(2) Cotreatment is not economically feasible when compared with the separate monotreatment plans of the MDC and Boston PWD. The cost of transportation of sludge to the South Bay site and the current federal and state grant systems are the major contributors to the economic infeasibility of cotreatment.

(3) The most economical sludge disposal method for MDC is monotreatment at Deer Island will full federal and state grants.

(4) If cotreatment were to be instituted, Deer Island would be the most economical site for MDC while South Bay would be the most economical site for the City of Boston.

(5) The conditions necessary to cause cotreatment to be economically feasible are: (a) having solid waste and sewage treatment facilities on the same or adjacent sites, (b) having one agency responsible for both solid waste and sewage disposal, (c) having a market for steam in close proximity to the facility, and (d) having federal money available for solid waste disposal through a grant system similar to that provided for water pollution control facilities.

Subsequent to the review of the Stone & Webster report by several agencies, the possibility was raised of co-incinerating MDC's sludge with the municipal refuse currently being burned at the RESCO incinerator in Saugus. (approximately 30 miles from downtown Boston). The RESCO facility is owned by Mr. Dominic DeMatteo and operated by Wheelabrator/Frye. Because the facility is currently operating below capacity two issues need to be explored:

1. Could the facility burn sludge with its solid waste with little or no design modifications?

2. How would the MDC sludge be transported to Deer Island?

It appears, based on a brief review of the design of the RESCO incinerator, that it could burn a dewatered sludge and refuse and still generate steam for the General Electric plant. The efficiency of the facility would depend on the percent solids in the sludge cake. Incinerators with a design similar to the RESCO facility currently burn solid waste and sludge in Europe.

Transporting the MDC's primary sludge to Saugus appears to present a slightly more complex problem. Several options could be considered:

1. Sludge could be dewatered at Deer Island using conventional belt filters. The Nut Island sludge would be transported to Deer Island via a pipeline under Boston Harbor. Following the dewatering process the sludge could be transported either by barge or truck to Saugus.

2. Liquid sludge could be pumped via pipeline to dewatering facilities at or near the RESCO facility.

The potential advantages of a RESCO/MDC facility are:

1. No new air pollutants would be generated at Deer Island.

2. No additional land would be required on Deer Island for primary sludge management.

3. The MDC ash would be disposed of with the ash currently generated by the RESCO facility.

4. The RESCO facility currently has excess capacity.

5. Energy would be recovered.

Initial review of the RESCO facility for sludge incineration also pointed out a number of potential disadvantages.

1. The transportation of sludge to the Saugus Facility could pose a number of problems. If the dewatered sludge were carried by truck, approximately 85 trips per day would be required through Wintrop.

2. Barging the sludge to Saugus would result in high operation and maintenance costs which would be borne by the MDC member communities.

3. Pipelining the sludge to Saugus also presents several problems:

a. Environmental impacts and social disruption depending on the location of the pipeline.

b. In order for any portion of the sludge handing including dewatering equipment to be eligible for federal financial assistance they must be owned by the MDC. MDC ownership of facilities at the privately owned RESCO facility may pose problems.

4. Combining the sludge with refuse would result in a greater amount of air emissions. For the purposes of regulation, the RESCO facility must comply with the standards of performance for refuse incinerators. These standards are less stringent than those set for sewage sludge incinerators.

Based on our review of the RESCO alternative it is EPA's opinion that this alternative presents very marginal if any benefits over the alternative to construct a sludge only facility at Deer Island. It also seems to make more sense to use the "excess" capacity at RESCO for sludge generated by communities on the north shore, many of whom now us the RESCO facility to dispose of their solid waste.

Consideration of the West Suburban Project (WSP) in Stoughton as a site for coincineration of MDC sludge is subject to the same process of review and eliminations as the RESCO facility. In addition the possibility of codisposal at WSP has been eliminated by action of the WSP policy committee.

- Grit and Screenings

Management of grit and screening requires a review at this point because of the relatively large quantities of grit and screenings generated at the headworks discharging to the Deer and Nut Island Plants. The expected quantities are discussed in Appendix N.

Because of the quality of such substances, the alternatives using land application are not suited for disposal of grit and screenings. At the Nut Island plant, grit and screenings are incinerated in a small (36 ton/day) multiple hearth incinerator. Continued use of this incinerator for grit and screenings appears most desirable for those alternatives not using incineration for sludge processing. Therefore, all incineration alternatives would include incineration of grit and screenings with primary sludge. Alternatives 4, 5, and 6 would include the incineration of grit and screenings from the headworks and Deer Island at the Nut Island incinerator with ash disposal via the major disposal route. Because the skimmings are typically low in metals, this sould have little effect on quality of material.

- Pasteurization

The Draft Technical Bulletin Guidelines include four alternative pathogen control techniques; the four alternative methods are (EPA, 1975A); pasteurization for 30 minutes at 70°C, high pH treatment, typically with line, at a pH greater than 12 for 3 hours, long term storage of liquid sludge, 60 days at 20°C or 120 days at 4°C or complete composting, temperatures above 55°C, due to bacterial oxidation for 30 days. It sould be noted that the Bulletin does not require pathogen control beyond stabilization on all projects.

At the beginning of this project, a tenative determination was made by the Massachusetts Department of Environmental Quality Engineering (DEQE) that pasteurization would be required for sludges applied to land (Anderson, 1975). However, that recommendation was not a firm policy statement, nor a specific departmental requirement. At the present time, DEQE is actively determining what the departmental policy should be on that matter. But since the initial response was to require pasteurization, it was included in Alternatives 5 and 6 which propose that sludge be applied to farmland.

- <u>Long Term Availability of Landfill Capacity</u>

For all of the land-oriented alternatives except Alternative 5, some landfill capacity is required for ultimate disposal Alternatives 1, 2, 8, 9, 10 and 11 all require 689,000 cubic yards of capacity for 20 years of operation and Alternative 6 would require 2,210,000 cubic yards of capacity for 20 years.

For Alternative 1, capacities would have to be available at inland landfill sites operated by either private owners or by other agencies. The landfills at either Amesbury or Randolph may have this much capacity but this is unlikely. The Clean Communities landfill at Plainville is nearly filled and expansion appears unlikely (I. Leighton, 1978).

For Alternatives 2 and 10, using cofferdammed fill sites either on the east ocean or on the harbor side of Deer Island, the size of the cofferdammed areas is based on the amount of ash for disposal, and would be sized for 20 years operation.

For Alternative 8, fill of non-hazardous ash can be used for site regrading at Deer Island, and thus the site capacity would be adequate.

For Alternative 9, fill of non-hazardous ash on Spectacle Island for use as grading material, the fill depth required (using about 16.2 ha or 40 acres for regrading) would be about 0.16m (0.53 ft) per year of use. Therefore, for 20 years use, the fill depth would be 3.2m (10.6 ft). According to recent information received (Ackerman, 1978), the Spectacle Island site is to be available as a recreation site within one to five years. Considering that two years minimum will be necessary for installation of equipment only 0.48 m (1.59 ft) of ash could be applied.

For Alternative 11, the 18 acre fill site at the lower end of Deer Island will be adequate for 20 years operation.

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